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Orbital O2 Environmental Monitoring Programme

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Summary:

This document has been prepared to support the marine licence application for the deployment, operation and decommissioning of the Orbital O2 2MW Tidal Turbine. The Environmental Monitoring Programme documents the proposed mitigation and monitoring measures relating to the installation, operation and decommissioning of the Orbital O2.

Rev.	Date	Author(s)	Check	Notes
0.1	21/09/18	EMEC [redacted]		
0.2	12/10/18	[redacted]	[redacted]	Final issue

Contents

Abbreviations

Abbreviation	Full title
ADCP	Acoustic Doppler Current Profiler
CMS	Construction Method Statement
DART	Drifting Acoustic Recorder and Tracker
EMEC	European Marine Energy Centre
EMF	Electromagnetic effects
EMP	Environmental Monitoring Plan
EMR	Environmental Monitoring Report
EPS	European Protected Species
ERCoP	Emergency Response Cooperation Plan
ERP	Emergency Response Procedure
FAD	Fish Aggregation Device
IMO	International Maritime Organisation
MMO	Marine Mammal Observer
MNNS	Marine Non-Native Species
MPA	Marine Protected Area
NNS	Non-Native Species
PMF	Priority Marine Feature
SAC	Special Area of Conservation
SMWWC	Scottish Marine Wildlife Watching Code
SNH	Scottish Natural Heritage
SOP	Standard Operating Procedure
pSPA	Proposed Special Protection Area
SPA	Special Protection Area
SRTP	Scotrenewables Tidal Power Ltd
SSSI	Site of Special Scientific Interest

1 Introduction

1.1 Background and Purpose

Orbital Marine Power (Orkney) plc ('Orbital'), a fully owned subsidiary of Orbital Marine Power Ltd (formerly known as Scotrenewables Tidal Power) have secured a berth at the European Marine Energy Centre (EMEC) to progress a long term demonstration of their next generation tidal turbine, the Orbital O2 (formerly known as the SR2-2000). The Orbital O2 is a floating 2MW generating capacity tidal turbine with two rotors. The turbine will be installed at test berth 5.

This Environmental Monitoring Programme (EMP) has been developed to support Orbital's application for a marine licence under the Marine (Scotland) Act 2010, Part 4. Orbital will be utilising EMEC's site-wide Section 36 consent to generate electricity at the site under the Electricity Act 1989.

The EMP should demonstrate an active attempt to capture, record and analyse data on the potential environmental impacts associated with Orbital O2 operation. To further Orbital's and the industry's understanding of the potential environmental impacts associated with the deployment of the device, equipment and/or sensors should be installed at the deployment site to gain a greater understanding of how marine species (particularly marine megafauna - mammals, basking shark, diving birds and fish) interacts with the tidal turbine.

1.2 Objectives

As part of the marine licence application it is necessary to identify monitoring and mitigation measures to reduce the likelihood of any potential environmental impacts occurring due to the proposed project and to quantify the extent of any existing impacts. During the EMP, opportunities to monitor the Orbital O2 will be identified to gather further information on issues of concern. EMEC encourages developers at its test sites to independently consider key environmental impact pathways, and supports developers and researchers in employing new and innovative monitoring strategies for understanding any potential environmental impact pathways.

As the EMP is an iterative document, Orbital will be responsible for ensuring the contents of the document are maintained up-to-date. The framework, principles and details of the EMP will be agreed with the Regulator, Marine Scotland, during the consent application process and later amendments agreed, as required. It is noted, that the commitments made therein are likely to be incorporated into licence conditions. The results of the mitigation and monitoring carried out in accordance with the EMP shall be submitted to the Regulator in fulfilment of licence conditions. As part of the EMP, appropriate reporting mechanisms or dissemination strategy has been suggested for each mitigation/monitoring measure. This will support Regulators and

stakeholders' awareness of consent compliance and any key results/findings from the monitoring.

The EMP is a project-specific annex to EMEC's Fall of Warness Environmental Appraisal (EMEC, 2014). The EMP has been developed in line with guidance provided within the appraisal.

The following process has been developed:

- 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;
- further understanding of environmental impacts and how to monitor and analyse; and
- provide opportunities to seek innovative solutions for mitigating impacts or for understanding the importance of interactions.

1.3 References

The following documents have been referred to during the development of the EMP.

Ref#	Document/Drawing Reference	Owner	Title
1	Orbital O2-1	Orbital Marine Power Ltd.	Product Specification
2	Orbital O2-81	Orbital Marine Power Ltd.	Orbital O2 Turbine Overview
3	SR-2000-100	Orbital Marine Power Ltd.	Implementing Plan – Environmental Monitoring
4	REP443-04-01	EMEC	Fall of Warness Environmental Appraisal

2 Project Overview

2.1 Project Description

The Orbital O2 has a generating capacity of 2MW and is composed of 2 rotors. The turbine will be maintained in position using a four-point mooring configuration with gravity-based anchors. The device will be located at test berth 5 at the Fall of Warness test site. The device will utilise the pre-existing subsea cable 5 at the Fall of Warness which is connected to EMEC's onshore Cauldale substation on Eday, Orkney.

The key components to be installed as part of the project, are outlined below:

- Orbital O2 tidal turbine including two 1MW generating capacity rotors;
- Four gravity based anchors with associated mooring lines;
- Dynamic umbilical cable; and
- Appropriate navigational aids including AIS AtoN.

It is anticipated that the device will be remotely monitored utilising on-board sensors. It is anticipated that any minor maintenance activities (including electrical and sensor maintenance) will be conducted onsite. It is not envisaged that it will be necessary to remove the Orbital O2 from site for maintenance unless significant component failure, device damage occurs or a significant maintenance overhaul is required.

Following the operation of the project, the device will the removed from the site and the site returned to the condition in which Orbital found it.

The *Orbital O2 Project Information Summary* document provides overarching information regarding the following:

- Device specification;
- Mooring specification;
- Device maintenance method and schedule;
- Electrical subsea cable and umbilical cable;
- Turbine specification; and
- Device monitoring and control system.

A full list of all material used during the installation, operation and decommissioning of the Orbital O2 is provided within the *Orbital O2 Project Information Summary*. No other types of deposits are foreseen. It is intended that all deposits will be removed on completion of the project and the seabed at the test berth and immediate surrounding location will be left in the condition in which it was found, following the full decommissioning of the project.

2.2 Project Location

The following coordinates outline the proposed marine licence boundary for the deployment of the Orbital O2 at test berth 5, Fall of Warness.

Position	Latitude	Longitude
A	59° 08.917' N	02° 49.374' W
B	59° 08.916' N	02° 48.558' W
C	59° 08.453' N	02° 48.560' W
D	59° 08.454' N	02° 49.376' W

The proposed licence boundary is marked on Figure 2 relative to EMEC's Fall of Warness test site. The excursion area of the Orbital O2 is estimated to be approximately 25m.

Once the final deployment location has been determined, the Regulator will be informed. The mooring spread of the Orbital O2 is anticipated to be 420m from upstream to downstream of the device and 220m laterally

2.3 Installation Method

The installation of the Orbital O2 has been designed such that small workboats, such as multicats, can complete the operation. The Orbital O2 will be pre-fabricated offsite and towed to the Orkney Islands where blades are likely to be connected.

The key steps for deploying the Orbital O2 are outlined below, however a further detailed description can be found within the *Orbital O2 Project Information Summary*.

1. Installation of Orbital O2 moorings
2. Installation of dynamic cable
3. Mooring connection trials
4. Install on moorings
5. First grid connection
6. Commissioning

Operations will only be conducted in safe tidal and weather conditions and when vessel availability allows. Orbital aim to minimise the use of vessels and vessel movements.

2.4 Decommissioning Method

The *Orbital O2 Decommissioning Programme,* which will be submitted prior to commencement of works for consultation, will provide an indication of the proposed decommissioning

methodology following completion of device testing. The anticipated key steps for decommissioning the Orbital O2 are outlined below.

1. Electrical connection to the platform unlocked and capped
2. Mooring connections unlocked and returned to neutral buoyancy position and marked with pickup buoy
3. Orbital O2 towed offsite using multicat workboat
4. Each of anchor cages and ballasts recovered including mooring lines
5. Reuse, recycling or disposal of device and anchors.

3 EMEC Design Envelope Approach

EMEC has developed a project envelope for testing activities at the Fall of Warness. The envelope outlines the type and characteristics of the devices likely to be deployed at the site and the types of marine operations and activities likely to be associated with the installation, operation and maintenance of the devices. An environmental appraisal was undertaken to assess the potential environmental impacts associated with testing devices within the envelope and cumulative impacts. The appraisal provides a detailed consideration of the potential natural heritage impacts and informs the consenting process for deployment and operation of tidal devices at the Fall of Warness, within the project envelope.

3.1 Parameter Comparison

The following table provides a comparison between the parameters associated with the operation of the Orbital O2 and the project envelope for the site.

Specification	Project Envelope	Orbital O2 Testing Campaign	Within project envelope?
Site location			
Site boundaries	Crown Estate lease area.	Situated at test berth 5.	✓
Facilities			
Subsea cable	Seven of the berths serviced by EMEC-installed/owned cables. Cable servicing the eighth berth owned by Orbital.	Utilising pre-installed subsea cable at test berth 5.	✓
Cable protection	Cast iron cable protectors installed where cable free-spans over underwater obstructions. Concrete mattresses laid where cables may cross each other.	Utilising pre-installed subsea cable at test berth 5. No additional cable protection to be installed.	✓
Potential activities / deployments			
Subsea cable	Installation of new subsea cable and associated cable protection systems (mattresses, armour) where required and potential	Umbilical dynamic cable connected between device and EMEC subsea cable.	✓

Specification	Project Envelope	Orbital O2 Testing Campaign	Within project envelope?
	recovery and replacement on the seabed of existing cabling from berths to shore, and repair/maintenance to existing cables or cable protection systems.		
Arrays	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.	Only a single device is to be deployed under this project.	✓
Scientific instruments	Deployment of scientific instrumentation and associated cabling.	It is anticipated that an ADCP will be deployed during the testing campaign. At this stage it is not anticipated that any scientific instruments utilising active acoustics will be deployed as part of this testing campaign.	✓
Buoys	Testing of buoys (maximum of two simultaneous tests).	No buoys are to be tested under the testing campaign.	✓
Mooring arrangement / component testing	Testing of mooring arrangements (e.g. tripod support structures) or individual stand-alone components of devices.	No mooring arrangements (without an associated test device) are included in the test campaign.	✓
SIMOPS	Potential for simultaneous operations, i.e. installation or maintenance activities, at more than one berth at the same time.	When and where there is a possibility of simultaneous operations, EMEC will advise to ensure adequate measures are being taken.	✓
Device characteristics			
Blade/rotor design	• 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	The two rotors on the Orbital O2 have blades with exposed tips on a single axis.	✓
Rotor diameter	25m (open-bladed rotors)	Rotor diameter of 20m	✓
Number of simultaneous turbines/rotors	12 devices with up to 18 rotors	The Orbital O2 is a single device with two rotors	✓
Rotor depth	Minimum depth - 2.5m clearance from sea surface	The minimum clearance whilst	Further discussion

Specification	Project Envelope	Orbital O2 Testing Campaign	Within project envelope?
		generating is greater than 2.5m (3.2m) whereas when the rotors are retracted the minimum depth clearance is 2.3m.	provided in Section 3.2.
Mooring/foundation Infrastructure			
Method	• 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 Orbital O2 will be anchored with four gravity-based anchors.	✓
Pile driving	Project envelope restricts pile/pin insertion to non-percussive methods (i.e. no pile driving).	No percussive drilling methods are included in the installation or testing campaign.	✓
Marine works			
Procedures and ERPs	All deployment/retrieval methods will be in accordance with EMEC's Standard Operating Procedures (SOPs) and subject to EMEC's Emergency Response Procedure . 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.	Orbital will produce and follow method statements and risk assessment for all works carried out at site. EMEC's SOPs and ERP will be followed. Orbital will conform with EMEC's Permit to Access site system and all methodologies will conform to health and safety and marine navigational safety requirements and regulations. Notice to Mariners will be issued in line with best practice.	✓
Pre-installation activity	Pre-installation • ROV/diver surveys • ADCP deployment/retrieval • Bathymetry surveys • Sub-bottom profiling • Acoustic surveys	Orbital may undertake any of the surveys outlined. The Regulator will be informed of upcoming survey work.	✓
Installation activity	Installation • Drilling and grouting	The planned installation work is within the project	✓

Specification	Project Envelope	Orbital O2 Testing Campaign	Within project envelope?
	• Lowering foundation/anchors/nacelle • Cable works and connection to device	envelope. Detailed method statements will be provided to EMEC.	
Testing activity	• Testing of nacelle, gravity foundations, anchors or scientific equipment • ADCP deployments • Acoustic surveys	Details of all testing activity will be provided to the Regulator prior to commencement of the works.	✓
Inspection and maintenance of devices	Inspection and maintenance of devices • ROV inspection • Diver activities • Repairs below/above surface on site • Biofouling removal	Details of the inspection and maintenance activity are provided in the *Orbital O2 Project Information Summary.*	✓
Temporary retrieval	Temporary retrieval and redeployment of nacelle, gravity foundations, anchors or scientific equipment.	Details of any retrieval works will be provided to the Regulator prior to commencement of the works.	✓
Cable works	Inspection, maintenance and replacement of cables and protection • ROV inspection • Diver activities • Cable lifting/laying • Placement of mattressing	It is not anticipated that this type of cable works will be required during the testing campaign.	✓

3.2 Rotor Depth

Within the project envelope for the Fall of Warness test site, the minimum rotor depth is stated as 2.5m clearance from the sea surface. When the Orbital O2 rotors are retracted (in a non-generating state) on the device, the rotors will sit laterally across the surface of the water. This may cause an additional navigational risk for vessels operating within the vicinity of the device, and therefore Orbital will need to account for this during the development of method statements during installation, maintenance and decommissioning. Further discussion regarding the increased risk of vessel collision is included in the *project-specific Navigational Risk Assessment*.

The reduced clearance of blades from the sea surface is not expected to increase the potential for collision risk with marine megafauna, including diving birds, as the rotors will be in a non-operational state.

When the rotors are extended and operational, there will be a minimum 3.2 m clearance between the sea surface and the uppermost blade tips.

4 Receptors

During EMEC's *Fall of Warness Environmental Appraisal* process a detailed analysis of the natural heritage context for each of the key environmental receptors present at the Fall of Warness was completed.

A summary of the findings from the appraisal is provided in the following table.

Receptor	Appraisal conclusion	High-level conclusion	Monitoring and/or mitigation identified?
Benthic Environment			
Substrate/ geogenic habitats	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. 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.	No important impacts	No
Benthic species	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.	No important impacts	Yes
Biogenic habitats	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.	No important impacts	Yes

Receptor	Appraisal conclusion	High-level conclusion	Monitoring and/or mitigation identified?
Cetaceans			
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.	Potentially important	Yes
Seals			
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.	Potentially important	Yes
Grey seals	LSE identified for Faray and Holm of Faray SAC, but no adverse effect on site integrity. However,	Potentially important	Yes

Receptor	Appraisal conclusion	High-level conclusion	Monitoring and/or mitigation identified?
	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.		
Marine Birds			
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.	Potentially important	Yes
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 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.	Potentially important	Yes
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.	Not important	Yes
Gannets	Gannets could potentially dive to a sufficient depth	Not important	None identified

Receptor	Appraisal conclusion	High-level conclusion	Monitoring and/or mitigation identified?
	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.		
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.	Potentially important	Yes
Skuas	No direct impact pathway – potential disturbance to prey species considered but not thought sufficient to be a significant impact on these species.	Not important	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.	Not important	None identified
Auks	Auks (especially common guillemot and black guillemot) are present at high frequency in the Fall of Warness test area and may potentially be impacted by disturbance from feeding areas or collision with operating turbines. Of these impacts only collision with turbine blades was	Potentially important	Yes

Receptor	Appraisal conclusion	High-level conclusion	Monitoring and/or mitigation identified?
	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.		
Fish			
Diadromous fish	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.	No important impacts, including no LSE on any European Sites	Yes
Marine fish	**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. **Clupeid species**: Any potential impacts are not regarded as important at a population level. **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. **Elasmobranch species** (except basking shark): 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. **Marine fin-fish**: Any potential impacts are not regarded as important at a population level.	No important impacts	Yes
Marine shellfish	**Crustaceans**: Any potential impacts are not regarded as important at a population level, but some monitoring and research in the context of	No important impacts	Yes

Receptor	Appraisal conclusion	High-level conclusion	Monitoring and/or mitigation identified?
	the test facility would have merit. Good practice should be adopted to reduce the risk of introducing non-natives. **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.		
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.	Potentially important	Yes

4.1 Designated Sites

Currently, the Fall of Warness test site does not lie within a protected area but there are several protected sites near to the test facility. These sites are summarised in the following table with an explanation of the reason for their designation.

In addition, the Fall of Warness test site is in close proximity to the proposed Special Protection Area (North Orkney pSPA). This site has been proposed due to its qualifying bird species:

Annex 1 species:

- Great northern diver
- Slavonian grebe
- Red-throated diver
- Arctic tern

Migratory species:

- Common eider
- Long-tailed duck
- Velvet scoter
- Red-breasted merganser
- European shag

Site Name	Protection Status	Qualifying Interests/ Notified Features/ Special Qualities
Doomy and Whitemaw Hill, Eday	Site of Special Scientific Interest	The site is one of Orkney's main locations for breeding whimbrel with at least 1% of the British breeding population present. This is a breeding population of national significance. This site is also of national significance for Arctic skua, with again at least 1% of the British breeding population.
Faray and Holm of Faray	Special Area of Conservation	Grey seals.
Faray and Holm of Faray	Site of Special Scientific Interest	The site is one of the most important breeding and haul out sites for grey seals in Orkney. In 2006, an estimated 3,148 pups were produced, equivalent to around 16% of the annual pup production for Orkney, and 7% of the total annual pup production for Britain.
Sanday	Special Area of Conservation	The various marine habitats of Sanday act as qualifying features with reefs, subtidal sandbanks and intertidal mudflats and sandflats. The area also has a qualifying population of harbour seals.
Muckle and Little Green Holm	Site of Special Scientific Interest	Grey seals.
Rousay	Special Protection Area	Aggregations of breeding birds: guillemot, Arctic skua, Arctic tern, kittiwake, fulmar and seabird assemblage.
Rousay	Site of Special Scientific Interest	Various notified habitats: blanket bog, maritime cliff, mesotrophic loch, subalpine wet heath, vascular plant assemblage. There is also a moorland breeding bird assemblage and a breeding seabird colony including Arctic skua, Arctic tern, guillemot and kittiwake.
Mill Loch, Eday	Site of Special Scientific Interest	Aggregation of breeding red-throated diver, one of the densest in the UK.
Calf of Eday	Special Protection Area	Aggregations of breeding birds: nationally important populations of great cormorant, Northern fulmar, common guillemot, black-legged kittiwake, and great black-backed gull, and extensive seabird assemblages.

Site Name	Protection Status	Qualifying Interests/ Notified Features/ Special Qualities
Calf of Eday	Site of Special Scientific Interest	Aggregation of breeding cormorant.

5 Potential Environmental Impacts

During a full review of the Fall of Warness Environmental Appraisal, the following potential risks to the marine environment and species have been identified that may be associated with the proposed deployment and operation of the Orbital O2:

- Acoustic disturbance due to increase vessel presence onsite, installation and maintenance work and the direct acoustic output from the turbine during operation.
- Risk of entanglement of marine megafauna with the mooring system and dynamic cable.
- Displacement and disturbance to species in the immediate vicinity.
- Seabed clearance including impact to benthos.
- Biofouling and introduction of non-native species during towing operations.
- Collision risk of marine megafauna with the moving parts of the device.

Prior to commencing the work outlined in the EMP, it will be crucial that all methodologies for mitigation and monitoring are agreed with the Regulator and Scottish Natural Heritage (SNH). Any key events or findings will be disseminated to the Regulator and appropriate consultees in line with the reporting mechanism outlined in Section 6.

5.1 Acoustic disturbance

5.1.1 Overview

There are potential effects on marine mammals, basking sharks, fish and seabirds from underwater noise generated by tidal device operation (from machinery housed subsurface structures). It is unlikely acute effects such as non-auditory/auditory tissue damage would be experienced but behavioural effects with respect to disturbance are possible. Currently the importance of hearing underwater and hearing thresholds for diving birds is unknown however, many studies have been completed to understand the hearing thresholds for marine mammals and fish. It is anticipated that the noise produced by the device may have the potential to cause displacement, avoidance, causing a reduction in foraging success.

In addition, as the Orbital O2 has machinery housed in surface-piercing components, there is the potential to affect diving birds due to the above surface noise generated.

During installation and maintenance work, there is anticipated to be an increased presence of vessels onsite though only one multi-cat and one RHIB are planned to be on site at any one

time. The noise generated by vessels onsite has the potential to disturb species in the immediate vicinity of the test site. It is expected that this impact will be temporary in nature.

5.1.2 Proposed mitigation and monitoring

The following table summarises the proposed mitigation measures and monitoring activity relating to each potential impact pathway associated with underwater noise. The reporting mechanism for each proposed mitigation and monitoring measure are also provided in the below table.

Impact pathway	Receptor	Proposed mitigation/monitoring measure	Reporting mechanism
All project phases			
Disturbance – Noise from vessel activity (including transiting to and from site)	Cetaceans, Basking shark, Seals	**Mitigation**: The Scottish Marine Wildlife Watching Code (SMWWC)[1] will be adhered.	
Installation			
Disturbance – Noise from mooring installation methods	Cetaceans, Basking sharks, Seals	**Mitigation**: The SMWWC will be adhered to throughout all operations, where possible.	
Operation and Maintenance			
Disturbance – Noise from operating turbine	Cetaceans, Harbour and grey seals	**Monitoring**: Acoustic monitoring of operational noise output to establish an acoustic signature of the Orbital O2 will be completed. A baseline assessment will be completed prior to device deployment. It is anticipated monitoring will be conducted utilising drifting acoustic surveys. The methodology will be agreed with SNH and Marine Scotland prior to works.	Methodology for acoustic monitoring will be provided in the EMP and agreed with the Regulator and SNH prior to use. Analysis will be conducted on the acoustic monitoring data.

[1] Scottish Marine Wildlife Watching Code is downloadable from the Scottish Natural Heritage website: http://www.snh.gov.uk/enjoying-the-outdoors/what-can-i-see/wildlife-watching/watching-wildlife-responsibly/

5.2 Entanglement Risk

5.2.1 Overview

It is considered unlikely that the potential exists for cetaceans and basking sharks to become entangled in the mooring lines and dynamic cable of size and dimension required to support the Orbital O2. The Orbital O2 moorings are made up of 95mm and 115mm studlink chain with a total dry weight of around 55 tonnes per line. It is anticipated that a marine mammal will effectively treat the mooring system as a solid structure, and therefore the likelihood of entanglement in the mooring lines is reduced significantly. Understanding this impact pathway further will be particularly important if an array of complex mooring lines (not under tension) are to be deployed.

The sensors on the mooring lines used to detect mooring loads on the machine cannot detect any change in loading of less than 3Te. Therefore, it is anticipated that it will not be possible that any marine mammal or basking shark would be able to impart enough load to the moorings for the impact to be detected.

The dynamic cable that is below the machine is 71mm in diameter, is under constant tension and weighs 7 Tonnes per km in water, therefore, from a risk of entanglement viewpoint, the dynamic cable is also effectively a solid structure. There is not sufficient slack at any time enough to allow loops to form in the water column.

There is a secondary concern that fishing lines, nets or other items could get fouled in the mooring system and then cause entanglement/entrapment or potentially act as ghost fishing gear.

5.2.2 Proposed mitigation and monitoring

The following table summarises the proposed mitigation measures and monitoring activity relating to each potential impact pathway associated with entanglement. The reporting mechanism for each proposed mitigation and monitoring measure are also provided in the below table.

Impact pathway	Receptor	Proposed mitigation/monitoring measure	Reporting mechanism
All project phases			
Injury or death due to entanglement with mooring system/cable	Cetacean, Basking shark	**Monitoring**: The likelihood of impact through entanglement is anticipated to be very low. Regular drop camera footage of the mooring lines will be reviewed to look for evidence of entanglement events and entanglement of fishing gear etc. A reporting protocol will be produced for the operator to follow in	Any entanglement events recorded will be reported to the Regulator immediately. Procedures for emergency shutdown will be followed in this event.

		the event of an entanglement event.	

5.3 Disturbance/Displacement

5.3.1 Overview

There is potential for displacement of essential activities of marine mammals, seabirds, fish and basking sharks due to the presence of the device and associated moorings. The displacement can be caused by the physical presence of the structures or other disturbances caused by the installation (such as noise etc.). The presence and operation of devices and associated mooring structures could potentially result in the displacement of species out of the development site and surrounding area. The significance of the displacement will depend on the importance of the habitat, i.e. is it important for essential activity (breeding, foraging, moulting, resting, etc.) and the availability of alternative habitat elsewhere.

Displacement can be a temporary issue, with behavioural patterns changing over time as birds habituate to the presence of device. Note, that there is the potential that birds, fish and possibly marine mammals could be attracted to the area due to the presence of the device, this may be as roosting location or to exploit new foraging opportunities that may arise if prey species are found to gather around the structures.

During deployment of the SR2000 device, up to 20 guillemots were recorded at any one time roosting on the surface of the SR2000 platform between the months of May 2018 and September 2018. Observances suggested that they used the SR2000 as a roost overnight and return to feeding behaviour during the day away from the device.

Guillemots of SR2000 machine 20.08 hrs 15/05/2018

02/05/2018 Guillemots roosting at night

5.3.2 Proposed mitigation and monitoring

The following table summarises the proposed mitigation measures and monitoring activity relating to the potential impact pathway. The reporting mechanism for each proposed mitigation and monitoring measure are also provided in the below table.

Impact pathway	Receptor	Proposed mitigation/ monitoring measure	Reporting mechanism
All project phases			
Disturbance – Presence or noise from vessel activity (including transiting to and from site)	Cetaceans, Basking shark	**Mitigation**: The Scottish Marine Wildlife Watching Code (SMWWC) will be adhered, including the following measures: – Vessel speeds will be reduced to 6 knots when a cetacean is sighted in close proximity to the immediate vessel transit route. – A steady speed and vessel course will be maintained if a cetacean approaches a vessel involved	Any incidents which deviate from this measure will be reported on in the appropriate EMR.

Impact pathway	Receptor	Proposed mitigation/ monitoring measure	Reporting mechanism
		in marine operations. – Utmost care will be taken in ensuring groups and mothers and young are not split up by vessels. – Sudden changes in speed and direction will be avoided to reduce the likelihood of any further disturbance to cetaceans in the vicinity. The completion of this mitigation measure will be dependent on ensuring safe navigation throughout activities, crew safety and completion of marine operations which are constrained by tidal or weather windows.	
Harassment/Disturbance – Presence of vessel activity (including transiting to and from site)	Harbour and grey seals	**Mitigation**: SMWWC will be adhered to including the measures outlined above. In addition, during all vessel activity a minimum approach distance will be complied with when passing designated seal haul-outs.	Any incidents which deviate from this measure will be reported on in the appropriate EMR.
Disturbance – Presence of vessel activity (including transiting to and from site)	Seabirds	**Mitigation**: SMWWC will be adhered to including following particular measures: – Rafts of birds will not be	Any incidents which deviate from this measure will be reported on in the appropriate EMR.

Impact pathway	Receptor	Proposed mitigation/ monitoring measure	Reporting mechanism
		intentionally flushed. – During seabird breeding season (April to August inclusive), vessel transit corridors will be at least 50m from shore in the vicinity of cliff-nesting seabirds to avoid disturbance.	
Installation			
Disturbance – Presence or noise from mooring installation works and vessel presence onsite	Cetaceans, Seals, Basking shark	**Mitigation**: All operations will be conducted in line with SMWWC.	Any incidents which deviate from this measure will be reported on in the appropriate EMR.
Operation and Maintenance			
Displacement – Barrier effect from the presence of device	Birds and potentially marine mammals, basking shark and fish	**Mitigation**: Mitigation only required if other research findings or monitoring indicates unacceptable impact. **Monitoring**: Record video footage from above-surface infrared cameras monitoring bird and marine mammal observations in the vicinity of the device[2]. In addition, roosting behaviour will be monitored. During device generation, an operator will be able to view video screens which show footage from both cameras[3]. Opportunistic	Findings from video analysis reported in appropriate EMR.

[2] Two fish-eye cameras will be mounted on the communication masts will be able to capture the turbine deck and sea surface in the vicinity of the device. The cameras will operate in infrared at night and low-visibility conditions.

[3] Following the commissioning stage, there is unlikely to be a permanent ongoing operator of the machine, with an automated operation process instead.

Impact pathway	Receptor	Proposed mitigation/ monitoring measure	Reporting mechanism
		recording of species behaviour will be recorded by the operator in line with an agreed protocol and reporting form.	

5.4 Seabed clearance

5.4.1 Overview

There is potential for direct loss of sub-littoral seabed communities due to the presence of the gravity-based moorings on the seabed. The installation of the new structures directly on the seabed, will result in the loss of habitat due to the placing of the structures. It may be necessary to conduct seabed clearance prior to installation. Small amounts of lost habitat may diminish populations of species that are recorded as rare.

There is also the potential for abrasion caused by mooring lines dragging or rubbing across the seabed or from vessel anchors during installation. Abrasion is likely to damage or kill species, which are sessile or sedentary.

It is anticipated that very little to no seabed clearance will be necessary during the installation works for the Orbital O2 anchors, as discovered during the installation of the mooring system associated with the SR-2000. It is anticipated that due to the tidal swept nature of the site, that the majority of the deployment location will be bedrock. The footprint of the anchor blocks is expected to be minimal and therefore, if any seabed clearance is necessary this would be limited.

5.4.2 Proposed mitigation and monitoring

The following table summarises the proposed mitigation measures and monitoring activity relating to the potential impact pathway. The reporting mechanism for each proposed mitigation and monitoring measure are also provided in the below table.

Impact pathway	Receptor	Proposed mitigation/monitoring measure	Reporting mechanism
Installation			
Seabed loss due to the direct footprint	Benthic communities	**Monitoring:** Pre-installation and post-installation seabed survey will be conducted to understand the extent of the effect on the benthic ecology and seabed character caused during installation activities.	Video footage collected during the survey will be analysed and reported on in the appropriate EMR.
Decommissioning associated with the Orbital O2			

Impact pathway	Receptor	Proposed mitigation/monitoring measure	Reporting mechanism
Colonisation and loss of new habitat	Benthic communities	**Monitoring:** Pre-decommissioning seabed survey will be conducted 2 months prior to decommissioning the anchors. The survey results will be used alongside the results from the surveys conducted when the mooring blocks were initially installed to investigate any effects on the benthic ecology and seabed character during the device deployment period.	A summary report will be submitted to the Regulator prior to decommissioning activities commencing.
Recolonisation	Benthic communities	**Monitoring:** Post-decommissioning (within 3 months) seabed surveys will be conducted to investigate the effects on the benthic ecology and seabed character caused during decommissioning activities. There is also an opportunity to investigate the likelihood of recolonisation when analysing these results.	The results from the survey will be reported on in the appropriate EMR.

5.5 Biofouling and non-native species

5.5.1 Overview

Biofouling is the gradual accumulation of waterbourne organisms on the surfaces of objects in the water. Biofouling may consist of microorganisms such as bacteria or protozoa or macro-organisms such as barnacles or seaweed. Biofouling can contribute to surface corrosion and may also reduce the efficiency of moving parts. Orbital O2 will utilise appropriate biofoulants to minimise the accumulation of biofouling on the turbine as far as practical.

Various guidelines and standards have been referred to in developing the proposed mitigation and monitoring measures (IMO, 2011). Despite the use of biofoulants, it is likely that a certain level of biofouling will accumulate, it is unlikely to pose a risk to introducing non-native species as movements will be limited to towing from shipyard to Orkney waters, as outlined below:

- Main hull and legs to be assemble in shipyard and towed to Orkney;
- Nacelles and hubs will be assembled in continental Europe and will not be put in to the water before they reach Orkney.

The spread of non-native organisms can occur through a variety of means including: shipping, transport of fish or shellfish; scientific research and public aquaria. These invasive non-native species can threaten marine diversity. Due to accumulation of non-native species in harbours and ports, during maintenance activities, the turbine and mooring system may act as locations for non-native species to grow and hence be transported to site and thus provide a stepping stone for colonisation.

5.5.2 Proposed mitigation and monitoring

The following table summarises the proposed mitigation measures and monitoring activity relating to the potential impact pathway. The reporting mechanism for each proposed mitigation and monitoring measure are also provided in the below table.

Impact pathway	Receptor	Proposed mitigation/monitoring measure	Reporting mechanism
All project phases			
Biofouling and the introduction of non-native species	Benthic communities	**Mitigation**: Compliance with good practice measures detailed in the 'Alien invasive species and the oil and gas industry – Guidance for prevention and management' produced by the IPIECA in 2010, 'Guidance for minimizing the transfer of invasive aquatic species as biofouling (hull fouling) for recreational craft' produced by the IMO in 2012 and the 'Code of Practice on Non-Native Species' made by Scottish Ministers under section 14C of the Wildlife and Countryside Act 1981.	Any deviance from the good practice measures will be reported on prior to the event occurring via the appropriate EMR.
		Mitigation: Local vessels will be used throughout all installation, maintenance and decommissioning operations therefore there is not likely to be any potential for the introduction of NNS than those NNS already present in Orkney waters.	The requirement to use a non-local vessel for any marine operations associated with the project will be agreed with the Regulator prior to works.
		Mitigation: Antifouling paints will be used which comply with the IMO International Convention on the Control of Harmful Anti-fouling Systems on Ships and national legislation.	N/A
Biofouling, introduction of non-native species and habitat creation	Sessile communities	**Mitigation**: Opportunistic inspections of biofouling will be implemented which will have a dedicated procedure for removing biofouling species from the device. The	Findings reported on in the appropriate EMR.

Impact pathway	Receptor	Proposed mitigation/monitoring measure	Reporting mechanism
for biofouling species		organisms removed will be analyzed by experts to ensure a comprehensive species list is compiled.	
Decommissioning (informed through the SR-2000)			
Habitat removal for biofouling species	Sessile communities	A full device biofouling inspection may be conducted as the device is decommissioned. This inspection will be conducted by an expert in the biofouling field to ensure that a comprehensive species list is compiled.	Findings reported on in the final EMR.

5.6 Collision Risk with Blades

5.6.1 Overview

There is potential for collision between marine mammals, basking sharks and seabirds and tidal energy devices and associated moorings. The risk of collision is considered to be a key potential impact for marine mammals and basking sharks during device operation. Direct physical interactions with a device has the potential to cause physical injury with potential consequences at a population level. However, there is considerable lack of empirical knowledge on this risk (Macleod *et al*., 2011).

Baleen whales and basking sharks are generally slow moving with a relatively low degree of manoeuvrability, potentially putting them at a high risk of collision with devices. In contrast, highly mobile species, such as small cetaceans and seals, should result in the capacity to both avoid and evade a device. However, this is reliant on a number of factors:

- individuals having the ability to detect the objects;
- perceiving them as a threat; and
- taking appropriate action at a suitable range.

Each species' ability to detect devices will depend on its sensory capabilities, and the visibility and level of noise emitted by the device. The potential for animals to avoid collisions with devices will also depend on their body size, social behaviour, foraging tactics, curiosity, habitat use, underwater agility, and the tidal and environmental conditions present at the test site (Macleod *et al*., 2011). Collision risk is likely to be highest in fast flowing areas where high approach speeds may delay the time available for animals to react or impede their navigational abilities.

Although the key concern relating to collision risk is associated with turbine blades striking and injuring or, potentially, killing an animal. It is also possible that species may collide with

stationary structures e.g. mooring lines, anchors and support structures. These are less likely to cause death but injuries from entanglement may result.

It is considered that a collision of a turbine blade is very unlikely for the following reasons:

- The blades are moving relatively slowly through the water such that a swimming animal could easily avoid the blade. The anticipated maximum RPM for the rotors on the Orbital O2 is 15.
- The area of the blades is small in comparison with the swept area. There are two blades which are composed of up to 5% of the swept area. Therefore, it is anticipated that there is significant 'clear' space for animals to pass between blade movements.

Observations of animals in the area, such as seals, show that the density of the marine mammals and their prey (fish) is linked to the tidal flow. Underwater observations in the area have noted that there are greater densities of prey during slack tide, when the turbine blades would be idle. It is therefore anticipated, that marine mammals and seabirds are less likely to be passing through the area when the tide is at full flow and the blades are turning.

Due to declining harbour seal population within Pentland Firth and Orkney Waters, the potential for encounter/collision between a harbour seal and the rotating blades of a tidal turbine is of particular concern. It is anticipated that the marine mammals actively avoid the turbine rotor however, it is desirable to capture evidence that corresponds to this hypothesis. As it is expected that potential of encounter will be species-specific, it is desirable to have this evidence for as many different species as possible. Within the marine energy industry there are certain practices already in use to capture such data, however the methods employed have had varying success. The following section provides an overview of planned monitoring to further industry's understanding of collision risk.

5.6.2 Proposed mitigation and monitoring

The following table summarises the proposed mitigation measures and monitoring activity relating to the risk to marine megafauna encountering a turbine, resulting in an increased risk of collision. It will be crucial that all methodologies for mitigation and monitoring are agreed with the Regulator and SNH prior to commencing work. The reporting mechanism for each proposed mitigation and monitoring measure are also provided in the below table.

Impact pathway	Receptor	Proposed mitigation/monitoring measure	Reporting mechanism
Operation and Maintenance			
Behavioural change, injury or death due to the interaction with turbine rotor with the potential for collision.	Diadromous fish; Gadoids, Cetacean, Basking shark or harbour and grey seal;	Continual review of monitoring work carried at other sites with installed tidal turbines to ensure any required mitigation and monitoring measures	Report any additional new information that requires an update to the EMP. Advice from SNH will be sought when sourcing underwater cameras and the determining an

Impact pathway	Receptor	Proposed mitigation/monitoring measure	Reporting mechanism
	All diving bird species (seaduck, red-throated diver, great cormorant, common guillemot, razorbill, Atlantic puffin, black guillemot, northern gannet).	are effectively employed. **Monitoring**: If possible, four underwater cameras will be mounted on the Orbital O2 system such that the full sweep of each blade can be observed. The cameras will only be effective during daylight hours[4]. The video footage can then be sampled at varying tidal states to understand fish, marine mammal, bird behaviour in close proximity to the device. A suitable measure for ensuring the camera lens remains free of biofouling and biofilms will also need to be determined.	appropriate sampling regime for the video data.

5.6.3 Research – Integrated monitoring system

Following experience with the SR2000, it is considered that a separate frame for mounting environmental monitoring systems offers a potential solution to reliably maintain the monitoring systems and to trial/optimise various systems as the technology/understanding advances rather than 'hardwiring' a single fixed system into the device.

Two research methods for understanding marine mammal behaviour in the near-field environment have been investigated.

- Hydrophone cluster: Deploying a hydrophone cluster on separate frame attached to the Orbital O2 to detect cetaceans. If this is in place, the data could be used as a triggering event allowing analysis of the blade footage to focus on time when mammals in the vicinity.
- Multi-beam sonar/echosounder: A multibeam sonar/echosounder could be deployed on a frame attached to the Orbital O2 looking at water column prior to rotor blade. This

[4] This monitoring measure is dependent on the ability to design a mounting arrangement for the cameras on the device and sourcing suitable underwater cameras.

data could be automatically analysed for targets moving into swept area for each rotor. This will allow more focused analysis of the video footage.

Both of these research concepts are dependent on finding further funding. Details regarding an integrated monitoring system would be able to be confirmed when the device design has been finalised. If further funding is achieved, advice from SNH will be sought on the instrument specification and location. It will be essential to consider the data storage capabilities and sampling frequency during the design phase of the integrated monitoring system.

5.6.4 Research - Accelerometers and strain gauges

It should be noted that accelerometers were installed on SR2000 blade tips and it was supposed that such instrumentation may be able to be used in collision detection. However, during blade testing it was noted that a fully grown man jumping on the blades could not get a signal to register on the accelerometers, due to heavy and stiff nature of the blades. As the Orbital O2 blades are longer and heavier than the SR-2000, the use of accelerometers to support collision risk detection does not appear to be a viable option.

It was also hypothesized that the strain gauges in blades (which detect blade bending for verification of structural loading models) might be able to be used in collision detection. However, data from the SR2000 project indicated that the data that comes from the gauges is very ‘spiky’ which shows the swirls and buffets of turbulence to which the blades are subjected. It is therefore anticipated that it would be infeasible to detect a collision event in this data.

For this reason, neither accelerometers or strain gauges are proposed for collision detection for the Orbital O2 project.

6 Reporting Mechanisms

The EMP will be continually updated to ensure the content remains in line with the current planned activities. Any new mitigation or monitoring methodologies that may offer a greater opportunity to Orbital to reduce the potential for or provide a greater understanding of an impact may be incorporated into the EMP.

At appropriate stages during the Orbital O2 testing campaign, Orbital will produce an Environmental Monitoring Report (EMR). The following table provides an overview of the intended reporting schedule for updates to the EMP and production of Environmental Monitoring Reports (EMRs).

Report Schedule	Type of Report
Prior to consent application	Originate Environmental Monitoring Programme (EMP) to support licence application

Report Schedule	Type of Report
Post consultation	Update EMP to include feedback from consultees and incorporate any necessary modifications.
Prior to installation	Agree methodologies for any monitoring during installation phase
6 weeks after commissioning	Environmental Monitoring Report (EMR) outlining results from installation monitoring and compliance with consent conditions
Agreed frequency with Regulator and SNH	Routine EMR outlining results from monitoring and any deviations from mitigation measures.
2 months following decommissioning	Final EMR outlining results from decommissioning monitoring and compliance with consent conditions prior to closure of licence.

7 Research

The FloTEC H2020 project will support the mitigation and monitoring measures identified within this EMP. However, there are additional research opportunities that have been identified as part of the EMP. At present there is not sufficient funding to complete such research and therefore Orbital and EMEC will actively pursue any further funding that becomes available to progress the identified research opportunities. Orbital are committed to working closely with EMEC, the Regulator and SNH to develop and further the EMP and associated research opportunities.

The Orbital O2 testing campaign at EMEC is a learning opportunity for Orbital and EMEC to gain a greater understanding of the potential environmental impacts associated with the deployment and testing of the Orbital O2 in the marine environment. It is hoped that the proposed monitoring suggested within the EMP will provide key information to inform future commercial projects both nationally and internationally. Due to the innovative nature of some of the proposed monitoring techniques in the EMP, it is not expected that all measures will be successful and an adaptive management approach will be adopted when agreeing how to shape the EMP as the project moves forward.