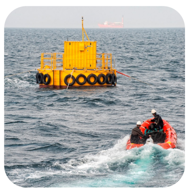
EMEC | Appendix G: Fall of Warness
Section 36 50MW Expansion

Project Environmental Monitoring Programme

Fall of Warness Tidal Test Site

December 2025






Purpose

Monitoring measures have been identified following a review of the project specific environmental impacts which are expected to occur throughout the 50MW expansion of the Fall of Warness within a specified envelope. These also take into consideration the site-wide environmental description, environmental appraisal and associated guidance provided by EMEC. This document describes monitoring, mitigation and management measures associated with the proposed expansion. This is an addendum within the Environmental Impact Assessment (EIA) being completed for the Fall of Warness 50MW expansion.

Document History

Revision	Date	Description	Originated by	Reviewed by	Approved by
1.0	01/12/2025	Final	[Reda	[Redacted]	[Reda

Disclaimer

This report is for the exclusive use of the persons to whom it is addressed and their advisers and must not be copied, reproduced or distributed (in whole or in part) or disclosed by recipients to any other person.

Contents

List of Figures

List of Tables

1 Introduction

EMEC has prepared this Project Environmental Monitoring Plan (PEMP) in support of the Fall of Warness site 50MW expansion project application under Section 36 of the Electricity Act 1989. This is being submitted alongside an Environmental Impact Assessment (EIA) which will expand on the existing EIA for the site's current 10MW Section 36 licence and relevant Environmental Appraisal. The PEMP attempts to mitigate the environmental risk of the project as reasonably practicable.

Furthermore, it outlines the proposed mitigation and monitoring measures relating to future devices and associated works at the site to ensure potential significant and negative impacts can be avoided. These have been established through reviewal of the project's envelope and related risks and will be consistently reviewed throughout the full period of consent given to continuously verify they are evidence-based, best practice, and fit for purpose.

1.1 Requirement and objectives

As part of a Section 36 application, it is necessary to identify monitoring and mitigation measures to reduce the likelihood of any potential environmental impacts occurring due to the proposed development, and to measure and assess the extent of any existing impacts. The PEMP should be used as the opportunity to propose methods for monitoring the device in respect to issues of concern identified. EMEC encourages developers at its test sites to independently consider environmental impacts, and the potential for developing new and innovative mitigation and monitoring techniques, not least because of the competitive advantage that assurance regarding the nature, or indeed absence, of such impacts could provide.

The PEMP is an iterative document, the framework, principles and details of which will be agreed as part of any consent from the regulator (Marine Directorate). The commitments made therein are likely to be incorporated into licence conditions. The results of mitigation and monitoring carried out in accordance with the PEMP must be submitted to the Marine Directorate in fulfilment of any licence conditions. It is recommended that all mitigation and monitoring actions have a reporting mechanism or dissemination strategy to ensure the Marine Directorate and statutory consultees are aware of compliance and any results or findings.

1.2 Contents and application of the PEMP

The PEMP is being submitted as a separate addendum of the EIA for EMEC's Section 36 50MW consent application. The PEMP will be formally agreed with Marine Directorate and NatureScot prior to the commencement of any works associated with activities at the Fall of Warness following its expansion.

During the development of the PEMP, the following should occur:

- Identify and support delivery of mitigation necessary for ensuring that residual impacts are reduced to an acceptable level;
- Identify and support delivery of mitigation and monitoring that demonstrate best practice in management of environmental impacts at the test site;
- Increase understanding of environmental impacts and how to monitor and analyse them, to the benefit of both the surrounding marine environment in addition to EMEC and the wider industry in relation to commercial upscaling and deployment; and

- Provide opportunities for EMEC, NatureScot and Marine Directorate, to seek innovative solutions for mitigating impacts and further understanding the importance of interactions between devices and the environment.

The PEMP is a live document and will be revisited throughout the lifetime of the development and therefore the document has been designed to be reviewed and updated as the testing and environmental monitoring progresses. It is important that the monitoring and research surrounding any device deployment within the Fall of Warness can be adjusted and amended as information on the device and its interactions with the receiving environment become available. This approach should allow new and innovative mitigation and monitoring techniques to consider as the testing programme progresses ensuring the PEMP remains current.

2 Project Overview

2.1 Fall of Warness Site

The Fall of Warness site has been established and operating since 2005. Figure 1 provides an overview of the layout of the site.

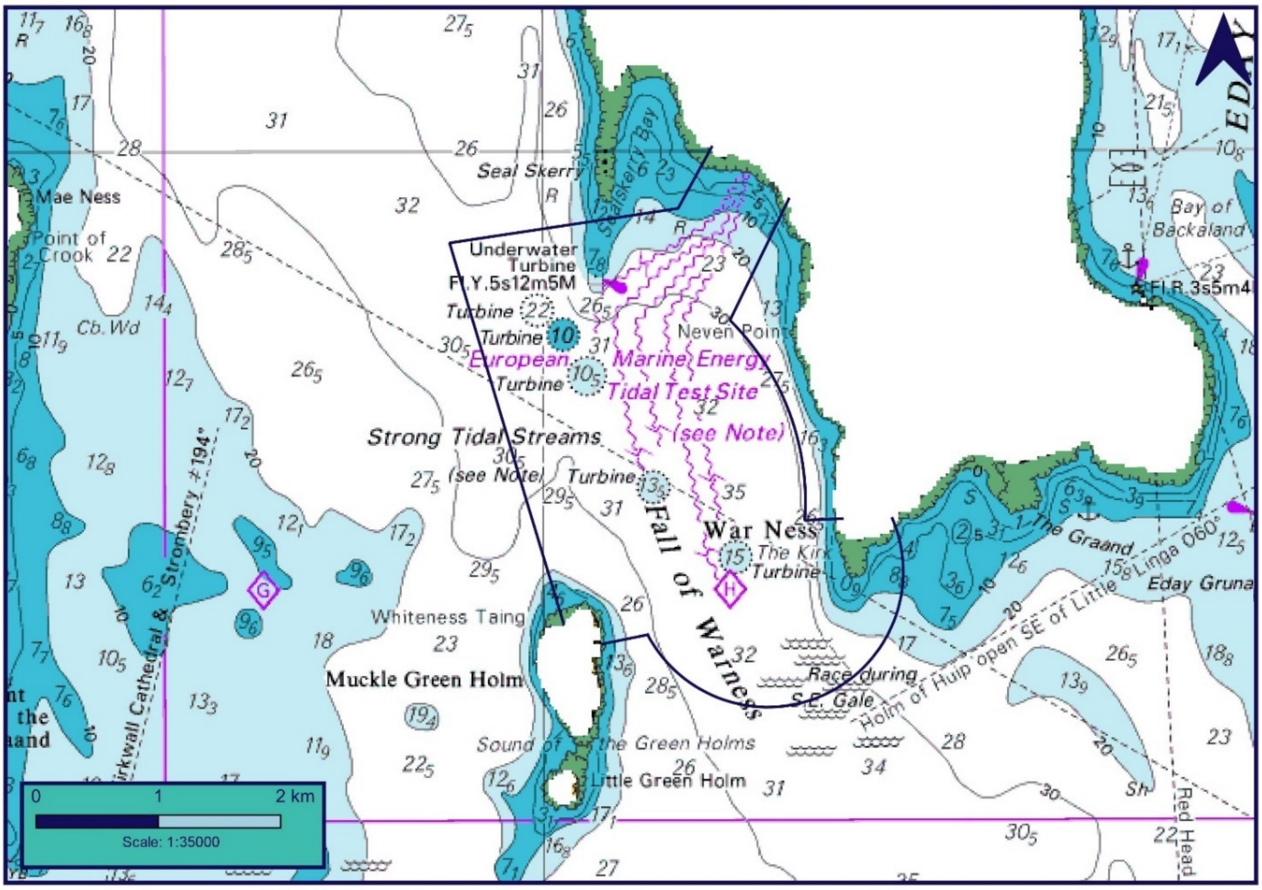


Figure 1. Existing Fall of Warness site

The site accommodates seven berths. Each berth occupies a circular area of approximately 200 m radius from its cable end, within which developers can install their device(s) and undertake testing activities. The berths can accommodate single devices or small arrays as well as individual components or mooring structures. Each test berth is individually connected to EMEC's shore-based substation at Caldale in Eday via an 11 kV armoured subsea cable, allowing onward transmission of the energy generated by the devices to the National Grid.

Entering 2022, the test site had 4 MW export capacity under the existing Embedded Generation Connection Agreement. This has increased to 7.2 MW total export capacity to support the testing of multiple longer-term demonstrations on site. The additional 3.2 MW is subject to Active Network Management.

2.2 Section 36 50MW Expansion

The Section 36 consent application does not relate to a new project, but rather to an extension of the project duration to 2043 (in line with existing funding) and an expansion of the site generating capacity up to 50 MW. Although the test site may be offered for testing components and mooring/foundation systems for a wider range of renewable energy devices than previously, no new types of activities are proposed at the site.

2.3 Project Envelope

As the precise activities at the Fall of Warness site up until 2043 cannot be fully predicted or defined in the EIA, a Project Design Envelope has been developed to describe the worst-case scenarios and provide a scope for the assessment. This section provides an overview of the infrastructure and activities included in the Project Design Envelope, which each assessment topic will consider when appraising potential impacts and importance.

The test site will be operated with a maximum of 60 devices, accommodating up to 50 MW of tidal energy, thereby supporting the testing of small arrays. The test site will also allow for the testing of non-grid-connected devices, although such testing will limit the number of grid-connected devices able to test on the site due to available sea space.

The following activities and deployments are included within the Project Design Envelope:

- Testing activities associated with single device and array deployments, including regular installation, maintenance and decommissioning works;
- Testing of mooring systems and foundation arrangements (e.g., tripod support structures or individual stand-alone components of devices);
- Installation, maintenance and testing of subsea cables;
- Deployment of scientific instrumentation and associated cabling;
- Testing of buoys (maximum of two simultaneous tests); and
- Potential for simultaneous operations, i.e., installation or maintenance activities, at more than one berth at the same time.

The following activities are ***not*** covered by the Project Design Envelope and would require further consultation and assessment:

- All onshore works (above MHWS) including installation of energy storage devices;
- Seabed preparation aside from boulder clearance (e.g., seaweed clearance, rock grinding/blasting);
- Geotechnical and geophysical surveys (these are considered and, where necessary, licensed through the Notification of Site Survey procedures);
- Use of acoustic deterrent, active acoustic or acoustic communication devices; and

- Deployment and operational activities outside the parameters defined in the Project Design Envelope.

A comprehensive overview of the technologies and activities, and the maximum parameters are considered within the accompanying project design envelope within the associated EIA.

3 Upcoming Projects within 50MW Expansion

Several projects are planned for deployment within the Fall of Warness site should consent be granted for the Section 36 50MW expansion. These will fall within the Project Design Envelope associated with the 50MW expansion application. The details of these projects and the marine licence numbers granted specifically for each can be found within Table 1.

Developer	Relevant Project(s)	Marine Licence No.	Number of devices	MW
Magallanes	ATIR Array	MS-00010880	2	3
Magallanes	ATIR 2.0	Awaiting submission	1	1.5
Orbital Projects 3 Ltd.	FORWARD2030 & EUROTIDES	MS-00010450	1	c. 2
Orbital Projects 4 Ltd.	FORWARD2030 & EUROTIDES	MS-00010451	2	4.8
Orbital Projects 8 Ltd.	FORWARD2030 & EUROTIDES	MS-00010626	1	c. 2.4
Orbital Projects 9 Ltd.	FORWARD2030 & EUROTIDES	MS-00010628	2	c. 4.8
Nova Innovation	SEASTAR	MS-00010650	16	4
Nova Innovation	OCEANSTAR	MS-00010649	19	10

Table 1. Description of projects within the Fall of Warness site should 50MW expansion be established

4 Research Opportunities within Projects

An overview of the funding associated with environmental research within these upcoming projects is found in Table 2. There are several environmental monitoring opportunities and activities EMEC can conduct through this funding and work packages specific to these projects. EMEC is available to discuss potential associated methodologies and activities with NatureScot.

Each of the projects in Table 1 has its own PEMPs to outline environmental effects, and mitigation and monitoring measures, as part of its marine licence application and granted consent. Additionally, some projects have also produced further Environmental Monitoring Plans (EMPs). An EMP is a live document which outlines project-specific risk assessments, and mitigation and monitoring plans regarding key evidence gaps and considerations such as biophysical; seabird; and seal interactions, for example. Table 2 summarises the funding allocated to environmental projects It is worth noting that not all tasks listed in Tables 3 to 6 are solely EMEC's responsibility and that they rely on collaborative activities within funded projects with associated developers and project partners.

Developer	Project	Funding Amount
Nova Innovation	SEASTAR	€ 328,558
Nova Innovation	OCEANSTAR	TBC

Developer	Project	Funding Amount
Orbital	EUROTIDES	Min €600,000
Orbital	FORWARD-2030	€340,000
Orbital	MAXBlades	€137,176

Table 2. Projects and funding for environmental monitoring provided within them

4.1 Nova

4.1.1 SEASTAR

WP Task	Key potential impacts	Activity	Objective
Biological receptors			
5.3 Environmental Monitoring and Mitigation	N/A	Design Environmental Monitoring and Mitigation Plan (EMMP)	Identify and prioritise gaps and effective monitoring/ mitigation measures key to the SEASTAR project – whilst consulting with Marine Directorate and statutory stakeholders – to create a live document that will be refined and updated as the project progresses
5.4 Critical Environmental Evidence Gaps Research	Collision risk in array context Animal presence and behaviour (inc. turbine interactions) Biofouling on monitoring equipment Acoustic noise	Turbine-mounted HD optical cameras	Monitor nearfield interactions between marine wildlife and turbines within array whilst enabling identification of species observed with high confidence
		Remote Observation Platform (ROP) on which monitoring instruments will be mounted (e.g., cameras, multibeam, sonar, etc.)	Gather nearfield turbine data on present marine species and their behaviour within the Fall of Warness site Use instruments such as additional optical cameras and multibeam sonar to increase effectiveness of target detection
		UV anti-biofouling light on ROP	Minimise instrument biofouling and review effectiveness
		Drifting hydrophone campaign	Measure turbine/ array noise for the SEASTAR project

			within the Fall of Warness site
Monitoring system performance evaluation			
5.5 Environmental Monitoring Reporting and Dissemination	N/A	Review and analysis of gap research and lessons learnt	Disseminate key learning and generate transferable evidence from WP Task 5.3 and 5.4 above that can be used to de-risk this and future tidal energy projects Prepare environmental monitoring reports and upload relevant data to the European Marine Observation and Data Network (EMODnet) Disseminate key monitoring results and knowledge through OES-Environmental and other fora Produce a final report and hold an event to disseminate findings to the EC and wider stakeholders Manage the Environmental * Regulatory Steering Group (ERSG) (when formed) and hold regular update meetings by teleconference to share and get feedback on SEASTAR plans, emerging best practice and regulator's concerns
5.6 Develop and Disseminate Sustainability Best Practice	N/A	Review and analysis of gap research and lessons learnt	Build on the findings from this array and from other offshore energy projects to capture and disseminate best practice in environmental management and sustainability of ocean energy projects to accelerate the sustainable development of the tidal energy sector. Outputs will include consent condition trackers; templates for Project Environmental

			Monitoring and Management Plans (EMMPs) and monitoring reports; clear distinctions between statutory obligations required through licence conditions and 'added value' activities; advice on how to get best value from advisory groups; and capturing learning on sustainable design and project delivery from several of the projects work packages. Where possible, recommend impact areas that can be "retired" because they are shown not to be an issue in practice. Hold an event near the end of the project to disseminate findings to the EC & wider stakeholders Additionally, OEE will produce a summary for policymakers that makes the results accessible to a wider audience.

Table 3. An overview of the SEASTAR project's environmental monitoring related work package tasks and associated monitoring activities

4.1.2 OCEANSTAR

WP Task	Key potential impacts	Activity	Objective
Biological receptors			
TBC	Collision risk in array context Animal presence and behaviour (inc. turbine interactions) Biofouling on monitoring equipment Acoustic noise	Turbine-mounted HD optical cameras	Monitor nearfield interactions between marine wildlife and turbines within array whilst enabling identification of species observed with high confidence
		Remote Observation Platform (ROP) on which monitoring instruments will be mounted (e.g., cameras, multibeam, sonar, etc.)	Gather nearfield turbine data on present marine species and their behaviour within the Fall of Warness site Instruments like additional optical cameras and multibeam sonar will increase effectiveness of target detection
		UV anti-biofouling light on ROP	Minimise instrument biofouling and review effectiveness
		Drifting hydrophone Campaign	Measure turbine/ array noise for the SEASTAR project within the Fall of Warness site
Monitoring system performance evaluation			
TBC		Producing formal reports to be submitted to MD-LOT (initially proposed on an annual basis)	Refine understanding of key aspects such as occupancy patterns, interactions, and behaviours of marine wildlife near the turbines and within the Fall of Warness site where the turbines will be deployed

Table 4. An overview of the OCEANSTAR project's environmental monitoring related work package tasks and associated monitoring activities (work packages not established but will follow similar monitoring activities to SEASTAR above)

4.2 Orbital

FORWARD-2030

WP Task	Key potential impacts	Activity	Objective
Biological receptors			
9.4 Environmental Monitoring	Predator-prey interactions Collision risk and near field behaviour Fish aggregations & displacement Habitat changes Displacement of EPS Species validation Acoustic characterisation	Device operational information and onboard ADCPs	Demonstrate wake effects and other near-field hydrodynamic effects on wider system interactions across the Fall of Warness site (e.g., seabird predator-prey interactions)
		Multibeam Sonar	Monitor near-field behaviours in vicinity of project device and its rotors, and aim to inform collision risk predictions.
		HD underwater camera	Ground-truth acoustic target detections and identify species where possible.
		Echosounder survey	Investigate fish biomass, presence in relation to the wake of the tidal turbine.
		Hydrophone campaign	Site use and potential displacement effects of marine mammals.
		Drifting acoustic survey campaign	Supporting consenting pipeline for arrays: Characterise the noise profile of device
Monitoring system performance evaluation			
9.4 Environmental Monitoring	N/A	*Integrated Environmental Monitoring System performance report:* Review and analysis of lessons learnt and system development	Design a protocol for environmental data management and assessment of IEMS

		Environmental monitoring report: Submitting a report to stakeholder groups and regulators on environmental monitoring	Utilise local flora and fauna data to inform collision risk predictions, understand marine mammal and fish interactions with technology

Table 5. An overview of the FORWARD2030 project's environmental monitoring related work package tasks and associated monitoring activities

4.2.1 EUROTIDES

WP Task	Key potential impacts	Activity	Objective
Biological receptors			
8.6.1 Wildlife Interaction and collision risk	Biophysical and predator-prey interactions in the nearfield of the devices Collision risk Aggregations Habitat changes Displacement	Farm – Integrated Environmental monitoring System (F-IEMS) scale up (also associated with Task 2.4.1).	Use sonar and camera systems to monitor near field behaviour and avoidance of marine animals around an array.
		ADCP echosounder campaigns	Investigate fish presence around array.
		Drone surveys	Investigate seabird behaviour around turbine, particularly nesting or foraging close to the devices.
		Onboard, above water, camera.	Investigate seabird behaviour around turbine, particularly nesting on the devices.
		Vantage point surveys	Investigate site usage of marine animals.
8.6.2 Acoustic characterisation and impact	Underwater noise created by the device(s)	Drifting acoustic survey campaign	Investigate the acoustic profile of the O2-X and how it changes with multiple devices.

	Displacement		
		Hydrophone campaign	Investigate marine mammal site usage around the array.
8.7 Biofouling and corrosion monitoring and mitigation	Reducing the potential deployment time of and damaging monitoring equipment	Trials of emerging biofouling and corrosion prevention measures such as UV lighting, anodes, and equipment with reduced maintenance needs	Investigating efficiency of biofouling measures utilised.
Monitoring system performance evaluation			
2.4.1 Environmental data management	N/A	Review and analysis of lessons learnt and system development	Design a protocol for environmental data management of farms.

Table 6. An overview of the EURO-TIDES project's environmental monitoring related work package tasks and associated monitoring activities

4.3 Magallanes

There is no committed funding for comprehensive monitoring opportunities and reporting within Magallanes projects. However, there will be drifting acoustic surveys and collision risk modelling associated with them as per their marine licence conditions.

5 Environmental Monitoring at EMEC

EMEC's capability in conducting environmental monitoring activities is significantly influenced by project funding, which would be unlocked if the site were to be consented for generation up to 50MW to. However, initial funding has become available for planning and methodology drafting. Additionally, EMEC is continuously submitting bids for environmental work to monitor devices and associated impacts whilst supporting data collection.

EMEC will take a proof-of-concept approach within the 50MW expansion of the Fall of Warness site with regards to the feasibility and practicality of environmental monitoring and associated equipment. This process will initially be iterative and will follow from the deployment of the device to the analysis of performance, instrumentation and impacts of the monitoring which will allow EMEC to feedback on lessons learned. Development and feedback on conducted data analysis, methodology, and dissemination will also occur – with a focus on ground truthing for use of various data types together, and how these types interact with each other to convey a comprehensive overview of the test site environment where the device is being deployed. Furthermore, methodologies for simultaneous surveying will be considered to minimise trips to site as much as possible.

Additionally, EMEC will also build on lessons learned globally from those conducting smaller scale testing and projects for consideration of how to best develop bespoke systems which both reflect efficient integration with devices and review device types (i.e., surface-piercing and bottom-mounted). Engagement with key industry stakeholders, academics, and instrumentation providers will be sought to establish as many lessons learned as possible whilst improving industry standards using various perspectives within the tidal energy sector. Being ISO/ IEC 17025 accredited (which is included in our IECRE RETL designation for tidal), EMEC will additionally feedback on surveying and how the standards coincide alongside advanced deployments.

It is worth noting that any data collected within this site, including raw data, will be publicly available, and can be provided to regulators and stakeholders on request. Below are detailed possible planning measures that can be used to gather a more comprehensive overview of the Fall of Warness test site's conditions and impacts on associated receptors.

5.1 Protected Areas

There are several protected areas around the Fall of Warness site which must be taken into consideration when doing any survey work – whether regarding device deployment or scientific reasoning. These are outlined in Table 7.

Site Name	Protection Status	Relation to the Fall of Warness Test Site	Qualifying Interests/ Notified Features/ Special Qualities
Muckle and Little Green Holm	Site of Special Scientific Interest	Immediately adjacent to Fall of Warness test site	Grey seal – breeding colony feature
Muckle and Little Green Holm	Designated Seal Haul-Out Site	See above	Grey seals – known to forage some considerable distance but tend to stay within 20km of colony during breeding season (late September to end of December)
Seal Skerry (Eday)	Designated Haul-Out Site	Adjacent to Fall of Warness test site	Harbour and grey seals – breeding colony feature
Faray and Holm of Faray	Special Area of Conservation	Located approximately 4km from the Fall of Warness test site	Grey seals – NatureScot concerned by 'unfavourable declining' status. Foraging distance is considerable but they tend to stay within 20km of colony during breeding season (late September to end of December)
Faray and Holm of Faray	Site of Special Scientific Interest	See above	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	Located approximately 13km from the Fall of Warness test site	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 – NatureScot

			concerned by 'unfavourable declining' status of these seals which show greater site fidelity throughout the year by staying approximately 50km of their breeding colony

Table 7. Protected areas which are relevant to the Fall of Warness test site

5.2 Control of Work

Operations to deploy scientific instruments or conduct surveys within EMEC's test sites will be managed under EMEC's Control of Work Standard Operating Procedure (SOP). All deployment and retrieval works will be performed in accordance with EMEC's SOPs and be subject to EMEC's Emergency Response Procedure (ERP). Methodologies will conform to health and safety requirements 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 under EMEC's Control of Work SOP. A Notice to Mariners describing appropriate works will be issued in a timely manner as part of this process.

5.3 Marine Works

Vessel routes to Fall of Warness regularly start from Stromness harbour, Kirkwall Pier or Hatson Pier. Table 8 provides details of typical vessels used in the deployment of scientific instruments. Vessel specifications are not given as maximum envelope figures but are typical specifications for information purposes only. Other vessels, not specified as example vessels, may be used at the site and specific vessel details with be detailed in the relevant Notice to Mariners. EMEC requires all vessels which engage in works on its test sites to be fitted with an Automatic Identification System (AIS). EMEC holds a register of all vessels permitted to work on the site. For a vessel to be included on the register, EMEC must hold a copy of the vessel's insurance and vessel's examination/registration certificate.

Vessel Type	Example Vessel	Length (m)	Max. Draft (m)
Workboat	MV Flamborough Light	17	2.2
Workboat (Cat 2)	MV Uskmoor Green Quest Causeway Explorer	16 17.8 11.8	1.7 1.5 1.3
Workboat (Cat 2) with dive support capability	MV Sunrise	21	3
Workboat (Cat 3)	Nigg Bay	13.4	1.3
Dive support boat	MV Karin	24	3
Survey vessel	MV Lodesman	22	-
Multicat workboat (Class 1)	MV Voe Viking C-Odyssey Orcadia	26 26 24	2.3 2.5 2

Table 8. Typical vessels utilised for scientific instrumentation deployment/retrieval and surveys at EMEC's test sites

5.4 Securing and Marking of Equipment

All equipment will be appropriately marked and lit where required. Instrumentation may be housed in or attached to a suitable foundation structure. Instrumentation will be anchored with gravity bases or clump weights, as appropriate, and not pinned or drilled into the seabed.

For any scientific instrument deployments which may have the potential to cause an obstruction or danger to navigation, EMEC will consult with the Northern Lighthouse Board (NLB) and, where appropriate, Orkney Islands Council Marine Services and comply with any advice on marking and lighting requirements. Additionally, NLB will be consulted on any deployment that has had an attached surface expression.

6 Monitoring Methodologies at EMEC

NatureScot methodology provides guidance on marine renewables in general, with some contents and associated research being specifically focussed on wave and tidal alongside associated evidence gaps (i.e., collision risk, entanglement, etc.) (NatureScot, 2023). Guidance notes to support Offshore Wind applications can be used in some cases (NatureScot, 2025). However, it is noted that there will be crucial differences as well as similarities in how these can be applied due to various factors such as the placements of components and how these differ between wind and tidal devices (e.g., surface-piercing versus bottom-mounted turbine, speed of rotors, etc.). Nevertheless, EMEC will consult with NatureScot to determine site-specific guidance regarding monitoring and mitigation measures to determine if these methodologies are useful. Additionally, EMEC will conduct different types of surveys simultaneously where possible to minimise environmental disturbance caused by vessel transit to and from the Fall of Warness test site.

Please note: As specified earlier, this is a live document, and the methodologies described are under consideration in real time and may change as deployments and operations are conducted, or where feasibility concerns arise. Any changes to methodologies will be flagged to MD-LOT and NatureScot who can advise on the best approaches to use if such occurrences should happen.

6.1 Previous Monitoring

EMEC's Wildlife Observations Programme (Scottish Government, 2014) consisted of extensive shore-based observations which provided presence, distribution and behavioural data relating to seabirds and marine mammals across its test sites. In-depth analysis of this observation data was conducted to provide an insight into the potential displacement and/or redistribution of wildlife within the study regions that can be associated with marine energy converter activity.

Observations of surface-visible species (such as basking shark, European otter, seabirds, and marine mammals including seals and harbour porpoise) around devices were relatively consistent across EMEC's test site study areas. While temporary displacement of animals was noted during the installation of Marine Renewable Energy (MRE) devices and likely associated with vessel activity, normal sightings resumed after the work phase was over and devices were operational (Long, 2017).

Under the Blue Growth and Innovation Fast Tracked (BlueGIFT) project, EMEC appointed contractors in 2021 to trial a five-day aerial video survey of marine wildlife across its Fall of Warness test site. The aim of the surveys was to develop an appropriate methodology to characterise marine species' presence and density, which could be used to validate the Wildlife Observations Programme. The survey was a valuable exercise in finding the most suitable approaches for clear observation of species targets while understanding principal constraints that should be factored into planning for future campaigns.

Furthermore, EMEC was involved in the Reliable Data Acquisition Platform for Tidal Energy (ReDAPT) project which aimed to provide a comprehensive suite of data on turbine operation, flow fields, and interactions between such, using Alstom's 1MW tidal device. A site characterisation was carried out (Sellar et. al 2016) alongside biofouling monitoring (Vance, et. al 2014), with the key environmental monitoring being the deployment of the prototype Integrated Monitoring Pod (IMP). The IMP consisted of hydrophones, active sonar, underwater video cameras, an ADCP and a CTD sensor. With lessons learnt feeding into ongoing projects.

These can facilitate part of EMEC's established baseline data. However, EMEC is aware further improving knowledge on seabird behaviour and interactions on site, including with deployed devices, is required on a more consistent basis. As part of this Section 36 application, vessel-based sea-bird surveys were conducted between 2023 and 2025 following the Joint Nature Conservation Committee (JNCC) Monitoring Seabirds at Sea methodology (JNCC, [A.] 2025). EMEC is also aiming to conduct the methodologies detailed in sections 6.2 to 6.8 within the Fall of Warness test site on a more consistent basis. However, this is dependent on opportunities (e.g., from additional projects, seal-specific survey grant and funding applications, etc.) that become available to support monitoring activities at EMEC test sites.

Nevertheless, studies such as Williamson et. al 2017 and Lieber et. al 2024 made use of the Fall of Warness site outside of EMEC's resources to encapsulate characterisation of the site and findings relevant to environmental mitigation and monitoring. Studies such as these are informing ongoing monitoring at the Fall of Warness to ensure scientifically robust and comparable data.

6.2 Drone Surveying

EMEC has recently acquired a drone through the Innovate UK funded WEDUSEA project to test a floating wave energy converter at Billia Croo which can be used within unmanned aerial vehicle (UAV) surveys at the Fall of Warness site. The specifications of this drone are in Table 9. Though specific methodology for use at the Fall of Warness site is still to be determined: methodology for drone surveying has been established for WEDUSEA with plans to combine ADCP echosounder data with the data obtained from static drone surveys. If drone surveying is to be conducted within the 50MW expansion project in a similar manner (i.e., within the EURO-TIDES project), EMEC will deploy a drone for overhead observational monitoring of seabird use and activity. Other surface-visible marine life could additionally be surveyed. Furthermore, drone campaigns can be planned in conjunction with seasonal periods (for example, the breeding seasons outlined in Section 5.12).

DJI Mavic 3 Pro Fly More Combo Specification	
Take-off weight	958g
Dimensions	Folded (without propellers): 231.1×98×95.4 mm (L×W×H) Unfolded (without propellers): 347.5×290.8×107.7 mm (L×W×H)

Max Ascent Speed	8 m/s
Max Descent Speed	6 m/s
Max Horizontal Speed (at sea level, no wind)	21 m/s
Max Take-off Altitude	6000m
Max flight time	43 mins (*Flying at a constant speed of 32.4 kph in a windless environment at sea level*)
Max Hovering Time	37 mins
Max Flight Distance	28 km
Max Wind Speed Resistance	12 m/s
Battery capacity	5000 mAh
Voltage	15.4 V
Charger rated power	65 W – 100W
Camera sensor	Hasselblad Camera: 4/3 CMOS, Effective Pixels: 20 MP Tele Camera: 1/2″ CMOS, Effective Pixels: 12 MP
Lens	Hasselblad Camera FOV: 84° Tele Camera FOV: 15°
Video resolution	Hasselblad Camera: 4K/120fps Tele Camera: 4K/60fps
Stills resolution	Hasselblad Camera: 20 MP Tele Camera: 12MP
Remote controller	Yes

Table 9. Specifications of drone acquired by EMEC for surveys

A key limitation for operating drones is their flight time due to battery life, which, depending on the model may vary between 30 – 45 minutes in pristine weather conditions and may be as low as 20 minutes in harsher conditions. Due to the distance of the Fall of Warness site from shore, vessel-based survey campaigns are proposed with fixed-point observations viewing directly down at the sea surface, positioned above and around the site. The outcome of these propositions will depend on what is deemed best suited alongside turbines on site. Nevertheless, a vessel-based survey will allow rotational use of battery packs between the drone and battery chargers, extending operations and limiting interruptions to switch out batteries between flight missions.

Previous surveys have mostly used moving vessels which sail continuously around nearby islands of targeted tidal zones (Slingsby.et al, 2021; Slingsby et al, 2022). However, issues arise with following this method due to potential disturbance of seals at Muckle and Little Green Holm SSSI and haul-out site if this was chosen. Previous studies have conducted drone surveys using vessel based transects within the Fall of Warness site (Scottish Government, 2014; Waggitt et al, 2016). However, feasibility of this type of routing will be assessed for when expected devices have been deployed within the area. EMEC will consult with NatureScot to identify the best transect methodology and vessel routing around the site.

The longevity of survey campaigns will vary depending on the monitoring objective and planned area of coverage by the drone system. It is envisaged that a single vessel-based campaign may extend up to five survey days (returning to shore at the end of each day). However, contingency on mobilisation will be crucial for the survey campaign, as unsuitable weather forms a major constraint for drone flights. Wind speeds must not exceed 21-24 metres per second (m/s) and there should be very little to no precipitation, as once water droplets sit on the camera lens, this will obscure image clarity and require the drone to be retrieved. In addition, drone operators must be aware if any potential temporary aviation restrictions have been set in place by controlling authorities.

During detailed flight planning, literature will be consulted on previous survey methods and guidance will be followed where available to investigate the most appropriate flight altitude that balances visibility of seabird targets with minimising potential incidental disturbance caused by the presence of the drone (for example, previous studies have flown an average altitude of 70 – 120m; Slinsgby et al, 2022; Lieber et al., 2019). Flights may incorporate an initial period of hovering to habituate seabirds to the presence of the overhead drone (Brisson-Curadeau et al., 2017).

All flight personnel and operations will respectively meet the requirements set by the UK Civil Aviation Authority (CAA), and all survey operations will be planned in line with EMEC's standard methodology and risk assessment process. Best practice for environmental monitoring will also be followed (Hodgson, 2016; Edney, 2023).

6.2.1 Survey Prerequisites

The following pre-requisites must be met before a survey can be carried out and double-checked both the week and day before survey.

- The wave height must be no more than 1.5 m (sea state 4).
- Wind speed must be no more than 16 knots (force 4 on the Beaufort scale).
- Visibility must be at least 3 miles and forecast to stay at this level for the duration of the survey period.
- The survey must be carried out at a time when no other activities (in particular those involving vessel traffic) are happening at the site, and the tidal device is fully operational.
- All necessary documentation such as Permit to Work, Notice to Mariners, Risk Assessments etc. must be in place.

A Local Notice to Mariners (LNTM) will be completed and circulated no later than 14 days ahead of the acoustic monitoring survey to the UK Hydrographic Office (UKHO) and local contacts as listed in EMEC's Maritime Safety Information SOP063. If the survey is short in duration, then only one LTNM is required. However, if there are significant changes to the survey activities then a further LNTM should be submitted.

6.2.2 Data Analysis of Drone Survey

Drone image and video sequences will be manually reviewed and subsequently post-processed using MATLAB. Images will be assigned corresponding geographical coordinates to allow for conversion of image units (pixels to metres), to support analysis of seabird abundance and wider spatial distribution. Data will be compared to site seabird surveys in order to understand the estimate of how many birds are to be expected per minute in a given area. Alongside drone data, environmental conditions will be taken into consideration such as tidal stage, time of day.

6.3 ADCP Campaigns

Acoustic Doppler Current Profilers (ADCPs) are highly important to the work being done at all EMEC sites for surveying purposes, especially at the Fall of Warness site. TADCPs are also required to be used to complete assessments which are part of accredited activities (relating to power performance assessment against both IEC TS 62600-100 for wave and IEC TS 62600-200 for tidal). Therefore, it is likely ADCPs could be deployed anywhere within the boundaries of EMEC test sites.

6.3.1 ADCP Campaigns

Several ADCP models are used at EMEC. A summary of these is given in Table 10.

Item	Frequency (kHz)	No. of Beams
Teledyne Sentinel SV50	500	5
Teledyne RDI Workhorse Monitor WHMW600	600	4
Teledyne RDI Workhorse Sentinel WHSW300	300	4
Nortek Signature 500	500	5

Table 10. ADCP model descriptions

ADCPs will use a high frequency range (300-600KHz), and a maximum of 10 will be deployed at the Fall of Warness site. The ADCPs could be deployed and retrieved several times, and this will depend on how many project or scientific monitoring surveys are required at the Fall of Warness site. However, it is worth mentioning that vessel trips may be lessened overall through carrying out ADCP-related activities whilst other operations are being simultaneously conducted (i.e., other site related work). A task risk assessment will be conducted for deployment and recovery, and a drop camera will be used to increase positional accuracy for every deployment, ensuring a level seabed and protecting any susceptible features. The ADCPs will transmit, and record continuously once deployed.

EMEC has utilised several methods of deploying ADCPs and rigging arrangements within test sites to characterise their tidal and wave conditions. Additionally, new methods may be developed depending on restrictions and requirements. A general rule EMEC has historically followed for rigging is using riser lines for short to medium length deployments in sites except the Fall of Warness tidal test site – where they are likely to disappear with the strength of the tide. Most recent deployments arranged have included the placement via vessel of battery-operated ADCPs on the seabed without riser lines of marker buoys. Nevertheless, a description of general methodologies including riser lines have been provided to outline steps used to conduct ADCP surveys with minimal impact. In the event of an integrated monitoring pod deployment alongside ADCPs, all scientific instruments contained within the pod will be assessed individually on a case-by-case basis, especially if instrumentation with active acoustic properties is included.

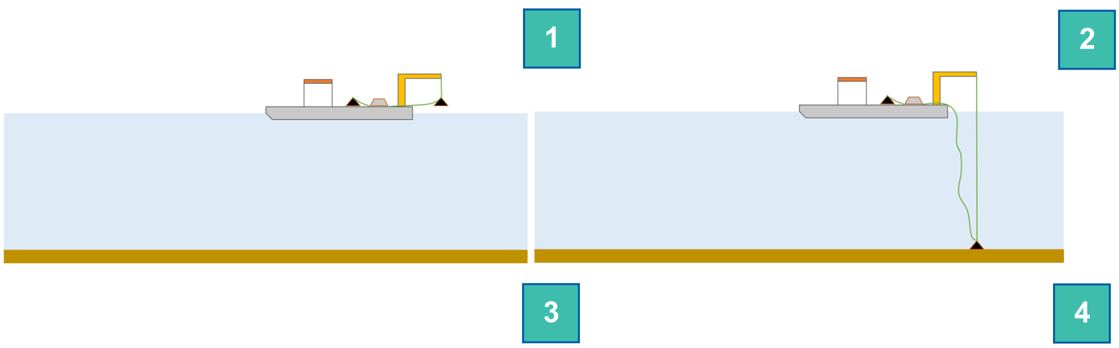
6.3.2 Ground Line Mooring Deployment

Once on site, EMEC representatives and vessel crew will prepare the ADCP rigging, and a pre-deployment checklist will be followed. Once completed, the ground line will be rigged onto the vessel's winch, and a chain clump will be connected to it after. Vessel crew will overboard and lower the first chain clump to the seabed using the winch. The ADCP frame will be attached to the ground line which the remaining of will be laid out on deck. The remaining chain clump will be connected and secured to this on deck whilst the ADCP frame is secured onto the vessel's crane using a lowering line on the winch. The ADCP frame will be lowered whilst the boat is brought into position, and the lowering line is kept vertical to limit tension on the ground line. This lowering line will be paid out until it becomes slack through the ADCP reaching the seabed. The time and ADCP position will be recorded and confirmed adequate before this line is released from the winch and recovered on deck to rig the remaining clump. The chain clump will be lowered upstream of the ADCP's position whilst keeping the lowering line vertical to limit tension on the ground line again. The lowering line will be released from the winch and recovered on deck once more.

For recovery, the ADCP positions and rigging arrangements will be identified whilst on site. An internal recovery checklist will be completed by an EMEC representative, and they will confirm readiness for ADCP recovery. A chain grapple will be deployed at the starting point of transit whilst the vessel is sailed along transit to reach the end of its position. The chain grapple will be recovered to the deck. If a grab has been successful, the vessel crew will secure the ground chain on deck. However, the vessel will sail across the transit again if unsuccessful. The chain clump will then be disconnected from the ground chain, and the ground chain will be connected to the vessel's main winch. The vessel will be moved towards the ADCP's frame position, and the ground chain will be recovered on the winch until rigging slings appear on the bow roller. The ADCP frame will be secured on the crane and brought on deck. The remaining groundline will be connected to the winch to recover the ground line and chain clump using it. The boat position will be adjusted to avoid dragging equipment on seabed or tangling of lines. The second chain clump will be secured on deck and recovered equipment will be further securely stored and deck tidied up.

6.3.3 U-Shape ADCP Deployment and Recovery

Once on site EMEC representatives and vessel crew will prepare ADCP rigging. Once ready, the first chain clump will be rigged on the vessel winch using a riser line. This will be deployed on seabed downstream of the ADCP's position, and the riser line and float released overboard. The ADCP frame will be lowered via crane using a lowering line whilst the vessel is brought into position, and the line will be paid out until becoming slack through the ADCP reaching the seabed. The lowering line will be recovered, and then the remaining clump will be rigged onto the winch using another riser line following similar procedures to the first whilst the vessel is positioned upstream of the ADCP's position. The figure below outlines this process.



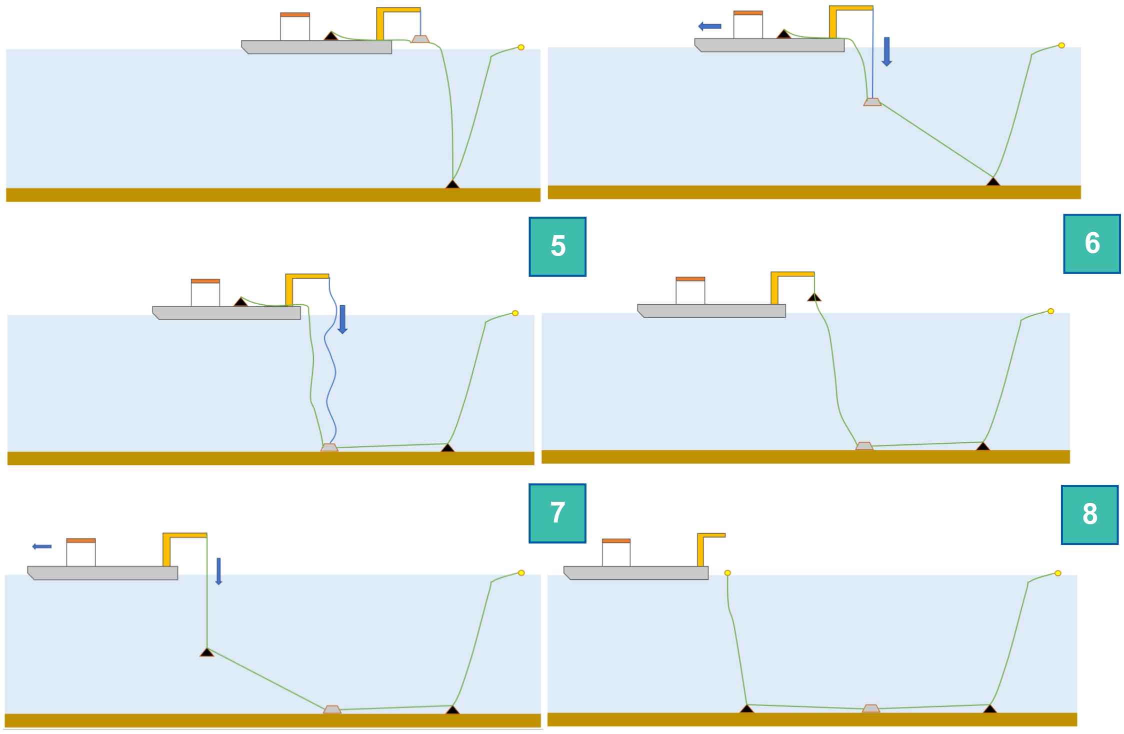
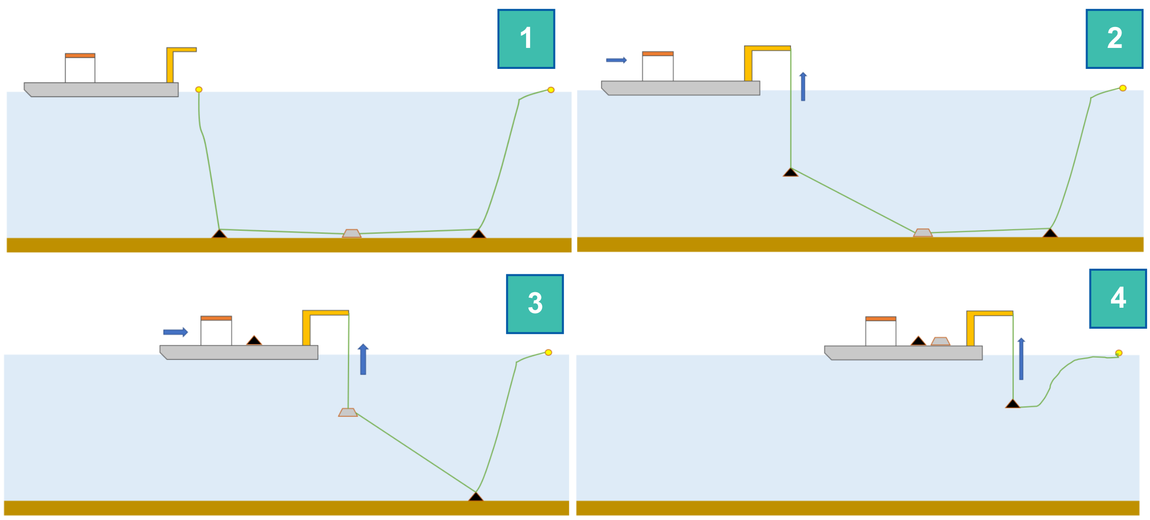


Figure 2. Diagram of U-Shape ADCP deployment

On retrieval (Figure 3), all equipment will be removed from the water. EMEC representatives and vessel crew will identify ADCP floats and rigging on site, and an internal recovery checklist will be conducted. The upstream float and riser line will then be collected using a boat hook and the riser line will be connected to the winch to start recovery of the first chain clump. Once the first chain clump is on deck, the ground line will be connected to the winch to recover the ADCP frame. The remaining ground line will be attached to the winch afterwards to recover the second chain clump and second riser line. In recovering the chain clumps and ADCP frame, the position of the boat will be adjusted to avoid dragging equipment on the seabed or tangling the lines



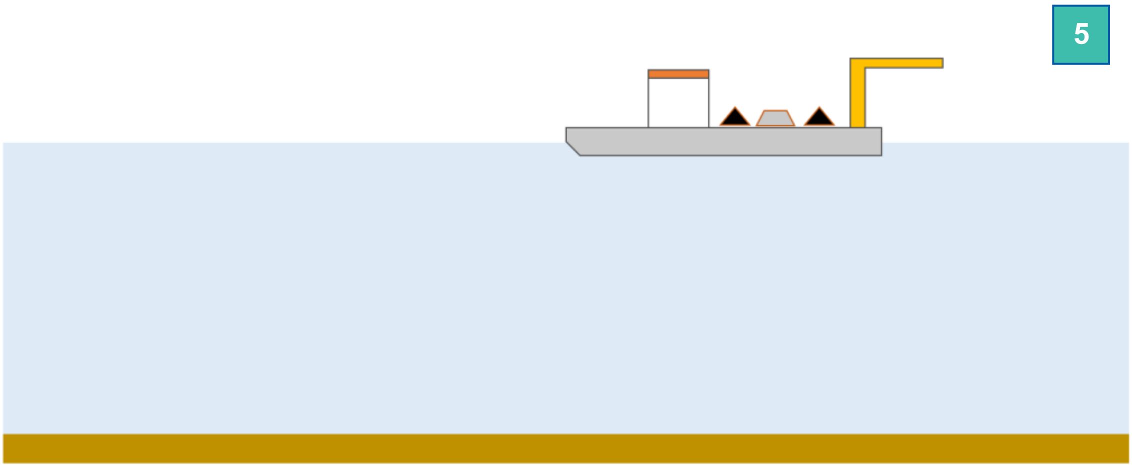


Figure 3. Diagram of U-Shape ADCP recovery

6.3.4 Data Analysis of ADCP surveys

Current data from standalone ADCP campaigns will be used to validate other data gathered from some of the survey methods below. Current data can also be used alongside ecological distribution data to understand how currents affect distributions of populations and so can be combined with upcoming bird surveys which will be conducted within projects like FORWARD2030.

ADCP current data is quality controlled via a standardised process sufficient for IEC TS 62600-200 power performance assessment and IEC TS 62600-201 power yield assessment of tidal turbines. This results in quality control flags being assigned to each data point, and the data itself being published ultimately in industry-standard NetCDF format with traceability to QARTOD tests. Processing is undertaken using in-house software built atop MATLAB. Turbulent intensity is captured by this process as well as depth profiles of current speeds in three dimensions.

In addition to these campaigns, ADCPs will be included on frames for multiple instruments (e.g., static hydrophones) and methodology of such can be reviewed below in relevant sections.

EMEC may also be able to gather wave data in future projects. ADCP wave data is extracted using proprietary mechanisms from each ADCP manufacturer. Surface elevation is recorded via pressure sensors present on the ADCP itself.

Other post-processing may be carried out as per project requirements.

6.4 Static Hydrophone Campaigns

Underwater acoustic monitoring is a key approach for assessing the presence, distribution, and behaviour of marine mammals in the vicinity of operational turbines as well as the acoustic outputs from the devices themselves. Within existing projects, EMEC has the opportunity to trial methodologies, strengthen technical and operational expertise, and report lessons learnt to assist with continual improvement of underwater acoustic monitoring and assessment within this industry. To do so, EMEC is currently considering the potential and limitations of both static and drifting hydrophones (e.g., as described in Section 6.5 below for DART surveys).

In the case of static hydrophone deployments, there is possibility to deploy a series of passive acoustic hydrophones mounted on subsea frames to detect vocalising cetaceans.

The primary objectives of such hydrophone deployments are to collect further data on marine mammal vocalisation activity in the vicinity of the tidal array. The focus will be on detecting marine mammal echolocation clicks, whistles and moans, which are a key indicator of their presence and behaviour near the devices. This will provide additional insight into how species such as harbour porpoise and other marine mammal species use the area and respond to the operating tidal array.

The data collection approach will draw on learnings from relevant environmental monitoring at EMEC and from other highly energetic sites, such as those at Fundy Ocean Research Centre for Energy (FORCE) and in the Pentland Firth. Existing projects at EMEC plan to deploy seabed-mounted hydrophone arrays around wave energy convertors, an example of which includes using three hydrophones and an acoustic recorder positioned in a triangular formation. The aim of this is to routinely record periods of audio and triangulate any audible marine mammal vocalisation. The ability to locate marine mammals in the water column around the turbine will be important to understand potential avoidance patterns.

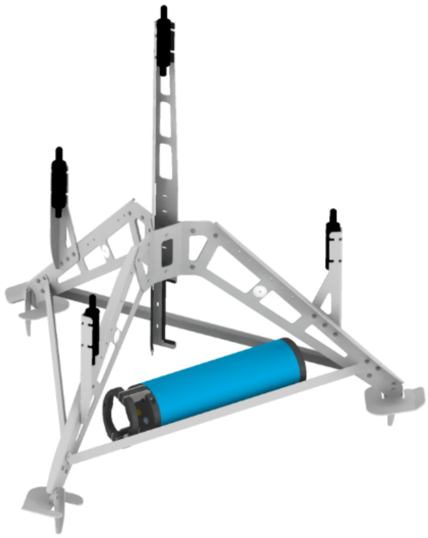
Options that are open to EMEC include a possible single subsea hydrophone frame in the Fall of Warness under the FORWARD2030 project, details of which are still being confirmed. Secondly, under the EURO-TIDES project, two approaches are currently being considered: the use of three hydrophones arranged in a triangular seabed-mounted configuration with an acoustic recorder (e.g. RESEA), or the deployment of one or more F-POD click detectors. The selection of equipment will be based on operational experiences and data quality outcomes from existing projects, ensuring the chosen method is best suited to the challenging tidal conditions and specific monitoring objectives of the site.

Challenges which we are still seeking to understand include difficulties mooring the hydrophones to the seabed making it difficult to maintain position and accuracy which affects tracking accuracy of acoustic signals; and ‘flow noise’ masking targeted acoustic signals of interest (e.g., species, turbine noise, etc.) and making them difficult to isolate due to the Fall of Warness’ highly dynamic tidal environment.

Enduring deployments of this technology would require significant investment for operational maintenance and data processing.

6.4.1 Acoustic System

To detect vocalising marine mammals an initial frame design under development includes 3 hydrophones mounted on the frame arranged in an equilateral triangle formation (see figure 4 for example). This configuration would allow the localization and bearings of received sounds to be determined. Spacing: At least 1 meter between hydrophones is required.



Note: The EMEC implementation shall only use 3 hydrophones mounted horizontally, for 2D triangulation, rather than the 4 pictured here. The example pictured here mounts 4 hydrophones with perfect 1 metre separation for 3D triangulation.

Figure 4. Example (Ocean Sonics) Subsea Tripod

Hydrophone mounts shall be placed in an equilateral triangle formation in the horizontal plane with 1m on each side of the triangle +/- 5cm. Please note EMEC does not expect 4 hydrophones as in the picture above, but 3, orientated in the horizontal plane only.

The hydrophone mounts must be >1m from the sea floor, once deployed, to limit noise effects from boundary conditions there.

While fixed platforms provide long-term data, such systems are highly susceptible to flow noise, which is a type of low-frequency noise contamination (< 1 kHz) caused by water flow advected over the pressure-sensitive element of a hydrophone. Flow noise can potentially mask true propagating sound into the tens of kilohertz band, thus making ambient noise and quantification of turbine noise challenging to measure. For example, in quantifying turbine generated noise, flow noise suffered by a static system tends to mask the frequencies (10's - 100's of Hz) of interest. Flow noise suppression shall be employed as previously mentioned.

Results from flow shield experiments are mixed. Several approaches to mitigate flow-noise are described in the IEC TS 62600-40 specifications and include employing a flow-shield that surrounds the pressure-sensitive element in a quiescent pocket (eliminating flow-noise from turbulent eddies shed by the element).

Flow-shields constructed of open cell foam have been shown to reduce flow-noise in some circumstances. "Turtle shell" flow-shields have also been reported to be relatively effective for fixed platforms, as well as a thin nylon shroud over a urethane cage protecting the pressure-sensitive element. EMEC will investigate the potential for mitigating flow noise contamination with use of an appropriate screen fitted to the upper end (pressure-sensitive element) of the hydrophones.

Hydrophones originally chosen to be used are Colmar GP1190 devices, and an acoustic recording device to output time-synchronised recording of the three hydrophones is required. For this purpose, EMEC have chosen a RTSYS EA-SDA14 unit. The RTSYS EA-SDA14 is cylindrical, and has the following dimensions:

Length: 12.6in / 32cm **Diameter:** 4.7in / 12cm **Weight:** 11lbs /5kg in air

EMEC may vary the model of hydrophone and recorder during development and testing. Therefore, there may be minor design amendments arising from such variations.

6.4.2 Data Analysis of Static Hydrophone Campaigns

Depending on the hydrophone chosen, PAMGuard is expected to be used for click, whistle and moan detection from cetaceans for the large datasets collected over a period. The PAMGuard software provides a suite of Detection, Classification, and Localisation algorithms developed specifically for the many types of sounds made by different species. Triangulation from the 3 hydrophones will aim to use time of arrival difference to pinpoint the location of the vocalisation. Some projects such as EUROTIDES may consider new types of hydrophones such as F-pods which have their own software for such detection, It uses the advanced KERNO-F classifier that pulls cetacean trains out of background noise. This will be finalised at a later date.

6.5 Drifting Acoustic Recorder and Tracker (DART) Surveying

The concept behind the DART design is to maximise the advantages of recording ambient sound from a drifting platform, minimising the disadvantages of being associated with a boat or other surface vessel or fixed in place to a static mooring. Hydrophones deployed from a vessel will unavoidably be subject to noise from that vessel while hydrophones on static moorings experience high levels of flow noise (where non-acoustic pressure fluctuations caused by water movement across the hydrophone are recorded as voltage fluctuations) when deployed in areas of high tidal flow, as well as the turbulent noise produced by water flowing around the mooring and recording equipment. The central feature of the design is that the hydrophone, rather than any other component, is fixed relative to the body of moving water and that other constituents do not impart artificial noise into the recordings.

To achieve this drifting platform, a hydrophone is placed inside the bounds of a large underwater drogue (a fabric 'kite' with high drag) which, when placed in the water, moves at the same speed as the tide to prevent flow noise. The underwater drogue at EMEC is currently being updated to match the 'C-DAISY' unit developed by the University of Washington with aims of making it easier to deploy, transport, and recover in addition to reducing flow noise (Marine Situ, [A.] 2025).

The drogue will be weighted to drift at depth and suspended from a buoy connected to a small floating canister containing a GPS system. A wide diameter hawser and shock chord is used to negate strum and add physical separation between the sensing and surface parts of the unit. The entire unit is self-contained and dropped into the water upstream of the area of interest to drift passively in the current over the area of interest, recording passive acoustic data as it drifts. The unit is retrieved further downstream. The floating canister includes a logging GPS unit so that, on download, the precise path of the drifter is known and can be time stamped to the acoustic recording. The key components of the DART system and their arrangement are shown in Figure 5.

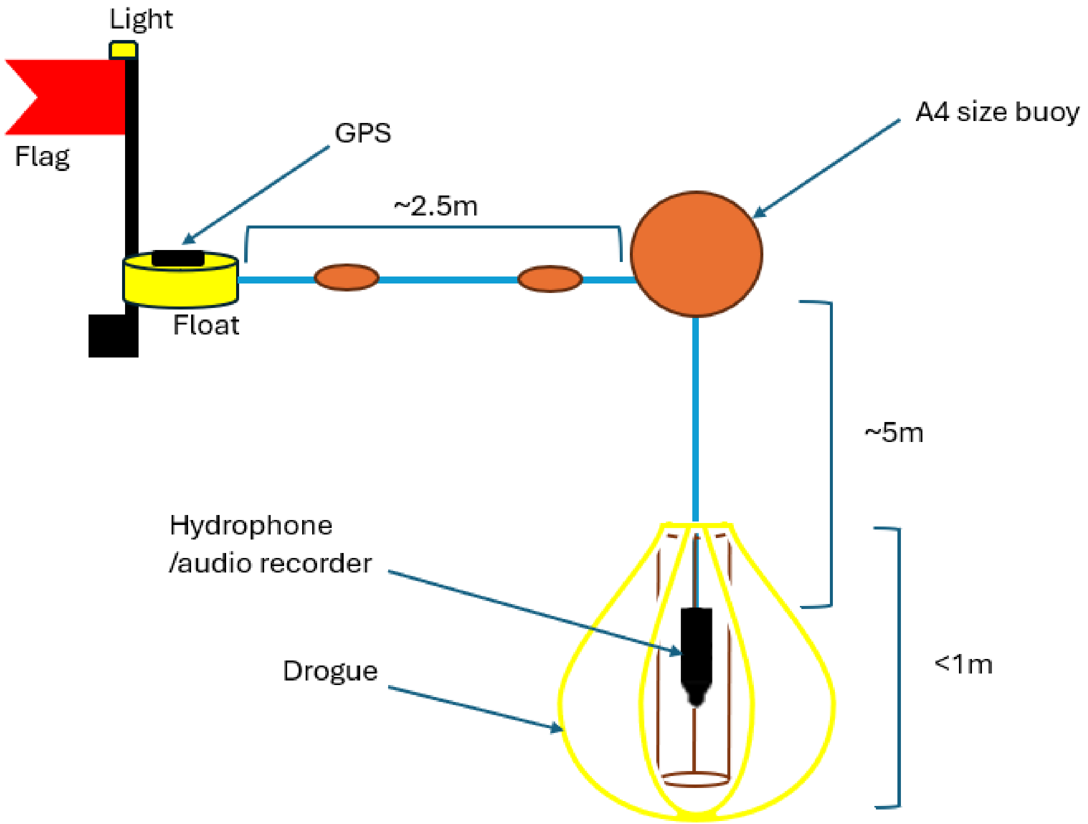


Figure 5. Updated DART redesign aspects

This upstream-drop and downstream-retrieve approach has the dual benefit of providing a solution to the ambient noise problem (outlined above) and recording from a swath of locations. This latter feature provides the potential to map the sound intensity over the area of interest. Furthermore, a single support boat can simultaneously deploy multiple DART units to increase and better quantify the spatial and temporal coverage of acoustic data recorded and make optimal use of brief weather or operational windows. Considerations have been made to improve the drifting system to make it suitable for smaller vessels, which can be more suitable in fast-moving tidal currents and narrow channels or constricted waterways, whilst being easily deployable and recoverable (SMRU, 2015).

6.5.1 Equipment Required

The equipment required for the carrying out of a DART survey is given in table 11. These are subject to vessel size and safety of deploying multiple systems.

Item	Quantity
Drogue, flag, float, rope, buoy combo.	3
Hydrophone - SoundTrap ST300HF recorder	3
SoundTrap ST300HF remote	3
Batteries (for SoundTrap ST300HF remote)	3

Item	Quantity
GPS	3
Silicone Grease	-
Binoculars	1
Knife	1
Sound Velocity Profiler	1

Table 11. Equipment required for the carrying out of a DART survey

Either immediately prior to, or immediately following, the data collection campaign, the recording equipment will be calibrated to measure the sensitivity and voltage response of the system across the range of frequencies of interest.

6.5.2 Survey Pre-requisites

The following pre-requisites must be met before a survey can be carried out and double-checked both the week and day before survey.

- The wave height must be no more than 1.5 m (sea state 4).
- Wind speed must be no more than 16 knots (force 4 on the Beaufort scale).
- Visibility must be at least 3 miles and forecast to stay at this level for the duration of the survey period.
- The survey must be carried out at a time when no other activities (in particular those involving vessel traffic) are happening at the site, and the tidal device is fully operational.
- All necessary documentation such as Permit to Work, Notice to Mariners, Risk Assessments etc. must be in place.

A Local Notice to Mariners (LNTM) will be completed and circulated no later than 14 days ahead of the acoustic monitoring survey to the UK Hydrographic Office (UKHO) and local contacts as listed in EMEC's Maritime Safety Information SOP063. If the survey is short in duration, then only one LTNM is required. However, if there are significant changes to the survey activities then a further LNTM should be submitted.

6.5.3 DART Unit Deployment

Once the vessel has manoeuvred into position its engine(s) should be put into neutral, and any vessel echosounders should be switched of, prior to the DART unit being released. Immediately prior to release, a time stamp should be noted. Before deployment of the DART units, the survey area needs to be checked for any vessels in motion that might cross the survey area during time of deployment, drifting and collection. Once the area is confirmed clear by all survey members, the DART units can be deployed.

With the boat's engine(s) in neutral, the unit should be deployed by two people, one holding the drogue and buoy and the other holding the recording canister. The drogue and hydrophone should be placed into the water first and the cable paid out. Once the drogue has filled with water the buoy can be placed into the water, followed by the recording canister. The drifting system must be allowed to clear the vessel before the engine(s) are re-engaged for moving to the next deployment site.

The boat should move upstream and to the centre of the units and its engine(s) stopped. It is important that the support boat goes quiet as soon as possible after deploying the unit(s) as any engine noise will contaminate the recordings. A watch must be kept on the drifting units and any other vessel movements in the area. If a drifting unit should enter an area of likely entanglement, get near to other vessels or get separated from the main flow, the support boat must restart its engine(s) and recover it. If a vessel should enter the area of the drifting DART units, it will be informed of the hazard by the skipper of the support boat and the units recovered if necessary.

In fast flow, a few seconds' travel of the DART unit can translate to large distances. There is a need to understand vessel response time if anything happens and create exclusion zones. It is important to keep the boat in line with direction of the DART to visually gauge the distance between the DART and the devices. Vessel response time should be understood from the training session.

In relation to the sample box, IEC guidelines recommend at least 65m distance from device, however from operational experience this should be extended to over 100m. This is to reduce the risk of entanglement with the device. Despite the precautions mentioned it is still important to note that there remains a degree of unpredictability in the direction the DART will take.

On completion of each recording session, or if light levels/visibility drops such that the drogues are not clearly visible or if sea conditions exceed force 4, the drifting DART units must be recovered and re-stowed on the boat. Once the vessel passes the sampling box area, two personnel should prepare to recover the DART unit who have been familiarised with the equipment and its handling (Figure 6).

6.5.4 DART Unit Recovery

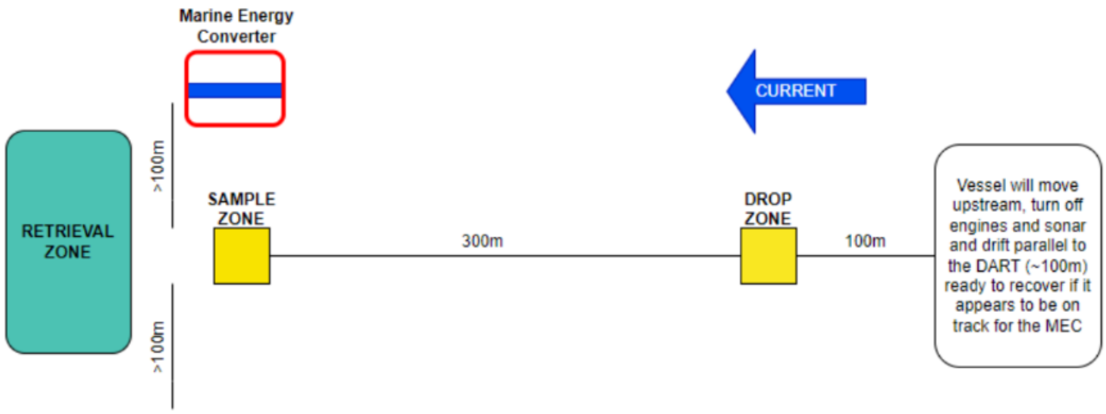


Figure 6. DART deployment and recovery diagram with distance greater than 100m from the device from EMEC operational experience

Each drifter will be approached as in a man-overboard manoeuvre and the first person will grab the float line between the buoy and recording case using a boat hook. Once the line has been secured by the boat hook, the vessel's engine(s) should immediately be put into neutral and not be re-engaged, except in an emergency, until the complete DART system has been recovered onto the deck (or re-deployed and completely free of the vessel as described below). A second person should lift the recording canister on-board and then assist the other person to pull the buoy and drogue on-board.

If the drogue gets carried under the vessel by the current and cannot be pulled free, a boat hook should be attached to the drogue held by a survey member to wiggle the drogue free. In case the drogue cannot be freed, the float and recorder case should be redeployed, and the boat hook used to free the complete DART system released, if required.

Recovery can then be re-attempted using the procedure described above. On no account should the vessel's engine(s) be re-engaged in an attempt to move the vessel away from the drogue while the drogue is still in the water, due to the very high risk that the drogue will foul the boat's propeller(s).

Once the DART unit has safely been recovered on board and any excess water dried off, retrieve the SoundTrap and save GPS track. If possible, initial QC checks will be performed throughout the survey. This entails inspecting a spectrogram for any obvious electrical noise or other source of interference, and an operator listening to short sections of the recording to ensure there is no audible interference which was missed on initial inspection of the spectrogram.

After all the files have been copied the unit will be prepared for the next deployment. If data QC is not possible to carry out during the survey, the same checks will be performed onshore each night, to ensure potential issues do not persist across multiple days of the survey.

6.5.5 Survey Records

Once deployed, the DART unit is allowed to drift with the tide until the area of interest has been covered. Survey records during each drift will be recorded using EMEC's DART Deployment Record Template. The survey records are important to support contextualisation of the acoustic measurements and interpreting results later. It is important to use the GPS watch for recording times as time will be used to put all the data together. Contents of records include:

- Environmental conditions: record wind speed and direction, sea state, visibility and precipitation, noting any changes (considering the environmental pre-requisites below in Section 8.2.2.4).
- Time on, time in: record both the times the acoustic equipment is switched on and when the DART is deployed into the water.
- Boat off, boat on: record the times the vessel is switched off and on, as well as during any repositioning.
- Vessel traffic: record any vessels visible at the start of the drift, adding details of any new vessels that come into view (including time and estimated bearing and distance from the DART).
- Miscellaneous events: record any events which might impact on the recordings, including presence of marine mammals or aircraft, and any significant noise generated from onboard the support boat.

6.5.6 Data Analysis of DART Surveys

Detailed technical guidance on processing and analysis is provided in the following resources:

Data processing software:

- **dBWav:** dBWav is a tool for analysing audio files. It can handle processing of large files and long-term recordings, offering a basic level review of data sets for quick identification of features and trends. dBWav does not require coding experience to operate.
- **PAMGuide:** PAMGuide is acoustic analysis software for the characterisation of the acoustic environment from sound recordings. PAMGuide can be used to produce calibrated spectrograms and statistical analyses of sound levels, and is provided in both MATLAB and R. The software therefore requires some coding experience but can offer more control in data manipulation and graphics for reporting. Merchant et al, 2015 provide guidance notes for PAMGuide using R and MATLAB within appendix 1 of their journal article.

Data analysis and metrics

Data analysis procedures have largely been dictated by the IEC TS 62600-40:2019 standards on underwater noise monitoring of marine energy convertors. Spectrograms (i.e., time series plots) are useful for visual and audio inspection of the dataset to identify noteworthy sounds or noise events, including potential sources of contamination caused by flow noise or the drifting measurement platform itself (e.g., via metal-to-metal contact). The following metrics are used to describe continuous sound outputs from an operational marine renewable energy converter (MREC):

- **Broadband sound pressure level (SPL):** for continuous sound, expresses sound amplitude within a given time window and frequency range as a single decibel (dB) value.
- **Power spectral density (PSD):** shows the energy distribution into frequencies that compose the acoustic signal, allowing the turbine's operational frequency to be identified and therefore to assess how the sound will be perceived by different species.
- **Third-octave band levels (TOL):** show the energy distribution at specific frequency bands, whose bandwidth is one third of an octave (where an octave represents a doubling in frequency). This approach simplifies the data and is appropriate for most considerations of environmental impact.

Further explanation of analysis procedures and metrics are given within Robinson et al, 2014 and Merchant et al, 2015.

Marine mammal impact and exposure criteria

Noise threshold values from available cetacean auditory data are used to identify the potential onset of disturbance and injury from continuous and impulsive (i.e. pulsed sounds such as pile-driving) sounds. Within EMEC we have documented local species and their expected hearing and vocalisation ranges to support this.

Note: Impact and exposure criteria are calculated in different ways across the literature which makes comparison very difficult. Currently there is no standard method in place for calculating marine species impact from continuous underwater noise generated by operational MRECs. Southall et. Al, 2007 and National Marine Fisheries Service, 2018 propose impact criteria that can be adopted as base guidelines for reporting.

Reporting of data analysis will be completed during EMEC's internal QA processes for project deliverables and follow guidance from Section 9 of the IEC TS 62600-40:2019 for information reporting.

Findings from previous surveys including review of methodologies found that some aspects of the current guidelines cannot be safely conducted for surface piercing turbines as the standards were potentially written with bottom mounted turbines in mind. For example, deploying a DART within 100m of the turbine blades highly increases the chance of collision with the device which can cause severe damage to the device and creates an unsafe situation for maintenance workers. Also deploying two DARTs at the same time poses a great challenge due to the fast flow of water making it very difficult to collect both Darts before one disappears. This can be somewhat mitigated by GPS on the hydrophones, but it is still very difficult to spot the DART equipment due to the fast-flowing water and wave action.

6.6 Echosounder Campaigns

Whilst campaigns are still to be finalised: the approach to the vessel based echosounder surveys currently considered follows a fine scale parallel line transect across up and downstream of the device on the Fall of Warness site. This will be to study the wake of the turbine on site for FORWARD2030. The vessel will have a dynamic positioning system and will always remain a safe distance from the outer most points of devices. Transects will run always against the tidal flow to avoid double counting fish and to characterise both the inflow and the downstream wake and associated flow fields in a similar method to Lieber et al. 2024 wherein the echosounder used will be on a pole mount deployed from the side of the vessel. The transect lines will be completed at a speed of 10 knots. However, this can be adjusted with sea state as required. The survey route will be completed in reverse during any periods of slack tide which will be encompassed with enough time during planned survey hours.

Furthermore, some projects such as EUROTIDES may also include seabed mounted echosounders. Methodology for such is still to be determined but may include the echosounder being positioned on a bottom-mounted frame which will point towards the surface alongside additional ADCPs and echosounders. Considerations established for determining methodology, for example, are the capabilities of positioning the echosounder upstream to analyse wake impacts on fish species around the turbine (e.g., disorientation and capability to move around the turbine, etc.) and seabird foraging, as well as power performance. Methods will be determined by discussion with the Metocean team within EMEC and through trialling different locations of the bottom-mounted echosounder alongside additional survey equipment. The trade-off between ADCP and echosounder capabilities are also still being considered.

Calibration of the echosounder will be done using a calibration sphere with a known target strength (TS), and material composition. This will be suspended into the water using a winch or pole mechanism. The vessel GPS live feed will be received and used to mark location and time stamp once the echosounder is switched on. As a backup EMEC can use its GPS system. The onboard screen will be monitored in real time during the survey to continuously check recorded data quality is acceptable.

In general, as depth increases, the time it takes for sound waves to travel to the bottom and back to the transducer (known as "ping time") also increases. If the ping rate (pulse repetition frequency or PRF) is too low, there may be gaps in the data, resulting in a less detailed image of the underwater environment. This is particularly important when trying to detect small or fast-moving objects, such as fish.

However, increasing the ping rate also increases the power consumption of the echosounder and can reduce the maximum range at which objects can be detected. Additionally, higher ping rates can result in more noise and clutter in the sonar image, making it more difficult to interpret.

If there is budget and time EMEC will aim to have marine mammal observers and bird surveyors onboard to collect additional data on species present during surveys.

6.6.1 Survey Prerequisites

The following pre-requisites must be met before a survey can be carried out and double-checked both the week and day before survey.

- The wave height must be no more than 1.5 m (sea state 4).
- Wind speed must be no more than 16 knots (force 4 on the Beaufort scale).
- Visibility must be at least 3 miles and forecast to stay at this level for the duration of the survey period.
- The survey must be carried out at a time when no other activities (in particular those involving vessel traffic) are happening at the site, and the tidal device is fully operational.
- All necessary documentation such as Permit to Work, Notice to Mariners, Risk Assessments etc. must be in place.

A Local Notice to Mariners (LNTM) will be completed and circulated no later than 14 days ahead of the acoustic monitoring survey to the UK Hydrographic Office (UKHO) and local contacts as listed in EMEC's Maritime Safety Information SOP063. If the survey is short in duration, then only one LTNM is required. However, if there are significant changes to the survey activities then a further LNTM should be submitted.

6.6.2 Data Analysis of Echosounder Surveys

Whilst specific data analysis methodologies are still being considered, the software Echoview will most likely be chosen for processing due to its user-friendly interface without the requirement of coding experience. The datasets used will include echograms from multiple frequencies which will allow EMEC to investigate presence of various species which could be present around the site. Additionally, the use of a Knowledge Transfer Partnership (see Section 10) and EMEC associates will be included to support data analysis.

6.7 Multibeam Sonar Surveying

With different tidal technologies being deployed and tested within the Fall of Warness site (e.g., both surface piercing and bottom-mounted devices), there are various methods of sonar surveying considered within projects which will occur if the 50MW expansion is granted. The differences between such are present within the upcoming Nova and Orbital projects, for example, in which FORWARD2030 and EURO-TIDES will have multibeam sonar integrated onto the tidal devices themselves whereas the SEASTAR and OCEANSTAR projects will include multibeam sonar within their Remote Observation Platform (ROP) which will be used for subsea monitoring outside of the devices.

Nevertheless, certain limitations when deploying multibeam sonars in any context within high-flow environments must be accounted for. These include interference with sonar instrumentation; difficulty in species level limitation; and interference with targeted species (Hastie et al., 2013; Melvin and Cochrane, 2014; Melvin and Cochrane, 2015). However, various limitations of multibeam sonar are anticipated to be overcame as more sonar systems and software packages are developed (Melvin and Cochrane, 2015).

6.7.1 Device-Integrated Sonar

Multibeam sonar deployment methods will be developed and scaled up within the Integrated Environmental Monitoring System (IEMS) of devices associated with the FORWARD2030 and EURO-TIDES projects respectively to assist in addressing uncertainties surrounding species interaction and collision risk whilst ground-truthing passive acoustic detections and species ID. In doing so, it will support informing high-priority regulatory concerns and emerging themes surrounding potential environmental impacts of large-scale arrays.

Best practice for sonar surveying is still to be determined through trials under FORWARD2030. However, design specification of the IEMS has presented a solution of a pole-mounted combination including multibeam sonar and camera equipment which was successfully deployed from the O2 device and was accessible to personnel to reduce operational complexity. The sonar and camera direction was positioned to look vertically towards the seabed. This location was chosen for suitability of instalment on the O2 and to enable the capture of the rotor swept area within the field of view of the sonar and camera, with two orientations completed: parallel with the turbine and perpendicular to the turbine. This positioning aimed to allow the capture of animals moving in front of the turbine rotor, and future trials will aim to deploy a second sonar further from the blades with the aim to capture avoidance behaviour between the first and second sonar. For the initial trail, the example pole mount length is less than 3 meters due to feasibility and to reduce drag and impact on power production.

Initial conversations with Orbital's Canadian partners FORCE and Acadia have led to new recommendations in sonar placement areas to better capture fish presence around the O2-X turbine.

The originally agreed upon positioning for the O2 device, aimed to encompass the full rotor diameter into the field of view (Figure 7). However, it has since been identified that including the rotor in the sonar field of view could introduce challenges when analysing the data in terms of falsely reporting marine animal presence and high impacts of vibration and entrapped air.

Figure 7. FORWARD2030 sonar placement for O2

Figure 8 presents an alternative arrangement, recommended by researchers at Acadia University in Canada, which aims at maximising usable data from the sonar, whilst positioning multiple cameras (blue/purple) in alternate locations to verify if animals are passing near the blades. There is also a second sonar (green/yellow) positioned away from the blades which could pick up avoidance behaviour from animals coming close to the turbine.

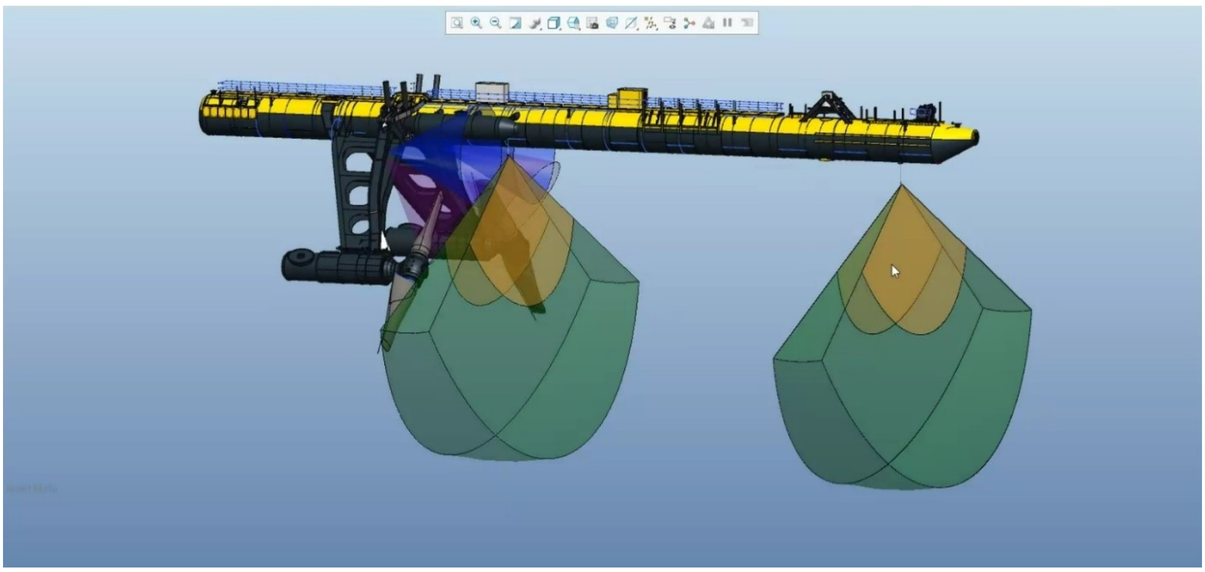


Figure 8. New option for sonar and camera placements for the O2-X in Canada

The new sonar placements are being considered when testing sonar use under the FORWARD2030 project as there is scope to gain the most insight possible from our trials and tests. However, if testing is likely to take place on the O2 rather than the O2-X, there are some mounting changes that will likely need to be discussed with Orbital.

With this in mind: the first trial will include a single sonar with closer position to blade. EUROTIDES will look to do two sonars on one turbine if not achieved through FORWARD2030 under a free sonar trial with Tritech Gemini and then purchase of an additional sonar. Please note, however, there are several aspects still to consider regarding these surveys, and this is only theoretical presently.

Regarding operational capability, the Sonar Head can be powered up out of water for brief periods of time (i.e., for bench testing), however, the unit should be immersed in water for extended amounts of testing to minimise the risk of the Sonar Head overheating.

The stated operation range for the Sonar Head in water is -2º to 38ºC. The Sonar Head can be powered on and started at temperatures between -20º to 45ºC. There is a built-in temperature monitor that will display a software warning message and automatically power down the Sonar Head before it overheats. The unit will require to be cooled before resuming full capabilities of the sonar.

6.7.2 Remote Observation Platform (ROP)

The design of Nova's ROP for use within the SEASTAR and OCEANSTAR projects are not yet finalised. However, it is pictured to include a low-profile steel frame with ballast to provide stability for fixing a junction box and sensor hardware to. The ROP will be directly connected to the turbines via cable for power and data transfer.

Optimal configuration will be set using the position of the ROP with respect to the associated turbine, optimal overlaps between the field of vision both for the sonar and cameras built into it, and sufficient nearfield environment coverage. Therefore, video data will be analysed alongside that of the sonar. Additionally, the ROP's position and orientation is still to be determined and will be done so whilst considering the site's seabed characteristics.

Consequentially, it may be positioned offset to the associated turbine or centrally aligned depending on optimal coverage of the rotor swept area and stability of the platform itself. Nevertheless, the distance in which the ROP will be deployed from the associated turbine has been determined to be between 10-20m.

The ROP will be able to monitor both up and downstream of the associated turbine – depending on tidal state – to provide near-field insight into the devices' bidirectional functionality. With the ROP sitting on the seabed at the Fall of Warness site, vessel movement will not be obstructed by its placement. However, any static or mobile benthic fishing gear should not be used within the immediate area around the ROP as this creates a snagging risk.

6.7.3 Data analysis of Sonar Surveys

There is currently ongoing experimentation with sonar data from previous and ongoing Fall of Warness projects, and there will be further testing of different sonar instrumentation to understand what software and equipment will work most effectively to collect and analyse relevant data. Thus far the use of MATLAB has been a key tool for reviewing initial sonar datasets collected under FORWARD2030.

Analysis will aim to assess how tidal conditions and sonar placements affect the quality of collected data. For example, how close in proximity the sonar can be to device blades will also be reviewed.

A major challenge and cost for tidal farm environmental monitoring is the data management and processing. Given the large volumes of underwater data collected in a short time using imaging sonar, a significant challenge lies in processing the data effectively to extract usable biological and environmental insights.

A comprehensive data storage and management strategy will be explored with support from technical experts. This plan will define the protocols for data handling, archiving, and accessibility, and will ensure compliance with regulatory requirements, contractual obligations, and long-term monitoring objectives. It will consider a range of storage options, including onshore servers and scalable cloud-based platforms, with emphasis on redundancy, security, and accessibility. This approach will ensure that the chosen data infrastructure is appropriately matched to the expected data volumes and technical requirements of the project, while also enabling seamless integration with automated processing tools and reporting systems.

Within this strategy, it is anticipated that automated processing will be employed to support the processing and interpretation of the large volumes of environmental monitoring data generated. Algorithms are planned be used to automate the identification and classification of marine species from both video and sonar data, mitigating observer bias and significantly increasing processing efficiency. This approach will work to streamline the data processing, enabling the project to focus on detections and behavioural insights. Raw datasets will be retained during initial phases to ensure full traceability and to validate the performance of automated classification models. Knowledge Transfer Partnerships (Section 6.10) and associate support will be utilised for this analysis. If appropriate other organisations such as Ecodetect will be considered to support analysis.

6.8 Vantage Point Surveying

EMEC will use vantage point surveying for complimentary analysis to the above methodologies by adding to characterisation of the Fall of Warness site. Through a series of watches from a fixed location objectives of these surveys include gathering information on:

- Seabird and marine mammal distribution and abundance within the Fall of Warness test site
- Seabird and marine mammal behaviour within the site (i.e., simply present or exhibiting specific behaviour, e.g., diving)
- The relationship between surface and subsea wildlife observations

The surveys can also help inform effective procedures within analysis of drone images / footage.

The exact methodology for these surveys is still to be decided. Generally, NatureScot's guidance notes on vantage point surveying will be used (NatureScot, 2023). Furthermore, EMEC will consult with NatureScot to determine where the most advantageous and effective vantage points would be to collect robust data which can be used to validate results from drone imagery. Additionally, EMEC would consider changing this survey type from land to vessel-based or contemplate alternatives where funds can be established for these. These could include further developments to onboard cameras for surface piercing devices to assess bird roosting occurrences or potentially conducting acoustic surveys in air.

Nevertheless, a visual transect through the site will be used from fixed points alongside binoculars or a telescope, and animals seen at the sea surface will be counted and recorded. The scanned area will be split into zones to make identifying animal counts within various parts of the site possible, alongside any corrections required to account for varying detectability at distance and watch times of individual scans. The counted animals will be identified to the exact species if possible. However, if this is unknown, the lowest taxonomic rank will be indicated (e.g., 'diver sp''., 'scoter sp.', etc.). A record of confidence in count quality (i.e., good, moderate, or poor) will additionally be recorded to gain more nuanced understanding of the quality of data and certainty of accurate identification.

The survey design will need to consider environmental conditions such as weather, tidal stages, diurnal cycles, sea states as well as time of year which will impact key stages for birds and marine mammals such as breeding seasons and pupping. Furthermore, it is generally accepted that the distance in which it is possible to identify and count birds is up to 2km from the shore (Waggitt et al., 2014). However, this may differ between bird species, and other animals, present within Fall of Warness. Alongside this, considerations will need to be made for surveyor biases such as detection bias, availability bias with the aim to limit as many variables as possible. Additionally, the significant impact simultaneous fieldwork and operations could have on disturbance of present species must be addressed as doing so would invalidate vantage point surveys (NatureScot, 2025).

6.9 Scottish Renewables Wave & Tidal Forum and SWTP OA

The Scottish Renewables Wave & Tidal Forum has established a dedicated group to address collision risk, particularly the potential for harbour seals to collide with tidal turbines. This issue is a major consenting challenge because seal populations in northern Scotland have declined, making regulators cautious despite no recorded collisions to date. Evidence suggests seals actively avoid turbines, but precautionary measures remain standard, creating delays in project approvals.

The Scottish Wave and Tidal Power Operators Agreement (SWTP OA) provide a unified framework for operators in Scottish waters to collaborate effectively, minimise operational conflicts, and ensure compliance with safety and environmental standards. Governance is led by Crown Estate Scotland with input from operators and R&D stakeholders and dedicated working groups for wave and tidal sectors drive technical coordination. EMEC are part of the Pentland Firth and Orkney waters (PFOW) which was established to foster collaboration among tidal energy developers in the region, with a primary focus on addressing consenting and operational challenges that could hinder project delivery. Key objectives include developing a fit-for-purpose policy and regulatory framework, coordinating cumulative environmental impact assessments, and ensuring proportionate and feasible monitoring through shared data and innovative technologies. The group also aims to close evidence gaps – particularly around collision risks for protected species such as harbour seals and diving seabirds – while promoting ecological enhancement and compensatory measures where necessary. By aligning industry, regulators, and researchers, the working group seeks to balance environmental stewardship with the strategic growth of tidal stream energy, enabling long-term scalability and cost reduction for future deployments.

6.10 Knowledge Transfer Partnership

Funding of over £300,000 has been provided to EMEC for development of a knowledge transfer partnership (KTP) with the University of Highlands and Islands (UHI). This will be focussing on transferring knowledge from academia to industry, with a particular focus on underwater acoustics and collision risk.

The goals of KTP between UHI and EMEC surround developing techniques for environmental monitoring within the marine renewable energy sector. By doing so, it aims to simplify the consent and marine licensing processes for developers, making it easier and faster to deploy marine renewable energy devices. Therefore, this will involve both:

- Enhancing environmental monitoring to improve EMEC's capabilities for consenting and licensing purposes, and
- Developing standard operating procedures for more efficient collection of environmental data

6.10.1 Integrated Environmental Monitoring System (IEMS)

The KTP objectives align closely with planned work under projects at the Fall of Warness. With deployment trials of the FORWARD-2030 IEMS completed and initial data collected, the next phase will focus on processing the sonar data to quantify ADCP interference and evaluate performance across different metocean conditions and turbine operating states. This data processing will provide EMEC with valuable insights into sensor integration and data quality to improve monitoring strategies and reduce uncertainty in environmental assessments. Knowledge gained will be shared through technical reports, presentations, and publications.

The lesson learnt will inform future system designs, such as determining the optimal number and placement of sonar devices, and support the development of improved detection, tracking, and classification algorithms. Importantly, these findings are likely to be applicable to multiple developers and not just to Orbital's devices. The investigations offer a strong foundation for academic publications through UHI and present opportunities for EMEC to commercialise improved monitoring configurations and data processing tools for broader application in the tidal energy sector.

6.10.2 Echosounder Surveys

The KTP can also support this project by addressing the technical and analytical challenges of operating echosounders in high-energy tidal environments. Turbulence and entrained air can introduce noise and compromise standard processing techniques, making target validation difficult. The KTP will focus on developing expertise in echosounder hardware and calibration, and advanced data processing. This work will help refine survey methodologies and improve the reliability of target detection and classification.

Projects will provide novel data and valuable results for academic research and publications on acoustic monitoring in challenging marine environments. For EMEC, the improved data quality and processing techniques will enhance site characterisation and contribute to streamlining the consenting process by reducing uncertainty around species presence and turbine interaction.

6.10.3 ADCP & Imaging Sonar

The KTP can contribute to associated projects by supporting the deployment and optimisation of seabed-mounted ADCPs and turbine-mounted imaging sonar systems. This work offers the opportunity to develop novel processing techniques that integrate data across different sensing technologies. For UHI, this has the potential to result in impactful academic papers, focussing on the use of ADCP data for environmental monitoring objectives. For EMEC, the KTP's contributions will be integral to the Environmental Monitoring Plan, helping to address key concerns around large-scale tidal arrays and ultimately reducing uncertainty in the consenting process through improved data quality and interpretation. In addition, by trialling novel integrated monitoring technologies, this work will strengthen EMEC's position as a leader in innovation within the marine energy and environmental monitoring industry

7 Impact Pathways and Measures within 50MW Expansion

The following sections describe the potential key environmental impact(s) considered relevant to the 50MW expansion of EMEC's Fall of Warness test site and associated activities. 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. The associated monitoring and mitigation measures can also be considered as supporting the Construction Environmental Management Plan of the S36 50MW expansion EIA.

7.1 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.) or during operation. There is potential for species to be displaced within the test site and/or surrounding area. There is a requirement to understand the importance of the habitat, i.e. is it important for essential activity (breeding, foraging, moulting, resting, etc.). If the habitat is deemed to be important, it is crucial to understand the availability of alternative habitat elsewhere. In addition, there is the potential to affect birds foraging success or moulting, if the test berth is located within a key foraging area or a moulting site.

Displacement is an effect that is not expected to be observed at the current scale of the tidal industry, around a single device; however, as arrays are deployed this potential impact may become more evident. It is anticipated that displacement will be observed at a certain threshold of devices (Hasselman et al., 2023).

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 structure. Table 12 summarises the proposed monitoring and mitigation measures for the relevant project phase relating to each potential impact pathway within disturbance/ displacement.

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**: Comply with the Scottish Marine Wildlife Watching Code (SMWWC), including the following measures: • Vessel speeds will be reduced to 6 knots when a cetacean is	Any incidents which deviate from this measure will be reported.

Impact Pathway	Receptor	Proposed Mitigation/Monitoring Measure	Reporting Mechanism
		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 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. In addition, during all vessel activity the behavioural state of seals on haul-outs will be monitored and the vessel speed and heading will be adjusted accordingly. If seals appear alert upon passage past or relatively close to the haul-out (heads raised and exaggerated movement towards the water line) the vessel speed will be reduced and course diverted away from the haul-out until seals appear to ignore the vessel	Any incidents which deviate from this measure will be reported.
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	Any incidents which deviate from this measure will be reported.

Impact Pathway	Receptor	Proposed Mitigation/Monitoring Measure	Reporting Mechanism
		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 device and anchor installation works	Cetaceans, Seals, Basking shark	**Mitigation**: All operations require to be conducted in line with SMWWC.	Observer records and any specific events will be reported.
Harassment/Disturbance – Presence of vessel activity during installation works	Harbour and grey seals	**Monitoring:** During the breeding seasons of both species of seal, vessels involved in decommissioning works will ensure a 500m distance is consistently maintained from local haul-out sites located near to the test berth and along the vessel transit route.	Any incidents that deviate from this will be reported.
Anchor installation – drilling in some related projects may cause minor disturbance/ displacement	Cetaceans, Seals, Basking sharks, Marine birds	**Mitigation:** SMWWC will be adhered to including the measures outlined above. Drilling operations will only be conducted up to six hours per anchor for related projects	Any incidents which deviate from this measure will be reported.
Operation and Maintenance			
Displacement – Barrier effect from presence of devices	Harbour and grey seals	**Monitoring:** Partake in site-wide monitoring of seal usage of the Fall of Warness, where possible e.g. providing operational data for seal tagging surveys; providing vessel activity data for seal haul-out study. **Monitoring:** Some projects – should funding be available – will be collecting data using multibeam sonars focused on the nearfield behaviour of fish, marine mammals, and diving birds in the vicinity of their devices. The sonar data will be validated using high-definition underwater cameras onboard the tidal devices also.	If funding for strategic site-wide research is obtained, findings relevant to the devices will be provided.
Displacement – Barrier effect from the presence of devices	Cetaceans, Basking shark, Marine birds, Fish	Continual review of relevant research to understand if any mitigation/monitoring measures are required. **Mitigation:** Mitigation only required if other research findings or monitoring indicates unacceptable impact.	If funding for strategic site-wide research is obtained, findings relevant to the devices will be provided.

Impact Pathway	Receptor	Proposed Mitigation/Monitoring Measure	Reporting Mechanism
		Monitoring: Some projects – should funding be available – will be collecting data using multibeam sonars focused on the nearfield behaviour of fish, marine mammals, and diving birds in the vicinity of their devices. The sonar data will be validated using high-definition underwater cameras onboard the tidal devices also.	
Decommissioning			
Disturbance – Presence of device decommissioning vessels and their moorings may cause minor impact (including when transiting to and from site)	Cetaceans, Seals, Basking sharks, Marine birds	**Mitigation**: All operations require to be conducted in line with SMWWC. Vessel presence on site will be kept to a minimum. **Monitoring:** During the breeding seasons of both species of seal, vessels involved in decommissioning works will ensure a 500m distance is consistently maintained from local haul-out sites located near to the test berth and along the vessel transit route.	Observer records and any specific events will be reported.
Anchor removal – noise may cause minor disturbance/ displacement	Cetaceans, Seals, Basking sharks, Marine birds	**Mitigation**: All operations require to be conducted in line with SMWWC. Vessel presence on site will be kept to a minimum.	Observer records and any specific events will be reported.

Table 12. Proposed monitoring and mitigation measures relevant to the impact pathway disturbance/displacement

The Scottish Marine Wildlife Watching Code (SMWWC) was developed by NatureScot and is in line with Section 52 of the Nature Conservation (Scotland) Act 2004. Although the code has been developed to provide recommendations, advice and information relating to commercial and leisure activities involving the watching of marine wildlife, the code outlines best practice to follow when encountering marine wildlife, a likely event at the Fall of Warness site. EMEC and developers are committed to following the SMWWC throughout all operations onsite and to and from site, providing that the health and safety of personnel is not compromised.

7.2 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 drilling activities during installation. There is a growing body of evidence that suggests operational noise is unlikely to cause acoustic injury to marine animals; however, behavioural responses are possible (Polagye & Bassett, 2020) and it has been shown that harbour seals (Phoca vitulina) avoid sounds from operational devices (Hastie et al., 2018) and harbour porpoise (Phocoena phocoena) activity was significantly reduced around operational devices compared to baseline levels (Tollit et al., 2019). Currently the importance of hearing underwater and hearing thresholds for diving birds is unknown but there is the potential it to cause displacement, avoidance, reduction in foraging success or it may have no effect.

Tidal devices with machinery housed in surface-piercing components have the potential to affect diving birds due to the above surface noise generated.

Table 13 summarises the proposed monitoring and mitigation measures for the relevant project phase relating to each potential impact pathway within 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 Sharks	**Mitigation**: All operations require to be conducted in line with SMWWC.	Observer records and any specific events will be reported.
Disturbance – Noise from vessel activity (including transiting to and from site)	Harbour and grey seals	**Mitigation**: All operations require to be conducted in line with SMWWC.	Observer records and any specific events will be reported.
Installation			
Disturbance – Noise from mooring installation methods	Cetaceans	**Mitigation**: All operations require to be conducted in line with SMWWC.	Observer records and any specific events will be reported.
Disturbance – Noise from mooring installation methods	Basking shark	**Mitigation**: All operations require to be conducted in line with SMWWC.	Observer records and any specific events will be reported.
Disturbance – Noise from mooring installation methods	Harbour and grey seals	**Mitigation**: All operations require to be conducted in line with SMWWC.	Observer records and any specific events will be reported.
Anchor installation – drilling and vessel activity may cause minor acoustic impact	Cetaceans, Seals, Basking sharks, Marine birds	**Mitigation**: All operations require to be conducted in line with SMWWC. Drilling operations will only last up to 6 hours per anchor for projects	Observer records and any specific events will be reported.
Operation and Maintenance			
Disturbance – Noise from operating turbines	Cetaceans	**Monitoring:** Acoustic monitoring of operational noise output to establish an acoustic signature. Monitoring will be conducted utilising either fixed RTSys or DART surveying. Funding dependant.	Results and findings from surveying will be disseminated.
Disturbance – Noise from operating turbines	Harbour and grey seals	**Monitoring:** As outlined above, the acoustic monitoring of operational noise output to establish an acoustic signature. Monitoring will be conducted utilising either fixed RTSys or DART surveying.	Results and findings from surveying will be disseminated.

Impact Pathway	Receptor	Proposed Mitigation/Monitoring Measure	Reporting Mechanism
Decommissioning			
Disturbance – Noise from increased activity will cause minor acoustic impact	Cetaceans, Seals, Basking shark, Marine birds	**Mitigation**: All operations require to be conducted in line with SMWWC. Vessel presence onsite will be kept to a minimum	Observer records and any specific events will be reported.
Anchor removal – drilling may cause minor acoustic impact or auditory injury	Cetaceans, Seals, Basking sharks	**Mitigation**: All operations require to be conducted in line with SMWWC.	Observer records and any specific events will be reported.

Table 13. Proposed monitoring and mitigation measures relevant to the impact pathway acoustic impact

7.3 Collision and Entanglement Risk

There is potential for a physical interaction 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 (i.e. collision) 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 higher risk of collision with devices. In contrast, being highly mobile underwater, such as small cetaceans and seals, should result in the capacity to both avoid and evade a device. However, this is reliant on 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. 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 Fall of Warness 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 blade 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.

There has been much research on potential collisions with single devices, and they are expected to be a rare event. Further research into the potential risk of scaling up to arrays could be achieved by using predictive models validated with collision risk data (Copping and Hemery, 2020).

It is also possible, but unlikely, that collisions may occur with stationary structures e.g., mooring lines, anchors and support structures. These are less likely to cause death but injuries from entanglement may result.

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

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	**Mitigation:** If interaction of basking shark with devices occurs then procedures for emergency shutdown and liaison with regulators should take place until a re-start or suitable mitigation is agreed. **Monitoring:** If strategic funding is obtained, strain gauges may be installed on the device and will be capable of alerting the operator to 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			
Vessel collision with large marine organisms	Cetaceans, Seals, Basking sharks	**Mitigation**: All operations require to be conducted in line with SMWWC.	Observer records and any specific events will be reported.
Entanglement of large marine organisms in potential temporary boat moorings	Cetaceans, Seals, Basking sharks	**Mitigation:** Mooring lines will be kept onsite for as short a period as possible.	Any events will be reported to the regulator as soon as possible on return to shore.
Entanglement with device tow lines	Cetaceans, Seals, Basking sharks	**Monitoring:** Potential for sensors, or cameras depending on funding available. **Mitigation:** Winching process is slow and infrequent, lines primarily taut.	Any events will be reported to the regulator as soon as possible on return to shore.
Operation and Maintenance			
Behavioural change, injury or death due to the interaction with turbine rotor with the potential for collision.	Diadromous fish, Gadoids	Continual review of monitoring work carried at other sites with installed tidal turbines to ensure any required mitigation and monitoring measures are effectively employed.	Report any additional new information

Impact Pathway	Receptor	Proposed Mitigation/Monitoring Measure	Reporting Mechanism
Behavioural change, injury or death due to the interaction with turbine rotor with the potential for collision.	Cetacean, Basking shark, Harbour or grey seal	**Mitigation**: If interaction between a cetacean, basking shark or seal with devices occurs then procedures for emergency shutdown and liaison with regulators should take place prior to a re-start or suitable mitigation is agreed. **Monitoring:** If strategic funding is obtained, the device may be equipped with accelerometer to ensure any interaction events or near misses are detected. Accelerometer data will be monitored as part of the live monitoring system and may be used as the triggering mechanism.	Periodical data analysis will be summarised, and any finding reported. If any trigger events are found to be due to an interaction between cetacean/ basking shark/ seal and the operating turbine, the regulator will be informed immediately.
Collision with turbines causing death or injury. There is uncertainty regarding avoidance rate of active turbines exhibited by birds	All diving species (sea duck, red-throated diver, great cormorant, common guillemot, razorbill, Atlantic puffin, black guillemot, northern gannet).	**Monitoring:** If strategic funding is obtained, the device may be equipped with cameras viewing the operation turbine blades, aimed at detecting an interaction between a diving bird and operational turbine.	Any interaction events recorded will be reported.
Decommissioning			
Vessel collision with large marine organisms	Cetaceans, Seals, Basking sharks	**Mitigation**: All operations require to be conducted in line with SMWWC.	Observer records and any specific events will be reported.
Entanglement of large marine organisms in potential temporary boat moorings	Cetaceans, Seals, Basking sharks	**Mitigation:** Mooring lines will be kept onsite for as short a period as possible.	Any events will be reported to the regulator as soon as possible on return to shore.
Entanglement with device tow lines	Cetaceans, Seals, Basking sharks	**Monitoring:** Potential for sensors, or cameras depending on funding available.	Any events will be reported to the regulator as soon as possible on return to shore.

Impact Pathway	Receptor	Proposed Mitigation/Monitoring Measure	Reporting Mechanism
		Mitigation: Winching process is slow and infrequent, lines primarily taut.	

Table 14. Proposed monitoring and mitigation measures relevant to the impact pathway collision and entanglement risk

7.4 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. The devices will utilise appropriate anti-fouling systems, such as paints recommended for new vessels and maintenance of underwater hulls and boot-up lines for up to 90 months drydocking interval, and complying with the International Convention of the Control of Harmful Antifouling Systems on Ships as adopted by IMO October 2001, to minimise the accumulation of biofouling as far as practical.

While biofouling is a natural process, it can facilitate a foothold for non-native species (NNS). The spread of NNS can occur through a variety of means including shipping, transport of fish or shellfish, scientific research, and public aquaria (Copping & Hemery, 2020). These invasive NNS 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 NNS to grow and hence be transported to site and thus provide a stepping-stone for colonisation.

Various guidelines and standards have been referred to in developing the proposed mitigation and monitoring measures. 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 assembled in UK shipyard and towed to Orkney.
- Nacelles and hubs will be assembled in continental Europe and briefly in water on tow from UK shipyard to Orkney.

EMEC and developers are committed to furthering industry understanding on biofouling and therefore, will make significant effort to collaborate where possible in any strategic research, with partners such as ICIT, SAMS and ERI. Any research conducted regarding biofouling, would aim to produce a species list identifying native and non-native species present.

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.

Impact Pathway	Receptor	Proposed Mitigation/Monitoring Measure	Reporting Mechanism
All Project Phases			
Biofouling and the introduction of non-native species (including rock anchors)	Benthic communities	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	Any deviance from the good practice measures will be reported. The requirement to use a non-local vessel

Impact Pathway	Receptor	Proposed Mitigation/Monitoring Measure	Reporting Mechanism
		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. 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. 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. When the devices are taken to calmer waters for maintenance, biofouling inspections of any surfaces that have potential for biofouling, removal of any biofouling and assessment of the integrity of anti-fouling paint coverage.	for any marine operations associated with the project will be agreed with the regulator prior to works. Findings after inspections will be reported.
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 in some related projects 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
Operation and Maintenance			
Accumulation of biofouling on devices	Benthic communities	**Mitigation:** Fouling resistant paint which complies with IMO	Findings reported to the regulator as soon

Impact Pathway	Receptor	Proposed Mitigation/Monitoring Measure	Reporting Mechanism
and anchors which may alter local ecosystem		International Convention on the Control of Harmful Anti-fouling Systems on Ships and national legislation may be used (e.g., silicone based). Toxic (e.g., copper based) paint is not anticipated. The devices will be cleaned periodically. In some projects, 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	as reasonably practicable through the appropriate documentation.
Decommissioning			
Habitat removal for biofouling species	Benthic communities	A full device biofouling inspection will be conducted as the device is decommissioned.	Findings reported to the regulator as soon as reasonably practicable through the appropriate documentation.

Table 15. Proposed monitoring and mitigation measures relevant to the impact pathway biofouling and introduction of non-native species

Biofouling inspections will be conducted on an opportunistic schedule when the device is taken to calmer waters for maintenance. Biofouling inspections will not be conducted at the full-scale test site. The technique for conducting biofouling inspections will be agreed with NatureScot prior to conducting the survey.

7.5 Habitat Creation

The physical presence of devices will inherently result in some direct habitat loss during device operation. However, the associated seabed moorings and anchors also have the potential to function as artificial reefs or fish aggregating devices. As cetacean, seals and basking shark distribution is influenced by prey distribution and associated prey habitat, this clearly leads to the potential of changes in the distribution of cetaceans and basking sharks. It is anticipated that fish may aggregate around the devices, henceforth a potential increase in prey for marine mammals within the vicinity of a device. In addition, the installation of a device may affect oceanographic conditions within the vicinity, for example, increasing water mixing. This may lead to a localised increase of certain megafauna in the area.

The physical structure of the devices could also offer enhanced foraging efficiency for some species as it may vary the tidal flows producing eddies and areas of slack water in close proximity to the device. Small cetaceans could use these areas to shelter when ambushing prey. Furthermore, the turbines on the devices have the potential to scatter, disorientate or injure prey leading to enhanced foraging efficiency. However, it is currently unclear whether such opportunities would provide enhancements to foraging or would simply lead to the attraction of animals into situations where the risk of collision is increased.

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

Impact Pathway	Receptor	Proposed Mitigation/Monitoring Measure	Reporting Mechanism
Operation and Maintenance			
Fish aggregation device (FAD) effects due to the introduction of new structures	Fish	As fish are likely to aggregate around the devices during slack water and periods of lower tidal flow, if research funding becomes available, a series of video cameras may be installed on devices not already scoped to have these to evidence any such occurrence. Otherwise, no mitigation or monitoring measures will be implemented as no significant impacts are expected.	Findings from the analysis will be reported.
Fish aggregation device (FAD) effects due to the introduction of new structures	Fish predators (e.g., fish, marine mammals)	If research funding becomes available, a series of video cameras may be installed on devices not already scoped to have these to evidence any such occurrence. Otherwise, no mitigation or monitoring measures will be implemented.	Findings from the analysis will be reported.
Creation of habitat around installed infrastructure for benthic species	Benthic communities	**Monitoring:** There is a likelihood of reef effects around installed infrastructure, particularly anchoring infrastructure. There is no proposed monitoring measure however, when the opportunity arises, any video footage of the moorings will be analysed to quantify the level of reefing taking place.	Findings from any analysis conducted will be reported.

Table 16. Proposed monitoring and mitigation measures relevant to the impact pathway habitat creation

7.6 Seabed Clearance

There is the potential for the direct loss of sub-littoral seabed communities due to the presence of the devices and associated anchoring system on the seabed. The installation of the new structures directly on the seabed, will result in the loss of habitat due the placing of the structures.

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 in the installation of the anchors of the devices. It is anticipated that due to tidal swept nature of the site, that the majority of the deployment location will be bedrock.

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

Impact Pathway	Receptor	Proposed Mitigation/Monitoring Measure	Reporting Mechanism
All Project Phases			
Seabed clearance and habitat loss/ disturbance from installation and removal of temporary vessel mooring equipment	Benthic communities	**Mitigation:** Drop-camera will be used during device installation and if any sensitive receptors are identified during installation, then these areas will be avoided through micro-siting of the device and lines/chains on the seabed.	N/A
Potential scouring/habitat disturbance due to movement of temporary mooring lines	Benthic communities	**Mitigation**: Drop-camera surveys will be conducted during deployment and decommissioning	Any damage to the seabed will be reported to Marine Scotland and NatureScot.
Installation			
Seabed loss due to the direct footprint	Benthic communities	Pre-installation and installation seabed survey using a camera will be conducted to understand the extent of the seabed impact on the benthic ecology and seabed character caused during installation activities.	Video footage collected during the survey will be analysed and reported
Installation of device causes damage to cultural heritage or archaeological objects within the site.	Cultural heritage and archaeological objects	**Mitigation:** The appropriate consultation with Historic Environment Scotland (HES) and relevant stakeholders will be undertaken if cultural heritage or archaeological objects are found during this operation.	The regulator and HES will be consulted if any cultural or archaeological objects are found during the operation.
Decommissioning			
Colonisation and loss of new habitat	Benthic communities	Decommissioning seabed survey will be conducted during decommissioning	Findings will be reported

Table 17. Proposed monitoring and mitigation measures relevant to the impact pathway seabed clearance

7.7 Electromagnetic field (EMF) effects

Basking sharks may be able to detect the magnetic fields associated with subsea cables. The electricity generated by the devices and transmitted through the cables will emit electromagnetic fields (EMFs). Elasmobranchs respond to EMFs and are thought to use the

Earth's magnetic field for migration, whilst they respond behaviourally to electric fields emitted by prey species and conspecifics. The potential for damage to the electrosensory system is considered low as E fields are only detected over short distances and will be encountered as a voltage gradient in the seawater to which the elasmobranch can respond accordingly.

While some scientific experiments have shown that some animals can detect EMFs from submarine cables, there is no conclusive evidence to determine if these EMFs will cause significant negative impacts to an individual animal or population levels (SEER, 2022). There is a consensus among researchers, developers and regulators that EMFs from cables from single or a small number of devices will have relatively low EMF intensity resulting in low risk to sensitive marine animals (Copping *et al*., 2020).

EMF effects are not expected to be significant around the EMEC subsea cable in which the devices will be connected nor the umbilical cable. Therefore, there are no mitigation or monitoring measures suggested for this unlikely impact however, if research funding is allocated, it may be possible to conduct tests.

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

Impact Pathway	Receptor	Proposed Mitigation/Monitoring Measure	Reporting Mechanism
Operation and Maintenance			
Behavioural changes	Diadromous fish, gadoids, elasmobranchii	If research funding becomes available, EMEC may undertake in situ measurements of strength and range Ei and B fields under different energy generation scenarios. Otherwise, no mitigation or monitoring measures will be implemented.	If such monitoring is undertaken, the methodology will be agreed with regulator and NatureScot prior to commencement of work. Findings will be reported.

Table 18. Proposed monitoring and mitigation measures relevant to the impact pathway EMF effects

7.8 Discharges to the Marine Environment

Contaminant release through spillages or contaminated sediments poses a risk to cetaceans and basking sharks that can have 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 (Ross, 2002). The likelihood of a large-scale contaminate spill associated with a tidal energy device is minimal due to strict current health and safety procedures, although the impacts of any spill have the potential to be significant.

The devices contain a variety of liquids including oils and coolants which if accidentally released could pose a risk to the natural environment. The oils and lubricants contained in the electrical system, gearbox and internal auxiliary system are expected to be contained within their system in the event of any leaks. Nevertheless, any fluid leakage which manages to escape into the main body of the device will be collected and later disposed safely onshore. All oils/lubricants used in the internal auxiliary systems are marine approved.

When onshore, all fluids will be stored in a suitable COSHH store, and all wastes will be disposed of in line with legislative requirements.

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.

Impact Pathway	Receptor	Proposed Mitigation/Monitoring Measure	Reporting Mechanism
All Project Phases			
Leakage of fuel or chemicals from vessels involved with installation, maintenance and 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.
Corrosion of materials used to construct device/ submersible drilling rig (SDR) for some devices introduce toxins to environment and disrupt ecosystem dynamics.	Potentially whole local ecosystem	**Mitigation:** Cathodic protection using sacrificial anodes will prevent accelerated degradation of metal structure on SDR	N/A

Table 19. Proposed monitoring and mitigation measures relevant to the impact pathway discharges to the marine environment

8 Statutory Reporting

Data and results from any surveys conducted by EMEC at the Fall of Warness test site will be presented to MD-LOT and NatureScot. These can be on an as and when basis, but further discussions of preferred reporting measures and timings can be discussed with both.

EMEC is also in communication with MD-LOT bi-weekly to report and discuss any actions occurring within its test sites, and so any aspect of the projects occurring within the Fall of Warness site can be included during regular intervals. It is worth noting that decisions on reporting mechanisms will be dependent of conditions on Section 36 50MW expansion.

9 Continuous Reviewal

As this PEMP is a live document, an ongoing review of all mitigation and monitoring measures within it will occur unless otherwise advised by regulators. MD-LOT and NatureScot will be consulted on any changes to the PEMP proposed by EMEC. Therefore, there will be a reviewal process demonstrated within any changes to this PEMP (Figure 9).

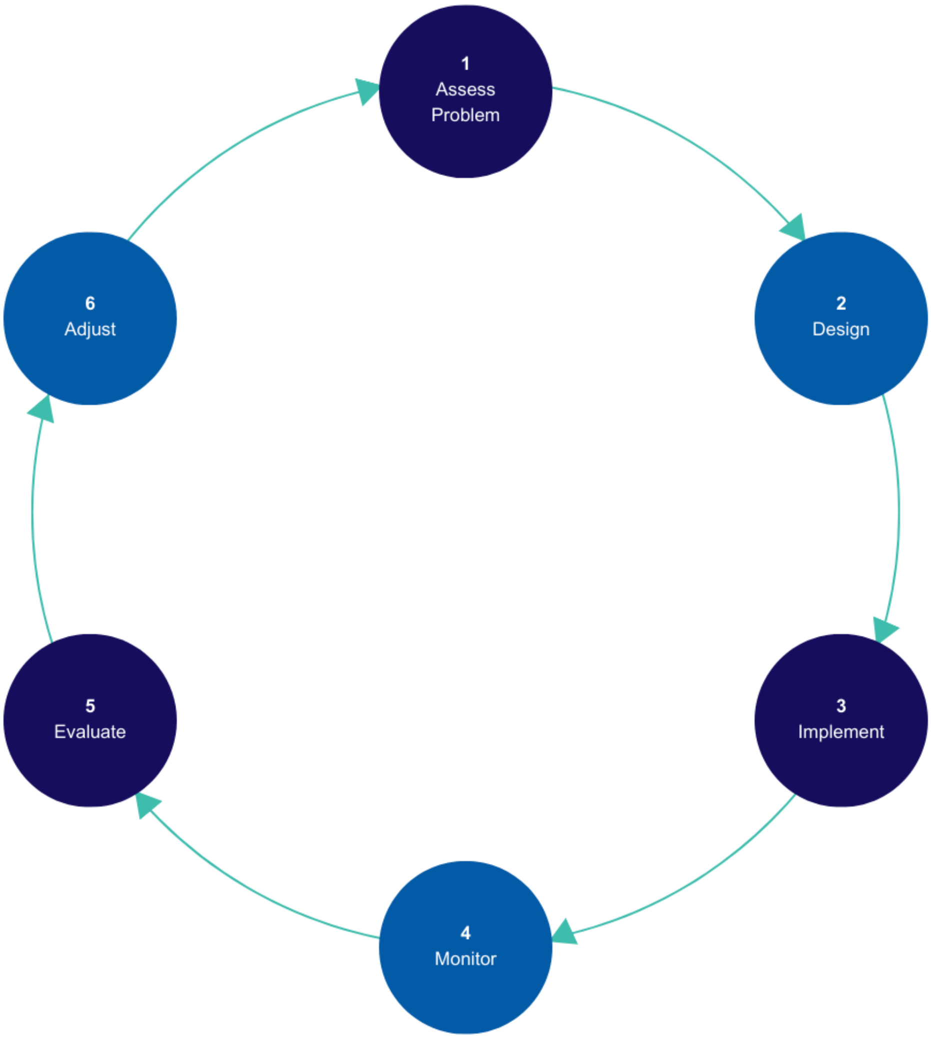


Figure 9. Overview of reviewal process for mitigation and monitoring measures at the Fall of Warness site following 50MW expansion

Step 1 of this process will be conducted through baseline monitoring and environmental assessment to establish issues and define measurable management objectives.

Steps 2 and 3 involve creating appropriate monitoring methodologies and mitigation plans and implementing them within deployments and activities within EMEC's Fall of Warness site.

Step 4 will include follow-up monitoring to collect data after deployments and activities on site.

Step 5 will compare the collected data from follow-ups to baseline studies to establish if any necessary rectifications or methodological changes are necessary. Step 6 will determine if issues initially identified should be finalised or methodology used should be adjusted.

10 References

Brisson-Curadeau, É., Bird, D., Burke, C., Fifield, D.A., Pace, P., Sherley, R.B., Elliott, K.H., 2017. Seabird species vary in behavioural response to drone census. Sci Rep 7, 17884. Available from: https://doi.org/10.1038/s41598-017-18202-3

Copping, A., Hemery, L. (2020). OES-Environmental 2020 State of the Science Report (No. PNNL-29976, 1632878). Available from: https://www.osti.gov/biblio/1632878/

Edney, A.J., Hart, T., Jessopp, M.J., Banks, A., Clarke, L.E., Cugniere, L., Elliot, K.H., Martinez, I.J., Kilcoyne, A., Murphy, M., Nager, R.G., Ratcliffe, N., Thompson, D.L., Ward, R.M., Wood, M.J. 2023. Best practices for using drones in seabird monitoring and research. *Marine Ornithology* 51:265-280 http://doi.org/10.5038/2074-1235.51.2.1544

EMEC. 2024 Fall of Warness Environmental Impact Assessment Report: Project Design Envelope. 1-18

Hasselman, D. J., Hemery, L. G., Copping, A. E., Fulton, E. A., Fox, J., Gill, A. B. and Polagye, B. (2023). 'Scaling up' our understanding of environmental effects of marine renewable energy development from single devices to large-scale commercial arrays. Science of the Total Environment.

Hastie, G., 2013. Tracking marine mammals around marine renewable energy devices using active sonar. SMRU Ltd. Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/232963/OESEA2_SMRU_tracking_marine_mammals_around_renewable_devices.pdf

Hastie, G. D., Russell, D. J.F., Lepper, P., Elliot, J., Wilson, B., Benjamins, S. and Thompson, D. 2018. Harbour seals avoid tidal turbine noise: Implications for collision risk. Journal of applied ecology. Volume 55, Issue 2. DOI: 10.1111/1365-2664.12981

Hodgson, J.C., Koh, L.P., 2016. Best practice for minimising unmanned aerial vehicle disturbance to wildlife in biological field research. Open Archive, 26, 10.

JNCC. Monitoring Seabirds At Sea. Accessed 2025. Available: https://jncc.gov.uk/our-work/monitoring-seabirds-at-sea/

Lieber, L., Nimmo-Smith, W.A.M., Waggitt, J.J., Kregting, L., 2019. Localised anthropogenic wake generates a predictable foraging hotspot for top predators. Commun Biol 2, 123. Available from: https://www.nature.com/articles/s42003-019-0364-z

Lieber, L., Fraser, S., Coles, D. *et al.* 2024. Sheared turbulent flows and wake dynamics of an idled floating tidal turbine. *Nat Commun* **15**, 8244. https://doi.org/10.1038/s41467-024-52578-x

Long, C. 2017. Analysis of the possible displacement of bird and marine mammal species related to the installation and operation of marine energy conversion systems. Scottish Natural Heritage Commissioned Report No. 947. Available from: https://www.nature.scot/doc/naturescot-commissioned-report-947-analysis-possible-displacement-bird-and-marine-mammal-species

Macleod, K., Lacey, C., Quick, N., Hastie, G. and Wilson J. (2011). Guidance on survey and monitoring in relation to marine renewables deployments in Scotland. Volume 2. Cetaceans and Basking Sharks. Published draft report to Scottish Natural Heritage and Marine Scotland. [online]. Available from: https://cieem.net/resource/guidance-on-survey-and-monitoring-in-relation-to-marine-renewables-deployments-in-scotland-seals/#:~:text=Guidance%20on%20Survey%20and%20Monitoring%20in%20Relation%20to,marine%20%28wave%20and%20tidal%29%20renewables%20developments%20in%20Scotland.

MarineSitu. Drifting Acoustic Instrumentation System (DAISY). Accessed 2025. Available: https://www.marinesitu.com/daisy

Melvin, G.D., and Cochrane, N.A. 2014. Investigation of the vertical distribution, movement and abundance of fish in the vicinity of proposed tidal power energy conversion devices. https://netzeroatlantic.ca/sites/default/files/2019-05/Final_Report_03Dec2014_Melvin_and_Cochrane.pdf

Melvin, G.D., Cochrane, N.A. 2015. Multibeam Acoustic Detection of Fish and Water Column Targets at High-Flow Sites. *Estuaries and Coasts* **38** (Suppl 1), 227–240. https://doi.org/10.1007/s12237-014-9828-z

Merchant, N.D., Fristrup, K.M., Johnson, M.P., Tyack, P.L., Witt, M.J., Blondel, P. and Parks, S.E. 2015. Measuring acoustic habitats. Methods Ecol Evol. 6: 257-265. https://doi.org/10.1111/2041-210X.12330

NatureScot. Last Updated: 2023. Wave and Tidal Energy. https://www.nature.scot/professional-advice/planning-and-development/planning-and-development-advice/renewable-energy/marine-renewables/wave-and-tidal-energy

NatureScot. Last Updated: 2025. Advice on marine renewables development. https://www.nature.scot/professional-advice/planning-and-development/planning-and-development-advice/renewable-energy/marine-renewables/advice-marine-renewables-development.

National Marine Fisheries Service, 2018. 2018 Revision to: Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing (Version 2.0): Underwater Thresholds for Onset of Permanent and Temporary Threshold Shifts. NOAA Technical Memorandum NMFS-OPR-59. Available: https://www.fisheries.noaa.gov/s3/2023-05/TECHMEMOGuidance508.pdf

NatureScot. Last Updated: 2025. Recommended bird survey methods to inform impact assessment of onshore windfarms. Available: https://www.nature.scot/doc/recommended-bird-survey-methods-inform-impact-assessment-onshore-windfarms#survey-methods

Polagye, B. and Bassett, C. 2020. Risk to marine animals from underwater noise generated by marine renewable energy devices. In A.E. Copping and Hemery, L. G. (Eds), OES-Environmental 2020 State of the Science Report: Environmental Effects of Marine Renewable Energy Development Around the World. Report for Ocean Energy Systems (OES) (pp. 66-85). Available online: osti.gov/servlets/purl/1633082/

Robinson, S.P., Lepper, P.A., Hazelwood, R.A., 2014. Good Practice Guide for Underwater Noise Measurement. National Measurement Office, Marine Scotland, The Crown Estate. Guide No. 133, ISSN: 1368-6550. Available: http://dx.doi.org/10.25607/OBP-21

Scottish Government. 2014. EMEC Fall of Warness Tidal Test Site: Wildlife Observations Project Annual Report. 5, 7. Available: https://www.gov.scot/publications/scottish-marine-freshwater-science-volume-5-number-7-emec-fall/documents/

Scottish Mammal Research Unit. 2015. The density and behaviour of marine mammals in tidal rapids. Report 7.1.2. Available: https://www.smru.st-andrews.ac.uk/files/2015/10/MR7-1-2_porpoise_in_tidal_rapids_VF1.pdf#:~:text=Even%20a%20large%20weight%20does%20not%20prevent,is%20that%20the%20positions%20of%20the%20hydrophone.

(SEER) U.S. Offshore Wind Synthesis of Environmental Effects Research. 2022. Electromagnetic Field Effects on Marine Life. Report by National Renewable Energy Laboratory and Pacific Northwest National Laboratory for the U.S. Department of Energy, Wind Energy Technologies Office. Available at https://tethys.pnnl.gov/seer

Sellar, B.G., Sutherland, D.R.J. 2016. Tidal Energy Site Characteristics at the Fall of Warness, EMEC, UK. Available: https://tidalenergydata.org/media/documents/Technical_Report_on_Tidal_Site_Characterisation_During_the_ReDAPT_Project_v4.0.pdf

Slingsby, J.; Scott, B.E.; Kregting, L.; McIlvenny, J.; Wilson, J.; Couto, A.; Roos, D.; Yanez, M.; Williamson, B.J. 2021. Surface Characterisation of Kolk-Boils within Tidal Stream Environments Using UAV Imagery. J. Mar. Sci. Eng.9, 484. https://doi.org/10.3390/jmse9050484

Slingsby, J., Scott, B.E., Kregting, L., McIlvenny, J., Wilson, J., Yanez, M., Langlois, S., Williamson, B.J., 2022. Using Unmanned Aerial Vehicle (UAV) Imagery to Characterise Pursuit-Diving Seabird Association With Tidal Stream Hydrodynamic Habitat Features. Frontiers in Marine Science. 9, 820722. Available at: https://www.frontiersin.org/articles/10.3389/fmars.2022.820722/full

Southall, B., Bowles, A.; Ellison, W.; Finneran, J.; Gentry, R.; Greene, C. Jr.; Kastak, D.; Ketten, D.; Miller, J.; Nachtigall, P.; Richardson, W.; Thomas, J.; Tyack, P. 2007. Marine Mammal Noise Exposure Criteria: Initial Scientific Recommendations. Aquatic Mammals, 33(4), 273-275. Available: https://sea-inc.net/wp-content/uploads/2019/10/Southall-et-al_2019_MM-Noise-critieria-update-with-errata_Aq-Mammals.pdf

Tollit, D. J., Joy, R., Wood, J., Redden, A. M., Booth, C., Boucher, T., Porskamp, P., and Oldrieve, M. 2019. Baseline presence of and effects of tidal turbine installation and operations on harbour porpoise in Minas Passage, Bay of Fundy, Canada. Journal of Ocean Technology, PP 24-48. Available online at: Article Preview – The Journal of Ocean Technology (thejot.net)

Vance, T., Ellis, R., Fileman, T. 2014. ETI MA1001 - Reliable Data Acquisition Platform for Tidal (ReDAPT) project: ME8.5 'Final Report'. Available: https://tidalenergydata.org/media/documents/ME8_5_BioFoulingFinalReport_V3.2.pdf

Waggitt, J.J., Cazenave, P.W., Torres, R., Williamson, B.J., Scott, B.E. 2016. Quantifying pursuit-diving seabirds' associations with fine-scale physical features in tidal stream environments, Journal of Applied Ecology. 53: 1653-1666. Available at: https://doi.org/10.1111/1365-2664.12646

Williamson, B.J., Fraser, S., Blondel, P., Bell, P.S., Waggitt, J.J. and Scott, B.E. Multisensor Acoustic Tracking of Fish and Seabird Behaviour Around Tidal Turbine Structures in Scotland.

2017 *IEEE Journal of Oceanic Engineering*, vol. 42, no. 4, pp. 948-965. doi: 10.1109/JOE.2016.2637179

The European Marine Energy Centre Limited
The Charles Clouston Building, ORIC, Back Road, Stromness, ORKNEY, KW16 3AW
Tel: 01856 852060
Email: info@emec.org.uk **Web:** www.emec.org.uk
Registered in Scotland no.SC249331 VAT Registration Number: GB 828 8550 90