Marine Environmental Appraisal of an Ocean Energy Test Site in Inner Galway Bay

Produced by

AQUAFACT International Services Ltd

On behalf of

Hydraulics & Maritime Research Centre
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1. Introduction

AQUAFACT International Services Ltd. was commissioned by the Hydraulics and Maritime Research Centre, University College Cork to carry out a marine environmental appraisal of an ocean energy test site in Inner Galway Bay. Figure 1 shows the location of this site. This site has been used to test a wave energy device known as the Ocean Energy Buoy (Figures 2 and 3) since 2006.

This environmental appraisal involved grab sampling five sites within the test site and one control site, approximately 650m south of the test site. Two replicate faunal grab samples were taken at each site in addition to a sediment sample. SCUBA diving was also used to collect sediment profile images and still photography of the sea bed. The report was also to include a desk survey of marine reptiles, mammals and birds that occur in the area and any possible impacts that might arise given the presence of the buoy.

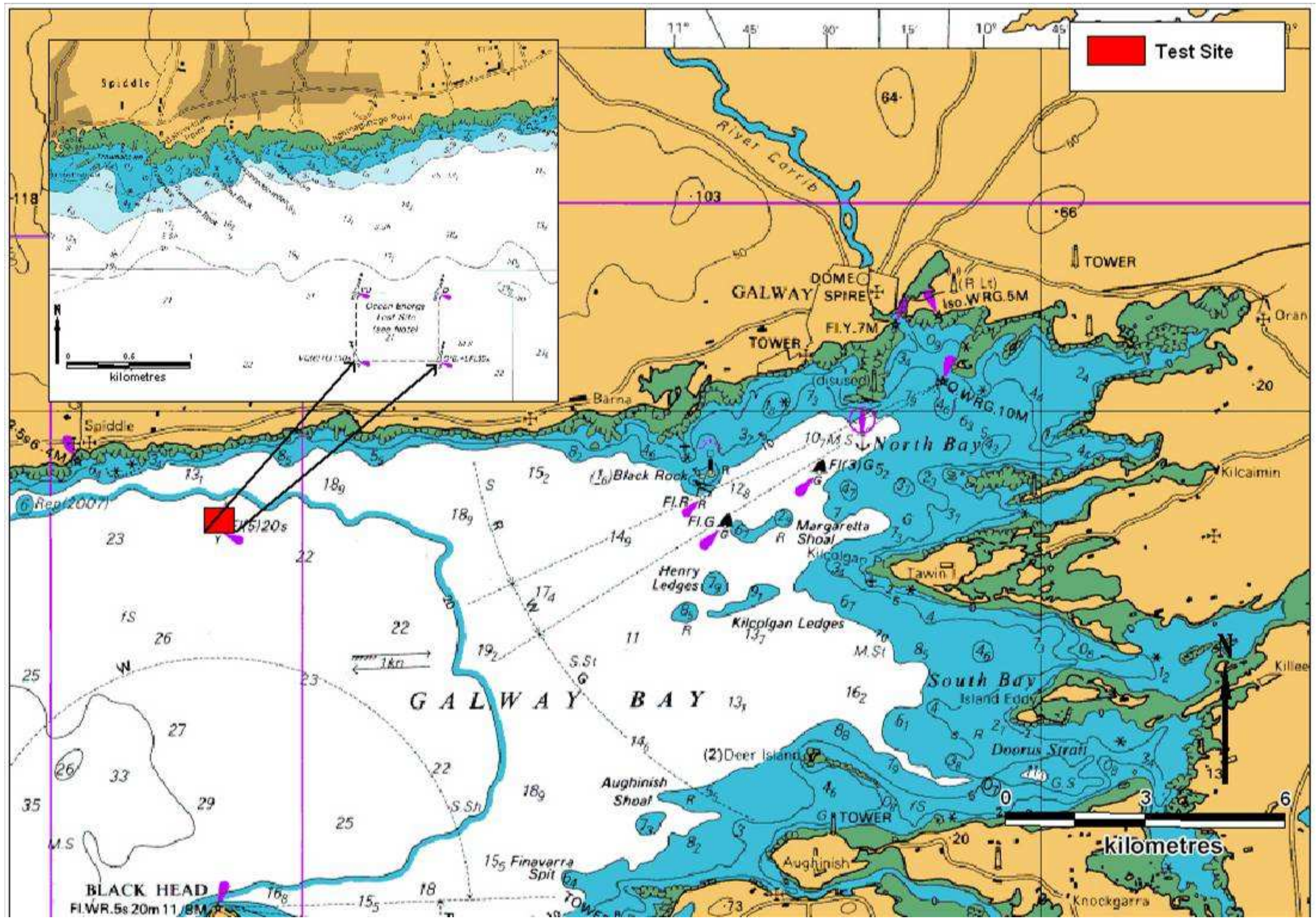

Figure 1: Location of the ocean energy site within Galway Bay.

Figure 2: Ocean Energy Buoy moored in Galway Docks.

Figure 3: Ocean Energy Buoy moored in Galway Bay.

2. Marine Benthos

2.1. *Sampling Procedure & Processing*

To carry out the marine environmental appraisal of the ocean energy test site in inner Galway Bay, AQUAFACT sampled a total of 6 stations. Five of these stations were located within the test site and 1 was located approximately 650m south of the test site and acted as the control station. Figure 4 shows the station locations and Table 1 gives the station coordinates.

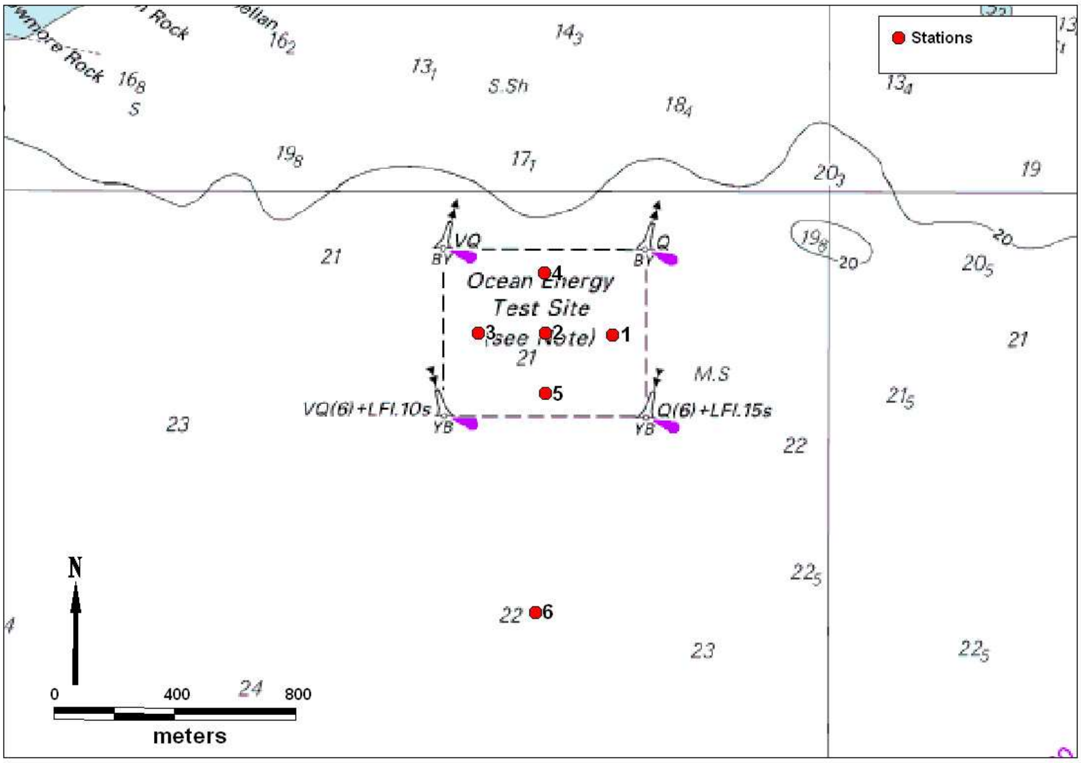

Figure 4: Map showing sampling locations

Table 1: Station co-ordinates.

Station	Longitude	Latitude	Easting	Northing	Depth (m)
1	-9.26079	53.2291	115851.3	220565.6	23.2
3	-9.26743	53.2291	115407.9	220577	22.3
2	-9.26411	53.2291	115630	220575.6	21.9
4	-9.26416	53.2309	115630	220772.8	21.3
5	-9.26408	53.2273	115627.9	220374.5	22.1
6	-9.26454	53.2208	115584.4	219647.8	25

Sampling was carried out on the 7th September 2009 from the *Tarrea Queen*. Stations were located using DGPS and this positioning method is accurate to within c. 1m. A 0.1m^2 Day Grab was used to collect the benthic samples. Two replicate samples were taken at each of the 6 stations. Data on each sample, e.g. station number, date, time, depth of sediment, surface features and visible macrofauna were logged in a field notebook. The faunal returns were sieved on a 1mm mesh sieve, stained with Rhodamine dye, fixed with 10% buffered formalin and preserved in 70% alcohol. Samples were then sorted under a microscope (x 10 magnification), into four main groups: Polychaeta, Mollusca, Crustacea and others. The 'others' group consisted of echinoderms, nematodes, nemerteans, cnidarians and other lesser phyla. The taxa were then identified to species level where possible.

An additional sample was taken at each station and used for sediment granulometric analyses. The sediment samples were taken through the opening on the top of the grab. All samples were stored immediately in a cold room on board the vessel and were frozen at –20^{o}C on return to the lab.

Particle size analysis was carried out using the traditional granulometric approach by AQUAFACT. Traditional analysis involved the dry sieving of approximately 100g of sediment using a series of Wentworth graded sieves. The process involved the separation of the sediment fractions by passing them through a series of sieves. Each sieve retained a fraction of the sediment, which were later weighed and a percentage of the total was calculated. Table 2 shows the classification of sediment particle size ranges into size classes. Sieves, which corresponded to the range of particle sizes (Table 2) were used in the analysis.

Table 2: The classification of sediment particle size ranges into size classes (adapted from Buchanan, 1984)

Range of Particle Size	Classification	Phi Unit
<63µm	Silt/Clay	>4 Ø
63-125 µm	Very Fine Sand	4 Ø, 3.5 Ø
125-250 µm	Fine Sand	3 Ø, 2.5 Ø
250-500 µm	Medium Sand	2 Ø, 1.5 Ø
500-1000 µm	Coarse Sand	1 Ø, 1.5 Ø
1000-2000 µm	Very Coarse Sand	0 Ø, -0.5 Ø
>2000 µm	Gravel	-1 Ø, -1.5 Ø, -2 Ø, -3 Ø, -4 Ø

2.2. Data Processing

All replicates for each station were combined to give a total abundance for each station prior to analyses. A data matrix of all the combined faunal abundance data was compiled and used for statistical analyses. The faunal analysis was carried out using the PRIMER ® (Plymouth Routines in Multivariate Ecological Research) programme.

Univariate statistics in the form of diversity indices were calculated on the combined replicate data. The following diversity indices were calculated:

1) Margalef's species richness index (D), (Margalef, 1958).

$$D = \frac{S-1}{\log_2 N}$$

where: N is the number of individuals

S is the number of species

2) Pielou's Evenness index (J), (Pielou, 1977).

$$J = \frac{H'(\text{observed})}{H'_{max}}$$

where: H'_{max} is the maximum possible diversity, which could be achieved if all species were equally abundant (= $\log_2 S$)

3) Shannon-Wiener diversity index (H'), (Pielou, 1977).

$$H' = -\sum_{i=1}^{S} p_i(\log_2 p_i)$$

where: p_l is the proportion of the total count accounted for by the i^{th} taxa

Species richness is a measure of the total number of species present for a given number of individuals. Evenness is a measure of how evenly the individuals are distributed among different species. The diversity index incorporates both of these parameters. Richness ranges from 0 (low richness) to 12 (high richness), evenness ranges from 0 (low evenness) to 1 (high evenness), diversity ranges from 0 (low diversity) to 5 (high diversity).

The PRIMER ® manual (Clarke & Warwick, 2001) was used to carry out multivariate analyses on the station-by-station faunal data. It must be noted here that the species that were present only once or twice in the survey were excluded from the multivariate analysis. All species/abundance data were fourth root transformed and used to prepare a Bray-Curtis similarity matrix in PRIMER ®. The fourth root transformation was used in order to down-weigh the importance of the highly abundant species and allow the mid-range and rarer species to play a part in the similarity calculation. The similarity matrix was then used in classification/cluster analysis. The aim of this analysis was to find "natural groupings' of samples, i.e. samples within a group that are more similar to each other, than they are similar to samples in different groups (Clarke & Warwick, *loc. cit.*). The PRIMER ® programme CLUSTER carried out this analysis by successively fusing the samples into groups and the groups into larger clusters, beginning with the highest mutual similarities then gradually reducing the similarity level at which groups are formed. The result is represented graphically in a dendrogram, the x-axis representing the full set of samples and the y-axis representing similarity levels at which two samples/groups are said to have fused.

The Bray-Curtis similarity matrix was also subjected to a non-metric multi-dimensional scaling (MDS) algorithm (Kruskall & Wish, 1978), using the PRIMER ® program MDS. This programme produces an ordination, which is a map of the samples in two- or three-dimensions, whereby the placement of samples reflects the similarity of their biological communities rather than their simple geographical location (Clarke & Warwick, 2001). With regard to stress values, they give an indication of how well the multi-dimensional similarity matrix is represented by the two-dimensional plot. They are calculated by comparing the interpoint distances in the similarity matrix with the corresponding interpoint distances on the 2-d plot. Perfect or near perfect matches are rare in field data, especially in the absence of a single overriding forcing factor such as an organic enrichment gradient. Stress values increase not only with the reducing dimensionality (lack of clear forcing structure), but also with increasing quantity of data (it is a sum of the squares type regression coefficient). Clarke and Warwick (*loc. cit.*) have provided a classification of the reliability of MDS plots based on stress values, having compiled simulation studies of stress value behaviour and archived empirical data. This classification generally holds well for 2-d ordinations of the type used in this study. Their classification is given below:

- Stress value < 0.05: Excellent representation of the data with no prospect of misinterpretation.
- Stress value < 0.10: Good representation, no real prospect of misinterpretation of overall structure, but very fine detail may be misleading in compact subgroups.
- Stress value < 0.20: This provides a useful 2-d picture, but detail may be misinterpreted particularly nearing 0.20.
- Stress value 0.20 to 0.30: This should be viewed with scepticism, particularly in the upper part of the range, and discarded for a small to moderate number of points such as < 50.
- Stress values > 0.30: The data points are close to being randomly distributed in the 2-d ordination and not representative of the underlying similarity matrix.

Each stress value must be interpreted both in terms of its absolute value and the number of data points. In the case of this study, the moderate number of data points indicates that the stress value can be interpreted more or less directly. While the above classification is arbitrary, it does provide a framework that has proved effective in this type of analysis.

2.3. Results

2.3.1. Fauna

The taxonomic identification of the benthic infauna across all 6 stations sampled in the ocean energy test site in inner Galway Bay yielded a total count of 117 species accounting for 1,746 individuals, ascribed to 7 phyla. A complete listing of these species abundance is provided in Appendix 1.

Of the 117 species enumerated, 56 were polychaetes (segmented worms), 31 were crustaceans (crabs, shrimps, prawns), 18 were molluscs (mussels, cockles, snails etc.), 6 species were echinoderms (brittlestars, sea cucumbers), 2 species were cnidarians (sea anemones, corals), 2 species were sipunculids (peanut worms) and 1 species was a phoronid (horseshoe worm).

2.3.1.1. UNIVARIATE ANALYSES

Univariate statistical analyses were carried out on the combined replicate station-by-station faunal data. The following parameters were calculated and can be seen in Table 3; species numbers, number of individuals, richness, evenness and diversity. Species numbers ranged from 49 (S5) to 60 (S1). Number of individuals ranged from 192 (S3) to 389 (S6). Richness ranged from 8.79 (S4) to 10.2 (S2). Evenness ranged from 0.87 (S1) to 0.89 (S3, S4, S5). Diversity ranged from 4.98 (S5) to 5.2 (S6).

Table 3: Diversity indices for the 6 stations sampled at the ocean energy test site.

Station	Species	Individuals	Richness	Evenness	Diversity
S1	60	358	10.03	0.87	5.12
S2	59	295	10.20	0.88	5.17
S3	51	192	9.51	0.89	5.08
S4	51	296	8.79	0.89	5.04
S5	49	216	8.93	0.89	4.98
S6	59	389	9.73	0.88	5.20

2.3.1.2. MULTIVARIATE ANALYSES

The dendrogram and the MDS plot can be seen in Figures 4 and 5 respectively. Two broad groupings can be identified initially. The control station, S6, separated from the other 5 stations at a similarity level of 56.09% (Group I). The remaining stations (all located within the test site) had a similarity level of 60.06%. These stations separated further into Group II and Group III. Group II had a similarity level of 63.15%. This Group consisted of stations, S1 and S4 (65.38% similarity) and station S2 (63.15% similarity). Group III consisted of stations S3 and S5, which had a 60.97% similarity level. It is important to note that all stations were >55% similar to each other indicating a homogeneous faunal community.

Station S6 (Group I) contained 59 species comprising 389 individuals. Of the 59 species present, 38 were present more than twice. Ten species accounted for 50% of the abundance at this station: the polychaetes *Tharyx* sp. (35 individuals; 9%), *Spiophanes kroyeri* (25 individuals; 6.4%), *Chaetozone setosa* (24 individuals; 6.2%), *Lumbrineris gracilis* (21 individuals; 5.4%), *Aricidea (Arcidea) minuta* (19 individuals; 4.9%), *Spiochaetopterus typicus* (17 individuals; 4.4%) *Glycera alba* (15 individuals; 3.9%), the mollusc *Phaxas pellucidus* (15 individuals; 3.9%), the polychaete *Nephtys hombergii* (12 individuals; 3.19%) and the amphipod *Phtisica marina* (12 individuals; 3.1%).

Within Group II, S1 contained 60 species comprising 358 individuals. Of the 60 species present, 33 were present more than twice. Nine species accounted for 50% of the abundance at this station: the polychatetes *Tharyx* sp, (31 individuals; 8.7%). *Glycera alba* (25 individuals; 7%), *Nephtys hombergii* (23 individuals; 6.4%), *Chaetozone setosa* (23 individuals; 6.4%), the mollusc *Thyasira flexuosa* (20 individuals; 5.6%), the polychaetes *Spiochaetopterus typicus* (19 individuals; 5.3%), *Lumbrineris gracilis* (18 individuals; 5%), *Scalibregma inflatum* (15 individuals; 4.2%) and *Ampharete lindstroemi* (15 individuals; 4.2%).

S4, which was 65.38% similar to S1, contained 51 species comprising 296 individuals. Of the 51 species present, 29 were present more than twice. Nine species were responsible for 50% of the abundance: the polychaetes *Scalibregma inflatum* (30 individuals; 10.1%), *Tharyx* sp. (23 individuals; 7.8%), *Spiochaetopterus typicus* (20 individuals; 6.8%), the mollusc *Thyasira* *flexuosa* (16 individuals; 5.4%), the amphipod *Ampelisca bre*vicornis (15 individuals; 5.1%), the polychaete *Diplocirrus glaucus* (12 individuals; 4.1%), the mollusc *Phaxas pellucidus* (12 individuals; 4.12%), the polychate *Apistobranchus tullbergi* (11 individuals; 3.7%) and the amphipod *Harpinina serrata* (11 individuals; 3.7%).

S2, which was 63.15% similar to stations S1 and S4, contained 59 species comprising 295 individuals. Of the 59 species present, 30 were present more than twice. Nine species accounted for 50% of the faunal abundance at this station: the amphipod *Photis longicaudata* (35 individuals; 11.9%), the mollusc *Thyasira flexuosa (*18 individuals; 6.1%), the polychaetes *Tharyx* sp. (17 individuals; 5.8%), *Aricidea (Arcidea) minuta* (15 individuals; 5.1%), *Ampharete lindstroemi* (15 individuals; 5.1%), *Diplocirrus glaucus* (13 individuals; 4.4%), *Lumbrineris gracilis* (12 individuals; 4.1%), *Spiochaetopterus typicus* (12 individuals; 4.1%) and *Scalibregma inflatum* (10 individuals; 3.4%).

Within Group III, S3 contained 51 species comprising 192 individuals. Of the 51 species present, 19 were present more than twice. Nine species accounted for 50% of the faunal abundance: the polychaetes *Chaetozone setosa* (17 individuals; 8.9%), *Spiochaetopterus typicus* (15 individuals; 7.8%), *Diplocirrus glaucus* (12 individuals; 6.3%), *Ampharete lindstroemi* (11 individuals; 5.7%), the amphipod *Ampelisca brevicornis* (11 individuals; 5.7%), the polychaetes *Tharyx* sp. (10 individuals; 5.2%), *Nephtys hombergii* (9 individuals; 4.7%), *Magelona alleni* (7 individuals; 3.7%)and *Scalibregma inflatum* (7 individuals; 3.7%).

Station S5 which was 60.97% similar to S3 contained 49 species comprising 216 individuals. Of the 49 species present, 24 were present more than twice. Eight species accounted for 50% of the faunal abundance: The molluscs *Thyasira flexuosa* (21 individuals; 9.7%) and *Phaxas pellucidus* (16 individuals; 7.4%), the polychaetes *Tharyx* sp. (15 individuals; 6.9%), *Chaetozone setosa* (14 individuals; 6.5%), *Scalibregma inflatum* (14 individuals; 6.5%), *Spiochaetopterus typicus* (12 individuals; 5.6%), *Diplocirrus glaucus* (12 individuals; 5.6%) and *Lumbrineris gracilis* (7 individuals; 3.2%).

These delineations were also preserved in the MDS plot. The stress value of the MDS ordination is 0.01; this results in an excellent representation of the data with no prospect of misinterpretation.

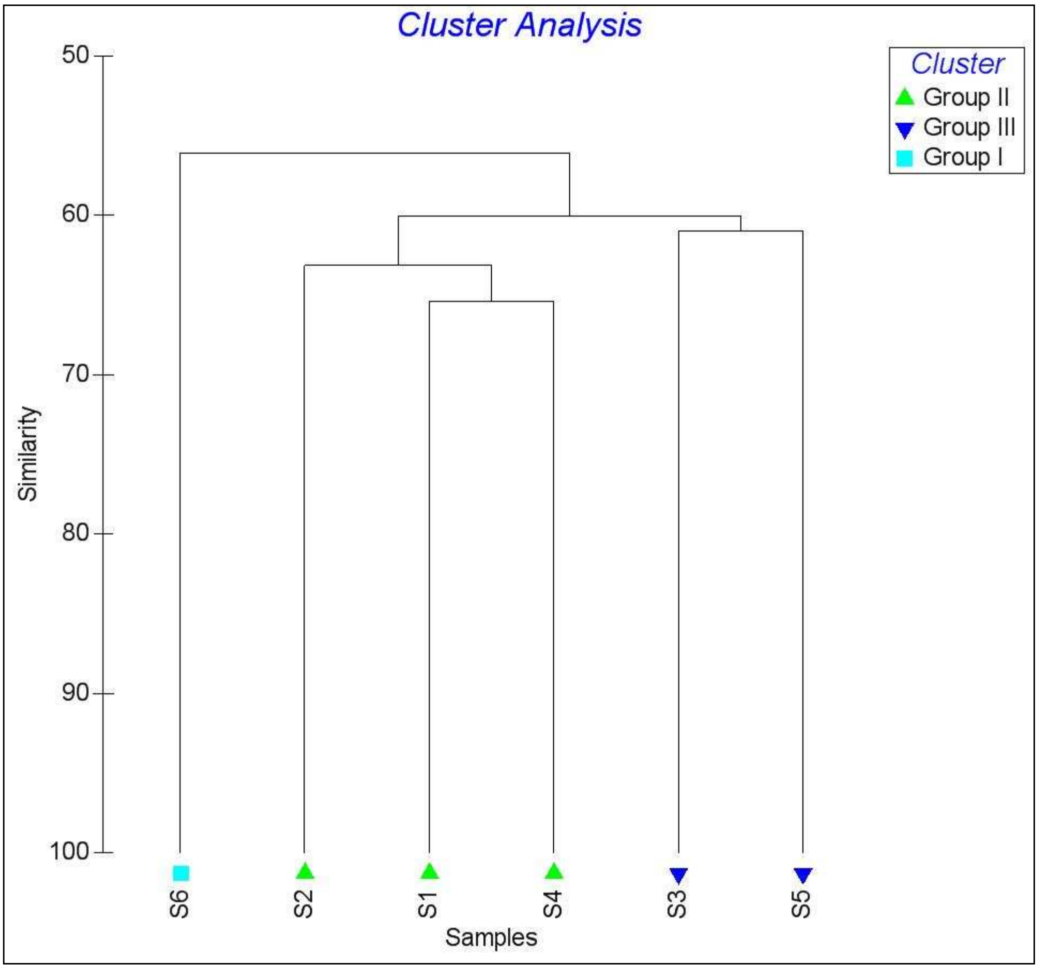

Figure 5: Dendrogram showing each station from the 6 stations sampled in the ocean energy test site.

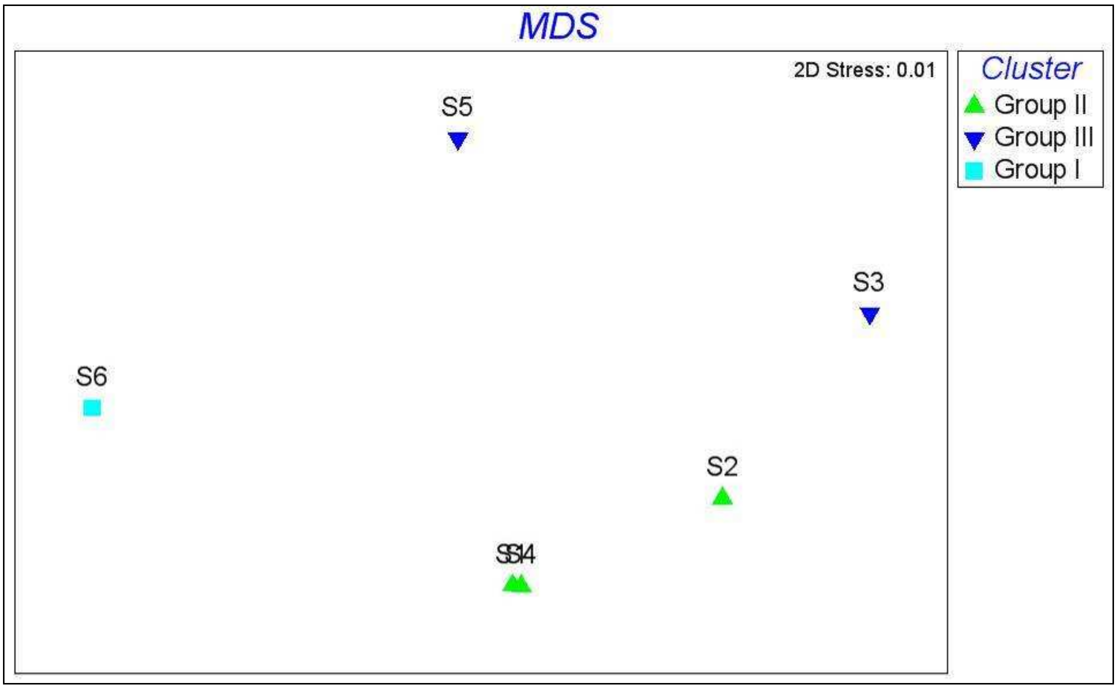

Figure 6: MDS ordination showing each station from the 6 stations sampled in the ocean energy test site.

2.3.2. Sediment

The results from the traditional granulometric analysis can be seen in Table 4. Figure 7 shows this data in graphical form. The sediment sampled during the survey was classified slightly gravelly muddy sand, muddy sand, sand and slightly gravelly sand according to Folk (1954).

The majority of stations were classified as muddy sand (Stations S2, S3 and S4) (See Figure 8). These stations were located in the northwestern part of the test site. Sand was present at station S5 in the southern part of the test site and slightly gravelly muddy sand was present at station S1 in the eastern part of the test site. The control site, S10 was classified as slightly gravelly sand.

Station S1 contained the highest percentage of gravel (1.7%), very coarse sand (1.7%), coarse sand (1.9%), medium sand (2.2%) and silt-clay (13.1%). Station S6 contained the highest percentage of fine sand and station S4 contained the highest percentage of very fine sand (74.5%).

Table 4: Granulometry results for the 6 stations sampled at ocean energy test site in Galway Bay (as percentage weight of the total sample).

Station	Gravel* (%)	Very Coarse Sand* (%)	Coarse Sand* (%)	Medium Sand* (%)	Fine Sand* (%)	Very Fine Sand* (%)	Silt-Clay*(%)	Folk (1954)*
1	1.7	1.7	1.9	2.2	13.9	65.4	13.1	Slightly Gravelly Muddy Sand
2	0.3	0.7	1.2	1.6	11.8	73.9	10.6	Muddy Sand
3	0.7	1	1.5	1.8	12.6	71.4	11	Muddy Sand
4	0.2	0.7	1.3	1.7	11	74.5	10.7	Muddy Sand
5	0.5	0.9	1.4	1.8	14.4	72	8.8	Sand
6	1.1	0.9	1.3	1.9	24.4	63.7	6.7	Slightly Gravelly Sand

*The particle size ranges for each classification (gravel, very coarse sand, coarse sand, medium sand, fine sand, very fine sand and silt clay) is adapted from Buchanan, 1984 and can be seen in Table 2 (page 6). The classifications according to Folk, 1954) are based on varying percentages of gravel, sand and silt-clay.

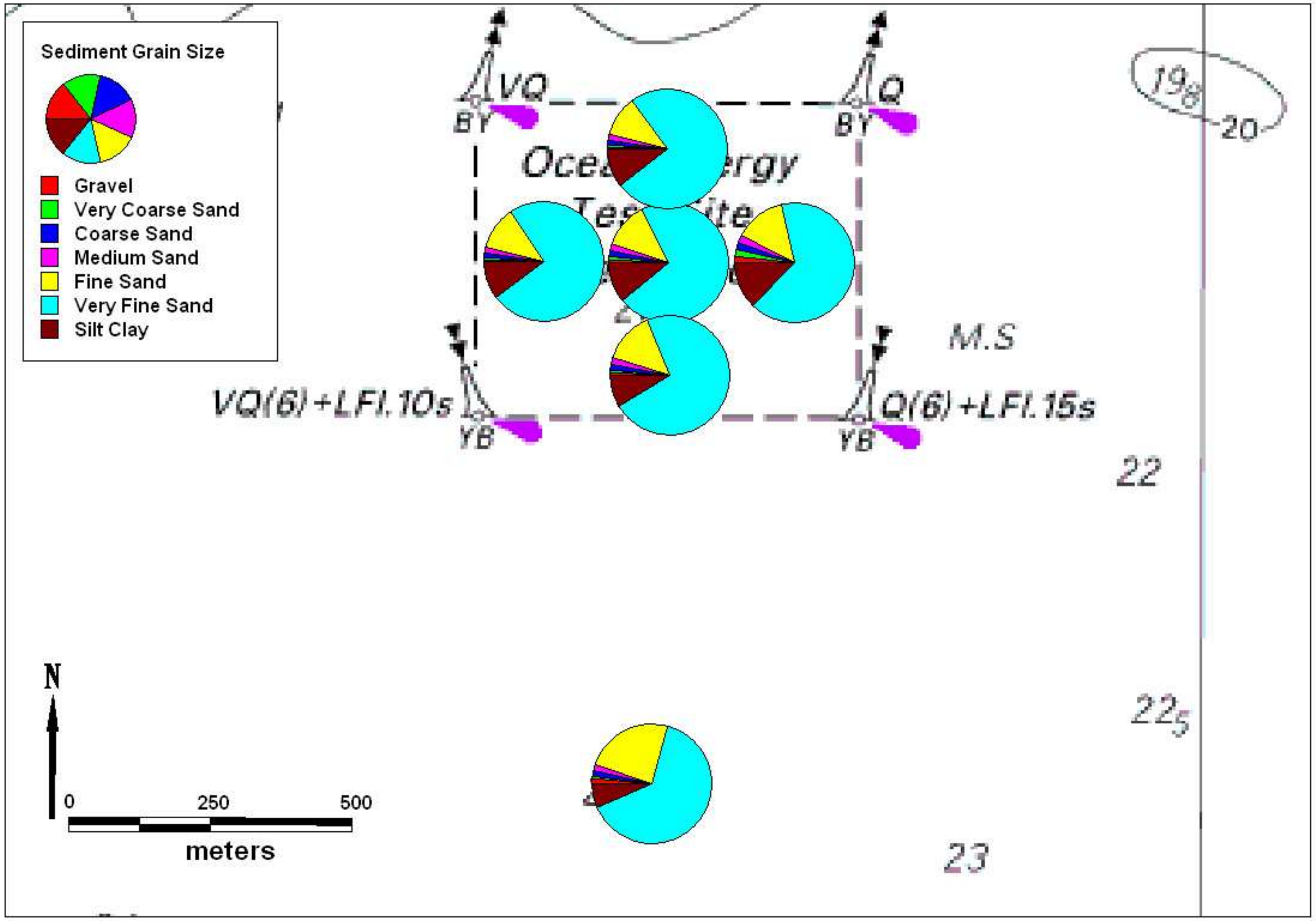

Figure 7: Sediment grain size data

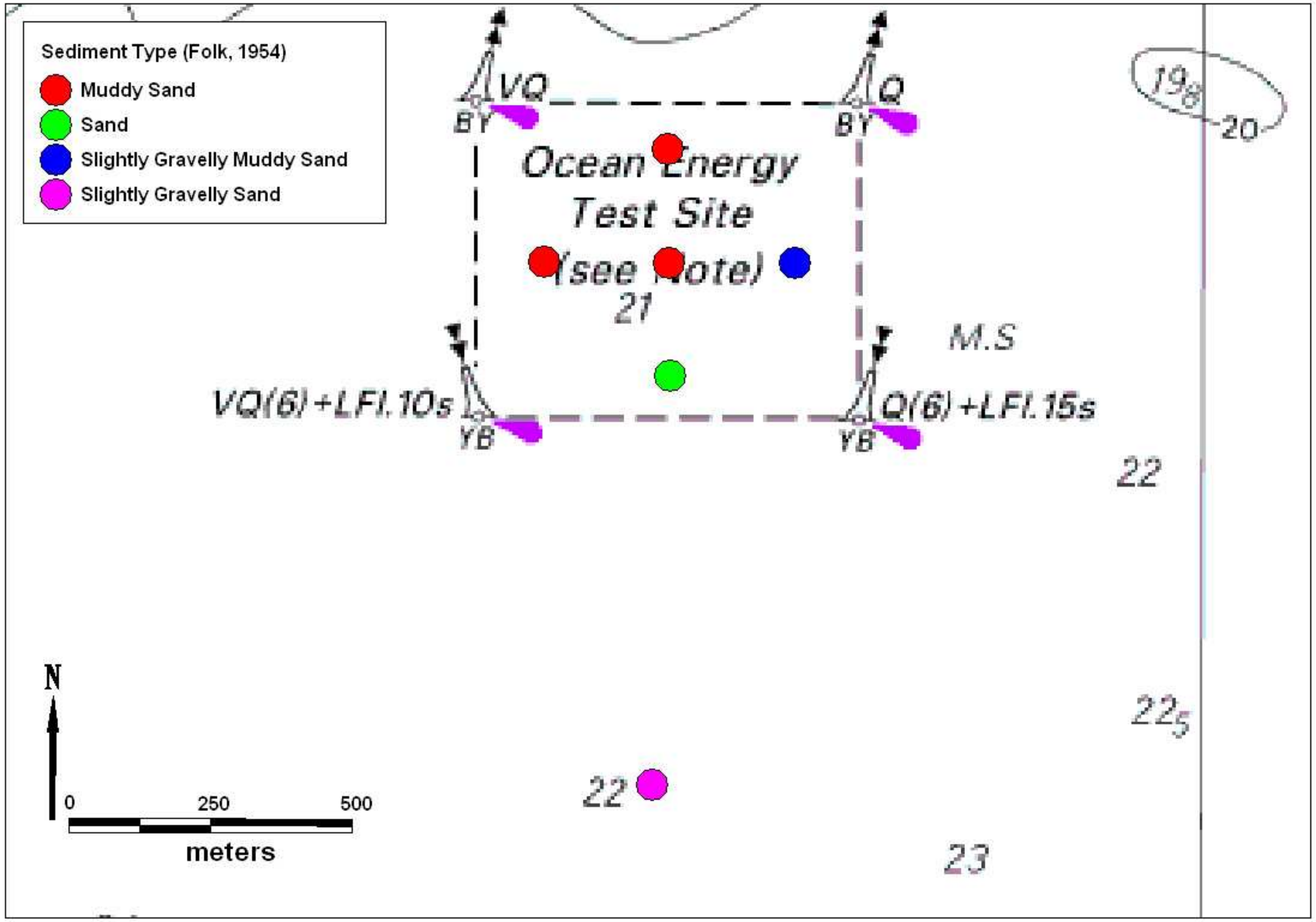

Figure 8: Sediment type according to Folk (1954)

2.3.3. Underwater imaging

Appendix 2 shows a selection of images taken of the sea floor and the mooring chains at the site. The sea bed was found to be a fine, muddy sand with biologically active infauna such as burrowing decapods. Large epibenthic species included *Goneplax rhomboides* and *Marthasterias glacialis*. Mussel shell debris was also noted and these represent material sloughed off the anchor chains and the structure itself. The mooring chains were found to be heavily settled by epifauna such as anemones, mussels, star fish and echinoids.

2.3.3.1. Sediment Profile Imaging (SPI)

SPI images were taken within the location where the ocean energy device had been deployed and were uniform in many respects (see Appendix 3 for representative photographs). The sediment was found to be a fine, muddy sand with well bioturbated sediments giving rise to deep redox layers throughout the site. Where present, surface boundary roughness was biologically-generated. These images indicated a biologically active benthos with a Stage III community present.

2.3.4. Discussion

The sediment type within the test site varied between muddy sand, sand and slightly gravelly muddy sand. The control site, station S6, was classified as slightly gravelly sand.

Species richness is a measure of the total number of species present for a given number of individuals. Evenness is a measure of how evenly the individuals are distributed among different species. The diversity index incorporates both of these parameters. Richness ranges from 0 (low richness) to 12 (high richness), evenness ranges from 0 (low evenness) to 1 (high evenness), diversity ranges from 0 (low diversity) to 5 (high diversity).

The results from the univariate statistical analyses are all typical of muddy coastal sediments off the West coast.

Table 5: Number of Species, Individuals, their Richness, Evenness and Diversity at each Station

Station	Species	Individuals	Richness	Evenness	Diversity
S1	60	358	10.03	0.87	5.12
S2	59	295	10.20	0.88	5.17
S3	51	192	9.51	0.89	5.08
S4	51	296	8.79	0.89	5.04
S5	49	216	8.93	0.89	4.98
S6	59	389	9.73	0.88	5.20

A benthic faunal study carried out by O'Connor & McGrath (1981) in inner Galway Bay in 1976 characterised the ocean energy test site as an *Abra nitida/Turritella communis* variation of the *Cylichna cylindracea* and *Ampelisca spinipes* silty sand community. The stations sampled in the present study revealed elements of the *Cylichna cylindracea* and *Ampelisca spinipes* silty sand community, however the *Abra nitida/Turritella communis* variation of this community was not evident.

The dominant species from this survey were the polychaetes *Tharyx* sp., *Scalibregma inflatum, Spiophanes kroyeri, Glycera alba, Spiochaetopterus typicus, Chaetozone setosa,* the amphipod *Photis longicaudata* and the molluscs *Thyasira flexuosa* and *Phaxas pellucidus.* Species richness and evenness was high at each station.

The results of the multivariate analyses indicate a high level of similarity between the sampled locations and suggest that there has been no noticeable change in benthic fauna within the site. This is further supported by the high level of similarity between the "in site" data and the control.

The SPI images indicate a healthy Stage community present at the site with both infaunal and epibenthic (decapods) species reworking and oxygenating the upper *ca* 15 cms of sediment to such a degree that no discontinuity in oxygen levels were noted on any of the images collected.

The only noticeable difference between the test site samples and the control was the occasional occurrence of mussel (*Mytilus edulis*) shells within the test area. These shells were probably sloughed off the ocean energy device while *in situ* or when it was being moved into the docks at Galway.

3. Marine reptiles, mammals and birds

3.1. Marine reptiles of Ireland's Atlantic margin.

Five species of marine turtle have been recorded in UK and Irish waters (Brongersma, 1972; Penhallurick, 1990; Langton *et al.*, 1996; Gaywood, 1997; Pierpoint & Penrose, 1999). Only one species however, the leatherback turtle *Dermochelys coriacea* is reported annually and is considered a regular and normal member of Irish marine fauna (Godley *et al*. 1998). Loggerhead turtles *Caretta caretta* and Kemp's ridley turtles *Lepidochelys kempii* occur less frequently, with most specimens thought to have been carried north from their usual habitats by adverse currents (Carr, 1987; Penhallurick, 1990; Mallinson, 1991). Records of two other vagrant species, the hawksbill turtle *Eretmochelys imbricata* and the green turtle *Chelonia mydas* are very rare (Brongersma, 1972; O'Riordan *et al*., 1984; Branson, 1997). Due to the rarity of the latter 4 species in the ocean energy device area and wider Galway Bay area, they are not discussed further.

<u>Leatherback turtle (*Dermochelys coriacea*)</u>

The leatherback turtle is the largest marine turtle that occurs in warm waters and has been regularly recorded in Irish waters. They breed circumglobally within latitudes approximately 40°N and 35°S, but range widely to forage in temperate and boreal waters outside the nesting season (Eckert, 1995). They are the only species of marine turtle to have developed adaptations to life in cold water (Greer *et al*. 1973; Goff & Stenson, 1988). It is an endangered species throughout its distributional range. The total number of leatherbacks nesting world-wide in 1995 was estimated at 34,529 (confidence interval 26,177 to 42,878) females (Spotila *et al*., 1996). About 80% of these animals were reported from sites in the Atlantic. Long-distance migration has been documented from tag returns and more recently using satellite telemetry. There are distinct seasonal peaks in the occurrence of leatherback turtles in northern waters. Around the UK, most turtles are reported between August and

October (Gaywood, 1997; Godley *et al.,* 1998). Using an expanded dataset, Pierpoint & Penrose (1999) report that leatherbacks have been reported from UK and Irish waters in every month, although live sightings peak in August. Strandings peak slightly later, in September and October. Leatherback turtles feed primarily on jellyfish. Their diet in temperate and boreal waters is known to include cnidarians (jellyfish) and tunicates (seasquirts) (salps, pyrosomes) (den Hartog & van Nierop, 1984; Davenport & Balazs, 1991). In UK and Irish waters they are often reported in the vicinity of jellyfish swarms, and there are several observations of leatherbacks feeding on jellyfish at the surface (e.g. Brongersma, 1972; Penhallurick, 1990). The leatherback turtle is included in the EU Habitats Directive and CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora). This species has been recorded in the Galway/Clare area and may be an occasional visitor to the ocean energy device site. As it is generally on the sea surface, it is considered unlikely that it would be affected by the workings of the device.

3.2. Marine Mammals of Ireland's Atlantic Margin

Irish waters are some of the most important in Europe for a wide range of cetacean (whales, dolphins and porpoise) species (Berrow, 2001). There is substantial background evidence promoting the Atlantic Margin as an area of high species richness for cetaceans (Ó Cadhla *et al.,* 2004). To date, 24 cetacean species have been recorded in Irish waters (Berrow, 2001). The majority of these have been recorded from sightings or acoustic recordings (as well as from strandings), whereas only three species have only been recorded as strandings, they are Gervais's beaked whale, pygmy sperm whale and True's beaked whale (IWDG, *pers. comm.*). Three species of pinnipeds (seals) have been reported from Irish waters.

Parturition (breeding) in Irish waters has been confirmed for a number of cetacean species including harbour porpoise *Phocoena phocoena*, common *Delphinus delphis*, bottlenose *Tursiops truncatus*, Risso's *Grampus griseus*, white sided *Lagenorhynchus acutus* and white-beaked *L albirostris* dolphins and pilot whale *Globiocephala melas,* while other species such as bottlenosed *Hyperoodon ampullatus* and minke whale *Balaenoptera acutorostrata* are also suspected of breeding. Many are not known to breed in Irish waters but migrate annually along the western seaboard (Charif & Clark, 2000), these include the blue whale *Balaenoptera musculus*, fin whale *B. physalus* and humpback whale *Megaptera novaegliana*.

Recent data suggests that some of these species feed year-round in waters along the south coast, including the fin and humpback whale (IWDG, *pers. comm.*), whereas others may over-winter in waters south of Ireland e.g. blue whale *Balaenoptera musculus* (Charif & Clark, 2000). Others such as beluga *Delphinapterus leucas* are vagrants on the edge of their range in the Northeast Atlantic and only occur infrequently

The grey and harbour seals are the two seal species native to Irish waters. Both species have established themselves in terrestrial colonies (or haul-outs) along all coastlines of Ireland, which they leave when foraging or moving between areas and to which they return to rest ashore, rear young, engage in social activity, etc. The haul-out groups of harbour seals have tended historically to be found among inshore bays and islands, coves and estuaries (Lockley, 1966; Summers *et al*., 1980), particularly around the hours of lowest tide. The grey seal breeds on exposed rocky shores, on sand bars or sea caves with ready access to deep water. Other haul-out areas for the grey seal are located on exposed rocky areas or steeply shelving sandbanks. Fur seal and walrus are also visitors to Atlantic waters (Ó Cadhla, *pers. comm.*).

Figure 9 below shows all whales and dolphins recorded from Galway Bay from January 2008 (Source: IWDG Sightings).

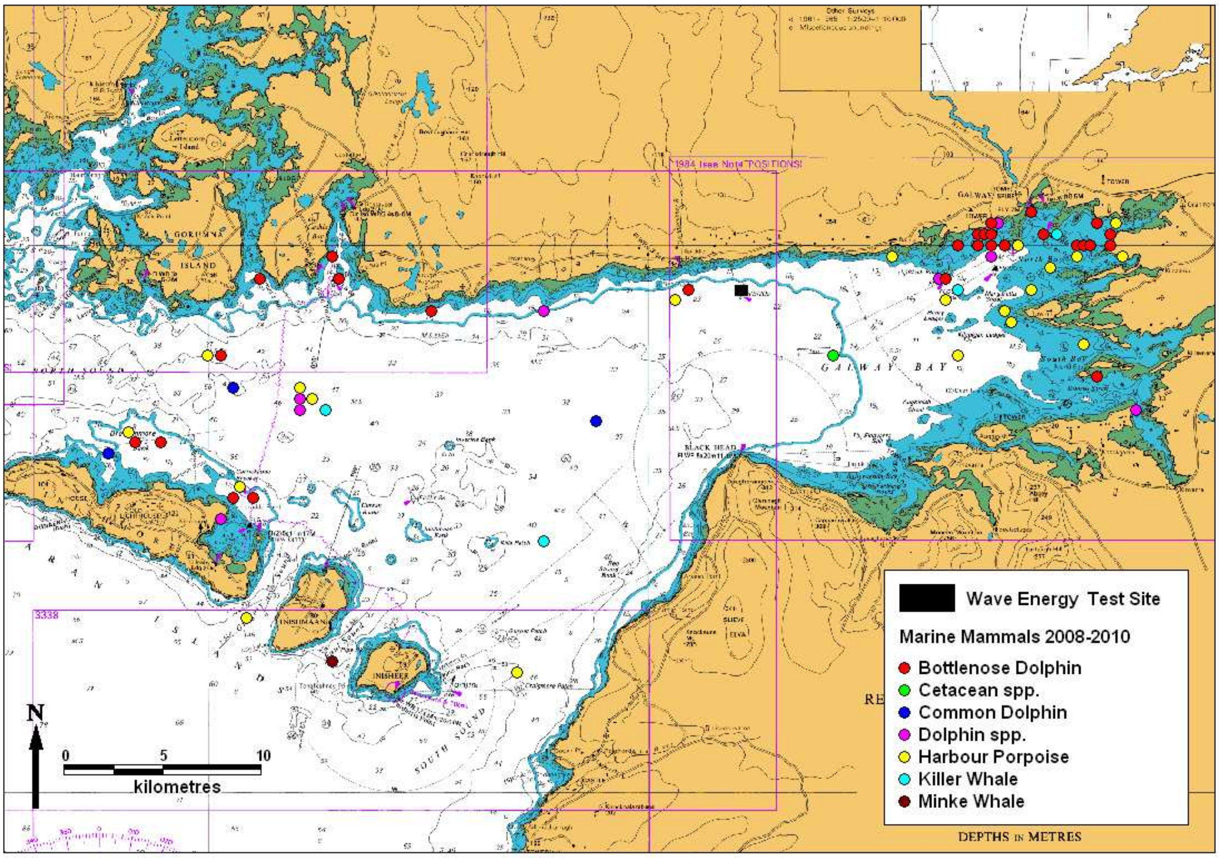

Figure 9: Map showing Wave energy test site and areas where cetaceans were recorded between 2008 and 2010

All marine mammals are considered to be able to swim at fast enough velocities so as to be able to avoid the physical actions of the device.

3.3. Birds of Ireland's Atlantic Margin

The exposed and inaccessible west coast of Ireland provides a perfect breeding habitat for many seabird species. In addition to this, coastal and offshore Irish waters provide local breeding and non-breeding seabirds, along with pelagic and passage migrants, with a rich source of nutrition, particularly near coastal upwelling and frontal systems (e.g. along the Irish Shelf front, north of the Porcupine Seabight). The availability and distribution of prey are considered to be the most important factors driving seabird distribution and abundance (Skov *et al.,* 1995; Begg & Reid, 1997; Ollason *et al.,* 1997), particularly around colonies during the breeding season (Boelens, *et al.,* 1999). The waters off western and southern Ireland are also internationally important fishing grounds and important nursery and spawning areas for fish and invertebrate species. Areas off the west coast of Ireland are regarded to be of the highest importance as feeding areas for seabirds.

Mackey *et al.* (2004) described the distribution, density and relative abundance of seabirds of Ireland's Atlantic Margin. The Atlantic Margin is characterised by a number of physical, climate and oceanographic features, which combine to produce one of the most productive areas of the northeast Atlantic Ocean. As a result, the waters off western and southern Ireland contain internationally renowned commercial fishing grounds (e.g. Porcupine Bank, Celtic Sea), important nursery and spawning areas for fish and invertebrate species, and areas of concentration for foraging seabirds and other predators (Boelens *et al.,* 1999).

3.3.1. Inner Galway Bay

<u>Inner Galway Bay Survey</u>

Inner Galway Bay is an internationally important bird site. The habitat of the site is composed of open rocky/boulder/shingle coastline along the northern and southern shores, estuarine habitat with shallow sandy bays and lagoons between Oranmore and Kinvarra, shallow tidal inlet bordered by saltmarsh (Lough Atalia) and an adjacent turlough (Ahapouleen). This site has been regularly monitored since the *Wetlands Enquiry (1971-74).* It is currently counted in four parts, all of which have been regularly monitored during all I-WeBS seasons. The total count area of the site is 10,321 hectares (103.21 km2). In more recent seasons (since the period of the Crowe, 2005 publication), these four sections have been further sub-divided into 24 count units.

Table 6 shows the mean number of water birds present in the area from 1996 to 2000.

Table 6: Mean number of water birds in the area from 1996 to 2000.

Group	Mean No.
Number of regularly occurring species	40
Wildfowl	4,424
Waders	11,544
Gulls	3,386

Inner Galway Bay supports the greatest diversity of waterbirds in the country. It is internationally important for great northern diver and light-bellied Brent goose and nationally important for a further 15 species. This site also supports significant concentrations of both black-headed and common gulls. Waterbird numbers overall have increased (by 51%) since the *Winter Wetlands (1984-86)*. There have been increases in most species, particularly great northern diver, cormorant, shoveler and wader species such as golden plover, lapwing, dunlin and bar-tailed godwit. The majority of species have continued to increase or remain stable at Inner Galway Bay during the I-WeBS period. Overall, the difference between the first five season peak mean (1994/95 to 1998/99) and the most recent (to 2000/01) illustrates that both wildfowl and waders have increased by 14% and 25% respectively. The long-term species declines in Nairn *et al*. (2000), such as grey heron, ringed plover, redshank and turnstone have either stabilised or reversed during I-WeBS.

The northeast and east sections of the bay generally support the majority of birds, while the islands of the inner bay are used by large concentrations of roosting waders. The open water habitats are of particular importance for great northern diver, little grebe, cormorant and red-breasted merganser. Numbers of some species vary considerably. Golden plover, lapwing and curlew regularly move inland to feed on fields, returning to the shoreline in large numbers when the ground is frozen. Some divers, seaducks and gulls are occasionally located far offshore and out of observation range, particularly when sea conditions are rough. However, this site is regularly counted, thereby increasing the likelihood that these flocks are counted at some stage in a given season.

Table 7 shows the significant concentrations of waterbirds in Inner Galway Bay between 1994/94 and 2000/01.

Table 7: Concentrations of waterbirds in Inner Galway Bay between 1994/95 and 2000/01.

Species	94-98	95-99	96-00	Month	% Flyway	% National	Rank	% change (WWS)
International								
Great Northern Diver	78	83	105	Mar	2.1	5.3	1	+401
Light-bellied Brent Goose	638	682	746	Mar	3.7	3.7	9	+39
National								
Cormorant	249	266	285	Nov	0.2	1.9	7	+65
Shelduck	127	146	155	Jan	0.1	1.0	23	+24
Wigeon	1,150	1,168	1,187	Jan	0.1	1.3	23	+2
Teal	612	700	797	Jan	0.2	1.4	19	+22
Shoveler	96	88	130	Nov/Jan	0.3	3.3	8	+66
Red-breasted Merganser	250	249	250	Nov	0.2	6.3	1	+17
Ringed Plover	297	335	287	Jan	0.4	1.9	5	-47

Species	**94-98**	**95-99**	**96-00**	**Month**	**% Flyway**	**% National**	**Rank**	**% change (WWS)**
Golden Plover	1,584	2,030	2,171	Nov/Mar	0.2	1.5	35	+98
Lapwing	3,360	3,969	4,189	Jan	0.2	2.1	13	+18
Dunlin	1,642	2,155	2.203	Jan	0.2	1.6	14	+75
Bar-tailed Godwit	402	447	475	Jan	0.4	2.6	12	+75
Curlew	650	697	689	Nov/Jan	0.2	1.0	21	+36
Redshank	506	505	508	Nov	0.3	1.5	18	-20
Greenshank	20	20	18	Nov	~	0.9	18	-4
Turnstone	160	182	2223	Nov	0.2	1.6	7	-15
Gulls								
Black-headed Gull	1,571	1,815	2,108	Jan	~	-	14	
Common Gull	988	1,017	999	Jan	0.1	-	7	

Inner Galway Bay (004031)	One of the most important ornithological sites in the western region. Supports an excellent diversity of wintering wetland birds, with divers, grebes, cormorants, dabbling duck, sea duck and waders all well represented. Internationally important wintering populations of Great Northern Diver (83) and Brent Goose (676). Nationally important populations of an additional sixteen species, i.e. Black-throated Diver (25), Cormorant (266), Mute Swan (150), Wigeon (1,157), Teal (690), Shoveler (88), Red-breasted Merganser (249), Ringed Plover (335), Golden Plover (2,030), Lapwing (3,969), Dunlin (2,149), Bar-tailed Godwit (447), Curlew (697), Redshank (505), Greenshank (20) & Turnstone (182) – all figures are average peaks for the 5 seasons 1995/96-1999/00. Of note is that the populations of Red-breasted Merganser and Ringed Plover represent 6.7% and 3.3% of the respective national totals. Black-throated Diver is a scarce species in Ireland and the Galway Bay population is the most regular in the country. Other species which occur in notable numbers include Little Grebe (35), Grey Heron (102), Longtailed Duck (19) and Scaup (40). The bay is an important wintering site for gulls, especially Black-headed Gull (1,815), Common Gull (1,011) and Herring Gull (216). In addition, the following species also use the site: Red-throated Diver (13), Great Crested Grebe (16), Mallard (200), Shelduck (139), Common Scoter (79), Oystercatcher (575), Grey Plover (60), Black-tailed Godwit (45) and Great Blackbacked Gull (124). The site provides both feeding and roost sites for most of the species, though some birds also commute to areas outside of the site. The site has several important populations of breeding birds, most notably colonies of Sandwich Tern (81 pairs in 1995) & Common Tern (99 pairs in 1995). A large Cormorant colony occurs on Deer Island (300 pairs in 1989).

Of the above species, the only ones that might occur at the wave energy site would be Great Northern, Black throated and Red Throated Diver, cormorant, shag, red breasted merganser, Gull and tern species. Other species that will occur on the site include Manx, Sooty, Great and Cory's shearwater, storm and fulmar petrels, Arctic and Great skua, gannet, white backed gull species, puffin, black and common guillemot and razorbill. There is also a number of rarer species such as Wilson's petrel, Little and Sabine's gull, little auk and grey phalarope that most likely can occur at the site. Eider duck are now known to breed at Slyne Head and if this southward extension of their distribution continues, this species may move through the ocean energy site with time.

Regarding these species, only the diving birds can be affected by ocean energy devices. These species are sooty shearwater, Great Northern, Black throated and Red Throated Diver, cormorant, shag, red breasted merganser, tern and auk species. The ocean energy device draws in a column of water that is ca 1 m in height and this same volume of water is exhaled approximately 6 seconds later. Any bird that may be drawn into the device will therefore be flushed out with this water.

Observations of the device show that gulls use it as a roosting and feeding site. Gulls were seen to alight on the structure and stay there for periods of time and were also seen to collect epifaunal species such as mussels and feed on them on the device.

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Appendix 1
Faunal Abundance List

Station			**1A**	**1B**	**2A**	**2B**	**3A**	**3B**	**4A**	**4B**	**5A**	**5B**	**6A**	**6B**
CNIDARIA	D	1												
ACTINIARIA	D	662												
Haloclavidae	D	749												
Peachia hastata	D	755		2			1							
Edwardsiidae	D	759												
Edwardsia sp.	D	764	4											
SIPUNCULA	N	1												
SIPUNCULIDEA	N	2												
GOLFINGIIFORMES	N	10												
Golfingiidae	N	11												
Nephasoma (Nephasoma) minutum	N	25		3				3			1		3	1
Phascolionidae	N	29												
Phascolion strombus	N	37			1		1							
ANNELIDA	P	1												
POLYCHAETA	P	2												
PHYLLODOCIDA	P	3												
Polynoidae	P	25												
Malmgreniella arenicolae	P					1			1	1				
Pholoidae	P	90												
Pholoe inornata	P	92						2			2			
Pholoe synophthalmica	P	94	9			2								
Sigalionidae	P	96												
Sthenelais sp.	P	106									1			
Sthenelais cf limicola	P	109	2		1	2	3	1	2			2	2	
Phyllodocidae	P	114												

Station			**1A**	**1B**	**2A**	**2B**	**3A**	**3B**	**4A**	**4B**	**5A**	**5B**	**6A**	**6B**
Eteone flava	P	117						2						
Phyllodoce (Anaitides) groenlandica	P	141				1								
Phyllodoce longipes	P	143		1										
Phyllodoce (Anaitides) rosea	P	148		1									1	
Eumida bahusiensis	P	164		3	2	5						1	8	3
Paranaitis kosteriensis	P	176			2			2						
Glyceridae	P	254												
Glycera alba	P	256	14	11	3		2		7	3	2	3	13	2
Glycera rouxii	P	263			3			2						
Goniadidae	P	266												
Goniada maculata	P	271			2						1			
Hesionidae	P	293												
Ophiodromus flexuosus	P	313				2		1		1	3	3	4	
Podarkeopsis capensis	P	319				2								
Syllidae	P	346												
Exogone hebes	P	421							2					
Autolytus sp.	P	434									1			
Nephtyidae	P	490												
Nephtys sp. (juv)	P	494												3
Nephtys cirrosa	P	498	1											
Nephtys hombergii	P	499	9	14	4	3	5	4	3	4			12	
EUNICIDA	P	536												
Lumbrineridae	P	569												
Lumbrineris gracilis	P	579	11	7	6	6	3	3	7		4	3	14	7
Abyssoninoe hibernica	P											1	2	
Dorvilleidae	P	598												

Station			**1A**	**1B**	**2A**	**2B**	**3A**	**3B**	**4A**	**4B**	**5A**	**5B**	**6A**	**6B**
Protodorvillea kefersteini	P	638								1				
ORBINIIDA	P	654												
Orbiniidae	P	655												
Scoloplos armiger	P	672	3	1								1		3
Paraonidae	P	674												
Aricidea (Arcidea) minuta	P	677	7		8	7	2	2	4	2		7	19	
Paradoneis lyra	P	699		1										3
SPIONIDA	P	707												
Apistobranchidae	P	709												
Apistobranchus tullbergi	P	712	2		1				2	9		3	4	3
Spionidae	P	720												
Prionospio sp.	P	763				1	3				4		4	7
Prionospio fallax	P	765											1	
Spio filicornis	P	790					3				2	2		
Spiophanes bombyx	P	794	2	2		2			3					
Spiophanes kroyeri	P	796						2		2	3		16	9
Magelonidae	P	802												
Magelona sp.	P	803											1	
Magelona alleni	P	804		2	2	3	3	4	2	2		2	3	2
Magelona filiformis	P	805	1											
Magelona minuta	P	806				2								3
Chaetopteridae	P	810												
Spiochaetopterus typicus	P	820	14	5	2	10	6	9	11	9	6	6	13	4
Cirratulidae	P	822												
Chaetozone setosa	P	834	9	14	9		7	10	7		3	11	20	4

Station			**1A**	**1B**	**2A**	**2B**	**3A**	**3B**	**4A**	**4B**	**5A**	**5B**	**6A**	**6B**
Chaetozone christiei	P		2											
Caulleriella killariensis	P	846									1			
Tharyx sp.	P	847	14	17	10	7	6	4	9	14	6	9	26	9
FLABELLIGERIDA	P	872												
Flabelligeridae	P	873												
Diplocirrus glaucus	P	878		4	6	7	7	5	5	7	9	3	7	4
CAPITELLIDA	P	902												
Capitellidae	P	903												
Mediomastus fragilis	P	919	3		2			2	1					3
Notomastus latericeus	P	921		1					2			2	2	
Maldanidae	P	938												
Euclymene lumbricoides	P	963		3									3	
OPHELIIDA	P	992												
Opheliidae	P	993												
Ophelina acuminata	P	1014				1								
Scalibregmatidae	P	1020												
Scalibregma celticum	P	1026			1			2						
Scalibregma inflatum	P	1027	15			10	7		7	23	8	6		
OWENIIDA	P	1089												
Oweniidae	P	1090												
Owenia fusiformis	P	1098	4	5		4	3	2		4		7	5	3
TEREBELLIDA	P	1099												
Pectinariidae	P	1100												
Pectinaria (Amphictene) auricoma	P	1102	2											
Ampharetidae	P	1118												
Melinna palmata	P	1124					1		1					
Ampharete sp.	P	1133												8

Station			**1A**	**1B**	**2A**	**2B**	**3A**	**3B**	**4A**	**4B**	**5A**	**5B**	**6A**	**6B**
Ampharete lindstroemi	P	1139	7	8	11	4	3	9		6				
Terebellidae	P	1179												
Lanice conchilega	P	1195											3	
Polycirrus medusa	P	1242		4							1			
CRUSTACEA	R	1												
AMPHIPODA	S	97												
Oedicerotidae	S	118												
Synchelidium maculatum	S	138									1		1	
Amphilochidae	S	152												
Amphilochus neapolitanus	S	159								1				
Leucothoidae	S	175												
Leucothoe lilljeborgi	S	178			1			1					2	1
Phoxocephalidae	S	252												
Harpinia sp.	S	253							1					
Harpinina serrata	S	258	3	2				4	4	7			7	4
Lysianassidae	S	271												
Orchomenella nana	S	321				1								
Synopioidea	S	348												
Argissa hamatipes	S	360	2	1		1				2				1
Ampeliscidae	S	422												
Ampelisca brevicornis	S	427	8	7	1		9	2	6	9	6		2	3
Ampelisca spinipes	S	438	7	3	1	3	5	1	3	4	2		2	2
Ampelisca tenuicornis	S	440	1		3	1				1	1			
Ampelisca typica	S	442			1									
Pontoporeiidae	S	40												
Bathyporeia tenuipes	S	459	1							1				

Station			1A	1B	2A	2B	3A	3B	4A	4B	5A	5B	6A	6B
Melitidae	S	495												
Abludomelita obtusata	S	498						1						
Cheirocratus sp.	S	503	1										1	
Melita sp.	S	522		1										
Melita dentata	S	523			2									
Isaeidae	S	537												
Photis longicaudata	S	552	2	1		35	1		2	5	2		2	
Caprellidae	S	639												
Pariambus typicus	S	651								1			1	
Phtisicidae	S	655												
Phtisica marina	S	657					1			2			3	9
ISOPODA	S	790												
Gnathiidae	S	792												
Gnathia oxyuraea	S	796					1							
Paragnathia formica	S	799											1	
Arcturidae	S	948												
Arcturella dilatata	S	951											2	1
TANAIDACEA	S	1099												
Anarthruidae	S	1115												
Tanaopsis graciloides	S	1142	1		3					3				
CUMACEA	S	1183												
Bodotriidae	S	1184												
Iphinoe serrata	S	1201	1	1		2		2	2	3	5		3	6
Leuconiidae	S	1204												
Eudorella truncatula	S	1208	1			2			1	1	1		3	
Pseudocumatidae	S	1231												
Pseudocuma longicornis	S	1236											1	1
Diastylidae	S	1244												

Station			**1A**	**1B**	**2A**	**2B**	**3A**	**3B**	**4A**	**4B**	**5A**	**5B**	**6A**	**6B**
Diastylis bradyi	S	1248								1	1			
DECAPODA	S	1276												
Processidae	S	1361												
Processa sp.	S	1362		1							2		2	1
Processa nouveli holthuisi	S	1367	1		2			1	3				2	
Crangonidae	S	1380												
Philocheras trispinosus	S	1390							1					
Corystidae	S	1550												
Corystes cassivelaunus	S	1552		1			1							
MOLLUSCA	W	1												
CHAETODERMATIDA	W	3												
Chaetodermatidae	W	7												
Chaetoderma nitidulum	W	9						1						
GASTROPODA	W	88												
MESOGASTROPODA	W	256												
Eulimidae	W	599												
Eulima glabra	W	604					2		1		2			
NEOGASTROPODA	W	670												
CEPHALASPIDEA	W	1002												
Cylichnidae	W	1024												
Cylichna cylindracea	W	1028	2	4	1	2		1	4	4			3	2
Phylinidae	W	1035												
Philine aperta	W	1038	4		3	3								2
PELECYPODA	W	1560												
NUCULOIDA	W	1561												
Nuculidae	W	1563												
Nucula sp.	W	1565				3					3			

Station			**1A**	**1B**	**2A**	**2B**	**3A**	**3B**	**4A**	**4B**	**5A**	**5B**	**6A**	**6B**
Nucula nitidosa	W	1569		1	1									
VENEROIDA	W	1815												
Lucinidae	W	1817												
Myrtea spinifera	W	1827									3		2	2
Thyasiridae	W	1833												
Thyasira flexuosa	W	1837	11	9	5	13		6	7	9	12	9	9	3
Montacutidae	W	1888												
Tellimya ferruginosa	W	1902		2				2	2	3	2			
Mysella bidentata	W	1906								8				2
Mactridae	W	1967												
Spisula subtruncata	W	1978	2											
Pharidae	W	1995												
Phaxas pellucidus	W	2006	10		2	4		2	5	7	9	7	7	8
Psammobiidae	W	2042												
Semelidae	W	2057												
Abra alba	W	2059				1					1	2		
Abra nitida	W	2061											1	
Veneridae	W	2086												
Chamelea striatula	W					1				2		2	12	
Timoclea ovata	W	2104						1						
Dosinia lupinus	W	2128											1	
MYOIDA	W	2140												
Corbulidae	W	2153												
Corbula gibba	W	2157	2		2	1			4	3				
PHORONIDA	ZA	1												
Phoronidae	ZA	2												
Phoronis sp.	ZA	3	3	1		2	2				2			
ECHINODERMATA	ZB	1												

Station			1A	1B	2A	2B	3A	3B	4A	4B	5A	5B	6A	6B
OPHIUROIDEA	ZB	105												
OPHIURIDA	ZB	121												
Amphiuridae	ZB	148												
Amphiura filiformis	ZB	154	3	2	5	4	2			2	1	2		
Ophiuridae	ZB	165												
Ophiura albida	ZB	168			5	1	1							
ECHINOIDEA	ZB	181												
ECHINOIDA	ZB	190												
Echinidae	ZB	194												
Echinocyamus pusillus	ZB	212				1								
SPATANGOIDA	ZB	213												
Loveniidae	ZB	221												
Echinocardium cordatum	ZB	223	2	3	3	3	2		2	2	1	2	2	
HOLOTHURIOIDEA	ZB	229												
DENDROCHIROTIDA	ZB	249												
Cucumariidae	ZB	266												
Leptopentacta elongata	ZB	280	2		6	3	1				1	1	1	
APODIDA	ZB	289												
Synaptidae	ZB	290												
Leptosynapta bergensis	ZB	292	2	2	1	2	2		2	1	1	2		
Labidoplax digitata	ZB	300											1	

Appendix 2

Underwater Photographs

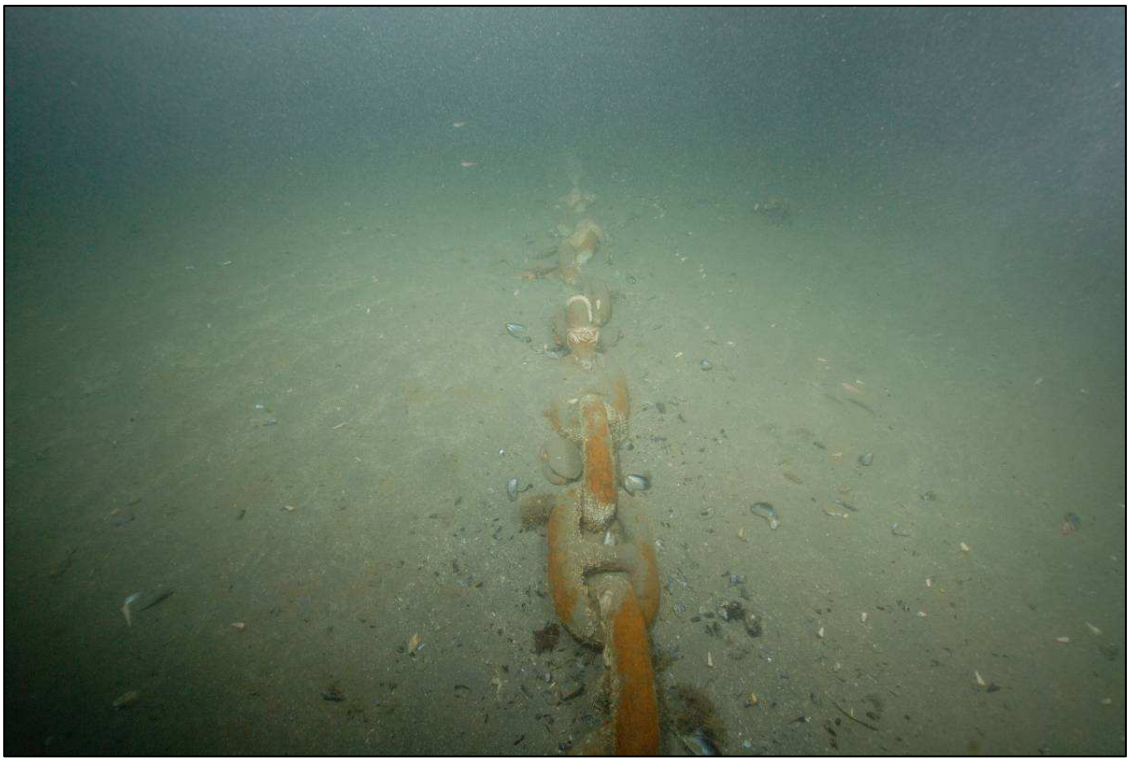

Figure 1: Anchor chain on mud at ocean energy device site

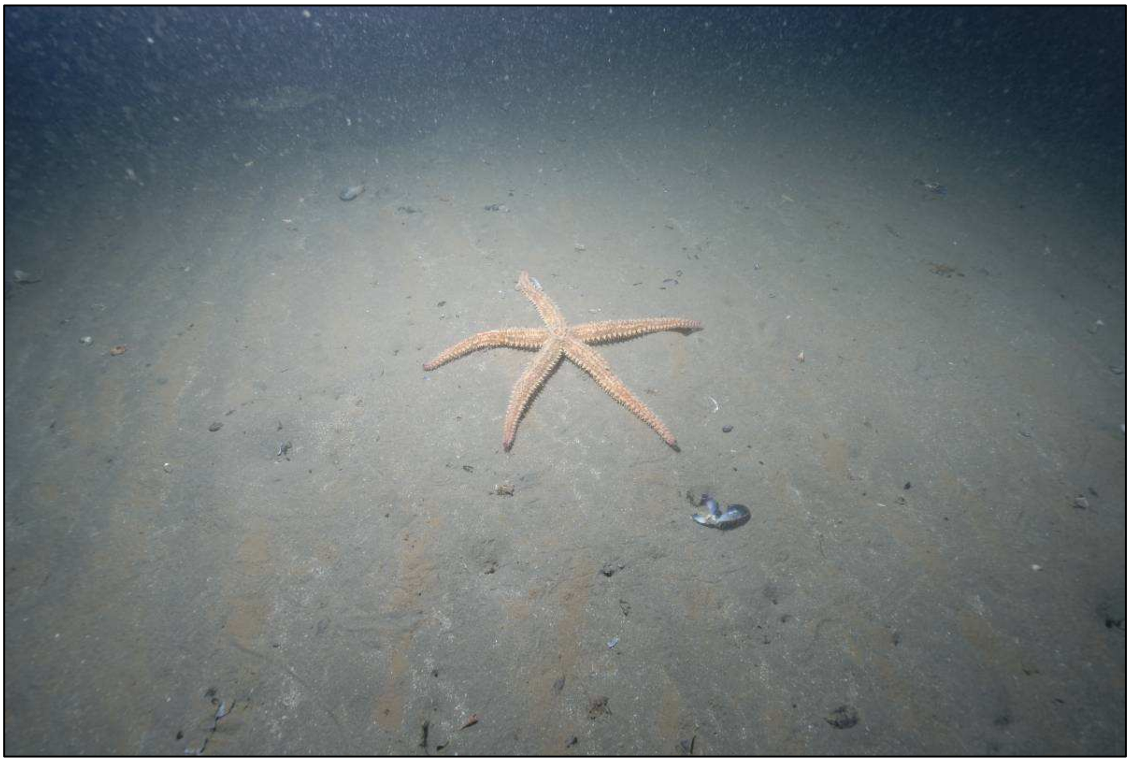

Figure 2: *Marthasterias glacialis* on muddy sand. Note presence of mussel shells

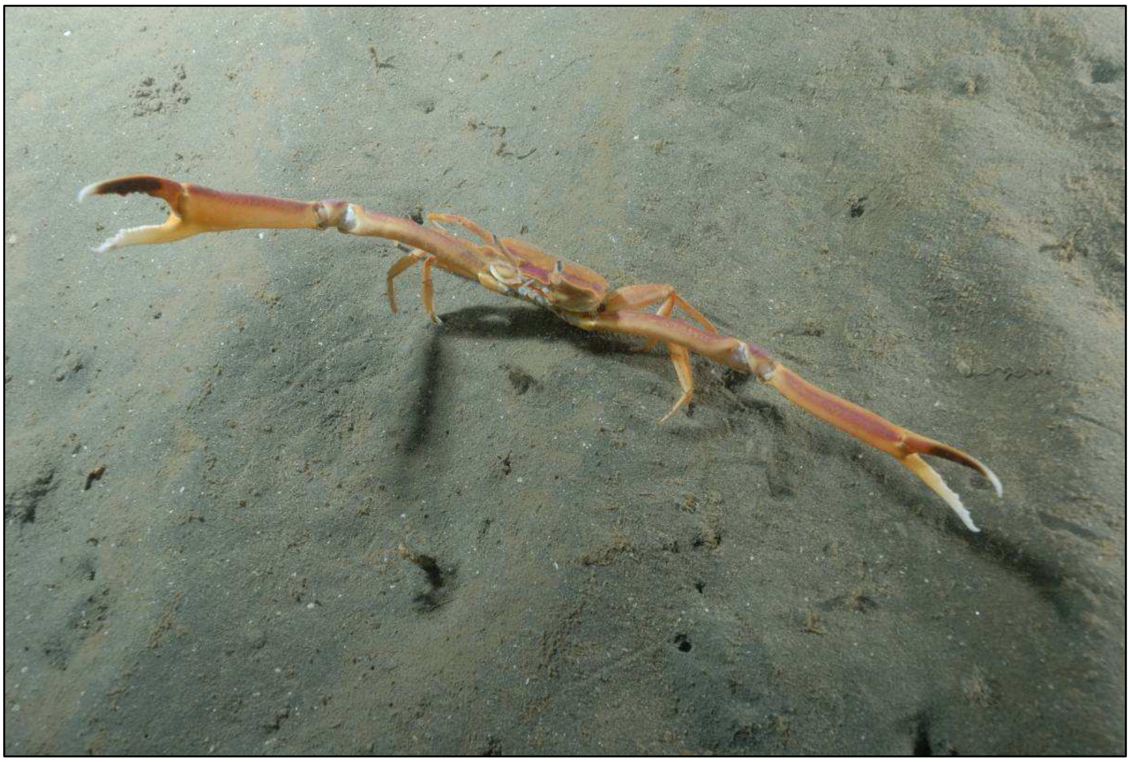

Figure 3: *Goneplex rhomboides* at ocean energy device site

Figure 4: Anchor chain with epifauna at ocean energy device site

Appendix 3

Sediment Profile Images

Figure 1: SPI image at ocean energy device site showing well oxygenated sediment with biologically generated surface boundary roughness.

Figure 2: SPI image showing a surface boundary which is not well defined