Marine ecological baseline surveys in support of the re-development of West Waterloo Dock: Liverpool.

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1 EXECUTIVE SUMMARY

Marine ecological surveys of west Waterloo Dock were undertaken by Ecospan Environmental Ltd between 31st October and 1st November 2018. The aims of the surveys were to characterise the habitats present within the docks, provide baseline data on fish populations utilising the docks and determine the physico-chemical composition of the sediments.

The water within the survey area were generally less than 1 m deep and brackish (19 ‰). Opportunistic macroalgae (chiefly *Chaetomorpha* sp) was abundant in all parts of west Waterloo Dock forming dense mats in places.

Only one habitat type was found within the sediments of the dock basin. This was EUNIS Habitat type A5.542: angiosperm communities in reduced salinity in association with *Pomatogeton pectinatus*. The macrobenthos of the sediments was quite poor, being dominated by a few highly abundant taxa. Most of these were either very tolerant of low salinities and/or pollution tolerant taxa. This Habitat type is not protected and unless the cumulative loss of this habitat type from other projects within the dock system is large, it is not considered that the small loss in this area will be of ecological significance.

The dock walls were characterised by infralittoral fouling seaweed communities (EUNIS habitat type A3.72) for the first 20 cm after which this habitat gave way to *Mytilus edulis* beds on reduced salinity infralittoral rock (A3.361). It is likely that the Habitat type and species composition is replicated elsewhere within the dock system and therefore it is probable that the new wall created by the infilling of the dock will be colonised by a similar community within a few years. Since the total area of wall will remain more or less constant, the infill will not result in any substantial change in available habitat.

The number and diversity of fish species within the dock when sampled was low. The dock obviously supports a good population of stickleback. Additionally a few sand smelt were caught and two gobies which indicate that these species are present but probably in relatively low numbers. One European eel was also caught Given that three fyke nets were baited and set for over 15 hrs overnight, this is a low catch and indicates that the population within the dock is low.

No habitats or species of conservation interest were recorded during either the sampling of the fauna within the sediments of the dock or the epi-fauna/flora of the dock wall. The starlet sea anemone *Nematostella Vectensis* was not found in any samples. One European eel was caught during the fish surveys. Although this is an IUCN red list species, the resident population within the dock is likely to be low based on the numbers caught. Since this species is highly mobile and the loss of habitat due to the infill is small, it is not anticipated that the project will have an adverse effect on the population within the dock.

Several INNS were recorded during the survey. These included high abundances of the pollution New Zealand mud snail *Potamopyrgus antipodarum* on the weed and sediment within the dock, dense colonies of Australian tube worm *Ficopomatus enigmaticus* on the walls together with a few individuals of the orange striped anemone *Diadumene lineata.* It is likely that the INNS observed during this survey are present throughout much of the Central Dock system and the likelihood of the transmission of these species to other waterbodies is extremely low. It is also expected that the new dock wall installed will become colonised by a similar community that already exists.

Sediments within the dock were relatively contaminated with metals. Concentrations of Pb and Zn exceeded the Probable Effect Level (PEL) at all stations. However, no metal concentrations exceeded CEFAS Action Level 2. Contamination by organotins was relatively low with only one exceedance of the threshold limit for DBT and one for TBT. Sediments were also highly contaminated with Poly Aromatic Hydrocarbons (PAHs), all of which exceeded CEFAS AL1 by a considerable margin and also exceeded the PEL where this exists. Sheet piling within the dock is only likely to cause localised re-suspension of material and therefore the risk to the marine ecology of the area is insignificant. However, consideration should be given to measures to mitigate the resuspension of sediments (e.g. the use of silt curtains) particularly if large scale dewatering is employed.

2 INTRODUCTION

As part of the on-going regeneration of Liverpool's central docks, a large scale residential development of West Waterloo dock on behalf of Romal Capital is proposed. This scheme will necessitate the infilling of an area of the dock to provide the required land for the development. The site is located on vacant and neglected land within the Central Docks area (Plot C-02 of neighbourhood C within the Liverpool Waters Outline Consent).

West Waterloo Dock borders the Liverpool Bay Special Protection Area (SPA) [1] which encompasses the intertidal habitats between Runcorn Bridge and Bromborough. The marine element of the SPA is a designated European Marine Site (EMS). The estuary is also a wetland of international importance (Ramsar site) and parts of the estuary are also designated as a SSSI under the Wildlife and Countryside Act.

Although the central docks are not within the designated areas, an Environmental Impact Assessment (EIA) is required for the works. Accordingly, to provide data to inform the EIA (Chapter 18), Ecospan Environmental Ltd has been asked to undertake marine ecological surveys of the proposed development area.

The key impacts (if any) to the marine ecology of the area are likely to be as a result of a loss of habitat and also potentially a resultant impact on the species that currently reside within, or utilise, West Waterloo Dock. To inform the EIA, therefore, it was necessary to determine what habitats are present and what the species composition of each habitat type is. This will enable the ecological 'value' of the habitats to be determined and also highlight any habitats or species that are of particular conservation importance. The dock encompasses habitats on hard substrates (i.e. the dock wall), as well as those on sediments (the seabed) and also an area of water that has the potential to support fish that may be resident or migratory.

2.1 Consultation

As part of the EIA process, written consultation was conducted and advice sought from Natural England (NE), the Marine Management Organisation (MMO), the Canal and River Trust and the Merseyside Environmental Advisory Service (MEAS). Of specific relevance to this marine assessment within the docks was the advice from NE that was provided in September 2018. It was suggested that that the impact of the dock infill on the supporting function of the dock waters in relation to qualifying features of the SPA and other designated sites should be considered. Additionally, NE advised that further survey work (via benthic grabs and scrapes) was required to understand the marine ecology of the dock and inform the EIA as well as determine the presence of Invasive Non Native Species (INNS) and of Species of Conservation Importance (SOCI) such as the starlet sea anemone. This baseline information would therefore enable an assessment of the impact of the development on protected species and on the potential spread of INNS to be undertaken.

The canal and river trust re-iterated NE's advice concerning the need for further surveys of the dock's aquatic fauna and flora. However, MEAS also advised that a fish survey should be undertaken and that the sediment contamination within the dock should be characterised to inform the EIA.

Following the surveys preliminary results were discussed with the above stakeholders on November 23rd.

3 AIMS

The principal aims of this survey were to:

- Characterise the dock in terms of the Habitats present and the species composition of those habitats.
- Determine the presence of any Habitats or Species of Conservation importance/interest (HOCI or SOCI) within the footprint of the development. These include those protected under the Habitats regulations 2017, those that appear on the IUCN list of endangered species (so called Red list species), and U.K. priority species or habitats.
- Determine the presence and abundance of any Invasive Non Native Species (INNS) within the sediments or hard substrata of the dock.
- Provide a baseline from which the fish species that use the dock and their abundance can be described.
- Make an assessment of the chemical contamination of the dock sediments.

4 METHODS

4.1 Survey dates

All surveys were undertaken between 31st October and 1st November 2018 from Ecospan Environmental Ltd's MCA cat 3 coded RIB *Pagrus*.

4.2 Survey of the sub-tidal sediments (dock floor)

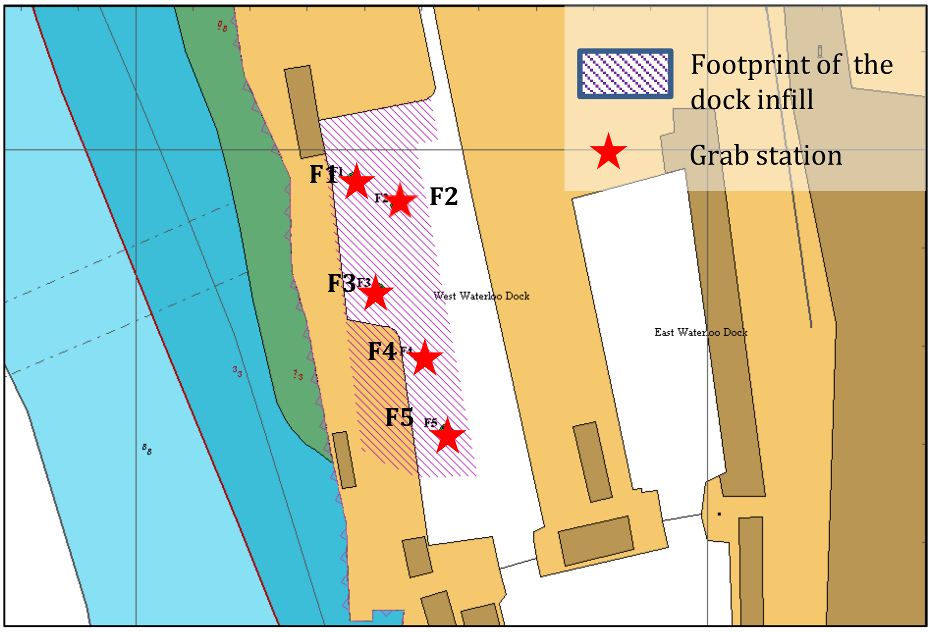
Due to the restricted access to the site (maximum air draft of the vessel <2.4 m) a half sized Van Veen grab had to be utilised to obtain sediment samples rather than a 0.1 m^2 Day grab. This was because the smaller grab could be deployed from a smaller vessel. Five 0.05m^2 samples of sediment were taken over the footprint of the proposed development as shown in Fig.1. The grid co-ordinates of each station are shown in Table A1 of the Appendix.

All sampling followed the ISO guidelines for quantitative sampling and sample processing of marine soft-bottom macrofauna [2], as well as the methods outlined in the Marine Monitoring Handbook [3]. Sampling was also consistent with the Environment Agency's methodology for sampling macrobenthos [4]. A digital photograph was also taken of all grab samples and the position of each grab sampling station recorded using differential GPS (which is typically accurate to within 5 meters).

Since it is well known that sediment granulometry has a large influence on benthic community structure [5], a further sample was taken for Particle Size Analysis (PSA) at each station.

Each core for fauna analysis was separated through a 0.5 mm mesh and the retained fauna preserved in 10% buffered formaldehyde following standard operating procedures for later analysis at Ecospan' s laboratory.

Fig. 1. Chart of West Waterloo Dock showing the grab sample locations.



4.2.1 Benthic macrofauna identification and enumeration

The retained fauna were identified and enumerated following Ecospan Environmental Ltd standard operating and internal quality control procedures. Benthic macrofauna analysis followed the quality standards set out by the Biological Effects Quality Assurance in Monitoring Programmes (BEQUALM) project and the National Marine Biological Analytical Quality Control Scheme (NMBAQCS) guidelines [6]. Ecospan Environmental Ltd takes part in the external quality assurance procedures carried out under NMBAQCS and is also ISO 9001 accredited.

4.2.2 Sediment PSA

Sediment granulometry at each station was determined by a combination of dry sieving and analysis using laser diffraction following Ecospan SOP LAB 025.

4.2.3 Contaminant analysis

Samples for contaminant analysis were taken using a half size Van Veen at 3 (F1, F2 and F3) of the fauna stations. Due to the historical use of these docks and the industrial nature of the area, analysis was undertaken for PSA, metals, PAHs, organo-tins and total hydrocarbons. Samples were frozen after sampling and stored frozen until sent to the analytical laboratory. Analysis was undertaken to the standards required by the Marine Monitoring Organisation (MMO) by SOCOTEC which is an MMO accredited laboratory.

4.3 Survey of the rocky substrata (dock walls)

The epi-fauna of the dock walls was assessed using two methods (surface scrapes of the dock wall and video transects). Four transects were sampled along the dock wall separated by approximately 50 m. The positions are shown in Fig. 2 and the grid co-ordinates given in Table A2 of the Appendix.

Fig. 2. Chart of West Waterloo Dock showing the location of the dock wall transects.

4.3.1 Surface scrapes

Surface scrapes of the dock wall were undertaken using a 0.5 mm net that was mounted on a metal frame attached to a pole. The edge of the frame was sharpened to facilitate the scraping process and an underwater video camera attached so that so that the quality of the scrape could be assessed whilst it was being taken (Fig. 3).

Fig. 3. Photograph of the net used to scrape the sides of the dockwall showing the attached underwater video camera.

A 20 cm scrape length was made to give a sampled area of 0.05 m^2. On each transect the abundance of fauna and flora within one 0.05m^2 surface scape was assessed at 2 depths. To provide a good representation of the fauna and flora present, each transect was split into 4 zones. The depth of the scrape relative to the surface of the water was then determined using a random number generator. The zone widths were selected based on the zones of fauna/flora observed on the dock wall prior to sampling. These are shown in Table 1.

On retrieval of the pole mounted net, the epifauna and flora was preserved using 10% borax buffered formaldehyde prior to being identified and enumerated at Ecospan's Laboratory.

Table 1. Sampling zones for the surface scrapes of the dock wall.

Zone No.	Sampling depth
0	0-20 cm
1	30-50 cm
2	50-70 cm
3	20 cm above sediment surface to the sediment surface

4.3.2 Underwater video transects of the dock wall

A semi-quantitative survey was made of the dock wall at each transect station using a pole mounted underwater HD video camera equipped with underwater lights. A two minute video of each transect was carried out using a camera mounted on a pole. The full depth of the dock wall was assessed at each transect. The footage was recorded using a DVR recorder and stored on a solid state hard drive. The identity and abundance of the taxa observed was determined via analysis of the video recordings back at the Laboratory. The abundance of each taxa was recorded semi-quantitatively using the SACFOR scale.

4.4 Fish surveys.

The aim of the fish surveys was to provide a baseline description of the fish species that use the dock and their abundance. This was to provide an understanding of which species utilise the survey area and an evaluation of the value of the habitat to fish to inform the EcIA.

The sediments of the dock were primarily composed of soft mud and sand. This, combined with the relatively small size of the area and the high density of opportunistic macroalgal matt, meant that the use of some standard fish sampling equipment such as beam trawls was not practical. For this reason two techniques were used: baited fyke nets and seine netting. The fyke netting targeted bottom dwelling fish such as the European eel (which is on the IUCN red list), gobies and small flatfish. The seine netting targeted more mobile species such as sand smelt, mullet, bass and demersal fish such as whiting.

The time and date of when the net was set (and retrieved for the fyke nets) was recorded for each station along with the water visibility, salinity, dissolved oxygen (DO) and temperature.

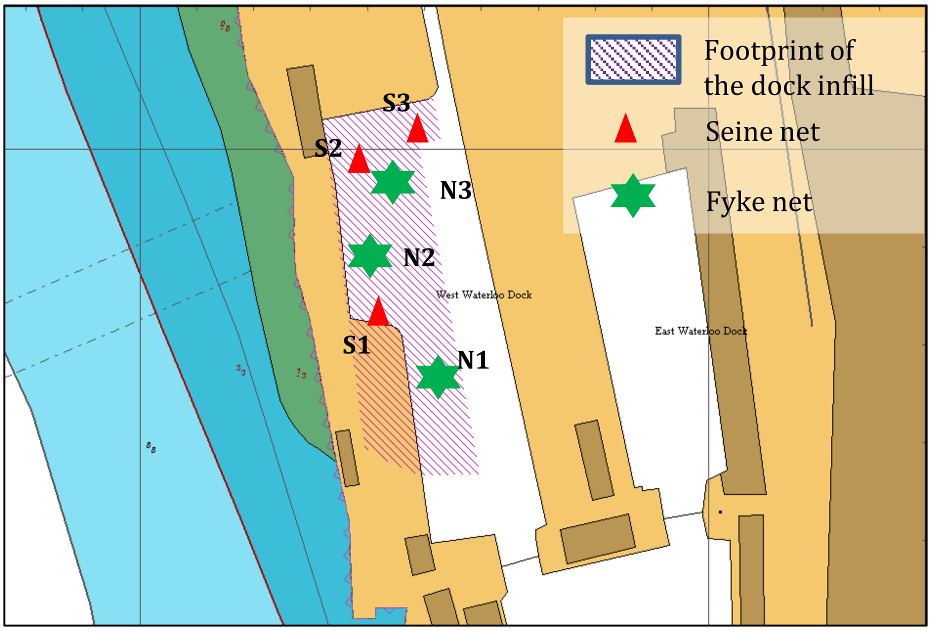
4.4.1 Fyke netting

Fyke nets were 2.75 m long 5 hooped singles with a 10mm mesh size and a 6m leader. Each net was baited with a combination of mackerel and squid. Nets were positioned at three locations spread over the survey area. The nets were set in the early afternoon of the 31st October and left to fish overnight before being retrieved during the morning of the 1st November. There was no detectable current at the locations surveyed. Consequently, the nets were set perpendicular to the dock walls at each sampling station. The positions of the fyke nets together with those of the seine nets are shown in Fig. 4 with the exact grid co-ordinates given in Table A3 of the Appendix.

4.4.2 Seine netting

The seine net used was 45 m long, 1.5 m deep and hade a 10 mm mesh size throughout. It also had a weighted ground rope to ensure that the bottom of the net was in contact with the seabed. The net was deployed from the shore using Ecospan Environmental Ltd's MCA cat 3 coded vessel *Pagrus*. At the target station one surveyor alighted from the boat and remained on-shore to hold the end of the net float line. The boat was then reversed away from the shore until half of the net was deployed. At that point the boat was directed back to the shore whilst the remainder of the net was deployed. This resulted in the net forming a horseshoe shape. Upon reaching the shore the second surveyor disembarked from the boat taking the end of the float line. The two surveyors then hauled the net towards each other to close the net. Three seine nets were deployed in total (Fig. 4 and Table A3 of the Appendix).

Fig. 4. Location of the fish sampling stations



4.4.3 Catch processing

All netted fish were transferred into appropriate containers of dock water which was periodically topped up to prevent the dissolved oxygen levels in the water falling. Each fish caught was identified to species level wherever possible by an experienced marine biologist. Identification aids were available for use in the field if necessary. A photographic reference collection of each species captured was collated for QC purposes.

The total body length of each fish captured was measured to the nearest millimetre using a measuring board. All measurements were recorded on a pro-forma sheet.

5 RESULTS

5.1 Overview of the dock environs.

The vast majority of the dock wall was vertical with a concrete face (Fig. 5). However the northern wall and an area of the western wall (where the dock width expands) were essentially formed by a bank of rubble and earth (Fig. 6).

Water depths within the part of the dock surveyed (i.e. out of the main channel which is not within the area of the proposed development) were shallow being typically less than 1m deep with a maximum depth recorded of 1.7m at station F1 which was closest to the channel. At the time of sampling the dock water was brackish (19 ‰).

Although the opportunistic macroalgae within the dock had obviously died back by the time of the survey, it was still abundant throughout the survey area and was dense in some areas (Fig. 7).

Fig. 5. Photograph showing a section of the western wall of Waterloo Dock

Fig. 6. Photograph showing the northern end of West Waterloo Dock

Fig. 7. Photograph showing dense macroalgae (*Chaetomorpha* sp.) in the north western corner of the dock

Discarded rubbish (litter, tyres, buoys, metal etc) was also common throughout the survey area.

5.2 Benthic macrofauna

The data taken at the time of sampling for each sediment station is shown in Table A4 of the Appendix. The bed of the dock was composed largely of mud and sandy mud with patches of gravel. The sediments of all samples appeared to be anoxic, but this was particularly apparent at station F1 which had some entrained algae (Fig. 8).

Fig. 8. Photograph of the sediment at station F1 showing the highly anoxic nature of the sediments and entrained opportunistic macroalgae.

A full list of the taxa identified and their abundance is shown along with the benthic fauna abundance table (Table A5). Only one Habitat type was identified within the dock sediments. This was EUNIS [7] Habitat type A5.542: angiosperm communities in reduced salinity in association with *Pomatogeton pectinatus* (now updated to *Stuckenia pectinata*).

The dominant flora observed within the dock basin were dense columns of the green algae *Chaetomorpha* sp. with the occasional tuft of the sago pondweed *Stuckenia pectinata*. It can be seen from Table A5 that the benthic infauna was characterised by a range of insects, amphipods, polychaetes and molluscs. Many of these are either lagoon specialists and/or taxa that are extremely tolerant of low DO or polluted sediments.

The amphipod *Microdeutopus gryllotalpa* was one of the most abundant taxa together with chironomid larvae. Pollution tolerant polychaete worms *Capitella capitata* [8] and *Polydora cornuta* [9], and the non-native gastropod *Potamopyrgus antipodarum were also abundant*. *Microdeutopus gryllotalpa* is known to be one of the most abundant amphipods living in saline lagoons in northern Europe [10]. Chironomid larvae are one of the most abundant group of insects in the aquatic environment and are known to be tolerant of pollution and low DO [11]. The New Zealand mud snail *Potamopyrgus antipodarum* is a non-native species which is also known to be extremely pollution tolerant [12]. The lagoon cockle *Cerastoderma glaucum* was present at all stations but abundant at stations F2 and F3.

5.2.1 Uni-variate analysis

A number of uni-variate summary indices have been calculated for the benthic macrofauna at each station. These include the number of taxa, the number of individuals and diversity/equitability indices such as Margalef's species richness, Pielou's eveness, the Shannon Weiner and Simpsons diversity indices. The results are shown in Table 2.

Table 2. Uni-variate diversity/equitability indices for benthic macrofauna at each station.

Station	No. of taxa	No. of individuals	Margalef's species richness	Pielou's eveness	Shannon Weiner diversity	Simpsons diversity
F1	5	5	2.49	1.00	0.70	1.00
F2	11	1390	1.38	0.76	0.79	0.79
F3	13	1507	1.64	0.53	0.59	0.65
F4	8	361	1.19	0.54	0.49	0.59
F5	10	453	1.47	0.60	0.60	0.67
Mean	**9.4**	**743.2**	**1.63**	**0.68**	**0.63**	**0.74**

It can be seen from this Table that the number of taxa was relatively low at all stations, but the fauna was particularly sparse at station F1. The generally low number of taxa was probably, at least in part, due to the brackish (19 ‰) nature of the water and the very low current. The paucity of fauna at station F1 is likely to be due to the extremely anoxic nature of the sediments in this area caused by the entrained opportunistic macroalgae. The high number of individuals from a few taxa that are either pollution tolerant or specialist lagoon species account for the relatively low diversity/species richness observed.

5.2.2 Multi-variate analysis

It is generally considered that multi-variate analysis of benthic macrofauna data provides a more sensitive measure of community change than uni-variate methods, since all the data are analysed collectively with no loss of information such as that which occurs when reducing the data to a single number or uni-variate statistic [13]. For this reason, the data has also been analysed using multi-variate statistical techniques.

Prior to subsequent analysis, the data was fourth root transformed to reduce the influence of very abundant taxa. The similarities between stations were then calculated using the Bray Curtis similarity matrix [14]. Following this a Multi-Dimensional Scaling (MDS) plot was produced of station similarities where the distance between the points is proportional to the similarity in community structure (i.e. the closer together two points are the more similar the macrofauna communities). The resulting MDS plot is shown in Fig. 9.

The significance of the groupings has been determined using the SIMPROF routine in PRIMER [15] is shown together with the similarity between stations in Fig. 10. It can be seen from this plot that all stations were statistically grouped together with a high similarity (c. 70%) except for station F1. The reasons for the dissimilarity at station F1 have been discussed in the previous section (section 5.2.1).

Fig. 9. MDS plot of the similarities in the benthic macrofauna in sediments from each station.

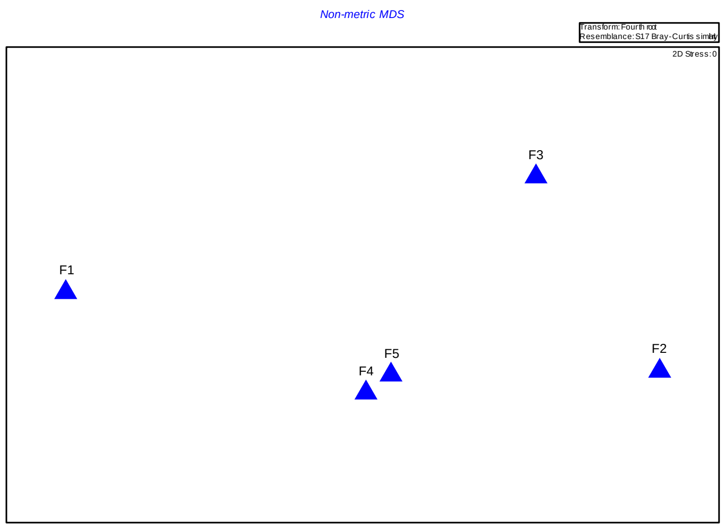
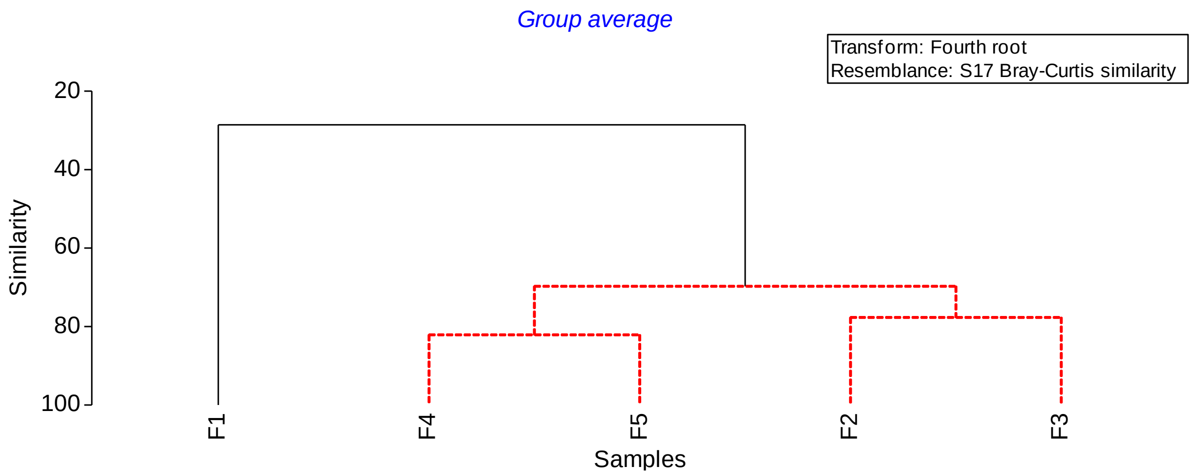


Fig. 10. Cluster diagram of station similarities with the dotted red-line indicating clusters of stations that are no significantly different from each other (SIMPROF).



5.3 Sediment physico-chemistry

5.3.1 Sediment granulometry

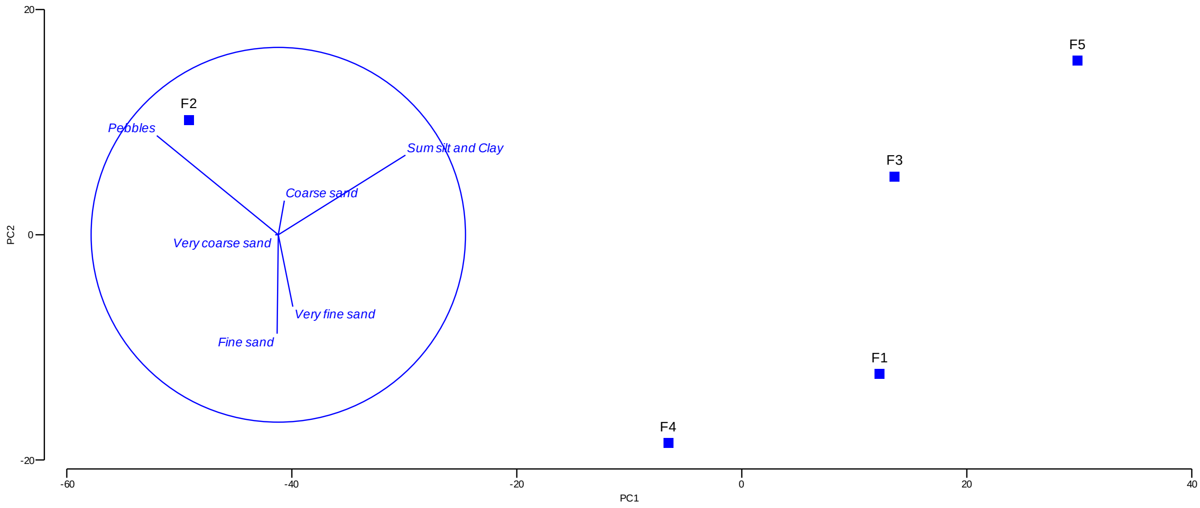
The sediment granulometry at each station is summarised according to the Wentworth scale in Table 3. The data has also been analysed using Principal Component Analysis (PCA) in PRIMER. The resulting plot is shown in Fig. 11.

It can be seen that the sediments were not particularly well sorted and consisted predominantly of medium to fine sand, silt and clay. However, there were coarser fractions in three of the samples which additionally contained pebbles and granules.

Table 3. Sediment granulometry at each station according to the Wentworth scale.

Station No.	Pebbles	Granules	Very coarse sand	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Silt	Silt	Silt	Clay
	>4mm	>2 <4 mm	>1 <2 mm	>0.5 <1 mm	>250 <500 µm	>125 <250 µm	>63 <125 µm	>31 <63 µm	>16 <31 µm	>8 <16 µm	>4 <8 µm	<4 µm
F1	0.0	0.0	0.1	2.0	9.1	21.0	22.2	17.2	10.4	7.6	5.8	4.6
F2	50.3	3.2	1.5	5.5	11.7	9.7	5.1	4.5	3.2	2.2	1.7	1.4
F3	8.3	1.9	0.9	1.9	7.1	11.5	14.0	17.5	13.3	9.9	7.7	6.1
F4	5.4	3.6	1.1	3.9	17.3	25.0	14.6	10.0	6.9	5.1	4.0	3.1
F5	0.1	0.1	0.2	12.2	6.5	6.9	5.7	20.2	16.7	13.2	10.4	7.6

Fig. 11. PCA plot of similarities in sediment PSA at each station



Station F2 was particularly different to other stations as the 50% of the sediments were comprised of pebbles.

5.3.1.1 Effects of sediment granulometry on the benthic macrofauna

Since it is well known that sediment granulometry often has a major effect on the benthic macrofauna [16], the effect of the sediment particle size at each station on the benthic macrofaunal communities present has been assessed using the BIOENV routine in PRIMER. Given the low number of replicates, the correlation was low (0.4) with the proportions of gravel, fine sand, and very fine sand providing the best explanation for the differences in community structure observed.

5.3.2 Sediment contaminants

The results from the chemical analyses are shown in Table 4.

Highlighted cells indicate values that exceed either the CEFAS guidelines [17] for the disposal of sediment at sea or the Canadian environmental sediment quality standards [18]. Those in yellow exceed either the Interim Marine Sediment Quality Guidelines (ISQG - sometimes known as the Threshold Effect Level i.e. the concentration that may affect certain sensitive species) or CEFAS Action level 1. Those in red exceed either the Probable Effects Level (PEL) (a concentration that will affect a wide range of species) or CEFAS Action Level 2. Where levels are below Action Level 1, sediments are considered to be clean, if levels are over Action Level 2 a disposal licence would usually be refused, and between 1 and 2 further assessment is often required.

It can be seen from Table 4 that the concentrations of metals within the sediments of the dock were relatively high. With the exception of Cr and Cd at F2, all concentrations exceeded the ISQG levels. Concentrations of Pb and Zn exceeded both the PEL and CEFAS AL1. The PEL and CEFAS AL1 were also exceeded for Cu and Hg at station F1.

Table 4: Sediment contaminant concentrations at each station.

Analyte		Station No.			CCME guideline limi		CEFAS action limit	
		F1	F2	F3	ISQG	PEL	AL1	AL2
Metals (mg/kg)	Arsenic (As)	16.7	11.7	17.5	7.24	41.6	20	100
	Cadmium (Cd)	0.73	0.52	0.68	0.7	4.2	0.4	5
	Chromium (Cr)	40.8	29	39.3	52.3	160	40	400
	Copper (Cu)	146.6	76.6	104.3	18.7	108	40	400
	Mercury (Hg)	0.76	0.44	0.66	0.13	0.7	0.3	3
	Nickel (Ni)	36.5	26.8	39.3	N/A	N/A	20	200
	Lead (Pb)	304.2	203.5	292.4	30.2	112	50	500
	Zinc (Zn)	454.1	274.9	348.3	124	271	130	800
Organotins (mg/kg)	Dibutyltin (DBT)	0.261	0.079	0.089				
	Tributyltin (TBT)	0.093	0.037	0.122			0.1	1
PAHs (µg/kg)	Acenaphthene	951	863	767	6.71	88.9	100	
	Acenaphthylene	201	143	179	5.87	128	100	
	Anthracene	1350	927	977	46.9	245	100	
	Benzo[a]anthracene	5330	3670	3920	74.8	693	100	
	Benzo[a]pyrene	6940	4820	6090	88.8	763	100	
	Benzo[b]fluoranthene	6450	4180	5270			100	
	Benzo[g,h,i]perylene	5150	3390	4180			100	
	Benzo(e)pyrene	5100	3410	4320			100	
	Benzo[k]fluoranthene	2730	1810	2290			100	
	C1 Naphthalene	1550	839	1280			100	
	C1 Phenanthrenes	3500	2410	2400			100	
	C2 Naphthalene	1620	993	1270			100	
	C3 Naphthalene	1660	1090	1210			100	
	Chrysene	5910	4120	4580			100	
	Dibenzo[a,h]anthracene	877	606	745	6.22	135	10	
	Fluoranthene	10500	7290	7990	113	1494	100	
	Fluorene	608	469	455	21.2	144	100	
	Indeno[1,2,3-cd]pyrene	4990	3360	4230			100	
	Naphthalene	832	477	586	34.6	391	100	
	Perylene	2010	1360	1700			100	
	Phenanthrene	4900	3840	3430	86.7	544	100	
	Pyrene	11100	8410	10500	153	1398	100	
Total Hydrocarbons (mg/kg)		<1	<1	<1			100	

Given that the sediments were taken from a dock environment, the levels of organotins (which were used in antifouling paint) were relatively low with CEFAS AL1 being exceeded for DBT at station F1 and TBT at station F3. All levels were below CEFAS AL2.

PAH contamination of the sediments was high with all stations substantially (at least one order of magnitude) exceeding CEFAS AL1 for all of the PAHs measured. Sediment PAH levels were also above the PEL where this exists generally by a large margin.

5.4 Fauna and flora of the dock wall

The sampling data for the scrapes of the dock wall and the video transects are shown in Table A7 of the Appendix.

From the results of the wall scrapes and the video transects it is clear that there were two Habitat types on the dock wall. The first occurred in the upper 20 cm of the walls and has been classified as EUNIS habitat type A3.72 (infralittoral fouling seaweed communities). This band was colonised by a few species macroalgae such as *Ulva* sp., *Cladophora* sp., and *Chaetomorpha* sp. The fauna within this zone was sparse being limited to mussels *Mytilus edulis*, sea squirts of the *Molgula* genus, and the non-native tube worm *Ficopomatus enigmaticus*.

The second Habitat type was found from below 20 cm to the bottom of the wall. This has been ascribed the EUNIS Habitat type A3.361 (*Mytilus edulis* beds on reduced salinity infralittoral rock). In this Habitat type the dock wall was heavily encrusted with mussels and *Ficopomatus enigmaticus*. Algal cover was sparse. High densities of amphipods (particularly *Microdeutopus gryllotalpa*, *Stenothoe monoculoides* and *Monocorophium acherusicum*) and the isopod *Jaera albifrons* were also found living between the mussels and tubes of *F. enigmaticus.* A few sea squirts of the *Molgula* genus and juvenile specimens of the lagoon cockle, *Cerastoderma glaucum*, were also found attached to mussel shells and algal filaments. A frame shot from the video of a typical part of this Habitat type (from T3) is shown in Fig. 12.

Fig. 12. Video still from station T3 showing Habitat type A3.361

The differences between these Habitat types are evident from the summary uni-variate statistics (Table 5). Scrapes from the upper A3.72 Habitat type had approximately 75% of the number of species, but only c, 15% of the number of individuals of the lower A3.361 Habitat type.

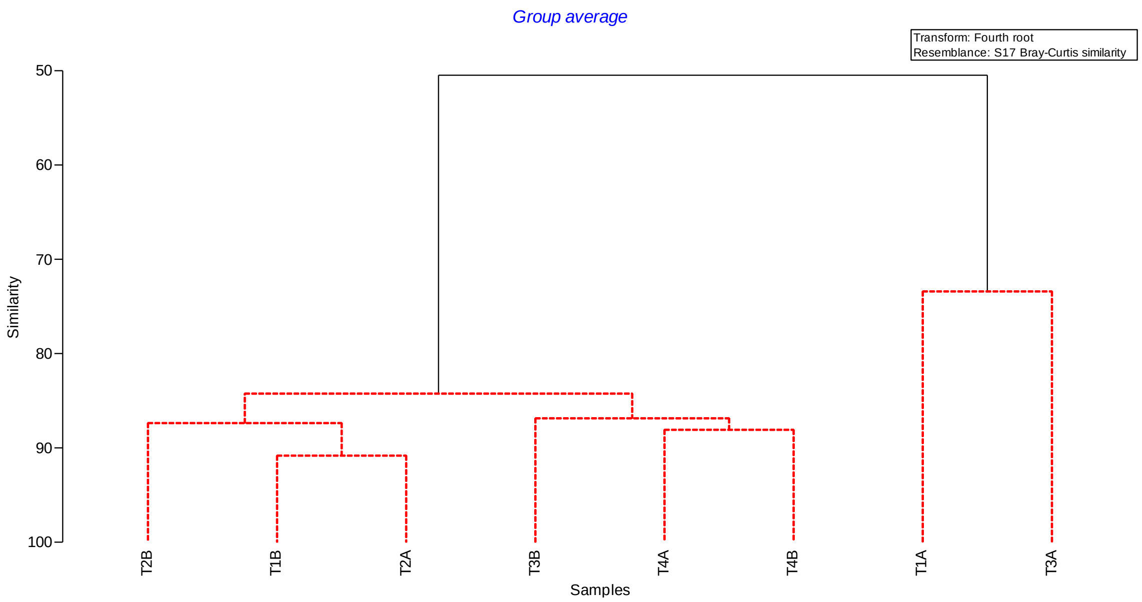
Table 5. Summary uni-variate statistics for each wall scrape sample.

Habitat type	Station	No. of taxa	No. of individuals	Margalef's species richness	Pielou's eveness	Shannon Weiner diversity	Simpsons diversity
A3.72	T1A	12	246	2.00	0.73	0.79	0.80
	T3A	13	141	2.42	0.49	0.55	0.51
	Mean	**12.5**	**194**	**2.21**	**0.61**	**0.67**	**0.66**
A3.361	T1B	17	1457	2.20	0.70	0.86	0.82
	T2A	17	1695	2.15	0.70	0.86	0.82
	T2B	18	2534	2.17	0.66	0.82	0.79
	T3B	16	1058	2.15	0.80	0.96	0.86
	T4A	16	1125	2.14	0.71	0.86	0.80
	T4B	17	895	2.35	0.71	0.88	0.82
	Mean	**16.8**	**1461**	**2.19**	**0.71**	**0.87**	**0.82**

The differences in the data from the video transects is less obvious (Table A8), although many of the taxa from the lower Habitat type were superabundant. One of the reasons for this is that the point of the video transects is to gather data on larger less abundant species; consequently small species such as amphipods are under-recorded.

Multi-variate analysis followed a fourth root transformation of the epi-fauna scrape abundance data. The CLUSTER plot produced in PRIMER (Fig. 13) shows that the samples from the four zones sampled separated into two groups: those scrapes taken above 20 cm (Habitat type A3.72) and those below 20 cm (Habitat type A3.361).

Fig. 13. CLUSTER diagram of wall scrapes at each transect with dotted red lines indicating insignificant differences as determined by SIMPROF.



This plot illustrates the high degree of similarity between samples in each of the two Habitat types. Samples within the A3.361 (*Mytilus edulis* beds on reduced salinity infralittoral rock) Habitat type had a Bray Curtis similarity of over 80% whilst those in the A3.72 (infralittoral fouling seaweed communities) were over 70% similar.

The video transects did not reveal the presence of any larger less abundant species with all of the taxa also being recorded in the scrapes.

5.5 INNS, SOCI and HOCI within the e

5.6 Fish surveys

5.6.1 Fyke netting.

The survey data (water parameters plus the net set and retrieve times) from the fyke netting is shown in Table A9 of the Appendix. Very few fish (or mobile invertebrate fauna such as crabs, shrimps etc) were caught at any station.

At station N1 the net was completely empty having no fauna of any kind. At station N2 one medium (52.5 cm) sized European eel *Anguilla anguilla* was caught along with one large common shore crab *Carcinus maenas* (Fig.14). At station N3 one 5.6 cm three spined stickleback *Gasterosteus aculeatus* (Fig. 15) was caught along with two large shore crabs.

Fig. 14. Photograph of the only European eel caught during the survey together with a large shore crab.

5.6.2 Seine netting

Due to the length of the seine net (45 m) and the small survey area (170 m long by a maximum of 70 m wide), the three seine nets sampled a relatively large proportion of the available area. The catch rate varied between the nets with the southernmost seine (S1) catching the fewest fish and the station closest to the main channel (S3) catching the highest number and the most species. Overall, three species of fish were caught in the seine nets. The most numerous were three spined stickleback (59) followed by sand smelt *Atherina presbyter* (12) (Fig.16) and the common goby *Pomatoschistus microps* (2).

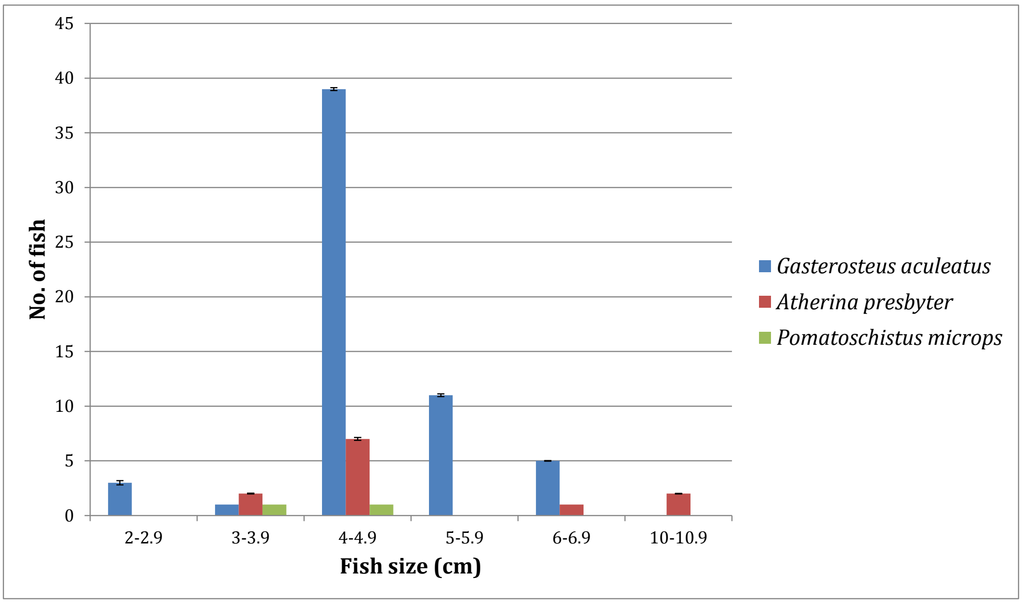
Fig. 15. **Three spined stickleback taken at N3.**

Fig. 16. **Photograph of a sand smelt**

The size frequency histogram of the fish caught is shown in Table 6. It can be seen from this diagram that the overwhelming majority of sticklebacks were between 4mm and 4.9 mm in length (i.e. they were adults [19]). The sand smelt caught ranged from 3.5 to 10 mm in length which is a mixture of 0 and 1 group fish [20]. Although the abundance of stickleback demonstrates that there is a well-established population in the dock, the small numbers of smelt show the population must be small as these fish are often found in dense shoals. Both species of fish are tolerant of low salinities with stickleback often being found in entirely freshwater habitats and sand smelts being one of the most numerically common fish trapped in some estuarine power station intakes [20].

It is surprising that none of the common UK species of mullet were caught during the seine netting. These fish are tolerant of reduced salinity and usually abundant in estuaries, harbours and docks. However, no adult or juvenile fish were observed during the course of the surveys. Therefore it is reasonable to assume that these fish were not present.

Table 6. Total catch size(=/- Standard Error) frequency histogram for the three fish species caught in the seine nets.



6 DISCUSSION AND CONCLUSIONS

6.1 Limitations of the survey work and data analysis

Given the size of the survey area it is considered that the surveys undertaken of the sediments and the dock wall provide excellent coverage of these habitats and that the data gives an accurate representation of those species present. The use of baited fyke nets also provides some data on the paucity of the mobile epi-fauna present within the dock.

Employing two different strategies for fish capture should have ensured that any fish that were likely to be in the dock at the time of the survey were sampled. It is possible that some fish (e.g. very small fish and perhaps some benthic flatfish e.g flounder) were under represented in the data. However, since the fyke nets were baited and the ground rope of the seine net was generally in contact with the dock bed, it is thought that some flatfish would have been caught if they were present.

The principle limitation to the fish surveys is that they were undertaken over a two day period and are therefore a 'snapshot' in time. The survey was undertaken in autumn which is a good time to survey if sampling cannot be undertaken during different seasons. This is because it is generally considered a transitional time when the summer species are still present and the winter species are also beginning to appear.

6.2 Assessment of the habitats and species of the dock floor

It can be concluded from the benthic macrofauna analysis that only one habitat type was present within the sediments of the dock basin. The majority of the stations had a similar, rather poor, community structure being composed of relatively few taxa having a high number of individuals. This is in part due to the brackish nature of the dock water and low current, but the abundance of pollution tolerant taxa also probably indicates an exposure to low dissolved oxygen concentrations that may be experienced within parts of the dock and/or pollution in the sediments. The large amount of opportunistic macroalgae observed during this survey indicates that this may be a contributory factor to low DO (if it occurs); particularly as the macroalgal mat had obviously died back at the time of this survey.

The Habitat type that occurred on the dock floor (A5.542: angiosperm communities in reduced salinity in association with *Pomatogeton pectinatus*) is not a protected habitat type and did not contain any SOCI. Unless the cumulative loss of this habitat type from other projects within the dock system is large, it is not considered that the small loss in this area will be of ecological significance.

6.3 Sediment contaminants

Unsurprisingly given the industrialised nature of the Mersey estuary and the former use of the docks, the sediments were relatively contaminated with metals. Concentrations of Pb and Zn exceeded the Probable Effect Level at all stations. However, no metal concentrations exceeded CEFAS AL2 and the CEFAS AL1 was only exceeded for DBT at one station and TBT at another.

Sediment PAH levels were high with CEFAS action level 1 being exceeded generally by at least one order of magnitude and PEL limits being breached for those PAHs for which the PEL has been determined. Anthropogenic sources of PAHs include their generation from the incomplete combustion of carbon containing fuels such as petroleum, oil, coal and wood. Since Waterloo Dock was operational from 1834 to 1988 which spans the most industrialised period on the Mersey, it is likely that the sources of the PAH sin the sediments within the dock are varied.

The high levels of PAHs and some metals suggest that this contamination is likely to adversely affect the biological communities that live within the sediments of the dock floor.

No dredging work is planned in association with this project. Possible means for the re-suspension of contaminants are limited to sheet and pile driving/drilling. These activities are likely to cause only localised re-suspension of material and are therefore the risk to the marine ecology of the area is insignificant. This is re-enforced by the probability that the sediments in the immediate receiving waters (i.e. the nearby dock system) are similarly contaminated. If large scale de-watering is carried out as part of the reclamation, this will probably require a separate assessment of its impacts. This will vary on a number of factors, not least being whether the water is pumped out into Waterloo Dock or into the Mersey estuary. However, possible mitigation methods such as the use of silt curtains should be considered where necessary.

6.4 Habitats and species of the dock walls

From the wall scrapes and video transects, it can be concluded that two Habitat types were identified on the dock walls. These were infralittoral fouling seaweed communities in the first 20 cm and *Mytilus edulis* beds on reduced salinity infralittoral rock) below this. It is likely that the Habitat type and species composition is replicated elsewhere within the dock system (it was observed to be the same on the eastern wall which was outside the survey area) and therefore it is probable that the new wall created by the infilling of the dock will be colonised by a similar community within a few years. Since the total area of wall will remain more or less constant, the infill will not result in any substantial change.

6.5 Fish surveys

The fish surveys showed that the number and diversity of fish species within the dock when sampled was low. No mullet or flounder were caught which species which might have been expected given the docks position and the brackish nature of the water. However, the dock obviously supports a good population of stickleback. Additionally a few sand smelt were caught and two gobies which indicate that these species are present but probably in relatively low numbers. One European eel which is an IUCN red list species (critically endangered) was caught. Given that three fyke nets were baited and set for over 15 hrs overnight, this is a low catch and indicates that the population within the dock is low as eels are very active foragers.

6.6 SOCI, HOCI and INNS

No habitats or species of conservation interest were recorded during either the sampling of the fauna within the sediments of the dock or the epi-fauna/flora of the dock wall. The starlet sea anemone *Nematostella Vectensis* was not found in any samples.

One European eel was caught during the fish surveys. Although this is an IUCN red list species, the resident population within the dock must be small. It was anticipated that the catch may have been higher. It is therefore possible that this part of the dock system does not provide a particularly good habitat for them (more extensive surveys would be required to confirm this). Since this hardy fish species is highly mobile and the loss of habitat due to the project is small, it is not anticipated that the project will have an adverse effect on the population within the dock.

Several INNS were recorded during the survey. These included high abundances of the pollution New Zealand mud snail *Potamopyrgus antipodarum* on the weed and sediment within the dock, dense colonies of Australian tube worm *Ficopomatus enigmaticus* on the walls and also a few individuals of the orange striped anemone *Diadumene lineata.*

The orange striped anemone is thought to have been introduced from Japan towards the end of the 19th century on ships hulls and is now widespread throughout the UK particularly in harbours and estuaries [21]. The Australian tube worm was first recorded in London docks in 1922 [22]. It occurs in waters of variable salinity and was possibly introduced from Australia on ships hulls. The New Zealand mud snail is known to be an extremely tolerant species and is widespread across freshwater and brackish habitats in England, Wales and Scotland [12].

It is likely that the INNS observed during this survey are present throughout much of the Central Dock system. It is also expected that the new dock wall installed will become colonised by a similar community that already exists. Any plant used on the water during construction will need to be craned in and out of the water at the dockside (due to access restrictions). Therefore, the likelihood of the transmission of these INNS to other waterbodies given standard precautionary techniques (washing and drying) is extremely low.

6.6.1 Potential impacts on birds and the Liverpool bay SPA

Since the proposed infill area is within the Liverpool Bay SPA buffer zone the effects of the development need to be considered in relation to the features of the SPA. The marine habitats recorded during this survey are not a feature of the SPA and therefore the limited loss of this habitat will have no impact on the SPA as regards the habitat itself.

The largest potential impact would be the loss of foraging area for bird species that are features of the SPA. Although not a rich feeding habitat for most species, some birds that predate on fish or can forage on the bottom of the dock (which is generally just under a metre deep) to feed on the benthic macrofauna will have a slightly smaller area to forage in. The potential effects of this loss of foraging area (and the cumulative loss from other developments) on birds that are a feature of the SPA have been considered in a separate report. [23].

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8 GLOSSARY OF TERMS

Abundance	Total number of all animals (individuals) in a sample
ANOSIM	Multi-variate statistical procedure that tests the significance of differences between two groups of data
Bray Curtis similarity	A method for determining the similarity (%) in community structure between stations/groups
CLUSTER	Multi-variate routine that provides a hierarchical clustering of samples based on their similarities
Community	A collection of fauna (or flora) cohabiting in and characteristic of an area of the environment
Community analysis	Statistical technique used to identify areas with a similar biological community
Margalef's species richness	A uni-variate statistic of the diversity of fauna in a sample
MDS plot	A two dimensional representation of similarities in community structure in which the distance between the points infers the degree of similarity.
Multi-variate statistics	Powerful statistical techniques for analysing data with many variables simultaneously to identify patterns & relationships
Shannon Weiner diversity index	Another index that is commonly used to characterize species diversity in a community. As with e Simpson's index, Shannon's index accounts for both abundance and evenness of the species present
SIMPER	Multi-variate statistical routine used to examine the species contributions to similarities and differences in community structure between groups.
SIMPROF	Multi-variate statistical routine which tests for evidence of structure in an *a priori* unstructured set of samples (i.e. whether the difference in clusters of samples is significant)
Simpson's index	Another index of fauna diversity, increases with fauna diversity
Taxon	A grouping of the fauna, may be a species or, if different species are indistinguishable, it may be based on a higher taxonomic group such as the genus or family
Uni-variate statistic	Statistics that describe the fauna in terms of a single number

9 APPENDIX

Table A1. Grid co-ordinates of the sediment sampling stations within Waterloo Dock.

Station	Grid Co-ordinates OSGB36 (BUG)	
	East	North
F1	333427	391363
F2	333452	391348
F3	333441	391300
F4	333465	391261
F5	333479	391219

Table A2. Grid co-ordinates of the surface scrape and video transect stations on Waterloo Dock wall.

Station	Grid Co-ordinates OSGB36 (BUG)	
	East	North
T1	333462	391233
T2	333454	391280
T3	333421	391310
T4	333419	391352

Table A3. Grid co-ordinates of the Fyke net (N) and seine net (S) stations.

Technique	Station	Grid Co-ordinates OSGB36 (BUG)	
		East	North
Fyke net (s= start, f= finish)	N1s	333478	391262
	N1f	333470	391260
	N2s	333424	391327
	N2f	333431	391331
	N3s	333455	391355
	N3f	333448	391364
Seine net	S1	333445	391288
	S2	333437	391371
	S3	333474	391383

Table A4. Data collected at the time of the sediment sampling.

Station No.	Time	Date	Water depth (m)	Sample depth (cm)	PSA (for fauna)	Contaminants	Sediment description and comments
F1	09:55	01.11.18	1.7	12.0	✓	✓	Very fine sand silt and clay plus *Chaetomorpha*
F2	10:10		0.8	6.5	✓		Very fine sand silt plus some gravel pebbles and shells
F3	10:20		1.1	7.0	✓	✓	Very fine sand and silt, some gravel
F4	10:40		1.0	8.0	✓		Very fine sand and silt, some gravel
F5	10:55		1.1	12.0	✓	✓	Very fine sand silt and clay

Table A5. Macrofauna abundance table for sediment samples.

Taxon	Station No. F1	F2	F3	F4	F5
Actiniaria			1		
Microdeutopus gryllotalpa	1	264	811	8	14
Gammarus tigrinus		48	11	5	3
Melita palmata					
Stenothoe monoculoides		3	10		1
Molgula		4			
Chironomidae	1	148	214	185	226
Streblospio					2
Capitella capitata agg.		63	286	136	43
Ficopomatus enigmaticus			1		
Polydora cornuta		153	119	18	117
Cerastoderma glaucum	1	53	10	1	4
Mytilus edulis <3 cm		3	2		
Potamopyrgus antipodarum	1	521	22	6	42
Monocorophium acherusicum		130	19	2	1
Jaera albifrons			1		
Baltidrilus costatus	1				

Table A6. Sampling details for the epifauna/flora scrapes and the video transects of the dock wall.

Transect No.	Sample	Depth (m)	Time	Date	Water depth (m)
T1	A	0.0-0.20		31.10.18	1.1
	B	0.90-1.10	09:30		
	Video start		10:36		
	Video finish		10:38		
T2	A	0.50-0.70		31.10.18	0.7
	B	0.30-0.50	09:42		
	Video start		10:46		
	Video finish		10:48		
T3	A	0.0-0.20		31.10.18	0.7
	B	0.30-0.50	09:50		
	Video start		10:51		
	Video finish		10:53		
T4	A	0.30-0.50		31.10.18	0.7
	B	0.50-0.70	10:00		
	Video start		11:02		
	Video finish		11:04		

Table A7. Abundance table of epi-fauna and flora from scrapes of the dock wall.

Taxon	T1		T2		T3		T4	
	T1A	T1B	T2A	T2B	T3A	T3B	T4A	T4B
Nematoda	3				1			
Microdeutopus gryllotalpa	1	302	225	316	4	174	106	101
Gammarus tigrinus		2	1		1			
Melita palmata		1	6	8		10	3	1
Stenothoe monoculoides	2	162	182	190	6	106	76	49
Molgula	1	6	9	9		11	8	8
Conopeum seurati		P	P	P		P	P	P
Eudendrium								P
Cerebratulus	1	19	15	35	1	12	23	4
Ficopomatus enigmaticus		232	437	426		207	111	244
Polydora cornuta				1				
Aurelia		3	15	12		25		
Cerastoderma glaucum		9	22	37	4	19	29	20
Mytilus edulis <3 cm	4	25	35	85	2	122	81	51
Mytilus edulis >3 cm		33	11	17		8	15	6
Ceramium		1		25			2	33
Chaetomorpha	25	19	20	25	1	50	2	33
Cladophora	15		20		1			
Ulva lactuca	15				1			
Ulva intestinalis	45	80	60	50	97	50	96	33
Potamopyrgus antipodarum								
Monocorophium acherusicum	74	416	440	964	14	212	438	258
Jaera albifrons	60	146	196	332	8	46	130	51
Diadumene lineata						5	4	1
Amphibalanus improvisus				1				
	(green)	Algae scored as the % of the total alage present						

Table A8. Abundances of species observed during the video transects (SACFOR scale).

Taxon	T1		T2		T3		T4	
	0-20 cm	20-Bottom	0-20 cm	20-Bottom	0-20 cm	20-Bottom	0-20 cm	20-Bottom
Molgula	C	A	C	A	C	A	A	A
Ficopomatus enigmaticus	A	S	A	S	C	S	A	A
Mytilus edulis	C	S	C	S	C	S	C	S
Ceramium		O		C		O		A
Chaetomorpha	A	A	C	A	S	S	A	A
Cladophora	O		O		O		O	
Ulva lactuca	O		O		O		O	
Ulva intestinalis	C		O		C		O	

Table A9. Survey data for the Fyke netting.

Station	Net set		Net retrieved		Water clarity	Salinity (‰)	D.O (%)	Temp (°C)
	Time	Date	Time	Date				
N1	13:05	31.10.18	08:24	01.11.18	> 4m	19.4	98	7.4
N2	13:20	31.10.18	08:40	01.11.18	> 4m	19.4	100	7.4
N3	13:30	31.10.18	08:50	01.11.18	> 4m	19.0	100	6.7