Project Title/ Location	Beatrice Offshore Wind Farm
Project Reference Number	LF000005-REP-585
Date:	14/12/2015

Beatrice Offshore Wind Farm

OWF Pre-construction Benthic Survey Report

Rev	Prepared By	Sign Off	Checked By	Sign Off	Approved By	Sign Off	Date of Issue
1	APEM						26/08/2015
2	APEM						1/10/2015
3	Søren Pears Tim Worsfold Marc Hubble	[Redacted]	Nick Brockie Anna Prior	[Redacted]	Lis Royle	[Redacted]	

Table of Contents

List of Tables

List of Figures

Executive summary

As part of a pre-construction sampling programme to partially discharge Condition 27 of the Section 36 consent, APEM Ltd was commissioned by Beatrice Offshore Windfarm Ltd (BOWL) to undertake a benthic grab survey at the Beatrice Offshore Wind Farm (OWF) site in June 2015.

Twelve grab stations were selected to provide representative coverage of the '*Moerella* spp. with venerid bivalves in infralittoral gravelly sand' (SS.SCS.ICS.MoeVen) biotope that was identified as being of high importance in the Beatrice OWF Environmental Statement and Supplementary Environmental Information Statement and is representative of the 'Tide-swept coarse sands with burrowing bivalves' Scottish Priority Marine Feature (PMF). Ten of the stations were located within the OWF boundary, with two reference stations located to the north east of the OWF. All stations corresponded to locations that were sampled during the Environmental Impact Assessment site characterisation study undertaken in 2010 (CMACS 2011). At each of the twelve locations, three replicate samples were acquired using a 0.1 m^2 Hamon grab. A 500 ml subsample was removed from each replicate for particle size analysis (PSA) and the remaining sediment was preserved in formal saline and used for macrobiota analysis.

PSA indicated sediment mainly comprised sand across the OWF site with some within-station and between station variation in sediment composition. There was very little mud and a few stations had small quantities of coarser material. Under the British Geological Survey (BGS) modified Folk classification (Folk 1954, Long 2006), all stations within the OWF site were categorised as either Sand, Slightly gravelly sand or Gravelly sand. Overall, these results corresponded closely with those of the 2010 EIA characterisation survey (CMACS 2011). At the reference stations, there was a slightly higher percentage of gravel in the sediment than at most of the OWF sites in both 2010 and from the current survey, with sediments primarily classed as Slightly gravelly sand or Gravelly sand. There is some variability in the sediment type characteristic of the target MoeVen biotope, which can be found in medium to coarse sand and gravelly sand (Connor *et al* 2004); therefore subtle changes in sediment type were only a partial consideration when describing biotopes present based on the results of the current survey.

There was a biologically diverse community across the survey area with a total of 231 taxa recorded across the twelve stations. Trends in both abundance and taxon richness across stations were found to be similar and were consistent across the OWF site and reference stations. The only recorded species with a conservation importance designation was the ocean quahog *Arctica islandica*, which is a bivalve listed as a Scottish PMF and is also on the OSPAR list of threatened and/or declining species and habitats (OSPAR 2008); nine individuals, all juveniles, were recorded across the survey. This is consistent with the 2010 EIA characterisation survey. No invasive non-native species were recorded. When higher abundances of invertebrate individuals and higher numbers of taxa were recorded at stations within the OWF site and at the reference stations, it was typically due to the contribution of polychaete worms and molluscs which was also the case for the 2010 EIA characterisation survey (CMACS 2011).

Across the survey, a total of 2,786 invertebrate individuals were recorded, post-truncation. Within the OWF site, abundance appeared to be slightly greater at the more northern stations, although there was no clear relationship with sediment type. There was, however,

some evidence of replicate-specific influence of sediment type, for example the highest abundance of invertebrates was recorded at Station G3, just south of the centre of the OWF site (1143 ± 693 individuals per m^2), primarily from one of the replicates with a gravel content of 22.3%, which was far higher than any of the other replicates across the survey. Across the remaining stations in the OWF site, mean abundance at stations varied between 320 ± 27 and 890 ± 387 individuals per m^2.

The most abundant species across the OWF site was the mollusc *Cochlodesma praetenue* with other abundant molluscs including *Abra prismatica*, *Moerella pygmaea* and *Spisula* spp. Other taxa found in high abundances were the pea sea urchin *Echinocyamus pusillus* and juvenile brittlestars (Ophiuridae). The most abundant polychaetes were *Spiophanes bombyx*, *Ophelia borealis*, and *Polycirrus* spp. When compared with the results of the 2010 EIA characterisation survey (CMACS 2011), there has been a decrease in the numbers of key polychaete taxa (e.g. *S. bombyx*), an increase in the numbers of the echinoderm *E. pusillus* and the key mollusc taxa *A. prismatica* and *C. praetenue*, and a slight decrease in the abundance of the mollusc *M. pygmaea*.

At one of the reference stations (G11), post-truncation mean abundance per m^2 was 1193 ± 240 individuals, which was greater than at any of the OWF sites, while at the other reference station (G12) mean abundance was far lower with 577 ± 250 individuals per m^2, which was towards the lower boundary of abundances recorded in the OWF site. Mean gravel content at these stations was similar, suggesting that factors other than sediment type were influencing invertebrate abundance. The most abundant taxa across the reference stations were juvenile brittlestars (Ophiuridae), followed by *A. prismatica* and *E. pusillus*. The most abundant polychaetes were *Owenia* spp., *Aricidea cerrutii* and *Glycera lapidum* agg. The decrease in polychaete numbers and increase in molluscs noted for the OWF sites was also apparent at the reference stations, especially for *A. prismatica*, which had a mean abundance of 112 ± 50 individuals per m^2 during the current survey, but was not recorded at the reference stations in 2010.

Three biotopes were allocated to replicates from this pre-construction survey. The biotope SS.SCS.ICS.MoeVen, which was recorded at all of the stations in the 2010 EIA characterisation survey (CMACS 2011), was allocated to all replicates at three of the stations across the OWF site (G3, 5 and 10) and was not assigned to the reference stations. The dominant biotope recorded at all of the other stations was '*Echinocyamus pusillus*, *Ophelia borealis* and *Abra prismatica* in circalittoral fine sand' (SS.SSa.CFiSa.EpusOborApri), for which the main characterising species were *E. pusillus* and *A. prismatica*. One replicate was assigned the biotope *Abra prismatica*, *Bathyporeia elegans* and polychaetes in circalittoral fine sand (SS.SSa.CFiSa.ApriBatPo). The biotopes SS.SCS.ICS.MoeVen, SS.SSa.CFiSa.EpusOborApri and SS.SSa.CFiSa.ApriBatPo are all component biotopes of Scottish PMFs: 'Tide-swept coarse sands with burrowing bivalves' for MoeVen, 'Offshore subtidal sands and gravels' for the other two biotopes (SNH 2014).

The change in biotope allocation at some of the OWF site stations, and to the reference stations, was probably due to a combination of small changes in the relative abundances of the taxa characteristic of the assigned biotopes (in particular increases in the abundance of *A. prismatica*), and to subtleties in the definitions of the biotopes, which would allow for differences in interpretation between analysts. The variations in taxon abundance are likely to be within the range of natural variation: sediment composition data suggest the differences are not associated with a significant habitat change. None of the communities in either the 2010 or 2015 surveys fitted the classification perfectly for the assigned biotopes and there is potential for transition between these biotopes, with subtle changes in the abundance of key taxa.

1 Introduction

1.1 Scope of Work

1.1.1 Project background

This report presents the results of a pre-construction benthic grab survey undertaken by APEM Ltd at the Beatrice Offshore Wind Farm (OWF) site. The survey was conducted to partially discharge Condition 27 of the Beatrice OWF Section 36 consent which states that the Project Environmental Monitoring Programme (PEMP) must cover, but not be limited to:

"Pre-construction, construction (if considered appropriate by the Scottish Ministers) and post-construction monitoring surveys as relevant in terms of the Environmental Statement and any subsequent surveys for….[6] benthic communities; and [7) (Seabed scour and) local sediment deposition."

The work forms part of the benthic monitoring strategy for the Beatrice OWF and Offshore Transmission Works (OfTW) cable corridor for Beatrice Offshore Windfarm Ltd (BOWL). The wider survey included investigation of areas of potential Annex I habitat (EC Habitats Directive 92/43/EEC) and targets of potential archaeological importance. Results of the Annex I habitat assessment and archaeological survey are provided in separate reports (BOWL Ref: LF000005-REP-584 and LF000005-REP-575, respectively). The scope of the pre-construction survey was presented and discussed at a technical consultation meeting between BOWL, Marine Scotland, Scottish Natural Heritage (SNH) and the Joint Nature Conservation Committee (JNCC) on 19th January 2015. The survey scope was subsequently discussed at a meeting of the Moray Firth Regional Advisory Group (MFRAG) on 11th May 2015 and thereafter agreed with Marine Scotland Science (MSS) prior to survey. The sample locations were confirmed with MSS via e-mail on 18th June 2015.

1.1.2 Survey Objectives

The objective of the benthic grab survey was to acquire samples from the marine benthic environment to help characterise benthic macrobiota communities within the OWF site and at selected reference stations. In particular, the aim was to provide a pre-construction baseline for areas that had been assigned the biotope '*Moerella* spp. with venerid bivalves in infralittoral gravelly sand' (SS.SCS.ICS.MoeVen: referred to hereon as the MoeVen biotope) following the Environmental Impact Assessment (EIA) benthic ecology site characterisation study undertaken in 2010 (CMACS 2011). The MoeVen biotope is a component biotope of the Scottish Priority Marine Feature (PMF) 'Tide-swept coarse sands with burrowing bivalves' (Scottish Natural Heritage 2014). This pre-construction baseline data set will enable subsequent comparison with post-construction survey results to test the predictions of the project Environmental Statement (ES) and Supplementary Environmental Information Statement (SEIS), and the associated degree of certainty in these predictions. As part of the assessment, any species of potential conservation importance or environmental concern, such as those on the International Union for the Conservation of Nature (IUCN) Red List of Globally Threatened Species (Bratton 1991), those under the OSPAR (2008) list of threatened and/or declining species and habitats, invasive non-native species (INNS) or Scottish Priority Marine Features (PMFs) were noted (SNH 2014).

1.1.3 Survey Design

Sampling was conducted at 12 grab stations (Figure 1) to provide representative coverage of the MoeVen biotope. This biotope is representative of the 'Tide-swept coarse sands with burrowing bivalves' PMF and was identified as being of high importance in the Beatrice OWF ES and SEIS. Ten of the stations were located within the OWF boundary, with two reference stations located to the north east of the OWF. All stations corresponded to locations that were sampled during the EIA site characterisation study undertaken by CMACS in 2010 (CMACS 2011). Target and actual sampling locations are presented in Appendix 1.

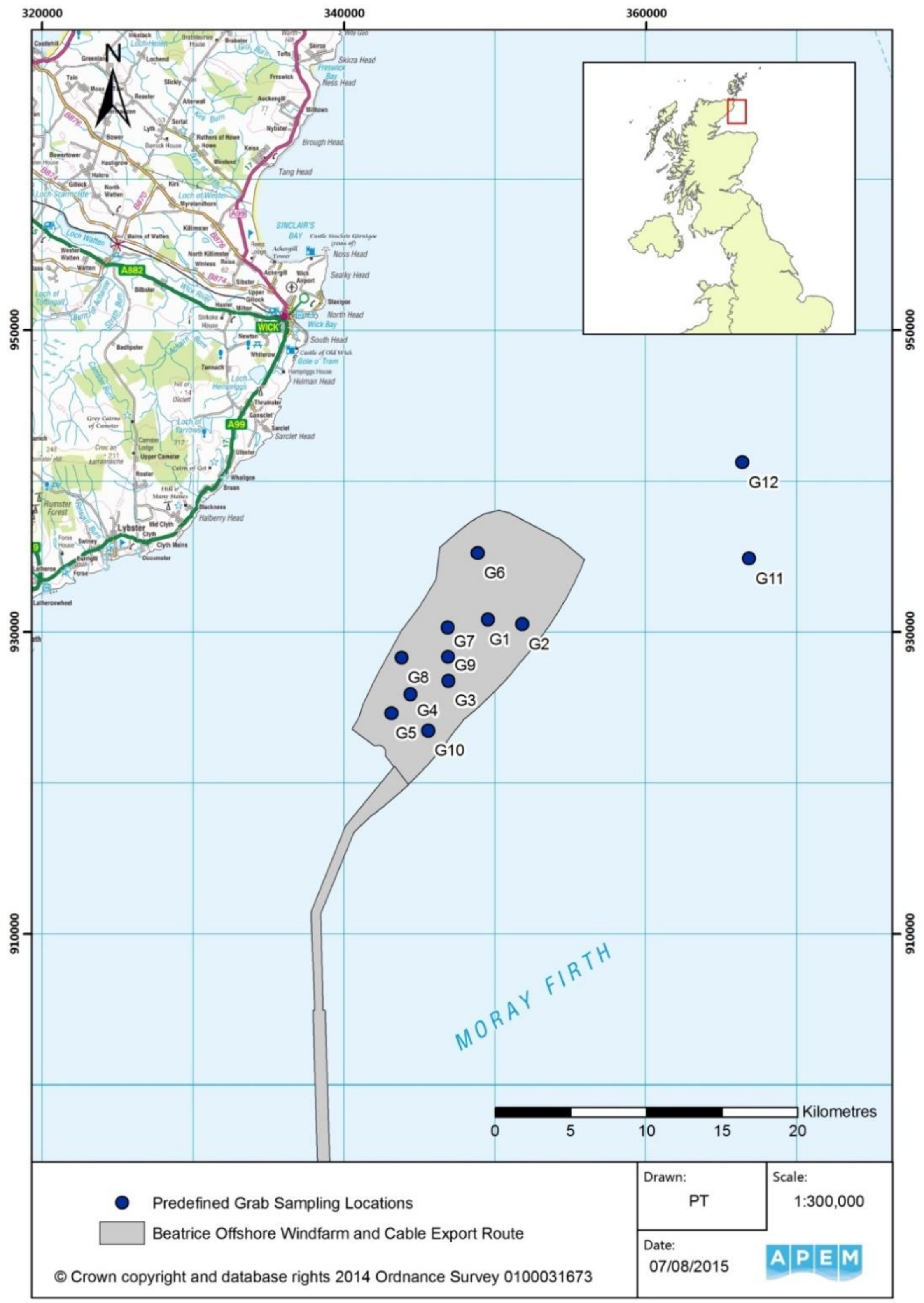

Figure 1: Sample station locations for benthic grab sampling.

2 Methodology

2.1 Survey Vessel and Permissions

Survey work was undertaken aboard the Moray First Marine vessel Coral Wind, a 14 m Category 2 vessel. The vessel was deployed from Lossiemouth and following the survey berthed at Lybster.

All survey permissions were obtained by Beatrice Offshore Windfarm Ltd (BOWL) prior to the survey commencing.

2.2 Grab Sampling

All grab sampling was completed on 23rd June 2015. Grab samples were collected using a 0.1 m^2 Hamon grab, with three replicate samples taken at each station. A 500 ml subsample of sediment was removed from each grab for particle size analysis (PSA), and the remaining sediment was then sieved over a 1.0 mm mesh and preserved for biological analysis.

A minimum of 5 litres of sediment was defined as an acceptable sample size. If this criterion was not met then a further four attempts were made at the same location, followed by three attempts at a different location 50 m from the original target. If the final attempt was also unacceptable, then whichever attempts yielded the largest volumes of sediment were kept as qualitative as opposed to quantitative samples.

For each grab attempt, the following information was recorded on a survey logsheet:

- Station and attempt number;
- Co-ordinates at which sample was taken;
- Water depth;
- Volume of the sample;
- Sample description (visual assessment, with additional notes on smell etc.);
- Time the grab reached the seabed;
- Any obvious or notable biota (e.g. Annex II species); and
- Reference numbers for photographs taken of the pre-sieved and post-sieved sediment.

For each grab sampling attempt, the following steps were followed in accordance with the protocols established by Cooper & Mason (2014):

1) Excess water was poured off from the sample over the sieve table;
2) Sample was photographed (with label);
3) Sample volume was measured by emptying the sample into a standardised container and measuring the depth of sediment using a steel ruler and comparing this to a pre-prepared depth-volume conversion table;
4) Sediment sub-sample was taken for PSA;

5) Sample was washed and sieved on the sieve table;
6) The material retained on the sieve table mesh was photographed; and
7) The sieved sample was transferred to a bucket and labelled internally and externally with the project number, date, station and sample number.

Upon return to port, all samples were retained in buckets and preserved in 4% formosaline solution.

2.3 Laboratory Processing

2.3.1 Macrobiota

To standardise the sizes of organisms recorded, and to separate preservative from the biota, all samples were washed over a 1 mm sieve in a fume cupboard. All biota retained in the sieve were then extracted, identified and enumerated, where applicable.

Taxa were identified to the lowest possible practicable taxonomic level using the appropriate taxonomic literature. For certain taxonomic groups (e.g. nemerteans, nematodes, and certain oligochaetes), higher taxonomic levels were used due to the widely acknowledged lack of appropriate identification tools for these groups. The National Marine Biological Analytical Quality Control (NMBAQC) Scheme has produced a Taxonomic Discrimination Protocol (TDP) (Worsfold & Hall 2010) which gives guidance on the most appropriate level to which different marine taxa should be identified, and this guidance was adhered to for the laboratory analysis. Where required, specimens were also compared with material maintained within the laboratory reference collection. Nomenclature followed the World Register of Marine Species (WoRMS), except where more recent revisions were known to supersede WoRMS.

All samples were subject to internal quality assurance procedures and, following analysis, 10% of samples were subject to formal Analytical Quality Control (AQC). For archiving purposes, all samples were stored in 70% industrial denatured alcohol (IDA) solution.

2.3.2 Biomass Estimations

The estimation of biomass was undertaken according to APEM's standard operating procedure and the NMBAQC Scheme guidance and TDP (Worsfold & Hall 2010).

APEM use a non-destructive biomass procedure that is fully compliant with the methods outlined in the Clean Seas Environmental Monitoring Programme (CSEMP) Green Book (CSEMP, 2012). Animals were blotted dry before transfer to a tared analytical balance. Biomass values were recorded as blotted wet-weight, +/- 0.0001g. Taxa weighing less than 0.0001g were given a nominal weight of 0.0001g. Barnacles, ascidians, cnidarians and non-countable taxa were not weighed.

Faunal biomass analysis was undertaken at recorded taxon level and included juveniles. Biomass (g^{-1} m^{2}) was then calculated on a per station basis.

To allow direct comparison with values in the 2010 site characterisation report (CMACS 2011), biomass values for each taxon were converted to Ash Free Dry Weight (AFDW) using the same conversion factors based on major taxonomic groups (Polychaeta, Oligochaeta, Crustacea, Mollusca, Echinodermata and 'Others') used in CMACS (2011) which were adapted from Ricciardi & Bourget (1998).

2.3.3 Particle Size Analysis

Sub-sampling and PSA was performed in accordance with NMBAQC Best Practice Guidance (Mason 2011), with the modification that the wet separation was performed at 2 mm rather than 1 mm, to determine the 'gravel' to 'sand and mud' proportions by weight. A combination of dry sieving and laser diffraction was used depending upon the characteristics of the sediment.

2.4 Data Analysis

2.4.1 Macrobiota

Truncation of the macrobiota data was undertaken before calculation of univariate and multivariate statistics. Juveniles were combined with adults of the same recorded taxon name for calculation of numbers of taxa and epitokes were also combined for the same taxon name.

For analyses based on numbers of individuals, non-countable taxa, copepods, fish and fragments of individuals were also omitted from analysis.

In accordance with EN ISO16665:2014 guidelines, an initial analysis was carried out with juveniles recorded separately from adults. Juveniles were identified to the lowest practicable taxonomic level, following APEM's taxonomic discrimination protocol. To determine the influence of juveniles within the samples, the mean abundance per 0.1 m^2 for all taxa at all stations both with and without juvenile taxa was compared in Primer v6 using a RELATE analysis. The results of the analysis informed whether the data set was to be analysed inclusive of juveniles, or if analysis of a separate adult-only data set was also to be required, in line with OSPAR (2004) guidance. However, as there is no inter-laboratory standard for definition of juveniles, the distinction is arbitrary.

The results of the RELATE analysis indicated that the full and adult-only data sets were over 97% similar. As such, all analyses of the macrobiota data was conducted on the full data set including juveniles. Where juveniles and adults of the same taxon were recorded, these were combined as a single entry for subsequent analysis of abundances. As a result of this process, six mollusc taxa (*Chamelea striatula, Clausinella fasciata, Cochlodesma praetenue*, *Gari tellinella, Gari fervensis and Spisula elliptica*) were combined with their respective juvenile entries.

2.4.2 Univariate analysis

Univariate community analyses were undertaken using the PRIMER (version 6) software package. Biological diversity within a community was assessed based on taxon richness (total number of taxa present) and evenness (considers relative abundances of different taxa). The following metrics were calculated:

- **Shannon-Wiener Diversity Index (*H'*(log$_e$):** This is a widely used measure of diversity accounting for both the number of taxa present and the evenness of distribution of the taxa (Clarke & Warwick 2006).

- **Margalef's species richness (*d*):** This is a measure of the number of species present for a given number of individuals.

- **Pielou's Evenness Index (*J'*):** This represents the uniformity in distribution of individuals spread between species in a sample. High values indicate more evenness or more uniform distribution of individuals. The output range is from 0 to 1.

- **Simpson's Dominance Index (1-λ):** This is a dominance index derived from the probability of picking two individuals from a community at random that are from the same species. Simpson's dominance index ranges from 0 to 1 with lower values representing a more diverse community without dominant taxa.

Where mean values have been calculated per station, the standard deviation has been provided.

2.4.3 Multivariate analysis

Macrofaunal data were subjected to multivariate analysis using the PRIMER (version 6) software package (Clarke & Warwick 2006).

Multivariate analyses were computed from resemblance or similarity matrices. The particle size data resemblance matrix was calculated using Euclidean Distance following normalisation. For the macrofaunal data set, the Bray-Curtis measure of similarity was used following a square root transformation of the data to reduce the influence of highly abundant or dominant species.

Cluster Analysis

CLUSTER analysis was utilised to provide a visual representation of sample similarity in the form of a dendrogram. CLUSTER analysis was conducted in conjunction with a SIMPROF (similarity profile) test to determine whether groups of samples were statistically indistinguishable at the 5% significance level, or whether any trends in groupings were apparent. Black lines on the dendrogram indicate statistical distinctions between sampling stations, whilst red lines indicate that the samples were statistically inseparable.

Ordination Analyses using non-Metric Multidimensional Scaling

Non-metric multidimensional scaling (MDS) is a type of ordination method which creates a 2- or 3-dimensional 'map' or plot of the samples from the Primer resemblance matrix. The plot generated is a representation of the dissimilarity of the samples (or replicates), with distances between the replicates indicating the extent of the dissimilarity. For example, replicates that are more dissimilar are further apart on the MDS plot. No axes are present on the MDS plots as the scales and orientations of the plots are arbitrary in nature.

Each MDS plot provides a stress value which is a broadscale indication of the usefulness of plots, with a general guide indicated below (Clarke & Warwick, 2006):

<0.05	Almost perfect representation of rank similarities;
0.05 to <0.1	Good representation;
0.1 to <0.2	Still useful;
0.2 to <0.3	Should be treated with caution;
>0.3	Little better than random points.

SIMPER

Where differences between groups of samples were found, SIMPER analysis (in Primer v6) was used to determine which taxa were principally responsible for the differences between the statistically distinct groups of stations.

RELATE & BIO-ENV

The RELATE function of PRIMER was utilised to find out whether there was a correlation between faunal assemblages and sediment composition. The RELATE routine uses permutation tests to estimate the likelihood of the biological and environmental resemblance matrices sharing a similar multivariate pattern. It uses a rank correlation coefficient to measure the agreement between all the elements in the similarity matrices. To determine which sediment particle sizes correlated most strongly with the patterns observed within the faunal communities, the data were tested using the BIO-ENV routine.

2.4.4 Particle Size Distribution

The particle size data from all survey replicates were combined as consistent size fractions and entered into GRADISTAT (Blott & Pye 2001) to produce sediment classifications, following Wentworth (1922) (Table 1) and Folk (1954) (Figure 2). To enable comparison with the outputs of the 2010 EIA characterisation report (CMACS 2011), GRADISTAT outputs were converted to the British Geological Survey (BGS) modified Folk categories based on Long (2006). Summary statistics were also calculated including mean (Phi), sorting (
Table 2), skewness and kurtosis (following Blott & Pye 2001).

2.4.5 Biotope allocation

The cluster analysis, SIMPROF and SIMPER results, in combination with the invertebrate count data and PSA results, were used to allocate biotopes to each replicate sample, following JNCC's National Marine Habitat Classification for Britain and Ireland: Version 04.05 (Connor *et al*. 2004).

Table 1: Sediment classifications based on Wentworth (1922).

Aperture in microns	Phi Aperture	Sediment Description
≥16000 to 2000	≤-4 to -2	Pebbles
<4000 to 2000	>-2 to -1	Granules
<2000 to 1000	>-1 to 0	Very Coarse Sand
<1000 to 500	>0 to 1	Coarse Sand
<500 to 250	>1 to 2	Medium Sand
<250 to 125	>2 to 3	Fine Sand
<125 to 63	>3 to 4	Very Fine Sand
<63 to 44	>4 to 4.5	Silt (Mud)

Table 2: Sediment sorting categories based on Wentworth (1922).

Sorting Coefficient (Graphical Standard Deviation)	Sediment Sorting Categories
0 < 0.35	Very well sorted
0.35 < 0.50	Well sorted
0.50 < 0.71	Moderately well sorted
0.71 < 1.00	Moderately sorted
1.00 < 2.00	Poorly sorted
2.00 < 4.00	Very poorly sorted
4.00	Extremely poorly sorted

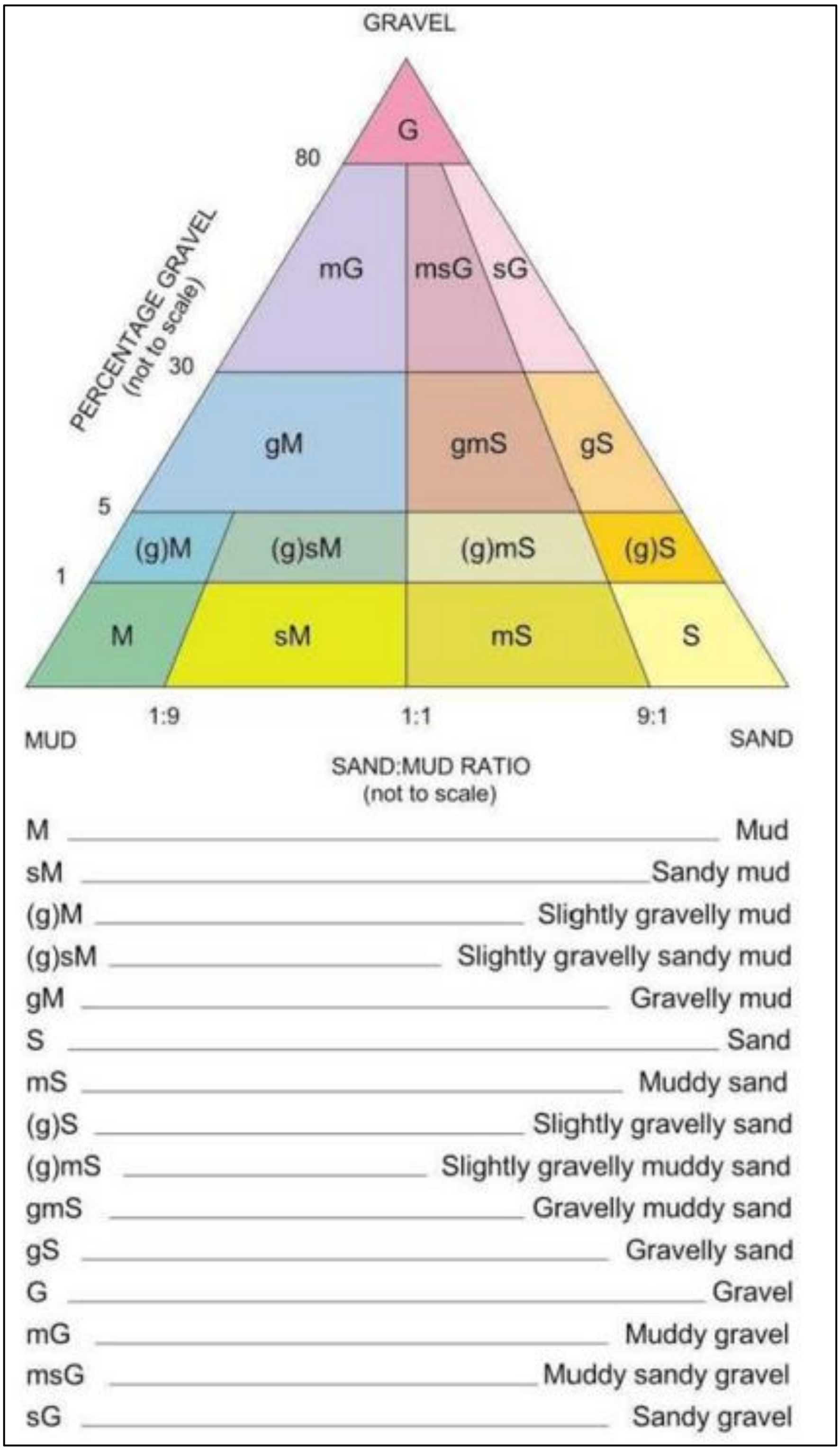

Figure 2: Folk sediment classification pyramid (Folk, 1954).

3 Results

3.1 Particle Size Analysis

Details of the PSA grab samples are presented in the field log sheets in Appendix 2. Raw PSA data are presented in Appendix 3.

3.1.1 OWF site

Overall, sediment type was similar across the survey area and was predominantly sandy. Mean particle size across the majority of samples was <400 µm, with the lowest mean value being 241 µm (replicate G1C) and only one sample (G3B, towards the centre of the OWF site) had a mean particle size above 1000 µm. Sediments within most samples typically had very high percentages of sand (i.e. particle size >63 µm to 2 mm), which was often >95%. However, the results indicated a small amount of within-station variability in sediment composition, and there were some slight differences in sediment composition between stations (Table 3, Figure 3).

Within all replicates, mud represented <2% of sediment composition (Table 3). Gravel also comprised very low percentages of the overall sediment composition, but gravel content was slightly higher at replicates B and C of Station G10 in the southern section of the site (5 and 8.5%, respectively) and replicate B at Station G7, located just north of the centre of the OWF (mean 4.4%). The highest percentage of gravel was recorded in sediment from replicate G3B (22.3%), located just south of centre of the OWF site (compared to 0.6% and 2.5% in the G3A and C replicates, respectively) (Table 3, Figure 3).

Replicates across the OWF site were generally classified as Medium sand under the Wentworth sediment classification scale and were often moderately sorted to moderately well sorted. Due to the gravel content indicated above, however, all replicates at Station G10 were classified as Coarse sand; G7B was classified as Coarse sand and G3B was classified as Very coarse sand (and poorly sorted), (Table 3).

Under the BGS modified Folk classification system, all replicates at Stations G1, G4, G5 and G6 (distributed across the OWF) were classed as Sand, with other stations comprising mainly Sand with some Slightly gravelly sand and/or Gravelly sand (Table 3).

3.1.2 Reference stations

In common with the OWF site results, replicates at the two reference stations, G11 and G12, located 10 to 15 km north east of the OWF site also had a very high percentage of sand (mean of 93.7 ± 3.5% at G11, and 95.6 ± 3.0% at G12), (Table 3). The mud content in replicate G11C (5.2%) was far higher than within other replicates across the OWF site and reference stations, and mean gravel content across replicates was found to be slightly higher at Stations G11 and Station G12 than at the majority of stations in the OWF (Table 3).

Under the Wentworth scale, sediment at G11 and G12 was primarily classed as Medium sand with Coarse sand in one of the replicates at each Station. Under the BGS modified Folk categories, Station G11 was a mix of Sand, Slightly gravelly sand and Gravelly sand (with different categories assigned to different replicates), while Station G12 was a mix of Sand and Slightly gravelly sand (Table 3).

Table 3: Summary of Particle Size Analysis data. SD = Standard deviation.

Station	Sample	Mean (µm)	Gravel (%)	Sand (%)	Mud (%)	Wentworth *	Folk **	Sorting
G1	A	273.5	0.8	97.7	1.5	mS	S	Moderately Well
G1	B	273.6	0.7	98.0	1.3	mS	S	Moderately Well
G1	C	240.7	0.0	98.4	1.6	fS	S	Moderately Well
Mean		**262.6**	**0.5**	**98.1**	**1.5**			
SD		**19.0**	**0.4**	**0.4**	**0.1**			
G2	A	373.0	1.5	97.6	0.9	mS	(g)S	Moderate
G2	B	331.5	0.3	96.6	3.1	mS	S	Moderate
G2	C	286.1	0.0	98.9	1.1	mS	S	Moderately Well
Mean		**330.2**	**0.6**	**97.7**	**1.7**			
SD		**43.5**	**0.8**	**1.2**	**1.2**			
G3	A	418.9	0.6	98.7	0.7	mS	S	Moderate
G3	B	1007.9	22.3	76.1	1.6	vcS	gS	Poor
G3	C	441.5	2.5	96.6	0.9	mS	(g)S	Moderate
Mean		**622.8**	**8.5**	**90.5**	**1.1**			
SD		**333.7**	**12.0**	**12.5**	**0.5**			
G4	A	353.0	0.6	98.3	1.2	mS	S	Moderate
G4	B	311.7	0.0	100.0	0.0	mS	S	Moderately Well
G4	C	308.2	0.0	98.9	1.1	mS	S	Moderately Well
Mean		**324.3**	**0.2**	**99.0**	**0.8**			
SD		**24.9**	**0.3**	**0.9**	**0.7**			
G5	A	351.8	0.3	99.7	0.0	mS	S	Moderately Well
G5	B	410.4	0.6	99.4	0.0	mS	S	Moderate
G5	C	323.5	0.4	99.6	0.0	mS	S	Moderately Well
Mean		**361.9**	**0.4**	**99.6**	**0.0**			
SD		**44.3**	**0.2**	**0.2**	**0.0**			
G6	A	290.6	0.3	97.9	1.8	mS	S	Moderately Well
G6	B	283.7	0.5	97.7	1.7	mS	S	Moderately Well
G6	C	279.8	0.0	98.4	1.6	mS	S	Moderately Well
Mean		**284.7**	**0.3**	**98.0**	**1.7**			
SD		**5.5**	**0.3**	**0.3**	**0.1**			

Station	Sample	Mean (µm)	Gravel (%)	Sand (%)	Mud (%)	Wentworth *	Folk **	Sorting
G7	A	274.3	0.0	98.6	1.4	mS	S	Moderately Well
G7	B	522.7	4.4	94.9	0.7	cS	(g)S	Moderate
G7	C	290.7	0.2	98.5	1.3	mS	S	Moderately Well
Mean		**362.6**	**1.5**	**97.3**	**1.1**			
SD		**138.9**	**2.5**	**2.1**	**0.4**			
G8	A	345.4	0.5	98.5	1.0	mS	S	Moderate
G8	B	301.4	1.9	97.0	1.1	mS	(g)S	Moderate
G8	C	303.6	0.4	98.3	1.3	mS	S	Moderately Well
Mean		**316.8**	**0.9**	**97.9**	**1.1**			
SD		**24.8**	**0.8**	**0.8**	**0.1**			
G9	A	303.5	0.6	98.3	1.0	mS	S	Moderate
G9	B	302.7	1.0	98.1	0.9	mS	(g)S	Moderate
G9	C	278.6	0.9	98.1	1.1	mS	S	Moderately Well
Mean		**294.9**	**0.8**	**98.2**	**1.0**			
SD		**14.2**	**0.2**	**0.1**	**0.1**			
G10	A	606.9	0.9	98.6	0.5	cS	S	Moderate
G10	B	559.4	5.0	94.0	1.0	cS	gS	Moderate
G10	C	752.0	8.5	90.9	0.5	cS	gS	Moderate
Mean		**639.4**	**4.8**	**94.5**	**0.7**			
SD		**100.3**	**3.8**	**3.8**	**0.3**			
G11	A	752.9	5.2	93.0	1.8	cS	gS	Moderate
G11	B	312.0	1.0	97.5	1.5	mS	S	Moderate
G11	C	379.8	4.2	90.6	5.2	mS	(g)S	Poor
Mean		**481.6**	**3.5**	**93.7**	**2.8**			
SD		**237.4**	**2.2**	**3.5**	**2.0**			
G12	A	438.9	1.9	97.4	0.7	mS	(g)S	Moderate
G12	B	548.3	7.2	92.1	0.7	cS	gS	Poor
G12	C	345.6	1.8	97.2	0.9	mS	(g)S	Moderate
Mean		**444.3**	**3.6**	**95.6**	**0.8**			
SD		**101.4**	**3.1**	**3.0**	**0.1**			

*Wentworth classifications: fS = Fine sand; mS = Medium sand; cS = Coarse sand; vcS = Very coarse sand.
*British Geological Survey modified Folk (1954) classifications: S = Sand, (g)S = Slightly gravelly sand; gS = Gravelly sand.

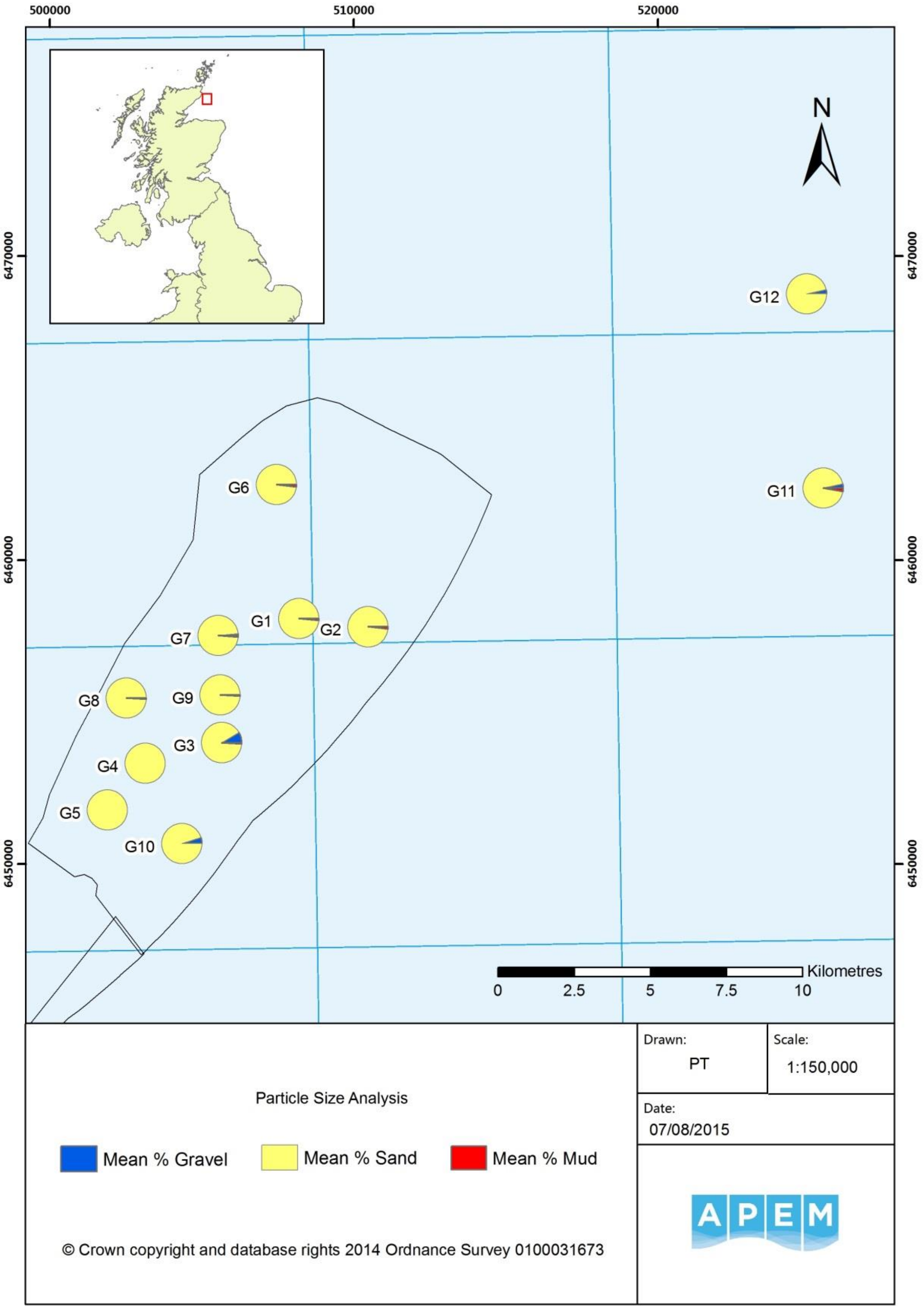

Figure 3: Proportions of sand, mud and gravel at sample stations (mean across replicates).

3.2 Macrobiota

Samples of adequate volume were successfully obtained at all twelve grab locations. Only one attempt yielded a volume of less than 5 litres (the first attempt at Station G12) but the three further attempts all yielded successful samples. Further details of the grab samples taken are provided in Appendix 2. Macrobiota data are presented in Appendix 3.

3.2.1 Species of conservation importance

A total of nine individuals of the ocean quahog *Arctica islandica* (all juveniles), were recorded across seven replicates at five of the twelve stations (Stations G5, G7-9 and G11 (one of the reference stations)). Of the seven replicates, four were classified as Sand, based on BGS modified Folk, and three were Slightly gravelly sand. This bivalve species is listed under the OSPAR (2008) list of threatened and/or declining species and habitats. No other species with conservation importance designations or protected species were recorded and no invasive non-native taxa were found in the samples. A single individual of the reef forming worm *Sabellaria spinulosa* was found in Replicate G2A but there was no evidence of *Sabellaria* reef (an Annex I habitat under the Habitats Directive). Several other taxa have been highlighted as being notable with reasons indicated in Appendix 4. It is common for a large-scale survey to include new UK records and potential new species, due to the unresolved taxonomy and lack of published data for many groups.

3.2.2 Univariate analysis

Across the survey a total of 231 taxa were recorded. Post truncation, 2,786 individuals were recorded and of these, 648 individuals were recorded as juveniles (23% of total abundance), comprising 30 taxa.

Abundance

OWF site

Overall, the most abundant taxonomic group was molluscs with a mean of 275 ± 107 individuals per m^2 (37% of total invertebrate abundance) with similar numbers of annelid polychaetes also recorded (mean of 262 ± 187 individuals per m^2 representing 35% of all individuals), (Table 4). Echinoderms constituted 15% of invertebrate abundance, 8% belonged to the ‘other taxa’ grouping and arthropod crustaceans comprised 5% (mean of 40 ± 29 individuals per m^2).

With the exception of Station G3, just south of the centre of the OWF site (which had a higher mean gravel content than most of the other stations), abundance was slightly greater at the stations in the northern section of the OWF (Figures 4 & 5). Station G3 was found to have the most abundant macrofaunal community with 1143 ± 693 individuals per m^2 (Table 5). For the remaining stations, abundance per m^2 varied between 320 ± 27 individuals at Station G5 (in the southwest section of the OWF site) and 890 ± 387 individuals at Stations G6 (northernmost station in the OWF site) and 890 ± 314 individuals at Station G7 (just north of centre of the OWF site) (Table 5, Figures 4 & 5). There was some variability in invertebrate abundance across replicate samples at the majority of stations, which was most evident at Station G3 and the higher overall abundance at this station was primarily due to the very high invertebrate abundance within replicate G3B (192 individuals) compared to the other replicates (59 and 92 individuals), (Figure 6). Replicate G3B had the highest gravel content of all replicates (22.3%), and invertebrate abundance was elevated due to increased numbers of annelid polychaetes, as well as some increases in abundance of ‘other taxa’ and echinoderms compared to other replicates (Figure 6).

The most abundant species across the OWF site was the mollusc *Cochlodesma praetenue*, with a mean of 83 ± 62 individuals per m^2 across replicates. Other abundant molluscs were *Abra prismatica* (mean of 50 ± 40 individuals per m^2), *Moerella pygmaea* (mean of 43 ± 36 individuals per m^2), and *Spisula* spp. (mean of 24 ± 22 individuals per m^2). *M. pygmaea* is a key component of the MoeVen biotope but is also characteristic of other biotopes, including ‘*Ophelia borealis* and *Abra prismatica* in circalittoral fine sand’ (SS.SSa.CFiSa.EpusObor Apri). The most abundant venerid bivalve was *Chamelea striatula* (mean of 13 ± 16 individuals per m^2), while other venerid bivalves *Clausinella fasciata*, *Timoclea ovata*, *Dosinia lupinus* and *D. exoleta* were recorded in very low numbers. Other taxa found in high abundances were the pea sea urchin *Echinocyamus pusillus* (45 ± 30 individuals per m^2), and juvenile brittlestars (Ophiuridae) (53 ± 44 individuals per m^2). The most abundant polychaetes were *Spiophanes bombyx*, *Ophelia borealis*, and *Polycirrus* spp., with abundances of 20 ± 18, 19 ± 13 and 19 ± 23 individuals per m^2, respectively. The polychaete *Glycera lapidum* (agg.) which can be characteristic of the MoeVen biotope had a mean abundance of 5 ± 11 individuals per m^2.

Distribution figures indicating abundance at the OWF site and reference stations are provided in Appendix 5 for *C. praetenue, M. pygmaea*, *A. prismatica* and *E. pusillus* which were four of the key taxa characterising the benthic communities within the OWF site. In general, abundance of *C. praetenue* was greatest at stations to the north and west of the OWF site; abundance of *M. pygmaea* was greatest in the south of the OWF site (with the exception of a high abundance at Station G2 east of centre); the two southernmost sites had the lowest abundances of *A. prismatica*; and no clear spatial patterns in distribution were evident for *E. pusillus*.

Reference stations

At the reference stations, the most abundant taxonomic group was polychaetes, with a mean of 315 ± 222 individuals per m^2 (36% of total invertebrate abundance) with similar numbers of molluscs (mean of 295 ± 96 individuals per m^2 representing 33% of all individuals), (Table 4). Echinoderms constituted 19% of invertebrate abundance, whilst 8% belonged to the ‘other taxa’ grouping and arthropod crustaceans comprised 4% (mean of 37 ± 18 individuals per m^2), (Table 4). The percentage contributions of the different taxonomic groups to the invertebrate assemblage was similar to the percentage contributions within the OWF site. At Station G11, invertebrate abundance per m^2 was 1193 ± 240 individuals, which was greater than at all of the OWF sites. In common with Station G3 in the OWF site, the higher abundance at Station G11 was primarily due to a higher abundance of annelid polychaetes, as well as a higher abundance of ‘other taxa’ and echinoderms compared to the other stations. At G12, mean abundance was far lower with 577 ± 250 individuals per m^2. Mean gravel content at these stations was similar (3.5 ± 2.2% at G11, and 3.6 ± 3.1% at G12) suggesting this was not a primary factor in the differences observed. It was noted, however, that at G12 replicate G12B (which had the highest percentage gravel content at 7.2%), had a greater invertebrate abundance than the other replicates (850 individuals per m^2, in comparison with 360 and 520 individuals per m^2 for the other replicates).

Table 4: Abundance and taxon richness within taxonomic groups. SD = Standard Deviation.

Taxonomic Group	Individuals			Taxon richness	
	Total Abundance	Mean abundance (per m^2 ± SD)	Percent Contribution	Total number of taxa	Percent Contribution
OWF site					
Polychaeta	785	262 ± 187	34.8	92	44
Crustacea	121	40 ± 29	5.4	32	15.3
Mollusca	824	275 ± 107	36.5	35	16.8
Echinodermata	336	112 ± 68	14.9	8	3.8
Other (countable)	189	63 ± 77	8.4	12	5.7
Other (non-countable)	-	-	-	10	4.8
Bryozoa	-	-	-	20	9.6
Total	**2255**	**NA**	**100**	**209**	**100**
Reference stations					
Polychaeta	189	315 ± 222	35.6	58	51.3
Crustacea	22	37 ± 18	4.1	12	10.6
Mollusca	177	295 ± 95	33.3	21	19.5
Echinodermata	102	170 ± 91	19.2	3	2.7
Other (countable)	41	68 ± 77	7.7	8	7.1
Other (non-countable)	-	-	-	6	5.3
Bryozoa	-	-	-	4	3.5
Total	**531**	**NA**	**100**	**112**	**100**

*Other taxa included: Cnidaria (*Cerianthus lloydii, Edwardsia claparedii*), Playtyhelminthes (Turbellaria), sessile Arthropoda (Sessilia), non-polychaete Annelida (*Grania,* Piscicolidae), Sipuncula (*Phascolion strombus*), Phoronida, Chordata (Ascidiaceae – fish were excluded), Nemertea and Nematoda.

Table 5: Summary statistics for each station averaged across replicates. SD = Standard deviation.

Station	Total no. taxa	Mean abundance (per m^2 ± SD)	Mean biomass (g m^{-2} ± SD)	Mean Shannon Wiener Diversity ($H'(\log_e)$)	Margalef's species richness (*d*)	Mean Pielou's Evenness (*J'*)	Mean Simpson's Dominance (1-λ)
G1	72	883 ± 107	1.9 ± 0.8	3.0 ± 0.3	7.4 ± 1.6	0.86 ± 0.03	0.92 ± 0.03
G2	71	850 ± 40	1.7 ± 1.6	3.2 ± 0.1	7.7 ± 0.6	0.90 ± 0.02	0.95 ± 0.01
G3	104	1143 ± 693	2.2 ± 1.0	3.4 ± 0.3	9.1 ± 1.8	0.90 ± 0.01	0.95 ± 0.01
G4	56	610 ± 60	8.3 ± 4.3	3.0 ± 0.4	6.4 ± 1.6	0.90 ± 0.04	0.93 ± 0.03
G5	38	320 ± 27	2.7 ± 1.7	2.6 ± 0.2	4.9 ± 0.9	0.91 ± 0.02	0.95 ± 0.02
G6	76	890 ± 387	3.9 ± 1.1	3.3 ± 0.2	8.1 ± 1.4	0.91 ± 0.02	0.95 ± 0.01
G7	59	890 ± 314	3.1 ± 1.0	2.9 ± 0.2	6.3 ± 1.5	0.88 ± 0.04	0.92 ± 0.01
G8	45	607 ± 47	1.2 ± 0.8	2.8 ± 0.2	5.6 ± 0.8	0.86 ± 0.04	0.92 ± 0.03
G9	55	573 ± 206	4.2 ± 2.0	3.0 ± 0.2	6.3 ± 0.8	0.91 ± 0.03	0.93 ± 0.01
G10	73	747 ± 102	1.5 ± 0.7	3.2 ± 0.2	7.6 ± 1.1	0.92 ± 0.01	0.95 ± 0.01
G11	96	1193 ± 240	1.8 ± 1.9	3.4 ± 0.1	9.8 ± 1.3	0.88 ± 0.01	0.95 ± 0.01
G12	52	577 ± 250	0.3 ± 0.3	2.7 ± 0.3	5.8 ± 2.0	0.87 ± 0.03	0.90 ± 0.02
Min	**38**	**320**	**0.3**	**2.6**	**4.9**	**0.86**	**0.90**
Max	**104**	**1193**	**8.3**	**3.4**	**9.8**	**0.92**	**0.95**
Mean	**66**	**774**	**2.7**	**3.0**	**7.1**	**0.89**	**0.94**
SD	**20**	**252**	**2.1**	**0.3**	**1.5**	**0.02**	**0.02**

The most abundant taxon across the reference stations was juvenile brittlestars (Ophiuridae; 118 ± 62 individuals per m^2), followed by the mollusc *A. prismatica* with a mean of 112 ± 54 individuals per m^2) (Appendix 5). Other molluscs with high abundances relative to other taxa at these stations, but not necessarily relative to the OWF site, were *C. praetenue* (27 ± 23 individuals per m^2) (Appendix 5), juvenile *Spisula* spp. (27 ± 23 individuals per m^2), *M. pygmaea* (25 ± 22 individuals per m^2), and *Goodallia triangularis* (25 ± 31 individuals per m^2). The venerid bivalves *C. striatula, C. fasciata* and *D. exoleta* were not recorded at the two reference stations, and *T. ovata*, *D. lupinus* were present in very low numbers, along with *Venus casina* which was not recorded at the OWF stations.

Some of the other more abundant taxa recorded at the reference stations included *E. pusillus* (48 ± 49 individuals per m^2), and the polychaetes *Owenia* spp. (30 ± 14 individuals per m^2), *Aricidea cerrutii* (20 ± 23 individuals per m^2) and *G. lapidum* agg. (15 ± 23 individuals per m^2).

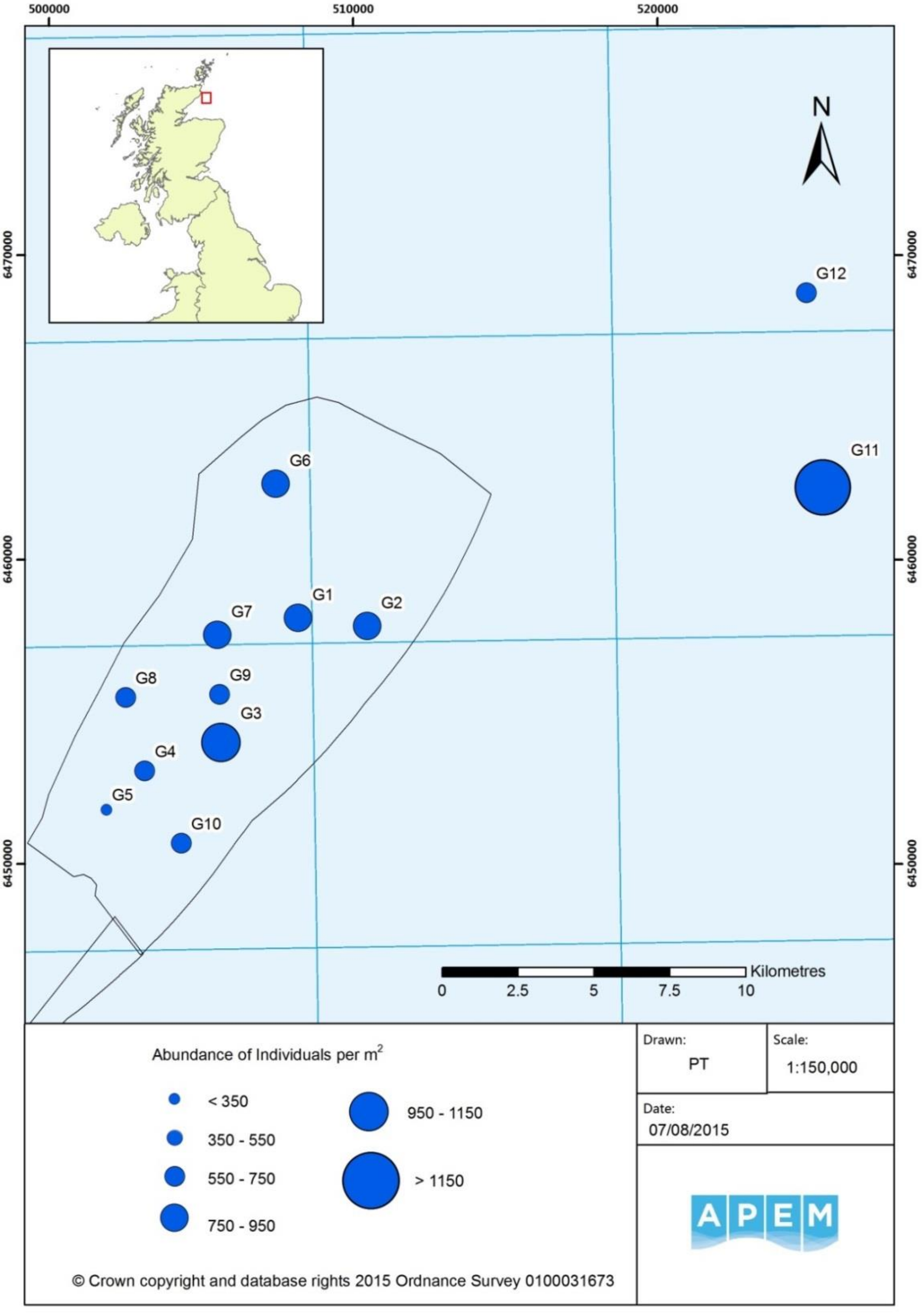

Figure 4: Abundance of invertebrates across stations (individuals m^{-2}) (mean across replicates).

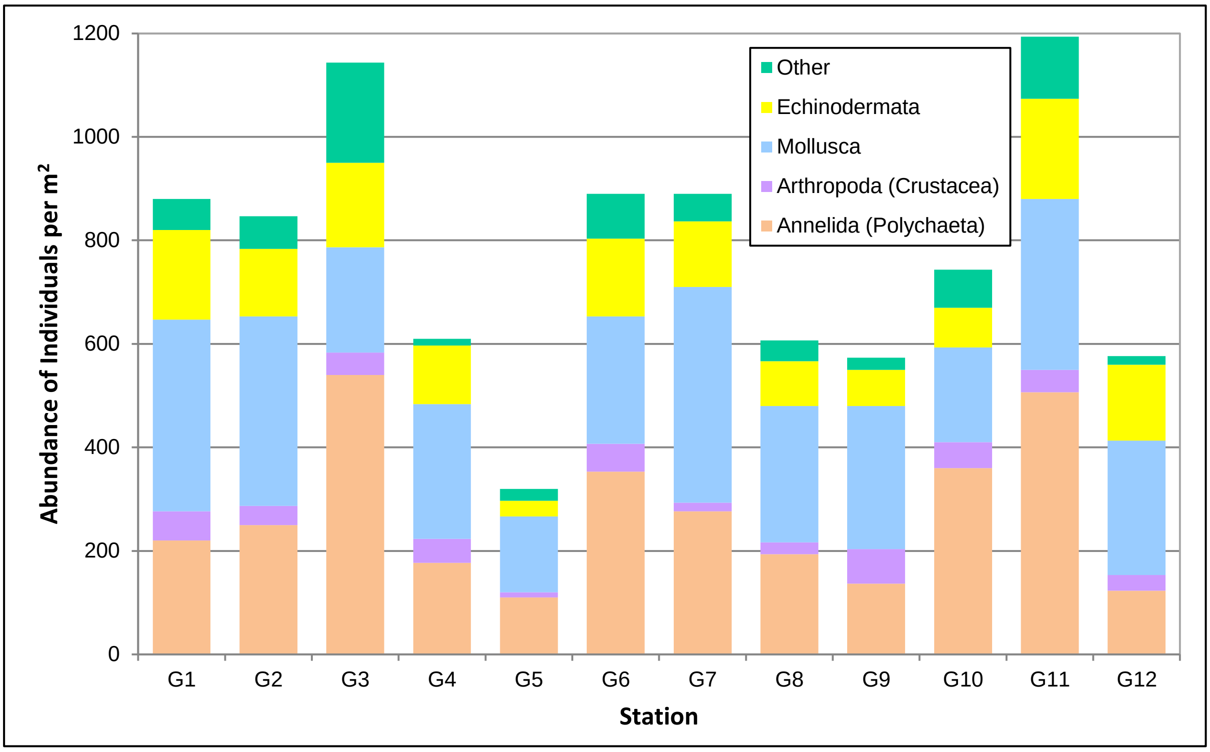

Figure 5: Abundance of individuals per m^2 for taxonomic groups (mean across replicates).

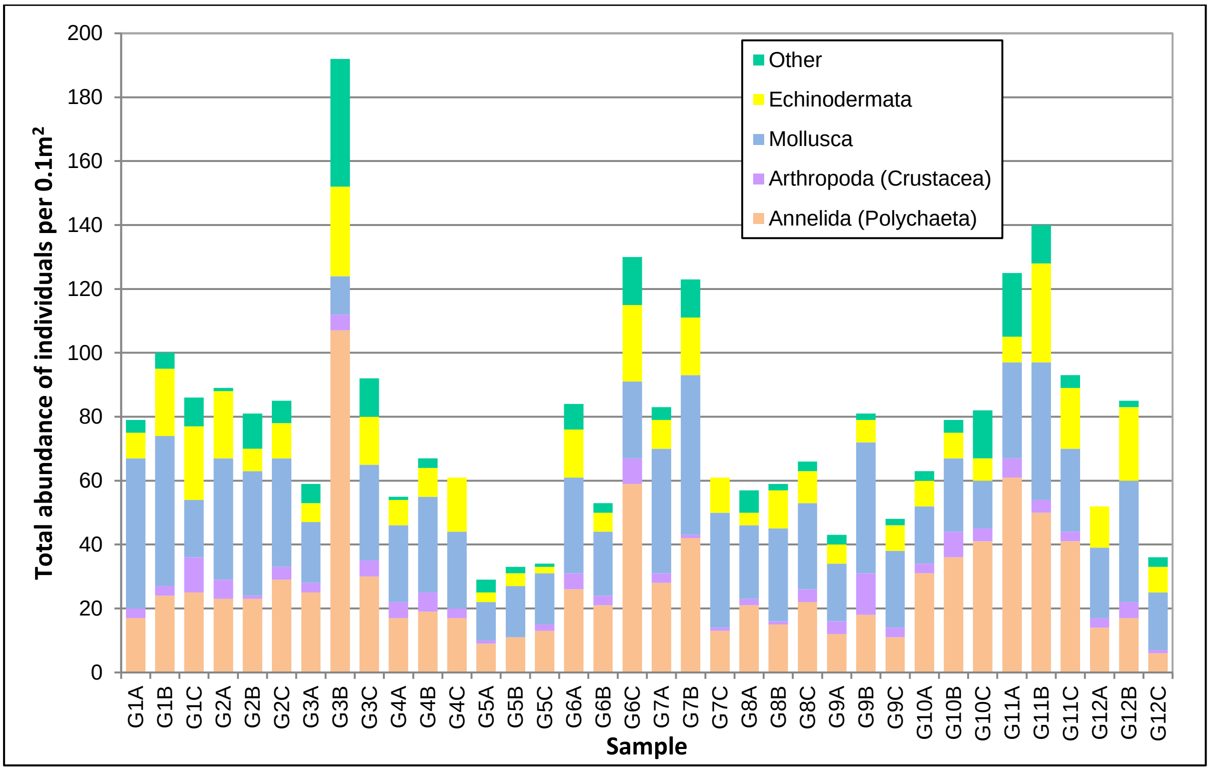

Figure 6: Total abundance of individuals for taxonomic groups across replicates.

Taxon richness

OWF site

A total of 209 taxa were recorded across the OWF site. Polychaetes had the greatest taxon richness with 92 taxa (44% of the total taxa). There were 35 mollusc taxa and crustaceans had a proportionally high taxon richness, with 32 taxa in total despite having the lowest total abundance (arthropods comprised 5% of invertebrates sampled in the OWF site) (Table 4). 'Other countable taxa' comprised a total of twelve taxa, 'Other non-countable taxa' included ten species and eight echinoderm taxa were recorded (Table 4). Additionally, 20 bryozoan taxa were noted. Over 50 taxa were present at the majority of stations (total of taxa across the three replicates) (Table 5, Figure 7 & 8). The lowest number of taxa was recorded at Station G5 (38 taxa) (Table 5, Figure 7 & 8). Variation in taxon richness between stations followed a similar trend to that identified for abundance of individuals with greatest taxon richness at Station G3 (104 taxa) (Figure 7 & 8). The higher taxonomic richness at Station G3 was due primarily to increased numbers of polychaete species, which also contributed to the higher abundance of individuals per m^2, as discussed above.

As noted for abundance of individuals, there was also some within-station variation in taxonomic richness of the macrobiota (Figure 9). Variations in the number of taxa present primarily corresponded to differences in the numbers of molluscs and polychaetes, with the composition of the three other taxonomic groups being relatively consistent.

Reference stations

In total, 112 taxa were recorded across the two reference stations. In common with the OWF sites, the group with greatest taxonomic richness at the reference stations was polychaetes, with 58 taxa recorded (51% of the taxa recorded), followed by molluscs (21 taxa) and crustaceans (12 taxa).

The total number of taxa recorded at Station G11 was 96, which was greater than all but one of the OWF stations. Taxon richness was a lot lower at G12 with 52 taxa. This reflects the pattern observed for invertebrate abundance with a far higher abundance at G11 than G12, and the high taxon richness at G12 was due to the high numbers of polychaete taxa present relative to the other stations in the OWF site.

There was notable within-station variation in taxon richness across replicates at both stations G12 (15 to 36 taxa) and G11 (41 to 57 taxa).

Diversity indices

OWF site

Mean Shannon-Wiener diversity index ($H'(\log_e)$) values indicated that there was moderate biological diversity within the marine communities sampled across the survey stations (Table 5). Mean index values ranged between 2.6 ± 0.2 at Station G5 in the southern section of the OWF site to 3.4 ± 0.3 at Station G3 just south of centre of the OWF site. Diversity at Stations G7 and G8 west of the OWF site was also relatively low with mean values of 2.9 ± 0.02 and 2.8 ± 0.02, respectively. The lowest diversity at Station G5 is consistent with the fact that mean abundance and taxon richness were lowest at this station. Margalef's species richness index (*d*) reflected the pattern observed for taxon richness and the Shannon-Wiener index with lower values at stations with low taxon richness and low Shannon-Wiener values.

The results of the Pielou's Evenness (*J'*) and Simpson's dominance indices indicated that the benthic communities across all survey stations were evenly distributed with little evidence of any dominant taxa (Table 5). Pielou's Evenness was high at all stations ranging from 0.86 ± 0.04 to 0.92 ± 0.01 (maximum potential value is 1). Similarly, Simpson's dominance index (1-λ) was very high (0.90 ± 0.02 to 0.95 ± 0.02, with a maximum potential value of 1), indicating the probability of any two individuals within a replicate being the same species was very low.

Reference stations

Benthic communities also had moderate biological diversity at the two reference stations. The mean of 3.4 ± 0.1 recorded for Station G11 equalled the highest diversity score for an OWF station (G3), while the 2.7 ± 0.3 recorded at G12 was near the lowest values in the OWF site (2.6 ± 0.2 at G5). The overall station diversity at G12 was reduced by the particularly low invertebrate abundance and taxon richness in replicate G12C. Generally, however, as indicated by the low standard deviation values, there was little variation in Shannon-Wiener diversity index values across replicates. These results for diversity are consistent with the results obtained for abundance and taxon richness at these stations with high abundance and taxon diversity across Station G11 relative to stations in the OWF, and particularly low abundance and diversity at G12.

Biomass

The total biomass (AFDW) of countable invertebrates across the stations sampled was 9.81 g, with a mean per replicate of 0.27 ± 0.25 g (i.e. 2.7 ± 2.5 g/m^{-2}). This is similar to the mean biomass recorded across the wider survey conducted in 2010 which was 2.98 g/m^{-2} (CMACS 2011).

OWF site

Mean biomass amongst stations did not correspond with the trends identified for taxon richness or abundance of individuals. The highest mean biomass was recorded at Station G4 (8.31 ± 4.25 g m^{-2}) in the south of the OWF site, which was almost twice the biomass of the sampling station with the second highest biomass (G9 with 4.20 ± 2.01 g m^{-2}), (Table 5, Figure 10). This is largely due to the presence of two adult sea urchins *Spatangus purpureus* and *Echinocardium cordatum* (total biomass of 0.40 g and 0.49 g, respectively) in one of the samples. Together, these two individuals contributed almost a third of biomass at replicate G4B. Station G3, which had the highest biological diversity and abundance of individuals, had a mean biomass of 2.19 ± 1.02 g m^{-2} (Table 5, Figure 10). The lower biomass at Station G3, despite high abundance of individuals and taxa, was primarily due to the fact that the invertebrate community at these stations consisted primarily of polychaetes which, although numerous, are mostly small, fragile organisms with low biomass.

Station G5, which was the most impoverished station in terms of taxon richness and abundance, had a mean biomass of 2.68 ± 1.69 g m^{-2}. The lowest biomass was recorded at Station G8, with an invertebrate biomass of just 1.16 ± 0.77 g m^{-2}.

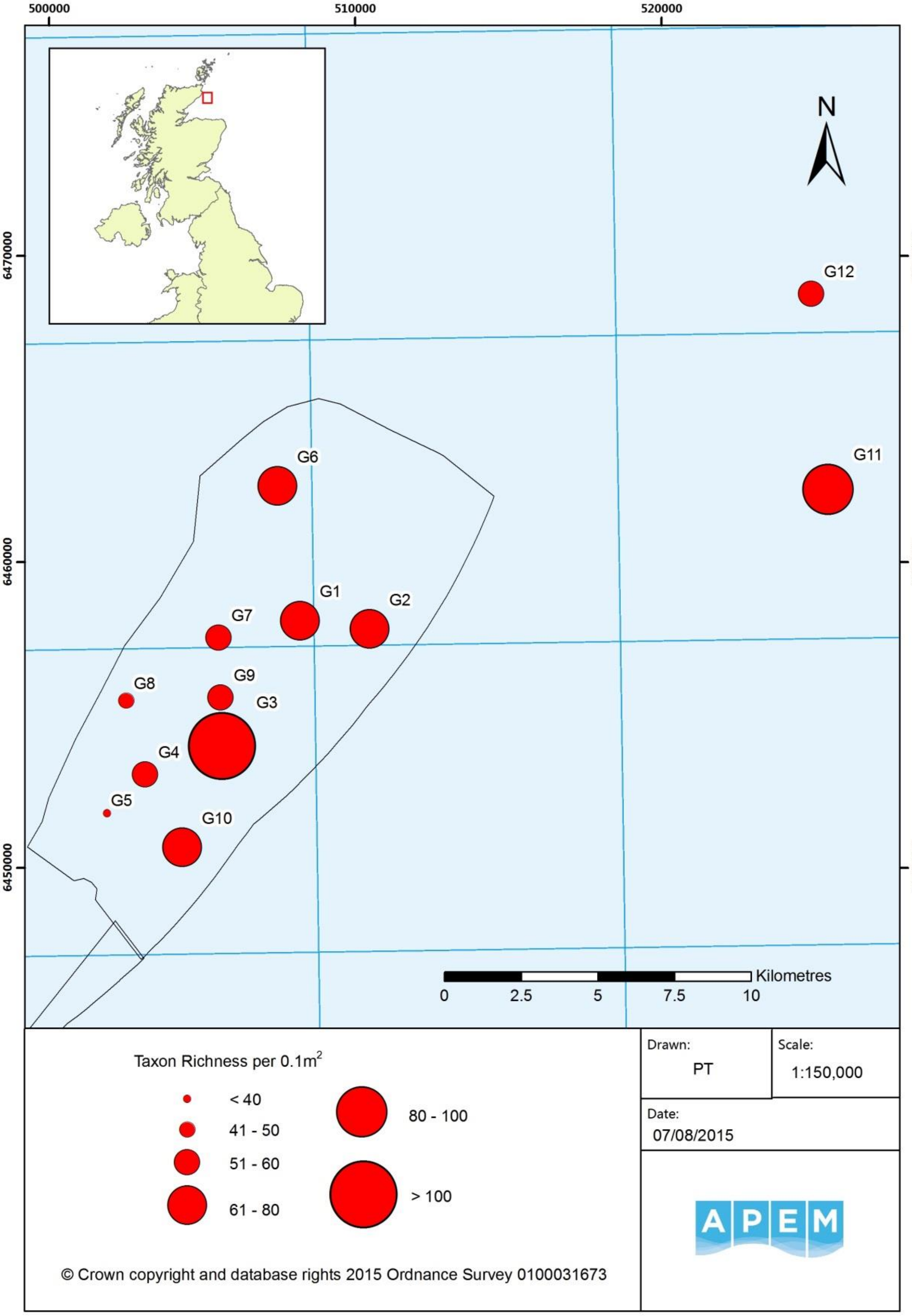

Figure 7: Number of taxa across stations (total across replicates).

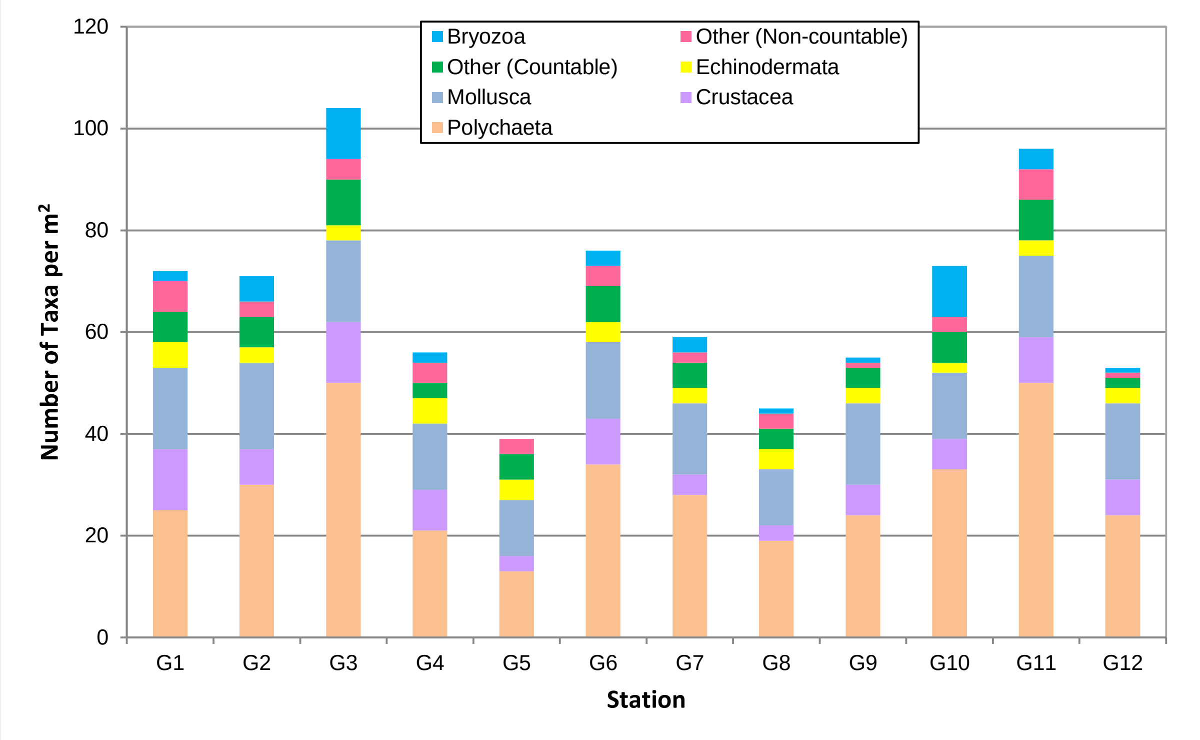

Figure 8: Taxon richness per 0.1 m^2 for taxonomic groups across stations (mean across replicates).

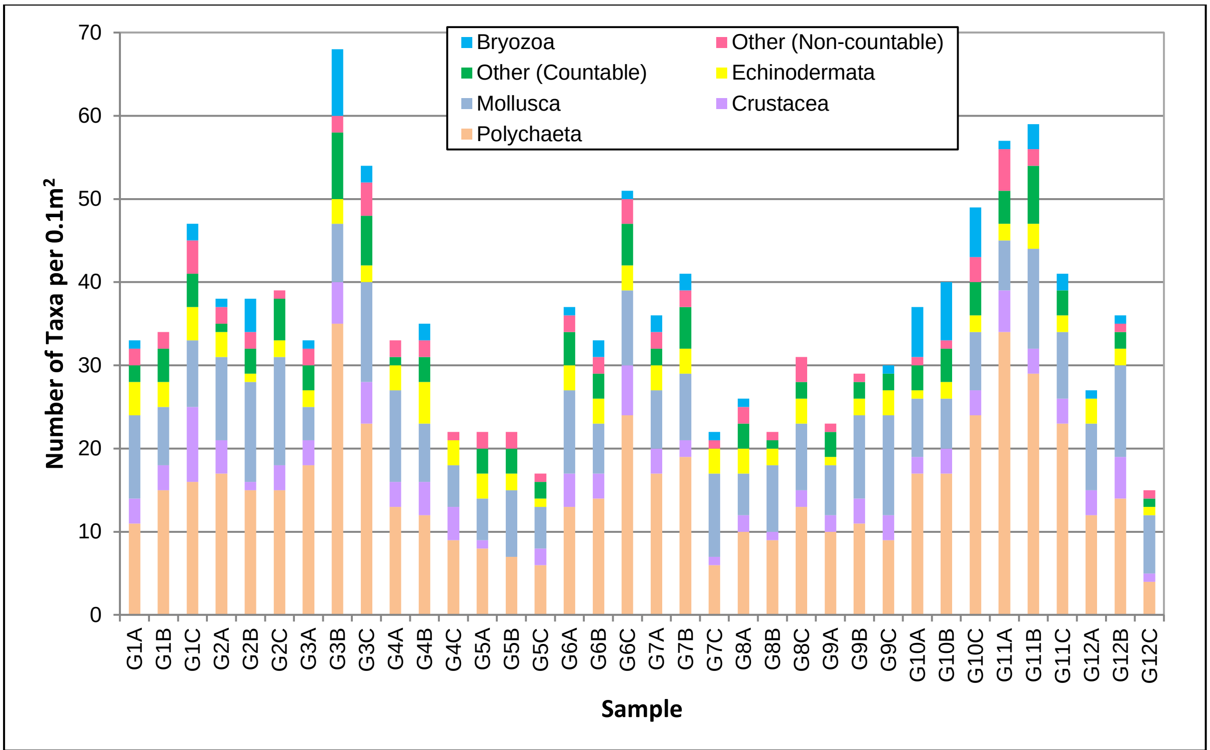

Figure 9: Taxon richness of taxonomic groups across replicates.

The species that was found to be the most abundant throughout the survey area (*C. praetenue*) also had the highest total biomass of any taxon, at 2.37 g. This was approximately a quarter of the total invertebrate biomass recorded across the OWF site and almost double the value for the species with the second highest biomass value (*G. fervensis*, with 1.38 g). These taxa are large molluscs, and a high proportion of adults were present in many of the samples.

Reference stations

Station G11, which had one of the highest numbers of taxa across the whole survey area (OWF site and reference stations) and had the greatest abundance of individuals across the survey area, had a mean biomass of 1.76 ± 1.92 g m^{-2}, which was towards the lower end of the biomass recorded at stations in the OWF site. Biomass at Station G12, however, was far lower than at any of the other stations. The main reason for the lower mean biomass at Station G12 compared to e.g. G9, which had a similar abundance of invertebrates, was the absence of adult *C. praetenue* and *G. fervensis.*

3.2.3 Cluster and Multi-Dimensional Scaling (MDS) analyses

The dendrogram derived from CLUSTER analysis indicated 20 of the 36 replicate samples were statistically inseparable with 40% similarity or greater. These comprised all three replicates at Stations G2, G4, G7 and G8, and two of the replicates at G1, G6, G9 and one of the reference stations (G12), (Figure 11). SIMPROF indicated that the replicates could be grouped into four clusters based on the invertebrate assemblages present (a true cluster requires three or more stations to be grouped) (Groups c, e, f and h). In addition, three isolated replicates were each assigned groups (Group a, b and g) and G1C and G6C were grouped together as a pair (Group d), (Figure 11). The individually isolated replicates were G12C, G9C and G3B. Replicate G12C (one of the reference station replicates) is likely to be isolated from replicates G12A and B due to its relatively low invertebrate abundance and taxon richness, however, this is not clearly attributable to sediment type as the proportion of mud, gravel and sand was very similar to replicate G12A and a number of other replicate samples across the OWF site. G3B differed from other replicates as it had a far higher proportion of gravel than all of the other replicates and this replicate was associated with the greatest abundance and taxon richness values across the OWF site and reference stations. G9C did not differ considerably from other replicates in terms of sediment composition, taxon richness or abundance and was differentiated based on community composition as indicated in Table 6.

The accompanying MDS plot provides an alternative visualisation of the groupings observed in the CLUSTER analysis (Figure 12). A stress value of 0.1 for an MDS plot indicates a good ordination, while 0.2 indicates a potentially useful 2-dimensional picture (Clarke & Warwick, 2001). With a stress value of 0.21, the MDS plot is on the higher boundary but is still considered a useful visual representation of the data.

SIMPER analysis indicated the main species driving the differences between SIMPROF groupings (SIMPER outputs are provided in Appendix 6); a combination of SIMPER outputs and the abundance of different taxa within replicates were considered when assigning biotopes to each replicate. Biotopes were assigned according to Connor *et al*. (2004) and notes made on any variations to the standard descriptions.

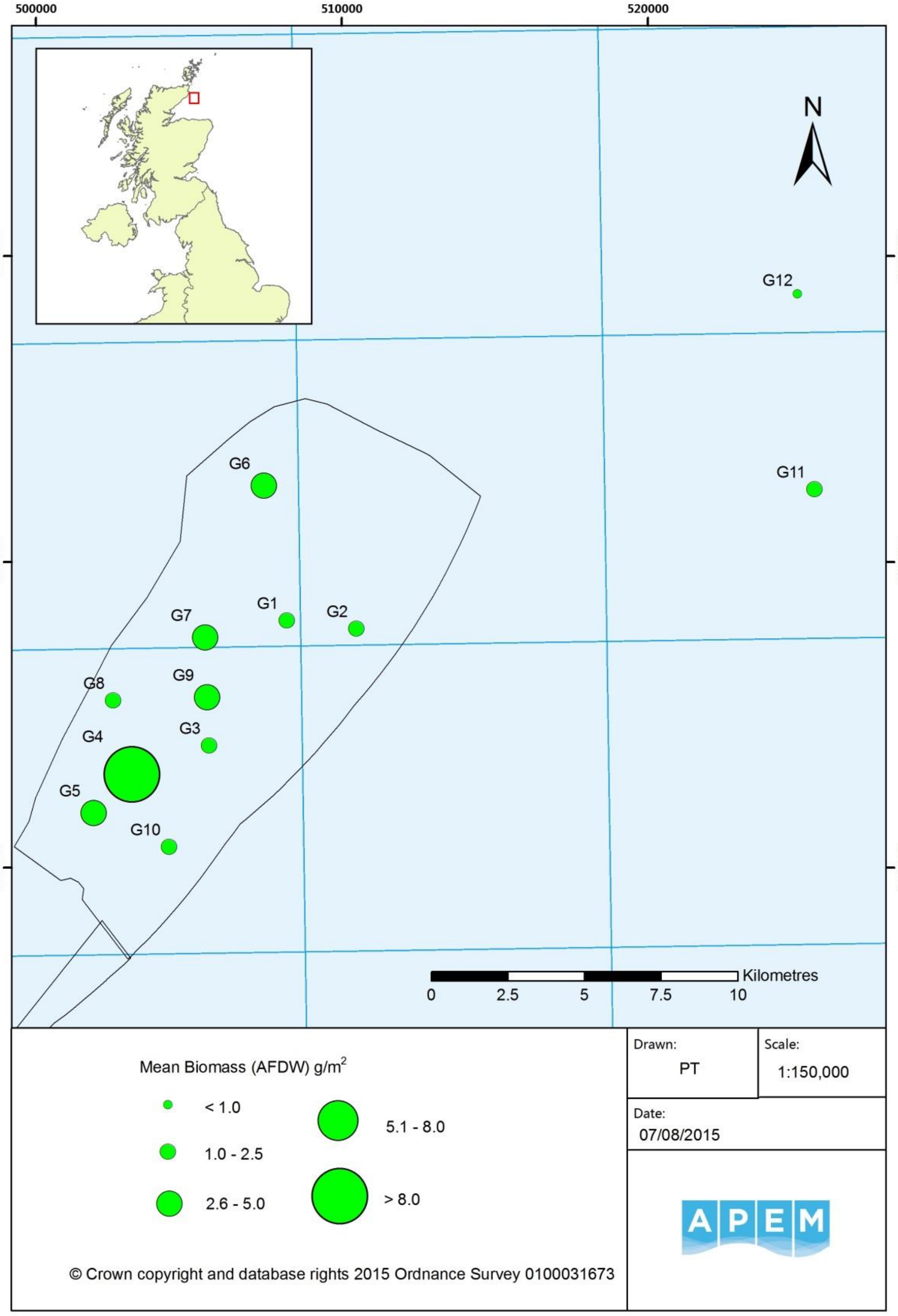

Figure 10: Invertebrate biomass (Ash Free Dry Weight) across stations (mean across replicates).

The prefix ‘cf.’ to the biotope code has been used to indicate biotopes that are closest to a particular described biotope but not necessarily an exact fit. ‘Variant’ has been used to indicate that the community has been ascribed to the described biotope but has certain noticeable differences. Three biotopes were assigned based on the SIMPROF groups and the most abundant taxa within replicates including some potential variants which have been noted (Table 6). The biotope groups for each replicate based on the SIMPROF outputs are indicated in Table 6.

3.2.4 Biotope assignment

The MoeVen biotope was assigned to three of the stations (G3, G5 and G10), which were represented by SIMPROF groups c, g and h (Table 6). MoeVen is generally characterised by *Moerella* spp. with the polychaete *G. lapidum* (agg.) and venerid bivalves. Typical species include *M. pygmaea* or *M. donacina* with other robust bivalves such as *D. lupinus*, *T. ovata*, *G. triangularis* and *Chamelea gallina*. SIMPER analysis indicated *M. pygmaea* was one of the top two species driving SIMPROF groupings for groups c and h (there are no outputs for g as there was only one station assigned to this group) and it was one of the two most abundant taxa across stations within the c and h groupings, other species contributing to the assignment of this biotope are indicated in Table 6 and Appendix 6.

The dominant biotope was *Echinocyamus pusillus*, *Ophelia borealis* and *Abra prismatica* in circalittoral fine sand (SS.SSa.CFiSa.EpusOborApri – referred to hereon as EpusOborApri) This biotope was assigned to all three replicates at 8 of the stations (including reference station G11), and two replicates at the reference station G12. EpusOborApri is characterised by *E. pusillus*, *A. prismatica* and the polychaete *O. borealis*. The biotope is similar to MoeVen and may also include many *M. pygmaea* and *G. lapidum*. SIMPER analysis indicated *E. pusillus* and *A. prismatica* were in the top four species driving SIMPROF groupings for groups d, e and f (there are no outputs for group b as there was only one station assigned to this group) (Appendix 6), and were in the top four most abundant species across stations within these groups. SIMPER indicated that the high abundance of Ophiuridae also drove these groupings and although this taxon is not mentioned in the standard biotope description, it is typical of soft sandy sediments. It should be noted that there is no typical species list given for this biotope beyond the biotope description text in Connor *et al*. (2004).

Most examples of EpusOborApri were close to the standard form, represented by SIMPROF groups b and e (Table 6). Two variants were present across five replicates (Table 6), for example, although the EpusOborApri biotope was also assigned to all replicates at Station G11, there was evidence that the slightly higher mud content had influenced the community present and it was recorded at this station as a variant to the standard form of the biotope, possibly closer to MoeVen.

Only one replicate (G12C; SIMPROF group a) was assigned the biotope *Abra prismatica*, *Bathyporeia elegans* and polychaetes in circalittoral fine sand (cf. SS.SSa.CFiSa.ApriBatPo - referred to hereon as ApriBatPo), as it was close to MoeVen but was more impoverished, and an individual of *Bathyporeia elegans* was recorded which is more typical of mobile sediments (Table 6).

From a conservation perspective is it noted that, in common with MoeVen, both EpusOborApri and ApriBatPo are component biotopes of Scottish PMFs: ‘Tide-swept coarse sands with burrowing bivalves' for MoeVen and 'Offshore subtidal sands and gravels' for the others (SNH 2014).

The MoeVen biotope is usually found in medium to coarse sand and gravelly sand and was present at Station G10, which had gravelly sand at two of the replicates, and Station G3 at which one of the replicates had a very high gravel content (Table 3). It should be noted, however, that this biotope was also recorded at Station G5, at which all replicates were classed as Sand indicating variation in the association of this biotope with different sediment types (although mean particle size was generally slightly higher for the G5 replicates than for most of the other replicates classed as Sand) (Table 3).

Generally, the EpusOborApri biotope is associated with medium to fine sand, which is consistent with the sediment types present at the majority of stations. The reference Stations G11 and G12, however, had relatively high gravel content compared to other stations and the dominant biotope at these locations was also EpusOborApri. G11 also had relatively high mud content compared to other stations, and the dominant biotope at G11 was recorded as a variant of EpusOborApri, with more mud-dependant species, such as *Abra alba* and *Scalibregma inflatum*, than at other stations allocated the EpusOborApri biotope. ApriBatPo is also generally associated with medium to fine sand and was assigned to replicate G12C, which was classed as Slightly gravelly sand. As indicated above, there was potential to assign MoeVen to G12C; however, aspects of the assemblage were considered to be more indicative of ApriBatPo (Table 6).

A RELATE test indicated a weak but apparent correlation between the multivariate patterns observed in the sediment data and in the faunal communities, which was statistically significant (Rho 0.395, Significance level (p) <0.1%). The full results of the RELATE test are presented in Appendix 7. BIO-ENV outputs indicated a weak but significant correlation between the faunal communities and different sediment types (Global test: Rho 0.537, Significance level (p) <1%). The results, however, indicate that a wide range of sediment types were contributing to the correlation with no specific sediment fractions driving the community composition (Appendix 7).

Consequently, the results indicate sediment type has the potential to influence the biotopes present but the two main biotopes, MoeVen and EpusOborApri, were assigned to replicates comprising sand or coarser sediments and factors other than sediment type are expected to be influencing the communities present.

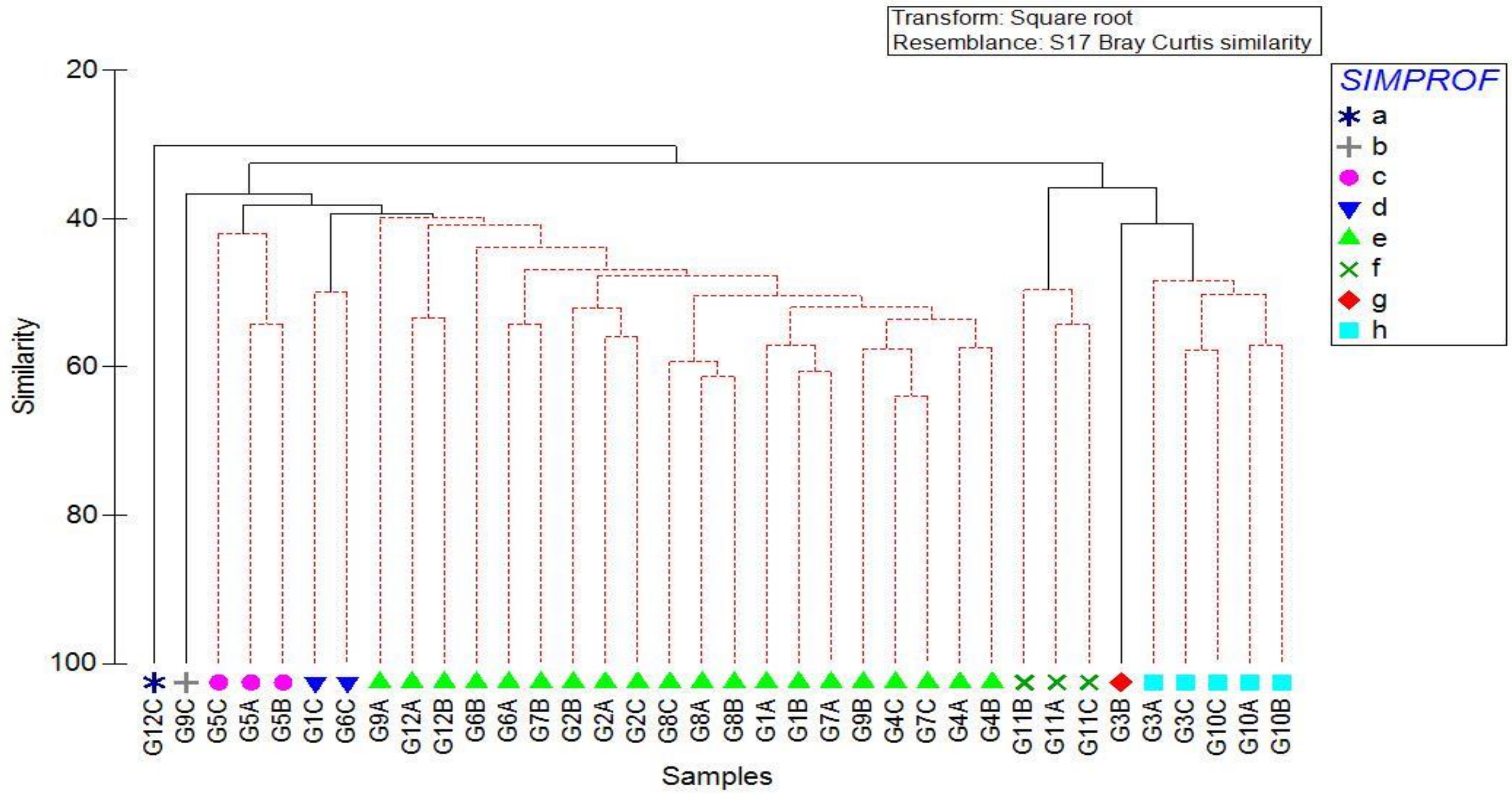

Figure 11: SIMPROF cluster dendrogram based on the square root transformed abundance data for each replicate.

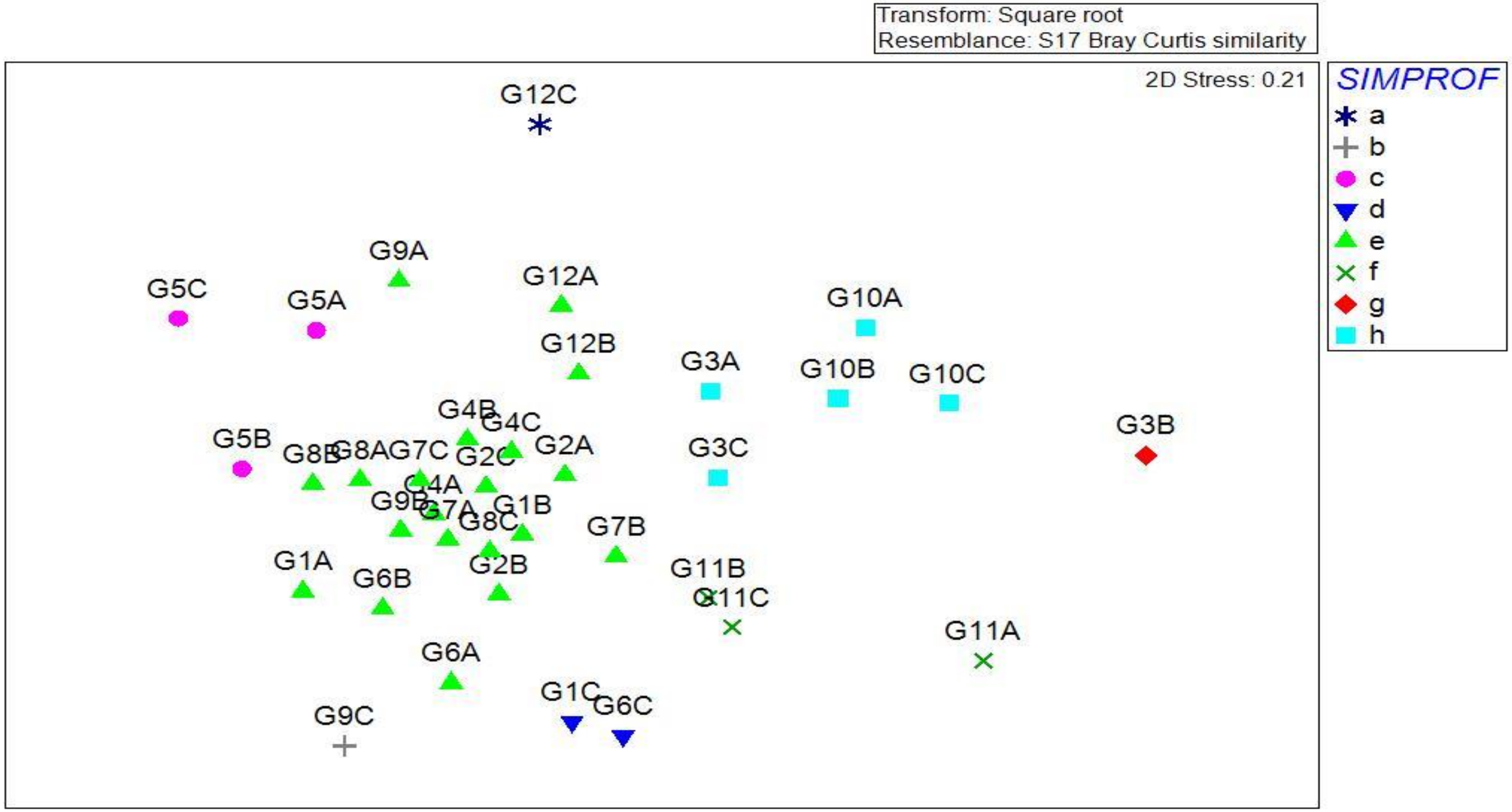

Figure 12: 2D Multidimensional Scaling (MDS) ordination based on the square root transformed infaunal abundance data for each replicate.

Table 6: Biotopes allocated to each SIMPROF group with sample replicates and descriptions.

Biotope	SIMPROF group	Replicates allocated	Description
Moerella spp. with venerid bivalves in infralittoral gravelly sand **cf. SS.SCS.ICS.MoeVen** Biotope found in medium to coarse sand and gravelly sand.	c	G5A, G5B, G5C	Group c (3 samples); Within-group similarity=46.17%. Community was similar to SS.SCS.ICS.MoeVen with more *Moerella pygmaea* and no *M. donacina*. There were also large numbers of *Echinocyamus pusillus* and *Cochlodesma praetenue*, not described for the typical form of the biotope, and there were no *Pisione remota* or *Apsedes latreillii*.
	g	G3B	Group g (1 sample); Within-group similarity=Not applicable. Community was similar to SS.SCS.ICS.MoeVen and included many *Pisione remota*, *Aonides paucibranchiata* and some *Morella pygmaea*. However, the fauna also showed similarities to SS.SCS.CCS.Blan, which has similar species and more *Echinocyamus pusillus* (common in cluster g) but no *Branchiostoma lanceolatum* were recorded.
	h	G3A, G3C G10A, G10B, G10C	Group h (5 samples); Within-group similarity=50.99%. Community was similar to SS.SCS.ICS.MoeVen; it was dominated by *Moerella pygmaea* and had no *M. donacina*. There were also large numbers of *Echinocyamus pusillus* and *Polycirrus* spp., not described for the typical form of the biotope.
Echinocyamus pusillus, *Ophelia borealis* and *Abra prismatica* in circalittoral fine sand **cf. SS.SSa.CFiSa.EpusOborApri** Biotope found in medium to fine sands.	b	G9C	Biotope found in medium to fine sands. Group b (1 sample); Within-group similarity=Not applicable. Community was similar to SS.SSa.CFiSa.EpusOborApri and had many *Echinocyamus pusillus* and *Abra prismatica* (dominant) but not *Ophelia borealis*. *Cochlodesma praetenue* was also common but is not mentioned in the standard biotope description (although there is no typical species list given for this biotope).
	e	G1A, G1B G2A, G2B, G2C G4A, G4B, G4C G6A, G6B G7A, G7B, G7C G8A, G8B, G8C G9A, G9B G12A, G12B	Group e (20 samples); Within-group similarity=46.95%. Community closely fitted SS.SSa.CFiSa.EpusOborApri, with large numbers of most of the species mentioned in the standard description.

Biotope	SIMPROF group	Replicates allocated	Description
Variant *Echinocyamus pusillus*, *Ophelia borealis* and *Abra prismatica* in circalittoral fine sand **SS.SSa.CFiSa.EpusOborApri (variant)** Biotope found in medium to fine sands.	d	G1C G6C	Group d (2 samples); Within-group similarity=50.01%. Community fitted SS.SSa.CFiSa.EpusOborApri, with large numbers of *Echinocyamus pusillus* and *Abra prismatica* and moderate abundance of *Ophelia borealis*. There were also many *Cochlodesma praetenue*, Ophiuridae juveniles and *Parexogone hebes* but these are absent from the standard description.
	f	G11A, G11B, G11C	Group f (3 samples); Within-group similarity=51.26%. Community was similar to SS.SSa.CFiSa.EpusOborApri but appeared to be a variant from muddier sediment, with some *Abra alba* and *Scalibregma inflatum* and *Ophelina acuminata*, instead of *Ophelia borealis*. It could be considered intermediate with muddy sand biotopes, such as *Abra alba* and *Nucula nitidosa* in circalittoral muddy sand or slightly mixed sediment 'SS.SSA.CMuSa.AalbNuc'.
Abra prismatica, *Bathyporeia elegans* and polychaetes in circalittoral fine sand **cf. SS.SSa.CFiSa.ApriBatPo** Biotope found in medium to fine sands.	a	G12C	Group a (1 sample); Within-group similarity=Not applicable. Community included Ophiuridae juveniles, *Moerella pygmaea* and *Abra prismatica* as dominant taxa but was impoverished relative to typical SS.SCS.ICS.MoeVen. There was also a specimen of *Bathyporeia elegans* to suggest that the biotope was closer to SS.SSa.CFiSa.ApriBatPo which is more typical of more mobile sediments than SS.SCS.ICS.MoeVen.

4 Discussion

The results in this report provide a robust pre-construction baseline for sediment composition and biota for comparison with the outputs of future post-construction sampling, which should be conducted using the same methodologies to ensure compatibility of results across surveys. The stations sampled during the current pre-construction baseline survey were also sampled during the 2010 EIA characterisation surveys, although three replicate grab samples were collected at each station for the current survey, whereas only one grab sample was taken at each station during the 2010 survey (CMACS 2011).

Overall, sediments were relatively homogenous across the OWF site and were predominantly sandy. Within the OWF site, Slightly gravelly sand was only recorded within one replicate at five of the stations. Gravelly sand was only recorded at one of the replicates at Station G3, and two replicates at Station G10. At the two reference stations G11 and G12, sediment was generally coarser than within the OWF site with sediment from just one replicate at Station G11 classed as Sand, and the other replicates classed as either Slightly gravelly sand or Gravelly sand. The results of PSA were similar to those for the 2010 site characterisation survey for the EIA, in which sediments at these stations were classed according to the same three categories (CMACS 2011). There is evidence that sediment type has remained broadly similar across the OWF site, with seven of the stations in the OWF site classed as Sand following the 2010 survey (based on BGS Folk categories) in comparison with the eight stations in 2015 at which two or more of the replicates were classed as Sand. In addition, the 2010 EIA characterisation survey results indicated that reference Station G11 was classed as Slightly gravelly sand, and G12 was Gravelly sand, which is consistent with the slightly greater gravel content of the reference stations recorded during the current pre-construction survey when compared to the majority of stations in the OWF site.

There was a biologically diverse community across the survey area, with a total of 231 taxa recorded across the twelve stations. There was some variation between stations in terms of both abundance and numbers of taxa, and trends in abundance across stations were found to reflect trends in taxon richness. The only species found with a conservation designation was the bivalve *Arctica islandica*, a Scottish PMF which is also on the OSPAR list of threatened and/or declining species and habitats. Nine *A. islandica* individuals were recorded across the survey and they were all juveniles, which is consistent with the three juvenile *A. islandica* recorded during the 2010 EIA characterisation survey (CMACS 2011). Several species were recorded that are new records or potential new species in UK waters; this is typical of large surveys due to the need for further taxonomic and ecological work on the British marine biota. No invasive non-native species were recorded.

The most abundant organism during the current survey was *C. praetenue,* a mollusc, which was recorded at every station and was also the taxon with the highest biomass. *C. praetenue* is a marine bivalve commonly found in temperate inshore sandy substrata and this taxon was also recorded in high abundances during the 2010 EIA characterisation survey (although it was not recorded at Stations G3 or G10 in the OWF site, or at the reference stations G11 or G12). Other abundant taxa included juvenile Ophiuridae (brittle stars), the pea sea urchin *E. pusillus* and the mollusc *A. prismatica.*

During the current survey, two sea urchin species (*S. purpureus* and *E. cordatum*) had high biomass at Station G4 only. *S. purpureus* and another sea urchin species *E. pusillus* had high biomass at two of the stations in 2010 (but not at the location of Station G4) (CMACS 2011). There were no clear attributes in the sediment composition data to explain the occurrence of these species at just one or two locations, although *S. purpureus* and *E. cordatum* are both large, mobile urchins and were found as single individuals only.

Across the OWF site and reference stations, molluscs and annelid polychaetes were the most abundant and species rich taxonomic groups, as was the case during the 2010 EIA characterisation survey (CMACS, 2011). A high abundance and diversity of marine polychaetes is typical of most marine sediments; Gage (2001) found that polychaetes consistently dominated soft bottom benthos from continental shelves to abyssal plains and revealed that over 50% of total macrofaunal individuals are generally composed of polychaete worms. There is evidence, however, that during this pre-construction baseline survey there were lower numbers of dominant polychaete taxa and notable differences in the abundance of dominant mollusc taxa when compared to the 2010 EIA characterisation survey (Table 7). There was a three-fold decrease in the abundance of *S. bombyx* within the OWF site stations with decreases most evident at Stations G2, 5, 6, 7, 8 and 9. Decreases in *O. borealis* were most evident at Stations G7-10, and for *G. lapidum* agg. were most evident at Stations G2, 7, 10 and 12. In addition, low numbers of *Hydroides norvegica* were recorded at Stations 1, 4, 5, 7 and 11 in the 2010 EIA characterisation survey but this species was not recorded from this pre-construction baseline survey. The small fanworm *Jasmineira caudata* was present at the reference Stations G11 and G12 during the 2010 EIA characterisation survey, but only one specimen (recorded as *Jasmineira* sp.) was found in samples from the pre-construction baseline survey and it was absent from G11 and G12.

In terms of molluscs, mean abundances of both *A. prismatica* and *C. praetenue* in samples from the pre-construction baseline survey were double those recorded in the 2010 EIA characterisation survey (Table 7). Increases in the abundance of *A. prismatica* were most evident at Stations G1, 2, 6, 7, 8, 9 and at both reference stations. The greatest increases in abundance of *C. praetenue* were at Stations 1, 2, 5, 6, 7 and 8, and some individuals were recorded at the reference stations in 2015 but not in 2010. There was a decrease in abundance of *M. pygmaea* between surveys within the OWF site which was most evident at Stations G4, 6, 7, 8, and 9; however, abundance of this species at the reference stations was greater in 2015 than in 2010. The abundance of *E. pusillus* within the OWF site in 2015 was almost double that recorded in 2010 during the EIA characterisation survey, and at the reference stations was almost five times the value recorded in 2010 (Table 7). However, the same key species were present across the survey area in 2010 and 2015 and such changes in relative abundance are likely to be within the range of potential natural variation, with variability in recruitment success and environmental conditions having a considerable influence on invertebrate abundance.

Overall, the results suggest that in broad terms there has been a limited degree of change in terms of the main substrate type at stations between the 2010 EIA characterisation survey and 2015 surveys, however, there have been changes in the abundances of key taxa. This has been reflected by a change in the dominant biotope assigned to stations across the survey stations.

All sample stations were assigned to the MoeVen biotope following the 2010 EIA characterisation survey (CMACS 2011). During this 2015 pre-construction survey, MoeVen was only assigned to three of the stations across the OWF site (G3, 5 and 10) and was not assigned to the reference stations. The dominant biotope at all of the other stations was EpusOborApri, for which the main characterising species were *E. pusillus* and *A. prismatica*.

Table 7: Comparison of abundance of key taxa between the 2010 EIA characterisation survey and the 2015 pre-construction survey.

Taxon	Number of individuals m^{-2} (mean across stations ± sd)			
	OWF site		Reference stations	
	2015	2010	2015	2010
Polychaeta				
Spiophanes bombyx	20 ± 18	66 ± 61	12 ± 17	20 ± 14
Ophelia borealis	19 ± 13	33 ± 34	0	0
Glycera lapidum agg.	5 ± 9	14 ± 22	15 ± 17	35 ± 35
Hydroides norvegica	0	7 ± 13	0	5 ± 7
Mollusca				
Abra prismatica	50 ± 40	20 ± 40	112 ± 50	0
Cochlodesma praetenue	83 ± 47	40 ± 26	27 ± 14	0
Moerella pygmaea	43 ± 31	63 ± 47	25 ± 21	5 ± 7
Echinodermata				
Echinocyamus pusillus	45 ± 20	24 ± 27	48 ± 50	10 ± 0

The MoeVen biotope was targeted by the survey due to its conservation status as a component biotope of the Scottish PMF 'Tide-swept coarse sands with burrowing bivalves' (SNH 2014). Although the number of stations assigned to MoeVen had decreased, the other two recorded biotopes, EpusOborApri and ApriBatPo, are component biotopes of the Scottish PMF 'Offshore subtidal sands and gravels' and are therefore also of marine nature conservation importance in Scottish territorial waters.

The difference in biotopes allocated following the 2010 and 2015 surveys are likely to be due primarily to changes in the relative abundances of the key taxa, which is likely to be due to natural variability, and potentially some variation in interpretation due to a lack of detailed definitions in the literature for some of the biotopes allocated (e.g. EpusOborApri), as opposed to a significant habitat change. For the MoeVen biotope, Connor *et al*. (2004) do not include *A. prismatica* within the list of characteristic taxa. One of the more noticeable differences in invertebrate communities between the 2010 and 2015 surveys was that *A. prismatica* was only recorded at five of the stations in 2010 and, when it was present, there were usually one or two individuals. In 2015, however, *A. prismatica* was recorded at every station and for many of the replicates was one of the most abundant taxa present, which has resulted in the allocation of the EpusOborApri biotope. It should be noted that none of the communities in either year fitted the classification perfectly for MoeVen or EpusOborApri and there is potential for transition between these biotopes with subtle changes in the abundance of key taxa.

Overall, multivariate statistical analyses found the invertebrate communities for 20 of the 36 replicates to be statistically indistinguishable. There was evidence of a weak correlation between the multivariate patterns observed in the sediment data and in the faunal communities. The main biotopes present were recorded as MoeVen or EpusOborApri, with the prefix ‘cf.’ used to indicate biotopes that were closest to a particular described biotope but not necessarily an exact fit which reflects uncertainty due to subjective definitions as indicated above. Further survey will clarify if EpusOborApri remains the dominant biotope across the survey area or if there is potential for natural transition back to the MoeVen biotope.

5 Bibliography

Blott S. J. & Pye K. 2001. GRADISTAT: a grain size distribution and statistics package for the analysis of unconsolidated sediments. *Earth Surface Processes and Landforms*, 26, 1237-1248.

Bratton J. H. 1991. *British Red Data Books: 3. Invertebrates other than insects*. Joint Nature Conservation Committee, Peterborough.

Clarke K. R. & Warwick R. M. 2006. *Change in marine communities: an approach to statistical analysis and interpretation*, 2nd edition. PRIMER-E: Plymouth, UK.

Connor D., Allen J., Golding N., Howell l K., Lieberknecht L., Northen K. & Reker J. B. 2004. *The Marine Habitat Classification for Britain and Ireland Version 04.05.* JNCC Report, Peterborough. ISBN 1 861 07561 8.

Cooper K. M. & Mason C., 2014. Regional Seabed Monitoring Plan (RSMP): Protocol for Sample Collection and Processing. Version 4.0. 31pp.

CMACS 2011. Beatrice Offshore Wind farm: Benthic Survey 2010 Technical Report. Ref: J3151 Beatrice Benthic Technical Report.

CSEMP 2012. Marine Assessment and Review Group (MARG) UK Clean Seas Environment Monitoring Programme (CSEMP) Green Book. Available from: http://cefas.defra.gov.uk/media/510362/greenbookv15.pdf

EC Habitats Directive 92/43/EEC. Council Directive of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora. [Accessed online 23-Sep-2010] Available from: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31992L0043:EN:html

EN ISO 16665:2014(E), 2014. Water Quality – Guidelines for qualitative sampling and sample processing of marine soft-bottom macrofauna.

Folk R. 1954. The distinction between grain size and mineral composition in sedimentary-rock nomenclature. *Journal of Geology*, 62: 344-359.

Gage J.D. 2001. Deep-sea benthic community and environmental impact assessment at the Atlantic Frontier. *Continental Shelf Research*, 21: 957-986.

Long D. 2006. BGS detailed explanation of seabed sediment modified folk classification. http://www.emodnet-seabedhabitats.eu/PDF/GMHM3_Detailed_explanation_of_seabed_sediment_classification.pdf.

Mason C. 2011. Particle Size Analysis (PSA) for Supporting Biological Analysis. NMBAQC's Best Practice Guidance. National Marine Biological Analytical Quality Control Scheme.

OSPAR 2004. OSPAR Guidelines for monitoring environmental impact of offshore oil and gas activities. Joint Assessment and Monitoring Programme. OSPAR Agreement 2004-11E. http://www.ospar.org/v_measures/browse.asp

OSPAR 2008. OSPAR List of Threatened and/or Declining Species and Habitats (OSPAR Reference Number: 2008-6). http://www.ospar.org/documents/DBASE/DECRECS/Agreements/08-06e_OSPAR%20List%20species%20and%20habitats.doc

Ricciardi A. & Bourget E. 1998. Weight-to-weight conversion factors for marine benthic macroinvertebrates. *Marine Ecology Progress Series*,163: 245-251.

Scottish Natural Heritage 2014. Priority Marine Features in Scottish Seas

Wentworth C. K., 1922. A scale of grade and class terms for clastic sediments. Journal of Geology, 30: 377-392.

Worsfold T. M & Hall D. J. 2010. National Marine Biological Analytical Quality Control Scheme: Guidelines for processing marine macrobenthic invertebrate samples: a Processing Requirements Protocol, Version 1.0, June 2010. Edited by Myles O'Reilly. National Marine Biological AQC Coordinating Committee.

Appendix 1 – Target and Actual Sampling Locations

Station	Sample	Water Depth	Target		Actual	
			Easting	Northing	Easting	Northing
G1	A	47.7	508190	6458076	508191	6458078
G1	B	46.0	508190	6458076	508182	6458070
G1	C	45.7	508190	6458076	508190	6458059
G2	A	45.8	510459	6457802	510466	6457805
G2	B	45.6	510459	6457802	510447	6457796
G2	C	46.0	510459	6457802	510458	6457792
G3	A	40.5	505649	6453993	505651	6453995
G3	B	40.6	505649	6453993	505641	6454006
G3	C	40.2	505649	6453993	505644	6453997
G4	A	41.4	503140	6453052	503141	6453060
G4	B	41.3	503140	6453052	503136	6453044
G4	C	40.9	503140	6453052	503140	6453053
G5	A	37.6	501891	6451778	501894	6451783
G5	B	37.7	501891	6451778	501893	6451783
G5	C	37.6	501891	6451778	501885	6451779
G6	A	50.5	507447	6462475	507468	6462480
G6	B	50.8	507447	6462475	507440	6462467
G6	C	50.9	507447	6462475	507438	6462474
G7	A	46.4	505533	6457517	505535	6457511
G7	B	46.8	505533	6457517	505525	6457515
G7	C	46.3	505533	6457517	505522	6457509
G8	A	43.2	502512	6455464	502521	6455456
G8	B	43.0	502512	6455464	502515	6455461
G8	C	43.2	502512	6455464	502513	6455459
G9	A	43.0	505599	6455562	505599	6455559
G9	B	43.1	505599	6455562	505601	6455557
G9	C	42.9	505599	6455562	505597	6455559
G10	A	38.8	504341	6450673	504333	6450686
G10	B	39.3	504341	6450673	504320	6450673
G10	C	39.5	504341	6450673	504339	6450668
G11	A	51.7	525425	6462365	525437	6462356
G11	B	51.4	525425	6462365	525429	6462354
G11	C	51.6	525425	6462365	525425	6462356
G12	A	45.3	524877	6468746	524881	6468733
G12	B	45.9	524877	6468746	524878	6468738
G12	C	46.0	524877	6468746	524870	6468746

Appendix 2 – Field Sampling Logsheets

Provided separately as an electronic data sheet

Appendix 3 – Raw Macrobiota Data and PSA Data

Provided separately as an electronic data sheet

Appendix 4 – Notable taxa recorded within samples

Code	Taxa ID	Qualifiers	Notes
P0319	*Podarkeopsis capensis*		Traditional usage; but possibly a related species
P0351	*Syllis garciai*		Not yet formally recorded from UK
P0351	*Syllis licheri*		Not yet formally recorded from UK
P0358	*Syllis parapari*		Not yet formally recorded from UK
P0358	*Syllis pontxioi*		Not yet formally recorded from UK
P0430	*Sphaerosyllis* cf. *taylori*		May be new species
P0458	*Rullierinereis ancornunezi*		only recently published as a UK species
P0783	*Scolelepis squamata*	Type A	Possible undescribed species
P0790	*Spio filicornis*	aggregate	May include undescribed species or new UK records
P0790	*Spio symphyta*		Not yet formally recorded from UK
P1117	*Sabellaria spinulosa*		Represents habitat of conservation value, if in large numbers
P1264	*Dialychone* "species A"		Possible new species
22110000	Piscicolidae		Rarely recorded
S0005	*Nebalia reboredae*		Not yet formally recorded from UK
S0132	*Pontocrates* "species A"		Possible undescribed species
S1168	*Tanaissus danica*		Northern species in UK waters
W1715	*Crenella decussata*		Northern species in UK waters
W2072	*Arctica islandica*	juvenile	Long lived; OSPAR-listed
ZG0444	*Ammodytes tobianus*		Commercially important

Appendix 5 – Distribution of key taxa across stations

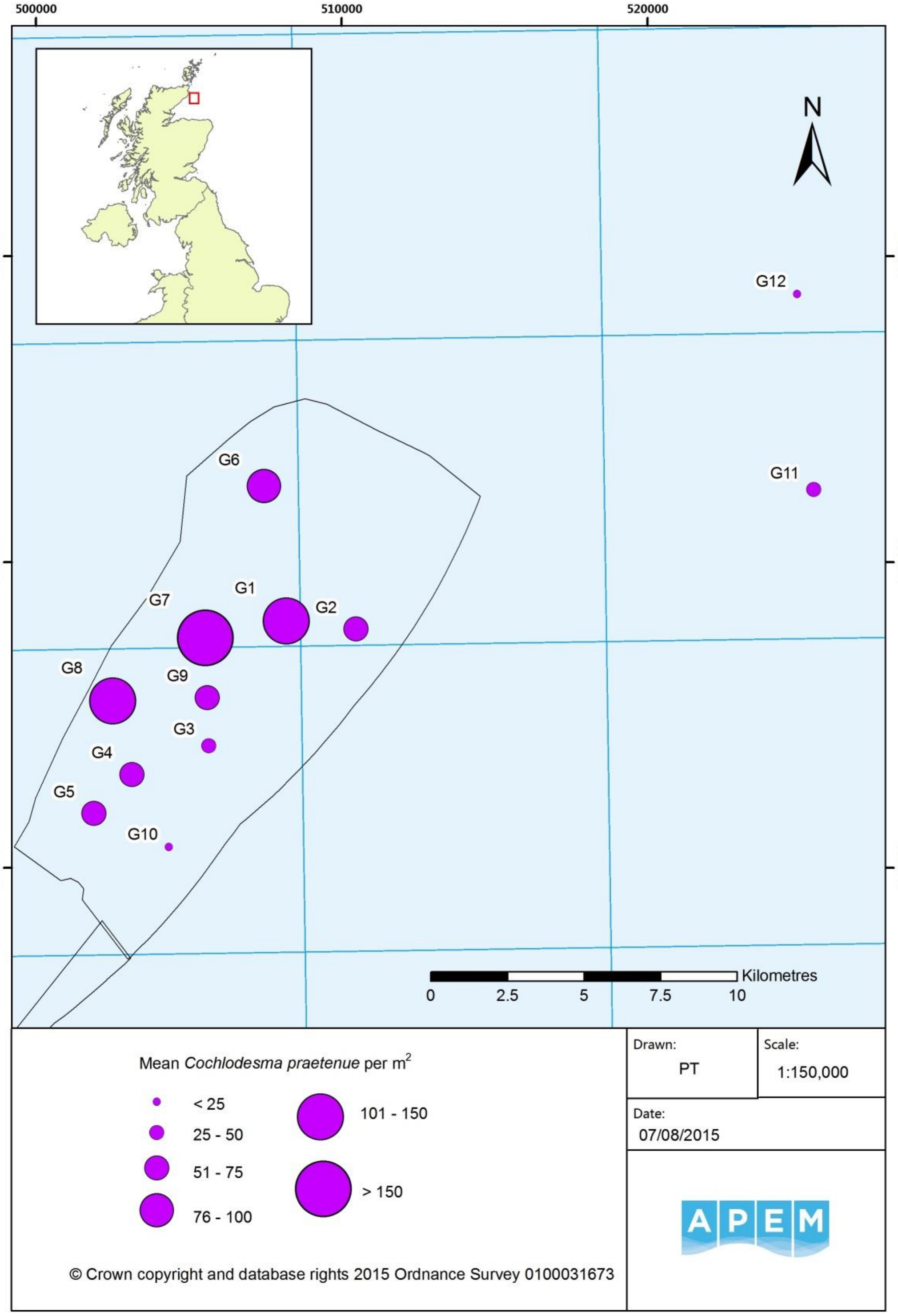

Figure A4.1: Number of *Cochlodesma praetenue* per m^2 across stations (mean across replicates).

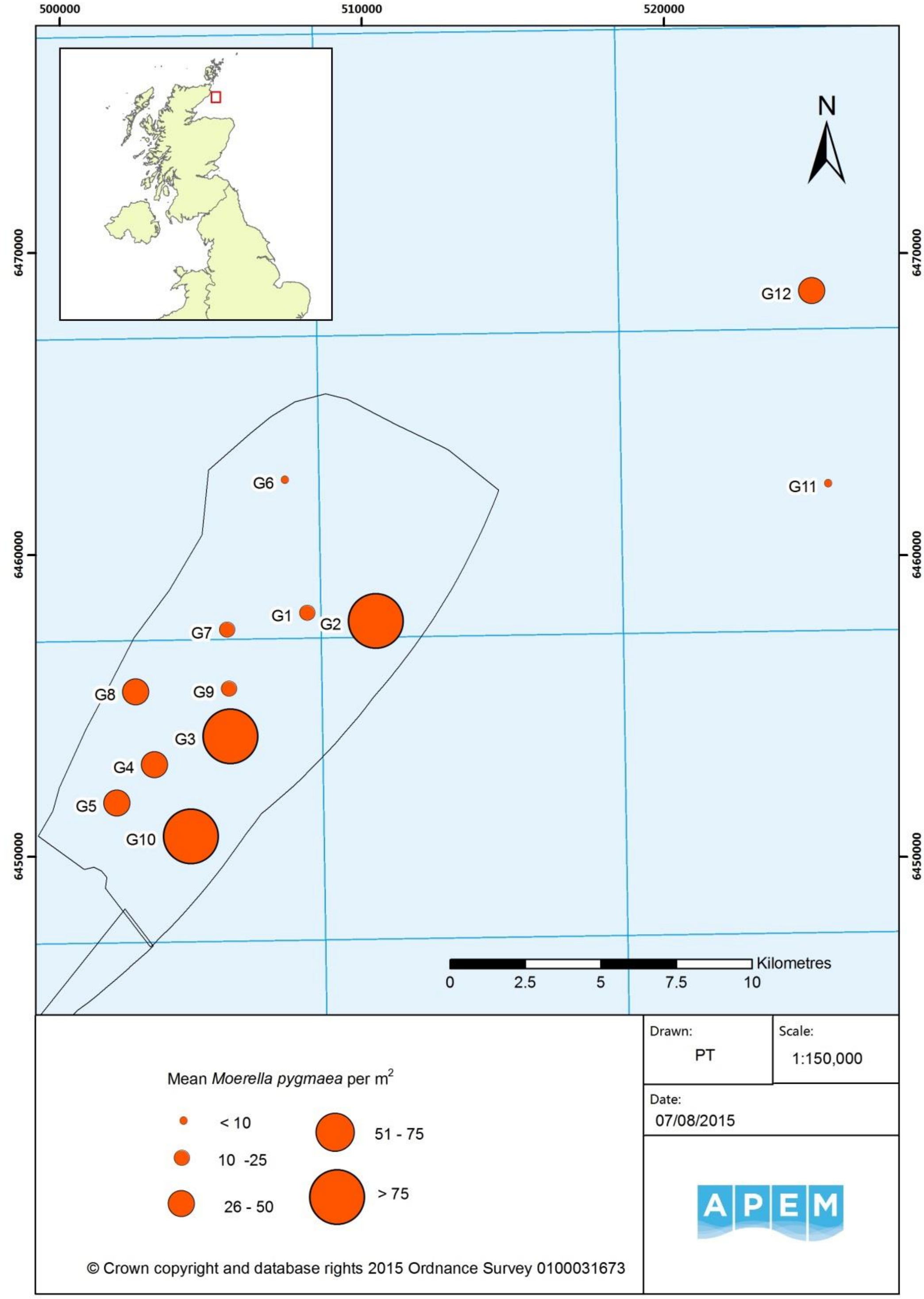

Figure A4.2: Number of *Moerella pygmaea* per m^2 across stations (mean across replicates).

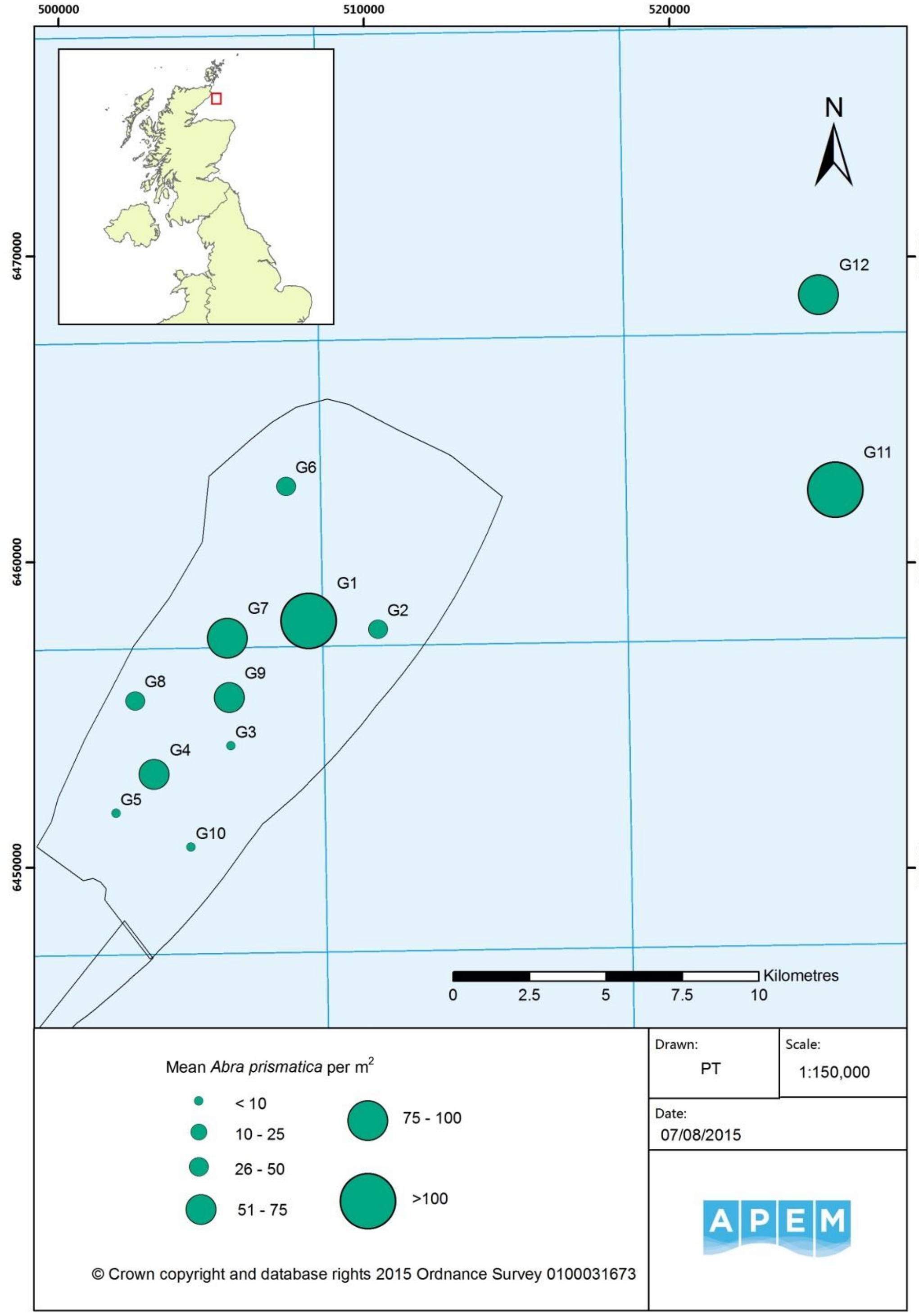

Figure A4.3: Number of *Abra prismatica* per m^2 across stations (mean across replicates).

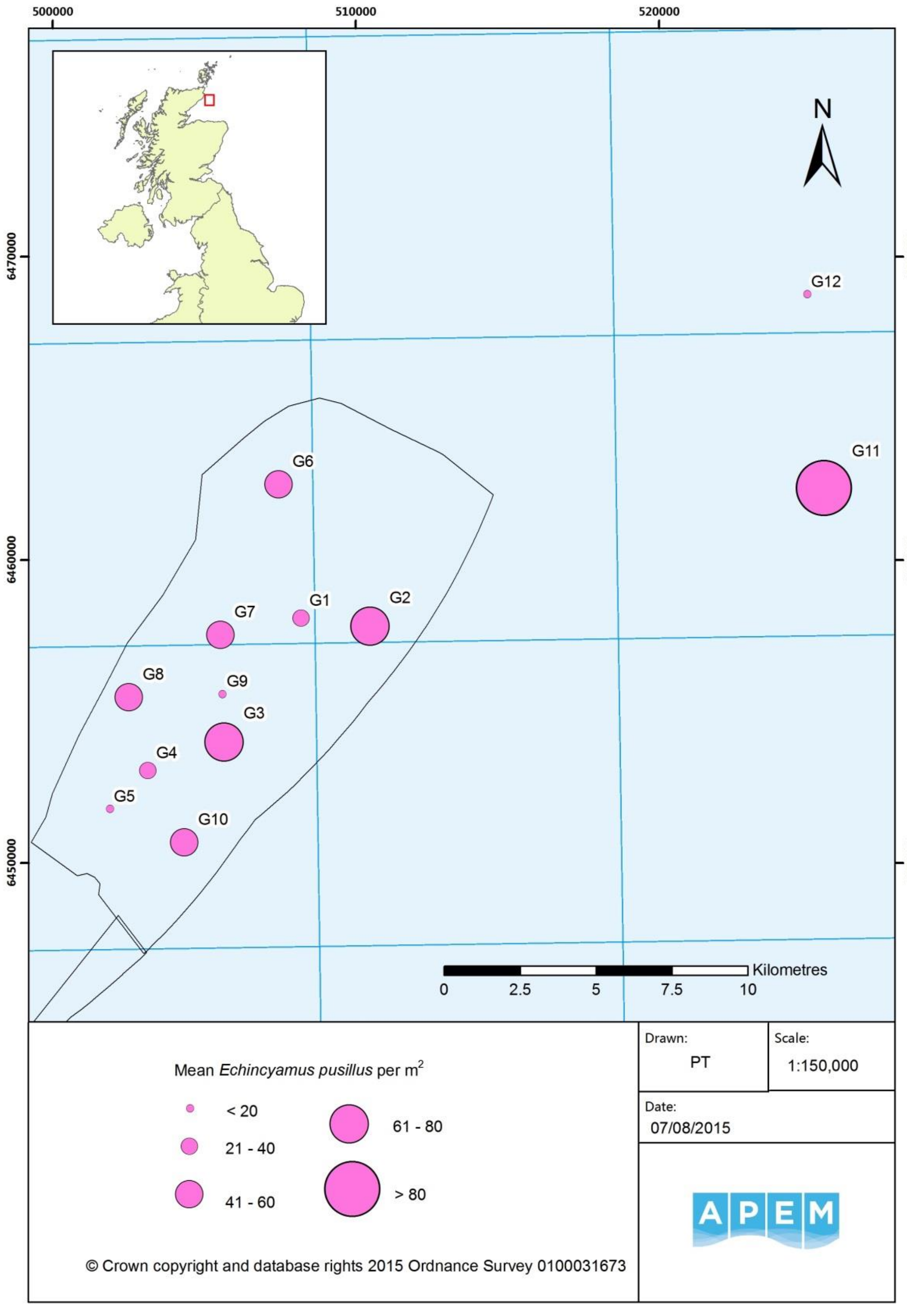

Figure A4.4: Number of *Echinocyamus pusillus* per m^2 across stations (mean across replicates).

Appendix 6 – SIMPER outputs

Similarity Percentages - species contributions

One-Way Analysis

Data worksheet
Name: Sq Rt Transformed
Data type: Abundance
Sample selection: All
Variable selection: All

Parameters
Resemblance: S17 Bray Curtis similarity
Cut off for low contributions: 90.00%

Factor Groups

Sample	SIMPROF
G1A	e
G1B	e
G2A	e
G2B	e
G2C	e
G4A	e
G4B	e
G4C	e
G6A	e
G6B	e
G7A	e
G7B	e
G7C	e
G8A	e
G8B	e
G8C	e
G9A	e
G9B	e
G12A	e
G12B	e
G1C	d
G6C	d
G3A	h
G3C	h
G10A	h
G10B	h
G10C	h
G3B	g
G5A	c
G5B	c
G5C	c
G9C	b
G11A	f
G11B	f
G11C	f
G12C	a

Group a
Less than 2 samples in group

Group b
Less than 2 samples in group

Group c
Average similarity: 46.17

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Cochlodesma praetenue	2.63	10.79	6.58	23.38	23.38
Moerella pygmaea	1.61	6.27	36.00	13.57	36.95
Spio goniocephala	1.28	5.06	4.33	10.95	47.90
Chaetozone christiei	1.28	5.05	4.52	10.94	58.84
Spisula elliptica	1.00	4.43	36.00	9.60	68.44
Ophiuridae	0.80	1.51	0.58	3.27	71.71
Dipolydora coeca	0.67	1.49	0.58	3.23	74.94
Spiophanes bombyx	1.08	1.49	0.58	3.23	78.17
Spisula	1.00	1.49	0.58	3.23	81.41
Ophelia borealis	0.91	1.43	0.58	3.10	84.51
Travisia forbesii	0.80	1.43	0.58	3.10	87.60
Abra prismatica	0.67	1.43	0.58	3.10	90.70

Group d
Average similarity: 50.01

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Ophiuridae	3.93	5.91	-	11.81	11.81
Echinocyamus pusillus	2.34	3.53	-	7.06	18.87
Parexogone hebes	2.28	2.73	-	5.47	24.33
Abra prismatica	2.37	2.73	-	5.47	29.80
Exogone naidina	1.41	2.23	-	4.46	34.26
Spiophanes bombyx	1.57	2.23	-	4.46	38.73
Ophelia borealis	1.57	2.23	-	4.46	43.19
Gattyana cirrhosa	1.00	1.58	-	3.16	46.35
Eumida ockelmanni	1.37	1.58	-	3.16	49.50
Sphaerosyllis cf. *taylori*	1.00	1.58	-	3.16	52.66
Sphaerosyllis cf. *taylori*	1.00	1.58	-	3.16	55.81
Scoloplos armiger	1.21	1.58	-	3.16	58.97
Aonides paucibranchiata	1.50	1.58	-	3.16	62.13
Chaetozone christiei	1.21	1.58	-	3.16	65.28
Leiochone	1.62	1.58	-	3.16	68.44
Perioculodes longimanus	1.00	1.58	-	3.16	71.59
Bathyporeia guilliamsoniana	1.00	1.58	-	3.16	74.75
Siphonoecetes striatus	1.21	1.58	-	3.16	77.91
Eudorellopsis deformis	1.37	1.58	-	3.16	81.06
Spisula	1.21	1.58	-	3.16	84.22
Cochlodesma praetenue	2.30	1.58	-	3.16	87.38
Amphiura filiformis	1.00	1.58	-	3.16	90.53

Group e
Average similarity: 46.95

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Cochlodesma praetenue	2.99	5.90	2.98	12.57	12.57
Abra prismatica	2.58	5.22	3.53	11.12	23.69
Ophiuridae	2.33	4.27	2.08	9.09	32.78
Echinocyamus pusillus	1.85	3.42	2.32	7.28	40.07
Moerella pygmaea	1.66	2.76	1.27	5.87	45.93
Spisula	1.38	2.03	1.04	4.31	50.25
Nephtys cirrosa	0.98	1.80	1.23	3.83	54.08

Spiophanes bombyx	1.24	1.78	1.04	3.79	57.87
Chamelea striatula	1.12	1.75	1.21	3.73	61.59
Crenella decussata	1.18	1.48	0.91	3.15	64.74
Ophelia borealis	1.02	1.39	0.89	2.96	67.71
Chaetozone christiei	0.91	1.11	0.77	2.37	70.08
Amphiuridae	0.85	1.07	0.80	2.28	72.36
Bathyporeia guilliamsoniana	0.84	1.05	0.80	2.24	74.60
Travisia forbesii	0.83	1.02	0.70	2.18	76.78
Polycirrus	0.90	1.02	0.69	2.16	78.94
Edwardsia claparedii	0.90	0.98	0.70	2.09	81.03
Gari fervensis	0.74	0.86	0.71	1.83	82.87
NEMERTEA	0.70	0.83	0.71	1.76	84.63
Scoloplos armiger	0.65	0.77	0.63	1.64	86.27
Spio goniocephala	0.69	0.72	0.63	1.54	87.80
Owenia	0.61	0.60	0.54	1.27	89.07
Phaxas pellucidus	0.49	0.44	0.48	0.93	90.00

Group f

Average similarity: 51.26

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Abra prismatica	3.80	5.12	11.95	9.99	9.99
Ophiuridae	3.14	3.60	5.54	7.03	17.02
Echinocyamus pusillus	2.79	3.36	2.30	6.56	23.58
Owenia	1.99	2.68	50.50	5.23	28.81
Abra alba	2.14	2.40	3.59	4.68	33.49
Aricidea cerrutii	1.87	2.26	5.25	4.40	37.89
Phascolion strombus	1.52	2.09	11.95	4.08	41.97
Scalibregma inflatum	1.66	1.86	2.46	3.63	45.60
Gattyana cirrhosa	1.55	1.69	4.08	3.29	48.90
Spiophanes bombyx	1.47	1.69	4.08	3.29	52.19
Eumida ockelmanni	1.00	1.48	11.95	2.88	55.07
Glycera lapidum	1.48	1.48	11.95	2.88	57.96
Goniada maculata	1.00	1.48	11.95	2.88	60.84
Nephtys	1.33	1.48	11.95	2.88	63.72
Chaetozone christiei	1.48	1.48	11.95	2.88	66.61
Ophelina acuminata	1.14	1.48	11.95	2.88	69.49
Polycirrus	1.14	1.48	11.95	2.88	72.37
Crenella decussata	1.14	1.48	11.95	2.88	75.26
Grania	1.24	1.48	11.95	2.88	78.14
Cochlodesma praetenue	1.56	1.13	0.58	2.21	80.35
Aponuphis bilineata	1.05	0.74	0.58	1.45	81.80
Sigalionidae	1.05	0.71	0.58	1.39	83.19
Urothoe marina	0.94	0.63	0.58	1.23	84.42
NEMATODA	1.76	0.63	0.58	1.23	85.66
Exogone verugera	0.91	0.53	0.58	1.03	86.68
Nephtys cirrosa	0.67	0.53	0.58	1.03	87.71
Nothria hyperborea	0.80	0.53	0.58	1.03	88.74
Notomastus	0.80	0.53	0.58	1.03	89.76
Pista cristata (sensu Jirkov)	0.67	0.53	0.58	1.03	90.79

Group g

Less than 2 samples in group

Group h

Average similarity: 50.99

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Moerella pygmaea	3.06	6.19	6.78	12.15	12.15
Echinocyamus pusillus	2.27	4.09	4.66	8.02	20.17
Polycirrus	1.90	3.43	4.35	6.73	26.90
Ophelia borealis	1.60	3.20	9.41	6.27	33.17

NEMATODA	1.78	2.80	4.15	5.49	38.66
Spisula	1.68	2.69	5.83	5.28	43.94
NEMERTEA	1.49	2.56	3.86	5.03	48.97
Glycera lapidum	1.25	2.38	5.20	4.68	53.65
Ophiuridae	1.59	1.99	1.12	3.89	57.54
Cochlodesma praetenue	1.42	1.62	0.98	3.17	60.72
Aonides paucibranchiata	1.20	1.56	1.05	3.06	63.77
Aricidea cerrutii	1.11	1.49	1.09	2.92	66.70
Syllis pontxioi	1.11	1.48	1.09	2.91	69.61
Aponuphis bilineata	1.11	1.46	1.14	2.86	72.47
Scoloplos armiger	0.88	1.32	1.15	2.59	75.06
Edwardsia claparedii	0.88	1.22	1.15	2.40	77.45
Spiophanes bombyx	0.80	1.22	1.15	2.39	79.84
Owenia	0.77	0.81	0.61	1.59	81.44
Pisione remota	0.77	0.73	0.61	1.42	82.86
Notomastus	0.80	0.72	0.62	1.41	84.27
Syllis parapari	0.60	0.60	0.62	1.18	85.44
Aglaophamus agilis	0.68	0.60	0.62	1.17	86.62
Abra prismatica	0.75	0.60	0.62	1.17	87.79
Thracia villosiuscula	0.75	0.60	0.62	1.17	88.96
Unciola planipes	0.60	0.57	0.62	1.12	90.07

Appendix 7 – RELATE and BIO-ENV test

RELATE

Rank correlation method: Spearman

Sample statistic (Rho): 0.395
Significance level of sample statistic: 0.1 %
Number of permutations: 999

Number of permuted statistics greater than or equal to Rho: 0

BIO-ENV

Parameters
Rank correlation method: Spearman
Method: BIOENV
Maximum number of variables: 16
Resemblance:
Analyse between: Samples
Resemblance measure: D1 Euclidean distance

Variables
1 Mean um
2 Coarse Gravel
3 Medium Gravel
4 Fine Gravel
5 V Fine Gravel
6 V Coarse Sand
7 Coarse Sand
8 Medium Sand
9 Fine Sand
10 V Fine Sand
11 V Coarse Silt
12 Coarse Silt
13 Medium Silt
14 Fine Silt
15 V Fine Silt
16 Clay

Global Test
Sample statistic (Rho): 0.537
Significance level of sample statistic: 1%
Number of permutations: 99 (Random sample)
Number of permuted statistics greater than or equal to Rho: 0

Best results

No.Vars	Corr.	Selections
6	0.537	1,6-8,10,16
7	0.537	1,4,6-8,10,16
8	0.536	1,4,6-10,16
5	0.536	1,6-8,16
6	0.536	4,6-8,10,16
4	0.536	1,6,7,16
6	0.536	1,6-8,10,15
9	0.536	1,4,6-10,15,16
5	0.535	4,6-8,16
7	0.535	1,6-10,16