Date of issue: June 2022

Deliverable ID: D8.7

ENFAIT
ENABLING FUTURE ARRAYS IN TIDAL

Year 5 Environmental Monitoring Report

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 745862.

EnFAIT

Document History

DOCUMENTATION SHEET	
Project Acronym	EnFAIT
Project Title	Enabling Future Arrays in Tidal
Grant Agreement number	745862
Call identifier	H2020-LCE-2016-2017
Topic identifier	LCE-15-2016
Funding Scheme	Research and Innovation Programme
Project duration	72 months (July 2017 – June 2023)
Project Officer	Francesca Harris (CINEA)
Coordinator	Nova Innovation Ltd
Consortium partners	Nova Innovation, IDETA, SKF, University of Edinburgh, Wood Group, RSK Environnement, ORE Catapult
Website	www.enfait.eu
Deliverable ID	D8.7
Document title	Year 5 Environmental Monitoring Report
Document reference	EnFAIT-EU-0067
Description	Report summarising the outcomes from the environmental monitoring up to year 3 of the EnFAIT project
WP number	WP8
Related task	T8.2
Lead Beneficiary	Nova Innovation
Author(s)	Kate Smith (Nova)
Contributor(s)	
Reviewer(s)	Gavin McPherson (Nova)
Dissemination level	PUBLIC- This document in whole, or in part, may be used in general and public dissemination.
Document status	Final
Document version	1.0

REVISION HISTORY					
Version	Status	Date of issue	Comment	Author(s)	Reviewer
0.1	DRAFT	June-2022	Initial draft for review	Kate Smith (Nova)	Gavin McPherson (Nova)
1.0	FINAL	June-2022	Final for publication	Kate Smith (Nova)	Seumas MacKenzie (Nova)

Contents

1 The Project

1.1 Introduction

A Funding Grant was awarded from the European Union's Horizon 2020 research and innovation programme in January 2017 to demonstrate a grid-connected tidal energy array at a real-world tidal energy site (the Shetland Tidal Array in Bluemull Sound, Shetland), propelling tidal energy towards competing on a commercial basis with alternative renewable sources of energy generation – Enabling Future Arrays in Tidal (EnFAIT). This was in response to the call LCE-15-2016: Scaling up in the ocean energy sector to arrays to generate significant learning through demonstration of cost-effective tidal arrays.

1.2 Purpose of this document

This document is the third in a series of reports on the environmental monitoring workstream of the EnFAIT project. It satisfies deliverable D8.7 of the EnFAIT project and summarises the key environmental monitoring activity of years 4 and 5 of EnFAIT. As the final report in the series, it sets out the key evidence and knowledge gained on the environmental effects of tidal turbines throughout the monitoring programme for the Shetland Tidal Array. It also shares critical learning in the development of cost-effective best practice monitoring for tidal turbines and arrays. As with the previous two EnFAIT environmental monitoring reports, it will be shared publicly on the project website[1].

The Year 1 environmental monitoring report (Nova Innovation, 2018) covered the key outcomes from surveys of marine mammals and birds at the Shetland Tidal Array project site in Bluemull Sound for the 12 months between May 2017 and April 2018. It also presented the results of subsea video monitoring of marine wildlife around the turbine observations gathered using underwater cameras attached to the turbines.

The Year 3 report (Nova Innovation, 2020) detailed the environmental monitoring activity carried out in years 2 and 3 of the EnFAIT project. This included results from a comprehensive analysis of the data gathered at the Shetland Tidal Array since the start of monitoring at the site in 2010. This analysis was completed during years 2 and 3 of EnFAIT, so key findings were presented in the Year 3 report along with recommendations for the environmental monitoring for the remainder of the EnFAIT project.

This final (Year 5) EnFAIT environmental monitoring report focuses on the contribution EnFAIT has made to the development of environmental evidence and best practice for cost-effective monitoring of tidal energy projects and the sustainable development of the sector. An overview of monitoring activity carried out over the duration of the project is provided, including details of how methods and approaches have evolved to ensure they remain fit for purpose and cost-effective as the Shetland Tidal Array has increased in size. Key evidence and knowledge on the environmental effects of tidal turbines gained through monitoring is summarised, along with details of how this learning has been shared and disseminated to maximise its impact. The forward plan for monitoring activity for the remainder of the EnFAIT project are presented, covering the period in which the remaining two turbines in the expanded array will be installed and the layout of turbines in the array reconfigured.

[1] https://www.enfait.eu/

2 Key project activity

2.1 Expansion of the Shetland Tidal Array (Phase 2)

Phase 1 of EnFAIT comprised three operational 100 kW Nova M100 tidal turbines (T1 to T3). Phase 2 involves the addition of three further 100kW turbines (T4 to T6) and the relocation of turbines within the array. In summer 2020 the first of three new direct-drive turbines (the Nova M100-D) was installed in Bluemull Sound. This increased the number of installed turbines to four and the total installed capacity of the Shetland Tidal Array to 400 kW. Figure 2-1 shows the new direct-drive turbine on the quayside in Bluemull Sound prior to installation in the Shetland Tidal Array.

Figure 2-1 Nova Innovation's M100-D turbine quayside before deployment in Bluemull Sound, Shetland. Nova Innovation 2020 ©.

The addition of the fourth turbine (T4) in summer 2020 will be followed in 2022/23 by the installation of a further two 100 kW direct-drive turbines (T5 and T6), and reconfiguration of turbines within the array, completing Phase 2 of the Shetland Tidal Array.

The expansion and reconfiguration of the Shetland Tidal Array provides a unique opportunity to gather data on the environmental effects of a multi-device array of turbines to improve the evidence base available to de-risk consenting of other projects. It also provides an opportunity to contribute to the development of best practice in environmental monitoring of tidal stream turbines and arrays.

2.2 Overview of environmental monitoring activity

Key environmental monitoring activity during years 4 and 5 of EnFAIT is summarised in Table 2-1.

Table 2-1 Key environmental monitoring activity during year 4 and 5 of the EnFAIT project.

Key activity	Detail
Evolution in the design of the environmental monitoring programme for the expanded Shetland Tidal Array (Phase 2).	The objectives and design of the environmental monitoring programme for the expanded Shetland Tidal Array (Phase 2) built on monitoring activity during Phase 1 (T1 to T3). To ensure monitoring in Phase 2 remains fit for purpose and cost effective it was informed by: - A critical review of vantage point surveys carried out at the Shetland Tidal Array (Phase 1) from 2010 to 2020. - A critical review of subsea video monitoring of marine wildlife around the first three turbines in the Shetland Tidal Array (Phase 1). - A review of the key results from environmental monitoring of Phase 1 of the Shetland Tidal Array to identify priority remaining knowledge and evidence gaps. - A review of environmental monitoring activity at other tidal stream projects to ensure transfer of learning. - Collaboration and partnership working with academic and technical experts to ensure environmental monitoring is scientifically robust, impartial and independent. - Discussion with regulatory bodies and their consultees to ensure environmental monitoring during Phase 2 met the requirements of project licence conditions. Changes to the environmental monitoring programme during Phase 2 have delivered improved cost-effectiveness and enhanced opportunities for scientific learning and contributed to the development of best practice in monitoring of tidal energy projects.
Ongoing environmental monitoring of Phase 2 of the Shetland Tidal Array.	Surface (vantage point) surveys and subsea video monitoring have continued over years 4 and 5 of the EnFAIT project, based on the revised methods for the expanded array (Phase 2) and building on monitoring during Phase 1. Ongoing environmental monitoring of the Shetland Tidal Array continues to contribute to what is widely recognised as one of the world's best datasets on the environmental effects of tidal stream turbines, extending a continuous record running back to November 2010. During years 4 and 5 of the EnFAIT project a forward plan has been developed for processing and analysing the environmental monitoring data to maximise its impact in improving the evidence base on the environmental effect of tidal stream turbines and de-risking consenting for future arrays.
Sharing of key learning from environmental monitoring of the Shetland Tidal Array.	Sharing learning and experience from the environmental monitoring workstream of the EnFAIT project is critical in facilitating the development of best practice for cost-effective environmental monitoring of tidal energy projects and the sustainable development of the sector. Sharing scientific evidence on the environmental effects of the Shetland Tidal Array and lessons learnt from the environmental monitoring has therefore been a critical activity during this final phase of the EnFAIT project. This has been delivered though the publication of data and key findings in industry and academic reports and papers, as well as presentations at workshops and conferences. Outputs from the environmental monitoring workstream of the EnFAIT project also informed applications for permits and the design of the environmental monitoring programme for Nova Innovation's proposed 1.5 MW project in the Bay of Fundy, Canada. This activity represents one of the first significant examples of 'evidence transfer' within the tidal stream sector, in which environmental evidence gathered from one project was used in evidence to de-risk and accelerate consenting of another project.

Further details of the environmental monitoring activities carried out in years 4 and 5 of EnFAIT are provided in the following sections.

3 Environmental monitoring programme

3.1 Overview

Nova has been conducting environmental monitoring in Bluemull Sound since November 2010 before to the EnFAIT project and prior to the installation of any turbines. The full environmental monitoring programme is relevant to the aims and objectives of the EnFAIT project so is considered in this report.

Early environmental monitoring for the Shetland Tidal Array was focused on gathering data to support applications for project consents. Following the installation of turbines in Bluemull Sound, activity has focussed on monitoring to understand the effects of the turbines (if any) on marine wildlife. Two main methods have been used to monitor the presence and behaviour of marine wildlife at the project location and gather data to understand how species interact with the turbines:

1. Surface visual surveys of marine mammals and birds in Bluemull Sound carried out from a vantage point overlooking the project site.
2. Subsea cameras attached to the turbines which gather video footage to understand how marine wildlife behaves around turbines underwater and interacts with them.

The methods for these two components of the Shetland Tidal Array monitoring programme were reviewed in 2019/20 on completion of Phase 1 (T1 to T3) to ensure they remained fit for purpose for Phase 2 (the expanded array). This included defining aims and objectives for monitoring throughout Phase 2, to ensure that the resulting data were of good quality and addressed the critical remaining evidence and knowledge gaps.

Details of the surface and subsea monitoring methods for Phases 1 and 2 of the Shetland Tidal Array are summarised in the Year 1 and Year 3 EnFAIT monitoring reports. Full details are also provided in the Shetland Tidal Array Environmental Monitoring Plan (Nova Innovation Ltd., 2021a) produced as a statutory condition of project licences. The Environmental Monitoring Plan has been approved by the regulator, Marine Scotland on advice from its environmental advisor NatureScot and is available to download from Marine Scotland's online portal.

The following sections provide an overview of the monitoring programme, with an emphasis on the key objectives and how methods have evolved over time to ensure they remain fit for purpose and deliver a proportionate and cost-effective solution to monitoring the turbines in the Shetland Tidal Array. Details of how the monitoring programme addresses the key data gaps and practical challenges in monitoring tidal turbines are provided.

Section 4 of this report details the contribution environmental monitoring of the Shetland Tidal Array has made to the development of best practice in cost-effective monitoring for the tidal stream energy sector and how this learning and experience has been shared and disseminated.

3.2 Surface monitoring of marine wildlife

3.2.1 Objectives

Surface monitoring of marine wildlife at the Shetland Tidal Array is delivered through visual surveys of marine mammals and birds carried out from a vantage point overlooking the project site in Bluemull Sound. The high-level objectives of the land-based vantage point surveys and how they have been updated from Phase 1 to 2 of the Shetland Tidal Array are presented in Table 3-1.

Table 3-1 The high-level objectives of land-based vantage point surveys during Phase 1 and 2 of the Shetland Tidal Array and rationale for key changes.

Phase 1 objective	Phase 2 objective	Rationale for change
Collect data on the presence and abundance of diving birds and marine mammals in the array area and surrounding area to understand the potential for general interactions with the project.	Collect data on the presence, abundance, fine-scale movements and behaviour of diving birds and marine mammals in the array area to understand the potential for direct interactions with operating turbines.	Objective updated to understand specific occupancy patterns and fine-scale movements of diving birds and marine mammals within the area of sea in which the six turbines are, or will be, located.

3.2.2 Methods

Full details of the vantage point survey methods for Phases 1 and 2 of the Shetland Tidal Array are provided in the Year 1 and Year 3 EnFAIT environmental monitoring reports and in the project Environmental Monitoring Plan (see reference list in Section 6).

Changes implemented in the vantage point survey design for Phase 2 enabled effort to focus on understanding the occupancy patterns and fine-scale movements of diving birds and marine mammals in the sea area in which turbines are installed. The key changes to survey methods in Phase 2 of the project and the rationale for any changes are detailed in Table 3-2.

Table 3-2 Comparison of key features of vantage point surveys during Phase 1 and Phase 2 of the Shetland Tidal Array and rationale for changes to methods.

Survey design feature	Phase 1	Phase 2	Rationale for change in Phase 2
Vantage point	60.69949°N 0.97091°W	60.69949°N 0.97091°W	No change. Vantage point provides excellent coverage of the existing and expanded array areas, with good visibility while avoiding any species disturbance (e.g., otters on the shoreline).
Survey area	0.58 km^2	0.19 km^2	Reduction in survey area in Phase 2 provides greater focus on the sea area in which turbines in the expanded array are, or will be, installed.
% survey effort on array area	10-20%	100%	Effort in Phase 2 surveys is focused on the sea area in which turbines in the expanded array are, or will be, installed.

Survey design feature	Phase 1	Phase 2	Rationale for change in Phase 2
Annual sub-divisions of surveys	4 annual seasons: - Feb to Apr - May to Jul - Aug to Oct - Nov to Jan	4 annual periods: - Apr to Jul - Aug to mid -Sep - Mid-Sep to Oct - Nov to Mar	Changes in Phase 2 enable better coverage of key annual stages in breeding cycles of diving birds and cetaceans and seal moulting and breeding periods. More likely to detect patterns in presence, abundance and behaviour according to key factors affecting impact risk.
Tidal sub-divisions of surveys	No formal structure around tidal cycle, but aim for coverage across tidal cycle within each of the 4 annual seasons	Tidal cycle divided into 6 periods. Surveys structured for equal coverage over tidal cycle in each of the 4 annual periods.	Changes in Phase 2 ensure systematic and consistent coverage of the tidal cycle across increasing flood, maximum flood, decreasing flood, increasing ebb, maximum ebb and decreasing ebb. Data are more likely to detect tidal patterns in presence, abundance and behaviour of birds and mammals, a critical factor affecting the risk of potential collisions with turbines.
Data gathered	Counts of birds and mammals in the array area and wider survey area	Counts of birds and mammals in the array area & detailed behavioural observations.	Provides for better understanding of behaviour and functional use of the sea area occupied by the turbines to better understand impact risk. Individual birds and mammals are watched for a period of time to record behaviours including diving, foraging, rafting and transiting.

The changes made to the vantage point survey design for Phase 2 enabled effort to focus on understanding the occupancy patterns and fine-scale movements of diving birds and marine mammals in the sea area in which turbines are or will be installed in the expanded array. This allows data to be gathered to better understand the likelihood of near-field interactions between marine wildlife and the turbines.

Near-field interactions are only possible if a bird or animal uses the area immediately around the turbine. Impacts such as collisions with turbines are only possible if a bird or animal uses the area immediately around the turbine when the tidal flow is above the minimum turbine cut-in speed of 0.8 m/s. Understanding how occupancy patterns and fine-scale movements of diving birds and marine mammals change with tidal flow is therefore also critical to understanding impact risk. The Phase 2 revised design is structured to enable even cover of survey effort across the full tidal cycle to allow any corresponding occupancy patterns and fine-scale movements with tidal flow (and therefore impact risk) to be identified.

3.3 Subsea monitoring of marine wildlife

3.3.1 Objectives

The high-level objectives of the subsea monitoring of the expanded array have remained largely unchanged throughout Phases 1 and 2 of the Shetland Tidal Array. They are:

1. To gather information on the presence and behaviour of fish, diving birds and marine mammals around turbines to improve understanding for the potential for interactions with the turbines.
2. To gather information on the nature and frequency of near-field interactions between fish, marine mammals and diving birds and the turbines, including any avoidance or evasion behaviour, or contact with turbine blades.

3.3.2 Methods

Full details of the subsea video monitoring methods for Phase 1 and Phase 2 of the Shetland Tidal Array are provided in the Year 1 and Year 3 EnFAIT environmental monitoring reports and the project Environmental Monitoring Plan.

The water clarity in Bluemull Sound means that turbine-mounted underwater video cameras are a highly cost-effective and reliable method to monitor near-field interaction between marine wildlife and the turbines. The approach has been used successfully throughout the operational phase of the Shetland Tidal Array. Three high-definition cameras are attached to the three turbines installed in Phase 1 of the Shetland Tidal Array (T1, T2 and T3). One camera is attached to the side of the nacelle looking towards the blades; one is attached to the top of the nacelle looking towards the blades and a third is attached on the bottom of the turbine looking towards the seabed.

In Phase 2 of the Shetland Tidal Array a single camera will be used on each of the three turbines in the extended array (T4, T5 and T6). The rationale for a reduction in the number of cameras per turbine for T4 to T6 is summarised below:

a. Each camera on T4 to T6 will have a horizontal field of view in water of 900, sensitivity of 0.1 lux and resolution of 1000 TV lines. For comparison, the cameras installed on T1, T2 and T3 have a horizontal field of view in water of 700, sensitivity 0.001 lux and resolution 750 TV lines. The system on T4 to T6 will therefore be superior, with a wider underwater field of view than the system on T1 to T3.
b. Examination of video footage from T1 to T3 demonstrated that the cameras attached to the side of the nacelles, facing the blades provide the most useful information on interactions between wildlife and the turbines in relation to collision risk.
c. The three turbines in Phase 1 of the array (T1 to T3) will continue to utilise the three-camera monitoring system. This will continue to record additional contextual information, such as the vertical movement of fish with changing tidal state to further build the evidence base on factors affecting collision risk. This information is not required from all six turbines in Phase 2.
d. The design of the existing turbine nacelles was modified to provide metal anchoring points for subsea cameras. Connecting cables provide power and transfer data into a communication module within the nacelle. These anchor points, cables and connectors are areas of potential failure within the overall design, for example through connector failure or ingress of seawater into the nacelle. Use of a single camera on T4, T5 and T6 will minimise potential points of weakness in the overall design without compromising the ability to deliver a robust monitoring programme.

4 Key learning from EnFAIT

4.1 Environmental effects of tidal turbines

Environmental monitoring of the Shetland Tidal Array has generated high quality data and one of the world's most comprehensive datasets on the environmental effects of tidal stream turbines. The subsea cameras combined with the vantage point surveys provide detailed information on the presence, distribution and behaviour of marine wildlife in and around the Shetland Tidal Array, and on the nature and frequency of near-field interactions with turbines.

The EnFAIT environmental monitoring workstream has made, and continues to make, a significant contribution to the evidence base on some of critical evidence needs identified for the tidal stream sector (ORJIP, 2020). These include:

a. Understanding near-field interactions between mobile species and tidal stream turbines.
b. Understanding occupancy patterns, fine-scale distribution and behaviour of mobile species in tidal stream habitats.
c. Understanding far-field responses of mobile species to tidal stream devices and arrays.
d. Tools for assessing and managing risk to mobile species populations for large-scale tidal stream development.
e. Tools and guidance for managing risk and uncertainty during the preparation of project environmental monitoring plans for tidal stream projects.

Results from the Shetland Tidal Array monitoring programme have been summarised in the EnFAIT Year 1 and 3 monitoring reports. Comprehensive results are also available in reports produced to satisfy requirements of project consents. Details of these reports are provided in the reference list in Section 6, while a summary of the key findings for fish, marine birds and mammals is outlined in the following sections. Details of how these key findings have helped fill the critical evidence gaps and improve knowledge on the environmental effects of turbines are also provided.

4.1.1 Fish

Saithe (*Pollachius virens*) has been the most frequently observed and abundant marine species in subsea video, with < 5 records of any other fish species in the monitoring programme.

Turbine-mounted cameras have shown groups of saithe aggregating around the turbines and moving vertically up and down in the water column according to tidal flow. This is consistent with observations of the species around shipwrecks and other artificial subsea structures, indicating that the turbines act as artificial reefs. Groups of saithe are frequently seen around the nacelle and blades during slack tide and slow current speeds when turbines are stationary, descending to the seabed as flow increases. The downward, seabed facing turbine-mounted cameras on T1 to T3 have enabled this important behaviour of saithe, exhibiting vertical movements with changes in tidal flow, to be observed and recorded. Examples of saithe in subsea video are shown in Figure 4-1.

Figure 4-1 Images of saithe around turbines in the Shetland Tidal Array, showing fish at nacelle height during slow tidal flows when turbines are not operating. Final image shows fish around the turbine substructure close to the seabed during stronger tidal flows, recorded by downward facing camera. Nova Innovation 2020 ©.

Small numbers of fish sometimes remain around the nacelle as tidal flow increases and turbines slowly start to rotate. Individuals are seen taking shelter behind turbine, eventually descending to the seabed as flow increases. Fish have not been observed at nacelle height when turbines are operating at full power. Some individual saithe have been seen approaching moving turbine blades before taking apparent evasive action to avoid contact. To date this apparent behavioural response to turbines has been observed on fewer than five occasions.

The change in fish distribution around the turbines with tidal flow have major implications for potential effects on marine predators (birds and mammals). Birds and mammals might only be expected to occur in proximity to turbine blades at times when fish are present during slack tide and slow tidal flows. During these times the blades are stationary as the turbines do not operate in slow flow conditions of less than 0.8 m/s. Predators might not be expected to occur near to turbine blades when fish are absent, during periods of higher tidal flow when the turbines are operating. This is further explored in the following sections.

4.1.2 Marine birds

Fifteen of the thirty-three bird species recorded at the project site are capable of diving to turbine depth (15m). Six of these species have been recorded diving and foraging in the array area. The most common two species, black guillemot (*Cepphus grylle*) and European shag (*Phalacrocorax aristotelis*) have been observed diving in the array area in fewer than 3% of vantage point surveys. Records of other bird species diving or foraging in the array area are negligible.

Records of diving birds in vantage point surveys are consistently low, but greater around low water slack and increasing flood tides than on ebb tides. This aligns with previously reported decreases in numbers of diving birds in Bluemull Sound as a function of increasing in current speed and indicates that diving birds avoid foraging in the site when tidal current velocities are high.

Based on the vantage point survey data, the likelihood of near-field encounters between birds and turbines is extremely low. This is because very few birds dive and forage around the turbines and those that do rarely do so at times when the turbines are operating. Near-field encounters are only possible if a bird uses the project site. The likelihood increases if the bird uses the area immediately around the turbines and increases again if the bird dives in the area around the turbine. To be at risk of interacting with operational turbines, birds must dive in the array area at times when the tidal flow is above the turbine cut-in speed (0.8 m/s).

Figure 4-2 Images of black guillemot (left) and European shag (central and right) from turbine-mounted subsea cameras. Image on far right shows a shag in pursuit of a shoal of saithe (*Pollachius virens*), which is regularly seen at nacelle height during periods of slack tide and slow current speeds. Nova Innovation 2020 ©.

Black guillemot and European shag are the only bird species that have been observed underwater around the turbines in subsea video. Black guillemot has been observed on six occasions and European shag on ten occasions. Neither species has been seen near the turbines when they are operating and the few observations to date are predominantly during slack water or flow slow speeds when blades are stationary. No collisions have been observed between diving birds and turbine blades (either moving or stationary).

Patterns in observations of diving birds around the turbines correspond to those of fish described in the preceding section. Birds have only been observed in proximity to turbines at times when fish are present (slack tide and slow current speeds). On occasion, birds have been seen pursuing fish during slack tide and times of limited tidal flow. Diving birds are absent from subsea video at higher tidal flows when turbines are operating and fish are also absent. Examples of black guillemot and European shag in subsea video are shown in Figure 4-2.

Results from monitoring to date show that the actual risk of impacts on birds from the Shetland Tidal Array is much lower than the perceived risk. No negative effects on marine birds have been detected in more than ten years of environmental monitoring. A significantly lower number of near-field interactions between diving birds and the turbines have been observed than is predicted by modelling of "encounter risk" based on known bird numbers in the general area. Modelling predicted there could be up to 300 black guillemot and 130 European shag near-field encounters with the turbines each year. Monitoring has shown that the number of observed encounters has been several orders of magnitude lower than was predicted.

4.1.3 Marine mammals

Observations of marine mammals in vantage point surveys were uncommon, with eight different species recorded in total, but many on only one or two occasions. Atlantic grey seal (*Halichoerus grypus*), common seal (*Phoca vitulina*) and harbour porpoise (*Phocoena phocoena*) were the most frequently recorded species, but each was only recorded in the array area in fewer than 1% of all surveys.

Records of marine mammals in vantage point surveys were consistently low across all tidal periods. Cetacean presence was generally greater around low water slack and on increasing flood tides than on ebb tides. Presence of seals was slightly lower around low slack water, when seals might be expected to be hauled out.

Based on the vantage point survey data, the likelihood of near-field encounters between marine mammals and turbines is extremely low because mammals are not regularly present around the turbines, and rarely at times when turbines are operating. Near-field encounters are only possible if a mammal uses the project site. The likelihood increases if the mammal uses the area immediately around the turbines. To be at risk of interacting with operational turbines, mammals must be present in the array area at times when the tidal flow is above the turbine cut-in speed (0.8 m/s).

Common seal is the only marine mammal species that has been observed underwater around the turbines in subsea video. Individuals have been observed on thirteen occasions, all of which were during slack water or flow slow speeds when blades are stationary. No collisions have been observed between marine mammals and turbine blades (either moving or stationary).

Patterns in common seal observations around the turbines align with those of fish. Seals have only been observed in proximity to turbines at times when fish are typically present (slack tide and slow current speeds) and are absent from subsea video when turbines are operating and fish are also absent. Examples of common seal in subsea video are shown in Figure 4-3.

Figure 4-3 Images of common seal from turbine-mounted subsea cameras. All images were captured during periods when flow speed was slow and turbines not operating. Nova Innovation 2020 ©.

Results from monitoring to date show that the actual risk of impacts on marine mammals from the Shetland Tidal Array is much lower than the perceived risk. No negative effects on marine mammals have been detected in more than ten years of environmental monitoring. As with diving birds, observed near-field interactions between mammals and the turbines are significantly lower than was predicted by modelling which predicted that approximately 25 instances of common seal would occur in the area immediately around the turbines each year. Observed encounters were orders of magnitude lower than this.

4.2 Best practice in cost-effective monitoring

In addition to improving knowledge and empirical data on the environmental effects of tidal turbines and arrays, the EnFAIT monitoring workstream has made significant contributions to the development of best practice in monitoring. Carrying out monitoring in areas of the sea like Bluemull Sound with very strong tidal flows can be extremely challenging. The development of methods and instruments to measure mobile species occupancy and behaviour in such high energy environments and around marine energy devices has been identified as a critical evidence need for the tidal stream sector (ORJIP, 2020).

The contribution the EnFAIT project has made to developing efficient and cost-effective techniques and practical solutions to some of the key challenges in monitoring tidal stream energy projects is summarised below.

4.2.1 Identification of clear monitoring objectives

A lack of clear objectives can result in monitoring that is “data-rich”, but “information-poor”. This has been observed in monitoring programmes for many marine renewable energy projects, which gather large amounts of data but fail to address key evidence gaps or improve understanding on environmental effects (MMO, 2014).

Clear objectives for the Shetland Tidal Array environmental monitoring programme were defined and agreed with the regulators and key stakeholders for the project. The monitoring programme was designed to address these objectives. These objectives ensured that all monitoring activity had a clear purpose and was designed to gather specific data to answer key questions. Analyses for data were defined in advance of monitoring activity so there was a clear pathway from data collection through to analysis and reporting.

4.2.2 Integrating ecological and engineering specialists

Much of the success of the environmental monitoring programme has been the result of in-project marine ecological and consenting specialists working alongside mechanical and electrical engineering and design specialists throughout the EnFAIT project. This enabled effective technical solutions to environmental consenting and monitoring issues and needs to be proactively developed and embedded within the project design from the earliest possible stage. Environmental monitoring has been as an equally critical project component as engineering design elements throughout the EnFAIT project.

4.2.3 Adaptive management of environmental monitoring

Engagement with regulators and other key environmental stakeholders throughout the EnFAIT project facilitated an iterative and adaptive approach to monitoring. Information on the results of the monitoring programme have been shared, as well as the difficulties and challenges in delivering cost-effective monitoring that is proportionate to project scale and the corresponding risk of environmental impacts.

This engagement has enabled objectives and methods to be reviewed throughout the environmental monitoring programme so that they remain fit for purpose, achievable and continue to address critical evidence needs. This systematic and adaptive approach to environmental monitoring, where objectives are refined as knowledge improves and monitoring methods are customised to answer specific questions is illustrated in Figure 4-4 and has been critical to the success of the EnFAIT monitoring workstream.

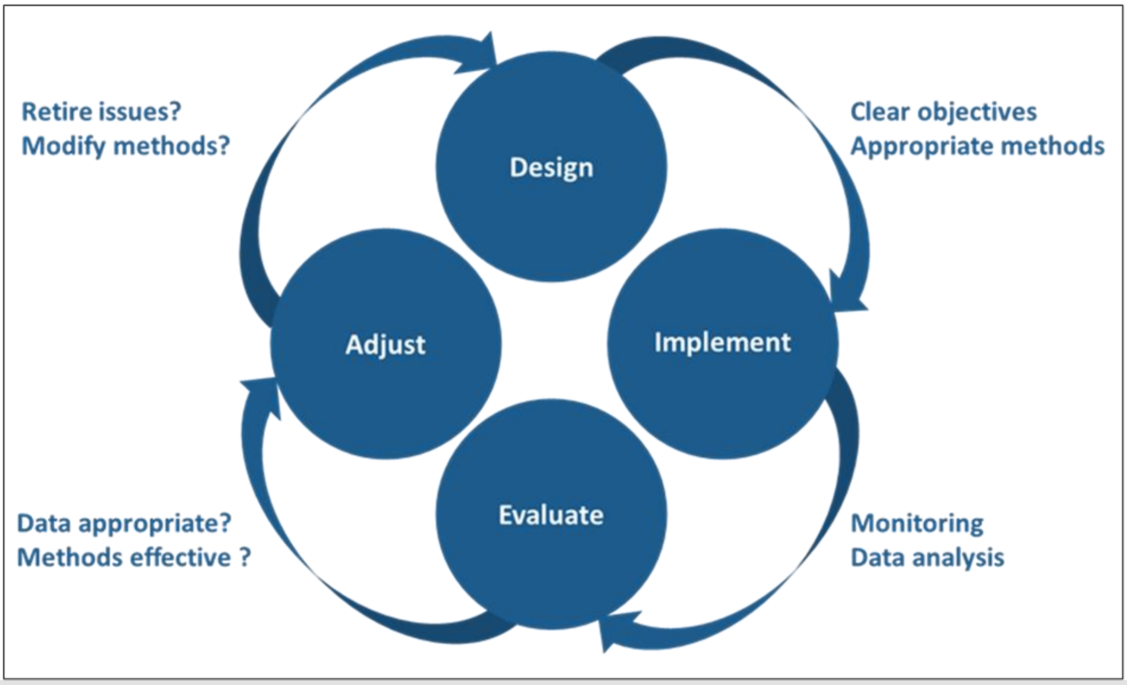

Figure 4-4 The iterative and adaptive approach taken to design and implement the Shetland Tidal Array environmental monitoring programme to ensure it remains fit for purpose and cost-effective.

4.2.4 Simple monitoring solutions

The challenges of working in tidally swept environments such as Bluemull Sound add complexity to designing and implementing environmental monitoring of tidal stream turbines and arrays. Monitoring technologies and systems (instruments, connectors and associated cables) must be capable withstanding the physically demanding conditions in tidal sites to ensure fault-free functioning and avoid failure.

Monitoring near-field interactions between marine wildlife and tidal turbines also generates significant quantities of data. Tidal projects are often located in remote areas where data connectivity is limited and broadband speeds are slow, as is the case with the Shetland Tidal Array. This can be challenging for transferring, processing and storing monitoring data to enable effective analysis and reporting.

These issues were addressed in the EnFAIT project by identifying simple, yet highly effective solutions and approaches. The turbines themselves were used as platforms on which to mount scientific monitoring instruments. This removed the need for separate monitoring platforms, cables and connectors, and the associated high potential for failure and maintenance. Turbine-mounting the monitoring instruments also enabled the download and management of monitoring data to be integrated and aligned with systems for the turbine performance data, creating further efficiencies and reducing areas of potential failure.

The turbine-mounted subsea video cameras record constantly, potentially generating huge volumes of data requiring manual processing and an effective “data mortgage” which available resource will never be sufficient to fully analyse. To address this issue, an “off the shelf” CCTV system was modified for use with the cameras. Although the cameras record constantly, only the footage which has been “motion-triggered” is retained for analysis, significantly reducing the volume of data requiring transfer from the project site and storage. The use of an “off the shelf” system provided a highly cost-effective and practical solution to the issue.

During years 4 and 5 of the EnFAIT project Nova has explored the development of software and Artificial Intelligence tools to assist with automatic processing and analysis of monitoring data. This includes proof of concept tools for intelligent extraction of underwater footage to reduce the manual processing of video footage and improve ‘event detection’ automation. This will improve efficiencies in data processing and reduce storage requirements, through automatic exclusion of ‘falsely’ triggered footage for example caused by moving blades or biofouling on the turbines.

4.2.5 Academic involvement in monitoring

Working in partnership with academic experts in wildlife research at tidal energy sites to design methods and analyse data from the Shetland Tidal Array environmental monitoring programme has ensured tailored approaches based on unbiased scientific input. Publishing results from the monitoring programme in peer-review journals and publications has provided further independent review and scrutiny (e.g., Copping & Hemery, 2020).

4.3 Sharing key learning

4.3.1 Overview

Nova believes it is important to share the results of the environmental monitoring for the Shetland Tidal Array, which demonstrate that the turbines in Bluemull Sound have had no negative effects on marine wildlife. The monitoring programme has collected one of the world’s best, most comprehensive datasets on the environmental effects of tidal turbines. The project has also pioneered the development of efficient, cost-effective methods and techniques for gathering data on the environmental effects of turbines. Sharing this experience and development of best practice in the environmental monitoring of tidal turbines is critical, so that any future monitoring is realistic, effective and generates high quality data.

To facilitate sharing of experience and evidence from EnFAIT, all key reports and publications from the Shetland Tidal Array monitoring programme are publicly available. A reference list is provided in Section 6.

Learning from the environmental monitoring workstream of the EnFAIT project has been widely shared and disseminated in a number of other ways, including:

a. Key results and lessons learnt have been published the US 2020 "State of the Science" report dedicated to examining the environmental effects of marine renewable energy technologies (Copping & Hemery, 2020). This 300-page report remains the most comprehensive international analysis to date on the issue.
b. Key results and experience are regularly shared and presented at UK and international workshops, conferences and seminars.
c. The environmental monitoring programme and its key findings are regularly promoted using social media channels, including to coincide with global initiatives such as COP26, World Oceans Day and World Earth Day.
d. The environmental monitoring programme, including footage from subsea video cameras, have featured on UK national television, including BBC One Countryfile which is one of the BBC's most popular programmes, airing weekly and reporting on rural agricultural and environmental issues in the UK.
e. Key findings and lessons learnt have been incorporated into key consenting and regulatory guidance documents, including a series of technical, topic specific Information Notes produced by the Welsh Government to provide a shared understanding of how the best available science and evidence is currently applied to key consenting issues[2].

4.3.2 Knowledge transfer to de-risk and accelerate consenting

Environmental monitoring of the Shetland Tidal Array has shown that the perception of the potential for tidal turbines to cause environmental harm or damage can be much greater than any realised or observed impacts. No negative effects on marine wildlife have been detected in more than ten years of monitoring the turbines in Shetland.

The precautionary approach taken to consenting early tidal energy projects based on theoretical risk was proportionate and rational when empirical evidence from monitoring operational turbines was lacking. As knowledge improves, such as through the Shetland Tidal Array environmental monitoring programme, it is critical that this evidence is used effectively to accelerate and de-risk consenting. This includes ensuring that pre-application surveys and monitoring to support consent applications are only required by regulators if they are essential to assess the potential for significant environmental effects. It should be reasonable and proportionate to expect some potential effects to be assessed based on transferring knowledge from existing projects without the need for additional survey or monitoring. Transfer of existing knowledge and evidence should also help ensure that monitoring of future tidal projects, if required, is realistic, effective, targeted on key issues and generates high quality data.

Nova has applied evidence and knowledge from the Shetland Tidal Array to inform consent applications and the design of monitoring programmes for its other tidal projects in the UK and overseas. This includes a proposed 1.5 MW tidal project in Petit Passage in the outer Bay of Fundy, Nova Scotia (the "Nova Tidal Array"). Evidence and scientific information on the environmental effects of the Shetland Tidal Array were used in Nova's applications for consent for the Nova Tidal Array. This enabled project consents to be issued

[2] The Information Notes are expected to be published in 2022 on Welsh Government's website https://gov.wales/

quickly (within 7 months of application) and without the need for any baseline survey. Instead, effort will focus on the incremental deployment of turbines combined with integrated monitoring. The design of the project monitoring plan, including clear objectives and methods, has been informed by key learning and experience from the Shetland Tidal Array. This has not only de-risked and accelerated consenting of the Nova Tidal Array but facilitated transfer of knowledge from the UK to enable the sustainable development of the sector in Canada, based on best available scientific evidence.

5 Forward plan

The monitoring programme for the Shetland Tidal Array will continue for the remainder of the EnFAIT project, covering a further period of expansion, as two further 100 kW turbines are added to the array (T5 and T6). Turbines in the extended array will also be reconfigured during the remainder of the EnFAIT project. Findings from the ongoing environmental monitoring programme will be fully disseminated using approaches set out in Section 4.3 to ensure that the results reach as wide an audience as possible.

Monitoring throughout the reminder of EnFAIT will add to the contribution the project has already made to improving knowledge on the environmental effects of tidal turbines and arrays and the development of practical, efficient and cost-effective monitoring solutions. Monitoring will be kept under review to ensure it remains proportionate and fit for purpose as the array is further expanded and reconfigured. This includes further refining methods to continue to focus on key outstanding uncertainties and knowledge gaps and considering phasing out monitoring that is no longer required.

Opportunities to further develop and expand the transfer of key knowledge and learning from the Shetland Tidal Array to benefit the wider tidal sector will also be further explored and developed throughout the remainder of EnFAIT. This includes using evidence gathered on the environmental effects of the turbines in the Shetland Tidal Array to de-risk consenting of other projects and continuing to improve environmental monitoring best practice in the tidal sector.

Opportunities to combine evidence and knowledge from the Shetland Tidal Array with that gained from environmental monitoring of Nova's other tidal energy projects, such as the Nova Tidal Array in Petit Passage, Canada will be explored. This is anticipated to deliver further benefits in de-risking and accelerating consenting, as well as reducing the burden and costs of monitoring for the tidal sector.

6 References

Copping AE and Hemery LG, editors (2020). OES-Environmental 2020 State of the Science Report: Environmental Effects of Marine Renewable Energy Development Around the World. Report for Ocean Energy Systems (OES). doi:10.2172/1632878.

MMO (2014). Review of post-consent offshore wind farm monitoring data associated with licence conditions. A report produced for the Marine Management Organisation, pp 194. MMO Project No: 1031. ISBN: 978-1-909452-24-4.

Nova Innovation Ltd. (2018). EnFAIT - Enabling Future Arrays in Tidal Y1 Environmental Monitoring Report. Available at: https://www.enfait.eu/publications/year-1-environmental-monitoring-report/

Nova Innovation Ltd. (2020). EnFAIT - Enabling Future Arrays in Tidal Y3 Environmental Monitoring Report. Available at: https://www.enfait.eu/publications/year-3-environmental-monitoring-report/

Nova Innovation Ltd. (2021a). Shetland Tidal Array Project Environmental Monitoring Plan (PEMP). EnFAIT-0362 Version 5.0. Available at: https://marine.gov.scot/data/project-environmental-monitoring-plan-pemp-shetland-tidal-array-extended-bluemull-sound

Nova Innovation (2021b). Shetland Tidal Array Monitoring Report: Vantage point surveys EnFAIT-0347. Available at: https://marine.gov.scot/data/vantage-point-survey-report-shetland-tidal-array-extended-bluemull-sound-shetland-0664200009110

Nova Innovation (2021c). Shetland Tidal Array Monitoring Report: Subsea video monitoring EnFAIT-0346. Available at: https://marine.gov.scot/data/subsea-monitoring-report-shetland-tidal-array-extended-bluemull-sound-shetland-0664200009110

ORJIP (2020). Wave and Tidal Stream Critical Evidence Needs. Report to The Crown Estate, Marine Scotland Welsh Government, Scottish Natural Heritage and Natural Resources Wales. Produced by the Offshore Renewables Joint Industry Programme for Ocean Energy.

Contact

HEAD OFFICE

Nova Innovation
45 Timber Bush
Edinburgh
EH6 6QH

Tel: +44 (0)131 241 2000
Email: info@enfait.eu

www.enfait.eu

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 745862.