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Norfolk Boreas Offshore Wind Farm

Consultation Report

Appendix 13.7 Updated Benthic and Contaminant sample analysis report v2

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Photo: Ormonde Offshore Wind Farm

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Norfolk Boreas Offshore Wind Farm

Benthic and Contaminant sample analysis

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19/10/17	D01	First draft for Royal HaskoningDHV review	EN / DT	DT	PP
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16/11/2017	D02	Updated based on CEFAS advice draft for Vattenfall review	EN/DT	AD	JL
20/11/2017	F02	Second Version of the report updated as per requests from Cefas	DT		

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1 INTRODUCTION

1.1 Project background

1. In December 2009, The Crown Estate awarded the consortium company East Anglia Offshore Wind (EAOW) Ltd (a 50:50 joint venture owned by Vattenfall Wind Power Ltd (VWPL) and Scottish Power Renewables (UK) Limited (SPR)) the rights to develop Zone 5 (later named the East Anglia Zone) of The Crown Estate's UK Offshore Wind Round 3 tender process. During early development of Zone 5 a Zonal Environmental Appraisal (ZEA) was conducted which included zonal wide benthic surveys; during which over 600 grab samples were collected and analysed.

2. The former East Anglia Zone has now been dissolved, with VWPL securing project specific agreements for the Area for Lease (AfL) from The Crown Estate for two projects within the northern part of what was the East Anglia Zone. The first project to be developed is Norfolk Vanguard with Norfolk Boreas being progressed approximately one year later. Both Norfolk Vanguard and Norfolk Boreas will have a capacity of 1,800MW. Norfolk Boreas is located to the North and East of Norfolk Vanguard (Appendix 1). Both projects will share the same offshore cable corridor, except for small spurs which connect into the individual projects.

3. SPR continue to develop projects (East Anglia ONE, East Anglia THREE, East Anglia ONE North and East Anglia TWO) within the southern part of the former East Anglia Zone.

4. The first version of this report was provided to the MMO and Natural England on the 23rd October 2017. This version (F02) has been updated to include presentation of the Particle Size Distribution data, which was not available for version F01 of the report and further PRIMER analysis which focuses on benthic samples which were collected from with the Norfolk Boreas site only. This update meets requests from Cefas shown in Appendix 3. New text added to this version (F02) following the Cefas requests is provided in orange.

5. Natural England provided the following response to version F01 of the report

   "Natural England are content that the initial benthic sample analysis provides validation that the Zonal Environmental Assessment (ZEA) benthic data is applicable for use in the Norfolk Boreas EIA."

   and

   "We acknowledge and welcome that the project exceeded the agreed scope by doubling the number of contaminant samples from 5 to 10. The level of contamination is sufficiently low and generally within Cefas Action Level 1 limits (two

out of the ten samples for marginally exceeded the Cefas Action Level 1 limits for arsenic) not to be of concern to Natural England".

1.2 Purpose of this document

6. A survey campaign for the entire East Anglia Zone was conducted in 2010 - 2011 (referred to as ZEA surveys). In August 2017, a marine survey campaign was completed across the Norfolk Boreas site, which included grab sampling for infauna and grab sampling for contaminated sediment.

7. The Norfolk Boreas infaunal survey was designed to:

- Collect infaunal data to allow site characterisation; and
- Determine if the ZEA survey data is still valid for use in site characterisation.

8. The Norfolk Boreas contaminant survey was designed to characterise the Norfolk Boreas site in terms of the contaminants present within the site.

9. The Norfolk Boreas survey included 35 sampling locations across the Norfolk Boreas site. The scope of the survey was presented to Natural England and the MMO (Appendix 1) and agreed during a meeting held on the 16th February 2017. Agreement was also confirmed in writing by the MMO (Appendix 2).

10. Also agreed at the meeting was an approach whereby a sub set of 10 samples for benthic infauna and five samples for contaminants was initially analysed. Following receipt of the results from this sub set, a decision on any further requirements for analysis would then be taken. This document presents these initial results and provides justification that no further sample analysis is required.

11. It is worth noting that Vattenfall have exceeded the agreed scope and have analysed a sub set of 10 contaminant samples as opposed to the five agreed.

12. This document:

- Sets out the results of the initial analysis from 10 benthic samples and 10 contaminant samples.
- Demonstrates that the benthic communities found in the Norfolk Boreas infaunal samples were virtually identical to those which were found in the ZEA surveys therefore validating the ZEA data for use in the Norfolk Boreas EIA.
- Provides justification that levels of contaminated sediment across the Norfolk Boreas site are low; and
- Provides evidence as to why further sample analysis (of the remaining 25 samples) is not considered necessary.

1.3 Existing data

13. The ZEA survey used grab sampling, scientific beam trawl and drop-down video (DDV) to characterise the zone (Marine Ecological Surveys Ltd, 2011). During these surveys 98 grab and DDV samples were taken from within what is now the Norfolk Boreas site.

14. The ZEA survey did not cover the Norfolk Boreas offshore cable corridor, however this area was surveyed during the Norfolk Vanguard benthic surveys carried out in 2016. Norfolk Vanguard and Norfolk Boreas have a shared offshore cable corridor. Therefore, results of the Norfolk Vanguard 2016 survey will be used within the Norfolk Boreas EIA to characterise the benthic ecology within the offshore cable corridor.

15. The ZEA survey also included the use of scientific beam trawls to sample the epifauna; 78 samples were taken of which 13 are located within what is now the Norfolk Boreas site. Fish and shellfish characterisation surveys were also undertaken using a commercial demersal otter trawl and commercial beam trawl gear of which three samples were located within the Norfolk Boreas site.

16. No sampling or analysis for sediment contamination was undertaken during the ZEA survey. However, recent sediment data for the general area is available from the North Norfolk Vanguard surveys. Six samples from the North Norfolk Vanguard site were analysed and seven from within the offshore cable corridor (**Figure 2.1**).

1.4 Consistency of approach

17. There are a number of offshore wind projects off the coast of East Anglia which are currently being developed with a view to securing a Development Consent Order under the 2008 Planning Act (E.g. Norfolk Vanguard, East Anglia THREE and others).

18. The conditions encountered by the projects are broadly analogous in terms of sediment type, distance from shore and water depth. The approach taken to the analysis of sampling and analysis of benthic and contaminant samples within the Norfolk Boreas project has been consistent with the approach taken on these projects, both in terms of risk based design and the consultation undertaken to date.

The density and approach to benthic sampling is consistent with, or exceeds that, of Norfolk Vanguard, East Anglia THREE and East Anglia ONE North and TWO. The approach to PSA and contaminant testing is also consistent. At this stage Norfolk Boreas has collected and analysed a greater number of sediment samples for potential contamination site characterisation than the four developments listed above in order to characterise the site. (Further details in Appendix 3).

2 SUMMARY OF APPROACH

2.1 Survey methodology

19. The full methodology used for the Norfolk Boreas survey is detailed in Appendix 1 and a summary is provided below.

20. Drop-down video (DDV) survey was conducted prior to any grab samples being taken to provide an indication of the habitat type and check for presence of *Sabellaria spinulosa* reef or aggregations. Samples for benthic infaunal analysis were taken using a Hamon grab and samples for contaminant analysis were obtained using a Day grab to ensure the sediment layers were preserved for analysis.

21. Following the collection of the contaminant sample a second grab sample was collected using a mini Hamon grab, the contents of which were taken for benthic infauna (species which reside within the sediment) identification and Particle Size Distribution (PSD).

22. The 35 locations at which samples were taken are illustrated in (**Figure 2.1**) with the analysed samples highlighted in yellow. These were sited following an onboard review of the geophysical data to ensure that all habitats were sampled.

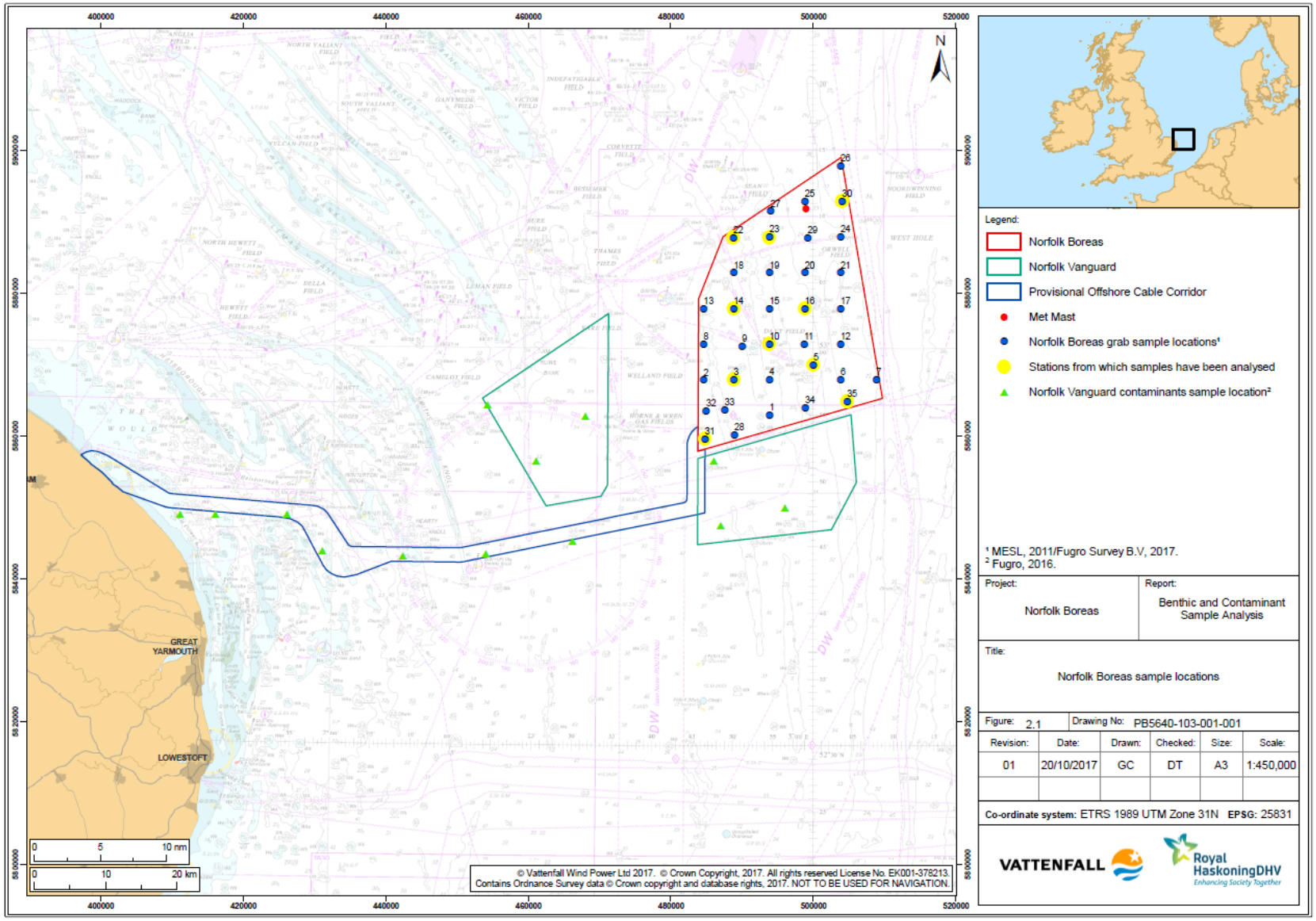
2.2 Sample analysis methodology

23. The survey has been designed to provide good coverage of the site and to allow a strategic approach to the sample analysis. Following a review of the geophysical data (side scan sonar and multibeam echo sounder) the first 10 samples were identified for infaunal analysis. The geophysical review assessed where boundaries in benthic habitats are likely to occur and samples were selected to represent the likely different habitats based on the geophysical and ZEA survey infaunal data.

24. Following guidance from the MMO, samples sent for contaminant analysis were mainly chosen based on high percentage of fine material and to ensure good coverage across the site. Due to time pressures caused by the degradation of samples and survey programme this was a visual assessment conducted by eye onboard the vessel. To ensure appropriate spatial distribution across the Norfolk Boreas site two sites were chosen which contained coarser sandy sediments (Station 10 and 14, **Figure 2.1**) to represent a large section of sandy sediments in the mid to west sections of the Norfolk Boreas site.

25. The fractional components of the PSD data are provided in Appendix 4.

Figure 2.1 Grab samples locations (Benthic and contaminant for Norfolk Boreas surveys and contaminant for Norfolk Vanguard surveys)



26. The seabed imagery acquired from the 35 DDV sites was reviewed onboard to broadly characterise the seabed habitat to determine the presence of Annex I habitats, in particular *S. Spinulosa* which was expected to be in the area as it was recorded during the ZEA surveys. At sites where *S. Spinulosa* was recorded, additional video drops were performed in order to map its extent.

27. The analysis of the grab samples comprised:

- Benthic infaunal analysis:
  - Species identification and enumeration;
  - Fully quantitative abundance recorded where possible;
  - Taxonomic nomenclature in accordance with Howson and Picton, 1997; and
  - Wet weight biomass estimates for each taxonomic group (family).

- Particle Size Distribution (PSD):
  - to determine sediment type, taken as a sub-sample from the contents of each benthic grab. This used a combination of dry sieving and laser particle size distribution. Laser diffraction was used for those samples where the <63µm fraction makes up greater than 5% of the sample. Any cobbles in the sediment were evaluated using Cefas guidelines, as appropriate.

- Contaminants analysis including:
  - Trace Metals: Arsenic, Mercury, Cadmium, Chromium, Copper, Nickel, Lead and Zinc;
  - Polychlorinated biphenyls (PCB);
  - Organotins: Tributyl Tin (TBT) and Dibutyl Tin (DBT); and
  - Poly Aromatic Hydrocarbons (PAH) and Total Petroleum Hydrocarbons (THC)

28. All samples were analysed in a suitably accredited laboratory (UKAS). The laboratory undertaking the faunal analyses was NMBAQC accredited and the contaminant samples were analysed at the National Laboratory Service (NLS) at the Environment Agency.

2.3 Data analysis methodology

29. A key element of the benthic infaunal data analysis was to establish if the ZEA data was still valid and therefore whether it could be used in conjunction with the Norfolk Boreas data to accurately characterise the Norfolk Boreas site. This approach focuses around demonstrating that the infaunal communities identified within Norfolk Boreas grab samples were similar to those found during the ZEA surveys.

30. For the contaminant data, the focus was on determining whether the Norfolk Boreas site contained sufficiently high levels of contamination to justify further sample analysis.

2.3.1 Seabed Imagery Analysis

31. The seabed imagery recorded at the 35 sample locations was reviewed in order to provide an overall characterisation of the site which was compared to the site characterisation established from the seabed imagery obtained during the ZEA survey.

2.3.2 Infaunal Univariate Analysis

32. Univariate statistical analysis was conducted to extract information including species abundance and the number of taxa present (taxonomic richness). The univariate analysis of the Norfolk Boreas data was compared to the ZEA univariate analysis results.

2.3.3 Infaunal Multivariate Analysis

33. Multivariate statistical analyses were conducted on a combined data set consisting of the Norfolk Boreas and the ZEA data using the Plymouth Marine Laboratories (PRIMER) v6 suite of programs (Clarke and Warwick, 2001; Clarke and Gorley, 2006).

34. Benthic grab data from both the ZEA and Norfolk Boreas surveys were imported into PRIMER, merged and initially subjected to fourth root transformation to reduce the influence of any highly abundant taxa allowing less abundant species a greater role in driving the emergent multivariate patterns. The transformed data were then organised into a resemblance matrix using a Bray Curtis index of similarity.

35. The full data set was then subjected to hierarchical clustering to identify sample groupings based on the same Bray Curtis index of similarity. This process combines samples into groups starting with the highest mutual similarities and then gradually lowering the similarity level at which groups are formed. The process ends with a single cluster containing all stations and is best expressed as a dendrogram showing the sequential clustering of stations against relative similarity.

36. To best describe the ecological differences between sample stations, the groups were identified on the basis of a slice at 20% similarity for the infaunal communities. This was informed by a SIMPROF test which confirmed that a 20% slice was a reasonable cut off. Similarity slices at around 20% are commonly used for a data set of this size and the multivariate analysis for the original ZEA data used a 20% cut off point as did the East Anglia THREE multivariate assessment (EATL, 2015).

37. The MDS (Multi-dimensional Scaling) procedure uses the same similarity matrix as that used by the cluster analysis to produce an ordination of stations which is multidimensional. This is carried out to satisfy the between-samples relationships indicated by the similarity matrix. This multi-dimensional ordination is then reduced

to a 2 or 3 dimensional representation that is a more accessible and useable representation. The representativeness of these 2-dimensional versions, in comparison to the multi-dimensional array, is indicated by a stress level. The closer this stress level is to zero, the better the representation.

38. As requested by Cefas in their response to the original report (F01) the above procedures were also conducted using only the samples collected from within the Norfolk Boreas site. This included the 98 ZEA samples and the 10 analysed samples from the Norfolk Boreas survey. The SIMPROF routine indicated that a 35% slice was a reasonable cut off point for establishing the different faunal groups within the site.

2.3.4 PSD Multivariate Analysis

39. As requested by Cefas in their response to the first version of this report (FO1) multivariate statistical analysis was carried out on the PSD data *"to confirm that the sediments are similar between the two time periods"*.

40. PSD data, provided as the fractional components mud (0 to 63µm) sand (> 63 to 2000µm) and gravel (>2000µm), from samples within the Norfolk Boreas site (both ZEA and Norfolk Boreas surveys) was initially subjected to a normalisation transformation as is appropriate for environmental data provided as percentages. The transformed data were then organised into a resemblance matrix using a Euclidean distance.

41. The transformed data were then subjected to hierarchical clustering to identify sample groupings. This process ends with a single cluster containing all stations and is best expressed as a dendrogram showing the sequential clustering of stations against relative similarity. To best describe the environmental differences between samples, the groups were identified on the basis of a slice at a Euclidean distance of 1.8; which was indicated as suitable using the SIMPROF routine.

2.3.5 Sediment Contaminant Analysis

42. The results of the sediment contamination samples were compared to Cefas Action Levels. Cefas Action Levels are commonly used to indicate contaminant levels within sediments and are considered an acceptable way of assessing the risks to the environment from other marine activities as part of the EIA. The Action Levels are set out in **Table 2.1**.

43. The MMO (using the Cefas Action levels) states that, in general, contaminant levels below Action Level 1 are not considered to be of concern. Sediment with persistent contaminant levels above Action Level 2 is generally considered to pose an unacceptable risk to the marine environment (and therefore sediment is unlikely to be considered suitable for disposal to sea). For sediment with persistent

contaminant levels between Action Levels 1 and 2, further consideration of additional evidence is usually required before the risk can be identified. Therefore, for EIA, in the same way, if contaminant levels in the sediment under consideration persistently exceed Action Levels, additional assessment is recommended.

Table 2.1 Selected Cefas Action Levels (taken from Cefas, 2000)

Contaminant	Action Level 1 (mg/kg)	Action Level 2 (mg/kg)
Arsenic	20	100
Cadmium	0.4	5
Chromium	40	400
Copper	40	400
Nickel	20	200
Mercury	0.3	3
Lead	50	500
Zinc	130	800
Polycyclic aromatic Hydrocarbons	0.1 (exception dibenz[a,h]anthracene which is 0.01)	None
Organotins (Tributyltin (TBT) and Dibutyltin (DBT))	0.1	1
Polychlorinated Biphenyls (sum of ICES 7)	0.01	None
PCBs (sum of 25 congeners)	0.02	0.2
Total Hydrocarbons (THC)	100	None

3 RESULTS

3.1 Seabed imagery analysis

44. 33 sites had fine sediments, analysed as mainly shelly sand or shelly gravelly sand. This corresponds to the ZEA survey results which found the sediments across the former East Anglia zone to be predominantly comprised of sandy substrates with varying levels of gravel composition. Examples of the common sediments recorded are displayed in **Plate 3.2**.

45. *S. Spinulosa* was recorded at two sites (5 (**Plate 3.1**) and 14). At site 5 three additional drops were performed (5A-C), and at site 14 one additional drop was performed (14A). At each of these sites the *S. Spinulosa* was not present in a reef formation and was therefore not classed as an Annex I habitat. The *S. Spinulosa* aggregations encountered as part of the survey were considered to be either 'Not reef' or 'Low reef' (using the methodology defined in Gubbay, 2007 as far as is possible from live, onboard DDV review); in order to be designated as an Annex I habitat classification as a 'Medium reef' or 'High reef' is required using the Gubbay criterea.

46. Generally, a low number of species were recorded at the 35 sample locations (between 1 and 17 species) with the most diverse locations being those which contained *S. Spinulosa* aggregations (sample 5 and 14). Species recorded at several locations include *Ophiura ophiura*, *Ophiura albida* and *Asterias rubens*. The SACFOR[1] abundance scale was used to measure relative abundances of fauna present at each site. The only species recorded as 'Super Abundant' were *O. ophiura* and *S. Spinulosa.*

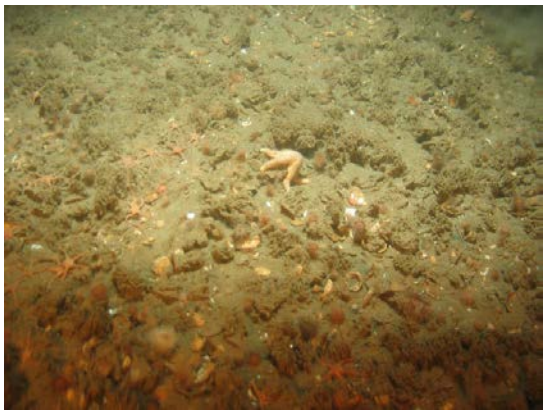


Plate 3.1 *Sabellaria* (site 5)

Plate 3.2 Rippled shelly sand (site 27)

[1] SACFOR: S = Superabundant, A = Abundant, C = Common, F = Frequent, O = Occasional, R = Rare

3.2 Univariate analysis

47. The infaunal species list from the Norfolk Boreas samples included 105 different entries, 100 of these were also recorded in during the ZEA survey. Not all individuals were identified to species level and therefore there may still be a greater overlap between the two surveys.

48. The five species recorded in Norfolk Boreas survey but not in the ZEA survey were: *Corystes cassivelaunus* (1 individual), *Mactra sp* (3 individuals), *Cerebratulus sp* (5 individuals), 2 individuals from the super family *Pectinoidea*, and an individual from the phylum *Platyhelminthes.* Of these five infauna only 12 individuals were recorded which represents 0.6% of the total number of individuals recorded.

49. Of the top ten most common species recorded in the Norfolk Boreas survey all were also recorded during the ZEA survey and five of them were also in the ten most common species recorded in the 2011 survey including: *S. spinulosa, Spiophanes bombyx, Abra alba, Pisidia longicornis* and *Echinocyamus pusillus.* These five species accounted for 59% of the total species counts in the Norfolk Boreas survey.

50. The most common phylum recorded in the Norfolk Boreas survey were Annelida (67%), Arthropoda (8%), Mollusca (17%) and Echinodermata (6.5%). This was also mirrored in the ZEA survey with the same dominant Phyla: Annelida (58%), Arthropoda (12%), Mollusca (9%), Echinodermata (15%). A comparison is provided in **Plate 3.3**.

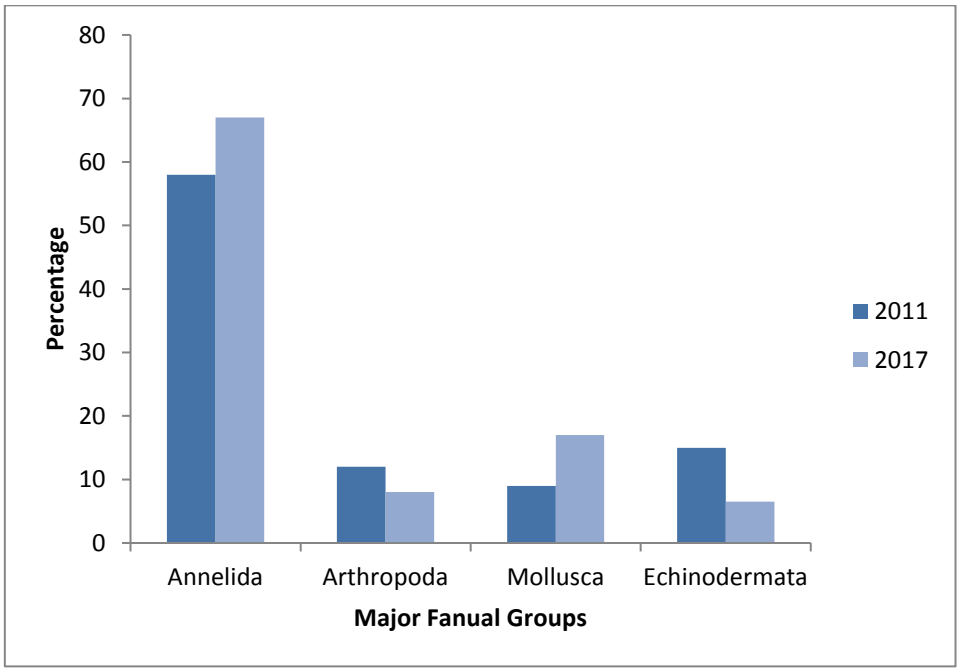


Plate 3.3 Major faunal groups recorded in the ZEA and the 2017 Norfolk Boreas benthic surveys

3.3 Multivariate analysis

3.3.1 Analysis of full ZEA and Norfolk Boreas data set

51. An MDS plot, with communities identified by survey, reveals that the ZEA data are largely comparable to the Norfolk Boreas data (**Plate 3.4**). If the communities had been significantly different the Norfolk Boreas and ZEA samples would be defined in two isolated groups. As can be seen in **Plate 3.4** the MDS plot exhibits a stress of 0.25 indicating that the two-dimensional image is a relatively poor representation of the multidimensional space (anything above 0.2 is generally regarded as a high stress). A three-dimensional plot has also been provided (**Plate 3.5**) which has a lower degree of stress, however to integrate this data properly it should be viewed in a three-dimensional space using the PRIMER software. Therefore, although the results provided in **Plate 3.4** and **Plate 3.5** are useful they should be treated with a degree of caution.

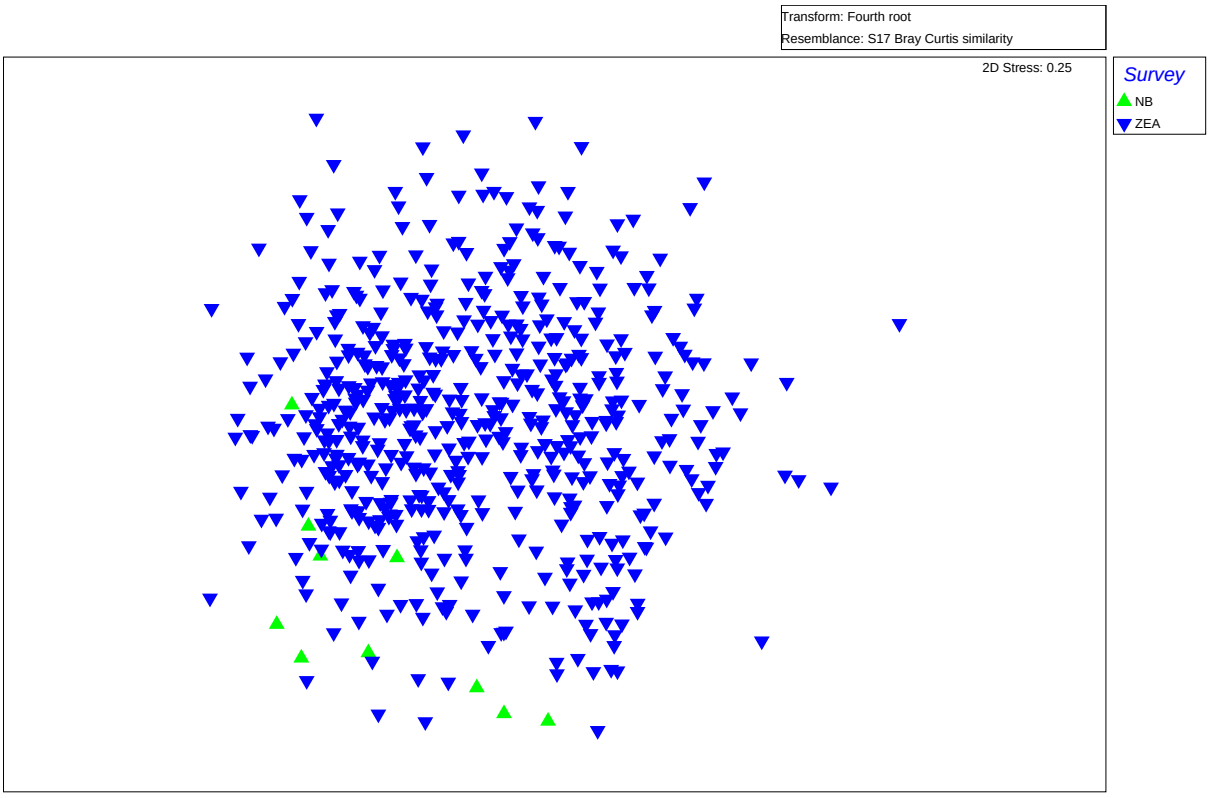


Plate 3.4 MDS 2-Dimensional plot showing the relationship of communities sampled during the Norfolk Boreas and ZEA surveys. NB= Norfolk Boreas Survey and ZEA = 2011 ZEA surveys.

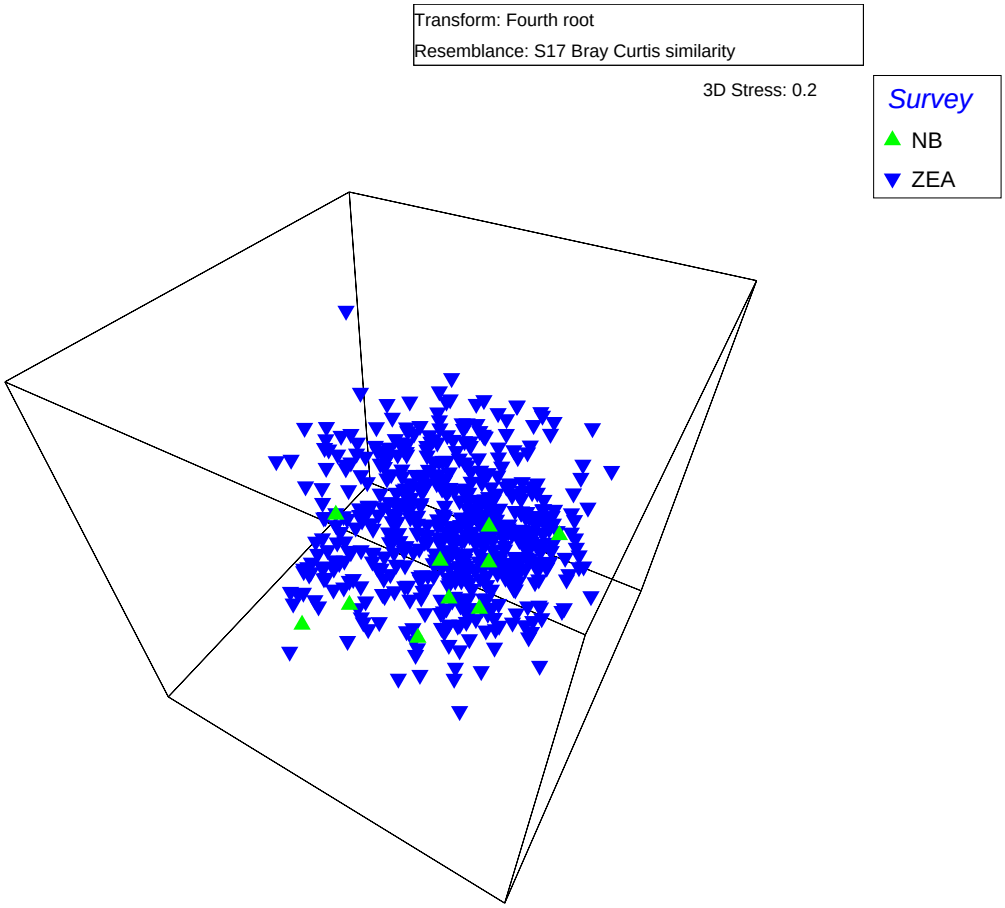


Plate 3.5 MDS 3-Dimensional plot showing the relationship of communities sampled during the Norfolk Boreas and ZEA surveys. NB= Norfolk Boreas survey and ZEA = 2011 ZEA surveys.

52. Following the cluster analysis (which cannot be displayed in this report as it is too large) 13 groups were identified from the combined ZEA and Norfolk Boreas data using a 20% slice (groups a to m). Only two groups were identified in the Norfolk Boreas samples, g (1 sample) and j (nine samples). Group j was the most common group across the combined data set with 300 samples in total and g was relatively common with 38 samples identified. Two and three-dimensional MDS plots are displayed in **Plate 3.6** and **Plate 3.7** showing the different faunal groups at a 20% slice.

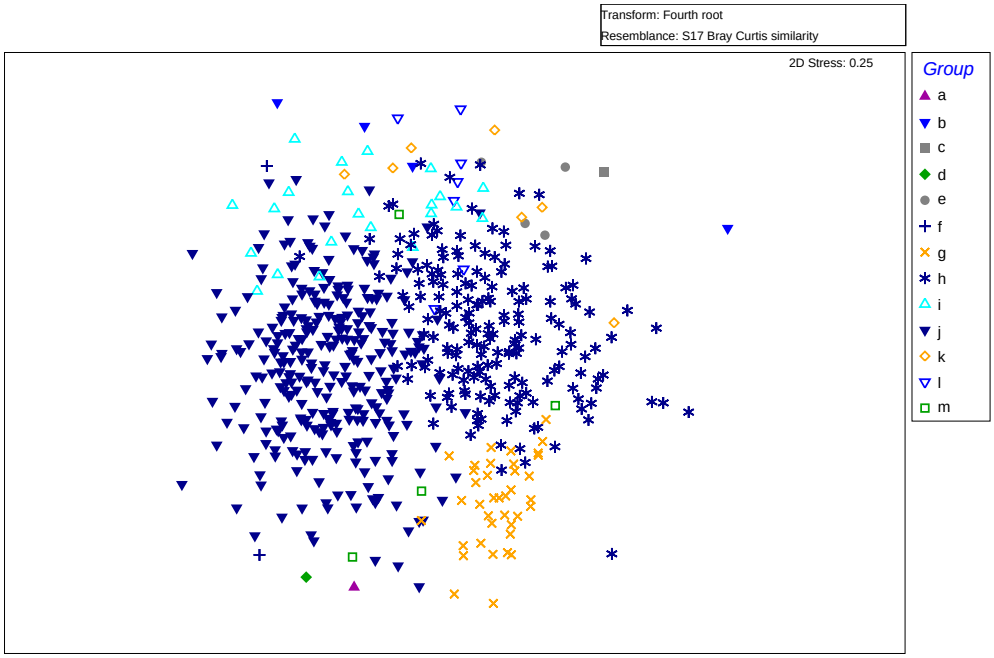


Plate 3.6 MDS 2-Dimensional plot showing groupings based on 20% similarity slice of ZEA and Norfolk Boreas faunal communities.

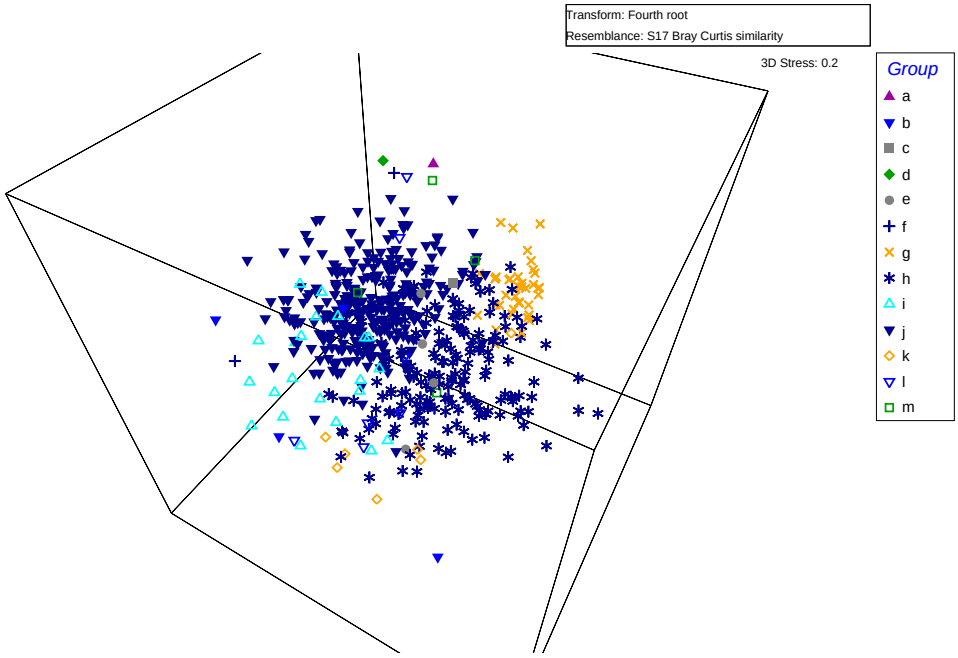


Plate 3.7 MDS 3-Dimensional plot showing groupings based on 20% similarity slice of ZEA and Norfolk Boreas faunal communities.

53. **Figures 3.1** and **3.2** show the locations of these faunal groups. **Figure 3.1** shows the combined data set and **Figure 3.2** shows the Norfolk Boreas sample points only. They are displayed separately so that it is easy to compare between the two surveys.

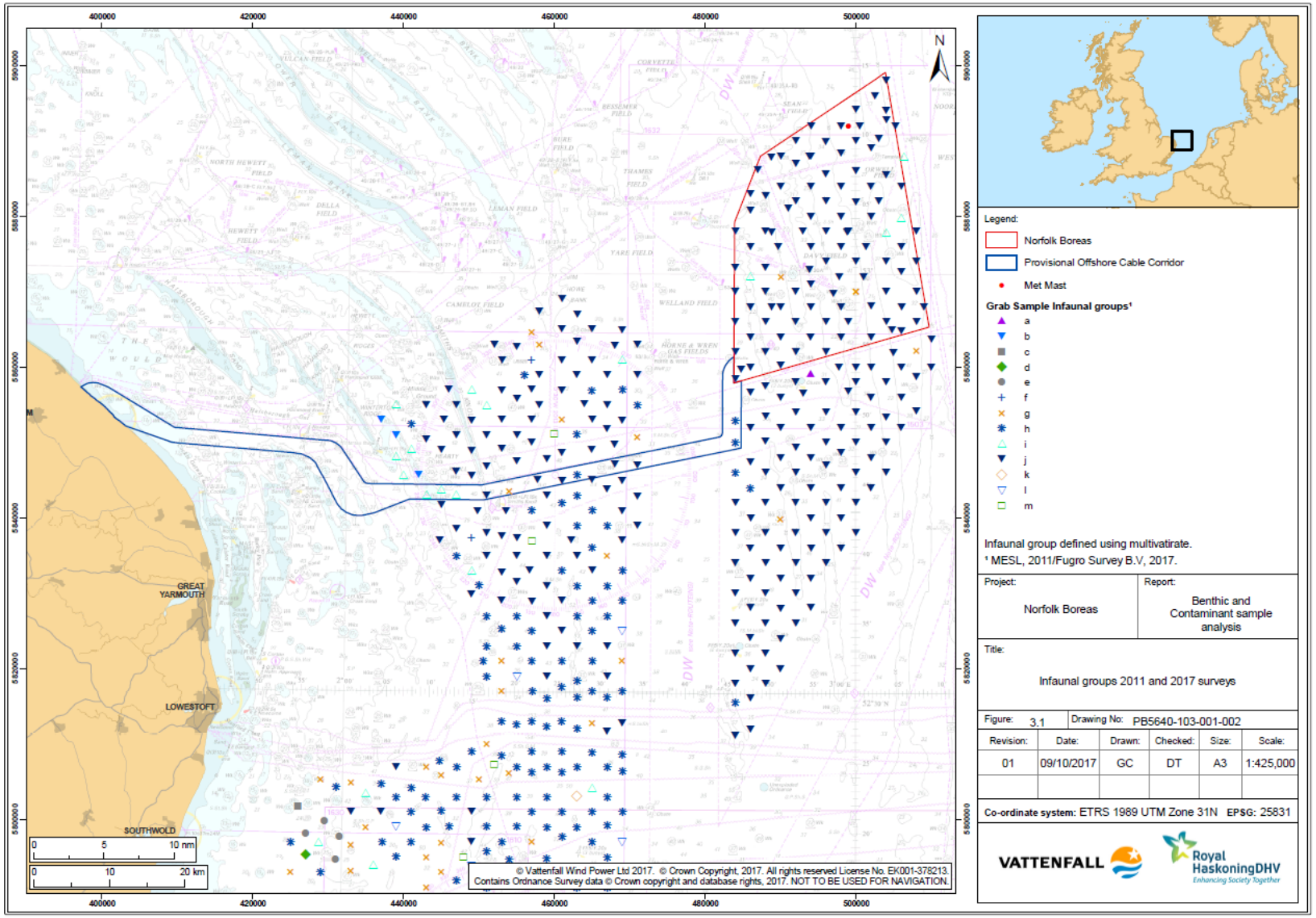


Figure 3.1 location of Infaunal groups as determined through multivariate analysis combined (ZEA 2011 and Norfolk Boreas 2017) data set

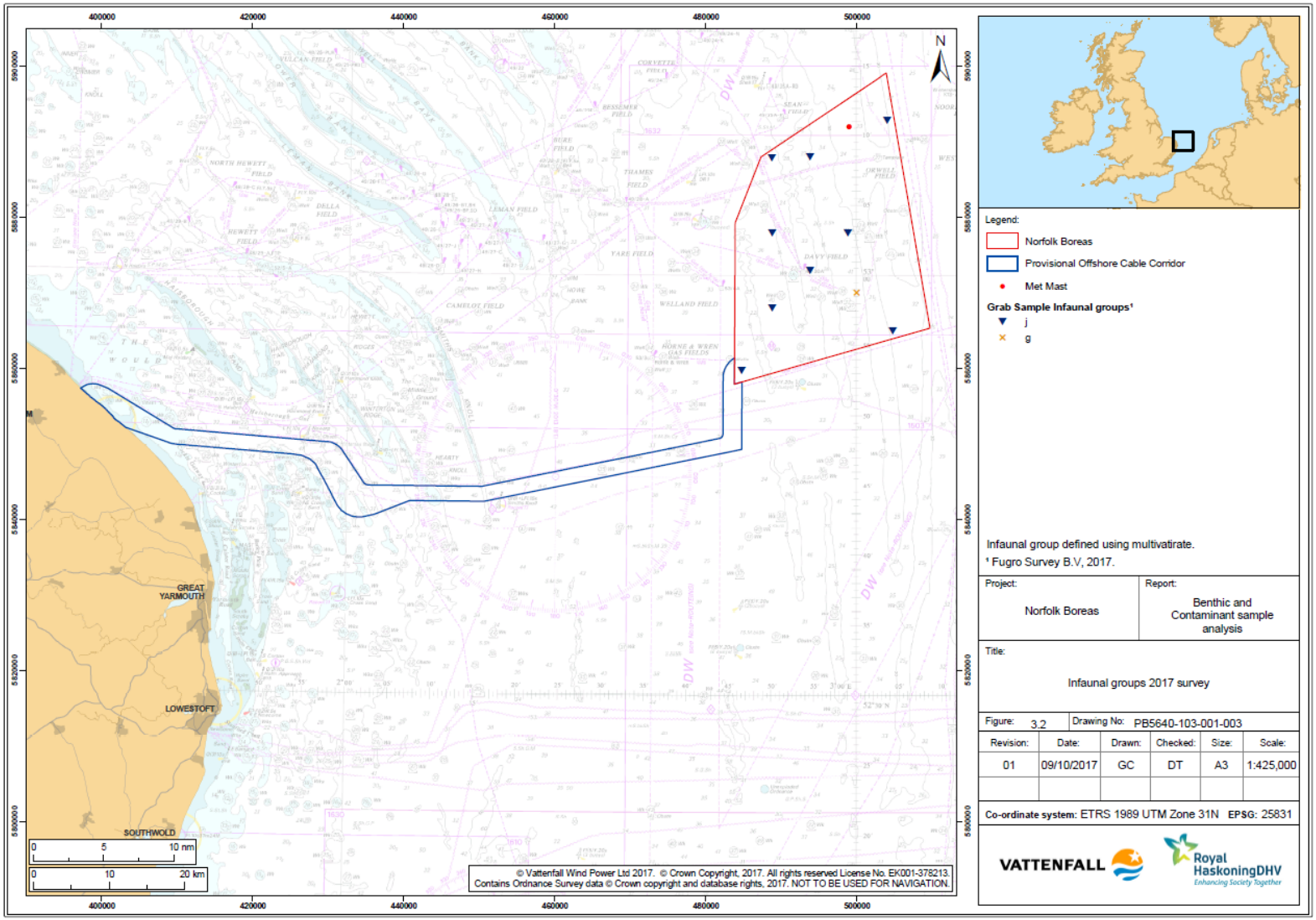


Figure 3.2 location of Infaunal groups as determined through multivariate analysis combined (ZEA 2011 and Norfolk Boreas 2017) data set. Showing only the Norfolk Boreas samples.

3.3.2 Analysis of samples from within the Norfolk Boreas site only

54. Cluster analysis of samples collected from within the Norfolk Boreas site only and the resultant dendrogram is presented **Plate 3.8**. The SIMPROF routine indicated that a 35% similarity slice was appropriate for identifying infaunal groups and at this level ten different faunal groups were identified.

55. **Plate 3.8** shows that the communities identified from the Norfolk Boreas surveys are widely distributed within the communities found in the ZEA data.

56. An MDS plot with communities identified by survey reveals that the ZEA data are largely comparable to the Norfolk Boreas data **Plate 3.9.** If the communities had been significantly different the Norfolk Boreas and ZEA samples would be defined in two isolated groups. As can be seen in **Plate 3.9** the MDS plot exhibits a stress of 0.24 indicating that the two-dimensional image is a relatively poor representation of the multidimensional space (anything above 0.2 is generally regarded as a high stress). A three-dimensional plot has also been provided (**Plate 3.10**) which has a lower degree of stress (0.19).

57. ANOSIM showed that there was no significant difference between samples from the different surveys (P= 13.2% and R = 0.099).

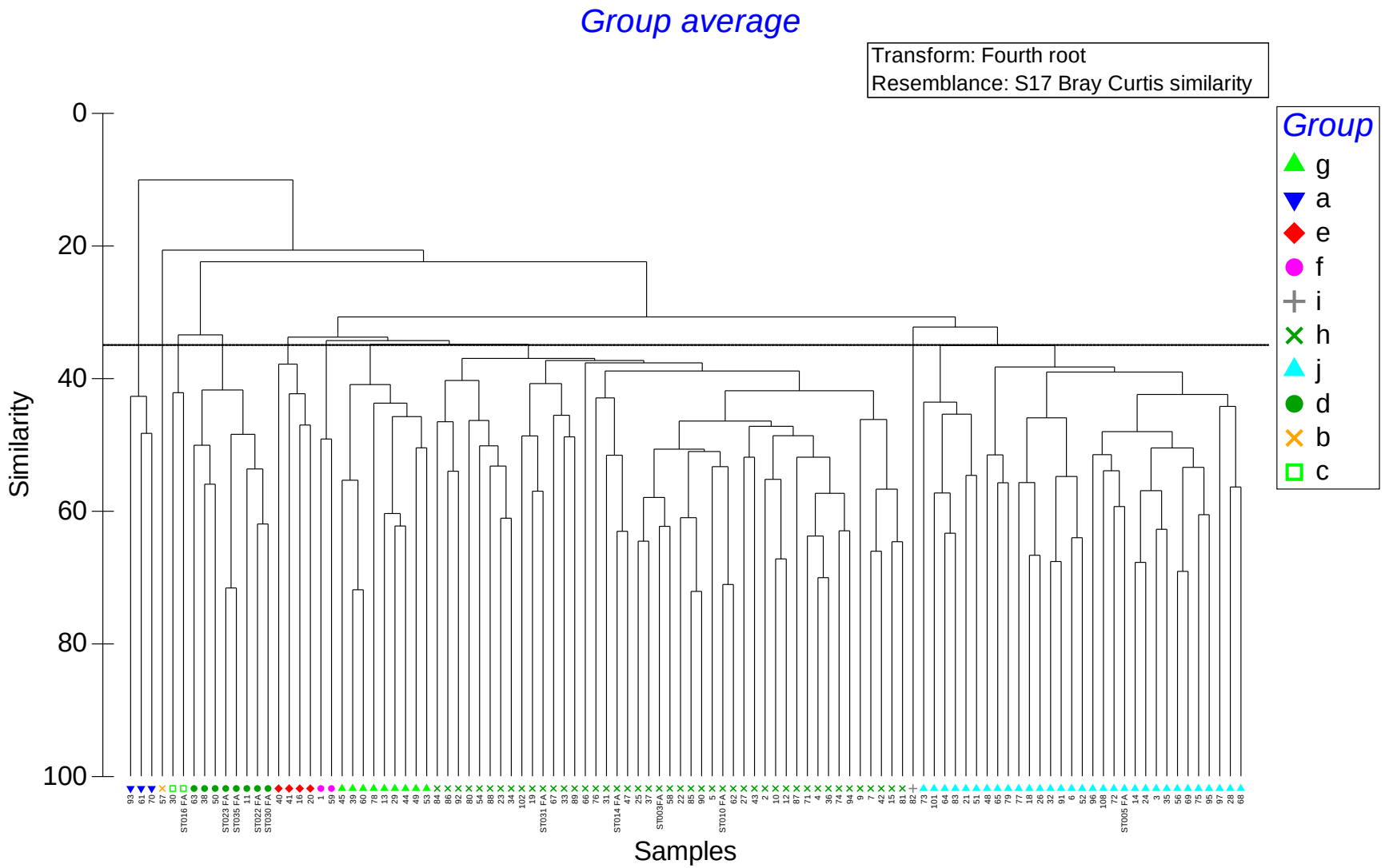


Plate 3.8 Dendrogram showing the results of the infaunal cluster analysis groupings based on 35% similarity slice for samples (ZEA and Norfolk Boreas Survey) within the Norfolk Boreas site (Samples from the Norfolk Boreas surveys can be identified by the ST prefix and FA suffix)

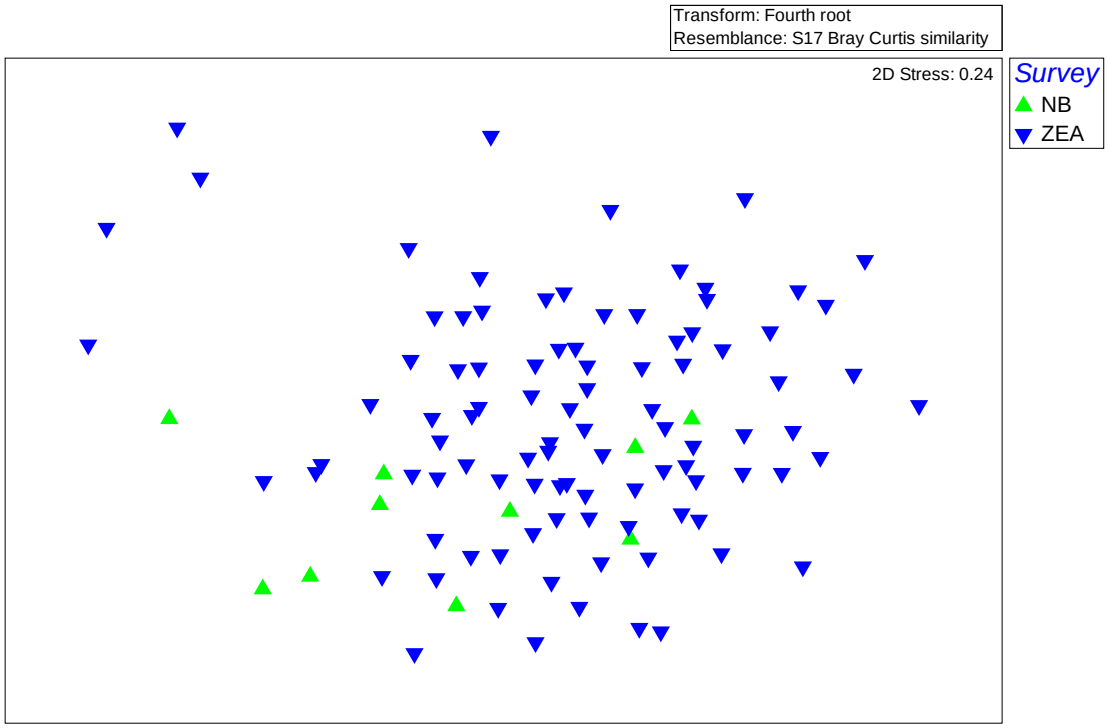


Plate 3.9 MDS 2-Dimensional plot showing the relationship of infaunal communities sampled from within the wind farm site from Norfolk Boreas and ZEA surveys. NB= 2017 Norfolk Boreas Survey and ZEA = 2011 ZEA surveys.

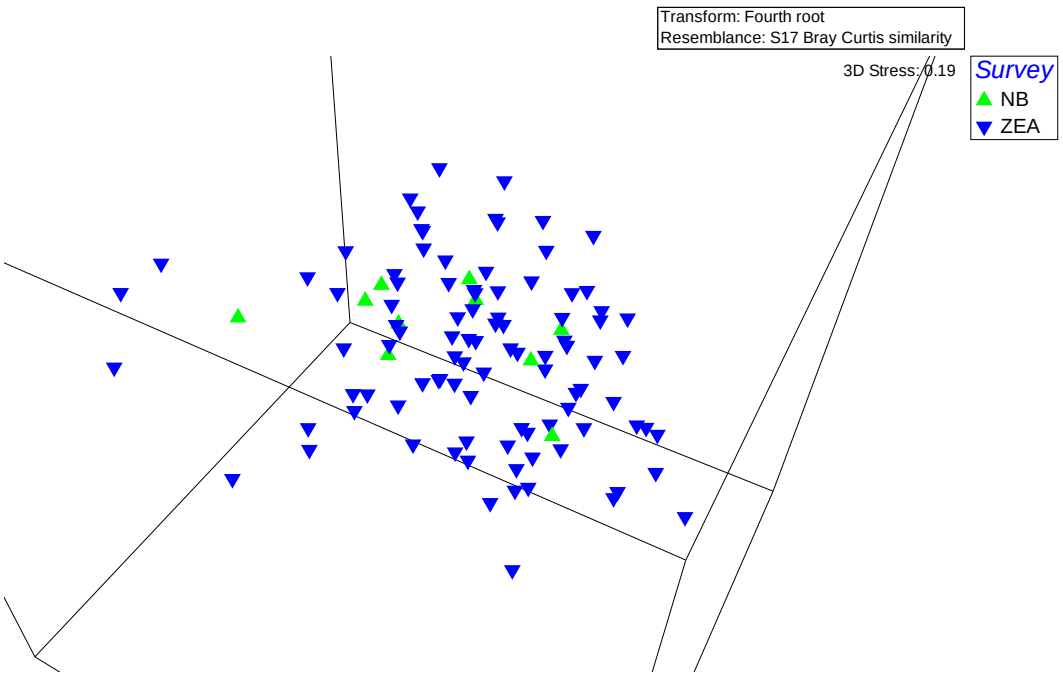


Plate 3.10 MDS 3- Dimensional plot showing the relationship of infaunal communities sampled from within the wind farm site from Norfolk Boreas and ZEA surveys. NB= 2017 Norfolk Boreas Survey and ZEA = 2011 ZEA surveys

3.4 Comparison of PSD data between years

58. The SIMPROF routine identified that a slice at a Euclidean distance of 1.8 was a suitable cut off for defining sediment groups. The dendrogram presented in **Plate 3.11** identifies seven distinct groups at this level with the no group containing samples from just the Norfolk Boreas surveys.

3.5 Sediment contamination analysis

59. **Table 3.1** summarises the sediment contamination data which have been compared to the Cefas Action Levels. Data highlighted in yellow indicates concentrations of contaminants that exceed Cefas Action Level 1. All organotin and PCB results were below the limits of detection (0.004 mg/kg and 0.0001 mg/kg respectively) and therefore have not been included in the table.

60. The data summarised in (**Table 3.1**) illustrates that sediment contamination within the site is low. Only two sites exceeded Cefas Action Level 1 and this was for concentrations of arsenic at ST03 and ST14. However, these exceedances are marginal as they are only just over the Action Level 1 concentration and are in line with other sediment contaminant data from the general area (Norfolk Vanguard surveys and East Anglia THREE surveys) and have been attributed to geological inputs and sea bed rock weathering. All other concentrations were below Cefas Action Level 1 and there were no Cefas Action Level 2 exceedances. Since these results indicate relatively low levels of contamination, analysis of the remaining stored samples is not considered necessary.

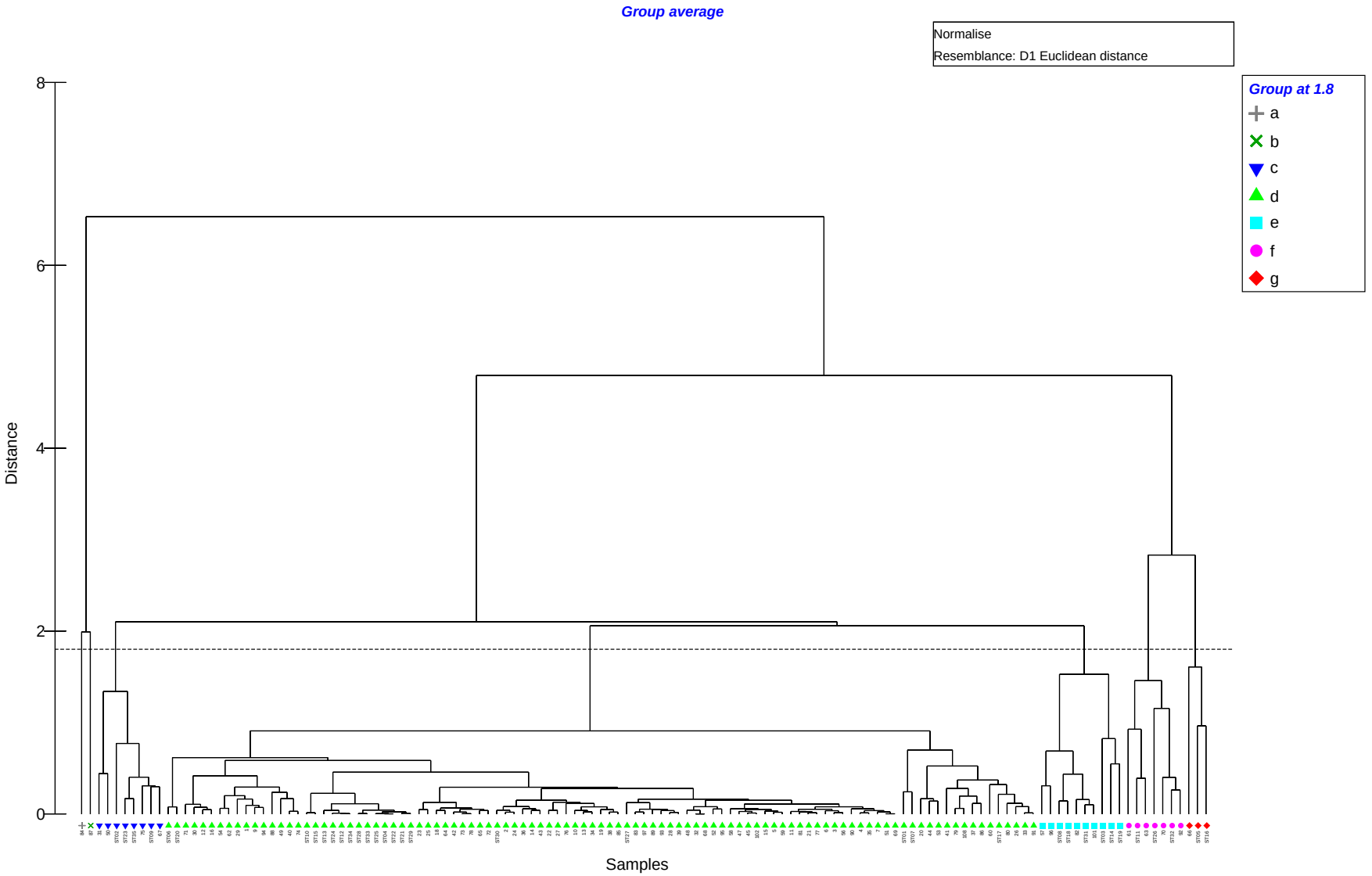


Plate 3.11 Dendrogram showing the results of the PSD cluster analysis groupings based on Euclidean distance slice of 1.8 for samples within the Norfolk Boreas site (Samples from the Norfolk Boreas surveys can be identified by the ST)

Table 3.1 Sediment contamination analysis results compared to Cefas Action Levels (yellow highlights where an exceedance of level one has occurred)

Contaminant (mg/kg)	Sample site									
	ST31	ST03	ST10	ST14	ST23	ST30	ST16	ST05	ST35	ST22
Arsenic	13.3	21	12	32.7	14.9	10.5	9.4	12.9	8.76	14.4
Cadmium	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Chromium	12.2	10	7.43	13.9	12.9	7.81	14.5	15.6	14.3	11
Copper	1.75	1.19	1.14	1.81	1.35	1.06	3.17	3.08	1.38	1.7
Nickel	5.4	4.41	4.57	6.41	5.22	4.2	6.95	7.85	5.49	6.1
Mercury	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.0108	<0.01	<0.01
Lead	4.39	7.17	4.67	9.91	5.09	4.63	6.62	6.74	4.61	4.87
Zinc	15.2	22.3	17.3	27	18.3	16.1	23.7	22.6	14.8	14.7
Hydrocarbons : Total	4.29	2.35	6.97	4.63	10.8	2.31	23.7	16	3.53	1.96
Acenaphthene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Acenaphthylene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Anthracene	<1	<1	<1	<1	<1	<1	<1	2.02	<1	<1
Benzo(a)anthracene	<1	<1	<1	<1	<1	<1	2.11	3.82	<1	<1
Benzo(a)pyrene	<1	<1	<1	<1	<1	<1	2.54	3.96	<1	<1
Benzo(b)fluoranthene	<1	<1	<1	<1	1.56	<1	4.07	5.04	<1	<1
Benzo(e) pyrene	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Benzo(ghi)perylene	<1	<1	<1	<1	1.29	<1	3.78	4.13	<1	<1
Benzo(j)fluoranthene	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Benzo(k)fluoranthene	<1	<1	<1	<1	<1	<1	1.85	2.49	<1	<1
Chrysene + Triphenylene	<3	<3	<3	<3	<3	<3	3.16	4.52	<3	<3
Chrysene	<3	<3	<3	<3	<3	<3	<3	3.55	<3	<3
Dibenzo(ah)anthracene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Dibenzothiophene	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Fluoranthene	<1	<1	<1	<1	1.55	<1	4.26	9.01	<1	<1
Fluorene	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Indeno(1,2,3-c,d)pyrene	<1	<1	<1	<1	<1	<1	2.39	3.15	<1	<1
Naphthalene	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Perylene	<5	<5	<5	<5	<5	<5	<5	7.88	<5	<5
Phenanthrene	<5	<5	<5	<5	<5	<5	6.03	6.62	<5	<5
Pyrene	<1	<1	<1	<1	1.3	<1	3.84	7.71	<1	<1
Triphenylene	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2

4 CONCLUSION

61. An analysis of seabed imagery, benthic infaunal communities and sediment contaminant data has been carried out for samples across the Norfolk Boreas site.

62. The analysis includes a comparison of the results from the Norfolk Boreas benthic survey and the results of the previous ZEA survey. The comparison has shown that the infaunal communities are similar across the two surveys.

63. The results from both surveys indicate that the habitat is predominantly comprised of sandy substrates with varying levels of gravel and mud composition. The infauna recorded in both surveys were dominated by the same phylum. Similarly, at the species level, the dominant species were the largely the same in both across both surveys.

64. Multivariate analysis showed that the composition of the infaunal communities was as very similar in the two surveys. This was shown to be the case when analysing the entire combined data set and also when focusing on the samples collected from within the Norfolk Boreas site in isolation.

65. All of the above demonstrate the suitability the ZEA survey data for characterisation of the Norfolk Boreas site.

66. The sediment analysis recorded low levels of contamination across the site. Arsenic was the only contaminant to marginally exceed Cefas Actions level 1 but this was only at two of the 10 sites.

4.1 Recommendations for further analysis

67. Due to the similarity of the benthic communities recorded across the 2011 ZEA data and the 10-sample sub set of the 2017 Norfolk Boreas data it is not recommended that any of the remaining 25 samples be subject to analysis. The data collected thus far is considered to be adequate to characterise the area for the purposes of an EIA for a wind farm development.

68. The sediment contaminant results are very similar to those found at other wind farm sites within the former East Anglia zone and are based on a higher number of analysed samples. Therefore, additional contaminant analysis is not considered necessary.

5 REFERENCES

Centre for Environmental, Fisheries and Aquaculture Science (Cefas) (2000). Monitoring surveillance of non-radioactive contaminants in the aquatic environment and activities regulating the disposal of wastes at sea, 1997. Lowestoft: Cefas. Science Series Aquatic Environment Monitoring Reports, No.52.

Clarke, K. R. and Gorley, R. N. (2006) Primer v6: user manual/tutorial Plymouth: PRIMER-E.

Clarke, K. R. and Warwick R. M. (2001) Change in marine communities: an approach to statistical analysis and interpretation 2nd edition, Plymouth: PRIMER-E.

East Anglia THREE Limited (2015) Chapter 10 Benthic Ecology Appendix 10.6 Multivariate Analysis of Combined Data. Available at: https://infrastructure.planninginspectorate.gov.uk/wp-content/ipc/uploads/projects/EN010056/EN010056-000291-6.3.10%20(6)%20Volume%203%20Chapter%2010%20Benthic%20Ecology%20Appendix%2010.6.pdf

Gubbay (2007). Defining and managing *Sabellaria spinulosa* reefs: Report of an inter-agency workshop 1-2 May, 2007; June 2007. JNCC Report No. 405

Marine Ecological Surveys Ltd (2011) East Anglia Offshore Wind Zonal surveys

Marine Ecological Surveys Ltd. (2011). East Anglia Offshore Windfarm Zonal Environmental Appraisal: Benthic Biological Characterisation Report.

APPENDIX 1 – APPROACH TO BENTHIC SAMPLING

69. Provided as separate document, first issued to the MMO and Natural England in February 2017.

APPENDIX 2 – MMO RESPONSE TO BENTHIC SURVEY CONSULTATION

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Your Ref: PB5640.104.102
Our Ref: DCO/2017/00002

20 April 2017

Dear Ms Wood,

Ref: Norfolk Boreas Offshore Wind Farm – Approach To Benthic Sampling

The Marine Management Organisation (MMO) received the above referenced document on 21 March 2017.

The MMO has reviewed the document along with our advisors at the Centre for the Environment, Fisheries and Aquaculture Science (Cefas). I set out our comments below:

Comments

1. The sample locations were selected using Zonal bathymetry, BGS and Zonal PSA along with Zonal benthic community analysis. The MMO would recommend a review of the new geophysical data to determine if there are any signatures indicative of Annex I reef which have not been targeted as part of the selected 35 stations.

2. A review of the video evidence collected would also be useful to determine the presence/absence of Sabellaria spinulosa and other reef forming species.

3. Contaminant analyses of samples containing the highest mud content should be undertaken if they contain greater fines than those selected close to the existing infrastructure.

Overall the methodology proposed is a sound approach.

If you have any queries regarding this response then please contact the undersigned.

Yours sincerely

[redacted]

[redacted]
Marine Licensing Case Officer

[redacted]

APPENDIX 3 – RESPONSE TO MMO ADVICE ON F01 OF THIS REPORT

70. Provided as separate document, including the Applicants Response to each comment. The Applicants Reponses are provided in blue text.

APPENDIX 4 – PSD DATA

71. The table below provides the Particle size distribution data organised by the fractural components of mud (0 to 63µm) sand (63.01 to 2000µm) and gravel (above 2000.01 µm and above) The samples which have been analysed for contaminant analysis are highlighted in yellow.

Station	Mud	Sand	Gravel
ST01	0.00	96.57	3.43
ST02	6.29	91.31	2.40
ST03	8.70	87.52	3.78
ST04	0.00	99.99	0.01
ST05	13.47	80.11	6.42
ST06	0.00	98.43	1.57
ST07	0.00	97.14	2.86
ST08	0.00	95.66	4.34
ST09	7.91	90.47	1.62
ST10	0.00	99.33	0.67
ST11	1.50	95.42	3.08
ST12	0.00	99.71	0.29
ST13	0.00	99.60	0.40
ST14	5.28	88.90	5.81
ST15	0.00	99.30	0.70
ST16	10.16	84.07	5.77
ST17	0.90	96.95	2.15
ST18	0.00	95.32	4.68
ST19	6.83	88.46	4.71
ST20	0.00	98.62	1.38
ST21	0.00	99.94	0.06
ST22	0.00	100.00	0.00
ST23	9.00	90.78	0.22
ST24	0.00	99.68	0.32
ST25	0.00	99.98	0.02
ST26	6.19	87.20	6.62
ST27	0.58	99.38	0.05
ST28	0.00	99.87	0.13
ST29	0.00	99.92	0.08
ST30	2.32	97.56	0.13
ST31	1.59	93.78	4.64
ST32	20.46	74.33	5.21
ST33	0.00	99.85	0.15
ST34	0.00	99.70	0.30
ST35	8.36	91.21	0.44