



Appendix L2 – Intertidal Survey Report

Langstone FCERM Scheme

Intertidal Benthic Ecology Survey Report
Phase I and II surveys

Coastal Partners

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Executive Summary

The Langstone Flood and Coastal Erosion Risk Management (FCERM) Scheme aims to develop and implement coastal management options (new or upgraded defences) to reduce the flood and erosion risk in Langstone, Hampshire.

An intertidal phase I biotope survey and phase II quantitative sampling of the intertidal habitats present along the Langstone scheme frontage was undertaken to contribute to baseline characterisation for the Environmental Impact Assessment (EIA), Habitat Regulations Assessment (HRA) and the Water Framework Directive (WFD) assessments for the scheme. The study area encompasses the intertidal habitat that extends either side of Langstone village, in Langstone and Chichester Harbours to identify any benthic receptors which have the potential to be affected by the scheme. The key designated sites within the study area are the Chichester and Langstone Harbours SPA/Ramsar site, the Solent Maritime SAC and SSSI for each of the harbours.

The survey included a Phase I walkover survey comprising a visual assessment of the habitats and species present comprising a total of 11 transects across the intertidal area. Additional transects were added at specific points of interest. As a means of investigating indicators of nutrient enrichment, the percentage of several opportunistic algae species was estimated and broadscale habitat and biotope distributions were mapped. Following the Phase I survey a Phase II sediment core sampling survey was undertaken for analysis of infauna, particle size analysis and determination of Total Organic Carbon (TOC). Where it was not possible to take a core sample, such as very high on the shore, close to existing flood defences, because of the presence of very coarse sediments, data were collected using images and target notes.

The results of the intertidal surveys identified nine broad-scale habitat types, with some variation in the dominant habitats in each of Langstone and Chichester harbours. The upper shore and littoral fringe in both harbours was dominated by 'littoral coarse sediment' and 'coastal shingle', particularly evident in the foreshore at Langstone village.

In Chichester Harbour, below the littoral fringe gravel and shingle, the intertidal habitat was a fragmented mosaic of saltmarsh patches within extensive mudflats. The saltmarsh was largely identified as dominated by the cord-grass *Spartina anglica*, in monoculture stands, which is generally thought to be of limited value to wildlife, despite the fact it is a designated feature of the Solent Maritime SAC. There were however, two tidal creeks in Langstone Harbour that support higher quality saltmarsh, with more examples of low-mid marsh and pioneer zone communities present. Although Chichester Harbour is reported as being an important area for saltmarsh, there has been a continued loss and degradation of this habitat in the Harbour over several decades.

The mudflats of Chichester Harbour were generally covered in a dense layer of the opportunistic green algae *Ulva* spp., with all but the first centimetre of the underlying sediment highly anoxic. The spire shell, or mud snail, *Peringia ulvae* and the oligochaete *Tubificoides benedii* were the dominant species, having the highest contribution to overall abundance. Some stations were also characterised by typical estuarine species such as the rag worm *Hediste diversicolor* and the bivalve *Limecola balthica*.

In Langstone Harbour, with the exception of upper to mid-shore littoral rock along the spit, benthic habitats were dominated by sediment biotopes of different proportions of mud, sand and gravel. The area was categorised as the broad-scale habitats 'littoral sand and sandy mud' and 'littoral mud' with increasing amounts of gravel in the north of the bay. In many of the samples collected in Langstone Harbour, the same species were dominant, but different biotopes were recorded due to the presence of more mixed and sandy sediments.

As well as high levels of growth of opportunistic green algae, nutrient enrichment was also evident in the measures of high TOC, in Chichester Harbour, which was positively correlated with the high proportion of fine particles in the sediment. Where gravel and mixed sediments were present, TOC was generally lower. The ecological status of macrobenthic infaunal invertebrate assemblages at all stations was 'Moderate', with the exception of a single 'Good' station in Langstone Harbour that was characterised by fewer opportunistic species than found at other stations.

A number of biotopes that qualify as habitats of principal importance, or are representative of Annex I habitats, largely mudflat and saltmarsh biotopes, were widespread across the two Harbours. No species afforded conservation protection were recorded during the intertidal phase II surveys. However, pacific oyster (*Magallana*

gigas) was found sporadically along the historic causeway (during the Phase I survey) and is considered to be an Invasive Non-Native Species (INNS).

1. Introduction

1.1 Project Background

The Langstone Flood and Coastal Erosion Risk Management (FCERM) Scheme aims to develop and implement coastal management options (new or upgraded defences) to reduce the flood and erosion risk in Langstone, Hampshire.

AECOM has been commissioned by Havant Borough Council (HBC), the coastal erosion and flood Risk Management Authority (RMA) to assist in implementing the Langstone Flood and Coastal Erosion Risk Management (FCERM) Scheme. The scheme will help protect the community, important heritage assets and the Langstone Road to Hayling Island (A3023) which separates Langstone and Chichester Harbour (Langstone to the west and Chichester to the east).

The coastal management options will be focussed in front of Langstone village and will consist of hard engineering coastal protections. Although the preferred option freeze for detailed design is still awaiting confirmation (due end of January 2022), the defence types are likely to include an earth embankment and refurbishment of the seawall in Langstone Harbour and new floodwalls and flood gates, as well as reinforcement of the existing wall in Chichester Harbour. Furthermore, rock armour revetment will be installed at the end of the spit in Langstone Harbour, towards the disused trestle railway bridge (as part of the Hayling Island railway line).

In order to provide baseline information for the Environmental Impact Assessment (EIA), Habitat Regulations Assessment (HRA) and the Water Framework Directive (WFD) assessment for the scheme, AECOM has undertaken an intertidal phase I biotope survey and phase II quantitative sampling of the intertidal habitats present along the whole Langstone scheme frontage. The results from this survey will also provide information for other elements of the Langstone scheme, including the saltmarsh restoration feasibility study, which is investigating the potential to restore and create saltmarsh habitat within the Chichester Harbour area adjacent to the scheme.

1.2 Aims and Objectives

The purpose of this report is to present the results of the phase I and phase II intertidal benthic surveys undertaken for this project, and to highlight key intertidal benthic receptors that may be affected by the Langstone FCERM Scheme.

This report is intended to form part of the benthic ecological baseline characterisation study that will be undertaken to inform the EIA, HRA and WFD assessment to be completed as part of the scheme. Consideration will be given to the extent and location of saltmarsh habitat, as well as abiotic data and the overall environmental quality within the study area, to help inform the saltmarsh restoration feasibility study for the scheme.

1.3 Study Area

The study area encompasses the intertidal habitat that extends either side of Langstone village, in Langstone and Chichester Harbours (see Figure 1, 1a and 1b below). This area was chosen on the basis that it would include any habitat adjacent to the Langstone FCERM Scheme, and identify any benthic receptors which have the potential to be affected by the scheme, including those which are afforded international, national, and regional protection. Sampling stations and transects were focussed in the foreshore in front of Langstone village (in Chichester Harbour) where hard engineering coastal protection has been proposed. Sampling stations and transects were also undertaken in Langstone Harbour where refurbishment of the existing sea wall will take place and installation of rock armour revetment at the end of the spit.

The study area falls within a number of designations including:

- Chichester and Langstone Harbours Ramsar;
- Chichester and Langstone Harbours Special Protection Area (SPA);
- Solent Maritime Special Area of Conservation (SAC);
- Chichester Harbour Site of Special Scientific Interest (SSSI); and
- Langstone Harbour SSSI (LUC, 2018).

There are also areas of local nature reserve within the harbours, whilst Chichester Harbour has been designated as an Area of Outstanding Natural Beauty (AONB), covering 74 km² of terrestrial and coastal habitat (LUC, 2018). Chichester Harbour consists of a large area of saltmarsh which has been labelled as England's seventh largest saltmarsh (Bardsley *et al.*, 2021). However, there has been a continued loss and degradation of this habitat in Chichester Harbour and it has been estimated that if the current rate of loss continues, by 2054 there will be just 44.4 ha of saltmarsh remaining in this area from the current coverage of 282.6 ha (English Nature, 2006). The Solent Maritime SAC is designated for the following marine and coastal qualifying features:

- Annex I habitats: estuaries (1130), spartina swards (*Spartinion maritimae*) (1320); Atlantic salt meadows (*Glauco-Puccinellietalia maritimae*) (1330); Sandbanks which are slightly covered by sea water all the time (1110); Mudflats and sandflats not covered by seawater at low tide (1140); Coastal lagoons (1150); Annual vegetation of drift lines (1210); Perennial vegetation of stony banks (1220); Salicornia and other annuals colonizing mud and sand (1310); "Shifting dunes along the shoreline with *Ammophila arenaria* ("white dunes")" (2120)
- Annex II species: Desmoulin's whorl snail (*Vertigo moulinsiana*) (1016)

1.4 Structure of Report

The remainder of the report is structured as follows:

- Section 2: Methodology – summarises the methodology for undertaking the phase I and phase II intertidal benthic surveys as well as the approaches taken for sample and data analysis;
- Section 3: Results – outlines the results of the phase I and phase II intertidal benthic surveys;
- Section 4: Discussion – Discusses the results of the project-specific surveys in relation to existing publicly available information; and
- Section 5: Conclusion – provides a summary of the findings of the project-specific surveys and a desk-based study for intertidal benthic ecology.

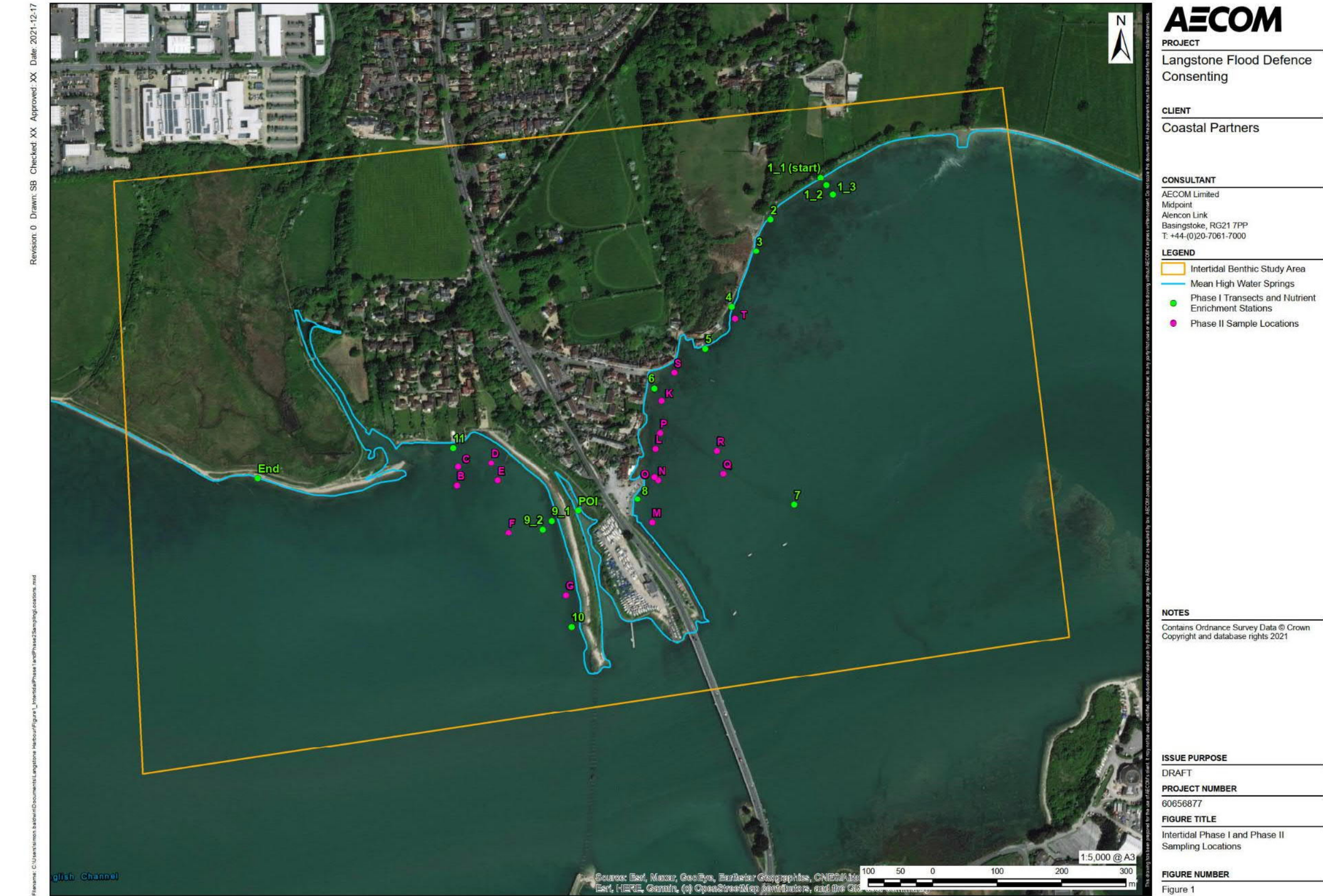


Figure 1. Intertidal Phase I and Phase II Sampling Locations



Figure 1a. Intertidal Phase I and Phase II Sampling Locations (Langstone Harbour – western extent)

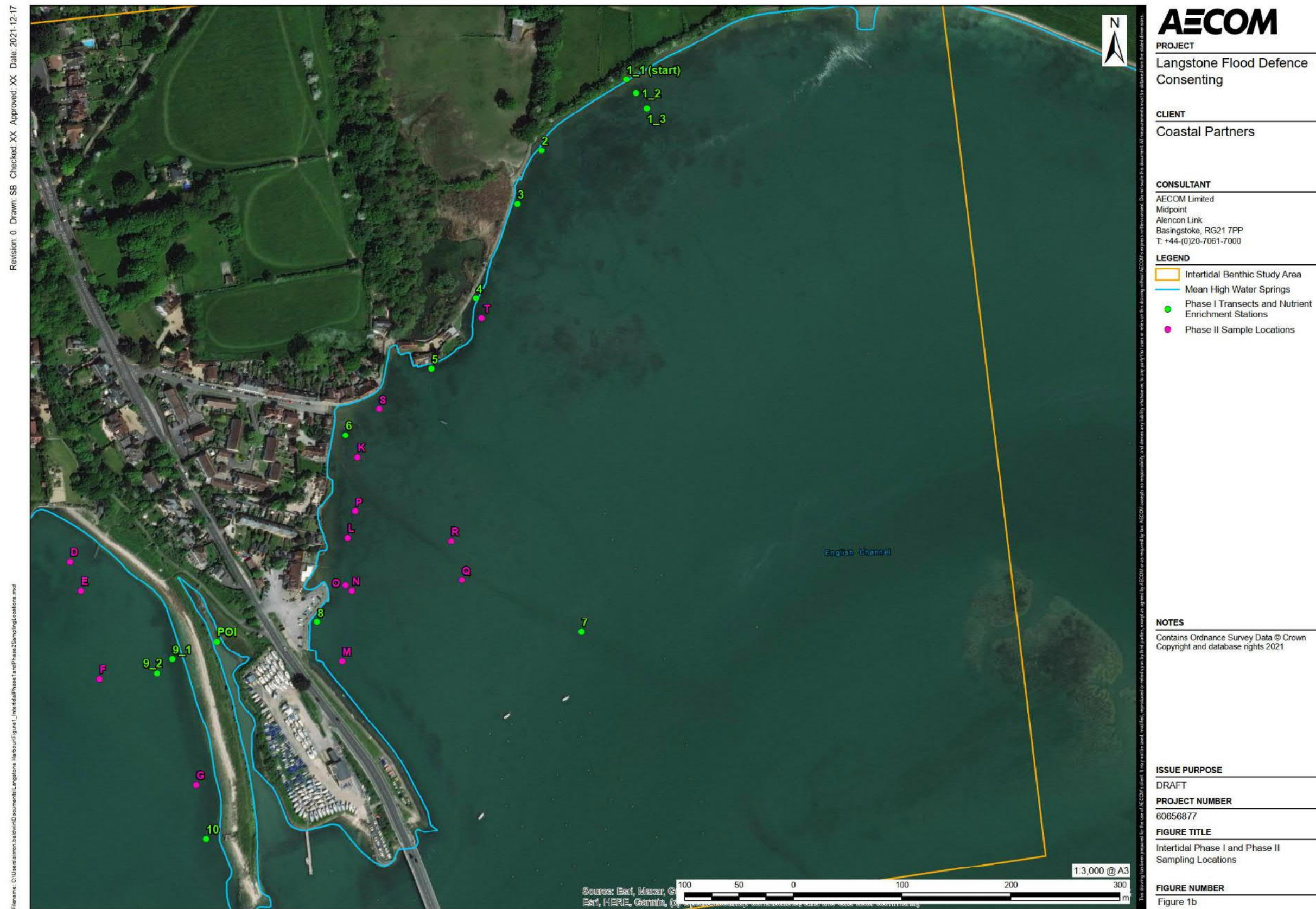


Figure 1b. Intertidal Phase I and Phase II Sampling Locations (Chichester Harbour – eastern extent)

2. Methodology

2.1 Field Surveys

The intertidal Phase I and Phase II surveys were undertaken in order to characterise the intertidal habitats and species present within the study area. An initial desk-based study was undertaken to identify any protected areas and habitats and species expected to be present within the study area. The surveys took place around low tide on the 24th and 25th August 2021 by two experienced AECOM marine ecologists.

The Phase I survey methodology comprised a walkover survey involving a full visual assessment of the intertidal study area in order to characterise the habitats and species present. A total of 11 transects distributed across the study area were sampled in the intertidal zone, whilst a final transect 'end' was sampled at the edge of the study area to the west (see Figure 1). An additional transect, labelled 'Point of Interest' ('POI'), was identified during the survey and was included due to the presence of good quality saltmarsh habitat. Due to the presence of very soft mud and sand in the mid to low shore posing a health and safety risk, the transects consisted of visual assessments from the upper most point (MHWS) of the upper, middle and lower shore environments which were used to identify and map the extent and distribution of the broad marine habitat types and species present. This is with the exception of transects 1 and 9, which were divided into three and two parts, respectively, to sample these separate shore environments. At each of the Phase I transect locations, an assessment of the percentage cover of opportunistic algae (including *Ulva* sp., *Chaetomorpha* sp., *Cladophora* sp., *Ceramium* sp., *Porphyra* sp., *Ectocarpus* sp., *Pilayella* sp.) was made as a means of assessing evidence of nutrient enrichment. This was undertaken using the methods detailed in guidance by WFD UK TAG (2014).

All field surveys were undertaken in accordance with the procedural guidelines outlined in the Marine Monitoring Handbook (Davies *et al.*, 2001). Photographs were taken and target notes recorded at the sampling stations including where any marine ecological features of interest were observed. The presence of any marine algae was also recorded, and notes were taken of any conspicuous fauna, as well as any evidence of, or potential for, the presence of protected and/or notable marine species.

The intertidal Phase II survey was undertaken in conjunction with the Phase I survey and involved taking intertidal cores for laboratory-based macroinvertebrate analysis, Particle Size Analysis (PSA) and Total Organic Carbon (TOC). In total, 16 sampling stations¹ were located across the intertidal zone between Mean High Water Springs (MHWS) and Mean Low Water Springs (MLWS) (see Figure 1 and Table 1). At each station, single 0.01 m² sediment cores to a depth of approximately 15 cm were taken. A sub-sample was removed for PSA and TOC analysis whilst the remaining sample was transferred to a suitably sized container and preserved using a 4% formalin solution for subsequent faunal analysis by a third-party laboratory where the sample was sieved through a 0.5 mm mesh.

Table 1. Phase II sample station coordinates

Station	Area	Decimal Degrees*		British National Grid (BNG)	
		Latitude	Longitude	Easting	Northing
B	Langstone Harbour	50.83757	-0.98424	471622	104718
C	Langstone Harbour	50.83783	-0.98421	471624	104747
D	Langstone Harbour	50.83788	-0.98348	471675	104753
E	Langstone Harbour	50.83764	-0.98334	471685	104726
F	Langstone Harbour	50.83691	-0.98311	471702	104645
G	Langstone Harbour	50.83602	-0.98187	471791	104548
K	Chichester Harbour	50.83871	-0.97971	471939	104849
L	Chichester Harbour	50.83804	-0.97985	471930	104775
M	Chichester Harbour	50.83702	-0.97995	471925	104661

¹ The number of sampling stations was reduced from the originally proposed 20 stations within the Scope of Works. This was due to the presence of soft sediment in the mid to low shore which posed as a health and safety risk, preventing samples being taken from these areas. The locations of each remaining station were adjusted to better sample the areas which could be accessed and to provide a representative assessment of the study area.

Station	Area	Decimal Degrees*		British National Grid (BNG)	
		Latitude	Longitude	Easting	Northing
N	Chichester Harbour	50.8376	-0.9798	471934	104726
O	Chichester Harbour	50.83765	-0.97989	471928	104731
P	Chichester Harbour	50.83826	-0.97975	471937	104799
Q	Chichester Harbour	50.83768	-0.97837	472035	104736
R	Chichester Harbour	50.83801	-0.97851	472025	104772
S	Chichester Harbour	50.83911	-0.97942	471959	104893
T	Chichester Harbour	50.83984	-0.97807	472053	104977

*The projected coordinate system is WGS_1984_Complex_UTM_Zone_30N

2.2 Laboratory and Data Analysis

2.2.1 Particle Size Analysis

PSA was undertaken by Ocean Ecology Limited (OEL) which is a North East Atlantic Marine Biological Quality Control (NMBAQC) participating laboratory. The analysis was completed in line with NMBAQC protocols (Mason, 2016), using dry sieving for the >1 mm fraction and laser diffraction for the fine fraction residue (<1 mm). Further information can be found in Appendix A.

The dry sieve and laser data were merged for each sample with the results expressed as a percentage of the whole sample. Once the data were merged, PSA statistics and sediment classifications were generated from the percentages of the sediment determined for each sediment fraction using the Gradistat v8 software (Blott and Pye, 2001).

Sediment descriptions were defined by their size class based on the Wentworth classification system (Wentworth, 1922) (Table 2). Statistics such as mean and median grain size, sorting coefficient, skewness and bulk sediment classes (percentage silt, sand and gravel) were also derived in accordance with the Folk classification (Folk, 1954).

Table 2. Classification used for defining sediment type based on the Wentworth Classification System (Wentworth, 1922)

Wentworth Scale	Phi units (ϕ)	Sediment Type
≥ 256 mm	≥ 8	Boulders
64 - 256 mm	-8 to -6	Cobble
4 - 64 mm	-6 to -2	Pebble
2 - 4 mm	-2 to -1	Granule
1 - 2 mm	-1 to 0	Very coarse sand
0.5 - 1 mm	0 to 1	Coarse sand
250 - 500 μ m	1 to 2	Medium sand
125 - 250 μ m	2 to 3	Fine sand
63 - 125 μ m	3 to 4	Very fine sand
15.63 - 63 μ m	4 to 5	Coarse silt
7.81 - 15.63 μ m	5 to 6	Medium silt
3.91 - 7.81 μ m	6 to 7	Fine silt
1.95 - 3.91 μ m	7 to 8	Very fine silt
<1.95 μ m	8 to 10	Clay

2.2.2 Macrofaunal Analysis

Macrobenthic analysis was undertaken by OEL in line with the NMBAQC Processing Requirement Protocol (PRP) (Worsfold and Hall, 2010). At OEL, the faunal samples were sieved over a 0.5 mm mesh and all fauna retained analysed to species level where possible. The biota were identified and counted by trained benthic taxonomists using the most up to date taxonomic literature and checked against existing reference collections and the World Register of Marine Species (WoRMS) for the latest taxonomic nomenclature. Colonial taxa (e.g. hydroids, bryozoans, and eggs) were identified to species level where possible and recorded as present (P).

Major group biomass (Annelida, Crustacea, Mollusca, and Anamalia) was measured to the nearest 0.0001 g blotted wet weight. As a standard, the conventional conversion factors as defined by Eleftheriou and Basford (1989) were then applied to provide equivalent dry weight biomass (Ash Free Dry Weight). A single reference collection preserved in 70% IDA of all taxa identified was retained for Quality Assurance (QA) purposes.

2.2.2.1 Univariate Analysis

As part of this report, the macrofaunal community structure and diversity was analysed using the following parameters:

1. abundance (N);
2. biomass (g);
3. species richness (S) (total number of species); and
4. species diversity (H' loge) (Shannon-Wiener index).

PRIMER v7 was used to calculate a series of univariate diversity metrics including species richness (S) and the Shannon-Weiner index (H' loge) at each station.

2.2.2.2 Multivariate Analysis

The PRIMER v7 software package (Clarke and Gorley, 2015) was utilised to undertake multivariate statistical analysis on the macrobenthic dataset. In order to fully investigate the community assemblage patterns in the data, a suite of analytical routines was employed – the results for which can be found in Section 3.2.4.

To remove the weighting of common or rare species within a sample, the data was first transformed (in this instance square-root transformed²). A similarity matrix, which groups samples based on their community assemblage, was then constructed, for which the Bray-Curtis coefficient (S') was produced. Following this, cluster analysis was performed which provides 'natural groupings' of samples which is displayed in a dendrogram. An additional 'similarity profile' (SIMPROF) permutation test was then used to find statistically similar cluster groupings. In addition, multi-dimensional scaling (MDS) plots were created, which gives a 2-dimensional representation of the similarity between samples. A Similarity Percentage analysis (SIMPER) test was then run to identify the individual species contributing the highest percentage to similarity within the cluster groupings.

To relate abiotic (environmental) factors to the biotic data, the BEST analysis was undertaken. This test identifies if any of the environmental variables measured are correlated with community patterns and provides a test statistic to determine which variables 'best explain'³ the community patterns. The BIOENV routine completes this analysis in combination with determining a test of significance to give a variable/combination of variables which correlates highest to the biotic community data. Prior to the analysis all abiotic data was normalised.

2.2.2.3 Ecological Quality

An assessment of the ecological quality of the infaunal communities was undertaken (Phillips *et al.*, 2014). The status of the sediment dwelling communities was determined using the Infaunal Quality Index (IQI) which was developed as part of the Water Framework Directive classification of transitional and coastal water bodies (Water Framework Directive TAG, 2008). The IQI is a multi-metric tool which utilises the AZTI Marine Biotic Index (AMBI), Simpson's evenness (a diversity index) and the number of taxa to produce an Ecological Quality Ratio (EQR) value which is a measure of the ecological quality of infaunal communities. From this, an IQI status can be assigned to a benthic community which can range from bad (<0.24) to high (0.75). Where possible, the most up to date AMBI ecological group scores were used, provided via the AMBI software (<http://ambi.azti.es>). Granulometric data for each sample was also used to inform the IQI analysis, as was the salinity regime ('coastal', 'mesohaline', 'oligohaline', 'polyhaline', and 'transitional').

² Data was transformed in order to prevent skewness and the presence of outliers. This was indicated by using a Draftsman Plot (a version of a scatter plot).

³ The variable or combination of variables with the highest correlation value. It must be noted that correlation does not necessarily imply causation.

The AMBI ecological groupings are as follows:

- AMBI EG-I: “Species very sensitive to organic enrichment and present under polluted conditions (Initial state)”;
- AMBI EG-II: “Species indifferent to organic enrichment, always present in low densities with non-significant variations over time (from initial state to slight unbalanced)”;
- AMBI EG-III: “Species tolerant to excess organic matter enrichment. These species may occur under normal conditions, but their populations are stimulated by organic enrichment (slight unbalanced situations)”;
- AMBI EG-IV: “Second order opportunistic species (slight to pronounced unbalanced situations), mainly small sized polychaetes”; and
- AMBI EG-V: “First-order opportunistic species (pronounced unbalanced situation)”.

2.2.3 Habitat Classification

Environmental, PSA and macrofaunal data obtained during the surveys was used to classify the habitats present in accordance with the European Union Nature Information System (EUNIS) classification system shown in Table 3 (EEA, 2012). This classification system uses standard descriptions called ‘biotopes’, which categorise habitats based on the marine zone, the physical nature of the habitat and the biological communities observed. For example, marine habitats can be divided into littoral (also known as intertidal) and subtidal zones, and then classified according to the physical nature of the substratum, either rock or sediment, and the biological community found. Habitats observed were recorded to the lowest level possible.

Table 3. Example of the five-level EUNIS classification system (EEA, 2012)

Level	Habitat Detail
1. Environment	Marine (A)
2. General Habitats	Littoral sediment (A2)
3. Broad Scale Habitat	Littoral mud (A2.3)
4. Biotope Complexes	Polychaete/oligochaete-dominated upper estuarine mud shores (A2.32)
5. Biotopes	A2.323 : <i>Tubificoides benedii</i> and other oligochaetes in littoral mud (A2.323)

2.3 Survey Limitations

Due to the presence of soft sand and mud in the mid to low shore (particularly in Chichester Harbour) posing a health and safety risk, the AECOM surveyors were unable to take intertidal core samples on the lower shore of the intertidal benthic habitat. However, samples were taken as low on the shore as possible, whilst the historic causeway was used to sample lower on the shore. Furthermore, visual assessments were made on the upper shore, rather than by walking on the upper, mid, and low shore. This made identifying saltmarsh species and habitats on the lower shores, more difficult.

Where the content of gravel was high on the surface sediment, it proved difficult to penetrate through the gravel to sample the less coarse material below using the intertidal core. This was most evident at station B where the content of gravel was highest, although a sample was still able to be taken. The foreshore in front of Langstone village (in Chichester Harbour) where hard engineering coastal protection has been proposed, consisted of predominantly shingle consisting of gravel. It was not possible to take intertidal cores at this location. Instead, numerous photos and notes were taken in order to characterise the habitat present within this area.

3. Results

3.1 Intertidal Phase I Survey

3.1.1 Broad-scale Habitats (Key Habitats and Species)

Results from the intertidal Phase I survey indicate that the study area can be divided into nine different broad-scale habitat types, with some variation in the dominant habitats found in Langstone Harbour compared to Chichester Harbour. These broad-scale habitats and their location are shown in Figure 11 and are discussed in more detail below. The location (grid-reference), the broad-scale habitats recorded, and photos for each of the transects are included in Appendix B.

A2.1: Littoral coarse sediment and Coastal Shingle (B2)

In Chichester Harbour, in front of Langstone Village, at the transects on the far east of the study area (transects 1, 2, and 3), 'littoral coarse sediment' (A2.1) was identified on the upper shore, consisting of predominantly gravel (see Figure 2). There was limited vegetation on this sediment, although there was some evidence of the presence of green algae. This habitat transitioned into 'coastal shingle' (B2) on the littoral fringe, above Mean High Water Springs (MHWS). This habitat extended in a westerly direction towards the Old Mill House (encompassing transect 4), but here was represented by a small strip of gravel between the sea wall and saltmarsh habitat. This strip consisted of a range of coastal vegetation, which was typically found at the fringe of the saltmarsh and shingle habitat. The presence of coastal vegetation decreased with distance from the Old Mill House, but included common halophyte species such as sea lavender (*Limonium vulgare*), lax-flowered sea lavender (*Limonium humile*), and occasional patches of glasswort (*Salicornia* sp.) (see Figure 3).

The presence of 'littoral coarse sediment' (A2.1), consisting of gravel with some evidence of green algae, extends from the Old Mill House, past the Royal Oak Havant public house, continuing to the slipway outside of the Ship Inn public house (see Figure 2). The habitat had little evidence of vegetation, although some patches of fringing saltmarsh habitat did occur on the lower limits of this habitat. From this area, a historic causeway, known as the 'Wadeway' which is medieval in date (built in the 14th Century) (Satchell, 2014), extended from the upper shore area to the very low shore, where it becomes covered by the main channel in Chichester Harbour (see Figure 2 and data for Transect 7). This causeway consisted of a raised bed of littoral coarse sediment with the presence of the blue mussel (*Mytilus edulis*), the Pacific oyster (*Magallana gigas*), and barnacles (*Semibalanus* sp.). These species were scattered (as one or two individuals) within the lower intertidal on and surrounding the causeway at Transect 7 (see Appendix B for photo record of Pacific oysters).



Figure 2. Coastal shingle (B2) and littoral coarse sediment (A2.1) at Transect 1 (top left) and Transect (6) (top right and bottom left); historic causeway, the 'Wadeway' (bottom right)



Figure 3. Coastal vegetation at transect 4: sea lavender (*Limonium vulgare*) (left), lax-flowered sea lavender (*Limonium humile*) (right), and glasswort (*Salicornia* sp.) (bottom)

Within Langstone Harbour (transects 9, and 10), shingle and gravel representing 'littoral coarse sediment' (A2.1) transitioning into 'coastal shingle' (B2) was present on the upper shore surrounding the bay which extended along the western side of the Langstone Spit. This sediment was covered in patches of dead and decaying brown algae on the strand line. On the upper fringe of this habitat, large areas of coastal vegetation were present including an abundance of sea beet (*Beta vulgaris*). On the lower shore, this sediment consisted of larger

boulders and cobbles, covered in green algae such as *Chaetomorpha* sp. and *Ulva lactuca*. Further along the shore, moving to the 'end' point of the Phase I survey (see Figure 1), similar 'littoral coarse sediment' (A2.1) and 'coastal shingle' (B2) is present. This habitat represented a shingle beach which extends into Mean Low Water Springs (MLWS); the lower shore consisting of mixed sediment (comprising mud, sand, cobbles, and boulders) with the presence of green filamentous algae. This shingle beach habitat was located from the spit at the mouth of the Langbrook Stream and continued to the beach in front of the Southmoor meadows.

A2.5: Coastal saltmarsh and saline reedbeds

Coastal saltmarsh habitat was present across both the Chichester and Langstone Harbour areas of the study site, and is represented by the following broad-scale habitats in Figure 11:

- Intermittent_A2.5: Coastal saltmarsh and saline reedbeds; A2.3: littoral mud; A2.4: Littoral mixed sediment;
- Sparse_A2.5: Coastal saltmarsh and saline reedbeds; A2.3: littoral mud; and
- Tidal Creek_A2.5: Coastal saltmarsh and saline reedbeds.

In Chichester Harbour, saltmarsh communities were present as a mosaic within an area of extensive intertidal mudflat habitat on the pioneer zone, with large amounts of fragmentation between communities. The saltmarsh habitat present in this area was identified as consisting of the cord-grass species *Spartina anglica*, and in general had low biodiversity overall (see Figure 4). Due to the limitations of working in very deep littoral mud and the ability to inspect these communities more closely, other species such as *Spartina maritima* and *Spartina alterniflora* were not identified. However, these species are known to occur in Chichester and Langstone Harbour, and have been identified on Hayling Island (Bardsley *et al.* 2021).

The density of saltmarsh habitat was highest at transect 4, in the eastern extent of the study area. However, the saltmarsh habitat became more fragmented and sparse westwards towards Langstone village. Beyond the slipway (located at the Ship Inn public house), there was no evidence of saltmarsh communities, with the habitat consisting of 'littoral mud' (A2.3) only. This intertidal mudflat habitat in Chichester Harbour, was the dominant habitat feature characterising the lower extent of the littoral area down to MLWS.

Small patches of 'littoral mixed sediment' (A2.4) were recorded sporadically within the areas of fragmented saltmarsh communities, consisting of gravel, shells, mud and sand. A number of channels were evident throughout Chichester Harbour, occurring between the fragmented saltmarsh communities. These were sources of freshwater inputs, including water running next to the Old Mill House and through a sluice gate from Langstone Mill Pond (see Figure 5).



Figure 4. Saltmarsh habitat located at transect 4 (left); *Spartina anglica* identified at transect 1 (right)



Figure 5. Channelisation in littoral mud (A2.3) (top left and right) and freshwater sources (Langstone Mill Pond sluice gate) (bottom)

Within Langstone Harbour, two tidal creeks were identified (transect 'POL' and during the walkover survey) where saltmarsh habitat was present and in good condition (see Figure 11). At both locations, the saltmarsh communities occurred in the pioneer zone above a small area of intertidal mud. The saltmarsh habitat was more diverse and densely populated than that found in Chichester Harbour, with more examples of low-mid marsh and pioneer zone communities present. These included golden samphire (*Limbarda crithmoides*), perennial glasswort (*Sarcocornia perennis*), sea lavender (*Limonium vulgare*), lax-flowered sea lavender (*Limonium humile*), *Spartina* sp., sea purslane (*Halimione portulacoides*), and glasswort (*Salicornia* sp.) (see Figure 6 showing examples of the pioneer zone communities present).

'Atlantic salt meadows saltmarsh' (1330) (including several communities such as SM4⁴: *Spartina maritima* community, SM5: *Spartina alterniflora* community, SM6: *Spartina anglica* community), 'Spartina swards' (1320) (SM6: *Spartina anglica* saltmarsh), and 'Salicornia and other annuals colonizing mud and sand' (1310) are all Annex I habitats and qualifying features of the Solent Maritime SAC.

⁴ SM codes refer to saltmarsh communities defined as part of the National Vegetation Classification (NVC) provided by the JNCC (2004)



Figure 6. Tidal creek saltmarsh habitat (west of A3023, transect POI) (top left); saltmarsh communities (top right); golden samphire (*Limbarda crithmoides*) (bottom left); second tidal creek (bottom right)

A1.3: Low energy littoral rock; A2.2: Littoral sand and muddy sand; A2.3: Littoral mud (Langstone Harbour – marine bay); A2.4: Littoral mixed sediment

Within Langstone Harbour (below the coarse sediment on the upper littoral fringe), the marine bay was divided into three distinct areas (see Figure 11) which were categorised into the following groups of broad-scale habitats:

- A1.3: Low energy littoral rock;
- A2.2: Littoral sand and muddy sand;
- A2.3: Littoral mud; and
- A2.4: Littoral mixed sediments.

'Low energy littoral rock' (A1.3) is found on sheltered to extremely sheltered rocky shores with weak tidal streams and are characterised by a dense cover of furoid seaweeds with distinct zones. Within the bay of Langstone Harbour, littoral rock in the form of boulders and cobbles were located along the upper-mid shore, extending south towards the spit and the disused trestle railway bridge (as part of the Hayling Island railway line) (transect 10, see Figure 7). The boulders were covered in bladder wrack (*Fucus vesiculosus*), serrated wrack (*Fucus serratus*), and spiral wrack (*Fucus spiralis*) as well as knotted wrack (*Ascophyllum nodosum*). Green algae such as *Chaetomorpha* sp. and *Ulva* sp. were also present. The sediment between the boulders was characterised by 'littoral mixed sediment' (A2.4) consisting of gravel and mud. A smaller area of littoral rock was identified around the groyne located close to transect 11.

On the mid-low shore of the southern area in the bay, the sediment consisted of sand and muddy sand which was compacted. This area has been categorised as the broad-scale habitats 'littoral sand and sandy mud' (A2.2) and 'littoral mud' (A2.3). Worm casts were visible across this habitat, and the green algae *Ulva* sp. and red algae *Ceramium* sp. were present sporadically. The characteristic sediment in this area transitioned as the Phase I survey moved further north in the bay (transect 11), where the content of sand decreased and was replaced by gravel. This area was categorised as 'littoral mixed sediment' (A2.4), which is poorly sorted and is generally found on sheltered shores. The gravel was present on the surface layer, with a higher proportion of mud below. Areas of 'littoral mud' (A2.3) were also present in fragments but generally increased in extent towards the lower shore.

Fucoid species were present on the surface of the 'littoral mixed sediment' (A2.4) habitat, including bladder wrack (*Fucus vesiculosus*) and serrated wrack (*Fucus serratus*).



Figure 7. Low energy littoral rock (A1.3) at Transect 10 (left) and 11 (right)

3.1.2 Nutrient Enrichment

At each of the Phase I transect locations, an assessment of the percentage cover of opportunistic algae was made as a means of assessing evidence of nutrient enrichment. This was undertaken using the methods detailed in guidance by WFD UK TAG (2014). The percentage cover of opportunistic algae was high across all stations (see Figure 8), ranging from 25% (transect 10) to 95% (transect 1). This is with the exception of transect 7, which was located on the historic causeway (the 'Wadeway'), and the assessment made at the POI transect, located in a tidal creek. In general, *Ulva lactuca* dominated the percentage cover across stations, forming large dense mats on the surface sediment (see Figure 9). In Chichester Harbour, these dense mats of *Ulva lactuca* covered most of the littoral area, with varying degrees of percentage cover. *Chaetomorpha* sp. dominated the percentage cover at transect 9 (see Figure 10), located in Langstone Harbour, whilst *Ulva intestinalis* made up a small percentage of the total cover across all stations (ranging from 2% and 10%).

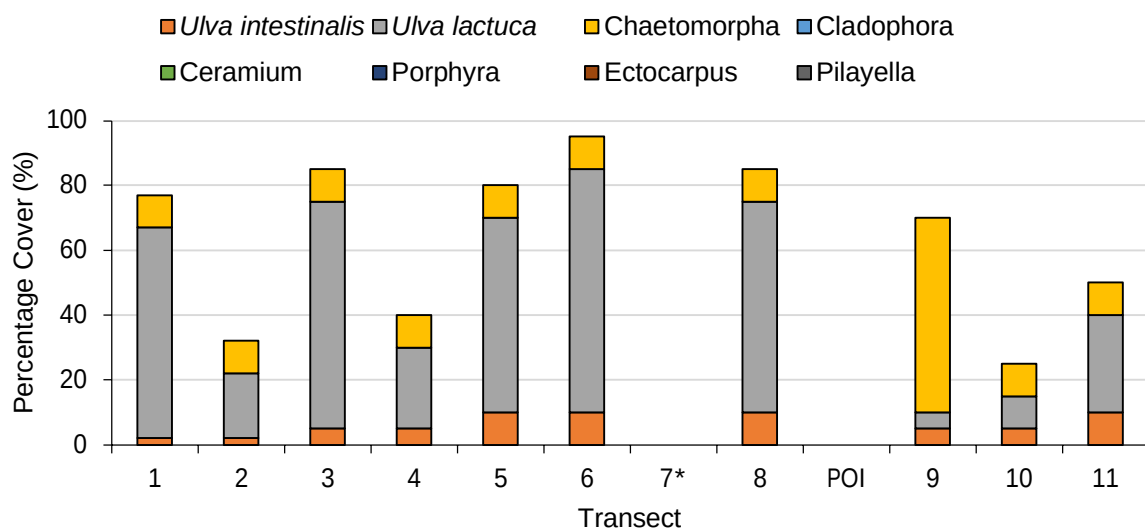


Figure 8. Percentage cover (%) of opportunistic algae recorded at each phase I transect

*Transect 7 was recorded on the historic causeway (the 'Wadeway') where there was no opportunistic algae cover



Figure 9. Example of dense mats of *Ulva* sp. at Transect 1 (left) and during the Phase II survey, near station N (right)



Figure 10. Example of *Chaetomorpha* sp. at Transect 9



Figure 11. Intertidal Phase I and II Broadscale Habitat and Biotope Map

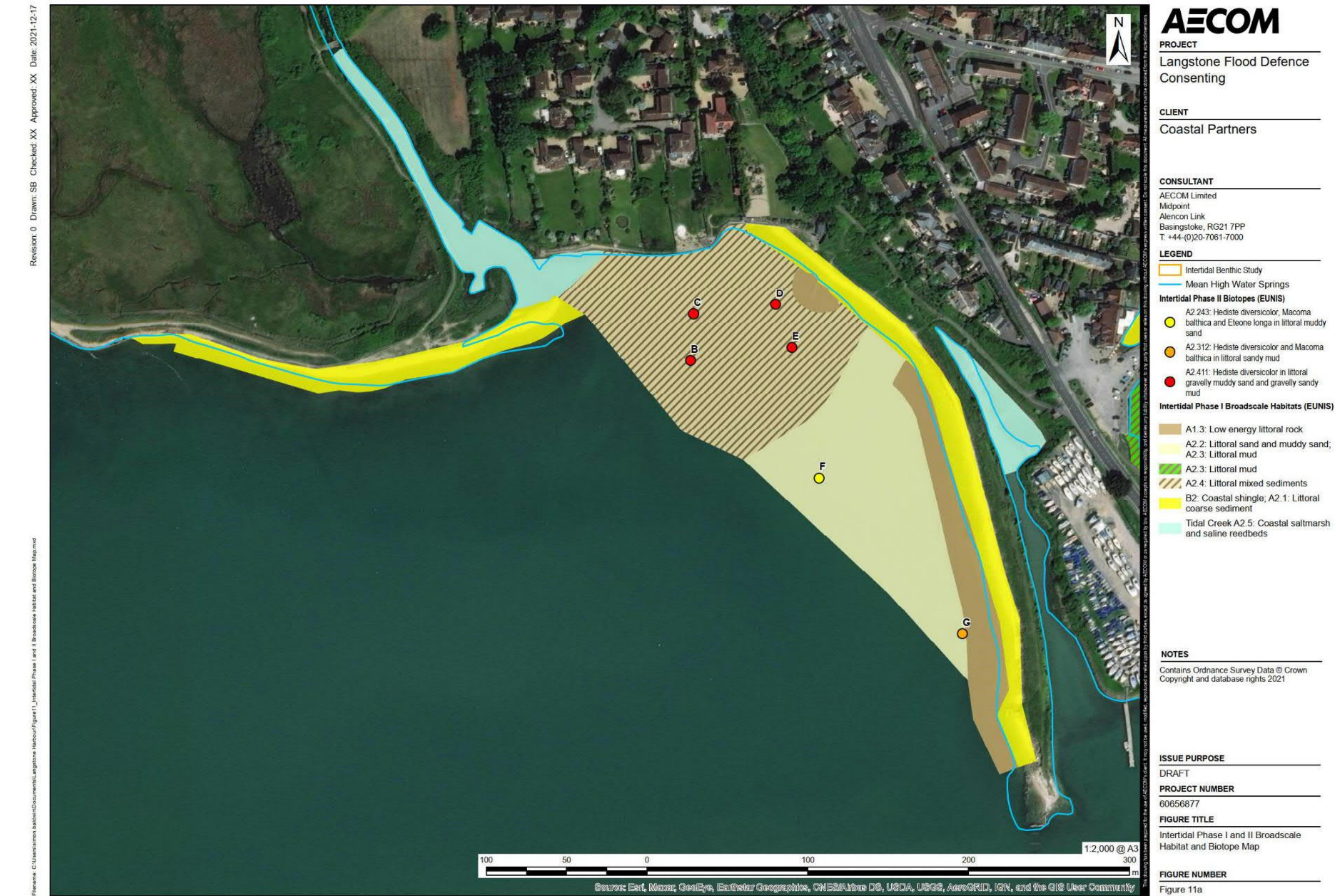


Figure 11a. Intertidal Phase I and II Broadscale Habitat and Biotope Map (Langstone Harbour – western extent)

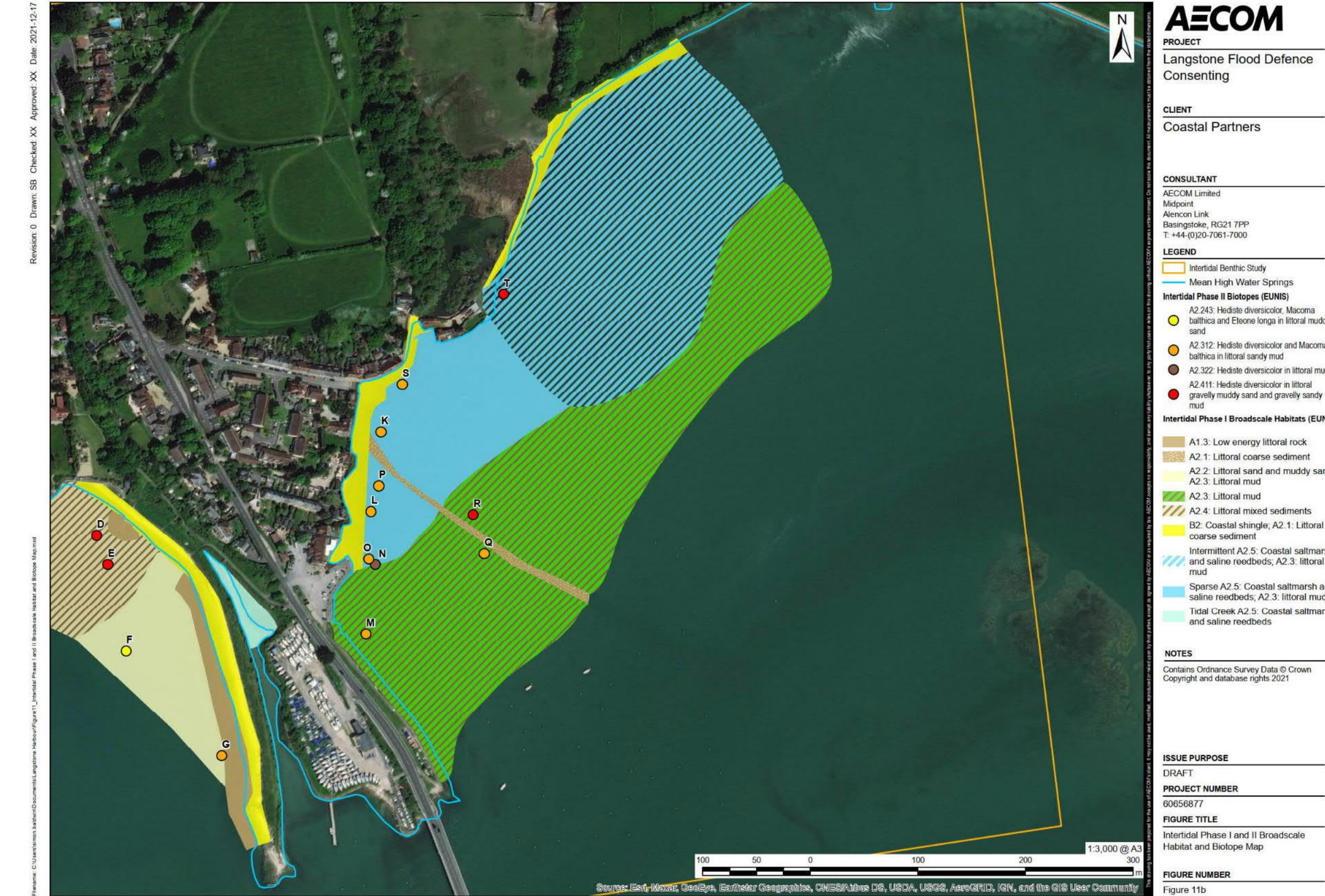


Figure 11b. Intertidal Phase I and II Broadscale Habitat and Biotope Map (Chichester Harbour – eastern extent)

3.2 Intertidal Phase II Survey

3.2.1 Particle Size Analysis (PSA)

The major sediment fractions at each sampling station are presented in Figure 12. The PSA data has been summarised and classified as per the Folk (1954) classification system (as described in Table 4). Stations (B - G) located in the west of the study area, in Langstone Harbour, comprised a relatively low component of mud (sediment $<63 \mu\text{m}$) which ranged from 2.5% (station F) to 25.6% (station D) (see Figure 1 for station locations). These stations comprised two areas, each consisting of either a sediment fraction that was dominated by gravel (sediment $\geq 2 \text{ mm}$) or sand (sediment $2 \text{ mm} > x \geq 63 \mu\text{m}$) (with some gradation in the content of sand between these areas). Stations B, C, D, and E all had a high content of gravel which represented greater than 50% of the total sediment fraction and were classified as either 'gravel', 'muddy gravel', or 'muddy sandy gravel'. The gravel at these locations was generally located on the surface of the sediment, below which the sediment consisted of mud and sand. Although station B had the highest content of gravel, it is thought that this is the result of the limitation of the intertidal core which proved difficult to penetrate through the gravel to sample the less coarse material below. Stations F and G consisted of predominantly sand (representing 97.5% and 79.7% of the total sediment content, respectively) and were classified as 'sand' and 'muddy sand'. No gravel was recorded at either of these stations.

The stations (K – T) located to the east of the study area, in Chichester Harbour, had a generally higher content of mud, with a small proportion of sand. Stations K, L, M, O, P, and S were all classified as 'sandy mud', which had a fraction of mud ranging from 67.0% to 87.9%, the remaining sediment consisting of sand only. Similarly, station N had a very high proportion of mud representing 93.0% of the total sediment content and was classified as 'mud'. The remaining stations (Q, R, and T) all had a sediment fraction which consisted of gravel. Stations Q and R, were located on either side of the historic causeway (the 'Wadeway', see Section 3.1.1), and had a gravel content of 4.6% and 6.6% and were classified as 'slightly gravelly sandy mud' and 'gravelly mud', respectively. Station T (the furthest station to the east), consisted of a mixture of gravel, sand, and mud (29.2%, 39.7%, and 31.1%), having the lowest proportion of mud of the stations sampled in Chichester Harbour.

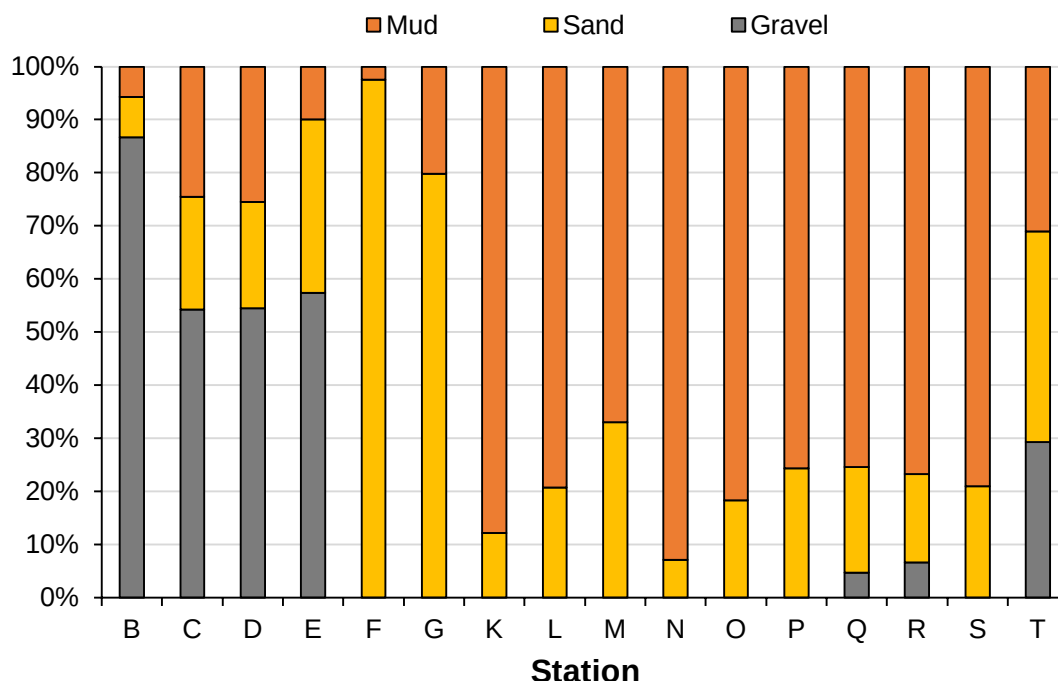


Figure 12. Major sediment fractions (%) at each sampling station

Stations B – G are located in Langstone Harbour; Stations K – T are located in Chichester Harbour

Table 4. Summarised PSA data as classified by Folk (1954)

Station no.	Area	Folk and Ward Description	Folk and Ward Sorting	Mean μ m	Mean phi	Sediment Classification	Modified Folk
B	Langstone Harbour	Medium Gravel	Very Poorly Sorted	15197.5	-3.926	Gravel	G
C	Langstone Harbour	Very Coarse Sand	Extremely Poorly Sorted	1764.3	-0.819	Muddy Gravel	mG
D	Langstone Harbour	Very Coarse Sand	Extremely Poorly Sorted	1166.5	-0.222	Muddy Gravel	mG
E	Langstone Harbour	Very Fine Gravel	Very Poorly Sorted	2192.1	-1.132	Muddy Sandy Gravel	msG
F	Langstone Harbour	Fine Sand	Well Sorted	202.8	2.302	Sand	S
G	Langstone Harbour	Fine Sand	Poorly Sorted	128.1	2.965	Muddy Sand	mS
K	Chichester Harbour	Medium Silt	Very Poorly Sorted	13.92	6.166	Sandy Mud	sM
L	Chichester Harbour	Coarse Silt	Very Poorly Sorted	20.57	5.603	Sandy Mud	sM
M	Chichester Harbour	Coarse Silt	Very Poorly Sorted	30.85	5.018	Sandy Mud	sM
N	Chichester Harbour	Medium Silt	Very Poorly Sorted	9.572	6.707	Mud	M
O	Chichester Harbour	Coarse Silt	Very Poorly Sorted	17.62	5.827	Sandy Mud	sM
P	Chichester Harbour	Coarse Silt	Very Poorly Sorted	23.17	5.432	Sandy Mud	sM
Q	Chichester Harbour	Coarse Silt	Very Poorly Sorted	24.50	5.351	Slightly Gravelly Sandy Mud	(g)sM
R	Chichester Harbour	Coarse Silt	Very Poorly Sorted	22.09	5.501	Gravelly Mud	gM
S	Chichester Harbour	Coarse Silt	Very Poorly Sorted	20.46	5.611	Sandy Mud	sM
T	Chichester Harbour	Medium Sand	Extremely Poorly Sorted	493.0	1.020	Gravelly Muddy Sand	gmS

3.2.2 TOC and Redox Layer

Total Organic Carbon (TOC) was measured as a percentage (%) of the total sediment sampled across all stations, the results of which are presented in Figure 13. In general, the highest TOC values were recorded in Chichester Harbour, with comparatively low values in Langstone Harbour. For example, TOC was highest at stations M, N, and O where the TOC was 6.82%, 6.52%, and 6.54% respectively. The TOC at stations B – G in Langstone Harbour ranged from 0.48% to 2.75.

At each station, once the sample had been taken, an assessment was made of the depth of the redox discontinuity layer. This layer appears as grey layer of sediment above a black anaerobic layer. Across all stations, the sediment was determined to be highly anoxic, with the redox layer occurring at 0.5-2 cm, below which the sediment was anoxic (see Figure 14).

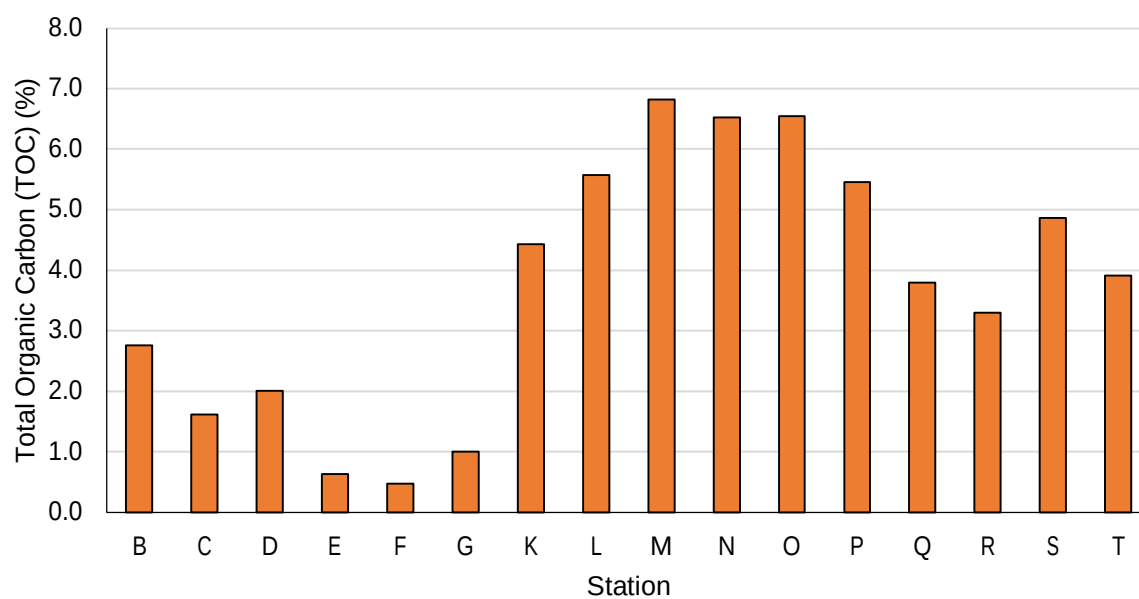


Figure 13. Percentage (%) of Total Organic Carbon (TOC) at each sampling station



Figure 14. Example of highly anoxic sediment within the study area (station S)

3.2.3 Macrobenthos

In total, 42 infaunal taxa were recorded across the 16 stations sampled. The macrobenthic community had a mean species richness of 11 taxa (stdev = ± 3.1) per sample. The mean abundance across all samples was 31,863 individuals/m² (stdev = $\pm 14,378$), which ranged from 63,400 individuals/m² at station K, and 10,600 individuals/m² at station R (see Figure 15). The raw data for macrofauna abundance can be found in Appendix C.

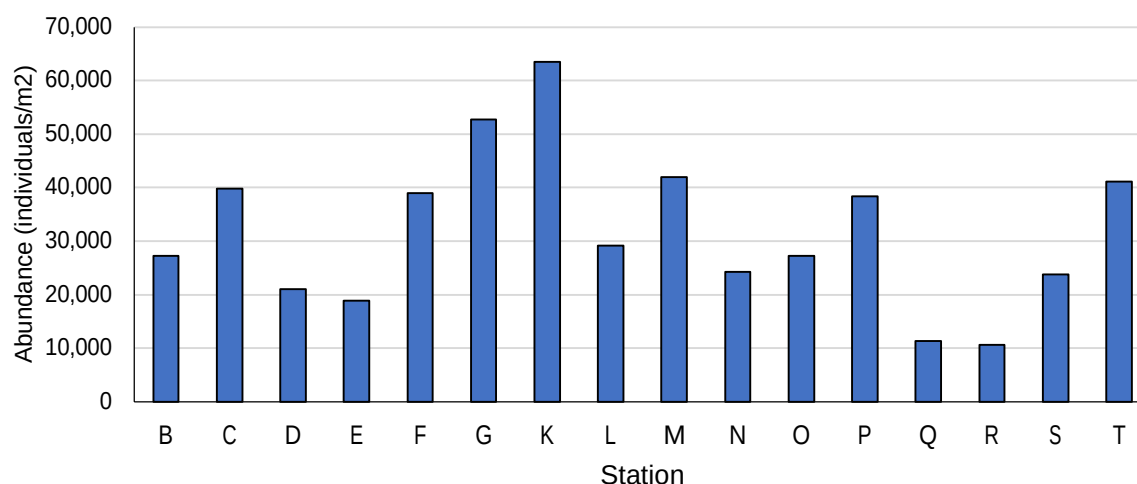


Figure 15. Abundance (individuals/m²) recorded at each of the 16 sampling stations

Gastropoda was the most abundant taxa recorded across all stations, with the small mud snail, *Peringia ulvae* representing the highest proportion of the overall abundance at 43.0% (see Figure 17). This species was recorded at all stations, but was most abundant at stations F, G, and K (see Figure 16), where 35,100, 40,200, and 46,100 individuals/m² were recorded. *Peringia ulvae* was recorded in the lowest abundance at stations M, and N (1,600 and 2,100 individuals/m², respectively). The only other Gastropod recorded was *Heterobranchia* sp., which was recorded in very low abundance at station T, only.

Oligochaeta were the second most abundant fauna recorded across all stations, and were found at all stations. The oligochaete species *Tubificoides benedii*, *Baltidrilus costatus*, and *Tubificoides pseudogaster* represented three of the top ten most abundant taxa during the Phase II survey, contributing 15.6%, 8.5%, and 0.7%, respectively (see Figure 17). In general, *Tubificoides benedii* was found in the highest abundances at stations in Chichester Harbour, particularly stations P and S (13,200 and 11,700 individuals/m², respectively).

Polychaeta was the next most dominant taxa, particularly *Capitella* sp., *Tharyx* sp., *Hediste diversicolor*, and *Streblospio shrubsolii* which collectively contributed 14.2% to the overall abundance. *Capitella* sp. were recorded in the highest abundance at station K (10,600 individuals/m²) and were generally absent from samples taken in Langstone Harbour, with the exception of relatively low numbers at station C and G where 100 individuals/m² were recorded, each. *Hediste diversicolor* was absent from stations F – L, Q, R, and T, and was found in the highest at station P (2,600 individuals/m²). All other polychaete taxa, including *Malacoceros vulgaris*, Nereididae, *Manayunkia aestuarina*, *Pygospio elegans*, and *Eteone longa*, were found sporadically.

Nematoda and the isopod *Cyathura carinata* were also found in high abundance, contributing 12.4% and 1.9% to the overall abundance across all stations, respectively. Nematoda was generally found in the lowest abundance in stations B – E in Langstone Harbour, and was absent from station B. In contrast, *Cyathura carinata* was only recorded at stations B – E, and stations G, where the abundance of this species ranged from 500 individuals/m² and 3,700 individuals/m².

The remaining taxa consisted of Bivalvia (including *Abra tenuis*, *Abra alba*, and *Cerastoderma edule*), Actiniaria, Amphipoda, Insecta (consisting of insect larvae of the long-legged fly family Dolichopodidae, and the non-biting midges family Chironomidae)⁵, Nemertea, Copepoda, and Decapoda, which collectively contributed 1.5% to the overall abundance across all stations. Actiniaria was recorded in low abundance (100 to 500 individuals/m²) at stations B – E, only.

⁵ These are not marine animals but there are species in this groups closely associated with riverine and coastal sediments in Britain (Drake, 2018).

The total biomass of all fauna recorded at each station was measured. Across all stations faunal biomass was dominated by annelida (composed of oligochaetes and polychaetes) and mollusca (bivalves and gastropods) (24.04 g (stdev = ± 22.67) and 114.63 (stdev = ± 142.36), respectively). The raw data for macrofauna biomass can be found in Appendix C.

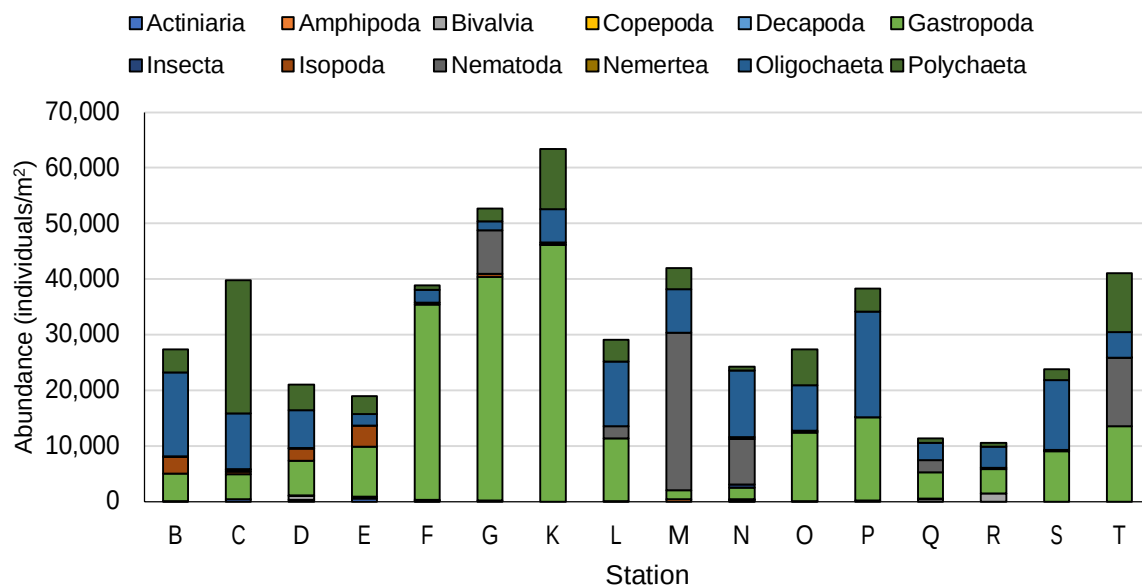


Figure 16. Relative contribution of the major taxonomic groups to the total abundance (individuals/m²) recorded at each of the sampling stations

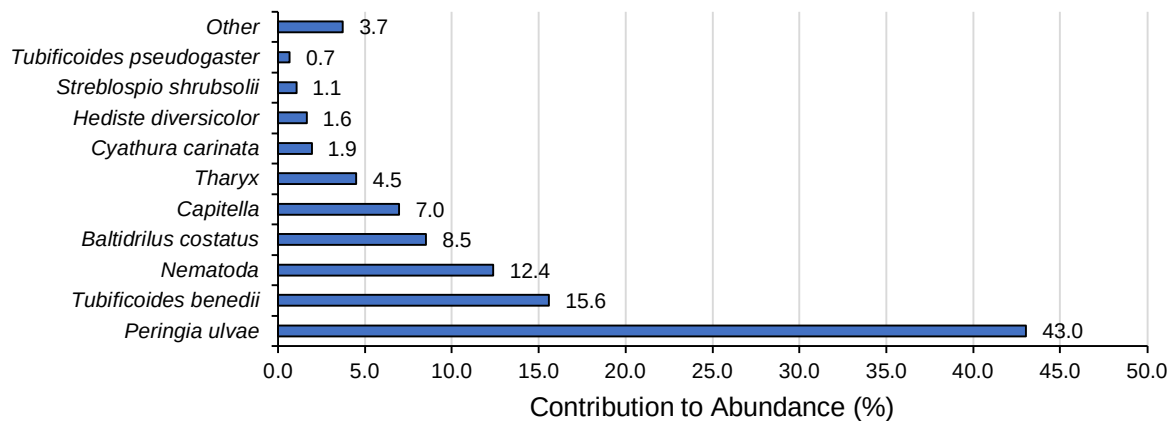


Figure 17. Percentage (%) contribution of all recorded taxa to average abundance across all sampling stations

The species richness (total number of species, S) and diversity (Shannon diversity index, H') at each station is presented in Figure 18. Species richness was highest at station C (S = 10), whilst the highest diversity index was recorded at station D (H' = 1.871). In general, the highest species richness and diversity index values were recorded at stations B – E, and lowest at the remaining stations, the lowest diversity index value being recorded at station F (H' = 0.450). However, of these remaining stations, species richness remained relatively higher (comparable to stations B – E) at stations G, N, and O, whilst higher diversity index values were recorded at stations N and T.

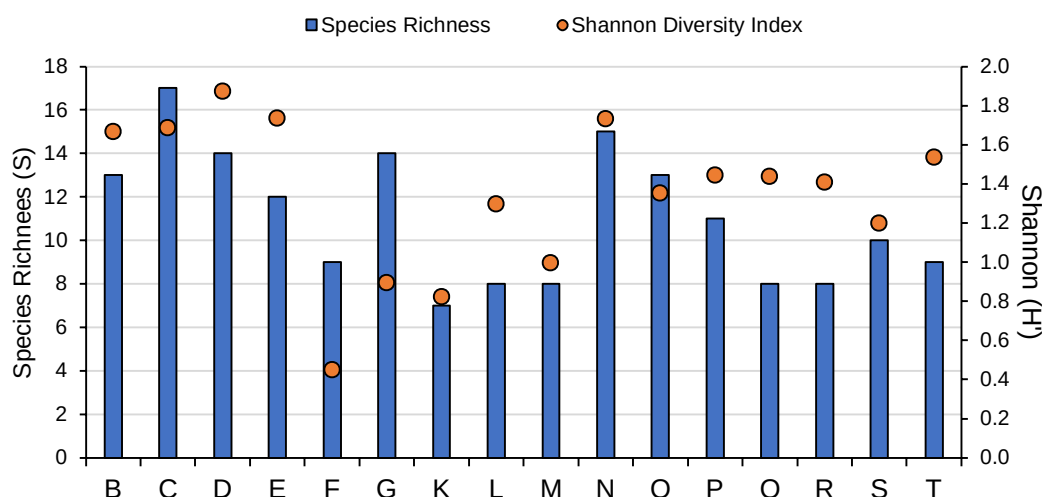


Figure 18. Species richness (S) and Shannon diversity index (H') recorded at each sampling station

3.2.4 Multivariate Analysis

Figure 19 shows the non-metric MDS plot⁶ of the community abundance data (square root transformed) from each station, following the Bray-Curtis dissimilarity analysis. Samples with greater similarities in species composition are placed closer to one another on the plot with more dissimilar samples placed further away.

The MDS plot shows a general clustering of samples from those taken in Chichester Harbour, particularly stations K – M and O – T. Stations taken from Langstone Harbour, including station B – E and to lesser extent stations G and F, were dissimilar to the community composition of these samples. Some dissimilarity in faunal communities compared to other samples was also evident for station N.

Cluster analysis and a SIMPROF test has identified five discrete groups of samples. The results of these tests have been overlaid on the MDS plot (Figure 19) and are reported in full on a cluster dendrogram in Figure 20. These analyses show conformity between those stations recorded in Chichester harbour, with group 'e' consisting of the majority of these stations (K – P, S, T). The remaining stations in this area, were assigned as group 'c' (stations N) and 'd' (stations Q and R, which were taken either side of the historic causeway, the 'Wadeway'). Group 'a' consists of the stations taken in Langstone Harbour where the gravel content was higher (stations B – E), whilst stations F and G were assigned to group 'b' where the proportion of sand was higher.

⁶ A multi-dimensional scaling (MDS) plots gives a 2-dimensional representation of the similarity between samples.

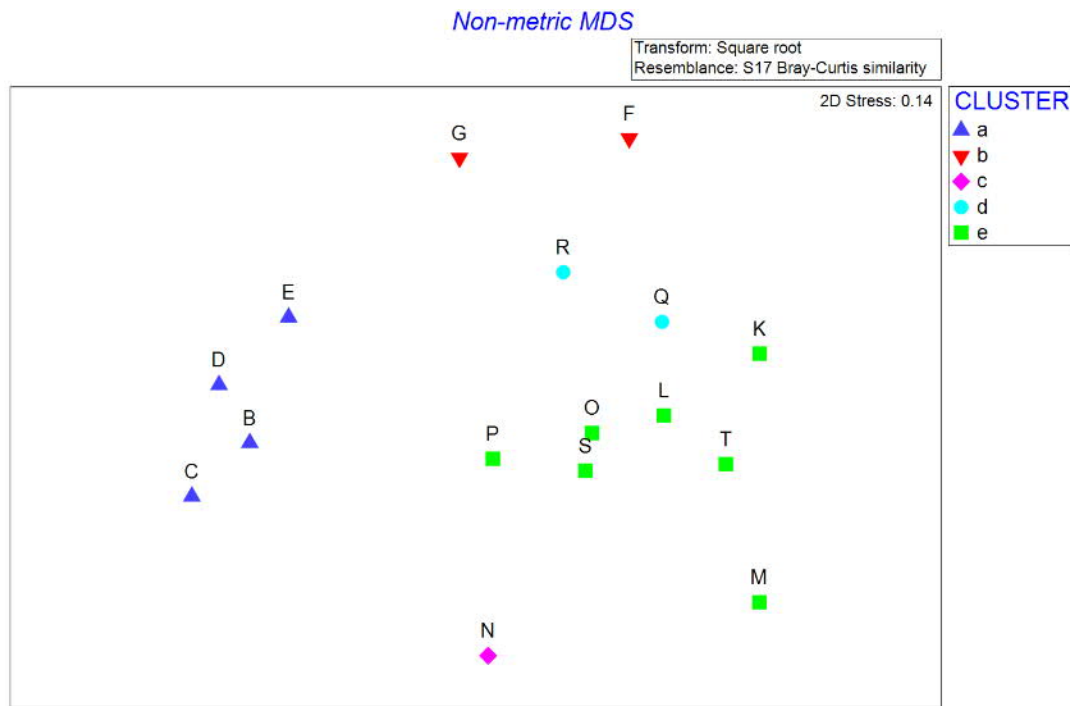


Figure 19. Non-metric MDS plot of community abundance data (square root transformed), with results of SIMPROF cluster analysis overlaid (station letters labelled)

SIMPER analysis has identified the key taxa which contribute the most to within group similarity in community composition. The results of the analysis are presented in Table 5. The species *Peringia ulvae* and *Tubificoides benedii* were both found to be key contributors to group similarity across all groups. For group 'a', *Baltidrilus costatus*, *Cyathura carinata*, and *Hediste diversicolor* were also found to contribute highly to similarity, as did *Capitella* sp. for group 'e'. Group 'c' consisted of one sample only (station N) and therefore no SIMPER results were produced. However, Nematoda, *Baltidrilus costatus*, *Tubificoides benedii*, and *Peringia ulvae* had the highest abundances at this station.

Table 5. Results of SIMPER analysis, comparing within cluster group similarity

Group A	Group B	Group C*
<i>Peringia ulvae</i> (22.76%)	<i>Peringia ulvae</i> (68.73%)	Nematoda
<i>Baltidrilus costatus</i> (17.51%)	<i>Tubificoides benedii</i> (9.71%)	<i>Baltidrilus costatus</i>
<i>Cyathura carinata</i> (12.02%)		<i>Tubificoides benedii</i>
<i>Hediste diversicolor</i> (9.50%)		<i>Peringia ulvae</i>
<i>Tubificoides benedii</i> (9.08%)		
Group D	Group E	
<i>Peringia ulvae</i> (40.36%)	<i>Peringia ulvae</i> (31.90%)	
<i>Tubificoides benedii</i> (34.42%)	<i>Tubificoides benedii</i> (30.47%)	
	<i>Capitella</i> (17.63%)	

*Less than two samples present in group and therefore no SIMPER results were produced. The species shown signify those that dominated the total abundance for that sample.

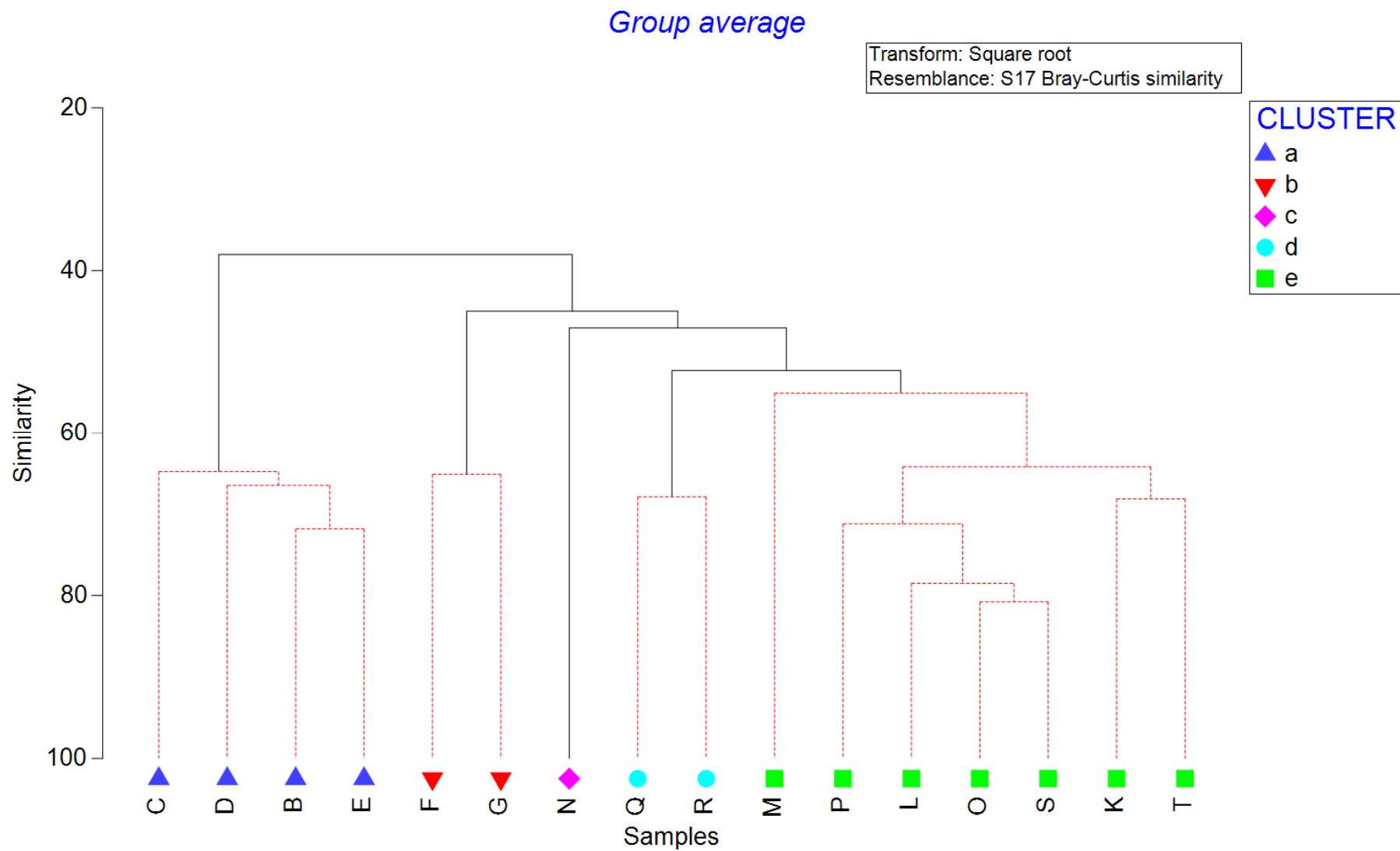


Figure 20. Cluster dendrogram of community abundance data (square root transformed), with results of SIMPROF cluster analysis overlaid

3.2.5 Environmental Data

The non-metric MDS plot for sediment data, presented in Figure 21, shows the Folk (1954) classifications of each sample overlaid on the faunal MDS plot. This gives a description of the sediment characteristics at each station, providing some explanation as to the difference in the benthic species assemblage for each sample.

A clustering of samples classified as 'mud', 'slightly gravelly sandy mud', 'gravelly mud', and 'sandy mud' comprised cluster groups 'c', 'd', and 'e', which were located in Chichester Harbour. This is with the exception of station T (group 'e') which was classified as 'gravelly muddy sand'. In Langstone Harbour, the cluster of stations which comprised group 'a' were classified as 'gravel', 'muddy gravel', and 'muddy sandy gravel', whilst stations F and G (group 'b') were classified as 'sand' and 'muddy sand'. Given the consistency in sediment classifications between cluster groups, it appears that sediment explains to some extent the dissimilarity between stations.

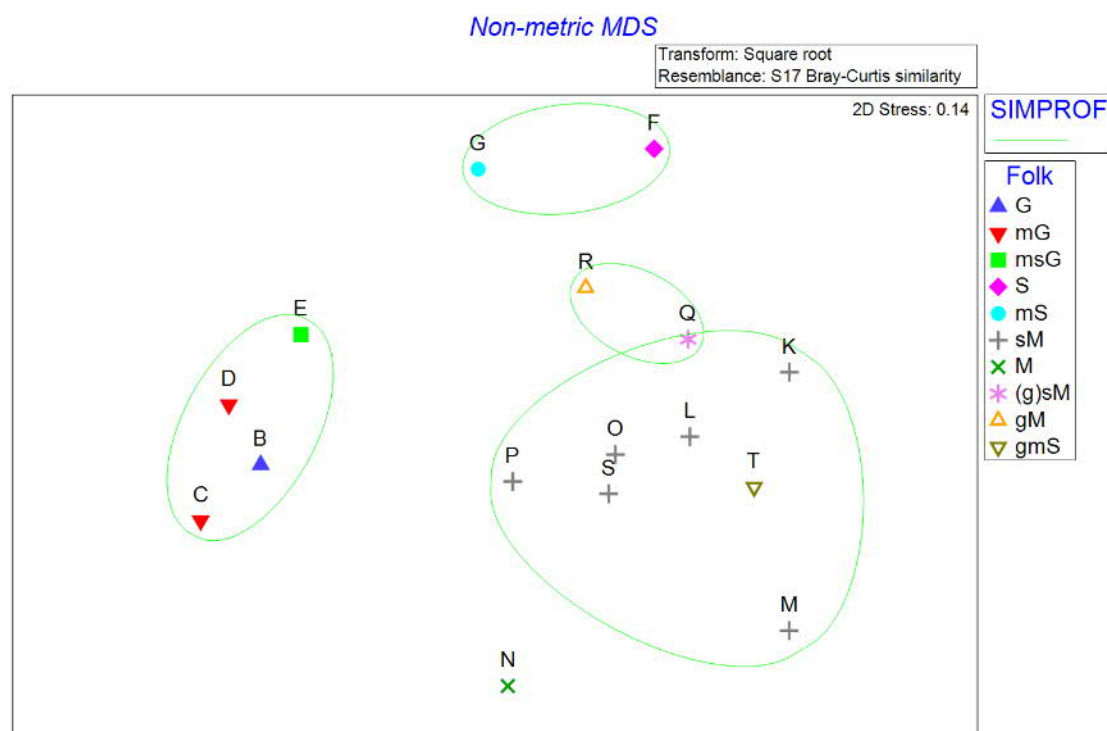


Figure 21. Non-metric MDS plot of community abundance data (square root transformed), with respect to Folk (1954) classification for each station (labels represent cluster groupings)

A BEST analysis, using the BIOENV method, was undertaken to determine if various abiotic factors could explain the dissimilarity between samples. The analysis was run looking at both mean particle size, the percentage content of mud, sand, and gravel in the sediment of each station, and the percentage of TOC recorded at each station. The results of the Global BEST Test indicated that a combination of both the percentage sediment content of gravel and TOC provided the best explanation for faunal community dissimilarity ($\rho = 0.631$). The next best explanation for dissimilarity was the percentage sediment content of gravel, mud, and TOC ($\rho = 0.582$). Looking at each variable individually, mean particle size has the highest correlation value overall ($\rho = 0.479$), although this was low when compared to using a combination of variables.

3.2.6 Environmental Quality

An EQR value has been calculated for each Phase 2 sample station, providing an overall infaunal quality index (IQI) status using Water Framework Directive (WFD) classification metrics, which includes a combination of AZTI Marine Biotic Index (AMBI) scores (ecological groupings, AMBI-EG's I-V, of sensitive and opportunistic species), Simpson's evenness, and environmental data (sediment PSA and salinity) (WFD TAG, 2008; Phillips *et al.*, 2014). The results of these calculations are presented in Figure 22.

Almost all stations were categorised as having 'Moderate' IQI status. This is with the exception of station G which had 'Good' IQI status, and is located in Langstone Harbour. This station was characterised by the presence of *Peringia ulvae*, Nematoda, *Streblospio shrubsolii* which are all assigned to AMBI-EG's III ('species tolerant'). This is in contrast to the remaining stations which were characterised by higher abundances of *Tubificoides benedii*,

Baltidrilus costatus, *Cyathura carinata*, and *Capitella* sp. which are all assigned to AMBI-EG's V ('First-order opportunistic species') (although *Peringia ulvae* was still dominant at most stations).

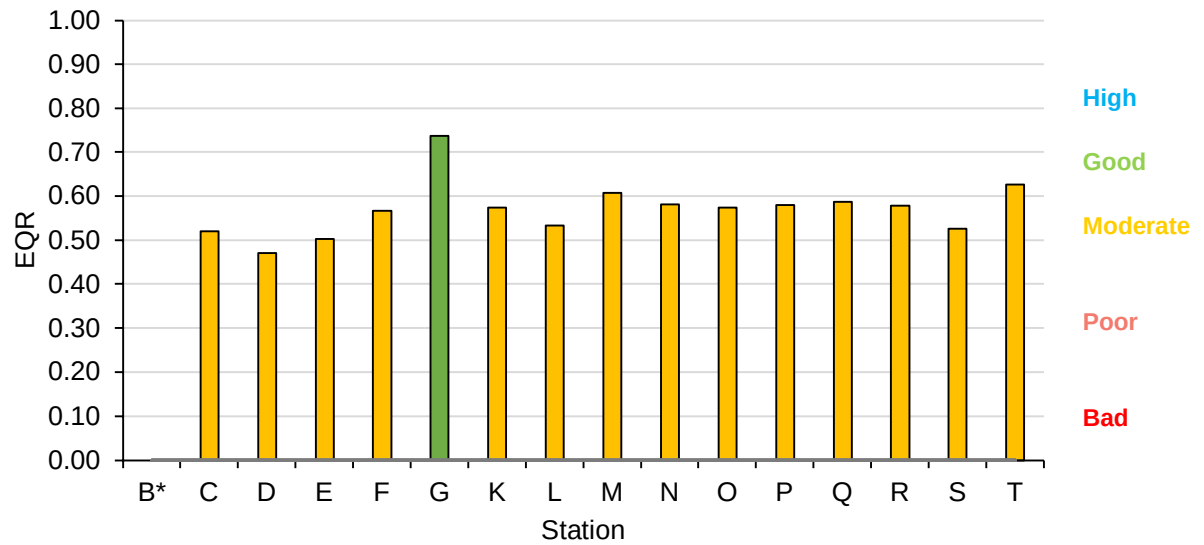


Figure 22. Mean ecological quality ratio (EQR) scores at each station to inform the overall infaunal quality index (IQI) status

*Sediment at station B was too coarse for an EQR score to be produced. It is considered that the EQR value at this station would be equivalent to stations C, D, or E

Ecological status boundaries for the IQI: High/Good = 0.75; Good/Moderate = 0.64; Moderate/Poor = 0.44; Poor/Bad = 0.24

3.3 Biotope Descriptions

The following biotopes and their descriptions were sampled at each of the Phase II stations and are based upon the descriptions outlined within the EUNIS habitat classification system (EEA, 2012). A habitat map showing the locations of these biotopes and the wider broad-scale habitats (for descriptions see section 3.1.1) are provided in Figure 11. The broadscale habitats listed below, including 'littoral sand and muddy sand' (A2.2), 'littoral mud' (A2.3), and 'littoral mixed sediments' (A2.4) are all representative of the Annex I habitats (as per the EU Habitats Directive) 'estuaries', 'mudflats and sandflats not covered by seawater at low tide', 'coastal lagoons', and 'large shallow inlets and bays'. Of these Annex I habitats, 'estuaries', 'mudflats and sandflats not covered by seawater at low tide', 'coastal lagoons' are all a qualifying feature of the Solent Maritime SAC but only the 'estuaries' and 'mudflats and sandflats not covered by seawater at low tide' features are present in the Langstone study area.

3.3.1 Littoral Sand and Muddy Sand (A2.2)

'Littoral sand and sandy mud' (A2.2) was identified during the Phase I and II survey in Langstone Harbour, where the sediment was comprised of predominately sand and a very small mud component (see Figure 11).

A2.243: *Hediste diversicolor*, *Limecola balthica* and *Eteone longa* in littoral muddy sand

MHCBI: LS.LSa.MuSa.HedMacEte

Stations: F

Description: This biotope is found at the lower extreme of estuaries, and in moderately exposed and sheltered bays and marine inlets, sometimes subject to variable salinity. The sediment consists of fine to very fine muddy sand. This biotope can occur on the mid shore, with A2.31 communities in muddier sediments on the lower shore.

The infaunal community is often dominated by the polychaetes *Eteone longa*, *Hediste diversicolor* and *Pygospio elegans*. The oligochaetes such as *Tubificoides benedii* and *Tubificoides pseudogaster* often characterise the community compositions, as do the crustaceans *Corophium volutator* and *Crangon crangon*. The spire shell *Peringia ulvae*, the baltic tellin *Limecola balthica*, the cockle *Cerastoderma edule* may also be abundant. The sand gaper *Mya arenaria* may be superabundant, though these species are not always present, or may be missed in core samples due to their large size. The polychaetes *Arenicola marina*, *Polydora cornuta* and *Capitella capitata*, the shrimp *Crangon crangon*, and the Mussel *Mytilus edulis* are sometimes present.



Figure 23. Biotope A2.243 at station F

3.3.2 Littoral Mud (A2.3)

'Littoral mud' (A2.3) often forms extensive mudflats as was identified in the intertidal Phase I (see Section 3.1.1) and II survey (see Figure 11).

A2.312: *Hediste diversicolor* and *Limecola balthica* in littoral sandy mud

MHCBI: LS.LMu.MEst.HedMac

Stations: G, K, L, M, O, P, Q, S

Description: This biotope is found in lower estuaries, sheltered bays and marine inlets, often subject to variable salinity occurring on mid and lower shore sandy mud or mud. This biotope may occur on the mid/lower shore of estuarine shores, with biotope A2.243 on the upper shore.

The main characterising species of this biotope are the ragworm *Hediste diversicolor*, the baltic tellin *Limecola balthica*, and the oligochaetes *Tubificoides benedii* and *Tubificoides pseudogaster*. Other polychaete species which are often common or abundant include *Pygospio elegans*, *Streblospio shrubsolii*, *Tharyx killariensis*, *Aphelocheata marioni*, *Capitella capitata* and *Manayunkia aestuarina*. The oligochaete *Baltidrilus costatus* and the amphipod *Corophium volutator* may also be abundant as could the spire shell *Peringia ulvae*. Other species which occur in a significant proportion of samples include the polychaetes *Eteone longa* and *Nephtys hombergii*, and bivalves such as the cockle *Cerastoderma edule* and *Abra tenuis*.



Figure 24. Biotope A2.312 at station K

A2.322: *Hediste diversicolor* in littoral mud

MHCBI: LS.LMu.UEst.Hed

Stations: N

Description: This biotope is found in sheltered marine inlets and estuaries, where the salinity is reduced or variable. The sediment for this habitat consists of mud and sandy mud shores and usually occurs lower on the shore (although can occur higher on the shore). The sediment remains water saturated during low tide and consists of an anoxic layer that occurs in the upper 5 cm of the surface and in some cases close to the surface. This biotope may occur on the same shores as units A2.312.

The infaunal community is often dominated by the polychaete *Hediste diversicolor*, as well as *Streblospio shrubsolii* and *Manayunkia aestuarina* which have a limited salinity range tolerance. Oligochaetes are often abundant, including *Baltidrilus costata* and *Tubificoides benedii*, whilst the amphipod *Corophium volutator* is often common.



Figure 25. Biotope A2.322 at station N

3.3.3 Littoral Mixed Sediment (A2.4)

'Littoral mixed sediment' (A2.4) is often found on mudflats in patches, which support infaunal communities which are similar to those of mud and sandy mud shores.

A2.411 - *Hediste diversicolor* in littoral gravelly muddy sand and gravelly sandy mud

MHCBI: LS.LMx.GvMu.HedMx

Stations: B⁷, C, D, E, R, T

Description: This biotope consists of sheltered gravelly sandy mud, found on the mid and lower shore where there is variable salinity. It is probable that there are broad transition areas between the sub-biotopes of A2.411, and the corresponding muddy sediment biotopes.

The infaunal community consists of *Hediste diversicolor*, *Pygospio elegans*, *Streblospio shrubsolii*, and *Manayunkia aestuarina* as well as oligochaetes (*Tubificoides* spp. and *Baltidrilus costata*), the amphipod *Corophium volutator*, the spire shell *Peringia ulvae*, and the bivalve *Limecola balthica*. Low densities of *Scrobicularia plana* can also be found.

⁷ Although station B had a high content of gravel and was therefore classified as 'littoral coarse sediment' (A2.1), it is thought that this is the result of the limitation of the intertidal core which proved difficult to penetrate through the gravel to sample the less coarse material below. Therefore, this station has been considered to be representative of 'littoral mixed sediment' (A2.4)



Figure 26. Biotope A2.411 at station D

3.4 Priority Habitat, Species and INNS

The biotopes '*Hediste diversicolor* and *Limecola balthica* in littoral sandy mud' (A2.312), '*Hediste diversicolor* in littoral mud' (A2.322), and '*Hediste diversicolor*, *Limecola balthica* and *Eteone longa* in littoral muddy sand' (A2.243) qualify as habitats of principal importance being listed under Section 41 of the NERC Act 2006 and belong to the habitat type, 'intertidal mudflats'. Whilst the biotope '*Hediste diversicolor* in littoral gravelly muddy sand and gravelly sandy mud' (A2.411) may occur as part of the habitat of principal importance 'sheltered muddy gravels'. Furthermore, the broadscale habitats which these biotopes represent, including 'littoral sand and muddy sand' (A2.2), 'littoral mud' (A2.3), and 'littoral mixed sediments' (A2.4) are all representative of the Annex I habitats (as per the EU Habitats Directive) 'estuaries', 'mudflats and sandflats not covered by seawater at low tide', 'coastal lagoons', and 'large shallow inlets and bays'. Of these Annex I habitats, 'estuaries', 'mudflats and sandflats not covered by seawater at low tide' and 'coastal lagoons' are all a qualifying feature of the Solent Maritime SAC but only the 'estuaries' and 'mudflats and sandflats not covered by seawater at low tide' features are present in the Langstone study area.

In addition to the habitats discussed above, the intertidal Phase I survey identified areas of 'coastal saltmarsh and saline reedbeds' (A2.5). This habitat also qualifies as a habitat of principal importance being listed under Section 41 of the NERC Act 2006 and belong to the habitat type, 'coastal saltmarsh'. Blue mussels were found scattered along the historic causeway in Chichester Harbour. However, these did not represent blue mussel beds which are considered a habitat of principle importance. In addition, seagrass (such as *Zostera marina*) was not recorded within the study area.

No species afforded conservation protection were recorded during the intertidal phase II surveys. However, pacific oyster (*Magallana gigas*) was found sporadically along the historic causeway (during the Phase I survey) and is considered to be an Invasive Non-Native Species (INNS).

4. Discussion

The results of the intertidal Phase I survey indicate that the study area can be divided into nine different broad-scale habitat types, with some variation in the dominant habitats found in Langstone Harbour compared to Chichester Harbour. In general, the upper shore and littoral fringe in both harbours was dominated by 'littoral coarse sediment' (A2.1) and 'coastal shingle', which was particularly evident in the foreshore in front of Langstone village.

In Chichester Harbour, saltmarsh communities were present as a mosaic within an area of extensive intertidal mudflat habitat on the pioneer zone, with large amounts of fragmentation between communities. The saltmarsh habitat present in this area was identified as consisting of the cord-grass species *Spartina anglica*, and in general had low biodiversity overall. Extensive stands of monoculture of *Spartina anglica* are thought to be of limited value to wildlife. They can be considered a threat to feeding waders, which are thought to decrease with increasing *Spartina anglica*, although there is no known causal effect determined between these variables (Bardsley *et al.*, 2020). Despite this, *Spartina anglica* forms part of the designated feature for the Solent Maritime SAC and acts as a precursor to saltmarsh development. Within Langstone Harbour, two tidal creeks were identified where the saltmarsh habitat was more diverse and densely populated than that found in Chichester Harbour, with more examples of low-mid marsh and pioneer zone communities present. These included golden samphire (*Limbarda crithmoides*), perennial glasswort (*Sarcocornia perennis*), sea lavender (*Limonium vulgare*), lax-flowered sea lavender (*Limonium humile*), *Spartina* sp., sea purslane (*Halimione portulacoides*), and glasswort (*Salicornia* sp.). The Solent Maritime SAC is designated for the Annex I habitats: *Spartina* swards (*Spartinion maritimae*) (1320); Atlantic salt meadows (*Glauco-Puccinellietalia maritimae*) (1330); and *Salicornia* and other annuals colonizing mud and sand (1310). Although Chichester Harbour consists of a large area of saltmarsh which has been labelled as England's seventh largest saltmarsh, there has been a continued loss and degradation of this habitat in the Harbour (Bardsley *et al.*, 2021), which was evident during the intertidal benthic survey.

In Langstone Harbour, the habitat along Langstone Spit was determined to be 'low energy littoral rock' (A1.2) located along the upper-mid shore, extending south towards the disused trestle railway bridge (as part of the Hayling Island railway line). On the mid-low shore of the southern area in the bay, the sediment consisted of sand and muddy sand which was compacted. This area has been categorised as the broad-scale habitats 'littoral sand and sandy mud' (A2.2) and 'littoral mud' (A2.3). The characteristic sediment in this area transitioned as the Phase I survey moved further north in the bay (transect 11), where the content of sand decreased and was replaced by gravel. This area was categorised as 'littoral mixed sediment' (A2.4), which is poorly sorted and is generally found on sheltered shores.

Four biotopes were recorded across the 16 Phase II sampling stations, the community compositions of which, although similar, were characterised by sediments of varying composition. Across all stations, the spire shell *Peringia ulvae* and the oligochaete *Tubificoides benedii* were the dominant species, having the highest contribution to overall abundance.

Stations (B - E) sampled in Langstone Harbour in the northern extent of the bay, were classified as the biotope '*Hediste diversicolor* in littoral gravelly muddy sand and gravelly sandy mud' (A2.411), which is generally found on the mid and lower shore where there is variable salinity (likely due to the influence of the nearby Langbrook Stream). These stations had a high content of gravel generally located on the surface of the sediment, below which the sediment consisted of mud and sand. The diversity at these stations was relatively high, the characterising species (other than *Peringia ulvae* and *Tubificoides benedii*) being the oligochaete *Baltidrilus costatus*, the isopod *Cyathura carinata*, and the polychaete *Hediste diversicolor*. This biotope was also recorded at station T and R, although the community composition at these stations was closer to other sample stations in Chichester Harbour, having a higher content of mud. The presence of gravel at these stations can likely be explained in part by their proximity to 'littoral coarse sediment' (A2.1) on the upper shore (station T) and on the historic causeway, the 'Wadeway' (station R).

The remaining stations in Chichester Harbour were classified as either the biotope '*Hediste diversicolor* and *Limecola balthica* in littoral sandy mud' (A2.312) or '*Hediste diversicolor* in littoral mud' (A2.322). Both biotopes are found in sheltered marine inlets, sheltered bays and estuaries and are often found on the same shores. The distinction between these biotopes at each station was based on the content of sand. Station N, where the content of sand was 7% was classified as the biotope '*Hediste diversicolor* in littoral mud' (A2.322). Station N had a high diversity and was characterised by the taxa Nematoda and the oligochaete *Baltidrilus costatus*. This is in contrast to the remaining stations which had a higher abundance of *Capitella* sp..

The biotope '*Hediste diversicolor* and *Limecola balthica* in littoral sandy mud' (A2.312) was also recorded at station G, located in Langstone Harbour. However, the community composition at this station was more similar to station F, which was also located in Langstone Harbour, both stations having a very high content of sand. These stations were characterised by the oligochaete *Tubificoides benedii* and spire shell *Peringia ulvae*, the latter species being recorded in the highest abundance at these stations. Diversity at these stations was low, although slightly higher at station G where the content of mud was higher. Station F was classified as the biotope '*Hediste diversicolor*, *Limecola balthica* and *Eteone longa* in littoral muddy sand' (A2.243) and is found at the lower extreme of estuaries, and in moderately exposed and sheltered bays and marine inlets, sometimes subject to variable salinity.

The biotopes '*Hediste diversicolor* and *Limecola balthica* in littoral sandy mud' (A2.312), '*Hediste diversicolor* in littoral mud' (A2.322), and '*Hediste diversicolor*, *Limecola balthica* and *Eteone longa* in littoral muddy sand' (A2.243) qualify as habitats of principal importance being listed under Section 41 of the NERC Act 2006 and belong to the habitat type, 'intertidal mudflats'. Whilst the biotope '*Hediste diversicolor* in littoral gravelly muddy sand and gravelly sandy mud' (A2.411) may occur as part of the habitat of principal importance 'sheltered muddy gravels'. Furthermore, the broadscale habitats which these biotopes represent, including 'littoral sand and muddy sand' (A2.2), 'littoral mud' (A2.3), and 'littoral mixed sediments' (A2.4) are all representative of the Annex I habitats (as per the EU Habitats Directive) 'estuaries', 'mudflats and sandflats not covered by seawater at low tide', 'coastal lagoons', and 'large shallow inlets and bays'. Of these Annex I habitats, 'estuaries', 'mudflats and sandflats not covered by seawater at low tide' and 'coastal lagoons' are all a qualifying feature of the Solent Maritime SAC but only the 'estuaries' and 'mudflats and sandflats not covered by seawater at low tide' features are present in the Langstone study area. In addition to the habitats discussed above, the intertidal Phase I survey identified areas of 'coastal saltmarsh and saline reedbeds' (A2.5). This habitat also qualifies as a habitat of principal importance being listed under Section 41 of the NERC Act 2006 and belong to the habitat type, 'coastal saltmarsh'.

Multivariate analysis determined that the grouping of the intertidal benthic communities within the study area can be explained in part by the sediment classification of the samples, in particular the percentage sediment content of gravel. Physical environmental factors, such as general circulation, tidal currents and wave exposure play an important part in determining the local nature of sediments via the processes of siltation and erosion, though biotic factors such as inhabiting species which stabilise the sediment are also important (Thrush, 1991). The sediment particle distribution can determine the favourability of a particular environment to certain species (Dauvin *et al.*, 2004). Therefore, to a certain extent the differences seen in the faunal community at stations B – E and stations F/G compared to other stations, can be attributed to the higher content of gravel and sand in these areas, respectively.

Total Organic Carbon (TOC) was also found to be an important factor that correlated with the nature of the benthic communities. There were elevated levels of TOC identified at stations M, N, and O (in Chichester Harbour), whilst the lowest TOC content was recorded at stations B – G in Langstone Harbour. Organic content is generally positively correlated with the sediment percent fines, which may explain in part why levels of TOC were elevated in Chichester Harbour (Nelson, 2020). However, high organic enrichment can have negative impacts on the benthic communities, reducing overall diversity (Ansari, 2014). The presence of organic wastes, such as domestic sewage, induce the formation of hydrogen sulphides and the reduction in benthic biota. Across all stations, the sediment was determined to be highly anoxic, with the redox layer occurring at 0.5-2 cm (below which the sediment was anoxic) indicating high levels of hydrogen sulphides. Furthermore, high levels of nutrient enrichment was evident across the study area, indicated by large mats of opportunistic algae (such as *Ulva lactuca*), with the highest percentage cover found in Chichester Harbour. The key anthropogenic nutrients known to be entering Chichester Harbour are phosphorus and nitrogen, and in 2008 the harbour was designated as a polluted water (eutrophic) under the Nitrates Directive and a Nitrate Vulnerable Zone was established in the catchment (Bardsley *et al.*, 2021). Further work is required to determine the sources of the high nutrients in the harbour, although these are likely to be from agricultural run-off and sewage outfalls in the area. Smothering of pioneer saltmarsh has been evident from previous studies, with rotting opportunistic algae recorded across the harbour (Bardsley *et al.*, 2021). During the intertidal Phase I and II survey, no other anthropogenic influences were noted such as from bait digging, and scars from fishing. However, channelisation within Chichester Harbour was noted, and likely from freshwaters inputs, such as the outfall adjacent to the Old Mill house.

The ecological status of macrobenthic infaunal invertebrate assemblages at all stations was 'Moderate', with the exception of station G for which the status was 'Good'. Communities classified as 'Moderate' are generally characterised by the presence of first-order opportunistic and tolerant taxa which are indicators of pollution, with a general absence of sensitive taxa to high levels of organic enrichment and pollution (Phillips *et al.*, 2014). Those assigned as having a 'Good' IQI status represents habitats which are only slightly disturbed. The stations

classified as 'Moderate', characterised by higher abundances of *Tubificoides benedii*, *Baltidrilus costatus*, *Cyathura carinata*, and *Capitella* sp., are likely the result of higher levels of nutrient and organic enrichment in these areas.

No species afforded conservation protection were recorded during the intertidal phase II surveys. However, pacific oyster (*Magallana gigas*) was found sporadically along the historic causeway (during the Phase I survey) and is considered to be an Invasive Non-Native Species (INNS).

5. Conclusion

The Phase I and Phase II intertidal benthic survey, undertaken as part of the Langstone FCERM Scheme in August 2021, sampled the area adjacent to the scheme within Langstone and Chichester Harbour to highlight key intertidal benthic receptors that may be affected by the scheme. Within this area is a range of habitats including saltmarsh habitat and intertidal mudflat habitat located in Chichester and Langstone Harbour. A summary of the findings of this survey is provided below:

- The intertidal Phase I survey revealed that the study area can be divided into nine broad-scale habitats, which in Chichester Harbour consists of saltmarsh communities that were present as a mosaic within an area of extensive intertidal mudflat habitat on the pioneer zone, with large amounts of fragmentation between communities. The saltmarsh habitat present in this area was identified as consisting of the cord-grass species *Spartina anglica*, and in general had low biodiversity overall. More diverse and densely populated saltmarsh habitat was recorded in two tidal creeks identified in Langstone Harbour. The Solent Maritime SAC is designated for the Annex I habitats: *Spartina* swards (*Spartinion maritimae*) (1320); Atlantic salt meadows (*Glauco-Puccinellietalia maritimae*) (1330); and *Salicornia* and other annuals colonizing mud and sand (1310).
- In general, the upper shore and littoral fringe in both harbours was dominated by 'littoral coarse sediment' (A2.1) and 'coastal shingle', which was particularly evident in the foreshore in front of Langstone village.
- During the intertidal Phase II survey, the intertidal mudflat was identified as consisting of the biotopes '*Hediste diversicolor* and *Limecola balthica* in littoral sandy mud' (A2.312), '*Hediste diversicolor* in littoral mud' (A2.322), '*Hediste diversicolor*, *Limecola balthica* and *Eteone longa* in littoral muddy sand' (A2.243), and '*Hediste diversicolor* in littoral gravelly muddy sand and gravelly sandy mud' (A2.411).
- These biotopes qualify as habitats of principal importance being listed under Section 41 of the NERC Act 2006 and belong to the habitat type 'intertidal mudflats'. Whilst the biotope '*Hediste diversicolor* in littoral gravelly muddy sand and gravelly sandy mud' (A2.411) may occur as part of the habitat of principal importance 'sheltered muddy gravels'. In addition to the habitats discussed above, the intertidal Phase I survey identified areas of 'coastal saltmarsh and saline reedbeds' (A2.5). This habitat also qualifies as a habitat of principal importance being listed under Section 41 of the NERC Act 2006 and belongs to the habitat type, 'coastal saltmarsh'.
- Furthermore, the broadscale habitats which these biotopes represent, including 'littoral sand and muddy sand' (A2.2), 'littoral mud' (A2.3), and 'littoral mixed sediments' (A2.4) are all representative of the Annex I habitats (as per the EU Habitats Directive) 'estuaries', 'mudflats and sandflats not covered by seawater at low tide', 'coastal lagoons', and 'large shallow inlets and bays'. Of these Annex I habitats, 'estuaries', 'mudflats and sandflats not covered by seawater at low tide', 'coastal lagoons' are all a qualifying feature of the Solent Maritime SAC but only the 'estuaries' and 'mudflats and sandflats not covered by seawater at low tide' features are present in the Langstone study area.
- Elevated levels of TOC were identified in Chichester Harbour, which corresponded to a high percentage cover of opportunistic algae (indicating nutrient enrichment), and highly anoxic sediment, with the redox layer occurring at 0.5-2 cm. Chichester Harbour was designated as a polluted water (eutrophic) under the Nitrates Directive in 2008 and a Nitrate Vulnerable Zone was established in the catchment (Bardsley *et al.*, 2020). Further work is required to determine the sources of the high nutrients in the harbour, although these are likely to be from agricultural run-off and sewage outfalls in the area.
- No species afforded conservation protection were recorded during the intertidal phase II surveys. However, Pacific oyster (*Magallana gigas*) was found sporadically along the historic causeway (during the Phase I survey) and is considered to be an INNS.

6. References

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Appendix A Particle Size Analysis (PSA) Methodology

Introduction

The method used involved drying all sediments at 80°C for at least 24 hours prior to dry-sieving all samples and only laser sizing the <2 mm fraction if >5 % of the whole sample was found to be <63 µm. Oven drying sediment causes the aggregation of particles in muddy sediments (>5 % mud) and for these reasons, such sediments should not be oven dried prior to particle size analysis (Mason, 2016). Therefore, a visual assessment of all thawed sediment samples was undertaken prior to drying to ensure the optimal analysis technique was used. Due to the obvious presence of mud in a large proportion of samples, some with a considerable mud content in excess of 5 %, all samples were analysed via a combination of both dry sieving (>1 mm fraction) and laser sizing (<1 mm fraction).

Sample Preparation

Frozen sediment samples were first transferred to a drying oven and thawed at 80°C for at least six hours prior to visual assessment of sediment type and wet sieving over a 1 mm sieve. Before any further processing (e.g. sieving or sub-sample removal), samples were mixed thoroughly with a spatula and all conspicuous fauna (>1 mm) which appeared to have been alive at the time of sampling were removed from the sample.

Dry Sieving

The >1 mm fraction was then returned to a drying oven and dried at 80°C for at least 24 hours prior to dry sieving. Once dry, the sediment sample was run through a series of Endecott BS 410 test sieves (nested at 0.5 φ intervals) using a Retsch AS200 sieve shaker to fractionate the samples into particle size classes. The dry sieve mesh apertures used are given in Table A-1.

Table A-1: Sieve series employed for Particle Size Analysis (PSA) by dry sieving (mesh size in mm)

Sieve aperture (mm)

63	45	31.5	16	11.2	8	5.6	4	2.8	2	1.4	1
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The sample was transferred onto the coarsest sieve at the top of the sieve stack, which was then shaken for a standardised period of 20 minutes. The sieve stack was then checked to ensure the components of the sample had been fractionated as far down the sieve stack as their diameter would allow. A further 10 minutes of shaking was undertaken if there was evidence that particles had not been properly sorted (e.g. veneers of silt overlying coarse fractions).

Laser Diffraction

The fine fraction residue (<1 mm sediments) was transferred to a suitable container and allowed to settle for 24 hours before excess water was syphoned from above the sediment surface. The fine fraction was analysed by laser diffraction using a wet element Beckman Coulter LS 13320. Due to the silty nature of the sediments, ultrasound was used to agitate particles and prevent aggregation of fines.

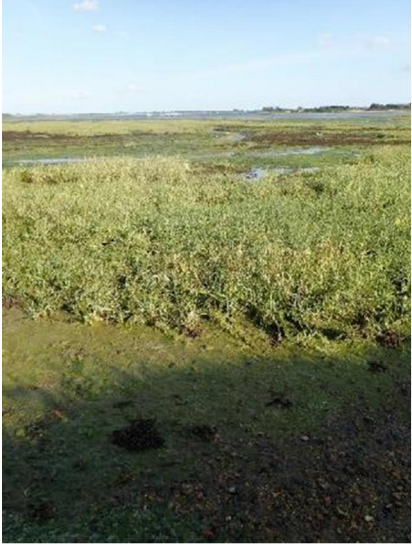
Appendix B Phase I Transect Photos

Phase I Transects

Table A-2: Photos of intertidal Phase I sampling stations

Transect number and coordinates	Broadscale Habitat	Photos
1_1 (upper shore) SU 72186 05196	B2: Coastal shingle; A2.1: Littoral coarse sediment	

1_2 (mid shore)	Intermittent_A2.5: Coastal saltmarsh and saline reedbeds; A2.3: littoral mud		
1_3 (lower shore)	Intermittent_A2.5: Coastal saltmarsh and saline reedbeds; A2.3: littoral mud		

2 SU 72108 05131	B2: Coastal shingle; A2.1: Littoral coarse sediment (right photo) And Intermittent_A2.5: Coastal saltmarsh and saline reedbeds; A2.3: littoral mud (left photo)		
3 SU 72086 05082	B2: Coastal shingle; A2.1: Littoral coarse sediment (right photo) And Intermittent_A2.5: Coastal saltmarsh and saline reedbeds; A2.3: littoral mud (left photo)		

4	B2: Coastal shingle; A2.1: Littoral coarse sediment (left photo)	
SU 72048 04995	And Intermittent_A2.5: Coastal saltmarsh and saline reedbeds; A2.3: littoral mud (right photo)	
5	Sparse_A2.5: Coastal saltmarsh and saline reedbeds; A2.3: littoral mud	

6
SU 71928 04869

B2: Coastal shingle; A2.1:
Littoral coarse sediment
(left photo)

And

Sparse_A2.5: Coastal
saltmarsh and saline
reedbeds; A2.3: littoral
mud (right photo)



7
SU 72145 04688

A2.1: Littoral coarse
sediment

Note Pacific oysters
(INNS) in right hand photo



8

A2.3: Littoral mud

SU 71902 04697



POI

Tidal Creek_A2.5: Coastal
saltmarsh and saline
reedbeds

SU 71810 04679



9_1
SU 71769 04663

A1.3: Low energy littoral
rock



9_2
SU 71755 04650

A2.2: Littoral sand and
muddy sand; A2.3: Littoral
mud



10 SU 71800 04498	A1.3: Low energy littoral rock And A2.2: Littoral sand and muddy sand; A2.3: Littoral mud	
11 SU 71616 04776	A2.4: Littoral mixed sediments (left photo) And A1.3: Low energy littoral rock (right photo)	

End
SU 71313 04729

B2: Coastal shingle; A2.1:
Littoral coarse sediment



Appendix C Raw Macrofauna Data

Table A-3: Raw macrofauna abundance (individuals) per station

Station	B	C	D	E	F	G	K	L	M	N	O	P	Q	R	S	T
Animalia (eggs)	-	-	-	-	-	-	-	-	P	-	-	-	-	-	-	-
Annelida																
Arenicolidae	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Baltidrilus costatus	130	90	60	8	-	-	1	1	1	78	2	55	-	2	2	4
Capitella	-	1	-	-	-	1	106	34	36	3	55	7	7	-	14	92
Chaetozone vivipara	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
Enchytraeidae	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-
Eteone longa	-	-	-	-	-	-	-	-	-	2	3	1	-	1	1	-
Glycera alba	1	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
Hediste diversicolor	21	12	10	7	-	-	-	-	2	2	2	26	-	-	2	-
Malacoceros vulgaris	2	1	-	-	-	-	2	4	-	-	2	7	-	-	3	8
Manayunkia aestuarina	-	16	2	-	-	-	-	-	-	-	-	-	-	-	-	-
Microphthalmus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6
Nereididae	6	6	3	10	-	2	-	-	-	-	-	1	-	-	-	-
Polydora cornuta	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pygospio elegans	-	-	1	-	6	3	-	-	-	-	-	-	-	1	-	-
Spio martinensis	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
Streblospio shrubsolii	8	14	-	12	2	10	-	1	-	-	1	-	1	5	-	-
Tharyx	3	187	30	3	-	5	-	-	-	-	1	-	-	-	-	-
Tubificoides benedii	18	7	8	10	23	7	59	116	77	32	78	132	32	36	117	42
Tubificoides pseudogaster	3	3	-	2	-	8	-	-	-	8	2	2	-	-	6	-

Tubificoides swirencoides	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
Arthropoda																
Aoridae	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-
Carcinus maenas	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
Chironomidae	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1	-
COPEPODA	-	-	-	-	1	2	-	-	-	-	-	-	1	-	-	-
Crangon crangon	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
Cyathura carinata	30	5	22	37	-	5	-	-	-	-	-	-	-	-	-	-
DECAPODA	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-
Dolichopodidae	-	-	-	-	-	-	-	-	-	6	-	-	-	-	-	-
Melita palmata	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-
Photis longicaudata	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-
Cnidaria																
ACTINIARIA	1	4	3	5	-	-	-	-	-	-	-	-	-	-	-	-
Mollusca																
Abra	-	-	-	-	-	-	-	-	-	1	-	-	2	-	-	-
Abra alba	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-
Abra tenuis	-	-	6	-	-	-	-	1	-	-	-	2	2	14	-	-
Cardiidae	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
Cerastoderma edule	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
HETEROBRANCHIA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4
Peringia ulvae	49	45	62	90	351	402	461	112	16	21	123	149	47	44	90	131
Ruditapes philippinarum	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
Nematoda	-	3	1	1	3	79	4	22	284	81	2	1	22	3	2	123
Nemertea	1	1	-	-	-	-	-	-	-	4	1	-	-	-	-	1

Table A-4: Raw macrofauna biomass (grams) per station

Station	B	C	D	E	F	G	K	L	M	N	O	P	Q	R	S	T
Animalia (misc)	0.0018	0.0086	0.0079	0.02	0.0002	0.0008	0.0004	0.0001	0.0004	0.02	0.0009	0	0.0002	0.0002	0.0001	0.0125
Annelida	0.861	0.5863	0.2467	0.2424	0.0582	0.0292	0.1538	0.2424	0.0596	0.1337	0.2415	0.4606	0.0315	0.0342	0.2633	0.2025
Crustacea	0.0149	0.0085	0.0724	0.0409	0.0133	0.0108	0	0	0.0024	0.001	0	0	0.0001	0	0	0.0001
Mollusca	0.174	0.1969	4.287	0.2425	3.4812	0.8085	4.0043	1.0724	0.0722	0.14	0.6145	0.5244	0.2541	0.5274	1.1392	0.8023