Marine Mammal Scientific Support Research Programme MMSS/002/15

Marine Renewable Energy MRE1

Annual Report

Marine Mammals and Tidal Energy

Sea Mammal Research Unit
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Executive Summary

The work presented under the Marine Renewable Energy (MRE) theme falls in to three tasks;

MRE 1.1 – Fine scale marine mammal behaviour around tidal energy devices.

MRE 1.2 – Harbour seal movement modelling.

MRE 1.3 – Estimating collision risk using available information.

Since the deliverables for MRE1.3 have been amalgamated into the Marine Scotland project CR/2014/12 (which has reported separately), and there is nothing to report for MRE 1.2 in this project year, this annual report presents on the progress for MRE 1.1.

MRE 1.1

- This task aims to monitor the behaviour of harbour seals (and other marine mammals) in the vicinity of an operational tidal turbine. A monitoring system utilising a combination of Passive Acoustic Monitoring (PAM), Active Acoustic Monitoring (AAM) and video cameras was designed to identify the species of marine mammal and to construct 3D tracks of animals in close proximity to the tidal turbine.
- The PAM system, consisting of three clusters of four hydrophones, to detect and track vocalising cetaceans was designed and built. This was successfully installed and tested with the Atlantis control systems on the Atlantis AR1500 Turbine Support Structure (TSS).
- A multibeam AAM system (using Tritech Geminis) to detect and track marine mammals in 3D was designed and manufactured. This has been mounted on a seabed platform 30 m to the side of the turbine axis, which should provide good coverage of the turbine and surrounding waters.
- A bespoke mounting frame for the sonars was designed and built allowing the pitch and roll angles of the sonars to be measured and adjusted as required. This was built with anodised steel and is controlled using two motorized actuators.
- To reduce post hoc analyses, new marine mammal classification algorithms and 3D tracking outputs had to be integrated into the existing multibeam sonar software. This was carried out by Tritech software engineers and has been fully implemented in a bespoke version of the SeaTec software (V2.0020.05).
- In collaboration with Atlantis engineers, a High Current Underwater Platform (HiCUP) to house the AAM system was redesigned to meet with deployment specifications, and to ensure stability in the current flow predicted at the tidal turbine location. The HiCUP construction was completed and lift tests and inspections have been certified by Atlantis. It was attached on a mounting bracket on the Atlantis TSS and loaded out onto the seabed.
- A two camera video system to image marine mammals at the turbine was designed and manufactured. The high-end video surveillance cameras used have an all-round view over a full hemisphere. The cameras were modified to include ultraviolet LED’s in custom built underwater housings in order to reduce biofouling on the windows. Cameras have been successfully installed on the Atlantis TSS, and tested with the Atlantis control systems prior to installation of the TSS on the seabed.
- The full sensor system was deployed successfully with the Atlantis TSS on 24th October 2016.
- Ten harbour seals were caught in the Inner Sound during September and October 2016 and were fitted with high resolution UHF/GPS and depth logger tags so that fine scale movement can be interpreted within a wider spatial context. These aim to provide real time locations of seals to base stations on shore each time a seal surfaces, providing supporting evidence helping to determine if a collision occurs between a seal and a turbine.

MRE1.2

- A prototype individual based model (IBM) of harbour seal movement over time scales of days/weeks has been developed for the Pentland Firth / Orkney area. Many of the parameters in the model are place-holders (albeit realistic ones), with values that will be refined in the next stage of model development. The prototype IBM has a simple structure but it nonetheless captures the basic movement patterns and behaviour that is observed in harbour seal telemetry data.
- Full description and analysis of the work carried out under this deliverable will be presented in the final report, to be submitted by July, 2017.

Contents

1 Marine Renewable Energy (MRE) Theme

Concerns about the impacts of tidal energy devices on marine mammals derive primarily from the potential for injury or mortality as a result of direct interactions (collisions) between animals and moving rotors of tidal devices. However, the true risks posed by these devices remain uncertain due to a paucity of information on a) how marine mammals behave in close proximity to operating tidal turbines, b) how marine mammals use tidally energetic areas proposed for development, and c) the individual consequences of turbine interactions with marine mammals.

The MRE 1 work package comprises three linked tasks. Together, these will be used to derive parameters required to populate improved collision risk models and to directly measure potential interactions on instrumented tidal turbines.

2 MRE1.1 - Fine scale marine mammal behaviour around tidal energy devices

2.1 Introduction

This task aims to monitor the behaviour of harbour seals (and other marine mammals) in the vicinity of an operational tidal turbine. It is based on the technology that was developed under the Scottish Government contract 'Demonstration strategy: Trialling methods for tracking the fine scale underwater movements of marine mammals in areas of marine renewable energy development' (Sparling *et al.,* 2016).

This used a combination of Active Acoustic Monitoring (AAM) and Passive Acoustic Monitoring (PAM) techniques, on the turbine and a seabed mounted platform respectively, to detect and track marine mammals at a high resolution (at a scale of metres). The work described here builds on the development phase by designing, manufacturing, and deploying a combination of an AAM sensor platform and turbine based PAM and video at an operating tidal turbine. This aims to provide data on the movements of marine mammals around the operating turbine that will form the basis of an analysis of close range encounter rates and marine mammal behavioural responses to the turbine.

This task will deploy the suite of AAM/PAM/Video sensors alongside an operating tidal turbine for an extended period (one year). This will be carried out at the MeyGen Inner Sound development in the Pentland Firth, which is comprised of an array of four tidal turbines (three Andritz Hydro Hammerfest HS1000 turbines and one Atlantis Resources Ltd AR1500 turbine; http://www.meygen.com/technology/); the sensor system has been integrated into the Atlantis AR1500 turbine. At the time of writing, all 4 turbines have been deployed and are undergoing commissioning prior to full operation. The Atlantis AR1500 turbine is a 1.5MW horizontal axis turbine complete with active pitch and yaw capability. It has 18 m diameter rotors that rotate at a maximum of 15 rpm; the total height of the turbine is approximately 24 m above the seabed.

Information on the movement tracks of animals will be matched with operational information from the turbine developer (e.g. turbine operational status, phase of tidal cycle and speed of the rotors) to allow a series kinematic analyses to quantify close range avoidance responses of marine mammals to the tidal turbine. Overall, the analyses aim to provide the information required to reduce uncertainty in current collision risk models.

2.2 Deliverables

Deliverable 1: Sensor platform commissioning and deployment at turbine.

Deliverable 2: Investigation of frequency of fine scale interactions between marine mammals and operational tidal turbine (initial findings report after one month of turbine operation).

Deliverable 3: Monthly reports of detections of marine mammals from AAM and PAM installed on the MeyGen tidal turbine (for 12 months from end of turbine commissioning).

Deliverable 4: A final report detailing the frequency and nature of the fine scale interactions between marine mammals and an operational tidal turbine, the broader scale movements of seals in relation to operating tidal turbines, and recommendations on monitoring equipment and protocols for the detection and tracking of marine mammals around tidal turbines.

Deliverable 5: A PhD thesis on the fine scale movements of top predators around a tidal turbine.

2.3 Progress and results

2.3.1 Deliverable 1

The design of the sensor system is a combination of Passive Acoustic Monitoring (PAM), Active Acoustic Monitoring (AAM) and video cameras to identify the species of marine mammal and to construct 3D (where possible) tracks of animals within several tens of metres from the operational tidal turbine. Further, where possible, species identification will be validated using underwater video deployed on the turbine. It is hoped that the detection of physical interactions with the turbine may also be possible using the video data from the turbine. Since the inception of this work, there has been a significant amount of software development and equipment design and manufacture to finalise the monitoring system for deployment around the turbine.

2.3.1.1 Passive Acoustic Monitoring (PAM)

The PAM system was successfully installed and tested with the Atlantis control systems on the Atlantis AR1500 Turbine Support Structure (TSS) at Nigg on the 3rd October 2016. As described in Sparling *et al.*, (2016), the PAM system consists of three clusters each of which contain four hydrophones (Figure 1). The hydrophones of each cluster are arranged in a tetrahedral pattern and are enclosed within a strong polythene housing to reduce the risk of damage from moving objects in the water (Figure 1). Each cluster is able to provide an unambiguous two-dimensional bearing to detected sounds but no range information. Sounds detected on multiple clusters can be fully localised in three dimensions.

One hydrophone cluster is mounted on each of the three Turbine Support Structure (TSS) legs. Precise hydrophone locations relative to a central point on the foundation were calculated from technical drawings supplied by MeyGen. The PAM system was thoroughly tested during the assembly and installation process, with the final tests being conducted dock-side after equipment had been mounted on the TSS. The tests confirmed that the PAM system was fully functional prior to deployment.

Small preamplifiers and cables connecting the analogue hydrophones to a central junction box were connected to each hydrophone assembly (Figure 1). The analogue cables run to a central junction box mounted close to the centre of the TSS. This junction box contains additional filtering and amplification of the hydrophone signals, the digitising electronics and processor for the PAM system, the Ethernet switches and power distribution to connect to the Gemini sonars, and the ‘pitch and roll’ system on the HiCUP (see Section 2.3.1.2) and the two video cameras.

High frequency digitisation at a sample rate of 500 kHz is realised using a National Instruments cRio-9067 controller chassis equipped with three four channel NI-9222 analogue to digital converter modules. Custom software developed for the cRio chassis acquires the analogue data and compresses it using a highly efficient lossless compression algorithm (Johnson & Hurst 2013) before using a networking protocol to relay compressed data in real time to a shore side PC. The shore side PC runs the PAMGuard software (Gillespie *et al.*, 2008: www.pamguard.org), modified to decompress the audio data from the cRio and process those data in real time for both cetacean whistles and echolocation clicks, and also to make noise measurements. Data volumes from the 12 channel system are too great to be stored in their raw data format (one Terrabyte per day of data collection). It was therefore agreed that only detection data and recordings down-sampled to a lower frequency will be permanently stored.

Figure 1. PAM four channel tetrahedral cluster during assembly (left) and mounted within its housing on the Atlantis TSS leg (right).

2.3.1.2 Active Acoustic Monitoring (AAM)

As described in the previous development work (Sparling *et al.*, 2016), it was decided that the optimal location for the dual seabed mounted active sonar devices was 30 m to the side of the turbine and oriented so that the turbine is approximately mid frame. This should provide the best coverage of the turbine swept area and would allow targets to be tracked accurately in the X and Y plane both upstream and downstream of the turbine. Furthermore, the utilisation of dual multibeam sonars (offset vertically by an angle of 17 degrees) can also be used to effectively localise and track marine mammals in the depth plane. Calculation of the depth of the target is based on measuring the ratio of the relative intensities of a target between the two sonars in the overlapping sonar swathes.

Through the original development work (Sparling *et al.*, 2016) a statistical means of classifying seals with relatively high accuracy using the sonar data was also developed. However, the new classification algorithms and 3D tracking had to be integrated into the SeaTec software to reduce post hoc analyses during the data collection period. Specifically, the classification code required an expanded series of size, shape, and movement parameters to be measured for each target and saved in a summary text (*.csv) file. In addition, for effective 3D tracking, parameters from each of the individual sonars were also required. This algorithm integration has now been carried out by Tritech software engineers and has been fully implemented in a bespoke version of the SeaTec software (V2.0020.05).

An important prerequisite of tracking animals accurately using the sonars is that their orientation relative to the turbine should be known. Given the potentially uneven sea bed around the turbine, there was a risk that the seabed platform would not be deployed on flat ground and the sonars would be at an inappropriate angle. A means of levelling the sonars was required, therefore, a bespoke mounting frame was designed and built, allowing the pitch and roll angles of the sonars to be measured and adjusted as required (Figure 2). The frame was built with anodised steel and movement was achieved using two motorized actuators. This provided adjustments up to approximately ±20 degrees in both the pitch and roll angles.

In addition, an electronic system to control the 'pitch and roll' actuators and the Gemini sonars was designed and built. This was based around an Arduino open-source electronics platform which allows users to control the power to each sonar and to the pitch and roll system, charge the pitch and roll battery, monitor the pitch and roll angles of the sonars and adjust these correspondingly in 1 degree increments. The system also includes an Ethernet switch and power distribution for the Gemini sonars, and was housed in the waterproof junction box that was designed to be mounted on the seabed platform (Figure 2). Testing of the AAM system with the Atlantis control systems was completed at Nigg on the 3rd October 2016. These tests confirmed that the AAM system was fully functional prior to deployment.

Figure 2. Dual stacked Gemini sonars mounted on the custom built pitch and roll system (left), and the waterproof junction box containing control electronics and power distribution for the pitch and roll system and the Gemini sonars.

2.3.1.3 Video cameras

A two camera video system was successfully installed on the Atlantis TSS, and was tested with the Atlantis control systems at Nigg on the on 3rd October 2016.

The video cameras are high end video surveillance camera (Adhua 4K IP 12MP 360 Degree Dome Camera) which have an all-round view over a full hemisphere (Figure 3). The cameras were modified to include ultraviolet LED’s in order to reduce biofouling on the windows in custom built underwater housings. Cameras receive power from and communicate to shore via the junction box described in Section 2.3.1.1.

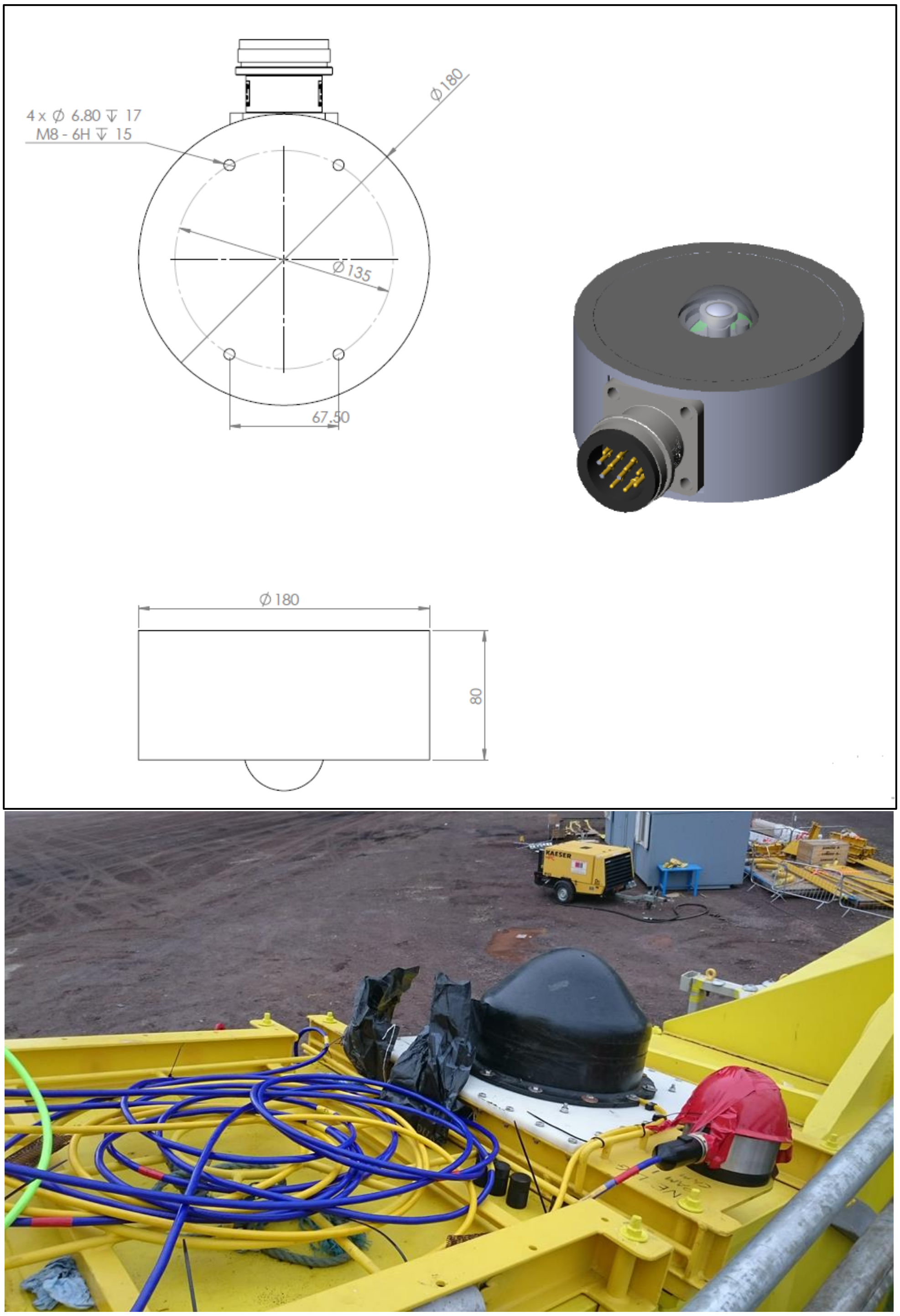

Figure 3. Schematic of the video camera (upper) and a photograph of the PAM module and video camera (lower) mounted on Atlantis AR1500 TSS (under a hard hat to protect the lens during construction).

Camera image resolution is high, at 3000 pixels across the 180 degree image, giving an angular resolution of 0.06 degrees. This means that a 1 m sized object 10 m from the camera would be 95 pixels across and a 1 m object 30 m away would have a size in the image of 30 pixels. One camera has been calibrated at SMRU to determine the precise relationship between pixel number and angle. This will enable conversion of individual pixels from camera images into precise 3D pointing vectors from each camera location, in order to compare and combine camera information with location information from the PAM and AAM systems.

The camera system was fully tested and was fully functional prior to deployment.

2.3.1.4 AAM HiCUP

The High Current Underwater Platform (HiCUP) was designed and built during the initial Demonstration Strategy development work. This consists of a steel tripod which is stable on uneven seabed, be stable in tidal currents of up to 6 knots, and could be retrieved a relatively small non-specialist vessel. The dimensions (0.5 m high and 1.8 m from centre to end of each leg), shape and design were based on calculations of turning moments and stability for a structure in a high tidal current.

In collaboration with Atlantis engineers, one of the original HiCUPs was redesigned to meet with the deployment specifications proposed by MeyGen, and to ensure stability in the current flow predicted for the Inner Sound site. This included additional ballast (400 kg), a subsea cable interface, a Remotely Operated Vehicle (ROV) handle, a protective ‘roll cage’ with lifting eyes located on the top, and a polyurethane, vertebrae type bend restrictor to prevent the main subsea cable being kinked at the HiCUP during deployment (Figure 4). Furthermore, the waterproof junction box, containing the pitch and roll system and the Gemini control electronics, was mounted on the side of the HiCUP. All cabling was protected from abrasion using flexible plastic cable sleeves and were mounted to the HiCUP at 15 cm intervals using heavy duty cable clamps (Stauff Ltd: http://www.stauff.co.uk/). A total of 10 anodes were also distributed over the HiCUP to provide galvanic corrosion protection (Figure 4).

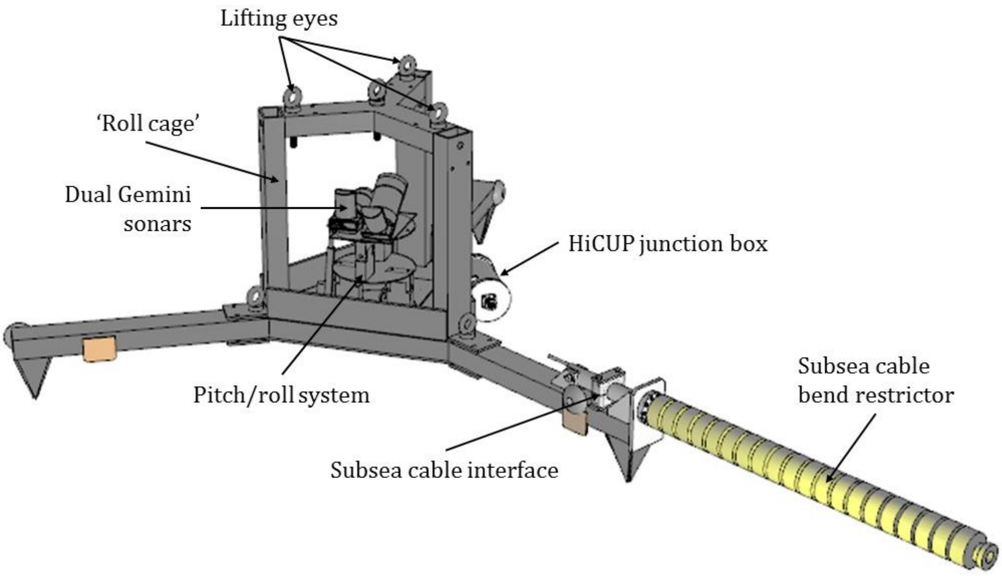

Figure 4. Schematic of the modified HiCUP for the Inner Sound deployment showing the lifting eyes, ‘roll cage’, dual Gemini sonars mounted on the custom built pitch/roll system, the HiCUP junction box containing the pitch/roll and Gemini control electronics, and the subsea cable interface and bend restrictor.

The HiCUP construction was completed, and lift tests and inspections were passed by Atlantis at Nigg on 13th October 2016. It was loaded out and transported, attached via a mounting bracket on the Atlantis TSS (Figure 5). The subsea cables were wound on this frame in a figure of eight. Once the TSS was placed on the seabed, a ROV attached the HiCUP to the installation vessel crane hook and the vessel moved it into its final location 30 metres from the TSS. The subsea cable was designed to spool out from the frame along the seabed. Due to modifications to the installation procedure, the HiCUP was deployed in a temporary location on the seabed on 24th October 2016 (Figure 6); it was subsequently moved to its final location on 19th January 2017 (Figure 7), approximately 30 metres to the side of the turbine, providing sonar coverage of both the ebb and flood upstream areas. Partial downstream coverage may also be possible, subject to the turbine shadow and downstream turbulence. Once power is provided to the HiCUP sensors, the true orientation of the HiCUP relative to the turbine will be assessed and the 'pitch and roll' system will be used to orientate the Gemini sonars if required.

Figure 5. HiCUP mounted on the Atlantis TSS assembly prior to load out and deployment in the Inner Sound.

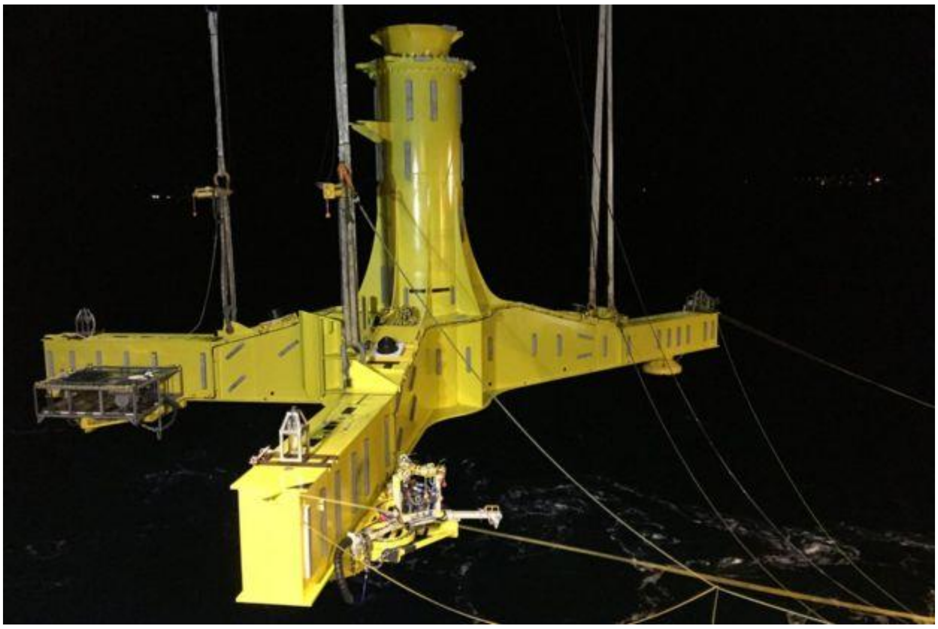

Figure 6. Atlantis TSS being deployed in the Inner Sound (image courtesy of Atlantis Resources Ltd). The HiCUP platform can be seen on the near leg of the TSS, and the PAM and video cameras can be seen towards the centre of each of the TSS legs.

Figure 7. Video still showing the HiCUP on the seabed in its final position 30 metres from the Atlantis turbine (image courtesy of Atlantis Resources Ltd).

2.3.1.5 Harbour seal telemetry

Ten harbour seals (Table 1) were caught in the Inner Sound between 26th September and 3rd October 2016 and were fitted with high resolution UHF/GPS tags so that fine scale movement can be interpreted within a wider spatial context. These tags aim to provide real time locations of seals to base stations on shore each time a seal surfaces, providing supporting evidence to determine if a collision occurs between a seal and a turbine. Furthermore, UHF dive loggers were deployed on each seal to provide high-resolution dive depth information (at 10 second intervals) during each dive. Acoustic pinger tags that can potentially be detected and tracked by the PAM system (within c. 100 m of the turbine) are currently being considered to allow the construction of 3D tracks of tagged seals around the turbine.

Table 1. Capture metrics for all seals tagged in the Pentland Firth in September/October 2016

Date	Sex	Age Class	UHF/GPS Tag ID#	UHF/Depth ID#	Mass (Kg)	Length (cm)	Girth (cm)
30-Sep-16	M	Adult	65191	51011	92.6	144	110
30-Sep-16	F	Adult	65199	51025	91.6	148	110
01-Oct-16	M	Adult	65201	51009	85	115	104
29-Sep-16	F	Juvenile	65231	51019	33.6	110	80
02-Oct-16	M	Adult	65239	51029	102	153	114
01-Oct-16	M	Adult	65242	51026	100.2	147	116
01-Oct-16	M	Adult	65246	51030	75.4	155	96
28-Sep-16	M	Adult	65254	51031	89.2	153	110
01-Oct-16	M	Adult	65334	51020	106.2	165	116
02-Oct-16	M	Adult	65446	51022	93	154	115

To date, all tags have collected large quantities of location and dive data and have transmitted these to the shore base stations (Figures 8 and 9). The quantity of data from the dive loggers were higher than expected and required weekly downloads from the base stations. New base stations with larger memories have been constructed to accommodate the higher data volume and these were deployed on 26th January 2017.

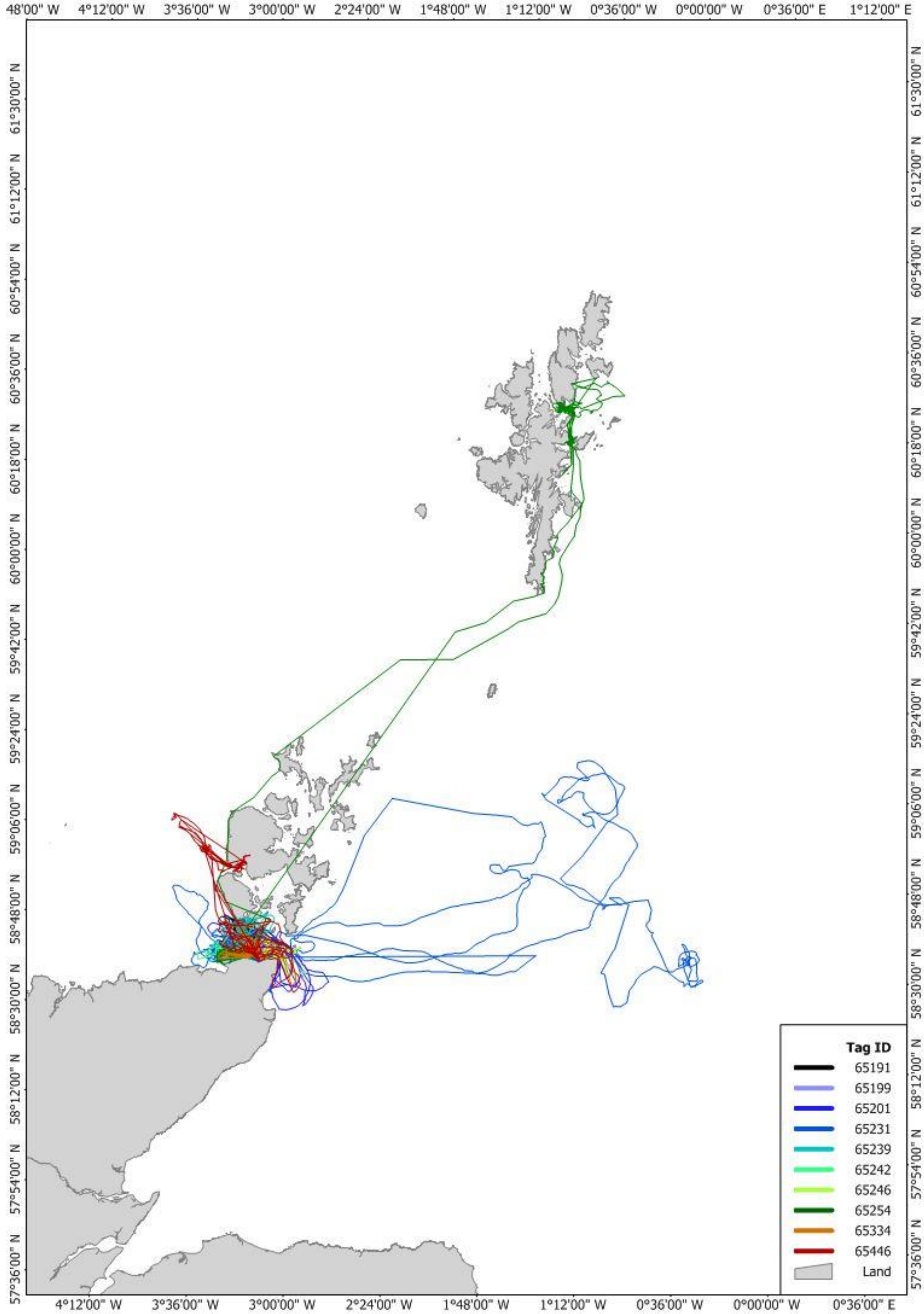

Figure 8. GPS tracks of the 10 seals (8 male, 2 female) tagged in the Pentland Firth in September/October 2016.

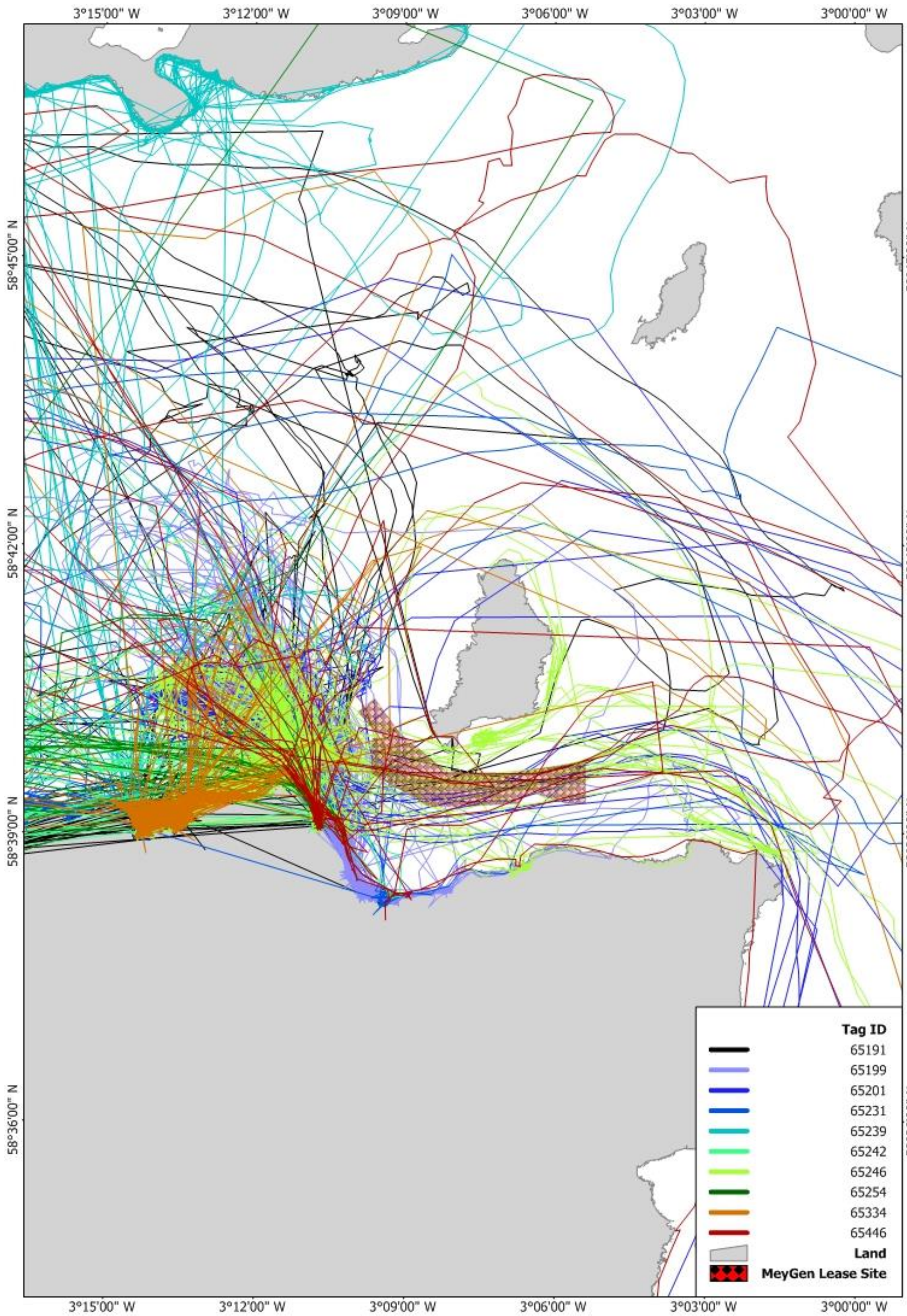

Figure 9. GPS tracks of the 10 seals (8 male, 2 female) tagged in the Pentland Firth in September/October 2016 with focus on the Inner Sound of the Pentland Firth.

2.3.2 Deliverable 2

This work will commence once the monitoring equipment starts to collect data.

2.3.3 Deliverable 3

This work will commence once the monitoring equipment starts to collect data.

2.3.4 Deliverable 4

This work will commence after data analysis carried out as part of Deliverables 2 and 3.

2.3.5 Deliverable 5

A PhD studentship (partly funded by Scottish Natural Heritage (SNH) through the Marine Alliance for Science and Technology (MASTS) Scotland) will utilise data from the sensors to track non-vocal species (e.g. seals and diving birds) to investigate: a) how these animals utilise tidal areas, and b) how they behave in relation to an operating tidal turbine. The studentship also utilises data from the animal-borne GPS tags deployed on harbour seals to measure the movements of seals around a tidal turbine at a broad spatial scale (tens – hundreds of metres). High-resolution 3D tracks of seals in close vicinity to an operating turbine will be constructed using information from animal-borne UHF/dive loggers and potentially acoustic tags in combination with the passive and active acoustic sensors. Data on the interactions of seabirds underwater may also be available from the active sonar sensors, as well as from telemetry.

The project will build on previous research in the movements of seabirds in relation to marine renewable energy installations, and will investigate how seabirds use a high velocity current tidal channel. The research will also include shore-based observations as background to any high resolution tracking information for seabirds.

2.4 Future tasks

- Data collection from the turbine based PAM, AAM, and video sensors will commence once power and communications are established, and once the turbine commissioning period is complete.
- The commissioning period will allow the development and optimisation of data management and processing protocols to allow regular report on detection rates throughout the deployment.
- Development of a final report detailing the analysis of up to 12 months of data on the frequency and nature of the fine scale interactions between marine mammals and an operational tidal turbine, including recommendations on monitoring equipment and protocols for the future detection and tracking of marine mammals around tidal turbines.
- A second harbour seal tagging trip is planned for April 2017 during which up to 20 seals will be tagged with UHF/GPS and UHF dive loggers as described above.

2.5 References

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3 MRE1.2 - Harbour seal movement modelling

A prototype individual based model (IBM) of harbour seal movement over time scales of days/weeks has been developed for the Pentland Firth / Orkney area. Many of the parameters in the model are place-holders (albeit realistic ones), with values that will be refined in the next stage of model development. The prototype IBM has a simple structure but it nonetheless captures the basic movement patterns and behaviour that is observed in harbour seal telemetry data.

The work carried out under this deliverable over years one and two of the project will be fully described in the final report, to be submitted by July, 2017.

4 MRE1.3 - Estimating collision risk using available information

The outputs of MRE 1.3 were reported in the Marine Scotland project "Refining estimates of collision risk for harbour seals and tidal turbines". The full report can be found here.