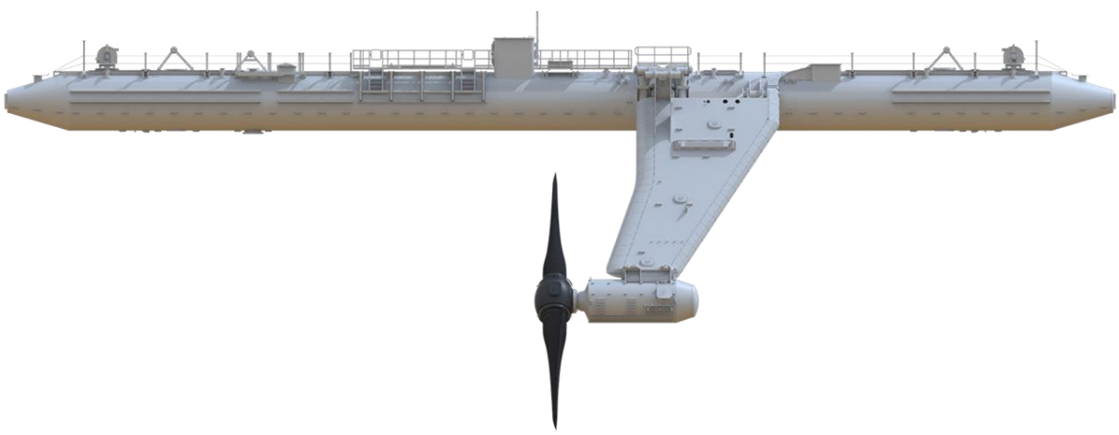
Orbital | O2.2 Tidal Turbine

Draft Project Environmental Monitoring Programme

EMEC Berth 3, Fall of Warness, Eday, Orkney

January 2025



Purpose

Mitigation and monitoring measures have been identified following a review of the project specific environmental impacts, taking into consideration the site-wide environmental description or environmental appraisal and associated guidance provided by EMEC. This document describes developer-identified mitigation, monitoring and management measures associated with the proposed project including any statutory reporting mechanisms. For a detailed description of the company, device, and project, please refer to the Project Information Summary.

Document History

Revision	Date	Description	Originated by	Reviewed by	Approved by
1	19/10/2023	For discussion with EMEC	James Murray	OW	OW
2	06/12/24	Draft for issue to regulators	James Murray	OW	OW
3	06/01/25	Minor updates	James Murray	OW	OW

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1 Background

The Orbital project at the EMEC Fall of Warness tidal test site, Berth 3 would involve the installation, operation and decommissioning of:

- One Orbital Marine Power tidal turbine;
- Associated mooring and anchoring system; and
- Additional subsea cable to connect the turbine to the existing EMEC cable at Berth 3.

Construction works would commence with the installation of 4 rock bolt anchors in 2025. The installation of mooring lines and electrical subsea cable installation would take place in the summer of 2026, followed by the installation of the turbine itself and full commissioning of the project around the end of 2026.

The turbine would then operate for the period of up to 25 years after which the site would be decommissioned.

1.1 Device Overview

Orbital Marine Power's Tidal Technology is a floating tidal stream energy generator. A cylindrical floating steel superstructure, which houses power conversion and auxiliary systems, provides reference and attachment for two leg structures with nacelles mounted at their ends. The leg structures have hinge attachments to the superstructure such that, with an actuation system, they can be lowered to position the nacelles and contra-rotating rotors in the optimal part of the tidal stream resource to generate power or be raised to bring the legs, nacelles and rotors to the surface for the purpose of servicing and turbine towing. Station keeping is provided to the superstructure via a multi-anchor catenary mooring system consisting of rope tethers, mooring chain, and anchors. Power is exported from the turbine via a dynamic cable from the superstructure to the seabed where it connects to seabed static cabling infrastructure that exports power ashore to the EMEC substation.

The O2.2 will be anchored with either/or a combination of rock bolt (drilled) anchors using the Leask Marine Ltd Submersible Drilling Rig (SDR) as the preferred choice or gravity anchors if one of more of the four anchor point's seabed conditions are not suitable for rock bolt anchors.

Figure 1 and Figure 2 illustrate the main device dimensions and Table 1 summarises that main device parameters

Figure 1 Orbital O2.2 in operational mode

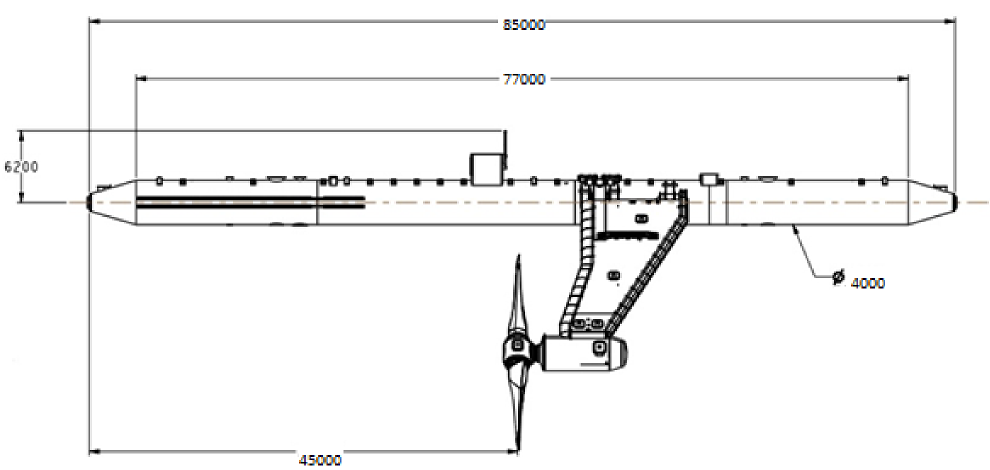

Figure 2 Orbital O2.2 in transport mode

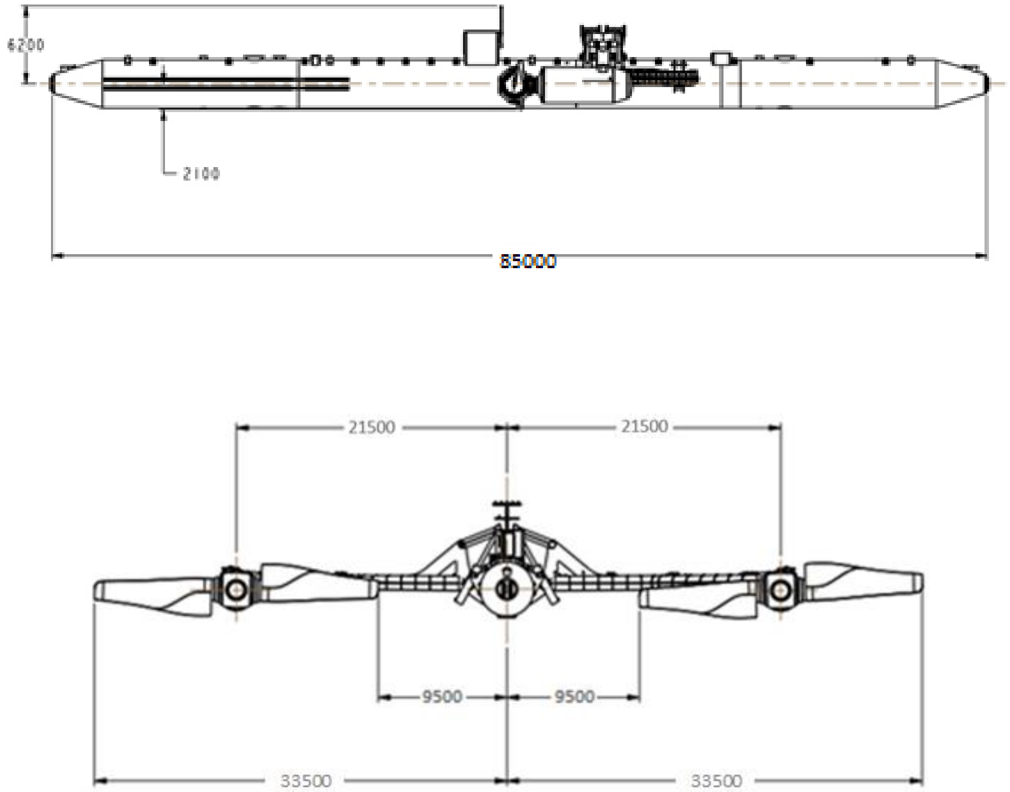

Table 1. O2.2 Device parameters

Summary of device parameters	
Rated power	c. 2 MW
Displacement	1000 metric Tonnes approx.
Rated current speed	2.5 m/s
Cut-in current speed	1 m/s
Shut down current speed	5 m/s
Maximum Hull length	85 m
Approximate Diameter of Hull tube	4 m
Approx Depth to uppermost rotor tip during operation (rotors extended)	3 m
Maximum Depth to bottom rotor tip (deepest point) during operation (rotors extended)	27 m
Maximum depth of platform below waterline	2.4 m
Height of hull tube exposed above the water surface	1.6 m
Maximum rotation speed	12 rpm
Maximum Rotor diameter	24 m
Maximum Rotor swept area	2 x 452 m^2

1.2 Construction and installation operations and associated vessel movements

The following describes the activities associated with the offshore construction and installation of the tidal turbine. More details are provided in the project information document. Approximate vessel movements associated with each phase are provided:

Anchor installation (summer 2025): A submersible and remotely operated drill rig will be deployed from a multi-cat vessel or similar inshore construction vessel. It will be operated by a hydraulic power unit (HPU) which will remain on the deck of the vessel during the operation. The drill rig will embed the rock anchor in the seabed; drilling time per anchor will be up to 12 hours per anchor.

There will be four anchors in total, so up to 48 hours of drilling in total.

If in the unlikely event that one or more of the four anchor locations is not compatible with a rock bolt anchor, a gravity based anchor will be utilised instead. This would comprise of a square steel ‘basket’ approximately 11 m x 11 m x 2.5 m height. This basket would be installed first, following by up to 1,500 tonnes of steel ballast.

In either case, the anchors would be installing using a single multi-cat workboat. In the case of rock bolt anchors or gravity anchors there would be around 2 days of general offshore mobilisation and operations per anchor.

Mooring line installation (summer 2026): There are four mooring lines. Each would take 1 day to install using a multi-cat workboat.

Umbilical cable installation (summer 2026): The floating platform will have a single 11 kV electrical cable spliced to the pre-installed EMEC static cable and will transmit both power and communications to and from the turbine. This new cable will be in two main components, separated by a cable anchor system; on the seabed a static section will run from the cable anchor to the splice and a riser component running from the cable anchor through the water column to the platform, known as the dynamic section.

Cable laying will follow on from offshore splicing to the static cable, during which a vessel platform such as a multi-category “multi-cat” vessel will be configured for cable laying and splicing operations. Such a vessel will be mobilised with cable laying equipment and splicing equipment ready for 24-hrs working based around a pre-installed fit-for-purpose 4 -point temporary mooring system to anchor the workboat in the tide.

The entire operation will take approximately 4 days during a period of neap tides.

Orbital O2.2 Platform Installation: Connection operation will take place over a neap tidal cycle (two slack periods) using the winching systems installed on the turbine to recover the catenary based mooring lines and latch into the single connection point on the platform. Once latched and locked into position the turbine will recover the dynamic riser section of cable for installation using the same winching process.

The cable end will be lifted and any temporary keep weights must be removed before passing over cable end to the turbine structure. Following connection of the turbine mechanically, the towing vessel will remove towing equipment and prepare the cable for installation. The turbine will then recover the cable into the turbine and connect to the electrical grid.

1.3 Ongoing Operations

The Orbital O2.2 is fundamentally designed for ease of access and inexpensive maintenance. As a floating device, scheduled and unscheduled maintenance operations on electrical, control and hydraulic systems can be carried out onboard the device simply by transferring personnel from a small vessel such as a RIB onto the hull of the Orbital O2.2. From here personnel can enter the hull and access the majority of equipment. It is envisaged that such regular maintenance could take around once per month.

For more significant maintenance operations or where weather conditions preclude a personnel transfer the Orbital O2.2 can be disconnected from its mooring and towed to a maintenance location, such as at Hatson pier.

The exact long-term O&M requirements and scheduling for the O2.2 will be informed by the O2 tidal turbine project Berth 5. It is expected that O&M operations would typically be around 2 days per month with a passenger transfer RIB for minor operations and around 2 days per year for more significant operations with a multi-cat.

2 Environmental Mitigation and Monitoring Objectives

2.1 Principles

Mitigation: This project has from the outset of the design process implemented an environmental impact mitigation hierarchy. In the first instance, the project has been designed to avoid impact risk entirely where practicable. This has been considered through the design of the O2.2 itself and associated installation, maintenance and decommissioning activities, including how to avoid or minimise the risk of pollution prevention through appropriate turbine design and maintenance procedures and utilising installation technologies that avoid loud, impulsive noise.

The deployment location of the O2.2 has also been selected with consideration of set-backs from seal-haul sites in the vicinity of the tidal test centre.

Where risks still exists, the project has sought to reduce the potential impact, through the implementation of mitigation measures as described in the following sections.

Research and Monitoring: In addition to managing environmental risk, a number of environmental research and monitoring activities are proposed. The principles around identifying these activities are to consider where the key uncertainties reside with respect to the environmental impacts of the project and also where the project despite its single turbine design could help address uncertainty around environmental impacts for array scale projects at EMEC and within the wider Westray Firth.

Furthermore, research could include addressing the design immaturity of environmental monitoring systems and methodologies through utilising the O2.2 as a platform for informing design development, towards installation of mature systems in the later stages of the project, on further installations at EMEC and by the sector as a whole to increase the body of evidence around environmental interactions.

Owing to the significant costs involved in environmental monitoring and associated data processing and because environmental monitoring systems around effective collision risk modelling are still under design development, it is likely that research and monitoring activities will be implemented in a phased manner with respect to funding availability and industry priorities around filling knowledge gaps and advancing the maturity of environmental monitoring systems.

Orbital will engage in discussion with regulators on how these priorities will be selected and implemented through periodic updates to the PEMP.

The following sections describe the potential key environmental impact(s) considered relevant to the installation, operation, maintenance and decommissioning of the O2.2 device at EMEC's test site. Within the following sections is a summary of the proposed monitoring and mitigation measures relating to each potential impact pathway for the relevant project phase. Any key findings from the monitoring will be disseminated to the regulator, Marine Scotland, and appropriate advisors, e.g. NatureScot.

2.2 Collision Risk during operation

There is the potential for collision between marine mammals, basking sharks, fish, seabirds and tidal energy devices and associated moorings. The risk of collision is considered to be a key potential impact during device operation. Direct physical interactions with a device have the potential to cause physical injury with potential consequences at a population level.

While, the risk of potential impact would be low for a single device, it is important where funding allows to contribute to the body of evidence on the presence and behaviour of protected species in the vicinity of tidal turbines to improve understanding of collision risk.

This is in the context of for instance, a harbour seal population that has seen a drastic decline in population in the Pentland Firth and Orkney Waters management area while there is a strategic recognition of the potential for tidal stream energy in the Pentland Firth and Orkney Waters as set out in the Scotland's National Marine Plan (2015).

The long term objective of the nearfield monitoring programme will be to operate an integrated environmental monitoring system (IEMS) on the O2.2 to provide data on the presence and behaviour of target species in the immediate vicinity of the device using multibeam imaging sonar technology and an accompanying underwater optical camera array to improve understanding of encounter rate and collision risk. Owing to the immaturity of available monitoring systems to cost effectively achieve these objectives for large scale devices, there may need to be a phased process around using the O2.2 project (and the nearly O2 turbine) to support the development of this system. The following describes the targeted end goal for the system functionality.

The goals for the monitoring system will be advance a system that can achieve the following:

- Data collection of the type, number, frequency and duration of interactions with the O2.2 by month, season, and tidal phase (i.e., ebb, flood);
- Target identification to the lowest taxonomic level possible (ideally to species);
- The behaviour of species when in proximity of the device, including any avoidance or evasion behaviour
- Any observed instances of physical strike between species and the rotating turbine blade.

Monitoring results will inform the wider PEMP including the present assumptions of encounter rate and collision risk modelling, any device specific operational mitigation measures.

Additionally, the monitoring system will be integrated with broader environmental research initiatives at EMEC.

2.2.1 Monitoring Concept

The key considerations that have been taken into account when developing the IEMS are the optimal positioning of monitoring instruments to capture detailed information on species interactions, with a particular focus on maximising coverage around the rotor swept area, as this data informs the encounter rate and collision risk models. By deploying sensors from the O2.2 device, rather than using independent seabed platforms, the system optimises the capability to detect targets around the rotor swept area given sonar swath geometry, visibility limitations of optical cameras, and side lobes reducing detection of near-surface / near-turbine targets from upward-facing seabed platforms.

Similarly, mounting sensors directly on the O2.2 device ensures fields of view and sonar swaths remain aligned with the floating turbine across all tidal states, and ensures efficient data collection, while also simplifying installation, power supply, and maintenance.

The core of the monitoring system is the use of multiple imaging sonars (potentially the Tritech Gemini) to provide robust data on species movements, upstream of the tidal turbine and the rotor-swept area. When implemented effectively, this data can yield valuable insights into species presence and behavior, including interactions with the turbine (avoidance or evasion).

The approach involves positioning two imaging sonars on the O2.2 hull to capture a three-dimensional view of species tracks. The sonar systems will be oriented to monitor two vertical planes: approximately 10m and 40m respectively upstream of the rotor swept zone as shown in Figure 4.

To complement this, stereo optical cameras will be mounted on the hull—or on the broader superstructure if that provides better coverage. These cameras will support species identification and offer a clearer understanding of species-turbine interactions. The system will include a trigger mechanism, where sonar detections of candidate targets will activate the camera recording allowing for targeted footage capture when species are detected, though in the initial phases all optical cameras footage will be stored until there is evidence that the system is operating effectively.

An adaptive environmental monitoring plan is key to this approach. As field data becomes available, the monitoring concept will be refined and improved. Insights from ongoing deployments and environmental assessments will be integrated into the IEMS design, ensuring that monitoring strategies evolve in response to emerging evidence and best practices.

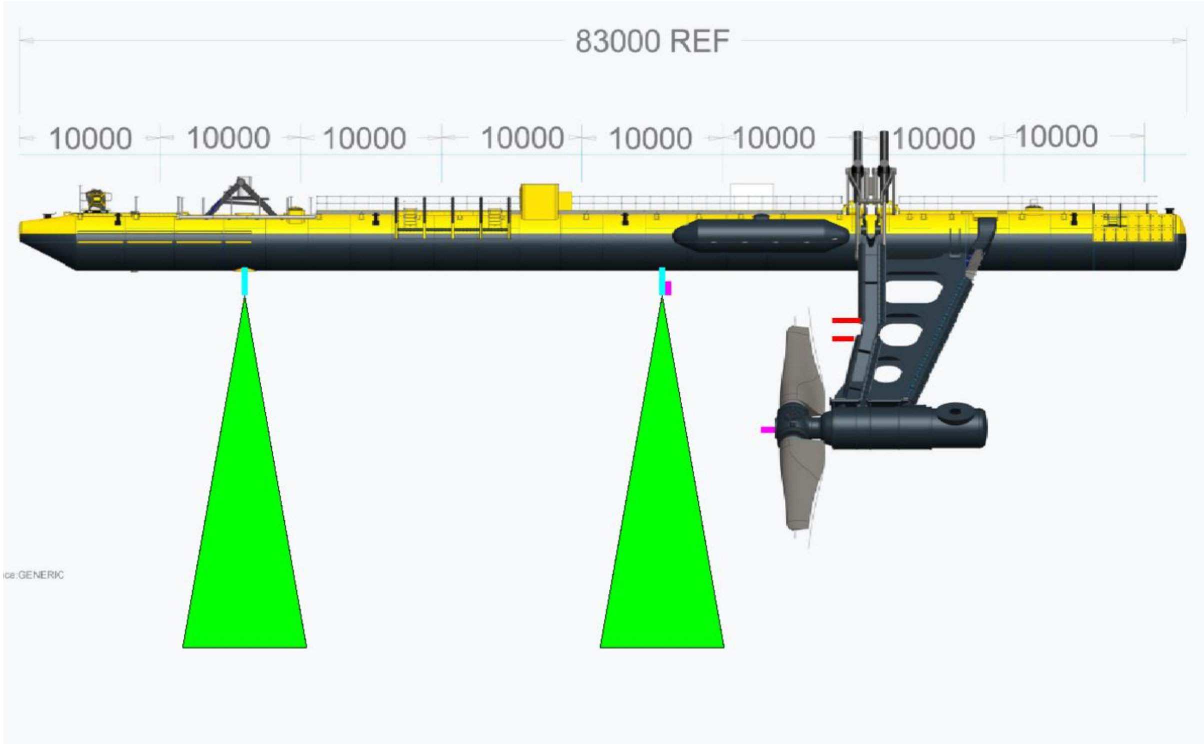

Figure 3 Stereo camera mount positions are shown as red poles extending forward from the O2.2 legs. Imaging sonars (and possibly an HR2 receiver) mounted on cyan pole beneath the O2.2 hull. Each sonar integrates, in the along-current sense, over a 20° beam shown in green. HR2 receivers could be mounted to magenta poles that extend forward from the nacelles.

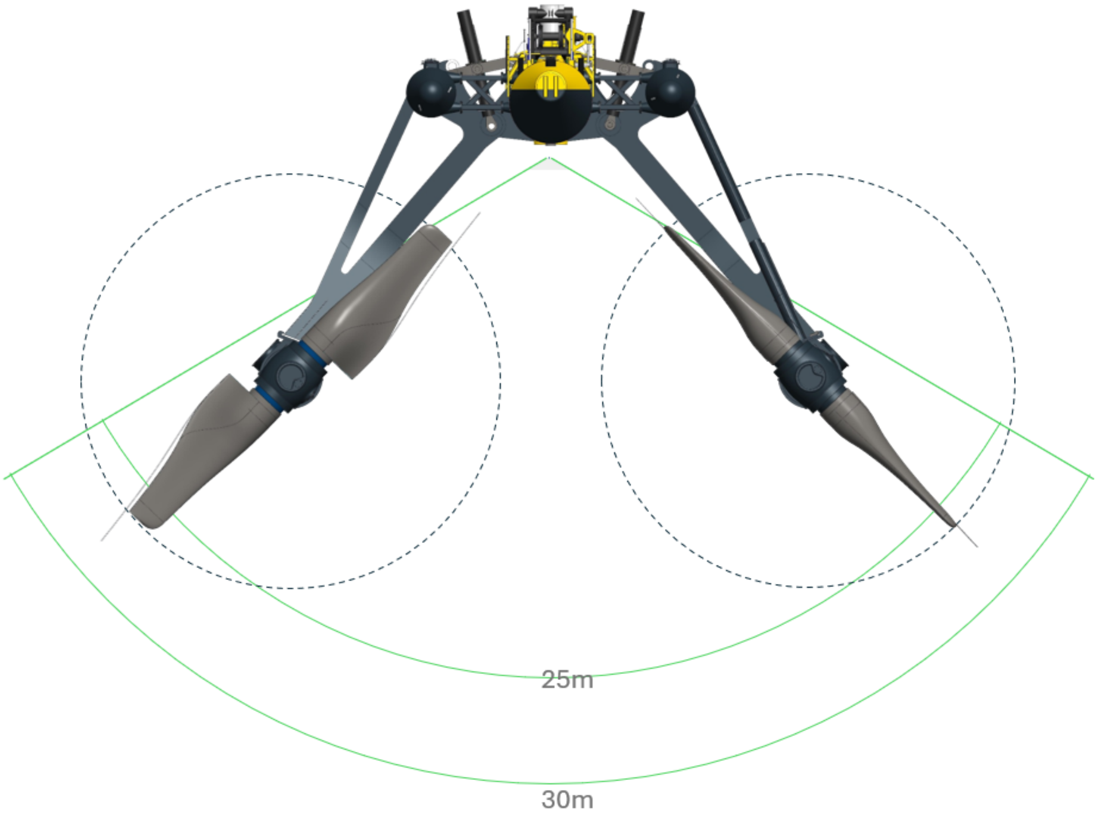

Figure 4 Front view illustrating 120-degree horizonal beamwidth with respect to rotor swept area with nominal target range. There will likely be a trade-off between deeper mounting locations of the imaging sonar to isolate from entrained air at high flow velocities, versus ease of mounting and maximising coverage of the rotor swept area at shallower mounting locations.

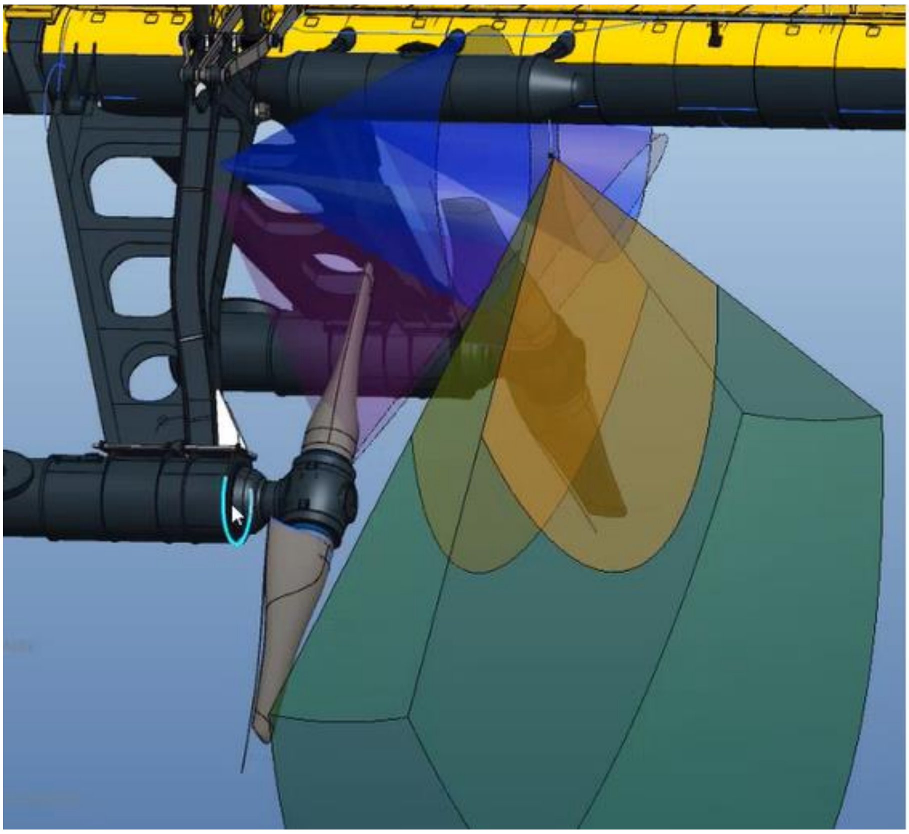

Figure 5 Potential upstream current facing camera mounting locations with indicative range shown in blue and purple cone. Final mounting locations, orientations and effective ranges will be informed through performance evaluation.

Orbital is currently commencing proof-of-concept testing of such a system through short-term deployments of the current O2 turbine at Berth 5 EMEC. Learning from this testing will help inform the detailed design of the IEMS, including detection performance, mounting location and hardware mounting design, data gathering and processing hardware and methodologies.

Orbital would welcome the opportunity to engage with MD and NatureScot on the design of the IEMS and the overall objectives around nearfield monitoring.

Table 2. Proposed monitoring and mitigation measures relevant to the impact pathway collision risk

Relevant Project Phase	Impact Pathway	Receptor	Proposed Mitigation/Monitoring Measure
Installation			
Vessel collision	Cetaceans, seals, basking sharks	**Mitigation:** Compliance with the SMWWC. Vessel presence onsite will be kept to a minimum.	Any non-compliance with the SMWWC will be reported to the regulator as soon as notified by the vessel skipper.
Operation and maintenance			

Relevant Project Phase	Impact Pathway	Receptor	Proposed Mitigation/Monitoring Measure
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; All diving bird species (seaduck, red-throated diver, great cormorant, common guillemot, razorbill, Atlantic puffin, black guillemot, northern gannet).	**Monitoring:** Data will be collected and analysed through an IEMS as outlined in Section 2.2.1	Report any additional new information that requires an update to the EMP. Advice from NatureScot and MSS will be sought on the IEMS design and implementation.
Decommissioning			
Vessel collision	Cetaceans, seals, basking sharks	**Mitigation**: Compliance with the SMWWC. Vessel presence onsite will be kept to a minimum.	Any non-compliance with the SMWWC will be reported to the regulator as soon as notified by the vessel skipper.

2.3 Disturbance/Displacement

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.

The following table summarises the proposed monitoring and mitigation measures for the relevant project phase relating to each potential impact pathway within disturbance/ displacement.

Table 3. Proposed monitoring and mitigation measures relevant to the impact pathway disturbance/displacement

Impact Pathway	Receptor	Proposed Mitigation / Monitoring Measure	Reporting Mechanism
All project phases			

Impact Pathway	Receptor	Proposed Mitigation / Monitoring Measure	Reporting Mechanism
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 to, 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 in marine operations. • Utmost care will be taken in ensuring groups / 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. Set-backs would be adhered to from seal-haul out sites when transiting to and from the site.	Any non-compliance with the SMWWC will be reported to the regulator as soon as notified by the vessel skipper.

Impact Pathway	Receptor	Proposed Mitigation / Monitoring Measure	Reporting Mechanism
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. All construction operations and all vessel movements would take place 600 m or more away from any seal-haulout sites.	Any non-compliance with the SMWWC will be reported to the regulator as soon as notified by the vessel skipper.
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 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	Any non-compliance with the SMWWC will be reported to the regulator as soon as notified by the vessel skipper.
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 non-compliance with the SMWWC will be reported to the regulator as soon as notified by the vessel skipper.
Rock Anchor installation – drilling may cause minor disturbance / displacement	Cetaceans, seals, basking sharks and marine birds	**Mitigation:** All operations will be conducted in line with SMWWC.	Any non-compliance with the SMWWC will be reported to the regulator

Impact Pathway	Receptor	Proposed Mitigation / Monitoring Measure	Reporting Mechanism
		All construction operations would take place 600 m or more away from any seal-haulout sites. No more than 12 hours drilling per anchor (48 hours in total) will be carried out.	as soon as notified by the vessel skipper.
Operation and Maintenance			
Displacement – Barrier effect from the presence of device	Birds and potentially marine mammals, basking shark and fish	**Monitoring:** Data will be collected using the IEMS focused on the nearfield behaviour of fish, marine mammals, and diving birds in the vicinity of the device to understand potential displacement effects. **Monitoring:** Data will be recorded from topside cameras to understand the use of the O2.2 by birds for roosting or feeding **Monitoring:** The operational acoustic signature of the O2.2 at various distances from the turbine will be characterised through onsite acoustic survey to inform the potential for long term disturbance.	A reporting format and frequency will be agreed with the regulator on the performance or the monitoring system and any target species behaviour.
Decommissioning			
Vessel activity – noise and presence may cause minor disturbance/ displacement (including when transiting to and from site)	Cetaceans, seals, basking sharks, marine birds	**Mitigation:** Compliance with the SMWWC. Vessel presence onsite will be kept to a minimum.	Any non-compliance with the SMWWC will be reported to the regulator as soon as notified by the vessel skipper.
Anchor removal – noise may cause minor disturbance/ displacement	Cetaceans, seals, basking sharks	**Mitigation:** Compliance with the SMWWC. No mitigation or monitoring is proposed.	Any non-compliance with the SMWWC will be reported to the regulator as soon as notified by the vessel skipper.

2.4 Acoustic impact

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) and the installation of rock anchors.

It is unlikely acute effects such as non-auditory/auditory tissue damage would be experienced[1] 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 operational device may have the potential to cause displacement, avoidance, though the OES State of the Science 2024, states that "*the scientific community has reached a general consensus that underwater noise from operational devices within small-scale MRE developments does not pose a risk to marine animals and can be retired for small numbers of devices (one to six devices)"*

However, it is important to validate the acoustic signature of the tidal device to inform the environmental assessment of larger future deployments and as such acoustic characterisation will be undertaken. This will be in line with the methodology used for the Orbital O2 Acoustic Characterisation and is provided alongside this document.

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.

It is anticipated that the drilling operation associated with the anchors will be completed in a short timescale (up to 12 hours per drilling operation), therefore, due to the temporary nature of the impact, it is not expected that any significant effects to marine mammals, fish or seabirds will result from the drilling operation. The drilling operation involves no impulsive noise and is being conducted with a relatively small drilling rig being provided by Leask Marine. However, acoustic monitoring of the anchor drilling is planned to better characterise the sound levels to inform the environmental assessment of future larger scale projects.

The following table summarises the proposed monitoring and mitigation measures for the relevant project phase relating to each potential impact pathway within acoustic impact.

Table 4. Proposed monitoring and mitigation measures relevant to the impact pathway acoustic impact

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:** All operations will be conducted in line with SMWWC	Any non-compliance with the SMWWC will be reported to the regulator as soon as notified by the vessel skipper.
Installation			
Anchor installation – drilling and vessel activity may cause	Cetaceans, seals, basking sharks and marine birds	**Mitigation:** All operations will be	Any non-compliance with the SMWWC will be reported to the regulator as

[1] https://tethys.pnnl.gov/publications/state-of-the-science-2024

Impact Pathway	Receptor	Proposed Mitigation / Monitoring Measure	Reporting Mechanism
minor acoustic impact or auditory injury		conducted in line with SMWWC Acoustic monitoring of the drilled anchor installation would be carried out to quantify the underwater noise associated with the installation. This would reduce uncertainty around the noise profile ahead of larger tidal array projects implementing this anchor technology.	soon as notified by the vessel skipper. A methodology for acoustic monitoring would be provided to be agreed with NatureScot and Marine Scotland prior to installation.
Operation and Maintenance			
Disturbance – Noise from operating turbine	Cetaceans, Harbour and grey seals	**Monitoring:** The acoustic signature of the tidal turbine across the range of operational speeds will be evaluated. The methodology will be in line with the Orbital O2 Acoustic Characterisation methodology provided along this PEMP. EMEC will use the outputs of this work to generate feedback to the international marine energy standards related to acoustic characterisation (IEC TS 62600-40:2019). This campaign would build upon a re-design of the Drifting Acoustic Recorder and Tracker (DART) system previously deployed at EMEC and will optimise the approach by investigating suitable ways to reduce the	Methodology for acoustic monitoring will be provided based on berth 5 O2 acoustic monitoring success. This will be agreed with NatureScot and Marine Scotland prior to use.

Impact Pathway	Receptor	Proposed Mitigation / Monitoring Measure	Reporting Mechanism
		common issue of 'flow noise contamination'. It may also be combined in later project years with acoustic monitoring of other O2.2 devices to validate cumulative acoustic output modelling. The methodology will be agreed with NatureScot and Marine Scotland prior to being carried out.	
Decommissioning			
Vessel activity – noise from increased activity will cause minor acoustic impact	Cetaceans, seals, basking sharks, marine birds	**Mitigation:** All operations will be conducted in line with SMWWC. Vessel presence onsite will be kept to a minimum.	Any non-compliance with the SMWWC will be reported to the regulator as soon as notified by the vessel skipper.
Anchor removal – drilling may cause minor acoustic impact or auditory injury	Cetaceans, seals, basking sharks	**Mitigation:** All operations will be conducted in line with SMWWC.	Any non-compliance with the SMWWC will be reported to the regulator as soon as notified by the vessel skipper.

2.5 Entanglement Risk

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 O2.2. The Orbital O2.2 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.

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.

The following table summarises the proposed monitoring and mitigation measures for the relevant project phase relating to each potential impact pathway within entanglement risk.

Table 5. Proposed monitoring and mitigation measures relevant to the impact pathway entanglement risk

Relevant Project Phase	Impact Pathway	Receptor	Proposed Mitigation/Monitoring Measure
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 the event of an entanglement event.	Any entanglement events recorded will be reported to the Regulator immediately. Procedures for emergency shutdown will be followed in this event.
Installation			
Entanglement with temporary vessel moorings	Cetaceans, seals, basking sharks	**Mitigation**: Mooring lines will be kept onsite for as short a period as possible.	N/A
Entanglement with SDR lifting lines	Cetaceans, seals, basking sharks	**Monitoring:** Cameras and sensors on the SDR device will provide alerts if entanglement event was to occur during removal	Any events will be reported to the regulator as soon as possible on return to shore.
Decommissioning			
Entanglement with temporary vessel moorings	Cetaceans, seals, basking sharks	**Mitigation**: Mooring lines will be kept onsite for as short a period as possible.	N/A
Entanglement with SDR lifting lines	Cetaceans, seals, basking sharks	**Monitoring**: Cameras and sensors on the SDR will provide alerts if entanglement event was to occur during removal	Any events will be reported to the regulator as soon as possible on return to shore.

2.6 Biofouling and non-native species (NNS) introduction

Biofouling is the gradual accumulation of waterborne 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 O2.2 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 into 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 steppingstone for colonisation.

The following table summarises the proposed monitoring and mitigation measures for the relevant project phase relating to each potential impact pathway within biofouling and the introduction/transfer of non-native species.

Table 6. Proposed monitoring and mitigation measures relevant to the impact pathway biofouling and introduction of non-native species

Relevant Project Phase	Impact Pathway	Receptor	Proposed Mitigation/Monitoring Measure
All project phases			
Biofouling and the introduction of non-native species (including rock anchors)	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'	Any deviance from the good practice measures will be reported on prior to the event occurring via the appropriate documentation. 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.

Relevant Project Phase	Impact Pathway	Receptor	Proposed Mitigation/Monitoring Measure
		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. **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. **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.	
Biofouling, introduction of non-native species and habitat creation for biofouling species (including rock anchors)	Sessile communities	**Mitigation:** Opportunistic inspections of biofouling will be implemented which will have a dedicated procedure for removing biofouling species from the device. The organisms removed will be analysed by experts to ensure a comprehensive species list is compiled.	Findings reported to the regulator as soon as reasonably practicable through the appropriate documentation.

Relevant Project Phase	Impact Pathway	Receptor	Proposed Mitigation/Monitoring Measure
Decommissioning			
Habitat removal for biofouling species	Sessile communities	A full device biofouling inspection may be conducted as the device (and moorings) 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 to the regulator as soon as reasonably practicable through the appropriate documentation.

2.7 Habitat Creation

The footprint of the rock bolt anchors, the most likely anchor solution, would each comprise an area of no more than 1m x 1m. As such, their installation would have negligible potential for habitat creation. If gravity anchors are utilised they would have an area of around 11m x 11m.

The device and the mooring lines could act as fish aggregating devices and the surface piercing element of the device may be used a roosting spot for birds – this was common on the SR-2000 device.

Cetacean, seal and seabird distribution may be influenced by prey distribution and associated prey habitat. The physical presence of the device may offer enhanced foraging efficiency for some species.

The following table summarises the proposed monitoring and mitigation measures for the relevant project phase relating to each potential impact pathway within habitat creation.

Table 7. Proposed monitoring and mitigation measures relevant to the impact pathway habitat creation

Impact Pathway	Receptor	Proposed Monitoring/Mitigation Measure	Reporting Mechanism
Operation			
Fish aggregation device (FAD) effect and colonisation of fouling organisms due to introduction of hard structure	Benthic communities (including fish and shellfish), benthic community predators (e.g. marine mammals and seabirds)	**Monitoring:** Data will be collected and analysed through an IEMS as outlined in Section 2.2.1 Further may be available for echo-sounding fish surveys around the tidal	Findings reported to the regulator as soon as reasonably practicable through the appropriate documentation.

Impact Pathway	Receptor	Proposed Monitoring/Mitigation Measure	Reporting Mechanism
		turbine to better understand FAD.	
Creation of habitat around installed infrastructure for benthic species	Benthic communities (including fish and shellfish)	There would be periodic camera surveys carried out of the anchor locations that could be utilised to understand the creation of any habitat for benthic species. This is likely to be more relevant in the case of gravity anchors which would have a larger footprint.	Findings reported to the regulator as soon as reasonably practicable through the appropriate documentation.

2.8 Seabed Clearance

The deployment may cause a temporary loss of benthic habitat as above.

The following table summarises the proposed monitoring and mitigation measures for the relevant project phase relating to each potential impact pathway within seabed clearance.

Table 8. Proposed monitoring and mitigation measures relevant to the impact pathway seabed clearance

Impact Pathway	Receptor	Proposed Mitigation/Monitoring Measure	Reporting Mechanism
Installation			
Seabed loss due to the direct footprint	Benthic communities (including fish and shellfish)	**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.	Findings from video footage analysis will be reported to the regulator as and when available.
Seabed clearance and habitat loss from installation of rock anchor	Benthic communities (including fish and shellfish)	**Mitigation:** Rock anchor technology has much smaller footprint in comparison with other anchor types and would be utilised if possible/	N/A

Impact Pathway	Receptor	Proposed Mitigation/Monitoring Measure	Reporting Mechanism
Decommissioning			
Colonisation and loss of new habitat	Benthic communities (including fish and shellfish)	**Monitoring:** Pre-decommissioning seabed survey will be conducted 2 months prior to decommissioning the anchors.	A summary report will be submitted to the Regulator prior to decommissioning activities commencing.
Recolonisation	Benthic communities (including fish and shellfish)	**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.	Findings from analysis will be reported to the regulator as and when available.

2.9 Discharges to the Marine Environment

Benthic species may be exposed to materials such as paints, hydraulic fuels and antifouling compounds originating directly from the SDR or O2.2 device. Accidental spillages from installation or maintenance vessels could also occur. Spillages pose a risk to marine mammals, fish, seabirds and benthic communities and can cause direct effects at the time of the spill or can result in chemical accumulation in body tissues leading to lagged effects on health and breeding success.

The following table summarises the proposed monitoring and mitigation measures for the relevant project phase relating to each potential impact pathway for discharges to the marine environment.

Table 9. Proposed monitoring and mitigation measures relevant to the impact pathway discharges to the marine environment

Impact Pathway	Receptor	Proposed Monitoring/Mitigation Measure	Reporting Mechanism
Installation			
Leakage of fuel or chemicals from vessels involved with installation can enter the food-web at any trophic level	Potentially whole ecosystem	**Mitigation:** Maintenance and oil change operations would take place within the hull / nacelle / pitching hub. Method statements ensure that there is minimal risk of discharge of any	Any incidents will be reported to the regulator as soon as possible.

Impact Pathway	Receptor	Proposed Monitoring/Mitigation Measure	Reporting Mechanism
		contaminants into the marine environmental with disposal at an onshore facility. For instance, any transfer of consumables between the O2.2 and maintenance vessel would be using secure containers and such transfers conducted in appropriate weather conditions. Vessel crews should follow standard procedures to avoid fuel and chemical spills. Suitable spill kits should be onboard all vessels involved in the project.	
Operation			
Corrosion of SDR polluting environment	Benthic communities (including fish and shellfish)	**Mitigation:** Cathodic protection using sacrificial anodes will prevent accelerated degradation of metal structure.	N/A
Decommissioning			
Leakage of fuel or chemicals from vessels involved with decommissioning can enter the food-web at any trophic level	Potentially whole ecosystem	**Mitigation:** Vessel crews should follow standard procedures to avoid fuel and chemical spills. Suitable spill kits should be onboard all vessels involved in the project.	Any incidents will be reported to the regulator as soon as possible.

3 Research Opportunities

The O2.2 is intended to become a long-term project of up to 25 years operation.

The following research activities are likely to be progressed if funding is available and there is research benefit. Priority research activities would be discussed with regulators and in the context of potentially combining with other O2.2 style deployments at the EMEC site to maximise research outputs for the available budget.

- EMEC could also monitor the presence of marine mammals around the farm via the use of hydrophones.
- To date, onboard surveillance has largely been focused on an O&M perspective, onboard deck surveillance cameras dedicated to monitoring seabird interactions could be implemented with devices in the farm.
- There could be further investigation of the influence of the turbulence features of the farm on seabird interactions, with at least one drone survey carried out to understand the location of seabirds relative to the turbulence of the farm. In parallel with the drone campaign, a sea-bed mounted ADCP with echosounder capability could be deployed. This would allow for a better understanding of fish presence in relation to seabird activity and the turbulence features.
- In addition, vantage point surveys could be carried out, which would contribute to data to further understand bird-farm interactions.
- Further work would be progressed on a protocol and hardware for environmental data management of farms. This would include consideration of the range of data required for environmental monitoring and the quantities associated in the farm context. Methods of how the data can be collected simultaneously would be explored as well as how a quality control plan will be integrated to ensure that the data is managed to a high standard.

4 Reporting Frequency

A six month reporting frequency is proposed in the first instance around the PEMP. It is proposed that this frequency could be updated based on the emerging results from the programme in agreement with the relevant stakeholders. The format of the report would align with the section heads of the PEMP, e.g.

- Collision Risk during operation
- Disturbance/Displacement
- Acoustic impact
- Entanglement Risk
- Biofouling and non-native species (NNS) introduction
- Habitat Creation
- Seabed Clearance
- Discharges to the Marine Environment
- Other

The outline scope of any associated monitoring reports would be submitted at least three months in advance of the report due date for agreement.