MARINET

Marine Renewables Infrastructure Network

Work Package 4: Research

4.17 Report on environmental monitoring protocols

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ABOUT MARINET

MARINET (Marine Renewables Infrastructure Network for Emerging Energy Technologies) is an EC-funded consortium of 29 partners bringing together a network of 42 specialist marine renewable energy testing facilities. MARINET offers periods of free access to these facilities at no cost to research groups and companies. The network also conducts coordinated research to improve testing capabilities, implements common testing standards and provides training and networking opportunities in order to enhance expertise in the industry. The aim of the MARINET initiative is to accelerate the development of marine renewable energy technology.

Companies and research groups working in wave, tidal and offshore-wind energy can access a range of test facilities free of charge to test devices or to conduct specific tests on cross-cutting areas, such as power take-off systems, grid integration, moorings and environmental data. In total, over 700 weeks of access is available to an estimated 300 projects and 800 external users.

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EXECUTIVE SUMMARY

This document presents a short review and overview of monitoring protocols developed and employed for surveying species and habitats in relation to offshore renewable energy developments. The document summarises the design phase of the monitoring process as well as providing a quick overview for key environmental descriptors (mammals, seabirds and benthic communities) which are protected under EU and national regulation. The main outcomes of this will be taken forward into D4.7 (Best practice report on environmental monitoring and new study techniques).

The core of this document is based on the "Guidance on survey and monitoring in relation to marine renewables deployment in Scotland[1]" developed by Scottish Natural Heritage and on "Guidelines for data acquisition to support marine environmental assessment of offshore renewable energy projects" developed by CEFAS in 2012 which have provided in depth reviews and analysis of protocols for environmental monitoring. This document highlights the key points of environmental protocols which are under development for monitoring the impact of marine and offshore energy converters on the marine environment. It is not the intention of this document to replicate or duplicate the work available in literature but to point users in the direction of more in-depth methodologies.

It is expected that the monitoring protocols described in this document will be improved with the growth of offshore renewable energy technology and through monitoring technology improvements, allowing for more specific and less intrusive monitoring programmes.

[1] This document is divided in 5 separate volumes.

CONTENTS

1 INTRODUCTION

1.1 AIMS

This document reviews existing methodologies and protocols developed for the acquisition of data for offshore renewable energy developments (OREDs) in order to provide generic guidance for environmental assessment and continuous monitoring. Many of the protocols developed thus far are not designed as regulatory instruments but to facilitate and support consultation between project developers with regulators, advisors and interested stakeholders.

The aims of this document are:

1. To identify the critical stages of environmental monitoring in relation to OREDs;
2. To identify the critical environmental "receptors" and "stressor" for each stage of development;
3. To define the design stages of environmental monitoring;
4. To provide an overview of methods for data acquisition for different environmental receptors along with a summary of protocols being developed to satisfy licensing requirements.

The core of this document is based on the "Guidance on survey and monitoring in relation to marine renewables deployment in Scotland[2]" developed by Scottish Natural Heritage [1] and on "Guidelines for data acquisition to support marine environmental assessment of offshore renewable energy projects" developed by CEFAS in 2012 [2] which have provided in depth reviews and analysis of protocols for environmental monitoring. This document highlights the key points of environmental protocols which are under development for monitoring the impact of marine and offshore energy converters on the marine environment. It is not the intention of this document to replicate or duplicate the work available in literature but to point users in the direction of more in-depth methodologies. Key experiences will be highlighted and will constitute the base for the Marinet "Best Practice Report on Environmental monitoring" in Deliverable 4.7.

1.2 BACKGROUND

It is widely recognised that one of the main non-technological barriers affecting the development of offshore renewable energy installations is related to their unknown impacts on the marine environment [3]. With increasing interest in harnessing the different forms of renewable energies available offshore (wind, waves and tides); it is necessary to provide developers with tools that will allow them to fulfil statutory licensing requirements [4][5]. Offshore Strategic Environmental Assessments (SEAs) [4], [6] developed in Europe have highlighted the lack of understanding on the impacts of OREDs on marine biodiversity; and in particular on marine mammals, seabirds, migratory fish and benthic ecology.

Given the regulatory requirements posed on a development by European and national legislation such as the EIA Directive 85/337/EEC (as amended by Directives 97/11/EEC, 2003/35EC and 2009/31/EC[3]), the Habitats Directive (92/43/EEC), and Birds Directive (2009/147/EC), it is necessary to establish "baseline conditions" for potential ORED sites for the following licences:

- Environmental Impact Assessment (EIA) of the project or Environmental Appraisal (EA) for smaller projects;
- Habitats Regulation Appraisal (HRA) and Appropriate Assessment (AA), in case of Natura 2000 areas;
- Post installation monitoring

[2] This document is divided in 5 separate volumes.
[3] Now codified in Directive 2011/92/EU.

In order to help project developers overcome possible hurdles presented by environmental regulation, protocols and guidance documents outlining methodologies for the monitoring and survey of environmental receptors affected are being developed and updated to bridge knowledge gaps. These protocols provide information on how to assess the potential impact that could affect a particular environmental parameter or feature during different phases of wave and tidal energy arrays or offshore wind farms. The stages of assessment and their outputs are presented in Table 1.

Table 1 – Stages of environmental monitoring for ORED developments. Stages marked with the * correspond to stages of the EIA process. Adapted from [1], [2], [7]**.**

Stage	Objective	Outputs
Scoping*	Process of defining the potential significant direct and indirect impacts of the proposed development, including methodologies for characterisation surveys and significance criteria.	Target parameters for specialist studies
Site characterisation*	Process of understanding the environmental components and to characterise the existing environment; and investigating parameters which may be affected by significant effects	Baseline information, including existing literature.
Impact assessment*	Determining the impacts of the development on the environmental components. Impacts should be characterized as follows: - Magnitude of the impact; - Extent; - Duration, time over which the impact will last; - Temporal scale, i.e. permanent or temporary; - Timing and frequency, i.e. coincidence with critical life stages - Cumulative effects - Confidence in future predictions	Environmental statements, EIA if required and mitigation measures
Targeted monitoring	Phase of evaluating the impacts that could be associated to the presence of marine renewable energy structures	Development and analysis of mitigation measures, including data collection.
Substantive review*	Phase of evaluation monitoring techniques and development of surveying best practice	Feedback to consenting, implementation of adaptive management procedures
Decommissioning	Monitoring phase to ensure that environmental effects associated with the removal infrastructure and environment restoration are appropriate.	Production of decommissioning report to regulators.

Early consultation with the Regulator and other expert parties can greatly benefit design of the environmental studies, both to inform an EIA and to inform an ensuing operational environmental monitoring programme. Specific benefits of early consultation include:

- Early-stage awareness and access to existing environmental data
- Early identification of potential environmental issues
- Establishment of a network of key contacts in key organisations which may be consulted with throughout the project
- Early indication of suitability of methodologies and analysis methods
- Advice on reporting requirements

Input from expert advisors is generally highly valuable in informing the methodologies to be employed in baseline characterisation studies, as well as providing access to existing relevant data. Expert advisors may include government agencies, university departments, conservation societies and local wildlife groups and recorders.

1.3 Design of monitoring activities

When designing environmental surveys it is important to ensure that the data collected are fit for purpose, robust and scientifically defensible. The objectives of the study need to be clearly stated and the activity should aim to answer clear questions, with the aims of [1]:

- Providing information on the distribution and abundance of key species to inform site location and facilitating decision making process;
- Providing a baseline against which impacts can be measured

The process of designing of surveys requires that common principles are addressed to define data acquisition strategies, as follows:

- What is the rationale of the survey? Which parameters should be assessed and why?
- Which data type needs to be collected and how will they be analysed?
- Are existing datasets available, are they sufficient to provide the information required or do they need integration with new datasets?
- Are there seasonal and temporal and spatial considerations to be applied?
- Which survey techniques will provide the data to meet the rationale?
- Are data sufficient for future predictions?

Surveying methodologies employed will be dependent on the type of the expected impact and on the monitoring phase, which will affect the resolution of the survey, its size and temporal scale and frequency. It is therefore important to understand how these parameters could affect the monitoring strategy for a given environmental descriptor. Common problems associated with gathering environmental baseline data which should be avoided are:

- Reliance on inadequate data. (Out-of-date, irrelevant or not at the required spatial/temporal coverage.)
- Omission of pre-existing relevant data.
- Spatial focus on development footprint whilst neglecting wider area which may form environmental footprint.
- Inadequate resources to conduct surveys (funding, expertise, time, equipment).
- Inadequate consideration of designated areas and potential connectivity relationships.
- Use of inappropriate survey techniques.
- Inadequate survey methodologies which have not been designed with full consideration of the hypotheses to be tested. Inadequate documentation of methodology which can hinder analysis.
- Concentration on straightforward aspects of survey whilst neglecting difficult aspects
- Inadequate acknowledgement of data limitations.

The clear definition of the objectives in the environmental studies will allow the development of a multi-stage framework for the successful implementation of assessments methods.

1.3.1 Establishing the significance of impacts to be measured

The installation of an offshore renewable structure, its operation and decommissioning can create an impact on the marine environment and alter the status of a space or habitat. Different types of impact could take place, from physical injuries to displacement/barriers effects to increased turbidity and contaminant displacement. Expected impacts are often species specific and will be presented in more detail later in the document. It is however important to note that not all of the activities related to OREDs will generate significant damage or alteration to the species or habitat considered.

The guidance document developed by SNH [1] has identified two types of significance:

> **Significance under the Habitat Directive**, which links the potential effects to the conservation objective of a particular site. If the potential impacts cannot be excluded and are deemed to affect sites of EU importance then an appropriate assessment may be required.
>
> **Statistical significance**; in this case the changes measured on the habitat or species are not deemed to pose a wider risk to conservation objectives although they may have statistical relevance. For example small changes to migratory routes may have statistical significance without posing a risk to the species' abundance. In this case objective judgement by regulators is needed.

In the case of OREDs the most relevant meaning of significance is that associated with the Habitat Directive and how the development of a site could affect protected species or habitats. On the other hand if, during monitoring, statistically significant changes on a population are observed, it will be necessary to associate these changes to the development of a site and exclude other factors. The design of survey activities should be tailored to ensure that the significance of the impacts can be correctly determined. One should note that **significance** is used to measure how a given impact affects a given receptor, whilst **magnitude** is associated with the size or strength of the impact. Design consideration on how to assess the magnitude of impacts are presented in section 1.3.5.

1.3.2 Temporal scale

The length of time and the frequency of sampling that characterises a particular survey are dependent on the receptor being considered and the metrics being measured. The timescales that may be associated with collecting relevant data will be affected by inherent variability in the environment. The environment within and surrounding a development area is not static. Conditions change seasonally and inter-annually. The duration of baseline data collection will depend on factors including the sensitivity of the site and species behaviour.

1.3.2.1 Sampling frequency

The sampling frequency of a survey is dependent on site-specific factors, such as site usage, seasonal variations and natural variability. During the characterisation phase of the site a single visit or few seasonal visit may suffice to provide the required information, however during the monitoring stage more frequent surveys may be required.

1.3.2.2 Survey and monitoring periods

The guidance documents developed by SNH [1] suggest that the minimum length of monitoring for baseline conditions should be of two years especially for surveying of mobile species to allow for an understanding of both seasonal and temporal variations and temporal inter-variations in population. These follow the guidelines developed by COWRIE for baseline data acquisition at offshore wind farms [13]. Whilst two years may a not provide a sufficient time frame to evaluate the abundance of the population, this timeframe should allow to detect changes due to the presence of OREDs.

1.3.3 Spatial consideration

In a similar way to monitoring frequency and period, it is important to determine the **development footprint** and the **potential impact footprint** for a given project. Whilst the development footprint may be limited, the footprint of potential impacts may be larger and will have to be taken into consideration for monitoring purposes. This could be the case for noise monitoring. Identifying the correct footprint for each descriptor will allow better design of correct monitoring methodology and selection of control areas for the evaluation of impacts.

It should be noted that all the effects and impacts presented previously can act cumulatively; for example where the same effect is created by a large number of devices or different marine activities. It was recognised from the inception of Environmental Impact Assessments (EIAs) that many of the most devastating environmental effects may not result from direct impacts of individual projects, but from the combination over time of individually minor effects of new and existing developments.

An EIA should cover any indirect, secondary and cumulative effects of a project and assess the "inter-relationships" and "inter-actions" between specified environmental factors. Depending on the location, a project can also have trans-boundary impacts that have to be assessed. In this case potentially affected parties have to be consulted early and notified if significant, adverse trans-boundary effects cannot be excluded. Multilateral cooperation is therefore usually required. For example, it may be necessary to obtain data from surrounding parties to better understand and assess migratory species issues.

1.3.4 Data type

Data plays a key role in assessing the potential impacts of ORED structures on the environment. It is important to note that the collection of data has to be centred on the aims of the survey and that historical data cannot always be used to determine the impacts of OREDs.

Collected data is normally classified in two categories; distribution/abundance data and behavioural data. When analysed in conjunction with operational data, both types of data can provide information on the interaction with OREDs. Abundance data provides an indication of abundance/distribution changes of particular species; it shows changes in particular environmental conditions, although this needs to be contextualised in relation to a particular driver. Behavioural data allows the determination of the relative importance of an area for key receptors and provides metrics for the assessment of potential impacts.

1.3.4.1 Data formats, metadata and sharing of monitoring information

The type and format of data are dependent on the methodology and equipment employed for monitoring a particular parameter. As in the case of wave data (discussed in [8]), consistent use of data and metadata allows comparison and bench marking of data systems. In this regard the European Union has released the Inspire Directive (2007/2/EC) which regulates how geo-spatial data are made available within the European Union, and provides standards for classifying data obtained environmental monitoring activities. An online tool for the creation of metadata can be accessed on the Inspire Geoportal (http://inspire-geoportal.ec.europa.eu/editor/), allowing for greater consistency among data repositories.

Due to recognized gaps and uncertainties related to potential impacts of OREDS on the marine environment, and in particular those from wave and tidal energy developments, international knowledge exchange initiative have been undertaken to tackle unknowns and provide a wider understanding on the interaction of marine energy converters with the environment. Examples can be found on the Ocean Energy System (OES) Annex IV's Tethys database and in the SOWFIA Project Data Management Platform.

Tethys (mhk.pnnl.gov) is an online database of environmental information, whilst the SOWFIA DMP (sowfia.hidromodo.com) provides data collected during monitoring campaigns at six different wave energy test centres across Europe. Both initiatives are freely accessible and have been developed to aid the development of OREDs project.

1.3.5 BACI and BAG designs

In order to measure the magnitude of any effects of a development on environmental descriptors it is essential to establish control areas for the collection of comparative data. The need to provide comparative information affects the design of the survey and has to be considered form the start of the monitoring campaign.

Two study designs are normally developed:

- BACI, Before and After Control Impact
- BAG, Before and After Gradient.

BAG designs are preferable for bird and marine mammal surveys as they require less monitoring effort in terms of spatial requirements. BACI designs are well established for biological impact assessment but have found limited use in OREDs development, since they can only be employed when the conditions for the control site are comparable and yet independent from the study site. BAG designs assume that the impacts will decrease with distance from the development, which is likely to be highly applicable to marine energy developments.

1.4 Key Environmental Receptors

The guidance documents produced by CEFAS and SNH indicate that there is a general lack of knowledge about the impacts of offshore renewable structures on the marine environment. These gaps in knowledge have led to the on-going development of surveys based on the more stringent legal requirements and impacts on other marine sectors. SNH guidelines for such surveys focus predominantly on marine mammals (separated into cetaceans and seals), seabirds (migratory and diving) and benthic ecology. Marine mammals and seabirds are protected under the Habitats and Birds directives and specific monitoring to support Appropriate Assessment instead of EIA may be required. Benthic characterisation is often required by the EIA as it provides important information on the status of the habitats around the development, whilst fish monitoring is often required to understand impacts on fish migration and on the local fishing industry. CEFAS guidelines also include fish studies, underwater noise, intertidal studies, and physical and sedimentary process studies; however for these receptors no protocol has been drafted yet and different methods are being used. Detailed information on the receptors can be found in [9].

2 MARINE MAMMALS

2.1 Why Monitor Marine Mammals

Marine Mammals are protected under different national and EU legislation [9]. In particular marine mammals are classified as European Protected Species (EPS) and are protected by the EU's Habitat Directives under Annex IV (species of community interest in need of strict protection). In addition to EPS, the Directive also protects important habitats, requiring the establishment of network sites to contribute to protection of habitats and species listed on the Annex I and II of the Directive. The presence of Annex II species, such as harbour porpoise and bottlenose dolphins, may require the designation of Special Area of Conservation (SAC). In case of a SAC an Appropriate Assessment may be required when the development directly affects the SAC or the potential impact footprint overlaps with an area/resource used by individuals that belong to the SAC.

2.2 Potential Impacts

Potential impacts on marine mammals can take place during the construction, operation and decommissioning of marine renewable energy developments. An overview of the impacts that could affect marine mammals are presented in Figure 1 [10][11]. It is important to note that some impacts may be specific to a particular technology whilst others may be similar across the spectra of technologies.

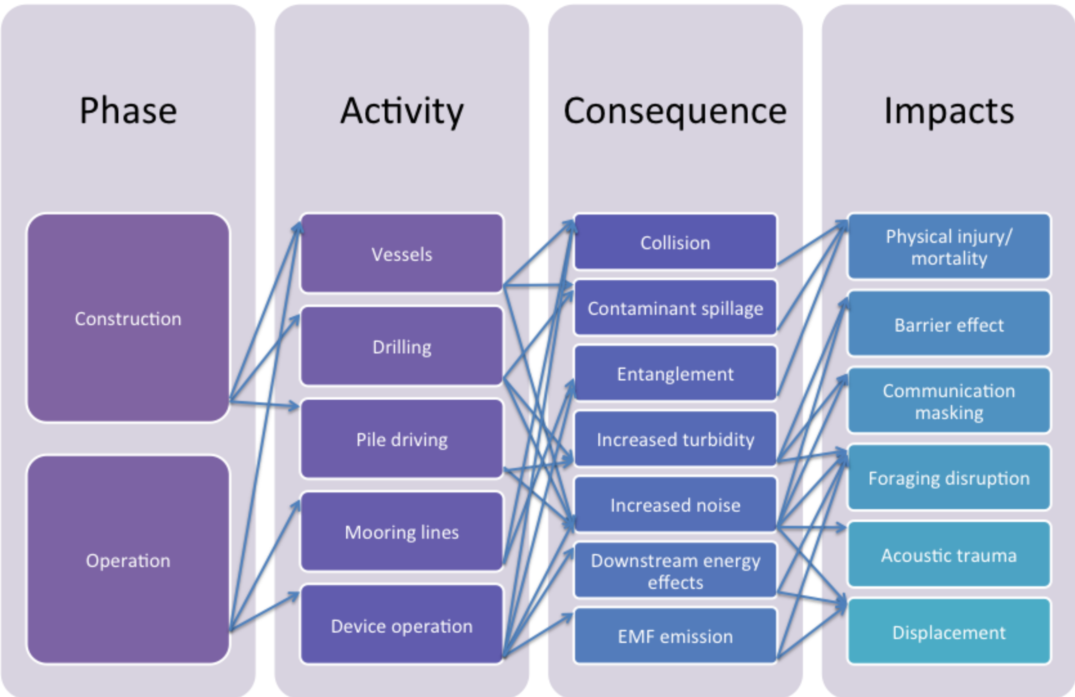

Figure 1 – Predicted impacts pathways of OREDs on Marine Mammals [10][11]

The principal issues of concern with marine mammals are displacement due to physical presence of devices and acoustic output of devices or vessels and processes involved in installation & maintenance activities. Further studies will inform whether these issues remain of concern.

2.3 Critical Monitoring Stages

2.3.1 Baseline characterisation

Baseline assessment, generally required as part of the EIA scoping, is used to identify the need for further targeted surveys to support the EIA and potential impact monitoring. At this stage a broad scale description of the abundance/distribution of marine mammals around the impact footprint is required. This description should include identification of sensitive species including seasonal, temporal and spatial patterns [2]. A desk-based assessment is an essential starting point in identifying existing data and recognising data gaps.
Areas which should be addressed include:

- Species present in the development footprint
- Number, distribution and location of sightings.
- Known migratory routes and movements in and around the development footprint.
- Typical ranges of species, and relation of this information to designated protection sites and estimation of connectivity.
- Site use, temporally and spatially, e.g. known seal haul out sites, known feeding or breeding grounds.

2.3.2 Environmental pressures description

It is critical to describe the environmental pressure during construction/operation and decommissioning to determine impacts and the development footprint [2]. Activities causing potential harm include vessel presence, drilling, pile driving, device operation and decommissioning.

2.3.3 Impact assessment

The magnitude, spatial and temporal extent of direct and indirect impacts of a development on sensitive species should be predicted and supported by evidence. The impact assessment should provide information of the changes in density of a population and an account of displaced/disturbed or injured individuals. This stage should also consider cumulative and combined effects[2], as well as trans-boundary effects for migratory species.

Methodologies used in impact assessment should ideally be agreed with the Regulator if impact monitoring is a licence requirement. Methodologies should be well-documented and transparent to allow accurate analysis.

Examples of potential effects which OREDs may have on marine mammals include:

- Collision/Entrapment
- Disturbance as a result of acoustic or light output
- Pollution from accidental discharges
- Physical obstruction leading to barrier effect, including interruption of migration routes
- Electromagnetic field effects
- Behavioural disruption, including communication masking
- Displacement from preferred breeding and haul-out sites and feeding areas

2.4 Monitoring Strategies

Different approaches have been developed for the monitoring of marine mammals presence in relation to offshore renewable energy developments, varying from desk studies to visual observation and acoustic surveys.

Monitoring methodologies and strategies designed to understand the potential impact of OREDs on marine mammals are varied and serve different purpose according to the scope of the survey and the site characteristics. Detailed descriptions and further information on monitoring strategies that can be employed for marine mammals complementing this short review are available in further literature, details of which are found in section 8.

Table 2 presents an overview of the methodologies developed for monitoring marine mammals at the characterisation stage.

Table 3 presents an overview of the methodologies developed for monitoring marine mammals at the impact assessment stage.

Table 2 – Monitoring methods for *characterisation* of marine mammals close to OREDs.
º Applicable to monitoring basking sharks, ✓ Indicates methodologies for cetaceans and ◆methods for seals [10][11]

Primary assessment type	Monitoring Objective	Monitoring Method								
		Strandingsº	Vantage Pointº	Line Transectº	Towed Array	Autonomous Acoustic Monitoring	Photo ID	Telemetryº	Aerial surveys of haul outs	Boat counts of hauls
EPS licence, appropriate assessment and EIA	Species present	✓	✓◆	✓◆	✓	✓			◆	◆
	Density/abundance		✓	✓◆	✓	✓	✓◆		◆	◆
	Habitat use		✓	✓	✓		✓◆	✓◆		
AA only	Connectivity SAC						✓◆	✓◆		

Table 3 – Monitoring methods for *impact assessment* of marine mammals close to OREDs.
º Applicable to monitoring basking sharks, ✓ Indicates methodologies for cetaceans and ◆methods for seals [10][11]

Monitoring Objective	Monitoring Method							
	Vantage point	Video range	Boat based Line Transectº	Aerial line transect	Autonomous Acoustic Monitoring	Photo ID	Telemetryº	Stranding schemes
Species present	✓◆		✓◆	✓◆	✓	✓	◆	◆
Density/abundance	✓◆		✓◆	✓◆	✓	✓◆	✓	
Productivity	◆			◆				
Distribution	✓◆	✓	✓◆	✓◆	✓		✓◆	
Behaviour	◆	✓	◆				◆	
Injury/mortality		✓					◆	✓◆
Communication/ masking					✓			
Barrier effects	✓							
SAC connectivity						✓◆	✓◆	

Table 4 provides an overview of methodology and equipment required for the monitoring of marine mammals. The SNH monitoring guidelines [10], [11] provide detailed information on how to carry out monitoring programme as presented in Table 4. Further information on equipment is available in the annexes of the CEFAS guidelines [2].

Table 4 – Summary of methods available for the monitoring of OREDS on cetaceans. The methods employed will be dependent on the approach chosen for the specific site. *Sonar methods are still under development [10][11].

Method	Metric	Equipment required	Survey design	Suggested monitoring interval	Analysis of change
Vantage Point	-Presence/ absence -Distribution -Relative abundance -Habitat use -Vantage Point -Behaviour	-Binoculars/ telescope -Theodolite -Inclinometer -Video-range	-Suitable elevated vantage point -Visual observation - continuous scan -Even sampling of spatial and/or temporal factors influencing detection -May need to be calibrated with line transect visual surveys	-Seasonally and annually if natural variability is to be established -At-least one in each development phase	-Very wide range of metrics may be gathered so very dependent upon questions being asked and data being collected
Autonomous Acoustic Data loggers	-Presence/ absence	-AADL eg. CPOD -Batteries -Boat-winch -Moorings	-Gradient/BACI design	-Continuous (need regular servicing)	-Regression analyses
Line transect visual surveys	-Relative abundance -Density -Abudance	-Platform -Inclinometer (aerial) -Reticle binoculars (ship) -Angleboard (ship) -Data recording software and laptop	-Randomly located lines -Various layouts (zig-zag, parallel)	-Seasonally and annually if natural variability is to be established -At-least one in each development phase -Intensive surveying within short periods may be more appropriate than regular surveying over extensive periods or throughout the year	-Baseline: Distance -Sampling analyses -Statistical tests between point estimates eg. Z-test -Regression analyses
Photo-ID	-Presence/absence -Abundance -Connectivity	-Small manoeuvrable boat -Digital SLR & 200+mm autofocus lens -GPS -Note-taking materials	-None specific – but area covered must be sufficient to sample population in question	-Population estimates may require 2 days per month or more concerted effort during shorter periods. Question dependent.	-Matching & grading photographs -Matching across catalogues -Estimator for abundance e.g. Petersen
Carcass recovery	-Species present -Cause of death -Movement /behaviours -Time-energy budget	-Trained observers -Equipment for moving animals -Vets	-Established stranding network	-Dedicated monthly coastline surveys or before and after activities/ phases of key interest (e.g. construction?)	-Species composition over time -Cause of death over time in conjunction with development phases
Active Sonar * and Underwater Photography	-Approach distance to Devices (tidal turbines, WECs).	-In development	N/A	N/A	-Statistical analyses

	-Impacts -Behaviour				

Table 5 presents the methodologies developed at EU test centres and commercial deployment locations as acquired by the SOWFIA Project, specifically for EU wave energy projects.

Table 5 – Summary of the marine mammal survey data for each wave energy test centre [9]

Test centre	Monitoring requirements	Sampling stations and time period	Used methodologies
AMETS (Ireland)	Data collected to satisfy EIA	October 2009-September 2010	Seasonal vessel-based line transects, towed hydrophone surveys, static acoustics and monthly land-based observations
Galway Bay (Ireland)	-	-	Desktop review and collation of existing information on marine mammals that occur in the area
Aquamarine Power (Lewis, UK)	Not known	Not known but monitoring started in 2010	Visual observations, methodology unknown
EMEC (Orkney, Scotland, UK)	Required by Licensing Authority	July/August 2011 (Billia Croo)	Weekly surveys from onshore single vantage point using visual survey technique. MMO monitoring from jack up barge using visual survey technique following EMEC MMO protocol. Also boat-based underwater noise monitoring for cetacean impact
		Various across multiple sites	Boat-based marine mammal observations using a visual survey technique following the EMEC MMO protocol (agreed and approved by Regulator & Statutory Environmental Advisors)
		Vantage point visual survey March 2009 - present	Land based marine mammal observations based on Marine Scotland approved methodology
Pelamis Farr Point (Scotland, UK)	Monitoring required for EIA.	For future	Pre-scoping process included creation of a metadata catalogue of all known available data and information sources with respect to relevant environmental sensitivities within the proposed area. Surveys for marine mammals are required for the EIA (yet to be carried out).
Pentland Firth, UK	Currently just scoping project	Desk based study	Seal habitat use based on current data collected by SMRU (aerial & ground counts of hauled out seals and telemetry)
Wave Dragon (Wales, UK)	Acoustic monitoring required for EIA	N/A	Desk based study collating existing information on marine mammals. Acoustic marine mammal monitoring
Wave Hub (Cornwall, UK)	Applied and fundamental research by UoE	Monthly boat –based surveys August 2008 – present and continuing	Opportunistic sightings of marine mammals on boat-based point counts of birds at 9 points located in a grid over the Wave Hub, and 10 points in increasing distances away from the Wave Hub in an easterly and westerly direction. Also continuous acoustic data on marine mammal occurrence & behaviour for same time period.
	Data collected to satisfy EIA	-	Desk based study of Cornwall Wildlife Trust sightings database. Acoustic detection of cetaceans in vicinity of the Wave Hub (TPOD)
Sotenas (Sweden)	-	2012- present	Acoustic marine mammal monitoring only
Peniche (Portugal)	-	-	No known marine mammal monitoring carried out
Pico (Portugal)	-	May & September 2010	Acoustic marine mammal monitoring only.
Ocean Plug – Portuguese Pilot Zone (Portugal)	Data were collected to satisfy the geophysical and environmental characterisation of the site required in the legislation	2011	Boat based and aerial surveys
Reunion	Required by national, European and International law	January 2012-present	Acoustic marine mammal monitoring only.

Runde (Norway)	-	-	No known visual or acoustic data collection for marine mammals
SEM-REV (France)	-	-	No known visual or acoustic data collection for marine mammals

3 SEABIRDS

3.1 WHY MONITOR SEABIRDS

In 2009 the EU published The Council Directive on the Conservation of Wild Birds 2009/147/EC also known as Birds Directive which sets conservation goals for birds, and together with the Habitats directive it regulates protection of avian species [9]. This regulation directly affects offshore renewable energy developments in terms of licensing and monitoring requirements; in particular when the proposed development impact could overlap directly with Natura 2000 or Special Protection Areas (SPAs). In this case Habitats Regulation Appraisals (HRA) and Appropriate Assessment (AA) are required[21].

3.2 POTENTIAL IMPACTS

The extent to which a particular species could be affected by OREDs depends on the importance of the area to the species and their vulnerability to the construction and operation phase of the development. In particular, it is important to understand how the development could affect foraging, preening and breeding of seabirds as well as affect their abundance and distribution over time. Potential impacts due to OREDs are shown in Figure 2.

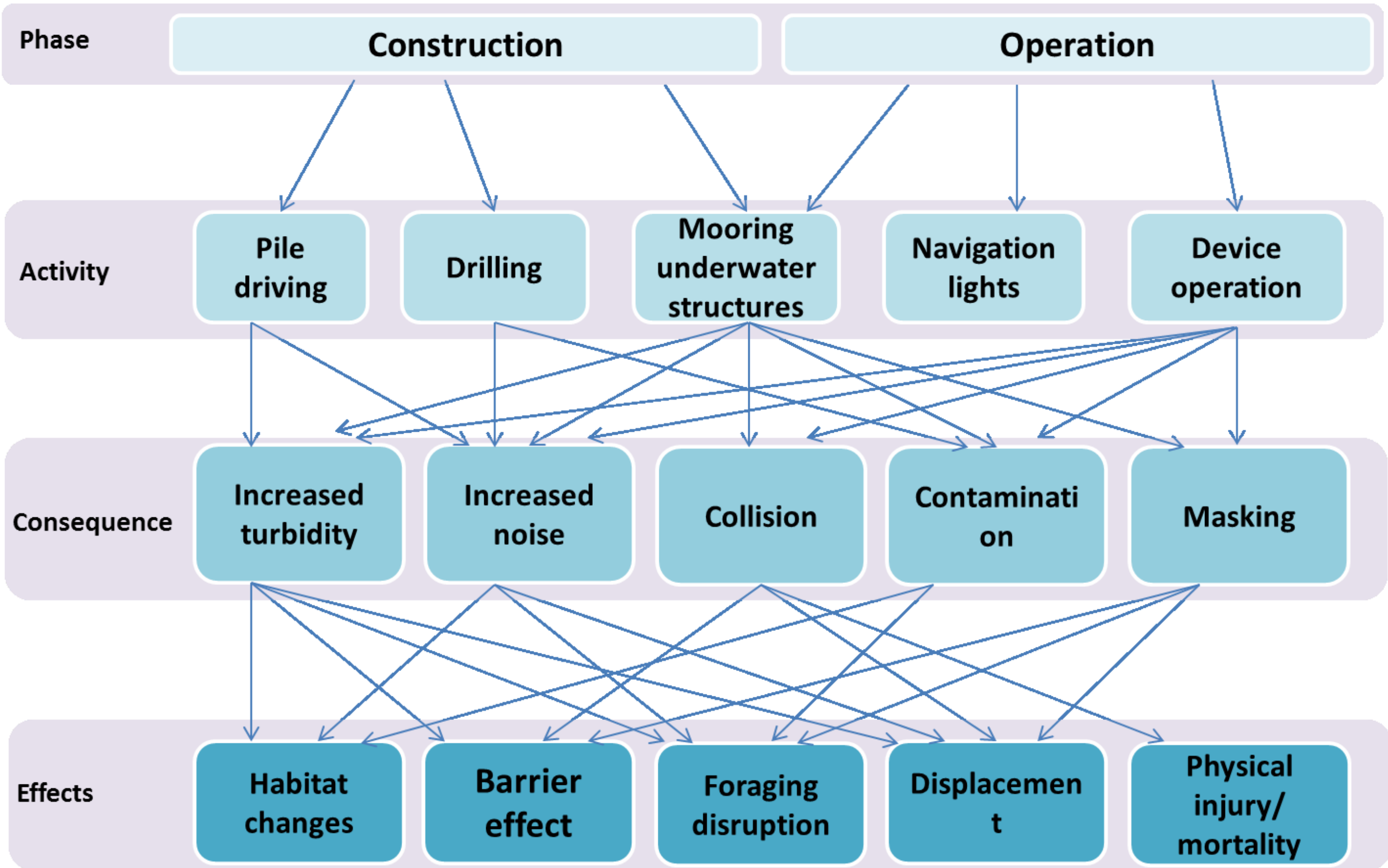

Figure 2 - Predicted impact pathways for OREDs on seabirds and avian fauna [21],[2]

3.3 Critical Stages

3.3.1 Baseline characterisation

The site characterisation phase for the monitoring of avian fauna is highly critical as it aims to identify important and sensitive species within and close to the area of the influence of the OREDs. This includes habitats, foraging grounds and migratory paths of relevance. A spatially extensive analysis is often required to obtain an exhaustive description of distribution and abundance of the species, and their seasonal spatial and temporal variation patterns [2]. Connectivity between birds present at the development site, Special Protection Areas (SPAs) and other designated sites will need to be considered.

The first phase of a baseline assessment is typically a desk-based study which includes consideration of:

- Species present
- Conservation Designations
- Nesting sites
- Breeding seasons
- Feeding areas
- Species usage of the water/air column
- Migratory routes
- Moulting areas
- Rafting/loafing areas.

The purpose of the desk-based study is largely to inform the requirements for further data collection and study.
A vital activity at this stage is engagement with Regulators, Agencies and other avian fauna experts to ascertain existing datasets that may be useful in characterisation of the impact footprint.

3.3.2 Environmental pressures

A description of the environmental pressures that are related to the OREDs is required to understand the possible impacts on the avian fauna. During operations the disturbance generated will be strongly dependent on the type of development, e.g. wind turbines will likely induce displacement risk and collision risk for migrating birds whilst tidal turbines have potential to affect foraging habitats for diving birds.

3.3.3 Impact assessment

This phase of monitoring should provide information with regards to the direct and indirect impacts predicted for a given development, in terms of temporal and spatial extent and magnitude. Assessment could be carried out on evidence or logic base related to identified environmental pressures and stress pathways. Cumulative impacts and trans-boundary effects should be considered and evaluated[22]. The types of impacts to assess include:

- Collision/Entrapment
- Disturbance as a result of emitted noise or light
- Pollution from accidental discharges
- Disturbance of breeding birds.
- Displacement from foraging areas
- Disturbance or displacement to moulting and rafting/loafing birds
- Creation of resting or breeding habitat

3.4 Monitoring Strategies

Different monitoring methodologies can be applied to the monitoring of avian species, including desk studies, aerial and boat surveys. Entities such as the joint Nature Conservation Committee (JNCC) in the UK provide training on the monitoring of seabirds. Generally baseline monitoring of avian fauna is undertaken for a minimum of two years. Boat surveys should be carried out at least once a month to ascertain spatial, temporal and seasonal variation of the species, whilst at least eight campaigns per year are required for aerial surveys as outlined in Table 6 [21].

Table 6 – Periods of the year for aerial marine bird survey.

Year Period	Description	Approximate dates
1	Mid-winter	January and February
2	Late winter	February and march
3	Early Breeding season	April to mid-May
4	Mid breeding season	Mid-May to mid-June
5	Late breeding season	Mid-June to end-July
6	Post breeding/moult	August to mid-September
7	autumn	Mid-September to October
8	Winter	November and December

Three general survey methods can be used for baseline characterization of birds at site: land based survey from a vantage point, boat-based transect and aerial-transect surveys. The choice of method employed often depends on the size of the development, as well as their distance from shore. Non-generic surveys have been developed in order to assess the behavioural response of particular species and to evaluate interconnectivity with breeding areas. Generic and non-generic methods developed for the baseline characterisation of birds colonies at a given site are presented in Table 7.

Table 7 – Monitoring methods for characterisation of avian fauna close to OREDs [2], [21].

Primary assessment type	Monitoring Objective	Monitoring methods					
		On land vantage	Boat Based Surveys	Aerial Surveys	Radar	Remote Tracking	Electronic tagging
EPS licence, appropriate assessment and EIA	Species present	<1.5 km	>1.5 km	>1.5 km			
	Density/abundance	<1.5 km	>1.5 km	>1.5 km			
	Habitat use	<1.5 km	>1.5 km	>1.5 km			
AA only	Connectivity				*	*	*

In general the same methods employed for baseline assessment of birds population, distribution and abundance at a given site are often also employed for monitoring the impacts due to construction and operation of the development. This insures that data is directly comparable and provides direct links between the renewable energy development and effects on avian fauna

Table 8 presents an overview of the methodologies developed for monitoring marine mammals at the impact assessment stage.

Table 8 – Monitoring methods for characterisation of avian fauna close to OREDs [21].

Method	Metric	Equipment required	Survey design	Suggested monitoring interval	Analysis of change
ESAS boat-based surveys transect	-Distribution, abundance and behaviour of seabirds. Seasonal changes.	-Survey vessel with suitable observation deck 5-25 m above sea level, binoculars, GPS unit, compass Note. 1. Binoculars are used to identify birds only and not to detect birds. 2. Vessel speed of 10 knots ideal (range 5-15 knots).	-Array of parallel transects, sampled approx. monthly through year, but according to needs.	-Variable. Annually at first, every 5 years after 3rd operating year.	-Visual and statistical comparisons of distribution and abundance.
Aerial transect surveys, direct observation method	-Distribution and abundance of seabirds. -Seasonal changes.	-Fixed wing light aircraft, binoculars, GPS unit, compass	-Array of parallel transects, sampled approx. monthly through year, but according to needs.	-Variable. Annually at first, every 5 years after 3rd operating year.	-Visual and statistical comparisons of distribution and abundance.
Aerial transect surveys, digital imaging method	-Distribution, abundance and behaviour of seabirds. -Seasonal changes	-Binoculars, spotting scope, compass, and equipment to measure distance/angle of declination.	-Various: snapshot scans, flying bird watches, focal bird watches, -Sampling approx. monthly through year, but according to needs.	-Variable. Annually at first, every 5 years after 3rd operating year.	-Visual and statistical comparisons of distribution and abundance.
Shore-based VP surveys	-Distribution, abundance and behaviour of seabirds. -Seasonal and interannual changes.	-Binoculars, spotting scope, compass, and equipment to measure distance/angle of declination.	-Various: snapshot scans, flying bird watches, focal bird watches, -Sampling approx. monthly through year, but according to needs.	-Variable. Annually at first, every 5 years after 3rd operating year.	-Visual and statistical comparisons of distribution and abundance.
Cliff-nesting raptors	-Breeding territory occupancy and productivity of eagles and peregrines.	-Binoculars & spotting scope	-Complete survey of areas of interest. -Usually 2-3 visits in breeding season (March-July).	-Annually.	-Comparison of occupancy and productivity rates.
Seabird colony counts	-Number of breeding seabirds.	-Binoculars & spotting scope. Digital camera. -Reference photos of colony geography	-Complete census of areas of interest. -Protocol varies with species. Usually based on one carefully timed visit. -Additional visit may be needed to measure productivity.	-Usually less than annually, depending on needs. 5-year interval likely to be appropriate.	-Comparison of numbers and productivity.
WeBS and NEWS type surveys	-Numbers of waders and waterbirds present along defined stretches of coast and inshore waters.	-Binoculars, spotting scope, GPS unit, field maps.	-Total counts of predefined stretches. -Usually monthly.	-Variable.	-Comparisons of distribution and abundance with time and regional/national trends.

Telemetry tagging of individual birds	-Data on ranging, site connectivity, barrier effects and foraging behaviour.	-Telemetry tags (many different designs) and tracking equipment. -Equipment to catch and handle birds.	-Tailored to project needs.	-Usually conducted as one-off study. -Repeating after an interval of several years could provide evidence of response to development infrastructure including with time habituation.	-Comparison of behaviour through time and in relation to proximity of development.
Radar	-Activity and travel routes of flying birds	-Specialist radar equipment	-Tailored to project needs.	-Usually conducted as one-off study. -Repeating after an interval of several years could provide evidence of habituation to development infrastructure.	-Comparison of behaviour preconstruction with post construction through time and in relation to proximity of development.
Collision monitoring	-Estimates of collision mortality.	-Protective gloves for handling dead birds.	-Systematic searches of depositional shores for corpses. -PM of corpses for evidence of trauma.	-Variable.	-Trends in numbers of dead birds found and attributed cause of death.

Table 9 presents the methodologies developed at EU test centres as acquired by the SOWFIA Project for EU wave energy projects [9].

Table 9 – Summary of the birds survey data for each wave energy test centre [9]

Test centre	Monitoring requirements	Sampling stations and time period	Used methodologies
Wave Hub (Cornwall, UK)	Applied and fundamental research by UNEXE	2008 – present	Near-monthly point counts conducted at 19 sampling stations stretching east-west across the Wave Hub development zone.
Wave Hub, (Cornwall, UK)	Data collected to satisfy EIA	2004 – 2005	300 m line transects to ascertain bird density by month (one year's survey effort).
EMEC (Orkney, Scotland, UK)	Required by Licensing Authority	2005 – present for tidal site 2009 – present for wave site (Billia Croo).	Multiple methods (site dependent) approved by Government regulator.
Ocean Plug – Portuguese Pilot Zone (Portugal)	Data were collected to satisfy the geophysical and environmental characterisation of the site required in the legislation	2004 – 2007 (data from Marine Important Bird Areas monitoring). 2010 – 2012 (data from Future of the Marine Atlantic Environment project) 2011- (data collected during the geophysical and environmental characterisation campaigns of the site)	Multiple methods used

Western & Northern Scotland	Applied and fundamental research. In fulfilment of MaREE	2011 – present	Visual surveys, tagging and tracking of individual birds
Runde (Norway)	Unknown	2009-2010	Unknown
AMETS (Ireland)	Data collected to satisfy EIA	2009-2010	Monthly land based visual methods for shore and open water bay habitats, for terrestrial habitats at the landfall site and on Inishglora Island (<3km from the AMETS) Monthly sea based surveys for area surrounding test site (~180km2) using the European Seabird at Sea standard method
Pentland-Orkney	Scoping data with respect to Scottish marine environment	Desk-based studies	Techniques review

4 BENTHIC HABITATS

4.1 WHY MONITOR BENTHOS

Benthos represent the living organism (animals and plants) living on the floor of the ocean and in inland bodies of water. Benthic species are classified as “macro”, “meio” and “micro” according to their size. Benthos life conditions are dependent on a series of factors such as sediment conditions, salinity and water depth. The benthos is normally divided into three functional groups, the infauna, the epibenthos and the hyper-benthos i.e. those organisms living within the substratum, on the surface of the substratum and just above it respectively [9].

Benthos and benthic habitats are protected under the Habitats directive, with important habitats listed in the Annex I of the directive. In Special Areas of Conservation (SACs), appropriate assessment may be required to understand impacts on benthos. EIA and national legislations and conditions for marine licensing require consideration of the impacts on benthic habitats. Comprehensive baseline characterisation of benthos is important in the understanding of changes and impacts caused by OREDs on mammals, seabirds foraging grounds and fish migration [2][23].

4.2 POTENTIAL IMPACTS

Possible effects of marine renewable energy developments on benthos are varied and to large extent still unknown. Structural installation and shifting of sediments may cause changes to the benthic communities or to individual species; particularly susceptible are non-mobile and suspension-feeding species. Furthermore, the construction of foundations and installation of mooring lines of OREDs effectively introduces hard substrata on the ocean floor attracting specific benthic species and causing changes in the habitat. Given the importance of the benthos on the marine ecosystem, the following should be considered in order to understand effects on benthic communities [14]:

- Spatial demands by sediment shifts → reduction of benthic association or of single species
- Introduction of hard-substrata, different hydrodynamics conditions→ changes in composition of species
- Presence of electric cables → rise in temperature and abundance of benthic communities.

In general most of the potential impacts associated with marine renewable energy development are likely to be similar to those associated in more mature industries (such as the oil and gas sector); however some impacts are specific to OREDs. Potential impacts on benthos and benthic habitats are summarised in Table 10 [2][23].

Table 10 – Predicted impacts for benthic communties due to construction and operation of OREDs [2][23].

Impact	Source	Phase			Device type				
		Construction	Operation	Decommissioning	Floating WEC	Sea based WEC	Tidal Turbine	Fixed Wind	Floating Wind
Direct loss of seabed area	Device footprint	✓	✓		✓	✓	✓	✓	✓
Contamination	Accidental spillage		✓	✓	✓	✓	✓	✓	✓
Smothering effects	Excavation, piling, dredging	✓	✓	✓		✓	✓	✓	✓
Scour/loss of substrate	Device structure	✓	✓	✓	✓	✓	✓	✓	✓
Introduction of not native/invasive species	Device transport and vessels from other areas	✓	✓	✓	✓	✓	✓	✓	✓
Vibration/noise	Piling, drilling, acoustic surveys	✓	✓	✓	✓	✓	✓	✓	✓

Impedance of current flow	Tidal turbine presence		✓				✓	✓	
Change in current regime	Tidal turbine presence		✓				✓		
Change in wave regimes	WEC wave shadowing		✓			✓			
Physical disturbance	Moorings, anchor lines, chains and construction debris	✓	✓	✓	✓	✓	✓	✓	✓

4.3 Critical Stages

4.3.1 Baseline characterisation

In this stage a broad-scale characterisation of the seabed environment of the development footprint is needed. This has to take into account spatial, temporal and seasonal variations. In this stage a single sampling station could be sufficient since the main purpose is to define the benthic habitats and their spatial extent. A suitable spatial frequency has to be applied.

4.3.2 Identification of environmental pressures

Different environmental pressure will be put on the benthic communities by different types of ORED. It is important to identify correlation between stressor and possible impacts, in particular the type of energy converter and how it is secured to the seabed. Monopiles for wind/tidal energy turbines may have different effects on benthic ecosystems compared to moored wave energy converters, due to the introduction of hard substrate in the environment.

4.3.3 Impact assessment

This stage of monitoring aims to determine the magnitude and extent of impacts on benthic communities. Impacts should take into consideration the role played by multiple parameters and should be support by evidence or by strong logical assumptions on the specific exposure pathways. Cumulative and combined impacts should be considered for EIA and SAC assessment.

The potential impacts that OREDs may have on benthic habitats include the following direct and indirect effects:

- Substratum / habitat loss / damage.
- Smothering.
- Scour around devices and other subsea infrastructure
- Increased suspended sediment and turbidity from installation of devices and other subsea infrastructure.
- Disturbance of contaminated sediments.
- Decrease in water flow and/or wave exposure.
- Pollution from routine and accidental discharges.
- Colonisation of subsea infrastructure.

4.4 Monitoring Strategies

A variety of methods have been developed for the baseline and impact monitoring of benthic habitats. Different methods can be applied and adapted to specific marine renewable energy technology based on the expected impact pathways. General methods for monitoring include: **acoustic surveys** aimed at identifying presence and strata of benthic communities; **grab and trawl methods**, designed to adequately sample the benthos near the development and analyse its composition and spatial dispersion; **remote visual observation**, species identification through the use of a Remote Operated Vehicle (ROV) [24]. **Targeted surveys** can be designed to identify single benthic communities, in order to understand the specific role of a given species within the habitat or when grabbing methods are not recommended due to the sensitivity of the environment.

An overview of methods is presented in Table 11.

Table 11 – Survey methods availbale for monitoing of benthic communities in the proximity of OREDs [2][23]

Methods	Metric	Equipment Required	Survey design	Monitoring interval	Analyses of changes
Acoustic survey	Substrate/ Habitat/ community distribution	AGDS, sidescan sonar Multibeam	Overlapping parallel tracks	One pre-installation then every 2-5 years	Visual comparison of seabed maps, GIS spatial analysis
Drop-down video/ photography	Distribution of habitats/ communities/ biotopes	Drop-down imaging system	Grid arrangement, Random sampling, stratified random sampling, transect sampling	One pre-installation then annually	Chi-square or Wilcoxon signed rank test comparison of biotope composition of site. Simple visual comparison of biotope frequency
	Presence of specified species Maintained presence of priority species at specific locations	Drop-down imaging system	Random sampling, stratified random sampling, transect sampling Directed visual sampling	One pre-installation then annually	Comparison of proportional occurrence Simple confirmation of presence
ROV video/ photography	Presence of specified species	ROV	As for drop-down video	As for drop-down video	As for drop-down video
Grab sampling	Species abundance per unit area Species richness Diversity indices	Van Veen grab Day grab Hamon grab	Grid arrangement, Random sampling, stratified random sampling, transect sampling	Annually, but at least two at pre-installation to establish natural variability	Analysis of Variance (ANOVA)
	Community composition	Van Veen grab Day grab Hamon grab	Grid arrangement, Random sampling, stratified random sampling, transect sampling	Annually, but at least two at pre-installation to establish natural variability	Ordination (MDS, PCA) ANOSIM
Diver core sampling	Species abundance per unit area Species richness Diversity indices	SCUBA, diver/deployed cores	Random sampling, stratified random sampling, transect sampling	Annually, but at least two at pre-installation to establish natural variability	ANOVA
	Community composition	SCUBA, diver/deployed cores	Grid arrangement, Random sampling, stratified random sampling, transect sampling		Ordination (MDS, PCA) ANOSIM
Diver video/ photography	Broad community character and substrate condition	SCUBA, underwater video or stills camera	Location directed	One pre-installation, then every 3-6 months (or synchronise with other diving tasks)	Simple visual comparisons
Diver transects (visual survey)	Semi-quantitative species abundance (MNCR Phase 2 surveys) Biotope presence and distribution	SCUBA (underwater video or stills camera optional)	Transects, stratified random sampling, directed 'spot dives'	One pre-installation, then a minimum of two per year	Direct comparison of community attributes (semi-quantitative abundance, biotope presence
Diver quadrats	Species abundance (individual abundance or %	SCUBA, quadrat	Replicated samples from plots arranged along transects	At least one pre-installation, then a minimum of two per	Ordination (MDS) ANOSIM, SIMPER

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	cover)			year	
	Species richness/ diversity	SCUBA, quadrat	Replicated samples from plots arranged along transects	At least one pre-installation, then a minimum of two per year	ANOVA
	Abundance of selected conspicuous species	SCUBA, quadrat	Replicated samples from plots arranged along transects	At least one pre-installation, then a minimum of two per year	ANOVA
Intertidal survey	Presence and spatial distribution of intertidal communities/ biotopes Beach profiles	Tape measure/ transect line	Vertical shore transect	One pre-installation survey then annually	Simple comparison of spatial arrangement of biological zonation relative to tidal height
	Selected species abundance	Tape measure/ transect line and, quadrats	Replicate quadrats within selected zones	One pre-installation survey then annually	ANOVA
	Maintained presence of priority species at specific locations	GPS	Visual location and repeated observation	One pre-installation survey then annually	Simple confirmation of maintained presence (may require additional information on condition.

The SOWFIA project compiled a catalogue of benthic monitoring activities undertaken at EU wave energy test centre; these are presented in Table 12.

Table 12 – Summary of the benthos survey data for each wave energy test centre [9]

Test centre	Monitoring requirements	Sampling stations and time period	Used methodologies and results
AMETS	Required under EIA	Twenty five stations were sampled in July and November 2010 at the two test site areas and along the cable route.	Four grab samples were taken at each station, one of them was used for particle size analysis and organic content and three were preserved for macrofaunal identification, using standard procedures (NMBAQC) Sediments were classified as infralittoral or circalittoral fine sands.
	Survey was part of survey of Ireland's seabed area, data was used in EIA.	All test centre area	Bathymetric survey undertaken in 2008 by Marine Institute and supplementary shallow water surveys conducted by IMAR survey in 2009
	Required under EIA	The two test site areas, the cable route and a buffer zone either side of the cable route.	Dropdown video survey and dive surveys. The video imagery was reviewed to assess the habitats and biotopes present. All species observed were recorded and an estimate was made of their abundance on a DAFOR scale
Bimep	Benthic characterisation has been made under the required EIA. Data on benthic communities were collected	Three stations on intertidal hard substrate were sampled in March 2008 Eight subtidal stations (4 on soft-bottom substrate and 4 on hard-bottom substrate) were sampled in April 2008 The sampled areas correspond to the two cable route alternatives	Desk based study using literature published on the subject for the or nearby the deployment area The replicates of 0,0625m2 and 0,15m depth were taken for each station. Replicates were sieved and preserved for the species identification and quantification Transects were filmed to complement sample collection data Community structural parameters have been determined through the application of diversity indices
EMEC		Monitoring of berths and deployment locations.	ROV surveys: Pre- and post- installation and post-decommissioning surveys. ROV footage, still photographs and reports.
Ocean Plug	A geophysical and environmental characterisation report is required; however no data on benthic communities have been collected. Shape files on the composition of superficial seabed sediments are available.		
SEM-REV	Benthic characterisation has been made under the	Six stations were sampled along the cable route and deployment area in June 2009	Samples were collected with grabs from a ship equipped with a crane and a winch. Two replicates of 0,25m2 were collected for each station

	required EIA. Data on benthic communities were collected		The sediments composition was characterised: dominant particle size in each station. Characterisation of species composition and abundance of infauna (organisms living within the substratum) and epibenthos (organisms living on the surface of the substratum)
Wave Hub	Benthic classification and biodiversity assessment.	Two sites each at the North, Centre and South of the station were surveyed during November 2010 and January 2011.	Baited remote underwater videos (BRUVs) were deployed at each site for a bottom recording time of 1hr 20 mins to 1hr 30 mins. For each camera drop, benthic composition was categorised using EUNIS classification. Sessile species were identified. Mobile species were identified and counted with time when first appearing in the footage being recorded.

5 FISH

5.1 WHY MONITOR FISH

Fish are protected under the EU Habitats Directive (92/43/EEC) which lists both coastal and halophytic habitats in *Annex I* and *II*. The construction and the operation of OREDs could affect fish fauna and cause changes in abundance/distribution of the ichthyic fauna. Changes in fish abundance will also impact surrounding fishing activities and play an indirect role on the distribution of birds and marine mammals that prey on fish.

5.2 POTENTIAL IMPACTS

An overview of the impacts that OREDs could cause on the fish fauna are presented in the Fig. 3. Impacts may be specific to a particular technology whilst others, such EMF effects, may be found across a wide spectrum of technologies.

Besides possible negative effects, OREDs could generate positive effects on fish abundance. OREDs are likely to act as Fish Aggregating Devices (FAD) or Artificial Reefs (ARs) [26], whilst the development of no take zones within the OREDs boundaries allow for the replenishment of fish stock. Reduction of fishing grounds will also have potential economic effects on local communities that are economically reliant on fishing [13]. In the UK, fisheries liaison officers have been established to facilitate interaction between fisheries representatives and OREDs developers.

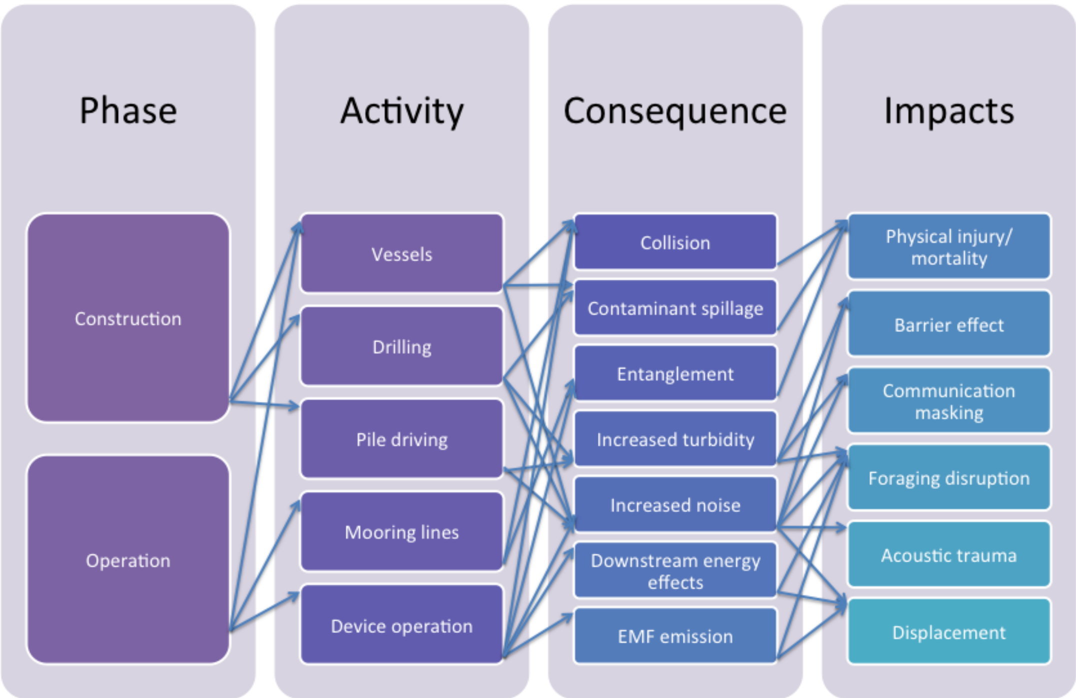

Fig.3 Impacts of OREDs on ichthyic fauna

5.3 Critical Monitoring Stages

5.3.1 Site characterization:

A broad scale description of fish distribution, abundance and ecology within and around the expected zone of influence is required at this stage. [27]
The characterization of the area should include:

- Identification of important and/or sensitive species or habitats
- Social and economic distribution and importance of commercial fisheries
- Identification of migratory species and routes
- Identification of possible spawning and nursery grounds
- Seasonal, temporal and spatial considerations

5.3.2 Environmental pressures:

Environmental pressures such as collision with OREDs structures and acoustic pressure generated by pile driving could cause injury, displacement and increased mortality rate within the fish population [28], [29]. Electromagnetic fields (EMFs) could cause displacement, reduction of reproduction and interruption of migratory routes, which may be significant to fish species. The US Department of Energy and Marine Scotland are undertaking a variety of lab studies to understand how species are affected by EMFs.

5.3.3 Impact assessment:

At this stage impacts should be characterized in term of: magnitude, extent, duration, temporal scale. Cumulative and trans-boundary effects should be assessed and confidence in predictions estimated. Assessment should be carried out on an evidence or logic base related to identified environmental pressures and stress pathways, in order to provide information of the changes in population density. Potential impacts on fish include:

- Physical habitat modification
- Acoustic trauma
- Displacement
- Collision/Entrapment

5.4 Monitoring Strategies

Monitoring methodologies and strategies designed to understand the potential impact of OREDs on marine fishes are varied and differ according to the aim of the survey and the site characteristics. Methods which can be applied to fish monitoring include [30]:

- Desk studies
- Commercial techniques (pots, trawls, fixed nets, lines etc)
- Underwater video and stills photography
- Grabs
- Acoustic Ground Definition System
- ‘Scientific’ echo-sounder
- Sidescan sonar
- Landings data
- Effort data

- Fisheries liaison
- Socio-economic evaluations

An overview of fishing monitoring activities in relation to OREDs, specifically those methods employed at Wave Hub [31], is presented in Table 13. Azti Tecnalia have recently begun assessment of fish population at the BIMEP wave energy site; details, however, are currently only available in Spanish.

Table 13 Monitoring methodologies for fish movement around OREDs [31]

Method	Metric	Equipment required	Survey design	Suggested monitoring interval	Analysis of change
Passive acoustic tracking	Habitat use Behaviour	Acoustic transmitting tags Underwater acoustic modem aboard a boat	At the site, 2m high seabed landers carry data-logging acoustic receivers. Suitable number (hundreds) of fish tagged with acoustic transmitters	Continuous Data uploaded remotely every few months	Fish behaviour over large spatio-temporal scales (departures, arrivals and occupancy times)
HD wide angle cameras	Presence/ absence Diversity Abundance	HD wide-angle cameras	Cameras deployed upon seabed and midwater column located along the interested zone	Continuous	Census of mobile species diversity and abundance

6 CONCLUDING REMARKS

This document presents a short review and overview of monitoring protocols developed and employed for surveying species and habitats in relation to offshore renewable energy developments. The main outcomes of this will be taken forward into D4.7 (Best practice report on environmental monitoring and new study techniques).

The document summarises the design phase of the monitoring process as well as providing a quick overview for key environmental descriptors (mammals, seabirds and benthic communities) which are protected under EU and national regulation. It is expected that the monitoring protocols described in this document will be improved with the growth of offshore renewable energy technology and through monitoring technology improvements, allowing for more specific and less intrusive monitoring programmes.

7 FURTHER INFORMATION

7.1 FURTHER INFORMATION ON MARINE MAMMAL MONITORING STRATEGIES

Reviews of studies carried on marine mammals, especially in relation to offshore wind farms related impacts can be found from various sources, such as experiences of environmental monitoring in the Danish Energy Authority [12], COWRIE [13] and German Government [14]. Detailed information on monitoring activities for the impacts on marine mammals due to the presence of tidal stream turbine can be found in Keenan et al., [15]; whilst issues and knowledge gaps related to monitoring activities have been discussed in depth in the Annex IV report [16]. Further literature is available on marine mammals monitoring and impacts, as discussed in [17–20].

Further information can also be found on the following websites.

- Draft list of Priority Marine Features for Scottish territorial waters, available:
    - www.snh.gov.uk/docs/B639755.pdf
    - www.snh.org.uk/pdfs/publications/naturallyscottish/whales.pdf
- Reid et al. (2003) Atlas of Cetacean distribution in north-west European waters:
    - jncc.defra.gov.uk/page-2713#download
- SCANS-II Final Report:
    - biology.st-andrews.ac.uk/scans2/inner-contact.html
- Joint Cetacean Protocol:
    - jncc.defra.gov.uk/page-5657
- North Atlantic Killer whales:
    - www.northatlantickillerwhales.com
- Minke whales:
    - www.crru.org.uk/minke.asp
- Bottlenose dolphins in Scottish waters:
    - www.snh.gov.uk/publications-data-and-research/publications/search-the-catalogue/publication-detail/?id=1727
- Basking sharks:
    - www.snh.org.uk/pdfs/publications/commissioned_reports/339.pdf
- Basking Shark factsheet:
    - www.baskingsharks.org/content.asp?did=26603&rootid=6224
- Special Committee on Seals (SCOS):
    - www.smru.st-andrews.ac.uk/pageset.aspx?psr=411
- Annual SMRU advice to SCOS:
    - www.smru.standrews.ac.uk/pageset.aspx?psr=411
- Grey Seal Report, McConnell et al, 2009:
    - www.offshoresea.org.uk/consultations/Offshore_Energy_SEA/OES_GreySeal_report.pdf
- Utilisation of space by grey and harbour seals in the Pentland Firth and Orkney waters, SMRU Ltd, 2010:
    - www.snh.org.uk/pdfs/publications/commissioned_reports/441.pdf
- SNH sitelink website; a source of information about seal populations at designated sites:
    - gateway.snh.gov.uk/portal/page?_pageid=53,910284,53_920288&_dad=portal&_schema=PORTAL
- Marine Spatial Plans and Regional Locational Guidance where available may have information on seal populations in specific areas e.g. :
    - www.scotland.gov.uk/Resource/Doc/295194/0105824.pdf
    - www.scotland.gov.uk/Resource/Doc/295194/0096885.pdf
- Marine Renewables SEA sections dealing with marine mammals and noise:
    - www.seaenergyscotland.net/public_docs/ER_C9_MarineMammals_final.pdf
    - www.seaenergyscotland.net/public_docs/ER_C17_Noise_final.pdf

- The Dept of Energy and Climate Change offshore SEAs:
    - www.offshore-sea.org.uk/site/
- Information on aerial surveys using a Piper Aztec PA-27:
    - www.gilesaviation.com/index.html
- Examples of Telemetry devices can be found at:
    - www.smru.standrews.ac.uk/Instrumentation/pageset.aspx?psr=339
    - www.wildlifecomputers.com/Products.aspx?ID=-1
    - www.jncc.gov.uk/protectedsites/sacselection/species.asp?FeatureIntCode=S1365
- Information on the estimation and modelling processes used by SCOS is available from:
    - www.smru.st-and.ac.uk/documents/341.pdf
- Details of the methods used to survey harbour seals are found in Duck & Thompson, 2009:
    - www.smru.st-and.ac.uk/documents/341.pdf

7.2 Further information on seabird monitoring strategies

Similar to marine mammals, information on the possible impacts of OREDs on seabirds has been primarily collected through offshore wind energy programmes [12], [13], [14]. Detailed description of protocols can be found in [21], [17], [20].

Websites providing further information on seabirds are available at the following links:

- jncc.defra.gov.uk/pdf/Camphuysenetal2004_COWRIEmethods.PDF
- www.offshorewindfarms.co.uk/Pages/Publications/Archive/Birds/Developing_Guidance_o%20n8ec95352/
- www.jncc.gov.uk/page-4514
- seamap.env.duke.edu/

7.3 Further Information on Benthos Monitoring

Information on benthos monitoring in the proximity of OREDs is available in reviews [12], [13], [14]; detailed monitoring information can be found in [23] and benthic community monitoring can be found in [25].

Websites providing further information on benthic species are available at the following links:

- www.marlin.ac.uk/speciesinformation.php?speciesID=4043
- www.jncc.gov.uk/pdf/mmh-pg%203-1.pdf
- www.marlin.ac.uk/speciesfullreview.php?speciesID=2582
- www.seageneration.co.uk/downloads/SeaGen%20biannual%20report%20April%202010.PDF
- www.jncc.gov.uk/PDF/MMH-Pg%203-13.pdf
- www.nmbaqcs.org/media/9295/nmbaqc%20epibiota%20questionnaire%20review_june%202010.pdf
- gateway.snh.gov.uk/sitelink/

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