From:	Dominika Phillips
To:	Hornsea Project Three; Kay Sully; KJ Johansson
Cc:	Andrew Guyton; Stuart Livesey
Subject:	Hornsea Project Three (UK) Ltd response to Deadline 3 (Part 4)
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Dear Kay, K-J

Please find attached the fourth instalment of documents.

Best regards,

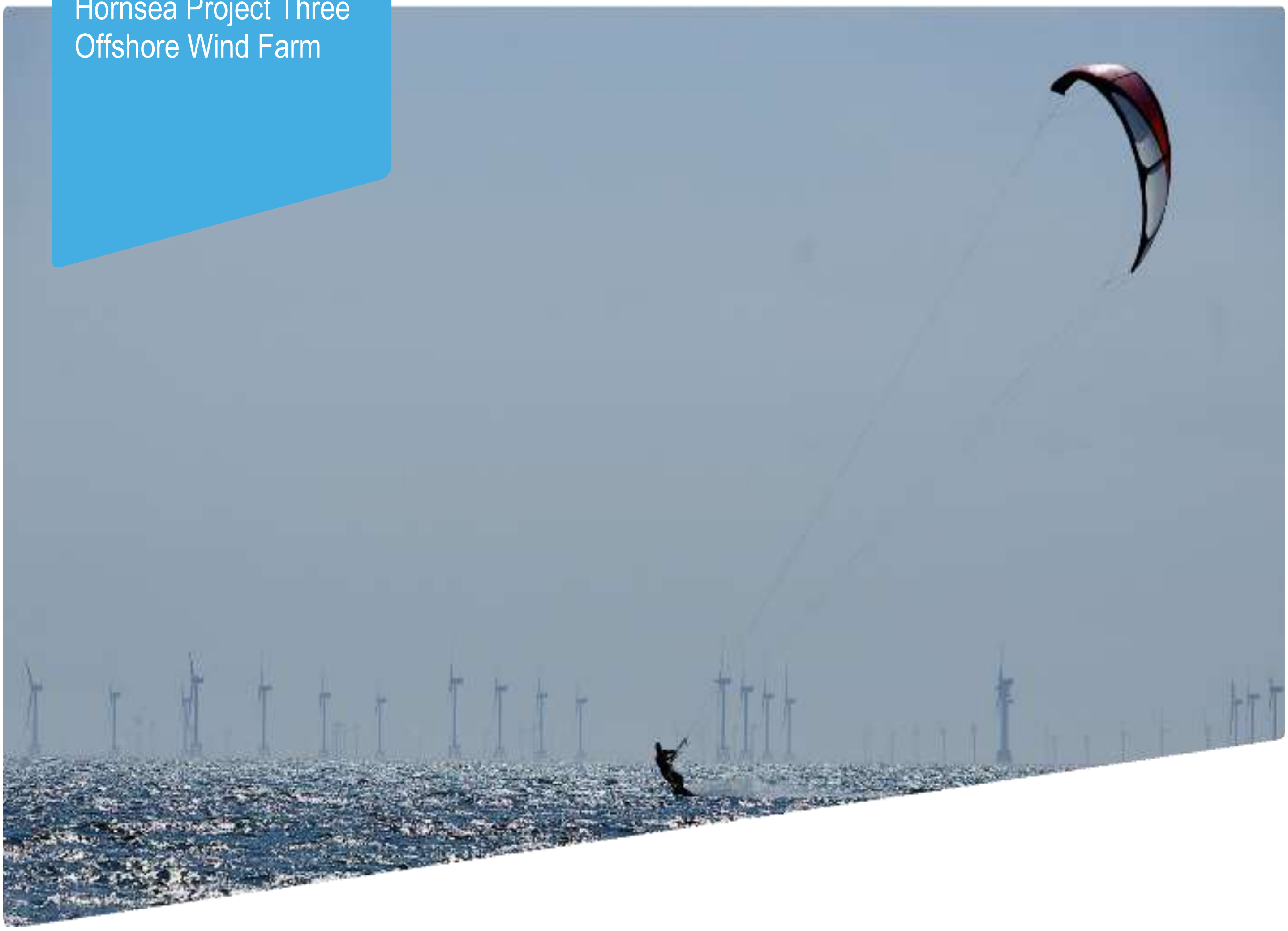
Dr Dominika Chalder PIEMA
Environment and Consent Manager

+44 (0) 7767 007 815

Environmental Management UK│ Wind Power
5 Howick Place │ London │ SW1P 1WG

Ørsted

Hornsea Project Three
Offshore Wind Farm



Hornsea Project Three

Offshore Wind Farm

Appendix 5 to Deadline 3 Submission – – Adrian Judd, Cefas 2011

Date: 14th December 2018

Hornsea 3
Offshore Wind Farm

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Ørsted

5 Howick Place,

London, SW1P 1WG

Front cover picture: Kite surfer near a UK offshore wind farm © Ørsted Hornsea Project Three (UK) Ltd., 2018.

Cefas

Cefas contract report: ME5403 – Module 15

Guidelines for data acquisition to support marine environmental assessments of offshore renewable energy projects

FINAL

Author: Adrian Judd

Issue date: 16th September 2011

Cefas Document Control

Guidelines for data acquisition to support marine environmental assessments for offshore renewable energy projects.

Submitted to:	Cathal Linnane (Defra) & Ashley Holt (MMO)
Date submitted:	16th September 2011
Project Manager:	Sonia Kirby
Report compiled by:	Adrian Judd
Quality control by:	Stuart Rogers
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Guidelines for data acquisition to support marine environmental assessments for offshore renewable energy projects

Author: Adrian Judd

Issue date: 16th September 2011

Head office

Centre for Environment, Fisheries & Aquaculture Science

Pakefield Road, Lowestoft, Suffolk NR33 0HT, UK

Tel +44 (0) 1502 56 2244 Fax +44 (0) 1502 51 3865

www.cefas.defra.gov.uk/

Cefas is an executive agency of Defra

Executive Summary

1.1. These guidelines will assist developers, environmental consultants, regulators, decision-makers and consultees in the design, review and implementation of environmental data collection and analytical activities associated with all stages of offshore renewable energy developments.

1.2. These guidelines provide a synthesis of the body of guidance that exists for such data acquisition activities and points the reader to where more detailed guidance can be found.

1.3. These guidelines are intended as the starting point for iterative dialogue between developers, environmental consultants, regulators, decision-makers and consultees to ensure that equipment, techniques and approaches are applied appropriately.

1.4. The main focus of the guidance is offshore wind farm development, but where approaches are more widely applicable to other offshore renewable energy technologies this has been highlighted.

1.5. The guidelines are structured to provide the reader with the mindset necessary to establish logical and targeted approaches to data acquisition with a supporting rationale. Included with this is the means to determine what approaches need to be utilized and which issues need to be investigated under specific circumstances to address specific questions.

Table of contents

1 Introduction

1.1 Aims

The Marine Management Organisation (MMO) commissioned Cefas to produce these guidelines under funding provided by the Department for Environment, Food and Rural Affairs (Defra). The stated deliverable from the MMO for this project was for a 'how to do it' manual for marine environmental data acquisition and processing.

This guidance will:

- Be relevant for all stages of the project lifetime (cradle-to-grave)
- Cover site selection
- Describe best-practices for offshore wind farm (OWF) EIA surveys
- Describe best-practices for OWF monitoring (pre-, during- and post-construction)
- Draw on lessons learned from UK and international experience in renewable energy developments (and analogous activities)

It is intended to be used by regulators[a], developers, environmental consultants and statutory consultees.

Scientific studies by their nature have to be designed to target specific objectives, which may alter during the course of the study as data and understanding improve or if further unforeseen questions arise and as such it is impossible for any guidance to be too prescriptive. As such these guidelines provide the user with the means to construct a rigorous survey programme through a process of:

- establishing the site specific data requirements,
- building the flexibility to respond to project outcomes during the study and
- designing the surveys to use appropriate gears, methods and analytical techniques.

1.2 Background

This project describes existing guidance documents but also provides a gap-analysis to identify where guidance is lacking. There is no "one-size-fits-all" approach to marine environmental data acquisition. If there were all environmental parameters and potential impacts would be assessed for every application and as such it is the intended purpose of these guidelines to facilitate the development of intelligent data acquisition strategies to eliminate unnecessary data collection, analyses and assessment. The nature and extent of desk-studies, sampling gear and approaches adopted are dependant on the questions being posed, the key site-specific environmental parameters under investigation as well as temporal and spatial considerations. Consequently, these guidelines will describe the basic approaches to marine environmental data acquisition and the application of the key survey techniques and gears. Given the similarities in the data acquisition and processing approaches at the various stages of offshore renewable energy (ORED) development the bulk of the gears, techniques, survey approaches, analyses and data processing are described in the Annexes (rather than duplicated throughout the text).

Key considerations for the design of all data acquisition projects:

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[a] Regulators in this context include the Infrastructure Planning Commission, Marine Management Organisation in England, Welsh Government, Marine Scotland orDepartment of Environment Northern Ireland depending in which administration the development is located.

- What parameters are to be assessed? Why do these parameters need to be assessed (rationale)?
- Which data need to be collected in order to answer the question being asked, and how will these data be analysed with statistical robustness?
- What existing data sources are there? Are these existing sources sufficient to meet your rationale? If not what new survey data are required?
- What seasonal, temporal and spatial considerations need to be applied?
- What survey techniques and gears will provide data to meet your rationale?

It is also prudent to consider what data types these approaches and gears will produce as these will guide what analytical techniques are best suited to these data outputs

To ensure that surveys and monitoring are soundly based it is essential that the data acquisition specifications and the resultant reports produced by developers clearly set out the criteria to describe what, why, how, when and where data acquisition is undertaken. In this way it should be readily apparent that the developer, their consultants, regulators[b] and interested parties[c] have a collective understanding and agreement on the fitness-for-purpose of the approaches applied, e.g. a survey specification or report that just contains data, analyses and conclusions provide little intelligence on the suitability of the data nor any conclusions drawn from it. Obtaining this buy-in to the approach by the relevant interested parties prior to undertaking the surveys and interpretation of the resultant data is a critical part of the process. As such any survey specification or report that does not contain this level of detail should be rejected – this is applicable to all stages of the project lifetime (including: Initial Site / Zone Selection; Site Selection – within R3 Zones; Site characterisation & impact assessment (EIA); Construction & Operation (monitoring) and Decommissioning), however, given the lack of specific existing guidance for these stages of development, the gears, techniques, methods and analyses for data acquisition are described in the Annex.

In the most part traditional approaches to marine environmental data acquisition have been employed, however, for some parameters (e.g. ornithological surveys) novel techniques are being investigated.

1.3 How to use this guide

This guide provides a summary of the existing best-practice for environmental data-acquisition associated with offshore renewable energy development; however, it is not intended as a substitute for the source reference material. To aid the user of this guidance, where available, hyperlinks have been provided to the source guidance materials. This guidance document for data acquisition has been structured to provide an:

- overview to generic survey design and planning
- outline to initial Site / Zone selection
- outline of Site Selection – within R3 Zones
- outline of Site characterisation & impact assessment (EIA)
- outline of Construction & Operation (monitoring)
- outline of Decommissioning

[b] Regulators in this context include the Infrastructure Planning Commision, Marine Management Organisation in England, Welsh Government, Marine Scotland or Department of Environment Northern Ireland depending in which administration the development is located.

[c] Interested parties in this context include Cefas, Joint Nature Conservation Committee and depending on the administration in which the development is located Natural England, Countryside Council for Wales or Scottish Natural Heritage.

For each of these sections the key considerations and basic approaches to environmental data acquisition are described. However, whilst the approaches to data acquisition may differ at each stage of development there is similarity in the gears, methods and analytical techniques so summaries of these are provided in the Annexes but a list of applicable techniques is provided against each stage of development.

This guidance is intended to provide the basis for informed discussion between developers, regulators[b] and interested parties[c]. Reading and understanding the content of these guidelines and initiating thinking on data requirements in advance of first contact is intended to facilitate a more efficient dialogue and use of resources. As such it is intended as a prompt and *aide memoir* throughout the engagement between interested parties and not as a substitute for it.

1.4 Terminology used in this guide

Certain terminology has been used in this guidance that may differ from that used in other regulations or guidelines. This terminology has been carefully chosen to reduce potential confusion or misinterpretation by describing the data not the process. Examples of such terminology that merit further explanation include:

- **Site Characterisation and Baseline**: The terms ‘site characterisation’ and ‘baseline’ are often used interchangeably however, this is not always appropriate and may compromise assessments through the inappropriate use of data. ‘Baseline’ data have a specific meaning in environmental studies in that they are the defined parameters against which change can be measured and as such need to be of a suitable resolution for statistical analyses (e.g. replicate samples, control stations, sufficient stations for power analysis). Conversely. ‘site characterisation’ data are intended to describe the environment and as such samples do not need to be replicated or subject to power analysis.

- **Environmental Pressure:** This terminology derives from the European Environment Agency DPSIR framework (Driver – Pressure – State – Impact – Response). The DPSIR framework provides a systems analysis approach where social and economic developments exert pressure on the environment which consequently changes the state of the environment. This leads to impacts that may elicit a societal response that feeds back on the driving forces, on the pressures or on the state or impacts directly, through adaptation or curative action. Pressure is used throughout these guidelines to describe those parameters to be investigated and managed in order to minimise or remove impact.

2 Overview of survey design and planning

Data are essential to all phases of offshore wind farm development and operation however data acquisition strategies must be developed to ensure that the requisite data for the intended purpose are collected. Clear objectives for environmental studies provide a basic framework on which the design and planning of data acquisition and processing can be built. This framework should provide the means to determine and justify the data and analytical requirements and establish which environmental parameters need to be assessed (and just as importantly those that do not need to be assessed). As such the framework is a powerful tool for both developers and regulators for determining where resources need to be deployed. In essence this framework for successful design, planning and implementation of assessments consists of scoping, site characterisation, impact assessment, targeted monitoring (as necessary), substantive review and decommissioning assessments. It may also assist in the identification and development of mitigation measures.

Scoping is the process of defining and agreeing the topics for inclusion, the methodologies for characterisation surveys and assessments including significance criteria and should be used to:

- identify the focus of the studies required as part of the EIA and the impact assessments which need to be undertaken for a scheme, to determine the 'proportionality' of approach to data collection, and allow for the scoping process to remove issues where no significant effect is predicted or where there is no effect pathway in place.
- Establish criteria against which risks / potential impacts will be identified and their significance assessed.
- Make an initial prediction of the zone of impact (footprint from direct and indirect effects). Establish collective understanding about the component parts of the proposed development (e.g. spatial extent, magnitude, timing, frequency, duration) to establish the extent of the zone of impact (i.e. defining the parameters to describe the Rochdale envelope)..
- Determine what data are required to adequately characterise the environment within the zone of impact.
- Conduct a desk-study to identify & collate existing information on the 'natural' environment, including temporal trends and
    - determine the suitability of existing data to adequately characterise the environment (data quality and age are important considerations for the reuse of existing data sets).
    - identify critical data gaps (temporal & spatial) that will necessitate new bespoke surveys.
- Identify the presence & extent of conservation features and other designated sites (e.g. geological sites of special scientific interest, heritage sites) and those biodiversity components of national and international importance (e.g. Natural Environment Rural Communities Act 2006 – Biodiversity list and action, Sections 41 (England) and 42 (Wales), OSPAR List of Threatened and/or declining species and habitats).
- Determine the features of local interest (e.g. local Biodiversity Action Plan species/habitats' Sites of Nature Conservation Importance, Local Nature Reserves etc.)
- Identify the presence & extent of socio-economic interests (e.g. fishing grounds)
- Collate evidence on outcomes and experience from previous synonymous activities
- Identify other activities occurring within the predicted zone of impact and set out the approaches assessing cumulative effects.
- Set out initial thinking and redesign/planning options for mitigating adverse effects
- Determine the schedule of work required to acquire and analyse data, including the setting of objectives (including hypotheses where appropriate).

- Uncertainty in the effect of the many potential scheme options can be managed by identifying an appropriate 'realistic worst case' scenario (Rochdale envelope). If a realistic worst case scenario is demonstrated to pose no significant impact, relatively less intrusive options maybe accounted. [Cefas comment: it may be necessary to choose more than one 'realistic worst case scenario' to define the Rochdale envelope depending on the combinations of foundation types, materials and installation methods because these will differ for specific receptors, i.e. the worst case for benthic receptors will differ to that for navigation. Developers may find it helpful to adopt a scenario based approach for this, assessing different permutations of various project components]
- Identify the consultees including local interest groups.

<u>Site characterisation</u> should be used to:

- Understand the environmental components, their interrelationships and dependencies. The amount of additional information required to fill gaps and adequately characterise the area will be site or case specific.
- Understand the importance of the site for the resident and migrant flora and fauna (e.g. why are they there and not elsewhere?; how critical is the site to the population?)
- Understand the sensitivity and vulnerability of these environmental components to change, including resident and migrant flora and fauna.
- Understand what other activities / uses are already in place and the seasonal, temporal and spatial extent and variability.
- Understand natural variability (this may require the evaluation of long-time series data sets) and the pressures being applied from existing activities.

<u>Impact assessment</u> should be used to:

- Determine the extent to which the development will impact the environmental components, including the interrelationships, dependencies, other pressures and variability, described in the site characterisation.
- Determine potential sources, pathways and receptors and type of impact.
- Evaluate the effects on other activities / users in the area and the consequences of such uses being excluded and or displaced.
- Describe the likely environmental *effects* on each of the receptors due to each environmental change that is caused by the activities associated with construction and operation, including both indirect and direct effects.
- Impact assessment should follow most recent guidelines on EcIA for marine and coastal ecosystems (IEEM, 2010).
- Impact assessment characterises the impact according to the following criteria:
    - i) Magnitude - size or amount of impact, determined on a quantitative basis if possible;
    - ii) Extent - area over which the impact occurs;
    - iii) Duration - the time over which the impact will last (i.e. time to recovery) - and should be distinguished from the duration of the activity;
    - iv) Temporal scale - permanent or temporary change in the ecology;
    - v) Timing and frequency - coincidence with critical life stages or seasons and time between recurring impacts (important in terms of ability to recover between impacts);
    - vi) Cumulative effects - consideration of the impacts against a background of other threats and impacts e.g. other proposals, completed projects; natural trends, climate change; and
    - vii) Confidence in predictions - likelihood that an impact will occur as predicted

- Evaluate integration of more complex ecology and the interactions between different receptor groups, e.g effects on fish and benthic ecology in relation mammals and bird populations (migrant or resident).
- Evaluate the short, medium and long-term effects of colonisation of OWF infrastructure (for single arrays and cumulatively with other developments internationally), particularly in regards to the spread of non-native species.
- Where feasible amend the infrastructure and construction design and methodologies to minimise impacts.
- Complete evidence and/or logic based socio-economic evaluations on impacts to other sea users.
- Complete evidence and/or logic based evaluation on disruption and displacement of other uses and users.
- Undertake cumulative and in-combination effects assessments.
- Determine and test the full range of mitigation measures to avoid or minimise any adverse effects identified.
- Reach evidenced based conclusions on the nature and extent of environmental impacts.
- Establish hypothesis[d] based monitoring proposals.
- Uncertainty in the effect of the many potential scheme options can be managed by identifying an appropriate 'realistic worst case' scenario (refining the Rochdale envelope established at the Scoping stage). If a realistic worst case scenario is demonstrated to pose no significant impact, relatively less intrusive options maybe accounted. [Cefas comment: it may be necessary to choose more than one 'realistic worst case scenario' to define the Rochdale envelope depending on the combinations of foundation types, materials and installation methods because these will differ for specific receptors, i.e. the worst case for benthic receptors will differ to that for navigation. Developers may find it helpful to adopt a scenario based approach for this, assessing different permutations of various project components.]
- Assessments should be clear about where it may not be possible to assess or detect impacts (e.g. due to a lack of evidence/knowledge, research gaps etc) to stimulate consideration of what can be achieved with the regulator and advisors.

<u>Targeted monitoring</u> should be used to:

- Test hypotheses on impacts attributable to Offshore Renewable Energy Development (ORED) construction and operation (as identified during the consenting process)
- Assess cause and effect relationships to validate predictions of environmental impacts identified in Environmental Statements and through the consents application process (this requires the establishment of a baseline against which change is assessed).
- Evaluate the short, medium and long-term effects of colonisation of OWF infrastructure (for single arrays and cumulatively with other developments internationally), particularly in regards to the spread of non-native species.

<u>Substantive review</u> should be used to:

- Ensure that monitoring outputs are fed back into consenting and licensing decisions.

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[d] A hypothesis is a testable statement used to explain an observation or effect, e.g. a prediction made in and Environmental Statement. Examples of testable hypotheses are:

- If the changes in hydrodynamic energy caused by wind farm foundations are sufficient to move sediments then scour pits will form.
- The wind farm is located in a silty environment so if organisms colonise the foundations they will be different from the biota resident in the sediments.
- The presence of the Wind Farm leads to significant changes in abundance of [named] bird species.

- Ensure that EIA and monitoring efforts are appropriately and proportionately targeted.
- Ensure that decisions are based on the most up-to-date scientific and technological criteria, once adopted as best practice.
- Ensure that stakeholder needs and objections are being appropriately addressed.
- Ensure that industry needs and government policy and targets are effectively considered.
- Ensure that assessment, advice and consenting / licensing decisions are managed adaptively.

Decommissioning assessment should be used to:

- Ensure that the environmental effects associated with the removal of the key components and infrastructure of OREDs and requirements for restoration of the marine environment are appropriately assessed and effective mitigation measures considered as necessary.

3 Site Selection – within Zones (e.g. Round 3)

This section relates to the voluntary Zone Appraisal and Planning (ZAP) approach in which Zones can be assessed to identify the optimal sites / locations for wind farm development within the allocated Zone.

The existing guidance[13] describes the type of data required but does not elaborate on how such data should be collected. Whilst it is implicit that the data requirements are at a broader scale than for Site Characterisation & EIA (see below) the precise resolution for these zonal assessments is not specified. However, the approaches to data acquisition and processing will be similar to those described below for EIA but at a different frequency and intensity. If a zonal assessment[13] is undertaken it is essential that the work is based on clear objectives that will guide subsequent survey, monitoring and assessment activities.

Key stages are:

- **Zone characterisation**: a spatially extensive description of the marine environment within the Zone including the identification of important and/or sensitive species or habitats (e.g. via suitable single sample station survey design), including seasonal, temporal and spatial considerations.
- Description of the **environmental pressures** associated with the development within the Zone.
- **Identification of site** / preferred areas of development
- **Impact assessment**: evidence based assessment of multiple parameters, including spatial extent and magnitude of direct and indirect impacts predicted for development within the Zone (see pages 5 and 6). Includes, consideration of: different layouts, designs, turbine/cable sizes; number and location of turbines / cables and percentage area(s) of the Zone for development. The assessment should focus on the interaction between the Zone characteristics and the identified pressures (described as a series of indicative exposure pathways). This is an important stage for the broad-scale identification of potential cumulative and in-combination impacts. Full reference should be made to Annex IV of Council Directive 85/337/EEC (As Amended) and IEEM (2010).

Various guidance documents and data sources are relevant for site selection:

- The Crown Estates R3 ZAP guidance[13] provides for the identification and selection of specific 'sites' within the defined zone development envelope – this does involve data acquisition and as such it is important that appropriate standards are applied, although it does not specify the type and resolution of the data required.
- The contents of the Regional Environmental Assessment: A Framework for the Marine Minerals Sector (2008) has resonance for the key issues and considerations for identifying areas / sites for development from a regional / zonal resolution of data.
- The Marine Environmental Data and Information Network[10] (MEDIN) provides guidance on metadata generation for data sets and advice on the information that should be recorded when different types of data are being collected. MEDIN provides a wealth of data beneficial to the offshore renewable energy industry.
- The MAGIC website[11] contains an interactive map designed to show datasets of environmental schemes and designations for England, Wales & Scotland, including marine areas as part of the Coastal and Marine Resource Atlas.

- The Marine Aggregate Levy Sustainability Fund commissioned a series of regional surveys[12] to develop understanding of Britain's submerged habitats and heritage. The aim of the Regional Environmental Characterisation (REC) surveys was to acquire data, of the highest quality and detail possible; to enable broadscale characterisation of the seabed habitats, their biological communities and potential historic environment assets within the regions. The Regional Environmental Characterisations (RECs) were conducted in the following areas: South Coast (2007 - 2010); Outer Thames (2007-2009); East Coast (2008 - 2011) and Humber (2008 - 2011).

4 Site characterisation and impact assessment (EIA)

This section provides an overview of the approached to data collection in studies designed to provide site characterisation and assess impacts as part of the EIA process. It is divided into key parameters, i.e. benthic studies, ornithological studies, fish studies, marine mammals, underwater noise, intertidal studies, physical and sedimentary process studies. It should be recognised that data collected at the Zonal Characterisation stage may define the scope and need of certain assessments and data collection at the EIA stage depending on the resolution of data collected.

4.1 Benthic Studies

The Guidelines for the Conduct of Benthic Studies at Aggregate Extraction Sites – MALSF Project Code: 08/P75 (Ware & Kenny (2011)) provides a key reference for data acquisition standards for benthic studies (refer also to DTLR 2002), including seabed sediment composition and benthic fauna, some of the key components are summarised here but for detailed analyses reference should be made to the source document. If a zonal assessment[13] is not undertaken it is essential that the site characterisation work is based on clear objectives that will guide subsequent survey, monitoring and assessment activities. If a zonal assessment has been undertaken then the site characterisation stage will build on and refine the objectives established for the zone.

Key stages are:

- **Site characterisation**: a broad scale description of the seabed environment within & around the expected zone of influence (e.g. offshore wind farm site, cable corridor and appropriate buffer) including the identification of important and/or sensitive species or habitats (e.g. via suitable single sample station survey design), including seasonal, temporal and spatial considerations. It is usually sufficient to use single sample stations (with no replication) as the purpose here is to define the main habitats and their spatial extent and as such a suitable spatial frequency needs to be applied.
- Description of the **environmental pressures** associated with the construction and operation of the development.
- **Impact assessment**: evidence and /or logic based assessment of multiple parameters, including the spatial and temporal extent and magnitude of direct and indirect impacts predicted for the development in the locale of the specified site (see pages 5 and 6), focussing on the interaction between the site characteristics and the identified pressures (described as a series of specific exposure pathways). Cumulative and in-combination impacts should also be considered. Full reference should be made to Annex IV of Council Directive 85/337/EEC (As Amended) and IEEM (2010).

Potential impacts on benthic receptors

- during construction: habitat disturbance, increased suspended sediment, sediment deposition, scour and abrasion, release of contaminants from dredged sediments, and

- during operation: changes in hydrodynamics potentially leading to changes in sediment type, introduction of new habitat from foundation structures (both positive and negative effects).

Use of oceanographic data in benthic surveys

Broadly speaking the hydrodynamic regime (tidal currents and waves), in combination with sediment source, determine the characteristics of seabed sediments and this ultimately determines a significant part of the broad scale community patterns we observe. Therefore understanding oceanographic conditions is a critical aspect of site assessment and monitoring for benthic communities in order to quantify these changes and allow evidence-based impact assessment.

Long term data sets provide a more realistic view of the situation compared to short term assessment and monitoring, especially in areas known to experience wide variations in oceanographic conditions. Variations between neap and spring tides, and summer and winter conditions should be considered so it is important to advocate the preferred seasons for such work and then, if repeat surveys are required follw this scheduling in subsequent years.
For further information on oceanographic techniques reference should be made to general texts such as UNESCO (1988, 1993), Emery and Thompson (1997) and ICES (2000).

Approaches to benthic surveys (summary taken from Ware & Kenny (2011))

There is no one-size-fits-all methodology for benthic site characterisation studies but the following approach provides for a sequentially targeted set of considerations for applying the available methods.

Acoustic surveys: are used to both inform & complement physical sampling methods. They can be used to delineate strata (e.g. bathymetry, substrate type) and such data are then used for informing design of ground-truthing surveys (to ensure that all strata are adequately sampled) and to identify the presence and extent of areas of interest (e.g. geological or sedimentary features, biogenic features of conservation importance, archaeological artefacts). The value and robustness of characterisation surveys is greatly enhanced where acoustic data (to an appropriate resolution) has been used to inform the design of surveys and contribute to the production of biotope description/map. It is recommended that in planning characterisation surveys, all existing acoustic data is sourced with any gaps identified and addressed.

Grab & trawl ground-truthing surveys:
Homogenous seabed: where acoustic data indicates a largely homogenous substrate (e.g. no directional gradients in substrate type or depth) the ground-truthing surveys should adopt a systematic (conventional) grid approach across the whole zone of potential impact – the number and spatial frequency of sampling will depend on how much existing knowledge and data there is about the seabed.

Heterogeneous seabed: where acoustic data indicates a heterogeneous substrate (e.g. the area of interest contains a number of strata characterised by different depths or substrate types) a stratified random approach is more appropriate. The stratified random approach should aim to identify and adequately sample all the strata present within the area of interest, spaced in relation to the predicted zone of impact (this is to ensure that the biotopes associated with the different strata are appropriately sampled.

Because the characterisation survey is intended to elucidate spatial patterns, a sampling strategy involving single (unreplicated) samples from a larger number of stations over a large spatial area is favoured over repetitive sampling as a smaller number of spatially restricted stations. The number of samples taken should reflect the size of the area being surveyed such that the principles of the species-area relationship are followed. Otherwise, there is the possibility of under-sampling and therefore missing species that occur in low densities or are locally rare. Each habitat type identified by the ground-truthing surveys should be sampled adequately.

Alternative survey methodologies:
Sampling of non-sedimentary substrates (e.g. pebbles or rock) or of features of conservation interest (e.g. biogenic reefs) necessitates alternative sampling approaches. Underwater video and stills photography (by Remotely Operated Vehicle) can be used for the assessment of all types of seabed habitat and in particular over hard and consolidated ground where the efficiency of other gears will be compromised or in sensitive habitats where damage should be minimised.

Targeted Surveys: should be carried out to adequately identify benthic communities within each habitat type and not just the habitats/areas of conservation/commercial/archaeological importance identified during the acoustic surveys. Otherwise, the benthic community would not be adequately described and it is important to understand the functional role that the benthic community has within the study area and its intrinsic ecological value. Where a combination of acoustic and ground-truthing techniques have identified areas of interest (e.g. species or habitats of conservation importance, fish and shellfish spawning grounds, areas of archaeological importance) further more targeted investigations may be required. As stated above the presence of some habitats of nature conservation value may necessitate a change in sampling method or expansion of the survey to avoid damage and to collect sufficient data to allow a decision to be made concerning the impact of the proposed activity (e.g. use of photographic methods). In the cases of temporally defined phenomena (e.g. spawning areas of commercial fish and shellfish species) seasonal considerations may be required when planning the associated surveys. Dialogue with the relevant bodies will facilitate the requisite refinement to survey designs.

Reference should also be made to: http://www.oceannet.org/marine_data_standards/medin_data_guide.html where the following data guidelines can be downloaded:

- MEDIN data guideline for sediment sampling by grab or core for benthos
- MEDIN data guideline for recording and archiving of digital photographs
- MEDIN data guideline for fish and benthos data by trawl and dredge
- MEDIN data guideline for transfer video survey data

Gears & techniques (see Annexes 1 and 2 for descriptions and application):

- Desk study
- Underwater video and stills photography
- Grabs and corers
- Trawls and dredges
- Current meters or Acoustic Doppler Current Profiler (ADCP)
- Optical sensors or backscatter sensors
- Surface mounted wave buoys or seabed mounted devices
- Sediment traps (passive, active or directional)

- Conductivity, Temperature and Pressure (CTD) systems
- Echo-Sounder (single line bathymetry)
- Acoustic Ground Definition System (AGDS)
- Sub-Bottom Profiling
- 'Scientific' Echo-Sounder
- Sidescan Sonar
- Digital Image Scanning Sonar
- Swath Bathymetry (Multibeam)

4.2 Ornithological Studies

In all cases the SNCAs should be contacted before any work is undertaken to design and plan ornithological studies. As such this section only provides a generic overview.

A range of birds could potentially be affected by offshore wind farms including seabirds, seaducks , waterbirds and wildfowl. Seabirds feed in marine waters and include gannets, shearwaters, skuas, petrels, auks, gulls, and terns. Water birds include divers and grebes that often spend a proportion of their time in freshwater, seaducks are marine birds outwith the breeding season. A wider range of species may move through the area of a wind farm, either locally on a daily basis or during national or international migration. Such species include those listed above, as well as other wildfowl and passerines.

The extent to which a species is affected by a wind farm depends on the importance of the area for the species and the species' vulnerability to impacts from the wind farm. In order to fully assess the potential impacts of any wind farm, it is necessary to understand the relative importance of the proposed wind farm area for birds; for foraging, preening, loafing and as a staging post for migration purposes. Moreover the changes in utility of offshore areas by seabirds on a seasonal basis need to be documented by the developer and relayed within any environmental statement. This can be gauged through an understanding of the distribution and abundance of the birds in the area over time, and through analysis of behaviour. Areas which are considered important for use by birds should be primarily avoided, with siting of wind farms preferentially taking place in areas of lesser significance.

A combination of methods are needed to understand both the distribution and abundance of ornithological interest features, and also to assess how the birds are using the area (see above). Analysis of results from other investigations (e.g. hydrography, geophysical data) and existing survey information (at sea and breeding colonies) will assist interpretation of the relevance of the area for bird species.

Detailed knowledge and understanding of the species and importance of offshore areas for seabirds will assist the development of mitigation measures (including appropriate siting of a development) aimed at reducing impacts as far as possible (discussed further in Section 5.5). Consideration of alternative sites to those which are important for use by birds is the primary recommended measure to avoid impacts.

Key stages are:

- **Site characterisation**: a spatially extensive description of the distribution and abundance of seabirds and migratory birds within & around the expected zone of influence including the

identification of important and/or sensitive species or habitats/feeding grounds/migration pathways - including seasonal, temporal and spatial considerations.
- Description of the **environmental pressures** associated with the construction and operation of the development and determination of the geographic scale of concern.
- **Impact assessment**: evidence and / or logic based assessment of multiple parameters, including the spatial and temporal extent and magnitude of direct and indirect impacts predicted for the development in the locale of the specified site (see pages 5 and 6), focussing on the interaction between the site characteristics and the identified pressures (described as a series of specific exposure pathways). Cumulative and in-combination impacts should also be considered (King et al 2009). Full reference should be made to Annex IV of Council Directive 85/337/EEC (As Amended) and IEEM (2010).

Approaches to ornithological data acquisition:

Traditional approaches to seabird surveys are either boat-based or aerial (aircraft). Which approaches are adopted depends on the survey objectives which may dictate that both approaches need to be taken to fully characterise seabird distribution and abundance. JNCC provide a range of references, resource downloads and recommended training outlets[14] for seabird surveys. For offshore wind farms methodologies for both approaches are described in Camphuysen et al, 2004 and refined and expanded in MacLean et al 2009. The survey should cover a sufficiently wide area to be able to place wind farm usage in a wider spatial context. Historical data should also be utilised to provide temporal and spatial context with regards to population trends and a better understanding of the importance and relevance of the study area to bird populations.

Surveys need to be designed to capture the temporal variation of the range of species likely to be present. For example one recommendation[3] is that surveys are conducted over a minimum of two years with surveys throughout the year – boat based surveys should be carried out monthly and aerial surveys at least eight times a year (three times in winter and 5 times in non-winter).

In addition to abundance and distribution, data should also be collected to inform the assessment of potential impacts, such as flight direction and height of flight.

The larger scale of the Round 3 offshore wind farm development zones presents a considerable challenge to the traditional approaches to seabird surveys. High definition or high resolution video and stills photographic methods are being developed and utilised. There has been considerable recent progress in research regarding high definition or high resolution still and video cameras[15,16,17,18,19,20]. As such there remains a specific need to further develop survey protocols to facilitate the use of high definition or high resolution imagery in bird surveys.

Please note that the Statutory Nature Conservation Agencies hold reservations on a number of aspects of Maclean et al 2009, e.g. those relating to collision risk. There are a number of aspects that have since been revised and the guidance and recommendation the agencies provide for Round 3 is no longer captured in the Maclean et al 2009 text and as such the SNCAs should be contacted for specific guidance.

Gears & techniques:
- Desk study
- Boat-based surveys
- Aerial surveys (including high definition or high resolution digital techniques)
- Additional methods – Radar, remote tracking, visual observations

4.3 Fish and Shellfish Studies

In general, the issues relating to fish and shellfish resources should be addressed from the perspectives of (a) the biology and ecology of the major commercial fish and shellfish species and species of conservation importance and (b) the commercial and recreational fisheries.

Considerable quantities of data for fish and shellfish distributions in inshore waters already exist. These sources should be investigated, and detailed consultations undertaken, **before** field sampling programmes are designed.

When new surveys need to be designed (established by the processes described in sections 1 and 2 of this guidance), it is essential that sampling methods are selected that are most appropriate for the issues on site (see the information box below), as entire fish communities cannot be sampled with a single type of sampling gear.

In determining which survey gear and methodology to undertake survey work, the developer must be clear about the fishery they are describing (e.g. beam trawls are suitable for coastal waters for flatfish and small-bodied demersal fish but cannot be used to survey pelagic or large-bodied species). If commercial species are of concern then gear and techniques employed by the local fishing industry should be mirrored in the survey design and where possible, the involvement of local fishermen in survey design and data collection is strongly recommended.

Survey design must include sufficient replication and coverage to take account of the mobile nature of fish populations. A detailed assessment of the commercial fishing activity at the site is also very important. This should include reference both to existing broad-scale datasets, as well as site-specific fishing intensity studies.

Detailed proposals for any survey should be submitted to the regulator[e] who will ensure that gear-type, data and analyses are adequate to meet the regulatory requirements (following advice from their advisors). However, the onus is on the developer to design the plan of works and they should only contact the regulator[e] once they have devised a plan of works based on this guidance note (including the collection of new data and computer modelling), to address the issues identified in this section. At the scoping discussions, the regulator[e] will comment on whether or not the proposed tools are sufficient to ensure that the type and quality of the data are suitable to assess the potential environmental impacts.

Key stages are:

- **Site characterisation**: a broad scale description of the fish and shellfish distribution, abundance & ecology within and around the expected zone of influence including the identification of important and/or sensitive species or habitats and the environmental, social and economic distribution and importance of commercial fisheries, including seasonal, temporal and spatial considerations, migratory species and spawning / nursery grounds.
- Description of the **environmental pressures** associated with the construction and operation of the development.
- **Impact assessment**: evidence based assessment of multiple parameters, including the spatial and temporal extent and magnitude of direct and indirect impacts predicted for the

[e] Regulator in this context will be the Marine Management Organisation in England, Welsh Government, Marine Scotland or Department of Environment Northern Ireland depending in which administration the development is located.

development in the locale of the specified site (see pages 5 and 6), focussing on the interaction between the site characteristics and the identified pressures (described as a series of specific exposure pathways), including ecological, social and economic effects on commercial fisheries (e.g. noise disruption, electromagnetic fields, impacts on spawning and over-wintering grounds, impacts on nursery grounds, impacts on feeding grounds, displacement of prey species, impacts on migratory pathways, impacts on locally abundant populations, impacts on commercial fisheries). Cumulative and in-combination impacts should also be considered. Full reference should be made to Annex IV of Council Directive 85/337/EEC (As Amended) and IEEM (2010).

Information Box: Considerations for fish and fisheries characterisation

- What species of fish and shellfish are present at the site and surrounding area?
  - Which of these species are of high importance in commercial and/or recreational fisheries?
  - Which of these species are of high conservation importance?
  - Which of these species is of high importance as prey to species of commercial and conservation importance?
  - Are there any other species that are locally abundant in the area?

- For those species of commercial and recreational importance
  - Are there locally important spawning grounds?
  - Are there locally important nursery grounds?
  - Are there locally important feeding grounds?
  - Do their migration routes pass through the area?
  - Are there locally important areas for their prey species?

- For those species of conservation importance:
  - Are they present in the area, and if so how abundant are they?
  - Do they have any critical habitat in the area, or are they occasional vagrants?

- If a species has spawning grounds in the area:
  - When does the species spawn?
  - Will construction affect the physical habitat used by egg-laying species?
  - How will construction activities least impact on spawning behaviour and the physical nature of spawning grounds?
  - what is the relative importance of the area in the context of the wider spawning area for each species?

- If a species has a nursery ground in the area:
  - What is the relative importance of the habitat for the species in the region as a whole?
  - Will wind farm construction reduce available habitat or enhance the habitat?

- If a wind farm site is in close proximity to an estuary:
  - What is the status of diadromous fishes in the area?
  - Will the site pose a serious threat to the migratory pathway of diadromous fish, taking other estuarine and coastal developments into consideration?
  - What are the timings of migrations through the site?
  - Is the site important for estuarine fish species for spawning, such as the flounder, that spawn in the open sea?

Approaches to fish & fisheries data acquisition:

The baseline information for fish within the ES should consist of a broad description of the species present in the area of the wind farm and along the cable corridor and the relative importance of the development area and cable corridor compared to the surrounding area for a complete annual cycle. A great deal of information on species distribution and habitat requirements is available in published sources and data on commercial catches and/or fishing surveys can be obtained from MMO[21] and the Scottish Executive[22]. A good source of information may be local knowledge (including the local IFCA[23] or the South Wales or North Western and North Wales Sea Fisheries Committees as appropriate), local angling records and commercial fishermen. For many species of conservation interest, commercial catch data may be lacking and surveys too infrequent to provide usable/robust data. In such cases, anecdotal information and in the case of species that have undergone severe declines, historic records of past fisheries may be the best source of information available. The use of anecdotal information carries a caveat regarding the potential data quality.

Information should be collected to describe local fish and shellfish resources both at the site and in the surrounding area. The presence and relative importance of fish resources will need to be described and assessed. Important fish resources should include:

- The major species of fish and shellfish in the area that are of significant importance in commercial and recreational fisheries.
- Those species of fish in the area that are of conservation importance.
- Elasmobranch fish (which are often also of commercial and recreational importance) that may be susceptible to the effects of electro-magnetic fields; hence special mention of these species ought to be made.
- Species that have a restricted geographical distribution and are locally abundant in the area.
- Prey species that are of importance to commercial fish species and species of conservation importance.

It is likely that the presence of a wind farm in relatively shallow coastal waters will interfere with the commercial fishing activity that takes place in the area. There are two issues that need to be considered. The first is the possibility that the wind farm will cause an adverse impact to the fish or shellfish population, and result in changes in abundance (whether such changes are positive or negative needs to assessed). It is also possible that the location of the wind farm, and the turbines themselves, provide a physical obstruction to the normal activity of inshore fishing boats, resulting in a change to normal practices and the implications to these changes need to be understood and assessed (see Mackinson *et al* 2006), e.g. the consequences if such fishing activities are displaced.

It is crucial that, at an early stage, local fishing industry representatives (individuals, organisations and charter boat skippers) are contacted for information concerning the scale and seasonality of fishing in the vicinity of the planned wind farm, and for their opinion as to the potential implications of the development.

A considerable quantity of information for the UK coastal zone is available in published documents and reports, and it is recommended that these sources of information are used to determine the presence, distribution and seasonality of the fish and shellfish resources. In those areas where insufficient information is available, it may be necessary to undertake specific site surveys for fish resources. Such surveys must be designed carefully and the EIA must describe precisely how and why the work was undertaken. An early appraisal of the most important fisheries resource issues at the site, and subsequent data collection either from existing sources or using new surveys, will be an important part of survey design.

The following aspects of fish ecology should be considered:

- Spawning grounds
- Nursery grounds
- Feeding grounds

- Over-wintering areas for crustaceans (e.g. lobster and crab)
- Migration routes

An atlas of spawning areas and seasons is available (Coull *et al*. 1998) and should be consulted along with Ellis et al 2010 which provides updates for certain species. In the absence of data regarding the importance of sites for spawning, studies may be required to determine whether mature fish in spawning condition are present in the area during the spawning season and/or whether there are eggs and larval stages present (see sections on underwater noise).

Commercial fisheries

In many cases, a desk-based study is all that would be required to enable an impact assessment to be made. However, where such data is lacking, fish surveys would be needed. Due consideration has to be given to appropriate timing of the survey to coincide with seasonal movements of fish species.

It is essential that consultation with the fishing industry is undertaken as early as possible, to adequately address fisheries issues as well as gathering of information relevant to fishery resources. Key representatives should be kept informed of progress of the project, so as to build a good working relationship with trust and co-operation.

Evidence should be provided of the major commercial fish and shellfish species in the area, stating which fisheries target these species and during which times of the year. The relative importance of the wind farm site as nursery, spawning, feeding and over-wintering grounds, and as migratory corridors should be assessed for these species. It is suggested that the following information is collated for the site and surrounding area:

Description of the fisheries in the area

Some summary information on the type and scale of fishing activity for England and Wales is available (e.g. Walmsley and Pawson, 2007), although consultation with local fishermen (e.g. commercial and recreational fishermen, fishing organizations such as the National Federation of Fishermen's Organisations[24], and fish merchants) and local fisheries managers (e.g. IFCA[23], local MMO/Welsh Government offices[21]) are critical to understanding the composition of the fleet, its general activities (seasonality, gear used etc.) and broad areas that are of greatest importance as fisheries grounds. It should be noted that not all fishermen will belong to organisations, and therefore, consultations with individual fishermen are of great importance. Depending on the area there may be data already collected by marine research institutes and local universities. It is therefore recommended that the developer contact the above organisations at the earliest opportunity in order to establish and maintain good relations and liaison.

Landings data

Landings data (e.g. from ICES[25], MMO[21], IFCA[23]) should be collated, remembering the caveats associated with such data (e.g. discards are not included, some species are recorded at a higher taxonomic level than species, landings from the inshore fleet (<10 m) may not be included). It is suggested that at least 5 years of data (pre-construction) are examined. These data should be viewed in context with any qualitative data or descriptive information obtained from local fishermen.

Effort data

Effort data (e.g. from Defra, local IFCA[23]) should be collated to identify those areas within the region that are most important for fishing activities. These data should be viewed in context with any qualitative data or descriptive information obtained from local fishermen. Effort data should examine annual and seasonal patterns in the spatial distribution of effort for the major gear used in the area.

Cumulative assessment

Given that the data for fisheries is often regional, and given that cumulative and in-combination impacts are critical to evaluating the impacts on the fishing industry it is strongly recommended that developers and their consultants work with other consultants operating in the same region. This will help to ensure a more standardised approach to fish and fisheries data collection, facilitate comparison between sites, and contribute to any coordinated post-construction monitoring programmes. Collaboration between developers will also help the production of broad scale regional overviews of fisheries, and contribute to Strategic Assessment.

Surveying methodologies

Once the important fish and shellfish species within the vicinity of the proposed site have been identified, those aspects of its biology that may be affected by the development of the wind farm (nursery grounds etc.) can be determined.

In many instances such data may be available in a variety of reports or scientific publications, and a desk study may be all that is required. Field sampling will not always be necessary.

For some sites, however, there may be either a lack of information, or an issue that is of local concern, and in such cases some field sampling may be required. If there are serious issues relating to the possible impacts of a wind farm development, then a monitoring programme may also be required. The protocols for fishing surveys are provided in the Annex.

Gears & techniques (see Annexes 2 and 4 for descriptions and application):

- Desk study
- Commercial gears (pots, trawls, fixed nets, lines etc)
- Underwater video and stills photography
- Grabs
- Acoustic Ground Definition System (AGDS)
- 'Scientific' Echo-Sounder
- Sidescan Sonar
- Landings data
- Effort data
- Fisheries liaison
- Socio-economic evaluations

Reference should also be made to: http://www.oceannet.org/marine_data_standards/medin_data_guide.html where the following data guidelines can be downloaded:

- MEDIN data guideline for static net, pot and trap data
- MEDIN data guideline for shellfish stock assessment data
- MEDIN data guideline for fish and benthos data by trawl and dredge

Underwater noise and fish

Many species are vulnerable to noise disruption, particularly with regard to spawning behaviour which may be disrupted by seismic surveys in the pre-construction phase. Placement of the turbines, piling and scour protection at the site, and cable laying operations may disrupt the behaviour of fish, particularly in relation to spawning and migration routes for diadromous fish and other migratory species. Studies indicate that a range of received sound pressure and particle motion levels will trigger behavioural responses in sole and cod (flat and round fish) (Mueller-Blenkle *et al* 2010). There is currently no scientific consensus on the precise threshold criteria to be applied for underwater noise effects on fish and as such stipulating specific approaches at this point in time could be counter productive. References such as Popper et al 2006 and Nedwell et al 2007 provide an indication of how thinking on this topic is evolving.

Most species of fish are broadcast spawners, and so changes to the seabed and the placement of turbines associated with the development of wind farms may not have severe long-term implications. However, disruption to the spawning periods of certain species in certain areas may need to be avoided during the construction phase.

Those species of fish that deposit eggs on the sea floor are more likely to be affected by any activities that may disturb or displace them to areas of different sediment type. The primary species of concern is herring *Clupea harengus*, although other egg-laying or nest building species, including rays (Rajidae), wolf-fish *Anarhichas lupus*, and black sea bream *Spondyliosoma cantharus* may be locally important. Herring spawning grounds are typically comprised of coarse sand, coarse shelly sand, gravel, and large unbroken shell fragments overlying gravel, and such habitats should retain their physical integrity. Edible crab also require coarse sediment in which to bury, and avoiding sedimentation at key sites should be considered.

The EIA should examine the spatial and temporal aspects of spawning, identify protocols to minimize the disruption to spawning activity/behaviour (including construction and any pre-construction surveys, such as seismic surveys) and identify the measures to be undertaken so that spawning grounds for egg-laying species will not be affected adversely by noisy activities such as pile-driving.

The possible effects of noise disturbance on the behaviour of spawning fish are unclear, and will need to be considered in the ES to address local concerns. The maps in Coull *et al* (1998), Ellis *et al* (2010) and Judd et al (2011) are used as the basis for the initial assessment to whether the proposed offshore wind farm is within or close to a fish spawning ground and this will be highlighted by the regulator[f] in their scoping advice. The available evidence suggests that behavioural responses in fish can potentially occur at relatively low levels of noise exposure and that noise propagation and therefore the zone of impact can be over large distances. Developers therefore need to consider the far field environment when considering noise impacts on fish, Thomsen *et al* (2006) demonstrated that fish can detect and react to noise over much larger distances than previously thought so any assessment will need to carefully consider the scale over which affects might present themselves. Cefas advice to the regulators is to ensure that the key life-stages of the key species are protected – as such the key focus is on the spawning period (Judd *et al* 2011).

Where the potential impact zone from the propagation of underwater noise overlaps with the spawning grounds identified in Coull *et al* (1998), Ellis *et al* (2010) and Judd *et al* (2011), it is likely that the regulators will impose a timing restriction on 'noisy' activities, e.g. seismic surveys and pile-

[f] Regulators in this context include the Infrastructure Planning Commission, Marine Management Organisation in England, Welsh Government, Marine Scotland or Department of Environment Northern Ireland depending in which administration the development is located but could also include consultation responses from Cefas, JNCC, CCW, SNH or Natural England.

driving during the spawning season of the key species of the area. As detailed in Judd *et al* (2011) this is the default position based on current scientific understanding, however, this should also be the trigger for developer to take action to:

- Ensure that the costs for such downtime on pile-driving are properly factored into the budgets and schedules for the construction of the offshore wind farm at the earliest opportunity;
- Investigate the need and scope for more detailed studies at the site to better define the timing and extent of the peak spawning period (via a combination of sea bed, newly hatched larvae and spawning state surveys) – this may require a series of surveys over a number of years, but will reduce the length of the noise restriction period and therefore downtime costs;
- Undertake noise propagation modelling, calibrated with locally relevant noise and seabed topography data;
- Investigate mitigation measures that can be designed into the construction or tested on site early in the project development to reduce noise emissions.
- Investigate alternatives to seismic surveys and pile-driving (i.e. options with reduced noise inputs)

If the above steps produce sufficient evidence to satisfy the regulator that the temporal and/or spatial extent of the impact on specific spawning grounds is less than predicted there may be scope for the timing restriction to be reduced (or removed) or to phase the works in such a way that impacts on spawning fish are reduced. In the absence of such evidence, or if the regulators are not satisfied that any new data are sufficient to justify a change the original timing restriction will remain in force.

Please refer to section 4.5 for an overview of approaches to noise data acquisition.

4.4 Marine Mammals

In all cases the SNCAs should be contacted before any work is undertaken to design and plan marine mammal monitoring studies. As such this section only provides a generic overview.

The report "Approaches to marine mammal monitoring at marine renewable energy developments" – MERA 0309 TCE (SMRU Ltd. (2010) and references therein) provides a key reference for marine mammal monitoring within the marine renewable environment. Reference is made here to some aspects of the report are summarised here, however, consult the document for detailed methodologies and analyses.

Site characterisation should start with a review of existing data on marine mammal distribution for the area. Historical data (previous surveys in the area, national surveys such as the SCANS surveys or existing databases such as the Joint Cetacean Database held by the JNCC[26]) should also be utilised. This will help inform the level of detail of any additional data that might be required, and what survey techniques may be appropriate and will also provide temporal and spatial context to any additional data collected.. The chosen survey methods and sample sizes will depend on the characteristics of the study area, the species present, their abundance and their potential sensitivity to the development, the importance of the region for marine mammals and the desired outputs of the survey. There are a wide range of possible marine mammal survey techniques, varying widely in their cost, ease of use and the type of data they generate. For example, in an area with harbour porpoises as the main marine mammal species of concern, autonomous acoustic monitoring (such as that provided by a porpoise detector may be sufficient to characterise the area, instead of more expensive systematic sightings surveys.

Visual observations have traditionally been used to survey marine mammals, taken from land, boat or aircraft, to obtain abundance and behavioural information. Subsequently, acoustic monitoring techniques have been developed which, unlike visual observations, are not as limited by weather/sea state conditions or time of day, although do depend on a vocalising animal and have limitations in the species that can be detected. Other methods of monitoring are detailed within the SMRU Ltd. (2010) scoping report (e.g. photo identification, platform of opportunity surveys and land based observations) but these are less relevant to the offshore wind renewables sector (although could be of use on a site specific basis) and will not be discussed within this document. More recently HD photography or video have been suggested as alternative method after successful use during offshore bird surveys, however, these techniques have not yet been validated, and there are several issues that need resolving before they can become a viable alternative to more traditional methods. Lastly, a computer based system for the collection of line transect data has been developed to automate data collection wherever possible. This approach has been applied in particular to the measurement (rather than the estimation) of distances and angles to sightings as work has shown that angle and distance errors can make a large contribution to the variance of abundance estimates and may cause considerable bias (Leaper *et al.,* 2008).

Objectives of marine mammal monitoring with regards to renewable development predominately focus on marine mammal distribution and abundance (characterisation stage) to allow environmental impact assessment to be carried out and monitoring the impact (behavioural / distribution changes) of the development (post consenting monitoring, see section 5.6)). Different survey techniques will provide different qualities of data. Importance is placed on whether abundance data gathered is relative or absolute. Absolute abundance data is the most useful, but is also the most expensive to collect. Collecting relative abundance data is cheaper, and if methods are kept consistent, relative abundance can be used to characterise an area and possibly to examine changes over time.

Whichever survey technique is used, observers should be trained and experienced and survey protocols should be standardised, to enable inter-site comparisons. Several tools are available to help plan survey design, data collection and analysis (e.g. DISTANCE, Thomas *et al.,* 2010).

To date, all marine mammal site characterisation for renewable development has taken place on a site specific basis. However, given marine mammals are wide ranging animals, it would be more appropriate for surveys to take place at a larger scale to effectively place site distribution and abundance into context of the wider natural range of populations. The Joint Cetacean Protocol being facilitated by JNCC is intended to integrate several data sources, some with disparate data types and establish what power the combined data resource may have to detect trends in range and abundance and should also enable developer data to be placed within a wider context. In addition, contributing developer's data to the JCP will build up the data pool and allow for more robust estimates of abundance and a more accurate picture of distribution and its variability.

Key stages are:

- **Site characterisation**: a broad scale description of the distribution and abundance of the marine mammal species present within & around the expected zone of influence including the identification of abundant and/or sensitive species –taking into consideration evidence for seasonal, temporal and spatial patterns. For seals, distance to haul-out sites and seasonal sensitivities should also be considered. These data should be sufficient to allow impact predictions to be made.
- Description of the **environmental pressures** associated with the construction and operation of the development and determination of the geographic scale of concern.
- **Impact assessment**: evidence based assessment of multiple parameters, including the spatial and temporal extent and magnitude of direct and indirect impacts predicted for the development in the locale of the specified site (see pages 5 and 6) (numbers disturbed/displaced, injured or a reduction in density from a certain area and period of time), focussing on the interaction between the site characteristics and the identified pressures (described as a series of specific exposure pathways). Cumulative and in-combination impacts should also be considered. Full reference should be made to Annex IV of Council Directive 85/337/EEC (As Amended).

Approaches to marine mammal surveys and survey design:

Desk study: Despite the increased survey efforts of the last two decades, current knowledge of the spatio-temporal distribution of cetacean species in UK waters (and indeed European waters) is limited. The most comprehensive information, including maps of species occurrence at a coarse scale and details on the spatio-temporal distribution and relative abundance of the most common cetacean species can be found in the *Atlas of cetacean distribution in the north-west European waters*[5]. The Atlas was produced using data both from dedicated and opportunistic sightings surveys. There are however several limitations in this dataset. All of the distribution maps (available online at http://www.jncc.gov.uk/page-3987[6] and www.seawatchfoundation.org.uk[7]), mask any inter-annual variation within the period covered (since data were collected over a period of two decades). In addition, monthly coverage is patchy and the consequences of wide variation in search effort are less likely to be masked at such a relatively fine temporal scale. Further information on cetacean distribution and abundance in UK waters can be found on the DECC's Strategic Environmental Assessments[8] and in the cetacean chapter of the Mammals of the British Isles

(2008)[9], and for Wales and neighbouring waters in the *Atlas of Marine Mammals in Wales* (Baines & Evans 2009)[10]. Estimates of density per broad region in some parts of UK waters can be obtained from the SCANS II and CODA[11] reports. However, it is important to bear in mind that the SCANS II and CODA[10] surveys are only synoptic since they were carried out in a single month of one year (2005 and 2007, respectively) and they did not cover the entire range of most populations.

It is suggested that developers start the review of baseline on marine mammals using this existing information and also local knowledge and records of sightings and strandings for example from the Sea Watch Foundation[7], Hebridean Whale and Dolphin Trust[12], Whale and Dolphin Conservation Society[13], etc. For grey and harbour seal monitoring data contact Sea Mammal Research Unit[6] (see SCOS reports[14]) and consult the JNCC website[15] for seal SACs locations and information.

Other data sources are also available (ferry and other platform of opportunity data, dedicated research projects, strandings, oil and gas Marine Mammal Observer data and other marine development survey data) and should be explored. Such existing data (if of good quality) will assist in characterisation and may even help planning the timing and frequency of surveys and as such should be undertaken in advance of commissioning any new surveys.

In some cases this desk top information will be sufficient to undertake impact assessment. However, should these reviews highlight that there is a lack of information in the area it may be necessary to undertake targeted marine mammal surveys. Dedicated surveys may be recommended by the statutory nature conservation agencies (SNCAs) over a number of months, seasons or years before the start of the activity (dependent on the planned timing, duration and frequency of the activity), to aid in the risk assessment and mitigation process. Advice on the need for these surveys should be sought from the SNCAs, which may also advise on methods and overall strategy of data collection.

Knowledge of the environmental factors that may be influencing animal distribution, such as prey availability, tidal state, underwater topography and oceanographic features will help understanding and even predicting the occurrence of animals in the area. Modelling animal distribution and abundance based on environmental factors is an active area of research but for many areas there is still great variability in the model predictions for us to be able to rely exclusively on these.

Dedicated surveys: Dedicated surveys for cetaceans (whales, dolphins and porpoises) differ from those for pinnipeds. For seals survey traditionally have been by annual counts, during their breeding (grey seal) or moulting (harbour seal, also known as the common seal) periods. There is government funded long-term monitoring of several seal populations involving counts on haul-out sites . For wind farm area characterisation, seal satellite tracking might provide at sea data and help establishing whether the affected area is an area where seals occur at high densities on a regular basis which would increase concerns on the effects of displacement on the populations

Key considerations for survey design are:

- Definition of the survey area.
- Design parameters (the required precision (CV) associated with the levels of survey effort (km) and the potential encounter rates need to be estimated).
- Sampling design (several options exist for in a line transect or point (POD) survey).
- Sampling frequency (the monitoring objective should dictate annual or seasonal surveys).
- Survey duration (the monitoring objective should dictate how many years data are suitable).
- Field protocols (defines the data collection/sampling methodologies to be used).

Gears & techniques (see Annex 5 for descriptions and application):

- Desk study
- Double platform ship-based line transect surveys
- Single platform ship-based line transect surveys
- Towed hydrophone arrays
- Double platform and single platform aerial surveys
- Telemetry
- Pinniped annual counts on haul-out sites
- Autonomous Acoustic Monitoring (AAM)

Marine mammals and underwater noise

Marine mammals are sensitive to sound; and they use their highly evolved acoustic capabilities to communicate, navigate, find prey, escape predators, and perceive their environment. An increase in the levels of sound in an area can therefore interfere with the normal behavioural patterns of these animals, and even cause auditory damage. Marine mammal species can be classified into three functional hearing groups based on their *auditory sensitivity*: low (7 Hz to 22 kHz), medium (150 Hz to 160 kHz) and high frequency (200 Hz to 180 kHz). The level at which the sound is received by the animal will depend on its frequency with relation to the species frequency sensitivity spectrum. Underwater, seals generally detect sound between 75Hz and 75 kHz, although harbour seals have been found to detect sound at 180 kHz if it is sufficiently intense. Seals' hearing in air is less acute, ranging to ~30 kHz rather than 75kHz.

Potential impacts on marine mammals from noise associated with wind farm developments fall into three categories:

- Physical effects such as hearing damage as a direct result of noise produced;
- Behavioural responses as a result of noise produced such as avoidance of an area; and
- Indirect effects such as impacts on food availability.

In order to assess the significance of any impacts on marine mammals from noise produced it is necessary to understand the distribution of marine mammals in the development area (see section 5.4).

Most assessments of potential impacts of noise on cetaceans concentrate on the use of sound propagation models to estimate transmission loss (the attenuation of the sound as it travels through water) and then calculate the received level (RL) of sound at several ranges from the source. The RL equals the source level (SL) minus the transmission loss (TL); RL = SL – TL. The received level can then be used in combination with other contextual information (e.g. behaviour at the time) to assess the likelihood of any of the following impacts in the receiving marine mammal:

- permanent hearing damage (or permanent threshold shift, PTS)
- temporary hearing damage (or temporary threshold shift, TTS)
- short-term behavioural alteration

- potential for disturbance as in The Conservation of Habitats and Species Regulations 2010 and The Offshore Marine Conservation (Natural Habitats, &c.) Regulations 2007 (amended in 2009 and 2010)
- sound masking i.e. where background noise interferes with or masks the ability of an animal to detect a sound signal which would normally be heard

Based on observed cetacean physiological and behavioural responses to anthropogenic sound, Southall *et al.* (2007) proposed precautionary noise exposure thresholds for physical injury (PTS onset) and behavioural disturbance. The noise exposure criteria presented by these authors are currently the best available and, even if still under development and not yet tested in the context of management, their use is recommended. Although there is still a great amount of uncertainty regarding the risks of anthropogenic sound to cetaceans, these suggested criteria set up a framework on which to build upon in the future as new evidence arises. Contact JNCC (seismic@jncc.gov.uk) for a copy of draft guidance on the protection of marine European Protected Species (EPS) from injury and disturbance (REF: JNCC, NE and CCW. Draft. The Protection of marine European Protected Species from injury and disturbance – Guidance for the marine area in England and Wales and the UK offshore marine area), which provides developers and regulators with an interpretation of the offences of injury and disturbance in the context of cetacean conservation and guidance on how to undertake noise risk assessments.

A key consideration of the impact assessment and licence application process is that of alternative solutions. It is generally agreed that pile driving activities for offshore wind farm construction will require an EPS licence due to the noise impacts involved and the assessed risk of disturbance to cetaceans. It has therefore been the advice of the SNCAs to developers that large monopile driving is the worst case scenario in terms of noise impacts, and as part of the project design process developers should seek alternatives to pile driving for their foundations. If these alternatives are not found to be satisfactory then a fair justification should be provided to the regulator[g] as to why pile driving is the preferred option. EPS licences can only be granted if the regulator is satisfied that alternatives that would not impact on EPS were sought by the developer and that none were found or they were not satisfactory. There are several possible alternatives to pile driving that carry a lower or possibly even a negligible risk of disturbance (e.g. gravity bases, floating, concrete drilling, and suction caissons)

In addition, the detailed description and justification for the mitigation measures adopted should form part of risk assessments. Measures include the monitoring of an exclusion danger zone around the noise source to make sure no marine mammals are so close they could get auditory injury, the use of energy ramp up procedures and engineering solutions to reduce noise emission (e.g. bubble curtains).

Please refer to section 4.5 for an overview of approaches to noise data acquisition.

[g] Regulators in this context include the Infrastructure Planning Commission, Marine Management Organisation in England, Welsh Government, Marine Scotland or Department of Environment Northern Ireland depending in which administration the development is located.

4.5 Underwater Noise

The specific considerations for underwater noise on fish and marine mammals are provided in sections 4.3 and 4.4 respectively. This section should therefore be read in conjunction with these sections to ensure that the approaches are appropriately applied. There are currently no published or agreed or guidelines or standards for the characterisation and monitoring of underwater noise from the construction of offshore renewable energy developments. The data acquisition guidelines below are intended to provide a basic generic steer.

Key stages are:

- **Site characterisation**: a description of the background noise sources and levels might be useful in providing some context and in contributing to in-combination assessment; this could include:
    - environmental (ambient), e.g winds, waves, biological activity
    - man-made (apparent), e.g. shipping, seismic surveys, munitions testing

- **Impact assessment**: evaluation of how noise associated with construction and operation may cause injury and/or disturbance, including displacement from migration and spawning areas. Noise effects include: masking; behavioural response (including displacement); injury and mortality. Biotic effects depend, singularly and cumulatively on:
    - Intensity (sound pressure level) at source
    - the pitch (frequency)
    - distance between source and receiver
    - duration (long-lasting, repeated)

- **Impact monitoring:** noise measurements during construction will allow the identification of any possible relationship that might exist between the observed animal behaviour and received noise levels. In addition, it will allow the corroboration of impact ranges predicted during the impact assessment process. This monitoring might be relevant mainly for areas where species are present in high densities and consequently the potential impact of disturbance is greatest. Regarding operational noise, in some areas with several large-scale wind farms it might be appropriate to undertake measurements of how operational noise adds to background levels and how this changes with time.

Approaches to underwater noise data acquisition:

There are no published or agreed standards to noise characterisation. As such the following suggestions are intended to help in the design of surveys but is not intended to be prescriptive.

When undertaking any sound propagation investigations, Transmission Loss (TL) is described as the loss of acoustic power with increasing distance from source (OSPAR, 2009).

TL at distance *x* = source level – measured received level

Theoretically sound will be transmitted equally 360^{o} (spherical spreading), however, in reality parameters such as water depth (in shallow water sound reflected); absorption (energy transfer to heat); temperature & salinity (reflecting boundary layers); obstructions (sand banks, bed forms, wrecks) will all contribute to transmission losses.

The decibel (dB) is a logarithmic scale that approximates to human hearing. Sound Pressure Levels are measured in dB referenced to the:

- pressure (Pa), in water this is ~ 1µPa, and distance (at x metres), and
- frequency range (as different species will be sensitive to different bandwidths) reported in Hz

e.g. 200 dB re 1 µPa @ 100m at 500Hz

Whilst this is applicable to humans it does not directly translate to what fish and marine mammals 'hear'. The common approach to relating noise measurements to fish and marine mammals are auditory / hearing thresholds, which are the average sound pressure level (SPL) just audible to a subject under quiet conditions. When plotted this is called an audiogram, where the x-axis describes frequency (Hz) and the y-axis describes the hearing threshold (dB re 1 µPa).

Sound pressure recording equipment (hydrophones) and appropriate sound recording software will be required. When taking measurements it is essential that the depth of hydrophone deployment, the distance from the noise source, water depth and background conditions (including sea state, weather, ambient and apparent noise sources are recorded) so that any measurements can be put into context. A logical approach is for measurements to be taken at a set of distances from the noise source (in more than one direction would be preferable). The location and number of transect lines should be determined based on the location and extent of receptors, hydrographic and bathymetric conditions and the outputs of any noise propagation modelling.

When presenting noise measurements, charts showing the measurement locations (references to the location of the wind farm and turbine locations once agreed), local bathymetry, with a scale should be provided in all studies (ME1117, 2010). Tabulating this information in any report is recommended to improve accessibility to the relevant data and aide its interpretation (ME1117, 2010), e.g.

Measurement Station	Date	Location			Water depth (m)	Distance from ref. point (m)	Sediment type*	Time of day	Sea state	Wind speed	No. operational turbines (if applicable)	Turbine velocity	Shipping traffic observed?
		RE: array	Lat.	Long.									
A		Outside											
B		Outside											
C		Between turbines											
D		Between turbines											
E		Etc.											
F etc.													

* This data be obtained by carrying out grab samples and PSA

Gears & techniques:

- Desk study (including hydrographic and bathymetric conditions, references of noise measurements to ecological investigations and sediment characterisation studies)
- Hydrophones
- Sea-going boat (fitted with positioning equipment)
- Noise propagation modelling

4.6 Intertidal Studies

The intertidal zone includes those habitats between the top of the splash zone and the low tide mark. Intertidal habitats are diverse, consisting of muddy or sandy sediment, mixed rock and sediment communities, rocky habitats or lagoons. These intertidal habitats support a wide range of species including maritime lichens, invertebrates such as sandhoppers (*Talitrus saltator)*, crabs (e.g. *Carcinus maenas)*, limpets (*Patella vulgate)*, seaweeds such as kelps (*Laminaria digitata)* or wracks (*Fucus serratus)*, sponges, biogenic reefs such as mussel beds (*Mytilus edulis)*, and fish. Many intertidal areas are included within designated sites, particularly Sites of Special Scientific Interest (SSSIs), National Nature Reserves (NNRs), Special Protection Areas (SPAs) and Special Areas of Conservation (SACs).

Approaches to intertidal data acquisition

Baseline habitat information is required for the intertidal area where the export cable will come ashore, and associated works. For certain sections of the UK coast, sufficient intertidal survey data may already exist with no additional survey required and advice should be obtained from the relevant SNCA on whether a desk-top study of existing information would be sufficient. If deemed insufficient, a baseline intertidal Phase 1 survey should be carried out following the methods in the CCW handbook for marine intertidal Phase 1 survey and mapping (Wyn, *et al*. 2006). This should include mapping on orthorectified aerial photographs, assigning biotopes to samples and stations and comparing results with other benthic surveys carried out. More detailed Phase 2 (Hiscock 1996) transects and granulometry for sediment shores should be taken across the chosen cable route. These should be sieved through a 0.5mm sieve and organisms identified to species level. When surveying and monitoring in the intertidal, invertebrate sampling should be carried out at lower, mid and upper shore levels along 3 transects running perpendicular to the shore to adequately represent the zonation of communities present.

Physical characteristics of the shore are also pertinent to a habitat assessment. The Environment Agency or local authority may provide beach topographic detail. Some regional projects also monitor coastal sediment movement and beach topography, for example for developments on the south coast of England (Portland to Thames), the South East Regional Strategic Monitoring Programme (www.channelcoast.org)[36] should be contacted.

Potential impacts

Impacts mainly arise from the construction phase, resulting from physical damage during cable laying and plant access, and increased turbidity from offshore construction. More specifically, impacts may include:

- Habitat loss through destruction of substrate and/or temporary displacement of sediments.
- Changes in the hydrography of the beach as a result of compression and compaction of the sediments.
- Abrasion arising from installation activities, i.e. anchor/skid placement of cable laying vessels, etc.
- Increased turbidity with potential smothering of benthic organisms following resettlement. The extent to which the sediment composition is restored with time would determine long-term restoration of the community.
- Displacement, particularly of infauna and non-mobile epifauna within the cable laying zone.
- Potential secondary effects of increased sediment loading (decreased water quality and light penetration for phytoplankton growth) on fish and birds which feed on the intertidal benthos.

Larger/multiple wind farm projects may require consecutive construction phases for the installation of a number of cables with construction activities lasting over a period of several years, and consideration should be given to the prolonged effect of this on habitat recoverability. The severity of these impacts would depend primarily on the hydrodynamics of the local environment, and the shore types present. The sensitivity (recoverability and vulnerability) of protected habitats/species would need particular consideration when assessing potential impacts (see Sections 9.3 and 9.4 below).

Reference should be made to the marlin web site, www.marlin.ac.uk[37], when assessing the impact of the cable laying and the associated construction footprint on different intertidal communities. In general, clean mobile exposed sandy shores recover more quickly than other sediment shore types. Bedrock, biogenic reef and muddy gravel shores are the most sensitive due to the more persistent change to the intertidal substrate, and the associated communities.

4.7 Physical and Sedimentary Processes Studies

Offshore wind farms have the potential to alter the hydrodynamic regime, which in turn can affect coastal, physical and sedimentary processes. Understanding these processes is important for determining the effects on offshore sand banks or designated sites on the coast. In particular the processes of accretion and erosion of marine features, such as beaches, dunes, saltmarshes and sand banks and how these may alter the physical and biotic environments should be considered. OWFs have the potential to cause changes in hydrodynamics during the operation phase, but changes in sediment dynamics (suspended sediment concentration, sediment deposition and scour) are most likely to occur during the construction phase due to piling and dredging activities. Geotechnical analysis should also include the examination of former prehistoric land surfaces and associated elements that are submerged and/or buried. All developments should be assessed according to the following:

- on a **site-specific** basis,
- to include **direct impacts** on hydrodynamics and sediment dynamics, and
- to include **indirect impacts** of these on other disciplines (e.g. benthos, fisheries, coastal protection, water quality, sediment quality, conservation-designated sites).

For any wind farm proposal it is necessary to assess the magnitude, and significance of change, caused both directly and indirectly to the following:

- **Hydrodynamics** (e.g. waves, tidal flows) – using surface and/or seabed-mounted buoys, (Acoustic Doppler Current Profiling; ADCP). [*Note: It is important that all field data provide information on seasonal variations such as calm and storm events; therefore deployment may be for weeks or months at a time*.]
- **Sedimentology** (e.g. composition, geochemical properties, contaminants, particle size) – sample collection may usefully be combined with the benthic sampling programme, suspended sediment concentrations (SSCs) – using adequately calibrated instrumentation.
- **Sedimentary environment** (e.g. sediment re-suspension, sediment transport pathways, patterns and rates, and sediment deposition) – using charts, bathymetry, side scan sonar. [*Note: The large-scale sediment transport patterns in many of the offshore wind farm sites have not been traditionally monitored, and may therefore be relatively unknown, which means that new field studies at a scale appropriate for the development site are essential to provide both baseline understanding and validation of any numerical modelling studies*.]
- **Geomorphology** (e.g. channels, banks, large-scale bedforms, bioturbation, depth of mixed layers).

Consideration of the above issues should be made with respect to the following **spatial scales**:

- Near-field (i.e. the area within the immediate vicinity of the turbine grid)
- Far-field (e.g. the coastline, sites of scientific and conservation interest and the 'zone of influence', as determined through consideration of tidal excursions, etc.) It is important for an impact assessment to identify appropriate study boundaries (especially when undertaking

modelling exercises); if inappropriate boundaries are chosen this presents a risk that not all potential impacts will have been identified.

Key stages are:

- **Site characterisation**: a spatially extensive description of the seabed environment within & around the expected zone of influence including the identification of hydrodynamics, sedimentology, oceanography & geology, including seasonal, temporal and spatial considerations.
- Description of the **environmental pressures** associated with the construction and operation of the development and determination of the geographic scale of concern.
- **Impact assessment**: evidence based assessment of multiple parameters, including the spatial and temporal extent and magnitude of direct and indirect impacts predicted for the development in the locale of the specified site (see pages 5 and 6), focussing on the interaction between the site characteristics and the identified pressures (described as a series of specific exposure pathways). Cumulative and in-combination impacts should also be considered. Full reference should be made to Annex IV of Council Directive 85/337/EEC (As Amended) and IEEM (2010).

There are a number of documents that contain guidance pertinent to the surveying and assessment of coastal and sedimentary processes for offshore wind farms[38,39,40,41,42,43,44]
Reference should also be made to: http://www.oceannet.org/marine_data_standards/medin_data_guide.html where the following data guidelines can be downloaded:

- MEDIN data guideline for the recording of oceanographic vertical profile data.
- MEDIN data guideline for the recording of moored instrument data.
- MEDIN data guideline for the recording of surface underway oceanographic data.

Approaches to physical process and sedimentary data acquisition

Site Characterisation

In order to assess potential impacts the developer must first fully understand the natural physical environment of their site and the surrounding area, including:

- Identification of processes maintaining the system, reasons for any past changes, and sensitivity of the system to changes in the controlling processes.
- Identification and quantification of the relative importance of high-energy, low frequency ("episodic" events), versus low-energy, high frequency processes.
- Identification of the processes controlling temporal and spatial morphological change (e.g. longevity and stability of bedforms), which may require review of hydrographic records and admiralty charts.
- Identification of sediment sources, pathways and sinks, and quantification of transport fluxes. [*Note: Any numerical models should be validated and calibrated, and should present field-data in support of site conditions, boundary conditions, complex bathymetry, flows and sediments, to include measurements of hydrodynamics, and suspended sediment, in order to demonstrate accuracy of model performance, and should include sensitivity analysis or estimate of errors in order to enable confidence levels to be applied to model results (see section on coastal processes modelling below)*.]

- Identification of the inherited geological, geophysical, geotechnical and geochemical properties of the sediments at the site, and the depth of any sediment strata. [*Note: A sediment sampling campaign (including surface samples and cores) should have far-field spatial coverage and include the range of sedimentary environments, with consideration of the controlling hydrodynamic flows, sediment pathways and sites of particular interest*.]

Baseline data may be available from the following: British Oceanographic Data Centre[45], Proudman Oceanographic Laboratory[46], Cefas (e.g. http://www.cefas.co.uk/data.htm)[47], Environment Agency[48], Shoreline Management Plans[49], Defra's Futurecoast (2002)[50], UKHO charts[51] (contemporary and historic), BGS seabed sediment mapping[52], Published scientific papers and reports. Where any of the above data are not available new studies will need to be commissioned to inform the ES.

Understanding the physical characteristics of the site are not just important for environmental considerations but also for the developer to design the structures and installation methodologies appropriate to the development area to ensure that that the integrity of the wind farm development is not compromised. All of the above parameters are therefore critical from an engineering perspective but can also be used in understanding the physical and biological impacts.

Impact Assessment

With knowledge of the site and its surroundings, informed by the above baseline assessment, the magnitude and significance of the impact of the development may be quantitatively and qualitatively assessed using hypothesis-driven investigation.

Impacts could be both direct and indirect through changing sediment erosion and deposition patterns. Key issues that should be considered in the environmental assessment of offshore wind farm developments are the potential changes to the hydrodynamics and sedimentary processes over a wide area, and potential changes to coastal processes and form, and the ecology of the region.

The physical effects of an offshore wind farm are predominantly from the presence of the foundation and transition pieces both in the sediment and the water column. The base of the tower and foundations will alter the local water flow across the sediment. Sedimentary habitats are primarily controlled by the hydrographic regime and the availability of sediment. Any structure that affects water flow or wave action is likely to change the sediment dynamics locally and potentially over a wide area within any given sedimentary regime. Sedimentary communities are themselves dependant on the stability of the sediment, its grain size and hence porosity, organic content and nutrient cycling, oxygen content and redox potential. Therefore, an activity or structure that significantly changes the hydrodynamics is likely to affect the benthic communities present.

The presence of multiple turbine towers and foundations (including scour protection) could potentially affect water flow around and through the development area, including the natural mixing processes and stratification. The structures themselves will alter the local hydrodynamics and could potentially lead to local accumulation or loss of sediments over quite a wide area (*i.e.* much more than is scoured in the immediate vicinity of the foundations). A decrease in sediment supply to intertidal areas could result in increased erosion and a decrease in the total intertidal area available for the marine fauna and birdlife that depend on this habitat. Loss of intertidal area could also have a knock-on effect on coastal habitats (sand dunes in particular) and flooding and erosion.

Potential cumulative or in-combination effects of multiple developments within a region may include potential changes in bed-form and height and hence hydrography, water flow and wave energy impinging on the coast.

Submarine cables installed for offshore developments should be buried for the majority of their length, depending on the properties of the seabed and ecological considerations. The cable should be buried to a depth that will not be exposed by natural variability in the seabed elevation. To bury the cables, trenches may be dug prior to cable laying or, alternatively they can be water-jetted or ploughed into the seabed. The potential impacts of the burial method(s) should be included in the EIA.

The impact assessment should specifically include an assessment of the following:

- Scour around turbine structures (with subsequent loss of benthos and increased sediment load) and the justification and requirements, if any, for scour protection material. Modelling studies of sediment deposition in the near-field and far-field should include an estimation of the size and dimensions of the sediment piles and predictions of winnowing time for deposited sediment to erode away completely – this allows for an estimation of the potential recovery time for benthic communities.
- Scour around any export cables overlying the sediment surface and the resulting potential for higher suspended sediment concentrations (SSCs), and the development of "free-spans" in the cable.
- Spatial design of the turbine grid array and the subsequent effect on the spatial distribution of wave patterns, tidal flows, and sedimentation (within the near-field), and additionally on wave direction and wave energy (at far-field and coastal sites).
- Non-linear interaction of waves and currents and the subsequent quantification of the extent to which bed sediment is mobilised.
- Sediment mobility and the natural variability of sediment depth within the near-field and the effect on turbine strength/ stability, choice of foundation material and turbine structure, and burial depth for cables.
- Effect of cable laying procedure on local levels of SSCs.
- The presence of highly dispersive substrates such as fine chalk particles either disturbed during cable laying or arising from the installation of foundations should be assessed in terms of the extent, duration and ecological consequences. This is particularly relevant where foundations may be drilled into the seabed and the disposal and fate of drill arisings needs to be considered. Gravity base foundations require the dredging of the seabed for foundation installation and the disposal of such excavated material must also be considered.
- Assessment of the scales and magnitudes of processes controlling sediment transport rates and pathways. This may also include mixed seabeds (silts, sands and gravels), and therefore any interpretations from numerical model output should acknowledge and assess the effect of any differences in sediments (between model and actual), particularly when assessing the significance of transport fluxes.
- Assessment of the impacts of climate change on the hydrodynamic, sedimentological, and geomorphological regimes, e.g. changes in wave height, direction, and frequency of occurrence, changes in sediment mobility.

Most offshore sandbanks are not static, they migrate. The dynamics and stability of sandbanks in the area must be addressed, particularly changes in their form and function over time (i.e. lifetime of the project) using historical sources (e.g. charts, maps etc) combined with sensitivity testing using scenarios of climate change from UKCP[53]. [UK Climate Projections]

Understanding the extent to which the site is an erosional or depositional environment is an important constraint on for example the depth of burial of the cable.

Survey Design

Survey specifications should be submitted to the regulator[h] who will seek scientific and nature conservation advice (from Cefas, Environment Agency and the SNCAs) to ensure that data and analyses are adequate to meet the regulatory requirements. However, the onus is on the developer and their environmental consultants to design the plan of works. The developers and their consultants should therefore only contact MMO once they have devised a plan of works (including the collection of new data and computer modelling) to address the issues identified in this section. At the scoping discussions, MMO (in consultation with its advisors) will comment on whether or not the proposed tools are fit for purpose to ensure that the data are of sufficient quality to be used to assess the potential environmental impacts.

Any computer modelling must be calibrated (and subsequently validated) with site specific data to assess the potential impacts of:

- Presence/absence of the wind farm
- Effects of different numbers of turbines, types of foundation and layouts
- Seasonal differences including storm events
- Wave diffraction (including effects of wind forcing). NB. Wave diffraction is a process that is unlikely to occur unless objects in the way of waves are large enough to cause diffraction or the spacing between objects is small. This can be assessed empirically and in most cases wave diffraction is not an issue (see http://www.cefas.defra.gov.uk/media/410846/sid5_ae1227.pdf). Waves may be altered by a number of issues such as friction/drag and reflection, but diffraction only becomes important when D/L > 0.2 (diameter over wavelength).

These survey specifications must clearly state the issues to be investigated, set hypotheses concerning the potential environmental impacts of the development to inform a detailed rationale to explain the choice of techniques to be utilised. They should describe in detail:

- Spatial and temporal coverage
- Sampling density
- Data collection techniques
- Data standards
- Analytical techniques
- Statistical techniques
- Quality control

Although not produced for the offshore wind industry the document 'Guidelines for the conduct of benthic studies at aggregate dredging sites, DTLR 2002' (currently being reviewed and due for publication 2011) provides a useful insight into the techniques, equipment and design of marine

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[h] Regulators in this context include the Infrastructure Planning Commission, Marine Management Organisation in England, Welsh Assembly Government, Marine Scotland orDepartment of Environment Northern Ireland depending in which administration the development is located.

seabed and oceanographic surveys. A route-map to best-practice guidelines on metocean data collection is provided in CIRIA 2008.

Physical Modelling

Approaches to physical processes numerical modelling for offshore wind farms are outlined in Lambkin et al 2009. The content of Lambkin et al 2009 is summarised here but readers should utilise the report in full. The process for determining numerical modelling requirements is summarised as:

1. What are the potential sensitive receptors by category or species? Are the sensitivity thresholds of the defined receptors understood and quantified?
2. What information about the physical environment is required to characterise the potential impacts on the identified receptors?
3. Can sufficient information be practically and effectively provided by existing knowledge and available field data without the need for numerical modelling?
4. If the answer to point 3 is 'no' can numerical models represent the processes involved sufficiently to provide the required information?
5. If the answer to point 4 is 'yes' can sufficient field data be obtained to adequately calibrate and validate the model to provide confidence in the results?
6. Does the regulating authority agree with the proposed approach to the study?

The best-practice advice associated with these questions for defining numerical modelling needs is summarised as:

- Choose a numerical modelling approach that is fit-for-purpose in reproducing the range of processes identified as important to the question being posed, including both baseline and scheme assessment.
- Ensure that a sufficient quantity, quality and resolution of data are available in order to support the modelling work being undertaken. The requirements will vary depending upon the complexity of the site dynamics and the accuracy required in order to answer the question being posed.
- Assess confidence in model accuracy through an appropriate, quantitative, model calibration and validation process. Confidence in model accuracy is ultimately limited by the properties of the data used to build and test the model, and by the inherent limitations on accuracy of the modelling approach used, including the ability of the model to account accurately for baseline physical processes and for the effect of the wind farm structures.
- Assess the effect of the scheme as the difference between the modelled baseline and the modelled scenario. In doing so, uncertainty regarding the absolute accuracy of the model is reduced.
- Reduce uncertainty in the effect of the many potential scheme options by choosing an appropriate 'realistic worst case' scenario (Rochdale envelope). If a realistic worst case scenario is demonstrated to pose no significant impact, relatively less intrusive options can be accounted for without explicit modelling. [Cefas comment: it may be necessary to choose more than one 'realistic worst case scenario' depending on the combinations of foundation types, materials and installation methods because these will differ for specific receptors, i.e. the worst case for benthic receptors will differ to that for navigation.]

The choice of numerical modelling approach needs to address several issues and questions, including:

- What model type(s) are required (e.g. tides/waves/sediments/water quality; 1D/2D/pseudo-3D/3D etc)
- What type of computational mesh?
- What spatial and temporal resolution and extent?

- What boundary conditions?
- What parameter settings to use?
- How to correct simulation of wind farm structures.

Appendix B of Lambkin et al 2009 includes details on the available numerical modelling tools.

Typical data requirements for building, calibrating and validating numerical marine environmental models include:

- Bathymetry/topography
- Tidal water levels
- Tidal current speed and direction
- Wave height, period, direction, spreading
- Seabed sediment/geotechnical information
- Turbidity
- Sediment transport rates and directions
- Design outlines for the wind farm scheme, delivered by the developer through a project design statement, in order to make informed model design choices

Appendix C of Lambkin et al 2009 includes details of data sources.

Larger scale modelling studies are required to understand the potential effects of larger wind farm developments. Scaling up from the minimal impact on, for instance the wave field, mixing/dissipation or sediment transport, expected for smaller wind farms to what may happen when there is proportionally much larger geographical coverage, is inappropriate.

It is recommended that the following modelling approach is adopted:

(a) model using nested rectangular grids of coarse, intermediate and fine dimensions

(b) using an empirically derived transmission coefficient to overcome the problem of over-representing the turbine masts in size in the refined model grid (this enables wave propagation to be simulated more realistically through a field of these obstacles)

(c) data to be tabulated for an array of wave extraction points along the 5 m depth contour

(d) parameters extracted from the model and used to assist with the assessment of predicted changes as a result of the wind farm should include:

- Significant wave height (H_s);
- Mean wave period (T_m);
- Mean wave direction (dir);
- Bed Shear Stress due to waves alone, currents alone and combined waves and currents

(f) modelling of tides [spring and neap] including low, high and both mid-tide stages

(g) wave conditions to be modelled for waves incident from a wide range of wave spectra expected at the wind farm array and cable route(s)

(h) modelling of 1 in 1 year wave scenario, as this will undoubtedly best reflect high magnitude/medium frequency events which are most relevant to changes in the sedimentary regime.

Gears & techniques (see Annexes 2 and 6 for descriptions and application):

- Desk study
- Numerical models
- Grabs and corers (Particle Size Analysis)

- Current meters or ADCP
- Optical sensors or backscatter sensors
- Surface mounted wave buoys or seabed mounted devices
- Sediment traps (passive, active or directional)
- Conductivity, Temperature and Pressure (CTD) systems
- Echo-Sounder (single line bathymetry)
- Acoustic Ground Definition System (AGDS)
- Sub-Bottom Profiling
- 'Scientific' Echo-Sounder
- Sidescan Sonar
- Digital Image Scanning Sonar
- Swath Bathymetry (Multibeam)

Reference should also be made to: http://www.oceannet.org/marine_data_standards/medin_data_guide.html where the following data guidelines can be downloaded:

- MEDIN data guideline for the recording of oceanographic vertical profile data.
- MEDIN data guideline for the recording of moored instrument data.
- MEDIN data guideline for the recording of surface underway oceanographic data.

4.8 Visual, Historic and Cultural Seascape

Introduction

Seascape assessment in the UK has primarily focussed on capturing the visual, historic and cultural aspects of our coastal and marine environment, not otherwise covered in assessments of the physical and biological environment. Seascape assessment has evolved over the last decade in the UK as a coastal and marine adaptation of the established concept of landscape character assessment. Seascape character assessment is still in its infancy and UK wide methodologies have yet to be agreed and adopted, however, robust methodologies for seascape characterisation are in the process of being developed in England and have been developed in Wales.

As the term 'landscape' is defined in the European Landscape Convention the definition of the term 'seascape' can be complemented as 'an area of sea, coastline and land, as perceived by people, whose character results from the actions and interactions of land and sea, by natural and/or human factors.'

In assessing the impacts of offshore wind farms on seascapes it is important to distinguish between assessing the baseline (usually through character assessment) and assessing impacts (in this case landscape or seascape and visual impact assessment). Within the landscape and seascape and visual impact assessment section of an EIA it is important to distinguish between assessing impacts on the character and assessing visual impacts. These distinctions aid clarity and avoid mixing different concepts and form the basis of how the following sections are structured, followed by advice on mitigating impacts.

Baseline Characterisation

Sources of baseline information on seascapes

Two complementary approaches have emerged in the UK over the last decade.

The first approach was developed by CCW and Marine Institute Ireland in 2001, being an approach to coastal landscape characterisation that also includes defined visual setting zones, both seaward and landward from the coastline. Seascape assessments have been carried out in Scotland and Wales based on this approach. Just as our visual perception does not normally extend below the sea surface, the scope of this work does not extend below the sea surface either.

The Scottish seascape assessment (which includes a sensitivity and capacity assessment for offshore wind farms) can be downloaded here:
http://www.snh.org.uk/pdfs/publications/commissioned_reports/F03AA06.pdf

The Welsh regional seascape assessment (which includes a sensitivity assessment for different offshore renewable energy development types) can be downloaded here:
http://www.ccw.gov.uk/pdf/Guide-to-best-practice-in-seascape-assessment.pdf

The second approach was later developed by English Heritage, and is known as Historic Seascape Characterisation. This four-layered characterisation approach covers coastal areas and the sea itself,

considering the sea surface, the water column, the sea bed and below the sea bed. Perceived character in this sense is cognitive since visual perception is not significant below the water surface. A number of pilot studies have been carried out in England. Further information can be downloaded here:
http://www.english-heritage.org.uk/professional/research/landscapes-and-areas/characterisation/historic-seascape-character/
and here:
http://ads.ahds.ac.uk/catalogue/projArch/alsf/seascapes.cfm?CFID=1129379&CFTOKEN=59692305

The main focus of the above studies is on the establishing the baseline character of the existing seascape. They are not in themselves methods for assessing the impacts of specific development proposals on seascape character. Sensitivity assessments are related to broad areas for spatial planning purposes and should not be assumed to indicate the sensitivity of a specific seascape location to a specific development proposal.

The most recent guidance on characterising seascape is to be published by Natural England, the Countryside Council for Wales and Scottish Natural Heritage in 2011.

Sources of baseline information on landscapes

Land-based character assessments cover the landward component of a seascape, and may provide a more detailed level and local scale of information to enhance seascape assessments. The two assessments, landscape and seascape, should be complementary and integrated. There are a variety of sources of baseline information, but in summary:

For England: National Character Areas (formally known as Joint Character Areas/JCAs) offer broad context, and County Landscape Character Assessments provide locally detailed information. Further information is available here:
http://www.landscapecharacter.org.uk/

In addition, English Heritage's programme of Historic Landscape Characterisation is detailed here:
http://www.english-heritage.org.uk/server/show/nav.1293

For Wales: Regional landscape character areas in Wales offer broad context, whilst LANDMAP landscape assessments provide locally detailed information. Further information is available here:
www.ccw.gov.uk/landmap

In addition, Wales's programme of Historic Landscape Characterisation and other work is detailed here:
http://www.cadw.wales.gov.uk/default.asp?id=108
In particular this includes the Register of Landscapes, Parks and Gardens of Special Historic Interest in Wales:

Part 1: Parks and Gardens (7 vols.) Cadw, 1993 – 2002;
Part 2.1: Landscapes of Outstanding Historic Interest, Cadw, 1998;
Part 2.2: Landscapes of Special Historic Interest, Cadw, 2001.

Designated landscapes and sites

Landscapes designated for their scenic or undeveloped quality or value, including National Park, Area of Outstanding Natural Beauty and Heritage Coast should be considered in relation to the reasons for their designation and their special qualities. Other local designations may be relevant including Special Landscape Areas as well as public amenity and recreational designations (e.g. long distance trail, Country Park, open access land) and designations reflecting the need to conserve important man-made or cultural aspects of landscape or urban character (e.g. World Heritage Sites and Conservation Areas). Consultation with relevant authorities is needed.

Further baseline information requirements

Character-based assessments provide broad coverage and context but will lack the necessary detail in which to consider impacts from a specific development on a specific site. Additional assessment is therefore needed to fill the gap. This may include more detailed divisions of seascapes into local character-based units, and site specific (point or feature-based) surveys.

As part of the survey stage, consultation with relevant authorities and NGOs is needed to agree key view points, and those to be used for preparation of photomontages, though at an early stage consultees will not be able to give more than suggestions for these, as it will take the detail of the impact assessment itself to establish the geographic extent of visual effects from a proposal. An iterative process will therefore be helpful.

The principles of carrying out a seascape assessment are set out in the Guide to Best Practice in Seascape Assessment (2001) available here:
http://www.ccw.gov.uk/pdf/Guide-to-best-practice-in-seascape-assessment.pdf

The methodology for historic seascape characterisation in England is set out here: http://www.cornwall.gov.uk/index.cfm?articleid=39985

A methodology for studying historic features in the marine environment in detail is set out here:
http://www.offshorewind.co.uk/Pages/Publications/Archive/Cultural%5FHeritage/Guidance_for_Assessmen31a53533/ and
Aa methodology for the assessment of cumulative impacts on the historic environment from offshore renewable energy is set our here:
http://www.offshorewind.co.uk/Assets/cowrie_ciarch%20web.pdf

The principles of landscape character assessment are set out in Guidance for England and Scotland here: http://www.landscapecharacter.org.uk/

The methodology used in LANDMAP landscape assessments, from which landscape character assessments in Wales should be based, is set out in a method guide here: www.ccw.gov.uk/landmap

In addition, it is helpful to have an understanding of the benefits and services to society provided by seascapes. Although there is no set method, work in England on 'Quality of Life Capital' (as applied to landscapes) is a useful starting point. Further information is available here:
http://www.environment-agency.gov.uk/research/policy/32923.aspx

NB. The Landscape Institute and Institute of Environmental Management and Assessment are presently producing a new edition of 'Guidelines for Landscape and Visual Impact Assessment'.

For locations where the setting of a historic environment is changes (i.e. where a wind farm is located in a parallel view to that of an historic site) it may well be the case that the most appropriate mitigation mechanism is for the developer to produce site interpretation material to explain the original seascape/landscape environment in which they existed.

The Archaeological Data Service (ADS) website describes the Historic Seascapes Characterisation (HSC) programme pilot projects conducted between 2004-2007 and that a method statement about how HSC should be implemented was produced in 2008, (see: http://archaeologydataservice.ac.uk/archives/view/seascapes/?CFID=2364&CFTOKEN=6A009D69-39ED-49AD-A3104FFEE3D63C68). A series of HSCs have been completed as part of the ALSF and once published should be available from the ADS website.

Impact Assessment

Assessment of the effects of a development on seascape and landscape character should cover all aspects of a project, including:

- temporary and permanent elements
- inshore and offshore
- auxillary aspects such as lighting and maintenance

Assessing impacts on seascapes

The former DTI produced a comprehensive document covering the method for assessing seascape and visual impacts in relation to offshore wind farms and can be found at: http://www.berr.gov.uk/files/file22852.pdf

A key reference underpinning the DTI document and other impact assessments is the 'Guidelines for Landscape and Visual Impact Assessment' (2nd Ed., 2002) produced by the Landscape Institute and Institute of Environmental Management and Assessment (not available on-line) ref: ISBN 0-415-23185-X.

The Registers of Landscapes of Outstanding and Special Historic Interest in Wales are now supplemented by a Guide to Good Practice on Using the Register of Landscapes of Historic Interest in Wales in the Planning and Development Process, by Cadw, 2nd (revised) edition, 2007, and have become a non-statutory material consideration in Planning decisions in Wales. The guidance document, known also as 'ASIDOHL2' is available here: http://www.cadw.wales.gov.uk/default.asp?id=132

English heritage are currently preparing Historic Seascape Characterisation sensitivity and capacity assessment guidance, please see
www.english-heritage.org.uk for details.

Much experience has been gained in the assessment of land-based wind farms and Scottish Natural Heritage's Visual representation of wind farms good practice guidance has become widely used: http://www.snh.org.uk/pdfs/publications/heritagemanagement/Visual%20Representation%20of%20windfarms%20-%20excerpt.pdf

A conclusion from recent UK experience of offshore wind farm developments is that good visibility in the middle of the day does not necessarily illustrate conditions when the wind turbines appear most prominent in the view. Early morning and evening lighting conditions produce strong contrasts to highlight the turbines, as can weather conditions where the turbines contrast with their background in views.

A resulting seascape and visual impact assessment will typically highlight the sensitive receptors, the magnitude of change to them, and the significance of these impacts. It will distinguish between impacts on the character or features of the area and visual impacts. Although an offshore wind farm development will not cause direct physical changes to the coastal landscapes, views from coastal landscapes may be changed, and our perceptions of special qualities of coastal landscapes such as tranquillity, remoteness and wildness, which are integral to their character, may be affected. Direct physical changes to the coastline may result where on-shore infrastructure is required. Impacts are usually distinguished from construction, operation and decommissioning impacts.

The resulting seascape and visual impact assessment document will typically include location plans, photomontages, ZTV (zone of theoretical visibility) maps, character areas, seascape units, locations and types of sensitive receptors.

Impacts on Recreation

The coast and inshore marine environment is of significant economic importance to tourism, in particular supporting amenity uses such as recreational boating. Government departments and agencies have a role in promoting access to the countryside and coast and have therefore worked closely with the tourism and amenity sectors to encourage recreational uses that are environmentally sustainable.

Developments near the coast may impinge on areas of high amenity value. Recreational use of marine and coastal areas is strongly seasonal and affected users may or may not live close to the impacted area. Marine and coastal recreational activities are also often closely linked to the visual, cultural and historic character of the landscape. It is therefore advised that the potential impacts of any offshore developments on recreation, tourism and amenity should be comprehensively assessed.

Developers should contact local stakeholders (i.e. through a Local Access Forum) to find out about recreational activity in the area concerned. The Countryside Council for Wales, Natural England, relevant Local Authorities, Regional Tourism Partnerships, and activity providers may also be able to supply information and advice.

Potential mitigation of Impacts

A good seascape and visual impact assessment document will demonstrate how the impact assessment process was carried out iteratively with the siting and design process. Without showing that iteration, it is very difficult to demonstrate how the proposal has been sited and designed to minimise any negative impacts.

Mitigating visual impacts

The most effective form of visual mitigation is to ensure the offshore wind farm is suitably located in the first instance, particularly when considering developments which are visible from the shore (much of Round 3 will be outwith this zone). Much work on this may be done at a strategic planning stage, before individual developments have been proposed. Once a development site has been proposed, typically only minor adjustments within the confines of the site boundary are then possible. Nevertheless, within the large scale of site and development, room for movement may still amount to kilometres. This may still allow coastal headlands to be used to limit the visibility of the

wind farm within certain sensitive embayments and views, where coastal geometry allows. Minor adjustments to layout and clustering of turbines can also assist in reducing the visual prominence where they are seen in key views (e.g. lining up versus dispersing turbines). CCW's seascape sensitivity evaluation criteria (Appendix document in their regional seascape assessment for Wales) offers a useful reference in which to consider this issue:
http://www.ccw.gov.uk/landscape--wildlife/protecting-our-landscape/seascapes/seascape-assessment-of-wales.aspx

In addition, the former DTI seascape and visual impact assessment provides location and design guidance to minimise visual impacts in its chapter 6. This chapter also includes discussion of lighting and contrast issues, which are very important when considering the visual prominence of objects at great distance, through changing atmospheric visibility and aspect to the sun. Night lighting is also considered. Different conditions are illustrated for a hypothetical offshore wind farm development:
http://www.berr.gov.uk/files/file22852.pdf

Mitigating impacts on character

Given that the development will be offshore, direct impacts on the physical character of coastal landscape will be limited to on-shore works, for example a grid connection and sub-station. Conventional approaches to siting and design in the landscape may provide mitigation.

Indirect impacts on the special qualities of a coastal landscape, such as on tranquillity, remoteness and wildness, are harder to mitigate, but given they are perceived visually, mitigation for visual impacts (see 0) will assist here.

Mitigating impacts on features or sites of historic or cultural importance

In Wales, this will broadly follow the guidelines for mitigating visual impacts and impacts on character with regard to registered historic landscapes in Wales, but with special reference to the impacts on the key historic character areas, historic elements and their settings identified in the ASIDOHL2 assessment. The character areas, elements or settings are regarded as being the equivalent of the 'receptors' in landscape visual impact assessments.

The English Heritage approach to Historic Seascapes Characterisation derives directly from the European Landscape Convention definition of landscape as described above. This is a fundamental consideration when addressing offshore seascape considerations out of sight of land, as it is not just the visual aspects of landscape that are considered through this approach. Historic Seascapes Characterisation will become of particular importance in supporting English Heritage advice on Offshore Wind Farm Developments and Marine Spatial Planning. English Heritage are currently preparing Historic Seascape characterisation sensitivity and capacity assessment guidance. See the English Heritage website for details (www.english-heritage.org.uk).

5 Monitoring (Construction and Operation)

5.1 Purpose of monitoring

Monitoring is used for a variety of purposes. Developers invest a lot of effort to produce Environmental Statements, the conclusions of which are often based on predictions derived from numerical models, extrapolation from site-specific and historic survey data and extrapolation from other analogous activities. However, there is a paucity of published peer-reviewed articles on the environmental impacts of offshore renewable energy devices (Gill, 2005) and only limited time-series data to monitor impacts (ME1117, (2010)). Monitoring conditions attached to consents and licences can therefore be used to validate predictions made in Environmental Statements. An extension of this testing of predictions is to identify unexpected outcomes or impacts and, where appropriate, trigger the development of corrective actions. Given the limited base information, monitoring can also be used to deal with uncertainties within Environmental Statements by testing hypotheses on the nature, extent and duration of potential novel impacts. Overall, monitoring is intended to investigate change relative to a defined "baseline" condition or set of parameters. This change could be: before and after construction; during construction with pre-construction; inside and outside the wind farm array; differences between seasons; differences between years; natural variation versus impacts from the offshore wind farm or any combination of these. **Given these complex issues it is imperative that developers establish detailed rationales and hypotheses for the monitoring programmes, i.e. what is being monitored and why, and which parameters will interact and why. Included in this is an assessment of the likelihood of being able to successfully monitor the parameters (which may assist regulators in formulating and prioritising research needs).**

Monitoring is therefore an integral part of all projects, but are the most robust, efficient and appropriate techniques and approaches being applied? To address this question ME1117 (2010) reviewed the existing FEPA monitoring datasets to provide some preliminary recommendations. It should also be noted that inadequacies highlighted within the report have arisen due to the learning curve associated with the relatively new technology of offshore wind development and issues apply to both the developer (undertaking the monitoring) and Licensing Body (providing the licence conditions). As more sites are developed and more monitoring and research data becomes available further reviews will be necessary in the future.

To be fully effective, integrated approaches to monitoring programmes should be developed where inter-relationships and dependencies between sediments – benthos – fish – birds – mammals - noise are fully assessed. It is essential that monitoring programmes include temporal and spatial considerations (including interaction with other wind farm sites and activities).

Monitoring may also be used to investigate potential positive effects of offshore wind farm development, however, it must be noted that there is a fine line between the form that this monitoring might take and research projects that will need intensive study and for which it may be unfair to burden individual developers. This statement is not intended to undermine the importance of such investigations but is made to highlight the importance of drafting research priority lists to complement and support the challenges faced by the industry. It also adds weight to the arguments made within this guidance to base monitoring on predictions made within Environmental Statements and based on testable hypotheses. So if a positive effect has been identified within an Environmental Statement then there is more justification to follow this up with monitoring. For fisheries, topics that might fall under this heading include:

a. protection/recovery of nursery habitats,

b. protection/recovery of spawning habitats,
c. protection of aggregations of spawning adults,
d. improvements to habitat integrity and feeding opportunities due to benthic recovery, or
e. increased biomass of resident populations as a consequence of removal of fishing activity. Monitoring could also investigate whether these effects spill over into adjacent (and likely fishable) waters.

Such research (or monitoring if applicable) should also try to distinguish between population enhancement and scenarios where fish are just accumulating in the area due to an attraction to turbine structures.

The need and extent of monitoring at an offshore wind farm site will be established during the EIA and consenting process. It is imperative that all monitoring programmes have a clear and stated purpose with measurable outcomes. It is therefore essential that monitoring programmes are based on testable hypotheses, drawn from impacts identified in the Environmental Statement. It may not be necessary for all parameters to be monitored in all cases so this guidance relates to how to undertake surveys without stipulating what monitoring is required under what circumstances (which can only proportionately be determined on a case-by-case basis). This guidance on monitoring is therefore not to be used as a checklist but the basis for iterative dialogue with the licensing authorities and their consultees to establish monitoring requirements.

5.2 International Experiences

It is useful to consider the monitoring requirements set out in and reviewed in the ME1117 (2010) report in the context of the monitoring that is required in other countries. A brief synopsis follows of monitoring requirements in the Netherlands, Belgium, Germany and Denmark.

The Netherlands:

The Masterplan[54] – Monitoring and researching ecological effects of Dutch offshore wind farms further enforces the need for clear monitoring objectives, e.g. what are the most important questions; what are the gaps in information; what methods can be used; what do they produce and how are the scientific outputs organised? Within the Masterplan[54] it is clear that as hypotheses are tested on the basis of the data, new hypotheses can (and often will need to) be formulated to further substantiate or adapt starting points for monitoring. This iterative component of monitoring programmes is often overlooked and it is important that developers plan and budget for the uncertainties that may accrue from the monitoring programme. The Dutch Masterplan[54] also reinforces the point that most monitoring and research programmes have only been undertaken over relatively short timescales so it is not yet possible to distinguish between short- and longer-term effects. A range of investigations are included within the Monitoring and Evaluation Programme (MEP) for the OWEZ wind farm including studies under the headings: bird flying patterns, characteristics, intensity, season, day/night with respect to estimate of risks of collision; bird disturbance of the living and feeding areas; bird barrier effects; the effect of underwater noise on fish and marine mammals; the variation and densities of underwater life and the function as a refuge. The interim results to date are available at http://www.noordzeewind.nl/[55]. The minimum requisite components of the MEPs for OWFs in Dutch Waters can be summarised as:

- Description of existing studies per issue, and how the proposed study links to this.
- Annual production of an independent, readable scientific progress report.
- Underwater noise recording:
    - Collecting data on pile driving noise and operational noise for use in models.
    - Measuring the effects of underwater noise on fish during pile driving (excluding fish and causing them to die).
- Marine mammals:
    - Determining the avoidance behaviour of porpoises during pile driving
    - Determining the migration behaviour of the common seal and greay seal.
- Birds:
    - Monitoring sea birds to determine their avoidance behaviour due to the wind farm.
    - Colony breeders and sea birds in and around the wind farm.
    - Quantitative and species-specific avoidance behaviour of birds and colony breeders inside the wind farm (micro-avoidance) and outside the wind farm (macro-avoidance).
    - Spatial distribution of breeding lesser black-backed gulls.
- Fish and Benthos:
    - Temporal and spatial variation in a distribution, abundance and diversity as a result of wind farm construction

Belgium:

The interim results of the Thornton Bank offshore wind farm in Belgium were published in 2010 (Degraer, S., Brabant, R. & Rumes, B. (Eds.) (2010)). The basic premise is that the monitoring will allow for a proper evaluation and auditing of the environmental impacts of offshore wind farms, as such the environmental permit includes a monitoring program to ensure:

1. the ability to mitigate or even halt the activities in case of extreme damage to the marine ecosystem and

2. an understanding of the environmental impact of offshore wind farms to support policy, management and design of future offshore wind farms.

The baseline monitoring deals with observing rather than understanding impacts and hence leads to area-specific results, which might form a basis for halting activities, whereas, targeted monitoring deals with understanding the processes behind the impacts and hence leads to more generic results, which might form a sound basis for impact mitigation. The monitoring program targets physical (i.e. hydro-geomorphology and underwater noise), biological (i.e. hard substratum epifauna, hard substratum fish, soft substratum macrobenthos, soft substratum epibenthos and fish, seabirds and marine mammals), as well as socio-economical (i.e. seascape perception and offshore renewables appreciation) aspects of the marine environment.

Germany:

The German Standard for the impacts of offshore wind turbines on the marine environment[56] sets the basic objectives for regulating offshore wind farms development with regards to investigating impacts on features of conservation interest, i.e. fish, benthos, birds and marine mammals in order to:

- determine their spatial distribution and temporal variability in the pre-construction phase (baseline);
- monitor the effects of construction, operation and decommissioning;
- establish a basis for evaluating the monitoring results.

A pilot phase, where a limited number of turbines are installed, provides for the collection of data on the environmental compatibility of possible expansion phases. Before and after this pilot phase baseline surveys and monitoring have to be undertaken with the scope of the monitoring being dependant on the results from the baseline surveys. The baseline survey remains valid for two complete years, however, if construction work has not commenced in the third year the baseline survey has to be updated with an additional cycle (baseline survey is made up of two successive complete seasonal cycles). The construction phase monitoring is required throughout the construction period as instructed by the approval authority to verify the assumptions made in the EIA. Monitoring is based around the project and reference areas for comparison. The approval authority will decide on the type and scope of further/ongoing monitoring based on annual reports. Part B includes specification for surveying.

Denmark:

Details of the environmental monitoring in Denmark are summarised in a November 2006 publication[57], based on the studies undertaken at Horns Rev and Nysted OWFs between 2000 and 2006. The projects in the environmental monitoring programme followed a “Before After Control Impact design” (BACI) with the aim of estimating the state of the environment before and after any change and in particular to compare changes at reference sites (or control sites) with the actual area of impact. The studies and analyses have dealt with:

- Benthic fauna and flora, with particular focus on the consequences of the introduction of a hard-bottom habitat, which is the turbine foundation and scour protection, this also included a survey of the in-fauna community in the wind farms.
- The distribution of fish around the wind turbines and the scour protection.
- Studies of the numbers and distribution of feeding and resting birds, performed by aerial surveys, and of the food choice of scoters.
- Migrating birds, including study of the risks of collision between birds and wind turbines.
- The behaviour of marine mammals – porpoises and seals – and their reaction to wind farms.
- The impact of electromagnetic fields on fish.
- Sociological and environmental-economic studies.
- Coastal morphology.

The Danish 2006 Report[57] concludes that appropriate siting of offshore wind farms is an essential precondition for ensuring limited impact on nature and the environment, and that careful spatial planning is necessary to avoid damaging cumulative impacts and that under 'the right conditions', environmental impacts may be within acceptable limits.

None of the outputs from the monitoring programmes described above state that ongoing monitoring is unnecessary nor do they recommend removal of any issues from monitoring programmes. However, the ME1117 (2010) review suggests improvements to rationalise and better target monitoring.

The following methodologies under the headings benthic studies, ornithological studies, fish and shellfish studies, marine mammal studies, physical and sedimentary process studies and intertidal studies are provided to cover all methodological requirements pertinent to a given receptor as a suite of available tools. Developers will still need to identify the correct tool(s) applicable to their project in consultation with the regulator.

5.3 Benthic Studies

Baseline:

These utilise the same techniques and equipment as described in Annexes 1 and 2. Such studies requires the establishment of a baseline of sample stations. These stations serve as sites for future monitoring and assessment over the lifetime of the licence. The design of the baseline monitoring should be informed by the characterisation study and impact assessment. The number of samples and replicates should be sufficient to detect effects, test the hypothesis and test predictions made in the ES. Such studies should be designed to be representative of the different habitats and footprint of the impacts associated with the development. The baseline will incorporate replicated sample stations for each predicted zone of impact, reference zones (within which there is no predicted impact) representative of the different habitat types. It should be noted that with increasing elapsed time between baseline sampling and the commencement of construction the baseline data are likely to become less reliable for the purpose of subsequent monitoring – moreover the risk of falsely attributing any 'natural' changes in the benthos to the impacts of ORED construction increases. In such cases additional more contemporary baseline data may need to be collected.

Typically baseline sampling stations will be located at pre-determined positions within the main characterisation survey area, including the offshore wind farm development site and export cable corridor and this subset of stations will be sampled to a level sufficient to detect effects to test the stated hypotheses. Pre-construction data acquired for these stations will form the baseline for subsequent post-construction monitoring studies and as such the survey should be designed in such a way to allow for meaningful interpretation of future monitoring data.

<u>Baseline for homogenous seabed</u>: a number of transect or grid based designs may be adopted for the positioning of the baseline stations. Where effects can be predicted along well defined gradients associated with factors such as tidal currents, weighted transects whose orientation follows the major axis of the tidal ellipse (cruciform) can be used. Where effects are not predicted to occur along clearly defined gradients away from the construction activity baseline sample stations should be symmetrically positioned to a 'weighted' or 'radiating' grid design. Both scenarios allow for increased density of sampling within and in the immediate vicinity of the construction activities, with sampling density decreasing with distance away from the predicted zone of impact. Such designs allows for validation of the predicted spatial extent and significance of impacts associated with the construction activity.

<u>Baseline for heterogeneous seabed</u>: a random stratified approach is more appropriate for positioning of baseline sampling stations. Aim should be to achieve adequate and balanced density of sampling within the predicted zones of impact and unimpacted (reference) stations.

All baseline monitoring should allow any changes that are attributable to the ORED to be delineated from the effects arising as a result of natural processes operating across the survey area.

Ongoing (during and post-construction) monitoring:

The frequency of ongoing monitoring surveys is largely site and licence specific and will depend on a number of considerations including, the sensitivity of the environment within which the ORED is located or the area of the physical footprint of the development.

Ongoing monitoring surveys should (where consistent with the hypothesis) be carried out at the same time of year as the baseline survey, if the same month cannot be accommodated then sampling in the same season should at least be ensured. This allows temporal compatibility between the data sets and reduces the effects of inter-seasonal variation on any comparisons made (particularly important in relation to the timing of epibenthic surveys where results are likely to be variable on a generally predictable seasonal basis but also inter-annually). Surveys may be designed in a more flexible way maintaining the validity and power of many statistical tests, such as ANOVA. Random sample collection from control and impact sites, for example allows for a robust process and avoids the problem of reference sites that may be 'lost' or otherwise compromised.

In ideal circumstances, baseline and subsequent monitoring surveys should be carried out in the period between February – April (i.e., before the main recruitment period for pelagic larvae takes place which generally occurs from early Summer onwards).

The survey design for ongoing monitoring should follow the baseline survey design, indeed sampling to generate the baseline forms the basis for the selection of 'ongoing' monitoring stations.

As part of an overall quality assurance strategy, it is important to check on the continued validity of stations selected as representative of impacted and reference conditions and some allowance must be made for the possibility of modifications in response to unanticipated man-made or natural influences.

Acoustic methods: used to inform and complement survey design.

Underwater video & stills photography:

- Used to inform micro-siting of foundations & cables
- Monitoring of sensitive/vulnerable habitats & species (e.g. biogenic reef)
- Foundation & scour protection colonisation studies and
- Surveys of locations inaccessible for other gears due to H&S considerations

Grabs & corers:

- Infaunal & sessile epifaunal community structure changes (indicators of change: cause & effect before-after construction)

Trawls & Dredges:

- Qualitative assessment of epifaunal distribution & abundance

Reference should also be made to: http://www.oceannet.org/marine_data_standards/medin_data_guide.html where the following data guidelines can be downloaded:

- MEDIN data guideline for sediment sampling by grab or core for benthos
- MEDIN data guideline for recording and archiving of digital photographs
- MEDIN data guideline for fish and benthos data by trawl and dredge
- MEDIN data guideline for transfer video survey data

5.4 Ornithological Studies

In all cases the SNCAs should be contacted before any work is undertaken to design and plan ornithological monitoring studies. As such this section only provides a generic overview.

It is important to establish an appropriate monitoring regime that will enable a statistically robust comparison to be made before, during and after the construction of the wind farm to determine the impacts attributable to the development (for example, a Before-After-Control-Impact (BACI) study, or a buffer-gradient analysis approach). Data should be collected before construction, for several years after construction and ideally during construction. It is important that studies explore the impacts of both construction and operational phases, as the potential effects can differ at each stage of the development. A distinction needs to be made between results that can be attributed to the wind farm and those arising from other factors such as natural change, perhaps linked to the distribution of prey availability (although if the distribution of prey has changed as a result of the wind farm it is essential that this is incorporated into the assessment and interpretation). It is preferable that the same methods are used to enable comparison and statistical evaluation of change.

Monitoring of seabird activity during the construction and operational phase of the wind farm is essential for two reasons:

- To assess the impacts of a particular development and the efficiency of mitigation techniques, and
- To validate the conclusions made within the environmental statement.

Planned and targeted monitoring post-construction will therefore enable refinement of impact assessment, monitoring and mitigation techniques and lead to improvement of the overall management of the risk of adverse impacts upon bird populations. For Round 3 developments a strategic approach to monitoring may be appropriate which will require collaboration of developers and statutory advisors to ensure that devised methods are appropriate to the determined monitoring objectives.

Monitoring should aim to measure changes in bird density/ abundance, movements and other behaviour resulting from the development as well as other relevant factors, e.g. prey availability (There may be a need to monitor food sources for the birds both before and after construction, e.g. pile-driving may lead to a loss of sand eels or herring. The work may also require studies at certain colonies which may be affected looking at changes in diet and breeding success). Considerations for monitoring could include habitat loss and displacement, barrier impacts, collision impacts and cumulative/in-combination effects. It is recommended that aerial and boat-based surveys are carried out for at least three years following construction and some monitoring may be required for the full lifetime of the development. Various novel and developing techniques may need to be employed to investigate specific impacts (e.g. radar, remote sensing etc) the specific details should be agreed between the developer, regulator and the relevant SNCA.

Longer term monitoring will be needed to evaluate gradual or incremental changes, for example the potential cumulative effect of increased mortality or where birds gradually habituate to the presence of turbines. Again, the specific details of such monitoring should be agreed between the developer, regulator and the relevant SNCA(s). It is essential that statistical expertise is considered in monitoring protocols and data analyses especially with regard to power analysis and sample size.

There have been problems in implementing an adequate monitoring approach particularly if the pre-construction data were collected using aerial surveys. The health and safety implications of flying planes below turbine height are such that the present methodology for post-construction monitoring through conventional aerial surveying may not be feasible. Alternative viable techniques, such as high definition or high resolution camera aerial surveys are under development to ensure that adequate monitoring can take place to satisfy environmental considerations but there is a need for the production of generic guidance on their use.

Gears & techniques:

- Desk study
- Boat-based surveys
- High definition or high resolution digital aerial survey techniques
- Additional techniques, e.g. radar, remote sensing

5.5 Fish and Shellfish Studies

Ostensibly utilises the same techniques as described in Annex 4. Given the large spatial extent and the number of variables involved investigating cause & effects relationships before and after construction can be problematical, particularly in terms of filtering out the effects of these multiple variables. Most fish monitoring to date therefore has tended to investigate difference between post-construction situations, e.g. fish distribution & abundance inside and outside the wind farm. Use of existing historic data sets relevant to the specific or general wind farm area/zone can be useful to understand local, regional and global trends in the context of the wind farm monitoring programme.

If a monitoring programme is proposed in the ES and/or required by the licensing authority, then at least three surveys (one during the spawning season and two at other times of year, depending on the seasonality of the major fisheries) and equivalent post-construction surveys are recommended.

Gears & techniques (see Annexes 2 and 4 for descriptions and application):

- Desk study
- Commercial gears (pots, trawls, fixed nets, lines etc)
- Underwater video and stills photography
- Grabs
- Acoustic Ground Definition System (AGDS)
- 'Scientific' Echo-Sounder
- Sidescan Sonar
- Landings data
- Effort data
- Fisheries liaison
- Socio-economic evaluations

Reference should also be made to: http://www.oceannet.org/marine_data_standards/medin_data_guide.html where the following data guidelines can be downloaded:

- MEDIN data guideline for static net, pot and trap data
- MEDIN data guideline for shellfish stock assessment data
- MEDIN data guideline for fish and benthos data by trawl and dredge

5.6 Marine Mammal Studies

In all cases the SNCAs should be contacted before any work is undertaken to design and plan marine mammal monitoring studies. As such this section only provides a generic overview.

The ES must include recommendations for post consent monitoring of the identified potential impacts of the wind farm; these proposals must be hypothesis driven with measurable outputs. It may also be necessary to undertake monitoring to ensure impacts are as predicted within the EIA. Data should be collected before, during and possibly after construction, to determine the associated impacts and/or recovery of populations. Once developmental consent has been given, a new baseline might need to be established immediately prior to construction as agreed with the relevant SNCAs. Developers will need to undertake some form of power analysis to inform how many samples are required, i.e. how many km surveyed, how many static acoustic monitors to place in the area, so that there is a level of confidence that if there is a difference in animal abundance between pre and during/post construction that difference will be picked up by the data collected.

For most cetacean species, impact monitoring in the field is very important to provide evidence of any animal displacement and its magnitude. Currently there is limited evidence for harbour porpoises and virtually no information on the behavioural responses of other species of concern such as bottlenose dolphins and harbour seals. Monitoring impact will be necessary at many sites to provide a record of disturbance and allow the monitoring of cumulative effects from the construction of several wind farms within the range of a population in order to prevent an impact on the Favourable Conservation Status (FCS). The risk of impacts on FCS should be modelled for all planned wind farms within the range of a populations and a threshold derived for the amount of disturbance that a population can cope with before an impact on FCS occurs. This modelling assessment might need to be undertaken at a strategic level though and not necessarily by individual developers. It is likely that not all sites will need impact (during construction) monitoring, but efforts should be concentrated at those sites where mammals are most abundant.

Before-After-Control-Impact (BACI) studies are often favoured when designing impact monitoring surveys, however, gradient sampling analysis (Ellis and Schnieder, 1997 and 2008) may be more sensible where a disturbance (e.g. pile-driving) attenuates from source, rather than having a highly defined boundary. Furthermore, choosing a control site for marine mammals is very difficult given the highly dynamic nature of their distribution and abundance. The SMRU Ltd. 2010 report discusses the pros and cons of each type of design and both should be assessed for suitability on a site specific basis. Developers are encouraged to engage in the development of viable techniques, to ensure that adequate monitoring can take place to satisfy environmental considerations.

Monitoring of marine mammal activity during the construction and operational phase of the wind farm is essential for two reasons:

- To assess the impacts of a particular development and the efficiency of mitigation techniques, and
- To validate the conclusions made within the environmental statement.

Planned and targeted monitoring post-construction will therefore enable refinement of impact assessment, monitoring and mitigation techniques and lead to improvement of the overall management of the risk of adverse impacts upon marine mammal populations. For Round 3 developments a strategic approach to monitoring may be appropriate which will require collaboration of developers and statutory advisors to ensure that devised methods are appropriate to the determined monitoring objectives. Collaboration during monitoring would not only provide a better assessment of cumulative effects, but also lower the cost implications for the developer.

Gears & techniques (see Annex 5 for descriptions and application):

- Desk study
- Double platform ship-based line transect surveys
- Single platform ship-based line transect surveys
- Towed hydrophone arrays
- Double platform and single platform aerial surveys
- Telemetry
- Pinniped annual counts on haul-out sites
- Autonomous static acoustic monitoring

5.7 Physical and Sedimentary Processes Studies

Utilises the same techniques as described in Annex 6. The ES must include recommendations for future monitoring of the identified potential impacts of the wind farm, these proposals must be hypothesis driven with measurable outputs.

It may be necessary to undertake monitoring to ensure impacts are as predicted within the EIA. It is suggested that bathymetric survey around turbines is undertaken within 3 months of completion of construction. Turbines should be selected to represent a range of seabed types within the whole array and at least 4 within each geomorphological unit. Seasonal or weather difficulties should also be considered when designing survey plans. This should be repeated every 6 months for 3 years. Monitoring of the cable route may also be required. Ideally monitoring should address the identified impacts, and be linked with benthic monitoring to allow for comparison amongst environmental parameters.

Where there may be sedimentary concerns regarding issues documented within the ES, particularly with results of any predictive modelling studies, a requirement for monitoring, both during, and following construction may be incorporated into the conditions of the Marine licence.

If used, a reference site should be geographically separate from development site (outside of tidal excursion) but physically and biologically similar.

Gears & techniques (see Annexes 2 and 6 for descriptions and application):

- Desk study
- Numerical models
- Grabs and corers (Particle Size Analysis)
- Current meters or ADCP
- Optical sensors or backscatter sensors
- Surface mounted wave buoys or seabed mounted devices
- Sediment traps (passive, active or directional)
- Conductivity, Temperature and Pressure (CTD) systems
- Echo-Sounder (single line bathymetry)
- Acoustic Ground Definition System (AGDS)
- Sub-Bottom Profiling
- 'Scientific' Echo-Sounder
- Sidescan Sonar
- Digital Image Scanning Sonar
- Swath Bathymetry (Multibeam)

Reference should also be made to: http://www.oceannet.org/marine_data_standards/medin_data_guide.html where the following data guidelines can be downloaded:

- MEDIN data guideline for the recording of oceanographic vertical profile data.
- MEDIN data guideline for the recording of moored instrument data.
- MEDIN data guideline for the recording of surface underway oceanographic data.

5.8 Intertidal Studies

Where it is thought there may be an impact on the intertidal communities, sampling regimes would need to be set up to monitor these impacts. A pre-construction survey along the finalised cable route in the intertidal should be undertaken, to be compared with post-construction surveys for assessment of the rate of recolonisation. Monitoring surveys should include those elements considered relevant following assessment of the potential impacts of the activity against the characterisation survey, for example sediment traps or beach profiling to monitor sediment loading, and repeat intertidal transect and granulometry surveys to monitor community recovery at the cable landfall.

5.9 Underwater noise

The approaches to underwater noise monitoring are the same as those described in section 5.5.

6 Decommissioning

At the end of the wind farms operational life, there is a need for the decommissioning of the infrastructure. Removal of the foundations and cabling will result in considerable disturbance of the seabed with resultant removal or physical disruption of benthic communities and re-suspension of sediment. A decommissioning plan will need to be prepared by the developer and agreed with the Marine Management Organisation and Statutory Nature Conservation Agencies (SNCAs) prior to removal of any wind farm infrastructure.

There is no specific guidance available for data acquisition methods for decommissioning. The EU state that the decommissioning of a wind farm is assumed to be a reversal of the installation process (Januario, *et al*. 2007) but that although it is considered straightforward, it can have a negative impact on the environment, neighbouring commercial activity, local populations, as well as cost implications for the project. The Energy Act 2004 introduces, under the legal framework for offshore renewable energy projects beyond the UK territorial waters, a statutory scheme for decommissioning of offshore renewable energy installations and their electricity lines (DTI, 2006). The Act defines 'decommissioning' in relation to an installation and/or an electric cable, which has to be removed from the bed of any waters by demolition or by dismantling. In 2006 The Offshore Renewable Energy Decommissioning (ORED) office, now within the Department of Energy and Climate Change, consulted with companies about the decommissioning costs and the best way to charge for them. OSPAR Decision 98/3 sets out binding requirements for the disposal of disused offshore oil and gas installations. Whilst there is no equivalent decision for offshore renewable energy installations, OSPAR has produced guidance documents on offshore wind farms, incorporating ideas on their decommissioning.

The decommissioning programme should be informed by an Environmental Impact Assessment (using the analysis already undertaken for the wider EIA done prior to consent of the installation plus any relevant new data) (DTI, 2006).

7 Annexes

Methods for Data Acquisition

Annex 1 – Benthic Studies

Annex 2 – Seabed Mapping

Annex 3 – Ornithology

Annex 4 – Fish

Annex 5 – Marine Mammals

Annex 6 – Coastal and Sedimentary Processes

Annex 1 - Benthic Studies

Gear & techniques:

Underwater video & stills photography: (summary taken from Ware and Kenny (2011)) provides a non-destructive methods for assessment of all seabed habitat types. These are particularly useful on hard & consolidated ground where other methods may be troublesome and allows for the identification of macro-epifauna. The technique is used best as characterisation and includes ROV; drop-down camera; sledge mounted; SPI. For more details on application & set up see the Marine European Seabed Habitats project (MESH)[59,60]. This approach is primarily used for:

- Presence & extent of features of conservation interest or commercial value (Maerl, *Sabellaria*, fish spawning/breeding areas)
- Spatial extent of dominant habitats and benthic communities (assemblages)
- Assessment of the condition of features.

For (semi-)quantitative analysis for stills the area of field of view will need to be calculated and for video length of video transect are needed if absolute species density values are to be derived. Physical or digital grids can be overlaid and the SACFOR[61,62] (Superabundant, Abundant, Common, Frequent, Occasional and Rare) scale can be applied. Species counts &/or percentage cover estimates can also be made. Interpretation and analyses of photographic materials needs to take account of visibility (water clarity), topography, altitude of the camera, tow speed, tow length. All surveys should follow the NMBAQC (National Marine Biological Analytical Control Scheme) QA protocol for analysing underwater video data[63].

Grabs & corers: (summary taken from Ware & Kenny (2011)) the choice of tool should be determined by the nature of the substrate to be sampled (i.e. hardness/compactness, grain size, topology), the organisms targeted for collection, the sensitivity or fragility of the habitat. Such gears are used for sampling resident infauna & epifauna and do not effectively sample larger or more mobile epifauna. They are not suitable for hard, compacted or impenetrable substrates and coarse grained sediments can compromise samples (preventing full closure)

Description of grabs used for the collection of sediment/benthos samples from the sea bed (from Ware & Kenny (2011))

Sampling Device	Surface Area Sampled	Approximate Weight (no sample)	Suitable for coarse sediments
Mini-Hamon Grab	$0.1m^2$	300kg (+ weights of up to 300kg)	Yes
Day Grab	$0.1m^2$	80kg (+ weights of up to 80kg)	No
Small van Veen Grab	$0.1m^2$	80kg	No
Costerus Grab	$2 \times 0.1m^2$	400-480kg	Yes
Shipek Grab	$0.04m^2$	80kg	Yes (not suitable for faunal assessment)

Mini-Hamon Grab: is most frequently used for collection of sediment/benthic samples in coarse sediments. 0.1 m^2 is the conventional surface sample unit employed in most benthic surveys so this provides direct comparison of results from a variety of other sources even if other sampling devices have been used. This is the preferred sampler for collecting benthic infauna samples. NB. The full size Hamon Grab takes a 0.25 m^2 sample and as such data are not directly comparable with that from other devices.

Day Grab: designed for sampling soft sediments (sands to muds); does not function well on coarse sediments.

van Veen Grab: in coarse sediments sample may be lost by incomplete closure it is widely used in benthic macrofauna studies in softer sediments. The greater leverage provided by side-arms may make this preferable to Day grab.

Costerus Twin Grab: designed to improve quality & efficiency of seabed sediment sampling in coarser sediments. It takes two independent 0.1 m^2 samples (one for physical & chemical analyses and one for faunal extraction). It is comparable with other devices (e.g. mini-Hamon Grab).

Shipek Grab: effective in sampling coarse substrata. Its small sample size (0.04 m^2) makes it unsuitable for macrofaunal investigations and data will not be directly comparable with those generated from other gear types.

Corers: have a low sampling efficiency on coarse or consolidated sediments. They are used to evaluate vertical structure and integrity of the sediment.

Trawls & Dredges: (summary taken from Ware & Kenny (2011)) these towed gears are used to sample epifauna over any terrain. Variability in their usage reduces accurate quantification and more than one gear type may be advised to ensure that a full range of benthic organisms sampled. The use of dredges should be avoided when other sampling tools (e.g. beam trawls) can be effectively deployed, i.e. only used where hard or uneven substrata preclude the use of trawls. The different modes of operation, mesh size and mouth/sample size need to considered when comparing data from different trawl & dredge types, hence at best data these are semi-quantitative or qualitative.

Description of trawls & dredges used for collection of semi-quantitative epifaunal samples (from Ware et al in prep)

Sampling Device	Surface Area Sampled	Approximate Weight (no sample)	Suitable for coarse sediments
2m Beam Trawl	Variable	60kg	Yes
Newhaven Scallop Dredge	Variable	Single dredge 90kg Three dredges on beam 400kg	Yes
Rallier du Baty Dredge	Variable	80kg	Yes
Anchor Dredge	Variable	65kg	Yes
Rock Dredge	Variable	140kg	Yes

<u>2 m Beam Trawl:</u> routinely used for epifaunal sampling in a variety of sediment types. They are designed to sample at and just above the surface of the seabed. A 3 mm mesh codend; should be towed over a distance which will collect a sufficiently large sample to adequately characterise the epifaunal assemblage (nominally between 200-800 m). The maximum speed of tow is 1.5 knots and it is essential that information on start and end positions, tidal state and weather conditions are recorded for each deployment and utilised in interpretation of sample analyses.

<u>Newhaven Scallop Dredge</u>: a commercially used device, suitable for use over very coarse terrain (but not bedrock or boulders). The maximum particle size likely to be retained within the dredge is 20 mm diameter. The same considerations as for the deployment of beam trawls should be employed. Samples should be treated as semi-quantitative. This is only recommended for use as a last resort for qualitative assessment of areas where less robust gear cannot be deployed.

<u>Rallier-du-Baty Dredge:</u> designed to work range of substrata (sand to cobbles). The same considerations as for the deployment of beam trawls should be employed. Samples should be treated as semi-quantitative or qualitative. This is suitable for collecting both infaunal and epifaunal organisms. Large volumes of sediment can be collected and this coupled with the uncertainty in the mode of action can complicate interpretation of macrofaunal data. This should only be used if specifically advised by Cefas.

<u>Anchor Dredge:</u> designed for use from small vessels on sandy sediments. It collects a discrete sample from a single point. As for the Rallier-du-Baty Dredge uncertainty in the mode of action complicates interpretation of the resulting macrofaunal data. Data are semi-quantitative. It is easy to handle, will collect a sample whatever way it hits the sea bed and relatively inexpensive.

<u>Rock Dredge:</u> robust device originally designed for collection of rock samples in deep waters. It can be used on gravels & cobbles and will even collect surface scrapings of bedrock. It is useful for 'pilot' surveys in areas where sampling conditions may be difficult.

<u>Sediment and faunal sample processing</u>

Introduction

The process of separating organisms from sediments and other residual material is usually separated into two stages. Initially, collected samples are processed by tipping them over sieves of appropriate mesh size onboard the survey vessel in order to reduce the bulk of the material transported back to the laboratory. The retained material is preserved immediately (using fixative), allowing for the final separation of the fauna from the residue to be done in the laboratory at a later stage. In cases where it is impractical to process samples onboard the survey vessel (e.g., due to restricted deck space or limited numbers of personnel), entire samples may be preserved in the field and dealt with on return to the laboratory. This section briefly describes the treatment of benthic samples obtained using grabs, trawls and dredges. Sections 9.5, 9.6 and 9.7 of the Guidelines for the Conduct of Benthic Studies at Aggregate Extraction Sites – MALSF Project Code: 08/P75 (Ware & Kenny (2011)), should be referred to for more thorough details of the procedures outlined below.

Processing of epifaunal samples from trawls and dredges

In the case of trawl samples estimates of total catch should be made and a photograph taken. Trawl samples often require sub-sampling and directions for this are given in Section 9.5 of the Guidelines for the Conduct of Benthic Studies at Aggregate Extraction Sites – MALSF Project Code: 08/P75 (Ware & Kenny (2011)). NB. Most of the identification and biomass assessment is likely to happen on board the vessel with some taxa returned to the lab for verification. Additional data (e.g. size frequency and stomach contents of fish) may sometimes required.

Processing quantitative samples collected by grabs

Several steps need to be followed in the processing of grab samples and again full details can be found in Section 9.5 of the Guidelines for the Conduct of Benthic Studies at Aggregate Extraction Sites – MALSF Project Code: 08/P75 (Ware & Kenny (2011)). In brief these steps are as follows:

I. Estimation of sample volume including any rejection of samples. Failed samples should never be pooled but must still be logged.
II. Separation of infauna from the sediment including sub sampling for Particle Size Analysis. Samples are sieved over a combination of 5 mm and 1 mm sieves.
III. Transfer of processed material to sampling containers
IV. Sample preservation using buffered formaldehyde solution at a final concentration of 4-5%.
V. Sample labelling using internal (waterproof) and external labels and logged in a pre-designed field log or electronic datasheet.

It is important that equipment is washed between samples to avoid cross contamination. Sample staining using a stain such as Rose Bengal is optional.

Laboratory processing of grab samples

Section 9.6 of the Guidelines for the Conduct of Benthic Studies at Aggregate Extraction Sites – MALSF Project Code: 08/P75 (Ware & Kenny (2011)) deals with the processing of grab samples in the laboratory. The process is described only briefly here and consists of:

I. Washing and sorting using suitable equipment such as an illuminated magnifying glass and binocular microscope.
II. Identification and enumeration using standard taxonomic keys. Only specimens with an anterior end are counted. Distinction should be made between adult and juvenile specimens.
III. Biomass analysis as wet weight and then converted to Ash Free Dry Weight (AFDW).
IV. Quality Assurance of 10% of the samples to UK NMBAQC guidelines.

V. Sample tracking
VI. Preservation and storage using 70% ethanol/IMS (Industrial Methylated Spirit).
VII. Reference collections

The collection and analysis of sediment samples for particle size analysis (PSA)

Further guidance on this can be found in section 9.7 of the Guidelines for the Conduct of Benthic Studies at Aggregate Extraction Sites – MALSF Project Code: 08/P75 (Ware & Kenny (2011)). Again these procedures are only described in brief here. Field survey methods and laboratory procedures for assessing seabed sediment particle size distributions are currently being evaluated by the NMBAQC scheme (see Mason, in prep, 2010).

I. Field subsampling sediment for particle size analysis from a macrofaunal sample typically using a 500 ml plastic scoop (and frozen in a sealed container preferably in the dark if chlorophyll or organic content is also to be assessed).
II. Laboratory splitting the sample into a coarse and fine fraction using different sieves depending on the method of analysis of the finer fraction.
III. Analysis of the coarser fraction using a dry sieve process using a stack of sieves nested at 0.5ϕ intervals for a period of 10 minutes.
IV. Analysis of the finer fraction by drying and using either settling techniques such as pipette and Sedigraph® analysis or optical methods such as laser diffraction (it should be noted that comparison of sieved and laser sized fractions is not straightforward).
V. Particle size data reporting using data from the analysis of both the coarse and fine fractions. Assigning of a description based on either Folk, 1974 or Wentworth, 1922. Statistics relating to particle size distributions can be calculated and described using the formulae given in Dyer (1986), using Gradistat, an Excel based programme (Blott, 2001).
VI. Quality Control using certified reference material is recommended as is membership of accredited QC schemes, such as the NMBAQC Scheme (see later) and the Particle Analysis and Characterisation Scheme (PACQS), co-ordinated by the Laboratory Government Chemist (LGS).

It is imperative that that an adequately qualified and experienced analyst conducts the data analysis and interpretation. QA/QC procedures should be employed on data analysis and supplied with the monitoring reports.

Reference should also be made to: http://www.oceannet.org/marine_data_standards/medin_data_guide.html where the following data guidelines can be downloaded:

- MEDIN data guideline for sediment sampling by grab or core for benthos
- MEDIN data guideline for recording and archiving of digital photographs
- MEDIN data guideline for fish and benthos data by trawl and dredge
- MEDIN data guideline for transfer video survey data

Annex 2 – Seabed mapping

The Guidelines for the Conduct of Benthic Studies at Aggregate Extraction Sites – MALSF Project Code: 08/P75 (Ware & Kenny (2011)) provides greater detail of such methodologies and applications. Where necessary geophysical surveying should be used to support archaeological interpretation and analysis to corroborate desk-based sources of information about the historic environment as might be affected by the proposed development. Further information about applying these technologies and that early survey planning is essential can be obtained from the COWRIE publication 'Historic Environment Guidance for the Offshore Renewable Energy Sector (2007).

Acoustic methods

Acoustic techniques can be used to inform survey design by providing a base map which allows efficient and thorough sampling strategies to be designed. The data can provide maps of the physical and biological features of the seabed. There are various technologies used, each with its own disadvantages and advantages (see Table 2) and the most suitable technique or combination of techniques is dependant on the requirements and constraints of each specific application. For further guidance on the risk of injury and disturbance to marine fauna arising as a result of acoustic techniques is given in JNCC draft guidance on the protection of European Protected Species from injury and disturbance (contact seismic@jncc.gov.uk for a copy).

System	Use	Resolution	Relative Cost	Environmental Applications
Echo-Sounder (single line bathymetry)	Line bathymetry	<100% - poor spatial coverage	Low	Detection of broadscale features Broadscale base map to inform direct sampling survey design
Acoustic Ground Definition System (AGDS)	Line bathymetry and sediment discrimination	Low spatial resolution (>10m), full coverage requires interpolation	Low	Habitat mapping Can help inform direct sampling survey design
Sub-Bottom Profiling	Sediment layers and shallow geology	Vertical resolution varies with frequency	High	Can help to infer habitat distribution through identification of geological features
Sidescan Sonar	Sediment texture and features	Very High (100% coverage possible)	Low to High (depending on system)	Identification and monitoring of specific habitats, sediment transport pathways etc. Broadscale base map to inform direct sampling survey design
Swath Bathymetry	Bathymetry and sediment discrimination (from backscatter)	Very High (100% coverage possible)	Moderate to High (entry level system). High performance systems very expensive	100% bathymetric coverage and detection of topographical features

Table 2. Summary of remote acoustic systems (prices are indicative at time of publication)

Echo-sounders

Echo-sounders can vary in their sophistication and cost but all work using the same principles. A transducer converts an electrical pulse into a mechanical pulse that creates a sound wave that is directed towards the seabed. Signal strength dissipates and becomes weaker with depth. This is not an issue when depth alone is recorded, but does affect measurement of the echo strength and interpretation capabilities.

It is unlikely that a habitat survey would be conducted using only a single beam echo-sounder, as the satisfactory cover would be time and financially inhibitive. It is more likely to be used along with a swath system.

Acoustic Ground Discrimination Systems (AGDS)

AGDS are based upon single beam echo-sounders and are designed to detect different substrata by their acoustic reflection and absorption properties. Hard surfaces result in strong echos while soft surfaces absorb sound and give weak echos. Examples include:

- RoxAnn™ (Sonavision, Scotland) – detects the tail of the first signal which is a measure of roughness. Hardness is measured by the strength of the second echo and not the first.
- Echo Plus™ (SEA Ltd, Bath) - Designed to be a digital version of RoxAnn.
- QTC-View™ (Quester Tangent Corp, Canada) - This converts the echo into a digital format and the software then uses a number of algorithms to extract parameters of the echo.
- 'Fish' Echo-Sounder - Fish or scientific echo-sounders can provide high quality data relative to standard single beam echo-sounders but they do cost more. They were initially designed for use in fisheries research but are proving useful in habitat mapping predominantly for the detection of marine algae.

The down sides of ADGS is that they need to be appropriately set up, the raw data is not intuitive, and careful editing is required.

Sub-Bottom Profiling

Sub-bottom profiling techniques obtain data on the layers of bedrock strata below the seabed. They create enough energy to penetrate the sediment and identify the different density layers (sediments) of the substrata.

This technique is used regularly at aggregate sites to map the resource. This is also helpful for wind farm developers to identify suitable locations for foundation placement, including understanding of the nature of the deposit, particularly the stability of the material over time (in relation to scour protection).

Sidescan sonar

Sidescan sonar (SSS) is a swath based system which insonifies a wide track of seabed generating an image analogous to a monochrome aerial photograph. The length of the shadow can be used to determine the height of the object and feature. Sediments with different reflective properties can also be distinguished.

The high resolution of images makes them an ideal tool for the detection of fine scale features, such as biogenic and geogenic reefs. However, interpretation of the images is time consuming and requires an experienced eye. Also sampling of ground types can be undertaken to aide confidence in the interpretations. Combined with sampling can provide evidence to make inferences about habitat distribution and fill the gaps around point samples. The images can also reveal transport features such as sand waves, allowing sediment transport pathways to be identified.

Digital Image Scanning Sonar

Scanning sonar are sidescan sonars where the transducer rotates within an oil-filled chamber through either 360^{o} or any sector of a full circle. The image appears like a radar image and the rate of rotation can be adjusted which alters the resolution of the image. Scanning sonar has been used for fisheries surveys searching for fish or on ROV for obstacle avoidance but is relatively unproven for environmental benthic surveys.

Multibeam Swath Bathymetry

Multibeam swath bathymetry (MBSB) is the collection of seabed bathymetric data using a system which collects data in a fan or swath oriented perpendicular to the survey vessel. Due to the beam geometry of the system they are able to collect data with 100% coverage. The spatial coverage and nature of the data provides a relatively detailed representation of the physical seabed environment, which allows for spatial patterns and distribution to be visualised, and provides base maps for survey planning and data overlay and interpretation.

MBSB provides the means for detecting small features and spatial patterns in sediment types that are required for habitat classification. The benefits of such a system include:

- Greater tracking speeds and therefore more cost effective
- The ability to export complimentary outputs that are geographically coincident into software for classification
- Versatility in the display of Digital Elevation Models (DEM) for feature detection, and
- DEMs acting as a backdrop for draping other layers of information and facilitating the integration of data for assessment purposes.

Annex 3 - Ornithology

At the time of writing the specifications for ornithological studies are being collaboratively developed by the SNCAs and developers on a case-by-case basis. This section will be completed at a later date if / when standard approaches are documented.

Annex 4 – Fish & Shellfish

Gear:

For collecting data on adult fish and shellfish, the gear used should mirror that used in local commercial fisheries. It is also strongly suggested that surveys for adult fish should involve chartering commercial fishing vessels to take advantage of local knowledge. Commercial species data collected from local fishermen, local IFCA[23], or MMO[21] should be used in planning trawl surveys including appropriate seasonal timing of the survey, selection of fishing areas and appropriate fishing gear for the range of species likely to be encountered.

Trawls will indicate which species are present but all types of trawl will miss some species and the fishing gear used should be appropriate to the type of fish expected in the area. It may be appropriate to use more than one type of trawl and would probably include otter trawl and/or beam trawls. It should be noted that trawl surveys, particularly those using beam trawls, may also collect a certain amount of information on the benthos and it may be possible to combine these surveys.

In general, otter trawls are suitable for groundfish (cod, whiting etc.), although such gear will also catch some pelagic fish (herring, sprat etc.) and some flatfish (plaice, sole). If flatfish are the primary target species, then the use of a large beam trawl (>4 m) should be considered. If juvenile flatfish are to be sampled (e.g. on a nursery ground), these may be better sampled by small (2 m) beam trawl or shrimp trawl. For shellfish, an appropriate trawl or potting gear should be used.

Applicants must apply for a dispensation from the provisions of the fisheries conservation measures where small mesh nets are to be used, or specimens below the minimum legal size are retained during the course of any survey work. Applicants can apply for a dispensation from the Marine Management Organisation who issue dispensations from national and European marine fisheries legislation for the purposes of genuine scientific research (see http://www.marinemanagement.org.uk/fisheries/management/dispensations.htm[77]).

The Environmental Statement (ES) should include a full gear description for all fishing gear used, including information on the length of the headline, length and type of the ground gear, mesh sizes along the net, mesh size of the cod-end liner (if used), length of sweeps and bridles and type of doors.

The use of other gears (e.g. pots, fixed nets) may be more appropriate for sampling some species of interest. For pots, the number and design of pots should be stated, and for the various types of fixed nets, the mesh-size and length of the net should be stated.

The identification of herring spawning grounds can be achieved using grab sampling and/or underwater camera/video.

Fish

Sampling protocol

Sampling should be undertaken in both daylight and hours of darkness, as fish behaviour varies between day and night. The ES should give full details of the sampling protocol, including the following information for all trawl samples:

- Start (shot): Time, latitude, longitude, depth

- Finish (hauling): Time, latitude, longitude, depth
- General: Gear description, trawl speed, trawl direction

Tows of commercial gear should be of 30 - 60 minutes duration, and all tows should be of a similar duration. Sampling with shrimp trawls or 2 m beam trawls should be 5 - 15 minutes duration, depending on the quantities of fish in the area. It is recommended that the use of small trawls for juvenile fish be conducted either in parallel with the main fishing survey or during a survey of the epibenthos.

If catches are small, then the entire catch should be processed, with species counted and measured. The sex and maturity of a suitable sample of the main target species should also be recorded.

In those cases where the catch is large, it should be fully sorted so that all the target species can be identified and an appropriate sample taken to record length distribution and maturity. For the remainder, all species should be sorted and an appropriate sub-sample taken for length-frequency analysis (ca. 50 fish).

The recommended identification guides for UK marine fish are Wheeler (1969, 1978) and Whitehead *et al*. (1984).

For the purposes of sampling, a minimum of five tows should be undertaken in the site of the proposed wind farm, but preferably more, depending on the size of the area. The samples should include the location of the proposed development and the immediate vicinity including suitable reference areas.

In general, many fish spawn in the spring, and so useful data may be collected during February or March. Seasonal fisheries in an area may also necessitate additional sampling in summer and/or winter as well. Consideration should also be given for the state of the tide as this also influences the behaviour of many, therefore data should be collected during both spring and neap tides, to adequately assess the importance of an area.

Data analysis

Trends in the relative abundance (catch per unit effort, given as number of fish per hour) of fish in trawl surveys are highly variable, and any data analysis should use extreme caution. Variance can be reduced by increasing the number of samples, and the frequency of sampling during a season. If fishing surveys are undertaken, therefore, they should focus on determining whether the appropriate life-history stages of the species of concern are present in the area.

Reference should also be made to: http://www.oceannet.org/marine_data_standards/medin_data_guide.html where the following data guidelines can be downloaded:

- MEDIN data guideline for static net, pot and trap data
- MEDIN data guideline for shellfish stock assessment data
- MEDIN data guideline for fish and benthos data by trawl and dredge

Annex 5 - Marine Mammals

Gears & techniques: The basic equipment and techniques for ship-based, visual and acoustic and aerial surveys are described and evaluated in the SMRU Ltd. 2010 scoping report and the following paragraphs summarises some of the key text. For all surveys, a standardised survey protocol and sighting and effort forms should be produced, containing key information such as general information (e.g. date, time, name of observer), environmental parameters (e.g. weather conditions, sea state), marine mammal sighting data (e.g. geographic coordinates, species, group size) and method used (e.g. type of platform, effort, specific parameters to the methodology).

Double platform ship-based line transect surveys: (provides absolute or relative abundance data) Requires a large, stable ship, with two elevated observation platforms (at least 5 m above sea level, audibly and visually isolated from one another and preferably with one platform higher than the other). Two teams of up to four observers are required with associated binoculars, angleboards and data recording laptops (automated or manual). A GPS is also useful. Survey speed should be approximately 10 knots.

Single platform ship-based line transect surveys: (provides relative abundance data) Requires a stable ship with one elevated viewing platform. One team of up to four observers is required, with the same equipment as for the double platform ship survey. Survey speed is again approximately 10 knots.

Towed hydrophone arrays: If towed hydrophones are required during the ship surveys, a hydrophone array (multiple hydrophone elements for detecting high (porpoise) and medium/low (dolphins and toothed whales) frequency signals, and a depth indicator), towing cable, computer and associated software (e.g. PAMGUARD), in addition to two dedicated PAM operators will also be required.

Double platform and single platform aerial surveys: (data provided as for the ship surveys) Requires a twin-engine aircraft (for safety and endurance), with high mounted wings with excellent all round visibility for observers (e.g. twin-engine Partenavia P-68 Observer). Either full or partial bubble windows are also recommended. The plane should be able to accommodate four observers for a double platform survey (two observers for a single platform survey) and NMEA (National Marine Electronics Association) outputs are required. Aerial surveys are also the most common way of surveying for pinnipeds (seals).

Autonomous static acoustic monitoring: acoustic data loggers (e.g. Porpoise Detectors or more commonly known as PODs) register click sounds of porpoises used for orientation and foraging via echolocation and for communication. The AMPOD project (Verfuß *et al* 2010) recommends a set of guidelines for using PODs to ensure that the aims of any study are clearly defined and that data are kept comparable (i.e. consistent use of deployment methods, devices, device sensitivities, device settings, analysis programmes etc).

The number of PODs (T PODS / C PODS) required will depend on the area to be surveyed. Monitoring surveys in Denmark used between two and eight PODS, in a wind farm consisting of between 11 and 80 turbines. Some researchers also suggest that up to double the number of PODS should be placed in the field to account for loss and/or failure. It should also be noted that the range of a POD is approximately 300 m, therefore adequate coverage of the survey area must be ensured.

Telemetry: Some telemetry data is collected by SMRU and should seals be scoped in as sensitive, it is recommended that a review of the available data is carried out. Should there be gaps or unanalysed data, collaboration between developers to gather this data may be required. Further information on telemetry methodologies is provided within the SMRU Ltd. 2010 report.

Cetacean - Line transect surveys (both double and single platform): The survey area should be defined and a set of pre-determined transect lines followed. The number of transect lines will depend on the region to be surveyed, however, as a rule, a minimum of 15 transect lines are required. No observations in a sea state 4 or above should be used in data analysis, and effort data is usually taken every 30 minutes or when any variable (e.g. sea state) changes. During the survey, observers record the perpendicular distance to each of the sightings (a technique known as distance sampling) together with data on the species and group size. In this way, a detection function (modelling the decrease in detectability of animals, the greater distance they are from the transect line) can be fitted and an effective width of the strip that has been searched estimated; this corrects for animals missed by observers further away from the transect line. The method generates unbiased estimates of density and abundance providing that three key assumptions are met:

1. Distances and angles from the observer to points of interest are measured without bias;

2. Animals are detected at their initial location, prior to any responsive movement to the survey platform;

3. Animals on the transect are detected with certainty, i.e. the detection function / probability *g(0)* = 1.

Assumption (3) is almost never met, irrespective of species or survey platform. However, certain field methods (e.g. double platform surveying) allow for empirical estimation of *g(0)*. Double platform surveys also help meet assumption (2).

With regards to aerial surveys, careful protocols are required; during a double platform survey, the observer teams must work independently. However, if this methodology can be applied, the resulting mark-recapture distance sampling analysis is incorporated into recent versions of DISTANCE (Thomas *et al.,* 2010). Additional methods for estimating *g(0)* during aerial surveys have also been developed, collected by two aircraft surveying the same track line in tandem, or by the "race-track" method, with one aircraft circling back after a sighting to simulate the second aircraft. However, an experienced analyst is required to evaluate this data.

Acoustic techniques: The usual techniques used are passive acoustic monitoring (PAM) systems, which detect vocalising cetaceans (not pinnipeds). These can be towed systems, or autonomous acoustic data loggers (AAM), which are left in place. Data can be collected 24 hours a day, and is not as reliant on weather conditions compared to visual observations.

Towed arrays can be deployed from most vessels and are simple and easy to use. A minimum water depth of approximately 10 m is necessary. Depending on the depth of water, a length of tow cable is required, with hydrophone elements and a depth sensor at the end. Hydrophone elements can be used to detect different species. There can be a high frequency component for detecting porpoises and a medium/low frequency component for other cetaceans. Multiple hydrophone elements allow the bearing to the detections to be estimated, which can then form the basis for distance sampling analysis to obtain a relative abundance estimate. While the harbour porpoise and the sperm whale have easily distinguishable vocalisations, other species do not. Dolphin vocalisations are more complex and are not yet easily recognisable to species level and reliable systems to automate their identification have yet to be developed.

Various autonomous acoustic data loggers are available for use (e.g. Cornell Pop-Up, Ecological Acoustic Recorders (EAR), PAM Buoys and PODs). All record raw data, and some will carry out real time analysis. The PODs have been most often used in Europe and were extensively used to monitor the impact of wind farms in Denmark, Germany and Holland. PODs are programmable, therefore can be set up to record the frequency range of interest. The most recent POD, the C POD, can detect all vocalising cetaceans within the 20 – 160 kHz range (apart from sperm whales). Data from the POD can take the form of 'porpoise positive' time (i.e. the amount of time (minutes/hours/days) that porpoise activity was recorded). Waiting time between encounters can also be calculated. However, as the PODs only measure acoustic activity, rather than numbers of animals, it is possible that a reduction in porpoise positive time would not mean a lower density of animals, but a change in behaviour.

Data processing & analytical techniques: Marine mammal observers (MMOs) require training, and need a good understanding of the ecology of marine mammals (species identification, biology, behaviour and distribution). Towed hydrophone array operators also need to be trained on the equipment. Ideally all MMOs and hydrophone operators will be both trained and experienced. It is also important that the MMO is dedicated, that is that their primary task is the collection of marine mammal data. Therefore, while the combination of seabird and marine mammal surveys is a good idea, dedicated observers for both seabirds and marine mammals will be required.

Data recording and analysis: Well designed recording forms are required (e.g.the JNCC forms for use during seismic surveys could be adapted for use). Units should also be consistent, for example, if the area is recorded in km, all effort and sighting distances should also be expressed in km. Where software is required, recognised, widely used and robust programmes should be used (LOGGER 2000, PAMGUARD and DISTANCE). The software and any associated modelling should be undertaken by experienced personnel to ensure no misinterpretation of the data or the generated results.

Presentation of data: Each developer should adhere to a standardised reporting format, to allow cross site comparisons. The report should include what monitoring was undertaken, why it was undertaken (against predictions made in the Environmental Statement), how successful the monitoring (including any issues), the results and conclusions. A set of data validation tests have been implemented for the Joint Cetacean Protocol at: *http://www.ruwpa.st-and.ac.uk/dpwebi/jcp/*

Annex 6 - Physical and Sedimentary Processes

Data collection will be determined on a site-specific basis, depending on the hydrodynamics and sediment transport regime at each site, but is likely to include:

- Where identified as necessary transects of the shoreline in the lee of the wind farm (extent of coastal stretch depending on incident wave direction(s));
- Profiling of wind farm array and cable route (sand bank or other subaqueous high) *e.g.* seismic survey or with sidescan sonar; [repeat surveys may be needed in areas of high variability]
- Due to the dynamic nature of sandbanks, a bathymetric survey should be carried out of the entire seabed form on which the wind farm is proposed, rather than just for the grid area of the proposed wind farm footprint;
- Where identified as necessary wave recording; ideally windward and leeward of wind farm and placed 1 year prior to wind farm construction and maintained for another year following completion;
- Where identified as necessary tidal current recording; depending on the data available, the developer may be required to measure 3 sites for tidal current recorders: one windward, one within and one immediately leeward of the wind farm, ideally placed 1 year prior to wind farm construction and maintained for another year after completion; [wave and tide recording could be combined]
- Sediment sampling and various sediment analyses including PSA, suspended sediment concentrations. Please note sediment sampling should be undertaken in co-ordination with other survey methods to indicate where other methods may be required to avoid damage of potential Annex 1 habitats by e.g. grab sampling (see Section 8.4).
- Where identified as necessary X-band radar/video recording equipment to record wave train conditions in the vicinity of the proposed wind farm, e.g. where GBS/hybrid foundations are to be used.

Oceanography

Currents and Tidal Elevation

A deployment of current meters or an Acoustic Doppler Current Profiler (ADCP) can be used to measure current dynamics. Several locations may be needed where there is spatial variation in current speeds and/or direction. This variation is typically due to changes in bathymetry or the convergence/divergence of two or more tidal streams.

Suspended sediment and turbidity

Suspended load has an important influence on the benthic community. Measurements of suspended sediment concentrations should be made over a sufficiently long period to observe any tidal resuspension due to spring tides and should be at sufficiently high resolution to observe short-term events such as waves and disturbance from anthropogenic activities.

The suspended load can be measured two ways, optical sensors (e.g. backscatter and transmissometer) for fine particles in suspension, and acoustic backscatter sensors for the coarser sands in suspension. Calibration with site specific suspended sediments is required and can be captured by water samples or sediment traps.

Waves

An assessment of the exposure to waves, from all directions and all seasons, can be used as an indicator of disturbance. This data can provide estimates of wave orbital velocities and wave height extremes.

Waves can be recorded by two methods, surface-mounted buoys and seabed-mounted gauges. Surface-mounted buoys use accelerometers or GPS technology to record wave dynamics, whereas the seabed-mounted devices use pressure, acoustic or electromagnetic sensors to record wave motion.

Sediment dynamics

Sidescan sonar surveys can be used to give an indication of sediment transport, including sand waves, sand ribbon, and scour mark features. However, these surveys represent the most recent activity and not necessarily highlight the long-term pathways.

Sediment traps can provide information on timings, rates, and direction of horizontal sediment transport. Measurements can be in three ways; passive, active and directional. Passive traps are simple and widely used, whereas active traps include some sort of mechanism to infer the timing or sequence of sediment transport events. Direction traps infer the directional source of the material.

Horizontal and vertical structure (temperature or salinity)

Horizontal or vertical gradients of temperature or salinity can affect the distribution of species and can be assessed by vertical conductivity, temperature and pressure (CTD) and Rosette casts or by undulating CTD systems. The CTD system collects data via a cable to give real time data whilst the rosette sampler carries multiple Niskin bottles for water sample collection.

Reference should also be made to: http://www.oceannet.org/marine_data_standards/medin_data_guide.html where the following data guidelines can be downloaded:

- MEDIN data guideline for the recording of oceanographic vertical profile data.
- MEDIN data guideline for the recording of moored instrument data.
- MEDIN data guideline for the recording of surface underway oceanographic data.

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Tel +44 (0) 1502 56 2244
Fax +44 (0) 1502 51 3865

Web www.cefas.defra.gov.uk

Centre for Environment, Fisheries & Aquaculture Science
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Tel +44 (0) 1305 206600
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