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Guidance on Marine Baseline Ecological Assessments & Monitoring Activities

for Offshore Renewable Energy Projects

Part 2 April 2018

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1. Executive summary

This document constitutes Part 2 of a 'two-part' *Guidance on Marine Baseline Assessments and Monitoring Activities for Offshore Renewable Energy Projects,* DCCAE, 2016. It provides technical guidance for the baseline data requirements and monitoring necessary to evaluate potential environmental impacts of offshore renewable energy projects in the marine area. It also provides an overview of best practice in relation to conducting baseline marine environmental assessments and monitoring programmes to support consent applications for, and operation of, offshore renewable energy projects. The guidance provides specific recommendations for the baseline survey and monitoring of the receptors detailed in Chapters 3 to 8.

It is primarily aimed at specialists (e.g. ecologists, archaeologists, oceanographers and modellers) who have the expertise to deliver the required surveys and analysis to professional standards. The document is not intended as a prescriptive list of survey and monitoring methods; it gives advice and suggests options as well as generally accepted methods for site characterisation surveys and impact monitoring programmes.

This guidance document supports the *Guidance on EIS and NIS Preparation for Offshore Renewable Energy Projects*, DCCAE 2016 and is supported by *Data and Information Sources for Offshore Renewable Energy Developments*[1], DCCAE, 2016.

This guidance recognises that there is currently a significant body of knowledge in existence relating to environmental pressures and impacts from offshore wind developments. In contrast, as wave and tidal energy is emerging technology, limited (but growing) information exists on the potential impacts that these technologies, and their associated infrastructure and construction methods, have on the receiving environment.

Part 1 sets out a non-technical summary of the baseline data requirements and monitoring necessary to evaluate potential environmental impacts of offshore renewable energy projects in the marine area. It is intended primarily for developers. However, it will also be of benefit to consenting authorities during the consenting processes.

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1 *Data and Information Sources for Offshore Renewable Energy Developments*. Available at: www.oceanenergyireland.com/Content/Documents/EnvData.xlsx

The guidance is consistent with relevant national and EU legislation and prevailing guidance, policy and advice, and it is informed by the requirements and monitoring programme of the Marine Strategy Framework Directive (MSFD).

The guidance also covers methods for conducting baseline assessments of offshore renewable energy projects and identifies likely impacts, indicators of impact, thresholds and monitoring methods for the following receptors:

Chapter 3: Benthos;
Chapter 4: Littoral habitats;
Chapter 5: Birds;
Chapter 6: Marine mammals, including cetaceans, seals and basking sharks;
Chapter 7: Marine reptile;
Chapter 8: Coastal processes;
Chapter 9: Cultural heritage;
Chapter 10: Fish and fisheries.

This guidance is based on generic descriptions of offshore renewable energy. With the exception of wind, the industry has not yet delivered commercially viable full scale production models of either wave or tidal energy devices.

Terrestrial habitats with the potential to be impacted by the construction of offshore renewable energy projects are outside of the scope of this document. In this regard, *Guidelines on the Information to be Contained in Environmental Impact Statements,* EPA, 2002, and *Advice Notes on Current Practice in the Preparation of Environmental Impact Statements*, EPA, 2003 offer guidance on the undertaking of Environmental Impact Assessment (EIA) generating an Environmental Impact Statement (EIS) that formally consider each impact of a project on all aspects of the receiving environment.

Similarly, Appropriate *Assessment of Projects and Plans in Ireland: Guidance for Planning Authorities*, DEHLG, 2009 provides guidance on the undertaking of Appropriate Assessment (AA) that may generate a Natura Impact Statement (NIS), where potential impact on a European site may arise from a proposed project. It is important to note that assessment of terrestrial habitats with the potential to be impacted by offshore renewable energy developments should form part of the EIS or AA. This assessment should not constitute a separate project.

As part of this guidance, a baseline survey tool and a monitoring tool have been developed as a separate appendix. It summarises and responds to observed generic offshore renewable energy project environmental effects. The **baseline survey** tool should direct and stress test the extent and type of surveys undertaken to establish an environmental baseline for a project's receiving environment. The **monitoring tool** is provided on the same basis, and acts as a guide and stress test for the identification of potential effects, impacts and indicators.

2. Introduction

Properly designed and executed baseline data gathering and surveys are critical for establishing the condition of the receiving environment for Appropriate Assessment (AA) and Environmental Impact Assessment (EIA). Formal comprehensive knowledge of the existing environment, including its natural variability, is a necessary benchmark against which change may be predicated, detected, mitigated and measured when seeking to detect change as a result of impact from a project. This information which includes a formal description of the dynamic receiving environment is called the "*Baseline*".

While offshore wind is reasonably well established, no full-scale commercial wave or tidal energy devices or farms have, at the time of writing, been developed and deployed. Therefore, only generic descriptions of the likely technology and their potential environmental impacts can be provided. A description of the various device types currently under development is provided in Appendix I of this document, and a summary provided below at box 1.

Wave Energy Devices (WEDs)

There is a range of devices suitable for location in the nearshore and offshore environment. All WEDs comprise a sub-surface component (moorings, lines, anchors, foundation) and some have a surface or above surface component). WEDs may be installed as a single device or as an array of devices, depending on the technology. There is a range of devices currently being tested and the technology remains novel. Ireland's wave resource is greatest on the west, south and north coast where environmental conditions are more extreme.

Tidal devices

Tidal devices are located in tidal streams, such as narrow straits and inlets, around headlands, and in channels between islands. Devices are mainly subsurface but there may also be a surface component. A single device or a number of devices may be located within a tidal stream. Ireland's tidal stream resource is limited; the best locations can be found on the north and north east coast, and on discrete sites such as the Shannon Estuary, with low potential elsewhere.

Wind

Wind turbines are the most established offshore technology. Wind farms are in operation at several offshore sites in Europe. Wind turbines have a subsurface component (foundation) but the main components are above surface (tower, hub, turbines). Wind turbines may be located singly or as an array. Ireland's wind resource potential is high around all of its coast line.

Box 1: Summary of current Offshore Renewable Energy technologies

2.1 Baseline data

The gathering of baseline data will vary considerably depending on the location, type and scale of the project, complexity of the receiving environment and the availability of existing data. A review of data currently available to the offshore renewable energy sector has been compiled in *Data and Information Sources for Offshore Renewable Energy Developments,* DCCAE, 2016 and should assist developers and professionals working on their behalf to identify data and information resources.

While this guidance aims to provide an overview of current best practice for the gathering of baseline data, it does not intend to be overly prescriptive, and should not be regarded as an exhaustive record of environmental topics for analysis. As renewable energy technology develops and rolls out at a commercial level, the body of scientific knowledge relevant to pressures and potential impacts will increase and better inform baseline surveys and monitoring techniques. Survey methods are constantly improving and being modified; based on new scientific research and the development of new technologies (e.g. spatial encoded and high definition video imagery). Therefore, this document sets out the generally accepted methods employed at the present time, and it recognises that individual professionals will amend and adapt the methods described, so that they are fit for purpose and project specific.

All potential receptors identified in this guidance occur in, or on the margins of the marine area; they differ from one another in habitat and/or sensitivities. But similar potential impacts of offshore renewable energy projects have been identified where the receiving environment is marine rather than terrestrial as described at box 2. Such impacts will require mitigation on a project by project basis.

Box 2 Examples of typical Offshore Renewable Energy environmental impacts on benthic

- **Construction phase:** Smothering of species and habitats and increased suspended solids causing reduced light penetration need to be considered.
- **Construction phase:** Trenching or ploughing activities to bury cables and pipes may lead to increased suspended solids causing turbidity and reduced light penetration.
- **Construction phase:** Rock armouring to bury cables that cannot be trenched may lead to the creation of structures on areas of previous sediment habitat; changing its structure and function and causing habitat fragmentation.
- **Operation phase:** Certain WEDs may have large underwater base plates which may lead to shading of the habitats below them; causing changes to the community composition and a resultant alteration of structure and function, due to reduced light levels.
- **Operation phase:** Tidal devices may cause significant changes to the hydrodynamics of an area. This could lead to changes in areas of sediment deposition, accumulation and erosion, and to changes in community composition, for example, through changes in tidal strength and direction.
- **Full project lifecycle:** Accidental spillage of fuel and /or oil from construction and maintenance vessels and vehicles, and the devices themselves, together with damage to biotopes and species from direct impact.

habitats and communities.

2.2 Assessment of likely and significant effects

Ireland has transposed the EU Directives on EIA into Irish law. The requirements deriving from EU law are reflected in current consenting processes. Although this legislation does not prescribe a measure of significance, guidance exists from the EPA[2] to aid the process of assigning the likelihood and significance of predicted change on any environmental receptor.

This document provides guidance on obtaining baseline information to assess likelihood and significance of a project impact on its receiving environment, in order to meet environmental assessment regulations. It is not a definitive set of rules, but assumes that specialists will be engaged to conduct the surveys and to use the information gathered to make an informed assessment of significance.

2.3 Assessment of thresholds

As part of the EIS mitigation commitments, indicators and appropriate thresholds should be established for each project pressure that could lead to a significant and unacceptable impact on a receptor. The indicator/monitoring combination should have sufficient sensitivity to detect impacts before they become significant. Thresholds are best derived from quantitative data. Where this is not possible, qualitative data may be used. Indicator thresholds should be set as a deviation from a baseline value.

It is important to determine a set of indicators that will allow such change to be detected. Indicators and thresholds values should be established once the baseline gathering stage of the project (pre-construction phase) has been completed, and they should be subsequently monitored. Surveillance indicators, that measures background changes not attributable to the project, can also be selected to enhance understanding of the environment and support interpretation of the monitoring results.

2.4 In-combination and cumulative effects

In-combination or cumulative effects refer to the combined effects of multiple activities and projects or the cumulative effect of change by a project on multiple receptors.

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[2] Guidelines on information to be contained in Environmental Impact Statements (EIS). Available at: http://www.epa.ie/pubs/advice/ea/guidelines/

When considering in-combination effects, the scope and design of the project potential effects must be assessed together with other unrelated developments (either *in-situ* or currently in development). For example, while a specific number of devices or arrays within a particular site may not lead to significant negative impacts on a particular receptor, increasing the number of devices or arrays may do so.

In the same way, while a particular project may not lead to significant negative impacts on a particular receptor, the predicated likely change to several receptors will need to be considered in relation to its cumulative significance.

Effects may be transboundary when in-combination effects of multiple projects and cumulative effects on multiple receptors occur. For certain receptors, it is difficult to accurately assess cumulative impacts on some highly mobile species e.g. birds and marine mammals. Data on the distribution and movement of these species is limited, both nationally and across jurisdictions. However, in the EIA process the precautionary principle applies, and every effort must be made to assess those effects.

Standardised frameworks for assessment of cumulative effects are identified in Section 4.6.6. of *Guidance on EIS and NIS Preparation for Offshore Renewable Energy Projects*, DCCAE 2016.

2.5 Practical considerations

Gathering data in marine environments is challenging. This is particularly relevant to offshore renewable energy projects, where the site has been selected for its exposure to high wind, wave and/or tidal conditions. For example, typical issues encountered may include the operation of drop down video in exposed areas, or when conducting dive surveys when weather conditions are unsuitable. Similarly, grab sampling cannot generally take place in a sea state of greater than force 4, and periods of heavy swell may prevent the sampling vessel approaching stations that are close to marine habitats.

When designing surveys, sites should be selected to avoid bias, while at the same time providing for practical considerations, such as inclement weather conditions. For instance, intertidal sampling can usually be undertaken at any time, but preferably between the months of May and September, when the predicted tidal height is no greater than 0.6 meters. Further examples include (but are not limited to);

- low aerial flights which may not be possible post-installation;

- detection of birds from the shore is diminished beyond 2km, therefore offshore surveys are required; and,
- boat, land and aerial surveys cannot be completed in certain sea states.

It is important to avoid data gaps; contingencies should be built into the survey design to ensure that required data can be gathered so that a meaningful evaluation can be made. This may necessitate longer survey periods and/or the use of modelling.

Practical considerations should inform proposed ongoing monitoring programmes. Monitoring effort should be proportional to risk, and a compromise between the quantity of resources required to detect change and the perceived consequence of that impact should be made.

In order for identified mitigation measures to be credible, and in the interests of efficient project design resources; baseline survey points will become the source for full lifecycle monitoring of receptors, where monitoring is required as part of an EIS or condition of consent.

2.6 Scope and scale of monitoring

The scope and scale of a monitoring programme should be consistent with the type and scale of the project and the pressures and likely significant effects identified and mitigated in the EIS, arising from the EIA.

3. Benthos

Habitats that extend below the Mean Low Water Spring (MLWS) mark are considered in this section. Benthic habitats are divided into sublittoral reef (including rock) and sublittoral sediment habitats. Within these two divisions the Annex I habitat; *Sandbanks which are slightly covered by seawater at all times* (EU habitat code: 1110) is considered to be subject to the same or similar impacts, survey methods and monitoring as other subtidal sediment and is not considered separately. Benthic habitats considered here include sublittoral reef, sublittoral sediment and sandbank below the MLWS.

Useful information on seabed habitats is available from the Department of the Community and Local Government (DECLG) as a result of the implementation of the Marine Strategy Framework Directive including the distribution of predominant seabed habitat types. Ireland's Marine Atlas also provides spatial information on seabed habitats including multi-beam echo sounder data and seabed sampling data, acquired during the national seabed mapping programmes. Collated EUNIS, EMODNet and Natura 2000 seabed habitat surveys are the primary sources of data used in the generation of this seabed substrates layer, see *Data and Information Sources for Offshore Renewable Energy Developments*, DCCAE, 2016.

3.1 Subtidal reef

Subtidal reef is characterised by rocky substrates and biogenic concretions, which arise from the seafloor in the sublittoral zone. Reefs can be either biogenic concretions or of geogenic origin. They are hard compact substrata on solid and soft bottoms, which arise from the sea floor in the sublittoral and littoral zone. Reefs may support a zonation of benthic communities of algae and animal species as well as concretions and corallogenic concretions. Box 3 provides a description of reef habitat as provided by the *The Interpretation Manual of European Union Habitats - EUR28*, EC, 2013.

- *"Hard compact substrata"*: rocks (including soft rock, e.g. chalk), boulders and cobbles (generally >64 mm in diameter).
- *"Biogenic concretions"*: concretions, encrustations, corallogenic concretions and bivalve mussel beds originating from dead or living animals, i.e. biogenic hard bottoms which supply habitats for epibiotic species. These reefs form particularly fragile ecosystems and are therefore more sensitive to change.
- *"Geogenic origin"*: reefs formed by non-biogenic substrata.
- *"Arise from the sea floor"*: the reef is topographically distinct from the surrounding seafloor.
- *"Sublittoral and littoral zone"*: the reefs may extend from the sublittoral uninterrupted into the intertidal (littoral) zone or may only occur in the sublittoral zone, including deep water areas such as the bathyal.
- Such hard substrata that are covered by a thin and mobile veneer of sediment are classed as reefs if the associated biota are dependent on the hard substratum, rather than the overlying sediment.
- A variety of subtidal topographic features are included in this habitat complex such as: Hydrothermal vent habitats, sea mounts, vertical rock walls, horizontal ledges, overhangs, pinnacles, gullies, ridges, sloping or flat bed rock, broken rock and boulder and cobble fields.

Box 3 Subtidal and intertidal reef habitats

While the biological community composition of subtidal reef provides important information on its health and conservation status, there is little information available on the community composition of subtidal reef in Ireland. The BioMar project which was completed in 2007 provides the most comprehensive data set for Irish subtidal reef habitats. However, the BioMar project was limited in its scope and extent and provides point data for a selected number of sites in Ireland.

In addition, the Marine Nature Conservation Review (MNCR), 2004 for Britain and Ireland, which describes the biotope classification scheme, is often difficult to apply to Irish reef habitats, as the information used to define the scheme lacked an adequate level of replication and spatial data relevant to Irish sites. Where a particular project site lacked relevant data, the MNCR anticipated that a site survey could be required, as set out at 'survey methods' below.

More recent surveys of the extent, distribution and broad community complexes of selected subtidal reef within Natura 2000 sites in Ireland has been conducted through a series of baseline mapping programmes conducted by the NPWS of the Department of Arts, Heritage and the Gaeltacht. These surveys were conducted remotely (bathymetric and dropdown video surveys), and data derived from them does not have the required resolution level to adequately measure change likely to arise from a project. However, they proved useful for Natura 2000 site selection and survey design.

3.1.1 Pre-construction baseline

Identification of potential impacts

Offshore energy projects throughout their life cycle (location, design, method of construction, operation and decommissioning) have the potential to cause habitat fragmentation, changes to community structure and function, species loss, the introduction of Invasive Alien Species (IAS), and the creation of structures which have an artificial reef type effect. All of these potential project lifecycle impacts should be assessed when creating a robust ecological baseline.

Every structure associated with offshore renewable energy will inevitably be colonised by sessile animals and algae. Biofouling of structures may have the potential to impact on subtidal reef habitats by facilitating recruitment of invasive alien species and their spread to subtidal reef, while the use of rock armouring may lead to habitat fragmentation of sediment communities.

Indicators for identified impact

Indicators can only be identified following initial site surveys to assess the characterising species and biotopes, depth, aspect and exposure of the subtidal reef habitat.

While notable species (rare, unusual, sensitive or Annex II species) may be present within the site, they may not necessarily represent good indicator species as their abundance or distribution may not be adequate in detecting change. They should however be recorded and flagged as present, and targeted during subsequent monitoring surveys.

Survey methods

Standard survey methods for the survey of subtidal reef should begin with the use of bathymetric mapping to measure the extent of the habitat area. This will normally be completed as part of the initial site suitability investigations, and should be used to map the extent of the habitat. Such remote mapping methods should be supplemented with dropdown video or Remotely Operated Vehicle (ROV) video to determine and map the characterising habitat complex and biotope complex. All video surveys should, where possible, be ground-truthed and supplemented by dive surveys (Marine Nature Conservation Review, Phase I surveys). Video surveys alone are not sufficient to fully characterise biotope complexes.

Modelling techniques should be conducted to calculate changes to flow regimes, especially in the case of tidal devices, where changes in the hydrodynamics of the site are more likely. (See section 8 for more detail).

The Before, After, Control, Impact (BACI) design can be employed to structure the project and provide a mechanism for future monitoring and measurement of change. Such a design should be proportional to the assumed risk, which will be greater for some elements of the project, and less for others.

When considering survey methods within marine Natura 2000 sites that have the potential to be impacted by a project the specific "*features of interest*" for the site should be considered. Any impact on a European site will generate the need for AA and an NIS to support an application for consent for that project. The NPWS has compiled conservation objectives with specific targets and attributes for marine European sites which aim to '*maintain or restore to favourable conservation status the habitats and species for which the site has been selected'*. In sites where the process of setting detailed conservation objectives has been finalised, specific targets and attributes have been set for selected habitats and species. These should be reviewed prior to planning a site's survey methodology to ensure that targets can be accurately assessed, measured and monitored.

Data analysis

Community level analyses, incorporating the whole species community present provides a statistically robust measure of an ecosystem response to change. It should therefore be used where the scale and scope of the project indicates sufficient potential impact. PRIMER (Plymouth Routines In Multivariate Ecological Research) is generally the software of choice for the analysis of community data in the marine environment. It has the capacity to carry out a range of univariate and multivariate routines for analysing the species and sample abundance matrices that result from macrofaunal sampling for impact studies and associated physio-chemical data.

Patterns in species composition and similarities between sample stations should be demonstrated using non-metric multidimensional scaling and statistical differences in communities, and sample stations can be evaluated using the analysis of similarities (ANOSIM) test.

3.1.2 Post-construction monitoring

Monitoring methods

Monitoring of the post-construction conditions should use the same methodology as that employed for the pre-construction baseline. Based on the pre-construction survey results, monitoring sites and frequency should be selected to represent the range of temporal and spatial variation of biotope complexes identified across the site, and should include the continued monitoring of selected control sites. Monitoring surveys should include an assessment of sessile epifauna and flora on the devices and their associated infrastructure. Changes to flow regimes should be measured.

Monitoring should be in accordance with environmental assessment findings and predicted impact. For example, in exposed subtidal reefs where the biotope has been identified to be characterised by low species diversity and abundance, there may be little merit in undertaking detailed quantitative monitoring studies. In such cases, remote survey methods (drop down video or RVO inspection) may be sufficient to assess the biotope and monitor change. However, there is evidence from other countries that using drop down video unsupported by diver ground-truthing can lead to erroneous assessments of biogenic reef habitat condition, and therefore some degree of diver-conducted verification is recommended.

Depending on the nature and scale of the project, surveys may be required on an annual basis for the first two years of the life of the development, and on a six yearly basis thereafter. As the impacts of wave and tidal energy devices are less well known than the impacts of wind energy devices, due to the lack of commercial development, annual monitoring for the first three years may be considered appropriate. As the knowledge base expands following full scale commercial development of the industry, it is possible that the monitoring frequency may be reduced. However, this will be dependent on the results of surveys as they become available.

3.2. Subtidal sediment

Subtidal sediment is often a feature of the EU Annex I habitat *Large Shallow Inlet and Bays* (EU habitat code 1160), but also occurs outside of this habitat type.

The following EU Habitats Directive, Annex I habitats are included:

- Sandbanks which are slightly covered by sea water all the time (EU Habitat code: 1110).
- Estuaries (EU Habitat code: 1130).

Subtidal sediments range from areas dominated by maërl communities to a range of fine, coarse and mixed sediments characterised by various community types.

The MNCR classification of sublittoral sediment habitats considers those that occur in the sublittoral near shore zone (i.e. covering the infralittoral and circalittoral zones), typically extending from the extreme lower shore down to the edge of the bathyal zone (200m). Within this zone, sediment ranges from boulders and cobbles, through pebbles and shingle, coarse sands, sands, fine sands, muds, and mixed sediments are described.

The depth, exposure, type of sediment, salinity and turbidity of the waterbody, together with its geographical location, will determine the diversity of associated species and communities present. Inshore sublittoral sediments and their associated communities are often highly variable, even across small spatial scales. For example, it is not uncommon to record five or six different community complexes within the same bay.

Natural changes in the extent of sublittoral sediments are not uncommon, particularly in areas of dynamic hydro-physical regimes. Variations in tidal or weather conditions, e.g. storm events or increased deposition of sediments will each contribute to a change in the extent and distribution of subtidal sediments, especially in near shore environments.

3.2.1 Pre-construction baseline

Identification of potential impacts

The potential impacts of WED's, tidal devices, wind energy structures and their associated infrastructure and construction methods on subtidal sediments are similar to those that apply to subtidal reef.

Indicators for identified impact

Potential indicators include; direct habitat and species loss, habitat fragmentation, changes to community structure and function, occurrence and/or increase in invasive alien species.

The pre-construction baseline survey dataset should be analysed to allow a set of suitable indicators to be identified and to estimate the threshold where changes to each indicator should be flagged.

Survey methods

Subtidal sediments may be highly variable in their distribution and patchiness. For this reason, the most important aspect of the survey design is to ensure that adequate replication of samples and sample stations takes place to predict and detect change resulting from the project. Adequate and appropriate control sites which represent the special scale and variation of the project site, while sufficiently distant to be outside of the zone of potential impact, also need to be considered.

In the first instance, a drop down video should be used to provide an overview of the seabed habitat type; prior to deciding on the most appropriate sampling method and to aid in the location of sampling stations.

Standard sampling methods for sediment habitats involve the sampling of a bite of the sediment so that a quantitative assessment of the macrofaunal community composition can be made. Various techniques are recommended depending on the depth and nature of the seabed. Typically, the use of a 0.1 m^2 Day grab, sufficiently weighted to take an appropriate bite of the sediment type in question, is recommended for soft sediments in relatively shallow (less than 50 meters Below Chart Datum) waters. Other grab sampling devices, such as a van Veen grab for harder sands, or a Hamon grab, for courser sediments, may be more appropriate. While in deep water, the use of a box corer should be considered. Depending on the nature of the sediment, each of these tools is suitable for obtaining quantitative samples.

All grab samples should be accompanied by a sediment sample from the exact same locations as the grab samples, so that the sediment particle (grain) size and organic content can be measured. Without this data, the results of the infaunal analysis cannot be fully assessed. Standard methods for the analysis of sediment particle (grain) size include dry sieving and laser diffraction particle sizing. While organic carbon is generally measured using the *Loss on Ignition method,* high temperature oxidation (using an elemental analyser) is also an option.

A range of additional survey methods for the assessment of subtidal sediment are available. For example, Chlorophyll measurements for the assessment of photosynthetic biomass on the sediment surface, and pH and Eh measurements can be used to assess acidity and redox balance. However, their use is not a standard requirement, when assessing the baseline relevant to the deployment of renewable energy devices.

Macrofaunal analysis should be carried out by competent expert taxonomists who will ensure that standard protocols for the identification, enumeration and quality assurance of all samples processed are observed. When considering survey methods within marine Natura 2000 sites, the specific "*features of interest*" for the site will need to be considered (Section 3.1.1).

Data analysis

Standard statistical analytical tools such as PRIMER and analysis of similarities (ANOSIM) test should be deployed to build a strong baseline (Section 3.1.1).

3.2.2 Post-construction monitoring

Monitoring methods

Subtidal sediment surveys should ideally take place between the months of May and September. They should take place at a pre-determined subset of the baseline survey stations to include continued monitoring sites. Surveys should take place on an annual basis for the first two years of the life of the development to assess recovery, and on a six yearly basis thereafter. (See section 3.1.2 for further detail on the rationale for monitoring frequency). In particularly exposed sites, where the baseline data shows the community composition to be characteristic of species-poor, and/or exposed sediment specialist species, monitoring could be reduced to a six yearly cycle following the initial base line survey.

4. Littoral habitats

Littoral habitats include all habitats within the intertidal area (between the upper limit of the strandline and Mean Low Water Spring (MLWS) tide). They include habitats comprised of rock, sands, gravel, cobble and pebbles of more exposed areas to the finer sands and muds that dominate more sheltered locations.

4.1 Intertidal reef

Intertidal reef is classed as a feature of the overall EU Habitat Reef (EU Habitat code 1170). It is characterised by rocky substrates and biogenic concretions, exposed at low water. Intertidal reefs can be either biogenic concretions or of geogenic origin. They are hard compact substrata on solid and soft bottoms, which arise from the sea floor in the littoral zone (See box 3).

The distribution of intertidal reef habitats and the communities it supports is strongly influenced by physical factors; exposure, gradient and general reef geomorphology. These factors create the dynamics of the reef community which is frequently unstable, due to a combination of the physical and biological factors. Intertidal reef communities often rely on a few keystone species which strongly influence the characteristic biotopes. Often the presence of a few key species can be sufficient to determine and map the biotopes present.

4.1.1 Pre-construction baseline

Identification of potential impacts

Due to the location of this habitat within offshore renewable energy project sites, it is most likely to experience potential impact via ancillary, facilitative development. Techniques for bringing cables ashore on intertidal reef habitats (littoral rock) will generally require directional drilling and/or the burial of cables and pipes with boulder material (rock armour) over existing hard substrates. Discharges of drill cutting and drilling fluid during directional drilling, has the potential to cause species loss and injury and should be considered in the monitoring programme.

The use of rock armour will lead to habitat and species loss and may lead to habitat fragmentation, changes to community structure and function, and increase the potential for the introduction of invasive alien species. If the rock used is of a different geological composition and structure to that of the intertidal reef, the impact will be greater.

Indicators for identified impact

These indicators can include direct habitat and species loss; habitat fragmentation; changes to community structure and function; occurrence and/or increase in invasive alien species and increased sedimentation of the adjacent waterbody, through overflow of containment pits used in directional drilling operations. The pre-construction baseline survey dataset should be analysed to allow a set of suitable indicators to be identified, and to estimate the threshold where changes to each indicator should be flagged.

Survey methods

Intertidal reef communities are subject to a high degree of natural change and reef community structure can vary greatly with time. It is therefore important that sampling methods are adequately designed to detect such natural variation, and to distinguish between natural and anthropogenic change. For this reason, a fully quantitative approach should be employed so that natural changes in community composition can be measured. This will require a well-designed approach, whereby the entire zonation of the shoreline is sampled along fixed transects at fixed quadrat locations, together with appropriately selected control sites.

Baseline surveys should calculate the total habitat area and the area of each biotope within the habitat. They should be designed to record the characterising species and their abundance within each biotope so that change can be measured in the future. Measuring the abundance of 15 to 30 key species in this instance may be sufficient to measure change.

Surveys should be planned to ensure that they take place when the predicted tidal height is no greater than 0.6 meters. All surveys should ideally take place between the months of May and September. When considering survey methods within marine Natura 2000 sites the specific "*features of interest*" for the site should be considered. (See section 3.1.1).

Data Analysis

The use of community level analyses as at sections 3.1.1 and 3.2.1, incorporating the whole species community present, is considered to provide a statistically robust measure of an ecosystem response to change and should therefore be used.

4.1.2 Post-construction monitoring

Monitoring methods

Monitoring requirements will be largely dependent on the construction methods used. For example, if rock armouring was employed during construction, monitoring of a pre-determined subset of the baseline site(s) could be conducted for three years post construction to assess recovery and potential effects of habitat fragmentation, and invasive alien species recruitment. In such cases, monitoring surveys should ideally take place between the months of May and September. If directional drilling rather than rock armouring was used, monitoring of the site is unlikely to be necessary.

The potential of this habitat to be an access route during operation and decommissioning of the project must be considered relative to receptors, in order to scope this area for further monitoring.

4.2 Intertidal sediment

Intertidal sediments are often a feature of the EU Annex I habitat "Large Shallow Inlet and Bays" (EU habitat code 1160). They include the EU Habitats Directive, Annex I Habitat "Mudflats and sandflats not covered by sea water at low tide" (EU Habitat code 1140). For completeness, the Annex I habitat "Annual vegetation of drift lines" (EU Habitat code 1210) has also been included in this section.

The intertidal area (between the upper limit of the strandline and Mean Low Water Spring (MLWS) tide includes habitats comprised of sands, gravel, cobble and pebbles of more exposed areas to the finer sands and muds that dominate more sheltered locations.

The MNCR classification of intertidal sediment habitats describes those that are dominated by shingle (mobile cobbles and pebbles), gravel, sand and mud or any combination of these which occur in the intertidal zone. Littoral sediment is defined further using descriptions of particle sizes: mainly gravel (16-4 mm), coarse sand (4-1 mm) and medium sand (1-0.25 mm); fine sand (0.25-0.063 mm) and mud (less than 0.063 mm) and various admixtures of these (and coarser grades)- muddy sand, sandy mud and mixed sediment (cobbles, gravel, sand and mud together).

Intertidal sediment shores are a feature of less exposed areas than intertidal reef shores. The composition of sediment shores can vary from cobbles and boulders on the more exposed sites, while the higher the degree of shelter from wave action, the finer the sediment size. Muddy and muddy sand shores generally occur in sheltered inlets and within estuaries where sediments can settle out.

Intertidal sediment habitats can be highly variable over seasonal cycles. Storms can cause considerable temporal variation in the macrofauna of intertidal sediment on exposed coasts. Flood events, leading to excessive amounts of freshwater and associated sediment load into estuaries, can also significantly alter both the macrofaunal component and bathymetry of the estuary. On the other hand, sheltered muddy shores where runoff from the land is not a factor, are generally more stable throughout the year.

4.2.1 Pre-construction baseline

Identification of potential impacts

Construction methods for ancillary project works involving bringing cables ashore are similar to those employed for intertidal reef, and are likely to be the main factor influencing the ecology of intertidal sediments. Generally cables are brought ashore on sandy or muddy sediments by trenching or ploughing techniques. Such activities and the construction traffic, track machines etc. associated with them have the potential to impact the sediment through disturbance and compaction. In areas where boulder and cobble are present, excavation of the material may be required. This may lead to disturbance and damage to species; particularly to the vascular plants that colonise these areas.

Trenching and ploughing on exposed sandy beaches is unlikely to cause a significant impact. Such shores are characterised by a low diversity and abundance of species that are specialists of exposed coasts, and capable of withstanding disturbance. Often trenching activities on exposed shores would be undetectable following a few tidal cycles. However, such activities on more sheltered shores, with more compact fine sands and muds, could lead to significant impacts. Intertidal sediments which host the marine angiosperm *Zostera noltii* are particularly vulnerable to impact by activities such as trenching and ploughing, and their associated plant and machinery.

Indicators for identified impact

Indicators can include: direct habitat and species (including vascular plants) loss; habitat fragmentation; changes to community structure and function; occurrence and/or increase in invasive alien species.

The pre-construction baseline survey dataset should be analysed to allow a set of suitable monitoring indicators to be identified if necessary.

Survey methods

Standard methods for the assessment of intertidal sediment require that the experimental design is based on a random stratified approach to the selection of sampling stations within the intertidal area. This should include adequate sampling of the low, mid and high shore zones of the area under consideration. However in some areas, where the gradient of the shore is particularly shallow, all three zones may not be present. Sampling should only take place when the predicated height of low water is no greater than 0.6 meters.

Typically, sampling five 0.01m^2 cores taken to a depth of 20cm and sieved through a 1mm mesh sized sieve, are required for benthic faunal analysis. Larger macrofauna is generally sampled by conducting a dig-over of a 1 x 1m^2 quadrat at the same station.

Each intertidal core station sampled needs to be accompanied by a sediment sample from the same location, so the sediment particle (grain) size and organic content can be measured. Without this data the results of the infaunal analysis cannot be fully assessed. Standard methods for the analysis of sediment particle (grain) size include dry sieving and laser diffraction particle sizing. While organic carbon is generally measured using the *Loss on Ignition* method, high temperature oxidation, using an elemental analyser is also an option.

Macrofaunal analysis should be carried out through competent expert taxonomists to ensure that standard protocols for the identification, enumeration and quality assurance of all samples processed are maintained.

Intertidal sediment habitats hosting the marine angiosperm *Zostera noltii* and other OSPAR listed intertidal species should be surveyed separately. In such instances quadrat sampling should be conducted to estimate biomass abundance and the exact extent of the biotope should be accurately mapped. When considering survey methods within marine Natura 2000 sites the specific "*features of interest*" for the site should be considered (See section 3.1.1).

Data Analysis

The use of community level analysis, as at sections 3.1.1, 3.2.1 and 4.1.1, incorporating the whole species community present, is considered to provide a statistically robust measure of an ecosystem response to change and should therefore be used.

4.2.2 Post-construction monitoring

Monitoring methods

Continuous or ongoing monitoring of intertidal sediments will not be necessary unless further disturbance (e.g. cable maintenance or inspection) is required. Mitigation measures can be designed for cable maintenance and inspection if they are needed.

5. Birds

5.1 Pre-construction baseline

Identification of potential impacts

Impacts vary and are based on a number of factors including: the type of device, their number, size and layout; the species present, their behaviour and use of the site (temporal and spatial; attraction to habitat features), and their sensitivity to change. Impacts will also vary with the project lifecycle stage.

Box 4 Examples of typical Offshore Renewable Energy potential impacts on birds

- **Common direct impacts are**; disturbance (noise, human activity, presence of structures); displacement (avoidance resulting from disturbance, loss of foraging habitat); attraction (roosting), underwater and above water collision; entrapment.

- **Common indirect impacts are**; changes in sedimentary process, pollution, change in foraging resource (e.g. fish aggregation effects) and displaced fishing effort with implications for foraging resources (positive and negative).

- **Key potential impacts dependent on device type:**
  Wave Energy Devices; disturbance (change in behaviour); displacement (habitat loss); attraction, and specifically underwater collision and entrapment. Above water collision should also be considered, but the risk will be lower for most WEDs as they lie close to the water surface. The use of near shore WEDs as a land bridge for predators gaining access to island breeding sites should also be considered.

  Tidal Devices; disturbance (change in behaviour); displacement (habitat loss); food supply (habitat alterations); attraction and specifically below water collision.

  Wind Turbines; Key potential impacts are disturbance (change in behaviour), displacement (habitat loss), attraction, and specifically above water collision and barrier to movement.

Indicators for identified impact

Impacts can be considered in terms of regional or local effects. Regional effects on seabird populations from a project may lead to changes to the composition of species present, their abundance, density and spatial distribution (displacement effects). There may also be changes in temporal patterns of abundance (with the influence of tide, season, time of day) and changes in habitat use (surface, mid- water, seabed, air-space), or in use of particular habitat features (tide race, shallows, etc.)[i]. Local effects are defined as disturbance causing change in behaviour (e.g. foraging activity), micro-avoidance (in the vicinity of a device), above and below water collision, and entrapment leading to injury of mortality.

The ability to predict likely impacts will depend on the quality of existing data together with baseline survey data. There is likely to be a lack of detailed data on the use of many sites by seabirds. Data for potentially linked or "connected" Special Protection Areas is also likely to be limited. Lack of data should be acknowledged in impact predictions and where necessary, a precautionary approach should be adopted. Grading the proposed development site in terms of the level of information available and confidence in survey results may be useful.

The likely significance of predicted impacts on bird populations can initially be assessed qualitatively, using risk assessment based on the scale and type of proposal and likely pressures, species sensitivity and conservation status. Quantitative predictions, using statistical analysis and modelling should be used where likely significant pressures are predicted in the risk assessment. Where species or areas protected under the EU Birds Directive, and RAMSAR sites are likely to be impacted, national and international population levels assessments will be required.

Survey methods

Survey design will depend on the project, its location and whether the species identified is likely to be significantly affected. Experts should assess the sensitivity of species as an inherent characteristic of the site, the type or numeracy of its interactions with the project and/or its conservation status and European site connectivity.

As natural variability in seabird distribution/abundance/productivity is substantial, long term data with a robust sample size is required to detect changes. Small scale changes may not be detectable due to the sample size (and substantial cost) that would be required. Aerial (digital or visual) surveys can cover a large area over a shorter period than boat or ship surveys with observers; however, this has considerable additional cost implications (the cost implications are reducing especially for large off-shore sites where digital aerial surveys have become the norm). Use of Remote Monitoring Technologies will provide additional data e.g. nocturnal activity; again at considerable extra cost for both survey and data analysis. As a result, where proposed development sites are sensitive, large, or likely to result in cumulative impacts survey effort should be proportionate, and greater and potentially more specialised survey effort will be required.

Detection of birds from the shore is diminished beyond 2km. Land based surveys are appropriate where the development footprint lies within 2km of the shore, otherwise offshore surveys are required. Common survey methods and issues encountered in offshore and on shore bird surveys are outlined in the next section which discusses bird survey design and scope

Box 5: Bird Survey - design and scope

Design-based approaches to bird surveys will require an element of transect randomisation which may be impractical for very small or very large sites. For large scale developments, parallel line transects that cover both the potential impact area and non-impacted area(s) (e.g. a surrounding buffer area or other control sites for before-after-control analysis) are recommended. For larger scale projects, transects should be placed 2 nm apart to reduce double-counting. This spacing will not be appropriate for smaller scale sites and should be narrowed as necessary, though still considering potential for double-counting. Priority is on ensuring good coverage of the study site rather than maintaining a 2 nm separation. Zig-zag surveys can be used to increase survey efficiency for large areas. *Sampling effort should be focused on increasing sampling events at the level of inference (area of impact) rather than on increasing subsamples within the area of impact (e.g. number of transects surveyed).*

Line transect data can be used to generate abundance and density information within the area of potential impact and in non-impacted areas. Transects positioned across the proposed development and surrounding buffer can be used for Before-After-Gradient (BAG) analysis. BAG should only be used if there is reasonable likelihood of effects decreasing systematically with distance in all directions from the projected impact. Projects using Before-After-Control-Impact (BACI) approaches require transects through both test and control sites, with adequate coverage in each zone. BACI analysis should be limited to projects for which one or more true control site(s) is available and resources allow for large sample sizes. Due to noisiness of seabird data, BACI analysis tends to be more effective for detecting a relatively large effect, and where changes are to be detected over a relatively short time period, rather than as part of a longer term monitoring programme.

For designed projects and applying estimated abundances to the non-sampled space, an element of randomisation in transect placement/selection (e.g. randomise transect start point for set of evenly spaced transects) may provide better data for such estimates. Where randomisation has not been applied, model-based inference may still be used to estimate densities for non-sampled areas.

Surveys should cover the proposed site and buffer zone around this area. The size of the buffer area should allow for an adequate number of seabird observations for Covariate Distance Sampling (CDS; >60). Buffer zones should be selected based on the survey method, plausible radius of potential impact, survey practicalities and size of site. The following general guidance is considered a useful starting point [i] 1km buffer for sites <5km^2, 2km buffer for sites 5-10km^2, 4km buffer for sites >10km^2.

If the project uses designed/quasi-designed BACI analysis, surveys should cover the proposed site and buffer zone and appropriate control sites. Depending on the type and scale of the proposal and the sensitivity of the area, up to three years of baseline data may need to be collected. Where long-term surveys are required, they should be temporally distributed across seasons, tide and time of day, as appropriate and should be monthly where possible. Where monthly surveys cannot be achieved, surveys within eight marine bird survey "periods" (mid-winter, late winter, early breeding, mid breeding, late breeding, post breeding/moult, autumn, early winter)[i], should be attempted. Where tidal energy devices are proposed survey effort should be divided equally across all tidal stages. Implementation of such coverage may be difficult where boat based surveys are required as boat use may be limited in areas of strong current.

In situations where shore based surveys methods are employed, monthly surveys should be completed ensuring coverage of all tidal states and times of day over a 2-3 year period, depending on the availability of existing data for the site; bearing in mind that existing data is not likely to cover all tidal states (e.g. I-WeBS). Attention should be given to the species known or likely to be present, as this will have some bearing on survey requirements.

5.1.1 Offshore surveys

The European Seabirds at Sea (ESAS) survey methodology is the standard method for surveying seabirds at sea. This method was developed for broad scale ship and aerial based surveys of seabirds in UK waters and involves transect surveys by boat or aircraft.

For boat based visual surveys, the European Seabirds at Sea (ESAS) standard method uses three elements: 'the band transect', 'the snapshot', and 'the scan' to give an assessment of the abundance, density and distribution of seabirds.

Using the band transect, birds are counted in a 300m perpendicular distance from the boat's route. Birds on the water in this 300 m area are allocated to distance bands from the boat's track (A = <50 m, B = 51-100 m, C = 101-200 m, D = 201–300 m, E >300 m).

The snapshot is used for flying birds, encountered at defined time intervals (dependant on boat speed) within a 300 m bow-to-beam quadrat. The scan records all species encountered in a 90^0 arc (from bow to beam). Direction of flight and behavioural data (passing, active feeding, searching, loafing) age class, and plumage can also be recorded for each species. For conventional distance sampling (CDS.MCDS), perpendicular distance (non-binned) to the observation should be recorded[i].

Recording methods are traditionally by sight, with one observer and one scribe; the use of a dictaphone can reduce personnel requirements. All observations (both in flight and on the water) should be georeferenced to the centre point of the appropriate survey segment, so that each observation has a known latitude and longitude. Weather conditions are relevant for surveys and it is preferable to only conduct observations in sea states <= Beaufort force 5 for boat based surveys. However, the likelihood is that most surveys will take place is sea states <= Beaufort force 4 for health and safety reasons.

The development of 'High Definition Aerial' imagery allows sites to be surveyed by aircraft utilising a camera and the data analysed by computer. The original guidelines for aerial surveys suggested surveys should be conducted in sea states <= Beaufort force 3. However, recent improvements in aerial survey techniques and technology development may allow for surveys in increased sea states.

Box 6: Boat based and aerial bird surveys

Collection of concurrent (georeferenced) oceanographic information (e.g. bathymetry, sea surface temperature, chlorophyll etc.) will support the development of density surface models and understanding of seabird habitat use. This can also help for BACI/BAG inference by accounting for a portion of observed variance, allowing improved detection of changes. Remotely sensed oceanographic data may be used where real-time collection is impractical. Feeding (e.g. surface-feed, shallow dive, deep dive, depth) and other relevant behaviour should be recorded as appropriate.

Standard methodological guidance for seabird at sea census techniques, specifically for offshore wind development, is presented in Camphuysen et.al.[ii].

This guidance has been adapted from the standard ESAS method, to include flight height assessment and modifications for the recording of divers and sea duck. The ESAS method has not been subject to any further adaptions specifically for wave and tidal energy development.

Collision risk to migratory birds that may be linked to distant Natura 2000 sites should also be considered. The extended Band model facilitates an indicative assessment of collision risk to migratory birds. Issues and uncertainties in such assessments are described in a BTO research report[iii].

Box 7 Bird survey flight height assessment

Flight height assessment is required for Collision Risk Modelling[1]. Flight heights can be recorded through a range of survey methods and expressed as bird density (e.g. number of birds flying at a given height as in the 'Snapshot' survey method), bird occupancy in a given airspace per unit time, or bird flux as expressed as birds passing an imaginary transect line per unit time. This data should be recorded as accurately as possible, e.g. +/- 10/20m, rather than in generic flight bands. This will ensure the usability of the data regardless of future changes in turbine design. In addition, this will allow a refinement of the collision risk model to reflect the fact that most seabirds fly close to the sea-surface and may only be at risk of collision with the lower sweep of the rotor. As detailed flight height data at sea may be difficult to record, typical flight heights gathered from other comparable sites[i] could also be used. Flight height data should be presented in terms of density, bird occupancy, or bird flux e.g. birds/km^2, to assess collision risk height with a turbine. At proposed wind farm sites where the collision risk is not negligible, further survey work may be required to assess the significance of the predicted mortality, particularly with regard to impacts on potentially sensitive species. Digital aerial survey techniques, telemetry and altimeters (pressure censors) are becoming increasingly used to gain more accurate flight height data for use in flight height and behavioural assessment.

5.1.2 Land -based surveys

Aside from general guidance [iv] there is no standard survey method for shore based bird surveys in tidal passes[v] or near shore waters. Reporting by EMEC in relation to vantage point watches at MREI test sites in Shetland[vi], provides some guidance on best practice.

Box 8 Shore based bird surveys

Shore based surveys involve vantage point watches from a sufficient number of locations to ensure coverage of the proposed site and buffer zone. Detection of species in good conditions (sea state 3 or less) is likely to be poor beyond 2km with a telescope and beyond 700m with binoculars. Detection can be improved with elevated vantage points.

Recording methods are traditionally by sight, with one observer and one scribe, the use of a dictaphone can reduce personnel requirements.

From each vantage point timed scans of a defined area (defined count sector or grid system) are completed in a consistent and methodological manner, using telescope and/or binoculars, depending on size of survey area. The naked eye may be more appropriate for scans closer to shore. Scans should be completed during a standard time period (assessed at the start of the survey and depending on the time taken to complete a scan and record activity). During scans, the species, number, location and behaviour of birds (e.g. surface feed, surface dive, deep dive, loaf, and aerial forage) are recorded. Data on bird distribution and on flight activity per unit of time can be presented. Radial distance and angle to observations should be recorded where detection is limiting (most scenarios). Provided that the same survey approach is used for each survey, errors such as double counting in the survey data will be repeated for each survey. Data will therefore be comparable between surveys, but absolute numbers will not be available for comparison with other sites. Focused watches may be required, e.g. foraging birds which may be linked to breeding sites, or estimating underwater diving activity.

To allow for the development of density estimates and density surface models[1], vantage point observations need to include radial distance and angle to the observation. This data may be analysed using R package nupoint, which accounts for non-uniform distribution (Cox et al, 2013). Detection declines with distance, even at distances <1km. Vantage point observations without this information cannot be used to develop reliable estimates of density and results should be presented as relative density. Alternatively, where the entire study area is close to the point of observation (e.g. a tidal narrows) and a (reliable) complete count can be made, data could be graphed as complete counts without the need for statistical inference.

5.1.3 Sea and land-based surveys

Surveys in sea states ≥ Beaufort force 5 should be avoided for boat based surveys according to COWRIE guidelines. Ideally land based vantage point surveys should not be undertaken above sea state 4 according to Scottish Natural Heritage guidelines. Weather conditions and the qualifications of the observer (e.g. ESAS accredited) should be recorded for all survey methods. This will allow data to be collated centrally and during analysis any variables can be accounted for, otherwise they present a potential source of bias in the results. The level of survey effort should be proportionate to the sensitivity of the site and the risk from the project. This will have been established as far as possible (given limitations of data availability) at the scoping stage.

Breeding seabird surveys may be required where there is a high potential of impact to a colony. Complete whole colony or sample plot counts depending on the colony size. Usefulness of colony/productivity monitoring should be carefully gauged due to substantial natural fluctuations in marine bird productivity, and difficulty in detecting impacts that are due to the proposed development from natural variations.

Remote Monitoring Techniques can be used to compliment baseline surveys and can provide additional ornithological understanding on the use of a site in both a regional and national/international context[vii]. Such techniques include radar (land, platform, boat and shore based), thermal cameras and night vision, and tagging techniques (radio, satellite, GPS and satellite GPS). Use of these techniques requires specialist equipment and practitioners and involves appropriate survey design. Remote techniques may be required to gather additional data on use of the site such as the following:

- Use of radar surveys to detect large night time migration movements of birds or daily commuting movements at dawn and dusk.
- Use of tracking or tagging devices where it is anticipated that a site may be used by foraging birds connected to a nearby Natura 2000 site or network of sites.

Best practice guidance[vii] is available focusing specifically on the use of Remote Ornithological Monitoring Techniques in the UK. With the growth in number and scale of MREI's in Ireland, the use of these techniques will become important for both single site and cumulative impact assessment.

Breeding bird surveys and use of telemetry devices will require license permits from the National Parks and Wildlife Service.

Data analysis

*A*s discussed in the section on '*survey design and scope',* substantial natural variability in seabird distribution/abundance/productivity means that long term data with a robust sample size is required to detect changes. Similarly, analysis of resultant data should be robust in order that potential change and effects are detectable, and appropriate monitoring regimes are designed.

Current approaches to analysis of bird survey data is set out in the box below.

Box 9: Bird Survey data analysis

Sea-based Survey Data

Line transect survey data should be corrected for declining detection from the centre line using Conventional or Multiple Covariate Distance Sampling (CDS/MCDS) methods and software DISTANCE[1] also available as R package 'Distance' [1].Adjusted densities can then be scaled up to the broader project area, assuming randomisation of transects and appropriate survey coverage.

Environmental impact assessment is trending towards model-based inference, focused on density surface modelling[1]. The approach uses CDS/MCDS adjusted densities in conjunction with spatially referenced covariates (e.g. lat/long, bathymetry, distance from shore) to fit density surface models (DSM). Pre-installation DSM can be used to estimate likely overlap with proposed installations. Covariates must have a reasonable likelihood of influencing distributions/densities to support the assumption that the model accurately captures the main drivers (or proxies) of distribution. Currently favoured is [1] Complex Regional Spatial Smoothing (CReSS) with model selection using the Spatially Adapted Local Smoothing Algorithm (SALSA). The CReSS/SALSA analysis can be completed using R package 'MRSea' which is supported by an extensive user's guide[1].

Digital aerial survey data can likely be analysed without the need for distance sampling corrections, provided that the strip is adequately narrow. The non-corrected strip approach is not recommended for boat-based surveys given the low likelihood of perfect detection. For the latter, data can still be presented as relative densities and used to index change but inference about absolute numbers will be limited.

Estimating population/SPA impacts: Much of the pre-installation estimates of impact will need to be assessed by running estimates in conservative (most plausible worst case scenario) population models. Where local population model data does not exist, published data from other areas may be used provided it is reasonably defended and tested under a range of values for each variable where non-local data was used (sensitivity analysis).

Modelling and collision risk assessment: Band 2012 should be consulted when modelling collision risk. Density estimates can be used for modelling collision risk in conjunction with the Band 2012 model. The Band model applies primarily to wind installations but could be co-opted for use in wave energy installations. This will require the generation of estimated avoidance rates, using published estimates of vulnerability as a generic guide. Local data on avoidance rates should be collected where possible, and data to estimate local population models collected where there is high risk to an SPA. A novel approach to modelling[1] considers heterogeneous rather than homogenous flight distribution of birds, within the risk height, where the latter potentially over-estimates the collision risk to birds.

For design-based approaches, hydrodynamic and/or oceanographic data can be incorporated into data analysis to reduce unexplained variance and improve the ability to detect an impact. Fitting a GAM with an 'impact' term and assessing optimal model with AIC rather than simple multi-factor ANOVA may be required to assess if there is a difference in abundances pre- and post-impact

Cumulative effects

Estimating cumulative effects can be challenging. In the case of seabirds, developing a population viability analysis (PVA) that assesses concurrent impacts (e.g. collision mortality, decreased breeding success, etc.) is currently the most likely feasible approach. The analysis should be run over a range of plausible impact scenarios (e.g. high mortality/low reproductive success through to low mortality/high reproductive success) to generate a plausible range of impact rather than a single estimate of impact[viii]. It is highly likely PVA will have significant uncertainty due to a lack of measured estimates.

As uncertainty is unavoidable, it should be acknowledged and specifically incorporated into both modelling processes and management/decision-making. For instance, this could be done through a science-based adaptive management approach.

Cumulative effects must also consider the presence of other stressors in the area (e.g. mortality from fishing entanglement) or in other parts of the species range (e.g. wintering grounds for breeding migrants) and how these might change with the introduction of energy development. If reliable data on other stressors is not available, it may be advisable not to incorporate the added uncertainty into the PVA, but rather to discuss potential impacts in qualitative terms.

To be meaningful, cumulative effects should be addressed across projects rather than simply at the project level. Ideally, there should be a publically accessible, spatially-explicit GIS resource showing current and historic seabird data, locations of existing, proposed, and planned developments, their risk and type of impact to seabirds, and the estimated spatial extent of impacts. However, this type of effort is beyond the capacity or responsibility of a single developer.

5.2 Post-construction monitoring

Monitoring methods

Displacement and macro avoidance: Methods similar to pre-construction monitoring.

Avoidance behaviour: Data on micro and macro avoidance behaviour can only be collected during post construction monitoring. Focused studies on changes in site use (flight altitude, micro avoidance, barrier effects) by target species or groups of species may be required. For most development sites, (excepting small scale developments close to land) direct observations of avoidance behaviour will not be possible and the use of *Remote Monitoring Techniques* will offer the most practical solution. Remote techniques (radar and thermal animal detection devices, altimeters, GPS and satellite telemetry) can provide data on flight activity and spatial use (for comparison with pre-construction data) and actual collision events or micro-avoidance behaviour (for comparison with predicted collision risk assessments). Remote techniques can provide continuous data over long periods during both day and night time. Specialist advice on the use of these techniques should be sought.

Where tagging and tracking studies (telemetry data) have shown a connection between the use of a proposed project site and an Special Protected Area (SPA), surveys may be required to assess changes in the population of the SPA as a result of the proposed development, e.g. changes in breeding success which may be linked to loss of foraging habitat/displacement as a result of the development. Where tracking data is not available, published estimated foraging distances and percentage displacement estimates may be used to establish connectivity and likely displacement e.g. BirdLife's Offshore IBA Toolkit (http://www.birdlife.org/eu/pdfs/Marinetoolkitnew.pdf).

Methods to assess loss of foraging habitat during the breeding and non-breeding season are being developed for offshore wind farms [ix]. Where displacement effects may impact breeding sites, the use of control sites to compare productivity data with similar colonies which are not affected by the MREIs, may be appropriate. Careful consideration of other variables which may affect breeding success at control sites will be required. Where there is a sufficient series of pre-development data, changes in productivity at a breeding colony, post-development may also be monitored. However, the significant natural variation of seabird productivity may make it very difficult to discern effects of an energy development, and the usefulness of these types of studies should be considered. Where connectivity data is available, determining the true effect of a development on the SPA will be very difficult. It will more likely be based on population modelling approaches with significant uncertainty.

Survey Coverage: For monitoring purposes, the level of survey effort may be determined from results of baseline surveys (species present, abundance, vulnerability, likely interactions) and the level of survey effort required to detect change in target species or species groups (vulnerable species, species of high conservation concern). Power analysis can be used to determine the level of survey effort required to detect predetermined threshold changes, and to ensure that resources are not wasted with additional unnecessary survey effort.

Surveys should cover the development and buffer area and, where applicable, the reference or control area. Missed surveys are to be expected due to the turbulent nature of prime marine energy sites; analyses and survey design must make allowance for this. In some cases, it may be appropriate to focus monitoring surveys on the months when the target species are most abundant and where there is greatest risk of impact. However, this should be judged on a site by site basis. There should be sufficient data to ensure that lack of coverage in some months does not affect the power to detect threshold change.

To take account of long and short term effects of MREI on bird populations, annual monitoring may be required for up to 3 years post consent, then on year 5, 10 and 15. This is a general guide based on the small amount of data and variability of bird use of offshore sites in Ireland. While Scottish National Heritage (SNH) guidelines recommend two years of baseline data, the existing data for Scotland is at a higher level than that available for Ireland. In the case of near-shore sites, where more data may be available, two years of baseline monitoring may be appropriate, but this reduction in monitoring should only be considered on case by case basis. Where less monitoring is proposed, justification should be presented. Over time, the species or groups of species may habituate to change, where effects identified in the first years of operation are not apparent in later years. It is also the case that effects may only be detected after several years of monitoring (e.g. low-level yet steady population declines due to collision mortality). The monitoring programme should be designed to account for this.

Where the use of Remote Monitoring Techniques is considered appropriate, specialised guidance should be sought on survey duration, extent and time.

Post-construction analysis: In common with baseline survey analysis, **t**ransect data should be corrected using CDS/MCDS as per pre-construction baseline. Post-installation DSM can be compared against pre-installation DSM to identify grid cells with statistically different estimated results.

5.3 Pre-construction baseline – onshore cable laying

Identification of potential impacts

Temporary disturbance leads to short term habitat loss. This may affect breeding birds, non-breeding summer birds, passage birds and/or wintering birds

Indicators for identified impact

Impacts can include; reduction in number of birds breeding at the development site and/or reduction in number of wintering, passage or summer birds using the site. Impacts will be more or less severe depending on the species present and availability of alternative habitat. However, impacts will be short term and timing and relocation of works, can be used to avoid critical times and sensitive species.

Survey methods

Where wintering birds are likely to be present, point counts of the shore following Irish Wetland Bird (I-WeBS) survey methods should be completed. Counts should be monthly between September and March and covering all tidal states. Data on species, number, activity and distribution should be collected. Counts are made from a suitable vantage point, covering a survey repeatable area. Data on weather, tidal state and disturbance should be collected during each count.

Where breeding birds are likely, standard breeding bird survey methods [x] [xi] should be followed ensuring suitable shoreline habitat for breeding waders (oystercatcher, ringed plover) or shore nesting seabirds (breeding terns) is covered. The National Parks and Wildlife Service should be consulted regarding any licenses required to complete breeding seabird surveys.

Surveys should be completed along with baseline monitoring for the rest of the development site, and cover up to 3 pre-construction years where required based on the risk assessment. Given the short term disturbance likely associated with cable laying, a reduced number of survey years may be sufficient.

Data analysis

The limited area of onshore disturbance associated with cable-laying will normally allow for full counts. For wintering birds, data on mean number of birds (with standard error) should be presented, for comparison with post construction data. Key foraging or resting areas should be mapped to present a pre-construction picture of site use. For breeding birds, present data on species, numbers and breeding status is required.

Practical considerations

Access to land for suitable vantage points should be considered.

In-combination/cumulative effects

Effects owing to cable-laying should be short term and temporary. However in cases where mitigation (spatial and temporal avoidance of sensitive species) residual effects remain, those species affected should be considered along with those affected by the rest of the development. Cumulative effects may arise where a species is disturbed from both onshore and offshore habitats. The number of species which utilise both shore and open water habitat is however limited (e.g. gulls).

5.4 Post-construction monitoring – onshore cable laying

Monitoring methods

Methods are similar to pre-construction. Surveys may be required to continue post construction; this will depend of the sensitivity of the site.

Statistical analysis

Where impacts have been predicted, despite mitigation, the effect of cable laying can be evaluated with a BACI approach if non-impacted, comparable sites are also surveyed. The impact site could also be compared against IWeBS data set concurrent with the years of pre- and post-installation surveys. Due to repeated measures and missing values, GAM analysis, including an impact term, would likely be required rather than multifactor ANOVA [xii].

6. Marine mammals and Basking sharks

The most common marine mammals; cetaceans and seals and their baseline survey and monitoring methods are set out in this section. Both cetaceans and seals are sensitive to similar potential impacts. Basking sharks have also been included in this section as the impacts and monitoring tools for the assessment of this species are similar to those for cetaceans and seals.

Identification of potential impacts

Although the possible impacts of offshore renewable energy developments on marine mammals has been extensively reviewed, empirical measurements are lacking due to the limited number and types of devices deployed. A review of both positive and negative impacts on biodiversity suggested that the main negative effects include some loss of habitat from physical displacement; collisions, where marine renewable energy devices have moving or rotating parts; disturbance of feeding and the impact of noise generated by working devices and during construction. The hard substrates that are created, especially with respect to offshore wind farms, may lead to an artificial reef type effect, but all devices may potentially act as Fish Aggregating Devices (FADS). The latter may positively impact on marine mammals especially if fish biomass is increased rather than concentrated around FADS, without depleting surrounding areas. In addition, the effective “exclusion zone” created around devices, or more realistically an aggregation of devices or farms, may act as no-take zones or marine-protected areas. However, as with the potentially negative effects, these issues are speculative as there is limited empirical data available to explore them.

Notwithstanding the lack of empirical data, the construction and operation of marine renewable energy devices are not considered to be benign. However, it may be possible to mitigate negative effects through the implementation of best practice and continued construction and post construction monitoring to measure impacts should they occur.

Impacts will vary depending on the type of device, the number of devices, the location of the device, the species present and interactions of the above. Impacts will also vary with project stage (construction, operation, decommissioning).

Direct impacts that can occur are; disturbance (noise, physical structure), collision, entanglement and displacement. Indirect impacts include; changes in sedimentary and oceanographic processes, and changes in food resources either due to displaced fishing effort or through acting as a "fish aggregating device" with implications for foraging resource.

Deployment of marine renewable devices may cause displacement or attraction of cetaceans to a site, mortality or injury, or changes in foraging resources with implications for breeding success. Effects also could be caused by increased boat traffic during construction and servicing, and increased risk of associated marine pollution events. Evidence of impacts of electromagnetic fields associated with cabling of energy ashore on cetaceans is very limited and not considered relevant. Monitoring of the potential impacts on marine mammals can use a scale-based approach to achieve a high probability of detecting effects from small and likely insignificant displacement of animals, through to population declines that would be considered to be a significant impact[xiii].

Most impacts are common to all marine renewable energy projects, but some technology may have a higher likelihood of interactions with specific aspects of their deployment or operation than others. Catenary (suspended mooring lines with curve shape between floating structure and the seabed) are thought to pose the greatest risk to different marine mammal groups. Risk of entanglement is considered to increase if derelict fishing gear is entangled in moorings and other associated structures.

Collision risk is considered higher for **tidal energy** than for other marine renewables as tidal devices, especially those with rotating blades, are deployed in high flow environments where flows combine with swimming speeds to produce high approach velocities with consequently reduced avoidance or evasive response times[xiv]. In Wales, higher porpoise densities in areas of more turbulent waters "downstream" from the area of strongest flow have been recorded[xv]. The location of these higher density areas moved to the "other side" of the highest current areas when the tidal stream reversed.

For **offshore wind**, the impacts associated with construction are of most concern and have been well documented, but less information is available for the operational or decommissioning phase. Pile driving during construction has been identified as the most significant impact on harbour porpoise and some dolphin species, in the absence of mitigation.

6.1 Cetaceans

6.1.1 Pre-construction baseline

Indicators for identified impact

Impacts can be considered in terms of general or regional effects and local effects. The general effects of renewable energy devices on marine mammal populations at a site will be determined by changes in the abundance and distribution of individuals (and to a lesser extent their behaviour within and adjacent to the site) and can be considered in terms of attraction or displacement. Changes which are considered greater than those associated with "normal" seasonal, diel, tidal or daily changes are useful indicators. Local effects include collision, entanglement and displacement events and all records are indicators of interactions. Increased mortality adjacent to the site can be an indicator of interactions.

Determining impacts will depend on the quality of the data gathered pre-survey and during monitoring. Substantial natural variability means that long term data with robust sample size are required to detect changes that can be attributed to the development. A useful approach is to grade the development site in terms of confidence in survey results. For example, if the site has good existing data, and field surveys are completed on a monthly basis for two years using an acceptable experimental design, there will be more confidence that monitoring will yield valid results at appropriate resolutions. However, for some sites existing data will be poor and the site could be located in an extreme environment. Extant and new survey data will be limited, and will lead to a lack of confidence in results. These limitations are real and valid and it is important that they are acknowledged.

Collision and entanglement cannot be measured pre-construction, however the likelihood/risk of these impacts arising can be assessed taking into account the behaviour of the species present in the area (informed by survey data and existing data) and the type of device being installed. A risk assessment based on the scale and type of proposed development and on species occurrences as reported during baseline survey, should be carried out and used to inform farm design (including moorings) or operation.

Survey methods

Vantage point surveys are useful for small, coastal sites. Surveys should be carried out in favourable sea conditions (sea state ≤3 or ≤2 if harbour porpoises are thought to occur at the site) and the duration of each watch quantified. Standardised VP watch methodologies are available[xvi,xvii]. Detectability declines as a function of distance from the VP and an attempt to account for this should be considered by recording the distance a sighting is from the VP and using distance analysis.

Line transects along pre-determined track lines, with distance sampling, is a standard methodology and can be boat-based or from the air (typically using high definition cameras). Distance sampling enables density estimates and absolute abundance to be calculated should sufficient sightings be made, but will also provide relative abundance estimates and used to assess surface densities. Visual surveys should be carried out in sea-state ≤2 if harbour porpoise are known to be present (inshore and coastal sites) or ≤3 for offshore sites. Ideally, surveys should be designed to be carried out in a single day or a maximum of two consecutive days if weather is suitable. Long temporal gaps between track lines within a survey will compromise the data as marine mammals are highly mobile. It is better to carry out two full surveys in consecutive days with wide track lines than to attempt to carry out one survey over two or more days. Photo-identification is a powerful tool in the study of some cetacean species (e.g. bottlenose dolphin and humpback whales) where photographs of individuals using unique markings on dorsal fins (dolphins) or the underside of flukes (humpback whales) can be used to explore site fidelity and inter-connectivity between sites elsewhere. Photographs should be collected opportunistically during boat-based surveys to assist in assessing impacts at the population scale.

Monitoring methods include:

- Visual surveys both land, boat and aircraft based along pre-determined track-lines and distance sampling, including use of high definition cameras and concurrent with seabird surveys.
- Passive Acoustic Monitoring (PAM) using towed hydrophones are typically used in addition to visual techniques during boat-based surveys.
- Hydrophones can detect both clicks and whistles of odontocetes and other vocalisations and stored as .wav files.
- Static Acoustic Monitoring (SAM) is now widely used at smaller scale, usually coastal, sites as it can provide high quality temporal data although SAM can be spatially constrained depending on the number of units deployed.
- For odontocetes, that produce echo-location clicks (e.g. harbour porpoise, dolphins, sperm and pilot whales) click recorders or loggers, such as CPODs are most suitable.
- Equipment such as SM2M, EAR or other recording equipment which stores data as .wav files, can be used for baleen whales, and to distinguish between dolphin species if this is

desirable, These data have to be processed to extract detections and some software packages are available (e.g. PamGuard, Raven).

Displacement and attraction can be measured using Before-After-Control-Indicator (BACI) or Before-After-Gradient (BAG) survey designs, especially using SAM data. Where BAG analysis is used the buffer zone may be 5-10 km depending on the site and where BACI analysis is being used a control site will be required. This control site should be at least over four times the detection distance of the acoustic loggers, but within the same depth contours and distance from shore.

Static Acoustic Monitoring (SAM) can provide statistically robust datasets for monitoring odontocete species (Harbour porpoise, dolphins) but to a lesser extent baleen whales. SAM should be used in conjunctions with other survey methods described above. All SAM equipment should be calibrated to account for different sensitivities and performance of individual units. When acquiring SAM data the size of the total area to be monitored should be calculated and stratified into defined geographical grids (grid size depends on the target species), to allow for a restricted stratified random sampling design and can be altered according to the number units available to a study. The number of units deployed should ensure that statistically robust data can be collected.

Mortality can be monitored through cetacean stranding schemes. A time-series of cetacean stranding's is available in Ireland and any increase adjacent to marine renewable sites should be detectable. Lesions on animals stranded at sites adjacent to marine renewables, which are thought to be consistent with entanglement or collisions, should be investigated through post-mortem examination.

Given the lack of local scale baseline data for most onshore and offshore sites around Ireland, the variability of the marine environment and the risk assessment, it is recommended that at least two years and preferably, three years (e.g. AMETS) of pre-construction data is required to account for inter-annual variability, with two years considered an absolute minimum where data is lacking. Visual surveys are required to cover each season and ideally on a monthly basis, although this is often not possible due to unfavourable weather (sea state ≥3). Surveys should also cover the impact area and a buffer zone around this area. (E.g. a radius of 10km was used during the AMETS monitoring to provide for control sites).

PAM surveys are much less weather dependent but should not be carried out in sea state ≥5 as the quality of data is compromised. SAM surveys are not restricted by weather or day night but can be spatially constrained depending on the number of units deployed. Where survey or monitoring activities are likely to cause disturbance or potentially effect cetaceans Mammal Observer (MMO) Forms provided by the NPWS of the Department of Arts, Culture and the Gaeltacht (DACG) should be filled out.

Data analysis

Visual surveys will provide distribution and relative abundance data but are unlikely to produce robust density and absolute abundance estimates, as distance software requires 40-60 sightings to derive robust estimates. This is a high number of sightings for any species within a single survey. Depending on the size of the project site, visibility of 1km or more around the zone of influence is recommended in *Guidance to Manage the Risk to Marine Mammals form Man-made Sound Sources in Irish Waters,* 2014, DAHG . This 1 km limit may be greater for larger potential sites and / or the project pressure predicted effects. Shape files with physical (depth, slope, seabed) and oceanographic (temperature, salinity, productivity, hydrography) layers can be used to explore species distribution.

PAM data can be analysed using PAMGUARD; a freeware programme which can be used in real-time during surveys to record detections, distance and angle to the detection, which are essential data for distance analysis. SAM data should be presented % DPMs (Detection Positive minutes) as a monitoring index over various temporal scales, taking into account total deployment time. This index can therefore be used to compare data between sites even when the number of samples (hours monitored) from different areas are unbalanced.

Similar seabird assessments data analysis is trending towards model-based inference, focused on density surface modelling (see Box 9). However generally fewer individual sightings of marine mammals are recorded compared to seabird sightings during surveys and this confounds the effectiveness of modelling. Acoustic datasets are much greater but spatially constrained however modelling can be effective in exploring use of the site and in developing monitoring indices. GAM and GLM models have been used to explore cetacean stranding's data to identify any trends in mortality.

Practical considerations

Weather is a key factor in the success of a field survey programme. For extreme sites (west coast of Ireland) it is important to factor likely data gaps into survey design owing to unfavourable weather for visual surveys. Surveys covering the autumn and winter season may not be possible, or coverage may be limited. Weather effects may prevent surveys proceeding at all, may limit coverage, or may result in poor quality data (e.g. lower detection with poor visibility or swell height). Acoustic survey techniques are much less weather dependent, especially static acoustics, though the area monitored acoustically can be limited depending on detection distance for specific groups.

SAM units deployed on site can be lost or interfered with. Units should be calibrated before a survey and on its completion to account for any differences in sensitivities or detection distance. Twice the number of units as SAM sites should be supplied and calibrated to facilitate changeover of units in the field and account for any equipment losses during survey. Mooring design will vary with site and exposure to both extreme weather and human use of the site. Acoustic releases can be used to protect SAM units from both. Modelling (e.g. GLMs and GAMs) can assist in accounting for data gaps.

In-combination effects

There is potential for in combination impacts as all cetacean species are highly mobile and wide-ranging.

6.2 Seals

6.2.1 Pre-construction baseline

Survey methods

Haul out surveys are useful for recording the use of the site by seals. Surveys are best carried out during the breeding season (August-November for grey seals and June-August for harbour seals), or during moult (December-March for grey seals and August-September for harbour seals). Seals (especially grey seals) are highly mobile and can forage great distances from their breeding sites; thus absence of haul out sites adjacent to a marine renewable site does not imply that the site is not used regularly by seals.

Vantage point surveys are useful for small, coastal sites; the guidance provided for VP surveys of cetaceans applies to seals.

Bio-telemetry is a very effective method of assessing the use of a site by seals. GPS tags can provide high quality data on the location and diving and haul out behaviour but can be expensive and not all sites are suitable for capture of seals.

Given the lack of local scale baseline data for most onshore and offshore sites around Ireland and the variability of the marine environment, three years of pre-construction data is recommended to account for inter-annual variability, with two years considered an absolute minimum where data is lacking. Haul-out surveys should be conducted monthly throughout the year, or weekly during the breeding and moulting seasons if such sites occur adjacent to the site (inshore and coastal).

Data analysis

Displacement and attraction can be measured using BAG or BACI analysis. Collision and entanglement cannot be measured pre-construction, however the likelihood/risk of these impacts arising can be assessed pre-construction. This assessment must take account of the behaviour of the species present in the area (informed by survey data and existing data) and the type of device being installed.

Haul out surveys should be conducted 1-2 hours either side of low water. Where possible, consideration should be made to account for those seals not hauled out during this period but in the water. Knowledge of how seals use a site is desirable, with a time-series of counts throughout both spring and neap tides useful for applying a correction factor.

Visual surveys will provide distribution and relative abundance data depending on the project site size. Similar guidance, as at cetaceans, applies to determine survey extents.

Practical considerations

Weather is a key factor in the success of a survey programme.   For extreme sites (e.g. west coast of Ireland), it is important to factor likely data gaps in boat-based or aerial surveys owing to unfavourable weather into survey design. Surveys covering the autumn and winter season may not be possible, or coverage may be limited. Weather effects may prevent surveys proceeding at all, may limit coverage or may result in poor quality data. Bio-telemetry can be expensive but provides high quality data and is not constrained by weather, once tags are deployed. Deployment is typically carried out post-moult to increase the duration of tag attachment.

In-combination/cumulative effects

There is potential for in-combination impacts as all cetacean species are highly mobile and wide-ranging.

6.3 Basking sharks

6.3.1 Pre-construction baseline

Survey methods

Vantage point surveys are useful for small, coastal sites. Surveys should be carried out in favourable sea conditions (sea state ≤1) and the duration of watch quantified. Standardised VP watch methodology is available. Detectability declines as a function of distance from the VP and an attempt to account for this should be considered. Line transects along pre-determined track lines with distance sampling is a standard methodology, and can be boat-based or from the air (including use of high definition cameras). Distance sampling enables density estimates and absolute abundance to be calculated should sufficient sightings be made but will also provide relative abundance estimates.

Biotelemetry using real time satellite tags is now available and has been used off the coast of southwest Scotland to assess the use of potential marine energy renewable sites by basking sharks.

Given the lack of local scale baseline data for most onshore and offshore sites around Ireland and the variability of the marine environment, three years of pre-construction data is recommended to account for inter-annual variability, with two years considered an absolute minimum where data is lacking. Visual surveys to record basking sharks are required from March to September, where possible, to coincide with the peak of sightings at the surface but only in sea state ≥2. Surveys should cover the impact area and a buffer zone around this area (10km), and can be combined with boat or aerial surveys for marine mammals.

Data analysis

Depending on the size of the farm, a 1km grid resolution is the minimum required but can be greater at larger sites. Shape files with physical (depth, slope, seabed) and oceanographic (temperature, salinity, productivity, hydrography) layers can be used to explore species distribution. Bio-telemetry data can be used to assess use of the site at very fine resolution including importance of tidal eddies, upwellings and oceanography.

Practical considerations

Basking sharks are very difficult to observe visually and are only seasonally abundant on the surface. Weather is a key factor in the success of a survey programme. For extreme sites (west coast of Ireland), it is important to factor likely data gaps in boat-based or aerial surveys owing to unfavourable weather, into survey design. Surveys covering the autumn and winter season may not be possible, or coverage may be limited. Weather effects may prevent surveys proceeding at all, may limit coverage or may result in poor quality data. Bio-telemetry can be expensive but provides high quality data; there is also the strong possibility that tagged animals will not be visiting the site.

In-combination/cumulative effects

There is potential for in-combination impacts as basking sharks are highly mobile and wide-ranging.

6.3 Post-construction monitoring of cetaceans, seals and basking sharks

Monitoring methods

As there is less information available about the interaction of some marine renewable energy devices with marine mammals and basking sharks, post-construction monitoring should continue at a lower level (temporally and spatially) than pre-construction to account for uncertainties in assessing impacts in this emergent field during the life of the development. Both the frequency of monitoring and the monitoring methodology selected (visual, acoustic for odontocetes, seals) will be depended on the most sensitive receptors (species) recorded at the site.

For instance, methods such as vantage point surveys which are cost effective can be undertaken if a site is close to land and with timed watches (at least 100 minutes) in favourable sea conditions (≤ sea state 2). For odontocetes, static acoustic monitoring, using CPODS or underwater recording devices, can create large datasets with high resolution and is the most cost effective way of monitoring the use of a site by key odontocete species over long time periods. CPODS can be recovered, downloaded and batteries replaced every four months.

Complex Region Spatial Smoother (CReSS) models (available on R package ‘MRSea’) are currently considered preferable over standard GAM/GAMMs for surface density modelling as they are spatially adaptive, when modelling data to identify redistribution or changes in abundance. However, the ability to detect post-impact changes using current data gathering requirements is still unclear. Therefore, a power analysis approach remains relevant and should also be used to quantify the "chance" that a genuine impact effect is detected. While it should be based on realistic features of the data, no methods have been developed to achieve this yet.

Standardised reporting of all incidences (collisions, entanglements) should be carried out and submitted to the competent authority for the life of site. A system should be established to report these incidences during the life of the farm as a template to include the nature of interaction and to enable an investigation as to how it occurred.

7. Marine Reptiles

7.1 Pre-construction baseline

Identification of potential impacts

Marine turtles are recorded each year in Ireland though with up to 15-20 sightings each year which may increase due to the effects of climate change. Nearly all sighting records are of leatherback turtles (*Dermochelys coriacea*) but those stranded include loggerhead turtle (*Caretta caretta*) and more rarely, Kemp's Ridley (*Lepidochelys kempii*)[xviii]. Those individual stranded turtles are almost always in poor condition and would die if there was no rehabilitation, while those sighted are foraging within their natural range. Leatherback turtles are considered a natural part of Ireland's migratory marine fauna[xix]and all turtles are protected under the Wildlife Act (1976) where it is an offence to harm or deliberately disturb them. Most sighting records (80%) of leatherback turtles occur in July and August but there are records in all months. Records are available from the National Biodiversity Data Centre (www.biodiversityireland.ie) and Ireland also contributes to a marine turtle recording scheme administered by Marine Environmental Monitoring in Wales, who produce annual reports of both sighting and stranding records (www.strandings.com).

Impacts of marine renewable energy devices will vary depending on the type of device, the number of devices, the location of the device and interactions of the above and with project stage. Direct impacts include disturbance, collision (especially with vessels during construction and servicing), entanglement and displacement. There is currently no existing data on whether turtles could be affected by sound exposure. However, barotrauma as a result of the impulsive energy produced when the hammer hits the pile, is a possibility based on knowledge of auditory thresholds. Indirect impacts are changes in sedimentary and oceanographic processes, and changes in food resources (jellyfish) with implications for foraging resource. Where devices result in impacts, this may cause displacement, mortality or injury or changes in foraging resources. Effects also could be caused by increased boat traffic during construction and servicing and increased risk of associated marine pollution events.

The main specific impact particularly associated with wave energy is thought to be displacement and entanglement and for tidal energy collision risk. For offshore wind, the potential impacts associated with non-auditory injury from pile driving during construction have been identified as the most significant impact on marine turtles. Large linear Renewable Energy Arrays (wind or wave) may impact on leatherback turtles as it is not known how they will navigate around such structures.

Providing an actual estimate of the number of leatherbacks foraging within Irish waters is difficult as their numbers may be extremely low[xx, xxi] this makes monitoring of these species difficult to assess relative to offshore renewable energy developments. Nonetheless, there are specific areas in Ireland where leatherbacks are regularly seen swimming parallel to the coast and the construction and operation of large Renewable Energy Arrays should consider such locations during site location.

Indicators for identified impact

Impacts can be considered in terms of general or regional effects and local effects. The general effects of renewable energy devices on marine turtle populations are considered low. Nevertheless, any increase in mortality of adult turtles can be significant, given some species are listed as critically endangered. Local effects include collision, entanglement and displacement events and all records are indicators of interactions. Any mortality within or adjacent to the site (stranded) can be an indicator of interactions.

Determining impacts is difficult as the abundance of marine turtles is very low. Collision and entanglement cannot be measured pre-construction, however the likelihood/risk of these impacts arising can be assessed taking into account turtle behaviour as informed by survey data and existing data, and the type of device being installed to inform farm design (including moorings), operation or location.

Survey methods

As turtles are still infrequently sighted in Irish waters, data are best gathered opportunistically in collaboration with marine mammal surveys (see Section 6). All interactions (collision/entanglement) should be reported.

Data analysis

Data are best analysed in collaboration with marine mammal surveys (see sections)

Practical considerations

Marine turtles are rare, they are very difficult to observe visually and are only seasonally abundant on the surface.

In-combination/cumulative effects

There is potential for in-combination impacts as basking sharks are highly mobile and wide-ranging.

7.2 Post-construction monitoring

Monitoring methods

As little is known about the interaction of some marine renewables dives with marine turtles, post-construction monitoring should continue at a lower level (temporally and spatially) in collaboration with marine mammal surveys during the life of the site. Standardised reporting of all incidences (collisions, entanglements) should be carried out and submitted to the competent authority for the life of site. A system should be established to report these incidences during the life of a farm to include the nature of an interaction and to enable an investigation into how it occurred.

8. Coastal Processes

Of Ireland's 7,000km coastline, approximately 3,000km in the southwest, west and north is rock dominated. By contrast, the east and south east are composed of glacial sediments with less rock outcropping. 500km of Ireland's coastline is considered to be actively eroding with average coastal erosion rates of 0.2-0.3 m/year and up to 1-2 m/year on susceptible southern and eastern coasts.

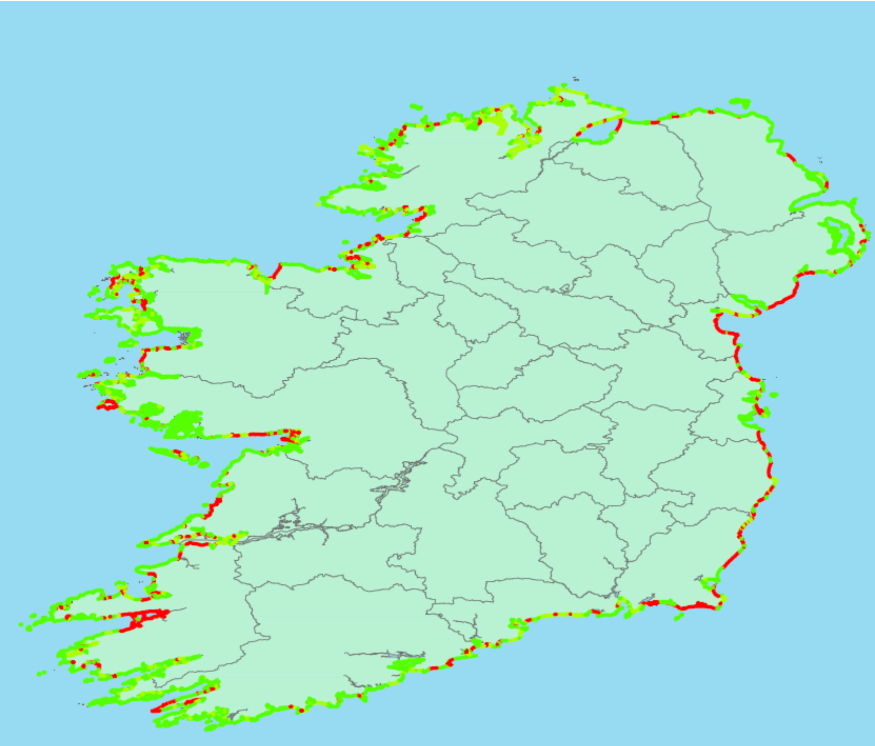

Fig. 1: Coastline where erosion is likely or currently taking place.
Source: Derived from the Eurosion Portal http://www.eurosion.org/

The movement of new sediments from offshore sources to the coast has almost ceased in Ireland; those present on beaches are being moved by long-shore coastal processes to other coastal environments.

8.1 Pre construction baseline

Identification of potential impacts

There are currently no commercial scale wave energy or tidal stream facilities, and any prediction of effects on coastal processes is based on mathematical modelling. WEDs have been shown through various models to decrease wave height at the shore by between 3% and 13 %[xxii]. This may be considered beneficial where soft shores are actively eroding.

However, some models suggest that particular WED alignments to incident shores, though still reducing wave energy, can increase near shore current velocity. This may potentially lead to increased rates of erosion or changes to other processes[xxiii].

Tidal energy devices can have considerable effects on current velocity which in turn may have effects on sediment transport regimes. Offshore sediment deposits play an important role in wave dynamics. Modelling studies have suggested that commercial tidal stream turbines will have both near and far field effects on sediment movements. There is potential for device-induced movements of sediment to change the incident wave pattern on the shore and affect erosion rates.

Wind energy turbines are considered to have a minimal effect on coastal processes and erosion, due to the relatively small size of the foundations 5-15m in relation to the distance between devices 300-500m.

Survey methods

The physical characteristics of the site and surrounding area should be determined using available data. Much of the data may be available through historical and present day data sets however any data gaps should be identified and filled. An understanding of natural variation in these processes is fundamental in order to quantify any future changes in coastal processes and erosion rates. Mathematical modelling of the proposed devices and their effects on the physical environment should be used to determine possible changes to coastal processes, and the likely extent of coastline that may be subject to change.

Acoustic Doppler Current Profilers (ADCP's) should be deployed for an appropriate period of time (generally 6 months) to measure wave and current data. Such data can be used to determine wave propagation characteristics and current data from offshore to nearshore, and provide calibration data for the numerical model.

An assessment is required where there is a risk of coastal erosion pressure on a coastline. Accurate bathymetric and topographical information is necessary to accurately assess any changes in coastal erosion rates at the site or potentially affected coastline. A bi-annual bathymetric and topographical survey should be undertaken of the potentially affected coastline identified in the modelling process. Ideally, a 3D model of the affected coastline should be generated from data, allowing calculation of volumetric change over time.

The maximum number of potential devices, arrays and types of devices should be incorporated in the wave energy analysis data regardless of the model chosen.

Sediment mobilisation during cable laying process should be accounted for by assessment of sediment cores and wave and current data.

8.2 Post-construction monitoring

Monitoring methods

Where necessary, bi-annual bathymetric and topographical surveys of affected coasts should be undertaken in spring and autumn.

9. Cultural heritage

9.1 Shipwrecks and associated remains

The shipwreck inventory of Ireland includes all known wrecks up to 1945 and at present lists 12,000 known wrecks. Wrecks over 100 years old and archaeological objects found underwater are protected under the National Monuments (Amendment) Acts 1987 and 1994. An Underwater Heritage Order may be placed on wrecks less than 100 years old because of their historical, archaeological or artistic significance. Underwater heritage orders may also be used to designate areas of seabed or land covered by water to more clearly define and protect wreck sites and archaeological objects.

9.1.1 Pre-construction baseline

Preservation *in situ* of shipwrecks and their associated remains is a fundamental principle of archaeology. WEDs, tidal stream devices and offshore wind energy structures have the potential to damage, destroy or alter the context of shipwrecks and their associated remains. With regard to all three energy generating systems, the construction phase is potentially the highest risk to shipwrecks and their associated remains, within the footprint of the proposed development. However, given the potential for change to sedimentation and other coastal processes associated with WEDs and tidal stream projects, there is the potential for damage during the operational phase of these projects too.

Foundation works, moorings, and cable laying during the construction phase of energy devices reflect where direct damage to wrecks is highly likely, if they are not identified in the baseline survey.

Survey methods

The *Framework and Principles for the Protection of the Archaeological Heritage,* 199, DAHCG (1999:33) outlines the State's general principles in relation to the management and protection of the archaeological heritage. This document outlines broad principles for the protection of the archaeological heritage which should be considered, prior to designing any site investigation surveys.

In the first instance, a desk based study should identify all existing information on known shipwrecks and associated remains within the footprint of the development from available primary and secondary sources. Such sources include cartographic and geological sources, the Irish excavations database, the National Shipwrecks inventory, the Record of Monuments and Places and topographical files held by the National Museum of Ireland, among other sources.

Field surveys should concentrate on areas where direct construction activities are to take place e.g. the installation of structures, drilling, piling, cable laying etc. and an appropriate buffer zone around the footprint of the development. The position where these activities will take place should form the basis of the site survey.

Targeted surveys, informed by the desk study, are likely to include diver visual surveys where practical, and metal detection surveys followed by geo-physical surveys.

Geo-physical surveys e.g. sidescan sonar should be able to resolve all objects 0.5 m above the seafloor. Magnetometer survey should be able to resolve anomalies of 5 nano Tesla (nT) and above. Multibeam survey should achieve a cell size better than 1m.

With correct planning, the geotechnical and geophysical surveys conducted during the planning phase of the development can provide important archaeological data. An archaeologist with specific expertise should be present for all relevant construction activities to monitor operations and assess any finds uncovered during excavations.

In-combination effects

Increased numbers of devices or other activities that could potentially lead to change in sedimentation regimes or other coastal processes may increase the likelihood of unexpected finds. Through modelling, tidal stream devices are predicted to have both far and near field effects on sediment transport. It is possible that such changes could lead to the exposure of buried shipwrecks and their associated remains.

9.1.2 Post-construction monitoring

Breaches of thresholds

Where unexpected finds happen during the lifecycle of the project, the most likely scenario is open excavation of the find.

9.2 Coastal archaeology and cultural heritage sites

Ireland's coastline has a history of occupation from the Mesolithic period to the present day. Several studies have shown that Ireland's coastal and estuarine environments hold an extremely rich historical record of human interaction with the sea, however this is poorly understood. Due to the location of these sites and the dynamic nature of the environment in which they are found, many of them are threatened or are currently being damaged by natural processes.

The archaeological heritage of the coastal zone needs be considered not only in conjunction with engineering constraints but also with other factors such as natural processes, coastal erosion, homes, farms and socio-economic factors. So while a particular cable land fall route, or suitable site for the installation of wind turbines may avoid sites of archaeological or cultural significance, it may also lead to impacts for local communities.

County archaeological inventories and the *Record of Monuments and Places* are available but may lack detail in some areas, particularly the maritime archaeological heritage.

9.2.1 Pre-construction baseline

The greatest risk to these sites will be during the construction phase of any offshore development particularly the laying of cable in the littoral zone, and any associated construction on the coast i.e. substation. Given that WEDs and tidal stream devices also have the potential to alter coastal processes it is possible that damage or disturbance of sites may occur during the operational phase of these developments.

Survey methods

The current protection of archaeological monuments is based on records of known monuments. Therefore, sites and features buried in coastal environments will not have been accounted for in the documentary evidence that is available. It is therefore only through a thorough desk-based and field survey that the full potential of the archaeological heritage of a proposed development site can be known.

In the first instance, a constraints study should be undertaken to identify all recorded archaeological features within the study area and to assess their legal status. This will include a review of available primary and secondary sources such as cartographic and geological sources, the Irish excavations database, the Record of Monuments and Places (RMP), the Irish Antiquities Division, the National Museum of Ireland topographical files, the National Inventory of Architectural Heritage (NIAH), published county Archaeological inventories and surveys and additional published literature.

The findings of the constraints report should be used to inform the final site selection process. If there is any doubt regarding the significance of archaeological or cultural sites identified, consultation should be undertaken with the relevant competent authority.

Following the completion of the constraints report field surveys should be conducted. These should include site walkovers to assess the area under consideration and to verify the extent and condition of recorded sites as well as identifying less obvious features through aerial imagery and desk based studies.

10. Fisheries

Commercial fisheries that may be impacted by offshore renewable energy development include fisheries for demersal (e.g. cod) and pelagic (e.g. herring and mackerel) finfish, bivalve molluscs such as oyster, mussels and scallops; as well as crustaceans e.g. crab, lobster and shrimp. Fisheries for species with distinct migratory patterns such as salmonids and eel may also be impacted. The assessment of baselines and fishery resources should also consider the possibility that there are unknown resources available, and the potential for developments having opportunity costs associated with preventing the future harvesting of resources should also be considered. Stock assessments, monitoring of commercially important fin and shell fish species, fishery measures for sustainable harvesting of these species, and the licensing and monitoring of the aquaculture industry in Ireland is the responsibility of various Government departments and state agencies.

10.1 Commercial fisheries

There is potential for both negative and positive impacts of offshore energy development on commercial fisheries. A survey of fishers undertaken in Ireland found 70% believe that marine energy developments and fishing can co-exist[xxiv].The greatest potential impact is restriction of access to traditional fishing grounds within the footprint of any development, and the exclusion of fishers from areas of infrastructure related to any development.

Commercial fish stocks may be affected by potential impacts from renewable offshore energy development. Changes to currents, sedimentation rates and other physical processes could be of importance in the Biologically Sensitive Area in the south west identified as important for larval/juvenile stages of hake, cod, herring and haddock. Studies on effects of electro-magnetic fields on fish species suggest they are likely to be short lived, but may be of particular concern for salmonids and eels, and species where juveniles undergo large migrations. There is potential for large-scale ocean energy developments to affect such migrations.

Some video evidence suggests that surface structures associated with offshore energy developments may act as fish aggregating devices (FAD's); that fish species may also aggregate at tidal stream devices[xxv] and at structures created by moorings, caisson etc. The significance of effect of a structure in this manner will be heightened where a species or stock is already depleted, or where a species is rare.

10.1.1 Pre-construction baseline

Identification of potential impacts

Devices have the potential to create artificial reef type effects and result in fish aggregation effects. Devices also have the potential to create Electromagnetic Fields (EMF). Pollution may result from spillage of oil or fuel from construction vessels and devices. Such impacts may have the potential to lead to a reduction in biomass/population size and changes to population structure, community assemblage, growth/productivity, and behaviour/catchability leading to potential changes in productivity and yield to the fishery. While there is a lack of current deployments against which potential impacts can be fully assessed, some evidence suggests that changes can occur in fish assemblages and densities at offshore energy sites[xxvi]. This may be due to the introduction of a new habitat type, or due to changes in ecological processes associated with the construction of the development.

Survey Method

The commercial fisheries, taking place within the footprint of the development and within any exclusion zones, should be identified through consultation with the relevant authority.

The baseline should identify the commercially important fish assemblages for the area of potential impact so that any changes in the community composition or biomass/yield can be tracked. Fisheries data may be used if available. Otherwise, it may be necessary to conduct acoustic/trawl surveys to collect the required data. Some level of direct baseline investigation is likely to be appropriate, due to concerns that not all resources may be identified and documented through the analysis of fishery dependent data alone. In this context, it is highly likely that there will be significant temporal differences in fish community assemblages, as well as abundance of individual species. This must be taken into consideration when planning for baseline surveys and monitoring.

10.1.2 Post construction monitoring

Underwater survey by diver or ROV to check for changes in fish assemblages at introduced structures associated with moorings, caissons, etc. Divers, ROV or UW video survey can be used to quantify fish aggregation occurring at surface structures associated with the offshore energy development.

10.2 Shell-fish fisheries

An offshore energy development and its associated infrastructure may impact shell fish fisheries in a number of ways. The greatest impact is likely to be exclusion from traditional fishing grounds during construction and operational phases of the development. Depending on the sea floor type, it is possible that moorings, foundations etc. associated with the development may increase habitat availability to certain target species. It is also possible to enhance this effect through specific design. The addition of holes to sea floor moorings has been shown to lead to a five-fold increase in brown crab, *Cancer pagurus,* densities and a reduction in spiny starfish, *Marthasterias glacialis* densities at offshore energy developments[xxvii].

During the construction and operational phases of an offshore energy development changes to coastal processes, sedimentation rates, tidal streams and currents have the potential to negatively impact on shell fish stocks.

10.2.1 Pre-construction baseline

Identification of potential impacts

The commercial shell-fish fisheries taking place within the foot print of the development and within any exclusion zones should be identified through consultation with the competent authority.

10.2.2 Post-construction monitoring

A survey of structures created by the development should be undertaken to monitor target species numbers at these structures by diver or ROV.

10.3 Fish species of Conservation importance

In Ireland, a small number of fish species of conservation importance spend part of their life cycle in the marine environment. These include Sea lamprey, Allis shad, Twaite shad and Atlantic salmon. Tracking the migration routes of migratory fish generally requires both an investment in technology and international collaboration that may be beyond the scope of individual site projects in the open ocean. Considerable research is focused on characterising the migration routes of the main migratory species (Salmon, sea trout and Eel) such as the Salsea project, the Eeliad project and the National salmon micro-tagging program, and it may be more appropriate for individual projects to rely on data from such international research collaborations than attempting to conduct site specific surveys. As such, advice on monitoring requirements should be sought from the competent authority if deemed applicable.

Appendix 1. Renewable energy devices

Wave Energy Devices (WEDs).

There are a range of devices suitable for location in the nearshore and offshore environment. All WEDs comprise a sub-surface component (moorings, lines, anchors, foundation) and some have a surface or above surface component). WEDs may be installed as a single device or an array of devices depending on the technology. There are a range of devices currently being tested and the technology remains novel. Ireland's wave resource is greatest on the west, south and north coast where environmental conditions are more extreme.

Tidal devices

Tidal devices are located in tidal streams, such as narrow straits and inlets, around headlands, and in channels between islands. Devices are mainly subsurface but there may also be a surface component. A single device or a number of devices may be located within a tidal stream. Ireland’s tidal stream resource is limited; the best locations are on the north and north east coast, and on discrete sites such as the Shannon Estuary, with low potential elsewhere.

Wind

Wind turbines are the most established offshore technology. Wind farms are in operation at several offshore sites in Europe. Wind turbines have a subsurface component (foundation) but the main components are above surface (tower, hub, turbines). Wind turbines may be located singly or as an array. Ireland's wind resource potential is high around the entire coast.

Wave Energy Devices				
Device type	**Features**	**Description**	**Examples**	**Location**
Attenuator	Surface & subsurface.	Sits high on water column or floats on water. Works perpendicular to wave direction. Jointed device.	Pelamis, Dexawave, Edinburgh Duck, Sea Power	Offshore
Point absorber	Surface & subsurface	Floats and absorbs energy through its movement at/near surface. Moored buoys or articulated units absorb energy along the line of travel of the wave. In some cases power take off can be located on the seabed. The system can comprise of an individual buoy or an array of smaller interacting units	Ceto, OPT Power-Buoy, Wave Star, Azura, Columbia Power Technologies, Oscilla Power, WaveNET Squid	Nearshore and offshore
Over topping device	Surface & subsurface	This consists of a run-up ramp over which the waves wash, collecting the water in a storage reservoir. The incoming waves create a head of water, which is released back to the sea through conventional low-head turbines installed at the bottom of the reservoir. An overtopping device may use collectors to concentrate the wave energy. Overtopping devices are typically large structures due to the space requirement for the reservoir, which needs to have a minimum storage capacity. They are floating or fixed in the nearshore or on the shoreline.	Wave Dragon, Wave Plane (Floating Sea Wave Slot Cone Generator Cyan Wave (Fixed)	Onshore, nearshore and offshore
Oscillating water column	Surface & subsurface	This is a partially submerged, hollow structure, which is open to the sea below the water surface so that it contains air trapped above a column of water. Waves cause the column to rise and fall, acting like a piston, compressing and decompressing the air. This air is channelled through an air turbine to produce power. When properly designed for the prevailing sea state, OWCs can be tuned to the incident wave period in order to resonate. By this means, OWC can actually be quite efficient and present point absorbing characteristics.	Sperboy, Backward bent duct type OE Buoy, Sea energies (floating). Classical OWCs are shoreline devices either built directly into the shoreline (Pico OWC, Limpet OWC) or	Nearshore, onshore and offshore

		Some OWC's are not open to the atmosphere and instead harness the flow of air through two internal chambers.	integrated in breakwaters (Mutriko OWC).	
Submerged pressure differential	Subsurface only	This is a submerged device typically located near shore and attached to the seabed. The motion of the waves causes the sea level to rise and fall above the device, inducing a pressure differential. The alternating pressure pumps fluid through a system to generate electricity.	AWS (Archimedes Wave Swing), M3 DMP, Wave Carpet.	Nearshore
Oscillating wave surge converter	Subsurface only	Oscillating wave surge converters extract energy from wave surges and the movement of water particles within them. The arm, often a flap, oscillates as a pendulum mounted on a pivoted joint in response to the movement of water in the waves. These devices are generally deployed in the nearshore area on a fixed foundation. However, floating, moored concepts have also been proposed.	Waveroller, Oyster, Langlee, Resolute, BioWave	Nearshore, offshore
Water pressure/bulge systems	Surface	These devices use water tubes on the sea surface where waves transfer water to a low head turbine via pressure variation along the tube. The seawater is then released back to the sea.	Anaconda, Jospa Irish Tube Compressor.	Offshore
Rotating mass point absorber	Surface	This type of devices consists of a rotating mass or gyroscope that is enclosed within the hull of a surface-floating buoy. The rotating mass can be mounted on either a horizontal or vertical axis. The buoy is moored to the seabed.	Penguin, SEA-REV	Offshore

Tidal Energy Devices				
Device type	**Features**	**Description**	**Examples**	**Location**
Horizontal axis	Surface and subsurface	Horizontal axis turbines work in a similar manner to wind turbines. The turbine is placed in the water and the tidal stream causes the rotors to rotate around the horizontal axis and generate power. Turbines generally have 2-3 blades, but more are possible. Some systems use a helical or Gorlov type arrangement. These are generally deployed on a fixed foundation on the seabed but can also be deployed from a platform that floats on the surface or in the water column. Multiple turbines may be mounted on the same structure.	Andritz Hydro Hammerfest, Atlantis AR-1000, MCT SeaGen, Open Hydro, Schottel, Tocardo, ORPC, Verdant,	Nearshore
Vertical axis	Surface and subsurface	Vertical axis turbines work in a similar manner to horizontal axis turbines. But the tidal stream causes the rotors to rotate around the vertical axis and generate power. Common blade arrangements include the Gorlov or Savonius type designs. These are generally deployed on a fixed foundation on the seabed, but can also be deployed from a platform that floats on the surface or in the water column. Multiple turbines may be mounted on the same structure.	Polo, Proteus, GKinetic	Nearshore
Reciprocating Devices (Oscillating hydrofoils)	Subsurface	Reciprocating Hydrofoils have a hydrofoil attached to an oscillating arm. The lift caused by the tidal stream causes the arm to oscillate and generate power.	Stingray, Turbofoil, Eel Energy, bioSTREAM	Nearshore

Venturi effect	Subsurface	Venturi Effect Devices are devices which funnel the water through a duct, increasing the water velocity. The resultant flow can drive a turbine directly or the induced pressure differential in the system can drive an air turbine.	Clean Current Turbine, Rochester Venturi	Nearshore
Archimedes Screw	Subsurface	The Archimedes Screw is a helical corkscrew-shaped device (a helical surface surrounding a central cylindrical shaft). The device draws power from the tidal stream as the water moves up/through the spiral turning the turbines.	Flumill power tower	
Tidal Kite	Subsurface	A tidal kite is tethered to the sea bed and carries a turbine below the wing. The kite 'flies' in the tidal stream, swooping in a figure-of-eight shape to increase the speed of the water flowing through the turbine.	Minnesto	Nearshore

Wind Energy				
Device type	**Features**	**Description**	**Examples**	**Location**
Horizontal axis turbines	Above and below surface	Horizontal axis wind turbines operate in the conventional sense with a main rotor shaft and electrical generator at the top of a tower. To operate they need to be pointed towards the direction of the prevailing wind.	Various Siemens models.	Nearshore and offshore
Vertical axis turbines.	Above and below surface	Vertical axis turbines have the main rotor shaft arranged vertically. In this arrangement the wind turbine does not need to be pointed into the wind.	Quiet revolution	Nearshore and offshore

Moorings, Anchors and Foundations *Note: A mooring system is made up of a mooring line, anchor and connectors, and is used for stabilising or fixing a floating structure in place.*				
Name	**Type**	**Features**	**Description**	**Location**
Single point	Mooring	Below surface and seabed	A single point mooring system connects all the lines to a single point on the seabed. It connects to platforms which are free to rotate 360 degrees (e.g. buoys)	Nearshore
Catenary	Mooring	Below surface and seabed	The catenary mooring system is the most commonly used system in shallow water. At the seabed, the mooring line lies horizontally; thus the mooring line has to be longer than the water depth. Increasing the length of the mooring line also increases its weight. As the water depth increases, the weight of the line lessens the working payload of the vessel. In that case, synthetic ropes are used. As water depth increases, conventional, catenary systems become less and less economical.	Nearshore
Spread or multiple point	Mooring	Below surface and seabed	A spread mooring system is a group of mooring lines distributed from a number of points on the structure at the surface to a number of anchors on the seafloor. The spread mooring system does not allow the floating platform to weathervane, or rotate in the horizontal plane due to wind, waves or current. Spread mooring is versatile as it can be used in any water depth.	Offshore, near shore
Taut leg	Mooring	Below surface and seabed	The taut leg system typically uses polyester rope that is pre-tensioned until taut. The rope comes in at a 30 to 45 degree angle on the seabed where it meets the anchor (suction piles or vertically loaded anchors), which is loaded vertically. When the platform drifts	Offshore

			horizontally with wind or current, the lines stretch and this sets up an opposing force.	
Semi-taut	Mooring	Below surface and seabed	The semi-taut system combines taut lines and catenary lines in one system. It is ideally used in deep-water.	Offshore
Gravity	Anchor/fixed foundation	seabed	Gravity foundations are mostly concrete or concrete and steel shells filled with ballast and are most suitable for hard or rocky sea-beds where drilling or blasting needs to be avoided. They are suitable for both sea-bed mounted and floating technology and for catenary and taut mooring systems. In areas of strong current scour protection might be necessary to prevent soil erosion.	Hard or rocky substrate
Drag embedment	Anchor	Seabed	Drag embedment anchors are used with mooring systems without vertical loads such as catenary mooring systems. When installed the anchor is embedded into the seabed substrate. They are suitable for most soft and medium seabed substrate conditions where it is possible to lower the anchor into the substrate at installation.	Soft/medium substrate sea-bed
Vertical Load	Anchor	Seabed	Vertical anchors are embedment anchors designed to withstand forces at angles of up to 50 degrees. This type of anchor is suitable for tensions leg mooring systems and can be used in most soft and medium soil conditions.	Soft/medium substrate sea-bed
Suction Bucket	Anchor	Seabed	This anchor looks like an upside down bucket. It is lowered onto the seafloor and kept in place by suction, which is created by the difference in pressure between inside the bucket and the surrounding area. The design of the bucket depends on the frictional forces of the seabed sediment. Suction buckets are suitable for most soft to medium soil conditions and can be used	Soft/medium substrate sea-bed

			with taut or catenary mooring systems.	
Jacket or Lattice	Fixed foundation	Subsurface/seabed	There are many variations of this support structure and foundation, but they are generally a steel lattice structure on 3 or 4 legs which are fixed to the seabed via pile foundations. These structures are considered most suitable for water depths ranging 20-50m. They are commonly used in the offshore oil and gas industries.	Near shore: Hard or rocky substrate
Triple Support	Fixed foundation	Subsurface/seabed	The triple structure is a three-legged jacket structure in the lower section connected to a monopile in the upper part of the water column. Base width and pile penetration depth can be adjusted to suit geological conditions. Suitable for water depths up to 25-40m.	Near shore: Hard or rocky substrate
Tripod Support	Fixed foundation	Subsurface/seabed	The tripod structure is considered to be a relatively light-weight three legged steel jacket compared to the lattice structure and it can be deployed in deeper depths. This system cannot be deployed in shallow waters (less than 10m). Three piles of circa 10-20m are required. Not suitable for uneven seabed with large boulders.	Near/offshore: Hard or rocky substrate
Monopiles	Fixed foundation	Subsurface/seabed	The monopile support structure is the foundation most commonly used in the offshore wind sector. Whereby the tower is directly piled into the subsurface. The pile penetration is adjustable to suit actual environmental and seabed conditions. Monopiles are suitable for 0-30m depth.	Near shore
Shallow draft barge	Floating foundation	Surface/subsurface	The shallow draft barge has a tank which floats on the surface of the water and has a large waterplane area. The barge is generally moored by catenary lines and stabilised by its water-plane area.	Offshore
Spar	Floating foundation	Surface/subsurface	The spar buoy is a ballast-stabilised design which has a long, cylindrical tank with ballast and a centre of gravity below the centre	Offshore

			of mass. The spar is generally moored by catenary or taut lines and achieves stability using ballast to lower the centre of mass below the centre of buoyancy.	
Tension leg	Floating foundation	Surface/subsurface	A tension-leg platform (TLP) or extended tension leg platform (ETLP) is a vertically moored floating structure is particularly suited for water depths greater than 300 meters and less than 1500 meters. The platform is permanently moored by means of tethers or tendons grouped at each of the structure's corners. A group of tethers is called a tension leg. A feature of the design of the tethers is that they have relatively low elasticity, such that virtually all vertical motion of the platform is eliminated.	Offshore

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