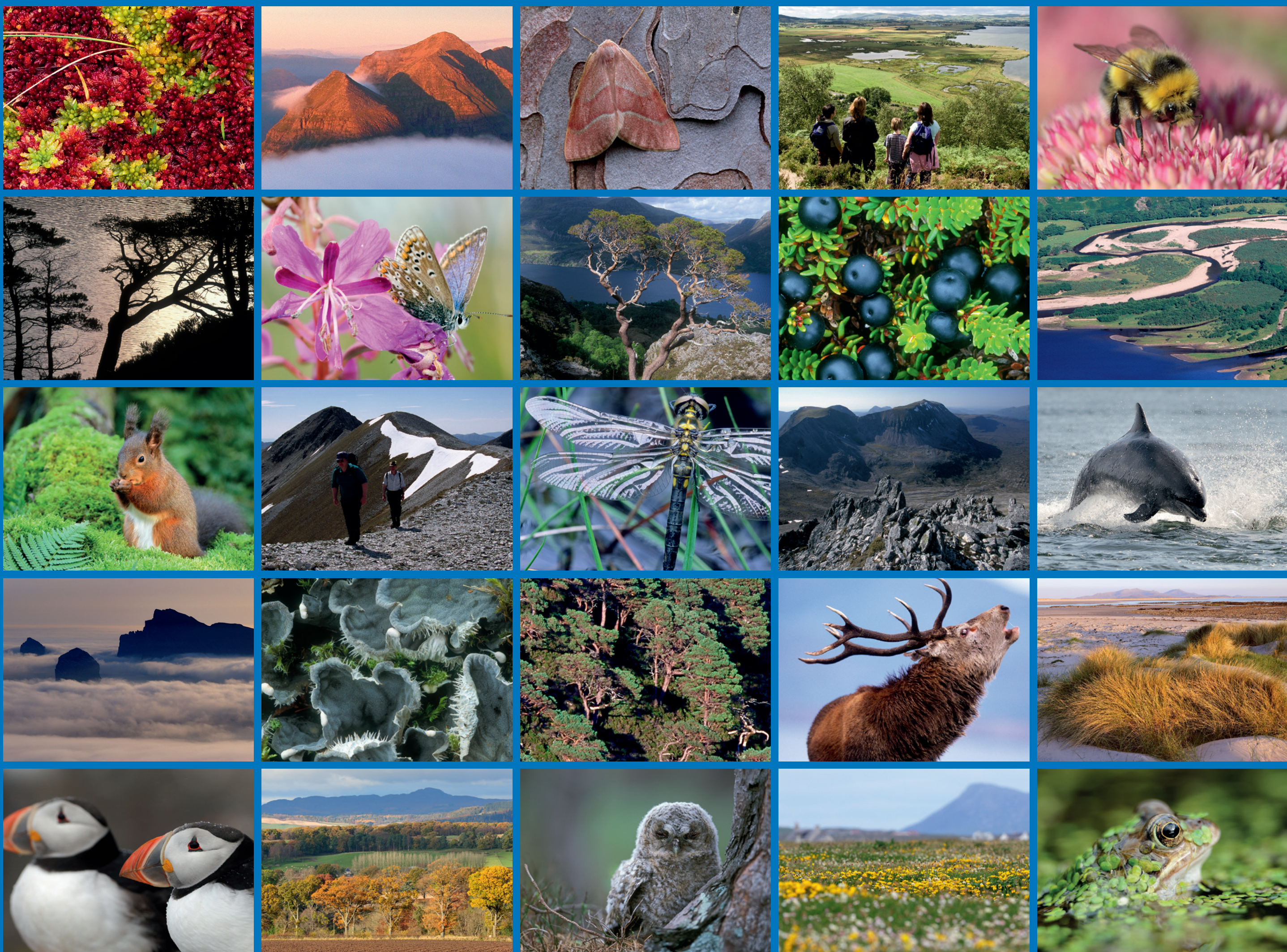
Research Report No. 1225

Review of underwater video data collected around operating tidal stream turbines



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RESEARCH REPORT

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Review of underwater video data collected around operating tidal stream turbines

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RESEARCH REPORT

Summary

Review of underwater video data collected around operating tidal stream turbines

Research Report No. 1225
Project No: 116895
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Keywords

marine; renewable; impact, environment; ecology; tidal; video; data; monitoring

Background

One of the most significant barriers to sustainable commercial scale development of the tidal energy sector is the level of uncertainty around the potential environmental risk posed by operating tidal turbines to protected marine wildlife. In order to reduce this uncertainty and better understand near-field behaviour of ecological receptors around operating devices, significant effort is being put into strategic monitoring and research projects around the world to gather data around the first single devices and arrays.

Monitoring data are needed to validate predictive models that describe the behaviour of key species around tidal turbines, in order to improve and refine input parameters for better estimates of collision risk and avoidance. However, monitoring near-field behaviour of ecological receptors around operational turbines and detecting any potential collision events requires a range of different technologies and processes. A variety of approaches have been implemented around the world to date and it is not clear what has been successful and where technical and procedural improvements are required going forward.

The principal aim of this project was to review environmental monitoring data collected around operational tidal energy projects to date, focusing on underwater video, in order to establish what data exist and how this data can be used to:

- Help ensure that experience to date with regards to the design and implementation of environmental monitoring programmes is captured and used to inform the development of proportionate future monitoring plans and to help reduce risk and costs wherever possible; and
- Improve our understanding of the potential effects of such developments on ecological receptors.

Main findings

Based on a high level analysis of suitable and available data, it can be concluded that much of the underwater video monitoring around operational tidal turbines to date has focussed on technical and performance-related objectives rather than capturing near-field wildlife behaviour and other environmental interactions.

Thirty-six recommendations regarding monitoring system planning and design, data collection, and data review and analysis were produced following the review which was undertaken by the team. Future environmental monitoring plans should consider these recommendations which are presented and discussed in full in the main report.

To facilitate future review of underwater video monitoring data two protocols were also developed:

- Protocol 1: Monitoring system review – a technical protocol for assessing the effectiveness of monitoring techniques, equipment and processes.
- Protocol 2: Environmental analysis of underwater video data – a protocol designed to support the standardisation of underwater video data review and analysis of near-field behaviour of ecological receptors around tidal stream turbines

The suitability and the quality of the datasets analysed for investigating near-field behaviour varied, affecting the ability to ascertain near-field behaviour events and patterns from the manual analysis of underwater video data available to the project.

One hundred and twenty-eight two-minute excerpts of video data were examined from three operational turbines. Wildlife observations were recorded in approximately 22% of all samples reviewed in this study. At current speeds of 0.8 m/s and below, certain fish behaviours were observed which included passing the nacelle, investigating the nacelle, or feeding off the nacelle, and shoaling around the device within the camera's field of view. These observations show fish acclimation behaviour and Fish Aggregating Device (FAD) effects. As current speed increased higher than 0.9 m/s, fish and birds were more frequently observed to move with or across the current. Birds were more commonly observed in greater current velocities of around 1.2 – 2.9 m/s. No collision events were observed in any of the samples reviewed.

Future research should focus on better understanding of near-field behaviour of wildlife around operational turbines. Definitive evidence around the ability of marine wildlife to evade/avoid tidal turbines would help inform future monitoring requirements and help ensure that these are proportionate and fit for purpose.

It is recommended, where appropriate, that high quality underwater video data continues to be collected around operating tidal turbines, where site conditions are suitable for this, as the data provide a unique opportunity to better understand near-field behaviour of marine wildlife around operating turbines. It should be noted, however, that manual analysis of such data is extremely time consuming and expensive. It is therefore essential that progress is made in the development of suitable software and processes to automate future underwater video data analysis.

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1. INTRODUCTION

1.1 Background

The International Energy Agency's Ocean Energy Systems (OES) Technology Initiative estimates that there is the potential to develop 300 GW of ocean energy by 2050[1]. Deployment of ocean energy projects can provide significant benefits in terms of jobs and investments, often in remote and peripheral communities. For example, the development of 300 GW of ocean energy is estimated to have the potential to create around 680,000 direct jobs, contributing significantly to global employment by harnessing renewable energy sources. The global carbon savings achieved through the deployment of ocean energy projects could save up to 500 million tonnes of carbon dioxide.

One of the most significant barriers to sustainable commercial scale development of the tidal energy sector is the level of uncertainty around the potential environmental effects risk posed by operating tidal turbines to protected marine wildlife. The most critical issue at this time is the scientific uncertainty associated with collision risk of marine animals and diving seabirds with operating tidal turbines. Uncertainty about collision risk has contributed to a limited number of consents / permits and licences being issued for tidal energy projects around the world. Where consents / permits have been issued, they have carried restrictions around build-out that can affect the financial viability of projects. This limitation is further exacerbated by the requirement for expensive and time consuming pre-application site characterisation studies and post-consent monitoring requirements for developers[2].

In order to reduce this uncertainty and better understand near-field behaviour of ecological receptors around operating devices, significant effort is being put into strategic monitoring and research projects around the world to gather data around the first single devices and arrays. The uncertainty around potential collision impacts can also require that developers undertake monitoring post consent to ascertain if predicted impacts in their Environmental Impact Assessment (EIA) Reports are underestimating, overestimating or accurately predicting risk; there is currently no available standard approach to doing so. This places considerable financial pressure on the first-movers in this nascent industry as well as regulatory agencies charged with managing interactions with protected species in the marine environment. It is critical that this issue is addressed at the earliest possible opportunity in order to realise the associated social and economic benefits from the responsible development of this new renewable energy resource.

1.1.1 The challenge

Monitoring will likely be necessary around all first arrays to determine the effects on marine wildlife. Without clearly defined objectives, improved processes and suitable equipment, there is a risk that monitoring does not help reduce scientific uncertainty and that valuable time and resources are wasted. In order to improve this situation, it is essential to maximise the value of the work that has already been undertaken around the world and to ensure that the lessons learned inform future plans and processes.

There has been a large volume of monitoring data gathered to date around operational tidal turbines which has not been fully analysed from an environmental perspective, limiting the lessons that can be learned to inform future strategic research and project monitoring requirements as well as consenting and decision making processes. The findings of monitoring studies need to be made available and accessible to regulators, developers, researchers, consultants, and other interested parties. This will encourage revisions and improvements to future baseline data collection and post-

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[1] Ocean Energy Systems, 2017. An International Vision for Ocean Energy. Available at: https://www.ocean-energy-systems.org/news/oes-vision-for-international-deployment-of-ocean-energy/

[2] Hutchison and Copping, 2016. A Coordinated Action Plan for Addressing Collision Risk for Marine Mammals and Tidal Turbines. Available at: https://tethys.pnnl.gov/sites/default/files/publications/Collision_Risk_Workshop_Final_Report.pdf

consent / permit monitoring studies that will ensure that data gathered are fit for their intended purpose[2].

Monitoring data are needed to validate predictive models that describe the behaviour of key species around tidal turbines, in order to improve and refine input parameters for better estimates of collision risk and avoidance[2]. However, monitoring near-field behaviour of marine wildlife around operational turbines and detecting any potential collision events requires a range of different technologies and processes. A variety of approaches have been implemented around the world to date and it is not clear what has been successful and where technical and procedural improvements are required going forward.

Environmental monitoring over time generates massive volumes of data that need to be transmitted, stored, processed and analysed. The first projects attempting to gather data to inform our understanding of the potential effects of tidal turbines on marine wildlife have all struggled with so-called 'data mortgages[3]'. Significant improvements in how data are gathered, transmitted and stored are required to streamline this process to ensure that future monitoring plans are manageable, proportionate, effective and affordable.

1.2 Aim of the project

The principal aim of this project is to review environmental monitoring data collected around operational tidal energy projects to date, in order to establish what data exist and how this data can be used to:

- Help ensure that experience to date with regards to the design and implementation of environmental monitoring programmes is captured and used to inform the development of proportionate future monitoring plans and to help reduce risk and costs wherever possible; and
- Improve our understanding of the potential effects of such developments on ecological receptors.

1.2.1 Objectives

Given the challenges and aims listed above, the following objectives form the focus of the project:

- Establishing what environmental impact monitoring data exists from past and ongoing tidal turbine projects;
- Establishing protocols for analysing existing environmental impact monitoring data;
- Assessing the effectiveness of techniques, equipment and processes used to date;
- Identifying the key challenges associated with environmental monitoring around operating ocean energy projects and areas where further effort and improvements are required;
- Reviewing and analysing previously gathered data to establish what can be learned regarding near-field behaviour of ecological receptors around tidal turbines; and
- Determining what environmental data is required from future monitoring and data gathering activities around operational ocean energy developments to address potential key consenting issues.

1.3 Project overview

The following tasks were undertaken during the project:

- Task 1: Identification and collation of existing data;
- Task 2: Establishment of protocols for analysing underwater video data;

[3] Large streams of data produced by monitoring equipment that need to be transmitted, stored, processed and analysed.

- Task 3: Assessment of the effectiveness of techniques, equipment and processes to date;
- Task 4: Review and analysis of existing underwater video data to establish what can be learned regarding near-field behaviour; and
- Task 5: Determining what data is required from future monitoring and data gathering activities to address key consenting issues.

An overview of each task undertaken is provided below:

Task 1: Identification and collation of existing data

The aim of this task was to establish what environmental impact monitoring data exist from past and ongoing tidal energy projects around the world to create a comprehensive global metadata catalogue. This catalogue can be used to help inform the design of future monitoring and research projects and helps raise awareness of the extent and types of environmental impact monitoring data collected to date by the sector.

The metadata catalogue is to be hosted and maintained on the Offshore Renewables Joint Industry Programme (ORJIP) Ocean Energy website. The current version is available via the wave and tidal energy pages on the NatureScot website.

Task 2: Establishment of protocols for analysing underwater video data

The aim of this task was to develop a series of protocols for improving and standardising underwater video data collection and analysis to form the basis of guidance and advice for future monitoring programmes. A standardised approach to data collection and analysis provides a framework that allows comparison of data across discrete datasets. The approach also improves stakeholder and regulator confidence in the analysis of these data in addition to streamlining the consenting process for future developments.

Two protocols were developed:

Protocol 1: Monitoring system review – technical protocol for assessing the effectiveness of monitoring techniques, equipment and processes

Protocol 2: Environmental analysis of underwater video data – protocol designed to support the standardisation of underwater video data review and analysis of near-field behaviour of ecological receptors around tidal stream turbines

The finalised protocols for data analysis (including the methodology, templates and instructional notes) are to be available via the NatureScot website wave and tidal energy page and the ORJIP Ocean Energy website, shortly after publication of this report.

Task 3: Assessment of the effectiveness of techniques, equipment, and processes to date

The aim of this task was to review the effectiveness of techniques, equipment and processes used in the recording of underwater video data of tidal turbines and produce a set of recommendations to improve underwater video data collection across all aspects of tidal developments.

Suitable video monitoring data around tidal current deployments was first identified and then analysed (using Protocol 1 produced during Task 2) in order to determine the effectiveness of techniques, equipment and processes (with identification of any limitations encountered). A summary of recommendations for improving underwater monitoring activities was compiled based on the outputs of each review.

Results of the assessment are provided in Section 2 of this report with full assessment reports in Annex 1.

Task 4: Review and analysis of existing underwater video data to establish what can be learned regarding near-field behaviour

Suitable, and available, underwater video datasets were reviewed to determine what can be learned from existing underwater video data regarding ecological receptor behaviour around operating tidal stream turbines, namely near-field behaviour.

A summary of key findings is presented in Section 3 of this report and the full results are compiled in Annex 2.

Task 5: Determining what data is required from future monitoring and data gathering activities to address key consenting issues

Based on the results of Tasks 1 – 4, a series of recommendations was produced to inform the development of future project-specific environmental monitoring plans and relevant research projects / programmes.

These recommendations are presented in Section 4 of this report.

1.4 Purpose of this report

The purpose of this report is to provide an overview of the project and its outputs, along with the detailed results of Tasks 3, 4 and 5 (as outlined in Section 1.3).

The outputs from Tasks 1 and 2 (Metadata Catalogue and Protocols 1 and 2) are to be available via the ORJIP Ocean Energy website; current versions are also available via the wave and tidal energy page of the NatureScot website.

1.5 Report structure

An overview of the report structure is provided below:

- Section 1 – Introduction; providing background to the project, a project overview, the project aim, purpose and structure;
- Section 2 – Assessment of the effectiveness of techniques, equipment, and processes to date (presenting an overview of the results of Task 3);
- Section 3 – Review and analysis of existing underwater video data to establish what can be learned regarding near-field behaviour (presenting an overview of the results of Task 4); and
- Section 4 – Determining what data is required from future monitoring and data gathering activities to address key consenting issues (presenting the results of Task 5).

Supplementary information is provided in Annexes:

- Annex 1 – Task 3, Review of effectiveness of underwater video monitoring techniques, equipment and processes to date; and
- Annex 2 – Task 4, Review and analysis of existing underwater video data to establish what can be learned regarding near-field behaviour.

2. ASSESSMENT OF THE EFFECTIVENESS OF TECHNIQUES, EQUIPMENT, AND PROCESSES TO DATE

2.1 Introduction

This section presents the results of Task 3. The specific aim of Task 3 was to assess the effectiveness of techniques, equipment and processes implemented during underwater video monitoring campaigns to date and, based on this review, develop a set of recommendations that can be used by developers and researchers to design and implement more effective environmental monitoring campaigns using underwater video cameras in the future.

This section presents the approach adopted, along with the recommendations developed from the review of the analysis process during Task 3. The recommendations were informed by a comprehensive review of a number of monitoring systems and datasets, the results of which can be found in Annex 1.

It should be noted that all comments and recommendations drawn in this section and Annex 1 are in relation to the monitoring systems' effectiveness in monitoring environmental effects. It should be recognised that many monitoring programmes around first deployments and arrays are focused on technical monitoring and therefore not yet optimised for environmental monitoring purposes. The lessons learned and recommendations presented in this document should not therefore be taken as a critique of previous/current monitoring systems, but as a series of recommendations for optimising future environmental monitoring systems.

2.2 Approach

2.2.1 Data collection

All technology developers (or other identified sources) known to hold underwater video monitoring data from around operational tidal stream turbines were contacted to participate in this project. Data were received from the following developers:

- SIMEC Atlantis;
- Sustainable Marine Energy;
- Scotrenewables[4] and
- Voith Hydro (via Aquatera).

The datasets received from the developers listed above were bolstered by the inclusion of publicly available information on other tidal stream developments, which were incorporated into the Metadata Catalogue (during Task 1) and informed the initial high level screening of underwater monitoring efforts (refer to section 2.2.2). Data was collected from the following developments:

- SIMEC Atlantis – MeyGen Tidal Array deployment at the Pentland Firth, northern Scotland;
- OpenHydro – 250 kW deployment at the European Marine Energy Centre (EMEC), Orkney;
- Ocean Renewable Power Company (ORPC) – RivGen deployment in the Kvichak River, Alaska;
- Sabella – D10 deployment at Fromveur Passage, France;
- Scotrenewables – SR250 deployment at EMEC;
- Scotrenewables – SR2000 deployment at EMEC;
- Sustainable Marine Energy (SME) – PLAT-I at Grand Passage, Nova Scotia, Canada; and
- Voith Hydro – HyTide deployment at EMEC.

[4] Scotrenewables have since rebranded to Orbital Marine Power. Orbital Marine Power are referred to in this report as Scotrenewables as, at the time of data collection, this was the correct name and also references the correct use of prefixes used in names of their devices e.g. SR250 and SR2000.

2.2.2 Initial high-level screening of received and publicly available data

Each dataset was considered in relation to the following factors in order to identify those suitable for further detailed analysis during Task 3:

- Availability of data to the project
- Image quality
- Water clarity
- Context (in relation to the turbine)
- Quantity of available data

The results of the screening process are shown below in Table 2.1:

Table 2.1. Dataset screening

Development	**Availability of data to the project**	**Image quality**	**Water clarity**	**Context (in relation to the turbine)**	**Quantity of available data**
MeyGen Tidal Array deployment at Pentland Firth	Available	Good	Moderate	Effective placement of cameras around turbine	~130GB – sufficient to inform report
OpenHydro 250 kW deployment at EMEC	Not available at time of report	N/A	N/A	N/A	N/A
Ocean Renewable Power Company's (ORPC) RivGen deployment in the Kvichak River, Alaska	Not available at time of report	N/A	N/A	N/A	N/A
Sabella D10 deployment at Fromveur Passage, France	Not available at time of report	N/A	N/A	N/A	N/A
Scotrenewables SR250 deployment at EMEC	Available	Moderate	Moderate	Effective placement of cameras around turbine	5GB - not sufficient to inform report
Scotrenewables SR2000 deployment at EMEC	Available	Moderate	Moderate	Effective placement of cameras around turbine	14TB – sufficient to inform report
Sustainable Marine Energy (SME) PLAT-I at Oban, Scotland	Available	Poor	Poor	N/A	N/A
Sustainable Marine Energy (SME) PLAT-I at Grand Passage, Nova Scotia, Canada	Not available at time of report	N/A	N/A	N/A	N/A
Voith HyTide deployment at EMEC	Available	Good	Moderate	Effective placement of cameras around turbine	~433GB – sufficient to inform report

2.2.3 *Underwater video monitoring data made available to the project*

Following the high-level screening process outlined in the previous section, the following underwater video monitoring datasets were analysed further during Tasks 3 and 4:

- SIMEC Atlantis – MeyGen Tidal Array deployment at the Pentland Firth, northern Scotland;
- Scotrenewables – SR2000 deployment at EMEC, Orkney; and
- Voith Hydro – HyTide deployment at EMEC.

2.2.4 *Data analysis*

Each dataset was analysed using Protocol 1 (Monitoring System Review), which was developed during Task 2. This ensured a consistent and robust approach to the analysis based on an agreed set of criteria. The results of each review are presented in Annex 1 and the protocol can be found via the wave and tidal energy page of the NatureScot website and, shortly after publication of this report, the ORJIP Ocean Energy website.

2.2.5 *Development of recommendations*

Following the initial high-level review and in-depth analysis of each relevant dataset, recommendations for developing and implementing environmental monitoring campaigns using video cameras were developed.

It should be noted that following the initial review of the datasets, it was concluded that environmental monitoring using underwater video cameras is predominantly useful when investigating potential near-field effects, namely:

- Collision risk; and
- Evasion, avoidance and attraction.

The guidance presented in this document therefore focuses on those recommendations as to how best design and implement an environmental monitoring campaign using video cameras to suit Environmental Monitoring Plan (EMP) objectives focused on these factors. It is critical that these objectives are discussed with the relevant stakeholders and clarified at the earliest opportunity as these will underpin the design of any EMP, particularly in relation to:

- Equipment selection;
- System configuration and setup;
- Biofouling management;
- Selection of any software systems;
- Data management; and
- Choice / definition of data analysis and reporting protocols.

The recommendations provided in Section 2.3 are structured in relation to the following phases or an environmental monitoring campaign:

- Planning – system design
- Implementation – data collection
- Reporting – review and analysis

All recommendations are clearly labelled and are collated and summarised at the end of this document in Section 2.6.

2.3 Recommendations during planning – system design

2.3.1 Development of an Environmental Monitoring Plan

To gain consent for deployment, most project developers/licence applicants will be required to produce an Environmental Monitoring Plan (EMP) (or equivalent) in consultation with the relevant regulators and stakeholders. To ensure that appropriate monitoring measures and reporting procedures are in place for each phase of the project, any EMP should clearly set out the objectives of the planned monitoring measures and detail the protocols to be implemented for data collection, analysis and reporting. The EMP should also include a robust and suitable consultation and review plan along with an overview of any adaptive management measures to be implemented during the project.

Recommendation 1: Consult with appropriate regulatory bodies and their advisers to develop an effective EMP
It is essential that consultation with relevant regulatory bodies and their advisers (those that advise and determine on consenting procedures, e.g. Marine Scotland and NatureScot, respectively, in Scotland) is conducted during EMP development to ensure that lessons learned from previous monitoring activities can be incorporated into the plan and therefore provide the best chance of reducing scientific uncertainty around potential impacts. To ensure that EMPs contain the most up to date and relevant measures, it is recommended that developers fully engage with these regulatory bodies.

Clarification of the objectives of the monitoring programme will ensure that the design of any underwater video monitoring system is fit for purpose, with an effective, and efficient, use of available equipment, software, protocols and labour.

2.3.2 Equipment selection

Recommendation 2: Use High Definition (HD) cameras where possible
Lower quality cameras are of limited use in capturing or defining environmental interactions via manual observations. Identification to species-level, which may be necessary to fully understand and define certain interactions, requires high quality video data which is only possible with HD cameras.

Recommendation 3: Use an on-board battery bank, where feasible, to power cameras
Where feasible, localised battery banks powered by the turbine itself provide an effective method for powering equipment to avoid possible issues entailed by connecting to a power supply external to the turbine (see Recommendation 4 below).

Recommendation 4: Use resilient power supply connections to connect cameras and localised storage
Faulty connections have hindered a number of video monitoring efforts; effective power supply solutions (and / or localised storage) should therefore be designed to withstand the environmental conditions within which they are to be deployed.

Recommendation 5: Use fibre optic cables, or on board storage (on the device) with online transmission capability to a local hard drive, where feasible
Device design will dictate the optimum data storage and transmission method, however, the use of fibre optic cables or on board storage with online transmission capability to a local hard drive allows for fast and effective transfer of data to a secure storage option.

Recommendation 6: Use localised hard drive storage and a secondary backup to an online portal to allow remote access to data
External localised hard drive storage provides a secure storage option but the ability to back up that data to an online portal additionally allows for remote access for analysis and research.

Recommendation 7: Connect all cameras with a minimum of 16mbps bandwidth for data transfer
Use of a HD camera system (see Recommendation 2) entails the transmission of large amounts of data. To ensure this is done quickly and effectively, a minimum camera bandwidth of 16mbps is suggested.

2.3.3 System configuration

After equipment choice has been finalised, it is necessary to configure that equipment and system in such a manner as to be effective in meeting the requirements and objectives set out in the EMP. When considering the functionality of cameras, available light proved to be a significant factor in determining the effectiveness of data.

Recommendation 8: Favour black and white over colour to improve low light functionality
Water clarity, turbidity and water depth create issues for capturing effective underwater video data. Colour functionality can reduce video quality when filming in low light and turbid conditions[5]. An example of these differences can be seen below in Figure 2.1 from data from the Scotrenewables SR250 device.

Figure 2.1. Comparison of quality of SR250 colour and monochrome video footage

Recommendation 9: Position cameras with consideration of the availability of natural light
Device design can affect optimum camera configuration. During the review, it was found that cameras positioned under nacelles at depth were less effective in the low light conditions whilst cameras positioned closer to blades could suffer from over exposure due to light reflection.

Recommendation 10: Do not use artificial lights but consider their use specific to site conditions and device deployment
Analysis of available data showed that lights placed adjacent to cameras are of limited use. Cameras function adequately in low light, and if not, lights are of limited use in aiding the assessment of environmental interactions from available footage. There is also potential for lights to affect species' behaviour. Evidence gathered during this study indicates that lights do not necessarily add value during monitoring but should still be considered in the planning phase relative to specific site objectives and conditions.

[5] Please note that the addition of colour to camera functionality may facilitate the identification of passing objects / species (see Annex 1), but not in low light and turbid (underwater) conditions.

Tidal devices do not show conformity of design and there is considerable divergence through their placement in the water column; either fixed to the seabed, floating at the surface or somewhere in between. This then presents additional options and considerations for camera layout; a turbine fixed to the seabed can make use of additional platforms to enhance fields of view which would be impractical for floating turbines such as the SR2000. An example of how developers can make use of additional structures to enhance monitoring can be seen below in Figure 2.2, with the developer making use of additional tripods to place Acoustic Doppler Current Profilers (ADCPs) and camera equipment to optimise monitoring capability:

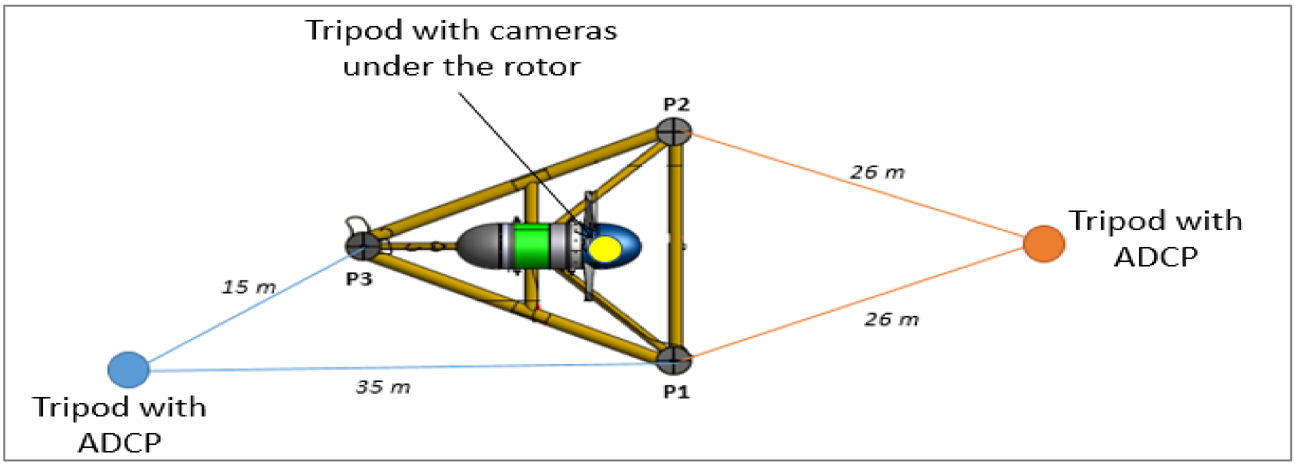

Figure 2.2. Sabella D10 camera schematic

Recommendation 11: Place cameras on additional structures where feasible to optimise video coverage

Additional structures can improve fields of view and coverage. Camera layout must give due consideration to the design of the device itself, availability of locations for camera placement, monitoring objectives and site characteristics and how these variables combined will dictate optimum camera choice and layout. The critical point is that the cameras are positioned in such a way that the data collected can help meet the objectives set out in the EMP.

Recommendation 12: Use a combination of wide and narrow angle cameras to effectively capture the full extent of the rotor swept area

Use of a single type of camera is of limited use in effectively capturing the full extent of the rotor swept area. This is necessary to review environmental interactions and ensure all aspects of near-field effects are captured. Wide angle cameras do not generally provide a sufficient depth of range to accurately identify near-field effects whilst narrow angle cameras do not provide a sufficient field of view to capture the full extent of the rotor movements. Evidence gathered during this study indicates that in most instances, a combination of different cameras types would help mitigate weaknesses inherent in a homogenous approach.

Recommendation 13: Direct fields of view to capture the full extent of the rotor swept area and optimise camera choice and configuration to allow effective identification of species and interactions

As mentioned in Recommendation 12 regarding fields of view, the camera system must suit EMP objectives. To do this, camera layout must also consider any trade-off between field of view and depth range, see Figure 2.3 below, with additional regard to visibility from site characteristics such as water clarity (see Recommendation 8).

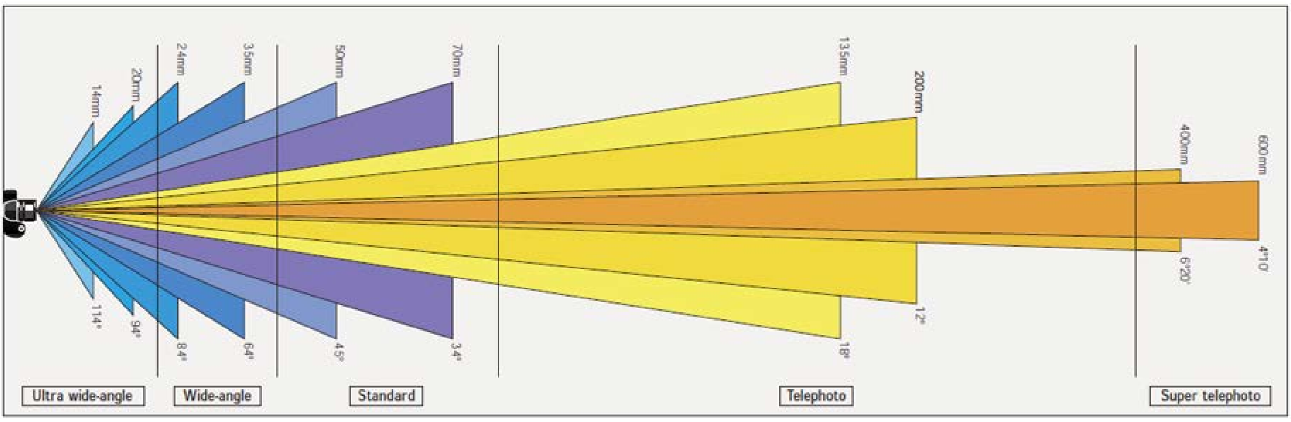

Figure 2.3. Camera field of view vs depth range [6]

Recommendation 14: Direct camera fields of view to capture an extent of the water column adjacent to blades
To capture all near-field events video data must be able to capture and identify avoidance behaviour, thereby requiring that behaviour in areas adjacent to the turbine blades is also captured.

One of the limitations noted during analysis of the available data was the difficulty associated with determining the relative scale of objects compared to the nacelle/blades.

Recommendation 15: Add a scale to the nacelle and / or turbine blades to aid video analysis
To aid identification of objects in footage, a scale (e.g. 2 metres) on the nacelle will help provide perspective. This will be particularly effective if an object passes close to the scale.

2.3.4 Biofouling management

Analysis of available data found that biofouling on cameras can be substantial and significantly reduce the usefulness of footage. Therefore, an effective monitoring system must incorporate a strategy or strategies with which to deal with biofouling on camera lenses. The following measures can be applied to help reduce the impacts of biofouling during data collection:

Recommendation 16: Place cameras facing into the current
Biofouling is a significant factor to consider when planning an EMP. Camera directionality relative to the current determines the rate of biofouling with cameras facing into the current experiencing less biofouling than those facing away from the current, see Figure 2.4.

Recommendation 17: Develop a cleaning schedule utilising maintenance windows to manage biofouling effects
A regular schedule to clean cameras, during maintenance, should be established where possible and maintained to limit the effects of biofouling. If possible, cameras should also be placed in locations that are easier to access and maintain.

Novel technologies can also reduce the effects of biofouling and can allow for an increase in biofouling management efficiency whilst reducing associated costs.

[6] Panasonic, 2018. How Focal Length Affects Viewing Angle. Available at: http://av.jpn.support.panasonic.com/support/global/cs/dsc/knowhow/knowhow12.html

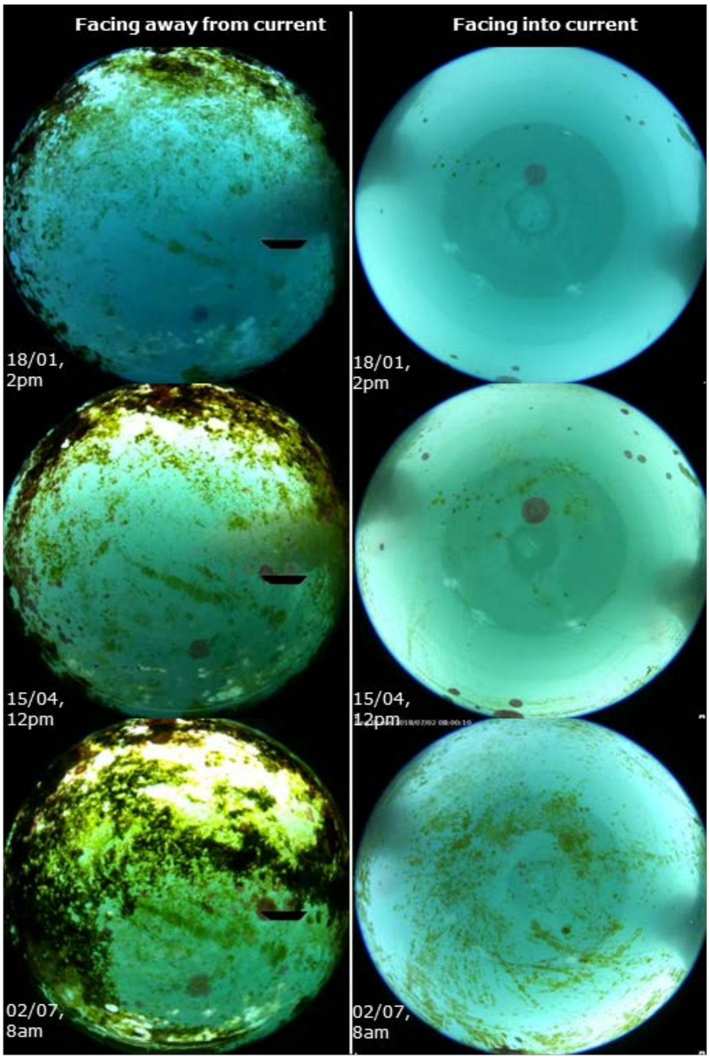

Figure 2.4. Differential effects of biofouling due to camera placement relative to current

Recommendation 18: Investigate the effectiveness of new technologies for biofouling management such as:

Recommendation 18a: Test wipers on cameras to periodically remove biofouling

This is new and unproven technology, however, it is recommended that future development aims to test these innovations if possible, see Zebra-Tech (2018)[7]. Zebra-Tech is a company specialising in the design and manufacture of instrumentation for underwater research and fisheries catch sampling.

Recommendation 18b: Test coating camera lenses in translucent anti-fouling paint

This is new and unproven technology, however, it is recommended that future development aims to test these innovations if possible, see Marine Scene (2015)[8] and Silicone Solutions (2018)[9]. Marine Scene is a marine chandlery providing boating and sailing equipment whilst Silicone Solutions provide custom silicone adhesives, sealants, gels and coatings.

Recommendation 18c: Test placing ultraviolet LEDs adjacent to cameras to reduce biofouling through the use of UV radiation

This is new and unproven technology, however, it is recommended that future development aims to test these innovations if possible, see Sonihull (2018)[10]. Sonihull are a company specialising in environmentally friendly antifouling solutions for marine vessels using ultrasonic technology.

[7] Zebra-Tech, 2018. Antifouling for Underwater Cameras - Zebra-Tech. Available at: https://www.zebra-tech.co.nz/antifouling-for-underwater-cameras/

[8] Marine Scene, 2015. TK Line Colorspray Antifouling Spray Paint - Clear - Clear Spray Antifouling - Discount Marine Chandlery and Sailing Equipment. Bargain Boat Spares and Clothing. Available at: https://www.marinescene.co.uk/product/11967/tk-line-colorspray-antifouling-spray-paint-clear

[9] Silicone Solutions, 2018. Silicone Antifouling Coating | Boat Antifouling. Available at: http://siliconesolutions.com/ss-5000a.html

[10] Sonihull, 2018. Ultrasonic Antifouling | Sonihull | NRG Marine antifoul system. Available at: https://www.nrgmarine.com/?gclid=CjwKCAiA0O7fBRASEiwAYI9QAmvkfTSNLkABeUjWOGzqMjq1XLbCF-VbvfANumUIZpaknvqjfND54xoC868QAvD_BwE

2.3.5 Data management

Due consideration must also be given to the management of data in the planning and design phase. The following recommendations are proposed to help ensure effective data storage and transmission and to help streamline analysis:

Recommendation 19: Time stamp all data
Clear labelling of all data allows for an effective sampling methodology to be implemented.

Recommendation 20: Use a standardised and non-proprietary data format with consistent frame rate (e.g. .mkv) for all video data
Data can be collected in various formats but the use of a non-proprietary format and consistent frame rate allows for more efficient and consistent analysis.

Recommendation 21: Store all data in hour long clips
Data can be collected and stored in various formats but the use of a consistent clip time allows for more efficient and consistent data storage and analysis. Hour long clips are an effective compromise when considering data storage of the size of files against number of files.

2.4 Recommendations for implementation – data collection

2.4.1 Development of an Environmental Monitoring Plan

The ability of the monitoring system to meet the objectives of the EMP is contingent on the effectiveness of that system during implementation.

Recommendation 22: Test camera functionality prior to installation on device and device deployment on site
During the study it was found that lack of basic functionality had hindered various data collection efforts. It is recommended that the robustness of underwater camera casing and all components in water are tested before installation on or around the device, in addition to having a 'dry' run of camera equipment once placed on the device before the device itself is deployed. If cameras are found to be non-functional, a detailing of exactly why and how these failures manifest would be useful in planning and designing future monitoring programmes.

2.4.2 Refinement of data

Although having a comprehensive dataset is preferable to limited data from which to review ecological impacts, large datasets require a range of logistical and sampling considerations. An effective methodology should be in place within the EMP to ensure that such considerations and available options are thoroughly reviewed in conjunction with equipment choice and layout before device deployment and data collections starts. The data collection plan must be appropriate and proportionate to the objectives set out in the monitoring plan with the amount of data required dependent on the objectives of the video monitoring. This then ensures that the collection of video data is suitable to meet the objectives specified in the EMP. The following recommendation is proposed to allow an effective and efficient collection of data for review:

Recommendation 23: Limit data recording to daylight hours if cameras don't have an effective low light or night-time functionality
If cameras do not have an effective low light or night-time functionality and if available daylight impedes on the quality of video data collected, only data that is fit for purpose should be collected to alleviate data management processes.

2.5 Recommendations for reporting – review and analysis

The review and analysis of data must be tailored to suit the objectives laid out in the planning and design stage of the environmental video monitoring programme. This stage must consider:

- An effective and consistent methodology for selecting what data to analyse; and
- An effective and consistent methodology for analysing data.

This will ensure that data is selected and analysed in an effective, consistent and scientifically robust manner.

2.5.1 Data preparation

Recommendation 24: Use Task 2 protocols[11] to isolate and refine data before analysis
This ensures that data reviewers' attention is strictly focused on the actual analysis of the data rather than concerned with the logistics of data organisation.

Recommendation 25: Integrate other available datasets to refine analysis
Integration of datasets such as AAM, PAM and telemetry (if available) help refine datasets to look at specific ecological impacts, such as near-field effects. Where feasible an integration of datasets to streamline analysis should be used.

Recommendation 26: Use algorithms, where possible, to speed analysis and reduce labour costs
Automated analysis techniques are in the process of being developed (Matzner *et al.*, 2017)[12] which can detect objects on video footage, enabling targeted portions of data to be manually looked at for potential interactions. This greatly decreases processing time compared to standard manual analysis techniques which can take tens to hundreds of hours (Broadhurst and Orme, 2014)[13]. It is recommended that these automated techniques are tested, with appropriate quality assurance checks to ensure all targets are being detected, whenever possible, to progress the standards of environmental monitoring of tidal turbines.

2.5.2 Data analysis

Recommendation 27: Conduct data analysis as soon as possible to allow data storage to be refined to useful footage
If data analysis is started as soon as feasible, this allows for a reduction in the costs and efforts associated with data storage.

Recommendation 28: Categorise environmental interactions within defined archetypes to simplify and speed data entry
The use of defined archetypes of environmental interactions not only increases the speed of analysis, but also simplifies its entry in data forms and allows easier comparison across divergent datasets. For example, selecting entries from a menu such as 'seal' and 'avoidance behaviour' saves time and simplifies the data entry. Datasets may be additionally categorised by device design e.g., position in the water column, size, power rating and by environmental variables such as current speed, water temperature and benthic substrate. This will help determine how tidal turbines interact

[11] Task 2 protocols establish a robust and consistent methodology with which to isolate samples and review video data effectively from large datasets.
[12] Matzner *et al.,* 2017. 'Triton : Igiugig Fish Video Analysis', (August). Available at: https://tethys.pnnl.gov/sites/default/files/publications/Triton-Igiugig-Report.pdf
[13] Broadhurst and Orme, 2014. 'Spatial and temporal benthic species assemblage responses with a deployed marine tidal energy device: A small scaled study', *Marine Environmental Research*. Elsevier, 99, 6–84. doi: 10.1016/j.marenvres.2014.03.012.

with their environment and creates a larger comparable dataset that will allow for predictions of future environmental impacts from proposed developments given set variables.

Recommendation 29: View 2-4 cameras' footage simultaneously, where feasible, to speed analysis

If automated video analysis is not possible, then up to 4 clips can be viewed simultaneously without creating a substantial detriment to accuracy, but beyond this, it is unlikely that quality analysis can be maintained. One possible iteration is that plans incorporate the use of a wide angle camera to provide a broad (but low quality, see recommendation 12) view of the rotor blades and initial analysis focuses on this footage, then, if possible interactions are observed, footage from narrow angle cameras (of higher quality but more specific range) are isolated to effectively review the interactions identified.

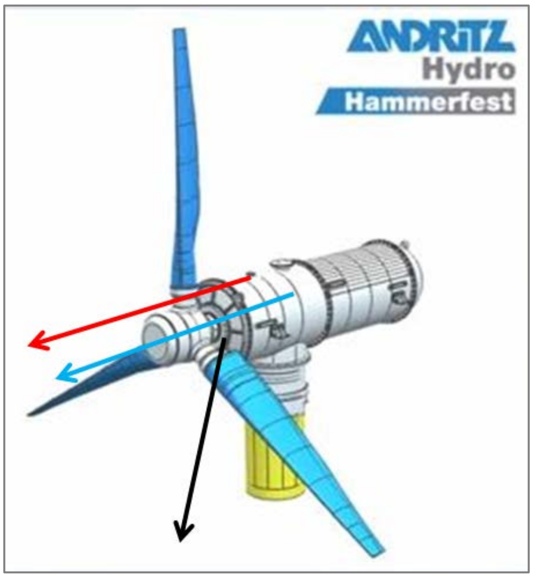

Figure 2.5. MeyGen turbine camera schematic

Recommendation 30: Ensure data reviewers are familiarised with camera layout and device schematics before analysis

To facilitate understanding of the footage which will be analysed, data reviewers should be familiar with the positioning of the cameras relative to the device. An integrated system of cameras adds complexity to the data which then needs to be accounted for if specific events are to be reviewed in more detail. Schematics should include not just where the cameras are placed but also indicate their direction (relative to the current), field of view and depth range with additional snapshots of footage (labelled to their relative camera) to illustrate the camera layout relative to the design of the device. Examples of appropriate schematics are provided in Figure 2.5 to the left and Figure 2.6 below:

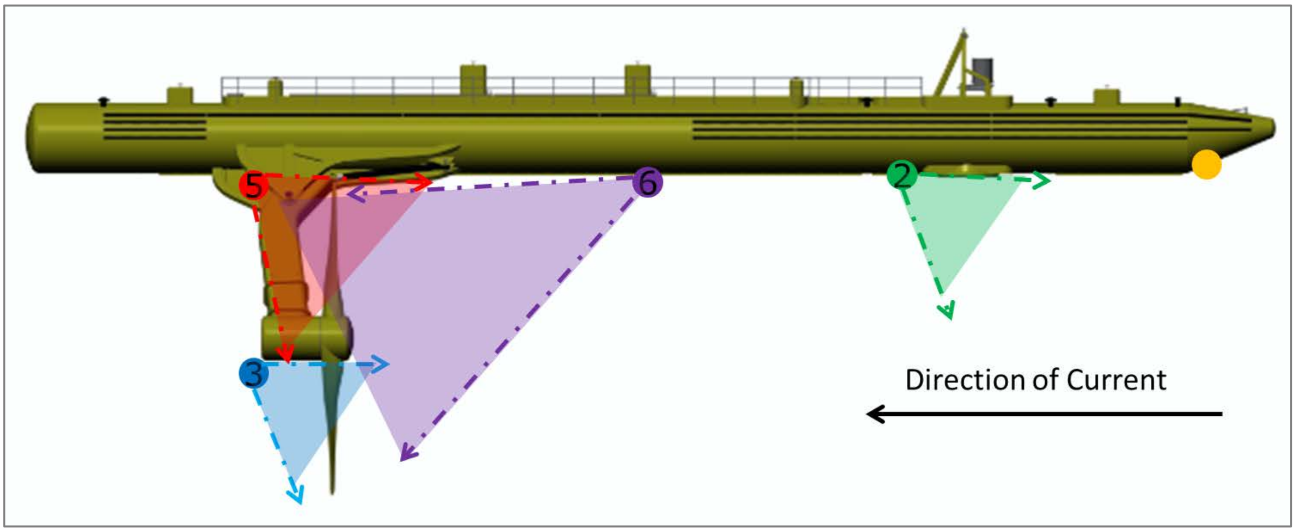

Figure 2.6. Scotrenewables SR2000 camera schematic

Recommendation 31: Ensure data reviewers have a trial period of 5 example clips per reviewer
A trial period helps to increase confidence, accuracy and consistency in analysis. From the study, 5 trial clips were found to be more than sufficient to familiarise reviewers with video data and ensure effective analysis.

Recommendation 32: Ensure independent analysis of clips followed by comparison and refinement of results to maintain accuracy
Independent analysis helps to increase confidence, accuracy and consistency but understandably there can be variation of analysis between reviewers. Collaborative input can help mitigate this.

Recommendation 33: Utilise a senior analyst to test accuracy of reviewers and act as an arbiter if necessary
A senior analyst conducting quality assurance checks of data analysis helps to increase confidence, accuracy and consistency in analysis. It also helps to ensure that analysis is effective and in-line with expert opinion.

Recommendation 34: Ensure data reviewers have regular breaks to ensure visual acuity and concentration is maintained
Data analysis can be a visually exhausting and monotonous procedure; as such, regular breaks for reviewers are needed to ensure that accuracy of analysis is maintained.

Recommendation 35: Investigate why cameras lose functionality (complete or partial) if this occurs, to inform future monitoring programmes
A review of faulty hardware should be conducted to inform future monitoring efforts. This can help determine where, and when, issues may occur and what needs to be done to increase effectiveness.

Recommendation 36: Review the approach used after all stages of the process have been completed to learn and disseminate lessons for future developments
A review of all future monitoring systems, will ensure that lessons learned can continue to inform the development of environmental monitoring techniques to help reduce scientific uncertainty, ultimately facilitating greater integration of marine renewables into international, national and regional energy portfolios.

2.6 Summary of recommendations

A table collating and summarising the recommendations listed in this report, Table 2.2, is provided below.

Table 2.2. Summary of Recommendations

Number	Recommendation
	Planning and design
1	Consult with appropriate regulatory bodies and their advisers to develop an effective Environmental Monitoring Plan (EMP)
2	Use High Definition (HD) cameras where possible
3	Use an on-board battery bank, where feasible, to power cameras
4	Use resilient power supply connections to connect cameras and localised storage
5	Use fibre optic cables, or on board storage (on the device) with online transmission capability to a local hard drive, where feasible
6	Use localised hard drive storage and a secondary backup to an online portal to allow remote access to data

7	Connect all cameras with a minimum of 16mbps bandwidth for data transfer
8	Favour black and white over colour to improve low light functionality*
9	Position cameras with consideration of the availability of natural light
10	Do not use artificial lights but consider their use specific to site conditions and device deployment
11	Place cameras on additional structures where feasible to optimise video coverage
12	Use a combination of wide and narrow angle cameras to effectively capture the full extent of the rotor swept area
13	Direct fields of view to capture the full extent of the rotor swept area and optimise camera choice and configuration to allow effective identification of species and interactions
14	Direct camera fields of view to capture an extent of the water column adjacent to blades to inform species' avoidance behaviour
15	Add a scale to the nacelle and / or turbine blades to aid video analysis
16	Place cameras facing into the current
17	Develop a cleaning schedule utilising maintenance windows to manage biofouling effects
18	Investigate the effectiveness of new technologies for biofouling management such as:
18a	Test wipers on cameras to periodically remove biofouling
18b	Test coating camera lenses in translucent anti-fouling paint
18c	Test placing ultraviolet LEDs adjacent to cameras to reduce biofouling through the use of UV radiation
19	Time stamp all data
20	Use a standardised and non-propriety data format with consistent frame rate (e.g. .mkv) for all video data
21	Store all data in hour long clips
Data collection	
22	Test camera functionality prior to installation on device and device deployment on site
23	Limit data recording to daylight hours if cameras don't have an effective low light or night-time functionality
Review and analysis	
24	Use Task 2 protocols to isolate and refine data before analysis
25	Integrate other available datasets to refine analysis
26	Use algorithms, where possible, to speed analysis and reduce labour costs
27	Conduct data analysis as soon as possible to allow data storage to be refined to useful footage
28	Categorise environmental interactions within defined archetypes to simplify and speed data entry
29	View 2-4 cameras' footage simultaneously, where feasible, to speed analysis
30	Ensure data reviewers are familiarised with camera layout and device schematics before analysis
31	Ensure data reviewers have a trial period of 5 example clips per reviewer
32	Ensure independent analysis of clips followed by comparison and refinement of results to maintain accuracy
33	Utilise a senior analyst to test accuracy of reviewers and act as an arbiter if necessary
34	Ensure data reviewers have regular breaks to ensure visual acuity and concentration is maintained

35	Investigate why cameras lose functionality (complete or partial) if this occurs, to inform future monitoring programmes
36	Review the approach used after all stages of the process have been completed to learn and disseminate lessons for future developments

*Note the addition of colour to camera functionality may facilitate the identification of passing objects / species, but not in conditions of low light and increased turbidity.

3. REVIEW AND ANALYSIS OF EXISTING UNDERWATER VIDEO DATA TO ESTABLISH WHAT CAN BE LEARNED REGARDING NEAR-FIELD BEHAVIOUR

3.1 Introduction

This section presents the results of Task 4. Full reports on the results of the analysis of each underwater video dataset are compiled in Annex 2.

The specific aim of Task 4 was to review and analyse existing underwater video data collected around operating tidal turbines to establish what can be learned regarding near-field behaviour of marine wildlife around tidal stream turbines from these datasets.

3.2 Approach

Datasets collected from the following tidal stream developments were analysed during Task 4:

- SIMEC Atlantis – MeyGen Tidal Array deployment at the Pentland Firth;
- Scotrenewables – SR2000 deployment at EMEC; and
- Voith Hydro – HyTide deployment at EMEC.

Samples from each dataset were analysed using Protocol 2 (Environmental analysis of underwater video data) which was developed during Task 2 (refer to Section 1.3), and is available via the wave and tidal energy page of the NatureScot website and, following publication of this report, the ORJIP Ocean Energy website.

It should be noted that the suitability of each dataset for further analysis was determined in relation to its ability to reduce scientific uncertainty regarding ecological receptor behaviour around operating tidal turbines via manual visual analysis of pre-selected samples only. It is highly possible that more useful data and information could be gained from each dataset via other means of analysis such as automated image analysis techniques, which are outwith the scope of this project.

3.3 Summary of results

A total of 128 two-minute samples were reviewed and analysed during Task 4. Typically, these represented the first two minutes in each hour of available data for the tidal stream developments concerned, over specified time periods (see Annex 1 for further details). Only 28 of these samples contained receptor observations, with the remaining 100 out of 128 two-minute samples showing no wildlife. These observations are summarised below in Table 3.1; further details are provided in Annex 1:

Table 3.1. Summary of near-field receptor observations from all datasets

Turbine status	Receptor	Observation	Number of receptors	Number of events	Dataset*
Two-minute samples which contained receptor observations					
Operational	Fish (possibly flatfish)	Moving with / against current through turbine blades	1	1	MeyGen
Operational	Unclear	Moving with current	1	1	Scotrenewables
Operational	Unclear	Moving with current	1	1	Scotrenewables
Operational	Unclear (possibly bird)	Moving with current (upwards between legs)	1	4	Scotrenewables

Operational	Unclear	Moving with current (upwards between legs)	1	2	Scotrenewables
Operational	Unclear	Moving across current (between legs towards portside)	1	1	Scotrenewables
Operational	Fish	Moving across current	1	1	Voith
Operational	Bird	Moving across current	1	1	Voith
Operational	Bird	Moving across current	1	1	Voith
Operational	Bird (possible auk)	Moving with current towards blades	1	1	Voith
Non-operational	Unclear (possibly bird)	Moving with current	1	1	Scotrenewables
Non-operational	Unclear (possibly jellyfish)	Moving with current	1	1	Scotrenewables
Non-operational	Unclear	Moving with current	1	1	Scotrenewables
Non-operational	Fish	Passing nacelle in slack water	1	1	Voith
Non-operational	Fish	Passing nacelle	1	1	Voith
Non-operational	Fish	Investigating nacelle and cameras, possibly feeding	12	1	Voith
Non-operational	Fish	Investigating nacelle and cameras, possibly feeding	7	1	Voith
Non-operational	Fish	Feeding off nacelle	1	1	Voith
Non-operational	Fish	Moving against current	3	1	Voith
Non-operational	Fish	Moving against current	1	1	Voith
Non-operational	Fish	Shoaling around camera / turbine – possible fish aggregating device effect	20	1	Voith
Non-operational	Fish	Shoaling around camera / turbine – possible fish aggregating device effect	30	1	Voith
Non-operational	Fish	Feeding off nacelle	2	1	Voith
Non-operational	Bird (possible auk)	Moving with current	1	1	Voith
			Total	**28**	
Two-minute samples which did not contain receptor observations					
Operational	No wildlife	No observations	0	63	Combined
Non-operational	No wildlife	No observations	0	37	Combined
			Total	**100**	

* Details of wildlife observations for each individual dataset are presented in Annex 2.

3.4 Key findings

The suitability of datasets analysed during Task 4 for investigating near-field behaviour varied; most observations were made during the review of data from the Voith Hydro HyTide dataset.

It is important to note the significant range in the quality of data and therefore the ability to ascertain near-field behaviour from the manual analysis of underwater video. An example of a marine wildlife interaction with a tidal turbine, which was less clearly defined, is presented below in Figure 3.1:

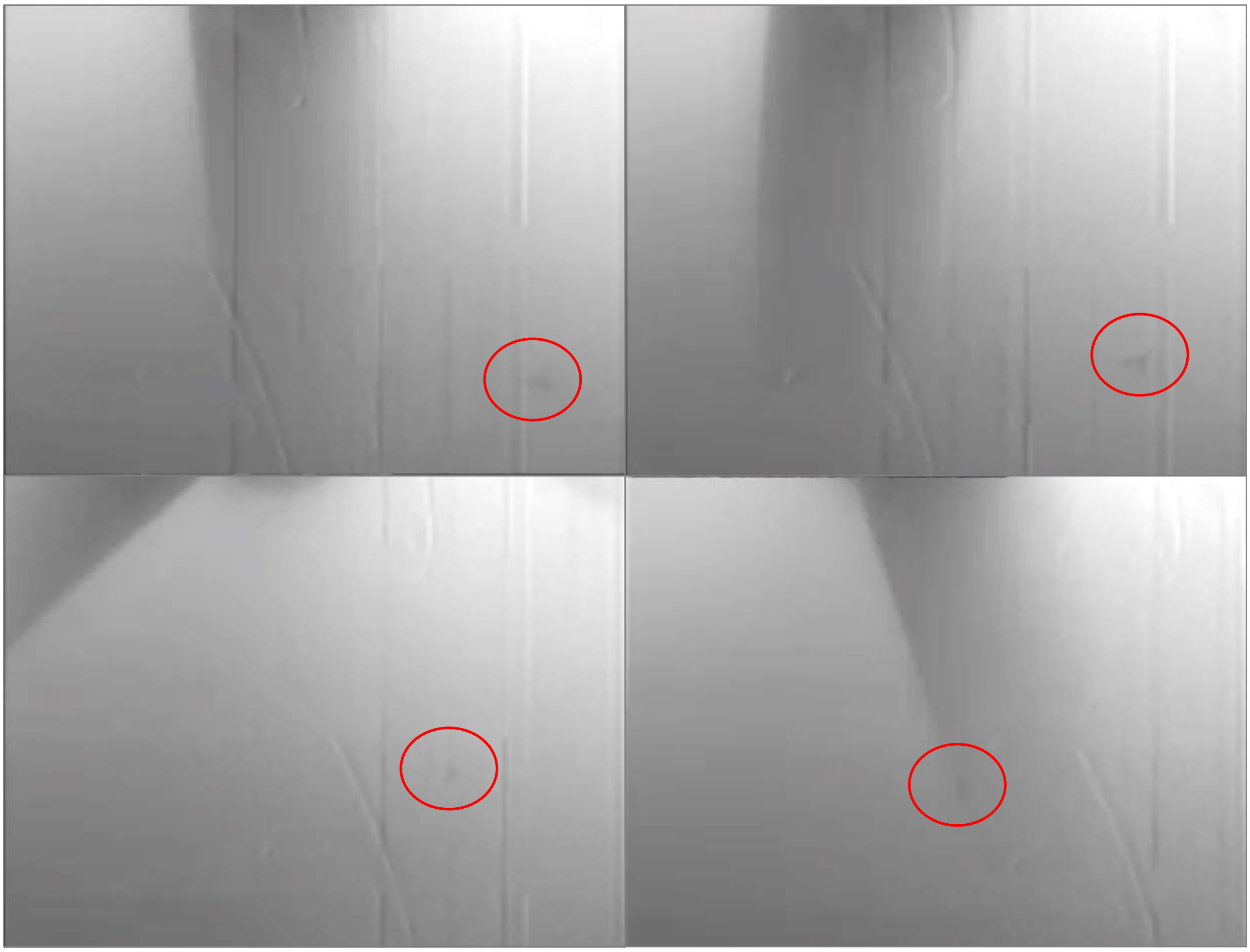

Figure 3.1. Sequential frames (top row first and left to right) of a marine wildlife interaction (circled in red) with a tidal turbine.

The frames illustrate what is believed to be a bird (possibly an auk) approaching the blades and then changing direction to avoid a collision. The frames also demonstrate the difficulty in categorising environmental interactions from underwater video monitoring. As such, the analysis of categorised data should take this into consideration to ensure that limitations in the data are understood and do not lead to inaccurate conclusions.

A comparatively clearer example of a marine wildlife interaction from the same dataset is presented below in Figure 3.2:

Figure 3.2. Clear observation of marine wildlife interactions with a non-operational turbine (Voith Hydro HyTide).

The frames demonstrate the shoaling of fish near the camera while the turbine is non-operational. The frames also demonstrate the differences in confidence of accurately identifying and categorising marine wildlife interactions due to distance from the camera; fish immediately adjacent to the camera are clear whilst those further back are less clearly defined.

Accounting for such variability, a number of environmental observations were made during the review:

- From 128 samples analysed, reviewers detected wildlife in only 28 samples;
- At current speeds of 0.8 m/s and below, certain fish behaviours were observed which included passing the nacelle, investigating the nacelle, or feeding off the nacelle, and shoaling around the device within the camera's field of view. Turbines were static during each of the eight observation events made at 0.8 m/s and below (this may be due to the turbine being non-operational or the current being below the necessary 'cut-in speed'). These observations demonstrate fish acclimation behaviour and FAD effects;
- As current speed increased higher than 0.9 m/s, fish and birds were more frequently observed to move with or across the current. The turbine was operational during fifteen out of the 20 observation events made at 0.9 m/s and above;
    - At maximum observed current speeds of 2.7 – 2.9 m/s, all receptors were noted to move with the current;
    - Birds were more likely to be observed in greater current velocities between 1.2 – 2.9 m/s. Six out of eight of observations of birds within this current range were made during operational periods; and
- No collision events were observed in any of the samples reviewed.

4. CONCLUSIONS AND NEXT STEPS

4.1 Conclusions

Based on the analysis of suitable and available underwater video data analysed during Task 4, to date, underwater video monitoring appears to have been designed and implemented to provide technical and performance data regarding the turbine systems, rather than to gather data on near-field wildlife behaviour around operational turbines and other environmental interactions (refer to Section 2 for more details).

Wildlife were not observed in the majority of the samples reviewed. Whilst this may be attributed to the quality of data, given that wildlife observations were recorded in ~22% of the samples reviewed, it seems more likely that wildlife were simply not present in the majority of the samples.

At current speeds of 0.8 m/s and below, certain fish behaviours were observed which included passing the nacelle, investigating the nacelle, or feeding off the nacelle, and shoaling around the device within the camera's field of view. These observations show fish acclimation behaviour and FAD effects. As current speed increased higher than 0.9 m/s, fish and birds were more frequently observed to move with or across the current. Birds were more commonly observed in greater current velocities of around 1.2 – 2.9 m/s. No collision events were observed in any of the samples reviewed.

The amount of time and resources required to manually review these data with a robust scientific methodology is extensive. In addition, the suitability of the data from the MeyGen and Scotrenewables datasets for manual environmental analysis restricted definitive identification of wildlife and the analysis of near-field behaviour; it is therefore concluded that further manual analysis of these datasets will not help to further reduce scientific uncertainty regarding the potential environmental interactions between marine wildlife and operational tidal turbines. It is, however, felt that further information regarding near-field behaviour could be gained from data collected around the Voith Hydro HyTide turbine installed at EMEC. It is hoped that this analysis can be undertaken at a future date when suitable resources are available.

Future monitoring methods will need to be developed regardless given the need and progress of the marine renewable sector, to ensure the sustainable development of these resources. At present, it is unclear whether future underwater video monitoring efforts would be more effective in understanding environmental impacts of tidal turbines with the recommendations presented in this report. If future research could ascertain the proportion of near-field behaviour relative to non-events, which would also be site specific, a more efficient use of resources would then be to focus analysis (possibly with the integration of other data capture methods) on data capturing near-field behaviour. Then following this analysis, and with higher quality data suited to the purposes of environmental monitoring, this would then allow a more informed opinion on the ability (or inability) of marine wildlife to avoid and evade tidal turbines, which is the key issue for the consenting process. If definitive evidence surrounding this issue is captured, this would allow for substantial reductions in the required amount of data capture and analysis to suit the requirements of environmental monitoring.

An overview of the factors that should be considered during the development of future monitoring plans and research proposals is provided in Table 4.1.

Table 4.1. Summary of overarching recommendations for future monitoring plans

Factor	Overarching recommendations
Aims and objectives	All future monitoring programmes should set out clear aims and objectives which are designed to reduce scientific uncertainty around priority issues, such as those set out in the Offshore Renewable Energy Joint Industry Programme (ORJIP) for Ocean Energy's 'Forward Look'[14].
Required outputs and anticipated impact	A clear set of outputs that will be generated from the monitoring programme should be defined and agreed with key stakeholders along with the anticipated impact of each output on either the consenting process, future monitoring projects or on the evidence base.
Approach and methodology	A clear approach and methodology for delivering the monitoring programme should be set out which is informed by best practice and the best available scientific data and information. This should include a 'project integration plan' which details how the monitoring programme will be integrated into the marine energy development (where relevant). This should be developed with the project developer or a suitable alternative.
Baseline data required (specify purpose)	Any baseline data requirements should be clearly defined and justified i.e. an explanation provided as to why the baseline data is required for the successful delivery of the monitoring programme output / impact.
Equipment and software	An inventory of equipment / software required for the successful delivery of the programme should be provided, along with an overview of the track record of the application of each within the context of the monitoring programme e.g. its use in high energy marine environments.
Reporting	A clear and realistic reporting programme should be set out for the programme. This should be developed in consultation with key stakeholders.
Data management plan	A data management plan should be produced for each programme, with details on how collected data will be stored, processed and transmitted to end users. This should include a risk assessment regarding each stage of the programme i.e. collection, pre-processing, storage, transfer, subsequent storage in-house etc.
Expert / technical support	Experts or technical support required at each stage of the programme should be identified along with any perceived gaps in the team.
Candidate project(s) / locations	Where a location / project / development for implementing the monitoring programme has not been defined, suitable options should be identified.
Data transferability	The 'transferability' of each output of the programme should be considered and outlined e.g. transfer of results to other locations/jurisdictions.
Timescales and budget	Project programme and budget should be provided.
Risk assessment	A robust and transparent risk assessment should be provided including; technical, health and safety, financial, schedule and administrative. This should identify the key challenges associated with delivering the programme and present a clear mitigation and management strategy for each.
Ongoing relevant research	A list / overview of other relevant ongoing research programmes should be provided.
Knowledge transfer plan	A knowledge transfer and project dissemination plan should be provided which clearly sets out how the outputs will be transferred to a set of defined end users to ensure that the programme has the intended impact(s).

[14] http://www.orjip.org.uk/sites/default/files/ORJIP%20Ocean%20Energy%20Forward%20Look%203%20FINAL.pdf

4.2 Next steps

It is important that the development of any future underwater video monitoring or data gathering activities is informed by the recommendations provided in Section 2 of this report. It is recommended that these be promoted by regulators and statutory advisors to developers during the consenting process and through consultation.

Suitable underwater video data collected around tidal turbines should also be reviewed using the protocols developed during this project. This will ensure a consistent approach is applied across the industry, allowing strategic and coordinated appraisals to be undertaken regarding the evidence base available, and thus better informing consenting and planning decisions.

It is recommended, where appropriate, that high quality underwater video data be collected around operating tidal turbines as the data provide a unique opportunity to better understand near-field behaviour of marine wildlife around operating turbines. It should be noted however, that manual analysis of such data is extremely time consuming and expensive. It is therefore essential that progress is made in the development of suitable software and processes to automate future underwater video data analysis.

Subsequent to the data analysis completed during this study, Aquatera has been provided with new underwater video data collected from a number of deployments around the world. The monitoring systems implemented at these sites were designed to investigate near-field behaviour around the respective turbines and have yielded high quality video data which when reviewed / analysed, will help increase our understanding, and bolster the supporting evidence base, regarding wildlife interactions with operating tidal turbines. It is recommended that these datasets, along with other available high quality datasets that become available, are reviewed using the protocols developed during this project at the earliest opportunity. Opportunities for facilitating this process are currently being pursued by Aquatera. Such analysis will help inform future consenting decisions, impact assessments, strategic planning activities and the development of future monitoring and research plans.

ANNEX 1 – TASK 3, THE REVIEW OF EFFECTIVENESS OF UNDERWATER VIDEO MONITORING TECHNIQUES, EQUIPMENT AND PROCESSES TO DATE

This annex can be downloaded from the NatureScot website as a separate document.

ANNEX 2 – TASK 4, THE REVIEW AND ANALYSIS OF EXISTING UNDERWATER VIDEO DATA TO ESTABLISH WHAT CAN BE LEARNED REGARDING NEAR-FIELD BEHAVIOUR

This annex can be downloaded from the NatureScot website as a separate document.

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