EMEC Fall of Warness Test Site: Environmental Appraisal

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EMEC ORKNEY
THE EUROPEAN MARINE ENERGY CENTRE LTD

Contents

Revision History

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Glossary of Terms

AA	Appropriate Assessment
ADCP	Acoustic Doppler Current Profiler
AIS	Automatic Identification System
ASCOBANS	Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas
BERR	UK Department for Business, Enterprise, and Regulatory Reform
BGS	British Geological Survey
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CMS	Construction Method Statement
CPA	Coast Protection Act 1949
DART	Drifting Acoustic Recorder and Tracker
DECC	Department of Energy and Climate Change
DP Vessel	Dynamic Positioning Vessel
EIA	Environmental Impact Assessment
EMEC	European Marine Energy Centre Ltd.
EMF	Electromagnetic Field
EPS	European Protected Species
ES	Environmental Statement
FEAST	Feature Activity Sensitivity Tool
FEPA	Food and Environment Protection Act 1985
FLOWBEC	Flow and Benthic Ecology 4D
GPS	Global Positioning System
GSM	Global System for Mobile communications
HRA	Habitats Regulations Appraisal
IALA	International Association of Lighthouse Authorities
IMS	Integrated Management System
JNCC	Joint Nature Conservation Committee
LSE	Likely Significant Effect
MAG	EMEC Monitoring Advisory Group
MarLIN	Marine Life Information Network
MCA	Maritime and Coastguard Agency
MECS	Marine Energy Convertor Systems
MGN	Marine Guidance Notice
MLWS	Mean Low Water Springs
MMO	Marine Mammal Observer
MNNS	Marine Non-native Species
MSFD	Marine Strategic Framework Directive
MS-LOT	Marine Scotland Licensing Operations Team
NRA	Navigational Risk Assessment
O&M	Operation and Maintenance
OIC	Orkney Islands Council
OWEZ	Offshore wind farm Egmond aan Zee
PBR	Potential Biological Removal
PCoD	Population Consequences of Disturbance
PEMP	Project-specific Environmental Monitoring Programme
PFOW	Pentland Firth and Orkney Waters
PMF	Priority Marine Features

PTS	Permanent Threshold Shift
RMS	Root Mean Square
ROV	Remotely Operated Vehicle
SAC	Special Areas of Conservation
SCANS II	Small Cetaceans in the European Atlantic and North Sea
Section 36	Section 36 Consent Under the Electricity Act 1989
SEPA	Scottish Environmental Protection Agency
SIMOPS	Simultaneous Operations
SMRU	Marine mammal Research Unit
SMWWC	Scottish Marine Wildlife Watching Code
SNH	Scottish Natural Heritage
SOP	Standard Operating Procedure
SPA	Special Protection Areas
SSSI	Site of Special Scientific Interest
TPV	Third Party Verification
TTS	Temporary Threshold Shift
UK BAP	UK Biodiversity Action Plan
UKAS	United Kingdom Accreditation Service
VMP	Vessel Management Plan
WANE	Wildlife and Natural Environment (Scotland) Act 2011
WCA	Wildlife and Countryside Act 1981

1 Introduction

In 2005, to support its application for the development of a test site at the Fall of Warness, Eday, the European Marine Energy Centre (EMEC) commissioned an Environmental Impact Assessment (EIA), including the production of an Environmental Statement (Foubister, 2005). The Food and Environment Protection Act 1985 (FEPA) and Coast Protection Act 1949 (CPA) licences and other consents as detailed in Table 1 below established the principle for the presence of the test site, but did not cover the deployment of individual tidal devices by developers. Consequently, each developer wishing to deploy their device(s) at the test site must apply to the Regulator (Marine Scotland) for a Marine Licence[1] (and Section 36 consent under the Electricity Act 1989, where total nominal rating of the device is greater than 1MW (Section 36)). In doing so, each developer must provide appropriate supporting information to assess the risk of impact of deploying, operating and decommissioning their device(s) on key natural heritage features and other topics, such as safety and navigation.

	EMEC	Developers
Previous and existing consents	3 CPAs (for the 7 cables) and 1 FEPA for the installation of cable protectors – all have expired. Planning permission for onshore facilities. Marine Licence for the deployment of scientific instrumentation.	Various CPA/FEPA/Marine Licence held by individual developers for device deployments. Includes a temporary cable (#8).
TCE seabed lease	15 year lease from Nov 2007. Expires 2022.	N/A.
Embedded Generation Connection Agreement	Limits total export capacity to 4MW. Expires November 2031.	N/A.
Existing appraisals	(Non statutory) EIA with ES produced in 2005 to support EMEC's CPA/FEPA applications. Assesses broad scale generic impacts from presence of test site. Device specific impacts not considered.	Appraisals to support individual developer CPA/FEPA and Marine Licence applications. Each focuses on individual device specific impacts.

Table 1: Summary of consents and licenses for the Fall of Warness test site – June 2013.

Prior to this Environmental Appraisal document and the associated process becoming current, all applications for individual deployments have required case-by-case appraisal by

[1] The principle of the Marine Licence was established under the Marine (Scotland) Act 2010, Part 4, Sections 20 to 64

Marine Scotland, and consultation with Scottish Natural Heritage (SNH) and other consultees. For this purpose, all of the documentation produced by EMEC for the original FEPA application in 2005 (e.g. the Environmental Statement (ES) and subsequent updated Environmental Description) has been made available to each developer to support their individual licence applications.

The Scottish Government's commitment to the capturing of wave and tidal resources through the Pentland Firth and Orkney Waters (PFOW) and Saltire Prize leasing rounds mean that resource demands on Marine Scotland and SNH are increasingly being directed to the assessment of commercial lease sites. Consequently, steps were taken to look at streamlining the appraisal required to inform the Marine Licence/Section 36 consenting process for deployments at EMEC. This, together with a requirement to review and update the EMEC site environmental documentation in order to incorporate findings from wildlife observation data collected at the site since June 2005, has led to the production of this Environmental Appraisal document.

Through funding received from the Scottish Government, EMEC has undertaken a programme of land-based vantage point surface wildlife observations at its test sites. Observations commenced at the Fall of Warness test site in July 2005 and are currently scheduled to end in March 2015. Data collected by this observation programme has been used to inform the appraisals described in Section 4, and the raw data is available to download in Microsoft Excel format from the Marine Scotland Interactive website[2].

This document aims to pre-appraise potential deployments within the context of the wider test site. The principles for this work are described below. Broadly, however, the appraisals provided in Section 4 of this document support detailed consideration of potential natural heritage impacts to inform the consenting process for deployment and operation of tidal device(s) at the Fall of Warness. The documentation also aims to support the development of mitigation, monitoring and research strategies to facilitate developers at this site, and the wider industry, through an improved knowledge base that supports their commercial aspirations.

The appraisals described in Section 4 of this document and in the subsequent Appropriate Assessment (AA) undertaken by Marine Scotland (available at http://www.scotland.gov.uk/Topics/marine/Licensing/marine/scoping/emec) constitute a Habitats Regulations Appraisal (HRA) to support any application for a Marine Licence or Section 36 consent for deployment at any of the berths in the Fall of Warness up until 2022. Where the project fits within the agreed 'project envelope' (see Section 2 & Annex 1 of this document) no further appraisal by Marine Scotland will be required. Where a project falls outside the agreed project envelope the developer may be required to provide further information to support any additional environmental appraisal and ensuing AA that may be required.

1.1 Principles of the Appraisal

The documentation that follows aims to facilitate the consenting process by reviewing *most* environmental information and providing an appraisal to inform developer licence

[2] http://www.scotland.gov.uk/Topics/marine/science/MSInteractive/Themes/EMEC-Wildlife/Fall-of-Warness

applications for the deployment of tidal devices for testing at the Fall of Warness. It is important to note that this exercise has explicitly excluded the following:

- Onshore (including intertidal) ancillary developments and infrastructure are not addressed in these appraisals (including the landfall of cables). Any such proposals require consultation under the Town and Country Planning (Scotland) Act 1997.
- This documentation does not seek to review or appraise any of the other aspects that require consideration for device deployment, such as navigational safety.
- This documentation does not appraise decommissioning which will be dealt with separately through the requirements set out by the Department of Energy and Climate Change (DECC).

These appraisals will not remove the requirement for each developer to apply for and be granted an individual Marine Licence (and Section 36 consent if applicable), but it will help inform the assessment process required to support these applications. For applications that require EIA (mostly projects requiring Section 36 consent), the appraisals within Section 4 may form a major component of the ES. These detailed environmental appraisals are delivered according to a defined ‘project envelope’ approach for the test site (see Section 2 & Annex 1 of this document). This project envelope describes the types and characteristics of Marine Energy Convertor Systems (MECS) likely to be deployed for testing at the EMEC grid-connected test site at the Fall of Warness. It also describes the types of marine operations and activities likely to be associated with the installation, operation and maintenance of these devices. Comprehensive environmental appraisals are provided, including aspects to satisfy the legal requirements of legislation relating to designated sites and protected species.

Where the details of any proposed project fall within the defined project envelope (as determined by Marine Scotland), such projects will be considered pre-appraised and therefore are unlikely to require further consultation with SNH in relation to determining potential impacts of the proposal. Where projects are deemed to not fit within the project envelope, additional appraisal will be required by the applicant (to be determined by Marine Scotland after further consultation).

However, as detailed within the appraisals, even when within the EMEC project envelope there are some activity-receptor combinations where pre-appraisal is not possible and additional case-by-case appraisal and consultation is relevant. Such activity-receptor combinations are as follows:

- Use of vessels with ducted propellers – potential physical interaction with seals leading to corkscrew injuries or death
- Use of active acoustic equipment – underwater noise that may lead to disturbance of seals or cetaceans
- Cable installation and associated vessel activity – may lead to disturbance, injury or death of otters

Furthermore, any substantive change in environmental parameters at the site, or in knowledge regarding potential impacts, may result in the need for further appraisal or an update to these documents. Indeed, these appraisals are live documentation and, as such, subject to periodic review and update. This should include review of the appraisals according to regular updates on information pertaining to the population status of various species, whether at the scale or designated sites, regional populations or management units. This is particularly relevant for impacts that may result in fatalities to wildlife, and where these impacts have been appraised against the context of these populations.

Developers should refer to the document *Guidance for Developers at the EMEC Fall of Warness Test Site: Consenting Process* (available to download from the EMEC website) to understand the details that they are required to submit to support their Marine Licence/Section 36 consent applications. This document contains a list of information requirements to ensure that the project parameters described are addressed. Developers can then use the appraisals described in Section 4 of this document to develop a Project-specific Environmental Monitoring Programme (PEMP), which should be formally agreed with Marine Scotland prior to the commencement of any works. Marine Scotland and SNH strongly recommend that the developer liaises closely with EMEC throughout the whole process, pre and post submission of any licence application.

Marine Scotland will consult SNH and other consultees as necessary upon the development and agreement of the PEMP. A first draft should be submitted with the Marine Licence application, but the process is likely to be an iterative one. Development of the PEMP should aim to:

- Identify and support delivery of mitigation necessary for ensuring that residual impacts are reduced to an acceptable level.
- Identify and support delivery of mitigation and monitoring that demonstrate best practice in management of environmental impacts at development sites.
- Increase understanding of environmental impacts and how to monitor and analyse them, to the benefit of individual developers and the wider industry in relation to commercial up-scaling and deployment.
- Provide opportunities for developers, with support from EMEC, SNH and Marine Scotland, to seek innovative solutions for mitigating impacts or for understanding the importance of interactions between their developments and the environment.

The EMEC Monitoring Advisory Group (MAG) has a role in maintaining an overview the outputs from all developer PEMPs and distilling the results to assess the requirements for and appropriateness of continued ongoing environmental monitoring at the FoW, for both EMEC and individual developers.

1.2 Key Reference Materials

Reference lists are provided within each of the receptor-specific appraisals. However, key materials that developers and their consultants should be familiar with for background information are listed below.

- Draft Marine Renewables Licensing Manual

  http://www.scotland.gov.uk/Topics/marine/Licensing/marine/LicensingManual
- A Guide to Marine Licensing

  http://www.scotland.gov.uk/Topics/marine/Licensing/marine/general
- Marine Scotland Interactive website

  http://www.scotland.gov.uk/Topics/marine/science/MSInteractive
- Marine Scotland Impact Assessment Tool for Marine Energy Developments

  http://www.scotland.gov.uk/Topics/marine/Licensing/marine/tool

- EMEC Fall of Warness Environmental Statement 2005 (available to download from http://www.emec.org.uk/services/consents/)
- EMEC Environmental Description for the Fall of Warness (available to download from http://www.emec.org.uk/services/consents/)
- EMEC Project Envelope for the Fall of Warness Test site (Annex 1)
- Guidance For Developers at the EMEC Fall of Warness Test Site: Consenting Process (available to download from http://www.emec.org.uk/services/consents/)
- Draft Guidance on Survey and Monitoring in Relation to Marine Renewables Deployments in Scotland (http://www.snh.gov.uk/docs/B925810.pdf)
- SNH SiteLink: http://gateway.snh.gov.uk/sitelink/index.jsp
- Scottish Government 2007 Strategic Environmental Appraisal for wave and tidal power http://www.scotland.gov.uk/Publications/2007/03/seawave
- Habitats Regulations 1994 (see Annex 2)
- Robbins (2011a): Analysis of bird and marine mammal data from Fall of Warness EMEC wildlife observations (2005-2010) http://www.scotland.gov.uk/Topics/marine/marineenergy/Research/snhwarness
- Other EMEC downloads: http://www.emec.org.uk/about-us/media-centre/downloads/

2 EMEC Fall of Warness Project Envelope

EMEC provides grid connected testing facilities at the Fall of Warness to enable developers of tidal stream MECS to deploy and test their devices in real-sea conditions. Testing is normally of entire devices with associated moorings, but may include components of devices or initial mooring tests. Each developer wishing to test at EMEC is required to apply for and obtain a Marine Licence (and Section 36 consent if the total nominal rating of the device is greater than 1 MW), from the Regulator, Marine Scotland. To date, EMEC has been granted licences/consents to establish the test site infrastructure and deploy scientific monitoring equipment, and several developers have been granted consent to deploy devices.

The full project envelope description is provided as Annex 1 of this document. This describes the types and characteristics of MECS likely to be deployed for testing at the Fall of Warness site at the time of writing. It also describes the types of marine operations and activities likely to be associated with the installation, operation and maintenance of these devices. This information provides a 'project envelope' description against which the potential environmental impacts of installation, operation and maintenance of MECS are subsequently appraised

3 Approach to the Environmental Appraisals

The appraisals that follow (Section 4) assess the environmental impacts during the installation, operation and maintenance phases of devices and infrastructure testing at the Fall of Warness test site. These appraisals are specifically focussed on the parameters outlined in the *project envelope* described in Annex 1 of this document. The appraisals account for all installations to date plus those that may be applied for in the lifetime of the current seabed lease (expires 2022). Through this process, it is considered that any application for a Marine Licence or Section 36 consent for deployment at any of the 7+1 (or future 9th) berths in the Fall of Warness up to 2022 may be regarded as pre-appraised in terms of its environmental impacts, *provided* the details of the application are within the parameters set out in the project envelope. Deviation from this envelope will necessitate additional appraisal and consultation. Further advice as to whether an application will necessitate additional appraisal and therefore consultation will be provided by EMEC in the first instance, but confirmation should be sought from Marine Scotland. **Marine Scotland and SNH strongly recommend that the developer liaises closely with EMEC throughout the whole consenting process, pre and post submission of any licence application**.

Declining population levels of Harbour Seal, in Orkney and Eastern Scotland, are also likely to result in increasingly lower Potential Biological Removal (PBR) rates for the region as a whole. Predicted additional fatalities for this species in relation to collision with operational turbines should, therefore, also be reviewed annually against the most up to date PBR rates at the time of application, and the appropriate licensing decision made accordingly.

In Section 4 below, each receptor-type has a separate appraisal. A number of steps have been taken to ensure the range of potential impacts and receptors appraised is comprehensive and follows a logical iterative process. The outcome of Step 1 is common to all appraisals and is shown below. Steps 2 and 3, which are also described below, have outputs specific to each receptor and are shown in those appraisals accordingly. Figure 1 below provides a graphical summary of the whole process.

Step 1 sets out the definitions and categories of potential effects to be considered in subsequent steps. These categories are applied to all receptor types, being used to identify which activities/effects require detailed appraisal, and are shown in Table 2 below. Where impact mechanisms are poorly understood, there is a preference at this stage for precautionary categorisation of ‘potentially important’. Consequently, that category not only addresses issues for which the importance is dependent on particular details of the proposal or site, but also those issues for which there is currently insufficient understanding of the potential impact mechanism.

Potential importance of effect	Effects (positive and/or negative)	Further assessment required?
Important	- Likely Significant Effect on European site(s); - Impact on European Protected Species; - Visual impacts upon the landscape/seascape and the special qualities of a National Scenic Area; - Impact on the integrity of a Site of Special Scientific Interest (SSSI) or damage to natural features of a SSSI; Impacts on the protected features of a Marine Protected Area (MPA); - Impacts on a Priority Marine Feature (PMF); - Impacts on other sensitive natural heritage features at a population/habitat scale of concern.	Yes.
Potentially important	- Potential Likely Significant Effect on European site(s); - Potential impact on European Protected Species; - Visual impacts upon the landscape/seascape and the special qualities of a National Scenic Area; - Potential impact on the integrity of a SSSI or damage to natural features of a SSSI); - Potential impacts on the protected features of a MPA; - Potential impacts on a PMF; - Potential impacts on other sensitive natural heritage features at a population/habitat scale of concern.	Yes. (further information will assist determination of importance, including consideration of uncertainties).
Not important	Negligible effects on natural heritage interests.	No.
No effect	No demonstrable impact on natural heritage interests.	No.

Table 2: Potential effect categories applied to Step 1 of the appraisal.

Step 2 identifies development activities and potential effect-pathways and assigns a level of importance (as per definitions from Step 1) for the receptor under consideration. Construction and installation effects are considered separately from those during operational and maintenance phases. This stage involves an initial evaluation of effects from tidal developments in broad principles only (i.e. no site-specific considerations) and receptors are generally considered in biologically relevant groups as required. This step of the evaluation also addresses potential effects prior to consideration of mitigation and monitoring options.

Step 3 progresses potential activities/effect-pathways regarded to be 'important' or 'potentially important' forward to full impact appraisal. Whereas the earlier steps have evaluated potential effects only in broad principles, at this stage site-specific knowledge of species, habitats and development details (as per the project envelope) at the Fall of Warness test site are taken into consideration. This allows the types of device, subsea cabling, and installation and retrieval methods associated with the site to be accounted for in the impact appraisal. Furthermore, whilst receptors have been previously grouped, they are now considered individually (i.e. to species-level) where appropriate.

The final detailed appraisal reports on the following outcomes:

1. Appraisal conclusion for each receptor/receptor group or impact type, including outcomes for protected sites and species.
2. Any species licensing needs.
3. Potential mitigation and monitoring measures.

Device applications out with the project envelope

This process provides consideration of the potential impacts of existing deployments at the EMEC Fall of Warness test site, and also aims to appraise future applications for deployments at the 7+1 berths already established (and future 9th) and supported by the previous FEPA and CPA consents (see Section 1). However, future Marine Licence applications for additional devices can only be regarded as pre-appraised if the application details are clearly within the defined project envelope, as determined by Marine Scotland. Any deviation from the project envelope, or lack of clarity in project details, may then require the developer to provide additional information or undertake an additional device-specific assessment. Developers should approach EMEC in the first instance for advice.

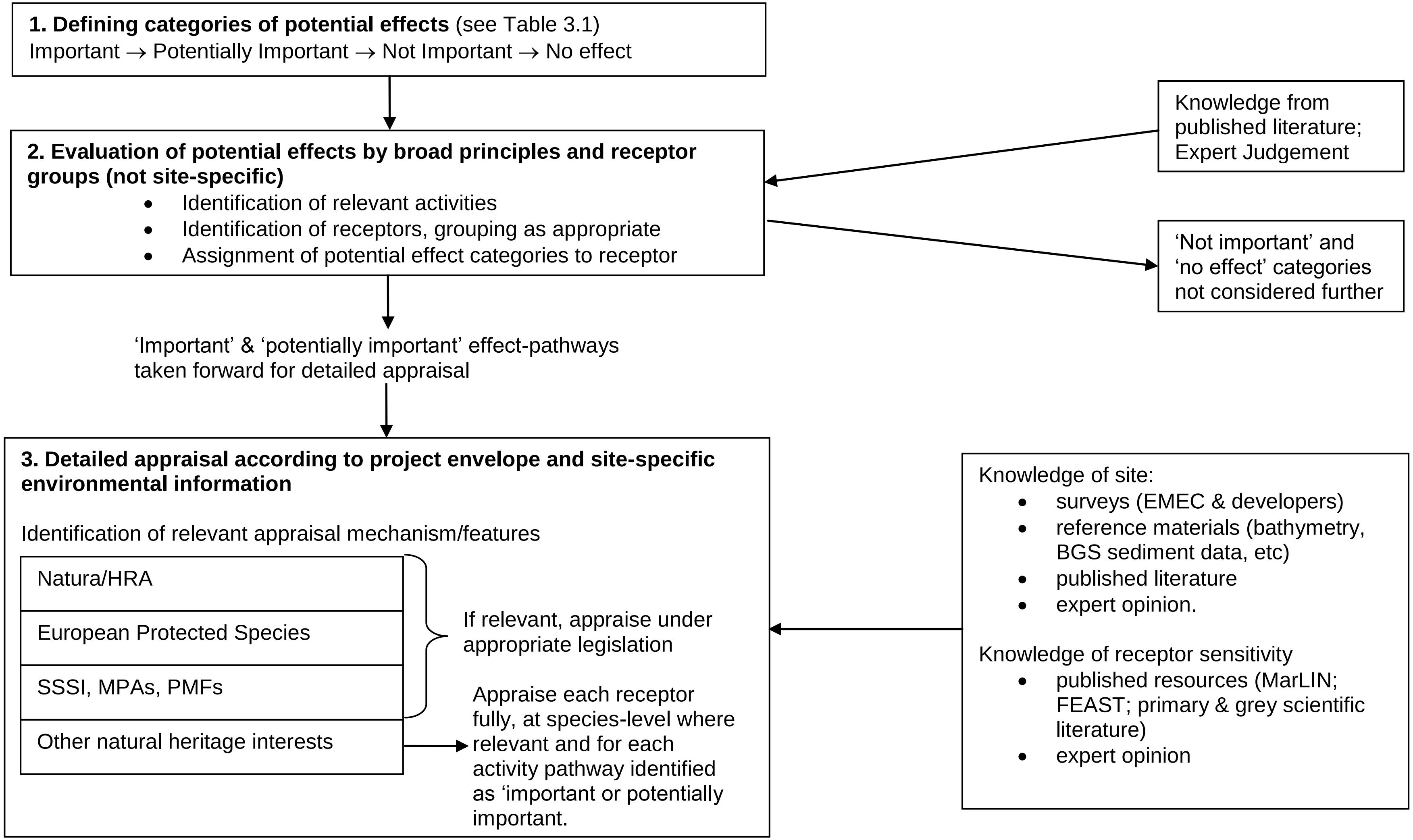

Figure 1: Summary of appraisal process, Steps 1 to 3.

4 Environmental Appraisals

4.1 Impact Appraisal: Benthic Environment

Prior to the fully detailed evaluations, this appraisal picks up at 'Step 2' as described in Section 3 of this document.

4.1.1 Potential effects

For benthic receptors, which are at this stage grouped into broad categories, the defined potential effect categories are applied to activities/effect pathways relevant to tidal energy developments comprising design-types involving the rotation of turbines within natural hydrodynamic conditions[3]. First, potential effects are considered in broad-principles. Deployment/installation effects (Table 3) are addressed separately from those during the operational and maintenance phases (Table 4).

Note that details specific to the Fall of Warness, both environmental and relating to project-specifications, are not considered until the detailed appraisal later in this section.

[3] Tidal developments that involve the manipulation of hydrodynamic conditions prior to the extraction of energy (e.g. tidal barrages) are explicitly excluded from the broad consideration of potential effects in Table 3 and Table 4.

Generic potential effects from device deployment		
Summary of activity categories – for detail see project envelope description (Annex 1) • Installation of device(s), and associated infrastructure (e.g. foundations; mooring systems; cabling; buoys) on the seabed, in the water column or above the surface • Use of vessels (e.g. jack-up barge; multi cat; workboat; DP vessel; dive-support vessel; crane-barge; tug; specialist cable-laying vessel.) • Deployment and use of equipment to monitor devices or other parameters during installation (e.g. ROV, cameras or acoustic devices).		
Activity/potential effect pathway	**Natural heritage feature**	**Potential importance**
Habitat loss/damage.	Substrate/ geogenic habitats.	Potentially important – some mooring/foundation designs, cable protection options and installation techniques result in loss/damage to larger areas than others. Effects range from the short- to long-term, partly due to the relative recoverability of substrate types. Importance will depend upon the ecological value of the affected substrate/habitat for biota, its recoverability and the overall footprint in the context of the wider availability of the substrate /habitat.
	Benthic species.	Potentially important - some mooring/foundation designs, cable protection options and installation techniques result in loss/damage to larger areas than others. Sensitivity (including recoverability) of benthic species is often linked to their natural resilience to disturbance events, with species associated with mobile substrates recovering relatively quickly. However, importance will also depend upon the scale of the impact in the context of the local and regional distribution of species, and the conservation value of the species concerned.
	Biogenic habitats.	Potentially important – most biogenic habitats are highly sensitive and slow to recover from loss or damage. Such habitats are also typically of high conservation value, supporting high biodiversity and ecological functionality. Importance will depend upon the extent and quality of biogenic habitats, and upon the scale of loss/damage in the

		context of the habitat locally/regionally.
Smothering by re-settlement of disturbed sediment or drill cuttings.	Substrate/ geogenic habitats.	Not important – while some settlement of disturbed sediment or drill cuttings may be expected, due to the high tidal flow of locations for tidal energy proposals it is considered that any settlement will be temporary (limited to a period of slack tide) or lasting effect on local substrate types.
	Benthic species.	Potentially important – in most tidally active areas, redistribution of such material is likely to be sufficient for smothering impacts on benthic species to be negligible. However, some potential for important effect remains for highly sensitive species – importance will depend upon the species present, their abundance and local/regional importance, the hydrodynamic conditions and the volume of suspended material above natural background levels.
	Biogenic habitats.	Potentially important - in most tidally active areas, redistribution of such material is likely to be sufficient for smothering impacts on biogenic habitats to be negligible. However, some potential for important effect remains for highly sensitive habitats – importance will depend upon the habitats present, their extent, quality and local/regional importance, the hydrodynamic conditions and the volume of suspended material above natural background levels.
Introduction of marine non-native species (MNNS) (via vessels, devices or other equipment).	Substrate/ geogenic habitats.	No effect – non-native species are unlikely to affect the physical nature of a substrate.
	Benthic species.	Potentially important – the potential effect of a proliferation of a MNNS on benthic species is difficult to predict but has the potential to be important. Importance will depend upon the conservation and ecological value of benthic species and the scale of a MNNS proliferation.
	Biogenic habitats.	Potentially important – the potential effect of MNNS on biogenic habitats is difficult to predict but has the potential to be important, particular given the typical ecological value of biogenic habitats. Importance will depend upon the conservation and ecological value of the habitats present and the scale of a MNNS proliferation.

Table 3: Potential effects on substrate integrity, benthic species and benthic habitats during device and infrastructure deployment, identifying activities/effect pathways and receptors for further assessment (note that these evaluations are made *prior* to consideration of details particular to the Fall of Warness site).

Generic potential effects from device operation and maintenance

Summary of activity categories – for detail see project envelope description (Annex 1)

- Physical presence of device(s), foundations, moorings, buoys and associated infrastructure on the seabed, in the water column or above the surface
- Operation of device(s)/power generation
- Repeat removal and redeployment of equipment for maintenance (e.g. turbine removed from water or floating structure removed from berth; replacement of mooring system).
- Other maintenance activities (e.g. Biofouling removal; ROV/diver inspection or repairs).
- Use of vessels (e.g. DP vessel; jack-up barge; multi cat; workboat; dive-support vessel; crane-barge; tug).
- Use of equipment to monitor devices in situ or other environmental parameters (e.g. ROV, cameras or acoustic devices).

Activity/potential effect pathway	Natural heritage feature	Potential importance
Habitat creation.	Substrate/ geogenic habitats.	Potentially important – devices, their foundations/mooring systems nd other infrastructure will introduce a new substrate that will differ from the natural state. The difference is less notable on hard geogenic substrates; artificial structures will alter the local environment more significantly when placed on sedimentary substrates. Importance will also depend upon the scale of new structures in the context of the local environment.
	Benthic species.	Potentially important – sessile species may colonise new structures, while more mobile species may aggregate around structures that provide some protection or feeding opportunities. Effects may be positive or neutral over hard substrates, where artificial structures may help offset lost habitat. Effects may be negative or neutral where hard structures are introduced to a sedimentary environment. Importance will also depend upon the scale of devices, foundations and infrastructure in the context of the local environment.
	Biogenic habitats.	Potentially important – biogenic habitats may form on new structures. Effects may be positive or neutral over hard substrates, where artificial structures may help offset lost habitat. Effects may be negative or neutral where hard

		structures are introduced to a sedimentary environment, but potentially also positive due to the functional value of biogenic habitats that may be depleted elsewhere. Importance will also depend upon the scale of devices, foundations and infrastructure in the context of the local environment.
Introduction/facilitation of marine non-native species (MNNS) (via vessels, devices, other equipment, or by provision of device and infrastructure as a stepping-stone in MNNS range expansion).	Substrate/ geogenic habitats.	No effect – non-native species are unlikely to affect the physical nature of a substrate.
	Benthic species.	Potentially important – the potential effect of a proliferation of a mnns on benthic species is difficult to predict but has the potential to be important. Importance will depend upon the conservation and ecological value of benthic species and the scale of a mnns proliferation.
	Biogenic habitats.	Potentially important – the potential effect of MNNS's on biogenic habitats is difficult to predict but has the potential to be important, particularly given the typical ecological value of biogenic habitats. Importance will depend upon the conservation and ecological value of the habitats present and the scale of a mnns proliferation.
Changes to hydrodynamic and sediment regime (including scour around devices and cables).	Substrate/ geogenic habitats.	Potentially important – arrays of devices could theoretically alter hydrodynamic processes to a degree that would influence scouring and sediment processes and thereby alter benthic substrates. More obvious, however, is the potential for changes in the immediate vicinity of devices or infrastructure. Importance will depend upon natural hydrodynamic conditions, substrate types, the value placed on their integrity and the design and layout of devices, foundations and infrastructure.
	Benthic species.	Potentially important – arrays of devices could theoretically alter hydrodynamic and sediment processes that could affect benthic species over a wide area. More obvious, however, is the potential for effects upon benthic species in the immediate vicinity of devices or infrastructure. Importance will depend upon natural hydrodynamic conditions, the conservation value and sensitivity of species and the design and layout of devices, foundations and infrastructure in the context of the distribution of important species.
	Biogenic habitats.	Potentially important – arrays of devices could theoretically alter hydrodynamic and sediment processes that could effect biogenic habitats over a wide area. More obvious, however, is the potential for effects in the immediate vicinity of devices or infrastructure. Importance will depend upon natural hydrodynamic conditions, the conservation value and sensitivity of habitats and the design and layout of devices, foundations and infrastructure in the context of the distribution of important habitats.

Electromagnetic Field (EMF) effects.	Substrate/ geogenic habitats.	No effect.
	Benthic species.	Not important – although the evidence base is limited, current physiological knowledge provides the expectation that only a limited range of species are expected to be of particular sensitivity to EMF. These are addressed in Section 4.2 of this document).
	Biogenic habitats.	Not important – as above for benthic species.
Thermal loading from cabling.	Substrate/ geogenic habitats.	No effect.
	Benthic species.	Not important – although the evidence base is limited, thermal loading from export and intra-array and export cables is expected to be so low and localised as to be almost immeasurable (BERR, 2008). Any effects on benthic species will be highly localised.
	Biogenic habitats.	Not important – as above for benthic species.

Table 4: Potential effects on substrate integrity, benthic species and benthic habitats during the operational and maintenance phase, identifying activities/effect pathways and receptors for further assessment (note that these evaluations are made *prior* to consideration of details particular to the Fall of Warness site).

4.1.2 Natural heritage context

In 2005 a preliminary seabed survey was conducted at the Fall of Warness site, with depths reaching 51m at the deepest berth sites to the shore for the then proposed cable routes (Foubister, 2005). Although not yet fully analysed, much useful information on the benthic species and habitats on the site has been derived from this. Furthermore, there have also been a series of developer-specific benthic survey reports delivered, typically focussing on more discrete areas of seabed around berth locations. The following broad characterisation of the benthic environment is possible from available reports.

Substrate/geogenic habitats

The Fall of Warness subtidal area consists largely of scoured and tide-swept bedrock and boulders, with areas of broken bedrock amongst sublittoral sandbanks in the shallower eastern and northern margins. Although largely bedrock and boulders in deeper areas, interstitial shell-sand is common in-between boulders from depths of 34-40m. Geogenic and sedimentary habitats support a variety of benthic species (see below), but throughout much of the site this comprises communities typical of tidally scoured areas.

Benthic species

Benthic species associated with bedrock and boulder areas at the Fall of Warness are typical of this substrate type in tidally scoured areas of the north of Scotland, with some areas of rock being relatively bare in flora and fauna. From developer-specific surveys of berths, more southern and eastern berth-sites may exhibit slightly denser faunal turfs on top of bedrock, boulders and cobbles. *Laminaria spp*., and the associated red algae *Rhodymenia palmate*, is present throughout the area although denser in shallower more sheltered areas, with other common species including various encrusting coralline algae species, sea anemones, sea stars and a variety of crustacean species. Benthic species associated with sedimentary substrates are also typical, including common polychaetes, amphipods and bivalves. Infauna is relatively sparse within the mobile sandy substrates in some margins of the site. With the exception of a possible record of some scattered maerl debris (*Lithothamnion corallioi* or *Phymatolithon calcareum*) (ScotRenewables, 2011), there have been no records of any benthic species listed as Priority Marine Features[4] (PMF) on either the rocky or sandy substrates at Fall of Warness. Evidence to date does not suggest there is a maerl bed present, in which case it would not be regarded as a PMF. No live maerl has been reported.

Biogenic habitats

Areas of relatively dense seaweed, including *Laminaria* spp., will provide biogenic habitat that supports a higher diversity and biomass of biota than area of bare rock or mobile sand. Biotope classification has not been completed, but this habitat may represent the PMF '*Kelp beds'*, or a component of the PMF *'Tide-swept algal communities'*. These habitat patches appear to be increasingly patchy with distance from shore. Seaweed habitats aside, there have been no records to date of species that would form subtidal biogenic habitats at the Fall of Warness site from the EMEC surveys in 2005, from the developer-specific benthic monitoring programmes, or from wider resources. Furthermore, given the tidally-scoured nature of the seabed at Fall of Warness, areas of seaweed habitat are likely to be sparse except in some of the relatively sheltered sublittoral margins of the site near the cable landfall.

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[4] http://www.snh.gov.uk/docs/A1327320.pdf

4.1.3 Summary of benthic impact appraisal process for the Fall of Warness

This impact appraisal takes account of a maximum-case scenario based on the project envelope (Annex 1) where all available berths within the test site are developed and operating at capacity. It addresses the differing consenting and licensing regimes (see Table 5 below). This appraisal will inform the consenting process for both Marine Licence and Section 36 consent applications. However, it should be noted that, if there are key deviations in the device design or in installation or maintenance activities, further appraisal work may be required. Any additional appraisal work required will be undertaken by the individual developer (further advice should be sought from EMEC in the first instance).

Feature type	Appraisal mechanism/relevant legislation	Applicable	Reasoning
Qualifying features of European sites.	Habitats Regulations Appraisal (HRA) - Habitats Regulations 1994 (as amended).	N	No connectivity with Special Areas of Conservation (SAC) with benthic qualifying features.
European Protected Species.	EPS legislation - Habitats Regulations 1994 (as amended in Scotland).	N	No benthic species are listed as EPS.
Notified features of SSSIs.	SSSI legislation - Nature Conservation (Scotland) Act 2004 (as amended).	N	No connectivity with SSSIs with benthic notified features.
Protected features of MPAs	Marine (Scotland) Act 2010.	N	Not capable of affecting protected benthic features of a MPA.
PMFs	Marine (Scotland) Act 2010.	N	No benthic PMFs known to be present.
Other sensitive natural heritage features.	Appraisal of other features under: - Electricity Works (EIA) (Scotland) Regulations (Amendment) 2008; - Marine Works (EIA) (Amendment) Regulations 2011; - Marine (Scotland) Act 2010.	Y	Captures assessment of all other sensitive natural heritage features at a population/habitat scale of concern.

Table 5: Appraisal mechanism for benthic species and habitats.

4.1.4 Appraisal of other natural heritage features

Substrate/geogenic habitats

Sedimentary substrates

There is a maximum of twelve devices and associated infrastructure, as described in the project envelope. Based on experience so far, the worst-case total footprint of device developments at the test site is considered as ~6000 m^2 (max 12 devices at 500 m^2 each), comprising 0.07% of the whole lease area (~9 km^2). This is a highly precautionary as it assumes use of the largest possible foundation types at all berths which, in reality, is very unlikely to occur. Nevertheless, when appraised against this worst case, it should be noted that berth sites are dominated by rocky substrates and so the scale of impact on sedimentary substrates is very small. Cabling works within the envelope are restricted to recovery and replacement of existing cables, plus short lengths connecting berth ends to new devices. Existing cabling (cables for power and data export), plus potential additional cabling in the future and associated protection from all berths amounts to a total cable length of approximately 31 km, but only crosses extensive areas of sedimentary substrates in the north of the site, with the remainder being on bedrock or cobble habitat. Cables are not buried, reducing impacts on sedimentary substrates during installation. Although some scouring is likely in the immediate vicinity of any cabling on sedimentary substrates, loss of or damage to sedimentary substrates on this scale, in the context of the development site and its wider availability, is not of ecological concern. Furthermore, sediment conditions are expected to recover relatively quickly following any works or decommissioning, particularly in such a tidally active location. Similarly, while the introduction of cabling infrastructure to sedimentary substrates results in the creation of a hard substrate, the scale of this in the context of the site (9 km^2) and similar substrates in the immediate area and throughout Orkney is very limited.

Hydrodynamic conditions and sediment processes are not expected to change to an important degree across the Fall of Warness site as a whole, due to the relatively small number of devices and level of energy extraction in the context of the tidal flow through the site (see Section 4.3 'Hydrodynamic and Physical Processes'). There may be highly localised changes in hydrodynamics and some scouring around cabling infrastructure on sedimentary substrates, but the routing of cables in parallel with peak flow directions should minimise this impact, and the scale of any residual impact is predicted to be unimportant in the context of the site and adjacent areas (HR Wallingford, 2005).

Appraisal conclusion for the physical integrity of sedimentary substrates: Any potential impacts are not regarded as important at the scale of the development and in the context of the wider environment.

Rock, boulder and cobble substrates

Although not within a SAC, areas of bedrock boulder and cobble reef are regarded as Annex 1 reef habitats.

There is a maximum of twelve devices and associated infrastructure, as described in the project envelope. The total worst-case footprint of developments at the berth sites is calculated as 6000 m^2 (max 12 devices at 500 m^2 each), comprising ~0.07% of the whole lease area at the Fall of Warness (total 9 km^2), the majority of which will be upon bedrock substrates. Much of the ~28km of export and data cabling from berths, and associated cable protection, crosses non-sedimentary substrates. These figures are highly precautionary as they assume use of the largest possible foundation types at all berths which, in reality, is very unlikely to occur. Nevertheless, even when appraised against this worst case, loss of or damage to rocky areas at these scales will not compromise the physical integrity of rocky substrates in the context of the Fall of Warness or the wider area. Similarly, the introduction of new hard surfaces in the form of the devices or associated infrastructure is not of a scale sufficient to have an important effect on the availability of natural substrates.

Hydrodynamic conditions around rocky substrates may be expected to change in the immediate vicinity of devices and may, in the longer-term, cause some localised scouring. However, these impacts will not be sufficient to have an important effect on the physical integrity of these substrates across the Fall of Warness. Indeed, the previous ES (Foubister, 2005) recommended regular ROV surveys around device foundations to consider impacts on the benthic environment from scouring or other device-specific impacts. Some minor scouring may be anticipated around some mooring chains, but evidence to date has not demonstrated impacts sufficient to be considered significant in this regard, presumably due to the solidity of the exposed seabed and low levels of mobile material. Consequently, it is not expected that this monitoring activity will need to continue at this site unless device-specific considerations suggest otherwise.

Appraisal conclusion for the physical integrity of rock, boulder and cobble substrates: The development footprint includes some rocky reef habitat, but any potential impacts are not regarded as important at the scale of the development and in the context of the wider area.

Sessile & low-mobility benthic species

On hard substrata, at this location, benthic species are relatively sparse, increasingly so at the more northern and western berth sites. In the absence of any sessile or low-mobility species of notable conservation importance associated with either hard or sedimentary substrates, it follows that the importance of any impacts upon flora and fauna associated with these habitats will also be limited. Habitat/loss or damage at the site is thus not considered an important stressor at the site. Following cabling works species on or in mobile sediments are likely to recover quickly, due in part to typically being well adapted to regular perturbations (i.e. see http://www.marlin.ac.uk). Species inhabiting rocky substrates are less inclined to rapid recovery, but any loss or damage will be in discrete areas and recovery will nevertheless occur, albeit over a longer period.

Habitat creation by installation of devices and infrastructure may have a positive or neutral impact on species associated with hard substrates, or a negative or neutral impact where the continuity of sedimentary substrates is altered by the introduction of solid structures. Any positive or negative impacts at Fall of Warness are not regarded as of ecological importance, due to the small portion of the site influenced by these changes, but some monitoring of colonisation of hard structures would be of value (see Table 7 below).

There is potential for the introduction of MNNS to the site by a variety of vectors, particularly via the hulls or ballasts of vessels, or through transport of the devices themselves from harbours. Devices and infrastructure may also provide a novel substrate that serves as a stepping-stone for MNNS introduced by other vectors. MNNS may pose a risk to native benthic species and, although no species of particular importance have been identified, the widespread proliferation of MNNS could be damaging to the benthic ecology of a large area. These risks should be managed accordingly by adoption of a series of protocols (see Table 7) that ensures MNNS are not transported on vessels or devices and that bio-fouling of devices is frequently inspected and cleared accordingly. Ongoing discussion with regulators should inform bio-fouling management requirements.

Sediment disturbance during installation procedures will be minimal, but there may be release of drill cuttings (cumulative max ~ 2400 m^3 (max 12 monopiles with 200 m^3 each)) during the installation of device foundations or mooring systems, and any recovery or replacement of cables will cause some disturbance. However, further to the limited volume of cuttings, drilling operations will be occasional and hydrodynamic conditions will disperse cuttings widely and rapidly, removing the risk of significant smothering impacts.

Appraisal conclusion for sessile and low-mobility benthic species: Any potential impacts are considered as not of ecological importance, but active management of the risk of introducing MNNS is appropriate as good-practice. Monitoring of the colonisation of devices and infrastructure by benthic flora and fauna could also form part of a MNNS management protocol.

Biogenic habitats

Some impacts on discrete areas of patchy seaweed habitats are possible, but there are no other known subtidal biogenic habitats at the Fall of Warness. Any cumulative loss of or damage to seaweed habitat would be constrained to a very small area in the context of its availability across the whole site and have no measurable implications for its ecological functionality. With the exception of small scoured areas in the immediate vicinity of infrastructure, changes to hydrodynamic conditions are unlikely to be sufficient to affect such habitats and are thus regarded as unimportant.

Sediment disturbance during installation procedures will be minimal, but there may be release of drill cuttings (cumulative max ~ 2400 m^3 (max 12 monopiles with 200 m^3 each)) during the installation of device foundations or mooring systems, and any recovery or replacement of cables will cause some disturbance. However, further to the limited volume of cuttings, drilling operations will be occasional and hydrodynamic conditions will disperse cuttings widely and rapidly, removing the risk of significant smothering impacts.

The likelihood of a threat to these seaweed habitats from invasive non-native species is considered very low, but cannot be ruled out. There is potential for the introduction of MNNS to the site by a variety of vectors, particularly via the hulls or ballasts of vessels, or through transport of the devices themselves from harbours. Devices and infrastructure may also provide a novel substrate that serves as a stepping-stone for MNNS introduced by other vectors. These risks should be managed accordingly by adoption of a series of protocols that ensures MNNS are not transported on vessels or devices and that bio-fouling of devices is frequently inspected and cleared accordingly; links to good-practice codes are provided in Table 7. Ongoing discussion with Marine Scotland should inform bio-fouling management requirements.

Turbines and infrastructure could provide a substrate that would support the establishment of some biogenic communities. However, the scale of potential new surfaces is small in the context of the whole site (precautionary max of 0.07% footprint plus ~31 km cabling across a ~9 km^2 area). Due to the biodiversity value of biogenic habitats, such habitat creation may be perceived as a positive impact. However, where this represents a departure from natural habitat it may also be negative. In either case, the scale of the impact is considered unimportant. Furthermore, much of the site is likely to remain too turbulent for prolific establishment of biogenic habitats.

Appraisal conclusion for the biogenic habitats: Any potential impacts are considered as not of ecological importance, but good-practice mitigation may be applied to minimise the risk of introducing MNNS.

4.1.5 Benthic receptor conclusions

A summary of the appraisal for each of the receptors is provided in Table 6 below. Note that, even where no important impacts on the development site are identified, in some cases there may still be a recommendation for some mitigation or monitoring. Under these circumstances, mitigation would be regarded as good-practice rather than a necessity, while monitoring may serve to improve generic understanding of the relationships between stressors and receptors.

Receptor	Conclusion	Monitoring and/or mitigation identified?
Substrate/ geogenic habitats.	No important impacts.	No.
Benthic species.	No important impacts.	Yes – see Table 7.
Biogenic habitats.	No important impacts.	Yes – see Table 7.

Table 6: Summary of benthic appraisal conclusions.

Given uncertainties regarding some potential impacts and the opportunity to learn from test deployments, some potential mitigation and monitoring measures are presented in Table 7 below (this table should be reviewed as knowledge increases). Some such measures will be appropriate as conditions on the Marine Licence, whereas others may just be recommended as good practice.

Site-wide monitoring and research ideas may be more effectively pursued at a strategic level (whether by EMEC, The Crown Estate or Marine Scotland, or by a developer consortium), but developer input or ideas are welcomed. Section 5 discusses this further.

Potential Residual Impacts	Relevant receptors	Relevant impact-pathway	Monitoring/Mitigation
Change to benthic communities.	Benthic species & habitats.	Habitat creation.	Monitor colonisation of selected devices and infrastructure. This may also form part of an invasive non-native species management protocol or bio-fouling management (see below).
	Benthic species & habitats.	Marine Non-Native Species.	Adopt good-practice as detailed in www.scotland.gov.uk/Resource/0039/00393567.pdf, www.mardep.gov.hk/en/msnote/pdf/msin1136anx1.pdf and www.ipieca.org/publication/alien-invasive-species-and-oil-and-gas-industry.

Table 7: Potential mitigation and monitoring measures relevant to benthic ecology.

4.1.6 References

BERR. 2008. Review of Cabling Techniques and Environmental Effects Applicable to the Offshore Wind Farm Industry – Technical Report. Department for Business, Enterprise and Regulatory Reform.

Foubister., L. 2005. EMEC Tidal Test Facility, Fall of Warness, Orkney. Environmental Statement. Prepared by Aurora Environmental Ltd.

ScotRenewables. 2011. Seabed survey report: cable route and potential mooring locations at Fall of Warness test site. Issued by: Aquatera Ltd; P353 – September 2010-January 2011

HR Wallingford. 2005. Tidal Test Facility, Orkney: Coastal and seabed processes review. HR Wallingford.

http://www.marlin.ac.uk

4.2 Impact Appraisal: Fish and Shellfish

Prior to the fully detailed evaluations, this part of the appraisal picks up at 'Step 2' as described in Section 3 of this document: *'Approach to the Environmental Appraisals'*.

4.2.1 Potential effects

For fish and shellfish receptors, which are at this stage grouped in to broad categories, the defined potential effect categories are applied to activities/effect pathways relevant to tidal energy developments comprising design-types involving the rotation of turbines within natural hydrodynamic conditions[5]. Deployment/installation effects (Table 8) are addressed separately from those during the operational and maintenance phases (Table 9).

Note that details specific to the Fall of Warness, both environmental and relating to project-specifications, are not considered until the detailed appraisal later in this section.

[5] Tidal developments that involve the manipulation of hydrodynamic conditions prior to the extraction of energy (e.g. tidal barrages) are explicitly excluded from the broad consideration of potential effects in tables 4.1.1 and 4.1.2.

Generic Potential Effects from Device Deployment

Summary of activity categories – for detail see project envelope description (Annex 1)

- Installation of device(s), and associated infrastructure (e.g. foundations; mooring systems; cabling; buoys) on the seabed, in the water column or above the surface
- Use of vessels (e.g. DP vessel; jack-up barge; multi cat; workboat; dive-support vessel; crane-barge; tug; specialist cable-laying vessel.)
- Deployment and use of equipment to monitor devices or other environmental parameters during installation (e.g. ROV, cameras or acoustic devices).

Activity/potential effect pathway	Natural heritage features	Potential importance
Installation vessel transits and manoeuvring leading to disturbance*.	Diadromous fish.	Not important – unlikely to be sufficiently noisy or widespread to have an important effect .
	Marine fish.	
	Marine shellfish.	

* The term ‘disturbance’ includes all behavioural responses of biological consequence, including displacement from the vicinity of the activity.

Underwater noise from foundation/mooring installation methods and vessels leading to: auditory injury, death or disturbance.	Diadromous fish.	Potentially important – different species exhibit different sensitivity to noise and vibration. Importance will depend upon the range and frequency of noise sources (including background noise), duration of activity and the proximity of the site to relevant rivers (including salmon SAC) and migration routes.
	Marine fish.	Potentially important - different species exhibit different sensitivity to noise and vibration. Importance will depend upon the range and frequency of noise sources (including background noise), duration of activity and the proximity of the site to important locations/routes for sensitive species.
	Marine shellfish.	Not important – shellfish are generally not physiologically adapted to be sensitive to noise sources. Any possible effects are expected to be minor, highly localised and unimportant at a population level.
Increased suspended sediment/turbidity (including release of drill cuttings).	Diadromous fish.	Not important – most tidal developments are unlikely to be built upon sedimentary substrates, so are unlikely to involve release of large volumes of material in to the water column. Nevertheless, any increase in suspended sediment will be quickly and widely dispersed in tidal streams and so very short-lived. Furthermore, diadromous species are well adapted to a wide range of turbidity conditions.
	Marine fish.	Potentially important – some marine fishes are sensitive to elevated suspended sediment concentration (SSC), particularly filter-feeding species. Importance will depend upon the severity of increase in SSC, its duration (dependent on tidal flow and particle size) and the importance of the locality for sensitive species.
	Marine shellfish.	Potentially important - some shellfish are sensitive to elevated SSC, particularly filter-feeding species. Importance will depend upon the severity of increase in SSC, its duration (dependent on tidal flow and particle size) and the importance of the locality for sensitive species.
Smothering by re-settlement of disturbed sediment or drill cuttings.	Diadromous fish.	Not important – diadromous fish species tend to be highly mobile and wide-ranging when in the marine environment. Some species have closer associations with the benthic/demersal environment than others, but are not known to be reliant on discrete areas and so important effects are unlikely.
	Marine fish.	Potentially important – some benthic fish are vulnerable to smothering, particularly those of low mobility or that lay eggs on the seabed. Importance will depend upon sediment characteristics (e.g. particle size), the volume of deposited material, local hydrodynamics and the importance of the locality for sensitive species.

	Marine shellfish	Potentially important - some benthic shellfish are vulnerable to smothering, particularly filter-feeders or those of low mobility. Importance will depend upon sediment characteristics (e.g. particle size), the volume of deposited material, local hydrodynamics and the importance of the locality for sensitive species.
Benthic habitat loss/damage.	Diadromous fish.	Not important - diadromous fish species tend to be highly mobile and wide-ranging when in the marine environment. Some species have closer associations with the benthic/demersal environment than others, but are not known to be reliant on discrete areas and so important effects are unlikely.
	Marine fish.	Potentially important – some marine fish have close associations with the benthic environment. Seabed preparation & placement of devices, foundations, mooring systems or cabling systems can therefore have effects. Importance will depend upon the footprint of the impacted area in the context of the habitats wider availability, duration of deployment, recoverability of the habitat and the importance of the locality for sensitive species.
	Marine shellfish.	Potentially important - many shellfish have close associations with the benthic environment. Seabed preparation & placement of devices, foundations, mooring systems or cabling systems can therefore have effects. Importance will depend upon the footprint of the impacted area in the context of the habitats wider availability, duration of deployment, recoverability of the habitat and the importance of the locality for sensitive species.
Introduction of marine non-native species via vessels, devices or other equipment.	Diadromous fish.	Not important – aside from some restricted migration routes, through which they are mobile, while at sea diadromous species are not known to have strong associations with any discrete areas in Scottish waters. Impacts from known non-natives are therefore unlikely to be important.
	Marine fish.	Potentially important – some marine fish have sufficiently close associations with discrete areas or habitat types that they could be vulnerable to invasive non-natives. Importance depends upon the implications of particular non-native species and the importance of the locality to sensitive fishes.
	Marine shellfish.	Potentially important – many shellfish have close associations with discrete areas or habitat types such that they could be vulnerable to invasive non-natives. Importance depends upon the implications of particular non-native species and the importance of the locality to sensitive fishes.
Underwater noise from active acoustic equipment leading to	Diadromous fish.	Not important – unlikely to be sufficiently noisy or widespread to have an important effect

disturbance.	Marine fish.	
	Marine shellfish.	Not important – shellfish are assumed to be relatively non-sensitive to underwater noise.

Table 8: Potential effects upon fish and shellfish during device and infrastructure deployment, identifying activities/effect pathways and receptors for further assessment (note that these evaluations are made *prior* to consideration of details particular to the Fall of Warness site).

Generic Potential Effects from Device Operation and Maintenance

Summary of activity categories – for detail see project envelope description (Annex 1)

- Physical presence of device(s), foundations, moorings, buoys and associated infrastructure on the seabed, in the water column or above the surface
- Operation of device(s)/power generation
- Repeat removal and redeployment of equipment for maintenance (e.g. turbine removed from water or floating structure removed from berth; replacement of mooring system).
- Other maintenance activities (e.g. Biofouling removal; ROV/diver inspection or repairs).
- Use of vessels (e.g. DP vessel; jack-up barge; multi cat; workboat; dive-support vessel; crane-barge; tug).
- Use of equipment to monitor devices in situ or other environmental parameters (e.g. ROV, cameras or acoustic devices).

Activity/potential effect pathway	Natural heritage features	Potential importance
Maintenance vessel transits and manoeuvring leading to disturbance*.	Diadromous fish.	Not important – unlikely to be sufficiently noisy or widespread to have an important effect .
	Marine fish.	

* The term 'disturbance' includes all behavioural responses of biological consequence, including displacement from the vicinity of the activity.

	Marine shellfish.	
Underwater noise from active acoustic equipment leading to disturbance.	Diadromous fish.	Not important – unlikely to be sufficiently noisy or widespread to have an important effect.
	Marine fish.	
	Marine shellfish.	Not important – shellfish are assumed to be relatively non-sensitive to underwater noise.
Habitat creation and fish aggregation device (FAD) effect.	Diadromous fish.	Not important – diadromous species are not known to aggregate around devices or structures at sea and are primarily considered to be in transit during this life history stage. Consequently, albeit with a degree of precautious uncertainty, there is unlikely to be an important effect.
	Marine fish.	Potentially important – some marine fish species are likely to aggregate around structures in the water column, while others may utilise structures as habitat or feeding locations. Implications are poorly understood but importance will depend upon any energetic, reproductive or predator avoidance benefits provided. Negative implications may include heightened collision risk for the fish or their predators. The use of underwater lights may attract some marine fish species, although the importance or implications of this are poorly understood.
	Marine shellfish.	Potentially important - some shellfish species are likely to utilise structures as habitat or feeding locations. Implications are poorly understood but importance will depend upon any energetic, reproductive or predator avoidance benefits provided. Negative implications may include heightened collision risk for predators. The use of underwater lights may attract some shellfish species, particularly pelagic crustaceans, although the importance or implications of this are poorly understood.

Underwater noise from turbine operation leading to: disturbance*.	Diadromous fish.	Potentially important – although of relatively low to moderate noise sensitivity, importance for diadromous fish will depend upon the location of a development relative to migration routes, the number and density of turbines, the noise characteristics of operating turbines and the baseline (natural and anthropogenic) noise of the surrounding environment.
	Marine fish.	Potentially important – while most species are either of low sensitivity or too mobile for important effects at the population-level, some species produce low-frequency sounds for communication. There is a high degree of uncertainty over implications, but importance may depend upon the location of a development relative to locations of importance for certain life-history stages, the number and density of turbines, the noise characteristics of operating turbines and the baseline (natural and anthropogenic) noise of the surrounding environment.
	Marine shellfish.	Not important – shellfish are assumed to be relatively non-sensitive to underwater noise.
Changes to hydrodynamic and sediment regime.	Diadromous fish.	Not important – diadromous species are well adapted to a range of sediment conditions and, while in the marine environment are not known to be reliant on particular conditions. The response of salmonids to near-field hydrodynamic conditions around devices is difficult to predict, but changes will be highly localised.
	Marine fish.	Potentially important – some marine fish species may be sensitive to changes in these conditions, particularly pelagic filter feeders or species with close associations with benthic habitats that may be affected. Importance will depend upon the severity of change, the duration of change and the importance of the locality to sensitive species.
	Marine shellfish.	Potentially important - some shellfish species may be sensitive to changes in these conditions, particularly pelagic filter feeders or species with close associations with benthic habitats that may be affected. Importance will depend upon the severity of change, the duration of change and the importance of the locality to sensitive species.
Introduction/facilitation of marine non-native species (via vessels,	Diadromous	Not important – aside from some restricted migration routes, through which they are mobile, while at sea diadromous species are not known to have strong associations with any discrete areas in Scottish waters.

devices, other equipment, or by provision of device and infrastructure as a stepping-stone in MNNS range expansion).	fish.	Impacts from known non-natives are therefore unlikely to be important.
	Marine fish.	Potentially important – some marine fish have sufficiently close associations with discrete areas or habitat types that they could be vulnerable to invasive non-natives. Importance depends upon the implications of particular non-native species and the importance of the locality to sensitive fishes.
	Marine shellfish.	Potentially important – many shellfish have close associations with discrete areas or habitat types such that they could be vulnerable to invasive non-natives. Importance depends upon the implications of particular non-native species and the importance of the locality to sensitive fishes.
Electromagnetic Field (EMF) effects.	Diadromous fish.	Potentially important – diadromous species utilise a magnetic sensitivity during migration at sea. Implications are poorly understood but importance depends upon the quantity, spacing and technical characteristics of cables and associated EMF, as well as proximity of cables to relevant rivers (including salmon SAC) and migration routes.
	Marine fish.	Potentially important – different marine fish have different levels of sensitivity to EMF, with sharks, skates and rays though to be the most sensitive. Implications are poorly understood but importance depends upon the quantity, spacing and technical characteristics of cables and associated EMF, as well as the importance of the locality for sensitive species.
	Marine shellfish.	Potentially important – based on their sensory physiology, shellfish are assumed to have low sensitivity to EMF, but there is a high degree of uncertainty in this. For any more sensitive shellfish species, importance may depend upon the quantity, spacing and technical characteristics of cables and associated EMF, as well as the importance of the locality for sensitive species.
Collision with turbine blades leading to: injury or death.	Diadromous fish.	Potentially important – some diadromous species may be at greater risk of collision than others. Potential for impact is poorly understood, but importance may depend upon turbine location relative to migration routes (including water depth) and the physical and rotational characteristics of turbines.
	Marine fish.	Potentially important - some marine fish may be at greater risk of collision than others. Potential for impact is poorly understood, but importance may depend upon the importance of the locality for species more likely to be vulnerable and the physical and rotational characteristics of turbines.
	Marine	Not important – most shellfish that would be large enough for heightened vulnerability to collision with turbine

	shellfish.	blades do not move in the water column. Planktonic invertebrates may be considered sufficiently populous and widely dispersed for any impacts to be of no concern at the population level.
Presence of tidal device (s) and associated infrastructure leading to: barrier effects.	Diadromous fish.	Potentially important – during transit between freshwater and the marine environment, diadromous species often rely on narrow channels and sounds that may also present opportunity for tidal development. Importance will depend upon the spatial occupancy of the channel by tidal devices (in three dimensions), physical and rotational characteristics of the devices, and the importance of the locality for sensitive species.
	Marine fish.	Not important – spatial arrangements of tidal devices are unlikely to present a barrier to marine fishes. Risks to basking sharks are considered in Section 4.4.
	Marine shellfish.	Not important – shellfish are generally of limited mobility, and for those that do migrate, tidal devices are unlikely to be a barrier to movement.

Table 9: Potential effects upon fish and shellfish during the operational and maintenance phase, identifying activities/effect pathways and receptors for further assessment (note that these evaluations are made *prior* to consideration of details particular to the Fall of Warness site).

4.2.2 Natural heritage context

Aside from anecdotal observations during benthic surveys and seabed investigations, there has been no targeted survey of fish and shellfish. However, it is possible to make reasonable assertions as to the likely species to be present, based primarily upon the habitats and physical conditions at the site. Foubister (1995) provides some further information, but a broad characterisation of the site is as below. Sources such as Coull *et al*. (1998) and Ellis *et al*. (2010) provide broadscale and generic information on spawning and nursery areas and times.

Diadromous fish

Salmon, trout and eels are present in Orkney waters; these species are all included in the PMF list[6]. Some of these may utilise rivers on Orkney (for salmon, this is restricted to larger rivers on Orkney Mainland and the island of Hoy). There is a possibility that some diadromous fish in Orkney waters may utilise rivers on mainland Scotland, but based on current knowledge the degree of connectivity of these rivers with Orkney is expected to be low (Malcolm *et al*., 2010).

Marine fish

The Fall of Warness is likely to support a wide range of marine fish species, some of which are included on the PMF list. Different species will utilise the site in different ways, not only for feeding and transit, but for some potentially for reproduction or as a nursery ground. Pelagic fish are likely to include key species such as herring and mackerel. Demersal species are likely to include various gadoids (e.g. cod, saithe), butterfish, gobies and, on sandier substrates, some flatfish and sandeels. Elasmobranches, including common skate and spurdog, may also be found. Diver observations during benthic surveys have made particular note of shoals of saithe.

Marine shellfish

Diver observations during benthic surveys have included scallops (on sandy/gravelly margins of site) and various crustaceans, including lobsters, velvet crab, brown crabs and squat lobsters. The latter two are more likely to occur on the softer sand substrates. A variety of other less conspicuous and/or ubiquitous species are also likely to occur across the site, but are not expected to be unique to the locality.

4.2.3 Impact appraisal mechanisms for the Fall of Warness

This impact appraisal takes account of a maximum-case scenario based on a project envelope description, where all available berths within the test site are developed and operating at capacity. It addresses the differing consenting and licensing regimes (see Table 10 below). This appraisal will inform the consenting process for both Marine Licence and/or Section 36 consent applications. However, it should be noted that, if there are key deviations in the device design or in installation or maintenance activities, further appraisal work may be required. Any additional appraisal work required will be undertaken by the individual developer (further advice should be sought from EMEC in the first instance).

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6 http://www.snh.gov.uk/docs/A1327320.pdf

Feature type	Appraisal mechanism/relevant legislation	Applicable	Reasoning
Qualifying features of European sites.	Habitats Regulations Appraisal (HRA) - Habitats Regulations 1994 (as amended).	N	No connectivity with salmon SAC.
European Protected Species.	EPS legislation - Habitats Regulations 1994 (as amended in Scotland).	N	Outside distribution of only fish listed as EPS (sturgeon).
Notified features of SSSIs.	SSSI legislation - Nature Conservation (Scotland) Act 2004.	N	No fish or shellfish are notified features.
Protected features of MPAs	Marine (Scotland) Act 2010.	N	Not capable of affecting protected fish of an MPA.
PMFs	Marine (Scotland) Act 2010.	Y	Fish PMFs likely to be present.
Other sensitive natural heritage features.	Appraisal of other features under: - Electricity Works (EIA) (Scotland) Regulations (Amendment) 2008; - Marine Works (EIA) (Amendment) Regulations 2011; - Marine (Scotland) Act 2010.	Y	Captures assessment of all other sensitive natural heritage features at a population/habitat scale of concern. However, note basking sharks are appraised in a Section 4.4.

Table 10: Appraisal mechanism for fish and shellfish.

4.2.4 Appraisal of qualifying species of European sites

Salmon are qualifying features of a number of Scottish rivers designated as Special Areas of Conservation, including some in the northern mainland around Caithness and the Moray Firth. Marine Scotland-Science has published a report reviewing the migratory routes and behaviour of Atlantic salmon, sea trout and European eel (Malcolm *et al*., 2010). While it is recognised that there is insufficient information to determine the relative importance of the waters around Orkney, it is considered that the Pentland Firth is likely to be an important route for Atlantic salmon migration and that migratory routes in northern Scottish water may be biased towards the Scottish coast (Malcolm *et al* ., 2010). With the exception of the Pentland Firth, existing evidence does not suggest that Orkney waters are of particular importance in the migratory routes of salmon from relevant SAC, but the relative paucity of data maintains some uncertainty on this issue. Nevertheless, given the scale of developments at the Fall of Warness, the temporary nature of operations and the limited nature of potential impact mechanisms on individuals from SAC, it is considered that there is no likely significant effect on any relevant SAC.

Appraisal conclusion for salmon as qualifying species of European sites: There is not a likely significant effect on salmon as qualifying features of SAC, so no further consideration under HRA is required.

4.2.5 Appraisal of PMFs and other natural heritage interests

Diadromous fishes

Diadromous species relevant to the seas around Orkney are Atlantic salmon, sea trout and European eel. River lamprey, sea lamprey and sparling are not thought to occur in these waters, but there have been some recent anecdotal records from the north coast of Scotland (*pers.comm.*, Iain Sime).

However, Orkney waters are used by salmon, trout and eel; these species are all included in the PMF list[7]. Indeed, there are salmon (on Orkney Mainland and the island of Hoy) and trout rivers in Orkney. Malcolm *et al.*, 2010 report that sea trout post-smolts do not migrate rapidly out to sea from inshore coastal areas, but tend to use near shore areas where available. Only one tagging study in the Northern Isles was mentioned in this report; all recaptures were within 2-3 miles of tagging. However, these findings may just reflect the restricted available data. Very little is known about the migration pathways of European eels, either as juveniles or adults, but the above report notes that waters around Orkney are particularly likely to contain migratory eels from northern continental Europe and the UK. Consequently, presence of these species at the Fall of Warness site may be considered likely but occasional.

Of the potential impacts identified in Table 8 and Table 9 as ‘potentially important’ (underwater noise, collision, EMF and barrier effects), it may be concluded that the potential for impact at a Scottish population-level is low due to the relatively small scale and temporary nature of developments at Fall of Warness lessening the capacity for impact, as well as the intermittent operating conditions of this non-commercial development. Potential impacts from underwater noise are further reduced by the relatively noisy baseline acoustic environment in the tidally active channel. Also, the device types and substrate on site neither necessitate nor allow noisy pile-driving operations, which would otherwise have potential disturbance impacts (pile-driving is explicitly excluded from the project envelope).

Some uncertainty remains around some impact mechanisms for fish, particularly EMF and collision risk (see Gill and Bartlett, 2010), and while the risk of population-level effects appears low, there may be merit in revisiting an impact appraisal on these topics at a later date. Various research projects are underway on these matters, including at the Fall of Warness test site, and are formally incorporated in the monitoring and research section of this document.

Appraisal conclusion for diadromous species: Any potential impacts are not regarded as important at a Scottish population level. However, some monitoring and research in the context of the test facility could have merit.

[7] http://www.snh.gov.uk/docs/A1327320.pdf

Marine Fishes

Gadoids

Aside from the commercial importance of most gadoids, species such as cod, whiting, saithe, ling, Norway pout and haddock are also of ecological and therefore conservation value. They have and will continue to be vulnerable and sensitive to a range of stressors, albeit to varying extents in different locations. Indeed, cod, whiting (juveniles only), saithe (juveniles only), ling and Norway pout are included on the PMF list[8]. Ling and Norway pout are unlikely to present at the Fall of Warness site, both preferring deeper waters and Norway pout also preferring water over muddy substrates (Fishbase, 2012). Although they are unlikely to have a particular dependence on it, cod, saithe, whiting and, to a lesser extent, haddock are all likely to be found periodically within and moving through the Fall of Warness site, including as juveniles. The locality of Fall of Warness is not known, however, as a high intensity spawning or nursery ground for these species (Coull *et al.,* 1998; Ellis *et al*., 2010).

Being of intermediate hearing ability, gadoids have some sensitivity to loud noises (Scottish Executive, 2007a), but the absence of pile-driving activity within the project envelope removes concern over the disturbance of these species. Although noise from drilling operations is likely to take place, such operations will be short-term, relatively localised, limited to a maximum of 12 devices at 9 berths, and to some extent masked by the naturally loud environment in a tidally active channel. However, some gadoids (e.g. cod, haddock) are known to use vocalisations for communication, including during breeding. The potential for lower-frequency operational turbine noise to impact upon these behaviours is poorly understood and merits further research. Nevertheless, at the scale of developments within the project envelope, population-level impacts are extremely unlikely. While the site is within the wider potential spawning grounds for some species (Coull *et al.,* 1998; Ellis *et al*., 2010), the Fall of Warness is not in itself known as a discrete spawning area.

Some gadoids (e.g. saithe) are relatively likely to aggregate around turbines and infrastructure, as they do around other offshore structures, such as oil and gas platforms (e.g. Soldal *et al.*, 2002), although it is not known if this is limited to periods of slack tide. The small number of devices within the project envelope means that population effects are very unlikely.

Gadoids are not particularly sensitive to suspended sediment, with most species being well adapted to a range of turbidity conditions and having mobility that allows avoidance of unacceptable conditions. Being pelagic spawners they are also not particularly vulnerable to smothering by sediment. Any residual impacts are very unlikely at the Fall of Warness, not least due to the likely rapid dispersal of material on the tide.

As demerso-pelagic species, gadoids have some degree of association with the seabed, but not with discrete patches of seabed. Consequently, and in the context of the small scale of the Fall of Warness project envelope, loss of or damage to seabed habitats, or alterations to benthic habitats through non-native species, are not of concern. Gadoids are also unlikely to be sensitive to changes in local hydrodynamics or sediment processes, particularly regarding the small scale of these changes expected at the Fall of Warness.

[8] http://www.snh.gov.uk/docs/A1327320.pdf

As for salmonids, there is some uncertainty over the issues of collision risk and EMF effects (Scottish Executive, 2007b), particularly given the potential for some aggregation around devices and infrastructure. A considered view is that these are unlikely to be important population-level issues for a relatively small development such as at Fall of Warness, but there may be opportunities for the test site to contribute to furthering understanding of this topic through research and monitoring. EMF effects are, however, logically expected to be of less concern for species other than elasmobranches and diadromous species, whose sensory physiology inherently increases their electro- and magnetic sensitivity, respectively.

Appraisal conclusion for gadoid species: Any potential impacts are not regarded as important at a population level, but some monitoring and research in the context of the test facility would have merit.

Clupeids

Herring and, to a lesser extent, sprat are species of commercial importance in Scottish waters. They are also both of ecological value as a food source for a variety of bird, mammal and fish predators. Herring stocks were severely depleted during the industrial fishing era and, while there has been considerable recovery of herring stocks, the stock centred around the PFOW area is one of the least well recovered (Marine Scotland, *pers.comm*). Consequently, further pressures on this stock should be avoided. Herring and sprat are both likely to occur in the Fall of Warness site. For herring the wider area is regarded as part of a spawning ground (Ellis *et al*., 2010), but the substrate type within most of the Fall of Warness site is not suitable for this purpose.

Due to the physiology of their swim-bladders and inner-ears, clupeids are hearing specialists and therefore sensitive to underwater noise (Scottish Executive, 2007a). Despite this, as for other species, concern over potential underwater noise impacts are removed by the lack of pile-driving activity as well as the small number of devices and the naturally loud conditions of this tidally active channel. Clupeids are not known to make vocalisations, so potential masking of these by turbine noise is not of concern.

As pelagic species, clupeids have limited association with the seabed and so impacts associated with the seabed, such as loss of/damage to habitats or the introduction of non-native species are not of concern. Herring do lay eggs on the seabed, but are limited in this to clean gravelly substrates, none of which is known to occur at the Fall of Warness.

The scale of the development in the Fall of Warness is considered very unlikely to have a measurable effect on hydrodynamics or sediment processes (see Section 4.3); in-turn, impacts on the feeding activity of clupeids, which often filter-feed plankton in well-mixed nutrient-rich waters such as this, are not expected. As pelagic species, clupeids are smaller, less inclined to aggregate around structures and higher in the water column. Consequently, they are not expected to be particularly vulnerable to collision with the turbine or to EMF effects. The limited scale and duration of operations in the Fall of Warness, coupled with the dominant substrate types and the tidally active nature of the site, also remove any potential concern over impacts upon suspended sediment concentrations or smothering impacts.

Appraisal conclusion for clupeid species: Any potential impacts are not regarded as important at a population level.

Sandeels

Sandeels are particularly important in Scottish inshore waters, providing an important food source for a variety of bird, mammal and fish predators. Some seabird species are almost entirely dependent on sandeels when feeding their chicks. As such, sandeels are included on the PMF list.

Sandeels have a strong benthic association, being of relatively low mobility and having a strong preference for coarse and medium grained sands (Holland *et al.*, 2005). Consequently, the largely rocky substrate of the Fall of Warness site is mostly unsuitable for sandeel populations of any importance. Impacts of collision, underwater noise and habitat creation are largely irrelevant to sandeels.

It is likely, however, that there may be patches of sandeel in sandy substrates in the shallow margins of the site, through which some cabling is routed. However, relevant cabling works covered within the project envelope are limited to the recovery and replacement of existing cables and so are spatially and temporally very limited in their potential impact. Loss of sandeel habitat at the scale of the development is therefore not of concern for sandeels at the population level. Sandeels are not thought to be sensitive to EMF, but any residual impacts are not considered important at the scale of this development.

Any impacts on hydrodynamics and sediment processes are considered insufficient to alter the distribution of available habitat (see Section 4.3). Furthermore, the strong tidal flow in the area, coupled with the limited number of berths, greatly limits any potential concern for suspended sediment or smothering of sandeel habitat by released sediments or drill cuttings.

Impacts associated with non-native species are not foreseen, but any unpredictable impacts should be addressed through precautionary good-practice mitigation.

Appraisal conclusion for sandeels: Any potential impacts are not regarded as important at a population level or of a degree that could have measurable effect on key predators.

Elasmobranches

Potential impacts on basking sharks are appraised in Section 4.4.

Other elasmobranch species include common skate and spiny dogfish (spurdog), both of which are on the PMF list. Other skate and ray species that occur in Orkney waters are less relevant than common skate as, despite a preference for soft substrates, common skate are also found in rocky areas. Orkney is thought to be one of the few remaining strongholds for common skate, which have been widely depleted in UK waters. Some useful information on local sightings can be found at www.orkneyskatetrust.org.uk/. Spurdog are an abundant shark of global distribution (Fishbase, 2012), but may be sensitive to a range of impacts. They occur both inshore and offshore. This includes areas such as Fall of Warness, although this may not be favoured habitat.

Elamobranch species are not regarded to be of particular sensitivity to noise, non-native species, suspended sediment or habitat creation, particularly at the small scale of such impacts in this development, and so are not considered further. As for other species-groups, any impacts on hydrodynamics and sediment processes are considered insufficient to alter the distribution of available habitat relevant to elasmobranches (see Section 4.4).

Elasmobranches may be particularly sensitive to EMF effects, but these effects are poorly understood (Scottish Executive, 2007b). Given the limited number of devices and associated cabling, any effects on elasmobranches are spatially restricted and not expected to be of importance at a population level. This topic should be revisited in due course with support from a better evidence base; there could be merit in a monitoring programme to improve understanding of EMF emissions from different cable types. Although likely to be periodically present, the site is not known for large numbers of elasmobranchs; this, in combination with the small number of devices, limits any residual concern over potential collision risk as unimportant at the population level.

Loss of habitat suitable for egg-case development may also be concern for common skate, while spurdog bear live young. However, the limited number and footprint of devices and cabling within the project envelope lessens concern considerably and is not important at the population level. The hydrodynamics of the locality remove any potential concern over risks of smothering of egg cases.

Appraisal conclusion for elasmobranch species: Any potential impacts are not regarded as important at a population level, but some monitoring and research in the context of the test facility would have merit.

Other marine fin-fish

Other fish and shellfish species may be of some ecological value on a local or regional scale. This may include some commercially caught species, and or species not on the PMF list such as butterfish, which are a key prey species for black guillemot. Of those fish species on the PMF list, anglerfish (juvenile only), sand goby and mackerel merit further consideration. While within a large area identified as potential nursery area for anglerfish, the Fall of Warness site is not expected to be of particular importance. Nor do any of the potential impacts mechanisms hold particular risks for this species. Sand goby are likely to be present in the sandy margins of the site but have habitat preferences that render most of the development site and associated impacts irrelevant. Mackerel is a pelagic fish not dissimilar to herring in its ecological importance and in the manner in which it uses sites such as the Fall of Warness. The hearing sensitivity of mackerel is less than that of herring, hence potential disturbance impacts are of even less concern. The potential impacts on mackerel are not regarded as being of concern at the population level. It is possible, however, that the continued use of the site by pelagic fish, such as mackerel and herring, heightens the risk of impacts such as collision on predatory birds and mammals. It is possible that some fish species would be attracted to the use of underwater lighting around turbines, which may in turn increases the risk to their predators. However, it is not known which, if any, species in Orkney waters would respond in this way. Any use of underwater lighting should incorporate some monitoring until this issue is better understood.

Appraisal conclusion for other marine fin-fish: Any potential impacts are not regarded as important at a population level.

Marine Shellfish

Crustaceans

The Fall of Warness supports a variety of crustacean species (Foubister, 2005), including some of commercial importance (e.g. brown crab, velvet crab and lobsters), and may well support others of conservation interest (e.g. European spiny lobster – on the PMF list). Loss of habitat for these species is inevitable, but is at such a small scale as to be unimportant in the context of the wider area. Furthermore, the device foundations, mooring and various infrastructure may provide new habitats that crustacean species would be likely to take advantage of and may therefore be perceived as a positive impact. It is possible that some species, such as some pelagic crustaceans, could be attracted by the use of underwater lights. However, the importance and implications of this possibility for their predators are poorly understood and any use of underwater lighting should incorporate some monitoring.

In the high-flow environment of the Fall of Warness, suspension and subsequent settlement of sediment or drill cuttings, and any release of contaminants, will be limited and therefore of little concern to crustaceans. Furthermore, given the limitations of the project envelope, Fall of Warness deployments are unlikely to have measurable impacts upon hydrodynamics and sediment processes (see Section 4.3). Some residual concern may exist over non-native species, but good practice should minimise risks.

The implications of EMF for crustaceans are poorly understood, although they are generally assumed to be of low sensitivity. Any residual impacts are unlikely to be important at the scale of this site, but there may be merit in monitoring or research on this topic.

Appraisal conclusion for crustaceans: Any potential impacts are not regarded as important at a population level, but some monitoring and research in the context of the test facility would have merit. Good practice should be adopted to reduce the risk of introducing non-natives.

Molluscs

A variety of gastropod and bivalve species may be present at the Fall of Warness site, although there is no reason to expect the locality to be of particular importance in the context of the wider area. As for other interests, the tidally active nature of the locality, coupled with the small scale and temporary nature of operations at the Fall of Warness test site, remove any significant concern over potential impacts of suspended sediment, or smothering. Habitat damage, EMF and changes to hydrology and sediment processes are unimportant at the scale of potential impacts.

Similar to crustaceans, habitat for mollusc attachment or grazing will be lost, but new habitat that some species can colonise will also be created. As particularly low-mobility or sessile species, molluscs are at some risk of impact from marine non-natives.

Appraisal conclusion for molluscs: Any potential impacts are not regarded as important at a population level, but some monitoring and research in the context of the test facility could have merit.. Good practice should be adopted to reduce the risk of introducing non-natives.

4.2.6 Fish and shellfish receptor conclusions

A summary of the appraisal for each of the receptors is provided in Table 11 below. Note that, even where no important impacts on the development site are identified, in some cases there may still be a recommendation for some mitigation or monitoring. Under these circumstances, mitigation would be regarded as good-practice rather than a necessity, while monitoring may serve to improve generic understanding of the relationships between stressors and receptors.

Receptor	Conclusion	Monitoring and/or mitigation identified?
Diadromous fish.	No important impacts, including no LSE on any European Sites.	Yes – see Table 12
Marine fish.	No important impacts.	Yes – see Table 12
Marine shellfish.	No important impacts.	Yes – see Table 12

Table 11: Summary fish and shellfish appraisal conclusions.

It is concluded that no important impacts of relevance to fish and shellfish ecology are expected from developments at the Fall of Warness EMEC test facility, based on the parameters of the project envelope described in Annex 1. However, given uncertainties regarding some potential impacts and the opportunity to learn from test deployments, some potential mitigation and monitoring measures are presented in Table 12 below (this table should be reviewed as knowledge increases). Some such measures will be appropriate as conditions on the Marine Licence, whereas others may just be recommended as good practice.

Site-wide monitoring and research ideas may be more effectively pursued at a strategic level (whether by EMEC, The Crown Estate or Marine Scotland, or by a developer consortium), but developer input or ideas are welcomed. This is discussed further in Section 5 of this document.

Potential Residual Impacts	Relevant receptors	Relevant impact-pathway	Monitoring/Mitigation
Death or injury.	Diadromous fish; gadoids.	Collision with blades.	Pursue passive and active monitoring at selected sites to inform knowledge base. Any use of underwater lighting at night to be gradual and alongside monitoring to determine any fish attraction and collision risk for predators.
Behavioural change.	Diadromous fish; gadoids; elasmobranchs.	EMF.	*In situ* measurements of strength and range of Ei and B fields under different energy generation scenarios.
Fish/shellfish community composition and behavioural change.	Some fish and shellfish species, particularly gadoids and crustaceans; (also, indirect	Habitat creation and fish aggregation.	Pursue passive and active monitoring at selected sites to inform knowledge base. Any use of underwater lighting at night to be gradual and alongside monitoring to determine any fish attraction and collision risk for predators.

	impacts on predators).		
Change to benthic communities.	Mostly shellfish and benthic fish.	Marine Non-Native Species.	Adopt good-practice as detailed in www.scotland.gov.uk/Resource/0039/00393567.pdf, www.mardep.gov.hk/en/msnote/pdf/msin1136anx1.pdf and www.ipieca.org/publication/alien-invasive-species-and-oil-and-gas-industry.

Table 12: Potential mitigation and monitoring measures relevant to fish and shellfish.

4.2.7 References

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4.3 Impact Appraisal: Hydrodynamic and Physical Processes

Prior to the fully detailed evaluations, this part of the appraisal picks up at 'Step 2' as described in Section 3 of this document. Although onshore impacts (including intertidal) are explicitly excluded from consideration throughout this documentation, this appraisal does give some consideration to the littoral fringe (i.e. the near-shore edge).

4.3.1 Potential effects

For receptors relating to hydrodynamic and physical processes, which are at this stage considered separately for the benthic, pelagic and coastal environments, the defined potential effect categories are applied to activities/effect pathways relevant to tidal energy developments comprising design-types involving the rotation of turbines within natural hydrodynamic conditions[9]. Deployment/installation effects (Table 13) are addressed separately from those during the operational and maintenance phases (Table 14).

Note that details specific to the Fall of Warness, both environmental and relating to project-specifications, are not considered until the detailed appraisal later in this section.

[9] Tidal developments that involve the manipulation of hydrodynamic conditions prior to the extraction of energy (e.g. tidal barrages) are explicitly excluded from the broad consideration of potential effects in Table 13 and Table 14.

Generic Potential Effects from Device Deployment		
Summary of activity categories – for detail see project envelope description (Annex 1) • Installation of device(s), and associated infrastructure (e.g. foundations; mooring systems; cabling; buoys) on the seabed, in the water column or above the surface • Use of vessels (e.g. DP vessel; jack-up barge; multi cat; workboat; dive-support vessel; crane-barge; tug; specialist cable-laying vessel.) • Deployment and use of equipment to monitor devices or other environmental parameters during installation (e.g. ROV, cameras or acoustic devices)		
Activity/potential effect pathway	**Natural heritage feature**	**Potential importance**
Changes to sedimentary processes (suspended sediment, sediment transport pathways and subsequent deposition) from foundation, mooring or cable installation.	Benthic environment.	Potentially important – changes to sediment processes through release of drill cuttings or dredge material during construction, and sediment deposition particularly, may effect the benthic environment but is likely to be temporary in the near-field[10]. Far-field effects may be longer-lasting, but will be limited by the dispersal of material. Importance will depend upon the sensitivity of the receiving environment to deposited sediment, local hydrodynamics, the physical characteristics of released sediment and the volume of sediment released.
	Pelagic environment.	Not important – in strong tidal streams, any changes to sedimentary processes in the pelagic environment during construction are expected to be very short-term in the near-field and negligible in the far-field.
	Littoral fringe.	Potentially important – increased sediment deposition to the coastal environment may occur as a result of release of drill cuttings or dredge materials during construction. The initial sensitivity and rate of recovery will be greater for some coastal habitats than others. Importance will also depend on the orientation and proximity of seabed works to sensitive coastal areas, local hydrodynamics and the volume and physical characteristics of released material.

Table 13: Potential effects upon hydrodynamic, sedimentary and coastal processes during device and infrastructure deployment; identifying activities/effect pathways and receptors for further assessment. Note that these evaluations are made *prior* to consideration of details particular to the Fall of Warness site.

[10] Near-field effects are considered to be those within the development envelope (i.e. lease area), including those in the immediate vicinity of individual devices and between devices. Far-field effects are further afield where the whle array influences the surrounding area.

Generic Potential Effects from Device Operation and Maintenance

Summary of activity categories – for detail see project envelope description (Annex 1)

- Physical presence of device(s), foundations, moorings, buoys and associated infrastructure on the seabed, in the water column or above the surface
- Operation of device(s)/power generation
- Repeat removal and redeployment of equipment for maintenance (e.g. turbine removed from water or floating structure removed from berth; replacement of mooring system)
- Other maintenance activities (e.g. Biofouling removal; ROV/diver inspection or repairs)
- Use of vessels (e.g. DP vessel; jack-up barge; multi cat; workboat; dive-support vessel; crane-barge; tug)
- Use of equipment to monitor devices in situ or other environmental parameters (e.g. ROV, cameras or acoustic devices)

Activity/potential effect pathway	Natural heritage feature	Potential importance
Changes to erosive forces/patterns and sedimentary processes (suspended sediment, sediment transport pathways and subsequent deposition) from presence/operation of devices & infrastructure.	Benthic environment.	Potentially important – altered hydrodynamics in the immediate vicinity of turbines may result in increased scouring and loss/release of sediment (if present). Far-field effects on the distribution and transport of sediment to and from the benthic environment may be difficult to predict, but may include increased sedimentation if energy has been removed from the system. Importance will depend upon the sensitivity of the surrounding benthic environment to changes in sediment dynamics, local hydrodynamics, the arrangement/spacing of devices and the level of energy extraction in the context of local conditions.
	Pelagic environment.	Not important – increases in suspended sediment are expected to be a result of scouring and therefore highly localised and rapidly dispersed in a tidally active area. The extraction of energy may result in higher rates of deposition/settlement of sediment over a wider area. This is unlikely to be of concern to the pelagic environment in a tidally active area.
	Littoral fringe.	Potentially important – extraction of energy from tidal areas may result in increased sediment deposition downstream (near and far field effects). Current speed may increase adjacent to devices/arrays, with a resultant increased likelihood of sediment entrainment. The presence of cabling and protection may alter patterns of scour and deposition in the near-shore and intertidal environments. Sensitivity will be greater for some coastal habitats than others. Importance will also depend on local hydrodynamic conditions, the availability of sediment, the

		physical arrangement/spacing of devices and the level of energy extraction in the context of local conditions.
Changes to biological productivity or feeding opportunities through alteration of the tidal or wave regime.	Benthic environment.	Potentially important – most arrangements of tidal devices that extract energy through rotating turbines are unlikely to alter hydrodynamics sufficiently to affect biological productivity or feeding opportunities in the benthic environment. However, developments with connectivity to sensitive estuarine or lagoon systems could have important effects in this regard. Importance will depend upon the level of energy extraction in the context of local conditions, and the sensitivity & functional role of affected benthic habitats.
	Pelagic environment.	Potentially important – only for very large arrays or deployments in areas of strong functional importance for mixing of nutrient rich waters (i.e. sea fronts) is it possible that there will be measurable effects in this regard. Such areas typically have high primary and secondary productivity and attract predatory fish, birds and mammals in large numbers.
	Littoral fringe.	Potentially important – mos arrangements of tidal devices that extract energy through rotating turbines are unlikely to alter hydrodynamics sufficiently to affect biological productivity or feeding opportunities in the coastal environment. However, developments with connectivity to sensitive estuarine or lagoon systems could have important effects in this regard. Importance will depend upon the level of energy extraction in the context of local conditions, and the sensitivity & functional role of affected benthic habitats.

Table 14: Potential effects upon hydrodynamic, sedimentary and coastal processes during the operational and maintenance phase; identifying activities/effect pathways and receptors for further assessment. Note that these evaluations are made *prior* to consideration of details particular to the Fall of Warness site.

4.3.2 Natural heritage context

Foubister (2005) provides detailed information on the coastal geology and hydrodynamic processes. Key extracts are as follows:

> *The shoreline near the landfall comprises low sandstone/mudstone cliffs fronted by a storm beach of cobbles and small boulders. The main beach comprises superficial sand overlaying rocky outcrops, constrained to the north and south by the rocky headlands at Sandybank and Neven Point. The intertidal bedrock forms a series of parallel ridges, with sand filling the intervening gullies.*
>
> *The Fall of Warness area is subject to strong tidal streams, with peak spring tide speeds in excess of 3.5 m/s. It is also exposed to high-energy waves from the southeast and the northwest. The main channel has a water depth of over 50 m, and the bed is rocky, with surface sediment along the coastal fringe. The surrounding shorelines are mainly rocky, with pocket beaches. The area is affected by tidal surges, with the 50 year return period surge level given as about 1.35 m. The combination of gale force weather conditions and the strength of tidal streams can make navigation hazardous in the Fall of Warness, as is shown Extract from Admiralty Sailing Directory below.*
>
> *The test facility area is directly exposed to wind sea and swell from the northwest and the southeast due to the orientation of the channel and the shelter derived from the surrounding islands. Waves from other directions can reach the area due to diffraction and refraction, making the area very dynamic. Overfalls, due to opposing wave and tide directions, are common in the area of the test bays. The landfall area is much more protected than the Fall area. Shelter from the westerly sector is provided by the intertidal rock out crop at Seal Skerry, but wind, sea and swell can still reach the nearshore from Stronsay Firth and beyond. Locally generated waves from the south are also significant (HR Wallingford, 2005). The mean significant wave height in the months of December-March is 2.5-3 m in the surrounding waters of Orkney. Wave heights in these waters are similar throughout the year, with 2-2.5 m in April and September- November, and 1.5-2 m in May-August (British Oceanographic Data Centre 1998).*

4.3.3 Impact appraisal mechanisms for the Fall of Warness

This impact appraisal takes account of a maximum-case scenario based on a project envelope description (Annex 1) where all available berths within the test site are developed and operating at capacity. It addresses the differing consenting and licensing regimes (see Table 15 below). This appraisal will inform the consenting process for both Marine Licence and Section 36 applications. However, it should be noted that, if there are key deviations in the device design or in installation or maintenance activities, further appraisal work may be required. Any additional appraisal work required will be undertaken by the individual developer (further advice should be sought from EMEC in the first instance).

Feature type	Appraisal mechanism/relevant legislation	Applicable	Reasoning
Qualifying features of European sites.	Habitats Regulations Appraisal (HRA) - Habitats Regulations 1994 (as amended).	N	No LSE or measurable impacts of relevance to nearby SAC or SPA.
European Protected Species.	EPS legislation - Habitats Regulations 1994 (as amended in Scotland)	N	No measurable impacts of relevance to EPS.
Notified features of SSSIs.	SSSI legislation - Nature Conservation (Scotland) Act 2004 (as amended)	N	No measurable impacts of relevance to nearby SSSIs.
Protected features of MPAs	Marine (Scotland) Act 2010.	N	Not capable of affecting protected features of MPAs.
PMFs	Marine (Scotland) Act 2010.	N	No measurable impacts of relevance to PMFs.
Other sensitive natural heritage features.	Appraisal of other features under: - Electricity Works (EIA) (Scotland) Regulations (Amendment) 2008; - Marine Works (EIA) (Amendment) Regulations 2011; - Marine (Scotland) Act 2010.	Y	Captures assessment of all other natural heritage features at a scale of concern.

Table 15: Appraisal mechanism for hydrodynamic and physical processes.

4.3.4 Appraisal of other natural heritage features

Under a worst-case scenario, the maximum number of devices being installed or operated at any one time will be 12 (at 9 berths). Any changes to hydrodynamics and physical processes during installation procedures of either devices or infrastructure will primarily be limited to the installation period. Wallingford (2005) previously determined that these could occur without serious consequence for physical process in the subtidal or intertidal. This appraisal considers that this determination can also apply now, even with extrapolation of potential impacts to the larger number of potential devices and cable length. Any disturbed or released material (e.g. drill cuttings) will be rapidly and widely dispersed.

Any changes during the operational phase will also be temporary, given the status of a site as a test-centre. Furthermore, given the small number of devices, the spacing of test berths and the intermittent nature of their operation at the test site, any measurable alterations to hydrodynamics and physical processes are predicted to be so small as to be of no importance to the local physical or biological environment. A similar conclusion is reached for cabling works (i.e. see Wallingford, 2005), partly due to the dominance of hard substrates and the routing of cables approximately parallel with the peak tidal stream. A previous assessment by Wallingford (2005), determined that there would be no determinable impact on hydrodynamic or physical processes, except a 0.25% reduction in energy within the Fall of Warness area from operation of test-devices at the four berths then being considered. The previous assessment actually considered multiple devices at each berth. The current project envelope considers a maximum potential of 18 rotors on 12 devices across 9 berths. However, even with a precautionary extrapolation and buffer of this statistic to 1.5% [11], this value remains negligible. Furthermore, Wallingford (2005) also noted that the test berths considered were all in locations with no deposits of mobile material so scour and sediment distribution is not a significant issue. This is still largely true with the additional four existing berths also now part of the appraisal; the southern and easternmost existing berths occupy a substrate comprising more cobble with some interstitial sand, but is still primarily a rocky substrate. Given the highly energetic character of the Fall of Warness, the nearfield effects are unlikely to cause geomorphological changes. In a similar sense the modest amount of energy expected to be removed when the devices are operational (which is intermittent), is only likely to be measurable relatively close into the devices. As a result flow patterns are likely to return towards background rates within a relatively close distance especially given the interaction of adjacent flows within the archipelago. Of the potential effects noted above, those in relation to changes in biological productivity, feeding opportunities or erosive forces due to an altered tidal or wave regime, and all those in relation to the coastal environment, are regarded as negligible to the extent that they will mostly be immeasurable. Consequently, within the specifications of the project/site envelope, no further assessment is required in relation to hydrodynamic and coastal processes.

Despite the absence of any concern over impacts upon hydrodynamics and physical processes at the EMEC test facility, it is likely that there will be such concerns for some commercial-scale projects. Consequently, advantage should be taken of any opportunity to measure any such changes in the immediate vicinity of devices and infrastructure, such that the results can be extrapolated to inform relevant aspects of EIAs for larger developments. Some device-specific monitoring may, therefore, have merit.

The current ES for the Fall of Warness site (Foubister, 2005) recommends regular ROV surveys around device foundations to consider impacts on the benthic environment from scouring or other device-specific impacts. Evidence to date has not demonstrated any impacts in this regard, presumably due to the solidity of the exposed seabed and low levels of mobile material. Consequently, it is not expected that this monitoring activity will be required to continue at this site unless device-specific considerations suggest otherwise.

Appraisal conclusion for all aspects of the hydrodynamic and physical environment/processes: Any potential impacts are not regarded as important at the scale of the development, but some device-specific monitoring may have merit to inform impact assessments at commercial sites.

[11] Wallingford (2005) estimated a 0.25% reduction of tidal energy based on devices at 4 berths. If single-rotor devices were under consideration, an extrapolation for 18 rotors would require a 4.5-fold increase, resulting in an estimated 1.125% reduction in energy. A precautionary 1.5% figure allows for the slight increase in the rotor diameter within the calculations and the potential for use of some multiple-turbine devices.

4.3.5 Hydrodynamic and physical processes receptor conclusions

A summary of the appraisal is provided in Table 16 below. Note that, even where no important impacts on the development site are identified, in some cases there may still be a recommendation for some mitigation or monitoring. Under these circumstances, mitigation would be regarded as good-practice rather than a necessity, while monitoring may serve to improve generic understanding of the relationships between stressors and receptors.

Receptor	Conclusion	Monitoring and/or mitigation identified?
Hydrodynamic and Physical Processes.	No important impacts.	Yes – see Table 17

Table 16: Summary of hydrodynamic and physical processes appraisal conclusions.

It is concluded that no important impacts of relevance to hydrodynamics or physical processes are expected from developments at the Fall of Warness EMEC test facility, based on the parameters of the project envelope described in Annex 1. No mitigation proposals are being made at present, but device-specific monitoring may have merit in understanding downstream effects of the device to inform impact assessments for commercial-scale proposals as detailed in Table 17 below (this table should be reviewed as knowledge increases).

Potential Residual Impacts	Relevant receptors	Relevant impact-pathway	Monitoring
Erosion and sedimentation.	Hydrodynamic and Physical Processes.	Changes to erosive and sedimentary processes.	Although not regarded as important for the Fall of Warness, acquiring an understanding of changes to hydrodynamic forces around particular devices would provide data that could inform impact modelling for later commercial-scale proposals. Lambkin *et al* (2008) may provide some useful information.

Table 17: Potential monitoring measures relevant to hydrodynamics and physical processes.

4.3.6 References

British Oceanographic Data Centre. 1998. United Kingdom Digital Marine Atlas, Third Edition Sponsored by Natural Environment Research Council.

Foubister, L. 2005. EMEC Tidal Test Facility, Fall of Warness, Orkney. Environmental Statement. Prepared by Aurora Environmental Ltd.

HR Wallingford. 2005. Tidal Test Facility, Orkney: Coastal and seabed processes review. HR Wallingford.

Lambkin DO, Harris JM, Cooper WS, Coates T. 2008. Coastal processes modelling for offshore wind farm Environmental Impact Assessment: best practice guide. Cowrie.

4.4 Impact Appraisal: Basking sharks

Prior to the fully detailed evaluations, this part of the appraisal picks up at ‘Step 2’ as described in Section 3 of this document.

4.4.1 Potential effects

For basking sharks, the defined potential effect categories are applied to activities/effect pathways relevant to tidal energy developments for design-types that involve the rotation of turbines within natural hydrodynamic conditions[12]. Deployment/installation effects (Table 18) are addressed separately from those during the operational and maintenance phases (Table 19).

Note that details specific to the Fall of Warness, both environmental and relating to project-specifications, are not considered until the detailed appraisal later in this section.

[12] Tidal developments that involve the manipulation of hydrodynamic conditions prior to the extraction of energy (e.g. tidal barrages) are explicitly excluded from the broad consideration of potential effects in table Table 18 and Table 19.

Generic Potential Effects from Device Deployment

Summary of activity categories – for detail see project envelope description (Annex 1)

- Installation of device(s), and associated infrastructure (e.g. foundations; mooring systems; cabling; buoys) on the seabed, in the water column or above the surface
- Use of vessels (e.g. DP vessel; jack-up barge; multi cat; workboat; dive-support vessel; crane-barge; tug; specialist cable-laying vessel.)
- Deployment and use of equipment to monitor devices or other environmental parameters during installation (e.g. ROV, cameras or acoustic devices)

Activity/potential effect pathway	Natural heritage feature	Potential importance
Underwater noise from active acoustic equipment leading to disturbance[13].	Basking shark.	Not important – hearing physiology of basking sharks is poorly understood, meriting revisiting of this topic in future. However, elasmobranches generally are considered to have relatively low sensitivity to noise, particularly at high frequencies.
Installation vessel (s) transits and manoeuvring leading to disturbance.	Basking shark.	Potentially important – basking sharks may be sensitive to vessel presence and associated activities (e.g. Kelly *et al*. 2004; Speedie *et al*. 2009). Importance will depend upon the duration and intensity of vessel activity, the likelihood and fidelity of basking sharks in the area, the opportunity for sharks to avoid areas of disturbance and the motivation for the basking sharks to be in that area (e.g. quality of feeding opportunity). The need for a licence to disturb basking shark should be considered.
Underwater noise from foundation/mooring installation methods and vessels leading to: auditory injury, death or disturbance.	Basking shark.	Potentially important – the hearing physiology of basking sharks is poorly understood, but they may be sensitive to noise and vibration from foundation installation activities, such as drilling, which are intuitively more likely to occur at audible frequencies. Importance will depend upon the range and frequency of noise sources (including background noise), duration and intensity of activity, the likelihood and fidelity of basking sharks in the area, the opportunity for sharks to avoid areas of disturbance and the motivation for the basking sharks to be in that area (e.g. quality of feeding opportunity). The need for a licence to disturb basking shark should be considered.

[13] The term 'disturbance' includes all behavioural responses of biological consequence, including displacement from the vicinity of the activity.

Increased suspended sediment/turbidity (including release of drill cuttings).	Basking shark.	Not important – although basking sharks, as filter feeders, could be negatively affected by increased suspended sediment concentrations, in tidally active sites suspended material will disperse quickly and widely and so basking sharks are unlikely to be exposed to the effect once construction activity is complete.
Entanglement in lines or cabling leading to: injury or death.	Basking shark.	Not important – it is unlikely that basking sharks will be exposed to this potential interaction during installation procedures as any construction activities with associated cables or lines not under tension would be likely to be of very short duration.

Table 18: Potential effects upon basking sharks during device and infrastructure deployment; identifies activities/effect pathways and receptors for further assessment. Note that these evaluations are made *prior* to consideration of details particular to the Fall of Warness site.

Generic Potential Effects from Device Operation and Maintenance

Summary of activity categories – for detail see project envelope description (Annex 1)

- Physical presence of device(s), foundations, moorings, buoys and associated infrastructure on the seabed, in the water column or above the surface
- Operation of device(s)/power generation
- Repeat removal and redeployment of equipment for maintenance (e.g. turbine removed from water or floating structure removed from berth; replacement of mooring system)
- Other maintenance activities (e.g. Biofouling removal; ROV/diver inspection or repairs)
- Use of vessels (e.g. DP vessel; jack-up barge; multi cat; workboat; dive-support vessel; crane-barge; tug)
- Use of equipment to monitor devices in situ or other environmental parameters (e.g. ROV, cameras or acoustic devices)

Activity/potential effect pathway	Natural heritage feature	Potential importance
Underwater noise from active acoustic equipment leading to disturbance[2].	Basking shark.	Not important – hearing physiology is poorly understood, meriting future revisit of this topic. However, elasmobranches are considered to have relatively low sensitivity to noise, particularly at high frequencies.
Maintenance vessel transits and manoeuvring leading to disturbance.	Basking shark.	Potentially important - basking sharks may be sensitive to vessel presence and activity (e.g. Kelly *et al*., 2004; Speedie *et al*., 2009). Importance will depend upon the duration and intensity of vessel activity, the likelihood and fidelity of basking sharks in the area and the opportunity for sharks to avoid areas of disturbance. The need for a licence to disturb basking shark should be considered.
Other maintenance activities (i.e. non vessel-based) leading to: disturbance.	Basking shark.	Not important – maintenance activities include inspection (e.g. divers/ROV), repairs or temporary retrieval and replacement of nacelles by winch. In all cases it is the presence of the accompanying vessel that presents the primary disturbance risk, and is appraised separately.
Underwater noise from turbine	Basking shark.	Potentially important – the hearing physiology of basking sharks is poorly understood. However, some other elasmobranches are attuned to low-frequency sounds for prey detection (Helfman *et al.* 1997), thus turbine

operation leading to: disturbance.		operation noise is potentially audible. Although precautionary at this stage, potential for impact remains. Importance will depend upon noise signatures in the context of background and anthropogenic noise, the layout of devices, the likelihood and fidelity of basking sharks in the area, the opportunity for sharks to avoid areas of disturbance and the motivation for the basking sharks to be in that area (e.g. quality of feeding opportunity). The need for a licence to disturb basking shark should be considered.
Entanglement in lines or cabling leading to: injury or death.	Basking shark.	Potentially important – relatively few tidal turbines involve rotating blades that are suspended mid-water or floating structures that are anchored/moored. However, those that do may present an entanglement risk, although the degree of risk is at present poorly understood. Importance will depend upon the likelihood of basking sharks occurring, the location and spacing of devices, and the design of mooring and cabling arrangements. The need for a licence to disturb basking shark should be considered.
Changes to hydrodynamic and sediment regime.	Basking shark.	Potentially important – the relationship between hydrodynamic conditions and the importance of an area for basking sharks is poorly understood, but there is some evidence to suggest that tidal front systems have some disproportionate value for this species (Speedie *et al*. 2009). Consequently, a precautionary view is taken at present that extraction of tidal energy on a sufficient scale could have biological implications for basking sharks.
Collision with turbine blades leading to: injury or death.	Basking shark.	Potentially important – Potential for impact is poorly understood, but importance may depend upon turbine location and spacing (including water depth), the physical and rotational characteristics of turbines, and the likelihood and fidelity of basking sharks occurring. Even where presence is occasional a licence to disturb basking shark may be required.
Electromagnetic Field (EMF) effects.	Basking shark.	Not important – understanding of EMF and animal responses is limited and merits revisiting in the future. While elasmobranch species are typically more sensitive to the electric component of EMF than other fish species, information to date suggests that in water the fields dissipate rapidly. As basking sharks swim in relatively deep water and are unlikely to spend much time close to the seabed at sites with high tidal flows, the likelihood of regular or prolonged exposure to high EMFs is very low.
Presence of tidal device (s) and associated infrastructure leading to: barrier effects.	Basking shark.	Potentially important – basking sharks may utilise or move though sounds and channels that may also present opportunity for tidal development. Importance will depend upon the spatial occupancy of the channel by tidal devices (in three dimensions), physical characteristics of the devices, the importance of the vicinity for passage of basking sharks and the likelihood of disturbance from operational noise of turbines.

Table 19: Potential effects upon basking sharks during the operational and maintenance phase; identifies activities/effect pathways and receptors for further assessment. Note that these evaluations are made *prior* to consideration of details particular to the Fall of Warness site.

4.4.2 Natural heritage context

Basking sharks are a wide ranging species occurring from temperate waters of the European continental shelf as far north as the Arctic (Sims, 2008). They are most commonly sighted along the western seaboard of British and Irish waters. Recent warming of European seas has resulted in basking sharks occurring further north in recent decades, including around the coasts of Orkney (Sims 2008). Presently no robust estimates exist for the global or regional population size of basking sharks. The global population status of basking sharks is assessed as 'Vulnerable' (A1a, d, A2d) in the 2000 IUCN Red List. Two subpopulations, the North Pacific and the North-East Atlantic are assessed as Endangered.

Basking shark records from Orkney are widely scattered with no particular concentration in any one area. They have been recorded around Orkney in most months of the year, most frequently between spring and late summer. The peak period for records is between July and September, with sightings between November and April being rare (Evans *et al*. 2003).

At the Fall of Warness test site, Wildlife Observations carried out by EMEC at the Fall of Warness site between 2005 and 2009 show basking sharks recorded between June and October, with peak sightings in July and August. The number of observations has been variable, with more than forty in 2005, to fewer than five in 2009 (Robbins 2011). Sightings at Fall of Warness reflect the general pattern of records from around Orkney, with peak records at the site being between July and September and very few records between November and April.

4.4.3 Impact appraisal mechanisms for the Fall of Warness

This impact appraisal takes account of a maximum case scenario based on a project envelope description (Annex 1) where all available berths within the test site are developed and operating at capacity. It addresses the differing consenting and licensing regimes (see Table 20 below). This appraisal will inform the consenting process for both Marine Licence and Section 36 consent applications. However, it should be noted if there are key deviations in the device design or in installation/maintenance activities then further appraisal work may be required. Any additional appraisal work required will be undertaken by the individual developer (further advice should be sought from EMEC in the first instance).

Feature type	Appraisal mechanism/relevant legislation	Applicable	Reasoning
Qualifying features of European sites.	Habitats Regulations Appraisal (HRA) - Habitats Regulations 1994 (as amended).	N	Basking shark is not a qualifying feature of any SAC.
European Protected Species.	EPS legislation - Habitats Regulations 1994 (as amended in Scotland).	N	Not an EPS, however licence requirements under the WANE Act 2011 for basking shark are similar to EPS.
Notified features of SSSIs.	SSSI legislation - Nature Conservation (Scotland) Act 2004.	N	Basking shark is not a notified feature of any SSSI.
Protected feature of MPAs	Marine (Scotland) Act 2010.	N	Not capable of affecting basking sharks as a proposed protected feature of an MPA proposal.
PMF	Marine (Scotland) Act 2010.	Y	Basking sharks occasionally present within the Falls of Warness.
Other sensitive natural heritage features.	Appraisal of other features under: - Electricity Works (EIA) (Scotland) Regulations (Amendment) 2008; - Marine Works (EIA) (Amendment) Regulations 2011; - Marine (Scotland) Act 2010; - Wildlife & Countryside Act 1981 (as amended, including the Wildlife and Natural Environment (Scotland) Act 2011).	Y	Captures assessment of the impacts to basking sharks, including protection and licensing under the Wildlife and Countryside Act 1981 (as amended).

Table 20: Appraisal mechanism for basking sharks.

4.4.4 Appraisal of PMFs and other natural heritage features

Summary of the legal requirements for basking sharks

Protection of basking sharks has progressed through amendments to the Wildlife and Countryside Act 1981 (WCA) by the Nature Conservation (Scotland) Act 2004 and, more recently, under the Wildlife and Natural Environment (Scotland) Act 2011 (WANE Act), with licensing requirements similar to those for EPS. They are also listed as a PMF.

Under section 16(3) of the WCA 1981 (as amended) certain activities which would otherwise constitute an offence can be carried out legally under a licence (including disturbance, injury and killing offences). The WANE Act has added a new licensing purpose to the WCA at section 16(3)(i): *'for any other social, economic or environmental purpose'* for certain (non-bird) protected species, including basking sharks. Consequently, under the WANE Act, administration of licences for the protection of species under domestic law has been brought into line with the protection of cetaceans under European law. For activities relating to marine developments, this licence is issued by Marine Scotland. The legislation should be referred to for a full list of offences and licensable impacts[14].

It is the responsibility of the applicant to demonstrate that the licence (and the action which it authorises) meets the tests described below. Licences can be subject to conditions, including appropriate mitigation. There is no statutory requirement under this licensing purpose to consider the impact of the proposed activity on the conservation status of the species in question. However, in line with decisions in other areas of species licensing and to take forward the inherent principles of Part 1 of the WCA Act (species protection), the appraisal here incorporates consideration of impacts upon the conservation status of the species.

Licence requirements

Licence to disturb basking sharks may be required for activities that have the potential to cause disturbance, injury or death to basking sharks at the Fall of Warness test site. Such impacts may arise from noise emitted during installation of device foundations (e.g. drilling), or from noise emitted by operating turbines. These, and the risk of death or injury from colliding with an operational turbine, necessitate consideration of licensing requirements and tests. The appraisals below are informed by knowledge of the basking shark population at the time of writing. New proposals may require further assessment if there is any change in the status of the population. Such changes may have implications for the requirement for a licence or appropriate mitigation. Suitable mitigation may negate the need for a licence or may be included as a condition of the licence.

Licences may be granted to authorise activities that could affect basking sharks which would otherwise be illegal under the WCA. The following two tests must be satisfied before the licensing authority can issue a licence to permit otherwise prohibited acts:

> Test 1:
> Undertaking the conduct authorised by the licence will give rise to, or contribute towards the achievement of, a significant social, economic or environmental benefit.

Climate change is widely recognised as one of the great environmental challenges facing the world today. Scottish, UK and European targets for reducing carbon dioxide include those set through the UK Climate Change Act (2008), The Renewable Energy Strategy (2009), the Renewables Obligation (Scotland) Order 2002, National planning guidance (NPPG 6 revised 2000), Climate Change (Scotland) Act 2010 and Scottish Planning Policy, among others. In order to meet this target technologies such as marine energy are likely to play a major role. The proposed device testing will provide an essential stepping stone on the path to commercial viability of the tidal energy sector, with potential to provide economic benefits

[14] Full text of amended legislation not available at time of writing this appraisal.

as well as the delivery of energy targets in response to climate change. Further considerations in relation to Test 1 may be given by Marine Scotland.

Test 2: There is no other satisfactory solution.

The European Marine Energy Centre (EMEC) has been established as a test site for wave and tidal energy conversion devices, with support from government. The purpose of the unique testing facility is to assist and hasten the development of these renewable energy industries, against a background commitment to achieve significant reduction in reliance on carbon dioxide producing alternatives. Any alternative location would be unlikely to be satisfactory in terms economic, political or environmental expediency. Further considerations in relation to Test 2 may be given by Marine Scotland.

Consequently, where a need for licensing is identified, the appraisals below address the additional consideration of the proposal on the conservation status of the basking shark population.

Further appraisal may be required if (a) a proposal is outside of the project envelope, (b) if knowledge/data on the status of basking sharks at the development site or in their natural range changes, or (c) if knowledge regarding potential impact pathways change. These scenarios aside, the appraisal below should be adequate to inform licensing and consenting decisions. Current knowledge on the population status of the population and its presence at the Fall of Warness is summarised in Section 4.4.2 above.

The following appraisals first consider impacts in relation to whether an offence is likely under the protection afforded to basking sharks under the Wildlife and Countryside Act 1981 (as amended). It then considers whether a species licence is required to address this and if so provides commentary in relation to impacts upon the conservation status of the species.

Disturbance impacts

The noisiest activity undertaken during marine works at the Fall of Warness is thought to be associated with drilling to insert pin piles or monopiles. Vessels used in relation to foundation /mooring installation or O&M activities could also contribute high levels of noise and as such are also assessed below. The maximum (worse) case scenario would see drilling and associated works occurring at two separate berths at the same time (see Annex 1, Section 4.4.2 for further details).

The current state of knowledge on the hearing ability of basking sharks is very poor, but knowledge of elasmobranches generally suggests they are not hearing specialists. Some elasmobranches are believed to hear well at low frequencies (40Hz to 800Hz) for the purpose of prey-detection (Helfman *et al.* 1997; Myrberg 2001), although this function should not be a requirement for basking sharks. Although caution is required with some of the interpretations that follow, and there is merit in revisiting these topics in the future, basking shark hearing is assumed to be of relatively low sensitivity. Nevertheless, due to the protection status of the species, further appraisal is necessary. Due to the paucity of information on basking shark hearing capabilities, aspects of the appraisal relating to underwater noise are qualitative.

Each impact-pathway with potential to lead to disturbance effects is addressed below in turn.

A. Underwater noise from foundation/mooring installation methods and vessels, leading to: auditory injury (permanent or temporary), death or disturbance.

For the purpose of this assessment we consider source levels for drilling to be between 145-190 dB re 1 µPa at 1m (OSPAR Commission 2009). For the placement of the anchor blocks at the Fall of Warness, Beharie and Side (2011) note a peak to peak sound pressure levels equivalent to 167 dB at 1m and sound pressure levels associated with the chains, equivalent to a maximum of 173 dB at 1m (peak to peak). Therefore, from the limited information available at present, and given the expectation that basking shark hearing is of relatively low sensitivity compared, for example, to cetaceans, the broadband noise levels emitted during non-percussive drilling and anchor/mooring installation activities are not expected to exceed the threshold for lethality, permanent threshold shift (PTS) or temporary threshold shift (TTS) onset.

Richardson *et al.* (1995) reported that drilling from bottom-founded platforms tends to have strongest tones at very low frequencies. Furthermore drilling noise has been reported to have the majority of its energy below 1kHz, mostly below 500 Hz (Kongsberg 2012, Nedwell *et al.* 2003 & 2010). The low frequency noise emitted from drilling operations may therefore be within the hearing range of basking sharks. Indeed, some elasmobranches hear low-frequency sounds well, but it is not known if this applies to basking sharks. Consequently, there is potential for a disturbance effect.

B. Installation and C. maintenance vessel transits and manoeuvring leading to disturbance

A variety of vessels are used at the Fall of Warness including multicats, jack-up barges, tug supply vessels, dive support vessels, small tugs and smaller workboats, the largest of which are between 50 -100m in length. Richardson *et al.* (1995) estimates a 25m tug pulling a barge to have a source level of 166 dB re 1 µPa at 1m. Vessels between 50-100m have been estimated by OSPAR Commission (2009) to have a source level range from 165 – 180 dB re 1 µPa at 1m, which we consider to adequately cover potentially noisier vessels most likely to be utilised at the FoW. From the limited information available at present, and given the expectation that basking shark hearing is of relatively low sensitivity compared, for example, to cetaceans, the broadband noise levels generated by vessels are not expected to exceed the threshold for lethality, PTS or TTS onset for basking sharks.

The frequency range of vessel noise is related to the size of the vessel, among other factors. In general, peak frequencies increase as vessel size decreases. Large ships emit noise from the tens up to hundreds of hertz. Medium size (approximately 30 m length) and smaller boats typically emit noise from 20 Hz to 6 kHz (Richardson *et al.* 1995) or to 10 kHz (Thomsen *et al*. 2006). The frequency range will vary depending on the types of vessel in the area, among other factors, but it is possible that the vessels operating in the Fall of Warness may be within the hearing range of basking sharks.

The maximum number of vessels operating in the Fall of Warness at any one time could be up to 14, although this occurrence is considered rare and moreover, most activity is likely to be aimed at times of lower tidal-stream flow and so the duration of multiple vessel activity is likely to be relatively focused. Nevertheless, there is potential for this noise (or vessel presence) to cause some form of disturbance effect, albeit in the context of an area with existing natural and anthropogenic noise, including vessel traffic.

D. Underwater noise from operating turbines leading to: auditory injury (permanent or temporary), death or disturbance

There is currently limited published data describing the acoustic signature of operational tidal turbines. While acoustic testing has been carried out on a number of the devices deployed at the Fall of Warness or is intended in the future, no published results are available as yet. The OSPAR Commission (2009) reports RMS ranges for source levels of operating tidal and wave devices as between 165 - 175 dB re 1 µPa @ 1m. Modelling carried out for the MeyGen ES estimated source levels for 1 MW and 2.4 MW turbines at 171 dB re 1 µPa and 177 dB re 1 µPa respectively using an uplift factor (Kongsberg 2012). From the limited information available at present, and given the expectation that basking shark hearing is of relatively low sensitivity compared, for example, to cetaceans, the broadband noise levels emitted from operating turbines are not expected to exceed the threshold for lethality, PTS or TTS onset for basking sharks.

At present very little information is available as to the behavioural response of marine megafauna to operating turbines. The noise output is thought to be similar to vessel noise in terms of its frequency range and may therefore be within the range of basking sharks. There is therefore the potential for a disturbance effect, albeit in the context of an area with existing natural and anthropogenic noise, including vessel traffic.

While the generation of power is the ultimate goal, the test site is fundamentally different from a commercial array, which would be striving for a continuous power generation output. As such, it is worth noting that operational noise at the test site will be greatly limited by the amount of time for which devices are actually installed and generating electricity.

Nevertheless, establishing the acoustic signature of operating devices is clearly an important knowledge gap that may be explored by monitoring at the Fall of Warness, aiding progression towards an appraisal of commercial-scale proposals. Any monitoring to understand any behavioural response of megafauna to operating turbines would also be of value. Obtaining meaningful information from the test site will necessitate a collaborative approach with all developers testing at the site. We therefore see this as a key strategic monitoring output.

In summary, we consider that there is potential for disturbance impacts upon basking sharks and, consequently, that **developers will need to submit application for a licence to disturb basking shark using project-specific details**. However, the short duration of drilling operations (typically around a week) or any simultaneous vessel activity, the small-scale of the lease area (~9km^2) in relation to the large ranges over which they travel and feed, and the apparent absence of basking shark fidelity to the site lead us to consider that the potential for this activity to result in significant disturbance is unlikely. As such, we do not consider that such disturbance would have negative implications for the conservation status of basking sharks. Adherence to the Scottish Marine Wildlife Watching Code (SMWWC) and extension of the Marine Mammal Observer (MMO) remit will help further reduce any residual effects.

Appraisal conclusion for disturbance impacts:

A licence to disturb basking shark is likely to be required to address potential disturbance impacts, particularly drilling.

Within the bounds of the project envelope description, it is considered that the potential disturbance impacts will not have negative implications for the conservation status of basking sharks.

E. Collision with operating turbine blades leading to: injury or death

Annex 3 provides details of the collision modelling process and key results, together with technical modelling detail and outputs. Note that vertical-axis, venturi, Archimedes screws and any other unforeseen device designs are explicitly excluded from this part of the appraisal and would therefore require additional assessment.

There is little basis on which to adopt assumed avoidance rates in collision risk modelling. For the purpose of consistency with assumed rates with minke whales, we adopt an assumed range of 95% to 98% avoidance for basking sharks. However, given limited knowledge of auditory and optical physiology of basking sharks, caution must be applied in interpretation of these results. The 95-98% avoidance assumption for basking sharks results in annual collision rates ranging from 0.57 to 0.23. These collision predictions are for the maximum device scenario only (please see Annex 3 - includes predictions for the current (July 2014) device scenario).

It should be noted that mean density figures from the EMEC wildlife observations have been used in the collision modelling procedures. It is acknowledged that there are inherent problems with visual observations of basking sharks, primarily relating to issues of availability for observation (i.e. at the water's surface). Unfortunately, the limited knowledge of basking shark behaviour has not allowed the application of correction factors as for other species, thus necessitating even greater emphasis on monitoring. However, compared to many equivalent situations, the Fall of Warness site is unusual in that there is at least five years of observation data available. Under these circumstances, the view has been taken that this data source and the experience of observers provides acceptable confidence in the representivity of the data.

The potential for basking sharks to interact with turbine blades is thus not fully understood, but cannot be ruled out. Although there are a number of uncertainties and assumptions within the underlying data and the model predictions, the best available approach to collision modelling suggests that collision is possible. As such a licence to disturb basking shark should be sought for the operational phase of a turbine deployment. This may be time-limited, with a review period built-in. Assumed prediction rates of 95-98% may be applied, albeit cautiously and in lieu of an improved evidence base. Although there is no widely-accepted figure for basking shark populations, nor a definition of the geographical scale of a reference population, it is not expected that the collision rates predicted would have negative implications for the overall conservation status of the species.

A basic comparison has been made between predicted collision rates with a 25m diameter and a generalised annular design device of various sizes (see Annex 3). The results suggest that annular devices within the project envelope are expected to have equivalent or lower rates of encounter with basking sharks than the 25m open-bladed design. Predicted impacts on basking sharks are not expected to exceed those described in the appraisal above. However, due to the different implications for different species (see Annex 3), the application of a project envelope that addresses all scenarios requires that annular devices greater than 6m diameter be substituted for three of the open-bladed device designs within the project envelope. Device combinations outside this, or designs that deviate from the generalised form considered in Annex 3, should be subject to separate appraisal.

Although mitigation is neither suitable nor practical for the device types covered within the project envelope at present, given the uncertainties surrounding collision risk, monitoring for device interactions should be a fundamental component of monitoring efforts at the test site. The use of innovative ways in which to monitor the operating devices and detect any impacts is clearly important in understanding impacts at the Fall of Warness and in moving forward to the commercialisation of these test devices. Currently monitoring is undertaken through a mixture of strain gauges in the blades themselves to detect impacts and the use of video camera mounted on the device showing some or all of the moving blades. Analysis of operational footage should enable detection of collisions and near misses but also provide insight into the behavioural reactions of any basking sharks to operating turbines. In case of a collision event, procedures for shut down and emergency response should be put in place by each developer, allowing review of the situation and consultation with the regulator before re-start of a device.

It should also be noted that there is no evidence to date of any interaction between any basking shark and the turbines at the Fall of Warness since the first turbine was deployed in 2006, or from elsewhere in the UK or Europe.

Appraisal conclusion for collision risk:
A licence to disturb basking shark will be required to cover the potential for collision with operational turbines. From the predicted collision risk estimates, it is considered that the potential impacts would not have negative implications for the conservation status of the species.

Nevertheless, uncertainties relating to underlying data and collision risk modelling place particular emphasis on the importance of monitoring at the test site.

F. Entanglement in lines or cabling leading to: injury or death
The risk of entanglement of marine mega-fauna in device mooring and cabling systems is poorly understood, but where there is sufficient slack or complexity in these systems it is intuitive that there is some potential risk. Benjamins *et al*. (2014) suggests that for most mega fauna, marine renewable energy devices are unlikely to pose a major threat in terms of entanglement risk[15]. The total number of berths as outlined in the project envelope description (Annex 1) is limited to 9, although the majority of current device designs are for bottom-mounted structures without mooring systems. Moreover, the relatively large diameter of synthetic ropes and chains used together with the likely need for a taut system further contributes to the reduction of potential risk.

The potential encounter rate for basking sharks at the test site appears relatively low and, combined with the low number of floating platforms with mooring systems, leads us to consider that such potential effects will not have negative implications for the conservation status of basking sharks. Nevertheless, there is still a degree of uncertainty on this issue, and the use of impact monitoring is clearly important in understanding entanglement impacts. As a test site, deployments at the Fall of Warness provide a valuable learning opportunity in moving forward to the commercialisation of these devices. Procedures for shut down and emergency response should be put in place by each developer. If floating or mid-water devices become more prevalent at the test-site than seabed-mounted devices, then this appraisal should be revisited.

Nevertheless, as the understanding of behavioural responses and the likelihood of an entanglement occurring remains poor, we would advise that the issue of a licence to disturb basking shark would be a sensible precautionary measure for any system that requires mooring lines and/or cables in the water column.

Appraisal conclusion for entanglement:
A licence to disturb basking shark, to cover the potential for injury or death from entanglement in mooring systems, will be required for any system that requires mooring lines and/or cables in the water column.

It is considered that the potential impacts from such entanglement risk will not have negative implications for the conservation status of basking sharks.

[15] http://www.snh.gov.uk/publications-data-and-research/publications/search-the-catalogue/publication-detail/?id=2174

Other potential impacts on basking sharks

Not all potentially important impacts upon basking sharks are relevant for consideration under the Wildlife and Countryside Act 1981, such as those that do not relate to disturbance or injury impacts. Consequently, this section addresses those remaining issues identified as *'potentially important'* in Table 18 and Table 19 (above) and considered to be relevant to the Fall of Warness.

G. Changes to hydrodynamic and sediment regime

The relationship between tidally-mixed areas and basking sharks is not well understood but, whether for feeding or transit, it may be that some areas influenced by tidal streams hold important functional value for basking sharks. Tidally mixed waters can support elevated primary and secondary productivity and, in turn, an abundance of foraging animals.

However, in the case of basking sharks tidal fronts on the continental shelf and shelf edge appear to attract aggregations more than high-energy tidal races such as the Fall of Warness (Speedie *et al*. 2009). Also wildlife observations at the Fall of Warness test site have so far indicated that basking sharks have variable abundance and do not appear to have particular fidelity to the site. Furthermore, the number of devices that may be deployed, as limited by the project envelope description, does not represent a significant extraction of energy from the site as a whole (a precautionary figure of 1.5% is estimated; see Section 4.3 on Hydrodynamic and Physical Processes). Consequently, alteration to the hydrodynamic regime to an extent that would influence the use of the site by basking sharks is considered unlikely and would not be significant at a population level.

Appraisal conclusion for changes to hydrodynamics: The potential for any effect on basking sharks at the Fall of Warness is very low and not considered to be significant at a population level.

H. Presence of tidal device (s) and associated infrastructure leading to: barrier effects

The potential for structures extracting tidal energy to represent a barrier to the passage of marine mega-fauna is not well understood, as the reaction of such animals to the devices is unknown. Information from the Wildlife Observations so far (Robbins, 2011) suggests that basking sharks sighted in the Fall of Warness are not utilising the site for extended periods or showing any apparent site fidelity. The risk of a barrier effect at the Fall of Warness test site is considered as relatively low because (a) the site leaves a large portion of the channel undeveloped and available for passage, (b) even with the maximum possible number of devices, the separation between most berth sites is relatively large and does not exclude the potential for passage between them, assuming an absence of behavioural avoidance to operational noise at that distance and (c) even if there is some disturbance effect in close proximity to operating turbines, operational periods at the test site are intermittent (i.e. not generating for commercial supply). Also, while basking sharks have been observed at the site, the number or variability of observations does not suggest that the locality is of particular value. This leads us to consider the potential for barrier effects would not be significant at population level. Further analysis of the ongoing Wildlife Observation sightings will help shed further light on basking shark movement throughout the site.

Appraisal conclusion for barrier effects: The potential for any barrier effect on basking sharks at the Fall of Warness is low and not considered to be significant at a population level.

4.4.5 Receptor conclusions

A summary of the appraisal for basking shark is provided in Table 21 below. Note that, even where no important impacts on the development site are identified, in some cases there may still be a recommendation for some mitigation or monitoring. Under these circumstances, mitigation would be regarded as good-practice rather than a necessity, while monitoring may serve to improve generic understanding of the relationships between stressors and receptors.

Receptor	Conclusion	Mitigation and or monitoring identified?
Basking shark.	There is no risk of injury or death from underwater noise generated by installation activities, vessel usage or operating turbines. A licence to disturb basking shark may be required during construction and operational phases due to potential disturbance, collision and entanglement risks. However, potential impacts from these impact-pathways are not predicted to have negative implications for the conservation status of basking sharks. Changes to the hydrodynamic regime and impact from barrier effects are not considered significant at a population level.	Yes – see Table 22

Table 21: Summary of basking shark assessment conclusions.

Given the uncertainties regarding some potential impacts, the protected status of basking sharks and the opportunity to learn from test deployments, some potential mitigation and monitoring measures are presented in Table 22 below (this table should be reviewed as knowledge increases). Some such measures will be appropriate as conditions on the Marine Licence, whereas others may just be recommended as good practice. Please see Section 5 for further details on the mitigation and monitoring highlighted below.

Site-wide monitoring and research ideas may be more effectively pursued at a strategic level (whether by EMEC, The Crown Estate or Marine Scotland, or by a developer consortium), but developer input or ideas are welcomed.

Potential Residual Impacts	Relevant impact Pathway	Mitigation	Monitoring
Disturbance – noise or presence.	Foundation installation. Vessel use. Operatng turbines.	Use of an MMO prior to the commencement of drilling operations (protocols may have to be adapted to specifically take account of basking sharks – i.e. may require more time to exit exclusion zone). Adherence to the SMWWC. Development of appropriate vessel management to be integrated with SIMOPS.	Acoustic monitoring of drilling and anchor/mooring installation noise at various distances and frequencies. Establishing the acoustic signature of operating devices.
Injury or death.	Collision with turbine blades.	If interaction of basking shark with devices occurs then procedures for emergency shutdown and liaison with regulators should take place until a re-start or suitable mitigation is agreed.	Use of appropriate method to detect collision or near miss, and monitor any other interaction between basking sharks and the operating device.
	Entanglement with mooring system or cables.	If interaction of basking shark with devices occurs then procedures for emergency shutdown and liaison with regulators should take place until a re-start or suitable mitigation is agreed.	Device monitoring should be capable of alerting the developer to an entanglement event.
Displacement.	Barrier effects.	Mitigation only required if monitoring indicates unacceptable impact.	Monitoring of behavioural reactions through wildlife surveys and opportunistic observations.

Table 22: Potential mitigation and monitoring measures relevant to basking sharks.

4.4.6 References

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4.5 Impact Appraisal: Cetaceans

Prior to the fully detailed evaluations, this part of the appraisal picks up at 'Step 2' as described in Section 3 of this document.

4.5.1 Potential effects

For cetaceans collectively, the defined potential effect categories are applied to activities/effect pathways relevant to tidal energy developments for design-types that involve the rotation of turbines within natural hydrodynamic conditions[16]. Deployment/installation effects (Table 23) are addressed separately from those during the operational and maintenance phases (Table 24).

Note that details specific to the Fall of Warness, both environmental and relating to project-specifications, are not considered until the detailed appraisal later in this section.

[16] Tidal developments that involve the manipulation of hydrodynamic conditions prior to the extraction of energy (e.g. tidal barrages) are explicitly excluded from the broad consideration of potential effects in Table 23 and Table 24.

Generic Potential Effects from Device Deployment

Summary of activity categories – for detail see project envelope description (Annex 1)

- Installation of device(s), and associated infrastructure (e.g. foundations; mooring systems; cabling; buoys) on the seabed, in the water column or above the surface
- Use of vessels (e.g. DP vessel; jack-up barge; multi cat; workboat; dive-support vessel; crane-barge; tug; specialist cable-laying vessel.)
- Deployment and use of equipment to monitor devices or other environmental parameters during installation (e.g. ROV, cameras or acoustic devices)

Activity/potential impact pathway	Natural heritage feature	Potential importance
Underwater noise from active acoustic equipment leading to disturbance[17].	Cetaceans.	Potentially important – although most unlikely to be sufficiently widespread to have an important effect on cetaceans, case-by-case consideration should consider the potential impacts and the need for a licence to disturb EPS to disturb. Importance will depend upon the duration and intensity of acoustic activity, the frequency and source levels used, the likelihood and fidelity of cetaceans in the area and the opportunity for animals to avoid areas of disturbance.
Installation vessel (s) transits and manoeuvring leading to disturbance.	Cetaceans.	Potentially important – cetaceans can be sensitive to vessel presence and associated activities. Importance will depend upon the duration and intensity of vessel activity, the likelihood and fidelity of cetaceans in the area and the opportunity for animals to avoid areas of disturbance. The need for a licence to disturb EPS should be considered.
Underwater noise from foundation/ mooring installation methods and vessels leading to: auditory injury, death or disturbance.	Cetaceans.	Potentially important – cetaceans can be sensitive to noise and vibration from foundation installation activities, such as drilling and piling. Importance will depend upon the range and frequency of noise sources (including background noise), duration and intensity of activity, the likelihood and fidelity of cetaceans in the area and the opportunity for animals to avoid areas of disturbance. Even where presence is occasional a licence to disturb EPS may be required.

[17] The term 'disturbance' includes all behavioural responses of biological consequence, including displacement from the vicinity of the activity.

Increased suspended sediment/ turbidity (including release of drill cuttings).	Cetaceans.	Not important – although cetaceans, particularly baleen whales, could be negatively affected by increased suspended sediment concentrations, they are unlikely to be exposed to it at tidal development sites as suspended material will disperse quickly and widely.
Entanglement in lines or cabling leading to: injury or death.	Cetaceans.	Not important – it is unlikely that cetaceans will be exposed to this potential interaction during installation procedures as any cables or lines not under tension would be likely to be of present for only very short durations.

Table 23: Potential effects upon cetaceans during device and infrastructure deployment; identifying activities/effect pathways and receptors for further assessment. Note that these evaluations are made *prior* to consideration of details particular to the Fall of Warness site.

Generic Potential Effects from Device Operation and Maintenance

Summary of activity categories – for detail see project envelope description (Annex 1)

- Physical presence of device(s), foundations, moorings, buoys and associated infrastructure on the seabed, in the water column or above the surface
- Operation of device(s)/power generation
- Repeat removal and redeployment of equipment for maintenance (e.g. turbine removed from water or floating structure removed from berth; replacement of mooring system).
- Other maintenance activities (e.g. Biofouling removal; ROV/diver inspection or repairs).
- Use of vessels (e.g. DP vessel; jack-up barge; multi cat; workboat; dive-support vessel; crane-barge; tug).
- Use of equipment to monitor devices in situ or other environmental parameters (e.g. ROV, cameras or acoustic devices).

Activity/potential impact pathway	Natural heritage feature	Potential importance
Underwater noise from active acoustic equipment leading to disturbance.	Cetaceans.	Potentially important – although unlikely to be sufficiently widespread to have an important effect on cetaceans at a population level, project-specific assessment should consider the potential impacts and the need for a licence to disturb EPS. Importance will depend upon the duration and intensity of acoustic activity, the frequency and source levels used, the likelihood and fidelity of cetaceans in the area and the opportunity for animals to avoid areas of disturbance.
Maintenance vessel (s) transits and manoeuvring leading to disturbance.	Cetaceans.	Potentially important – cetaceans can be sensitive to vessel presence and associated activities. Importance will depend upon the duration and intensity of vessel activity, the likelihood and fidelity of cetaceans in the area and the opportunity for animals to avoid areas of disturbance. The need for a licence to disturb EPS should be considered.
Other maintenance activities (i.e. non vessel-based) leading to: disturbance.	Cetaceans.	Not important – maintenance activities include inspection (e.g. divers/ROV), repairs or temporary retrieval and replacement of nacelles by winch. In all cases it is the presence of the accompanying vessel that presents the primary disturbance risk, and is appraised separately.

Underwater noise from turbine operation leading to: disturbance.	Cetaceans.	Potentially important – Potential for impact is poorly understood, but importance may depend upon turbine design number and spacing, the characteristics of background noise (natural and anthropogenic), species sensitivity, the likelihood and fidelity of cetaceans occurring and the opportunity for animals to avoid areas of disturbance. The need for a licence to disturb EPS should be considered.
Entanglement in lines or cabling leading to: injury or death.	Cetaceans.	Potentially important – thus far, relatively few tidal turbines involving rotating blades are suspended mid-water or have floating structures that are anchored/moored. However, those that do may present an entanglement risk, although the degree of risk is at present poorly understood. Importance will depend upon the likelihood and fidelity of cetaceans occurring, the location and spacing of devices, and the design of mooring and cabling arrangements. The need for a licence to disturb EPS should be considered.
Changes to hydrodynamic and sediment regime.	Cetaceans.	Potentially important – the relationship between hydrodynamics conditions and the importance of area for cetaceans is at present poorly understood, but it is possible that tidal front systems present disproportionately valuable foraging opportunities for some species. Consequently, a precautionary view is taken at present that extraction of tidal energy on a sufficient scale could have biological implications for cetaceans.
Collision with turbine blades leading to: injury or death.	Cetaceans.	Potentially important – the potential for impact is poorly understood, but importance may depend upon turbine location & spacing (including water depth), the physical and rotational characteristics of turbines, and the likelihood and fidelity of cetaceans occurring. For animals with sufficient records from survey data, encounter rate modelling should be conducted. Even where presence is occasional a licence to disturb EPS may be required.
Presence of tidal device (s) and associated infrastructure leading to: barrier effects.	Cetaceans	Potentially important – cetaceans may utilise or move though sounds and channels that may also present opportunity for tidal development. Importance will depend upon the spatial occupancy of the channel by tidal devices (in three dimensions), physical characteristics of the devices, the importance of the vicinity for passage of cetaceans and the likelihood of disturbance from operational noise of turbines.

Table 24: Potential effects upon cetaceans during the operational and maintenance phase; identifying activities/effect pathways and receptors for further assessment. Note that these evaluations are made *prior* to consideration of details particular to the Fall of Warness site.

4.5.2 Natural heritage context

All species of cetaceans are listed in Annex II of CITES, Annex II of the Bern Convention Annex, and in Annex IV of the EC Habitats Directive as species of European Community interest and in need of strict protection. Those species listed on Annex IV are termed European Protected Species (EPS). The harbour porpoise is also covered by the terms of ASCOBANS (Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas).

The most frequently occurring cetacean species observed in Orkney waters are: harbour porpoise, killer whale, minke whale, Risso's dolphin, white-beaked dolphin and bottlenose dolphin (Evans *et al*. 2011). More 'casual visitors' are Atlantic white-sided dolphin, short-beaked common dolphin, sperm whale and long-finned pilot whale (Evans *et al*. 2011). At the Fall of Warness, harbour porpoise is the most frequently sighted cetacean (Robbins 2011). Other species recorded during site surveys at Fall of Warness were minke and killer whales, and white beaked and Risso's dolphin as indicated in Table 25 below. Although other cetacean species could occur at the site, only these five species undergo specific appraisal. However, due to their higher occurrence, they may be regarded as precautionary proxies for all other possible cetacean species. For information on species range and distribution, including detail within Orkney waters, see Evans *et al*. (2011).

Species	Management regions (draft) and status
Harbour porpoise.	Within the proposed North Sea Management Unit, the current population estimate of 228,800 is considered stable. However, it is noted that the boundary with the nearby West Scotland Management Unit is arbitrary and some interchange is expected.
Minke whale.	Within the proposed European North Atlantic Management Unit (British and Irish Waters), the current population estimate of 23,163 is considered stable.
Risso's Dolphin.	Within the proposed European North Atlantic Management Unit (British and Irish Waters), there is no current population estimate.
Atlantic white-beaked dolphin.	Within the proposed British and Irish Waters Management Unit, there is a current population estimate of 15,895 animals, although the status (e.g. declining/stable) of this figure is unknown.
Killer whale.	Management units have not been proposed for killer whales and there are no current population estimates. However, genetic and photo-ID work suggests that animals visiting the Northern Isles are from a small group also associated with Iceland and the Faroe Islands, as distinct from a west of Scotland sub-population (Foote *et al*. 2009, 2010).

Table 25: Overview of most frequently sighted cetacean species at the Fall of Warness and their current status (JNCC, draft in prep).

For the Fall of Warness, analysis of data from the EMEC wildlife observations between July 2005 and December 2009 indicates just over a tenth of all observation days (n=1056) recorded the presence of harbour porpoise (n=135). With an hourly encounter rate highest between May and August, peaking at 0.5 harbour porpoise per hour. The distribution of harbour porpoise across the survey area was significantly varied, concentrating around Sealskerry Bay on Eday (Robbins 2011).

Less frequent summer sightings include minke whales observed on 18 of the 1056 days with most sightings made up of single individuals between June and August. On 5 of the observation days, minke whale were recorded feeding. Killer whales were only sighted on one observation day with a pod of 7 travelling through the site. Risso's dolphins were observed on 8 days between 2007 and 2009 with the largest pod made up of 10 individuals observed in July. White-beaked dolphins were observed on 4 days, recorded in August 2005 and 2006 in pods ranging between 2 and 5 individuals (Robbins 2011). In summary, the evidence available to date for the Fall of Warness illustrates limited sightings of a small number of cetacean species mostly concentrating in the summer months (although there are caveats associated with the use of visual survey techniques for cetaceans).

Analysis of the EMEC wildlife observations data by Robbins (2011) has not been corrected for *distance* or *detectability* (SNH are currently funding further analysis to account for this). This appraisal will require review once this has been completed, together with analysis of the wildlife observation data covering the period from 2009 to date.

Table 26 below shows mean surface density estimates of the two most common cetacean species from the wildlife observation data (Annex 3 provides further information on how this is calculated). The table also provides density figures derived from SCANS II data. There are clear disparities between these different figures, although SCANS II carries various caveats, including that they are based on data extrapolated over large areas from snapshots of data. There is no single ideal method for quantifying cetacean use of a discrete area, so precaution is required in the use of any of these figures.

Species	Wildlife Observations (mean) density estimate	SCANS II density estimate
Harbour porpoise.	1.81 $\times 10^{-8}/m^2$	0.274 $\times 10^{-6}/m^2$ (SCANS II Area J – Orkney and Shetland)
Minke Whale.	1.22 $\times 10^{-9}/m^2$	0.022 $\times 10^{-6}/m^2$ (North Sea)

Table 26: Summary of surface density estimates from different sources for the two most commonly observed cetacean species at the Fall of Warness.

4.5.3 Impact appraisal mechanisms for the Fall of Warness

This impact appraisal takes account of a maximum-case scenario based on the project envelope description where all available berths within the test site are operating at capacity and addresses the differing consenting and licensing regimes such as EPS and EIA. This appraisal should be adequate to inform the consenting process for both Marine Licence and Section 36 consent applications. It addresses the differing consenting and licensing regimes (see Table 27 below). However, it should be noted if there are key deviations in the device design or in installation/maintenance activities then further appraisal work may be required. Any additional appraisal work required will be undertaken by the individual developer (further advice should be sought from EMEC in the first instance).

Feature Type	**Appraisal Mechanism/relevant legislation**	**Applicable**	**Reasoning**
Qualifying features of European sites.	Habitats Regulations Appraisal (HRA) - Habitats Regulations 1994 (as amended).	N	No/limited connectivity with Moray Firth SAC designated for Bottlenose dolphin or Skerries & Causeway cSAC for Harbour porpoise.
European Protected Species.	EPS legislation - Habitats Regulations 1994 (as amended in Scotland).	Y	All cetaceans are EPS.
Notified features of SSSIs.	SSSI legislation - Nature Conservation (Scotland) Act 2004 (as amended).	N	No SSSIs with cetaceans as notified features.
Protected features of MPAs	Marine (Scotland) Act 2010	N	Not capable of affecting protected features of MPAs.
PMFs	Marine (Scotland) Act 2010	Y	Cetacean PMFs occur at Falls of Warness site.
Other sensitive natural heritage features.	Appraisal of other features under: - Electricity Works (EIA) (Scotland) Regulations (Amendment) 2008; - Marine Works (EIA) (amendment) Regulations 2011; - Marine (Scotland) Act 2010	Y	Captures aspects of assessment not addressed under EPS legislation at a population/habitat scale of concern.

Table 27: Table 4.5.5: Appraisal mechanism for cetaceans.

4.5.4 Qualifying features of European sites

The Moray Firth SAC is the only SAC in Scotland to have a cetacean qualifying feature (bottlenose dolphin). Although this species is wide-ranging, there are limited observations in Orkney waters (Thompson *et al.* 2011) and so it is considered that there is no likely significant effect to bottlenose dolphins at the Moray Firth SAC from the test site at the Fall of Warness.

Harbour porpoise are a qualifying feature of the Skerries and Causeway SAC in Northern Ireland. The Fall of Warness is remote from this site (>300km) and despite the highly mobile abilities of this species, is too far to consider there to be a measurable degree of connectivity. Consequently, it is concluded that there is no likely significant effect to harbour porpoise at the Skerries and Causeway SAC from the test site at the Fall of Warness.

Conclusion:
There is no likely significant effect to bottlenose dolphin as a qualifying feature of Moray Firth SAC, or to harbour porpoise as a qualifying feature of the Skerries and Causeway SAC, an appropriate assessment is therefore not required.

4.5.5 European Protected Species (EPS)

Certain species are listed on Annex IV of the Habitats Directive as species of European Community interest and in need of strict protection. The protective measures required are outlined in Articles 12 to 16 of the Directive. The species listed on Annex IV whose natural range includes any area in the UK are termed European Protected Species (EPS).

SNH is the statutory nature conservation body which provides advice on EPS in respect of the Habitats Regulations in Scotland.

Summary of the legal requirements for EPS

(1) It is an offence:

(a) deliberately or recklessly to capture, injure or kill a wild animal of a European protected species;

(b) deliberately or recklessly –

i. to harass a wild animal or group of wild animals of a European protected species;

ii. to disturb such an animal while it is occupying a structure or place which it uses for shelter or protection;

iii. to disturb such an animal while it is rearing or otherwise caring for its young;

iv. to obstruct access to a breeding site or resting place of such an animal, or otherwise to deny the animal use of the breeding site or resting place;

v. to disturb such an animal in a manner that is, or in circumstances which are, likely to significantly affect the local distribution or abundance of the species to which it belongs;

vi. disturb such an animal in a manner that is, or in circumstances which are, likely to impair its ability to survive, breed or reproduce, or rear or otherwise care for its young; or

vii. to disturb such an animal while it is migrating or hibernating;

(c) deliberately or recklessly to take or destroy the eggs of such an animal; or

(d) to damage or destroy a breeding site or resting place of such an animal.

(2) Subject to the provisions of this Part, it is an offence to deliberately or recklessly disturb any dolphin, porpoise or whale (cetacean). The Scottish Government has also provided

guidance on the 2007 amendments addressing EPS – Explanatory guidance for species related activities.[18]

Licence requirements

A licence to disturb EPS is likely to be required for activities that have the potential to cause disturbance, injury or death of cetaceans at the Fall of Warness test site. Such impacts may arise from noise emitted during installation of device foundations (e.g. drilling), from noise emitted by operating turbines or through the use of active acoustic scientific equipment. These, and the risk of death or injury to cetaceans from colliding with an operational turbine, necessitate consideration of EPS licensing requirements and tests. The appraisals below are informed by knowledge of cetacean populations at the time of writing. New proposals may require further assessment if there is any change in the status of cetacean populations. Such changes may have implications for the requirement for a licence to disturb EPS or appropriate mitigation. Suitable mitigation may negate the need for a licence to disturb EPS, or may be included as a condition of the licence.

Licences may be granted to authorise activities that could affect EPS which would otherwise be illegal under the Habitats Regulations. Three tests must be satisfied before the licensing authority can issue a licence under Regulation 44(2) of the Conservation (Natural Habitats &c.) Regulations 1994 (as amended) to permit otherwise prohibited acts. An application for a licence will fail unless the following tests are satisfied:

Test 1: The licence application must demonstrably relate to one of the purposes specified in Regulation 44(2) (as amended). For development proposals, the relevant purpose is likely to be Regulation 44(2)(e) for which Marine Scotland is currently the licensing authority. This regulation states that licences may be granted by Marine Scotland only for the purpose of "preserving public health or public safety or other imperative reasons of overriding public interest including those of a social or economic nature and beneficial consequences of primary importance for the environment."

Climate change is widely recognised as one of the great environmental challenges facing the world today. Scottish, UK and European targets for reducing carbon dioxide include those set through the UK Climate Change Act (2008), The Renewable Energy Strategy (2009), the Renewables Obligation (Scotland) Order 2002, National planning guidance (NPPG 6 revised 2000), Climate Change (Scotland) Act 2010 and Scottish Planning Policy, among others. In order to meet this target technologies such as marine energy are likely to play a major role. The proposed device testing will provide an essential stepping stone on the path to commercial viability of the tidal energy sector, with potential to provide economic benefits as well as the delivery of energy targets in response to climate change. Further considerations in relation to Test 1 may be given by Marine Scotland.

Test 2: No satisfactory alternative. Regulation 44(3)(a) states that a licence may not be granted unless the licensing authority is satisfied "that there is no satisfactory alternative".

The European Marine Energy Centre (EMEC) has been established as a test site for wave and tidal energy conversion devices, with support from government. The purpose of the unique testing facility is to assist and hasten the development of these renewable energy

[18] Scottish Government Guidance available at: http://www.scotland.gov.uk/Resource/Doc/1221/0050637.pdf

industries, against a background commitment to achieve significant reduction in reliance on carbon dioxide producing alternatives. Any alternative location would be unlikely to be satisfactory in terms of economic, political or environmental expediency. Further considerations in relation to Test 2 may be given by Marine Scotland.

Test 3:
Regulation 44(3)(b) states that a licence cannot be issued unless the licensing authority is satisfied that the action proposed "will not be detrimental to the maintenance of the population of the species concerned at a favourable conservation status in their natural range".

Favourable conservation status is in Article 1(i) of the EC Habitats Directive; conservation status is regarded as favourable when:

- *Population dynamics data on the species concerned indicate that it is maintaining itself on a long-term basis as a viable component of its natural habitats;*
- *The natural range of the species is neither being reduced nor is likely to be reduced for the foreseeable future.*
- *There is, and will probably continue to be, a sufficiently large habitat to maintain its populations on a long term basis.*

Further appraisal may be required if (a) a proposal is outside of the project envelope description, (b) if knowledge/data on the status of cetaceans at the test site or in their natural range changes, or (c) if knowledge regarding potential impact pathway changes. These scenarios aside, the appraisal below should be adequate to inform licensing and consenting decisions. Current knowledge on the population status of species relevant to the Fall of Warness is summarised in Section 4.5.2 above.

The following appraisals first consider impacts in relation to whether an offence is likely under the protection afforded to cetaceans under the Habitats Regulations. It then considers whether a licence to disturb EPS is required to address this and if so provides commentary in relation to impacts upon Favourable Conservation Status (i.e. Test 3).

Disturbance impacts

The noisiest activity undertaken during marine works at the FoW is thought to be associated with drilling to insert pin piles or monopiles. Vessels used in relation to foundation/mooring installation or O&M activities could also contribute high levels of noise and as such are also assessed below. The maximum (worse) case scenario would see drilling and associated works occurring at two separate berths at the same time (see Annex 1, Section 4.4.2 for further details).

Table 28 below outlines the criteria mostly commonly used to assess lethality and auditory injury criteria for cetaceans.

	Exposure Limit	Effect	Reference
Peak	240 dB re 1 μPa	Lethality	Yelverton and Richmond (1981)
	230 dB re 1 μPa	PTS auditory injury onset	Southall *et al.* (2007)
	224 dB re 1 μPa	TTS auditory injury onset	Southall *et al.* (2007)
SEL M-weighted	215 dB re 1 $\mu Pa^2 s$	PTS auditory injury onset	Southall *et al.* (2007)
	183 dB re 1 $\mu Pa^2 s$	TTS onset	Southall *et al.* (2007)
RMS	180 dB re 1 μPa	Auditory injury criteria	NMFS (1995)
	160 dB re 1 μPa	Behavioural disturbance, level B, Harassment	NMFS (1995)
	140 dB re 1 μPa	Low level disturbance	HESS (1997)

Table 28: Underwater noise impact criteria commonly used for cetaceans.

Overview of cetacean hearing frequencies

Odontocetes or toothed whales, e.g. killer whale, dolphins and porpoises are mid to high frequency specialists. Their range of best hearing is approximately between 10 kHz to 140 kHz (Richardson *et al.,* 1995). Above and below these frequencies, their hearing abilities become less sensitive.

There are no audiograms in existence for mysticetes (i.e. minke whales) (Richardson *et al*., 1995). However, it is assumed that they hear at least the frequency range of their vocalisations. Erbe (2002) considered mysticete hearing by taking into account; their vocalisations, observed reactions to known sound emissions and the physical structure of whale ears. This work resulted in the generation of a notional hearing threshold, which suggests the range of best hearing to be between 200 Hz to 10 kHz. Mysticetes may therefore be more sensitive to low frequency industrial noise.

Each impact-pathway likely to lead to disturbance effects is addressed below in turn.

A. Underwater noise from foundation/mooring installation methods, leading to auditory injury (permanent or temporary), death or disturbance.

For the purpose of this assessment, we consider source levels for drilling to be between 145-190 dB re 1 µPa at 1m (OSPAR Commission, 2009). For the placement of the anchor blocks at the Fall of Warness, Beharie and Side (2011) note a peak to peak sound pressure levels equivalent to 167 dB at 1m and sound pressure levels associated with the chains, equivalent to a maximum of 173 dB at 1m (peak to peak). Therefore, from the limited information available at present, the broadband noise levels emitted during non-percussive drilling and anchor/mooring installation activities are not expected to exceed the threshold for lethality, PTS or TTS onset as documented in Table 28 above for cetaceans.

Richardson *et al.* (1995) reported that drilling from bottom-founded platforms tends to have strongest tones at very low frequencies. Furthermore drilling noise has been reported to have the majority of its energy below 1kHz, mostly below 500 Hz (Kongsberg, 2012; Nedwell *et al.,* 2003 & 2010). The low frequency noise emitted from drilling operations is therefore likely to be within the range of minke whales and poorer hearing range for Odontocetes. Consequently, there is potential for a disturbance effect.

B. Installation and C. maintenance vessel(s) transits and manoeuvring leading to disturbance.

A variety of vessels are used at the Fall of Warness including multicats, jack-up barges, tug supply vessels, dive support vessels, small tugs and smaller workboats, the largest of which are between 50 – 100m in length. Richardson *et al.* (1995) estimates a 25m tug pulling a barge to have a source level of 166 dB re 1 µPa at 1m. Vessels between 50-100m have been estimated by OSPAR Commission (2009) to have a source level range from 165 – 180 dB re 1 µPa at 1m, which we consider to adequately cover the potentially noisier vessels most likely to be utilised at the FoW. From the limited information available at present, the broadband noise levels generated by vessels are not expected to exceed the threshold for lethality, PTS or TTS onset for cetaceans.

The frequency range of vessel noise is related to the size of the vessel, among other factors. In general, peak frequencies increase as vessel size decreases. Large ships emit noise from tens up to hundreds of hertz. Medium size (around 30 m length) and smaller boats such as work boats emit noise from 20 Hz to 6 kHz (Richardson *et al.* 1995) or to 10 kHz (Thomsen *et al*. 2006). The frequency range will vary depending on the types of vessel in the area, among other factors, but it is likely that the vessels operating in the Fall of Warness will be within the range of minke whales and poorer hearing range for Odontocetes. Consequently, there is potential for a disturbance effect.

The maximum number of vessels operating in the Fall of Warness at any one time could be up to 14, although this occurrence is considered rare and, moreover, most activity is likely to be aimed at times of lower tidal-stream flow and so any multiple vessel activity is likely to occur in a narrow time-window. Nevertheless, there is potential for this noise (or vessel presence) to cause some form of disturbance effect, albeit in the context of an area with existing natural and anthropogenic noise, including vessel traffic.

D. Underwater noise from active acoustic equipment leading to disturbance.

Although the use of geophysical or geotechnical equipment is unlikely to be required at the FoW and has not been included in the project envelope description and therefore is not considered part of this appraisal, there may be projects that require the use of active acoustic equipment, e.g. sonar for monitoring underwater animal behaviour. Scientific equipment with active acoustic outputs vary in their frequencies and source levels, some of which may be audible to and therefore disturb cetaceans. The need for a licence to disturb EPS will depend upon the acoustic characteristics of the equipment used. However, given the poor understanding of the impact pathway and the large variety of potential technologies,

this issue requires a project-specific assessment and has not been appraised any further here.

E. Underwater noise from operating turbines leading to auditory injury (permanent or temporary), death or disturbance.

There is currently limited published data describing the acoustic signature of operational tidal turbines. While acoustic testing has been carried out on a number of the devices deployed at the Fall of Warness or is intended in the future, no published results are available as yet. The OSPAR Commission (2009) reports RMS ranges for source levels of operating tidal and wave devices as between 165 - 175 dB re 1 µPa @ 1m. Modelling carried out for the MeyGen ES estimated a source levels for 1 MW and 2.4 MW turbines at 171 dB re 1 µPa and 177 dB re 1 µPa respectively using an uplift factor (Kongsberg, 2012). From the limited information available at present, the broadband noise levels emitted from operating turbines are not expected to exceed the threshold for lethality, PTS or TTS onset for any of the identified five species of cetaceans.

At present very little information is available as to the behavioural response of cetacean species to operating turbines. The noise output is thought to be similar to vessel noise in terms of its frequency range so will be within the range of poorer hearing for Odontocetes and within the hearing capabilities of minke whale. There is therefore the potential for a disturbance effect, albeit in the context of an area with existing natural and anthropogenic noise, including vessel traffic.

While the generation of power is the ultimate goal, the test site is fundamentally different from a commercial array, which would be striving for a continuous power generation output. As such, it is worth noting that operational noise at the test site will be greatly limited by the amount of time for which devices are actually installed and generating electricity.

Establishing the acoustic signature of operating devices is clearly an important knowledge gap that may be explored by monitoring at the Fall of Warness, aiding progression towards an appraisal of commercial-scale proposals. Any monitoring to understand any behavioural response of megafauna to operating turbines would also be of value. Obtaining meaningful information from the test site will necessitate a collaborative approach with all developers testing at the site. We therefore see this as a key strategic monitoring output.

In summary, we consider that there is potential for disturbance impacts upon cetaceans and, consequently, that developers will be required to apply for a licence to disturb EPS using project-specific details. However, the short duration of drilling operations (typically around a week) or any simultaneous vessel activity, the small-scale of the lease area (~9km^2) relative to the scale of relevant management units (see Table 25) and the absence of any evidence to suggest the site is of particular importance for any species, lead us to consider that the potential for this activity to result in significant disturbance is unlikely. As such, we consider that such disturbance would not be detrimental to the maintenance of the populations of any cetaceans in their natural range. This assessment is made in the context of populations defined at the scales define in Table 25. Adherence to the SMWWC and extension of the MMO remit will help further reduce any residual effects.

Appraisal conclusion for disturbance impacts:

The use of active acoustic monitoring devices requires a project-specific appraisal and appropriate consultation to determine the need for a licence to disturb EPS.

A licence to disturb EPS will be required to address potential disturbance impacts, particularly drilling.

Within the bounds of the project envelope description, it is considered that the potential disturbance impacts from such installation noise will not be detrimental to the maintenance of the population of the five identified species concerned at Favourable Conservation Status in their natural range.

F. Collision with operating turbine blades leading to injury or death.

Annex 3 provides details of the collision modelling process and key results, together with technical modelling detail and outputs. Note that vertical-axis, venturi, Archimedes-screws and any other unforeseen device designs are explicitly excluded from this part of the appraisal and would therefore require additional assessment. Of the cetaceans that may occur at the site, only minke whale and harbour porpoise were deemed to have sufficient observational data to support collision risk modelling. Consequently, any impacts upon other potential cetacean species are expected to be of lesser or equivalent importance.

There is little basis on which to adopt assumed avoidance rates in collision risk modelling. Nevertheless, harbour porpoise are relatively small and agile, so may be expected to more easily achieve near-field avoidance of turbines, compared to minke whales. However, minke are not only relatively small and powerful baleen whales, but are also expected to respond to visual and acoustic cues from an operational device. Ongoing monitoring and research will be important in refining understanding of avoidance rates, but as a starting point we assume avoidance rates of 98% for harbour porpoise (resulting in 0.32 collisions per year) and 95-98% for minke whales (0.76 to 0.30 collisions per year). These collision predictions are for the maximum device scenario only (please see Annex 3 - includes predictions for the current (July 2014) device scenario).

It should be noted that mean density figures from the EMEC wildlife observations have been used in the collision modelling procedures. It is acknowledged that there are inherent problems with visual observations of cetaceans, primarily relating to issues of availability for observation (i.e. at the waters surface). Annex 3 details the calculation and use of correction factors aimed at addressing the former issue. Furthermore, compared to many equivalent situations, the Fall of Warness site is unusual in that there is at least five years of observation data available. Under these circumstances, the view has been taken that this data source is preferable to alternatives, such as SCANS II data, which is gathered at a large spatial scale of limited relevance to a small inshore area.

The potential for cetacean species to interact with turbine blades is thus not fully understood, but cannot be ruled out. Although there are a number of uncertainties and assumptions within the underlying data and the model predictions, the best available approach to collision modelling suggests that collision of cetaceans is possible. As such a licence to disturb EPS should be sought for the operational phase of a turbine deployment. This may be time-limited, with a review period built-in. Assumed prediction rates of 98% (harbour porpoise) and 95-98% (minke whales) may be applied, albeit cautiously and in lieu of an improved evidence base. However, in the context of the reference populations defined in Table 25 (harbour porpoise: 228,800 in North Sea Management Unit; minke: 23,163 in European North Atlantic Management Unit), even the higher collision rates at a more precautionary

90% assumed avoidance rate (see Annex 3) would not be considered to be detrimental to the maintenance of the populations of the species concerned at Favourable Conservation Status in their natural range.

A basic comparison has been made between predicted collision rates with a 25m diameter open-bladed rotor and a generalised annular design device of various sizes. The results, based only on rotor geometry rather than any accommodation for effects of fluid dynamics, suggests that annular devices of an equivalent diameter to open-bladed counterparts may have higher rates of encounter with harbour porpoise. The pattern is not repeated for minke whales, for which the geometry of neither device design allows much potential for safe passage between turbine blades. Of the device-sizes tested for both of these cetacean species, only the 6m annular device is likely to have collision rates less than or equivalent to the 25m open-bladed design. Due to the different implications for different species, annular devices greater than 6m diameter may be substituted for three of the open-bladed device designs within the project envelope. Device combinations outside this, or designs that deviate from the generalised form considered in Annex 3, should be subject to separate appraisal.

It is important to note that all of the modelling of encounter rates is highly generalised, with it currently not possible to incorporate factors such as fluid dynamics or behavioural reactions (initial or learned) of animals. In relation to annular style devices particularly, it is not yet understood how the geometry/solidity of such a device may influence the detection of the structure by an animal, the likelihood of avoidance to it, or indeed the potential for a fatal injury if there is a collision. In practice, there may even, depending upon the spacing of the turbine blades, and the size of the animal, be insufficient space to allow passage of larger animals between the blades reducing, substantially, the actual collision risk. Modelling of collision risk is likely to require regular review as these matters become better understood.

While for the device types covered within the project envelope description mitigation is neither suitable nor practical at present, given the uncertainties surrounding collision risk, monitoring for device interactions should be a fundamental component of monitoring efforts at the test site. The use of innovative ways in which to monitor the operating devices and detect any impacts is clearly important in understanding impacts at the Fall of Warness and in moving forward to the commercialisation of these test devices. Currently monitoring is undertaken through a mixture of strain gauges in the blades themselves to detect impacts and the use of video camera mounted on the device showing some or all of the moving blades. Analysis of operational footage should enable detection of collisions and near misses but also provide insight into the behavioural reactions of cetaceans to operating turbines. In case of a collision event, procedures for shut down and emergency response should be put in place by each developer, allowing review of the situation and consultation with the regulator before re-start of a device.

It should also be noted that there is no evidence to date of any interaction between any cetacean species and the turbines at the Fall of Warness since the first turbine was deployed in 2006, or from elsewhere in the UK or Europe.

Appraisal conclusion for collision risk:

A licence to disturb EPS will be required to cover the potential for collision between turbines and cetacean species that may occur at the site. Due to their sufficient frequency in the data, modelling is conducted only for harbour porpoise and minke whales; other cetacean species may occur at the site, but are sufficiently infrequent that any impacts are consider to be less than or equivalent to those modelled species. From the predicted collision risk estimates, it is considered that the potential impacts will not be detrimental to the maintenance of the population of the species concerned at Favourable Conservation Status in their natural range.

Nevertheless, uncertainties relating to underlying data and collision risk modelling place particular emphasis on the importance of monitoring at the test site.

Entanglement impacts

G. Entanglement in lines or cabling leading to injury or death.

The risk of entanglement of marine mega-fauna in device mooring and cabling systems is poorly understood, but where there is sufficient slack or complexity in these systems it is intuitive that there is some potential risk. Benjamins *et al*. (2014) suggests that for most mega fauna, marine renewable energy devices are unlikely to pose a major threat in terms of entanglement risk. However, baleen whales may be at greatest risk, due to their large size and foraging behaviour[19]. The total number of berths as outlined in the project envelope description is limited to 9, although the majority of current device designs are for bottom-mounted structures without mooring systems. Moreover, the relatively large diameter of synthetic ropes and chains used together with the likely need for a taut system further contributes to the reduction of potential risk.

There are some species such as minke whale in particular that may be more susceptible to this risk than the other identified species (Northridge *et al*. 2010). The absence of any evidence that the site is of particular importance to any cetacean species, combined with the low number of floating platforms with mooring systems, lead us to consider that such effects would not be detrimental to the maintenance of the populations of any cetacean species in their natural range. Nevertheless, there is still a degree of uncertainty on this issue, and the use of impact monitoring is clearly important in understanding entanglement impacts. As a test site, deployments at the Fall of Warness provide a valuable learning opportunity in moving forward to the commercialisation of these devices. Procedures for shut down and emergency response should be put in place by each developer. If floating or mid-water devices become more prevalent at the test-site than seabed-mounted devices, then this appraisal should be revisited.

Nevertheless, as the understanding of behavioural responses and the likelihood of an entanglement occurring remains poor, we would advise that the issue of a licence to disturb EPS would be a sensible precautionary measure for any system that requires mooring lines and/or cables in the water column.

[19] http://www.snh.gov.uk/publications-data-and-research/publications/search-the-catalogue/publication-detail/?id=2174

Appraisal conclusion for entanglement: A licence to disturb EPS, to cover the potential for injury or death from entanglement in mooring systems, will be required for any system that requires mooring lines and/or cables in the water column. It is considered that the potential impacts from such entanglement risk will not be detrimental to the maintenance of the population of the species concerned at Favourable Conservation Status in their natural range.

4.5.6 Other natural heritage interests

Not all potentially important impacts upon cetaceans are relevant for consideration under EPS legislation, such as those that do not relate to disturbance or injury impacts. Consequently, this section addresses those remaining issues identified as *'potentially important'* in Table 23 and Table 24 and considered to be relevant to the Fall of Warness.

Hydrodynamic impacts

H. Changes to hydrodynamic and sediment regime.
The relationship between tidally-mixed areas and cetaceans is not well understood but, whether for feeding or transit, it may be that some areas influenced by tidal streams hold important functional value for some species. Tidally mixed waters can support elevated primary and secondary productivity that, in turn, supports food resources for some cetaceans. However, Wildlife Observations at the Fall of Warness test site have so far indicated that cetaceans, including harbour porpoise, although occasionally present do not appear to utilise the site for extended periods or indicate a disproportionate importance of the area. Furthermore, the number of devices that may be deployed, as limited by the project envelope description, does not represent a significant extraction of energy from the site as a whole (a precautionary figure of 1.5% is estimated; see Section 4.3 on Hydrodynamic and Physical Processes). Consequently, alteration to the hydrodynamic regime to an extent that would influence the use of the site by any of the identified cetacean species is considered unlikely and would not be significant at a population level for any of the five identified species.

Appraisal conclusion for changes to hydrodynamics: The potential for any effect on cetaceans at the Fall of Warness is very low and not considered to significant at a population level.

Barrier effects

I. Presence of tidal device (s) and associated infrastructure leading to barrier effects.
The potential for structures extracting tidal energy to represent a barrier to the passage of marine mega-fauna such as cetaceans is not well understood, as the reaction of such animals to the devices is unknown. Information from the Wildlife Observations so far (Robbins, 2011) suggests that cetaceans sighted in the Fall of Warness are not utilising the site for extended periods or demonstrating any apparent site-fidelity. The risk of a barrier effect at the Fall of Warness test site is considered as relatively low, even for the more abundant species like harbour porpoise, because (a) the site leaves a large portion of the channel undeveloped and available for passage, (b) even with the maximum possible

number of devices, the separation between most berth sites is relatively large and does not exclude the potential for passage between them, assuming an absence of behavioural avoidance to operational noise at that distance and (c) even if there is some disturbance effect in close proximity to operating turbines, operational periods at the test site are intermittent (i.e. not generating for commercial supply). Also, while cetaceans of a number of different species have been observed at the site, the number of observations does not suggest that the locality is of particular value, even for harbour porpoise. This leads us to consider the potential for barrier effects would not be significant at population level. Further analysis of the ongoing EMEC wildlife observation data will help shed further light on cetacean movement throughout the site.

Appraisal conclusion for barrier effects:
The potential for any barrier effect on cetaceans at the Fall of Warness is low and not considered to be significant at a population level.

4.5.7 Receptor conclusions

A summary of the appraisal for cetaceans is provided in Table 29 below. Note that, even where no important impacts on the test site are identified, in some cases there may still be a recommendation for some mitigation or monitoring. Under these circumstances, mitigation would be regarded as good practice rather than a necessity, while monitoring may serve to improve generic understanding of the relationships between stressors and receptors.

Receptor	Conclusion	Mitigation and or monitoring identified?
Harbour porpoise, minke and killer whale, white-beaked and Risso's dolphin.	There is no risk of injury or death from underwater noise generated by installation activities, vessel usage or operating turbines. A licence to disturb EPS may be required during construction and operational phases due to potential disturbance, collision and entanglement risks. However, potential impacts from these impact-pathways are not considered to be detrimental to the maintenance of the population of these species concerned at Favourable Conservation Status in their natural range. Changes to hydrodynamic regime and impact from barrier effects are not considered significant at a population level. A project-specific assessment is required for use of active acoustic equipment, together with the need for a licence to disturb EPS.	Yes – see Table 30

Table 29: Summary of assessment conclusions.

Where EPS licensing needs have been identified, in all cases the conclusion reached is that the potential impacts will *not* be detrimental to the maintenance of the population of the species concerned at Favourable Conservation Status in their natural range.

Cetacean species other than those specifically appraised have been or could be seen in the Fall of Warness. However, such records are infrequent. It is considered, therefore, that any potential impacts to other cetaceans are unlikely to be important due to low numbers in the project area. Furthermore, any mitigation and monitoring identified for other marine mammal species will also be applicable to cetaceans.

Given the uncertainties regarding some potential impacts, the protected status of cetacean species and the opportunity to learn from test deployments, some potential mitigation and monitoring measures are presented in Table 30 below (this table should be reviewed as knowledge increases). Some such measures will be appropriate as conditions on the Marine Licence, whereas others may just be recommended as good practice. Please see Section 5 for further details on the mitigation and monitoring highlighted below.

Potential Residual Impacts	**Relevant impact Pathway**	**Mitigation**	**Monitoring**
Disturbance (noise or presence).	Foundation installation methods. Vessel use. Operating turbines.	Use of an MMO prior to the commencement of drilling operations. Adherence to the SMWWC. Development of appropriate vessel management to be integrated with SIMOPS.	Acoustic monitoring of drilling and anchor/mooring installation noise at various distances and frequencies. Establishing the acoustic signature of operating devices.
Injury or death.	Collision with turbine blades.	If interaction of cetaceans with devices occurs then procedures for emergency shutdown and liaison with regulators should take place until a re-start or suitable mitigation is agreed.	Use of appropriate method to detect collision or near miss, and monitor any other interaction between cetaceans and the operating device.
	Entanglement with mooring system or cables.	If interaction of cetaceans with devices occurs then emergency procedures and liaison with regulators should take place until a re-start or suitable mitigation is agreed.	Device monitoring should be capable of alerting the developer to an entanglement event.
Displacement.	Barrier effects.	Mitigation only required if monitoring indicates unacceptable impact.	Monitoring of behavioural reactions through wildlife surveys and opportunistic observations.

Table 30: Potential mitigation and monitoring measures relevant to cetaceans.

Site-wide monitoring and research ideas may be more effectively pursued at a strategic level (whether by EMEC, The Crown Estate or Marine Scotland, or by a developer consortium), but developer input or ideas are welcomed.

Project-specific assessments are required for aspects of the following impact pathway and will include the need for each developer to identify any appropriate mitigation and or monitoring:

- Use of active acoustic equipment

4.5.8 References

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4.6 Impact Appraisal: Seals

Prior to the fully detailed evaluations, this part of the appraisal picks up at 'Step 2' as described in Section 3 of this document.

4.6.1 Potential effects

For seals, the defined potential effect categories are applied to activities/effect pathways relevant to tidal energy developments for design-types that involve the rotation of turbines within natural hydrodynamic conditions[20]. Deployment/installation effects (Table 31) are addressed separately from those during the operational and maintenance phases (Table 32).

Note that details specific to the Fall of Warness, both environmental and relating to project-specifications, are not considered until the detailed appraisal later in this section. First, we consider potential effects in broad-principles.

[20] Tidal developments that involve the manipulation of hydrodynamic conditions prior to the extraction of energy (e.g. tidal barrages) are explicitly excluded from the broad consideration of potential effects in Table 31 and Table 32.

Generic Potential Effects from Device Deployment

Summary of activity categories – for detail see project envelope description (Annex 1)

- Installation of device(s), and associated infrastructure (e.g. foundations; mooring systems; cabling; buoys) on the seabed, in the water column or above the surface
- Use of vessels (e.g. DP vessel; jack-up barge; multi cat; workboat; dive-support vessel; crane-barge; tug; specialist cable-laying vessel.)
- Deployment and use of equipment to monitor devices or other environmental parameters during installation (e.g. ROV, cameras or acoustic devices)

Activity/potential impact pathway	Natural heritage feature	Potential importance
Underwater noise from active acoustic equipment leading to disturbance*	Harbour seal.	Potentially important - Importance will depend upon the range and frequency of noise sources (including background noise), duration and intensity of activity and the likelihood of seals in the area.
	Grey seal.	
Installation vessel(s) transits and manoeuvring leading to disturbance.	Harbour seal.	Potentially important – Activity of vessels in close proximity to designated haul-out sites could lead to disturbance (haul-out sites are protected under the Protection of Seals (Designation of Haul-out Sites) (Scotland) Order 2014)[21]).
	Grey seal.	
Underwater noise from foundation/mooring installation	Harbour seal.	Potentially important – Importance will depend upon the range and frequency of noise sources

* The term 'disturbance' includes all behavioural responses of biological consequence, including displacement from the vicinity of the activity.
[21] http://www.scotland.gov.uk/Topics/marine/marine-environment/species/19887/20814/haulouts

methods and vessels leading to: auditory injury (permanent or temporary), death or disturbance.	Grey seal.	(including background noise), duration and intensity of activity and the likelihood of seals in the area.
Interaction with vessel propellers used for dynamic positioning (e.g. Kort or some types of Azimuth thrusters) leading to: corkscrew injuries or death.	Harbour seal.	Potentially important – Depending on the time of year, proximity to seal haul-outs and propellers characteristics of vessel (s) used.
	Grey seal.	
Entanglement in lines or cabling leading to: injury or death.	Harbour seal.	No effect – No evidence to date to suggest that seal species are at risk from this impact pathway. No further assessment therefore required at this point.
	Grey seal.	

Table 31: Potential effects upon seals during device and infrastructure deployment; identifying activities/effect pathways and receptors for further assessment. Note that these evaluations are made *prior* to consideration of details particular to the Fall of Warness site.

Generic Potential Effects from Device Operation and Maintenance		
Summary of activity categories – for detail see project envelope description (Annex 1) • Physical presence of device(s), foundations, moorings, buoys and associated infrastructure on the seabed, in the water column or above the surface • Operation of device(s)/power generation • Repeat removal and redeployment of equipment for maintenance (e.g. turbine removed from water or floating structure removed from berth; replacement of mooring system) • Other maintenance activities (e.g. Biofouling removal; ROV/diver inspection or repairs) • Use of vessels (e.g. DP vessel; jack-up barge; multi cat; workboat; dive-support vessel; crane-barge; tug) • Use of equipment to monitor devices in situ or other environmental parameters (e.g. ROV, cameras or acoustic devices)		
Activity/potential impact pathway	**Natural heritage feature**	**Potential importance**
Underwater noise from active acoustic equipment leading to disturbance*.	Harbour seal.	Potentially important – Importance will depend upon the range and frequency of noise sources (including background noise), duration and intensity of activity and the likelihood of seals in the area.
	Grey seal.	
Maintenance vessel (s) transits and manoeuvring leading to disturbance.	Harbour seal.	Potentially important – Activity of vessels in close proximity to designated haul-out sites could lead to disturbance (haul-out sites are protected under the Protection of Seals (Designation of Haul-out Sites) (Scotland) Order 2014)
	Grey seal.	

Underwater noise from operating turbines leading to: auditory injury (permanent or temporary), death or disturbance*.	Harbour seal. Grey seal.	Potentially important – Importance will depend upon the range and frequency of noise sources (including background noise), duration and intensity of activity and the likelihood of seals in the area.
Other maintenance activities (non vessel based) leading to: disturbance.	Harbour seal. Grey seal.	Not important – maintenance activities include inspection (e.g. divers/ROV), repairs or temporary retrieval or replacement of nacelles by winch. In all cases it is the presence of the accompanying vessel that presents the primary disturbance risk, which is appraised separately.
Collision with operating turbine blades leading to: injury or death.	Harbour seal. Grey seal.	Potentially important – Potential for impact is poorly understood, but importance may depend upon turbine location & spacing, (including water depth), the physical and rotational characteristics of turbines, and the likelihood of seals passing through the risk window.
Presence of tidal device (s) and associated infrastructure leading to: barrier effects.	Harbour seal. Grey seal.	Potentially important – Seals may utilise or move through Sounds that may also present opportunity for tidal development. Importance will depend upon the spatial occupancy of the channel by tidal devices (in three dimensions), the physical and rotational characteristics of the devices and the importance of the vicinity for passage of seals.
Entanglement in lines or cabling leading to: injury or death.	Harbour seal. Grey seal.	No effect – Although evidence is not available, seals are intuitively of a size and mobility that greatly limits the potential for this interaction. Future review of this matter may be required, but no further assessment therefore required. This will be kept under review through ongoing research.
Interaction with vessel propellers	Harbour seal.	Potentially important – Depending on the time of year, proximity to seal haul-outs and propellers characteristics of vessel (s) used.

* The term 'disturbance' includes all behavioural responses of biological consequence, including displacement from the vicinity of the activity.

used for dynamic position (e.g. Kort or some types of Azimuth thrusters) leading to: corkscrew injuries or death.	Grey seal.	

Table 32: Potential effects upon seals during the operational and maintenance phase; identifying activities/effect pathways and receptors for further assessment. Note that these evaluations are made *prior* to consideration of details particular to the Fall of Warness site.

4.6.2 Natural heritage context

Harbour seals

Scotland holds around 79% of the UK's population of harbour seals and the UK holds around 30% of Europe's harbour seals, although this proportion has declined from approximately 40% in 2002. They are widespread around the west coast of Scotland and throughout the Hebrides and Northern Isles, with a more limited distribution restricted to concentrations in the major estuaries on the east coast such as Firth of Tay, Moray Firth, The Wash and the Thames. Major declines have been documented around Scotland since 2000 with a 66% reduction in Orkney, 50% in Shetland, 36% in the Outer Hebrides, 46% in the Moray Firth and 84% in the Firth of Tay. These declines are not thought to be linked to the phocine distemper virus epidemic in 2002 that saw declines around The Wash (SCOS, 2011).

For the Fall of Warness, analysis of data from the EMEC wildlife observations between July 2005 and December 2009 indicates that around a third of all observation days (n=1056) recorded the presence of harbour seals (n=373) (Robbins, 2011). The hourly encounter rate was highest between May and October, peaking at 0.7 harbour seals per hour in May and falling to 0.4 in October. In addition, unclassified seals were also recorded, peaking at 1.6 per hour in September. The distribution of harbour seals across the survey area was significantly varied, concentrating around Sealskerry Bay on Eday. Note that, for application in the collision risk models, the dataset for site-specific densities is refined (see Appendices 7 and 8 for details). The EMEC wildlife observations seal data has not been corrected for distance bias or detectability and that Robbins (2011) only reports on data collected from 2005 to 2009; SNH are currently funding further analysis. This assessment will then require review once this has been completed, together with analysis of the Wildlife Observation data covering the period from 2009 to date.

Telemetry studies focussing on seals within the PFOW area found harbour seal (tagged with Argos tags) tracks through the Fall of Warness site (SMRU Ltd, 2011)

Counts of harbour seals during moults at surrounding haul outs are notable but lower than for grey seals (see below), with an average of 25 at 'Muckle and Little Greenholm' between 2006 and 2010, to the south-western edge of the test site. Counts from 'Eday & Calf' indicate an average of 59, a high proportion of which is from Seal Skerry, at the north of the Fall of Warness site. Sanday SAC for the same period comprises an average count of 314 individuals (Duck and Morris, 2011). Ongoing tagging studies by SMRU Ltd on individuals tagged near the Fall of Warness should help add further information on the behaviour of individuals using the test site, although it is likely they are breeding, moulting and foraging in this area.

Grey seals

Around 38% of the world's grey seal population breed in the UK, of these 88% breed in colonies in Scotland, with the majority in the Hebrides and Orkney. While numbers of grey seal pups have increased steadily since the 1960s, there is evidence that this growth is levelling off particularly in Orkney and possibly some of the colonies in the North Sea (SCOS, 2011).

At the Fall of Warness, grey seals were more frequently observed (60% of observation days) during the EMEC wildlife observations between 2005 and 2009 in comparison to harbour seals (35% of observation days). The highest proportion of all grey seal observations coincided with their pupping season during the autumn months. The average encounter rate between December and August was less than 1 grey seal per hour (0.2 – 0.9), increasing to 4.3 individuals per hour during October. In addition, unclassified seals were also recorded, peaking at 1.6 per hour in September. Unsurprisingly, grey seal observations have been more frequent in the near-shore parts of the survey area, particularly adjacent to haul-outs. Note that, for application in the collision risk models, the dataset used to derive seal density is refined to those survey grid-cells that overlap with berth-sites (see Annex 3 for details). The proximity of the Faray and Holm of Faray SAC together with Muckle and Little Greenholm SSSI and other non designated nearby haul outs all frequented by grey seals (e.g. Seal Skerry), partly explains the higher numbers of grey seals using the Fall of Warness in comparison to harbour seals. They were also found to significantly vary in their distribution across the site concentrating around Muckle Green Holm to the west of the test site (Robbins, 2011).

Observations of grey seals during the annual August (harbour seal) mount count surveys at 'Muckle and Little Greenholm' between 2006 and 2010, to the south-western edge of the test site, indicate an average of 47 individuals. Observations from 'Eday & Calf' indicate an average count of 211, a high proportion of which is from Seal Skerry, at the north of the Fall of Warness site. However, the yearly counts show much more variation in comparison to the harbour seal counts. Faray and Holm of Faray SAC (including nearby Rusk Holm) for the same period comprise an average count of 492 individuals (Duck and Morris, 2011).

Based on count data from Muckle and Little Green Holm between 1998 and 2008, the average number of estimated pups was 1161. Telemetry studies (using Argos and GSM/GPS tags) on 44 individuals mostly outwith the breeding season indicated that grey seals are capable of moving over large distances; tracks also show the movement of seals through the Fall of Warness (SMRU Ltd, 2011).

Higher numbers of grey seal use the Fall of Warness in comparison to harbour seals and they are present during both the breeding (late September to early October) and moulting periods whereby females moult in the following January to March whereas males generally moult later during March to May. The tagging studies have shown that individuals are transiting through the Fall of Warness and it is likely that they are also using this area when foraging (SMRU Ltd, 2011).

4.6.3 Summary of impact appraisal process for the Fall of Warness

This impact appraisal takes account of a maximum-case scenario based on the project envelope description where all available berths within the test site are developed and operating at capacity. It addresses the differing consenting and licensing regimes (see Table 33 below). This appraisal will inform the consenting process for both Marine Licence and Section 36 application(s). However, it should be noted that, if there are key deviations in the device design or in installation or maintenance activities, further appraisal work may be required. Any additional appraisal work required will be undertaken by the individual developer (further advice should be sought from EMEC in the first instance).

Feature Type	Appraisal mechanism/relevant legislation	Applicable	Reasoning
Qualifying features of European sites.	Habitats Regulations Appraisal (HRA) - Habitats Regulations 1994 (as amended).	Y	Captures assessment of harbour and grey seals as qualifying species of SAC.
European Protected Species.	EPS legislation - Habitats Regulations 1994 (as amended in Scotland).	N	Neither are EPS.
Notified features of SSSIs.	SSSI legislation - Nature Conservation (Scotland) Act 2004 (as amended).	Y	Captures assessment of SSSIs with seal notified features.
Protected features of MPAs	Marine (Scotland) Act 2010	N	Neither seal species is a protected feature of MPAs under the Marine (Scotland) Act 2010.
PMFs	Marine (Scotland) Act 2010	Y	Both seal species are PMFs and present at Falls of Warness.
Other sensitive natural heritage features.	Appraisal of other features under: - Electricity Works (EIA) (Scotland) Regulations (Amendment) 2008; - Marine Works (EIA) (Amendment) Regulations 2011; - Marine (Scotland) Act 2010. - The Protection of Seals (Designation of Haul-out Sites) (Scotland) Order 2014.	Y	Captures assessment required under EIA, and in relation to Seal Management Units and designated haul outs.

Table 33: Appraisal mechanism for seals.

4.6.4 Qualifying features of European sites

The following commentary outlines the appraisal undertaken in relation to the seal SAC qualifying features. See Section 4.7 for the Natura Proforma which underpins the advice summarised in Table 34 below for those SAC considered to have connectivity for which a significant effect is considered likely. See Annex 2 for background commentary on the Habitats Regulations.

Step 1:
Is the tidal turbine test site at the Fall of Warness directly connected with or necessary for the conservation management of the SAC?

The test site is not directly connected with or necessary to site management for the conservation management of any of the SAC in Scotland.

Step 2:
Is the test site at the Fall of Warness likely to have a significant effect on the qualifying interests of the SAC either alone or in combination with other plans or projects?

This step acts as a screening stage: it removes from the HRA those proposals (plans or projects) which clearly have no connectivity to SAC qualifying interests or where it is very obvious that the proposal will not undermine the conservation objectives for these interests, despite a connection.

Those SAC with seal qualifying features considered in respect of the test site are wide-ranging – reflecting that seals can make long foraging trips, although they tend to be more site faithful during the breeding season. This means that the test site may be 'connected to' SAC, even at great distances.

Determination of 'likely significant effect' is not just a record of presence or absence of seal species at a test site, but also involves a judgement as to whether any of the SAC conservation objectives might be undermined. Such judgement is also informed by a simple consideration of the importance of the area in question for the relevant species.

Given the species biology of seals, impacts upon even a relatively small number of animals could have important implications, particularly considering the current potential for cumulative impacts within Orkney waters. This is particularly relevant for Harbour seals as there has been a sharp fall in the UK population, particularly in Shetland, Orkney and Firth of Tay. The SAC in Orkney which has harbour seals as a qualifying feature is in unfavourable condition (as assessed through site condition monitoring) and, overall, the conservation status for harbour seals at a UK level has been assessed as 'unfavourable-inadequate'. As such, harbour seals in particular are currently vulnerable to any impacts which could lead to their further population decline or prevent their recovery.

The advice below relates to SAC considered to have potential connectivity with the Fall of Warness test site, primarily based upon data acquired through telemetry-tagging studies carried out by SMRU Ltd. Only qualifying features of each SAC with connectivity have progressed to this stage in the appraisal; for example, although seals (as the SAC species qualifying feature) are discussed below, the habitats that are also qualifying features of each SAC are not appraised further.

Grey seals are known to range widely to forage and, while they can frequently travel up to several hundred kilometres offshore, most foraging is likely to occur within 100km of a haul out site (SCOS, 2012, Cronin *et al*., 2012). 100km has therefore been chosen as a threshold for considering connectivity, whereas harbour seals are generally considered to forage within 40-50km of their haul out site (SCOS, 2012). As knowledge increases these thresholds may require updating.

Harbour seal

The test site is approximately 15km from Sanday SAC which has the largest colony of breeding harbour seals in Orkney. The test site is within the 50km typical maximum foraging range for this species (SCOS, 2012). Moreover, harbour seals in UK waters show some degree of fidelity to their breeding sites year round and so remain in relative proximity to these sites out with the breeding season (SMRU Ltd, 2011). Harbour seals occur all year round in the Fall of Warness with an increase in average encounter rate between May and October (Robbins, 2011).

Conclusion:
There is potential for the test site to have a likely significant effect on harbour seals from Sanday SAC. There is no likely significant effect to harbour seals from any other SAC.

Grey seal
The test site is around 4km from Faray and the Holm of Faray SAC which is one of the most important breeding and haul out sites for grey seals in Orkney. The site supports the third largest breeding colony in the UK (and the fourth in the world). In 2008, pup production was estimated to contribute 6% of the UK's annual production (SMRU Ltd, 2011). The site is within the 100km foraging range considered reasonable for this species (SCOS, 2012). Grey seals occur all year round in the Fall of Warness with a higher average encounter rate during September and October (Robbins, 2011).

Recent telemetry data suggests movement of grey seals between Orkney and a number of SAC that are located out with Orkney waters, specifically: North Rona SAC, Isle of May SAC and Berwickshire and North Northumberland SAC (SMRU Ltd, 2011). However, in considering the large distances involved, we are mindful of their wide-ranging behaviour out with the breeding season, which is in contrast to greater site fidelity displayed during breeding. As such, we advise that there is no likely significant effect to grey seals from these more distant SAC.

Conclusion:
There is potential for the test site to have a likely significant effect on grey seals from Faray and Holm of Faray SAC. There is no likely significant effect to grey seals from any other SAC.

As mentioned above, a Natura Proforma (see Section 4.7) for both Sanday and Faray and Holm of Faray SAC underpins the summarised commentary outlined below. It includes the Conservation Objective for both sites.

Step 3:
Can it be ascertained that the test site will not adversely affect the integrity of the SAC, either alone or in-combination with other plans or projects?

This stage of HRA is termed the **Appropriate Assessment**. This stage is undertaken by the competent authority (Marine Scotland), with advice provided by SNH. Appropriate Assessment considers the implications of the proposed development for the conservation objectives of the qualifying interests for which a likely significant effect has been determined. We discuss this below for each of the SAC and their qualifying seals interests.

The key question in any Appropriate Assessment for the testing of tidal devices at the Fall of Warness is whether it can be ascertained that this proposal, alone or in-combination, will not adversely affect either of the above mentioned seal Natura sites, where it has been advised that there is a likely significant effect. As the test site does not overlap with any of the seal SAC, the conservation objectives that require further consideration are **(ii)** – significant disturbance to seals and **(iii)** population of the species as a viable component of the SAC, as these can include impacts to seals while they are out-with the SAC.

This appraisal should help inform the Appropriate Assessment, however as stated above any deviation from the project envelope description may require further information and subsequent appraisal.

In relation to disturbance impacts upon seals, future revisions of this appraisal should utilise the Population Consequences of Disturbance (PCoD) framework, currently under development by SMRU Ltd. This should aid a more quantitative approach to assessing disturbance impacts.

Conclusion:
The proposal will not adversely affect site integrity of Sanday SAC or Faray and Holm of Faray SAC.

Activity/Potential Impact Pathway	Installation Operation & Maintenance	Summary of Appraisal Assessment
Underwater noise from active acoustic equipment leading to disturbance*.	All	PROJECT-SPECIFIC ASSESSMENT REQUIRED.
Vessel(s) transits and manoeuvring leading to disturbance.	All	We consider there may be potential for disturbance effects from multiple vessels activity on site due to the likely ability of seals to detect vessel noise, albeit in the context of an area with existing natural and anthropogenic noise, including vessel traffic. However, even if seals were displaced (considered to be ultra- precautionary) from the test site, and we have no evidence to suggest that this is the case or not, evidence from telemetry studies (SMRU Ltd, 2011) indicates that seals tagged in this part of Orkney are using vast areas of the North sea to the north and east of the Orkney archipelago and as such the site is unlikely to be especially important in terms of foraging. As such, we do not consider that such disturbance/ displacement effects would negatively effect the population of either seal species as a viable component of either SAC, particularly if suitable mitigation is applied to limit or avoid disturbance near haul-outs during the breeding season. Future revisions of this appraisal should utilise the Population Consequences of Disturbance (PCoD) framework, currently under development by SMRU Ltd. This should aid a more quantitative approach to assessing disturbance impacts.
Underwater noise from foundation/mooring installation methods and vessels leading to: auditory injury (permanent or temporary), death or disturbance.	Installation	The range of source levels expected from drilling or anchoring operations and vessel noise are considerably lower than the level at which fatal injury, PTS or TTS to harbour or grey seal is considered to occur. It is therefore unlikely that harbour or grey seals from either SAC would be killed or experience auditory injury as a consequence of underwater noise emitted from installation operations at the Fall of Warness. Drilling noise is considered likely to be within the range of poorer hearing for both seal species. This combined with the short duration of drilling operations (typically around a week) lead us to consider that

* The term 'disturbance' includes all behavioural responses of biological consequence, including displacement from the vicinity of the activity.

		the potential for any behavioural impacts to constitute significant disturbance to either species of seal from either SAC is unlikely. Vessel noise is likely to be audible to both seal species. There is potential for this noise to cause some form of disturbance effect, however, we have no further data or information at this stage that would explicitly confirm or explain the extent of this potential impact pathway. Nevertheless, we do not consider that such disturbance or displacement effects would negatively effect the population of either seal species as a viable component of either SAC due to the small scale of the test site combined with evidence from telemetry studies of alternative available foraging habitat for both species of seal.
Interaction with vessel propellers used for dynamic positioning (e.g. Kort or some types of Azimuth thrusters) leading to: corkscrew injuries or death.	All	PROJECT-SPECIFIC ASSESSMENT REQUIRED.
Underwater noise from operating turbines leading to: auditory injury (permanent or temporary), death or disturbance*.	Operation & Maintenance	Likely source levels from operating turbines are lower than the level at which injury, PTS or TTS to harbour or grey seal is considered to occur. It is therefore unlikely that either species from either SAC would be killed or experience auditory injury as a consequence of underwater noise emitted from operational turbines at the Fall of Warness. The noise output is likely to be similar to vessel noise in terms of its frequency range so will be audible to seals. There is potential for this noise to cause some form of disturbance effect, however, we have no further data or information at this stage that would explicitly confirm or explain the extent of this potential impact pathway. Nevertheless, we do not consider that such disturbance or displacement effects would negatively affect the population of either seal species as a viable component of either SAC due to the small scale of the test site combined with evidence from telemetry studies of foraging ranges for both species of seal.
Collision with operating turbine blades leading to: injury or death.	Operation & Maintenance	For the maximum device scenario, and assuming avoidance rates of 98% for both seal species, collision rates per year are 0.34 for harbour seals (assuming U-shaped dives) and 0.77 to 1.82 for grey seals (U and V-shaped dives, respectively). Considering the high likelihood that a large proportion of seals using the Fall of Warness are not associated with these SAC, plus knowledge of seal population trends in the

* The term 'disturbance' includes all behavioural responses of biological consequence, including displacement from the vicinity of the activity.

		SAC and further afield, and a number of precautionary layers within the modelling, it is concluded as unlikely that any additional mortality from collision with operational turbines at the Fall of Warness will be statistically distinguishable from natural or other forms of mortality for seals as qualifying interests of Sanday SAC or Faray and Holm of Faray SAC. However, the continued absence of empirical data to fully support assumptions made in the modelling process, necessitate a robust monitoring programme at the Fall of Warness to record any physical interaction of animals with device or any other observations of animal behaviour in the near-field.
Presence of tidal device (s) and associated infrastructure leading to: barrier effects.	Operation & Maintenance	There is potential for the operating turbines to cause some sort of barrier effect at the Fall of Warness test site. The likelihood of the test site acting as a complete barrier to movement is considered to be relatively low due to the small scale of the overall development footprint from the 9 berths compared to the overall extent of the site which equates to 0.07%. This, together with the availability of alternative habitat, as evidenced through telemetry studies, lead us to consider the potential impact from barrier effects to both species of seal from both SAC to be minimal, such that we do not consider it would negatively effect the population of either seal species as a viable component of either SAC.

Table 34: Summary of Natura assessment for both Sanday and Faray and Holm of Faray SAC – See Section 4.7 for further details.

4.6.5 Notified features of Site of Special Scientific Interest (SSSI)

SSSIs are designated under the Nature Conservation (Scotland) Act 2004 (as amended) and it is an offence for any person to intentionally or recklessly damage the protected natural features of an SSSI. More information can be found on the SNH website, including SSSI citations and Site Management Statements[22]. Assessment of impacts to SSSI should consider the likelihood of adverse impacts to the integrity of the area or damage to the natural features for which the site is notified.

Appraisal of impacts of SSSI seal features

Muckle and Little Green Holm SSSI

Muckle and Little Green Holm SSSI is immediately adjacent to southern part of the test site, comprising two neighbouring uninhabited islands (Muckle Green Holm and Little Green Holm). The SSSI regularly supports around 2% of the grey seal pups born in the UK and is one of the largest sites for breeding grey seals in Orkney. Of those pups produced across all the grey seal colonies in Orkney in 2008, this SSSI contributed 5% with estimates given as 658 pups on Muckle and 271 pups on Little Green Holm (SMRU Ltd, 2011). This SSSI is in favourable maintained condition.

The same impact pathways as summarised above have been used to assess potential impacts on this SSSI.

Conclusion:
Providing a 500m exclusion zone is applied around these islands, and the principles of the SMWWC are followed, the test site will have no adverse impact on the notified feature (grey seal).

4.6.6 Appraisal of other features

Marine (Scotland) Act 2010

Potential Biological Removal

In addition to protection measures afforded to seals associated with SAC and SSSIs, all seals are afforded a level of protection under the Marine (Scotland) Act 2010 and the Conservation (Natural Habitats, &c.) Regulations 1994 (as amended). It is an offence to kill, injure or take a seal at any time of year except to alleviate suffering or where a licence has been issued to do so by Marine Scotland. Licence applications are assessed against Potential Biological Removal (PBR) for each of seven Management Regions (East coast, Moray Firth, Shetland, Orkney and the North coast, Outer Hebrides, West Highland, South-West Scotland). PBR is the number of individual seals that can be removed from each of these meta-populations without population-level implications and is calculated annually using the latest seal data. The management unit relevant to this appraisal for both harbour and grey seals is 'Orkney and North Coast'.

[22] http://www.snh.gov.uk/protecting-scotlands-nature/protected-areas/national-designations/sssis/

Harbour Seal

Harbour seals are in a declining status across UK waters. The harbour seal population in the Orkney and North Coast Management Unit has undergone a prolonged decline with the population count (at time of writing; June 2013) stated as 2799, with results of the most recent partial survey undertaken in 2012 indicating a continued decline (SMRU, 2013). The harbour seal PBR for the Orkney and North Coast management unit is regularly revised; at the time of writing this appraisal (June 2013), it was set at 17 individuals, with licenses granted to shoot 5 harbour seals to protect fisheries and salmon farms[23].

Grey Seal

The population estimate (at time of writing; June 2013) is 31,750 for grey seals in the Orkney and the North Coast Management Unit. Grey seal populations in all management units have undergone a period of prolonged growth and appear to have stabilised at historically high levels. At the time of writing this appraisal, the grey seal PBR for the Orkney and North Coast Management Unit is 1448 (SMRU, 2013), with licences granted to shoot 220 grey seals to protect fisheries and salmon farms[3].

Appraisal of impacts within the management unit

Table 35 below provides an overview of our appraisal of the Fall of Warness test site on the Orkney and North Coast Management Unit in light of the PBR. This will need to be reviewed regularly in light of updated population and PBR figures. Further technical discussions of the impact pathways are available in the Natura proforma for the SAC (Section 4.7).

Potential Impact Pathway	**Appraisal for Management Unit**	
	Harbour seal	**Grey seal**
Collision risk.	At the time of writing (Agust 2014), the predicted collision rates for the maximum device scenario were within the harbour seal PBR limits for the Orkney & North Coast Management Unit (17, with 6 licences granted), as defined under Marine Scotland's seal licensing system. Given the status of harbour seal populations, and the changing nature of the PBR, it is particularly important that these figures are reviewed with the most up to date information prior to the issue of any individual Marine Licence for deployment of a tidal turbine.	At the time of writing (August 2014), the predicted collision rates for the maximum device scenario were within the grey seal PBR limits for the Orkney & North Coast Seal Management Unit (1448, with 232 licences granted), as defined under Marine Scotland's seal licensing system. These figures should be reviewed with the most up to date information prior to the issue of any individual Marine Licence for deployment of a tidal turbine.

[23] http://www.scotland.gov.uk/Topics/marine/Licensing/SealLicensing

Corkscrew injuries.	PROJECT-SPECIFIC ASSESSMENT REQUIRED. Given the status of harbour seal populations and the uncertainties regarding this impact, it is recommended that this matter is given project-specific appraisal in light of the most recent population and PBR figures. Potential mitigation includes consideration of alternatives to using vessels with ducted propellers and/or avoiding the breeding season if possible.	Set against the size and stability of the grey seal population in the Orkney and North Coast Management Unit, the potential for interaction with vessel propellers is very unlikely to have a population-level effect or contribute significantly to the PBR. However, given the proximity of several haul-outs, good-practice mitigation includes the consideration of alternatives to using vessels with ducted propellers and avoiding the breeding season if possible. Also note the need for project-specific assessment in relation to Faray and Holm of Faray SAC (see section 4.6.4).
Disturbance from increased vessel activity.	Very unlikely to lead to fatality. Any potential impact upon productivity at nearby haul-outs is considered negligible, particularly in the context of the area covered by the management unit. Also, the simultaneous occurrence of vessels accounted for as the maximum case scenario in the project envelope is rare, and most activity is likely to be focussed on discrete time-periods (lower tidal-stream flow).	As for harbour seals.
Disturbance from installation works such as drilling.	Very unlikely to lead to fatality. Any potential impact upon productivity at nearby haul-outs is negligible, particularly in the context of the area covered by the management unit and given the temporary nature of works.	As for harbour seals.
Disturbance due to operational turbines.	Very unlikely to lead to fatality, and may reduce collision risk if animals are disturbed away from devices.	As for harbour seals.
Disturbance from active acoustic equipment .	For the HRA (Section 4.7), project-specific assessment is required. However, this impact pathway is very unlikely to lead to fatality and any impact on productivity negligible in the context of the management unit.	As for harbour seals.
Barrier effects.	A barrier effect is not considered likely. Moreover, any residual impact is very unlikely to lead to fatality, and may reduce collision risk if animals perceive a barrier to passage/transit.	As for harbour seals.

Table 35: Appraisal of impacts against the Orkney and North Coast Management Unit and PBR.

Conclusion:
Only impacts of (a) collision risk with operational turbines and (b) corkscrew injuries from interaction with vessel propellers are of relevance for considering in relation to PBR and seal licensing under the Marine (Scotland) Act 2010.

Due to the changing nature of PBR rates, predicted additional fatalities in relation to collision with operational turbines should be reviewed against the most up to date information at the time of application, and the appropriate licensing decision made accordingly.

Potential for corkscrew injuries and suitable mitigation requires device-developer-specific appraisal at the time of application.

Designated seal on haul out sites

Under The Protection of Seals (Designation of Haul-out Sites) (Scotland) Order 2014 it is an offence to intentionally or recklessly harass seals at designated haul-out sites[24]. As discussed above, due to population declines harbour seals are currently particularly sensitive to any impacts, including harassment, which could lead to their further decline or prevent their recovery.

There are a number of designated haul out sites within the immediate vicinity of the tidal test site, these include Seal Skerry for harbour seal, Muckle Green Holm and Little Green Holm for grey seal breeding colonies, the eastern coastline of Egilsay, Rusk Holm and off the point at War Ness for both species of seal. It is considerd that harassment of seals hauled out at these sites can be avoided through appropriate vessels management. This, and adherence to the principles laid out in the SMWWC, will be particularly pertinent during periods of laying up when vessels are off berth waiting for suitable tidal conditions or during transits to and from the berth and offsite.

Conclusion:
Providing the principals of the SMWWC are followed and transits are considered via appropriate vessel management, the risk of harassment to seals hauled out at any of the designated seal haulout sites is likely to be minimal.

4.6.7 Seal receptor conclusions

A summary of the appraisal for each of the receptors is provided in Table 36 below. Note that, even where no important impacts on the development site are identified, in some cases there may still be a recommendation for some mitigation or monitoring. Under these circumstances, mitigation would be regarded as good-practice rather than a necessity, while monitoring may serve to improve generic understanding of the relationships between stressors and receptors.

[24] http://www.scotland.gov.uk/Topics/marine/marine-environment/species/19887/20814/haulouts

Receptor	Conclusion	Mitigation and or Monitoring Identified?
Harbour seals	LSE identified for Sanday SAC, but no adverse effect on site integrity. However, ongoing monitoring required. No important effects on wider harbour seal populations or haul-outs.	Yes – see Table 37
Grey seals	LSE identified for Faray and Holm of Faray SAC, but no adverse effect on site integrity. However, ongoing monitoring required. No damage to the natural features of Muckle and Little Green Holm SSSI. No important effects on wider grey seal populations or haul-outs.	Yes – see Table 37

Table 36: Summary of assessment conclusions.

Given the uncertainties regarding some potential impacts, the protected status of both seal species and the opportunity to learn from test deployments, some potential mitigation and monitoring measures are presented in Table 37 below (this table should be updated as knowledge increases). Some such measures will be appropriate as conditions on the Marine Licence, whereas others may just be recommended as good practice. Please see Section 5 for further details on the mitigation and monitoring highlighted below.

Site-wide monitoring and research ideas may be more effectively pursued at a strategic level (whether by EMEC, The Crown Estate or Marine Scotland, or by a developer consortium), but developer input or ideas are welcomed.

Potential Residual Impacts	Relevant Receptors	Relevant Impact- pathway	Mitigation	Monitoring
Disturbance.	Harbour and Grey seal.	Underwater noise from drilling/installation activity.	Use of an MMO prior to the commencement of drilling operations. Use of exclusion zones around haul-outs. Adherence to the SMWWC.	Acoustic monitoring of drilling and anchor/mooring installation noise at various distances and frequencies. Depending on timing and duration of activities specific short term monitoring of, for example, seal haul outs may be required.

Disturbance.		Underwater noise from vessel activity.	Adherence to the SMWWC. Appropriate vessel management – integrated with simultaneous developer activities.	Monitor vessel activity during the breeding seasons of both species. Depending on timing and duration of activities, specific short term monitoring of, for example, seal haul outs.
Harassment/ Disturbance.		Noise from vessel activity (including presence).	Adherence to the SMWWC Appropriate vessel management – integrated with simultaneous developer activities and use of exclusion zone as appropriate.	Monitor vessel activity during the breeding seasons of both species.
Disturbance.		Underwater noise from operating turbines.		Establishing the acoustic signature of operating devices at various distances and frequencies.
Death or injury.		Collision risk from operating turbines.	(Revisit if monitoring indicates impacts).	Use of appropriate method to detect collision or near miss, and monitor any other interaction between seals and the operating device.
Displacement.		Barrier effect from presence of devices.	(Revisit if monitoring indicates impacts).	Monitor seal usage of the Fall of Warness.

Table 37: Potential mitigation and monitoring measures relevant to seals.

Project-specific assessments are required for aspects of the following impact pathways and will include the need for each developer to identify appropriate mitigation and or monitoring:

- Assessment of active acoustic equipment
- Interactions with vessel propellers

4.6.8 References

Duck, C., Morris, C. 2011. Survey of Harbour (common) seals in Orkney in August 2010. *Scottish Natural Heritage Commissioned Report No. 439*

Cronin, M., Pomeroy P., Jessopp, M. 2012. Size and seasonal influences on the foraging range of female grey seals in the northeast Atlantic. *Marine Biology* DOI 10.1007/s00227-012-2109-0

Jones E., McConnell B., Sparling C., Matthiopoulus J. 2013. Grey and Harbour seal density maps. Marine Mammal Scientific Support Research Programme MMSS/001/11; Task MR 5. Marine mammal Research Unit report to Scottish Government.

Robbins, A. 2011. Summary of Bird and Marine Mammal Data for the Fall of Warness and Billia Croo, Orkney and Review of Observation Methodologies: *A report to Scottish Natural Heritage*.

SMRU Ltd. 2011. Utilisation of Space by Grey and Harbour Seals in the Pentland Firth and Orkney waters. *Scottish Natural Heritage Commissioned Report No. 441*

SMRU. 2013. Report to the Scottish Government from SMRU. 2013. Provisional Regional PBR for Scottish seals in 2013

SCOS. 2011. Scientific Advice on Matters Related to the Management of Seal Populations

SCOS. 2012. Scientific Advice on Matters Related to the Management of Seal Populations

4.7 Natura Appraisal: Special Area of Conservation (Seals)

Please see Annex 2 for legislative background on Habitats Regulations Appraisal (HRA).

4.7.1 Site details

1(a) Name of Natura site affected & current status:

From our screening exercise the following seal SAC were identified as requiring further appraisal based on current knowledge of foraging range, impact pathways and consideration of seal usage on and near the site using the EMEC Wildlife Observation data:

SAC name	Current status
Sanday SAC	Classified
Faray and Holm of Faray SAC	Classified

1(b) Name of component SSSI if relevant:

East Sanday Coast SSSI

Faray and Holm of Faray SSSI

1(c) European qualifying interest(s) & whether priority/non-priority:

Name of SAC	Qualifying interest	Comments
Sanday	Common (harbour) seal	See below
	Intertidal mudflats and sandflats	No impact pathway; this habitat is not appraised further as the test site will have no impact on this feature.
	Reefs	No impact pathway; this habitat is not appraised further as the test site will have no impact on this feature.
	Subtidal sandbanks	No impact pathway; this habitat is not appraised further as the test site will have no impact on this feature.
Faray and Holm of Faray	Grey seal	See below

1(d) Conservation objectives for qualifying interests:

Sanday Special Area of Conservation:

To avoid deterioration of the habitats of the qualifying species (listed below) or significant disturbance to the qualifying species, thus ensuring that the integrity of the site is maintained and the site makes an appropriate contribution to achieving favourable conservation status for each of the qualifying features; and

- To ensure for the qualifying species that the following are maintained in the long term:
- Population of the species as a viable component of the site
- Distribution of the species within site
- Distribution and extent of habitats supporting the species
- Structure, function and supporting processes of habitats supporting the species
- No significant disturbance of the species

Qualifying Species:

• Common (harbour) seal

Faray and Holm of Faray Special Area of Conservation:

To avoid deterioration of the habitats of the qualifying species (listed below) or significant disturbance to the qualifying species, thus ensuring that the integrity of the site is maintained and the site makes an appropriate contribution to achieving favourable conservation status for each of the qualifying features; and

- To ensure for the qualifying species that the following are maintained in the long term:
- Population of the species as a viable component of the site
- Distribution of the species within site
- Distribution and extent of habitats supporting the species
- Structure, function and supporting processes of habitats supporting the species
- No significant disturbance of the species

Qualifying Species:

• Grey seal

4.7.2 Proposal details

2(a) Proposal Title:	Fall of Warness Test Site Environmental Appraisal
2(b) Date consultation sent:	N/A
2(c) Date consultation received	N/A
2(d) Name of consultee	SNH
2(e) Name of competent authority	Marine Scotland

2(f) Details of proposed operation (inc. location, timing, methods):

This appraisal is being carried out in response to the redevelopment of the environmental documentation used by developers at EMEC in order to assist in streamlining the appraisal process required to inform the Marine Licence/Section 36 consenting process for deployments at the existing test site at the Fall of Warness. For further details please see the introduction in Section 1 of this document, together with the project envelope description in Annex 1 which explain the parameters included within this appraisal.

The test site at the Fall of Warness has been in existence since 2005. There are currently (as of July 2014) 7+1 berths, all assigned to different developers. The project envelope (Annex 1) describes the maximum parameters used in this appraisal.

4.7.3 Appraisal in relation to Regulation 48 of the Habitats Regulations

3(a) Is the operation directly connected with or necessary to conservation management of the site?

No

3(b) Is the operation likely to have a significant effect on the qualifying interest? Consider each qualifying interest in relation to the conservation objectives:

Please note that as our understanding of seal behaviour and movements improves, this appraisal may need to be revisited.

Sanday SAC – Harbour (Common) Seal - Yes
Sanday SAC is located approximately 15km from the test site and is the largest colony of breeding harbour seal in Orkney. The test site is within the 50km foraging range for this species (SCOS, 2011). Moreover, harbour seals in UK waters show some degree of fidelity to their breeding sites year round and so remain in relative proximity to these sites outside the breeding season (SMRU Ltd, 2011).
Harbour seals occur all year round in the Fall of Warness with an increase in average encounter rate between May and October (Robbins, 2011). There is therefore potential for the test site to have a likely significant effect on harbour seals from this SAC. This SAC is in unfavourable declining condition.

Faray and Holm of Faray SAC – Grey Seal - Yes
Faray and the Holm of Faray SAC is located approximately 4km to the north of the test site and is one of the most important breeding and haul out sites for grey seals in Orkney. The site supports the third largest breeding colony in the UK (and the forth in the world). In 2008, pup production was estimated to contribute 6% of the UK's annual production (SMRU Ltd, 2011). The site is within the 100km foraging range considered appropriate for this species (SCOS, 2011).
Grey seals occur all year round in the Fall of Warness with a higher average encounter rate during September and October (Robbins, 2011). There is therefore potential for the test site to have a likely significant effect on grey seals from this SAC. This SAC is in favourable maintained condition.

Summary of potential impacts pathways on harbour and grey seals from the installation, operation and maintenance of tidal turbines at the Fall of Warness Test site:

Please refer to Table 31 and Table 32 in Section 4.6 for further commentary on these impact pathways.

Installation

- Underwater noise from active acoustic equipment leading to disturbance*
- Installation vessel (s) transits and manoeuvring leading to disturbance
- Underwater noise from foundation/mooring installation methods and vessels leading to: auditory injury (permanent or temporary), death or disturbance
- Interaction with vessel propellers (e.g. Kort or some types of Azimuth thrusters) leading to: death from corkscrew injuries

Operation and maintenance

- Underwater noise from active acoustic equipment leading to disturbance*
- Maintenance vessel (s) transits and manoeuvring leading to disturbance
- Underwater noise from operating turbines leading to: auditory injury (permanent or temporary), death or disturbance*
- Collision with operating turbine blades leading to: injury or death
- Presence of tidal device (s) and associated infrastructure leading to: barrier effects
- Entanglement in lines or cabling leading to: injury or death
- Interaction with vessel propellers (e.g. Kort or some types of Azimuth thrusters) leading to: death from corkscrew injuries

Decommissioning – will be dealt with separately on a case-by-case basis and is not dealt with as part of this appraisal process.

3(c) Appraisal of the implications for the site in view of the site's conservation objectives: In the light of the appraisal, ascertain whether the proposal will not adversely affect the integrity of the site for the qualifying interests.

(i) Overview of existing information

Harbour Seal usage of the Fall of Warness

EMEC wildlife observations analysis (Robbins, 2011)[25]

Wildlife observations are carried out on a four-hour scan system 5 days a week, from a vantage point 50m above sea level. The survey area is defined by grid cells approximately 500m x 500m across the whole of the test site. This analysis has not been corrected for Distance bias or detectability; SNH are currently funding further analysis to account for this. This assessment will then require review once this has been completed, together with analysis of the EMEC Wildlife Observation data covering the period from 2009 to date.

Analysis of data between July 2005 and December 2009 (Robbins, 2011) indicates that around a third of all observation days (n=1056) recorded the presence of harbour seals (n=373). With an hourly encounter rate highest between May and October, peaking at 0.7 harbour seals per hour in May and falling to 0.4 in October. The distribution of harbour seals across the survey area was significantly varied, concentrating around Sealskerry Bay on Eday.

* The term 'disturbance' includes all behavioural responses of biological consequence, including displacement from the vicinity of the activity.

[25] Data from this report covers the period from 2005 – 2009 only.

For the purpose of collision-risk modelling, using the EMEC Wildlife observation data, a density estimate has been derived for harbour seal from the period July 2005 – March 2011 for the survey grid-cells overlapping with berth-ends (2.696 $\times 10^{-8}$ per m^2 - please see Annex 3 for further details). Due to the availability of more than five-years of site-specific observations, and concerns over applicability of alternative data sources to small-scale inshore areas, these density figures have been favoured over those available through the Marine Scotland telemetry-derived densities in 'seal usage maps' (Jones *et al*., 2013).

Survey of harbour seals in Orkney in 2010 (Duck and Morris, 2011)
Harbour seals generally give birth in June and July and moult in August (SCOS, 2011). Moult counts at 'Muckle and Little Greenholm' between 2006 and 2010, to the south-western edge of the test site indicate a medial number of 19 individuals. Counts from 'Eday & Calf' indicate a medial count of 62, a high proportion of which is from Seal Skerry, at the north of the Fall of Warness site. Sanday SAC for the same period comprises a medial count of 315 individuals.

Utilisation of space in PFOWs (SMRU Ltd, 2011)
Telemetry studies focussing on seals within the Pentland Firth and Orkney Waters found harbour seals (tagged with ARGOs tags) generally foraged within 20km of their departure haul out. The ARGOS and flipper tags revealed restricted movement between haul out regions. Tags deployed on pups showed less persistent fidelity to at-sea locations and many of the offshore trips were long and meandering in nature. Tagging tracks were noted through the Fall of Warness.

Of the 17 tags deployed, 15 were from Orkney, either at Sanday, Eynhallow, Rousay or Stronsay. The median trip duration was 3.2km (with 1.8 – 8.9km 25% and 75% quantiles). The mean maximum dive depth was 30.91m with mean dive duration of 4.14 minutes.

Conclusions from existing data sources for harbour seals
Harbour seals are clearly present in the Fall of Warness during June and July when pups are born and during August when adults haul out to moult. The tagging work reveals that individuals are transiting through the Fall of Warness and it is likely that they are also using this area when foraging. The number of harbour seals at surrounding haul outs is relatively low compared to grey seals. Ongoing tagging work on individuals tagged near the Fall of Warness should help add another layer of information as to the behaviour of individuals using the test site. There is a strong possibility that those harbour seals transiting through the FoW, or utilising any of the nearby haul outs, could be associated with Sanday SAC.

Grey Seal usage of the Fall of Warness

EMEC wildlife observations analysis (Robbins, 2011)
Grey seals were more frequently observed (60% of observation days) in comparison to harbour seals. The highest proportion of all grey seal observations coincided with their pupping season during the autumn months. The average encounter rate between December and August was less than 1 grey seal per hour (0.2 – 0.9), increasingly to 4.3 individuals per hour during October. They were also found to significantly vary across the site concentrating around Muckle Green Holm to the west of the test site.

For the purpose of collision-risk modelling, using the EMEC Wildlife observation data, a density estimate has been derived for grey seal from the period July 2005 – March 2011 for the survey grid-cells overlapping with berth-ends (6.176 $\times 10^{-8}$ per m^2 - please see Annex 3 for further details). Due to the availability of more than five-years of site-specific observations, and concerns over applicability of alternative data sources to small-scale inshore areas, these density figures have been favoured over those available through the Marine Scotland telemetry-derived densities in 'seal usage maps' (Jones *et al*., 2013).

Survey of grey seals in Orkney in 2010 (Duck and Morris, 2011)
Grey seals tend to spend longer hauled out during their breeding season, which in Orkney occurs between October and November before the annual moult (usually January). Moult counts at 'Muckle and Little Greenholm' between 2006 and 2010, to the south-western edge of the test site indicates a medial number of 32 individuals. Counts from 'Eday & Calf' indicate a medial count of 111, a high proportion of

which is from Seal Skerry, at the north of the Fall of Warness site. However, the yearly counts show much more variation in comparison to the harbour seal counts. Faray and Holm of Faray SAC (including nearby Rusk Holm) for the same period comprises a medial count of 506 individuals.

Utilisation of space in PFOW (SMRU Ltd, 2011)
Based on count data from Muckle and Little Green Holm between 1998 and 2008, the average number of estimated pups was 1161. Telemetry studies using both ARGOS and GSM/GPS tags on 44 individuals, mostly out with the breeding season, indicated that grey seals are capable of moving over large distances. Movement of seals was observed through the Fall of Warness. Grey seals generally travel large distances between haul out regions outside the breeding season. This suggests that those seals hauled out at Faray and Holm of Faray SAC may not necessarily breed there and conversely that seals from other SAC may be present out-with the breeding season. .

The median trip extent reported is 9.9km (4.3 – 22.4km 25% and 75% quantiles). The mean dive duration is similar to harbour seal at 3.82 minutes. The mean maximum dive depth is similar for both species at around 30m, with a maximum depth of up 100m.

Conclusions from existing data sources for grey seal
Higher numbers of grey seal use the Fall of Warness in comparison to harbour seals, which given the location of the Faray and Holm of Faray SAC together with Muckle and Little Greenholm SSSI, and other non designated nearby haul outs frequented by grey seals (e.g. Seal Skerry), is not surprising. The grey seal population is also substantially larger than that of the harbour seal. It is highly likely that some of these animals using the Fall of Warness are part of the population from Faray and Holm of Faray SAC. They are present during both the breeding and moulting period. The tagging work reveals that individuals are transiting through the Fall of Warness and it is likely that they are also using this area when foraging.

(ii) Appraisal of Impacts

INSTALLATION
Methods used to install foundations at the FoW include non-percussive drilling to insert a monopile (e.g. Voith) or twin pile foundation (e.g. Open Hydro), use of pin piles (e.g. TGL) as well as lowering of gravity based foundations (e.g. Atlantis, Hammerfest Strom, Open Hydro) but does not include pile-driving. It also includes the use of gravity anchors with mooring system (e.g. ScotRenewables) or pin-piled anchors.

Impact Pathway	**Underwater noise from foundation/mooring installation methods and vessels, leading to: auditory injury (permanent or temporary), death or disturbance**

The noisiest activity undertaken during the installation of foundations or mooring systems at the FoW is thought to be associated with drilling to insert pin piles or monopiles. Vessels used in relation to foundation/mooring installation could also contribute high levels of noise and as such are also assessed below.

The maximum worse case scenario would see drilling and associated works occurring at two separate berths at the same time. Please see Section 4.4.2 of Annex 1 (Simultaneous Marine Works) for further details.

Fall of Warness acoustic baseline characteristics
The tidal current at the FoW can reach 7 knots (3.5m/s) during spring tides; the seabed substrate is mostly rock with some coarse sand and is considered to be a low-loss acoustic environment. The site is exposed to the north-west and south-east and background noise is likely to include wave noise from the Eday and Muckle Green Holm shorelines together with sediment transportation and turbulent flow noise during tidal flows and noise from wind and precipitation. Existing anthropogenic noise includes local fishing boats, ferries and large shipping traffic passing through or nearby, albeit infrequently. There are a number of fish farms in the area some of which use seal scarer devices (Harland, 2013).

Studies by Wilson and Carter (2008) using drifting ears technology to characterise the site revealed considerable variation in the intensity of sound across the site and at specific frequencies. Additional characterisation studies by Harland (2013) showed that tidal-stream flow noise makes a significant contribution to the background sound field above 2 kHz. Five locations of high frequency tidal-stream flow noise within the test site area were identified and thought likely to be the tidal race and overfalls which develop during strong tides or may be associated with bottom features causing strong currents around obstructions. Tidal-steam flow noise levels can vary by up to 26 dB across the test site. Major contributors to the sound field were identified as tidal-stream flow noise, precipitation noise, shipping noise and MECS operating at the site. Wind and wave noise would also be expected to contribute to the noise field.

Underwater noise impact criteria commonly used for pinnipeds

	Exposure Limit	Effect	Reference
Peak	240 dB re 1 µPa	Lethality	Yelverton and Richmond (1981)
	218 dB re 1 µPa	PTS auditory injury onset	Southall *et al*. (2007)
	212 dB re 1 µPa	TTS auditory injury onset	Southall *et al*. (2007)
SEL M-weighted	203 dB re 1 µPa^{2}s	PTS auditory injury onset	Southall *et al*. (2007)
	183 dB re 1 µPa^{2}s	TTS onset	Southall *et al*. (2007)
RMS	190 dB re 1 µPa	Auditory injury criteria	NMFS (1995)
	160 dB re 1 µPa	Behavioural disturbance, level B, Harassment	NMFS (1995)
	140 dB re 1 µPa	Low level disturbance	HESS (1997)

Frequencies of seal hearing

Richardson *et al*. (1995) conclude that pinnipeds have essentially flat audiograms from 1 kHz to around 30-50kHz although this data is generated from a limited number of seals. Harbour seals are thought to also detect some underwater sound at higher frequencies up to 180 kHz if it is sufficiently intense; however sensitivity above 60kHz is poor and different frequencies cannot be discriminated. Kastelein *et al*. (2009) stated that the harbour seal's range of best hearing was from 0.5 - 40 kHz, but with poorer sensitivity below 1kHz and above 40kHz.

Drilling noise

Noise generated from underwater drilling through the installation of pin piles (small diameter grouted piles) or a monopile (hollow pile with concrete or other filling, with or without grouting) is considered to be significantly less than for hammered piles. Piling is not included within the project envelope for the Fall of Warness test site and so is not considered further. For the purpose of this assessment we consider source levels for drilling to be between 145-190 dB re 1 µPa at 1m (OSPAR Commission 2009). This is considered to be realistic in light of information presented from Strangford Lough where the one second sound pressure level measured during the pin pile drilling operations for the quadropod base of the SeaGen tidal turbine varied from 105 - 139 dB re 1 µPa, with the source level noise measured at 162 dB re 1 µPa at 1m (Nedwell and Brooker, 2008). Noise monitoring carried out during the installation of the monopole at the Voith Hydro test berth at the Fall of Warness estimated the drilling source level to be 168 dB re 1 µPa at 1m (MeyGen, 2012). Drilling of the 2.3m diameter pile with a drill socket depth of 11m was complete in around 2 days (Aquatera, 2011). Drilling 1m diameter pin piles to a depth of a few meters was estimated to take approximately 1 hour per pile (Exodus Group Ltd 2008). From the limited information available at present, the broad scale noise levels emitted during non-percussive drilling activities are not expected to exceed the threshold for lethality, PTS or TTS onset for seals.

Richardson *et al*. (1995) reported that drilling from bottom founded platforms tends to have strongest tones at very low frequencies. Furthermore drilling noise has been reported to have the majority of its energy below 1kHz, mostly below 500 Hz (Konsberg, 2012; Nedwell *et al*., 2003, 2010). The low frequency noise emitted from drilling operations is therefore likely to be within the range of poorer hearing for seals.

Anchor placement
For completeness, the placing of anchor blocks and clump weighs on the seabed has also been considered. During the placement of the ScotRenewables anchor blocks and mooring lines, background noise levels were estimated to have ranged between 112 dB and 127 dB re 1µPa, with a mean value of 122 dB. For the placement of the anchor blocks, the recorded peak to peak sound pressure levels was equivalent to 167 dB at 1m, where as greater sound pressure levels were associated with the chains, equivalent to a maximum of 173 dB at 1m (peak to peak). The recorded sound pressure levels associated with the placement of the secondary clump weight were lower, with peak to peak values always being less than 154 dB at 1m (Beharie and Side, 2011). From the limited information available at present, the broad scale noise levels emitted during placement of anchor blocks and chains are not expected to exceed the threshold for lethality, PTS or TTS onset for seals.

Vessel noise
A variety of vessels are used at the Fall of Warness including multi-cats, jack-up barges, tug supply vessels, dive support vessels, small tugs and smaller workboats, the largest of which are between 50 - 100m in length. Richardson *et al*. (1995) estimates a 25m tug pulling a barge to have a source level of 166 dB re 1 µPa at 1m, where as broadband source levels for most small ships (55-85m) were estimated at 170-180 dB re 1 µPa at 1m. Monitoring of vessel noise during installation of the SR250 device recorded a maximum sound pressure level from Voe Viking (26m length) of 162 dB re 1µPa at 1m (Beharie and Side 2011). Vessels between 50-100m have been estimated by OSPAR Commission (2009) to have a source level range from 165 – 180 dB re 1 µPa at 1m, which we consider to adequately cover the range of vessels most likely to be utilised at the site, although there will also be smaller boats present e.g. workboat/rib which will have a higher frequency output as discussed below. From the limited information available at present, the broad scale noise levels generated by vessels are not expected to exceed the threshold for lethality, PTS or TTS onset for seals.

The frequency range of vessel noise is related to the size of the vessel. In general, peak frequencies increase as vessel size decreases. Large ships emit noise from the ten's of Hz up to 100s of Hz. Medium size (around 30 m in length) and smaller boats such as work boats emit noise from 20 Hz to 6 kHz (Richardson *et al*., 1995) or to 10 kHz (Thomsen *et al*., 2006). The frequency range will vary depending on the types of vessel in the area, but it is likely that the vessels operating in the Fall of Warness will be audible to seals.

Cumulative noise
EMEC have a standard operating procedure that enables multiple developers to access the site to carry out works at the same time. The maximum (worse) case scenario for this is estimated to be 14 vessels as outlined in the project envelope description (Annex 1) under Simultaneous Operations. However, the potential for occurrence of 14 vessels simultaneously at the test site is considered to be very rare. In the future, appraisal of cumulative impacts could be revisited in the context of any changes to background levels and targets under the Marine Strategic Framework Directive (MSFD) (see Van de Graaf *et al*, 2012).

The maximum number of drilling operations allowed within the project envelope has been set at two. While this may increase the area of additional noise energy output, the limited hearing of seals in this frequency range is such that cumulative drilling noise is not considered to be significant.

Impact pathway conclusion

Impact of noise on SAC seals - Lethality
The range of source levels outlined above from drilling or anchoring operations and vessel noise are considerably lower than the level at which fatal injury to harbour or grey seal is considered to occur, as outlined in the *drilling noise* and *vessel noise* sections above. There is therefore no potential for either species from either SAC to be killed as a consequence of underwater noise emitted from installation operations at the Fall of Warness.

Impact of noise on SAC seals - Auditory injury

Repeated, high sound levels (in excess of the 180 dB re 1 µPa) are considered to potentially cause permanent or temporary hearing damage. Moreover, Southall *et al* (2007) put forward sounds pressure levels of 218 dB re 1 µPa (Peak) for PTS and 212 dB re 1 µPa for TTS.

The range of source levels outlined above from drilling or anchoring operations and vessel noise are sufficiently low that both the PTS and TTS impact criteria are not exceeded and so auditory injury to either seal species from either SAC is considered unlikely.

Impact of noise on SAC seals - Behavioural response

The frequency range of seals as outlined above is such that drilling noise is considered likely to be within the range of poorer hearing for seals. This combined with the short duration of drilling operations (typically around a week) lead us to consider that the potential for behavioural impacts leading to significant disturbance to either species of seal from either SAC is unlikely. However, further consideration may be required should such noisy works coincide with the breeding season – see the mitigation section below.

Seals are likely to be able to hear vessel noise. The maximum number of vessels operating in the Fall of Warness at any one time could be up to 14, although this occurrence is considered rare and moreover, most activity is likely to be aimed at times of lower tidal-stream flow and so the duration of multiple vessel activity is likely to be relatively focused. Nevertheless, there is potential for this noise (or vessel presence) to cause some form of disturbance effect. While we have no further data or information at this stage that would explicitly confirm or explain the extent of this potential impact pathway, ongoing work by SMRU on tagged seals may help clarify this in the future – upon which this assessment will be reviewed.

In light of this uncertainty, a precautionary view considers that disturbance effects may be likely from vessel noise and that this could lead to the displacement of seals from the Fall of Warness. However, evidence from telemetry studies (SMRU Ltd, 2011) indicates that seals tagged in this part of Orkney are using vast areas of the North Sea to the north and east of the Orkney archipelago, such that the Fall of Warness is unlikely to be especially important in terms of foraging. Consequently, it is not considered that such disturbance/displacement effects would negatively effect the population of either seal species as a viable component of either SAC, providing suitable mitigation is undertaken should works coincide with the breeding season.

Its is also worth noting that in the last 50 years the background noise levels of the worlds oceans have increased mainly due to increased vessel activity. This has lead to various initiatives such as a requirement under the Marine Strategy Framework Directive to monitor background noise (indicator 11.2.1) and further research looking at the impact of such rises through the International Quiet Ocean Experiment.

In relation to disturbance impacts upon seals, future revisions of this appraisal should utilise the PCoD framework, currently under development by SMRU Ltd. This should aid a more quantitative approach to assessing disturbance impacts.

Mitigation

Use of the Marine Mammal Observer Protocol with the inclusion of seals will help reduce any residual impact by ensuring as far as reasonably possible that seals are not present in the area, immediately prior to the start of drilling operations or other ‘noisy’ marine works. Adherence to the guidance associated with the Scottish Marine Wildlife Watching Code (SMWWC; www.marinecode.org) will also help reduce any residual disturbance impact from the vessel and/or installation activity. Vessel exclusion zones around pupping or haul areas may also be appropriate.

Monitoring

Acoustic monitoring of drilling and anchor/mooring installation noise at various distances and frequencies will be invaluable in understanding impacts at the Fall of Warness and in moving forward to the commercialisation of these test devices. Obtaining meaningful information from the test site will necessitate a collaborative approach with all developers testing at the site. We therefore see this as a key strategic monitoring output. In addition to the acoustic monitoring mentioned above, monitoring seal behaviour before, during and after noisy marine works would help provide further information to understand what activities (if any) could be affecting these populations of seals and how.

INSTALLATION, OPERATIONS and MAINTENANCE

Impact Pathway	Installation/maintenance vessel (s) transits and manoeuvring leading to disturbance

Vessel use information
Analysis of vessels usage within 5NM of the tidal site undertaken for a Navigation Risk Assessment (NRA) of the Fall of Warness site in 2010 revealed an average of 7 vessels per day in the summer (2009) and 4-5 in the winter (2010) (Anatec Ltd, 2010). The vast majority of vessels that passed within 5NM of the lease area were inter-island ferries. Of those vessels transiting through the site, the inter-islands ferries used this route 8 times during a 6 week winter survey period trying to reduce vessel motion in prevailing wave and tidal conditions. The route was used 23 times during a 12 week summer/winter study period by vessels transiting between the Westray Firth and Stronsay Firth; these comprised large passenger, tugs supply, military, fishing and fisheries patrol vessels.

Analysis of creeling activity at the site during 2006 – 2009, revealed approximately 3 hours of creeling activity per 20 hour of watch keeping per week. The majority of creelers were observed to be operating in Sealskerry Bay on the west coast of Eday with a minority close to the east coast of the Muckle Green Holm.

Table 5 of the project envelope description (Annex 1) details some of the typical vessels which may frequently feature at the Fall of Warness test site. These vessel specifications are not given as maximum envelope figures, but are typical specifications (for information only) for vessels used to support likely activities. Other vessels not listed may be used at the site (specific vessels will be detailed in individual project descriptions). EMEC requires all vessels which engage in works at its test sites to use Automatic Identification System (AIS) to aid location and tracking. Many of the marine works carried out at the site may require the presence of more than one vessel type on-site at the same time. Also, the type of vessel used can often be driven by availability rather than function (e.g. workboat used as a dive support boat).

In relation to disturbance impacts upon seals, future revisions of this appraisal should utilise the PCoD framework, currently under development by SMRU Ltd. This should aid a more quantitative approach to assessing disturbance impacts.

Wildlife Observations and vessel presence
Robbins (2011) found that the presence of boats at the FoW between 2005 and 2009 did not affect the seal encounter rate such that the hourly encounter rate for seals (both species) was not significantly related to the number of boats recorded per day. It must be noted however, that the amount of developer activity at the test site as increased since this period.

Impact pathway conclusion
As mentioned above the standard operating procedure allowing multiple developers to perform operations on site simultaneously could result in up to a maximum of 14 vessels within the test site at any one time, although we consider this occurrence to be rare. Furthermore, most activity is likely to be aimed at times of lower tidal-stream flow and so the duration of multiple vessel activity is likely to be relatively focused. As outlined above (under the impact pathway, *underwater noise from foundation/mooring installation methods and vessels*) we consider there may be potential for disturbance effects from multiple vessels activity (noise and or presence) on site. However, even if seals were displaced from the test site, and we have no evidence to suggest that this is the case or not, evidence from telemetry studies (SMRU Ltd, 2011) indicates that seals tagged in this part of Orkney are using vast areas of the North sea to the north and east of the Orkney archipelago and as such the Fall of Warness is unlikely to be especially important in terms of foraging. As such we do not consider it would negatively effect the population of either seal species as a viable component of either SAC.

Mitigation
Adherence to the principles set out in the SMWWC will help reduce the potential for disturbance effects from vessel activity. Furthermore, appropriate project-specific vessel management should be considered

alongside simultaneous developer activity proposals to help mitigate any residual impacts at the Fall of Warness test site and during transits out with the site.

Monitoring

Monitoring of the amount of vessel activity on site, particularly during the breeding season for both species would be beneficial in understanding such impacts further.

Impact Pathway	**Underwater noise from active acoustic equipment leading to disturbance** **PROJECT-SPECIFIC ASSESSMENT REQUIRED**

Impact pathway conclusion

The use of geophysical or geotechnical equipment is unlikely to be required at the FoW and has not be included in the project envelope description and therefore is not considered part of this appraisal. However, there may be projects that require the use of active acoustic equipment (e.g. sonar equipment). Assessment of sound exposure levels will depend on the specific equipment being used and as such we recommend project-specific assessments are undertaken.

This impact pathway is therefore not considered further in this assessment.

Impact Pathway	**Interaction with vessel propellers (e.g. Kort or some types of Azimuth thrusters) leading to: death from corkscrew injuries** **PROJECT-SPECIFIC ASSESSMENT REQUIRED**

Current understanding on interactions

Thompson *et al*. (2010) highlights preliminary finding from investigations into the cause of severely damaged seal carcasses found on beaches across eastern Scotland, the Norfolk coast in England and the Strangford Lough area in Northern Ireland. SCOS (2012) reports harbour seals with similar injuries in Orkney. These carcasses are predominately harbour seals, mainly adult females although some grey seals have also been recorded. The injuries are consistent with seals being drawn through a ducted propeller such as a Kort nozzle or some types of Azimuth thrusters. Such systems are common to a wide range of ships including tugs, self propelled barges and rigs, various types of offshore support vessels and research boats. These types of vessels are likely to be deployed for installation and operation/maintenance activities at the Fall of Warness. Although there have been no records of seal carcasses with these corkscrew injuries at the test site, this is an emerging issue that requires further investigation to determine whether or not there is a link between ducted propellers and these carcasses. SMRU are currently delivering further work as part of the Marine Mammal Scientific Support Research Programme to look at this issue. There have been recent cases of carcasses found within Orkney waters.

Impact pathway conclusion

Assessment of the risk will depend on the project-specific information as will appropriate mitigation measures. This will need to be undertaken by each device-developer and incorporated into their PEMP. To note, as the FoW is around 7NM to the nearest harbour seal SAC and 2NM to the nearest grey seal SAC, we consider the risk to breeding females to be medium. Appropriate mitigation may be required, particularly if marine works utilising vessels with propeller characteristics considered to pose a risk to seals coincide with the breeding season of either species.

Mitigation

Recommendations for reducing this risk include the consideration of alternatives to using vessels with ducted propellers and avoiding the breeding season if possible. This should be informed by project-specific project details and assessed on a case-by-case basis.

Monitoring

The use of innovative ways of monitoring seal-propeller interactions would be beneficial, this could encompass vessel-based remote monitoring or shoreline carcass searches.

OPERATION & MAINTENANCE

Impact Pathway	Underwater noise from operating turbines leading to: auditory injury (permanent or temporary), death or disturbance*

Acoustic signatures of operational turbines
There is currently limited published data describing the acoustic signature of operational tidal turbines. While acoustic testing has been carried out on a number of the devices deployed at the Fall of Warness or is intended in the future, no published results are available as yet. Information is available from elsewhere in the UK, specifically from the 300kW Marine Current Turbines tidal turbine deployed in the Bristol Channel; extrapolation of the underwater noise recorded at a number of ranges from this operational device gave a source level of 165.7 dB re 1 µPa at 1m (Richards *et al*. 2007). The OSPAR Commission (2009) report RMS ranges for sources levels of operating tidal and wave devices as between 165 - 175 dB re 1 µPa @ 1m.

Modelling carried out for the MeyGen Environmental Statement estimated source levels for 1 MW and 2.4 MW turbines at 171 dB re 1 µPa and 177 dB re 1 µPa respectively using an uplift factor (Kongsberg 2012). In keeping with the majority of industrial noise, the main acoustic output of operational tidal turbines is likely to be low frequency. There is limited data currently available on the acoustic output; however, Akvaplan-niva (2010) reported the frequency range for the Hammerfest Strom HS300 to be below 2 kHz.

Harland (2013) concluded that turbines operating at the test site can be heard across large areas of the Fall of Warness. Although these sounds are not loud, the low-loss propagation on the site means that they are likely to be heard widely by all of the marine mammal species identified at the site. However, he suggests that under rough water conditions the volume insonified will decrease as the sound is scattered from surface waves and the sounds masked by increasing background noise.

The array-like layout of berths across the Fall of Warness is likely to mean that operating devices will be audible to seals as they transit through the site, it may not mean that an operating device at the north of the site is also audible at the southern end.

Impact pathway conclusion

Impact of noise on SAC seals - Lethality
From the limited information we have as outlined above, likely source levels are lower than the level at which injury to harbour or grey seal is considered to occur. It is therefore unlikely that either species from either SAC would be killed as a consequence of underwater noise emitted from operational turbines at the Fall of Warness.

Impact of noise on SAC seals - Auditory injury
The range of likely source levels outlined above from operational turbines, as far as is known at present, are sufficiently low that both the PTS and TTS impact criteria are not exceeded and so auditory injury to either seal species from either SAC is considered unlikely.

Impact of noise on SAC seals - Behavioural response
Tidal turbines have been tested at the Fall of Warness since the Open Hydro device was first installed in late 2006. As of the beginning of 2013, all 7+1 berths are being utilised by developers with 6 devices currently deployed. The test site enables all aspects of the tidal energy technology to be tested from pre-installation through to decommissioning and while the generation of power is the ultimate goal, the test site is fundamentally different from a commercial array, which would be striving for a continuous power generation output.

At present very little information is available as to the behavioural response of seals to operating turbines. The noise output is thought to be similar to vessel noise in terms of its frequency range so will be audible to seals. There is therefore the potential for a disturbance effect which may lead to displacement from the site. Again, we have no evidence to suggest that this is the case or not; however, evidence from telemetry studies (SMRU Ltd, 2011) indicates that seals tagged in this part of Orkney are using vast areas of the North sea to the north and east of the Orkney archipelago and as such the Fall of Warness is unlikely to be especially important in terms of foraging. As such, we do not consider that such disturbance/displacement effects would negatively effect the population of either seal species as a viable component of either SAC.

Mitigation
n/a

Monitoring
Establishing the acoustic signature of operating devices is clearly important to understand impacts at the Fall of Warness and in moving forward to the commercialisation of these test devices, as will be monitoring to understand any behavioural response to operating turbines. Obtaining meaningful information from the test site will necessitate a collaborative approach with all developers testing at the site, with a view to delivering this as a key strategic monitoring output.

Impact Pathway	**Collision with operating turbine blades leading to: injury or death**

Please see Annex 3 for a summary of the collision modelling undertaken and key outputs for the maximum device scenario. Annex 3 provides detailed information, including technical information and the full suite of model outputs and analyses.

Predicted collision rates with and without avoidance ranges, for the maximum device scenario.

	ASSUMED AVOIDANCE RATE					
SPECIES & DIVE-SHAPE	**0% or Encounter rate**	**50%**	**90%**	**95%**	**98%**	**99%**
harbour seal U-dive	16.8	8.42	1.68	0.84	0.34	0.17
harbour seal V-dive	39.6	19.81	3.96	1.98	0.79	0.40
grey seal U-dive	38.7	19.36	3.87	1.94	0.77	0.39
grey seal V-dive	91.1	45.56	9.11	4.56	1.82	0.91

Preliminary analysis of telemetry tag data from similar sites suggest that U-shaped dives are predominant for harbour seals (SMRU, unpublished). Equivalent data for grey seals is not yet available for interrogation, so the ranges presented for both U and V-shaped dives need to be considered. There is limited basis on which to adopt assumed avoidance rates in collision risk modelling. Nevertheless, both seal species are relatively agile, and are also expected to respond to visual and acoustic cues from an operational device, so may be expected to readily achieve near-field avoidance of turbines. Ongoing monitoring and research will be important in refining understanding of avoidance rates, but as a starting point we assume avoidance rates of 98% for harbour seals (resulting in 0.34 collisions per year with U-shaped dives) and grey seals (0.77 to 1.82 collisions per year, depending on dive-shape). These collision predictions are for the maximum device scenario only (Annex 3 includes predictions for the current (July 2014) device scenario).

Understanding of the modelling process is required for objective consideration of these predictions. Annex 3 describes the modelling approach in detail, but key issues include:

- Although seal data used in models has been refined to the 15 core grid-cells of the EMEC test site (see Annex 3), the distribution and size of these grid cells relative to berth sites and stretches of coast of disproportionate importance to seals is imperfect and may be skewing the density figures applied to the whole site. This is particularly likely for grey seals, for which there are a number of regular haul-outs on adjacent coasts.
- Although data has not been made available, due to commercial confidentialities, devices at the

test site are very unlikely to run at 100% of their operational capacity. There are likely to be long periods during which devices are either not present or generating power (e.g. maintenance).

***Sanday SAC*:** This site is approximately 15km from the Fall of Warness, with harbour seals as a qualifying interest. This distance is well within the foraging range of harbour seals from haul-outs, so it is likely that some of the seals from this site use the Fall of Warness for foraging and/or transit. However, this distance, plus the presence of other (albeit smaller) harbour seal haul-outs in the vicinity of the Fall of Warness and wider Orkney sea area, make it highly likely that a large proportion of the harbour seals present are not associated with Sanday SAC. Also, there is a good availability of quality foraging habitat near Sanday that makes it unlikely that the Fall of Warness is important in this regard. Consequently, under an assumed 98% avoidance rate and predominance of U-shaped dives, the annual collision rates predicted above are unlikely to be statistically distinguishable from natural mortality of animals from the SAC. Nevertheless, due to the unfavourable declining status of this qualifying interest of Sanday SAC, particular vigilance is merited and robust monitoring programmes should be adopted. Duck and Morris (2011) detail the trend of harbour seal decline in Sanday SAC and other sites in Orkney. However, it is notable that the declining trend precedes any activity at the Fall of Warness and reflects trends throughout the north and east of Scotland.

***Faray and Holm of Faray SAC*:** This site is approximately 4km from the Fall of Warness, with grey seals as the qualifying interest. This distance is well within the foraging range of grey seals from haul-outs, so it is likely that many of the seals from this site use the Fall of Warness for foraging and/or transit. However, there are several other grey-seal haul outs in the vicinity and Orkney generally, including some with even greater proximity to the Fall of Warness (e.g. Muckle and Little Green Holm; Seal Skerry). Consequently, it is highly likely that a large proportion of the grey seals present in the Fall of Warness are not associated with Faray and Holm of Faray SAC. In turn, under an assumed 98% avoidance rate, and also considering the various caveats that add precaution to the modelling, the annual collision rates predicted above are unlikely have an adverse effect on site integrity. To this end it is also worth noting that the SAC population is in ‘favourable maintained’ status and has not shown any changes that can be linked to the operation of tidal turbines at the Fall of Warness to date.

It should also be noted that there is no evidence to date of any interaction between either seal species and the turbines at the Fall of Warness since the first turbine was deployed in 2006, or from elsewhere in the UK or Europe.

Impact pathway conclusion
Assuming a 98% avoidance rate for both species, and considering the high likelihood that a large proportion of seals using the Fall of Warness are not associated with these SAC, it is concluded as unlikely that any additional mortality from collision with operational turbines at the Fall of Warness will be statistically distinguishable from natural or other forms of mortality for seals as qualifying interests of Sanday SAC or Faray and Holm of Faray SAC. Also note that, at the time of writing (August 2014), these collision rates are within the PBR limits defined under Marine Scotland’s seal licensing system (http://www.scotland.gov.uk/Topics/marine/Licensing/SealLicensing). However, the continued absence of empirical data to fully support assumptions made in the modelling process, necessitate a robust monitoring programme at the Fall of Warness to record any physical interaction of animals with device or any other observations of animal behaviour in the near-field.

Mitigation
Specific mitigation is not recommended at this stage, nor is it feasible or practical. Device monitoring should be capable of detecting any collision events, which should trigger device shutdown and liaison with the Regulator to determine the introduction of any mitigation or an agreement regarding the re-start of device operation.

Monitoring
The use of innovative ways in which to monitor the operating devices and detect any impacts is clearly important in understanding impacts at the Fall of Warness and in moving forward to the commercialisation of these test devices. Currently monitoring is undertaken through a mixture of strain gauges in the blades themselves to detect impacts and the use of video camera mounted on the device showing some or all of the moving blades. Analysis of operational footage should enable detection of collisions and near misses but also provide insight into the behavioural reactions of seals to operating turbines.

Impact Pathway	Presence of tidal device (s) and associated infrastructure leading to: barrier effects

Current understanding of barrier effects
Little is currently known as to how seals react to tidal turbines in the water column or what potential there is for tidal turbine arrays to cause a barrier to movement to these species. Evidence from tagged seals from Strangford Lough indicated some degree of local avoidance of the SeaGen turbine up to a distance of approximately 250m either side. This pattern was similar regardless of whether the turbine was operational or not (Royal Haskoning, 2011).

The distribution of seals across the site was found to vary significantly with the highest proportion of sightings along the Eday coastline and towards Seal Skerry as well as adjacent to Muckle Green Holm. This is not surprising given the existence of long established haul outs and breeding sites in these areas (Robbins, 2011). Data from seals tagged prior to the establishment of the test site shows seals transiting through the Fall of Warness (SMRU Ltd, 2012), as do currently deployed tags although the data for this has yet to be published.

Impact pathway conclusion
The test site is small in scale such that a maximum of 12 devices (18 rotors) can be deployed at any one time. Moreover, the test site has a restricted power output which means all 12 devices are not necessarily generating power at the same time. See impact pathway '*underwater noise from operating turbines'* above in relation the potential for disturbance effects from operating turbines.

Considering the potential for barrier effects at the Fall of Warness quantitatively, the test site is around 9km^2 across the site as a whole. The project envelope covers 9 berths in total and if each 'development' footprint at each berth was considered to be 500m^2 in size, the total area of 'development' across the site would be 6000m^2. This equates to 0.07% of the total site as a whole. This, together with the availability of alternative habitat, as evidenced through telemetry studies, leads us to consider the potential impact from barrier effects to both species of seal from both SAC to be minimal, such that we do not consider it would negatively effect the population of either seal species as a viable component of either SAC.

Mitigation
n/a

Monitoring
A review of the data from the currently deployed tags once published will help further understanding of such effects and influence whether further monitoring is required in relation to this aspect. Continuation of the wildlife observations would be of benefit.

Conclusion:

Sanday SAC: It is concluded that activities within the Fall of Warness project envelope, as appraised above, will not adversely effect the integrity of the site.

Faray and Holm of Faray SAC: It is concluded that activities within the Fall of Warness project envelope, as appraised above, will not adversely effect the integrity of the site.

4.7.4 Conditions or modifications required

Condition:	***Reason:***
Use of the Marine Mammal Observer Protocol with the inclusion of seals, ensuring as far as reasonably possible that seals are not present in the area, immediately prior to the start of drilling operations or other particularly 'noisy' marine works. Exclusion of installation and maintenance vessels from the vicinity of haul-outs, particularly during the breeding season. This may be achieved by adherence to the guidelines associated with the Scottish Marine Wildlife Watching Code (SMWWC; www.marinecode.org) during all vessel-based activities. Any conditions required arising from project-specific appraisals, as identified above for impacts relating to (a) underwater noise from active acoustic equipment, leading to disturbance, and (b) interaction with vessel propellers, leading to death from corkscrew injuries.	To minimise the potential for behavioural disturbance or injuries during the noisiest activities and use of vessels.

4.7.5 Conclusion

Likely significant effect, but the appraisal carried out demonstrates that it will not adversely affect the integrity of any of the aforementioned SAC if subject to the mitigation mentioned above.

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4.8 Impact Appraisal: Otters

Prior to the fully detailed evaluations, this part of the appraisal picks up at 'Step 2' as described in Section 3 of this document.

4.8.1 Potential effects

For otters the defined potential effect categories are applied to activities/effect pathways relevant to tidal energy developments offshore comprising design-types involving the rotation of turbines within natural hydrodynamic conditions[26]. Deployment/installation effects (Table 38) are addressed separately from those during the operational and maintenance phases (Table 39).

Note that details specific to the Fall of Warness, both environmental and relating to project-specifications, are not considered until the detailed appraisal later in this section. First, we consider potential effects in broad-principles.

[26] Tidal developments that involve the manipulation of hydrodynamic conditions prior to the extraction of energy (e.g. tidal barrages) are explicitly excluded from the broad consideration of potential effects in Table 38 and Table 39.

Generic Potential Effects from Device Deployment		
Summary of activity categories – for detail please see the project envelope description (Annex 1) • Installation of device(s), and associated offshore infrastructure (e.g. foundations; mooring systems; cabling; buoys) on the seabed, in the water column or above the surface • Use of vessels (e.g. DP vessel; jack-up barge; multi cat; workboat; dive-support vessel; crane-barge; tug; specialist cable-laying vessel.) • Deployment and use of equipment offshore to monitor devices or other environmental parameters during installation (e.g. ROV, cameras or acoustic devices)		
Activity/potential effect pathway	**Natural heritage features**	**Potential importance**
Underwater noise from active acoustic equipment leading to disturbance[27].	Otters	Not important – unlikely to be sufficiently close to shore, noisy or widespread to have an important effect on otters.
Device/foundation installation vessel transits and manoeuvring leading to disturbance.	Otters	Potentially important – some operations occurring in proximity to the shore may cause disturbance of otters at holts or resting sites and may require a licence to disturb EPS. The degree of effect and need for any licence conditions will depend upon vessel types and activities, proximity to shore and the presence and usage of any known otter holts.
Underwater noise from foundation/mooring installation methods and vessels leading to: auditory injury, death or disturbance.	Otters	Not important – foundation drilling operations produce underwater noise and are therefore unlikely to cause a disturbance offence at holt or resting sites above ground, as per the Conservation (Natural Habitats, &c.) Regulations 1994 (as amended).

[27] The term 'disturbance' includes all behavioural responses of biological consequence, including displacement from the vicinity of the activity.

Cable installation methods and vessels leading to: injury death or disturbance.	Otters	Potentially important – such activities occurring in proximity to the shore may cause disturbance to otters at holts or resting sites and may require a licence to disturb EPS. The degree of effect and need for any license conditions will depend upon vessel types and activities, proximity to shore and the presence and usage of any known otter holts.
Habitat loss/damage.	Otters	Not important – damage to or loss of subtidal foraging habitat by device foundation or cable/infrastructure placement is unlikely to result in a significant loss of foraging ground for a highly mobile and wide-ranging species such as this. **(NB: this appraisal does not address loss or damage of onshore habitats).**

Table 38: Potential effects upon otters during device and infrastructure deployment, identifying activities/effect pathways and receptors for further assessment. Note that these evaluations are made *prior* to consideration of details particular to the Fall of Warness site.

Generic Potential Effects from Device Operation and Maintenance

Summary of activity categories – for detail please see project envelope (Annex 1)

- Physical presence of device(s), foundations, moorings, buoys and associated infrastructure on the seabed, in the water column or above the surface
- Operation of device(s)/power generation
- Repeat removal and redeployment of equipment for maintenance (e.g. turbine removed from water or floating structure removed from berth; replacement of mooring system)
- Other maintenance activities (e.g. Bio-fouling removal; ROV/diver inspection or repairs)
- Use of vessels (e.g. DP vessel; jack-up barge; multi cat; workboat; dive-support vessel; crane-barge; tug)
- Use of equipment to monitor devices in situ or other environmental parameters (e.g. ROV, cameras or acoustic devices)

Activity/potential effect pathway	Natural heritage features	Potential importance
Underwater noise from active acoustic equipment leading to disturbance.	Otters	Not important – unlikely to be sufficiently close to shore, noisy or widespread to have an important effect on otters.
Maintenance vessel (s) transits and manoeuvring leading to: disturbance.	Otters	Potentially important – some operations occurring in proximity to the shore may cause disturbance of otters at holts or resting sites and may require a licence to disturb EPS. The degree of effect and need for any licence conditions will depend upon vessel types and activities, proximity to shore and the presence and usage of any known otter holts.
Other maintenance activities (non vessel based) leading to: disturbance.	Otters	Not important – maintenance activities include inspection (e.g. divers/ROV), repairs or temporary retrieval or replacement of nacelles by winch. In all cases it is the presence of the accompanying vessel that presents the disturbance risk, which is appraised separately.
Underwater noise from turbineoperation leading to	Otters	Not important – unlikely to be sufficiently close to shore or noisy to have an important effect on otters.

disturbance .		
Collision with turbine blades leaing to: injury or death.	Otters	Potentially important – most turbine designs operate at water depths beyond the normal foraging range of otters (most foraging dives are within water <10m deep and <100m from shore). However, alternative designs could operate closer to shore and may require a licence to disturb EPS.

Table 39: Potential effects upon otters during the operational and maintenance phase, identifying offshore activities/effect pathways and receptors for further assessment. Note that these evaluations are made *prior* to consideration of details particular to the Fall of Warness site.

4.8.2 Natural heritage context

The Eurasian otter (*Lutra lutra*) is listed as EPS on Annex IV of the Habitats Directive, and through transposition of this directive into Scottish and UK law, is protected by national and international legislation. Links to the relevant legislation can be found on the SNH website[28]. The otter is also listed on Annex 1 of CITES, Annex II of the Bern Convention and Annex II of the Habitats Directive. It is also afforded protected under schedule 5 of the Wildlife and Countryside Act 1981, and is on the PMF list.

Otters are ubiquitous around the coast of Orkney, with the shallow coastal waters and availability of freshwater near the coast providing ideal habitat. Foubister (2005) concludes from coastal surveys in the vicinity of Fall of Warness, including a survey conducted in 2010 at the cable landfall site, that otters use the area, with signs of foraging and rest areas present along the south-west coast of Eday and upon Faray and Holm of Faray to the north of the test site. Most otter cubs in this part of Scotland are thought to be born during the winter months but breeding can occur at any time of year (Chanin, 2003).

This appraisal only considers impacts upon otters from activities occurring in the offshore/marine areas associated with the Fall of Warness test site (although noise disturbance transmitting from the marine to onshore areas is addressed). Otters also range widely in the onshore environment and may be impacted by onshore aspects of development activities, however this is outwith the bounds of the project envelope and therefor not addressed in this appraisal.

4.8.3 Impact appraisal mechanisms for the Fall of Warness

This impact appraisal takes account of a maximum-case scenario based on a project envelope where all available berths within the test site are developed and operating at capacity. It addresses the differing consenting and licensing regimes (see Table 40 below). This appraisal will inform the consenting process for both Marine Licence and/or Section 36 applications. However, it should be noted if there are key deviations in the device design or in installation/maintenance activities then further appraisal work may be required. Any additional appraisal work required will be undertaken by the individual developer (further advice should be sought from EMEC in the first instance).

Feature type	Appraisal mechanism/relevant legislation	Applicable	Reasoning
Qualifying features of European sites.	Habitats Regulations Appraisal (HRA) - Habitats Regulations 1994 (as amended).	N	No connectivity with otter SAC (see detail below).
European Protected Species.	EPS legislation - Habitats Regulations 1994 (as amended in Scotland).	Y	Otters are EPS and may be present at or near the site.

[28] http://www.snh.gov.uk/protecting-scotlands-nature/protected-species/legal-framework/habitats-directive/regulations/

Notified features of SSSIs.	SSSI legislation - Nature Conservation (Scotland) Act 2004.	N	There are no SSSIs in Orkney with otter as a notified feature.
Protected features of MPAs	Marine (Scotland) Act 2010	N	There are no MPAs with otters as protected features.
PMFs	Marine (Scotland) Act 2010	Y	Otters are on the PMF list.
Other sensitive natural heritage features.	Appraisal of other features under: - Electricity Works (EIA) (Scotland) Regulations (Amendment) 2008; - Marine Works (EIA) (Amendment) Regulations 2011; - Marine (Scotland) Act 2010.	Y	Captures assessment of all other sensitive natural heritage features at a population/habitat scale of concern.

Table 40: Appraisal mechanism for otters.

4.8.4 Qualifying features of European sites

During the last national survey of in 2003-29, the survey concluded that there is a stable population at or near carrying capacity of otters in the Orkney Isles. There has been concern that the density of otters in the Orkney Isles is lower than that achieved in the Shetlands, The reasons for this are unclear but it is possible that sources of freshwater for coastal living otters in the Orkney Isles are limited due to the local geology.

Home ranges in coastal habitats are typically smaller than elsewhere, allowing a higher population density to be sustained. This is possible primarily because of the high productivity of the inshore marine environment, particularly in the more favoured otter areas. In these very productive areas, otter home ranges may be as small as 4-5km of coastline.30

The only SAC in Orkney with otter as a qualifying feature is the Loch of Isbister SAC; this site is on Orkney West Mainland and is more than 27km from the Fall of Warness. There is no connectivity with this site and therefore no (LSE). Consequently, no further consideration of otters in regard to European Sites is required.

Conclusion:
There is no a likely significant effect to otter as qualifying features of Loch of Isbister SAC so no further consideration under HRA is required.

[29] Strachan, R. (2007). National survey of otter *Lutra lutra* distribution in Scotland 2003–04.

Scottish Natural Heritage Commissioned Report No. 211 (ROAME No. F03AC309).

[30] http://www.snh.org.uk/publications/on-line/wildlife/otters/biology.asp

4.8.5 European Protected Species (EPS)

Otters are listed on Annex IV of the Habitats Directive as species of European Community interest and in need of strict protection. The protective measures required are outlined in Articles 12 to 16 of the Directive. The species listed on Annex IV whose natural range includes any area in the UK are termed European Protected Species (EPS).

SNH is the statutory nature conservation body who provides advice and licences on terrestrial EPS in respect of the Habitats Regulations in Scotland.

Summary of the legal requirements for EPS

(1) It is an offence:

(a) deliberately or recklessly to capture, injure or kill a wild animal of a European protected species;

(b) deliberately or recklessly:

i. to harass a wild animal or group of wild animals of a European protected species;

ii. to disturb such an animal while it is occupying a structure or place which it uses for shelter or protection;

iii. to disturb such an animal while it is rearing or otherwise caring for its young;

iv. to obstruct access to a breeding site or resting place of such an animal, or otherwise to deny the animal use of the breeding site or resting place;

v. to disturb such an animal in a manner that is, or in circumstances which are, likely to significantly affect the local distribution or abundance of the species to which it belongs;

vi. disturb such an animal in a manner that is, or in circumstances which are, likely to impair its ability to survive, breed or reproduce, or rear or otherwise care for its young; or

vii. to disturb such an animal while it is migrating or hibernating;

(e) deliberately or recklessly to take or destroy the eggs of such an animal; or

(f) to damage or destroy a breeding site or resting place of such an animal.

The SNH website offers further guidance in respect of licensing requirements for EPS including otters.[31]

Licence requirements

A licence to disturb EPS may be required for installation of any cabling and or alterations to existing cabling between offshore devices and onshore infrastructure, depending on the proximity to the shore and the methods employed. This appraisal does not consider potential intertidal or onshore works, which should be considered separately through the Town and Country Planning Act 1997.

Although methods/equipment may fall within the project envelope description, for otters, new proposals may require assessment on a case-by-case basis. This is due to the potential changes in the patterns of use of the shoreline area at the site by otters that may occur over relatively short time periods. These changes may include signs of activity at a previously unused holts or resting sites, establishment of new holts or resting sites or occupancy of a

[31] http://www.snh.gov.uk/protecting-scotlands-nature/species-licensing/mammal-licensing/otters/

natal holt by a female with cubs. Such changes may have implications for the requirement for a licence to disturb EPS or appropriate mitigation, the design of which may need to be informed by a pre-construction otter survey. We highlight that suitable mitigation may negate the need for a licence to disturb EPS, or may be included as a condition of the licence.

Licences may be given, authorising activities that could affect EPS which would otherwise be illegal under the Habitats Regulations. Three tests[32] must be satisfied before the licensing authority can issue a licence under Regulation 44(2) of the Conservation (Natural Habitats &c.) Regulations 1994 (as amended) to permit otherwise prohibited acts. An application for a licence will fail unless the following tests are satisfied:

> Test 1:
> The licence application must demonstrably relate to one of the purposes specified in Regulation 44(2) (as amended). For development proposals, the relevant purpose is likely to be Regulation 44(2)(e) for which Marine Scotland is currently the licensing authority. This regulation states that licences may be granted by Marine Scotland only for the purpose of "preserving public health or public safety or other imperative reasons of overriding public interest including those of a social or economic nature and beneficial consequences of primary importance for the environment."

Climate change is widely recognised as one of the great environmental challenges facing the world today. Scottish, UK and European targets for reducing carbon dioxide include those set through the UK Climate Change Act (2008), The Renewable Energy Strategy (2009), the Renewables Obligation (Scotland) Order 2002, National planning guidance (NPPG 6 revised 2000), Climate Change (Scotland) Act 2010 and Scottish Planning Policy, among others. In order to meet this target technologies such as marine energy are likely to play a major role. The proposed device testing will provide an essential stepping stone on the path to commercial viability of the tidal energy sector, with potential to provide economic benefits as well as the delivery of energy targets in response to climate change. Further considerations in relation to Test 1 may be given by Marine Scotland.

> Test 2:
> No satisfactory alternative.
>
> Regulation 44(3)(a) states that a licence may not be granted unless the licensing authority is satisfied "that there is no satisfactory alternative".

EMEC has been established as a test site for wave and tidal energy conversion devices, with support from government. The purpose of the unique testing facility is to assist and hasten the development of these renewable energy industries, against a background commitment to achieve significant reduction in reliance on carbon dioxide producing alternatives. Any alternative location would be unlikely to be satisfactory in terms economic, political or environmental expediency. Further considerations in relation to Test 2 may be given by Marine Scotland.

[32] http://www.snh.gov.uk/protecting-scotlands-nature/species-licensing/forms-and-guidance/guidance/

Test 3:
No detrimental impact on favourable conservation status

Regulation 44(3)(b) states that a licence cannot be issued unless the licensing authority is satisfied that the action proposed "will not be detrimental to the maintenance of the population of the species concerned at a favourable conservation status in their natural range".

Favourable conservation status is in Article 1(i) of the EC Habitats Directive; conservation status is regarded as favourable when:

- *Population dynamics data on the species concerned indicate that it is maintaining itself on a long-term basis as a viable component of its natural habitats;*
- *The natural range of the species is neither being reduced nor is likely to be reduced for the foreseeable future.*
- *There is, and will probably continue to be, a sufficiently large habitat to maintain its*

Further appraisal may be required if (a) a proposal is outside of the project envelope description; (b) if knowledge/data on the status of otters at the development site or in their natural range changes; or (c) if knowledge regarding potential impact-pathway changes.

Available data has previously indicated that the species is maintaining itself on a long-term basis as a viable component of its natural habitats, the natural range of the species is neither being reduced nor is likely to be reduced for the foreseeable future and there is, and will probably continue to be, a sufficiently large habitat to maintain its populations on a long term basis [33].

The following appraisals first consider impacts in relation to whether an offence is likely under the protection afforded to otter under the Habitats Regulations. It then considers whether a licence to disturb EPS is required to address this and if so provides commentary in relation to impacts upon Favourable Conservation Status.

Disturbance Impacts

Each impact-pathway likely to lead to disturbance effects is addressed below in turn.

A. Cable installation methods and vessels leading to: injury death or disturbance.

Disturbance impacts are only necessary in relation to cabling works (installation and or maintenance) in the near-shore and intertidal environment, for activities requiring consent from Marine Scotland. It is considered that any activities at the actual berth sites are too far from shore to cause a disturbance impact to otters at holts or resting sites.

The potential for usage of holts and resting sites to change regularly means that consideration of the potential for disturbance through cable works close to shore will need to be undertaken through a project-specific assessment. Scottish Natural Heritage will be able to advise on the necessity for a pre-construction survey and whether a licence to disturb EPS or any mitigation is required. Any changes to baseline information will be used by the licensing authority to advise whether the works would be detrimental to the maintenance of

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[33] Strachan, R. (2007). National survey of otter Lutra lutra distribution in Scotland 2003–04.

Scottish Natural Heritage Commissioned Report No. 211 (ROAME No. F03AC309).

the population of otters at a Favourable Conservation Status in their natural range and therefore whether a licence to disturb EPS may be issued.

In many cases, cabling work may be too far from shore to result in disturbance impacts, but this will be confirmed through consultation with the licensing authority and SNH as required. Mitigation and monitoring may be included as a condition of a licence or may negate the need for a licence.

B. Installation and C. maintenance vessel transits and manoeuvring leading to disturbance

The berth sites at the Fall of Warness are in water of depths averaging 36m, mostly around 30 – 40m and are at least 500m from the nearest shore. Most otter foraging dives are in waters less than 10m deep and within 100m from shore (Kruuk, 2006). Vessel movement is most likely to be in deeper waters away from areas in which otter could be foraging or transiting and unlikely to be close enough to the shoreline to disturb otter using holts or resting places. Adherence to the SMWWC will help further reduce any residual effects. This impact-pathway is therefore not considered further.

Appraisal conclusion for disturbance impacts:
The installation or maintenance of cabling requires a project-specific appraisal and appropriate consultation to determine the need for a licence to disturb EPS.

Disturbance, injury or death is considered unlikely from vessel usage. A licence to disturb EPS is therefore not considered necessary.

Death or injury from collision with operating turbines

D. Collision with operating turbine blades leading to: injury or death

As mentioned above, the berth sites at the Fall of Warness are all in water of depths averaging 36m and are at least 500m from the nearest shore. Given that most foraging dives are in waters less than 10m deep and within 100m from shore (Kruuk, 2006), interactions between otters and operating turbines is very unlikely. Most tidal devices are currently bottom-mounted, with clearance to the surface at lowest astronomical tide ranging from 10m to 17m. Some tidal energy devices have turbines nearer the surface (i.e. on the under-side of floating structures) and so, although their berths are in water deeper than that of their typical foraging depth, otters could potentially swim out over open water and so could in theory encounter these devices. However, it is regarded as very unlikely that an otter would swim into the strong tidal currents of the Fall of Warness and as such is all the more unlikely to encounter an operating turbine. Consequently, it is concluded that an encounter between an otter and an operational tidal turbine is considered unlikely at the Fall of Warness and that neither a licence to disturb EPS nor mitigation is therefore required.

Appraisal conclusion for turbine collision:
An interaction leading to injury or death between an otter and an operational tidal turbine is considered unlikely. A licence to disturb EPS is therefore not considered necessary.

4.8.6 Appraisal of PMF and other natural heritage interests

Otter are listed on several non statutory lists indicating their conservation value and vulnerability, including the UK Biodiversity Action Plan (UK BAP) Priority Species List, the Scottish Biodiversity List and, most recently, the PMF list. As regards the impact management of activities regarded to be potentially important, considerations and measures under the legal requirements as a European Protected Species are sufficient and further consideration is required.

4.8.7 Receptor conclusions

A summary of the appraisal is provided in Table 41 below. Note that, even where no important impacts on the development site are identified, in some cases there may still be a recommendation for some mitigation or monitoring. Under these circumstances, mitigation would be regarded as good-practice rather than a necessity, while monitoring may serve to improve generic understanding of the relationships between stressors and receptors.

Receptor	Conclusion	Monitoring and/or mitigation identified?
Otters.	A project-specific assessment is required for cabling installation/maintenance activities together with the need for a licence to disturb EPS. This may include a requirement for pre-consultation survey work. Injury or death or disturbance is unlikely for vessel usage, non-cabling maintenance activities or operating turbines.	Yes – see Table 42.

Table 41: Summary of otter appraisal conclusions

Given the uncertainties regarding some potential impacts, the protected status of otters and the opportunity to learn from test deployments, some potential mitigation and monitoring measures are presented in Table 42 below (this table should be updated as knowledge increases). Some such measures will be appropriate as conditions on the Marine Licence, whereas others may just be recommended as good practice. Please see Section 5 of this document for further details on the mitigation and monitoring highlighted below.

Site-wide monitoring and research ideas may be more effectively pursued at a strategic level (whether by EMEC, The Crown Estate or Marine Scotland, or by a developer consortium), but developer input or ideas are welcomed.

Potential Residual Impacts	Relevant impact-pathway	Monitoring/Mitigation
Disturbance.	Installation/ maintenance of cabling.	A project-specific assessment is required for installation of cabling equipment together with the need for a licence to disturb EPS.
Disturbance.	Vessels, other non-cabling maintenance activity.	Adherence to the SMWWC. Consideration within a Construction Method Statement.

Table 42: Potential mitigation and monitoring measures relevant to otters.

4.8.8 References

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Strachan, R. (2007). National survey of otter *Lutra lutra* distribution in Scotland 2003–04. Scottish Natural Heritage Commissioned Report No. 211 (ROAME No. F03AC309).

4.9 Impact Appraisal: Seabirds

Prior to the fully detailed evaluations, this part of the appraisal picks up at 'Step 2' as described in Section 3 of this document.

4.9.1 Potential effects

For seabird receptors, which are at this stage predominately grouped at a family level, the defined potential effect categories are applied to activities/effect pathways relevant to tidal developments for design-types that involve the rotation of turbines within natural hydrodynamic conditions[34]. Deployment/installation effects (Table 43) are addressed separately from those during the operational and maintenance phases (Table 44).

Note that details specific to the Fall of Warness, both environmental and relating to project-specifications, are not considered until the detailed appraisal later in this section.

[34] Tidal developments that involve the manipulation of hydrodynamic conditions prior to the extraction of energy (e.g. tidal barrages) are explicitly excluded from the broad consideration of potential effects in Table 43 and Table 44.

Generic Potential Effects from Device Deployment

Summary of activity categories – for detail see project envelope description (Annex 1)

- Installation of device(s), and associated infrastructure (e.g. foundations; mooring systems; cabling; buoys) on the seabed, in the water column or above the surface
- Use of vessels (e.g. DP vessel; jack-up barge; multi cat; workboat; dive-support vessel; crane-barge; tug; specialist cable-laying vessel.)
- Deployment and use of equipment to monitor devices or other environmental parameters during installation (e.g. ROV, cameras or acoustic devices)

Activity/potential impact pathway	Natural heritage feature	Potential importance
Installation vessel(s) transits, manoeuvring and activity (includes noise) leading to disturbance[35].	Seaducks.	Potentially important – some seaducks species are vulnerable to disturbance by vessels (Furness *et al*., 2012, Merkel *et al.,* 2009). Evidence from OSWFs suggests seaduck numbers are lower during construction. Importance will depend upon intensity, speed and regularity of vessel activity, the importance of the location for particular species and the degree of connectivity with designated or other sites for these species.
	Divers.	Potentially important – divers are typically vulnerable to disturbance by vessels (Furness *et al*., 2012). Evidence from OSWFs suggests diver numbers are lower during construction. Importance will depend upon intensity, speed and regularity of vessel activity, the importance of the location for divers and the degree of connectivity with designated sites for these species.
	Petrels.	Not important – unlikely to be vulnerable to disturbance. All species show little or no response to ship traffic (Furness *et al*., 2012).
	Gannets.	Potentially important – evidence from OSWFs suggests gannet numbers are lower during prolonged/intense

[35] The term 'disturbance' includes all behavioural responses of biological consequence, including displacement from the vicinity of the activity.

		vessel activity during construction.
	Cormorants & shags.	Potentially important – cormorants can be vulnerable to disturbance by vessels (Furness *et al*., 2012). Importance will depend upon intensity, speed and regularity of vessel activity, the importance of the location for cormorants and the degree of connectivity with designated sites for these species.
	Skuas.	Not important – unlikely to be vulnerable to disturbance. Skuas show little or no response to ship traffic (Furness *et al*. 2012).
	Gulls & terns.	Potentially important – unlikely to be vulnerable to most disturbance. Gull and terns show some response to ship traffic, but primarily an attraction (Furness et al. 2012). However, terns nesting close to shore could be disturbed by near-shore vessel activities, such as cable-laying, potentially effecting breeding success.
	Auks.	Potentially important – auks can be vulnerable to disturbance by vessels (Furness *et al*., 2012) and evidence from offshore windfarms suggests lower numbers during construction. Importance will depend upon intensity and regularity of vessel activity, the importance of the location for auks and the degree of connectivity with designated sites for these species.
Disturbance of foraging habitat and prey during construction.	Seaducks.	Not important – seaducks can forage in tidal races, but utilise a wide variety of foraging habitats and often prefer areas of low current with sediment present (Furness *et al*., 2012).
	Divers.	Not important – divers can forage in tidal races, but is more usually associated with sandy substrates which are not usually correlated with strong tidal currents (Furness *et al*., 2012).
	Petrels.	Not important – large foraging range, not exclusive to tidal races.
	Gannets.	Not important – large foraging range, not exclusive to tidal races.
	Cormorants &	Potentially important – both species are known to actively forage in and along the edges of tidal streams (Furness *et al*., 2012). Importance will depend upon proximity to breeding sites, availability of alternative habitat and the

	shags.	influence of the foraging range for either species.
	Skuas.	Potentially important - skuas feed predominantly by kleptoparasitism, so potential effects would primarily relate to associations with species such as terns, auks and kittiwake. Impacts on gulls and terns are not considered important. Impacts on auks are potentially important and they are a regularly exploited species group for skuas.
	Gulls & terns.	Not important – terns generally feed within the top 1-2 meters of water and not exclusively in tidal races. Gulls and kittiwakes feed from the surface, utilise a wide range of habitats and are not exclusively linked to tidal streams.
	Auks.	Potentially important – auks species, particularly black guillemot are known to actively forage in tidal streams (Furness *et al*. 2012). Importance will depend upon proximity to breeding sites, availability of alternative habitat and the influence of the foraging range for each species.

Table 43: Potential effects upon birds during device and infrastructure deployment; identifying activities/effect pathways and receptors for further assessment. Note that these evaluations are made *prior* to consideration of details particular to the Fall of Warness site.

Generic Potential Effects from Device Operation and Maintenance

Summary of activity categories – for detail see project envelope description (Annex1)

- Physical presence of device(s), foundations, moorings, buoys and associated infrastructure on the seabed, in the water column or above the surface
- Operation of device(s)/power generation
- Repeat removal and redeployment of equipment for maintenance (e.g. turbine removed from water or floating structure removed from berth; replacement of mooring system)
- Other maintenance activities (e.g. Biofouling removal; ROV/diver inspection or repairs)

Activity/potential impact	Natural heritage feature	Potential importance
Maintenance vessel (s) transits, manoeuvring and activity leading to disturbance*.	Seaducks.	Potentially important – some sea ducks species are vulnerable to disturbance by vessels (Furness *et al*., 2012, Merkel *et al*., 2009). Importance will depend upon intensity, speed and regularity of vessel activity, the importance of the location for particular species and the degree of connectivity with designated or other sites for these species.
	Divers.	Potentially important – divers are typically vulnerable to disturbance by vessels (Furness *et al*., 2012). Importance will depend upon intensity, speed and regularity of vessel activity, the importance of the location for divers and the degree of connectivity with designated sites for these species.
	Petrels.	Not important – unlikely to be vulnerable to disturbance. All species show little or no response to ship traffic (Furness *et al*., 2012).
	Gannets.	Not important – activity intensity & duration (compared to construction) unlikely to cause important disturbance. Gannets show little response to general ship traffic (Furness *et al*., 2012).
	Cormorants &	Potentially important – cormorant can be vulnerable to disturbance by vessels (Furness *et al*., 2012). Importance will depend upon intensity, speed and regularity of vessel activity, the importance of the location for cormorants

	shags.	and the degree of connectivity with designated sites for these species.
	Skuas.	Not important – unlikely to be vulnerable to disturbance. Skuas show little or no response to ship traffic (Furness *et al*., 2012).
	Gulls & terns.	Not important – unlikely to be vulnerable to disturbance. Gull and terns show little response to ship traffic (Furness *et al*., 2012).
	Auks.	Potentially important – auks can be vulnerable to disturbance by vessels (Furness et al. 2012). Importance will depend upon intensity, speed and regularity of vessel activity, the importance of the location for auks and the degree of connectivity with designated sites for these species.
Collision with turbine blades leading to: injury or death[36].	Seaducks.	Potentially important – although they generally avoid foraging in tidal races, this can be site-specific. Eider and other sea ducks are benthic feeders so may be vulnerable to bottom-sited and suspended turbines (Furness *et al*., 2012).
	Divers.	Potentially important – although they generally avoid foraging in tidal races, this can be site-specific; thus, divers may be vulnerable from turbines suspended from floating infrastructure and bottom-sited devices (Furness *et al*., 2012).
	Petrels.	Not important – petrels can dive below the surface but fulmars and Manx shearwaters predominantly feed at or near the surface and storm petrel pick from surface or plunge dive near the surface (Furness *et al*., 2012).
	Gannets.	Potentially important – aerial diving species that could be vulnerable to bottom-sited and suspended turbines, depending on clearance of blades to sea surface (Furness *et al*., 2012).

[36] For the purpose of this generic assessment, it is assumed that rotors of horizontal-axis turbines are at least 2.5 metres below the sea surface.

	Cormorants & shags.	Potentially important – both are diving species although shag are known to dive deeper. Potentially vulnerable to both bottom-sited and suspended turbines (Furness *et al*., 2012).
	Skuas.	Not important – Skuas predominantly feed by kleptoparasitism of other seabird species, either on or above the water surface (Furness *et al*., 2012). These other species may be impacted by collision risk, but indirect impacts seem unlikely to manifest themselves as important to skuas.
	Gulls & terns.	Not important – terns plunge dive (1-2m) where as kittiwake and gulls feed from the surface.
	Auks	Potentially important – Most species capable of diving within range of bottom-sited turbines and also potentially vulnerable to suspended turbines.
Presence of tidal device and associated infrastructure leading to displacement (including underwater noise from operational turbines)	Seaducks	Potentially important – although they generally avoid foraging in tidal races, this can be site-specific. Importance will depend upon proximity to breeding sites, availability of alternative habitat and the influence of the foraging range for each species.
	Divers	Potentially important – although they generally avoid foraging in tidal races, this can be site-specific. Importance will depend upon proximity to breeding sites, availability of alternative habitat and the influence of the foraging range for each species.
	Petrels	Not important – large foraging range, not exclusive to tidal races.
	Gannets	Potentially important – importance will depend upon proximity to breeding sites, importance of the area for foraging/loafing, availability of alternative habitat and the influence of the foraging range for each species.
	Cormorants & shags	Potentially important – importance will depend upon proximity to breeding sites, importance of the area for foraging, availability of alternative habitat and the influence of the foraging range for each species.

	Skuas	Potentially important – skuas feed predominantly by kleptoparasitism, so potential effects would primarily relate to associations with species such as terns, auks and kittiwake.
	Gulls & terns	Not important – all species utilise a wide range of habitats and are not exclusively linked to tidal streams.
	Auks	Potentially important – auk species, particularly black guillemot, are known to actively forage in tidal streams (Furness *et al*., 2012). Importance will depend upon proximity to breeding sites, importance of the area for foraging/loafing, availability of alternative habitat and the influence of the foraging range for each species.
Presence of tidal device infrastructure leading to attraction, specifically roosting/resting opportunities	Seaducks	Potentially important – eider may rest on surface structures (Furness *et al*., 2012) or feed on/forage around biofouling on infrastructure.
	Divers	Not important – unlikely to utilise man-made structures (Furness *et al*., 2012).
	Petrels	Not important – pelagic species, unlikely to utilise man-made structures (Furness *et al*., 2012).
	Gannets	Not important – unlikely to utilise man-made structures (Furness *et al*., 2012).
	Cormorants & shags	Potentially important – evidence from OSWFs suggests that cormorant in particular could utilise man-made structures to roost/rest (Furness *et al*., 2012) or as a foraging platform. Prey species may also aggregate around infrastructure.
	Skuas	Not important – unlikely to utilise man-made structures (Furness *et al*., 2012).
	Gulls & terns	Potentially important – gulls and terns are known to use man-made structures, either as a roost or foraging platform (Furness *et al*., 2012)

	Auks	Potentially important – could utilise man-made structures to roost/rest or as a foraging platform. Prey species may also aggregate around infrastructure.
Loss of/alteration to foraging habitat (includes indirect effects)	Seaducks	Not important – seaducks generally avoid tidal races; preferring areas of low current with sediment present (Furness *et al*., 2012).
	Divers	Not important – foraging is more usually associated with sandy substrates which are not usually correlated with strong tidal currents (Furness *et al*., 2012).
	Petrels	Not important – large foraging range, not exclusive to tidal races..
	Gannets	Not important – large foraging range, not exclusive to tidal races.
	Cormorants & shags	Potentially important – both species are known to actively forage in and along the edges of tidal streams (Furness *et al*., 2012). Importance will depend upon proximity to breeding sites, importance of the site for foraging, availability of alternative habitat and the influence of the foraging range for either species.
	Skuas	Potentially important – skuas feed predominantly by kleptoparasitism, so potential effects would primarily relate to associations with species such as terns, auks and kittiwake. Availability of feeding auks could be impacted.
	Gulls & terns	Not important – terns generally feed within the top 1-2 meters of water, where as gulls and kittiwakes feed from the surface. All species utilise a wide range of habitats and are not exclusively linked to tidal streams.
	Auks	Potentially important – auks species, particularly black guillemot, are known to actively forage in tidal streams (Furness *et al*., 2012). Importance will depend upon proximity to breeding sites, importance of the site for foraging, availability of alternative habitat and the influence of the foraging range for each species.
	Seaducks	Potentially important – likelihood of attraction to underwater light unknown, but not thought likely to attract eiders that feed mainly on molluscs and crustacean but potentially could attract species feeding on small fish (i.e.

Attraction to underwater lights		sawbills).
	Divers	Potentially important – likelihood of attraction to underwater light unknown, including indirect impacts through any potential fish attraction, but could exacerbate any potential collision risk.
	Petrels	Potentially important - Manx shearwater could be attracted to lights and able to dive sufficiently deep to reach rotors. Not important for other species as limited diving ability means any attraction would not result in increased collision risk with rotors.
	Gannets	Potentially important – likelihood of attraction to underwater light unknown, including indirect impacts through any potential fish attraction, but could exacerbate any potential collision risk.
	Cormorants & shags	Potentially important – likelihood of attraction to underwater light unknown, including indirect impacts through any potential fish attraction, but could exacerbate any potential collision risk.
	Skuas	Not important – likelihood of attraction to light unknown, but absence of diving behaviour removes any increased collision risk with rotors.
	Gulls & terns	Not important – potentially attracted to lights but limited diving ability means any attraction would not result in increased collision risk with rotors.
	Auks	Potentially important – likelihood of attraction to underwater light unknown, including indirect impacts through any potential fish attraction, but could exacerbate any potential collision risk.
Attraction to above surface lights	Seaducks	Potentially Important – some evidence that eider are attracted to lighting on vessels (Merkel 2010), less so for long-tailed ducks.
	Divers	Not important - evidence (from lighthouse records) is that divers are not attracted to lighted structures.

	Petrels	Potentially important – some evidence of attraction to lights, which may lead to collision with structures. Manx shearwater most likely species to be affected (Archer *et al*., 2010), fulmar and small petrels less so. See Rodreguez and Rodreguez (2009) on attraction of shearwaters and petrels to urban lighting. Single lighted structure will be less attractive. However attraction to single lit structures seems to impact more Manx shearwater than fulmar or smaller petrels. Information from Bardsey lighthouse presented by Archer *et al*. (2010) suggests that Manx shearwater are attracted to lights but fulmar does not feature in the list, although present locally in substantial numbers.
	Gannets	Not important – No existing evidence (e.g. from light houses) that above-surface lights are an attractant.
	Cormorants & shags	Not important – No existing evidence (e.g. from light houses) that above-surface lights are an attractant.
	Skuas	Mot important – No existing evidence (e.g. from light houses) that above-surface lights are an attractant.
	Gulls & terns	Not important - evidence (from lighthouse records etc) is that gulls and terns are not attracted to lighted structures. These species do not feature as strongly attracted to lights in literature studies e.g. Archer *et al*. 2010
	Auks	Not important – no existing evidence (e.g. from light houses) that above-surface lights are an attractant. Low level of reports from lighted vessels in Merkel 2010.

Table 44: Potential effects upon birds during the operational and maintenance phase; identifying activities/effect pathways and receptors for further assessment. Note that these evaluations are made *prior* to consideration of details particular to the Fall of Warness site.

4.9.2 Natural heritage context

The following text summarises knowledge of the presence and use of the Fall of Warness site by various bird species, utilising analyses of the EMEC wildlife observations data and wider knowledge of species ecology, as appropriate. Note that figures given in relation to the EMEC Wildlife Observation data here relate to the entire survey area. Subsequent work in relation to the detail of collision risk modelling (see Annex 3) refines this dataset by focussing on the core grid squares of the test site.

Seaducks

The UK estuaries and inshore waters are used by important numbers of wintering sea ducks. Common eider and red-breasted mergansers also breed around the coasts of Scotland. JNCC have undertaken regular targeted aerial surveys, which identified important wintering concentrations of seaducks, including eider and long-tailed ducks around Scapa Flow in Orkney (e.g. Lewis *et al*., 2008; Lewis *et al*., 2009). Many seaducks feed on molluscs, crustaceans and small fish (Owen *et al*., 1986; Kirby *et al*., 1993); eider and long-tailed ducks prefer concentrating on feeding at mussel beds, while sawbills, such as red-breasted mergansers, feed primarily on small fish (Owen et al., 1986).

For the Fall of Warness, three species of seaduck have been frequently recorded: eider, long-tailed duck and red-breasted merganser. Analysis of data from the EMEC wildlife observations between July 2005 and December 2009 indicates eider is one of the most frequently seen bird species, with sightings recorded on 874 of the total observation days (n=1056). Encounter rates for this species peak in March, prior to the breeding season with a mean of 68 birds/hour but fell to 1 bird/hour from June to August. Distribution across the site varied significantly with most encounters either to the north of Muckle Green Holm or within Sealskerry Bay (Robbins, 2011a). Further analysis by Robbins (2011b) between July 2005 and December 2010 showed that eider were recorded on coastal grid squares on 1011 days and in deeper-water on 359 days (n = 1028) providing consistency with literature on this species which notes that as benthic feeders they forage close to the shore and in depths up to 4m deep (Owen *et al.,* 1986).

Long-tailed duck are recorded at the Fall of Warness during the winter months from October through to April. They were observed on 267 days with a peak encounter rate of 1.7 birds/hour in March. Distribution was also significantly varied concentrating coastally around Sealskerry Bay (Robbins, 2011a).

Red-breasted merganser was similarly observed from October to March on 213 of the observation days. The highest encounter rate was recorded in October with a mean of 1 bird/hour (Robbins, 2011a).

Divers

Red-throated and black-throated divers both breed in internationally important numbers within Scotland (Stroud *et al*., 2001). During the breeding season both species utilise freshwater systems, (Mudge and Talbot, 1993; Dillon *et al*., 2009) but red-throated divers, in particular, also forage on inshore waters (Gibbons *et al*., 1997). Outside of the breeding season they use the marine environment extensively, spending a large proportion of their time on the sea (Stone *et al*., 1995). Great-northern diver winters in the UK in important numbers (Stone *et al*., 1995, Barton and Pollock, 2004). Studies have shown divers predominately feed on fish, i.e. lesser sandeels, herring and cod, but also crustaceans (Madsen, 1957; Dillon *et al*., 2009; Guse *et al*., 2009;).

Three species of diver have been observed at the Fall of Warness; red-throated on 588 days, great-northern on 369 days and black-throated on 5 days (n=1056). The hourly encounter rate for red-throated diver was highest from September to March (1 bird/hour) and dropped during April to August (0.2/hour). The highest encounter rate for Great northern diver was recorded during April and May (0.5/hour). Both were significantly distributed around Sealskerry Bay (Robbins, 2011a). Further analysis by Robbins (2011b) of observations between 2005 and 2010 revealed that divers were recorded in a higher number of observations days during autumn, winter and spring, but that the concentrations of birds during summer observations was higher.

Petrels
Northern fulmars breed in internationally important numbers around Britain and Ireland, with the most important concentrations around the Northern and the Western Isles (Lloyd et al., 1991). Unlike most other seabirds, fulmars occupy their nest site year round and therefore can be found on near-shore water near their colonies all year round (Tasker, 2004).

Manx shearwaters breed around the UK coastline while other species of shearwater are vagrant or passage migrants that are scarce around the Scottish coastline (Snow and Perrins, 1998). Britain and Ireland hold most of the world's breeding population of Manx shearwaters, with the world's largest colony on the Isle of Rum (Newton *et al*., 2004). They are only present in UK during the breeding season; they migrate to tropical seas off eastern South America during the winter (Snow and Perrins, 1998). Manx shearwaters are principally offshore feeders, and can spend a considerable amount of time foraging outside British waters, even during the breeding season.

Within the UK there are internationally important numbers of breeding European storm petrel. The Leach's storm petrels have a wider global distribution; however, the only known UK breeding colonies are in Scotland (Mitchell *et al*. 2004). Both species are pelagic, breeding on offshore islands, and like Manx shearwaters, they also only return to land during the hours of darkness. Storm petrels are predominately surface, visual feeders, however they have been recorded diving below the surface (Flood *et al.* 2009).

The data recording methods employed at Fall of Warness resulted in the exclusion of non-diving species – however Northern fulmar (*Fulmaris glacialis*) was common on site (A Robbins pers comm). At nearby Billia Croo wildlife observations recorded Northern fulmar as the most frequently observed bird species, while Manx shearwater was recorded on one occasion and European storm petrel on two occasions.

Gannet
Northern gannet is the largest seabird in the North Atlantic. They may catch fish at depths exceeding 20m but, as aerial plunge divers, more commonly dive within 10m depth (Furness *et al.,* 2012). There are 21 gannetries around the British Isles and populations in Scotland have been steadily increasing since the 1969/70, although this rate of increase has slowed in recent years (JNCC, 2012).

Northern gannet have been recorded all year at the Fall of Warness on 719 observation days (n=1056). The mean encounter rate peaked in October with 6.1 birds/hour (Robbins, 2011a). Robbins (2011b) also noted that 75% of observations were in the grid squares adjacent to the coast, compared with 25% in deeper water.

Cormorants & Shag
European shag is a widespread species breeding throughout Europe, north to Finland and south to Morocco. They breed around the coastline of Scotland utilising cliffs, caves and crevices and feed on a range of small fish, particularly sandeels during the breeding season. Since 1987, shag have shown a decline in abundance with no clear trend of productivity (SNH, 2012). Trends in abundance show marked regional variation for great cormorant, with population declines witnessed in northern Scotland (JNCC, 2012) since the late 1900s, but increased numbers further south. Some of the observed increase in England is due to

increases in the inland nesting population at least part fuelled by the colonisation from the continent by *P.c. sinensis*. In Orkney just over 400 pairs were recorded in Seabird 2000 (Mitchell *et al.* 2004), more recent estimates put the population at around 500 pairs (Meek 2005).

Shag was the most frequently recorded species at the Fall of Warness, with year round observations recorded on 1015 of the 1056 days; cormorant were also frequently seen with observations on 861 days. It is also worth noting that a high proportion of birds were unidentified, such individuals being recorded on 890 days. The highest mean encounter rate for shag was in December (28.2 birds/ hour) and lowest in June (4.3 birds/hour), whereas the highest cormorant encounter rates were recorded in August and September (2.8/hour). The encounter rate for unidentified shag/cormorants was highest in December (48 birds/hour), dropping to 2 birds/hour in July (Robbins, 2011a).

Cormorants breed near to the Fall of Warness on Little Green Holm and at a recently established Little Linga colony (60 adults in 2009) approximately 6.5 km away from the test site, although it appears from count data that relatively infrequent use is made of the site during the breeding season.

Skuas

There are two species of skua that breed in Scotland; the Arctic skua and great skua. While the Arctic skua is at the southern limit of its circumpolar breeding range, the great skua (or bonxie) are restricted to just the north east Atlantic, with 60% of the worlds population breeding in Scotland. Both species UK breeding centres are in Shetland and Orkney, with smaller concentrations in the Western Isles (Furness, 1987). Arctic skuas obtain much of their prey by stealing from other seabirds such as black-legged kittiwakes, terns and auks (such as guillemots), known as kleptoparasitism. Furness (2007) outlined the main threats acting upon the population as depredation by great skuas, sandeel scarcity, breeding habitat loss and human persecution. Great skua also forage by stealing food from other seabirds including gannets, but as generalists they feed on fishery discard as well and some specialise in seabird predation (Votier *et al*., 2004a,b).

Gulls and terns

Black-legged kittiwakes are a common and widespread circumpolar breeding seabird, typically breeding on exposed cliffs. Kittiwake numbers in Scotland peaked in the early 1990s and have declined since then. In recent years, Orkney and Shetland have witnessed complete colony failures as birds have struggled to find sufficient food for their chicks. 2010 saw a temporary improvement in productivity. Other gulls species (great black-backed gull, herring gull, common gull, black-headed gull and lesser black-backed gull) are also widespread breeders, with colonies on many Orkney Islands. Populations of larger gulls have declined generally since the end of the 20th century.

Arctic terns are the commonest breeding seabird in Britain and Ireland, with 73% of the population based in the Northern Isles (Mitchell et al 2004). Since 1986, Arctic terns have steadily declined, reaching their lowest level in 2011. This is also thought to be linked to food shortages, as well as predation by non-native species such as American mink (SNH, 2012). Common terns breed in small numbers throughout the Northern Isles – often in association with Arctic terns. The larger Sandwich tern is patchily distributed around the coast of Britain and Ireland, with less than 10% of the population breeding in Scotland, most at one Aberdeenshire colony. Small numbers of Sandwich terns breed in Orkney.

Gulls and terns have only been recorded sporadically at the Fall of Warness. There are no known colonies adjacent to the test site, but Arctic terns were observed foraging on 103 days between May and August with an hourly encounter rate of 12 birds/hour between May and July, dropping to 6 birds per hour in August. Black-legged kittiwakes were observed less with sightings on 33 days between May and September and an hourly encounter rate of 5.3 birds/hour during June (Robbins, 2011a).

Auks

Common guillemot is one of our most abundant seabirds with around 750, 000 pairs in Scotland – approximately 10-11% of the world population (Mitchell *et al.,* 2004). Productivity has declined since 2001, reaching its lowest level between 2006 and 2007. Razorbills breed on both sides of the Atlantic, as far south as Brittany, north to Svalbard and east to north-west Russia. Productivity has declined in Scotland since the early 1990s, thought to coincide with food shortages and a decrease in energy content of fish brought to chicks (JNCC, 2012). Around 10% of the North Atlantic and adjacent Arctic Ocean population of Atlantic puffin breeds in Britain. The reduction in productivity since the 1990s has contributed to a declining population trend in Scotland overall. The breeding range of the Atlantic puffin stretches from Spitzbergen and North-west Greenland to bay of Fundy and Brittany in the south. The British population is mostly based in the north and west, with substantial colonies in the Firth of Forth and on the Farne Islands. About a third of the UK population breeds in the Northern Isles. Black guillemot, which unlike other auk species do not migrate, are a circumpolar species. Abundance in Scotland has remained relatively stable since monitoring began in 1986 (SNH, 2012).

At the Fall of Warness, black guillemot was the second most frequently seen bird species with observations on 890 days recorded throughout the year. The highest (mean) encounter rate was recorded between March and August with over 20 birds/hour, dropping to around 2 birds/hour between September and January. Distribution was significantly varied, but highest densities concentrated around Muckle Green Holm and along the shoreline from Sealskerry Bay south to the point at Warness (Robbins, 2011a).

Common guillemot were observed on 568 days, the hourly encounter rate for this species reveals an increase in May and June with a peak rate of 69.4 birds/hour in June. Common guillemot was observed throughout the middle of the Fall of Warness (Robbins, 2011a). Robbins (2011b) also revealed that 91% of common guillemots were observed in water 20m or deeper.

Atlantic puffins were observed on 396 days with the mean encounter rate increasing from March and peaking in June (5.7 birds/hour) (Robbins, 2011a). Like guillemots, puffins also were observed in deeper water parts of the site (Robbins, 2011b).

Razorbills were the least recorded auk, with observations on 166 days. Encounter rates peaked in April and decreased throughout the breeding season (Robbins, 2011a). Razorbills sightings were primarily distributed in the deeper water parts of the site (Robbins, 2011b).

4.9.3 Impact appraisal mechanisms for the Fall of Warness

This impact appraisal takes account of a maximum-case scenario based on the project envelope, where all available berths within the test site are developed and operating at capacity. It addresses the differing consenting and licensing regimes such as HRA and EIA (see Table 45 below). This appraisal will inform the consenting process for both Marine Licence and Section 36 applications. However, it should be noted that, if there are key deviations in the device design or in installation or maintenance activities, further appraisal work may be required. Any additional appraisal work required will be undertaken by the individual developer (further advice should be sought from EMEC in the first instance).

Feature type	Appraisal mechanism/relevant legislation	Applicable	Reasoning
Qualifying interests of European sites.	Habitats Regulations Appraisal (HRA) - Habitats Regulations 1994 (as amended).	Y	Various qualifying species from a variety of SPA may have connectivity with the site.
European Protected Species.	EPS legislation - Habitats Regulations 1994 (as amended in Scotland).	N	No bird species are listed as EPS.
Notified features of SSSIs.	SSSI legislation - Nature Conservation (Scotland) Act 2004.	Y	Captures assessment of SSSIs with birds as notified features
Protected features of MPAS	Marine (Scotland) Act 2010	N	No connectivity with any MPAs with protected bird features.
PMFs	Marine (Scotland) Act 2010	N	No bird species are listed as PMFs.
Other sensitive natural heritage features.	Appraisal of other features under: - Electricity Works (EIA) (Scotland) Regulations (Amendment) 2008; - Marine Works (EIA) (amendment) Regulations 2011; - Marine (Scotland) Act 2010.	Y	Captures assessment of all other sensitive natural heritage features at a population/habitat scale of concern.

Table 45: Appraisal mechanism for birds.

4.9.4 Qualifying interests of European sites

The following commentary outlines the appraisal undertaken in relation to the seabird SPA qualifying interests. See Section 4.10 for the Natura Proforma which underpins the advice summarised below for those SPA considered to have connectivity and for which a significant effect is considered likely.

Note that this appraisal may need to be revisited following delivery of ongoing work relating to potential new marine SPA.

Step1:
Is the tidal turbine test site at the Fall of Warness directly connected with or necessary for the conservation management of the SPA?

The test site is not directly connected with or necessary to site management for the conservation management of any of the SPA in Scotland.

Step 2:
Is the test site at the Fall of Warness likely to have a significant effect on the qualifying interests of the SPA either alone or in combination with other plans or projects?

This step acts as a screening stage: it removes from the HRA those proposals (plans or projects) which clearly have no connectivity to SPA qualifying interests or where it is very obvious that the proposal will not undermine the conservation objectives for these interests, despite a connection.

Connectivity between qualifying interests from SPA and Fall of Warness test site has been judged using the results of the EMEC Wildlife Observation data to determine which species are present at the test site and within foraging range of their SPA and in sufficient abundance. Data from Birdlife International[37] and Thaxter *et al.* (2012) on the mean foraging range, the mean of the maximum foraging range and the maximum foraging range. As these ranges are subject to some variance they have not been used as a definitive threshold (e.g. an SPA only a few kilometres further than the foraging range has not been automatically scoped out). Current casework advice from SNH is to use the mean of maximum ranges given in Thaxter *et al.* (2012) in the first instance.

The SPA bird species considered in respect of the test site are wide-ranging – marine birds can make long foraging trips, which means that the test site may be ‘connected to’ SPA even at great distances. Although connectivity is thus established, where the proposal is located further away from a designated site, impacts are less likely on qualifying species associated with that SPA. Likelihood of impact on an SPA qualifying interest is, however, not necessarily always correlated with distance from the development site, also depending on a number of other factors, such as flight-lines and distribution/availability of foraging habitat/prey species.

Determination of ‘likely significant effect’ is not just a record of presence or absence of seabird species at a test site, or the potential for connectivity, but also involves a judgement as to whether any of the SPA conservation objectives might be undermined. Such judgement is also informed by a simple consideration of the importance of the area in question for the relevant species.

Consideration has also been given to the condition status of each of the species as qualifying interests to the SPA. Impacts upon even a relatively small number of animals could have important implications, particularly considering the current potential for cumulative impacts within Orkney waters. This is particularly relevant for a number of seabird species, including European shag, Arctic skua, herring gull, great black-backed gull, black-legged kittiwake, Sandwich, common and Arctic terns, and common guillemots, for which there have been declines in Scottish populations (Foster and Marrs, 2012). These species in particular are currently vulnerable to any impacts, which could lead to their further population decline or prevent their recovery.

[37] http://seabird.wikispaces.com/

Two key stages have been applied in determining advice on LSE:

1. Table 46 below relates to SPA considered to have potential connectivity with the Fall of Warness test site, primarily based upon published data on foraging ranges. Only qualifying interests of each SPA with potential connectivity have progressed to this stage in the appraisal.
2. Table 47 below then refines this list further to qualifying species with at least moderate potential connectivity and a potential impact pathway with an activity/stressor.

Qualifying Interest	**SPA Name**	**Distance to FoW**	**Mean** -Thaxter *et al* 2012	**Mean Max** -Thaxter *et al* 2012	**Max** - Thaxter *et al* 2012	**Connectivity** -High[38] -Moderate[39] -Low[40]
Red-throated diver	No SPA within maximum range reported in Thaxter *et al* 2012		4.5km	9km	9km	
Fulmar	Buchan Ness to Collieston Coast	192	47.5km	400km	580km	Moderate
	Calf of Eday	6				High
	Cape Wrath	127				Moderate
	Copinsay	24				High
	East Caithness Cliffs	80				Moderate
	Fair Isle	74				Moderate
	Fetlar	185				Moderate
	Flannan Isles	287				Moderate
	Forth Islands	325				Moderate
	Foula	110				Moderate
	Fowlsheugh	245				Moderate
	Handa	157				Moderate

[38] Site within the mean foraging range and the mean maximum +10% and/or the 95% CFD

[39] Site within the maximum foraging range and either the mean maximum + 10% or 95% CFD (or close to these)

[40] Site within the maximum foraging range

	Hermaness, Saxa Vord and Valla Field	209				Moderate
	Hoy	35				High
	Mingulay and Berneray	379				Moderate
	North Caithness Cliffs	53				High
	North Rona and Sula Sgeir	163				Moderate
	Noss	146				Moderate
	Rousay	5				High
	St Kilda	354				Moderate
	Sumburgh Head	113				Moderate
	The Shiant Isles	241				Moderate
	Troup, Pennan and Lion's Heads	159				Moderate
	West Westray	15				High
Manx shearwater	Rum	299	2.3km	330km	330km	Moderate
	St Kilda	354				Low
European storm petrel	Auskerry	15			T- 65km	High
Leach's storm petrel	Foula	110		T- 91.7km	T- 120km	Low
	Sule Skerry and Sule Stack	88				Moderate
Gannet	Ailsa Craig	451	92.5km	229.4km	590km	Low
	Fair Isle	74				High
	Forth Islands	325				Low
	Hermaness, Saxa Vord and Valla Field	209				Moderate
	North Rona and Sula Sgeir	163				Moderate
	Noss	146				Moderate
	St Kilda	354				Low
	Sule Skerry and Sule Stack	88				High
Great cormorant	Calf of Eday	6	5.2km	25km	35km	High

Shag	No SPA within maximum range reported in Thaxter *et al* 2012		5.9km	14.5km	17km	
Arctic skua	Fair Isle	74	6.4km	62.5km	75km	Low
	Hoy	35				Moderate
	Rousay	5				High
	West Westray	15				Moderate
	Papa Westray (North Hill and Holm)	20				Moderate
Great skua	Fair Isle	74	35.8km*	86.4km	219km	Moderate
	Fetlar	185				Low
	Foula	110				Low
	Handa	157				Low
	Hermaness, Saxa Vord and Valla Field	209				Low
	Hoy	35				High
	Noss	146				Low
	Ronas Hill – North Roe and Tingon	168				Low
Herring gull	East Caithness Cliffs	80	T- 10.5km	T- 61.1km	T- 92km	Low
Great black-backed gull	Calf of Eday Copinsay East Caithness Cliffs Hoy	6 24 80 35	10.5km	61.1km (use herring gull value)	92km	High Moderate Low Moderate
Lesser black-backed gull	No SPA within maximum range reported in Thaxter *et al* 2012		71.9km	141km	181km	
Black-legged kittiwake			24.8km	60km	120km	
	Calf of Eday	6				High
	Copinsay	24				High
	East Caithness Cliffs	80				Low

	Fair Isle	74				Low
	Foula	110				Low
	Hoy	35				Moderate
	Marwick Head	30				Moderate
	North Caithness Cliffs	53				Moderate
	Rousay	5				High
	Sumburgh Head	113				Low
	West Westray	15				High
Arctic tern	Auskerry	15	7.1km	24.2km	30km	Moderate
	Papa Westray (North Hill and Holm	20				Moderate
	Rousay	5				High
	West Westray	15				Moderate
Common tern	No SPA within maximum range reported in Thaxter *et al* 2012		4.5km	15.2km	30km	
Common guillemot	Calf of Eday	6	37.8km	84.2km	135km	High
	Cape Wrath	127				Low
	Copinsay	24				High
	East Caithness Cliffs	80				Moderate
	Fair Isle	74				Moderate
	Foula	110				Low
	Hoy	35				High
	Marwick Head	30				High
	North Caithness Cliffs	53				Moderate

	Rousay	5				High
	Sule Skerry and Sule Stack	88				Low
	Sumburgh Head	113				Low
	West Westray	15				High
Razorbill	East Caithness Cliffs	80	23.7km	48.5km	95km	Low
	Fair Isle	74				Low
	North Caithness Cliffs	53				Low
	West Westray	15				High
Atlantic puffin	Cape Wrath	127	4km	105.4km	200km	Low
	East Caithness Cliffs	80				Moderate
	Fair Isle	74				Moderate
	Foula	110				Low
	Hoy	35				Moderate
	North Caithness Cliffs	53				Moderate
	North Rona and Sula Sgeir	163				Low
	Noss	146				Low
	Sule Skerry and Sule Stack	88				Moderate

Table 46: Screening of SPA with seabird species as qualifying interests (*range data from seabird wikispaces).

Table 47 below applies generic information on potential impact pathways (from Table 43 and Table 44) to qualifying interests that have at least moderate potential connectivity to the test site, providing a refined list of SPA with potential for a likely significant effect.

Qualifying Interest (with connectivity only)	SPA Name	Activity/Potential Impact Pathway
Manx shearwater	Rum	• Collision with turbine blades leading to: injury or death – dive depth mean value is 1m in Furness et al 2012 (but Aguilar gives *P. mauritanicus* 15.5m mean. Both species have a value of 26m max dive depth. • Potential attraction to underwater artificial light • Potential attraction to above-surface lighting
Northern gannet	Fair Isle Hermaness, Saxa Vord and Valla Field North Rona and Sula Sgeir Noss Sule Skerry and Sule Stack	• Installation vessel(s) transits, manoeuvring and activity (includes noise) leading to disturbance • Collision with turbine blades leading to injury or death • Presence of tidal device and associated infrastructure leading to displacement (including underwater noise from operational turbines) • Potential attraction to underwater artificial light
Great cormorant	Calf of Eday	• Installation vessel(s) transits, manoeuvring and activity (includes noise) leading to disturbance • Disturbance of foraging habitat and prey during construction • Loss of/alteration to foraging habitat (includes indirect effects) • Maintenance vessel (s) transits, manoeuvring and activity leading to disturbance* • Collision with turbine blades leading to: injury or death • Presence of tidal device and associated infrastructure leading to displacement (including underwater noise from operational turbines) • Presence of tidal device infrastructure leading to attraction, specifically roosting/resting opportunities • Potential attraction to underwater artificial light
Arctic skua	Hoy Papa Westray (North Hill & Holm) Rousay West Westray	• Disturbance of foraging habitat and prey during construction • Loss of/alteration to foraging habitat (includes indirect effects) • Presence of tidal device and associated infrastructure leading to displacement (including underwater noise from operational turbines)
Great skua	Fair Isle Hoy	• Disturbance of foraging habitat and prey during construction • Loss of/alteration to foraging habitat (includes indirect effects) • Presence of tidal device and associated infrastructure leading to displacement (including underwater noise from operational turbines)

Great black-backed gull	Calf of Eday Copinsay Hoy	• *Installation vessel(s) transits, manoeuvring and activity (includes noise) leading to disturbance*[41] • *Presence of tidal device infrastructure leading to attraction, specifically roosting/resting opportunities*
Black-legged kittiwake	Calf of Eday Copinsay Hoy Marwick Head North Caithness Cliffs Rousay West Westray	• Installation vessel(s) transits, manoeuvring and activity (includes noise) leading to disturbance • Presence of tidal device infrastructure leading to attraction, specifically roosting/resting opportunities
Arctic tern	Auskerry Papa Westray (North Hill & Holm) Rousay West Westray	• Installation vessel(s) transits, manoeuvring and activity (includes noise) leading to disturbance • Presence of tidal device infrastructure leading to attraction, specifically roosting/resting opportunities
Common guillemot	Calf of Eday Copinsay East Caithness Cliffs Fair Isle Hoy Marwick Head North Caithness Cliffs Rousay West Westray	• Installation vessel(s) transits, manoeuvring and activity (includes noise) leading to disturbance • Disturbance of foraging habitat and prey during construction • Maintenance vessel (s) transits, manoeuvring and activity leading to disturbance* • Collision with turbine blades leading to: injury or death • Presence of tidal device and associated infrastructure leading to displacement (including underwater noise from operational turbines) • Presence of tidal device infrastructure leading to attraction, specifically roosting/resting opportunities • Loss of/alteration to foraging habitat (includes indirect effects) • Potential attraction to underwater artificial light

[41] The term 'disturbance' includes all behavioural responses of biological consequence, including displacement from the vicinity of the activity.

Razorbill	West Westray	• Installation vessel(s) transits, manoeuvring and activity (includes noise) leading to disturbance • Disturbance of foraging habitat and prey during construction • Maintenance vessel (s) transits, manoeuvring and activity leading to disturbance* • Collision with turbine blades leading to: injury or death • Presence of tidal device and associated infrastructure leading to displacement (including underwater noise from operational turbines) • Presence of tidal device infrastructure leading to attraction, specifically roosting/resting opportunities • Loss of/alteration to foraging habitat (includes indirect effects) • Potential attraction to underwater artificial light
Atlantic puffin	East Caithness Cliffs	• Installation vessel(s) transits, manoeuvring and activity (includes noise) leading to disturbance • Disturbance of foraging habitat and prey during construction • Maintenance vessel (s) transits, manoeuvring and activity leading to disturbance* • Collision with turbine blades leading to: injury or death • Presence of tidal device and associated infrastructure leading to displacement (including underwater noise from operational turbines) • Presence of tidal device infrastructure leading to attraction, specifically roosting/resting opportunities • Loss of/alteration to foraging habitat (includes indirect effects) • Potential attraction to underwater artificial light
	Fair Isle	
	Hoy	
	North Caithness Cliffs	
	Sule Skerry and Sule Stack	

Table 47: Screening of SPA qualifying interests with potential impact pathway and at least moderate potential connectivity to the Fall of Warness.

Once theoretical connectivity and potential impact pathways are considered, the local context of the Fall of Warness test site and a deeper understanding of species biology needs to be taken into account. In some instances it then becomes obvious that the conservation objectives will not be undermined despite a theoretical connection, including those cases where impacts may be positive. As such, the following particular SPA/qualifying interests are not progressed for further appraisal, despite inclusion Table 47 above:

Manx shearwater *(Rum SPA)* - Manx shearwaters do not breed in close proximity to the test site but have a very large foraging range. They have several methods of foraging, often surface feeding and not diving to depths sufficient to encounter turbine blades. Moreover they prefer to forage offshore, consequently they are only infrequently seen passing through the test site and highly unlikely to dive in proximity to the turbines.

Kittiwake *(Calf of Eday SPA, Copinsay SPA, Hoy SPA, Marwick Head SPA, North Caithness Cliffs SPA, Rousay SPA, West Westray SPA)* – the only impact pathways identified at this test site could be considered as a positive impact and/or not of consequence for the conservation objectives.

Great black-backed gull *(Calf of Eday SPA, Copinsay SAP, Hoy SPA)* – the only impact pathways identified at this test site could be considered as positive impacts or not of consequence for conservation objectives.

Arctic tern *(Auskerry SPA, Papa Westray SPA, Rousay SPA, West Westray SPA)* – the only impact pathway identified at this test site could be considered as a positive impact and/or not of consequence for the conservation objectives. There are no colonies sufficiently close to be affected by cable laying .

For Arctic skua and great skua there is a lack of survey data, and impacts may be both direct and indirect (i.e. through impacts to other species). However, given the precautionary nature of the Habitat Regulations, they are being taken forward for further appraisal under HRA. All other species highlighted in the above table are also being taken forward.

Conclusion:
There is potential for the test site to have a likely significant effect on various bird species designated as qualifying interests of SPA, as per Table 46 above.

Table 48 below details SPA requiring further appraisal. As mentioned above, a Natura Proforma underpins the summarised commentary outlined in Table 49 below. It includes the relevant Conservation Objectives.

SPA Name
Calf of Eday SPA
Copinsay SPA
East Caithness Cliffs SPA
Fair Isle SPA
Foula SPA
Hermaness, Saxa Vord and Valla Field SPA
Hoy SPA
Marwick Head SPA
North Caithness Cliffs SPA
North Rona and Sula Sgeir SPA
Noss SPA
Papa Westray (North Hill and Holm) SPA
Rousay SPA
Sule Skerry and Sule Stack SPA
West Westray SPA

Table 48: SPA requiring further appraisal.

Step 3:
Can it be ascertained that the test site will not adversely affect the integrity of the SPA, either alone or in-combination with other plans or projects?

This stage of HRA is termed the **Appropriate Assessment**. This stage is undertaken by the competent authority with advice provided by SNH. Appropriate Assessment considers the implications of the proposed development for the conservation objectives of the qualifying interests for which a likely significant effect has been determined. The outcomes of this appraisal are detailed in Section 4.10 and summarised below.

The key question in any Appropriate Assessment for the testing of tidal devices at the Fall of Warness is whether it can be ascertained that this proposal, alone or in-combination, will not adversely affect the detailed Natura sites, where it has been advised that there is a likely significant effect. As the test site does not overlap with any of the identified SPA, the conservation objectives that require further consideration are **(ii)** significant disturbance to the qualifying species and **(iii)** population of the species as a viable component of the SPA, as these can include impacts to birds while they are out-with the SPA. Other conservation objectives of relevance outside the SPA do not require further consideration due to the distances involved and/or scale of the proposal.

This appraisal should help inform the Appropriate Assessment, however as stated above any deviation from the project envelope description (see Annex 1) may require further information and subsequent appraisal.

Activity/potential impact pathway	Installation	Operation or Maintenance	Summary of appraisal assessment
Installation and maintentance vessel transits, manoeuvring and activity (including noise) leading to disturbance.	Northern gannet Great cormorant Common guillemot Razorbill Atlantic puffin Great skua Arctic skua	Northern gannet Great cormorant Common guillemot Razorbill Atlantic puffin Great skua Arctic skua	There may be potential for disturbance effects from multiple vessels activity (noise and/or presence) on site for common guillemot and razorbill, but not for great cormorant, northern gannet, Atlantic puffin, Arctic skua or great skua. However we consider that if disturbance of northern guillemot and razorbill were to occur the availability of alternative habitat in relation to the small scale of the Fall or Warness is such that we do not consider it would negatively impact on the conservation objective for any of the connected SPA.
Loss of/alteration to foraging habitat (includes indirect effects).	Great cormorant Common guillemot Razorbill Atlantic puffin	Great cormorant Common guillemot Razorbill Atlantic puffin	Changes to the tidal characteristics at the Fall of Warness as a result of the presence and or operation of turbines are not considered to be important at the scale of the test site and as such it is unlikely that there would be significant impact to the surrounding benthic habitats and the associated prey species. This, together with the large foraging range of the northern gannet, great cormorant, common guillemot, razorbill and Atlantic puffin leads to the conclusion that this impact pathway is unlikely to hava negative effect on any of the conservation objectives of the SPA.
Collision with turbine blades leading to injury or death.	Not applicable to installation phase.	Northern gannet Great cormorant Common guillemot Razorbill Atlantic puffin	Risk of mortality due to collision with active turbine blades is a possibility for several species. For common guillemot the modelled rates predict mortality of greater than 1 bird per year even at 99% avoidance. However assessment of the predicted levels of mortality against the populations of seabirds within range of the turbines indicates that these levels of mortality will not have an impact on the conservation objectives for the SPA.

Presence of tidal device and associated infrastructure leading to displacement (including underwater noise from turbine operation).	Not applicable to installation phase.	Northern gannet Great cormorant Common guillemot Razorbill Atlantic puffin Arctic skua Great skua	Direct experience of the likely reaction to underwater turbines and even above surface structures is very limited – although some parallels can be drawn from offshore wind installations. It is considered that any reaction will be close to the turbines and the size of the installations compared to the feeding ranges of the birds leads to a conclusion of no significant impacts on the populations of these species and therefore no negative impact on the conservation objectives of the SPA.
Presence of tidal device infrastructure leading to attraction, specifically roosting/resting opportunities.	Not applicable to installation phase.	great cormorant common guillemot razorbill Atlantic puffin	The small scale of development footprint together with the limited number of devices being tested is unlikely to be significant in comparison to the foraging ranges and available habitat of species considered at risk. Great cormorant has shown attraction to infrastructure associated with offshore wind farms, but other species considered here much less so. Some small benefit might be gained by cormorants, and no negative impacts were identified. Therefore it is not considered that this pathway will impact on the conservation objectives of the SPA.
Presence of artificial underwater lighting leading to attraction.	Not applicable to installation phase.	Northern gannet Great cormorant Common guillemot Razorbill Atlantic puffin	Potential exists to attract piscivorus diving species if fish are attracted to underwater lighting. Although birds are known to be attracted to some above surface lighting, there is no evidence that underwater lighting itself attracts birds. The type of lighting to be deployed (most likely to enable photographic monitoring of installations) is not known, and as such project-specific assessment of this aspect is required.

Table 49: Summary of Natura assessment for SPA – see Section 4.10 for further details.

Conclusion:
The proposal will not adversely affect site integrity of any SPA.

4.9.5 Notified features of Site of Special Scientific Interest (SSSI)

SSSIs are designated under the Nature Conservation (Scotland) Act 2004 (as amended) and it is an offence for any person to intentionally or recklessly damage the protected natural features of an SSSI. More information can be found on the SNH website, including SSSI citations and Site Management Statements[42]. Assessment of impacts to SSSI should consider the likelihood of adverse impacts to the integrity of the area or damage to the natural features for which the site is notified.

Appraisal of impacts of SSSI bird features

Of the coastal SSSIs in the immediate vicinity of the Fall of Warness, none have any bird species as notified features. Some other coastal SSSIs in the wider area of Stronsay Firth and Westray Firth do have birds as notified features; these sites could conceivably be adjacent to transit routes for some vessels in use at the Fall of Warness, and so disturbance by vessels is considered further here. However, these firths already support a moderate amount of vessel activity, including creel boats likely to work in relatively shallow margins. Consequently, additional vessel traffic associated with the Fall of Warness is unlikely to add significantly to any disturbance impact. Following good practice in vessel operations (e.g. through application of SMWWC[43] guidelines) should be sufficient to limit any residual disturbance impact to acceptable levels.

Conclusion:
Providing the principles of the SMWWC are followed by vessel skippers, we do not consider that the test site would have an adverse impact on the notified bird features of any SSSIs.

4.9.6 Appraisal of other features

Various bird species at the Fall of Warness are either not qualifying interests or features of the above mentioned SPA or SSSIs, respectively, or also have populations outside of these sites that are relevant for detailed consideration of potential impacts at the Fall of Warness. The appraisals below consider the use of the local area by such species that have been observed in notable abundance at the Fall of Warness, appraising potential impacts against the context of population estimates for Scotland. Where such information is available, we also consider the regional population within Orkney.

Such species that occur are discussed below in turn. Note that appraisals for some of these species may need to be revisited following delivery of ongoing work relating to potential new marine SPA.

[42] http://www.snh.gov.uk/protecting-scotlands-nature/protected-areas/national-designations/sssis/
[43] www.marinecode.org

Eiders

Eiders were very abundant in the EMEC Wildllife Observations, but with the vast majority of observations in coastal grid-cells either immediately north of Muckle Green Holm or within Sealskerry bay (Robbins, 2011a). This is consistent with the expectation that eiders are benthic feeders primarily foraging close to shore in depths to approximately 4m deep (Owen *et al.,* 1986). The most recent estimates of the Scottish eider population is 20,000 nesting females, with 2000 nesting females in Orkney (Forrester and Andrews 2007). This is consistent with the estimate of 39000 birds in Scotland and 3500 birds in Orkney from surveys in the 1990s (Ross and Furness 2000), given that eider populations (outside of Shetland) have been increasing in recent years.

However, despite the habitat and foraging preferences noted above, eiders are physically capable of diving to depths that would put them at risk of collision with operational turbines. The collision risk modelling assessed the risk for eiders observed in the core grid-cells (see Annex 3 for information on berth and grid-cell locations). For the maximum-turbine scenario modelled, if assuming a 98% behavioural avoidance rate, a collision prediction of 1.6 eiders per year was made (see Annex 3 for more information on the modelling undertaken). However, it is likely that this is an overestimate, skewed by one survey grid cell positioned such as to overlap with a single berth site (berth 1) in one corner, and an area of shallow coastal habitat with high eider density in the other corner. This is an unfortunate artefact of the survey design with 500m x 500m grid cells and therefore requires some reasoned interpretation of the data. Accordingly, against the context of the Scottish/Orkney eider populations mentioned above and considering likely rates of natural mortality, it is unlikely that collision with devices would have a measurable influence on the population. Nevertheless, monitoring for any bird-device interactions with devices, particularly at the berths closest to high animal densities, would have merit.

Other noteworthy potential impacts on eider may include disturbance by vessel traffic, and displacement from or attraction to devices. For the former, the preference of this species for shallow coastal areas away from the actual berth sites should greatly limit the potential for disturbance, particularly against the background of existing vessel activity in the area and ready availability of similar habitat nearby. Furthermore, likely construction and maintenance activities will be of sporadic frequency and limited extent. Any residual impact should be further limited to acceptable levels by adherence to guidelines under the SMWWC[44]. Through onshore planning processes, cabling works coming to shore should consider any sensitivities associated with nesting birds.

Given the evident preference of eiders at the Fall of Warness for shallow coastal areas, any impacts of displacement away from turbine locations is considered unlikely to have any discernable impact. The potential for attraction of eiders to devices, whether due to roosting opportunities on above-surface infrastructure, growth of potential prey on the infrastructure or by any use of underwater lighting, is largely unknown but may increase collision risk if they are attracted during turbine operation. Although it is thought unlikely that eiders will forage at the depths required during high tidal flows for this to be a significant risk, monitoring of this situation would be useful in determining what further action, if any, was required.

Appraisal conclusion for eiders: Any potential impacts are not regarded as important at a Scottish population level, although monitoring of potential collision impacts has merit. Adherence to the guidelines associated with the SMWWC should sufficiently limit residual disturbance impacts.

[44] www.marinecode.org

Red-throated divers

Observations of red-throated divers at the site have been moderately frequent, particularly between September and March, but also concentrated in the shallow coastal areas of Sealskerry Bay, mostly away from the actual berth sites. This is also consistent with the anticipated foraging habitat preferences of this species.

For the maximum-turbine scenario modelled (and if assuming a 98% behavioural avoidance rate), a collision prediction of 0.2 red-throated divers per year has been made (see Annex 3). The most recent estimates of the red-throated diver population in Scotland is 1255 pairs, with 97 pairs in Orkney (Dillon *et al.* 2009). Red-throated divers are present in Orkney in winter, but many British wintering birds are from outside the UK (Forrester and Andrews 2007). The encounter rate of divers at Fall of Warness is considerably higher in winter (September to March 1 bird per hour) than in summer (0.2 birds per hour), with birds tending to be close to shore (Robbins 2011). Section 4.9.6 considers that the SPA in Orkney with red-throated divers as a qualifying interest are too distant and have sufficient nearby foraging habitat for any significant degree of connectivity with the Fall of Warness. It can therefore be assumed that the observed birds are primarily from local non-SPA locations. Even considering the most recent counts of this species across the islands closest to the site (Eday, Westray, Egilsay, Rousay, Shapinsay), which have fewer than 30 pairs in total (most on Eday and Rousay), the predicted collision rate is low. Given the behaviour and habitat use preferences observered at Fall of Warness, combined with the much lower encounter rate during the breeding period, it is considered that the risk to the local population is low. Against the context of the Scottish/Orkney populations, and considering likely rates of natural mortality, it is unlikely that collision with devices would have a measurable influence on the population. Nevertheless, monitoring for any bird-device interactions with devices, particularly at the berth-sites closest to high animal densities, would have merit.

Similar to eider, the preference of this species for shallow coastal areas away from the actual berth sites should greatly limit the potential for disturbance by vessels, particularly against the background of existing vessel activity in the area and ready availability of similar habitat nearby. Furthermore, likely construction and maintenance activities will be of sporadic frequency and limited extent. Any residual impact should be further limited to acceptable levels by adherence to guidelines under the SMWWC[45].

Divers are unlikely to utilise man-made structures for roosting or foraging, as they tend to rest on the sea and only rarely come ashore outside the breeding season. Like other species, it is unknown whether divers are likely to be attracted to any use of underwater light, but any such response may increase collision risk, such that monitoring for interactions is merited.

Appraisal conclusion for red-throated divers: Any potential impacts are not regarded as important at a Scottish population level, although monitoring of potential collision impacts has merit. Adherence to the guidelines associated with the SMWWC should sufficiently limit residual disturbance impacts.

Shags

Shag is an abundant species in the Fall of Warness and throughout the Northern Isles, although the Scottish population has been in long-term decline. The most recent population estimates for Scotland is 21487 (nests) recorded during the Seabird 2000 surveys, of which

[45] www.marinecode.org

1872 nests were in Orkney (Mitchell *et al.* 2004). Shag roost in several areas of the coastline adjacent to the Fall of Warness and, consequently, their density is also heavily skewed to coastal grid-cells (see Annex 3). The modelled collision rate of 3 shags per year (see Annex 3) for the maximum-turbine scenario modelled (and assuming a 98% behavioural avoidance rate). In the context of Scottish & Orkney populations and natural mortality rates for this species, this rate is highly unlikely to have a measurable impact upon the population.

Shags are not considered sensitive to disturbance by vessel traffic (Furness *et al,* 2012), but other potential impacts of relevance may include alteration to foraging habitat, displacement from existing foraging habitat or attraction to new foraging habitat around infrastructure (including through foraging and roosting opportunities, potentially increasing collision risk). Uncertainty surrounds the potential implications and some monitoring is merited but, in the context of Scottish and Orkney populations, the ready availability of similar habitats and the sporadic and limited extent of likely construction and maintenance activities, such impacts are unlikely to be important.

Appraisal conclusion for shags: Any potential impacts are not regarded as important at a Scottish population level, although monitoring of potential collision impacts has merit. Adherence to the guidelines associated with the SMWWC should sufficiently limit residual disturbance impacts.

Cormorants

Great cormorant is also a relatively abundant species in the Fall of Warness and throughout Orkney, although at the Scottish level their distribution and abundance is patchy, with a general trend of decline in the north of Scotland, although the population of the UK is increasing. There were 3626 occupied nests of great cormorant in Scotland during the Seabird 2000 surveys (Mitchell *et al.* 2004). The Orkney population is around 500 breeding pairs.

Cormorant also roost in the coastal margins of the site, but their observed distribution appears to be less heavily skewed to the coastal margins than that of shag, for example. The modelled collision rate of 1.6 cormorants per year (see Annex 3) for the maximum-turbine scenario modelled (assuming a 98% behavioural avoidance rate) is, however, unlikely to be important in the context of Scottish & Orkney populations and natural mortality rates for this species.

Compared to shag, cormorants are considered more likely to be disturbed by vessel activity (Furness *et al.*, 2012), but likely construction and maintenance activities will be of sporadic frequency and limited extent, so adherence to guidelines associated with the SMWWC is expected to be sufficient to ensure such disturbance is not excessive. Any residual disturbance is unlikely to be problematic, particularly against the background of existing vessel activity in the area and ready availability of similar habitat nearby. Other potential impacts are similar to those for shag, but are equally unlikely to be important at the population level.

Appraisal conclusion for cormorants: Any potential impacts are not regarded as important at a Scottish population level, although monitoring of potential collision impacts is considered important. Adherence to the guidelines associated with the SMWWC should sufficiently limit residual disturbance impacts.

Black guillemots

Black guillemots were the second most frequently observed bird species at the Fall of Warness. The Scottish population is currently estimated at 37505 individuals with 5812 birds in Orkney. Overall black guillemot populations appear to be fairly stable since the seabird colony register counts of the 1960s (Mitchell *et al*. 2004).

Black guillemots do not nest in large colonies, but are likely to nest in a dispersed manner along most of the rocky coastal areas adjacent to the site. Black guillemots have been observed in notable numbers throughout the site, but densities also tend to be skewed to particular coastal survey grid-cells. Maximum-case collision modelling (with 98% behavioural avoidance) predicts 4.5 collisions per year. Monitoring of animal-device interactions has merit, but it is unlikely that these collision rates would be important in the context of Scottish & Orkney populations and natural mortality rates for this species.

Other impacts black guillemot may be exposed to include vessel-based disturbance, displacement from foraging habitat, loss of or alteration to foraging habitat and attraction to new artificial foraging habitat. In all cases, these impacts are unlikely to be important due to the availability of alternative space and foraging habitats, the background of existing vessel activity and the sporadic frequency and limited extent of likely construction and maintenance activities.

Appraisal conclusion for black guillemots: Any potential impacts are not regarded as important at a Scottish population level. Monitoring of potential collisions is considered to be important

4.9.7 Seabird receptor conclusions

A summary of the appraisal for each of the receptors is provided in Table 50 below. Note that, even where no important impacts on the development site are identified, in some cases there may still be a recommendation for some mitigation or monitoring. Under these circumstances, mitigation would be regarded as good-practice rather than a necessity, while monitoring may serve to improve generic understanding of the relationships between stressors and receptors.

Receptor	Conclusion	Mitigation and or monitoring identified?
Seaducks.	Seaducks (eider and long-tailed duck) are at risk from disturbance by vessel traffic and collision with turbine blades during foraging. Levels of disturbance registered on site surveys, and levels of predicted mortality against population estimates show that these impacts will not affect maintenance of local populations.	Installations should continue to be monitored to determine any behavioural changes – including attraction of ducks to structures – that might lead to increased risk of collision with blades. Vessel use should be monitored to determine level of activity. Where possible vessel use should follow SMWWC guidelines.
Divers.	The predicted collision rates for red-throated divers is relatively high given the size of the local breeding population. However given the behaviour of the	Installations should continue to be monitored to determine any behavioural changes such as

	species and the timing of the majority of recorded sightings it is not considered that in reality this will impact on the local breeding population of birds, and therefore will not be significant at a regional level.	avoidance of active turbines. Vessel use should be monitored to determine level of activity. Where possible vessel use should follow SMWWC guidelines.
Petrels.	The only important impact pathway considered was that of attraction to lighted above sea surface structures. The type of structures present, and potential use of the area by these species indicate that this will not cause significant impact.	Lighting of above surface structures should be designed to provide sufficient light for purpose, but avoid excessive bright lights. Flashing or coloured lights may decrease attraction and impact of any lighting.
Gannets.	Gannets could potentially dive to a sufficient depth to collide with turbine blades in operation. The low frequency of encounter predicted by the encounter rate models indicates that this will not be a significant risk to local populations.	None identified.
Cormorants & shags.	Shags and cormorants are present at high frequency in the Fall of Warness test area and could potentially be impacted by disturbance from feeding areas or collision with operating turbines. They could also be attracted to above surface structures. Of these impacts only collision with turbine blades was considered to be significant. The modelled level of mortality from the encounter rate model suggests that no significant impact on local population will result from this pressure.	Use of the site by cormorants and shags should be monitored to determine if behavioural changes may occur that would affect the predictions of the encounter rate model. Turbines should be ‘soft started’ to allow birds feeding close by more opportunity to escape.
Skuas.	No direct impact pathway – potential disturbance to prey species considered but not thought sufficient to be a significant impact on these species.	None identified.
Gulls & terns.	Disturbance was considered to be the most likely impact, but this was not predicted to occur at a level that would affect local populations of these species.	None identified.
Auks.	Auks (especially common guillemot and black guillemot) are present at high frequency in the Fall of Warness test area and potentially be impacted by disturbance from feeding areas or collision with operating turbines. Of these impacts only collision with turbine blades was considered to be significant. The modelled level of mortality from the encounter rate model suggests that no significant impact on local population will result from this pressure.	Use of the site by auk species should be monitored to determine if behavioural changes may occur that would affect the predictions of the encounter rate model. Turbines should be ‘soft started’ to allow birds feeding close by more opportunity to escape.

Table 50: Summary of assessment conclusions for seabirds.

Given the uncertainties regarding some potential impacts, the protected status of various species and the opportunity to learn from test deployments, some potential mitigation and monitoring measures are presented in Table 51 below. Some such measures will be appropriate as conditions on the Marine Licence, whereas others may just be recommended as good practice. Please see Section 5 for further details on the mitigation and monitoring highlighted below.

Site-wide monitoring and research ideas may be more effectively pursued at a strategic level (whether by EMEC, The Crown Estate or Marine Scotland, or by a developer consortium), but developer input or ideas are welcomed. This is discussed further in Section 5.

Potential Residual Impacts	**Relevant receptors**	**Relevant impact-pathway**	**Mitigation/Monitoring**
Uncertainty regarding avoidance rate of active turbines exhibited by birds.	All diving species (seaduck, red-throated diver, great cormorant, common guillemot, razorbill, Atlantic puffin, black guillemot, northern gannet).	Collision with turbines causing death or injury.	Photographic monitoring of operating turbines. Searches of nearby areas (determined by tidal flows) for seabird corpses.

Table 51: Potential mitigation and monitoring measures relevant to seabirds.

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4.10 Natura Appraisal: Special Protection Areas (Seabirds)

See Annex 2 for legislative background on Habitats Regulations Appraisal (HRA).

4.10.1 Site details

1(a) Name of Natura site affected & current status

1. The following appraisal is for breeding seabird SPA in relation to the site wide environmental appraisal of the EMEC Fall of Warness test site (see 2(g) below). The appraisal only considers impacts to breeding populations. Birds present within the test site in winter are likely to be different birds from the SPA breeding populations. The agencies and JNCC are currently assessing how to undertake assessments on non-breeding seabirds populations. However, as the majority of seabird species are wide-ranging during the winter, it is considered unlikely that the test site would have a significant effect on any breeding seabird SPA populations during the non-breeding season. This appraisal, therefore, considers potential impacts to breeding populations only.

2. The EMEC Falls of Warness test site is within an area that has been identified as part of a suite of 14 draft SPAs for marine birds. The North Orkney area has been identified as important under the Birds Directive for a range of marine bird species including several sea duck species, great northern diver, red-throated diver, Arctic tern and European shag, and consequently may be taken forward for public consultation as a marine Special Protection Area. More information on marine SPAs is available on our website (http://www.snh.gov.uk/protecting-scotlands-nature/protected-areas/international-designations/spa/marine-spas/). This draft marine SPA has not been appraised here, but may need further consideration in future revisions.

3. From our screening exercise (see Section 4.9), the following SPA were identified as requiring further appraisal based on foraging range, impact pathway and consideration of bird usage of the site using the EMEC Wildlife Observation data:

SPA Name	Current status
Calf of Eday SPA	Classified
Copinsay SPA	Classified
East Caithness Cliffs SPA	Classified
Fair Isle SPA	Classified
Hermaness, Saxa Vord and Valla Field SPA	Classified
Hoy SPA	Classified
Marwick Head SPA	Classified
North Caithness Cliffs SPA	Classified
North Rona and Sula Sgeir SPA	Classified
Noss SPA	Classified
Papa Westray (North Hill and Holm) SPA	Classified
Rousay SPA	Classified
Sule Skerry and Sule Stack SPA	Classified
West Westray SPA	Classified

1(b) Name of component SSSI if relevant

Copinsay SSSI	Component of Copinsay SPA
Berriedale Cliffs SSSI	Component of East Caithness Cliffs SPA
Duncansby Head Dunnet Head Stroma SSSI	Components of North Caithness Cliffs SPA
Rousay SSSI	Component of Rousay SPA
Marwick Head SSSI	Component of Marwick Head SPA
Sule Skerry SSSI	Component of Sule Skerry and Sule Stack SPA
West Westray SSSI	Component of West Westray SPA

1(c) European qualifying interest(s) & whether priority/non-priority:

Name of SPA	Qualifying interest	Comments
Calf of Eday	Seabird assemblage, breeding	See individual qualifiers
	Great cormorant, breeding	Requires further appraisal - See below
	Northern fulmar, breeding	No impact pathway – not carried forward
	Great black-backed gull, breeding	No impact pathway – not carried forward
	Common guillemot, breeding	Requires further appraisal - See below
	Black-legged kittiwake, breeding	No impact pathway – not carried forward
Copinsay SPA	Seabird assemblage, breeding	See individual qualifiers
	Northern fulmar, breeding	No impact pathway – not carried forward
	Great black-backed gull, breeding	No impact pathway – not carried forward
	Common guillemot, breeding	Requires further appraisal - See below
	Black-legged kittiwake, breeding	No impact pathway – not carried forward
East Caithness Cliffs SPA	Seabird assemblage, breeding	See individual qualifiers
	Great cormorant, breeding	Beyond max foraging range – not carried forward
	Northern fulmar, breeding	No impact pathway – not carried forward
	Great black-backed gull, breeding	Low connectivity – not carried forward as availability of alternative habitat means the Fall of Warness is unlikely to be of importance in terms of foraging.
	Common guillemot, breeding	Requires further appraisal - See below
	Herring gull, breeding	Low connectivity – not carried forward as availability of alternative habitat means the Fall of Warness is unlikely to be of importance in terms of foraging.
	Black-legged kittiwake, breeding	Low connectivity – not carried forward as availability of alternative habitat means the Fall of Warness is unlikely to be of importance in terms of foraging.
	Peregrine falcon, breeding	No impact pathway – not carried forward
	Atlantic puffin, breeding	Requires further assessment - See below
	Razorbill, breeding	Low connectivity – not carried forward as availability of alternative habitat means the Fall of Warness is unlikely to be of importance in terms of foraging.
	Shag, breeding	Beyond max foraging range – not carried forward

Fair Isle SPA	Seabird assemblage, breeding	See individual qualifiers
	Arctic skua, breeding	Low connectivity – not carried forward as availability of alternative habitat means the Fall of Warness is unlikely to be of importance in terms of foraging.
	Arctic tern, breeding	Low connectivity – not carried forward as availability of alternative habitat means the Fall of Warness is unlikely to be of importance in terms of foraging.
	Fair Isle wren, breeding	No impact pathway – not carried forward
	Northern fulmar, breeding	No impact pathway – not carried forward
	Northern gannet, breeding	Requires further assessment - See below
	Great skua, breeding	Requires further assessment - See below
	Common guillemot, breeding	Requires further assessment - See below
	Black-legged kittiwake, breeding	No impact pathway – not carried forward
	Atlantic puffin, breeding	Requires further assessment - See below
	Razorbill, breeding	Low connectivity – not carried forward as availability of alternative habitat means the Fall of Warness is unlikely to be of importance in terms of foraging.
	European shag, breeding	Beyond max foraging range – not carried forward
Hermaness, Saxa Vord and Valla Field SPA	Seabird assemblage, breeding	See individual qualifiers
	Northern fulmar, breeding	No impact pathway – not carried forward
	Northern gannet, breeding	Requires further assessment - See below
	Great skua, breeding	Low connectivity – not carried forward as availability of alternative habitat means the Fall of Warness is unlikely to be of importance in terms of foraging.
	Common guillemot, breeding	Beyond max foraging range – not carried forward
	Black-legged kittiwake, breeding	No impact pathway – not carried forward
	Atlantic puffin, breeding	Beyond max foraging range – not carried forward
	Red-throated diver, breeding	Beyond max foraging range – not carried forward
	European shag, breeding	Beyond max foraging range – not carried forward
Hoy SPA	Seabird assemblage, breeding	See individual qualifiers
	Arctic skua, breeding	Requires further assessment - See below
	Northern fulmar, breeding	No impact pathway – not carried forward
	Great skua, breeding	Requires further assessment - See below
	Great black-backed gull, breeding	No impact pathway – not carried forward
	Common guillemot,	Requires further assessment - See below

	breeding	
	Black-legged kittiwake, breeding	No impact pathway – not carried forward
	Peregrine falcon, breeding	No impact pathway – not carried forward
	Atlantic puffin, breeding	Requires further assessment - See below
	Red-throated diver, breeding	Low connectivity – not carried forward as availability of alternative habitat means the Fall of Warness is unlikely to be of importance in terms of foraging.
Marwick Head SPA	Seabird assemblage, breeding	See individual qualifiers
	Common guillemot, breeding	Requires further assessment - See below
	Black-legged kittiwake, breeding	No impact pathway – not carried forward
North Caithness Cliffs SPA	Seabird assemblage, breeding	See individual qualifiers
	Northern fulmar, breeding	No impact pathway – not carried forward
	Common guillemot, breeding	Requires further assessment - See below
	Black-legged kittiwake, breeding	No impact pathway – not carried forward
	Peregrine falcon, breeding	No impact pathway – not carried forward
	Atlantic puffin, breeding	Requires further assessment - See below
	Razorbill, breeding	Requires further assessment - See below
North Rona and Sula Sgeir SPA	Seabird assemblage, breeding	See individual qualifiers
	Northern fulmar, breeding	No impact pathway – not carried forward
	Northern gannet, breeding	Requires further assessment - See below
	Great black-backed gull, breeding	No impact pathway – not carried forward
	Common guillemot, breeding	Low connectivity – not carried forward as availability of alternative habitat means the Fall of Warness is unlikely to be of importance in terms of foraging.
	Black-legged kittiwake, breeding	No impact pathway – not carried forward
	Leach's storm-petrel, breeding	No impact pathway – not carried forward
	Atlantic puffin, breeding	Low connectivity – not carried forward as availability of alternative habitat means the Fall of Warness is unlikely to be of importance in terms of foraging.
	Razorbill, breeding	Beyond max foraging range – not carried forward
	European storm petrel, breeding	No impact pathway – not carried forward
Noss SPA	Seabird assemblage, breeding	See individual qualifiers
	Northern fulmar, breeding	No impact pathway – not carried forward

	Northern gannet, breeding	Requires further assessment - See below
	Great skua, breeding	Low connectivity – not carried forward as availability of alternative habitat means the Fall of Warness is unlikely to be of importance in terms of foraging.
	Common guillemot, breeding	Low connectivity – not carried forward as availability of alternative habitat means the Fall of Warness is unlikely to be of importance in terms of foraging.
	Black-legged kittiwake, breeding	No impact pathway – not carried forward
	Atlantic puffin, breeding	Low connectivity – not carried forward as availability of alternative habitat means the Fall of Warness is unlikely to be of importance in terms of foraging.
Papa Westray (North Hill & Holm) SPA	Arctic tern, breeding	No impact pathway – not carried forward
	Arctic skua, breeding	Requires further assessment - See below
Rousay SPA	Seabird assemblage, breeding	See individual qualifiers
	Arctic skua, breeding	Requires further assessment - See below
	Arctic tern, breeding	No impact pathway – not carried forward
	Northern fulmar, breeding	No impact pathway – not carried forward
	Common guillemot, breeding	Requires further assessment - See below
	Black-legged kittiwake, breeding	No impact pathway – not carried forward
Sule Skerry and Sule Stack SPA	Seabird assemblage, breeding	See individual qualifiers
	Northern gannet, breeding	Requires further assessment - See below
	Common guillemot, breeding	Requires further assessment - See below
	Leach's storm-petrel, breeding	No impact pathway – not carried forward
	Atlantic puffin, breeding	Requires further assessment - See below
	European shag, breeding	Beyond max foraging range – not carried forward
	European storm petrel, breeding	No impact pathway – not carried forward
West Westray SPA	Seabird assemblage, breeding	See individual qualifiers
	Arctic skua, breeding	Requires further assessment - See below
	Arctic tern, breeding	No impact pathway – not carried forward
	Northern fulmar, breeding	No impact pathway – not carried forward
	Common guillemot, breeding	Requires further assessment - See below
	Black-legged kittiwake, breeding	No impact pathway – not carried forward
	Razorbill, breeding	Requires further assessment - See below

1(d) Conservation objectives for qualifying interests

The conservation objectives for all SPA outlined in section 4.10.1c. above are: To avoid deterioration of the habitats of the qualifying species (listed above) or significant disturbance to the qualifying species, thus ensuring that the integrity of the site is maintained; and To ensure for the qualifying species that the following are maintained in the long term: • Population of the species as a viable component of the site • Distribution of the species within site • Distribution and extent of habitats supporting the species • Structure, function and supporting processes of habitats supporting the species • No significant disturbance of the species

4.10.2 Proposal details

2(a) Proposal title:	Fall of Warness Test site – Environmental Appraisal
2(b) Date consultation sent:	N/A
2(c) Date consultation received	N/A
2(d) Name of consultee	SNH
2(e) Name of competent authority	Marine Scotland

2(f) Details of proposed operation

This appraisal is being carried out in response to the redevelopment of the environmental documentation used by developers at EMEC in order to assist in streamlining the appraisal process required to inform the Marine Licence/Section 36 consenting process for deployments at the existing test site at the Fall of Warness. For further details please see the introduction (Section 1) and the project envelope description (Annex 1) which will explain the parameters included within this appraisal. The test site at the Fall of Warness has been in existence since 2005. There are currently (as of July 2014) 7+1 berths, all assigned to different developers, some of who hold a Marine Licence for their projects. The project envelope description describes the maximum parameters used in this appraisal.

4.10.3 Appraisal in relation to Regulation 48

3(a) Is the operation directly connected with or necessary to conservation management of the site? YES/NO

No

3(b) Is the operation likely to have a significant effect on the qualifying interest? Consider each qualifying interest in relation to the conservation objectives.

Calf of Eday SPA – Great cormorant – Favourable Maintained – Yes
Calf of Eday SPA is 6 km away from the test site and holds 3% of the GB population of breeding great cormorants. The test site is within the mean foraging range of this species. Many cormorants remain close to their breeding areas outside of the breeding season, although move further south (Wernham *et al*., 2002). The highest cormorant encounter rates at the Fall of Warness were in August and September (Robbins, 2011). Great cormorants are also considered to be of high vulnerability to tidal turbine impacts (Furness *et al*., 2012). Therefore there is potential for the test site to have a likely significant effect on great cormorant from this SPA. This qualifying feature is in favourable maintained condition.

Calf of Eday SPA – Common guillemot – Unfavourable No change – Yes
Calf of Eday SPA is 6 km away from the test site and holds 1% of the GB population of breeding guillemot. The test site is within the mean foraging range of this species. The highest encounter rate for common guillemot was in May and June (Robbins, 2011). Common guillemots are considered to be of high vulnerability to tidal turbine impacts (Furness *et al*., 2012). Therefore there is potential for the test site to have a likely significant effect on common guillemot from this SPA. This qualifying feature is in unfavourable condition.

Calf of Eday SPA – Seabird Assemblage – Unfavourable Declining – Yes
The seabird assemblage of the SPA held 30,000 breeding seabirds at the time of classification. The major representatives are common guillemot, northern fulmar and black-legged kittiwake. As there is a potential for the test site to have a significant impact on the common guillemot it follows that there is also the potential to have a significant impact on the seabird assemblage. Due to declines in guillemot and kittiwake populations especially this feature is in unfavourable condition.

Copinsay SPA – Common guillemot – Unfavourable Declining – Yes
Copinsay SPA is 24km away from the test site and holds 3% of the GB population of breeding guillemot. The test site is within the mean foraging range of this species. The highest encounter rate for common guillemot was in May and June (Robbins, 2011). Common guillemots are considered to be of high vulnerability to tidal turbine impacts (Furness *et al*., 2012). Therefore there is potential for the test site to have a likely significant effect on common guillemot from this SPA. This qualifying feature is in unfavourable declining condition.

Copinsay SPA – Seabird Assemblage – Unfavourable No Change – Yes
The seabird assemblage of the SPA held 70,000 breeding seabirds at the time of classification. The major representatives are common guillemot, fulmar and kittiwake. As there is a potential for the test site to have a significant impact on the common guillemot it follows that there is also the potential to have a significant impact on the seabird assemblage. Due to recent declines in common guillemot and black-legged kittiwake populations especially this feature is in unfavourable condition.

East Caithness Cliffs SPA – Common guillemot – Favourable Maintained – Yes
East Caithness Cliffs SPA is 80km away from the test site and holds 3.2% of the East Atlantic population of breeding common guillemot. The test site is within the mean-max foraging range of this species. The highest encounter rate for common guillemot was in May and June (Robbins, 2011). Common guillemots are considered to be of high vulnerability to tidal turbine impacts (Furness *et al*. 2012). Therefore there is potential for the test site to have a likely significant effect on Common guillemot from this SPA. This qualifying feature is in favourable maintained condition.

East Caithness Cliffs SPA – Atlantic puffin – Favourable Maintained – Yes
East Caithness Cliffs SPA is 80km away and holds 1750 pairs of breeding puffin. The test site is within the mean-max foraging range of this species. Atlantic puffins encounter rate increased from March and peak in June (Robbins, 2011). They are considered to be of moderate vulnerability to tidal turbine impacts (Furness *et al*., 2012). Therefore there is potential for the test site to have a likely significant effect on Atlantic puffin from this SPA. This qualifying feature is in favourable condition.

East Caithness Cliffs SPA – Seabird Assemblage – Favourable maintained – Yes
The seabird assemblage of the SPA held 300,000 breeding seabirds at the time of classification. The major representatives are common guillemot, Atlantic puffin, razorbill, northern fulmar and black-legged kittiwake. As there is a potential for the test site to have a significant impact on the common guillemot and Atlantic puffin it follows that there is also the potential to have a significant impact on the seabird assemblage. Despite some recent declines in common guillemot and black-legged kittiwake populations this feature is in favourable condition.

Fair Isle SPA – Northern gannet – Favourable Maintained – Yes
Fair Isle SPA is 74km away from the test site and holds 0.6% of the GB population of breeding gannet. The test site is within the mean foraging range of this species. Northern gannet encounter rate increased from July and peak in October (Robbins, 2011). They are considered to be of low vulnerability to tidal turbine impacts (Furness *et al*., 2012) however this study does not consider site-specific impacts and is based on knowledge of seabird ecology and interactions with other activities and industries, not on deployed tidal and wave energy devices. Therefore there is potential for the test site to have a likely significant effect on northern gannet from this SPA. This qualifying feature is in favourable maintained condition.

Fair Isle SPA – Common guillemot – Favourable Maintained – Yes
Fair Isle SPA is 74km away from the test site and holds 3% of the GB population of breeding common guillemot. The test site is within the mean-max foraging range of this species. The highest encounter rate for common guillemot was in May and June (Robbins, 2011). Common guillemots are considered to be of high vulnerability to tidal turbine impacts (Furness *et al*., 2012). Therefore there is potential for the test site to have a likely significant effect on common guillemot from this SPA. This qualifying feature is in favourable maintained condition.

Fair Isle SPA – Great skua – Favourable Maintained – Yes
Fair Isle SPA is 74km away from the test site and holds 1% of the GB population of breeding great skuas. The test site is within the mean-max foraging range of this species. Great skua has not been recorded in the EMEC wildlife observations as the surveys concentrate on diving species only. Furness *et al*. (2012) considered this species to be of very low vulnerability to tidal turbine impacts however this study does not consider site-specific impacts and is based on knowledge of seabird ecology and interactions with other activities and industries, not on deployed tidal and wave energy devices. Given the lack of information on site-specific usage of the Fall of Warness by this species, we consider as a precaution, there is potential for the test site to have a likely significant effect on great skua from this SPA. This qualifying feature is in favourable condition.

Fair Isle SPA – Atlantic puffin – Unfavourable Declining – Yes
Fair Isle SPA is 74km away from the test site and holds 2% of the GB population of breeding Atlantic puffin. The test site is within the mean-max foraging range of this species. The encounter rate increased from March and peak in June (Robbins, 2011). They are considered to be of moderate vulnerability to tidal turbine impacts (Furness *et al*., 2012). Therefore there is potential for the test site to have a likely significant effect on Atlantic puffin from this SPA. This qualifying feature is in unfavourable declining condition.

Fair Isle SPA – Seabird Assemblage – Favourable maintained – Yes
The seabird assemblage of the SPA held 180,000 breeding seabirds at the time of classification. The major representatives are northern fulmar, Atlantic puffin, common guillemot, black-legged kittiwake and northern gannet. As there is a potential for the test site to have a significant impact on the northern gannet, common guillemot, Atlantic puffin and great skua it follows that there is

also the potential to have a significant impact on the seabird assemblage. This feature is in favourable condition.

Hermaness, Saxa Vord and Valla Field SPA – Northern gannet – Favourable Maintained– Yes
Hermaness, Saxa Vord and Valla Field SPA is 209km away from the test site and holds 4.6% of the North Atlantic population of breeding northern gannet. The test site is within the mean-max foraging range of this species. Northern gannet encounter rate increased from July and peak in October (Robbins, 2011). They are considered to be of low vulnerability to tidal turbine impacts (Furness *et al*., 2012) however this study does not consider site-specific impacts and is based on knowledge of seabird ecology and interactions with other activities and industries, not on deployed tidal and wave energy devices. Therefore there is potential for the test site to have a likely significant effect on Northern gannet from this SPA. This qualifying feature is in favourable maintained condition.

Hermaness Saxa Vord and Valla Field SPA – Seabird Assemblage – Favourable maintained – Yes
The seabird assemblage of the SPA held 157,500 breeding seabirds at the time of classification. The major representatives are Atlantic puffin, northern gannet, common guillemot and northern fulmar. As there is a potential for the test site to have a significant impact on gannet it follows that there is also the potential to have a significant impact on the seabird assemblage. This feature is in favourable condition.

Hoy SPA – Arctic skua – Unfavourable Declining – Yes
Hoy SPA is 35km away from the test site and holds 2% of the GB population of breeding Arctic skua. The test site is within the mean-max foraging range of this species. Arctic skua has not been recorded in the EMEC wildlife observations as the surveys concentrate on diving species only. Furness *et al*. (2012) considered this species to be of very low vulnerability to tidal turbine impacts however this study does not consider site-specific impacts and is based on knowledge of seabird ecology and interactions with other activities and industries, not on deployed tidal and wave energy devices. Given the lack of information on site-specific usage of the Fall of Warness by this species, we consider as a precaution, there is potential for the test site to have a likely significant effect on Arctic skua from this SPA. This qualifying feature is in unfavourable condition.

Hoy SPA – Great skua – Favourable Maintained – Yes
Hoy SPA is 35km away from the test site and holds 14% of the world biogeographic population of breeding Great skuas. The test site is within the mean foraging range of this species. Great skua has not been recorded in the EMEC wildlife observations as the surveys concentrate on diving species only. Furness *et al*. (2012) considered this species to be of very low vulnerability to tidal turbine impacts however this study does not consider site-specific impacts and is based on knowledge of seabird ecology and interactions with other activities and industries, not on deployed tidal and wave energy devices. Given the lack of information on site-specific usage of the Fall of Warness by this species, we consider as a precaution, there is potential for the test site to have a likely significant effect on great skua from this SPA. This qualifying feature is in favourable condition.

Hoy SPA – Common guillemot – Unfavourable Declining – Yes
Hoy SPA is 35km away from the test site and holds 2% of the GB population of breeding common guillemot. The test site is within the mean foraging range of this species. The highest encounter rate for common guillemot was in May and June (Robbins, 2011). Common guillemots are considered to be of high vulnerability to tidal turbine impacts (Furness *et al*., 2012). Therefore there is potential for the test site to have a likely significant effect on common guillemot from this SPA. This qualifying feature is in unfavourable declining condition.

Hoy SPA – Atlantic puffin – Unfavourable Declining – Yes
Hoy SPA is 35km away from the test site and holds 0.7% of the GB population of breeding puffin. The test site is within the mean-max foraging range of this species. The encounter rate increased from March and peak in June (Robbins, 2011). They are considered to be of moderate

vulnerability to tidal turbine impacts (Furness *et al*., 2012). Therefore there is potential for the test site to have a likely significant effect on Atlantic puffin from this SPA. This qualifying feature is in unfavourable declining condition.

Hoy SPA – Seabird Assemblage – Favourable maintained – Yes
The seabird assemblage of the SPA held 120,000 breeding seabirds at the time of classification. The major representatives are northern fulmar, common guillemot, Atlantic puffin and black-legged kittiwake. As there is a potential for the test site to have a significant impact on common guillemot and Atlantic puffin it follows that there is also the potential to have a significant impact on the seabird assemblage. This feature is in favourable condition.

Marwick Head SPA – Common guillemot – Favourable Maintained – Yes
Marwick Head SPA is 30km away from the test site and holds 1.1% of the East Atlantic population of breeding common guillemot. The test site is within the mean foraging range of this species. The highest encounter rate for common guillemot was in May and June (Robbins, 2011). Common guillemots are considered to be of high vulnerability to tidal turbine impacts (Furness *et al*., 2012). Therefore there is potential for the test site to have a likely significant effect on common guillemot from this SPA. This qualifying feature is in favourable maintained condition.

Marwick Head SPA – Seabird Assemblage – Unfavourable declining – Yes
The seabird assemblage of the SPA held 120,000 breeding seabirds at the time of classification. The major representatives are common guillemot and black-legged kittiwake. As there is a potential for the test site to have a significant impact on common guillemot it follows that there is also the potential to have a significant impact on the seabird assemblage. This feature is in unfavourable condition.

North Caithness Cliffs SPA – Common guillemot – Favourable Maintained – Yes
North Caithness Cliffs SPA is 53km away from the test site and holds 1.2% of the East Atlantic population of breeding guillemot. The test site is within the mean-max foraging range of this species. The highest encounter rate for common guillemot was in May and June (Robbins, 2011). Common guillemots are considered to be of high vulnerability to tidal turbine impacts (Furness *et al*. 2012). Therefore there is potential for the test site to have a likely significant effect on common guillemot from this SPA. This qualifying feature is in favourable maintained condition.

North Caithness Cliffs SPA – Atlantic puffin – Favourable Maintained – Yes
North Caithness Cliffs SPA is 53km away from the test site and holds 1750 pairs of breeding Atlantic puffin. The test site is within the mean-max foraging range of this species. Atlantic puffins encounter rate increased from March and peak in June (Robbins, 2011). They are considered to be of moderate vulnerability to tidal turbine impacts (Furness *et al*., 2012). Therefore there is potential for the test site to have a likely significant effect on Atlantic puffin from this SPA. This qualifying feature is in favourable maintained condition.

North Caithness Cliffs SPA – Razorbill – Unfavourable Declining – Yes
North Caithness Cliffs SPA is 53km away from the test site and holds 3% of the GB population of breeding razorbill. The test site is within the mean-max (plus 10%) foraging range of this species. Razorbill encounter rates peaked in April and decreased throughout the breeding season (Robbins, 2011). Razorbills are considered to be of high vulnerability to tidal turbine impacts (Furness *et al*., 2012). Therefore there is potential for the test site to have a likely significant effect on razorbills from this SPA. This qualifying feature is in Unfavourable declining.

North Caithness Cliffs SPA – Seabird Assemblage – Favourable maintained – Yes
The seabird assemblage of the SPA held 110,000 breeding seabirds at the time of classification. The major representatives are common guillemot, northern fulmar and black-legged kittiwake. As there is a potential for the test site to have a significant impact on common guillemot it follows that there is also the potential to have a significant impact on the seabird assemblage. This feature is in favourable condition.

North Rona and Sula Sgeir SPA – Northern gannet – Unfavourable No change – Yes
North Rona and Sula Sgeir SPA is 163km away from the test site and holds 3.4% of the North Atlantic population of breeding northern gannet. The test site is within the mean-max foraging range of this species. Northern gannet encounter rate increased from July and peak in October (Robbins, 2011). They are considered to be of low vulnerability to tidal turbine impacts (Furness *et al*., 2012) however this study does not consider site-specific impacts and is based on knowledge of seabird ecology and interactions with other activities and industries, not on deployed tidal and wave energy devices. Therefore there is potential for the test site to have a likely significant effect on Northern gannet from this SPA. This qualifying feature is in unfavourable condition.

North Rona and Sula Sgeir SPA – Seabird Assemblage – Favourable maintained – Yes
The seabird assemblage of the SPA held 130,000 breeding seabirds at the time of classification. The major representatives are common guillemot, northern gannet and northern fulmar. As there is a potential for the test site to have a significant impact on northern gannet it follows that there is also the potential to have a significant impact on the seabird assemblage. This feature is in favourable condition.

Noss SPA – Northern gannet – Favourable Maintained – Yes
Noss SPA is 146km away from the test site and holds 2.8% of the North Atlantic population of breeding northern gannet. The test site is within the mean-max foraging range of this species. Northern gannet encounter rate increased from July and peak in October (Robbins, 2011). They are considered to be of low vulnerability to tidal turbine impacts (Furness *et al*., 2012) however this study does not consider site-specific impacts and is based on knowledge of seabird ecology and interactions with other activities and industries, not on deployed tidal and wave energy devices. Therefore there is potential for the test site to have a likely significant effect on Northern gannet from this SPA. This qualifying feature is in favourable maintained condition.

Noss SPA – Seabird Assemblage – Favourable maintained – Yes
The seabird assemblage of the SPA held 35,000 breeding seabirds at the time of classification. The major representatives are common guillemot, northern gannet and northern fulmar. As there is a potential for the test site to have a significant impact on northern gannet it follows that there is also the potential to have a significant impact on the seabird assemblage. This feature is in favourable condition.

Papa Westray (North Hill & Holm) SPA – Arctic skua – Unfavourable Declining– Yes
Papa Westray (North Hill & Holm) SPA is 20km away from the test site and holds 0.4% of the North Atlantic population of breeding Arctic skua. The test site is within the mean foraging range of this species. Arctic skua has not been recorded in the EMEC wildlife observations as the surveys concentrate on diving species only. Furness *et al*. (2012) considered this species to be of very low vulnerability to tidal turbine impacts however this study does not consider site-specific impacts and is based on knowledge of seabird ecology and interactions with other activities and industries, not on deployed tidal and wave energy devices. Given the lack of information on site-specific usage of the Fall of Warness by this species, we consider as a precaution, there is potential for the test site to have a likely significant effect on Arctic skua from this SPA. This qualifying feature is in Unfavourable declining condition.

Rousay SPA – Arctic skua – Unfavourable Declining - Yes
Rousay SPA is 16km away from the test site and holds 4% of the GB population of breeding Arctic skuas. The test site is within the mean foraging range of this species. Arctic skua has not been recorded in the EMEC wildlife observations as the surveys concentrate on diving species only. Furness *et al*. (2012) considered this species to be of very low vulnerability to tidal turbine impacts however this study does not consider site-specific impacts and is based on knowledge of seabird ecology and interactions with other activities and industries, not on deployed tidal and wave energy devices. Given the lack of information on site-specific usage of the Fall of Warness by this species, we consider as a precaution, there is potential for the test site to have a likely significant effect on Arctic skua from this SPA. This qualifying feature is in unfavourable condition.

Rousay SPA – Common guillemot – Favourable Recovered - Yes
Rousay SPA is 16km away from the test site and holds 1% of the GB population of breeding guillemot. The test site is within the mean foraging range of this species. The highest encounter rate for common guillemot was in May and June (Robbins, 2011). Common guillemots are considered to be of high vulnerability to tidal turbine impacts (Furness *et al*., 2012). Therefore there is potential for the test site to have a likely significant effect on common guillemot from this SPA. This qualifying feature is in favourable recovered condition.

Rousay SPA – Seabird Assemblage – Unfavourable declining – Yes
The seabird assemblage of the SPA held 30,000 breeding seabirds at the time of classification. The major representatives are common guillemot and black-legged kittiwake. As there is a potential for the test site to have a significant impact on common guillemot it follows that there is also the potential to have a significant impact on the seabird assemblage. As black-legged kittiwake populations have been in decline recently this feature is in unfavourable declining condition.

Sule Skerry and Sule Stack SPA – Northern gannet – Favourable Maintained – Yes
Sule Skerry and Sule Stack SPA is 88km away from the test site and holds 1.9% of the North Atlantic population of breeding northern gannet. The test site is within the mean foraging range of this species. Northern gannet encounter rate increased from July and peak in October (Robbins, 2011). They are considered to be of low vulnerability to tidal turbine impacts (Furness *et al*., 2012) however this study does not consider site-specific impacts and is based on knowledge of seabird ecology and interactions with other activities and industries, not on deployed tidal and wave energy devices. Therefore there is potential for the test site to have a likely significant effect on Northern gannet from this SPA. This qualifying feature is in favourable maintained condition.

Sule Skerry and Sule Stack SPA – Common guillemot – Favourable Maintained – Yes
Sule Skerry and Sule Stack SPA is 88km away from the test site and holds 0.9% of the GB population of breeding common guillemot. The test site is within the mean-max (plus 10%) foraging range of this species. The highest encounter rate for common guillemot was in May and June (Robbins, 2011). Common guillemots are considered to be of high vulnerability to tidal turbine impacts (Furness *et al*., 2012). Therefore there is potential for the test site to have a likely significant effect on common guillemot from this SPA. This qualifying feature is in favourable maintained condition.

Sule Skerry and Sule Stack SPA – Atlantic puffin – Favourable Maintained – Yes
Sule Skerry and Sule Stack SPA is 88km away from the test site and holds 10.4% of the GB population of breeding Atlantic puffin. The test site is within the mean-max foraging range of this species. Atlantic puffins encounter rate increased from March and peak in June (Robbins, 2011). They are considered to be of moderate vulnerability to tidal turbine impacts (Furness *et al*., 2012). Therefore there is potential for the test site to have a likely significant effect on Atlantic puffin from this SPA. This qualifying feature is in favourable maintained condition.

Sule Skerry and Sule Stack SPA – Seabird Assemblage – Favourable Maintained – Yes
The seabird assemblage of the SPA held 100,000 breeding seabirds at the time of classification. The major representatives are puffin, guillemot, gannet and fulmar. As there is a potential for the test site to have a significant impact on common guillemot, northern gannet and Atlantic puffin it follows that there is also the potential to have a significant impact on the seabird assemblage. This feature is in favourable maintained condition.

West Westray – Common guillemot – Favourable Maintained – Yes
West Westray SPA is 15km away from the test site and holds 1.3% of the East Atlantic population of breeding guillemot. The test site is within the mean foraging range of this species. The highest encounter rate for common guillemot was in May and June (Robbins, 2011). Common guillemots are considered to be of high vulnerability to tidal turbine impacts (Furness *et al*., 2012). Therefore there is potential for the test site to have a likely significant effect on common guillemot from this SPA. This qualifying feature is in favourable maintained condition.

West Westray – Razorbill – Favourable Maintained – Yes
West Westray SPA is 15km away from the test site and holds 1% of the GB population of breeding razorbill. The test site is within the mean foraging range of this species. Razorbill encounter rates peaked in April and decreased throughout the breeding season (Robbins, 2011). Razorbills are considered to be of high vulnerability to tidal turbine impacts (Furness *et al*., 2012). Therefore there is potential for the test site to have a likely significant effect on razorbills from this SPA. This qualifying feature is in favourable maintained condition.

West Westray – Arctic skua – Unfavourable Declining – Yes
West Westray SPA is 15km away from the test site and holds 2% of the GB population of breeding Arctic skua. The test site is within the mean foraging range of this species. Arctic skua has not been recorded in the EMEC wildlife observations as the surveys concentrate on diving species only. Furness *et al*. (2012) considered this species to be of very low vulnerability to tidal turbine impacts however this study does not consider site-specific impacts and is based on knowledge of seabird ecology and interactions with other activities and industries, not on deployed tidal and wave energy devices. Given the lack of information on site-specific usage of the Fall of Warness by this species, we consider as a precaution, there is potential for the test site to have a likely significant effect on Arctic skua from this SPA. This qualifying feature is in unfavourable condition.

West Westray SPA – Seabird Assemblage – Unfavourable declining – Yes
The seabird assemblage of the SPA held 113,000 breeding seabirds at the time of classification. The major representatives are common guillemot and black-guillemot kittiwake. As there is a potential for the test site to have a significant impact on common guillemot and razorbill it follows that there is also the potential to have a significant impact on the seabird assemblage. This feature is in unfavourable condition.

Summary of potential impacts pathways from the installation, operation and maintenance of tidal turbines at the Fall of Warness Test site:

The table below provides as summary of the potential impact pathways identified for each species according to those activities likely to occur through the installation, operation and maintenance of tidal turbines at the Fall of Warness test site. Please refer to Table 43 and Table 44 in Section 4.9 for further commentary on these impact pathways. The following section appraises each impact in turn.

Marine Works Phase / Impact pathway	Installation	Operation or maintenance
Installation and maintenance vessel(s) transits, manoeuvring and activity (includes noise) leading to disturbance*	Northern gannet Great cormorant Common guillemot Razorbill Atlantic puffin Arctic Skua Great Skua	See left
Loss of/alteration to foraging habitat (includes indirect effects)	Great cormorant Common guillemot Razorbill Atlantic puffin Arctic skua Great skua	See left
Collision with turbine blades leading to: injury or death	Not applicable to installation – see operation or maintenance column	Northern gannet Great cormorant Common guillemot Razorbill Atlantic puffin
Presence of tidal device and		Northern gannet

associated infrastructure leading to displacement (including underwater noise from operational turbines)	Not applicable to installation – see operation or maintenance column	Great cormorant Common guillemot Razorbill Atlantic puffin Arctic skua Great skua
Presence of tidal device infrastructure leading to attraction, specifically roosting/resting opportunities	Not applicable to installation – see operation or maintenance column	Great cormorant Common guillemot Razorbill Atlantic puffin
Presence of below surface artificial lighting leading to attraction and potentially collision with turbine blades	Not applicable to installation – see operation or maintenance column	Northern gannet Great cormorant Common guillemot Razorbill Atlantic puffin

* The term 'disturbance' includes all behavioural responses of biological consequence, including displacement from the vicinity of the activity.

Note that decommissioning will be dealt with separately on a case-by-case basis and is not dealt with as part of this appraisal process.

3(c) Appraisal of the implications for the site in view of the site's conservation objectives

Overview of existing information

EMEC wildlife observations analysis (Robbins, 2011)
Wildlife observations are carried out on a four-hour watch system 5 days a week from a vantage point 50m above sea level. Data has been collected since July 2005. The survey area is defined by grids approximately 500m x 500m across the whole of the test site. This analysis has not been corrected using *Distance* software or detectability; SNH are currently funding further analysis to account for this. All data collected to date, once corrected, will be re-analysed under the same contract.

Appraisal of impacts

IMPACTS FROM INSTALLATION, OPERATION & MAINTENANCE ACTIVITIES
Methods used to install foundations at the FoW include non-percussive drilling to insert a monopile (e.g. Voith) or twin pile foundation (e.g. Open Hydro), use of pin piles (e.g. TGL) as well as lowering of gravity based foundations (e.g. Atlantis, Hammerfest Strom, Open Hydro) but does not include pile-driving. It also includes the use of gravity anchors with mooring system (e.g. Scotrenewables) or pin-piled anchors. Please see Annex 1 for a summary of likely marine works associated with installation, operation and maintenance activities.

Impact pathway:	**Installation and maintenance vessel (s) transits, manoeuvring and activity (including noise) leading to disturbance**

Vessel use information
Analysis of vessels usage within 5NM of the tidal site undertaken for the Navigation Risk Assessment, revealed an average of 7 vessels per day in the summer (2009) and 4-5 in the winter (2010) (Anatec Ltd, 2010). The vast majority of vessels that passed within 5NM the lease area were inter-island ferries. Of those vessels transiting through the Fall of Warness the inter-islands ferries used this route 8 times during a 6 week winter survey period trying to reduce vessel motion in prevailing wave and tidal conditions. The route was used 23 times during a 12 week summer/winter study period by vessels transiting between the Westray Firth and Stronsay Firth; these comprised large passenger, tugs supply, military, fishing and fisheries patrol vessels.

Analysis of creeling activity at the Fall of Warness during 2006 – 2009, revealed approx 3 hours of creeling activity per 20 hour of watch keeping per week. The majority of creelers were observed to be operating in Sealskerry Bay on the west coast of Eday with a minority close to the east coast of the Muckle Green Holm.

A variety of types and sizes of vessels are used at the Fall of Warness by developers depending on the activity being undertaken and the availability of vessels at that time. The project envelope description (Annex 1) provides an outline of typical activities, likely vessels and simultaneous marine works scenarios that have been considered.

Wildlife Observations and vessel presence

Robbins (2011) found that the presence of boats at the Fall of Warness between 2005 and 2009 did not affect the bird encounter rate such that the hourly encounter rate for birds (for all species) was not significantly related to the number of boats recorded per day. It must be noted however, that the amount of developer activity at the test site has increased since this period, and the report did not analyse whether there was any spatial overlap between boat activity and bird distribution or consider species separately.

The response of seabirds to boat traffic is considered to vary between species, with the magnitude of the bird's response typically increasing with boat velocity and distance offshore at least for some species (Ronconi and St Clair 2002). Langton *et al*. (2011) suggested that it was possible some species may habituate to regular predictable stimuli better than unpredictable irregular ones and the magnitude of behavioural change may decrease over time (Schwemmer *et al*, 2011).

Species specific commentary

Northern gannet	**Fair Isle SPA**
	Hermaness, Saxa Vord and Valla Field SPA
	North Rona and Sula Sgeir SPA
	Noss SPA
	Sule Skerry and Sule Stack SPA

Gannets are considered to be fairly unresponsive to boat traffic (Garthe and Hüppop, 2004) and are know to aggregate around fishing vessels, however a decrease in numbers has been observed during the construction phase of some offshore wind farms such as Robin Rigg (Canning *et al*., 2012).

Great cormorant	**Calf of Eday**

Cormorants are considered to have moderate flush distances by boats (Furness *et al.* 2012; Garthe and Hüppop 2004; Rodgers and Schwikert 2003). However, increased cormorant numbers have been observed during the construction and operational phases of offshore wind farms such as Robin Rigg (Canning *et al*. 2012) suggesting disturbance from this source is not an issue.

Common guillemot	**Calf of Eday SPA**
	Copinsay SPA
	East Caithness Cliffs SPA
	Fair Isle SPA
	Hoy SPA
	Marwick Head SPA
	North Caithness Cliffs SPA
	Rousay SPA
	Sule Skerry and Sule Stack SPA
	West Westray SPA

Common guillemots are considered to have moderate flush distances by boats and may show some avoidance at short range (Furness *et al.,* 2012, Garthe and Hüppop, 2004).

Razorbill	**North Caithness Cliffs SPA**
	West Westray SPA

Razorbills are considered to have moderate flush distances by boats and may show some avoidance at short range (Furness *et al.,* 2012, Garthe and Hüppop, 2004).

Atlantic puffin	**East Caithness Cliffs SPA**
	Fair Isle SPA
	Foula SPA
	Hoy SPA
	North Caithness Cliffs SPA
	Sule Skerry and Sule Stack SPA

Puffins are considered to be fairly unresponsive to boat traffic (Garthe and Hüppop, 2004) with slight avoidance/short range flush distances (Furness *et al*., 2012).

Arctic skua	**Papa Westray (North Hill and & Holm) SPA**
	Rousay SPA
	West Westray SPA and Hoy SPA

Arctic skuas are considered to show little or no response to vessel activity (Garthe and Hüppop, 2004).

Great skua	**Fair Isle SPA**
	Hoy SPA

Great skuas are considered to show little or no response to vessel activity (Garthe and Hüppop, 2004).

Impact pathway conclusion

As mentioned above the standard operating procedure allowing multiple developers to perform operations on site simultaneously could result in up to maximum of 14 vessels within the test site at any one time, although we consider this occurrence likely to be extremely rare. Furthermore, most activity would most probably be aimed at times of lower tidal-stream flow and so the duration of multiple vessel activity is likely to be relatively focused.

We consider there may be potential for disturbance effects from multiple vessels activity (noise and or presence) on site for common guillemot and razorbill, but not for great cormorant, northern gannet, Atlantic puffin, Arctic skua or great skua. However, we consider that if disturbance of common guillemot and razorbill were to occur, the availability of alternative habitat in relation to the small scale of the Fall of Warness is such that we do not consider it would negatively impact on the conservation objectives for any of the connected SPA, specifically the maintenance of the populations of these species as a viable component of the SPA.

Mitigation

Adherence to the principles set out in the Scottish Marine Wildlife Watching Code will help reduce the potential for disturbance effects from vessel activity. Furthermore, the development of appropriate project-specific vessel management to be considered alongside simultaneous developer activity proposals will help to mitigate any residual impacts at the Fall of Warness test site and during transits out with the site.

Monitoring
Monitoring of the amount of vessel activity on site, particularly during the breeding season would be beneficial in understanding such impacts further.

Impact pathway:	**Loss of/alteration to foraging habitat (includes indirect effects)**

There is potential for the presence and operation of tidal turbines to lead to the loss or alteration of foraging habitat due to changes in tidal flow around the turbines. Alteration of species communities, through direct loss of habitat or colonisation of hard structures albeit at a local scale could also lead to changes in prey distribution (Grecian *et al*., 2010) and have a knock on effect for species utilising the Fall of Warness to forage. Conversely the presence of structures in the tidal swept areas could promote fish aggregation around the devices and increase foraging opportunities (Langton *et al*., 2011).

The vulnerability of seabird species to these effects is likely to be related to a number of factors including foraging range, as well as flexibility in habitat use and prey selection.

Species specific commentary

Great cormorant	**Calf of Eday**

Cormorants feed on a range of mostly benthic prey items including flatfish, blennies, sea-scorpions, sculpins and gadoids, with sandeels, salmonids, labrids and eels also featuring. The depth of water in which they can forage is limited, and hence have a largely coastal water distribution that extends to around 30m depth (Ropert-Coudert *et al,* 2005). They tend to use the edges of tidal races and avoid the high flow areas (Holm and Burger, 2002).

Common guillemot	**Calf of Eday SPA**
	Copinsay SPA
	East Caithness Cliffs SPA
	Fair Isle SPA
	Hoy SPA
	Marwick Head SPA
	North Caithness Cliffs SPA
	Rousay SPA
	Sule Skerry and Sule Stack SPA
	West Westray SPA

Guillemots forage usually above the seabed over flat or varied relief and composition particularly where ocean processes concentrate prey that can be located more predictably, such as at ocean fronts and topographically induced flow gradients (Decker *et al*., 1996). Prey items include pelagic fish, such as sandeel, herring, sprat and Capelin but small gadoids and crustaceans can also be important (Birdlife International 2013a).

Razorbill	**North Caithness Cliffs SPA**
	West Westray SPA

Razorbills generally feed in relatively shallow waters offering predictable feeding conditions, often over sandy sea beds and at upwellings or tidal fronts. Prey species include mainly schooling fish, mostly sandeels supplemented by herring, sprats, and rockling although the composition of their diet will vary between colonies and years to reflect changes in local availability of prey species (Birdlife International 2013a).

Atlantic puffin	**East Caithness Cliffs SPA**
	Fair Isle SPA
	Hoy SPA
	North Caithness Cliffs SPA
	Sule Skerry and Sule Stack SPA

Puffins feed predominantly on small to mid-sized schooling mid-water fish, typically sandeel, sprat, capelin, whiting, saithe, red-fish, haddock, herring and rockling species. Variation in diet between colonies and years has been documented by several studies, usually linked to reduced availability of principal prey items causing a switch in foraging behaviour. Tidal fronts are thought to be important foraging areas for foraging puffins with prey being brought to the surface by flow gradients (Birdlife International 2013a).

Arctic skua	***Papa Westray (North Hill and & Holm) SPA***
	Rousay SPA
	West Westray SPA and Hoy SPA

Arctic skuas generally practice kleptoparasitism in the North-east Atlantic such that they force other seabirds to disgorge their food during aerial pursuit which they then retrieve for themselves. As such they do not have a specific foraging habitat; instead foraging areas are determined by the opportunities for kleptoparastism and they are commonly associated with colonies of terns, kittiwakes and auks (Birdlife International 2013a).

Great skua	***Fair Isle SPA***
	Hoy SPA

Great skuas obtain fish prey by either splash diving, surface seizing, practicing kleptoparasitism or predating on other seabirds often caught in flight. They are able to switch readily between prey groups depending on availability. Consequently, the distribution, foraging habitat and range varies considerably depending on their diet; for example it can be associated with sandbanks when feeding on sandeels, commercial fishing grounds when feeding on discards, and colonies when preying on seabirds (Birdlife International 2013a).

Impact Pathway conclusion

The appraisals in Sections 4.1, 4.2 and 4.3 outline in more detail the likely impact of changes in tidal conditions to benthic and fish/shellfish communities as well as hydrodynamic processes at the Fall of Warness. They conclude that any changes to the tidal characteristics at the Fall of Warness, as a result of the presence and or operation of turbines are not considered to be important at the scale of the test site and as such, we do not consider it likely that there would be a significant impact to the surrounding benthic habitats and their associated prey species. This together with the large foraging range and alternative habitat available to northern gannet, great cormorant, common guillemot, razorbill and Atlantic puffin leads us to conclude that this impact pathway is unlikely to have a negative effect on any of the conservation objectives of the SPA identified above including maintenance of the populations of these species as a viable component of any of the SPA. It follows that it would not negatively affect either of the skua species as outlined above.

Mitigation

The requirement for seabed preparation has not been appraised through this process and therefore must be assessed on a device-developer basis; consideration of appropriate mitigation to minimise any potential impacts may therefore be required.

Monitoring

Continued monitoring of the distribution for species across the site is important and is likely to be delivered through the EMEC Wildlife observation surveys although it may be appropriate to carry out focal bird studies for particular devices to help establish any changes in foraging behaviour.

OPERATION & MAINTENANCE
Annex 1 provides a summary of likely marine works associated with installation, operation and maintenance activities.

Impact pathway:	Collision with turbine blades leading to: injury or death

There is potential for an interaction between diving seabirds and the operating blades of tidal turbines. Of the identified SPA qualifying features, northern gannet, great cormorant, common guillemot, razorbill and Atlantic puffin all dive to depth within range of the operating turbines likely to be deployed at the Fall of Warness as outlined in the project envelope description, and as such could be at risk of impact. At present very little is known about how likely the risk is. To help quantify this risk, encounter rate and collision risk modelling has been carried out for those species outlined below. Please see Annex 3 for background information to the models and refinements used, together with details of the process and full results of the modelling exercise.

It should also be noted that there is no evidence to date of any interaction between any seabird species and the turbine blades at the Fall of Warness since the first turbine was deployed in 2006, or from elsewhere in the UK or Europe (McCluskie *et al*, 2012).

Species specific commentary

Northern gannet	**Fair Isle SPA**
	Hermaness, Saxa Vord and Valla Field SPA
	North Rona and Sula Sgeir SPA
	Noss SPA
	Sule Skerry and Sule Stack SPA

The encounter rate for northern gannet without avoidance is predicted to be 1.5 encounters during the breeding season based on the maximum project envelope across 9 berths. The collision rate is predicted to be 0.2, 0.1, and 0.0 birds per year when applying the avoidance rate assumptions of 90%, 95%, and 98% respectively.

Given the size of the northern gannet population on SPA that has connectivity with Fall of Warness the values for collisions clearly suggest that there would be no negative impact on the conservation objectives for any of the connected SPA, specifically the maintenance of the populations of these species as a viable component of the relevant SPA.

Great cormorant	**Calf of Eday**

The encounter rate for cormorant without avoidance is predicted to be 80.3 encounters during the breeding season based on the maximum project envelope across 9 berths. The collision rate is predicted to be 8.0, 4.0, 1.6, and 0.8 birds per year when applying the avoidance rate assumptions of 90%, 95%, 98% and 99%, respectively.

The population level as provided by the SPA citation is 223 pairs, while other significant non-SPA colonies exist close to the Fall of Warness, specifically 60 pairs at Little linga (6.5 km to east) and an additional colony at Little Green Holm – part of Muckle and Little Green Holm SSSI (approx. 2km SW).The Orkney population is currently around 500 pairs. It would therefore be expected that between 1000 and 2000 birds would be present in the Orkney population (including immature birds) – with perhaps half of these being within 10km of the Falls of Warness. Cormorants were one of the most frequently observed species reported during the site surveys (Robbins 2011).

The predicted collision rate suggests that (at 98% avoidance) approximately 0.2% of SPA birds would be at risk, if all collisions were assigned to the SPA (this calculation is based on 223 pairs plus non-breeding population of equal size (age of first breeding of cormorant is 3 years)). It is likely that not all these casualties should be assigned to the SPA population, as there are an additional approximately 120 pairs breeding at sites as close or closer than the SPA population. Also the modelled collisions are spread throughout the year and the wintering population is probably drawn from a wider pool than just the local sites (Wernham *et al*, 2002),

The relatively high number of sightings of cormorants in the test area (Robbins 2011), which results in a model prediction of a high collision rate, is thought to be misleading in that avoidance of the installed devices would be expected to be high. Cormorants feed at the edge of tidal streams avoiding strong tidal flows (Holm and Burger 2002) and therefore will avoid the immediate sites of tidal turbine installations. Observations of cormorants at the Fall of Warness were mainly in the coastal grid squares, away from the berths of generation devices. The UK population trend shows that nationally numbers of cormorants are increasing (Baillie *et al*, 2013).

Taking into account evidence that the avoidance rate will be high the likely impact on the SPA breeding birds will not be significant. The conclusion is that there will be no negative impact on the conservation objectives for the connected SPA, specifically the maintenance of the population of this species as a viable component of the Calf of Eday SPA.

Common guillemot	**Calf of Eday SPA**
	Copinsay SPA
	East Caithness Cliffs SPA
	Fair Isle SPA
	Hoy SPA
	Marwick Head SPA
	North Caithness Cliffs SPA
	Rousay SPA
	Sule Skerry and Sule Stack SPA
	West Westray SPA

The encounter rate for common guillemot without avoidance is predicted to be 347 encounters during the breeding season based on the maximum project envelope across 9 berths. The collision rate is predicted to be 35, 17, 6.9, and 3.5 birds per year when applying the avoidance rate assumptions of 90%, 95%, 98% and 99%, respectively.

The combined population levels of connected SPA as provided by the citations is 329,543 individuals. The Orkney population in Seabird 2000 is listed as 181,026 (significant numbers are found on the Caithness and Fair Isle SPA). Some smaller non-SPA colonies exist within Orkney. Despite the fact that few non-breeding immatures would be expected to be present in these counts, and that populations will have fallen significantly since the SPA citation figures were compiled (e.g. Copinsay population in 2012 was just 28% of the 1998 count and Fair Isle population in 2010 was approx. 60% of citation figure) the predicted collision rate suggests that (at 98% avoidance) in the region of 0.002% of SPA birds would be at risk, if all collisions were assigned to the SPA populations.

The conclusion is that there will be no negative impact on the conservation objectives for any of the connected SPA, specifically the maintenance of the population of this species as a viable component of the SPA.

Razorbill	**North Caithness Cliffs SPA**
	West Westray SPA

The encounter rate for razorbills without avoidance is predicted to be 4.6 encounters during the breeding season based on the maximum project envelope across 9 berths. The collision rate is predicted to be 0.5, 0.2, 0.1, and 0.0 birds per year when applying the avoidance rate assumptions of 90%, 95%, 98% and 99%, respectively. The figures for the SPA showing at least moderate connectivity are that 6540 birds were present at time of classification. Although this number would be expected to be considerably smaller now, the percentage mortality expected from the Fall of Warness test site as described in the project envelope, and assuming 98% avoidance will be much less than 0.05 %. At these levels we conclude that there will be no negative impact on the conservation objectives for any of the connected SPA.

Atlantic puffin	**East Caithness Cliffs SPA**
	Fair Isle SPA
	Hoy SPA
	North Caithness Cliffs SPA
	Sule Skerry and Sule Stack SPA

The encounter rate for puffins without avoidance is predicted to be 24.2 encounters during the breeding season based on the maximum project envelope across 9 berths. The collision rate is predicted to be 2.4, 1.2, 0.5, and 0.2 birds per year when applying the avoidance rate assumptions of 90%, 95%, 98% and 99%, respectively.

Large populations of Atlantic puffins are recorded for the list of SPA with at least moderate connectivity to the Fall of Warness test site. Total breeding adults on SPA sites with at least moderate connectivity is 108,900 birds. The calculated collision rates indicate that at 98% avoidance less than 0.01% of the population of SPA based birds would be lost in a year. This value is considered to be sufficiently low as to allow us to conclude that there will be no negative impact on the conservation objectives of the connected SPA.

Impact pathway conclusion

Risk of mortality due to collision with active turbine blades was considered a possibility for several species which are qualifying interests of SPA with at least moderate connectivity to the Fall of Warness test site. For common guillemot, even with 99% avoidance of the turbines assumed, this would account for more than 1 bird per year. However assessment of the predicted levels of mortality against the populations of seabirds within range of the test site indicates that the collision with turbines leading to injury or death is unlikely to occur at a level to negatively impact the conservation objectives for any of the SPA.

Mitigation

Potential mitigation measures include the use of soft start, where the turbines are started gradually to enable any seabirds around the device at slack water or after periods of standstill (i.e. when the turbines do not operate in the tide) to move out of the area – this may not be applicable to every turbine.

Monitoring

The use of innovative ways in which to monitor operating turbines and detect any impacts is clearly important in understanding this impact pathway further. Existing methods predominately rely on the use of underwater video cameras – key issues for the use of this technology include visibility at depth and whether any lighting is required as well as covering sufficient field of view. We do not consider that strain gauges would be sensitive enough to detect any impact with a seabird.

Impact pathway:	**Presence of tidal device and associated infrastructure leading to displacement (including underwater noise from operation turbines)**

Displacement in this context is considered to include behavioural change by individuals within areas that were previously utilised as a consequence of the introduction of a novel stimulus, e.g. a tidal turbine device below the water surface or turbine components above the surface. Some studies from offshore wind farms have identified different species that have shown varying levels of behavioural change from localised disturbance to displacement from area - see species specific commentary below.

A focal bird study of the Scotrenewables (SR250) turbine carried out at Berth 8 at the Fall of Warness, found no evidence of displacement, although the survey period was limited to one summer period (Hamilton, 2012). Monitoring of the surface piercing SeaGen device at Strangford Narrows detected very small scale displacement for some seabird species, although there was no evidence of an overall decrease in abundance of seabirds using the area (Keenan *et al*, 2011). However, very little is currently known on how birds react to tidal turbines in the water column or what potential there is for tidal turbine arrays to disturb, displace or act as a barrier to birds.

Very little is known about how diving birds respond to underwater noise, i.e. from generating tidal turbines, as they are primarily adapted for hearing in air. A single study has suggested birds showed no significant response to seismic airguns (Turnpenny and Nedwall 1994), which may be a consequence of lower hearing sensitivity underwater.

Species specific commentary

Northern gannet	**Fair Isle SPA**
	Hermaness, Saxa Vord and Valla Field SPA
	North Rona and Sula Sgeir SPA
	Noss SPA
	Sule Skerry and Sule Stack SPA

Gannet numbers at the Offshore wind farm Egmond aan Zee (OWEZ), decreased during the construction phase with a further decrease observed during post construction with most birds flying round the development (Lindeboom *et al*., 2011, Leopold *and* Dijkman, 2011). The above surface infrastructure associated with the Falls of Warness installations as described in the project envelope are considerably less intrusive than those of OWEZ. If gannets were to avoid the area of the turbines the total loss of foraging area to gannets is considered insufficient to impact on the conservation objectives of the 5 SPA with moderate or high connectivity.

Great cormorant	**Calf of Eday**

Cormorants are neritic birds concentrating around nearshore coastal (or inland) areas. Evidence from the OWEZ wind farm located 10 -18km off the Dutch mainland coast showed an increase in the number of cormorant in and around the wind farm footprint. The birds using this area were observed flying, swimming, resting and feeding and demonstrated a clear attraction to the met mast as well as foundation structures. This means this species now occurs at latitudes that they would not have been found at prior to the development of this offshore wind farm (Leopold and Dijkman, 2011). A similar situation has occurred at Robin Rigg in the Solway Firth which has also seen a strong association with/attraction to, the wind farm (Canning *et al*., 2012).

While most of the tidal turbines deployed at the Falls of Warness are fully submerged there are some devices and structures that have above surface components and as such it is possible that these could be used by cormorant for resting (including wing drying) and as such may be beneficial to this SPA qualifying feature.

Common guillemot	**Calf of Eday SPA**
	Copinsay SPA
	East Caithness Cliffs SPA
	Fair Isle SPA
	Hoy SPA
	Marwick Head SPA
	North Caithness Cliffs SPA
	Rousay SPA
	Sule Skerry and Sule Stack SPA
	West Westray SPA

There is some evidence from the Horns Rev offshore wind farm (14km west of Jutland in the Danish North Sea) that guillemots tend to avoid the development area however this is not unequivocal. (Petersen and Fox, 2007). The relationship at OWEZ wind farm is less clear and further monitoring is required (Leopold and Dijkman, 2011).Similarly at Robin Rigg some avoidance was shown during construction with numbers increasing during the operational phase (Canning *et al*., 2012). Small scale avoidance of the area of the Fall of Warness test site during the construction, installation and maintenance phases of test machines is considered unlikely to negatively impact on the conservation objectives of the SPA sites with moderate to high connectivity to the test site. The reaction of guillemots to underwater noise produced by active turbines in unknown. Auks have ears that are adapted to hearing in air, and do not appear to be unusually sensitive to sound nor to use underwater sound for communication, navigation or hunting. It therefore follows that it is unlikely that underwater noise will prevent guillemots from utilising a large area of sea around the test site. The conclusion drawn is that this impact pathway is unlikely to negatively impact on the conservation objectives of the SPA listed above.

Razorbill	**North Caithness Cliffs SPA**
	West Westray SPA

Evidence from OSWFs for razorbill is thought to be similar to that of guillemot (see commentary above). Very little is known about how they may react to tidal turbines, although following the logic above then it is considered unlikely to negatively impact on the conservation objectives of North Caithness Cliffs SPA and West Westray SPA.

Atlantic puffin	**East Caithness Cliffs SPA**
	Fair Isle SPA
	Foula SPA
	Hoy SPA
	North Caithness Cliffs SPA
	Sule Skerry and Sule Stack SPA

Evidence from OSWFs for puffin is thought to be similar to that of guillemot (see commentary above). Very little is known about how they may react to tidal turbines, although following the logic above then it is considered unlikely to negatively impact on the conservation objectives of Papa Westray SPA, Rousay SPA and West Westray SPA.

Arctic skua	***Papa Westray (North Hill and & Holm) SPA***
	Rousay SPA
	West Westray SPA and Hoy SPA

Little or no information is available from offshore windfarm studies as to whether Arctic skua is likely to be displaced or not. In considering the impact of indirect effects, Arctic skuas are generally associated with colonies of species in which they can kleptoparasitize and as such the Falls of Warness does not therefore represent prime foraging habitat for this species. Moreover, they show little or no response to ship traffic (Garthe and Hüppop 2004). The conclusion is that there would not be a negative impact on the conservation objectives for the SPA which list this species as a qualifying interest.

Great skua	***Fair Isle SPA***
	Hoy SPA

Little or no information is available from offshore windfarm studies as to whether Great skua is likely to be displaced or not. In considering the impact of indirect effects, Great skuas utilise a wide range of foraging techniques and habitat and as such the Falls of Warness is not thought to represent prime foraging habitat for this species. Moreover, they show little or no response to ship traffic (Garthe and Hüppop, 2004). The conclusion is that there would not be a negative impact on the conservation objectives for the SPA which list this species as a qualifying interest.

Impact pathway conclusion
While some information can be gleaned from experience at offshore wind farm development sites, it is less clear how those species discussed above may react to underwater turbines or their above surface components. However, any reaction is likely to occur in the vicinity of the turbines themselves. Considering this quantitatively, the Falls of Warness test site is around 9km^2 across the site as a whole. The project envelope covers 9 berths in total and if each 'development' footprint at each berth was considered to be 500m^2 in size (which is considered precautionary), the total area of 'development' across the site would be 6000m^2. This equates to 0.07% of the total site as a whole. The small scale of 'development' footprint together with the limited number of devices being tested is therefore likely to be insignificant in comparison to the foraging ranges and available habitat of the aforementioned species. Even if displacement was to occur from the 'development' footprint across all berths and we have no evidence that this is the case, we do not considered that it would have a negative effect the populations of these species as a viable component of any of the SPA as identified above.

Mitigation
We are currently unaware of any appropriate mitigation.

Monitoring
Depending on the device and the future intentions for commercialisation, it may be appropriate to carry out focal bird studies to learn how certain species react to the presence of particular device types. This could be carried out in conjunction with the sightings data from the EMEC Wildlife Observation data. Furthermore, cross referencing footage from underwater cameras against the EMEC Wildlife Observation data and or focal birds studies may also provide useful analysis.

Impact pathway:	**Presence of tidal device infrastructure leading to attraction, specifically roosting/resting opportunities**

Some tidal device designs may have structures above the water, which could provide some seabirds with a roosting platform. These additional platforms could also extend their potential foraging area and provide a base from which to conserve energy while foraging in a tidal stream.

Species specific commentary

Great cormorant	**Calf of Eday**

Cormorants are known to use a range of man-made structures for standing, preening and wing drying. These structures include mussel buoys (Roycroft *et al*. 2004), platforms on offshore wind farms and even wind turbine foundation structures prior to completion of construction (Kahlert *et al.,* 2004; Lindeboom *et al.,* 2011). As discussed above, cormorants at the OWEZ wind farm demonstrated clear attraction to the met mast and foundation structure and were observed flying, swimming, resting and feeding within the wind farm footprint area (Leopold and Dijkman., 2011). A similar situation has occurred at Robin Rigg in the Solway Firth which has also seen a strong association with/attraction to, the wind farm (Canning *et al*., 2012).

Common guillemot	**Calf of Eday SPA**
	Copinsay SPA
	East Caithness Cliffs SPA
	Fair Isle SPA
	Hoy SPA
	Marwick Head SPA
	North Caithness Cliffs SPA
	Rousay SPA
	Sule Skerry and Sule Stack SPA
	West Westray SPA

It is possible that above surface components of tidal turbines could provide a suitable platform on which guillemot could rest. Hamilton (2012), found some evidence of guillemots using the Scotrenewables device to perch although this was more frequently observed in relation to black guillemots which actively forage in tidal streams, where as common guillemots tend to use the edge of high flow areas (Holm and Burger, 2002). The level of interaction expected from this species, and the magnitude of impacts derived from that interaction indicate that this impact pathway will not negatively affect the conservation objectives of the SPA listed above.

Razorbill	**North Caithness Cliffs SPA**
	West Westray SPA

It is possible that above surface components of tidal turbines could provide a suitable platform on which razorbill could rest or forage from. However, as this species tends to use the edge of high flow areas (Holm and Burger, 2002) it is less obvious how beneficial this may be. The level of interaction expected from this species, and the magnitude of impacts derived from that interaction indicate that this impact pathway will not negatively affect the conservation objectives of the SPA listed above.

Atlantic puffin	**East Caithness Cliffs SPA**
	Fair Isle SPA
	Hoy SPA
	North Caithness Cliffs SPA
	Sule Skerry and Sule Stack SPA

It is possible that above surface components of tidal turbines could provide a suitable platform from which puffins could rest, however they show no preference for foraging in tidal stream habitats (Furness *et al*., 2012) and so any benefits to this particularly pelagic species in utilising such a platform are not obvious.

Impact pathway conclusion
While cormorants have shown clear attraction to offshore windfarms structures (so potentially also above surface structures for tidal devices) and thereby extract some form of benefit, the evidence is less clear for the other species as considered above. At the Fall of Warness, the number of berths with above surface components (currently installed or planned) covers three devices and as such presents limited opportunity for perching. Whether this is beneficially energetically or not, we do not consider there to be a negative effect to the populations of the aforementioned species as a viable component of any of the SPA as identified above, nor any impact on other conservation objectives of the SPA.

Mitigation
No appropriate mitigation currently exists.

Monitoring
It may be appropriate for those devices with above surface components to carry out focal bird studies to learn how certain species react to the presence of the device. This could be carried out

in conjunction with the sightings data from the EMEC Wildlife Observation data. Furthermore, cross referencing footage from underwater cameras against the EMEC Wildlife Observation data and or focal birds studies may also provide useful analysis.

Impact pathway:	**Presence of artificial underwater lighting leading to attraction PROJECT-SPECIFIC ASSESSMENT REQUIRED**

Lighting of tidal stream devices will be in keeping with Northern Lighthouse Board's aids to navigation strategy. Lighting for tidal devices is significantly different to the lighting scenario required for offshore windfarms and oil rig platforms which require lights for aviation as well as vessel navigational safety. At the Falls of Warness, developers in some instances may seek to utilise underwater lighting of tidal devices, e.g. for monitoring purposes.

Species specific commentary
This impact pathway has the potential to affect the following five species (northern gannet, great cormorant, common guillemot, razorbill and Atlantic puffin) from their corresponding SPA as identified at 3(b) above.

Very little is known about attraction to lights underwater, and it is possible that diving species may be indirectly attracted to any subsurface lighting which attracts fish. Birds are known to be attracted to sources of artificial lighting above the water (Jones and Francis 2003). Poot *et al.* (2008) found birds were disoriented and attracted by red and white light (containing visible long-wavelength radiation) but less disoriented by blue and green light. It is possible that if underwater lighting did have an attraction effect, that in turn this could increase the potential for collision with operating blades by placing more birds in the area of risk, however we have no evidence to suggest that this is the case. Collision risk is discussed above.

Impact pathway conclusion
Assessment for the risk of underwater lighting will depend on the specifics of the lighting proposed. This will need to be undertaken by each device-developer and incorporated into their PEMP.

Mitigation
Recommendations for reducing this risk include a gradual introduction and increase in the use of lighting.

Monitoring
Any introduction of underwater lighting should be monitored and cross-referenced using other survey methods to monitor interactions around the lighting e.g. underwater cameras.

Conclusion:
It is considered that the Fall of Warness test site will not adversely affect the integrity of any of the aforementioned SPA.

4.10.4 Conditions or modifications required.

Condition:	***Reason:***
No conditions required for HRA purposes however recommendations for monitoring and or mitigation to be incorporated into the PEMP.	

4.10.5 Conclusion

Conclusion: Likely significant effect but the appraisal carried out demonstrates that it will not adversely affect the integrity of any of the aforementioned SPA. The predicted rates of mortality caused by collision with turbines could be sufficient to adversely affect the breeding population of the SPA.

4.10.6 References

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4.11 Impact Appraisal: Seascape, Coastal Character and Visual Amenity

Prior to the fully detailed evaluations, this part of the appraisal picks up at 'Step 2' as described in Section 3 of this document.

4.11.1 Potential effects

For receptors relating to seascape, coastal character and visual impacts (offshore impacts only), the defined potential effect categories are applied to activities/effect pathways relevant to tidal energy developments comprising design-types involving the rotation of turbines within natural hydrodynamic conditions[46]. Effects during deployment/installation (Table 52) are addressed separately from those during the operational and maintenance phases (Table 53).

Aside from 'coastal character', 'landscape' impacts are explicitly excluded from this appraisal, which is limited to infrastructure below the level of Mean Low Water Springs (MLWS).

Note that details specific to the Fall of Warness, both environmental and relating to project-specifications, are not considered until the detailed appraisal later in this section.

[46] Tidal developments that involve the manipulation of hydrodynamic conditions prior to the extraction of energy (e.g. tidal barrages) are explicitly excluded from the broad consideration of potential effects in Table 52 and Table 12.

Generic Potential Effects from Device Deployment

Summary of activity categories – for detail see project envelope description (Annex 1)

- Installation of device(s), and associated infrastructure (e.g. mooring systems; buoys) above the surface
- Use of vessels (e.g. DP vessel; jack-up barge; multi cat; workboat; dive-support vessel; crane-barge; tug; specialist cable-laying vessel.)
- Deployment and use of equipment to monitor devices or other environmental parameters during installation

Activity/Potential Effect Pathway	Natural heritage feature	Potential Importance
Vessel presence/manoeuvring (including infrastructure under tow).	Seascape, coastal character and visual amenity.	Not important – Installation/deployment activities are of a temporary nature and as such will not be in-situ sufficiently long enough to alter the seascape, coastal character or visual amenity. Whilst multiple activities can be visually obtrusive, all such activities are highly temporary and reversible.

Table 52: Potential effects upon the seascape, landscape and visual amenity during device and infrastructure deployment, identifying activities/effect pathways and receptors for further assessment. Note that these evaluations are made prior to consideration of details particular to the Fall of Warness site.

Generic Potential Effects from Device Operation and Maintenance

Summary of activity categories – for detail see project envelope description (Annex 1)

- Physical presence of device(s), above the surface
- Repeat removal and redeployment of equipment for maintenance (e.g. turbine removed from water or floating structure removed from berth)
- Other maintenance activities (e.g. Biofouling removal; ROV/diver inspection or repairs)
- Use of vessels (e.g. DP vessel; jack-up barge; multi cat; workboat; dive-support vessel; crane-barge; tug)

Activity/Potential Effect Pathway	Natural Heritage Feature	Potential Importance
Presence of surface-piercing devices and associated infrastructure.	Seascape, coastal character and visual amenity.	Potentially important – Relatively few tidal stream device designs include surface-piercing components. However, those that do may alter the coastal character or visual amenity. Buoys and other surface-piercing parts of the infrastructure may also contribute to an impact. Importance will depend upon the current coastal character type (including local and national landscape designations) and the experiential value of the area to receptors (e.g. householders, walkers, ferry passengers, drivers, etc). Local and national landscape designations could include wild coast, country park, settlement settings etc. The number, design and spatial arrangement of devices and infrastructure are also important.
Vessel presence/manoeuvring.	Seascape, coastal character and visual amenity.	Not important – even where visually obtrusive, all such activities are highly temporary and reversible.

Table 53: Potential effects upon seascape, landscape and visual amenity during the operational and maintenance phase, identifying activities/effect pathways and receptors for further assessment. Note that these evaluations are made *prior* to consideration of details particular to the Fall of Warness site.

4.11.2 Natural heritage context

Aurora (2005) describes the local seascape, coastal character and visual amenity at and adjacent to the Fall of Warness, including some viewpoint analysis. The immediately adjacent shores provide a variety of coastal environments, from sandy beaches with low-lying dunes flanked by rocky outcrops, to sandstone cliffs and exposed intertidal bedrock. The wider area comprises relatively low-lying islands of rural but sparse populations, separated by channels and sounds. Fall of Warness itself is part of a wider body of water at the intersection of Westray Firth and Stronsay Firth. An area nominally demarcated by the shores of Eday and the rock outcrops of Muckle and Little Green Holm, separate the Fall of Warness from undeveloped expanses of these firths.

Although adjacent islands are sparsely populated, the site is visible from some remote residences and minor roads. However, the visibility of the site is primarily of relevance to vessels in transit through the Stronsay and Westray Firths, including passenger ferries and some cruise ships. The vicinity is indeed subject to moderate intensity use by a variety of other vessels, including those from the fishing, aquaculture and shipping sectors, which themselves contribute to the baseline visual environment. The existing situation also includes the presence of surface-piercing and surface-buoyant devices already in existence at the Fall of Warness, namely the supporting infrastructure for the OpenHydro 6m device at berth 4 and the occasional deployment of the ScotRenewables device.

The Landscape Character Assessment for Orkney (Land Use Consultants, 1998) includes detailed information on the characterisation of the relevant areas of coastline.

The Orkney Islands Council (OIC) apply a number of local landscape designations to parts of Eday. These are as follows:

(a) The north end of Eday (Red Head), Calf Sound, the township of Calfsound and the Calf of Eday is a ‘Site of Landscape Character’

(b) 90% of the island's coastline is considered to be 'Undeveloped Coast'

(c) 10% of the island's coastline is considered to be 'Isolated Coast'

4.11.3 Summary of impact appraisal process for the Fall of Warness

This impact appraisal takes account of a maximum-case scenario based on the project envelope description, where all available berths within the test site are developed and operating at capacity. It addresses the differing consenting and licensing regimes (see Table 54 below). This appraisal will inform the consenting process for both Marine Licence and Section 36 applications. However, it should be noted that, if there are key deviations in the device design or in installation or maintenance activities, further appraisal work may be required. Any additional appraisal work required will be undertaken by the individual developer (further advice should be sought from EMEC in the first instance).

Feature type	Appraisal mechanism/relevant legislation	Applicable	Reasoning
Qualifying features of European sites.	Habitats Regulations Appraisal (HRA) - Habitats Regulations 1994 (as amended).	N	Landscape, seascape and visual amenity not relevant to SAC or SPA.
European Protected Species.	EPS legislation - Habitats Regulations 1994 (as amended in Scotland) .	N	Landscape, seascape and visual amenity not relevant to EPS.
Notified features of SSSIs.	SSSI legislation - Nature Conservation (Scotland) Act 2004.	N	Landscape, seascape and visual amenity not relevant to SSSIs.
Protected features of MPAs	Marine (Scotland) Act 2010	N	Landscape, seascape and visual amenity not relevant to MPAs
PMFs	Marine (Scotland) Act 2010	N	Landscape, seascape and visual amenity not relevant to PMFs
Other sensitive natural heritage features.	Appraisal of other features under: - Electricity Works (EIA) (Scotland) Regulations (Amendment) 2008; - Marine Works (EIA) (Amendment) Regulations 2011; - Marine (Scotland) Act 2010.	Y	Captures assessment of all other natural heritage features, including any landscape designations.

Table 54: Appraisal mechanism for visual impacts.

4.11.4 Appraisal of other features

Presence of surface-piercing devices and associated infrastructure

Most tidal-stream devices do not include any surface-piercing or surface-buoyant aspects. There is potential for more of these devices, however, and a maximum case scenario at the Fall of Warness dictates consideration of up to 12 such devices (at 9 berths), although this is considered an unlikely scenario.

Navigational markers and lights are expected to be visible in most weather conditions and at night.

Nevertheless, even with this maximum scenario, the following reasons lead to consideration that any impacts on seascape, coastal character and visual amenity are not important:

- Berths sites are relatively spread out over a sea area of moderate extent and are sufficiently far from shore that they would not be expected to dominate the seascape or coastal character
- The areas of adjacent shoreline are sparsely populated, have very few roads and are available as an amenity resource to a relatively small number of people, thus limiting the impact
- Device deployments are temporary and reversible
- Nearby areas identified as a 'Site of Landscape Character' do not have line of sight to the Fall of Warness, nor from ground or sea-level are they likely to fall within the same line of sight from other viewpoints
- The site and adjacent areas are subject to moderate intensity anthropogenic activities with a visual element, primarily through transit of a variety of vessel traffic

In addition, the degree of visual impact will be strongly influenced by the meteorological conditions of Orkney. Consequently, clear visibility will likely be restricted to periods of good weather during the summer months due to the longer daylight hours and more regular incidence of calm conditions.

Appraisal conclusion for all aspects of the seascape, landscape and visual amenity: Any potential impacts are not regarded as important.

4.11.5 Seascape, landscape and visual amenity receptor conclusions

A summary of the appraisal is provided in Table 55 below.

Receptor	Conclusion	Mitigation and or monitoring identified?
Seascape landscape and visual amenitie.s	No important impacts.	No

Table 55: Summary of seascape, landscape and visual amenities appraisal conclusions.

It is concluded that no important impacts of relevance to the seascape, coastal character or visual amenity are expected from developments at the Fall of Warness EMEC test facility, based on the parameters of the project envelope described in Annex 1. No mitigation or monitoring proposals have been made at present. Note however that this appraisal does not address onshore infrastructure, which requires consideration through the Town and Country Planning Act 1997.

4.11.6 References

Land Use Consultants. 1998. Orkney landscape character assessment. Scottish Natural Heritage Review, No. 100.

Aurora. 2005. EMEC Tidal Test Facility Environmental Statement. Aurora Ltd.

Guidance for Landscape and Visual Impact Assessment (GLVIA) - http://landscapeinstitute.co.uk/knowledge/GLVIA.php

SNH Guidance - *Offshore Renewables – guidance on assessing the impact on coastal landscape and seascape* - http://www.snh.gov.uk/docs/A702206.pdf

5 Mitigation, Monitoring and Research

The preceding appraisals provide detailed consideration of potential natural heritage impacts to inform the consenting process for deployment and operation of tidal devices at the Fall of Warness. Through pre-appraisal of these impacts, within the bounds of the project envelope (see Annex 1), it is intended that developers focus greater effort into the development and delivery of mitigation, monitoring and research strategies. This section summarises mitigation and monitoring options identified in each of the previous receptor appraisals. Information on past and present research are also summarised.

The environmental impact appraisals describe the likelihood and nature of potential impacts and their subsequent importance for the various natural heritage features. *Mitigation* seeks to reduce the severity of identified environmental impacts, whereas *monitoring* may be used (a) to track the status of a potential impact to either eliminate or inform the need for the introduction of mitigation and/or (b) to improve understanding of the importance of potential impacts, either to benefit the particular developer or for the wider industry and regulators. In the context of this document, we regard *research projects* to have a subtle difference from monitoring in that they are typically less device specific. Consequently, research at the test site is less likely to be tied to a particular Marine Licence and more likely to be delivered through EMEC, with the involvement of developers, academic institutions, Marine Scotland or SNH, for example.

Mitigation and monitoring activities should be agreed with Marine Scotland and SNH through the development of (a) a Project-specific Environmental Monitoring Programme (PEMP); (b) a Construction Method Statement (CMS); and (c) a Vessel Management Plan (VMP). The CMS and VMP may be incorporated as sections within the PEMP. Developers should submit a draft PEMP along with their Marine Licence application, but it is recognised that subsequent iterations and refinements may be necessary to reach an agreed version prior to the commencement of works. Section 6 of this document provides a suggested structure and content for a PEMP, together with the minimum expected contents of a CMS and VMP from an environmental perspective.

This section of the document has two functions:

- **To summarise recommended mitigation and development-specific monitoring activities from all of the preceding appraisals.** Some such measures will be appropriate as licence conditions, whereas others may be recommended as good practice. For development proposals regarded to fit within the project envelope for the Fall of Warness test site, developers can then use this summary to inform the writing of their PEMP, CMS and VMP specific to their project. Some impact types described below will not be relevant to all device types and development methods, and should be filtered as required.

- **To highlight research projects and site-wide monitoring, including those that are ongoing and those with potential as future projects.** Individual developers should consider how work to date and future opportunities should influence the content of their PEMP and their aspirations for furthering understanding of impacts on the marine environment from tidal energy developments, specifically to aid future consent applications.

5.1 Summary of Potential Mitigation Activities

Where site-specific appraisals conclude that potential impacts could be of importance for features of the marine environment, each appraisal section identifies relevant mitigation measures that would help reduce impacts to a more acceptable level. Where protected sites and species are concerned, these mitigation measures must be sufficient to satisfy the relevant tests of the legislation and are prime candidates for adoption as licence conditions. The compilation of mitigation measures is summarised in Table 56 below. This is not necessarily an exclusive or exhaustive list; other mitigation options may become available as the sector and associated technologies progress. **Developers are encouraged to independently consider impacts and the potential for developing new and innovative mitigation measures at the test site.**

Impact/Pathway	Receptors	Mitigation	Species licensing requirement?	Likely condition of consent?
Marine non-natives (introduction/facilitation).	Benthic species and habitats; shellfish.	Adopt good-practice non-natives and bio-fouling management as detailed in www.scotland.gov.uk/Resource/0039/00393567.pdf, www.mardep.gov.hk/en/msnote/pdf/msin1136anx1.pdf and www.ipieca.org/publication/alien-invasive-species-and-oil-and-gas-industry	n/a	Possible
Disturbance during installation & maintenance activities. (drilling noise; vessel activity & transit; cable works).	Cetaceans; basking sharks; seals; otters.	All: Adherence to the SMWWC guidelines (www.marinecode.org) during vessel use. Consideration of vessel and construction noise within a Construction Methods Statement, integrating with simultaneous operations by other developers.	n/a	Possible
		Cetaceans & Basking sharks: Application of the EMEC MMO protocol for drilling operations (protocols may have to be adapted to specifically take account of basking sharks – i.e. may require more time to exit exclusion zone).	Yes	Yes
		Seals: Extension of the EMEC MMO protocol to limit exposure of seals to disturbance during drilling operations.	No	Yes

		Apply exclusion zone around haul-outs (i.e. to be avoided during vessel transits).		
		Otters: A project-specific assessment is required for installation, replacement or maintenance of cable infrastructure. (Requirement for otter survey, licensing and any mitigation will be determined through consultation with SNH as the licensing authority.)	Possible	Possible
Collision with turbine blades.	Cetaceans; seals; basking sharks; diving birds.	Cetaceans and basking sharks: EPS and basking shark licensing provide opportunity for considering project-specific mitigation measures, if deemed appropriate. If interaction of a cetacean or basking shark with a device occurs then procedures for emergency shutdown and liaison with regulators should take place until a re-start or suitable mitigation is agreed.	Yes (licence to disturb EPS & basking sharks could potentially be time-limited with a review period.)	Yes
		Seals: If interaction of a seal with a device occurs then procedures for emergency shutdown and liaison with regulators should take place until a re-start or suitable mitigation is agreed.	No	Yes
		Diving birds: Potential mitigation measures include the use of soft start, where the turbines are started gradually to enable any seabirds around the device at slack water or after periods of standstill (i.e. when the turbines do not operate in the tide) to move out of the area – this may not be applicable to every turbine.	No	Possible
Entanglement with mooring and cable system.	Cetaceans; basking sharks.	EPS and basking shark licensing provide opportunity for considering device-specific mitigation measures, if deemed appropriate. If entanglement of a cetacean or basking shark occurs then procedures for emergency procedures and liaison	Yes (licence to disturb EPS & basking sharks could potentially be time-limited	Yes

		with regulators should take place until a re-start or suitable mitigation is agreed.	with a review period.)	
Barrier effect of device presence	Cetaceans; basking sharks; seals	Mitigation only required if monitoring indicates unacceptable impact	Unlikely	Unlikely
Potential corkscrew injuries from interaction with ducted propellers	Seals	Harbour (common) seals: Give project-specific appraisal in light of the most recent population and PBR figures. Potential mitigation includes consideration of alternatives to using vessels with ducted propellers and avoiding the breeding season if possible.	No	Possible
		Grey seals: Give project-specific assessment in relation to Faray and Holm of Faray SAC, in light of the most recent population figures. For non-SAC seals, good-practice mitigation includes the consideration of alternatives to using vessels with ducted propellers and avoiding the breeding season if possible.	No	Possible

Table 56: Potential mitigation measures for deployments at the EMEC Fall of Warness test site.

5.2 Potential Project-specific Monitoring Activities

Monitoring of environmental parameters and their interaction with different aspects of a development serves two key purposes for a particular device or developer. Firstly, in the event of an interaction between wildlife and the device, such monitoring can be used to trigger an emergency response and to alert the developer and regulator to a need for ongoing or new adaptive mitigation. This type of monitoring is primarily aimed at marine mega-fauna that have some associated species protection legislation and for which impacts upon even small numbers of animals could have legal and biological implications. Given the links to legal requirements, this type of monitoring may best be adopted through the Marine Licensing process (i.e. as conditions on developers' Marine Licences).

Secondly, where there is a degree of uncertainty in understanding of the impact mechanism and its significance, impact monitoring can also be important in advancing this knowledge base. This is particularly relevant to the EMEC test sites, a key purpose of which is to further the collective and device-specific understanding of environmental impacts, quantitatively where possible. For some impact mechanisms, the small scale and limited number of devices at Fall of Warness has allowed scientific judgement to determine that an impact is not important in the context of this test site. However, learning from the EMEC test sites should be maximised in order to assist developers in scaling up to commercial developments with maximum investor confidence in the collective understanding of environmental risks. Using the EMEC test sites to investigate impacts likely to be of greater importance at larger-scale developments should help deliver this.

5.3 Research and Site-wide Monitoring: Past, Present and Future Opportunities

This section summarises research and site-wide monitoring projects that have been delivered or are ongoing across the whole Fall of Warness test site. Future opportunities and aspirations for research are not detailed here, but a list is maintained by and available from EMEC. It is likely that previously unconsidered issues will continue to emerge, particularly as novel device designs and development methods come forward. Similarly, research and monitoring results may lead to a lesser emphasis on potential impacts about which there is currently uncertainty.

The use of marine renewable energy test sites, such as the Fall of Warness, not only provides an opportunity for research and development activities pertaining to proof of engineering concepts and design evolution, but should also be of particular value in advancing an understanding of potential environmental interactions. While there is a limit to the knowledge to be gained from device deployments at a small and temporary scale, given the young and burgeoning nature of the industry and the legislative requirements that apply to larger-scale deployments, there remains considerable value in research and long-term monitoring into the potential implications of such developments on biological, physical and chemical parameters of the environment.

Table 57 below summarises previous and ongoing projects. **Developers are encouraged to independently consider impacts and the potential for developing new and innovative research at the test site, and to bring these ideas to the EMEC MAG (through discussion with EMEC)**. Part of the role of EMEC MAG is to maintain an overview of emerging research and technology and identify new requirements. They also seek to identify sources of available funding and have a role in the review and dissemination of findings from research and monitoring at the EMEC test sites.

The projects and research topics do not all relate solely to tidal energy developments; many apply equally to offshore wind or wave energy developments, or indeed to marine industries more generally. Nevertheless, a broad appreciation of these topics has merit so that progress can be sought by developer groups, by academic or government organisations, or by consortiums of various interested parties where appropriate. This information should also be used to guide developers in the collective understanding of environmental conditions and impacts and how this may inform the development of their PEMP in maximising the benefits for commercial-scale developments.

Topic	Project	Status
UNDERWATER NOISE	Initial testing of drifting acoustic equipment at Fall of Warness, Jan 2008 ('Drifting Ears' project).	Report available, Wilson & Carter (2008)[47], SAMS
	Further 'drifting ears' surveys and use of hydrophone in June 2010.	Report available, Wilson, *et al* (2010)[48], SAMS
	Baseline Acoustic Characterisation: Review of existing data; Further survey work and development of Drifting Acoustic Recorder & Tracker (DART) system.	Final report due 2012 (project code 0094)
BENTHIC	Benthic habitats video surveys.	Survey work completed. Analysis and reporting of survey results outstanding.
WILDLIFE OBSERVATIONS	Shore based vantage-point watches for seabirds and marine mammals. SNH funded analysis of data and review of methods.	Surveys commenced July 2005; ongoing. Analysis & methods reports up to March 2011 (Robbins, 2011[49]).
MULTI-DISCIPLINARY	FLOWBEC (http://noc.ac.uk/project/flowbec) RESPONSE ( )	Ongoing Ongoing

Table 57: Complete and ongoing monitoring and research activities at Fall of Warness delivered by EMEC or partners.

An awareness of research at other locations is also important. Information is available from various locations, including the following:

- Tethys knowledge management system: http://mhk.pnnl.gov/wiki/index.php/Tethys_Home
- Marine Scotland research web-page: http://www.scotland.gov.uk/Topics/marine/marineenergy/Research
- NERC Marine Renewable Energy Knowledge Exchange Portal: https://ke.services.nerc.ac.uk/MARINE/Pages/Home.aspx

[47] Wilson, B. & Carter, C. 2008. Acoustic monitoring of the European Marine Energy Centre Fall of Warness tidal-stream test site; Phase 2: Development, testing and application. EMEC report.

[48] Wilson, B., Carter, C. & Elliott, J. 2010. A baseline acoustic survey of the Fall of Warness test site & assessment of the acoustic output of the vessel CS Sovereign during R.O.V. & cable laying operations. EMEC report.

[49] Robbins, A. 2011. Summary of bird and marine mammal data for the Fall of Warness and Billia Croo, Orkney, and Review of observation methodologies: *A report to Scottish Natural Heritage.*

6 Guide to Developing a Project-specific Environmental Monitoring Programme

6.1 Purpose and Approach

A Project-specific Environmental Monitoring Programme (PEMP) has several purposes. Firstly, the PEMP should ensure that there is compliance with conditions of consent in relation to environmental impacts, assuring the Regulator that these are kept within acceptable limits. A PEMP should also be an integral part of the Marine Licence application process, providing each developer with a structured approach to learning more about the interaction of their device with the environment and, more broadly, accumulating learning for the marine renewable energy sector in general. Furthermore, a PEMP that clearly identifies the series of required actions and standards should contribute to good project management and cost reduction.

For applications that sit within the project envelope (Annex 1), impact appraisals have already been completed for the EMEC Fall of Warness test site, including those with legislative requirements (see Section 4). Section 5 of this document summarises potential mitigation and monitoring measures identified. Individual developers are required to prepare and agree a PEMP with Marine Scotland and EMEC prior to commencement of works at the Fall of Warness test site. The PEMP should include a Construction Method Statement (CMS) and Vessel Management Plan (VMP).

Developers should familiarise themselves with the preceding appraisals (Section 4) and recommendations for mitigation and monitoring (Section 5) to guide the iterative development of their PEMP. An initial draft of the PEMP should form a fundamental part of a developer's Marine Licence/Section 36 consent application. Subsequent iterations of the PEMP can then be submitted as further details become available, with final agreement of the content by Marine Scotland prior to the commencement of works. Marine Scotland and SNH strongly recommend that the developer liaises closely with EMEC throughout the whole process, pre- and post- submission of any licence application.

The PEMP should be clear in its distinction between *mitigation* and *monitoring*. Monitoring in itself should not be regarded as mitigation, but cases where monitoring is deliberately in place to trigger mitigation measures when an impact threshold is crossed, should be clearly explained. For example, monitoring for encounters between animals and devices should trigger mitigation if an encounter results in a collision event. Initially the mitigation is likely to be device shutdown, until a new evaluation of the impact and associated risks can be conducted. There should be recognition that there are gaps in our knowledge and understanding of impacts from the device on receptors, which may result in necessary interim measures or monitoring.

The PEMP should also provide an opportunity to contribute to industry solutions both in terms of developing good practice and in developing new innovative approaches to industry-wide problems. Best-practice and innovation from developers in considering options for mitigation, monitoring and research is welcomed by the Regulator. Opportunities to explore should be wide-ranging, from simple demonstration of engineering concepts, to different ways of mitigating, monitoring, recording and analysing interactions between developments and all aspects of the environment. Through successful delivery of such work via PEMPs, developers working at EMEC test sites should collectively aid the progression of the sector to commercial-scale developments through enhancement of the evidence base.

6.2 Sources of Information

Section 4 of this document provides key information, containing broad and then detailed receptor-specific appraisals and identification of mitigation and monitoring options. Species licensing requirements are also appraised. Technical annexes provide further detail if required.

Section 5 of this document summarises the recommended mitigation and monitoring measures, and licensing requirements, identified across the individual appraisals. Research and site-wide monitoring projects that have been previously undertaken or are ongoing are also summarised. Familiarity with these should be used to guide the content of the PEMP.

Other sources of information of value include:

- EMEC Marine Mammal Observer (MMO) protocol
- Scottish Marine Wildlife Watching Code (SMWWC) and associated guidelines (www.marinecode.org)
- Non-natives good-practice management - guidance specific to the renewables industry has yet to be produced, but guidance for other related industries is useful:
    - A Code of Practice on non-native species has been published by the Scottish Government to provide guidance on the recently amended legislation in Scotland - www.scotland.gov.uk/Resource/0039/00393567.pdf
    - International Maritime Organisation (IMO) guidelines for the control and management of ships' biofouling to minimize the transfer of invasive aquatic species. Resolution MEPC.207(62). MEPC 62/24/Add.1 Annex 26. Adopted 15 July 2011 www.mardep.gov.hk/en/msnote/pdf/msin1136anx1.pdf
    - Guidance for the prevention and management of invasive species in the oil and gas industry - www.ipieca.org/publication/alien-invasive-species-and-oil-and-gas-industry
- Marine Scotland's marine energy research pages: www.scotland.gov.uk/Topics/marine/marineenergy/Research
- Scottish Government EPS guidance (in prep.)
- Draft Marine Renewables Licensing Manual http://www.scotland.gov.uk/Topics/marine/Licensing/marine/LicensingManual
- Research reports and peer-reviewed literature

6.3 Suggested Contents of a PEMP

6.3.1 Project Description and PEMP summary

- Summary of the PEMP's remit (from a device and developer point of view).
- Information on the designs, methods, equipment and other details to provide a thorough understanding of the project, including:
    - device design and operating characteristics
    - foundation/infrastructure installation methods
    - device deployment methods
    - maintenance methods, including device removal and redeployment
- Likely timescales and dates for the following phases:

- foundation and infrastructure installation activities
- device deployment(s)
- operation and maintenance activities, including device removal and redeployment (including likely frequency of repeat events)

- Construction Methods Statement (CMS) and Vessel Management Plan (VMP) -see below.
- Details of commitments to be undertaken by the developer (to include proposed mitigation, monitoring and research, and how/when these will be implemented).
- Reference to gaps in knowledge and understanding and how this will be addressed.
- Timetable for revision and finalising the PEMP, together with a reporting schedule for both mitigation and monitoring results. These documents may develop in an iterative fashion, but should be presented in a manner that maintains clarity in the version control and in the conclusions reached at each stage.

6.3.2 Mitigation proposed (by receptor category)

- Description of receptors and the potential residual impacts.
- Description of mitigation and recording procedures proposed.
- Reporting schedule:
    - results and effectiveness of mitigation, recommendations for improvement and future opportunities (including those that may be helpful for a commercial scale)

6.3.3 Monitoring proposed (by receptor category)

- Description of receptors and the potential residual impacts.
- Description of monitoring methods proposed, including recording and analysis procedures.
- Reporting schedule:
    - results and analysis of the monitoring, evaluation of the effectiveness of the monitoring undertaken, recommendations for improvement and future opportunities (including those that may be helpful for a commercial scale)

6.3.4 Appendices

- Summarised Table of Commitments.
- Recording templates.
- Copy of the relevant Marine Licence (and/or Section 36 consent) conditions when available.

6.4 Integration of the PEMP with the CMS and VMP

As stated above, a CMS and VMP should be included within the PEMP for projects at the Fall of Warness test site. This will allow these three elements (PEMP, CMS and VMP) to be developed as a ‘toolbox’ to help developers, contractors, vessel skippers and MMOs to discharge their responsibilities and for Marine Scotland to be assured of the discharge of licence conditions. The CMS and VMP sections of the PEMP should cover:

- Timing and duration of works.
- Detail of methods employed in marine works.
- MMO protocols.
- Personnel responsible for discharge of relevant conditions while at sea.
- Vessel management protocols and procedures relevant to potential environmental impacts (e.g. Good practice measures to minimise disturbance impacts upon wildlife from vessel movements and activity).

7 Summary

This Environmental Appraisal assess the potential impacts on relevant environmental receptors at the EMEC Fall of Warness test site during the installation, operation and maintenance phases of device and infrastructure testing. The appraisal focuses on the parameters described in the project envelope (Annex 1), and accounts for all installations to date plus those that may be proposed within the lifetime of the current seabed lease for the test site.

The appraisals described in Section 4 of this document, together with the subsequent Appropriate Assessment undertaken by Marine Scotland Licencing Operations team (available at http://www.scotland.gov.uk/Topics/marine/Licensing/marine/scoping/emec) constitute a Habitats Regulations Appraisal (HRA). MS-LOT are in agreement with the findings of the appraisal in Section 4 and are content that there will be no adverse effect on site integrity of any SPA or SAC provided the devices fit within the project envelope (Annex 1). Provided that a project falls within the parameters set out in the Project Envelope, it will be considered as pre-appraised in terms of its environmental impacts and no further environmental appraisal by Marine Scotland will be required. Projects falling out-with the envelope may necessitate additional appraisal and consultation, and further advice should be sought from EMEC in the first instance. This further appraisal will have to be agreed with MS-LOT and SNH in writing.

7.1 Conclusions from Receptor Appraisals

A detailed environmental appraisal of each receptor type present at the Fall of Warness test site was undertaken by SNH (see Section 4). The conclusions drawn from these appraisals are described below.

7.1.1 Benthic environment

The appraisal concludes that while the development footprint includes some rocky reef habitat, any potential impacts on the physical integrity of sedimentary substrates and of rock, boulder and cobble substrates are not regarded as important at the scale of the development and in the context of the wider environment.

Any potential impacts the biogenic habitats and sessile and low-mobility benthic species are considered as not of ecological importance. Good-practice mitigation should be applied to minimise the risk of introducing MNNS. In this regard monitoring of the colonisation of devices and infrastructure by benthic flora and fauna could also form part of a MNNS management protocol.

7.1.2 Fish and shellfish

The appraisal concludes that there is no LSE on salmon as qualifying features of any SAC, so no further consideration under HRA is required. Any potential impacts on diadromous species, gadoid species, clupeid species and elasmobranch species are not regarded as important at a Scottish population level. However, some monitoring and research in the context of the test facility could have merit. Potential impacts on any other marine fin-fish are not regarded as important at a population level.

Potential impacts on sandeels are not regarded as important at a population level, or of a degree that could have any measurable effect on key predators.

The appraisal considers any potential impacts on crustaceans and molluscs to be unimportant at a population level, but suggests that some monitoring and research in the context of the test facility would have merit, and good practice should be adopted to reduce any risk of introducing MNNS.

7.1.3 Hydrodynamic and physical processes

Any potential impacts on hydrodynamic and physical processes are not considered to be important at the scale of the development, but some device-specific monitoring by developers may have merit in informing impact assessments at commercial sites.

7.1.4 Basking sharks

The appraisal concludes that within the bounds of the project envelope description, potential disturbance and barrier impacts will not have any negative implications for the conservation status of basking sharks.

From the predicted collision risk estimates, it is considered that any potential impacts would not have negative implications for the conservation status of the species, nevertheless uncertainties relating to underlying data and collision risk modelling place particular emphasis on the importance of monitoring at the test site. It is also considered that the potential impacts from entanglement with mooring lines will not have negative implications for the conservation status of basking sharks.

The appraisal indicates that a licence to disturb basking shark will be required, to address potential disturbance impacts (e.g. drilling), and to cover the potential for collision with operational turbines. Furthermore, a licence to disturb basking shark will be required to cover the potential for injury or death from entanglement in mooring systems for any system that requires mooring lines and/or cables in the water column.

Regarding changes to hydrodynamics, the appraisal considers the potential for any effect on basking sharks at the Fall of Warness to be very low and not likely to be significant at a population level.

7.1.5 Cetaceans

The Moray Firth SAC is the only SAC in Scotland to have a cetacean qualifying feature (bottlenose dolphin) and although this species is wide-ranging, there have been limited observations in Orkney waters (Thompson *et al.* 2011). Harbour porpoise are a qualifying feature of the Skerries and Causeway SAC in Northern Ireland. The Fall of Warness is remote from this site (>300km) and despite the highly mobile abilities of this species, the site is considered to be too far away to have any measurable degree of connectivity. The appraisal concludes that there is no LSE to bottlenose dolphin as a qualifying feature of Moray Firth SAC, or to harbour porpoise as a qualifying feature of the Skerries and Causeway SAC, and an Appropriate Assessment is therefore not required.

Within the bounds of the project envelope description, the appraisal concludes that the potential disturbance impacts from installation noise will not be detrimental to the maintenance of the population of the five identified species concerned (Harbour porpoise, Minke whale, Risso's dolphin, Atlantic white-beaked dolphin, and Killer whale) at Favourable Conservation Status in their natural range. However, a licence to disturb EPS may be required to address potential disturbance impacts (e.g. drilling) during installation.

A licence to disturb EPS will be required to cover the potential for collision between turbines and cetacean species that may occur at the site. From the predicted collision risk estimates, it is considered that any potential impacts will not be detrimental to the maintenance of the population of the species concerned at Favourable Conservation Status in their natural range. Nevertheless, uncertainties relating to underlying data and collision risk modelling place particular emphasis on the importance of monitoring at the test site.

Any system that utilises mooring lines and/or cables in the water column will require a licence to disturb EPS, to cover the potential for injury or death from entanglement in mooring systems. It is considered that the potential impacts from such entanglement risk will not be detrimental to the maintenance of the population of the species concerned at Favourable Conservation Status in their natural range.

The appraisal considers the potential for any barrier effect and the effect of hydrodynamic changes on cetaceans at the Fall of Warness to be low and not likely to be significant at a population level.

The use of active acoustic monitoring devices (e.g. sonar) will require a project-specific appraisal and appropriate consultation to determine the need for a licence to disturb EPS and any additional mitigation and/or monitoring.

7.1.6 Seals

Grey seals are a notified feature of the Fary and Holm of Faray and Sandy SAC. Although there is possible LSE, provided that the principals of the SMWWC are followed and transits are considered via appropriate vessel management plans, the risk of harassment to seals hauled out at either of these consultation sites is likely to be minimal. The appraisal concludes that activities within the Fall of Warness project envelope will have no adverse impact and will not adversely effect the integrity of these sites.

The appraisal suggests that only impacts of collision risk with operational turbines and the potential corkscrew injuries from interaction with vessel propellers are of relevance for considering in relation to PBR and seal licensing under the Marine (Scotland) Act 2010. Due to the changing nature of PBR rates, predicted additional fatalities in relation to collision with operational turbines should be reviewed against the most up to date information at the time of Marine Licence/Section 36 application. Potential for corkscrew injuries and suitable mitigation will require project-specific appraisal.

7.1.7 Otters

European Otter is a qualifying feature of Loch of Isbister SAC. The appraisal considers that there is no LSE on otter and therefore no further consideration under HRA is required.

The installation or maintenance of cabling will require a project-specific appraisal and appropriate consultation to determine the need for a licence to disturb EPS. Disturbance, injury or death is considered unlikely from vessel usage or any interaction between otters and operational tidal turbines and therefore a licence to disturb EPS is not considered necessary for offshore activities.

7.1.8 Seabirds

There are no SSSIs in the immediate vicinity of the Fall of Warness which have any bird species as notified features. While some other coastal SSSIs in the wider area of Stronsay Firth and Westray Firth do have birds as notified features, and could conceivably be adjacent to transit routes for some vessels in use at the Fall of Warness, these areas already support a moderate amount of vessel activity, including creel boats likely to work in relatively shallow margins. It is therefore concluded that provided the principles of the SMWWC are followed by vessel skippers, any additional vessel traffic associated with the Fall of Warness test site is unlikely to add significantly to any disturbance impact or have any adverse impact on the notified bird features of these SSSIs.

Table 46 above provides details of SPA with various seabird species as qualifying interests for which there is potential for the Fall of Warness test site to have a LSE. This environmental assessment of the potential effect of the Fall of Warness test site on these qualifying species concludes that although there is a LSE, the appraisal carried out demonstrates that it will not adversely affect the integrity of any of these SPA.

The appraisal concludes that, for all seabirds, any potential impacts are not regarded as important at a Scottish population level, although monitoring of potential collision impacts has merit. Adherence to the guidelines associated with the SMWWC should sufficiently limit any residual disturbance impacts.

7.1.9 Seascape, coastal character, and visual amenity

The appraisal concludes that for all aspects of the seascape, landscape and visual amenity all potential impacts are regarded as unimportant.

7.2 Summary of Monitoring Required

Monitoring projects summarised in Table 58 below are largely suitable for delivery by individual developers. Other projects may have a site-wide or more strategic application and are more likely to be delivered by EMEC and/or their public sector or academic partners.

Note that the summary below should not be regarded as an exhaustive list of potentially relevant monitoring. **Developers are encouraged to independently consider impacts and the potential for developing new and innovative monitoring at the test site, not least because of the competitive advantage that assurance regarding the nature, or indeed absence, of impacts could provide.**

Impact/ Pathway	Receptors	Monitoring	Likely condition of licence/ consent?
Various	Birds; seals; cetaceans; basking sharks.	Site-wide monitoring of wildlife abundance and density is currently delivered by EMEC for the developers. In the event that EMEC become unable to fund or conduct this monitoring, each developer must contribute accordingly to the continuation of this monitoring and data analysis.	Possible
Various	Birds; seals; cetaceans; basking sharks.	Focal studies on animal behaviour in the vicinity of devices and marine works.	No
Marine non-natives	Benthic species and	Monitor colonisation of selected devices and infrastructure. This may also form part of a MNNS	No

(introduction/facilitation); Change to benthic communities	habitats; shellfish	management protocol or bio-fouling management.	
Collision with turbine blades	Cetaceans; seals; basking sharks; diving birds; fish	<u>All:</u> Use of appropriate method(s) to detect collision or near miss, and monitor any other interaction between mega-fauna and the operating device. Existing monitoring methods include use of strain gauges, video cameras, sonar, and hydro-acoustics. In practice, no single approach has yet been identified that is capable of detecting all such collisions or near misses. Accordingly, combinations of existing techniques and/or piloting of innovative new approaches is encouraged.	Yes
		<u>Fish & birds</u>: Any use of underwater lighting at night to be gradual and alongside monitoring to determine any fish/bird attraction and collision risk for predators.	
EMF effects	Diadromous fish; gadoids; elasmobranches.	*In situ* measurements of strength and range of Ei and B fields under different energy generation scenarios.	No
Habitat creation and fish aggregation	Fish and shellfish; benthic species and habitats; diving birds	Pursue passive and active monitoring on and around selected devices and infrastructure to inform knowledge base. This may also form part of a MNNS management protocol. Any use of underwater lighting at night to be gradual and alongside monitoring to determine any fish or bird attraction and collision risk for predators.	No
Changes to erosive and sedimentary processes	Hydrodynamic and physical processes	Monitoring changes to hydrodynamic forces around particular devices would provide data that could inform impact modelling for later commercial-scale proposals. Lambkin *et al* (2008) may provide some useful information.	No
Disturbance (foundation installation noise; vessel activity and transit; device operational	Cetaceans; basking sharks; seals; otters	<u>All</u>: Acoustic monitoring of drilling and anchor/mooring installation noise at various distances and frequencies, particularly if novel methods are in use. Establishing the acoustic signature of operating devices Reporting of observations from MMO records.	Yes

noise)		Seals: Depending on timing and duration of activities specific short term monitoring of, for example, seal haul outs may be required.	
Entanglement with mooring and cable system	Cetaceans; basking sharks.	Device monitoring should be capable of alerting the developer to an entanglement event (e.g. use of load cells, underwater video).	Yes
Barrier effects	Cetaceans; seals; basking sharks	Reporting of behavioural reactions through wildlife surveys (e.g. underwater video) and opportunistic observations.	No

Table 58: Potential monitoring measures for deployments at the EMEC Fall of Warness test site.

Although some of the monitoring suggested in Table 58 above is described as not being required by the Regulator as a licence/consent condition, developers may choose to undertake research in these areas for their own purposes. Where this is the case developers can include such monitoring projects within a 'Research and Development' section of their PEMP (which will not be subject to reporting requirements by the Regulator under consent conditions).

The EMEC MAG provides an ideal forum for discussion of research and monitoring initiatives that may be delivered at the test sites, and developers and their environmental consultants are encouraged to bring forward their ideas to this Group, via EMEC.

EMEC Fall of Warness Test site Environmental Appraisal

ANNEX 1

Project Envelope for Devices and Operations

Contents

1 Introduction

The European Marine Energy Centre (EMEC) provides testing facilities at the Fall of Warness, Eday, for developers of tidal stream marine energy converter devices to deploy and test in real-sea conditions. Testing is normally of entire devices with associated moorings, but may also include testing components of devices and testing of mooring systems. Each developer wishing to test at EMEC is required to apply for and obtain a Marine Licence from the Regulator, Marine Scotland (or a scientific exemption for some activities). EMEC has been granted several licences/consents to establish the site infrastructure and deploy scientific monitoring/data gathering equipment, and several developers have been granted licences/consents to deploy devices to date.

In 2005 EMEC commissioned an Environmental Impact Appraisal (EIA) for establishing the Fall of Warness test site, which resulted in the production of an Environmental Description of the site in 2006. This environmental documentation was upgraded in 2014 in order to further streamline the consenting process for developers coming to EMEC and to incorporate findings from the wildlife data collected from the site since June 2005.

This document describes the types and characteristics of MECS likely to be deployed for testing at the EMEC grid-connected test site at the Fall of Warness. It also describes the types of marine operations and activities likely to be associated with the installation, operation and maintenance of these devices. This information provides a ‘project envelope’ description against which the potential environmental impacts of installation, operation and maintenance of marine energy conversion systems (MECS) can be appraised. The project envelope is based on parameters from existing deployments at EMEC together with those emerging elsewhere in the UK.

2 Site Location

The EMEC grid-connected test site is situated in the Fall of Warness, off the island of Eday, Orkney (see Figure 1 below). The red lines show the approximate routes of the EMEC subsea cables (green line indicates a developer-owned cable), and the yellow line shows the approximate route of the cable for the EMEC fixed ADCP. The blue line shows the approximate route of the cable connecting the EMEC scientific monitoring pod to the EMEC sub-station.

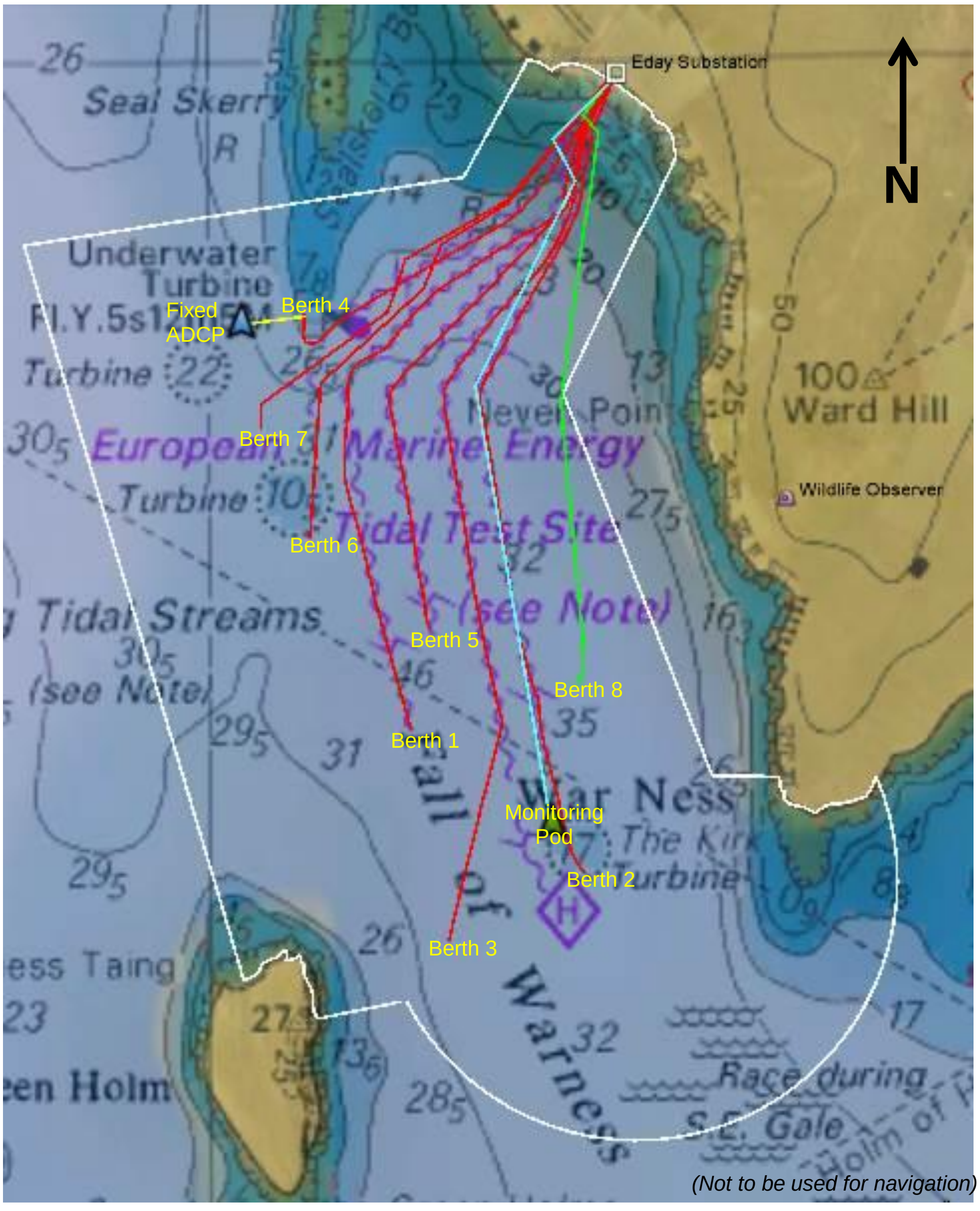

Figure 1: Map showing area of EMEC test site at Fall of Warness, Orkney.

The site boundaries are indicated by lines joining the coordinates shown in Table 1 below (outlined white in Figure 1 above). Essentially, the shoreward site boundary corresponds to the 30m depth contour as far as is practicable and safe.

Site	Coordinates
EMEC Test site, Fall of Warness, Orkney Islands.	Points along site boundary: 59° 09. 780'N 002° 47. 890'W 59° 09. 250'N 002° 48. 400'W 59° 08. 360'N 002° 47. 760'W 59° 08. 370'N 002° 47. 440'W 59° 08. 370'N 002° 47. 010'W 59° 07. 600'N 002° 47. 570'W 59° 07. 860'N 002° 49. 110'W 59° 07. 820'N 002° 49. 500'W 59° 07. 910'N 002° 49. 830'W 59° 09. 590'N 002° 50. 800'W 59° 09. 740'N 002° 48. 840'W 59° 10. 010'N 002° 48. 550'W

Table 1: Coordinates of the Fall of Warness test site.

3 Facilities

3.1 Existing Infrastructure at the Fall of Warness

The grid-connected test site occupies an area of approximately 4km x 2km and consists of 7+1[1] individually cabled berths. Each berth occupies a circular area of approx. 200m radius from the cable end, within which developers can install their device(s) and undertake testing activities.

Energy generated by devices at each test berth is transmitted via heavily armoured sub-sea cables back to a shore-based sub-station for onward transmission to the National Grid. The berths can accommodate single devices or small arrays as well as components or mooring structures.

The sub-sea cables connecting each test berth to the sub-station are laid directly onto the seabed. Cast iron cable protectors are installed around the cable at points where the cable free-spans over underwater obstructions. Concrete mattresses are laid across the cables to provide added protection at points where cables may cross one another. In total approximately 30km of sub-sea cable is installed at the site.

A fixed ADCP has been installed by EMEC at the NW end of the site (see Figure 1 above). This equipment sends data in real-time via the cable connecting berth 1 to the EMEC shore-based sub-station (a short cable connects the ADCP to the cable-end at berth 4).

A scientific monitoring pod has been installed approximately 100m west of the device currently deployed at berth 2. The monitoring pod contains a sensor array (temperature, turbidity and salinity sensors), hydrophones, an acoustic doppler current profiler (operating at 600kHz), and sonar (5-200kHz transmission bandwidth). The unit is connected by a sub-sea power/data cable to the EMEC substation on Eday, to provide power to the instruments on board and transmit data (see Figure 1 above).

EMEC's existing Embedded Generation Connection Agreement currently limits the total export capacity of the grid connection at the Fall of Warness site to 4MW, but it is envisaged that more grid capacity will become available. Under a generation scenario of >4MW, any environmental appraisals will still apply provided that the application details are within the bounds of the project envelope described here (i.e. number of devices and their physical parameters). Any devices falling out-with this project envelope will require further appraisal.

[1] Seven of the berths are serviced by EMEC-installed/owned cables. The cable servicing the eighth berth is currently owned by a developer.

4 Device and Operations Envelope

This project envelope will be used in the appraisal of the potential impacts of devices and operations at the EMEC Fall of Warness test site (e.g. EIA, HRA, etc). The following sections describe device parameters and deployment activities to be included within the envelope.

4.1 Potential Activities/Deployments

The following activities/deployments are included within the project envelope and should be considered by each receptor appraisal:

- Installation of new sub-sea cable and associated cable protection systems (mattresses, armour) where required and potential recovery and replacement on the seabed of existing cabling from berths to shore, and repair/maintenance to existing cables or cable protection systems.
- A maximum of 9 berths, accommodating up to 12 tidal energy devices at any one time, thereby supporting the testing of small arrays or additional non-grid-connected devices.
- Deployment of scientific instrumentation and associated cabling (see Section 6 for details).
- Testing of buoys (maximum of two simultaneous tests).
- Testing of mooring arrangements (e.g. tripod support structures) or individual stand-alone components of devices.
- Potential for simultaneous operations, i.e. installation or maintenance activities, at more than one berth at the same time (see Section 4.4.2 for details).

The following activities are ***not*** covered by this project envelope and would require further consultation and assessment/appraisal:

- Seabed preparation (e.g. seaweed clearance, rock grinding/blasting)
- Geotechnical and geophysical surveys (these are considered and, where necessary, licensed through the Notification of Site Survey procedures).
- Installation of energy storage devices above MHWS.
- Use of acoustic deterrent devices.
- Deployment and operational activities outside the parameters defined in this document.

4.2 Device Characterisation

The dimensions, materials, structure and weights of devices will vary. Devices included in the pre-appraised project envelope may feature the following blade/rotor designs:

- Blades with exposed tips (may include multiple rotors, on single or multiple axles)
- Blades with enclosed tips (may include multiple rotors, on single or multiple axles), including 'annular' and 'venturi' style devices.
- Blades with contra-rotating mechanism (may include multiple rotors, on single or multiple axles)
- Single or multiple Archimedes rotors

A summary of the default device/rotor maxima and other key envelope parameters are provided in Table 2 below. However, there are some variations and exceptions particular to the appraisal sections in the Environmental Appraisal document relating to collision risk modelling, as explained below.

Design/activity parameter	Project Envelope Maxima
Mooring/foundation design and installation method	As per section 4.3 below.
Rotor diameter	25m (open-bladed rotors – see comments below regarding 'annular' devices).
Number of simultaneous turbines/rotors	12 devices with up to 18 rotors
Rotor depth	Minimum depth - 2.5m clearance from sea surface

Table 2: Key development envelope maxima for EMEC Fall of Warness test site.

Collision/encounter modelling has only been developed for horizontal-axis 'traditional-style' open bladed devices and, to some extent, for 'annular' style devices. While most aspects of other device designs may fit within the EMEC Fall of Warness project envelope (e.g. foundation type, installation methods), applications for device designs not consistent with the modelling carried out to date may require further appraisal in this regard. Furthermore, rudimentary modelling of the 'annular' style device suggests encounter rates for equivalent diameter devices may, theoretically, be greater than for open-bladed devices for some species. Consequently, until this situation can be reviewed with more advanced modelling or other evidence, the project envelope is limited to allowing comparison of a 6m annular device with a 25m open-bladed rotor, while larger 'annular' designs may be substituted for multiple (i.e. 3:1 for 18 or 20m diameter annular rotors) 25m open-bladed rotors.

In addition to deployment of MECS, there may be a requirement to test devices associated with marine renewable energy which do not generate any electrical output, e.g. testing of associated buoyage, mooring systems, or energy storage devices. The use of energy storage devices within the Fall of Warness poses too many unknowns at this time, and therefore details of such devices have not been included within this project envelope. Any proposals to test energy storage devices will therefore be subject to separate environmental appraisal within the context of this envelope description.

Full device details including design, structure, materials and weights, and any device-specific mooring arrangement and foundation materials will be specified by the developer in the project-specific supporting documentation submitted to Marine Scotland as part of the Marine Licence (or Section 36 consent) application documentation.

4.3 Mooring/Foundation Infrastructure

EMEC does not generally provide mooring or foundation infrastructure at its grid-connected test site. Devices deployed at the site are installed utilising developers' own custom-made foundation/moorings. Methods used may include:

- Mono/twin-pile(s) fixed into the seabed (non-percussive drilling only)
- Tripod structure, pinned to the seabed (non-percussive drilling only)
- Tripod structure held on seabed by gravity
- Other mooring structure pinned to (non-percussive drilling only) or held on the seabed by gravity
- Gravity-based anchor(s) with mooring line(s) attached
- Embedment anchor(s) with mooring lines attached

The fixing of piles and pins into the seabed at this site involves the drilling of holes, followed by insertion of the pile/pin with grouting to secure its position. In this way the project envelope restricts pile/pin insertion to non-percussive methods (i.e. no pile driving).

Table 3 below describes mooring arrangements typically employed by developers at EMEC.

Mooring Type
Mono/Twin-pile(s) fixed to seabed (non-percussive drilling only - no pile driving)
Tripod structure, pinned to seabed (pinned using non-percussive drilling)
Tripod structure, held on seabed by gravity
Gravity-based anchor(s) with mooring line(s) attached (eg concrete, chain, gravel ballast)
Embedment anchor(s) with mooring line(s) attached

Table 3: Typical mooring methods at Fall of Warness test site.

4.4 Marine Works

The term 'Marine Works' is used in this document to describe any operational activities across all phases of a project (i.e. pre-installation, installation, testing, and maintenance). All deployment/retrieval methods will be in accordance with EMEC's Standard Operating Procedures (SOPs) and subject to EMEC's Emergency Response Procedures (ERPs). Methodologies will conform to health and safety and marine navigational safety requirements, and full method statements and risk assessments will be required for review and approval by EMEC prior to issue of a work permit to allow works to proceed. Notice to Mariners describing appropriate works will be issued as part of this process.

4.4.1 Range of developer marine works

Typical operational activities associated with the deployment and testing of marine energy converter devices and associated components and activities at the Fall of Warness are detailed in Table 4 below.

Activity	Likely vessels	Typical frequency/duration*
Pre-installation† • ROV/diver surveys • ADCP deployment/retrieval • Bathymetry surveys • Sub-bottom profiling • Acoustic surveys	Workboat, survey vessel, dive support vessel	=< 1 week
Installation • drilling & grouting • lowering foundation/anchors/nacelle • Cable works and connection to device	Tug, workboat, multicat workboat, dive support vessel, crane barge, DP vessel	=< 1 month
• Testing of nacelle, gravity foundations, anchors or scientific equipment • ADCP deployments • Acoustic surveys	n/a	This will be specified in the test schedule to be submitted by each developer as supporting documentation to Marine Scotland in support of seeking approval to install.
Inspection & maintenance of	Tug, workboat, multicat workboat,	This will be specified in the test

devices • ROV inspection • Diver activities • Repairs below/above surface on site • Biofouling removal	dive support vessel	schedule to be submitted by each developer as supporting documentation to Marine Scotland in support of seeking approval to install. Likely to be visits at regular intervals, over 3-12 months.
Temporary retrieval and redeployment of nacelle, gravity foundations, anchors or scientific equipment	Tug, workboat, multicat workboat, dive support vessel, crane barge, DP vessel	=< 1 month
Inspection, maintenance and replacement of cables and protection • ROV inspection • Diver activities • Cable lifting/laying • Placement of mattressing/rock armouring	Tug, workboat, multicat workboat, dive support vessel, specialist cable-laying vessel	=< 1 week

Table 4: Typical operational activities undertaken at the Fall of Warness.

*All schedules will be subject to suitable environmental conditions, and thus adverse weather may affect operations at the test sites. Some operations at the tidal site may require to be carried out during neap tidal cycles, so delays due to bad weather may cause schedules to slip significantly. This may result in works having to be rescheduled, and as a consequence, potentially falling within environmentally sensitive periods.

† Geophysical and geotechnical surveys are out-with the scope of the project envelope – Notification for Site Survey will be submitted to Marine Scotland for case-by-case consideration.

Table 5 below details some typical vessels which may frequently feature at the Fall of Warness test site. These vessel specifications are not given as maximum envelope figures, but are typical specifications (for information only) for vessels used to support activities listed in Table 4 above. Other vessels not listed below may be used at the site (specific vessels will be detailed in individual project descriptions). EMEC requires all vessels which engage in works at its test sites to use Automatic Identification System (AIS) to aid location and tracking.

Vessel type	Example vessel	Length (m)	Max. Draft (m)	Gross tonnage (t)	Max. Speed (kn)
Tug	MV Harald	32	4. 8	-	12. 8
Workboat	MV Flamborough Light	17	2. 2	21	-
Workboat (Cat 2)	MV Uskmoor	16	1. 7	-	9
Workboat (Cat 2) with dive support capability	MV Sunrise	21	3	-	8
Dive support boat	MV Karin	24	3	-	8
Survey vessel (ROV compatible)	MV Lodesman	22	-	-	8
Multicat workboat (Class 1)	MV Voe Viking C-Odyssey	26 26	2. 3 2.5	350 350	10 10

	Orcadia	24	2	370	10
Jack-up barge	Pauline	48	2. 5	-	n/a
Crane barge	MV BD6074 (Smit)	42	2. 5	750	-
DP Class II Anchor Handler Tug	MV Olympic Zeus	94	7. 5	6839	18
Specialist cable-laying vessel	CS Sovereign	130	7. 0	11242	12. 5

Table 5: Typical vessels employed in activity at the Fall of Warness test site.

The type of vessel used can often be driven by availability rather than function (e.g. workboat used as a dive support boat). Many of the activities listed in Table 4 above may require the presence of more than one vessel type on-site at the same time.

4.4.2 Simultaneous marine works

Developer access to EMEC test sites to undertake works of any kind is strictly controlled by EMEC under a Permit to Access the site system. Under this system the EMEC Operations team ensure that all work is carried out in a safe environment with minimal risk to health and safety and marine navigation. In addition to this, EMEC has Standard Operating Procedures (SOP) in place to ensure that simultaneous activities and operations carried out at EMEC sites are conducted using safe management and communication processes which are, so far as reasonably practicable, safe and without risk to health, safety or the environment (EMEC SOP093 & SOP095).

For environmental appraisal, the absolute *worse-case* scenario for simultaneous marine works at the test site would be for noisy activity (e.g. drilling for monopile installation) to be taking place at all eight berths over the same time period. Such a scenario however would be highly unlikely due to practical operational constraints (vessel/crew availability) and would not be permitted by EMEC on the grounds of navigational safety. A more realistic approach would be to consider a *worse-case* scenario as being noisy activity to be taking place at a maximum of two berths over the same time period, with inspection/maintenance activities happening at a maximum of two other berths simultaneously (although in practice even this scenario would be highly unlikely due to the constraints mentioned above).

Table 6 below describes the maximum simultaneous marine works likely to occur at the test site based upon consideration of a *worse-case* scenario as described above and experience to date. Further environmental appraisal may be required if a proposal would result in worse-case simultaneous marine works in excess of this envelope.

Activity	Marine Works	No. of Berths	Likely types of associated vessels
Pre-installation	Seabed survey; ADCP deployment/recovery	1	Survey vessel Dive support boat Workboat
Installation	Drilling; (Lowering gravity anchors or mooring system); (Lowering device)	2	DP vessel Multicat workboat Dive support boat
O&M	Device/infrastructure inspection; Device removal; Device redeployment	1	Survey vessel Dive support boat Multicat workboat
Other	ADCP deployment/recovery; Acoustic survey	across site	Workboat Survey vessel
Max. No. of vessels operating at site simultaneously:			**14**

Table 6: Worse-case maximum simultaneous marine works based on experience to date.

Marine works at the Fall of Warness test site typically involve periods of inactivity due to weather/tidal flow conditions, during which vessels may move away from the berth/site. Therefore in the scenario described above all vessels would not necessarily be working concurrently all the time.

4.5 Scientific Instruments

Developers planning to deploy devices in the EMEC test sites need to have a good understanding of the resource into which deployment will be made, so data gathering using acoustic doppler current profilers and wave measurement buoys is essential, for device design and planning of operations. In addition to the developer need for resource data, EMEC operates as a UKAS-accredited performance assessment facility for the testing of wave and tidal energy conversion devices, whichrequires real-time resource assessment of the MetOcean conditions at the test sites. In addition, there is an increasing requirement for studies involving acoustic measurement, benthic investigations (e.g. ROV survey, grab samples etc.), and geological investigation (e.g. core sampling) at the test sites.

It is envisaged that the following categories of scientific instruments/procedures will need to be deployed at the EMEC test site from time to time and will be included within the project envelope when undertaking environmental appraisal:

- Acoustic Doppler Current Profilers - various types may be deployed, e. g. ADCP.
- Wave Measurement Buoys - e.g. Waverider buoys, Triaxis buoys (combined wave and current measurement)
- Acoustic measurement devices (passive recorders) - may be seabed mounted, mid-water moored buoys, or drifting hydrophones and associated equipment
- ROV surveys
- Testing of anti-fouling coatings (using commercially available products approved for use in the marine environment)
- Underwater cameras
- CTD measurement instruments (to measure conductivity, temperature, and water depth)
- Potential redeployment of EMEC monitoring pod, including associated cabling, to alternative locations within the test site.

Note that instrumentation with active acoustic properties (e.g. sonar) will not be appraised and will require consideration on a case-by-case basis to determine the need for a licence to disturb European Protected Species. Where such acoustic devices are part of pre-installation surveys (e.g. geophysical surveys), Marine Scotland should be consulted via the Notification of Site Survey process.

The instruments described above may be deployed as single devices or in combination as part of a scientific monitoring package (e.g. ADCP, acoustic recorder, underwater camera and active sonar installed within a seabed mounted scientific monitoring pod). Deployment of instrumentation may be short-term (up to 3 months at a time) or longer term,. In the latter case data-transfer to shore may be via wireless (e.g. waverider buoys) or cabled to shore (e.g. a seabed-mounted monitoring pod, long term deployment of hydrophones etc.).

All equipment will be appropriately marked and lit where required. Instrumentation may be housed in or attached to a suitable foundation structure. Instrumentation will be anchored with gravity bases or clump weights as appropriate, but not drilled into the sea floor.

For any scientific instrument deployments which may have the potential to cause an obstruction or danger to navigation, EMEC will consult with the Northern Lighthouse Board and Orkney Islands Council Marine Services and comply with any advice on marking and lighting requirements.

EMEC Fall of Warness Test site Environmental Appraisal

ANNEX 2

Habitats Regulations

The two most influential pieces of European legislation relating to nature conservation are the Habitats and Birds Directives. The 'Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora' was adopted in 1992 and is commonly known as the Habitats Directive. It complements and amends (for classified SPA) Directive 2009/147/EC of the European Parliament and of the Council on the conservation of wild birds (this is the codified version of Directive 79/409/EEC as amended), commonly known as the Birds Directive.

The Birds Directive protects all wild birds, their nests, eggs and habitats within the European Community. It gives EU member states the power and responsibility to classify Special Protection Areas (SPAs) to protect birds which are rare or vulnerable in Europe as well as all migratory birds which are regular visitors.

The Habitats Directive builds on the Birds Directive by protecting natural habitats and other species of wild plants and animals. Together with the Birds Directive, it underpins a European network of protected areas known as Natura 2000 comprising Special Protection Areas (SPAs) classified under the Birds Directive and Special Areas of Conservation (SAC) designated under the Habitats Directive.

The Habitats Directive is transposed into domestic law in Scotland by the 'Conservation (Natural Habitats, &c.) Regulations 1994' which came into force on 30 October 1994 – commonly referred to as the **Habitats Regulations**. Certain provisions of The Conservation of Habitats and Species Regulations 2010, as amended (the "2010 Habitats Regulations") apply to Natura sites in Scotland where they may be affected by activities consented under Section 36 or Section 37 of the Electricity Act 1989.

Habitats Regulation Appraisal

Where a plan or project could affect a Natura site, regulation 48 of the Habitats Regulations requires the competent authority (the authority with the power to undertake or grant consent, permission or other authorisation for the plan or project in question) to:

- determine whether the proposal is directly connected with or necessary to site management for conservation; and, if not,
- determine whether the proposal is likely to have a significant effect on the site either individually or in combination with other plans or projects; and, if so, then
- make an Appropriate Assessment of the implications (of the proposal) for the site in view of that site's conservation objectives.

This process is now commonly referred to as **Habitats Regulations Appraisal** (HRA). HRA applies to any plan or project which has the potential to affect the qualifying interests of a Natura site, even when those interests may be at some distance from that site.

The competent authority (Marine Scotland), with advice from SNH, decides whether an Appropriate Assessment is necessary and carries it out if so. It is the applicant who is usually required to provide the information to inform the assessment. Appropriate Assessment focuses exclusively on the qualifying interests of the Natura site affected and their conservation objectives. A plan or project can only be consented if it can be ascertained that it will not adversely affect the integrity of a Natura site (subject to regulation 48 considerations).

EMEC Fall of Warness Test site
Environmental Appraisal

ANNEX 3

Detailed Collision Risk Assessment:
Marine mammals, Basking Shark, and Diving Birds

(Bill Band, September 2014)

Contents

1 Introduction

This report presents a generic assessment of the collision risk to marine mammals, basking shark, and diving birds resulting from the installation of tidal energy generating devices which may be installed at the European Marine Energy Centre (EMEC) test site at the Fall of Warness, Orkney.

The marine mammal species considered are:

- Harbour porpoise
- Harbour seal
- Grey seal
- Minke whale

The diving birds considered are

- Eider
- Red-throated diver
- Gannet
- Cormorant
- Shag
- Black guillemot
- Common guillemot
- Razorbill
- Puffin

The paper also considers collision risk with basking shark.

The primary objective of this paper is to predict potential collision rates for a 'maximum scenario' representing the situation if all test berths were occupied with tidal generating devices of the maximum scale likely, as described in the Fall of Warness project envelope (Section 2). However this paper also provides context by modelling collision rates for single devices and for the current scenario – the set of devices presently deployed or planned. As such, key objectives of this paper are to evaluate collision risk for:

- a single tidal turbine with a rotor 25m diameter and 3 blades; showing how the risk varies with number of blades (2, 3 or 4), rotor diameter and depth of installation; how the risk varies across the nine berth sites; and, for diving birds, showing how the risk breaks down for each species as between breeding season and non-breeding season;
- the currently-planned scenario (July 2014) wherein devices are installed or expected to be installed in the existing eight test berths. Two of the devices have two rotors, and the devices are of various depths and diameters;
- a 'maximum case' of a fully-occupied test site with 12 devices across 9 berths of which 6 have a single 3-bladed rotor, 6 have two 3-bladed rotors, 25 m diameter, thus totalling 18 rotors. This combination is considered to represent the 'maximum case' in terms of the maximum number and size of devices/rotors at any time.

Model development has thus far been focussed upon horizontal axis turbines with a 'traditional' open-bladed design (e.g. similar in form to conventional wind turbines), with alternative device-types requiring adaptations to these models or, potentially, completely new models. Consequently, this modelling exercise explicitly excludes the following, plus any other unforeseen designs:

- Vertical-axis turbines
- Archimedes screw device-types
- Venturi device-types

However, the assessment does consider the collision risk potentially arising from two less common device designs:

- a single turbine with two contra-rotating rotors
- an annular (ring) device

An annualr style device is already in place at the site, so it is important that it is considered as part of the Fall of Warness project envelope.

The models used to evaluate the possible rate of encounters between marine animals and devices are highly generalised, and based on devices of a traditional open rotor design. In particular, no account is taken of the role of fluid dynamics around different structures/device designs in influencing the potential encounter rate. Device-specific variations to this modelling approach may well be appropriate, particularly for novel designs.

This collision risk assessment was originally carried out in September 2013, and the outputs discussed with EMEC, Scottish Natural Heritage (SNH) and Marine Scotland at a meeting in February 2014. As a result of these discussions this updated version of the assessment was commissioned, the principal objectives being:

- to correct a misunderstanding over the number of site scans undertaken in each observation period in the wildlife survey programme;
- to extend the analysis to use the 15 observation grid cells covering the core of the EMEC test site as the basis of analysis, rather than the 10 grid cells close to current berths;
- to update the animal densities using observation data available to 2014

For the September 2013 assessment, data on marine mammal and diving bird densities were provided by SNH who undertook the analysis of survey datasets provided by EMEC. For this current version, all animal densities have been recalculated by the author, using the same general methodology as used by SNH but starting with an EMEC dataset spanning the period July 2005-March 2014. Section 4 (EMEC Wildlife Observation Programme) describes in detail how the EMEC data was manipulated to derive the animal densities used in the collision risk assessment.

2 Models Used

The assessment uses two alternative models to evaluate the 'encounter rate' or 'no-avoidance collision rate' for the animals considered. The main model used is the Encounter Rate Model (ERM). An 'encounter' occurs whenever the trajectories of animals and turbine blades are such as would lead to a collision, assuming no avoidance action whatsoever is taken – either emergency avoidance action in the vicinity of the rotors or avoidance of use of the site by the animals. However some results are compared with the results of the Collision Risk Model (CRM), used widely in assessing collision risk of birds with windfarms.

The terminology used in the two models differs, but the output is similar in nature:

'Encounter rate' as calculated in the ERM is equivalent to
'Collision risk assuming no avoidance' in the CRM.

For both models, considerations of avoidance then lead to applying an appropriate factor to make allowance for avoidance, and hence an assessment of potential or likely collision rates. The analysis in this paper shows the effects of applying a range of avoidance factors but does not consider which of the avoidance factors are appropriate.

2.1 Encounter Rate Model

The main model used is the ERM described by Wilson *et al* (2007) but with the relevant formulae corrected as described below. This model is based on one used to describe the encounters between marine predators and prey. The key result for each species is an estimated annual encounter rate.

The ERM considers the number of animals likely to encounter each blade, treating a blade as a 'predator' and the animal potentially subject to collision as the 'prey'. The animals are assumed to be swimming in random directions relative to the water body, and with random orientation, usually in the direction of their swimming.

The ERM does not take account of blade shape, and hence contains simplifications in terms of the geometry of collisions, so there are significant errors in the model. Nonetheless I have concluded in a previous review (Band, 2012b) that it is a valid model which gives a reasonably good order of magnitude for encounters between turbines and marine mammals. Subject to the following reservation, this is also likely to be true for diving birds.

For small animals, the ERM is likely to over-estimate encounter rate, as it does not take account of the geometry of the blade and under-estimates the likelihood that a small animal moving downstream may pass between blades, making use of the pitch of the blade to allow free passage. This may apply to the smaller of the diving bird species considered in this report; it would also apply if the model were used for smaller species such as fish.

For large animals like marine mammals, an encounter with more than one successive blade is quite possible. As the ERM calculates the encounter rate with individual blades, rather than with the turbine as a whole, it counts such events as multiple encounters, which may be hard to interpret. In contrast, the CRM counts such events as a single no-avoidance collision. This is an issue particularly for basking shark and minke whale, because of their body length. It is unlikely to be an issue for diving birds, the largest of which is only a little over one metre wingspan.

2.2 Collision Risk Model

The assessment also calculates encounter rates using the SNH/Band CRM (Band, 2000; Band 2012a) which is widely used to estimate the risk to birds flying through wind farms. In a first stage, the model calculates the number of turbine transits which would be made by birds during a period such as a year. In a second stage, it multiplies that transit rate by the collision risk for a single transit, calculated using the geometry of an idealised bird and turbine.

The idealised bird shape used in the model is as shown in Figure 1 below, flying in a direction along its longitudinal axis and with its flapping wings describing nearly a full circle (shown in blue). This shape is quite well matched to the shape of a marine mammal, if the circle mapped out by the flapping wings is replaced by a body cross-section, at its widest point, of the marine mammal; such that the marine mammal is pictured as two solid cones, stuck together base to base. However the idealised shape is not particularly well matched to the shape of a diving bird – especially as the orientation of a steeply diving bird when swept through a turbine by a tidal current seems likely to be very variable.

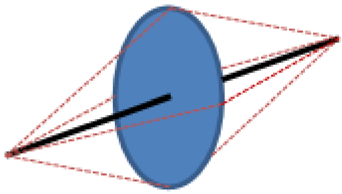

Figure 1: Idealised shape of an animal (red dotted lines) used in collision risk model.

The CRM is also unsatisfactory because of its assumption that all birds fly in a horizontal plane and normal to the plane of the rotor. This is an assumption very much untrue for diving birds which dive at a relatively small angle relative to the rotor plane. The assumption made by the ERM is that incoming animals have trajectories and orientations which are randomly distributed with respect to the water body. This is also not wholly true, but is more akin to the reality than the assumption made by the CRM. Nonetheless, in calculating the risk of collision for an animal swimming horizontally and directly towards a turbine, and in quantifying the number of transits made in a given time period, the CRM provides some insight as to the likely order of risk to animals making a passage through a marine turbine.

For devices which are not simple open rotors, the second stage of the CRM calculation (the probability of collision for a single transit) may be replaced by some other calculation of the risk for a single passage through the device.

2.3 Exposure Time Approach

The 'exposure time approach' has been developed by Grant, Trinder & Harding (2014) during the course of this work. It avoids attempting any quantitative assessment of collision risk for animals passing through turbines, or avoiding them, but estimates the minimum collision rate required to have a damaging effect on species populations. Given the limited knowledge base and poor understanding of the underwater movements of diving birds and their behavioural responses to underwater devices, SNH consider this approach an appropriate and useful method for assessing collision risk for diving birds. However for the purposes of this study, and in the interest of developing some quantitative estimates of the potential for collision, the ERM model has been preferred. Despite its substantial simplifications, it provides a valid order-of-magnitude estimate of the potential encounter rate (ie before factoring in avoidance behaviour) with blades of a turbine.

2.4 Formulae Used by Models

This section summarises the formulae used by the models in calculating encounter rates. Further detail is provided in Appendix 2 of this document.

Animal density

The encounter rate in both models is proportional to the true density D, i.e. the number of animals per m^3. Areal density D_A is the number of animals at any depth in unit area of sea, expressed in animals m^{-2} or animals km^{-2}. Assume a proportion Q_{2R} swim at depths within the risk depth range of the turbines, that is from the lowest point of the rotor to the highest point of the rotor, a depth range of 2R in total if R is the radius of the rotor. Then the areal density of animals swimming in this risk depth range is simply D_AQ_{2R}. The true density, assuming that they are uniformly distributed throughout that range, is:

$$D = D_AQ_{2R} / 2R \qquad (1)$$

D is the true animal density, i.e. animals per m^3
D_A is the animal density measured in area terms, i.e. animals/m^2 at any depth
Q_{2R} is the proportion of animals within the range of depths at risk of collision, from the greatest to the least depth of a turbine, i.e. twice the turbine radius
R is the turbine radius

Different turbines may occupy different depth ranges and hence Q_{2R} is highly dependent on the turbine and its diameter.

Encounter rate model

Z is the encounter rate for a single turbine, and must be multiplied by the number of turbines, and the time operating, to yield an estimate of the number of encounters in a given period:

$$Z = D\ b\ (w+2r)\ (R+r)\ v\ (1 + (u^2/3v^2)) \qquad \text{where } r = L/f \qquad (2)$$

D is the 'prey animal' density, per m^3, given by equation (1)
b is no of blades
w is the width of a turbine blade, as viewed along the direction of relative approach
R is the length of a turbine blade
f is a shape factor between 2 and 4 (see below)
r is the effective encounter radius of the prey animal, mean equal to L/f
L is the length of the prey animal
v is the blade speed relative to the water
u is the prey animal's swim speed relative to the water

The spreadsheet 'Diving birds ERM' undertakes this calculation for the species considered in this report.

Shape factor

The ERM was developed from a model used to estimate interactions between predators and prey in the marine environment. Prey were assumed to be spherical with diameter L and radius r = L/2. If their trajectory came closer than radius r to the range of the predator (also assumed spherical) then the predator would 'encounter' the prey. When applying this to animals like fish which are long and thin, not spherical, an 'effective radius' is used to allow for the probability that the long dimension of the 'prey' animal may be aligned so as to have a minimum cross-section relative to the predator. If random alignment is assumed, then the effective radius can be shown to be halved, i.e. r=L/4 (Band, 2012b).

More generally, one can take the effective radius to be L/f where f is a 'shape factor'. The limits of the shape factor are 2 (for a spherical prey) and 4 (for a long thin stick-like prey). Appendix 3 of this report provides a detailed calculation of the appropriate shape factor for a 'flat disc-shaped prey', evaluated as 2.55. Marine mammals and diving birds which use their feet to propel themselves underwater have been modelled as long thin stick-like prey (f=4), while diving birds which use their wings to scull underwater have been modelled as flat disc-shaped prey (f=2.55).

In principle, this approach opens the possibility of using an intermediate shape factor which is not linked theoretically to a particular shape (sphere=2, disc=2.55 or stick=4). However that course is not followed in this report; the animal shapes are all modelled as either discs or sticks.

Collision risk model

No of collisions = No of transits x Risk of collision during a single transit (3)

For a single turbine,

No of transits = $D (\pi R^2) v$ (4)

D is diving bird density, in animals/m^3, given by equation (1)
πR^2 is the cross-sectional area of a turbine
v is the speed of the diving bird relative to the turbine

It is assumed that the birds are swimming in random directions relative to the water, such that their speed relative to the water body averages to zero. The mean speed of a diving bird relative to the turbine is therefore approximated by the mean current speed. This is a simplification; actually there will be a distribution of speeds determined by the vector combination of current speed and the swim speed (in random directions) of the bird, and the collision risk depends in a non-linear way on that combined speed.

Risk of collision during a single transit =

$p(r) = (b\Omega/2\pi v)\ [\ |\pm c \sin \gamma + \alpha\, c \cos \gamma| + \max (L, W\alpha)\ ]$ averaged over rotor area (5)

where
r is the radius from the rotor centre at the point of transit
b is no of blades
Ω is rotational speed
v is speed of animal relative to rotor
c is the chord width of the blade
γ is the pitch angle of the blade, relative to the rotor plane
L is the length of the bird
W is its wingspan
$\alpha = v/r\Omega$

The + sign in the $\pm c \sin \gamma$ term refers to upstream passage; the – sign to downstream. The majority of transits will be downstream, swept by the current, so the negative sign option in equation (5) is used hereafter in this report, appropriate for downstream travel.

As diving birds swim upwards or downwards at a steep angle, the orientation of a diving bird relative to the rotor is uncertain. For this analysis both the length dimension L and the wingspan W are set equal to the wingspan (consistent with using, in the ERM, the wingspan as the basis for calculating the effective radius).

A spreadsheet (Band, 2000) was used to calculate this average p(r); this is included as the 'Single transit risk' sheet in the spreadsheet accompanying this report[1].

Modified collision risk model

The CRM approach is particularly helpful when considering non-standard turbines, for which it may be possible to estimate the probability of collision during a single transit, without detailed recourse to the geometry of the device.

Annular devices have a ring of blades, surrounding an open central core (e.g. the OpenHydro device installed at EMEC). The open core is typically sufficiently large to allow clear passage through for small animals of the size of a diving bird. A simple approach to collision estimation is to regard 'porosity' of the structure as given by the area of the open core as a proportion of the overall device cross-sectional area, though allowing for the body-width of the animal to clear the annulus, either within the open core or outside the turbine:

Probability of passing through without collision =

$$\pi (R_{in} - r)^2 / \pi (R_{out} + r)^2$$

where R_{in} is the inside radius of the annulus, R_{out} the outside radius, and r is half the effective bodywidth of the animal. The probability of collision is therefore

$$p(coll) = 1 - (R_{in} - r)^2 / (R_{out} + r)^2 \quad \ldots \quad (6)$$

Having calculated p(coll), this may then be used in a modified CRM approach.

First, the animal density in the water column is calculated in the same way as for the ERM or CRMs, including any adjustments for animals unseen because they are underwater, or for watch time, then using the dive frequency and the time per dive at risk depth to calculate the proportion at risk depth. The number of transits per year is then calculated as in the first stage of the CRM approach: number of transits = D A u t where u is the speed of approach, taken as the mean current speed, and t is the no of seconds in a year. The number of transits is then multiplied by p(coll), calculated using equation (6), to give the expected number of no-avoidance collisions per year.

In this paper, the approximate proportions of the OpenHydro device are used to provide a proxy for annualr devices. This is highly generalised however, and device-specific variations to this modelling approach may be appropriate.

Contra-rotating rotor devices

Some devices are planned with contra-rotating rotors, that is with two rotors mounted on the same axis but operating in reverse rotational directions. The two rotors may be designed

[1] Available on request from SNH.

with different numbers of blades and different rotational speeds, so as to minimise the likelihood of cyclic stresses on the supporting structure.

Let the collision risk through each of the two rotors, i.e. the probability of colliding with the rotor, be f1 and f2 respectively. Then the probability of safe passage through the first rotor on its own is (1-f1), the probability of safe passage through the second rotor on its own is (1-f2), and hence the probability of a safe passage through both rotors is (1-f1)(1-f2). The probability of collision during an attempted passage through both rotors is then the inverse, i.e. 1 – (1-f1)(1-f2), which simplifies to:

Collision risk = f1 + f2 – f1 f2

Thus, the CRM may be used for each rotor separately to find the collision risk for each rotor separately. If these calculated, say, to 26% and 38% then:

Combined collision risk = 0.26 + 0.38 – (0.26*0.38) = 0.54 or 54%

This collision risk may then multiplied in the usual way by the number of transits per year to get the collision rate per year.

The formulae above demonstrate that the combined collision risk for a two-rotor contra-rotating device will never be greater than the sum of two separate but otherwise equivalent rotors. The analysis which follows of the current scenario and maximum scenario include the collision risk for each rotor separately, hence it represents a ‘maximum case’ in which rotors are independent. If a pair of rotors are mounted so as to contra-rotate, the encounter rate will reduce by the proportion represented by the - f_1f_2 term.

3 Project Installations

3.1 Turbine Details

The underwater turbines are modelled in a very simple way. In the ERM, a turbine blade is assumed to have a length R and a width w, and a mean blade speed v, which is the speed of the midpoint of the blade. In the CRM the blade also has a pitch (relative to the rotor plane), and it has a chord width and tapering profile.

Information is not available on the rotational speed of the turbines. However tidal generation theory indicates that for effective generation, the 'tip speed ratio' , i.e. the ratio between the blade tip speed v_{tip} and the current speed c , should be around 6.0 for a 2-blade device, 5.0 for a 3-blade device, and 4.0 for a 4-blade device. These are drawn from various articles on tidal generation and may well require revision in the light of better information and further practical experience. Thus:

$v_{tip} = c\,\lambda$ where λ is the tip speed ratio

and v (mean blade speed, measured at midpoint of blade) $= c\,\lambda / 2$

EMEC have provided hourly tidal records over a complete one-month cycle (23/12/2009 to 23/1/2010). These show an average current speed c in the Fall of Warness of 1.61 m s^{-1}. However, there are periods when a tidal turbine will be inoperative because the current speed is too low or too high. As the collision risk is assumed zero for a stationary turbine, these periods must be excluded from the average current flow during operation. Excluding these periods (see 'operational time' below), the average current speed c is 1.82 m s^{-1}.

The parameters used for this analysis are as follows:

b=2, 3 or 4	For turbines with 2, 3 or 4 blades.
w = 0.3m	The turbine blade is assumed to have an average width (from front to back) of 0.3M, a chord width of 0.6m and an average pitch of 30 degrees.
R	The key result uses a 'maximum case' assumption of a rotor diameter of 25m (radius R=12.5m).
λ	Tip Speed Ratio: assumed to be 6.0 for a 2-blade device, 5.0 for a 3-blade device, and 4.0 for a 4-blade device. The tip speed is thus assumed to be λv.
c	Current speed 1.82 m s^{-1} (see above)
v	The mean blade speed is then taken as the speed of the midpoint of a blade, being half the tip speed: $v = c\,\lambda /2$
Ω	Rotation speed Ω is given by RΩ = tip speed. The result is then converted from radians s^{-1} to rpm (revolutions per minute). Table 1 below shows the assumed mean blade speed and the rotation speed for rotors with 2, 3 and 4 blades.

	λ tip speed ratio	mean blade speed ($m\ s^{-1}$)	Ω assumed mean rotation speed (rpm)
2 blades	6.0	5.46	8.34
3 blades	5.0	4.55	6.95
4 blades	4.0	3.64	5.56

Table 1: Assumptions on tip speed ratio, mean blade speed and mean rotation speed.

At present data is not available on the blade width profile of a turbine blade, or the pitch of the blade (which will vary along the length of a blade). The CRM spreadsheet calculations therefore use the variation of blade width with length for a wind turbine, and a constant pitch of 30 degrees (relative to the rotor plane). These aspects may be refined if more detailed information on typical marine turbines is made available.

3.2 Operational Time

Tidal turbines may not be operational when the tidal current is too low (below 'cut-in speed') or when it is too strong (above 'cut-out speed'). They may also be inoperative when closed down for repair, maintenance or development work, or if the grid is temporarily unable to accept the power generated. Different turbine designs may differ in cut-in and cut-out speeds, though an ongoing aim of their developers will be to maximise the proportion of time during which they can operate.

For this assessment, cut-in and cut-out current speeds of 0.5m/sec and 4.0m/sec have been assumed; this is the widest quoted range of the tidal turbines in the MeyGen assessment. Using hourly channel velocities in the Fall of Warness channel as provided by EMEC for the period 23/12/2009 to 23/1/2010, and evaluating these in relation to the cut-in and cut-out speeds of the turbines, gives 12.4% of time when the current is below cut-in; and the current never exceeds cut-out speed. Thus the assessment assumes that turbines will be inoperative for 12.4% of time because of unsuitable current speeds. It should be noted that this figure is based on only one month's tidal speed data; given the fluctuations in tides over a year it would be preferable to use a complete year of data for this calculation. It should be noted that the result is a product both of the distribution of tidal current speeds in the Fall of Warness, and the cut-out speeds assumed for the tidal turbines used; the proportion of inoperative time would differ at different locations or if different turbines were used.

No allowance is made in this assessment for non-operational times due to maintenance, development work or grid constraints. The collision rates in this assessment should simply be multiplied by the proportion of time the machines are available for operation.

3.3 Current Scenario

The berths at the EMEC Fall of Warness test site are currently (July 2014) only partially occupied, but commitments have been made to test different devices in eight of the berths. These devices have different sizes and different installation depths. Table 2 below shows the rotor sizes and depths assumed for each of these eight berths, based on information currently available.

	berth 1	berth 2	berth 3	berth 4	berth 5	berth 6	berth 7	berth 8	total
number of rotors	1	1	1	annular device	2	1	1	2	**10**
diameter	21	20	20	6	20	18	16	8	
depth range	17-38m	14-34m	15-35m	2.5 -8.5m	3-23m	10-28m	10-26m	4-12m	

Table 2: Current scenario – devices currently installed or planned in each berth.

Encounter rates for the current scenario have been based on the assumption that devices have only 12.4% non-operational time, due to rotors not spinning during slack tides. In practice it may be expected that during the trial phase of development when devices are installed at EMEC, there may initially be a very high proportion of time when devices are closed down for repair or maintenance or during data analysis; and indeed devices may from time to time be towed off-site for maintenance or modification. Therefore, ideally, all the total encounter rates in the 'current scenario' tables should be multiplied by some factor representing the average proportion of time that devices are 'operationally active'. (A device is 'operationally active' if it operates at suitable tides, albeit that some of the time it will not operate due to slack tides.) Thus:

Encounter rate = Encounter rate assuming only 12.4% non-operational time x Proportion of time device is operationally active

The proportion of time a device is 'operationally active' may increase over a period of years, as testing moves from prototype to full-scale commercial 'road-testing'. This stage can only be calculated for each device when detailed information is available on test cycles and timing; indeed it may only be possible to calculate it in arrears. Developers for each device might be asked to predict the 'operationally active proportion of time' , and how that is likely to change over the time installed at EMEC, as part of the environmental information supplied to EMEC; though such predictions are very likely to change in the light of their operational experience.

3.4 Maximum Scenario

The EMEC tidal energy test site is designed to accomodate a number of devices on test. Potentially, 12 devices could be accommodated at any one time. This assessment therefore covers what is judged to be a realistic 'maximum scenario' in terms of environmental impact:

12 devices distributed across the EMEC test site:

6 devices each with a single open rotor, 3-bladed, diameter 25m
6 devices each with two open rotors, 3-bladed, diameter 25m
i.e. 18 rotors in total.

Consideration is also given to the possible collision impact of devices with an annualr design.

It is assumed that all devices are 100% operational except to the extent of slacks in the tidal current, i.e. the assumption is maintained that turbines will be inoperative for 12.4% of time because of unsuitable current speeds.

4 EMEC Wildlife Observation Programme

The EMEC wildlife observation programme has included regular survey of an area of approximately 8.75 km^2 covering the tidal test site, since July 2005. Observations have been made using binoculars and telescope from a single observation point on the island of Eday over-looking the test site. The area of sea was notionally divided into a 7x5 grid of 500m x 500m squares, and bird and marine mammal counts were located by square. The division was 'notional' because there were no boundary markers, so the allocation to grid square was a matter of estimation by the observer. Figure 2 below shows the grid of squares, and the position of the wildlife observer. The fifteen squares in the centre of this grid - squares B-1, B0, B1, B2, B3; C-1, C0, C1, C2, C3; and D-1, D0, D1, D2, D3 – are considered to form the core of the EMEC test site.

Figure 2: Map of grid squares used for Wildlife Observational programme.

In each week there were normally 5 days of observation, i.e. 20 days in each month. Each observation day involved four observation hours, thus each month included around 80 hours of observation. The exact number of hours for each month is recorded in the data. Each observation hour comprised four 15-minute scans. Two of these scans are entire-site scans using binoculars, while the other two scans each cover half the site, using a telescope. It has been assumed, therefore, that each hour of observation represented 3 full scans of the site. During each scan a count was maintained of diving birds and any marine mammals and basking shark visible at the sea surface. Birds in flight were not included. No allowance was made for animals underwater at the time of the scan.

For certain animals – cetaceans, seals, shags and cormorants, and diving birds, it was not always possible to identify all sightings to species level. Such sightings were recorded eg as ‘unidentified cetacean’ or ‘unidentified phalacrocorax’. At the data processing stage, such sightings were allocated to a species according to the relative proportions of successfully-identified animals in each month (see page 17 ‘*Allocating counts of unidentified species*’).

4.1 Uncertainties

There are a number of uncertainties inherent in the survey methodology:

- The observers themselves have commented on the difficulty of allocating locations to grid cell.
- While the pattern in each observation hour - two full scans using binoculars plus two half scans using a telescope - was a ‘norm’, there was variation from this, eg to make use of the telescope to identify species while doing a binocular scan.
- Though EMEC have described them as ‘snapshot counts’, it is likely that they are in fact ‘short-duration watches’. A snapshot count is analogous to a set of photographs covering the site, each taken at an instant of time and allowing a count of animals within that field of view at that instant. In a short-duration watch, the scan would maintain watch of a given field of view for a period, or would pan slowly such that any point remained in view for that period. In such a short-duration watch, animals would be counted if they appeared on the surface at any time during that short-duration period of watch.

4.2 Deriving Animal Density from Site Observational Data

In the September 2013 draft of this assessment, the data processing, taking data from the EMEC wildlife observation programme, applying distance corrections, correcting for non-identification of seal species, and concluding with a mean count for each grid cell, was undertaken by SNH. That draft took the outputs of that data processing, in terms of monthly mean counts per grid cell, as the starting point for calculating animal densities. Data was only available up to March 2011.

For this updated assessment, all animal densities have been recalculated by the author, using the same general methodology as used by SNH, but starting with an updated EMEC dataset spanning the period July 2005 – March 2014.

For the impact appraisals in this document, all the available data from July 2005 up to March 2014 have been utilised, a time span of 8 or 9 years, dependent on the month.

Format of EMEC data

The data provided by EMEC consists of a list of count records, provided in an Excel spreadsheet. A count record relates to a single observation hour and a single species – marine mammal, basking shark or diving bird – and identifies the year and month of the count, the grid cell and the number of animals sighted. Although null counts (observation hours with no sightings) are not included in the listing, the data also specifies the total number of observation hours in each month/year, thus enabling calculation of mean counts per observation hour.

The following paragraphs outline how the data was processed to yield best estimates of mean animal density (per km^2) observed at the surface of the sea D_S, then mean animal density (per km^2) including those underwater D_A. Figure 3 below summarises the various steps in the data processing.

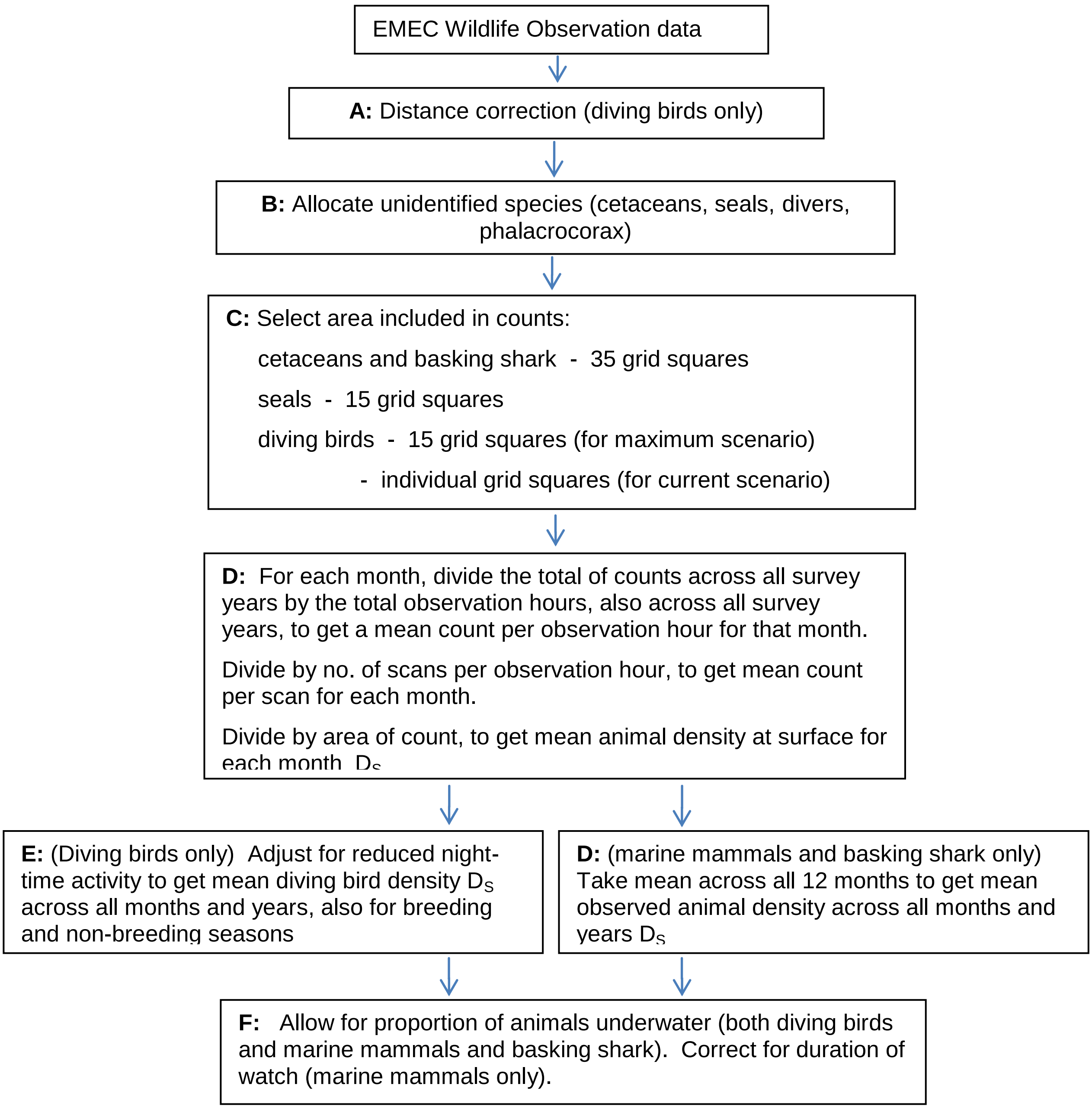

Figure 3: Overview of data processing stages.

The data was analysed by summarising it in an Excel table, for a given species and a given grid cell (or a range of grid cells), showing total counts for that species for each month and year. A corresponding table was produced indicating the number of observation hours in each month and year.

Stage A: Distance correction

To allow for the likelihood that diving birds may not be observed because of distance and restricted visibility, a simple distance correction factor was applied to the diving bird counts, based on the distance from the observation point to the centre of each grid cell. In the absence of data suitable for analysis using Distance software, the factors used are not drawn from any standardised approach but had been used and considered satisfactory by SNH for a previous study at the Lewis Wave Array (Lewis Wave Power Ltd 2012)[2]. Table 3 below shows the factors as they relate to distance from the observer, and Table 4 below shows how this was applied to the grid squares used in the EMEC survey, using the distance between the wildlife observer and the centre of each grid square.

Distance correction was not applied to flocks of birds of 25 or more, on the premise that flocks are more readily visible than individual birds. As the data provided did not give information on flocks, it was simply assumed that any count of 25 or more within a single grid cell in one observation hour would have included a flock and therefore was exempt from distance correction.

As the diving bird analysis has been limited to the 15 grid cells comprising the core area of the EMEC test facility (shaded pale orange), most of the more extreme factors are avoided (though not in grid cell B0).

	Distance (m) between observer and observed birds						
	0-500	**500-750**	**750-1000**	**1000-1250**	**1250-1500**	**1500-1750**	**1750-2000**
Auk and diving ducks	1	1	1.7	2	4	8	16
Divers	1	1	1	1	2	4	6
Gannet	1	1	1	1	1	1	1
Shag & cormorant	1	1	1	1.5	2	4	6
Gulls/terns/shearwaters	1	1	1.6	2.4	3	4	4

Table 3: Distance correction factor – as a function of distance (m) from observer (see footnote).

Distance correction was undertaken before the allocation of unidentified species, as there is a high likelihood that distant parts of the site would be most prone to difficulties in distinguishing species.

[2] SNH recommends that where possible, developers and their consultants should use Distance software, rather than this non-standard approach.

Distance correction (from Alex Robbins 26.5.2014)													
	Common guillemot	Razorbill	Atlantic puffin	Black guillemot	European shag	Great cormorant	Unidentified phalacrocorax	Red-throated Diver	Black-throated Diver	Unidentified diver species	Common eider	Northern gannet	Great northern diver
Grid Cell													
A0	16	16	16	16		6	6	6	6	6	1	1	6
A1	16	16	16	16		6	6	6	6	6	1	1	6
A2	16	16	16	16	6	6	6	6	6	6	1	1	6
A3	16	16	16	16	6	6	6	6	6	6	1	1	6
A4	16	16	16	16	6	6	6	6	6	6	1	1	6
B0	16	16	16	16	6	6	6	6	6	6	1	1	6
B1	8	8	8	8	4	4	4	4	4	4	1	1	4
B-1	-	-	-	8	6	6	6	6	6	6	1	1	6
B2	8	8	8	8	4	4	4	4	4	4	1	1	4
B3	16	16	16	16	6	6	6	6	6	6	1	1	6
B4	16	16	16	16	6	6	6	6	6	6	1	1	6
B5	16	16	16	16	-	-	-	-	-	-	1	1	-
C0	4	4	4	4	2	2	2	2	2	2	1	1	2
C1	4	4	4	4	2	2	2	2	2	2	1	1	2
C-1	8	8	8	8	6	6	6	6	6	6	1	1	6
C2	4	4	4	4	2	2	2	2	2	2	1	1	2
C3	4	4	4	4	2	2	2	2	2	2	1	1	2
C4	8	8	8	8	4	4	4	4	4	4	1	1	4
C5	16	16	16	16	6	6	6	6	6	6	1	1	6
D0	2	2	2	2	1.5	1.5	1.5	1.5	1.5	1.5	1	1	1.5
D1	1.7	1.7	1.7	1.7	1	1	1	1	1	1	1	1	1
D-1	4	4	4	4	2	2	2	2	2	2	1	1	2
D2	1.7	1.7	1.7	1.7	1	1	1	1	1	1	1	1	1
D3	2	2	2	2	1.5	1.5	1.5	1.5	1.5	1.5	1	1	1.5
D4	4	4	4	4	2	2	2	2	2	2	1	1	2
D5	-	-	-	-	6	6	6	6	6	6	1	1	6
E0	2	1.7	-	-	1	1	1	1	1	1	1	1	1
E1	1	1	1	1	1	1	1	1	1	1	1	1	1
E-1	2	2	2	2	1.5	1.5	1.5	1.5	1.5	1.5	1	1	1.5
E2	1	1	1	1	1	1	1	1	1	1	1	1	1
E3	1.7	1.7	1.7	1.7	1	1	1	1	1	1	1	1	1
E4	2	2	2	2	1.5	1.5	1.5	1.5	1.5	1.5	1	1	1.5
E5	-	-	8	8	-	-	-	-	-	-	1	1	-

Table 4: Distance correction factors as applied to grid squares of EMEC wildlife observations.

Stage B: Allocating counts of unidentified species

For certain species (cetaceans, seals, diving birds, cormorant and shag) some field observations recorded sightings but were unable to determine the species. Such sightings were recorded (e.g.) as 'unidentified seal'. The records of those seals which were identified to species level were then used to determine the proportion of harbour seal and grey seal. This proportion was then applied to the unidentified-species count records and added to the respective counts for harbour and grey seal. The same procedure was applied to the following groups, where the 'target species' i.e. those used in the encounter rate analysis, are underlined:

cetaceans
harbour porpoise
minke whale
killer whale
Rossi's dolphin
white-beaked dolphin

seals
harbour seal
grey seal

divers
red-throated diver
black-throated diver
great northern diver

phalacrocorax
great cormorant
european shag

Stage C: Determining the area used for counts

The sea area over which animal counts were included for the purpose of this assessment varied according to species group, reflecting their different mobilities and degree of localisation.

For harbour porpoise, minke whale and basking shark, their mobility is such that their trajectory between successive surfacings may span several grid cells. Therefore the counts used for this analysis were not broken down by grid cell, but included counts within the entire grid of 35 cells, area 8.75 km^2.

For harbour seal and grey seal, the location of underwater activity is more likely to be represented by the location of surface sightings, though both species are also highly mobile. The analysis therefore uses only the data for the 15 grid cells which comprise the core of the EMEC test facility: their total area is 15 x 0.25 km^2 or 3.75 km^2.

For diving birds, the data for each grid cell is assumed to be representative of underwater diving bird activity in that cell. For the maximum scenario, the density calculated has been based on an average of diving bird counts in all 15 grid cells comprising the core of the EMEC test facility (as for seals above). However, for the current scenario, diving bird density has been based on the counts for only those grid cells closest to each of the berths being used.

Stage D: Deriving mean density from mean counts
It is clear from the data that animal density varies seasonally – for example, eider are more abundant in the winter, while razorbill are present mainly in the summer. The general presumption has been that year-to-year variation is semi-random (eg due to fluctuating biological factors) and hence a mean over all 8-9 survey years[3] will yield a 'best representation' of animal density; while month-to-month variation reflects important biological cycles such as seasonal breeding behaviour, and should be preserved in the analysis.

For each month, the mean count per observation hour has been calculated by totalling all counts (across all survey years) in that month and dividing by the total number of observation hours in that month. If $C_{m\,y}$ is the count in month m of year y, and $O_{m\,y}$ is the number of observation hours in that month, then this gives: mean count/observation hour = $\Sigma_y\ C_{m\,y}\ /\ \Sigma_y\ O_{m\,y}$ for month m. This approach gives equal weight to each observation hour. This is the approach adopted for the main analysis in this document[4].

The key figures calculated were thus:

- the mean count per observation hour, across all survey years, for each month
- the overall mean count per observation hour, averaging across the 12 months

For marine mammals and basking shark, the overall mean count/observation hour was taken as a straight average over all 12 months, i.e. overall mean count/observation hour =
$\Sigma_m\ ((\ \Sigma_y\ C_{m\,y}\ )\ /\ (\ \Sigma_y\ O_{m\,y}\ ))\ /\ 12$.

For diving birds, account was taken that some species may be less active at night than during daytime. Survey data was assumed to be representative of all daylight hours.

[3] As the survey began in July 2005 and survey data runs up to March 2014, there are 9 years of survey data for the months January-March and July-December, but only 8 survey years for April-June.

[4] An alternative approach (as used by SNH in providing data for a previous draft) is to calculate the mean count per observation hour for each month and year, and take an average of this ratio over all survey years. This gives $\Sigma_y\ (C_{m\,y}\ /\ O_{m\,y}\ )$ / (no of survey years). This approach gives equal weight to the value of the factor ($C_{m\,y}\ /\ O_{m\,y}$) for each of the survey years. However it does not take any account of variations in the accuracy of ($C_{m\,y} / O_{m\,y}$) due to differences in the number of observation hours per month. While not used for the main analysis, this approach was deployed for the years 2006-2013 when exploring the year-to-year variation in the data, as portrayed in Figures 10, 12 and 13.

Cormorant and shag were assumed to be inactive at night. All other species were assumed, in the absence of evidence to the contrary, to be as active during night as during daylight hours. Stage E below describes how the densities were adjusted to take account of night-time activity.

These figures were then divided by the number of scans in an observation hour (three) to yield the mean count (or overall mean count) per scan.

Finally, these mean counts per scan were divided by the area covered by the count (35 or 15 or 1 x 0.25 km^2) to yield the observed animal density at the sea surface D_s .

Stage E: Adjusting for reduced activity at night

For obvious reasons survey observations do not cover night-time periods, and the information available on night-time activity of species is far from complete. This analysis assumes that for any one species the rate of night-time diving activity is a fraction K of day-time diving activity. If the species does not forage by night, then K=0. If it is just as active at night as during daytime, then K=1. If dive frequency were half daytime frequency, then one would set K = 0.5.

Shag and cormorant do not forage by night, and have been attributed K=0. All other species have at present been attributed a value of K=1, representing a precautionary 'maximum case' of constant 24-hour activity; this may be revised downwards if better information comes available. Hence the adjustment factor, and allowing for changing daylight hours, has not been applied to marine mammals - it has only been applied to diving birds and (at present) affects only cormorant and shag.

Daytime and night-time hours vary across the months of the year, dependent on latitude. Forsythe *et al*. (1995)[i] have published a formula for calculating these hours, reproduced in the 'day and night hours' spreadsheet. For this analysis the latitude of the Fall of Warness site has been taken as 59.142 degrees North.

For any month let the observed survey density be D_i, daytime hours d_i and night-time hours n_i.

Then the total time in a year = $\Sigma (d_i + n_i)$;

Bird occupancy of unit area over year (in bird-secs) = $\Sigma (D_i d_i + K D_i n_i)$;

So average density $\underline{D_s}$ = bird occupancy / total time $\Sigma (D_i d_i + K D_i n_i) / \Sigma (d_i + n_i)$;

where the summations are over the 12 months of the year.

This average density has been used in the analysis for diving birds, with K=0 or K=1 as appropriate for each species. This properly weights the observed densities by the changing daytime (and night-time) hours across the years, as well as reducing the average density where appropriate to allow for reduced or zero activity by night.

Note that seasonal changes in foraging rate, for example during the breeding season, will be reflected in the higher observed densities of birds during that season; these do not require any additional weighting factor.

Stage F: Allowing for time spent underwater and duration of watch

Both for marine mammals and diving birds, the true areal density of animals present D_A is not simply that recorded by such observation, because at any instant of time a proportion of the species concerned are underwater. Unfortunately, the survey methodology used does not allow rigorous quantitative treatment of the results, as it is not clear the extent to which the survey provides a 'snapshot' count or a 'short-duration watch' count.

The difference between a snapshot count and a short-duration watch lies in the adjustment factor applied to allow for animals underwater at the time of the scan. Taking minke whale as an extreme example (for which surfacing time is only 3.5 seconds within a dive cycle of mean duration 90 seconds), if the observed surface count is a snapshot count, it should be multiplied by around 26 to reflect the total number of minke whales including those underwater. However if the count is a short-duration watch of 15 seconds duration, then there are 3.5 + 15 = 18.5 seconds in each dive cycle during which the whale (or part of it) will be visible at the surface. The corresponding multiplying factor is then only 4.9, over five times less than if the count were a true snapshot.

I estimate from the detailed report on survey methodology that the binocular scans follow a route through the site of order 6km, and if the field of view of the binoculars is around 6 degrees (0.1 radian) then the width of the field of view would be around 100m at a viewing distance of 1 km. Thus to cover the 6km route would require 60 successive frames, and to do this in 15 minutes as required would entail a maximum of 15 seconds viewing of each frame.

Snapshot counts

If the scans were analogous to snapshots – as if a camera had taken successive photos of each binocular/telescope field of view – then the survey observations would record an observed density D_s - the number of animals on the surface on the target area of water at those instants of time. If generic information is available for the species concerned about the proportion of time spent on the surface, or on dive frequency and dive time, D_s may then be multiplied by an adjustment factor to take account of the proportion of animals likely to be underwater at that instant, yielding a value for the true areal density D_A, which includes animals underwater as well as on the surface:

$$D_S = D_A \times \text{proportion of time visible at surface}$$

thus $$D_A = D_S / \text{proportion of time visible at surface} \qquad \ldots \qquad (7)$$

For marine mammals which spend most of their time underwater, surfacing only briefly in each dive cycle, the proportion of time visible at the surface may be quite small and hence D_A may be much greater than D_S.

Let the frequency of dives by any one animal be F dives/unit time (this is the frequency overall, the time spanning rest periods on the sea surface as well as when diving); and the mean duration of a dive be p. Then the number of dives in time t (per animal) is F t and their total duration F t p; hence the proportion of time spent underwater is Fp and the proportion of time at the surface is 1-Fp. Putting this in equation (2) gives:

true areal density $$D_A = D_S / (1 - Fp) \qquad \ldots \qquad (8)$$

Short-duration watch counts

In contrast, if the scans include a watch of each area of water for a period of time, then the counts would include animals surfacing during that watch period, as well as animals on the surface at the outset of the period.

Let an animal be at the surface for time t_s , and underwater for time t_u . Let the watch period be t_w. Consider a complete dive cycle consisting of t_s seconds at the surface and t_u seconds underwater. The time during which the animal may be observed at the surface is $t_s + t_w$, ie not just the duration of its surfacing, but allowing for the watch period t_w during which the surfacing might be observed. If the watch period t_w is longer than the dive time t_u then this allowance for the watch period will be curtailed by the start of the next dive cycle, thus the time during a single dive cycle when the animal may be observed at the surface is, more generally, $t_s + \min(t_w, t_u)$. The proportion of a dive cycle during which the animal is visible at the surface is thus $(t_s + \min(t_w, t_u)) / (t_s + t_u)$. Equation (7) then yields the true areal density:

$$D_A = D_S / ((t_s + \min(t_w, t_u)) / (t_s + t_u)) \quad \ldots \quad (9)$$

For watch periods longer than the dive period, this reduces to $D_A = D_S$, reflecting that there is no need to adjust for animals underwater, as each animal will have surfaced and been counted during the watch period.

If the watch period t_w is zero, this reduces to the same expression as for a snapshot count, given in equation (7): the denominator becomes (1 – proportion of time underwater).

The analysis of encounter rate and collision risk for marine mammals uses equation (9), and assumes that the EMEC data is equivalent to 10-second short duration watch data. For basking shark, given the variability of diving and surfacing behaviour, no correction is made for underwater time, and the true density D_A is assumed to be the same as the observed surface density D_S. For diving birds, the analysis assumes that the data is equivalent to a snapshot count, thus equation (8) is used.

5 Marine Mammals and Basking Shark

5.1 Animal Densities

Marine mammal and basking shark densities

Marine mammal and basking shark densities were calculated using the sightings recorded in the EMEC Wildlife Observational programme, on the assumption that these are a representative sample of all daylight hours, as described in the previous chapter. In the absence of evidence to the contrary, it was assumed that these species maintain a similar level of activity during night hours.

Marine mammals spend a high proportion of time underwater, especially while foraging, and hence the observed density of animals represents only a small proportion of the animals present. As described in the previous chapter, the proportion seen at the surface depends on the watch period, i.e. the period during which each particular field of view of the sea surface is monitored. Dependence on watch period is most acute for animals like minke whales with long dive periods and short surfacing periods. Table 6 below outlines generic data on dive times and surfacing times obtained from various sources and shows, for different assumed watch durations, the corresponding ratio of true areal density to observed areal density resulting from the use of equation (9). It should be noted that the data used is that which has come most readily to hand, and is not based on a comprehensive literature search.

As discussed above, the methodology used by EMEC was most likely to be represented by a short-duration watch, with a period of watch no more than around 15 seconds for each field of view within the binoculars used. **For the purpose of this analysis for marine mammals the central assumption is made that the survey was a short-duration watch of 10 seconds.** This builds in a level of precaution over and above the potential for the watch to be of 15 second duration (see above) but avoids the more extreme multiplying factors required by considering the data to be a strict snapshot survey. The results section examines how the conclusions on encounter rate would vary if alternative assumptions on watch duration are used.

For basking shark, an expert view (Sims *et al*, 2005, Sims *et* al, 2008) is that the probability of sighting this species at the surface is entirely dependent on habitat type and prey behaviour and may vary by several orders of magnitude as a result of these factors. The results have been calculated with no correction for animals underwater, i.e. $D_A = D_S$ for this species, and this potential undercounting must be borne in mind when considering the significance of the results.

Table 5 below shows the observed overall mean areal density of marine mammals and basking shark D_S , as calculated from survey observations, and the derived areal density D_A, after allowing for the proportion of time animals spend underwater and the effect of watch time.

	Areal density - animals / km^2		
	EMEC observations - observed at surface D_S	Derived areal density D_A – using watch duration 10 sec	SCANS survey
harbour porpoise	3.40 x 10^{-3}	7.36 x 10^{-3}	274 x 10^{-3}
harbour seal	3.57 x 10^{-3}	15.83 x 10^{-3}	
grey seal	10.6 x 10^{-3}	27.98 x 10^{-3}	
minke whale	0.216 x 10^{-3}	1.45 x 10^{-3}	22 x 10^{-3}
basking shark	1.08 x 10^{-3}	1.08 x 10^{-3}	

Table 5: Observed areal density of marine mammals and basking shark.

Data are also available for a wider area from SCANS survey for harbour porpoise and minke whale, as shown in the final column. If these SCANS data were used as the source data, the encounter rates would have to be increased by an appropriate factor, reflecting the greater animal densities record by SCANS. The uprating factor is calculated in the 'Results' section (see Table 14 and associated text). Due to known limitations of the SCANS data for small inshore areas, and given the distinctive geography and habitat at the Fall of Warness, we have preferred in this analysis to rely on the marine mammal densities derived from local observations. However, as will be seen, there are uncertainties in the EMEC data relating to the degree to which animals swimming underwater are adequately accounted for. Therefore, calculation of the encounter rate using the SCANS density estimates should remain in mind as a useful comparator.

	mean dive time (s)	mean surface time (s)	Source of info on dive and surfacing duration	Ratio D_A/D_S of true areal density to observed density, allowing for animals underwater				
				(snapshot) watch 0 sec	watch 10 sec	watch 20 sec	watch 30 sec	watch 60 sec
harbour porpoise	26.2	3.9	Otani *et al* (2000)	7.72	2.17	1.26	1.00	1.00
grey seal	297	165	Beck *et al* (2000)	2.80	2.64	2.50	2.37	2.05
harbour seal	180	39.5	Batty *et al* (2012), Chudzinska (2009)	5.56	4.43	3.69	3.16	2.21
minke whale	87	3.5	Stern (1992), Heide-Jørgenson & Simon	25.86	6.70	3.85	2.70	1.43
basking shark	?	?	Sims *et al* (2008)	no basis for calculation				

Table 6: Ratio of true areal density to observed density, allowing for animals underwater, under different watch assumptions.

Dimensions and swim speed

Table 7 below shows the average length and swim speed used in this assessment. Body length and swim speed for the marine mammals have been copied from the SRSL report for the MeyGen Tidal Array environmental statement (Batty *et al*. 2012). Body width (used in the collision risk model) is taken as one quarter of the animal's length.

Adult basking sharks are known to grow up to 12m length[ii] but average length is less, thought to be 6-8m (Wikipedia, 2013). Swim speed is drawn from Sims (2000).

	length L (m)	body width W (m)	swim speed u (m s^{-1})
harbour porpoise	1.6	0.4	2.2
harbour seal	1.5	0.375	1.2
grey seal	2.0	0.5	2.0
minke whale	8.8	2.2	2.1
basking shark	7.0	1.75	1.0

Table 7: Dimensions and swim speed of marine mammals and basking shark.

Depth distribution

Q_{2R} , the proportion swimming at risk height, depends on the risk height range of the turbine, and on the depth distribution of the species when diving.

Different data sets are available recording the depth distribution of different species:

Harbour porpoise

This analysis makes use of the approach used by SRSL for the MeyGen tidal array proposal (Batty et al 2012), using data acquired during a study of harbour porpoise dive behaviour by Westgate et al (1995) in the Bay of Fundy, Canada. The graph against depth of the proportion of time spend below that depth is an exponentially diminishing graph fitted by $y = 0.729\ e^{-0.11\ x}$ where x is the depth in metres and y is the proportion of time spent at or below that depth. This curve was for a site of approximately 30m depth, and thus similar in depth to the Fall of Warness site.

Thus if a turbine lies between a minimum depth d and a maximum depth d+2R, the proportion of harbour porpoise within this depth range is given by:

$$Q_{2R} = 0.729\ (e^{-0.11\ d} - e^{-0.11(d+2R)}) \qquad \ldots \qquad (10)$$

Harbour and grey seals

The dive patterns of harbour and grey seals are known to be characterised either as U-dives, i.e. diving to the bottom, feeding on the bottom, then returning to the surface, or V-dives, with minimal time spent at the seabed, or as W-dives, in which a seal moves up and down in the water column during a dive. Tagged harbour seals in the Inner Sound, Pentland Firth, which is of a depth around 30 metres, comparable with the Fall of Warness site, show dive patterns characteristic of U-dives. It has been shown that the distribution of time harbour seals spent at different depths was close to that predicted by a model of U-dives using chosen descent and ascent rates. Dive profiles for grey seals have not yet been analysed.

SRSL in their assessment of the MeyGen tidal array (Figure 2 of Batty *et al* 2012) used a model for U-dives wherein for a sea depth of 31.5m, the seals spend 18% of time at the surface (0-1.5m), 49% of time at the seabed (30-31.5m) and 1.7% of time in each 1.5m range between those limits. For V-dives, the model indicates 18% at the surface (0-1.5m), 6% at the seabed (30-31.5m), and 4% of time in each 1.5m range between these limits.

As the depth of the seabed at Fall of Warness is similar, these same proportions – as set out in Table 8 below - are used in this assessment as the basis for calculating Q_{2R}, the proportion of seals at risk depth. Results are calculated assuming either a U-dive pattern or a V-dive pattern. The latter is the 'maximum case', in that more time is spent in the water column, but the U-dive data is presented because that is the dive pattern known to be most characteristic for harbour seals in water of comparable depth in the Pentland Firth Inner Sound.

	U-dives	**V-dives**
surface (0-1.5m)	18%	18%
1.5-3.0m	1.7%	4.0%
3.0-4.5m	1.7%	4.0%
….etc	…etc	…etc
28.5-30m	1.7%	4.0%
seabed (30-31.5m)	49%	6%

Table 8: Assumptions on time spent at different depths for harbour and grey seals.

Minke whales and basking shark

Little is known about the depth distribution of minke whales and basking shark. As a default, it is assumed that their distribution is uniform throughout the depth of the Fall of Warness channel. As the site is around 30m average depth, the height range of a turbine occupies the proportion (diameter/30) of the available depth. Thus for a 25m turbine, Q_{2R} is taken as 25/30 or 83.33%.

5.2 Results: Encounter Rate for a Single Turbine

The data above has been used to calculate:

(i) the number of encounters per year, using the Encounter Rate Model
(ii) the number of turbine transits per year expected, using Stage 1 of the Collision Risk Model
(iii) the number of encounters per year resulting, assuming no avoidance, using Stage 2 of the Collision Risk Model

Table 9 below shows these results for a single 25m diameter turbine located at depth range 2.5m – 27.5m, a 'maximum case' turbine. The second column (shaded green) shows the encounter rate using the ERM for each species. The analysis which follows of the effect of number of blades, depth of installation, and of breeding season breakdown are all related to this central set of figures, which is repeated, also shaded green, in the relevant tables.

It should be borne in mind that the animal density used for basking shark does not take account of the proportion of basking shark underwater at the time of survey, so the encounter rate could be substantially larger than shown here.

3 blade 25m diameter turbine 2.5m min depth						
	ERM encounter rate	**CRM no. of transits**	**CRM encounter rate**	**ratio CRM/ERM**	**adjusted CRM**	**ERM adjustment factor**
harbour porpoise	0.88	3.8	1.21	1.37		
harbour seals U-dive	0.94	4.4	1.34	1.43		
harbour seals V-dive	2.20	10.4	3.14	1.43		
grey seals U-dive	2.15	7.82	3.10	1.44		
grey seals V-dive	5.06	18.4	7.30	1.44		
minke whale	1.36	1.19	1.19	0.88	0.85	0.63
basking shark	0.75	0.89	0.89	1.19	0.64	0.85

Table 9: Single turbine - encounter rate from ERM and CRMs.

Comparison of CRM and ERM encounter rates

There is a significant difference between the encounter rates calculated using the ERM and the CRM tools (Table 9). For porpoise and both species of seal the CRM figures are around 1.4 times greater than the ERM figures.

For the reasons set out in the 'Models used' section, generally I consider that the ERM encounter rate is likely to provide a better indication of true encounter rate for animals of the size of porpoises and seals than the CRM encounter rate.

However, the ERM counts blade encounters rather than turbine encounters. For a large animal like minke whale, several successive blade encounters will result from one swim-through. It will be noted that while the CRM results for porpoise and seal are around 1.4 times the ERM results, that factor is much less (1.19) for basking shark, and for minke whale the ERM result exceeds the CRM result (ratio=0.88). That is an indication of the extent to which the ERM is 'double counting' in the sense of separately counting multiple blade encounters. For these two species, a better indication of the encounter rate with turbines, counting multiple encounters with successive blades as a single turbine encounter, is likely to be obtained by using the CRM figure and dividing by the ratio 1.4 . This is shown as the 'adjusted CRM' encounter rate in the penultimate column of Table 10, for minke whale and basking shark. Dividing this best estimate, the 'adjusted CRM' value, by the ERM encounter rate then gives an ERM adjustment factor which, if applied to an ERM calculation for these species, yields the equivalent adjusted CRM value without working through the CRM: for example for minke whale, 0.63 times the calculated ERM encounter rate of 1.36 gives the adjusted CRM estimate of 0.85.

Dependence on depth of device

The depth range 2.5m – 27.5m has been chosen as the reference depth, though it is not strictly a 'maximum case'. Both harbour seals and grey seals spend a significant proportion of time at the surface (around 18% in the data used); thus if the depth range were from 0-

25m, a turbine would encounter an additional 18% of seals. It is therefore assumed that a standard precaution will be to ensure a turbine is underwater by an amount such that it will not encounter marine mammals (or any other animals, like birds) on the surface. Table 10 below shows the effect of placing a 25m turbine with a minimum depth of 0m, 2.5m and 5m respectively.

	0m min depth	2.5m min depth	5m min depth
harbour porpoise	1.16	0.88	0.67
harbour seals U-dive	1.47	0.94	0.94
harbour seals V-dive	2.66	2.20	2.20
grey seals U-dive	3.39	2.15	2.15
grey seals V-dive	6.12	5.06	5.06
minke whale	1.36	1.36	1.36
basking shark	0.75	0.75	0.75

Table 10: Single turbine - encounter rate dependence on minimum depth.

The effect of siting a turbine still deeper depends on the species. For species like harbour porpoise whose density diminishes with depth, the encounter rate decreases if the turbine is placed deeper: Figure 4 below shows how the encounter rate for harbour porpoise with a 15m turbine varies with the minimum depth of the turbine. (A turbine diameter of 15m has been chosen solely to illustrate the dependence on a range of device depths within a channel whose depth is around 30m). For seals, whether performing U-dives or V-dives, excluding those seals at the surface or close to the seabed, the distribution of seals across depth is uniform, so that increasing depth further does not further reduce the proportion at risk. However there is some indication from the Pentland Firth Inner Sound data that the model under-predicts the proportion of time spent a few metres above the sea bed; if so, one should expect the encounter rate to increase for a turbine placed such that its maximum depth is close to the seabed. For minke whales, little is known about the depth distribution. The above calculations assume a uniform distribution with depth, such that the encounter rate would not be dependent on the depth of a turbine.

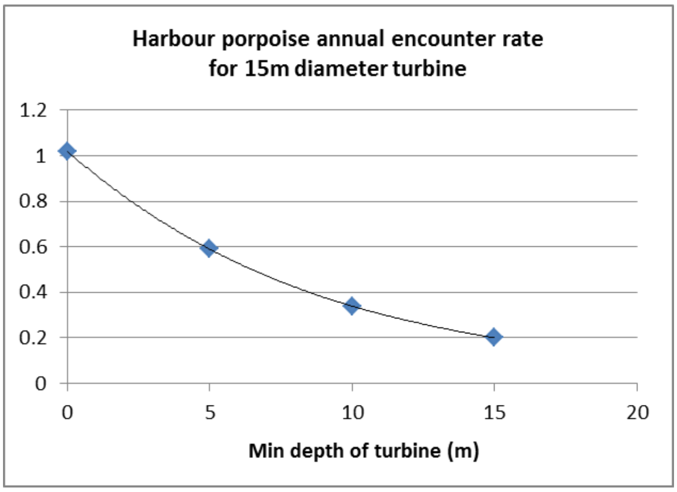

Figure 4: Dependence of encounter rate on depth.

Dependence on number of blades

These results are all calculated for a 3-bladed 25m diameter turbine. The effect of different numbers of blades may be seen in Table 11 below which compares the collision rate and encounter rate for 2, 3 and 4 blade turbines; all assuming the turbine parameters including tip speed ratio and rotational speed described above. With these parameters, collision/encounter rate decreases slightly with the number of blades, such that a 2-bladed turbine gives an encounter rate only around 80% of that of a 3-bladed turbine. Note that this is a consequence of the particular assumptions made over λ, the tip speed ratio: results for a specific turbine may differ.

	2 blade		3 blade		4 blade	
	ERM encounter rate	CRM collision rate	ERM encounter rate	CRM collision rate	ERM encounter rate	CRM collision rate
harbour porpoise	0.69	0.97	0.88	1.21	0.98	1.29
harbour seals U-dive	0.74	1.07	0.94	1.34	1.01	1.42
harbour seals V-dive	1.75	2.52	2.20	3.14	2.38	3.35
grey seals U-dive	1.69	2.49	2.15	3.10	2.37	3.32
grey seals V-dive	3.97	5.85	5.06	7.30	5.58	7.80
minke whale	1.06	1.19	1.36	1.19	1.50	1.19
basking shark	0.59	0.89	0.75	0.89	0.80	0.89

Table 11: Single turbine – dependence on number of blades.

Dependence on rotor diameter

Both the number of transits expected, and the encounter rate, increase with rotor diameter. Figure 5 below shows the encounter rate for harbour porpoise and harbour seal, for rotors of diameter ranging from 5m to 25m, assuming that all are located so that their minimum depth is 2.5m.

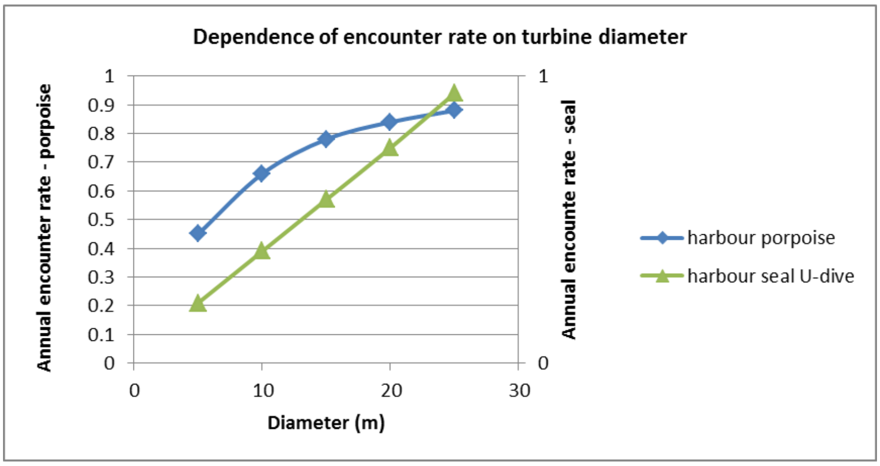

Figure 5: Dependence of encounter rate on turbine diameter.

It should be noted that the encounter rate is not proportional to the cross-sectional area of the rotor, as might be expected: for a given tip speed, a smaller turbine rotates faster to achieve the same tip speed. The varying distribution of marine mammals with depth must also be factored in. For harbour seal undertaking U-dives, for which the distribution with depth is uniform (except at the surface or at the seabed), this results in a linear dependence on turbine diameter. For harbour porpoise, the encounter rate flattens off as the rotor includes greater depths, which have a lower density of porpoises.

Non-standard devices

A 6m diameter annular OpenHydro device is already on test at the EMEC site, and there is a possibility of a larger version, up to 20m in diameter, being tested. The section above on the 'modified CRM approach' (see page 7) describes how an encounter rate may be calculated for an annular device, using the OpenHydro design as a proxy at present, and assuming that animals cannot pass through the annular ring but can pass through the central hole if there is sufficient body clearance.

Table 12 below compares the encounter rate for a 6m, 18m and 20m diameter annular device with the encounter rate for a 25m open rotor, all positioned at a minimum depth of 2.5m. Scaling dimensions off photographs of an OpenHydro device suggests that the central core is approximately 0.4 of the outer diameter of the device.

For most species, the encounter rate is significantly higher than for the open rotor, reflecting the greater porosity of an open rotor. As the values for the annular device are calculated using a modified CRM approach, it may be appropriate to reduce them by a factor of 1.4, just as has been done to the CRM values for minke whale and basking shark, recognising that the 'swim-direction-normal-to-rotor' assumption in the CRM may overestimate the encounter rate. However it is stressed that this is only the encounter rate, i.e. assuming no behavioural response by the animals; it is not yet understood whether the geometry/solidity of such a device influences the likelihood of avoidance.

		annular devices diameter		
	25m open rotor	**6m**	**18m**	**20m**
harbour porpoise	0.88	0.44	2.2	2.5
harbour seals U-dive	0.94	0.24	2.0	2.5
harbour seals V-dive	2.20	0.56	4.8	5.9
grey seals U-dive	2.15	0.43	3.6	4.5
grey seals V-dive	5.06	1.02	8.5	10.5
minke whale	0.85*	0.07	0.61	0.75
basking shark	0.64*	0.05	0.45	0.55

Table 12: Comparison of encounter rate for annular device with open rotor.
(*reduced from CRM value by factor of 1.4)

The depth dependence of the encounter rate for such a device will follow a similar pattern to that for open rotors, namely that the encounter rate for shallow-dive species reduces with increasing depth, until at depths beyond maximum dive depth there is no risk at all; while for deep-dive species, the encounter rate remains broadly constant.

Dependence on watch period assumptions

The encounter rates in Table 9 - Table 12 above are based on the density of marine mammals and basking shark observed on the site, corrected for animals underwater using the assumption that the scan had an effective watch period of 10 seconds. Table 13 below shows the results of varying this assumption, from treating the counts as a true snapshot count (watch period = 0 secs) to a 'full watch' i.e. assuming that the watch of each area of sea was maintained long enough for all animals to have surfaced, such that the true areal density was the same as the observed density. Table 6 above lists the ratios between true and observed areal density used to calculate these encounter rates. As described in the section above on the EMEC wildlife observation programme, it seems unlikely that the effective watch period was routinely longer than 15 seconds though it is possible that that was extended at locations where animal activity was observed.

The important point to draw from this table is the level of uncertainty in marine mammal density estimates arising from this source. That uncertainty is particularly acute for minke whale and for harbour porpoise.

ERM annual encounter rate - dependence on watch period						
watch period (seconds)	**0**	**10**	**20**	**30**	**60**	**full watch**
harbour porpoise	3.14	0.88	0.51	0.41	0.41	0.41
harbour seal U-dive	1.17	0.94	0.78	0.67	0.47	0.21
harbour seal V-dive	2.76	2.20	1.83	1.57	1.10	0.50
grey seal U-dive	2.28	2.15	2.04	1.93	1.67	0.81
grey seal V-dive	5.37	5.06	4.79	4.54	3.94	1.92
minke whale	5.23	1.36	0.78	0.55	0.29	0.20
basking shark			no basis for calculation			

Table 13: Effect on annual encounter rate of using differing assumptions on watch period (the column shaded green reflects the central assumption used in the main analysis).

Comparison with SCANS data

For harbour porpoise and minke whale, there are also average areal density estimates over a wider area available from SCANS. Table 14 below shows how the SCANS densities compare with the EMEC Wildlife Observational data (after adjusting the EMEC data to account for animals underwater to yield a true areal density using the assumption of a 10 second watch period). The final two columns compare the annual encounter rate (for a single 25m diameter 3-bladed turbine at 2.5m minimum depth) using the EMEC and the SCANS data.

If reliance were to be placed on the SCANS data, in preference to the EMEC observational data, then the encounter rates estimated in this assessment for harbour porpoise should be increased by a factor of 37.2 and those for minke whale by a factor of 15.2. Thus, for harbour porpoise and minke whale, the SCANS data suggest densities substantially higher than EMEC site observations would indicate. Nonetheless, given the distinctive geography and habitat of the Fall of Warness, it is considered that calculations based on local site observations seem more likely to reflect local circumstances.

It should be noted that the analysis of the EMEC data uses average animal densities over the period July 2005-March 2014. For harbour porpoise, these survey figures show a clear declining trend over that period. Therefore, the encounter rate based, for example, on the last three years of data would be significantly less than that calculated here over the full period.

	Density estimates (animals/km^2)			Annual encounter rates	
	EMEC observations adjusted for 10 sec watch period	**SCANS**	**Ratio**	**using EMEC data**	**using SCANS data**
harbour porpoise	7.36×10^{-3}	27.4×10^{-2}	37.2	0.88	32.8
minke whale	1.45×10^{-3}	22.0×10^{-3}	15.2	0.85*	12.9*

Table 14: Comparison of EMEC observational data with SCANS data.
(* derived using CRM result divided by 1.4)

Conclusion on encounter rate for single rotor

The encounter rate for a single rotor is taken for a 25m diameter 3-bladed turbine, positioned with its highest point at 2.5m water depth. At any lesser depth, there would be an increased likelihood of rotors breaching the surface, such that encounters with animals at the surface would have to be added to the assessment above of encounters with diving animals. The assumption is made that rotors will be positioned so as to avoid such surface encounters and hence 2.5m minimum depth is taken as the 'maximum case'.

The ERM encounter rate is more likely to reflect true encounter rates with turbines than the CRM for harbour porpoise, harbour seal and grey seal. The 'adjusted CRM' rate, i.e. calculated using the CRM then divided by 1.4, is more likely to reflect a true encounter rate for minke whale and basking shark.

In summary, the preferred encounter rates for use in impact assessment are as shown in Table 15 below.

harbour porpoise	0.88
harbour seals U-dive	0.94
harbour seals V-dive	2.20
grey seals U-dive	2.15
grey seals V-dive	5.06
minke whale	0.85*
basking shark	0.64*

Table 15: preferred encounter rate per year to be used for each species.
(* after applying ERM adjustment factor)

5.3 Results: Encounter Rate for Current Scenario

Table 16 below shows the encounter rates calculated for each of the test devices currently in position or planned, as envisaged in the 'current scenario'. The encounter rates for minke whale and basking shark have been reduced from the values calculated in the ERM by an adjustment factor, 0.62 for minke whale and 0.84 for basking shark, to bring these in line with the 'adjusted CRM' values; as discussed above, this avoids the double-counting associated with very large animals in the encounter rate model (see Table 9 and associated text for the source of these ratios). The encounter rate for the annular device uses the modified CRM approach described above.

	berth 1	berth 2	berth 3	berth 4	berth 5	berth 6	berth 7	berth 8	total
number of rotors	1	1	1	annular device	2	1	1	2	**10**
diameter	21	20	20	6	20	18	16	8	
depth range	17-38m	14-34m	15-35m	2.5 -8.5m	3-23m	10-28m	10-26m	4-12m	
	annual encounter rate								
harbour porpoise	0.17	0.24	0.21	0.44	1.6	0.36	0.35	0.99	4.4
harbour seal U dive	0.79	0.75	0.75	0.24	1.5	0.68	0.61	0.64	6.0
harbour seal V dive	1.9	1.8	1.8	0.56	3.5	1.6	1.4	1.5	14.0
grey seal U dive	1.8	1.7	1.7	0.43	3.5	1.6	1.4	1.5	13.7
grey seal V dive	4.3	4.1	4.1	1.02	8.2	3.7	3.3	3.5	32.2
minke whale	0.73	0.70	0.70	0.07	1.4	0.65	0.59	0.71	5.6
basking shark	0.54	0.52	0.52	0.05	1.0	0.47	0.43	0.51	4.1

Table 16: Current scenario – annual encounter rate for devices currently planned in each berth.

These results for the current scenario are based on the same assumption as used in the 'maximum case' of only 12.4% non-operational time. In practice, as described above under the heading 'operational time', these encounter rates should be multiplied by a factor representing the proportion of time devices are operationally active – this may be quite low while devices are in a test phase.

5.4 Results: Encounter Rate for Maximum Scenario

The maximum scenario includes 12 devices, with a total of 18 open rotors. The maximum potential encounter rate is therefore taken as 18 times the encounter rate for a single open rotor.

It should be noted that the calculation ignores the potential for decrease in marine mammal population within the site as a consequence of collision mortality: it is assumed that avoidance factors are sufficiently high that the level of mortality will not significantly affect the marine mammal density using which the encounter rate is calculated. That is assumed to be the case across the site (i.e. the marine mammal density at the last turbine site is not significantly decreased from that at the first) and over time (i.e. the density does not decrease over time as a result of collision mortality).

The encounter rate for all 12 devices is shown in Table 17 below, based on the single turbine rates listed in Table 15 above.

harbour porpoise	15.8
harbour seals U-dive	16.8
harbour seals V-dive	39.6
grey seals U-dive	38.7
grey seals V-dive	91.1
minke whale	15.2
basking shark	11.4

Table 17: Annual encounter rate for maximum scenario - all 12 devices, with 18 rotors, potentially located at test site.

These are the annual encounter rates assuming that all 18 rotors are in action, available for operation, throughout the period; i.e. the only time they are inoperative is when the tidal current velocity is too low. Also, it should be borne in mind that the animal density used for basking shark does not take account of the proportion of basking shark underwater at the time of survey, so the encounter rate for that species could be substantially larger than shown here.

These figures are based on the encounter rate for a particular set of turbine parameters. If the turbines used differ significantly from those used in this analysis, then the encounter rate will differ. In particular if the rotation speed is increased, the encounter rate will increase. It will also increase with blade width, though not with high sensitivity.

5.5 Avoidance

The above models calculate encounter rates, so take no account of action taken to avoid or evade the turbines. Marine mammals and basking sharks may do both – they may change foraging routes so as to avoid or limit the time spent among the turbines, or they may sense the nearby presence of a turbine and swim in such a way as to avoid it. Table 18 below shows the resulting 'encounter rate with avoidance' for the 'current scenario' if 50%, 90%, 95%, 98% or 99% of the animals were successful in avoiding a potential collision. Table 19 does likewise, but for the 'maximum scenario'. This assessment stops at that point: it is for others to consider how realistic or otherwise such avoidance rates may be.

Current scenario - encounter rate per year with avoidance						
Avoidance assumption:	**0%**	**50%**	**90%**	**95%**	**98%**	**99%**
harbour porpoise	4.4	2.2	0.4	0.2	0.1	0.0
harbour seal U-dive	6.0	3.0	0.6	0.3	0.1	0.1
harbour seal V-dive	14.0	7.0	1.4	0.7	0.3	0.1
grey seal U-dive	13.7	6.8	1.4	0.7	0.3	0.1
grey seal V-dive	32.2	16.1	3.2	1.6	0.6	0.3
minke whale	5.6	2.8	0.6	0.3	0.1	0.1
basking shark	4.1	2.1	0.4	0.2	0.1	0.0

Table 18: Current scenario encounter rate, under various avoidance assumptions.

Maximum scenario - 18 rotors - encounter rate per year with avoidance						
Avoidance assumption:	**0%**	**50%**	**90%**	**95%**	**98%**	**99%**
harbour porpoise	15.8	7.92	1.58	0.79	0.32	0.16
harbour seal U-dive	16.8	8.42	1.68	0.84	0.34	0.17
harbour seal V-dive	39.6	19.81	3.96	1.98	0.79	0.40
grey seal U-dive	38.7	19.36	3.87	1.94	0.77	0.39
grey seal V-dive	91.1	45.56	9.11	4.56	1.82	0.91
minke whale	15.2	7.62	1.52	0.76	0.30	0.15
basking shark	11.4	5.71	1.14	0.57	0.23	0.11

Table 19: Maximum scenario encounter rate, under various avoidance assumptions.

6 Diving Birds

6.1 Diving Bird Density

Observed densities

The section on the EMEC Wildlife Observational Programme describes the survey data acquired over the period July 2005 – March 2014, recording the number and species of diving birds on the sea surface within the tidal test site. The same cycle and frequency of observations was used as for marine mammals (5 days observation in each week, i.e. 20 days in a month, each day involving four one-hour observation periods during each of which the site was scanned the equivalent of 3 times). Birds in flight were not counted, nor any allowance made for birds underwater.

The data were processed as described in Section 4 on the EMEC Wildlife Observational Programme. Analysis was confined to the 15 grid cells forming the core of the EMEC test facility (cells B-1, B0, B1, B2, B3; C-1, C0, C1, C2, C3; D-1, D0, D1, D2, D3). Correction factors were applied to the diving bird data to take account of the typical decrease of visibility of species with distance. Unidentified divers and phalacrocorax species were allocated to species in the same proportions as identified birds in that month. Adjustments to mean density were included to take account of reduced foraging activity of cormorant and shag during night-time.

For each month of the year, the figures used in this encounter rate assessment are the mean bird densities (in birds/ km^2), derived from the corrected mean counts per observation hour, averaging over all observation hours in that month across 9 survey years.

Bird density varies across the year in different ways for different species: for some (e.g. eider), the density of birds was highest during winter months while for others (e.g. guillemot) density was highest during the summer breeding season.

Areal density for diving birds D_A

To convert from the density of birds observed at the surface D_S to true areal density D_A, one needs information on the proportion of time spent diving. Literature on individual diving bird species rarely records the overall frequency of dives per bird, but instead describes foraging patterns, including the number of dives while foraging, the number and length of diving bouts, and within each bout, the mean dive period and the mean pause or recovery period following a dive. Or it may describe the number of dives and duration of a typical foraging trip. Two methods may be used to derive the overall dive frequency, F:

(i) If P_2 is the proportion of time foraging (i.e. the time occupied by diving bouts, including pause or recovery periods between dives, but excluding rest periods or periods flying to and from a colony or to another foraging location), and F_2 is the frequency of dives when foraging, then the number of dives per bird in time t is then $P_2 F_2 t$ and hence:

$$F = P_2 F_2$$

If the mean duration of dives p is known, and the mean duration of pause or recovery periods between dives d, then the duration of a single dive cycle is p+d and the frequency of dives:

$$F_2 = 1/(p+d)$$

(ii) If a complete foraging trip lasts T seconds and P_3 is the proportion of the foraging trip spent at sea (i.e. on the seas surface or underwater) at the foraging location, and if the mean number of dives in a foraging trip is U, then the frequency of dives while at sea is:

$$F = U / P_3 T$$

Proportion of time at risk Q_{2R}

For diving birds, the proportion of time at risk Q_{2R} is the proportion of time while diving spent within the range of risk depths from least deep to deepest rotor level. For this purpose, dive types have been classified in two categories:

- deep dives, typically U-dives, in which the bird dives near-vertically from the surface, through the risk zone, to the sea bottom, forages there at depths deeper than the lowest depth of the turbines, then returns through the risk zone to the surface. The 'risk time' H for a single dive is then the diameter of the turbine, divided by the vertical swim speed, for each of the descent and ascent:

  $H = 2R / u_d + 2R/u_a$ where descent and ascent speeds are u_d and u_a

  For most species descent and ascent swim speeds do not differ widely and a mean vertical speed u has been used:

  $$H = 2 (2R)/u$$

  However for gannets, given the predominance of plunge-diving, the former formula is used in full.

- shallow dives, in which the principal foraging occurs within the range of risk depths. The risk time for a single dive is the full dive duration p, less the time taken to dive to, and return from, the upper risk level h_{upper}.

  $$H = p - h_{upper} / u_d - h_{upper}/u_a$$

  or when descent and ascent speeds do not differ widely:

  $$H = p - 2 h_{upper}/u$$

The proportion of time at risk for any one bird is then given by its overall dive frequency F multiplied by the time at risk during one dive while within the depth range, H:

$$Q_{2R} = F H$$

Allowing for night-time activity

Table 20 below shows examples for two species of calculating an all-hours average density based on the diving birds survey data for each month for the 15 grid cells. The penultimate row shows the night activity factor K assumed for each species: cormorant and shag are assumed not to forage by night, so this is set to 0 for cormorant and shag, and 1 for all other species including eider. The final row gives the all-hours average density, taking account of assumed night-time activity, as described above in the section on the EMEC Wildlife Observational programme, i.e.

$$D_s = \Sigma (D_i d_i + K D_i n_i) / \Sigma (d_i + n_i)$$

where d_i and n_i are the daylight and night-time hours respectively in month i. This all-hours average is the key bird density figure used in the calculation of encounter rates.

Areal density (birds/km^2) direct from survey	eider	cormorant
Jan	0.190	0.226
Feb	0.167	0.206
Mar	0.155	0.179
Apr	0.028	0.106
May	0.002	0.051
Jun	0.001	0.053
Jul	0.000	0.048
Aug	0.004	0.099
Sep	0.009	0.186
Oct	0.065	0.222
Nov	0.165	0.166
Dec	0.192	0.281
relative night activity factor K	**1**	**0**
all-hours average density $\underline{D}_s$ birds/km^2	**0.081**	**0.066**

Table 20: Examples of allowing for night-time activity.

Table 21 below lists this all-hours average for each species and shows the contributions made to this average from daylight hours activity (and thus derived from survey data), and from assumed night hours activity. This demonstrates that for many species the assumption over night-time activity plays a major role. For eider in particular, assumed night-time activity contributes over 55% to the overall bird density; and that is entirely due to the assumption, based on expert opinion in the absence of night-time survey data, that K=1 is appropriate for this species (no further use of this breakdown is made in the analysis below, except in the discussion of uncertainties). The bar chart in Figure 6 below shows the mean bird density for all nine species.

Species	Night activity factor k	All-hours average density $\underline{D}_s$ birds/km^2	of which daylight hours activity contributes	of which assumed night hours activity contributes
eider	1	0.081	0.029	0.052
red-throated diver	1	0.011	0.005	0.006
gannet	1	0.037	0.020	0.017
cormorant	0	0.066	0.066	0
shag	0	0.129	0.129	0
black guillemot	1	0.571	0.332	0.239
common guillemot	1	0.798	0.572	0.226
razorbill	1	0.011	0.008	0.004
puffin	1	0.078	0.056	0.022

Table 21: Contribution of daylight hours and night hours activity to the all-hours average.

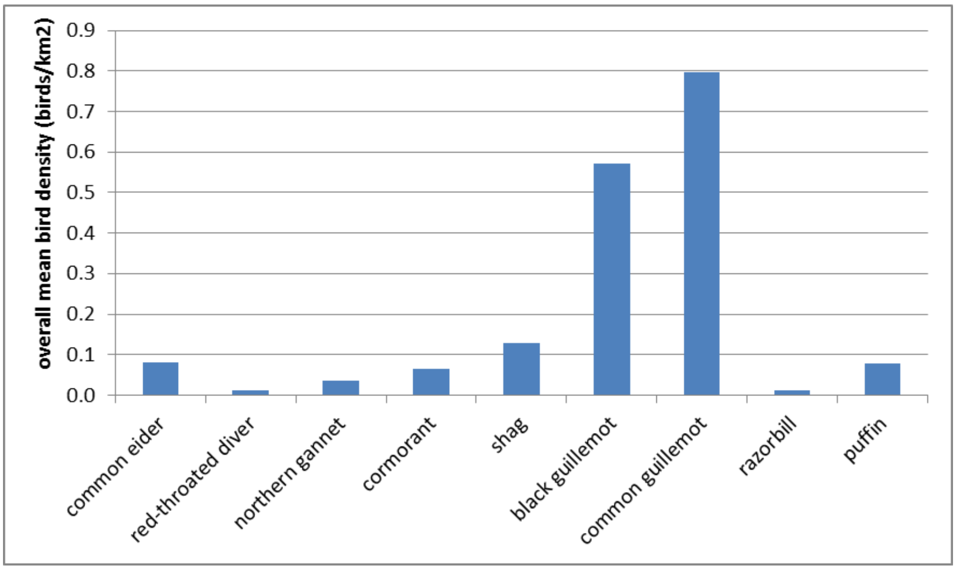

Figure 6: Mean bird density for all nine species.

Bird density broken down for the breeding and non-breeding seasons

The analysis below also provides a breakdown of the encounters expected in the breeding season and outwith the breeding season. For this purpose, the average density is also calculated for each species separately for the breeding season and outwith the breeding season. Table 22 below shows the period assumed as the breeding season for each species (information provided by SNH) and the resulting densities. These take account of assumed night-time activity, and the averages are again worked out using the total daylight hours and night hours for the relevant months, as given by the Forsythe *et al*. (1995) formula.

Species	breeding season	all-hours average density $\underline{D_s}$birds/km^2	non-breeding season average density	breeding season average density
		all taking account of night activity		
eider	Apr-Jul	0.081	0.118	0.008
red-throated diver	Mar-Aug	0.011	0.016	0.006
gannet	Apr-Sep	0.037	0.026	0.048
cormorant	Feb-Sep	0.066	0.072	0.063
shag	Feb-Aug	0.129	0.134	0.126
black guillemot	Apr-Jul	0.571	0.506	0.700
common guillemot	Apr-Jul	0.798	0.074	2.241
razorbill	Apr-Jul	0.011	0.002	0.030
puffin	Apr-Aug	0.078	0.002	0.184

Table 22: areal density during non-breeding and breeding seasons.

Bird parameters

The following length and diving parameters have been used. Bird length and wingspan dimensions are drawn from BTO Bird Facts (British Trust for Ornithology, 2013). Shape factor is according to whether diving is wingtip-propelled (f=2.55) or foot-propelled (f=4). Vertical swim speed is the average of descent and ascent swim speeds, except for gannet for which descent is a rapid plunge. Where the source is SNH, these are values provided by SNH (actual reference source not checked). For razorbill, the swim speeds used are those given by Thaxter *et al*. (2010), which differ substantially from the values quoted by Watanuki *et al*. (2006). For eider, red-throated diver, black guillemot and puffin, there is no information on vertical swim speeds, so available figures for other species of similar size have been used. These figures are shown in *italics* in Table 23 below.

Shape factor - Encounter radius of diving bird

Diving birds may be propelled through water by wingtips, or by feet:

- Foot-propelled species adopt a streamlined profile when diving, with wings tucked in, their shape akin to a plump fish. Foot-propelled species include eider, red-throated diver, cormorant and shag.
- Wingtip propelled species use their wings in a sculling action, opening their wings but not to full extent, and sculling largely within one plane. Wingtip propelled species include gannet, black guillemot, common guillemot, razorbill and puffin.

The foot-propelled species are somewhat similar in shape to marine mammals, and hence these have been modelled as long thin stick-like objects, just as for marine mammals, with a shape factor of 4. This is not appropriate however for wingtip-propelled diving birds; but neither is the assumption that they occupy a spherical volume, which would overstate the space their swimming action utilises. Wingtip-propelled diving birds have therefore been modelled as flat discs of diameter L, for which the appropriate shape factor f is 2.55 (see page 6).

Species	L length	W wingspan	f shape factor	u vertical swim speed (m sec^{-1})	
Eider	0.60	0.94	4	*1.44*	no info – taken as for shag
Red-throated diver	0.61	1.11	4	*1.44*	no info – taken as for shag
Gannet	0.94	1.72	2.55	descent 4.3, ascent 1.2	Garthe et al (2000)
Cormorant	0.90	1.45	4	*1.44*	no info – taken as for shag
Shag	0.72	0.98	4	1.44	Scottish Natural Heritage (2013)
Black guillemot	0.31	0.55	2.55	*1.48*	no info – taken as for common guillemot
Common guillemot	0.40	0.67	2.55	1.48	Scottish Natural Heritage (2013) - average of figures
Razorbill	0.38	0.66	2.55	0.64	Thaxter et al (2010)
Puffin	0.28	0.55	2.55	*1.61*	no info – taken as for Watanuki *et al*.(2006) for razorbill

Table 23: Bird parameters used.

Areal density of birds at sea

In order to get the density of birds at sea from the density of birds observed, for most species the method used was $D_A = D_S / (1 - F_2 P_2 p)$ where P_2 is the proportion of time foraging, F_2 is the frequency of dives while foraging, and p the duration of a dive. Overall dive frequency F is the product of the proportion of time foraging and the frequency of dives while foraging. Table 24 below shows the data used and points to the sources – these are mainly (but not all) drawn from a collation of information on diving birds prepared by Scottish Natural Heritage (2013). Information from the literature is patchy; figures in *italics* in Table 24 are only an estimate informed by figures for similar species. For red-throated diver, the dive frequency quoted is well documented but of questionable relevance as it is for birds during migration. For puffin, a figure is directly available on overall frequency of dives.

For gannet, dive time is very short and the proportion of birds underwater at any one time can be ignored; the crucial parameters are the proportion on the sea surface and the proportion in flight at any one time, which have been studied.

Species	Proportion of time foraging P_2	Dive frequency while foraging F_2 (sec^{-1})	Overall dive frequency F (sec^{-1})	Mean dive duration p (secs)	Sources of info on dive frequency and period	Proportion at sea surface
eider	*60%*	19.1×10^{-3}	11.47×10^{-3}	25.9	Guillemette (2004)	0.703
red-throated diver	*40%*	*30.9×10^{-3}*	12.34×10^{-3}	23.3	Polak & Ciach (2007)	0.712
gannet			0.375×10^{-3}	10.9	Garthe et al (2000 and 2003)	0.442
cormorant	*100%*	*6.85×10^{-3}*	6.852×10^{-3}	40.0	Snow & Perrins (1998)	0.726
shag	100%	6.85×10^{-3}	6.852×10^{-3}	62	Wanless (1993)	0.575
black guillemot	*37.33%*	9.95×10^{-3}	9.95×10^{-3}	43.0	Cairns (1992); Snow & Perrins (1998)	0.840
common guillemot	37.33%	8.70×10^{-3}	3.714×10^{-3}	77.64	Evans et al (2013)	0.748
razorbill	29.41%	26.3×10^{-3}	7.35×10^{-3}	23.10	Thaxter et al (2010)	0.821
puffin			3.199×10^{-3}	48.70	Spencer (2012)	0.844

Table 24: Proportion of foraging birds at the sea surface.

Proportion of time spent at risk depth

The proportion of birds at risk depth was then calculated. For this purpose the birds were classed as either shallow-diving (i.e dives no deeper than the maximum depth of the rotor) or deep-diving (diving deeper than the maximum depth of the rotor); the maximum depth assumed is 27.5m, ie a 2.5m minimum depth plus the 25m diameter of the 'maximum case' rotor.

Based on the information in the references identified in Table 25, eider, red-throated diver, gannet and razorbill have been classed as shallow-diving: razorbill are known on occasion to dive to depths, but the study reported in Thaxter et al (2010) indicates that for most of the time foraging involves rather shallow dives, with a mean dive depth of only 6.5m[5]. Cormorant, shag, black guillemot, common guillemot and puffin have been classed as deep-diving.

For eider, red-throated diver, cormorant and black guillemot, no information on the proportion of time foraging could be found, and guesses have been made based on similar species. Likewise for cormorant, no information on dive frequency while foraging could be found, and the corresponding figure for shag has been used. These figures are shown in *italics* in Table 25 below.

See the section on calculating '*Proportion of time spent at risk - Q_{2R}*' (page 36) for the formulae used in evaluating the time spent by each species at risk depths.

Species	**Overall dive frequency per bird F (sec^{-1})**	**Dive type**	**Vertical swim speed u (m sec^{-1})**	**Time per dive (secs) spent at risk depth H**	**Proportion of birds at risk depth Q_{2R}**
eider	*11.47×10^{-3}*	shallow	*1.44*	22.4	25.7%
red-throated diver	*12.34×10^{-3}*	shallow	*1.44*	19.8	24.5%
gannet	0.375×10^{-3}	shallow	descent 4.3, ascent 1.2	0.2	
cormorant	*6.852×10^{-3}*	deep	*1.44*	34.7	23.8%
shag	6.852×10^{-3}	deep	1.44	34.7	23.8%
black guillemot	*9.95×10^{-3}*	deep	*1.48*	33.8	12.5%
common guillemot	3.714×10^{-3}	deep	1.48	33.8	11.0%
razorbill	7.35×10^{-3}	shallow	0.64	15.3	11.8%
puffin	3.199×10^{-3}	deep	1.61	31.1	9.9%

Table 25: Proportion of time spent at risk depths.

[5] *SNH note that the categorisation of 'shallow' and 'deep' diving species is particular to existing knowledge of their behaviour in tidal streams, such that these species may be expected to dive to greater depths outside of tidal streams or during low-flow conditions. These data differ markedly from those presented in the Birdlife Seabird Wikispaces database, but Furness et al (2012) stress concerns about the origins of data in that database, including potentially exaggerated dive depths. Thaxter et al (2010) supports the expectation that razorbills rarely utilise their full diving capacity, exhibiting dives mostly to less than 10m depth. Preliminary data from the RSPB FAME project also suggests that razorbills are not utilising their full diving capacity at some other tidal-stream locations. It is acknowledged that understanding of this matter is incomplete, thus necessitating reconsideration of this issue in the future.*

6.2 Results: Encounter Rate for a Single Rotor

The data above has been used to calculate for each species:

(i) the density of diving birds
(ii) the encounter rate using the ERM

for a standard 3-bladed rotor, 25m diameter and installed with a minimum depth of 2.5m, i.e. the rotor spans a depth range of 2.5-27.5m.

The spreadsheet 'Diving birds ERM' shows the diving bird density and ERM calculation for each species.

The second column of Table 26 below (shaded green) summarises the results for a single 3-blade turbine, 25m diameter, installed with a minimum depth of 2.5m – this is the single-turbine 'maximum case' encounter rate for each species. The analysis which follows of the effect of number of blades, depth of installation, and of breeding season breakdown are all related to this central set of figures, which is repeated, also shaded green, in the relevant tables.

3 blade 25m diameter turbine 2.5m min depth			
	ERM encounter rate (birds/year)	**CRM encounter rate (birds/year)**	**ratio CRM/ERM**
eider	4.54	5.85	1.29
red-throated diver	0.63	0.86	1.35
gannet	0.086	0.09	1.03
cormorant	4.46	6.40	1.44
shag	8.39	10.96	1.31
black guillemot	12.4	10.30	0.83
common guillemot	19.3	17.02	0.88
razorbill	0.26	0.23	0.90
puffin	1.34	1.11	0.83

Table 26: ERM and CRM annual encounter rates.

Comparison of CRM and ERM encounter rates

Table 26 above also shows the encounter rate worked out using the CRM, and the ratio of the two results (rate from CRM /rate from ERM). The 'CRM Results' spreadsheet shows the CRM calculation for each species and compares it with the ERM results. For the foot propelled species modelled with a shape factor of 4 (eider, red-throated diver, cormorant and shag), the ratio ranges from 1.29 to 1.44, which is broadly consistent with the factor of 1.4 found when comparing ERM with CRM figures for marine mammals; they were also modelled using a shape factor of 4. For the wing propelled species modelled with a shape factor of 2.55, the CRM result is rather lower: for gannet the ratio is 1.03 while for black and common guillemot, razorbill and puffin the CRM encounter rate is lower than that derived from the ERM by a factor of 0.83-0.90.

The main conclusion to be drawn here is that both ERM and CRMs give broadly comparable results. However, to obtain a more refined estimate from either model will require more rigorous account to be taken of the range of orientations of the diving bird with respect to a turbine, and the cross-sectional area it presents. At present, more reliance should be placed on the ERM result, because its assumption of random swim direction and orientation is more akin to the real situation than the CRM assumption of perpendicular approach.

Dependence on depth of device

Encounter rates depend on the depth of installation of a turbine. That dependence is markedly different for 'shallow-diving' species which penetrate to distances of only 10m or so below the surface, and 'deep-diving' species which swim to the sea bottom to forage. Figure 7 below shows the effect of increasing the minimum rotor depth from 2.5m to 20m for a 15m diameter turbine. (A 15m diameter turbine has been chosen for illustration, so as to allow for a range of device depths within an overall water depth of around 30m.) The corresponding encounter rate is shown for three shallow-diving species (eider, gannet and razorbill) and two deep-diving species (cormorant and common guillemot), and is expressed relative to that for a minimum rotor depth of 2.5m.

For 'shallow-diving' species, much of dive time may be at levels above the minimum rotor depth; the time spent at risk depth is reduced if the turbine is sited deeper and, of course, if the rotor is deeper than the maximum dive depth, the risk reduces to zero. For these species, the important parameter is their vertical swim speed. Essentially, a bird is at risk for the entire duration of a dive, except for the time it takes to swim down to the minimum rotor depth, and back up again. The encounter rate drops to zero if the maximum dive depth is less than the minimum rotor depth.

For 'deep-diving' species, there is no risk while foraging at the sea bottom. The time at risk is during descent and ascent and is the same regardless of the depth of the turbine, if the turbine diameter and ascent/descent swim speeds remain the same. Again the critical parameter is the vertical swim speed, which determines the time spent within risk range.

The simple shape of these curves is the result of the very simplified assumptions made, and the simple formulae used to estimate the time spent at risk depth during a dive (see page 36, factor H). In practice shallow-diving birds will have a distribution of dive depths, so the abrupt transition to 'zero risk' is likely to be more gradual; and deep-diving birds may well spend some time foraging within risk depths, rather than proceeding directly to and from the seabed.

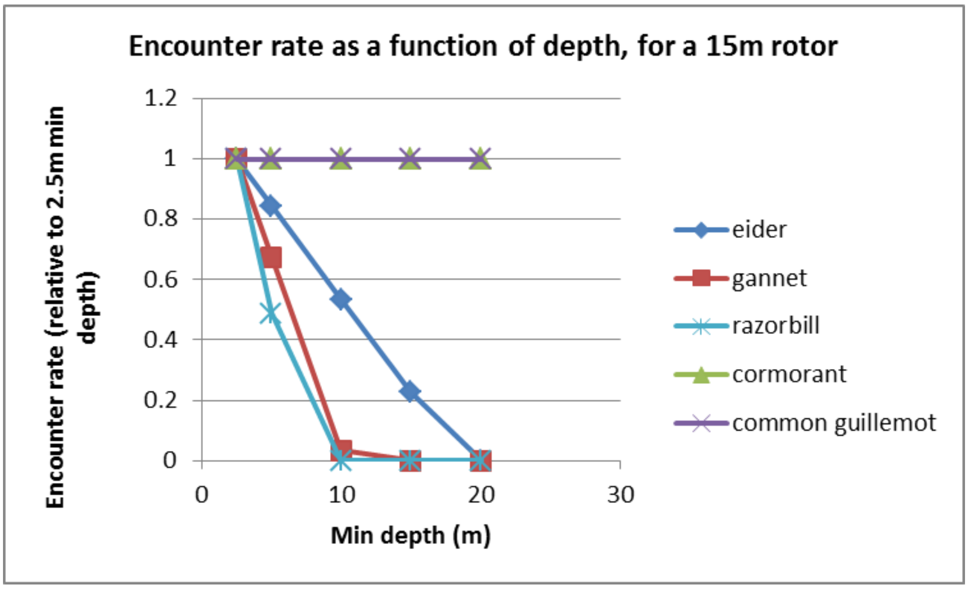

Figure 7: Deeper turbines reduce encounter rate for shallow-diving bird species.

For the purpose of this assessment of a 'maximum case' of 25m diameter turbines, the depth range 2.5m-27.5m has been chosen as a reference depth for the turbines. Strictly this is not a 'maximum risk' case, in that if the minimum depth were 0m, rotors could collide with birds floating on the surface as well as those diving. However it is assumed that a standard environmental precaution will be to ensure that a turbine is underwater by an amount such that it will not encounter birds swimming or resting on the sea surface. A minimum depth of 2.5m is used in this analysis, which then represents a 'maximum case' encounter rate for shallow-diving birds; as Figure 7 above shows, their encounter rate could be reduced markedly by increasing the minimum depth.

Dependence on number of blades

The above results are all calculated for a 3-bladed 25m diameter rotor. Table 27 below shows the effect of different numbers of blades, assuming the turbine parameters including tip speed ratio and rotational speed described above.

	ERM annual encounters		
	2-blade	**3-blade**	**4-blade**
eider	3.6	4.54	4.9
red-throated diver	0.50	0.63	0.69
gannet	0.068	0.086	0.093
cormorant	3.53	4.46	4.84
shag	6.64	8.39	9.11
black guillemot	9.8	12.4	13.5
common guillemot	15.3	19.3	20.9
razorbill	0.21	0.26	0.28
puffin	1.06	1.34	1.46

Table 27: Effect of number of blades.

Dependence on rotor diameter

Figure 8 below shows how encounter rate varies with rotor diameter, for two shallow-diving species (eider, gannet) and two deep-diving species (cormorant, common guillemot). Again there is a marked difference. For the deep-diving species, the time at risk is the time taken to descend then to ascend through the range of depths encompassed by the rotor. Therefore the risk increases linearly with increasing rotor diameter. For the shallow-diving species, there is relatively little dependence on rotor diameter, with a tendency for smaller rotor diameters to show a slight increase in encounter rate. The 'maximum case' analysis uses a standard rotor diameter of 25m, which gives the maximum encounter rate for deep-diving species.

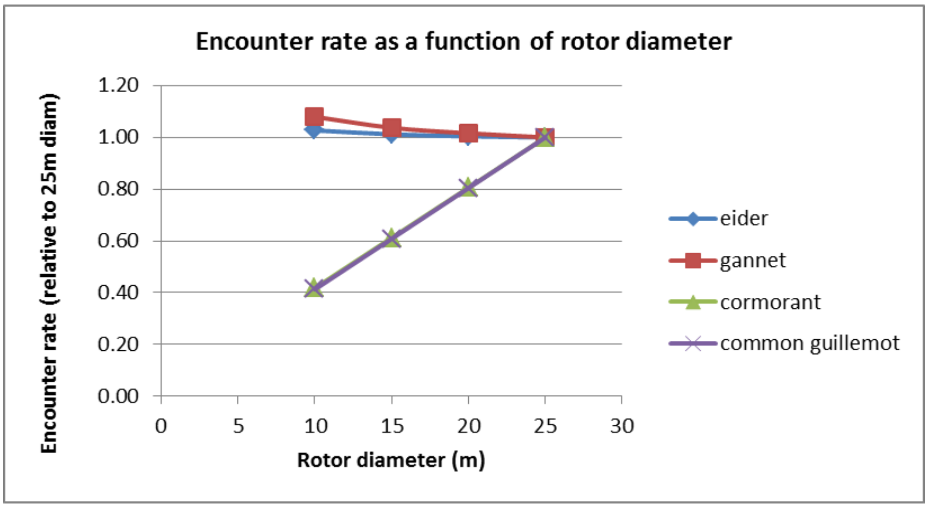

Figure 8: Encounter rate as a function of rotor diameter.

It should be noted that though risk increases linearly with rotor diameter for deep diving species, energy capture is likely to increase linearly with rotor area, i.e. with the square of the rotor diameter. Thus the encounter rate risk per unit of energy capture will *reduce* linearly with rotor diameter. For shallow-diving species, if the encounter rate is regarded as largely independent of rotor diameter, the encounter rate per unit of energy capture will reduce with the *square* of rotor diameter. Thus for both types of species, big turbines are likely to be much more benign per unit of energy capture than small turbines.

Non-standard devices

A 6m diameter annular OpenHydro device is already on test at the EMEC site, and there is a possibility of a larger version, up to 20m in diameter, being tested. The section above on the 'modified CRM approach' describes how an encounter rate may be calculated for an annular device, assuming that animals cannot pass through the annular ring but can pass through the central hole if there is sufficient body clearance.

Table 28 below compares the encounter rate for a 6m, 18m and 20m diameter annular device with the encounter rate for a 25m open rotor, all positioned at a minimum depth of 2.5m. Scaling dimensions off photographs of an OpenHydro device suggests that the central core is around 0.4 of the outer diameter of the device. For all species, the encounter rate is significantly higher than for the open rotor, reflecting the greater porosity of an open rotor. However it is stressed that this is only the encounter rate, i.e. assuming no behavioural response by the animals; it may well be that the geometry of such a device makes successful avoidance much more likely than for an open rotor.

		annular device: diameter		
	25m open rotor	6m	18m	20m
eider	4.5	6.19	18.03	20.00
red-throated diver	0.63	0.78	2.27	2.51
gannet	0.086	0.06	0.16	0.18
cormorant	4.46	1.11	9.57	11.78
shag	8.39	2.68	23.37	28.81
black guillemot	12.4	4.25	37.23	45.90
common guillemot	19.3	5.88	51.29	63.21
razorbill	0.26	0.34	0.99	1.10
puffin	1.34	0.46	4.01	4.94

Table 28: Comparison of encounter rate for annular device with open rotor.

The depth dependence of the encounter rate for such a device will follow a similar pattern to that for open rotors, namely that the encounter rate for shallow-dive species reduces with increasing depth, until at depths beyond maximum dive depth there is no risk at all; while for deep-dive species, the encounter rate remains broadly constant.

For the current scenario, one berth includes an OpenHydro annular device of diameter 6m, and the encounter rate for this is included for Berth 4 in the current scenario.

Breakdown by breeding/non-breeding season

Table 29 below shows the annual encounter rates subdivided into the encounters expected during the breeding season, and those during the non-breeding season. The breeding season for each species is as described above in Table 22 and associated text. The calculation takes account of the changes in daylight and night hours within these seasons. Figure 9 below, using this data, shows that for some species the majority of encounters would take place in the non-breeding months, while for others encounters are concentrated in the breeding months; this is simply a reflection of the bird densities over the year, and the assumptions over relative activity by night.

		ERM encounters		
	months of breeding season	non-breeding season	breeding season	all-year
eider	Apr-Jul	4.40	0.14	4.54
red-throated diver	Mar-Aug	0.47	0.16	0.63
gannet	Apr-Sep	0.03	0.06	0.09
cormorant	Feb-Sep	1.64	2.82	4.46
shag	Feb-Aug	3.63	4.75	8.39
black guillemot	Apr-Jul	7.31	5.07	12.39
common guillemot	Apr-Jul	1.19	18.08	19.27
razorbill	Apr-Jul	0.03	0.23	0.26
puffin	Apr-Aug	0.02	1.33	1.34

Table 29: Breakdown by breeding/non-breeding season.

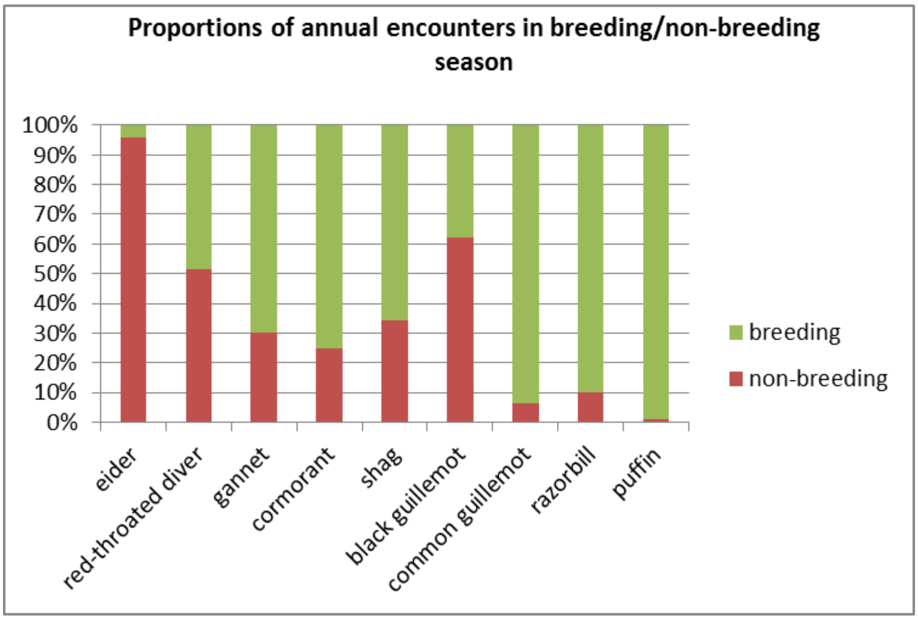

Figure 9: Proportions of encounters in breeding and non-breeding seasons.

Relative risk in different parts of site

The EMEC Wildlife Observations for diving birds allocated each bird observed to one of 35 grid cells. That data has been used to analyse whether there are 'riskier' and 'less risky' parts of the test site, looking only at the 15 grid cells which represent the core of the EMEC test site: grid cells B-1, B0, B1, B2, B3; C-1, C0, C1, C2, C3; and D-1, D0, D1, D2, D3. The analysis has only been undertaken for diving birds, as foraging distances for marine mammals are such that surfacing observations are more likely to be recorded in a different grid cell from the foraging location.

Making use of data subdivided by grid cell, rather than data aggregated over 15 grid cells, opens the risk that the variability in data will conceal any trend. Therefore the variability in the data has also been explored.

For any one grid cell, eight years' of bird data have been used from January 2006 – December 2013. Data from July-December 2005 and January-March 2014 have been excluded, so as to leave eight full years without the possibility of skewing data towards certain months of the year. For each year the mean count per observation hour (across months) was calculated. These eight years of data are considered as eight samples (n=8) of the underlying population of annual bird counts per observation hour. The mean $\underline{X}$ and standard deviation s of these eight sample points were calculated (using $\sqrt{(n-1)}$ to divide when calculating s, as this is a sample of the 'population' of years).

$\underline{X}$ is then an estimate of the population mean with confidence interval given by:

$$\underline{X} \pm t_c \, (s/\sqrt{n})$$

where t_c is the critical value from the Student t distribution with n-1 (=7) degrees of freedom for the level of certainty sought.

90% certainty was chosen (i.e. an uncertainty of 10%) for which $t_c = 1.895$. Thus the population mean (i.e. mean across all years, assuming no trends) for each grid cell is $\underline{X} \pm 1.895 \, (s/\sqrt{8})$, with 90% confidence.

The results are plotted for each species in

Figure 10 below. The bars in each chart show the mean bird density in birds km^{-2} for the fifteen grid cells, plus an error bar showing the 90% confidence interval.

Some conclusions are evident:

- Cell D-1 is a 'preferred location' for eider, red-throated diver, gannet, cormorant, and shag. It is also well used by black guillemot, common guillemot and razorbill.
- Cells B-1 and C-1 are scarcely used by any species
- Cell C1 is very lightly used, by gannet and both species of guillemot
- Cell B0 is also scarcely used by any species, except a little by common guillemot.

- Cell B3 is well-used by common guillemot, black guillemot, and puffin, but less so by razorbills.
- Cell C0 is well-used by these same three species, and also by razorbills.
- Cell D3 is much used by puffin and black guillemot, but only a little by common guillemot or razorbill.

One may crudely list the relative risk of the cells, rating each cell by adding up the proportion in that cell of the mean count, across all 15 cells, for each species; thus not weighting species in any way. Figure 11 shows the outcome, indicating that grid cell D-1 is by far the cell with the highest bird count, with B3, C0, B1, D3, and D2 following; while B-1, C-1 and B0 are at the other end of the range. This indicates, for example, that the same turbine would present the highest collision risk if installed in grid cell D-1, fairly high in cells B3, C0, B1, D3 and D2, and the lowest collision risk if installed in grid cells B-1, C-1 or B0. It would be possible to include a weighting for certain species in this calculation, should collision risks be considered more important for certain species than for others.

It should be noted that these graphs are based only on the bird count in each grid cell. Collision risk is not simply proportional to bird count, as the seasonal abundance and the length of daylight hours come into play in calculating collision risk, as well as the depth dependence of the species. However the broad trends in relative risk shown by these charts are likely to persist in a more refined calculation.

Figure 10: Mean bird densities D_S (birds/km^2) in each grid cell, for each species.

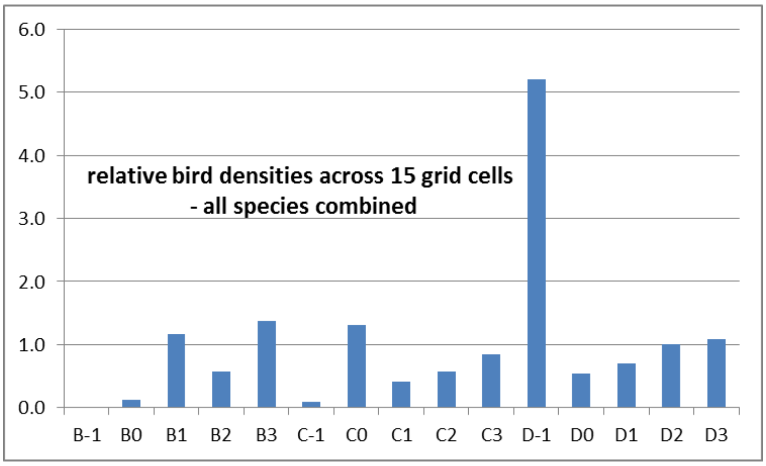

Figure 11: Total across all nine species of bird densities as a proportion of the 15-cell mean for that species (this gives a crude indication of the relative risk of different grid cells: if all 15 cells were equally populated, the bars would all have value 1).

6.3 Results: Encounter Rate for Current Scenario

Table 30 below shows the encounter rates calculated for the test devices currently installed, or planned for installation, in eight of the nine berths. Berth 4 currently (July 2014) accommodates an OpenHydro annular device while all other berths are occupied by/planned for traditional open rotor devices of the dimensions shown.

The calculation makes use of diving bird densities within the grid cells occupied by the berth (or immediately adjacent to the berth). Thus the variation in encounter rate is a result of both the variation in bird density and the encounter rate associated with different sizes and types of rotor. The grid cells whose bird density is used for each berth are:

Berth 1: grid cell C2

Berth 2: grid cells C3, D3 (i.e. density D used is 0.5 D(C3) + 0.5 D(D3))

Berth 3: grid cell B3

Berth 4: grid cells C-1, D-1 (i.e. density D used is 0.5 D(C-1) + 0.5 D(D-1))

Berth 5: grid cell C1

Berth 6: grid cells B0, C0 (i.e. density D used is 0.5 D(B0) + 0.5 D(C0))

Berth 7: grid cells B0, C0 (i.e. density D used is 0.5 D(B0) + 0.5 D(C0))

Berth 8: grid cell D2

The final column in Table 30 below compares the encounter rate for the current scenario with the potential encounter rate for the maximum scenario. Generally this shows that the current scenario will give rise to an encounter rate in the range 24-42%% of the total 'maximum case' scenario outlined above.

	berth 1	berth 2	berth 3	berth 4	berth 5	berth 6	berth 7	berth 8	total	
number of rotors	1	1	1	annular device	2	1	1	2	10	
diameter	21	20	20	6	20	18	16	8		
depth range	17-38m	14-34m	15-35m	2.5 - 8.5m	3-23m	10-28m	10-26m	4-12m		
grid cells used for bird density	C2	C3, D3	B3	C-1, D-1	C1	B0, C0	B0, C0	D2		
	annual encounter rate (birds/yr)									**proportion of maximum scenario**
eider	0.00	0.00	0.42	39.64	0.11	0.32	0.32	0.92	**41.7**	51%
red-throated diver	0.00	0.11	0.05	0.78	0.44	0.16	0.17	2.05	**3.8**	33%
gannet	0	0.00	0.00	0.06	0.09	0.00	0.00	0.18	**0.33**	21%
cormorant	2.10	4.86	10.19	1.11	4.36	4.65	4.15	2.47	**33.9**	42%
shag	1.58	4.41	6.88	2.68	2.99	3.38	3.01	2.87	**27.8**	18%
black guillemot	6.71	15.95	17.06	4.25	9.33	8.15	7.26	14.0	**83**	37%
common guillemot	20.07	13.85	40.30	5.88	28.38	18.55	16.55	3.3	**147**	42%
razorbill	0.00	0.00	0.00	0.34	0.20	0.00	0.00	0.58	**1.12**	24%
puffin	0.85	1.84	3.23	0.46	1.05	0.61	0.55	1.49	**10.1**	42%

Table 30: Current scenario – annual encounter rate for devices currently planned in each berth.

These results for the current scenario are based on the same assumption as used in the 'maximum case' of only 12.4% non-operational time. In practice, as described above under the heading 'operational time', these encounter rates should be multiplied by a factor representing the proportion of time devices are operationally active – this may be quite low while devices are in a test phase.

Note that the encounter rate for the 6m diameter annular device in berth 4 is higher for some species than the generic encounter rate for a 6m device stated in Table 28; this is because the current scenario makes use of the bird density data for each individual grid cell, while Table 28 makes use of density data averaged across all the 15 grid cells comprising the core of the EMEC test site.

Results: Encounter Rate for Maximum Scenario

The maximum scenario includes 12 devices, with a total of 18 open rotors. The maximum potential encounter rate is therefore taken as 18 times the encounter rate for a single open rotor, and is listed in Table 31 below.

The calculation ignores the potential for decrease in diving bird population within the site as a consequence of collision mortality: it is assumed that avoidance factors are sufficiently high that the level of mortality will not significantly affect the diving bird density using which the encounter rate is calculated. That is assumed to be the case across the site (i.e. the diving bird density at the last turbine site is not significantly decreased from that at the first) and over time (i.e. the density does not decrease over time as a result of collision mortality).

	ERM encounter rate single rotor device	ERM encounter rate all 12 devices/18 rotors
eider	4.54	81.7
red-throated diver	0.63	11.4
gannet	0.086	1.5
cormorant	4.46	80.3
shag	8.39	151
black guillemot	12.4	223
common guillemot	19.3	347
razorbill	0.26	4.6
puffin	1.34	24.2

Table 31: Annual encounter rate for maximum scenario.

If the set of devices includes one or more annular devices, then Table 28 may be used to calculate the additional encounter rate, for each such device, which must be added to this maximum scenario.

6.4 Avoidance

The above models calculate potential encounter rates, so take no account of action taken to avoid or evade the turbines. Diving birds may do both – they may change foraging locations so as to avoid or limit the time spent among the turbines, or they may sense the nearby presence of a turbine and dive in such a way as to avoid it. Table 32 below shows, for the current scenario, the resulting estimated collision rate if 50%, 90%, 95%, 98% or 99% of the animals were successful in avoiding a potential collision. Table 33 below similarly shows the estimated collision rates for the 'maximum scenario'. This assessment stops at that point: it is for others to consider how realistic or otherwise such avoidance rates may be.

	Assumed avoidance rate					
	0%	**50%**	**90%**	**95%**	**98%**	**99%**
eider	**41.9**	21.0	4.19	2.10	0.84	0.42
red-throated diver	**3.8**	1.9	0.38	0.19	0.08	0.04
gannet	**0.33**	0.2	0.03	0.02	0.01	0.00
cormorant	**33.9**	16.9	3.4	1.7	0.68	0.34
shag	**63.4**	31.7	6.3	3.2	1.3	0.6
black guillemot	**83**	41	8.3	4.1	1.7	0.8
common guillemot	**147**	73	14.7	7.3	2.9	1.5
razorbill	**1.12**	0.56	0.11	0.06	0.02	0.01
puffin	**10.0**	5.0	1.00	0.50	0.20	0.10

Table 32: Annual estimated collision rate (birds/year) for current scenario at tidal test site, assuming 0%, 50%, 90%, 95%, 98% and 99% avoidance – assuming current scenario of planned installations. Note that these figures assume the test devices are 100% operationally active.

	Assumed avoidance rate					
	0%	**50%**	**90%**	**95%**	**98%**	**99%**
eider	81.7	40.9	8.2	4.1	1.6	0.8
red-throated diver	11.4	5.7	1.1	0.6	0.2	0.1
gannet	1.5	0.8	0.2	0.1	0.0	0.0
cormorant	80.3	40.1	8.0	4.0	1.6	0.8
shag	151	75.5	15.1	7.5	3.0	1.5
black guillemot	223	111	22	11	4.5	2.2
common guillemot	347	173	35	17	6.9	3.5
razorbill	4.6	2.3	0.5	0.2	0.1	0.0
puffin	24.2	12.1	2.4	1.2	0.5	0.2

Table 33: Annual estimated collision rate (birds/yr) for maximum scenario, assuming 0%, 50%, 90%,95%, 98% and 99% avoidance . These figures assume that devices are 100% operationally active, i.e. operating whenever the tide is suitable.

7 Uncertainties

The major sources of uncertainty in the above assessments of encounter rate (quite apart from the lack of knowledge regarding the behavioural response of the animals and likely rates of avoidance) are described below.

7.1 The Encounter Rate Model

Uncertainties attributable to the ERM used include:

- Simple model dive patterns are used to assess the proportion of time at risk; real dives may be much more complex.
- The model of a rotor and its interaction with birds is highly simplified.
- The distribution of swim directions differs from the 'random direction relative to water body' assumed in the model.

7.2 Survey Method

The following uncertainties exist within the observation methodology used in the EMEC wildlife observation programme:

- The survey data has inherent errors due to detectability/visibility, although correction factors have been applied, and in estimating the location of animals.
- The location of the survey sightings within grid cells was a matter of difficult estimation by the observers.
- The survey method does not allow a clear quantitative approach as to the proportion of animals not recorded because they are underwater. Table 6 above shows that, for harbour porpoise and minke whale the true animal density may be more than double, or less than half that used in the calculations, if the 'watch period' were very short or very long.
- Levels of night-time activity (characterised by factor K) are not informed by day-time survey. For those species known not to be active at night, this is not a source of error, but where a species is active, but at a level unknown compared to daytime activity, then setting K=1 may overstate the encounter rate by anything up to a half - over a whole year, night hours account for nearly 1/3 of all hours.

One window into the uncertainties in the survey data is to look at year-to-year variance, which may be due to natural inter-annual variation in species abundance or due to random variation in the sampled counts. For sea mammal species and basking shark, and for each of the diving bird species, the total count in each year 2006 to 2013 across the relevant grid cells provides an eight-point sample of the average annual count for each species. The mean of this sample, averaging over these eight years, and the 90% confidence interval are shown in Figure 12 and Figure 13 below.

Figure 12 for marine mammals and basking shark shows the year-to-year variance for these five species. 90% confidence intervals span from 32% up to nearly 150% of the mean. Harbour seal exhibit the greatest variance of the species included, as they have been subject to a decreasing population trend (Duck and Morris 2014).

Figure 13 shows that variability differs across diving bird species too. For black guillemot the confidence interval is tight, only ±13% around the mean value, reflecting a consistent number in the population. For most species the confidence interval ranges between ±30% to ±70% around the mean value. For common guillemot it is around ±90%, reflecting a considerable annual variation in the number of those species present.

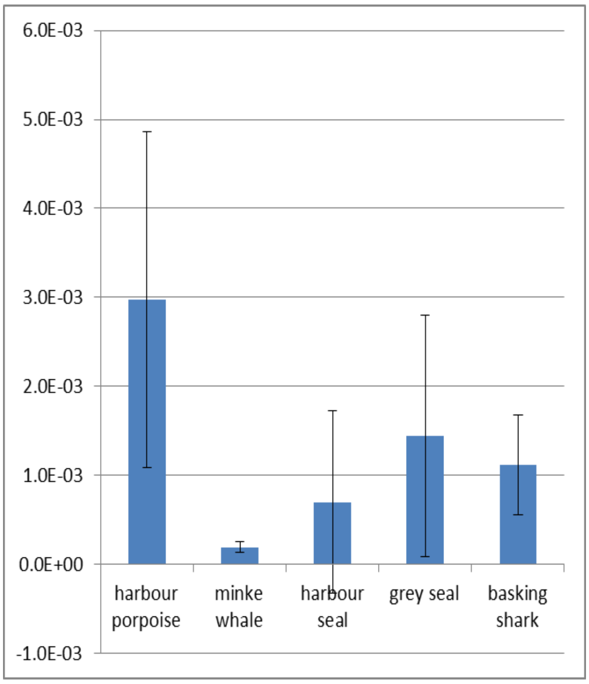

Figure 12: Marine mammal and basking shark densities with 90% confidence intervals.

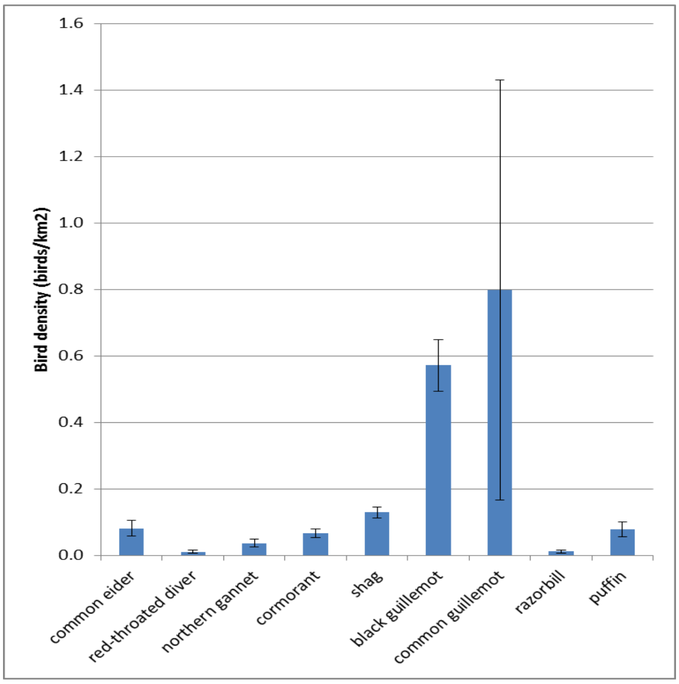

Figure 13: Bird densities showing 90% confidence intervals.

The 90% confidence intervals are shown on the basis of year-to-year variability. The data used for these charts covers 2006-2013 only.

Assembling these considerations on uncertainty, one might identify at least five independent sources of uncertainty:

- variance in survey count data including inaccuracies in location
- uncertainty due to watch period duration
- lack of information on night-time activity
- simplistic dive modelling
- simplifications inherent in ERM model

Some of these, eg the variance in survey count data, the uncertainty due to lack of specification of the watch period, and the uncertainty relating to lack of knowledge of night-time activity, are amenable to quantitative expression, but others (dive modelling, and simplifications in the ERM model) are better addressed by expert view. Almost certainly the combination of all these sources of possible inaccuracy would lead to an uncertainty factor of at least two – ie the encounter rates (before factoring in avoidance) might be twice as large as those calculated, or half as large.

While this is a substantial margin of uncertainty, that result should be set in the context of the level of uncertainty surrounding the behavioural response of marine animals. The uncertainty over the proportion of animals taking avoiding action as yet may range over several orders of magnitude, such is the paucity of monitoring information available. In that context, having an estimate for encounter rate (before avoidance) within a factor of two or thereabouts is a significant step forwards in estimating potential collision risks.

SNH's programme of research recognises the need to reduce these uncertainties, and work is underway to obtain information which in time will reduce the magnitude of these uncertainties, including the lack of understanding of behavioural avoidance.

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APPENDIX 1: Notes on the Spreadsheets

Two spreadsheets accompany this document[56], one for marine mammals and basking shark, the other for diving birds. An additional spreadsheet was used to analyse the EMEC Wildlife Survey Programme data to provide input values on marine mammal and bird densities to the other two spreadsheets. These spreadsheets are discussed in turn below.

1. Marine mammals and basking shark
These notes refer to the 'marine mammals and basking shark' spreadsheet which includes four linked sheets.

Marine mammals ERM
This is the master spreadsheet with the ERM calculations.
The 'species data' rows 5-7 are used to enter data on animal length, effective radius and swim speed.

The 'Surface density' is the figure derived from field survey – the observed surface density D_S. This is the overall mean density for each species, as resulting from Stage D of the initial data processing (see Figure 3, page 16). Dive time, surface time (data sourced from literature), and duration of watch then enable the correction to be made to allow for underwater animals, yielding the areal density D_A, that is to say rows 9-12 undertake Stage F.

Given the minimum depth and a formula for density at various depths – which differs from species to species – see the cells in row 14 – that enables calculation of the proportion at risk and hence the true density, i.e. per m^3.

Row 17 allows entry of the current speed, and rows 18-24 details of the rotor from which tip speed is calculated in row 25. From row 22 on the table splits to show 2, 3 and 4 blade options for each species – the calculations progress in parallel.

Using the effective area A in the encounter rate model (row 27) then enables calculation of the encounter rate Z per second and per year – rows 29 and 30.

Three entry fields are shaded blue. These are copied across to all the species columns, so the user need only adjust the blue shaded figures. These are for minimum depth (cell C13), rotor diameter (cell C19) and assumed watch period (cell C11). The user can easily test results for different turbines and watch periods by varying these fields. The standard output has been derived for 2.5m min depth, 25m rotor diameter and 10 second watch period.

Below, under the heading 'Current Scenario', these calculations are repeated for each berth, though each berth now has its own min depth and diameter. This table provides the information for the 'Current scenario' tables in the report, on the assumption that all devices are open rotor devices. To allow for an annular device in berth 4, subtract the encounter rate for an open rotor in this berth and add the encounter rate for the annular device. A calculator for an annular device using the 'modified CRM approach' is included below in rows 102 to 107. Note that this only works if the minimum depth and device diameter are set in cells C13 and C19.

Results – marine mammals
This sheet undertakes the CRM calculation, starting from the areal density (adjusted for animals underwater) and calculating the expected number of transits per year. It then uses the average collision risk during a single transit – calculated in the 'CRM single transit risk' sheet – to give the 'no-avoidance collision rate' (i.e. the encounter rate) from the CRM

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[56] Available from SNH upon request

The sheet then copies in the results from the previous sheet to the 'Encounters/yr' rows and compares them to find the CRM/ERM ratio.

(This sheet also includes some tables on the right side which contain dynamic links to the data and are only included for convenience in preparing the report. These are not a validated part of the report.)

Single transit collision risk
This is the CRM sheet used to determine the average risk of collision for a single animal transiting through a rotor. The 'downwind' result is used as downstream travel is more likely than upstream.

Tables and charts
For convenience in preparing the report, many of the tables of information are assembled here – or to the right in the 'Results – marine mammals' sheet - using dynamic links to the other sheets. Note that if other parameters are tested in the marine mammals – ERM sheet then the figures in 'Tables and charts' will also change! For this reason the figures in the tables and charts sheet should be ignored, they are not a validated part of the report.

The tables, for appropriate parameters, have been copied into the report; the links to the report are not dynamic.

2. Diving birds

These notes refer to the 'diving birds' spreadsheet which includes seven linked sheets:

Diving bird densities
This sheet fulfils stage E of the data processing for diving birds. Data entered here is that, for each species, in the 'mean sightings/observation hour' column – this is survey data totalled for the fifteen relevant 0.25 km^2 grid cells, corrected for detectability/visibility. The 'density' column converts this to mean density (birds/ km^2) using the cell area and number of scans per observation hour.

The table of daylight, night and total hours in columns A-C are entered from the **Daylight & night hours** sheet (this is not automatically linked).

The 'daylight hours average' is not used, but shown for interest: this is the density which is solely based on survey observation. k is the assumed relative night activity; at present that is copied for use both during the non-breeding and breeding season.

For each of the non-breeding and breeding seasons, time and average density are calculated using a 'sumproduct' function which multiplies daylight hours and night hours in each month by the respective number of hours in the month; also including as a factor the figure shown in the column of '1's , so as to pick out the non-breeding or breeding months as appropriate. The All-hours average does similarly, but over all 12 months.

(For each species, the spreadsheet contains two columns: the first contains '1's for non-breeding months and the second '1's for breeding months. Every month has a '1' in one or other of these two columns. The spreadsheet operates by multiplying the daylight and K-weighted night hours for a month by the value in the non-breeding or breeding column as appropriate. Thus for each, the '1's have the effect of selecting out only those months relevant to that season. A benefit of this approach is that if ever there is felt a need to refine the breeding season to use half months or weeks (e.g. mid-Mar – third week Aug), that can be achieved by entering 0.5 in both the breeding and non-breeding column for March; and 0.75 (breeding) and 0.25 (non-breeding) for August. Clearly the rule must be maintained that the sum of entries for any month is 1.0).

The figures carried forward to the 'Diving birds' spreadsheet are the 'non-breeding season average density', the 'breeding season average density' and the 'all-hours average density'.

The sheet makes provision for different values of k to be used for the non-breeding and breeding season respectively. That provision has not been used in this analysis, but is included to allow for such refinement as and when better data on night-time activity becomes available.

Daylight and night hours
Only one parameter – latitude – needs to be entered here, the formulae then calculate the day and night hours on a daily basis and total for each month. Latitude should be entered in decimal degrees; Fall of Warness is 59.142 degrees North.

Diving birds ERM
This is the master spreadsheet with the ERM calculations:

The '**Species data**' rows (4-9) are used to enter data on bird size, swim speed and shape factor.

In the '**Bird density'** rows, the 'time in season' and 'surface density' row import the time (season length) and density data output from the 'Diving bird densities' sheet – linked automatically. Data for 'proportion of time foraging', 'dive frequency foraging' and 'mean duration' are input manually. The spreadsheet then calculates the adjusted at sea density.

In the '**Bird density at risk depth**' rows the spreadsheet uses the minimum depth to calculate the 'time per dive at risk depth', 'proportion at risk depth' and 'density at risk depth'. Note that the formulae used for 'time per dive at risk depth' differ as between 'shallow-dive' and 'deep-dive' species; and again are varied for 'shallow dive with plunge'.

'**Tide data**' and '**Rotor data**' rows are straightforward; note the width is the width of a rotor looked at from the side, i.e. the back-to-front distance.

Under '**Single rotor encounter rate'**, the calculations are first done for three blade options – 2-blade, 3-blade and 4-blade, generating the encounter rate (per year) for each – this is the row in pale orange. Then the calculations are repeated for the 3-blade option, but separately for non-breeding and breeding seasons as well as all-year – the supporting figures for bird density are those in bright yellow shading.

Note that the parameters 'minimum depth' (cell C22) and 'rotor diameter (cell C31) – highlighted in blue – are copied across for use for all species, so that the user can readily change the blue-highlighted figure to test other rotors.

Under '**Current scenario**' the calculations are repeated using the information on number of rotors, minimum depth, and rotor diameter given in column C for each berth. The calculations are the same as those above, but make use of this separate information on these parameters. (This can be seen by changing the blue highlighted figures, say, to minimum depth 17, diameter 21. the figures above should then replicate those in Berth 1). As before the formulae to calculate 'time per dive at risk depth' depend on whether the species is shallow-dive or deep-dive. The data on bird density are obtained from the table below which shows, for each species, the bird density in each grid cell. (Only 10 grid cells lie close to those berths currently in use or planned for use.)

Finally the '**OpenHydro**' block uses the modified CRM method described in the text to calculate annual encounter rate.

CRM results
This sheet imports the density data D_A and Q_{2R} from the 'Diving birds ERM' sheet, and uses it to calculate the number of transits/yr. It multiplies that by the collision risk for a single transit – using

the **Single transit collision risk** sheet to get encounters/yr; it compares that with the results from the ERM from the 'Diving birds ERM' sheet.

Single transit collision risk
A max chord of 0.6m and a pitch of 30 degrees yields a blade of width (front to back) of 0.3m, as used in the ERM calculations. Both bird 'length' and 'Bodywidth' should be set to the wingspan of the species involved – this is just a parameter to reflect the size of the animal as it is swept through a turbine. F (flapping or gliding) should be set to 'flapping'. The bird speed used is the mean current speed. The analysis uses the downwind p(collision) value – on the basis that birds will be swept through the turbine downstream.

The pale orange column showing values for c/C (chord width/maximum chord width) for increasing r/R has figures for a wind turbine. These could be updated if data were available for a marine turbine.

Tables and charts
This sheet gathers the data output from the Diving birds ERM and the CRM results sheet, into tables and charts many of which have been transcribed into the report. If data in the spreadsheet is changed, it will change the tables in this sheet, but it will not automatically change those in the report . The tables in the spreadsheet are not a validated part of the report.

Rpm calculator
Given a tip speed ratio λ, a current speed v and a radius R, this sheet calculates the rotational speed Ω and the tip speed RΩ, for use in entering a mean blade speed in the Diving birds ERM sheet.

3. FoW Data Analysis July 2014
This spreadsheet contains 20 worksheets and serves to analyse the EMEC data to provide figures for the animal or bird densities required as input to the two main spreadsheets.

'Data' contains the data provided by EMEC, and 'Description contains some detailed notes on the processing. The data is selectively copied into spreadsheets 'Cetaceans', 'Seals' (15 grid cells only) and 'Diving birds' (15 grid cells only). These are the master tables which are used as the basis for the analysis.

'Cetacean analysis' contains the analysis for cetaceans. 'Seal analysis' contains the analysis for seals. The analysis for diving birds is contained in 'Bird analysis (15 cells)' and in a sheet for each species: 'Eider', 'RTDiver', 'Gannet', 'Cormorant', 'Shag', 'Black guillemot', 'Comm guillemot', 'Razorbill', and 'Puffin'.

In support of the diving bird analyses, there are sheets on 'Daylight and Night hours' and on 'Distance': this latter contains the distance correction factors used to compensate for decreasing visibility with distance.

The 'Pivot' sheet contains four components:

- a table of observation hours in each month and year
- a table showing the reciprocal of these values. This is just a device to facilitate the use of the SUMPRODUCT function in Excel. We need the no of bird counts divided by the number of observation hours; this is equal to the product of the no of bird counts x the reciprocal of the number of observation hours.

- a general 'pivot table' as featured in Excel, enabling the analysis to be selected for individual or several species, and for individual or multiple zones (described as 'Zone trim' as leading and trailing spaces have been trimmed)
- a table which mimics the function of the Excel pivot table, but with added features: firstly, it ensures there is a row for every month and every year, even if all values are zero; secondly, it allows a secondary 'species' to be listed and a proportion added in to the count. This is used for species where there is a count of unidentified animals, so as to add in a due proportion to the main count.

Finally there is a 'Blank' worksheet which was used during development and should be ignored.

APPENDIX 2: Encounter Rate Model and Collision Risk Model

Encounter rate model

The encounter rate Z is the density D of 'prey' – in this case the marine mammal in question – multiplied by the volume swept by each blade in unit time, then multiplied by the number of blades b. The volume swept in unit time is determined by the cross-sectional area presented by the blade, and its speed of approach:

$Z = D\ b\ A \times \text{speed of approach}$ (A1)

If the blade has width w and length R then the blade itself has a cross-sectional area wR. However, allowance must also be made for the size of the 'prey', as an encounter will occur whenever the area of the prey overlaps with the area of the blade. If the prey is characterised by an encounter radius r, then the cross-sectional area A within which an encounter will occur is (w + 2r) (R + r). The factor 2 is included because the blade cross-section has two edges which the prey may overlap[57].

The speed of approach of a blade towards a 'prey' is a function of the blade speed v and the prey swim speed u. The encounter rate model assumes that swim orientations and directions are random with respect to the body of water. In that case, the mean speed of approach is:

$[(u + v)^3 - |u - v|^3] / 6uv$ (A2)

which simplifies, if blade speed v > swim speed u to $v(1 + (u^2/3v^2))$ (A3)

or if blade speed v< swim speed u to $u(1 + (v^2/3u^2))$ (A4)

For marine turbines, except at times of slack water, it may be assumed that blade speed exceeds swim speed and therefore the first of these applies; this is the assumption made by Wilson et al.

The effective encounter radius r of the prey is that of a long thin animal with random orientation, such that at times the animal may be aligned along the line of relative approach, and thus show no cross-sectional area towards an approaching blade; while at other times it may lie normal to the line of approach and therefore present its full length L (and hence an encounter radius of L/2). Taking an average over all possible orientations gives an average encounter radius of L/4. (The derivation borrowed for Wilson *et al*'s equation (7) is incorrect; this analysis has since been corrected.)

Putting these components together, encounter rate is

$Z = D\ b\ (w+2r)(R+r)\ v(1 + (u^2/3v^2))$ where $r = L/4$ (A5)

which combines equations (6) and (8) from Wilson et al.

D is 'prey' animal density, per m^3
b is no of blades
w is the width of a turbine blade, as viewed along the direction of relative approach
R is the length of a turbine blade
r is the effective encounter radius of the prey animal, mean equal to L/4
L is the length of the prey animal
v is the blade speed relative to the water
u is the prey animal's swim speed relative to the water
Z is the encounter rate for a single turbine, and must be multiplied by the number of turbines, and the time operating, to yield an estimate of the number of encounters in a given period.

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[57] Note that this factor 2 is not included in the encounter rate model as described by Wilson et al, but is in use by these authors in subsequent assessments

Collision risk model

Take a rotor of cross-sectional area A in a water body containing a density D of marine animals. If they are travelling normal to the rotor plane with speed v then the number passing through that plane in each second will be the number within a cylinder of base A and length v, i.e.

$$\text{animal flux} = D\,A\,v \qquad \text{(A6)}$$

This assumes that all are travelling in one direction; if half travel in one direction and the other half in the other direction, then the flux is also $\frac{1}{2}DAv + \frac{1}{2}DAv = DAv$.

The number of collisions in a given period is the number of transits through the rotor, multiplied by the probability of collision during a single transit.

The probability of collision in a single transit is described and calculated in the SNH Band collision risk model[ii, iii]. It is a matter of the geometry of the rotating blade relative to a passing bird. It depends on number of blades, rotation speed, the chord width of the blade and its pitch, and how these vary over the length of the blade, the radius of the blade, the bird dimensions, its flight speed and whether it flight style is gliding or flapping. For the flapping case:

Risk of collision during a single transit =

$$p(r) = (b\Omega/2\pi v)\,[\,|\pm c \sin\gamma + \alpha c \cos\gamma| + \max(L, W\alpha)\,] \text{ averaged over rotor area} \qquad \text{(A7)}$$

where

- r is the radius from the rotor centre at the point of transit
- b is no of blades
- Ω is rotational speed
- v is speed of animal relative to rotor
- c is the chord width of the blade
- γ is the pitch angle of the blade, relative to the rotor plane
- L is the length of the animal
- W is its body width
- $\alpha = v/r\Omega$
- + sign is for upwind flight, - for downwind

A spreadsheet (SNH 2000[ii]) was published with the original 2000 guidance, used to calculate this average p(r). This spreadsheet is included as the 'Single transit risk' sheet in the spreadsheet accompanying this paper.

Thus annual number of collisions assuming no avoidance is:

$$D\,A\,v \quad \text{times} \quad \text{the average over the rotor disc of } p(r) \qquad \text{(A8)}$$

APPENDIX 3: Effective Prey Radius of a Flat Circular Prey

The encounter rate model was originally developed assuming prey animals could be modelled as a sphere of radius r. Whenever that sphere overlapped with the range of a predator – that range was also assumed spherical – then an encounter would occur (Gerritsen and Strickler, 1976). That model was further developed (Bailey and Batty, 1983) to consider prey animals which were long and thin, but of random orientation. In that case the range of overlap is given by the mean of the projection of the long thin animal upon a line which is normal to the relative approach trajectory, and along which line is the distance of closest approach. It is shown in a previous review (Band 2012b) that this mean projection should be L/4 if the long thin prey animal is of length L.

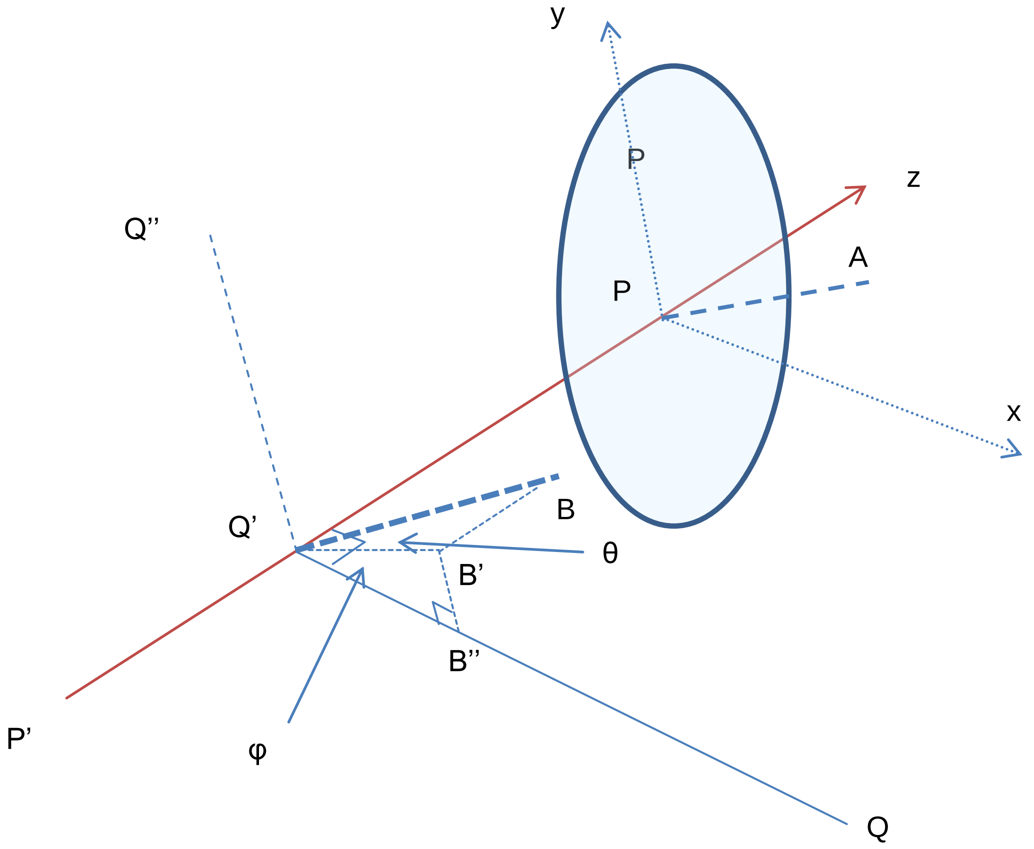
With reference to Figure 1, take a prey centred at P and predator centred at Q. View in a frame in which the predator is stationary. Draw the line of approach of P towards Q as PP'. Now draw the normal from Q to this line PP', meeting this line at point Q'. Q' is then the point of nearest approach of the prey to the predator. If the predator has an encounter radius R_b and the prey an encounter radius R and if QQ' is less than $(R_b + R)$, then the predator will encounter the prey.

If the prey is a flat disk-shaped animal (or one whose limbs sweep out a flat disk) of radius R and random orientation, the question is, taking an average over all possible orientations of the disk, how much of the distance QQ' will the projection of that disk shape occupy, at its point of nearest approach?

The analysis below is in two stages. First, QQ' is calculated for a given orientation of the disk-shaped prey. Second, this value is averaged over all possible orientations of the disk-shaped prey, assuming that orientation is randomly distributed.

For this second stage, spherical polar coordinates are used, centred at Q' with the polar axis along the direction of relative approach PP'. The plane QQ'Q'' normal to PP' and containing the line QQ' is the equatorial plane of these coordinates. Take θ as the angle out from this equatorial plane, such that the point P has angle $\theta=\pi/2$ and the point Q has angle $\theta=0$. Take φ as the angle of the projection of a point in the equatorial plane, relative to the line Q'Q which defines $\varphi=0$.

1. Projection of circle on QQ' for a given orientation



Let a circle centred at P represent the disk-shaped animal. Take xyz coordinates centred at P, with x parallel to Q'Q, y parallel to Q'Q'', and z along the line of relative approach P'P. The circle will have an elliptical projection on the x-y plane. Let PA be the vector $\underline{r}$ = (a,b,c) normal to this circle.

The plane normal to this vector through the origin P is given by (a,b,c).(x,y,z) = 0 i.e.

$$ax + by + cz = 0 \quad \text{(B1)}$$

A sphere of radius R centred at the origin has equation:

$$x^2 + y^2 + z^2 = R^2 \quad \text{(B2)}$$

A circle in a plane through the origin normal to (a,b,c) must satisfy both (B1) and (B2).

The projection of this circle on the x-y plane can be obtained by expressing z from (B1) as:

$$z = -(a/c)x - (b/c)y$$

and substituting in (B2):

$$x^2 + y^2 + (-(a/c)x - (b/c)y)^2 = R^2$$

i.e. $$(1 + (a/c)^2)\, x^2 + (1 + (b/c)^2)\, y^2 + (2ab/c^2)\, xy = R^2 \quad \text{(B3)}$$

which is the equation of an ellipse. (Note that without loss of generality, c can be set =1:

$(1 + a^2)\, x^2 \;+ (1 + b^2)\, y^2 + 2ab\, xy \;= R^2$) (B4)

Now transpose this into spherical coordinates $\underline{r}= (r, \theta, \varphi)$.

$a = r \cos\theta \cos\varphi \qquad b = r \cos\theta \sin\varphi \qquad c = r \sin\theta$

Equation (B3) becomes:

$$(1 + (\cos\theta \cos\varphi / \sin\theta)^2)\; x^2 \;+ (1 + (\cos\theta \sin\varphi / \sin\theta)^2\, y^2$$
$$+ 2 (\cos^2\theta \cos\varphi \sin\varphi / \sin^2\theta)\, xy \;= R^2 \qquad \text{(B5)}$$

write as $A x^2 + B y^2 + C xy = R^2$where

$A = 1 + \cos^2 \varphi / \tan^2 \theta \qquad B = 1 + \sin^2 \varphi / \tan^2 \theta \qquad C = 2 \cos\varphi \sin\varphi / \tan^2 \theta$ (B6)

or $\quad B y^2 \;+ Cx\, y + \;(Ax^2 – R^2)\; = 0$

Using the formula for quadratic roots:

$$y \;= (1/2B)\; (-Cx \pm\sqrt{}(C^2x^2 – 4B(Ax^2\text{-}R^2)\;) \qquad \text{(B7)}$$

The limits of this ellipse along the x-axis are given by the points where $dy/dx = \infty$

$$dy/dx = (1/2B)\; (-C \pm\; (2C^2x – 8\, B\, A\, x)/(2 \sqrt{}(C^2x^2 – 4B(Ax^2\text{-}R^2)))$$

which can approach ∞ only when:

$$C^2\, x^2 – 4\, BA\, x^2 +4\, BR^2 \;= 0$$

i.e. $\quad x^2 = -\, 4\, B\, R^2 / (C^2 – 4\, BA) \qquad$ or $x = \pm\, R \sqrt{}\, (4B / (4BA – C^2)$ (B8)

[or, more simply, the two roots of y in (B7) converge to a single point when $C^2x^2 - 4B(Ax^2\text{-}R^2) = 0$]

In spherical coordinates, substituting from equations (6), these limits are

$$\pm\, R \sqrt{}\, \{\, 4\, (1 + \sin^2 \varphi / \tan^2 \theta)\;\; / \;\; [\, 4\, (1 + \sin^2 \varphi / \tan^2 \theta)(1 + \cos^2 \varphi / \tan^2 \theta) - 4 \cos^2 \varphi \sin^2 \varphi / \tan^4 \theta\,]\, \}$$

$$= \pm\, R \sqrt{}\, \{\, (1 + \sin^2 \varphi / \tan^2 \theta)\;\; / [\, 1 + (\sin^2\varphi + \cos^2\varphi)/\tan^2\theta\,]\;\, \}$$

$$= \pm\, R \sqrt{}\, \{\, (\tan^2\theta + \sin^2\varphi) / (\, \tan^2 \theta + 1)\, \}$$

$$= \pm\, R \sqrt{}\, \{\, \cos^2\theta\, (\tan^2\theta + \sin^2\varphi)\, \}$$

$$x = \pm\, R \sqrt{}\, \{\, \sin^2\theta + \cos^2\theta \sin^2\varphi\, \} \qquad \text{(B9)}$$

These limits determine the maximum projection on the x-axis (and hence on QQ') of a circle radius R normal to a vector direction θ, φ.

For example when θ=0, the normal is in the QQ'Q'' plane and the circle is edge on, i.e. its projection on the plane is a line and its projection on QQ' is between limits ± R sin φ. When θ = π/2, the normal is along PQ', the circle in is the QQ'Q'' plane and the maximum projection along the x-axis is ±R.

Random distribution of directions

Now assume that the normal to the circle r (and hence its associated circle of radius R to which it is normal) may take any direction at random. Then the average projection along QQ' becomes:

$$\int_{\varphi=0}^{2\pi} \int_{\theta=-\pi/2}^{\pi/2} |R \sqrt{(\sin^2\theta + \cos^2\theta \sin^2\varphi)}| \cos\theta \, d\theta \, d\varphi \; / \; \int_0^{2\pi} \int_{-\pi/2}^{\pi/2} \cos\theta \, d\theta \, d\varphi \qquad \text{(B10)}$$

where the additional cosθ is included because the increment of solid angle is cos θ dθ dφ. The denominator integrates simply to 4π, i.e. the average projection is

$$R \int_{\varphi=0}^{2\pi} \int_{\theta=-\pi/2}^{\pi/2} | \sqrt{(\sin^2\theta + \cos^2\theta \sin^2\varphi)} | \cos\theta \, d\theta \, d\varphi \; / \; 4\pi \qquad \text{(B11)}$$

Doing this integration numerically, taking increments of π/36 *(i.e. 5 degrees) for both θ and φ, yields a value of 0.7847 R. This is the mean 'effective prey radius' for a flat circular prey assuming a random distribution of orientations.

This should be compared with the mean projection on QQ' of a spherical prey of diameter 2R, radius R, which would give an effective prey radius of R; or the mean projection calculated previously for a stick-like prey – a long thin animal, for which the effective prey radius is one quarter the length (0.5R if the length is 2R):

spherical prey, radius R	1.0 R	(=L/2)	
flat circular prey, radius R	0.7847 R	(=L/2.55)	(B12)
long thin prey, half length R	0.5 R	(= L/4)	

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