Fal & Helford SAC Subtidal Sediment Data Analysis Report 2017

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Fal & Helford SAC Subtidal Sediment Data Analysis Report v2.0

for

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Natural England

Johnson, G., Burrows, F., Crabtree, R., and Warner, I. 2017. Fal and Helford SAC Subtidal Sediment Data Analysis. A Report for Natural England.

Executive Summary

The aim of this project was to analyse sediment infauna data to quantify any changes in community composition at the Fal and Helford Special Area of Conservation (SAC). This will contribute towards Natural England (NE) condition assessment using conservation advice for each site and sub-feature.

MarineSpace Ltd (MarineSpace) was commissioned by NE to analyse and report on subtidal sediment grab data collected by the Environment Agency (EA) as part of its Water Framework Directive (WFD) and monitoring from the Fal and Helford. Data were provided from surveys conducted in 2001, 2009, 2010, 2013 and 2016.

Biodiversity indices (including total number of species in each sample (S), total number of Individuals in each sample (N), Pielou's Evenness Index (J'), Shannon-Weiner Diversity Index (H'), and Simpson index (1-λ')) were tested using a Kruskall-Wallis test by ranks to see if there were significant differences over time. All univariate tests were conducted in the R statistical computing environment.

Community data were examined using the PRIMER v7 software package. ANOSIM was used to test for differences in species composition between groups. SIMPER analysis was then utilised to see which species contributed to similarities and dissimilarities between groups.

Site 1 was situated in the Fal River in the upper reaches of the Fal Estuary. Site 1 had low to moderate richness and diversity and there were no significant differences in biodiversity indices between years. Community composition was significantly different between years, but was due to small changes in the relative abundance of common species. Sediments were sandy Mud. Overall, the community was characterised as a typical SS.SMu.SMuVS.AphTubi community (*Aphelochaeta marioni* and *Tubificoides* spp. in variable salinity infralittoral mud).

Site 2 was situated in the upper reaches of the Carrick Roads in the Fal Estuary. Site 2 had low to moderate richness and diversity and there were no significant differences in biodiversity indices between years. Community composition was significantly different between years, but was due to small changes in the relative abundance of common species. Sediments were typically sandy or gravelly Mud. Overall, the site was best characterised as SS.SMu.SMuVS.AphTubi, though there were elements of SS.SMu.ISaMu.MelMagThy in 2001.

Site 3 was situated towards the upper reaches of the Carrick Roads in the Fal Estuary. Heavy metal concentrations in the sediment are known to be especially high here due to extensive historical mining in the Fal Estuary, though no chemical samples were analysed as part of this work. Site 3 had low to high richness and diversity and there were no significant differences in biodiversity indices between years. Community composition was significantly different between years, but was due to small changes in the relative abundance of common species. Sediments were typically either muddy Gravel or Gravel. Overall, the site was best characterised as SS.SMu.SMuVS.AphTubi (*Aphelochaeta marioni* and *Tubificoides* spp. in variable salinity infralittoral mud) though there were elements of SS.SMx.IMx.VsenAsquAps (*Venerupis senegalensis, Amphipholis squamata* and *Apseudes latreilli* in infralittoral mixed sediment) in 2001.

Although the most common assemblage at Sites 1-3 was characteristic of SS.SMu.SMuVS.AphTubi, this biotope is comprised of predominately of r-strategists or opportunistic species, characterised by high fecundity, small body size, and short generation time. This biotope is known to have low sensitivity to chemical pressures and representative taxa can recover rapidly from impacts (<1 year).

Site 4 was situated in the mid region of the Carrick Roads in the Fal Estuary. Site 4 had moderate to high richness and diversity and there were no significant differences in biodiversity indices between years. Community composition was significantly different between years, but was due to small changes in the relative abundance of common species. Sediments were predominantly gravelly Mud, but were variable and also included Mud, muddy Sand and Sand. Overall, the biotope is best represented as a slightly gravelly variant of the *Mellina* biotope SS.SMu.ISaMu.MelMagThy (*Melinna palmata* with *Magelona* spp. and *Thyasira* spp. in infralittoral sandy mud).

Site 5 was situated in the outer region of the Carrick Roads in the Fal Estuary. Site 5 had moderate richness and diversity and there were no significant differences in biodiversity indices between years. Community composition was significantly different between years, but was due to small changes in the relative abundance of common species. Sediments were typically Sand or muddy Sand. Across the 2001 and 2013 surveys, the biotope is best represented as SS.SSa.IMuSa.FfabMag (*Fabulina fabula* and *Magelona mirabilis* with venerid bivalves and amphipods in infralittoral compacted fine muddy sand). In 2001, there were high levels of *Capitella* spp. at Site 5 that indicated possible organic enrichment, but these were not present in 2013.

Site 6 was situated in the outer region of the Carrick Roads in Falmouth Bay. Site 6 had low to moderate richness and diversity and there were no significant differences in biodiversity indices between years. Community composition was significantly different between years, but was due to small changes in the relative abundance of common species. Sediments were typically gravelly Sand or sandy Gravel. Overall, the community was best characterised as a classic SS.SCS.CCS.MedLumVen (*Mediomastus fragilis, Lumbrineris* spp. and venerid bivalves in circalittoral coarse sand or gravel). This biotope has previously been described as the 'Deep Venus Community' and the 'Boreal Off-Shore Gravel Association'.

Site 7 was situated in the outer region of the Helford River. Site 7 had moderate richness and diversity and there were no significant differences in biodiversity indices between years. Community composition was significantly different between years, but was due to small changes in the relative abundance of common species. Sediments were typically gravelly Sand or sandy Gravel, though there was a larger component of silt in 2010. Overall, the biotope was best characterised as SS.SCS.CCS.Pkef (*Protodorvillea kefersteini* and other polychaetes in impoverished circalittoral mixed gravelly sand), though in 2010 and 2013 there were additional elements of SS.SSa.IMuSa.FfabMag (*Fabulina fabula* and *Magelona mirabilis* with venerid bivalves and amphipods in infralittoral compacted fine muddy sand) associated with elevated silt content.

Site 9 was located in the inner region of the Helford River. Site 9 had moderate richness and diversity and there were no significant differences in biodiversity indices between years. Community composition was significantly different between years, but was due to small changes in the relative abundance of common species. Sediments were typically sandy Mud, but there was a higher component of gravel in 2010 (gravelly Mud). Across all surveys, the most consistent characterising taxa were *Protodorvillea kefersteini, Caulleriella bioculata,* Nemertea and Nematoda, which bears a very strong resemblance to the community SS.SCS.CCS.Pkef (*Protodorvillea kefersteini* and other polychaetes in impoverished circalittoral mixed gravelly sand).

Though there were significant changes in relative species composition observed during the survey period, these were not sufficient to lead to changes in biotope classification, which have not deviated significantly from the 2001 survey.

Based upon the findings of this study and acknowledging limitations with subsequent monitoring surveys, there is no evidence that feature presence or distribution, the presence of typical species, sediment composition and distribution, or species composition of component communities have changed since the 2001 survey, outside of what might be expected due to natural change in such a dynamic environment.

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1. Introduction

1.1. Overview

Natural England (NE) commissioned this project to analyse and report on subtidal sediment grab data collected by the Environment Agency (EA) as part of its Water Framework Directive (WFD) and monitoring from Fal and Helford Special Area of Conservation (SAC).

For a number of years, the EA has been taking benthic grab samples at sites around England to meet the requirements of Article 8 of the WFD in relation to monitoring and, more recently, assisting NE in collecting benthic samples from marine protected areas (MPAs) of different designations for site condition monitoring. In the southwest, there is now a time series of data from grab samples. NE commissioned analyses of these data and other data from within Fal and Helford SAC and sub-features:

- Subtidal coarse sediment;
- Subtidal mixed sediment;
- Subtidal mud; and
- Subtidal sand.

1.2. Aims and Objectives

The aim of this project is to analyse sediment infauna data to quantify any changes in community composition. This will contribute towards NE condition assessment using conservation advice for each site and sub-feature. To achieve this aim, the following objectives have been set:

1. Analyse macrofauna data to identify any spatial and temporal changes in community structure within the designated sediment sub-features; and
2. Place any findings in context of the distribution and structure of benthic communities and, where possible, make comments on the use of the data to assess feature condition.

The report analyses changes in sediment, infauna communities and biotopes that have occurred across the MPA using historical survey data (Table 1.1).

Table 1.1: Summary of site monitoring data for Fal and Helford Special Area of Conservation

Site	Year	Survey Contractor
Fal & Helford SAC	2016	EA
	2013	EA
	2010	EA
	2009	EA
	2001	Institute of Estuarine and Coastal Studies (IECS)

Specifically, this report:

- Describes and maps the distribution of sediment types;
- Describes the distribution of characteristic biotopes in each MPA;
- Considers whether any continued change has occurred within the sediments and infaunal communities within the study area; and
- Considers change in faunal communities of MPA sub-features and the applicability of monitoring data to inform feature condition assessments in each MPA

2. General Approach

2.1. Data Preparation

2.1.1. Faunal Data

Due to the variety of methods employed in different surveys, data were standardised to allow for meaningful statistical analyses.

Prior to data analysis the steps taken to truncate and organise the data included:

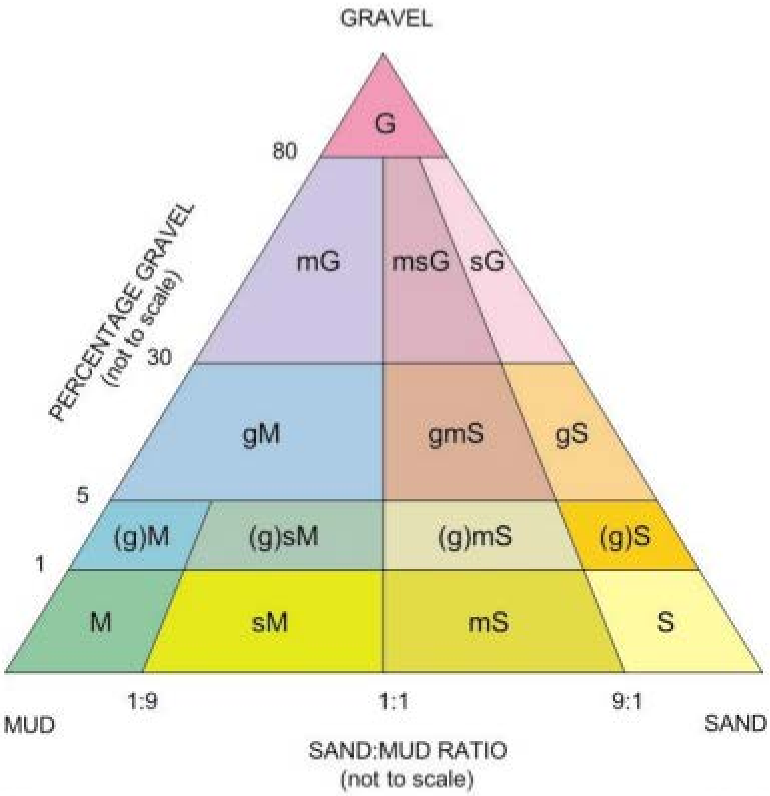
- Removal of epifauna due to inconsistencies in enumeration of colonial taxa and the utilisation of infauna-specific sampling methods. Epifauna could be used to aid assignment of biotopes if considered advantageous;
- Removal of meiofauna due to potential bias to assemblages based on high abundance of meiofauna;
- Removal of planktonic data as unrepresentative of benthic assemblages;
- Remove of freshwater and non-marine taxa as unrepresentative of coastal and marine assemblages (including insects);
- Removal of qualifiers (juv, sp., spp., indet, epitoke, larva, zoea, Type A, (?), female and agg) from the datasets and aggregate to parent taxon to ensure standardisation between datasets; and
- Combining taxa from groups with identification inconsistencies due to insufficient identification and QA protocols.

The metadata showed that grab samples had been processed through different sieve mesh sizes depending on the survey. Some surveys processed samples through a 500 µm, some used a 1000 µm sieve mesh, and some used both. The use of different mesh sieve sizes during sample processing creates problems in statistical analysis due to differences in the amount of fauna retained, including increased species numbers and abundance associated with the use of smaller mesh sizes that are not easily corrected (Reish, 1959). To minimise data bias the decision was taken and agreed with NE to compare datasets using presence-absence transformed data.

2.1.2. Particle Size Analysis Data

PSA data were split into sediment fractions (µm) for analysis and checked to ensure that the total percentage of sediment added up to 100%. The PSA data were then split into % mud (<63µm), % sand (63 - 1,999µm) and % gravel (2,000 - >63,000µm) components. Folk classifications were assigned to each sample as per Folk (1954) (Figure 2.1) to facilitate biotope classification.

Figure 2.1: Folk Classification System Based on Folk (1954) used in British Geological Survey Sediment Maps (From: Long, 2006)



M ________ Mud
sM ________ Sandy mud
(g)M ________ Slightly gravelly mud
(g)sM ________ Slightly gravelly sandy mud
gM ________ Gravelly mud
S ________ Sand
mS ________ Muddy sand
(g)S ________ Slightly gravelly sand
(g)mS ________ Slightly gravelly muddy sand
gmS ________ Gravelly muddy sand
gS ________ Gravelly sand
G ________ Gravel
mG ________ Muddy gravel
msG ________ Muddy sandy gravel
sG ________ Sandy gravel

The above classification is based on that of R.L.Folk, 1954, J. Geol., 62 pp344-359.

2.2. Statistical Analysis

Data were analysed both as a complete dataset, to observe changes at a site level, and by site or experimental box, which was the design employed in the 2001 survey (see Section 3.3.1).

All data analyses were conducted using PRIMER v7 with PERMANOVA+ statistical software (Clarke and Warwick, 2001; Clarke *et al*., 2014; Clarke and Gorley, 2015).

2.2.1. Univariate Statistics

Data were initially examined through the PRIMER v7 software package (Clarke and Gorley, 2015). Anomalous or outlier results were removed due to their ability to skew or hide significant interactions. The DIVERSE routine was used to define univariate biodiversity indices including:

- Total number of species in each sample (S);
- Total number of individuals in each sample (N);
- Pielou's evenness index (J');
- Shannon-Weiner diversity index (H'); and
- Simpson index (1-λ')

Pielou's evenness index (J') considers the evenness of a population in terms of the number of individuals and their dominance. The Simpson index (1-λ') calculates the probability of any two individuals within a sample being the same species and is a complementary measure of evenness. Shannon-Weiner (H') provides an estimate of biodiversity, and considers the overall species numbers along with aspects of dominance.

Biodiversity indices have been displayed spatially within the report as bubbles overlain on maps of MPA sub-features to illustrate any changes in the distribution of biodiversity over time (See Annexes C-E).

Due to the unbalanced design and in case the data were not normal, the biodiversity indices were tested using a Kruskall-Wallis test by ranks to see if there were significant differences over time. All univariate tests were conducted in the R statistical computing environment (R Core Development Team, 2014).

2.2.2. Multivariate Statistics

A Bray-Curtis resemblance measure between taxa was used to create a similarity matrix (Bray and Curtis, 1957). Both 2- and 3-dimensional non-metric multi-dimensional scaling (nMDS) ordinations were produced to compare stress values and assess the accuracy of the 2-dimensional MDS. Different transformations ($\sqrt{}$-, $\sqrt[4]{}$-, log-transformation) were applied and multiple nMDS plots produced to observe patterns with different weightings of rare species. If the stress value for the 2D plot was high, then principal co-ordinates analysis (PCO) in PERMANOVA was considered as an alternative method of ordination. Sediment data were untransformed as it was presented as % composition.

A hierarchical agglomerative cluster analysis was undertaken on the dissimilarity matrix, using SIMPROF to identify statistically significant differences in groupings.

For *a priori* structured datasets, ANOSIM was used to test for differences in species composition between groups. SIMPER analysis was then utilised to see which species contributed to similarities and dissimilarities between groups.

2.2.3. Biotope Classification

Faunal assemblages were identified using PRIMER v7 and PERMANOVA+ during multivariate community analysis. A hierarchical agglomerative cluster analysis was also undertaken on the dissimilarity matrix with SIMPROF to identify statistically significant differences in groupings. Multiple statistical tests were applied and compared to identify which species characterise each group of samples. For habitats with relatively low species abundance, it was necessary to consider the raw data to enable a biotope to be assigned.

Clusters identified in cluster analysis do not necessarily represent truly different communities. Results were interpreted by experts in order to identify whether patterns shown are real or due to inconsistencies in the data.

Interpretation was aided by expert judgement of sedimentary habitats and using the Marine Habitat Classification for Britain and Ireland (Connor *et al*., 2004) and recent JNCC guidance (Parry, 2015).

Biotopes were assigned based upon all characterising variables used in the classification in order to describe the physical as well as biological environment (biological zone, substrate, energy level, salinity and species composition) using the guidance provided by Parry (2015).

2.2.4. Spatial Analysis

ArcGIS version 10.4 was used to produce mapping outputs. National Grid OS maps were used for base-mapping. Maps were produced to show:

- Any change in distribution of sediment types across the three sites over time; and
- Any change in distribution of biodiversity indices across the three sites over time.

3. Fal and Helford SAC

3.1. Background

The Fal and Helford SAC is located on the southern coast of west Cornwall. This site was confirmed as a Site of Community Importance (SCI) in December 2004 and was designated as a Special Area of Conservation (SAC) in April 2005. The location of the site is shown in Figure 3.1.

The site comprises the Fal and Helford drowned river valley system and Falmouth Bay. The site supports a wide range of communities associated with shallow inlets and bays. Both ria systems within the SAC have low levels of freshwater input, therefore, they contain a number of fully marine habitats and have a high species diversity. The area supports extensive and rich sediment communities, which include the largest and most south-westerly maerl *Phymatolithon calcareum* bed in the UK. The habitats are influenced by levels of exposure, which range from extremely sheltered mudflat in the upper Fal to exposed rock near the Helford mouth. As the site is located in the southwest there are warmer sea temperatures compared with the rest of the UK and this allows species to occur that are normally more southern in their distribution (Natural England, 2015a).

The shores of the upper Fal and Helford are mainly fringed by sheltered intertidal sandflats and mudflats. These areas host important sediment dwelling species including some nationally rare species and communities, and are particularly recognised for the importance of the species living in the sediments, including amphipods, polychaete worms, the sea cucumber *Leptopentacta elongate* and bivalve mollusc species. The mudflats and sandflats also support a range of important bird communities. Atlantic salt meadows are also present within the SAC and there is also salt meadows transition to woodland, which is rare in the UK. These support particularly rich and nationally important sediment communities in the Fal / Ruan estuary, Percuil River and in Passage Cove, including beds of dwarf eelgrass *Zostera noltei* and diverse invertebrate communities (JNCC, 2017).

Sublittoral sandbanks are present throughout much of the ria system and Falmouth Bay. There are particularly rich sublittoral sand invertebrate communities (JNCC, 2017). In Falmouth Bay there are extensive beds of maerl, a coralline red algae. These maerl beds support a high diversity of species including large numbers of the thornback ray *Raja clavata*. These are the largest beds in southwest Britain and harbour a rich variety of both epifaunal and infaunal species, including some which are rarely encountered, such as Couch's goby *Gobius couchi* (JNCC, 2017). There are also beds of subtidal seagrass *Zostera marina* within the site, which act as important nursery areas for some fish species as well as cuttlefish. The site also contains a population of native oyster *Ostrea edulis*. There are intertidal and subtidal rocky reefs present in the SAC. This includes circalittoral reef in Falmouth Bay, which supports the pink sea fan *Eunicella verrucosa* (Natural England, 2015a, 2015b).

The designated habitats and species for the Fal and Helford SAC, for which sediment monitoring has been carried out, are summarised below.

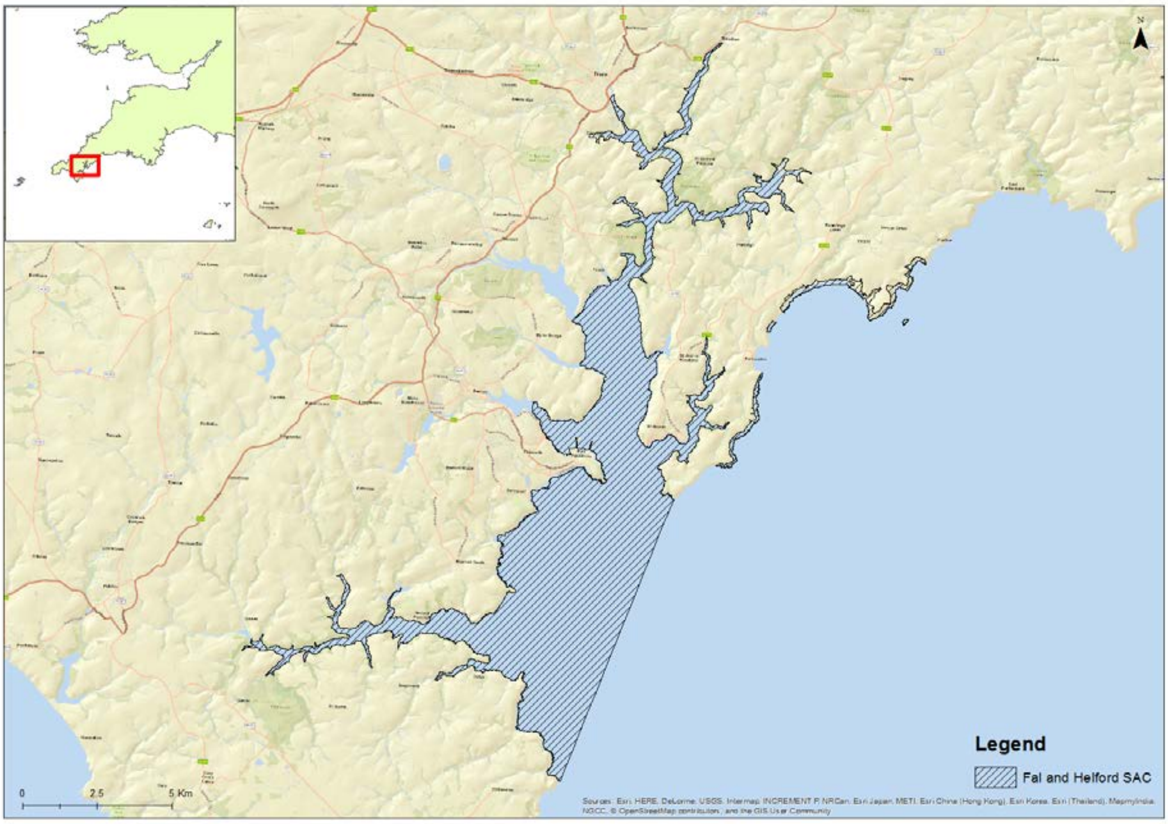
Annex I habitats that are a primary reason for selection of this site:

- Sandbanks which are slightly covered by sea water all the time;
- Mudflats and sandflats not covered by seawater at low tide; and
- Large shallow inlets and bays.

Annex I habitats present as a qualifying feature, but not a primary reason for selection of this site, for which sediment monitoring has been carried out:

- Estuaries.

Figure 3.1: Location of the Fal and Helford Special Area of Conservation



3.2. Methods

A summary of the survey data that were considered for inclusion in this report is presented in Table 3.1. A map showing the difference in spatial distribution of the sampling arrays is included as (Figure 3.3).

Table 3.1: List of benthic grab datasets included in this report

Site	Year	Survey Contractor	Number of Samples
Fal & Helford SAC	2001	Institute of Estuarine and Coastal Studies	10 grabs from each of 9 survey blocks. 0.1 m^2 Day grab
	2009	EA	30
	2010	EA	122
	2013	EA	92
	2016	EA	35

3.2.1. 2001 Survey

The 2001 survey of the Fal and Helford SAC was undertaken on 23 to 25 May 2001 by the University of Hull, aboard the survey boat *MV Karina Olsen*. An intensive seabed sampling survey was undertaken, with the key sediment types that had previously been identified and 10 representative grab samples taken at random at each site to characterise the sediment (Allen and Proctor, 2003). At each pre-determined station position, a 0.1 m^2 Day grab was lowered to the seabed and the resulting sample was recovered. Samples were processed through either a 500 µm or a 1000 µm sieve mesh size depending on the predicted sediment type. When the vessel approached the sample position, the video camera was lowered over the side and the survey vessel allowed to drift over the sampling site.

Figure 3.2: Survey plan for the Fal and Helford (from Allen and Proctor, 2003)

Sites	Predicted Substratum	Actual Substratum	Mesh Size
Block 1	Shallow estuarine mud	Shallow estuarine mud	0.5 mm sieve
Block 2	Shallow muddy gravel	Shallow muddy gravel & shell	1 mm sieve
Block 3	Shallow muddy gravel	Shallow muddy gravel	1 mm sieve
Block 4	Shallow mud amongst bedrock outcrops	Shallow muddy sand amongst bedrock outcrops	1 mm sieve
Block 5	Shallow muddy gravel	Shallow muddy sand, gravel & shell grit	1 mm sieve
Block 6	Mixed sublittoral sediment with dead maerl and maerl gravel	Mixed sublittoral sediment with dead maerl and maerl gravel[1]	1 mm sieve
Block 7	Shallow sand and gravel amongst bedrock outcrops	Shallow sand & shell grit amongst bedrock outcrop	1 mm sieve
Block 8	Shallow muddy sand	Shallow muddy sand & shell	1 mm sieve
Block 9	Shallow estuarine mud	Shallow estuarine mud	0.5 mm sieve

[1] The report does not say whether the maerl gravel was alive or not

3.2.2. 2009 Survey

The 2009 survey was undertaken by the Environment Agency on 1 April 2009. This was a grab survey of Inner Carrick Roads (upper Fal Estuary) using a 0.1 m^2 Day grab. The survey gathered infaunal species data and particle size analysis (PSA) data.

There was also a Natural England survey conducted in 2009, but the samples were discarded due to formaldehyde fixing issues of infauna samples.

3.2.3. 2010 Survey

The 2010 survey was a repeat of the 2009 survey by the Environment Agency, with some extra sites included. The survey was conducted on 15 April 2010. This was a grab survey of Inner Carrick Roads (upper Fal Estuary) using a 0.1 m^2 Day grab. The survey gathered infaunal species data and PSA data.

Natural England also took clusters of samples from six sites around the SAC.

3.2.4. 2013 Survey

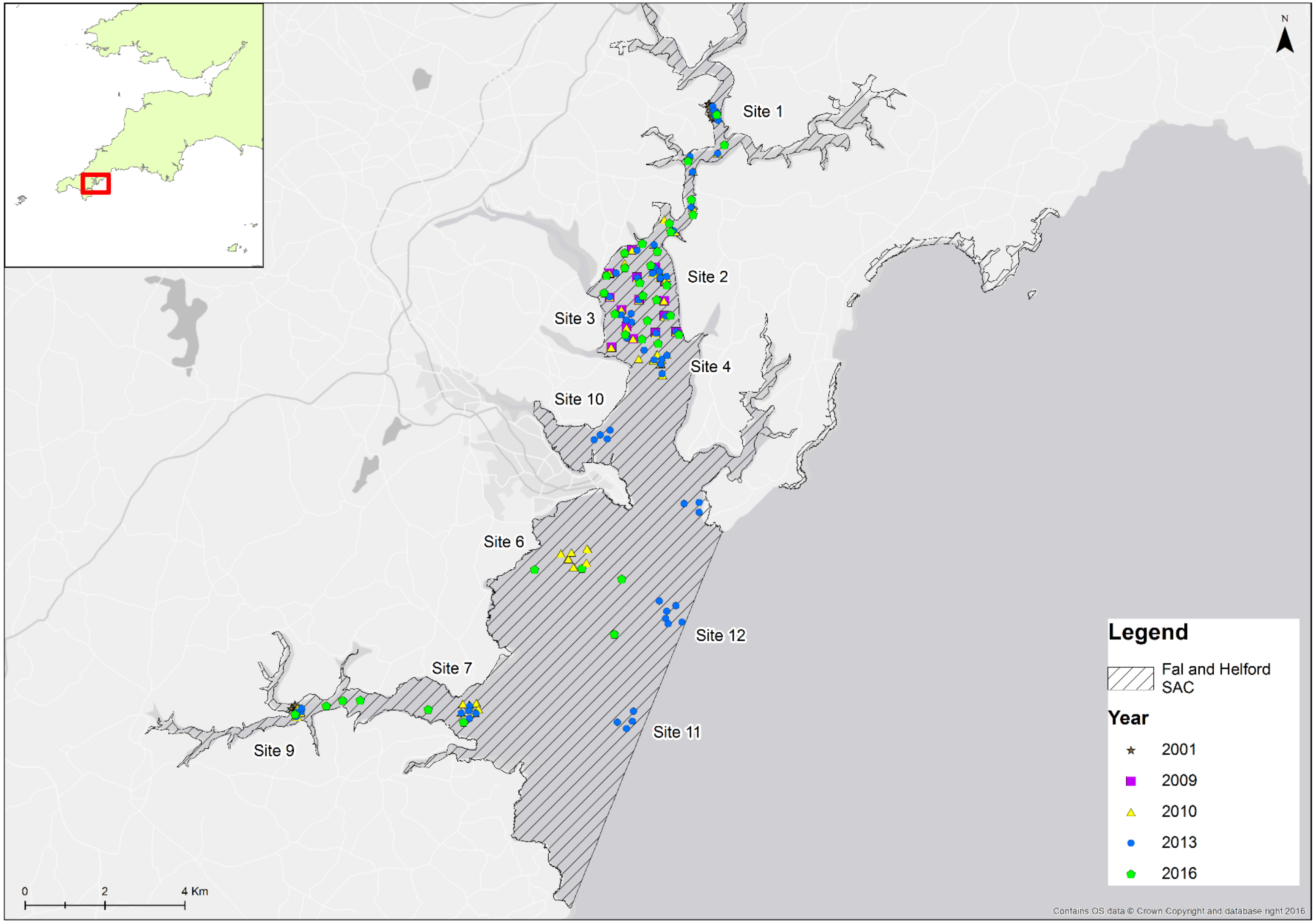
The 2013 survey was a repeat of the 2009 / 2010 surveys by the Environment Agency. The survey was conducted between 1 and 3 May 2013. This was a grab survey of Inner Carrick Roads (upper Fal Estuary) using a 0.1 m^2 Day grab. The survey gathered infaunal species data and PSA data.

Natural England also took clusters of samples from more sites around the SAC.

3.2.5. 2016 Survey

The 2013 survey was a repeat of the previous surveys by the Environment Agency. The survey was conducted on 5 and 6 April 2016. This was a grab survey of Inner Carrick Roads (upper Fal Estuary) using a 0.1m^2 Day grab. The survey gathered infaunal species data and PSA data.

Figure 3.3: Monitoring survey arrays at the Fal and Helford Special Area of Conservation



Contains OS data @ Crown Copyright and Database right 2016

3.3. Results

3.3.1. Site overview

3.3.1.1. Sediment composition

For the purposes of mapping the site has been divided into three regions based upon the geographic clustering of grab stations:

- Layout 1: Fal River region of the Fal Estuary;
- Layout 2: Carrick Roads area of the Fal Estuary; and
- Layout 3: Helford River.

Maps of sediment composition and Folk classification are provided in Annexes A and B.

There were far fewer PSA grab samples taken during the survey period than biological grabs and those that were taken were often in different regions of the SAC, making direct comparison impossible. Of the monitoring survey design used in the 2001 survey by Allen and Proctor (2003), only Sites 2, 4, 6, 7 and 9 were sampled again in 2010 (Table 3.2).

Table 3.2: Sediment types from grab sample analysis in 2001 and 2010 at Fal and Helford Special Area of Conservation

Site	Year	Folk (1954) Sediment Classification										
		M	sM	gM	S	mS	gmS	gS	G	mG	msG	sG
1	2001		✓									
	2010											
2	2001		✓									
	2010			✓								
3	2001						✓		✓			
	2010											
4	2001						✓					
	2010	✓		✓	✓	✓						
5	2001				✓	✓		✓				✓
	2010											
6	2001										✓	✓
	2010										✓	✓
7	2001							✓				✓
	2010				✓			✓			✓	✓
8	2001				✓			✓				✓
	2010											
9	2001		✓			✓						
	2010		✓	✓								

Sediment at Site 2 was relatively homogeneous, with only one sediment type identified in both 2001 and 2010. The sediment type changed from sandy Mud in 2001 to gravelly Mud in 2010 due to an increase in the relative content of Gravel, which was not found at all in 2001 but ranged from 14.8-26.7% in 2010.

Sediment at Site 4 was similar in 2010 to 2001, but with marginally higher and more variable silt content (6.9-85.1% compared with 18.9-34.0%). Three of six samples from 2010 were gravelly Mud and only differed from the 2001 samples in a slightly higher gravel content.

Sediment samples from Site 7 were, in general, equivalent in 2010 and 2001. Some stations had higher (but overall more variable) silt content in 2010 (0-8.4%) compared with 2001 (1.21-5.14%), with some lacking a silt component altogether.

Sediment samples from Site 9 were very similar in 2001, with nine of ten samples characterised as sandy Mud and one muddy Sand. All had zero gravel content and roughly equal proportions of sand and silt. In 2010, gravel was found in three of six samples (8.9-23.9%) and the sediment characterised as gravelly Mud. Of the remaining stations, there was marginally more silt relative to sand compared to 2001.

3.3.1.2. Benthic Community Data

Each benthic survey employed a different survey array, so analysis of the entire benthic dataset is included here only for perspective of the whole SAC. The benthic community data appeared similar across all four surveys with no obvious separation of groups (Figure 3.7). Despite this, ANOSIM revealed there to be a small, but statistically significant difference between all years except 2010 and 2016 (Table 3.4).

Figure 3.4: nMDS ordination of all 1 mm benthic community data from Fal and Helford Special Area of Conservation

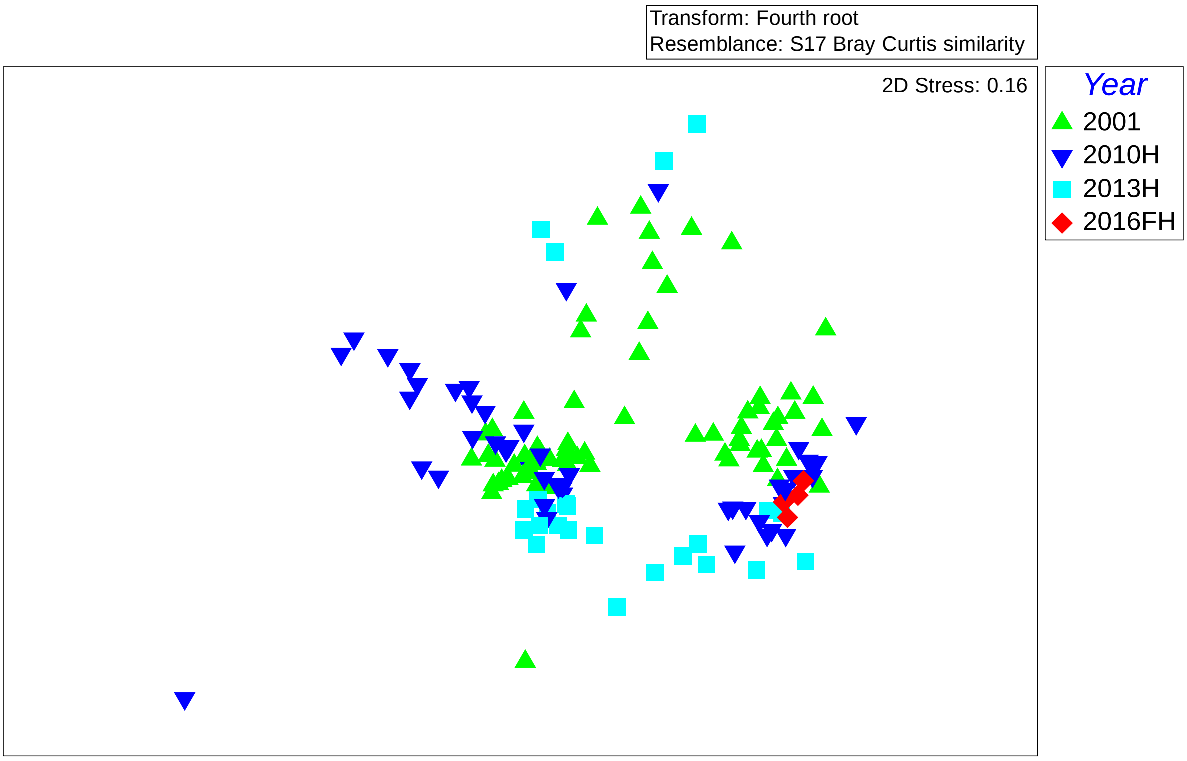


Table 3.3: ANOSIM results of all 1 mm benthic community data from Fal and Helford Special Area of Conservation (Global R: 0.204, Significance level: 0.1%)

Groups	R Statistic	Significance Level %	Possible Permutations	Actual Permutations	Number ≥ Observed
2001, 2010	0.192	0.1	Very large	999	0
2001, 2013	0.259	0.1	Very large	999	0
2001, 2016	0.289	0.8	1150626	999	7
2010, 2013	0.124	1.1	Very large	999	10
2010, 2016	0.141	10.4	292825	999	103
2013, 2016	0.331	2.6	20475	999	25

There was a large difference between 2001 and 2010 (86.96%), with higher abundance of *Chaetozone gibber* in 2010 compared with 2001 (average abundance of 106.04 in 2010 compared with 53.60 in 2001), and lower abundances of *Mediomastus fragilis* (57.00 to 98.87), *Melinna palmata* (29.49 to 41.86), *Tubificoides benedii* (5.51 to 50.40), and *Aphelochaeta marioni* (0.92 to 57.24) in 2010. There was a similar dissimilarity between 2001 and 2013 (87.64%), with higher abundance of *Mediomastus fragilis* (109.08 to 98.87), *Kurtiella bidentata* (28.29 to 17.16), and *Verruca stroemia* (47.67 to 0.00) in 2013 compared with 2010, and lower abundances of *Chaetozone gibber* (44.92 to 53.60) and *Melinna palmata* (38.13 to 41.86). Between 2001 and 2016 the level of dissimilarity was 85.98%, caused by lower abundances of *Mediomastus fragilis* (34.25 to 98.87), *Chaetozone gibber* (0.00 to 53.60) and *Melinna palmata* (0.00 to 41.86) in 2016 compared with 2001, and higher abundances of *Lumbrineris* (20.50 to 0.00) and *Polygordius* (19.50 to 5.44). In general, differences between years were due to changes in the relative abundance of a few characteristic species and though there was variation over time, there were no major trends. Given that the survey arrays were so different between years, these results should be interpreted with caution. Data are analysed by site in the following sections.

Figure 3.5: nMDS ordination of all 0.5 mm benthic community data from Fal and Helford Special Area of Conservation

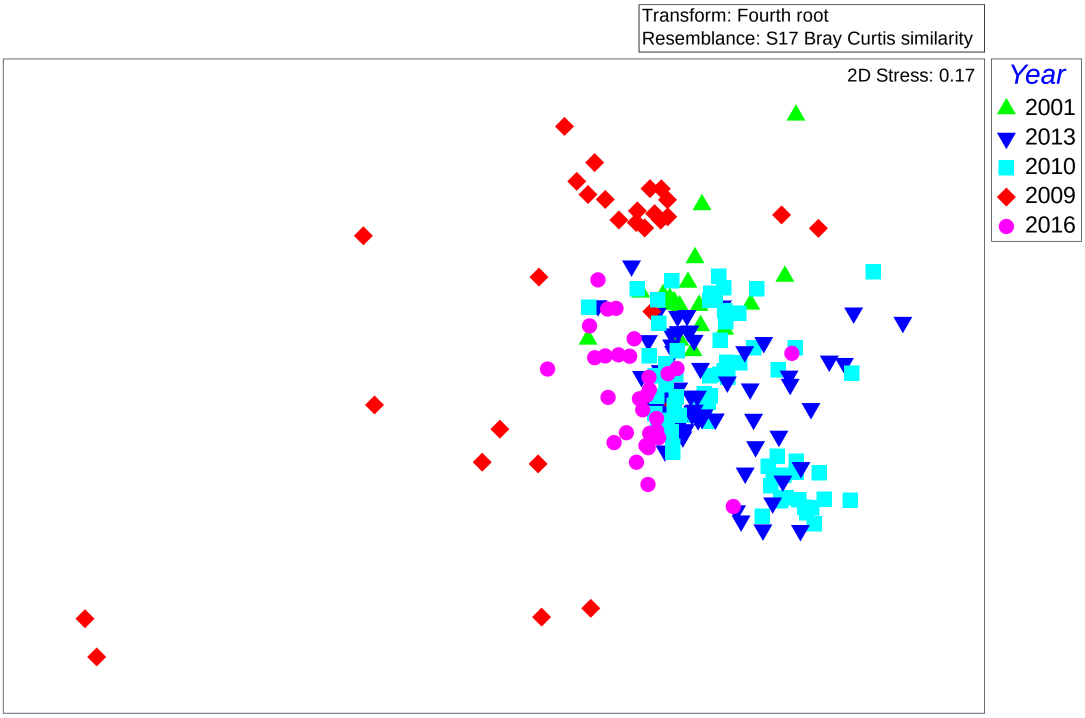


Table 3.4: ANOSIM results of all 0.5 mm benthic community data from Fal and Helford Special Area of Conservation (Global R: 0.332, Significance level: 0.1%)

Groups	R Statistic	Significance Level %	Possible Permutations	Actual Permutations	Number >= Observed
2001, 2009	0.293	0.1	Very large	999	0
2001, 2010	0.265	0.1	Very large	999	0
2001, 2013	0.314	0.1	Very large	999	0
2001, 2016	0.622	0.1	Very large	999	0
2009, 2010	0.661	0.1	Very large	999	0
2009, 2013	0.702	0.1	Very large	999	0
2009, 2016	0.501	0.1	Very large	999	0
2010, 2013	0.082	0.1	Very large	999	0
2010, 2016	0.204	0.2	Very large	999	1
2013, 2016	0.234	0.1	Very large	999	0

The largest average dissimilarity was between 2009 and 2013, where numbers of *Mediomastus fragilis* (353.55 to 4.03), Nematoda (152.19 to 15.55), and *Aphelochaeta marioni* (176.78 to 0.14) were much higher in 2013 compared with 2009 and average abundances of *Tubificoides* benedii (51.03 to 190.45) and *Peringia ulvae* (0.76 to 166.41) were much lower. However, the 2009 survey only sampled the Carrick Road area of the SAC, so it is to be expected that the 2013 survey grabbed much more widely sampled different communities. Given that the survey arrays were so different between years, these results should be interpreted with extreme caution. Data are analysed by site in the following sections.

3.3.2. Site 1 Fal Estuary

Site 1 was situated in the in the Fal River in the upper reaches of the Fal Estuary, where depths ranged from 0 to 4.5 m Chart Datum (CD) (Allen and Proctor, 2003). This region of the estuary is predominantly polyhaline (18-30 psu).

3.3.2.1. Diversity Indices

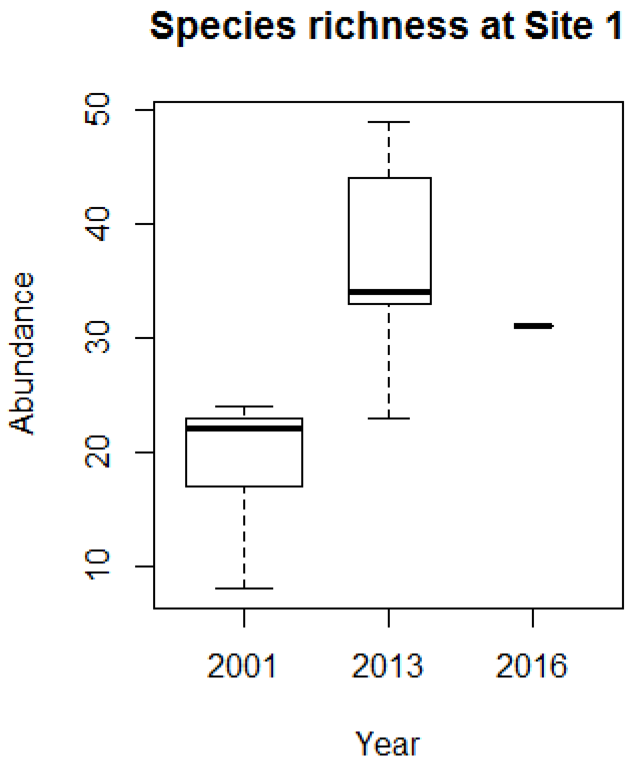
The number of species (S) and number of individuals (N) were consistent at the site between years (Table 3.4; Figure 3.6). A Kruskal-Wallis test shows that there was no statistically significant difference in number of species (S) between years, $\chi^2(10) = 12.44$, $p = 0.257$. Nor was there a statistically significant difference in number of individuals (N) between years (χ^2 (15) = 15.0, p = 0.451) or Margalef's index of species richness (D) ($\chi^2(15) = 15.0$, $p = 0.451$) (Table 3.4).

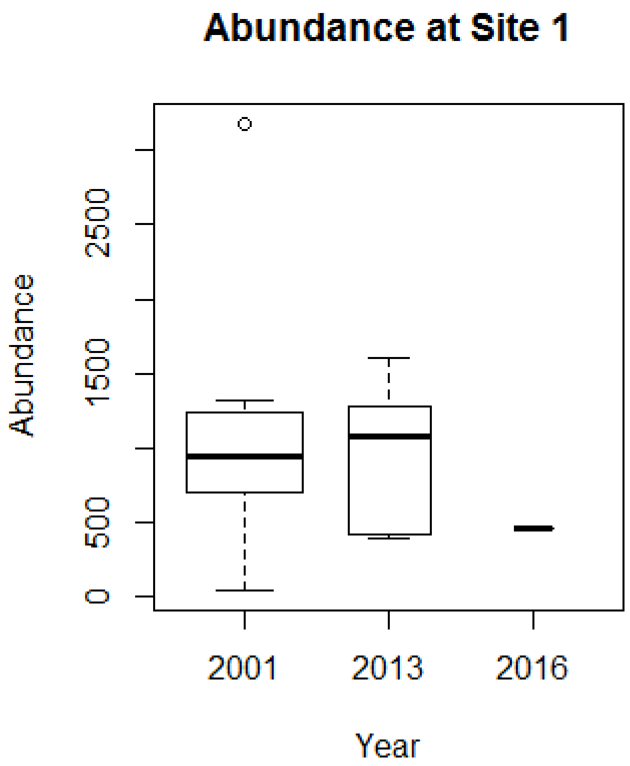
Table 3.5: Mean diversity statistics of benthic communities at Site 1 (n = mean number of samples, S = number of Species in each sample, N = number of Individuals in each sample, D = Margalef's index for species richness, J' = Pielou's evenness index, H'(log_e) = Shannon's diversity index, 1-λ' = Simpson's dominance Index)

	2001		2013		2006	
n	10		5		1	
S	19.80	± 4.87	36.60	± 10.16	31.00	-
N	1092.20	± 825.24	954.40	± 536.84	459.00	-
D	2.80	± 0.56	5.26	± 1.16	4.89	-
J'	0.57	± 0.14	0.64	± 0.12	0.62	-
H'(loge)	1.66	± 0.39	2.30	± 0.51	2.13	-
1-λ'	0.69	± 0.16	0.81	± 0.10	0.81	-

The results should be interpreted with caution due to the effects of different survey contractors, benthic laboratories, and sample sizes. However, the lack of any statistically significant differences suggests that there have been no changes in biodiversity over the survey period.

Figure 3.6: Species richness and abundance of benthic macrofauna from Site 1

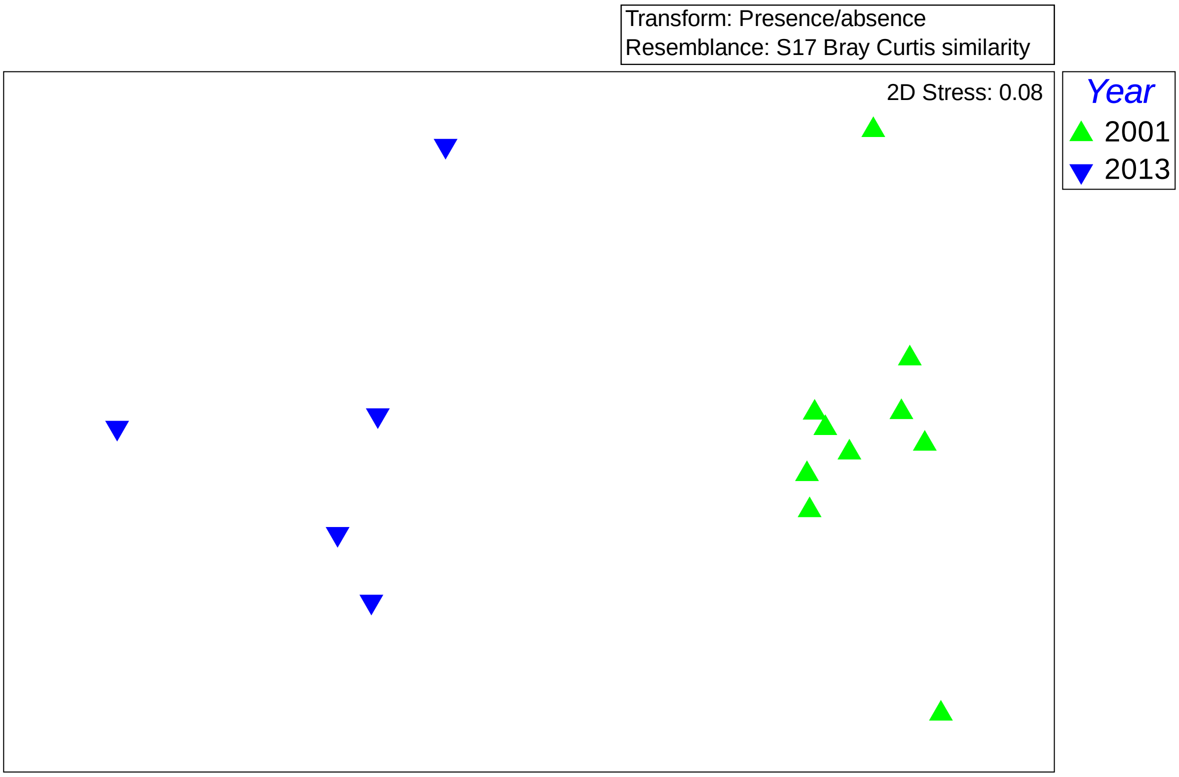




3.3.2.2. Faunal Assemblages

At Site 1, benthic community structure differed between years which is reflected in the spread of data (Figure 3.7). An ANOSIM test indicated that differences in benthic community structure between years are significant and the effect of sampling year is strong (Global R = 0.951, p = 0.1%).

Figure 3.7: Non-metric multi-dimension scaling ordination of benthic community structure from Site 1 (Bray-Curtis similarity and $\sqrt[4]{}$-transformation)



SIMPER analysis for each year indicated sample pairs had an average similarity of 61.69% in 2001 with a maximum contribution (8.43%) from the polychaetes *Nephtys hombergii, Aphelochaeta marioni,* and *Melinna palmata* and the oligochaete *Tubificoides galiciensis* (Figure 3.5).

Average similarity was 49.87% in 2013, with eight taxa contributing most to similarity: polychaetes *Pholoe inornata, Nephtys sp., Aphelochaeta marioni, Chaetozone gibber,* and *Melinna palmata,* the oligochaete *Tubificoides galiciensis* and the cumacean *Eudorella truncatula* (Table 3.5).

Table 3.6: SIMPER analysis of benthic community data from Site 1 by Year (top ten taxa) (P-A transformation)

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Group 2001: Average similarity 61.69%					
Nephtys hombergii	1.0	5.2	5.26	8.43	8.43
Aphelochaeta marioni	1.0	5.2	5.26	8.43	16.86
Melinna palmata	1.0	5.2	5.26	8.43	25.29
Tubificoides galiciensis	1.0	5.2	5.26	8.43	33.72
Streblospio sp.	0.9	4.1	1.82	6.64	40.36
Chaetozone gibber	0.9	4.1	1.82	6.64	47.00
Cossura pygodactylata	0.9	4.1	1.82	6.64	53.65
Mediomastus fragilis	0.9	3.81	1.94	6.18	59.83
Abra sp.	0.9	3.81	1.94	6.18	66.02
Phoronis sp.	0.9	3.81	1.94	6.18	72.20
Group 2013: Average similarity 49.87%					
Pholoe inornata	1.0	2.8	5.99	5.61	5.61
Nephtys sp.	1.0	2.8	5.99	5.61	11.23
Nephtys hombergii	1.0	2.8	5.99	5.61	16.84
Aphelochaeta marioni	1.0	2.8	5.99	5.61	22.45
Chaetozone gibber	1.0	2.8	5.99	5.61	28.06
Melinna palmata	1.0	2.8	5.99	5.61	33.68
Tubificoides galiciensis	1.0	2.8	5.99	5.61	39.29
Eudorella truncatula	1.0	2.8	5.99	5.61	44.90
Scoloplos (Scoloplos) armiger	0.8	1.82	1.14	3.65	48.55
Peringia ulvae	0.8	1.82	1.14	3.65	52.21

3.3.2.3. Biotopes

The sediment data from Site 1 was restricted to 2001. It showed that sediment at the site was sandy Mud with the silt / clay fraction ranging from 68.43% to 86.77%. In terms of sediment type the stations were relatively consistent across the area indicating that the area was relatively homogeneous.

The characterising benthic species were similar in 2001 and 2013 and the average similarity within year was moderate (≥50%), though slightly lower in 2013, possibly as a reflection of the lower number of samples. *Nephtys hombergii, Aphelochaeta marioni, Melinna palmata, Tubificoides galiciensis,* and *Chaetozone gibber* were all characterising species in both years.

In 2001, Allen and Proctor (2003) identified the biotope within Site 1 as a typical SS.SMu.SMuVS.AphTubi community (*Aphelochaeta marioni* and *Tubificoides* spp. in variable salinity infralittoral mud).

Though there were significant differences detected in species composition between years at Site 1, the changes were mainly caused by shifts in the relative average abundance of the same characteristic species. On untransformed data, dissimilarities were due to slightly higher average abundances of *Aphelochaeta marioni* and *Melinna palmata* in 2013 and lower average abundances of *Tubificoides galiciensis*.

3.3.3. Site 2 Fal Estuary

Site 2 was situated in the upper reaches of the Carrick Roads in the Fal Estuary, where depths ranged from 1 to 3 m CD (Allen and Proctor, 2003). This region of the estuary is predominantly euhaline (>30 psu).

3.3.3.1. Diversity Indices

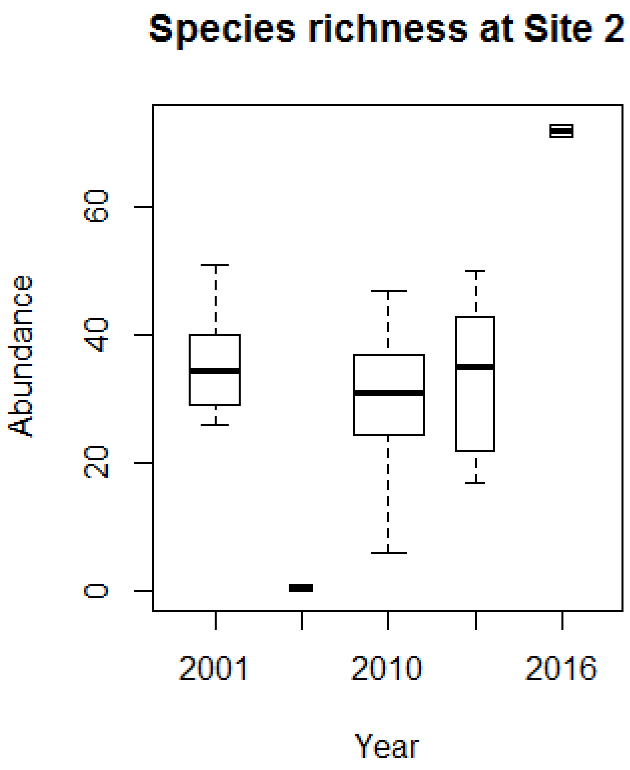
The number of species (S) and number of individuals (N) were consistent at the site between years (Table 3.6; Figure 3.8). A Kruskal-Wallis test shows that there was no statistically significant difference in number of species (S) between years, $\chi^2(29) = 33.27$, $p = 0.267$. Nor was there a statistically significant difference in number of individuals (N) between years (χ^2 (38) = 38.0, p = 0.470) or Margalef's index of species richness (D) ($\chi^2(37) = 38.0$, p = 0.424) (Table 3.6).

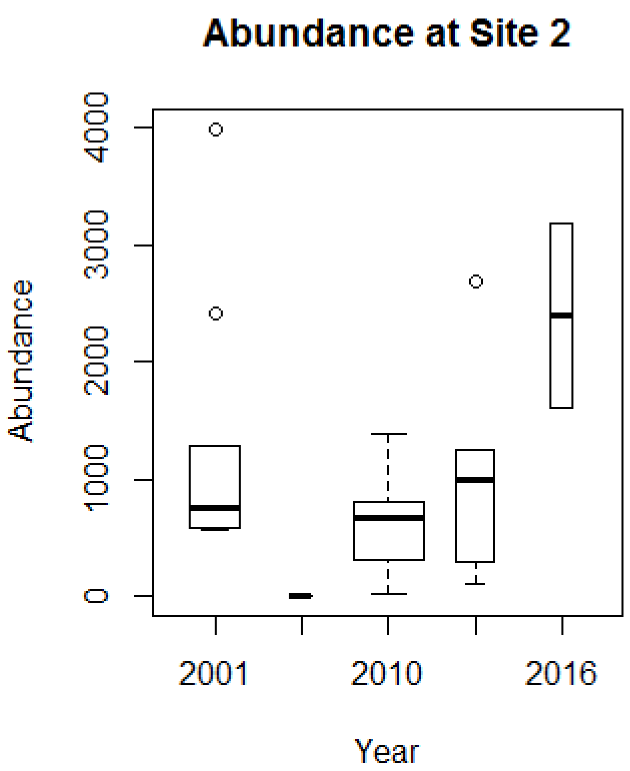
Table 3.7: Mean diversity statistics of benthic communities at Site 2 (n = mean number of samples, S = number of Species in each sample, N = number of Individuals in each sample, D = Margalef's index for species richness, J' = Pielou's evenness index, H'(log_e) = Shannon's diversity index, 1-λ' = Simpson's dominance Index)

	2001		2009		2010		2013		2016	
n	10		2		19		6		2	
S	35.60	8.40	0.50	0.71	29.74	10.50	33.67	12.42	72.00	1.41
N	1250.80	1112.65	2.00	2.83	594.58	361.59	1055.33	925.59	2390.00	1110.16
D	4.98	0.81	0.00	0.00	4.60	1.32	4.88	1.21	9.22	0.76
J'	0.59	0.09	0.00	0.00	0.55	0.12	0.57	0.13	0.68	0.01
H'(loge)	2.10	0.33	0.00	0.00	1.80	0.30	1.98	0.49	2.92	0.02
1-λ'	0.80	0.10	0.00	0.00	0.70	0.11	0.74	0.11	0.89	0.01

The results should be interpreted with caution due to the effects of different survey contractors, benthic laboratories, and sample sizes. However, the lack of any statistically significant differences suggests that there have been no changes in biodiversity over the survey period.

Figure 3.8: Species richness and abundance of benthic macrofauna from Site 2





3.3.3.2. Faunal Assemblages

At Site 2, benthic community structure differed between years which is reflected in the spread of data (Figure 3.9). An ANOSIM test indicated that differences in benthic community structure between years are significant, although the effect of sampling year is moderate (Global R = 0.48, p = 0.1%). Pairwise comparisons indicate significant differences between samples in 2001 and all other years (2010 and 2013) and also between 2010 and 2013 (Table 3.6). In addition, pairwise comparisons indicate significant differences between samples in 2002 and both 2001 and 2013 (Table 3.6).

Figure 3.9: Non-metric multi-dimension scaling ordination of benthic community structure from Site 2 (Bray-Curtis similarity and $^4\sqrt{}$-transformation)

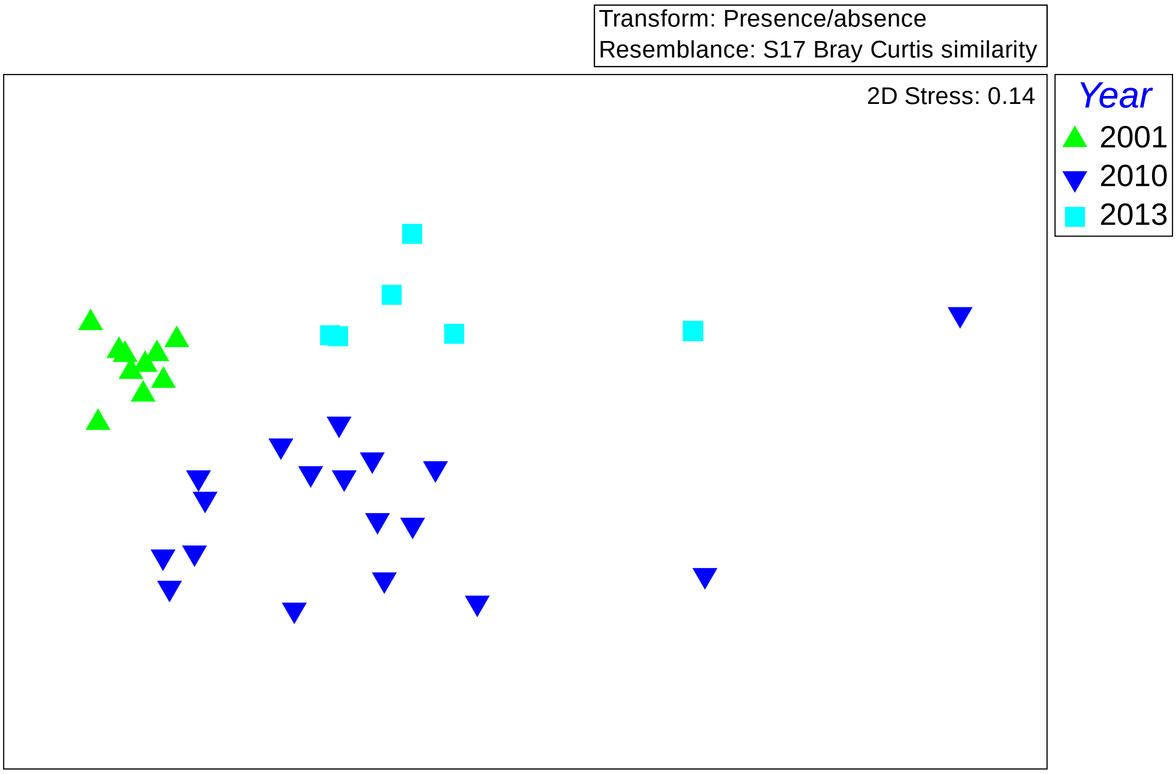


Table 3.8: ANOSIM of benthic community data from Site 2 over consecutive monitoring surveys (*denotes significance at the 5% level)

Groups	R Statistic	Significance Level %	Possible Permutations	Actual Permutations	Number ≥ Obs
2001, 2010	0.47	0.1	13123110	999	0
2001, 2013	0.866	0.1	8008	999	0
2010, 2013	0.338	1.9	134596	999	18

SIMPER analysis for each year indicated sample pairs had an average similarity of 62.21% in 2001 with a maximum contribution (4.62%) from nine taxa: polychaetes *Phyllodoce sp., Platynereis dumerilii, Nephtys hombergii, Cirriformia tentaculate, Mediomastus fragilis,* and *Melinna palmata*, the bivalve *Abra alba*, the oligochaete *Tubificoides galiciensis*, and Nematoda (Figure 3.8).

Average similarity was 35.54% in 2010 with the similarity due to the polychaetes *Mediomastus fragilis, Polynoidae,* and *Capitella* sp. In 2013, average similarity was 38.24% and was due to Nematoda and polychaetes *Harmothoe impar, Exogone naidina,* and *Ophryotrocha* sp (Table 3.8).

Table 3.9: SIMPER analysis of benthic community data from Site 2 by Year (top ten taxa)

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Group 2001: Average similarity 62.21%					
Nematoda	1.00	2.87	6.69	4.62	4.62
Phyllodoce sp.	1.00	2.87	6.69	4.62	9.23
Platynereis dumerilii	1.00	2.87	6.69	4.62	13.85
Nephtys hombergii	1.00	2.87	6.69	4.62	18.46
Cirriformia tentaculata	1.00	2.87	6.69	4.62	23.08
Mediomastus fragilis	1.00	2.87	6.69	4.62	27.69
Melinna palmata	1.00	2.87	6.69	4.62	32.31
Tubificoides galiciensis	1.00	2.87	6.69	4.62	36.92
Abra alba	1.00	2.87	6.69	4.62	41.54
Protocirrineris sp.	0.90	2.33	1.87	3.75	45.29
Group 2010: Average similarity 35.54%					
Mediomastus fragilis	0.89	2.45	1.80	6.88	6.88
Polynoidae	0.83	2.34	1.31	6.58	13.46
Capitella sp.	0.83	2.2	1.43	6.18	19.64
Chaetozone gibber	0.83	2.1	1.42	5.91	25.55
Kirkegaardia dorsobranchialis	0.78	1.93	1.18	5.43	30.98
Nematoda	0.72	1.66	0.94	4.68	35.66
Ophryotrocha sp.	0.67	1.57	0.81	4.41	40.07
Abra alba	0.67	1.30	0.85	3.67	43.74
Cirriformia tentaculata	0.67	1.28	0.85	3.61	47.35
Aoridae	0.61	1.27	0.70	3.57	50.92
Group 2013: Average similarity 38.24%					
Nematoda	1.00	3.12	4.04	8.17	8.17
Harmothoe impar	1.00	3.12	4.04	8.17	16.34
Exogone naidina	1.00	3.12	4.04	8.17	24.50
Ophryotrocha sp.	1.00	3.12	4.04	8.17	32.67
Aphelochaeta marioni	0.83	1.92	1.29	5.03	37.70
Mediomastus fragilis	0.83	1.92	1.29	5.03	42.73
Mytilus edulis	0.67	1.43	0.76	3.74	46.47
Nereididae	0.67	1.37	0.75	3.59	50.06
Chaetozone gibber	0.67	1.15	0.76	3.00	53.07
Sphaerosyllis taylori	0.67	0.99	0.78	2.59	55.66

3.3.3.3. Biotopes

The sediment type at Site 2 was found to be predominantly sandy Mud in 2001 and gravelly Mud in 2010 with the site appearing relatively homogeneous within year.

The characterising benthic species were also relatively similar between years, with *Mediomastus fragilis, Chaetozone gibber* and *Cirriformia tentaculate* all common. However, within year, average similarity was relatively low (35-38%) indicating heterogeneity or sparse distribution of fauna, with the exception of 2001. This is likely to be a reflection of the different sieve mesh sizes used, with 1.0 mm used in 2001, 0.5 mm in 2013 and both used in 2010.

In 2001, Allen and Proctor (2003) found that the site was dominated by *Tubificoides galiciensis*, *Cirriformia tentaculate*, *Mediomastus fragilis*, *Melinna palmata*, *Abra alba* and *Nephtys hombergii*. They concluded that the biotope was similar to Site 1, with elements of SS.SMu.SMuVS.AphTubi (*Aphelochaeta marioni* and *Tubificoides* spp. in variable salinity infralittoral mud), but with additional elements of SS.SMu.ISaMu.MelMagThy (*Melinna palmata* with *Magelona* spp. and *Thyasira* spp. in infralittoral sandy mud). In 2010 and 2013, there were much lower numbers of *Melinna palmata* and much higher number of *Mediomastus fragilis* compared to 2001. This suggests that in general the biotope is a better fit to the classic SS.SMu.SMuVS.AphTubi.

Though there were significant differences detected in species composition between years at Site 2, this may have been due in part to the use of different sieve mesh sizes in sample processing. Overall, the site was best characterised as SS.SMu.SMuVS.AphTubi, though there were elements of SS.SMu.ISaMu.MelMagThy in 2001. It is thought that SS.SMu.SMuVS.AphTubi grades into SS.SMu.ISaMu.MelMagThy as salinity increases, particularly in transitional zones of the Fal estuary.

3.3.4. Site 3 Fal Estuary

Site 3 was situated towards the upper reaches of the Carrick Roads in the Fal Estuary, where depths ranged from 0.5 to 1.5 m CD (Allen and Proctor, 2003). This region of the estuary is predominantly euhaline (>30 psu). Heavy metal concentrations in the sediment are high here due to extensive historical mining in the Fal Estuary (Warwick, 2001), though no chemical samples were analysed as part of this work.

3.3.4.1. Diversity Indices

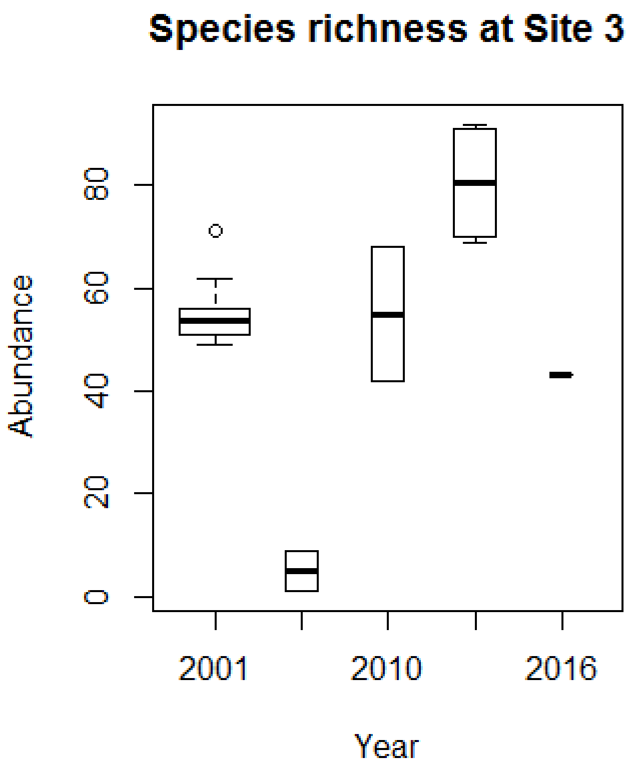
The number of species (S) and number of individuals (N) were consistent at the site between years (Table 3.9; Figure 3.10). A Kruskal-Wallis test shows that there was no statistically significant difference in number of species (S) between years, $\chi^2(14) = 15.74$, $p = 0.330$. Nor was there a statistically significant difference in number of individuals (N) between years (χ^2 (18) = 18.0, p = 0.456) or Margalef's index of species richness (D) ($\chi^2(17) = 15.74$, $p = 0.543$) (Table 3.9).

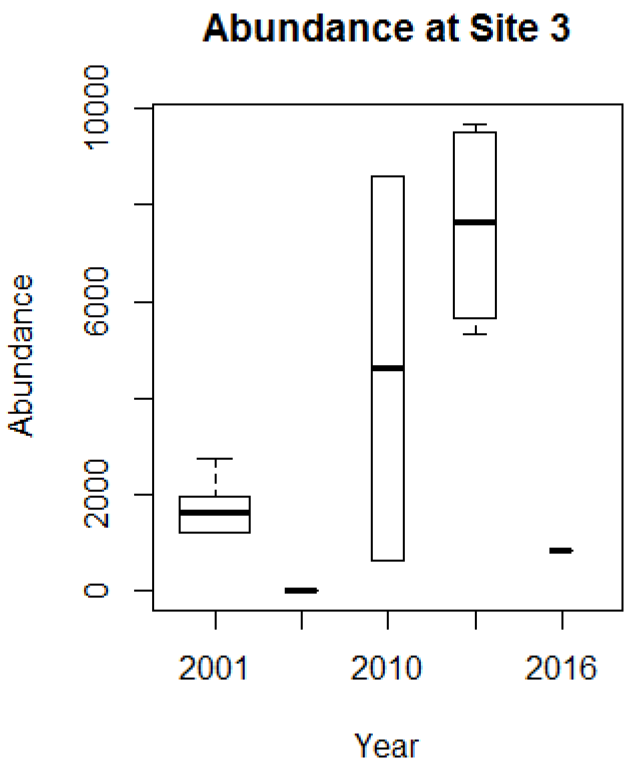
Table 3.10: Mean diversity statistics of benthic communities at Site 3 (n = mean number of samples, S = number of Species in each sample, N = number of Individuals in each sample, D = Margalef's index for species richness, J' = Pielou's evenness index, H'(log_e) = Shannon's diversity index, 1-λ' = Simpson's dominance Index)

	2001		2009		2010		2013		2016	
n	10		2		2		4		1	
S	55.60	6.50	5.00	5.66	55.00	18.38	80.50	12.18	43.00	-
N	1693.80	483.14	13.50	13.44	4627.00	5634.23	7592.25	2236.58	830.00	-
D	7.38	0.80	1.28	1.80	6.87	0.75	8.97	1.67	6.25	-
J'	0.64	0.05	0.40	0.56	0.69	0.02	0.66	0.06	0.64	-
H'(loge)	2.58	0.16	0.87	1.24	2.74	0.30	2.91	0.34	2.41	-
1-λ'	0.87	0.02	0.38	0.54	0.90	0.03	0.91	0.04	0.85	-

The results should be interpreted with caution due to the effects of different survey contractors, benthic laboratories, and sample sizes. However, the lack of any statistically significant differences suggests that there have been no changes in biodiversity over the survey period.

Figure 3.10: Species richness and abundance of benthic macrofauna from Site 3

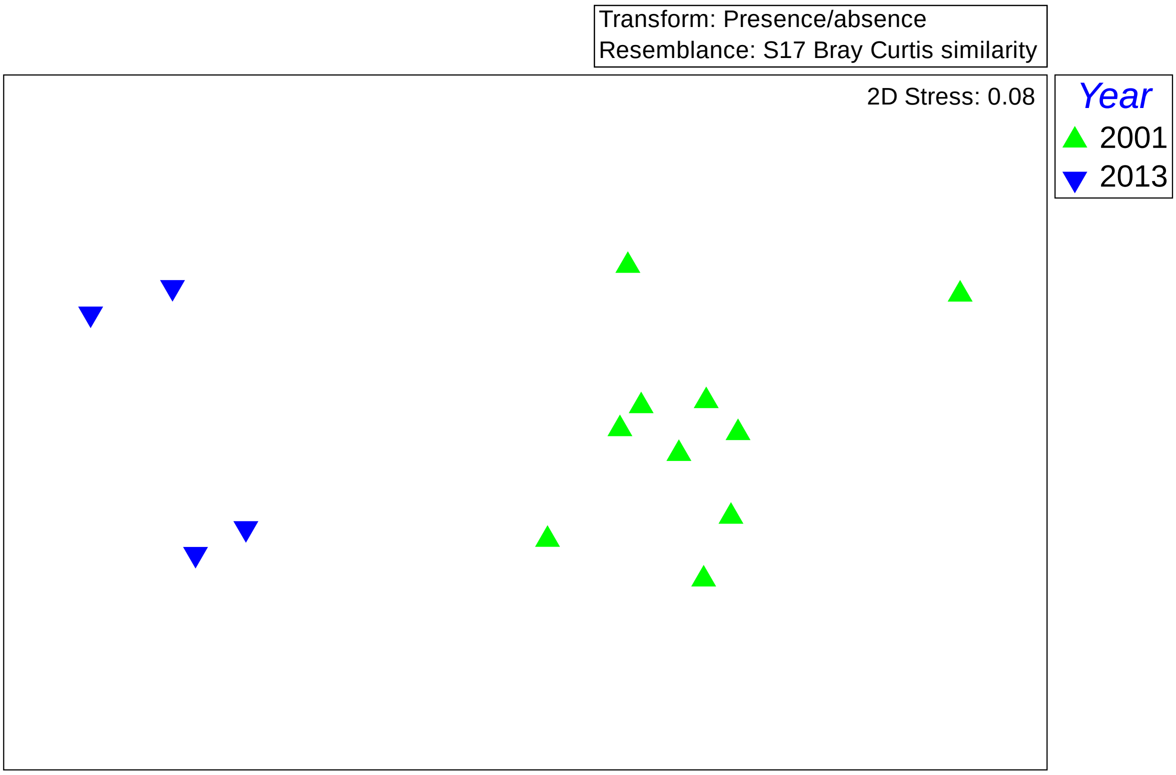




3.3.4.2. Faunal Assemblages

At Site 3, benthic community structure differed between years which is reflected in the spread of data (Figure 3.11). An ANOSIM test indicated that differences in benthic community structure between years are significant and the effect is relatively large (Global R = 0.976, p = 0.3%).

Figure 3.11: Non-metric multi-dimension scaling ordination of benthic community structure from Site 3 (Bray-Curtis similarity and $^4\sqrt{}$-transformation)



SIMPER analysis for each year indicated sample pairs had an average similarity of 64.77% in 2001 with a maximum contribution (2.79%) from the polychaetes *Pholoe inornata, Phyllodoce sp., Platynereis dumerilii, Aphelochaeta marioni, Chaetozone gibber, Cirriformia tentaculate,* and *Mediomastus fragilis* and the oligochaetes *Tubificoides galiciensis* and *Tubificoides benedii* (Table 3.10). Average similarity was 64.30% in 2013 due to Nematoda and the polychaetes *Pholoe inornata, Phyllodoce mucosa, Syllidia armata, Exogone naidina, Erinaceusyllis erinaceus, Sphaerosyllis taylori, Prosphaerosyllis tetralix, Platynereis dumerilii* and *Perinereis cultrifera*.

Table 3.11: SIMPER analysis of benthic community data from Site 3 by Year (top ten taxa)

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Group 2001: Average similarity 64.77%					
Pholoe inornata	1.00	1.81	14.07	2.79	2.79
Phyllodoce sp.	1.00	1.81	14.07	2.79	5.58
Platynereis dumerilii	1.00	1.81	14.07	2.79	8.37
Aphelochaeta marioni	1.00	1.81	14.07	2.79	11.17
Chaetozone gibber	1.00	1.81	14.07	2.79	13.96
Cirriformia tentaculata	1.00	1.81	14.07	2.79	16.75
Mediomastus fragilis	1.00	1.81	14.07	2.79	19.54
Tubificoides galiciensis	1.00	1.81	14.07	2.79	22.33
Tubificoides benedii	1.00	1.81	14.07	2.79	25.12
Microdeutopus anomalus	1.00	1.81	14.07	2.79	27.91
Group 2013: Average similarity 64.30%					
Nematoda	1.00	1.25	11.87	1.94	1.94
Pholoe inornata	1.00	1.25	11.87	1.94	3.89
Phyllodoce mucosa	1.00	1.25	11.87	1.94	5.83
Syllidia armata	1.00	1.25	11.87	1.94	7.77
Exogone naidina	1.00	1.25	11.87	1.94	9.72
Erinaceusyllis erinaceus	1.00	1.25	11.87	1.94	11.66
Sphaerosyllis taylori	1.00	1.25	11.87	1.94	13.60
Prosphaerosyllis tetralix	1.00	1.25	11.87	1.94	15.54
Platynereis dumerilii	1.00	1.25	11.87	1.94	17.49
Perinereis cultrifera	1.00	1.25	11.87	1.94	19.43

3.3.4.3. Biotopes

The sediment types at Site 3 ranged from muddy Gravel to Gravel in 2001, but the sediment was heterogeneous. The characterising species from surveys in 2001 and 2013 were similar, despite a 1.0 mm sieve mesh size being used for processing in 2001 and a 0.5 mm sieve being used in 2013. Common characterising species between years were *Pholoe inornata, Phyllodoce sp.,* and *Platynereis dumerilii.* In 2001, Allen and Proctor (2003) determined that the site was likely a transitional community between SS.SMu.SMuVS.AphTubi (*Aphelochaeta marioni* and *Tubificoides* spp. in variable salinity infralittoral mud) and SS.SMx.IMx.VsenAsquAps (*Venerupis senegalensis, Amphipholis squamata* and *Apseudes latreilli* in infralittoral mixed sediment) and the site required no sub-division. This was due to the dominance of *Mediomastus fragilis*, *Tubificoides* oligochaetes, *Chaetozone gibber* and *Aphelochaeta marioni*, but also *Abra alba*, *Cirriformia tentaculata*, *Phoronis* sp. and *Melinna palmata*.

Though there were significant differences detected in species composition between years at Site 3, this may have been due in part to the use of different sieve mesh sizes in sample processing. In 2013, there were much higher number of Syllidae, including *Erinaceusyllis erinaceus*, *Sphaerosyllis taylori* and *Prosphaerosyllis tetralix* which contributed to the dissimilarity. Most of these species are not characteristic of any current biotope and SS.SMu.SMuVS.AphTubi is still the biotope that Site 3 most resembles in 2001 and 2013. SS.SMu.SMuVS.AphTubi has low sensitivity to chemical pressures such as heavy metals pollution which has historically occurred in proximity to Site 3 (De Bastos and Hiscock, 2016), for instance *Aphelochaeta marioni* is tolerant of heavy metal contamination occurring in the heavily polluted Restronguet Creek (Bryan and Gibbs, 1983)

3.3.5. Site 4 Fal Estuary

Site 4 was situated in the mid region of the Carrick Roads in the Fal Estuary where depths ranged from 3.0 to 4.0 m CD (Allen and Proctor, 2003). This region of the estuary is predominantly euhaline (>30 psu).

3.3.5.1. Diversity Indices

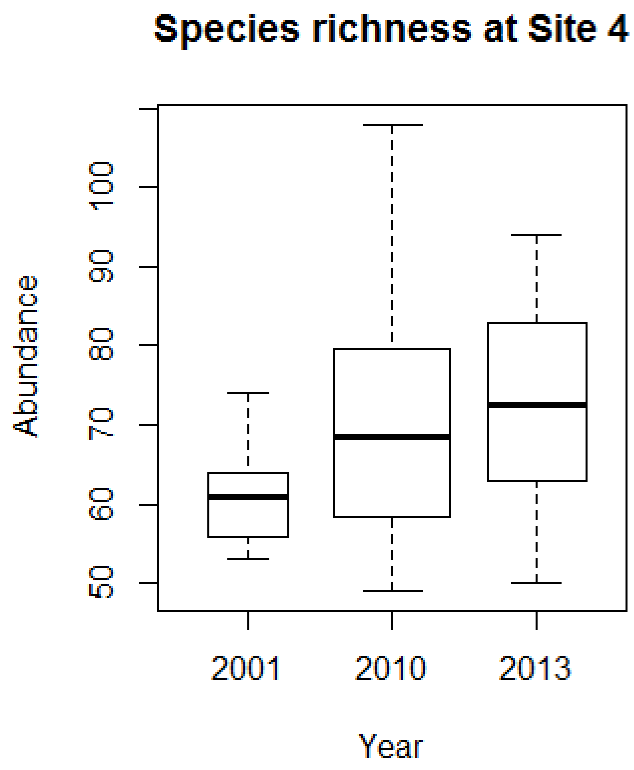
The number of species (S) and number of individuals (N) were consistent at the site between years (Table 3.11; Figure 3.12). A Kruskal-Wallis test shows that there was no statistically significant difference in number of species (S) between years, $\chi^2(30) = 28.46$, $p = 0.546$. Nor was there a statistically significant difference in number of individuals (N) between years (χ^2 (42) = 42.21, $p = 0.462$) or Margalef's index of species richness (D) ($\chi^2(43) = 43.0$, $p = 0.471$) (Table 3.11).

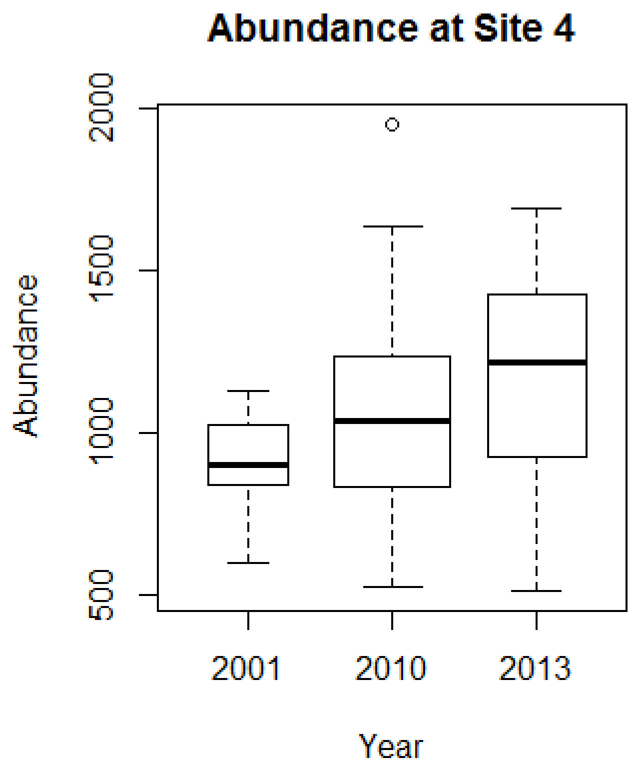
Table 3.12: Mean diversity statistics of benthic communities at Site 4 (n = mean number of samples, S = number of Species in each sample, N = number of Individuals in each sample, D = Margalef's index for species richness, J' = Pielou's evenness index, H'(log_e) = Shannon's diversity index, 1-λ' = Simpson's dominance Index)

	2001		2010		2013	
n	10		20		14	
S	61.30	6.38	69.60	14.86	72.43	12.97
N	916.70	155.84	1062.70	350.31	1187.93	340.26
D	8.88	1.07	9.89	1.97	10.16	1.84
J'	0.69	0.03	0.73	0.03	0.69	0.07
H'(loge)	2.86	0.15	3.09	0.21	2.94	0.28
1-λ'	0.90	0.02	0.92	0.02	0.89	0.05

The results should be interpreted with caution due to the effects of different survey contractors, benthic laboratories, and sample sizes. However, the lack of any statistically significant differences suggests that there have been no changes in biodiversity over the survey period.

Figure 3.12: Species richness and abundance of benthic macrofauna from Site 4





3.3.5.2. Faunal Assemblages

At Site 4, benthic community structure differed between years which is reflected in the spread of data (Figure 3.13). An ANOSIM test indicated that differences in benthic community structure between years are significant, although the effect of sampling year is relatively weak (Global R = 0.762, p = 0.1%). Pairwise comparisons indicate significant differences between samples in 2001 and all other years (2010, 2013) and between 2010 and 2013 (Table 3.6).

Figure 3.13: Non-metric multi-dimension scaling ordination of benthic community structure from Site 4 (Bray-Curtis similarity and $\sqrt[4]{}$-transformation)

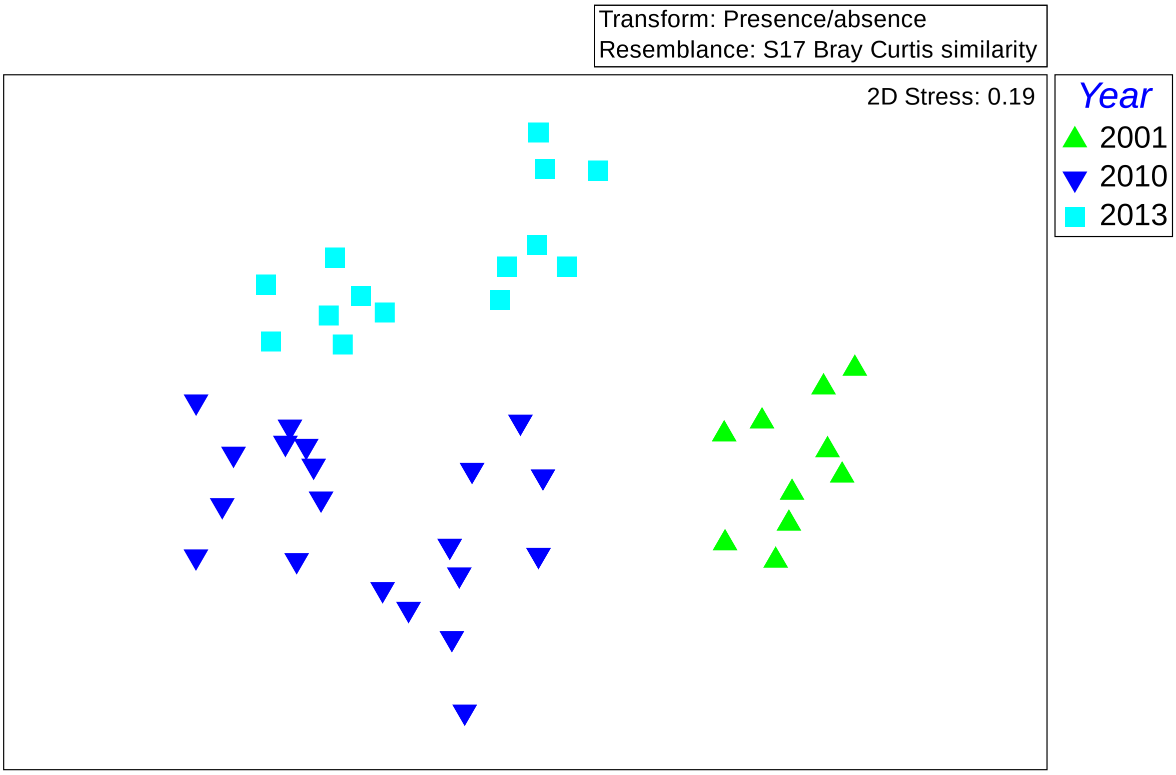


Table 3.13: ANOSIM of benthic community data from Site 4 over consecutive monitoring surveys (*denotes significance at the 5% level)

Groups	R Statistic	Significance Level %	Possible Permutations	Actual Permutations	Number ≥ Obs
2001, 2010	0.925	0.1	30045015	999	0
2001, 2013	0.97	0.1	1961256	999	0
2010, 2013	0.502	0.1	Very large	999	0

SIMPER analysis for each year indicated sample pairs had an average similarity of 60.78% in 2001 with a maximum contribution (2.70%) from Nemertea, Nematoda, and polychaetes *Nephtys kersivalensis, Lysidice unicornis, Prionospio fallax, Magelona alleni, Chaetozone gibber, Kirkegaardia dorsobranchialis, Protocirrineris sp.* and *Mediomastus fragilis.*

Average similarity was 52.72% in 2010 due to polychaetes *Prionospio fallax, Magelona minuta, Chaetozone gibber, Kirkegaardia dorsobranchialis, Tharyx killariensis* and *Mediomastus fragilis.* In 2013, average similarity was 54.29% and similarity was due to polychaetes *Pholoe inornata, Prionospio fallax, Magelona minuta, Kirkegaardia dorsobranchialis,* and *Mediomastus fragilis*

Table 3.14: SIMPER analysis of benthic community data from Site 4 by Year (top ten taxa)

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Group 2001: Average similarity 60.78%					
Nemertea	1.00	1.64	15.24	2.70	2.70
Nematoda	1.00	1.64	15.24	2.70	5.39
Nephtys kersivalensis	1.00	1.64	15.24	2.70	8.09
Lysidice unicornis	1.00	1.64	15.24	2.70	10.78
Prionospio fallax	1.00	1.64	15.24	2.70	13.48
Magelona alleni	1.00	1.64	15.24	2.70	16.17
Chaetozone gibber	1.00	1.64	15.24	2.70	18.87
Kirkegaardia dorsobranchialis	1.00	1.64	15.24	2.70	21.56
Protocirrineris sp.	1.00	1.64	15.24	2.70	24.26
Mediomastus fragilis	1.00	1.64	15.24	2.70	26.96
Group 2010: Average similarity 52.72%					
Prionospio fallax	1.00	1.47	7.08	2.78	2.78
Magelona minuta	1.00	1.47	7.08	2.78	5.56
Chaetozone gibber	1.00	1.47	7.08	2.78	8.34
Kirkegaardia dorsobranchialis	1.00	1.47	7.08	2.78	11.12
Tharyx killariensis	1.00	1.47	7.08	2.78	13.90
Mediomastus fragilis	1.00	1.47	7.08	2.78	16.68
Galathowenia oculata	1.00	1.47	7.08	2.78	19.46
Melinna palmata	1.00	1.47	7.08	2.78	22.25
Tubificoides amplivasatus	1.00	1.47	7.08	2.78	25.03
Eudorella truncatula	1.00	1.47	7.08	2.78	27.81
Group 2013: Average similarity 54.29%					
Pholoe inornata	1.00	1.40	8.23	2.58	2.58
Prionospio fallax	1.00	1.40	8.23	2.58	5.16
Magelona minuta	1.00	1.40	8.23	2.58	7.74
Kirkegaardia dorsobranchialis	1.00	1.40	8.23	2.58	10.32
Mediomastus fragilis	1.00	1.40	8.23	2.58	12.90
Praxillella affinis	1.00	1.40	8.23	2.58	15.48
Melinna palmata	1.00	1.40	8.23	2.58	18.06
Tubificoides galiciensis	1.00	1.40	8.23	2.58	20.64
Tubificoides amplivasatus	1.00	1.40	8.23	2.58	23.22
Eudorella truncatula	1.00	1.40	8.23	2.58	25.79
Kurtiella bidentata	1.00	1.40	8.23	2.58	28.37

3.3.5.3. Biotopes

The sediment types at Site 4 were predominantly gravelly Mud, but were variable and also included Mud, muddy Sand and Sand. In 2001, the silt / clay fraction ranged from 18.89% to 33.97% whilst gravel content ranged from 6.47% to 12.75% and sand content varied from 57.11% to 72.44%. In 2010, the sediment types were far more variable; the silt / clay fraction ranged from 6.9% to 85.1% whilst gravel content ranged from 4.5% to 28.1% and sand content varied from 7.6% to 76.4%.

The characterising benthic species across years were *Prionospio fallax, Magelona* spp., *Kirkegaardia dorsobranchialis* and *Mediomastus fragilis*.

In 2001, Allen and Proctor (2003) described the community within Site 4 as consistent and a slightly gravelly variant of the *Mellina* biotope SS.SMu.ISaMu.MelMagThy (*Melinna palmata* with *Magelona* spp. and *Thyasira* spp. in infralittoral sandy mud). Benthic communities in 2010 and 2013 were equally similar within year (53-54%).

Though there were significant differences detected in species composition between years at Site 4, this may have been due in part to the use of different sieve mesh sizes in sample processing. In 2001, a 1.0 mm sieve mesh size was used, and in 2010 and 2013 a mixture of 0.5 mm and 1.0 mm meshes were used. The presence of *Magelona alleni* in 2001, and *Magelona minuta i*n 2010 and 2013, was one of the main causes of dissimilarity and may be down to misidentification. Similarly, the presence of smaller oligochaete species in 2010 and 2013, was likely due to the use of a smaller sieve mesh size in sample processing.

3.3.6. Site 5 Fal Estuary

Site 5 was situated in the outer region of the Carrick Roads in the Fal Estuary, where depths ranged from 3 m to 30 m CD (Allen and Proctor, 2003). This is a region of the estuary that is euhaline (>30 psu).

3.3.6.1. Diversity Indices

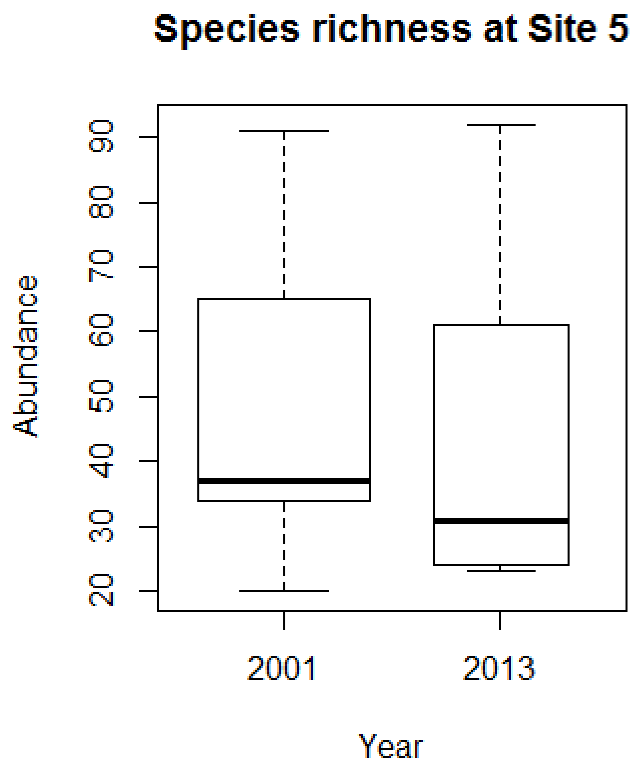
The number of species (S) and number of individuals (N) were consistent at the site between years (Table 3.14; Figure 3.14). A Kruskal-Wallis test shows that there was no statistically significant difference in number of species (S) between years, $\chi^2(13) = 13.0$, $p = 0.448$. Nor was there a statistically significant difference in number of individuals (N) between years (χ^2 (15) = 15.0, $p = 0.451$) or Margalef's index of species richness (D) ($\chi^2(15) = 15.0$, $p = 0.451$) (Table 3.14).

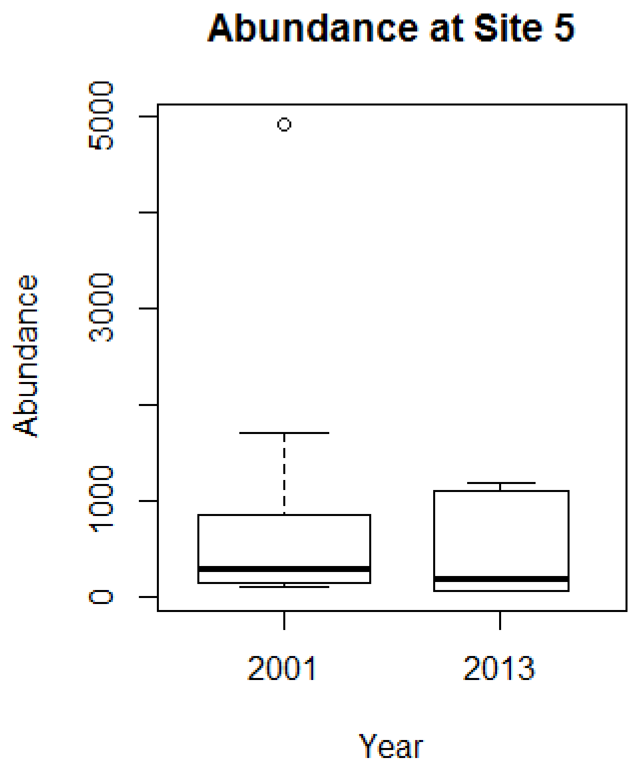
Table 3.15: Mean diversity statistics of benthic communities at Site 5 (n = mean number of samples, S = number of Species in each sample, N = number of Individuals in each sample, D = Margalef's index for species richness, J' = Pielou's evenness index, H'(log_e) = Shannon's diversity index, 1-λ' = Simpson's dominance Index)

	2001		2013	
n	10		6	
S	47.40	22.53	43.67	27.49
N	917.00	1489.06	467.00	534.38
D	7.84	3.31	7.33	2.95
J'	0.69	0.21	0.80	0.11
H'(loge)	2.61	0.86	2.88	0.26
1-λ'	0.82	0.19	0.91	0.04

The results should be interpreted with caution due to the effects of different survey contractors, benthic laboratories, and sample sizes. However, the lack of any statistically significant differences suggests that there have been no changes in biodiversity over the survey period.

Figure 3.14: Species richness and abundance of benthic macrofauna from Site 5

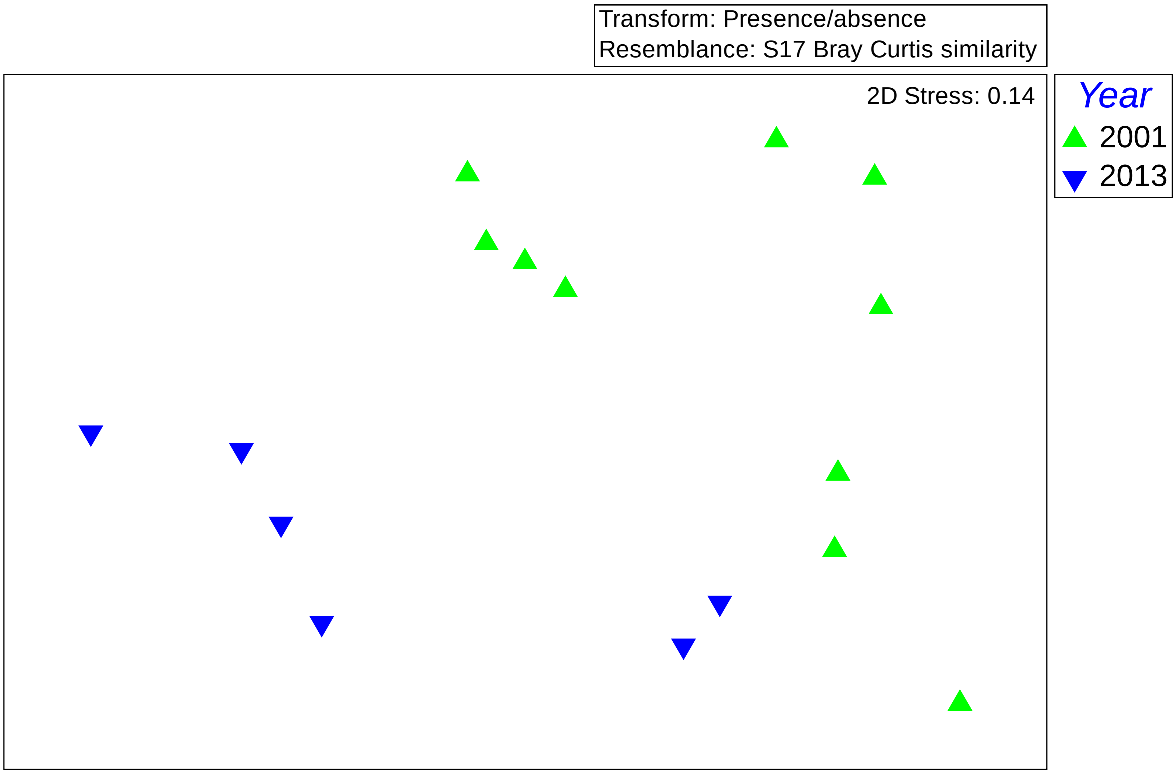




3.3.6.2. Faunal Assemblages

At Site 5, benthic community structure differed between years which is reflected in the spread of data (Figure 3.15). An ANOSIM test indicated that differences in benthic community structure between years are significant and the effect of sampling year is moderate (Global R = 0.536, p = 0.1%).

Figure 3.15: Non-metric multi-dimension scaling ordination of benthic community structure from Site 5 (Bray-Curtis similarity and $\sqrt[4]{}$-transformation)



SIMPER analysis for each year indicated sample pairs only had an average similarity of 24.45% in 2001 with the maximum contributions from the bivalves *Chamelea gallina, Corbula gibba and Kurtiella bidentata, nemerteans,* and polychaete *Mediomastus fragilis* (Table 3.15). Average similarity was only 27.15% in 2013 due to the amphipod *Synchelidium maculatum,* nemerteans and *polychaetes Magelona filiformis, Nephtys cirrosa* and *Spiophanes bombyx*.

Table 3.16: SIMPER analysis of benthic community data from Site 5 by Year (top ten taxa)

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Group 2001: Average similarity 24.45%					
Chamelea gallina	0.90	1.70	1.71	6.95	6.95
Nemertea	0.80	1.27	1.17	5.18	12.14
Corbula gibba	0.70	1.19	0.86	4.87	17.01
Phaxas pellucidus	0.70	1.12	0.88	4.56	21.57
Kurtiella bidentata	0.70	1.01	0.88	4.15	25.72
Mediomastus fragilis	0.70	0.99	0.84	4.03	29.75
Nephtys kersivalensis	0.60	0.72	0.65	2.95	32.70
Edwardsiidae	0.50	0.64	0.53	2.60	35.30
Dosinia exolete	0.50	0.56	0.52	2.27	37.57
Lucinoma borealis	0.50	0.55	0.50	2.25	39.82
Group 2013: Average similarity 27.15%					
Synchelidium maculatum	1.00	2.62	2.68	9.65	9.65
Nemertea	0.83	1.58	1.16	5.81	15.46
Magelona filiformis	0.83	1.58	1.16	5.81	21.27
Nephtys cirrosa	0.67	1.48	0.78	5.45	26.72
Spiophanes bombyx	0.67	1.48	0.78	5.45	32.16
Chaetozone christiei	0.67	1.48	0.78	5.45	37.61
Perioculodes longimanus	0.67	1.48	0.78	5.45	43.06
Bathyporeia elegans	0.67	1.48	0.78	5.45	48.50
Tubulanus polymorphus	0.67	0.87	0.71	3.20	51.70
Nematoda	0.67	0.81	0.73	2.98	54.68

3.3.6.3. Biotopes

The sediment types in Site 5 were highly variable in 2001, ranging from Sand to muddy Sand to gravelly Sand to gravelly muddy Sand. The silt / clay fraction ranged from 0.82% to 30.54% whilst gravel content ranged from 0% to 31.7% and sand content varied from 61.31% to 99.18% (Allen and Proctor, 2003).

In 2001, Allen and Proctor (2003) identified four cluster groups within the site, reflecting the heterogenous sediment types, but found it difficult to categorically link them to biotopes due to the low sampling power of each group:

1) *Urothoe elegans* and *Nephtys* sp. with *Phaxas pellucida* and *Moerella pygmaea* in slightly muddy gravelly sand (possible variant of SS.SCS.ICS.MoeVen (*Moerella* spp. with venerid bivalves in infralittoral gravelly sand)) (1 sample);
2) *Chamelea gallina*, *Chaetozone setosa*, *Fabulina fabula* and *Phaxas pellucida* in medium sands (SS.SSa.IMuSa.FfabMag (*Fabulina fabula* and *Magelona mirabilis* with venerid bivalves and amphipods in infralittoral compacted fine muddy sand)) (4 samples);
3) *Mediomastus fragilis*, *Protodorvillea kefersteini*, *Polycirrus* spp. and *Apseudes latreilli* in gravelly sand (SS.SCS.CCS.MedLumVen (*Mediomastus fragilis*, *Lumbrineris* spp. and venerid bivalves in circalittoral coarse sand or gravel)) (2 samples); and
4) *Anaitides mucosa*, *Mediomastus fragilis*, *Melinna palmata*, *Edwardsia* and *Corbula gibba* in muddy sand or gravelly muddy sand (SS.SMu.ISaMu.MelMagThy (*Melinna palmata* with

Magelona spp. and *Thyasira* spp. in infralittoral sandy mud), though high levels of *Capitella* may indicate organic enrichment) (3 samples).

The characterising species across the site as a whole were *Chamelea gallina, Nemertea* spp. *Mediomastus fragilis* and *Mysella bidentate*. From the 2013 species, the main characterising species were *Chaetozone* spp., *Magelona* spp., *Bathyporeia* spp., and Nemertea. There were fewer samples taken, but these seem to be representative of SS.SSa.IMuSa.FfabMag. Significantly, the high numbers of *Capitella* that were present in 2001 were absent in 2013, suggesting less organic enrichment (Pearson, 1975; Pearson and Rosenberg, 1978).

Though there were significant differences detected in species composition between years at Site 4, this may have been due in part to the use of different sieve mesh sizes in sample processing. In general, the variety of habitats sampled in 2001 was much greater than in 2013.

3.3.7. Site 6 Fal Estuary

Site 6 was situated in the outer region of the Carrick Roads in Falmouth Bay, where water depths ranged from 12 m to 16 m CD (Allen and Proctor, 2003). This is a region of the estuary which is euhaline (>30 psu).

3.3.7.1. Diversity Indices

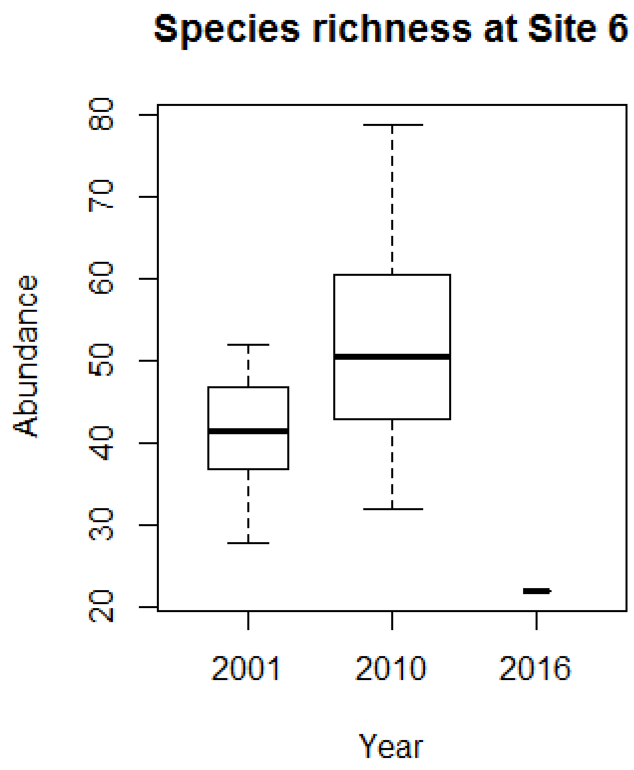
The number of species (S) and number of individuals (N) were consistent at the site between years (Table 3.16; Figure 3.16). A Kruskal-Wallis test shows that there was no statistically significant difference in number of species (S) between years, $\chi^2(22) = 19.61$, $p = 0.607$. Nor was there a statistically significant difference in number of individuals (N) between years (χ^2 (30) = 30.0, p = 0.466) or Margalef's index of species richness (D) ($\chi^2(30) = 30.0$, $p = 0.466$).

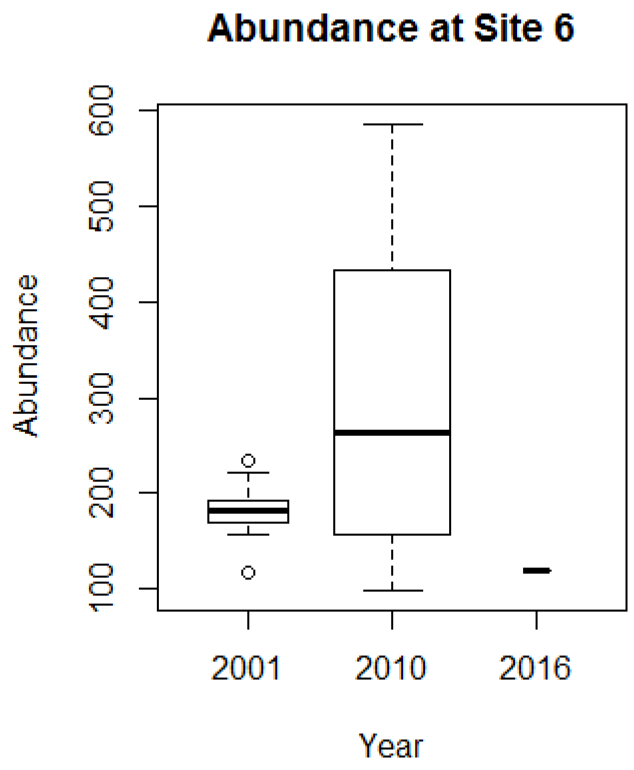
Table 3.17: Mean diversity statistics of benthic communities at Site 1 (n = mean number of samples, S = number of Species in each sample, N = number of Individuals in each sample, D = Margalef's index for species richness, J' = Pielou's evenness index, H'(log_e) = Shannon's diversity index, 1-λ' = Simpson's dominance Index)

	2001		2010		2016	
n	10		20		1	
S	41.60	7.20	52.95	12.11	22.00	-
N	181.60	32.60	297.60	156.03	119.00	-
D	7.82	1.30	9.26	1.50	4.39	-
J'	0.79	0.08	0.79	0.07	0.59	-
H'(loge)	2.94	0.38	3.10	0.24	1.83	-
1-λ'	0.89	0.07	0.91	0.04	0.70	-

The results should be interpreted with caution due to the effects of different survey contractors, benthic laboratories, and sample sizes. However, the lack of any statistically significant differences suggests that there have been no changes in biodiversity over the survey period.

Figure 3.16: Species richness and abundance of benthic macrofauna from Site 6

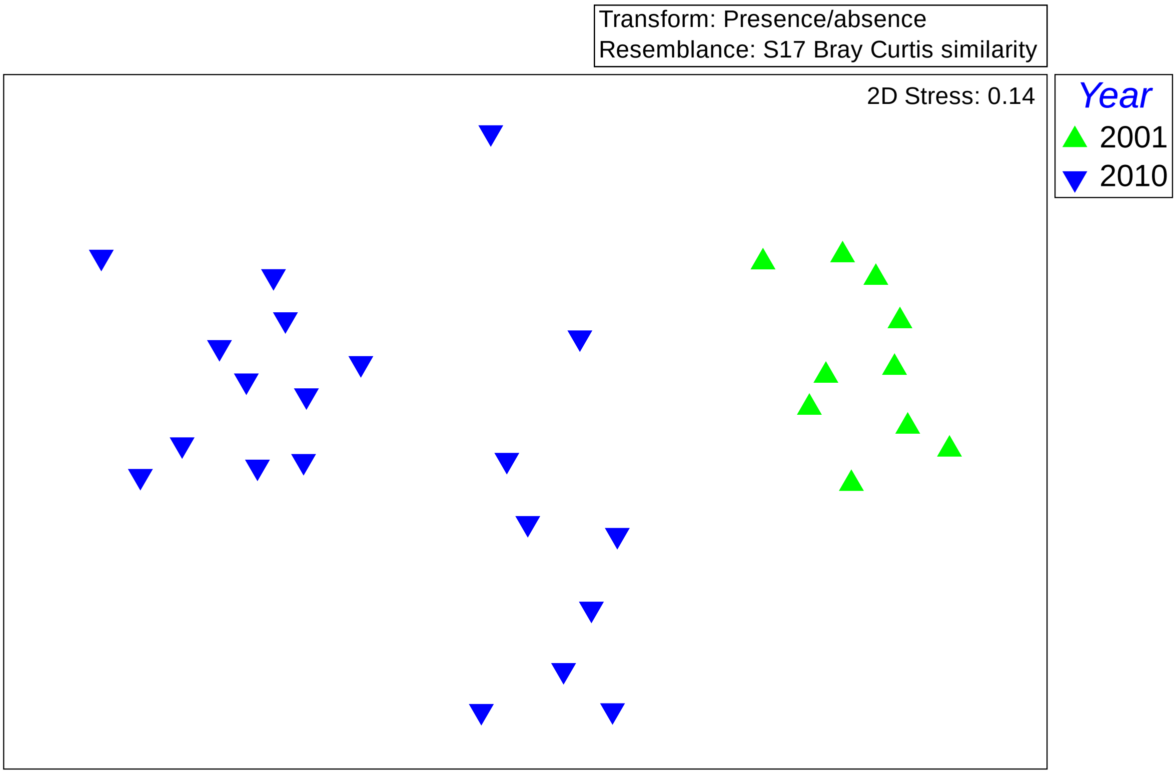




3.3.7.2. Faunal Assemblages

At Site 6, benthic community structure differed between years which is reflected in the spread of data (Figure 3.17). An ANOSIM test indicated that differences in benthic community structure between years are significant and the effect of sampling year is relatively large (Global R = 0.757, p = 0.1%).

Figure 3.17: Non-metric multi-dimension scaling ordination of benthic community structure from Site 6 (Bray-Curtis similarity and $^4\sqrt{}$-transformation)



SIMPER analysis for each year indicated sample pairs have an average similarity of 51.31% in 2001 with a maximum contribution (4.74%) from nemerteans and the polychaetes *Glycera lapidum, Sphaerosyllis bulbosa, Hilbigneris gracilis, Aurospio banyulensis, Mediomastus fragilis* and *Notomastus sp.* In 2010, the average similarity between samples was less, at only 40.92%, and was due to the presence of polychaetes *Hesiospina aurantiaca, Mediomastus fragilis* and *Lumbrineris sp.,* nematodes and nemerteans.

Table 3.18: SIMPER analysis of benthic community data from Site 6 by Year (top ten taxa)

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Group 2001: Average similarity 51.31%					
Nemertea	1.0	2.43	8.62	4.74	4.74
Glycera lapidum	1.0	2.43	8.62	4.74	9.49
Sphaerosyllis bulbosa	1.0	2.43	8.62	4.74	14.23
Hilbigneris gracilis	1.0	2.43	8.62	4.74	18.98
Aurospio banyulensis	1.0	2.43	8.62	4.74	23.72
Mediomastus fragilis	1.0	2.43	8.62	4.74	28.47
Notomastus sp.	1.0	2.43	8.62	4.74	33.21
Amphipholis squamata	1.0	2.43	8.62	4.74	37.95
Nematoda	0.9	1.94	1.91	3.78	41.74
Kurtiella bidentata	0.8	1.52	1.24	2.97	44.70
Group 2010: Average similarity 40.92%					
Hesiospina aurantiaca	1.0	1.93	6.45	4.72	4.72
Mediomastus fragilis	1.0	1.93	6.45	4.72	9.45
Lumbrineris sp.	0.95	1.74	2.68	4.24	13.69
Nematoda	0.95	1.70	2.74	4.15	17.84
Nemertea	0.9	1.60	1.92	3.91	21.75
Glycera lapidum	0.9	1.54	1.91	3.76	25.51
Sphaerosyllis bulbosa	0.9	1.52	1.91	3.73	29.23
Amphiuridae	0.8	1.22	1.26	2.99	32.22
Aurospio banyulensis	0.8	1.21	1.28	2.95	35.18
Pholoe inornata	0.8	1.17	1.27	2.85	38.03

3.3.7.3. Biotopes

The sediment type at Site 6 in 2001 was predominantly gravelly Sand or sandy Gravel. The silt / clay fraction varied from 0.97% to 13.74% whilst gravel content varied from 35.36% to 59.95% and sand content varied from 34.39% to 60.61%. In 2010, sediment types ranged from sandy Gravel to muddy sandy Gravel with gravel content ranging from 33.6% to 72.7%.

In 2001, Allen and Proctor (2003) found that the benthic community at Site 6 was relatively homogeneous, but was difficult to link to a single biotope due to the low abundances. It was best characterised as SS.SCS.CCS.MedLumVen (*Mediomastus fragilis, Lumbrineris* spp. and venerid bivalves in circalittoral coarse sand or gravel), though it was also similar to SS.SCS.OCS.GlapThyAmy (*Glycera lapidum*, *Thyasira* spp. and *Amythasides macroglossus* in offshore gravelly sand) and SS.SCS.ICS.HeloMsim (*Hesionura elongata* and *Microphthalmus similis* with other interstitial polychaetes in infralittoral mobile coarse sand). Characteristic species in 2010 were *Mediomastus fragilis, Lumbrineris gracilis, Amphipholis squamata,* and *Glycera lapidum* in relatively low numbers and *Polygordius* sp. which was present at 80% of the stations. In 2013, there were more *Lumbrineris* spp. which made the site more like SS.SCS.CCS.MedLumVen. This biotope has been described as the 'Deep Venus Community' and 'Boreal Off-Shore Gravel Association' (Ford 1923; Jones 1950) and may be part of the Venus community described by Thorson (1957) and Glémarec (1973).

Though there were small significant differences detected in species composition between years at Site 6, this was partly due to the relatively depauperate community and species composition was broadly similar to the typical 'Deep Venus Community' in all years.

3.3.8. Site 7 Helford River

Site 7 was situated in the outer region of the Helford River, where water depths ranged from 7 m to 8 m CD (Allen and Proctor, 2003). This is an area of the estuary which is euhaline (>30 psu).

3.3.8.1. Diversity Indices

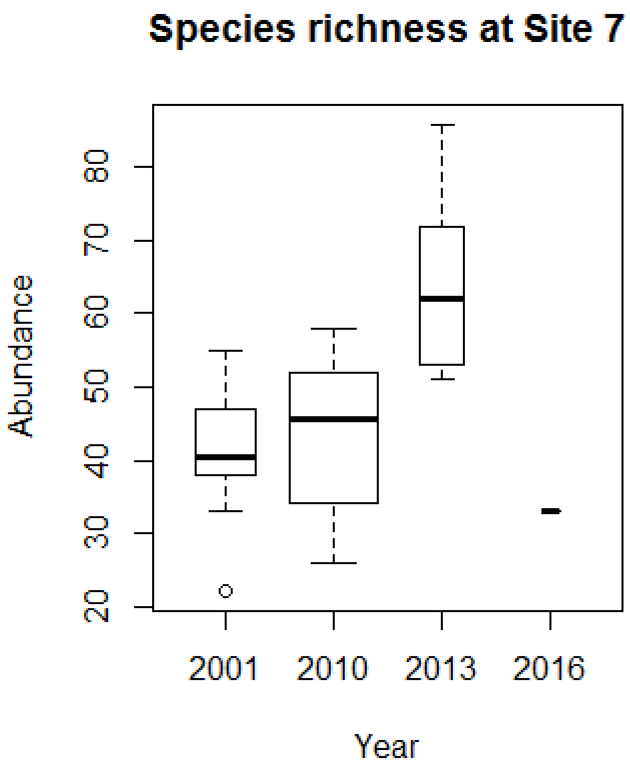
The number of species (S) and number of individuals (N) were consistent at the site between years (Figure 3.18; Table 3.18). A Kruskal-Wallis test shows that there was no statistically significant difference in number of species (S) between years, $\chi^2(23) = 25.53$, $p = 0.324$. Nor was there a statistically significant difference in number of individuals (N) between years (χ^2 (34) = 33.74, $p = 0.480$) or Margalef's index of species richness (D) ($\chi^2(33) = 35.0$, $p = 0.373$).

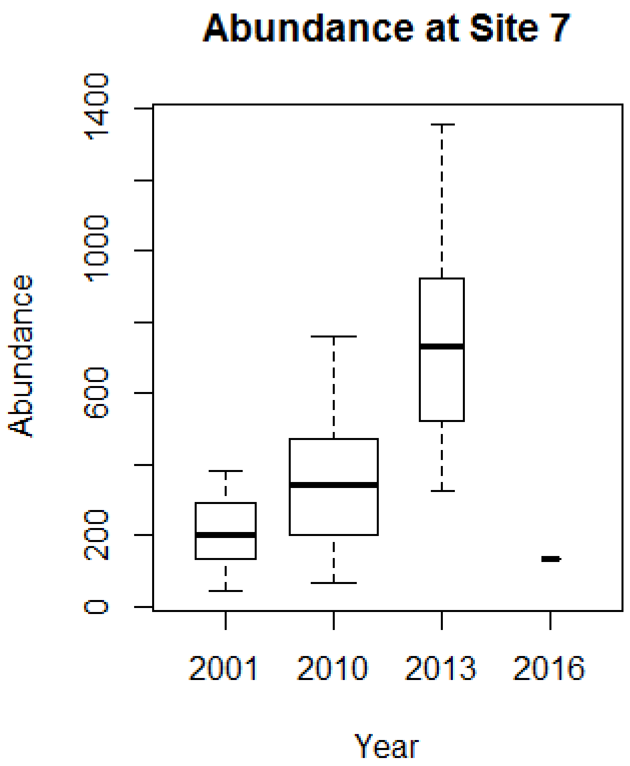
Table 3.19: Mean diversity statistics of benthic communities at Site 7 (n = mean number of samples, S = number of Species in each sample, N = number of Individuals in each sample, D = Margalef's index for species richness, J' = Pielou's evenness index, H'(log_e) = Shannon's diversity index, 1-λ' = Simpson's dominance Index)

	2001		2010		2013		2016	
n	10		20		5		1	
S	41.10	9.39	43.30	9.85	64.80	14.48	33.00	-
N	207.40	100.36	341.95	174.53	771.40	397.39	131.00	-
D	7.65	1.24	7.40	1.28	9.72	1.73	6.56	-
J'	0.78	0.09	0.74	0.10	0.70	0.05	0.83	-
H'(loge)	2.85	0.28	2.76	0.35	2.92	0.34	2.89	-
1-λ'	0.90	0.05	0.88	0.07	0.89	0.03	0.93	-

The results should be interpreted with caution due to the effects of different survey contractors, benthic laboratories, and sample sizes. However, the lack of any statistically significant differences suggests that there have been no changes in biodiversity over the survey period.

Figure 3.18: Species richness and abundance of benthic macrofauna from Site 7





3.3.8.2. Faunal Assemblages

At Site 7, benthic community structure differed between years which is reflected in the spread of data (Figure 3.19). An ANOSIM test indicated that differences in benthic community structure between years are significant and the effect of sampling year is moderate weak (Global R = 0.355, p = 0.2%). Pairwise comparisons indicate significant differences between samples in 2009 and all other years (2010, 2013) (Table 3.6).

Figure 3.19: Non-metric multi-dimension scaling ordination of benthic community structure from Site 7 (Bray-Curtis similarity and $^4\sqrt{}$-transformation)

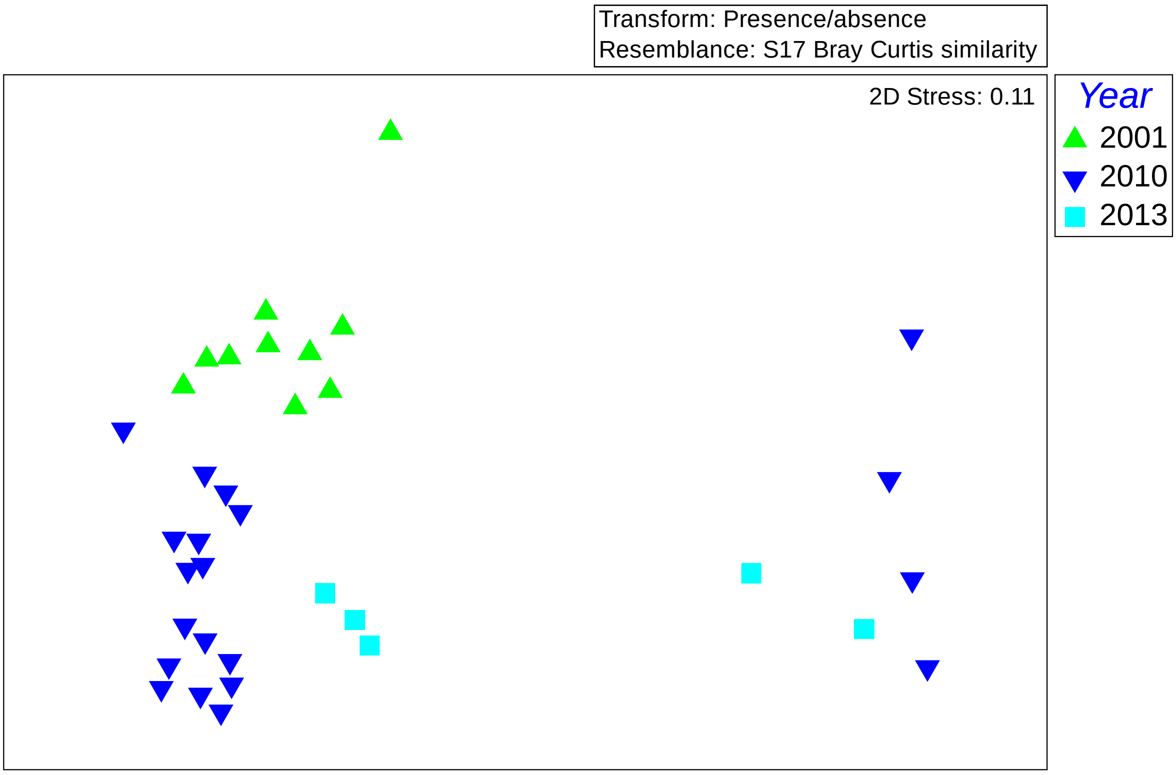


Table 3.20: ANOSIM of benthic community data from Site 7 over consecutive monitoring surveys (*denotes significance at the 5% level)

Groups	R Statistic	Significance Level %	Possible Permutations	Actual Permutations	Number ≥Obs
2001, 2010	0.37	0.1	30045015	999	0
2001, 2013	0.793	0.2	3003	999	1
2010, 2013	0.216	6	53130	999	59

SIMPER analysis for each year indicated sample pairs had an average similarity of 45.75% in 2001 with a maximum contribution (5.44%) from nematodes and the polychaetes *Pisione remota, Psamathe fusca, Syllis cornuta,* and *Protodorvillea kefersteini* (Table 3.20).

In 2010, average similarity was lower (34.41%) and similarities were predominantly due to nematodes, nemerteans and the polychaetes *Pisione remota, Syllis cornuta, Sphaerosyllis bulbosa* and *Protodorvillea kefersteini.* Average similarity in 2013 was similar to that of 2010 (36.76%) and was again due to nemerteans and nematodes, but also the amphipods *Parametaphoxus fultoni* and *Apseudopsis latreilliid.*

Table 3.21: SIMPER analysis of benthic community data from Site 7 by Year (top ten taxa)

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Group 2001: Average similarity 45.75%					
Nematoda	1.00	2.49	6.23	5.44	5.44
Pisione remota	1.00	2.49	6.23	5.44	10.88
Psamathe fusca	1.00	2.49	6.23	5.44	16.32
Syllis cornuta	1.00	2.49	6.23	5.44	21.76
Protodorvillea kefersteini	1.00	2.49	6.23	5.44	27.20
Nemertea	0.90	1.87	1.93	4.09	31.29
Glycera lapidum	0.90	1.87	1.93	4.09	35.37
Glycinde nordmanni	0.80	1.54	1.23	3.37	38.74
Caulleriella bioculata	0.80	1.47	1.25	3.22	41.96
Mediomastus fragilis	0.80	1.47	1.25	3.22	45.17
Group 2010: Average similarity 34.41%					
Nematoda	0.95	2.09	2.68	6.06	6.06
Nemertea	0.85	1.68	1.52	4.89	10.95
Pisione remota	0.80	1.42	1.27	4.13	15.08
Syllis cornuta	0.80	1.42	1.27	4.13	19.21
Sphaerosyllis bulbosa	0.80	1.42	1.27	4.13	23.35
Protodorvillea kefersteini	0.80	1.42	1.27	4.13	27.48
Caulleriella bioculata	0.80	1.42	1.27	4.13	31.61
Polygordius spp.	0.80	1.42	1.27	4.13	35.74
Glycera lapidum	0.75	1.22	1.09	3.55	39.30
Trypanosyllis coeliaca	0.75	1.20	1.09	3.49	42.79
Group 2013: Average similarity 36.76%					
Nemertea	1.00	1.57	7.70	4.26	4.26
Nematoda	1.00	1.57	7.70	4.26	8.52
Parametaphoxus fultoni	1.00	1.57	7.70	4.26	12.78
Apseudopsis latreillii	1.00	1.57	7.70	4.26	17.05
Kurtiella bidentata	1.00	1.57	7.70	4.26	21.31
Myodocopida	0.80	1.02	1.15	2.76	24.07
Caulleriella alata	0.80	0.93	1.14	2.53	26.60
Mediomastus fragilis	0.80	0.93	1.14	2.53	29.14
Protodorvillea kefersteini	0.80	0.90	1.14	2.44	31.57
Paradoneis spp.	0.80	0.90	1.14	2.44	34.01

3.3.8.3. Biotopes

The sediment type at Site 7 was found to be predominantly gravelly Sand or sandy Gravel in 2001 with a small quantity of silt, although one sample was different with coarse sand and approximately 5% silt and gravel. The silt fraction ranged from 1.21% to 5.14% whilst gravel content ranged from 5.84% (as an outlier) to 41.19% and sand content varied from 57.6% to 89.02%. In 2010, the sediment types ranged from Sand to gravelly Sand to sandy Gravel to muddy sandy Gravel.

In 2001, Allen and Proctor (2003) identified one main community at Site 7 with an outlier corresponding to the low gravel content sample. It was identified that this sample was likely an impoverished version of the main group. The community was recognised as a likely variant of SS.SCS.CCS.MedLumVen (*Mediomastus fragilis, Lumbrineris* spp. and venerid bivalves in circalittoral coarse sand or gravel) although the low abundance shows some similarity with SS.SCS.CCS.Pkef (*Protodorvillea kefersteini* and other polychaetes in impoverished circalittoral mixed gravelly sand), SS.SCS.OCS.GlapThyAmy (*Glycera lapidum, Thyasira* spp. and *Amythasides macroglossus* in offshore gravelly sand) and SS.SCS.ICS.HeloMsim (*Hesionura elongata* and *Microphthalmus similis* with other interstitial polychaetes in infralittoral mobile coarse sand).

The characterising species across all surveys were *Protodorvillea kefersteini, Caulleriella bioculata,* Nemertea and Nematoda, which bears a very strong resemblance to SS.SCS.CCS.Pkef (*Protodorvillea kefersteini* and other polychaetes in impoverished circalittoral mixed gravelly sand). In 2010 and 2013, there was a slight divergence in the relatively homogeneous community observed in 2001. This was caused in general by an increased abundance in *Magelona filiformis* and *Chaetozone* spp. and a decrease in *Pisione remota,* Nematoda, *Syllis cornuta, Sphaerosyllis bulbosa* and *Protodorvillea kefersteini* at six stations. These stations represented a mix of 0.5 mm and 1.0 mm mesh, so signifies a genuine shift. This biotope most closely resembles SS.SSa.IMuSa.FfabMag (*Fabulina fabula* and *Magelona mirabilis* with venerid bivalves and amphipods in infralittoral compacted fine muddy sand) and is likely due to the marginally higher silt content of the sediment.

Though there were small significant differences detected in species composition between some years at Site 7, the changes were mainly caused by small shifts in the relative abundance of mainly polychaete species and could have been due to an altered survey array. In more recent surveys, there was an observed increase in *Magelona filiformis* and *Chaetozone* species: *Magelona* spp. are thought be respond in a positive way to smothering (Hiscock *et al*., 2004) and a negative way to nutrients (Pearson and Black, 2001) and *Chaetozone* spp. are thought to respond in a positive way to hydrocarbons (Davies *et al*., 1984). *Protodorvillea kefersteini* has declined in numbers in recent surveys and is thought to respond in a positive way to both hydrocarbons (Oug *et al*., 1998) and nutrients (Pearson and Black, 2001). As such, and given the available data, there is no clear single anthropogenic pressure driving consistent change in indicator species, but may be linked to an increase in sediment fines.

3.3.9. Site 9 Helford River

Site 9 was located in the inner region of the Helford River where water depths ranged from 0 m to 1.6 m CD (Allen and Proctor, 2003). This is a region of the estuary which is on the boundary of euhaline (>30 psu) and polyhaline (18-30 psu).

3.3.9.1. Diversity Indices

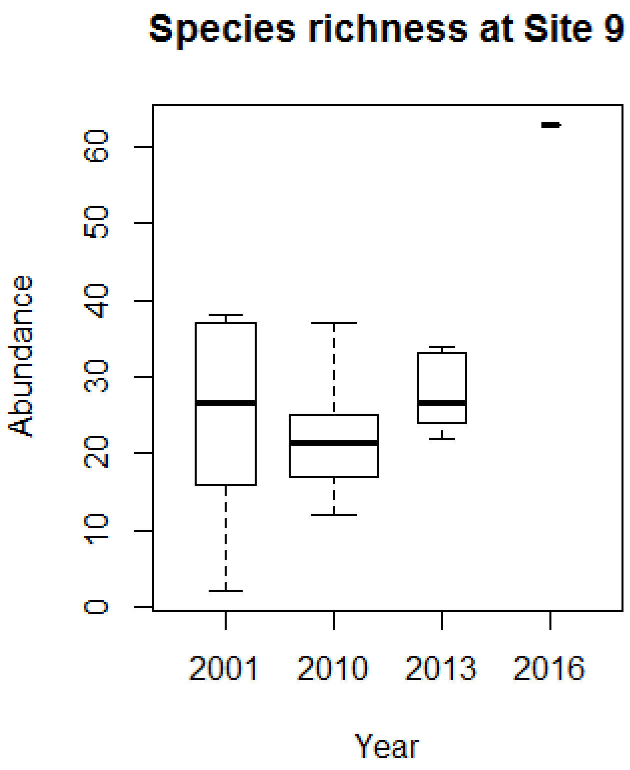
The number of species (S) and number of individuals (N) were consistent at the site between years (Table 3.21; Figure 3.20). A Kruskal-Wallis test shows that there was no statistically significant difference in number of species (S) between years, $\chi^2(20) = 33.27$, $p = 0.226$. Nor was there a statistically significant difference in number of individuals (N) between years (χ^2 (35) = 38.0, p = 0.421) or Margalef's index of species richness (D) ($\chi^2(32) = 38.0$, $p = 0.374$).

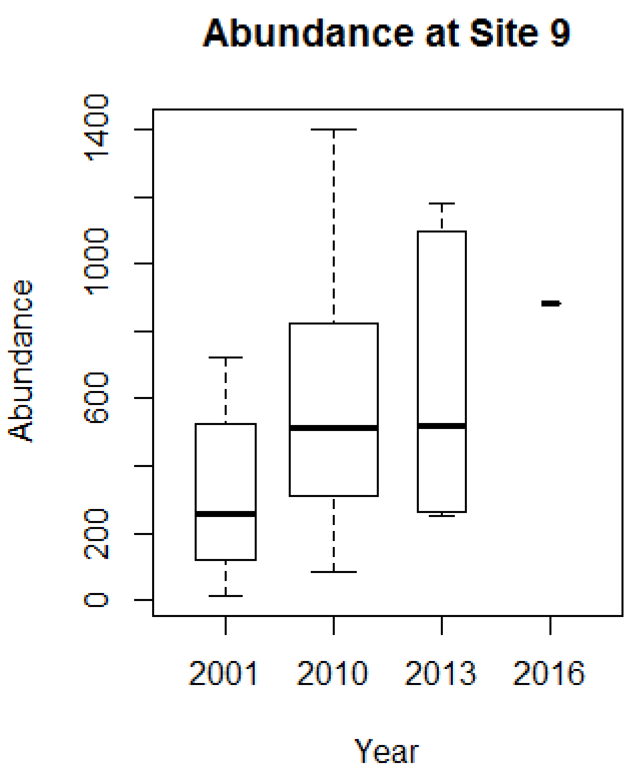
Table 3.22: Mean diversity statistics of benthic communities at Site 9 (n = mean number of samples, S = number of Species in each sample, N = number of Individuals in each sample, D = Margalef's index for species richness, J' = Pielou's evenness index, H'(log_e) = Shannon's diversity index, 1-λ' = Simpson's dominance Index)

	2001		2010		2013		2016	
n	10		20		6		1	
S	24.40	12.82	21.85	6.23	27.67	4.84	63.00	-
N	316.20	248.30	586.35	342.50	637.33	434.56	882.00	-
D	4.06	1.91	3.36	0.88	4.30	0.69	9.14	-
J'	0.68	0.13	0.41	0.11	0.70	0.10	0.75	-
H'(loge)	1.97	0.67	1.24	0.33	2.31	0.31	3.10	-
1-λ'	0.75	0.15	0.47	0.14	0.84	0.06	0.93	-

The results should be interpreted with caution due to the effects of different survey contractors, benthic laboratories, and sample sizes. However, the lack of any statistically significant differences suggests that there have been no changes in biodiversity over the survey period.

Figure 3.20: Species richness and abundance of benthic macrofauna from Site 9





3.3.9.2. Faunal Assemblages

At Site 9, benthic community structure differed between years which is reflected in the spread of data (Figure 3.21). An ANOSIM test indicated that differences in benthic community structure between years are significant and the effect of sampling year is relatively strong (Global R = 0.732, p = 0.1%). Pairwise comparisons indicate significant differences between samples in 2001 and all other years (2010, 2013) and also between 2010 and 2013 (Table 3.22). In addition, pairwise comparisons indicate significant differences between samples in 2002 and both 2001 and 2013.

Figure 3.21: Non-metric multi-dimension scaling ordination of benthic community structure from Site 9 (Bray-Curtis similarity and $\sqrt[4]{}$-transformation)

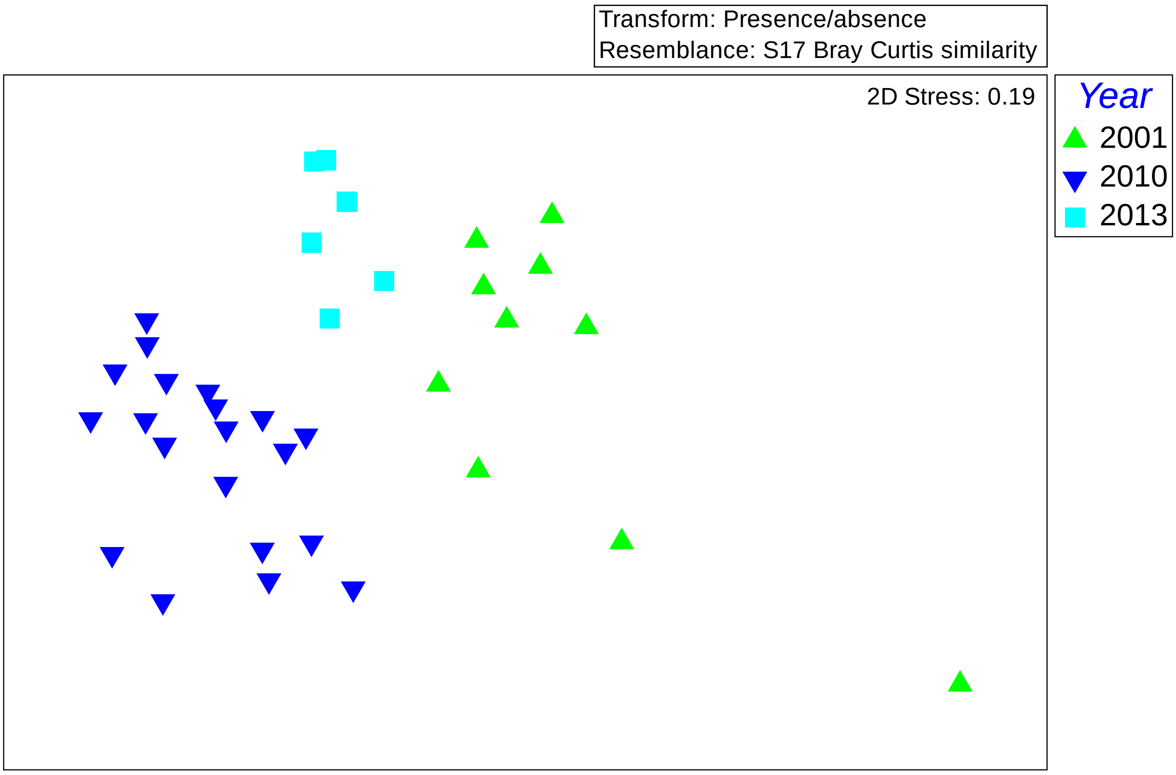


Table 3.23: ANOSIM of benthic community data from Site 9 over consecutive monitoring surveys (*denotes significance at the 5% level)

Groups	R Statistic	Significance Level %	Possible Permutations	Actual Permutations	Number ≥Obs
2001, 2010	0.81	0.1	30045015	999	0
2001, 2013	0.387	0.3	8008	999	2
2010, 2013	0.745	0.1	230230	999	0

SIMPER analysis for each year indicated sample pairs have an average similarity of 36.74% in 2001 with maximum contributions from the polychaetes *Melinna palmata, Sabella pavonina, Mediomastus fragilis, Nephtys hombergii* and *Chaetozone gibber* and nematodes (Table 3.23).

In 2010, the average similarity between samples was higher (46.53%) with similarity due to polychaetes *Chaetozone gibber, Tharyx sp.* and *Capitella spp.,* oligochaetes *Tubificoides pseudogaster,* and bivlaves *Abra nitida* and *Abra alba.* Average similarity was similar to 2010 in 2013 (53.17%), due to the presence of nematodes and polychaetes *Exogone naidina, Nephtys hombergii, Scoloplos armiger* and *Chaetozone gibber.*

Table 3.24: SIMPER analysis of benthic community data from Site 9 by Year (top ten taxa)

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Group 2001: Average similarity 36.74%					
Melinna palmata	0.90	4.07	1.20	11.07	11.07
Sabella pavonina	0.90	3.82	1.18	10.39	21.46
Nematoda	0.90	3.21	1.62	8.74	30.20
Mediomastus fragilis	0.90	3.21	1.62	8.74	38.93
Nephtys hombergii	0.80	2.22	1.20	6.05	44.99
Chaetozone gibber	0.80	2.22	1.20	6.05	51.04
Tubificoides galiciensis	0.80	2.22	1.20	6.05	57.09
Kurtiella bidentata	0.70	1.66	0.87	4.52	61.61
Cossura pygodactylata	0.70	1.62	0.89	4.40	66.01
Abra nitida	0.60	1.16	0.67	3.16	69.17
Group 2010: Average similarity 46.53%					
Chaetozone gibber	1.00	4.75	5.13	10.20	10.20
Tubificoides pseudogaster	1.00	4.75	5.13	10.20	20.40
Tharyx killariensis	0.90	3.73	1.86	8.01	28.41
Tharyx sp.	0.85	3.32	1.49	7.14	35.55
Capitella spp.	0.85	3.27	1.49	7.03	42.58
Abra nitida	0.80	2.97	1.23	6.39	48.97
Abra alba	0.75	2.51	1.06	5.40	54.37
Cossura pygodactylata	0.70	2.22	0.93	4.78	59.15
Tubificoides galiciensis	0.65	1.86	0.81	3.99	63.14
Galathowenia oculata	0.65	1.84	0.82	3.96	67.10
Group 2013: Average similarity 53.17%					
Nematoda	1.00	3.65	9.50	6.87	6.87
Exogone naidina	1.00	3.65	9.50	6.87	13.74
Nephtys hombergii	1.00	3.65	9.50	6.87	20.60
Scoloplos armiger	1.00	3.65	9.50	6.87	27.47
Chaetozone gibber	1.00	3.65	9.50	6.87	34.34
Cossura pygodactylata	1.00	3.65	9.50	6.87	41.21
Mediomastus fragilis	1.00	3.65	9.50	6.87	48.08
Melinna palmata	1.00	3.65	9.50	6.87	54.95
Tubificoides amplivasatus	1.00	3.65	9.50	6.87	61.81
Sphaerosyllis taylori	0.83	2.37	1.35	4.46	66.27

3.3.9.3. Biotopes

The sediment type at Site 9 was consistently recorded as sandy Mud in 2001, with the silt / clay fraction ranging from 43.08% to 71.06% whilst gravel was absent from the stations and sand content varied from 28.24% to 56.92%. In 2010, half of the six samples were gravelly mud, with a gravel content between 8.9% and 23.9%.

In 2001, Allen and Proctor (2003) observed that the site was highly variable, but split the site into two main benthic communities:

- Group 1 characterised by *Chaetozone gibber, Tubificoides galiciensis, Mediomastus fragilis,* Nematoda and *Nephtys hombergii* which were found at all stations. *Cossura longocirrata, Sabella pavonina* and *Melinna palmata* were also abundant; and
- Group 2 which was slightly muddier and somewhat impoverished but was characterised by *Sabella pavonina* and *Melinna palmata* in cohesive muddy sand / sandy mud.

The authors concluded that the groups were likely variants of SS.SMu.ISaMu.MelMagThy (*Melinna palmata* with *Magelona* spp. and *Thyasira* spp. in infralittoral sandy mud) and SS.SMx.IMx.SpavSpAn (*Sabella pavonina* with sponges and anemones on infralittoral mixed sediment). There are also elements of the SS.SMu.SMuVS.AphTubi community (*Aphelochaeta marioni* and *Tubificoides* spp. in variable salinity infralittoral mud) likely due to the reduced salinities and the site is probably transitional between these types.

The characterising species across all surveys were *Protodorvillea kefersteini, Caulleriella bioculata,* Nemertea and Nematoda, which bears a very strong resemblance to SS.SCS.CCS.Pkef (*Protodorvillea kefersteini* and other polychaetes in impoverished circalittoral mixed gravelly sand).

Though there were small significant differences detected in species composition between years at Site 9, the changes were mainly caused by small shifts in the relative abundance of mainly polychaete species: *Chaetozone gibber*, *Cossura* spp., and *Exogone* spp. In terms of potential indictors of anthropogenic pressure, *Chaetozone* spp. are thought to respond in a positive way to hydrocarbons (Davies *et al*., 1984) and *Exogone* spp. is a strong negative indicator of TBT (Matthiessen *et al*., 1999). *Tubificoides* spp. also contributed to dissimilarities between years at Site 9, being highest in 2013, and is typically more abundant when heavy metals (Shillabeer & Tapp, 1990) and nutrients (Warwick, 2001) are high. As such, and given the available data, there is no clear single anthropogenic pressure driving consistent change in indicator species.

4. Conclusions

- There were a number of issues associated with the benthic survey data supplied that took considerable time to address before analysis could begin. These steps typically involved some form of truncation and standardisation due to the varied survey designs and sampling and processing techniques, but there were also problems with missing data and a lack of supporting information that meant some data were not able to be used. The most robust monitoring design for future surveys would follow the method used in the earlier 2001 survey (Allen and Proctor, 2003) in order to make best use of existing data.
- The benthic survey data used in the site assessment came from a number of different surveys that had utilised different survey techniques, processing methods, and experimental designs. As such, the analyses undertaken reflected the quality of the data and any results should be interpreted with caution.
- The seabed sediments within the Fal and Helford SAC are extremely variable across the site, from shallow estuarine mud to shallow sand and gravel amongst bedrock outcrops to mixed sublittoral with maerl gravel.
- Site 1 had low to moderate richness and diversity and there were no significant differences in biodiversity indices between years. Community composition was significantly different between years, but was due to small changes in the relative abundance of common species. Sediments were sandy Mud. Overall, the community was characterised as a typical SS.SMu.SMuVS.AphTubi community (*Aphelochaeta marioni* and *Tubificoides* spp. in variable salinity infralittoral mud).
- Site 2 had low to moderate richness and diversity and there were no significant differences in biodiversity indices between years. Community composition was significantly different between years, but was due to small changes in the relative abundance of common species. Sediments were typically sandy or gravelly Mud. Overall, the site was best characterised as SS.SMu.SMuVS.AphTubi, though there were elements of SS.SMu.ISaMu.MelMagThy in 2001.
- Site 3 had low to high richness and diversity and there were no significant differences in biodiversity indices between years. Community composition was significantly different between years, but was due to small changes in the relative abundance of common species. Sediments were typically either muddy Gravel or Gravel. Overall, the site was best characterised as SS.SMu.SMuVS.AphTubi (*Aphelochaeta marioni* and *Tubificoides* spp. in variable salinity infralittoral mud) though there were elements of SS.SMx.IMx.VsenAsquAps (*Venerupis senegalensis, Amphipholis squamata* and *Apseudes latreilli* in infralittoral mixed sediment) in 2001. Heavy metal concentrations in the sediment are high here due to extensive historical mining in the Fal Estuary, though no chemical samples were analysed as part of this work.
- Site 4 had moderate to high richness and diversity and there were no significant differences in biodiversity indices between years. Community composition was significantly different between years, but was due to small changes in the relative abundance of common species. Sediments were predominantly gravelly Mud, but were variable and also included Mud, muddy Sand and Sand. Overall, the biotope is best represented as a slightly gravelly variant of the *Mellina* biotope SS.SMu.ISaMu.MelMagThy (*Melinna palmata* with *Magelona* spp. and *Thyasira* spp. in infralittoral sandy mud).
- Site 5 had moderate richness and diversity and there were no significant differences in biodiversity indices between years. Community composition was significantly different between years, but was due to small changes in the relative abundance of common species.

Sediments were typically Sand or muddy Sand. Across the 2001 and 2013 surveys, the biotope is best represented as SS.SSa.IMuSa.FfabMag (*Fabulina fabula* and *Magelona mirabilis* with venerid bivalves and amphipods in infralittoral compacted fine muddy sand). In 2001, there were high levels of *Capitella* spp. at Site 5 that indicated possible organic enrichment, but these were not present in 2013.

- Site 6 had low to moderate richness and diversity and there were no significant differences in biodiversity indices between years. Community composition was significantly different between years, but was due to small changes in the relative abundance of common species. Sediments were typically gravelly Sand or sandy Gravel. Overall, the community was best characterised as a classic SS.SCS.CCS.MedLumVen (*Mediomastus fragilis, Lumbrineris* spp. and venerid bivalves in circalittoral coarse sand or gravel). This biotope has previously been described as the 'Deep Venus Community' and the 'Boreal Off-Shore Gravel Association' by other workers (Ford 1923; Jones 1950) and may also be part of the Venus community described by Thorson (1957) and in the infralittoral forms described by Glémarec (1973).
- Site 7 had moderate richness and diversity and there were no significant differences in biodiversity indices between years. Community composition was significantly different between years, but was due to small changes in the relative abundance of common species. Sediments were typically gravelly Sand or sandy Gravel, though there was a larger component of silt in 2010. Overall, the biotope was best characterised as SS.SCS.CCS.Pkef (*Protodorvillea kefersteini* and other polychaetes in impoverished circalittoral mixed gravelly sand), though in 2010 and 2013 there were additional elements of SS.SSa.IMuSa.FfabMag (*Fabulina fabula* and *Magelona mirabilis* with venerid bivalves and amphipods in infralittoral compacted fine muddy sand) associated with elevated silt content.
- Site 9 had moderate richness and diversity and there were no significant differences in biodiversity indices between years. Community composition was significantly different between years, but was due to small changes in the relative abundance of common species. Sediments were typically sandy Mud, but there was a higher component of gravel in 2010 (gravelly Mud). Overall, the two dominant biotopes are best represented as variants of SS.SMu.ISaMu.MelMagThy (*Melinna palmata* with *Magelona* spp. and *Thyasira* spp. in infralittoral sandy mud) and SS.SMx.IMx.SpavSpAn (*Sabella pavonina* with sponges and anemones on infralittoral mixed sediment).
- Though there were changes in relative species composition observed during the survey period, these were not sufficient to lead to changes in biotope classification, which have not deviated significantly from the 2001 survey.
- The favourable condition table for the relevant subfeatures of the Fal and Helford SAC is given in Table 5.1. Based upon the survey data used within the scope of the project, any observed changes have been minor and within what could reasonably be expected through natural change, so it is concluded that the condition of the site has effectively been maintained over the survey period. Any minor changes have been concluded to be as a result of natural change due to the transitional nature of the biotope and the species contributing to these changes not being indicative of any particular human activity or disturbance. At Site 5 (outer Carrick Roads), there were actually fewer *Capitella* spp. – which can be an indicator of organic enrichment – in 2013 compared to 2001.

Feature information[2]:

- Estuaries: the upper reaches of both the Fal and the Helford are considered estuaries along with the upper Percuil River. This also includes the majority of the creeks which branch from these rivers including Porthnavas and Frenchman's Creek on the Helford, and Cowland and Lamouth Creek on the Fal.
- Mudflats and sandflats not covered by seawater at low tide: the majority of the upper shores of the Fal and Helford estuaries and associated creeks are fringed by sheltered intertidal mudflats and sandflats. Within the upper reaches of the site the sediments are stable and diverse. Muds and muddy sands characterise areas such as Malpas, Ardevora Veor, and Mawgan Creek, whereas mixed and coarse sediments are present in Place Cove, Gillan Creek and the Bar on the Helford amongst others.
- Large shallow inlets and bays: the large shallow inlets and bays feature of the Fal and Helford SAC covers the Carrick Roads, Falmouth Bay and the lower Helford. Differences in wave exposure and tidal flows throughout the embayment, along with varying topography, contribute to the high diversity in marine environments.
- Sandbanks which are slightly covered by sea water all the time: Subtidal sandbanks are widespread throughout the site. In the Fal, sandbanks cover a large proportion of the Carrick Roads, extending into the mouth of the Percuil River. In Falmouth Bay, sandbank features can be found throughout the bay and found both close inshore and offshore up to the site boundary. These features also extend from Falmouth Bay reaching far up the Helford.

[2] Fal and Helford SAC: DRAFT supplementary advice on conserving and restoring site feature. Natural England pp158

Table 4.1: Review of feature condition attributes for the Fal and Helford Special Area of Conservation

Attribute	Subtidal Sandbanks	Large Shallow Inlets and Bays	Mudflats and Sandflats	Estuaries	Subtidal Coarse Sediment	Subtidal Mixed Sediments	Subtidal Sand	Subtidal Mud	Assessment
Extent and distribution: Maintain the total extent and spatial distribution to ensure no loss of integrity, whilst allowing for natural change and succession.	✓	✓	✓	✓	✓	✓	✓	✓	Not assessed due to the lack of data allowing complete mapping of the features and sub-features across the SAC. In order to assess this attribute in future, a characterisation survey of the entire site is required, including geophysical data collection linked to a stratified groundtruthing array.
Distribution: Maintain the presence and spatial distribution of typical communities according to the map.	✓	✓	✓	✓	✓	✓	✓	✓	Whilst the monitoring data analysed here was not intended to characterise the whole of the Fal and Helford SAC (distribution), analysis of the data by Site has allowed determination of distribution at key points within the site where there were data (presence). Analysis of biotopes across the surveys showed that although there is variability within some of the sites, in general, the features and sub-features identified in 2001 (Allen and Proctor, 2003) were also present in 2009, 2010, 2013 and 2016. The exception to this was at Site 7 (Helford River) where an increase in the relative proportion of silt in 2010 and 2013 had led to a new biotope with increased *Magelona mirabilis* and *Chaetozone* spp. In addition, there was an additional component of gravel found at Site 9 in 2010 and 2013 which led to a new characterisation of SS.SCS.CCS.Pkef (*Protodorvillea kefersteini* and other polychaetes in impoverished circalittoral mixed gravelly sand), though most of the characterising species had also been found in 2001.
Structure (morphology): Maintain the characteristic morphological regime of the feature.		✓		✓					Not assessed due to the lack of data allowing complete mapping of the features and sub-features across the SAC. In order to assess this attribute in future, a characterisation survey of the entire site is required, including geophysical data collection.

Attribute	Subtidal Sandbanks	Large Shallow Inlets and Bays	Mudflats and Sandflats	Estuaries	Subtidal Coarse Sediment	Subtidal Mixed Sediments	Subtidal Sand	Subtidal Mud	Assessment
Structure (presence and abundance of typical species): [Maintain OR Recover OR Restore] the abundance of listed typical species, to enable each of them to be a viable component of the habitat.	✓	✓	✓	✓	✓	✓	✓	✓	Analysis of community data across the surveys showed that although there is variability within some of the sites, in general, the features and sub-features identified in 2001 (Allen and Proctor, 2003) were also present in 2009, 2010, 2013 and 2016. The exception to this was at Site 7 (Helford River) where an increase in the relative proportion of silt in 2010 and 2013 had led to a new biotope with increased *Magelona mirabilis* and *Chaetozone* spp. In addition, there was an additional component of gravel found at Site 9 in 2010 and 2013 which led to a new characterisation of SS.SCS.CCS.Pkef (*Protodorvillea kefersteini* and other polychaetes in impoverished circalittoral mixed gravelly sand), though most of the characterising species had also been found in 2001.
Structure (sediment composition and distribution): Maintain the existing distribution of sediment composition types across the feature.	✓					✓	✓	✓	There were limited sediment data available for analysis compared to benthic grab data. Analysis of available PSD data shows that in general sediment types remained consistent across the surveys. The exception to this was at Site 4 (Carrick Roads) where the silt content was highly variable and with a higher average content in 2010 compared to 2001, ranging from 6.9-85.1% compared with 18.9-34.0%. Though the gravel content was similar between years, the relative sand and gravel content varied, causing shifts in sediment type.
Structure (sediment movement, sources and sinks): Maintain sediment regime and budget within the estuary, including sediment sources, sinks and movement.		✓		✓					There were limited sediment data available for analysis compared to benthic grab data. Analysis of available PSD data shows that in general sediment types remained consistent across the surveys. The exception to this was at Site 4 (Carrick Roads) where the silt content was highly variable and with a higher average content in 2010 compared to 2001, ranging from 6.9-85.1% compared

Attribute	Subtidal Sandbanks	Large Shallow Inlets and Bays	Mudflats and Sandflats	Estuaries	Subtidal Coarse Sediment	Subtidal Mixed Sediments	Subtidal Sand	Subtidal Mud	Assessment
									with 18.9-34.0%. Though the gravel content was similar between years, the relative sand and gravel content varied causing shifts in sediment type.
Structure (species composition of component communities): Maintain the species composition of component communities.	✓	✓	✓	✓	✓	✓	✓	✓	Analysis of species data across the surveys showed that although there is variability within some of the sites, in general, the features and sub-features identified in 2001 (Allen and Proctor, 2003) were also present in 2009, 2010, 2013 and 2016. The exception to this was at Site 7 (Helford River) where there was increased *Magelona mirabilis* and *Chaetozone* spp. In addition, due to changes in the relative proportions of previously observed taxa, Site 9 was best characterised in 2010 and 2013 as SS.SCS.CCS.Pkef (*Protodorvillea kefersteini* and other polychaetes in impoverished circalittoral mixed gravelly sand), which was not proposed in 2001.
Structure (substrate composition and distribution): Maintain the distribution, composition and character of substrate across the feature (and each of its sub-features). Maintain the distribution of sediment composition types across the feature (and each of its sub-features) (presence / absence of areas mapped in GIS), compared to an established baseline, to ensure continued structural habitat integrity and connectivity.		✓							Not assessed. The monitoring data collected since 2001 was insufficient in terms of the spatial spread across the feature to assess the distribution of substrate across the large shallow inlets and bays feature.

5. References

Allen J.H., and Proctor N.V., 2013. Monitoring Subtidal Sandbanks of the Isles of Scilly and the Fal and Helford Special Areas of Conservation. *A Report to Natural England*. Institute of Estuarine and Coastal Studies, University of Hull pp114.

Bray J.R. and Curtis J.T, 1957. An ordination of the upland forest communities of southern Wisconsin. *Ecological Monographs*. 27: 325-349.

Clarke K.R., and Gorley R.N., 2015. PRIMER v7: User Manual/Tutorial. PRIMER-E, Plymouth, 296pp.

Clarke K.R, Gorley R.N., Somerfield P.J., and Warwick R.M., 2014. *Change in marine communities: an approach to statistical analysis and interpretation,* 3rd edition. PRIMER-E, Plymouth, 260pp.

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

Connor D.W., Allen J.H., Golding N., Howell K.L., Lieberknecht L.M., Northen K.O. and Reker J.B., 2004. The Marine Habitat Classification for Britain and Ireland Version 04.05. In: JNCC (2015) *The Marine Habitat Classification for Britain and Ireland* Version 15.03

Davies J.M., Addy J.M., Blackman R.A., Blanchard J.R., Ferbrache J.E., Moore D.C., Somerville H.J., Whitehead A. & Wilkinson T., 1984. Environmental effects of the use of oil-based drilling muds in the North Sea. *Marine Pollution Bulletin*, 15, 363-370.

Ford E.J., 1923. Animal communities of the level sea-bottom in the waters adjacent to Plymouth. *Journal of the Marine Biological Association of the United Kingdom (*New Series), 13(01): pp.164-224.

Glémarec M., 1973. The benthic communities of the European North Atlantic continental shelf. *Oceanography and Marine Biology: an Annual Review*, 11: pp.263-289.

Hiscock K., Langmead O. and Warwick R. 2004. Identification of seabed indicator species from time-series and other studies to support implementation of the EU Habitats and Water Framework Directives. *Report to the Joint Nature Conservation Committee and the Environment Agency from the Marine Biological Association*. Plymouth: Marine Biological Association. JNCC Contract F90-01-705. 109 pp

JNCC (Joint Nature Conservation Committee), 2017. Fal and Helford. Available online at: http://jncc.defra.gov.uk/protectedsites/sacselection/sac.asp?EUCode=UK0013112 [Accessed January 2017].

Jones N.S., 1950. Marine bottom communities. *Biological Reviews*, 25(3): pp.283-313.

Long D., 2006. BGS detailed explanation of seabed sediment modified Folk classification. Available online at: http://www.emodnet-seabedhabitats.eu/PDF/GMHM3_Detailed_explanation_of_seabed_sediment_classification.pdf [Accessed January 2017].

Matthiessen P., Kilbride R., Mason C., Pendle M., Rees H.L. and Waldock R., 1999. *Monitoring the recovery of the benthic community in the River Crouch following TBT contamination*. Final Report for the Department of the Environment, Transport and the Regions (DETR). Centre for Environment, Fisheries and Aquaculture Science, 51 pp.

Natural England, 2015a. Fal and Helford Special Area of Conservation: site information (draft). Available online at: https://www.gov.uk/government/publications/marine-conservation-advice-for-special-area-of-conservation-fal-and-helford-uk0013112/fal-and-helford-sac-site-information-draft [Accessed January 2017].

Natural England, 2015b. Plymouth Sound and Estuaries Special Area of Conservation: site information (draft). Available online at: https://www.gov.uk/government/publications/marine-conservation-advice-for-special-area-of-conservation-plymouth-sound-and-estuaries-uk0013111/plymouth-sound-and-estuaries-sac-site-information-draft [Accessed January 2017]

Oug E., Naes K. and Rygg B., 1998. Relationship between soft bottom macrofauna and polycyclic aromatic hydrocarbons (PAH) from smelter discharge in Norwegian fjords and coastal waters. *Marine Ecology Progress Series*, 173, 39-52.

Parry M.E.V., 2015. *Guidance on Assigning Benthic Biotopes using EUNIS or the Marine Habitat Classification of Britain and Ireland* JNCC report No. 546, Joint Nature Conservation Committee, Peterborough.

Pearson T.H., 1975. The benthic ecology of Loch Linnhe and Loch Eil, a sea-loch system on the west coast of Scotland. IV. Changes in the benthic fauna attributable to organic enrichment. *Journal of Experimental Marine Biology and Ecology*, 20(1): pp.1-41.

Pearson T.H. and Black K.D., 2001. The environmental impacts of marine fish cage culture. In *Environmental Impacts of Aquaculture* (ed. K.D. Black), pp. 1-31. Sheffield: Academic Press.

Pearson T.H., and Rosenberg R., 1978. Macrobenthic succession in relation to organic enrichment and pollution of the marine environment. *Oceanography and Marine Biology Annual Review*, 16: pp.229-311.

Reish, D.J., 1959. A discussion of the importance of the screen size in washing quantitative marine bottom samples. Ecology, pp.307-309.

Shillabeer N. and Tapp J.F., 1990. Long-term studies of the benthic biology of Tees Bay and the Tees Estuary. *Hydrobiologia*, 195, 63-78.

Thorson G., 1957. Bottom communities (sublittoral or shallow shelf). *Geological Society of America Memoirs*, 67: pp.461-534.

Warwick, R., 2001. Evidence for the effects of metal contamination on the intertidal macrobenthic assemblages of the Fal Estuary. *Marine Pollution Bulletin*, 42(2), 145–148.

6. Appendices

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