

5. BENTHIC ORGANISMS

Summary of previous survey results

With two years post-construction data available, it is possible to suggest that observed variability in the measured benthic invertebrate community parameters is more closely related to factors that are believed to be subject to natural variability, such as local sediment characteristics, than the construction and operation of the offshore wind farm.

Benthic communities would be expected to respond to variation in seabed sediment characteristics, especially particle size, as a primary factor influencing community composition and distribution. The absence of any identifiable trend in sediment particle size characteristics associated with construction of the offshore wind farm suggests that North Hoyle has not, to date, affected benthic invertebrate communities through this mechanism.

5.1 INTRODUCTION

As part of the FEPA benthic monitoring programme devised with the input from the relevant statutory agencies, 17 sites were identified for an annual benthic grab survey to monitor impacts of the NHOWF on the subtidal benthic invertebrate communities. These 17 sites were initially surveyed in 2002 prior to construction activity and then again in 2003 when some construction activities were still being undertaken but all of the wind farm monopiles were in place and cabling completed. For the 2003 survey three new sites were added within the turbine array (following further consultation with CCW). These were located at 65, 117 and 168 m west of turbine 18 (chosen at random) and were designed to monitor the impacts of scour (if any) upon the benthic communities within the wind farm array. All 20 sites were surveyed again during 2004, 2005 and finally in 2006 as part of the ongoing monitoring programme for North Hoyle (see Figure 5.1 for monitoring site locations).

The following section presents the data from the 2006 grab survey, in addition to reviewing the data from all five of the monitoring surveys (2002-2006) endeavouring to test if the statements within the NH EIA concerning the impacts of the wind farm construction and operational phases upon the surrounding benthic communities were indeed correct.

5.2 METHODS

5.2.1 Field survey

Surveys were planned and undertaken during September 2006 to maximise comparability between previous surveys. As with the previous monitoring surveys all samples were obtained using a standard 0.1^m2 (10 litre) Day grab and all the monitoring survey sites were repeated. The survey was undertaken using the survey vessel 'Aquadynamic' (Aquatech Ltd) operating on a daily basis out of the Port of Conwy.

The methods used for the 2006 post-construction surveys were the same as those in the post construction surveys of 2005 and 2004, the construction survey of 2003, pre-construction

survey of 2002 and the initial baseline survey of 2001. This was to allow direct comparisons to be undertaken from results of all three surveys.

Triplicate grab samples were taken at each of the 20 monitoring sites for faunal analysis. Standard CMACS Quality Control (QC) measures were applied to all grab samples with grabs being rejected if the volume of the returned grab was less than 5 Litres in volume. Grabs were also rejected if the jaws were held open e.g. by loose stones or gravel on the return to surface. If samples were rejected then the grab was redeployed to obtain a sample suitable for analysis. No sample was obtained from site 14 due to pebbles repeatedly preventing the jaws from closing.

Once a suitable sample had been recovered it was released from the grab onto a 1mm mesh sieve and photographed prior to being washed using a seawater hose. Once the majority of the <1mm sediment had been washed through the sieve, the remaining sample volume was transferred into a labelled bucket and fixed with a buffered formalin solution with a final concentration of 4%.

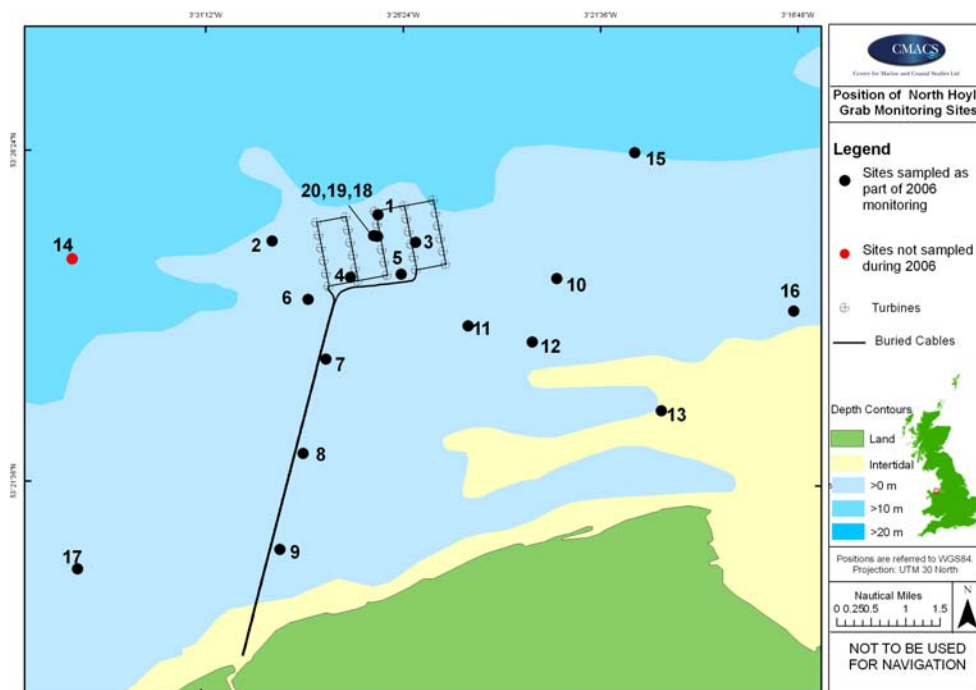


Figure 5.1: Benthic monitoring site locations (refer to Appendix for coordinates)

5.2.2 Laboratory Sample Analysis

In the laboratory each sample was carefully rinsed over a 1mm sieve using fresh water until all the formalin was removed. The samples were then carefully sorted with the aid of low power microscopes where necessary, and all fauna were sorted into pots according to major faunal groups (molluscs, worms, crustacea, echinoderms and “others”) and preserved in 70% alcohol.

All fauna were identified to the highest possible taxonomic level i.e. to species wherever possible, and numbers were counted. In general, where specimens were damaged the number of heads present was used as the indicator of numbers (e.g. worms) and colonial fauna were recorded on a presence or absence basis. All data was then entered into an Access database.

Quality control procedures included the preparation of a reference collection containing examples of all taxa found, which was stored in alcohol, the re-sorting by an experienced sorter of a random selection of the samples (typically 10%) with the requirement that if specimens equating to more than 5% of the total specimens found (or more than 10% of any one group), then that batch of samples would all have to be re-sorted; cross-checking of all data entered into the database against lab records; and the use of a experienced benthic laboratory which has analysed thousands of samples from the North Wales coast and takes part in the National Marine Biological Quality Control (NMBAQC) scheme.

5.2.3 Data Analysis

Once the raw data had been obtained from the sorted samples and transferred into electronic format, statistical analysis was undertaken using a variety of univariate and multivariate techniques to provide information concerning species richness, universal features of community structure and diversity indices. PRIMER Version 5 was used for the multivariate analyses.

Multivariate analysis was in general based on square-root transformed abundance of species numbers, which balances the effects of rare and common species, and using the Bray-Curtis similarity coefficient (Bray and Curtis, 1957). The whole dataset was used (i.e. very rare organisms were not ignored, as is sometimes done), and colonial organisms, which were recorded on a presence or absence basis, were assigned a value of 1 for analytical purposes.

Multi-Dimension Scaling (MDS) plots together with the associated dendrograms (both based on the Bray-Curtis similarity coefficient) were used as the visual outputs from the multivariate analysis. These were based on individual sample data in order to investigate the relationships between replicates and between sample sites in the 2005 survey, and on combined data from each site (averaged so that sites with less than three replicates could be included) in order to allow easier comparison between different years. Stress values are provided for each MDS plot; a stress value of <0.05 indicates that there is an excellent representation of the relationship between the various samples, 0.1 indicates good ordination and 0.2 indicates a potentially useful 2-dimensional picture (Clarke and Warwick, 1994). In order to investigate the effect of the environmental data on the stations, the MDS plot from the above analysis was repeated with sediment classification superimposed.

Additional statistical analysis was also undertaken on the 5 year monitoring data set using ANOSIM (analysis of similarity) again using Primer V5 (see section 5.5). The main purpose of this analysis was to investigate whether there was any detectable change in communities over the five year period within and adjacent to the NHOWF.

5.3 RESULTS FROM 2006 MONITORING SURVEY

Invertebrate abundance data from the 2006 grab sampling survey at the NHOWF are provided in Appendix 5.3. In total 9,664 individuals from 244 taxa were recorded. The number of individuals found at each site has been geographically displayed in Figure 5.2. This figure is based upon the count of identified individual benthic invertebrates pooled across the three replicate samples obtained at each monitoring site. A further 21 species of colonial invertebrates (mostly bryozoans and tunicate species) were recorded as present at several sites across the development area. These have been included within the taxa counts but not the individual counts as they were recorded on a presence or absence basis due to the difficulty of quantifying such species.

The largest numbers of individuals were recorded at site 18 (1531) which is the monitoring site located closest to one of the operating turbines within the array (see inset of Figure 4 below). Overall, sites with the largest numbers of individuals were recorded from either within the array or along the cable route. The lowest numbers of individuals were recorded from the monitoring sites located to the east of the wind farm: sites 15 (76), 11 (77) and 13 (80).

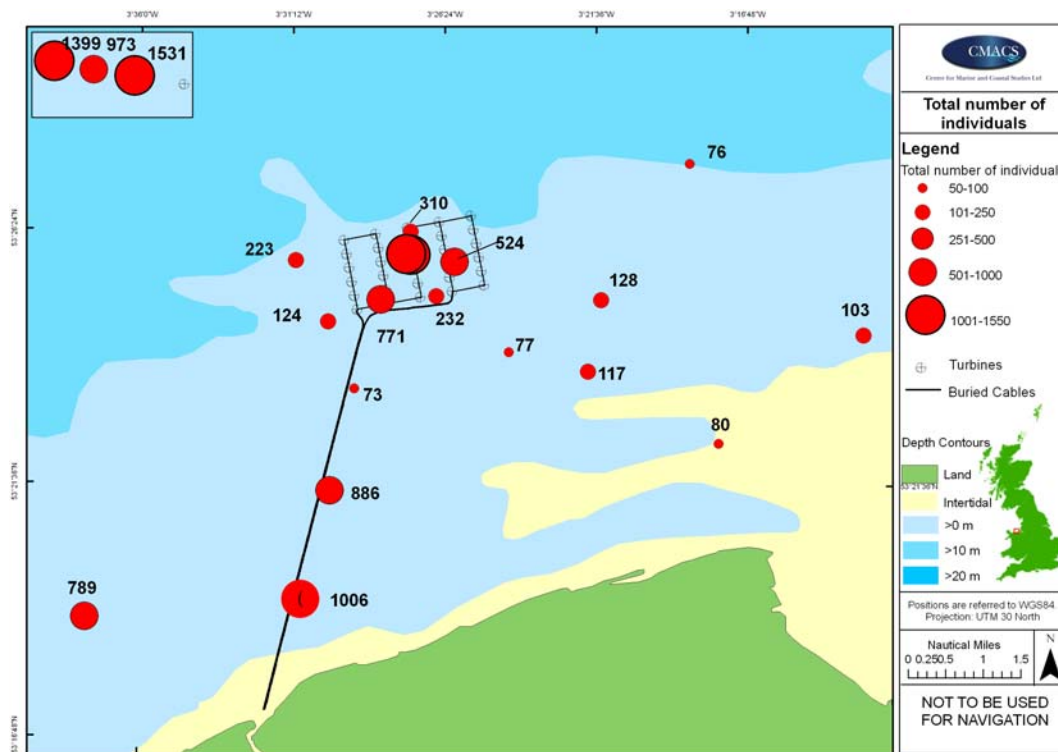


Figure 5.2 Total numbers of individuals. These data represent the pooled number of individuals recorded from 3 replicate sediment samples taken at each grab station (see Figure 5.1 for site locations). Colonial taxa not recorded numerically are not included above. These taxa were recorded as present or absent and are listed within Error! Reference source not found..

Invertebrate abundance data from all grab sampling surveys (2002-2006) at NHOWF are displayed graphically in Figure 5.3. The results for sites 18, 19 and 20 have been displayed separately within Figure 5.4 below as monitoring did not commence at these sites until after turbine construction during 2003. As highlighted within previous monitoring reports a general decline in invertebrate numbers is evident across the monitoring sites both within the array area itself and at outside control sites from the start of the data collection in 2002 up to 2005. An increase is then observed during 2005 with sites 4, 5, 8, 9 and 12 recording some of the highest numbers for the time series monitored. Sites 4 and 5 are located within the wind farm array and sites 8 and 9 are located at the inshore area of the cable route. Site 12, which had the highest number of individuals from all sites for 2005, is one of the control sites located to the east of the wind farm. High numbers for this site in 2005 were attributable to large records of the molluscan species *Donax vittatus* (banded wedge shell).

The 2006 results also display a similarity to the number of individuals recorded during 2005 at the majority of sites both within and outside the turbine array. The greatest exception to this is observed at site 12 (outside the array) where there is a large difference in the number of individuals compared to 2005. This is again attributable to the species *Donax vittatus* (only 11 recorded during 2006 compared to 1146 in 2005- based upon averaged data). This species is considered to be an important food source for several bird species occurring in Liverpool Bay including the common scoter, *Melanitta nigra*, and such fluctuations in the abundance of this species both seasonally and from year to year are relatively common.

The most consistent overall downward trend in numbers from 2002 through to 2006 is observed at sites 6, 11 and 13, all of which are outside of the wind farm. The greatest reduction was at site 13, close to the mouth of the Dee estuary, where a community rich in polychaetes and anemones on sandy-gravel sediments in 2002 was replaced by less rich communities on sandier sediments in subsequent years.

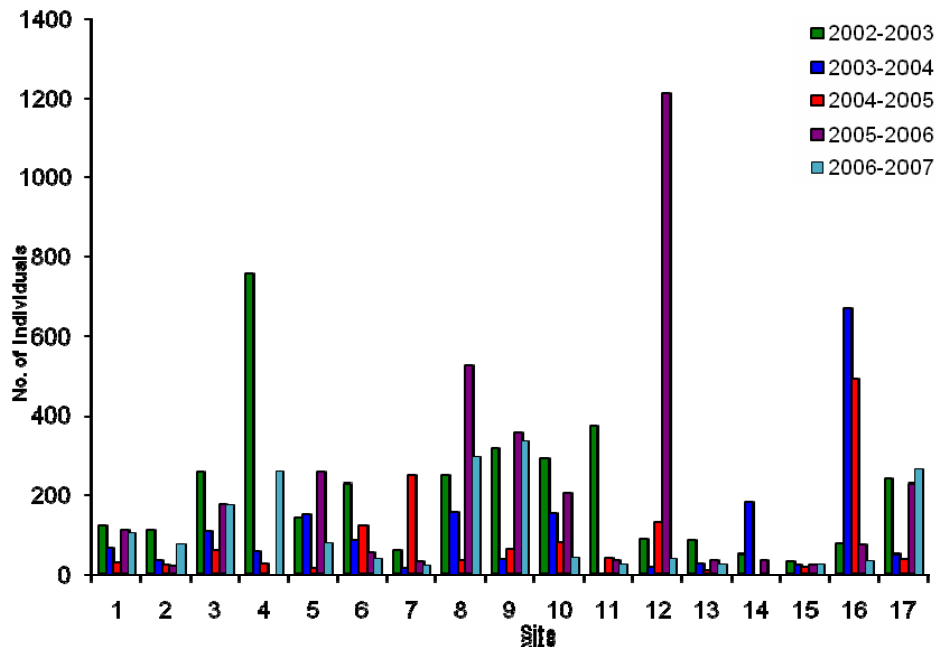


Figure 5.3 Numbers of individuals per 0.1 m² displayed graphically for 2002 (green), 2003 (royal blue), 2004 (red), 2005 (purple) and 2006 (pale blue) as averaged over 3 replicates per site.

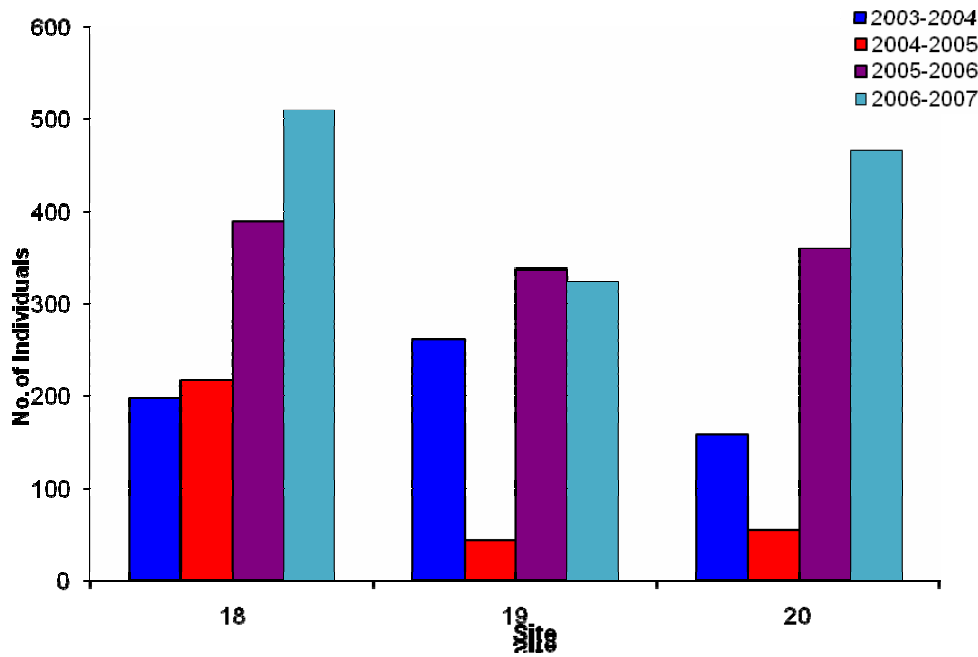


Figure 5.4 Numbers of individuals per 0.1 m² for sites 18, 19 and 20 displayed graphically for 2003 (blue), 2004 (red), 2005 (purple) and 2006 (royal blue) averaged over 3 replicates per site.

The number of taxa recorded at each monitoring site is displayed within Figure 5.5 below (based upon averaged data). Of the 20 sites surveyed, site 18 within the wind farm array was the most species-rich with 69 followed by sites 19 and 20 with 61 and 60 comparatively. Indeed, overall relatively high numbers of taxa were observed across sites within the array itself and along the cable route compared to the control sites which were generally less species rich. Sites with the lowest numbers of taxa were recorded to the east of the turbine array at sites 12 (9 species), 13 (9 species) and 16 (10 species).

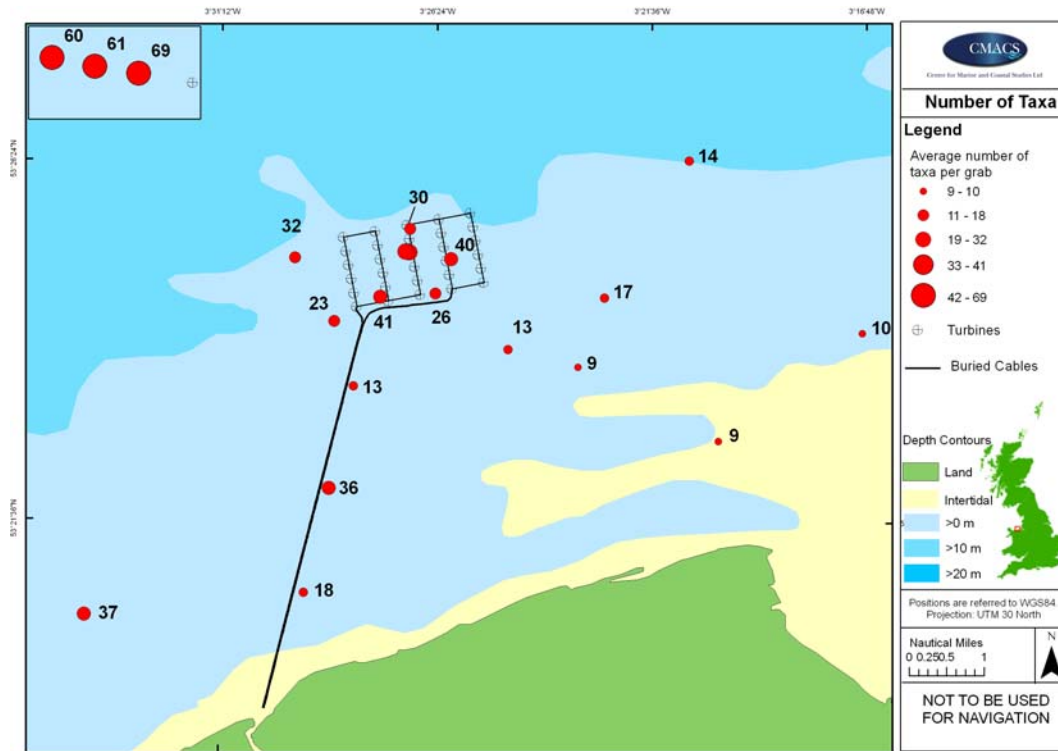


Figure 5.5 Total numbers of taxa. These data represent the mean number of species recorded across 3 replicate sediment samples taken at each grab station (see Figure 5.1 for site locations).

Species richness data from all grab surveys (2002-2006) at NHOWF are displayed in Figure 5.6. Data recorded at sites 18, 19 and 20 are again graphed separately in Figure 5.7 due to the disparity with monitoring commencement. As highlighted previously there appears to be an overall decline in the number of taxa recorded per site over the development area between 2002-2004. Data from the 2005 survey did show an overall increase in diversity with this trend being continued with the results from 2006 which show the highest number of taxa recorded since monitoring began at 13 of the 20 sites. This includes 6 of the 7 sites located within the array itself (1, 3, 4, 18, 19 and 20) where taxa numbers exceed all those previously recorded. However, this is not just limited to the wind farm area itself and is also evident at control sites 6, 11, 15, and 17.

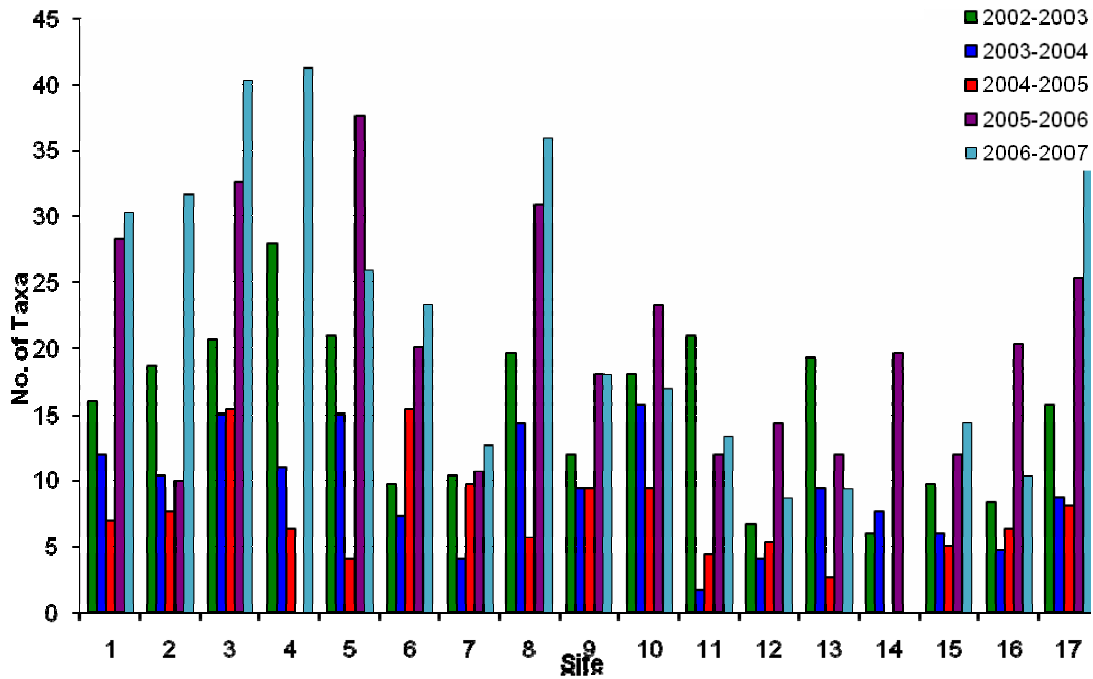


Figure 5.6 Numbers of taxa per 0.1 m² for 2002 (green), 2003 (royal blue), 2004 (red), 2005 (purple) and 2006 (pale blue), averaged over 3 replicates per site (excludes sites 18, 19 and 20 which were not sampled in 2002).

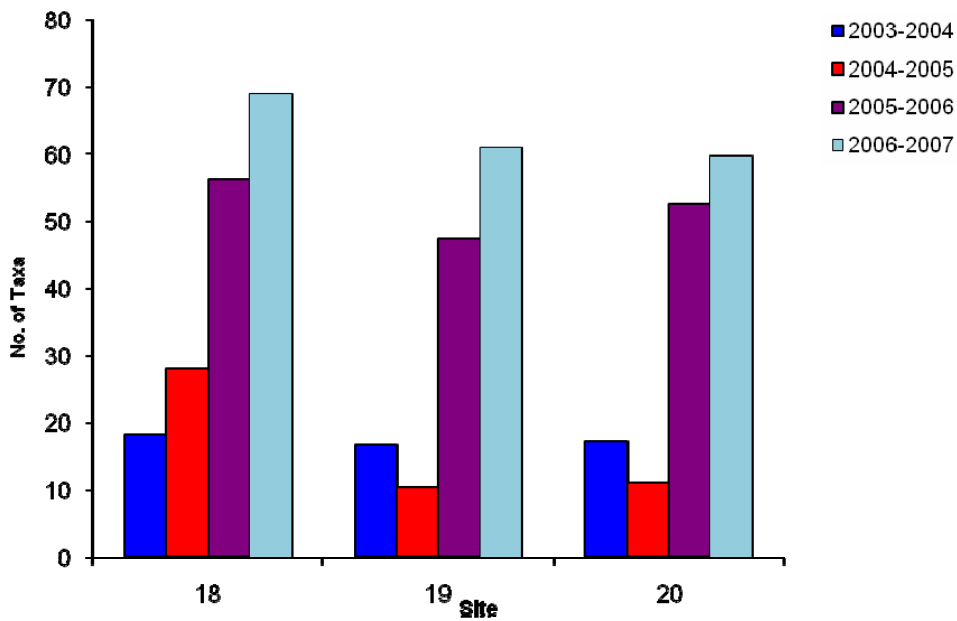


Figure 5.7 Numbers of taxa per 0.1 m² for sites 18, 19 and 20 for 2003 (blue), 2004 (red), 2005 (purple) and 2006 (pale blue), averaged over 3 replicates per site.

The most common species recorded were the ribbon worms *Nemertea* spp. These were recorded from 18 of the 20 monitoring sites with the highest number from site 4 (107) within the turbine array (Figure 5.8). The bristle worm, *Magelona johnstoni*, was also common and was observed at 10 of the 20 sites surveyed (Figure 5.9). This species was most numerous at site 9 (826) on the cable route, where the sediment was predominantly well-sorted medium sand (mean phi = 1.75). The largest numbers were recorded at the inshore cable route site 9 (815) and the inshore monitoring site 17. Few were recorded at locations within the array. High numbers of the polychaete worm *Pista cristata* were also recorded (Figure 5.10). These were nearly all recorded from sites located within the array with the highest numbers from site 18, 19 and 20 where the sediments were mostly composed of poorly sorted coarse sand and gravels.

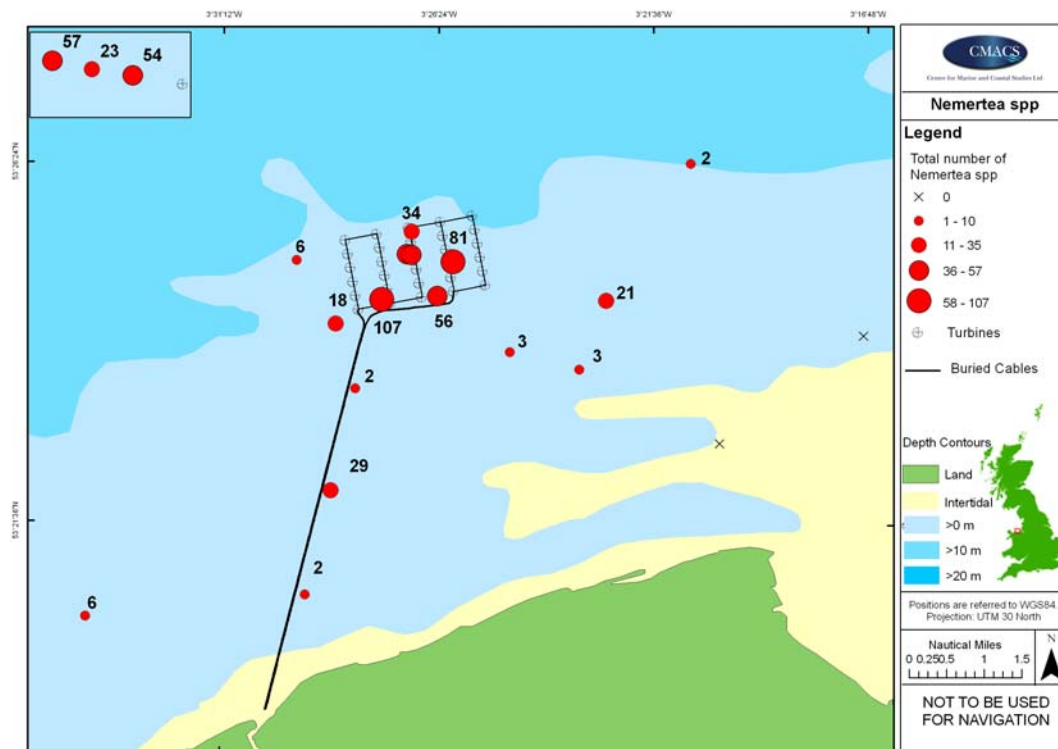


Figure 5.8 Total number of *Nemertea* spp. Data represents the pooled number of individuals recorded from 3 replicate sediment samples taken at each grab station.

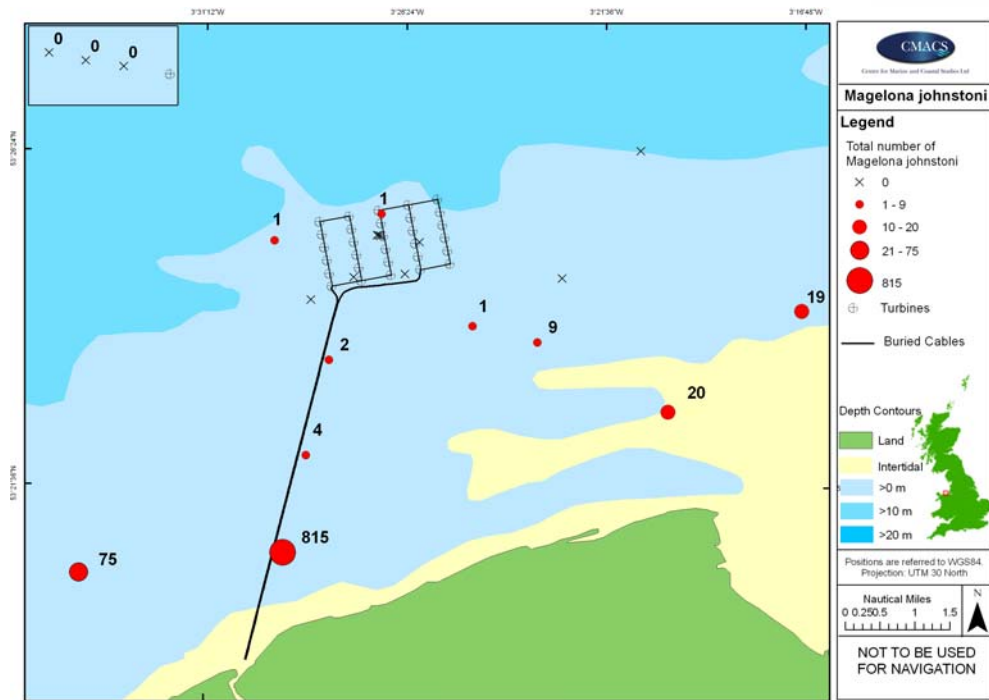


Figure 5.9 Total number of *Magelona johnstoni*. Data represents the pooled number of individuals recorded from 3 replicate sediment samples taken at each grab station.

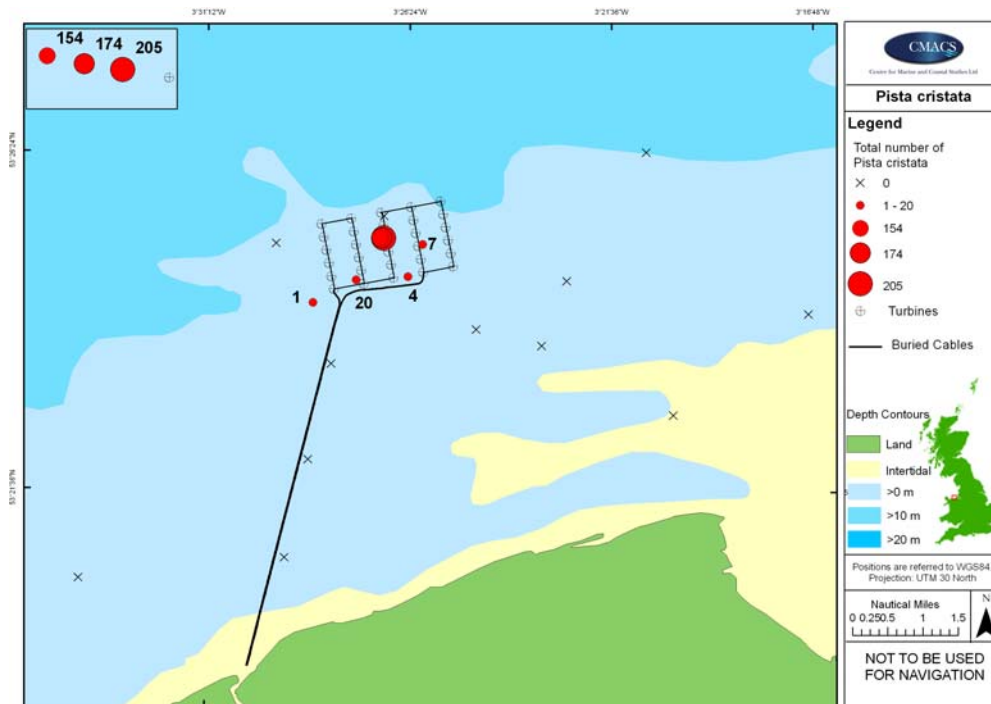


Figure 5.10 Total number of *Pista cristata*. Data represents the pooled number of individuals recorded from 3 replicate sediment samples taken at each grab station.

In previous years the abundance of the Thumbnail crab *Thia scutellata* has been considered during the analysis of the monitoring results. This is due to its previous identification as a scarce species due to its limited habitat distribution. Small numbers of this species were again recorded from the 2006 survey (see Figure 5.11) with a total of 17 individuals noted from 7 of the monitoring sites (2 of which were located within the turbine array). The highest numbers were recorded from sites 20 (4 individuals) and 1 (5 individuals) within the wind farm. The sediments at the locations where this crab were recorded were mostly well sorted medium sands which is the habitat with which this species has a strong association (Rees, 2001) although the two sites where the crab was recorded at the highest numbers were both poorly sorted coarse sediment habitats. Well-sorted (or very well-sorted) medium sand was also reported at sites 2, 7 and 15 where the crab was recorded in 2006 and also from sites 7 and 17 where the crab was absent but had been recorded in previous years.

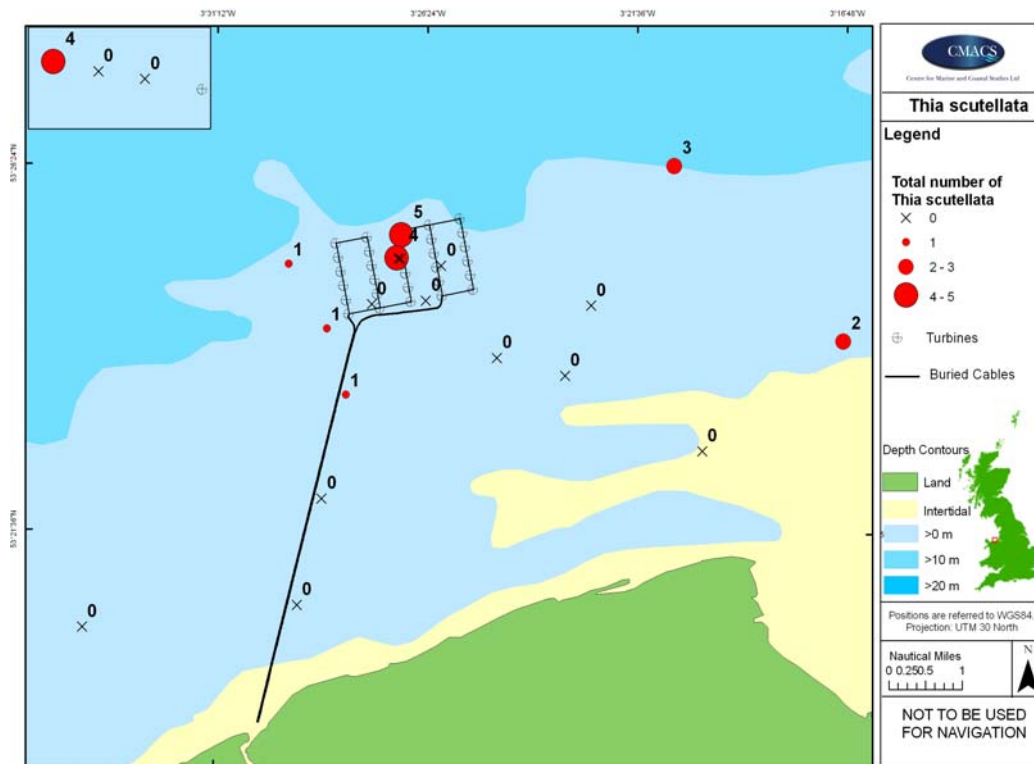


Figure 5.11 Total number of *Thia scutellata*. These data represent the pooled number of individuals recorded from 3 replicate sediment samples taken at each grab station.

5.3.1 Site Similarity

The MDS plot and dendrogram displayed in Figures 5.12 and 5.13 respectively present the relationship between all replicates at all sites for the 2006 monitoring survey. From this data it can be seen that replicates from the same site show strong correlations with each other at a Bray-Curtis similarity of 50% or higher. The strongest correlations were observed at site 9 (located inshore, along the cable route) which showed a 75% similarity. This was followed by sites 17, 3, 18, 19 and 20 which also displayed very strong within site similarity.

Exceptions to strong within-site correlation are displayed at sites 1 and 5 (both located within the wind farm array). Sediment analysis of the replicates at sites (based upon photographs and field notes alone due to actual processed sediment grabs being independent of fauna grabs) show the sediment at the all three replicates of both of these sites to be very similar to each other, therefore differences cannot be attributed to faunal communities based upon different sediment types. At site 1 replicate numbers 1 and 3 show a 60% similarity with replicate 2 displaying a difference. A review of the raw data for the replicates at site 1 shows that replicate 2 contains a higher number of taxa and individuals compared to replicates 1 and 3. This is mostly attributable to higher numbers of Annelid worms such as *Nemertea* spp, *Polycirrus medusa* and *Ophelia borealis* and others. At site 5 it was also replicate 2 displaying a difference to replicates 1 and 3 (which together displayed a Bray-Curtis similarity of nearly 60%) but again, sediments (based upon field notes and photographs) were the

same for all three replicates. The raw data shows that replicate 2 at site 5 did have a slightly lower number of species and individuals compared with replicates 1 and 3.

Due to the high number of sites displaying either strong or very strong within-site similarity, it was decided to pool the data to look at the between sites similarity. The MDS and dendrograms displaying the results of this are displayed within Figures 5.14 and 5.15. The results show the strongest clustering to be at sites 18, 19 and 20 with a Bray-Curtis similarity of 70%. These sites also cluster well with 4 (50%) similarity. Sites 12, 13 and 16 (all located to the East of the wind farm towards the mouth of the Dee Estuary) displayed strong site similarities together as did sites 7, 11 and 15. From this data, a correlation between sites located within the wind farm and those located away from the wind farm showing strong similarity together can be observed.

To study this relationship further, the information from the pooled site similarity MDS analysis has been overlain with the sediment data (mean phi) for each site in Figure 5.16. This shows that sites are obviously clustering together based upon sediment types (proving how much faunal characteristics are influenced by the sediments which support them) rather than being directly influenced by their location to the wind farm. Sites 18, 19 and 20 and 4 represent samples from where the sea bed is classed as being sandy gravel such sediments usually support rich and diverse fauna. Sites 12, 13 and 16 all had a very similar mean phi (see Figure 4.3) and were classed as mostly sandy communities supporting slightly less diverse faunal populations which were very similar to each other.

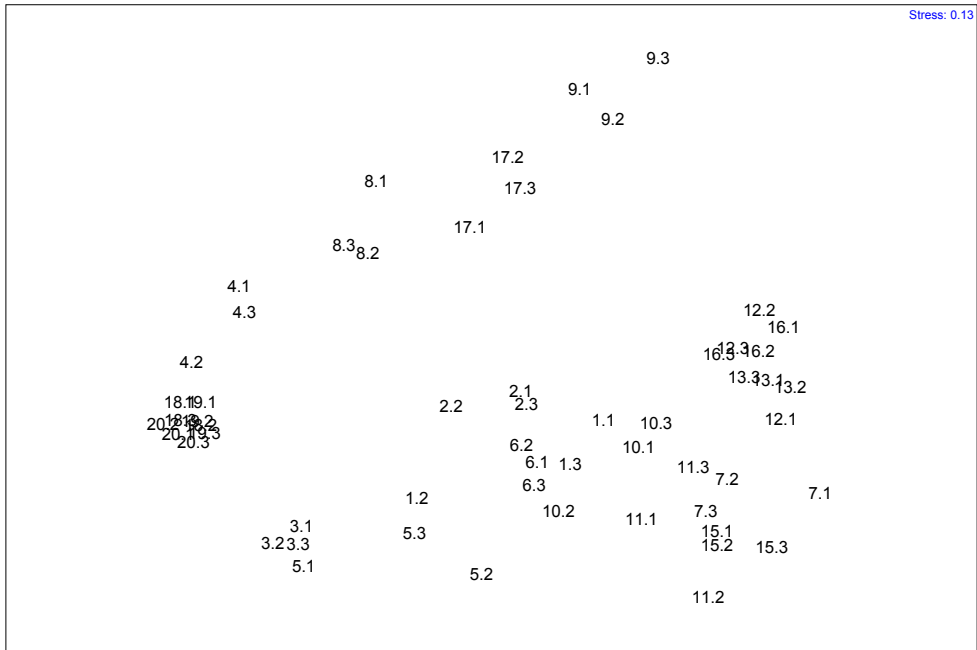


Figure 5.12: MDS plot showing within site similarity between replicates for 2006 monitoring survey

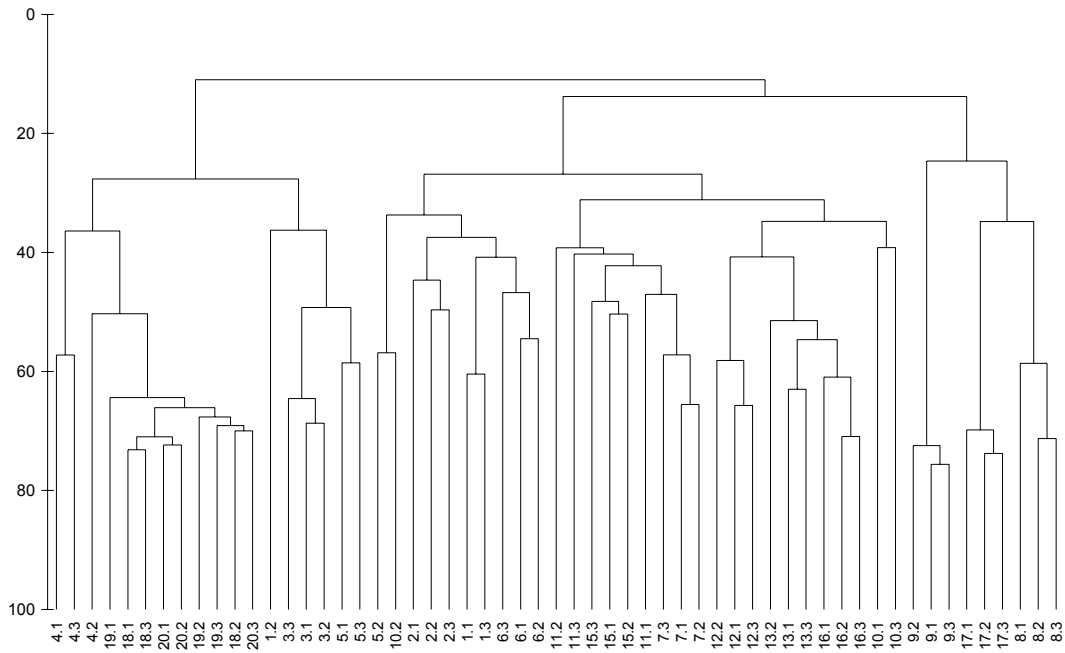


Figure 5.13: Dendrogram of the within site similarity between replicate faunal samples for 2006 monitoring survey.

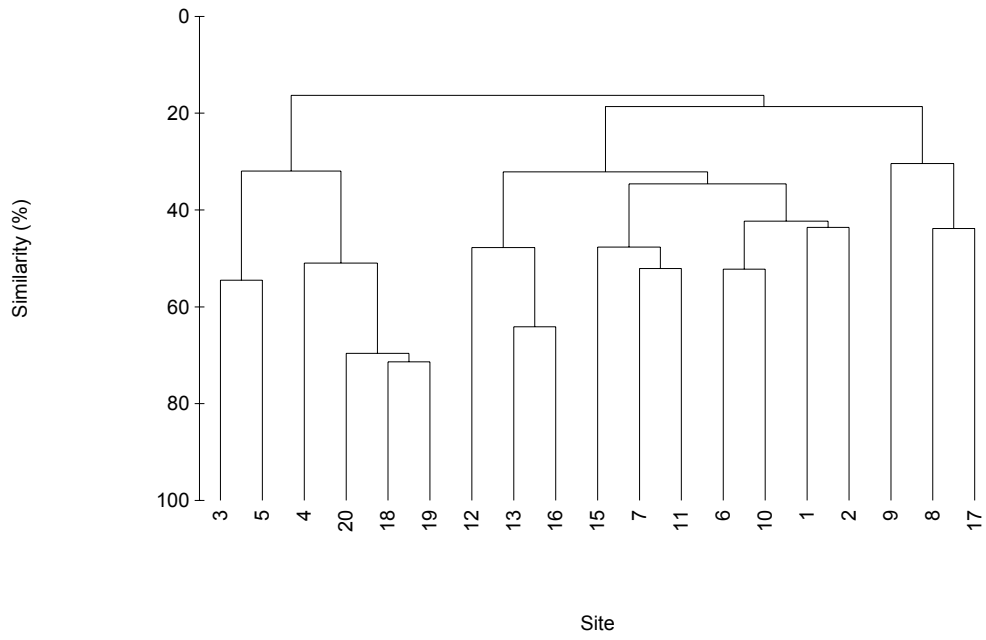


Figure 5.14: MDS plot to show the inter-site similarities (based upon pooled data) for the 2006 monitoring survey. Groupings base on 30% similarity as deduced from Figure 3.15 are shown.

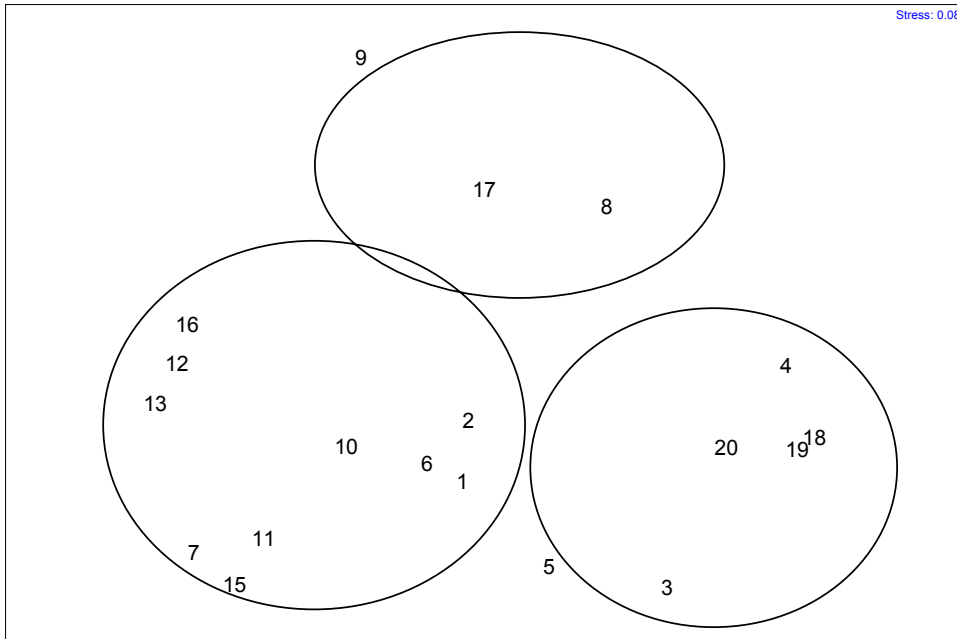


Figure 5.15: Dendrogram of the inter-site similarities (based upon pooled data) for the 2006 monitoring survey. Groupings base on a 30% similarity are shown.

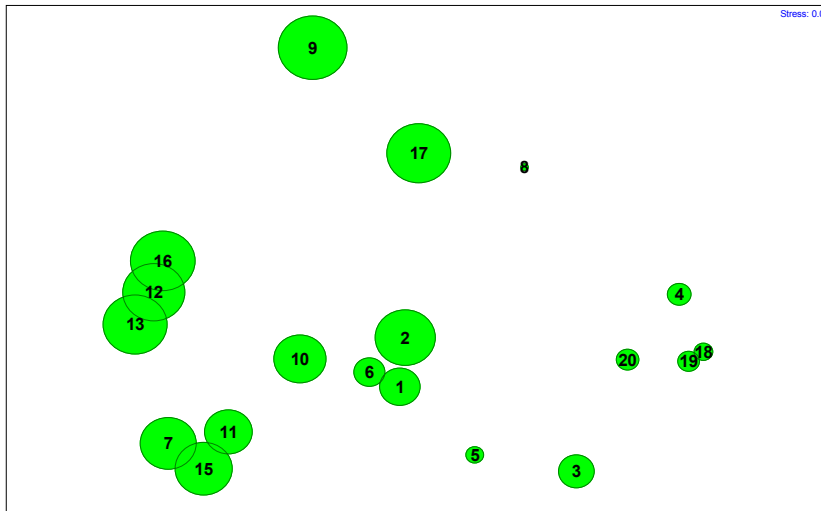


Figure 5.16: MDS plot displaying the inter-site similarities (based upon pooled data) overlain with sediment data (mean phi) for 2006 monitoring survey.

5.3.2 Shannon-Wiener Diversity Index

The Shannon-Wiener diversity index was calculated for each site from the 2006 monitoring survey (based upon pooled data) and the results have been geographically displayed within Figure 5.17. Sites displaying the highest diversity are located within the wind farm array itself (18, 19, 20, 3, 4 and 5). Those with the lowest are either inshore of the wind farm or located to the south-east of the turbines towards the mouth of the Dee Estuary. Again, this pattern in diversity is attributable to the sediment types found at these sites with the sandier locations inshore and to the west supporting less diverse fauna than the gravelly ones found within and around the NHOWF where the deeper sedimentary environment is mostly coarse sand and gravels.

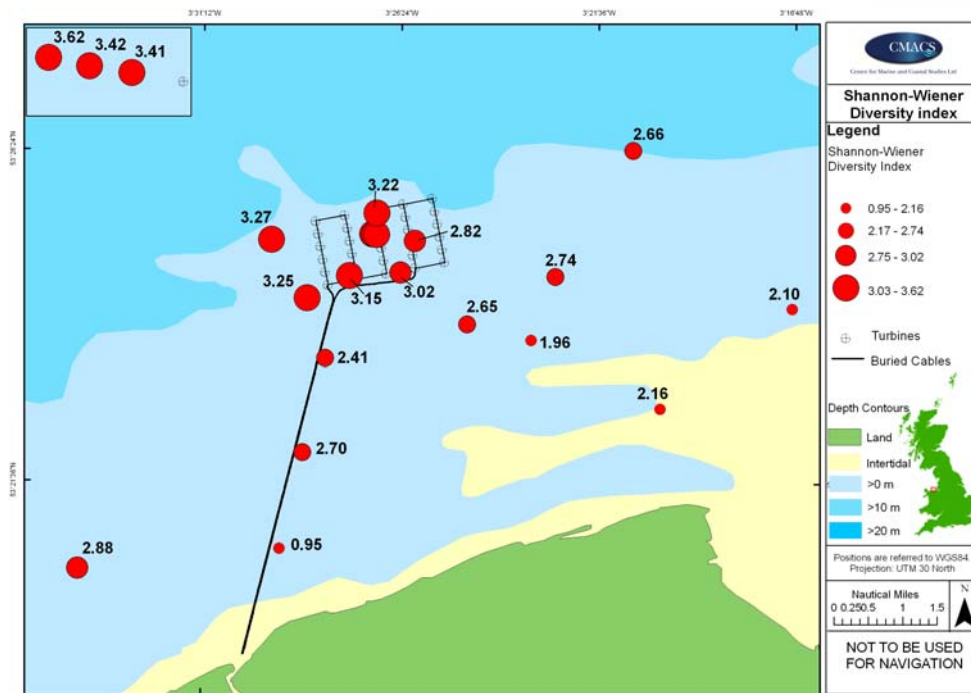


Figure 5.17: Shannon Wiener diversity index (based upon pooled data) for each site from the 2006 monitoring survey.

5.3.3 Community description 2006

Community description was based upon the MDS and dendrogram presented in Figure 5.14 and Figure 5.15, and has been largely presented in terms of biotope definitions as given by Connor et al (2004). Whilst an attempt has been made to produce a biotope map on the basis of these results (Figure 5.17) it must be born in mind that reliable assignment of biotopes generally requires larger numbers of samples over a wide area, whereas here a smaller number of sites with replicated samples has been used, as this is more appropriate for monitoring purposes.

Using a similarity level of 30%, three main groupings of sites (pooled data) can be identified that cluster reasonably well together (Figure 5.14 and 5.15) and in the main correspond moderately well with biotopes from Connor et al (2004). These also correspond broadly with differences in sediment type as determined from the particle size analysis (e.g. Figure 5.16). However, each of these main groupings could easily be subdivided further on the basis of higher similarity levels, or on relationships apparent from the MDS, and where these subdivisions seem discrete or relevant to particular biotope descriptions these are further discussed below. Table 5.1 shows the numbers of the most abundant overall species at each site plus the numbers of further taxa mentioned in the discussion of communities below, although reference may also be needed to the full results in Appendix 5.1 on occasion

The largest cluster consisted of sites 1, 2, 6, 7, 10, 11, 12, 13, 15 and 16. Of these, sites 7, 10, 11, 12, 13, 15 and 16 contain low numbers of both taxa and individuals, and are dominated by species typical of very mobile shallow sands, notably the catworm *Nephtys*

cirrosa and amphipods of the genus *Bathyporeia* (*B guilliomsonianan* and *B elegans*). The worm *Ophelia borealis* – another species typical of mobile wave exposed sands - was also fairly abundant. Overall the community corresponds well with the biotope **SS.SSA.IfSa.NcirBat (Nephtys cirrosa and Bathyporeia spp. in infralittoral sand)**. The sediments were predominantly sandy, although there was a moderate gravel content in some, notably at sites 10 and 11. Sites 1, 2 and 6, which also cluster with the above sites at the 30% similarity level, had a similar community, again with a lot of *N. cirrhosa*, *Ophelia borealis* and *Bathyporeia* spp, but the overall community was clearly rather richer. There were larger numbers of *Ophelia* and *Bathyporeia*, and many additional species; nemerteans and the polychaete worm *Spiophanes bombyx* were particularly abundant, and there were a much wider variety of small worm and crustacean species, as well as a larger number of encrusting bryozoans and hydroids associated with the occasional larger pebbles and stones. Some mollusc taxa associated with the biotope **SS.SCS.ICS.MoeVen (Moerella spp. with venerid bivalves in infralittoral gravelly sand)** (*Dosinia* spp and *Spisula solida* in particular) were found in moderate numbers but overall these samples are probably better regarded as a rich version of the NcirBat biotope.

Sites 3; 4; 5; 18; 19 and 20, which were all found in the development area had a rich community in coarse sediments with a moderate or high gravel content. The community is heavily dominated by polychaete worms, with *Mediomastus fragilis* being well represented. Other abundant worms or worm like organisms included *Aonides paucibranchiata*, *Protodorvillea kefersteini*, *Nemertea* spp, *Ampharete lindstroemi*, and *Pholoe baltica*, although the latter two species were almost absent from sites 3 and 5. The holothurians (burrowing echinoderms) *Leptosynapta inhaerens* and *Thyone fusus* and were also very abundant but absent from sites 3 and 5. Overall, the community matches the biotope **SS.SCS.CCS.MedLumVen (Mediomastus fragilis, Lumbrineris spp. and venerid bivalves in circalittoral coarse sand or gravel)** better than any other. However, *Lumbrineris* is almost absent and the venerid bivalve component is poorly represented – those robust bivalves that are present, albeit in very low numbers (e.g. *Spisula solida* and *Dosinia* spp) arguably suggest some similarity with the biotope MoeVen. Other taxa present in these samples that are suggestive of the MedLumVen biotope include amphipods such as *Ampelisca spinipes*, the brittle star *Amphipholis squamata*, and “Actiniaria” (in this case mostly *Sagartiidae* sp.). Sites 3 and 5 were less rich than the other sites, and were a less clear match for the MedLumVen biotope; however this was still probably the most appropriate match.

The remaining sites (8, 9 and 17), which only just clustered together at the 30% level, have considerable differences from each other. Nevertheless, based on the presence of characterising species such as *Magelona johnstoni* and *Magelona filiformis*, and *Fabulina fabula*, and others, sites 9 and 17 showed a strong similarity with the biotope **SS.SSA.ImuSa.FfabMag (Fabulina fabula and Magelona mirabilis with venerid bivalves and amphipods in infralittoral compacted fine muddy sand)**. These species were absent, or almost so, from site 8, which was characterised mainly by very high densities of *Lagis koreni* and other polychaete worms, anemones *Sagartiidae* sp, and the bivalve *Mysella bidentata*. This site showed no very clear similarity with any biotope. However, based on the presence of moderate numbers of *Abra alba*, *Echinocardium cordatum*, *Nephtys hombergii*, and *Spiophanes bombyx* (all of which typically occur in the FabMag biotope), together with

the fact that it clusters fairly closely with site 9 and 17, suggesting an overall similarity in the community, it has been assigned to the same (FfabMag) biotope.

Biotopes as discussed above have been mapped in Figure 5.8.

Name	1	2	3	4	5	6	7	8	9	10	11	12	13	15	16	17	18	19	20
Magelona johnstoni	1	1	0	0	0	0	2	4	815	0	1	9	20	0	19	75	0	0	0
Pista cristata	0	0	7	20	4	1	0	0	0	0	0	0	0	0	0	0	205	174	154
Nemertea spp.	34	6	81	107	56	18	2	29	2	21	3	3	0	2	0	6	54	23	57
Lagis koreni	3	0	2	11	1	10	0	330	0	0	0	0	0	0	0	9	17	27	11
Sagartiidae sp.	0	5	0	161	0	2	0	76	0	0	0	0	0	0	0	0	31	43	34
Ampharete lindstroemi	0	0	0	73	2	0	0	2	0	0	0	0	0	0	0	0	1	87	93
Spiophanes bombyx	38	12	0	0	0	9	7	15	36	10	20	0	5	14	6	146	0	0	7
Aonides paucibranchiata	0	0	127	2	9	0	0	0	0	2	0	0	0	0	0	0	84	33	64
Leptosynapta inhaerens	0	0	1	16	0	0	0	0	0	0	0	0	0	0	0	0	142	52	104
Protodorvillea kefersteini	0	0	106	0	36	0	0	0	0	1	0	0	0	0	0	0	62	14	86
Corophium bonnellii	0	22	0	26	0	0	0	0	0	0	0	0	0	0	0	0	83	44	115
Mediomastus fragilis	0	0	24	12	4	10	0	1	0	0	0	0	0	0	0	0	111	46	81
Nephtys cirrosa	16	20	1	0	4	15	26	0	0	38	18	27	19	25	36	11	0	0	2
Thyone fusus	1	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0	115	87	35
Owenia fusiformis	2	2	0	19	0	2	0	66	4	2	1	0	6	1	2	125	0	0	3
Pholoe baltica	3	0	1	66	5	0	0	20	0	0	0	0	0	0	0	1	60	17	47
Bathyporeia	55	58	0	0	17	2	0	0	1	6	0	10	11	0	4	1	0	0	24
Mysella bidentata	2	2	0	46	0	0	0	36	4	0	0	0	0	0	3	4	39	5	2
Nereis longissima	0	2	2	0	0	0	0	9	0	0	0	0	0	0	0	0	50	28	43
Bathyporeia elegans	14	7	0	0	3	6	13	0	0	7	1	27	11	1	11	0	0	0	9
Pisione remota	0	0	25	0	1	0	0	0	0	0	0	0	0	0	0	0	8	19	55
Bodotria scorpioides	0	2	1	3	0	0	0	0	0	0	0	0	0	0	0	0	47	26	26
Polycirrus sp.	11	1	8	13	10	1	0	0	0	1	0	0	0	0	0	0	27	12	20
Lanice conchilega	1	1	1	4	0	1	0	3	1	1	0	0	0	0	0	68	4	5	2
Anaitides mucosa	1	0	0	0	0	0	0	38	1	0	0	0	0	0	0	49	0	0	0
Polinices pulchellus	1	4	6	9	5	9	1	11	0	3	3	0	1	0	2	5	10	12	7
Eteone longa/flava (agg.)	0	2	1	0	1	2	0	38	0	9	1	2	1	0	2	26	1	1	1
Malmgreniella arenicolae	0	0	2	7	0	0	0	0	2	0	0	0	0	0	0	26	17	12	13
Eumida sp.	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	59	9	3	5
Upogebia deltaura	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	28	29	16
Ophelia borealis	20	2	0	0	8	11	1	0	0	7	7	0	0	3	0	0	0	0	2
Dosinia exoleta	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Spisula solida	1	0	5	0	0	1	0	0	0	0	0	0	0	2	0	0	1	2	0
Ampelisca spinipes	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	6	9	10
Amphipholis squamata	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
Magelona filiformis	0	0	0	0	0	0	0	0	53	0	0	0	0	0	0	12	0	0	0
Fabulina fabula	0	0	0	0	0	0	0	1	5	0	0	0	0	0	0	3	0	0	0
Echinocardium cordatum	5	0	0	0	0	0	0	8	0	0	0	0	1	0	9	3	0	0	6
Abra alba	0	0	0	1	0	0	0	7	1	1	0	0	0	0	0	1	0	0	0
Nephtys hombergii	0	0	0	0	0	0	0	4	6	0	0	0	0	0	0	0	0	0	0
Moerella pygmaea	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2
Ensis arcuatus	0	0	2	0	2	0	1	0	0	0	0	0	0	0	0	10	1	1	3
Ensis ensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Ensis sp. damaged	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 5.1: Numbers of the most abundant overall taxa found in 2006 at each site (3 replicate samples combined) plus other taxa mentioned in the text.

5.3.4 Comparing communities with those identified in 2001

The biotope map produced in 2001 as part of the NHOWF EIA (Innogy, 2002) is reproduced in Figure 5.18 along with the biotopes determined in 2006. The 2001 map utilised much larger numbers of samples, including anchor dredge samples (for larger bodied fauna) as well as Day Grabs, and maps of the main seabed features produced using sidescan sonar. Furthermore, the biotope classification has been revised since then (Connor et al, 2004, cf the 1997 classification [Connor et al 1997] used previously) with some biotopes definitions having been changed substantially. Fortunately the biotopes involved in the North Hoyle area have generally not been affected by these refinements to the classification system. The main change of significance to this work is that the biotope called IGS.Sell under the 1997 classification has been split into two different biotopes under the 2007 classification, one of which is SS.SCS.ICS.MoeVen Moerella spp. with venerid bivalves in infralittoral gravelly sand. This biotope was found widely in the Gwynt y Mor EIA surveys (RWE npower, 2005) which regarded much of the inshore area (based partly on a reanalysis of the original North Hoyle surveys) as this biotope. The biotopes found in the 2006 surveys do not match particularly well with MoeVen, although single individuals of *Moerella pygmaea* were found at sites 1 and 2, and other bivalve species typical of this biotope such as *Spisula* spp and *Dosinia* spp are also found in small numbers. Instead the samples appear to be very rich in polychaetes and are a better match for the biotope MedLumVen (as described above) which was also noted widely in the Gwynt y Môr EIA surveys, though generally further offshore. However, Connor et al (2004) note that the biotopes MoeVen and MedlumVen are similar to each other, one of the most obvious distinguishing feature being the greatly increased abundance of the worms *Mediomastus fragilis* and *Lumbrinereis gracilis* in the latter.

In 2001 an additional biotope SS.SSA.IMuSa.EcorEns *Echinocardium cordatum* and *Ensis* spp. in lower shore and shallow sublittoral slightly muddy fine sand was identified at site 12 and in much of the adjacent area, almost reaching site 11. Conner et al (2004) note that this EcorEns biotope requires further consideration, and that it may be better to regard it as an epibiotic overlay which may be superimposed over a number of infaunal biotopes, such as NcirBat, FfabMag and AalbNuc. Certainly the definition of areas as EcorEns in 2001 was heavily influenced by the presence of large numbers of *E. cordatum* in anchor dredge samples, a semi-quantitative sampling methodology more suited to collection of this large-bodied species than the Day Grabs used for later quantitative monitoring purposes. In 2006 *Echinocardium cordatum* was found in the Day Grabs in moderately high numbers inshore at sites 8 and 16. Overall, this does not, therefore, represent a conflict between the 2001 and 2006 surveys.

A further additional biotope was also identified at the inshore area of the cable route in 2001. This was CMS.AbrNucCor molluscs *Abra alba*, *Nucula nitida* and *Corbula gibba* in circalittoral muddy sand or slightly mixed sediment. This biotope is known from sheltered environments within the Irish Sea. This biotope was not identified from the 2006 survey as the inshore site was deemed to be better represented by the FabMag biotope due to the presence of a few defining species but overall this habitat is not considered to have changed.

Overall, given particularly the lack of evidence of community differences identified by multivariate analysis outlined earlier, it is suggested that the apparent changes in biotopes outlined above are not significant.

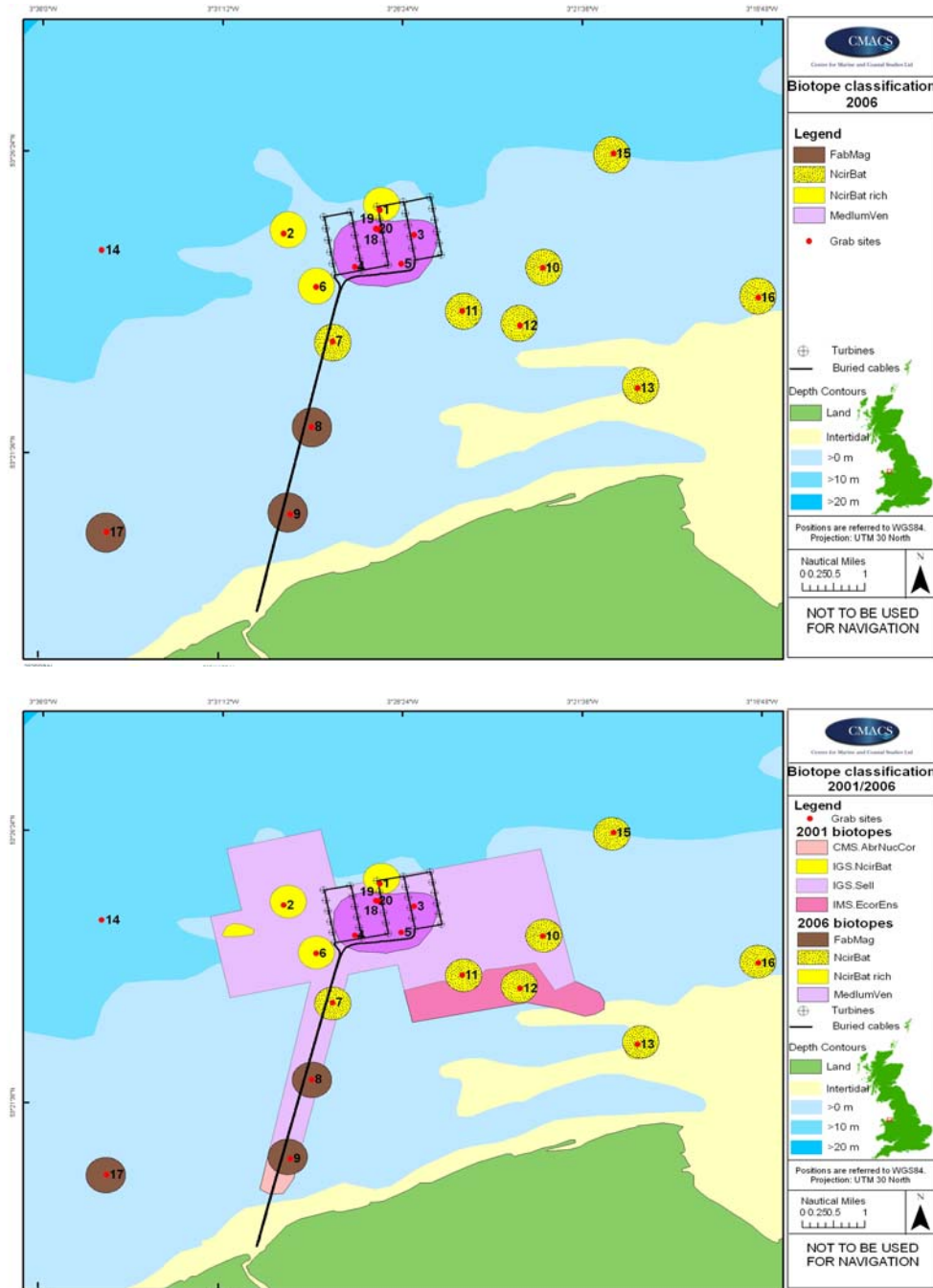


Figure 5.18 Biotopes associated with the 19 sites sampled in 2006 (top). In the bottom map these results have been superimposed over the biotope map from 2001 that was prepared from much higher numbers of samples. (NB Circles in particular are symbolic only and their size does not indicate an area around the sample site to which the relevant biotope can be assigned).

5.4 RESULTS FROM OVERALL 5 YEAR MONITORING SURVEY

Inspection of the results, whether graphically or in the presentation of maps of numbers of taxa, numbers of organisms, or individual taxa, or of MDS, has strongly suggested that there is great variation in these factors both within and outside of the wind farm and that there is no apparent link in any changes to the development. Variation is therefore thought to be linked to natural variation in factors such as the nature of the sediment or recruitment and survival of organisms, both of which are known to vary greatly from year to year in shallow water marine environments. This is further investigated here by the use of multivariate analysis of all five years of data, and by ANOSIM. For this purpose all data was pooled from 3 replicates in each site. When data for 1 or 2 replicates were not available, the number of individuals per site was adjusted upwards pro-rata to make them comparable. In a few cases data was missing for the whole site i.e. the 3 replicates. Data was missing in the following years/sites:

- 2004 (6.3, 18.2, 18.3 & all of site 14)
- 2005 (2.2, 2.3 and all of site 4)
- 2006 (site 14)

For this purpose, sites 18, 19 and 20 were usually not used, as they were not sampled in the pre-construction baseline. The data was square root transformed prior to analysis. Bray-Curtis similarity coefficient was used.

Figure 5.19 shows MDS plots of all data from all five years, including sites 18, 19 and 20 that were not sampled in 2002, while the associated dendrogram is presented in Figure 5.20. It is clear that sites had a tendency to cluster closely together irrespective of year. Sites 3, 15 and 17, noticeably, showed strong similarity in all five years, but in all other cases there appeared to be at least one year that clustered less well, i.e. had a somewhat different community. For example, site 9 (2002, 2003, 2005 and 2006 clustered strongly together, but site 9 (2004) was considerably different.

If there was a strong long term effect of the wind farm development upon the community structure, for example from long term changes to sediment regime within the immediate wind farm environment, it would be expected that sites 1, 3, 4 and 5 in particular would show evidence of this by clear clustering of the later samples away from the 2002 sample. If there were a strong, but short term effect of the wind farm, for example caused by direct disturbance to the seabed followed by subsequent recovery, one might similarly expect samples from 2003 and/or 2004 (the year following construction) to cluster away from the other years, particularly at sites 1, 3 4 and 5 (within the development). Such a pattern arguably occurs for site 4 where the 2003 and 2004 samples were apparently different from the 2002 and 2006 samples (unfortunately this site could not be sampled in 2005); and site 5, where the 2004 sample was somewhat different to the others. However, there was clearly no such pattern for site 3, which showed strong similarity in all five years. Thus one could arguably construe a very short term effect on community structure at sites 1, 4 and 5 (one or two years at most) but none at site 3. However, similar, or even more significant shifts in community were apparent outside of the wind farm, sometimes associated with the NHOWF development period timeframe and sometimes not. Site 13 was apparently different in 2003

and slightly different in 2004; site 12 showed an apparent difference while sites 10 and 11 all showed considerable variation in community over time. At site 2, which is approximately a kilometre or so from the development, the 2003 sample was somewhat dissimilar to the others.

Along the cable route in all three cases there was again a possible shift in community at all three sites in 2004 only, suggesting a very temporary but consistent effect of the installation of the cable in the year following installation. If this effect was real then again recovery at all three sites seemed to be very rapid.

At sites 18, 19 and 20 there may also have been a similar effect, but the absence of baseline data from 2002 makes it impossible to know for certain. However, the pattern with respect to the years 2003 to 2006 is the same as that described above for all three sites, in that there is a deviation in the community in 2003 and 2004 from that found in 2005 and 2006. The deviation was apparently small in 2003 and more significant in 2004, at least at sites 19 and 20 (though remaining small at site 18). In 2005 and 2006 these three sites showed a high degree of similarity with each other in both years (Figure 3.19), with the group averaged similarity between these two years being around 65%. In all years these sites were very rich and diverse, and in 2006 there was an average of 67 taxa and 469 countable individuals per 0.1m^2 at these sites (pooled values of over 100 taxa and 1400 individuals per site).

In order to further allow sensible discussion of the nature of these apparent community changes, richness and diversity indices for the sites are presented in Table 5.2, and some of these indices (number of taxa and number of individuals) have been superimposed upon the MDS plot, along with sediment descriptions according to BGS version of Folk triangles (Figure 5.20 b-d). These indices were also presented graphically earlier, in Figures 5.2 - 5.7. It is clear that in all cases, both inside and outside the NHOWF and along the cable route, the changes in community in 2003 and 2004 are associated with large reductions in numbers of taxa, and in most cases they were also associated with reductions in total number of individuals. Not surprisingly, therefore, there was also an association with a lowering of diversity index in most cases. Figure 5.20 also illustrates that there was fairly consistently a link between community and sediment type, and that in many cases, large temporal changes in community at a particular site were associated with change in sediment classification. Whether these are entirely natural changes with time, chance variation due to highly heterogeneous seabed, or the result of the presence of the NHOWF, cannot be determined with certainty. Again, however, the fact that the changes occurred both within and outside of the NHOWF strongly suggests that the changes are not directly associated with its presence. Changes in sediments are discussed more fully in Section 4.

ANOSIM has been used to investigate more rigorously whether there was any statistically significant change in communities over the five year period inside and / or outside of the NHOWF that might be attributable to the development. Since sites 18, 19 and 20 were not sampled in 2002 (pre-development) these sites were omitted from this analysis. Sites 1, 3, 4 and 5 were classed as being positioned within the development; sites 7, 8 and 9 as being positioned on the cable route (which might be subject to different potential impacts than the development sites) and the remaining sites as being positioned outside the development. The results of a two way crossed ANOSIM test (two factors being year of sampling and

position of the site with respect to NHOWF and cable route) are presented in Appendix 5.4. The null hypothesis that there is no difference in the change in community over time between the three positions (inside; cable route; outside) was accepted for all possible combinations of position (i.e. inside versus outside; inside versus cable route; outside versus cable route). Thus these apparent community changes with time, that appeared to suggest a possible link with the NHOWF development and cable route, were overall no more significant statistically than the changes found in communities at sites away from the NHOWF.

North Hoyle benthic data (pooled) 2002-2006

RED = 2002
PINK = 2003
PURPLE = 2004
BLUE = 2005
GREEN = 2006

a)

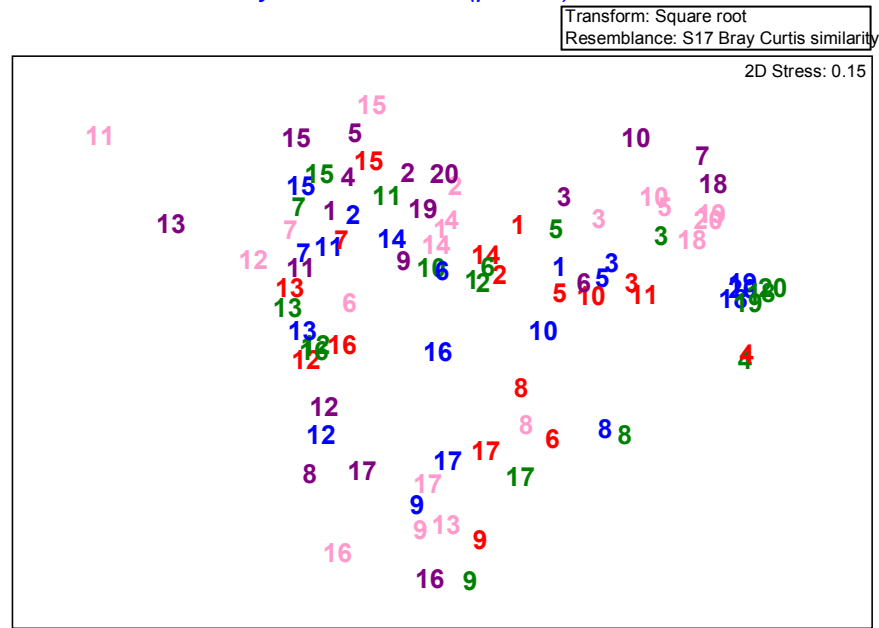
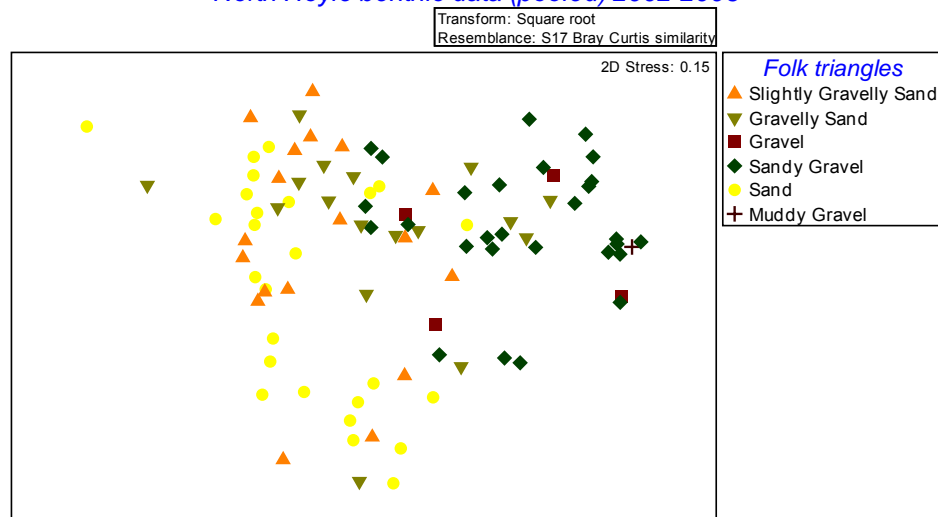


Figure 5.19: MDS plot of all data from all five years, and based on Bray Curtis similarity between sites (pooled data) a) colour coded according to year. b) with sediment classification according to the BGS system superimposed c) and d) overleaf with number of taxa and number of individuals superimposed. The associated dendrogram is shown in Figure 5.20.

North Hoyle benthic data (pooled) 2002-2006

b)



North Hoyle benthic data (pooled) 2002-2006

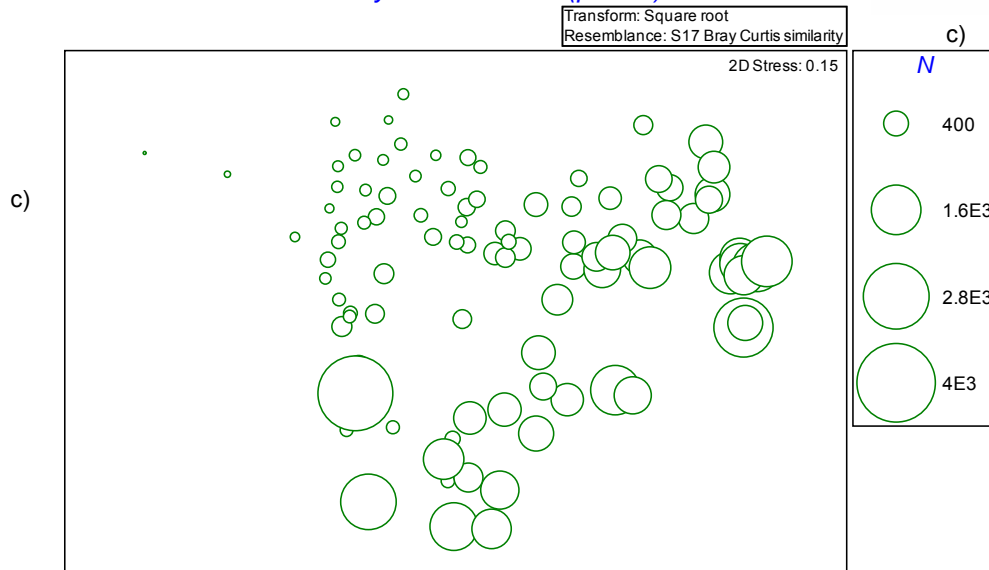
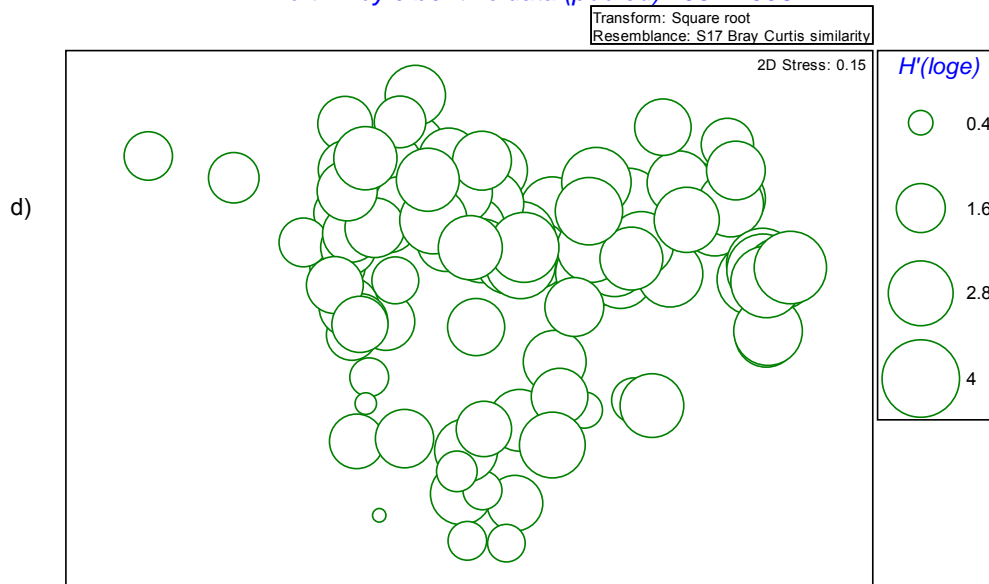


Figure 5.19: continued.

North Hoyle benthic data (pooled) 2002-2006



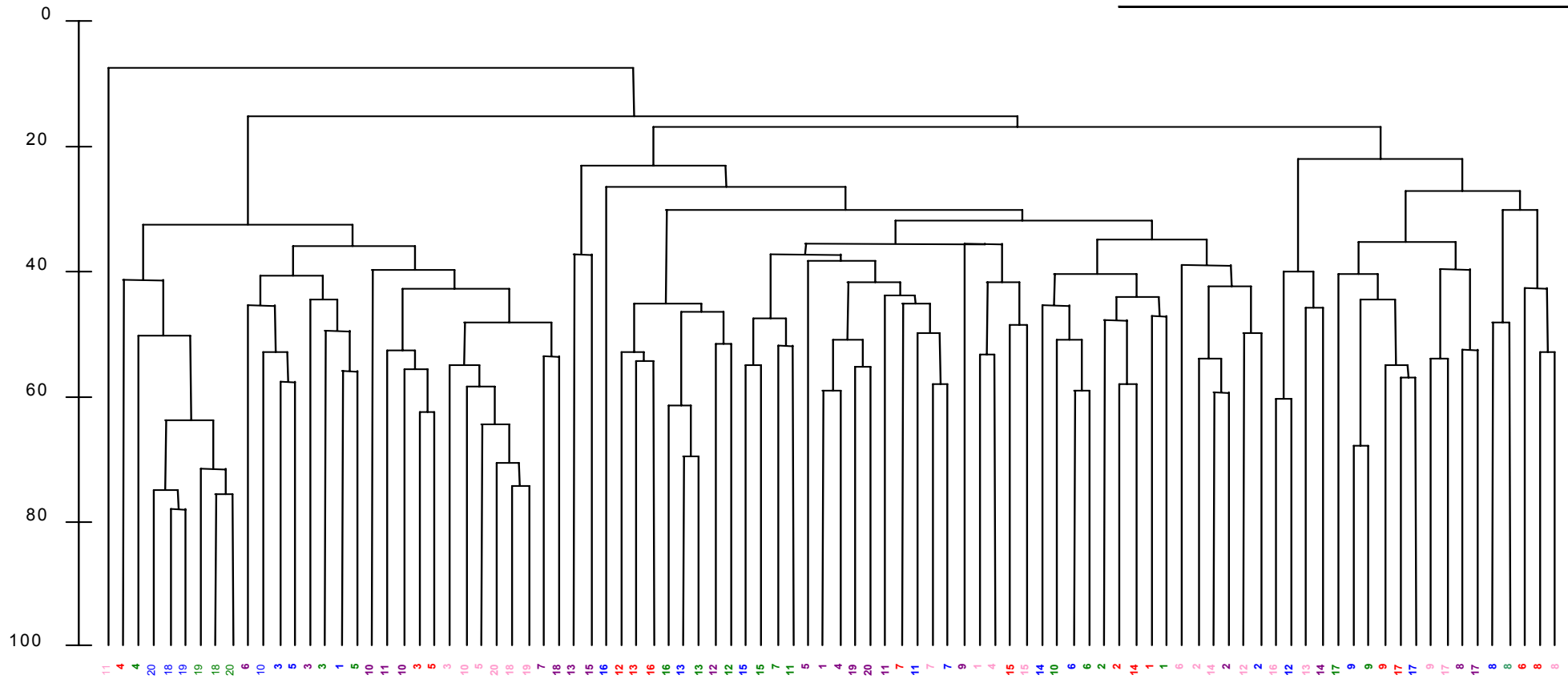


Figure 5.20 Dendrogram of all data from all five years without sites 18, 19 and 20, colour coded according to year. Based on Bray Curtis similarity between sites (pooled data). Associated MDS plot is shown in Figure 3.2. RED = 2002 PINK = 2003 PURPLE = 2004 BLUE = 2005 GREEN = 2006.

Site	No of taxa / 0.1m ²					No of individuals / 0.1m ²					Shannon Wiener diversity index H'(loge)				
	2002	2003	2004	2005	2006	2002	2003	2004	2005	2006	2002	2003	2004	2005	2006
1	48	36	21	53	58	361	191	86	336	323	2.77	2.98	2.28	3.14	3.22
2	56	31	23	10	60	329	108	67	180	247	3.10	2.82	2.44	1.46	3.26
3	62	45	46	50	66	762	323	174	529	546	3.06	3.11	3.22	2.80	2.82
4	84	33	19	-	77	2270	173	74	-	789	2.60	2.83	2.05	-	3.15
5	63	45	12	79	48	418	449	44	777	242	3.30	2.66	1.78	2.63	3.02
6	29	22	46	34	43	681	253	537	165	143	0.87	1.47	3.03	2.73	3.25
7	31	12	29	19	22	169	52	744	93	81	2.58	1.72	1.83	2.18	2.41
8	59	43	17	58	58	738	466	107	1584	894	2.63	2.13	1.97	1.33	2.70
9	36	28	28	28	33	949	118	182	1064	1009	2.07	2.53	2.23	1.10	0.95
10	54	47	28	52	38	868	459	234	611	135	2.83	2.70	2.13	2.31	2.74
11	63	5	13	23	28	1123	6	122	107	85	2.89	1.56	2.05	2.38	2.65
12	20	12	16	23	15	257	57	388	3634	120	1.73	1.59	1.00	0.31	1.96
13	18	23	8	25	16	150	545	26	105	84	2.05	1.01	1.70	2.39	2.16
14	58	28	-	38	-	253	83	-	116	-	3.18	2.34	-	3.03	-
15	29	18	15	23	28	97	76	49	76	84	2.78	2.42	2.00	2.35	2.66
16	25	14	19	39	15	227	2005	1471	224	103	2.21	0.12	1.00	2.18	2.10
17	47	26	24	42	56	716	149	111	684	796	2.53	2.65	2.27	2.04	2.88
18		55	28	82	108		590	651	1173	1553		2.81	2.30	3.45	3.42
19		50	31	72	100		782	128	1017	994		2.58	2.53	3.43	3.43
20		52	33	85	109		472	162	1088	1662		2.87	2.31	3.49	3.50

Table 5.2: Richness and diversity indices for the twenty benthic sample sites over the five years monitoring period, based on pooled values for up to three 0.1m² replicates per site

5.5 CONCLUSION

From the results it is postulated that the observed variability within the measured benthic invertebrate community parameters is more closely related to factors that are believed to be subject to natural variability, such as local sediment characteristics, than the construction and operation of NHOWF. Benthic communities would be expected to respond to variation in seabed sediment characteristics, especially particle size, as a primary factor influencing community composition and distribution. The absence of any identifiable trend in sediment particle size characteristics associated with NHOWF suggests that it has not had any impact upon the benthic invertebrate communities through this mechanism other than at a very localised scale due to the physical presence of the monopile foundations or, potentially, very localised effects of scour or scour protection within 50m of turbines in areas that are not routinely sampled. Multivariate analysis of infaunal communities, together with trends in numbers of taxa and numbers of individuals, does suggest some possibility that there were changes in communities within the NHOWF and along the cable route in the construction year (2003) and the year immediately following construction (2004). Although the possibility of some local short term effect cannot be completely ruled out, statistical analysis using ANOSIM concluded that these possible detrimental changes within the NHOWF and cable route, based on apparent community differences with time, were overall no more significant statistically than the changes found in communities at control sites.

In summary, the marine biotopes classified using the data obtained from the 2006 benthic infaunal survey are not considered to be significantly different to those biotope communities identified from the 2001 benthic surveys undertaken pre NHOWF development.

5.5.1 Conclusions referring to original EIA hypotheses

As the fifth year of monitoring at the NHOWF is now complete, the overall results of the monitoring programme have been considered and an assessment against the original EIA hypotheses (see Table 5.3) to concur if these statements relating to the impacts to benthic fauna were indeed correct.

EIA Statement	Results from FEPA Monitoring Programme
Construction Phase	
“Minor and localised impacts would arise from construction e.g. from physical impact of driving piles (including the use of jack-up barge to provide the drilling platform) and the loss of seabed habitat directly below piles. The faunal assemblages present are widespread and common throughout Liverpool Bay and recovery of communities from any damage is likely to be rapid, impacts will be negligible.”	The results of the benthic marine community monitoring programme indicate that this statement is indeed true.
“Invertebrate communities will in no way be affected by sedimentation arising from the wind farm construction as: no appreciable increases in suspended sediments are predicted and; benthic invertebrates present are well adapted to these conditions”	Again, the results from the monitoring programme have revealed nothing to disprove this statement.
Operation Phase	
“scour from the turbines will remove finer sediments leaving sediments more coarse than previous with a greater component of stone and shell fragments which will affect the fauna able to colonise the sediment”.	The marine fauna and communities of the wind farm and surrounding areas have not significantly changed following wind farm construction.
“there is little evidence to suggest that benthic invertebrates are able to perceive noise and vibration produced by OWF. Colonisation of the turbines are expected allowing an increase in local species diversity and productivity”	Information from the underwater visual survey of the turbines following construction (2004) proved extensive colonisation of the turbines to have occurred and that this statement was indeed correct (CMACS & MarineSeen, 2004).

Table 5.3: Assessment of the accuracy of the statements made within the NH EIA (2002) regarding the impacts of the development upon the benthic populations of the wind farm and its surrounding area.

There is consistent evidence that both temporal variation and short-scale spatial variability in benthic communities are more affected by natural processes such as seabed heterogeneity and, we presume, environmental and biological factors, than the construction and operation of the NHOWF. For example, major trends in benthic invertebrate abundance and diversity have been evident throughout wind farm array, near-field and control sites. Overall, it can therefore be concluded that the original statements made within the North Hoyle Environmental Statement are indeed correct and that the NHOWF has not had an impact to the benthic communities present within Liverpool Bay.

5.5.2 Reference to other OWF monitoring programme results

Findings from the monitoring of the benthic communities at Horns Rev (Denmark) have also found fluctuations within number of taxa and species for sites both within and outside the wind farm for different years. Reasons for this were also attributed to natural variations and fluctuations within species populations. Overall, it was concluded that: “no significant impact on the infauna in the wind farm area was detectable concerning distance-related effects. Though general reductions in the population size of some of the character species in the surveyed areas might be related to changes in the sediment structure, the infauna community at Horns Rev showed no obvious signs of stress response as a consequence of possible impact from construction and operating activities.” (Elsam Engineering, 2005).

Findings from the monitoring surveys at the Nysted OWF (Denmark) undertaken in 1999, 2001 and 2005 concluded that the spatial variations and temporal changes observed in the benthic fauna have not been caused by the construction of the wind farm or the presence of the turbines foundations (Danish Energy Authority, 2006)

The results from the NHOWF monitoring programme are consistent with the findings from benthic monitoring programmes from similar sized wind farms located in Denmark. Spatial variations in benthic populations are present at all monitoring sites (including controls) and appear to have no influence from the presence of the wind farm itself.

5.6 LIMITATIONS OF MONITORING PROGRAMME

The inclusion of more sites, especially within but also away from the wind farm, would increase the ability of the work to determine whether there was any effect of the development. More than one pre-development year of study may have helped to determine with more certainty the natural variation in the communities present within the area (although the methodology of the monitoring programme was agreed with the relevant statutory agencies prior to commencement).

Whilst it was important to have sites in the near field in case there was a very strong effect of the wind farm, with hindsight it may arguably have been preferable to have a clearer distinction between the “within site” sites and control sites so as to better determine whether there was an effect within the NHOWF i.e. better distinctions between control and wind farm sites.

It would probably have improved the monitoring programme to have taken sediments directly from the faunal grabs in order to see more clearly any correlation of changes in community with changes in sediment, rather than taking a separate sediment sample as carried out here. The site was quite heterogeneous, being very stony in some places but very sandy in many others, and therefore no one grab method was ideal for sampling. A Day style grab was used but failure to sample was an occasional problem. Use of a Mini-Hamon grab may have improved sampling from stony areas but these grabs do not always work well on hard packed sand and on balance the method used was considered to be the most appropriate.

Sampling of sites 18, 19 and 20 (those sites close to a turbine) in 2002, prior to the development, would have aided in the determination of any localised effects.