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Understanding commercial fish space use around Marine Renewable Energy sites: novel acoustic array-based fish tracking and monitoring at Wave Hub, Cornwall

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MBA Report to DECC, November 2013

This document was produced as part of the UK Department of Energy and Climate Change's offshore energy Strategic Environmental Assessment programme

Deployment of MBA Seafloor Acoustic Lander at the WaveHub, Cornwall

DECC URN: 14D/061

Final Report to the Department of Energy and Climate Change

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Executive Summary

- To assess adequately the impacts of offshore renewable energy installations (OREI) on marine fish abundance and diversity there is a burgeoning need to determine the movements, space use and spatial dynamics of commercially important species within and adjacent to OREIs.

- Unique seabed lander technology housing data-logging acoustic receivers has been developed by the Marine Biological Association for long-term monitoring of fish movements in difficult-to-study offshore locations subject to significant current speeds and wave height.

- The current project has succeeded in deploying six seabed landers to form an acoustic monitoring array around the Wave Hub site off Hayle in North Cornwall that is now capable of supporting long-term tracking of transmitter-tagged fish.

- Over 140 fish including rays, plaice and sole have been tagged with acoustic transmitters or data-storage tags in the vicinity of the Wave Hub. Acoustic–tagged fish movements are being tracked automatically by the receiver array while data storage tags are returned when fish are caught through the fishery.

- Early results show that rays exhibit short-term philopatry to localised inshore habitats adjacent to the Wave Hub that is interspersed with longer ranging movements to deeper offshore habitats where fishing pressure is higher.

- The deliverables of the current project and that of the NERC QBEX project (2012-2014) will have put in place the required long-term fish and shellfish monitoring arrays/tags and developed the tools for analysis; the next step requires an extended period of consolidation of the data recording and analysis phases.

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Rationale

Food supply from fisheries (proteins derived from fish, crustaceans and molluscs) presently accounts for about 17% of the animal protein intake of human populations worldwide in spite of global declines in fish stocks. Commercial fish populations are under strain in UK coastal waters and the current review of the European Union's Common Fisheries Policy (CFP) will highlight the need for sustaining fish stocks through protection of the key areas they occupy. Marine offshore renewable energy sites are likely to have direct and indirect impacts on shelf and coastal environments over a wide range of scales. Environmental effects may include: habitat change; increased water turbidity and contaminant remobilisation during construction and decommission; and increased habitat heterogeneity, noise, vibration and electromagnetic fields during operation. These impacts are likely to affect the movement, activity and behaviour of marine fish, and hence their population sptial dynamics, however little detailed information exists. Moreover, the role of such sites in promoting fish abundance and diversity as well as fisheries is also at present poorly understood.

The wave climate in southwest UK waters is favourable for the establishment of 'wave farms,' whose properties (by excluding mobile fishing gear) tend towards the *de facto* establishment of marine protected areas. Hence, the scientific monitoring of such sites provides an opportunity to quantify how they can potentially benefit fisheries through sea area protection. In particular, the region off southwest England comprises an area of high fish species diversity, where many northern and southern species coexist, and consequently supports generally diverse fisheries. Although yet to reach its potential, the Wave Hub (off Hayle North Cornwall) is well placed to assist in the wider assessment of how marine renewables will affect fish and fisheries in this biologically diverse region.

Research leading to the Current Project

Through the Natural Environment Rearch Council's (NERC) *Oceans 2025* Strategic Research Programme the Marine Biological Association (MBA) became the first UK institute to acquire Vemco VR3 fish recording and data-logging equipment to undertake long-term monitoring of fish movements. Long-term monitoring of fish movements in offshore sites is challenging and here required the design, testing and proving of new seabed lander technologies as these deployments (up to around 5 years) is far in excess of traditional mooring installations, which in waters subject to wave action generally have to be serviced annually.

Using MBA expertise and our multibeam hydrographic survey equipment and similar available data for the Wave Hub site, we modelled the terrain to determine the parameters of a lander that would be suitable for our test site and deployment at the Wave Hub site and determined that a 2m antenna height above the seabed was appropriate. With assistance at the NERC Moorings Workshop and the engineering department of NOC, Liverpool we designed a lander to house a VR3 receiver at the optimal height above the seabed.

We were able to assess the likely water flow that would cause the lander to move when deployed (Greaves, *pers com.*) at around of 1.8 ms^{-1}, which rises to 2.9 ms^{-1} when the additional foot weights are added. Using further Wave Hub-derived data for wave height (H_s), period (T_p) and water depth we modelled the expected near-seabed water orbital velocity experienced at Wave Hub between 26 Nov 2008 and 27 Jan 2010 (324 days equivalent due to a break in data gathering between 22 March 2009 and 1 Jul 09) by combining derived seabed orbital velocity and tidal flow (**Figure 1**). On only 3 of the two-hourly-derived data sets comprising the 324 days were the total seabed water speeds greater than 1.8 ms^{-1} and the maximum for this period was 2.0ms^{-1}, (**Figure 2**) which is much less than the 2.9ms^{-1} than the ballasted lander can tolerate.

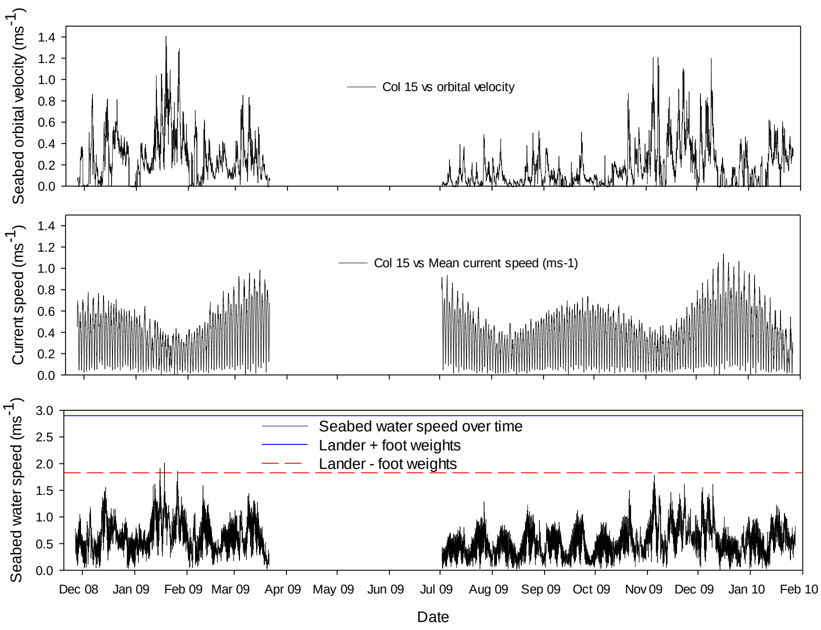

Figure 1. Top, derived seabed orbital velocity (ms^{-1}) for 324 days equivalent between 26 Nov 2008 and 27 Jan 2010, with gaps. Middle, ADCP current speed data (ms^{-1}) for the same period (courtesy of Wave Hub Ltd). Bottom, total seabed water speed (ms^{-1}) and expected stability thresholds for the landers without and with added foot weights.

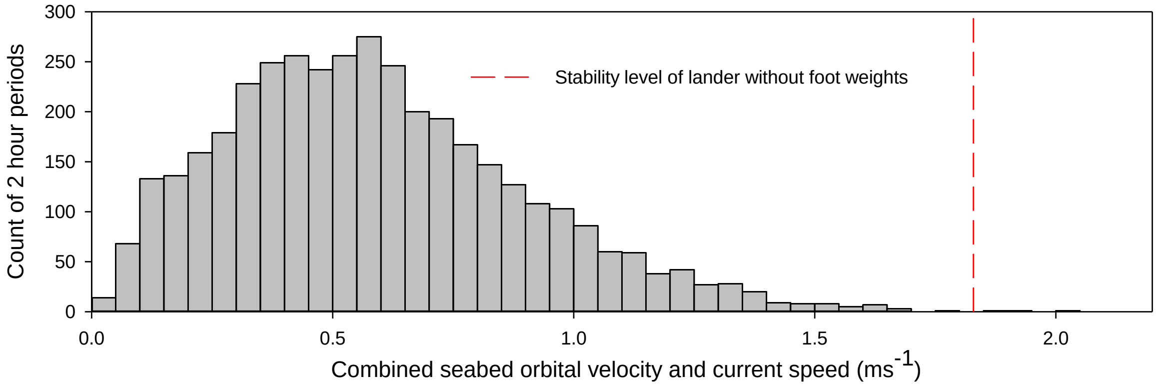

Figure 2. Frequency histogram showing total seabed water speed ms^{-1} in two-hourly periods and expected stability threshold for the landers without added foot weights.

Therefore, this lander (**Figure 3**) is a cost effective, easy to transport modular form that is stable and robust, does not need marking with a buoy at the sea surface, occupies a small spatial footprint and has a reliable on-board recovery system allowing it to be "popped up" and removed when its deployment ends. We tested and improved various components of the lander including its deployment and recovery mechanisms and six of these landers have been operating in Whitsand Bay, Cornwall since January 2010 (**Figure 4**) with 197 fish and shellfish from 12 species tagged to date (e.g. **Figure 5**); research at this site is progressing.

Figure 3. Left, completed, rendered PowerSHAPE-e CAD image of lander and additional foot weights and right, the tack-welded prototype.

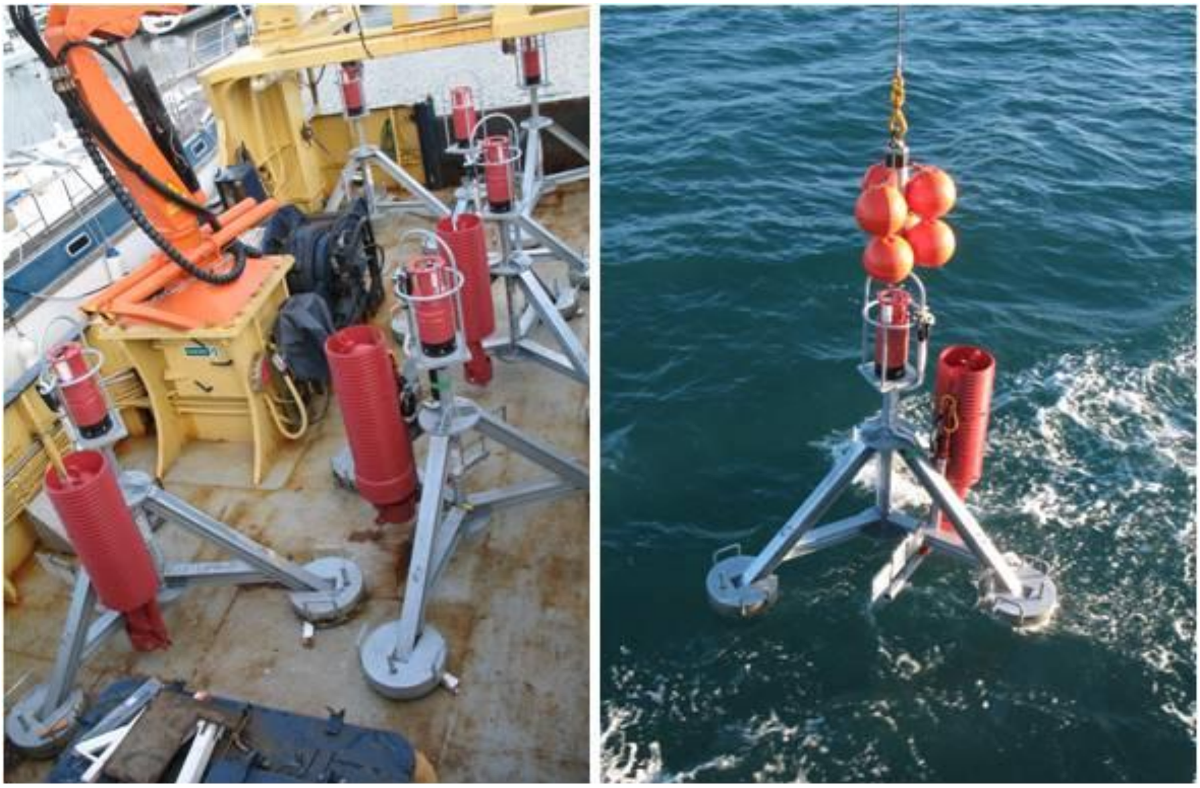

Figure 4. Left, VR3 equipped landers aboard *Plymouth Quest* and right, being deployed at the test site in Whitsand Bay, Cornwall.

Figure 5. Examples of acoustic transmitter-tagged (V9) fishes (*Raja microocellata*, small eyed ray; *Scophthalmus maximus*, turbot; *Solea solea*, sole) and close-up of the tag attachment (with MBA embossed and numbered Petersen disk).

Current Project Deliverables

This final report presents progress using this seabed lander technology for each of the three deliverables, namely lander-borne acoustic receiver and electronic tag deployments and subsequent data analysis.

(1) Lander deployments: Deployment of up to six MBA seabed landers each housing an acoustic datalogging receiver, with landers deployed to form a spatial array at the Wave Hub site for long-term fish monitoring.

(2) Tag deployments: Attachment of up to 80 acoustic transmitter tags on commercially important fish species from the Wave Hub area, with data retrieval from landers at least once within the project period. Secondly, attachment of up to 80 long-term data storage tags on fish of the same species from the Wave Hub area.

(3) Analysis: Initial assessment using acoustic array data of the fine-scale species movements (sex differentiated, where possible) including features of diurnality, site philopatry, movement response to noise and electrical sensitivity within Wave Hub Development Area, and the spatial dynamics across wider scales into adjacent regions from data-storage tag returns.

Wave Hub lander Consenting process (Deliverable 1)

The installation of these landers was carried out under the Marine and Coastal Access Act (2009), whereas our earlier deployment in Whitsand Bay was under the Coast Protection Act (1949). We were able to demonstrate, and it was agreed by the Marine Management Organisation (MMO), that we would not need a Marine Licence, which greatly simplified the process. The MMO did require us to liaise with several groups and we recognised that the project would work better scientifically though dialogue with local fishermen, their representatives and representatives of Wave Hub. Consequently, these discussions had been developing for several years. Through these discussions we agreed a spatial plan for the installation of six VR3 receiver-equipped fish tracking landers just outside the perimeter of the Wave Hub Development Area. This aimed to best deal with the uncertainty of final location of Wave Energy Converters (WECs) at Wave Hub, in terms of which ‘bays’ would be occupied by which type of device and where any particular WEC would be situated within its bay.

As previously, the MMO also required us formally to announce the intention to deploy the landers through the Kingfisher Bulletin (maintained by Seafish) and to create a Hydrographic Note once the landers were installed so that relevant Admiralty charts could be updated. We sought and were granted a Small Works Consent from The Crown Estate which comprised six 100 x 50m rectangular boxes in the locations agreed with all the stakeholders.

Wave Hub lander preparation (Deliverable 1)

Six VR3 receivers each attached to a seabed lander were assembled at the MBA in Plymouth. Few modifications were made to these when compared to the initial deployment of the earlier set of six that were installed in Whitsand Bay, Cornwall in early 2010. An exception was to use three 11”, 950m trawl floats for the recovery mechanism at Wave Hub, where only two were used previously in the Whitsand Bay array. This necessitated a slightly longer cowl for the floats and release mechanism so three were cut from a 3m length of 300mm pipe where four had been made previously. The float cowl was also expanded slightly so that its internal diameter was ~380mm rather than 340mm on earlier landers. A further minor change was to use a different, perhaps better antifouling paint and have this professionally applied by pressure spraying. It did seem that the initial light sandblasting to all the parts to be antifouled (with the exception of the VR3s themselves) improved the key of the future coats, especially on the parts that can flex. The benefit of this additional expense will only be evident when it comes time to retrieve the landers, but it is hoped to observe biofouling qualitatively by the use of a drop-down camera if possible. The galvanised steel release assembly complete with cowl and plastic release parts made up one of the parts to be painted with antifouling paint. The others were the float pellet span and the line canister and acoustic release housing. The line was ready-wound inside the canister at this stage and the release housing was masked so that the acoustic releases could be fitted later. After painting these parts were fitted to the landers and foam blocks inserted to minimize contact and paint abrasion from vibrations during transport. These blocks were removed prior to deployment.

The VR3 units themselves were also prepared. This included a waterproof test, establishing that they would detect and log valid ping identification (ID) numbers from the transmitters and that these data could be retrieved via the through-water modem. A final check was to ensure that the clocks in each VR3 were synchronised. Once complete the VR3s were stored to dry off for several days, then masked prior to painting with antifouling paint. After this they were dry stored and foam packed for transport. They were only installed onto the landers once the latter were loaded aboard the deployment vessel.

Wave Hub lander deployment (Deliverable 1)

There were logistical challenges in deploying the six landers at Wave Hub. Ideally they would have been transported by road to a convenient port location on Cornwall’s north coast to keep ship costs to a minimum. There, few appropriate facilities exist and none have suitable vessels. Instead, we recognised that the landers would be transported by road (Figure 6), to either Falmouth (or Penryn) for loading. We examined the feasibility of different vessels and companies and settled on using MV *Grey Bear*, operated by MTS Group, which has UK offices in Brixham and Falmouth. Lacking accommodation, *Grey Bear* was loaded with the landers and deployment equipment in Penryn, sailed around to St Ives for personnel to be added and then operated at Wave Hub for the day, before disembarking and then transiting back to her home port where equipment was retrieved.

Figure 6. Loading 6 completed landers (minus the VR3 fish tracking and recording device) on to the lorry at the MBA. The blue parts are the antifouled release and recovery mechanism, which at this time have the anti-vibration foam blocks inserted.

When installing the test array in Whitsand Bay, Cornwall (**Figure 4**) we lowered the landers to the seafloor and once the position had been checked we triggered the IXSEA 2500 acoustic release, which de-coupled the lander from its deployment wire leaving the float-assisted release to return to the surface. Although other deployment methods could have been used in the 25 to 30m water depths here, part of the reason for this arrangement was for the anticipated installation of the array at Wave Hub, where expected water depths are just deeper than 50m. A significant discussion point for us with MTS and wire manufacturers was to determine the specifications of a wire that would be strong enough to safely do the job, could fit onto the powered spool of the hiab and be long enough to reach the sea-floor with the expected catenary characteristics of the prevailing tide and weather conditions. It was also necessary for *Grey Bear* to manoeuvre if there was a small amount of swell with the lander on the seabed and with the wire slack before triggering the acoustic release. We opted for 160m of 9mm non-rotating wire which would give *Grey Bear* seven vessel lengths of manoeuvring space before a lowered, but yet to be released lander, would be toppled had anything gone wrong with the manoeuvre.

After moving the landers to Penryn in mid June 2013, the first available weather window, which coincided with suitable tides came on the first weekend of July. Final preparations were made including rigging the three dunker units and the MBA's GeoAcoustics survey pole assembly (**Figure 7**). These were the IXSEA 2500 unit to deposit the lander on the seafloor, the VR3's Link-Quest through-water modem, used to talk to the lander to ascertain its depth and attitude or tilt after deployment and a Sonordyne dunker, used to communicate with the lightweight release transponder (LRT), (part of the lander's recovery mechanism). Although less 'intelligent' than the VR3 modem the Sonordyne LRT works better over vessel engine noise and can range onto the lander more quickly generally. The survey pole was used to keep the dunker/modem units firmly in place during manoeuvring and well below the vessel to assist with communication fidelity.

Figure 7. Left, the three dunker units for the IXSEA 2500, the Sonordyne lightweight release transponder and the Link-Quest modem for the VR3. Also visible is the IXSEA 2500 and its supplementary flotation. Right, the MBA's GeoAcoustics survey pole and mount in position. Inset is a screenshot of the VR3 host software, used to verify the location and attitude of the lander during deployment and once on the sea bottom. This one shows the tilt on lander 3 at the southwest corner of the Wave Hub Deployment Area, which had the greatest tilt angle of all those deployed at Wave Hub.

At the Wavehub site, each lander was successfully deployed (**Figure 8**) and we were able to establish, via the VR3 modem, that all devices were operational and upright before *Grey Bear* headed back to St Ives for unloading of some equipment.

Figure 8. Left, lander being picked up from the deck of MTS Grey Bear using hiab winch, wire and the IXSEX 2500. Mid, lander being steadied and swung outboard. Right, lander being lowered into the water before final positioning and lowering to seabed.

Wave Hub fish tagging (Deliverable 2)

It proved particularly difficult to catch fish using suitable gear to keep fish in prime condition so they can be tagged and released in the vicinity of the Wave Hub. We explored options for trawling using both small, local vessels, as well as chartering larger fishing boats from Newlyn, both without success. The small, local fishing trawlers, which are very few in number tend to fish the small patches of softer sediment well away from the Wave Hub area and were not able to explore new areas where their knowledge and experience suggested their gear would likely suffer. Similarly, the larger trawlers from Newlyn would fish patches of soft sediment well to the east of the Wave Hub at specific times of the year, but were not keen to undertake this work at other times. The only other fishing boats with active gear in the area tend to be the large beam trawlers that operate just to the north of the Wave Hub area early in the year. These are much too expensive to charter for this work and otherwise cannot be relied upon to fish where we would like.

There are several local fishing boats in St Ives, Newquay and Padstow though the majority of these use pots for brown and spider crabs during the summer and tend to fish on Cornwall's southern coast during the winter or when bad weather is expected. Few of these boats fish with trammel or tangle netting and those netters who do operate tend to set their gear well offshore and stay with it over an entire neap cycle of tides. Therefore, it was financially prohibitive to use these vessels. Instead, we were able to encourage a local fisherman from St Ives to set four large-mesh tangle nets ~750m each at the Wave Hub in September 2012 and a further two of these nets to the west of St Ives and the south of Wave Hub for a 36 hour lay. None of the nets at the Wave Hub had any fish large enough to tag, although we were able to deploy 9 data storage tags (DSTs, Star-Oddi milli-F) on large *Raja brachyura* (blonde ray) from the western tiers.

In early 2013 the CFPO put us in touch with another fisherman and we were able to afford a total of three days of fishing over two tides to deploy the remaining DSTs and acoustic transmitters immediately after the landers were installed. We explored the same areas as used previously and had good success in deploying the remaining Star-Oddi DSTs (n = 84) on *R. brachyura* as well as number tagging a further 11 blonde ray. We continued to explore fishing opportunities near the Wave Hub and caught one turbot and one brill on 25th Sep 2013, and a further 37 fish across 6 species on 26th Sep 2013 (**Table 1**).

We were also able to tag 4 *Palinurus elephas* (European spiny lobster) with the crustacean version of the Cefas G5 DST (**Figure 9**) and it is hoped that this work will make a small but significant contribution to improving the knowledge of this relatively poorly understood species.

Table 1. Counts of species caught and tagged with V9 pingers at Wave Hub in 2013, n = 39.

Date	Sex	*Raja microocellata*	*R. montagui*	*Pleuronectes platessa*	*Scophthalmus rhombus*	*S. maximus*	*Solea solea*
25/09/2013	Unknown				1	1	
26/09/2013	Female	3	7	8			
	Male	1	6	5			
	Unknown				1		6
Total		4	13	13	2	1	6

Figure 9. Male *Palinurus elephas* (European spiny lobster) tagged with the crustacean version of the Cefas G5 DST.

Initial analyses (Deliverable 3)

To date we have had three re-captures of DST tagged *R. brachyura* (**Table 2**), one from a local fisherman in St Ives and two from visiting French trawlers. Two of the recaptures were from the rays tagged in September 2012, though unfortunately one of these loggers failed during deployment and one had a relatively short time at liberty. Further analyses of these data are on-going. These centre on the animals' vertical behaviour, which shows apparently complex movement patterns. For example, a large blonde ray displayed nocturnal activity cycles and during active periods spent a surprising amount of time well away from the seabed and relatively close to the sea surface (**Figure 10**). Progress has also been made in reconstructing the horizontal tracks of individual fish, using a probabilistic tidal geolocation model to estimate likely locations in relation to habitats and substrates (**Figure 11**). For example, figure 11 shows an individual blond ray remaining for a month in a localised area to the west of the Wave Hub, prior to moving offshore into deep water where it was caught by a French trawler. This indicates some philopatry to shallower habitat in addition to wider ranging behaviours to deeper habitats.

Table 2. Wave Hub recaptures of DST attached *R. brachyura*.

TL (mm)	Width (mm)	Weight (g)	Sex	Tag number	Tag release	Tag recapture	Days of data	Days at liberty
856	625	4920	m	B0467	02/09/2012	17/06/2013	147	288
913	663	6380	f	B0468	02/09/2012	03/01/2013	123	123
811	561		m	B0561	16/07/2013	02/08/2013	17	17

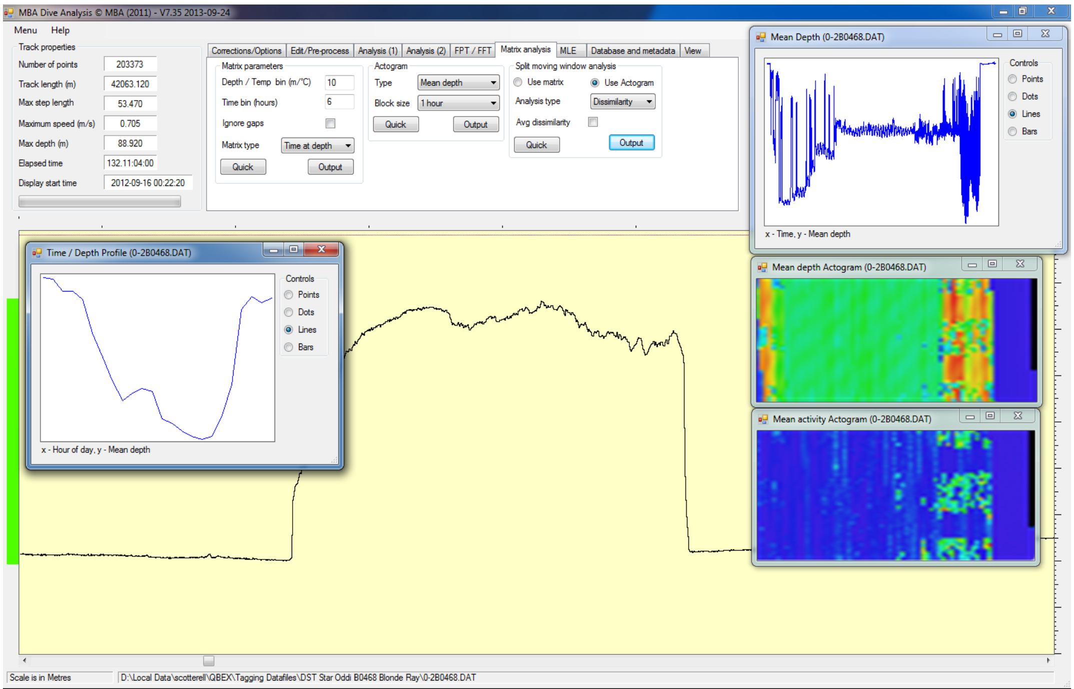

Figure 10. MBA Dive analysis program showing a portion of the data retrieved from tag B0468 showing where the female *R. brachyura* was on the sea bottom then in the water column for a period of approximately 3 hours between 02:00 and 05:00 on 16/9/12 before returning to the sea floor. Overlaid are the time at depth profile showing the general diel vertical behaviour and total dive profile, (top right) and mean depth and mean activity as actograms.

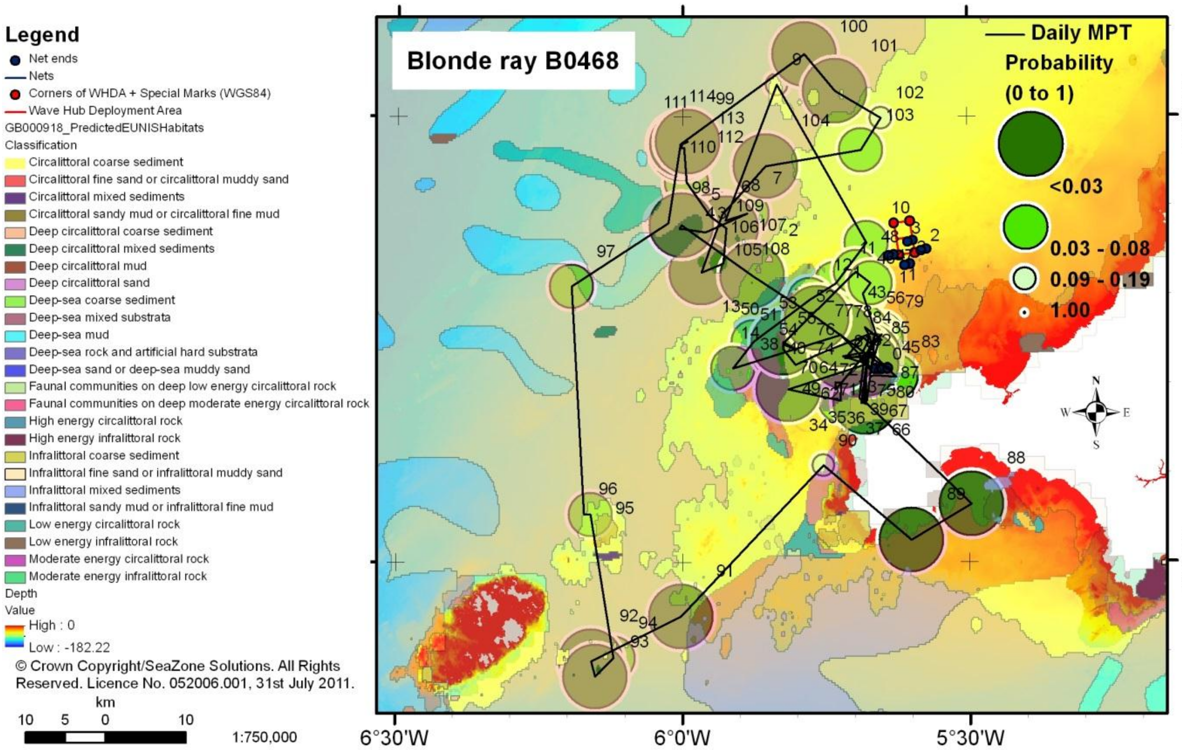

Figure 11. Probabilistic reconstruction of the estimated horizontal movements of a female *R. brachyura* (blond ray) based on initial tidal geolocation analysis of 123 days of DST data overlaid on substrates and habitats. Note: improvements and updates are being made to this model.

It is understood that a further 5 DST-tagged *R. brachyura* have been recaptured, although the tags have not yet been returned to the MBA. Only one fish tagged with an acoustic pinger has been re-caught. This was a spotted ray (*R. montagui*), which was caught by a UK registered scallop dredger fishing well to the north of the Wave Hub. Furthermore, a data upload from the acoustic receivers on landers will be completed when conditions allow.

Links to the NERC-Defra QBEX project

The broad objective to monitor the long-term movements of fish using a seabed lander-borne acoustic receiving array has progressed during the NERC-Defra QBEX project (Jan 2012 – Dec 2014) (see http://www.mba.ac.uk/simslab/qbex). The principal aim of the project is to quantify the extent to which 'spillover' of bioresource abundance (fish and invertebrate species) enhances adjacent areas as a consequence of fishing exclusions within and around Offshore Renewable Energy Installations (OREIs). The focus of the research is to use novel technologies for determining the spatial movements of fish and shellfish across a wide-range of spatio-temporal scales (spanning metres to 100s of kilometres, and minutes to years). Space use is being related quantitatively to the changing physical and biological environment and informs an understanding of the effects of fish spatial dynamics on field monitoring-derived estimates of abundance of fish and macroinvertebrates comprising the community assemblage found within and adjacent to OREI sites. The social and economic costs of MREIs on fisheries are also being assessed, which together with the novel combination of tracking technologies and environmental sampling will allow the first test of the importance of potential spillover to regions adjacent to OREIs.

The research programme comprises investigations at two sites: a small-spatial scale, wave energy test site (the Wave Hub, off Hayle, Cornwall), and at Round 1 (R1) wind farms (North Hoyle and Rhyl Flats, North Wales) and the area north of this towards the R2 Gwynt-y-Mor wind farm currently under construction. The novel field research methodologies are fully operable and transportable across the spatial scales identified and represent a tractable technique to monitor fish and shellfish automatically in difficult-to-study environments where OREIs are often placed.

Next steps

The maintenance and data servicing of the array once deployed is relatively low cost, but the potential of the monitoring infrastructure will only be fully realised when long-term studies >5 years are conducted across different types of OREI sites. The achievements of the current project and of the NERC QBEX project has been to put in place the required monitoring arrays; what is now required is consolidation of the data recording and analysis phases.

Acknowledgements

This document was produced as part of the UK Department of Energy and Climate Change's offshore energy Strategic Environmental Assessment programme. We are very grateful to the assistance of the SAHFOS workshop for the use of their forklift while building the landers at Citadel Hill. We would like to thank the crew of MTS Grey Bear, the St Ives' Harbourmaster and all the fishermen who have helped with this work including those who have returned tags.