Cyfoeth Naturiol Cymru
Natural Resources Wales

Menai Strait and Conwy Bay SAC intertidal monitoring of muddy gravels, 2004-2019

Report No: 662

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Aquatic Survey & Monitoring Ltd. & Natural Resources Wales

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Contents

List of Figures

List of Tables

Crynodeb Gweithredol

Mae'r Gyfarwyddeb Cynefinoedd yn sefydlu y dylai rheolaeth Ardaloedd Cadwraeth Arbennig (ACA) anelu at gyflawni statws cadwraeth ffafriol nodweddion cynefinoedd a rhywogaethau a restrir ganddi yn Atodiad I a II. Ar gyfer Ardaloedd Cadwraeth Arbennig yng Nghymru, mae'n ofynnol felly i Cyfoeth Naturiol Cymru (CNC) adrodd yn rheolaidd ynghylch a yw nodweddion mewn statws cadwraeth ffafriol. Yn ACA Afon Menai a Bae Conwy, mae CNC a'i gontractwyr wedi datblygu rhaglenni monitro cyflwr nodweddion.

Mae ardaloedd o ddiddordeb penodol yn cynnwys fflatiau llaid a fflatiau tywod o fewn Afon Menai, lle mae amrywiaeth uchel o rywogaethau yn nodweddu rhai nodweddion. Mae'r adroddiad hwn yn disgrifio rhaglen fonitro a gynhaliwyd ar gynefinoedd graean lleidiog ar hyd arfordir gogledd-orllewin Afon Menai. Dechreuodd y rhaglen yn 2004 ac mae wedi cael ei hailadrodd o bryd i'w gilydd. Mae adroddiadau blaenorol wedi disgrifio prif nodweddion y cymunedau; mae'r adroddiad hwn yn disgrifio canlyniadau dadansoddiadau amseryddol ar gyfer y cyfnod 2004 i 2019.

Arolygwyd a samplwyd naw gorsaf fonitro, a nodweddir fel cynefin graean lleidiog. Casglwyd samplau craidd gwaddod ar gyfer dadansoddiad macroffawna, casglwyd samplau o waddod ar gyfer dadansoddi maint gronynnau, a chofnodwyd epibiota amlwg yn y fan a'r lle. Defnyddiwyd dadansoddiad o'r data canlyniadol i fonitro cyflwr y cymunedau.

Y canlyniadau mwyaf nodedig o'r dadansoddiadau amseryddol oedd y canlynol:

i) Nid yw'r data maint gronynnau gwaddod yn dangos llawer o newid rhwng arolygon, ac eithrio mewn un orsaf ym Mae Biwmares, lle roedd cyfran y ffracsiynau mân yn is yn y blynyddoedd diweddarach.

ii) Roedd y cyfoeth rhywogaethau (o samplau craidd) yn amrywio'n sylweddol rhwng arolygon, ond bu gostyngiad yn y cyfoeth a oedd yn arwyddocaol yn ystadegol rhwng 2016 a 2019. Nid yw'r rheswm dros y gostyngiad hwn yn hysbys. Digwyddodd gostyngiadau ym mron pob ffylwm ac nid oeddent yn ganlyniad (yn bennaf o leiaf) i wahaniaethau mewn gwahaniaethu ar sail tacsa gan ddadansoddwyr sampl. Nid oes unrhyw berthynas â data maint gronynnau gwaddod yn amlwg.

iii) Ni chanfuwyd unrhyw dueddiadau na gwahaniaethau nodedig mewn unrhyw fesurau amrywiaeth eraill. Fodd bynnag, roedd gwahaniaethau mawr yn nifer yr unigolion a gofnodwyd o samplau rhwng blynyddoedd mewn rhai gorsafoedd.

iv) Mae dadansoddiad amlamrywedd o ddata cymunedol (o samplau craidd) yn amlygu'r gwahaniaethau rhwng gorsafoedd ac yn awgrymu rhai tueddiadau gofodol (rhwng y gogledd a'r de) ac amser gwannach. Mae'r tueddiadau gofodol ac amser yn cael eu gyrru'n bennaf gan newidiadau yn y niferoedd o fwydod bach amrywiol, gyda rhai rhywogaethau'n fwy toreithiog yn y blynyddoedd cynnar ac eraill yn fwy niferus yn y blynyddoedd diweddarach.

v) Mae dadansoddiad o'r perthnasoedd rhwng data cymunedol a data amgylcheddol (maint gronynnau) yn canfod rhai cydberthnasau sy'n arwyddocaol

yn ystadegol, ond awgrymir y gallai newidynnau amgylcheddol eraill fod yn bwysicach ar gyfer egluro'r amrywioldeb biolegol.

vi) Disgrifir amrywiadau amseryddol mawr yn y doreth o dacsa unigol amrywiol, yn enwedig rhai mwydod bach (gan gynnwys Nematoda, *Tharyx*, *Tubificoides benedii* a *Phyllodoce mucosa*), y ddeudroed *Corophium volutator*, y falwen laid *Peringia ulvae* a'r gragen ddeuglawr *Kurtiella bidentata*. Fodd bynnag, gall y patrymau a ddangosir fod yn bennaf oherwydd amrywiadau naturiol.

Aseswyd cyflwr y gorsafoedd monitro fel a ganlyn:

Ansicr – mae amrywiadau yng nghymeriad gwaddodion, cyfansoddiad cymunedol a helaethrwydd rhywogaethau wedi digwydd yn y gorsafoedd a fonitrwyd ers i'r rhaglen ddechrau yn 2004 ac ystyrir bod y rhan fwyaf yn naturiol. Fodd bynnag, disgrifiwyd gostyngiad a oedd yn arwyddocaol yn ystadegol yng nghyfoeth rhywogaethau a gofnodwyd rhwng 2016 a 2019 ac nid oes esboniad.

Executive Summary

The Habitats Directive establishes that the management of Special Areas of Conservation (SACs) should aim to achieve the favourable conservation status of habitat and species features listed within its Annex I and Annex II. For SACs in Wales, Natural Resources Wales (NRW) is therefore required to report on a regular basis on whether features are in favourable conservation status. In Menai Strait and Conwy Bay SAC, programmes of feature condition monitoring have been developed by NRW and its contractors.

Specific areas of interest include mudflats and sandflats within the Menai Strait, where some features are characterised by a high diversity of species. This report describes a monitoring programme carried out on muddy gravel habitats along the north west coast of the Strait. The programme began in 2004 and has been repeated at intervals. Previous reports have described the main characteristics of the communities; this report describes the results of temporal analyses for the period 2004 to 2019.

Nine monitoring stations, characterised as muddy gravel habitat, were surveyed and sampled. Sediment core samples were collected for macrofauna analysis, samples of sediment collected for particle size analysis and conspicuous epibiota recorded *in situ*. Analysis of the resulting data has been used to monitor the condition of the communities.

The most notable results of the temporal analyses were:

vii) Sediment particle size data show little change of note between surveys, except at one station in Beaumaris Bay where the proportion of fine fractions was lower in the later years.

viii) Species richness (from core samples) fluctuated considerably between surveys, but there was a statistically significant reduction in richness between 2016 and 2019. The reason for this reduction is not known. Reductions occurred in almost all phyla and were not due (at least primarily) to differences in discrimination of taxa by sample analysts. No relationship with sediment particle size data are evident.

ix) No notable trends or differences were found in any other diversity measures. However, large differences in the numbers of individuals recorded from samples occurred between years at some stations.

x) Multivariate analysis of community data (from core samples) highlights the differences between stations and suggests some weaker spatial (north south) and temporal trends. The spatial and temporal trends are driven primarily by changes in the abundance of various small worms, with some species more abundant in the early years and others more abundant in later years.

xi) Analysis of relationships between community data and environmental (particle size) data finds some statistically significant correlations, but it is suggested that other environmental variables may be more important for explaining the biological variability.

xii) Large temporal fluctuations in the abundance of various individual taxa are described, particularly some small worms (incl. Nematoda, *Tharyx*, *Tubificoides benedii* and *Phyllodoce mucosa*), the mud shrimp *Corophium volutator*, the mud

snail *Peringia ulvae* and the bivalve *Kurtiella bidentata*. However, the patterns shown may be due primarily to natural fluctuations.

The condition of the monitoring stations has been assessed as:

Uncertain - fluctuations in sediment character, community composition and species abundances have occurred at the monitored stations since the programme began in 2004 and most are considered natural. However, a statistically significant decrease in recorded species richness between 2016 and 2019 has been described and is unexplained.

1 Introduction

The management of Special Areas of Conservation (SACs) should aim to achieve favourable conservation status of habitat and species (*features*) listed within its Annex I and Annex II. For SACs in Wales, Natural Resources Wales (NRW) is responsible for reporting under the 2019 Regulations, which make the Habitat Regulations 2017 operable having left the EU. To do this NRW has developed programmes of feature condition monitoring, which include intertidal features of marine SACs. Aquatic Survey & Monitoring Ltd. (ASML) have been contracted by NRW to develop and manage the monitoring programme for these intertidal features for the period 2006 to 2023; working as a team with NRW staff.

Menai Strait and Conwy Bay Special Area of Conservation (SAC) is designated for five Annex I habitats: *Sandbanks which are slightly covered by sea water all the time*, *Mudflats and sandflats not covered by seawater at low tide*, *Reefs*, *Large shallow inlets and bays* and *Submerged or partially submerged sea caves*. Conservation objectives for each feature are given in the Regulation 37 advice for the Menai Strait and Conwy Bay SAC (NRW 2018).

Muddy gravel habitats are found in many areas of the Menai Strait but are particularly prevalent along the north east shore. They are, by definition, poorly sorted sediments and often include some pebbles and larger stones that provide habitat for attached epibiota as well as a diverse range of infauna. Polychaetes and oligochaetes typically dominate in numbers, but from a very high diversity of families, from tubiculous and other sessile forms to errant surface and sub-surface species, filter-feeders, deposit feeders and predators, small and large. Other worms, including nematodes and nemerteans are often also present in large numbers. Bivalves are often present and can represent a variety of families. Other infaunal taxa include amphipods and ophiuroids. Typical epibiota include anemones, barnacles, crabs, snails, bryozoa, red, brown and green algae.

The heterogeneity of these muddy gravels and the associated diversity of the epibiota and infauna are dependent on the hydrodynamic regime in the Strait. They are also vulnerable to physical disturbance, like digging or dredging.

A programme to monitor muddy gravel habitats in the Menai Strait began in 2002 (Barnes 2003) and was more fully established in 2004 (Allen *et al*. 2004). The sampling in 2002 followed the ‘habitat characterisation’ method outlined in the MNCR methods, which involved pooling the cores. The data from 2002 are therefore not comparable for analysis with subsequent years and excluded from this report. The 2004 survey mapped the muddy gravel biotopes along approximately 5 km of coast from just south of Beaumaris to just north of Lleiniog and then established nine sampling stations. The stations are roughly divided into three geographically defined groups: Beaumaris, Fryars Bay and Lleiniog. These stations have been sampled on four occasions: 2004, 2013, 2016 and 2019. This report describes the results from all monitoring surveys up to June 2019.

The program objectives are:

- To monitor the composition of communities of infauna and epibiota present in muddy gravel habitats at nine stations in the Menai Strait.
- To assess the condition of those communities

This is relevant to the following Menai Strait and Conwy Bay SAC attributes (NRW 2018):

- Distribution and Extent: Variety of mudflat and sandflat communities
- Structure and Function: Sediment characteristics (granulometry)
- Typical Species: Typical mudflat and sandflat species (variety abundance, biomass)

The overall aim of the program is to establish reference conditions for the interest features of the SAC and distinguish any deviations from those conditions, using established monitoring stations to describe natural and unnatural changes in the communities. This enables continued development of conservation objectives and informs appropriate management of those SAC features.

Other previous reports on this programme include Allen *et al*. (2004), Moore *et al*. (2017) and Moore (2018).

Moore (2018) assessed the condition of the muddy gravel communities at these stations and gave the following assessment:

> ***Favourable (2018)*** *- The muddy gravel communities in 2013 and 2016 were different from each other and from those of 2004, but those recorded changes in species richness, species composition and abundance do not indicate any trends of concern and appear to be within a normal range of natural fluctuations. The data suggest some possible increases in taxonomic richness and diversity*.

2 Methods

2.1 Data collection

A summary of the monitoring methodology is given below. Detailed methodologies and protocols for sediment coring are given in Moore (2016d), which are based on the methodologies and protocols described in the 2004 survey report (Allen *et al.* 2004). Additional methods and protocols are given in Moore and Brazier (2016) (common procedures) and Moore 2016c (*in situ* recording of sediment biotopes). They include rationale, site and station details, protocols, proformas, equipment lists, and Quality Assurance (QA) and Quality Control (QC) procedures.

Core sampling methodology: Handheld GPS is used to relocate each fixed monitoring station, during a period of low spring tide. Five 0.01 m^2 core sample are taken from each station and sieved through a 0.5 mm mesh. Each sample is transferred to a bag or pot, and individually labelled. A sample of sediment is also collected from each station for granulometry analysis. The samples are preserved in formalin and transported to an accredited laboratory for analysis of the infauna and the sediment granulometry. Photographs are taken and notes are made on sediment character and conspicuous fauna and flora on the surface.

Note: a smaller corer (0.0078 m^2) was used in the 2004 survey, sampling a 22% smaller area compared to the later monitoring surveys. This will have had an effect on the amount of infauna collected, including the number of species. Calculating abundances per unit area would make some of the analyses more comparable but this was not done for this report as initial tests suggested that it had little effect on the results.

Monitoring station locations are shown in Figure 1 and tabulated in Appendix 1. More details about the establishment of each station are given in the 2004 survey report (Allen *et al.* 2004) and in survey metadata held by NRW.

Monitoring surveys were normally carried out in June (but early August in 2004), during a five-day survey period in which surveys of various other sites and features in the SAC were also carried out. Field logs for each survey (available from NRW or ASML on request) describe the work carried out, including dates, times and surveyors. A summary is given in Appendix 1.

2002 survey (Barnes 2003): Four of the muddy gravel stations (MS09, MS10, MS13, MS18) were first established and surveyed in August 2002 (as part of a larger descriptive survey), but the sampling methodology was different. 6+ core samples were taken within a fixed radius at each station and pooled to produce a single sample, representing 0.064 m^2. Direct comparison of data with the later monitoring surveys is therefore limited and they have not been included in this report.

See Appendix 1 for details of sample stations and number of samples each year.

Figure 1 Locations of muddy gravel monitoring stations in the Menai Strait. Maps based upon Ordnance Survey material © Crown copyright. All rights reserved. Natural Resources Wales, 100018813 [2024].

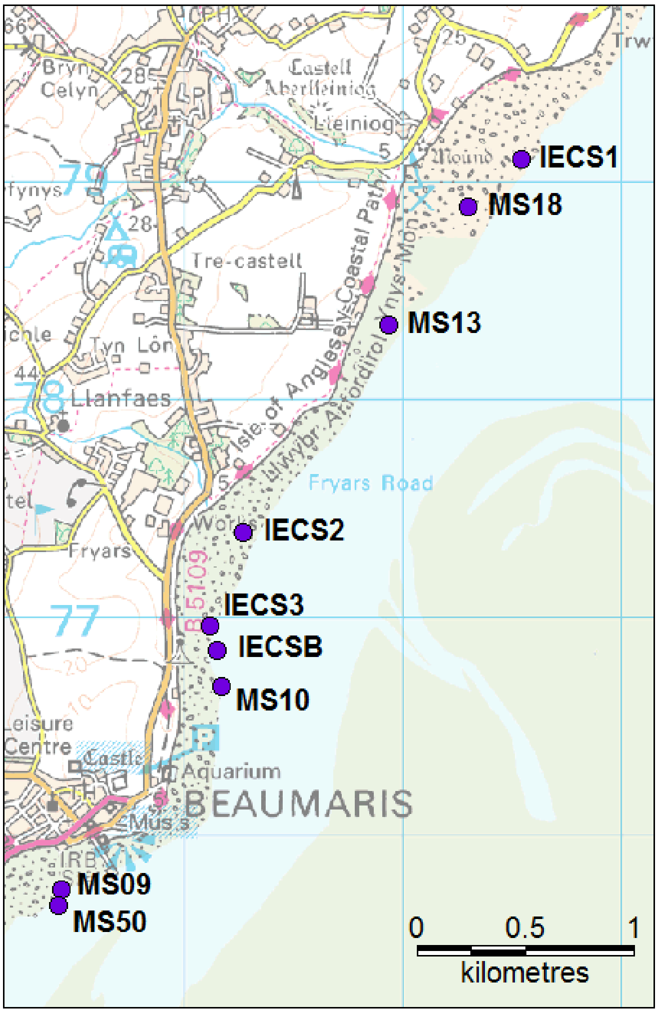


Figure 2 Core sampling at Lleiniog monitoring station IECS1, June 2013.

2.2 Samples analysis

Samples for both biological analysis and sediment particle size analysis (granulometry) were analysed by different laboratories each year (see Appendix 1), but using standardised protocols supplied by NRW. There were some changes in taxonomic nomenclature, identification and the use of qualifiers between each survey dataset, but these have been rationalised (see Section 2.3.1) to make data as comparable as possible.

Sediment particle size analysis was carried out with standard sieve analysis methodologies (1 phi intervals), without any additional detailed analysis of the silt and clay fraction (<63µm).

More detailed laboratory methods are available on request.

2.3 Data management and analysis

2.3.1 Data structure

Taxa abundance data, sediment particle size data and all associated metadata are stored in Excel spreadsheets.

The following key attribute data are linked to each taxon abundance record: Year, Location (Beaumaris, Fryars Bay and Lleiniog), Station (MS09 to IECS1), and Rep (core replicate 1 to 5). Additional attribute data that have been used in analyses include Core size (0.0078 or 0.001) and Period (Early, Later).

Sediment particle size data (PSA) are similarly stored with the same metadata, except Rep as only one PSA sample was taken from each station in each monitoring survey.

The list of recorded taxa (*entities*) has been rationalised to provide a level of standardisation appropriate for temporal analysis. Each entity is defined as a taxon (using the agreed taxonomic nomenclature provided by the WoRMS website) and any qualifiers (e.g. encrusting, juvenile, etc) that are typically recorded. Attribute data linked to each entity includes the AphiaID, taxonomic authority and classification details available from the WoRMS website, and a taxon code based on the UK Marine Species Directory (used for sorting in a conventional taxonomic order).

2.3.2 Data analysis tools

Summary statistics, tabulation and graphs were prepared in Excel for use in reports. Tabulated data from Excel were also imported into Marine Recorder and PRIMER (Clarke & Gorley 2015).

Summary statistics were calculated from sediment particle size data using *GradiStat* (Version 9.1, Kenneth Pye Associates Ltd., http://www.kpal.co.uk/gradistat.html). Mean phi (M_z), Sorting (σ_I), Skewness (Sk_I) and Kurtosis (K_I) statistics used in this report are those based on the Folk & Ward method, which is less sensitive to inaccuracies caused by high proportions of unspecified silt/clay fraction.

Multivariate analyses on the community data from the core samples (count data only) and the sediment particle size data were carried out in PRIMER, primarily using the following routines and tools:

- Transformation – an overall log(x+1) transformation was applied to all of the count data. A square root transformation was initially tested but shade plots showed that the data were still dominated by only a small number of taxa.
- Resemblance matrices with Bray-Curtis similarity
- MDS - non-metric Multi-Dimensional Scaling
- ANOSIM - Analysis of Similarity (one-way and two-way)
- SIMPER – contribution of each taxon to the dissimilarities between groups of samples
- DIVERSE – diversity measures (from the untransformed count data)
- TAXDTEST – Taxonomic distinctiveness
- BEST (BIOENV) – relationships between community data and environmental (sediment particle size statistics) data.

Univariate analyses (including significance tests and Spearman rank correlation) were carried out in Excel (including add-in from www.real-statistics.com).

Some of the analyses have focused on a comparison between 2004 and average data from the later years (2013-2019). This is because initial multivariate analyses highlighted considerable similarity in infaunal community data between the later years and considerable dissimilarity between those and 2004.

Many of the tables in this report include coloured data bars (using conditional formatting features from Excel) to aid visualisation of temporal changes and differences / similarities between monitoring stations.

3 Results

3.1 General description

The muddy gravel monitoring stations were characterised by very poorly sorted mixtures of silt and clay, sand, granules and pebbles. Silt and clay content of sediment samples averaged around 10%, in 2004, 2013 and 2016 but was greater (approx. 15%) in 2019. The infaunal communities were dominated, numerically and to a large extent in biomass, by polychaete, oligochaete and nematode worms. Species richness amongst the polychaetes was high, representing many families. The most abundant polychaete taxa included *Mediomastus fragilis*, *Tharyx*, *Phyllodoce mucosa*, *Aphelochaeta marioni*, *Polydora ciliata* and *Lanice conchilega*. Other infaunal groups included bivalves and amphipods, with various taxa represented. Epibiota included barnacles, littorinid snails, prawns, anemones and various algae. A full list of taxa, from core samples and *in situ* survey records, is given in Appendix 2.

3.2 Sediment particle size data

Data from particle size analysis are shown in Figure 3. They show that the sediment at each monitoring station has its own particle size distribution pattern and that at most stations there was little change in the pattern between 2004 and the later years. The main differences are in the abundance of the larger sized pebbles, which is typically inconsistent between replicate samples of sediment unless very large samples are taken. The only notable temporal change is evident in data from station MS09, in Beaumaris Bay, where the percentage weight of the finer fractions (silt and clay and very fine sand) was significantly lower in the later years.

3.3 Other Physical Data

Additional attributes that are recorded in the field provide some context to the species community analysis. Table 1 shows the depth of the anoxic layer in cm, which denotes the depth to which the sediments are oxygenated. Oxygen depletion in the sediments can result from high levels of carbon, low perturbation and/or high levels of nutrients. The very stable sediments in the locations sampled, typically have a shallow depth of oxygenation. The data shows a slight shallowing of the depth of oxygenation, but this is not considered to be significant to the species community.

Table 1 The depth of the anoxia black layer at each station for each year.

Year	IECS1	IECS2	IECS3	IECSB	MS09	MS10	MS13	MS18	MS50
2004	2	2	0.5	0.5	2	2	2	2	n/a
2013	2	2	0.5	0.5	2	2	2	2	2
2016	1	5	1	1	1	1	1	1	1
2019	2	1	1	0.5	1	0.5	0.5	1	0.5

Analysis of the extent of standing surface water at each station during sampling has been completed, but no trends have been found. The standing water on the surface depends on the slope of the shore, but the measure is also in-part, dependent on how soon after high water the sampling was carried out. The stations at Lleiniog consistently have the greatest % cover of standing water, reflecting the low profile of these shores (Figure 4).

Figure 3 Results from particle size analysis. Percentage weight of size fractions and summary statistics from 8 monitoring stations – comparison of 2004 data with average values for 2013-16. Coloured shading of rows to aid visualisation of size fractions. Stations ordered from south (left) to north (right).

2004		MS09	MS10	IECS B	IECS3	IECS2	MS13	MS18	IECS1
> 8 mm	Pebble_medium	0.6	3.4	3.3	18.7	17.6	5.8	8.1	5.8
4-8 mm	Pebble_small	5.7	4.6	3.6	12.4	12.2	4.5	12.9	4.3
2-4 mm	Granule	8.7	7.0	4.4	7.0	8.5	3.7	10.2	5.2
1-2000 µm	Sand_v_coarse	6.3	7.0	2.9	4.4	5.2	1.7	6.5	3.5
500-1000 µm	Sand_coarse	6.3	12.8	2.4	3.9	4.5	2.3	7.0	4.7
250-500 µm	Sand_medium	16.3	39.9	9.7	10.7	16.1	24.0	16.4	14.9
125-250 µm	Sand_fine	14.5	19.2	51.0	15.3	13.9	34.8	18.5	48.1
63-125 µm	Sand_v_fine	17.9	3.0	15.1	12.4	8.9	12.2	11.4	9.0
< 63 µm	Silt_and_clay	23.8	3.2	7.6	15.1	13.0	11.0	9.0	4.5
	Mean phi	2.30	1.00	2.22	0.66	0.54	1.97	0.78	1.46
	Sorting	2.96	1.75	1.86	3.49	3.37	2.31	2.89	2.03
	Skewness	-0.03	-0.34	-0.27	-0.16	-0.14	-0.19	-0.18	-0.58
	Kurtosis	1.15	1.39	2.97	0.80	0.86	2.34	0.90	1.78

2013-19		MS09	MS10	IECS B	IECS3	IECS2	MS13	MS18	IECS1	MS50
> 8 mm	Pebble_medium	9.2	6.7	6.1	16.7	16.9	3.4	19.4	4.1	5.8
4-8 mm	Pebble_small	10.6	3.6	3.5	8.3	7.4	10.8	7.8	4.3	5.1
2-4 mm	Granule	12.3	5.5	5.6	9.9	10.3	11.6	7.8	5.2	5.7
1-2000 µm	Sand_v_coarse	11.0	7.0	3.5	7.9	9.0	5.4	6.1	3.9	4.9
500-1000 µm	Sand_coarse	7.6	17.1	4.0	7.5	8.2	4.3	10.1	7.6	6.5
250-500 µm	Sand_medium	11.7	37.0	14.0	14.0	17.6	17.1	17.6	23.1	12.9
125-250 µm	Sand_fine	12.3	14.3	36.2	14.9	8.8	25.3	17.8	39.0	14.5
63-125 µm	Sand_v_fine	13.1	3.7	12.2	9.7	7.3	12.0	8.7	7.6	17.1
< 63 µm	Silt_and_clay	12.3	5.1	14.9	11.3	14.7	9.9	4.6	5.2	27.6
	Mean phi	0.69	0.88	1.96	0.49	0.50	1.20	0.13	1.49	2.35
	Sorting	3.03	1.99	2.62	3.17	3.24	2.65	2.78	1.94	3.20
	Skewness	0.02	-0.27	-0.17	-0.10	0.13	-0.25	-0.31	-0.39	-0.12
	Kurtosis	0.92	1.73	2.04	0.87	1.00	0.91	0.77	1.84	1.10

Figure 4 Percent cover of standing water at each station each year

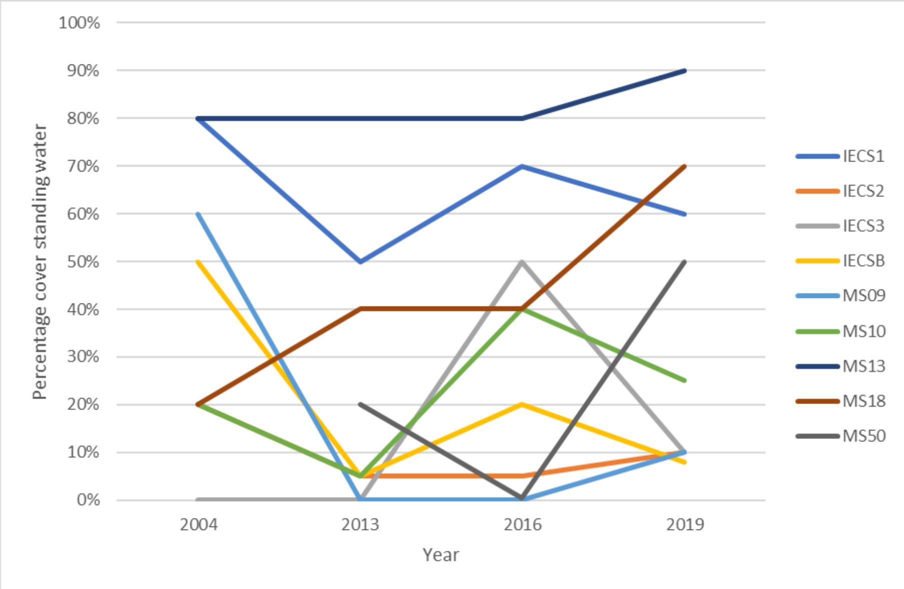


Table 2 Shows the additional attributes collected at each station each year, for comparative purposes. The variability in the presence of a sub-surface coarse layer or clay layer illustrates the highly variable nature of the wave sheltered muddy gravel habitat.

Table 2 Table of Physical description and details for each Station in each year.

Station	Year	Location	Granulometry	Black layer (cm)	Standing water %	Casts	Tubes	Algal mat	Sub-surface coarse layer	Sub-surface clay	Surface silt/floc
IECS1	2004	Lleiniog	Muddy fine sand with gravel and with subsurface clay.	2	80%	no	**yes**	no	no	**yes**	no
IECS1	2013	Lleiniog	Muddy fine sand with gravel and with subsurface clay.	2	50%	no	**yes**	no	no	**yes**	no
IECS1	2016	Lleiniog	Muddy fine sand with gravel and with subsurface clay.	1	70%	no	**yes**	**yes**	no	**yes**	no
IECS1	2019	Lleiniog	Poorly sorted muddy sand and gravel with some pebbles. Clay layer below.	2	60%	**yes**	**yes**	**yes**	no	**yes**	no
IECS2	2004	Fryars Bay	Gravelly mud and fine sand	2	20%	no	no	no	**yes**	**yes**	no
IECS2	2013	Fryars Bay	Gravelly mud and fine sand	2	5%	no	no	no	**yes**	**yes**	no
IECS2	2016	Fryars Bay	Muddy fine sand and gravel	5	5%	no	no	no	no	no	no
IECS2	2019	Fryars Bay	Very poorly sorted very muddy shelly gravel	1	10%	no	no	no	no	no	no
IECS3	2004	Fryars Bay	Muddy Sand with Gravel, Shell and Pebble	0.5	0%	**yes**	**yes**	no	**yes**	no	no
IECS3	2013	Fryars Bay	Muddy Sand with Gravel, Shell and Pebble	0.5	0%	**yes**	**yes**	no	**yes**	no	**yes**
IECS3	2016	Fryars Bay	Muddy Sand with Gravel, Shell and Pebble	1	50%	**yes**	**yes**	no	no	no	**yes**
IECS3	2019	Fryars Bay	Very poorly sorted fine sand gravel pebbles broken and whole shells and cobbles	1	10%	**yes**	**yes**	no	no	no	no
IECSB	2004	Fryars Bay	Muddy fine sand and gravel	0.5	50%	**yes**	**yes**	no	no	no	**yes**
IECSB	2013	Fryars Bay	Gravelly mud with fine to coarse sand	0.5	5%	**yes**	**yes**	no	no	no	**yes**
IECSB	2016	Fryars Bay	Muddy fine sand and gravel	1	20%	**yes**	no	no	no	no	no
IECSB	2019	Fryars Bay	Very poorly sorted fine sand gravel pebbles broken and whole shells and cobbles	0.5	8%	no	**yes**	no	no	no	no
MS09	2004	Beaumaris	Mud and Gravel	2	60%	no	no	no	**yes**	no	no

Station	Year	Location	Granulometry	Black layer (cm)	Standing water %	Casts	Tubes	Algal mat	Sub-surface coarse layer	Sub-surface clay	Surface silt/floc
MS09	2013	Beaumaris	Muddy, shell and stone gravel with subsurface gravel.	2	0%	no	no	no	**yes**	no	no
MS09	2016	Beaumaris	muddy Gravel	1	0%	no	no	no	no	no	no
MS09	2019	Beaumaris	Very poorly sorted coarse shell sand gravel and mud	1	10%	no	no	no	no	no	no
MS10	2004	Fryars Bay	Muddy fine sand and gravel	2	20%	no	no	no	**yes**	**yes**	no
MS10	2013	Fryars Bay	Gravelly mud with fine to coarse sand with pebbles	2	5%	no	no	no	no	**yes**	no
MS10	2016	Fryars Bay	Muddy fine sand and gravel	1	40%	no	no	no	no	no	no
MS10	2019	Fryars Bay	Very poorly sorted fine sand gravel pebbles broken and whole shells and cobbles	0.5	25%	no	no	no	no	**yes**	no
MS13	2004	Lleiniog	Muddy fine sand and gravel	2	80%	**yes**	**yes**	no	**yes**	no	**yes**
MS13	2013	Lleiniog	Gravelly mud with subsurface gravel and mud floc.	2	80%	**yes**	**yes**	no	**yes**	no	**yes**
MS13	2016	Lleiniog	Muddy fine sand and gravel	1	80%	no	no	no	no	no	no
MS13	2019	Lleiniog	Poorly sorted muddy sand and gravel. Coarse gravel layer below.	0.5	90%	**yes**	**yes**	no	**yes**	no	no
MS18	2004	Lleiniog	Gravelly mud and fine sand with subsurface gravel and surface pebbles.	2	20%	no	**yes**	no	**yes**	no	no
MS18	2013	Lleiniog	Gravelly mud and fine sand with subsurface gravel and surface pebbles.	2	40%	**yes**	**yes**	no	**yes**	no	no
MS18	2016	Lleiniog	Gravelly mud and fine sand with subsurface gravel and surface pebbles.	1	40%	no	no	no	**yes**	no	no
MS18	2019	Lleiniog	Very poorly sorted muddy gravel sand and pebbles with some cobbles.	1	70%	no	**yes**	no	no	no	no
MS50	2013	Beaumaris	Very muddy, gravelly fine sand with subsurface gravel.	2	20%	no	no	no	no	**yes**	no
MS50	2016	Beaumaris	Mud and Gravel	1	1%	no	no	no	no	**yes**	no
MS50	2019	Beaumaris	Very poorly sorted muddy shelly gravel	0.5	50%	no	no	no	no	**yes**	no

3.4 Taxonomic diversity

3.4.1 Species richness

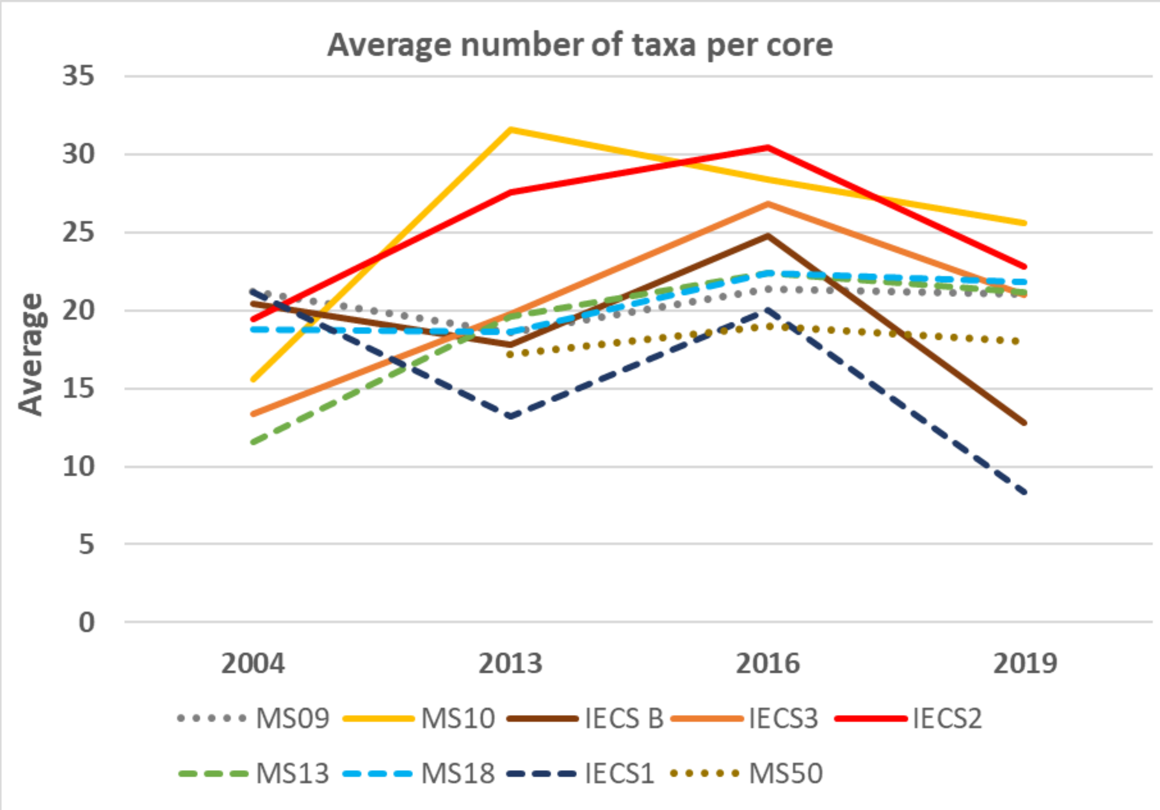
A total of 254 individual taxa (*entities*) have been recorded from laboratory analysed core samples in these monitoring surveys (all samples, 2004 to 2019); including 24 colonial animals and algae. Data from *in situ* surveys of conspicuous species adds a further 28 taxa. A full list of taxa is given in Appendix 2. Note: analyses of species richness in this section are confined to the core sample data, excluding the 24 colonial animals and algae which were inconsistently recorded.

Figure 5 shows some fairly large fluctuations in average species richness over the four survey years. One-way analysis of variance shows the differences between the years was statistically significant (n=40/year, F=8.31, p<0.0001), but Tukey HSD post-hoc tests show that the only significant differences between years were 2004:2016 and 2016:2019 (see Appendix 3 for more details). The smaller sized cores taken in 2004 is expected to have had an effect on the number of species sampled but the difference between 2004 and 2013 was not significant.

The reason for the significant reduction in average species richness between 2016 and 2019, evident at all monitoring stations, is not known. A more detailed taxonomic analysis shows that reductions in richness occurred in all phyla (except Pycnogonida sea spiders, which increased). It is possible that the increase is due, to some extent, to differences in the discrimination of some taxa by the sample analysts (see more details below). However, those differences in discrimination should be removed if data are aggregated to higher taxa. Additional Anova tests were therefore carried out using data aggregated to Genus level and also to Family level. One-way Anova found statistically significant differences between years for Genera richness (n=40/year, F=8.38, p<0.0001) and for Family richness (n=40/year, F=6.94, p<0.001). Tukey HSD post-hoc tests also confirmed significant differences between 2016:2019, though the level of significance was relatively low (0.0043) for Family richness.

Figure 5 also shows a notable difference in the pattern of changes between the Fryars Bay and Lleiniog stations, indicated by the different line styles. Thus, there was a large increase in richness between 2004 and 2013 at the Fryars Bay stations, but a decrease at the Lleiniog stations.

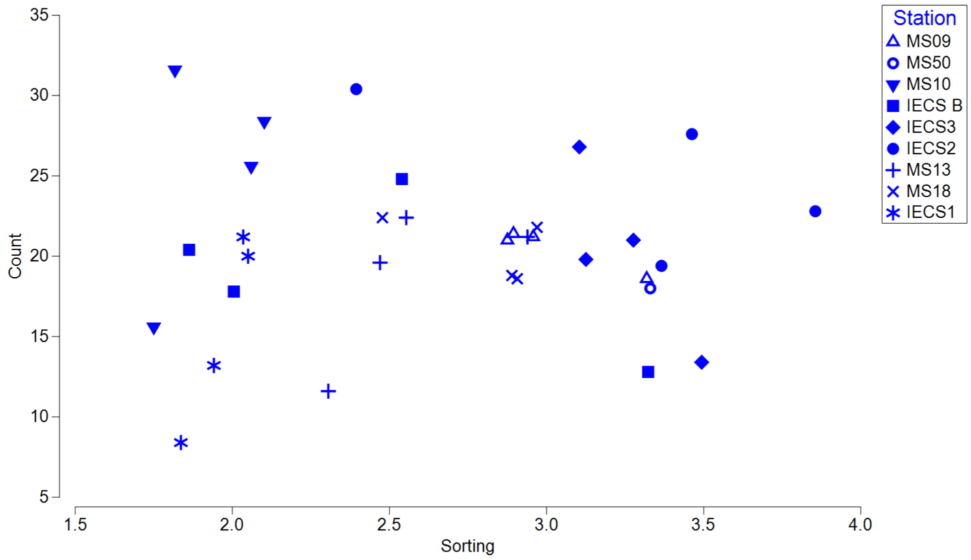
Figure 5 Fluctuations in species richness (average number of taxa per core) at 9 muddy gravel monitoring stations. Values exclude colonial taxa. Line styles indicate area of coast: Dotted line: Beaumaris, solid lines: Fryars Bay, dashed lines: Lleiniog.



Temporal changes in total and average number of taxa (by year, across all monitoring stations) are given at the bottom of Figure 8. The average values reflect the pattern described above, but the total numbers mainly highlight an increase between 2004 and the later years. As mentioned above, it is possible that increase is due, to some extent, to differences in the discrimination of some taxa by the sample analysts. For example, the number of entities (entity = taxon plus qualifier) identified as juveniles was lowest in 2004 (10 juvenile entities) and highest in 2016 (23 juvenile entities). Note that 2004 samples are from August sampling which may also influence numbers of juveniles. Surprisingly, the 2004 records also contain almost no gastropods (including the mud snail *Peringia ulvae* - Figure 10 and the top shell *Steromphala cineraria* which were frequent at many stations in all later years).

The relationship between species richness and the available environmental data (sediment particle size data) was studied with simple scatter plots, but no apparent correlations were found. Species richness is often positively correlated with habitat heterogeneity, which in sediments may be measured by the sorting coefficient. However, Figure 6 shows no apparent correlation.

Figure 6 Plot of the average taxonomic richness (excluding colonial taxa) and the sediment sorting coefficient.



3.4.2 Other diversity measures

A range of other diversity measures have been calculated from the community data (Table 3).

The most striking differences are in the numbers of individuals recorded at some monitoring stations and in some years – thus, the three most northerly stations (MS13, MS18 and IECS1) were characterised by relatively very low numbers, and 2013 had low numbers in almost all stations. Other diversity and evenness indices vary between years and stations, but without any obvious trends. On average, most of the diversity measures were lower in 2019 than previous years, but the differences are not statistically significant.

Analyses of average taxonomic distinctness (Δ+) found no apparent spatial or temporal effects. A few of the samples had average values that were below the expected levels (in funnel plots, not shown in this report), but no ecological significance is apparent from this analysis.

3.5 Community composition

Multivariate analysis of infaunal community data from the muddy gravel core samples show that differences between all years and between all monitoring stations are statistically significant (two-way ANOSIM: Years: Global R = 0.515, P=0.1%; Stations: Global R = 0.758, P=0.1%; pairwise tests between years and stations all give P<1%). See Appendix 3 for more details.

Table 3 Diversity measures from 9 muddy gravel monitoring stations, 2004 to 2019. Based on abundance data for 230 taxa (count data only) from 0.05 m^2 (summed counts from 5 cores). Stations ordered from south (left) to north (right).

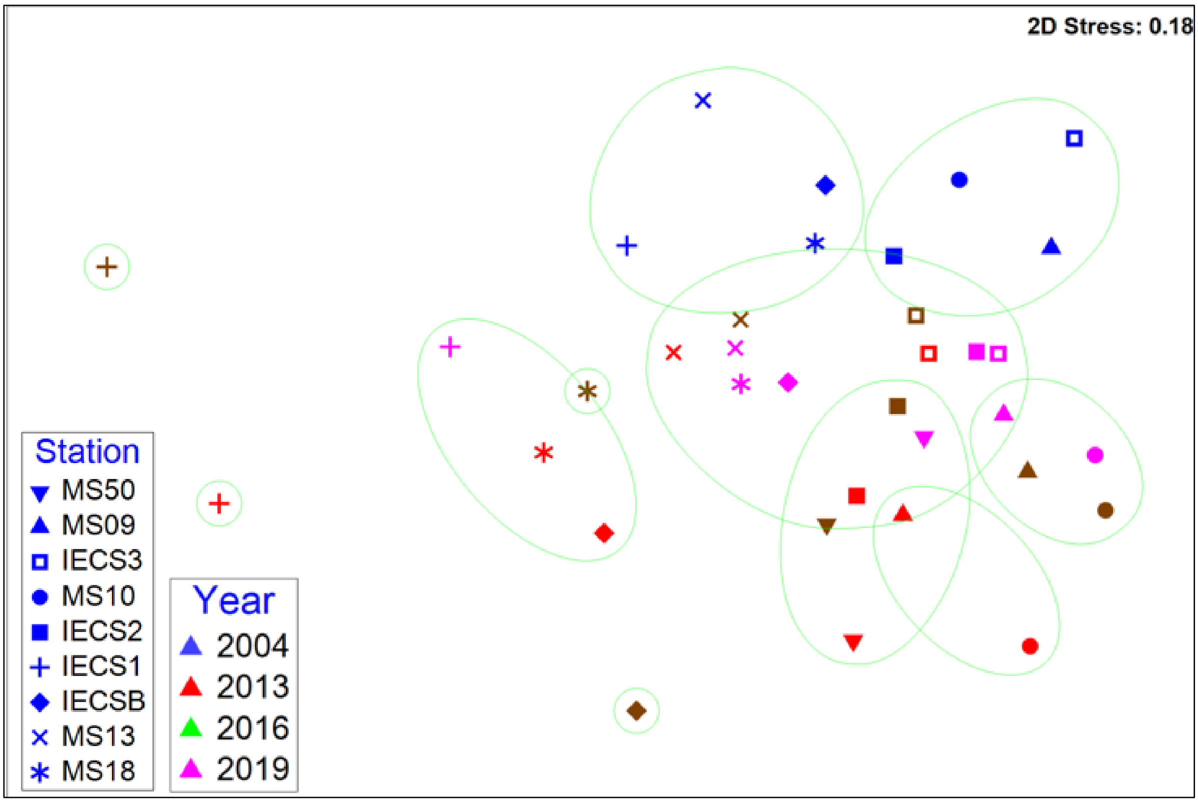
	MS09	MS10	IECS B	IECS3	IECS2	MS13	MS18	IECS1	MS50
Number of taxa (S)									
2004	38	44	45	26	38	26	39	42	#N/A
2013	40	66	48	44	50	42	40	41	33
2016	47	65	50	50	50	41	41	43	38
2019	51	54	34	41	41	35	48	24	37
Number of individuals (N)									
2004	4313	1273	2548	2201	2157	279	605	423	#N/A
2013	629	1019	244	2725	1016	574	315	180	676
2016	3949	1304	1174	4627	2848	1144	659	354	1055
2019	2660	2315	391	2899	1203	625	585	62	1065
Shannon diversity index (H'(loge))									
2004	1.74	1.15	0.91	0.99	1.60	1.94	2.14	2.91	#N/A
2013	2.26	2.63	3.08	1.59	2.86	2.76	2.88	2.46	2.48
2016	1.21	2.53	1.97	2.05	2.34	2.33	2.49	3.05	2.32
2019	1.99	1.82	1.82	1.75	2.54	2.37	2.54	2.99	2.05
Margalef species richness index (d)									
2004	4.4	6.0	5.6	3.2	4.8	4.4	5.9	6.8	#N/A
2013	6.1	9.4	8.5	5.4	7.1	6.5	6.8	7.7	4.9
2016	5.6	8.9	6.9	5.8	6.2	5.7	6.2	7.2	5.3
2019	6.3	6.8	5.5	5.0	5.6	5.3	7.4	5.6	5.2
Pielou's evenness index (J)									
2004	0.48	0.30	0.24	0.30	0.44	0.60	0.58	0.78	#N/A
2013	0.61	0.63	0.79	0.42	0.73	0.74	0.78	0.66	0.71
2016	0.32	0.61	0.50	0.52	0.60	0.63	0.67	0.81	0.64
2019	0.51	0.46	0.52	0.47	0.68	0.67	0.66	0.94	0.57

The MDS plot in Figure 7 clearly shows that the 2004 sample data (along the bottom of the plot) stand out from the later years. In a 3D MDS plot it is also clear that 2013 sample data are clearly separated from the other years, but that 2016 and 2019 sample data overlap. There is a slight suggestion of a temporal trend (see below). There is also an imperfect south north trend in Figure 7 emphasised by 3 of the northernmost stations (IECS1, MS13, MS18) mapping together to one side of the plot. Overall, these and other community analyses show that each station has its own character (as previously mentioned from their granulometry in Section 3.2), with some overlying spatial and temporal trends.

Section 3.4.1 highlights differences in the species richness data between years that could be due in part to differences in discrimination of some taxa by laboratory analysts. To minimise the effect of such inconsistencies on the multivariate analyses, the species abundance data were aggregated up to family level and run through MDS and ANOSIM routines again. The results were almost exactly the same, but the stress values in the MDS plots were slightly lower (2D stress: 0.15) than that in Figure 7. This provides extra credibility to the patterns described in the paragraph above.

SIMPER analyses (see details in Appendix 3) show that the taxa contributing most to the differences between 2004 and the later years are various small worms, which also dominate numerically in the community. They include more abundant in 2004: Nematoda and *Tharyx*; more abundant in the later years: *Tubificoides benedii* and *T. pseudogaster*) and *Mediomastus fragilis*. Abundance patterns in these species, and others, are described further in Section 3.6.

Figure 7 MDS plot of infaunal core sample data from muddy gravels, 2004 to 2019. Each dot represents data from 5 replicate cores, with similarities calculated from log(x+1) transformed counts for 230 taxa. Overlain with groups at 50% similarity from Hierarchical Cluster Analysis.



Section 3.4.1 mentioned the apparent differences in species richness patterns between the Fryars Bay stations (just north of Beaumaris) and the Lleiniog stations (further north). The multivariate analyses also find a very significant difference between those two bays (two-way ANOSIM: Years: Global R = 0.438, P=0.1%; Locations: Global R = 0.302, P=0.1%; pairwise test between Fryars Bay and Lleiniog P = 0.1%). However, the Beaumaris and Fryars Bay stations data were relatively similar and the differences between those two areas were not significant.

SIMPER analyses (see details in Appendix 3) show that the same small worms mentioned above also top the list of taxa contributing to the differences between Fryars Bay and Lleiniog; Fryars Bay characterised by higher abundances of those and several other taxa. It is these abundance differences that create the south to north trend apparent in Figure 7.

Relationships between the biological community data and the sediment particle size data were analysed using PRIMER's BEST (BIOENV) routine (see details in Appendix 3). Biological data were represented by the resemblance matrix behind Figure 7. Sediment parameters included in the test were those listed in Figure 3. The analysis showed that no single sediment parameter was well correlated with the resemblance data (best Spearman rank correlation (Rho) was 0.223 for coarse sand (log%)) and even a combination of four parameters (very coarse sand, very fine sand, silt and clay and the sorting coefficient) still produced a correlation of only 0.454. The significance level was 1%, but it is clear that other environmental variables may be more important for explaining the biological variability.

3.6 Individual taxa

The abundance of the most frequently occurring taxa from the core samples are tabulated in Figure 8 (by year) and Figure 9 (by monitoring station and period). Graphs in Figure 10 and Figure 11 show how abundances in selected taxa have fluctuated. They show that a variety of abundance fluctuation patterns are represented, with peaks of some species and very low abundances of other species in every survey year. Some taxa show very large fluctuations between surveys (e.g. Nematodes, Figure 10a), while others have relatively stable abundances (e.g. *Scoloplos armiger*, Figure 10c). Some taxa had very patchy distributions, with large standard error (e.g. *Aphelochaeta marioni*, Figure 10f), while others were more uniformly distributed (e.g. *Phyllodoce mucosa*, Figure 10b).

The abundance of the most frequently occurring taxa from the *in situ* recorded conspicuous taxa are tabulated in Figure 12 (by year and by station). Again, there are some notable fluctuations. However, those data are limited, with inadequate replication or details for formal analysis; so they are best used to support other analyses.

The lack of any clear trends or relationships between taxa suggest that the patterns shown in these tables and figures may be primarily due to natural fluctuations. No formal analyses have been used to look for temporal or spatial patterns in higher taxonomic groups or functional groups, but no trends of potential ecological concern are apparent from inspection of the data or graphs.

Figure 8 Visualisation of the number of records and average abundance (counts per core) of the most frequently recorded infaunal taxa, across all stations.

Taxon	No of records				Average count/core			
	2004	2013	2016	2019	2004	2013	2016	2019
Nemertea	7	9	8	6	0.2	0.3	0.3	0.2
Nematoda	39	32	40	38	180.2	17.8	141.7	55.9
Pholoe inornata	11	10	8	9	0.3	0.2	0.2	0.4
Eteone longa_agg	16	34	38	34	0.6	2.3	3.6	2.6
Phyllodoce mucosa	26	26	37	32	1.4	3.5	10.4	5.2
Eumida	23	3	0	0	2.1	0.1	0.0	0.0
Parexogone hebes	14	11	23	20	1.0	1.0	3.8	1.2
Exogone naidina	15	1	10	10	1.2	0.0	0.4	0.4
Eunereis longissima	5	9	9	6	0.1	0.2	0.2	0.2
Nephtys_juvenile	6	3	19	1	0.2	0.1	1.0	0.0
Nephtys hombergii	4	4	15	11	0.1	0.1	0.4	0.3
Scoloplos armiger	18	30	17	29	1.3	2.0	1.3	1.4
Aonides oxycephala	3	5	16	7	0.1	0.1	0.7	0.4
Dipolydora quadrilobata	5	28	24	22	0.1	7.9	4.9	3.6
Pygospio elegans	16	6	25	14	0.9	0.3	2.0	1.0
Spio decorata	6	18	20	10	0.2	0.9	1.1	0.4
Spiophanes bombyx	6	22	22	9	0.2	1.2	1.1	0.3
Chaetozone gibber	35	16	36	26	36.4	6.1	23.1	8.8
Tharyx_Type A	7	15	16	10	37.6	2.4	3.0	9.3
Aphelochaeta marioni	20	13	9	5	3.7	1.5	0.2	0.5
Capitella_agg	37	40	42	40	24.0	17.2	37.8	24.6
Mediomastus fragilis	8	31	37	26	0.4	1.9	3.7	1.6
Notomastus	3	12	18	7	0.1	0.7	0.7	0.2
Scalibregma inflatum	14	10	15	8	0.7	0.4	1.2	0.3
Galathowenia oculata	3	2	20	12	0.1	0.1	1.5	0.6
Lagis koreni	0	31	0	0	0.0	2.7	0.0	0.0
Ampharete acutifrons	0	0	4	32	0.0	0.0	0.2	5.3
Ampharete grubei	15	28	0	0	0.7	4.6	0.0	0.0
Lanice conchilega	12	35	34	10	0.5	6.2	3.7	0.8
Tubificoides benedii	35	35	39	36	29.5	51.4	63.6	50.2
Tubificoides pseudogaster	30	20	38	35	5.0	5.2	17.0	12.3
Balanus crenatus	0	2	0	25	0.0	0.0	0.0	52.5
Corophiidae	4	16	21	7	0.1	4.2	12.0	0.4
Corophium volutator	16	18	27	16	1.2	3.4	12.8	3.6
Pariambus typicus	9	7	11	7	0.7	0.2	0.4	0.2
Crangon crangon	5	13	11	12	0.1	0.6	0.4	0.6
Portunidae_juvenile	0	9	6	11	0.0	0.4	0.3	0.6
Peringia ulvae	0	5	16	11	0.0	1.3	2.4	0.6
Bivalvia	6	22	0	0	0.2	1.6	0.0	0.0
Mytilus edulis_juvenile	36	28	11	9	6.5	2.5	0.4	0.3
Kurtiella bidentata	4	11	12	5	0.1	0.4	1.5	0.1
Cerastoderma edule_juv	0	2	23	5	0.0	0.1	0.9	0.2
Abra alba	1	11	19	11	0.0	0.5	0.6	0.5
Mya arenaria_juvenile	0	0	17	10	0.0	0.0	0.9	0.6

Figure 9 Visualisation of the average abundance (counts per core) of the most frequently recorded infaunal taxa, for each monitoring station, within two periods. Values for 2004 are averages from 5 cores. Values for 2013-2019 are averages from 15 cores (3 years x 5 cores).

Taxon	2004								2013-19								
	MS09	MS10	IECS B	IECS3	IECS2	MS13	MS18	IECS1	MS09	MS50	MS10	IECS B	IECS3	IECS2	MS13	MS18	IECS1
Nemertea	0.8	0.2	0.2	0.0	0.0	0.2	0.2	0.0	0.2	0.0	0.9	0.0	0.3	0.3	0.1	0.3	0.1
Nematoda	253.4	181.2	420.6	309.2	214.0	15.6	33.2	14.6	245.8	13.1	19.4	41.3	182.5	88.3	28.3	25.2	2.5
Pholoe inornata	0.4	0.0	0.8	0.2	0.2	0.0	0.4	0.4	0.5	0.0	0.6	0.1	0.5	0.4	0.1	0.3	0.2
Eteone longa_agg	1.2	0.2	0.4	0.0	0.2	0.0	0.8	1.6	3.1	3.6	3.4	1.3	6.1	3.5	2.0	2.1	0.7
Phyllodoce mucosa	4.0	1.2	0.4	1.0	1.6	0.0	2.4	0.6	16.7	0.9	14.0	1.9	13.9	6.3	2.1	0.9	0.6
Eumida	8.8	0.2	2.4	1.0	1.4	0.0	1.4	1.2	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.1
Parexogone hebes	0.2	0.6	0.0	0.0	2.4	0.2	0.4	4.2	0.1	0.1	1.6	0.0	0.2	8.7	4.1	2.0	0.8
Exogone naidina	0.0	0.4	5.8	0.6	0.2	0.0	0.4	1.8	0.0	0.0	0.3	0.8	0.4	0.9	0.1	0.0	0.0
Eunereis longissima	0.2	0.2	0.0	0.0	0.0	0.0	0.2	0.4	0.2	0.3	0.3	0.2	0.0	0.5	0.0	0.3	0.0
Nephtys_juvenile	0.2	0.0	0.2	0.0	0.2	0.8	0.0	0.2	0.8	0.5	0.0	0.1	0.1	0.3	0.2	0.3	1.0
Nephtys hombergii	0.0	0.0	0.4	0.0	0.4	0.0	0.0	0.0	0.1	0.1	0.1	0.9	0.1	0.0	0.5	0.3	0.4
Scoloplos armiger	0.2	0.2	3.0	0.0	0.4	0.4	2.6	3.8	0.1	0.5	0.4	1.5	0.7	1.0	2.1	5.0	2.5
Aonides oxycephala	0.0	0.2	0.0	0.0	0.4	0.0	0.0	0.0	0.7	0.5	1.6	0.0	0.1	0.7	0.0	0.1	0.0
Dipolydora quadrilobata	0.4	0.0	0.0	0.0	0.4	0.0	0.2	0.0	1.4	1.0	0.1	0.4	37.6	2.4	5.3	1.0	0.2
Pygospio elegans	0.0	0.0	2.8	0.0	0.6	0.4	2.0	1.0	0.0	0.3	0.0	1.5	0.9	1.5	3.3	2.3	0.1
Spiophanes bombyx	0.0	0.6	0.0	0.0	0.0	0.2	0.0	0.8	0.1	0.0	0.0	1.3	0.1	0.3	1.1	2.4	1.8
Chaetozone gibber	0.0	0.2	0.2	0.0	0.2	0.0	0.0	1.0	0.7	0.3	0.3	1.3	1.1	2.2	0.2	0.7	0.8
Tharyx_Type A	84.6	0.4	26.2	3.4	99.8	19.6	43.4	13.8	0.4	22.3	0.3	12.8	11.2	15.9	46.2	4.5	0.3
Aphelochaeta marioni	300.0	0.4	0.2	0.0	0.0	0.0	0.0	0.0	6.3	35.8	1.3	0.2	0.4	0.2	0.0	0.0	0.1
Capitella_aggregate	6.8	0.4	0.0	14.0	7.2	0.4	0.2	0.4	0.1	0.1	0.9	0.0	4.0	0.3	1.1	0.4	0.0
Mediomastus fragilis	103.6	5.6	11.8	5.6	50.0	2.2	5.8	7.4	23.5	45.7	11.3	15.5	58.2	56.4	17.7	9.9	0.5
Notomastus	0.6	1.6	0.0	0.0	0.2	0.0	0.0	0.4	2.1	2.8	2.4	0.8	2.1	5.7	3.5	1.5	0.7
Scalibregma inflatum	0.2	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.9	1.5	0.2	0.5	0.4	1.3	0.0	0.0	0.0
Galathowenia oculata	0.8	0.0	0.8	0.0	0.4	0.0	0.2	3.4	0.0	0.2	0.0	0.6	0.3	0.3	0.3	1.5	2.7
Lagis koreni	0.0	0.0	0.2	0.0	0.0	0.2	0.2	0.0	0.2	0.8	0.0	0.4	1.9	1.1	0.8	0.8	0.5
Lagis koreni_juv	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	0.0	1.1	0.7	0.6	2.5	0.8	1.4	0.2
Ampharete acutifrons	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.9	4.1	0.1	1.6	4.9	2.5	1.1	0.1	0.0
Ampharete grubei	2.4	0.0	0.2	1.2	1.4	0.0	0.4	0.0	0.8	3.1	0.4	0.5	5.8	2.9	0.1	0.1	0.0
Lanice conchilega	0.0	0.2	0.2	0.0	0.6	0.2	0.8	2.2	1.7	0.8	1.1	3.4	1.8	1.1	4.9	8.3	9.1
Tubificoides benedii	68.6	39.4	7.8	92.8	21.8	1.4	3.8	0.2	72.0	26.1	80.4	4.7	272.8	35.5	2.3	1.8	0.3
Tubificoides pseudogaster	0.2	1.0	9.4	0.4	5.4	8.6	6.0	9.0	30.3	1.8	20.1	0.6	14.7	11.4	10.6	10.5	3.7
Balanus crenatus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	52.2	1.8	78.4	15.1	0.1	3.3	0.0	6.7	0.0
Corophiidae	0.0	0.0	0.0	0.2	0.4	0.2	0.2	0.0	0.3	3.7	0.1	0.6	19.6	23.1	2.1	0.3	0.0
Corophium volutator	5.0	0.0	0.2	0.6	3.0	0.0	0.8	0.0	0.3	8.5	0.0	0.5	20.1	27.0	2.6	0.3	0.0
Pariambus typicus	0.2	0.0	4.4	0.0	0.0	0.0	0.0	0.8	0.0	0.1	0.1	0.7	0.9	0.5	0.0	0.1	0.5
Crangon crangon	0.0	0.2	0.2	0.0	0.0	0.2	0.0	0.4	0.3	0.2	0.0	0.1	0.9	0.6	0.9	1.1	0.8
Portunidae_juv	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	2.3	0.1	0.3	0.1	0.0	0.4	0.0
Peringia ulvae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.1	0.9	9.9	1.1	0.1	0.3
Bivalvia	0.4	0.0	0.0	0.0	1.0	0.2	0.0	0.0	0.7	0.3	0.1	0.3	0.1	2.1	0.2	0.4	0.3
Mytilus edulis_juv	10.8	12.2	2.0	3.4	12.8	1.0	7.8	2.0	1.8	0.6	2.2	0.2	1.4	2.7	0.3	0.3	0.1
Kurtiella bidentata	0.6	0.2	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.9	3.3	0.1	0.1	1.8	0.1	0.0	0.0
Cerastoderma edule_juv	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.3	0.0	0.3	0.6	0.3	1.4	0.3	0.1
Abra alba	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.5	0.3	0.4	0.7	1.4	0.5	0.5	0.6	0.0
Mya arenaria_juv	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.3	1.9	0.9	0.1	0.0	0.0	0.1	0.0

Figure 10 Graphs of temporal change in abundance (average count per core, ± standard error) for selected infaunal taxa. Each value is averaged from 40 core samples (5 cores x 8 stations).

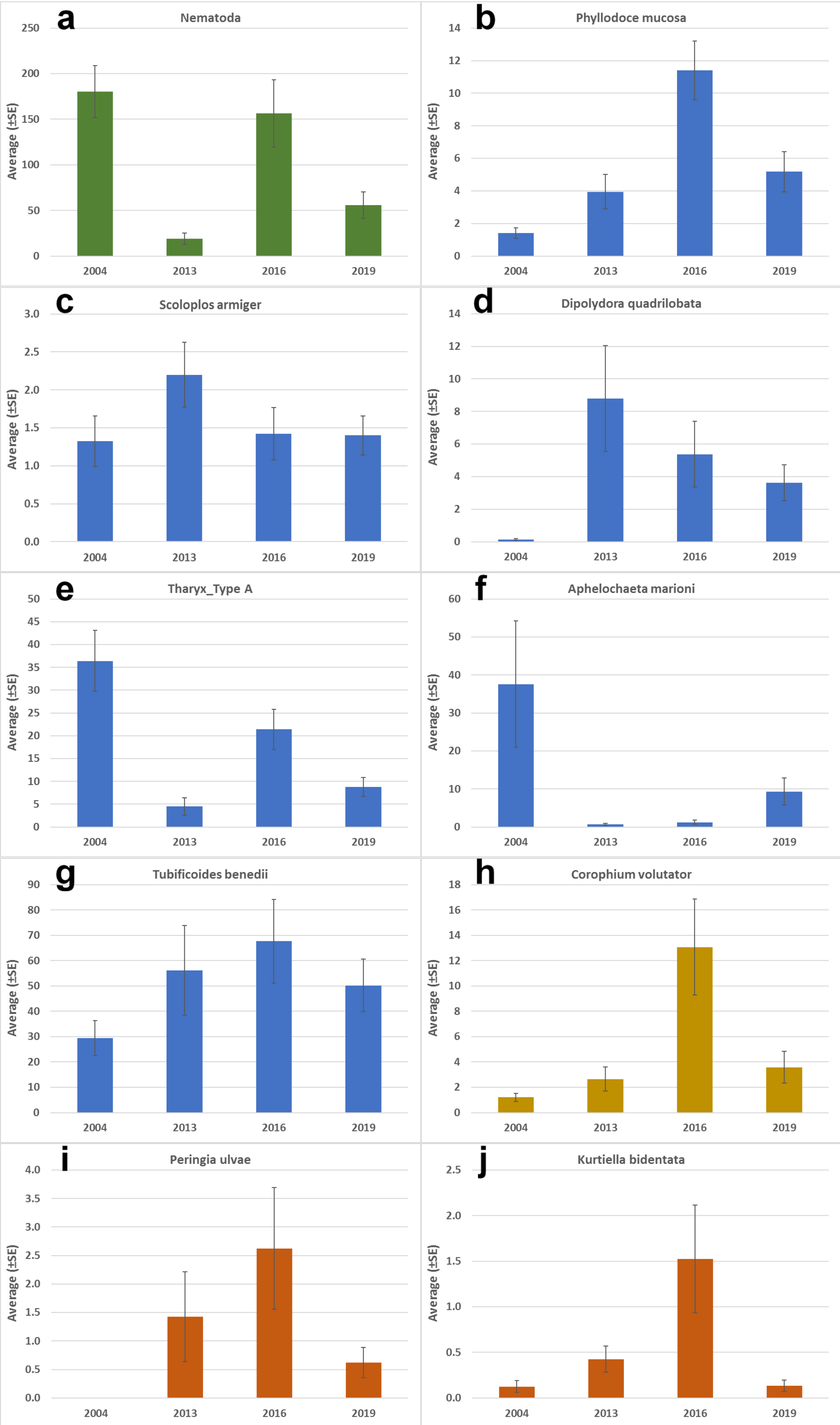


Figure 11 Continuation of graphs of temporal change in abundance (average count per core, ± standard error) for selected infaunal taxa. Each value is averaged from 40 core samples (5 cores x 8 stations).

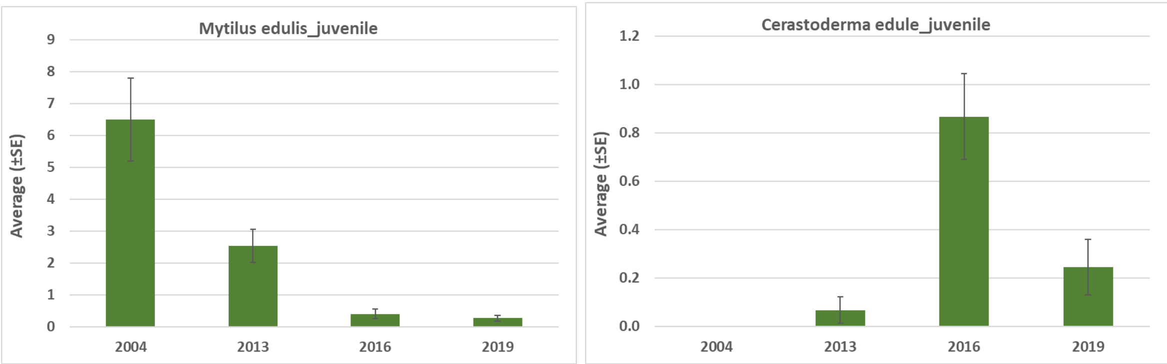


Figure 12 Visualisation of the number of records (from 27 events: 9 stations x 3 years) of the most frequently recorded **conspicuous** taxa, by year (left hand columns) and by station (right hand columns).

	2013	2016	2019	MS09	MS50	MS10	IECSB	IECS3	IECS2	MS13	MS18	IECS1
Sagartia troglodytes	3		2	1	1	1		1			1	
Spionidae (tubes)	4				1					1	1	1
Arenicola marina (casts)	4	2	3				2	2		3		2
Lanice conchilega	3	6	5	1			2	1	1	3	3	3
Cirripedia [aggregate]	7	7	7	3	3	3	3	1	3		3	2
Semibalanus balanoides	5	4	6	2	2	2	2	1	3		3	
Balanus crenatus	3	5	7	3	2	2	1		2		3	2
Austrominius modestus	3	3	5	1	2	1			3		3	1
Corophium	1		2		2				1			
Paguridae		2	2	1		1					1	1
Carcinus maenas (juvenile)	5	6	5	2	1	1	2	3	2	1	2	2
Lepidochitona cinerea		1	2						1		1	1
Gibbula cineraria		3	1	2		1			1			
Gibbula umbilicalis		5	1		1	1			1	1	2	
Littorina littorea	2	5	5	1	2	3	1		3		2	
Mytilus edulis	2	2	2	3	3							
Cerastoderma edule		2	1			1		1	1			
Rhodophyta (filamentous)	3	2					1			1	1	2
Dumontia contorta	1	2	2	1		2					2	
Corallinaceae (encrusting)	1	1	1	1		2						
Chondrus crispus	1	2	3	2		3			1			
Osmundea hybrida	3		2	2		2					1	
Chorda filum	2	1				1	1					1
Fucus serratus	2	1	3				1	2		1	1	1
Fucus vesiculosus	2	1	1	1	1	1				1		
Ulva (flat)	2	1	1				1	2				1

3.6.1 Named Species

Named species that are considered of particular interest for the Mudflats and Sandflats Feature across Wales include, *Arenicola marina, Cerastoderma edule, Corophium arenarium, Echinocardium cordatum, Hydrobia ulvae, Mytilus edulis* and *Zostera noltii*. None of these are a major part of the species community in muddy gravels. Table 4 lists the status of each of these species.

Table 4 Status of named species in muddy gravel stations.

Named Species	Status
Arenicola marina	Very low numbers, too few to identify trends: - <2 m^{-2} at IECS1 (2013, 2019), IECS3 (2013, 2019), MS13 (2013, 2016, 2019)
Corophium arenarium	A single record in 2019 (MS13). *Corophium volutator* was recorded much more frequently – see Figure 10, peaking in 2016.
Peringia ulvae	Frequently recorded in IECS1 (2016), IECS2 (2013, 2016, 2019), IECS3 (2016) and MS13 (2016, 2019) - see Figure 10, peaking in 2016.
Cerastoderma edule	Adults only recorded in 2 cores in 2016. Juveniles recorded 2013 – 2019, peaking in 2016, averaging <1 individual per core (primarily in IECS3, IECSB, MS13 and MS50) – see Figure 11.
Mytilus edulis	Juvenile *Mytilus edulis* showed a marked decline from 2004 to 2019, in -line with observations elsewhere in Wales. There has been a recovery since 2019 (pers obs). No adult *M. edulis* have been recorded.
Echinocardium cordatum	Not suitable habitat – none recorded
Zostera noltii	None recorded, although the habitat may be suitable for establishment of seagrass.

4 Discussion and conclusions

4.1 Temporal changes and differences between monitoring stations

The main conclusion from the results is that the composition of both the infauna and epibiota communities are variable, with some spatial (north south) and temporal trends, and that few notable features of potential ecological concern are apparent. Overall, the fluctuations are considered natural and the habitat is generally considered to be in favourable condition. However, a statistically significant reduction in average species richness between 2016 and 2019, is evident at all monitoring stations, and the reason for this is not known. Some of this reduction may be due to differences in the discrimination of taxa by different analysts, but that cannot account for the significant reductions at the level of Genus and Family?

4.2 Methods and protocols

Inconsistency of sampling and recording between surveyors and between analysts is a constant concern in this type of monitoring. It inevitably limits the ability to detect real change and can result in apparent changes that are not real. While such concerns are not particularly apparent in the data described in this report, a review of the methodology to assess possible ways to reduce variability and improve consistency should be considered. This could include more detailed protocols supplied to analytical laboratories for assigning qualifiers to macrofauna in samples.

5 Condition assessment

Uncertain - fluctuations in sediment character, community composition and species abundances have occurred at the monitored stations since the programme began in 2004 and most are considered natural. However, a statistically significant decrease in recorded species richness between 2016 and 2019 has been described and is unexplained.

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Appendix 1 - Surveys of muddy gravel habitats in the Menai Strait

Year	Stations	Dates	Surveyors initials	Laboratory
2002	21 stations (5 common to later surveys	12-13 August	CCW, Hebog staff	Hebog Environmental
2004	8 (MS50 not sampled)	4 & 5 August	IECS: SB, EM, NP	EMU (now Fugro EMU)
2013	9	24 & 28 June	ASML: JJM NRW: DPB, LK, RS	Hebog Environmental
2016	9	09 June	ASML: JJM, FDB, JMJ, AS NRW: LK, DPB, EWJ, LAJ, LG	Institute of Estuarine and Coastal Studies (IECS)
2019	9	06 June	ASML: JJM, FDB, JAT NRW: DPB, LG, KSB	Hull Marine Laboratory (HML) (previously IECS)

More details are given in the survey field logs, which are available on request from NRW.

Station locations, Ordnance Survey grid references (OSGB36 datum) and number of cores sampled per station (2002 data not used in this report)

Station	Location	Easting	Northing	2002	2004	2013	2016	2019
IECS B	Fryars Bay	261140	376853	6 (pooled)	5	5	5	5
IECS1	Lleiniog	262534	379117	0	5	5	5	5
IECS2	Fryars Bay	261256	377399	0	5	5	5	5
IECS3	Fryars Bay	261103	376965	0	5	5	5	5
MS09	Beaumaris	260407	375679	6 (pooled)	5	5	5	5
MS10	Fryars Bay	261158	376684	6 (pooled)	5	5	5	5
MS13	Lleiniog	261924	378352	6 (pooled)	5	5	5	5
MS18	Lleiniog	262294	378894	6 (pooled)	5	5	5	5
MS50	Beaumaris	260423	375749	0	5	5	5	5

Appendix 2 - Full list of taxa recorded

Taxonomic names are according to the World Register of Marine Species (WoRMS, http://www.marinespecies.org), updated for this report in April 2020. Qualifiers, for some taxa, are given after the name. Total number of records from all core samples and *in situ* records are given in brackets. Taxa are sorted in a taxonomic order based on the Species Directory codes of Howson & Picton 1997.

SPONGES
Hymeniacidon perleve (1)
HYDROIDS
Lovenella clausa (1)
Aglaophenia (1)
Hydrallmania falcata (1)
Sertularella gayi (1)
Sertularia (1)
Campanulariidae (1)
Clytia hemisphaerica (2)
Gonothyraea loveni (2)
Obelia dichotoma (4)
Obelia longissima (2)
ANEMONES
Actiniaria (2)
Urticina felina (1)
Sagartia troglodytes (5)
RIBBON WORMS
Nemertea (30)
Tubulanus polymorphus (4)
Cerebratulus (7)
NEMATODE WORMS
Nematoda (140)
POLYCHAETE WORMS
Polychaeta_indet (2)
Phyllodocida_Juv (2)
Pisione remota (1)
Polynoidae (11)
Gattyana cirrhosa (7)
Malmgrenia_Juv (2)
Malmgrenia (2)
Malmgrenia darbouxi (2)
Harmothoe extenuata (1)
Harmothoe imbricata (5)
Harmothoe impar_Agg (7)
Malmgrenia castanea (1)
Harmothoe glabra (2)
Malmgrenia marphysae (1)
Lepidonotus squamatus (1)
Pholoe_Juv (2)
Pholoe inornata (38)

POLYCHAETE WORMS cont.
Pholoe baltica (18)
Sthenelais boa (1)
Eteone longa_Agg (112)
Mysta picta (3)
Phyllodoce groenlandica (1)
Phyllodoce mucosa (117)
Phyllodoce rosea (2)
Eulalia viridis (3)
Eumida (26)
Eumida bahusiensis (9)
Eumida sanguinea (2)
Phyllodoce (1)
Glycera (1)
Glycera fallax (1)
Glycera tridactyla (17)
Goniadella gracilis (1)
Sphaerodoridium minutum (3)
Hesionidae (3)
Podarkeopsis capensis (11)
Psamathe fusca (4)
Microphthalmus aberrans (1)
Odontosyllis gibba (2)
Parexogone hebes (68)
Exogone naidina (36)
Sphaerosyllis (2)
Sphaerosyllis taylori (3)
Myrianida (2)
Nereididae_Juv (14)
Hediste diversicolor (13)
Alitta virens (8)
Eunereis longissima (27)
Nephtys_Juv (25)
Nephtys caeca (3)
Nephtys cirrosa (2)
Nephtys hombergii (33)
Ophryotrocha (3)
Ophryotrocha labronica_Agg (10)

POLYCHAETE WORMS cont.
Protodorvillea kefersteini (1)
Scoloplos armiger (94)
Aricidea (Aricidea) minuta (22)
Poecilochaetus serpens (3)
Spionidae_tubes (4)
Aonides oxycephala (27)
Malacoceros (2)
Malacoceros_Juv (1)
Malacoceros girardi (2)
Malacoceros fuliginosus (9)
Malacoceros tetracerus (6)
Polydora (1)
Dipolydora caulleryi (11)
Polydora ciliata_Agg (16)
Dipolydora flava (1)
Polydora cornuta (9)
Dipolydora quadrilobata (73)
Pseudopolydora pulchra (2)
Pygospio elegans (60)
Spio (3)
Spio armata (2)
Spio decorata (21)
Spio filicornis (1)
Spio martinensis (2)
Spiophanes bombyx (54)
Magelona johnstoni (16)
Magelona filiformis (18)
Caulleriella alata (5)
Chaetozone christiei (1)
Chaetozone zetlandica (1)
Chaetozone gibber (56)
Protocirrineris chrysoderma (1)
Cirriformia tentaculata (5)
Tharyx_Type A (104)

Aphelochaeta marioni (38)
Capitella_Agg (47)
Mediomastus fragilis (149)
Notomastus (92)
Arenicola marina_casts (9)
Euclymene oerstedii (14)
Ophelina acuminata (4)
Scalibregma inflatum (34)
Galathowenia oculata (46)
Owenia (1)
Owenia fusiformis (4)
Lagis koreni (34)
Lagis koreni_Juv (31)
Sabellaria spinulosa (2)
Melinna palmata (12)
Ampharete (23)
Ampharete acutifrons (32)
Ampharete grubei (38)
Lanice conchilega (100)
Lanice conchilega_Juv (4)
Polycirrus (2)
Polycirrus medusa (1)
Manayunkia aestuarina (3)
Serpulidae (1)
Spirobranchus (5)
Spirobranchus lamarcki (17)

OLIGOCHAETE WORMS

Paranais litoralis (4)
Tubificoides_cf. galiciensis (1)
Tubificoides amplivasatus (1)
Tubificoides benedii (136)
Tubificoides pseudogaster_Agg (119)
Tubificoides swirencoides (3)
Enchytraeidae (2)
Grania (5)

SEA SPIDERS

Pycnogonida_Juv (2)
Nymphon brevirostre (1)
Nymphon brevitarse (1)
Achelia echinata (1)
Amothella longipes (2)
Callipallene_Juv (1)
Anoplodactylus petiolatus (1)
Phoxichilidium femoratum (2)

BARNACLES

Cirripedia_Juv (7)
Semibalanus balanoides (16)
Balanus balanus (1)
Balanus crenatus (40)
Austrominius modestus (23)

COPEPODS

Copepoda (19)
Harpacticoida (7)

OSTRACODS

Ostracoda (1)
Eusarsiella zostericola (1)

MYSIDS

Mysidae_Juv (1)

AMPHIPODS

Apherusa jurinei (1)
Metopa pusilla (1)
Dexamine spinosa (1)
Ampelisca brevicornis (3)
Bathyporeia (1)
Gammaridae (17)
Melitidae_Juv (1)
Melita palmata (16)
Microprotopus maculatus (9)
Photis longicaudata (1)
Aoridae (1)
Aora gracilis (1)
Corophiidae (41)
Corophium arenarium (1)
Corophium volutator (67)
Caprellidae (1)
Pariambus typicus (34)

ISOPODS

Cyathura carinata (3)
Jaera_Juv (7)
Jaera (Jaera) albifrons_Agg (22)

CUMACEANS

Bodotria pulchella (4)
Bodotria scorpioides (5)
Cumella (Cumella) pygmaea (1)

CRABS

Decapoda_Juv (6)
Decapoda_megalopa (16)
Caridea (3)
Crangon crangon (42)
Paguridae_Juv (8)
Paguridae (4)
Pagurus bernhardus (4)
Portunidae_Juv (42)
Carcinus maenas (12)
Pilumnus hirtellus (4)

INSECTS

Collembola (1)
Chironomidae_larva (1)
Hemiptera_nymph (1)

CHITONS

Lepidochitona cinerea (10)
Boreochiton ruber (2)

GASTROPODS

Gastropoda (5)
Trochidae (2)
Steromphala cineraria (7)
Steromphala umbilicalis (8)
Littorina (1)
Littorina littorea (16)
Littorina saxatilis (1)
Peringia ulvae (31)
Muricidae (2)
Nucella lapillus (1)
Tritia reticulata (1)
Philine_Juv (3)
Retusa obtusa (7)
Onchidorididae (5)

BIVALVES

Bivalvia (26)
Nucula_Juv (1)
Nucula nitidosa (4)
Mytilus edulis_Juv (81)
Mytilus edulis (6)
Anomiidae_Juv (1)
Veneroidea (1)
Lucinoma borealis (16)
Lucinoma borealis_Juv (3)
Thyasira flexuosa (7)
Kurtiella bidentata (28)
Cardiidae_Juv (22)
Cerastoderma edule_Juv (26)
Cerastoderma edule (5)
Spisula subtruncata (1)
Ensis_Juv (1)
Tellinoidea (23)
Tellinoidea_Juv (10)
Fabulina fabula (7)

Moerella donacina_Juv (1)
Moerella donacina (2)
Limecola balthica (6)
Scrobicularia plana (2)
Abra alba (41)
Veneridae_Juv (9)
Venerupis corrugata_Juv (2)
Chamelea striatula (3)
Timoclea ovata (3)
Mya truncata (1)
Mya arenaria (9)
Mya arenaria_Juv (25)
Hiatella arctica (1)
Thracia phaseolina (3)
BRYOZOA
Amathia (1)
Cryptosula pallasiana (1)
Eucratea loricata (1)
Conopeum reticulum (4)
ECHINODERMS
Asteroidea_Juv (3)
Asterias rubens (1)
Ophiuroidea (9)
Amphiuridae (1)
Acrocnida brachiata (2)
Amphiura filiformis (1)
Amphipholis squamata (8)
HEMICHORDATES
Enteropneusta (1)
FISH
Callionymus reticulatus_Juv (1)
Pleuronectidae (4)
Buglossidium luteum_Juv (1)
RED ALGAE
Rhodophyta_filamentous (4)
Dumontia contorta (5)
Hildenbrandia (1)
Corallinaceae_encrusting (3)
Gracilaria (2)
Mastocarpus stellatus (1)
Chondrus crispus (6)
Plocamium cartilagineum (3)
Ceramium (2)
Osmundea hybrida (5)
Polysiphonia (3)
CILIATES
Folliculinidae (1)
BROWN ALGAE
Chromophycota_fil (1)
Ochrophyta (8)
Dictyota dichotoma (1)
Chorda filum (3)
Laminaria saccharina_sporelings (1)
Fucus serratus (6)
Fucus vesiculosus (4)
GREEN ALGAE
Chlorophyta_filamentous (1)
Ulva intestinalis_Agg (1)
Ulva_flat (4)
Cladophora (2)

Appendix 3 - Detailed results of analyses

More detailed results from analyses summarised in Sections 3.4.1 and 3.5.

ANOVA: Species richness between Years

Analysis of Variance and Tukey HSD post-hoc tests (see Section 3.4.1)
Data: Species richness (quantitative taxa only), 40 samples x 4 years

DESCRIPTION (alpha = 0.05)

Group	***Count***	***Sum***	***Mean***	***Variance***	***SS***	***Std Err***	***Lower***	***Upper***
Y2004	40	708	17.7	24.984	974.4	1.019	15.687	19.713
Y2013	40	834	20.85	59.105	2305.1	1.019	18.837	22.863
Y2016	40	983	24.575	26.763	1043.77	1.019	22.562	26.588
Y2019	40	773	19.325	55.353	2158.77	1.019	17.311	21.338
ANOVA								
Sources	***SS***	***df***	***MS***	***F***	***P value***	***F crit***	***RMSSE***	***Omega Sq***
Between Groups	1035.92	3	345.308	8.310	3.67E-05	2.662	0.456	0.1205
Within Groups	6482.05	156	41.551					
Total	7517.97	159	47.282					

TUKEY HSD/K (alpha = 0.05)

group	***mean***	***n***	***ss***	***df***	***q-crit***				
Y2004	17.7	40	974.4						
Y2013	20.85	40	2305.1						
Y2016	24.58	40	1043.7						
Y2019	19.33	40	2158.7						
		160	6482.1	156	3.673				
Q TEST									
group 1	***group 2***	***mean***	***std err***	***q-stat***	***lower***	***upper***	***p-value***	***mean-crit***	***Cohen d***
Y2004	Y2013	3.15	1.0192	3.0906	-0.595	6.894	0.1318	3.744	0.4887
Y2004	Y2016	6.875	1.0192	6.7454	3.131	10.619	2.5E-05	3.744	1.0665
Y2004	Y2019	1.625	1.0192	1.5944	-2.119	5.369	0.6732	3.744	0.2520
Y2013	Y2016	3.725	1.0192	3.6548	-0.019	7.469	0.0516	3.744	0.5779
Y2013	Y2019	1.525	1.0192	1.4963	-2.219	5.269	0.7155	3.744	0.2366
Y2016	Y2019	5.25	1.0192	5.1510	1.506	8.994	0.0021	3.744	0.8145

ANOSIM: Year x Station

Analysis of Similarities (see Section 3.5)
Two-Way Analysis – Year x Station
Data – Bray-Curtis similarities derived from log(x+1) transformed counts for 230 taxa
Factors: Year (ordered): 2004, 2013, 2016, 2019 x Station (unordered): MS09, IECS3, IECS B, MS10, IECS2, MS13, MS18, IECS1

Tests for differences between ordered Year groups (across all Station groups)
Global Test
Sample statistic (Average R): 0.515. Significance level of sample statistic: 0.1%
Number of permutations: 999 (Random sample from a large number)
Number of permuted statistics greater than or equal to Average R: 0

Pairwise Tests

Groups	R Statistic	Significance Level %
2004, 2013	0.879	0.1
2004, 2016	0.9	0.1
2004, 2019	0.859	0.1
2013, 2016	0.739	0.1
2013, 2019	0.731	0.1
2016, 2019	0.76	0.1

Tests for differences between unordered Station groups (across all Year groups)
Global Test
Sample statistic (Average R): 0.758. Significance level of sample statistic: 0.1%
Number of permutations: 999 (Random sample from a large number)
Number of permuted statistics greater than or equal to Average R: 0

Pairwise Tests

Groups	R Statistic	Significance Level %
MS09, IECS3	0.821	0.1
MS09, IECS B	0.771	0.1
MS09, MS10	0.816	0.1
MS09, IECS2	0.845	0.1
MS09, MS13	0.971	0.1
MS09, MS18	0.906	0.1
MS09, IECS1	0.854	0.1
IECS3, IECS B	0.806	0.1
IECS3, MS10	0.929	0.1
IECS3, IECS2	0.964	0.1
IECS3, MS13	0.934	0.1
IECS3, MS18	0.969	0.1
IECS3, IECS1	0.837	0.1
IECS B, MS10	0.871	0.1
IECS B, IECS2	0.76	0.1
IECS B, MS13	0.702	0.1
IECS B, MS18	0.584	0.1
IECS B, IECS1	0.7	0.1
MS10, IECS2	0.97	0.1
MS10, MS13	0.994	0.1
MS10, MS18	0.975	0.1
MS10, IECS1	0.855	0.1
IECS2, MS13	0.931	0.1
IECS2, MS18	0.883	0.1
IECS2, IECS1	0.834	0.1
MS13, MS18	0.753	0.1
MS13, IECS1	0.775	0.1
MS18, IECS1	0.585	0.1

SIMPER: Period

To establish what influence the timing of the field survey may have on individual species.

Similarity Percentages - species contributions (see Section 3.5, page 16)
One-Way Analysis – Period
Data – Log(x+1) transformed counts for 230 taxa
Analysis parameters: S17 Bray-Curtis similarity; Cut off for low contributions: 70.00%
Factor Groups: Period (Early = 2004, Later = 2013-2019)

Early & Later - Average dissimilarity = 68.26

Species	Early Av.Abund	Middle Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Nematoda	4.44	2.73	4.78	1.16	7.00	7.00
Tharyx_Type A	2.78	1.35	3.80	1.30	5.56	12.56
Tubificoides benedii	2.42	2.60	3.63	1.24	5.32	17.89
Mediomastus fragilis	2.30	2.57	2.79	1.28	4.09	21.98
Tubificoides pseudogaster_agg	1.36	1.76	2.48	1.26	3.64	25.62
Mytilus edulis_Juv	1.60	0.44	2.39	1.36	3.50	29.11
Phyllodoce mucosa	0.66	1.37	1.88	1.26	2.76	31.87
Lanice conchilega	0.27	0.95	1.71	0.89	2.51	34.37
Aphelochaeta marioni	0.75	0.47	1.61	0.58	2.36	36.74
Capitella_Agg	0.91	0.28	1.61	0.86	2.36	39.10
Corophium volutator	0.50	0.86	1.53	0.95	2.23	41.33
Eteone longa_Agg	0.34	1.05	1.49	1.31	2.18	43.51
Dipolydora quadrilobata	0.09	0.93	1.48	0.81	2.18	45.69
Notomastus	0.18	0.90	1.42	1.15	2.08	47.77
Scoloplos armiger	0.55	0.72	1.41	1.01	2.06	49.83
Parexogone hebes	0.41	0.63	1.23	0.94	1.80	51.63
Balanus crenatus	0.00	0.71	1.21	0.42	1.77	53.39
Eumida	0.75	0.02	1.17	0.97	1.72	55.11
Pygospio elegans	0.42	0.46	1.07	0.89	1.57	56.68
Corophiidae	0.08	0.65	0.99	0.62	1.45	58.13
Ampharete grubei	0.37	0.31	0.90	0.73	1.32	59.46
Cardiidae_Juv	0.51	0.00	0.89	0.84	1.30	60.75
Exogone naidina	0.47	0.16	0.87	0.75	1.28	62.03
Galathowenia oculata	0.34	0.30	0.84	0.71	1.23	63.26
Spiophanes bombyx	0.12	0.41	0.83	0.75	1.21	64.48
Ampharete acutifrons	0.00	0.48	0.80	0.53	1.17	65.65
Chaetozone gibber	0.12	0.42	0.76	0.77	1.12	66.77
Spio decorata	0.40	0.03	0.69	0.75	1.02	67.78
Pariambus typicus	0.27	0.18	0.63	0.61	0.93	68.71
Lagis koreni_Juv	0.00	0.36	0.62	0.52	0.90	69.61
Crangon crangon	0.09	0.29	0.59	0.61	0.87	70.48

SIMPER: Location

To elucidate the differences between Fryars Bay and Lleiniog grouped sampling stations.

Similarity Percentages - species contributions (see Section 3.5, page 16
One-Way Analysis – Location
Data – Log(x+1) transformed counts for 230 taxa
Analysis parameters: S17 Bray-Curtis similarity; Cut off for low contributions: 70.00%
Factor Groups: Location (Fryars Bay & Lleiniog)

Fryars Bay & Lleiniog - Average dissimilarity = 72.21

Species	Fryars Bay Av.Abund	Lleiniog Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Tubificoides benedii	3.61	0.65	4.90	1.72	6.79	6.79
Nematoda	3.18	1.65	3.87	1.38	5.36	12.15
Mediomastus fragilis	3.08	1.65	3.15	1.27	4.36	16.51
Tharyx_Type A	1.39	1.59	2.80	1.17	3.88	20.40
Tubificoides pseudogaster_agg.	1.73	1.65	2.48	1.23	3.43	23.83
Phyllodoce mucosa	1.86	0.50	2.42	1.55	3.35	27.18
Lanice conchilega	0.64	1.55	2.25	1.14	3.12	30.30
Dipolydora quadrilobata	1.18	0.77	2.07	1.01	2.86	33.16
Corophium volutator	1.28	0.41	1.95	0.97	2.70	35.87
Balanus crenatus	0.86	0.25	1.86	0.49	2.57	38.44
Corophiidae	1.09	0.29	1.67	0.83	2.32	40.76
Scoloplos armiger	0.50	1.21	1.57	1.19	2.17	42.93
Parexogone hebes	0.61	0.88	1.50	1.14	2.08	45.01
Notomastus	0.99	0.78	1.46	1.21	2.02	47.02
Eteone longa_Agg	1.28	0.77	1.45	1.21	2.01	49.03
Spiophanes bombyx	0.23	0.80	1.24	1.12	1.72	50.75
Pygospio elegans	0.43	0.69	1.21	0.94	1.68	52.43
Ampharete acutifrons	0.52	0.19	1.06	0.63	1.46	53.90
Galathowenia oculata	0.16	0.58	1.01	0.77	1.40	55.29
Peringia ulvae	0.57	0.25	1.00	0.70	1.39	56.69
Mytilus edulis_Juv	0.59	0.16	1.00	0.82	1.38	58.07
Lagis koreni_Juv	0.43	0.30	0.99	0.73	1.37	59.43
Chaetozone gibber	0.56	0.31	0.98	0.96	1.36	60.79
Ampharete grubei	0.51	0.05	0.90	0.55	1.25	62.04
Crangon crangon	0.17	0.50	0.90	0.83	1.25	63.29
Polydora ciliata_Agg	0.51	0.03	0.78	0.45	1.08	64.37
Capitella_Agg	0.39	0.22	0.78	0.63	1.08	65.45
Lagis koreni	0.31	0.32	0.74	0.75	1.02	66.47
Kurtiella bidentata	0.46	0.02	0.69	0.61	0.95	67.43
Austrominius modestus	0.32	0.16	0.69	0.40	0.95	68.38
Abra alba	0.38	0.20	0.68	0.77	0.94	69.32
Ampharete	0.35	0.16	0.65	0.59	0.90	70.21

BEST (BIOENV)

Biota and/or Environment matching (see Section 3.5, page 16)
Biological data: Bray-Curtis similarities derived from mean log(x+1) transformed counts for 230 taxa
Environmental data: Particle size data for 33 samples

Parameters
Correlation method: Spearman rank Method: BIOENV Maximum number of variables: 5
Analyse between: Samples
Resemblance measure: D1 Euclidean distance

VARIABLES

Log(Pebble_medium)	Trial
Log(Pebble_small)	Trial
Log(Granule)	Trial
Log(Sand_v_coarse)	Trial
Log(Sand_coarse)	Trial
Log(Sand_medium)	Trial
Log(Sand_fine)	Trial
Log(Sand_v_fine)	Trial
Log(Silt_and_clay)	Trial
Mean phi	Trial
Sorting	Trial
Skewness	Trial
Kurtosis	Trial

Best result for each number of variables

No.Vars	Corr.	Selections
1	**0.223**	**Log(Sand_coarse)**
2	0.372	Log(Sand_v_fine),Log(Silt_and_clay)
3	0.444	Log(Sand_v_coarse),Log(Sand_v_fine),Log(Silt_and_clay)
4	0.454	Log(Sand_v_coarse),Log(Sand_v_fine),Log(Silt_and_clay),Sorting
5	0.446	Log(Sand_v_coarse),Log(Sand_coarse),Log(Sand_v_fine),Log(Silt_and_clay),Sorting

Global Test
Sample statistic (Rho): 0.454
Significance level of sample statistic: 1%
Number of permutations: 99 (Random sample)
Number of permuted statistics greater than or equal to Rho: 0

Best results

No.Vars	Corr.	Selections
4	0.454	Log(Sand_v_coarse),Log(Sand_v_fine),Log(Silt_and_clay),Sorting
5	0.446	Log(Sand_v_coarse),Log(Sand_coarse),Log(Sand_v_fine),Log(Silt_and_clay),Sorting
3	0.444	Log(Sand_v_coarse),Log(Sand_v_fine),Log(Silt_and_clay)
5	0.442	Log(Sand_v_coarse),Log(Sand_medium),Log(Sand_v_fine),Log(Silt_and_clay),Sorting
4	0.428	Log(Sand_v_coarse),Log(Sand_medium),Log(Sand_v_fine),Log(Silt_and_clay)
4	0.427	Log(Sand_v_coarse),Log(Sand_coarse),Log(Sand_v_fine),Log(Silt_and_clay)
5	0.424	Log(Sand_v_coarse),Log(Sand_fine),Log(Sand_v_fine),Log(Silt_and_clay),Sorting
4	0.420	Log(Sand_coarse),Log(Sand_v_fine),Log(Silt_and_clay),Sorting
4	0.418	Log(Sand_v_coarse),Log(Sand_fine),Log(Sand_v_fine),Log(Silt_and_clay)
5	0.415	Log(Sand_v_coarse),Log(Sand_medium),Log(Sand_fine),Log(Sand_vfine),Log(Silt_clay)

Appendix 4 - Data archive

Data outputs associated with this project are archived in the NRW Document Management System on server–based storage at Natural Resources Wales.

The data archive contains:

[A] The final report in Microsoft Word and Adobe PDF formats.

[B] Excel spreadsheets of all data and analyses

[C] A Primer workbook with analyses

[F] A full set of images from the survey, in jpg format.

Metadata for this project is publicly accessible through Natural Resources Wales' Library Catalogue (English Version) and Catalog Llyfrgell (Welsh Version) by searching 'Dataset Titles'. The metadata is held as a record within 'Intertidal Monitoring'.

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