OFFSHORE RENEWABLES JOINT INDUSTRY PROGRAMME (ORJIP) FOR OFFSHORE WIND

Appendix 4: Biological Traits Analysis Report

ORJIP BenCH – Benthic habitat changes post-construction of offshore wind

September 2025

ORJIP Offshore Wind

The Offshore Renewables Joint Industry Programme (ORJIP) for Offshore Wind is a collaborative initiative that aims to:

- Fund research to improve our understanding of the effects of offshore wind on the marine environment.
- Reduce the risk of not getting, or delaying consent for, offshore wind developments.
- Reduce the risk of getting consent with conditions that reduce viability of the project.

The programme pools resources from the private sector and public sector bodies to fund projects that provide empirical data to support consenting authorities in evaluating the environmental risk of offshore wind. Projects are prioritised and informed by the ORJIP Advisory Network which includes key stakeholders, including statutory nature conservation bodies, academics, non-governmental organisations and others.

The current stage is a collaboration between the Carbon Trust, EDF Energy Renewables Limited, Ocean Winds UK Limited, Equinor ASA, Ørsted Power (UK) Limited, RWE Offshore Wind GmbH, SSE Renewables Services (UK) Limited, TotalEnergies OneTech, Crown Estate Scotland, Scottish Government (acting through the Offshore Wind Directorate and the Marine Directorate) and The Crown Estate Commissioners. For further information regarding the ORJIP Offshore Wind programme, please refer to the Carbon Trust website, or contact Ivan Savitsky (ivan.savitsky@carbontrust.com) and Žilvinas Valantiejus (zilvinas.valantiejus@carbontrust.com).

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Who we are

Our mission is to accelerate the move to a decarbonised future. We have been climate pioneers for more than 20 years, partnering with leading businesses, governments and financial institutions globally. From strategic planning and target setting to activation and communication - we are your expert guide to turn your climate ambition into impact.

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1. Introduction

A biological trait approach to data analysis has the potential to identify the impact that colonising species and shifts in benthic community composition may have on biological diversity and ecosystem functioning (Boutin *et al.*, 2023). The construction of (OWF) provides new hard substrate throughout the water column which is then available for colonisation by epibiotic species. A clear vertical succession of colonisers is observed often characterised by barnacles in the intertidal zone, to mussels in the upper subtidal and anemones and tunicates below that on the lower regions of the foundation (De Mesel *et al.*, 2015; Mavraki *et al.*, 2020). Furthermore, fish species are known to aggregate near turbine foundations (Reubens *et al.*, 2011; Langhamer, 2012). Modification of infaunal benthic communities has been reported in conjunction with increases in proportions of the fine fraction and organic components of the sediment (Coates *et al.*, 2013), with deposition of faecal material from colonising organisms in addition to biomass falling from the structures being the likely source of these observed sedimentary changes (Krone *et al.,* 2013).

While organic material in sediments represents an important source of food for benthic fauna, enrichment may result in the modification of the infaunal communities with reductions in species richness, abundance and biomass with resultant shifts from sensitive species to opportunistic disturbance tolerant species (Pearson and Rosenberg, 1978).

Changes in community structure may also result in changes in the distribution of biological traits across a community such as organism size, living and feeding habits and bioturbation characteristics (Caswell *et al.*, 2018). A biological trait-based approach to assessing communities investigates the non-taxonomic grouping of taxa that have similar traits and are therefore expected to have similar influence on the environment (Gitay *et al.*, 1999) or similar responses to environmental change (Gladstone-Gallagher *et al.*, 2019). The links between biological traits and ecosystem function also provides insight on the recovery potential and resilience of benthic communities (e.g., Gladstone-Gallagher *et al.*, 2019).

Biological traits analysis uses a series of life history, morphological and behavioural characteristics of species present in assemblages to provide insight to their ecological functioning. Changes in the patterns of trait expression within benthic assemblages, for example changes in the relative abundance of taxa exhibiting the traits, can be used to indicate the effects of disturbance on ecological functioning (Bremner *et al.*, 2006).

The strength of this approach is that it can be tailored to detect specific functional changes that are reflective of potential disturbance impacts, which may not be as apparent when using traditional diversity-based metrics or species identity (i.e. species name) in multivariate analyses. In this context, it was considered that traits analysis may be useful in investigating RQ 4: Is there a change in ecological function (e.g. functional groups) due to biological changes?

2. Anonymisation of OWF sites

All data collated was anonymised to retain the integrity of the initial findings of the OWF monitoring surveys. Any identifiable information for each OWF was anonymised, including the anonymisation of OWF site name to OWF 1, OWF 2 etc., and survey years were only referred to as pre-construction and 1st post-construction, 2nd post-construction etc.

Table 1. Individual site details for analysis

Site	Survey years	Data collated
OWF 1	**Pre-construction** **1st post-construction** **2nd post-construction** **3rd post-construction**	Benthic fauna and PSA for each survey year
OWF 2	**Pre-construction** **1st post-construction** **2nd post-construction** **3rd post-construction**	Benthic fauna and PSA for each survey year
OWF 3	**Pre-construction** **1st post-construction** **2nd post-construction** **3rd post-construction** **4th post-construction** **5th post-construction**	Benthic fauna and PSA for each survey year

2.1 OWF 1

A pre-construction survey was undertaken before construction, with two post-construction surveys undertaken after construction. The monitoring survey design encompassed 25 sites (22 of which were included in the biological traits analysis) from which three replicate faunal samples were collected along with sediment for physicochemical analyses.

Survey monitoring results of sediment and benthic fauna have shown a change from before to after construction. The changes observed in the benthic community after construction of the wind farm were a higher diversity of species and a higher number of individuals than before construction of OWF 1.

Similar changes are seen both in the wind farm area, the cable area but also at the reference site. This led to the conclusion that changes over time within the wind farm area were not caused by the construction or operation of the wind farm, but more likely by the natural dynamics of the marine environment where OWF 1 is located.

For the biological traits analysis, sites were divided into a number of site groupings, which covered various areas of the wind farm site and adjacent habitats:

WF - Five sites within the wind farm area

ADJ - Four sites within the near-field area of the monopile foundations

EB - Four sites at the eastern boundary of the wind farm, within the area affected by sediment transport and deposition

TE - Five sites within the tidal excursion to the north, north-west, west, south-west and south of the turbine array.

CON - Four control sites outside the tidal excursion spaced at reasonable distances round the development area.

2.2 OWF 2

The monitoring programme for OWF 2 consists of one pre-construction survey and three post-construction surveys. The survey design encompassed 29 sites from which three replicate faunal samples were collected along with sediment for physicochemical analyses.

The original monitoring report concluded that the construction and operation of OWF 2 had no detectable effect on the sediment characteristics or diversity of taxa across the study area. Subtle changes to faunal communities (e.g. small increases and decreases in abundances/species richness across all treatment zones) were detected although there was no evidence to suggest large scale impacts. The faunal communities remained similar to the baseline conditions and therefore any changes identified by the monitoring programme were considered to be either within the measurable baseline variation or not significant.

For the biological traits analysis, the 29 sites which were divided into a number of site grouping which covered various areas of the wind farm site and adjacent habitats:

TUR_50m – 50m from nearest turbine;

TUR_100m – 100 from nearest turbine;

TUR_250m – 250m from nearest turbine;

WF – other sites within array;

ADJ – sites located outside of array but within 1km of nearest turbine;

MID – sites located outside of array within between 2 and 4km from nearest turbine; and

CON – sites located outside the array between 6 and 14 km of nearest turbine – these sites are considered as control sites.

3. Methodology

The Cefas data set 'key biological traits of marine benthic invertebrates surveyed in Northwest Europe' (Clare *et al.,* 2022) were used to match the relevant functional traits to the collated benthic species recorded during the OWF monitoring. Species within samples were assigned the following biological traits according to their behavioural, morphological and reproductive characteristics (further detailed is provided in Annex 4a):

- Maximum size;
- Lifespan;
- Living habitats;
- Sediment position;
- Feeding mode;
- Bioturbation.

Following the assignment of traits, a species and site trait matrix was constructed and subsets of traits (for example those sensitive to disturbance) could then be analysed using univariate and multivariate analyses. A Bray-Curtis similarity matrix was constructed and analysed by cluster analysis and Multi-Dimensional Scaling (MDS) plots (Bray and Curtis, 1957) to help visualise spatial and temporal similarities in benthic communities according to biological trait distributions.

A step-by-step process of analysis is as follows:

1. Abundance data converted to relative dominance at each site;
2. Relative dominance represented by each trait calculated – where a taxon is represented by more than one trait sub-category the relative dominance is divided equally between each sub-category;
3. The relative dominance represented by each taxa for each sub-category is summed to give total for each site;
4. The resulting figures are collated in a site by trait sub-category table;
5. Table imported into primer and resemblance matrix produced;
6. Subsequent analysis: cluster/MDS to determine spatial and temporal patterns and PERMANOVA to identify potential drivers of any identified patterns;
7. Analysis undertaken on each trait individually to include all sub-categories – traits derived by Clare et al (2022) available at: Cefas Data Portal - View.
8. Analysis of control sites to determine level of natural variability against which other patterns can be compared;
9. Traits used: Maximum size (mm); Lifespan (years); Living habitat; Sediment position; Feeding mode; Bioturbation; and
10. Factors used: Year (pre/post-construction); Site grouping; organic carbon content of sediment (LOI); proportion of fines.

4. Results

4.1 OWF 1

4.1.1 Maximum Size

Generally, across the site groupings and all years taxa with maximum sizes of between 101 and 200mm represented the highest proportion of the communities recorded contributing on average 39.7% of all individuals across the study period (annual range = 36.9 % to 44.0%), while those with maximum size of between 21 and 100mm represented on average 29.4% (annual range = 15.9% to 26.8%) and those sized <20mm represented on average 24.7% of individuals (annual range = 21.6% to 36.6) (Table 2). Increases in sizes <20mm were observed over the monitoring period across the study area with average increases of 53% observed in the <10mm category (largest proportional increase in WF) and 31% in the 10-20mm category (largest proportion increase in ADJ); these smaller size ranges may reflect small, r-selected species, which can be indicators of stressful conditions. Corresponding falls in sizes >20mm was observed to varying degrees across all site groupings. Overall, the magnitude of changes is relatively small, and the distribution of size categories remains fairly consistent across most of the study area throughout the study period. Strong to very strong correlations were observed between sites and years, with the exception of site ADJ during the second post-construction survey, where several moderate to weak correlations were recorded. However, in post-construction year 2, site ADJ still showed moderately strong correlations with other sites within the same grouping (Table 3).

Table 2. Relative dominance represented by each maximum size category by year and site grouping. Shading is proportional to the values from 0% (no shading) to 100% (full shading).

ADJ: near field of foundations; EB: Eastern boundary; WF: habitat types within array area; TE: within tidal excursion; CON: controls.

Trait	Category	ADJ			WF			EB		
		Pre	Post yr 1	Post yr 2	Pre	Post yr 1	Post yr 2	Pre	Post yr 1	Post yr 2
Maximum size (mm)	<10	5.2	9.5	8.2	2.8	6.2	17.6	12.1	4.3	13.6
	10-20	6.8	12.5	37.4	13.0	8.5	26.9	14.4	8.7	21.7
	21-100	47.1	31.1	30.5	29.0	16.6	16.0	34.6	43.9	33.9
	101-200	29.7	40.3	14.6	48.2	63.5	32.9	30.6	36.3	23.8
	201-500	9.9	6.0	8.3	6.2	5.0	6.1	7.5	6.6	6.0
	<500	1.2	0.6	1.1	0.8	0.2	0.5	0.8	0.2	1.1

Trait	Category	TE			CON		
		Pre	Post yr 1	Post yr 2	Pre	Post yr 1	Post yr 2
Maximum size (mm)	<10	13.0	15.8	24.5	8.4	11.7	15.5
	10-20	8.6	7.3	12.2	7.3	9.4	8.0
	21-100	26.8	15.9	21.0	27.9	28.1	38.0
	101-200	44.0	54.6	36.9	54.9	50.0	35.8
	201-500	6.4	6.1	5.3	1.2	0.4	2.5
	<500	1.1	0.3	0.2	0.3	0.3	0.1

Table 3. Pearson correlation coefficients for comparisons of distribution of maximum size categories by year and site grouping. Shading is proportional to the values from 0 (no shading) to 1 (full shading).

	ADJ Pre	ADJ post yr 1	ADJ post yr 2	WF Pre	WF post yr 1	WF post yr 2	EB Pre	EB post yr 1	EBpost yr 2	TE Pre	TE post yr 1	TE post yr 2	CON Pre	CON post yr 1
ADJ post yr 1	0.85													
ADJ post yr 2	0.46	0.42												
WF Pre	0.78	0.98	0.37											
WF post yr 1	0.54	0.88	0.10	0.93										
WF post yr 2	0.37	0.74	0.58	0.73	0.74									
EB Pre	0.93	0.95	0.57	0.88	0.69	0.67								
EB post yr 1	0.98	0.94	0.47	0.89	0.69	0.51	0.97							
EBpost yr 2	0.84	0.83	0.79	0.73	0.49	0.70	0.94	0.86						
TE Pre	0.76	0.98	0.24	0.96	0.93	0.73	0.89	0.87	0.71					
TE post yr 1	0.51	0.86	0.05	0.89	0.98	0.75	0.69	0.66	0.49	0.94				
TE post yr 2	0.56	0.85	0.22	0.79	0.82	0.82	0.78	0.67	0.67	0.91	0.90			
CON Pre	0.73	0.97	0.22	0.97	0.96	0.72	0.85	0.84	0.67	0.99	0.95	0.87		
CON post yr 1	0.74	0.97	0.27	0.96	0.94	0.76	0.88	0.85	0.72	0.99	0.94	0.90	1.00	
CON post yr 2	0.91	0.95	0.39	0.87	0.73	0.62	0.97	0.95	0.87	0.92	0.75	0.84	0.88	0.91

Cluster analysis showed a common similarity of close to 90% for all sites and years in the distribution of maximum size trait categories with ADJ post-construction year 2 showing the lowest similarity to other sites, reflecting the correlation patterns discussed above (Figure 1). However, the MDS plot in Figure 2 indicates that the patterns highlighted in the dendrogram are not strongly related to factors considered here.

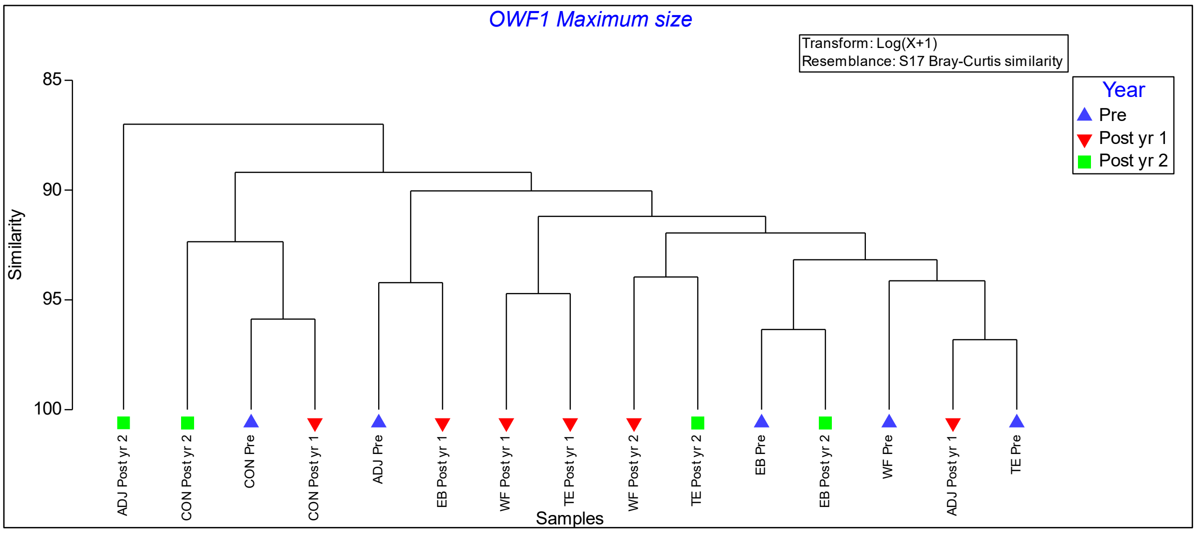

Figure 1. Dendrogram showing the relative similarities in OWF1 benthic communities in relation to six maximum size trait categories.

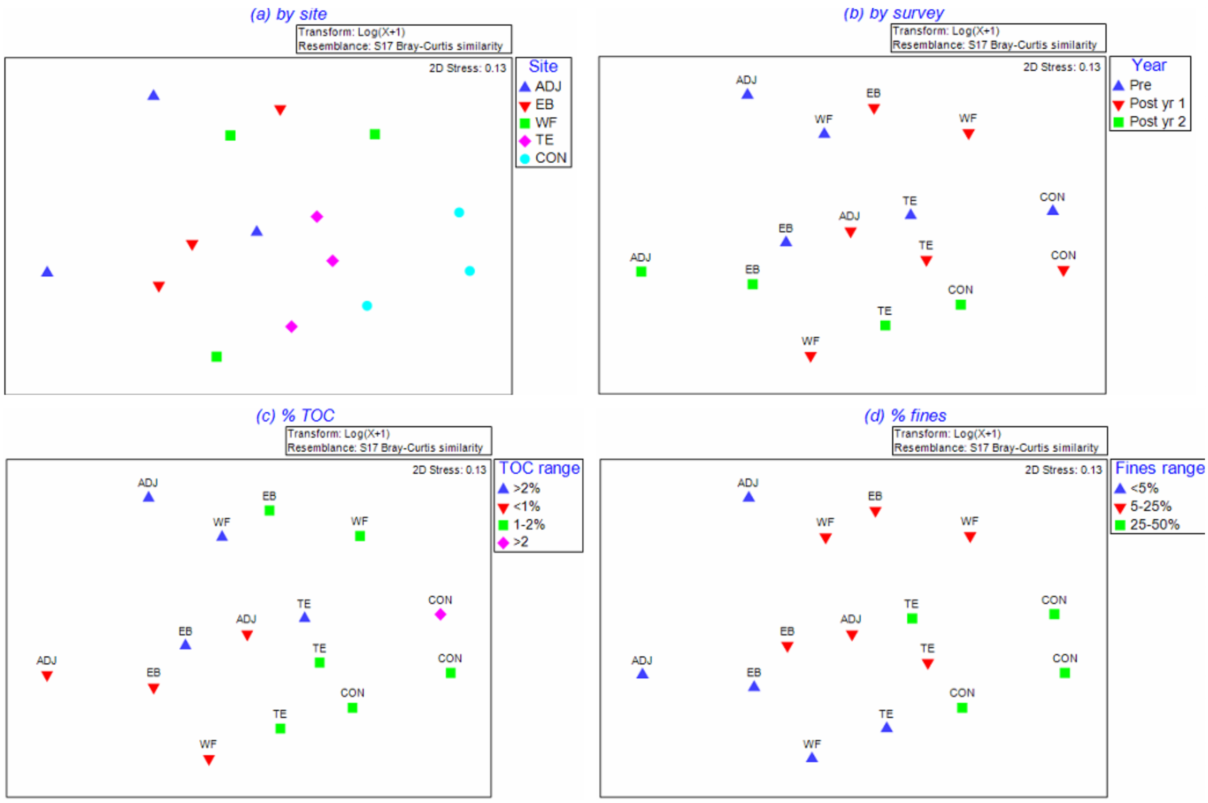

Figure 2. MDS showing the relative similarities in OWF1 benthic communities in relation to maximum size trait categories compared to factors: (a) Year; (b) Site Group; (c) % TOC; (d) % Fines.

Analysis of all years and sites by PERMANOVA indicated no significant difference between the pre-construction survey and the first post-construction survey in post-construction year 1 ($p = 0.258$), although differences were evident between pre-construction and post-construction year 2 ($p = 0.003$) and post-construction year 1 and post-construction year 2 ($p = 0.001$). While the patterns described above were also observed at control sites (CON) sites they were not so marked as those seen within the array (ADJ and WF) sites and PERMANOVA indicated no significant difference over the years within this group of sites ($p = 0.516$). When the distribution of trait categories was looked at with year and site group in conjunction no significant relationship was observed ($p = 0.6341$).

When considering sediment characteristics, the proportion of total organic carbon (as derived by loss on ignition) and proportion of fines (silt and clay i.e. <63µm) were examined as this may reflect additional inputs of organic and fine particulate material (silt and clay) from epibenthic colonisers of wind farm infrastructure. As discussed above values for TOC decreased between pre-construction and post-construction year 1 and subsequently in post-construction year 2 – a pattern reflected in the proportion of fines in sediments across the majority of the study area (Figure 3). These patterns were evident at sites closest to turbines (ADJ) where average TOC fell from 3.2% to 0.7% between pre-construction and post-construction year 2, while the proportion at sites likely to be affected by sediment transport and deposition (EB) values fell from 3.0% to 0.7%; corresponding changes in the proportion of fines at these sites were 4.1 – 23.8% (ADJ) and 17.3 – 1.7% (EB). It should be noted that changes in TOC at CON sites fell over the monitoring period from 4.5% to 1.9%, while the proportion of fines marginally increased from 32.1% to 42.3%. It should be noted that fines at control sites increased post-construction, although modelling indicates that sediment disturbed by construction activity would not be deposited at these sites.

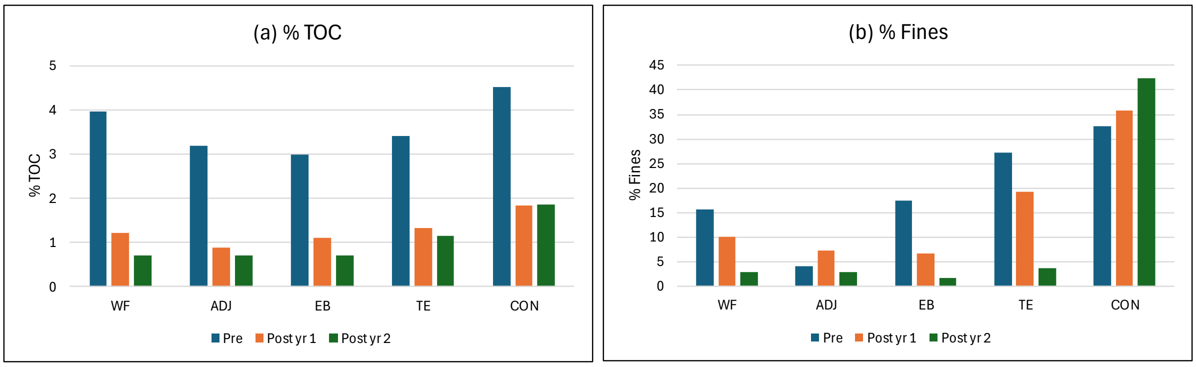

Figure 3. Pre- and post-construction levels of TOC and fines.

When the distribution of the maximum size categories was examined in relation to TOC, moderate negative correlations were evident for animals <20mm, while a weak negative correlation was observed in maximum size (201-500mm); other size categories exhibited weak positive correlations to TOC (Figure 4). However, none of the observed patterns can be considered as statistically significant ($p>0.05$).

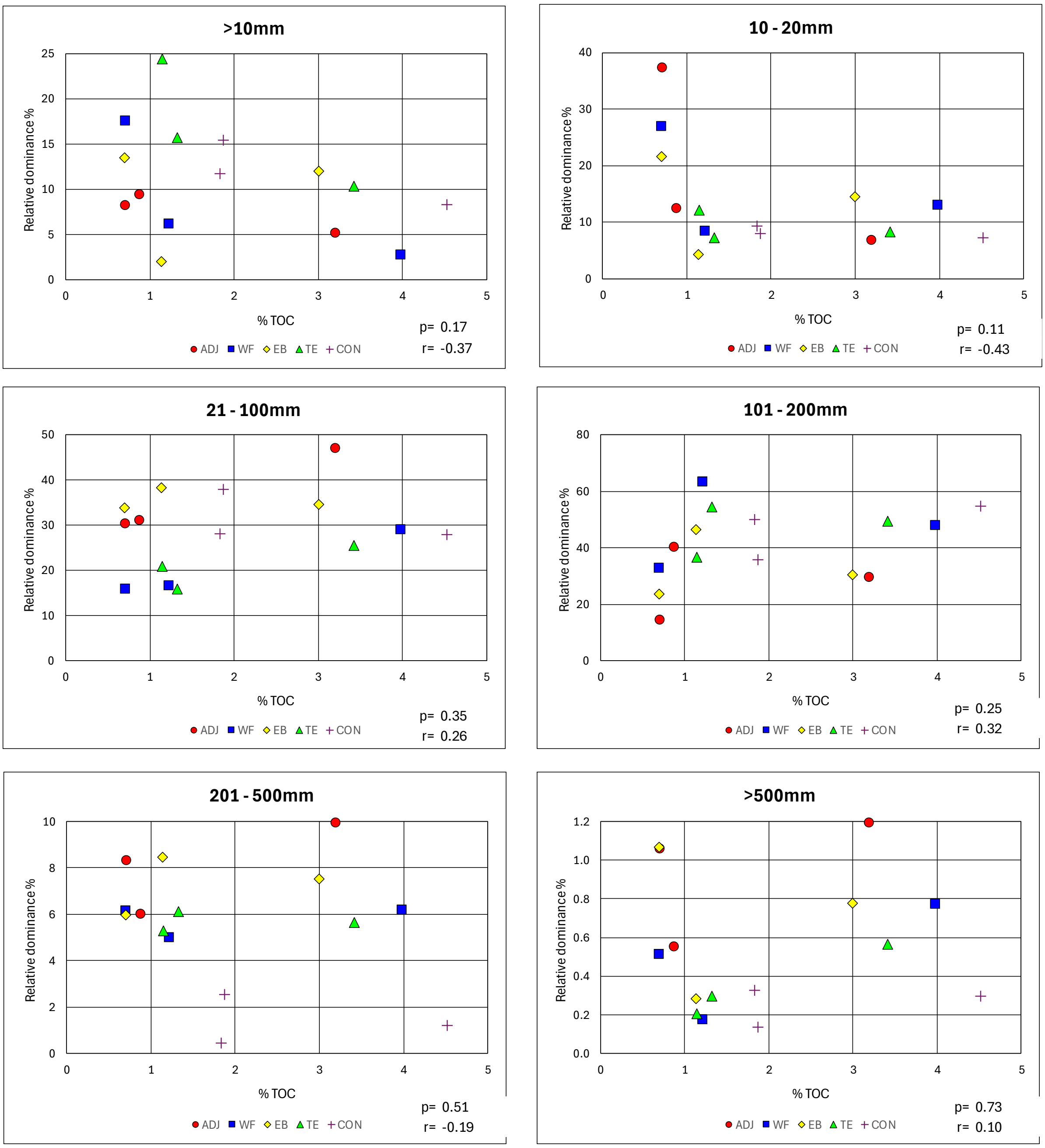

Figure 4. Mean relative dominance represented by each maximum size category by TOC and site grouping. (Correlation co-efficient and p-value for combined data indicated)

The proportion of fines decreased across the majority of the study area between pre-construction and post-construction year 1 and subsequently in post-construction year 2, although patterns within site grouping were not so clear cut. At sites closest to turbines (ADJ) average fines increased from 4.1% to 7.3% between pre-construction and post-construction year 1 and subsequently fell back to 2.8% in post-construction year 2, while within EB sites proportion fell from 17.3% in pre-construction to 6.7% in post-construction year 1 and 1.7% in post-construction year 2. However, the proportion of fines at CON increased between pre-construction and post-construction year 2 from 32.1% to 42.3%. It is considered that these observed changes are related to natural variability rather than to any influence of the wind farm.

When the distribution of the maximum size categories was examined in relation to the proportion of fines in the sediment strong to very strong negative correlations were evident for animals >200mm, while a moderate negative correlation was observed in maximum size 10-20mm; other size categories were weakly or moderately positively correlated to fines (Figure 5). Of the observed patterns only that for 201-500mm can be considered statistically significant (p<0.01).

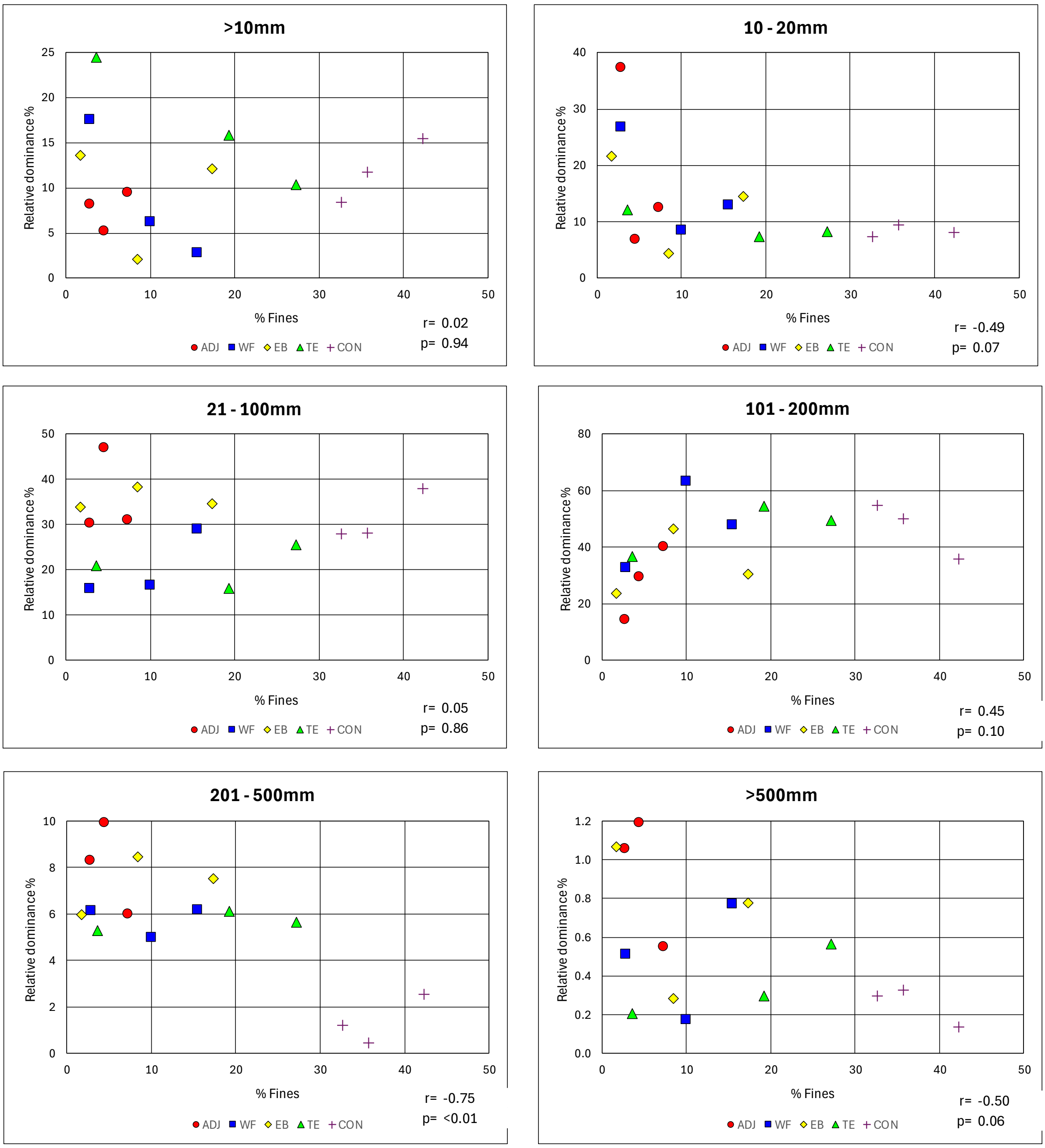

Figure 5. Mean relative dominance represented by each maximum size category by % fines and site grouping. (Correlation co-efficient and p-value for combined data indicated)

Results of PERMANOVA analysis indicate differences between relative dominance of size categories in relation to TOC (p = 0.004), specifically between sites where TOC <1%. However, when the distribution of maximum size trait categories was looked at with TOC, year and site group in conjunction no significant relationship was observed (p = 0.056). Similarly, significant differences were evident in relation to proportion of fines in sediment, although no consistent pattern was evident and when considered in conjunction with year and site grouping no significant differences were observed. It should be noted that in relation to both TOC and fines significant differences were evident at CON sites (p = 0.008) which would indicate some level of natural variability in the relationship between sediment characteristics and maximum faunal size.

Overall, there appears to be no influence of the construction of the wind farm on the spatial and temporal patterns in TOC with no subsequent impacts evident in relation the relative dominance of the maximum size categories across the study area with any spatial or temporal variability observed being considered to be driven by natural factors.

4.1.2 Lifespan

Generally, across the site groupings and all years taxa with lifespan of 3-10 years contributed on average 53.2% of all individuals across the study period (annual range = 46.9 % to 62.4%) (Table 4), while those with lifespan >10 years represented on average 29.0% (annual range = 17.4% to 37.8%). Some variations were observed over the monitoring period with increases seen in the 3 – 10-year group at all site groupings over the monitoring period with an average increase of 34% (largest proportional increase in WF – 69%). Some variability was observed in proportional changes in the <1 year category, although actual values were low and any change resulted in a large proportional change. At ADJ and EB sites where potential effects of the wind farm may be anticipated the low proportion and falls in relative dominance of short-lived taxa (i.e. potential r-selected indicators of stress) would suggest limited effects, although falls in dominance of >10-year category were also observed at these sites. However, the magnitude of changes overall are relatively small and the distribution of lifespan categories remain relatively consistent throughout the study period and across the majority of the study area with predominantly strong to very strong correlations evident between sites and years (Table 5).

Table 4. Relative dominance represented by each lifespan category by year and site grouping. Shading is proportional to the values from 0% (no shading) to 100% (full shading).

Trait	Category	ADJ			EB			WF		
		Pre	Post Yr 1	Post Yr 2	Pre	Post Yr 1	Post Yr 2	Pre	Post Yr 1	Post Yr 2
Life span (years)	<1	9.5	2.2	2.0	6.1	2.4	2.2	1.1	1.6	1.1
	1-3	18.7	12.0	14.5	24.1	12.7	20.8	18.6	4.3	8.3
	3-10	57.8	56.9	77.7	48.0	69.9	63.1	39.2	37.9	66.2
	>10	14.1	28.9	5.7	21.8	15.0	13.9	41.2	56.1	24.3

Trait	Category	TE			CON		
		Pre	Post Yr 1	Post Yr 2	Pre	Post Yr 1	Post Yr 2
Life span (years)	<1	0.4	0.4	4.1	1.5	0.0	1.4
	1-3	11.3	4.6	15.0	9.4	18.5	21.7
	3-10	46.8	46.6	52.0	42.6	40.7	53.1
	>10	35.2	48.4	28.9	46.5	40.7	13.9

Table 5. Pearson correlation coefficients for comparisons of distribution of lifespan categories by year and site grouping. Shading is proportional to the values from 0 (no shading) to 1 (full shading).

	ADJ Pre	ADJ post yr 1	ADJ post yr 2	WF Pre	WF post yr 1	WF post yr 2	EB Pre	EB post yr 1	EBpost yr 2	TE Pre	TE post yr 1	TE post yr 2	CON Pre	CON post yr 1
ADJ post yr 1	0.90													
ADJ post yr 2	1.00	0.89												
WF Pre	0.95	0.94	0.93											
WF post yr 1	0.99	0.95	0.99	0.95										
WF post yr 2	0.99	0.92	0.99	0.98	0.99									
EB Pre	0.55	0.84	0.52	0.74	0.63	0.62								
EB post yr 1	0.33	0.70	0.29	0.48	0.43	0.36	0.92							
EBpost yr 2	0.95	0.99	0.94	0.94	0.98	0.95	0.76	0.61						
TE Pre	0.86	0.99	0.84	0.94	0.90	0.89	0.90	0.75	0.96					
TE post yr 1	0.55	0.86	0.53	0.67	0.65	0.58	0.95	0.97	0.79	0.88				
TE post yr 2	0.89	1.00	0.88	0.94	0.94	0.91	0.86	0.71	0.98	1.00	0.86			
CON Pre	0.53	0.84	0.50	0.67	0.62	0.57	0.97	0.97	0.77	0.88	1.00	0.85		
CON post yr 1	0.59	0.86	0.56	0.77	0.66	0.65	1.00	0.90	0.78	0.92	0.95	0.88	0.97	
CON post yr 2	0.98	0.91	0.97	0.99	0.97	1.00	0.64	0.36	0.93	0.89	0.58	0.91	0.57	0.68

There was a common similarity of close to 60% for all sites and years in the distribution of lifespan trait categories, although above that level some variability was evident with two broad clusters reflecting the temporal differences highlighted above (Figure 6). However, the MDS plot in Figure 7 indicate that the patterns highlighted in the dendrogram are not strongly related to factors considered here.

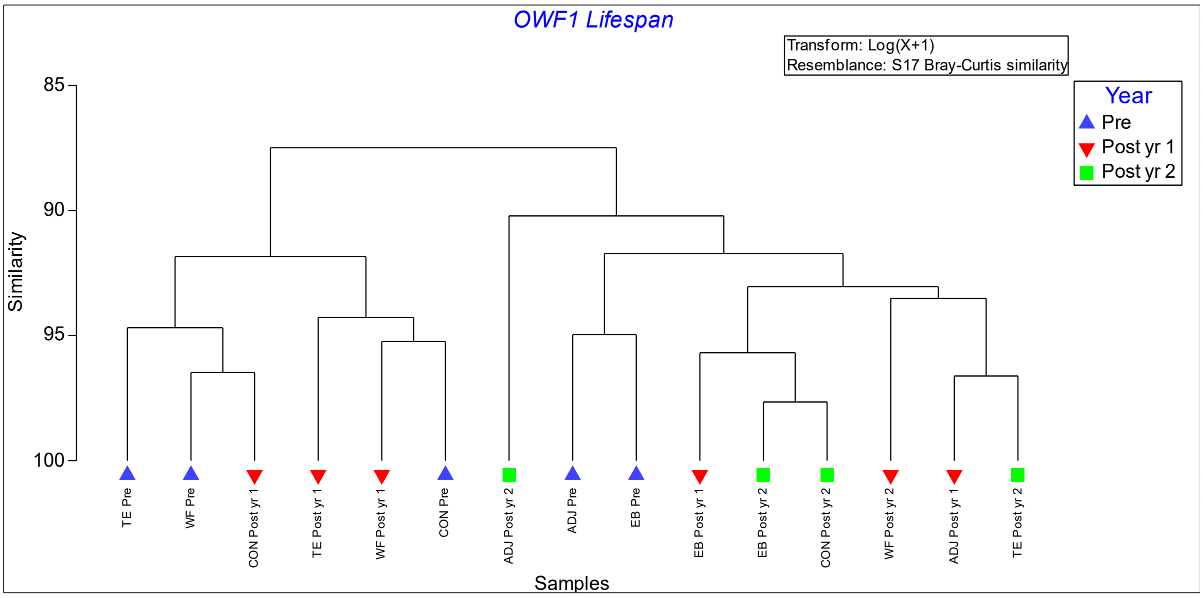

Figure 6. Dendrogram showing the relative similarities in OWF1 benthic communities in relation to four lifespan trait categories.

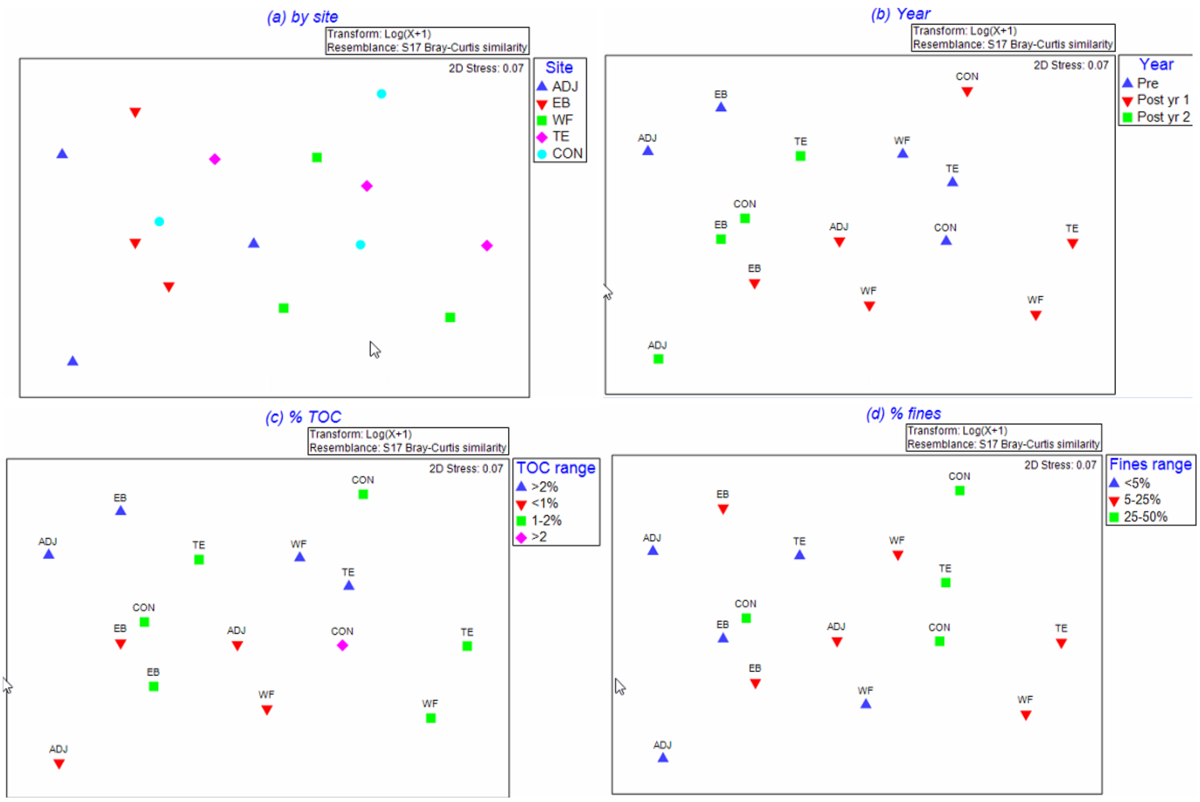

Figure 7. MDS showing the relative similarities in OWF1 benthic communities in relation to lifespan trait categories compared to factors: (a) Year; (b) Site Group; (c) % TOC; (d) % Fines.

Across the monitoring period taxa with lifespans above 3 years represented between 77 and 93% of individual across the survey, while the shortest-lived taxa represented consistently the lowest proportion of individuals (Table 4). As with the maximum size trait, PERMANOVA analysis indicated no significant difference between the pre-construction survey and the first post-construction survey in post-construction year 1(p = 0.278), although differences were evident between pre-construction and post-construction year 2 (p = 0.014) and post-construction year 1 and post-construction year 2 (p = 0.001); when looking at CON sites in isolation no difference between years was observed (p = 0.268). However, when the distribution of lifespan trait categories was looked at with year and site group in conjunction no significant relationship was observed (p = 0.471).

In relation to levels of TOC and lifespan similar patterns to those discussed above were evident with taxa with maximum lifespan >3 years being dominant, although overall patterns were consistent between different levels of TOC across the study area. When the distribution of the lifespan categories was examined in relation to TOC a strong negative correlation was evident for animals with lifespan of 3-10 years (r=-0.57, p=0.03), while for other categories weak positive correlations to TOC were evident (Figure 8).

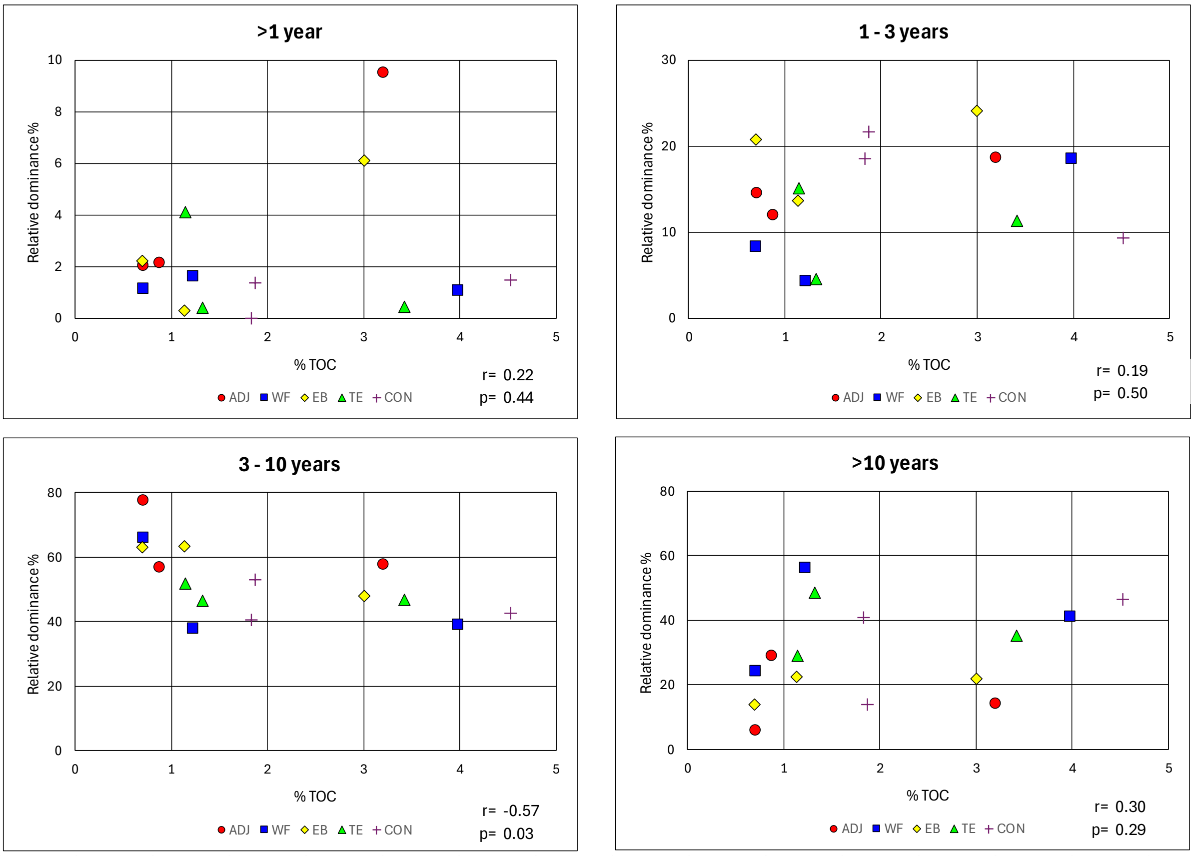

Figure 8. Mean relative dominance represented by each lifespan category by TOC and site grouping. (Correlation co-efficient and p-value for combined data indicated)

Taxa with lifespans greater than three years represented between 57 and 93% of individuals across the study area, although as proportion of fines increased the dominance of those with a lifespan of 3-10 years showed a fall in all years while those with a lifespan of >10 years showed a corresponding increase. As with TOC the shorter-lived taxa represented the lowest proportion of individuals across years in relation to proportion of fines. When the distribution of the lifespan categories was examined in relation to the proportion of fines in the sediment, strong negative correlation was evident for animals with lifespan of 3-10 years (r=-0.57, p=0.03), while a moderate negative correlation was observed in lifespan of <1 year. Other size categories were weakly or moderately positively correlated to fines (Figure 15).

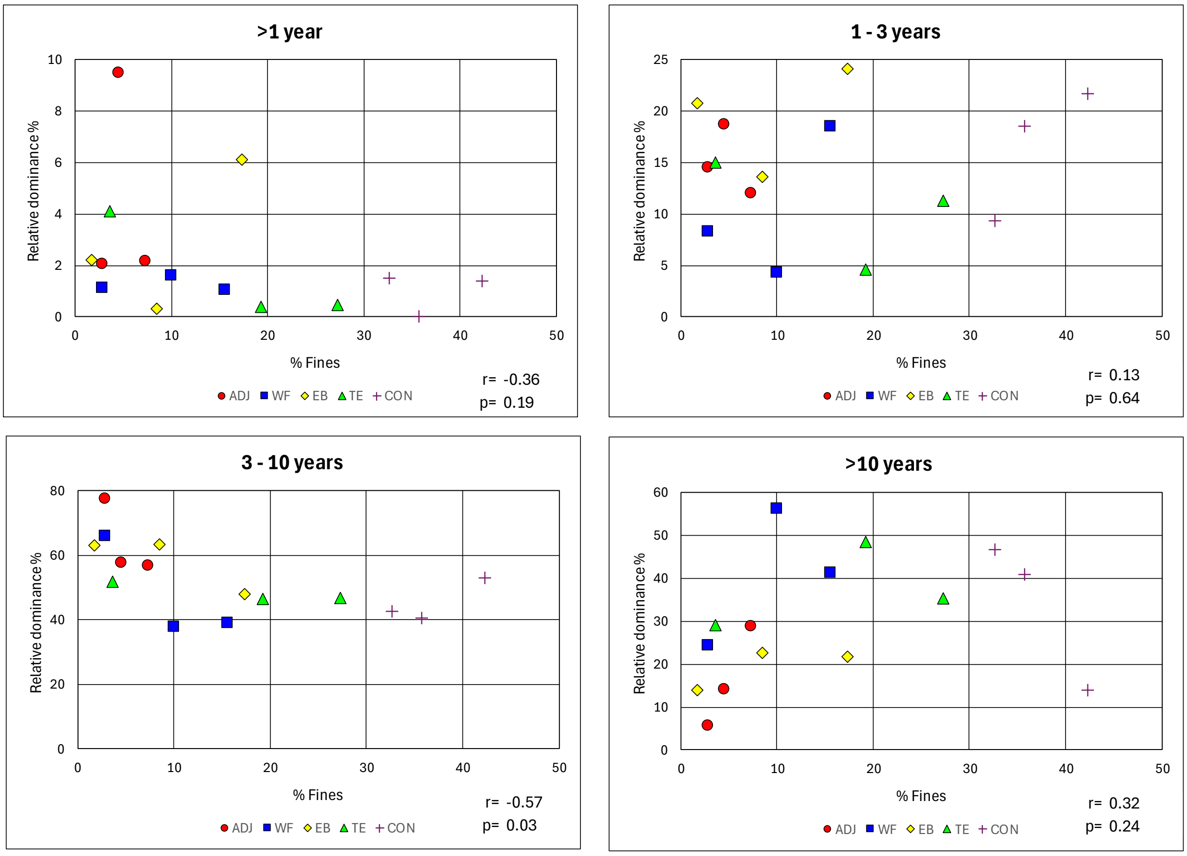

Figure 9. Mean relative dominance represented by each lifespan category by fines and site grouping. (Correlation co-efficient and p-value for combined data indicated)

Results of PERMANOVA analysis indicate differences between relative dominance of lifespan categories in relation to TOC (p <0.001), specifically between sites where TOC <1% and where higher levels are recorded (**Error! Reference source not found.**). However, when the distribution of lifespan t rait categories was looked at with TOC, year and site group in conjunction no significant relationship was observed (p = 0.239). Similarly, significant differences were evident in relation to proportion of fines in sediment, although no consistent pattern was evident (**Error! Reference source not found.**) and w hen considered in conjunction with year and site grouping no significant differences were observed (p = 0.140).

Overall, there appears to be no influence of the construction of the wind farm on the spatial and temporal patterns in TOC with no subsequent impacts evident in relation to the relative dominance of the lifespan trait categories across the study area. Any spatial or temporal variability observed is considered to be driven by natural factors.

4.1.3 Living habitat

Generally, across the site groupings and all year's, free living taxa contributed on average 51.2% of all individuals across the study period (annual range = 39.3% to 67.2%), while burrow dwellers represented on average 20.8% (annual range = 11.1% to 30.1%). In all site groupings, the proportion of burrowing taxa increased over the study period from an average of 15% of taxa in pre-construction to 25.7% in post-construction year 2, Generally, across the site groupings and all years free living taxa contributed on average 51.2% of all individuals across the study period (annual range = 39.3% to 67.2%), while burrow dwellers represented on average 20.8% (annual range = 11.1% to 30.1%). In all site grouping the proportion of burrowing taxa increased over the study period from an average of 15.0% of taxa in pre-construction to 25.7% in post-construction year 2, while the proportion of tube dwellers fell from an average of 15.6% to 5.5% (Table 6Table 6Table 6Table 6Table 6). However, it should be noted that the magnitude of changes overall are relatively small and the distribution of living habitat categories remain relatively consistent throughout the study period and across the majority of the study area with strong to very strong correlation evident between sites and years (Table 7).

Table 6. Mean relative dominance represented by each living habitat category by year and site grouping. Shading is proportional to the values from 0% (no shading) to 100% (full shading).

Trait	Category	ADJ			EB			WF		
		Pre	Post Yr 1	Post Yr 2	Pre	Post Yr 1	Post Yr 2	Pre	Post Yr 1	Post Yr 2
Living habitat	Tube dwelling	12.4	7.0	2.2	27.0	11.6	5.9	20.7	3.1	3.8
	Burrow dwelling	13.8	13.7	22.1	13.7	8.7	26.0	11.1	13.1	22.2
	Free-living	60.6	57.4	67.2	43.4	64.0	58.0	43.2	48.1	55.5
	Crevice/hole/under stones	10.0	17.3	4.4	13.0	9.7	6.3	21.9	30.8	14.9
	Epi/endo-biotic	3.3	3.8	3.4	2.2	2.2	1.8	2.3	3.4	3.1
	Attached to substratum	0.0	0.8	0.7	0.6	3.7	2.0	0.7	1.6	0.5

Trait	Category	TE			CON		
		Pre	Post Yr 1	Post Yr 2	Pre	Post Yr 1	Post Yr 2
Living habitat	Tube dwelling	8.6	4.0	5.3	4.8	11.9	10.4
	Burrow dwelling	19.5	23.8	30.1	18.2	17.7	27.9
	Free-living	44.4	39.3	43.3	51.5	45.0	42.5
	Crevice/hole/under stones	21.8	27.4	16.2	23.1	17.1	12.3
	Epi/endo-biotic	2.7	4.1	2.7	0.5	0.2	1.2
	Attached to substratum	3.0	1.4	2.5	1.8	8.0	5.5

Table 7. Pearson correlation coefficients for comparisons of distribution of living habitat categories by year and site grouping. Shading is proportional to the values from 0 (no shading) to 1 (full shading).

	ADJ Pre	ADJ post yr 1	ADJ post yr 2	WF Pre	WF post yr 1	WF post yr 2	EB Pre	EB post yr 1	EBpost yr 2	TE Pre	TE post yr 1	TE post yr 2	CON Pre	CON post yr 1
ADJ post yr 1	0.98													
ADJ post yr 2	0.97	0.96												
WF Pre	0.91	0.85	0.80											
WF post yr 1	0.99	0.97	0.95	0.88										
WF post yr 2	0.96	0.94	0.99	0.81	0.93									
EB Pre	0.91	0.91	0.80	0.95	0.90	0.80								
EB post yr 1	0.85	0.93	0.82	0.71	0.84	0.80	0.88							
EBpost yr 2	0.96	0.98	0.98	0.80	0.94	0.98	0.85	0.90						
TE Pre	0.96	0.98	0.93	0.90	0.94	0.94	0.95	0.92	0.97					
TE post yr 1	0.79	0.88	0.81	0.66	0.75	0.83	0.80	0.95	0.91	0.91				
TE post yr 2	0.86	0.89	0.92	0.72	0.81	0.95	0.76	0.84	0.96	0.92	0.93			
CON Pre	0.93	0.98	0.92	0.80	0.91	0.92	0.90	0.97	0.98	0.98	0.95	0.93		
CON post yr 1	0.96	0.97	0.93	0.87	0.95	0.94	0.91	0.90	0.96	0.98	0.88	0.91	0.97	
CON post yr 2	0.90	0.89	0.94	0.80	0.85	0.97	0.79	0.79	0.95	0.94	0.87	0.98	0.91	0.94

There was a common similarity of close to 87% for all sites and years in the distribution of lifespan trait categories, although above that some level variability was evident with three broad clusters reflecting the temporal patterns highlighted above (Figure 10). However, the MDS plot in Figure 11 indicates that the patterns highlighted in the dendrogram are not strongly related to factors considered here.

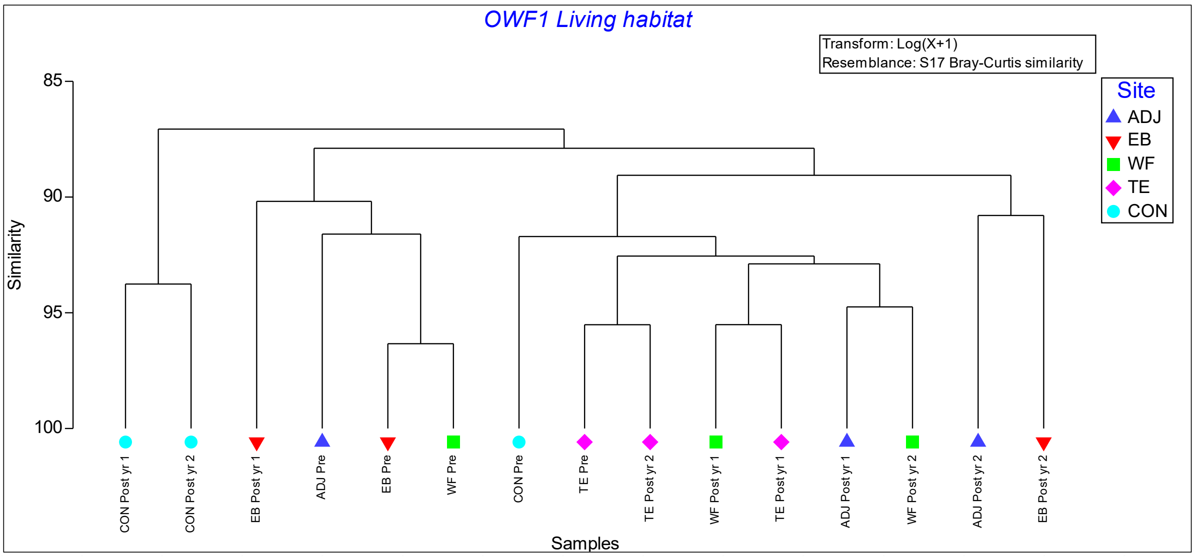

Figure 10. Dendrogram showing the relative similarities in OWF1 benthic communities in relation to six living habitat trait categories.

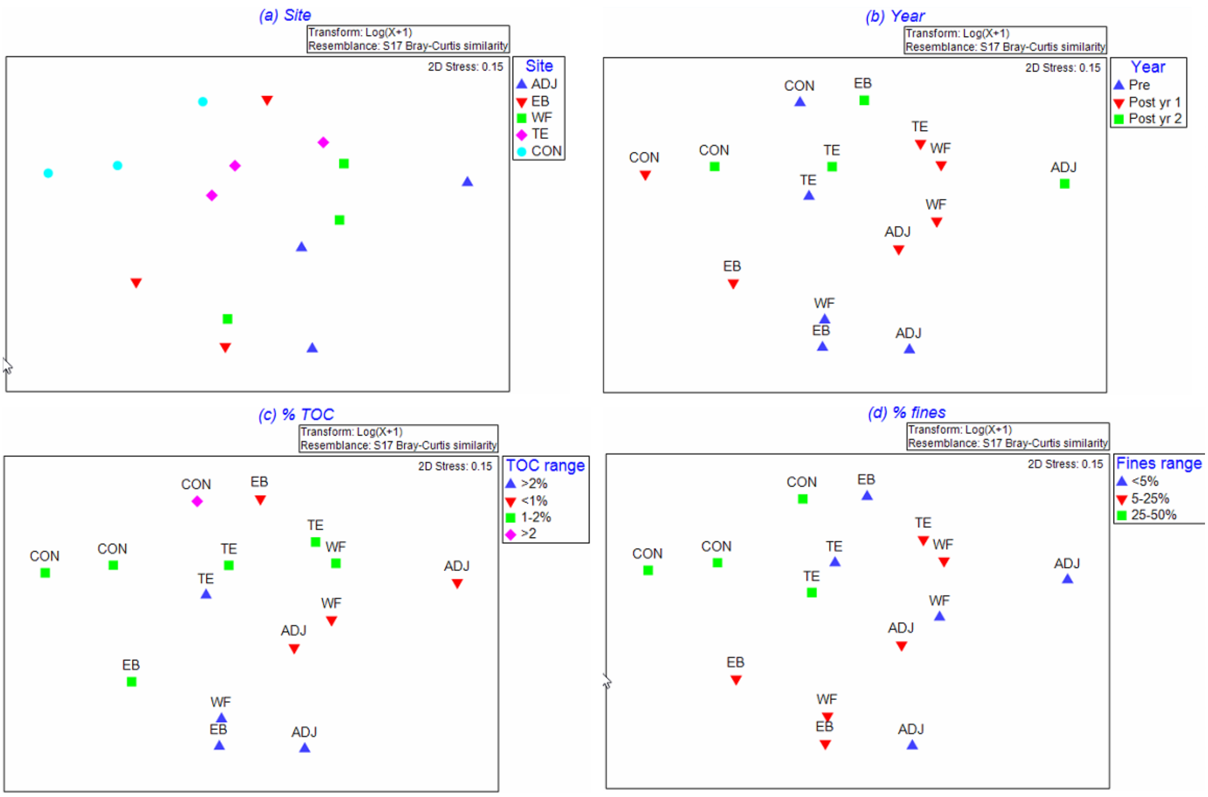

Figure 11. MDS showing the relative similarities in OWF1 benthic communities in relation to living habitat trait categories compared to factors: (a) Year; (b) Site Group; (c) % TOC; (d) % Fines.

Analysis of all years and sites by PERMANOVA indicated no significant difference between the pre-construction survey and the first post-construction survey ($p = 0.614$), although differences were evident between pre-construction and the second post-construction survey ($p = 0.002$) and post-construction year 1 and post-construction year 2 ($p = 0.008$). While analysis indicated no significant difference over the years within CON ($p = 0.543$). When the distribution of living habitat trait categories was looked at with year and site group in conjunction no significant relationship was observed ($p = 0.772$).

When the distribution of the living habitat categories was examined in relation to TOC no strong patterns were evident in relation to TOC with a moderate positive correlation evident for tube dwelling fauna, while burrow dwellers and free living fauna showed moderate negative correlations to TOC, although these patterns are not statistically significant (Figure 12).

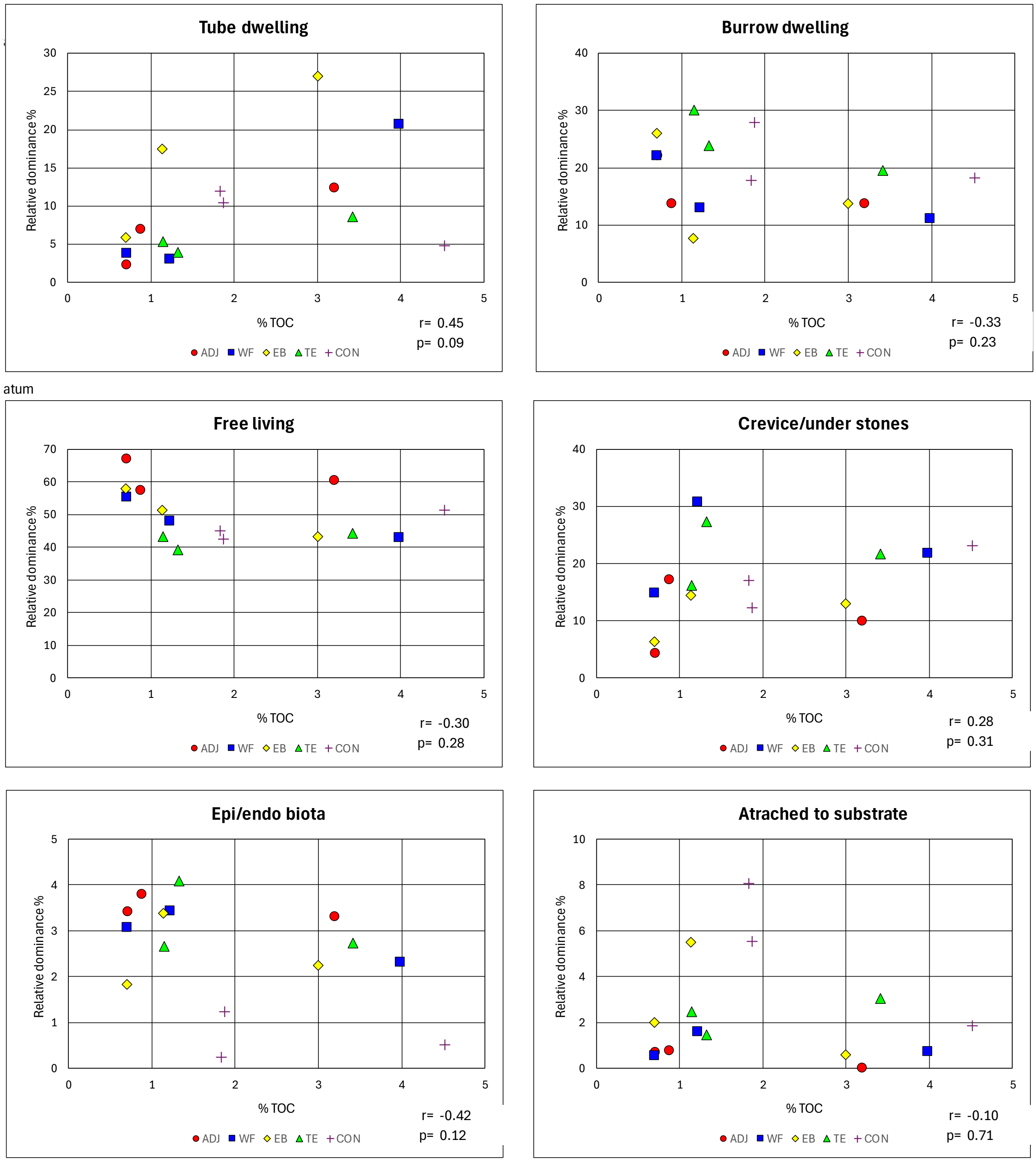

Figure 12. Mean relative dominance represented by each living habitat category by TOC and site grouping. (Correlation co-efficient and p-value for combined data indicated)

When the distribution of the lifespan categories were examined in relation to the proportion of fines in the sediment, a moderate negative correlation was evident free-living species (r= -0.58, p=0.02) - Figure 23. Similarly, a moderate correlation was observed for epibiota (r= -0.68, p=0.01), although this category never represented more than 4.1% of fauna across the study. Only weak positive correlations between tube and burrow dwellers were evident.

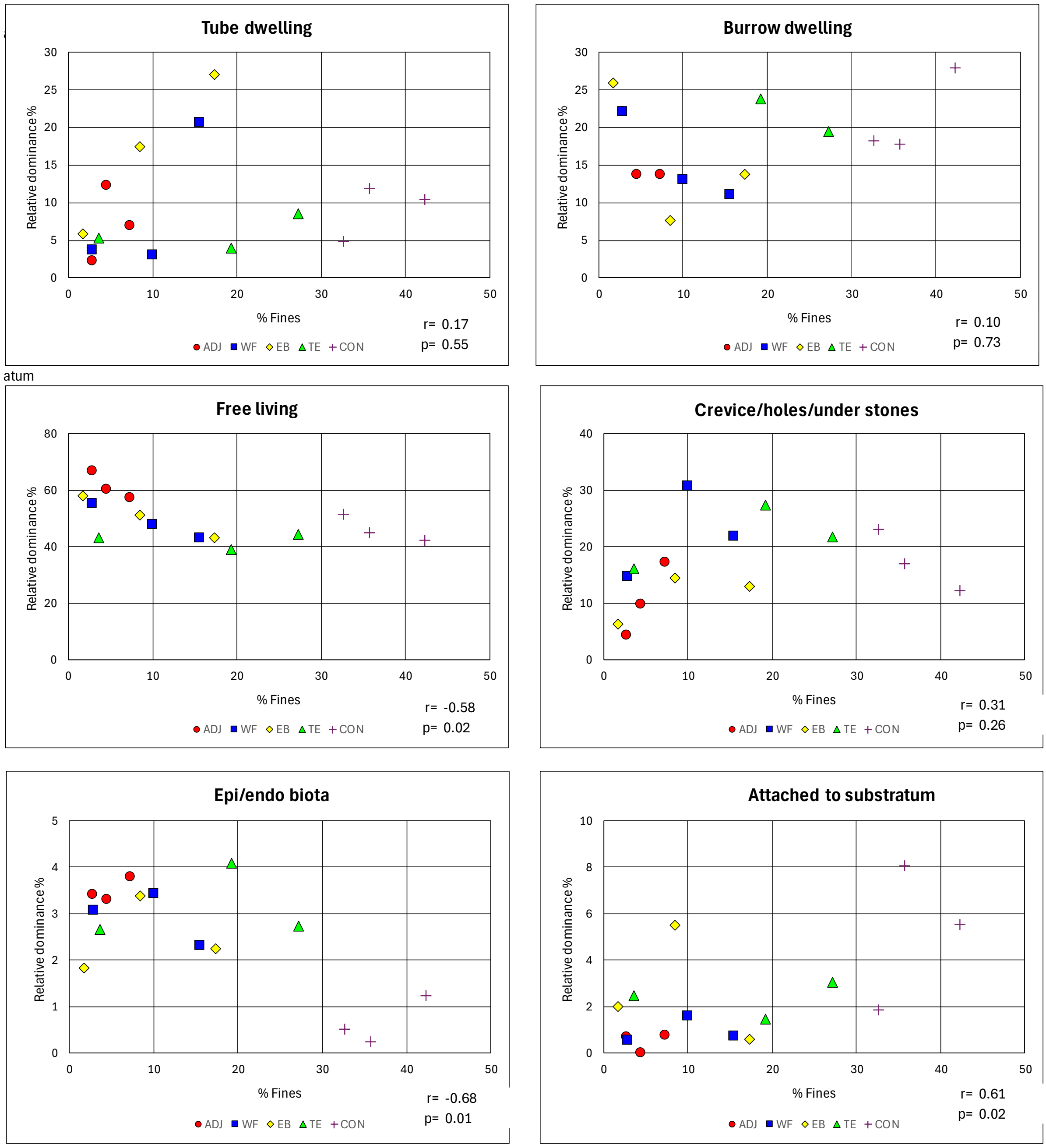

Figure 13. Mean relative dominance represented by each living habitat category by % fines and site grouping. (Correlation co-efficient and p-value for combined data indicated)

Results of PERMANOVA analysis indicate differences between relative dominance of living habitat categories in relation to TOC (p <0.001), specifically between sites where TOC <1% and where higher levels are recorded. However, when the distribution of living habitat trait categories was looked at with TOC in conjunction with year and site group no significant relationship was observed (p=0.309).

Overall, there appears to be no influence of the construction of the wind farm on the spatial and temporal patterns in TOC with no subsequent impacts evident in relation the relative dominance of the living habitat trait categories across the study area with any spatial or temporal variability observed being considered to be driven by natural factors.

4.1.4 Sediment position

Generally, across the site groupings and all years shallow infauna represented the greatest proportion of the communities recorded contributing between 46% and 80% of all individuals across all site groups and years with surface dwelling taxa representing between 9% and 26% and mid-depth fauna between 7% and 17% (Table 8). This reflects typical depth distribution of benthic macrofauna where approximately 60–90% of individuals are found in the top 5 cm of the sediment with a few large taxa existing below 15cm (Holme, 1953). While organic enrichment can alter depth distribution of benthic fauna with a shallowing of inhabited sediment as enrichment increases (Pearson and Rosenberg, 1978), no such pattern is observed here in the site groups which may be influenced by increased organic input from epibenthic colonising species associated wind farm infrastructure. Indeed, the distribution of sediment position categories remain consistent throughout the study period and across the study area with very strong correlation evident between sites and years (Table 9). Consequently, any variability in the relative dominance of taxa within the sediment position categories is likely to be due to the influence of natural variability rather than that of the wind farm.

Table 8. Relative dominance represented by each sediment position category by year and site grouping. Shading is proportional to the values from 0% (no shading) to 100% (full shading).

Trait	Category	ADJ			EB			WF		
		Pre	Post Yr 1	Post Yr 2	Pre	Post Yr 1	Post Yr 2	Pre	Post Yr 1	Post Yr 2
Sediment posiiton	Surface	24.4	14.3	16.7	26.4	19.9	15.6	11.7	9.4	15.0
	Shallow infauna	45.6	60.9	64.4	51.3	52.0	61.4	69.8	75.7	71.9
	Mid-depth infauna	17.2	12.8	10.5	13.0	14.4	12.8	9.9	8.4	7.0
	Deep infauna	12.9	12.0	8.4	9.3	13.6	10.3	8.6	6.5	6.1

Trait	Category	TE			CON		
		Pre	Post Yr 1	Post Yr 2	Pre	Post Yr 1	Post Yr 2
Sediment position	Surface	14.2	9.0	15.2	5.5	9.6	11.5
	Shallow infauna	65.6	76.7	72.5	80.4	72.9	71.5
	Mid-depth infauna	11.1	8.0	6.9	7.2	10.6	9.9
	Deep infauna	9.1	6.4	5.4	6.9	6.8	7.1

Table 9. Pearson correlation coefficients for comparisons of distribution of sediment position categories by year and site grouping. Shading is proportional to the values from 0 (no shading) to 1 (full shading).

	ADJ Pre	ADJ post yr 1	ADJ post yr 2	WF Pre	WF post yr 1	WF post yr 2	EB Pre	EB post yr 1	EBpost yr 2	TE Pre	TE post yr 1	TE post yr 2	CON Pre	CON post yr 1
ADJ post yr 1	0.96													
ADJ post yr 2	0.98	1.00												
WF Pre	1.00	0.94	0.97											
WF post yr 1	0.98	0.99	1.00	0.97										
WF post yr 2	0.97	1.00	1.00	0.95	1.00									
EB Pre	0.96	1.00	1.00	0.94	0.99	1.00								
EB post yr 1	0.96	1.00	0.99	0.93	0.99	1.00	1.00							
EBpost yr 2	0.98	1.00	1.00	0.96	1.00	1.00	1.00	0.99						
TE Pre	0.99	0.99	1.00	0.98	1.00	0.99	0.99	0.99	1.00					
TE post yr 1	0.95	1.00	0.99	0.93	0.99	1.00	1.00	1.00	0.99	0.99				
TE post yr 2	0.98	1.00	1.00	0.97	1.00	1.00	1.00	0.99	1.00	1.00	0.99			
CON Pre	0.94	1.00	0.99	0.92	0.98	0.99	1.00	1.00	0.99	0.98	1.00	0.99		
CON post yr 1	0.95	1.00	0.99	0.93	0.99	1.00	1.00	1.00	0.99	0.99	1.00	0.99	1.00	
CON post yr 2	0.96	1.00	1.00	0.94	0.99	1.00	1.00	1.00	1.00	0.99	1.00	1.00	1.00	1.00

There was a common similarity of over 90% for all sites and years in the distribution of sediment position trait categories reflecting the patterns discussed above (Figure 14), while the MDS plot in

Figure 15 indicate that patterns highlighted in the dendrogram are not strongly related to factors considered here.

Analysis of all years and sites by PERMANOVA indicated no significant difference between the pre-construction survey or the subsequent post-construction surveys (p = 0.466), while no significant differences were highlighted when considering site grouping by year (p = 0.753). Similarly, no significant differences were evident within CON between years (p = 0.764).

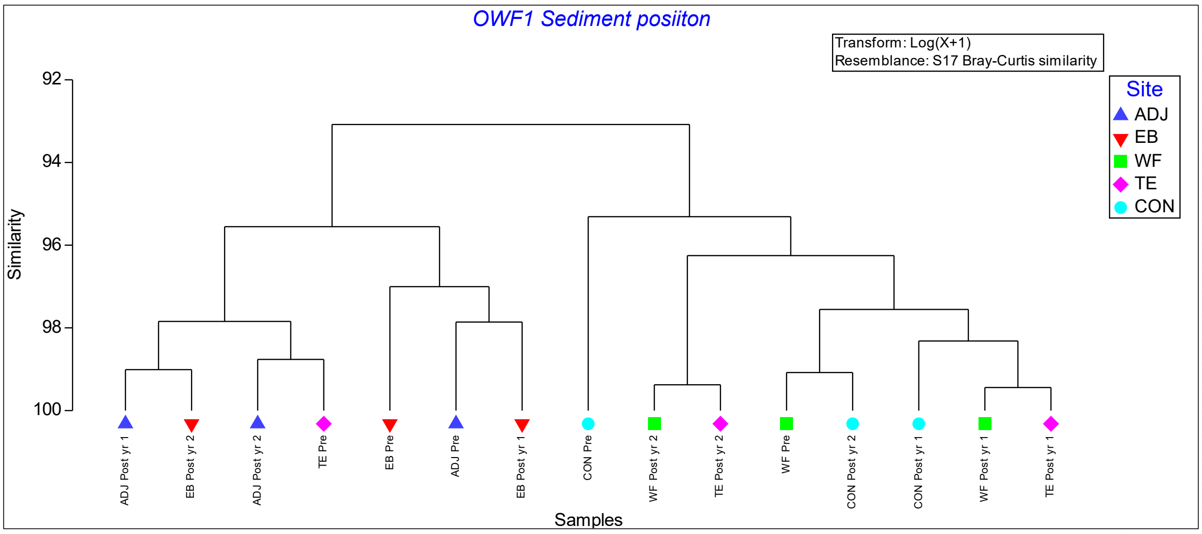

Figure 14. Dendrogram showing the relative similarities in OWF1 benthic communities in relation to four sediment position trait categories.

Figure 15. MDS showing the relative similarities in OWF1 benthic communities in relation to sediment position trait categories compared to factors: (a) Year; (b) Site Group; (c) % TOC; (d) % Fines.

When the distribution of the sediment position categories was examined in relation to TOC no strong patterns were evident with a very weak correlation evident for all categories (Figure 16). However, for fines a moderate positive correlation was evident for shallow infauna and while a moderate negative correlation was evident for surface dwellers, although these relationships were not statistically significant (Figure 17).

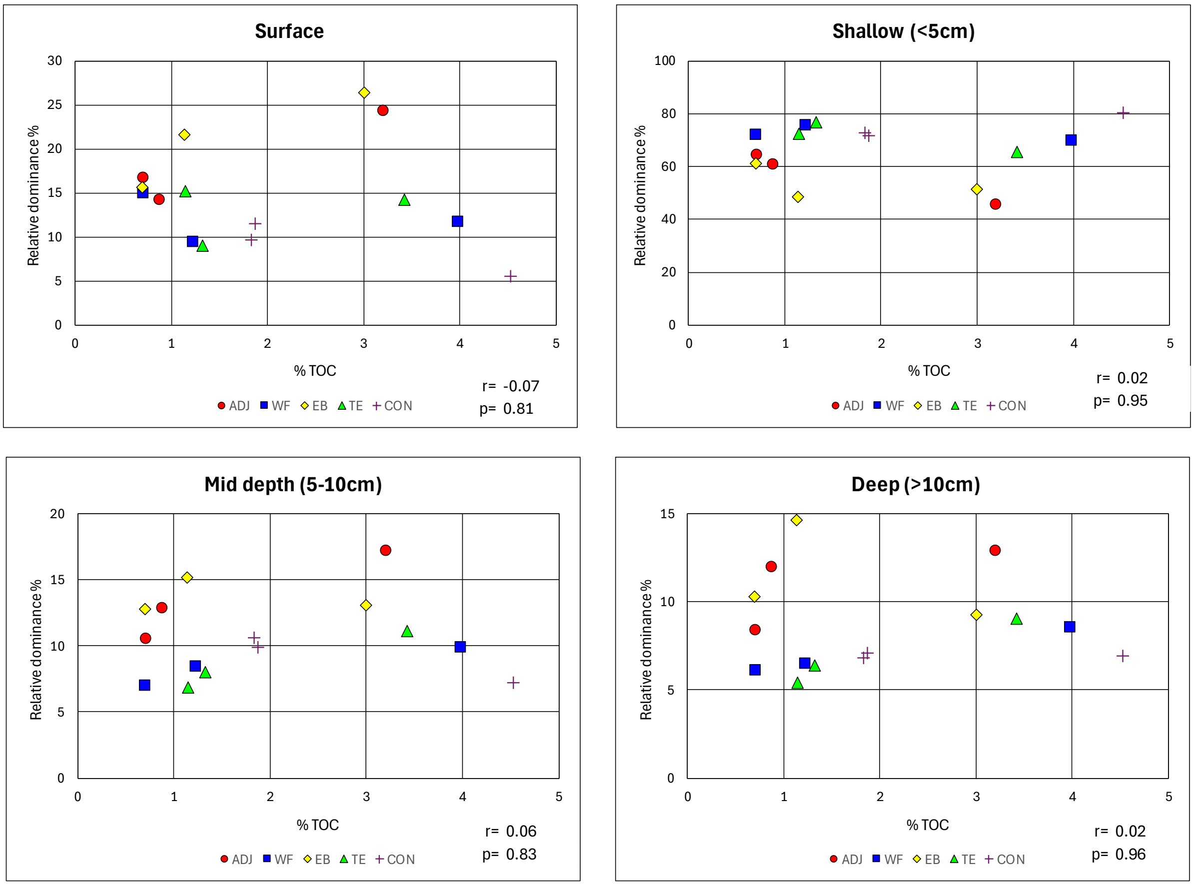

Figure 16. Mean relative dominance represented by each sediment position category by TOC and site grouping. (Correlation co-efficient and p-value for combined data indicated)

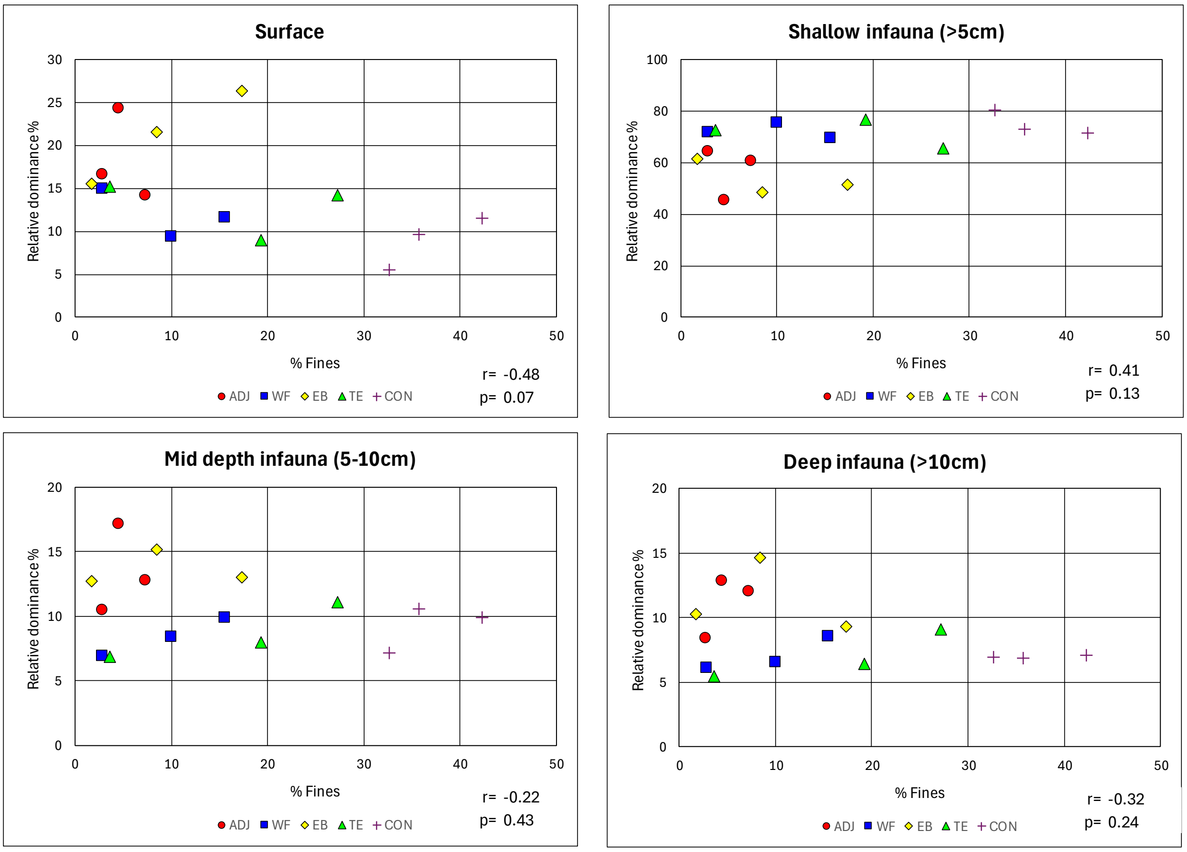

Figure 17. Mean relative dominance represented by each sediment position category by % fines and site grouping. (Correlation co-efficient and p-value for combined data indicated)

Results of PERMANOVA analysis indicate no differences between relative dominance of sediment position depth categories in relation to TOC (p = 0.289), although some differences in relation to % fines were evident (P = 0.0093) with differences between proportions of fines >25% and lower categories. However, when the distribution of sediment position trait categories was looked at with fines in conjunction with year and site group no significant relationship was observed (p = 0.309).

Overall, there appears to be no influence of the construction of the wind farm on the spatial and temporal patterns in TOC with no subsequent impacts evident in relation the relative dominance of the sediment position trait categories across the study area with any spatial or temporal variability observed being considered to be driven by natural factors.

4.1.5 Feeding mode

The average dominance of feeding mode categories showed little temporal variation across the study area with all modes (with the exception of parasites) representing on average between 8% and 38% of taxa, with suspension feeders and surface deposit feeders being the most common modes (Table 10).

Generally, across the site groupings and most years surface deposit and suspension feeders were the most common feeding modes contributing on average 30.6 and 27.9% respectively of all individuals across the study period, while predators and scavengers were also important, particularly at sites within the array (Table 10). While there was some variation in the proportion of each category the magnitude of changes overall are relatively small and the distribution of feeding mode categories remain relatively consistent throughout the study period and across the majority of the study area with mostly strong to very strong correlations evident between sites and years, although some weak to moderate correlations were evident particularly between ADJ pre-construction and ADJ post-construction year sites out with the wind farm (Table 11).

Table 10. Relative dominance represented by each feeding category by year and site grouping. Shading is proportional to the values from 0% (no shading) to 100% (full shading).

Trait	Category	ADJ			EB			WF		
		Pre	Post Yr 1	Post Yr 2	Pre	Post Yr 1	Post Yr 2	Pre	Post Yr 1	Post Yr 2
Feeding mode	Suspension	15.2	24.1	13.0	27.7	24.0	16.8	34.7	34.7	20.9
	Surface deposit	22.1	27.7	29.2	32.9	21.0	24.2	36.2	36.2	30.7
	Sub-surface deposit	12.0	9.9	25.1	8.4	5.3	18.5	6.9	7.0	19.2
	Scavenger	22.2	17.0	15.3	11.8	22.9	17.1	9.8	7.4	9.5
	Predator	28.4	21.3	17.5	19.2	26.9	23.4	12.1	14.7	19.7
	Parasite	0.1	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0

Trait	Category	TE			CON		
		Pre	Post Yr 1	Post Yr 2	Pre	Post Yr 1	Post Yr 2
Feeding mode	Suspension	33.5	34.0	29.0	37.5	39.4	37.3
	Surface deposit	30.9	36.2	33.1	37.0	29.9	30.3
	Sub-surface deposit	8.4	11.3	18.0	8.4	12.9	13.8
	Scavenger	11.0	6.3	8.3	7.9	7.9	8.3
	Predator	16.2	12.2	11.5	9.2	9.9	10.4
	Parasite	0.0	0.0	0.0	0.0	0.0	0.0

Table 11. Pearson correlation coefficients for comparisons of distribution of feeding mode categories by year and site grouping. Shading is proportional to the values from 0 (no shading) to 1 (full shading).

	ADJ Pre	ADJ post yr 1	ADJ post yr 2	WF Pre	WF post yr 1	WF post yr 2	EB Pre	EB post yr 1	EBpost yr 2	TE Pre	TE post yr 1	TE post yr 2	CON Pre	CON post yr 1
ADJ post yr 1	0.81													
ADJ post yr 2	0.61	0.64												
WF Pre	0.63	0.96	0.60											
WF post yr 1	0.89	0.89	0.37	0.75										
WF post yr 2	0.89	0.85	0.88	0.74	0.74									
EB Pre	0.40	0.86	0.49	0.96	0.61	0.56								
EB post yr 1	0.43	0.87	0.49	0.97	0.62	0.59	0.99							
EBpost yr 2	0.62	0.85	0.87	0.88	0.55	0.88	0.80	0.82						
TE Pre	0.56	0.94	0.55	0.99	0.73	0.69	0.98	0.99	0.85					
TE post yr 1	0.36	0.83	0.56	0.94	0.53	0.59	0.99	0.99	0.85	0.97				
TE post yr 2	0.37	0.80	0.71	0.90	0.45	0.66	0.93	0.93	0.91	0.91	0.97			
CON Pre	0.32	0.81	0.47	0.93	0.53	0.51	0.99	0.99	0.78	0.96	0.99	0.94		
CON post yr 1	0.27	0.77	0.44	0.87	0.50	0.50	0.95	0.95	0.75	0.93	0.96	0.94	0.97	
CON post yr 2	0.30	0.78	0.49	0.89	0.51	0.53	0.96	0.95	0.79	0.93	0.97	0.95	0.98	1.00

There was a common similarity of close to 91% for all sites and years in the distribution of sediment position trait categories reflecting the patterns highlighted above (Figure 32). However, the MDS plots in Figure 35 indicate that the patterns highlighted in the dendrogram are not strongly related to factors considered here.

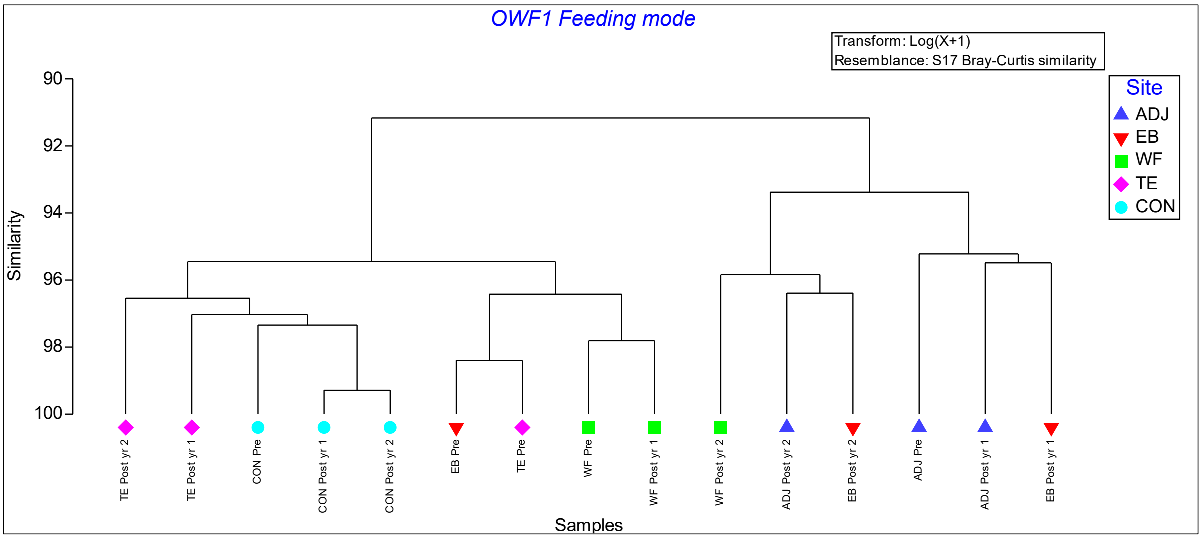

Figure 18. Dendrogram showing the relative similarities in OWF1 benthic communities in relation to six feeding mode trait categories.

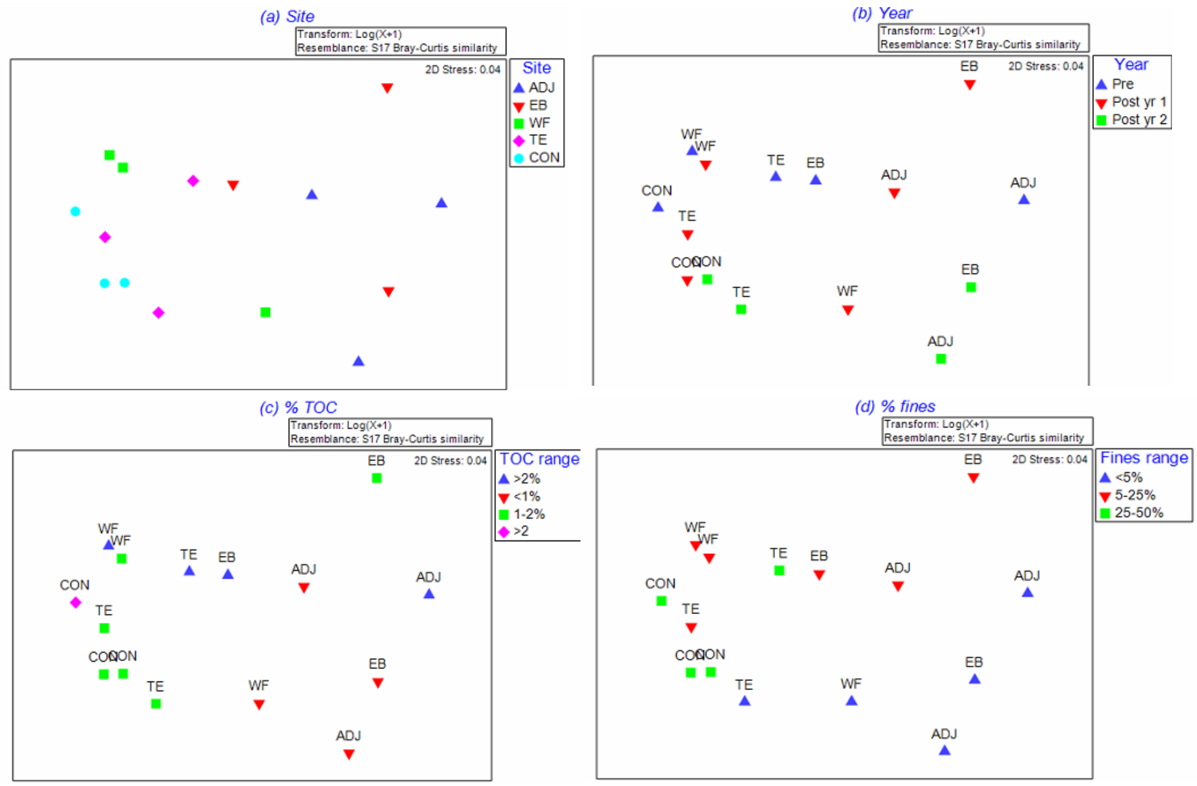

Figure 19. MDS showing the relative similarities in OWF1 benthic communities in relation to sediment feeding mode categories compared to factors: (a) Year; (b) Site Group; (c) % TOC; (d) % Fines.

Analysis of all years and sites by PERMANOVA indicated no significant difference between the pre-construction and the first post-construction survey in post-construction year 1 ($p = 0.754$), although differences were evident between pre-construction and post-construction year 2 ($p = 0.013$) and post-construction year 1 and post-construction year 2 ($p = 0.014$). While analysis indicated no significant difference over the years within CON ($p = 0.543$). When the distribution of feeding mode trait categories was looked at with year and site group in conjunction no significant relationship was observed ($p = 0.889$).

When the distribution of the feeding mode categories was examined in relation to TOC a strong negative correlation was evident for subsurface deposit feeders (r=-0.53, p=0.04), while for other categories no significant correlations with TOC were evident (Figure 20). However, in relation to proportion of fines suspension feeders showed a very strong positive correlation to increasing levels (r= 0.79, p<0.01), while predators (r=-0.67, p=0.01) and scavengers both showed strong negative correlations (r=-0.54, p=0.04) (Figure 21).

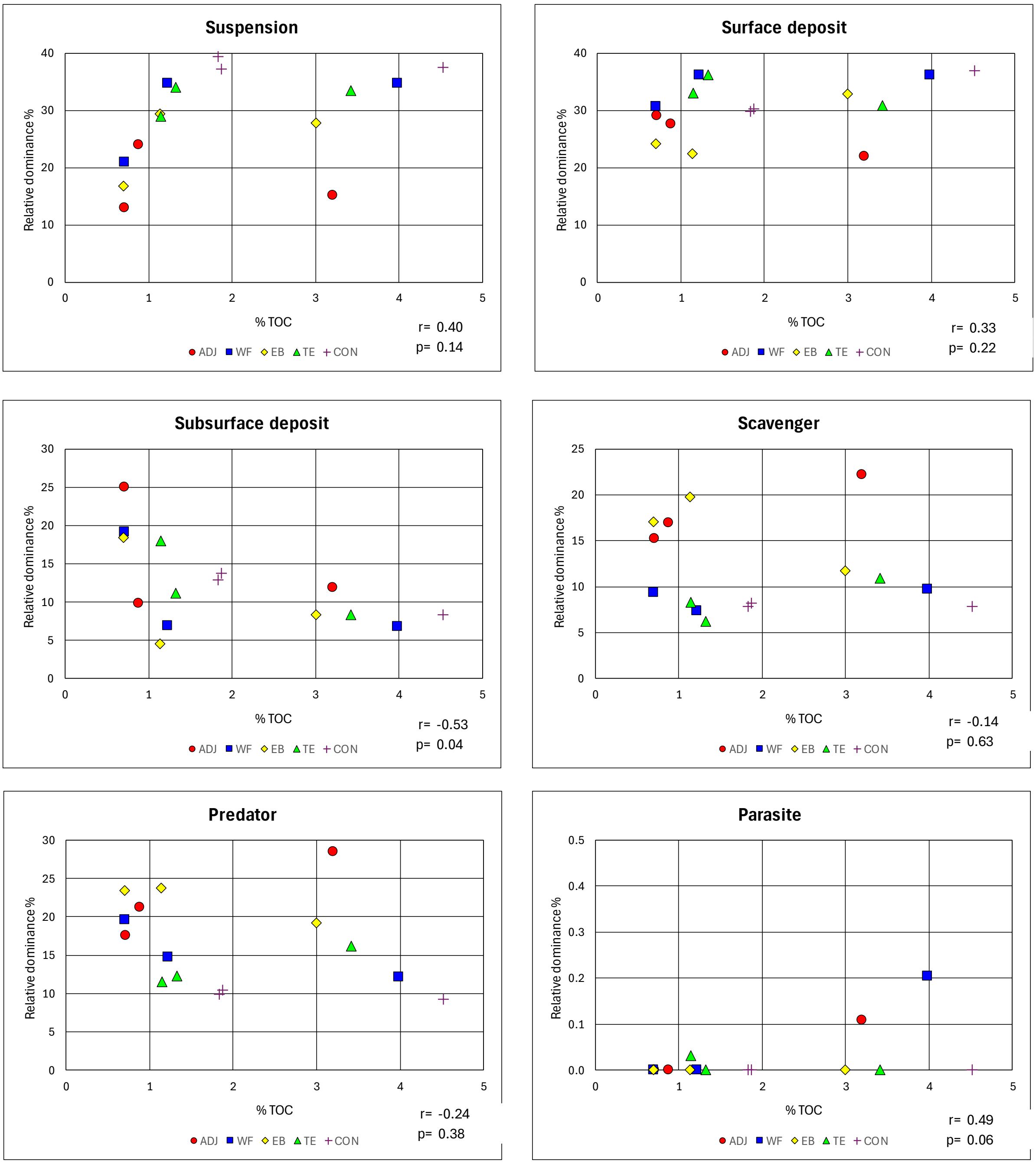

Figure 20. Mean relative dominance represented by each feeding mode category by TOC and site grouping. (Correlation co-efficient and p-value for combined data indicated)

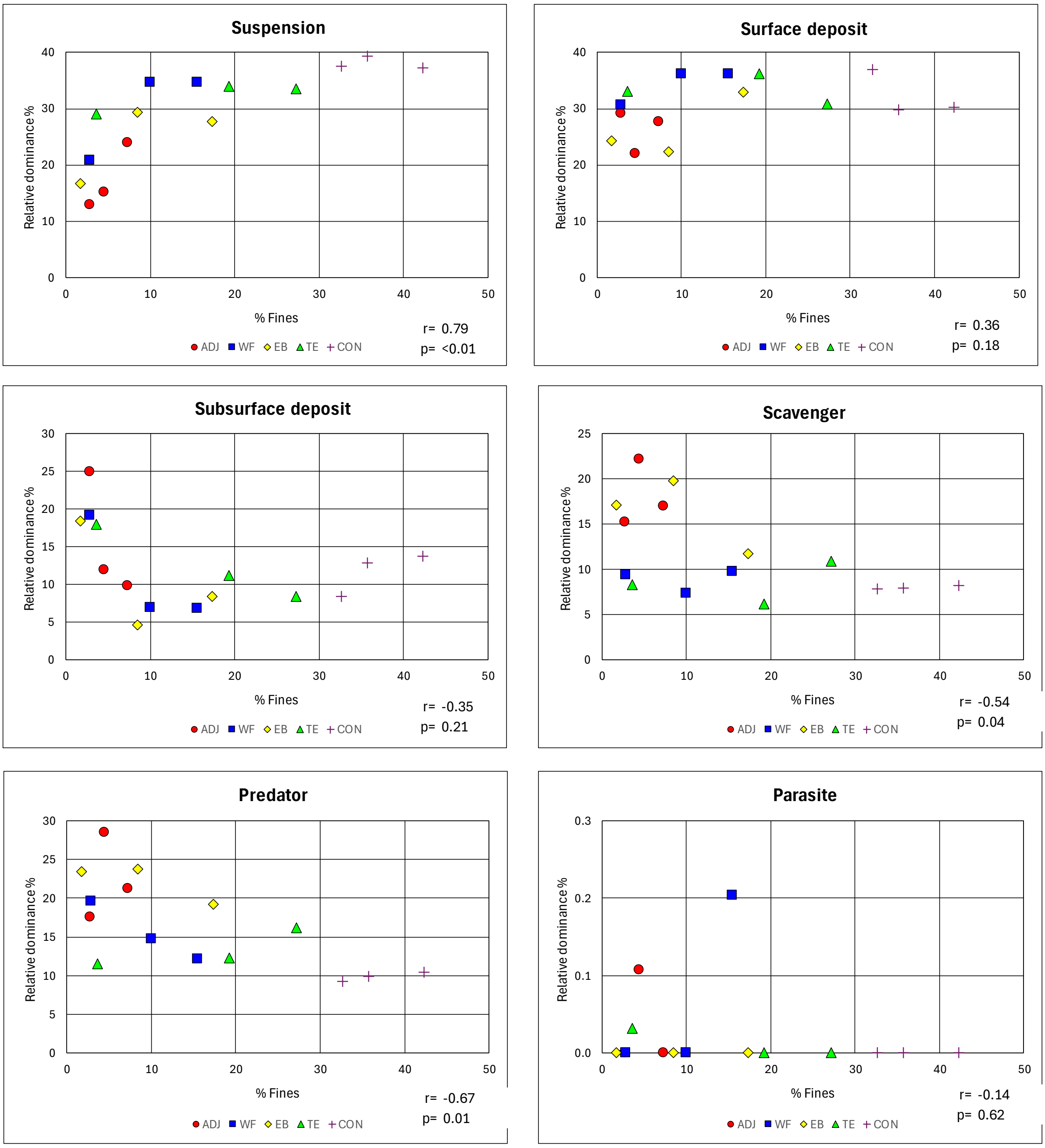

Figure 21. Mean relative dominance represented by each feeding mode category by % fines and site grouping. (Correlation co-efficient and p-value for combined data indicated)

Results of PERMANOVA analysis indicate differences between relative dominance of feeding mode categories in relation to TOC across the study period (p 0.002), specifically between sites where TOC <1% and where higher levels are recorded. Significant differences were also highlighted when the distribution of feeding mode trait categories was looked at with LOI, year and site group in conjunction ($p = 0.023$). Similarly, significant differences were evident in relation to proportion of fines in sediment across the study period ($p<0.001$), although no consistent pattern was evident when considered in conjunction with year ($p = 0.378$) or site grouping ($p = 0.583$).

Overall, there appears to be no influence of the construction of the wind farm on the spatial and temporal patterns in TOC with no subsequent impacts evident in relation to the relative dominance of the feeding mode categories across the study area with any spatial or temporal variability observed being considered to be driven by natural factors.

4.1.6 Bioturbation

Generally, across the site groupings and all years, diffuse mixing taxa represented the highest relative dominance in relation to bioturbation trait categories contributing on average 48.9% of all individuals across the study period (annual range = 40.4% to 57.3%), while surface deposition taxa represented an average of 40.9% of all individuals across the study period (annual range = 27.7 % to 49.3%) (Table 12). However, no clear temporal patterns were evident in the relative dominance represented by any of the trait categories. While some variation was evident, the magnitude of changes overall are relatively small. The distribution of bioturbation categories remains relatively consistent throughout the study period and across the majority of the study area with consistently very strong correlations evident between sites and years (Table 13).

Table 12. Relative dominance represented by each bioturbation category by year and site grouping. Shading is proportional to the values from 0% (no shading) to 100% (full shading).

Trait	Category	ADJ			EB			WF		
		Pre	Post Yr 1	Post Yr 2	Pre	Post Yr 1	Post Yr 2	Pre	Post Yr 1	Post Yr 2
Bioturbation	Diffusive_mixing	53.8	57.3	53.2	40.4	57.1	47.2	42.7	54.2	46.7
	Surface_deposition	37.5	38.2	43.0	46.7	27.7	40.9	42.4	41.1	49.3
	Upward_conveyor	2.8	0.5	0.7	1.8	0.2	3.6	1.8	0.5	1.7
	Downward_conveyer	5.8	2.7	2.7	10.5	7.8	7.2	11.5	1.8	1.3
	None	0.2	1.3	0.4	0.6	7.3	1.1	1.6	2.4	1.0

Trait	Category	TE			CON		
		Pre	Post Yr 1	Post Yr 2	Pre	Post Yr 1	Post Yr 2
Bioturbation	Diffusive_mixing	45.4	48.3	42.4	56.5	45.0	48.8
	Surface_deposition	44.3	46.3	48.0	36.9	34.7	34.7
	Upward_conveyor	1.9	0.6	1.9	1.3	1.5	3.3
	Downward_conveyer	5.1	2.7	3.1	1.8	2.8	2.6
	None	3.3	2.1	4.6	3.5	16.0	10.6

Table 13. Pearson correlation coefficients for comparisons of distribution of bioturbation categories by year and site grouping. Shading is proportional to the values from 0 (no shading) to 1 (full shading).

	ADJ Pre	ADJ post yr 1	ADJ post yr 2	WF Pre	WF post yr 1	WF post yr 2	EB Pre	EB post yr 1	EBpost yr 2	TE Pre	TE post yr 1	TE post yr 2	CON Pre	CON post yr 1
ADJ post yr 1	1.00													
ADJ post yr 2	0.99	0.99												
WF Pre	0.94	0.92	0.96											
WF post yr 1	0.96	0.97	0.94	0.83										
WF post yr 2	0.99	0.98	1.00	0.98	0.92									
EB Pre	0.96	0.95	0.98	0.99	0.88	0.99								
EB post yr 1	0.99	1.00	1.00	0.95	0.95	0.99	0.97							
EBpost yr 2	0.96	0.96	0.98	0.98	0.87	0.99	0.98	0.98						
TE Pre	0.94	0.94	0.97	1.00	0.84	0.98	0.99	0.96	0.99					
TE post yr 1	0.97	0.97	0.99	0.98	0.90	0.99	0.99	0.99	1.00	0.99				
TE post yr 2	0.94	0.94	0.97	0.98	0.85	0.97	0.98	0.96	1.00	0.99	0.99			
CON Pre	0.99	1.00	0.99	0.91	0.97	0.98	0.94	1.00	0.95	0.93	0.97	0.93		
CON post yr 1	0.93	0.95	0.95	0.87	0.93	0.92	0.90	0.96	0.93	0.90	0.94	0.93	0.96	
CON post yr 2	0.97	0.99	0.98	0.90	0.96	0.96	0.93	0.99	0.95	0.92	0.97	0.94	0.99	0.99

There was a common similarity of close to 87% for all sites and years in the distribution of bioturbation trait categories indicating high level of similarity between all sites in all years reflecting the patterns highlighted above (**Error! Reference source not found.**). The MDS plot in Figure 23 indicate that the patterns highlighted in the dendrogram are not strongly related to factors considered here. Analysis of all years and sites by PERMANOVA indicated no significant difference between any of the three surveys (p = 0.253). When the distribution of bioturbation trait categories was looked at with year and site group in conjunction no significant relationship was observed (p = 0.839).

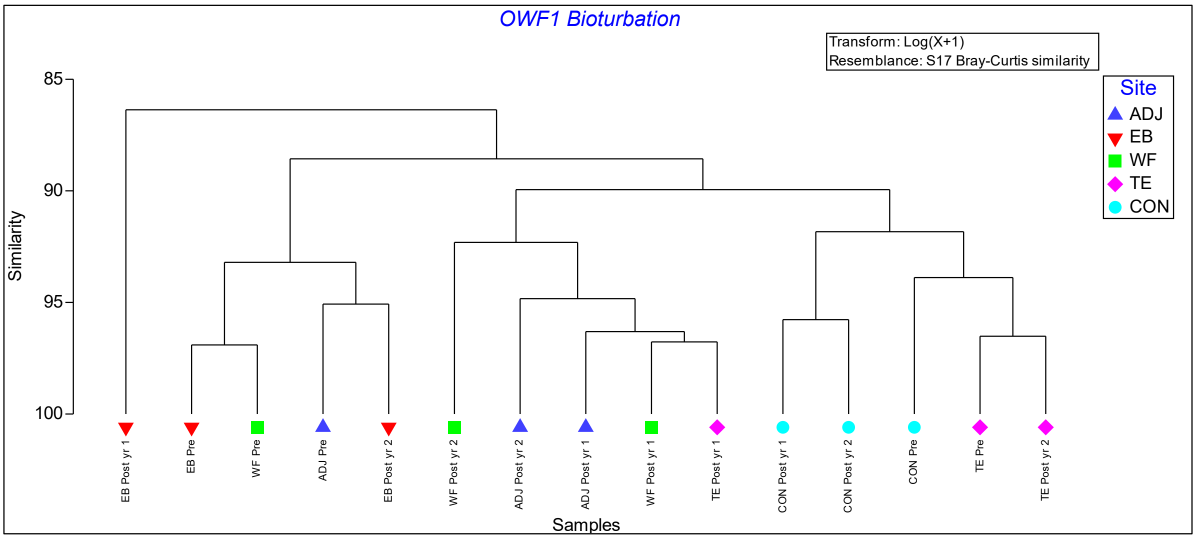

Figure 22. **Dendrogram showing the relative similarities in OWF1 benthic communities in relation to five bioturbation trait categories.**

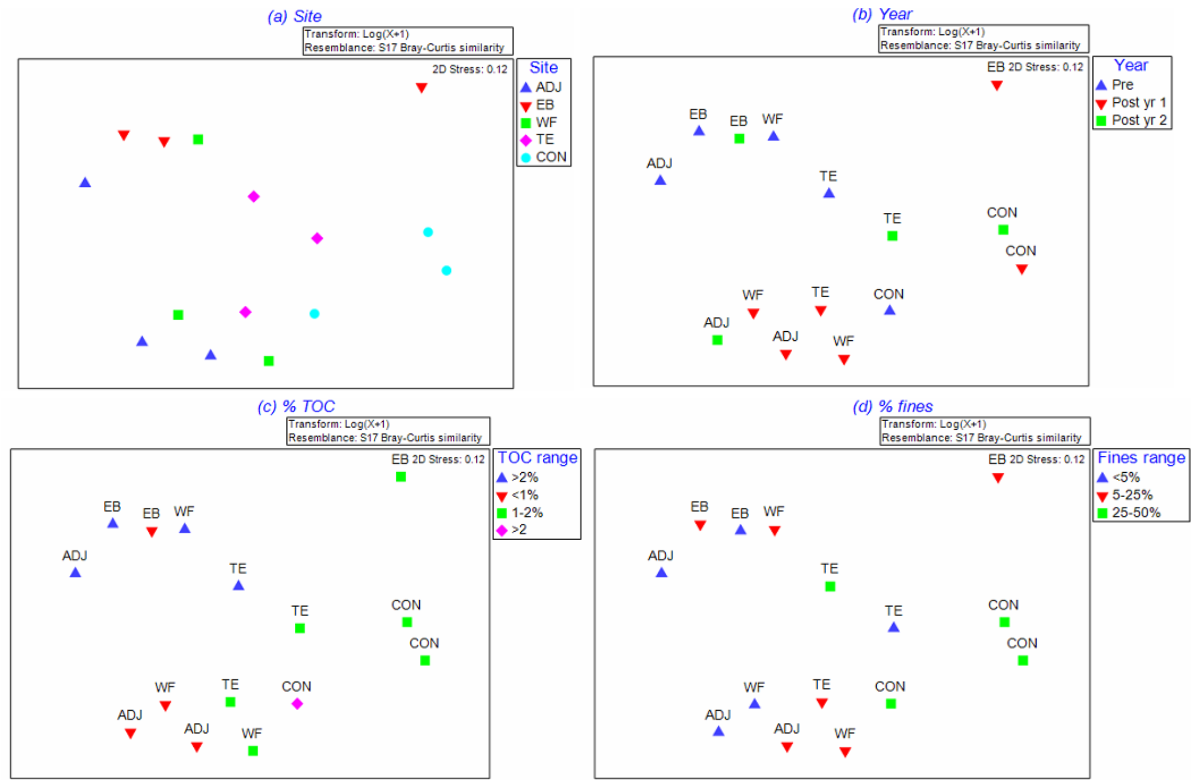

Figure 23. MDS showing the relative similarities in OWF1 benthic communities in relation to bioturbation categories compared to factors: (a) Year; (b) Site Group; (c) % TOC; (d) % Fines.

No significant correlations were evident between TOC levels and bioturbation categories (Figure 24). Similarly, no significant correlations were evident between % fines and bioturbation categories (Figure 25).

Results of PERMANOVA analysis indicate differences between relative dominance of feeding mode categories in relation to TOC across the study period (p 0.021), specifically between sites where TOC <1% and where higher levels are recorded. However, no significant differences were highlighted when the distribution of bioturbation trait categories was looked at with LOI, year and site group in conjunction ($p = 0.394$). Similarly, significant differences were evident in relation to proportion of fines in sediment across the study period ($p = 0.002$), although no consistent pattern was evident and when considered in conjunction with year ($p = 0.106$) or site grouping ($p = 0.234$).

Overall, there appears to be no influence of the construction of the wind farm on the spatial and temporal patterns in TOC with no subsequent impacts evident in relation to the relative dominance of the bioturbation trait categories across the study area. Any spatial or temporal variability observed is considered to be driven by natural factors.

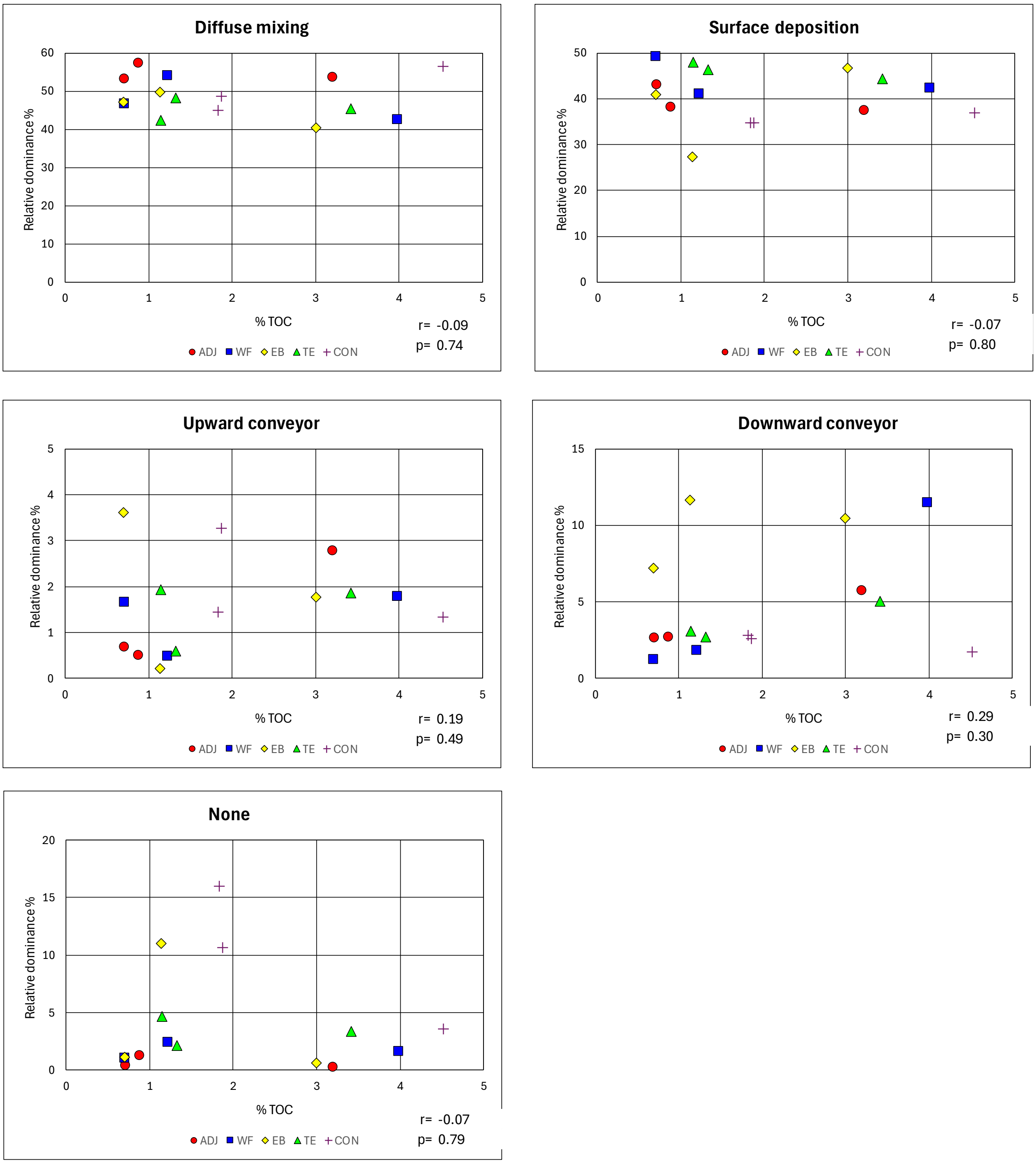

Figure 24. Mean relative dominance represented by each bioturbation category by TOC and site grouping. (Correlation co-efficient and p-value for combined data indicated)

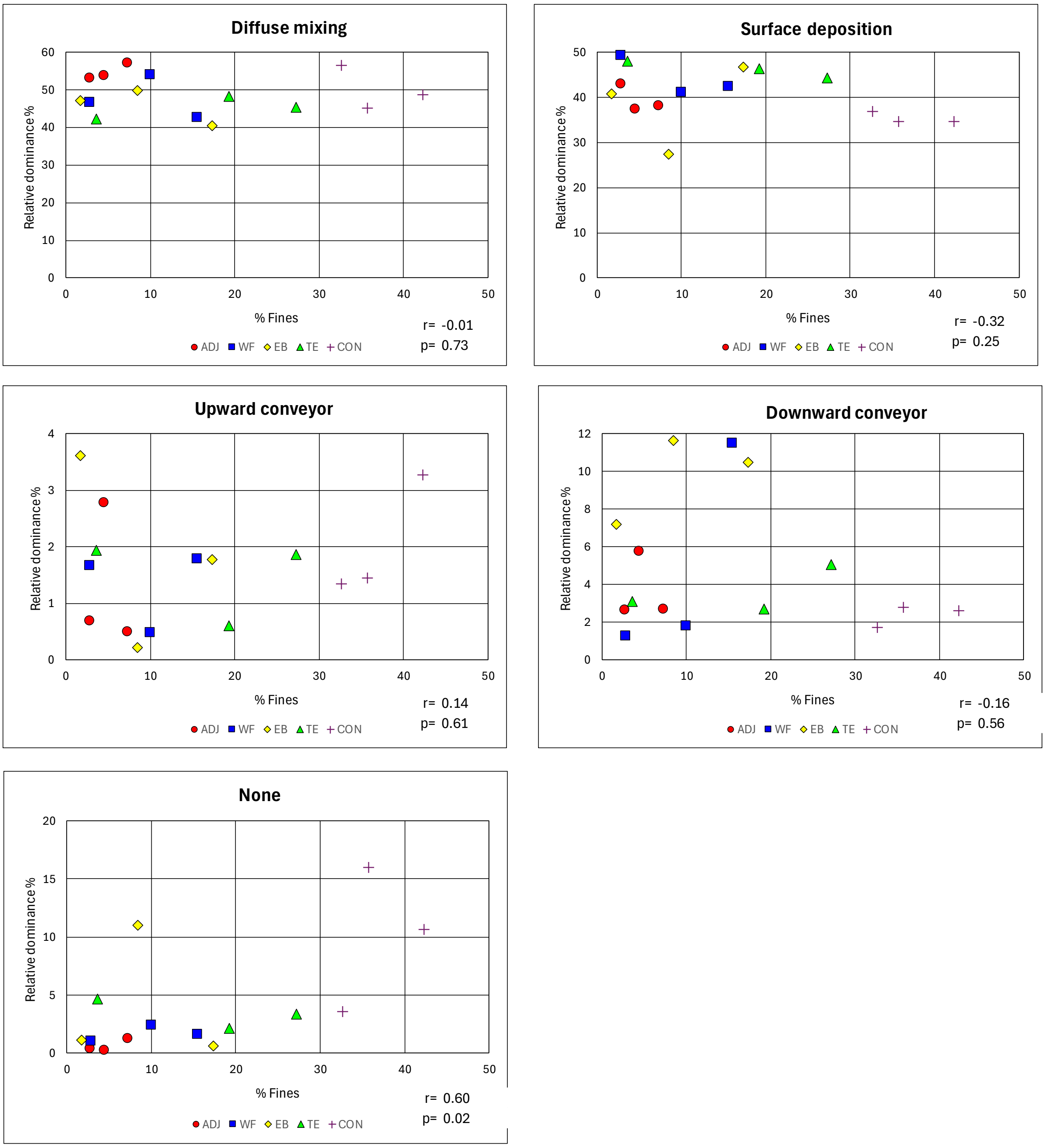

Figure 25. Mean relative dominance represented by each bioturbation category by % fines and site grouping. (Correlation co-efficient and p-value for combined data indicated)

4.1.7 Conclusions – OWF 1

For OWF 1, there appears to be no influence of the OWF construction in relation to the relative dominance of all benthic traits. No consistent patterns in traits, either spatially or temporally, were observed in relation to the OWF. Where evident, the magnitude of changes are proportionally small and this, combined with the lack of any consistent patterns, would indicate that these are related to natural variability and/or wider regional environmental factors. As such, the traits analysis does not highlight any influence of the OWF development on distribution of traits across the benthic communities. This conclusion is consistent with that of the original benthic study undertaken as part of the post-construction monitoring programme which employed more traditional univariate and multivariate statistical analyses.

4.2 OWF 2

4.2.1 Maximum size

Generally, across the site groupings and all years taxa with maximum sizes of between 10 and 20mm represented the highest proportion of the communities recorded contributing on average 45.4% of all individuals across the study period (annual range = 38.5 % to 52.2%), while those with maximum size of between 21 and 100mm represented on average 25.3% (annual range = 21.2% to 30.3%) and those sized <10mm represented on average 17.6% of individuals (annual range = 14.4% to 19.2%) (Table 14). Taxa of maximum size between 101 and 200mm represented on average 9.2% (annual range = 6.7% to 11.6%), while taxa above 200mm were generally sparse, particularly at sites within the array where they never represented more than 1.7% of individuals at any site in any year. Those taxa with maximum size <20mm showed little variation between site groups and years with the highest proportion (83.9%) recorded at ADJ in post-construction year 3, although similarly proportions were observed in the same year at TUR 100m (74.6%) and CON (70.5%).

However, no clear temporal patterns were evident in the relative dominance represented by any of the trait categories and while some variation was evident, the magnitude of changes overall are relatively small and the distribution of maximum size categories remain relatively consistent throughout the study period and across the majority of the study area being predominantly strong to very strong correlations evident between sites and years (

Table 15).

Table 14. Relative dominance represented by each maximum size category by year and site grouping. Shading is proportional to the values from 0% (no shading) to 100% (full shading).

Trait	Category	TUR_50m				TUR_100m				TUR_250m			
		Pre	Post Yr 1	Post Yr 2	Post Yr 3	Pre	Post Yr 1	Post Yr 2	Post Yr 3	Pre	Post Yr 1	Post Yr 2	Post Yr 3
Maximum size (mm)	<10	27.0	21.3	20.4	20.0	37.8	23.2	16.3	26.5	20.4	23.2	16.3	14.0
	10-20	42.7	47.1	48.9	51.0	26.3	35.6	49.7	48.2	46.1	30.0	42.9	49.5
	21-100	19.5	26.5	24.9	19.5	16.0	31.9	23.5	17.1	24.1	39.1	26.5	26.5
	101-200	10.6	5.0	5.9	9.0	18.2	9.3	10.4	8.1	9.3	7.5	14.3	9.9
	201-500	0.1	0.1	0.0	0.5	1.7	0.0	0.0	0.2	0.1	0.1	0.0	0.1
	<500	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Trait	Category	WF				ADJ				MID			
		Pre	Post Yr 1	Post Yr 2	Post Yr 3	Pre	Post Yr 1	Post Yr 2	Post Yr 3	Pre	Post Yr 1	Post Yr 2	Post Yr 3
Maximum size (mm)	<10	19.5	22.0	23.8	29.1	4.3	16.5	4.0	8.4	7.9	9.5	6.7	9.4
	10-20	38.5	30.6	31.9	31.4	43.5	43.5	60.5	75.5	52.1	48.1	65.1	60.0
	21-100	24.4	33.0	32.1	30.8	29.4	19.0	18.1	7.5	24.0	30.0	22.7	24.6
	101-200	17.2	12.8	11.5	7.6	10.8	15.3	11.6	4.4	9.5	6.2	4.0	3.3
	201-500	0.4	1.7	0.6	1.1	11.3	4.8	5.1	3.9	5.7	6.0	1.4	2.5
	<500	0.0	0.0	0.2	0.0	0.6	0.9	0.7	0.3	0.8	0.2	0.2	0.2

Trait	Category	CON			
		Pre	Post Yr 1	Post Yr 2	Post Yr 3
Maximum size (mm)	<10	13.6	18.6	13.3	20.5
	10-20	44.5	34.3	44.6	50.0
	21-100	30.7	32.9	31.7	22.4
	101-200	6.0	9.5	6.1	5.0
	201-500	3.3	3.7	3.4	1.8
	<500	2.0	1.0	0.9	0.3

Table 15. Pearson correlation coefficients for comparisons of distribution of maximum size categories by year and site grouping. Shading is proportional to the values from 0 (no shading) to 1 (full shading).

	TUR1_50 Pre	TUR1_50 Post yr 2	TUR1_50 Post yr 2	TUR1_50 Post yr 3	TUR2_100 Post yr 1	TUR2_100 Post yr 2	TUR2_250 Pre	TUR2_250 Pre	TUR2_250 Post yr 1	TUR2_250 Post yr 2	TUR1_250 Post yr 3	WF Pre	WF Post Yr 1	WF Post Yr 2	WF Post Yr 3	ADJ Pre	ADJ Post Yr 1	ADJ Post Yr 2	ADJ Post Yr 3	MID Pre	MID Post Yr 1	MID Post Yr 2	MID Post Yr 3	CON Pre	CON Post Yr 1	CON Post Yr 2	CON Post Yr 3
TUR1_50 Post yr 1	0.96																										
TUR1_50 Post yr 2	0.97	1.00																									
TUR1_50 Post yr 3	0.97	0.98	0.99																								
TUR2_100 Pre	0.82	0.66	0.65	0.66																							
TUR2_100 Post yr 1	0.92	0.95	0.93	0.88	0.72																						
TUR2_100 Post yr 2	0.95	0.98	0.99	0.99	0.61	0.91																					
TUR1_100 Post yr 3	0.99	0.96	0.97	0.98	0.76	0.88	0.96																				
TUR2_250 Pre	0.97	0.99	1.00	0.99	0.69	0.94	0.99	0.97																			
TUR2_250 Post yr 1	0.79	0.86	0.83	0.74	0.64	0.97	0.78	0.74	0.83																		
TUR2_250 Post yr 2	0.93	0.97	0.97	0.96	0.64	0.94	0.98	0.92	0.98	0.85																	
TUR1_250 Post yr 3	0.92	0.98	0.98	0.98	0.56	0.91	1.00	0.93	0.98	0.81	0.99																
WF Pre	0.95	0.94	0.95	0.94	0.74	0.94	0.96	0.92	0.97	0.84	0.99	0.96															
WF Post Yr 1	0.86	0.89	0.87	0.81	0.72	0.99	0.85	0.80	0.89	0.98	0.91	0.86	0.92														
WF Post Yr 2	0.89	0.92	0.89	0.84	0.75	0.99	0.86	0.84	0.91	0.98	0.92	0.87	0.93	1.00													
WF Post Yr 3	0.90	0.90	0.88	0.82	0.81	0.98	0.82	0.85	0.88	0.96	0.86	0.82	0.88	0.97	0.98												
ADJ Pre	0.73	0.85	0.86	0.84	0.27	0.79	0.89	0.74	0.86	0.72	0.89	0.92	0.82	0.76	0.74	0.66											
ADJ Post Yr 1	0.94	0.94	0.96	0.98	0.64	0.86	0.99	0.95	0.97	0.72	0.97	0.97	0.96	0.81	0.82	0.78	0.88										
ADJ Post Yr 2	0.81	0.87	0.89	0.92	0.36	0.72	0.94	0.85	0.89	0.56	0.89	0.94	0.84	0.65	0.66	0.59	0.92	0.94									
ADJ Post Yr 3	0.82	0.85	0.88	0.93	0.40	0.65	0.91	0.88	0.87	0.47	0.83	0.89	0.78	0.55	0.58	0.55	0.82	0.92	0.97								
MID Pre	0.85	0.93	0.94	0.95	0.41	0.82	0.97	0.87	0.94	0.70	0.94	0.98	0.89	0.76	0.76	0.70	0.96	0.96	0.98	0.94							
MID Post Yr 1	0.84	0.94	0.95	0.92	0.42	0.88	0.96	0.86	0.94	0.80	0.95	0.98	0.89	0.83	0.83	0.77	0.97	0.92	0.93	0.87	0.98						
MID Post Yr 2	0.85	0.93	0.94	0.95	0.41	0.79	0.97	0.89	0.93	0.66	0.92	0.97	0.86	0.72	0.73	0.68	0.93	0.95	0.98	0.96	0.99	0.97					
MID Post Yr 3	0.87	0.95	0.96	0.96	0.43	0.83	0.97	0.90	0.95	0.71	0.93	0.98	0.88	0.75	0.77	0.73	0.94	0.95	0.97	0.95	0.99	0.98	1.00				
CON Pre	0.88	0.97	0.97	0.93	0.50	0.93	0.97	0.88	0.96	0.86	0.96	0.98	0.91	0.89	0.89	0.85	0.94	0.92	0.89	0.83	0.96	0.99	0.94	0.96			
CON Post Yr 1	0.87	0.94	0.92	0.86	0.62	0.99	0.90	0.84	0.93	0.97	0.94	0.92	0.92	0.98	0.98	0.94	0.86	0.85	0.75	0.66	0.85	0.92	0.82	0.85	0.96		
CON Post Yr 2	0.87	0.97	0.96	0.93	0.50	0.93	0.96	0.87	0.96	0.87	0.96	0.98	0.92	0.89	0.90	0.85	0.94	0.92	0.89	0.82	0.95	0.99	0.94	0.96	1.00	0.96	
CON Post Yr 3	0.96	0.99	1.00	0.99	0.64	0.91	0.99	0.98	0.99	0.79	0.95	0.98	0.93	0.84	0.86	0.85	0.85	0.96	0.91	0.91	0.94	0.94	0.95	0.97	0.96	0.90	0.95

There was a common similarity of close to 87% for all sites and years in the distribution of maximum size trait categories reflecting the patterns highlighted (Figure 26). However, there appears to be some difference between sites within the wind farm and those outside of the array area, although, considering the common similarity indicated, these differences are considered to be not significant. The MDS plots in Figure 27 indicate that the patterns highlighted in the dendrogram are not strongly related to factors considered here, although some weak association with both % TOC and % fines, related to lower levels of both sediment components at ADJ and CON, were observed.

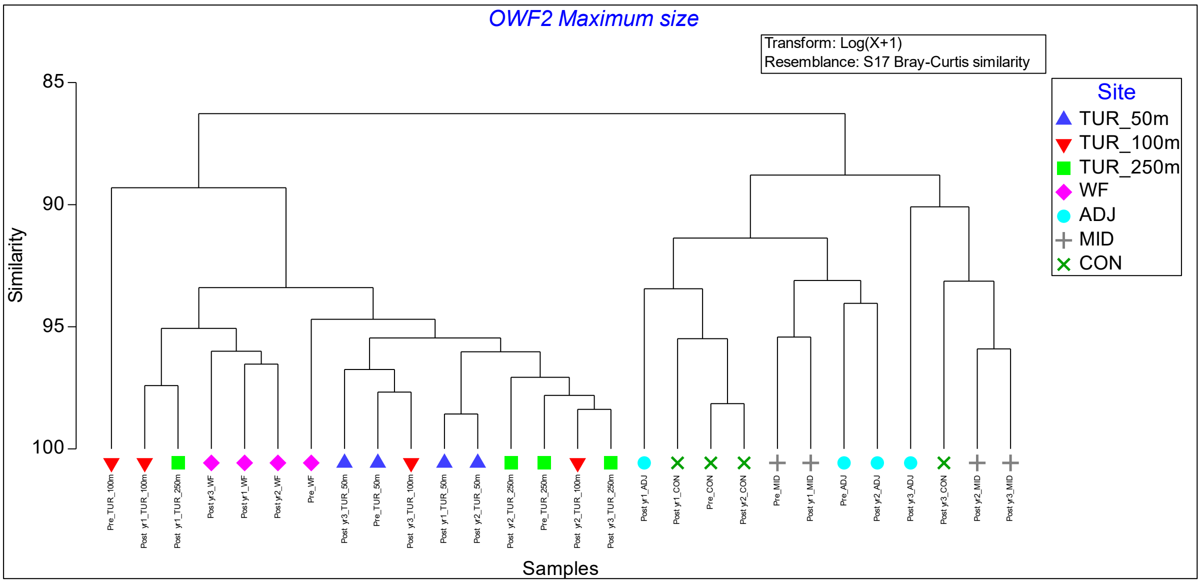

Figure 26. Dendrogram showing the relative similarities in OWF1 benthic communities in relation to six maximum size trait categories.

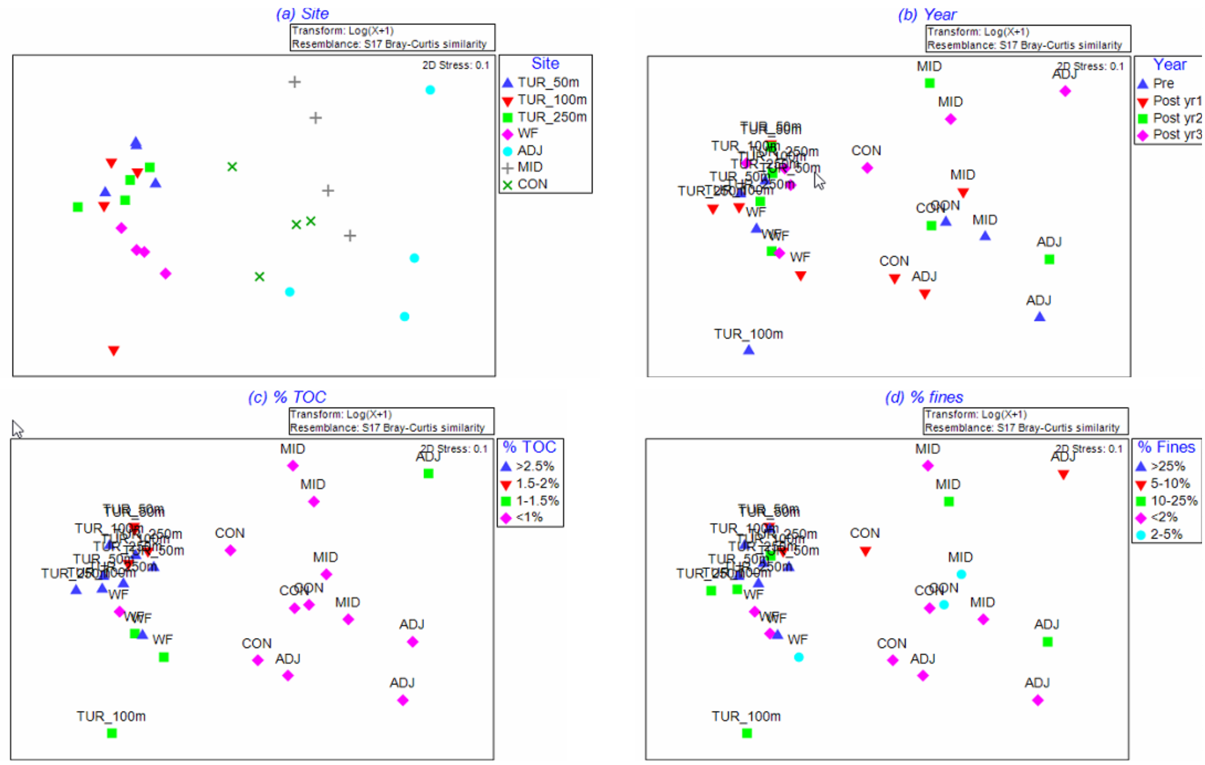

Figure 27. MDS showing the relative similarities in OWF1 benthic communities in relation to maximum size trait categories compared to factors: (a) Year; (b) Site Group; (c) % TOC; (d) % Fines.

Analysis of all years and sites by PERMANOVA indicated no significant difference between years (p = 0.391), a pattern reflected in the CON sites (p = 0.957) when considered alone. Similarly, no significant difference between site groups were observed either over the monitoring period as a whole (p = 0.395) or when considered in conjunction with year of sampling (p = 1).

In relation to sediment characteristics Total Organic Carbon (TOC) as derived by loss on ignition and proportion of fines were examined. Levels of TOC were considerably higher at sites within 250m of a turbine than elsewhere. While increases in TOC were observed in post-construction year 1 at sites located at 100m and 250m from a turbine with levels remaining stable in subsequent years no change was seen at sites within 50m of turbines (Figure 28). Small increases in TOC in post-construction year 1 were also seen at WF and ADJ. These patterns may indicate some influence of the wind farm reflecting inputs of organic and fine particulate material (silt and clay) from epibenthic colonisers of turbines and associated hard structures. Levels of fines were also higher at sites closest to the turbines, although no consistent temporal patterns were evident at these sites or others within the wind farm. Overall, TOC and % fines showed a strong correlation (r=0.74, p<0.01).

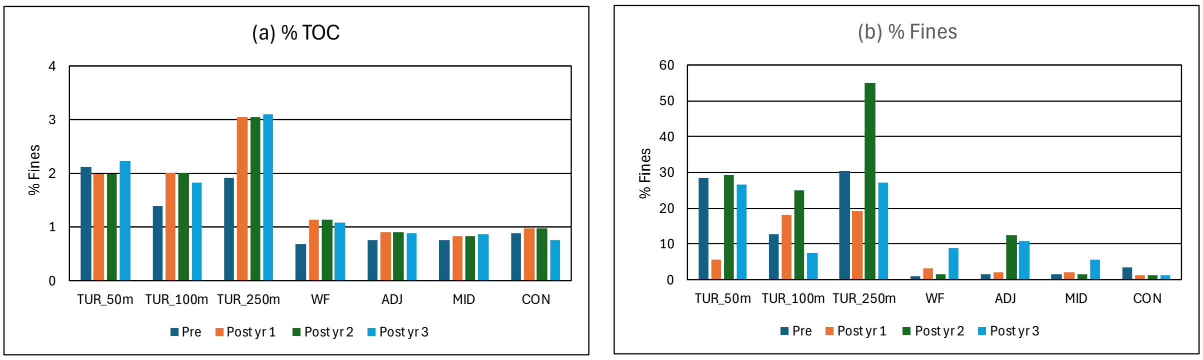

Figure 28. Pre and post-construction levels of TOC and fines.

In relation to TOC taxa with maximum sizes of between 10 and 20mm represented the highest proportion of the communities recorded across the study area ad period contributing on average 50.0% of all individuals across the study period (annual range = 41.4 % to 57.1%), while those with maximum size of between 21 and 100mm represented on average 25.6% (annual range = 22.4% to 29.9%) and those sized <10mm represented on average 12.5% of individuals (annual range = 10.8% to 15.3%) (**Error! Reference source not found.**). Taxa of maximum size between 101 and 200mm represented on a verage 8.0% (annual range = 4.8% to 10.4%), while taxa above 200mm were generally sparse where TOC <2%, although this group represented relatively low proportions of the fauna throughout with the highest figures observed pre-construction. Those taxa with maximum size <20mm showed little variation between TOC categories and years with the highest proportions recorded in post-commissioning year 2 for >45 TOC (92.4%); similarly high levels were observed the same year for TOC 1.5 – 2% (89.5%) and for TOC 2 – 2.5% (83.9%).

When the distribution of the maximum size categories were examined in relation to TOC a strong positive correlation was evident for those sizes 11-20mm (r=0.59, p<0.01) and 201-500mm (r=0.58, p<0.01), while a strong negative correlation was evident for fauna sized <10mm (r=-0.73, p<0.01) - **Figure 29**. Other categories showed only weak correlations to % fines. Not surprisingly similar patterns were evident in relation to fines and distribution of maximum size categories with recorded for TOC with strong positive correlation was evident for those sizes 11-20mm (r=0.64, p<0.01) and 201-500mm (r=0.58, p<0.01), while a strong negative correlation was evident for fauna sized <10mm (Figure 30).

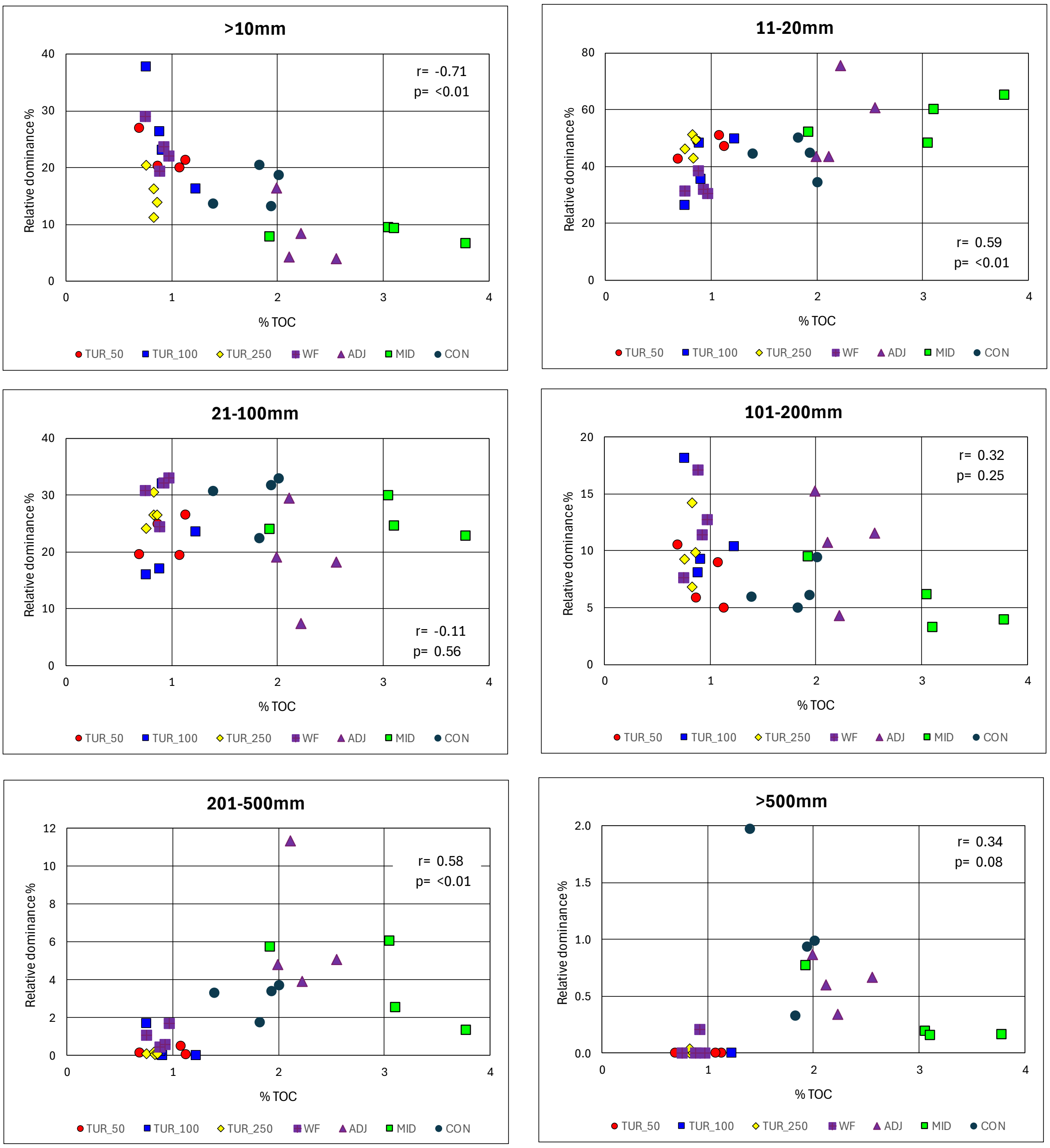

Figure 29. Mean relative dominance represented by each maximum size category by TOC and site grouping. (Correlation co-efficient and p-value for combined data indicated)

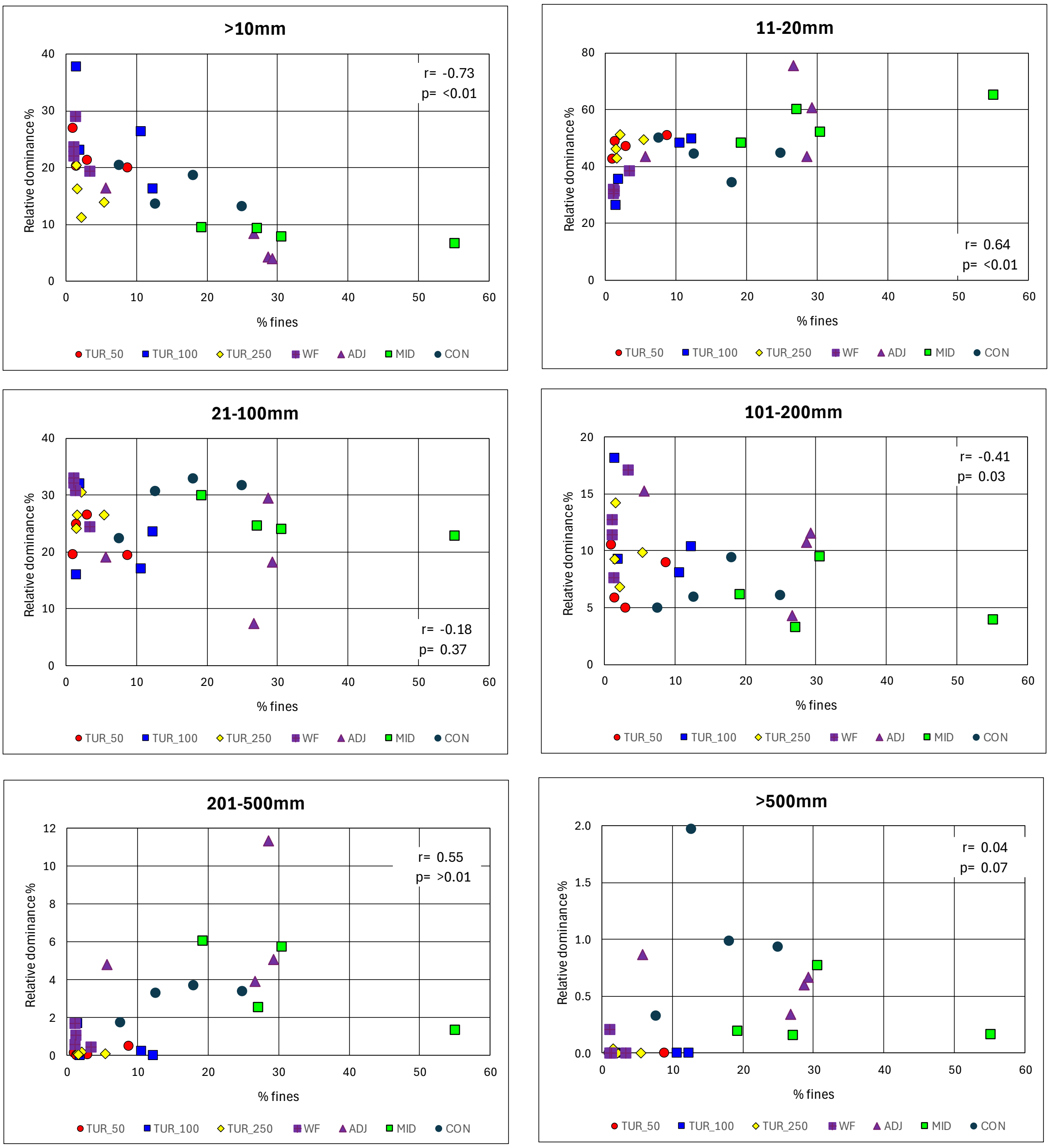

Figure 30.Mean relative dominance represented by each maximum size category by % fines and site grouping. (Correlation co-efficient and p-value for combined data indicated)

Results of PERMANOVA analysis indicate differences between relative dominance of size categories in relation to TOC ($p = 0.0001$), specifically between sites where TOC <1%. However, when the distribution of maximum size trait categories was looked at with TOC no significant relationships were observed in relation to year (0.561) and site group ($p = 0.927$). Similarly, significant differences were evident in relation to proportion of fines in sediment ($p = 0.0001$), specifically between <5% and where fines >10%, although when considered in conjunction with year and site grouping no significant differences were observed ($p = 0.916$). These patterns reflected in those for CON where there were no temporal differences for wither TOC ($p = 0.826$) or fines ($p = 0.773$).

Overall, while there may be some influence of the construction of the wind farm on the spatial and temporal patterns in TOC, this has no evident impact in relation the relative dominance of the maximum size categories across the study area with any spatial or temporal variability observed being considered to be driven by natural factors.

4.2.2 Lifespan

Generally, across the site groupings and all years taxa with lifespan of between 3 and 10 years represented the highest proportion of the communities recorded contributing on average 52.7% of all individuals across the study period (annual range = 43.5 % to 65.3%), while those with age span of 1 to 3 years represented on average 29.3% (annual range = 16.8% to 40.8%) and those with age span <1 represented on average 15.5% of individuals (annual range = 12.7% to 17.3%) (Table 16). Taxa of lifespan >10 years were the least common category across all sites. Those taxa with lifespan <1 year were more dominant at sites within the array representing 21.5% of all individuals across the study period, although no consistent temporal pattern was evident. This group was also important at CON where it represented 14.6% of individuals over the study period, although no consistent temporal pattern was evident and any variation is considered to be within the range of natural variability.

However, no clear temporal patterns were evident in the relative dominance represented by any of the lifespan trait categories and while some variation was evident, the magnitude of changes overall are relatively small and the distribution of maximum categories remain relatively consistent throughout the study period and across the majority of the study area being predominantly strong to very strong correlations evident between sites and years (Table 17).

Table 16. Relative dominance represented by each lifespan category by year and site grouping. Shading is proportional to the values from 0% (no shading) to 100% (full shading).

Trait	Category	TUR_50m				TUR_100m				TUR_250m			
		Pre	Post Yr 1	Post Yr 2	Post Yr 3	Pre	Post Yr 1	Post Yr 2	Post Yr 3	Pre	Post Yr 1	Post Yr 2	Post Yr 3
Lifespan (years)	<1	22.6	21.1	20.1	20.0	33.6	20.3	16.0	26.4	20.4	22.9	15.0	13.8
	1-3	3.1	37.1	45.8	38.7	6.8	23.3	32.5	20.0	2.5	22.6	40.7	16.0
	3-10	73.8	41.8	33.7	41.0	59.5	53.0	50.2	52.9	77.1	51.2	42.9	70.2
	>10	0.5	0.0	0.4	0.3	0.0	3.4	1.3	0.7	0.0	3.3	1.4	0.0

Trait	Category	WF				ADJ				MID			
		Pre	Post Yr 1	Post Yr 2	Post Yr 3	Pre	Post Yr 1	Post Yr 2	Post Yr 3	Pre	Post Yr 1	Post Yr 2	Post Yr 3
Lifespan	<1	19.5	21.3	23.2	28.2	3.2	7.6	2.5	7.7	3.0	0.8	0.7	6.5
	1-3	5.8	11.4	23.5	28.1	35.1	29.5	49.3	63.7	33.6	28.0	48.2	37.6
	3-10	74.7	65.9	51.1	43.4	57.2	60.6	45.3	27.9	59.0	59.5	42.4	48.9
	>10	0.0	1.5	2.2	0.3	4.4	2.5	2.8	0.7	4.4	11.8	8.7	7.0

Trait	Category	CON			
		Pre	Post Yr 1	Post Yr 2	Post Yr 3
Lifespan (years)	<1	11.5	16.6	11.6	18.6
	1-3	30.5	29.8	45.5	30.6
	3-10	55.6	49.3	39.1	49.7
	>10	2.4	4.3	3.8	1.2

Table 17. Pearson correlation coefficients for comparisons of distribution of lifespan categories by year and site grouping. Shading is proportional to the values from 0 (no shading) to 1 (full shading).

	TUR1_50 Pre	TUR1_50 Post yr 1	TUR1_50 Post yr 2	TUR1_50 Post yr 3	TUR2_100 Post yr 1	TUR2_100 Post yr 2	TUR2_250 Pre	TUR2_250 Pre	TUR2_250 Post yr 1	TUR2_250 Post yr 2	TUR1_250 Post yr 3	WF Pre	WF Post Yr 1	WF Post Yr 2	WF Post Yr 3	ADJ Pre	ADJ Post Yr 1	ADJ Post Yr 2	ADJ Post Yr 3	MID Pre	MID Post Yr 1	MID Post Yr 2	MID Post Yr 3	CON Pre	CON Post Yr 1	CON Post Yr 2	CON Post Yr 3
TUR1_50 Post yr 1	0.61																										
TUR1_50 Post yr 2	0.29	0.94																									
TUR1_50 Post yr 3	0.57	1.00	0.95																								
TUR2_100 Pre	0.96	0.62	0.31	0.57																							
TUR2_100 Post yr 1	0.92	0.86	0.63	0.84	0.89																						
TUR2_100 Post yr 2	0.78	0.96	0.81	0.95	0.73	0.96																					
TUR1_100 Post yr 3	0.94	0.83	0.58	0.79	0.95	0.98	0.90																				
TUR2_250 Pre	1.00	0.61	0.30	0.57	0.95	0.93	0.78	0.93																			
TUR2_250 Post yr 1	0.93	0.86	0.63	0.83	0.91	1.00	0.94	0.99	0.93																		
TUR2_250 Post yr 2	0.55	0.98	0.94	0.99	0.51	0.83	0.95	0.75	0.56	0.81																	
TUR1_250 Post yr 3	0.96	0.75	0.49	0.72	0.89	0.98	0.90	0.95	0.97	0.97	0.73																
WF Pre	1.00	0.65	0.34	0.60	0.95	0.94	0.81	0.94	1.00	0.94	0.60	0.98															
WF Post Yr 1	0.99	0.70	0.40	0.66	0.95	0.96	0.84	0.97	0.99	0.96	0.64	0.98	1.00														
WF Post Yr 2	0.91	0.88	0.65	0.85	0.91	0.99	0.95	0.99	0.91	1.00	0.82	0.96	0.93	0.95													
WF Post Yr 3	0.78	0.94	0.78	0.91	0.83	0.93	0.92	0.95	0.77	0.94	0.85	0.83	0.79	0.83	0.96												
ADJ Pre	0.72	0.86	0.73	0.86	0.59	0.89	0.95	0.78	0.74	0.85	0.91	0.88	0.76	0.78	0.85	0.76											
ADJ Post Yr 1	0.83	0.86	0.68	0.85	0.72	0.95	0.97	0.87	0.84	0.93	0.88	0.95	0.86	0.88	0.92	0.82	0.98										
ADJ Post Yr 2	0.40	0.87	0.89	0.90	0.29	0.70	0.87	0.57	0.42	0.66	0.95	0.63	0.46	0.50	0.67	0.66	0.91	0.84									
ADJ Post Yr 3	-0.02	0.75	0.92	0.79	-0.06	0.36	0.61	0.25	-0.01	0.33	0.82	0.22	0.04	0.09	0.35	0.47	0.62	0.50	0.88								
MID Pre	0.74	0.84	0.70	0.84	0.62	0.90	0.95	0.80	0.76	0.86	0.90	0.90	0.79	0.81	0.86	0.76	1.00	0.99	0.89	0.58							
MID Post Yr 1	0.77	0.72	0.54	0.71	0.60	0.86	0.88	0.75	0.79	0.82	0.79	0.90	0.81	0.81	0.81	0.65	0.97	0.97	0.81	0.44	0.98						
MID Post Yr 2	0.33	0.80	0.83	0.83	0.19	0.62	0.81	0.48	0.35	0.57	0.90	0.57	0.39	0.43	0.58	0.56	0.89	0.80	0.99	0.88	0.87	0.81					
MID Post Yr 3	0.63	0.88	0.80	0.89	0.50	0.84	0.94	0.73	0.64	0.80	0.94	0.81	0.68	0.70	0.81	0.74	0.99	0.96	0.96	0.72	0.98	0.94	0.94				
CON Pre	0.82	0.90	0.73	0.89	0.73	0.96	0.99	0.89	0.83	0.94	0.91	0.94	0.85	0.88	0.94	0.86	0.98	1.00	0.86	0.55	0.98	0.94	0.81	0.96			
CON Post Yr 1	0.82	0.93	0.77	0.92	0.76	0.97	1.00	0.92	0.83	0.96	0.93	0.93	0.85	0.88	0.96	0.91	0.96	0.98	0.84	0.56	0.96	0.90	0.78	0.94	0.99		
CON Post Yr 2	0.38	0.92	0.95	0.94	0.32	0.70	0.88	0.60	0.39	0.67	0.98	0.60	0.43	0.48	0.69	0.73	0.87	0.81	0.98	0.92	0.85	0.74	0.96	0.93	0.84	0.84	
CON Post Yr 3	0.81	0.95	0.80	0.94	0.77	0.97	1.00	0.93	0.81	0.96	0.93	0.91	0.84	0.87	0.97	0.95	0.93	0.96	0.83	0.57	0.93	0.86	0.76	0.91	0.98	1.00	0.84

There was a common similarity of close to 81% for all sites and years in the distribution of lifespan trait categories reflecting the patterns highlighted above (Figure 31). However, the MDS plot in Figure 32indicate that the patterns highlighted in the dendrogram are not strongly related to factors considered here, although some weak association with % TOC may be indicated specifically where proportion of fines is <1% as found at ADJ and CON.

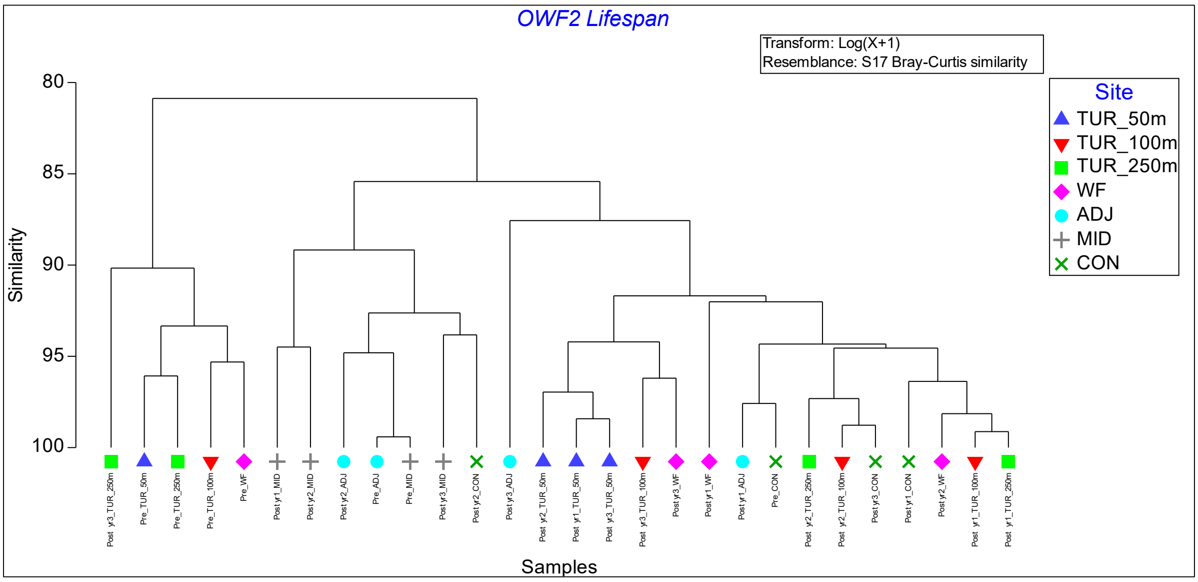

Figure 31. Dendrogram showing the relative similarities in OWF2 benthic communities in relation to four lifespan trait categories.

Figure 32. MDS showing the relative similarities in OWF1 benthic communities in relation to lifespan trait categories compared to factors: (a) Year; (b) Site Group; (c) % TOC; (d) % Fines.

Analysis of all years and sites by PERMANOVA indicated significant difference between years ($p = 0.007$), with differences identified between pre-construction and both post-construction year 2 ($p = 0.001$) and year 3 ($p = 0.011$). However, when considering site group and years together no significant differences were identified in distribution of lifespan categories across the study area ($p = 0.998$).

When the distribution of the lifespan categories were examined in relation to TOC only weak correlations were evident (Figure 33). Similarly, no significant correlations between distribution of lifespan categories and levels of fines in sediments were evident (Figure 34).

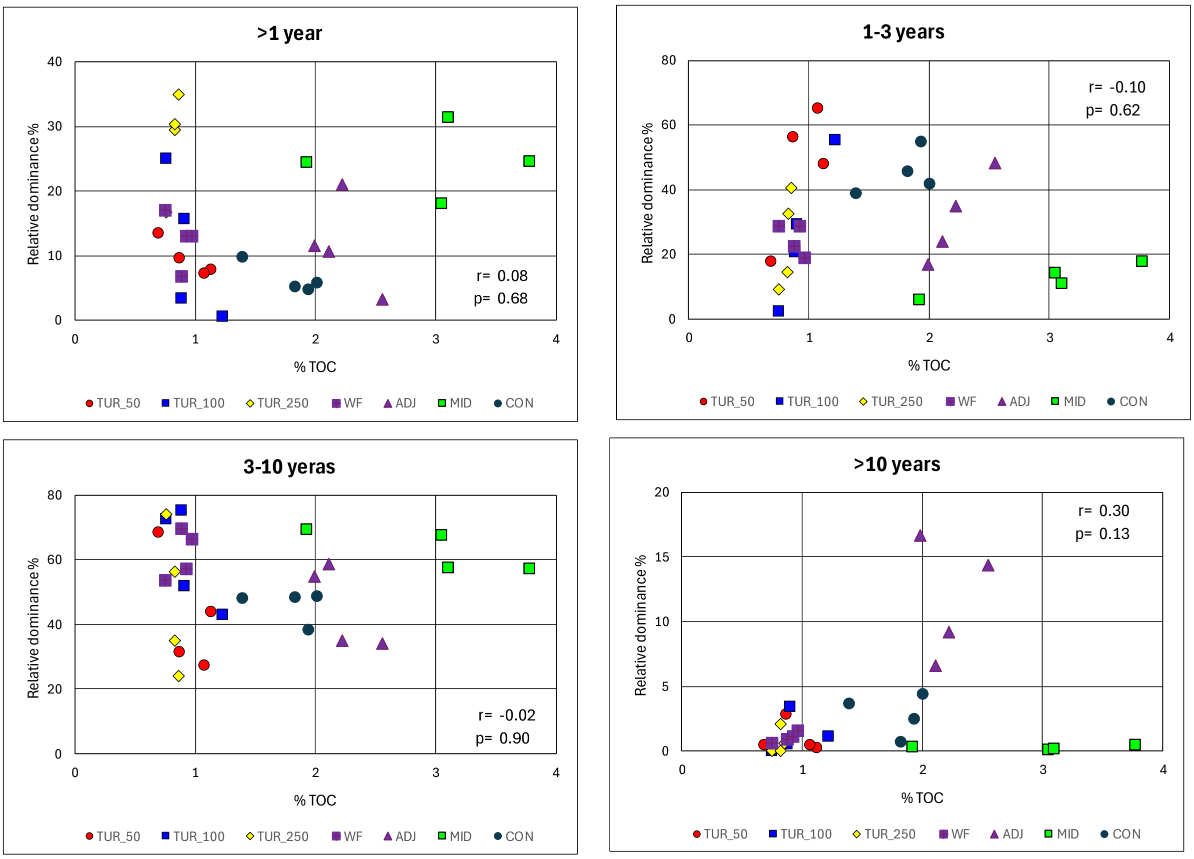

Figure 33. Mean relative dominance represented by each lifespan category by TOC and site grouping. (Correlation co-efficient and p-value for combined data indicated)

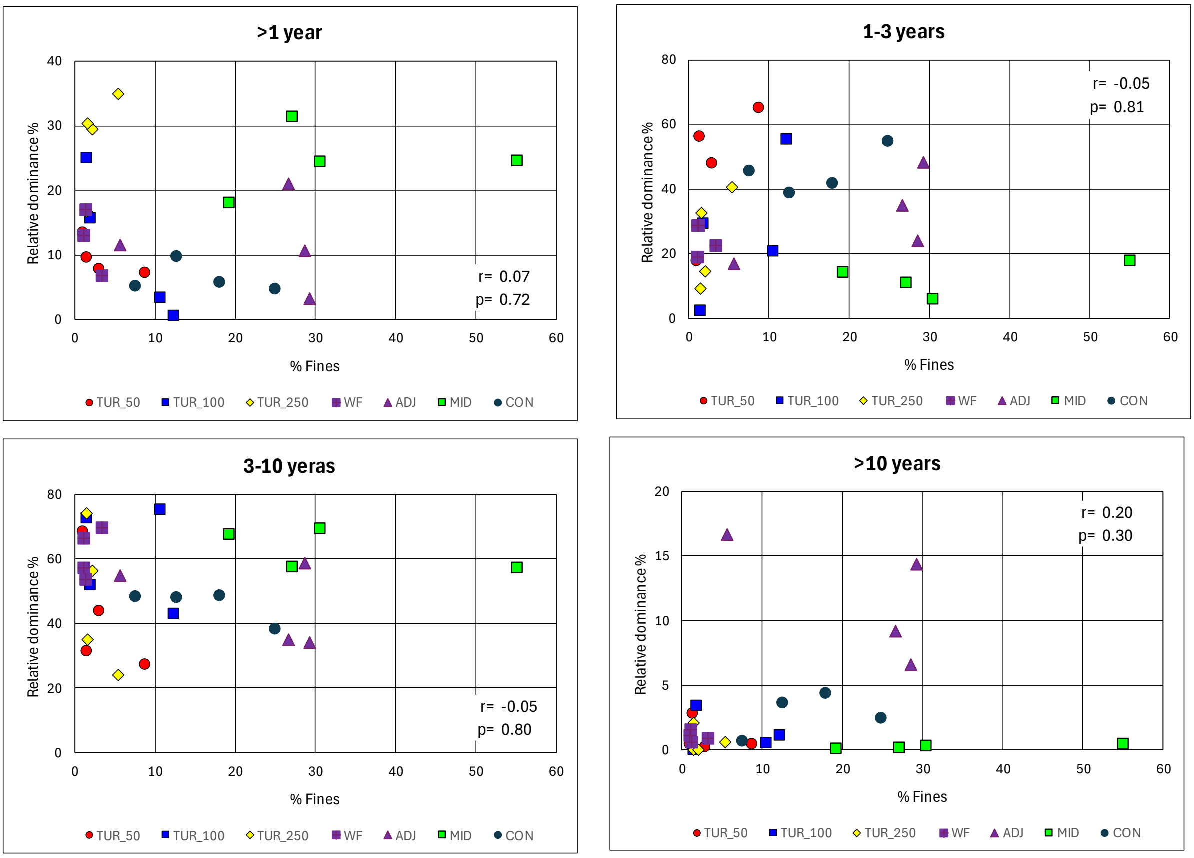

Figure 34. Mean relative dominance represented by each lifespan category by % fines and site grouping. (Correlation co-efficient and p-value for combined data indicated)

Where the proportion of fines was <25% taxa with lifespan of 3-10 years were the dominant group across the site groupings represented on average 58.0% of all individuals across the study period (annual range = 52.6% to 66.8%), while those with lifespan 1-3 years represented on average 27.8% (annual range = 22.3% to 35.7%). Where the proportion of fines was >25% the 1-3 lifespan category was the most common represented on average 56.0% of individuals (annual range = 50.1% to 69.9%), while the 3-10 year lifespan category represented on average 3.35% of individuals (annual range = 11.4% to 42.6%). The proportion of individuals in the <1 year lifespan was lower at within the higher proportion of fines categories with on average the highest proportion of this age group seen at <5% fines. While the highest individual proportion of individual with <1 year lifespan (30.1%) at 5-10% fines in post-construction year 3 no consistent temporal patterns were evident, and proportions of each lifespan category are considered to be within the likely range of natural variability in relation to the proportion of fines.

Results of PERMANOVA analysis indicate differences between relative dominance of lifespan categories in relation to TOC (p <0.001), specifically between sites where TOC <1% and where higher levels are recorded. However, when the distribution of lifespan trait categories was looked at with TOC, year and site group in conjunction no significant relationship was observed (p = 0.754). Similarly, significant differences were evident in relation to proportion of fines in sediment, primarily between TOC <5% and higher proportions, although when considered in conjunction with year and site grouping no significant differences were observed (p = 0.631).

Overall, while there may be some influence of the construction of the wind farm on the spatial and temporal patterns in TOC, this has no evident impact in relation the relative dominance of the lifespan categories across the study area with any spatial or temporal variability observed being considered to be driven by natural factors.

4.2.3 Living habitat

Generally, across the site groupings and all years free living taxa represented the highest proportion in the communities recorded contributing on average 63.1% of all individuals across the study period (annual range = 55.5 % to 75.2%), while burrow dwellers represented on average 26.0% (annual range = 15.3% to 33.2%) (Table 18). However, the proportion of free-living taxa fell over the study period which was mirrored by an increase in the proportion of burrow dwellers, a pattern particularly evident at sites within the array. However, the combined proportion of these two categories remained consistent over the study period ranging between 86.7% and 90.5%.

However, no clear temporal patterns were evident in the relative dominance represented by any of the lifespan trait categories and while some variation was evident, the magnitude of changes overall are relatively small and the distribution of maximum categories remain relatively consistent throughout the study period and across the majority of the study area being predominantly strong to very strong correlations evident between sites and years (Table 19).

Table 18. Relative dominance represented by each living habitat category by year and site grouping. Shading is proportional to the values from 0% (no shading) to 100% (full shading).

Trait	Category	TUR_50m				TUR_100m				TUR_250m			
		Pre	Post Yr 1	Post Yr 2	Post Yr 3	Pre	Post Yr 1	Post Yr 2	Post Yr 3	Pre	Post Yr 1	Post Yr 2	Post Yr 3
Living habitat	Tube dwelling	0.3	0.7	5.5	3.8	0.0	0.2	2.8	0.5	0.2	0.7	7.2	0.2
	Burrow dwelling	8.2	40.3	42.3	31.1	1.4	25.5	33.2	19.5	8.5	29.4	31.7	13.9
	Free-living	91.4	59.0	52.1	64.8	90.1	69.3	63.5	70.4	91.2	64.9	58.5	56.4
	Crevice/hole/under stones	0.1	0.0	0.0	0.0	0.2	1.7	0.0	0.0	0.0	1.7	0.0	0.0
	Epi/endo-biotic	0.1	0.0	0.0	0.1	4.2	0.0	0.0	0.0	0.0	0.0	0.5	0.0
	Attached to substratum	0.0	0.0	0.0	0.3	4.2	3.3	0.5	9.5	0.2	3.3	2.1	29.5

Trait	Category	WF				ADJ				MID			
		Pre	Post Yr 1	Post Yr 2	Post Yr 3	Pre	Post Yr 1	Post Yr 2	Post Yr 3	Pre	Post Yr 1	Post Yr 2	Post Yr 3
Living habitat	Tube dwelling	0.0	1.7	1.3	1.2	14.1	7.3	7.3	4.2	8.9	12.4	12.0	4.3
	Burrow dwelling	1.5	11.6	10.5	11.0	30.2	29.7	42.7	59.9	35.9	31.4	46.1	41.9
	Free-living	98.3	86.7	87.6	87.3	51.8	59.3	47.2	34.7	52.1	52.0	37.6	34.5
	Crevice/hole/under stones	0.1	0.0	0.0	0.2	0.3	0.8	0.4	0.5	0.9	0.9	0.6	0.3
	Epi/endo-biotic	0.1	0.0	0.0	0.2	0.0	0.4	0.4	0.2	0.6	0.3	0.7	0.7
	Attached to substratum	0.0	0.0	0.7	0.2	3.6	2.5	2.0	0.4	1.6	3.0	3.1	18.3

Trait	Category	CON			
		Pre	Post Yr 1	Post Yr 2	Post Yr 3
Living habitat	Tube dwelling	14.4	15.5	22.9	15.7
	Burrow dwelling	21.7	14.8	26.0	27.9
	Free-living	51.7	58.9	42.0	53.4
	Crevice/hole/under stones	2.3	2.3	1.6	0.6
	Epi/endo-biotic	4.3	4.0	4.5	1.0
	Attached to substratum	5.5	4.4	3.0	1.3

Table 19. Pearson correlation coefficients for comparisons of distribution of living habitat categories by year and site grouping. Shading is proportional to the values from 0 (no shading) to 1 (full shading).

	TUR1_50 Pre	TUR1_50 Post yr 1	TUR1_50 Post yr 2	TUR1_50 Post yr 3	TUR2_100 Post yr 1	TUR2_100 Post yr 2	TUR2_250 Pre	TUR2_250 Pre	TUR2_250 Post yr 1	TUR2_250 Post yr 2	TUR1_250 Post yr 3	WF Pre	WF Post Yr 1	WF Post Yr 2	WF Post Yr 3	ADJ Pre	ADJ Post Yr 1	ADJ Post Yr 2	ADJ Post Yr 3	MID Pre	MID Post Yr 1	MID Post Yr 2	MID Post Yr 3	CON Pre	CON Post Yr 1	CON Post Yr 2	CON Post Yr 3
TUR1_50 Post yr 1	0.84																										
TUR1_50 Post yr 2	0.78	0.99																									
TUR1_50 Post yr 3	0.93	0.98	0.96																								
TUR2_100 Pre	0.99	0.78	0.71	0.88																							
TUR2_100 Post yr 1	0.96	0.95	0.92	0.99	0.93																						
TUR2_100 Post yr 2	0.91	0.99	0.97	1.00	0.86	0.99																					
TUR1_100 Post yr 3	0.98	0.91	0.86	0.96	0.96	0.99	0.96																				
TUR2_250 Pre	1.00	0.84	0.78	0.93	0.99	0.96	0.91	0.98																			
TUR2_250 Post yr 1	0.94	0.98	0.94	1.00	0.90	1.00	1.00	0.98	0.94																		
TUR2_250 Post yr 2	0.90	0.99	0.97	1.00	0.86	0.98	1.00	0.95	0.90	0.99																	
TUR1_250 Post yr 3	0.86	0.75	0.68	0.81	0.87	0.86	0.80	0.92	0.86	0.84	0.79																
WF Pre	1.00	0.80	0.73	0.90	1.00	0.94	0.88	0.96	1.00	0.91	0.87	0.86															
WF Post Yr 1	1.00	0.86	0.81	0.94	0.99	0.97	0.93	0.98	1.00	0.95	0.92	0.86	0.99														
WF Post Yr 2	1.00	0.86	0.80	0.94	0.99	0.97	0.92	0.98	1.00	0.95	0.92	0.87	0.99	1.00													
WF Post Yr 3	1.00	0.86	0.80	0.94	0.99	0.97	0.92	0.98	1.00	0.95	0.92	0.86	0.99	1.00	1.00												
ADJ Pre	0.87	0.96	0.96	0.98	0.82	0.95	0.98	0.92	0.87	0.96	0.99	0.76	0.84	0.89	0.89	0.89											
ADJ Post Yr 1	0.92	0.98	0.96	1.00	0.88	0.99	1.00	0.96	0.92	0.99	1.00	0.81	0.89	0.94	0.93	0.93	0.99										
ADJ Post Yr 2	0.74	0.98	1.00	0.94	0.67	0.89	0.95	0.83	0.74	0.92	0.96	0.66	0.69	0.77	0.76	0.76	0.95	0.94									
ADJ Post Yr 3	0.43	0.85	0.90	0.74	0.34	0.66	0.77	0.57	0.44	0.72	0.77	0.40	0.37	0.47	0.46	0.46	0.77	0.74	0.92								
MID Pre	0.84	0.99	0.99	0.98	0.78	0.95	0.99	0.90	0.84	0.97	0.99	0.73	0.80	0.86	0.85	0.86	0.99	0.98	0.98	0.85							
MID Post Yr 1	0.87	0.98	0.97	0.98	0.82	0.95	0.98	0.92	0.87	0.97	0.99	0.76	0.84	0.89	0.89	0.89	1.00	0.99	0.96	0.79	0.99						
MID Post Yr 2	0.58	0.92	0.96	0.84	0.50	0.77	0.86	0.69	0.58	0.82	0.87	0.52	0.52	0.62	0.60	0.61	0.89	0.85	0.98	0.97	0.93	0.90					
MID Post Yr 3	0.55	0.87	0.89	0.79	0.49	0.74	0.81	0.71	0.56	0.79	0.82	0.68	0.49	0.58	0.57	0.58	0.81	0.80	0.91	0.91	0.86	0.82	0.92				
CON Pre	0.95	0.93	0.91	0.98	0.91	0.97	0.97	0.96	0.95	0.97	0.98	0.81	0.92	0.96	0.95	0.95	0.98	0.98	0.88	0.64	0.95	0.98	0.78	0.71			
CON Post Yr 1	0.97	0.86	0.82	0.94	0.96	0.95	0.92	0.96	0.97	0.93	0.93	0.82	0.97	0.98	0.98	0.98	0.93	0.94	0.79	0.50	0.88	0.92	0.66	0.59	0.98		
CON Post Yr 2	0.80	0.88	0.90	0.90	0.74	0.86	0.90	0.82	0.80	0.87	0.92	0.62	0.77	0.82	0.81	0.81	0.97	0.92	0.89	0.71	0.93	0.96	0.85	0.70	0.95	0.90	
CON Post Yr 3	0.89	0.95	0.95	0.98	0.84	0.95	0.97	0.92	0.89	0.96	0.98	0.74	0.86	0.91	0.90	0.91	1.00	0.98	0.93	0.73	0.98	0.99	0.86	0.76	0.99	0.95	0.97

There was a common similarity of less than 65% for all sites and years in the distribution of living habitat trait categories, although below this most sites show a common similarity of 78%, the exceptions being pre-construction samples collected at two sites within the wind farm (TUR_100 and WF). Generally, only small differences were seen between years at most sites, (Figure 35). The MDS plots given in Figure 36 indicate that the patterns here show little association with the factors considered here and highlight the similarity between years at most sites.

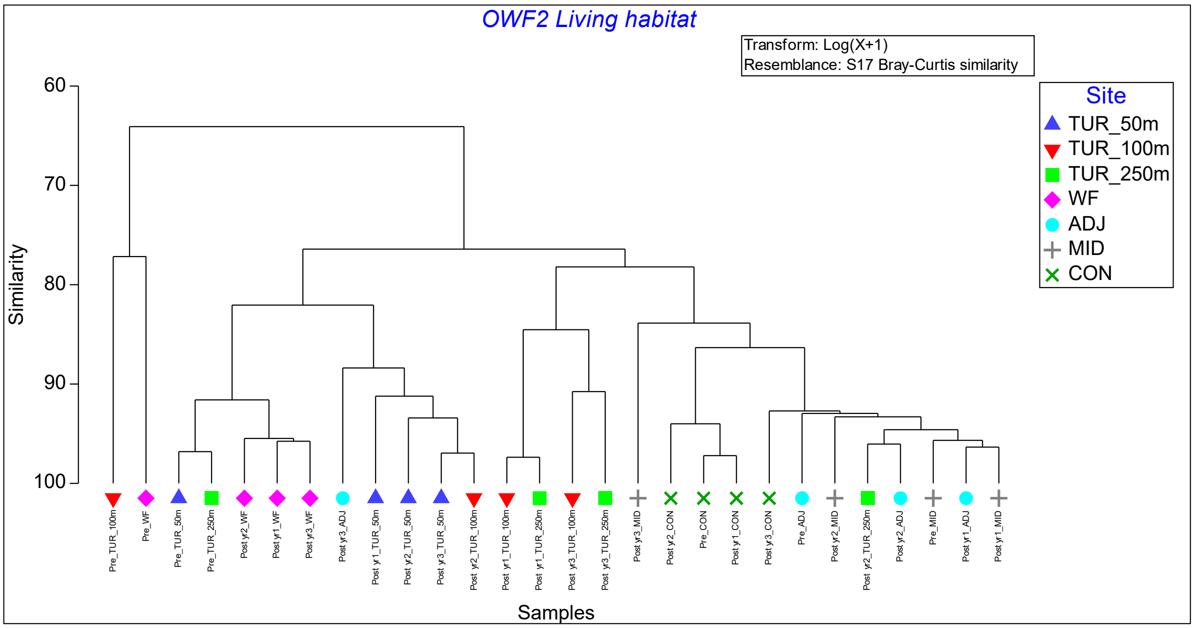

Figure 35. Dendrogram showing the relative similarities in OWF1 benthic communities in relation to six living habitat trait categories.

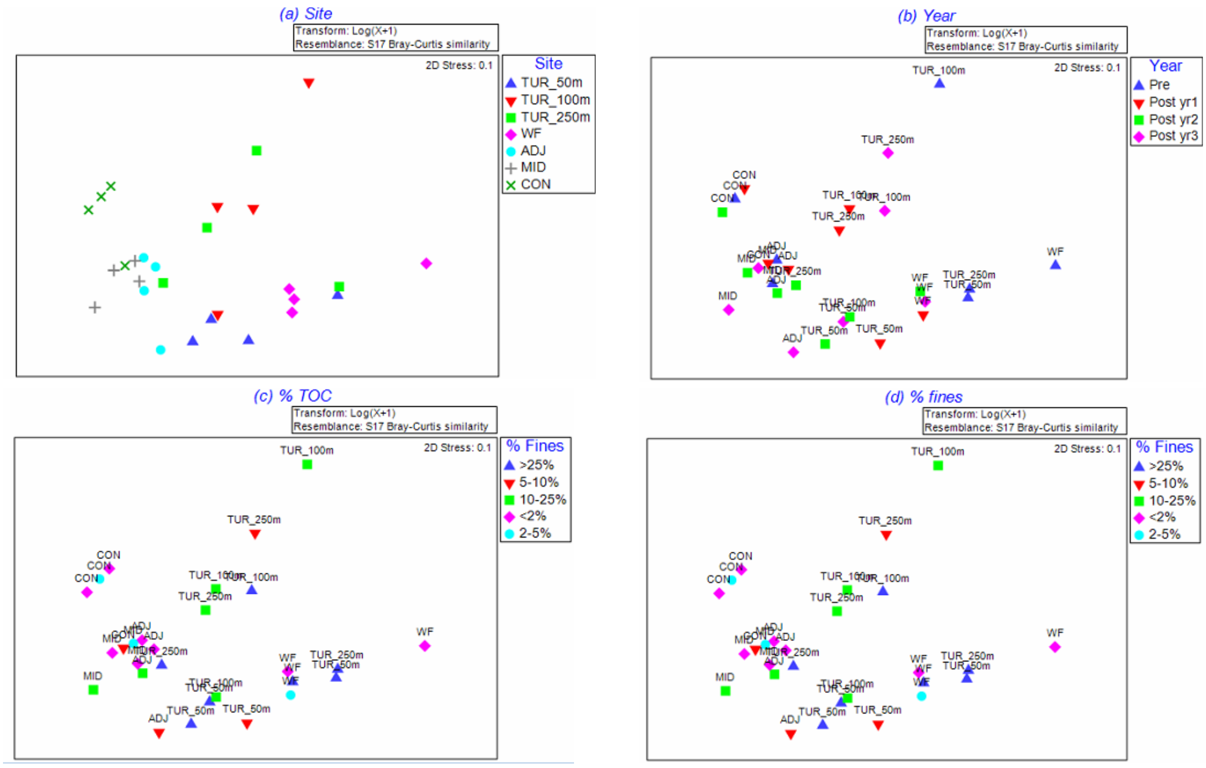

Figure 36. MDS showing the relative similarities in OWF1 benthic communities in relation to six living habitat trait categories compared to factors: (a) Year; (b) Site Group; (c) % TOC; (d) % Fines.

Analysis of all years and sites by PERMANOVA indicated no significant difference between years (p = 0.110). However, differences between site grouping were evident (p = 0.0001), although, when considering site group and years together no significant differences were identified in distribution of living habitat categories across the study area (p = 0.991).

When the distribution of the living habitat categories was examined in relation to TOC only weak correlations were evident (Figure 37). Similarly, no significant correlations between distribution of lifespan categories and levels of fines in sediments were evident (Figure 38).

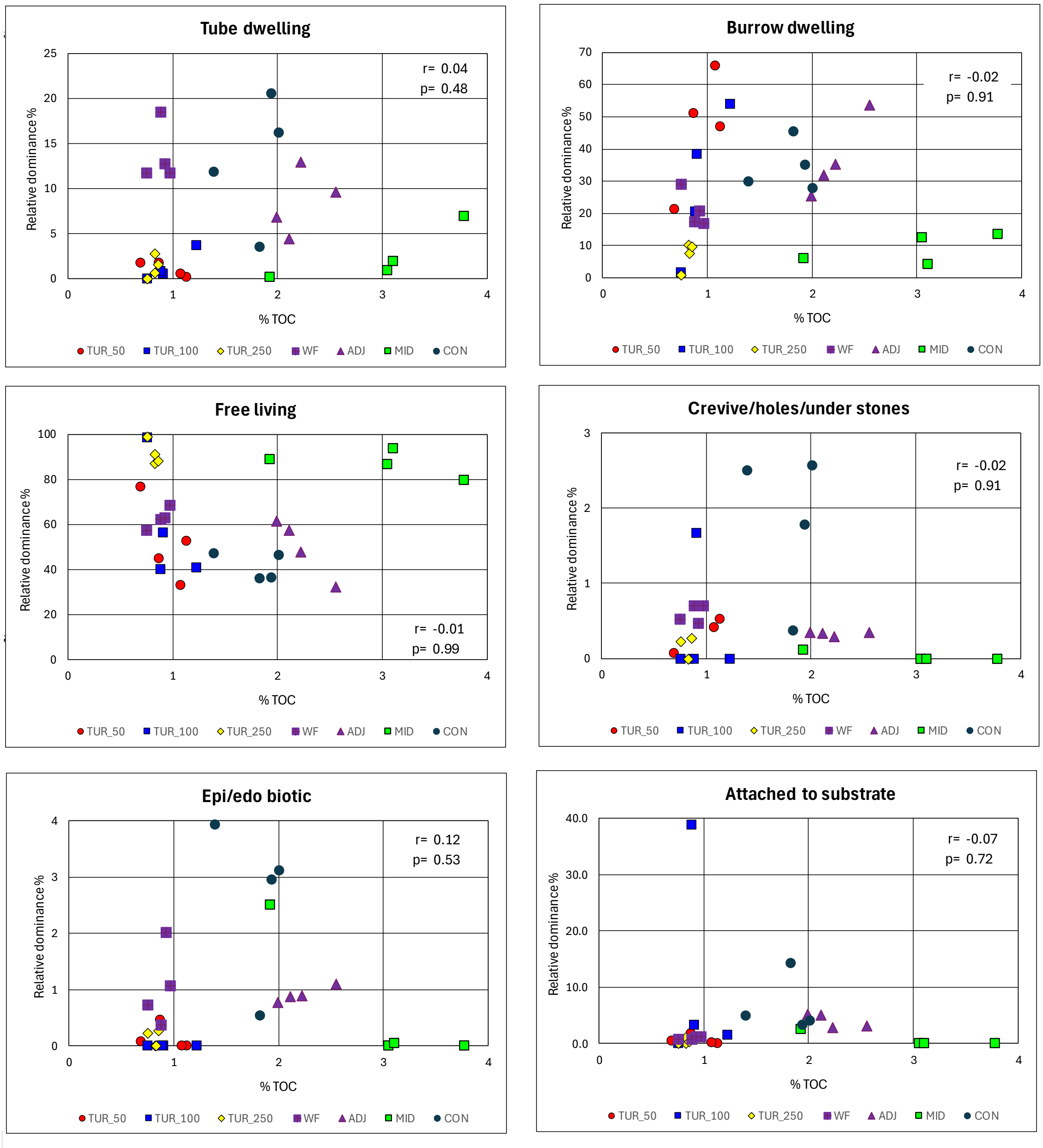

Figure 37. Mean relative dominance represented by each living habitat category by TOC and site grouping. (Correlation co-efficient and p-value for combined data indicated)

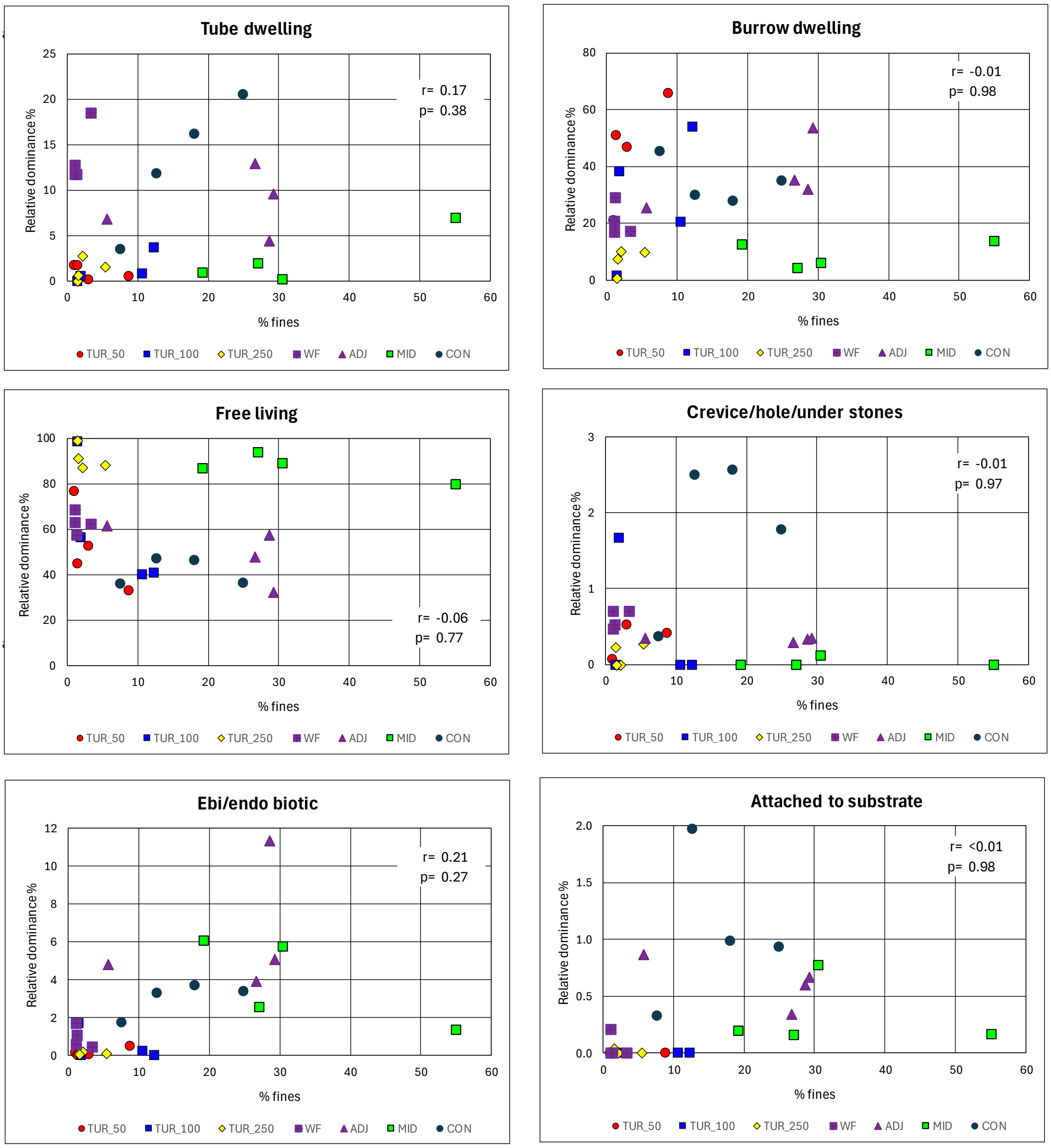

Figure 38. Mean relative dominance represented by each living habitat category by % fines and site grouping. (Correlation co-efficient and p-value for combined data indicated)

Results of PERMANOVA analysis indicate differences between relative dominance of living habitat categories in relation to TOC ($p < 0.001$), specifically between sites where TOC <1% and where higher levels are recorded. However, when the distribution of living habitat trait categories was looked at with TOC in conjunction with year and site group no significant relationship was observed ($p = 0.849$). Similarly, significant differences were evident in relation to proportion of fines in sediment, although no consistent pattern was evident although when considered in conjunction with year and site grouping no significant differences were observed ($p = 0.849$).

Overall, while there may be some influence of the construction of the wind farm on the spatial and temporal patterns in TOC, this has no evident impact in relation to the relative dominance of the living habitat categories across the study area with any spatial or temporal variability observed being considered to be driven by natural factors.

4.2.4 Sediment position

Generally, across the site groupings and all years, mid-depth dwelling taxa represented the highest proportion in the communities recorded contributing on average 52.7% of all individuals across the study period (annual range = 43.5 % to 65.3%). While there was some variability in the relative dominance of taxa in this category, the highest levels were consistently seen in pre-construction survey at all sites, although no subsequent consistent patterns were evident (Table 20). Shallow infauna represented on average 29.3% of individuals across the study period (annual range = 16.8% to 40.8%). However, this category was generally pre-construction at sites within the wind farm area which increased appreciably in post-construction surveys with less variability evident at sites outwith the array. Surface dwelling taxa also represented greater relative dominance at sites within the wind farm, although numbers remained relatively stable at all sites throughout the study period.

However, no clear temporal patterns were evident in the relative dominance represented by any of the sediment position trait categories and while some variation was evident, the magnitude of changes overall are relatively small and the distribution of maximum categories remain relatively consistent throughout the study period and across the majority of the study area being predominantly strong to very strong correlations evident between sites and years (

Table 21). However, slightly lower correlation was evident between one outlying site (TUR_50M_250 Post yr 3 located in array area 250m from turbine) and other sites, although even here the values for r indicated strong similarities existed between this site and all others.

Table 20. Relative dominance represented by each sediment position category by year and site grouping. Shading is proportional to the values from 0% (no shading) to 100% (full shading).

Trait	Category	TUR_50m				TUR_100m				TUR_250m			
		Pre	Post Yr 1	Post Yr 2	Post Yr 3	Pre	Post Yr 1	Post Yr 2	Post Yr 3	Pre	Post Yr 1	Post Yr 2	Post Yr 3
Sediment position	Surface	22.6	21.1	20.1	20.0	33.6	20.3	16.0	26.4	20.4	22.9	15.0	13.8
	Shallow infauna	3.1	37.1	45.8	38.7	6.8	23.3	32.5	20.0	2.5	22.6	40.7	16.0
	Mid-depth infauna	73.8	41.8	33.7	41.0	59.5	53.0	50.2	52.9	77.1	51.2	42.9	70.2
	Deep infauna	0.5	0.0	0.4	0.3	0.0	3.4	1.3	0.7	0.0	3.3	1.4	0.0

Trait	Category	WF				ADJ				MID			
		Pre	Post Yr 1	Post Yr 2	Post Yr 3	Pre	Post Yr 1	Post Yr 2	Post Yr 3	Pre	Post Yr 1	Post Yr 2	Post Yr 3
Sediment position	Surface	19.5	21.3	23.2	28.2	3.2	7.6	2.5	7.7	3.0	0.8	0.7	6.5
	Shallow infauna	5.8	11.4	23.5	28.1	35.1	29.5	49.3	63.7	33.6	28.0	48.2	37.6
	Mid-depth infauna	74.7	65.9	51.1	43.4	57.2	60.6	45.3	27.9	59.0	59.5	42.4	48.9
	Deep infauna	0.0	1.5	2.2	0.3	4.4	2.5	2.8	0.7	4.4	11.8	8.7	7.0

Trait	Category	CON			
		Pre	Post Yr 1	Post Yr 2	Post Yr 3
Sediment position	Surface	11.5	16.6	11.6	18.6
	Shallow infauna	30.5	29.8	45.5	30.6
	Mid-depth infauna	55.6	49.3	39.1	49.7
	Deep infauna	2.4	4.3	3.8	1.2

Table 21. Pearson correlation coefficients for comparisons of distribution of sediment position categories by year and site grouping. Shading is proportional to the values from 0 (no shading) to 1 (full shading).

	TUR1_50 Pre	TUR1_50 Post yr 1	TUR1_50 Post yr 2	TUR1_50 Post yr 3	TUR2_100 Post yr 1	TUR2_100 Post yr 2	TUR2_250 Pre	TUR2_250 Pre	TUR2_250 Post yr 1	TUR2_250 Post yr 2	TUR1_250 Post yr 3
TUR1_50 Post yr 1	1.00										
TUR1_50 Post yr 2	1.00	1.00									
TUR1_50 Post yr 3	1.00	1.00	1.00								
TUR2_100 Pre	0.91	0.91	0.91	0.89							
TUR2_100 Post yr 1	0.99	0.99	0.99	0.98	0.95						
TUR2_100 Post yr 2	1.00	1.00	1.00	1.00	0.89	0.98					
TUR1_100 Post yr 3	0.96	0.97	0.97	0.95	0.98	0.99	0.95				
TUR2_250 Pre	1.00	1.00	1.00	1.00	0.90	0.99	1.00	0.96			
TUR2_250 Post yr 1	0.99	0.99	0.99	0.98	0.95	1.00	0.98	0.99	0.99		
TUR2_250 Post yr 2	1.00	1.00	1.00	1.00	0.90	0.99	1.00	0.96	1.00	0.99	
TUR1_250 Post yr 3	0.76	0.77	0.77	0.74	0.91	0.84	0.74	0.91	0.75	0.85	0.75
WF Pre	0.99	0.99	0.98	0.99	0.84	0.95	0.99	0.91	0.99	0.95	0.99
WF Post Yr 1	0.99	0.99	0.99	1.00	0.87	0.97	1.00	0.93	0.99	0.97	0.99
WF Post Yr 2	0.99	0.99	0.98	0.99	0.91	0.97	0.99	0.94	0.99	0.97	0.99
WF Post Yr 3	0.98	0.98	0.97	0.97	0.93	0.97	0.98	0.95	0.98	0.97	0.97
ADJ Pre	0.98	0.98	0.99	0.98	0.93	0.99	0.97	0.99	0.98	1.00	0.98
ADJ Post Yr 1	0.99	1.00	1.00	0.99	0.91	0.99	0.99	0.97	1.00	1.00	1.00
ADJ Post Yr 2	1.00	1.00	1.00	1.00	0.88	0.98	1.00	0.95	1.00	0.98	1.00
ADJ Post Yr 3	0.99	1.00	1.00	1.00	0.90	0.99	0.99	0.96	1.00	0.99	1.00
MID Pre	0.99	0.99	1.00	0.99	0.92	1.00	0.99	0.98	0.99	1.00	0.99
MID Post Yr 1	1.00	1.00	1.00	0.99	0.92	1.00	0.99	0.97	1.00	1.00	1.00
MID Post Yr 2	0.99	0.99	0.99	0.99	0.93	1.00	0.99	0.98	0.99	1.00	0.99
MID Post Yr 3	0.93	0.94	0.94	0.92	0.96	0.97	0.92	0.99	0.93	0.98	0.93
CON Pre	0.92	0.93	0.93	0.91	0.97	0.97	0.91	0.99	0.92	0.97	0.92
CON Post Yr 1	0.93	0.94	0.94	0.92	0.98	0.98	0.92	1.00	0.93	0.98	0.93
CON Post Yr 2	0.96	0.96	0.96	0.95	0.97	0.99	0.95	1.00	0.96	0.99	0.96
CON Post Yr 3	0.97	0.97	0.97	0.96	0.97	0.99	0.96	1.00	0.97	0.99	0.97

	WF Pre	WF Post Yr 1	WF Post Yr 2	WF Post Yr 3	ADJ Pre	ADJ Post Yr 1	ADJ Post Yr 2	ADJ Post Yr 3	MID Pre	MID Post Yr 1	MID Post Yr 2	MID Post Yr 3	CON Pre	CON Post Yr 1	CON Post Yr 2	CON Post Yr 3
WF Pre	0.65															
WF Post Yr 1	0.68	1.00														
WF Post Yr 2	0.71	0.99	0.99													
WF Post Yr 3	0.73	0.97	0.98	1.00												
ADJ Pre	0.86	0.94	0.95	0.94	0.94											
ADJ Post Yr 1	0.80	0.97	0.98	0.97	0.96	0.99										
ADJ Post Yr 2	0.75	0.99	0.99	0.98	0.96	0.98	1.00									
ADJ Post Yr 3	0.78	0.98	0.98	0.97	0.96	0.99	1.00	1.00								
MID Pre	0.82	0.96	0.97	0.96	0.96	1.00	1.00	0.99	1.00							
MID Post Yr 1	0.80	0.97	0.98	0.98	0.97	0.99	1.00	1.00	1.00	1.00						
MID Post Yr 2	0.84	0.96	0.97	0.96	0.96	1.00	1.00	0.99	1.00	1.00	1.00					
MID Post Yr 3	0.94	0.87	0.89	0.90	0.90	0.98	0.96	0.93	0.95	0.96	0.96	0.97				
CON Pre	0.95	0.85	0.87	0.88	0.89	0.97	0.95	0.91	0.93	0.95	0.94	0.96	1.00			
CON Post Yr 1	0.94	0.87	0.89	0.91	0.92	0.97	0.95	0.92	0.94	0.96	0.95	0.97	1.00	1.00		
CON Post Yr 2	0.91	0.90	0.92	0.93	0.94	0.99	0.97	0.95	0.96	0.98	0.97	0.98	1.00	0.99	1.00	
CON Post Yr 3	0.90	0.92	0.94	0.94	0.95	0.99	0.98	0.96	0.97	0.99	0.98	0.99	0.99	0.99	0.99	1.00

The above correlation pattern is highlighted by cluster analysis which indicates that except TUR_50M_250 Post yr 3 there was a common similarity of over 60% for all sites and years in the distribution of sediment position trait categories with three groups with close to 80% within group similarity (Figure 39). When compared with various factors the MDS plots given in Figure 22 indicate that the patterns here show some association with the proportion of TOC, although no clear temporal patterns are evident (Figure 40).

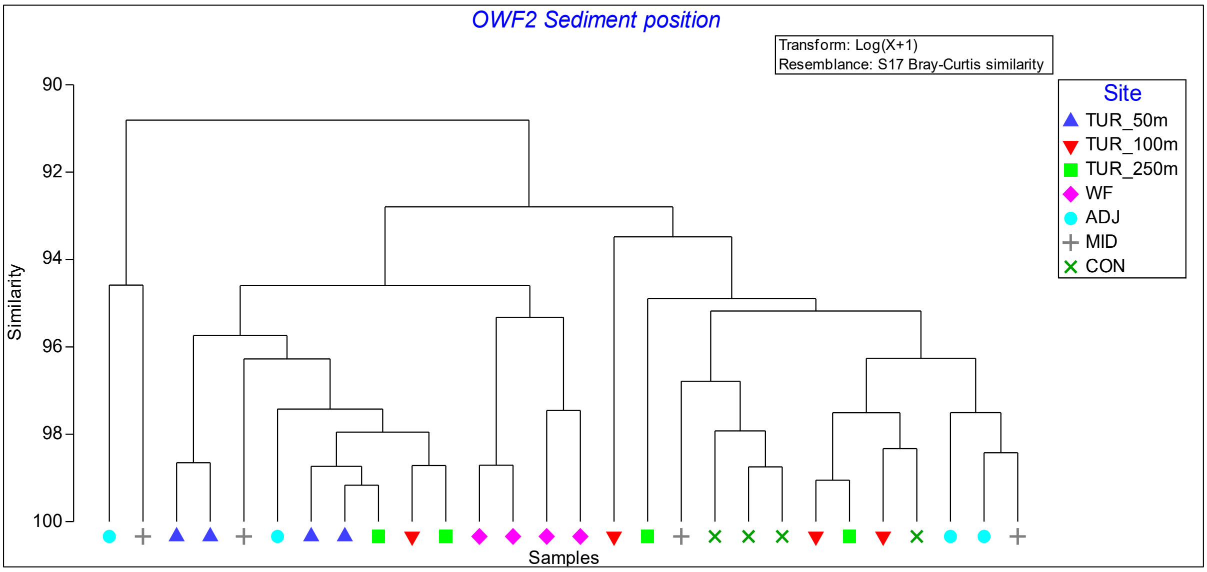

Figure 39. Dendrogram showing the relative similarities in OWF1 benthic communities in relation to four sediment depth trait categories.

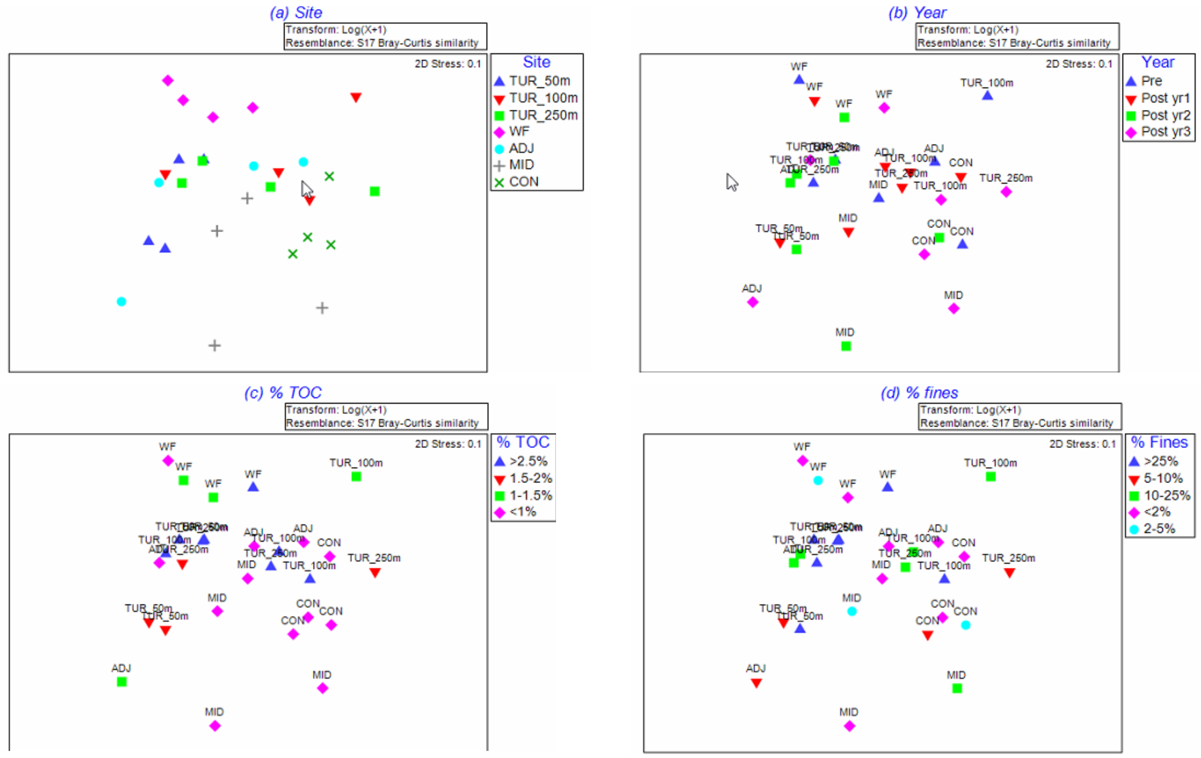

Figure 40. MDS showing the relative similarities in OWF1 benthic communities in relation to sediment depth trait categories compared to factors: (a) Year; (b) Site Group; (c) % TOC; (d) % Fines.

Analysis of all years and sites by PERMANOVA indicated no significant difference between years ($p = 0.393$). However, when considering site group alone differences were indicated ($p = 0.038$), although when considering site group and years together no significant differences were identified in distribution of lifespan categories across the study area ($p = 0.995$).

When the distribution of the sediment position categories was examined in relation to TOC only weak correlations were evident (Figure 41). Similarly, no significant correlations between distribution of sediment position categories and levels of fines in sediments were evident (Figure 42).

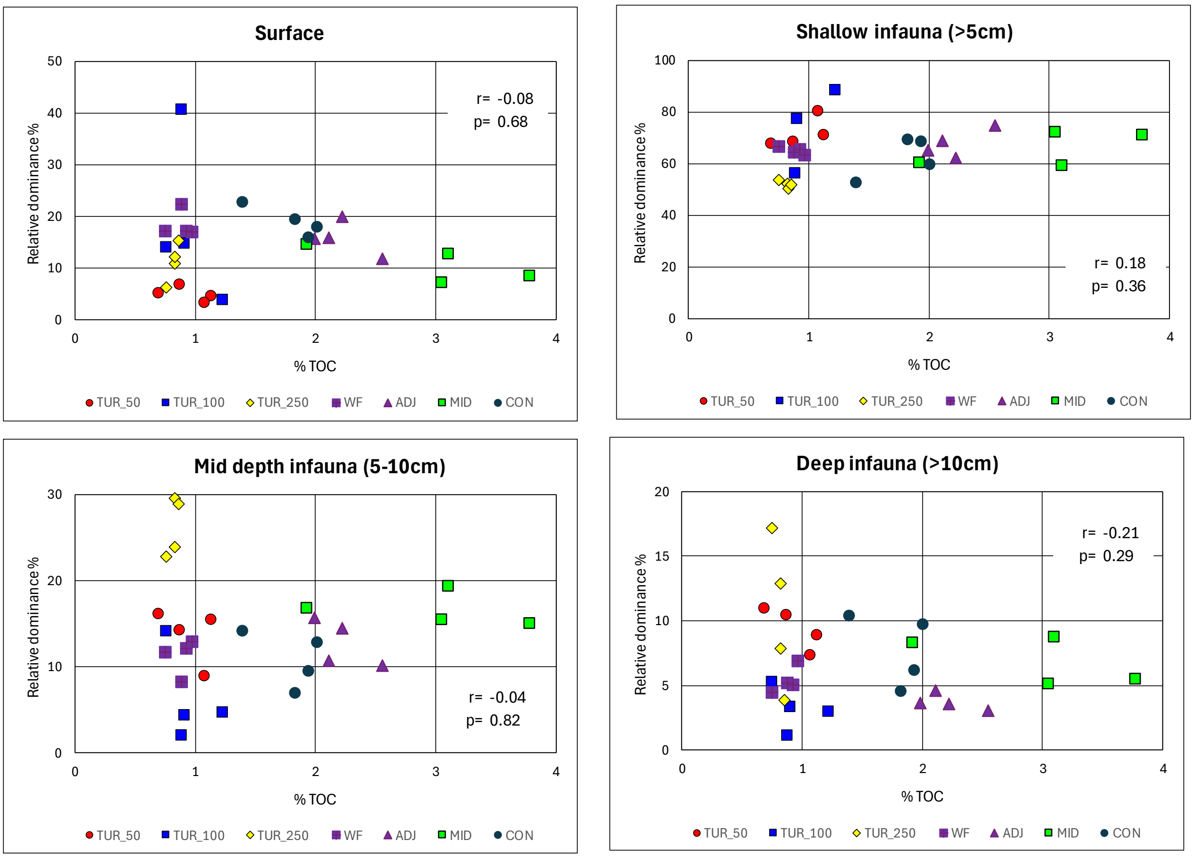

Figure 41. Mean relative dominance represented by each sediment position category by TOC and site grouping. (Correlation co-efficient and p-value for combined data indicated)

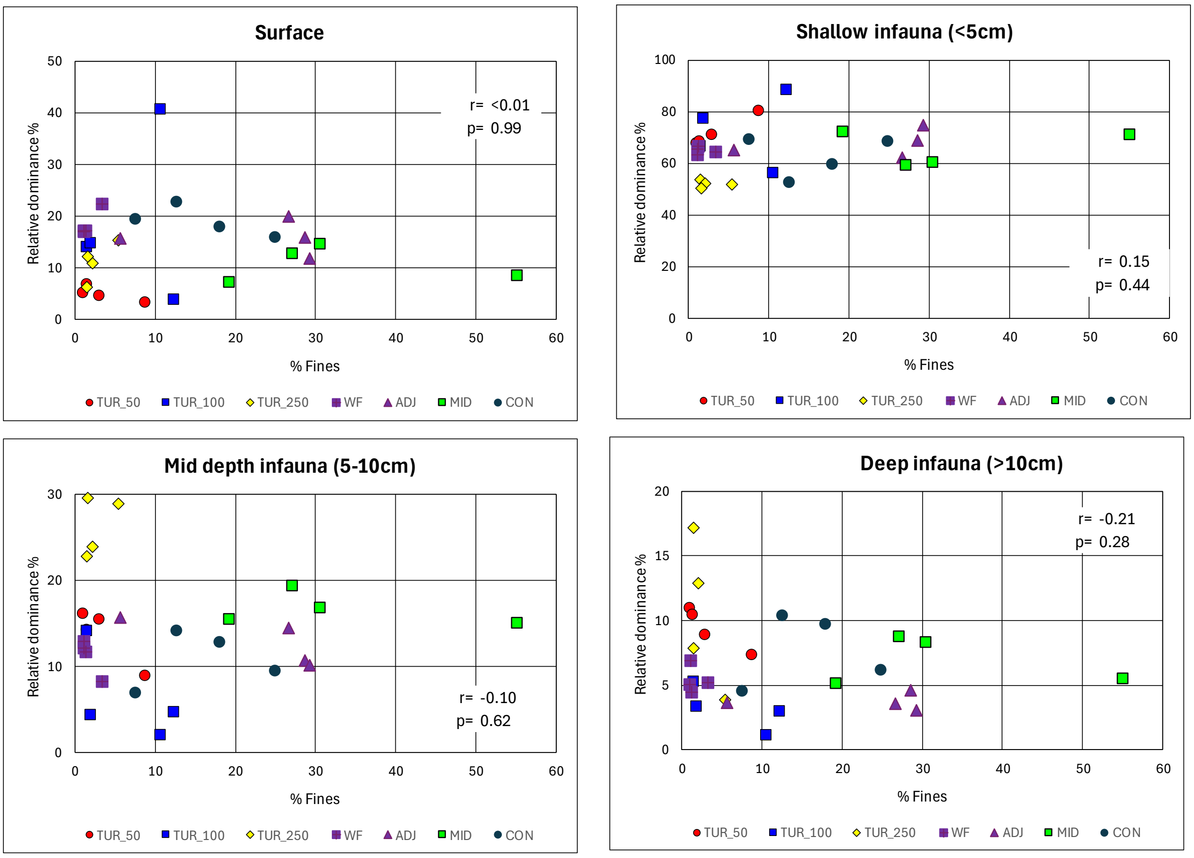

Figure 42. Mean relative dominance represented by each sediment position category by % fines and site grouping. (Correlation co-efficient and p-value for combined data indicated)

Results of PERMANOVA analysis indicate differences between relative dominance of sediment position categories in relation to TOC ($p < 0.001$), although no consistent pattern was evident. However, when the distribution of sediment position trait categories was looked at with TOC in conjunction with year and site group no significant relationship was observed ($p = 0.985$). No significant differences in in relation to proportions of fines and the relative dominance of taxa assigned to sediment position categorises were evident ($p = 0.121$).

Overall, while there may be some influence of the construction of the wind farm on the spatial and temporal patterns in TOC, this has no evident impact in relation to the relative dominance of the sediment position categories across the study area with any spatial or temporal variability observed being considered to be driven by natural factors.

4.2.5 Feeding mode

Generally, across the site groupings and all years, surface deposit and sub-surface deposit feeders represented the highest relative dominance in relation to feeding mode trait categories. Surface deposit feeders contributed on average 32.67% of all individuals across the study period (annual range = 31.9% to 33.2%), while sub-surface deposit feeders represented an average of 31.2% of all individuals across the study period (annual range = 29.1 % to 33.0%). The low temporal variability observed for these two categories was also seen in spatial patterns with little difference observed in the relative dominance of these two categories across the study area (Table 22). Similarly, the relative dominance of scavengers and predators remained relatively stable across the study area.

However, no clear temporal patterns were evident in the relative dominance represented by any of the feeding mode trait categories and while some variation was evident, the magnitude of changes overall

are relatively small and the distribution of maximum categories remain relatively consistent throughout the study period and across the majority of the study area being predominantly strong to very strong correlations evident between sites and years (

Table 23). However, some slightly weaker correlations were evident, although even here the values for r indicated moderate to strong similarities existed even where these weaker correlations were recorded.

Table 22. Relative dominance represented by each feeding category by year and site grouping. Shading is proportional to the values from 0% (no shading) to 100% (full shading).

Trait	Category	TUR_50m				TUR_100m				TUR_250m			
		Pre	Post Yr 1	Post Yr 2	Post Yr 3	Pre	Post Yr 1	Post Yr 2	Post Yr 3	Pre	Post Yr 1	Post Yr 2	Post Yr 3
Feeding Mode	Suspension	7.3	18.6	17.7	10.4	9.0	15.8	14.5	16.7	7.6	19.5	16.4	34.3
	Surface deposit	36.9	38.1	37.4	36.1	28.1	29.3	33.0	32.0	39.8	32.0	30.4	22.1
	Sub-surface deposit	33.6	33.1	32.0	29.0	30.3	29.2	32.1	31.4	33.5	25.6	30.9	21.8
	Scavenger	11.1	5.1	6.4	12.1	16.3	12.9	10.2	8.5	9.6	11.5	10.3	10.9
	Predator	11.1	5.1	6.4	12.4	16.3	12.9	10.2	11.4	9.6	11.5	11.9	10.9
	Parasite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Trait	Category	WF				ADJ				MID			
		Pre	Post Yr 1	Post Yr 2	Post Yr 3	Pre	Post Yr 1	Post Yr 2	Post Yr 3	Pre	Post Yr 1	Post Yr 2	Post Yr 3
Feeding Mode	Suspension	0.9	6.7	7.3	5.9	22.1	14.9	17.7	22.5	21.3	19.8	24.7	34.1
	Surface deposit	30.1	33.2	31.9	33.4	25.9	27.7	27.3	33.8	28.1	37.5	37.1	30.3
	Sub-surface deposit	29.1	28.4	44.7	48.8	29.7	27.7	33.3	33.7	29.8	32.1	30.3	28.1
	Scavenger	19.9	15.8	7.6	5.4	10.8	13.3	10.4	4.5	10.0	4.6	3.5	3.2
	Predator	19.9	15.8	8.4	6.5	11.5	16.4	11.3	5.5	10.8	5.9	4.4	4.3
	Parasite	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0

Trait	Category	CON			
		Pre	Post Yr 1	Post Yr 2	Post Yr 3
Feeding Mode	Suspension	25.6	18.7	24.7	21.1
	Surface deposit	34.7	34.6	34.4	36.2
	Sub-surface deposit	26.2	27.5	27.7	32.7
	Scavenger	6.0	8.3	5.4	4.0
	Predator	7.5	11.0	7.9	6.0
	Parasite	0.0	0.0	0.0	0.0

Table 23. Pearson correlation coefficients for comparisons of distribution of sediment position categories by year and site grouping. Shading is proportional to the values from 0 (no shading) to 1 (full shading).

	TUR1_50 Pre	TUR1_50 Post yr 1	TUR1_50 Post yr 2	TUR1_50 Post yr 3	TUR2_100 Post yr 1	TUR2_100 Post yr 2	TUR2_250 Pre	TUR2_250 Pre	TUR2_250 Post yr 1	TUR2_250 Post yr 2	TUR1_250 Post yr 3	WF Pre	WF Post Yr 1	WF Post Yr 2
TUR1_50 Post yr 1	0.92													
TUR1_50 Post yr 2	0.93	1.00												
TUR1_50 Post yr 3	0.99	0.93	0.94											
TUR2_100 Pre	0.95	0.81	0.83	0.95										
TUR2_100 Post yr 1	0.95	0.94	0.95	0.96	0.94									
TUR2_100 Post yr 2	0.97	0.97	0.98	0.97	0.92	0.99								
TUR1_100 Post yr 3	0.95	0.98	0.98	0.96	0.90	0.99	0.99							
TUR2_250 Pre	1.00	0.94	0.95	0.99	0.93	0.94	0.97	0.95						
TUR2_250 Post yr 1	0.90	0.96	0.97	0.94	0.85	0.97	0.96	0.97	0.91					
TUR2_250 Post yr 2	0.95	0.97	0.97	0.96	0.92	0.99	0.99	1.00	0.95	0.97				
TUR1_250 Post yr 3	0.42	0.68	0.67	0.49	0.41	0.66	0.61	0.67	0.43	0.76	0.67			
WF Pre	0.88	0.63	0.66	0.86	0.95	0.80	0.78	0.73	0.84	0.68	0.76	0.13		
WF Post Yr 1	0.97	0.82	0.84	0.97	0.98	0.92	0.92	0.89	0.95	0.86	0.90	0.35	0.96	
WF Post Yr 2	0.95	0.89	0.90	0.90	0.91	0.92	0.94	0.93	0.94	0.82	0.93	0.42	0.79	0.88
WF Post Yr 3	0.94	0.88	0.89	0.89	0.89	0.90	0.93	0.91	0.93	0.80	0.91	0.40	0.77	0.85
ADJ Pre	0.83	0.93	0.93	0.85	0.82	0.95	0.94	0.96	0.83	0.95	0.96	0.83	0.60	0.77
ADJ Post Yr 1	0.93	0.89	0.90	0.95	0.96	0.99	0.96	0.96	0.92	0.94	0.97	0.62	0.84	0.94
ADJ Post Yr 2	0.91	0.94	0.95	0.91	0.90	0.98	0.98	0.98	0.90	0.94	0.99	0.70	0.71	0.85
ADJ Post Yr 3	0.86	0.99	0.98	0.87	0.77	0.93	0.95	0.97	0.88	0.95	0.96	0.76	0.54	0.75
MID Pre	0.87	0.96	0.96	0.89	0.83	0.97	0.96	0.98	0.87	0.97	0.98	0.81	0.62	0.80
MID Post Yr 1	0.90	1.00	1.00	0.92	0.80	0.94	0.97	0.98	0.92	0.96	0.96	0.71	0.60	0.80
MID Post Yr 2	0.83	0.98	0.97	0.85	0.71	0.89	0.92	0.94	0.85	0.95	0.93	0.79	0.48	0.71
MID Post Yr 3	0.62	0.87	0.85	0.66	0.52	0.77	0.78	0.82	0.64	0.86	0.81	0.93	0.23	0.49
CON Pre	0.79	0.96	0.95	0.84	0.69	0.89	0.90	0.93	0.82	0.96	0.91	0.84	0.47	0.70
CON Post Yr 1	0.92	0.98	0.99	0.95	0.85	0.96	0.97	0.98	0.93	0.99	0.98	0.72	0.68	0.86
CON Post Yr 2	0.82	0.97	0.97	0.85	0.72	0.90	0.92	0.95	0.84	0.97	0.93	0.82	0.49	0.72
CON Post Yr 3	0.88	1.00	0.99	0.90	0.78	0.93	0.96	0.97	0.90	0.96	0.96	0.73	0.57	0.78

	WF Post Yr 3	ADJ Pre	ADJ Post Yr 1	ADJ Post Yr 2	ADJ Post Yr 3	MID Pre	MID Post Yr 1	MID Post Yr 2	MID Post Yr 3	CON Pre	CON Post Yr 1	CON Post Yr 2	CON Post Yr 3
WF Post Yr 3	1.00												
ADJ Pre	0.85	0.83											
ADJ Post Yr 1	0.89	0.86	0.93										
ADJ Post Yr 2	0.94	0.93	0.98	0.95									
ADJ Post Yr 3	0.87	0.86	0.96	0.87	0.95								
MID Pre	0.87	0.85	1.00	0.94	0.98	0.98							
MID Post Yr 1	0.87	0.87	0.93	0.88	0.94	0.99	0.96						
MID Post Yr 2	0.80	0.79	0.93	0.83	0.91	0.99	0.95	0.99					
MID Post Yr 3	0.63	0.62	0.90	0.70	0.82	0.92	0.90	0.89	0.94				
CON Pre	0.74	0.73	0.93	0.84	0.89	0.97	0.95	0.97	0.99	0.95			
CON Post Yr 1	0.85	0.84	0.94	0.94	0.94	0.97	0.97	0.98	0.97	0.86	0.97		
CON Post Yr 2	0.78	0.77	0.95	0.86	0.91	0.98	0.96	0.98	0.99	0.95	1.00	0.97	
CON Post Yr 3	0.87	0.86	0.94	0.88	0.95	1.00	0.97	1.00	0.99	0.91	0.97	0.98	0.98

With the exception of WF, all sites showed a common similarity of 92% reflecting the very high correlation discussed above (Figure 43). However, the MDS plot in Figure 44 indicate that the patterns highlighted in the dendrogram are not strongly related to factors considered here.

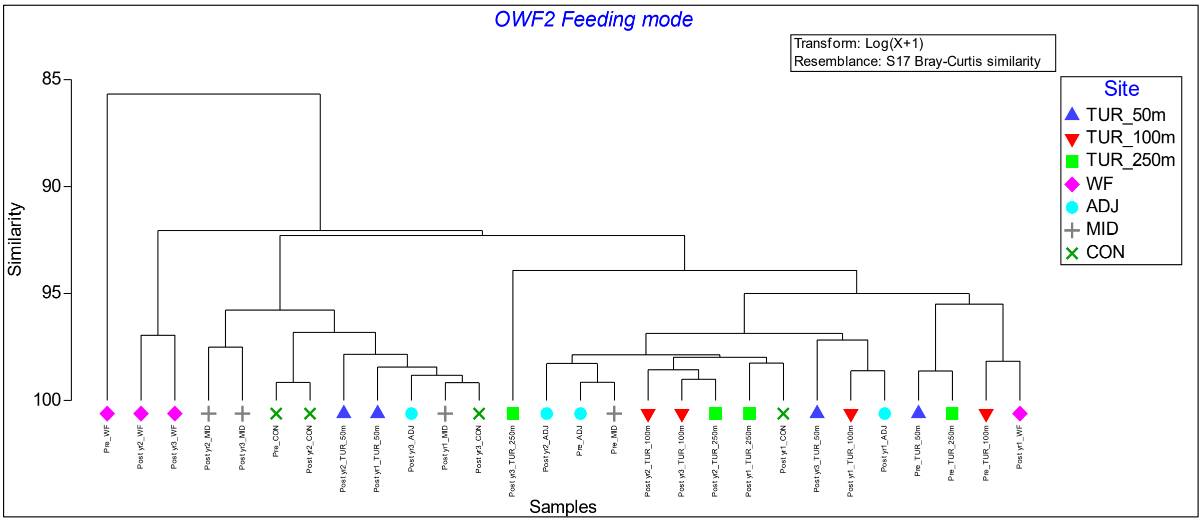

Figure 43. Dendrogram showing the relative similarities in OWF2 benthic communities in relation to six feeding mode trait categories.

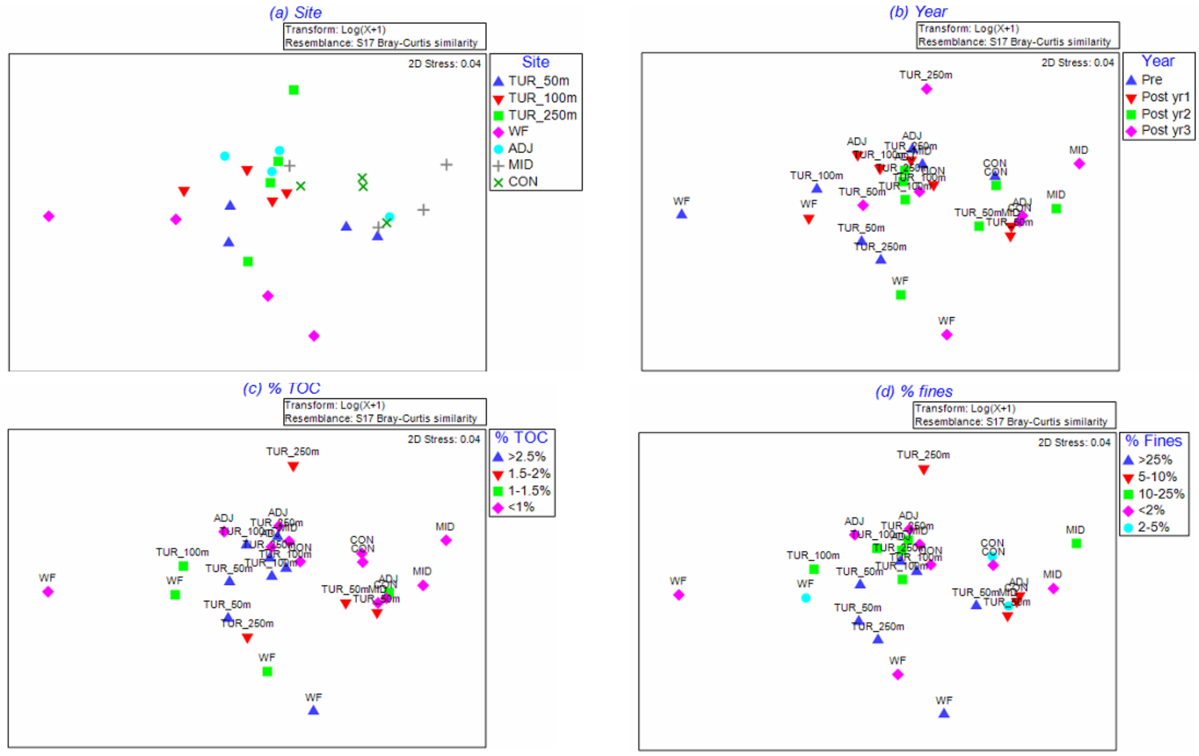

Figure 44. MDS showing the relative similarities in OWF2 benthic communities in relation to feeding mode trait categories compared to factors: (a) Year; (b) Site Group; (c) % TOC; (d) % Fines.

Analysis of all years and sites by PERMANOVA indicated no significant difference between years (p = 0.312). However, when considering site group alone differences were indicated (p = 0.049), although when considering site group and years together no significant differences were identified in distribution of lifespan categories across the study area (p = 0.999).

When the distribution of the feeding mode categories was examined in relation to TOC only weak correlations were evident (Figure 45). Similarly, no strong correlations between distribution of feeding mode categories and levels of fines in sediments were evident (Figure 46).

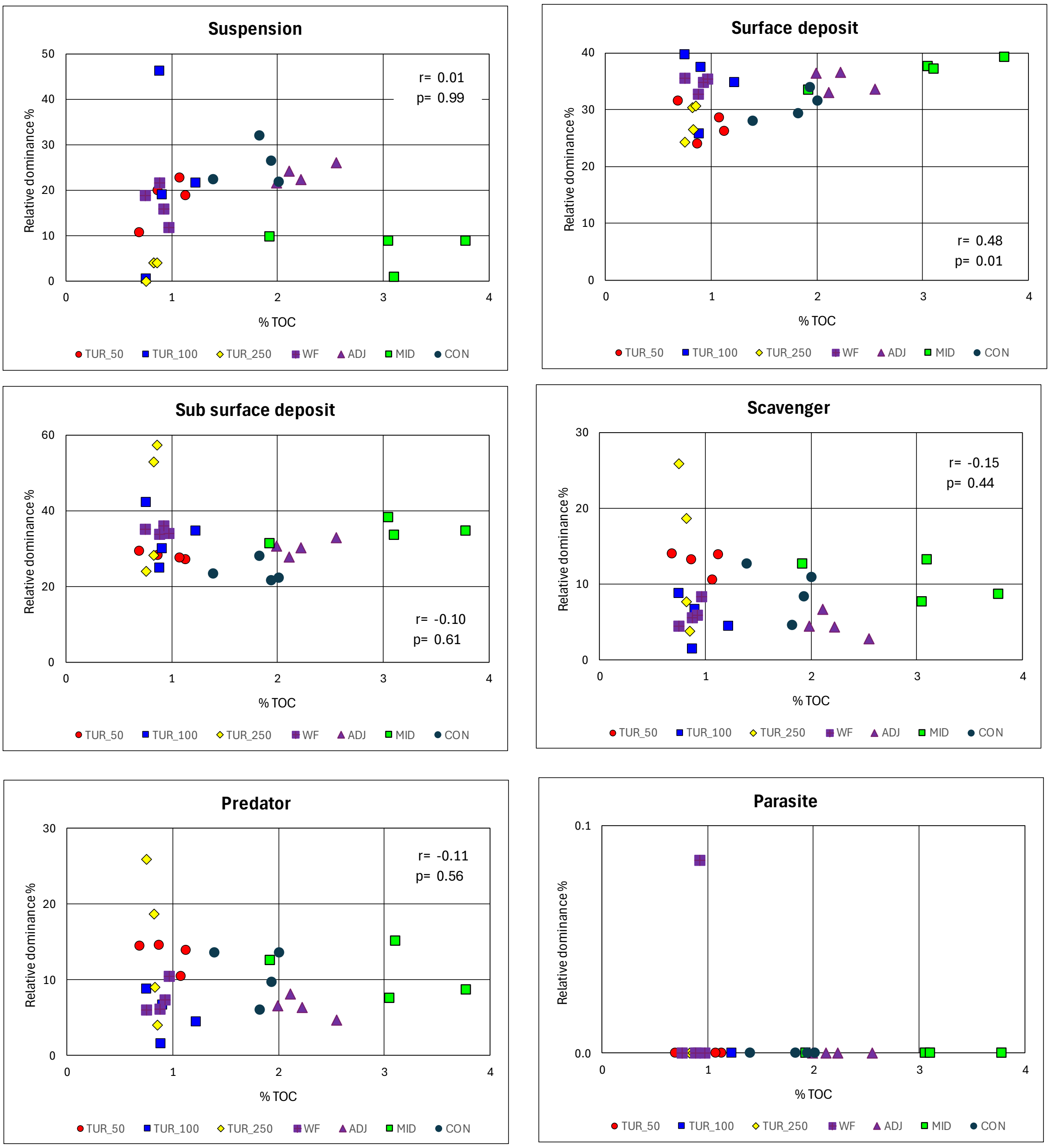

Figure 45. Mean relative dominance represented by each feeding mode category by TOC and site grouping. (Correlation co-efficient and p-value for combined data indicated)

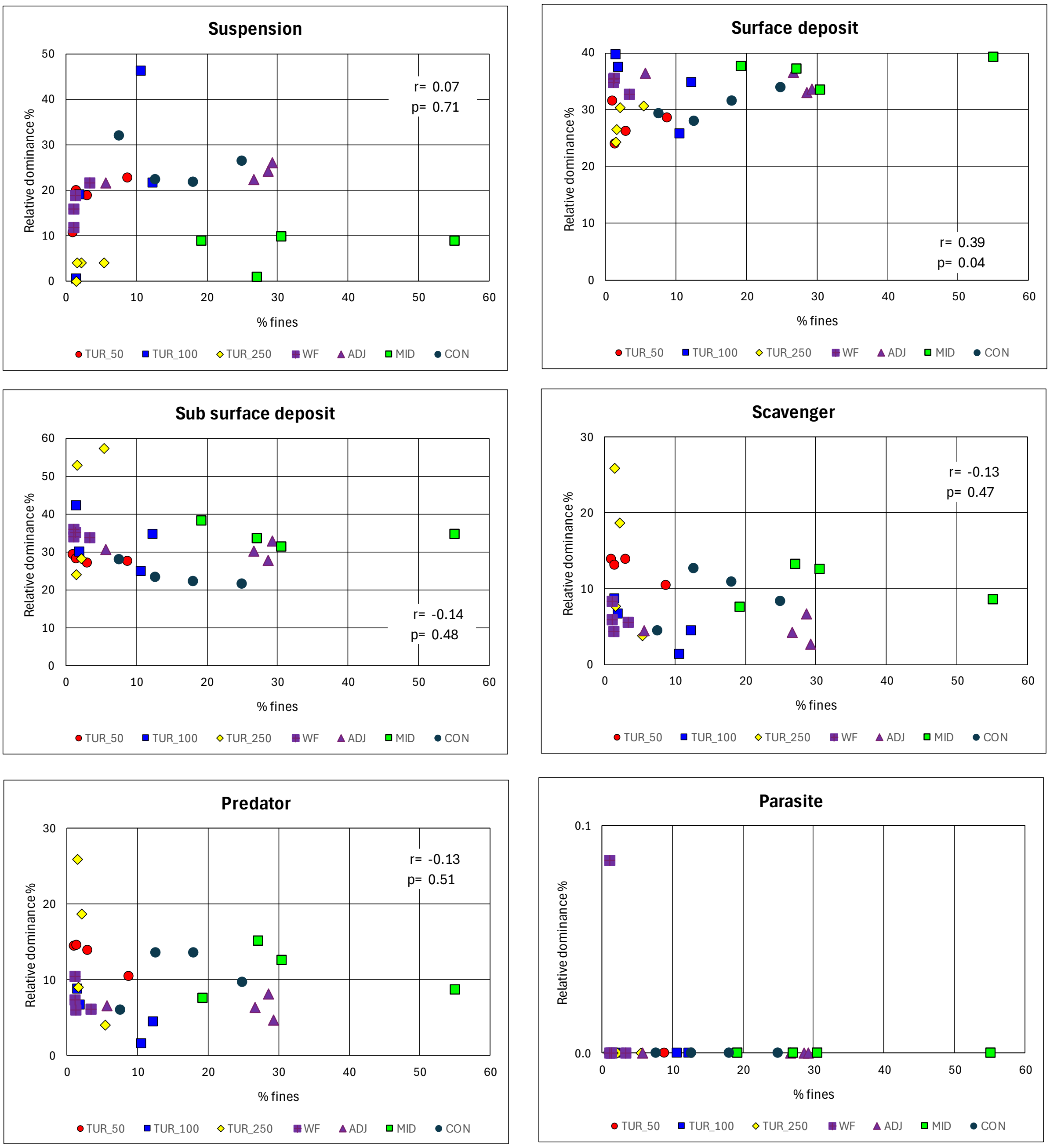

Figure 46. Mean relative dominance represented by each feeding mode category by % fines and site grouping. (Correlation co-efficient and p-value for combined data indicated)

Results of PERMANOVA analysis indicate differences between relative dominance of feeding mode categories in relation to TOC across the study period (p = 0.0001), specifically between sites where TOC <1% and where higher levels are recorded. However, no significant differences were highlighted when the distribution of feeding mode trait categories was looked at with TOC, year and site group in conjunction (p = 0.902). Similarly, significant differences were evident in relation to proportion of fines in sediment across the study period (p<0.001) with differences evident between % fines <5% and higher proportion, although no consistent pattern was evident and when considered in conjunction with year and site groups (p = 0.411).

Overall, while there may be some influence of the construction of the wind farm on the spatial and temporal patterns in % fines, this has no evident impact in relation the relative dominance of the feeding mode categories across the study area with any spatial or temporal variability observed being considered to be driven by natural factors.

4.2.6 Bioturbation

Generally, across the site groupings and all years diffuse mixing taxa represented the highest relative dominance in relation to bioturbation trait categories contributing on average 61.3% of all individuals across the study period (annual range = 58.2% to 64.5%), while surface deposition taxa represented an average of 25.9% of all individuals across the study period (annual range = 22.6 % to 28.2%). Diffuse mixing taxa showed slightly higher relative dominance at sites within the wind farm, while surface deposition taxa were more dominant at sites outwith the wind farm. However, no clear temporal patterns were evident in the relative dominance represented by any of the trait categories (Table 24).

However, no clear temporal patterns were evident in the relative dominance represented by any of the lifespan trait categories and while some variation was evident, the magnitude of changes overall are relatively small and the distribution of maximum categories remain relatively consistent throughout the study period and across the majority of the study area being predominantly very strong correlations evident between sites and years (Table 25).

Table 24. Relative dominance represented by each bioturbation category by year and site grouping. Shading is proportional to the values from 0% (no shading) to 100% (full shading).

Trait	Category	TUR_50m				TUR_100m				TUR_250m			
		Pre	Post Yr 1	Post Yr 2	Post Yr 3	Pre	Post Yr 1	Post Yr 2	Post Yr 3	Pre	Post Yr 1	Post Yr 2	Post Yr 3
Bioturbation	Diffusive_mixing	72.4	70.7	63.0	68.1	72.2	73.7	67.5	64.9	74.8	75.3	59.8	52.5
	Surface_deposition	26.8	14.8	21.2	18.9	20.5	22.6	19.2	21.3	23.7	20.3	22.6	25.8
	Upward_conveyor	0.5	0.0	0.0	0.0	2.6	0.0	0.0	0.0	0.3	0.5	3.6	0.0
	Downward_conveyer	0.3	14.5	15.8	12.8	0.6	3.7	13.3	9.4	0.8	4.0	12.1	6.9
	None	0.0	0.0	0.0	0.1	4.2	0.0	0.0	4.4	0.3	0.0	1.9	14.8

Trait	Category	WF				ADJ				MID			
		Pre	Post Yr 1	Post Yr 2	Post Yr 3	Pre	Post Yr 1	Post Yr 2	Post Yr 3	Pre	Post Yr 1	Post Yr 2	Post Yr 3
Bioturbation	Diffusive_mixing	80.3	78.9	74.7	78.3	46.9	50.4	52.2	54.6	53.1	49.1	47.1	44.6
	Surface_deposition	19.6	20.2	19.2	16.4	37.0	34.8	22.0	14.9	32.2	38.4	32.3	28.6
	Upward_conveyor	0.0	0.2	4.2	3.3	5.6	3.0	6.1	1.0	1.8	2.9	0.5	1.0
	Downward_conveyer	0.1	0.7	1.9	2.0	9.1	8.8	18.6	29.0	11.9	6.2	18.2	16.7
	None	0.0	0.0	0.0	0.0	1.4	3.0	1.1	0.5	1.0	3.4	1.9	9.1

Trait	Category	CON			
		Pre	Post Yr 1	Post Yr 2	Post Yr 3
Bioturbation	Diffusive_mixing	51.7	46.3	43.2	50.4
	Surface_deposition	37.5	43.1	37.5	32.4
	Upward_conveyor	1.1	3.0	3.0	1.5
	Downward_conveyer	7.5	5.4	13.9	14.1
	None	2.2	2.2	2.3	1.7

Table 25. Pearson correlation coefficients for comparisons of distribution of sediment position categories by year and site grouping. Shading is proportional to the values from 0 (no shading) to 1 (full shading).

	TUR1_50 Pre	TUR1_50 Post yr 1	TUR1_50 Post yr 2	TUR1_50 Post yr 3	TUR2_100 Post yr 1	TUR2_100 Post yr 2	TUR2_250 Pre	TUR2_250 Pre	TUR2_250 Post yr 1	TUR2_250 Post yr 2	TUR1_250 Post yr 3	WF Pre	WF Post Yr 1	WF Post Yr 2	WF Post Yr 3	ADJ Pre	ADJ Post Yr 1	ADJ Post Yr 2	ADJ Post Yr 3	MID Pre	MID Post Yr 1	MID Post Yr 2	MID Post Yr 3	CON Pre	CON Post Yr 1	CON Post Yr 2	CON Post Yr 3
TUR1_50 Post yr 1	0.96																										
TUR1_50 Post yr 2	0.96	0.99																									
TUR1_50 Post yr 3	0.97	1.00	1.00																								
TUR2_100 Pre	0.99	0.96	0.96	0.97																							
TUR2_100 Post yr 1	1.00	0.98	0.98	0.99	1.00																						
TUR2_100 Post yr 2	0.97	1.00	1.00	1.00	0.97	0.99																					
TUR1_100 Post yr 3	0.99	0.99	0.99	0.99	0.99	1.00	0.99																				
TUR2_250 Pre	1.00	0.97	0.97	0.98	1.00	1.00	0.98	0.99																			
TUR2_250 Post yr 1	0.99	0.98	0.98	0.99	1.00	1.00	0.99	1.00	1.00																		
TUR2_250 Post yr 2	0.99	0.99	0.99	1.00	0.98	0.99	1.00	0.99	0.99	0.99																	
TUR1_250 Post yr 3	0.96	0.91	0.93	0.93	0.96	0.96	0.93	0.96	0.96	0.95	0.94																
WF Pre	0.99	0.97	0.97	0.98	1.00	1.00	0.98	0.99	1.00	1.00	0.98	0.95															
WF Post Yr 1	0.99	0.98	0.97	0.98	1.00	1.00	0.98	0.99	1.00	1.00	0.99	0.95	1.00														
WF Post Yr 2	0.99	0.97	0.97	0.98	1.00	1.00	0.98	0.99	1.00	1.00	0.98	0.94	1.00	1.00													
WF Post Yr 3	0.98	0.98	0.97	0.98	1.00	0.99	0.98	0.99	0.99	1.00	0.98	0.93	1.00	1.00	1.00												
ADJ Pre	0.93	0.83	0.89	0.87	0.87	0.90	0.87	0.89	0.91	0.88	0.91	0.89	0.87	0.88	0.87	0.85											
ADJ Post Yr 1	0.96	0.88	0.92	0.91	0.91	0.94	0.91	0.93	0.94	0.92	0.94	0.93	0.91	0.92	0.91	0.89	0.99										
ADJ Post Yr 2	0.95	0.98	0.99	0.98	0.93	0.96	0.99	0.97	0.95	0.96	0.99	0.89	0.95	0.95	0.95	0.95	0.90	0.92									
ADJ Post Yr 3	0.83	0.94	0.95	0.93	0.83	0.87	0.94	0.90	0.84	0.87	0.91	0.79	0.85	0.85	0.85	0.86	0.75	0.79	0.96								
MID Pre	0.96	0.92	0.96	0.95	0.93	0.95	0.95	0.95	0.95	0.94	0.97	0.93	0.93	0.94	0.93	0.91	0.98	0.99	0.96	0.85							
MID Post Yr 1	0.93	0.83	0.88	0.87	0.88	0.91	0.87	0.90	0.91	0.89	0.91	0.92	0.88	0.88	0.87	0.85	1.00	0.99	0.88	0.72	0.98						
MID Post Yr 2	0.91	0.89	0.94	0.91	0.86	0.90	0.92	0.91	0.89	0.89	0.94	0.89	0.87	0.88	0.86	0.85	0.96	0.97	0.95	0.88	0.98	0.95					
MID Post Yr 3	0.93	0.91	0.95	0.93	0.90	0.93	0.94	0.94	0.92	0.92	0.95	0.95	0.90	0.91	0.89	0.88	0.94	0.97	0.94	0.87	0.98	0.95	0.98				
CON Pre	0.95	0.86	0.91	0.89	0.90	0.92	0.90	0.92	0.93	0.91	0.93	0.93	0.90	0.90	0.89	0.87	0.99	1.00	0.91	0.77	0.99	1.00	0.97	0.96			
CON Post Yr 1	0.88	0.75	0.82	0.80	0.82	0.85	0.80	0.83	0.85	0.82	0.85	0.87	0.82	0.82	0.81	0.78	0.99	0.98	0.82	0.65	0.95	0.99	0.93	0.91	0.98		
CON Post Yr 2	0.88	0.80	0.87	0.85	0.82	0.86	0.85	0.86	0.86	0.84	0.88	0.86	0.82	0.83	0.82	0.80	0.99	0.98	0.89	0.76	0.97	0.98	0.98	0.95	0.98	0.98	
CON Post Yr 3	0.95	0.91	0.95	0.94	0.91	0.94	0.94	0.94	0.93	0.93	0.96	0.92	0.91	0.92	0.91	0.89	0.98	0.99	0.96	0.86	1.00	0.97	0.99	0.98	0.99	0.95	0.98

There was a common similarity of 80% for all sites and years in the distribution of bioturbation trait categories with six broad cluster groups evident at higher similarity (Figure 47). This is supported by the MDS plots given in Figure 48 which indicate that the patterns here show some association with the proportion of fines in the sediment, specifically where fines are <1% (Figure 48).

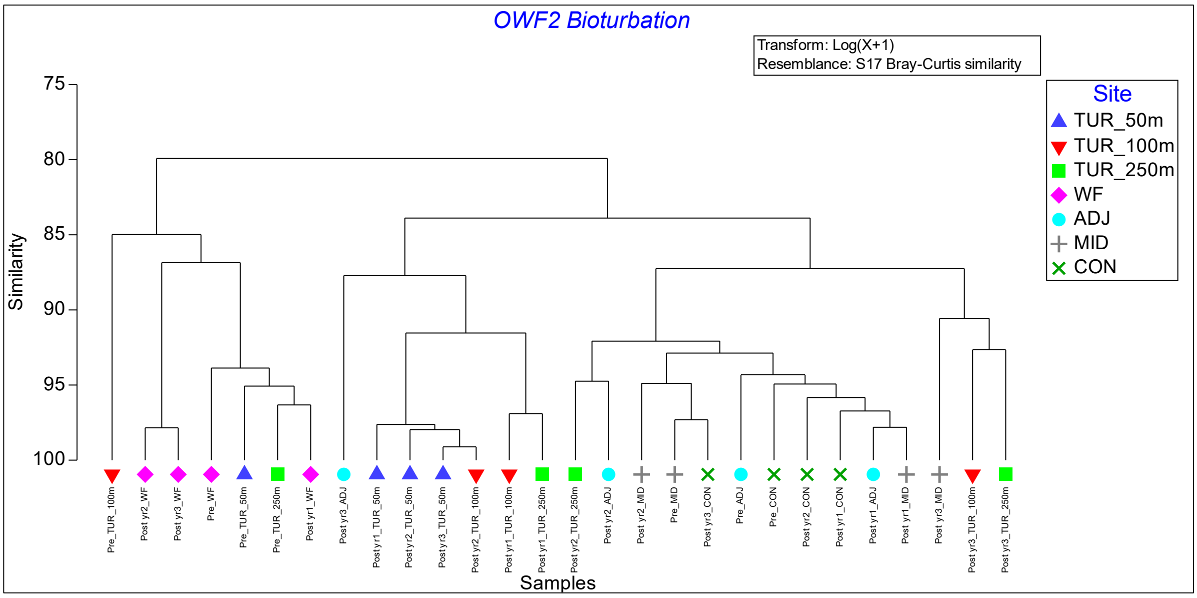

Figure 47. Dendrogram showing the relative similarities in OWF1 benthic communities in relation to five bioturbation trait categories.

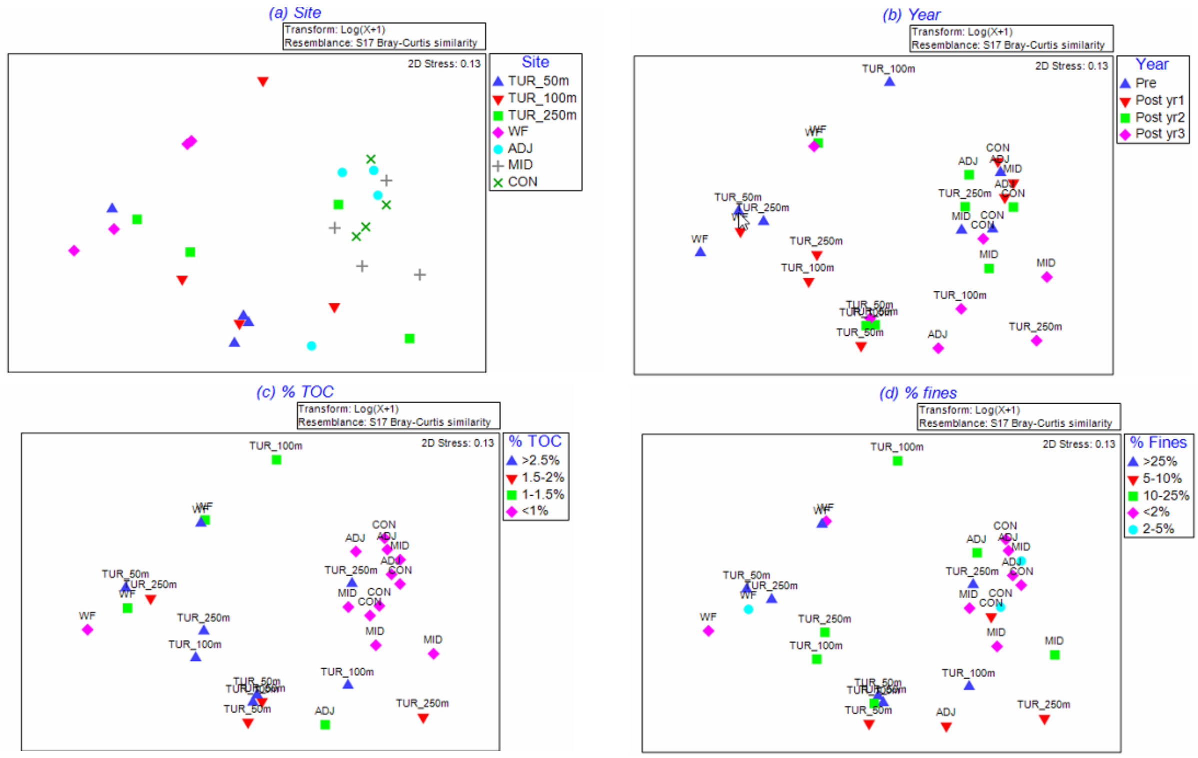

Figure 48. MDS showing the relative similarities in OWF1 benthic communities in relation to bioturbation trait categories compared to factors: (a) Year; (b) Site Group; (c) % TOC; (d) % Fines.

When the distribution of the feeding mode categories was examined in relation to TOC only weak correlations were evident (Figure 49). Similarly, no strong correlations between distribution of feeding mode categories and levels of fines in sediments were evident (Figure 50).

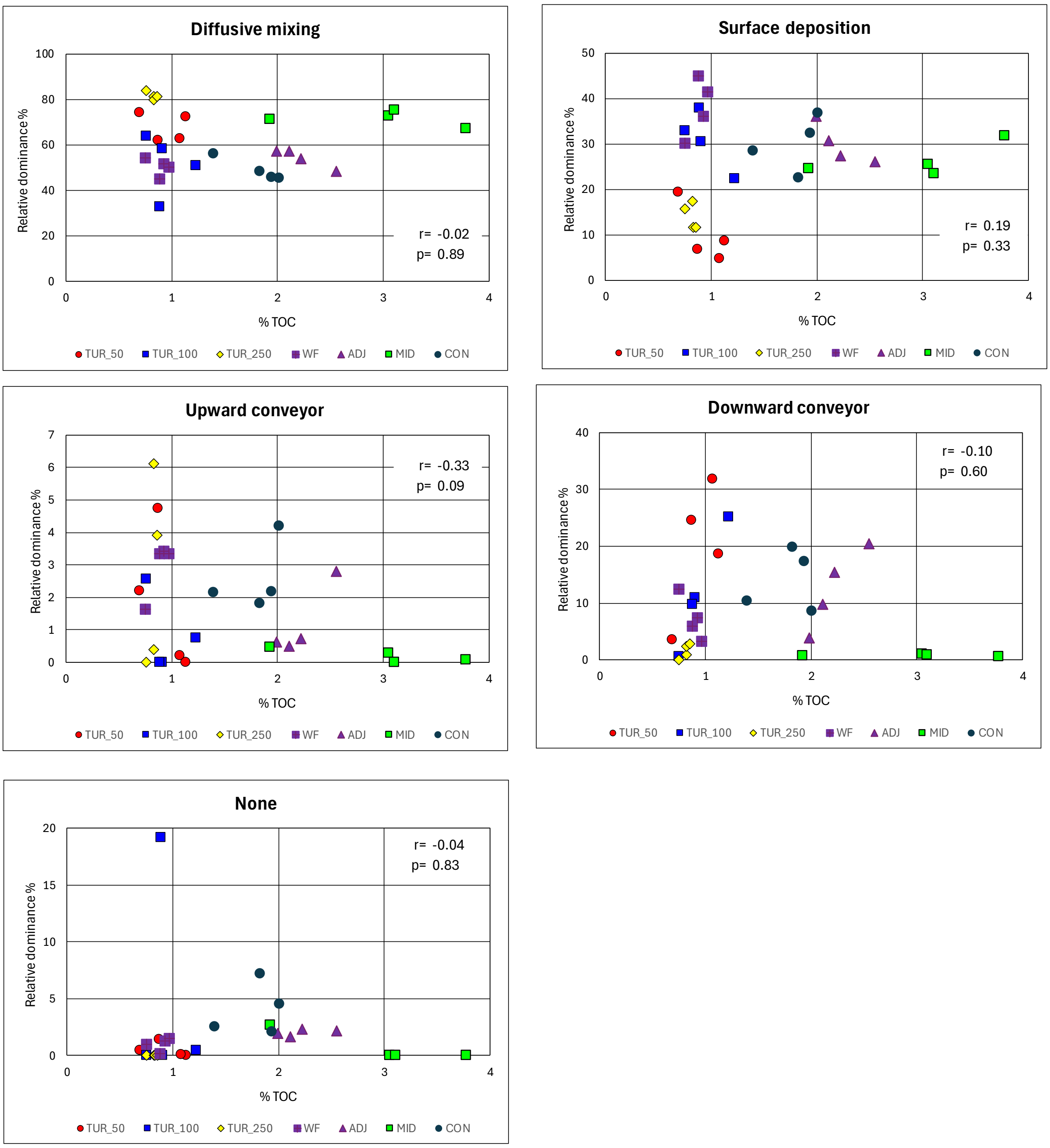

Figure 49. Mean relative dominance represented by each bioturbation category by TOC and site grouping. (Correlation co-efficient and p-value for combined data indicated)

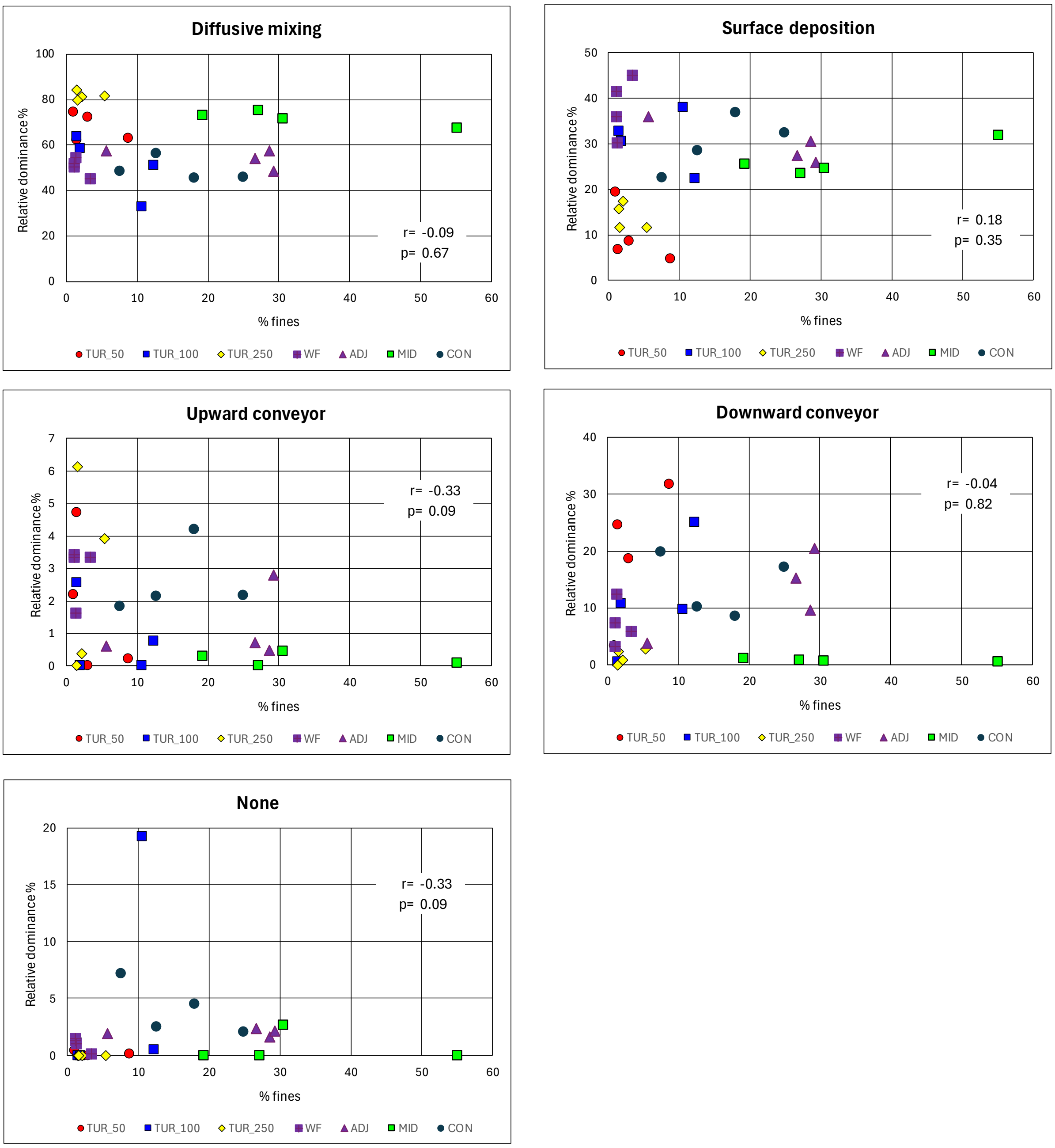

Figure 50. Mean relative dominance represented by each bioturbation category by % fines and site grouping. (Correlation co-efficient and p-value for combined data indicated)

Results of PERMANOVA analysis indicate differences between relative dominance of bioturbation categories in relation to TOC across the study period (p 0.0001), primarily between sites where TOC <1% and where higher levels are recorded. However, no significant differences were highlighted when the distribution of bioturbation trait categories was looked at with LOI, year and site group in conjunction (p = 0.362). Similarly, significant differences were evident in relation to proportion of fines in sediment across the study period (p = 0.0001), although no consistent pattern was evident and when considered in conjunction with year and site grouping (p = 0.362).

Overall, while there may be some influence of the construction of the wind farm on the spatial and temporal patterns in % fines, this has no evident impact in relation to the relative dominance of the bioturbation categories across the study area with any spatial or temporal variability observed being considered to be driven by natural factors.

4.2.7 Conclusions – OWF 2

For OWF 2, some spatial and temporal variability is evident in the traits data with the magnitude of any changes being proportionally small and showing no clear correlation with the OWF. Consequently, considering the magnitude of the observed changes and the lack of any clear driver, it is concluded that the spatial or temporal variability in the distribution of biological traits are related to natural factors and/or wider regional environmental factors with no measurable influence of OWF 2 evident. The original monitoring report also concluded that construction and operation had no detectable effect on sediment characteristics or faunal diversity.

4.3 OWF 3

4.3.1 Maximum size

Generally, across the site groupings and all years taxa with maximum sizes of between 101 and 200mm represented the highest proportion of the communities recorded contributing on average 39.9% of all individuals across the study period (annual range = 31.45 % to 47.1%), while those with maximum size of between 21 and 100mm represented on average 34.2% (annual range = 27.9% to 41.0%) (Table 26). Taxa of maximum size between 201 and 500mm represented on average 11.7% (annual range = 9.7% to 15.2%). Those taxa with maximum size <20mm showed little variation between site groups and years.

However, no clear temporal patterns were evident in the relative dominance represented by any of the trait categories and while some variation was evident, the magnitude of changes overall are relatively small and the distribution of maximum size categories remain consistent throughout the study period and across the study area indicted by the consistently very strong correlations evident between sites and years (

Table 27).

Table 26. Relative dominance represented by each maximum size category by year and site grouping. Shading is proportional to the values from 0% (no shading) to 100% (full shading).

Trait	Category	WIN						CR					
		Pre	Post Yr1a	Post Yr1b	Post Yr2	Post Yr3	Post Yr4	Pre	Post Yr1a	Post Yr1b	Post Yr2	Post Yr3	Post Yr4
Maximum size (mm)	<10	2.8	4.0	3.3	1.5	0.0	1.5	13.5	14.8	11.8	7.7	7.8	2.1
	10-20	11.9	7.7	0.0	2.9	5.6	2.4	5.5	6.2	8.1	9.4	5.5	3.5
	21-100	46.7	29.9	47.0	46.1	27.5	37.1	40.7	31.6	32.6	51.0	29.9	31.9
	101-200	28.9	45.1	32.1	34.6	42.3	50.9	31.1	33.2	36.7	17.6	38.8	46.4
	201-500	9.5	13.0	17.1	14.9	7.9	8.0	9.2	14.0	10.8	14.4	18.0	16.0
	<500	0.2	0.2	0.4	0.0	0.0	0.0	0.0	0.2	0.1	0.0	0.0	0.0

Trait	Category	CON					
		Pre	Post Yr1a	Post Yr1b	Post Yr2	Post Yr3	Post Yr4
Maximum size (mm)	<10	4.8	1.2	11.1	2.7	19.7	21.5
	10-20	9.2	4.2	2.9	6.9	8.3	3.7
	21-100	35.7	22.1	27.3	31.7	17.2	29.9
	101-200	38.5	62.8	48.1	42.2	48.2	39.8
	201-500	11.3	9.4	10.6	16.5	4.9	5.1
	<500	0.4	0.3	0.0	0.0	1.7	0.0

Table 27. Pearson correlation coefficients for comparisons of distribution of maximum size categories by year and site grouping. Shading is proportional to the values from 0 (no shading) to 1 (full shading).

	WIN_Pre	WIN_Post Yr1a	WIN_Post Yr1b	WIN_Post Yr2	WIN_Post Yr3	WIN_Post Yr4	CR_Pre	CR_Post Yr1a	CR_Post Yr1b	CR_Post Yr2	CR_Post Yr3	CR_Post Yr4	CON_Pre	CON_Post Yr1a	CON_Post Yr1b	CON_Post Yr2	CON_Post Yr3
WIN_Post Yr1a	0.96																
WIN_Post Yr1b	0.97	0.99															
WIN_Post Yr2	0.97	1.00	1.00														
WIN_Post Yr3	0.99	0.97	0.96	0.98													
WIN_Post Yr4	1.00	0.98	0.98	0.99	1.00												
CR_Pre	0.97	1.00	1.00	1.00	0.97	0.99											
CR_Post Yr1a	0.99	0.99	0.99	0.99	0.99	1.00	0.99										
CR_Post Yr1b	1.00	0.97	0.97	0.98	1.00	1.00	0.98	0.99									
CR_Post Yr2	0.99	0.98	0.98	0.99	1.00	1.00	0.99	0.99	1.00								
CR_Post Yr3	0.98	0.99	1.00	0.99	0.98	0.99	1.00	0.99	0.98	0.99							
CR_Post Yr4	0.96	0.92	0.93	0.94	0.96	0.95	0.94	0.97	0.96	0.95	0.95						
CON_Pre	0.99	0.98	0.97	0.98	1.00	1.00	0.98	0.99	1.00	1.00	0.98	0.95					
CON_Post Yr1a	0.99	0.98	0.97	0.98	1.00	1.00	0.98	0.99	1.00	1.00	0.98	0.95	1.00				
CON_Post Yr1b	0.99	0.98	0.97	0.98	1.00	1.00	0.98	0.99	1.00	1.00	0.98	0.94	1.00	1.00			
CON_Post Yr2	0.98	0.98	0.97	0.98	1.00	0.99	0.98	0.99	0.99	1.00	0.98	0.93	1.00	1.00	1.00		
CON_Post Yr3	0.93	0.85	0.90	0.88	0.88	0.90	0.89	0.90	0.91	0.89	0.92	0.91	0.88	0.88	0.88	0.86	
CON_Post Yr4	0.95	0.89	0.93	0.92	0.92	0.94	0.92	0.94	0.94	0.92	0.95	0.94	0.91	0.92	0.91	0.89	0.99

There was a common similarity of close to 84% for all sites and years in the distribution of maximum size trait categories with some temporal and spatial variability between site groups (Figure 51). However, the MDS plot in Figure 52 indicate that the patterns highlighted in the dendrogram are not strongly related to factors considered here.

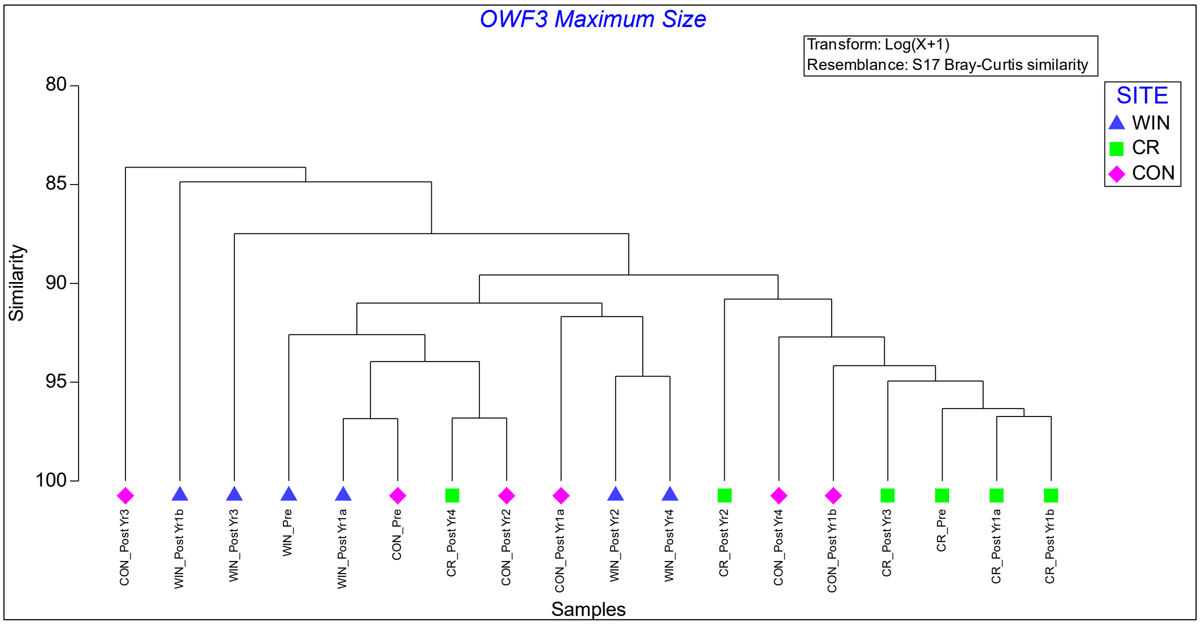

Figure 51. Dendrogram showing the relative similarities in OWF3 benthic communities in relation to six maximum size trait categories.

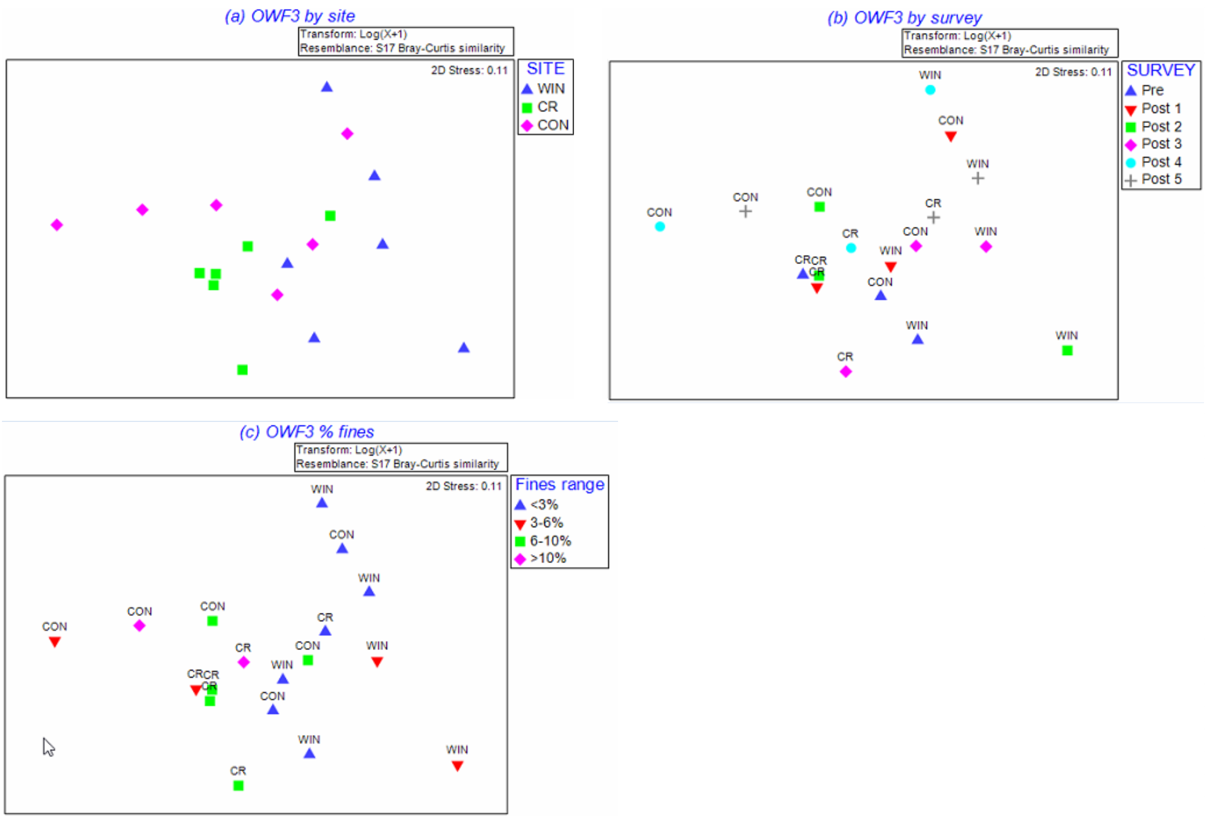

Figure 52. MDS showing the relative similarities in OWF3 benthic communities in relation to maximum size trait categories compared to factors: (a) Year; (b) Site Group; (c) % Fines.

Analysis by PERMANOVA indicated no difference between individual years for overall survey data (p = 0.518), although when site grouping was considered differences between WIN and CR (p=0.017) and WIN and CON (p= 0.042) were evident.

In relation to sediment characteristics, analysis of TOC was not possible at this site because the majority of the results reported throughout the study were recorded as "less than" values and no meaningful patterns could be determined. Consequently, TOC is not discussed further in relation to OWF 3.

Fines at WIN sites increased from a pre-construction level of 0.5% to 2.7% in the first post-construction survey, with subsequent levels remaining close to 3% (Figure 53). A similar pattern was seen at CON sites with pre-construction level of 0.5% increasing over the next two surveys to 6%. In the last survey the men level had increased to 30%, although this was due to levels of 85% fines recorded at one site. At CR mean % fines increased steadily from 5.4% pre-construction to 9.4% in third post-construction survey. Subsequently, a level of 23% was recorded, although this was due to three sites where sediments were comprised between 44 and 65% fines. These patterns may indicate some influence of the wind farm at sites close to the turbines reflecting inputs of fine particulate material from epibenthic colonisers of turbines and associated hard structures. However, as the majority of particulate material originating from this route is likely to be organic in nature, although this is difficult to determine from the data available, considering the patterns observed at more remote sites it is considered that the changes reported are related to natural variability rather than any influence of the wind farm.

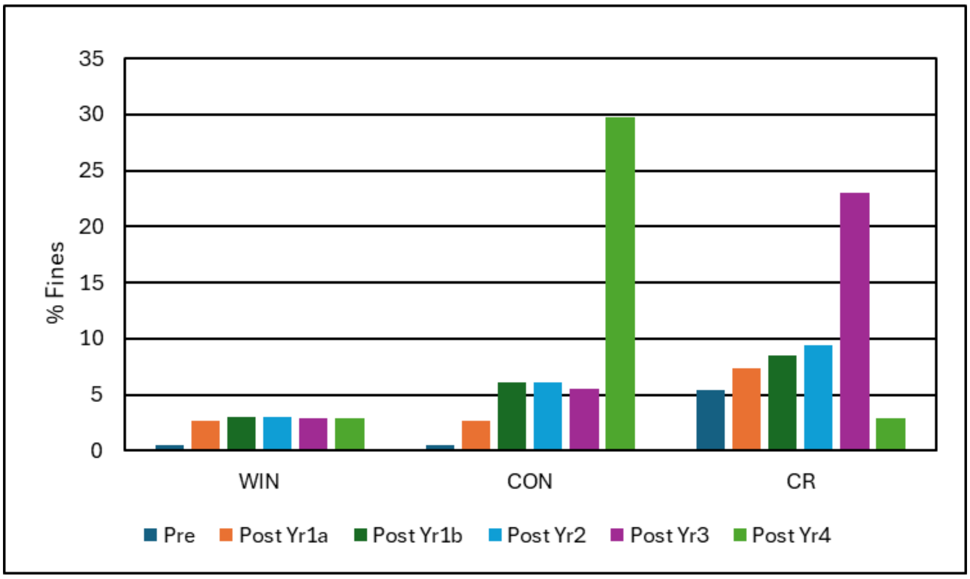

Figure 53. Pre- and post-construction levels of fines.

When the distribution of the maximum size categories was examined in relation to % fines a strong positive correlation with <10mm category (r=61, p=0.01), although no significant relationships with other size categories and % fines were evident (Figure 54). When analysed by PERMANOVA no significant differences were evident in relation to proportion of fines across the study as a whole (p=0.365).

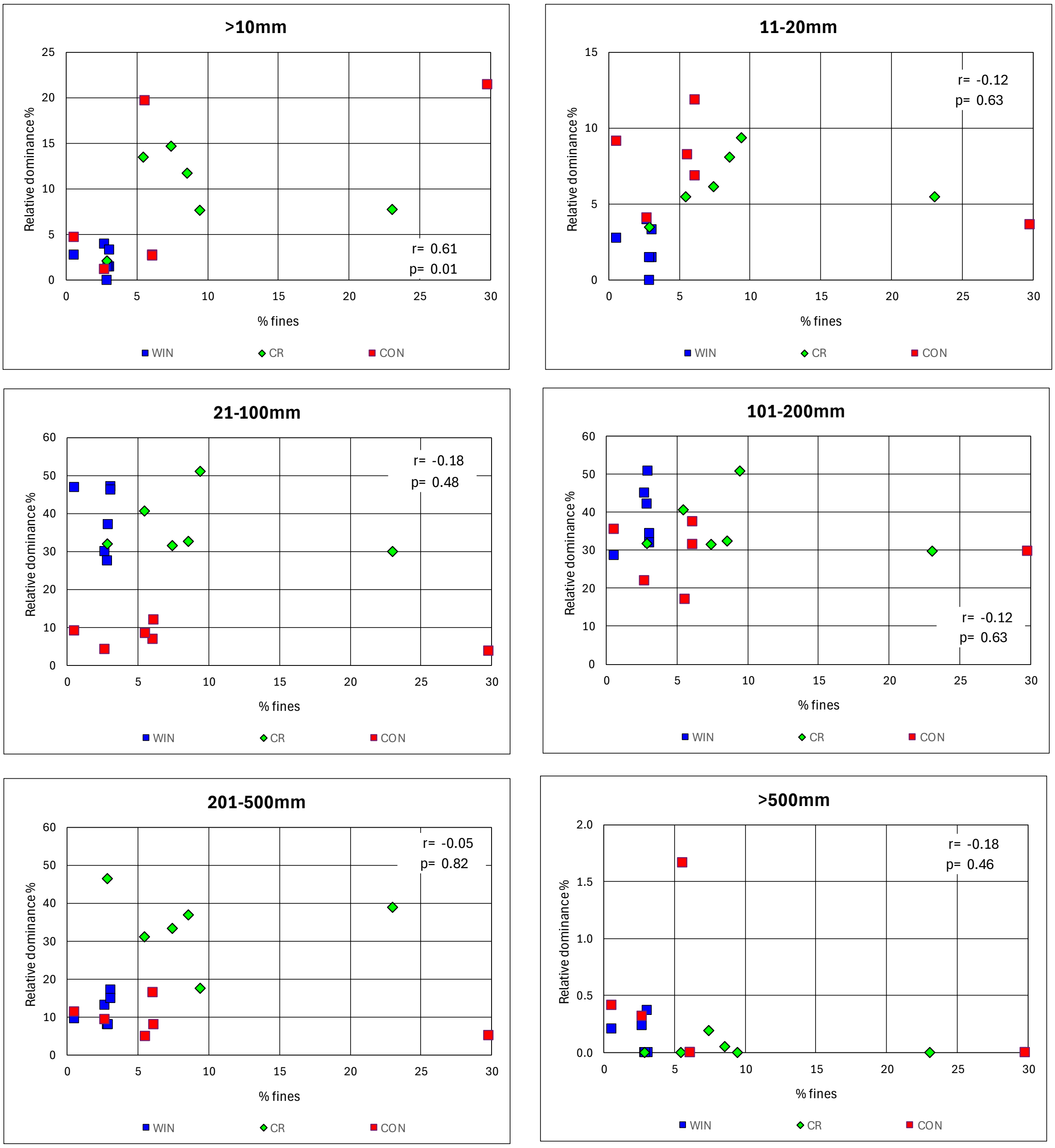

Figure 54. Mean relative dominance represented by each maximum size category by % fines and site grouping. (Correlation co-efficient and p-value for combined data indicated)

Overall, while there may be some influence of the construction of the wind farm on the spatial and temporal patterns in fines at wind farm sites, although these likely insignificant compared to natural variability. Consequently, it is considered that there are no impacts associated with the development in relation the relative dominance of the maximum size categories across the study area with any spatial or temporal variability observed being considered to be driven by natural factors.

4.3.2 Lifespan

Generally, across the site groupings and all years taxa with lifespan of between 1 and 3 years represented the highest proportion of the communities recorded contributing on average 75.8 % of all individuals across the study period (annual range = 68.6 % to 83.6%), while those with age span of 3 to 10 years represented on average 21.9% (annual range = 14.1% to 26.7%) (However, no clear spatial or temporal patterns were evident in the relative dominance represented by any of the trait categories and while some variation was evident, the magnitude of changes overall are relatively small and the distribution of lifespan categories remain consistent throughout the study period and across the study area indicted by the consistently very strong correlations evident between sites and years (Table 29).

Table 28). Overall, no consistent temporal pattern was evident, and any variation is considered to be within the range of natural variability.

However, no clear spatial or temporal patterns were evident in the relative dominance represented by any of the trait categories and while some variation was evident, the magnitude of changes overall are relatively small and the distribution of lifespan categories remain consistent throughout the study period and across the study area indicted by the consistently very strong correlations evident between sites and years (Table 29).

Table 28. Relative dominance represented by each lifespan category by year and site grouping. Shading is proportional to the values from 0% (no shading) to 100% (full shading).

Trait	Category	WIN						CR					
		Pre	Post Yr1a	Post Yr1b	Post Yr2	Post Yr3	Post Yr4	Pre	Post Yr1a	Post Yr1b	Post Yr2	Post Yr3	Post Yr4
Lifespan (years)	<1	0.1	0.0	0.0	0.0	0.0	0.8	0.0	0.9	0.0	4.2	1.6	2.8
	1-3	81.0	77.0	87.7	82.4	66.2	66.8	77.9	79.4	75.4	87.6	70.6	66.1
	3-10	18.0	22.7	12.3	15.8	17.2	32.4	20.5	18.7	22.1	7.4	25.8	31.1
	>10	0.9	0.3	0.0	1.8	0.0	0.0	1.6	0.9	2.5	0.8	2.0	0.0

Trait	Category	CON					
		Pre	Post Yr1a	Post Yr1b	Post Yr2	Post Yr3	Post Yr4
Lifespan (years)	<1	0.0	0.0	0.0	0.0	1.6	0.0
	1-3	73.3	67.3	72.5	80.6	69.1	83.4
	3-10	26.1	32.7	27.5	19.1	28.3	16.6
	>10	0.6	0.0	0.0	0.2	1.0	0.0

Table 29. Pearson correlation coefficients for comparisons of distribution of lifespan categories by year and site grouping. Shading is proportional to the values from 0 (no shading) to 1 (full shading).

	WIN_Pre	WIN_Post Yr1a	WIN_Post Yr1b	WIN_Post Yr2	WIN_Post Yr3	WIN_Post Yr4	CR_Pre	CR_Post Yr1a	CR_Post Yr1b	CR_Post Yr2	CR_Post Yr3	CR_Post Yr4	CON_Pre	CON_Post Yr1a	CON_Post Yr1b	CON_Post Yr2	CON_Post Yr3
WIN_Post Yr1a	1.00																
WIN_Post Yr1b	1.00	0.99															
WIN_Post Yr2	1.00	0.99	1.00														
WIN_Post Yr3	1.00	1.00	0.99	1.00													
WIN_Post Yr4	0.96	0.98	0.94	0.95	0.97												
CR_Pre	1.00	1.00	0.99	1.00	1.00	0.97											
CR_Post Yr1a	1.00	1.00	1.00	1.00	1.00	0.96	1.00										
CR_Post Yr1b	1.00	1.00	0.99	0.99	1.00	0.98	1.00	1.00									
CR_Post Yr2	0.99	0.97	1.00	0.99	0.98	0.90	0.98	0.98	0.97								
CR_Post Yr3	0.99	1.00	0.98	0.98	1.00	0.99	1.00	0.99	1.00	0.95							
CR_Post Yr4	0.97	0.98	0.94	0.96	0.98	1.00	0.98	0.97	0.98	0.91	0.99						
CON_Pre	0.99	1.00	0.97	0.98	0.99	0.99	0.99	0.99	1.00	0.95	1.00	0.99					
CON_Post Yr1a	0.96	0.98	0.93	0.95	0.97	1.00	0.97	0.96	0.98	0.90	0.99	1.00	0.99				
CON_Post Yr1b	0.99	1.00	0.97	0.98	0.99	0.99	0.99	0.99	0.99	0.94	1.00	1.00	1.00	0.99			
CON_Post Yr2	1.00	1.00	1.00	1.00	1.00	0.97	1.00	1.00	1.00	0.98	0.99	0.97	0.99	0.97	0.99		
CON_Post Yr3	0.98	0.99	0.96	0.97	0.99	1.00	0.99	0.98	0.99	0.94	1.00	1.00	1.00	1.00	1.00	0.99	
CON_Post Yr4	1.00	1.00	1.00	1.00	1.00	0.96	1.00	1.00	1.00	0.99	0.99	0.96	0.99	0.95	0.98	1.00	0.98

There was a common similarity of close to 83% for all sites and years in the distribution of lifespan trait categories, although above that level some variability was evident with three broad clusters at 88% similarity reflecting the temporal and spatial differences highlighted above (Figure 55). However, the

MDS plot in Figure 56 indicate that the patterns highlighted in the dendrogram are not strongly related to factors considered here.

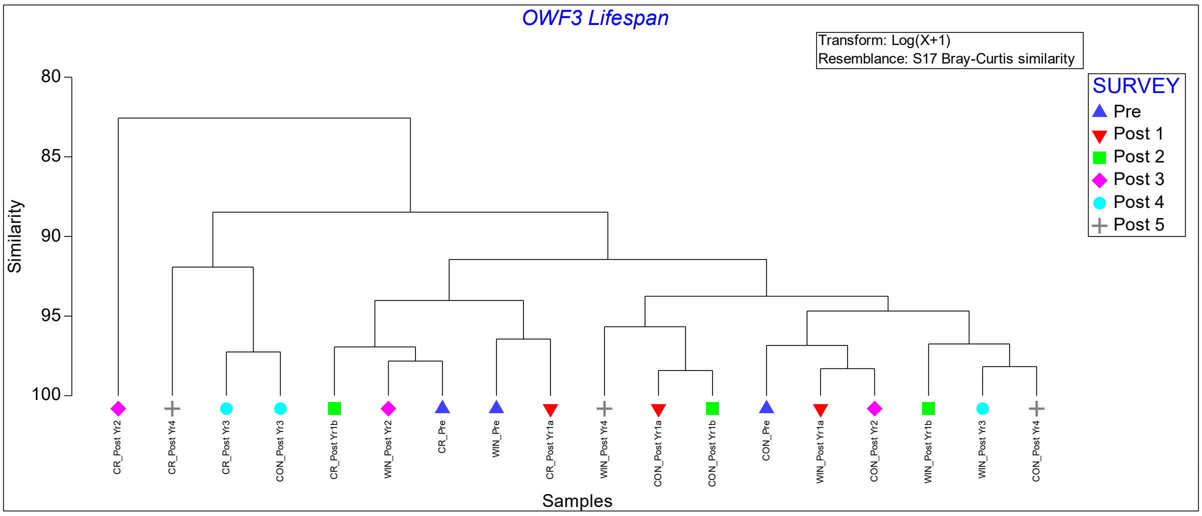

Figure 55. Dendrogram showing the relative similarities in OWF3 benthic communities in relation to four lifespan trait categories.

Figure 56. MDS showing the relative similarities in OWF3 benthic communities in relation to lifespan trait categories compared to factors: (a) Year; (b) Site Group; (c) % Fines.

Analysis by PERMANOVA indicated no difference between individual years for overall survey data (p = 0.423), although when site grouping was considered differences between WIN and CR (p=0.047) and WIN and CON (p= 0.048) were evident.

When the distribution of the lifespan categories was examined in relation to % fines only weak correlations were evident (Figure 57) and when analysed by PERMANOVA no significant differences were evident in distribution of lifespan categories in relation to proportion of fines across the study as a whole (p=0.210).

Overall, while there may be some influence of the construction of the wind farm on the spatial and temporal patterns in fines at wind farm sites, although these likely insignificant compared to natural variability. Consequently, it is considered that there are no impacts associated with the development in relation the relative dominance of the lifespan categories across the study area with any spatial or temporal variability observed being considered to be driven by natural factors.

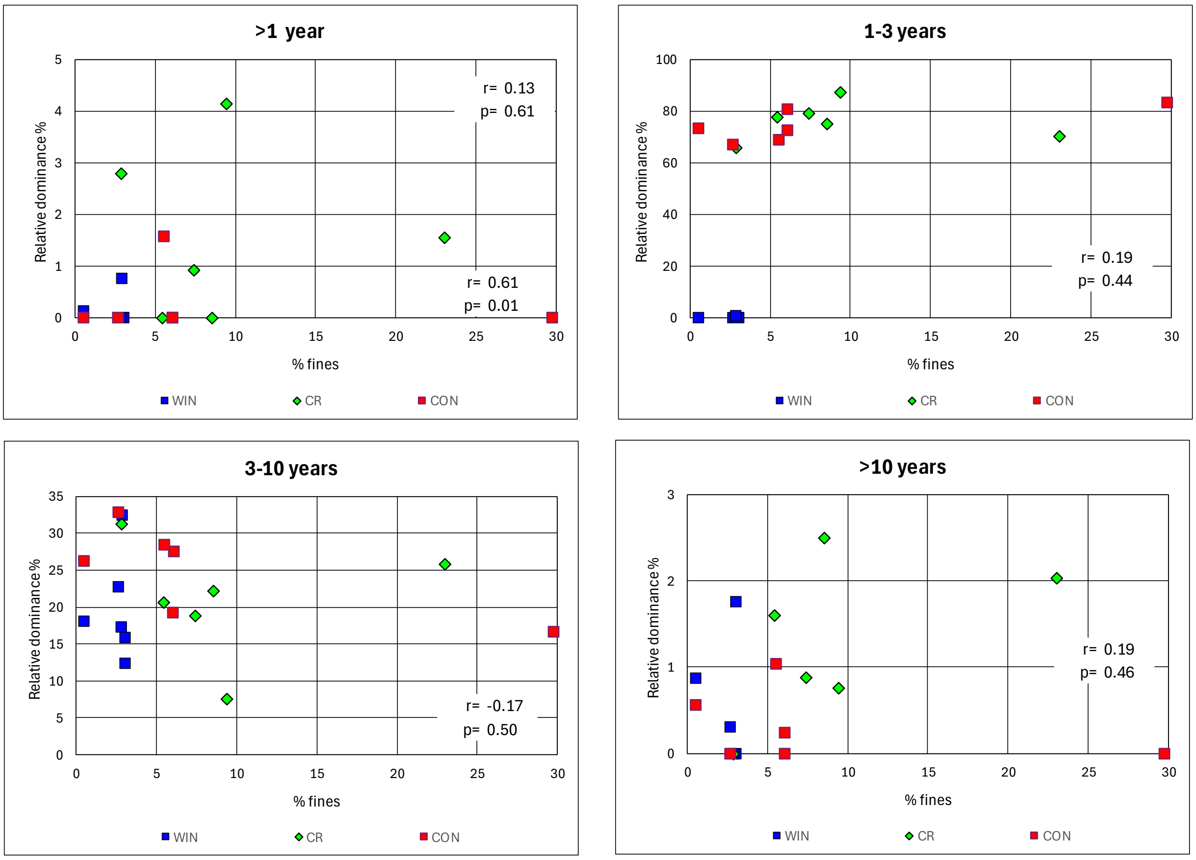

Figure 57. Mean relative dominance represented by each lifespan category by % fines and site grouping. (Correlation co-efficient and p-value for combined data indicated)

4.3.3 Living habitat

Generally, across the site groupings and all years free living taxa represented the highest proportion of the communities recorded contributing on average 45.9 % of all individuals across the study period (annual range = 25.1 % to 59.5%), while tube dwelling taxa represented on average 42.8% (annual range = 23.9% to 59.6%) (Table 30). Overall, no consistent temporal patterns were evident in the relative dominance represented by any of the trait categories and while some variation was evident, the magnitude of changes overall are relatively small and the distribution of living habitat categories remain consistent throughout the study period and across the study area indicted by the predominantly very strong correlations evident between sites and years (Table 31). However, some weak to moderate correlations were evident particularly for CON in post-construction years 3 and 4 and other sites out with the array, although it should be noted that this included comparisons with CON post-construction year 2.

Table 30. Relative dominance represented by each living habitat category by year and site grouping. Shading is proportional to the values from 0% (no shading) to 100% (full shading).

Trait	Category	WIN						CR					
		Pre	Post Yr1a	Post Yr1b	Post Yr2	Post Yr3	Post Yr4	Pre	Post Yr1a	Post Yr1b	Post Yr2	Post Yr3	Post Yr4
Living habitat	Tube dwelling	61.4	52.6	69.9	64.5	29.5	22.9	46.1	41.2	43.6	55.0	44.6	33.5
	Burrow dwelling	1.4	0.6	1.1	2.0	0.0	0.0	7.1	4.5	5.3	18.8	9.2	6.0
	Free-living	29.9	39.0	27.7	27.4	53.8	62.4	41.5	48.4	44.5	16.4	39.7	54.5
	Crevice/hole/under stones	2.2	1.6	0.4	3.5	0.0	11.5	1.0	1.0	2.2	4.4	2.0	3.0
	Epi/endo-biotic	2.6	1.0	0.9	2.4	0.0	3.2	1.7	3.9	2.1	4.7	2.6	3.0
	Attached to substratum	2.5	5.2	0.0	0.2	0.0	0.0	2.6	0.9	2.3	0.7	1.9	0.0

Trait	Category	CON					
		Pre	Post Yr1a	Post Yr1b	Post Yr2	Post Yr3	Post Yr4
Living habitat	Tube dwelling	50.6	36.4	35.3	59.4	8.4	15.4
	Burrow dwelling	1.4	0.0	0.0	0.5	2.1	17.7
	Free-living	43.3	57.7	63.5	31.5	84.9	59.4
	Crevice/hole/under stones	0.7	2.3	0.0	3.3	2.3	3.7
	Epi/endo-biotic	0.7	1.7	0.0	3.7	2.3	3.7
	Attached to substratum	3.3	1.9	1.1	1.6	0.0	0.0

Table 31. Pearson correlation coefficients for comparisons of distribution of living habitat categories by year and site grouping. Shading is proportional to the values from 0 (no shading) to 1 (full shading).

	WIN_Pre	WIN_Post Yr1a	WIN_Post Yr1b	WIN_Post Yr2	WIN_Post Yr3	WIN_Post Yr4	CR_Pre	CR_Post Yr1a	CR_Post Yr1b	CR_Post Yr2	CR_Post Yr3	CR_Post Yr4	CON_Pre	CON_Post Yr1a	CON_Post Yr1b	CON_Post Yr2	CON_Post Yr3
WIN_Post Yr1a	0.97																
WIN_Post Yr1b	1.00	0.95															
WIN_Post Yr2	1.00	0.95	1.00														
WIN_Post Yr3	0.72	0.86	0.67	0.68													
WIN_Post Yr4	0.55	0.72	0.49	0.51	0.96												
CR_Pre	0.93	0.98	0.91	0.91	0.91	0.78											
CR_Post Yr1a	0.86	0.95	0.83	0.83	0.97	0.88	0.98										
CR_Post Yr1b	0.91	0.97	0.87	0.88	0.94	0.84	1.00	0.99									
CR_Post Yr2	0.91	0.82	0.94	0.93	0.49	0.28	0.80	0.68	0.74								
CR_Post Yr3	0.93	0.98	0.91	0.91	0.90	0.77	1.00	0.98	0.99	0.81							
CR_Post Yr4	0.75	0.87	0.70	0.71	1.00	0.95	0.93	0.98	0.96	0.54	0.93						
CON_Pre	0.95	1.00	0.92	0.93	0.90	0.78	0.99	0.98	0.99	0.78	0.99	0.91					
CON_Post Yr1a	0.77	0.89	0.72	0.73	1.00	0.95	0.93	0.98	0.96	0.53	0.92	0.99	0.93				
CON_Post Yr1b	0.73	0.86	0.67	0.68	1.00	0.96	0.91	0.97	0.95	0.49	0.91	0.99	0.91	1.00			
CON_Post Yr2	1.00	0.98	0.99	0.99	0.75	0.59	0.94	0.88	0.92	0.89	0.94	0.77	0.96	0.79	0.75		
CON_Post Yr3	0.34	0.54	0.27	0.28	0.89	0.96	0.64	0.76	0.70	0.07	0.63	0.87	0.62	0.86	0.89	0.38	
CON_Post Yr4	0.41	0.58	0.35	0.36	0.90	0.92	0.70	0.80	0.75	0.23	0.71	0.90	0.66	0.86	0.89	0.44	0.96

There was a common similarity of close to 73% for all sites and years in the distribution living habitat trait categories, although above that level some variability was evident reflecting the temporal and spatial differences highlighted above (Figure 58). However, the MDS plot in Figure 59 indicate that the patterns highlighted in the dendrogram are not strongly related to factors considered here.

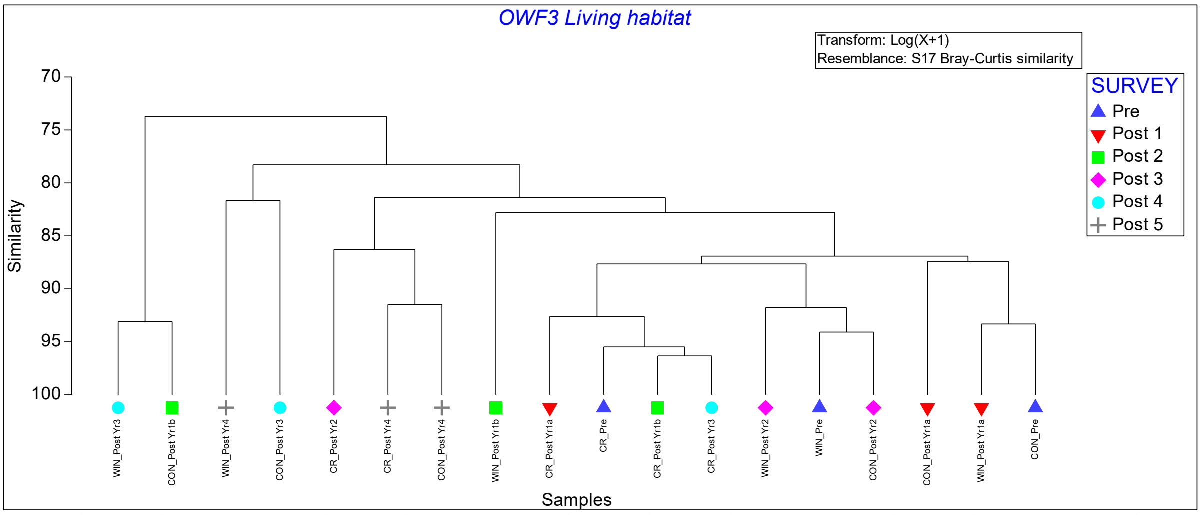

Figure 58. Dendrogram showing the relative similarities in OWF3 benthic communities in relation to six living habitat trait categories.

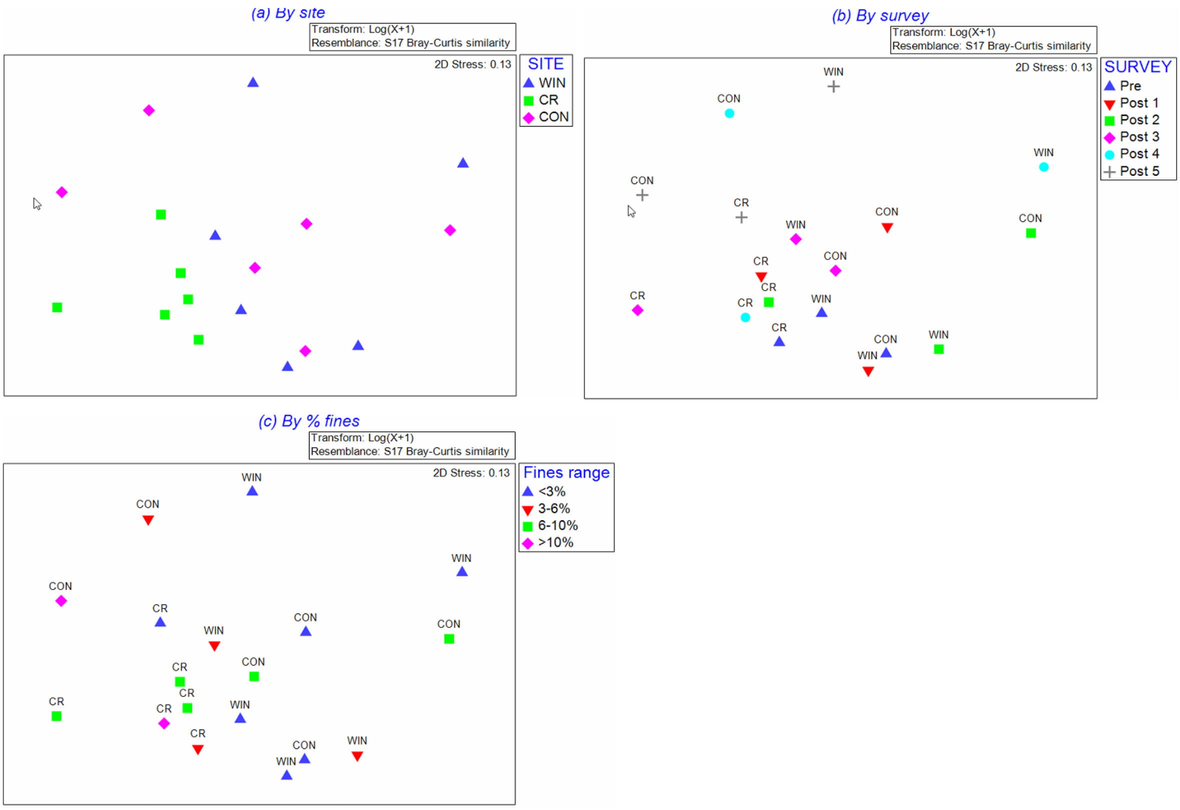

Figure 59. MDS showing the relative similarities in OWF3 benthic communities in relation to living habitat trait categories compared to factors: (a) Year; (b) Site Group; (c) % Fines.

Analysis by PERMANOVA indicated no difference between individual surveys for overall survey data (p = 0.093). Similarly, no difference between individual site groups across the study were evident (p = 0.095).

When the distribution of the living habitat categories was examined in relation to % fines a strong positive correlation with burrow dwelling fauna (r=0.73, p=<0.01), although no significant relationships with other size categories living habitat % fines were evident (Figure 60). When analysed by

PERMANOVA no significant differences were evident in relation to proportion of fines across the study as a whole (p=0.164).

Overall, while there may be some influence of the construction of the wind farm on the spatial and temporal patterns in fines at wind farm sites, although these likely insignificant compared to natural variability. Consequently, it is considered that there are no impacts associated with the development in relation the relative dominance of the living habitat categories across the study area with any spatial or temporal variability observed being considered to be driven by natural factors.

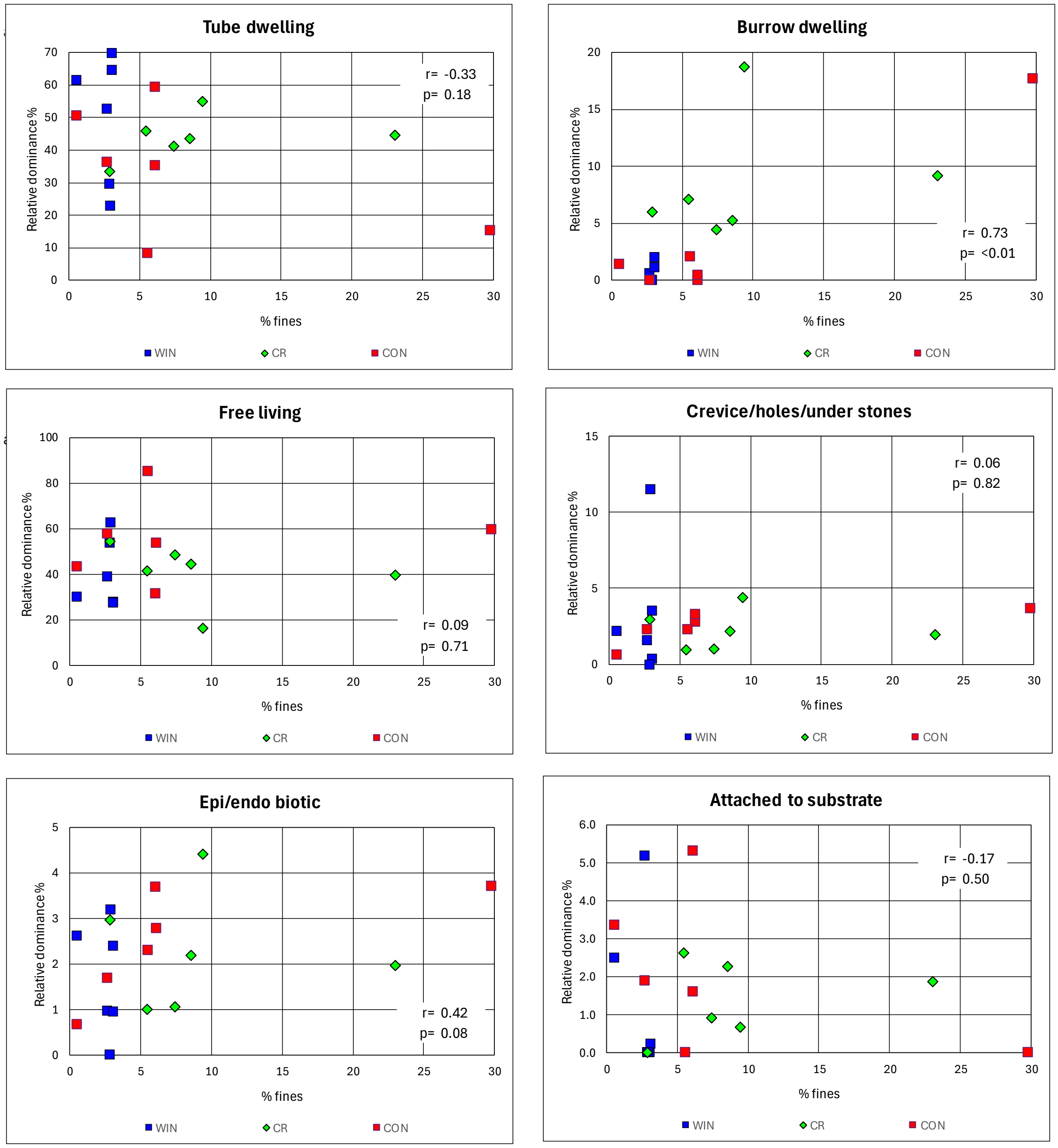

Figure 60. Mean relative dominance represented by each living habitat category by % fines and site grouping. (Correlation co-efficient and p-value for combined data indicated)

4.3.4 Sediment position

Generally, across the site groupings and all years, surface dwelling taxa represented the highest proportion of the communities recorded contributing on average 51.4% of all individuals across the study period (annual range = 41.4 % to 58.9%). Shallow infauna represented on average 25.7% (annual range = 21.7% to 28.5%), while mid depth dwelling taxa represented 19.0% (annual range = 15.4% to 21.6%) of fauna (Table 32). No clear temporal patterns were evident in the relative dominance represented by any of the trait categories and while some variation was evident, the magnitude of changes overall were small and the distribution of sediment position categories remain consistent throughout the study period and across the study area indicted by the consistently very strong correlations evident between sites and years (Table 33).

Table 32. Relative dominance represented by each sediment position category by year and site grouping. Shading is proportional to the values from 0% (no shading) to 100% (full shading).

Trait	Category	WIN						CR					
		Pre	Post Yr1a	Post Yr1b	Post Yr2	Post Yr3	Post Yr4	Pre	Post Yr1a	Post Yr1b	Post Yr2	Post Yr3	Post Yr4
Sediment position	Surface	45.1	58.1	59.2	58.7	30.8	53.0	48.3	55.7	58.0	51.3	53.7	42.7
	Shallow infauna	32.2	22.9	20.3	21.4	28.8	25.3	25.4	22.7	25.9	24.6	23.2	29.6
	Mid-depth infauna	21.3	18.8	18.8	18.3	21.9	21.1	21.4	16.9	13.7	14.4	17.1	21.3
	Deep infauna	1.4	0.2	1.8	1.6	1.9	0.6	5.0	4.7	2.4	9.8	6.0	6.3

Trait	Category	CON					
		Pre	Post Yr1a	Post Yr1b	Post Yr2	Post Yr3	Post Yr4
Sediment position	Surface	55.4	39.4	54.6	66.6	39.7	54.1
	Shallow infauna	26.3	30.8	26.8	19.2	33.4	23.0
	Mid-depth infauna	15.7	29.1	17.4	13.6	25.3	16.9
	Deep infauna	2.6	0.7	1.1	0.6	1.7	5.9

Table 33. Pearson correlation coefficients for comparisons of distribution of sediment position categories by year and site grouping. Shading is proportional to the values from 0 (no shading) to 1 (full shading).

	WIN_Pre	WIN_Post Yr1a	WIN_Post Yr1b	WIN_Post Yr2	WIN_Post Yr3	WIN_Post Yr4	CR_Pre	CR_Post Yr1a	CR_Post Yr1b	CR_Post Yr2	CR_Post Yr3	CR_Post Yr4	CON_Pre	CON_Post Yr1a	CON_Post Yr1b	CON_Post Yr2	CON_Post Yr3
WIN_Post Yr1a	0.94																
WIN_Post Yr1b	0.91	1.00															
WIN_Post Yr2	0.92	1.00	1.00														
WIN_Post Yr3	0.96	0.81	0.76	0.78													
WIN_Post Yr4	0.97	0.99	0.98	0.99	0.86												
CR_Pre	0.97	1.00	0.99	0.99	0.86	1.00											
CR_Post Yr1a	0.92	1.00	1.00	1.00	0.77	0.98	0.98										
CR_Post Yr1b	0.93	0.99	0.98	0.99	0.79	0.98	0.98	0.99									
CR_Post Yr2	0.90	0.98	0.98	0.98	0.73	0.96	0.96	0.99	1.00								
CR_Post Yr3	0.92	1.00	1.00	1.00	0.77	0.98	0.98	1.00	1.00	0.99							
CR_Post Yr4	1.00	0.96	0.94	0.95	0.93	0.98	0.98	0.95	0.96	0.93	0.95						
CON_Pre	0.95	0.99	0.98	0.99	0.82	0.99	0.99	0.99	1.00	0.99	1.00	0.97					
CON_Post Yr1a	0.95	0.85	0.82	0.83	0.98	0.90	0.90	0.81	0.81	0.75	0.81	0.94	0.84				
CON_Post Yr1b	0.96	0.99	0.98	0.99	0.85	0.99	1.00	0.99	0.99	0.98	0.99	0.98	1.00	0.87			
CON_Post Yr2	0.88	0.99	0.99	0.99	0.72	0.97	0.97	1.00	0.99	0.99	1.00	0.92	0.98	0.76	0.98		
CON_Post Yr3	0.98	0.87	0.83	0.84	0.99	0.91	0.91	0.83	0.85	0.79	0.83	0.96	0.87	0.99	0.90	0.79	
CON_Post Yr4	0.92	1.00	1.00	1.00	0.77	0.98	0.98	1.00	1.00	0.99	1.00	0.94	0.99	0.80	0.99	1.00	0.83

There was a common similarity of over 90% for all sites and years in the distribution of sediment position trait categories reflecting the high level of correlation between sites and surveys highlighted above (Figure 61). The MDS plot in Figure 62 indicate that and small variations highlighted in the dendrogram are not related to factors considered here.

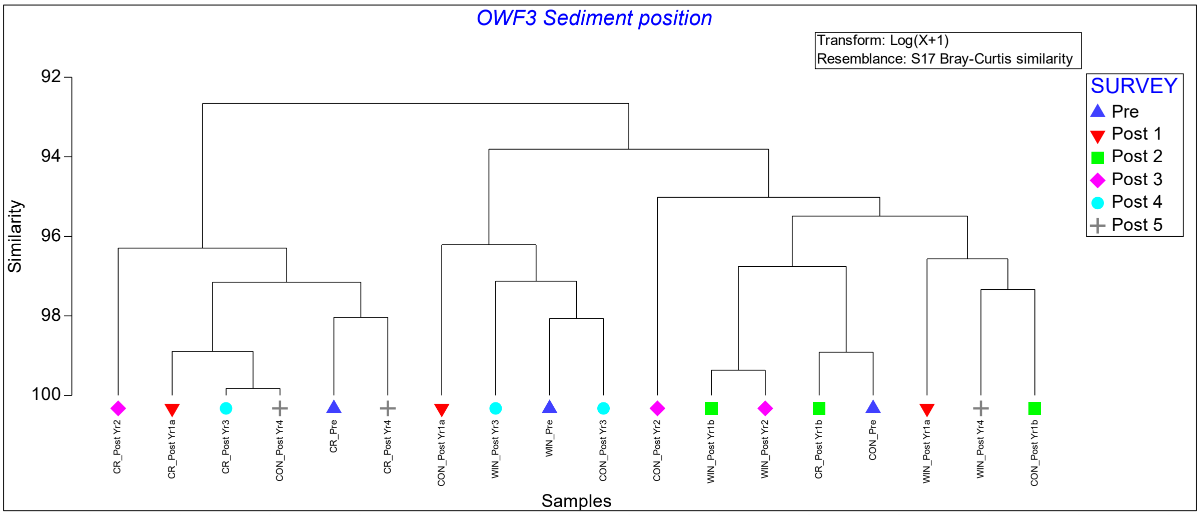

Figure 61. Dendrogram showing the relative similarities in OWF3 benthic communities in relation to sediment position trait categories.

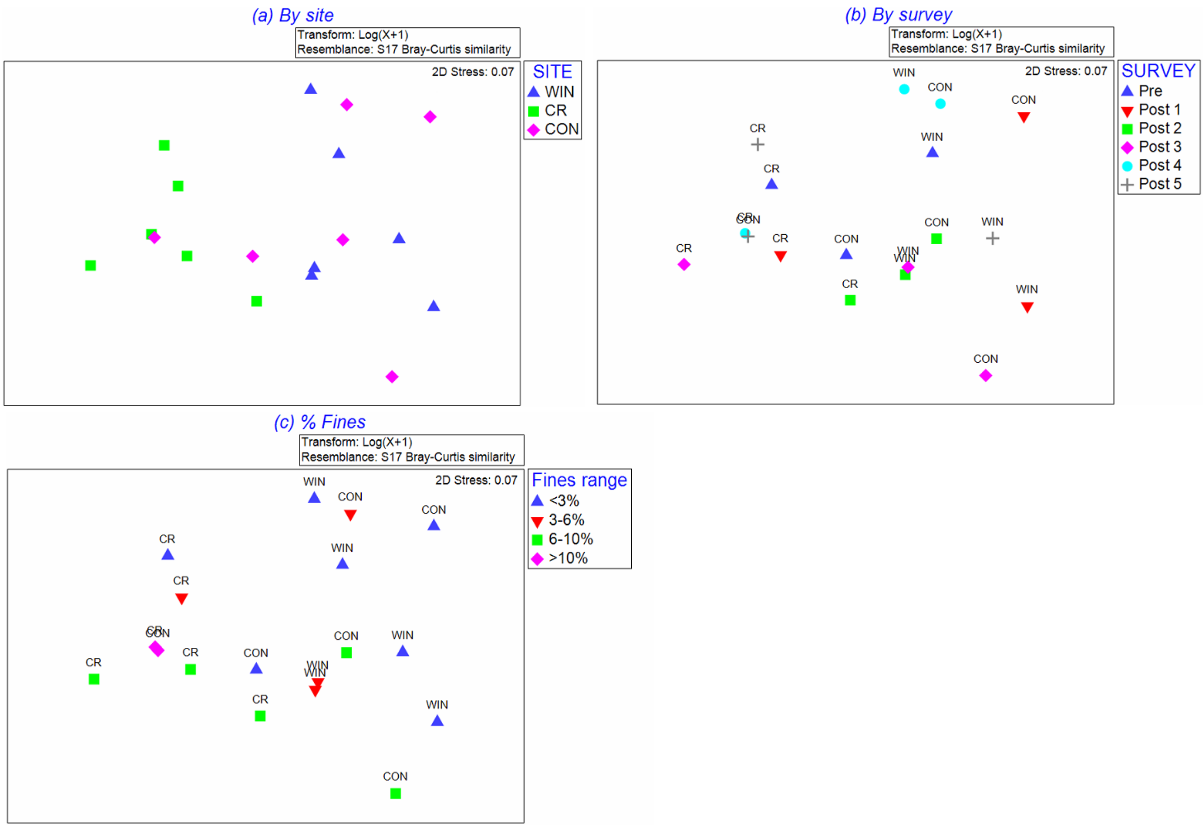

Figure 62. MDS showing the relative similarities in OWF3 benthic communities in relation to sediment position trait categories compared to factors: (a) Year; (b) Site Group; (c) % Fines.

Analysis by PERMANOVA indicated no difference between individual surveys for overall survey data (p = 0.686). Similarly, no difference between individual site groups across the study were evident (p = 0.095).

When the distribution of the sediment position categories was examined in relation to % fines a moderate positive correlation with deep infauna (r=0.52, p=0.03), although no significant relationships with other sediment position categories and % fines were evident (Figure 63). When analysed by

PERMANOVA no significant differences were evident in relation to proportion of fines across the study as a whole (p=0.167).

Overall, while there may be some influence of the construction of the wind farm on the spatial and temporal patterns in fines at wind farm sites, although these likely insignificant compared to natural variability. Consequently, it is considered that there are no impacts associated with the development in relation the relative dominance of the sediment position categories across the study area with any spatial or temporal variability observed being considered to be driven by natural factors.

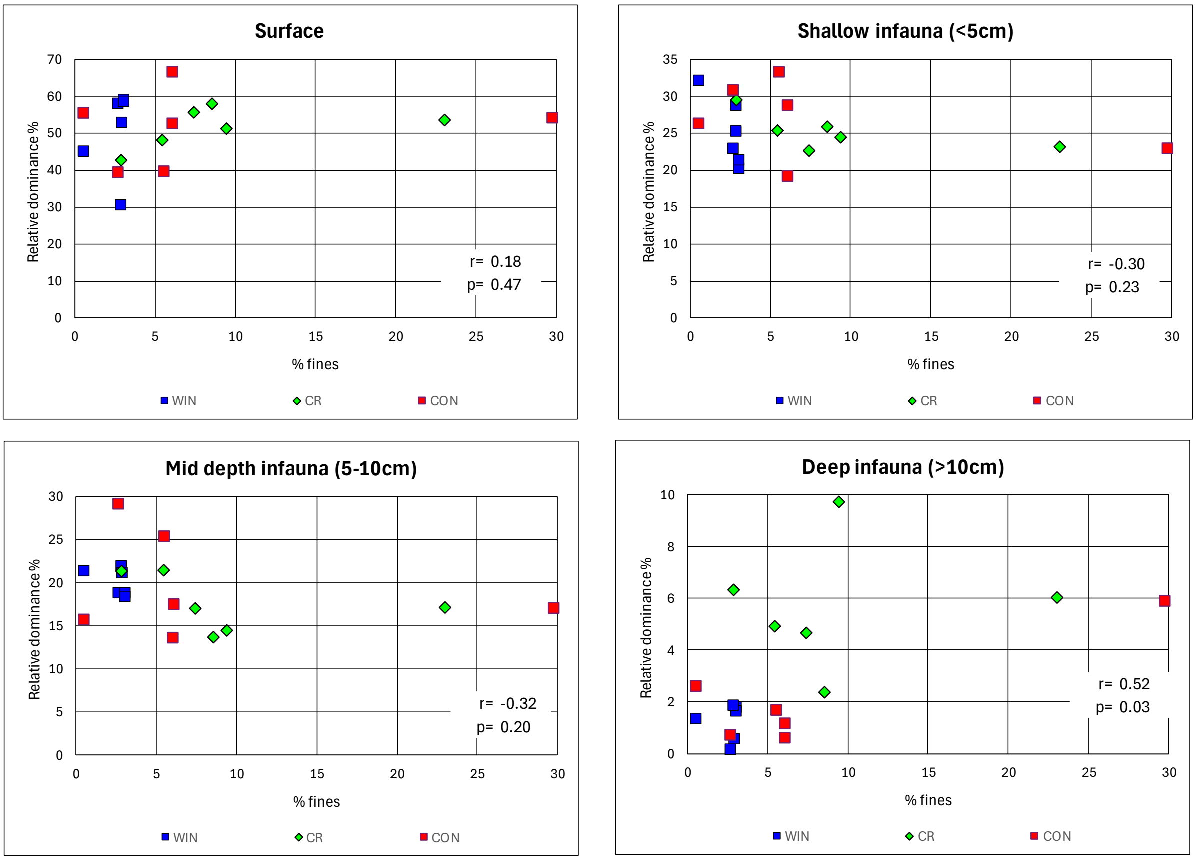

Figure 63. Mean relative dominance represented by each sediment position category by % fines and site grouping. (Correlation co-efficient and p-value for combined data indicated)

4.3.5 Feeding mode

Generally, across the site groupings and all years, suspension feeders represented the highest proportion of the communities recorded contributing on average 37.0% of all individuals across the study period (annual range = 24.4 % to 49.2%). Predators represented on average 23.7% (annual range = 14.8% to 33.3%), while scavengers represented 22.3% (annual range = 13.4% to 33.1%) of fauna (

Table 34). No clear spatial or temporal patterns were evident in the relative dominance represented by any of the trait categories and while some variation was evident, the magnitude of changes overall were small and the distribution of feeding mode categories remain consistent throughout the study period and across the study area indicted by the predominantly strong to very strong correlations evident between sites and years (Table 35).

Table 34. Relative dominance represented by each feeding mode category by year and site grouping. Shading is proportional to the values from 0% (no shading) to 100% (full shading).

Trait	Category	WIN						CR					
		Pre	Post Yr1a	Post Yr1b	Post Yr2	Post Yr3	Post Yr4	Pre	Post Yr1a	Post Yr1b	Post Yr2	Post Yr3	Post Yr4
Feeding mode	Suspension	37.3	50.3	50.3	47.1	23.8	23.4	31.2	39.3	39.3	45.4	46.5	34.5
	Surface depo	13.4	1.7	6.6	4.3	5.6	1.1	13.0	6.5	8.6	21.0	7.9	8.8
	Sub-surface d	22.4	6.6	20.1	17.0	5.7	0.0	17.5	8.4	6.4	18.0	5.9	0.0
	Scavenger	13.1	20.6	11.5	15.4	24.1	37.7	18.6	21.6	20.1	7.2	19.1	28.1
	Predator	13.8	20.8	11.5	16.3	24.1	37.7	19.8	24.1	25.5	8.4	20.6	28.6
	Parasite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Trait	Category	CON					
		Pre	Post Yr1a	Post Yr1b	Post Yr2	Post Yr3	Post Yr4
Feeding mode	Suspension	49.2	32.1	34.8	55.1	10.3	15.4
	Surface depo	12.2	2.5	5.2	5.6	9.0	8.9
	Sub-surface d	1.0	4.9	3.4	1.9	0.0	8.9
	Scavenger	18.7	30.2	24.1	17.7	39.8	33.4
	Predator	19.0	30.2	32.5	19.8	40.9	33.4
	Parasite	0.0	0.0	0.0	0.0	0.0	0.0

Table 35. Pearson correlation coefficients for comparisons of distribution of feeding mode categories by year and site grouping. Shading is proportional to the values from 0 (no shading) to 1 (full shading).

	WIN_Pre	WIN_Post Yr1a	WIN_Post Yr1b	WIN_Post Yr2	WIN_Post Yr3	WIN_Post Yr4	CR_Pre	CR_Post Yr1a	CR_Post Yr1b	CR_Post Yr2	CR_Post Yr3	CR_Post Yr4	CON_Pre	CON_Post Yr1a	CON_Post Yr1b	CON_Post Yr2	CON_Post Yr3
WIN_Post Yr1a	0.80																
WIN_Post Yr1b	0.96	0.89															
WIN_Post Yr2	0.93	0.95	0.98														
WIN_Post Yr3	0.50	0.81	0.51	0.66													
WIN_Post Yr4	0.20	0.62	0.23	0.42	0.95												
CR_Pre	0.92	0.87	0.86	0.91	0.79	0.56											
CR_Post Yr1a	0.77	0.98	0.82	0.91	0.90	0.73	0.91										
CR_Post Yr1b	0.75	0.96	0.79	0.88	0.90	0.73	0.90	0.99									
CR_Post Yr2	0.93	0.73	0.91	0.84	0.32	0.01	0.78	0.66	0.67								
CR_Post Yr3	0.82	0.99	0.88	0.94	0.80	0.60	0.89	0.98	0.98	0.77							
CR_Post Yr4	0.52	0.86	0.56	0.70	0.97	0.89	0.77	0.93	0.94	0.42	0.88						
CON_Pre	0.77	0.96	0.84	0.89	0.75	0.55	0.84	0.94	0.95	0.79	0.99	0.86					
CON_Post Yr1a	0.50	0.84	0.55	0.70	0.99	0.94	0.77	0.92	0.91	0.32	0.83	0.97	0.77				
CON_Post Yr1b	0.56	0.88	0.60	0.74	0.97	0.89	0.80	0.95	0.96	0.42	0.88	0.98	0.84	0.98			
CON_Post Yr2	0.79	0.99	0.88	0.93	0.75	0.55	0.84	0.95	0.95	0.78	0.99	0.84	0.99	0.78	0.84		
CON_Post Yr3	-0.07	0.30	-0.10	0.09	0.80	0.93	0.33	0.47	0.48	-0.25	0.31	0.72	0.28	0.76	0.70	0.24	
CON_Post Yr4	0.14	0.43	0.09	0.27	0.88	0.95	0.52	0.60	0.59	-0.09	0.43	0.78	0.37	0.84	0.77	0.35	0.97

There was a common similarity of over 80% for all sites and years in the distribution of sediment position trait categories reflecting the high level of correlation between sites and surveys highlighted above (Figure 64). The MDS plot in Figure 65 indicate that and small variations highlighted in the dendrogram are not related to factors considered here.

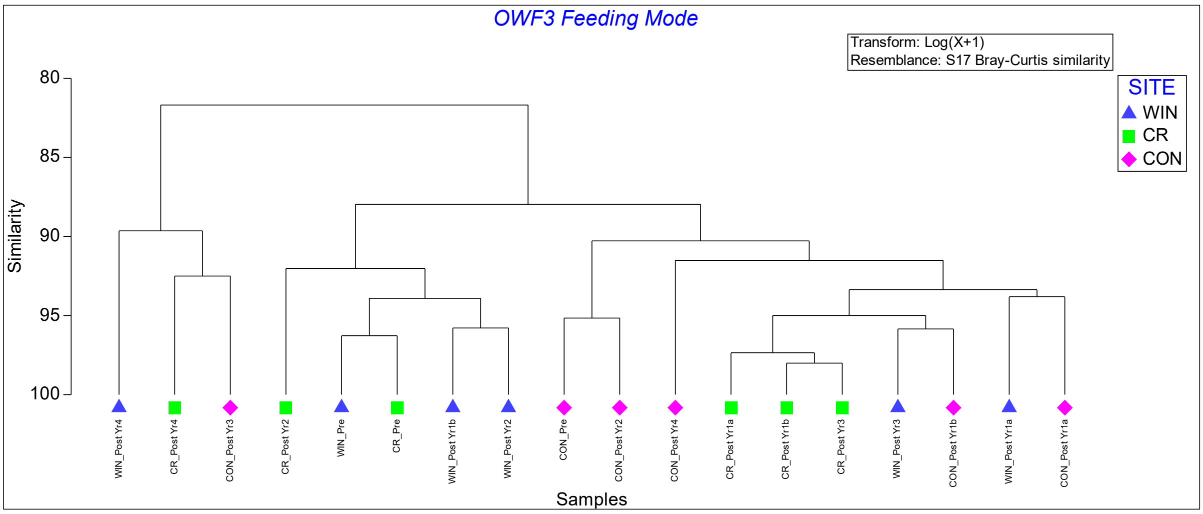

Figure 64. Dendrogram showing the relative similarities in OWF3 benthic communities in relation to feeding mode trait categories.

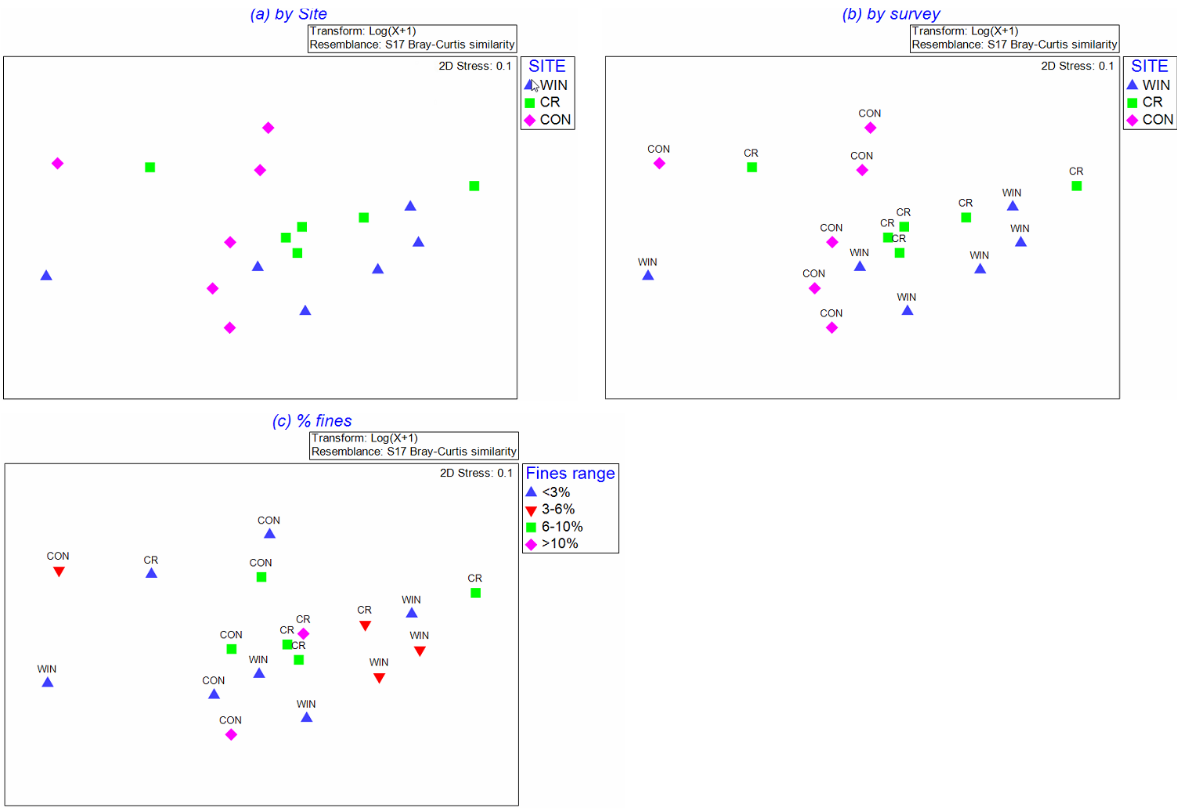

Figure 65. MDS showing the relative similarities in OWF3 benthic communities in relation to feeding mode trait categories compared to factors: (a) Year; (b) Site Group; (c) % Fines.

Analysis by PERMANOVA indicated no difference between individual surveys for overall survey data (p = 0.065). Similarly, no difference between individual site groups across the study were evident (p = 0.250).

When the distribution of the feeding mode categories was examined in relation to % fines only weak correlations were evident (Figure 66) and when analysed by PERMANOVA no significant differences were evident in distribution of lifespan categories in relation to proportion of fines across the study as a whole (p=0.133).

Overall, while there may be some influence of the construction of the wind farm on the spatial and temporal patterns in fines at wind farm sites, although these likely insignificant compared to natural variability. Consequently, it is considered that there are no impacts associated with the development in relation the relative dominance of the feeding mode categories across the study area with any spatial or temporal variability observed being considered to be driven by natural factors.

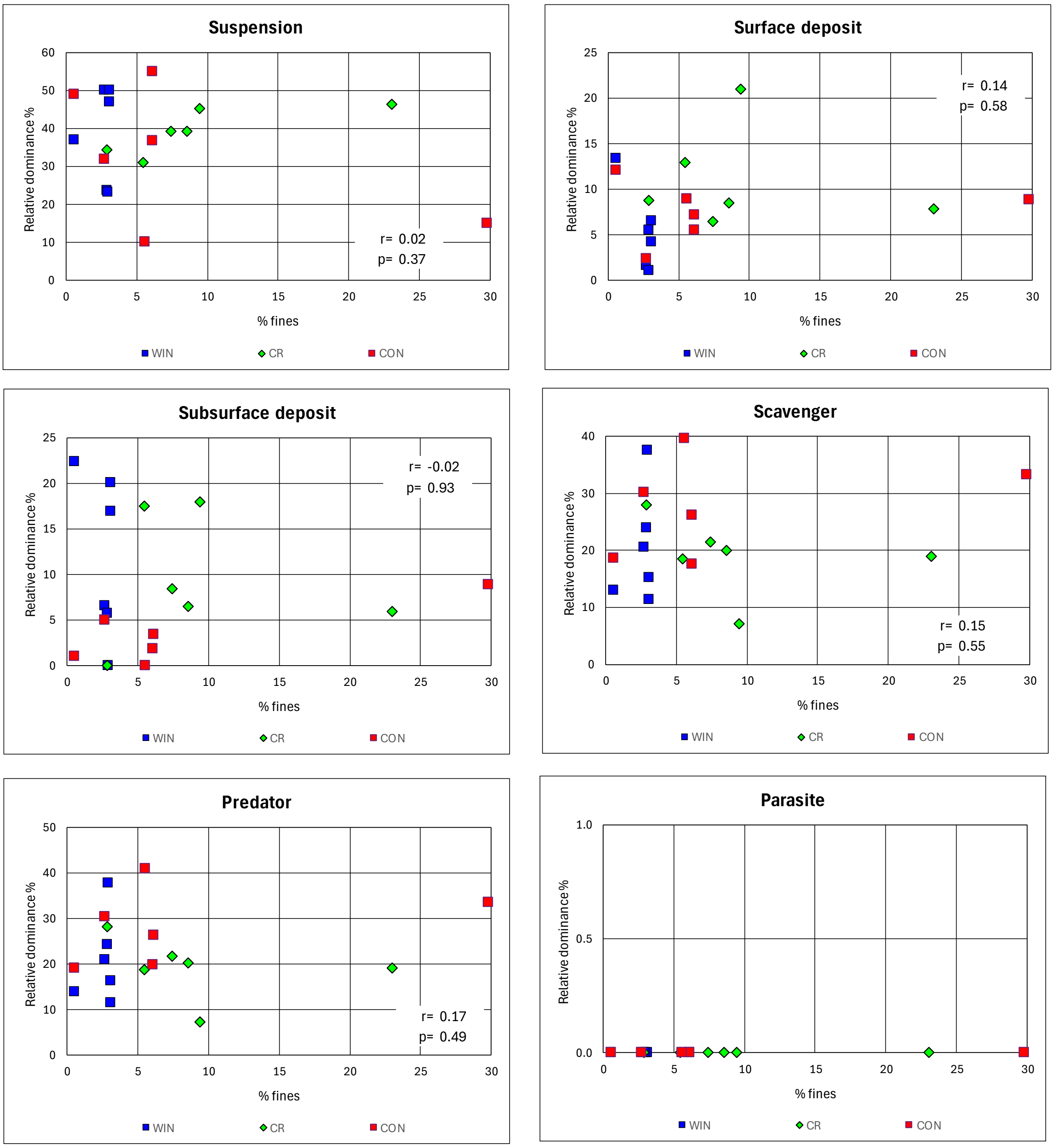

Figure 66. Mean relative dominance represented by each feeding mode category by % fines and site grouping. (Correlation co-efficient and p-value for combined data indicated)

4.3.6 Bioturbation

Generally, across the site groupings and all years the surface deposition category represented the highest proportion of the communities recorded contributing on average 67.2% of all individuals across the study period (annual range = 58.8 % to 72.2%). Diffusive mixing fauna represented on average 21.9% (annual range = 12.7% to 32.4%). No clear temporal patterns were evident in the relative dominance represented by any of the trait categories and while some variation was evident, the magnitude of changes overall were small and the distribution of bioturbation categories remain consistent throughout the study period and across the study area indicted by the consistently very strong correlations evident between sites and years (Table 37).

Table 36. Relative dominance represented by each bioturbation category by year and site grouping. Shading is proportional to the values from 0% (no shading) to 100% (full shading).

Trait	Category	WIN						CR					
		Pre	Post Yr1a	Post Yr1b	Post Yr2	Post Yr3	Post Yr4	Pre	Post Yr1a	Post Yr1b	Post Yr2	Post Yr3	Post Yr4
Bioturbation	Diffusive_mixing	11.1	16.8	10.6	10.4	29.7	25.5	16.3	28.8	15.9	15.8	27.0	36.9
	Surface_deposition	60.4	75.1	69.9	69.2	47.9	73.8	65.1	66.7	73.5	57.1	65.5	59.6
	Upward_conveyor	22.4	6.3	19.5	16.9	5.7	0.0	15.5	0.0	3.6	8.8	0.5	0.0
	Downward_conveyer	5.6	1.9	0.0	3.4	0.0	0.8	2.6	2.9	6.0	17.5	4.6	3.4
	None	0.5	0.0	0.0	0.1	0.0	0.0	0.5	1.6	0.9	0.8	2.3	0.0

Trait	Category	CON					
		Pre	Post Yr1a	Post Yr1b	Post Yr2	Post Yr3	Post Yr4
Bioturbation	Diffusive_mixing	17.4	26.5	25.0	11.9	34.3	34.9
	Surface_deposition	77.1	66.8	73.2	79.5	63.0	65.1
	Upward_conveyor	0.6	4.9	1.1	1.9	0.0	0.0
	Downward_conveyer	4.9	1.8	0.6	4.9	2.6	0.0
	None	0.0	0.0	0.0	1.9	0.0	0.0

Table 37. Pearson correlation coefficients for comparisons of distribution of bioturbation categories by year and site grouping. Shading is proportional to the values from 0 (no shading) to 1 (full shading).

	WIN_Pre	WIN_Post Yr1a	WIN_Post Yr1b	WIN_Post Yr2	WIN_Post Yr3	WIN_Post Yr4	CR_Pre	CR_Post Yr1a	CR_Post Yr1b	CR_Post Yr2	CR_Post Yr3	CR_Post Yr4	CON_Pre	CON_Post Yr1a	CON_Post Yr1b	CON_Post Yr2	CON_Post Yr3
WIN_Post Yr1a	0.95																
WIN_Post Yr1b	1.00	0.97															
WIN_Post Yr2	0.99	0.98	1.00														
WIN_Post Yr3	0.82	0.92	0.85	0.85													
WIN_Post Yr4	0.89	0.99	0.92	0.93	0.96												
CR_Pre	0.98	0.99	0.99	0.99	0.91	0.96											
CR_Post Yr1a	0.86	0.97	0.89	0.90	0.97	1.00	0.94										
CR_Post Yr1b	0.93	1.00	0.95	0.97	0.90	0.98	0.98	0.97									
CR_Post Yr2	0.92	0.96	0.92	0.95	0.86	0.94	0.95	0.93	0.98								
CR_Post Yr3	0.87	0.97	0.90	0.91	0.97	1.00	0.94	1.00	0.97	0.94							
CR_Post Yr4	0.78	0.91	0.81	0.82	0.99	0.96	0.88	0.98	0.91	0.87	0.98						
CON_Pre	0.92	1.00	0.94	0.96	0.91	0.99	0.97	0.98	1.00	0.97	0.98	0.92					
CON_Post Yr1a	0.90	0.98	0.93	0.94	0.97	1.00	0.97	0.99	0.98	0.94	0.99	0.97	0.98				
CON_Post Yr1b	0.90	0.99	0.93	0.94	0.96	1.00	0.96	1.00	0.99	0.94	1.00	0.96	0.99	1.00			
CON_Post Yr2	0.93	0.99	0.95	0.97	0.88	0.97	0.97	0.95	1.00	0.97	0.96	0.88	1.00	0.96	0.97		
CON_Post Yr3	0.82	0.94	0.85	0.86	0.99	0.98	0.91	0.99	0.93	0.89	0.99	1.00	0.94	0.98	0.98	0.91	
CON_Post Yr4	0.82	0.94	0.85	0.86	0.99	0.98	0.91	0.99	0.93	0.89	0.99	1.00	0.94	0.99	0.98	0.91	1.00

There was a common similarity of 80% for all sites and years in the distribution of sediment position trait categories reflecting the high level of correlation between sites and surveys highlighted above (Figure 67). The MDS plot (Figure 68) indicate that and small variations highlighted in the dendrogram are not related to factors considered here.

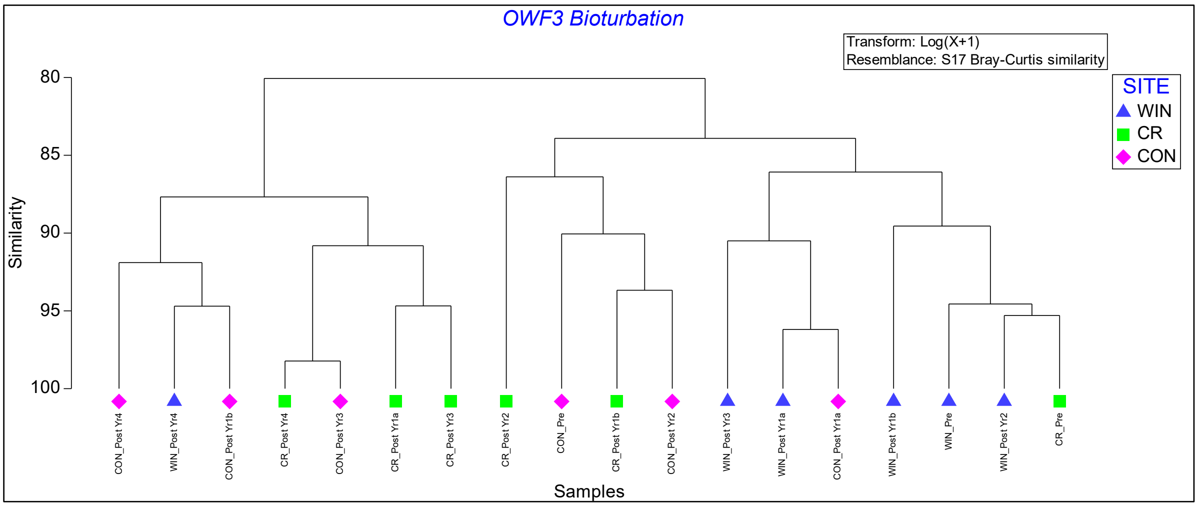

Figure 67.Dendrogram showing the relative similarities in OWF3 benthic communities in relation to bioturbation trait categories.

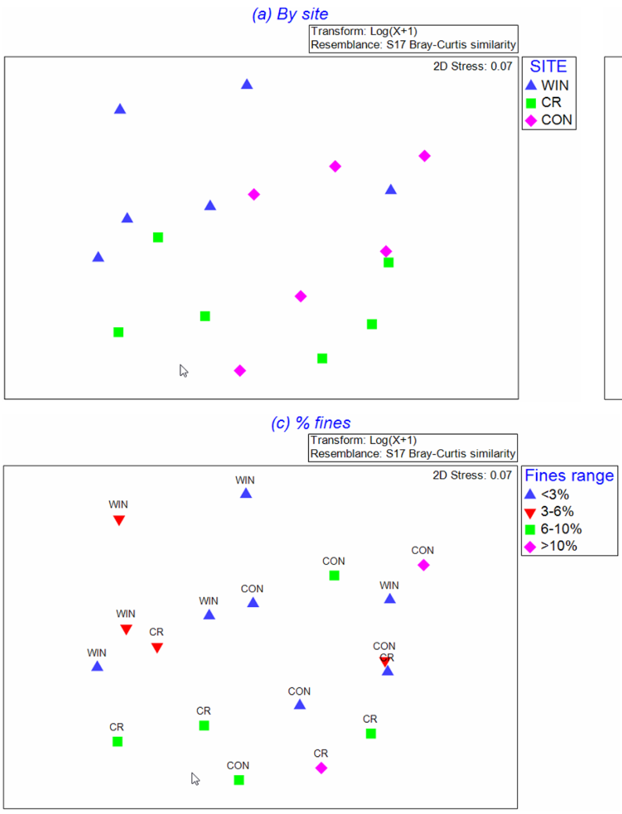

Figure 68. MDS showing the relative similarities in OWF3 benthic communities in relation to bioturbation trait categories compared to factors: (a) Year; (b) Site Group; (c) % Fines.

Analysis by PERMANOVA indicated no difference between individual surveys for overall survey data (p = 0.075). However, when looking at differences between sites a significant difference was determined in the overall study data (p = 0.037), although when examining individual differences between sites no significant differences were evident (p >0.05).

When the distribution of the bioturbation categories was examined in relation to % fines only weak correlations were evident (Figure 69) and when analysed by PERMANOVA no significant differences

were evident in distribution of lifespan categories in relation to proportion of fines across the study as a whole (p=0.133).

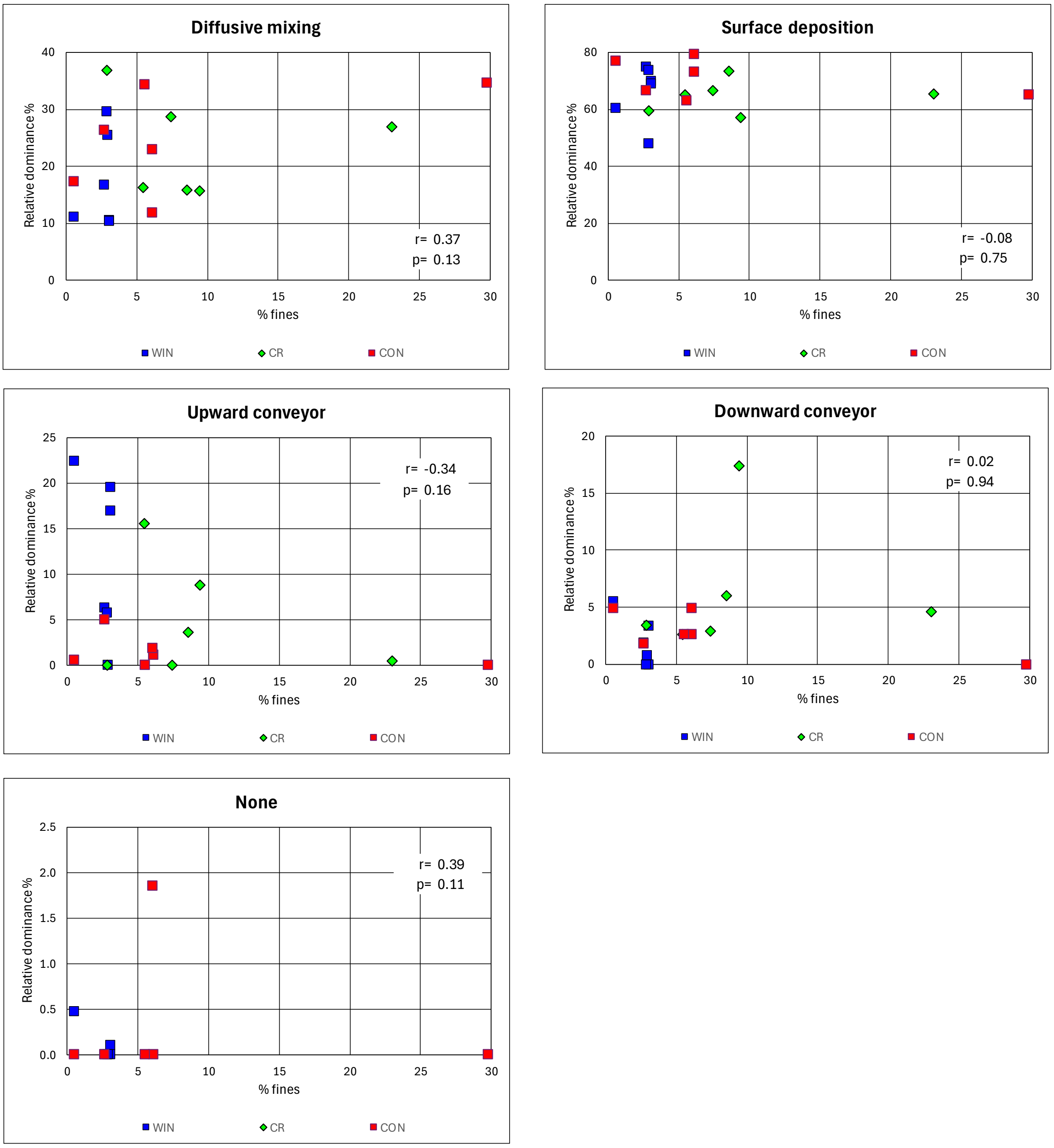

Figure 69. Mean relative dominance represented by each feeding mode category by % fines and site grouping. (Correlation co-efficient and p-value for combined data indicated)

Overall, while there may be some influence of the construction of the wind farm on the spatial and temporal patterns in fines at wind farm sites, although these likely insignificant compared to natural variability. Consequently, it is considered that there are no impacts associated with the development in relation the relative dominance of the bioturbation categories across the study area with any spatial or temporal variability observed being considered to be driven by natural factors.

4.3.7 Conclusions – OWF 3

For OWF 3, some spatial and temporal variability is evident in the traits data with the magnitude of any changes being proportionally small and showing no clear correlation with the OWF. Consequently, considering the magnitude of the observed changes and the lack of any clear driver, it is concluded that the spatial and temporal variability in the distribution of biological traits are related to natural factors with no measurable influence of OWF 3 evident. The original monitoring report also concluded that construction and operation had no detectable effect on sediment characteristics or faunal diversity.

5. Discussion

There do appear to be some temporal changes in sediment characteristics at the three wind farm sites considered here, although these changes are small, and, considering that the patterns were widespread and included control sites as well as those within the footprint of the wind farms or identified zone of influence, these are considered likely to be related to natural variability rather than any influence of the wind farm developments. Similarly, the relatively small variability seen within the distribution of the six traits investigated, a pattern evident in all 31 trait categories, would support this, and where some correlation between environmental change and biological trait change does occur the magnitude of change was within what would be expected under the influence of undisturbed biotic factors.

Any effects of organic enrichment would only become apparent once a threshold input of organic material is exceeded, beyond which a measurable effect can be detected. This threshold depends on the sediment conditions of the receiving environment (Tillin and Tyler-Walters, 2015), and it seems likely that such thresholds were not reached within the OWF sites studies here. However, this does not preclude the possibility of enrichment effects occurring at locations closer to turbine structures. Due to the distance of sampling stations from turbines at the sites considered here, such localised changes may have gone undetected. For example, Coates *et al.* (2013) reported increases in sediment organic content, along with increases in species richness, abundance, and biomass within 25 m of turbines in the North Sea, while Degraer *et al.* (2020) recorded increases in TOC close to turbine foundations (<50 m) three to six years after installation.

However, the monitoring programmes for the three OWF sites reviewed here did not conduct sampling closer than 50 m from any turbine. Consequently, it is recommended that future monitoring programmes associated with offshore wind farms should as standard incorporate sampling sites closer to the turbines than 50m and as close to the turbines as is practical and safe.

Much of the current understanding of macrofaunal benthic community responses to organic enrichment is related to the model proposed by Pearson and Rosenberg (1978) which describes a successional change in benthic communities from a total lack of fauna in grossly enriched conditions to high abundances of a few opportunistic species succeeding gradually with time and/or distance from the source of enrichment to greater species richness, larger species, lower abundances and increasingly complex sediment burrowing structures. Opportunists tend to be small, short lived rapidly reproducing species (r-selected) as opposed to the larger, longer lived slow growing less tolerant k-selected species which characterise undisturbed conditions (Pianka, 1970). Consequently, in organically enriched sediments, in addition to structural community changes functional changes would also be expected, such as changes in bioturbation rates, feeding types (Word, 1979). However, significant changes in functional traits such as maximum size, lifespan and bioturbation which may be expected in face of organic enrichment are not seen in the present study. Furthermore, where any change has been identified these do not follow and consistent spatial or temporal patterns related to the OWFs considered. Again, this does not preclude this occurring closer to turbines than the nearest sites (>50m) sampled in the monitoring programmes considered here.

Some variation in the relative dominance of specific categories was evident between OWF sites, with higher similarities highlighted between OWF1 and 2 compared to OWF3. However, this is considered to be related to natural environmental conditions as it has been highlighted that different environmental conditions are characterised by particular traits. For instance, in unimpacted assemblages of coarse sediments in shallower regions communities are proportionally dominated by the diffusive mixers, burrowers, scavengers and predators (Bolam *et al.*, 2017), and while this does not fully fit the data sets included here, there are enough similarities both biological and sedimentary to consider that the biological traits patterns in this study broadly fit this profile.

It is considered that the results here do not indicate any significant spatial or temporal effects and that any variability is driven by natural environmental factors, and it should be stressed that due to the fact that such factors covary it can be difficult to distinguish relationships between biological traits and specific causative effects. This may also be exacerbated by the survey which, for the OWFs considered, were not designed specifically with traits analysis in mind, which can reduce the power of the data collected to accurately identify any effect.

6. Conclusions

The biological traits analyses at all three OWF sites revealed similar conclusions in that the analyses suggest that OWF construction did not significantly change the biological traits of the benthic communities at the sites with any observed variability attributed to natural factors rather than construction disturbance. Common patterns emerged across various traits, particularly between OWF1 and OWF2, where medium to small-sized taxa dominated communities, with organisms possessing 3-10 yr lifespans consistently representing the majority of individuals. Free-living taxa predominated at both locations, while feeding mode distributions remained stable throughout the monitoring periods, with suspension and deposit feeders remaining dominant in both pre- and post-construction phases. Bioturbation communities were similarly structured at both sites, with diffusive mixers and surface depositors.

Some differences were evident between the patterns described above for OWF1 and OWF2 compared to those observed at OWF3. At OWF3 medium sized taxa dominated, while taxa with lifespans of 1-3 years were the most common. While free-living taxa were also important at OWF tube-dwelling taxa were the most abundant, although both groups could be considered as co-dominant. While suspension and deposit feeders remained the most dominant feeding modes scavengers and predators were slightly more prevalent at OWF3 than at the other two OWFs. However, these differences are related to natural environmental factors with faunal patterns at OWF3 driven by the high energy mobile sandy habitats being characterised by relatively sparse communities of low diversity dominated typical taxa such as amphipod crustacea and mobile polychaete species. However, it should be noted that, as with OWF1 and OWF2, little spatial or temporal variability was evident, and such variability is considered to be related to natural factors rather than any influence of the wind farm.

In general, where temporal or spatial variations in trait composition were detected, these patterns were also observed at control stations, suggesting that natural variability, rather than OWF-related impacts, was the primary driver of benthic community variability.

7. Limitations

In relation to the limitations of the study, the primary concern relates to the nature of the potential effects on benthic communities of changes in sedimentary characteristics associated with changes in fining of the sediment and increases in TOC in relation to potential changes in hydrodynamic regimes and material released by colonising epifauna on OWF infrastructure. In relation to fining of sediments lower grain size has been reported as a result in reduction in current speed close to the OWF (Leonhard and Pedersen, 2005). Similarly, increases in TOC have been reported in the vicinity of OWF foundations (Coates *et al.*, 2013). However, in both cases such observations were recorded within 25m of the foundations with no significant effects evident at greater distances. It should be noted that for samples considered in the present study none were collected closer than 50m from a turbine. Other studies have also noted that distant changes of altered current flow on particulate transport and organic enrichment might be difficult to measure, especially within dynamic environments subject to high natural variability (Wilding, 2014; Dannheim *et al.*, 2020). Consequently, it is considered that any significant influence of the OWFs on sediment characteristics in the present study are unlikely to be manifested at the sampling locations and that any observed patterns in the benthic community data will not be driven by OWF related sediment changes. To better assess any such influences sampling should be undertaken in closer proximity to foundations, ideally within 25m of any structures.

It should be considered that the monitoring programmes assessed here were not designed with the use of traits analysis in mind, and as such the power to detect change may be limited. Going forward, if the use to traits analysis is to be considered in any given monitoring programme the survey design should be informed by the subsequent analysis likely to be undertaken. With this in mind, proximity of sampling stations to turbines should be carefully considered to ensure that areas likely to be influenced by factors likely to modify sediment characteristics are encompassed.

Another limitation identified across the reviewed OWFs is the lack of robust pre-construction data, with most sites having only a single sampling event prior to construction. This poses challenges for trait-based approaches, which typically require comprehensive baseline datasets to reliably distinguish natural variability from changes induced by OWF development, and to link biological changes to shifts in ecosystem functioning. Given that the acquisition of additional pre-construction data is generally unfeasible due to temporal and financial constraints, alternative strategies must be employed, albeit with important limitations. These include the use of ecologically comparable reference sites, selected based on similarity in key environmental parameters (e.g., depth, substrate, salinity), to serve as proxies for baseline conditions. In addition, historical datasets, even if methodologically inconsistent or insufficient for formal statistical analyses, can still offer valuable context. When used cautiously, such data can provide insights into past community structure and trait composition. Trait-based analyses could be applied to historical datasets from the development area, where available, helping to frame observed changes within the broader envelope of natural variability.

Considerable temporal variability is evident in the data collected at control sites at all three wind farm sites. Such variability, allied to the limited number of reference sites sampled, undermines the robustness of the reference data against which any changes elsewhere can be compared. This has the consequence that identifying significant change and the drivers of any change more difficult. It is therefore recommended that additional control sites are incorporated in future studies to better quantify natural variability with power analysis being used to determine the appropriate sample size for a study in order to ensure that the monitoring programme has sufficient power to detect any effect.

Furthermore, the Cefas catalogue did not have all potential traits recorded for each taxon within the collated data sets. This may have led to a reduction in reliability and accuracy in analysis results. Other databases were considered to fill any gaps in trait data found in the Cefas catalogue, such as BIOTIC, however, these were unavailable at the time of this analysis. Moreover, the catalogue translates traits to genus level only, so any potential nuances at the species level would not be detected.

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Annex 4a Biological traits, categories and descriptions (Clare *et al*., 2022).

Trait	Category	Description
Maximum size (sr)	< 10	The maximum size (mm) that the taxon is known to reach during the adult stage.
	10–20	
	21–100	
	101–200	
	201–500	
	> 500	
Morphology (m)	Soft	External tissue is soft and not covered by any form of protective casing.
	Tunic	Body is covered by a protective outer tissue made up of, for example, cellulose, e.g., tunicates.
	Exoskeleton	Body is covered or encased in either a thin chitinous layer or calcium carbonate shell.
	Crustose	Body is hard and forms a thin layer over the substratum or another organism.
	Cushion	Body is soft and forms a cushion-like layer over the substratum or another organism.
	Stalked	Body is erect and typically attached.
Lifespan (l)	< 1	The maximum reported lifespan (years) of the adult stage of the taxon.
	1–3	
	3–10	
	> 10	
Egg development location (ed)	Asexual	Can reproduce asexually, either by fragmentation, budding, epitoky, etc.
	Sexual - pelagic	Eggs are released into the water column.
	Sexual - benthic	Eggs are released onto/into the seabed, either free or attached, e.g. by mucous.
	Sexual - brooded	Fertilised eggs are maintained by adult for protection, either within parental tube or body cavity.
Larva development location (ld)	Pelagic - planktotrophic	Larvae feed on plankton and spend a relatively long time in the water column.
	Pelagic - lecithotrophic	Larvae feed on yolk reserves and spend a relatively short time in the water column.
	Benthic (direct)	Larval stage missing (eggs develop directly into juveniles) or larvae are limited to the seabed.
Living habit (lh)	Tube-dwelling	Adults live in a tube, which may be lined with sand, mucus or calcium carbonate.
	Burrow-dwelling	Adults live in a permanent or temporary burrow.
	Free-living	Adults do not inhabit a restrictive structure. Able to move freely within and/or on sediments.
	Crevice/hole/under stones	Adults typically cryptic and inhabit spaces within coarse/rock substrate or algal holdfasts.

Trait	Category	Description
	Epi/endo-biotic	Adults live on or in another organism.
	Attached to substratum	Adults are attached to coarse substrate or rock.
Sediment position (sp)	Surface	Adults live on or just above the seabed.
	Shallow infauna	Adults live below sediment surface between 0 and 5 cm depth.
	Mid-depth infauna	Adults live below sediment surface between 5 and 10 cm depth.
	Deep infauna	Adults live below sediment surface at greater than 10 cm depth.
Feeding mode (f)	Suspension	Feeds on particulate food resources suspended in the water column.
	Surface deposit	Feeds on detritus (including algal material) on the sediment surface.
	Sub-surface deposit	Feeds on detritus located within the sediment matrix.
	Scavenger	Feeds on dead animals (carrion).
	Predator	Actively predates on animals (including small zooplankton).
	Parasite	Derives nutrition from its host organism.
Mobility (mob)	Sessile	Adults have little or no mobility. Typically attached or lives in (semi-) permanent burrow/tube.
	Swim	Adults actively swim in the water column (many return to the bed when not feeding).
	Crawl/creep/climb	Adults capable of some (typically limited) movement along the sediment or rock surface.
	Burrower	Adults capable of active movement within the sediment matrix.
Bioturbation mode (b)	Diffusive mixing	Vertical and horizontal redistribution of sediment and/or other particles.
	Surface deposition	Deposition of particles at sediment surface, e.g. from defecation or egestion (pseudofaeces).
	Upward conveyor	Translocation of particles from depth to sediment surface, e.g. during sub-surface deposit-feeding.
	Downward conveyor	The subduction of particles from sediment surface to depth, e.g. by feeding and/or defecation.
	None	Does not have any bioturbative capacity.

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