Environmental Aspects of Developing Ireland's Atlantic Marine Energy Test Site (AMETS)

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***Abstract*— This paper examines the environmental aspects associated with the development of Ireland's Atlantic Marine Energy Test Site (AMETS), which is being developed off the west coast of County Mayo near Belmullet by the Sustainable Energy Authority of Ireland (SEAI) in conjunction with its project partners, ESB International (ESBI), the Marine Institute and TONN Energy. The test site will provide a grid-connected national test facility, at which full scale pre-commercial wave energy converters (WEC) could be deployed during their final stages of pre-commercial development. It will facilitate small arrays of up to five WECs each. It is an integral component of Irelands Ocean Energy Strategy and will facilitate testing and validation of wave energy converters in an open ocean environment. It will be operational for a period of up to twenty years and will be decommissioned thereafter. The results of a year long environmental assessment of the use of the site by birds and marine mammals together with details of subtidal, intertidal and terrestrial habitats are presented. The test site will provide a facility, not only for testing WEC's, but also for gaining experience on how to develop wave farms for electricity generation, what environmental impacts are associated with such developments and how electricity generated from WEC's can be integrated and connected to the existing electricity network.**

I. Introduction

Ireland dependence on fossil fuel imports (more than 90% of its energy demands is a key factor influencing Irelands drive to develop local renewable sources of energy. These will target a reduction of some 80% in greenhouse gas emissions over the next four decades. Ocean Energy, as a source of renewable energy, forms part of the Ocean Energy Strategy for Ireland, which is ideally placed geographically to maximise potential wave energy utilisation. Ocean Energy development within Ireland is underpinned by Ireland's Offshore Renewable Energy Development Plan (OREDP) [1], which has undergone a full Strategic Environmental Assessment (SEA) and Appropriate Assessment under the EU Habitats Directive, including the preparation of a Natura Impact Statement (NIS) in 2011.

Ocean Energy has been the subject of ongoing research and development over the past few decades. In recent years prototype devices, termed Wave Energy Converters or WECs, to convert wave energy to electricity have been proposed and developed by a number of ocean energy companies, both internationally and also in Ireland. Irish Government renewable energy programmes make projections for inclusion of various levels of electricity generation from wave power in future years. The potential exists to develop a significant ocean energy industry with sustainable long term employment and expertise. As part of the Ocean Energy Strategy an offshore Atlantic Marine Energy Test Site (AMETS) is proposed for the Belmullet Area of County Mayo.

II. Project Description and Components

A. *Wave resource off the west coast of Ireland*

The mean annual theoretical wave energy resource, MWh/m off the west coast of Ireland is shown in Figure 1. Up to 400 MWh/m is predicted near the west coast.

B. *Atlantic Marine Energy Test Site*

The test site will be located off Annagh Head, Co. Mayo in the North West of Ireland, which has one of Europe's best wave climates. It will provide a grid-connected national test facility, at which full scale pre-commercial wave energy converters could be deployed during their final stages of pre-commercial development. It is an integral component of Irelands Ocean Energy Strategy and will facilitate testing and validation of various wave energy converters in an open ocean environment. Performance can be assessed in terms of WEC's ability to generate electricity over their full envelope of proposed operation and with regard to their survivability in such open ocean conditions. It will be operational for a period of up to 20 years and will be decommissioned thereafter.

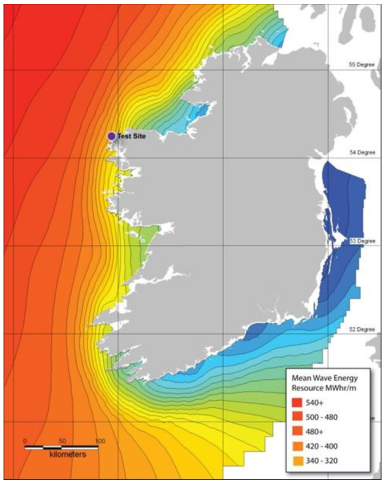

Fig. 1 Mean Annual Wave Resource off the west coast of Ireland [2]

There are currently a small number of wave energy test sites available around the world. Each site is serving not only a geographical area, but also a specific stage in the development of the devices. Companies developing Wave Energy Converters (WEC's) generally follow a phased development, testing and evaluation protocol, such as the phases in the Hydraulics and Maritime Research Centre (HMRC) testing and evaluation protocol, as outlined in Figure 2. At each one of these phases specific test facilities are required to evaluate the WEC.

The test site will provide a facility, not only for testing WEC's, but also for gaining experience on how to develop wave farms for electricity generation, what the environmental impacts are associated with such developments and how electricity generated from WEC's can be integrated and connected to the existing electricity network.

C. *AMETS Project Team*

The Irish full scale wave energy test site has been named: the 'Atlantic Marine Energy Test Site' (AMETS) and is being developed by the Sustainable Energy Authority of Ireland (SEAI) in cooperation with ESB International (ESBI) who is providing the technical and engineering services with responsibility for all elements of civil, electrical, mechanical and environmental design and development on the project, the Irish Marine Institute (MI) is providing marine survey and wave and tidal data capture services and the users perspective from Tonn Energy: an Irish wave farm development company, Arup is providing project management services to SEAI for the development of the test site. Specialist environmental surveys have been undertaken for ecology (MERC Consultants Ltd), Cultural Heritage (Moore Archaeology), Navigation Risk Assessment (Arup), visual impact and noise.

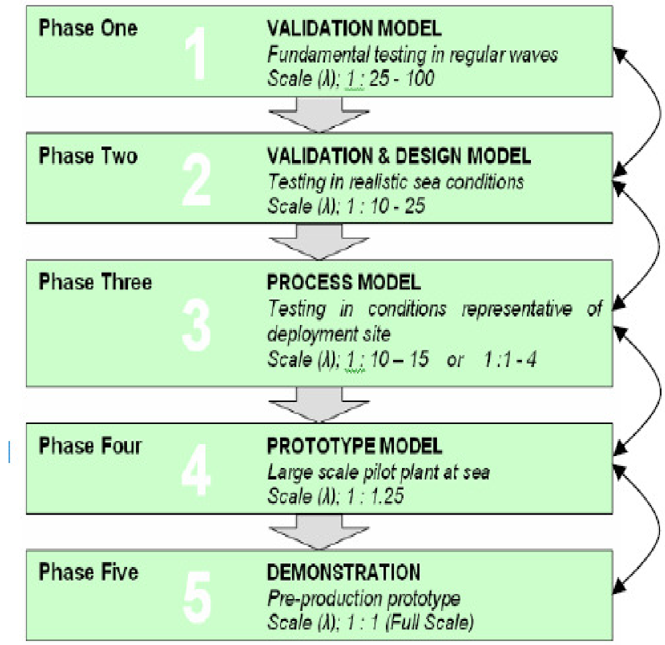

Figure 2: Testing and evaluation protocol (image courtesy of HMRC)

D. *Wave Energy Converters (WEC's)*

The development of a full scale, grid connected, wave energy test site is a unique and challenging project for Ireland. The test site must cater for WEC's that have not yet been developed at full scale. WEC's are still under development and those that succeed in reaching full scale development are not envisaged to be available before 2014. Although the high level functional requirements of the project are well defined, the evolving nature of WEC design and development requires the design approach to incorporate a reasonable degree of flexibility where practicable, to enable the design to adapt to changing requirements. As such the design allows for deployment of a maximum of 10 WECs in two arrays in the deep water test area and in discussion with WEC developers test areas have been sized to accommodate this scenario. Environmental impact assessments have been made on the the basis of this worst case scenario. An important part of this project is the interaction with the technology developers and potential suppliers of the equipment that will be used in the test site.

E. *AMETS Functional Requirements*

The key requirements for the test site are to:

- provide an offshore area in the marine environment where arrays of different WEC's can be deployed.
- provide a grid connected test facility with exporting of electricity generated by WEC's via submarine electricity cables to the onshore electricity network.
- accommodate a range of WEC technology requirements in two separate test areas : one at the 50m water depth and one at the 100m water depth.

The maximum export capacity of the test site is set at 10MW.

F. *AMETS Site Selection and Evaluation Study*

The information available about the seabed surrounding the Irish coastline was mainly limited to the UK Hydrographic Office admiralty charts. In recent years however, the Irish government has embarked on a national seabed survey programme called INFOMAR (**IN**tegrated Mapping **FO**r the Sustainable Development of Ireland's **MA**rine **R**esource). This study has made available detailed bathymetry and seabed classification information for large sections of the Irish coastline. This data was analysed by ESB International and the Marine Institute and used to undertake a detailed site selection and evaluation study which was completed in 2008 [3]. Site selection criteria included the available wave resource, seabed topography and composition, water depth, access to local ports, environmental and planning constraints and the cost of connecting into the local electricity network. All were combined into a weighted scoring matrix comparing the various alternative locations.

The analysis of the INFOMAR data highlighted the importance of the seabed topography and composition as limiting criteria when identifying prospective locations. A sediment based substrate is required for the test areas for mooring purposes and suitable sediment is also a key requirement when identifying a suitable cable route corridor back to shore.

Seven primary sites were assessed. The location off Annagh Head, Co. Mayo near the town of Belmullet was identified as the most suitable to develop a full scale wave energy test site. It offers deep water (to 100m water depth) within 17km of the coast, a non rocky seabed in the proposed test site areas and a non rocky seabed over most of the proposed cable route to shore. It also offered technically feasible landing locations within the Annagh Bay area with good road access to the area and a potential grid connection to Belmullet substation.

Environmental Aspects

Specific requirements related to environment were assessed. These included

- The need to recognise environmental constraints such as designated marine and terrestrial areas (SACs, NHAs, pNHAs, SPAs and potential protected habitats such as subtidal and intertidal reef structures) and to avoid or minimise potential impact on such sites
- The related issue of planning permission where applicable to land side development.
- Recognition of stakeholder issues that would only arise after a site had been selected.
- Keeping the scale of operations at a level that would minimise environmental obligations and overall cost.

Although the terrestrial coastal area is within a Special Area of Conservation (SAC) preliminary assessment indicated that any environmental impact would be minimal if care was exercised selecting a route from cable landfall to the proposed substation.

The immediate landside of the Bay is mainly within the Natura 2000 site Mullet/Blacksod Bay Complex (SAC Site Code 000470) and will be traversed by the cable landing in the shore area at Belderra. The landside development of the project comprising substation and overhead line interface is outside any designated site.

The offshore test areas and submarine electricity cable routes are not within any designated area under national and international legislation. However, within fifteen kilometres of the area, Special Protection Areas (SPAs) under the EU Birds Directive have been designated; Termoncarragh Lake, Cross Lough and Inishglora/Inishkerragh Islands and also SAC areas such as the Inishkea islands (also an SPA), important for birds and grey seal breeding population.

The test areas are located some 6.5km and 16km offshore at 100m and 50m water depths respectively (Figure 3).

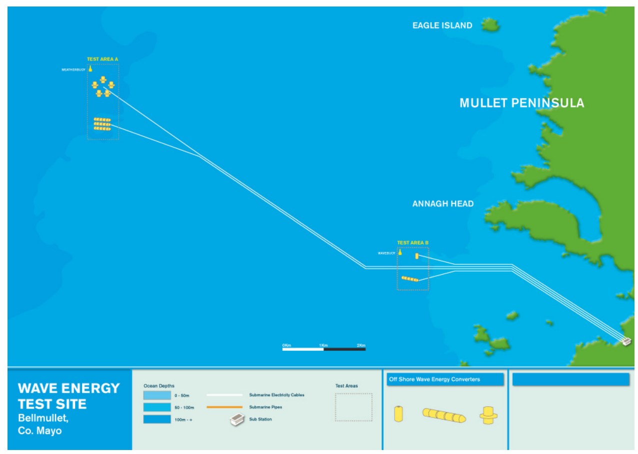

Figure 3 AMETS Test Area Locations

G. *AMETS Project Components*

Two submarine electricity cables will run from the cable transition joint bay at Belderra to Test Area A (100m water depth), each cable length will be approximately 16 km. They cables will be installed to an optimum depth of 1m below the seabed where sandy substrate exists. Where rocky substrate is encountered (4km of the cable length) the cable will be laid on the surface of the seabed and protected using suitable materials. Cable protection will be required at locations in water depths of between 50 and 87 metres. The height of the cable protection is expected to be 1m and hence will have little impact on water depth.

The cables will terminate within the test area with approximately 300m of each cable consisting of a dynamic cable riser, a flexible section of the cable which will allow connection to the WECs. Two further cables will run from the landside cable transition joint bay to Test Area B (50m water depth), each cable length will be approximately 6.5km. These cables will again be installed to a depth of 1m below the seabed. These cables will also have 150m sections of dynamic cable riser.

The four cables will follow a sandy substrate corridor over most of their length to the landing location on Belderra Strand. A corridor width of twice the water depth is required in order to accommodate cable fault repairs but the cables will converge as they approach the strand area.

The cable type will be 3-core extruded insulation, with an overall cable diameter of approximately 14cm. Four separate land side cable circuits will be installed from the cable transition joint bay to the landside substation. These will be similar in nature to the submarine cables but of smaller diameter and different specification.

Cable deployment will be performed by a dedicated cable-lay vessel.. Cable embedment will be either by ploughing in the cables or trenching by water jetting.

Vessels will operate from established ports that will also be used as supply bases. Access from standard slipway facilities is available nearby the test site.

Cables will landfall at Belderra Strand and will run below the beach to the cable transition joint bay located behind the Strand. The cable corridor at the low water mark will be approximately 40m in width and will further reduce to a 10m corridor as the route approaches the cable transition joint bay location (Figure 4). The cables will be installed at a depth of ~1-2m in conduits under the beach surface between the low water mark and the cable transition joint bay. The landfall will cross the intertidal zone, and the works associated with their construction will affect the zone below the high water mark as well as above the high water mark near to an existing car park area.

A landside electricity substation will be constructed to transmit the electricity to the local electricity network. It will be located outside any environmentally designated sites.

Construction activities are planned for the period June to September 2013.

H. *Consents to development*

The required consents for the project construction and operation include both a foreshore lease and a foreshore licence under the Foreshore Acts (1933–2003) from the Irish Government's Department of the Environment, Heritage and Local Government (DEHLG) for all installations between the high water mark and the 12 nautical mile limit.

An Environmental Scoping Report was prepared following consultation with key Institutions and statutory stakeholders including the National Parks and Wildlife Section of the DEHLG [4].

A full environmental Impact Statement is being prepared and submitted as required under the European Communities (Foreshore) Regulations 2009 (S.I. No. 404 of 2009).

Any dredging or dumping activities associated with the construction will require a separate consent regulated under the Dumping at Sea Act (1996). This act implements the requirements of the OSPAR Convention. All permit applications for the dumping of dredged spoil at sea are processes by the DEHLG.

The land based element (substation) requires planning permission from Mayo County Council, the Local Authority within whose functional area the project is located.

III. Environmental Considerations

Potential environmental effects from offshore marine renewable energy projects have been discussed in the OREDP Strategic Environmental Assessment and Natura Impact Statement and in numerous publications [4,5,] including EMEC publications and EIS documents and environmental statements related to wave energy converter deployment at test sites. In general these include:

- Biological impacts on flora and fauna in both the marine end terrestrial environments
- Visual Impact effects both on Landscape and seascape
- Coastal processes
- Cultural Heritage
- Socio economic – fishing, tourism, recreational use etc.
- Transport and Navigation
- Noise
- Cumulative impacts

The Annagh Bay area, where the submarine electricity cables will reach landfall, comprises land areas largely designated under the EU Habitats and Birds Directives. The offshore area is integral to the inshore fishing industry, mainly for lobster and crab potting but with some trawling activity in the sandy seabed areas. Belderra Strand is frequented by surfers and other amenity users. A full environmental impact assessment has been undertaken. As part of this, ecological assessments included surveys of subtidal, and intertidal marine habitats, surveys of adjacent terrestrial habitats, year long surveys of offshore, inshore and terrestrial bird species and marine mammals, using shore based vantage points, at sea surveys and passive acoustic monitoring.

Cultural heritage assessment of the marine and terrestrial environment has been completed. Specific studies on navigation, traffic and transport, noise, EMF, visual impact and coastal zone processes have been undertaken. Integral to the EIA process was the aspect of stakeholder management in an area which has become sensitised to the potential impacts of major projects of this nature. This included extensive stakeholder consultation which will be ongoing throughout the development's lifetime. No significant adverse effect is predicted in the environmental impact assessment.

A. *Bathymetric survey*

A full cable route bathymetric survey was undertaken west of the Mullet Peninsula using the Marine Institute R.V. Celtic Voyager to identify a cable route from the test areas to landfall that would avoid rocky ground wherever possible and also the straightest and shortest possible route.

Bathymetry and seabed topography

Water depths in the area surveyed vary from approximately 10.0m in the east to 110.0m in the northwest. The seabed shoals gently from northwest to southeast with bathymetric contours generally orientated northeast-southwest. Localised moderate to steep seafloor gradients are found in the vicinity of bedrock outcrop. Multibeam shaded relief imagery (Figure 4) was used to assess seafloor topography and seabed expression. The seafloor topography in the region can be broadly designated as:

- Seabed with localised relief (bedforms) comprising sands and gravels with localised development of bedforms
- Seabed of low relief with gentle slopes comprising sands and glacial tills
- Seabed of moderate relief with moderate to steep slopes comprising bedrock outcrop with multiple deformation events with extensive fault and fracture patterns. Folded bedrock outcrop is also observed

The shaded relief image indicates that the proposed route is generally free from large variations in seafloor relief and is characterised by gently sloping seabed.

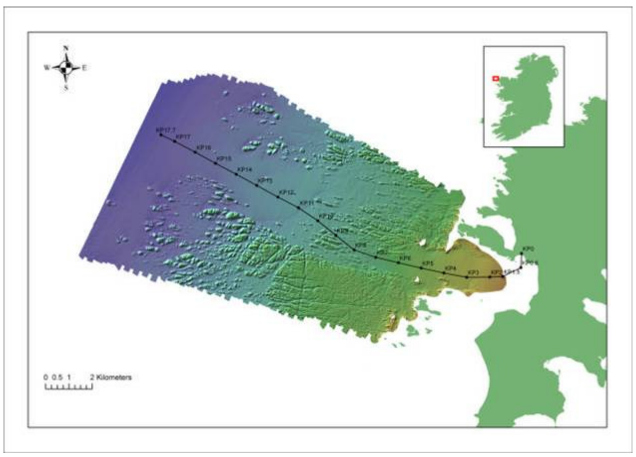

Figure 4 Seabed topography

B. *Biological assessment*

Biological assessments of sub tidal reefs, benthic communities, marine mammals, sea birds and terrestrial ecology were undertaken.

Sub tidal reefs

The majority of the area under consideration is comprised of a mosaic of soft sediments (sands of varying grain size) and geogenic reefs (infralittoral and circalittoral). Geogenic reefs are a widespread but important feature of conservation interest in Ireland and are included under the Annex I habitat “Reefs (Habitat code 1170)” of the EU Habitats Directive [7]. They may be composed of bedrock, boulders or cobble and form a variety of subtidal topographic features such as hydrothermal vent habitats, sea mounts, vertical rock walls, horizontal ledges, overhangs, pinnacles, gullies, ridges, sloping or flat bed rock, broken rock and boulder and cobble fields.

Reef habitats are of conservation importance for a number of reasons. In temperate areas, infralittoral reefs generally support kelp communities and these form an important habitat for a wide variety of species of other plants and animals. Such habitats are one of the most biologically diverse habitats on the planet [8]. They are also extremely productive habitats, exporting biomass to the wider marine environment.

Circalittoral reef communities are less productive than the shallower kelp dominated infralittoral communities. However, they still support diverse assemblages of encrusting and erect species. Our knowledge of these biotopes is poor due to the depths in which they occur and the resultant technical difficulties associated with their survey [9].

A detailed survey of the reef habitats within the AMETS Project area was conducted during the summer of 2010. The test site encompassing the two test areas, the cable route and a buffer zone either side of the cable route were surveyed by drop down video during July 2010. Locations are shown in Figure 5. The average spacing of dropdown video stations along the cable route between the lower shore and the inshore Area was 780m and 1,500 m in the outer cable route section. A number of additional drops were made in both the inshore and offshore test areas to capture seabed imagery within these areas. More detailed surveys of the inner bay area were conducted by continuous line transects across the width of the bay.

A scientific dive team extensively surveyed the inshore area of the site during July and October 2010. Dive surveys were conducted using standard MNCR phase 2 survey techniques [10] for the In situ survey of subtidal (epibiota) biotopes and species. Diver video and diver stills imagery of the habitats and species were recorded in situ on every dive to assist with future monitoring of the site.

The present survey indicated that the most common reef morphotype present consisted of flat and sloping bedrock with numerous crevices and gullies. The biotopes recorded for this morphotype were consistent with deep, exposed circalittoral communities, which would be relatively common in their extent and distribution off the west coast of Ireland. The most interesting aspect of these biotopes appears to be the associated sponge communities. Although it was not possible to identify many of the encrusting sponge species by drop down video.

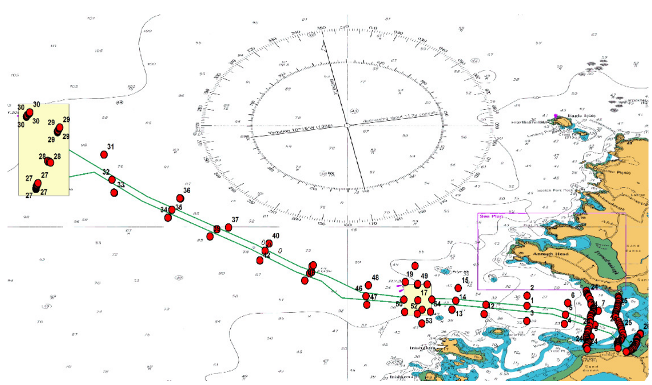

Figure 5 Benthic survey drop down video locations

Smaller areas of cobble were also identified along some sections of the cable route; these were all relatively species poor, which is most likely due to the effect of wave action causing mobility of the cobble and a subsequent lack of encrusting species.

The shallower inshore, infralittoral reefs were characterised by vertical rock walls and pinnacles with numerous crevices, gullies and overhangs. The only biotope recorded was *Laminaria hyperborea* on moderately exposed vertical rock. This biotope is very common in infralittoral areas off the west coast of Ireland.

Dives conducted in the shallow circalittoral inshore areas indicated that the most common morphotype consisted of smooth and rounded bedrock with numerous gullies and crevices and the biotope community "Echinoderms and crustose communities" a community that is relatively common off the west coast of Ireland.

Almost all of the reefs examined by both drop down video or dive surveys showed evidence of sand scour and had a covering of sediment.

The non-reef areas surveyed by drop down video or dives were classified as either "Infralittoral mobile clean sand with sparse fauna" or "offshore circalittoral sands". Grab sampling of these sections were undertaken

The biotopes present within the site, at both the infralittoral and circalittoral reef areas, are all characteristic of exposed communities already subject to extreme wave action. They all showed evidence of being subjected to the effects of sand scouring and sediment movement during the survey and any sedimentation caused during the cable laying process is unlikely to have any more effect on these communities than a natural storm event would have. The impact of the development on the reef biotopes of both the inshore and offshore areas is considered to be low.

The impact of the placement of cable protection such as rock armour over sections of the cable route and within the mid-shore box has the potential to cause long term habitat loss and fragmentation and damage to or loss of certain species. It may also cause an alteration to the existing environment by the creation of new habitats. The creation of artificial reef is likely to alter the species composition of existing reef habitats and cause species not previously associated with the area to colonise the new artificial reef areas. A review of the reef effect caused by wind turbine footings and other artificial substrates raises some concern about the reef effect of introduced artificial substrates [11]. It is not clear that the increased diversity effect is always positive. However, many of the studies reviewed are from shallow water in coastal developments where the association with invasive species may be as a result of interaction with the proximity to ports and shipping traffic, and to other sources of anthropogenic disturbance. This is not the case at AMETS which is remote from major ports. The community that develops on artificial reefs will depend on the nature of the substrate introduced and on the proximity of natural substrates and their natural communities. In the AMETS case the close proximity of natural reefs may result in colonisation by their natural communities thereby reducing impact. Impact can be further mitigated by using similar bedrock material to that existing in the seabed. This would allow for the development of a diverse epifaunal community with positive effects on diversity.

The baseline developed through the monitoring programmes will also allow an assessment of any ongoing artificial reef impacts in the project area as part of continued monitoring of the site.

Intertidal Habitats

Belderra strand is an extremely exposed small embayment with a high proportion of fine and medium sands backed by a shingle and gravel bank caused by the repeated wave exposure at this site. A survey of the intertidal area of Belderra Strand, in the vicinity of the proposed cable landfall, was conducted in July 2010. Intertidal core samples were collected from two transects at Belderra Strand in July 2010. Both transects ran across a beach of mixed sandy sediments, dominated by fine sand with a variable proportion of medium sand mixed in. The sediments contain very little organic matter and consequently very few species of invertebrate.

Only one biotope complex is present between the lower and upper shores and this was most consistent with "Amphipods and *Scolelepis* spp. in littoral medium-fine sand" (LS.LSa.MoSa.AmSco). The common biotope "Talitrids on the upper shore and strand-line" was recorded at the strandline, which was characterised by a typical strandline of decaying seaweed and sandhoppers. Transect 1 contained only two species in the lower and middle shore, with no fauna found in the upper shore. The fauna was dominated numerically by the opportunistic, robust, spionid polychaete worm, *Scolelepis squamata*, a species that is typical of exposed sandy shores and one predatory *Nephtys cirrosa* (cat worm) specimen was also encountered, a species also typical of sandy environments. Transect 2 was very similar to Transect 1 in that the same two species were encountered in the lower and middle shore, with only slight differences in numbers separating them. The upper shore of Transect 2 did however contain several small crustacean species, the isopod *Eurydice pulchra* and the amphipod *Bathyporeia pilosa*, both highly typical of high energy sandy beaches. No species of nature conservation importance were encountered during the analysis.

The paucity of species in all cores taken at Belderra Strand was notable. Both species diversity and biomass was so low that it precluded any statistical analysis of the results. Low species diversity and biomass can be expected in such exposed sandy shores and the extremely low diversity of species and biomass at Belderra Strand indicates the particularly harsh environment at this site, where even the most robust species were lacking. The lack of organic matter in the sand, a factor of the exposure regime and lack of any silt input into this area has contributed to the lack in species diversity and biomass.

The site is characterised by a high-energy, mobile biotope that occurs in this area due to the constant disturbance of the beach by severe weather events. Any alteration to this habitat as a result of cable trenching would be extremely unlikely to be detected even within the following season. The impact of any development on the intertidal areas of Belderra Strand is likely to be of short duration and not significant.

Sub tidal benthos

Twenty-five stations were sampled at the proposed test sites and along the proposed cable route. Sampling occurred in July and November 2010. Station position was recorded using a differential GPS. At each station, four 0.1 m^2 Day grab samples were taken. One grab was used for particle size distribution and organic content (LOI) analysis. Three were preserved for macrofaunal identification.

Sediment distribution along the proposed cable route and in the proposed test Areas is quite consistent, with most stations being classified as infralittoral or circalittoral fine sands. These habitats are characterised by frequent disturbance due to wave action and currents and the macrofaunal communities tend to be robust to disturbance events [12, 13, 14].

The most common species identified was the pea urchin *Echinocyamus pusillus* a small flattened animal <15mm in length that inhabits mobile sands and gravels in fully saline water. *Echinocardium cordatum*, the sea potato, is a larger urchin distributed in sands and muddy sands in circalittoral, infralittoral and littoral sediments. *Minuspio multibranchiata* and *Cirriformia tentaculata* are both small polychaete worms that deposit feed on the surface layer of sands and muddy sands in circalittoral and infralittoral sediments. Nemertean worms, *Spiophanes bombyx* and *Nephtys cirrosa* are common species in circalittoral and infralittoral sands. The distribution of species and individuals among major taxonomic groups is typical of infralittoral and circalittoral sands.

While there are several published accounts concerning the environmental impacts of fibre optic cable laying on the seafloor [15, 16], there is very little published describing the effects of buried electrical cable laying on the macrobenthos. Andrulewicz *et al*. [17] describe the environmental effects of the installation and functioning of the submarine SwePol Link HVDC transmission line in the Polish Marine Area of the Baltic Sea. They found that one year after the cable had been laid no mechanical disturbances on the dynamic sandy bottom were visible. Studies of the bottom macrofauna indicated that there had been no significant changes in zoobenthos species composition, abundance or biomass, which could have been clearly related to cable installation. Changes in the components of the magnetic field, although significant in the vicinity of the cable itself, did not exceed natural variability at a distance of 20 m. Given that the proposed site for this development is also a dynamic sandy bottom, this would indicate that a recovery time in the order of one year is likely for this development.

Marine Mammals

A baseline of marine mammals in the vicinity of the project area was developed from the database held by the Irish Whale and Dolphin Group (IWDG) and through a dedicated marine mammal survey in the area. The dedicated marine mammal survey used a combination of visual and acoustic techniques and both land based and at sea survey methods. Land based surveys comprised monthly watches between October 2009 and September 2010 from Annagh Head overlooking the northern end of the proposed route. Each watch was of 100 minute duration and was only carried out whenever possible in favourable conditions. (sea-state is two or less i.e. no white caps present) and visibility $\geq$15 km as per the IWDG Inshore Cetacean Monitoring Programme protocol [18]. All marine mammals sighted were recorded

Sea based Line transect surveys (Figure 6), using three observers, were carried out using a vessel with a platform at least 2-3m above sea level. Track-lines were pre-determined and changed on each survey to provide full coverage of the site. Lines were chosen to cross depth gradients and provide as close to equal coverage probability as possible. Track-lines surveyed each day totalled approximately 50 nmls in length. All effort data and sightings/detections were digitally mapped in both National Grid reference (ITN) and Latitude and Longitude (WGS84).

Photo-identification was used for individual recognition of bottle nosed dolphins where possible using the Inshore Bottlenose Dolphin Photo-id Catalogue lodged with the National Biodiversity Data Centre [19] and www.iwdg.ie/photo-id

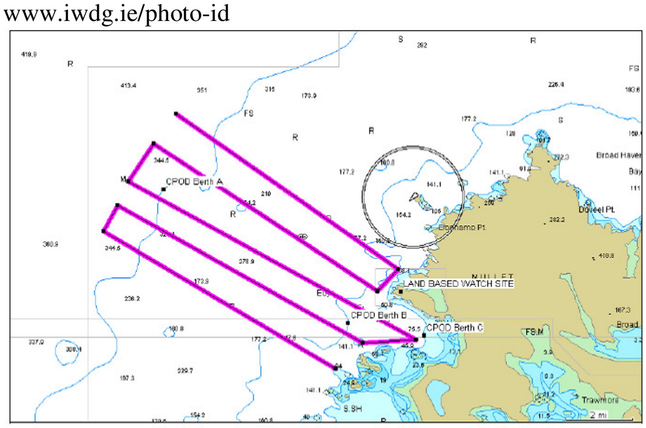

Figure 6 Sea based marine mammal transects

Passive Acoustic Monitoring using a towed hydrophone array was used during three dedicated acoustic surveys. The collection of acoustic data during visual surveys added an extra dimension to the monitoring dataset. Acoustic monitoring allowed for the detection of cetaceans, which are beyond the visual observers view and therefore increased the capacity of the survey.

Static acoustic monitoring (SAM) was also undertaken using C-PODs to log the echolocation clicks of porpoises and dolphins. C-PODs were deployed at two locations, inshore and offshore on 15 October 2009, and these sites were monitored for the duration. An additional 5 sites were monitored with C-PODs between July and October 2010 and included 4 control sites.

The IWDG records indicated that the most frequently recorded species was the bottlenose dolphin, followed by Common dolphin, Risso's dolphin , killer whale and harbour porpoise and minke whales. In addition there were two records of Atlantic white-sided dolphin and one record each of striped dolphin, humpback whale and sei whale.

The project land based survey recorded a total of 16 sightings with sightings recorded on 54% of watches. Species observed were Common dolphin, Bottlenose dolphin, harbour porpoise and grey seal.

At sea line transect surveys recorded the presence of both cetaceans and seals. Common dolphin was the most frequently recorded cetacean species with 17 sightings followed by harbour porpoise (15 sightings) and minke whale and bottlenose dolphin (2 sightings). Two unidentified dolphin sightings were also recorded and were most likely common dolphin. Common dolphin was also the most abundant species with up to 200 recorded on 5 March 2010. The second largest group of cetaceans recorded was bottlenose dolphins, when a group of 50 were recorded on 15 October 2010. Two seal species were recorded, grey and common seal. Grey seal was the most frequently recorded and the most abundant. Occasional sightings of basking shark and sunfish were also recorded (on two occasion each).

The studies and reports show that there is a rich marine mammal community in, and adjacent to, the Atlantic Marine Energy Test Site.

The Atlantic Marine Energy Test Site is a relatively small area when considering mobile marine species such as marine mammals. Never-the-less seven cetacean species, two seal species and two other marine megafauna species have been recorded within the site and another three adjacent to it. Nearby Broadhaven Bay at the northern end of the Mullet peninsular has been shown to have a rich marine mammal fauna including nine cetacean and two seal species as a consequence of intensive monitoring carried as part of the Corrib Gas Project [20].

Potential impacts on marine mammals considered at the site include noise associated with construction and entanglement, collision and disturbance of feeding (vessel traffic) and possible migratory behavioral change through interference by electromagnetic fields during the operational phase. The deposition of rock armour may create a disturbance to marine mammals.

The assessment of potential impacts is largely speculative due to the paucity of specific studies and the fact that full scale wave energy converters of the scale and nature have not yet been deployed at the site. However, given the small scale of the development in the overall context of the area significant impacts on marine mammals are not predicted. A programme of ongoing monitoring of the test site general area is being undertaken to further develop the baseline and provide a basis for assessment of any potential impacts that may arise.

Avifauna

An avifauna baseline for the test area was developed from published information, established national database and dedicated land based and sea based monitoring programmes. The Mullet peninsula and its nearby islands are protected by a number of Special Protection Areas for Birds (SPAs). Six SPAs, lie within five km of the study site, two lie within 15km of study site and a further two lie 20-30 km from the study site. These SPAs are nationally and internationally important for a range of breeding and wintering birds. The Mullet Peninsula is included in the Irish Wetland Bird Survey (I-WeBS) wintering waterbird monitoring scheme (http://www.birdwatchireland.ie). Within this scheme the Mullet Peninsula is known as the The Mullet, Broad Haven and Blacksod Bays I-WeBs count site [21]. Results from the IWeBS [21, 22] show that a number of species occur within this site in numbers of national and, or, international importance.

Belderra Strand, the cable landing location is a sub-site of the The Mullet, Broad Haven and Blacksod Bays I-WeBS count site and lies within the study site. Specific data for part of the study site was available from the I-WeBS scheme.

Land based surveys of the shore and open waters of the Bay were undertaken monthly from September 2009 until August 2010 from five vantage points, Figure 8. The shore or intertidal habitats at Annagh Beach, Emlybeg Beach and Belderra Strand were counted using standard I-WeBS count methods for wintering waterbirds [23, 24]. Shore counts were also completed at Cross Point and along the viewable shore from Annagh Head.

Terrestrial habitats at Belderra Strand, Emlybeg and Annagh Beach were surveyed using line transect methods [24] and as used by the Countryside Bird Survey. A one-day winter survey was completed in February 2010 and a breeding bird survey was completed in Spring 2009. The breeding bird survey involved a one day early breeding season visit in April, followed by a repeat survey in June, to cover later breeding species.

Results of land based avifauna surveys

Waders and Gulls used the shore habitats all year round. Numbers of waders were generally low, though relatively high numbers of Ringed Plover and Sanderling were recorded at Annagh Beach. The most significant count was a nationally important flock of Sanderling recorded at Annagh Beach in March. Regularly recorded wader species were Oystercatcher, Curlew, Sanderling, and Dunlin. Turnstone and Purple Sandpiper were less frequently recorded and Purple Sandpiper only at Cross Point. Gulls used the shores year round, with highest numbers occurring in the summer months, when flocks of immature, mainly Herring and Common Gull, were roosting there. The inner Bay was used by wintering Long tailed duck, Eider, Great-Northern and occasionally Red-throated Diver. Great-Northern Diver were present from October to May, with peak numbers of 17 recorded in March. In the summer Terns were present from May to July and a raft of 300 Manx Shearwater was recorded in July. Shag and Gulls were present year round and Gannet and Auks were present mainly in the summer months. The outer Bay was used by Auks, Gannets, Gulls, Shearwaters, Shag and divers. Numbers of Auks, Gannets and Manx Shearwater were highest between April and May. Rafts of Manx Shearwater were present in April when two rafts of 690 Manx Shearwater were recorded (this was west of Annagh Head and strictly outside of the survey area). Up to two, Great Northern Diver, were regularly recorded from the outer Bay.

Terrestrial avifauna

During winter dune and coastal grassland habitats at Annagh Beach, Emlybeg and Belderra Strand were used by resident species typical of these habitats such as Meadow Pipit and Skylark. Common and widespread ubiquitous species, such as Jackdaw, Hooded Crow and Magpie were also recorded. Species more associated with winter foraging were Raven, Goldfinch and the migratory species Fieldfare and Redwing. Large foraging flocks of the latter two species are common in winter. Snipe and Golden Plover, which typically use coastal habitats during the winter season, were present. Rock Dove, a species with limited distribution within Ireland [25], was present.

During summer typical breeding birds of coastal dune and grassland habitats were recorded during the breeding season. These included both resident species such as Skylark and Meadow Pipit and migratory species such as Wheatear. Small breeding numbers of the waders, Ringed Plover and Common Sandpiper were recorded. Of note was a small Sand Martin colony of about 20 nest holes in a sand bank at Emlybeg. During breeding bird surveys, birds using the shore were also noted, with large numbers of roosting Gulls recorded and flocks of the passage wader Whimbrel.

The Storm Petrel survey on Inishglora Island showed numbers nesting in the stone walls to be comparable with those recorded in 2001 and sample plots were successfully established for future monitoring.

Sea based surveys

Gannets were by far the most common bird encountered throughout the survey, occurring in relatively high numbers throughout all months. The Auk species (Razorbill, Puffin and Guillemot) were also present in all survey months with the exception of Razorbill, which was absent during August 2010. Fulmar, Kittiwake and Great Black-backed Gull were the remaining three species recorded during all survey visits. Manx Shearwater, Storm Petrel and Arctic Tern were recorded only during the summer months, most likely reflecting their return to breeding colonies near the study site and along the west coast of Ireland. Neither Great Shearwater nor Sooty Shearwater were recorded between March and July indicating the migratory nature of these birds. All Shearwater species (Manx, Great and Sooty) observed in the study area were observed both flying and in rafts.

The total mean densities of birds observed throughout the monthly surveys varied considerably. Highest monthly densities occurred in October 2009 and 2010 although particularly large numbers of single species may distort this picture with over 50% of the birds recorded in October 2009 being Great Shearwater. Gannets accounted for over 80% of the October 2010 total. Relatively high mean bird densities from April through to July are apparent with lowest mean densities being recorded in August.

Various reports, reviews and workshops [26, 27, 28, 29] have outlined the potential impacts from wave energy devices.

Disturbance during construction will be mitigated to ensure activities occur during the summer months when wintering waders are not present. All construction activities will be guided by an ecologist. Cable protection activities, such as rock armouring, will be minimised and suitable materials will be used. Avian monitoring is being continued to further develop the avian baseline and to identify potential impacts as the test site develops and becomes operational.

C. *Cultural Heritage*

A Cultural Heritage baseline was developed by Moore Archaeological Services Ltd. based on desktop review and field surveys. Desktop review included an examination of Ordnance Survey Maps, records and publications of the Archaeological Survey of Ireland, documentation and archive material from various institutions and standard publications, such as the Record of Monuments and Places, National Shipwreck Inventory and Ports and Harbours Archive. A programme of visual field inspection survey, diver survey (visual and metal detection) and high resolution marine geophysical survey, (side scan sonar and marine magnetometer), was carried out on the site during September and October 2010.

No marine archaeology was identified along the cable route or at the test areas and although the general area is rich in cultural diversity careful routing of the submarine electricity cables will ensure that no significant impact on known cultural heritage will occur. Standard mitigation such as the presence of an archaeologist during the construction phase are included in the mitigation requirements of the project.

D. *Navigation Risk Assessment*

A navigation risk assessment of the project test area was prepared by Arup on behalf of SEAI based on AIS data, RADAR surveys and consultation with the Coastguard and Fishermen's Organisations were held.

AIS data indicates that there is little traffic in the area and that any vessels would have adequate sea room to pass the test area which will be marked with Cardinal marker buoys. Radar surveys and consultation with interest groups indicated that inshore crab fishing occurs in the area fringing the sea bed reefs. Limited trawling activity occurs in the sandy sea bed areas. Fishing interests were taken into account in selecting the final location of the outer test area.

IV. Conclusion

The development of the test site off Annagh Head will fulfil a number of important national objectives. It will provide a grid-connected national test facility for full scale pre-commercial wave energy converters (WEC) during their final stages of pre-commercial development in an open ocean environment. It will facilitate testing of individual WECs or small arrays of up to five WECs each. The test site will provide a facility, not only for testing WEC's, but also for gaining experience on how to develop wave farms for electricity generation, what environmental impacts are associated with such developments and how electricity generated from WEC's can be integrated and connected to the existing electricity network. It will be integral to the development of offshore renewable energy in Ireland particularly in providing a template for the identification and management of environmental issues and in defining the consenting needs and key constraints associated with its development. The impact assessment predicts that no significant impacts will occur given the relatively small scale of the development, the open ocean environment and the current state of understanding of the interaction between WECs and the natural environment. However, the paucity of research data must be considered when moving to larger scale developments. The environmental baseline already established and the ongoing benthic, avian and marine mammal monitoring programmes will contribute significantly to increasing baseline knowledge and to enhancing our understanding of the key interactions and potential impacts of the project components and future developments.

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