Marine Mammal Scientific Support Research Programme MMSS/001/11

MR 7.1.1:

Report

Quantifying porpoise depth distributions and underwater behaviour in tidal rapids areas

Sea Mammal Research Unit
Report to
Scottish Government

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Editorial Trail

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1 Executive summary

A vertical hydrophone array has been developed to provide new insights into harbour porpoise dive depths, underwater movements and echolocation behaviour in tidal habitats. This information is of direct relevance to understanding and reducing environmental impacts of tidal current driven turbines. Analysis of field data is on-going however we have demonstrated that it is possible to investigate the behaviour of porpoises in tidal areas using passive acoustics and further work is likely to yield reliable depth distributions.

2 Introduction

MR7 seeks to estimate the risk to marine mammals posed by tidal turbine devices. Work has been proceeding along two parallel paths, one focused on describing the individual behaviour of porpoises in areas with high tidal current, and the other examining movements of seals which will be addressed elsewhere. Here we report on the cetacean related work during the first year.

The deliverables for this part of MR7 are:

- Information on densities and behaviour of marine mammals in tidal rapids areas
- Information on porpoise depth distributions and underwater behaviour in tidal rapids.
- Collision risk models for both seals and porpoises based on the observed patterns of distribution and 3D movements in tidal rapids (using seal and porpoise data from this study and the NERC RESPONSE project).

Good progress has been made during the first year in delivering on the first two of these points. Tools have been developed and refined and we now have a good sized sample of 3 dimensional underwater track lines denoting porpoise behaviour at three sites in one area.

3 Field work overview

The first field season in 2012 took place in Orkney between the 24th of June and 27th July. In order to maximise resources, work was integrated with the seal aversive playback project (MR8) and shared the same research vessel, accommodation and field team. The research vessel used was the *Ruby May*, a 12 meter fiberglass motor catamaran (Figure 1). This vessel was chosen because she provided a useful dry working space for electronic equipment, a crane capable of deploying the large weight need for the hydrophone array and suitable maximum speed for both projects.

Figure 1. Fieldwork Vessel *Ruby May* in Orkney

Our existing vertical hydrophone array system was extensively rebuilt taking into considerations findings and lessons learned from our previous developmental project in 2011 (Gordon *et al.*, 2011). Six evenly spaced hydrophones were mounted on 25 meters of non-stretch low profile Kevlar rope in order reduce the effects of drag and maximise localisation accuracy. In addition a crossed array of four hydrophone elements was built. This was rigidly mounted to the stern of the vessel during drifting mode. It was hoped that with this additional hydrophone cluster would allow the calculation of three dimensional bearings to vocalising animals. Combined with data from the vertical array, this would provide a complete 3D location, from an array in a practical configuration to use in strong tidal currents

In addition to building new equipment, preparatory work was undertaken to improve and introduce new capabilities into PAMGUARD, the open source analysis software used for detection, classification and localisation of cetaceans using passive acoustics. A comprehensive new MEAL (multi element array localiser) module was added, introducing a framework to allow PAMGUARD to localise cetaceans using complex 2D and 3D hydrophone arrays (Figure 2).

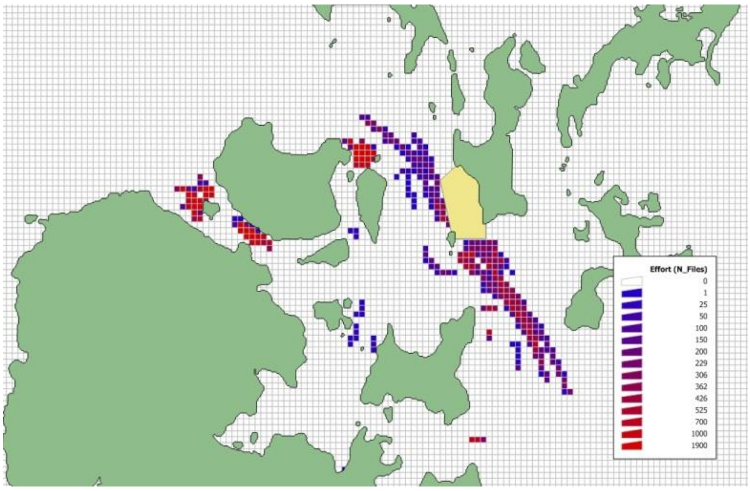

Figure 2. Screenshot of the new MEAL PAMGAURD module used to localise the position of a vocalising harbour porpoises using just a vertical array. The red circle represents the possible locations of the animal. In this case a circle of possible locations with a well-defined depth is expected from the 2D (depth/ range) localisation data possible from a vertical array.

The new module is currently capable of localising click-like vocalisations; however it has been designed to be readily adaptable to allow the localisation of whistles and other vocalisations as well as allowing the addition of new localisation algorithms. Incorporating this new functionality into PAMGUARD allows other research groups, consultants and industry to use these methods for academic and applied research.

After allowing for time lost to poor weather, 17 days were available for field work. Effort was concentrated in three tidal areas, the Falls of Warness area, Eynhallow Sound and the Sound of Longataing (see Figure 3). It was, unfortunately, not possible to operate in the EMEC site due to operating restrictions stipulated by EMEC that would have limited the vertical array to an impractical length.

The initial survey approach with the hydrophone array was to simply drift through large tidal areas, such as the Falls of Warness with the current and wait for animals to come within range. It was very soon evident however, that in these areas, porpoise densities were so low that this “passive” strategy would result in very few detections. Thus adopting a more active approach using a towed hydrophone array, and visual searches, to find animals and then deploying the vertical array in areas where animals had been detected. Although this would make it impossible to use data from the vertical array and visual observation to determine densities, as initially intended, it was felt

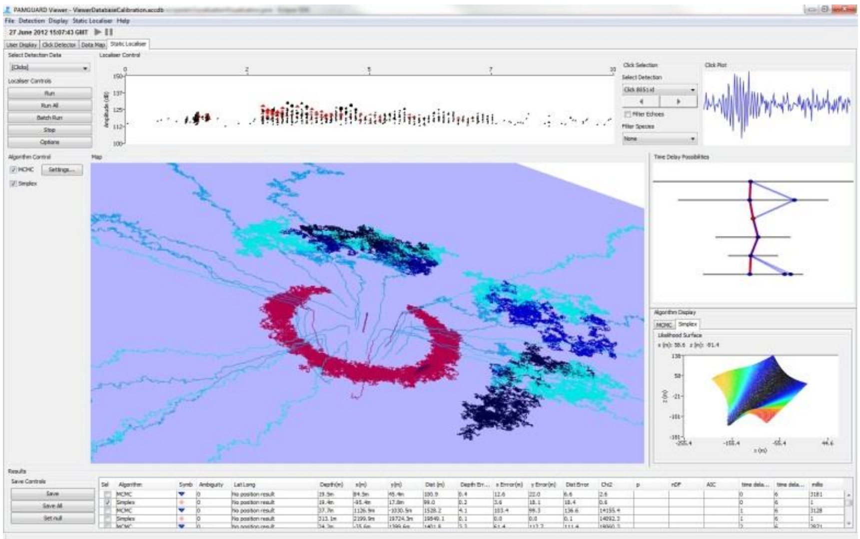

Figure 1. Acoustic effort over 17 days of survey work. Effort was concentrated in three tidal areas, the Falls of Warness Area, Eynhallow Sound and the Sound of Longataing

more important to collect a substantial dataset on porpoise on dive behaviour. It was acknowledged that the capacity to measure underwater behaviour was unique while many other groups including developers can and are measuring densities in these areas.   In addition, to compensate for losing density information six C-PODs were deployed in various locations in order to investigate occurrence and temporal (diurnal and tidal) patterns of usage of different parts of tidal rapids systems.

Generally the electronic field equipment worked well and over 2.6TB of raw acoustic data were recorded from the hydrophone array while drifting in tidal currents. All six C-PODs were recovered successfully after deployments of between 40 and 50 days. In addition to acoustic data collection, visual watches were maintained and video methods used to determine bearing and range to animals. Poor weather conditions restricted the amount of visual data that could be collected despite the hard work of a large visual team.

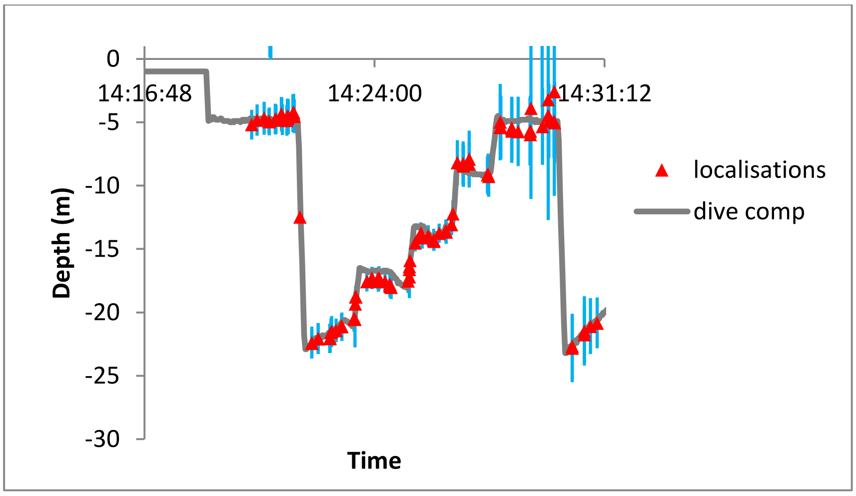

Figure 4. Graph comparing the true depth of a pinger producing simulated porpoise clicks, and the results from attempting to localise those clicks using a vertical array. This particular example demonstrates the accuracy possible using an array of six evenly spaced hydrophones up to a range of 110 m

4 Data analysis and preliminary results

Analysis of the vertical array data is still on-going. All of the 2.6TB of sound files have now been analysed in PAMGUARD for porpoise vocalisations, with over 100000 typical narrow band high frequency (NBHF) clicks detected. Of these clicks 22,914 were detected on a sufficient number of elements within the array to attempt a 2D (depth and range) or 3D (depth, range and angle) localisation.

A major initial task was to model the movement of the array underwater. Although the vertical array had a substantial weight attached, it did move underwater largely as a result of vessel drift. This is evident from depth and angle changes of an open tag sensor placed near the bottom hydrophone element . This is a major consideration as the location of the different hydrophones in the array, , must be known to determine animal locations. Modelling the array movement required collecting and cross referencing data from several different instruments: a vector GPS, an inclinometer and three axis gyroscope, and a magnometer and accelerometer to estimate the position of every hydrophone element with a temporal resolution of a second. MATLAB was used to build the hydrophone locator algorithm and extensive modifications were made to the open source acoustic software package PAMGUARD, to allow changing hydrophone positions and vector GPS data to be imported.

The new PAMGUARD MEAL localiser module was then used to calculate positions of porpoises using measured time delays and the modelled location of hydrophone elements. Several small modifications were made to this module in order to optimise batch localisation of large datasets. The Markov chain based localisation algorithms used required a significant amount of processing power. Even with the use of three Intel i7 based, computers running in parallel, several weeks of processing were required to localise all detections. Each calculated localisation also has an associated error in each relevant dimension and a χ^2 value. Locations with very large errors were discarded as were "nonsense" positions such as those above the sea surface, (These usually occurred due to attempting to localise an echo) and those with a χ^2 value which indicated a very bad fit to the data. After these locations had been filtered out 9,312 locations remained in the dataset.

One field day was devoted to assessing the accuracy of the hydrophone array using a hydrophone broadcasting simulated porpoise clicks deployed at different ranges and depths. Unfortunately the vector GPS failed on this day, along with a gyroscope sensor, meaning the array positions couldn't be modelled as accurately as was possible on other occasions. However 2D data, a sample of which shown in Figure 4, were not affected and 3D results were encouraging showing that localisations of sub meter accuracy are possible.

Calibration results, both from this survey and various other experiments demonstrate that this methodology provides accurate locations. The next stage of analysis is using this data to gain an insight into behaviour in tidal habitats.

One of the most important advantages of this methodology is that it can provide a more accurate assessment of collision risk by better describing underwater behaviour and dive profiles. This will indicate the proportion of time spent at the depths swept by different types of tidal turbine and such information could also be used to reduce collision risk by altering the depth at which turbines should be deployed. Acoustic localisation provides the depth and location at which clicks that are picked up on sufficient hydrophones were made. This is a useful first indication of an animal's dive profile but we will also need to consider how best to infer the animals' tracks between these localised vocalisations and minimise any biases.

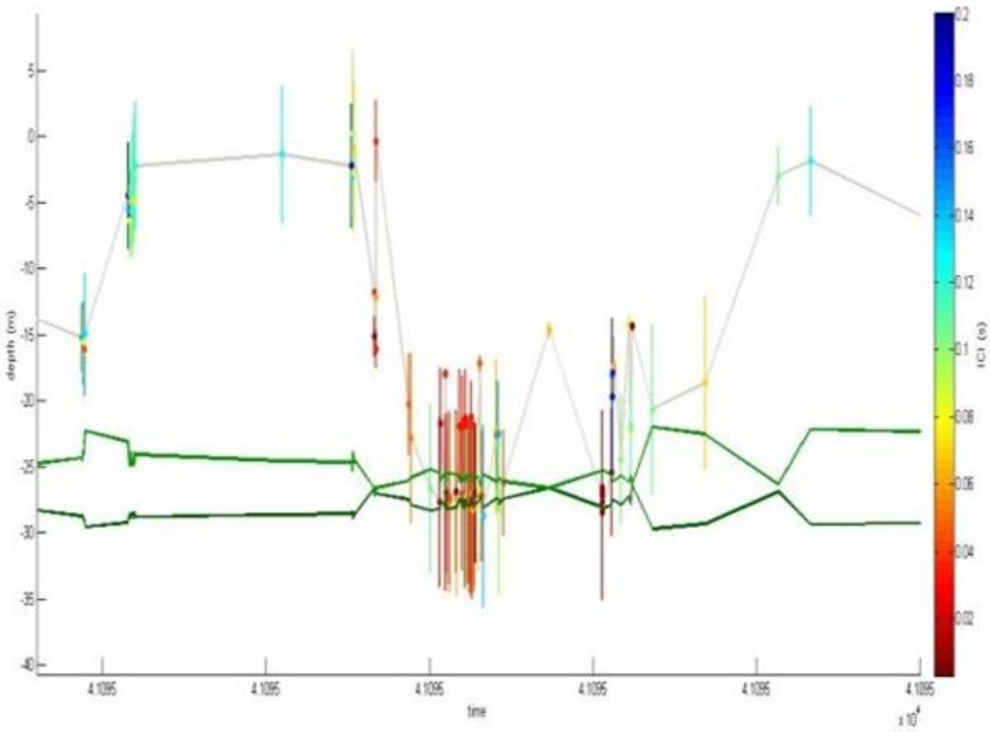

Figure 5. Localisation data showing a dive profile with an arrow indicating the position of the buzzes in Figure 4. The green lines indicate the maximum and minimum possible seabed depths. Localisations are coloured corresponding to their ICI and error bars show the 95% confidence in depth. In this case it is likely that the porpoise was feeding near the seabed

The key to determining the distribution of depths is to reconstruct underwater tracks by joining the intermittent locations that the acoustic information provides. In Figure 5, a profile is relatively easy to reconstruct just by joining up the dots. However, often localisation data are not as easy to interpret. A current area of consideration is therefore how to produce a statistically sound method of reconstructing likely dive profiles. This in turn will allow determination of depth distributions within a given area.

Studies with captive porpoises and wild porpoises carrying recording telemetry devices have provided insights into porpoise echolocation behaviour and how they use this in the context of foraging. These observations indicate that some characteristic vocal behaviour can be associated with actives such as feeding and socialising, (based mainly the amplitude of and interval between clicks (ICI)). By recognising such characteristic acoustic events the aim is to gain some insight into their behaviour in the field in strong tidal current areas.

A floating array is a quiet and slow moving measurement platform and is thus ideal for recording of vocal patterns. A preliminary analysis of this data shows some characteristic "approach phase vocalisations" (a decreasing of the ICI) followed by a rapid buzzing (ICI < 10ms): calls which captive studies indicate are often associated with feeding behaviour. Clicks within buzzes tend to be 20dB quieter than clicks during 'normal' behaviour which will make them difficult to detect. So far only 10 clear examples of such buzzes have been obtained. However the much louder clicks made during the approach phases can be detected more readily and may prove to be a more reliable indicator of feeding behaviour. More data, however, are required to explore this. Currently, work is underway to plot acoustic locations and clicks rates in conjunction with fine scale bathymetric data. A preliminary plot showing inter click interval (ICI) coded by colour for each 3D localisation is shown in Figure 6.

Plots like this can indicate how animals are moving within the terrain and where they are producing echolocation signals such as those associated with feeding.

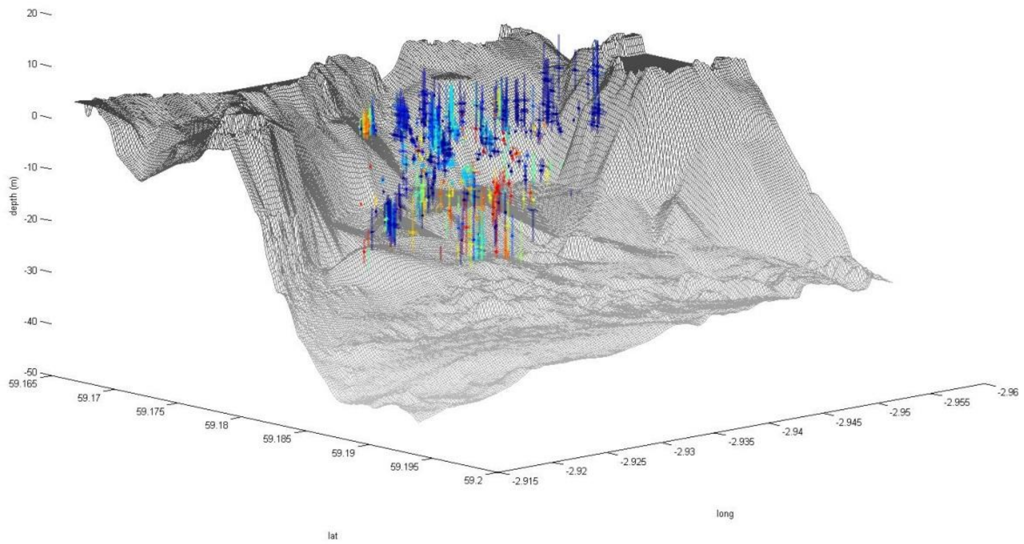

Figure 6. A single day of 3D localisations along with bathymetry data. Localisations are coloured by ICIC and error bars show the 95% confidence interval in latitude, longitude and depth.

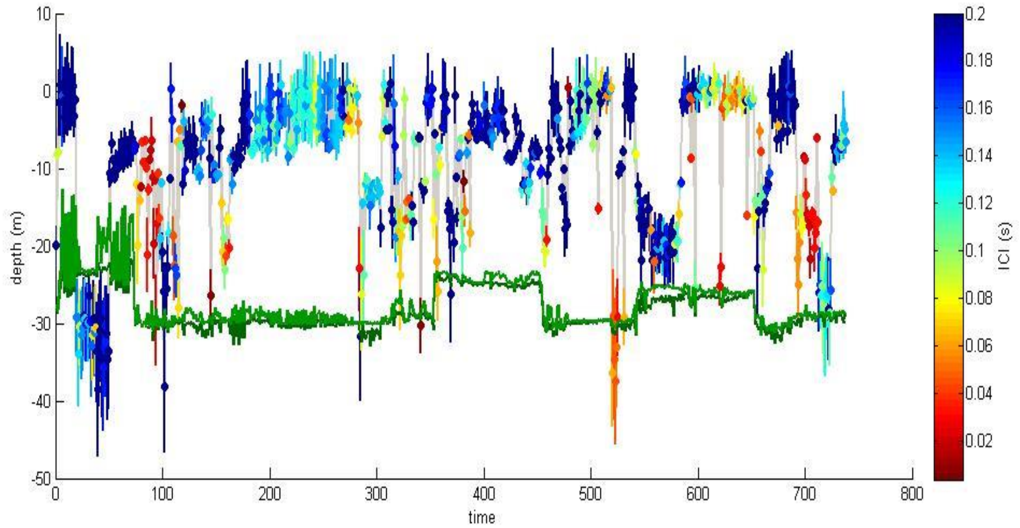

Figure 7. 2D representation of data in figure 4. Localisations are binned in chronological order rather than represented as a true time series. Errors bars show the 95% confidence interval in depth and results are coloured by ICI. In this particular example most buzzes occurred either near the seabed or the sea surface. Note that some of the localisations appear below the sea bed. This is likely due to the fact that the bathymetry data is interpolated from 3D data points which are often 10-20m apart. It is therefore possible that some localisations have occurred in areas where seabed features have been missed.

To obtain more accurate click train and ICI measurements the plan is to develop a click train detector which can automatically pick out click trains and assign them to characteristic echolocation behaviour categories. Collecting a greater volume of data during the upcoming field season and programming such a detector in PAMGUARD will speed up analysis of data and ensure consistency between both the 2012 and the future 2013 datasets.

Six C-pods were also deployed within tidal rapid areas in Orkney Fig 8. CPOD data were analysed using CPOD.exe. An initial impression during the survey that porpoise densities were lower than in other areas appears to be supported by comparison of CPOD detection rates in Orkney and other areas. There is as yet no established methodology for calculating absolute density estimates from CPOD data.

CPODs are good for providing continuous long term datasets from specific locations and these are useful to determining temporal patterns. An initial analysis indicates that, as we have found in other locations, turbulent areas either side of the restricted passes with the highest current are preferred at the state of the tide when they are down current from the restriction e.g. Figure 9.

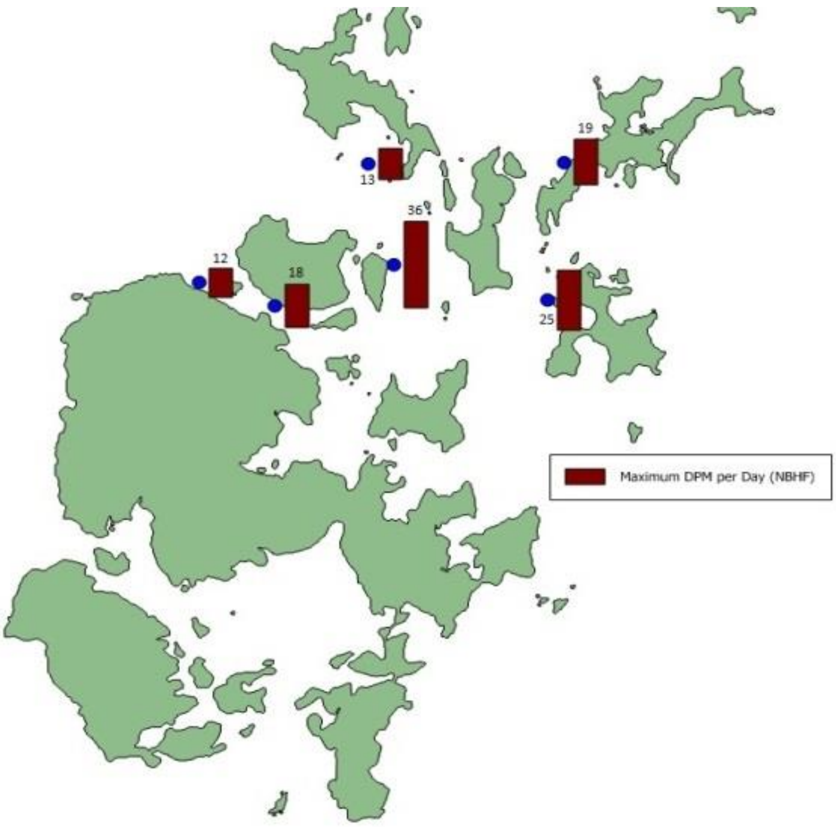

Figure 8. Locations of C-Pod deployments with maximum number of detection positive minutes per day

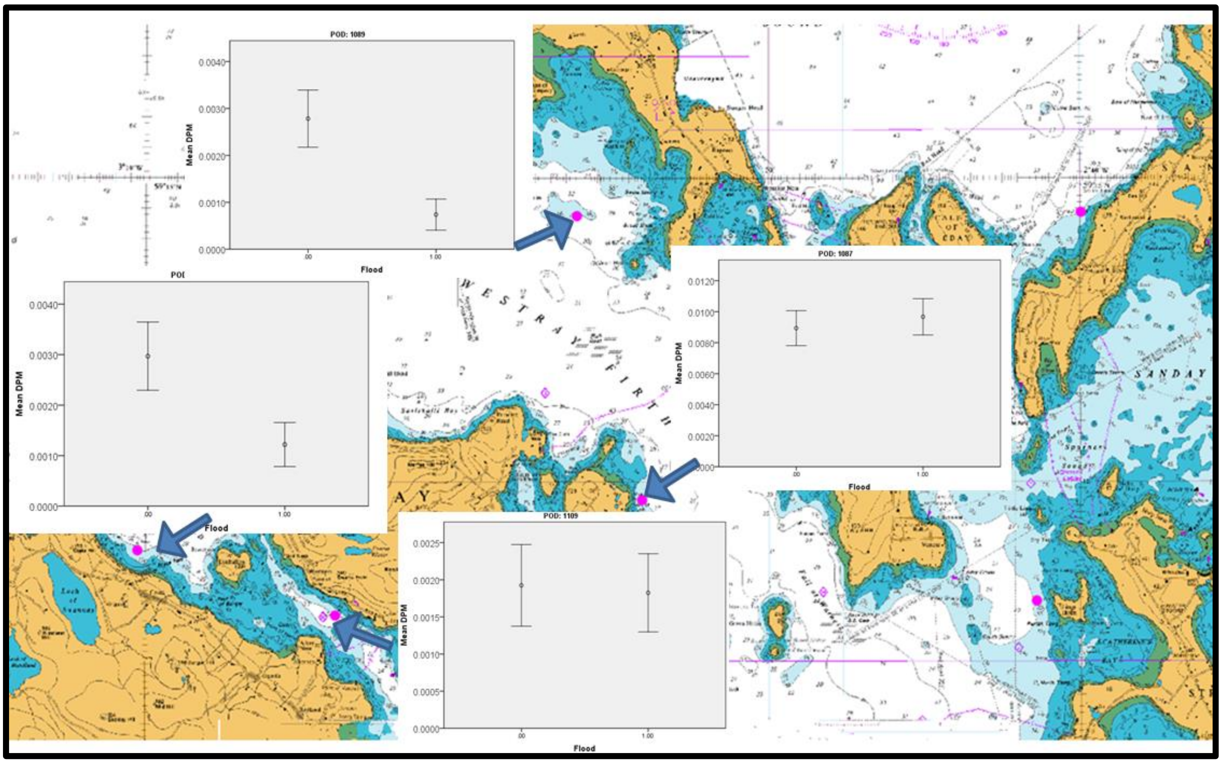

Figure 9. Detection rates during the Flood Tide (right hand bar) and the Ebb tide (left hand bar) for four pods in two tidal sites in Orkney. For westerly sites the detection rates are highest during the Ebb tide, when the tidal current is flowing in a direction that means these locations are downstream of the restrictions where currents are strongest. This is also the time when these sites are at their most turbulent.

5 Conclusions

In conclusion, the vertical array data is providing interesting and new insights into harbour porpoise dive depths, underwater movements and echolocation behaviour in tidal habitats. Most of this information is of direct relevance to understanding and reducing environmental impacts of tidal current driven turbines. It is unlikely such data could be collected in these habitats by any methodology other than the vertical array system whose development the Scottish Government has been supporting for the last few years. Analysis of field data is on-going however this research has demonstrated that it is possible to investigate the behaviour of porpoises in tidal areas using passive acoustics and further work is likely to yield reliable depth distributions. Although none of the areas where data collection was possible are likely to host tidal turbines in the near future, these methods can be used by developers at putative tidal turbine sites to attain the information on habitat usage and distribution required to help to understand and mitigate the potential impacts of tidal power developments.

6 References

Gordon, J., Macaulay, J., Wittich, A. , Watherup, G. , Gordon, T. & Northridge, S. (2011). Acoustic monitoring in areas of high tidal current: Sea Mammal Research Unit, University of St Andrews, Report to Scottish Government, St Andrews, 38pp.