The Lake Lothing (Lowestoft) Third Crossing Order 201[*]

Lake Lothing THIRD CROSSING

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Appendix 11F

Benthic Survey

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Lowestoft Third River Crossing — Benthic Survey

WSP

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Dr Christopher Ashelby, Søren Pears, Dr Tim Worsfold

Client: WSP

Address: St John's House,
Queen Street,
Manchester,
M2 5JB

Project reference: P00001654

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Project Director: David Hall

Project Manager: Dr Christopher Ashelby

APEM Ltd
Diamond Centre
Works Road
Letchworth Garden City
Hertfordshire
SG6 1LW

Tel: 01462 677502

Registered in England No. 02530851

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1. Executive Summary

The biology of part of Lake Lothing, Lowestoft was characterized by an environmental survey, completed in April 2018, as part of an environmental impact assessment for a proposed crossing (the Scheme). The survey included *in situ* records, grab samples, wall scrapes, quadrats and trawls.

The habitats in the footprint of the Scheme comprised a narrow marine inlet bounded by artificial walls, with shallow mud in the bed of the inlet. The mid intertidal region of the walls was colonised by fucoid barnacle mosaics typical of moderate exposure shores. The mud included impoverished cirratulid communities grading into reduced biota mobile mud.

Trawl samples recorded mainly gobies and shrimp, with low numbers of commercially important fish, including one eel. The eel represents the only feature of specific conservation importance, although the wider environment (estuary) is a priority habitat. No other rare or declining species were found.

Several non-native species were recorded, including the first U.K. record of the bivalve *Theora lubrica* and a range extension for the tubeworm *Hydroides ezoensis*, as well as large numbers of the barnacle *Austrominius modestus*.

It is recommended that the Scheme ensures that there is no restriction of passage for migratory fish and that care is taken to avoid transport of sediment and other materials, which may assist the spread of non-native species, from the site to areas outside the estuary.

2. Introduction

2.1 Background

APEM Ltd was commissioned to undertake a series of marine ecology site characterisation surveys to provide a robust dataset to inform an Environmental Impact Assessment for proposed developments at Lake Lothing, Lowestoft. This report presents intertidal and subtidal environmental data obtained from the survey conducted in April 2018.

2.2 Survey objectives

The primary objective of the survey was to provide a robust biological and physicochemical baseline data set and to characterise the subtidal and intertidal benthic communities in Lake Lothing. Surveys were conducted using industry standard, repeatable methodologies to ensure comparability with studies elsewhere or future studies in Lake Lothing. Infaunal benthic communities were assessed through grab sampling, whilst epibenthic invertebrates and fish were assessed from trawl samples. Intertidal fouling communities on the walls were examined through quadrats and wall scrape samples. Samples were analysed to provide data on the flora and fauna, sediment types and habitats within the study area.

3. Methodology

3.1 Survey methods

3.1.1 Health and Safety

Prior to mobilisation, APEM reviewed the Health & Safety (H&S) requirements of the benthic ecology surveys for the Scheme in conjunction with the vessel suppliers. Appropriate Risk Assessments were undertaken and accompanying method statements were produced prior to commencement of the surveys. All survey staff were made aware of the Risk Assessments, appropriate PPE, COSHH forms, incident handling and reporting procedures, responsibilities, contact details and staff details, including training and certification. A Dynamic Field Risk Assessment form was used to update risks as necessary throughout the survey. The purpose of the Dynamic Risk Assessment form was to cover any risks perceived on-site that were not covered by the original assessment or that had been introduced since the production of the assessment (e.g. due to changes in weather conditions). No changes were necessary for this survey.

At the start of each working day, a Tool-Box Talk was held in which details of the day's survey operations were discussed and Health and Safety aspects reiterated, including any information that introduced additional H&S concerns for that day (e.g. heavy winds and swell). At the end of the survey day, a wrap up meeting was also held during which any issues encountered could be highlighted and discussed. All surveyors had the power to issue a 'Stop the Job' order if they deemed that continued operations may introduce a H&S risk. Surveyors were likewise encouraged to highlight any concerns to the ship's captain or other qualified person at the earliest opportunity.

3.1.2 Biosecurity

The potential for spreading non-native species was assessed in the risk assessment for this work and suggested biosecurity measures were implemented following this review.

Rigorous biosecurity measures were employed throughout the survey work. All survey equipment was cleaned and thoroughly dried following its previous use. Prior to deployment in this survey, it was checked to ensure that it was clean. Following use in this survey, it was likewise cleaned and left to dry.

At each wall sampling site, the community was assessed prior to sampling to investigate the potential presence of non-native species. When the wall samples were taken, particular care was taken to ensure that these were taken in such a manner that they did not pose a risk of accidental spread (e.g. through fragmentation of macroalgae).

3.1.3 Survey design

In order to establish a comprehensive baseline, sampling was undertaken in all major habitats present within the immediate footprint of the Scheme.

In order to sample benthic communities and sediments, eight benthic grab stations were established in the immediate impact area for the Scheme. An additional two stations were established at the location of a proposed pontoon on the south side of the river, adjacent to the entrance to Kirkley Ham. These impact stations were termed G01-G10. For comparative purposes, eight reference grab stations were also established (RG01-RG08), four upstream and four downstream of the Scheme.

The wall fouling communities were assessed at four stations in the impact area (S01-S04) and eight reference sites (RS01-RS08). The walls were assessed at mid-tide level in the algal zone. Qualitative samples were also obtained from wall fouling communities.

To gain an understanding of the potential use of the estuary by fish and mobile, epifaunal invertebrates, four trawl stations were established: two parallel trawls in the impact area, one upstream and one downstream.

The distribution of sampling stations is shown in Figure 1, with further detail of those in the impact area shown in Figure 7. All sampling positions are provided in Appendix 1.

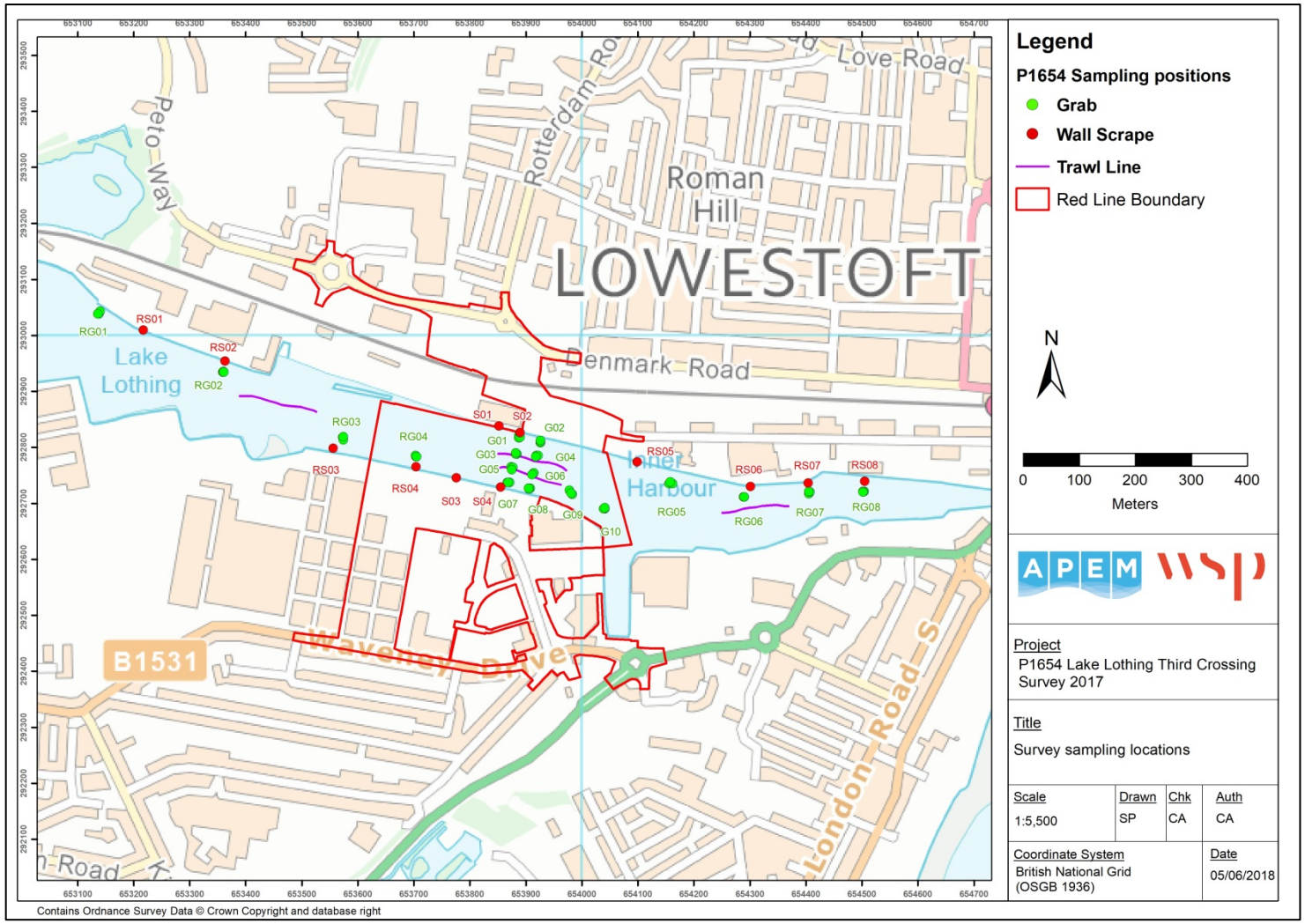

Figure 1. Distribution of all sampling stations in Lake Lothing

3.1.4 Survey permissions and notifications

A number of permissions and notifications were required before sampling occurred.

A dispensation for the use of an undersized trawl mesh (for Council Regulation 850/98 use of undersized nets) and for the retention of undersized fish was obtained from the Marine Management Organisation (MMO) and a letter of derogation was obtained from the Eastern Inshore Fisheries Commission (Eastern IFCA). As a condition of their agreement, the Eastern IFCA requested that a copy of the trawl data be made available to them. An FR2 form (application for authorisation to use fishing instruments other than rod and line in England) was also submitted to the Environment Agency, who in return supplied an S27a permit for the works. The benthic sampling works were exempt from a Marine Management Organisation (MMO) Marine Licence.

Notification was made to the Statutory Harbour Authority prior to the survey and a Notice to Mariners was issued detailing planned survey activities and was updated throughout the duration of the works.

3.1.5 Survey timings

The survey was conducted between 16th and 18th April 2018. These dates were chosen to coincide with suitable spring tides to maximise duration on site and to allow maximum access to stations where the water depth was a limiting factor. The tide times for each survey day are provided in Table 1 below.

Table 1. Tide times for the survey dates

Date	Time (BST)	Tidal Height
16/04/2018	04:24	0.37 m
	10:47	2.55 m
	16:41	0.69 m
	22:51	2.67 m
17/04/2018	05:03	0.34 m
	11:25	2.57 m
	17:20	0.61 m
	23:33	2.69 m
18/04/2018	05:43	0.38 m
	12:03	2.56 m
	18:00	0.57 m

3.1.6 Survey vessels and position fixing

Two survey vessels were used during the field work. Grab sampling and trawling were undertaken aboard the MV FlatHolm, whilst wall sampling was undertaken from the Yorkshire coble MV Lead Us.

3.1.6.1 MV FlatHolm

MV FlatHolm is a 24 m survey vessel owned and operated by CMS-Geotech with a 50 square meter aft deck and is classified by the UK Maritime Coastguard Authority to work up

to 60 nm offshore. She is fully COWRIE compliant, JNCC and UK MCGA Category II classified and is one of the few vessels available in her class that fully complies with these specifications. Her full time crew is fully trained to STCW95 qualifications. The vessel is fitted with a full suite of survey equipment, winches, cranes and 'A' frames. FlatHolm has an endurance at sea of approximately 6 days, usually limited by fresh water usage; where possible she remained at anchor on site between survey days, returning to port where necessary for resupplying and refuelling or during periods of bad weather. She is based in Lowestoft.

Figure 2. The survey vessel MV FlatHolm used for grab sampling and trawling operations. (Image reproduced by kind permission of CMS-Geotech Ltd. ©CMS-Geotech)

The primary positioning system used on board the FlatHolm is a Hemisphere dGPS system accurate to within ±2m. The FlatHolm also possesses 2 backup Hemisphere dGPS systems. To calibrate the machine, readings are compared to a known Ordnance Survey point, to ensure accuracy, and are calibrated in the harbour before leaving. The system is designed to record the position of the grab being deployed, and not the boat.

On the FlatHolm, the offset position of the grab is calculated before leaving port from the dGPS antenna on the wheelhouse bridge to the end of the crane arm when the grab is deployed (distances aft and to starboard). A heading output is derived from the Hemisphere Vector dGPS system that provides vessel orientation and the deployment position is calculated using simple trigonometry in real-time at 10Hz using Trimble HydroPRO software. The grab sample positions are entered into the dGPS system prior to mobilisation and the vessel (end of crane arm) is steered to the sample position.

Although there is potential for any non-perpendicularity within the water column from the vessel to affect the actual position of the grab, if this is too great then the grab will not land square with the seabed and will not obtain a valid sample. Furthermore, within the confines

of Lowestoft Harbour, the water depths are so shallow that the grab will not have the opportunity to drift much. Any deviation from the recorded sampling position is therefore regarded as minimal.

Trawls were deployed from the rear 'A' frame and positions were calculated using a layback technique to work out the position of the trawl relative to the vessel. The position of the trawl once it made contact with the seabed was recorded as the start position and then additional positions were recorded approximately every 30 seconds until the trawl left the seabed on retrieval.

3.1.6.2 MV Lead Us

Wall sampling was undertaken from the vessel MV Lead Us. This vessel was used due to having a very shallow draft which allowed access to most wall sampling locations. Lead us is a 32ft 1980's clinker-built Yorkshire coble first registered in Scarborough and is driven by a Ford 4D 80hp fully marinised diesel engine. She is MCGA Category III vessel, moored on Oulton Broad with a 20 nm range.

Figure 3. The survey vessel MV Lead Us used for wall sampling. (Image reproduced by kind permission of Lead Us Charters. ©Lead Us Charters)

3.1.7 Wall sampling methods

The term wall is used here to refer to the boundary of the river channel and refers to any hard substrata including any man-made vertical structures, such as wooden jetty pilings, sheet metal, concrete or brick walls.

At each station, the general community on the wall was photographed, visually described and large, easily identified animals and algae recorded. Three replicate quadrats were used to quantitatively record the macroalgal community and other fouling taxa present. Three wall scrape samples were collected from the algal zone, according to the layout in Figure 4, and their location recorded using a hand-held GPS in WGS84 format.

At each wall scrape sampling station, a 0.01 m^2 sample was obtained of the biotic community at approximately mid tide level, in accordance with the methodologies described by Worsfold (1998).

Using a 0.01 m^2 sampling device (Figure 5), marine growth was scraped into a bag. Samples were not sieved on board but were transferred to an appropriate container and fixed with 4% buffered formaldehyde solution in seawater. Samples were sieved on return to the laboratory over a 0.5 mm sieve.

Qualitative samples for taxon identification of larger fouling organisms were also collected from certain areas of particularly dense fouling. These qualitative samples were manually removed from the substratum and were not a defined size.

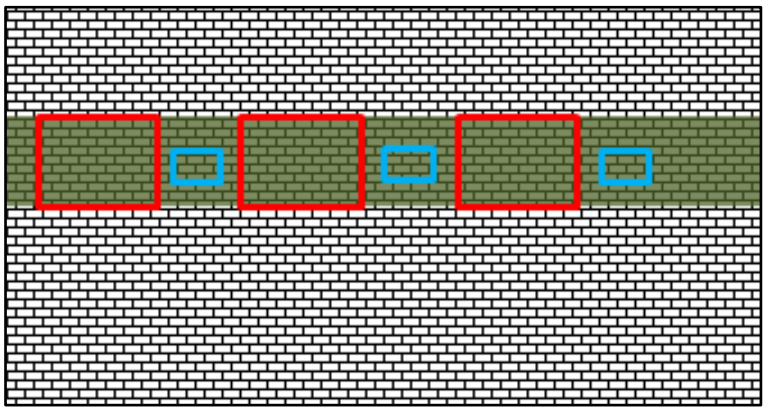

Figure 4. Example section of harbour wall indicating how the quadrat (red squares) and wall scrape samples (blue) were positioned at each station within the algal zone

Figure 5. APEM's wall scrape sampling device

3.1.8 Grab sampling methods

At each grab station, three replicate grab samples were obtained. From the first replicate sample at each station, a subsample or 500-1000 ml was removed for particle size analysis (PSA) (WFD UKTAG 2014).

All samples were assessed on retrieval for suitability according to standard criteria detailed in Davies et al. (2001) and Ware & Kenny (2011). It was not necessary to reject any grab sampling attempts in the survey; thus all sampling attempts were retained for analysis.

A station log sheet was maintained providing information of all sampling attempts at each station. For each sampling attempt, the following information was recorded:

- Station number and attempt;
- Volume of the sample;
- Sample position;
- Sample description (visual assessment, with additional notes on smell etc.);
- Time of collection;
- Any obvious or notable taxa observed (e.g. Annex II species);
- Photograph of the unsieved sample.

Water depths were not recorded since the water depth at most stations was so shallow that the movement of the boat stirred up the sediment making readings obtained from the echo-sounder meaningless.

The entire retrieved grab sample was photographed prior to processing, then field sample processing was conducted in accordance with the guidance provided in Cooper & Mason (2017), using the following steps.

1. Remove PSA subsample (500-1000 ml; replicate 1 only)
2. Pour off excess water from the sample over the sieve table;
3. Photograph the sample (with identification label);
4. Measure the sample volume;
5. Wash and sieve the sample on the sieve table over a 0.5 mm mesh;
6. Transfer material to a suitable container and remove biota from the sieve mesh using forceps.
7. Preserve and label (internal and external) the sieved sample.

To facilitate sieving and to prevent damage to smaller, fragile animals, a coarse mesh sieve (5.0 mm) was used above the 0.5 mm sieve to remove any larger material.

All material retained on the sieves was fixed with 4% buffered formaldehyde solution in seawater and placed in sample containers (labelled inside and outside), following guidance in Ware and Kenny (2011) and Davies et al. (2001). Once the sieved sample was labelled and preserved, all apparatus and sieves were thoroughly cleaned to prevent cross-contamination before moving to the next station.

3.1.9 Trawl sampling methods

Trawl sampling was conducted at four stations. Positions were recorded approximately every 30 seconds to allow the path to be accurately recorded rather than assume a straight line between a start and an end location. One trawl sample (T04) was repeated due to low sample volume, following the initial tow.

The catch of each trawl was placed into a calibrated container and the net was then checked for any remaining epifauna and fish. Excess sediment was rinsed away and the approximate total unsorted volume of the catch estimated. The samples were initially cleared of large debris and the total catch photographed. Due to comparatively low abundance, it was not necessary to subsample any of the trawl samples and all organisms were counted. Fish were sorted from invertebrates, divided into groups, identified to species level and counted. Fish and commercially important crustaceans were measured (to the nearest millimetre) using a fish board or callipers, according to the schematic below (Figure 6).

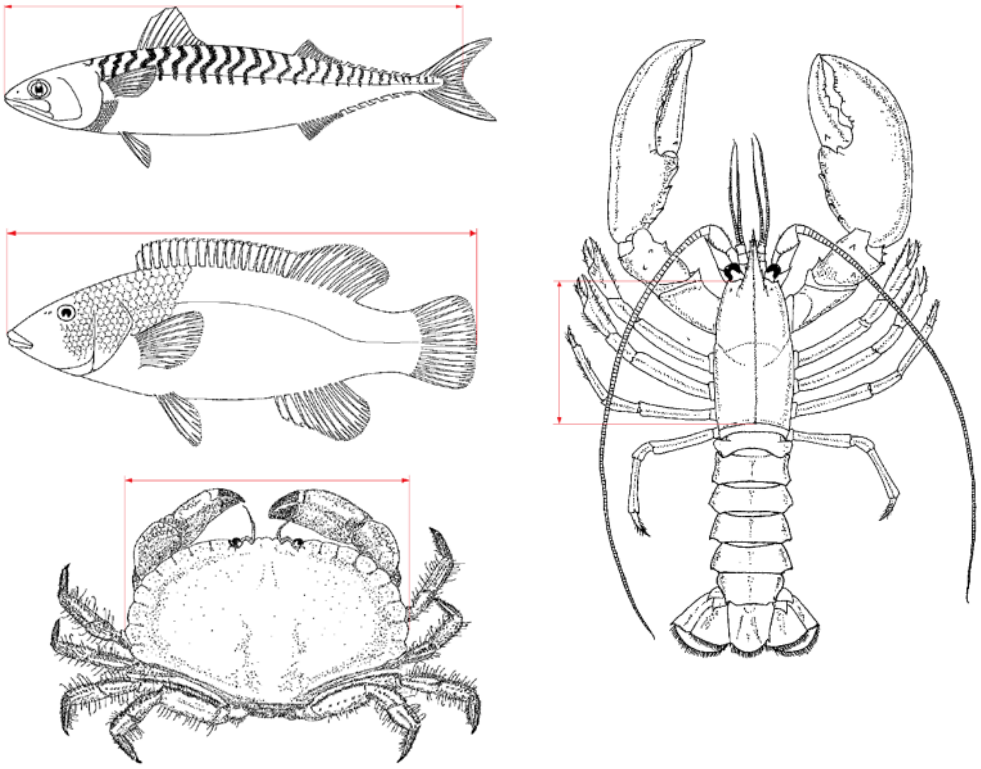

Figure 6. Schematic for points of measurement for concave tailed fish, convex tailed fish and commercially important crustacean species.

3.2 Laboratory methods

3.2.1 Biological samples

Samples were processed according to APEM's standard operating procedure for marine benthic sample analysis and in full compliance with the North-east Atlantic Marine Biological Analytical Quality Control (NMBAQC) Scheme's Processing Requirement Protocol (Worsfold & Hall, 2010).

Benthic grab and wall scrape samples were sieved over a 0.5 mm mesh in accordance with WFD guidance for benthic sampling in transitional waters (WFD-UKTAG, 2014) but, to standardise the sizes of organisms and improve sorting efficiency, samples were sieved through a stack of 4.0, 2.0, 1.0 and 0.5 mm mesh sieves in a fume cupboard. All biota retained in the sieves were then extracted under low power microscopes, identified and enumerated, where applicable. It was not necessary to subsample any of the samples from these surveys.

Most of the processing of trawl samples was conducted in the field but some specimens of taxonomically problematic taxa or those requiring microscopic identification were taken to the laboratory for confirmation or identification where required. A sub-sample of the trawl was also collected for analysis of smaller organisms. In the laboratory, these trawl samples were also sieved through a stack of sieves with a base mesh of 1.0 mm but, due to the mesh used on the trawl itself, the <4 mm fractions can only be considered as qualitative.

Taxa were identified to the lowest practicable taxonomic level, using the appropriate literature. For certain taxonomic groups (e.g. nemerteans, nematodes, and certain oligochaetes), higher taxonomic levels were used due to the widely acknowledged lack of appropriate identification tools for these groups. The NMBAQC Scheme has produced a Taxonomic Discrimination Protocol (TDP) (Worsfold & Hall 2010) which gives guidance on the most appropriate level to which some marine taxa should be identified, and this guidance was followed for the laboratory analysis. Where required, specimens were also compared with material maintained within the laboratory reference collection. Fish and shrimp retained from the trawl samples were measured as described above using callipers. Nomenclature followed the World Register of Marine Species (WoRMS, 2018), except where more recent revisions were known to supersede WoRMS.

At least one example of each taxon recorded from the surveys was set aside for inclusion in APEM's in-house reference collection. This collection acts as a permanent record of the biota recorded.

All samples were subject to internal quality assurance procedures, whereby the residues and identifications from each sample were secondarily checked by another analyst. To ensure consistency, taxonomic quality control was conducted by the same individual. Following analysis, 10% of samples were subject to formal Analytical Quality Control (AQC) to produce pass/fail statistics.

3.2.2 Particle Size Analysis (PSA) and Total Organic Carbon (TOC)

PSA samples were analysed in accordance with NMBAQC Guidelines for Particle Size Analysis (PSA) for Supporting Biological Analysis (Mason, 2016) to provide data over the complete particle size range allowing determination of the gravel to sand plus mud ratio. Samples were wet separated at 1.0 mm to allow sieve analysis of the >1.0 mm fractions; however, no material >1.0 mm was present and therefore all material from the sub-1.0 mm fraction was analysed via laser diffraction (size range 0.04 µm to 1.0 mm).

Total organic carbon (TOC) has been calculated as percentage loss on ignition (LOI). For calculating TOC by LOI, samples were dried in an oven at 70°C for 24 hours, left to cool in a desiccator and their weight taken. Samples were then transferred to a muffle furnace and incinerated at 430°C, cooled in a desiccator and re-weighed. This method is a slightly modified version of the procedure outlined in ASTM D2974-07a (Standard Test Methods for

Determination of Moisture, Ash and Organic Matter of Peat and Other Organic Soils) which avoids carbonate mineral decomposition and minimises loss of structural water from clays. The standard method (ASTM D2974-07a) uses a higher temperature of 450°C. Using higher temperatures runs the risk of some breakdown of minerals other than organic carbon forms. This problem is reduced by using a temperature of 430°C, although not completely eliminated. Data were converted from percentage loss on ignition to TOC using standard conversion factors (Broadbent, 1953).

3.3 Data analysis methods

3.3.1 Macrobiota

Calculation of univariate diversity indices (e.g. numbers of taxa, density, diversity, evenness) and multivariate analyses (e.g. Cluster Analysis, MDS), were carried out using PRIMER version 6 (Clarke & Warwick, 2001; Clarke & Gorley, 2006).

Before analysis, all data were checked for errors. Summary statistics were calculated and outlying values investigated to identify possible data transcription errors.

Univariate techniques

The DIVERSE component of Primer was used to calculate a number of univariate statistics for each sample. In the interest of consistency, colonial taxa such as bryozoans and hydroids were included when calculating the total number of taxa, but excluded from calculating the total number of individuals and other diversity indices.

Biological diversity within a community was assessed based on taxon richness (total number of taxa present) and evenness (considers relative abundances of different taxa). The following metrics were calculated:

- **Taxon richness:** The total number of taxa in a sample.
- **Density:** The number of individuals per unit area (e.g. per square metre).
- **Shannon-Wiener Diversity Index (*H'*(log$_e$)):** A widely used measure of diversity accounting for both the number of taxa present and the evenness of distribution of the taxa (Clarke & Warwick, 2001).
- **Margalef's species richness (*d*):** A measure of the number of species present for a given number of individuals.
- **Pielou's Evenness Index (*J'*):** A representation of the uniformity in distribution of individuals spread between species in a sample. The output range is from 0 to 1, with higher values indicating more evenness or more uniform distribution of individuals.
- **Simpson's Dominance Index (1-λ):** A dominance index derived from the probability of picking two individuals from a community at random that are from the same species. Simpson's dominance index ranges from 0 to 1, with higher values representing a more diverse community without dominant taxa.

Multivariate techniques

Multivariate analyses were conducted using resemblance (similarity) matrices. Of the 46 taxa recorded in the grab samples, 23 were non-countable (mostly colonial taxa or algae recorded as presence/absence) and abundances of countable taxa were very low.

Therefore, all taxa were included; prior to multivariate analyses, the abundance data were transformed to presence/absence and Jaccard similarity was used for analysis.

Cluster Analysis

Hierarchical cluster analysis was carried out on a Jaccard similarity matrix of the macrobenthic data in order to visualise the biological similarity between samples. The similarity profile (SIMPROF) test was carried out as part of the clustering routine in order to distinguish clusters of samples that cannot be statistically differentiated at the 5% significance level. Since there were replicates with no biota or very low numbers of taxa, a zero-adjusted similarity matrix was created by the addition of a dummy variable with a value of '1' for all replicates. This reduces the problem of similarity being undefined for two samples with no taxa and large variations caused by near-blank samples (Clarke and Gorley, 2006).

Ordination Analyses using non-Metric Multidimensional Scaling

Non-metric multidimensional scaling (NMMDS) is an ordination method which creates a 2- or 3-dimensional 'map' or plot of the samples from the Primer resemblance matrix. The plot generated is a representation of the dissimilarity of the samples (or replicates), with distances between the replicates indicating the extent of the dissimilarity. For example, replicates that are more dissimilar are further apart on the MDS plot. No axes are present on MDS plots, as the scales and orientations of the plots are arbitrary in nature.

Each MDS plot provides a stress value which is a broad-scale indication of the usefulness of plots, with a general guide indicated below (Clarke & Warwick, 2001):

- <0.05 Almost perfect representation of rank similarities;
- 0.05 to <0.1 Good representation;
- 0.1 to <0.2 Still useful;
- 0.2 to <0.3 Should be treated with caution;
- >0.3 Little better than random points.

The analyses used the same zero-adjusted Jaccard similarity matrix as the hierarchical clustering process described above.

3.3.2 Particle Size Analysis

The laser and sieve data were mathematically merged to produce sediment classifications, following Folk (1954) and Blott & Pye (2012) and calculations of particle size summary parameters (percentages of mud, sand, and gravel, silt/clay ratio, sand/mud ratio, mean particle size, sorting, skewness and kurtosis, d10, d90) calculated using GRADISTAT software (Blott & Pye, 2001).

3.3.3 Biotope allocation

The data were further examined to determine the characteristic biota for each sampling station. Taxa were separated into those that were fully enumerated in the samples and those which were not countable (e.g. plants and colonial taxa such as bryozoa and hydroids). For countable taxa, the mean abundance was calculated for the three replicates; for non-countable taxa, the percentage of replicates in which each taxon was present was

calculated. The results were then examined in tandem with the particle size data so that a biotope could be assigned following JNCC's National Marine Habitat Classification for Britain and Ireland: Version 04.05 (Connor et al., 2004). EUNIS codes corresponding to each biotope are also provided (JNCC 2010; Parry 2015).

4. Results

4.1 Description of site and major habitats

The benthic survey took place in the inner harbour area (Lake Lothing) between 52.47656°N 1.726216°E upstream and 52.47303°N 1.745980°E downstream. The survey area was euryhaline (salinity variable but generally close to marine values) and tidal throughout. In most areas, the harbour was bound to both the north and south by artificial construction walls. These were predominately sheet metal, concrete or wood but there were some areas with rubber cladding. There was a small area to the west of the Scheme footprint where the south channel bank had not been modified. Here the bank was formed of a steep rock step, with a small beach of sand and coarse sediment. The seabed throughout was formed of soft mud and the central channel is regularly dredged to maintain a depth of approximately 4.5 m. There were several vessel moorings along the north bank, where the depth is maintained to approximately 3.5 m, whilst along much of the southern bank, heavy siltation occurs and in many places the water depth at low tide was 0 m.

4.2 Survey constraints, incidents, near misses and issues arising

4.2.1 Health and Safety Incidents

There were no incidents, near misses or other issues that require reporting under our Health and Safety procedures.

4.2.2 Access constraints and other issues

Several or the reference stations were relocated in the field from their target positions. A natural shore, rather than artificial walls, was present at the proposed wall sampling locations for RS01, RS02 and they were relocated to the opposite bank to maintain comparability with other wall stations. Heavy siltation along much of the south bank of the channel, particularly around the area of Kirkely Ham, has resulted in very shallow water depths in this region and it rapidly becomes exposed once the tide turns; consequently, it was deemed unsafe to operate the vessel in this region and wall sampling was not attempted for this reason. RS06, RS07 and RS08 were all relocated to the north wall opposite their respective target positions, whilst S03 and S04 were moved slightly upstream to accessible areas. However, wall sampling at S05 and S06 was abandoned, since there was no obvious area to relocate these impact stations. Given that no sample data from laboratory analysis would be available a decision was made to conduct a visual assessment of the wall communities at these stations with several photographs taken to provide qualitative data and facilitate comparison with successfully sampled wall stations. In addition, S01, S02 and RS05 were all relocated slightly upstream due to moored vessels at the target positions.

On several occasions, it was necessary to temporarily halt sampling procedures to allow other vessel traffic to pass in the main dredged channel but this did not interfere with station location.

As part of routine maintenance operations by the Statutory Harbour Authority, the entire harbour area was dredged between 2nd April and 11th April 2018, using a combination of plough dredging, bucket dredging and suction dredging. This dredging activity did not directly affect the survey operations but may have caused the benthic communities to differ from those that would otherwise have been present.

4.3 Samples obtained and processed

4.3.1 Samples obtained

Grab sampling was undertaken at 18 stations, with three replicates being collected for macrobenthic analysis and one sample collected for particle size analysis at each station.

Wall sampling was attempted at 14 stations. However, it was not possible to reach the wall stations at S05 and S06 (see access constraints above). At those stations where sampling was undertaken, three quadrats were analysed *in situ* and three 0.01 m^2 wall scrape samples were taken for laboratory analysis.

Four trawl samples were collected and three qualitative samples were collected from the fouling communities on the walls, of specimens required for confirmation of field identifications. Samples collected at each station are listed in Table 2 below and all sampling positions are provided in Appendix 1.

4.3.2 Samples processed

It was decided to only process samples from the impact area (i.e. those collected at G01-G10 and S01-S06, Figure 7). Since quadrats and trawls were largely processed in the field, data for these reference samples have been included in the analysis and qualitative samples have likewise been processed since they were required to confirm identifications in impact samples. The grabs collected from RG01-RG08 and wall scrapes from RS01-RS08 have been retained in storage at APEM's laboratory.

Table 2. Samples collected at each sampling station

Sampling location	Samples collected					
	Macrobiota Grabs	PSA	Quadrats	Wall Scrape	Qualitative	Epibenthic / Fish Trawl
G01	✓✓✓	✓				
G02	✓✓✓	✓				
G03	✓✓✓	✓				
G04	✓✓✓	✓				
G05	✓✓✓	✓				
G06	✓✓✓	✓				
G07	✓✓✓	✓				
G08	✓✓✓	✓				
G09	✓✓✓	✓				
G10	✓✓✓	✓				
RG01	✓✓✓	✓				
RG02	✓✓✓	✓				
RG03	✓✓✓	✓				
RG04	✓✓✓	✓				
RG05	✓✓✓	✓				
RG06	✓✓✓	✓				
RG07	✓✓✓	✓				
RG08	✓✓✓	✓				
S01			✓✓✓	✓✓✓		
S02			✓✓✓	✓✓✓		
S03			✓✓✓	✓✓✓		
S04			✓✓✓	✓✓✓		
S05			-	-		
S06			-	-		
RS01			✓✓✓	✓✓✓		
RS02			✓✓✓	✓✓✓		
RS03			✓✓✓	✓✓✓		
RS04			✓✓✓	✓✓✓		
RS05			✓✓✓	✓✓✓		
RS06			✓✓✓	✓✓✓		
RS07			✓✓✓	✓✓✓		
RS08			✓✓✓	✓✓✓		
Qualitative_01					✓	
Qualitative_02					✓	
Qualitative_03					✓	
T01						✓
T02						✓
T03						✓
T04						✓
Total Samples	**54**	**18**	**36**	**36**	**3**	**4**

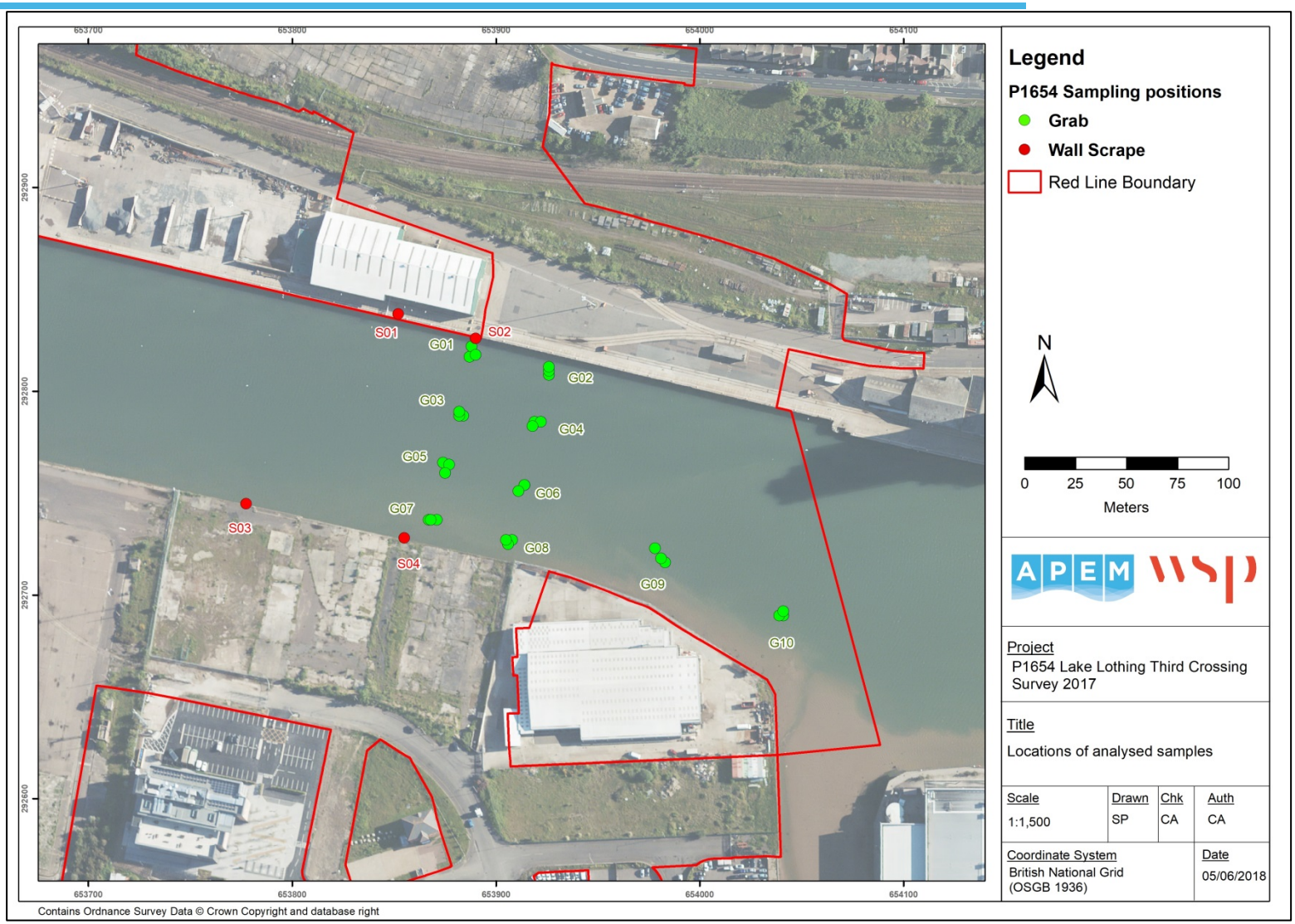

Figure 7. Wall and grab sampling stations within the impact area with positions of replicates processed.

4.4 Total Organic Carbon

Percentage total organic carbon (TOC) data, expressed as percentage loss on ignition (LOI), are shown in Table 3 for each station. The lowest value (12.79%) was recorded at Station G04 whilst the highest value (19.81%) was recorded at Station G06. Values at most stations were broadly similar and varied by less than 1% but the values recorded at G05, G06 and G10 were elevated compared to the other stations.

Table 3. Percentage TOC at each subtidal grab station

Station	Loss on ignition (%)
G01	13.78
G02	13.27
G03	13.61
G04	12.79
G05	18.07
G06	19.81
G07	13.48
G08	13.60
G09	12.97
G10	15.65

4.5 Particle Size Analysis

Full PSA data for the subtidal sediments are presented in Appendix 2, whilst summary data are given in Table 4.

The PSA data show that sediments were broadly similar at all stations, comprising >92% mud (i.e. particles <63 µm) with varying proportions of sand (63-2000 µm). No gravel (particles >2.0 mm) was recorded in any of the samples. Sediment at all stations was classified as mud, according to the traditional classification system of Folk (1954). According to the updated classification system (Blott & Pye, 2012), most samples were classified as very slightly sandy mud with the exception of G04, G09 and G10, which were classified as slightly sandy mud due to the higher proportions of sand at these stations. Sediments were classified as very poorly sorted at all stations except G02, where it was poorly sorted. The sediment distributions were either leptokurtic (G02, G06 and G07) or mesokurtic (all other stations). Leptokurtic distribution indicates that the size of most particles was close to the mean size, whilst a mesokurtic distribution indicates a normal range of distribution.

Table 4. Summary particle size data from each subtidal grab station

Station	Mean particle diameter (µm)	Gravel (%)	Sand (%)	Mud (%)	Statistics calculated using Folk and Ward (1957) formulae			Classification	
					Sorting	Skewness	Kurtosis	Blott & Pye (2012)	Folk (1954)
G01	6.7	0.0	4.1	95.9	Very Poorly Sorted	Fine Skewed	Mesokurtic	Very slightly sandy mud	Mud
G02	7.4	0.0	3.3	96.7	Poorly Sorted	Fine Skewed	Leptokurtic	Very slightly sandy mud	Mud
G03	5.6	0.0	3.2	96.8	Very Poorly Sorted	Fine Skewed	Mesokurtic	Very slightly sandy mud	Mud
G04	7.4	0.0	8.0	92.0	Very Poorly Sorted	Fine Skewed	Mesokurtic	Slightly sandy mud	Mud
G05	5.6	0.0	2.9	97.1	Very Poorly Sorted	Fine Skewed	Mesokurtic	Very slightly sandy mud	Mud
G06	6.3	0.0	2.8	97.2	Very Poorly Sorted	Fine Skewed	Leptokurtic	Very slightly sandy mud	Mud
G07	6.3	0.0	4.5	95.5	Very Poorly Sorted	Fine Skewed	Leptokurtic	Very slightly sandy mud	Mud
G08	6.2	0.0	3.6	96.4	Very Poorly Sorted	Fine Skewed	Mesokurtic	Very slightly sandy mud	Mud
G09	7.4	0.0	7.1	92.9	Very Poorly Sorted	Fine Skewed	Mesokurtic	Slightly sandy mud	Mud
G10	6.8	0.0	6.8	93.2	Very Poorly Sorted	Fine Skewed	Mesokurtic	Slightly sandy mud	Mud

4.6 Macrobiota

4.6.1 Benthic Grabs – Univariate Statistics

The complete benthic dataset for the subtidal grab samples is provided in Appendix 2 and photographs of the unsieved grab samples are presented in Appendix 3. The samples were generally impoverished but a total of 46 benthic taxa was identified from the 30 analysed subtidal benthic grab samples. Among these, the polychaete *Tharyx* 'species A' was the most frequently recorded taxon, being present in 21 (70%) of the samples. This species was also the most abundant taxon recorded, with a total of 203 individuals, accounting for 71.2% of the total number of countable organisms from the samples. It was most abundant in samples G07a (48 individuals) and G09c (39). Numerically, annelid worms dominated the samples, whilst very few crustacean taxa were recorded (4 taxa, 9 individuals). Non-countable taxa (e.g. algae, bryozoans, hydroids) accounted for 22 (47.8%) of the taxa.

The univariate diversity indices are presented in Table 5. Two samples (G01a and G05a) contained no recordable biota. A further five samples (G01b, G01c, G02c, G05b, G06a) contained only non-countable taxa. For these samples, diversity indices could not be calculated.

Numbers of taxa ranged from 0, in samples G01a and G05a, to 14, in G09a and G09c, with a mean of 5.33 across all samples. Numbers of individuals ranged from 0, in samples G01a-c, G02c, G05a-b and G06a, which were either abiotic or contained only colonial taxa, to 56 in sample G09c, with a mean of 9.5 individuals per 0.1m² sample. The maximum density was therefore 560 individuals per m^2.

Margalef's species richness index (*d*) ranged from a low of 0.39, in sample G03a, to a high of 2.16, in sample G08a, with a mean value of 1.16 across the survey, although this index could not be calculated for 14 of the samples due to insufficient numbers of countable taxa and/or individuals.

Pieliou's Evenness (*J*') ranged from 0.29, in sample G07a (low evenness primarily influenced by large numbers of *Tharyx* 'species A'), to 1 in sample G08a (high evenness as all countable taxa were represented by just a single individual), with a mean value of 0.71 across the survey, although as with the other diversity indices this index could not be calculated for 14 of the samples due to insufficient numbers of countable taxa and/or individuals.

Shannon-Wiener diversity ($H'\log_e$) also indicated low diversity in sample G03a with a value of 0.27. The highest value was found in in sample G07b (1.53). The mean value across all samples was 0.92, although again this index could not be calculated for 14 of the samples due to insufficient numbers of countable taxa and/or individuals.

Simpson Dominance, which measures the dominance of individual taxa, based on the probability of picking two individuals from a community at random that are from the same species, varied from 0.15, in samples G03a and G07a, to 1, in G08a. Higher values usually indicate a more diverse community without dominance by any one taxon but the value at G08a is influenced by the fact that each of the four countable taxa in the sample was represented by a single individual. The lower values in samples G03a and G07a are caused by the comparatively large numbers of *Tharyx* 'species A' relative to other taxa in these samples.

Table 5. Univariate statistics for the subtidal stations *

Sample	Number of Taxa	Number of individuals	Density (individuals per m^2)	Margalef's species richness (*d*)	Mean Pielou's Evenness (*J'*)	Mean Shannon Wiener Diversity (*H'*(log_e))	Mean Simpson's Dominance (1-λ)
G01a	0	0	0	-	-	-	-
G01b	9	0	0	-	-	-	-
G01c	1	0	0	-	-	-	-
G02a	1	3	30	-	-	-	-
G02b	2	1	10	-	-	-	-
G02c	1	0	0	-	-	-	-
G03a	2	13	130	0.39	0.39	0.27	0.15
G03b	7	8	80	1.44	0.77	1.07	0.64
G03c	7	11	110	0.83	0.78	0.86	0.56
G04a	4	4	40	0.72	0.81	0.56	0.50
G04b	6	10	100	0.87	0.58	0.64	0.38
G04c	8	6	60	0.56	0.65	0.45	0.33
G05a	0	0	0	-	-	-	-
G05b	5	0	0	-	-	-	-
G05c	4	7	70	-	-	-	-
G06a	2	0	0	-	-	-	-
G06b	2	1	10	-	-	-	-
G06c	4	1	10	-	-	-	-
G07a	5	52	520	0.51	0.29	0.31	0.15
G07b	9	17	170	1.76	0.86	1.53	0.79
G07c	3	6	60	0.56	0.65	0.45	0.33
G08a	5	4	40	2.16	1.00	1.39	1.00
G08b	3	1	10	-	-	-	-
G08c	2	10	100	-	-	-	-
G09a	14	22	220	1.62	0.68	1.22	0.59
G09b	11	22	220	1.29	0.62	0.99	0.52
G09c	14	56	560	1.49	0.54	1.05	0.49
G10a	9	12	120	1.61	0.88	1.42	0.79
G10b	12	13	130	1.56	0.86	1.38	0.76
G10c	8	5	50	1.24	0.96	1.05	0.80
Min	**0**	**0**	**0**	**0.39**	**0.29**	**0.27**	**0.15**
Max	**14**	**56**	**560**	**2.16**	**1.00**	**1.53**	**1.00**

* diversity indices could not be calculated for samples with low numbers of countable taxa and/or individuals

4.6.2 Benthic Grabs – Cluster analysis

The results of SIMPROF cluster analysis on the macrobenthic data for each station are presented in Figure 8. Black lines denote significant structure within the group to that point

and red lines connect samples that cannot be significantly differentiated at the 95% confidence interval. The SIMPROF test identified two main groups of samples and one single replicate that can be considered statistically distinct from one-another at the 95% confidence level.

Group A comprised only replicate b from station G01. This sample was characterised by colonial taxa and contained no countable fauna. It was the only replicate in which the taxa *Amathia* and *Pedicellina* were found, which may have caused the separation from the other samples seen in the cluster dendrogram. The other replicates were all split between Groups B (12 samples) and C (17 samples). The samples in group B had generally lower diversity, with a mean of 1.58 taxa per sample, compared to a mean of 7.76 taxa per sample in Group C.

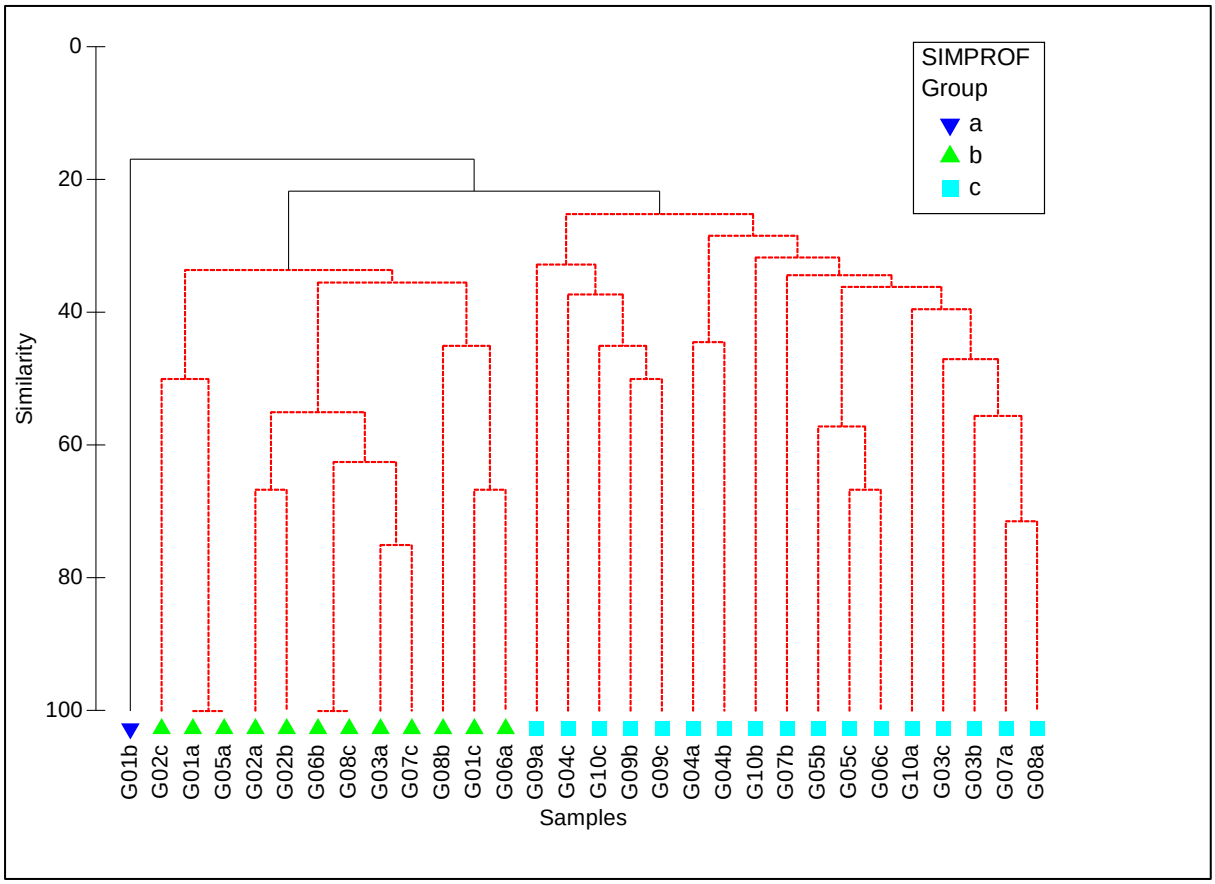

Figure 8. SIMPROF Cluster dendrogram of Jaccard similarity between macrobenthic presence/absence data for each replicate.

4.6.3 Non-metric multi-dimensional scaling (NMMDS)

The MDS plot for the macrobenthic data is presented in Figure 9. The stress value of 0.15 is reasonably low, suggesting a useful two dimensional picture of the higher dimensional relationships between samples. The plot complements the pattern seen in the cluster dendrogram, with the samples forming cluster group B grouped to the left of the plot, group C grouped towards the right and the single sample comprising group a separated from the other samples towards the top of the plot. Figure 9 also shows a wide separation between replicates for many of the stations, with some stations having replicates split between cluster

groups b and c. This indicates heterogeneity between replicates from the same station, most likely resulting from the low numbers of taxa in many of the samples.

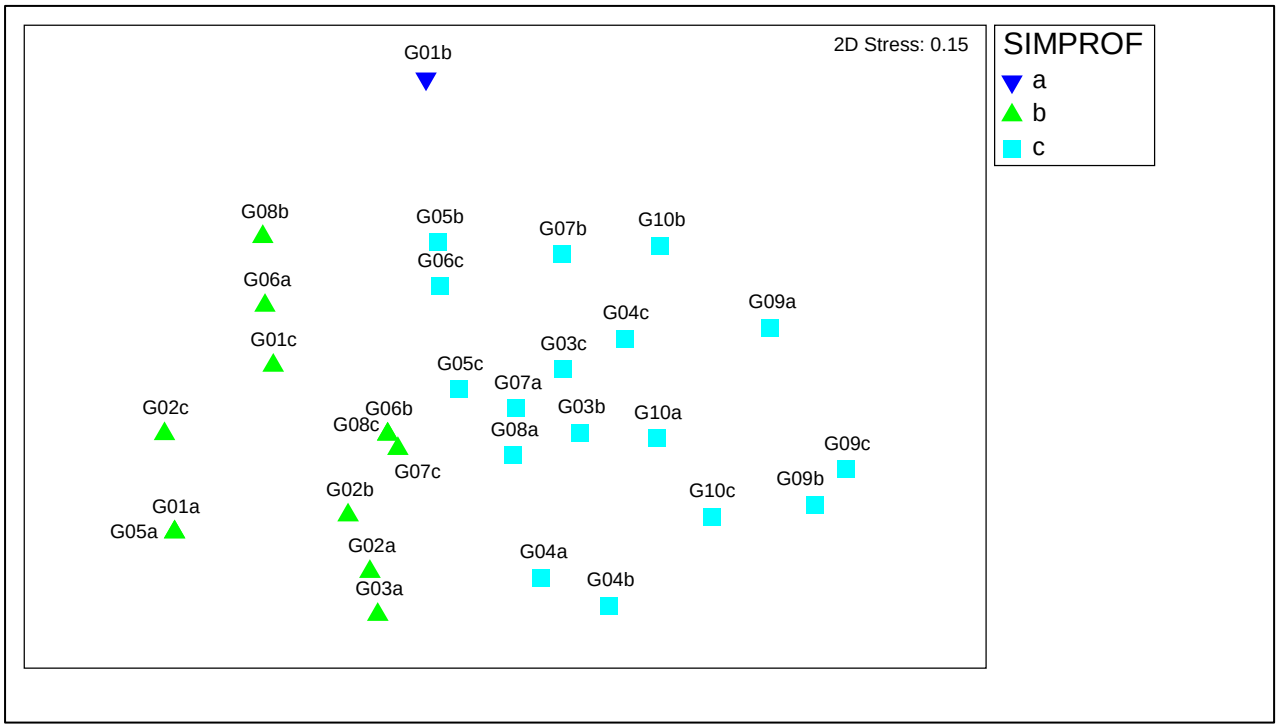

Figure 9. MDS plot of Jaccard similarity between macrobenthic presence/absence data for each replicate

Overlaying the number of taxa for each replicate onto the MDS plot (Figure 10), the samples show a clear gradation from the lowest numbers in cluster group B on the left of the plot (samples G01a and G05a contained no taxa) to the highest numbers towards the right of the plot.

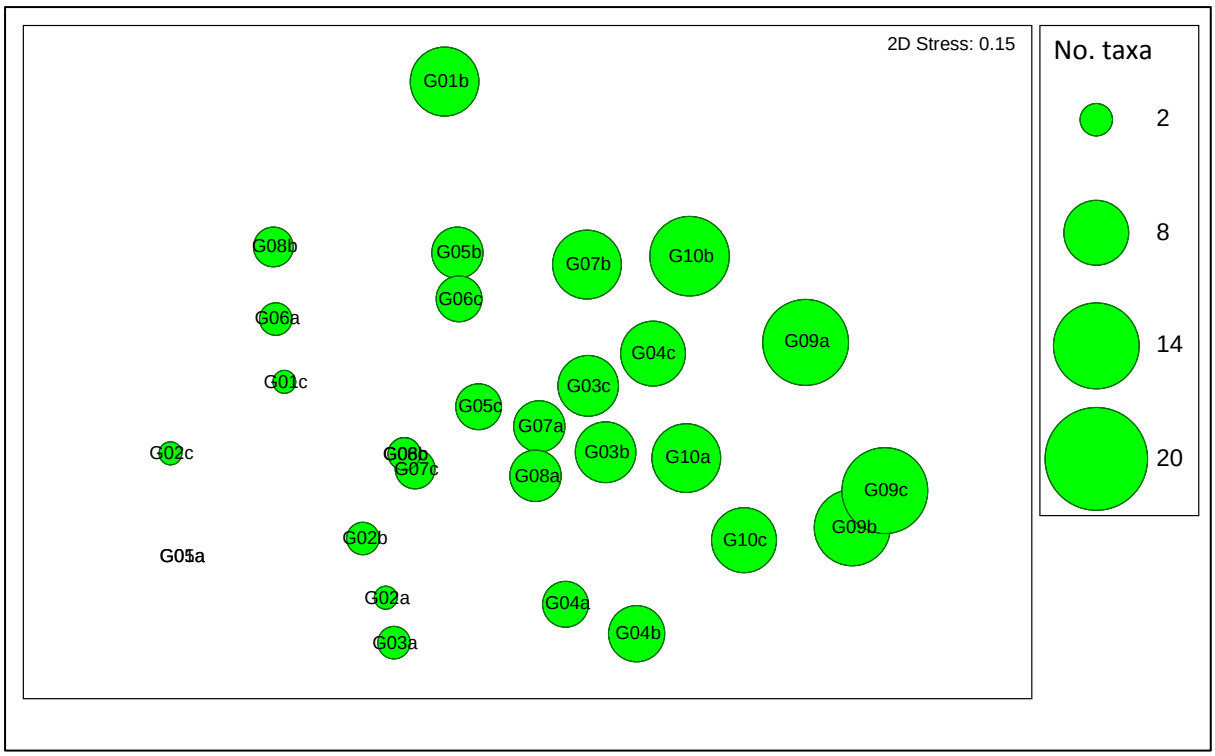

Figure 10. MDS bubble plot of Jaccard similarity between macrobenthic presence/absence data for each replicate with overlays showing numbers of taxa in each sample

4.6.4 Correlation between PSA data and biological variables

The results of the BEST analysis are presented in Table 6. The results show that the highest correlation of 0.424 is achieved with the combination of three variables: sorting (phi), skewness (phi) and % coarse silt, with a slightly lower correlation of 0.422 by the addition of % medium silt to these three variables and a correlation of 0.421 with the addition of % medium silt and % very fine sand. However, the global test result gives a significance level of 23.8%, indicating that the correlation is not significant and the null hypothesis of 'no agreement between PSA and biological multivariate patterns' must therefore be accepted.

Table 6. Results of the BEST analysis

No. Variables	Spearman Correlation (σ)	Physical Variables
3	0.424	Sorting (phi), Skewness (phi), % coarse Silt (16-31 µm)
4	0.422	Sorting (phi), Skewness (phi), % coarse Silt (16-31 µm), % Medium Silt (8-16 µm)
5	0.421	Sorting (phi), Skewness (phi), % Very Fine sand (63-125 µm), % coarse Silt (16-31 µm), % Medium Silt (8-16 µm)
5	0.412	Sorting (phi), Skewness (phi), % Fine sand (125-250 µm), % coarse Silt (16-31 µm), % Medium Silt (8-16 µm)
4	0.409	Skewness (phi), % Very Fine sand (63-125 µm), % coarse Silt (16-31 µm), % Medium Silt (8-16 µm)
5	0.405	Sorting (phi), Skewness (phi), % Fine sand (125-250 µm), % coarse Silt (16-31 µm), % clay (<2 µm)
5	0.403	Mean grain size (µm), Sorting (phi), Skewness (phi), % coarse Silt (16-31 µm), % Medium Silt (8-16 µm)
4	0.402	Skewness (phi), % Fine sand (125-250 µm), % coarse Silt (16-31 µm), % Medium Silt (8-16 µm)
4	0.400	Mean grain size (µm), Skewness (phi), % coarse Silt (16-31 µm), % Medium Silt (8-16 µm)
5	0.399	Sorting (phi), Skewness (phi), % Very Coarse Silt (31-63 µm), % coarse Silt (16-31 µm), % Medium Silt (8-16 µm)

Global Test
Sample statistic (Rho): 0.424
Significance level of sample statistic: 23.8%
Number of permutations: 999 (Random sample)
Number of permuted statistics greater than or equal to Rho: 237

4.6.5 Biotope composition

Since many samples were significantly impoverished, data were averaged across each station prior to assigning biotopes and biotopes were assigned at station level rather than strictly reflecting the cluster groups. The two identified biotopes are very similar differing primarily in the numbers of cirratulids present. Eighteen samples (all replicates from G03, G04, G07, G08, G09 and G10) were assigned to SS.SMu.SMuVS.AphTubi (*Aphelochaeta marioni* and *Tubificoides* spp. in variable salinity infralittoral mud; EUNIS A5.322). The cirratulid polychaete *Tharyx* 'species A' was the most consistent component of these samples. The biotope description (Connor et al., 2004) notes that other cirratulids may replace *A. marioni* and that the description may include inconsistent cirratulid identifications. The remaining twelve samples (replicates from G01, G02, G05 and G06) were assigned to SS.SMu.SMuVS.MoMu (Infralittoral fluid mobile mud; EUNIS A5.324).

Table 7. Biotope assignment, AMBI and IQI Scores for each subtidal grab sample

Sample	AMBI	Disturbance Classification	IQI Score	IQI Ecological Status	SIMPROF Group	Biotope	EUNIS
G01a	7*	Extremely disturbed	0	Bad	b	SS.SMu.SMuVS.MoMu	A5.324
G01b	7*	Extremely disturbed	0.84	High	a	SS.SMu.SMuVS.MoMu	A5.324
G01c	7*	Extremely disturbed	0	Bad	b	SS.SMu.SMuVS.MoMu	A5.324
G02a	4.5*	Moderately disturbed	0.27	Poor	b	SS.SMu.SMuVS.MoMu	A5.324
G02b	4.5*	Moderately disturbed	0.41	Poor	b	SS.SMu.SMuVS.MoMu	A5.324
G02c	7*	Extremely disturbed	0	Bad	b	SS.SMu.SMuVS.MoMu	A5.324
G03a	4.615*	Moderately disturbed	0.31	Poor	b	SS.SMu.SMuVS.AphTubi	A5.322
G03b	4.313	Moderately disturbed	0.49	Moderate	c	SS.SMu.SMuVS.AphTubi	A5.322
G03c	4.95*	Moderately disturbed	0.46	Moderate	c	SS.SMu.SMuVS.AphTubi	A5.322
G04a	4.5*	Moderately disturbed	0.46	Moderate	c	SS.SMu.SMuVS.AphTubi	A5.322
G04b	4.2*	Moderately disturbed	0.44	Poor	c	SS.SMu.SMuVS.AphTubi	A5.322
G04c	4*	Moderately disturbed	0.53	Moderate	c	SS.SMu.SMuVS.AphTubi	A5.322
G05a	7*	Extremely disturbed	0	Bad	b	SS.SMu.SMuVS.MoMu	A5.324
G05b	7*	Extremely disturbed	0.74	Good	c	SS.SMu.SMuVS.MoMu	A5.324
G05c	4.5*	Moderately disturbed	0.33	Poor	c	SS.SMu.SMuVS.MoMu	A5.324
G06a	7*	Extremely disturbed	0.71	Good	b	SS.SMu.SMuVS.MoMu	A5.324
G06b	4.5*	Moderately disturbed	0.27	Poor	b	SS.SMu.SMuVS.MoMu	A5.324
G06c	3*	Slightly disturbed	0.57	Moderate	c	SS.SMu.SMuVS.MoMu	A5.324
G07a	4.442*	Moderately disturbed	0.35	Poor	c	SS.SMu.SMuVS.AphTubi	A5.322
G07b	3	Slightly disturbed	0.55	Moderate	c	SS.SMu.SMuVS.AphTubi	A5.322
G07c	4.75*	Moderately disturbed	0.31	Poor	b	SS.SMu.SMuVS.AphTubi	A5.322
G08a	4.125	Moderately disturbed	0.49	Moderate	c	SS.SMu.SMuVS.AphTubi	A5.322
G08b	1.5*	Slightly disturbed	0.56	Moderate	b	SS.SMu.SMuVS.AphTubi	A5.322
G08c	4.5*	Moderately disturbed	0.26	Poor	b	SS.SMu.SMuVS.AphTubi	A5.322
G09a	3.9	Moderately disturbed	0.53	Moderate	c	SS.SMu.SMuVS.AphTubi	A5.322
G09b	3.886	Moderately disturbed	0.54	Moderate	c	SS.SMu.SMuVS.AphTubi	A5.322
G09c	3.911	Moderately disturbed	0.54	Moderate	c	SS.SMu.SMuVS.AphTubi	A5.322
G10a	3.5	Moderately disturbed	0.53	Moderate	c	SS.SMu.SMuVS.AphTubi	A5.322
G10b	3.923	Moderately disturbed	0.58	Moderate	c	SS.SMu.SMuVS.AphTubi	A5.322
G10c	3.6*	Moderately disturbed	0.67	Good	c	SS.SMu.SMuVS.AphTubi	A5.322

* <3 taxa after truncation

The distributions of the identified biotopes are mapped in Figure 11, below. Since biotopes were assigned at station level and are clearly patchy, even at a station level (as indicated by assignment of different replicate samples from a station to separate cluster groups), biotopes have been mapped as points rather than trying to assign arbitrary ranges to their distributions. As noted above, the two biotopes are very similar differing primarily in the number of individuals, particularly cirratulid polychaetes. It is possible that the recent dredging activity has reduced the numbers of animals in the regions assigned to the mobile mud biotope SS.SMu.SMuVS.MoMu. This idea is supported by the fact that the four stations

to the south (G07, G08, G09, G10), where dredging has not taken place for several years, were all assigned to the cirratulid biotope SS.SMu.SMuVS.AphTubi.

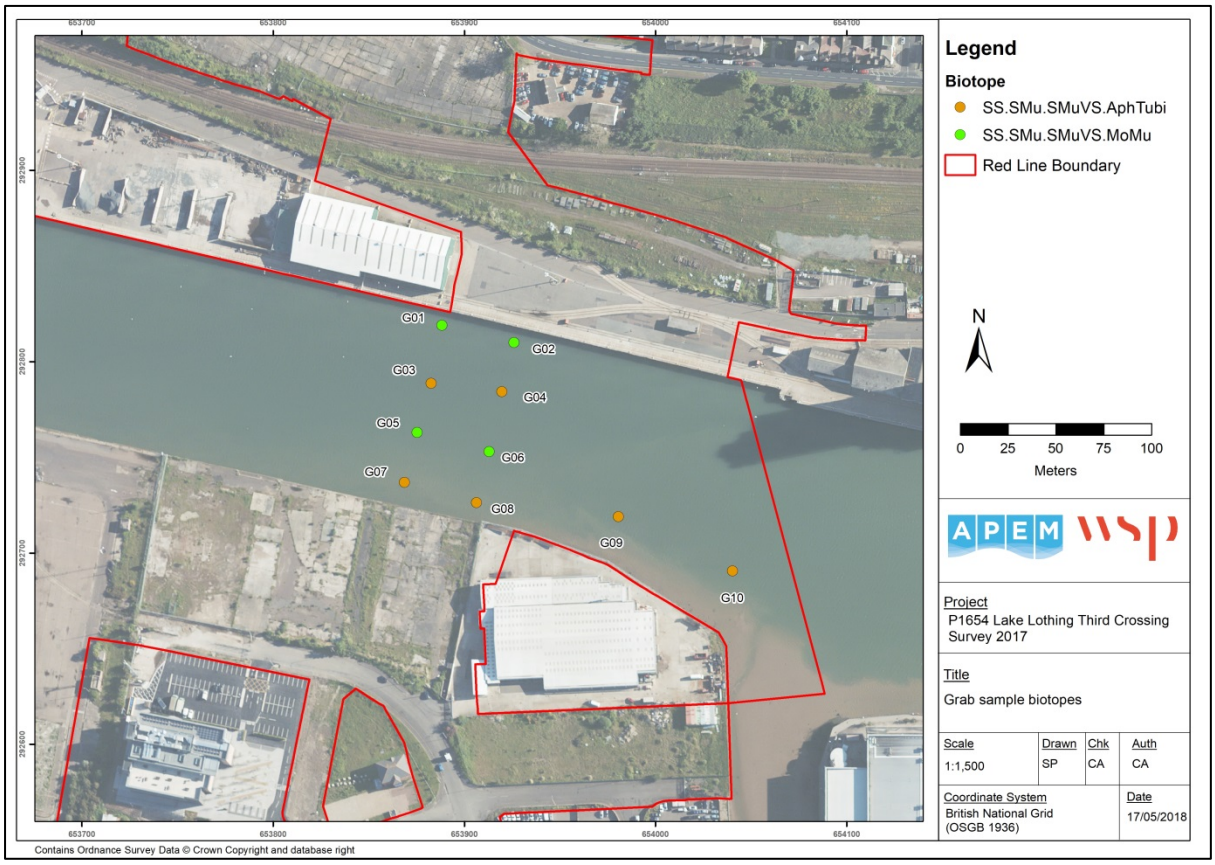

Figure 11. Biotopes present at each grab station.

4.6.6 Infaunal Quality Index (IQI) and AMBI Scores

AMBI scores for most samples were high, leading to classification as either moderately or extremely disturbed. However, sixteen of the samples had less than three taxa following truncation, which is likely to have affected their overall scores. Under the AMBI scoring system, taxa are given abundance weighted scores based on pollution tolerances of the species. Certain taxa are excluded as part of the process of calculating the score and some of the remaining taxa may not have a score assigned (e.g. those that have not been identified to species level). The average score of all scored taxa present in a sample provides the classification. Thus, if a sample has only a single pollution tolerant taxon with a score of 7, it automatically receives a classification of extremely disturbed, whereas another sample that contains the same taxon but also several others may have a lower score and therefore a different classification. Abiotic samples automatically score a maximum score of 7 and a classification of extremely disturbed.

Similarly, the IQI scores may have been influenced by low number of taxa in some samples. Four samples had an IQI Ecological Status of bad, with a score of 0. Nine samples had a status of poor, thirteen had a status of moderate, whilst three samples were classed as good. Only sample G01b achieved a status of high but the status is likely influenced by the lack of infaunal taxa in this sample.

4.6.7 Wall samples

All wall stations had a dense covering of algae and fouling fauna. The communities were very similar on all wall constructions (wood, metal, concrete or rubber). Since fouling communities overgrow one another, the percentage coverage from the quadrats frequently showed more than 100% coverage, accounting for the 3-dimensional structure. Upper walls showed a distinct band of green algae (mostly *Ulva* spp.), whilst lower down the wall, a dense zone of *Fucus* was present (both *F. vesiculosus* and *F. spiralis* were noted in quadrat samples). Barnacles (mostly *Austrominius modestus* but with occasional *Semibalanus balanoides*) were ubiquitous and several other algal species were present in the lower wall communities. Subtidally, especially where the walls were indented or had overhangs, there was dense ascidian growth, a qualitative sample of which was obtained and identified in the laboratory as *Ascidiella aspersa*, although it possible that other ascidian species may have been present in this habitat, together with a variety of other biota. Photographs of all wall sampling stations are provided in Appendix 4 and the complete data for both wall scrape and quadrat samples are provided in Appendix 2.

A SIMPROF cluster analysis was conducted on the wall scrape data for each replicate and is presented in Figure 12. The results show that none of the samples can be statistically differentiated at the 95% confidence interval, indicating similar species assemblages in all samples. All wall stations were therefore assigned to the biotope LR.MLR.BF.FvesB (*Fucus vesiculosus* and barnacle mosaics on moderately exposed mid eulittoral rock; EUNIS A1.213). Although no quadrats or wall sampling could be undertaken at stations S05 and S06, photographs taken of these stations clearly show a similar community to be present as at other stations, with a well-defined green algal zone at the top and a dense *Fucus* covering lower down the wall. Based on the visual assessment of these stations and the statistical similarity of all other wall stations, they were also assigned to the biotope LR.MLR.BF.FvesB.

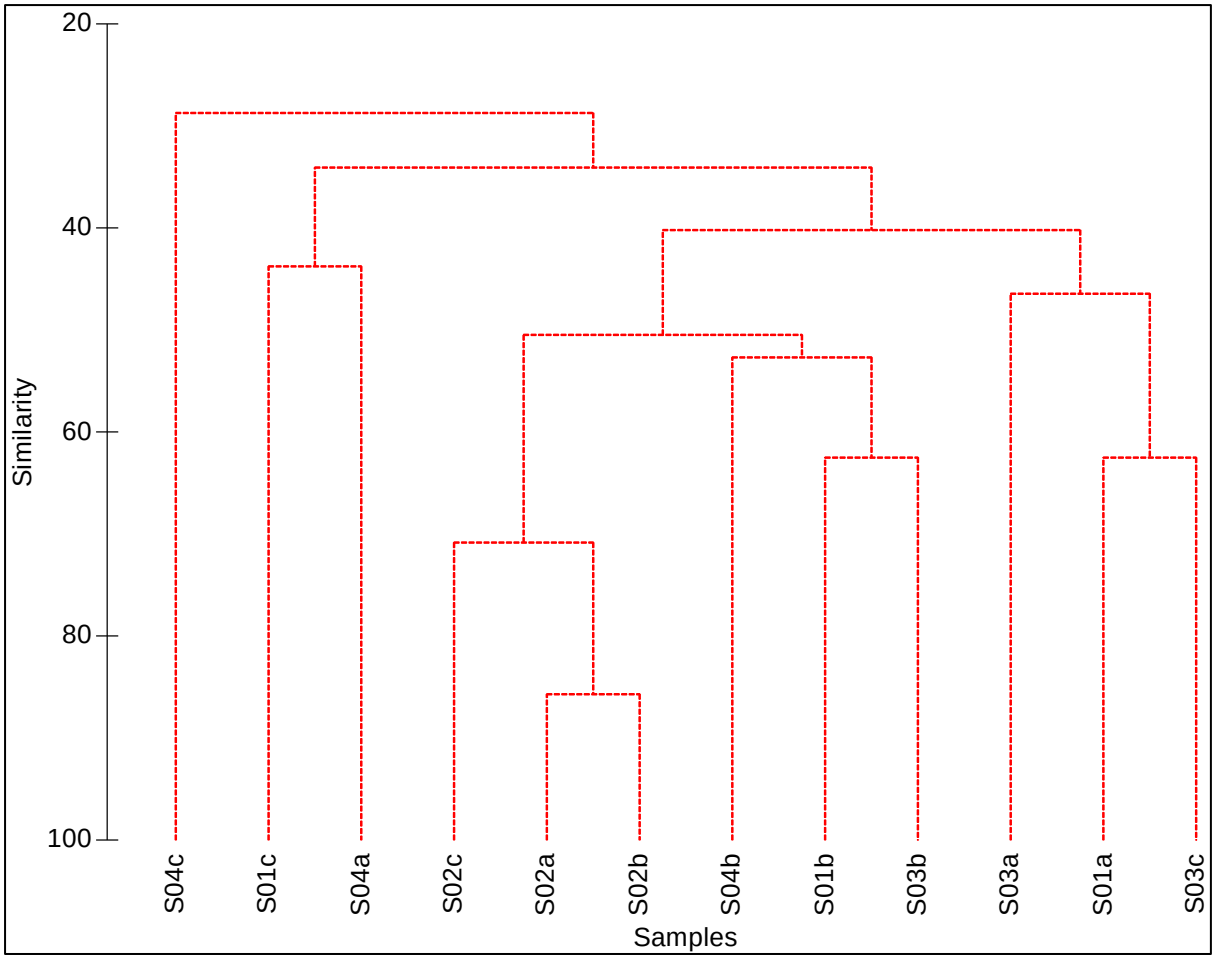

Figure 12. SIMPROF Cluster dendrogram of Jaccard similarity between wall scrape presence/absence data for each replicate.

4.6.8 Trawls

A total of 25 invertebrate taxa and eight fish species were recorded from the beam trawl samples. The majority (~88%) of taxa recorded in the trawl samples were not recorded in any of the other sample types. Data from the trawl samples are presented in Appendix 2 and photos of each trawl sample are presented in Appendix 5.

The number of taxa ranged from 12, in T04, to 24, in T02; T02 also contained the highest number of individuals (610). The most abundant taxon recorded from the beam trawls was brown shrimp (*Crangon crangon*), with a total of 740 individuals recorded, although 60% of these were recorded in sample T02. Mysids (opossum shrimps – mostly *Schistomysis kervillei* but also *S. spiritus*, *Neomysis integer* and *Siriella armata*) were also common.

Lozano's goby (*Pomatoschistus lozanoi*) was the most abundant fish species but sand gobies (*P. minutus*), transparent gobies (*Aphia minuta*) and common gobies (*P. microps*) were also recorded in reasonable numbers. Eel (*Anguilla anguilla*), sprat (*Sprattus sprattus*), bass (*Dicentrarchus labrax*) and eelpout (*Zoarces viviparus*) were each represented by a single individual.

One of the more interesting findings in the trawl samples was the non-native bivalve *Theora lubrica*, which has not previously been reported from Britain and was recorded in T01 and T02.

4.6.9 Notable taxa

The only species of conservation interest to be recorded was the European eel *Anguilla anguilla*. Eels are protected under the *Eels (England and Wales) Regulations 2009*. They are also listed as a UK BAP Priority Species in England, Wales, Scotland and Northern Ireland; they feature on the OSPAR list of threatened and/or declining species and habitats, a species of principal importance for the purpose of conservation of biodiversity under the Natural Environment and Rural Communities Act 2006 and as critically endangered on the IUCN Red List. They are also commercially important. The single individual, measuring 151, mm was recovered from trawl T01. Other commercially important species recorded in the trawl samples included brown shrimp (*Crangon crangon*), blue mussels (*Mytilus edulis*), bass (*Dicentrarchus labrax*) and sprat (*Sprattus sprattus*).

No other species considered rare (e.g. those listed by Bratton, 1991; Sanderson, 1996; Betts, 2001; Chadd & Extence, 2004) or protected under the Wildlife and Countryside Act 1981 (as amended) or the Habitats Directive were recorded.

Several non-native or cryptogenic species were recorded. The Australasian barnacle *Austrominius modestus* was present at all wall sampling stations and frequently in high abundance. It reached maximum density in sample S04c with 22,900/m^2, although the percentage cover in the associated quadrats was comparatively low (10-20%). The Asian Semele, *Theora lubrica*, was recorded in T01 and T02. Although only 27 individuals were recorded, these records are significant since the species has not previously been reported from northern Europe. The tubeworm *Hydroides ezoensis* was sampled as part of qualitative sample Q03. Previous records of this species from Britain have been confined to the south coast around the Solent and so the present records extend its British distribution. Similar tubeworms were found in several quadrat samples but were recorded in the field at family level (Serpulidae), since microscopic examination is required for species level identification; they are tentatively referred to *H. ezoensis*. The non-native bryozoan *Bugula neritina* was recorded in three grab samples and the cryptogenic ascidian *Ascidiella aspersa* was found in all trawl samples as well as the qualitative sample Q02.

5. Discussion

Lake Lothing is a marine inlet that connects to the southern bite of the North Sea at Lowestoft, Suffolk, near a harbour complex. It extends inland for about 3 km, from where it is separated from Oulton Broad by road and rail bridges. The Scheme is planned to be about 1 km upstream of the harbour entrance. The environmental conditions at this point are tidal and euryhaline. The area is discussed within the context of Oulton Broad in the JNCC Coastal Directory (Barne et al., 1998).

The marine environment within the footprint of the Scheme has been characterized through trawls and benthic grab samples on the sediment and by quadrats and wall scrape samples along the walls. Subtidally, the seabed comprised mud, with minor sand components in some samples. Walls extended from the shallow subtidal, through the intertidal to terrestrial environments; they comprised wood, metal, concrete or rubber.

The biology of the subtidal mud appears to be affected by regular dredging for navigation purposes and the area was dredged shortly before the surveys described here, between 2 and 11 April 2018 (survey: 16-18 April 2018). This was reflected in the relatively low diversity of biota recorded from the grab samples. Those with the most animals belonged to a widespread estuarine, shallow mud biotope (SS.SMu.SMuVS.AphTubi) but the community was impoverished compared to examples of this biotope recorded from other areas (see Connor et al., 2004). There was a transition between these samples and those that represented impoverished mobile mud, with little biota (SS.SMu.SMuVS.MoMu); two samples had no biota. It is likely that the natural biotope for the area was SS.SMu.SMuVS.AphTubi but that regular dredging has reduced the survival rate of the species present, leading to a shift to SS.SMu.SMuVS.MoMu in the most extreme cases. The more diverse or numerically rich samples correspond to the areas most often missed by the dredging. The benthic communities are typical of subtidal mud but the minor differences in sediment composition between samples did not correspond to the differences in biota.

The trawl data provide a view of the larger, mobile organisms that pass over the mud. It is likely that most would stay in the disturbed areas for only a short time while searching for feeding grounds or other resources not provided by the environment within the Scheme footprint itself. The gobies, which dominated the trawl data, are widespread and a common component of estuaries, although the distribution of *Pomatoschistus lozanoi* in the North Sea and estuarine habitats was relatively recently recognised (Eick, 2012), relative to standard literature (Maitland & Herdson, 2009). Commercially important fish species were found in low numbers, including one specimen of the critically endangered European eel (*Anguilla Anguilla*) which is a protected species under the *Eels (England and Wales) Regulations 2009*. The benthic organisms found in the trawls, such as the non-native bivalve *Theora lubrica* (see below) have potentially been collected together over a wide area, parts of which may have been less affected by dredging, and may explain their absence from the grab samples that sample a much smaller area.

Although only the mid shore biotopes were examined on the walls, they are well enough characterized to show that they represent typical moderate exposure fucoid barnacle mozaics, which are widespread nationally. Their most distinctive feature was the high proportion of non-native species. The dominant barnacle was the Australasian species *Austrominius modestus*, which is now abundant in estuarine habitats, nationally (Eno et al., 1997). There were also growths of the non-native tubeworm *Hydroides ezoensis* (see below).

Although the wider environment is classified as a priority habitat, estuaries, the biological communities identified within the Scheme impact zone are of limited conservation value. The construction and maintenance of the Scheme will have little impact relative to the pressures already present from dredging and artificial habitats. The main conservation interest is commercially important fish, which appear to pass through the area in low numbers. In particular, eels may migrate through Lake Lothing, between their freshwater feeding grounds and offshore spawning grounds. It is important that any developments in the area allow for the passage of migratory fish.

There were many non-native (Eno et al., 1997; Minchin et al., 2013) and cryptogenic (species that based on distribution or other evidence may be non-native but for which there is no definitive proof) animals in the area. Two of these represent notable range extensions.

The small bivalve *Theora lubrica* ('Asian Semele') was found in some of the trawl samples. It is native to the northwest Pacific from southern Russia and Japan southwards to Hong Kong (Huang 2001; Lutaenko et al. 2006). It has not previously been reported in northern Europe but has been accidentally introduced to the Basque Coast, southern Bay of Biscay (Adarraga & Martínez, 2011), Italy (Campani et al., 2004) and Israel (Bogi & Galil, 2007). It has also been introduced to California (Seapy 1974), New Zealand (Climo, 1976) and Australia (Wilson et al., 1998). It usually occurs in soft muddy subtidal sediments but may also be found in the lower intertidal areas. It is often found in areas with rich organic matter and is considered tolerant of pollution, being often dominant in highly polluted sediments (Saito, 2006; Johnston 2005). It is also considered an opportunistic coloniser of highly disturbed environments, where much of the native fauna has been extirpated (Hayward 1997; Johnston 2005).

The non-native tube worm *Hydroides ezoensis* was recorded from the quadrats and a qualitative sample and aggregations of its tubes were common in certain areas. Although already known from Britain (Thorpe et al., 1987; Zibrowius & Thorpe, 1989), it has to date been considered restricted to the Solent area (Eno et al., 1997). The records from Lowestoft therefore extend its known distribution in Britain and provide the first records from the east coast of England.

The non-native species are most likely to have been introduced to the area through shipping, in some form, possibly from overseas, although it is not possible to be certain which species have spread from within British waters or when they arrived. As Lowestoft may be the first U.K. point of arrival for some species, possibly including future introductions, special care must be taken to ensure that no biological material is spread from the area to other parts of Britain or Europe. A biosecurity risk assessment should be undertaken as part of the planning for the Scheme and a management plan put in place to avoid potentially facilitating the spread of non-native species during construction. This plan should particularly cover risks of material removed from the inlet during construction being transported beyond the harbour, without an assessment of the recipient area. It may also consider aspects of the vessels and equipment used in the process and their subsequent use in other areas.

6. References

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APPENDICES

Appendix 1 Sampling positions

Wall sampling positions

Station / Sample	Date	Time (UTC)	OSGB36		WGS84	
			Eastings	Northings	Latitude	Longitude
S01	18/04/2018	15:41:43	653852	292838	52.47438	1.736516
S02	18/04/2018	15:28:37	653890	292826	52.47426	1.737068
S03	18/04/2018	14:22:24	653777	292745	52.47359	1.735347
S04	18/04/2018	14:09:28	653855	292728	52.47340	1.736480
S05*	18/04/2018	15:03:00	653972	292697	52.47307	1.738161
S06*	18/04/2018	14:59:00	654026	292667	52.47277	1.738946
RS01	17/04/2018	16:17:18	653217	293009	52.47621	1.727327
RS02	17/04/2018	16:01:48	653363	292954	52.47566	1.729421
RS03	17/04/2018	15:42:16	653556	292798	52.47416	1.732147
RS04	17/04/2018	15:17:20	653704	292765	52.47380	1.734290
RS05	18/04/2018	15:15:55	654099	292774	52.47369	1.740099
RS06	18/04/2018	15:03:00	654301	292730	52.47321	1.743030
RS07	18/04/2018	14:52:13	654404	292736	52.47322	1.744548
RS08	18/04/2018	14:40:01	654505	292739	52.47319	1.746038

* target sampling positions used since the stations were inaccessible and so were not physically sampled. All assessments made visually from the vessel (see Sections 4.2.2 and 4.6.7above)

Trawl sampling positions (positions taken approx. every 30 seconds along the trawl line)

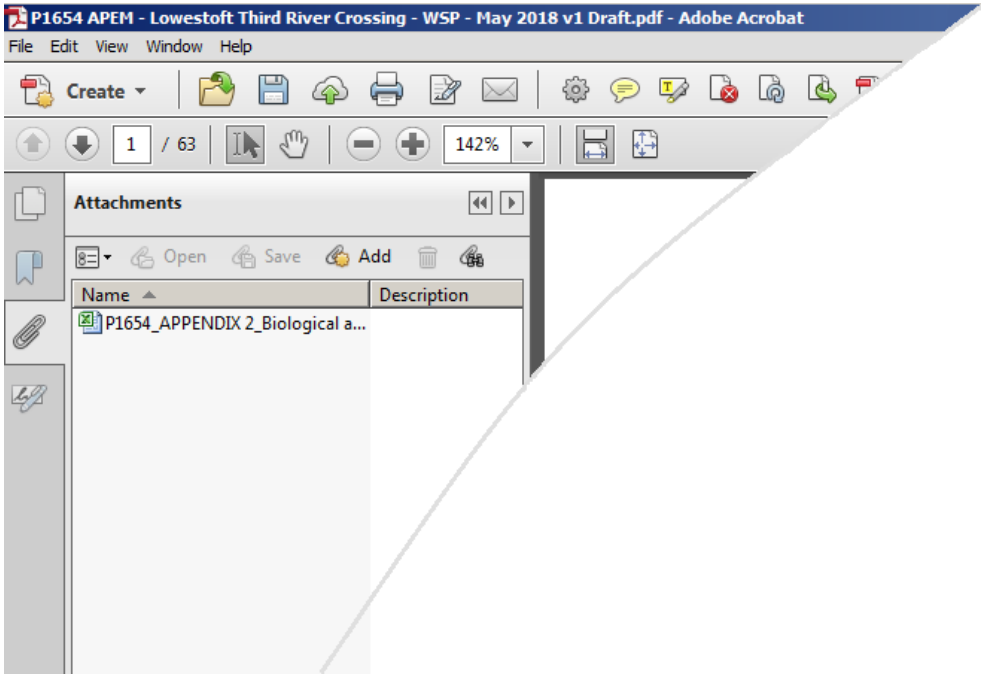
Station / Sample	Date	Time (UTC)	OSGB36		WGS84	
			Eastings	Northings	Latitude	Longitude
Trawl 1	18/04/2018	10:29:16	653849	292789	52.47395	1.736439
Trawl 1	18/04/2018	10:29:44	653862	292789	52.47394	1.736630
Trawl 1	18/04/2018	10:30:14	653876	292787	52.47392	1.736834
Trawl 1	18/04/2018	10:30:44	653889	292784	52.47389	1.737022
Trawl 1	18/04/2018	10:31:13	653900	292781	52.47385	1.737182
Trawl 1	18/04/2018	10:31:44	653913	292776	52.47380	1.737369
Trawl 1	18/04/2018	10:32:13	653927	292774	52.47378	1.737573
Trawl 1	18/04/2018	10:32:44	653941	292773	52.47376	1.737778
Trawl 1	18/04/2018	10:33:14	653955	292769	52.47372	1.737981
Trawl 1	18/04/2018	10:33:42	653966	292764	52.47367	1.738138
Trawl 1	18/04/2018	10:33:59	653973	292758	52.47361	1.738237
Trawl 2	18/04/2018	10:10:56	653842	292761	52.47370	1.736315
Trawl 2	18/04/2018	10:11:33	653859	292765	52.47373	1.736567
Trawl 2	18/04/2018	10:11:53	653870	292764	52.47371	1.736728
Trawl 2	18/04/2018	10:12:25	653887	292758	52.47365	1.736973
Trawl 2	18/04/2018	10:12:54	653899	292753	52.47360	1.737146
Trawl 2	18/04/2018	10:13:25	653912	292748	52.47355	1.737333
Trawl 2	18/04/2018	10:13:54	653923	292744	52.47351	1.737492
Trawl 2	18/04/2018	10:14:25	653936	292739	52.47346	1.737679
Trawl 2	18/04/2018	10:14:56	653950	292736	52.47343	1.737882
Trawl 2	18/04/2018	10:15:17	653959	292734	52.47340	1.738013
Trawl 2	18/04/2018	10:15:28	653964	292733	52.47339	1.738085
Trawl 3	18/04/2018	09:52:26	653388	292892	52.47509	1.729744
Trawl 3	18/04/2018	09:52:55	653398	292892	52.47508	1.729891
Trawl 3	18/04/2018	09:53:25	653410	292892	52.47508	1.730068
Trawl 3	18/04/2018	09:53:55	653425	292888	52.47503	1.730285
Trawl 3	18/04/2018	09:54:25	653441	292883	52.47498	1.730516
Trawl 3	18/04/2018	09:54:55	653453	292880	52.47495	1.730690
Trawl 3	18/04/2018	09:55:23	653464	292876	52.47491	1.730849
Trawl 3	18/04/2018	09:55:53	653475	292874	52.47488	1.731009
Trawl 3	18/04/2018	09:56:24	653487	292873	52.47487	1.731184
Trawl 3	18/04/2018	09:56:54	653498	292872	52.47486	1.731345
Trawl 3	18/04/2018	09:57:24	653509	292869	52.47482	1.731505
Trawl 3	18/04/2018	09:57:54	653521	292866	52.47479	1.731679
Trawl 3	18/04/2018	09:58:12	653527	292863	52.47476	1.731764
Trawl 4	18/04/2018	10:55:51	654249	292683	52.47281	1.742234
Trawl 4	18/04/2018	10:56:19	654263	292684	52.47281	1.742441
Trawl 4	18/04/2018	10:56:49	654275	292686	52.47283	1.742618
Trawl 4	18/04/2018	10:57:20	654287	292690	52.47286	1.742798
Trawl 4	18/04/2018	10:57:50	654299	292692	52.47287	1.742976
Trawl 4	18/04/2018	10:58:19	654311	292693	52.47287	1.743153
Trawl 4	18/04/2018	10:58:49	654321	292695	52.47289	1.743301
Trawl 4	18/04/2018	10:59:19	654334	292696	52.47289	1.743493
Trawl 4	18/04/2018	10:59:53	654347	292697	52.47289	1.743684
Trawl 4	18/04/2018	11:00:24	654360	292695	52.47287	1.743874
Trawl 4	18/04/2018	11:00:37	654365	292695	52.47287	1.743947
Trawl 4	18/04/2018	11:00:47	654368	292695	52.47286	1.743991
Trawl 4	18/04/2018	11:00:53	654370	292695	52.47286	1.744021

Grab sampling positions

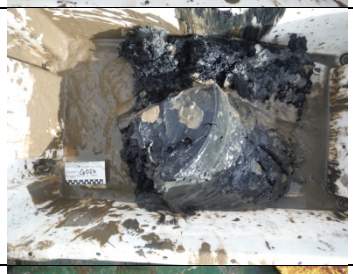
Station / Sample	Date	Time (UTC)	OSGB36		WGS84	
			Eastings	Northings	Latitude	Longitude
G01a	17/04/2018	08:24:28	653887	292817	52.47418	1.737018
G01b	17/04/2018	08:32:36	653890	292818	52.47419	1.737063
G01c	17/04/2018	08:19:08	653888	292822	52.47423	1.737037
G02a	17/04/2018	08:01:53	653926	292810	52.47410	1.737586
G02b	17/04/2018	08:08:19	653926	292812	52.47412	1.737587
G02c	17/04/2018	07:56:07	653926	292808	52.47408	1.737584
G03a	17/04/2018	07:45:44	653882	292788	52.47392	1.736923
G03b	17/04/2018	07:50:41	653882	292790	52.47394	1.736924
G03c	17/04/2018	07:40:53	653884	292788	52.47392	1.736952
G04a	16/04/2018	16:32:08	653922	292785	52.47388	1.737508
G04b	17/04/2018	07:36:12	653918	292783	52.47386	1.737448
G04c	16/04/2018	16:24:20	653919	292785	52.47388	1.737464
G05a	16/04/2018	15:38:04	653877	292764	52.47371	1.736831
G05b	16/04/2018	15:46:41	653875	292760	52.47368	1.736799
G05c	16/04/2018	15:28:39	653874	292765	52.47372	1.736788
G06a	16/04/2018	16:08:30	653914	292754	52.47360	1.737367
G06b	16/04/2018	16:17:07	653911	292751	52.47358	1.737321
G06c	16/04/2018	15:52:50	653914	292754	52.47360	1.737367
G07a	17/04/2018	09:01:11	653867	292737	52.47347	1.736664
G07b	17/04/2018	09:01:37	653868	292737	52.47347	1.736678
G07c	17/04/2018	08:40:10	653871	292737	52.47347	1.736722
G08a	17/04/2018	09:30:46	653906	292725	52.47335	1.737227
G08b	17/04/2018	09:36:03	653905	292727	52.47337	1.737214
G08c	17/04/2018	09:23:50	653908	292727	52.47336	1.737258
G09a	17/04/2018	09:51:09	653978	292723	52.47330	1.738284
G09b	17/04/2018	09:58:47	653981	292718	52.47325	1.738324
G09c	17/04/2018	09:48:15	653983	292716	52.47323	1.738352
G10a	17/04/2018	10:17:01	654039	292690	52.47297	1.739155
G10b	17/04/2018	10:22:24	654041	292692	52.47299	1.739185
G10c	17/04/2018	10:11:49	654041	292690	52.47297	1.739184
RG1a	17/04/2018	12:37:03	653140	293043	52.47656	1.726216
RG1b	17/04/2018	12:42:33	653136	293038	52.47651	1.726153
RG1c	17/04/2018	12:32:28	653138	293038	52.47651	1.726182
RG2a	17/04/2018	13:01:02	653360	292935	52.47549	1.729366
RG2b	17/04/2018	13:03:27	653361	292934	52.47548	1.729380
RG2c	17/04/2018	12:58:03	653359	292934	52.47548	1.729350
RG3a	17/04/2018	13:29:02	653574	292813	52.47429	1.732417
RG3b	17/04/2018	13:37:51	653574	292819	52.47435	1.732421
RG3c	17/04/2018	13:22:07	653573	292818	52.47434	1.732406
RG4a	17/04/2018	13:49:52	653703	292785	52.47398	1.734291
RG4b	17/04/2018	13:56:40	653705	292783	52.47396	1.734319
RG4c	17/04/2018	13:44:44	653704	292783	52.47396	1.734304
RG5a	17/04/2018	10:34:18	654162	292735	52.47332	1.740996
RG5b	17/04/2018	10:37:39	654158	292738	52.47335	1.740939
RG5c	17/04/2018	10:30:49	654156	292735	52.47332	1.740908
RG6a	18/04/2018	08:06:37	654289	292711	52.47304	1.742843
RG6b	18/04/2018	08:09:42	654290	292711	52.47304	1.742858
RG6c	18/04/2018	08:04:12	654290	292711	52.47304	1.742858
RG7a	18/04/2018	07:46:36	654407	292720	52.47307	1.744583
RG7b	18/04/2018	07:49:26	654405	292721	52.47308	1.744555
RG7c	18/04/2018	07:43:14	654405	292717	52.47304	1.744552
RG8a	18/04/2018	07:33:04	654502	292721	52.47303	1.745980
RG8b	18/04/2018	07:36:50	654502	292720	52.47303	1.745979
RG8c	18/04/2018	07:29:53	654504	292721	52.47303	1.746009

Appendix 2 Biological and sediment data

See attached file within this PDF



Appendix 3 Photographs of each benthic grab sample

Station	Replicate 1	Replicate 2	Replicate 3
G01			
G02			
G03			
G04			
G05			
G06			

Station	Replicate 1	Replicate 2	Replicate 3
G07			
G08			
G09			
G10			
RG01			
RG02			

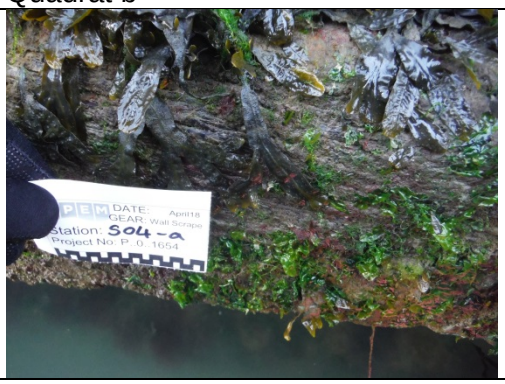
Station	Replicate 1	Replicate 2	Replicate 3
RG03			
RG04			
RG05			
RG06			
RG07			
RG08			

Appendix 4 Photographs of each wall sampling station

Station		
S01		
	Quadrat a	Quadrat b
		
	Quadrat c	Scrape a
		
	Scrape b	Scrape c

Station		
S02		
	Quadrat a	Quadrat b
		
	Quadrat c	Scrape a
		
	Scrape b	Scrape c
		
	S02 – Station Overview	

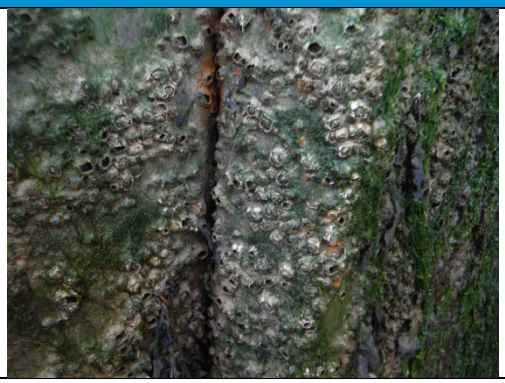
Station		
S03		
	Quadrat a	Quadrat b
		
	Quadrat c	Scrape a
		
	Scrape b	Scrape c

Station		
S04		
	Quadrat a	Quadrat b
		
	Quadrat c	Scrape a
		
	Scrape b	Scrape c

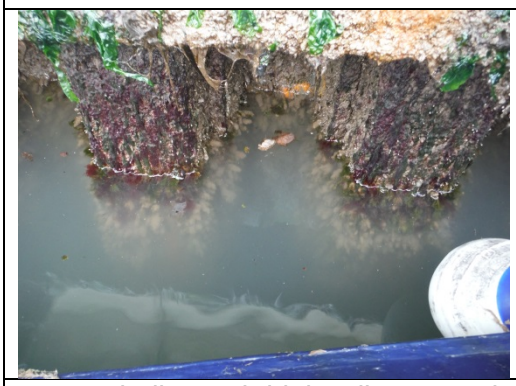
Station		
S05		
	Station overview	Station overview
		
	Station overview	
S06		
	Station overview	Station overview

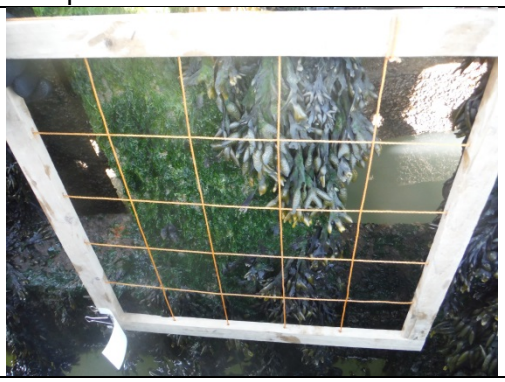
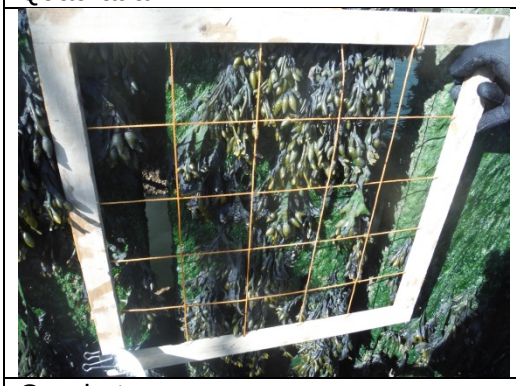
Station		
RS01		
	Quadrat a	Quadrat b
		
	Quadrat c	

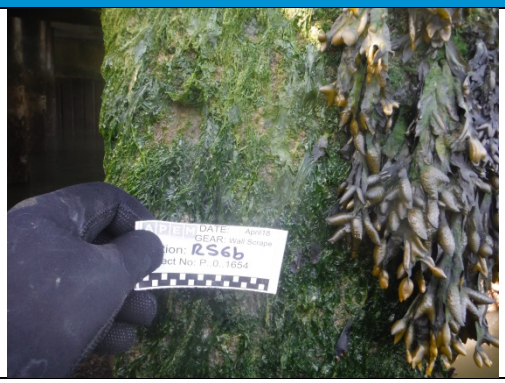
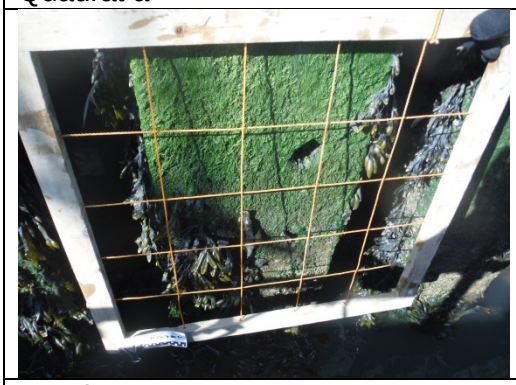
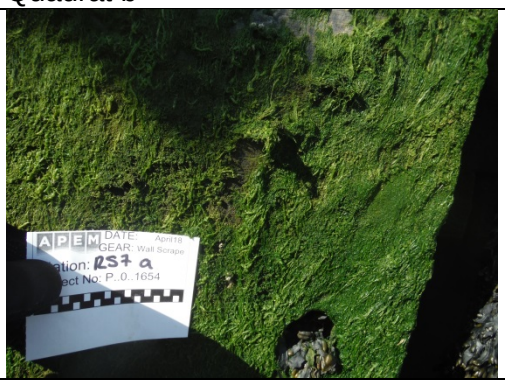
Station		
RS02		
	Quadrat a	Quadrat b
		
	Quadrat c	Scrape a
		
	Scrape b	Scrape c
		
	Quadrat b – detail of barnacles present	Quadrat b – detail of barnacles present

Station		
RS02		
	Quadrat c – detail of barnacles present	
RS03		
	Quadrat a	Quadrat b
		
	Quadrat c	Scrape a
		
	Scrape b	Scrape c

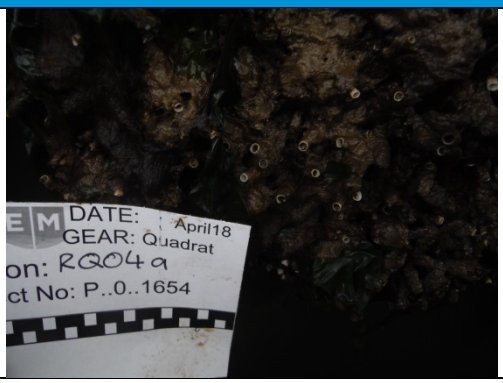
Station		
RS04		
	Quadrat a	Quadrat b
		
	Quadrat c	
		
	Quadrat a – detail of barnacles present	Quadrat b – detail of seaweed present
		
	Quadrat c – detail of *Fucus* present	Quadrat c – detail of serpulid tubes

Station		
RS04		
	Scrape a	Scrape b
		
	Scrape c	Scrape a – detail of serpulid tubes present
		
	RS04 Shallow subtidal wall community	
RS05		
	Quadrat a	Quadrat b

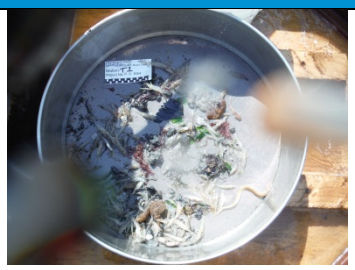
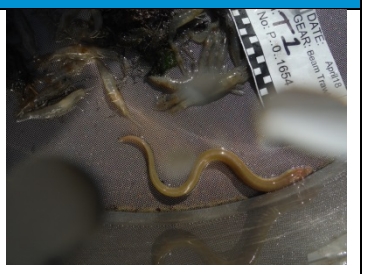
Station		
RS05		
	Quadrat c	Scrape a
		
	Scrape b	Scrape c
RS06		
	Quadrat a	Quadrat b
		
	Quadrat c	Scrape a

Station		
RS06		
	Scrape b	Scrape c
		
	Quadrat a	Quadrat b
		
	Quadrat c	Scrape a
		
	Scrape b	Scrape c

Station		
RS08		
	Quadrat a	**Quadrat b**
		
	Quadrat c	**Scrape a**
		
	Scrape b	**Scrape c**
Qualitative 1		
	Limpet (*Patella vulgata*)	

Station		
Qualitative 2		
	Serpulid tubes (*Hydroides ezoensis*)	Serpulid tubes (*Hydroides ezoensis*)
Qualitative 3		
	Subtidal ascidians (*Ascidiella aspersa*)	

Appendix 5 Photographs of each trawl sample

Trawl			
T01	 		
T02	 	 	
T03			
T04