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Langstone Village Saltmarsh Restoration Benthic Survey 2024: Technical Report.

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Abbreviations

AFDW	Ash Free Dry Weight
AL	Action Level
AONB	Area of Outstanding Natural Beauty
BAC	Background Assessment Concentration
BSH	Broad Scale Habitat
BUDS	Beneficial Use of Dredged Sediment
CCO	Channel Coastal Observatory
CSQG	Canadian Sediment Quality Guideline
EA	Environment Agency
EPA	Environmental Protection Agency
ERL	Effect Range Low
EUNIS	European Nature Information System
dGPS	Differential Global Positioning System
HOCI	Habitats of conservation interest
IDA	Industrial Denatured Alcohol
INNS	Invasive Non-Native Species
ISO	International Organization for Standardization
ISQG	International Sediment Quality Guideline
JNCC	Joint Nature Conservation Committee
LOD	Limit of Detection
MMO	Marine Management Organisation
MNCR	Marine Nature Conservation Review
NERC	Natural Environment and Rural Communities
NMBAQC	NE Atlantic Marine Biological Analytical Quality Control
nMDS	Non-metric Multidimensional Scaling
NRW	National Resources Wales
OEL	Ocean Ecology Ltd
PAH	Polycyclic Aromatic Hydrocarbons
PCA	Principal Component Analysis
PCB	Polychlorinated Biphenyl
PEL	Probable Effect Level
PSD	Particle Size Distribution
SAC	Special Area of Conservation
SEPA	Scottish Environmental Protection Agency
SOCI	Species of conservation interest
SPA	Special protection area
SRDB	Saltmarsh Restoration Drag Box
SSSI	Site of special scientific interest
TEL	Threshold Effect Level
TOC	Total Organic Carbon
WFD	Water Framework Directive

Non-Technical Summary

The Langstone Village saltmarsh restoration project is looking into the feasibility of undertaking beneficial use of dredged sediment (BUDS) to restore an area of intertidal saltmarsh habitat. Ocean Ecology Ltd (OEL) has been commissioned by Havant Borough Council to undertake an intertidal benthic characterisation survey to determine the baseline conditions and habitats within the proposed saltmarsh restoration area.

The survey was undertaken during low spring tide on the 19th and 20th September 2024. Survey operations were carried out utilising OEL's 4-man hovercraft *Solea* and consisted of a Phase I walkover survey and a Phase II survey which included the collection of sediment cores for further sediment and macrobenthic analyses. Five sediment cores were also analysed for sediment chemistry. Sediments were classified as littoral muds with varied gravel and sand components with mean grain size ranging from 18 – 2,910 µm. Across all stations, the concentrations of heavy and trace metals, organotins, nitrate, the 7 ICES PCBs and most PAHs were below the limit of detection or the CEFAS Action Level 1 (AL1). Seven PAHs were above the OSPAR BAC level, notably at station ST006, and for Fluoranthene at most sites where the AL1 was also exceeded. Total organic carbon, phosphate, exchangeable ammonium and total nitrogen levels are provided and discussed in relation to the habitats found.

The habitat map produced identified 6 different biotopes. However, the Langstone Village survey area was relatively homogeneous and with 76 % being characterised by EUNIS biotope MA622 'Faunal communities of variable salinity Atlantic littoral mud' on the mid to upper shore and MA6223 '*Nephtys hombergii*, *Macoma balthica* and *Streblospio shrubsolii* in Atlantic littoral sandy mud' on the mid to lower shore. The biotope MA225 'Atlantic pioneer saltmarshes' was primarily mapped in the western extent of the site and comprised of *Spartina* sp. A total area of 22,840 $m^2$of saltmarsh was recorded, 7% of the survey area. All three habitats are listed as Annex I and OSPAR priority habitats and their species compositions and key physical characteristics are described in this report (along with all biotopes mapped).

One species of seagrass was identified across the survey area: *Zostera noltei*, in small patches across the site, but these did not qualify as seagrass beds. Opportunistic macroalgae was recorded across the survey area and formed dense mats along much of the site. One Invasive and Non-Native Species (INNS) was noted across the survey area, the Pacific oyster *Magallana gigas*.

It is concluded that the proposed BUDS area is suitable for saltmarsh restoration. However, the environmental cost of the replacement of the mudflat habitats that are currently present in this area needs to be assessed against the benefits of such a change. Given the wide range of benefits that saltmarsh habitat gives, the fact that it is far less widespread within the harbour than the mudflats that it would replace, and that Natural England have identified an urgent need for saltmarsh area to be increased within the harbour, it seems likely that a more detailed ecological impact assessment would conclude that the scheme would be of net benefit.

However, the key factor in making this assessment will be determining the potential impacts of the loss of a small proportion of the mudflats within the harbour on birds. An assessment of the grain size and contaminant load of potential dredged material to be used will also be essential.

1. Introduction

1.1. Project Overview

There has been a loss of 58 % of saltmarsh habitat within Chichester Harbour between 1946 and 2016 and, on average, 2.54 ha of saltmarsh is currently being lost every year across the harbour, as evidenced in Natural England's latest condition assessment for the site (Bardsley et al. 2020). At the current rate of decline, the harbour could lose all its remaining saltmarsh habitat by 2142. At the same time, the marinas within the harbour are regularly dredged and the material taken offshore instead of being kept within the estuarine system and used to restore the marshes. The Natural England condition review recommends that restoration of saltmarsh in Chichester Harbour is undertaken as a matter of urgency and that sources of sediment should be investigated for stabilising the marshes.

The Langstone Village saltmarsh restoration project is looking into the feasibility of undertaking Beneficial Use of Dredged Sediment (BUDS) to restore an area of intertidal habitat that historically used to have a large amount of saltmarsh present in the vicinity of Langstone Village in the north-west of Chichester Harbour, Hampshire.

Subject to the findings of a site characterisation assessment and obtaining the required permissions, the proposal is to use dredged sediments from marinas in Chichester Harbour, but also potentially from marinas in the wider Solent, for beneficial reuse and placement on the mid-upper intertidal area in the vicinity of Langstone Village to restore saltmarsh. The proposed saltmarsh restoration area is shown in Figure 1. Initially a smaller trial area will be progressed (red area on Figure 1), with the aim to scale this up to the wider area (green area on Figure 1) in the longer term.

The method for the placement of the dredged sediment is still being developed, but one potential method being explored is using the Saltmarsh Restoration Drag Box (SRDB) technique developed for the BUDS saltmarsh restoration project at West Itchenor, also in Chichester Harbour. The SRDB technique involves the dredged material being deposited by spilt hopper barges on low shore / subtidal areas and the SRDB is then used to move that sediment to the higher shore areas. However, the restoration of saltmarsh via BUDS on this site needs to be approved in principle first before the method is confirmed.

To inform the saltmarsh restoration site characterisation assessment, Coastal Partners on behalf of Havant Borough Council have commissioned Ocean Ecology Ltd (OEL) to undertake a benthic survey of the existing intertidal habitat in the proposed BUDS disposal site / saltmarsh restoration area. This benthic survey will inform an assessment of site suitability for the placement of dredged sediment on the mid-upper intertidal area to restore the saltmarsh habitat. The results will also form part of the disposal site characterisation assessment to support a future marine licence application for the proposed Langstone Village BUDS saltmarsh restoration project, and set a baseline for future monitoring.

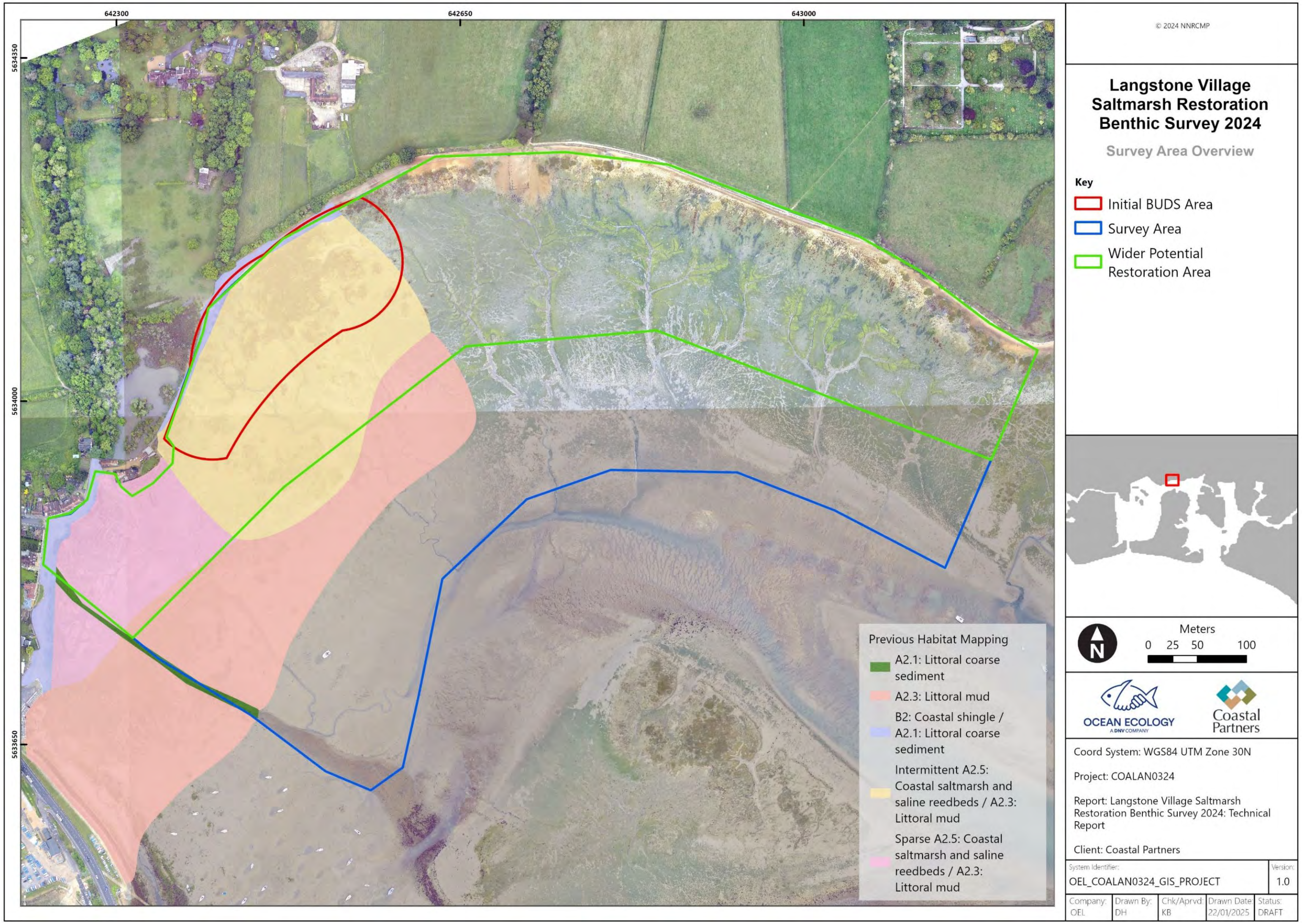

Figure 1 Overview of the Langstone Village saltmarsh restoration benthic survey area.

1.2. Site Information

1.2.1. Site Location

Chichester Harbour is an inlet of the English Channel approximately 9,226 ha in size in Hampshire on the south coast of the United Kingdom located to the south-west of Chichester and north of the Solent. The survey area is located at Langstone Village within the northwest of Chichester Harbour.

1.2.2. Designated Sites

Chichester Harbour is one of the most important sites for wildlife in the UK and is globally important for migratory birds (Natural England 2021). The harbour is designated as a SSSI, SAC, Ramsar site, SPA and National Landscape as detailed below.

The designations within the harbour recognise a number of key features and habitats including Atlantic salt meadows (*Glauco-Puccinellietalia maritimae*), coastal lagoons, estuaries, mudflats and sandflats and sandbanks, as well as the important breeding and over-wintering bird populations that these habitats support.

Chichester and Langstone Harbours SPA

This large (5,811 ha), mostly marine site supports nationally and internationally important breeding bird populations and overwintering waterbird populations of 18 different species. Breeding populations include little, common and Sandwich terns *Sterna albifrons*, *Sterna hirundo*, and *Sterna sandvicensis*. The overwintering populations include dunlin *Calidris alpina alpina*, ringed plover *Charadrius hiaticula*, red-breaster merganser *Mergus serrator*, and common shelduck *Tadorna tadorna*, all with 3% or more of Great Britain's population. Supporting habitats for the bird populations protected by the SPA include Annex I 'Mudflats and sandflats not covered by seawater at low tide (H1140)' and Spartina Swards '(H1320)' protected under the Conservation of Habitats and Species Regulations 2017 (as amended).

Chichester and Langstone Harbours Ramsar site

This site covers the same area as the above SPA. It is of particular significance for over-wintering wildfowl and waders and also a wide range of coastal and transitional habitats supporting important plant and animal communities. It notes three species of *Zostera* (*Z. angustifolia, Z. marina* and *Z. noltei*) as noteworthy flora, although it should be noted that *Z. angustifolia* and *Z. marina* are now considered to be the same species, *Z. marina*. It was designated to protect the following birds: ringed plover *C. hiaticula*, black-tailed godwit *Limosa limosa islandica* and common redshank *Tringa totanus tetanus* in spring/autumn, dark-bellied brent goose *Branta bernicla bernicla*, common shelduck *T. tadorna*, grey plover *Pluvialis squatarola*, and dunlin *C. alpina* over winter and little tern *S. albifrons* during the breeding season.

Solent Maritime SAC

This is a large area (11,243 ha) is designated for the protection of Annex I habitats including 'Estuaries', 'Mudflats and sandflats not covered by seawater at low tide', 'Salicornia and other annuals colonising mud and sand', 'Spartina swards' and 'Atlantic salt meadows'. The Solent and its inlets are unique in Britain and Europe for their hydrographic regime of four tides each day, and for the complexity of the marine and estuarine habitats present within the area. Habitats include extensive estuarine flats, with intertidal areas supporting seagrass *Zostera* spp., green algae, sand and shingle spits, and natural shoreline transitions. There are very sheltered almost fully marine muds in Chichester Harbour, and an unusual sandy 'reef' of *Sabellaria spinulosa* on the steep eastern side of the entrance to Chichester Harbour.

The Solent Maritime SAC is the only site designated for smooth cord grass *Spartina alterniflora* in the UK and is one of only two sites where significant amounts of small cord grass *Spartina maritima* are found. The Solent contains the second-largest aggregation of Atlantic salt meadows in south and south-west England and is representative of the ungrazed type.

Chichester Harbour SSSI

Chichester Harbour is a large estuarine basin where at low water, extensive mud and sandflats are exposed. These are drained by channels which unite to make a common exit to the sea. The SSSI has a total area of 3,734 ha with littoral sediments supporting habitats such as saltmarsh and seagrass beds. The site is of particular significance for wintering wildfowl as well as waders and breeding birds both within the Harbour, and in the surrounding permanent pasture fields and woodlands. At present, c. 80 % of the designated features within the site are in 'Unfavourable – declining' condition. This is due to several factors including the synergistic impacts of climate change, disruption to natural coastal processes caused by flood defence structures, inappropriate coastal management and excessive nutrient inputs into the harbour.

The most recent condition assessment (2020) for the littoral sediment habitats across the site (Unit 11) described them as 'Unfavourable – declining' with low confidence due to insufficient and varying quality data. This means the condition of the site is getting worse and it won't improve without changes to management or external pressures. The main threats identified were inappropriate coastal management, dredging, and pollution from agricultural run-off and wastewater discharge.

Chichester Harbour National Landscape

Designated in 1964 (as an Area of Outstanding Natural Beauty (AONB), renamed to National Landscape in 2023), Chichester Harbour National Landscape is the largest natural harbour in southeast England and the largest recreational boating harbour in Europe, in terms of number of moorings. It is internationally recognised for the high presence of birdlife, particularly overwintering populations. Alongside the birds, Chichester Harbour has the largest colony of seals in the Solent, with around 50 harbour (common) seal *Phoca vitulina*, and 10 grey seal (*Halichoerus grypus*).

1.3. Saltmarsh

Saltmarshes are an important habitat which are in heavy decline, with close to 100 ha of saltmarsh being lost per year in the Solent area (Natural England 2022). Saltmarshes within the UK mainly consist of species belonging to the genus *Spartina* and are represented by European Nature Information System (EUNIS) habitats within MA2 'Atlantic pioneer saltmarshes (OSPAR, 2009). Saltmarshes are a habitat noted as a 'habitat of principle importance' within the UK under the Natural Environment and Rural Communities (NERC) Act 2006. The intertidal habitats of the Solent have been subject to progressive change and decline. Prior to the late 19th Century, the area was made up of gently sloping shallow mudflat habitat. This was then colonised by *Spartina anglica,* which subsequently developed into salt marsh habitats which have been progressively declining since the 1960s (Bardsley et al. 2020).

1.3.1. Threats to Saltmarsh

There are a number of threats posed to saltmarshes around the UK. These include:

- Exposure to a number of pollutants, which may be derived from agricultural production on adjacent land or the contamination of water courses and sediments by processes such as industry and sewage disposal. These pollutants can lead to loss of biodiversity and cause eutrophication which can block light and reduce oxygen needed by salt marsh plants (Natural England 2021).
- Coastal squeeze which is defined as 'the loss of natural habitats or a deterioration in their quality caused by man-made structures or human activity'. Coastal squeeze prevents these habitats from migrating towards land and transgressing in response to rising sea levels (Environment Agency 2021). Coastal squeeze can increase salt marsh erosion and interrupt natural sediment supplies (Natural England 2021).
- Erosion by wave action; increases in the magnitude of wave action and the frequency of extreme events could increase the risks posed to saltmarsh habitats.

1.3.2. Saltmarsh Restoration Methods

In order to restore the Langstone Village saltmarsh using BUDS, the movement and deposition of sediments is necessary. Suitable Dredged sediments will be moved from marinas in Chichester Harbour and, potentially, the wider Solent area. In order to do this a number of techniques may be utilised. For example:

- Bottom placement, whereby material is deposited by opening a split hopper barge directly above a deposit location.

- Thin layer placement involves the piped, direct, delivery of sediment to high tidal elevations, onto and around existing vegetated saltmarsh areas using direct pumping from a cutter suction dredger or double-handling with pumping from pontoon.
- Hydraulic rainbow disposal which involves sediment sprayed onshore from a dredger creating a rainbow effect. This is usually done at slack low water to maximise onshore sediment transport. This allows sediment to be placed high on the foreshore.
- Other methods for restoration include the SRDB technique (as described in Section 1) and viscous pumping.

All methods involve the use of heavy machinery and additional factors, such as the density and viscosity of the sediment that is to be placed at the Langstone Village site, will influence the restoration of the saltmarsh.

1.4. Aim and Objectives

The aim of this study was to undertake an intertidal baseline survey within the proposed BUDS disposal site / saltmarsh restoration area and of the areas at a lower tidal height to understand the site suitability for BUDS, and to inform a site characterisation assessment / ecological impact assessment and any future marine licence application and funding applications.

The objectives were:

- To undertake a Phase I biotope survey and Phase II quantitative sampling survey of the intertidal habitats present within the survey area.
- Survey the extent and species composition of existing saltmarsh present within the proposed restoration area.
- Produce a GIS intertidal habitat map for the Langstone Village saltmarsh restoration area.
- Undertake sediment sampling at selected stations to meet the requirements of an agreed sample plan from the Marine Management Organisation (MMO) to inform a future marine licence application for a BUDS disposal site / saltmarsh restoration works at Langstone Village.

1.5. Document Overview

This technical report details the results of the above and includes habitat maps of the survey area observed. GIS layers are provided as appendices.

2. Survey Methodology

2.1. Overview

The distribution and extent of littoral sediment biotopes, interest features, and species that are representative and/or notable within the study area were achieved by examining geo-referenced Channel Coastal Observatory (CCO) aerial imagery and subsequently ground-truthing defined habitats via field survey in order to establish the Habitat types present (as per Procedural Guidelines 1-1 Intertidal resource mapping using aerial photographs in the Marine Monitoring Handbook (Davies *et al.* 2001). Habitat classification followed the Marine EUNIS Classification (EUNIS 2022) system to level 5 wherever possible. A phased approach was used to obtain the data required. Phase I provides a habitat map with some semi-quantitative data and Phase II provides the quantitative fauna, flora, sediment granulometry and sediment contamination data. These Phased surveys were carried out concurrently during low spring tides on the 19th and 20th September 2024. The tidal height at low tide on these days ranged from 0.43 m – 0.61 m (above Chart Datum).

2.2. Methods

2.2.1. Phase I Survey

The aim of this Phase I survey was to provide a habitat map of the intertidal areas within the survey area following Wynn et al, 2006. This included an assessment of the habitats of conservation interest (HOCI) and species of conservation interest (SOCI). The presence of invasive and/or non-native species (INNS) were also highlighted where observed. This Phase provided information on the following attributes: habitat composition, habitat distribution, extent of sub-features and notable habitat types. The extent of saltmarsh was also mapped during this phase and the species composition added as target notes to the area of saltmarsh present.

Habitat mapping encompassed 100% of the intertidal zone within the survey area. This was achieved by flying the hovercraft slowly in a zig-zag fashion over the survey area and stopping where the boundaries of the habitat types were observed. The track of the hovercraft was recorded using a handheld differential Global Positioning Satellite (dGPS). To facilitate this, transects were positioned at regular intervals throughout the survey area, avoiding any gulleys / channels while maintaining a representative coverage of the overall area (Figure 2).

In areas where the habitat type was not immediately apparent or where the boundaries of each habitat type were unclear, it was necessary to examine the species composition of sediments using a spade at regular intervals whilst transiting the intertidal areas.

If the habitat type still could not be determined a sediment core was taken, labelled and stored separately prior to processing and preservation. The cores were sieved using a BS410 standard 0.5 mm sieve, and the retained fauna fixed with 10 % borax buffered formaldehyde. The abundance and composition of characterising species were then determined at OEL's NE Atlantic Marine Biological Analytical Quality Control (NMBAQC) participating laboratory. To keep costs to a minimum, species identification and enumeration was limited to that sufficient to identify the biotope for these cores.

During the survey, the presence of any HOCI or SOCI were noted where encountered together with any pertinent information such as anthropogenic inputs and, if visible, the zone of their influence mapped in line with (Wynn et al 2006) and the National Resources Wales (NRW) Benthic habitat assessment guidance for marine developments and activities, Guidance note GN030b, A guide to characterising and monitoring intertidal sediment habitats[1]

During the Phase I survey, descriptions of the habitat types encountered were recorded digitally using ESRI Field Maps and on Joint Nature Conservation Committee (JNCC) Marine Nature Conservation Review (MNCR) forms as a backup.

[1] https://cdn.naturalresources.wales/media/689357/gn030b-intertidal-sediments-final-24jun2019.pdf

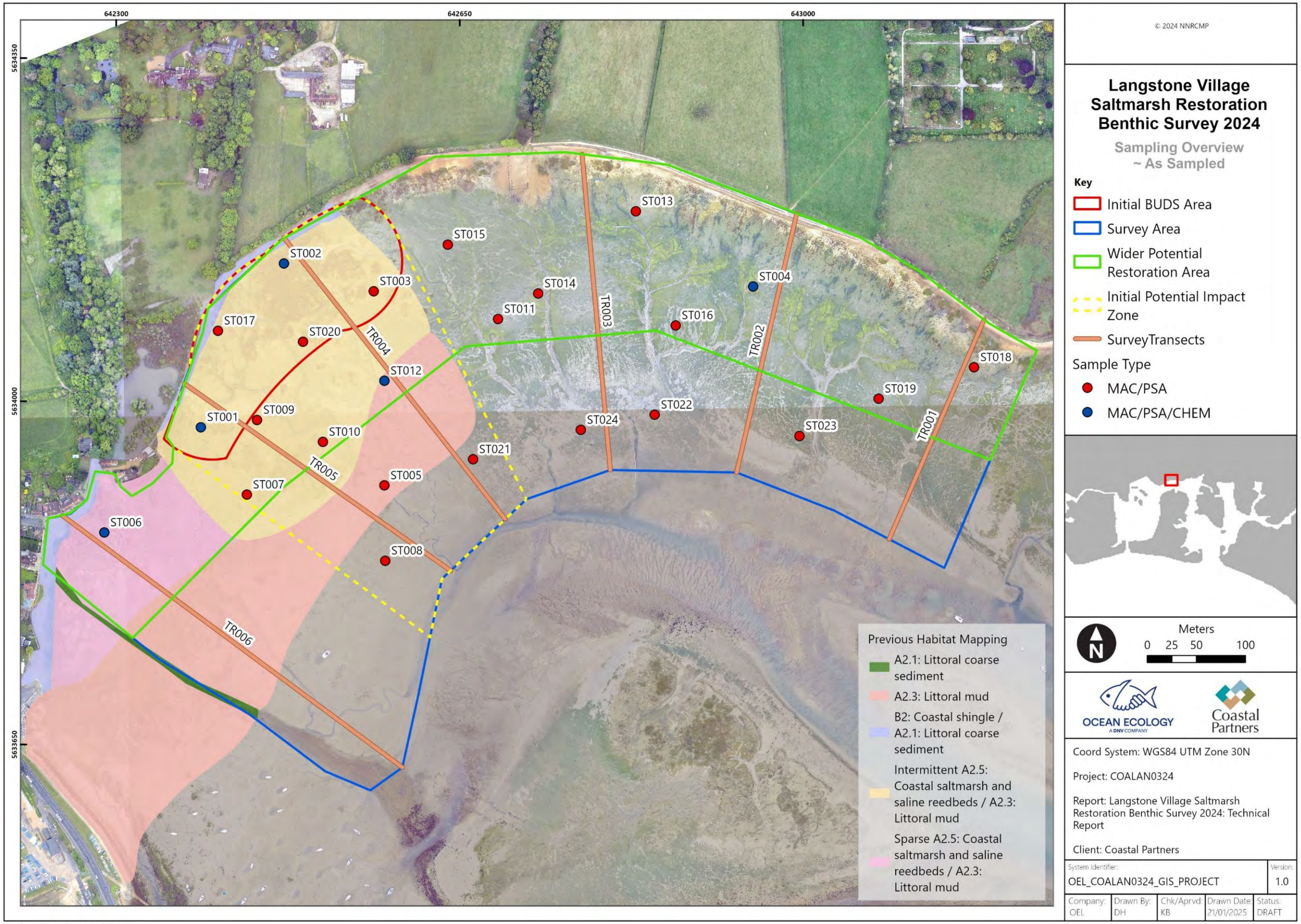

Figure 2 Sampling plan of the Langstone Village saltmarsh restoration benthic survey 2024.

2.2.2. Phase II Sampling

Quantitative sampling was focussed on the intertidal sediments within the proposed Langstone BUDS saltmarsh restoration area. The sampling plan was designed to be statistically robust in order to support ongoing monitoring and was pre-agreed with the Client and shared with Natural England. The sampling was planned to provide effective spatial coverage across the survey area and the habitat types present following guidance within (Davies et al. 2001). Previous habitat mapping undertaken by AECOM in (AECOM 2022) suggested that the lower tidal areas below the proposed BUDS area are mostly one habitat type whereas within the BUDS area there are several (intermittent coastal saltmarsh, littoral mud, coastal shingle and littoral coarse sediment). For this reason and to provide a greater density of data on those habitat types that will be directly affected by the deposition of sediments, the majority of the cores were collected within the initial BUDS area and the wider potential restoration area (red and green outlines, respectively, in Figure 2). At five of the stations in this area, samples were also collected for contaminant analysis to MMO standards (blue MAC/PSA/CHEM dots).

Sediment samples were collected using a 0.01 m^2 intertidal sediment corer to a depth of 15 cm following the International Organization for Standardization (ISO) guidelines for quantitative sampling and sample processing of marine soft-bottom macrofauna (ISO 16665 2014)[2]. Sampling was consistent with the Environment Agency (EA) Infaunal quality index: Water Framework Directive (WFD) classification scheme for marine benthic invertebrates[3] and the JNCC monitoring guidance for marine benthic habitats[4] and littoral sediments[5].

At each station the following information was recorded using ESRI Field Maps and on MNCR type site record forms as a backup:

- Exact sampling co-ordinates
- Sediment description (including granulometry)
- Depth of the redox discontinuity
- Interstitial salinity
- Penetrability (very firm to very soft)
- Comments (e.g. presence of negative indicators, macroalgal mat, INNS, HOCI or SOCI)
- Abundance of conspicuous species (using SACFOR scaling)
- Presumptive habitat type.
- Photographs of the sediment, up shore, down shore and cross shore aspects

[2] https://www.iso.org/standard/54846.html
[3] https://assets.publishing.service.gov.uk/media/5a7ef73840f0b6230268ca69/Water_Framework_Directive_classification_scheme_for_marine_benthic_invertebrates_-_report.pdf
[4] https://data.jncc.gov.uk/data/9ade4be8-63dd-4bbc-afd0-aefe71af0849/JNCC-Report-598-REVISED-WEB.pdf
[5] https://data.jncc.gov.uk/data/9b4bff32-b2b1-4059-aa00-bb57d747db23/CSM-LittoralSedimentHabitats-2004.pdf

Each sediment sample was sieved to 0.5 mm and the fauna retained preserved in 10% borax buffered formaldehyde. All macrobenthic analysis was carried out by OEL which participates in the NMBAQC scheme.

Sediment contaminant analysis was undertaken by SOCOTEC and the Particle Size Distribution (PSD) analysis by OEL. All analyses were undertaken to MMO standards.

2.3. Survey Craft

To maximise efficiency, quality and safety, the fieldwork was conducted from OEL's four-man hovercraft, *Solea* (Plate 1). The hovercraft can safely and efficiently cover large areas of mudflat and sandflat and access areas in which safety considerations would otherwise limit or prohibit access. All required permissions were sought from the relevant authorities prior to the survey.

Plate 1 OEL's dedicated four-man survey hovercraft, *Solea*.

3. Laboratory Analysis & Interpretation

3.1. Macrobenthic Analysis

All elutriation, extraction, identification, and enumeration were undertaken at OEL's NMBAQC scheme participating laboratory in line with the NMBAQC Processing Requirement Protocol (Worsfold & Hall 2010). All processing information and macrobenthic records were recorded using OEL's cloud-based data management application ABACUS that employs MEDIN validated, controlled vocabularies ensuring all sample information, nomenclature, qualifiers, and metadata are recorded in line with international data standards.

For each macrobenthic sample, the excess formalin was drained off into a labelled container over a 0.5 mm mesh sieve in a well-ventilated area. The samples were then re-sieved over a 0.5 mm mesh sieve to remove all remaining fine sediment and fixative. The low-density fauna was then separated by elutriation with freshwater, poured over a 0.5 mm mesh sieve, transferred into a Nalgene and preserved in 70 % Industrial Denatured Alcohol (IDA). The remaining sediment from each sample was subsequently separated into 0.5 mm, 1 mm, 2 mm and 4 mm fractions and sorted under a stereomicroscope to extract any remaining fauna (e.g., high-density bivalves not 'floated' off during elutriation).

All fauna present were identified to species level, where possible, and enumerated by trained benthic taxonomists using the most up to date taxonomic literature and checks against existing reference collections. Nomenclature utilised the live link within ABACUS to the World Register of Marine Species (WoRMS) web services to ensure the most up to date taxonomic classifications are recorded. Colonial fauna (e.g., hydroids and bryozoans) were identified to species level where possible and recorded as present (P). The following taxa were only recorded as present and not enumerated: Nematoda, Thoracica (identified, if possible), Copepoda (non-parasitic), and Ostracoda (split only to myodocopida & podocopida) For subsequent data analysis, taxa recorded as P were given the numerical value of 1. A full reference collection will be retained including at least one example specimen of each taxon.

Biomass was measured as blotted wet weight in grams to at least 4 decimal places for all countable taxa (i.e., at species level where possible). As a standard, the conventional conversion factors as defined by (Eleftheriou & Basford 1989) were applied to biomass data to provide equivalent dry weight biomass (Ash Free Dry Weight (AFDW)).

The conversion factors applied are as follows:

- Annelida = 15.5 %
- Crustacea = 22.5 %
- Mollusca = 8.5 %
- Echinodermata = 8.0 %
- Miscellaneous = 15.5 %

3.2. Particle Size Distribution Analysis

Particle Size Distribution analysis of the sediment samples was undertaken by in-house laboratory technicians at OEL's NMBAQC participating laboratory in line with NMBAQC best practice guidance (Mason 2016) using a combination of dry sieving and laser diffraction. The five samples being analysed for chemical contaminants (see Section 3.3) were analysed to MMO PSD standards.

Frozen sediment samples were transferred to a drying oven and thawed at 80 °C for at least 6 hours before visual assessment of sediment type. 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 removed from the sample. A representative sub-sample of the whole sample was then removed for laser diffraction analysis before the remaining sample screened over a 1 mm sieve to sort coarse and fine fractions. The >1 mm fraction was then returned to a drying oven and dried at 80 °C for at least 24 hours before 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 1.

Table 1 Sieve series employed for PSD analysis by dry sieving.

Sieve aperture (mm)												
63	45	32	22.5	16	11.2	8	5.6	4	2.8	2	1.4	1

The sample was then transferred onto the coarsest sieve at the top of the sieve stack and shaken for a standardised period of 20 minutes. The sieve stack was checked to ensure the components of the sample had been fractioned as far down the sieve stack as their diameter would allow. A further 10 minutes of shaking may be undertaken if there is evidence that particles had not been properly sorted.

The sub-sample for laser diffraction was first screened over a 1 mm sieve and the fine fraction residue (<1 mm sediments) transferred to a suitable container and allowed to settle for 24 hours before excess water syphoned from above the sediment surface until a paste texture is achieved. The fine fraction was then analysed by laser diffraction using a Beckman Coulter LS13 320. For silty sediments, ultrasound was used to agitate particles and prevent aggregation of fines.

The dry sieve and laser data was then merged for each sample with the results expressed as a percentage of the whole sample.

Once data was merged, PSD statistics and sediment classifications were generated from the percentages of the sediment determined for each sediment fraction using Gradistat v9 software.

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 derived following the Folk classification (Folk 1954).

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

Wentworth Scale	Phi Units (φ)	Sediment Types
>64 mm	<-6	Cobble and boulders
32 – 64 mm	-5 to -6	Pebble
16 – 32 mm	-4 to -5	Pebble
8 – 16 mm	-3 to -4	Pebble
4 - 8 mm	-3 to -2	Pebble
2 - 4 mm	-2 to -1	Granule
1 - 2 mm	-1 to 0	Very coarse sand
0.5 - 1 mm	0 – 1	Coarse sand
250 - 500 µm	1 – 2	Medium sand
125 - 250 µm	2 – 3	Fine sand
63 - 125 µm	3 – 4	Very fine sand
31.25 – 63 µm	4 – 5	Very coarse silt
15.63 – 31.25 µm	5 – 6	Coarse silt
7.813 – 15.63 µm	6 – 7	Medium silt
3.91 – 7.81 µm	7 – 8	Fine silt
1.95 – 3.91 µm	8 – 9	Very fine silt
<1.95 µm	<9	Clay

A Principal Component Analysis (PCA) on the full PSD data was used in PRIMER to facilitate the statistical analysis and interpretation. This procedure transforms a high-dimensional dataset into a new set of uncorrelated variables called principal components which can be visualised and simplified to the key sediment types. The PCA analysis was also used to facilitate the statistical analysis and interpretation of macrobenthic data.

3.3. Chemical Contaminant Analysis

All sediment chemical contaminant analyses were undertaken by SOCOTEC who are validated by the MMO for conducting chemical analysis of sediments for marine licencing purposes. Analyses were undertaken for:

- Heavy Metals
- Polycyclic aromatic hydrocarbons (PAH)
- Polychlorinated biphenyl (PCB)
- Organotins
- Total Organic Carbon (TOC)
- Nutrient Enrichment
- Total Nitrogen
- Nitrate
- Nitrite
- Phosphate s PO_4
- Exchangeable ammonium

Where available, metal and PAH concentrations were compared to the OSPAR Background Assessment Concentration (BAC) (OSPAR et al. 2009), the USA Environmental Protection Agency (EPA) Effect Range Low (ERL) (NJDEP 2009), CEFAS Action Level (AL) 1 and AL 2 (DEFRA 2003), and the Canadian Sediment Quality Guideline (CSQG) Threshold Effect Level (TEL) and Probable Effect Level (PEL) (CCME 2001). Note that ERL, TEL and PEL are based on field research programmes based on North American data that have demonstrated associations between chemicals and biological effects by establishing cause and effect relationships in particular organisms (CCME 2001).

This means they provide a measure of environmental toxicity compared to the other reference levels which instead provide information on the degree of contamination of the sediments. At levels above the TEL, adverse effects may occasionally occur, whilst at levels above the PEL, adverse effects may occur frequently; concentrations below the ERL rarely cause adverse effects in marine organisms. Additionally, the TEL has been adopted as the International Sediment Quality Guideline (ISQG) (CCME 2001), while ERL has been adopted by OSPAR to assess the ecological significance of contaminant concentrations in sediments, where concentrations below the ERL rarely cause adverse effects in marine organisms. For these reasons ERL, TEL and PEL are presented here as reference values despite being based on North American data.

Background Assessment Concentrations were developed to assess the status of contaminant concentrations in sediment within the OSPAR framework with concentrations significantly below the BAC considered to be near background levels for the North-East Atlantic. Cefas ALs are used as part of a 'weight of evidence' approach to assessing dredged material and its suitability for disposal to sea (DEFRA 2003). Contaminant levels in dredged material which fall below AL1 are of no concern and are unlikely to influence decision-making, while contaminant levels above AL2 are generally considered unsuitable for at-sea disposal.

3.4. Habitat Mapping

EUNIS habitats and biotopes were identified in line with JNCC guidance on assigning benthic biotopes (Parry 2019) to allow the communities to be mapped and allow comparison with existing data. All habitat / biotope determination was undertaken through consideration of the following:

- Existing habitat mapping (where available)
- Latest available aerial imagery (2022 CCO data)
- Review and interpretation of target field notes
- Sediment MAC/PSD analysis

All mapping processes were conducted in ESRI ArcPro Version 3.3.2. Target point notes alongside sediment macrofauna, particulate size distribution analysis and existing habitat mapping was used to manually delineate the boundaries (polygons) of the various habitats and biotopes encountered across the survey area. Confidence scores were assigned to each polygon to give an indication of their accuracy.

The full extent of the survey area was sampled, with target notes located throughout, enabling almost every polygon in the survey area to be surveyed.

The highest confidence score (2) was given to polygons where all data sources identify the same habitat/biotope, with distinct class boundaries. In these cases, an adequate amount of sampling was undertaken to identify each polygon, and boundaries were delineated using aerial imagery dating from 2022 (CCO data). This was of particular use as the imagery is full coverage and is of good quality throughout the survey extent.

A lower score (1) was assigned to polygons where data was limited, and boundaries difficult to distinguish in the aerial imagery. In these cases, polygons were drawn based upon expert judgement, given the information available.

4. Results

4.1. Phase I Survey

4.1.1. Overview

In total, target notes were collected at 20 locations to provide localised information on habitats and features of interest present across the survey area and assign Broad Scale Habitats (BSHs) and EUNIS classifications *in situ* to assist in ground truthing of existing data. Habitats were assigned to a level 6 biotope by digging over sediments with a spade to observe any fauna within the sediment where necessary and possible. Example imagery of the habitats and biotopes recorded during the Phase I survey are displayed in Plate 2 and their locations are mapped in Figure 3.

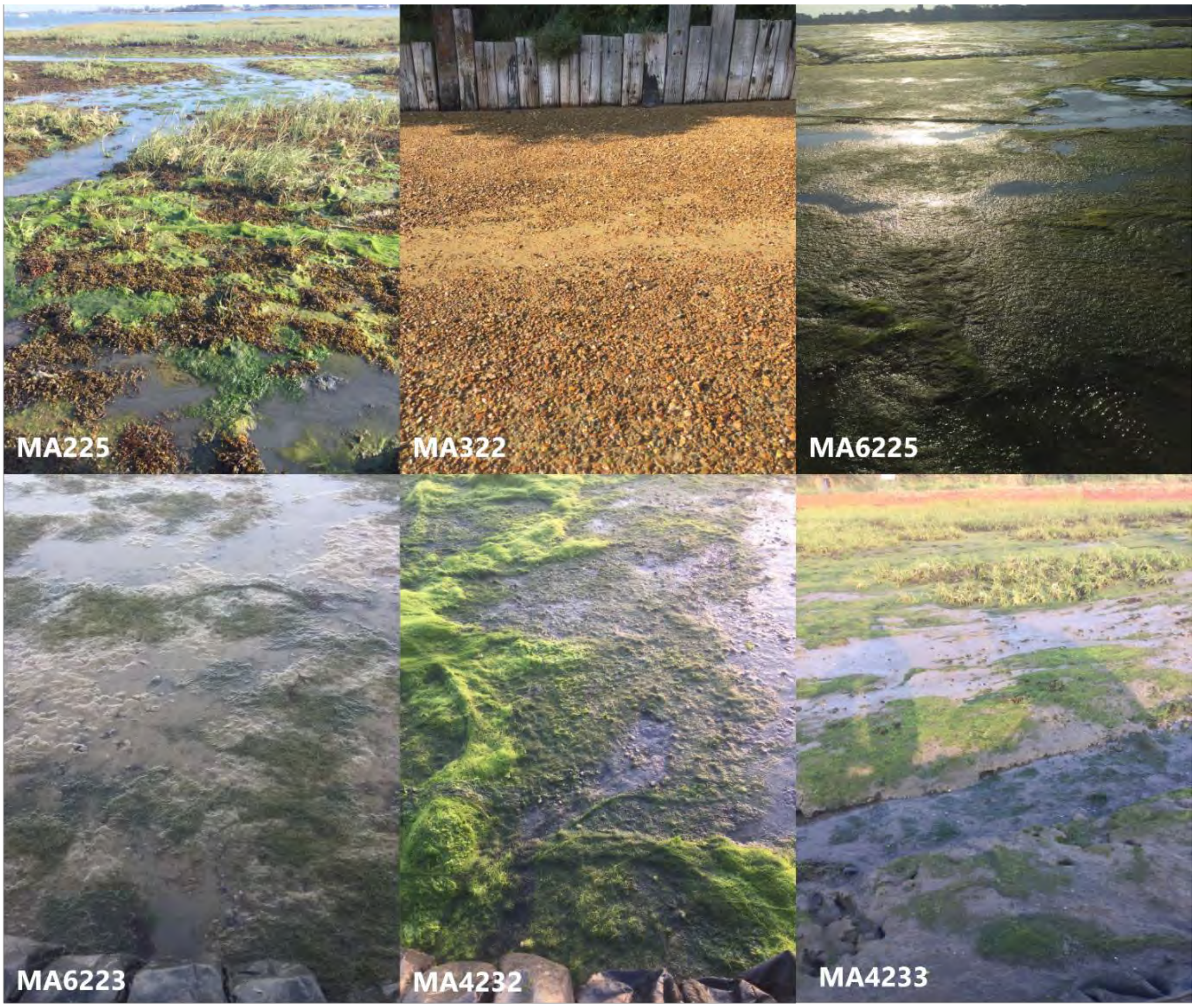

Plate 2 Example images of each habitat encountered across the Langstone Village survey area.

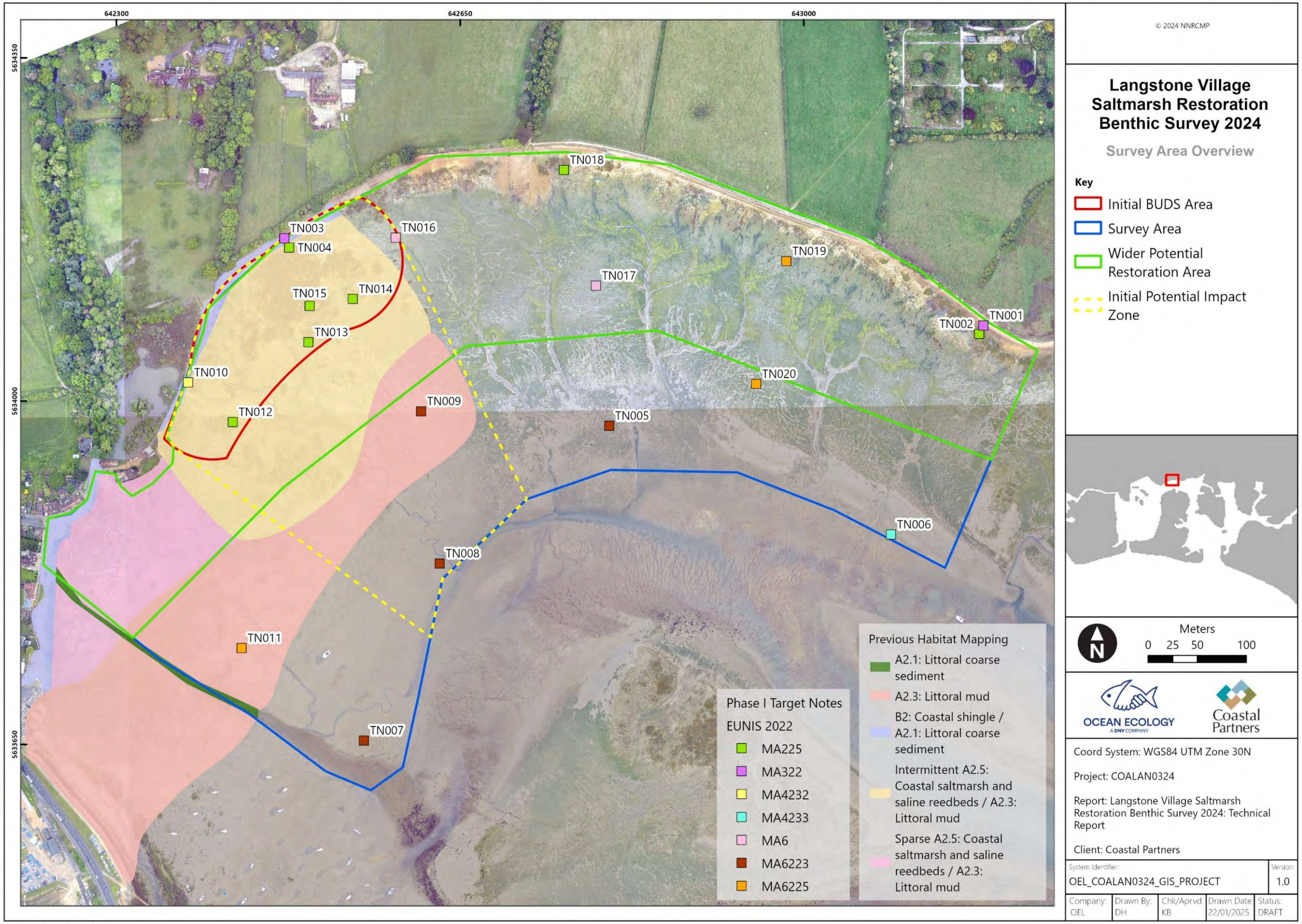

Figure 3 Langstone Village survey area overview and Phase I target notes.

4.1.2. Phase I Habitat Types

A total of 6 individual habitats and biotopes were observed and recorded and are summarised in Table 3.

Table 3 Broadscale habitats and EUNIS biotopes identified across the Langstone Village survey area during Phase I.

BSH	EUNIS Code	EUNIS Description
MA3	MA322	Faunal communities on variable salinity Atlantic littoral coarse sediment
MA6	MA6225	*Hediste diversicolor, Macoma balthica* and *Scrobicularia plana* in littoral sandy mud
	MA6223	*Nephtys hombergii, Macoma balthica* and *Streblospio shrubsolii* in littoral sandy mud
MA4	MA4232	*Hediste diversicolor* dominated gravelly sandy mud shores
	MA4233	Cirratulids and *Cerastoderma edule* in littoral mixed sediment
MA2	MA225	Atlantic pioneer saltmarshes

The biotope MA225 'Atlantic pioneer saltmarshes' was documented in the Phase I survey at 7 locations as shown in Figure 3 (TN: 002, 004, 012, 013, 014, 015, 018). This biotope was primarily seen in the upper areas of the shore and was more dominant in the westerly extent of the survey area within the initial BUDS area and aligned with the pre-existing habitat map (see Section 4.3 for further description). The only saltmarsh species observed was *Spartina* sp.

The littoral mud BSH (MA6) was recorded at a total of 9 locations across the majority of the lower and mid shore which corroborated well with the existing habitat map. The biotope MA6223 '*Nephtys hombergii, Macoma balthica* and *Streblospio shrubsolii* in littoral sandy mud' was observed at four locations within the centre, south and westerly extents of the mid to lower shore (TN: 005, 007, 008, 009). A second littoral mud biotope, MA6225 '*Hediste diversicolor, Macoma balthica* and *Scrobicularia plana* in littoral sandy mud', was observed three times in the upper-mid and mid shore areas (TN: 011, 019, 020). These records, along with those at two further locations that could only be identified as littoral mud (BSH), were spread across the survey area but were not taken directly within the proposed initial BUDS area. The Phase I logs in the BUDS area were predominately saltmarsh, as described above.

Two littoral mixed sediment BSHs were recorded during the Phase I survey. A single point of the biotope MA4233 'Cirratulids and *Cerastoderma edule* in littoral mixed sediment' was observed in the southeastern limit of the survey area (TN006) whilst MA4232 '*Hediste diversicolor* in Atlantic littoral gravelly muddy sand and gravelly sandy mud' was observed in the northwestern extent just within the initial BUDS area (TN010).

One coarse sediment BSH was recorded as biotope MA322 'Faunal communities on variable salinity Atlantic littoral coarse sediment' at two locations on the highest zone of the upper shore both within and outside of the proposed initial BUDS area. This was well-aligned with the shift to coarser sediments from mid to upper shore seen in the pre-existing habitat map.

4.1.3. Notable Species & Impacting Influences

There were no INNS or species of commercial/conservation importance noted during the Phase I survey. The existing saltmarsh within the survey area was identified as solely *Spartina sp*. It was patchy and primarily located in the western extent of the survey area within the proposed initial BUDS area but also on the upper shore in the centre and far east of the survey area.

Small patches of seagrass (*Zostera noltei)* were identified throughout the survey area. However, these areas did not meet the qualifying criteria to be classified as seagrass bed (OSPAR 2009a).

Much of the survey area was covered in thick opportunistic macroalgae including *Chaetomorpha* sp. and *Ulva* sp. which made it difficult to observe sediments and macrofauna below (Plate 3).

Freshwater input in the form of a spring was observed close to station TN004.

Plate 3 Examples images of macroalgae cover identified across the survey area.

4.2. Phase II Sampling

Core samples were obtained from 24 stations throughout the survey area for sediment PSD and macrobenthic analysis, five of which were additionally sampled for sediment chemistry analysis. Full logs are provided in Appendix I.

4.2.1. Sediment Granulometry

Of the 24 sampled stations summarised in Table 4, 19 were representative of EUNIS BSH MA6 'Littoral mud', including the textural groups Slightly Gravelly Sandy Mud ((g)sM) and Sandy mud (sM). The remaining 5 stations belonged to EUNIS BSH MA4 'Littoral Mixed Sediment' and were classified as Gravelly Mud (gM), and Muddy Sandy Gravel (msG). The MA4 assignment included the saltmarsh station. Textural groups at each station are presented in Figure 4 and raw sediment data is provided in Appendix II. The MMO template of results is provided separately in Appendix III.

Table 4 Summary of BSH identified from the PSD analysis.

BSH	Description	No. of Stations
MA6	Littoral mud	19
MA4	Littoral mixed sediment	5

All stations except station ST017, were dominated by mud with variable gravel and sand content. Conversely, station ST017 was dominated by gravel. The percentage contribution of gravels (> 2 mm), sands (0.63 mm to 2 mm), and fines (< 63 µm) at each station are presented in Figure 5 and Figure 6. The mean proportion (± Standard Error, SE) of sands across all stations was 29 % (± 1.6 %), the mean (± SE) gravel and mud content across the survey area was 5 % (± 2.9 %) and 66 % (±3 .1 %) respectively.

Mean grain size across the survey area ranged from 18 µm at station ST014 to 2,910 µm at station ST017 with the proportional split of gravel, sand and mud shown in Figure 7. There was no obvious pattern regarding mean grain size across the survey area.

The PCA conducted on the full PSD identified the key components were the mud, gravel and sand fractions. These were extracted from the dataset and visualised in Figure 8. The BSHs assigned match well with the stations within 'MA4 littoral mixed sediment' having more gravel than the stations in 'MA6 littoral mud' which spread across the mud and sand components.

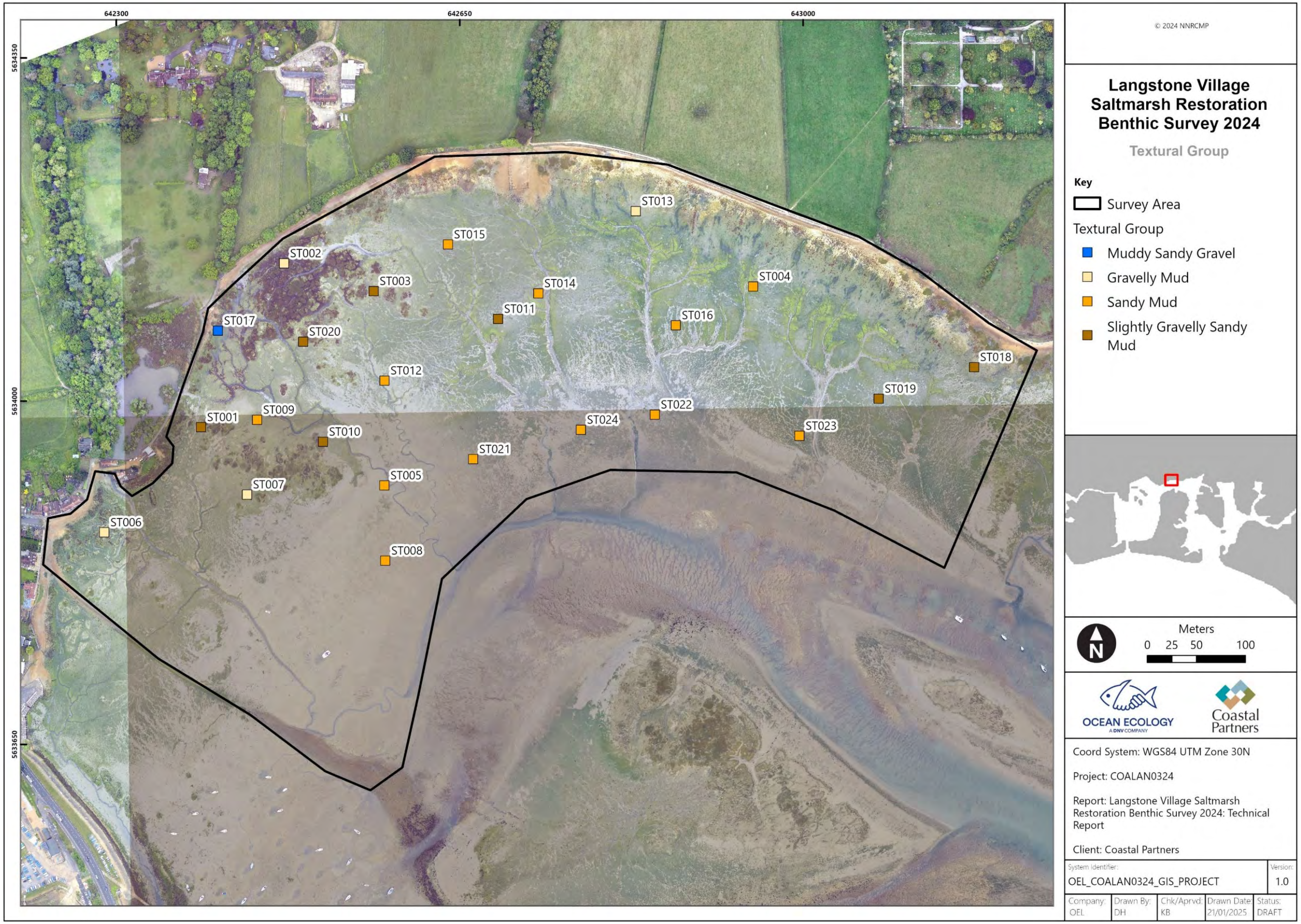

Figure 4 Textural group classification of sediment samples taken across the survey area.

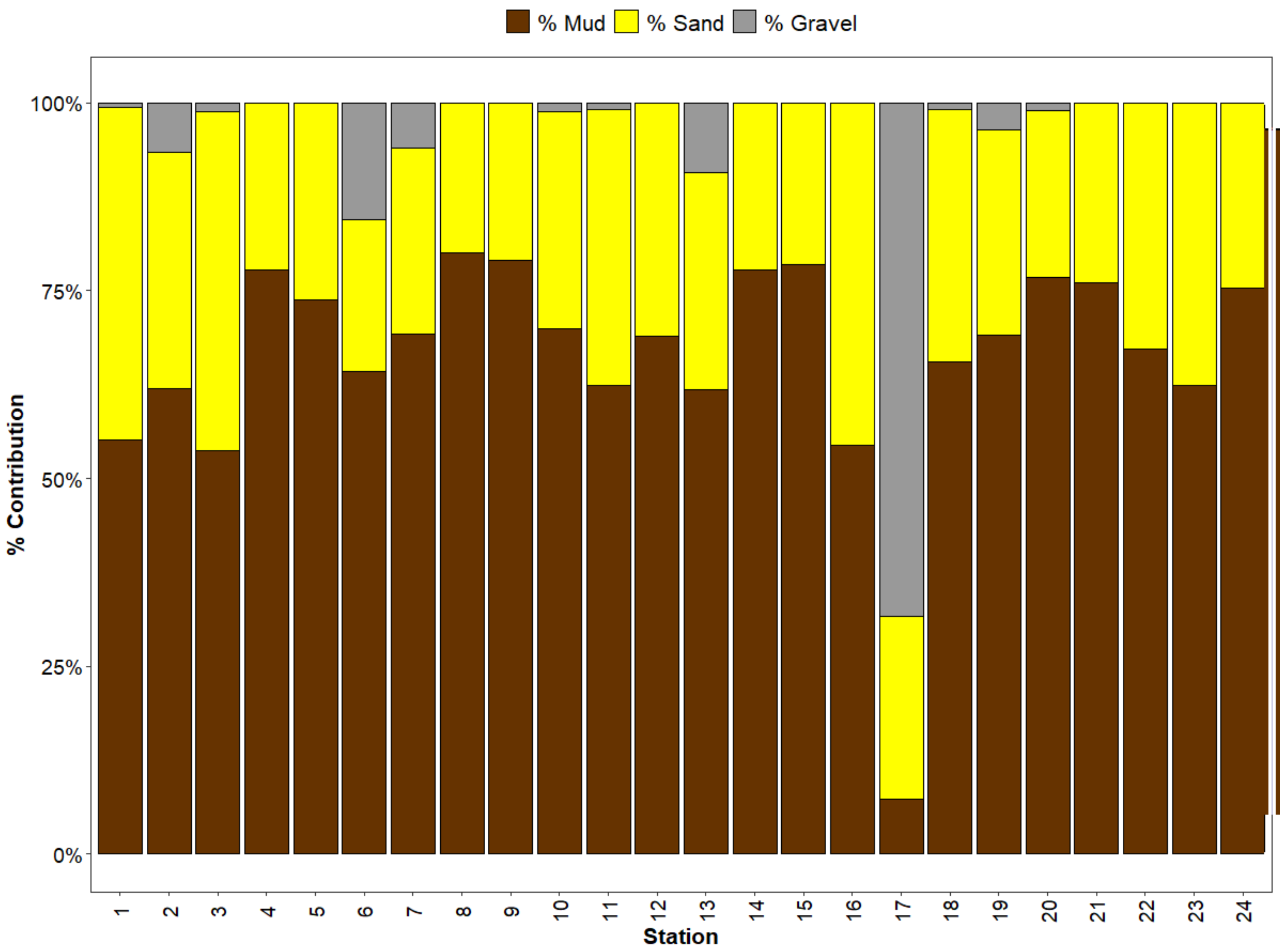

Figure 5 Relative contribution of major sediment fractions (Gravel, Sand, Mud) by volume at each sampling stations

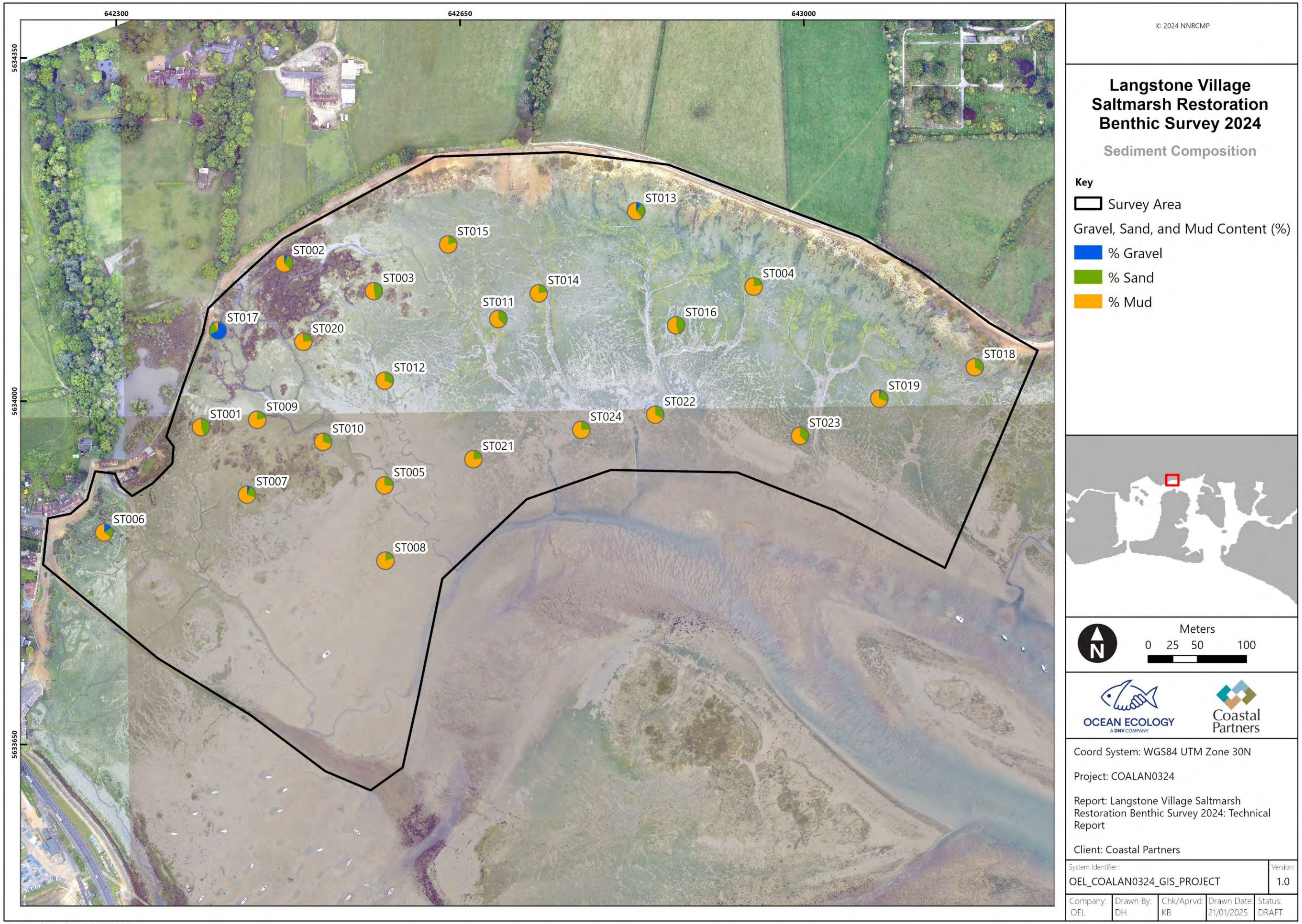

Figure 6 The principal sediment components (Gravel, Sand, Mud) as determined from PSD analysis of samples collected across the Langstone Village survey area.

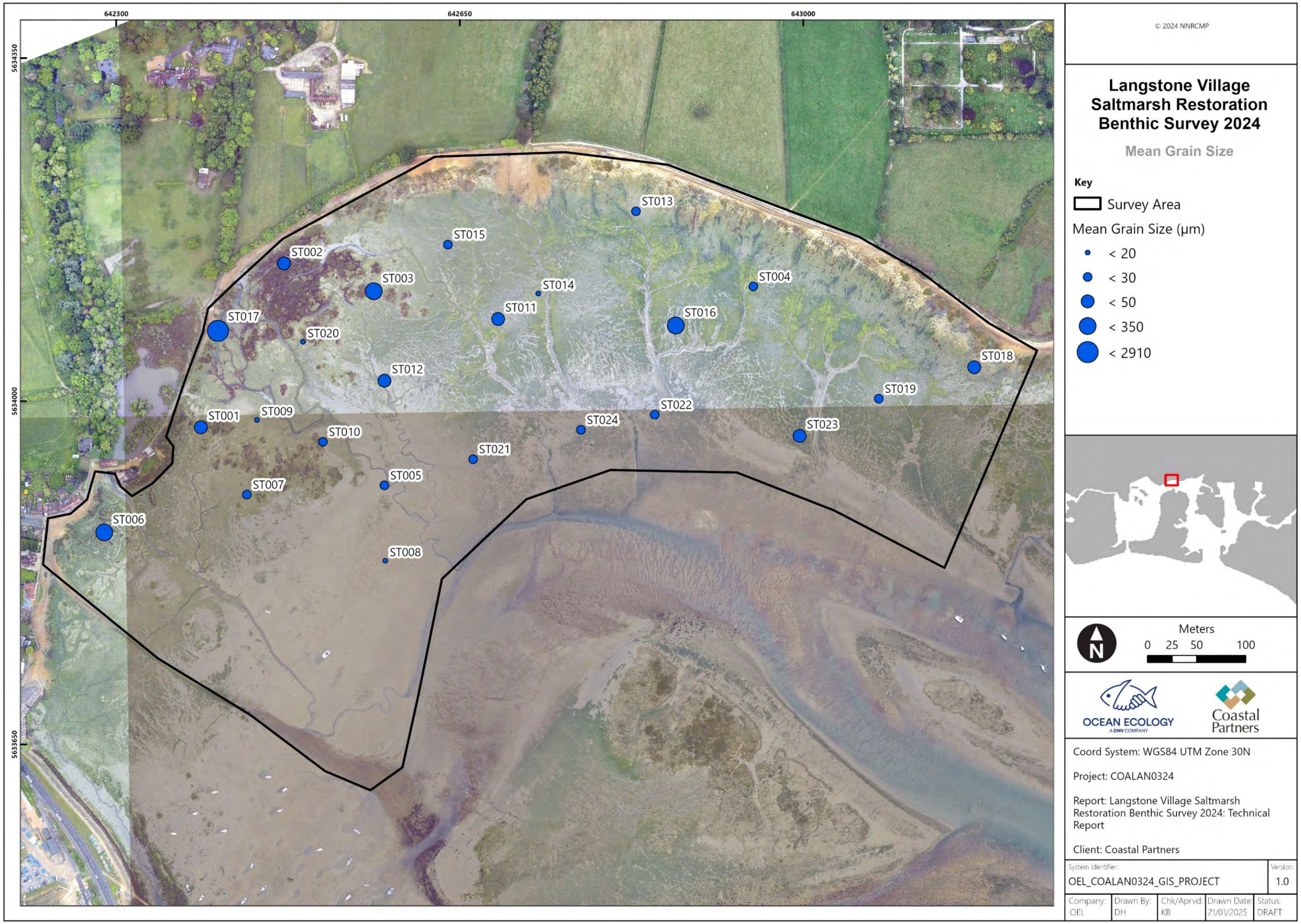

Figure 7 Average grain size (um) across the survey area.

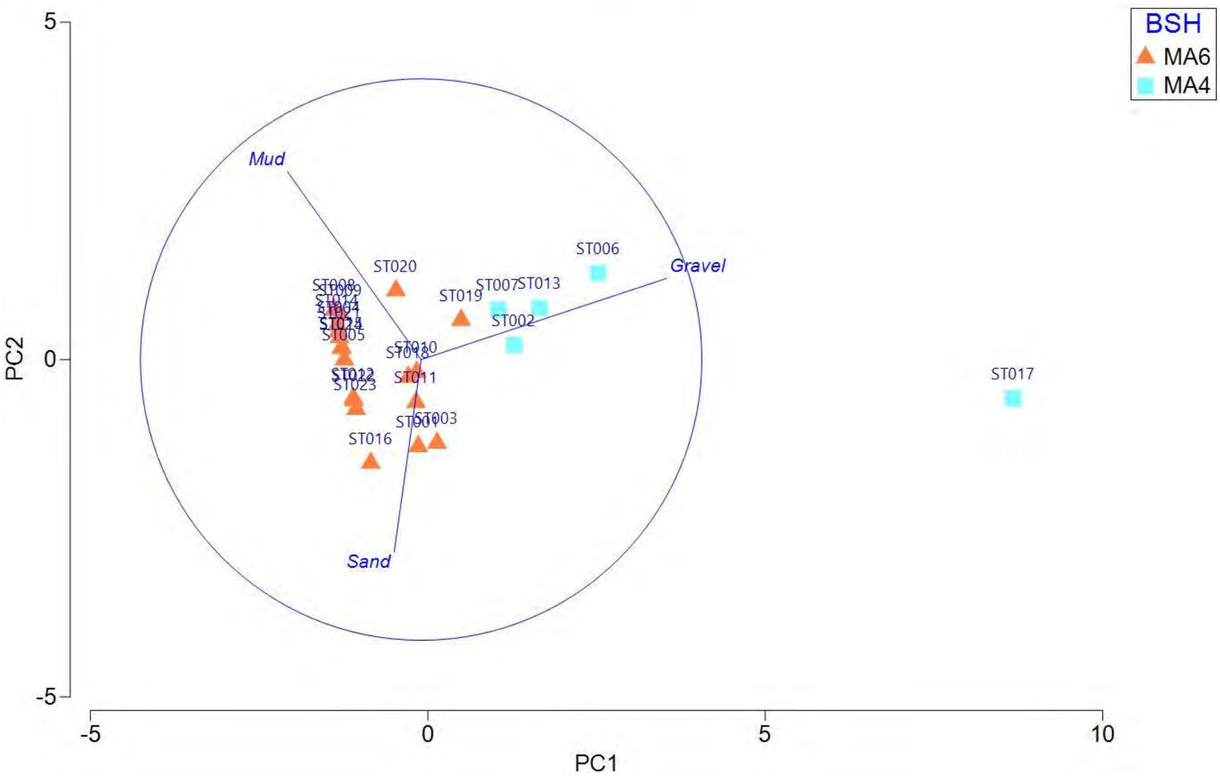

Figure 8 A Principal Component Analysis plot of the sand, gravel and mud fractions of the PSD across all core sampling stations, showing the BSH assigned for each station.

4.2.2. Sediment Chemistry

Five sediment samples were collected across the survey area for subsequent chemical analysis. Sediment chemical samples were collected at stations ST001, ST002, ST004, ST006 and ST012. The results are provided together with the PSD in the MMO template in Appendix III.

4.2.3. Total Organic Carbon

Total Organic Carbon ranged from 1.3 % at station ST004 to 3.1 % at station ST001 with a mean (± SE) value of 1.9 % ± 0.5. There was no obvious pattern with TOC and sediment granulometry i.e. the station with the finest sediments did not contain the highest TOC, as shown in Figure 9.

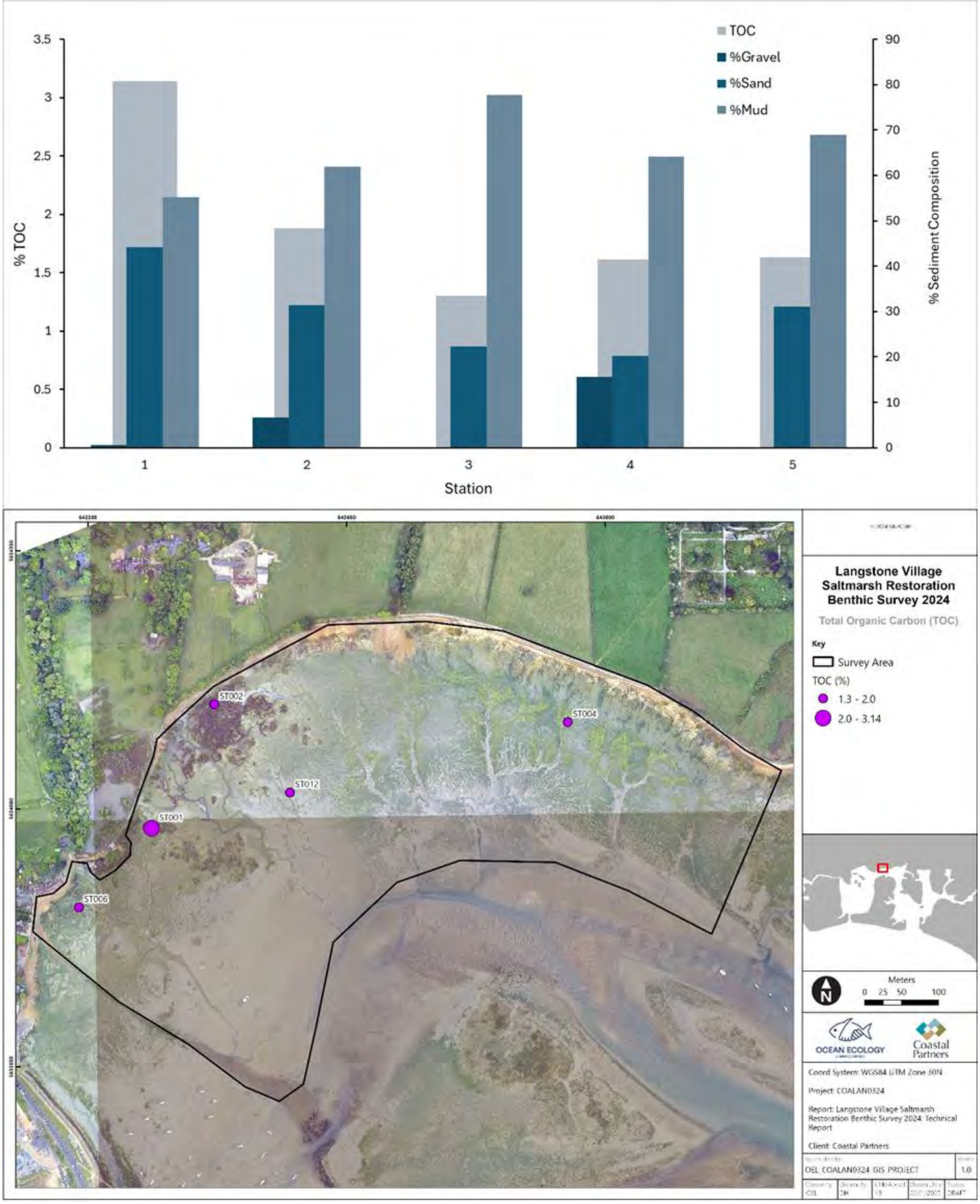

Figure 9 Total Organic Carbon with percentage sand, gravel and mud at each station sampled for sediment chemistry and map of sampling locations.

4.2.4. Heavy and Trace Metals

A total of 8 heavy and trace metals were analysed from sediments taken at each of the 5 sampled stations. These were: Arsenic (As), Cadmium (Cd), Chromium (Cr), Copper (Cu), Lead (Pb), Mercury (Hg), Nickel (Ni), and Zinc (Zn). Raw data for primary metals are provided in Appendix III.

Of the 8 heavy and trace metals measured, only Ni exceeded any of the available reference levels. Nickel exceeded CEFAS AL1 and ERL at station ST001 by 3 and 4 mg kg^{-1} respectively but remained lower than OSPAR BACs of 36 mg kg^{-1}. Summary data (dry-weight concentration, mg kg^{-1}) are shown in Table 5, together with available reference levels. Zinc was recorded in the highest concentrations across the survey area with a maximum concentration of 58.5 mg kg^{-1} measured at station ST001 however this was well below all available reference levels.

Table 5 Summary of heavy and trace metal concentrations (mg kg^{-1}). Values highlighted in red exceeded known reference levels.

Station	As	Cd	Cr	Cu	Pb	Hg	Ni	Zn
ST001	5.10	0.27	35.00	9.70	12.40	0.02	24.00	58.50
ST002	1.70	0.07	6.00	2.10	3.20	<0.01	4.80	13.50
ST004	5.50	0.17	23.00	4.90	8.00	0.01	14.60	44.80
ST006	4.00	0.21	25.40	7.00	9.30	0.01	17.70	44.40
ST012	3.10	0.13	11.40	3.00	5.20	0.01	7.70	26.00
Min	1.70	0.07	6.00	2.10	3.20	<LOD	4.80	13.50
Max	5.50	0.27	35.00	9.70	12.40	0.02	24.00	58.50
Mean	1.54	0.08	20.16	5.34	7.62	0.01	13.76	37.44
SE	0.69	0.03	5.16	1.38	1.60	-	3.45	7.91
CEFAS AL1	**20**	**0.4**	**40**	**40**	**50**	**0.3**	**20**	**130**
CEFAS AL2	**100**	**5**	**400**	**400**	**500**	**3**	**200**	**800**
OSPAR BAC	**25**	**0.31**	**81**	**27**	**38**	**0.07**	**36**	**122**
ERL	**8.2***	**1.2**	**81**	**34**	**47**	**0.15**	**21**	**150**
TEL	**7.24***	**0.7**	**52.3**	**18.7**	**30.2**	**0.13**	**-**	**124**
PEL	**41.6**	**4.2**	**160**	**108**	**112**	**0.7**	**-**	**271**

*The ERL and TEL for As are below the BACs therefore As concentrations are usually assessed only against the BAC.

PAHs

The full range of EPA PAHs were tested and raw data reported in Appendix III. The most abundant PAH was fluoranthene which had an average concentration of 115 µg kg^{-1} (± 35 µg kg^{-1}) across the survey area and ranged from 13.7 µg kg^{-1} at ST001 to 213 µg kg^{-1} at ST006 with spatial patterns mapped within Figure 10. The second most abundant PAH was pyrene with an average concentration of 109 µg kg^{-1} (± 34 µg kg^{-1}) and ranged from 14 µg kg^{-1} at ST001 to 216 µg kg^{-1} at station ST006 mapped in Figure 11. Fluoranthene was above OSPAR BAC at all stations except for ST001, all other PAHs above reference levels are presented in Table 6.

Table 6 Summary of PAH concentrations (µg kg^{-1}). Values highlighted in red exceeded known reference levels.

Station	Anthracene	Benzo[a]pyrene	Benzo[ghi]perylene	Fluoranthene	Indeno[1,2,3-cd]pyrene	Naphthalene	Phenanthrene
ST001	<5	<5	<5	13.7	<5	<5	9.81
ST002	10.5	59.3	48.7	100	53.1	<5	26.9
ST004	11.3	90.9	68	167	71	<5	55.4
ST006	20.3	173	135	213	146	16.6	56.6
ST012		52.4	40.1	82.6	41	<5	23.6
Cefas AL1	100	100	100	100	100	100	100
Cefas AL2	-	-	-	-	-	-	-
BAC	5	30	80	39	103	8	32
ERL	85	430	85	600	240	160	240
TEL	46.9	88.8	-	113	-	34.6	86.7
PEL	245	763	-	1494	-	391	544

Figure 10 Spatial patterns in the concentration of Fluoranthene (mg kg^{-1}) across the Langstone Village survey area.

Figure 11 Spatial patterns in the concentration of Pyrene (mg kg^{-1}) across the Langstone Village survey area.

4.2.5. PCBs

The majority of measured PCBs had concentrations below the Limit of Detection (LOD) across the survey area. CEFAS Action Levels do not exist for each individual PCB with the only limit being for the sum of the 7 ICES PCBs (ΣICES7) which is 100 µg kg^{-1} (OSPAR 2010).

The 7 ICES PCBs (CB congeners 28, 52, 101, 118, 138, 153, 180) congeners were analysed from the sediments taken at each station and raw data are presented in Appendix III. The 7 ICES PCBs were selected to cover the range of toxicological properties of the group and when summed together, were well below the CEFAS AL of 100 µg kg^{-1}.

PCB 153 had the highest concentration across the survey area ranging from below the LOD at station ST001 to 0.00027 mg kg^{-1} at ST002 with an average of 0.0002 mg kg^{-1} ± 0.00005 mg kg^{-1}.

4.2.6. Organotins

All analysed organotins were measured below the LOD at all stations.

4.2.7. Nitrate

All stations measured for sediment chemistry had Nitrate concentrations below the LOD.

4.2.8. Phosphate as PO_4

Phosphate levels varied from 7.1 mg l^{-1} at station ST001 to 48.4 mg l^{-1} at station ST004.

4.2.9. Exchangeable Ammonium

Levels of exchangeable ammonium varied from 10.0 mg kg^{-1} at station ST001 to 46.8 mg kg^{-1} at station ST012. No threshold levels were available for coastal sediments.

4.2.10. Total Nitrogen

Total Nitrogen levels varied from 0.16 % at station ST004 to 0.32 % at station ST001. No threshold levels were available for coastal sediments.

4.2.11. Macrobenthos

Samples for macrobenthic analysis were taken at all 24 stations.

4.2.12. Univariate

A number of univariate metrics such as the number of species, number of individuals, Margalef's species richness and the Shannon Weiner diversity index were calculated for each station to determine whether there are any qualitative differences between the habitat types or stations. The results are shown in Table 7.

Table 7 Results of Macrobenthos Univariate metrics.

Stations	Number of Taxa (S)	Abundance (N)	Margalef's species richness (d)	Pielou`s evenness (J)	Shannon Weiner diversity index (H)
ST001	7	145	1.21	0.29	0.81
ST002	5	77	0.92	0.57	1.33
ST003	4	20	1.00	0.87	1.74
ST004	7	108	1.28	0.49	1.37
ST005	16	661	2.31	0.52	2.07
ST006	6	289	0.88	0.25	0.64
ST007	9	351	1.37	0.49	1.55
ST008	15	315	2.43	0.68	2.64
ST009	8	101	1.52	0.65	1.94
ST010	7	140	1.21	0.66	1.84
ST011	5	46	1.04	0.58	1.34
ST012	6	93	1.10	0.67	1.73
ST013	6	54	1.25	0.66	1.71
ST014	3	51	0.51	0.86	1.36
ST015	5	166	0.78	0.55	1.27
ST016	11	138	2.03	0.58	2.01
ST017	9	121	1.67	0.43	1.36
ST018	11	191	1.90	0.64	2.21
ST019	14	443	2.13	0.50	1.90
ST020	10	112	1.91	0.61	2.03
ST021	10	207	1.69	0.60	1.98
ST022	10	237	1.65	0.58	1.94
ST023	13	134	2.45	0.51	1.90
ST024	12	256	1.98	0.47	1.70

A total of 4,456 individuals and 47 taxa were recorded across the survey area. The mean (± SE) number of taxa per station was 9 ± 1 taxa, mean (± SE) abundance was 186 ± 30 individuals per station and mean (± SE) biomass was 0.61 ± 0.147 gAFDW. The full macrobenthic abundance matrix is provided in Appendix IV while the biomass matrix with taxa divided by major group (Annelida, Crustacea, Mollusca, Echinodermata and Miscellaneous) is provided in Appendix V.

As shown in Figure 12, the annelid *Tubificoides benedii* was the most abundant taxon sampled accounting for 43 % of all individuals recorded and was the most frequently occurring having been found in 100 % of the samples. This species also reported the maximum average density per sample. The other key taxa were juveniles of *Abra* sp. which reported the highest maximum abundance per sample and the gastropod *Peringia ulvae* which was second to *T. benedii* for contribution to total abundance, occurrence and highest average density per sample.

Figure 13 illustrates the relative contributions to total abundance, diversity in terms of number of taxa, and biomass of the major taxonomic groups in the macrobenthic community sampled across the survey area. Annelida taxa contributed the most to overall abundance, accounting for approximately 52 % of all individuals recorded. Mollusca taxa contributed the most to the total biomass of microbenthic assemblages, accounting for 70 %. Annelida taxa also contributed the most to overall diversity accounting for 58 %, followed by Mollusca with a total contribution of 31 %. There was no identification of species within the major group Echinodermata recorded throughout the macrobenthic samples.

The highest total abundance was observed at station ST005 with a mean (± SE) of 15 (± 8) individuals, followed by station ST019 with a mean (± SE) of 10 (± 6) (Figure 14). The highest diversity was recorded at station ST005 with a with a mean (± SE) of 9 (± 0.7) different taxa identified across both samples. Total biomass was greatest at station ST001 with a mean (± SE) total biomass of 0.06 gAFDW (± 0.01) (Figure 14).

The largest contributors to the overall biomass were Mollusca followed by annelids. *P. ulvae* and *Cerastoderma edule* were the top two contributing taxa to overall biomass with *Nephtys hombergii* and *T. benedii* following. Biomass at station ST001 was highest across the survey area followed by station ST007 (Figure 14) and was driven by Mollusca at both stations. A higher abundance of *P. ulvae* was observed at station ST001.

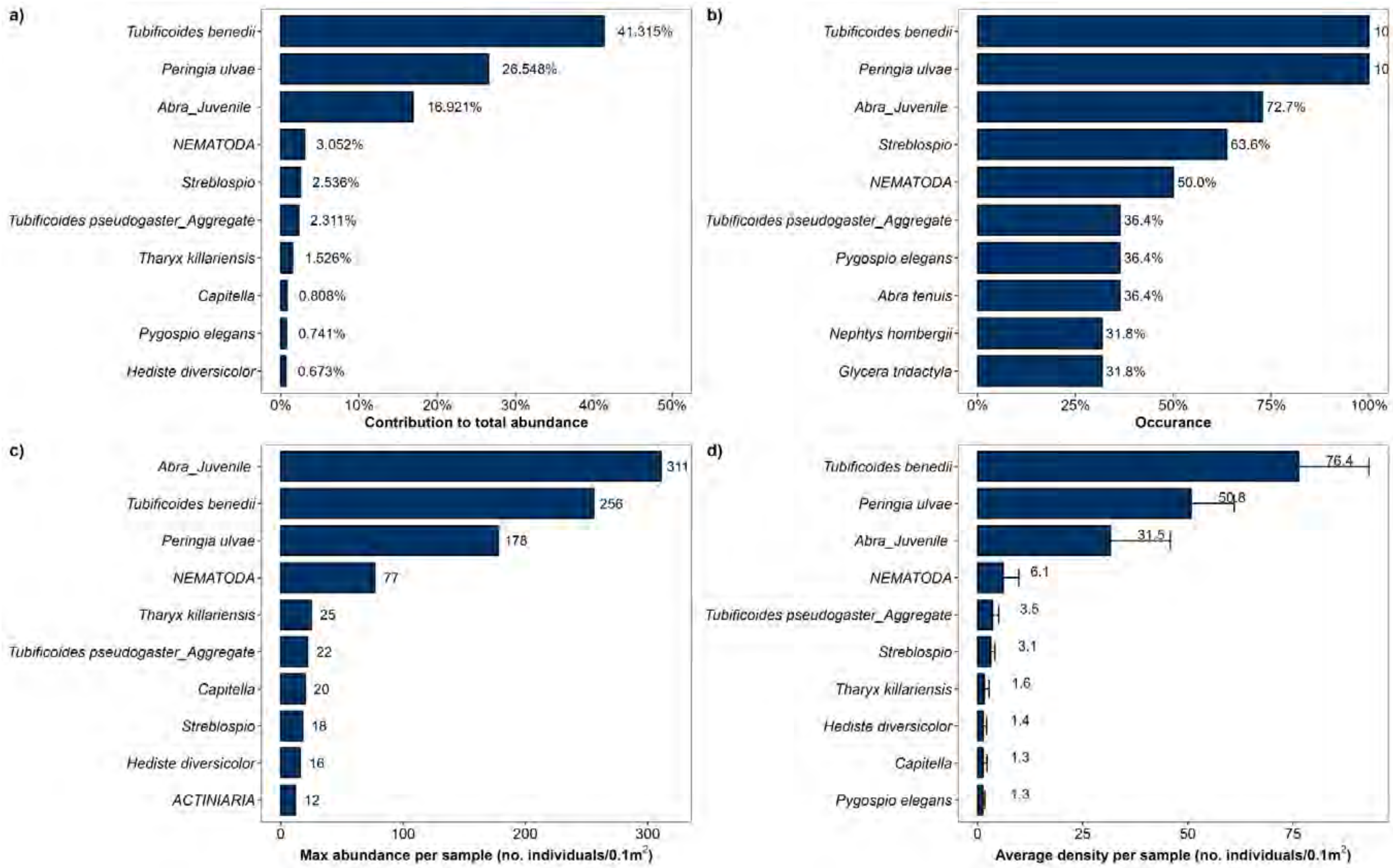

Figure 12 Percentage contributions of the top 10 macrobenthic taxa to total abundance (a) and occurrence (b) from samples collected across the Langstone Village survey area. Also shown are the maximum densities of the top 10 taxa per sample (c) and average densities of the top 10 taxa per sample (d).

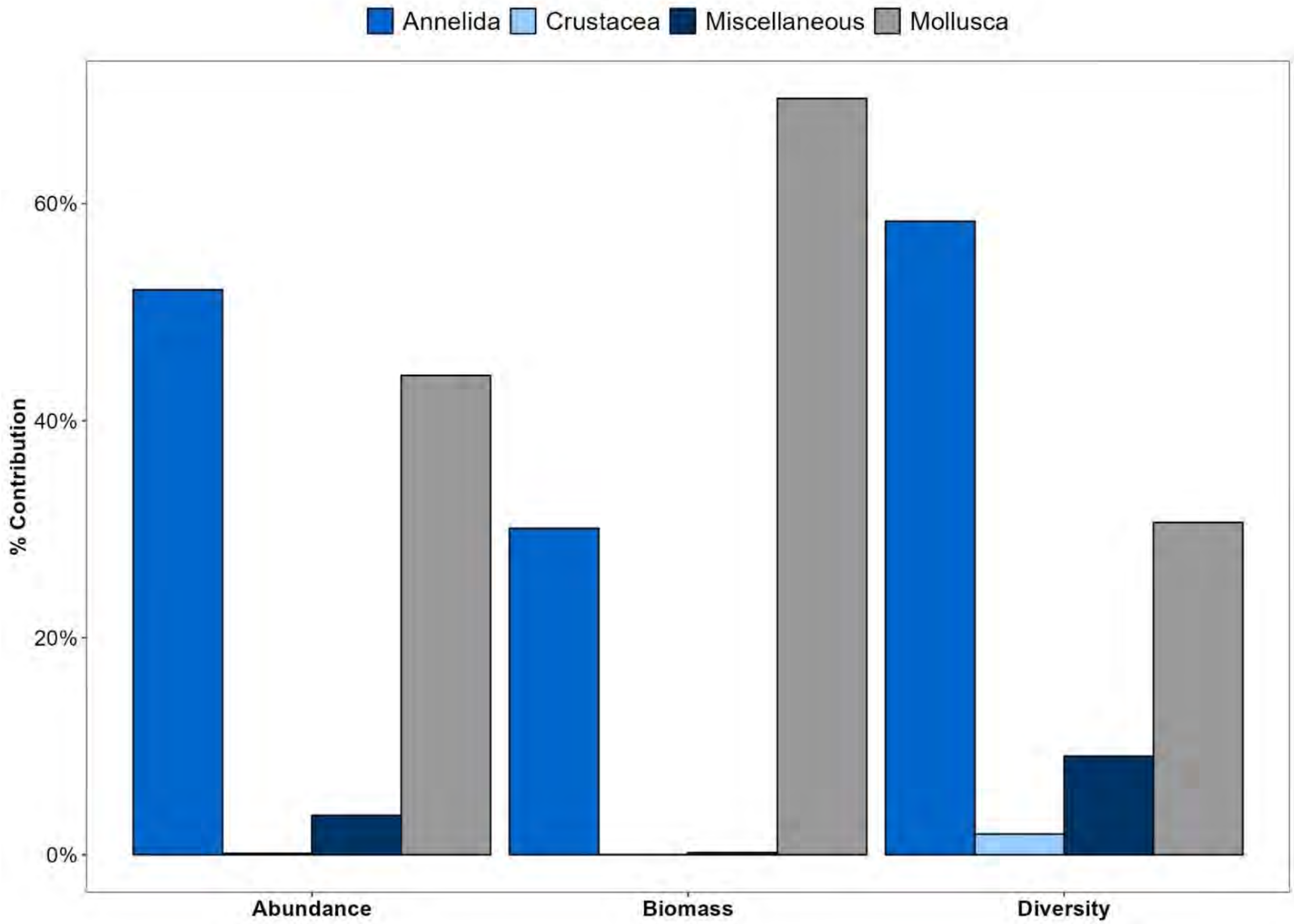

Figure 13 Relative contribution of the major taxonomic groups to the total abundance, diversity and biomass of the macrobenthos sampled across the Langstone Village survey area.

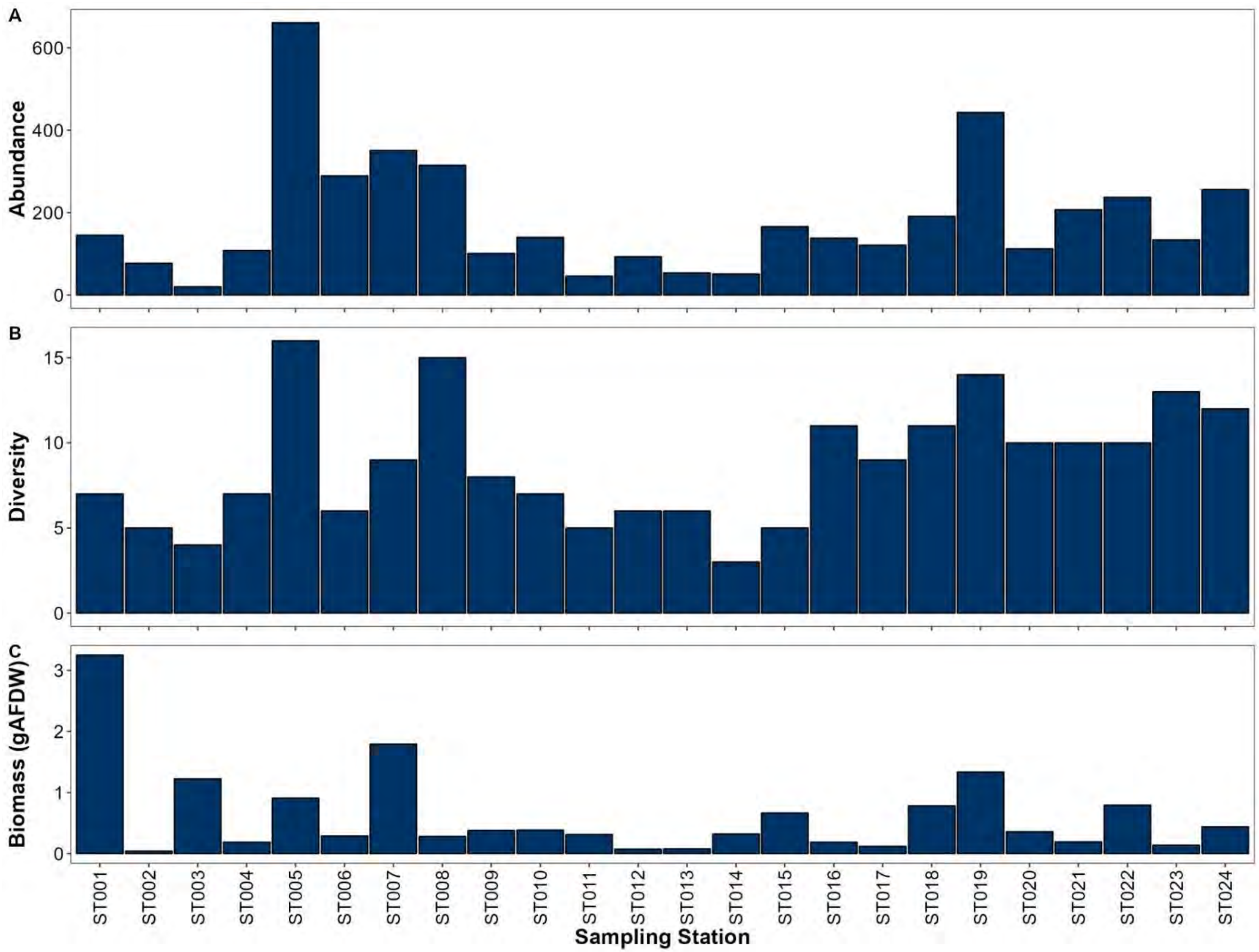

Figure 14 Abundance, diversity and biomass per station across the Langstone Village survey area.

4.2.13. Notable Species

During Phase II survey operations the INNS Pacific oyster *Magallana gigas* was observed at station ST013 in the northern extent of the survey area.

4.2.14. Multivariate Analysis

Multivariate analysis was undertaken after a dispersion weighting transformation was applied to the macrobenthic abundance data (counts) to account for variations in the macrobenthic composition. Multivariate analyses were then carried out to identify spatial distribution patterns in the macrobenthic assemblages across the Langstone Village survey area and identify characterising taxa present.

Cluster analysis of the macrobenthic data was performed on a Bray-Curtis similarity matrix to analyse the spatial similarities in macrobenthic communities recorded across the survey area. The dendrogram resulting from the cluster analysis and associated Type 1 SIMPROF (similarity profile routine) permutation test of all nodes within the dendrogram, identified one statistically significantly similar group containing all stations. The dendrogram resulting from the cluster analysis and associated Type 1 SIMPROF permutation test are provided in Figure 15.

To visualise the relationships between the sampled macrobenthic assemblages, a non-metric Multidimensional Scaling (nMDS) plot was generated on the community abundance data (Figure 16). The nMDS represents the relationships between the communities sampled, based on the distance between sample (station) points. The stress value of the nMDS ordination plot (0.18) indicates that the two-dimensional plot provides a sufficient representation of the similarity between stations for high level comparisons of within and in-between variability between samples.

SIMPER (Similarity Percentage) analysis was used to identify the key taxa contributing to the within group similarity of the macrobenthic group. The key contributing taxa across all stations were the sludge worm *Tubificoides benedii* and the mudsnail gastropod *Peringia ulvae* which contributed 47.5 % to the macrobenthic group average similarity.

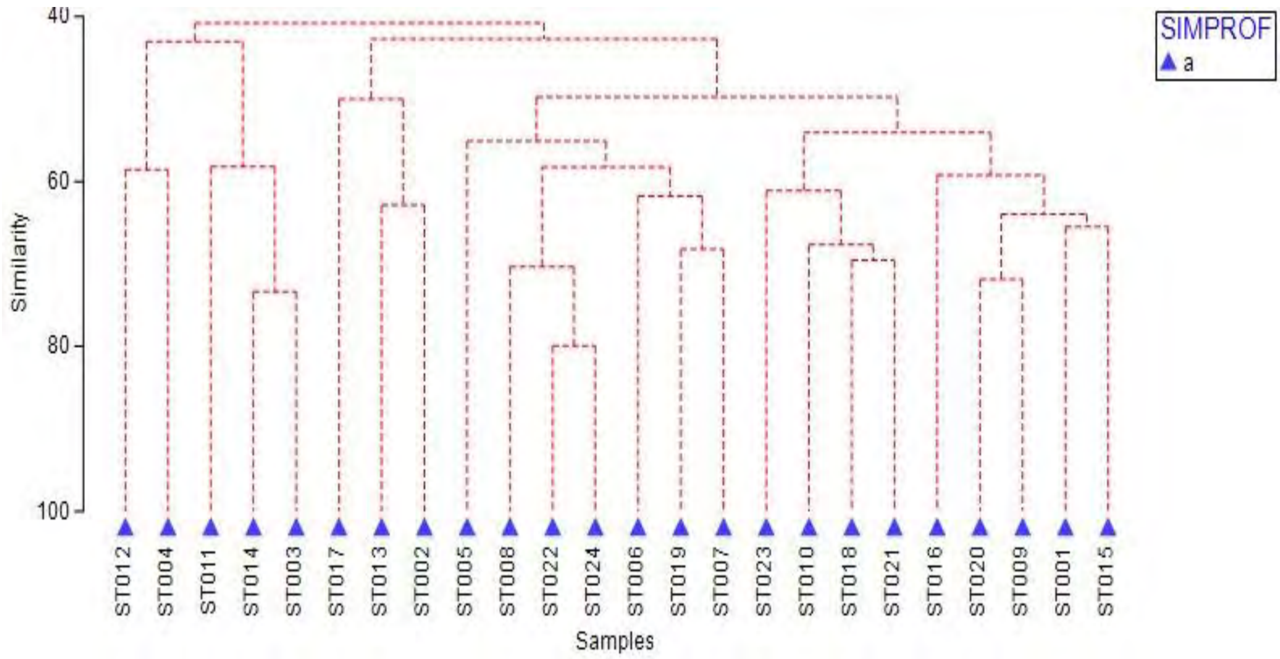

Figure 15 Dendrogram of macrobenthic communities sampled across the Langstone Village survey area based on square root transformation and Bray-Curtis similarity abundance data.

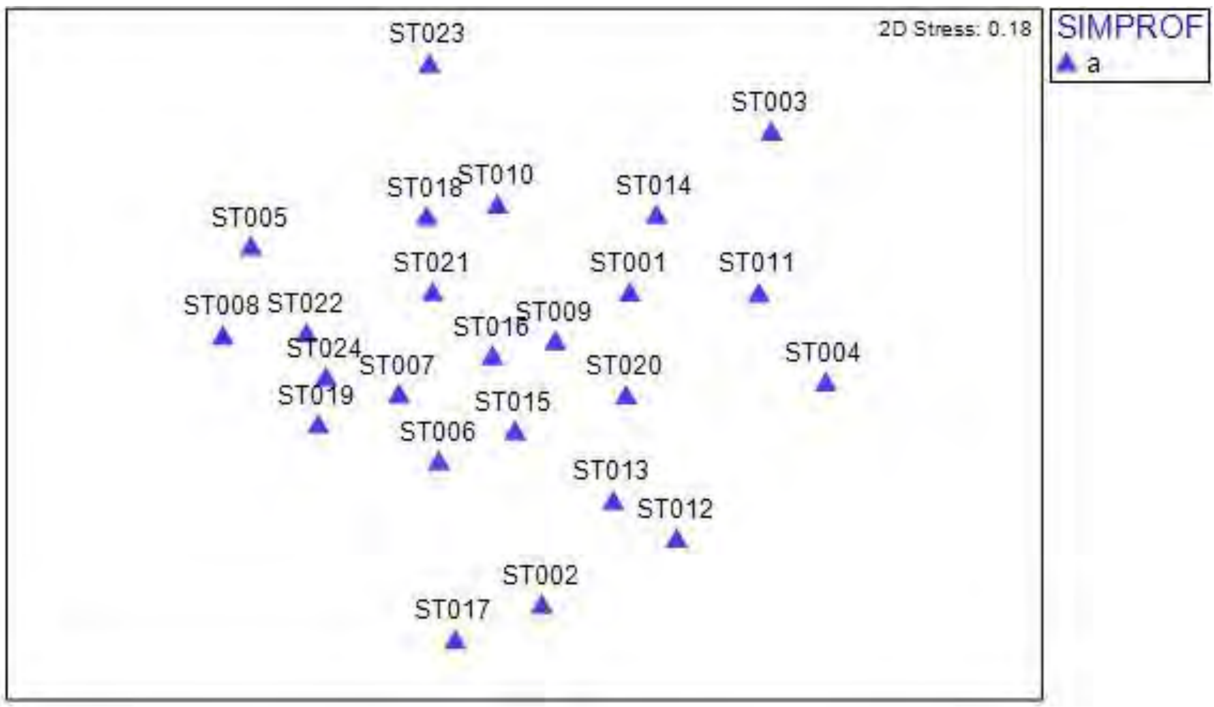

Figure 16 Two-dimensional nMDS ordination of macrobenthic communities sampled across the Langstone Village survey area based on square root transformation and Bray-Curtis similarity abundance data.

4.3. Habitat/Biotope Mapping

4.3.1. Overview

To map the principal habitats that occurred throughout the Langstone Village survey area, a full interrogation of all available data was carried out. This included results from the Phase I survey (target notes and 2022 CCO imagery) as well as interpreting the results of the cores sediment and macrobenthic analysis.

A clear linear zonation of habitats was observed across 6 biotopes with MA321 'Faunal communities on full salinity Atlantic littoral coarse sediment' observed in the upper shore leading down to MA6223 '*Nephtys hombergii*, *Macoma balthica* and *Streblospio shrubsolii* in Atlantic littoral sandy mud' which dominated the lower shore. However, the Langstone Village survey area was relatively homogeneous and primarily characterised by the latter (MA6223) and MA622 'Faunal communities of variable salinity Atlantic littoral mud'. Together these two biotopes represented 76 % of the total survey area and can be considered typical for low to moderate energy hydrodynamic regimes such as those found in this location.

The distribution and extent of the habitats/biotopes identified across Langstone Village survey area are presented in Table 8 and Figure 17. Polygons of the mapped habitats identified are provided as shapefiles in Appendix VI.

Table 8 Biotopes determined with the associated confidence level (1 = low, 2 = high) from habitat mapping, with total mapped extent in m^2.

BSH	EUNIS Code	EUNIS Description	Confidence	Area (m^2)	% of Total Area
MA3	MA321	Faunal communities on full salinity Atlantic littoral coarse sediment	2	11,219	3
MA6	MA622	Faunal communities of variable salinity Atlantic littoral mud	1	108,145	31
	MA6223	*Nephtys hombergii*, *Macoma balthica* and *Streblospio shrubsolii* in littoral sandy mud	1	154,798	45
MA4	MA4232	*Hediste diversicolor* dominated gravelly sandy mud shores	1	37,928	11
	MA4233	Cirratulids and *Cerastoderma edule* in littoral mixed sediment	1	1,2584	4
MA2	MA225	Atlantic pioneer saltmarshes	2	22,840	7

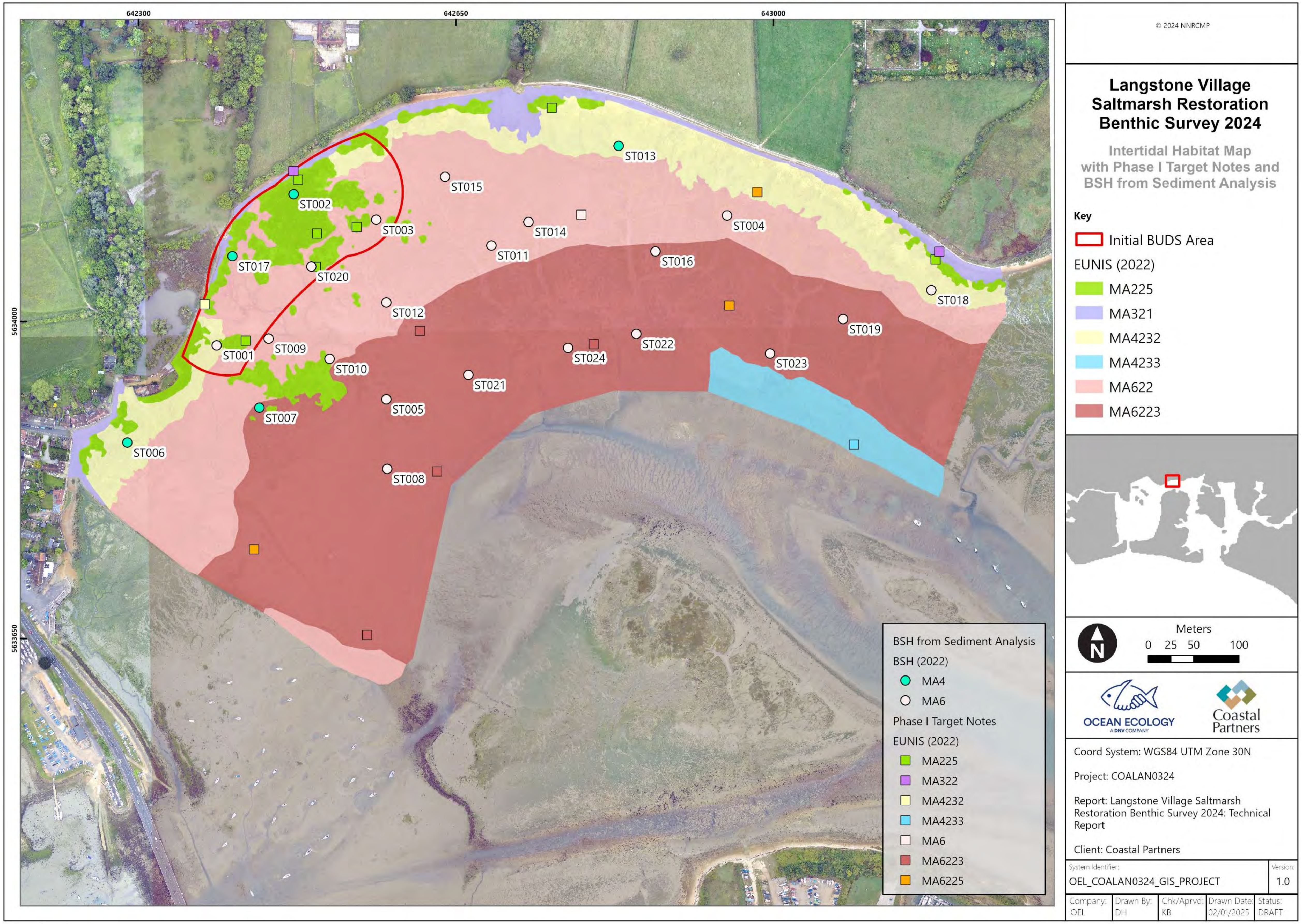

Figure 17 Habitat types observed across the Langstone Village survey area.

The SIMPER routine was used across all stations to describe the assigned biotope groups. The results for this are provided in Appendix VII. As expected from the earlier analyses (Figure 14 and Figure 15), the cores taken within each biotope had a low similarity (47 – 56 %). The dissimilarity in the species composition across the cores between different biotopes ranged from 47 % to 60 %. This can be seen in the nMDS plot in Figure 18 by that lack of any significant clustering (no green Simprof lines). The SIMPER analysis once again showed homogeneity in the species composition across the survey area; *T. benedii* and *P. ulvae* contributed to 80 % of the similarity between cores in MA4232 '*Hediste diversicolor* dominated gravelly sandy mud shores' and MA622 and to 57 % in MA6223. Their slightly lower contribution to similarity in latter biotope is replaced by juvenile *Abra* sp. (18 %) which may explain why this biotope clusters more closely on the plot and in the SIMPER results.

A PCA of sediment types based on the Sediment PSD data is presented as on overlay on the nMDS plot in Figure 18. This shows that sediment alone does not describe the species composition within the survey area that is composed of mixed sediments and muds with gravelly or sandy components. The key characteristics recorded in each of the mapped biotopes from interpretation of all available data are described below and summarised in Appendix VIII.

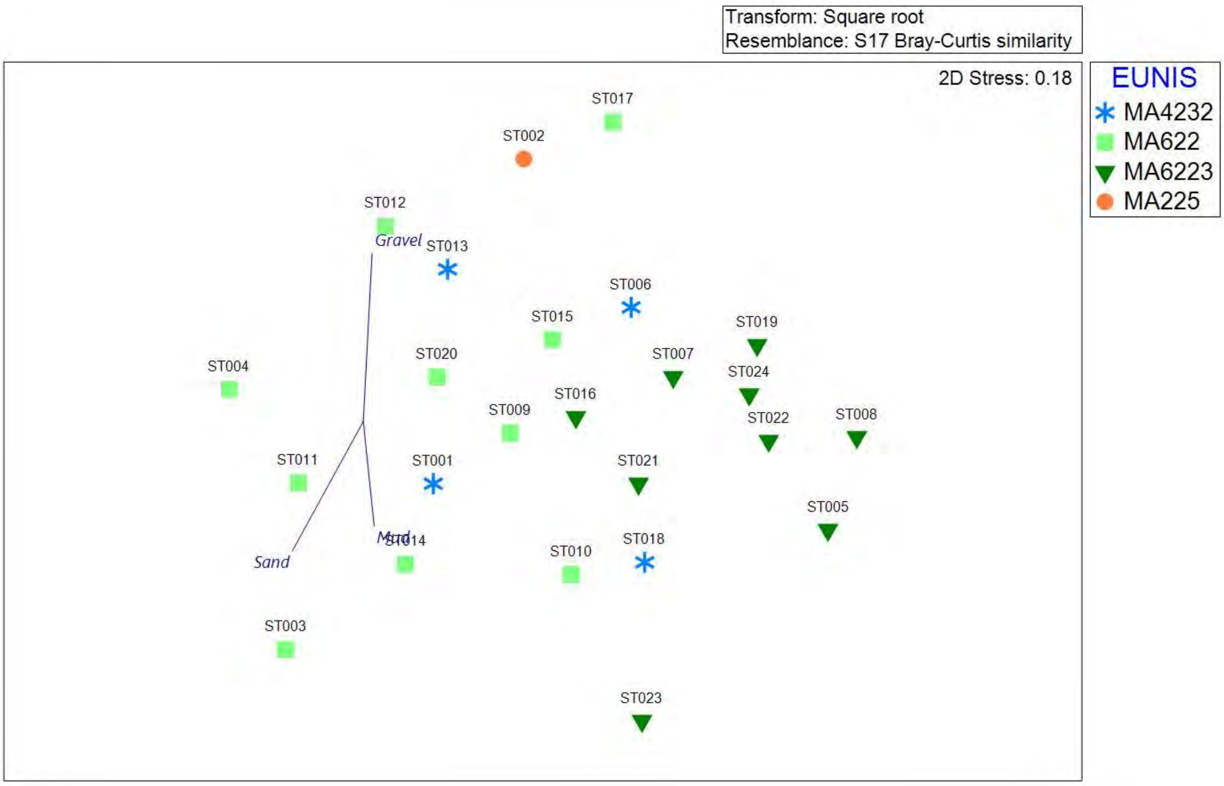

Figure 18 nMDS plot of each station's assigned EUNIS biotope code and sediment type PCA overlay.

4.3.2. Atlantic pioneer saltmarshes (MA225)

Saltmarsh mapped as MA225 'Atlantic Pioneer saltmarshes' was most prominent in the westerly region of the survey area with a small area of saltmarsh also observed in the upper northeastern extent. The only saltmarsh species recorded throughout the survey was *Spartina* sp. as seen in (Plate 4) and in the survey photograph library provided in Appendix IX.

The existing saltmarsh appears irregular with many small patches mapped. The total area of saltmarsh mapped within the Langstone Village survey area was 22,840 m^2, or 2.3 hectares, and 7 % of the current survey area extent.

One core was taken within the area assigned as MA225 (core ST002); however, this habitat type was noted as present across the survey area with several cores taken on the border of this habitat. The core collected within the MA225 'Atlantic Pioneer saltmarsh' habitat type was composed of ~ 7 % gravel and was described by PSD analysis as the BSH MA4 'Littoral Mixed Sediment'.

Macrobenthic analysis of the sediments obtained at station ST002 showed that *T. benedii* was the most abundant species within this biotope with a total of 51 individuals. The polychaete *Streblospio* spp. was the second most abundant with a total abundance of 18. The core taken in the mud adjacent to this habitat type, on which there was a dense macroalgal mat, contained 5 species and a total of 77 individuals. *Spartina* sp. was noted as common within the vicinity of station ST002. The total biomass of taxa recorded at this station was 0.0430 g of which *P. ulvae* contributed the most (0.0276 g) followed by *T. benedii* (0.0105 g).

A 1 cm redox layer was observed at this station and salinity was 32 ppt.

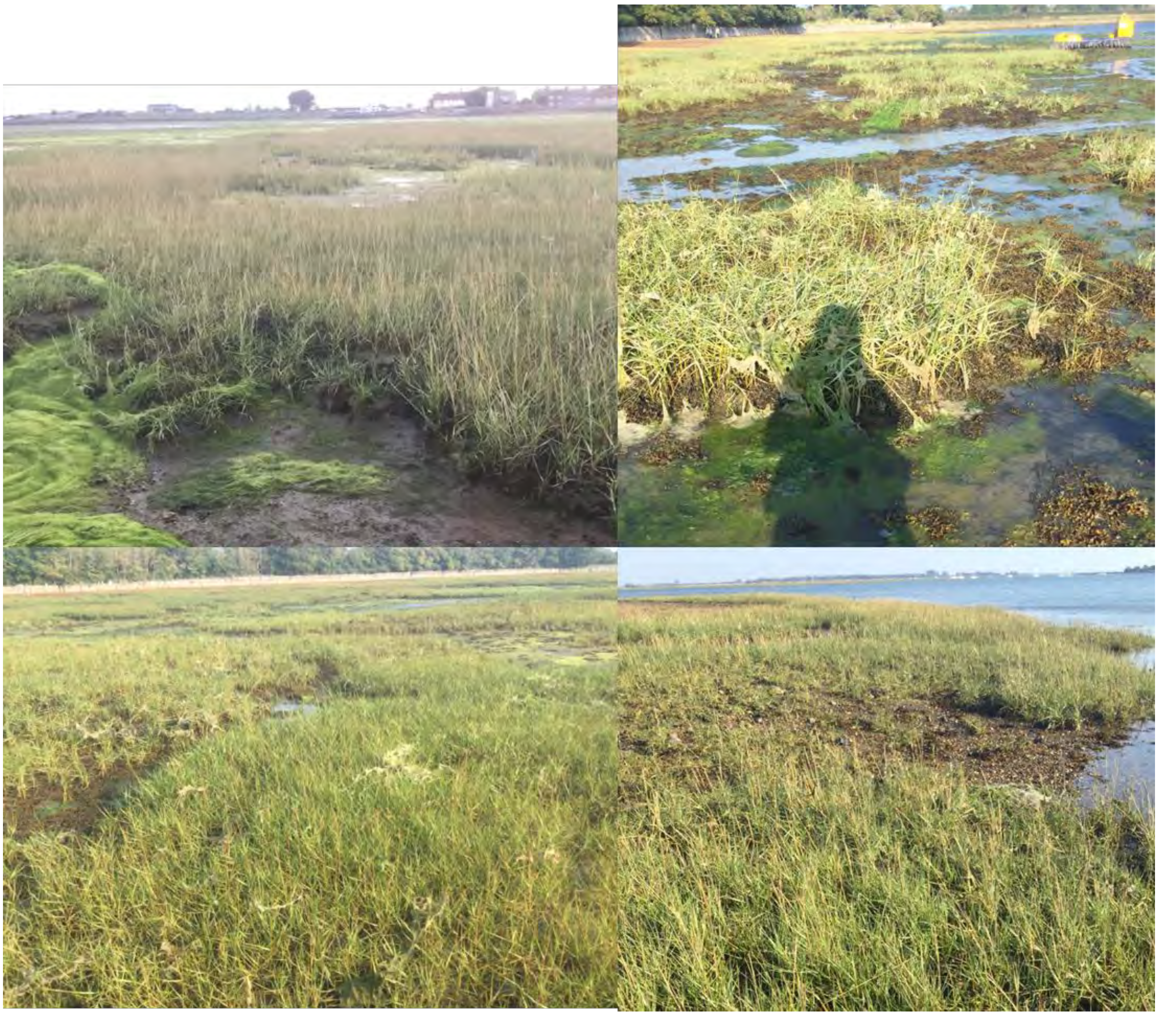

Plate 4 Examples of the MA225 'Atlantic pioneer saltmarsh' biotope at core station ST002 (top right) and Phase I targets TN013 (bottom left) and TN002 (bottom right), as well as saltmarsh present in close vicinity to core sample ST010 taken in biotope MA622 (top left).

4.3.3. Faunal communities of variable salinity Atlantic littoral mud (MA622)

Ten cores were collected within this habitat type (ST003, ST004, ST009, ST010, ST011, ST012, ST014, ST015, ST017 and ST020). This biotope covered 108,145 m^2 (10.8 hectares) which constituted approximately 31 % of the survey area (Plate 5 and Appendix IX).

This habitat is defined as Upper estuarine sandy mud and mud shores which typically forms mudflats. Little oxygen penetrates the sediments, and an anoxic layer is often present within millimetres of the sediment surface. The upper estuarine mud communities support few infaunal species and are principally characterised by a restricted range of polychaetes and oligochaetes.

Sediments observed within the cores taken within the region assigned as this biotope were dominated by mud at all stations, except station ST017, and were all classified by PSD analysis as the BSH MA6 'Littoral Mud'. Station ST017 had a significant higher gravel content than other stations within this biotope (68 %) and was representative of the BSH MA4 'Littoral Mixed Sediment'.

The primary species observed within the habitat type were *P. ulvae* and *T. benedii* with a total abundance across all stations of 348 and 314 respectively. The total abundance across all stations assigned to this biotope was 958 with 19 different taxa recorded. For all stations assigned as this biotope, the total biomass of all taxa recorded was 4.0414 g. *P. ulvae* accounted for 2.5829 g of the total biomass across these stations which was considerably more than any other taxa.

Cores and observations within this habitat type therefore provide a good match to the EUNIS biotope MA622 'Faunal communities of variable salinity Atlantic littoral mud'.

An anoxic layer of 1 cm was observed and noted at all stations located within this biotope and either *Chaetomorpha* sp. or *Ulva* sp. species were abundant or superabundant at all stations in the form of matts on the surface of the sediments. The salinity at stations assigned to this biotope ranged from 27 – 32 ppt.

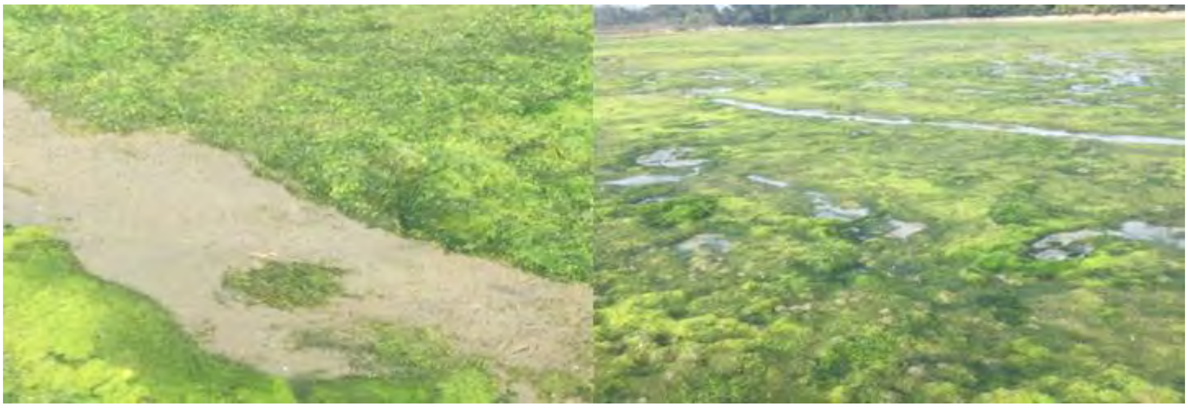

Plate 5 Examples of MA622 biotope (left: TN016 and right: TN017).

4.3.4. *Nephtys hombergii*, *Macoma balthica* and *Streblospio shrubsolii* in littoral sandy mud (MA6223)

Nine cores (ST005, ST007, ST008, ST016, ST019, ST021, ST022, ST023 and ST024) were taken from within the area assigned as this biotope which was dominant across the survey area. This biotope covered approximately 45 % of the survey area and spanned 154,798 m^2 (15.5 hectares) (Plate 6 and Appendix IX).

This biotope is described by soft mud and fine sand in variable salinity conditions and is often found close to the head of estuaries The infaunal community of this biotope is typically dominated by the polychaetes *S. shrubsolii* and *N. hombergii* and the Baltic tellin *M. balthica* (jncc.gov.uk).

All but one of the stations assigned to this biotope were described by sediment PSD analysis as the BSH MA6 'Littoral Mud' with station ST007 representing the BSH MA4 'Littoral Mixed Sediment'. Several of this biotope's characterising taxa were present in cores including the mud snail *P. ulvae* which was recorded a total of 602 times across the 9 stations, *Streblospio* sp. (n = 80), *M. balthica* (n = 1) and *N. hombergii* (n = 15). The total abundance across all stations assigned to this biotope was 2742 with a total of 47 different taxa recorded. Total biomass at these stations was 6.0787 g. *P. ulvae* also contributed most to total biomass at the stations assigned to this biotope with a total biomass of 3.3957 g. *N. hombergii* contributed the second highest to total biomass with a total of 0.9295 g across these stations.

A redox layer of 1 cm was noted at all stations within this biotope. The salinity was 30 ppt across all 9 stations.

Plate 6 Examples of MA6223 biotope (TN008).

4.3.5. *Hediste diversicolor* dominated gravelly sandy mud shores (MA4232)

Four cores were taken within the area assigned to this biotope (ST001, ST006, ST013 and ST018) which covered an area of 37,928 m^2 (3.8 hectares) and accounted for 11 % of the total survey area (Plate 7 and Appendix IX).

This biotope is typified by sheltered gravelly sandy mud in reduced salinity (jncc.gov.uk). Sediment PSD analysis of the cores collected within this biotope describe stations ST001 and ST018 as the BSH MA6 'Littoral Mud' and stations ST006 and ST013 as the BSH MA4 'Littoral Mixed Sediment'.

Although *Hediste diversicolor* was not recorded in any of the cores taken within this biotope, other characterising taxa such as *Pygospio elegans, Streblospio* spp. and *T. benedii* were present. The total abundance across these four stations was 679 with a diversity of 17 different taxa recorded. *T. benedii* was the most commonly occurring species found in this biotope (n = 338) followed by *P. ulvae* (n = 227). The total biomass across these stations was 4.4006 g. The two taxa contributing most to total biomass were *P. ulvae* (2.1818 g) and *C. edule* (1.9383 g).

A 1 cm redox layer was noted at all stations. Salinity ranged from 25 – 30 ppt.

Plate 7 Examples of MA4232 biotope (left: ST013 and right: ST018).

4.3.6. Cirratulids and *Cerastoderma edule* in littoral mixed sediment (MA4233)

No cores were taken within this habitat type which was situated in the southeast corner extent of the survey area. However, detailed Phase I survey notes described the sediments as firm Littoral mixed sediments with gravel, sand and mud present (Plate 8 and Appendix IX). This biotope covered 12,584 m^2 (1.3 hectares) accounting for 4 % of the total survey area.

Species such as *Cerastoderma* sp., *Cirratulidae* sp., *Hydrobiidae* sp., *Littorina* sp., bivalves and amphipods were all noted within the Phase I survey as being common within this biotope.

Plate 8 Examples of MA4233 biotope (TN006).

4.3.7. Littoral coarse sediment (MA321)

No cores were taken at this biotope which covered an area of 11,219 m^2 (1.1 hectares) and constituted 3 % of the total survey area.

Primary habitat characteristics of MA321 'Littoral coarse sediment' include shores of highly mobile pebbles, cobbles and gravel, which are subject to high degrees of drying between tides. In turn resulting in few species which are able to withstand and survive within this environment (jncc.gov.uk) (Plate 9 and Appendix IX).

This habitat was only observed within the very upper shore areas of the survey area. Although no cores were taken within this habitat type, observations from the Phase I survey confirmed that sediments were coarser and gravellier with no species observed within this habitat type throughout the surveys. Therefore, observations conclude that the area mapped as MA321 'Littoral coarse sediment' is a good match to the EUNIS description.

Plate 9 Examples of MA321 biotope (left: TN001 and right: TN003).

4.3.8. Ecological Value

All observed habitats across the Langstone Village survey area, except for MA321 'Littoral coarse sediment', are listed as habitats of principle importance under the NERC Act 2006. The biotope MA6223 '*Nephtys hombergii, Macoma balthica* and *Streblospio shrubsolii* in Atlantic littoral sandy mud' is also registered under Annex V of the OSPAR convention Strategy on the Protection and Conservation of the Ecosystems and Biological Diversity of the Maritime Area.

Both MA622 Faunal communities of variable salinity Atlantic littoral mud' and MA6223 '*Nephtys hombergii, Limecola balthica* and *Streblospio* shrubsolii in Atlantic littoral sandy mud' are also associated with the Annex I habitat 'Mudflats and Sandflats not covered by seawater at low tide' and the OSPAR priority habitat 'Intertidal Mudflats' which in turn are supporting habitats of the SPA and Ramsar habitats (see Section 1.2.2).

5. Discussion

5.1. Sediment Composition

For the 24 samples analysed for particle size, mud was the dominant sediment fraction across the survey area with an average contribution of 66 %. In contrast, gravel was low across the survey area with only 8 stations having more than 1 % gravel in their sediments with an exception at station ST017 having a majority gravel content at 68 %. Overall, sediments across the Langstone Village survey area were relatively homogenous.

Based on the sediment analysis, two primary habitats were observed: MA4 'Littoral Mixed Sediment' and MA6 'Littoral Mud'. The mapped and observed area of mud throughout the survey area was larger than that of mixed sediment. However, sediment cores collected within the saltmarsh areas revealed that the sediments there were predominantly more mixed sediments. While two BSH classifications were identified based on sediment composition, these did not represent the final mapped sediments and habitats, as intertidal areas are highly variable and subject to change.

Soft sediment habitats can be highly heterogenous as they are heavily influenced by ambient environmental conditions such as sediment composition (Cooper et al. 2011), hydrodynamic forces and physical disturbance (Hall 1994), depth (Ellingsen 2002) and salinity (Thorson 1966) and are therefore subject to natural fluctuations.

5.2. Sediment Chemistry

Several guidelines exist to assess the degree of contamination and likely ecological impacts of contaminants in marine sediments. These guidelines define the levels below which effects are of no concern and/or rarely occur (AL1, BAC, TEL) and the levels above which adverse biological effects are considerable and/or occur frequently (AL2, ERL, PEL). *Ad hoc* decisions need to be made when contaminant concentrations fall between these levels. To note that CEFAS AL1s are typically the most conservative measures to assess sediment contamination and often result in "false positives", meaning that non-toxic sediment samples fail to pass this screening test but are relevant for the disposal of dredged sediments. Among all metals measured within the survey area, Ni exceeded AL1 and ERL reference levels at station ST001. Whilst these thresholds were exceeded, the recorded concentration of 24 mg kg^{-1} was only slightly higher than AL1 (20 mg kg^{-1}) and ERL (21 mg kg^{-1}) and remained well below OSPAR BAC (36 mg kg^{-1}) and AL2 (200 mg kg^{-1}). The majority of Polychlorinated Biphenyls (PCBs) were measured below the LOD at all stations and did not exceed CEFAS AL1 at any of the stations. In contrast, Fluoranthene and Pyrene, the most abundant PAHs did. These were most prominent at the east and west sampling stations with Fluoranthene above CEFAS AL1 at all stations except for ST001 and ST012. Pyrene was above CEFAS AL1 at stations ST004 and ST006.

TOC content in sediments across the survey area ranged from 1.3 % at station ST004 to 3.1 % at station ST001. The average content of TOC is measured at 0.5 % for the deep ocean or 2 % for coastal seas (Seiter et al. 2004) suggesting high levels of TOC at station ST004 but an average for the area in line with the value for coastal seas. Within the aquaculture industry TOC in sediments is measured to assess organic enrichment as a potential impact from fish farm activities. In this context, the threshold level of TOC is set at 9 % by the Scottish Environmental Protection Agency (SEPA) and TOC above 9 % is considered a sign of organic enrichment. All TOC measurements across the Langstone Village survey area were below 9 %.

All organotins and Nitrate measured were below the detection limit at all stations.

In saline waters, nitrogen is usually the key nutrient involved in eutrophication, but phosphorus may also be important in some estuarine situations. Phosphate levels varied from 7.1 mg $^{-}$l at station ST001 to 48.4 mg $^{-}$l at station ST004 and total Nitrogen levels varied from 0.16 % at station ST004 to 0.32 % at station ST001. Although based on rivers, Government guidance recommends that rivers should not exceed annual mean phosphate concentrations of 0.1 mg l^{-1} (DEFRA 2012) suggesting that Phosphate levels within the Langstone Village survey area are high. However, it is likely that phosphate levels within sediments would be higher than those observed within water due to the accumulation in sediments. However, elevated levels of phosphates within sediments may be contributing towards the large mats of macroalgae observed across the survey area. No threshold values for % nitrogen could be found. Levels of exchangeable ammonium varied from 10.0 mg kg^{-1} at station ST001 to 46.8 mg kg^{-1} at station ST012.

5.3. Macrobenthos

The faunal community observed during the survey was typical of that normally associated with intertidal mud habitats, including *T. benedii*, *H. diversicolor* and the mud snails *Hydrobiidae*. The macrobenthic community across the survey area was relatively homogeneous. Multivariate analysis showed that all stations belonged to the same macrobenthic grouping as determined by SIMPROF. It is probable therefore that the habitat types mapped are of a similar ecological value and that any impacts will be mediated primarily by a change in the sediment composition (if this occurs) and the proximity of the habitat to the deposited sediments. The greatest impact will be on those areas on which the greatest amount of sediment is deposited in the first instance. These will exhibit further change as the saltmarsh begins to establish itself.By far the largest contributing taxa to the overall biomass of the inter-tidal sediments were the molluscs followed by the annelids. The mean biomass per core varied across stations. Both core stations ST001 (situated in MA225) and ST007 (located within MA6223 '*Nephtys hombergii, Limecola balthica and Streblospio shrubsolii* in Atlantic littoral sandy mud') had the highest biomass, and these stations were relatively close together. Much of this biomass at these sampled stations was due to the presence of the mud snail *P. ulvae*. Mud snails (*Hydrobiidae*) were found at almost every station and were present within all 24 macrobenthic samples. *P. ulvae* presented the highest value in terms of biomass across the survey area and is a key species in the diet of the Dunlin (*Calidris alpina*) and Redshank (*Tringa totanus tetanus)* which are important species as part of the designations of the Chichester and Langstone Harbours SPA and Chichester and Langstone Harbours Ramsar site.

Core station ST019 was the next most abundant in terms of biomass and was also dominated by Mollusca biomass from the mud snail. However, this station also had a higher abundance and biomass of annelids in the form *T. benedii,* although the highest annelid biomass was observed at sampled station ST022. Both core stations ST019 and ST022 were mud habitats situated in the MA6223 '*Nephtys hombergii, Limecola balthica* and *Streblospio shrubsolii* in Atlantic littoral sandy mud' biotope which covered a large extent of the inter-tidal area. *T. benedii* is an important food source for many macroinvertebrates, fish and birds. Up to 67 % of flounder and plaice stomachs examined from the Medway estuary contained the remains of *T. benedii* which in turn support higher trophic levels of predatory birds and fish (Van den Broek 1978).

Three of the top 5 core stations with the highest biomass (ST005, ST007, ST019) were situated within the MA6223 '*Nephtys hombergii, Limecola balthica and Streblospio* shrubsolii in Atlantic littoral sandy mud' habitat suggesting this habitat is important in terms of providing food sources for the majority of over-wintering birds within the survey area.

Two species of opportunistic macroalgae were recorded during survey: sea emerald, *Chaetomorpha* spp., and sea lettuce, *U. lactuca*. Increased algal growth is associated with nutrient over enrichment causing algae to grow over sediments, blocking light and reducing oxygen (Jones & Unsworth 2016). Multiple elements contribute to the increased cover of macroalgae including the discharges of both treated and untreated sewage effluent and introduction of nutrients via agricultural run-off. Too much macroalgae can be detrimental to saltmarsh habitats as it can hinder the growth of saltmarsh habitats due to smothering and the breaking of culms (Newton & Thornber 2013). Due to the nature of opportunistic macroalgae which grows on the surface, on top of the sediments, there were instances where the high cover of macroalgae made it difficult to accurately record information regarding the sediments and macrobenthic communities below. Macroalgal mats such as this can substantially alter the underlying macrobenthos and can cause a large reduction in the diversity of the community, which may have contributed to the homogeneity observed in the macrobenthic abundance data.

Increased nutrient pollution into coastal waters can stimulate epiphytic biofilm and macroalgae growth (Brodersen & Kühl 2022). Epiphyte cover and macroalgal decomposition can increase the nitrogen concentration within sediments which in turn can positively influence saltmarsh growth in areas of nitrogen deficiency. However, saltmarshes are likely to be negatively hindered by macroalgae cover due to smothering and breakage of culms (Newton & Thornber, 2013). Macroalgal blooms are predicted to intensify in the future with rising temperatures and increased eutrophication, and as Langstone Harbour has previously been documented as having high eutrophication and nutrient input within the area (Maier et al.

2009), the ecological impacts associated with this need to be continuously monitored in order to preserve the saltmarshes and may present challenge in relation to successful restoration using BUDS.

One INNS was found: the Pacific oyster (*M. gigas*) observed within the northern extent of the site at station ST013. Invasive Pacific oysters can modify the habitat around them, increasing habitat complexity and altering water flow. Additionally, it has been shown that this species can cause sulphide accumulation in sediments which can have a negative impact on saltmarsh habitats by reducing culm, root and rhizome biomass (Koch & Mendelssohn 1989). However, there was only one observation of this species in the northern extent of the survey area at station ST013.

5.4. Habitat Mapping

Habitat mapping was carried out in the field and finetuned afterwards based on the aerial images from the CCO and with the support of target notes and sediment PSD and Macrobenthic analysis results.

Some slight discrepancies were present between the Phase I walkover survey observed habitats and the habitats mapped. After reviewing all data and incorporating results of the PSD and macrobenthic analysis it became clear the upper shore was MA321 'Faunal communities on full salinity Atlantic littoral coarse sediment' and not MA322 'Faunal communities on variable salinity Atlantic littoral coarse sediment'. Likewise, areas within the middle of the survey area, were initially presented as MA6225 '*Hediste diversicolor, Limecola balthica* and *Scrobicularia plana* in Atlantic littoral sandy mud' whereas after further analysis has been mapped as MA622 'Faunal communities of variable salinity Atlantic littoral mud' .

It is likely that areas determined as MA622 'Faunal communities of variable salinity Atlantic littoral mud' were also MA6223 '*Nephtys hombergii, Macoma balthica* and *Streblospio shrubsolii* in Atlantic littoral sandy mud' but it was not possible to fully determine this with confidence based on the macrobenthic community observed within the cores collected within this habitat type and therefore these areas were left at EUNIS level 4 MA622 'Faunal communities of variable salinity Atlantic littoral mud'.

The dominant habitats MA622 'Faunal communities of variable salinity Atlantic littoral mud' and MA6223 '*Nephtys hombergii, Limecola balthica* and *Streblospio* shrubsolii in Atlantic littoral sandy mud' have an infauna community usually dominated by the polychaete worms.

Based on the information collected in both the Phase I and Phase II surveys, the majority of the survey area was determined as EUNIS habitat complex MA622 'Faunal communities of variable salinity Atlantic littoral mud' and biotope MA6223 '*Nephtys hombergii, Macoma balthica* and *Streblospio shrubsol*ii in Atlantic littoral sandy mud'. These habitats are protected under the Annex I habitat 'Mudflats and Sandflats not covered by seawater at low tide' and the OSPAR priority habitat 'Intertidal Mudflats'. Intertidal Mudflats are widespread throughout the UK and are characterised by high biological productivity and abundance of organisms. They provide important feeding and resting areas for internationally important populations of migrant and wintering waterfowl and are also important nursery areas for flatfish. The importance of this habitat has been recognised within this study which has presented the MA6223 '*Nephtys hombergii, Limecola balthica* and *Streblospio* shrubsolii in Atlantic littoral sandy mud' habitat as hosting invaluable food sources for surrounding wildlife.

6. Site Suitability for Saltmarsh Restoration

It is known that just over 2.5 ha of saltmarsh is being lost from Chichester Harbour every year (Bardsley et al. 2020) and that at its current rate of decline the harbour could lose all the remaining saltmarsh by the year 2142. This mirrors the UK situation throughout England where it is estimated that 85 % of saltmarsh has been lost since the middle of the nineteenth century (UK Centre for Ecology and Hydrology 2023). It is also the primary reason that Natural England has recommended that the restoration of saltmarsh within Chichester Harbour is undertaken as a matter of urgency. It has been suggested that this could be achieved using a number of different techniques, including managed realignment and BUDS which should mitigate against a drop in saltmarsh biodiversity.

The loss of saltmarsh habitat within the harbour would not only result in a large drop in the biodiversity within the harbour, but also in the loss of the other considerable benefits that saltmarsh is known to provide. These benefits include:

- Carbon sequestration – it has been estimated that between 3 and 14 tonnes of carbon dioxide are sequestered every year for each hectare of saltmarsh (Mason et al. 2022)
- Protecting the shore from erosion and flooding by buffering waves and trapping sediments.
- Improving water quality by filtering runoff from agricultural and urban areas.
- Acting as an important resource for wading birds and wildfowl. Saltmarshes are used as high tide refuges for birds feeding on adjacent mudflats, as breeding sites for waders, gulls and terns and as a source of food for birds particularly in autumn and winter. In winter, grazed saltmarshes are used as feeding grounds by large flocks of wild ducks and geese (JNCC 2008).
- Providing sheltered nursery sites for several species of fish.

Since the proposed restoration area previously supported much more saltmarsh than it currently does, it is very probable that the area will be suitable for restoration, although the success of any restoration will depend on how it is achieved and whether the restoration addresses the reasons for the decline of saltmarsh in the area. It is likely that the reasons for this decline include rising sea level in the south of England caused by the post-glacial isostatic readjustment and climate change (Bardsley et al. 2020). However, it has also been suggested that the increased urbanisation of the coastal fringe around the Solent combined with coastal flood defences which stabilise the coast has reduced the sediment supply to the Solent marshes contributing to their net loss (Tubbs 1999). Beneficial use of dredged sediment to increase the height of the mudflats relative to chart datum would obviously mitigate these factors and should therefore be successful in restoring the saltmarsh particularly if the sediment is then actively re-populated with saltmarsh plants. Such transplantation of saltmarsh plants into placed dredged sediments may also mitigate any smothering of macroalgal mats that may be present.

The creation of any habitat necessarily results in the loss of the habitat it replaces (unless the expansion is vertical, e.g. the installation of piles on rock). For this restoration project, this will primarily be the corresponding loss of inter-tidal mudflats (also protected habitats) which are primarily MA622 'Faunal communities of variable salinity Atlantic littoral mud' and MA4232 '*Hediste diversicolor* dominated gravelly sandy mud shores' habitat types (Figure 17). Both of these habitat types were characterised by relatively high numbers of mud snails (*Peringia ulvae*) and oligochaetes (principally *Tubificoides benedii*) as well as lower numbers of bivalve molluscs (e.g. *Abra* sp.). Of the two habitat types, MA622 was the most diverse.

It is likely that the disturbance and deposition of sediments within these habitat types will only result in short term changes in the benthic macrofauna until such time as the saltmarsh re-establishes itself, as long as the sediments that are used are of similar granulometry and do not contain high levels of contaminants. This is because it has been shown that recovery of some species such as *Hediste diversicolor* and *Peringia ulvae* can be rapid, occurring within a week for the two aforementioned species (Bolam et al. 2004). This is made more likely by the small area that is likely to impacted. The MA4232 habitat is also listed as having a low sensitivity to heavy smothering by MarLin (the MA622 habitat type has no similar assessment as it is a lower level of habitat type, but the higher level habitats such as MA6223 also exhibit a low sensitivity to heavy smothering). Therefore, the key assessment is whether the long-term loss of the mudflats that are replaced by saltmarsh outweighs the benefits of the restored saltmarsh.

The mudflats provide foraging areas for the birds, whereas the saltmarsh provides more roosting opportunities as well as potentially also being foraging areas themselves. Whether the loss of the mudflat habitat would result in any significant impact on bird populations will require further investigation.

Both nationally and within Chichester Harbour, saltmarshes are approximately 6 times less widespread than inter-tidal mudflats. Since the saltmarsh provides a number of other benefits and the baseline in the 1960's was a much greater proportion of saltmarsh than is now present, it seems likely that the replacement of a small amount (up to 12 ha in total) of the much more widespread mud habitat types will be of net benefit. It is presumed that a thorough assessment of the ecological costs and benefits would be undertaken as part of the disposal site characterisation assessment and marine licence application should this project proceed.

Identifying the added value of saltmarsh creation and restoration over existing mudflat can be challenging. The creation or restoration of saltmarsh can provide significant ecosystem service benefits, the scale of the benefits can be site specific, and the scale of intervention can also affect the benefits of the restoration. Generally, there is a reduction in benefits with increasing size of the intervention (Brander et al. 2006, Hudson et al. 2023). However, given Natural England's recommendation for increasing the extent of saltmarsh within Chichester Harbour, schemes such as this will be required unless the additional areas can be created by re-alignment.

7. Catalogue of Data Deliverables

Deliverable	Type	Format	Description
Intertidal baseline survey report	Report	MS Word & PDF	Technical survey report detailing the work undertaken, reporting the survey and analytical findings and the baseline habitat mapping.
Habitat mapping	GIS	ESRI ArcGIS version 10 Shapefiles & MS Excel	Habitat mapping of the Phase 1 habitats/biotopes and Phase 2 core samples & summary statistics.
Photographs & Log	Images & Report	JPEGS & MS Word	Photographs from field work and sediment samples
Field survey sheets	Data	MS Excel & PDF	Completed field log and MNCR type field survey forms (Phase I and Phase II target notes)
Sample analysis results	Data	MS Excel	Data spreadsheets of sediment analysis - for infauna, PSA and contaminants
MMO Sample Plan Results Template	Data	MS Excel	Completed MMO Sample Plan Results template

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