Plymouth Sound & Estuaries SAC Subtidal Sediment Data Analysis Report 2017

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Plymouth Sound & Estuaries SAC Subtidal Sediment Data Analysis Report

for

Natural England

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Executive Summary

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

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 Plymouth Sound and Estuaries. Data were provided from surveys conducted in 1998, 1999, 2011, and 2015. The scope of the analysis covered site features – estuaries, large shallow inlets and bays, subtidal sandbanks – and sub-features – subtidal coarse, mixed, mud and sand sediments.

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.

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. <u>As such, the analyses undertaken reflected the quality of the data and any results should be interpreted with caution.</u>

<u>Cawsand Bay</u> had low to moderate species richness and total abundance and there were no significant differences in biodiversity indices between years, except for Pielou's evenness. Evenness decreased with survey year and sampling effort and it is thought to be due to the variable benthic assemblages and low sampling effort in later years (2011 and 2015). Sediments predominantly consisted of sands, but there was a variable quantity of silt and gravel present at the stations, and there was a general north-east to south-west (onshore-offshore) gradient with somewhat finer sediments in the inshore areas and coarser, poorly sorted gravelly sediments offshore. Community composition was statistically significantly different between some years – between 1998 and 1999 and also between 2015 and both 2008 and 2009 – though sampling effort and hence possible ANOSIM permutations varied dramatically between surveys. The most abundant taxa at Cawsand Bay were *Chaetozone gibber*, *Magelona filiformis, Melinna palmata* and *Galathowenia oculata*. Overall, the benthic assemblages were best characterised by two biotopes: SS.SMu.ISaMu.MelMagThy (*Melinna palmata* with *Magelona* spp. and *Thyasira* spp. in infralittoral sandy mud) and SS.SCS.ICS.MoeVen (*Moerella* spp. with venerid bivalves in infralittoral gravelly sand). Community composition remained similar from 1998 to 1999. Though there were changes in composition in 2015, this was primarily due to changes of species within genus (*Magelona* spp., *Bathyporeia* spp., *Chaetozone* spp., and *Chamelea* spp.) and could be due to analytical reasons rather than any genuine shift.

<u>Torpoint</u> had moderate to high species richness and total abundance and there were no significant differences in biodiversity indices between years, though variability was far higher in 1998 where sampling effort was highest. The seabed at Torpoint was observed to be very heterogeneous with a

high proportion of gravel, pebbles, cobbles, boulders and shell with variable amounts of sand and mud. Community composition was statistically significantly different between all years, but largest between 2011 and both 1998 and 1999. The most abundant taxa at Torpoint were *Aphelochaeta marioni, Melinna palmata, Chaetozone gibber* and *Mediomastus fragilis*. The dominant biotope in all surveys was SS.SCS.CCS.MedLumVen (*Mediomastus fragilis, Lumbrineris* spp. and venerid bivalves in circalittoral coarse sand or gravel), but with apparent elements of other biotopes. In 1998 and 1999, this was SS.SMx.IMx.VsenAsquAps (*Venerupis senegalensis, Amphipholis squamata* and *Apseudes latreilli* in infralittoral mixed sediment), but in 2011 was SS.SMu.ISaMu.MelMagThy (*Melinna palmata* with *Magelona* spp. and *Thyasira* spp. in infralittoral sandy mud). The change in composition from 1998-9 and 2011 was mainly due to a reduction in *Aphelochaeta marioni, Amphicteis gunneri*, or *Apseudopsis latreillii* and an increase in the bivalve *Kurtiella bidentata.* This change could be linked to a slight increase in silt observed in sediment samples due to sample location in 2011 being predominantly in the outer edge of the Torpoint site or the fact that the reduced sampling effort sampled fewer habitats.

The River Yealm had low to moderate species richness and total abundance and there were no significant differences in biodiversity indices between years, though variability was higher in 1998 and 1999 where sampling effort was highest. The sediment composition at the River Yealm site was heterogeneous with stony gravelly sand along the northern side of the Inner Yealm, fine-medium sand and silty sands in the central inner Yealm, and predominantly fine sand in the outer Yealm. Community composition was statistically significantly different between 1998 and all other years and between 1999 and 2011. The biggest difference was between the benthic community in 1998 and that in 2015. The most abundant taxa at River Yealm were *Apseudopsis latreilliid, Gammarella fucicola, Amphipholis squamata,* and *Calyptraea chinensis*. The average similarity within year at River Yealm was extremely low, indicating an extremely diverse range of benthic assemblages. The most common biotope at the site was SS.SSa.IFiSa.NcirBat (*Nephtys cirrosa* and *Bathyporeia* spp. in infralittoral sand). The other dominant biotope was SS.SMx.IMx.VsenAsquAps (*Venerupis senegalensis*, *Amphipholis squamata* and *Apseudes latreilli* in infralittoral mixed sediment). The presence of of *Melinna palmata, Magelona* spp., *Spio filicornis* and *Galathowenia oculata* also indicated elements of SS.SMu.ISaMu.MelMagThy (*Melinna palmata* with *Magelona* spp. and *Thyasira* spp. in infralittoral sandy mud). From 1998 to 1999, there were small changes in the relative abundance of some characteristic species, such as *Apseudopsis latreilliid, Magelona filiformis,* and *Spio filicornis*. In 2011, *Magelona johnstoni*, *Bathyporeia elegans* and *Spio armata* were all sampled and were not represented in 1999, though were represented by other species within the genus in 1999 (*Magelona filiformis, Bathyporeia guilliamsoniana* and *Spio filicornis*). Sampling effort at River Yealm was highly variable over the surveys, as was the spread of samples, with more stations taken from the estuarine region of the site in 1998 and 1999, with finer sediments and freshwater influence. As such, it is difficult to conclude anything with confidence, but it is suggested that observed changes were primarily caused by changes in survey design.

Plymouth Breakwater had low to moderate species richness and total abundance and there was a statistically significant difference in both species number and total abundance with year, though not in any of the other biodiversity indices. Variability in metrics was substantially higher in 1998 compared to other years and associated with higher sampling effort. The Breakwater site had relatively homogenous substratum that is predominantly fine silty sand with small amounts of gravel, though stations closer to the coast were comprised of coarser gravelly sand with low silt content. The most abundant taxa at Breakwater were *Melinna palmata, Chaetozone gibber, Ampelisca tenuicornis, Magelona filiformis*, and *Aphelochaeta marioni*. As with the other sites, there were a number of different benthic assemblages present at Breakwater. The most common of these was SS.SMu.ISaMu.MelMagThy (*Melinna palmata* with *Magelona* spp. and *Thyasira* spp. in infralittoral sandy mud). A few sampling stations were characteristic of SS.SMu.SMuVS.AphTubi (*Aphelochaeta marioni* and *Tubificoides* spp. in variable salinity infralittoral mud) and SS.SMx.CMx.MysThyMx (*Mysella bidentata* and *Thyasira* spp. in circalittoral muddy mixed sediment) respectively. In 1998, 1999 and 2015 the dominant species were similar and there were small changes in the relative abundance of characterising species indicating fluctuations on the transition between SS.SMu.ISaMu.MelMagThy and SS.SMu.SMuVS.AphTubi. In 2011, increased numbers of *Eudorella truncatula, Kurtiella bidentata,* and *Prionospio* spp. indicate elements of SS.SMx.CMx.MysThyMx (*Mysella bidentata* and *Thyasira* spp. in circalittoral muddy mixed sediment) were becoming more important. This difference appeared to be caused by a reduced sampling effort and a greater proportion of samples being taken closer to the coast and introducing potentially new habitats.

There were a number of issues associated with the benthic 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.

Though there were changes in relative species composition observed during the survey period, it has not been possible to separate these from effects of changes in survey array and sampling effort. In general, though some biodiversity indices changed with survey year, dominant taxa and characteristic biotopes remained similar and were within the envelope of what might be expected due to natural change (e.g. shifts between SS.SMu.ISaMu.MelMagThy and SS.SMu.SMuVS.AphTubi).

It is recommended that future surveys replicate the 1998 survey design and array in order to be able to more reliably comment upon changes to the sites sub-features. If other areas of the site need to be monitored, new areas should be defined and a baseline sampled following the principles of Murray (2001). Due to the range of habitats present, it is suggested that sampling effort be increased substantially in order to be able to report on condition of all the subtidal sedimentary sub-features.

Based upon the findings of this study and acknowledging limitations with the different sources of survey data, 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 1998-9 surveys outside of what might be expected due to natural change in such a dynamic and heterogenous environment. This assessment is made with low confidence due to the change in survey array and the lack of sampling effort in specific areas of interest in 2011 and 2015.

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1. Introduction

1.1. Overview

Natural England 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) monitoring from Plymouth Sound and Estuaries 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 Natural England in collecting benthic samples from marine protected areas (MPAs) of different designations for site condition monitoring.

In the south west, there is now a time-series of data from sediment grab samples. Natural England commissioned analysis of data from within Plymouth Sound and Estuaries 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 based upon historical monitoring data. 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 three MPAs using historical survey data, which is summarised in Table 1.1.

Table 1.1: Summary of survey information for Plymouth Sound and Estuaries SAC

Site	Year	Survey Contractor
Plymouth Sound and Estuaries SAC	2015	EA
	2011	EA
	2007	EA
	1998/99	Institute of Estuarine and Coastal Studies

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 variations in the methodology over sampling years, data were standardised to allow for meaningful statistical analyses.

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

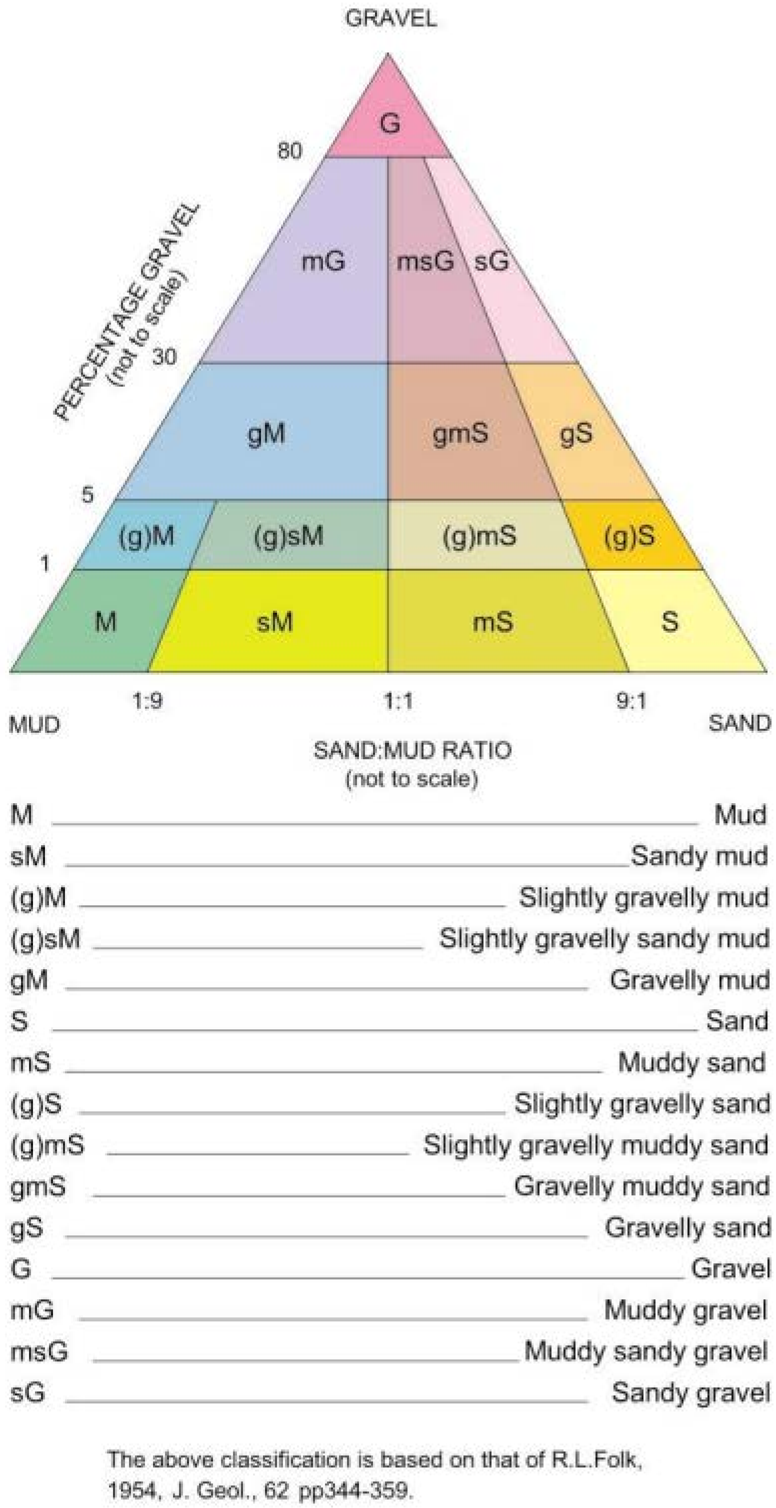
- Removal of epifauna due to inconsistencies in enumeration of colonial taxa and the utilisation of infauna-specific sampling methods. Epifauna could be used to aid assignment of biotopes if considered advantageous;
- Remove of meiofauna due to potential bias to assemblages based on high abundance of meiofauna;
- Remove of planktonic data as unrepresentative of benthic assemblages;
- Remove of freshwater and non-marine taxa as unrepresentative of coastal and marine assemblages (including insects);
- Remove 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
- Combine 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. Biological samples were processed through a mixture of 0.5 mm, 1.0 mm and/or 4.0 mm sieves. 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). As there were more samples processed through 1.0 mm sieves and the experimental design employed in 1998-9 typically sampled areas with coarser sediment (Figure 3.2), all 1.0 mm samples were included in the analysis.

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)



2.2. Statistical Analysis

Data were analysed both as a complete dataset, to observe changes at a site level, and by region, which was the design employed in the 1998-9 survey (see Section 3.2).

All data analysis was 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 was initially examined through the PRIMER v7 software package (Clarke and Gorley, 2015). Any anomalous or outlier results would have been removed due to their ability to skew or hide significant interactions, but for Plymouth Sound and Estuaries SAC there were none. 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
- The 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 (√-, ^{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. A two-way crossed test was used to detect any differences in species composition over time in the different sub-features. SIMPER analysis was then utilised to see which species contributed to similarities and dissimilarities between groups (i.e. which species were most consistently sampled within each site).

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.

Groups 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 Plymouth Sound and Estuaries SAC over time; and
- Any change in distribution of biodiversity indices across Plymouth Sound and Estuaries SAC over time.

3. Plymouth Sound and Estuaries SAC

3.1. Background

Plymouth Sound and Estuaries SAC is located on the south coast of the UK and straddles the coast of both Devon and Cornwall. The site was designated as an SAC on 1st April 2005. The SAC covers 6,402 hectares. It includes both marine areas i.e. land covered continuously or intermittently by tidal waters and land which is not subject to tidal influence. The location of the site can be seen in Figure 5.1.

The tributaries associated with Plymouth Sound comprise a complex site of marine inlets. As a result of the varied reef and sedimentary habitats and the salinity conditions within the area, diverse communities representative of ria systems are found at this site. There are also some unusual features including southern Mediterranean-Atlantic species that are not normally found in Britain. This site is also known to be a spawning site for the Allis shad *Alosa alosa*.

This SAC is designated for the presence of sandbanks, which consist of a range of sandy sediments. These sediments include tide-swept sandy banks in estuarine habitats, sandy muds north of the Breakwater, muddy sands in Jennycliff Bay, fine sands with eelgrass *Zostera marina* and a rich associated flora and fauna in the Yealm entrance, and tide-swept sandy sediments with associated hard substrates (JNCC, 2017b).

Throughout the SAC there are extensive mudflats. These are highly productive systems containing extensive and varied inafunal communities, rich in bivalves and other invertebrates. These mudflats also provide an important feeding ground for internationally important assemblages of wildfowl (Natural England, 2015b).

Plymouth Sound and Estuaries SAC is representative of ria estuaries in the south west, with the Rivers Tamar and Lynher linked at their mouths. The estuaries also exhibit a well-developed estuarine salinity gradient and as a result, they have one of the best UK examples of changing estuarine communities with changing salinity regime. Rocky reefs found in low salinity are unusual and support species such as the hydroid *Cordylophora caspia*.

The Plymouth Sound SAC hosts a number of important and rare species. The subtidal muddy habitats north of the Breakwater support communities of slender sea pens *Virgularia mirabilis*; this is uncommon in the south of the UK. Fan mussels *Atrina fragilis* have been recorded in the sediment around Plymouth Hoe and this species is nationally scarce. The tentacle lagoon worm *Alkmaria romijni* which is also nationally scarce, has been recorded as present in the Yealm Estuary (Natural England, 2015b).

Within the Pymouth Sound and Estuaries SAC there are extensive areas of saltmarsh, particularly on the Lynher Estuary. This habitat is scarce in the south west and it provides an important roosting area for many bird species. The fringes of the saltmarsh also act as a nursery area for some fish species, including bass *Dicentrarchus labrax*.

Plymouth Sound has a wide variety of intertidal and subtidal reef habitats and is of importance for its reef communities, which contain a number of notable species. Of particular importance in this area is the limestone reef, which runs from West Hoe to Batten Bay, as this is one of only to areas of Devonian limestone reef on the south coast. The rock is relatively soft and is therefore heavily bored by marine worms and bivalves, in particular the bivalve *Hiatella arctica* and the spionid worms *Polydora* spp. In the sublittoral this steep-sided, wave-sheltered reef is dominated by a dense hydroid and bryozoan turf with anemones and ascidians. A number of rarely recorded low shore biotopes also occur in the intertidal reefs. Rockpools at Wembury, Penlee, Hooe Lake Point and the mouth of the Yealm have nationally uncommon sponge, seasquirt and red algae communities. The sublittoral reefs are of importance for their kelp and animal-dominated habitats, which includes the south-western kelp *Laminaria ochroleuca* as well as the rare sea slug *Okenia elegans*, and the trumpet anemone *Aiptasia mutabilis*. In the approaches to Plymouth Sound, abundant populations of the slow-growing, long-lived, nationally important pink sea-fan *Eunicella verrucosa* occur (JNCC, 2017b; Natural England 2015b).

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

- Sandbanks which are slightly covered by sea water all the time;
- Estuaries;
- Large shallow inlets and bays;
- Reefs;
- Atlantic sea meadows (Glauco-puccinellietalia maritimae).

Annex I habitats present as a qualifying feature, but not a primary reason for selection of this site:

- Mudflats and sandflats not covered by sea water at low tide.

Annex II species that are a primary reason for selection of this site

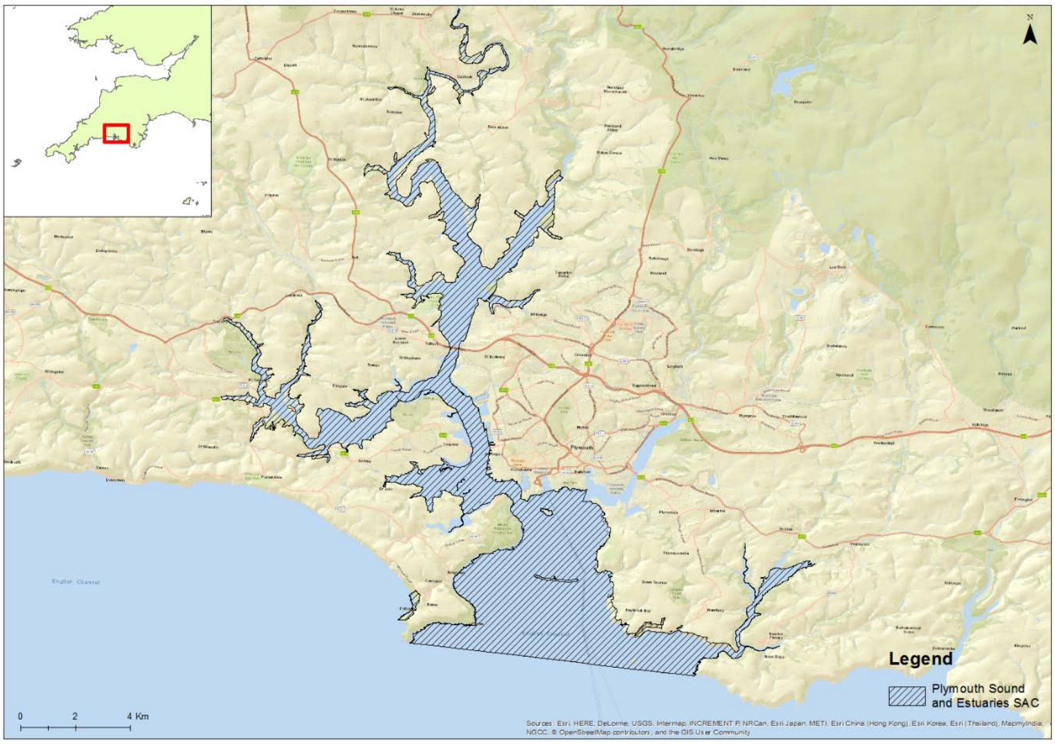
- Shore dock *Rumex rupestris*.

Annex II species present as a qualifying feature, but not a primary reason for selection of this site:

- Allis shad *Alosa alosa*.

Only the Annex I habitats subtidal sandbanks, estuaries, large shallow inlets and bays were within the scope of this report.

Figure 3.1: Location of the Plymouth Sound and Estuaries SAC



Sources: Esri, HERE, DeLorme, ISGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri Thailand, Mapmyindia, NGCC. ©OpenStreetMap contributors, and the GIS user Community.

3.2. Methods

A summary of the survey data that was 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 3.2.

Table 3.1: List of Benthic Grab Datasets included in this Report

Site	Year	Survey Contractor	Number of Samples
Plymouth Sound and Estuaries SAC	2015	EA	37
	2011	EA	108
	2007	EA	10
	1998/99	Institute of Estuarine and Coastal Studies	1998 – 80, 1999 – 34 x 0.1 m^2 Day grab

A description of the surveys that have been used for each SAC is presented in the following sections.

3.2.1. 1998-1999 Survey

The 1998 and 1999 surveys were conducted by the University of Hull. An intensive seabed sampling survey was undertaken within the key habitats identified, Cawsand Bay, Inner Breakwater, Torpoint, Jennycliff Bay, River Yealm Entrance. For each survey area, 20 sites covering the main habitat types were sampled. A local boat with knowledge of the area was used as the survey platform from which a Day grab ($0.1m^2$) was employed in conjunction with FM2000 seabed video camera. Position fixing was attained through a Sercell NR51 DGPS system and positions corrected to the OSGB36 datum for input into GIS.

Taxonomic analysis and particle size analysis was conducted in the laboratory.

3.2.2. 2011 Survey

The 2011 Plymouth Sound Grab and Estuaries SAC Survey was a combined survey between the Environment Agency and Natural England. The surveys were undertaken during April and May 2011. The Environment Agency sampled around Plymouth Sound, and Natural England sampled up the Tamar, the Yealm, and also in Plymouth sound. The PSA and infaunal samples were analysed separately.

3.2.3. 2015 Survey

The 2015 survey was conducted by Natural England and the Environment Agency during May 2015. Samples were taken within Plymouth Sound and Whitsand Bay.

3.2.4. Survey array and sites

The experimental design used for the 1998 and 1999 surveys was used as a template for analysis (Figure 3.3). This was based on sampling key habitats at Cawsand Bay, Inner Breakwater, Torpoint, and River Yealm Entrance. The survey design was chosen because it allowed comparison over four years and was at a more refined spatial resolution that took account of the heterogeneity of the seabed habitats. Grab samples from 2011 and 2015 were subsequently linked to the sites within the Plymouth Sound and Estuaries SAC for analysis.

The approach meant that the data from the inner Tamar Estuary from 2011 and 2015 were not analysed as it were not suited to this approach. It is recommended that the data from 2015-16 be analysed separately to provide a baseline for the sub-features it covers following the methods used in Murray (2001).

Figure 3.2: Monitoring survey arrays at the Plymouth SAC and experimental design from the 2001 survey (Allen and Proctor, 2003)

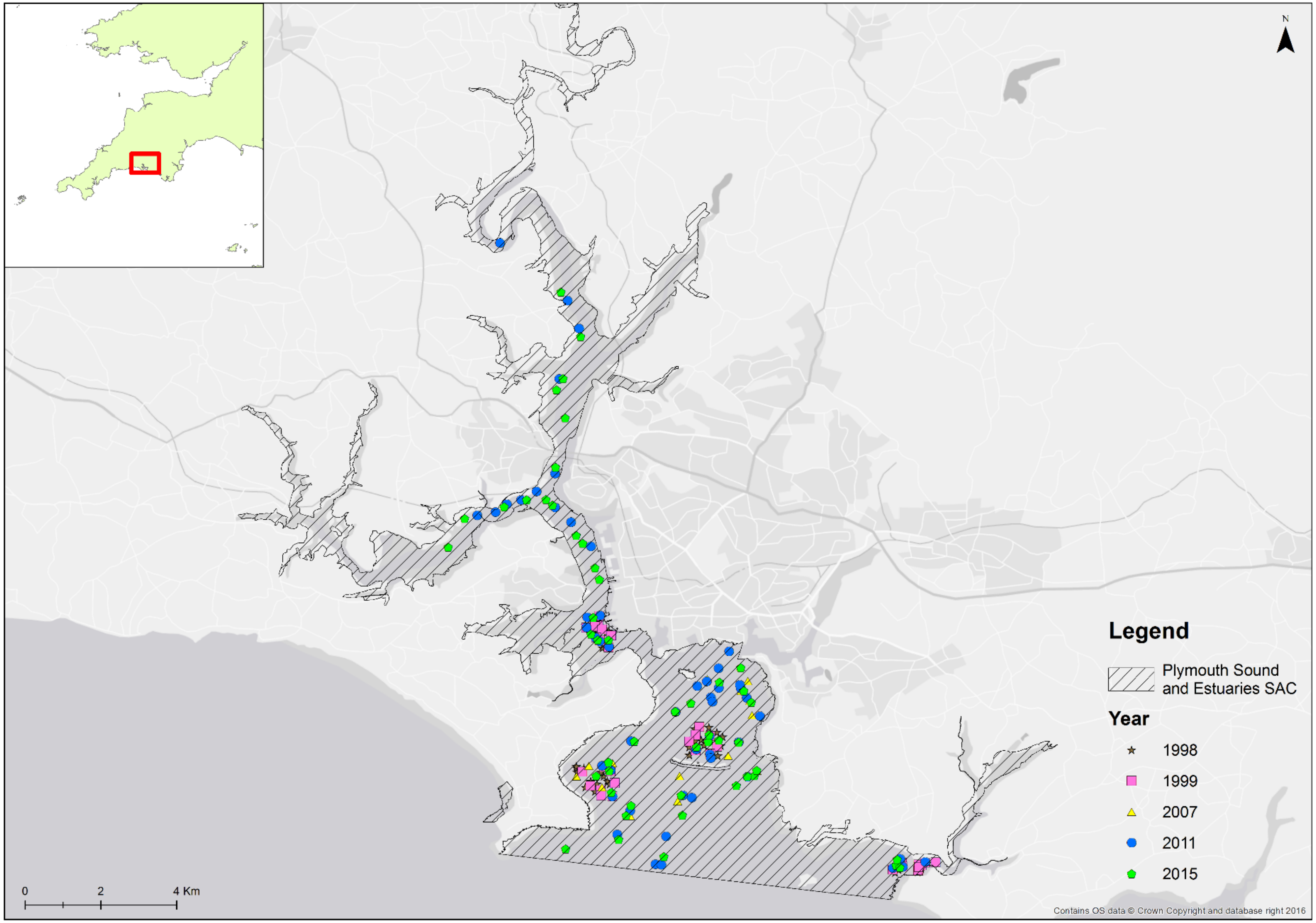
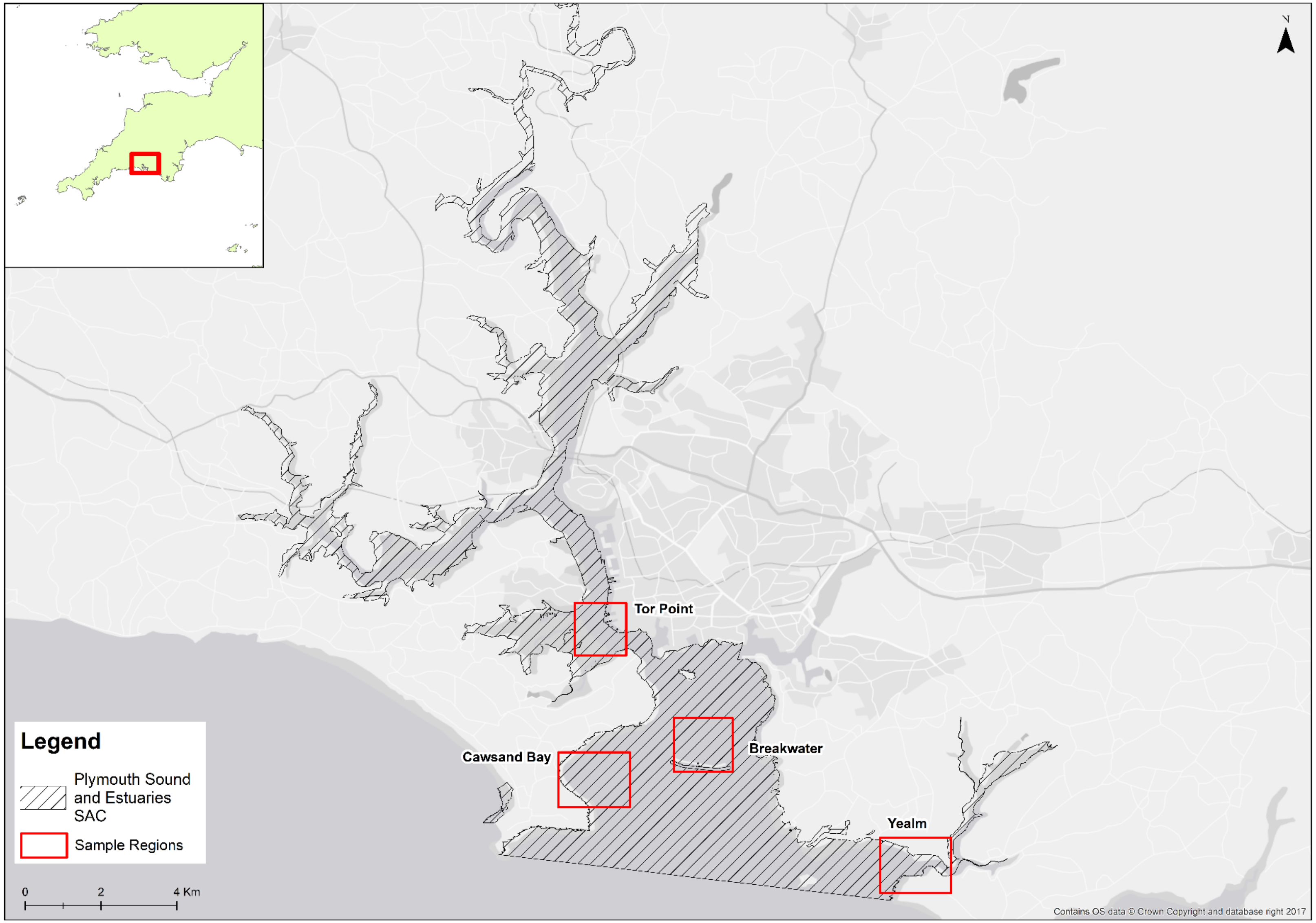


Figure 3.3: Survey design from the 1998-1999 surveys (Murray, 2001)



3.3. Results

3.3.1. Site overview

3.3.1.1. Sediment composition

PSD data were available for 1998, 1999, 2011 and 2015. Grab stations were assigned to sediment categories based on a modified Folk classification (Long, 2006), in addition to proportions of mud, sand and gravel. For purposes of analysis, the grab stations have been divided up into Breakwater, Cawsand, River Yealm and Torpoint, which were the regions used in the 1998-9 survey arrays (Annexes A-B).

Sediment PSA indicated that sediments within Plymouth Sound and Estuaries SAC are highly diverse and heterogeneous (Table 3.2). There were far fewer sediment samples collected in these regions in 2011 and 2015 compared to 1998 and 1999 which account for the decreased variability in these years.

Table 3.2: Range of sediment types sampled at Plymouth Sound and Estuaries SAC

Site	1998	1999
Breakwater	mS, gmS, gS	sM, mS, msG
Cawsand	mS, S, gS	mS, S, gS
River Yealm	mS, S, gS, sG, G	gmS, S, gS, G
Torpoint	mS, gmS, gS, msG, sG, G	sM, gmS, mG, msG, G

Site	2011	2015
Breakwater	sM	sM, gM, mS
Cawsand	mS, S	S
River Yealm	S, msG	S
Torpoint	sM, gM, mG	mG, msG

It should be noted that survey arrays and sampling effort varied considerably from 1998-2015. As such, sediment composition and distribution are reviewed here on a descriptive rather than quantitative basis.

Cawsand Bay

Sediments in Cawsand Bay were classified predominantly as moderately sorted silty sands (inshore) and coarser gravelly sands (offshore). In general, there was a north-east to south-west (onshore-offshore) gradient in sediment type apparent in 1998 with somewhat finer sediments with a higher silt content in the inshore areas and coarser gravelly and poorly sorted sediments offshore. There was a single grab of sandy Mud in 1999, but otherwise sediments followed the distribution observed in 1998. Fewer samples were taken in 2011 and 2015 and all from the offshore region of the site, but they matched the distribution described in 1998 and 1999. Overall, from the data available, the sediment composition and distribution appears to have remained consistent at Cawsand Bay from 1998-2015.

Across the surveys, gravel content at the site ranged from 0 to 28.9%, sand from 0 to 98.5%, and mud from 0 to 87.4%.

Torpoint

Torpoint has a very heterogeneous substratum with a high proportion of gravel, pebbles, cobbles, boulders and shell with variable amounts of sand and mud. Twenty grab samples were taken in 1998 and found a wide range of sediment types, including muddy Sand, gravelly muddy Sand, gravelly Sand, muddy sandy Gravel, sandy Gravel, and Gravel. The area off Devonport Naval Base on and around Rubble Bank and in the main channel was particularly coarse with areas of rough ground. In 1999, fewer samples were taken but the composition and distribution of sediment was similar to 1998, with the addition of a gravelly Mud and sandy Mud habitat. In 2011, there were fewer samples and those restricted to the channel. In general, there was a slight increase in silt, so that samples were predominately characterised as muddy Gravel and gravelly Mud. In 2015, two of four samples were muddy Gravel, but the other two were muddy sandy Gravel, returning to the coarse sediments of 1998-9. Overall, from the data available, the sediment composition and distribution appears to have remained consistent at Torpoint from 1998-2015.

Across the surveys, gravel content at the site ranged from 1.83 to 96.8%, sand from 3.01 to 84.5%, and mud from 0.18 to 85.1%.

River Yealm

From analysis of the 1998 grab samples, sediments in the River Yealm are heterogeneous with an area of Gravel and sandy Gravel along the northern side of the Inner Yealm and gravelly Sand, Sand, and muddy Sand in the central inner Yealm (Murray, 2001). The outer Yealm area is predominantly fine Sand with coarser gravelly Sands to the south. In 1999, sediment composition and distribution were similar, with Sand in the outer Yealm, Gravel in the northern side of the inner Yealm, and gravelly Sand, Sand and gravelly muddy Sand in the central inner Yealm. In 2011 and 2015, there were fewer samples restricted to the outer Yealm, but these were fine Sand supporting what was found in 1998-9. Overall, from the data available, the sediment composition and distribution appears to have remained consistent at River Yealm from 1998-2015.

Across the surveys, gravel content at the site ranged from 0 to 88.8%, sand from 10.8 to 99.8%, and mud from 0 to 15.8%.

Breakwater

In 1998, grab samples were collected from a discrete area to the north of Plymouth Breakwater. Sediments closer to the Breakwater were all muddy Sand, grading through gravelly muddy Sands to gravelly Sand to the north. Sediment composition and distribution was slightly different in 199, with sandy Mud close to the Breakwater and muddy sandy Gravel further to the north. This distribution was also seen in 2011, with the addition of gravelly Sand and Gravel to the east of the Breakwater.

Across the surveys, gravel content at the site ranged from 0 to 30.5%, sand from 19.0 to 88.8%, and mud from 1.93 to 80.2%.

3.3.2. Cawsand Bay

Sampling stations at Cawsand Bay were moderately-shallow with depths ranging from 7.9m to 12.5m below CD (Murray, 2001). Sediments predominantly consisted of sands with all stations having over 75% sand content. There was a variable quantity of silt and gravel present at the stations, which is reflected in the variability of the mean grain size and moderate to poor sediment sorting. In general, there was a north-east to south-west (onshore-offshore) gradient in sediment type with somewhat finer sediments with a higher silt content in the inshore areas and coarser gravelly and poorly sorted sediments offshore.

3.3.2.1. Diversity indices

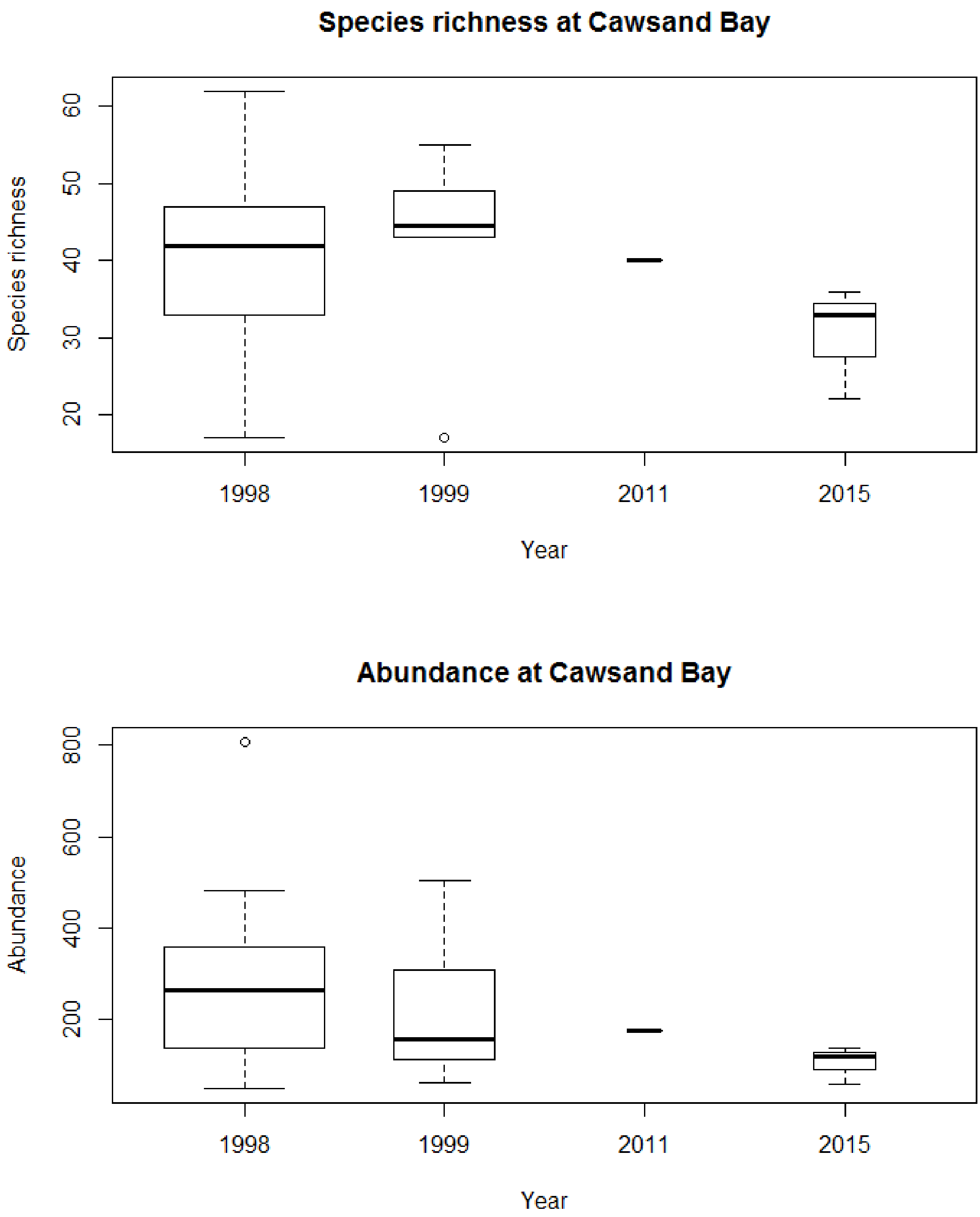
The number of species (S) and number of individuals (N) varied at the site between years (Table 3.3; Figure 3.3). A Kruskal-Wallis test shows that there was no statistically significant difference in number of species (S) between years, $\chi^2(3) = 4.039.2$, p = 0.257. Neither was there any statistically significant difference in total abundance ($\chi^2(3) = 3.722$, p = 0.293), Margalef's index for species richness ($\chi^2(3) = 6.192.2$, p = 0.103), or Shannon's diversity index ($\chi^2(3) = 6.442$, p = 0.092).

There was however a statistically significant difference in Pielou's evenness ($\chi^2(3) = 9.912$, p = 0.019), with lower evenness associated with surveys with more samples and higher species numbers and likely a factor of sampling effort.

Table 3.3: Mean diversity statistics of benthic communities at Cawsand Bay (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'(loge) = Shannon's diversity index, 1-λ' = Simpson's dominance Index)

	1998	1999	2011	2015
n	20	10	3	2
S	40.60 ± 11.37	43.13 ± 11.43	40.00	30.33 ± 7.371
N	279.0 ± 183.5	215.3 ± 154.1	176.0	104.7 ± 40.45
D	7.194 ± 1.316	8.102 ± 2.012	7.543	6.323 ± 1.038
J'	0.737 ± 0.069	0.805 ± 0.074	0.829	0.853 ± 0.032
H'(loge)	2.691 ± 0.252	2.999 ± 0.454	3.060	2.886 ± 0.121
1-λ'	0.870 ± 0.051	0.917 ± 0.046	0.931	0.929 ± 0.005

Figure 3.4: Species richness and abundance of benthic macrofaunal from Cawsand Bay



3.3.2.2. Faunal assemblages

At Cawsand Bay, benthic community structure differed between years which is reflected in the spread of data (Figure 3.6). An ANOSIM test indicated that differences in benthic community structure between years are significant and the effect of sampling year is moderate (Global R = 0.321, p = 0.3%). Pairwise comparisons indicate significant differences between samples in 1998 and 1999 and also between 2015 and both 2008 and 2009, though sampling effort and hence possible permutations varied dramatically (Table 3.6).

Figure 3.5: Non-metric multi-dimension scaling ordination of benthic community structure at Cawsand Bay

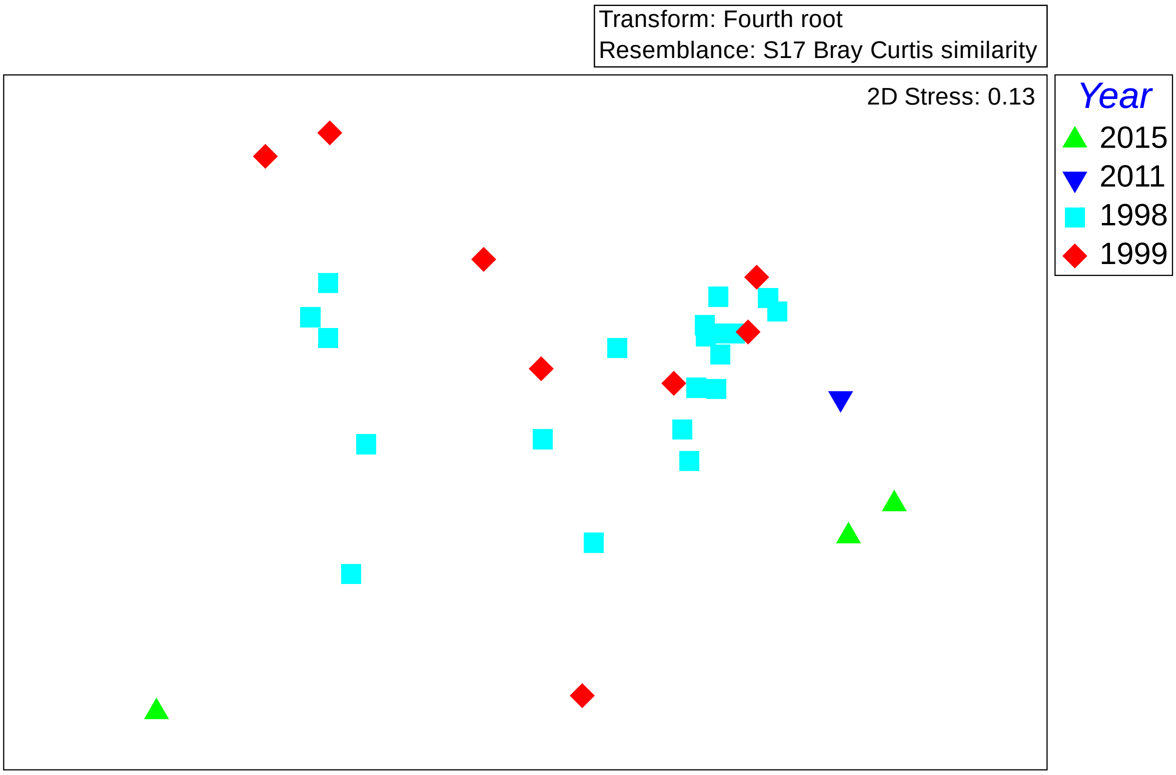


Table 3.4: ANOSIM results of all benthic community data from Cawsand Bay (Global R: 0.321, Significance level: 0.3%)

Groups	R statistic	Significance level %	Possible permutations	Actual permutations	Number ≥ Observed
2015, 2011	0.111	50.0	4	4	2
2015, 1998	0.588	0.9	1771	999	8
2015, 1999	0.478	1.8	165	165	3
2011, 1998	0.205	28.6	21	21	6
2011, 1999	0.134	44.4	9	9	4
1998, 1999	0.202	3.7	3108105	999	36

SIMPER analysis for each year indicated sample pairs have a relatively low average similarity of 24.34-34.29%. The species that contributed most to similarity in 1998, 1999 and 2015 were *Chaetozone gibber* (6.80%), *Nucula nitidosa* (5.99%), and *Loimia medusa* (14.70%).

Table 3.5: SIMPER analysis of benthic community data from Cawsand Bay by monitoring survey

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Group 2015 – average similarity 24.34%					
Loimia medusa	1.46	3.58	3.72	14.7	14.70
Magelona johnstoni	1.40	1.62	0.58	6.65	21.35
Magelona filiformis	1.35	1.47	0.58	6.04	27.39
Chaetozone gibber	1.20	1.34	0.58	5.51	32.90
Synchelidium maculatum	0.84	1.17	0.58	4.83	37.73
Glycera tridactyla	0.96	1.02	0.58	4.19	41.92
Scoloplos (Scoloplos) armiger	1.00	1.02	0.58	4.19	46.11
Phaxas pellucidus	1.02	1.02	0.58	4.19	50.30
Echinocyamus pusillus	0.91	0.99	0.58	4.06	54.36
Dosinia lupines	0.67	0.93	0.58	3.84	58.19
Group 1999 – average similarity 26.37%					
Nucula nitidosa	1.20	1.58	1.64	5.99	5.99
NEMERTEA	1.19	1.58	1.67	5.98	11.98
Magelona filiformis	1.26	1.52	0.90	5.76	17.74
Chamelea gallina	0.98	1.30	1.67	4.94	22.67
Spio filicornis	1.00	1.25	0.95	4.73	27.40
Lumbrineris latreilli	0.77	1.12	1.02	4.26	31.66
Terebellidae	1.13	1.02	1.02	3.86	35.52
NEMATODA	0.97	0.96	1.04	3.66	39.18
Chaetozone gibber	1.21	0.94	0.69	3.57	42.75
Scoloplos (Scoloplos) armiger	0.97	0.84	0.70	3.20	45.95
Group 1998 – average similarity 34.29%					
Chaetozone gibber	1.98	2.33	1.40	6.80	6.80
Magelona filiformis	1.91	2.19	1.30	6.39	13.19
Chaetozone setosa	1.23	1.66	1.41	4.85	18.04
Nucula nitidosa	1.20	1.56	1.45	4.54	22.58
Melinna palmata	1.58	1.49	1.01	4.35	26.93
Euclymene oerstedii	1.36	1.48	1.20	4.32	31.25
Chamelea gallina	1.03	1.48	1.20	4.30	35.55
NEMERTEA	1.11	1.43	1.47	4.18	39.73
Owenia fusiformis	1.07	1.39	1.24	4.04	43.78
Galathowenia oculata	1.43	1.25	0.82	3.65	47.43

3.3.2.3. Biotopes

Characteristic species at Cawsand Bay were *Moerella donacina, Nephtys cirrosa, Pisione remota,* Nematoda, *Magelona* spp., *Chaetozone* spp., and *Melinna palmata*.

There were two distinct benthic assemblages within Cawsand Bay with components of other biotopes, reflecting the diverse range of habitats found at the site. The dominant biotopes were SS.SMu.ISaMu.MelMagThy (*Melinna palmata* with *Magelona* spp. and *Thyasira* spp. in infralittoral sandy mud) and SS.SCS.ICS.MoeVen (*Moerella* spp. with venerid bivalves in infralittoral gravelly sand). Both were unrepresented by bivalve taxa, likely due to the shallow sampling of the grab employed and the sparse distribution of the bivalves.

SS.SMu.ISaMu.MelMagThy (*Melinna palmata* with *Magelona* spp. and *Thyasira* spp. in infralittoral sandy mud). This biotope is characteristic in many southern UK marine inlets and in some areas e.g. Plymouth Sound during high levels of recruitment when *Melinna palmata* often occurs in abundances between 500 to 1000 per m2 moderate numbers of the species often 'overspill' into adjacent biotopes (Allen et al. 2001).

SS.SCS.CCS.MedLumVen (*Mediomastus fragilis, Lumbrineris* spp. and venerid bivalves in circalittoral coarse sand or gravel). Circalittoral gravels, coarse to medium sands, and shell gravels, sometimes with a small amount of silt and generally in relatively deep water (generally over 15-20m), may be characterised by polychaetes such as *Mediomastus fragilis, Lumbrineris* spp., *Glycera lapidum* with the pea urchin *Echinocyamus pusillus*.

Similarity in benthic composition within years was low, ranging from 24.3-34.3%, and reflecting the heterogeneity of seabed habitats at the site. Dissimilarity between years was in general caused by changes in the relative abundance of common species. The differences between 1998 and 1999 surveys were predominately caused by marginally higher abundances of polychaete worms (*Chaetozone gibber, Melinna palmata, Galathowenia oculata, Euclymene oerstedii, Magelona filiformis,* and *Moerella donacina*) in 1998 compared to 1999. In 2011, there were a number of species recorded that were not present in 1999: *Magelona johnstoni, Magelona minuta, Chaetozone christiei, Bathyporeia elegans, Galathowenia oculata*, and *Bathyporeia tenuipes*. Conversely, *Echinocyamus pusillus* was recorded in 1999 but was absent in 2011. Some of these species that appeared in 2011 were then absent again in the 2015 survey: *Nucula nitidosa, Magelona minuta, Bathyporeia elegans*, and *Bathyporeia tenuipes*. Species present in 2015 but not 2011 included *Loimia medusa*, *Echinocyamus pusillus,* and *Glycera tridactyla.*

It should be noted that there was only a single grab sample taken from the site in 2011 and three in 2015, compared to 10 in 1999 and 20 in 1998, which could have a large effect on the number of species sampled, with increasing number of taxon with sampling effort (see Figure 3.5).

In general, the assemblages sampled in 1998 and 1999 can be characterised as a mix of SS.SMu.ISaMu.MelMagThy and SS.SCS.ICS.MoeVen. Though species composition changed marginally in 2015, this was primarily due to changes of species within genus: *Magelona* spp., *Bathyporeia* spp., *Chaetozone* spp., and *Chamelea* spp. These results should be interpreted with caution as there is potential for these differences to be due to classification by different analysts, especially due to the length of time between survey sample analysis.

3.3.3. Torpoint

Torpoint is an area of moderate depths (9-27m) with a very heterogeneous substratum with a high proportion of gravel, pebbles, cobbles, boulders and shell with variable amounts of sand and mud. The area off Devonport Naval Base on and around Rubble Bank and in the main channel is particularly coarse with areas of rough ground.

During analysis, sample T4 from 1999 was removed as an outlier due to a very low number of individuals (1x *Melinna palmata*, 2 x *Tritia reticulata*, 1 x *Tritia incrassata*).

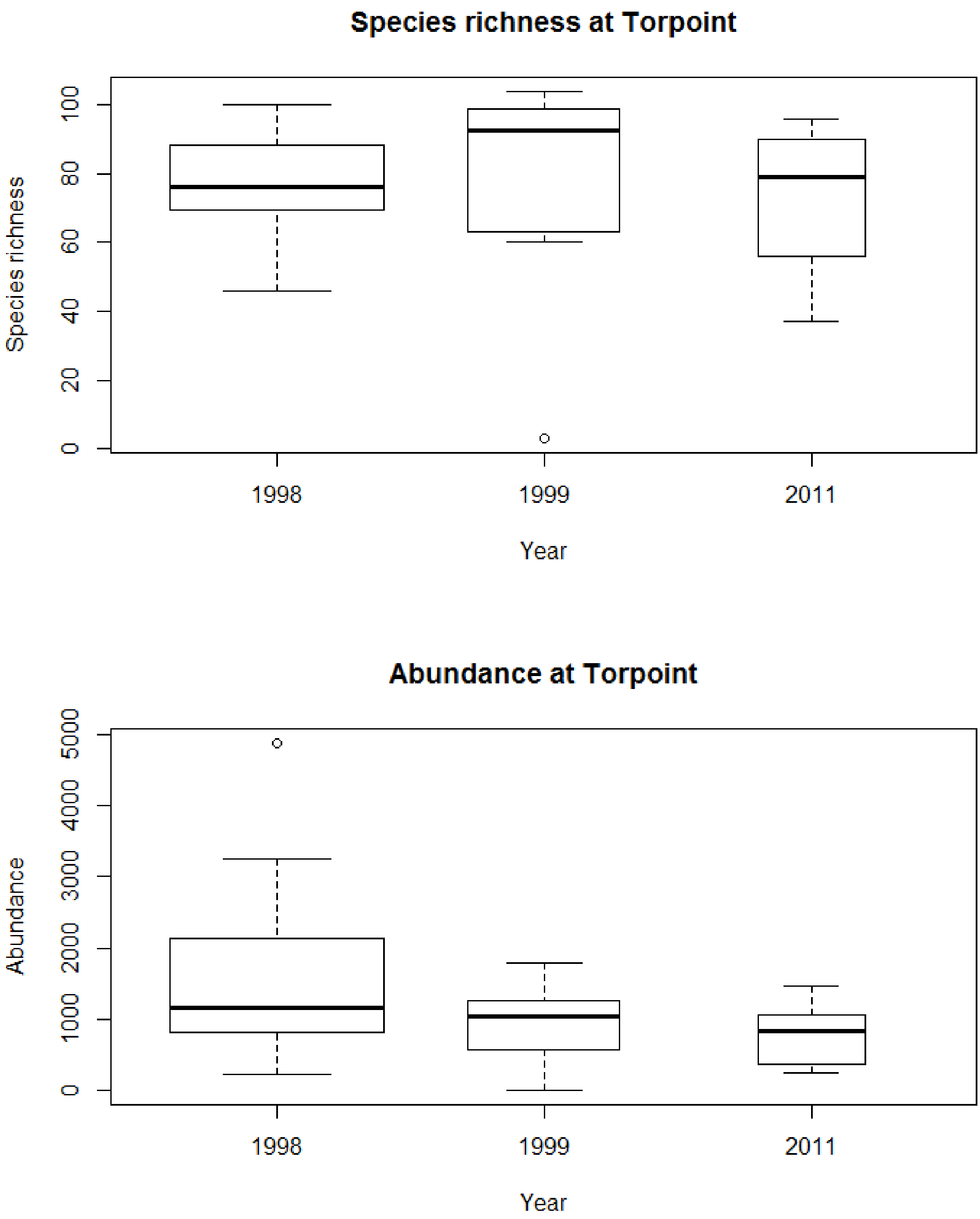
3.3.3.1. Diversity indices

The number of species (S) and number of individuals (N) were similar between years, though variability was in general higher in years where more samples were collected (Table 3.8; Figure 3.6). A Kruskal-Wallis test shows that there was no statistically significant difference in number of species (S) between years, $\chi^2(3) = 1.250$, $p = 0.535$. Neither was there any statistically significant difference in total abundance ($\chi^2(3) = 3.057$, $p = 0.217$), Margalef's index for species richness ($\chi^2(3) = 2.981$, $p = 0.225$), Pielou's evenness ($\chi^2(3) = 2.519$, $p = 0.284$), or Shannon's diversity index ($\chi^2(3) = 1.766$, $p = 0.414$).

Table 3.6: Mean diversity statistics of benthic communities at Torpoint (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'(loge) = Shannon's diversity index, 1-λ' = Simpson's dominance Index)

	1998	1999	2011
n	20	10	5
S	77.10 ± 14.52	78.00 ± 30.89	71.60 ± 24.64
N	1568.6 ± 1148.4	938.3 ± 528.1	795.6 ± 500.8
D	10.71 ± 1.572	11.32 ± 3.944	10.66 ± 2.795
J'	0.680 ± 0.113	0.741 ± 0.103	0.656 ± 0.105
H'(loge)	2.937 ± 0.490	2.973 ± 0.760	2.772 ± 0.556
1-λ'	0.886 ± 0.071	0.899 ± 0.052	0.828 ± 0.114

Figure 3.6: Species richness and abundance of benthic macrofaunal from Torpoint



3.3.3.2. Faunal assemblages

At Torpoint, benthic community structure differed between years which is reflected in the spread of data (Figure 3.8). An ANOSIM test indicated that differences in benthic community structure between years are significant and the effect of sampling year is moderate (Global R = 0.646, p = 0.1%). Pairwise comparisons indicate significant differences between all years, but largest between 2011 and the other two sampling years (Table 3.9).

Figure 3.7: Non-metric multi-dimension scaling ordination of benthic community structure at Torpoint

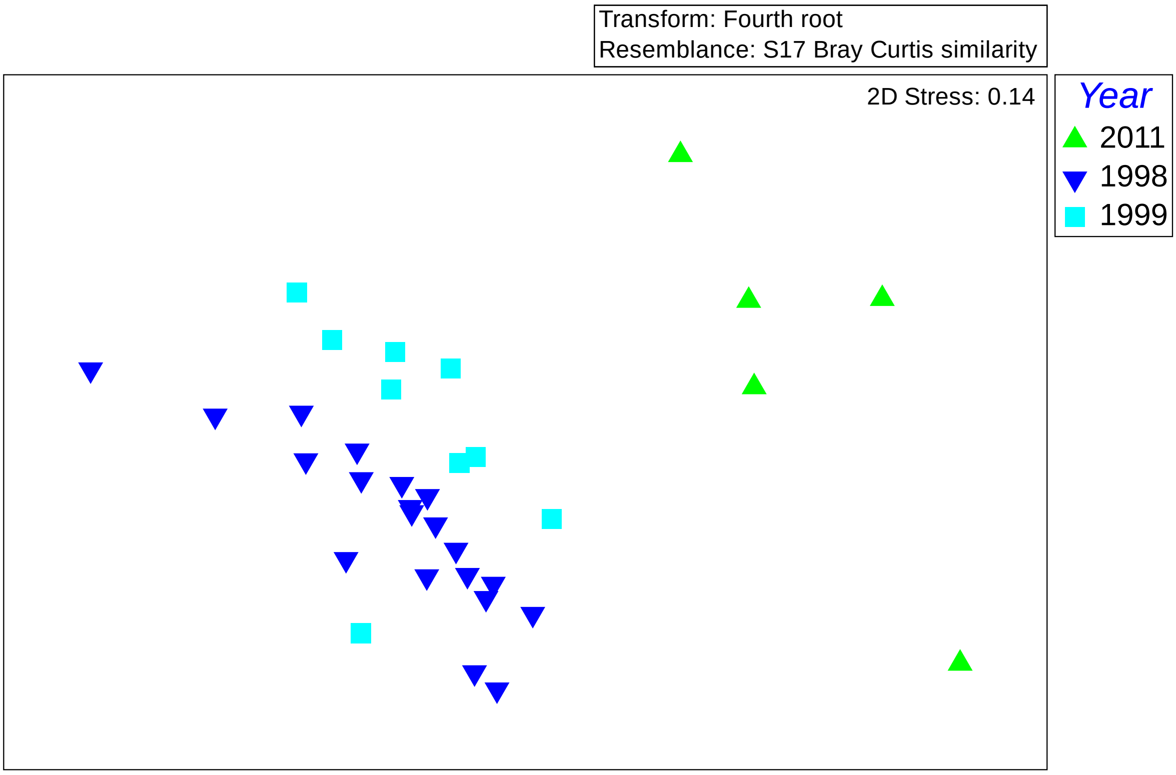


Table 3.7: ANOSIM results of all benthic community data from Torpoint (Global R: 0.646, Significance level: 0.1%)

Groups	R statistic	Significance level %	Possible permutations	Actual permutations	Number ≥ Observed
2011, 1998	0.923	0.1	53130	999	0
2011, 1999	0.953	0.3	2002	999	2
1998, 1999	0.441	0.1	10015005	999	0

SIMPER analysis for each year indicated sample pairs have an average similarity of 46.14% in 1998 and 46.13% in 1999 with a maximum contribution in both years from the terebellid polychaete *Aphelochaeta* spp.(Table 3.10). Average similarity was 34.90% in 2011 and the polychaete *Mediomastus fragilis* and the bivalve *Kurtiella bidentata* contributed the most to similarity (6.58% and 5.59% respectively).

Table 3.8: SIMPER analysis of benthic community data from Torpoint by monitoring survey

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Group 2011 – average similarity 34.90%					
Mediomastus fragilis	2.80	2.30	5.22	6.58	6.58
Kurtiella bidentata	2.50	1.95	3.31	5.59	12.16
Melinna palmata	2.43	1.79	2.09	5.12	17.29
Chaetozone gibber	1.91	1.53	3.37	4.38	21.67
Amphicteis midas	1.70	1.42	5.76	4.07	25.74
Verruca stroemia	2.68	1.40	1.10	4.03	29.76
Kirkegaardia dorsobranchialis	1.81	1.36	3.09	3.91	33.67
Mytilus edulis	1.26	1.17	4.48	3.36	37.04
Notomastus sp.	1.34	1.14	4.91	3.26	40.30
NEMATODA	1.55	0.96	1.08	2.76	43.06
Group 1999 – average similarity 46.13					
Aphelochaeta A	2.84	2.05	5.44	4.44	4.44
Amphicteis gunneri	2.55	1.68	3.41	3.65	8.08
Calyptraea chinensis	2.47	1.61	4.90	3.48	11.57
Monocorophium sextonae	2.63	1.53	3.39	3.31	14.88
Syllidia armata	2.11	1.48	5.86	3.21	18.09
Apseudopsis latreillii	2.03	1.46	8.63	3.17	21.26
Spirobranchus	2.34	1.46	3.25	3.16	24.42
Chaetozone gibber	2.25	1.38	2.42	3.00	27.42
Mediomastus fragilis	1.96	1.34	3.43	2.90	30.32
Maera grossimana	1.88	1.31	4.62	2.83	33.15
Group 1998 – average similarity 46.14%					
Aphelochaeta marioni	3.59	2.41	3.97	5.21	5.21
Apseudopsis latreilliid	2.52	1.87	5.17	4.06	9.27
Mediomastus fragilis	2.47	1.63	3.49	3.54	12.81
Chaetozone gibber	2.69	1.53	1.57	3.32	16.12
Amphicteis gunneri	2.21	1.38	1.82	2.98	19.11
Amphipholis squamata	2.00	1.37	2.39	2.96	22.07
Caulleriella alata	1.91	1.28	2.43	2.77	24.84
Tubificoides swirencoides	2.27	1.21	1.28	2.62	27.46
Calyptraea chinensis	1.92	1.19	1.75	2.58	30.04
Syllidia armata	1.76	1.19	2.55	2.57	32.61

3.3.3.3. Biotopes

Characteristic species at Torpoint were *Aphelochaeta* spp., *Chaetozone gibber, Amphicteis gunneri,* and *Syllidia armata.*

There were two distinct assemblages at Torpoint separated by survey. The benthic communities in 1998 and 1999 were similar (average similarity 42.88%) and characterised by *Apseudopsis latreilliid, Mediomastus fragilis, Chaetozone gibber, Amphicteis gunneri,* and *Amphipholis squamata*. This biotope is best characterised as a complex of SS.SCS.CCS.MedLumVen (*Mediomastus fragilis, Lumbrineris* spp. and venerid bivalves in circalittoral coarse sand or gravel) and SS.SMx.IMx.VsenAsquAps (*Venerupis senegalensis, Amphipholis squamata* and *Apseudes latreilli* in infralittoral mixed sediment).

In 2011, the benthic community had a low level of similarity (average similarity 34.90%), but was characterised by *Mediomastus fragilis, Kurtiella bidentate, Melinna palmata, Chaetozone gibber*, and *Amphicteis midas.* There were still elements of SS.SCS.CCS.MedLumVen, but with no *Aphelochaeta marioni, Amphicteis gunneri*, or *Apseudopsis latreillii*. Instead, there was *Kurtiella bidentata* which indicated a resemblance to SS.SMu.ISaMu.MelMagThy (*Melinna palmata* with *Magelona* spp. and *Thyasira* spp. in infralittoral sandy mud). This corresponds to a less diverse range of sediments observed in 2011 with a marginal increase in average silt content compared to 1998 and 1999.

As with other sites, it is worth noting that there were fewer samples collected in 2011 (5), compared to 1998 (20) and 1999 (10).

3.3.4. River Yealm

The Yealm River is a narrow ria with shallow waters (3-10m CD) divided by a sand bar (Murray, 2001). The substratum is heterogeneous with an area of stony gravelly sand along the northern side of the Inner Yealm, fine-medium sand and silty sands in the central inner Yealm. The outer Yealm area is predominantly fine sand with coarser gravelly sands and rough ground to the south.

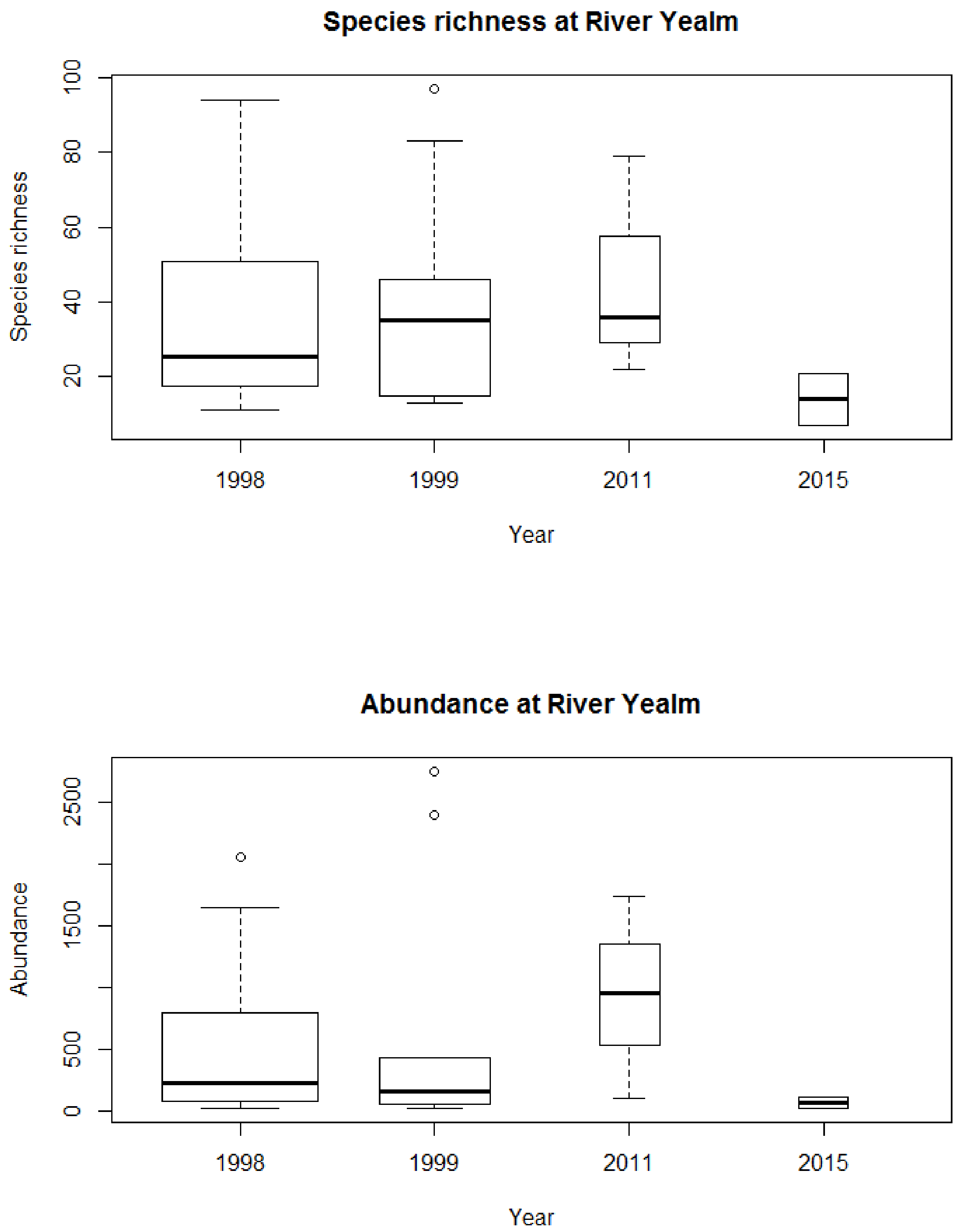
3.3.4.1. Diversity indices

The number of species (S) and number of individuals (N) were similar between years, though variability was in general higher in years where more samples were collected (Table 3.8; Figure 3.6). A Kruskal-Wallis test shows that there was no statistically significant difference in number of species (S) between years, $\chi^2(3) = 2.975$, $p = 0.396$. Neither was there any statistically significant difference in total abundance ($\chi^2(3) = 3.236$, $p = 0.357$), Margalef's index for species richness ($\chi^2(3) = 3.573$, $p = 0.311$), Pielou's evenness ($\chi^2(3) = 2.718$, $p = 0.437$), or Shannon's diversity index ($\chi^2(3) = 4.543$, $p = 0.209$).

Table 3.9: Mean diversity statistics of benthic communities at River Yealm (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'(loge) = Shannon's diversity index, 1-λ' = Simpson's dominance Index)

	1998	1999	2011	2015
n	20	10	3	2
S	34.00 ± 21.79	39.80 ± 28.87	45.67 ± 29.70	14.00 ± 9.899
N	520.4 ± 632.3	638.9 ± 1032.0	936.3 ± 817.7	68.50 ± 61.52
D	5.616 ± 2.603	6.713 ± 3.071	6.678 ± 3.282	3.051 ± 1.679
J'	0.703 ± 0.182	0.763 ± 0.188	0.662 ± 0.118	0.671 ± 0.246
H'(loge)	2.362 ± 0.743	2.641 ± 0.748	2.401 ± 0.308	1.579 ± 0.094
1-λ'	0.805 ± 0.203	0.849 ± 0.194	0.853 ± 0.050	0.666 ± 0.184

Figure 3.8: Species richness and abundance of benthic macrofaunal from River Yealm



3.3.4.2. Faunal assemblages

At the River Yealm, benthic community structure differed between years which is reflected in the spread of data (Figure 3.10). 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 = 0.248, p = 0.1%). Pairwise comparisons indicate significant differences between 1998 and all other years and between 1999 and 2011 (Table 3.12). The biggest difference was between the benthic community in 1998 and that in 2015.

Figure 3.9: Non-metric multi-dimension scaling ordination of benthic community structure at River Yealm

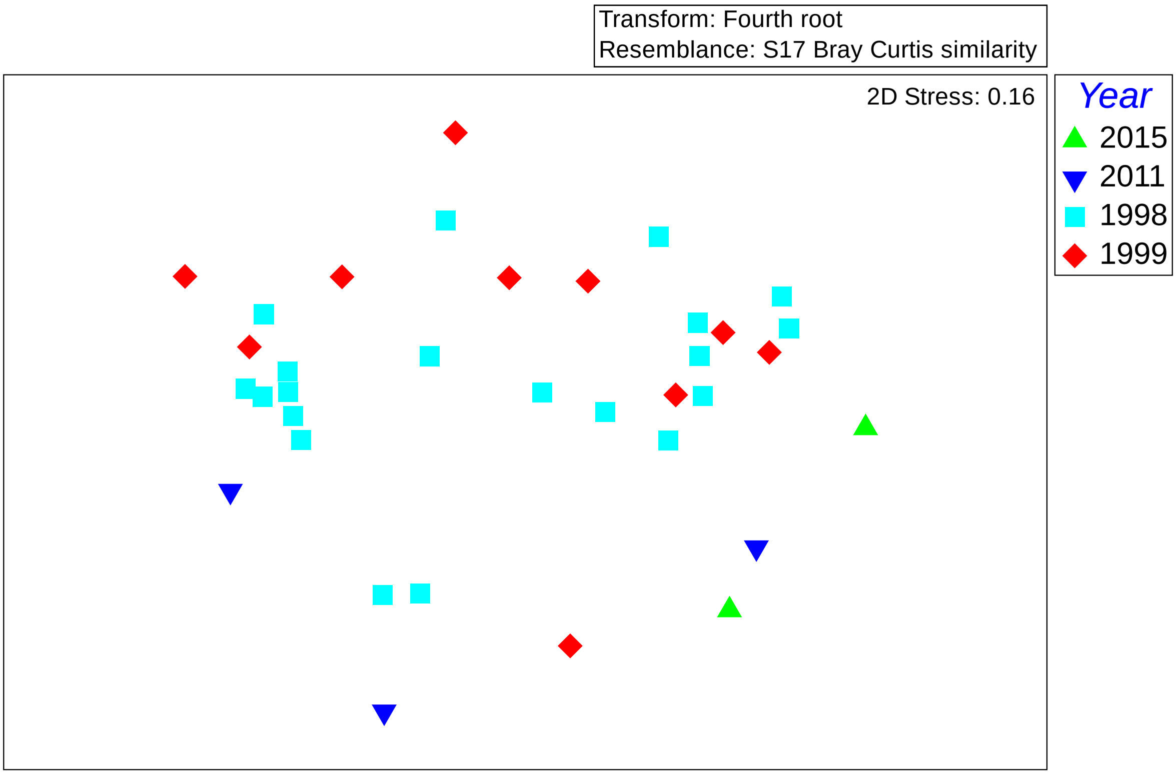


Table 3.10: ANOSIM results of all benthic community data River Yealm (Global R: 0.248 Significance level: 0.1%)

Groups	R statistic	Significance level %	Possible permutations	Actual permutations	Number ≥ Observed
2015, 2011	0.250	20.0	10	10	2
2015, 1998	0.452	0.4	231	231	1
2015, 1999	0.320	7.6	66	66	5
2011, 1998	0.375	0.5	1771	999	4
2011, 1999	0.396	1.4	286	286	4
1998, 1999	0.131	2.4	30,045,015	999	23

SIMPER analysis for each year indicated that average similarity was low (10.6-28.5%). *Spio filicornis* contributed most to similarity in 1998 and 1999 (20.82% and 18.42% respectively). In 2011, average similarity was very low (10.6%) likely due to the low number of samples and nematodes contributed by far the most to similarity (23.7%). In 2015, average similarity was highest, though there were only two samples, and *Magelona* spp. contributed most to similarity.

Table 3.11: SIMPER analysis of benthic community data from River Yealm by monitoring survey

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Group 2015 – average similarity 28.45%					
Magelona johnstoni	2.32	9.82	#######	34.53	34.53
Magelona filiformis	1.38	6.95	#######	24.41	58.94
Nephtys cirrosa	1.34	5.84	#######	20.53	79.47
Iphinoe trispinosa	1.21	5.84	#######	20.53	100
Group 2011 – average similarity 10.62%					
NEMATODA	2.63	2.52	3.04	23.70	23.70
Eteone longa	1.11	1.19	0.58	11.23	34.93
Parexogone hebes	0.67	0.76	0.58	7.18	42.11
Diastylis rugosa	0.77	0.76	0.58	7.18	49.29
Apseudopsis latreillii	2.11	0.67	0.58	6.29	55.58
Mytilus edulis	1.11	0.59	0.58	5.54	61.11
Phyllodoce mucosa	1.30	0.53	0.58	5.00	66.12
Dosinia exoleta	0.80	0.45	0.58	4.24	70.36
Notomastus sp.	1.26	0.45	0.58	4.21	74.57
MYODOCOPIDA	0.84	0.45	0.58	4.21	78.77
Group 1999 – average similarity 18.42%					
Spio filicornis	1.15	2.11	0.96	11.45	11.45
Nephtys cirrosa	0.79	1.62	0.65	8.80	20.25
Chaetozone setosa	0.71	1.37	0.67	7.46	27.71
NEMERTEA	0.92	1.19	0.72	6.48	34.19
Magelona filiformis	0.76	1.19	0.63	6.45	40.65
Galathowenia oculata	0.78	1.04	0.66	5.67	46.32
Bathyporeia guilliamsoniana	0.58	0.69	0.44	3.76	50.08
NEMATODA	0.88	0.62	0.59	3.35	53.43
Pontocrates altamarinus	0.47	0.61	0.38	3.32	56.75
Lucinoma borealis	0.85	0.52	0.63	2.83	59.58
Group 1998 – average similarity 20.82%					
Spio filicornis	1.10	1.66	0.61	7.98	7.98
NEMATODA	1.24	1.45	0.95	6.98	14.96
Apseudopsis latreillii	1.51	1.44	0.93	6.92	21.88
Exogone verugera	1.29	1.43	0.91	6.88	28.76
Magelona mirabilis	0.77	1.26	0.46	6.04	34.80
NEMERTEA	1.27	1.18	0.83	5.68	40.48
Pontocrates altamarinus	0.64	0.99	0.52	4.77	45.25
Mediomastus fragilis	1.01	0.66	0.58	3.16	48.40
Nephtys cirrosa	0.45	0.58	0.34	2.77	51.17
Magelona filiformis	0.63	0.51	0.31	2.43	53.60

3.3.4.3. Biotopes

Characteristic species from the River Yealm site were *Spio filiformis, Nephtys cirrosa*, and *Magelona filiformis,* though there was very low similarity within year classes indicating heterogeneity and multiple biotopes at the site.

The most common assemblage was characterised by *Magelona mirabilis, Nephtys cirrosa, Magelona filiformis, Spio filicornis, Pontocrates altamarinus,* and *Bathyporeia guilliamsoniana,* which is best represented by SS.SSa.IFiSa.NcirBat (*Nephtys cirrosa* and *Bathyporeia* spp. in infralittoral sand).

The other dominant assemblage was characterised by *Apseudopsis latreillii, Calyptraea chinensis, Nemertea, Mediomastus fragilis, Lepidochitona cinereal*, and *Venerupis corrugata* which bears a resemblance to both SS.SMx.IMx.VsenAsquAps (*Venerupis senegalensis*, *Amphipholis squamata* and *Apseudes latreilli* in infralittoral mixed sediment) and SS.SCS.CCS.MedLumVen (*Mediomastus fragilis, Lumbrineris* spp. and venerid bivalves in circalittoral coarse sand or gravel).

At this site, many samples showed little similarity (<20%) with any other samples, but the presence of *Melinna palmata, Magelona* spp., *Spio filicornis* and *Galathowenia oculata* indicates SS.SMu.ISaMu.MelMagThy (*Melinna palmata* with *Magelona* spp. and *Thyasira* spp. in infralittoral sandy mud) was represented.

From 1998 to 1999, there were small changes in the relative abundance of some characteristic species, such as *Apseudopsis latreilliid, Magelona filiformis,* and *Spio filicornis*.

In 2011, *Capitella* sp., *Eteona longa*, *Magelona johnstoni*, *Bathyporeia elegans* and *Spio armata* were all sampled and were not represented in 1999. Most of these species were not characteristic in 2011, and many were represented by other species within the genus in 1999 (*Magelona filiformis, Bathyporeia guilliamsoniana* and *Spio filicornis*).

In 2015, *Magelona johnstoni* became a more important component, contributing most to similarity between samples. *Magelona johnstoni* is not characteristic of any particular biotope, but there has historically been confusion in identifying between *Magelona johnstoni* and *Magelona mirabilis* and many specimens originally identified as *Magelona mirabilis* have now been reclassified as *Magelona johnstoni*.

As with other sites, it is worth noting that the sampling power has decreased across the surveys and that there were more samples collected in 1999 (20), compared to 1998 (10), 2011 (3) and 2015 (2).

3.3.5. Breakwater

The survey area at the Breakwater was an area of moderate depths (11-14m) with a relatively homogenous substratum that is predominantly fine silty sand with small amounts of gravel (Murray, 2001). Sediments at two sites to the north west were comprised of coarser gravelly sand with low silt content.

3.3.5.1. Diversity indices

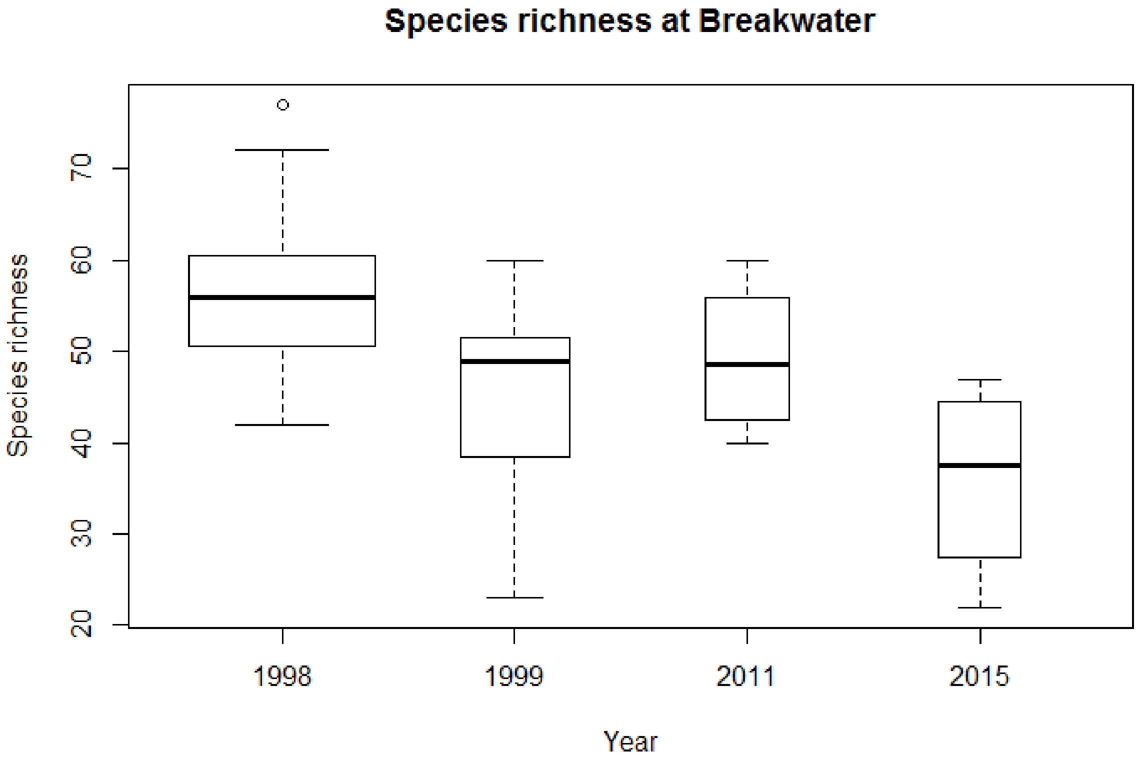
The number of species (S) and number of individuals (N) were similar between years, though higher in 1998 (Table 3.14; Figure 3.11). A Kruskal-Wallis test shows that there was a statistically significant difference in number of species (S) ($\chi^2(3) = 11.203$, $p = 0.011$) and total abundance ($\chi^2(3) = 15.508$, $p = 0.001$) between years. Indices were highest and more variable in 1998, when substantially more samples were taken.

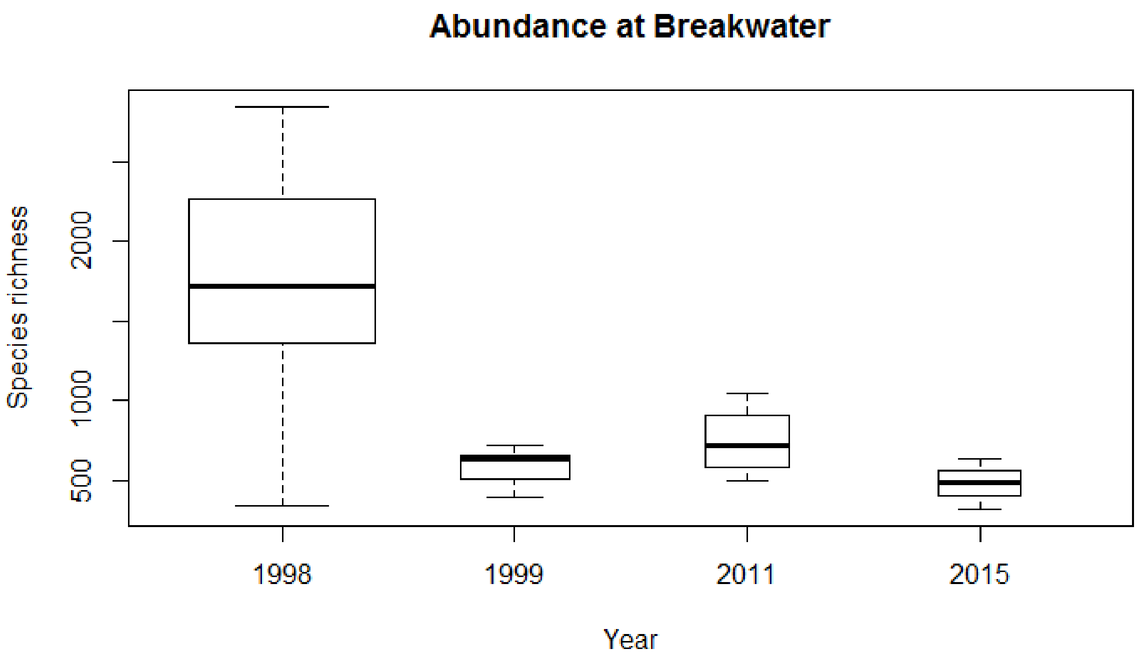
There was no statistically significant difference in Margalef's index for species richness ($\chi^2(3) = 3.543$, $p = 0.315$), Pielou's evenness ($\chi^2(3) = 3.414$, $p = 0.332$), or Shannon's diversity index ($\chi^2(3) = 3.606$, $p = 0.307$).

Table 3.12: Mean diversity statistics of benthic communities at Plymouth Breakwater (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'(loge) = Shannon's diversity index, 1-λ' = Simpson's dominance Index)

	1998	1999	2011	2015
n	20	7	4	4
S	55.85 ± 8.738	44.57 ± 12.79	49.25 ± 8.694	36.00 ± 10.99
N	1665.0 ± 684.5	584.1 ± 116.7	746.8 ± 230.0	482.5 ± 127.7
D	7.640 ± 1.846	6.869 ± 2.028	7.305 ± 1.032	5.664 ± 1.697
J'	0.591 ± 0.097	0.590 ± 0.107	0.653 ± 0.063	0.579 ± 0.070
H'(loge)	2.382 ± 0.474	2.239 ± 0.550	2.532 ± 0.165	2.063 ± 0.402
1-λ'	0.815 ± 0.063	0.751 ± 0.137	0.848 ± 0.028	0.749 ± 0.107

Figure 3.10: Species richness and abundance of benthic macrofaunal from Plymouth Breakwater





3.3.5.2. Faunal assemblages

At Plymouth Breakwater, benthic community structure differed between years which is reflected in the spread of data (Figure 3.12). An ANOSIM test indicated that differences in benthic community structure between years are significant and the effect of sampling year is moderate (Global R = 0.704, p = 0.1%). Pairwise comparisons indicate significant differences between all years except 2011 and 2015 (Table 3.15). The largest differences were between 1999 and both 2011 and 2015.

Figure 3.11: Non-metric multi-dimension scaling ordination of benthic community structure at Plymouth Breakwater

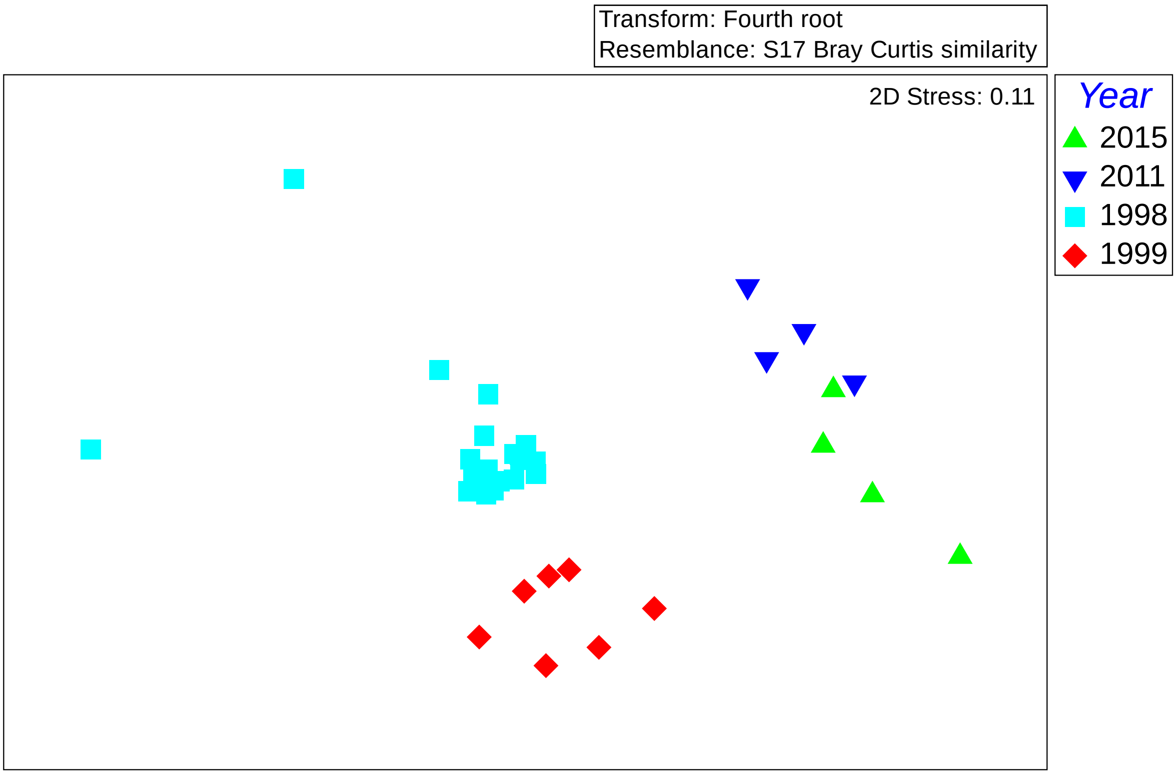


Table 3.13: ANOSIM results of all benthic community data from Plymouth Breakwater (Global R: 0.704, Significance level: 0.1%)

Groups	R statistic	Significance level %	Possible permutations	Actual permutations	Number ≥ Observed
2015, 2011	0.490	2.9	35	35	1
2015, 1998	0.799	0.1	10,626	999	0
2015, 1999	0.995	0.3	330	330	1
2011, 1998	0.708	0.3	10,626	999	2
2011, 1999	1.000	0.3	330	330	1
1998, 1999	0.611	0.2	888,030	999	1

SIMPER analysis for each year indicated sample pairs have a moderate average similarity of 52.7-59.2% (Table 3.16). In all years, either *Melinna palmata* or *Chaetozone gibber* or a combination of the two contributed most to similarity within year.

Table 3.14: SIMPER analysis of benthic community data from Breakwater by monitoring survey

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Group 2015 – average similarity 52.66%					
Melinna palmata	3.74	6.89	5.57	13.09	13.09
Turritella communis	2.46	4.13	3.17	7.84	20.93
Sternaspis scutata	2.25	3.75	2.06	7.12	28.05
Kurtiella bidentata	2.12	3.51	5.93	6.66	34.71
Nephtys incisa	1.85	3.01	2.65	5.71	40.42
Phoronis sp.	1.51	2.73	5.64	5.19	45.61
Amphiura filiformis	1.60	2.69	8.95	5.11	50.73
Thyasira flexuosa	1.50	2.68	4.31	5.09	55.81
Magelona alleni	1.56	2.51	7.28	4.78	60.59
Pholoe baltica	1.22	2.08	6.06	3.94	64.53
Group 2011 – average similarity 59.20%					
Chaetozone gibber	3.61	4.32	8.29	7.30	7.30
Melinna palmata	3.18	3.87	7.20	6.53	13.83
Sternaspis scutata	3.13	3.84	4.98	6.49	20.33
Edwardsia claparedii	2.08	2.52	4.54	4.26	24.58
Eudorella truncatula	2.24	2.47	4.73	4.17	28.76
Turritella communis	2.39	2.45	3.27	4.14	32.9
Tubificoides galiciensis	1.74	2.20	7.64	3.72	36.62
Nucula nitidosa	1.78	2.19	14.48	3.70	40.32
Magelona alleni	1.56	2.04	9.87	3.44	43.76
Kurtiella bidentate	1.53	2.04	12.32	3.44	47.2
Group 1999 – average similarity 54.59%					
Melinna palmata	3.84	5.62	3.00	10.29	10.29
Chaetozone gibber	2.69	3.79	3.75	6.93	17.22
Magelona filiformis	2.12	2.98	5.32	5.47	22.69
Aphelochaeta A	2.17	2.78	3.75	5.08	27.77
Magelona alleni	1.73	2.57	4.21	4.71	32.48
Nemertea	1.76	2.52	2.76	4.62	37.1
Myriochele	1.83	2.52	9.16	4.61	41.71
Ampharete lindstroemi	1.54	2.06	4.32	3.77	45.48
Phoronis sp.	1.44	1.99	4.28	3.64	49.12
Turritella communis	1.68	1.80	1.42	3.30	52.41
Group 1998 – average similarity 57.31%					
Chaetozone gibber	4.28	4.31	4.49	7.51	7.51
Melinna palmata	4.44	4.23	2.31	7.38	14.89
Ampelisca tenuicornis	2.85	2.66	6.06	4.63	19.53
Magelona filiformis	2.75	2.60	2.38	4.54	24.07
Aphelochaeta marioni	2.61	2.26	2.40	3.94	28.02
Galathowenia oculata	2.17	2.04	3.98	3.56	31.57
NEMATODA	1.95	1.86	4.81	3.24	34.81
NEMERTEA	1.99	1.80	1.91	3.15	37.96
Magelona alleni	1.82	1.80	5.14	3.13	41.10
Euclymene oerstedii	2.00	1.66	2.07	2.89	43.98

3.3.5.3. Biotopes

Characterising species at the Breakwater site were *Melinna palmata, Magelona alleni, Turritella communis,* and *Chaetozone gibber.*

Similarity within year was moderate and there were a number of characteristic biotopes. The most common assemblage was characterised by *Melinna palmata, Chaetozone gibber, Magelona filiformis, Ampelisca tenuicornis, Aphelochaeta marioni*, and *Thyasira flexuosa*, which is a good representation of SS.SMu.ISaMu.MelMagThy (*Melinna palmata* with *Magelona* spp. and *Thyasira* spp. in infralittoral sandy mud).

Several samples contained increased numbers of *Aphelochaeta* and *Tubificoides*, which indicates a transition between SS.SMu.ISaMu.MelMagThy and SS.SMu.SMuVS.AphTubi (*Aphelochaeta marioni* and *Tubificoides* spp. in variable salinity infralittoral mud).

Furthermore, in a few samples, elevated numbers of *Kurtiella bidentata*, Nemertea and *Thyasira flexuosa* indicate possible elements of SS.SMx.CMx.MysThyMx (*Mysella bidentata* and *Thyasira* spp. in circalittoral muddy mixed sediment).

Differences in species composition between 1998 and 1999 were primarily explained by small changes in the relative abundance of characterising species: *Aphelochaeta* spp., *Ampelisca tenuicornis, Chaetozone gibber,* and *Tharyx* sp. Species found in 1998, but not present in 1999, include *Galathowenia oculata, Eudorella truncatula, Harpinia pectinata*, and *Pontocrates altamarinus*. This indicates a small shift along the transition from SS.SMu.ISaMu.MelMagThy to SS.SMu.SMuVS.AphTubi.

In 2011, SS.SMu.SMuVS.AphTubi and SS.SMu.ISaMu.MelMagThy were still the dominant biotopes, but increased numbers of *Eudorella truncatula, Kurtiella bidentata,* and *Prionospio* spp. indicate elements of SS.SMx.CMx.MysThyMx (*Mysella bidentata* and *Thyasira* spp. in circalittoral muddy mixed sediment) were becoming more important.

In 2015, the dominant biotopes were still SS.SMu.ISaMu.MelMagThy and SS.SMx.CMx.MysThyMx, and dissimilarity was due to small changes in the relative abundance of *Chaetozone gibber, Eudorella truncatula,* and *Tharyx killariensis*, as well as changes in the species of *Tubificoides* present.

As with other sites, it is worth noting that the sampling power has decreased across the surveys and that there were more samples collected in 1999 (20), compared to 1998 (7), 2011 (4) and 2015 (4), reflected in the increased species number and abundance recorded in 1999 (Figure 3.10).

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 1998-99 surveys (Murray, 2001) in order to make best use of existing data. Any new areas to be added to the design would require a different baseline.
- 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 Plymouth Sound and Estuary SAC are extremely variable across the site and represent nearly the full range of the Folk triangle (Folk, 1954).
- Cawsand Bay had low to moderate species richness and total abundance and there were no significant differences in biodiversity indices between years, except for Pielou's evenness. Evenness decreased with survey year and sampling effort and it is thought to be due to the variable benthic assemblages and low sampling effort in later years (2011 and 2015). Sediments predominantly consisted of sands, but there was a variable quantity of silt and gravel present at the stations, and there was a general north-east to south-west (onshore-offshore) gradient with somewhat finer sediments in the inshore areas and coarser, poorly sorted gravelly sediments offshore. Community composition was statistically significantly different between some years – between 1998 and 1999 and also between 2015 and both 2008 and 2009 – though sampling effort and hence possible ANOSIM permutations varied dramatically between surveys. The most abundant taxa at Cawsand Bay were *Chaetozone gibber*, *Magelona filiformis, Melinna palmata* and *Galathowenia oculata*. Overall, the benthic assemblages were best characterised by two biotopes: SS.SMu.ISaMu.MelMagThy (*Melinna palmata* with *Magelona* spp. and *Thyasira* spp. in infralittoral sandy mud) and SS.SCS.ICS.MoeVen (*Moerella* spp. with venerid bivalves in infralittoral gravelly sand). Community composition remained similar from 1998 to 1999, though species abundances shifted. Though there were changes in composition in 2015, this was primarily due to changes of species within genus (*Magelona* spp., *Bathyporeia* spp., *Chaetozone* spp., and *Chamelea* spp.) and could be due to analytical reasons rather than any genuine shift.
- Torpoint had moderate to high species richness and total abundance and there were no significant differences in biodiversity indices between years, though variability was far higher in 1998 where sampling effort was highest. The seabed at Torpoint was observed to be very heterogeneous with a high proportion of gravel, pebbles, cobbles, boulders and shell with variable amounts of sand and mud. Community composition was statistically significantly different between all years, but largest between 2011 and both 1998 and 1999. The most abundant taxa at Torpoint were *Aphelochaeta marioni, Melinna palmata, Chaetozone gibber* and *Mediomastus fragilis*. The dominant biotope in all surveys was SS.SCS.CCS.MedLumVen (*Mediomastus fragilis, Lumbrineris* spp. and venerid bivalves in circalittoral coarse sand or gravel), but with apparent elements of other biotopes. In 1998 and 1999, this was SS.SMx.IMx.VsenAsquAps (*Venerupis senegalensis, Amphipholis squamata* and *Apseudes latreilli* in infralittoral mixed sediment), but in 2011 was SS.SMu.ISaMu.MelMagThy (*Melinna*

palmata with *Magelona* spp. and *Thyasira* spp. in infralittoral sandy mud). The change in composition from 1998-9 and 2011 was mainly due to a reduction in *Aphelochaeta marioni, Amphicteis gunneri*, or *Apseudopsis latreillii* and an increase in the bivalve *Kurtiella bidentata.* This change could be linked to a slight increase in silt observed in sediment samples due to sample location in 2011 being predominantly in the outer edge of the Torpoint site or the fact that the reduced sampling effort sampled fewer habitats.

- The River Yealm had low to moderate species richness and total abundance and there were no significant differences in biodiversity indices between years, though variability was higher in 1998 and 1999 where sampling effort was highest. The sediment composition at the River Yealm site was heterogeneous with stony gravelly sand along the northern side of the Inner Yealm, fine-medium sand and silty sands in the central inner Yealm, and predominantly fine sand in the outer Yealm. Community composition was statistically significantly different between 1998 and all other years and between 1999 and 2011. The biggest difference was between the benthic community in 1998 and that in 2015. The most abundant taxa at River Yealm were *Apseudopsis latreilliid, Gammarella fucicola, Amphipholis squamata,* and *Calyptraea chinensis*. The average similarity within year at River Yealm was extremely low, indicating an extremely diverse range of benthic assemblages. The most common biotope at the site was SS.SSa.IFiSa.NcirBat (*Nephtys cirrosa* and *Bathyporeia* spp. in infralittoral sand), characterised by *Magelona mirabilis, Nephtys cirrosa, Magelona filiformis, Spio filicornis, Pontocrates altamarinus,* and *Bathyporeia guilliamsoniana.* The other dominant biotope was SS.SMx.IMx.VsenAsquAps (*Venerupis senegalensis*, *Amphipholis squamata* and *Apseudes latreilli* in infralittoral mixed sediment). The presence of of *Melinna palmata, Magelona* spp., *Spio filicornis* and *Galathowenia oculata* also indicated elements of SS.SMu.ISaMu.MelMagThy (*Melinna palmata* with *Magelona* spp. and *Thyasira* spp. in infralittoral sandy mud). From 1998 to 1999, there were small changes in the relative abundance of some characteristic species, such as *Apseudopsis latreilliid, Magelona filiformis,* and *Spio filicornis*. In 2011, *Capitella* sp., *Eteona longa*, *Magelona johnstoni*, *Bathyporeia elegans* and *Spio armata* were all sampled and were not represented in 1999. Most of these species were represented by other species within the genus in 1999 (*Magelona filiformis, Bathyporeia guilliamsoniana* and *Spio filicornis*). In 2015, *Magelona johnstoni* became a more important component, but other *Magelona* spp. were identified in other years and overall there was no change in abundance of the genus. Sampling effort at River Yealm was highly variable over the surveys, but also spread of samples, with more stations taken from the estuarine region of the site in 1998 and 1999, with finer sediments and more freshwater influence. As such, it is difficult to conclude anything with confidence, but it is suggested that any observed changes have been caused by changes in survey design.
- Plymouth Breakwater had low to moderate species richness and total abundance and there was a statistically significant difference in both species number and total abundance with year, though not in any of the other biodiversity indices. Variability in metrics was substantially higher in 1998 compared to other years and associated with higher sampling effort. The Breakwater site had relatively homogenous substratum that is predominantly fine silty sand with small amounts of gravel, though stations closer to the coast were comprised of coarser gravelly sand with low silt content. The most abundant taxa at Breakwater were *Melinna palmata, Chaetozone gibber, Ampelisca tenuicornis, Magelona filiformis*, and *Aphelochaeta marioni*. As with the other sites, there were a number of different benthic assemblages present at Breakwater. The most common of these was SS.SMu.ISaMu.MelMagThy (*Melinna palmata* with *Magelona* spp. and *Thyasira* spp. in infralittoral sandy mud), characterised by *Melinna palmata, Chaetozone gibber, Magelona*

filiformis, Ampelisca tenuicornis, Aphelochaeta marioni, and *Thyasira flexuosa*. A few sampling stations with elevated numbers of *Aphelochaeta* and *Tubificoides* and *Kurtiella bidentata* and *Thyasira flexuosa* were characteristic of SS.SMu.SMuVS.AphTubi (*Aphelochaeta marioni* and *Tubificoides* spp. in variable salinity infralittoral mud) and SS.SMx.CMx.MysThyMx (*Mysella bidentata* and *Thyasira* spp. in circalittoral muddy mixed sediment) respectively. In 1998, 1999 and 2015 the dominant species were similar and there were small changes in the relative abundance of characterising species indicating fluctuations on the transition between SS.SMu.ISaMu.MelMagThy and SS.SMu.SMuVS.AphTubi. In 2011, increased numbers of *Eudorella truncatula, Kurtiella bidentata,* and *Prionospio* spp. indicate elements of SS.SMx.CMx.MysThyMx (*Mysella bidentata* and *Thyasira* spp. in circalittoral muddy mixed sediment) were becoming more important. This difference appeared to be caused by a reduced sampling effort and a greater proportion of samples being taken closer to the coast and introducing potentially new habitats.

- Though there were changes in relative species composition observed during the survey period, it has not been possible to separate these from effects of changes in survey array and sampling effort. In general, though some biodiversity indices changed with survey year, dominant taxa and characteristic biotopes remained similar and were within the envelope of what might be expected due to natural change (e.g. shifts between SS.SMu.ISaMu.MelMagThy and SS.SMu.SMuVS.AphTubi).
- It is recommended that future surveys replicate the 1998 survey design and array in order to be able to more reliably comment upon changes to the sites sub-features. If other areas of the site need to be monitored, new areas should be defined and a baseline sampled following the principles of Murray (2001).
- The favourable condition table for the relevant sub-features of the Plymouth Sound and Estuaries SAC is given in Table 4.1. 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.

Feature information[1]:

- Estuaries: The rivers Tamar, Tavy, Lynher and Yealm have major estuaries within the site; all are tidally influenced, and display the classic topographical characteristics of ria estuary systems. There are smaller estuarine creeks branching off each of the larger estuaries such as Tamerton Lake on the Tamar and the River Tiddy on the Lynher. The Yealm is almost entirely natural, it has not been diverted or dammed and is unusual in the low levels of freshwater it receives meaning that marine communities typical of full salinity seawater penetrate a significant distance up the estuary.
- Mudflats and sandflats not covered by seawater at low tide: Important intertidal mudflat areas can be found above the Hamoaze in the Tamar-Tavy Estuaries, in the Lynher Estuary, and throughout the Yealm Estuary (Bunker et al., 2002, Curtis, 2010a, Curtis, 2010b). Areas of sand and muddy sand are also an important component of the estuaries, particularly in St.

[1] Plymouth Sound and Estuaries SAC: DRAFT supplementary advice on conserving and restoring site feature. Natural England pp147

John's Lake and the northern Lynher Estuary as well as the Tamar-Tavy Estuary. Additionally, extensive areas of sand and coarse sediments are found on beaches within the Sound (e.g. Cawsand, Bovisand, and Crownhill bays), and at Wembury Bay.

- Large shallow inlets and bays: The large shallow inlets and bays feature of this site is found in the outer part of the site and includes all of Plymouth Sound and Wembury Bay up to the mouths of the Tamar and Yealm estuaries. This feature includes a range of sediment and rock sub-features.
- Sandbanks which are slightly covered by sea water all the time: The subtidal sandbanks feature is found in the outer, higher energy areas of the site such as around the mouth of the Yealm Estuary, in Cawsand Bay and in parts of Plymouth Sound. The sandbanks tend to be tideswept and are made up of a range of sediment types from fine muddy sand to gravel, including mixed sediment.

Sub-features

- Subtidal coarse sediment: Sublittoral coarse sediment, comprised of unstable gravels and cobbles is typically found in high energy areas of the site. There are patches of this sub-feature across Plymouth Sound in varying water depths. It does not occur in the estuaries of the site.
- Subtidal mixed sediments: Sublittoral mixed sediments can be found widely across the site and are a sub-feature of estuaries, large shallow inlets and bays and sandbanks. In Plymouth Sound, mixed sediments occur at varying water depths and can be exposed to a range of tidal streams and wave action. The mixed substrata provide a range of niches supporting a variety of species assemblages.
- Subtidal mud: The larger areas of sublittoral mud are located directly inside the Breakwater, in the shelter of Cawsand Bay and to the north and east of Drake Island. Sublittoral mud is present throughout the main river channels of the estuaries and is often contiguous with the intertidal mudflats. Sublittoral mud is found in a range of salinities and depths throughout the site and supports various communities, predominantly infaunal, at different locations. These muddy substrata often adjoin areas of coarser sand, gravel and cobble and where they mix they form the sub-feature subtidal mixed sediments.
- Subtidal sand: Sublittoral sand is an important sub-feature of subtidal sandbanks for which the site was designated. It occurs in patches in Plymouth Sound and around the mouth of the Yealm Estuary. The largest patch is found near Cawsand Bay in Plymouth Sound. There tends to be no clear boundary between sublittoral sand and other sublittoral sediment habitats which have higher levels of mud or gravel components.

Table 4.1: Review of feature condition attributes for the Plymouth Sound and Estuaries 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 of the feature 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 wasn't intended to characterise the whole of the Plymouth Sound and Estuaries 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 1998 and 1999 (Murray, 2001) were also present in 2011 and 2015. The exception to this was at Plymouth Breakwater, where in 2011 and 2015 increasing numbers of *Eudorella truncatula, Kurtiella bidentata,* and *Prionospio* spp. indicated elements of SS.SMx.CMx.MysThyMx were becoming more important. This difference appeared to be caused by a drift in some sampling stations closer to the coast and introducing potentially new habitats. At Torpoint, there was a reduction in *Aphelochaeta marioni, Amphicteis gunneri*, or *Apseudopsis latreillii* and an increase in the bivalve *Kurtiella bidentate* in 2011 linked to an increase in finer sediments associated with sampling effort shifting to the outer edge of the Torpoint site. Estuaries – not assessed

Attribute	Subtidal sandbanks	Large shallow inlets and bays	Mudflats and sandflats	Estuaries	Subtidal coarse sediment	Subtidal mixed sediments	Subtidal sand	Subtidal Mud	Assessment
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.
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 1998-9 (Murray, 2001) were also present in 2011 and 2015. The exception to this was at Plymouth Breakwater, where in 2011 and 2015 increasing numbers of *Eudorella truncatula, Kurtiella bidentata,* and *Prionospio* spp. indicated elements of SS.SMx.CMx.MysThyMx were becoming more important. This difference appeared to be caused by a drift in some sampling stations closer to the coast and introducing potentially new habitats. At Torpoint, there was a reduction in *Aphelochaeta marioni, Amphicteis gunneri*, or *Apseudopsis latreillii* and an increase in the bivalve *Kurtiella bidentate* in 2011 linked to an increase in finer sediments associated with sampling effort shifting to the outer edge of the Torpoint site. Estuaries – not assessed
Structure (sediment composition and distribution): Maintain the existing distribution of sediment composition types across the feature (and each of its sub-features).	✓				✓	✓	✓	✓	Analysis of PSD data shows that in general sediment types remained consistent at the sites across the surveys. The slight exception to this was at Torpoint where the gravel content increased slightly towards the southern edge of the channel in 2015 (>50%) compared to 2011 (<50%), though survey arrays were different and habitats at the site were heterogeneous. Taking into consideration the change in survey array, there was no change in the sediment composition of Cawsand Bay, River Yealm, and Breakwater.

Attribute	Subtidal sandbanks	Large shallow inlets and bays	Mudflats and sandflats	Estuaries	Subtidal coarse sediment	Subtidal mixed sediments	Subtidal sand	Subtidal Mud	Assessment
<u>Structure (sediment movement, sources and sinks)</u>: Maintain sediment regime and budget within the estuary, including sediment sources, sinks and movement.		✓		✓					Analysis of available PSD data shows that in general sediment types remained consistent at the sites across the surveys. The slight exception to this was at Torpoint where the gravel content increased slightly towards the southern edge of the channel in 2015 (>50%) compared to 2011 (<50%), though survey arrays were different and habitats at the site were heterogeneous. Taking into consideration the change in survey array, there was no change in the sediment composition of Cawsand Bay, River Yealm, and Breakwater. Estuaries – not assessed
<u>Structure (species composition of component communities)</u>: 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 1998-9 (Murray, 2001) were also present in 2011 and 2015. he exception to this was at Plymouth Breakwater, where in 2011 and 2015 increasing numbers of *Eudorella truncatula, Kurtiella bidentata,* and *Prionospio* spp. indicated elements of SS.SMx.CMx.MysThyMx were becoming more important. This difference appeared to be caused by a drift in some sampling stations closer to the coast and introducing potentially new habitats. At Torpoint, there was a reduction in *Aphelochaeta marioni, Amphicteis gunneri*, or *Apseudopsis latreillii* and an increase in the bivalve *Kurtiella bidentate* in 2011 linked to an increase in finer sediments associated with sampling effort shifting to the outer edge of the Torpoint site. Estuaries – not assessed

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Annexes

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