Review of underwater video data collected around operating tidal stream turbines

Metadata catalogue

Version 6

Report to Scottish Natural Heritage

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1 INTRODUCTION

Aquatera Ltd and its project partners OceanPixel are undertaking a programme of work with the aim to review underwater video monitoring data collected around operational tidal energy projects to date, in order to establish what data exists 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.

The review of existing underwater video monitoring data involves the following tasks:

- Task 1 – Identification and collation of existing data
- Task 2 – Establishment of protocols for analysing underwater video data
- Task 3 – Assessment of the effectiveness of techniques, equipment and processes to date
- Task 4 – Review and analysis of existing data to establish what can be learned regarding near-field behaviour
- Task 5 – Determining what data are required from future monitoring and data gathering activities to address key consenting issues

This report provides the outputs of Task 1 – Identification and collation of existing data. The aim of this report is to provide the first comprehensive global metadata catalogue of available environmental impact monitoring data gathered around operational tidal current turbines. This report will be updated as future monitoring data becomes available.

1.1 REPORT STRUCTURE

This report contains the following:

- Section 1: Introduction and background to the project
- Section 2: Metadata catalogue – past and ongoing projects with data collection including video
- Section 3: Metadata catalogue – other past and ongoing projects (without video)

1.2 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 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. 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[1].

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.

1.2.1 The challenge

Monitoring will 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 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-consent/permit monitoring studies that will ensure that data gathered are fit for their intended purpose[1].

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[1]. 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[2]'. 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.

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[1] Hutchison, I. and A. 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

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

1.2.2 Objectives of this project

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

- Establishing what environmental impact monitoring data exists from past and ongoing tidal current 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 marine wildlife around tidal turbines;
- 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 PURPOSE OF THIS REPORT

This metadata catalogue serves as a resource for researchers, regulators, academics, consultants and developers to identify datasets that have been gathered during past and ongoing projects. This will encourage revisions and improvements to future data collection and monitoring studies, ensuring data gathered are fit for their intended purpose. The metadata catalogue includes project-specific details for each available dataset and a comprehensive description of all aspects of the video data. While this project has a particular focus on underwater video data, it was considered beneficial to identify and catalogue knowledge of any other datasets gathered during these deployments (e.g. hydrophone, sonar, strain gauge, ADCP data) as these may feed into future phases of the project. Therefore, a description of these other datasets has been included where appropriate.

1.4 APPROACH

Information was sought from tidal stream energy developers with developments where underwater video was known to have been gathered. This version of the metadata catalogue is a 'live' document which provides the most comprehensive catalogue of available underwater video datasets that have been collected globally. Work is ongoing to maintain dialogue with developers and to help contextualise the project and demonstrate the potential for industry-wide value to be achieved. The metadata catalogue should be considered as a working document that can be updated as and when new information/data from new or existing projects becomes available.

Where data have not been provided by developers, publically available information has been used.

This version of the metadata catalogue includes the following projects where video data were collected (those marked * indicate where information and data have been provided by the relevant developers):

- MeyGen Tidal Array deployment at Pentland Firth (Section 2.1)*;
- OpenHydro 250 kW deployment at EMEC (Section 2.2)*;
- Ocean Renewable Power Company's (ORPC) RivGen deployment in the Kvichak River, Alaska (Section 2.3);
- SABELLA D10 deployment at Fromveur Passage, France (Section 2.4)*;
- Orbital Marine Power (formerly Scotrenewables) SR250 deployment at EMEC (Section 2.5)*;
- Orbital Marine Power (formerly Scotrenewables) SR2000 deployment at EMEC (Section 2.6)*;
- Sustainable Marine Energy (SME) PLAT-I at Grand Passage, Nova Scotia, Canada (Section 2.7)*; and
- Voith HyTide deployment at the European Marine Energy Centre (EMEC) (Section 2.8).

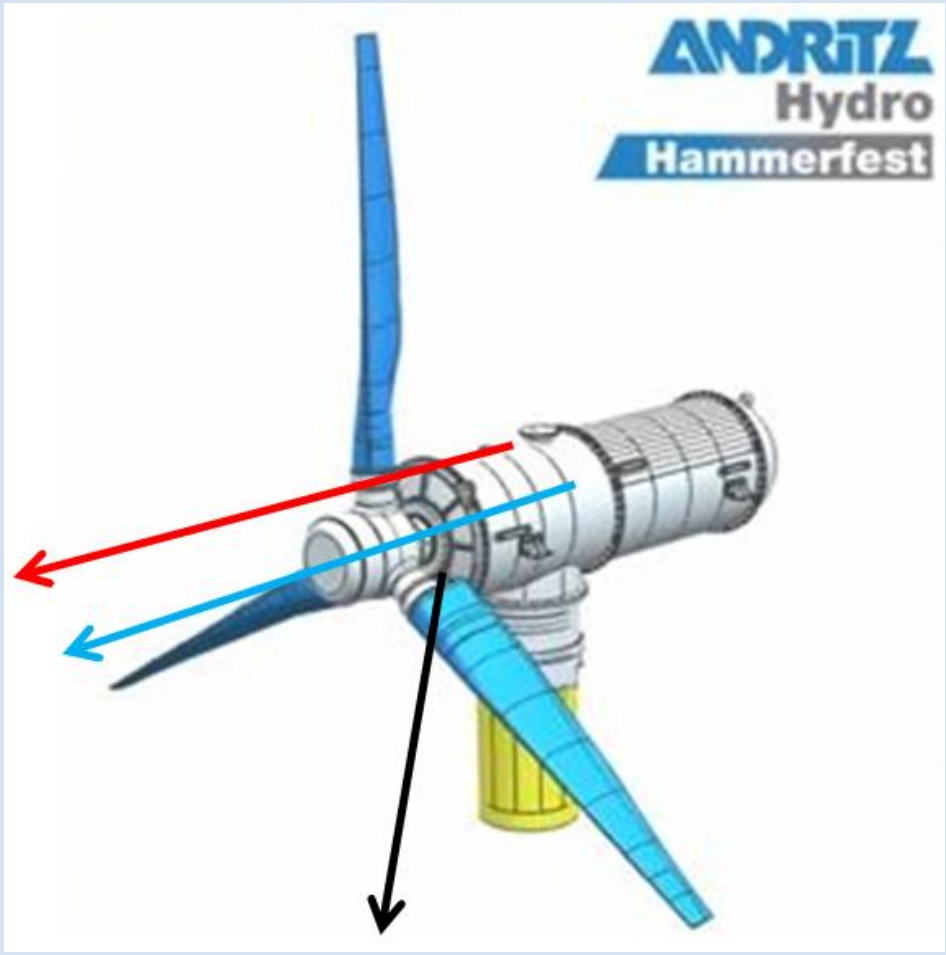
While the number of tidal stream energy projects that gathered underwater video data is relatively limited, there have been a number of projects that gathered other environmental monitoring data. For example, sonar, visual observations, acoustic outputs of the device, harbour seal telemetry etc., during various phases of deployment. The majority of these datasets are not available in their raw format, however where links to or contacts to obtain raw data are not available, reports which describe and evaluate these datasets have been referenced in Section 3. Datasets which cover at least the operational phase of deployments have been prioritised. Where only baseline data were gathered this has not been included as it has limited potential to help meet the project objectives.

2 METADATA CATALOGUE – EXISTING AND ONGOING VIDEO MONITORING

2.1 MEYGEN TIDAL ARRAY DEPLOYMENT AT PENTLAND FIRTH, SCOTLAND

Table 2.1 MeyGen Tidal Array, Pentland Firth (Scotland) deployment

Project Details	
Project name	MeyGen
Project location (site name, region, country)	Pentland Firth, Scotland
Developer name	MeyGen Limited
Project description	6MW tidal stream array. Three 1.5MW Andritz Hydro Hammerfest (AHH) HS1500 turbines and one 1.5 MW Atlantis Resources AR1500 turbine
Date of installation	October 2016 – gravity based support structures deployed first
Underwater video monitoring data	
Was underwater video or stills data gathered as part of the environmental monitoring for this development?	Video data are gathered from multiple cameras on each turbine.
Project details (**as present at time the video monitoring took place** (i.e. technology type, number of devices, etc.)	Three 1.5MW, 18m diameter, Andritz Hydro Hammerfest (AHH) gravity based tidal stream devices. Turbine 2 only has two out of three cameras operational. One Atlantis AR1500 turbine.
Aims/objectives of underwater video data collection	To inform on blade condition and environmental monitoring
Is a Project Environmental Management Plan (PEMP) or Monitoring Plan available that provides information on the monitoring undertaken/proposed? If yes, please provide file or link to access document.	Yes https://www2.gov.scot/Resource/0050/00509795.pdf
Make and model of underwater video camera(s) used	Seacam Ultra Wide Angle Monochrome UV camera on AHH Turbines

Number and location of underwater video camera(s) (if possible, please provide a diagram)	Three cameras per turbine, the cameras are mounted on the nacelle just behind the hub and positioned at 120° around the nacelle to capture 360° view of the turbine rotor.  **Figure 2.1 Schematic of MeyGen Andritz Hydro Hammerfest turbine with red, blue and black lines depicting camera placement and view direction**
Field of view of underwater video camera(s)	Limited field of vision of the cameras each camera seeing approximately a 3m x 3m square.
Any lighting?	No

Software used (if yes, please provide details)	No
Format of data (if known), e.g. file type – (.mkv, etc.) and time interval of data within each file	.mkv Each file holds 5-minutes of data
Timing of data collection (start date, end date)	First information generated in February 2017. The cameras will be generating and storing data continuously as the turbines are deployed and operational.
Is video data time-stamped?	Yes
Any further details of frequency of occurrence of data collection (e.g. continuous, intermittent periods, if intermittent, was there any trigger mechanism for recording data?)	Continuous collection if electrical power is on.
Operational status of device during video data collection i.e. non-operational (static), operational (producing electricity), free-spinning (turbine spinning, but not producing electricity) or a combination of the above.	Operational
Estimate of available video data (hours or days), at the time of writing	As of 26/9/2017 there are around five months of data (divided between the three AHH turbines), i.e. 3600 hours divided between each turbine.
Is data anticipated to continually be collected? If so, please estimate how many hours of data per day, for the whole project	72 hours for the three AHH turbines and 24 hours for the Atlantis turbine. Dependent upon deployment and operational status.
Any known issues or problems with data collection?	Each AHH turbine produces 1TB per month, however it is not yet apparent what proportion of this is video data.
Approximate cost of data collection	TBC
Data analysis	
Has any data analysis of this underwater video or stills data been carried out to date? If yes, please provide details or link(s) to monitoring reports, published papers, etc.	No

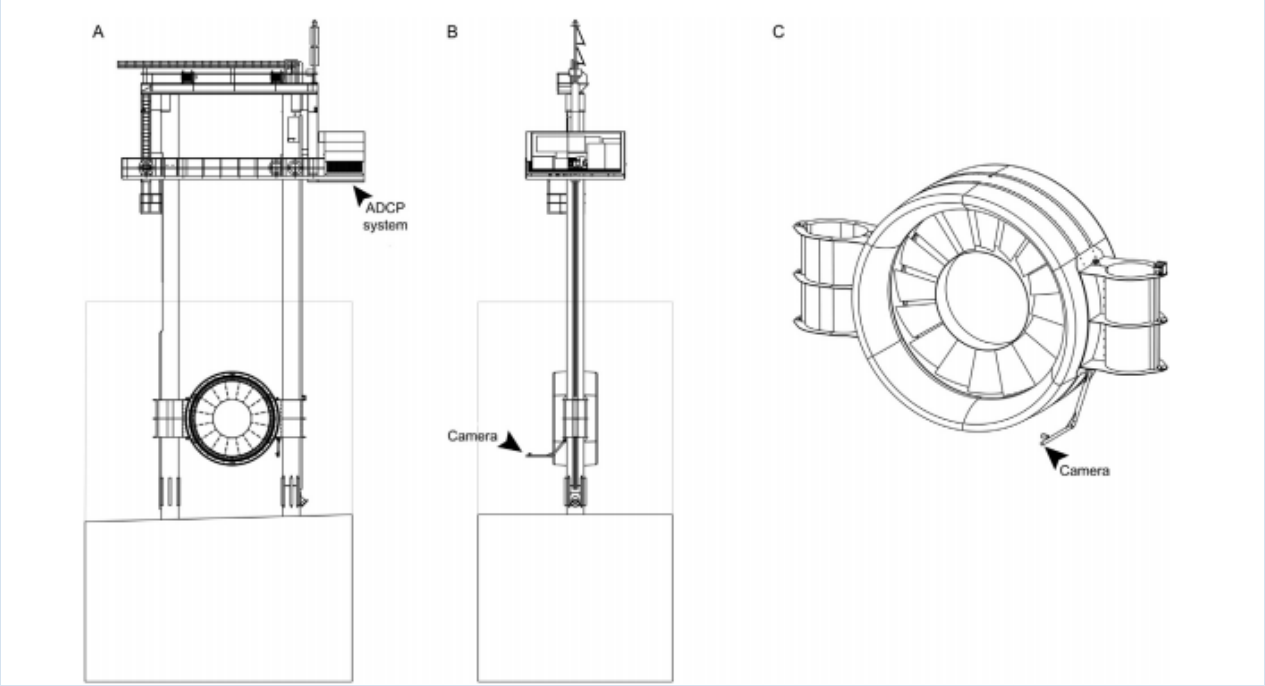
Is there any data analysis currently underway? If yes, please provide a brief summary and the anticipated date of reporting.	No
Data access	
Is the underwater video data described above, available for use for this project?	Yes
Owner of data (organisation, named contact, contact details)	Cara Donovan, Environment & Consent Manager
Access to data - URL or hard drive(s)	Data can be made available to the project via hard drives sent directly to MeyGen. Data could also be made available online via a cloud system.
Approximate memory size of data (if known)	Each turbine produces around 1TB of data per month, it is unclear how much of this data is video data.
Any other data collection systems undertaken alongside video monitoring that in future could help interpretation of the video data? (If yes, please provide details)	
Sonar/acoustic monitoring systems	No, however it is planned to install a dual horizontally stacked Tritech Gemini multibeam sonar, on the High Current Underwater Platform (HiCUP) on the north east side of the Atlantis turbine. Additionally, an EK60 multi frequency echosounder will be housed in the FLOWBEC platform which will placed in front of the Atlantis turbine on ebb tide and in its wake on flood tide.
ADCPs, if yes how many	Three turbines have a horizontally mounted ADCP in the nose cone and one additional turbine has one ADCP vertically mounted on the nacelle
Passive Acoustic Monitoring equipment	No
Strain gauges	Yes, one strain gauge in one blade of each turbine
Other	No
Is there any integration of these data collection systems? If yes, please provide details.	No

Any other comments
Foundation-mounted video monitoring data from the Atlantis Turbine which is being collected as part of Scottish Government Demonstration Strategy (SGDS) should become available through SMRU and Aberdeen University following its redeployment later in 2017. This data will be integrated with the FLOWBEC and HiCUP platforms. Video data from the SGDS will be streamed ashore to the control station at Ness of Quoys with data being stored locally on Digital Video Recorder (DVR). Data will be periodically collected and any times of detections from the other systems (PAM and sonar) will be checked on the video.

2.2 OPENHYDRO 250 KW PROTOYPE DEVICE DEPLOYMENT AT EMEC

Table 2.2 OpenHydro 250 kW, EMEC deployment

Project Details	
Project name	OpenHydro - EMEC
Project location (site name, region, country)	Fall of Warness, Orkney, Scotland
Developer name	OpenHydro
Project description	Deployment of a single 250 kW prototype OpenHydro open centre horizontal-axis turbine
Date of installation	Summer 2006
Underwater video monitoring data	
Was underwater video or stills data gathered as part of the environmental monitoring for this development?	Yes
Project details (**as present at time the video monitoring took place** (i.e. technology type, number of devices, etc.)	Testing of OpenHydro's prototype 250 kW 6 m diameter open centre horizontal axis turbine which was fixed to the seabed by a dual monopile structure.
Aims/objectives of underwater video data collection	To monitor the ecological interactions around a tidal turbine
Is a Project Environmental Management Plan (PEMP) or Monitoring Plan available that provides information on the monitoring undertaken/proposed? If yes, please provide file or link to access document.	No
Make and model of underwater video camera(s) used	The underwater footage was recorded using a video Triplex 8 Channel DVR, linked to a Submertec Camera System mounted to the outside of the OpenHydro Ltd platform device (see Figure 2.2).

Number and location of underwater video camera(s) (if possible, please provide a diagram)	The camera system was mounted approximately 2 m from the face of the turbine allowing continuous recording of the entire 6 m turbine area (see Figure 2.2).  **Figure 2.2 Schematic of OpenHydro turbine with camera and ADCP setup. Front view (A), side view (B) and close view (C) (Broadhurst, Barr and Orme, 2014)**
Field of view of underwater video camera(s)	The entire 6 m turbine area is visible
Any lighting?	No, but the device was sited in relatively shallow water (approximately 11 m deep) and because of the long summer days experienced at these latitudes when the video data was being recorded, the data is able to be analysed over the full 24 hour period.
Software used (if yes, please provide details)	The video footage was collected manually after the full trial period each year and transferred to a compatible video computer Programmable Logic Controller (PLC) software system.
Format of data (if known), e.g. file type – (.mkv, etc.) and time interval of data within each file	TBC

Timing of data collection (start date, end date)	June-July 2009 and June 2010 each data collection campaign gathered data for 15 days resulting in a total of 30 days of video data.
Is video data time-stamped?	TBC
Any further details of frequency of occurrence of data collection (e.g. continuous, intermittent periods, if intermittent, was there any trigger mechanism for recording data?)	Continuous during the data collection periods
Operational status of device during video data collection i.e. non-operational (static), operational (producing electricity), free-spinning (turbine spinning, but not producing electricity) or a combination of the above.	Operational and non-operational
Estimate of available video data (hours or days), at the time of writing	261 hours for the 2009/2010 trial period, however total quantity of data to be confirmed
Is data anticipated to continually be collected? If so, please estimate how many hours of data per day, for the whole project	No
Any known issues or problems with data collection?	The 2010 trial lost nine days of video footage after day seven. This was due to a weak cable link between the recording device and the camera. The fault was identified during the survey and fixed straight away, with the survey extending for a further nine days to account for the missing data. It is noted that some of the footage may need to be excluded where weather conditions affect the quality of the data and where the field of view is obscured by marine algae debris.
Approximate cost of data collection	TBC
Data analysis	
Has any data analysis of this underwater video or stills data been carried out to date? If yes, please provide details or link(s) to monitoring reports, published papers, etc.	Yes, see Broadhurst, Barr and Orme (2014).
Is there any data analysis currently underway? If yes, please provide a brief summary and the anticipated date of reporting.	No

Data access	
Is up to one months' worth of underwater video data described above, available for use for this project?	Yes. OpenHydro have expressed support for the project as they view it as having the potential to reduce regulatory burden and move forward environmental monitoring of tidal technology. OpenHydro are actively developing projects globally and have a number of data sources, coupled with a requirement to understand how monitoring can be made more efficient, reducing time, risk and cost to projects and the environment.
Owner of data (organisation, named contact, contact details)	OpenHydro, Sue Barr, Sue.barr@openhydro.com
Access to data - URL or hard drive(s)	Hard drive
Approximate memory size of data (if known)	TBC
Any other data collection systems undertaken alongside video monitoring that in future could help interpretation of the video data? (If yes, please provide details)	
Sonar/acoustic monitoring systems	No
ADCPs	Yes, a Nortek Aquadopp two beam ADCP was deployed at the platform in order to measure the horizontal tidal current flow around the turbine and through the Fall of Warness over a 24 h cycle. The two beams were deployed either side of the platform to measure flow on flood (North) and ebb (South) tides. (see Figure 2.2)
Passive Acoustic Monitoring equipment	No
Strain gauges	No
Other	No
Is there any integration of these data collection systems? If yes, please provide details.	N/A
Any other comments	

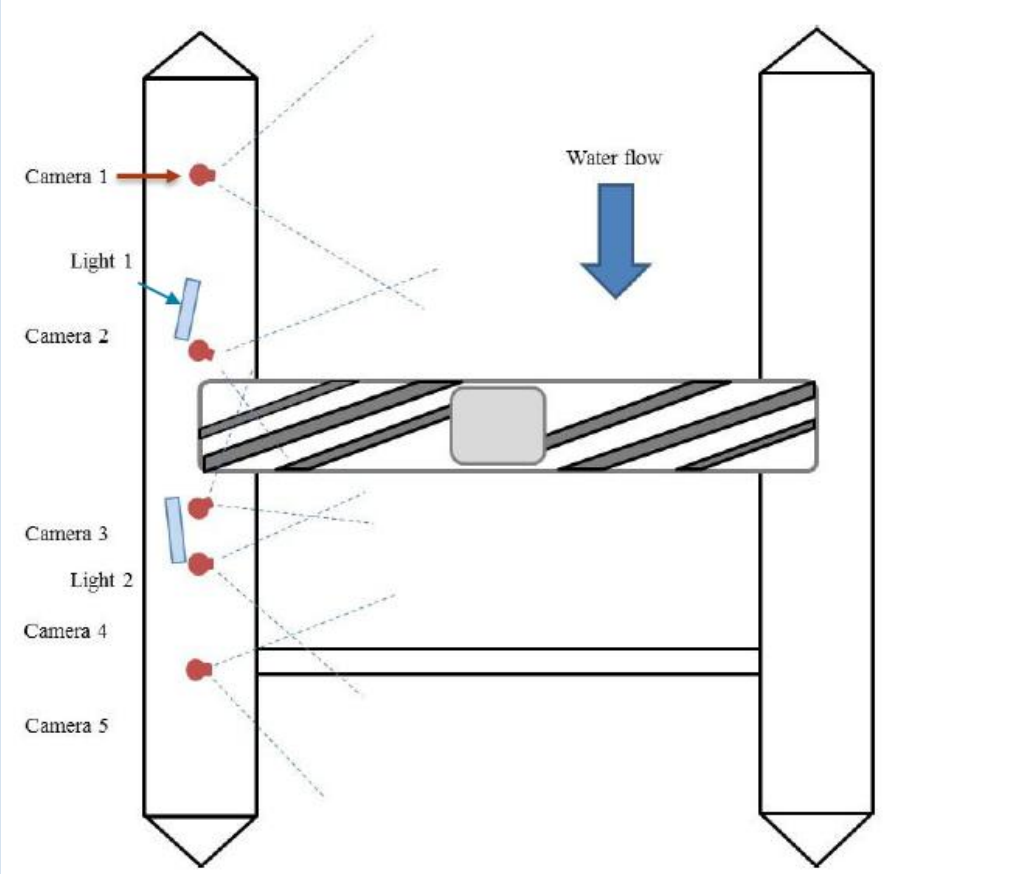
References

Broadhurst, M. and Orme, C. D. L. (2014) 'Spatial and temporal benthic species assemblage responses with a deployed marine tidal energy device: A small scaled study', Marine Environmental Research. Elsevier, 99, pp. 76–84. doi: 10.1016/j.marenvres.2014.03.012.

2.3 OCEAN RENEWABLE POWER COMPANY (ORPC) RIVGEN DEPLOYMENT AT KVICHAK RIVER, ALASKA

Table 2.3 ORPC RivGen, Kvichak River (Alaska) deployment

Project Details	
Project name	RivGen device – Kvichak River
Project location (site name, region, country)	Kvichak River, Igiugig Village, Alaska, United States
Developer name	Ocean Renewable Power Company (ORPC)
Project description	25kW RivGen device
Date of installation	19 July 2015
Underwater video monitoring data	
Was underwater video or stills data gathered as part of the environmental monitoring for this development?	Yes
Project details (**as present at time the video monitoring took place** (i.e. technology type, number of devices, etc.)	25kW RivGen device. The device's two-turbines are supported by a chassis incorporating a pontoon support structure (see Figure 2.3).
Aims/objectives of underwater video data collection	To assess the impact of the RivGen device on the Kvichak River's fish communities
Is a Project Environmental Management Plan (PEMP) or Monitoring Plan available that provides information on the monitoring undertaken/proposed? If yes, please provide file or link to access document.	No
Make and model of underwater video camera(s) used	Customized SeeMate™ colour to monochrome units with a F2.9 angle lens.

Number and location of underwater video camera(s) (if possible, please provide a diagram)	Five video cameras aligned on one side of the device – two upstream of the rotor and three downstream of the turbine foils. See Figure 2.3 below.  **Figure 2.3 Schematic of ORPC RivGen turbine with camera and light placement (Matzner et al, 2017)**
Field of view of underwater video camera(s)	See Figure 2.3
Any lighting?	Yes, illumination from two artificial light sources was used between, approximately, 2300 and 0600 each night. Lights were SeeBrite™ omnidirectional model 24L-SS-LED-350.

Software used (if yes, please provide details)	Automated analysis was investigated to develop algorithms for detecting fish presence in the video, so that an entire video data set could feasibly be analysed automatically without the need for manual sampling. See Matzner, S., et al. (2017) Triton: Igiugig Fish Video Analysis report for further details.
Format of data (if known), e.g. file type – (.mkv, etc.) and time interval of data within each file	.mp4 6,418 files; 30 minute blocks
Timing of data collection (start date, end date)	19 to 25 July and 19 to 28 August in 2015
Is video data time-stamped?	TBC
Any further details of frequency of occurrence of data collection (e.g. continuous, intermittent periods, if intermittent, was there any trigger mechanism for recording data?)	Continuous
Operational status of device during video data collection i.e. non-operational (static), operational (producing electricity), free-spinning (turbine spinning, but not producing electricity) or a combination of the above.	Non-operational, operational, free-spinning.
Estimate of available video data (hours or days)	368 hours over 16 days
Any known issues or problems with data collection?	There was difficulty associated with estimating distance of objects from the turbine and therefore exact distances of objects from the turbine were not able to be determined.
Approximate cost of data collection	TBC
Data analysis	
Has any data analysis of this underwater video or stills data been carried out to date? If yes, please provide details or link(s) to monitoring reports, published papers, etc.	Yes (Matzner et al, 2017)
Is there any data analysis currently underway? If yes, please provide a brief summary and the anticipated date of reporting.	No

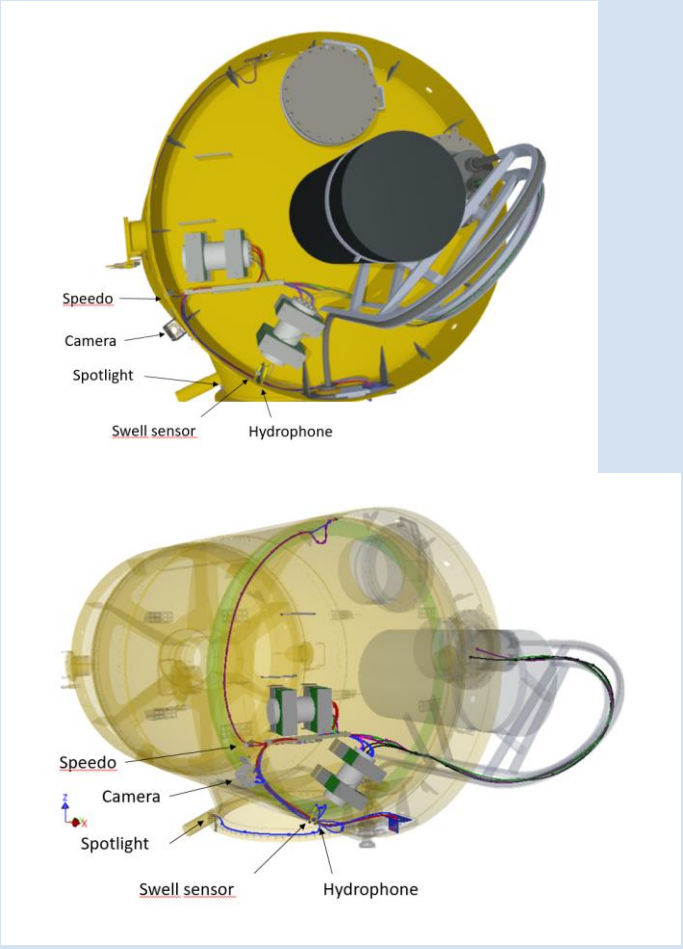
Data access	
Is the underwater video data described above, available for use for this project?	TBC. Awaiting confirmation from Nathan Johnson, although preliminary conversations suggest it will be.
Owner of data (organisation, named contact, contact details)	ORPC, Nathan Johnson, njohnson@orpc.co
Access to data - URL or hard drive(s)	TBC
Approximate memory size of data (if known)	TBC
Any other data collection systems undertaken alongside video monitoring that in future could help interpretation of the video data? (If yes, please provide details)	
Sonar/acoustic monitoring systems	No
ADCPs, if yes how many	No
Passive Acoustic Monitoring equipment	No
Strain gauges	No
Other	N/A
Is there any integration of these data collection systems? If yes, please provide details.	N/A
Any other comments	

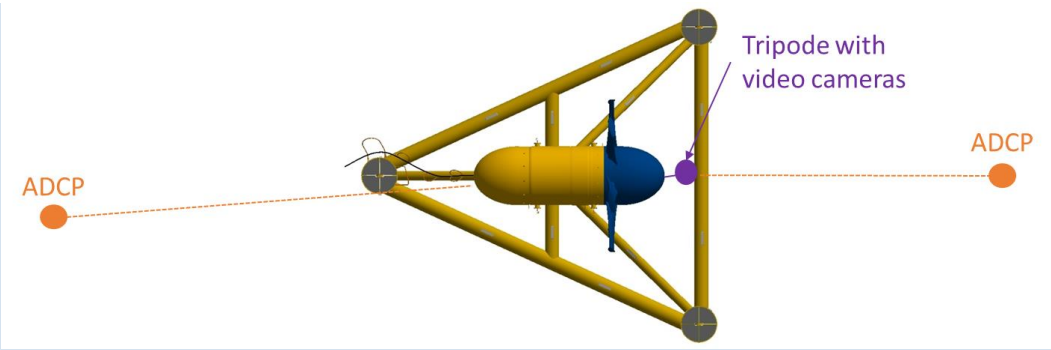
References
Matzner, S. et al. (2017) 'Triton : Igiugig Fish Video Analysis', (August). Available at: https://tethys.pnnl.gov/sites/default/files/publications/Triton-Igiugiq-Report.pdf (Accessed: 16 October 2018).

2.4 SABELLA D10 DEPLOYMENT AT FROMVEUR PASSAGE, FRANCE

Table 2.4 SABELLA D10, Fromveur Passage (France) deployment

Project Details	
Project name	D10
Project location (site name, region, country)	Fromveur Passage off Ushant Island, France
Developer name	SABELLA
Project description	1MW Seabed based Tidal Turbine
Date of installation	First installation June 2015 – July 2016; second installation October 2018 – April 2019
Underwater video monitoring data	
Was underwater video or stills data gathered as part of the environmental monitoring for this development?	Yes
Project details (**as present at time the video monitoring took place** (i.e. technology type, number of devices, etc.)	1MW rated turbine deployment from October 2018 for 6 months (new deployment planned July 2020 – August 2021)
Aims/objectives of underwater video data collection	To assist engineering analysis of turbine operations and to advance understanding of interactions of marine life with the system which, in turn, will ease the path for consent for future projects.
Is a Project Environmental Management Plan (PEMP) or Monitoring Plan available that provides information on the monitoring undertaken/proposed? If yes, please provide file or link to access document.	Yes (internal)
Make and model of underwater video camera(s) used	LUXUS HD Ethernet and SAIS IP HD underwater camera

Number and location of underwater video camera(s) (if possible, please provide a diagram)	1 x LUXUS HD Ethernet underwater camera installed on the back of the turbine:  **Figure 2.4 Schematics of the D10 with locations of all sensory equipment detailed** An additional tripod to be placed under the turbine with 1 x LUXUS HD Ethernet underwater camera and 1 x SAIS IP HD:

	 **Figure 2.5 Schematic of tripod deployment around the D10 for cameras and ADCP units**
Field of view of underwater video camera(s)	Camera on device facing forward towards the blades. On tripod, one camera will be looking up to the blades and the other camera will be looking down towards the seabed.
Any lighting?	Each camera has one controllable spotlight.
Software used (if yes, please provide details)	TBC
Format of data (if known), e.g. file type – (.mkv, etc.) and time interval of data within each file	TBC
Timing of data collection (start date, end date)	During whole deployment October 2018 to April 2019. To start again from commencement of re-installation (July 2020).
Is video data time-stamped?	TBC
Any further details of frequency of occurrence of data collection (e.g. continuous, intermittent periods, if intermittent, was there any trigger mechanism for recording data?)	TBC

Operational status of device during video data collection i.e. non-operational (static), operational (producing electricity), free-spinning (turbine spinning, but not producing electricity) or a combination of the above.	TBC
Estimate of available video data (hours or days), at the time of writing	TBC
Is data anticipated to continually be collected? If so, please estimate how many hours of data per day, for the whole project	TBC
Any known issues or problems with data collection?	TBC
Approximate cost of data collection	TBC
Data analysis	
Has any data analysis of this underwater video or stills data been carried out to date? If yes, please provide details or link(s) to monitoring reports, published papers, etc.	TBC
Is there any data analysis currently underway? If yes, please provide a brief summary and the anticipated date of reporting.	TBC
Data access	
Is up to one months' worth of underwater video data described above, available for use for this project?	TBC

Owner of data (organisation, named contact, contact details)	SABELLA, Diane Dhomé, d.dhome@sabella.bzh, +33 6 18 66 88 99
Access to data - URL or hard drive(s)	Hard Drives
Approximate memory size of data (if known)	TBC
Any other data collection systems undertaken alongside video monitoring that in future could help interpretation of the video data? (If yes, please provide details)	
Sonar/acoustic monitoring systems	One hydrophone (HTI-99-HF) with data recorded on acoustic recorder (SDA14) on the device mooring structure
ADCPs	Three standalone tripods each with an ADCP (1 x Rowe Technologies SeaPROFILER and 1 x Nortek Signature 500) – one placed upstream and the other downstream. See Figure 2.5
Passive Acoustic Monitoring equipment	2 x C-Pods during initial installation from November 2015 – July 2016. Recorded data from before turbine was operational in addition to when turbine was operational. 1 C-POD installed on the camera tripod next to the rotor.
Strain gauges	In one blade.
Other	1 x Airmar CS4500 ultrasonic speed sensor 1 x RBR RBRsolo D|wave swell sensor Fouling development monitoring plates also installed on the gravity based foundation (since June 2015), with plates facing the current and others parallel to the current, at different locations on the structure.
Is there any integration of these data collection systems? If yes, please provide details.	All data will be used to provide a detailed understanding of environmental impacts of the device. Integration of the data will allow more accurate and more efficient analysis of ecological interactions. It is intended to use the different equipment collaboratively to identify 'target' incidents that may potentially be attributable to marine wildlife that could subsequently be checked during analysis of the recorded video footage.
Any other comments	

2.5 ORBITAL MARINE POWER SR250 DEPLOYMENT AT EMEC

Table 2.5 Orbital Marine Power SR250, EMEC deployment

Project Details	
Project name	SR250
Project location (site name, region, country)	EMEC, Falls of Warness, Orkney, Scotland
Developer name	Orbital Marine Power (formerly Scotrenewables)
Project description	250kW Floating Tidal Turbine
Date of installation	2nd of April 2011
Underwater video monitoring data	
Was underwater video or stills data gathered as part of the environmental monitoring for this development?	Yes
Project details (**as present at time the video monitoring took place** (i.e. technology type, number of devices, etc.)	1 x 250kW floating tidal turbine deployed in the Falls of Warness, Orkney, Scotland
Aims/objectives of underwater video data collection	To assist engineering analysis of turbine operations and to advance understanding of interactions of marine life with the system which, in turn, will ease the path for consent for future projects
Is a Project Environmental Management Plan (PEMP) or Monitoring Plan available that provides information on the monitoring undertaken/proposed? If yes, please provide file or link to access document.	Yes, available upon request
Make and model of underwater video camera(s) used	Pan-Tilt-Zoom (PTZ) Dome Precision Subsea (Composite) Fixed Camera (TBC)

Number and location of underwater video camera(s) (if possible, please provide a diagram)	1 x PTZ Dome slightly aft of turret 2 x Precision Subsea (Hi def) Fixed Cameras slightly forward of rotors
Field of view of underwater video camera(s)	PTZ Dome – towards aft of vessel Precision Subsea (Hi def) Fixed Cameras towards rotor blades, entirety of blade visible
Any lighting?	Yes, two lights positioned forward of the 2 fixed cameras with orientation towards the blades matching camera view – but not used
Software used (if yes, please provide details)	DVR – Composite video
Format of data (if known), e.g. file type – (.mkv, etc.) and time interval of data within each file	AVC, WMV – TBC
Timing of data collection (start date, end date)	From 02/04/11 to end of 2013 / 2014. On / off deployment
Is video data time-stamped?	Yes
Any further details of frequency of occurrence of data collection (e.g. continuous, intermittent periods, if intermittent, was there any trigger mechanism for recording data?)	Continuous when deployed, intermittent deployment
Operational status of device during video data collection i.e. non-operational (static), operational (producing electricity), free-spinning (turbine spinning, but not producing electricity) or a combination of the above.	All operational states
Estimate of available video data (hours or days), at the time of writing	TBC

Is data anticipated to continually be collected? If so, please estimate how many hours of data per day, for the whole project	Yes, when deployed
Any known issues or problems with data collection?	TBC
Approximate cost of data collection	£5,000
Data analysis	
Has any data analysis of this underwater video or stills data been carried out to date? If yes, please provide details or link(s) to monitoring reports, published papers, etc.	No
Is there any data analysis currently underway? If yes, please provide a brief summary and the anticipated date of reporting.	No
Data access	
Is up to one months' worth of underwater video data described above, available for use for this project?	Yes
Owner of data (organisation, named contact, contact details)	Trevor Walls, Orbital Marine Power, t.walls@orbitalmarine.com
Access to data - URL or hard drive(s)	Hard Drive
Approximate memory size of data (if known)	TBC
Any other data collection systems undertaken alongside video monitoring that in future could help interpretation of the video data? (If yes, please provide details)	
Sonar/acoustic monitoring systems	Hydrophone
ADCPs	One on nose of device and one as a separate deployment adjacent to site

Passive Acoustic Monitoring equipment	Hydrophone
Strain gauges	Yes, in blades
Other	MRU – Motion Response Unit to show pitching and rolling, general stability of device Ultrasonic vector
Is there any integration of these data collection systems? If yes, please provide details.	There is a Supervisory Control and Data Acquisition (SCADA) system with constant monitoring of temperatures and pressures. All data will be used to provide as detailed an understanding of environmental impacts of the device. Integration of the data will allow more accurate and more efficient analysis of ecological interactions. It is intended to use the different equipment collaboratively to identify 'target' incidents that may potentially be attributable to marine wildlife that could subsequently be checked during analysis of the recorded video footage.
Any other comments	
Analysis of hydrophone data during anchor installation showed that broadband noise levels are not expected to exceed the threshold for lethality, permanent threshold shift (PTS) or temporary threshold shift (TTS) onset for basking sharks or marine mammals (Beharie and Side, 2011; EMEC, 2014). Data was not used for other analysis, hydrophone on SR250 malfunctioned during deployment	

References

Beharie, R. and Side, J. 2011. Sub-Sea Acoustic Monitoring - North-West mooring leg installation for the Scotrenewables SR250. A report commissioned by Scotrenewables (International Centre for Island Technology, Report No. 2011/04/SR)

EMEC (2014) EMEC Fall of Warness Tidal Test Site - ES. Available at: https://tethys.pnnl.gov/sites/default/files/publications/Fall-of-Warness-Environmental-Appraisal.pdf (Accessed: 14 November 2018).

2.6 ORBITAL MARINE POWER SR2000 DEPLOYMENT AT EMEC

Table 2.6 Orbital Marine Power SR2000, EMEC deployment

Project Details	
Project name	SR2000
Project location (site name, region, country)	EMEC, Falls of Warness, Orkney, Scotland
Developer name	Orbital Marine Power (formerly Scotrenewables)
Project description	2MW Floating Tidal Turbine
Date of installation	October 2016
Underwater video monitoring data	
Was underwater video or stills data gathered as part of the environmental monitoring for this development?	Yes
Project details (**as present at time the video monitoring took place** (i.e. technology type, number of devices, etc.)	1 x 2MW floating tidal turbine deployed in the Falls of Warness
Aims/objectives of underwater video data collection	To assist engineering analysis of turbine operations and to advance understanding of interactions of marine life with the system which, in turn, will ease the path for consent for future projects
Is a Project Environmental Management Plan (PEMP) or Monitoring Plan available that provides information on the monitoring undertaken/proposed? If yes, please provide file or link to access document.	TBC
Make and model of underwater video camera(s) used	Vivotek bullets – IP8332 surface cameras Vivotek domes – FE8174 underwater cameras

Number and location of underwater video camera(s) (if possible, please provide a diagram)	4 underwater cameras – Vivotek Domes FE8174 1 towards both blades on leg brace, 1 under turret and 1 each on the turbines nacelles, aimed towards the tips of the port and starboard side turbines respectively. Another 2 were originally placed next to each other around the centre of the hull but did not work and were subsequently removed from the plans. Starboard side nacelle camera was also not functional during deployment.

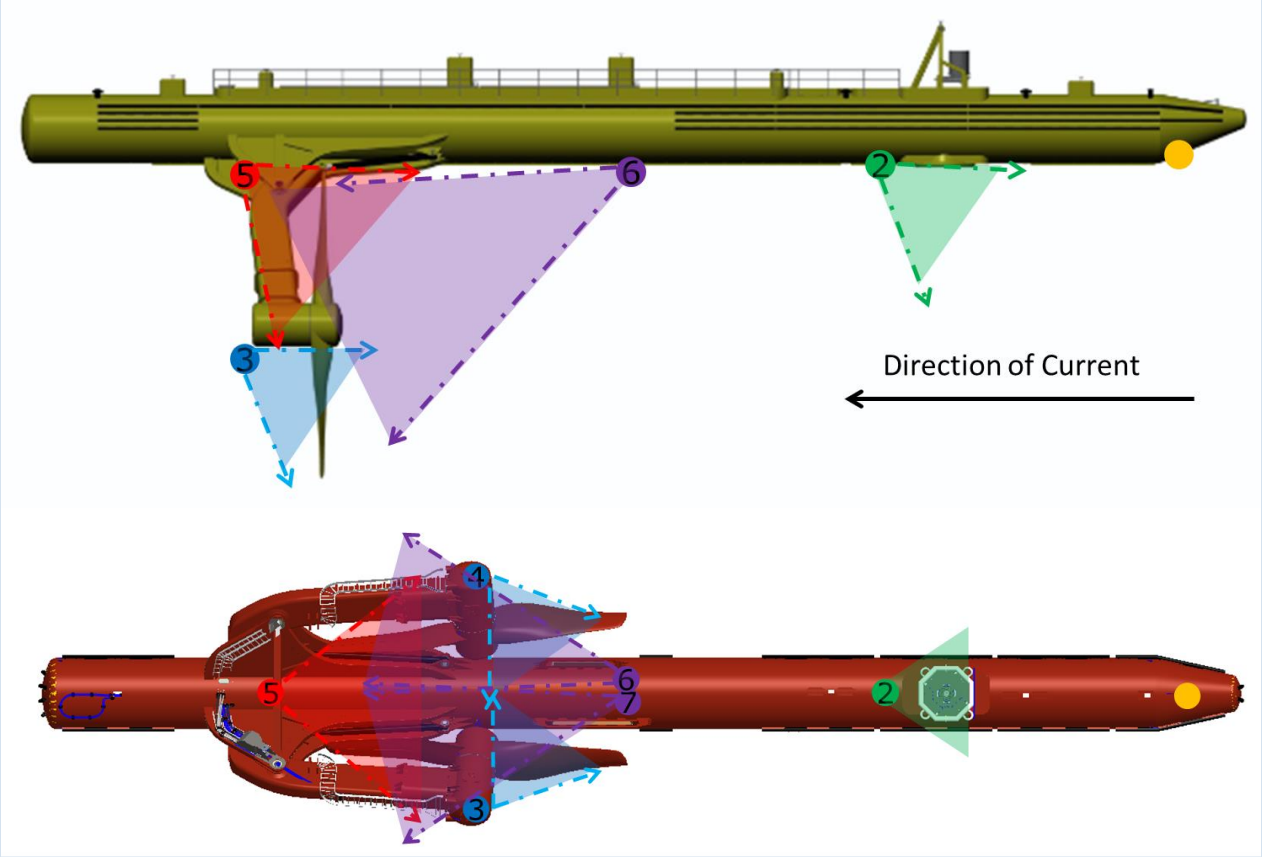


Figure 2.6 Schematics of the SR2000 device with coloured circles indicating camera placement

Number and location of underwater video camera(s) (if possible, please provide a diagram)	

Key	
2	Vivotek dome camera, functional during deployment but footage not used as part of this review as field of view covered turret, not turbine blades
3	Vivotek dome camera, functional during deployment and footage used as part of this review
4	Vivotek dome camera, not functional during deployment, therefore footage not used as part of this review
5	Vivotek dome camera, functional during deployment and footage used as part of this review
6	Vivotek bullet cameras, not functional during deployment, therefore footage not used as part of this review
7	Vivotek bullet cameras, not functional during deployment, therefore footage not used as part of this review
	Acoustic Doppler Current Profiler (ADCP)

2 surface cameras – Vivotek Bullets IP83302

Both on the communication mast, one pointing forward and one pointing aft.

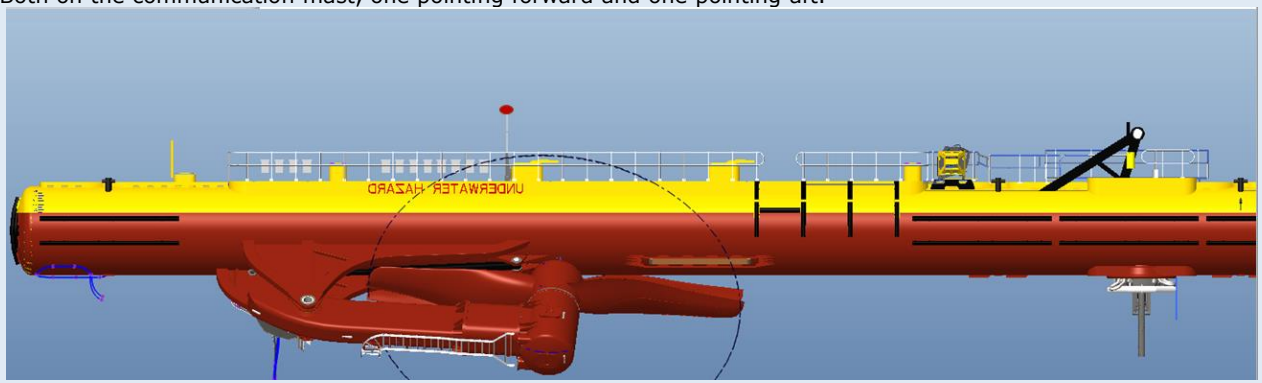


Figure 2.7 Schematic of the SR2000 showing locations of the 2 topside cameras (red circle)

Field of view of underwater video camera(s)	Camera 1: Both blades but not in their entirety Camera 2: The mooring lines connecting to the turret Cameras 3 & 4: The tips of the blades

Any lighting?	Two lights but not used
Software used (if yes, please provide details)	Vivotek
Format of data (if known), e.g. file type – (.mkv, etc.) and time interval of data within each file	Avi – 5 minute segments
Timing of data collection (start date, end date)	Jan 2018 to July 2018
Is video data time-stamped?	Yes
Any further details of frequency of occurrence of data collection (e.g. continuous, intermittent periods, if intermittent, was there any trigger mechanism for recording data?)	Continuously
Operational status of device during video data collection i.e. non-operational (static), operational (producing electricity), free-spinning (turbine spinning, but not producing electricity) or a combination of the above.	All operational modes of device recorded
Estimate of available video data (hours or days), at the time of writing	7 months
Is data anticipated to continually be collected? If so, please estimate how many hours of data per day, for the whole project	Yes – same as before
Any known issues or problems with data collection?	Limited useful footage during the night; there was additional lighting available around the cameras, but it was not used during this deployment. Cameras were not always working. There was some biofouling on cameras, especially during the summer; they needed cleaning roughly once per month. Cameras occasionally leaked.
Approximate cost of data collection	£17,500

Data analysis	
Has any data analysis of this underwater video or stills data been carried out to date? If yes, please provide details or link(s) to monitoring reports, published papers, etc.	No
Is there any data analysis currently underway? If yes, please provide a brief summary and the anticipated date of reporting.	No
Data access	
Is up to one months' worth of underwater video data described above, available for use for this project?	Yes
Owner of data (organisation, named contact, contact details)	Trevor Walls, Orbital Marine Power, t.walls@orbitalmarine.com
Access to data - URL or hard drive(s)	Hard Drive
Approximate memory size of data (if known)	19TB
Any other data collection systems undertaken alongside video monitoring that in future could help interpretation of the video data? (If yes, please provide details)	
Sonar/acoustic monitoring systems	No

ADCPs	Yes, 1 ADCP on device but not recording continuously. Another ADCP on a separate frame deployed for 2 months SW of device
Passive Acoustic Monitoring equipment	No
Strain gauges	Yes, in blades
Other	MRU – Motion Response Unit to show pitching and rolling, general stability of device

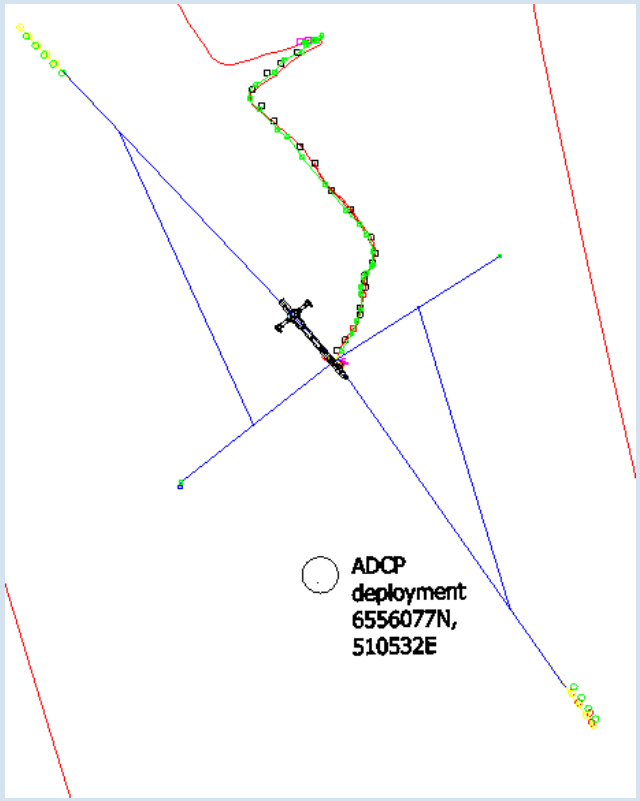


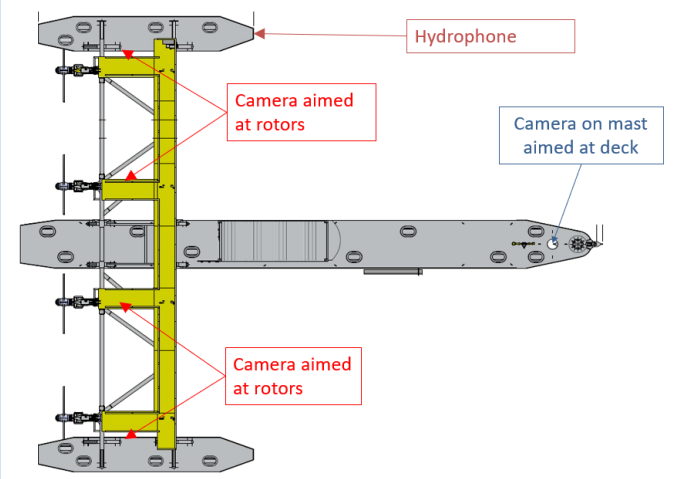
Figure 2.8 ADCP adjacent to SR2000 deployment

Is there any integration of these data collection systems? If yes, please provide details.	There is a Supervisory Control and Data Acquisition (SCADA) system with constant monitoring of temperatures and pressures. All data will be used to provide as detailed an understanding of environmental impacts of the device. Integration of the data will allow more accurate and more efficient analysis of ecological interactions. It is intended to use the different equipment collaboratively to identify 'target' incidents that may potentially be attributable to marine wildlife that could subsequently be checked during analysis of the recorded video footage.
Any other comments	

2.7 SUSTAINABLE MARINE ENERGY (SME) PLAT-I DEPLOYMENT AT GRAND PASSAGE, CANADA

Table 2.7 SME PLAT-I, Grand Passage (Canada) deployment

Project Details	
Project name	PLAT-I 4.63 @ Grand Passage
Project location (site name, region, country)	Grand Passage, Digby County, Nova Scotia, Canada
Developer name	Sustainable Marine Energy (Canada) Ltd., SCHOTTEL Hydro
Project details	Ongoing deployment of PLAT-I floating tidal energy convertor
Date of installation	September 2018. Operation commenced February 2019.
Underwater video monitoring data	
Was underwater video data gathered as part of the environmental monitoring for this development?	A limited amount of video footage was gathered during the commissioning period (September 2018 to February 2019) for the purposes of demonstrating system functionality to the Canadian regulator (Dept. of Fisheries and Oceans). Video was recorded during operating periods since operations began in February 2019.
Project details (as present at time the video monitoring took place (i.e. technology type, number of devices, etc.)	'Open Houses' presentations provide general details on the deployment – location, duration, operating constraints and environmental monitoring. Copies available upon request. Project description for current phase available here: https://energy.novascotia.ca/sites/default/files/files/Permit_2018-004_A01_-_Extended_to_Dec_2020_-_SMEC.pdf
Aims/objectives of underwater video data collection	The objective is to significantly advance understanding of interactions of marine life with the system which, in turn, will ease the path for consent for future projects. Specifically footage will be gathered of the SCHOTTEL Instream Turbine while operational with the multiple aims of i) complying with DFO permits (i.e. 'Authorization') and other permits ii) providing input data to associated research projects.
Is Project Environmental Management Plan (PEMP) or Monitoring Plan available that provides information on the monitoring undertaken/proposed? If yes, please provide file or link to access document.	An Environmental Effects Monitoring Programme has been completed and submitted to DFO (and Nova Scotia Dept. of Energy and Mines). Contact Sustainable Marine Energy (Canada) Ltd. for more information.
Make and model of camera(s) used	MacArtney LUXUS Compact PUR underwater video cameras

Number and location of camera(s) (please provide a diagram)	4 x pole-mounted cameras as shown below.  **Figure 2.9 Schematics of SME PLAT-I with camera placement**
Field of view of camera(s)	Slightly angled with respect to direction of flow. Full view of rotors.
Any lighting?	No
Software used (if yes, please provide details)	Hikvision IVMS-4200
Format of data (if known)	MP4
Details of integration of data collection systems (e.g. with sonar, etc). If yes, please provide details of equipment/system used.	No integration. Hydrophone data collection separate.
Timing of data collection (start date, end date)	Intermittently, February 2019 through February 2020.
Any further details of frequency of occurrence of data collection (e.g. continuous, intermittent periods, etc.)	Continuous during operating periods, which were confined to daylight hours.
Details of device operation	Device operated during daylight hours intermittently from February 2019 through February 2020.

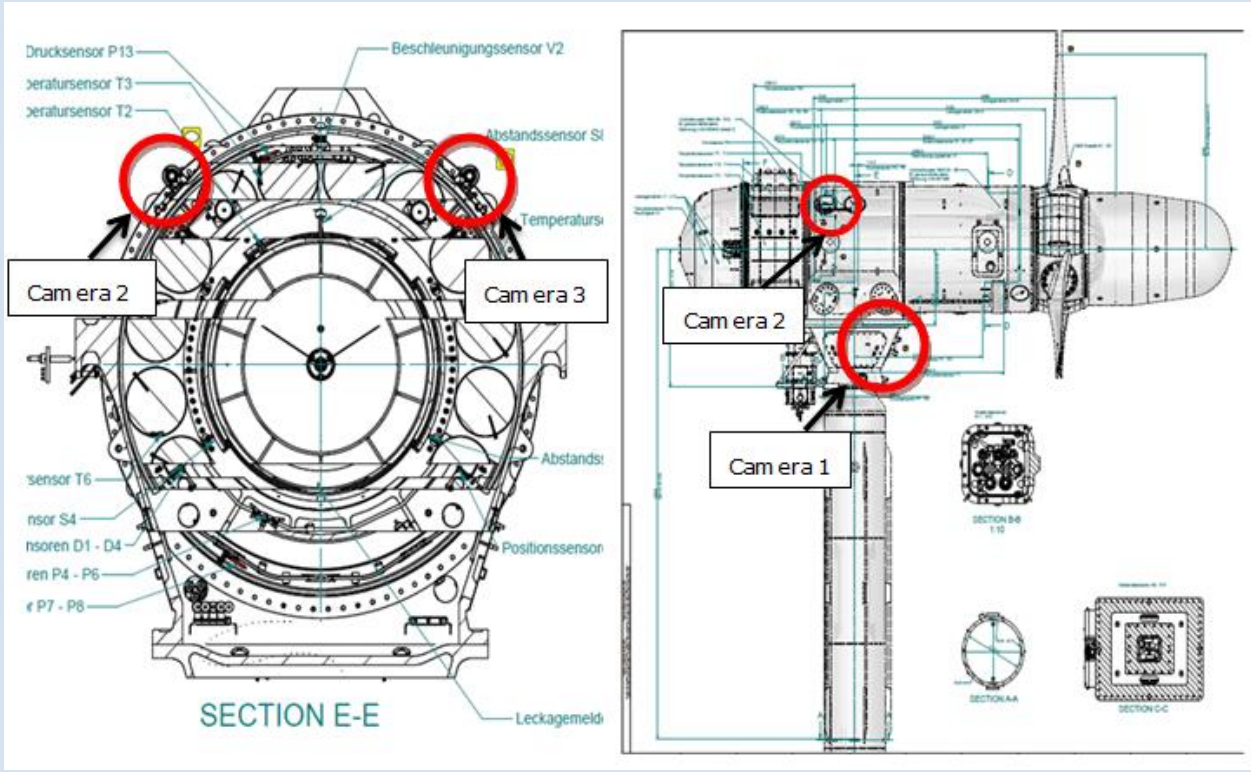
Estimate of available data (hours or days)	Not available.
Estimate of number of hours collected while turbine was operational	Not available.
Any known issues or problems with data collection?	No. Water clarity was variable throughout data collection periods.
Approximate cost of data collection	Not available.
Data analysis	
Has any data analysis of this underwater video data been carried out to date? If yes, please provide details or link(s) to monitoring reports, published papers, etc.	Yes. Analysis conducted by third party for regulatory reporting purposes. No public sources available.
Is there any data analysis currently underway? If yes, please provide a brief summary and the anticipated date of reporting.	Yes. On an ongoing basis as above.
Data access	
Is the underwater video data described above, available for use for this project?	Yes
Owner of data (organisation, named contact, contact details)	Sustainable Marine Energy (Canada) Ltd., Craig Chandler, craig.chandler@sustainablemarine.com, +1 902 832 3676
Access to data - URL or hard drive(s)	Please contact SMEC (see above).
Approximate memory size of data (if known)	Several TB. Data collection is ongoing.
Any other data collection systems undertaken alongside video monitoring that in future could help interpretation of the video data? (If yes, please provide details)	
Sonar/acoustic monitoring systems	No
ADCPs, if yes how many	No
Passive Acoustic Monitoring equipment	Yes, single hydrophone via icListen HF
Strain gauges	No
Other	Please contact SME (see above).

Is there any integration of these data collection systems? If yes, please provide details.	No
Any other comments	

2.8 VOITH HYTIDE DEPLOYMENT AT EMEC

Table 2.8 Voith HyTide, EMEC deployment

Project Details	
Project name	Voith Hydro HyTide Fall of Warness
Project location (site name, region, country)	EMEC, Fall of Warness, Orkney, Scotland
Developer name	Voith Hydro
Project description	1MW HyTide tidal turbine
Date of installation	HyTide turbine installed March 2014
Underwater video monitoring data	
Was underwater video or stills data gathered as part of the environmental monitoring for this development?	Yes
Project details (**as present at time the video monitoring took place** (i.e. technology type, number of devices, etc.)	1 x 1MW HyTide tidal turbine
Aims/objectives of underwater video data collection	To investigate the effectiveness of underwater video footage for monitoring collision risk for marine wildlife; To monitor effects of turbine presence and operation during device testing on marine mammals, fish and birds.
Is a Project Environmental Management Plan (PEMP) or Monitoring Plan available that provides information on the monitoring undertaken/proposed? If yes, please provide file or link to access document.	Yes. Aquatera, 2015 Voith Hydro's deployment of a tidal energy converter at EMEC's tidal test site - Environmental Monitoring Report. Report to Marine Scotland. Copies available upon request
Make and model of underwater video camera(s) used	Tritech Tornado low light monochrome video cameras

Number and location of underwater video camera(s) (if possible, please provide a diagram)	Three cameras; two on the nacelle and one on the monopile.  **Figure 2.10 Schematic of Voith HyTide turbine and camera placement**
Field of view of underwater video camera(s)	See diagrams in EMP
Any lighting?	No lighting was installed to facilitate video camera monitoring outside daylight hours.
Software used (if yes, please provide details)	No
Format of data (if known), e.g. file type – (.mkv, etc.) and time interval of data within each file	Data from footage taken in May is in .asf format and the length of video ranges from 1 minute – 2 ½ hours long June and July data is in mkv format and is in 15 minute clips.
Timing of data collection (start date, end date)	12 – 18 May 2014, 20th May and 28 May – 13 July 2014

Is video data time-stamped?	.mkv files are timestamped in the file name and in the actual video. .asf files have the start time in the file name
Any further details of frequency of occurrence of data collection (e.g. continuous, intermittent periods, if intermittent, was there any trigger mechanism for recording data?)	Between the 12th and 31st May, video footage was recorded during discrete periods only whereas footage was recorded continuously from 1st June to 13th July.
Operational status of device during video data collection i.e. non-operational (static), operational (producing electricity), free-spinning (turbine spinning, but not producing electricity) or a combination of the above.	The testing programme began in April 2014. Initially, the testing programme involved the turbine being operational for a few minutes at a time. The testing programme continued throughout subsequent months, with the turbine operational for up to several hours at a time.
Estimate of available video data (hours or days), at the time of writing	There is 55 days' worth of data, however, it should be noted that a significant proportion of this data will have been recorded outwith daylight hours.
Is data anticipated to continually be collected? If so, please estimate how many hours of data per day, for the whole project	N/A – turbine decommissioned
Any known issues or problems with data collection?	Initially, all three cameras were operational, providing clear images when the turbine was at standstill and when it was in operation. Some level of interference was visible on all cameras in the form of vertical lines constantly moving horizontally across the screen. Biofouling of camera lenses completely obscured visibility of one of the cameras after approximately 4 weeks of deployment. Another camera experienced a high degree of biofouling, however a relatively clear image is still visible by 13th July.
Approximate cost of data collection	TBC
Data analysis	
Has any data analysis of this underwater video or stills data been carried out to date? If yes, please provide details or link(s) to monitoring reports, published papers, etc.	Yes, see Aquatera, 2015 Further Analysis of Underwater Video Monitoring of Voith Hydro's HyTide turbine – 2014 Copies available on request.
Is there any data analysis currently underway? If yes, please provide a brief summary and the anticipated date of reporting.	No

Data access	
Is the underwater video data described above, available for use for this project?	Yes
Owner of data (organisation, named contact, contact details)	Aquatera Ltd, Ian Hutchison, ian.hutchison@aquatera.co.uk
Access to data - URL or hard drive(s)	Hard drives
Approximate memory size of data (if known)	~433 GB
Any other data collection systems undertaken alongside video monitoring that in future could help interpretation of the video data? (If yes, please provide details)	
Sonar/acoustic monitoring systems	Was installed, but was defective because of failure in the cable connector.
ADCPs, if yes how many	Two ADCPs deployed, one upstream and one downstream of the device, however one of the ADCPs was defective therefore it was not possible to undertake a comparison of current profiles upstream and downstream of the turbine.
Passive Acoustic Monitoring equipment	No
Strain gauges	Yes, one strain gauge in one of the blades. Initial analysis of the strain gauge data showed there were so many spikes that it would not be possible to differentiate between background turbulence and any possible collision event. See Further Analysis of Underwater Video Monitoring of Voith Hydro's HyTide turbine – 2014 report for more details.
Other	N/A
Is there any integration of these data collection systems? If yes, please provide details.	It was intended to use a strain gauge and sonar camera along with the video cameras to identify 'target' incidents that may potentially be attributable to marine wildlife that could subsequently be checked during analysis of the recorded video footage. However, due to faults with the sonar equipment this was not possible.
Any other comments	

3 METADATA CATALOGUE – OTHER PROJECTS WHERE VIDEO DATA WAS NOT COLLECTED

Table 3.1 Metadata table of existing environmental monitoring datasets from projects that never gathered video data

Type of Data Collection/ Data Analysed	Receptor	Stressor	Phase in which monitoring was carried out	Start and End Date	Specific Data Types	Purpose of Data Collection	Reference / contact
ORPC Cobscook Bay, Maine							
Visual observations (MMOs)	Marine mammals	Vessel disturbance, noise	Device deployment and retrieval	20 March 2012 -7 December 2012	Number of sightings	To monitor for marine mammals within a 1000ft exclusion zone during device installation	See ORPC (2013)[3] p48-55
Visual observations (incidental)	Marine mammals	Vessel disturbance, noise	Device deployment and retrieval	3 January 2012 -29 November 2012	Number of sightings	To attempt to monitor the potential for any change in use of the area by marine mammals during normal operational activities	
Hydroacoustic monitoring data from Simrad EK60 split beam echosounder	Fish	Dynamic device	When the device was free-spinning or still. Interference between the data and power transmission cables prevented data collection when generating power	01 October 2012 - 05 October 2012	Echosounder data Side looking hydro-acoustic data	To monitor potential collisions with the moving turbine components	See ORPC (2013) p29 methodology, results p35

[3] ORPC Cobscook Bay Tidal Energy Project: 2012 Environmental Monitoring Report Final Draft. Available at: http://www.orpc.co/permitting_doc/environmentalreport_Mar2013.pdf (Accessed: 16/11/18).

Type of Data Collection/ Data Analysed	Receptor	Stressor	Phase in which monitoring was carried out	Start and End Date	Specific Data Types	Purpose of Data Collection	Reference / contact
Hydroacoustic monitoring data from Simrad ES60 single beam echosounder	Fish	Dynamic device	Pre and post deployment	2010-2012, 1 24hr sampling period in at least 6 months of the year	Down-looking hydroacoustic data	To monitor potential collisions with the moving turbine components	See ORPC (2013) p25 for methodology, results p33
Acoustic monitoring of the device	Marine mammals	Noise	Pre-deployment and during operation	Pre-deployment 2011 and operation April 2013	Reson Hydrophone data	To monitor the noise levels produced by the operational device allowing subsequent analysis of its potential to cause harm to marine life	See ORPC (2014)[4] p10
Diver assisted camera surveys and DDV (Sea Viewer Sea-Drop 650 series) of cable route	Benthic habitats	Cable trenching, Electro-magnetic field (EMF)	Pre-deployment, during operation/post-deployment	2013	Video recordings and analysis of species	To monitor the effects of cable installation and operation	See ORPC (2014) p24
Biofouling assessment	NA	Static device	Immediately following removal	15 July 2013	Type, abundance and distribution of species on the device	To assess the extent of marine growth on the turbine	See ORPC (2014) p28

[4] ORPC. 2013. Cobscook Bay Tidal Energy Project: 2013 Environmental Monitoring Report Final Draft. Available at: https://tethys.pnnl.gov/sites/default/files/publications/ORPC-2014-Cobscook.pdf (Accessed: 16/11/18).

Type of Data Collection/ Data Analysed	Receptor	Stressor	Phase in which monitoring was carried out	Start and End Date	Specific Data Types	Purpose of Data Collection	Reference / contact
SeaGen, Strangford Lough							
Shore based observations	Marine mammals	Vessel disturbance/noise, dynamic device, static device	Pre-deployment, installation and operation	May 2005-December 2010	Number of sightings	Monitoring of potential displacement effects and vessel disturbance impacts	See Keenan et al, (2011)[5] p24 for methodology, p33 for results. Also see Savidge et al, (2014)[6]
Acoustic monitoring	Harbour porpoise	Dynamic device, static device	Operation	2006-2011	Passive acoustic monitoring (T-PODs)	Monitoring of displacement effects and avoidance behaviour	See Keenan et al, (2011) bottom of p25 for methodology p36 for results. Also see Savidge et al, (2014)
Incidental marine mammal observations (pile based)	Marine mammals	Dynamic device, static device	Operation	July 2008-August 2009	Number of sightings	Monitoring of displacement effects and avoidance behaviour	See Keenan et al, (2011) p23 onwards. Also see Savidge et al, (2014)

[5] Keenan, G., Sparling, C., Williams, H. and Fortune, F. 2011. SeaGen Environmental Monitoring Programme Final Report. Royal Haskoning. Available at: https://tethys.pnnl.gov/sites/default/files/publications/Final_EMP_report_SeaGen.pdf (Accessed: 16/11/18).

[6] Savidge, G., Ainsworth, D., Bearhop, S., Christen, N., Elsaesser, B., Fortune, F., Inger, R., Kennedy, R., McRobert, A., Plummer, K. E., Pritchard, D. W., Sparling, C. and Whittaker T. 2014. Strangford Lough and the SeaGen tidal turbine. From book: *Marine Renewable Energy Technology and Environmental Interactions.* pp. 153-172. Available at: https://www.researchgate.net/publication/260437857_Strangford_Lough_and_the_SeaGen_Tidal_Turbine (Accessed: 16/11/18).

Type of Data Collection/ Data Analysed	Receptor	Stressor	Phase in which monitoring was carried out	Start and End Date	Specific Data Types	Purpose of Data Collection	Reference / contact
Acoustic monitoring	Marine mammals	Dynamic device	Operation	2008-2011	Active sonar data	Monitoring of collision risk potential/ behavioural interactions with the device	See Keenan et al, (2011) p30 for methodology, p45 for results Also see Savidge et al, (2014)
Carcass surveys	Seals	Dynamic device	Operation	2005-2009	Post mortem evaluation of all strandings	Monitoring of potential collision risk incidents	See Keenan et al, (2011) p27 for methodology Also see Savidge et al, (2014)
Aerial survey	Seals	Dynamic device, static device, vessel activity at the site	Pre-deployment and during operation	2003 and 2006-2010	Thermal imaging camera from helicopter to determine overall numbers of harbour seals	Monitoring of potential displacement effects	See Keenan et al, (2011) p27 for methodology, p40 for results Also see Savidge et al, (2014)
Harbour seal telemetry	Harbour seals	Dynamic device, static device, vessel activity at the site	Pre-installation, during installation and commissioning and operation	2006 (April-July) pre-installation, 2008 (March-July) installation, 2010 (April July), operation	Tracking of 3 groups of 12 individuals using GPS phone tags	Monitoring of potential displacement effects	See Keenan et al, (2011) p28 for methodology, p42 for results Also see Savidge et al, (2014)
Diver, acoustic and drop-down video survey	Benthic ecology	Dynamic device, static device	Pre-installation and post installation/ operation	March 2008 – pre-installation, 1st-4th post installation surveys carried out between July 2008 – April 2010	Video and acoustic survey data	Monitoring of habitat creation/ artificial reef effects	See Keenan et al, (2011) p53 for methodology p56 for results Also see Savidge et al, (2014)

Type of Data Collection/ Data Analysed	Receptor	Stressor	Phase in which monitoring was carried out	Start and End Date	Specific Data Types	Purpose of Data Collection	Reference / contact
ADCP survey data	Tidal flow regime	Energy removal	Pre-deployment and post-deployment phase	At various points between April 2004 and June 2011	Far field and near field ADCP data taken from transects in the Lough	To monitor changes in flow regime up- and downstream of the device	See Keenan et al, (2011) p64
Shore-based counts	Birds	Dynamic device, static device, vessel activity at the site	Pre-installation, construction and post construction (including periods of operation and non-operation	May 2005-Deceber 2010	Number of sightings	Monitoring of potential displacement effects	See Keenan et al, (2011) p70 Also see Savidge et al, (2014)
Verdant Power, East River, NYC							

Type of Data Collection/ Data Analysed	Receptor	Stressor	Phase in which monitoring was carried out	Start and End Date	Specific Data Types	Purpose of Data Collection	Reference / contact
Hydro-acoustic data	Fish	Dynamic device	Pre-deployment and during operation	August 29 2012-September 14 2012	DIDSON multibeam analysis and data from RAD system	Monitoring of collision risk potential/ behavioural interactions with the device	See Bevelheimer et al, (2016)[7] p11, discussion on p45
Hydro-acoustic data	Fish	Dynamic device	Pre-deployment, operation and following removal	September 1-14 2008	Splitbeam data examining far-field effects	Monitoring of collision risk potential/ behavioural interactions with the device	See Bevelheimer et al, (2016) p33
EMEC Fall of Warness							

[7] Bevelheimer, M., Colby, J., Adonizio, M. A., Tomichek, C. and Scherelis, C. 2016. Informing a tidal turbine strike probability model through characterization of fish behavioural response using multibeam sonar output. *Oak Ridge National Laboratory*. Available at: https://info.ornl.gov/sites/publications/Files/Pub67733.pdf (Accessed: 16/11/18).

Type of Data Collection/ Data Analysed	Receptor	Stressor	Phase in which monitoring was carried out	Start and End Date	Specific Data Types	Purpose of Data Collection	Reference / contact
FLOWBEC multibeam sonar and echosounder monitoring	Marine mammals and fish	Dynamic device	Operational and non-operational	12 July 2012-05 July 2013	Vertical swath imagenex 837B Delta T and a vertically-mounted Simrad EK60 multi-frequency echosounder.	Monitoring of potential displacement effects and behavioural interactions	Contact Benjamin Williamson, b.williamson@abdn.ac.uk, University of Aberdeen
High-intensity land-based wildlife observations focussed above the FLOWBEC device	Birds	Dynamic device, static device	Operational and non-operational	13-27 June 2012 03-15 June 2013 18 June-03 July 2013	Species abundance and feeding behaviour	Shore-based observational surveys were used to record the abundance and behaviour of black guillemots and European shags on the sea surface within the study area.	Contact Benjamin Williamson, b.williamson@abdn.ac.uk, University of Aberdeen
Boat-based wildlife surveys (RESPONSE Project)	Birds	Dynamic device, static device	Operational and non-operational	01 May 2012-31 October 2013 (6 days in May and 7 days in October)	Foraging seabird species abundance and behaviour (actively foraging or resting)	To assess the extent to which tidal stream environments are exploited by a range of seabird species	Contact Benjamin Williamson, b.williamson@abdn.ac.uk, University of Aberdeen

Type of Data Collection/ Data Analysed	Receptor	Stressor	Phase in which monitoring was carried out	Start and End Date	Specific Data Types	Purpose of Data Collection	Reference / contact
Land-based vantage point surveys	Birds and marine mammals	Dynamic device, static device	Baseline, while technologies were operating and after decommissioning	11 July 2005-28 July 2015	Species diversity and species abundance in survey area which was split into grid squares	Marine mammal and seabird sightings were recorded from a hilltop on the island of Eday, overlooking the site. Data were collected to provide information on distribution and 'relative' abundance of animals in and around the study area.	http://data.marine.gov.scot/dataset/european-marine-energy-centre-fall-warness-wildlife-observation-data[8] Also see Robins (2012)[9] and Lees (2017)[10]

[8] European Marine Energy Centre (EMEC) (2015). Fall of Warness Wildlife Observation Data. DOI: 10.7489/1684-1

[9] Robbins, A. 2012. Analysis of Bird and Marine Mammal Data for Fall of Warness Tidal Test Site, Orkney. Scottish Natural Heritage Commissioned Report No. 614. Available at: https://tethys.pnnl.gov/sites/default/files/publications/Analysis-of-Bird-and-Marine-Mammal-Data-for-Fall-of-Warness.pdf (Accessed: 16/11/18).

[10] Lees, G. (2017) 'Analysis of the possible displacement of bird and marine mammal species related to the installation and operation of marine energy conversion systems', SNH Commissioned Report, (947). Available at: https://tethys.pnnl.gov/sites/default/files/publications/Long-2017-SNH-947.pdf (Accessed: 16/11/18).

Type of Data Collection/ Data Analysed	Receptor	Stressor	Phase in which monitoring was carried out	Start and End Date	Specific Data Types	Purpose of Data Collection	Reference / contact
TEL Deltastream Demonstration Ramsey Sound, Wales							
Acoustic monitoring	Marine mammals	Dynamic device, static device	Operation	October 2014 – April 2015 (TBC)	Passive acoustic monitoring (PAM)	Monitoring of collision risk potential/ behavioural interactions with the device	See Broudic (2014)[11] and survey data[12]
Acoustic monitoring	Marine mammals	Dynamic device, static device	Operation	October 2014 – April 2015	Active acoustic monitoring (AAM) with active acoustic sonar (AAS)	Monitoring of collision risk potential/ behavioural interactions with the device	See Broudic (2014) and survey data
Marine mammal observers (MMO)	Marine mammals	Dynamic device, static device	Operation	October 2014 – April 2015	Number of sightings	Monitoring of displacement effects and avoidance behaviour	See Broudic (2014) and survey data

[11] Broudic, M. 2014. NERC Marine Renewable Energy Knowledge Exchange. *Marine mammal behaviour monitoring using acoustic technology at DeltaStream Demonstration, Ramsey Sound.* Available at: http://www.nerc.ac.uk/innovation/activities/infrastructure/offshore/internship-report-merin-broudic/ (Accessed: 16/11/18).

[12] Survey data: http://www.marinedataexchange.co.uk/search?q=#fq=fq%3DDeveloperName%253A(%2522St%2520David's%2520Head%2522) (Accessed: 16/11/18).