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Dredged Material Disposal Site Monitoring Round the Coast of England: Results of Sampling (2015-16)

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Executive Summary

- This report presents the scientific findings of, and implications for subsequent monitoring based on the results from dredged material disposal site monitoring conducted under a Cefas/Marine Management Organisation Service Level Agreement (SLA 1.3) project (C6794 hereafter) round the coast of England during 2015-16, together with those obtained following the processing of biological and sediment contaminant samples acquired during 2014.
- The main aims of this report are: to aid the dissemination of the monitoring results; to assess whether observed changes resulting from dredged material disposal are in line with those expected; to compare the results with those of previous years (where possible); and, to facilitate our improved understanding of the impacts of dredged material disposal at both a site-specific and a national (i.e. non site-specific) level.
- Targeted monitoring was conducted at two disposal sites during 2015, at Blyth (northeast coast) and Site Y (Liverpool Bay, west coast), and samples taken during 2014 were processed from a further three sites; Nab Tower and South Falls along the south and southeast coast respectively, and Site Z (Liverpool Bay).
- Parameters monitored varied between sites (governed by site-specific issues) but included sediment particle size, sediment organic carbon and contaminants (e.g., polycyclic aromatic hydrocarbons or PAHs, organohalogens (e.g., pesticides, flame retardants) and trace metals) concentrations and macrofaunal assemblages.
- Variations (both spatially and temporally) in the concentrations of the various contaminant types were somewhat site-specific, and, in general, indicated that concentrations remain temporally stable or show a slight decline.
- For the sites where biological assemblages were sampled, the results reveal that disposal sites habour assemblages that are either at least as rich as those outside the disposal site, or ones which, at worst, represent an altered community structure, depending on the site.
- The implications of these findings for each site are discussed with respect to the need for subsequent monitoring under C6794. However, these data do not represent the sole basis of such final decisions regarding monitoring; in addition, up-to-date intelligence regarding potential changes to the disposal regime and/or concerns raised from stakeholders are all embraced within the selection process for disposal site monitoring under this project.

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1. Introduction

1.1 Regulation of disposal activity in England

Disposal of waste at sea is strictly regulated through the licensing requirements of the Marine and Coastal Access Act 2009 (MCAA). The MCAA provides the principal statutory means by which the UK complies with EU law, such as the Water Framework Directive (WFD, 2000/60/EC), the Habitats and Species Directive (92/43/EEC), the Wild Birds Directive (79/409/EEC) and international obligations such as under the OSPAR Convention and the London Protocol, in relation to disposals at sea.

Pursuant to the OSPAR Convention and the London Protocol, only certain wastes or other matter are permitted for disposal at sea. During the 1980s and 1990s, the UK phased out sea disposal of most types of waste, including industrial waste and sewage sludge. Since then, dredged material from ports and harbours, and a small amount of fish waste, has been the only type of material routinely licensed for disposal at sea.

The Marine Management Organisation (MMO) regulates, and is responsible for, licensing activities in the marine area around England including the disposal of dredged material at sea. The MMO assesses the suitability of dredged material for disposal at sea in line with the OSPAR Guidelines for the management of dredged material (OSPAR, 2014). These guidelines provide generic guidance on determining the conditions under which dredged material may (or may not) be deposited at sea and involve the consideration of alternative uses, disposal sites and the the suitability of the dredged material for disposal to sea including the presence and levels of contaminants in the material, along with perceived impacts on any nearby sites of conservation value.

One of the roles of Cefas is to provide scientific advice to the MMO on the suitability of the material for sea disposal at the application stage and, once a licence is granted, to provide technical advice on any monitoring undertaken as a result of licence conditions. Advice on the licensing of dredged material disposal at sea is provided by Cefas' Sustainable Environment and Advice for Licensing (SEAL) team, work conducted under C6794 helps underpin the scientific rationale for such advice (see Section 1.3).

1.2 Disposal sites around England

There are approximately 155 open sites designated for dredged material disposal round the coast of England, not all of which are used in any one year. While the majority of these are located along the coast of the mainland, generally within a few miles of a major port or estuary entrance, a significant number are positioned within estuaries (e.g., Humber) or on intertidal mudflats as part of beneficial use schemes (Bolam et al., 2006).

In total, approximately 40 Mt (wet weight) are annually disposed to coastal sites around England, although this varied from 28 to 57 Mt (wet weight) for the period between 1986 and 2010. Individual quantities licensed may range from a few hundred to several million tonnes, and the nature may vary from soft silts to stiff clay, boulders or even crushed rock according to origin, although the majority consists of finer material (Bolam et al., 2006).

1.3 Overview of Cefas / MMO MoU contract C6794 'Monitoring of dredged material disposal sites'

The dredged material disposal site monitoring project C6794, funded by the MMO, falls under a new service level agreement (or SLA) between the MMO and Cefas. Operationally, this project represents a continuation of the disposal site monitoring programme SLAB5 which was a component of a former SLA between Defra and Cefas; this SLA formerly ceased at the end of March, 2015. C6794 was initiated on 1st April 2015, and, thus, while the project and work planned under this project is termed here under C6794, any reference to its predecessor project is inevitable (i.e. to its survey work, reports or other scientific outputs), and will continue to be referenced as SLAB5.

In summary, C6794 provides field evaluations ('baseline' monitoring and 'trouble-shooting' surveys) at dredged material disposal sites round the coast of England. A major component of the project is, therefore, the commissioning of sea-going surveys at targeted disposal sites. Such field evaluations under C6794 are designed to ensure that:

- environmental conditions at newly designated sites are suitable for the commencement of disposal activities;
- predictions for established sites concerning limitations of effects continue to be met; and,
- disposal operations conform with licence conditions.

The outcomes of such surveys contribute, either directly or indirectly, to the licensing/enforcement process by ensuring that any evidence of unacceptable changes or practices is rapidly communicated and acted upon by the MMO. As such, there are inherently strong links and ongoing discussions between the approaches and findings of this project with the work carried out by Cefas' SEAL team and case licensing officers within the MMO. The scientific outcomes of the work undertaken within C6794 are circulated to the Cefas SEAL team and the MMO *via* a number of routes including peer-reviewed publications (including both activity-specific and site-specific findings), reports, direct discussions and internal and external presentations. The production of this report, within which a summary of the annual findings is presented (Section 2), forms an important element of such scientific communication. The current report, which presents the findings of work undertaken during 2015-6, is the eighth in the series; the previous ones are accessible *via* the Defra website (https://www.gov.uk/government/publications?departments%5B%5D=centre-for-environment-fisheries-and-aquaculture-science). It is not the purpose of this report to present a detailed appraisal of the processes giving rise to impacts at a particular site (see Section 1.5) but to encapsulate the essence of the impacts associated with this activity in its entirety round the coast of England.

1.4 Sites monitored

To aid with determining which disposal sites should be selected for sampling in any one year, Cefas has derived a tier-based approach that classifies a number of possible issues or environmental concerns that may be associated with dredged material disposal into a risk-based framework (Bolam et al., 2009; Birchenough et al., 2010). The issues that pertain to a particular disposal site, and where these lie within the tiering system (i.e.,

their perceived environmental risk) depict where that site lies within the tiered system. This ultimately determines whether that site is considered for sampling during a particular year. It is intended that this approach increases the transparency of the decision-making process regarding disposal site selection for C6794 monitoring, i.e., it establishes a model for site-specific decisions regarding sampling.

A tiered survey design and site assessment system, therefore, facilitates the prioritisation of dredged material disposal sites in terms of the need for, and the scale of, monitoring required at each site. In practice, this method will provide a scientifically valid rationale for the assessment of risks associated with relinquished, current and proposed disposal sites to the surrounding environment and amenities.

The disposal sites targeted for Cefas monitoring during 2015-16 are listed in Table 1.1. These sites were identified following consultation between Cefas' SEAL team, Cefas scientists in a number of key disciplines (e.g., benthic ecology, sediment contaminants), together with a significant involvement from the MMO.

Table 1.1. Dredged material disposal sites targeted for monitoring under C6794 during 2015-16.

Disposal site	Geographical location off English coast	Code	Prioritisation assessment: Tier
Blyth	Northeast	TY042	1
South Falls	Southeast	TH070	2
Nab Tower	South	WI060	2
Site Y	Northwest	IS150	1
Site Z	Northwest	IS140	2

1.5 Aims and structure of this report

This report does not aim to present a critique of the processes leading to observed changes at dredged material disposal sites around the coast of England. Such appraisals are conducted *via* other reporting routes, either *via* discussions with Cefas' SEAL team, presentations and subsequent publications at national and international conferences, and *via* papers in peer-reviewed journals (e.g. Bolam and Whomersley, 2005; Bolam et al., 2006; Birchenough et al., 2006; Bolam, 2014; Bolam et al., 2014a; Rumney et al., 2015; Bolam et al., 2016). The aims of this report are:

- To present the results of sampling undertaken during 2015-16 under C6794, thereby aiding the dissemination of the findings under this project;
- To indicate whether the results obtained are in line with those expected for each disposal site, or whether subsequent investigations should be conducted;
- Where possible, to compare the 2015-16 results with those of previous years to provide a temporal assessment (see Bolam et al., 2009; 2011a; 2012a; 2012b; 2014b; 2015a; and 2015b for reports of previous years' monitoring);
- To facilitate our improved understanding of the impacts of dredged material disposal at both a site-specific level and a national level; and,

- To promote the development of scientific (or other) outputs under C6794.

In accordance with the format first established for Bolam et al. (2011a), and that used within subsequent reports (Bolam et al., 2012a; 2012b; 2014b; 2015), the conclusions regarding each site are contained within Section 2 (below). The more detailed scientific data (e.g., acoustic, sediment particle size, organic carbon, macrofauna, contaminants) for each site are presented in Appendix 1. For background information regarding each disposal site monitored, the reader is directed towards this appendix. Appendix 2 contains information regarding the analytical and numerical methods used during the assessments of sediment contaminants (the reader may need to consult these whilst appraising Section 2).

2. Conclusions and implications for further monitoring

The main findings of the monitoring undertaken during 2015-16 are presented within this section (see Appendix 1 for more detail), together with their implications regarding the need for subsequent monitoring under C6794. However, it should be noted that these data, and the conclusions based on them, do not represent the sole basis of such final decisions regarding monitoring; up-to-date intelligence regarding potential changes to the disposal regime and/or concerns raised from any stakeholder are all embraced within the selection process for disposal site monitoring under this project. Thus, the recommendations for monitoring presented here for each site, although representing a major component of the decision-making process, may or may not be altered by other factors.

2.1 Blyth (TY042)

The Blyth dredged material disposal site, off the northeast coast of England, has been used for the disposal of various wastes since at least the 1960s. Recent concerns regarding the site, however, pertain to the potential for impacts associated with disposal activity on specific features of the recently designated nearby Coquet to St. Mary's Marine Conservation Zone (MCZ). Seventeen stations were sampled within, and along the main sediment transport pathway from, the disposal site, together with a small number of stations within the MCZ boundary.

The data acquired reveal that sediments in this region are predominantly mixed, comprising mainly gravelly muddy sands and muddy sands. Organic carbon values (in the <2mm sediment fraction) range from 0.27 to 5.62 %, with highest levels being observed within the disposal site and from inshore stations.

Polycyclic aromatic hydrocarbon (PAH) concentrations of the sediments indicated that the Effect Range Low (ERL) for low molecular weight (LMW) PAHs was exceeded at nine stations, and the Effects Range Median (ERM) for low molecular weight (LMW) PAHs was exceeded at two of these stations (one inside and one to the northwest of the disposal site). These two stations also exceeded the ERL for high molecular weight (HMW) PAHs, but the ERM for high molecular weight PAHs was not exceeded at any station.

Regarding organohalogens (OHs), $\sum_6$DDTs concentrations were above Cefas action level 1 at eight stations. According to the OSPAR guidelines, most stations had 'good' environmental status for all ICES 7 CBs (polychlorinated biphenyls) and 'good' status overall. One station had 'bad' environmental status for CB118 but 'good' status overall and no stations had 'bad' status overall for CBs.

Although a moderate enrichment of trace metals was observed when measured concentrations were assessed according to the OSPAR background assessment concentration (BAC) values, there was either no enrichment or slight enrichment for the stations when metals concentrations were assessed using the regional baselines. Where slight enrichment was observed, this was generally at the more southerly stations.

There was no evidence, based on univariate metrics of community structure and taxonomic composition, to suggest that macrofaunal assemblages sampled at Blyth were impacted by disposal activity. Assemblages within and immediately surrounding the disposal site were neither species poor, nor comprised high abundances of taxa that are generally not present in non-disposal site assemblages. Indeed, assemblages within parts of the disposal site exhibited relatively high biomass and numbers of taxa. One station to the north of the survey area, within the Coquet to St. Marys MCZ, was relatively faunistically poor and displayed a different assemblage structure to those of the other stations. The dissimilar sediment type (poorly sorted and higher gravel component) and low concentrations of contaminants observed for this station indicated that, however, the disparate nature of the assemblage there is not likely to be a response of disposal activity.

In summary, the data acquired for the sediments around Blyth indicate that impacts associated with the disposal activity currently licensed are within what would be regarded as expected for the site. The variability in sediment physical, chemical and biological characteristics are comparable with those observed at other dispersive sites around the English coast. These results may be used to aid any assessment regarding whether disposal activity here is potentially impacting the designatory features of the Coquet to St. Mary's MCZ. No further monitoring at Blyth is required based on the data presented, unless specific issues continue to pertain or new issues arise.

2.2 South Falls (TH070)

South Falls is a large disposal site located off the Greater Thames Estuary in the southern North Sea. In 2013, the MMO issued a marine licence to deposit 6.2MT comprising of London Clay, gravel and sand; this volume represented a significant increase above the normal annual average for the site. Monitoring of the site was conducted by Cefas, most recently in 2014 when an acoustic survey, together with the collection of samples for macrofauna, was conducted. Here, the findings of the processing of the macrofaunal samples taken in 2014 are presented, and the data are compared with those obtained in 2013 to allow an assessment of the biological impacts of, and recovery from, the large disposal regime to this site.

A total of eleven stations from within (five stations) and surrounding the South Falls disposal site were sampled. Annelid worms and bryozoans (or "moss animals") were the numerical dominant taxa across the survey area,

and the number of taxa of both these two goups increased within the disposal site between the 2013 and 2014 surveys while decreasing within the reference (non-disposal site) stations. The number of solitary taxa, colonial taxa, total abundance and total biomass of the assemblages were comparable between disposal and reference stations in 2013, however, these metrics were all significantly higher in the stations inside the disposal site during 2014 compared to those outside the licensed boundary.

Multivariate analyses of the community structure revealed that the assemblages inside and outside the disposal area were evidently distinct in 2014. Thus, not only were the disposal site assemblages richer in terms of numbers of species, total density and biomass, they encompassed a selection of different species. These results indicate that the impacts associated with the deposition of large amounts of material to South Falls during the past year or so have not resulted in a discernibly negative impact on seabed assemblages but, *a contrario*, disposal site assemblages appear enhanced with respect to a number of structural properties in 2014 which were not apparent in 2013 towards the end of the disposal campaign. The data acquired to date for this site under C6794 and its predecessor project SLAB5 imply that no subsequent monitoring is particularly imperative.

2.3 Nab Tower (WI060)

Nab Tower is a well-used disposal site approximately 13 km southwest of Bembridge, Isle of Wight, with a depth of approximately 30 – 40 m. The site is the main recipient of maintenance and capital material from ports, harbours, berths and navigational channels in Southampton, Portsmouth and the Isle of Wight and, in recent years, there have been a number of applications for large amounts of material to be disposed of to this site.

Akin to the situation pertaining to South Falls, Cefas recently conducted (in 2014) an acoustic survey of the Nab Tower disposal site which allowed an assessment of the fate of the material on the bed. Macrofaunal samples collected from stations within and surrounding the disposal site during this 2014 survey were processed under the auspices of C6794 during 2015 and the data presented are herein. The results revealed that assemblages within the disposal site, together with those of the two stations sampled further offshore (to the south) of the disposal site are relatively taxon-poor and possess lower densities and biomass compared to those in more inshore, shallower areas to the north of the disposal site. Assemblages within the disposal site were characterised particularly by the presence of the sedentary worm *Lumbrineris cingulata* (agg.), nemerteans (or ribbon worms), together with other species of worms such as *Notomastus*, *Aonides paucibranchiata* and *Spiophanes bombyx*.

These data, when assessed alongside the information gained from the acoustic survey during 2014, indicate that dredged material remains on the seabed within the disposal site and negatively impacts the macrofaunal assemblages within the licensed boundary. There is no evidence, however, that impacts on biological assemblages are extending far beyond the limits of the licensed boundary, although the fact that the area to the southwest of the site disposal site was not surveyed must be considered alongside such conclusions. Subsequent monitoring at this site does not appear particularly warranted, although potential issues pertaining to the nearby

MCZ may have a direct bearing on such needs and may potentially override the verdict here based purely on the data presented.

2.4 Site Y (IS150)

Site Y (and Site Z; see below) is situated within Liverpool Bay on the west coast of the UK and receives material resulting from dredging of the docks and navigation channels, and that from capital projects, in the Mersey. The site has recently received large quantities of non-erodable, capital material followed by more erodable material from dredging as part of the Liverpool II docks campaign. While dredging management practices aimed to ensure that the more contaminated material that required dredging was treated separately (i.e., not disposed of to sea), the possibility of elevated concentrations of certain contaminants (e.g., PAHs and Hg) being disposed to Site Y remained.

The survey conducted under the auspices of C6794 during 2015 found that while the silt/clay content of the sediments of the two (north and south) reference areas were generally comparable, those in the southern section of the disposal site where finer, maintenance dredged material had recently been disposed, were elevated. Sediment organic carbon values (in the <2mm sediment fraction) at Site Y were relatively low compared to those generally observed in coastal marine sediments.

PAH concentrations indicated that the sediment disposed of at Site Y contained elevated concentrations of PAHs, but the resulting concentrations did not exceed any ERL or ERM within the site. Furthermore, PAH concentrations were low at both the northern or southern reference areas of Site Y, potentially indicating that the material was largely contained within the site.

Concentrations of CBs and dieldrin measured were below Cefas action level 1 for all stations sampled at Site Y. $\sum_{6}$DDTs concentrations were above Cefas action level 1 at seven of the 16 stations and, according to the OSPAR guidelines, four reference stations had 'good' environmental status for all ICES 7 CBs and 'good' status overall. The remaining 12 stations had one CB with 'bad' environmental status but 'good' status overall. No station was classed as 'bad' overall status for CBs.

Most trace metals were either not enriched or slightly enriched according to their regional baseline values. Those stations where slight enrichment was observed were located in the disposal site, and most stations outside displayed concentrations below regional baselines. Hg, however, was moderately enriched inside the disposal area and slightly enriched at the references. However, as Hg was shown to be similarly elevated at Site Z in 2014 (see above), it is doubtful that this observation at Site Y resulted solely from the disposal of material from the Liverpool II docks project.

Biological assemblages within the Site Y disposal site displayed reduced numbers of taxa, total abundance and wet biomass, and possessed a greater proportion of molluscs and colonials (e.g., bryozoans, cnidarans) and less

annelid worms compared to those of the references. There is no indication that assemblages at either of the two reference areas showed signs of impacts associated with the deposition at Site Y, harbouring, for example, 28 and 33 separate taxa per grab for the north and south references respectively.

These data, acquired under C6794 during 2015, indicate that impacts resulting from the disposal of large quantities of material to the Site Y site are evident in terms of contaminants and macrofaunal assemblages, but these appear to be restricted to within the site and such characteristics at both the north and south references are as one would expect for sediments in this region. While subsequent monitoring of the site for these sediment characteristics would obtain data of scientific interest, allowing the recovery of the site to be studied, such sampling is not particularly warranted under the licence-focussed remit of C6794.

2.5 Site Z (IS140)

Site Z, located not far south of Site Y, receives modest amounts of maintenance material each year from dredging within the Mersey, and elevated concentrations of some contaminants have occasionally been observed through Cefas monitoring. In 2014, sediments from a number of stations were sampled on an *ad hoc* basis and these sediments were processed for contaminants concentration assessment during 2015 under C6794.

The sediments within and in the vicinity of the Site Z disposal site are generally unimodal slightly gravelly sand or slightly gravelly muddy sand, with comparatively low organic carbon values relative to those from other regions. Fifteen stations from within and surrounding the disposal site were sampled in 2014 for sediment contaminants, the PAH concentrations revealing that the ERL for LMW PAHs was breached at only one station (south of the disposal site), and the ERM for LMW PAHs was not exceeded at any station. Furthermore, neither the ERL nor the ERM for HMW PAHs were exceeded at any station. Summed PAH values found at Site Z are similar to those found at found at Site Y, with values typical of those found in offshore sediments along the west coast of England and Wales.

Concentrations of CBs and dieldrin at all stations were below Cefas action level 1 while $\sum_{6}$DDTs concentrations were above Cefas action level 1 at five stations. According to the OSPAR guidelines, five stations were classed as 'good' environmental status for all ICES 7 CBs and 'good' status overall. Four stations showed 'bad' environmental status for two CBs and therefore 'bad' status overall. When compared with previously-acquired data, OH concentrations for Site Z appear temporally consistent, albeit a slight decline, although BDE209 concentrations here still remain essentially the highest for those of marine sediments across the English coast.

When compared to the more applicable regional baseline values (as opposed to the OSPAR BACs), trace metals at Site Z were generally slightly to moderately enriched, although this enrichment was more-or-less confined to the stations within (and those located just to the east of) the disposal site; enrichment was not generally observed for the reference stations. Enrichment, however, was greater and spatially wider for Cd, Pb, and

particularly Hg. Trace metals have shown a slightly decreasing trend at stations outside the disposal site since 2006.

Future monitoring of sediment contaminants concentrations at Site Z would appear prudent but, given the temporally consistent nature of the data observed to date, monitoring every three years would appear to represent a suitable approach. Of course, such forward-looking monitoring plans should be revised in the light of any potential or realised change in the disposal regime.

3. Acknowledgements

A large number of Cefas staff has helped contribute to the work which has been conducted to produce this report. Such staff have been involved in all aspects of the work from an early stage, e.g., during discussions of the specific issues regarding dredged material disposal sites around the England coast (e.g. Cefas' SEAL team), through to the field sampling and the laboratory processing of the various components. In particular, staff within Cefas' Chemistry Function i.e., Boby Thomas, Pauline Learmonth and Joanna Uzyczak (organohalogens); Kerry Potter, Malgorzata Wilczynska and Phil Mellor (PAHs); and Lee Warford (metals), and the Sedimentology Function, i.e. Briony Silburn and Caroline Limpenny, are gratefully thanked for processing the large numbers of samples that are required under C6794 and which form the core of this report. The structure and content of this report have been significantly improved following comments provided by Dr. Chris Vivian (and others) at various stages.

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APPENDICES

Appendix 1. Results

1.1 Blyth (TY042)

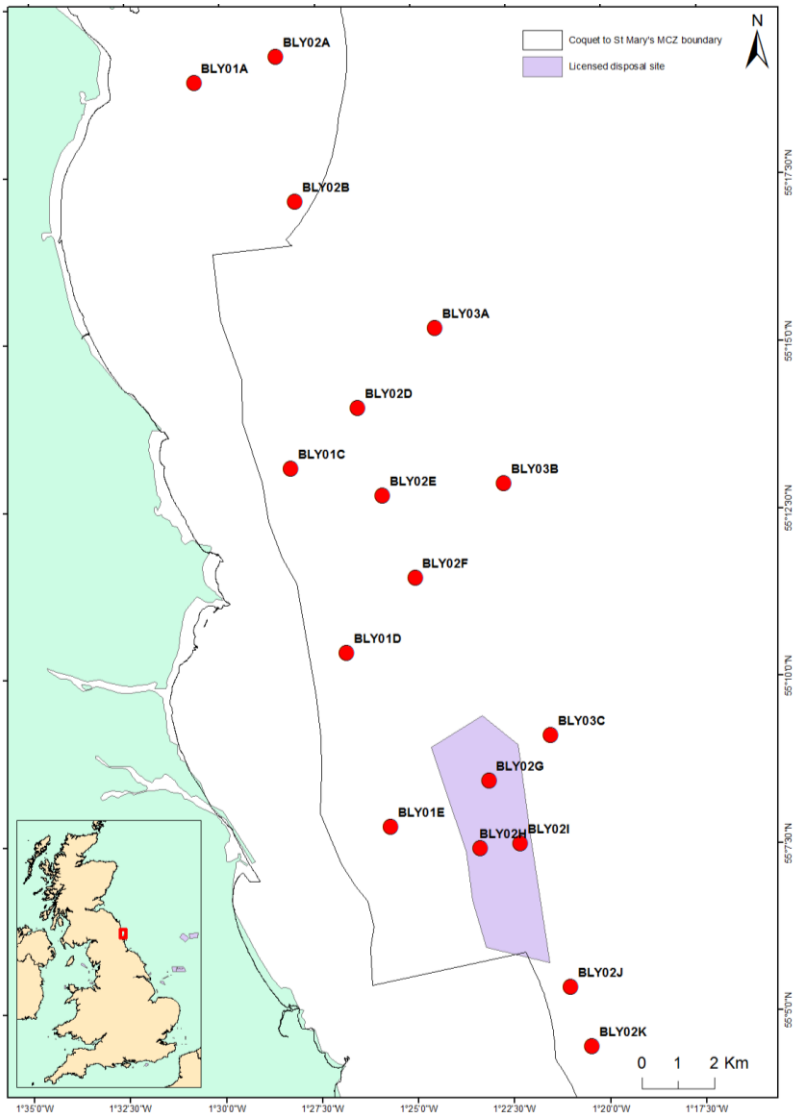

Figure A1.1.1. The location of Blyth dredged material disposal site and the stations sampled under C6794 during 2015. The boundary of the Coquet to St. Mary's MCZ is shown.

1.1.1 Background

The Blyth dredged material disposal site has been used for the disposal of various wastes since at least the 1960s. During the early part of this period, the site received a wide range of materials, primarily associated with the mining industry (e.g. colliery waste) and fly-ash from coal-fired power stations. Dredged material was also disposed of to the site during that early period, and this waste represents the sole material now disposed to Blyth. Thus, Blyth has, over the years, received large quantities of sediments that range in their physical (both granulometric and density), mineralogic and chemical characteristics. The ecological effects associated with these various types of material are likely to vary (Bamber, 1983), partly as whilst dredged material

predominantly originates from the marine environment, the non-marine derived sediments resulting from the mining and power industries are fundamentally dissimilar to those that marine fauna are naturally exposed and adapted to.

The dredged material currently disposed to Blyth originates chiefly from Blyth Harbour and annual quantities (since 2008) are approximately 460,000 tonnes. This material is muddy sand in nature (87% silt/clay on average). Concentrations of metals, organotins (e.g. TBT) and PCBs in the source material have, since 2008, been close to Cefas action level 1, and, thus, unlikely to present any ecological issues following disposal. Historically, high levels of PCBs were observed in the sediments of Battleship Wharf in the inner harbour at Blyth, although the risk of any associated impacts resulting from this was greatly reduced following reclamation of the Wharf. Recently, high levels of PAHs have been measured in the source sediments, although monitoring of these compounds has indicated that their concentrations have declined. An elevation in total hydrocarbons (THCs) was observed during 2011 and 2014 from the 'mid channel' area, however, the relatively high proportions of black coal (which reduces the biological toxicity of THCs) in the sediments is likely to reduce the likelihood of such THCs presenting an ecological risk.

Recent concerns regarding the site, however, pertain to the newly proposed Coquet to St. Mary's Marine Conservation Zone (MCZ), the boundary of which lies very close to that of the Blyth (and that of North Tyne to the south) disposal site (Figure A1.1.1). Blyth, akin to most sites around England, is a dispersive site and varying proportions (depending on sediment particle size, bulk density, amount disposed, etc.) of material are dispersed either immediately following release or subsequently *via* bedload transport. The main transport pathway at this site runs more-or-less parallel with the coastline in a NNW – SSE direction, although the long-term fate of the material is likely to be more governed by residual currents and storm effects.

Monitoring planned for Blyth under the auspices of C6794 during 2015 involved a spatial assessment of the biological (macrofauna), physical (sediment particle size) and chemical (organic carbon, trace metals, polycyclic aromatic hydrocarbons (PAHs) and organohalogens (OHs)) characteristics of the sediments. Stations lying inside the site, and at varying distances along an approximate route of the tidal pathway, were sampled, with some stations being located inside the MCZ boundary (Figure A1.1.1). **While this survey aimed to provide important data regarding the physical, chemical and biological characteristics of the sediments in this region, an area that has not been recently sampled, the data cannot be used to unequivocally address the issue regarding impacts on the designatory features of the proposed MCZ.** Without an assessment of the natural temporal variability of those designatory features, together with the absence of pre-disposal baseline data, ascertaining impacts resulting from a long-term disposal site is fundamentally very difficult. The data acquired under C6794 in 2015 should, however, aid any subsequent attempts to address this issue by providing a suitable characterisation from which ensuing monitoring may be based.

Prioritisation assessment: Tier 1

- where there is the potential for the occurrence of elevated contaminant concentrations (between Cefas action levels of 1 and 2 in proposed dredge sediments) arising from historical or current activities at source (especially heavily urbanised/industrialised estuaries)
- where disposal activities pose a threat to protected areas
- where specific concerns have been raised
- that have been observed or pose an increased risk to the surrounding area and receptors
- that have large pending applications (not necessarily approved).

1.1.2 Parameters to be assessed:

Sediment particle size

Sediment organic carbon

Sediment contaminants (PAHs, organohalogens, trace metals)

Macrofaunal assemblages

1.1.3 Results

1.1.3.1 Sediment particle size

Blyth sediments are predominantly mixed, being mainly gravelly muddy sands and muddy sands (Table A1.1.1). The majority of the stations possess very poorly sorted sediments, except for BLY1A at the northern limit of the survey which, in contrast, displays sediments classed as moderately well sorted.

Table A1.1.1 Average sediment descriptions and statistics for each sample at Blyth under C6794, 2015.

Sample name	Sample Type	Sediment description
BLY01A	Unimodal, Moderately Well Sorted	Slightly Gravelly Sand
BLY01C	Bimodal, Very Poorly Sorted	Slightly Gravelly Muddy Sand
BLY01D	Polymodal, Very Poorly Sorted	Gravelly Mud
BLY02A	Unimodal, Very Poorly Sorted	Slightly Gravelly Muddy Sand
BLY02B	Unimodal, Very Poorly Sorted	Slightly Gravelly Muddy Sand
BLY02D	Bimodal, Very Poorly Sorted	Slightly Gravelly Muddy Sand
BLY02E	Bimodal, Very Poorly Sorted	Slightly Gravelly Muddy Sand
BLY02F	Trimodal, Very Poorly Sorted	Slightly Gravelly Muddy Sand
BLY02G	Bimodal, Very Poorly Sorted	Slightly Gravelly Muddy Sand
BLY02H	Bimodal, Very Poorly Sorted	Slightly Gravelly Muddy Sand
BLY02I	Bimodal, Very Poorly Sorted	Slightly Gravelly Muddy Sand
BLY02J	Polymodal, Very Poorly Sorted	Gravelly Muddy Sand
BLY02K	Polymodal, Extremely Poorly Sorted	Gravelly Muddy Sand
BLY03A	Unimodal, Very Poorly Sorted	Slightly Gravelly Muddy Sand
BLY03B	Unimodal, Poorly Sorted	Slightly Gravelly Muddy Sand
BLY03C	Trimodal, Very Poorly Sorted	Slightly Gravelly Muddy Sand

Sample name	Gravel (%)	Sand (%)	Silt/clay (%)	Very coarse sand (%)	Coarse sand (%)	Medium sand (%)	Fine sand (%)	Very fine sand (%)
BLY01A	3.16	94.36	2.48	4.16	70.88	16.16	2.02	1.13
BLY01C	0.31	52.68	47.00	0.20	3.88	2.70	25.60	20.30
BLY01D	11.07	25.67	63.26	4.42	0.00	0.01	6.86	14.37
BLY02A	0.52	74.88	24.60	0.49	8.02	44.55	15.62	6.20
BLY02B	1.17	75.55	23.27	0.95	5.05	26.72	32.75	10.09
BLY02D	0.43	64.88	34.69	0.59	5.51	14.09	31.51	13.17
BLY02E	0.40	65.53	34.07	0.53	5.55	16.38	33.28	9.79
BLY02F	3.53	64.67	31.81	4.52	9.47	14.37	25.37	10.93
BLY02G	0.93	62.76	36.32	1.35	3.21	8.05	35.31	14.85
BLY02H	0.32	60.30	39.38	1.42	9.52	16.64	22.59	10.13
BLY02I	0.75	60.91	38.33	0.74	3.67	7.39	32.37	16.74
BLY02J	9.01	58.13	32.85	5.20	7.41	7.95	20.17	17.40
BLY02K	19.90	40.79	39.30	7.20	6.48	7.96	9.33	9.82
BLY03A	0.55	74.14	25.31	2.20	11.09	25.04	31.14	4.67
BLY03B	0.63	83.13	16.24	1.68	13.01	36.86	28.21	3.38
BLY03C	0.53	75.18	24.29	0.74	12.20	22.27	32.56	7.40

BLY02D contains low level of asbestos so a full PS distribution could not be completed for this sample.

The spatial variation in the proportional representation of gravel, sand and silt/clay for each sampling station in 2015 is shown in Figure A1.1.2. These confirm the predominantly sandy nature of the sediments with varying proportions of silt/clay, with lesser, but equally variable, proportions of gravel. Silt/clay content is highest at BLY1D (63%), and lowest at the most northerly station (BLY1A; 2.5%) which is within the Coquet to St. Marys MCZ (Figure A1.1.2). Gravel fractions are generally low in the sediments within the survey region, with relatively high levels in the stations to the south of the disposal site.

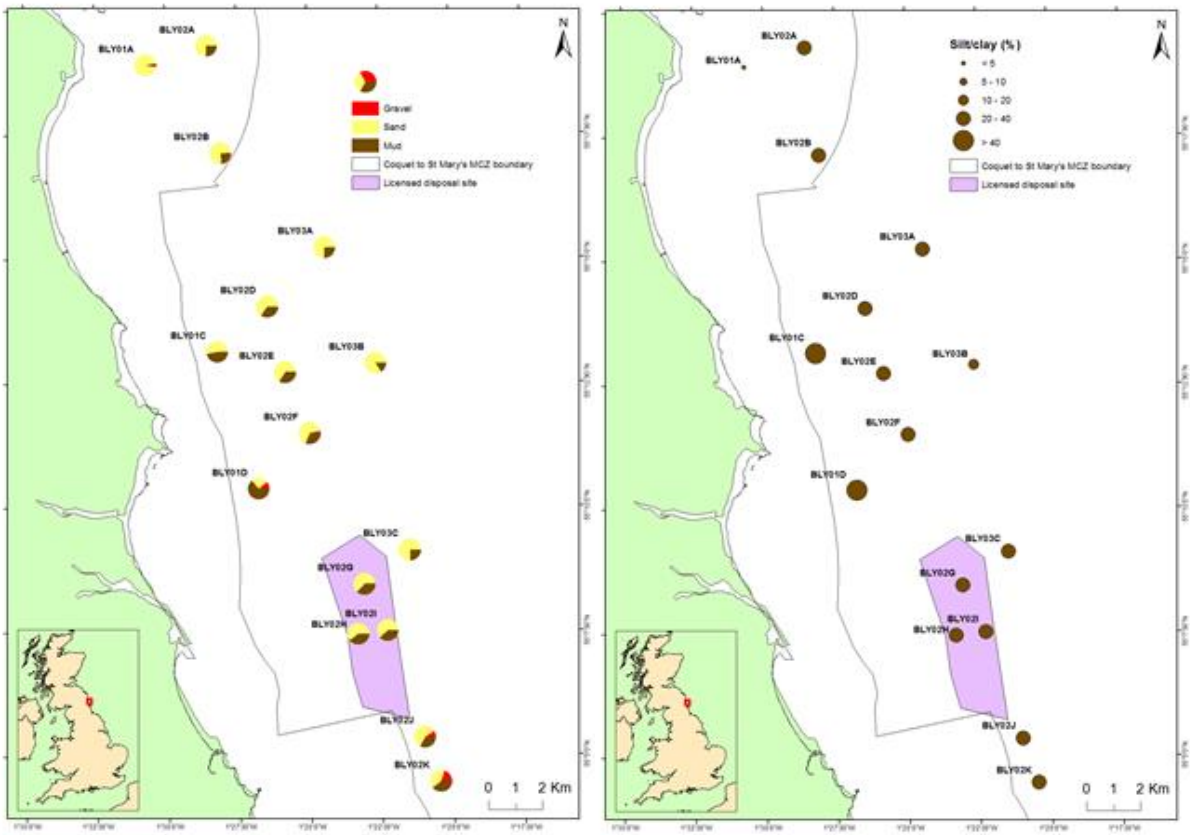

Figure A1.1.2. Pie charts of gravel, sand and silt/clay (left) and silt/clay content (%) (right) of sediments sampled at Blyth under C6794, 2015.

1.1.3.2 Sediment organic carbon

Organic carbon values (in the <2mm sediment fraction) range from 0.27 to 5.62 % (Figure A1.1.3) with highest levels being observed within the disposal site and in inshore stations. Organic carbon values (in the <63µm sediment fraction) range from 3.21 to 4.35 % (Figure A1.1.3). The silt/clay content at BLY01A was too low to allow organic carbon on this fraction to be assessed. Furthermore, sediments from BLY02D (north of the disposal site) contained low levels of asbestos rendering it not possible to measure organic carbon for this station.

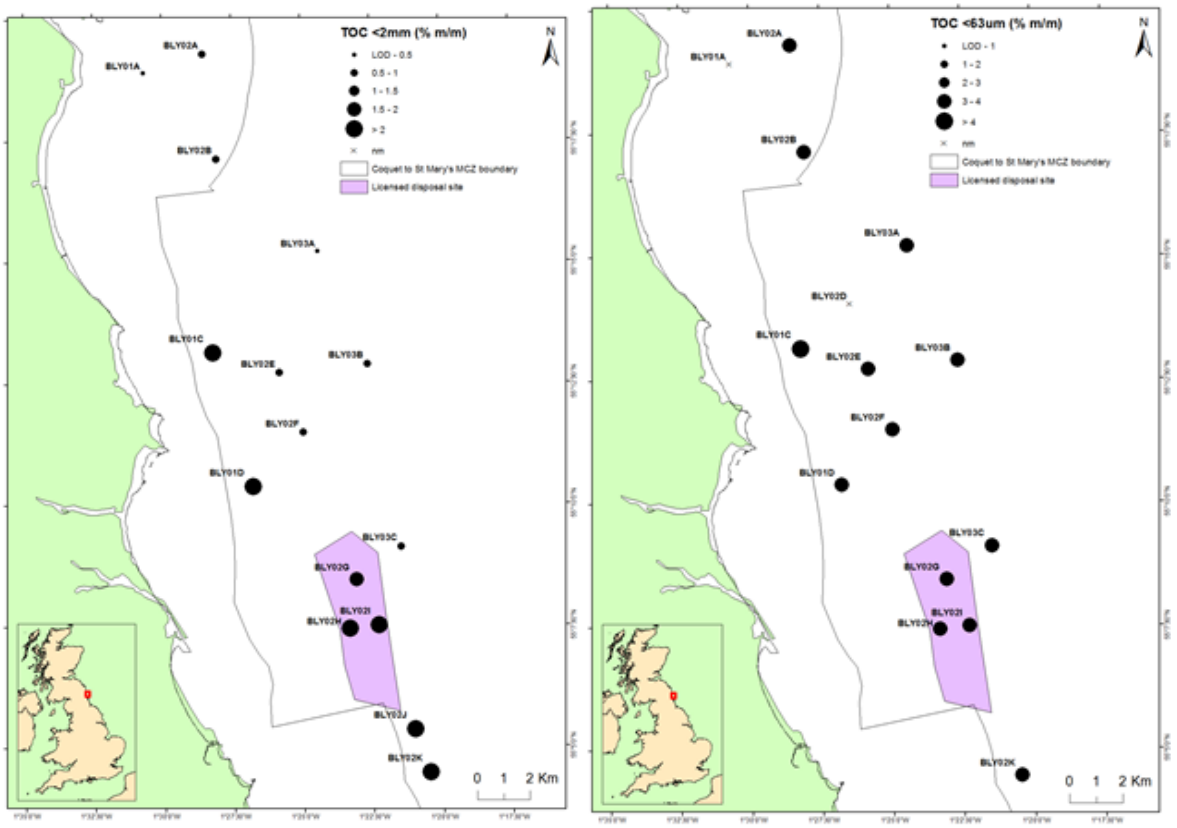

Figure A1.1.3. Organic carbon (%) in the <2mm fraction (left) and in the silt/clay fraction (<63µm) (right) at in the sediments sampled at Blyth under C6794, 2015.

1.1.3.3 Sediment contaminants

1.1.3.3.1 PAHs

The highest summed PAH concentration (ΣPAH) at Blyth in 2015 (35,800 µg kg^{-1} dry weight) was found at BLY02H, within the confines of the disposal site (Figure A1.1.4). The second highest concentration (31,100 µg kg^{-1} dry weight) was located at BLY01D, approximately 5 km to the north west of the disposal site (Figure A1.1.4). The lowest summed PAH concentration (701 µg kg^{-1} dry weight), however, was sampled at BLY01A which is located to the north of the sampling survey within the MCZ. Relatively low PAH concentrations (i.e., <5000 µg kg^{-1}) were found offshore to the north of the disposal site.

Disposal activity (maintenance dredging) since 2011 is currently ongoing with 153,120 tonnes disposed in 2011, 210,100 tonnes in 2012, less in 2013 with 50,860 tonnes, and 149,830 tonnes in 2014.

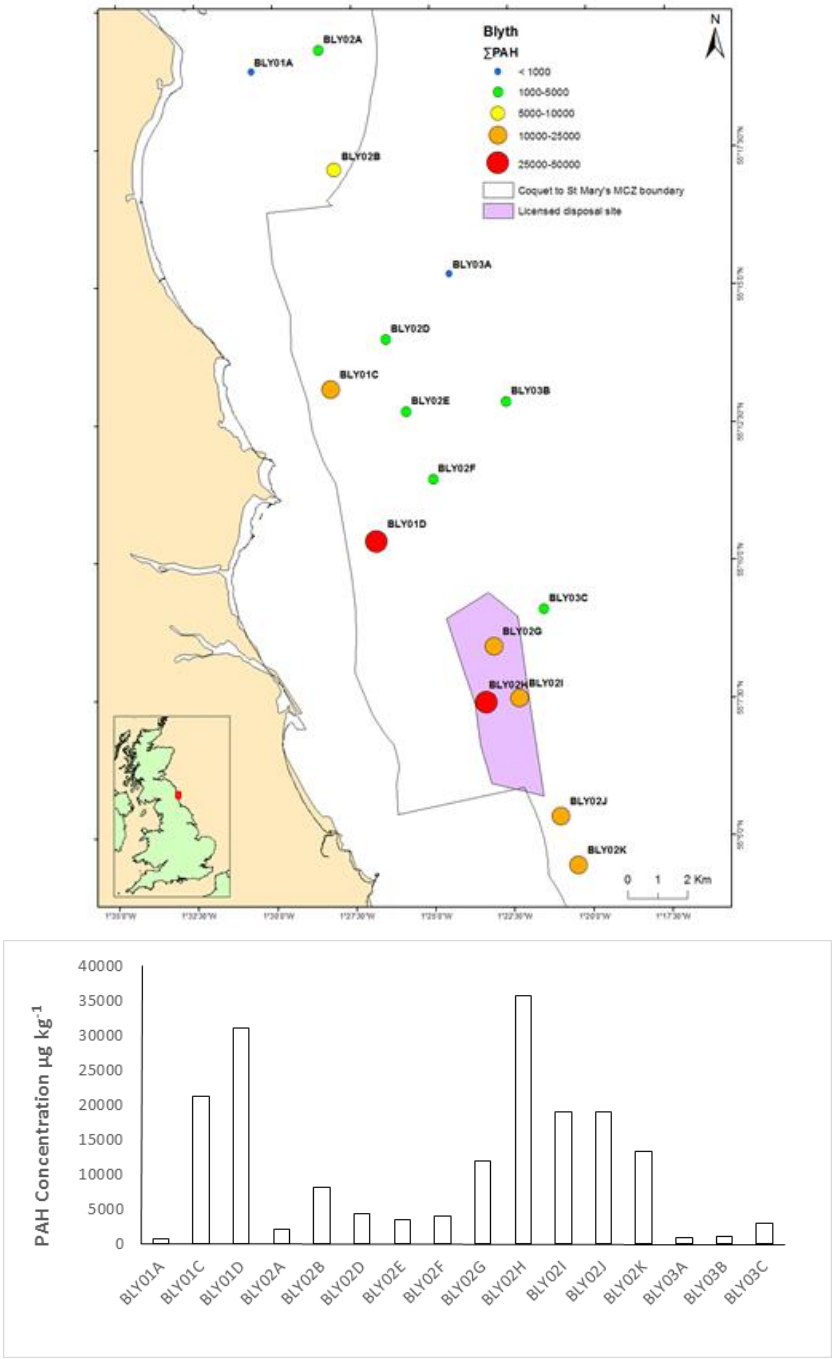

Figure A1.1.4. Map (top) and bar chart (bottom) of summed PAH concentrations (µg kg^{-1} dry weight) for stations sampled in 2015 at Blyth.

The Effect Range Low (ERL) for low molecular weight (LMW) PAHs was exceeded at nine of the sixteen stations (Figure A1.1.5) and the Effects Range Median (ERM) for low molecular weight (LMW) PAHs was exceeded at two of these stations (BLY02H and BLY01D; inside and to the northwest of the disposal site respectively). BLY02H and BLY01D also exceeded the ERL for high molecular weight (HMW) PAHs, but the ERM for high molecular weight PAHs was not exceeded at any station (Figure A1.1.5). Summed PAH values found at Blyth are similar compared to those found at other disposal sites around UK waters. More locally, summed PAH concentrations of 30,000µg/kg have recently been observed *via* monitoring conduncted under SLAB5 at sites such as North

Tyne. It has been postulated that these elevated concentrations are associated with historic and industrial inputs.

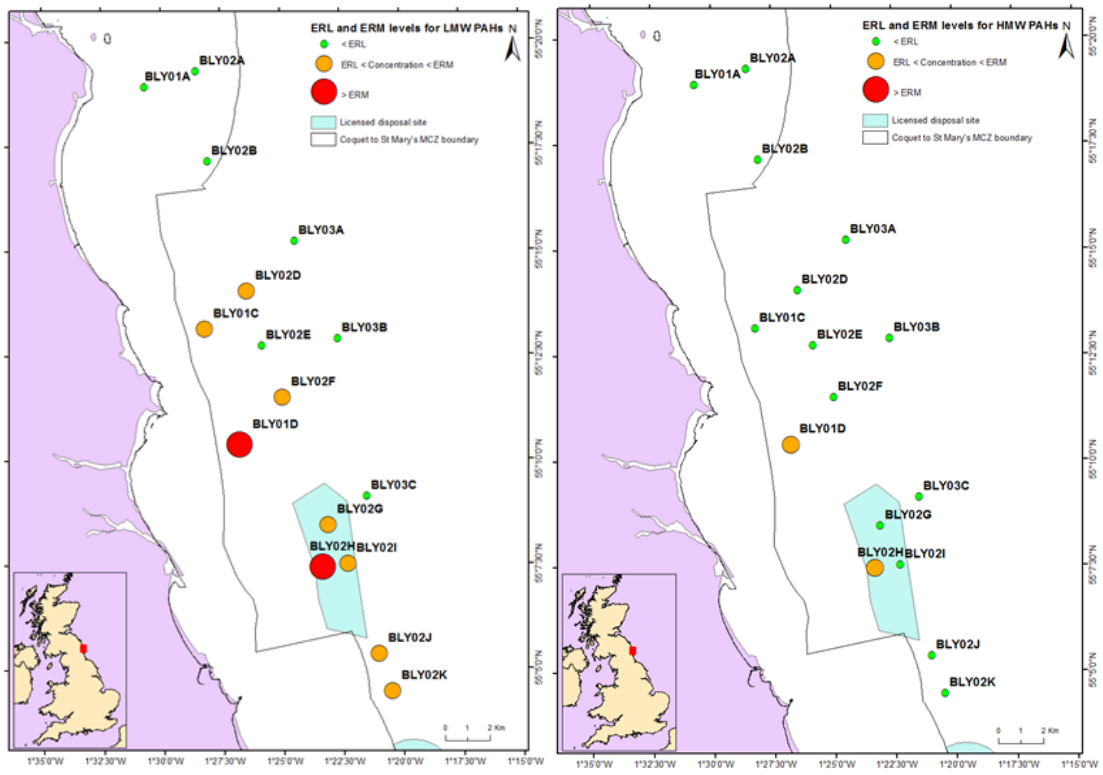

Figure A1.1.5. Map of stations showing relationships between summed PAH concentrations observed with those for Effects Range Low (ERL) and Effects Range Medium (ERM) for low molecular weight (left) and high molecular weight (right) PAHs.

Evaluation of the PAH data indicated that the source in all the sediment samples were predominantly oily, with approximately >70% of the PAH content arising from oil sources as opposed to combustion sources, with the highest percentage at 87% found at BLY02H.

1.1.3.3.2 Organohalogens

At Blyth, polychlorinated biphenyls (CBs) were detected at all stations (∑ICES7 CBs range <0.07-4.37 µg/kg dw; Figure A1.1.6). Concentrations of CBs were lowest at BLY01A at the north end of the survey area, with ∑ICES7 CBs < LOQs, low concentrations also being observed at stations to the north and east of the disposal site. Relatively higher concentrations were evident at the stations within the disposal site, inshore stations and those south of the disposal area. For example, the highest CB concentration was found at BLY01D (∑ICES7 CBs 4.37 µg/kg dw) and the second highest at BLY02J (∑ICES7 CBs 2.49 µg/kg dw) (Figure A1.1.6).

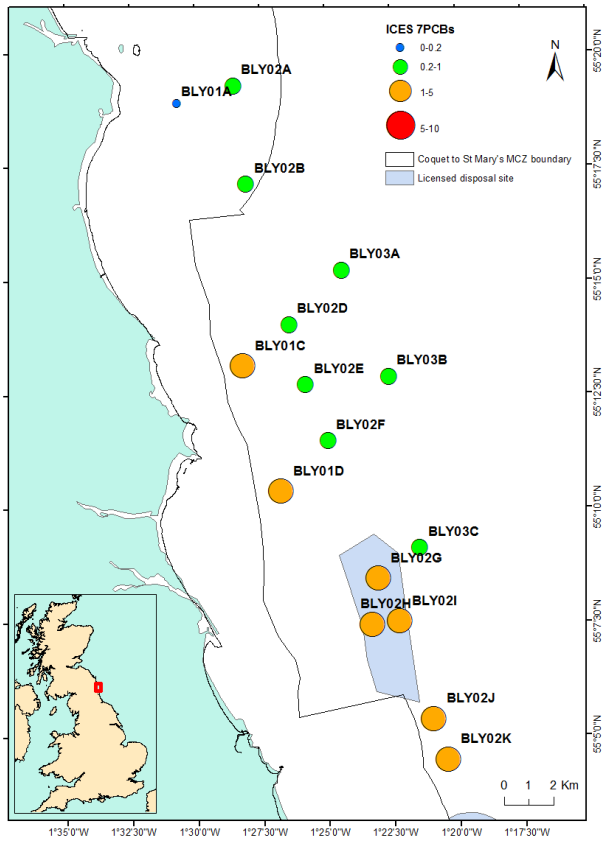

Figure A1.1.6. ∑ ICES7 CB concentrations for the Blyth Stations, 2015.

Organochlorine pesticides (OCPs) were detected at every station except BLY01A. $\sum_6$DDTs concentrations ranged from <0.14-3.82 µg/kg dw, the highest present at BLY01D (3.82 µg/kg dw) and BLY01C (2.48 µg/kg dw) (Figure A1.1.7). Dieldrin was detected at 11 out of 16 stations (range <0.05-0.584 µg/kg dw), with the highest values

correlating with those for high concentrations of OCPs, i.e. BLY01D (0.584 µg/kg dw) and BLY01C (0.497 µg/kg dw).

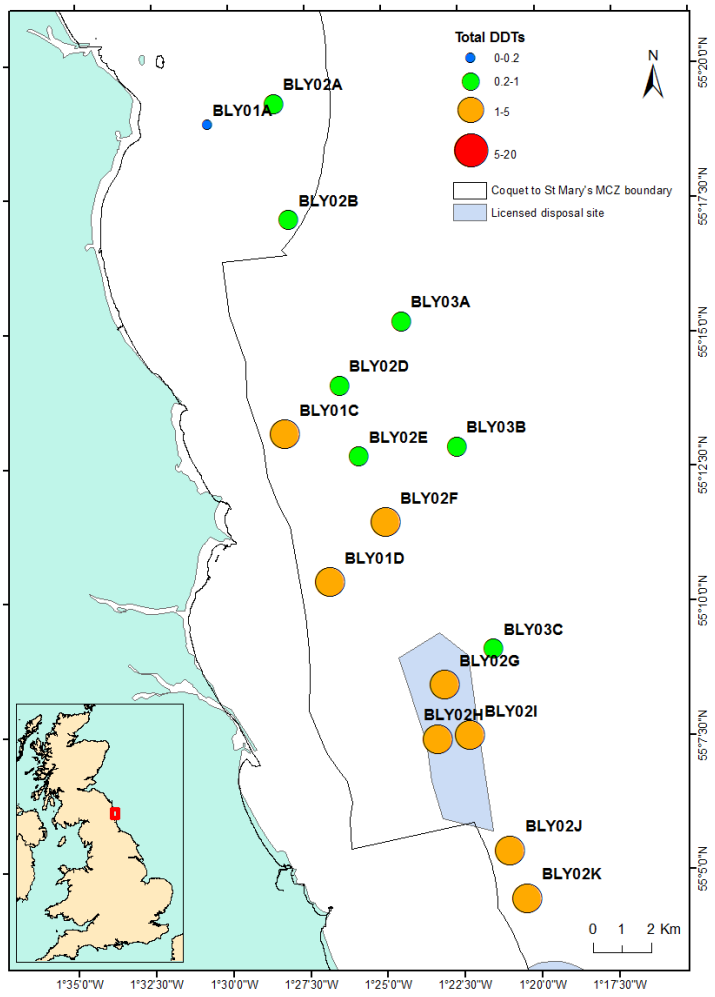

Figure A1.1.7. ∑ $_6$DDTs concentrations for the Blyth Stations, 2015.

Brominated diphenyl ethers (BDEs) were detected at all stations (∑11 BDEs range 0.0921-6.49 µg/kg dw; Figure A1.1.8). Similar to CBs and OCPs, the lowest concentration was at BLY01A within the Coquet to St. Marys MCZ. Concentrations of BDEs were relatively low to the north and east of the disposal site; displaying, therefore, similar spatial patterns as those observed for CBs. The highest BDE concentration (6.49 µg/kg dw) was found at the most southerly station (BLY02K), located close to the North Tyne disposal site. BLY01D and BLY02J were the next highest, with BDE concentrations of 3.66 and 3.10 µg/kg dw, respectively. BDE47 and BDE99 are the dominant congeners present, indicative of the pentaBDE technical mixture, but BDE183 was also detected, suggesting that the octaBDE or decaBDE technical mixture was also in use. Penta and octa technical mixtures are no longer in use, having been banned in the EU since 2004.

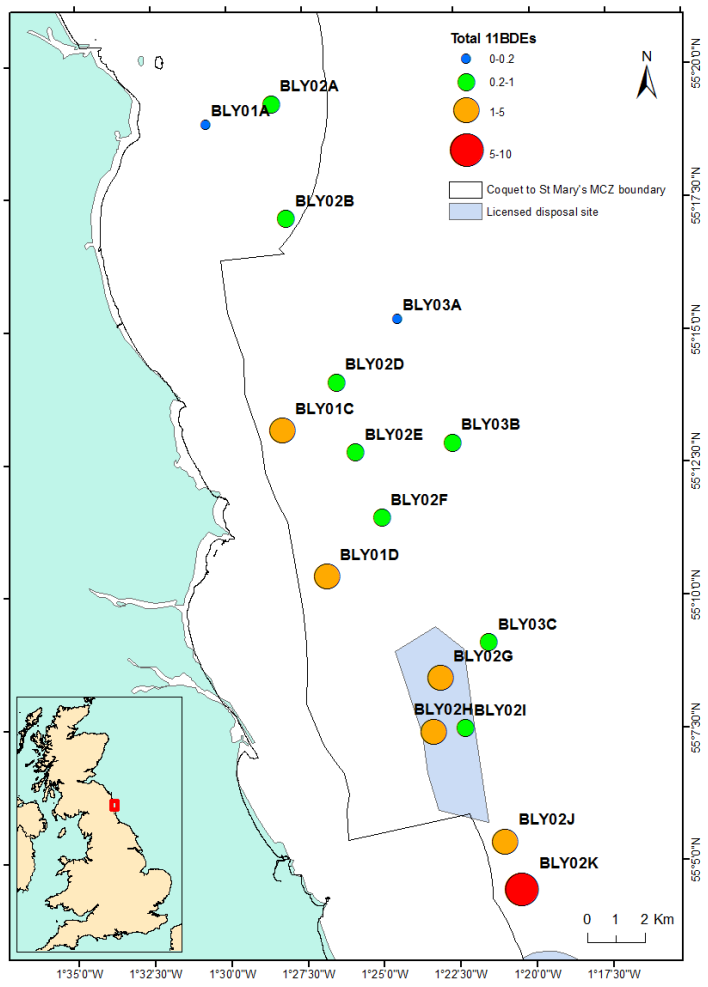

Figure A1.1.8. ∑ 11 BDEs concentrations for the Blyth Stations, 2015.

BDE209 was detected at all stations and was at higher concentrations than the other measured organohalogens (range 0.165-29.9 µg/kg dw, Figure A1.1.9). When included with the other BDEs, BDE209 usually made up >80% of the BDEs present (range 48-87%). BDE209 is indicative of the decaBDE technical mixture, which had been in use more recently than the other technical mixtures, although it's use too has now been restricted in the EU since 2008. Once again, the lowest concentration was at BLY01A in the MCZ boundary. Highest concentrations of 29.9, 26.3 and 21.6 µg/kg dw were found at BLY01C, BLY01D and BLY02J, respectively, none of which are within the disposal site (Figure A1.1.9).

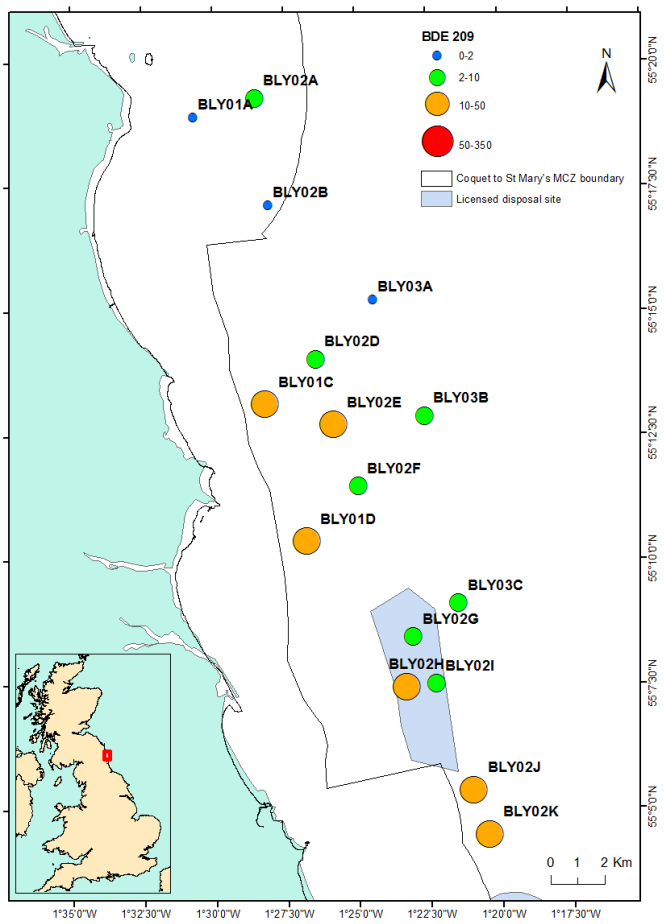

Figure A1.1.9. BDE209 concentrations for the Blyth Stations, 2015.

Concentrations of CBs and dieldrin were below Cefas action level 1 at all stations. $\sum_6$DDTs concentrations were above Cefas action level 1 at eight of the 16 stations. No Fepa action levels exist for BDEs including BDE209. According to the OSPAR guidelines, most stations had 'good' environmental status for all ICES 7 CBs and 'good' status overall. BLY02A had 'bad' environmental status for CB118 but 'good' status overall. No stations had 'bad' status overall for CBs. No OSPAR guidelines exist for BDEs at present.

There are limited data available to compare the 2015 data with those from 2005 and 2006; while a small number of stations sampled in 2015 are located close to previous stations they do not, however, exactly co-occur. Although direct comparisons must be made with some reservation, the 2015 results, in general, are similar to or lower than those previously measured, with the exception of CBs at BLY02G and BLY02H which are higher in 2015 (Tables A1.1.2-A1.1.4).

Table A1.1.2. Temporal trends (2005-2015) of ∑ICES 7 CBs concentration (in µg/kg) at Blyth in the stations sampled during 2015.

2015 Station	Previous station	∑ICES 7 CBs concentration (in µg/kg)			
		2005	2006	~	2015
BLY02F	G1		1.64		0.824
BLY02G	G4	*0.7*			1.34
BLY02H	G5	1.47	1.45		2.42
BLY02I	G12	0.81	1.33		1.18

Concentrations in italic represent estimates of concentrations for samples where all ICES 7 congener concentrations were below LODs. Limits of detection for CBs improved between 2013 and 2014, therefore values assigned to congeners below LOD are lower from 2014 onwards and, resulting in a step decrease in ∑ICES7 CBs concentration for samples with congeners below LODs.

Table A1.1.3. Temporal trends (2005-2015) of $\sum_3$DDTs concentration (in µg/kg) at Blyth in the stations sampled during 2015.

Station code	Old station code	∑ICES 7 CBs concentration (in µg/kg)				
		2005	2006	~	2015	2015[a]
BLY02F	G1		1.51		0.872	1.05
BLY02G	G4	1.47			1.22	1.44
BLY02H	G5	1.7	0.63		1.68	2.00
BLY02I	G12	1.3	0.88		1.06	1.23

a ∑6DDTs includes *o,p'*-DDE, *o,p'*-TDE and *o,p'*-DDT in addition to *p,p'*-DDE, *p,p'*-TDE and *p,p'*-DDT in ∑3DDTs

Table A1.1.4. Temporal trends (2005-2015) of ∑11 BDEs concentration (in µg/kg dw) at Blyth in the stations sampled during 2015.

Station code	Old station code	∑ICES 7 CBs concentration (in µg/kg)			
		2005	2006	~	2015
BLY02F	G1		1.55		0.668
BLY02G	G4	0.967			1.07
BLY02H	G5	2.07	1.44		1.51
BLY02I	G12	1.44	1.36		0.995

Concentrations in italic represent estimates of concentrations for samples where all 11 BDEs congener concentrations were below LODs. Limits of detection for BDEs improved between 2013 and 2014, therefore values assigned to congeners below LOD are lower 2013 onwards, resulting in a step decrease in ∑11 BDEs concentration for samples with congeners below LODs.

1.1.3.3.3 Trace metals

Sixteen stations were successfully sampled, and their sediments analysed for trace metals, at Blyth 2015. Levels of trace metals concentration enrichment for these 16 stations, based on OSPAR BAC and regional baseline values, are presented in Figure A1.1.10. The results reveal that concentrations of As and Cd show no enrichment at any station: their concentrations are, thus, lower than the OSPAR BAC and the baseline values. Copper was observed to show slight enrichment relative to both assessment methods, although no enrichment was observed at BLY01A which is located within the Coquet to St. Marys MCZ boundary.

Mercury is moderately enriched at most stations, with two stations (BLY02E and BLY02K) showing higher level of enrichment when compared with the OSPAR BAC values. The level of enrichment is much less pronounced when assessed against the baseline values where most stations are either not enriched or slightly enriched.

Levels of Cr, Ni and Zn are found to be slightly enriched using the OSPAR BAC assessment whereas no enrichment was observed for most stations when assessed against the baseline values. Pb enrichment is moderately enriched for all stations when assessed against OSPAR BAC values, enrichment is much less using the baseline value approach.

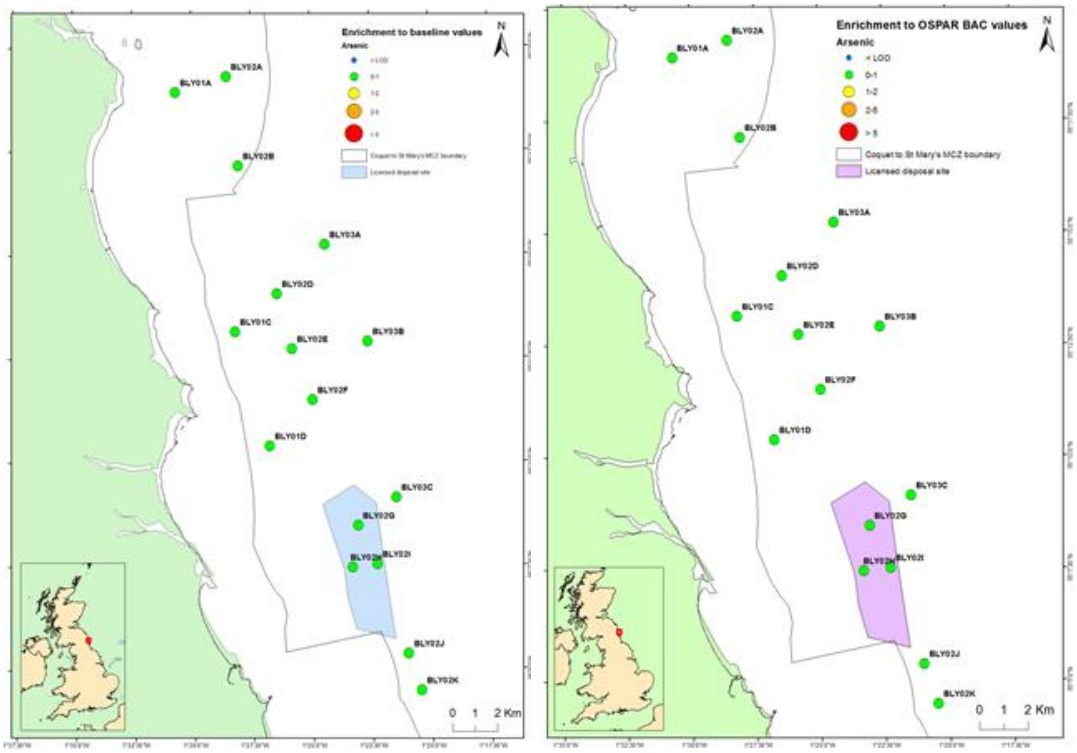

Figure A1.1.10. Map showing the enrichment of trace metals concentrations observed at Blyth, 2015, compared with regional baseline (left) and OSPAR BAC values (right).

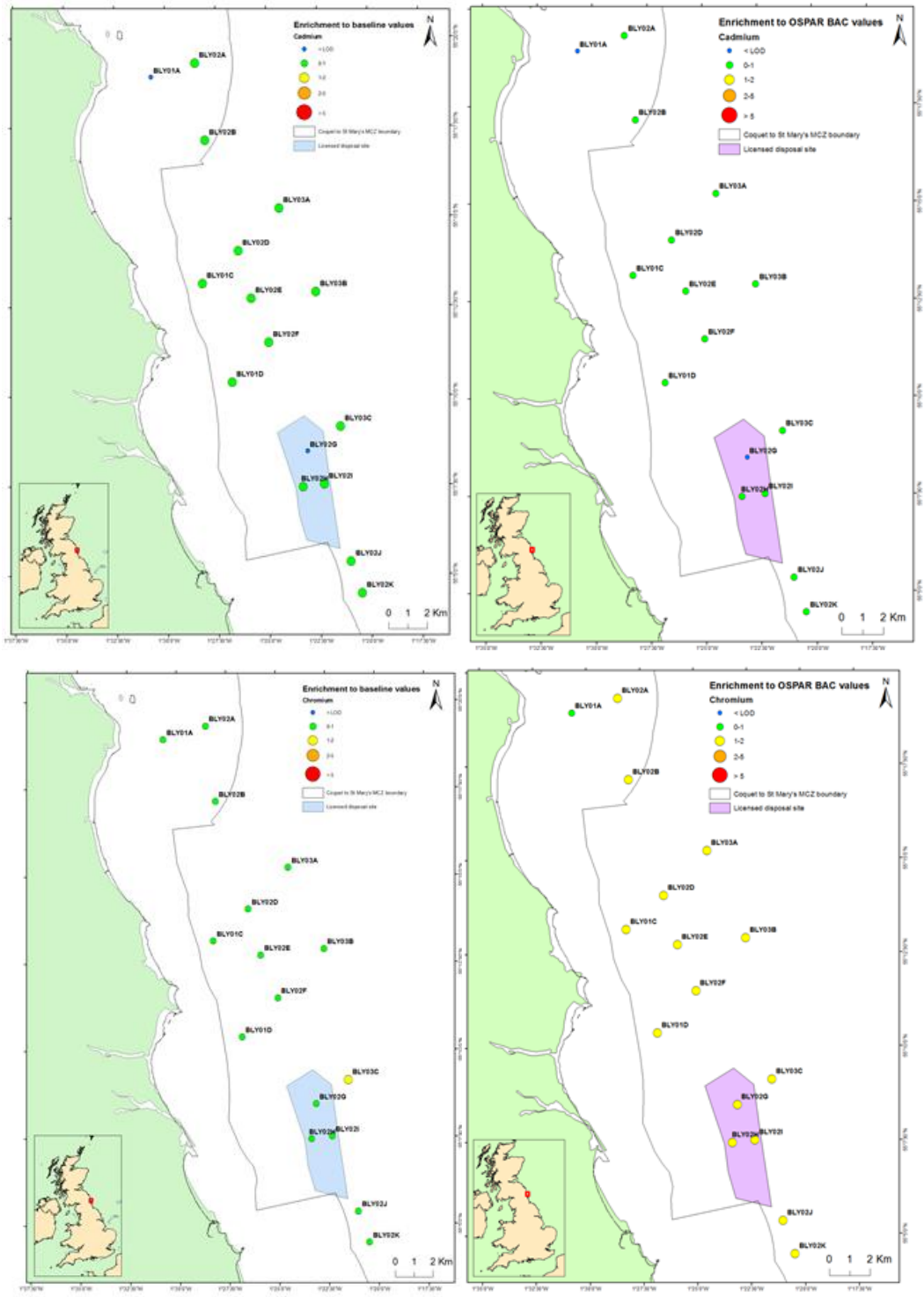

Figure A1.1.10. Continued.

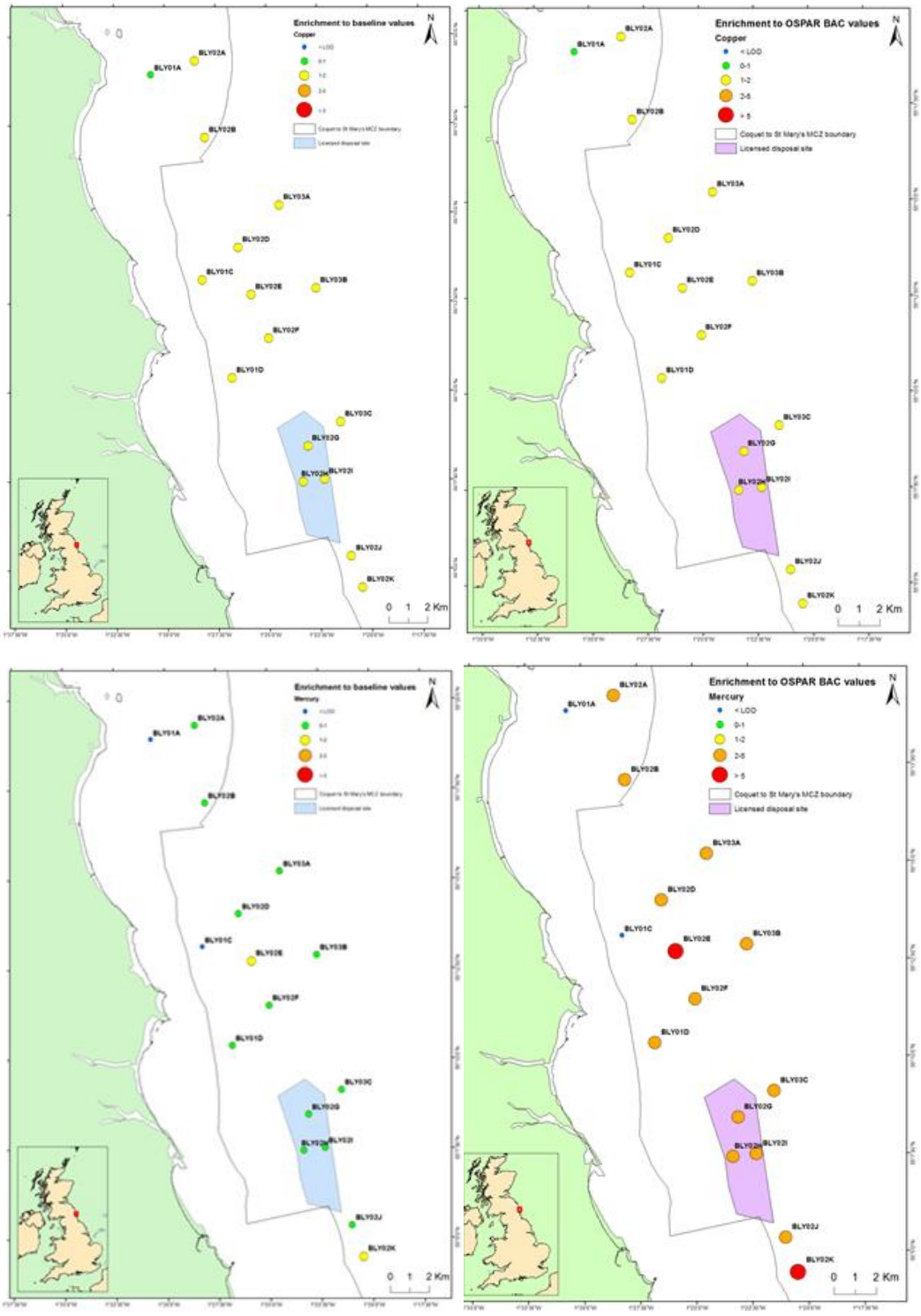

Figure A1.1.10. Continued.

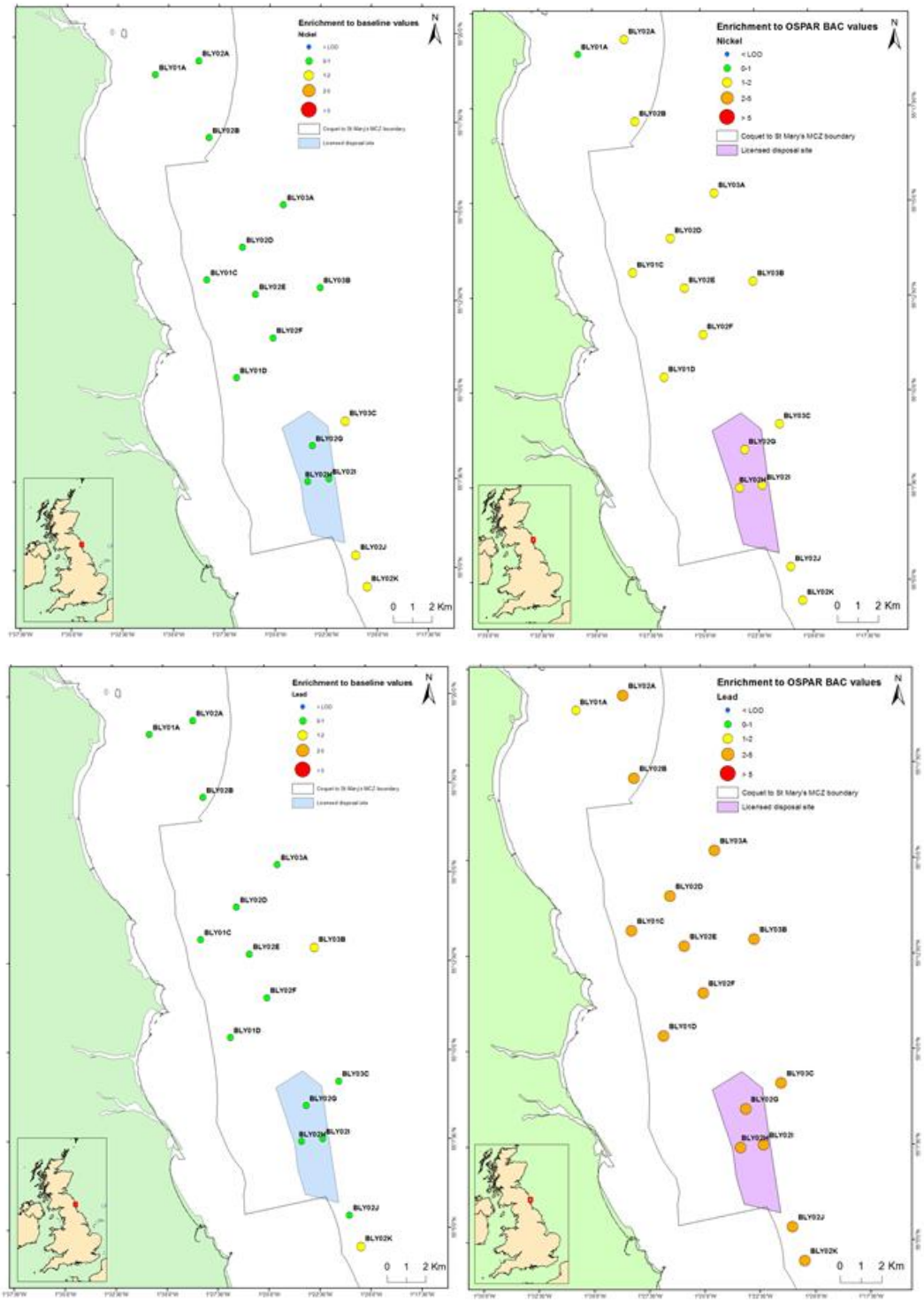

Figure A1.1.10. Continued.

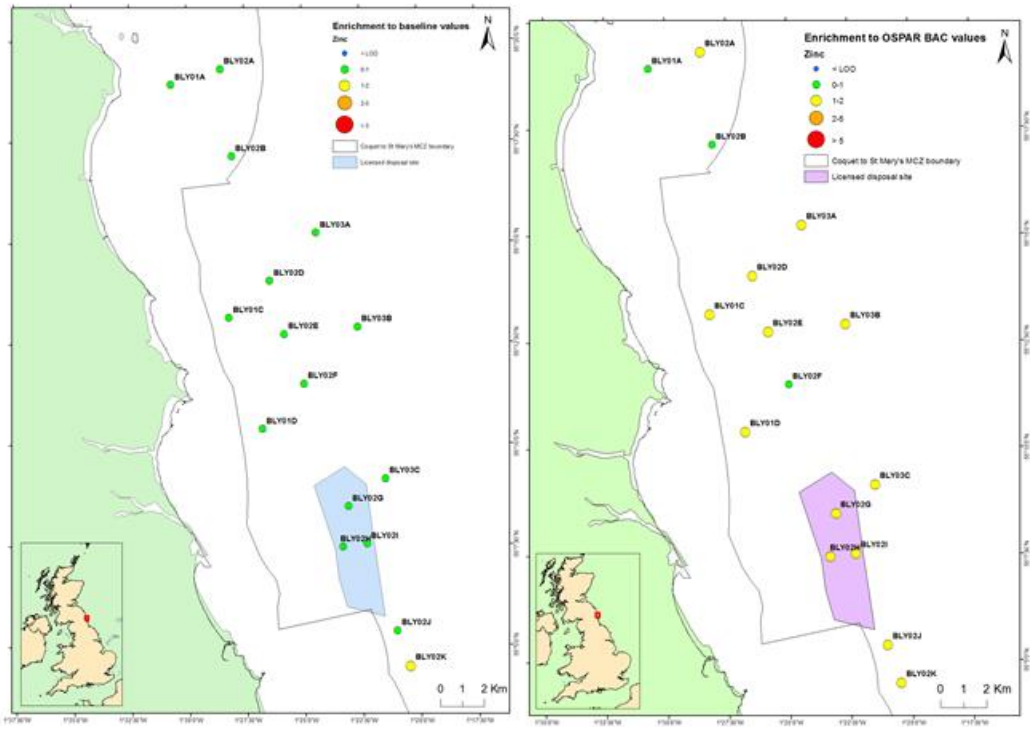

Figure A1.1.10. Continued.

1.1.3.4 Macrofaunal assemblages

Of the 45 samples taken for macrofauna at Blyth (3 reps at all 15 stations sampled), a total of 7001 macrofaunal individuals were sampled from 259 taxa. The most well represented phylum was annelids, or segmented worms (124 taxa sampled), followed by molluscs (44 taxa), crustaceans (42 taxa) and echinoderms (17 taxa). The most abundant taxon sampled was the worm *Lumbrineris cingulata* (agg.) with 1070 individuals sampled (15.3 % of total individuals), followed by the brittlestar *Amphiura filiformis* (868 individuals) and *Phoronis* (388 individuals). The former two of these taxa (*L. cingulata* (agg.) and *A. filiformis*), together with nemerteans, were also very ubiquitous, being present at all 15 stations sampled. The annelids worms *Spiophanes bombyx*, *Spiophanes kroyeri* and the mollusc *Chaetoderma nitidulum* were sampled at 14 of the 15 stations sampled.

The variability in the mean number of taxa per grab, total abundance and total biomass is displayed in Figure A1.1.11 which indicates that while these metrics of community structure spatially vary, it is difficult to discern any evident spatial pattern. One notable feature is the relatively low values of all three metrics for the assemblage of BLY1A, one of the two stations sampled within the northern section of the Coquet to St. Marys MCZ. The three stations within the disposal site have comparable numbers of taxa per grab as those ouside the site, and total abundance and wet biomass are also within the variability as those for non-disposal site assemblages. Biomass is relatively low in the three stations to the north of the disposal site, comparable with that of the assemblage at BLY3C, situated just offshore of the disposal area.

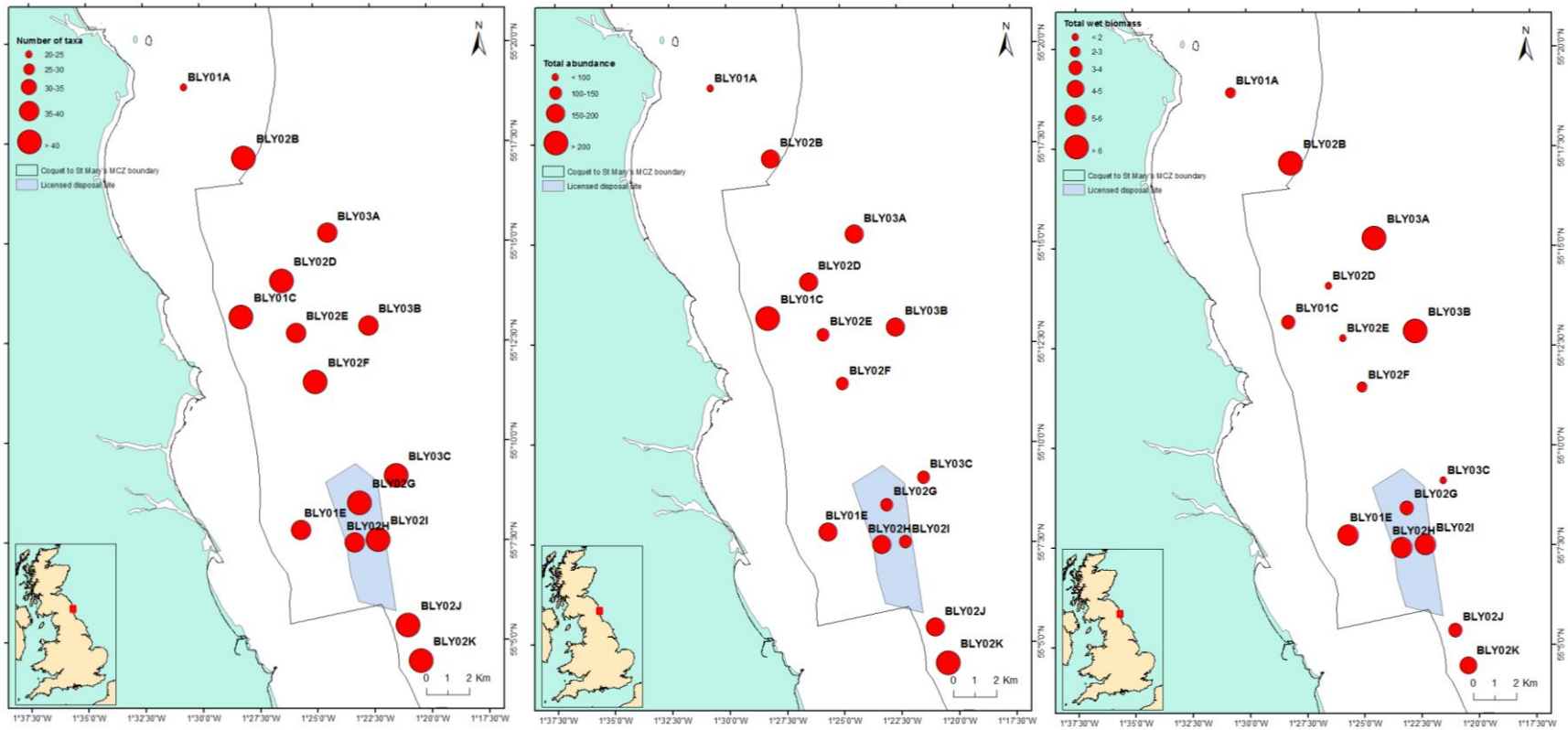

Figure A1.1.11. Mean number of taxa (left), total individuals (centre) and wet biomass (g) (right) per grab for each of the stations sampled for macrofauna at Blyth, 2015.

Multivariate numerical analyses were conducted on the taxonomic structure of the faunal data. A 2d MDS ordination plot of the square root-transformed abundance data indicated that two stations exhibited relatively different community structures: BLY1E and BLY1A. These stations are both along the more inshore transect of the survey, while the former is inshore of the disposal site, BLY1A is located within the Coquet to St. Marys MCZ, at the northern limits of the survey. These stations differ from all the other stations by their relative low abundances of some of the taxa that dominate the assemblages of the other 13 stations such as *L. cingulata* (agg.), *A. filiformis*, *Diplocirrus glaucus* and *S. bombyx* (Table A1.1.5). In contrast, the assemblage of BLY1A is characterised by relatively higher proportions of the bivalve mollusc *Spisula elliptica,* the sedentary worm *Polycirrus* and the urchin E*chinocyamus pusillus*, while that of BLY1E shows notable abundances of the Ross worm *Sabellaria spinulosa* and the barnacle *Verruca stroemia*. The fauna of the remaining stations are relatively similar, although the SIMPROF routine indicated that clusters of faunal groups were apparent (Figure A1.1.12). One evident observation is that the station replicates are, except for BLY2G, grouped within the same cluster which indicates that while some station variability exists, small-scale station replicate variability is small. When the faunal cluster groups derived by SIMPROF are mapped (Figure A1.1.13), one can see that the assemblages within the disposal site are variable, one station being comparable with assemblages further offshore, one with those further north, and one assemblage within the disposal site being structurally different from all others. The assemblages of the two stations south of the site are different from all the others surveyed.

In summary, the macrofaunal assemblage data sampled at Blyth 2015 indicate that univariate metrics of community structure, together with taxonomic composition, do not show marked impacts associated with disposal activity. Assemblages within and immediately surrounding the disposal site are neither species poor, nor comprise high abundances of taxa that are generally not found in non-disposal site assemblages. Indeed, assemblages within parts of the disposal site exhibit relatively high biomass and numbers of taxa. The station to the north of the survey area, within the Coquet to St. Marys MCZ, is relatively faunistically poor and displays a different assemblage structure from others sampled. The results of the sediment analysis indicate that this station possesses a different sediment type (poorly sorted and higher gravel component) and low concentrations of contaminants.

Table A1.1.5. Results of SIMPER routine (square root-transformed abundance data) between the assemblages of BLY1A, BLY1E and those of all the other stations grouped.

Average dissimilarity	Taxon	BLY1A	Station main group
90.7%			
	Lumbrineris cingulata (agg.)	0.7	24.9
	Amphiura filiformis	0.3	21.9
	Spisula elliptica	13.0	0.1
	Polycirrus	9.7	0.1
	Diplocirrus glaucus	0	8.3
	Echinocyamus pusillus	10.3	1.2
81.7%		BLY1E	Station main group
	Amphiura filiformis	4.0	21.9
	Sabellaria spinulosa	10.3	0
	Verruca stroemia	40.7	0
	Lumbrineris cingulata (agg.)	32.7	24.9
	Diplocirrus glaucus	0	8.3
	Spiophanes bombyx	0	7.7
93.3%		BLY1A	BLY1E
	Lumbrineris cingulata (agg.)	0.6	32.7
	Spisula elliptica	13.0	0
	Sabellaria spinulosa	0	10.3
	Echinocyamus pusillus	10.3	0
	Polycirrus	9.7	0
	Verruca stroemia	0	40.7

The main taxa responsible for the differences between assemblages are listed, together with their mean densities per grab.

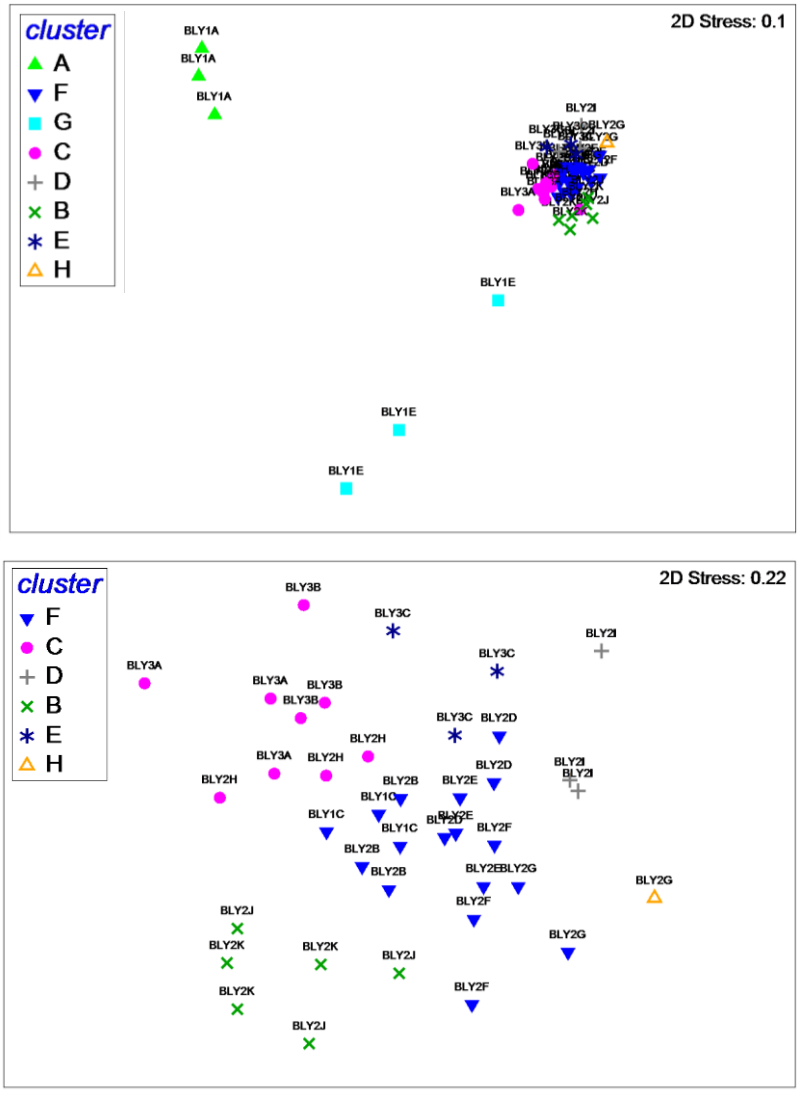

Figure A1.1.12. 2-dimensional MDS plots of macrofaunal assemblage structure of all grabs sampled at Blyth 2015. Based on Bray-Curtis similarity matrix derived from square root-transformed macrofaunal abundance data. Stations BLY1A and BLY1E have been removed in bottom plot. Stations are presented according to their faunal cluster group as attained by the SIMPROF routine.

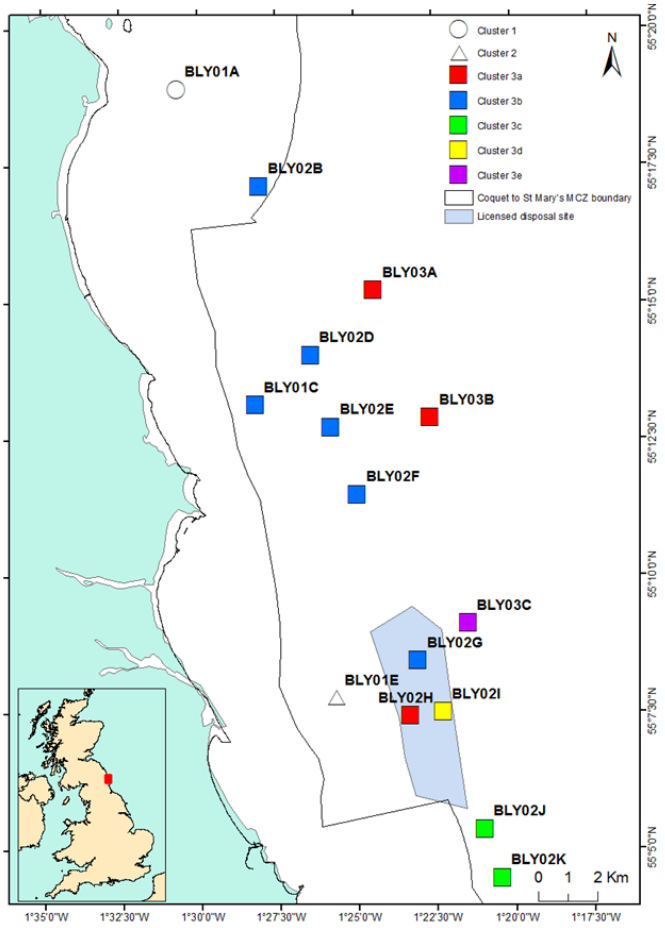

Figure A1.1.13. Map of macrofaunal assemblage cluster groups derived by SIMPROF. Based on macrofaunal assemblage data sampled during 2015 under C6794.

1.2 South Falls (TH070)

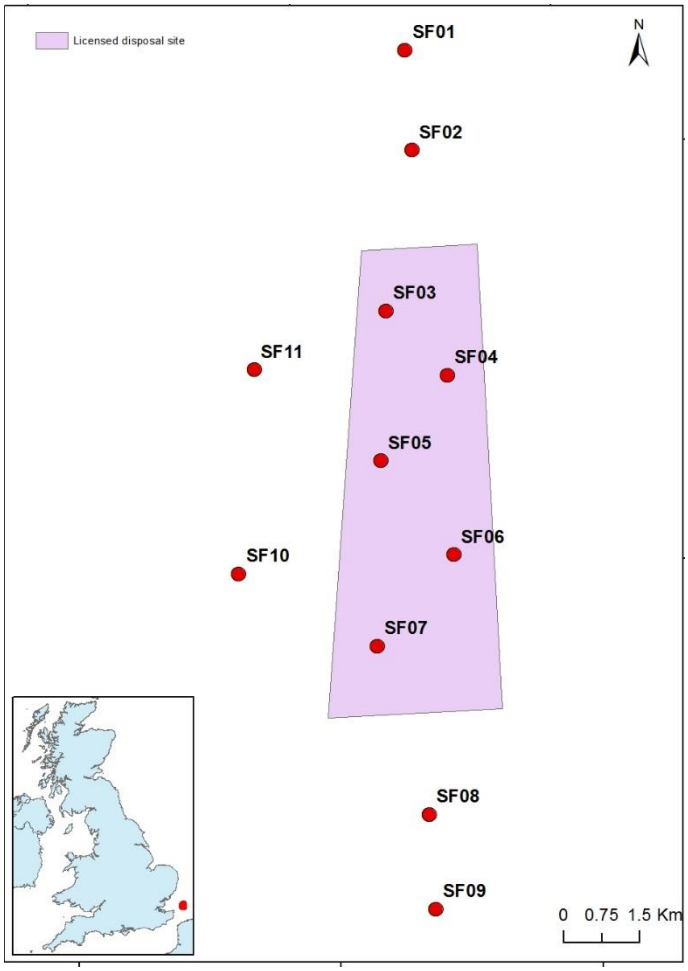

Figure A1.2.1 Location of South Falls dredged material disposal site, and the locations of stations sampled for macrofaunal assemblages sampled under C6794 during 2014.

1.2.1 Background

South Falls is a large disposal site located off the Greater Thames Estuary in the southern North Sea (Figure A1.2.1). The site receives approximately 130,000 tonnes per annum of dredged material with a maximum deposition in any one year (between 1984 and 2010) of 350,000 wet tonnes. However, in 2013, the MMO issued a marine licence to deposit a large amount of capital dredged material arising from the London Gateway Port development in the Thames Estuary. The volume of material licensed was 6.2MT comprising of London Clay (1.48MT), gravel (1.26MT) and sand (3.28MT). This volume, therefore, represented a significant increase above the normal annual average for the site. In view of this disposal, acoustic and seabed sediment physical (granulometry) and biological data were acquired under the auspices of SLAB5 during September 2013 and, subsequently, during November 2014. These data were used to assess the characteristics of the site during, and after cessation of, the large disposal campaign (Bolam et al., 2015a, 2015b). However, the macrofaunal samples collected during the 2014 survey were not processed under SLAB5 and thus, an assessment of the temporal

changes occurring within the in the vicinity of the site could not be undertaken. In 2015, these faunal samples were processed under C6794 and here the findings of this biological data are presented, enabling an assessment of the macrofaunal assemblages present in 2014 compared to those in 2013 to be made.

Prioritisation Tier 1;

- where a significant increase in the quantity of material disposed of has occurred

1.2.2 Parameters monitored:

Macrofaunal assemblages

1.2.3 Results

1.2.3.1 Macrofaunal assemblages

A total of 227 taxa (including colonial epifauna) were recorded from 63 grab samples taken at South Falls during the 2013 and 2014 surveys. Triplicate grabs were collected at all stations with the exception of SF08 (1 replicate in 2013) and SF09 (2 replicates in 2013). 180 free living macrofaunal invertebrate taxa were identified, 79 % to species, with the most prevalent species including the polychaetes *Aonides paucibranchiata,* present in 34 of the 63 samples; *Nephtys cirrosa*, present in 28 samples; and NEMERTEA, present in 25 samples. 47 taxonomic groups of colonial epifauna were identified, 64 % to species, with the most prevalent species including the Bryozoans *Conopeum reticulum*, present in 19 of the 63 samples; GYMNOLAEMATA, present in 18 samples; and *Aspidelectra melolontha*, present in 14 samples.

Segmented worms (ANNELIDA) were typically the most abundant macroinvertebrate group present at South Falls, with stations within the disposal site typically having a greater abundance than those in the Reference stations (Figure A1.2.2). Sea mats (or BRYOZOANs) represented the most abundant colonial taxa with more representation within disposal site than in Reference stations (**Error! Reference source not found.**A1.2.2). Both of these dominant taxa increased within the disposal site between the 2013 and 2014 surveys while decreasing within the Reference stations.

The number of solitary taxa (S), total abundance (N) and total biomass (blotted wet weight g) did not significantly differ between Disposal and Reference stations in 2013, however, all metrics were significantly higher in the Disposal stations in 2014 (Table A1.2.1, Table A1.2.2). The total number of colonial taxa (Sc) was significantly higher in the Disposal stations in 2014 ($W = 229$, $p<0.001$).

Table A1.2.1 Results of the non-parametric Wilcox-Mann-Whitney test results (W statistic and probability value) showing significant differences (in bold) between Reference and Disposal stations in the metrics assessed following the 2013 and 2014 surveys.

Comparison of Disposal and Reference stations	S		N		Biomass	
	W	p	W	p	W	p
2013	146	0.17	144	0.20	156	0.07
2014	259	**<0.0001**	252	**<0.0001**	219	**<0.01**

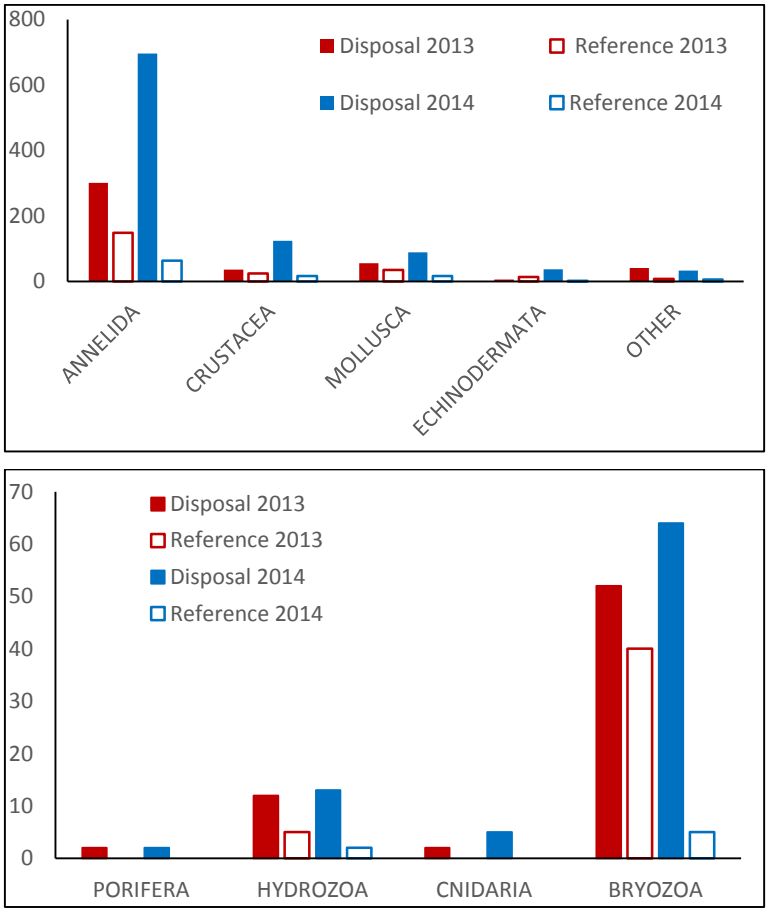

Figure A1.2.2 Histogram showing the total number of individuals (top) and occurrence (out of 63 grabs) of colonial taxa (bottom) split into major groups present within Disposal and Reference stations.

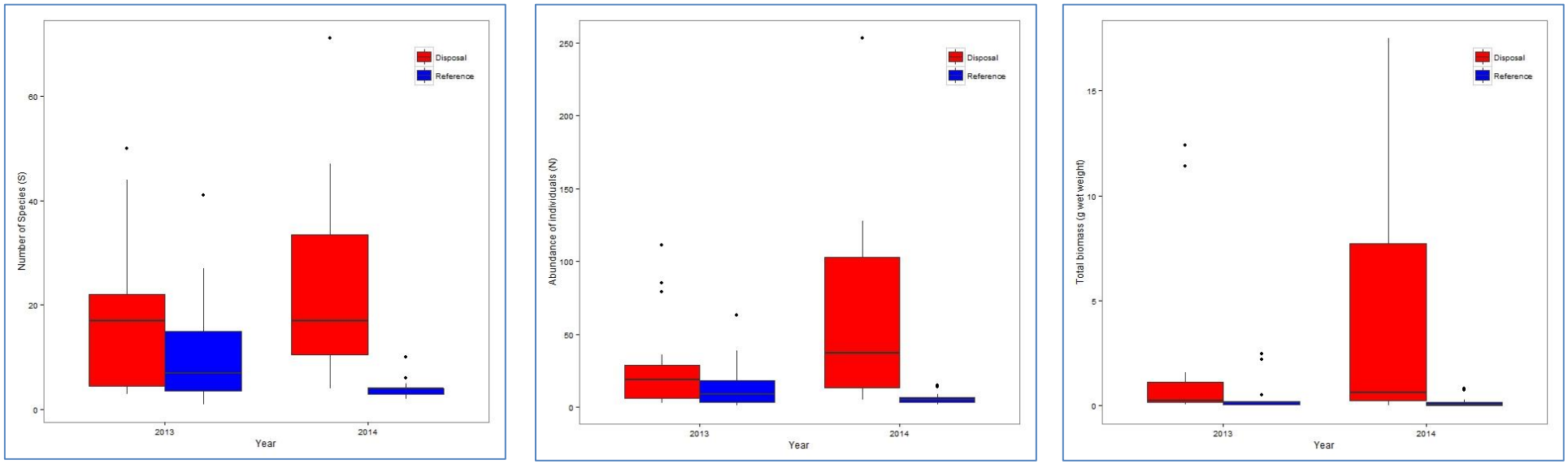

Figure A1.2.3. Box-whisker plots showing the number of taxa (S), left, total number of individuals (N), centre, and total biomass (blotted wet weight g), right, in disposal (red) and reference (blue) stations for the 2013 and 2014 surveys.

Table A1.2.2. Summary statistics showing the total number of solitary taxa (S), total number of colonial taxa (Sc), abundance of individuals (N) and biomass (blotted wet weight g) for disposal and reference stations surveyed in 2013 and 2014.

		S	Sc	N	Biomass
2013 Disposal	Range	2 – 40	0 -11	3 - 111	0.0385 – 43.8694
	Median	11	4	19	0.2639
	Mean	14	4	29	4.8402
	St. Dev.	12.19	3.83	34.09	11.53
	Variance	148.70	14.70	1162.10	132.98
2013 Reference	Range	1 - 26	0 – 15	1 - 63	0.0025 – 2.453
	Median	7	1	9	0.17380
	Mean	8	3	15	0.43681
	St. Dev.	7.37	4.41	17.81	0.78
	Variance	54.40	19.43	317.26	0.61
2014 Disposal	Range	4 - 58	0 – 13	5 - 253	0.0174 – 17.4799
	Median	12	7	37	0.6464
	Mean	19	6	65	4.2487
	St. Dev.	15.39	4.35	68.73	6.21
	Variance	236.81	18.95	4723.94	38.58
2014 Reference	Range	2 - 9	0 – 1	2 - 15	0.0007 – 0.8300
	Median	4	0	5	0.05500
	Mean	4	0	6	0.16177
	St. Dev.	1.64	0.50	3.71	0.24
	Variance	2.68	0.25	13.75	0.06

One replicate from station SF01 (2013) consisted of only 2 individuals and its assemblage was, accordingly, very dissimilar to those of the other stations (Figure A1.2.4A1.2.4). The data from this sample were not included in the ordination presented in the lower plot in **Error! Reference source not found.**A1.2.4, however, they were used in the calculation of multivariate test statistics. Pairwise comparisons of the Disposal and Reference stations implied a small separation of benthic communities between Disposal and Reference stations in 2014 (R_{2014} = 0.26, p<0.001) but not in 2013 (R_{2013} = 0.03, p=0.20); this observation is supported by the MDS plot (Figure A1.2.4). The results in Table A1.2.2 infer that this disposal-reference site difference in community structure in 2014 was also accompanied by higher numbers of taxa and abundances within the disposal site.

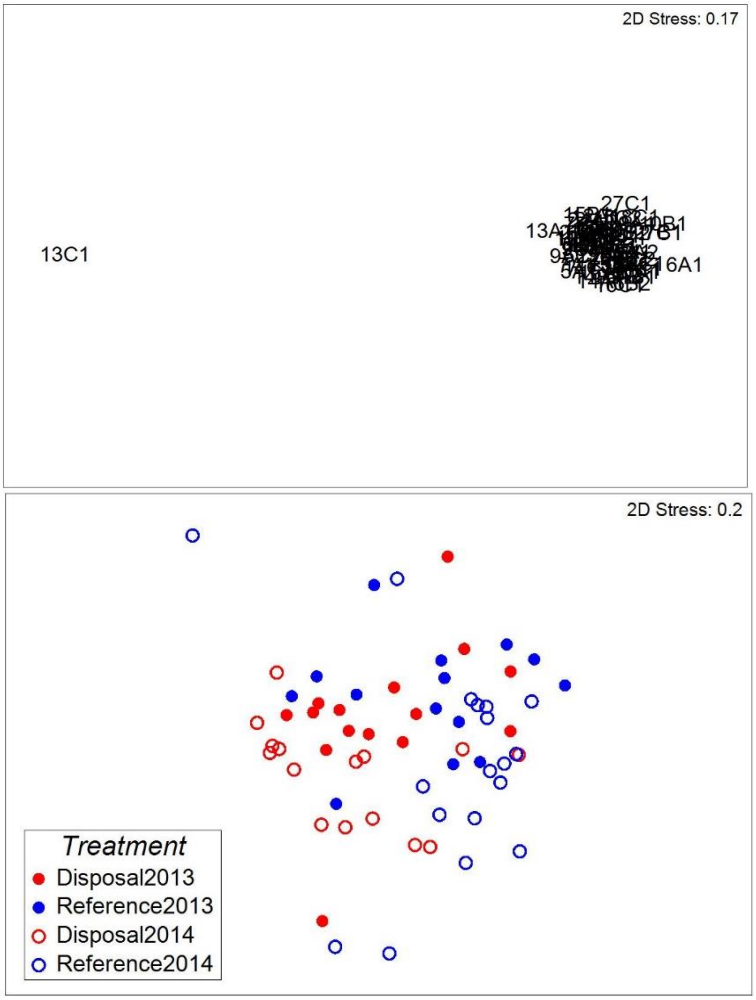

Figure A1.2.4. Non-parametric Multidimensional Scaling (nMDS) ordination plot of the square root-transformed abundance macrofaunal data (solitary macroinvertebrates) showing the outlier stations (top) and a plot showing a subset of (excluding the outlier stations) showing a small separation of benthic communities between disposal (filled) and reference (open) stations in 2014 (blue).

1.3 Nab Tower (WI060)

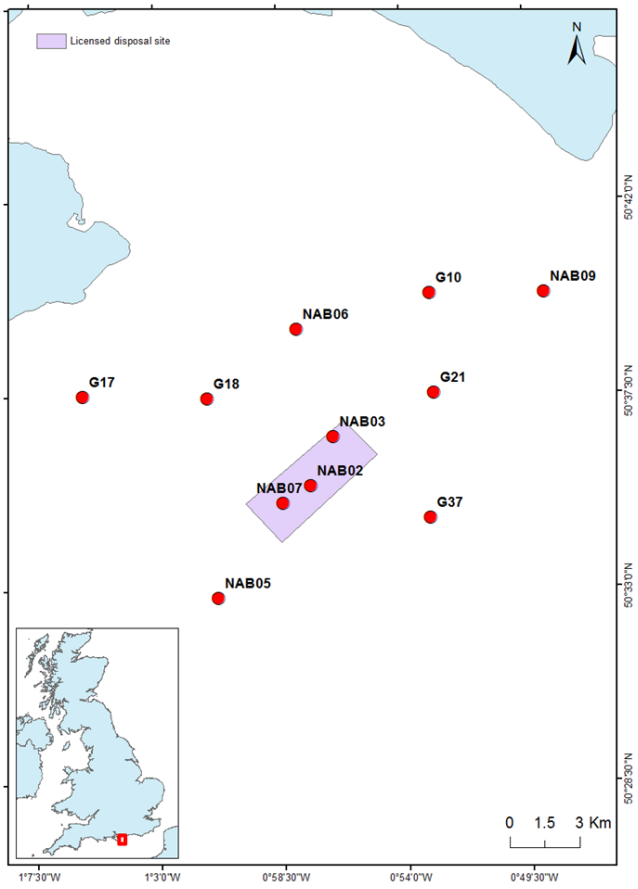

Figure A1.3.1. Location of Nab Tower dredged material disposal site, and the stations sampled for macrofaunal assemblages under C6794 during 2014.

1.3.1 Background

Nab Tower is a well-used disposal site, 30-40 m in depth and approximately 13 km southwest of Bembridge, Isle of Wight (Figure A1.3.1). The site is the main disposal location for both maintenance and capital material from ports, harbours, berths and navigational channels in Southampton, Portsmouth and the Isle of Wight. Between 1990 and 2010, over 28 million tonnes of dredged material were disposed to the site; although the site normally receives 500,000 to 750,000 tonnes per annum, peaks over 1 million tonnes in 1999, 2001 and 2004 were disposed. The largest capital campaigns were, however, in 1995 and 1996 when 5.3 million and 6.3 million tonnes (respectively) were disposed.

In recent years, there have been a number of applications for large amounts of material to be disposed to Nab Tower from the Cowes Outer Harbour Development Project, the Southampton Approach Channel Deepening project and a deepening project for Portsmouth HMNB. In view of such increased attention regarding this site, recent monitoring under the auspices of SLAB5 at Nab Tower during 2011 (Bolam et al., 2012) focused on the acquisition of multibeam acoustic bathymetry and backscatter data, and a follow-up survey during 2014 provided more contemporary data to allow an evaluation of any physical changes to the nature of the seabed

since 2011 to be made (Bolam et al., 2015b). The results allowed an assessment of the relative amounts of deposited material on the seabed within the disposal site boundary (Figure A1.3.2). However, macrofaunal samples taken under SLAB5 at that time remained unprocessed. In 2015, under the auspices of C674, the macrofaunal samples from the 2014 survey were processed, the data being used to make an assessment of the spatial variability of the macrofauna within and outside the disposal site.

Prioritisation Tier 1;

- where a significant increase in the quantity of material disposed of has occurred
- where specific concerns have been raised

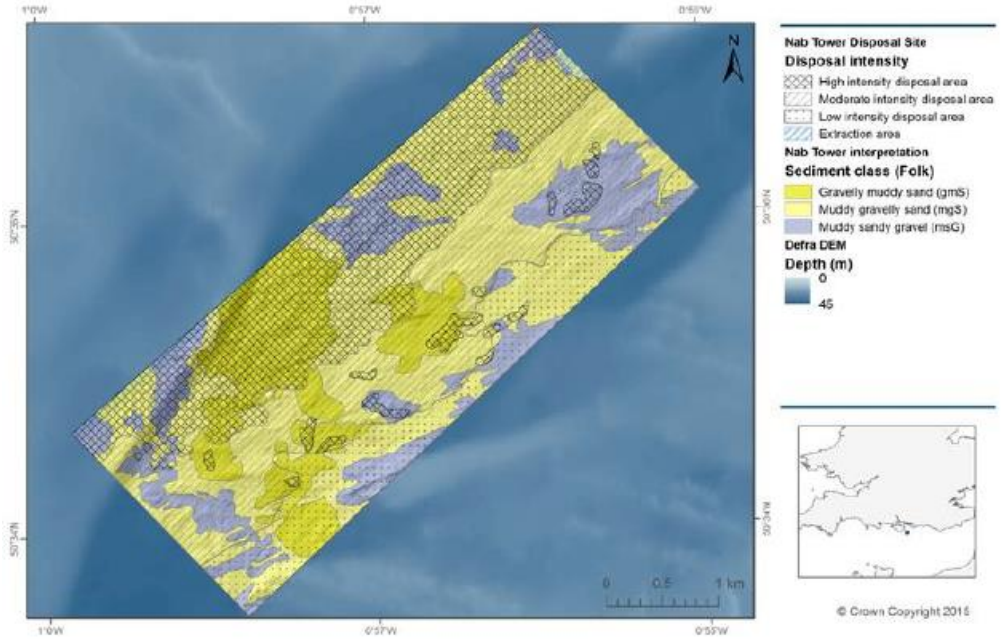

Figure A1.3.2. Relative intensity of disposed dredged material on the seabed at Nab Tower, November 2014. Data collected under the auspices of SLAB5 (Bolam et al., 2015b).

1.3.2 Parameters monitored

Macrofaunal assemblages

1.3.3 Results

1.3.3.1 Macrofaunal assemblages

Of the 29 samples taken for macrofauna at the 11 stations sampled at Nab Tower (Figure A1.3.3), a total of 2008 macrofaunal individuals were sampled from 207 taxa (including the colonials). The most well-represented phylum was annelids (109 taxa sampled), followed by crustaceans (32 taxa), molluscs (18 taxa) and bryozoans (17 taxa). The most abundant taxa sampled were the mobile amphipod crustacean *Ampelisca spinipes* (175 individuals), the bivalve mollusc *Nucula nucleus* (139 sampled) and the tube-dwelling worm *Lanice conchilega* (129 sampled). *Lumbrineris cingulata* (agg.) was the most ubiquitous taxa across the 11 stations sampled, being

present in grabs at all stations, followed by *Notomastus* (sampled at 10 stations), *Pholoe balthica* and nemerteans (both sampled at eight of the 11 stations).

The variability in the mean number of taxa (including colonials) per grab, total abundance and total biomass is displayed in Figure A1.3.3. These figures indicate that the assemblages within the disposal site, together with those of the two stations sampled further offshore of the disposal site (NAB05, G37), are relatively taxon-poor and possess lower densities and biomass compared to those in more inshore, shallower areas to the north of the disposal site.

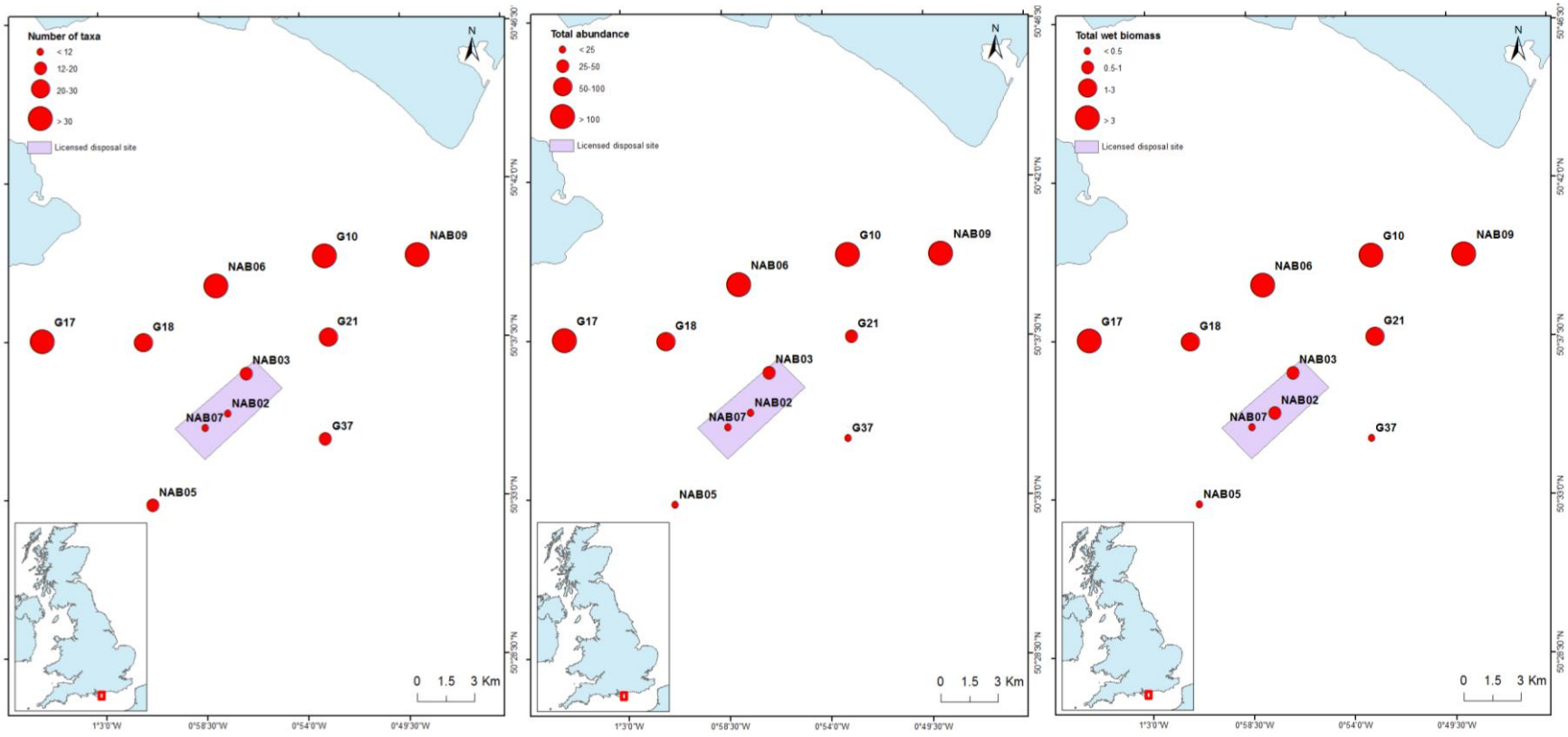

Figure A1.3.3. Mean number of taxa (left), total individuals (centre) and wet biomass (g) (right) per grab for each of the stations sampled for macrofauna at Nab Tower, 2014.

Multivariate numerical analyses were conducted on the taxonomic structure of the faunal data. To aid interpretation of these data, the stations were factored according to their location with respect to the disposal and subsequent transport of the disposed material. The results of sediment transport modelling (Cefas, unpubl. data) was used to predict the fate of material disposed at Nab Tower (generally along a southwest-northeast trajectory) and this was the basis for allocating stations into 'disposal', 'near field', 'far field' and 'reference' regimes. A 2d MDS ordination plot of the square root-transformed abundance data indicated that there was a discernible relationship between the structure of the macrofaunal assemblages and their sampling location with respect to the disposal regime (Figure A1.3.4). For example, the stations within the disposal site are located on the left hand side of the MDS plot, the two stations representing the near field are located together, and the location of the three replicates of the far field is positioned between the near field and the reference stations. The reference station located on the southeast of the disposal site, G37 (all the others are located northwest of the disposal site) does, however, display a different macrofaunal structure relative to the other reference stations. In general, replicate variability at the stations is comparatively small compared to between station variability and certainly smaller than between regime differences.

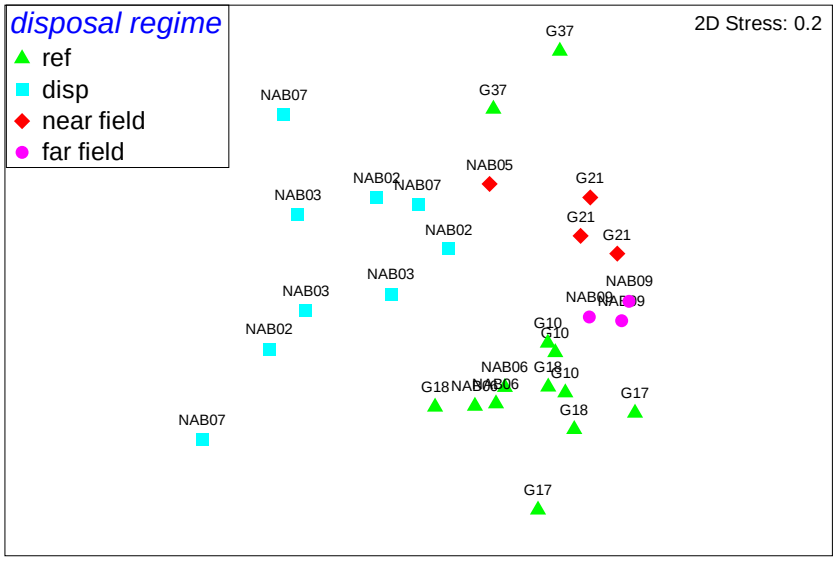

Figure A1.3.4. 2-d non-metric multidimensional scaling (nMDS) ordination plot of the macrofaunal assemblages of the stations sampled at Nab Tower, 2014. Raw species abundance data were square root-transformed prior to the production of a Bray-Curtis similarity matrix. Stations are labelled according to their disposal regime.

A SIMPER routine was conducted on the square root-transformed abundance data based on the by the SIMPROF routine identified four faunal cluster groups as being significantly different from each other when the data for each station were averaged across the replicates. These faunal clusters supported the notion of the relationship between assemblage structure and location relative to the disposal

regime (Figure A1.3.4). Cluster group A comprised two of the three near field stations, Cluster b was an outlier represented by a single reference station, cluster C comprised three reference stations while the largest cluster group, D, contained the three disposal site stations, together with the reference station G37 and one of the near field stations (Figure A1.3.5). Table A1.3.1 presents the taxa representing each of these faunal cluster groups. Assemblages of the stations within, and offshore from, the disposal site are more dominated by *Lumbrineris cingulata* (agg.), nemerteans and the worm *Notomastus*, those north of the site are more dominated by the tube-building worm *Lanice conchilega* and the bivalve mollusc *Nucleus nucleus* (although the numerical dominant here is the amphipod *Ampelisca spinipes*, this species is found across all station), while the two stations along the near and far field to the northeast of the site are more characterised by sedentary worms *Mediomastus fragilis* and *L. cingulata* (agg.) (Figure A1.3.6).

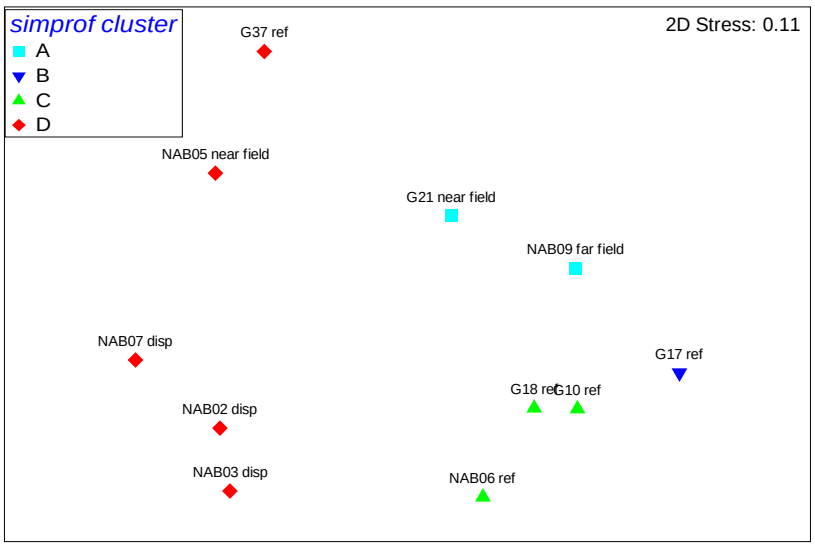

Figure A1.3.5. 2-d non-metric multidimensional scaling (nMDS) ordination plot of the macrofaunal assemblages (replicates averaged per station) of the stations sampled at Nab Tower, 2014. Raw species abundance data were square-root-transformed prior to the production of a Bray-Curtis similarity matrix. Stations are labelled according to their faunal cluster group.

Table A1.3.1. Results of SIMPER routine (square root-transformed abundance data) between the assemblages of the four faunal cluster groups identified by the SIMPROF routine.

Faunal cluster	Taxon	Abundance per grab
A	*Mediomastus fragilis*	6.0
	Lumbrineris cingulata (agg.)	7.5
	Glycera lapidum	2.5
	Leiochone	2.5
	NEMATODA	2.3
C	*Lanice conchilega*	13.3
	Nucula nucleus	7.3
	Sthenelais boa	2.6
	Spirobranchus lamarcki	4.8
	Ampelisca spinipes	19.2
D	*Lumbrineris cingulata* (agg.)	1.3
	NEMERTEA	0.7
	Notomastus	1.1
	Aonides paucibranchiata	0.5
	Spiophanes bombyx	3.0

The five main taxa responsible characterising each of the assemblages are listed, together with their mean densities per grab. Faunal cluster B comprised a single station so could not impart to the SIMPER routine.

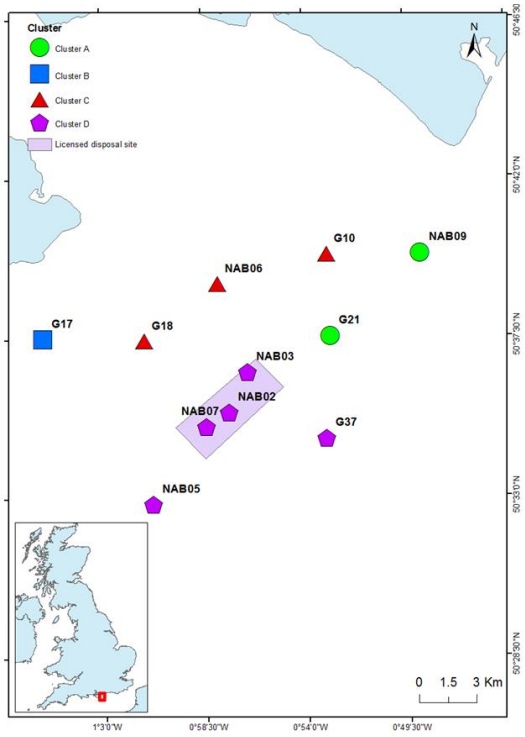

Figure A1.3.6. Locations of the macrofaunal cluster assemblages derived by the SIMPROF routine for the Nab Tower survey data, 2014.

1.4 Site Y (IS150)

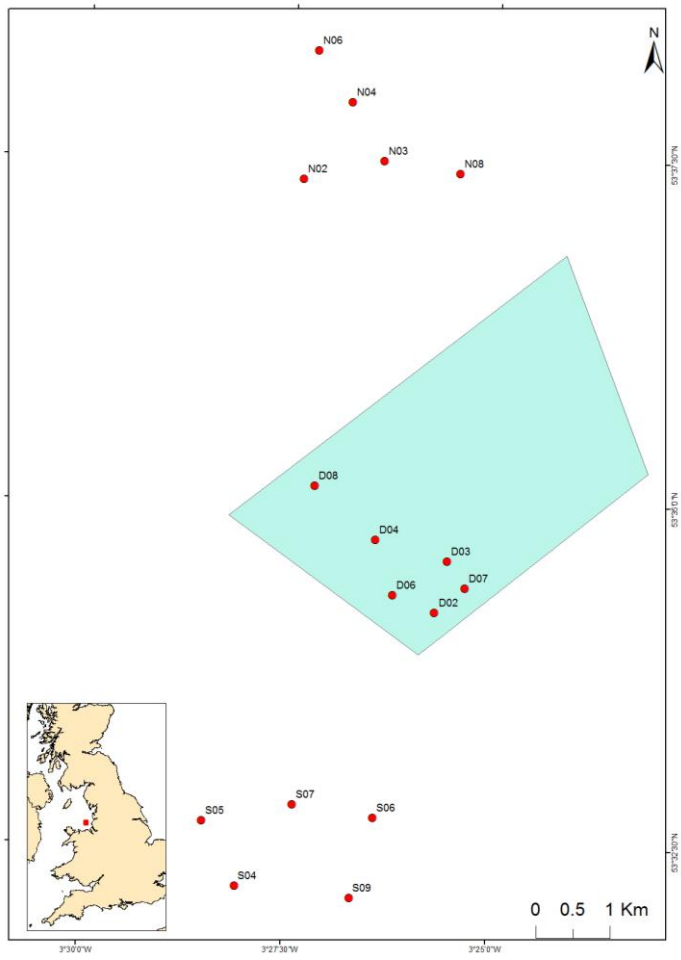

Figure A1.4.1. Location of Site Y dredged material disposal site, Liverpool Bay, and the locations of the stations sampled under C6794 during 2015.

1.4.1 Background

Site Y and Site Z (see Section 1.5) are situated within Liverpool Bay on the west coast of the UK (Figure A1.4.1). Both sites are licensed to receive dredged material resulting from dredging of the maintenance docks and navigation channels, and that of capital projects, in the Mersey Channel.

Site Y (IS150), the larger of the two sites by area, has a seabed sloping to the southwestern edge of the site, with large sand waves to the western side of the site orientated north to south (Bolam et al., 2015a, 2015b). The average water depth for the disposal site is 20m below Chart Datum; while the northeastern section shallows to approximately 16 m, deeper waters (27 m below Chart Datum) can be found in the western sector. The sediments within this site are generally moderately well-sorted, slightly gravelly sand (Bolam et al., 2015a, 2015b). Approximately 1.8 MT (wet weight) of capital dredged material, derived from the construction of the new deep water container terminal, Liverpool II, was disposed to Site Y during 2013. To prevent shoaling at Site Y, the stiff, consolidated material was licensed to be disposed of in a grid fashion, with the subsequent finer maintenance dredged material

to be disposed as evenly as possible over the disposal site. Monitoring at Site Y conducted under the auspices of SLAB5 focussed on the acquisition of acoustic and sediment granulometric data to determine the location of the disposed material on the bed and conformity to licence conditions (Bolam et al., 2015a). The data obtained showed that each deposit of capital material resulted in an acoustically-identifiable mound on the seabed (Figure A1.4.2); this, in turn, allowed an assessment of conformity with licence conditions. This monitoring was followed the subsequent year by a second acoustic survey to ascertain the fate of finer material disposed of to the deeper regions of the site (Bolam et al., 2015b).

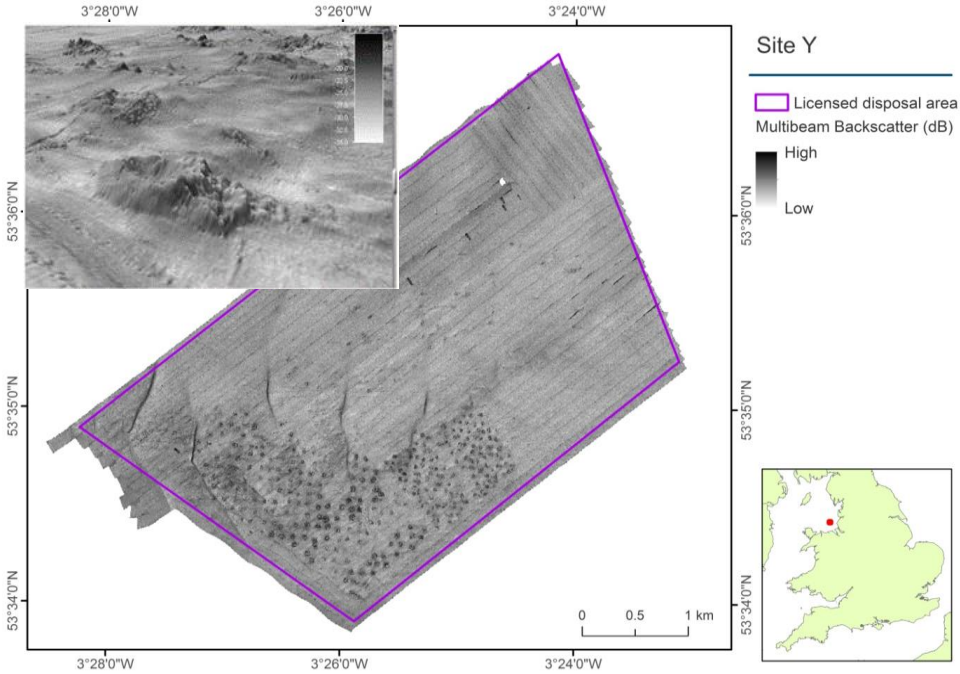

Figure A1.4.2. Multibeam backscatter data for the Site Y disposal site, 2013. The small, dark blotches in the southern section of the site represent the disposal mounds associated with the capital material (Bolam et al., 2015a). The inset figure represents disposal material 3d profile and backscatter draped over bathymetry (vertical exaggeration 0.5 m applied to the drape).

Following this capital disposal operation, the project at Liverpool II required a maintenance dredging campaign. While the geological, capital material posed no contamination risk, extensive sampling of the sediments to be subsequently dredged in Liverpool docks demonstrated that some of the material was unacceptable for marine disposal due to elevated levels of certain contaminants (e.g., Hg and PAHs). While management practices were implemented to prevent the more contaminated material going to sea (a proportion of the material was destined for land-based disposal) and ensure that material disposed to Site Y possessed contaminants below Cefas action level 2, there remained the potential for increased contaminant concentrations being present at this disposal site.

Monitoring conducted under C6794 during 2015 at Site Y primarily focussed on the acquisition of data to assess the spatial variability in sediment contaminant concentrations within the Site Y region. This was to provide reassurance that measures to ensure that the more contaminated material was not placed to sea were successful and that the concentrations in the region remain acceptable. Sampling of the macrofauna was additionally undertaken during the survey to allow a contemporary assessment of the biological assemblages of the area following the placement of the large amounts of both the recently deposited capital, and subsequent maintenance, dredged material. This site has not been the subject of neither sediment contaminant nor macrofaunal assemblage data acquisition in recent years.

Priorisation Tier 1;

- where a significant increase in the quantity of material disposed of has occurred
- where there is the potential for the occurrence of elevated contaminant concentrations (between Cefas action levels of 1 and 2 in proposed dredge sediments) arising from historical or current activities at source (especially heavily urbanised/industrialised estuaries)

1.4.2 Parameters monitored: Sediment particle size
Sediment organic carbon
Sediment contaminants (PAHs, organohalogens, trace metals)
Macrofaunal assemblages

1.4.3 Results

1.4.3.1 Sediment particle size

Site Y sediments are predominantly poorly-sorted, slightly gravelly muddy sand or slightly gravelly sands (Table A1.4.1). Slightly higher gravel contents (>5%) are found at two stations of the south reference and one station within the disposal site (Table A1.4.1, Figure A1.4.3). While the silt/clay content of the sediments of the two reference areas are generally comparable, those of the disposal site are elevated, especially in the stations in the south of the disposal site where finer, maintenance dredged material was placed the previous year (Bolam et al., 2015b).

Table A1.4.1 Average sediment descriptions and statistics for stations at Site Y.

Sample name	Sample Type	Sediment description
D02	Bimodal, Very Poorly Sorted	Slightly Gravelly Muddy Sand
D03	Unimodal, Poorly Sorted	Slightly Gravelly Muddy Sand
D04	Unimodal, Poorly Sorted	Slightly Gravelly Muddy Sand
D06	Unimodal, Very Poorly Sorted	Slightly Gravelly Muddy Sand
D07	Trimodal, Very Poorly Sorted	Gravelly Muddy Sand
D08	Unimodal, Poorly Sorted	Slightly Gravelly Sand
N02	Unimodal, Poorly Sorted	Slightly Gravelly Muddy Sand
N03	Unimodal, Poorly Sorted	Slightly Gravelly Sand
N04	Unimodal, Poorly Sorted	Slightly Gravelly Muddy Sand
N06	Unimodal, Poorly Sorted	Slightly Gravelly Muddy Sand
N08	Unimodal, Very Poorly Sorted	Slightly Gravelly Muddy Sand
S04	Unimodal, Poorly Sorted	Gravelly Sand
S05	Bimodal, Poorly Sorted	Gravelly Sand
S06	Unimodal, Moderately Sorted	Slightly Gravelly Sand
S07	Unimodal, Poorly Sorted	Slightly Gravelly Sand
S09	Unimodal, Poorly Sorted	Slightly Gravelly Muddy Sand

Sample name	Gravel (%)	Sand (%)	Silt/clay (%)	Very coarse sand (%)	Coarse sand (%)	Medium sand (%)	Fine sand (%)	Very fine sand (%)
D02	1.31	68.07	30.62	0.53	3.12	9.45	35.82	19.15
D03	0.30	71.58	28.12	0.21	0.00	0.49	33.86	37.02
D04	0.05	78.29	21.66	0.06	0.00	2.14	44.73	31.37
D06	0.06	70.18	29.76	0.14	2.45	9.08	34.00	24.50
D07	7.59	56.82	35.59	1.95	5.07	20.86	19.56	9.38
D08	0.36	92.95	6.69	0.32	28.39	52.10	10.86	1.29
Average	1.61	72.98	25.41	0.54	6.50	15.69	29.81	20.45
N02	0.24	86.15	13.61	0.19	15.42	45.20	23.23	2.10
N03	0.07	92.09	7.84	0.15	17.10	46.22	26.56	2.05
N04	0.37	88.09	11.54	0.15	14.05	41.24	30.24	2.41
N06	0.33	89.68	9.99	0.52	12.42	38.27	36.02	2.45
N08	2.71	79.30	17.98	2.06	14.89	35.84	23.88	2.64
Average	0.74	87.06	12.19	0.61	14.78	41.36	27.99	2.33
S04	6.39	86.31	7.30	8.06	45.94	27.61	3.93	0.77
S05	6.14	86.71	7.15	7.15	17.42	36.00	24.78	1.36
S06	1.31	94.77	3.92	3.99	32.19	46.24	10.99	1.37
S07	2.36	91.89	5.75	6.41	40.51	33.49	10.43	1.06
S09	1.71	86.39	11.90	0.71	27.03	44.24	12.94	1.46
Average	3.58	89.21	7.20	5.26	32.62	37.52	12.61	1.20

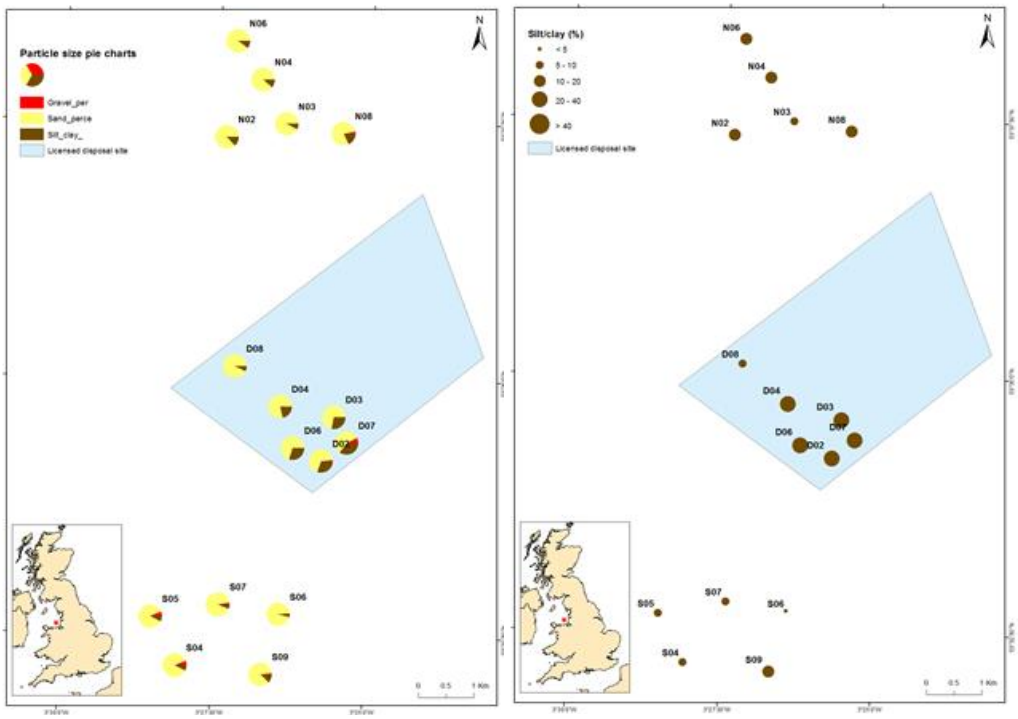

Figure A1.4.3. Pie charts of gravel, sand and silt/clay (left) and silt/clay content (%)(right) of sediments sampled at Site Y under C6794, 2015.

1.4.3.2 Sediment organic carbon

Organic carbon values (in the <2mm sediment fraction) at Site Y were low for marine sediments across all the stations sampled (Figure A1.4.4), ranging from 0.15% (at S04) to 0.65% (D07). Similarly, organic carbon values in the <63µm sediment fraction were low, from 0.46% (at D07) to 2.51% (at S07) (Figure A1.4.4). Sediments from D02 and D03 (both within the disposal site) contained low levels of asbestos preventing an assessment of the organic carbon for these stations.

Figure A1.4.4. Organic carbon (%) in the <2mm fraction (left) and in the silt/clay fraction (<63µm) (right) at in the sediments sampled at Site Y under C6794, 2015.

1.4.3.3 Sediment contaminants

1.4.3.3.1 PAHs

The highest summed PAH concentration (ΣPAH) in 2015 at Site Y was 3,000 µg kg^{-1} dry weight at D04, within the disposal site (Figure A1.4.5). The second highest concentration was also from within the disposal site at D03 (2,800 µg kg^{-1} dry weight). Relatively low summed PAH concentrations (<1000 µg kg^{-1}) were found at the two reference areas, approximately 3km north and south of the disposal site. The lowest summed PAH concentration, 119 µg kg^{-1} dry weight, was sampled at S06 in the southern reference area (Figure A1.4.5).

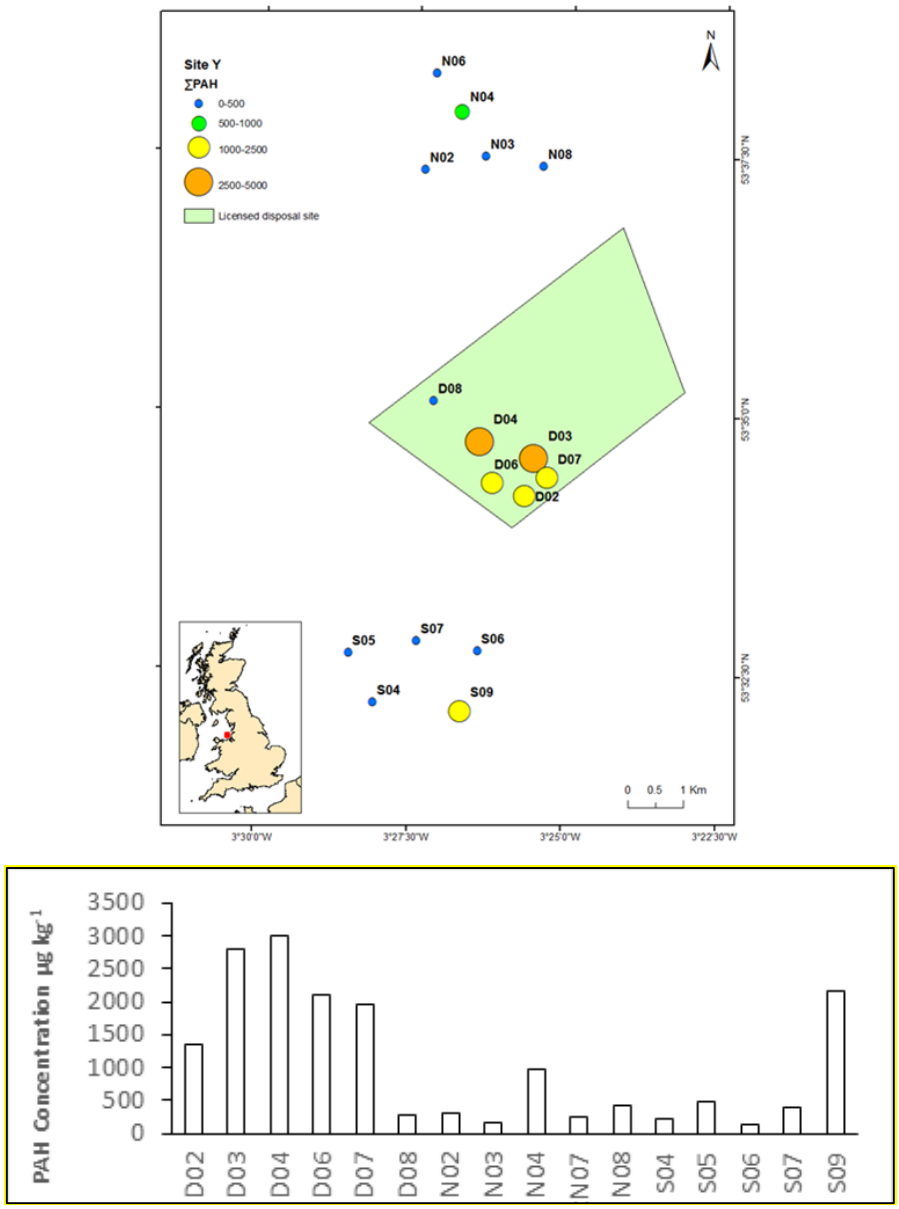

Figure A1.4.5. Map (top) and bar chart (bottom) of summed PAH concentrations (µg kg^{-1} dry weight) for stations sampled at Site Y under C6794, 2015.

Summed PAH concentration values found at Site Y during the 2015 survey were found to be low, neither the ERL or ERM for either the low or high molecular weight PAHs were exceeded at any station sampled (Figure A1.4.6). Evaluation of the PAH data indicated that the source in all the sediment samples were of mixed sources, generally with approximately 45% of the PAH content arising from combustion sources and approximately 55% of the PAH content arising from oil sources. Summed PAH concentrations observed here were similar to those found at other disposal sites located along the west coast of England and to those found further offshore within this region (approx. <500 µg kg^{-1} dry weight Station 715 of the CSEMP monitoring programme, 2012).

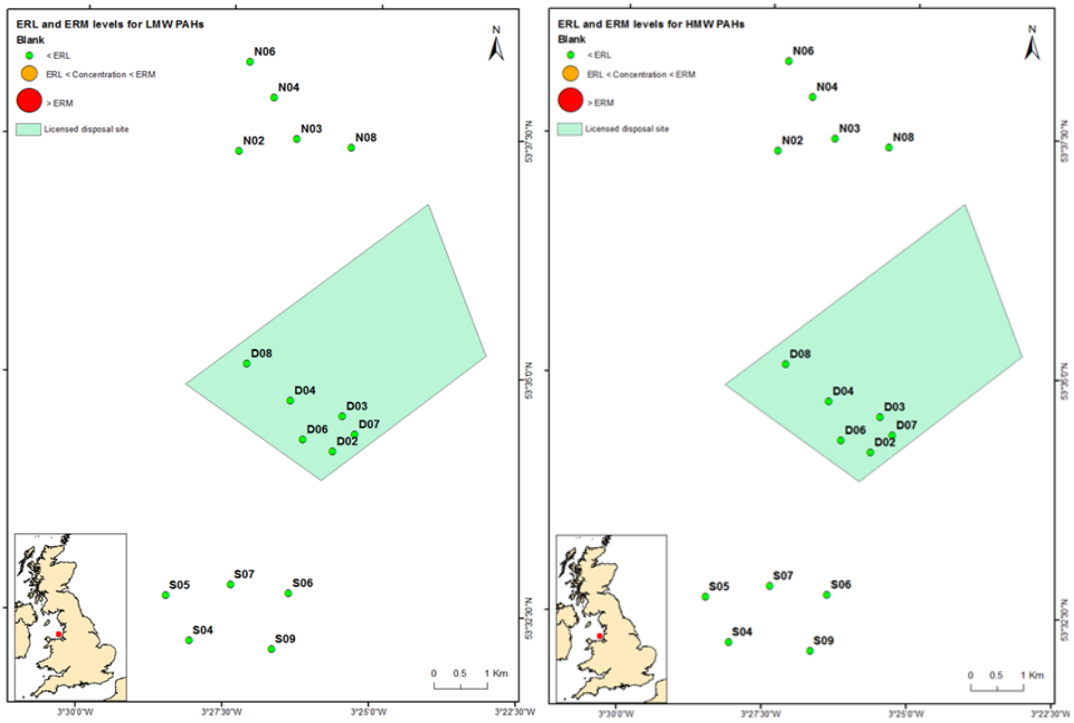

Figure A1.4.6. Map of stations showing relationships between summed PAH concentrations observed with those for Effects Range Low (ERL) and Effects Range Medium (ERM) for low molecular weight (left) and high molecular weight (right) PAHs.

In general, therefore, these PAH data indicate that the sediment disposed of at Site Y contained elevated concentrations of PAHs, but the resulting concentrations were not above any ERL or ERM. This suggests that the dredging regime at the Liverpool II docks in the Mersey, whereby the more contaminated material was dredged and treated separately from the less contaminated material which destined for marine disposal, was successful. Furthermore, PAH concentrations at both the northern and southern reference areas of Site Y were low, indicating that the increases within the site are somewhat contained.

1.4.3.3.2 Organohalogens

At Site Y, ICES 7 CBs were detected in sediments from all of the stations (∑ ICES 7 CBs range 0.113-3.04 µg/kg dw) sampled and processed at Site Y. The highest concentration of 3.04 µg/kg dw was at D09 within the disposal site (Figure A1.4.7). ∑ ICES 7 CB concentrations were <1 µg/kg at all other stations apart from at disposal site stations D04, D06, D03 and D02, and N04, where concentrations of 2.92, 2.73, 2.01, 1.46 and 1.37 µg/kg dw, respectively, were observed (Figure A1.4.7).

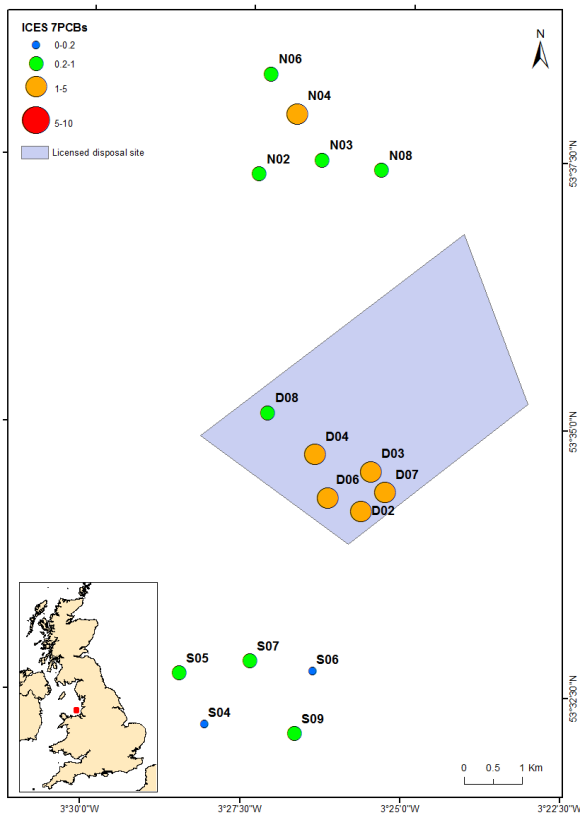

Figure A1.4.7. ∑ ICES7 CB concentrations for the Site Y Stations, 2015.

OCPs were detected at all stations at Site Y. ∑ $_6$DDTs concentrations ranged from <0.21-19.2 µg/kg dw, with the highest values within the disposal site at D03 (19.2 µg/kg dw), D07 (3.14 µg/kg dw) and D04 (2.62 µg/kg dw) (Figure A1.4.8). Dieldrin was detected at only three stations (range <0.05-0.257 µg/kg dw), these being S04 (0.257 µg/kg dw) and two within the disposal site at D04 (0.152 µg/kg dw) and D07 (0.133 µg/kg dw).

BDEs were detected in all stations (∑ 11 BDEs range 0.177-0.791 µg/kg dw). The highest concentrations of 0.791 and 0.604 µg/kg dw were both at reference stations, N04 and S05. Four of the next five highest ∑ 11 BDEs concentrations were, however, located within the disposal site. BDE47 and BDE99 are the dominant congeners present, indicative of the pentaBDE technical mixture, but BDE183 was also detected, suggesting that the octaBDE or decaBDE technical mixture was also in use.

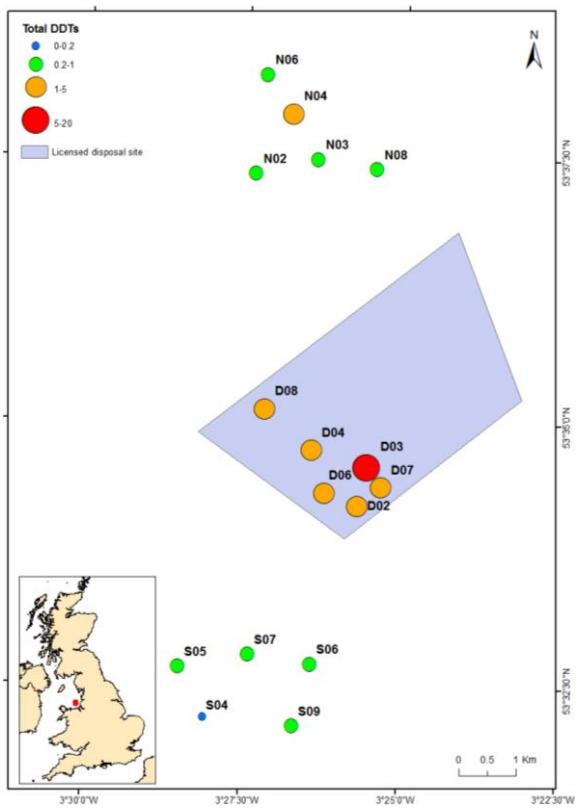

Figure A1.4.8. ∑ $_6$DDTs concentrations for the Site Y stations, 2015.

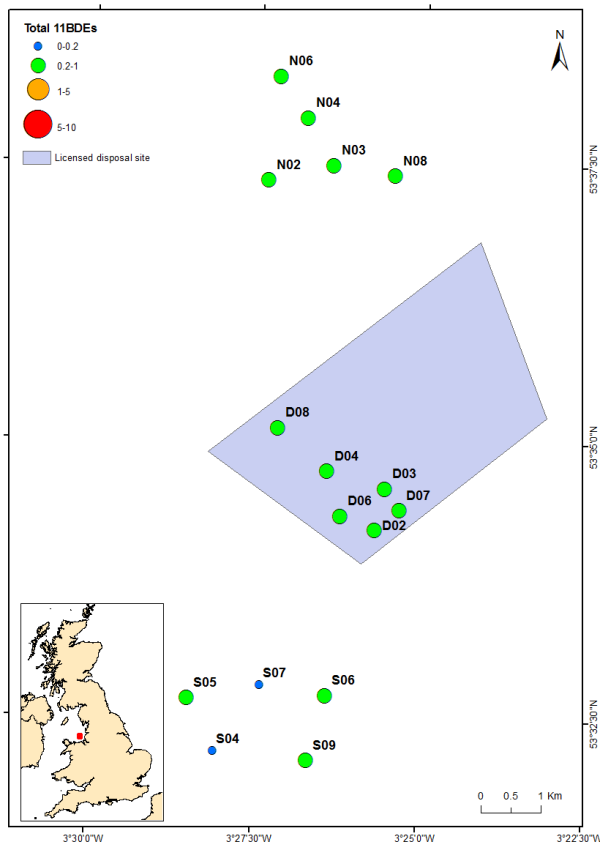

Figure A1.4.9. ∑ 11 BDEs concentrations for the Site Y stations, 2015.

BDE209 was detected in sediments sampled from all stations at Site Y, making it the most ubiquitous organohalogen contaminant analysed (range 10.3-162 µg/kg dw). BDE209 made up >87% of the total for 12 BDEs at all stations (range 87-95%). Highest concentrations were at stations D07, D04 and N04 with values of 162, 106 and 101 µg/kg dw. High concentrations of 90.8, 69.9 and 59.9 µg/kg dw were also present at stations D06, D02 and D03 in the disposal site (Figure A1.4.10).

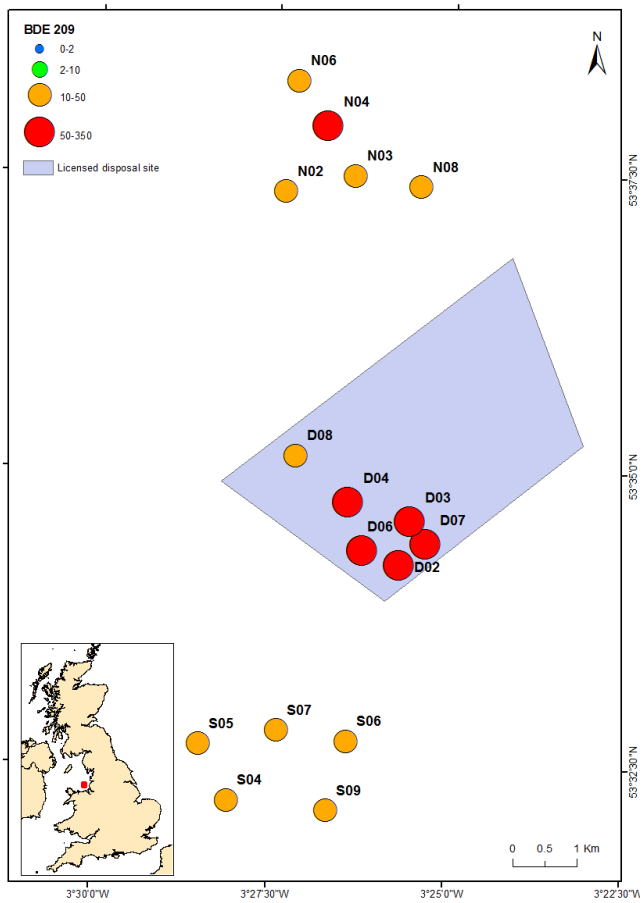

Figure A1.4.10. BDE209 concentrations for the Site Y Stations, 2015.

Concentrations of CBs and dieldrin at all stations were below Cefas action level 1. ∑ 6DDTs concentrations were above Cefas action level 1 at seven of the stations, while no Cefas action levels exist for BDEs including BDE209. According to the OSPAR guidelines, four reference stations (N02, N03, N06 and S04) had 'good' environmental status for all ICES 7 CBs and 'good' status overall. The other 12 stations had one CB (CB118) with 'bad' environmental status but 'good' status overall. No station was classed as 'bad' overall status for CBs. No OSPAR guidelines exist for BDEs at present.

1.4.3.3.3 Trace metals

The levels of enrichment, using both the OSPAR BAC and regional baseline values, for the trace metals sampled from the sediments at Site Y during 2015 are displayed in Figure A1.4.11. For As, concentrations sampled at the majority of stations are lower than the OSPAR BAC and the baseline

values, i.e., not enriched. Slight enrichment is, nevertheless, observed for three or four stations, depending on assessment method, within the disposal site. Both enrichment assessments concluded moderate enrichment is observed for Cd at three stations located within the disposal site; elsewhere Cd is not enriched.

Levels of Cr and Ni are found to be slightly enriched using the OSPAR assessment whereas no enrichment was observed for most stations when assessed against the baseline values. As was the case for As, slight enrichment was still observed for three or four stations located within the disposal site for Cr and Ni. Generally, Cu is slightly to moderately enriched at most stations when using the OSPAR BAC approach. This enrichment is less pronounced with the baseline assessment; while no stations outside the disposal site were enriched, four stations within the disposal site depict slight enrichment.

Levels of Hg are very enriched when assessed against the OSPAR BAC values, the degree of enrichment is, however, lower when assessed using the baseline assessment (i.e., three stations were moderately enriched, the remaining stations slightly enriched). The large disparity between the two methods for Hg is a reflection that the OSPAR BACs do not account for the relatively high natural concentrations of this element in the Irish Sea. However, the enrichment observed for Hg according to the regional baseline values may reflect elevated Hg levels in the material dredged and subsequently disposed of at Site Y from the the Liverpool II docks, although without pre-disposal data it is difficult to place that conclusion with a high degree of certainty. The high Hg concentrations observed at Site Z in 2014 (see Section 1.5) would suggest that the high levels at Site Y do not, however, result solely from the disposal of material from Liverpool II docks.

Levels of Pb are very moderately enriched when assessed against the OSPAR BAC values, the enrichment being less pronounced with the regional baseline assessment where all stations are either slightly or not enriched. Concentrations of Zn are found to be slightly enriched using the OSPAR assessment to moderately enriched for three stations within the disposal site whereas slight enrichment was observed for those stations when assessed against the baseline values; no enrichment was depicted elsewhere.

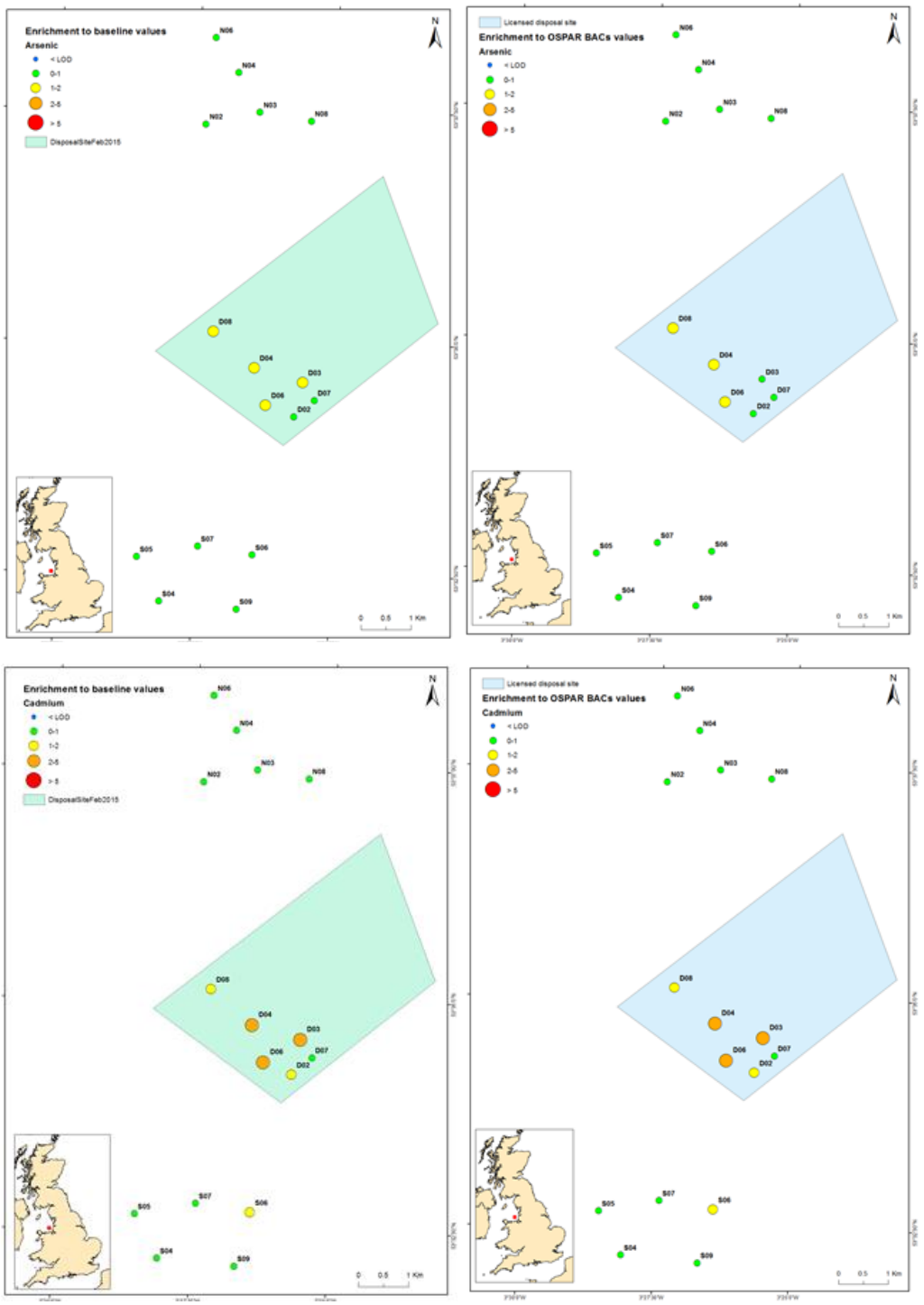

Figure A1.4.11. Map showing the enrichment of trace metals concentrations observed at Site Y, 2015, compared with regional baseline (left) and OSPAR BAC values (right).

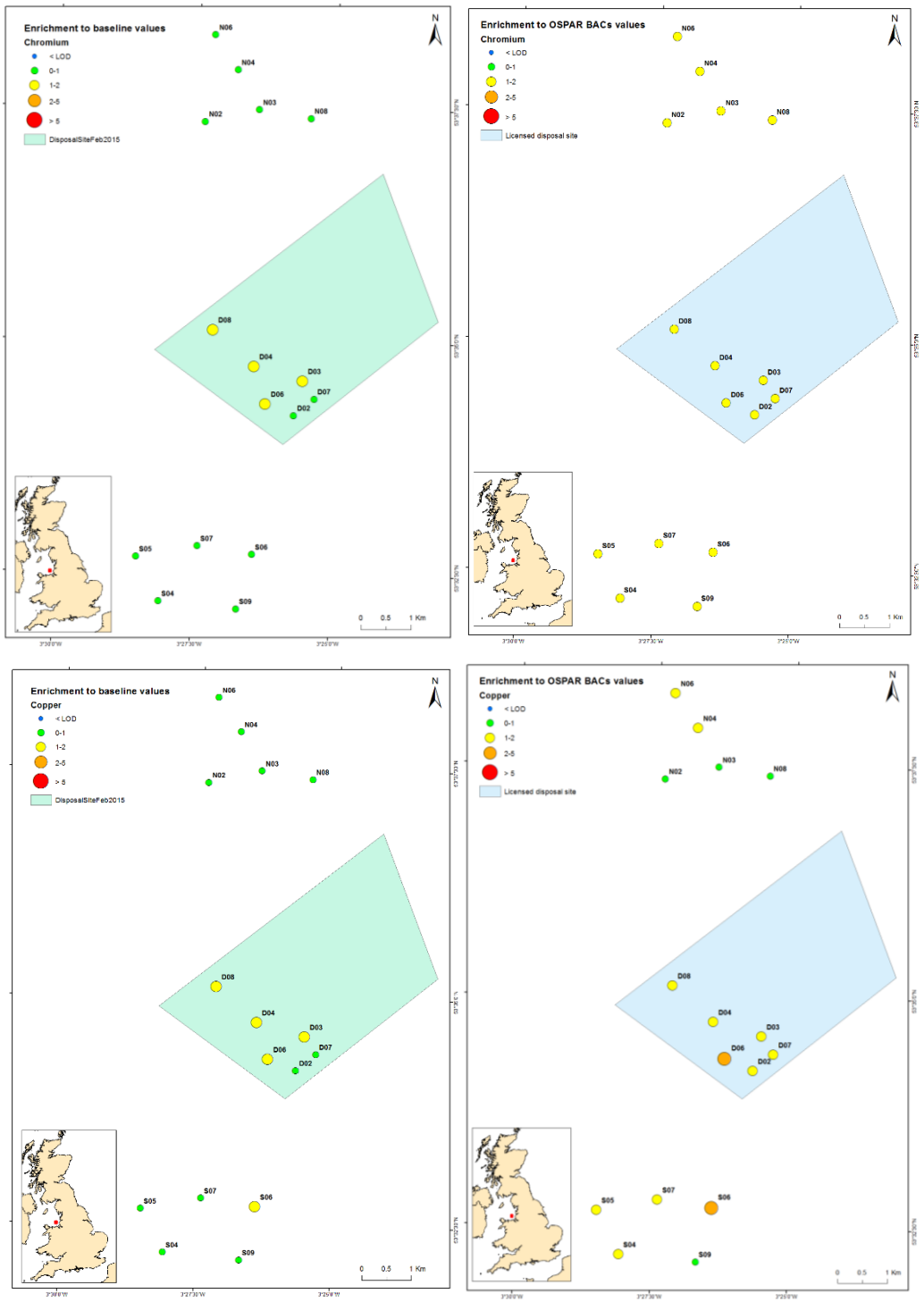

Figure A1.4.11. Continued.

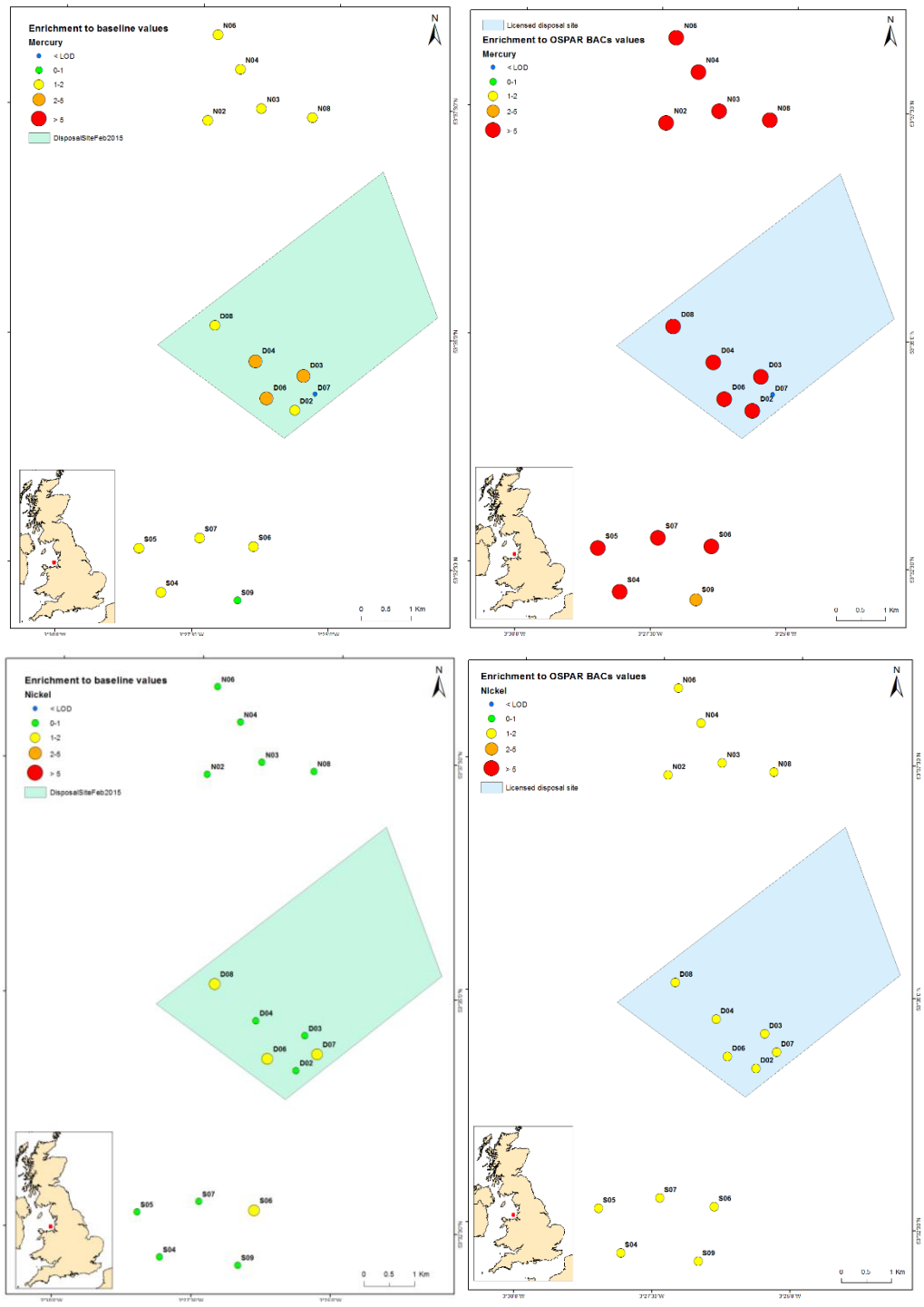

Figure A1.4.11. Continued.

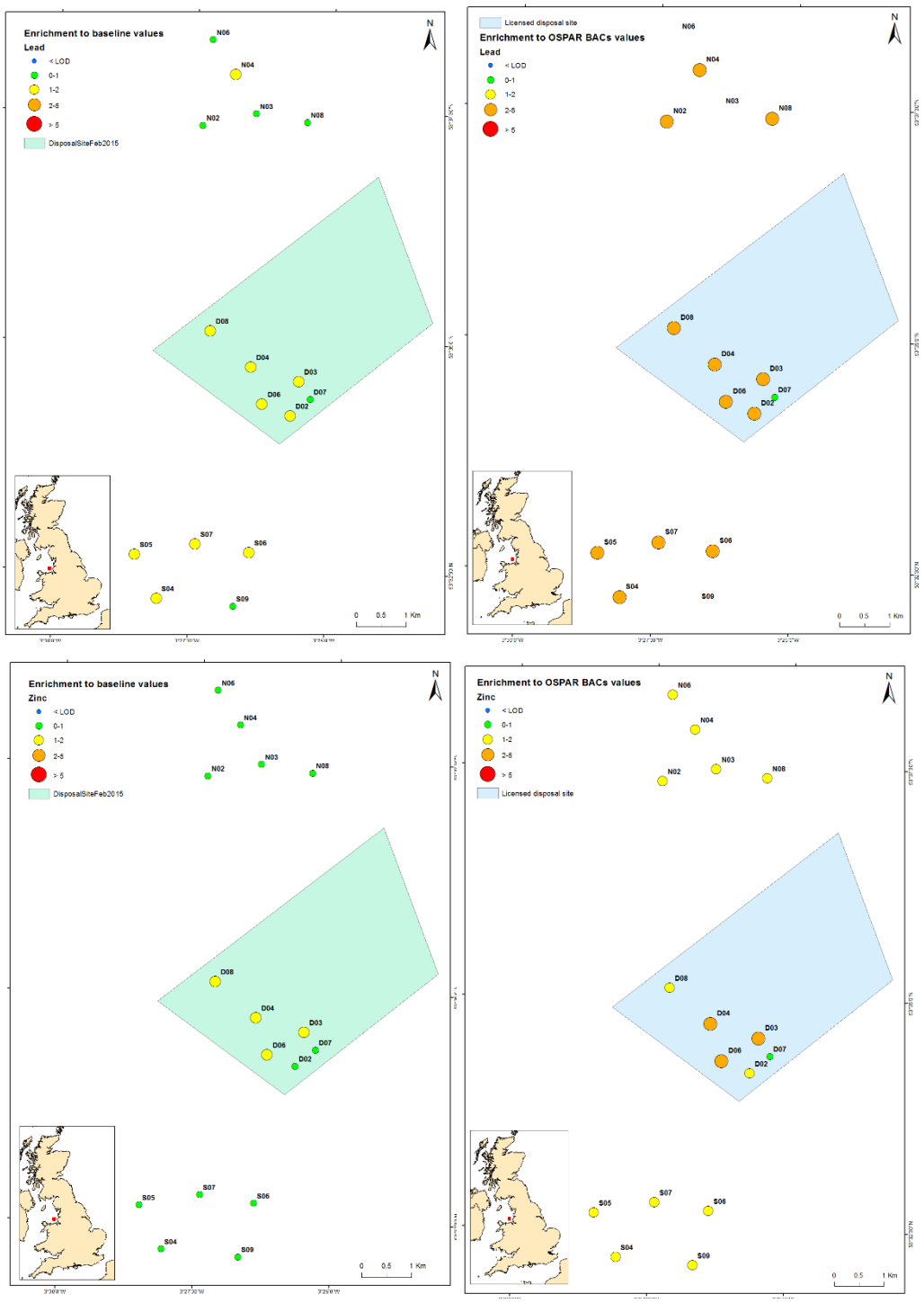

Figure A1.4.11. Continued.

1.4.3.4 Macrofaunal assemblages

A total of 138 taxa (including colonial epifauna) were recorded from the 16 grab samples (a single replicate was taken at each station) taken at Site Y during the 2015 survey. One hundred and twenty eight free living macrofaunal invertebrate taxa were identified (80 % identified to species level), the most ubiquitous taxa including the bivalve molluscs *Phaxus pellucidus and Mysella bidentata* (present in 16 and 15 samples respectively), and the polychaete *Scalibregma inflatum* and Nemertea spp. (ribbon worms), both present in 15 samples. Ten taxonomic groups of colonial epifauna were identified (70 % identified to species), with the most prevalent taxa occurring in a maximum of 5 samples (A sertulariid hydroid and a BRYOZOAN, *Amathia lendigera*).

Segmented worms, or annelids, were typically the most abundant macroinvertebrates encountered, with stations within the disposal site typically having a lower abundance of them than those in the reference areas (**Error! Reference source not found.**A1.4.12). Molluscan taxa were, however, more abundant within the Site Y disposal site compared to reference areas, this was also the situation for the main colonial taxa (Figure A1.4.12). The

mean number of solitary taxa, total abundance and total biomass (wet weight) of the assemblages of the disposal site were lower than those for either of the reference areas (

Figure A1.4.13, Table A1.4.2).

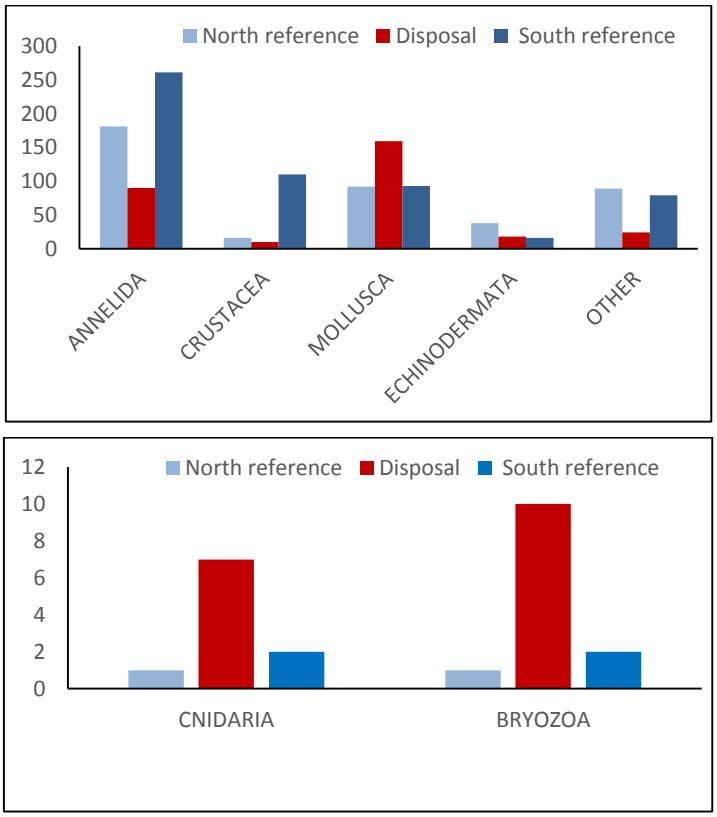

Figure A1.4.12. Histogram showing total number of individuals per grab (top) and the occurrences (out of 16 stations) of colonial taxa (bottom) across the major phyla within disposal and reference stations.

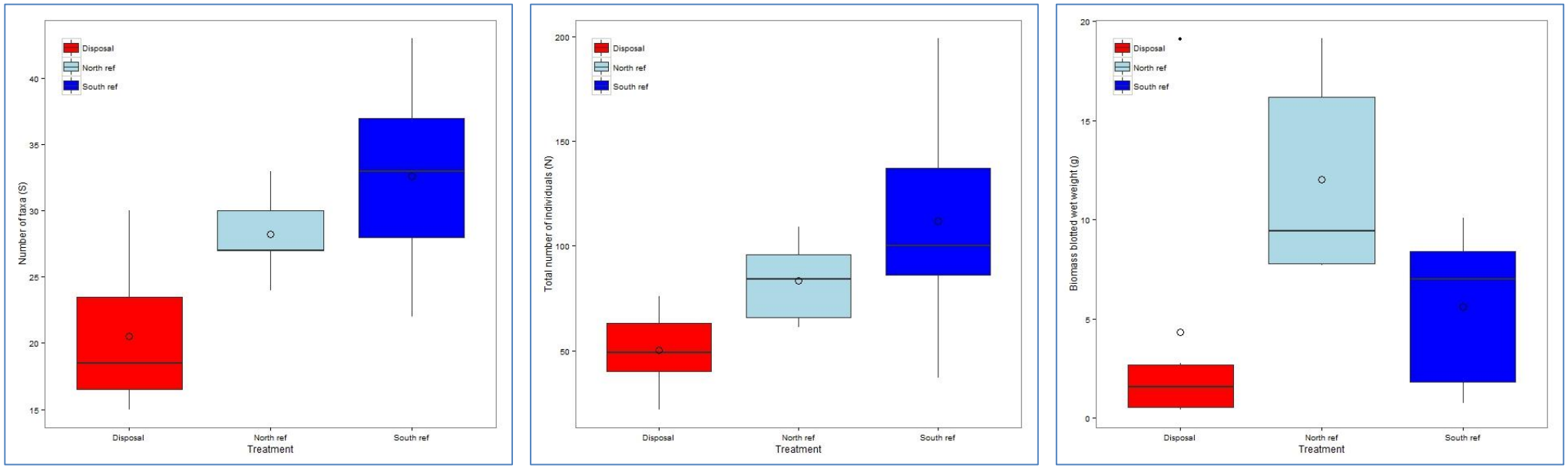

Figure A1.4.13. Box-whisker plots showing the number of taxa (S) (left), total number of individuals (N) (centre) and total biomass (blotted wet weight g) (right) in disposal (red) and reference (blue) stations.

Table A1.4.2. Summary statistics showing the total number of taxa (S), abundance of individuals (N) and biomass (blotted wet weight g) per grab for disposal and reference stations.

		S	N	Biomass
Disposal	Range	15 – 30	22 – 76	0.4491 – 1-00868
	Median	19	49	1.5978
	Mean	21	50	4.3353
	Standard variation	5.82	19.74	7.30
	Variance	33.90	389.77	53.28
North reference	Range	24 - 34	61 - 109	7.7140 – 19.1180
	Median	27	84	9.418
	Mean	28	83	12.042
	Standard variation	3.42	20.12	5.26
	Variance	11.70	404.70	27.69
South reference	Range	22 - 43	37 - 199	0.7394 – 10.0770
	Median	33	100	7.0158
	Mean	33	112	5.6086
	Standard variation	8.08	60.50	4.12
	Variance	65.30	3659.70	16.98

Pairwise comparisons (using the ANOSIM test on PRIMER) implied a separation of benthic community structures between assemblages of the disposal stations and those of both north and south reference stations ($R = 0.58$, $p<0.001$; $R = 0.65$, $p<0.001$, for north and south reference respectively). There was a lesser degree of separation between the two reference area communities ($R = 0.30$, $p<0.05$). These results are supported by the locations of the stations on the 2d ordination plot (Figure A1.4.14).

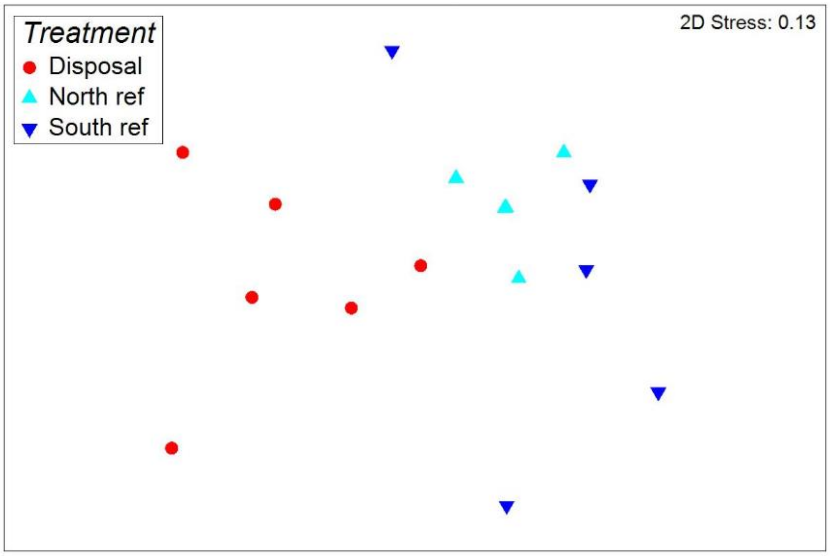

Figure A1.4.14. Non-parametric Multidimensional Scaling (nMDS) ordination plot of the square root-transformed abundance macrofaunal data (colonial macroinvertebrates enumerated as one prior to transformation) showing the separation of benthic communities between disposal and reference stations at Site Y, 2015.

In summary, the macrofaunal assemblages sampled within, and at the north and south reference areas for, the Site Y disposal site show wide spatial variability, with those of the disposal site being dissimilar to those of the reference areas. Assemblages within the area that has recently received large amounts of both capital and maintenance material (see Figure A1.4.2) displayed reduced numbers of taxa, total abundance and wet biomass, and possessed a greater proportion of molluscs and colonials (bryozoans, cnidarans) and less annelid worms compared to those of the references. There is no indication that assemblages at either of the two reference areas show signs of impacts associated with the deposition at Site Y, harbouring, for example, 28 and 33 separate taxa per grab for the north and south references respectively.

1.5 Site Z (IS140)

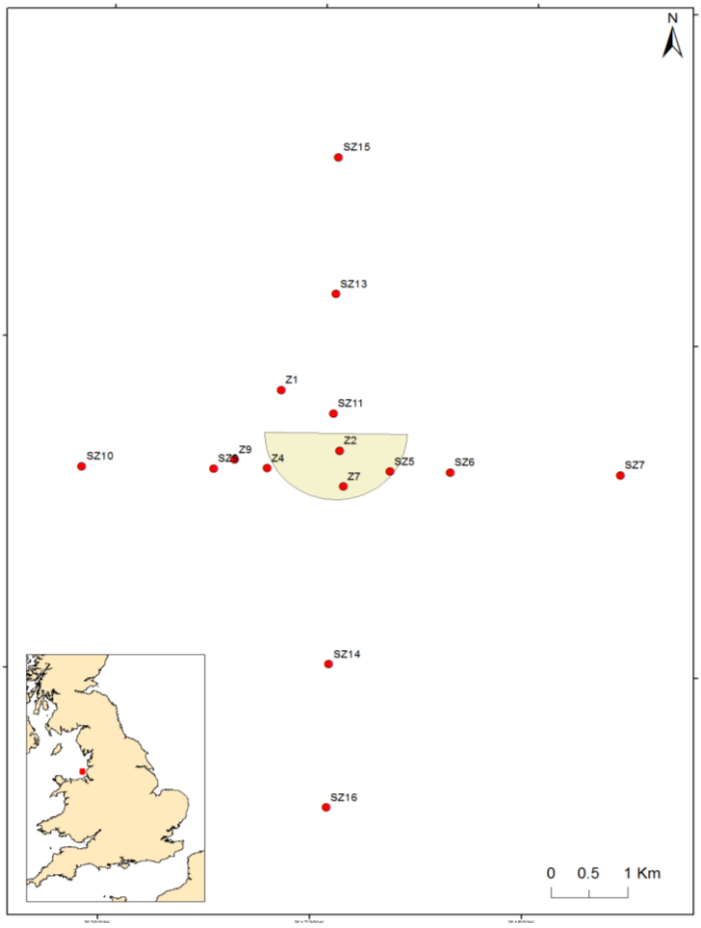

Figure A1.5.1. Location of Site Z dredged material disposal site, Liverpool Bay, together with the locations of the stations sampled for sediment particle size, organic carbon and sediment contaminants concentrations, September 2014.

1.5.1 Background

Site Z (IS140), which has been in use as a disposal site since the late 1800's, was moved to the present location in 1982 to the west of the 'former' Site Z as a result of shoaling in the centre of the licensed area. This site is shallower than Site Y and has sediments comprising predominantly unimodal sands with some sandy muds/muddy sands (Bolam et al., 2015a). 1.16 MT (wet weight) of capital and 0.4 MT (wet weight) of maintenance dredged material were disposed of to Site Z during 2013 which is more-or-less in line with average annual tonnages disposed of to this site (1.7 MT per annum since 1986). The maintenance material is derived from the Liverpool and Birkenhead docks and the approach channel to the river Mersey. Site Z also received some of the less-stiff capital dredged material from the construction of Liverpool II, the majority of which was placed at Site Y (Section 1.4.1). As the site is susceptible to shoaling, quantities of capital dredged material disposed to this site are limited and very dependent on their physical characteristics.

During the 2014 survey at Site Y, the sediments at 22 stations within and surrounding the Site Z disposal site were opportunistically sampled. Although the site was not formerly proposed for monitoring in 2014 (monitoring was, however, conducted during 2013; Bolam et al., 2015a), the samples collected *ad hoc* during

2014 were acquired to potentially later contribute to the time-series data regarding sediment contaminants for the site. Site Z receives modest amounts of maintenance dredged material each year, and elevated concentrations of some contaminants are occasionally observed (Bolam et al., 2015a). In 2015, the majority of these samples were processed for contaminants under the auspices of C6794 in order to facilitate our on-going understanding of the spatial and temporal changes in contaminant concentrations at this site.

Prioitisation Tier 1;

- where there is the potential for the occurrence of elevated contaminant concentrations (between Cefas action levels of 1 and 2 in proposed dredge sediments) arising from historical or current activities at source (especially heavily urbanised/industrialised estuaries)

1.5.2 Parameters monitored

Sediment particle size and organic carbon

Sediment contaminants (PAHs, organohalogens, trace metals)

1.5.3 Results

1.5.3.1 Sediment particle size

The sediments within and in the vicinity of the Site Z disposal site are generally unimodal (apart from the bimodal distribution shown at SiZ1), slightly gravelly sand or slightly gravelly muddy sand (Table A1.5.1), with varying degrees of sorting. Silt/clay contents are low (<10%) except for sediments west and south of the disposal site (Figure A1.5.2)

Table A1.5.1 Average sediment descriptions and statistics for each sediment group at Site Z.

Sediment group	Number of samples	Sample Type	Sediment description
SiZ1	7	Bimodal, Very Poorly Sorted	Slightly Gravelly Sandy Mud
SiZ2a	8	Unimodal, Poorly Sorted	Slightly Gravelly Muddy Sand
SiZ2b	16	Unimodal, Poorly Sorted	Slightly Gravelly Muddy Sand
SiZ3a	15	Unimodal, Well Sorted	Slightly Gravelly Sand
SiZ3b	11	Unimodal, Moderately Sorted	Slightly Gravelly Sand
SiZ3c	20	Unimodal, Well Sorted	Slightly Gravelly Sand
SiZ3d	12	Unimodal, Well Sorted	Slightly Gravelly Sand
SiZ3e	2	Unimodal, Poorly Sorted	Slightly Gravelly Sand

Sediment group	Gravel (%)	Sand (%)	Silt/clay (%)	Very coarse sand (%)	Coarse sand (%)	Medium sand (%)	Fine sand (%)	Very fine sand (%)
SiZ1	0.08	45.95	53.97	0.23	0.73	7.21	18.71	19.07
SiZ2a	0.58	81.68	17.73	0.39	1.29	9.85	60.67	9.48
SiZ2b	0.85	80.25	18.90	0.33	0.50	1.85	39.19	38.38
SiZ3a	0.09	98.37	1.54	0.09	0.15	3.46	77.04	17.63
SiZ3b	1.45	92.01	6.55	0.39	0.99	21.88	61.87	6.88
SiZ3c	0.41	97.96	1.63	0.25	0.56	14.26	79.28	3.61
SiZ3d	0.55	99.09	0.36	0.34	1.01	35.52	61.26	0.95
SiZ3e	3.54	96.28	0.18	7.25	19.02	43.36	25.05	1.60

The temporal changes in sediment groups for Site Z sampling stations since 1996 are minimal. Changes observed in 2013 at SZ14, south of the site, have continued in 2014, while stations within the disposal site (Z7 and Z1), immediately north-west of the site, have returned to a similar sediment type as in 2010 due to lower mud content compared with 2013 (Table A1.5.2). The relatively high silt/clay fractions in stations to the west and south of the disposal site in 2014 (sediment groups SiZ1 and SiZ2) are consistent with previous years.

Table A1.5.2 Sediment groups for each sample code between 1996 and 2014 inclusive at Site Z.

	Year							
Sample code	1996	2001	2002	2003	2006	2010	2013	2014
SZ1	nm	nm	nm	nm	nm	SiZ3c	SiZ3a	nm
SZ2	nm	nm	nm	nm	nm	SiZ3d	SiZ3c	SiZ3e
SZ3	nm	nm	nm	nm	nm	SiZ3c	nm	as
SZ4	nm	nm	nm	nm	nm	SiZ2b	nm	SiZ3a
SZ5	nm	nm	nm	nm	nm	SiZ3a	SiZ3a	SiZ3a
SZ6	nm	nm	nm	nm	nm	SiZ3a	SiZ3a	SiZ3a
SZ7	nm	nm	nm	nm	nm	SiZ3c	SiZ3c	SiZ3c
SZ8	nm	nm	nm	nm	nm	SiZ3a	nm	SiZ3a
SZ9	nm	nm	nm	nm	nm	SiZ2b	SiZ1	as
SZ10	nm	nm	nm	nm	nm	SiZ2a	SiZ2a	SiZ2a
SZ11	SiZ3b	nm	nm	nm	nm	SiZ3d	nm	SiZ3c
SZ12	SiZ3b	nm	nm	nm	nm	SiZ3c	nm	as
SZ13	nm	nm	nm	nm	nm	SiZ3d	SiZ3c	SiZ3d
SZ14	nm	nm	nm	nm	nm	SiZ3c	SiZ2b	SiZ2b
SZ15	nm	nm	nm	nm	nm	SiZ3d	SiZ3d	SiZ3d
SZ16	nm	nm	nm	nm	nm	SiZ1	SiZ1	SiZ1
Z1	SiZ3b	SiZ2a	SiZ3c	SiZ3c	SiZ3c	SiZ3b	SiZ2a	SiZ3b
Z2	SiZ3b	SiZ3d	SiZ3c	SiZ3c	SiZ3c	SiZ3c	nm	SiZ3c
Z3	SiZ3b	SiZ2b	SiZ3b	SiZ3c	SiZ3c	SiZ3c	nm	SiZ3b
Z4	nm	SiZ3a	SiZ2b	SiZ2a	SiZ2b	SiZ2b	nm	SiZ2b
Z6	nm	nm	nm	SiZ3d	SiZ3d	SiZ3e	nm	SiZ3d
Z7	SiZ3b	nm	nm	nm	SiZ1	SiZ3a	SiZ2b	SiZ3a
Z8	nm	nm	nm	SiZ3b	nm	nm	nm	nm
Z9	nm	nm	nm	SiZ2b	SiZ2b	SiZ2b	SiZ2b	as
Z10	nm	nm	nm	nm	SiZ2a	nm	nm	nm
Z11	nm	nm	nm	nm	SiZ2b	nm	nm	nm
Z12	nm	nm	nm	nm	SiZ2b	nm	nm	nm
Z13	nm	nm	nm	nm	SiZ1	nm	nm	nm
Z14	nm	nm	nm	nm	SiZ3a	nm	nm	nm
Z15	nm	nm	nm	nm	SiZ2a	nm	nm	nm
Z16	nm	nm	nm	nm	SiZ1	nm	nm	nm
Z17	nm	nm	nm	nm	SiZ3a	nm	nm	nm

nm – not measured/collected, as (2014 only) Z9, SZ3, SZ9 and SZ12 contained low levels of asbestos and therefore a full PS distribution was not completed.

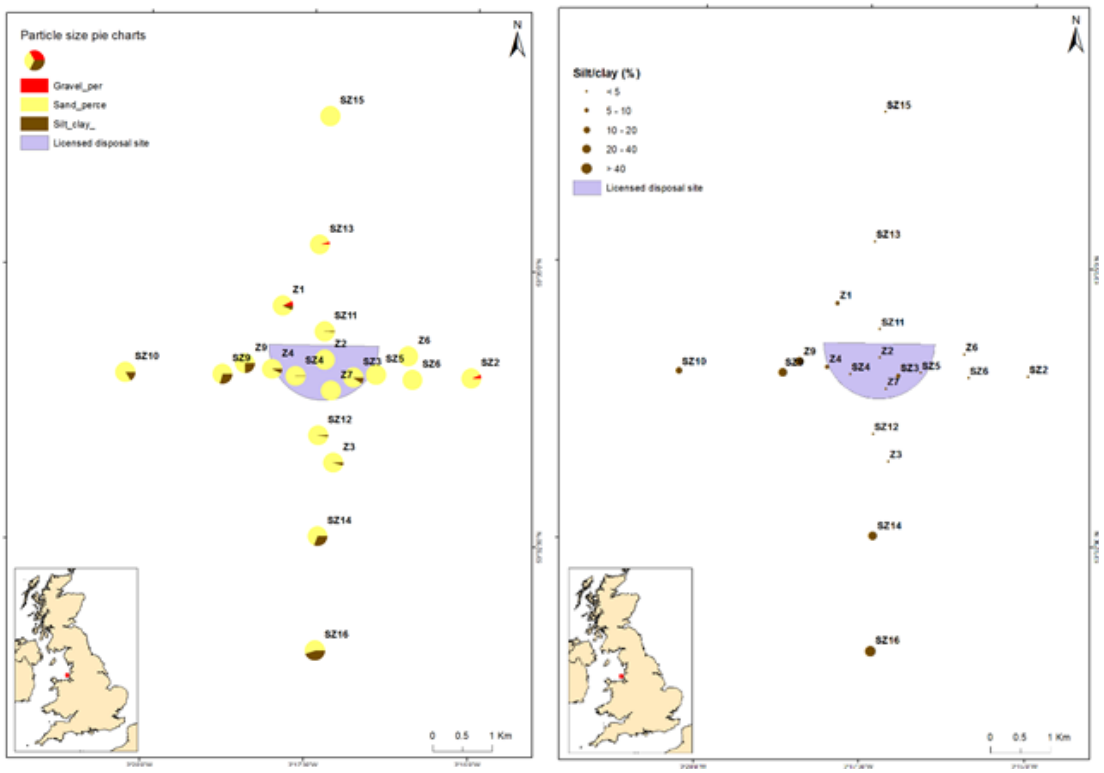

Figure A1.5.2. Pie charts of gravel, sand and silt/clay (left) and silt/clay content (%)(right) of sediments sampled at Site Z under C6794, 2014.

1.5.3.2 Sediment organic carbon

Organic carbon values in the <2mm sediment fraction were all comparatively low relative to those of other regions (e.g., Blyth; Section 1.1.3), from 0.12% to a maximum of 1.07% at SZ16, at the southern limit of the stations sampled (Figure A1.5.3). Correspondingly, low carbon levels in the <63µm sediment fraction were observed, ranging from 1.72% to 2.35% (at SZ11). The silt/clay fractions of the sediments of seven stations (i.e., Z2, Z7, SZ5, SZ6, SZ7, SZ13 and SZ15) were too low (Figure A1.5.2) to allow an assessment of organic carbon on the <63µm fraction. The sediments from SZ9 and Z9 (both west of the disposal site) contained low levels of asbestos preventing an assessment of the organic carbon contents for these stations.

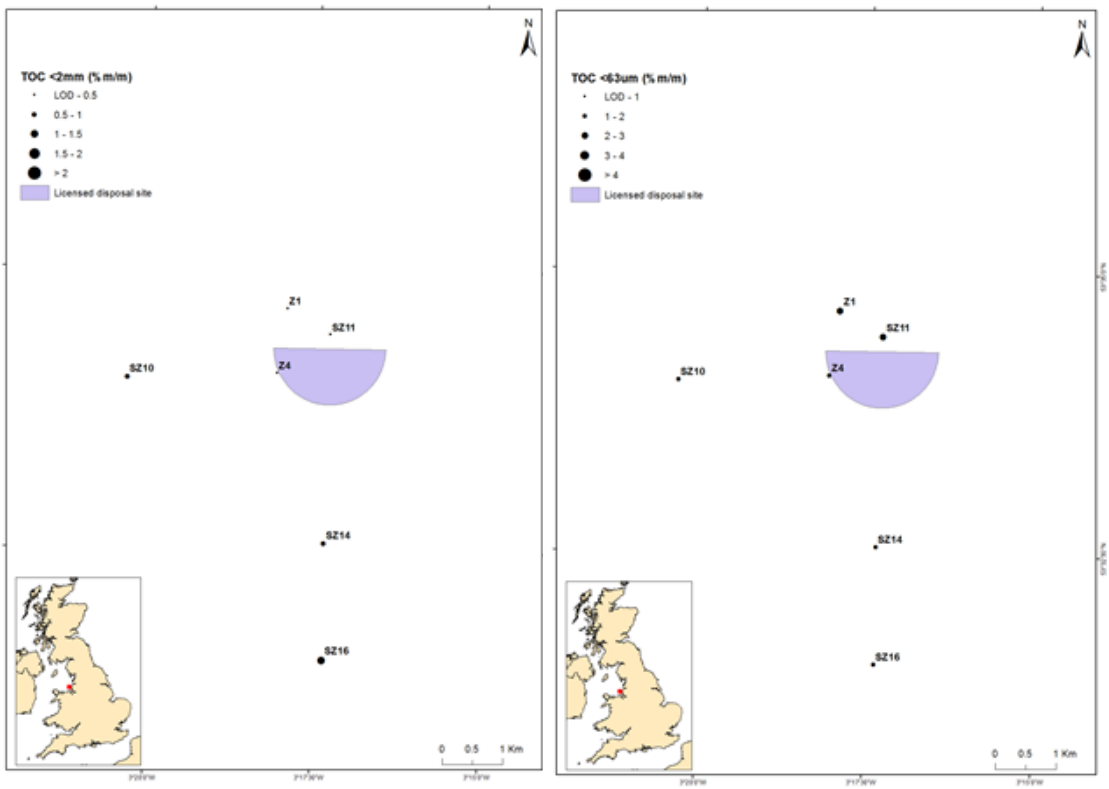

Figure A1.5.3. Organic carbon (%) in the <2mm fraction (left) and in the silt/clay fraction (<63µm) (right) in the sediments sampled at Site Z, 2014.

1.5.3.3 Sediment contaminants

1.5.3.3.1 PAHs

The highest summed PAH concentration (ΣPAH) at Site Z in 2014 was 4,140 µg kg^{-1} dry weight, at SZ16, the most southerly station, which also had the highest concentration (4,100 µg kg^{-1}) in a 2013 survey of the area (Figure A1.5.4). The second highest concentration (3,320 µg kg^{-1} dry weight) during 2014 was at Z9, approximately 0.5 km west of the disposal site; a similar concentration was observed here in 2013 (Figure A1.5.4).

The lowest summed PAH concentration was 24 µg kg^{-1} dry weight, was found at Z7 which is located on the mid-southern edge of the disposal site. In general, lowest PAH concentrations (<100 µg kg^{-1}) were found at the stations located within the disposal site and at those to the north and east of the disposal site (Figure A1.5.4).

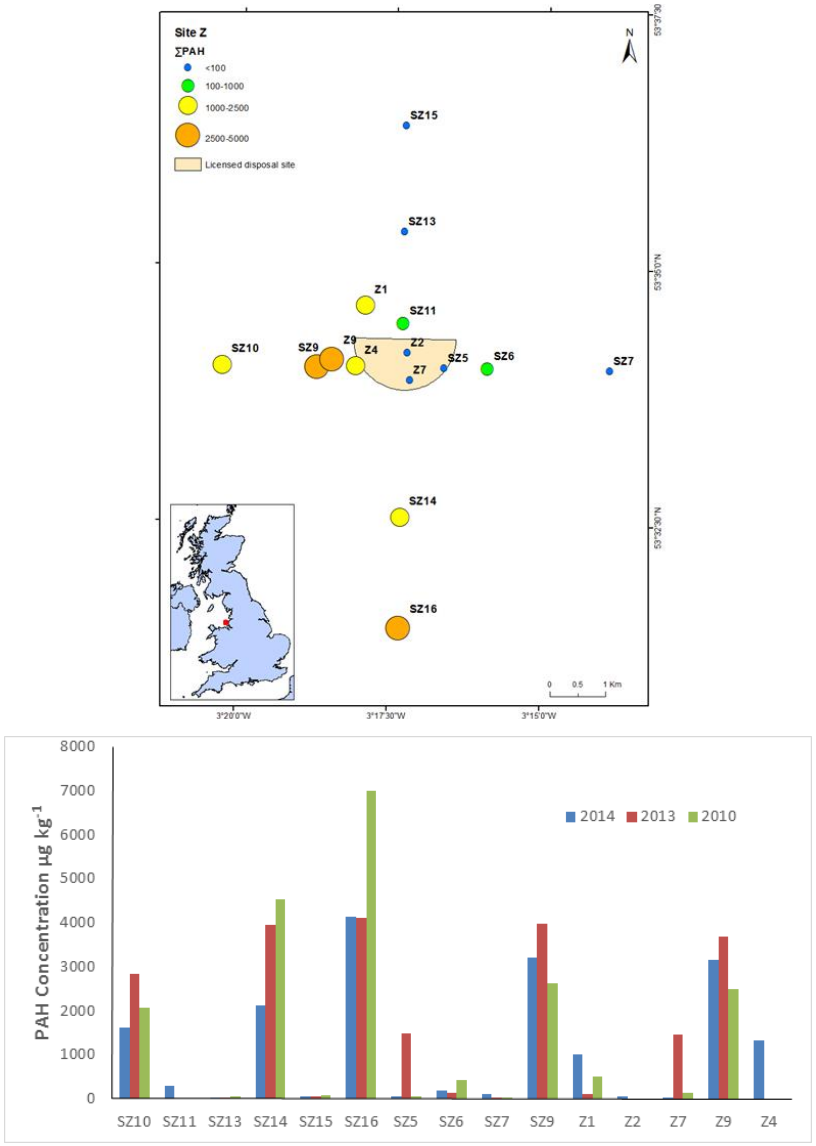

Figure A1.5.4. Top: map of summed PAH concentrations (µg kg^{-1} dry weight) for stations sampled at Site Z under C6794, 2014. Bottom: bar charts showing summed PAH concentrations for stations sampled 2010-2014.

The ERL for LMW PAHs was breached at SZ16 to the south of the disposal area, but the ERM for LMW PAHs was not exceeded at any station in 2014 (Figure A1.5.5). Furthermore, neither the ERL or the ERM for HMW PAHs were exceeded at any station. Summed PAH values found at Site Z are comparable with those found at found at Site Y (Section 1.4.3) and those typically exhibited by offshore sediments along the west coast of England and Wales. Evaluation of the PAH data indicated that the sediments were of mixed sources, generally with approximately 45% of the PAH content arising from combustion sources (except 69% at SZ13) and approximately 55% from oil sources.

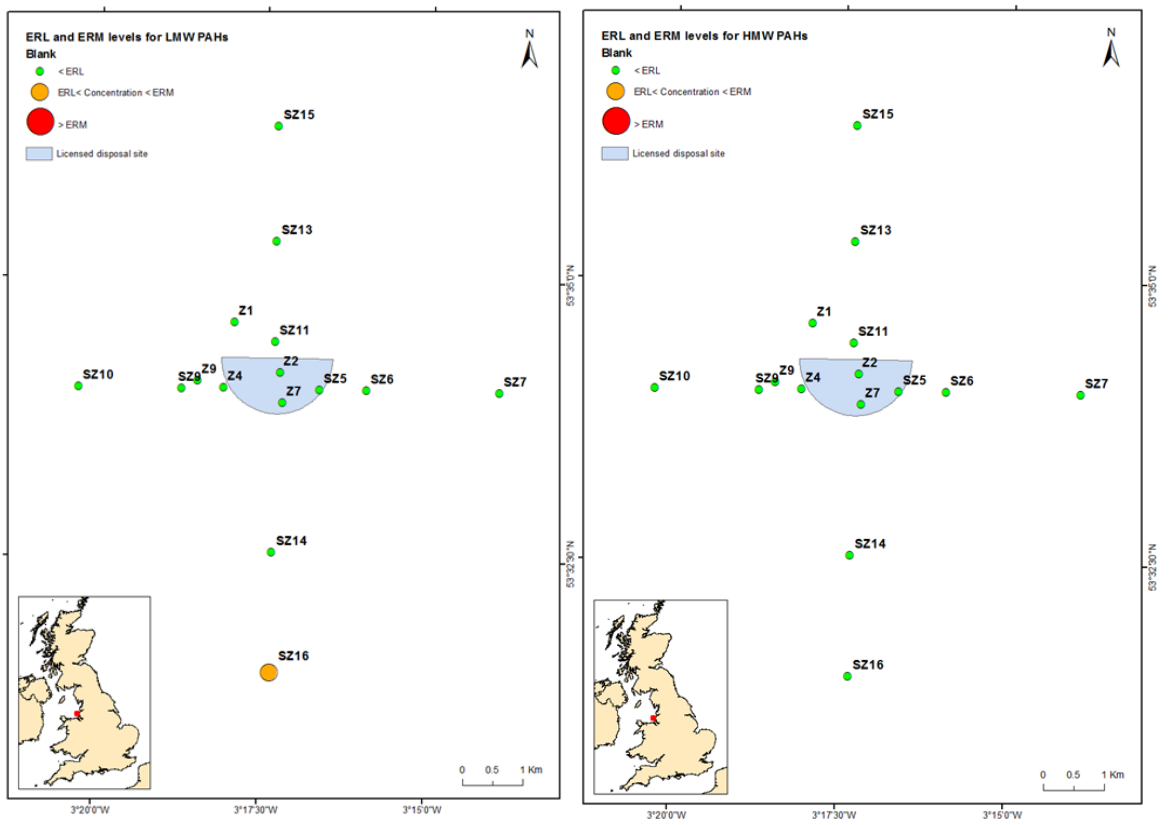

Figure A1.5.5. Map of stations showing relationships between summed PAH concentrations observed with those for Effects Range Low (ERL) and Effects Range Medium (ERM) for low molecular weight (left) and high molecular weight (right) PAHs.

1.5.3.3.2 Organohalogens

At Site Z, ICES 7 CBs were detected at all of the 15 stations where sediments were processed (∑ ICES 7 CBs range 0.151-5.85 µg/kg dw), using the improved detection limits (see Appendix 2.2 for methods). The highest concentration, 5.85 µg/kg dw, was at SZ9 to the west of the disposal site. ∑ ICES 7 CB concentrations were <1 µg/kg at all other stations apart from SZ16, Z9, SZ14 and SZ10 which had levels of 4.99, 2.66, 1.98 and 1.69 µg/kg dw, respectively (Figure A1.5.6).

OCPs were detected at every station apart from Z7, inside the disposal site. $\sum_6$DDTs concentrations ranged from <0.14-5.21 µg/kg dw, with the highest values at SZ16 (5.21 µg/kg dw), SZ9 (2.69 µg/kg dw) and Z9 (2.60 µg/kg dw) to the west and south of the disposal site (Figure A1.5.7). Dieldrin was detected at only two of the stations (range <0.05-0.139 µg/kg dw), at SZ9 (0.139 µg/kg dw) and Z9 (0.120 µg/kg dw), both west of the disposal site.

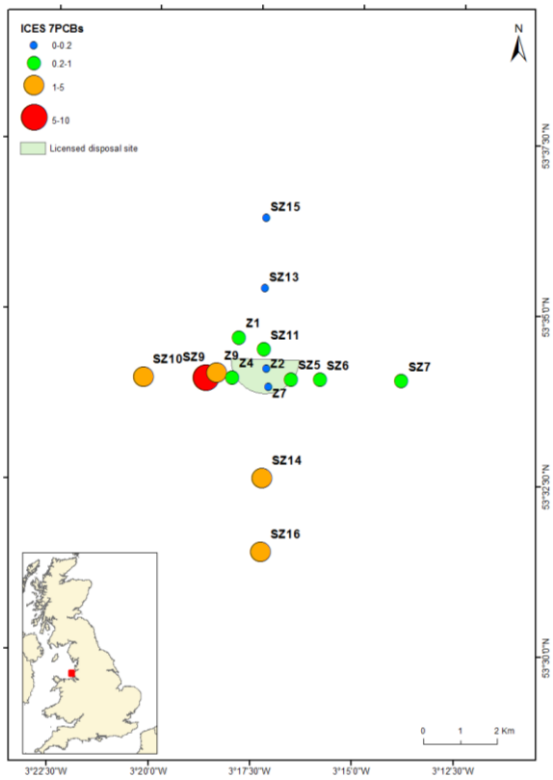

Figure A1.5.6. ∑ ICES7 CB concentrations for the Site Z stations, 2014.

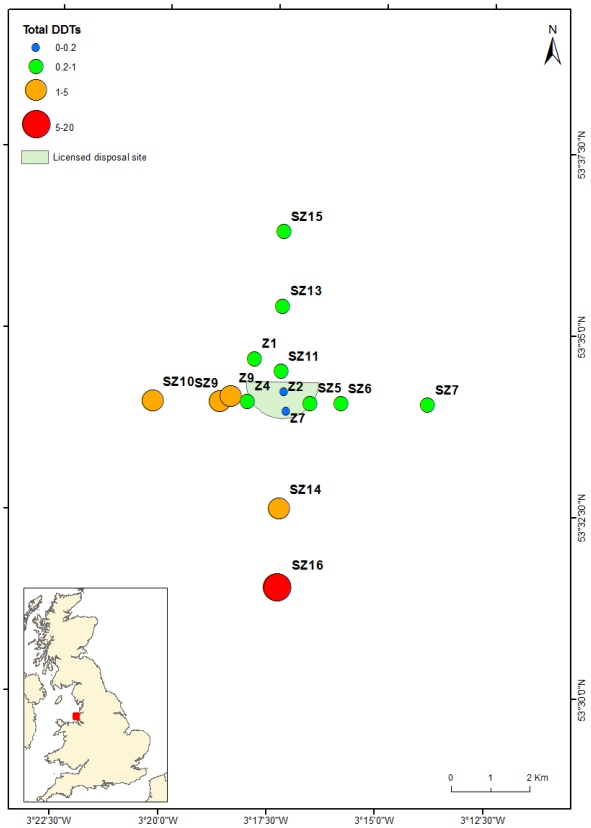

Figure A1.5.7. ∑ $_6$DDTs concentrations for the Site Z Stations, 2014.

At Site Z, BDEs were detected at nine stations (∑ 11 BDEs range <0.075-0.965 µg/kg dw). The highest concentrations, 0.965 and 0.939 µg/kg dw, were at stations SZ16 and SZ14 to the south of the disposal site (Figure A1.5.8). ∑ 11 BDEs concentrations were <0.3 µg/kg dw at all other stations apart from SZ10, SZ9 and Z9 where concentrations of 0.846, 0.333 and 0.304 µg/kg dw, respectively, were measured. Levels at all stations within the disposal site were low. BDE47 and BDE99 are the dominant congeners present, indicative of the pentaBDE technical mixture, but BDE183 was also detected, suggesting that the octaBDE or decaBDE technical mixture was also in use.

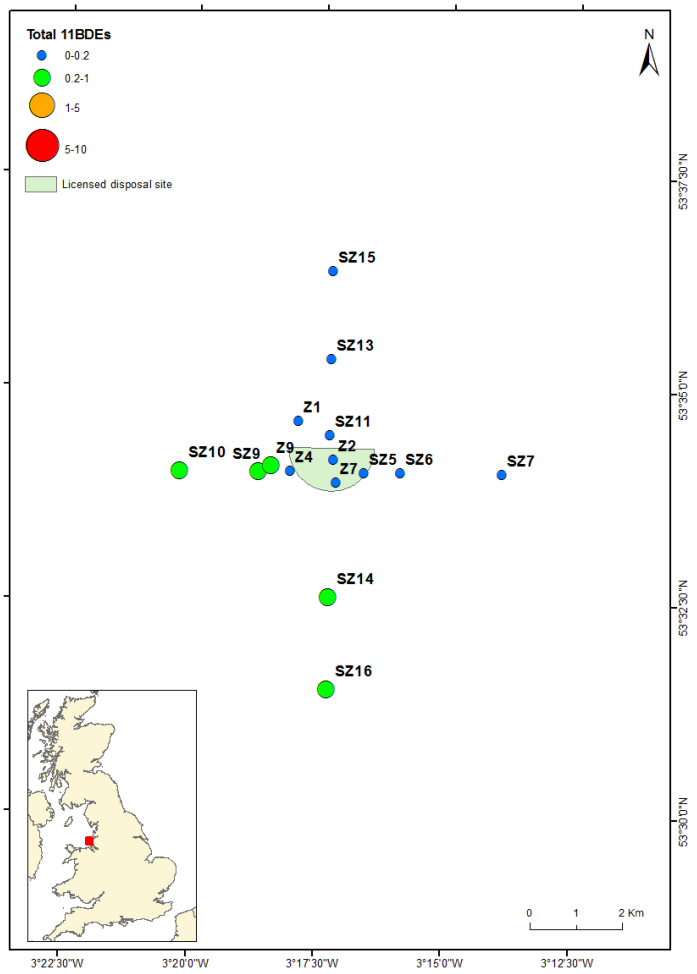

Figure A1.5.8. ∑ 11 BDEs concentrations for the Site Z Stations, 2014.

BDE209 was detected in all 16 stations at Site Z, making it the most ubiquitous contaminant analysed (range 0.49-363 µg/kg dw; Figure A1.5.9). BDE209 made up >88% of total 12 BDEs at all stations apart from Z7 (range 74-96%). Highest concentrations were at stations SZ16, SZ9 and Z9, all south or west of the disposal site, with values of 336, 182 and 153 µg/kg dw. High values of 207, 232 and 111 µg/kg dw were also present at stations Z9, SZ9 and SZ10 to the west of the disposal site.

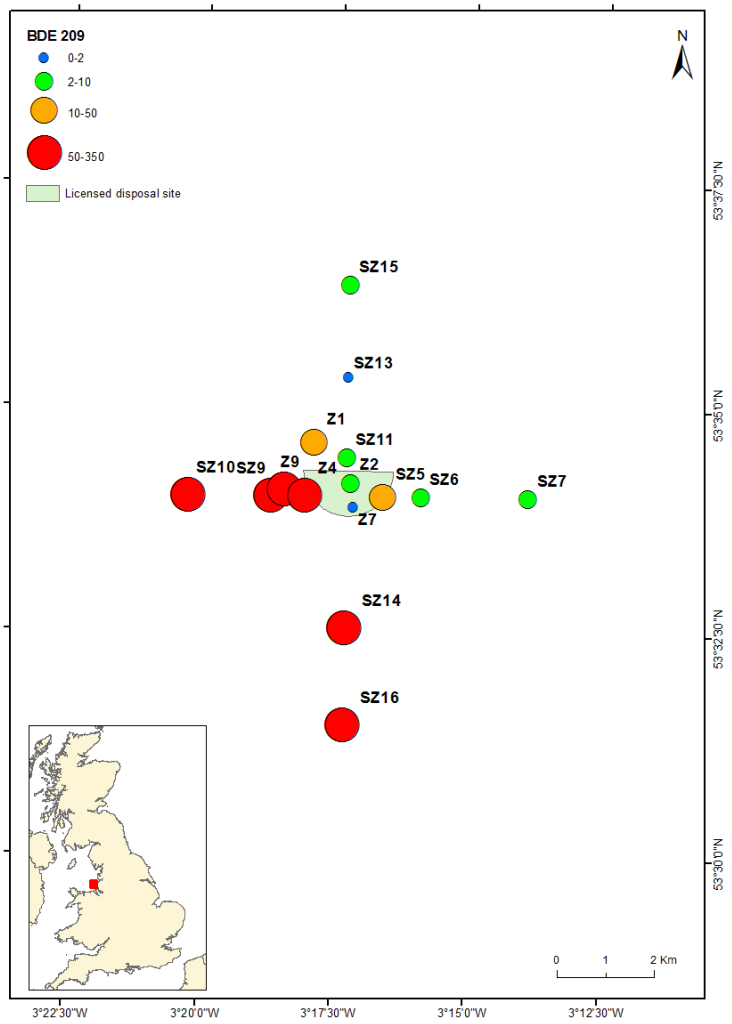

Figure A1.5.9. BDE209 concentrations for the Site Z Stations, 2014.

Concentrations of CBs and dieldrin at all stations were below Cefas action level 1. ∑ 6DDTs concentrations were above Cefas action level 1 at five out of the 16 stations. No Cefas action levels exist for BDEs including BDE209. According to the OSPAR guidelines, five stations had 'good' environmental status for all ICES 7 CBs and 'good' status overall. Exceptions with one CB with 'bad' environmental status but 'good' status overall were SZ6, SZ7, SZ10, SZ14, Z1 and Z4 (for CB118). Station SZ11, SZ16, SZ9 and Z9 had 'bad' environmental status for CB28 and CB118 and therefore 'bad' status overall. No OSPAR guidelines exist for BDEs at present.

There are data available for a subset of the Site Z stations between 2002 and 2013 with which to compare CB, OCP and BDE concentrations, and from 2010 for BDE209 concentration comparisons (Tables A1.5.3-A1.5.6). For CBs, stations either showed consistent concentrations with previous years or a decline, with the exception of SZ9 (to the west of the disposal site) which has increased over the last 3 sampling years. As is seen for CBs, DDT levels are similar to or lower than those measured previously. Again, for BDEs, stations either showed consistent concentrations with previous years or a decline, with the exception of SZ14 to the south of the disposal site

which has increased over the last 3 sampling years. BDE209 concentrations are similar to or lower than those measured previously, but remain some of the highest measured in UK marine sediments.

Table A1.5.3. Temporal trends (2002-2014) of ∑ICES 7 CBs concentration (in µg/kg) at Site Z in the stations sampled during 2014.

Station	∑ICES 7 CBs concentration (in µg/kg)								
	2002	2003	~	2006	~	2010	~	2013	2014
SZ16						5.2		3.46	4.99
SZ4				1.13		*0.7*			
Z3	*0.7*	*0.7*		1.22		*0.7*			
SZ12						*0.7*			
SZ10						0.91		0.92	1.69
SZ9						1.44		2.68	5.85
Z9	2.07	*2.48*		2.57		1.06		3.16	2.61
Z4	1.56					0.99			0.952
SZ15						*0.7*		*0.7*	0.124
SZ13						*0.7*		*0.7*	0.160
Z1		*0.7*		1.14		*0.7*		*0.7*	0.811
SZ11						*0.7*			0.767
Z2	*0.7*			0.81		*0.7*			0.178
SZ14						0.9		2.59	1.98
SZ1						0.81		*0.7*	
Z7	*0.7*			2.4		0.84		0.82	0.151
SZ3						*0.7*			
SZ5						*0.7*		*0.7*	0.274
Z6	*0.7*	*0.7*		0.7		*0.7*			
SZ6						*0.7*			0.275
SZ2						*0.7*		*0.7*	
SZ7						*0.7*		*0.7*	0.223
SZ8						*0.7*			

Concentrations in italic represent estimates of concentrations for samples where all ICES 7 congener concentrations were below LODs. Limits of detection for CBs improved between 2013 and 2014, therefore values assigned to congeners below LOD are lower from 2014 onwards and, resulting in a step decrease in ∑ICES7 CBs concentration for samples with congeners below LODs.

Table A1.5.4. Temporal trends (2002-2014) of ∑$_3$DDTs concentration (in µg/kg) at Site Z in the stations sampled during 2014.

Station	∑$_3$DDTs concentration (in µg/kg) (except [a])								
	2002	2003	~	2006	~	2010	~	2014	2014[a]
SZ16						2.76		3.53	5.21
SZ4						*0.3*			
Z3	1.63	0.86		0.80		0.49			
SZ12						0.48			
SZ10						0.76		1.10	1.49
SZ9						0.90		2.01	2.69
Z9	2.04	2.34		1.83		1.06		2.02	2.6
Z4	2.25			0.58		0.77		0.674	0.875
SZ15						*0.3*		0.164	0.234
SZ13						0.46		0.185	0.326
Z1		0.76		0.55		0.60		0.463	0.668
SZ11						0.46		0.262	0.411
Z2	0.81			0.40		*0.3*		0.090	0.160
SZ14						1.03		1.04	1.47
SZ1						*0.3*			
Z7	1.42			1.61		0.47		*0.07*	*0.14*
SZ3						*0.3*			
SZ5						0.51		0.140	0.244
Z6	0.78	0.57		0.3		0.54			
SZ6						0.54		0.174	0.274
SZ2						*0.3*			
SZ7						*0.3*		0.118	0.239
SZ8						0.54			

a ∑6DDTs includes *o,p'*-DDE, *o,p'*-TDE and *o,p'*-DDT in addition to *p,p'*-DDE, *p,p'*-TDE and *p,p'*-DDT in ∑3DDTs

Table A1.5.5. Temporal trends (2003-2014) of ∑11 BDEs concentration (in µg/kg dw) at Site Z in the stations sampled during 2014.

Station	∑ 11 BDEs concentration (in µg/kg dw)							
	2003	~	2006	~	2010	~	2013	2014
SZ16					1.95		0.627	0.965
SZ4					*0.11*			
Z3	0.71		*0.69*		0.18			
SZ12					0.93			
SZ10					0.75		0.273	0.846
SZ9					1.49		0.645	0.333
Z9	0.75		1.58		0.23		0.33	0.304
Z4			*0.69*		0.20			0.151
SZ15					*0.11*		*0.11*	*0.0750*
SZ13					*0.11*		*0.11*	0.0775
Z1	*0.69*		*0.69*		0.13		*0.11*	0.153
SZ11					*0.11*			0.109
Z2			*0.69*		*0.11*			*0.0750*
SZ14					*0.11*		0.593	0.939
SZ1					0.31		0.292	
Z7			0.79		*0.11*		0.185	*0.0750*
SZ3					*0.11*			
SZ5					*0.11*		*0.11*	*0.0750*
Z6	*0.69*		*0.69*		*0.11*			
SZ6					*0.11*		*0.11*	*0.0750*
SZ2					*0.11*		*0.11*	
SZ7					*0.11*		*0.11*	*0.0750*
SZ8					*0.11*			

Concentrations in italic represent estimates of concentrations for samples where all 11 BDEs congener concentrations were below LODs. Limits of detection for BDEs improved between 2007 and 2008 and between 2013 and 2014, therefore values assigned to congeners below LOD are lower from 2008 onwards and from 2013 onwards, resulting in a two-step decrease in ∑11 BDEs concentration for samples with congeners below LODs.

Table A1.5.6. Temporal trends (2010-2014) of BDE209 concentration (in µg/kg dw) at Site Z in the stations sampled during 2014.

Station	BDE209 concentration (in µg/kg dw)			
	2010	~	2013	2014
SZ16	302		303	336
SZ4	0.899			
Z3	15.9			
SZ12	15.6			
SZ10	79.0		111	101
SZ9	94.7		232	182
Z9	102		207	153
Z4	73.5			61.8
SZ15	3.51		2.05	2.28
SZ13	0.822		0.66	1.25
Z1	35.6		7.59	28.5
SZ11	5.59			8.71
Z2	1.26		0.753	3.47
SZ14	112		249	125
SZ1	1.56		18.7	
Z7	4.52		75.3	0.49
SZ3	*0.05*			
SZ5	*0.05*		81.7	10.6
Z6	1.17			
SZ6	11.1		4.04	5.72
SZ2	*0.05*			
SZ7	*0.05*		0.478	6.38
SZ8	3.68			

1.5.3.3.3 Trace metals

During the 2014 survey, sediments from 15 of the stations sampled were processed for trace metals, and their enrichment according to both regional baseline and OSPAR BACs values are presented in Figure A1.5.10. Arsenic is either slightly or not enriched with both assessments, although there are more slightly enriched stations with the baseline approach than with the OSPAR BAC assessment. All stations are slightly enriched for Cd, with a higher degree of enrichment for SZ5 and Z7 (both located within the disposal site). Cu is slightly enriched at most stations except for the northerly station (SZ15) while no enrichment is depicted for all the other stations using the OSPAR BAC approach. This enrichment is less pronounced with the baseline assessment.

As per 2013's survey, Hg concentrations are generally more elevated than the OSPAR BAC making sediments of the Site Z area particularly enriched in Hg. When using baseline approach, the degree of enrichment is less pronounced, however, most stations remain moderately enriched, with station SZ5 still depicting very levels of Hg when compared to the baseline value. Although a decrease in Hg concentration was observed at stations outside the disposal site from 2010 to 2013, levels of this trace element increased in 2014 (Figure A1.5.11).

Slight enrichment is observed for all stations with the OSPAR BAC approach for Ni while no enrichment was depicted when assessing against the regional baseline value, except for the three most easterly stations where

slight enrichment is observed. Pb enrichment is moderate for all stations when assessed against OSPAR BAC, this enrichment is reduced using the baseline value approach.

When assessment was conducted using the OSPAR BAC approach, Zn and Cr show a slight enrichment for most stations situated north and west of the disposal site, whereas stations located within and east of the disposal site are moderately enriched. Enrichment is less according to the regional baseline method.

The temporal data presented in Figure A1.5.11 indicate that, for sediments within the disposal site, trace metals concentrations in 2014 were generally comparable with those observed in 2010, although concentrations for most showed a reduction in 2013. The exceptions to this are Cd and Cu which display a continuing decrease in concentrations since 2010 while Rb has increased during this period. The temporal changes in metals concentrations outside the disposal site are somewhat different from those inside, although this might partly result from the availability of earlier data (2006) which provides a different starting point for such comparisons. Concentrations outside the disposal site have generally decreased since 2006 for most metals to varying degrees (Figure A1.5.11).

Figure A1.5.10. Enrichment to regional baseline values (left) and OSPAR BACs values (right) for trace metals concentrations sampled at Site Z, 2014.

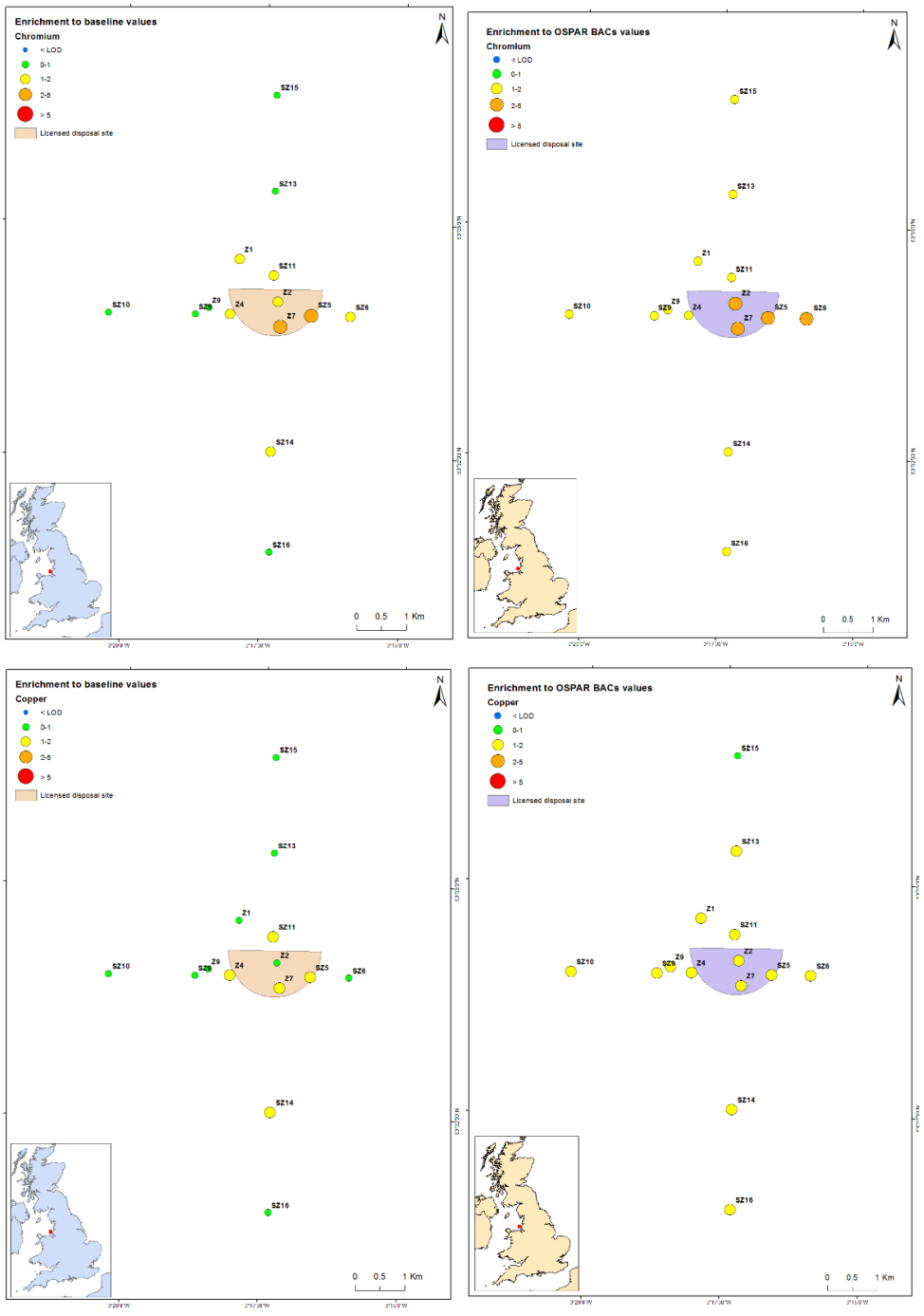

Figure A1.5.10. Continued.

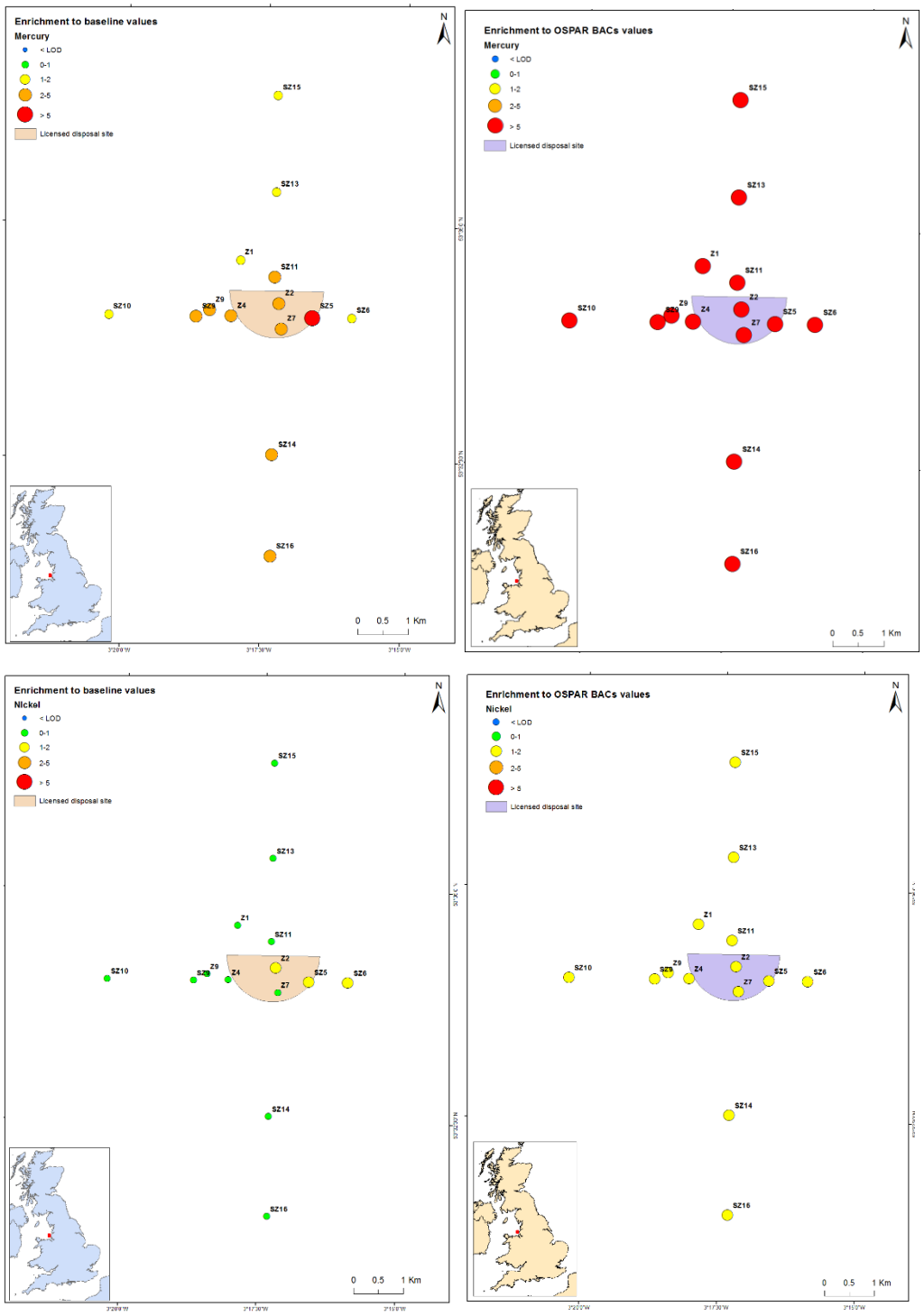

Figure A1.5.10. Continued.

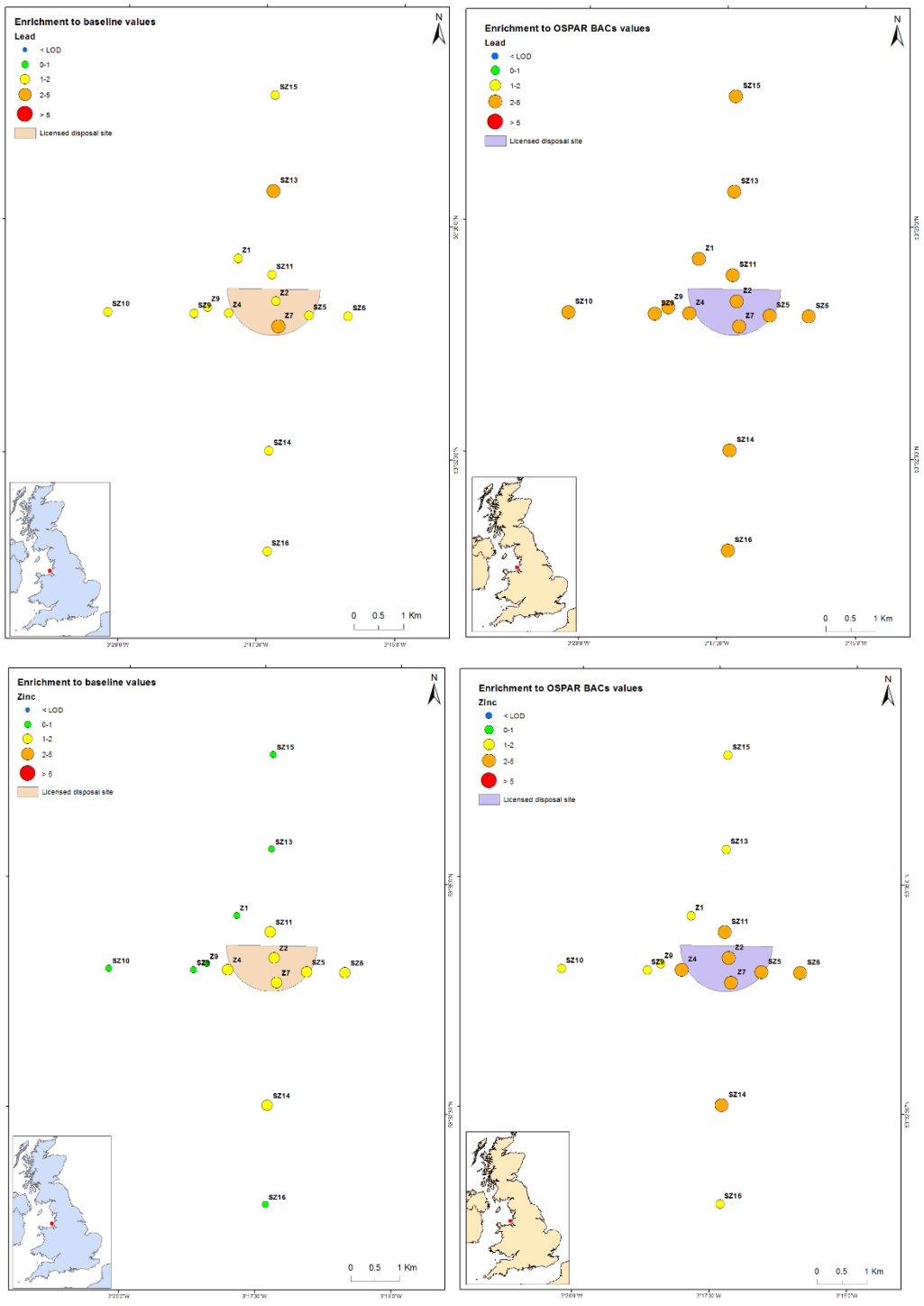

Figure A1.5.10. Continued.

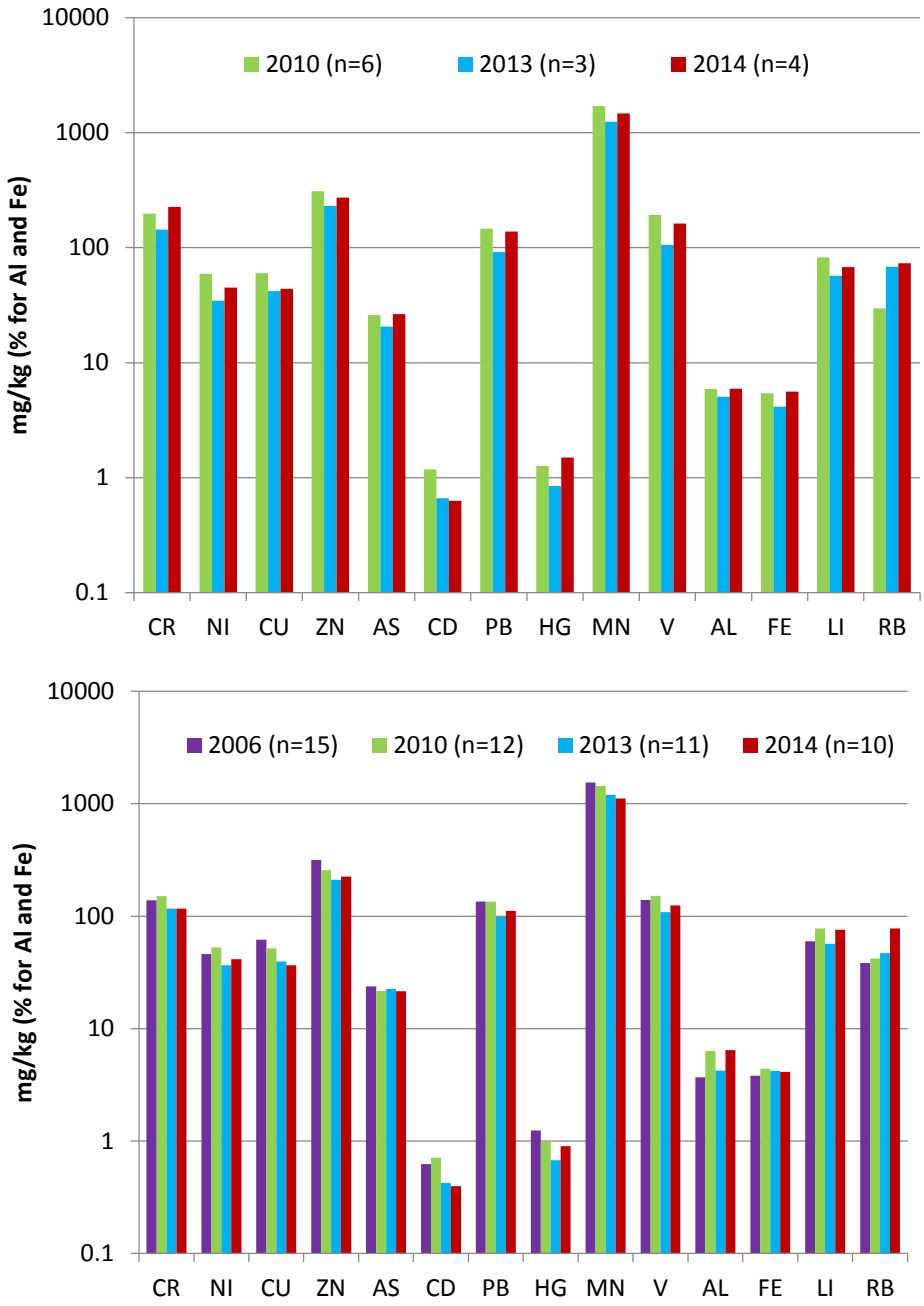

Figure A1.5.11. Site Z trace metals temporal data, 2006, 2010, 2013 and 2014. Data for stations within the disposal site (top) and for those outside the disposal site (bottom) are presented separately. n indicates the number of samples used in the assessment.

Appendix 2. Assessment methods for sediment contaminants

2.1 PAHs

2.1.1 Methodology

Sediment samples, collected in glass jars, were frozen immediately after collection and not defrosted until required for analysis. Each homogenised wet sediment sample was extracted using alkaline saponification followed by liquid/liquid extraction. A sample of sediment was taken for a total solids determination as all results are reported on a dry weight (DW) basis. The sample extract was then passed through an alumina chromatography column in order to remove polar compounds, concentrated to 1 ml and sealed in a vial. A suite of alkylated and parent PAH were then determined using coupled gas chromatography/mass spectrometry (GC/MS). Quantification was by means of deuterated internal standards added prior to digestion, with analytical quality control samples being run within each sample batch. Full details can be found in Kelly et al. (2000).

2.1.2 Method used for assessment

Cefas currently has action level limits for contaminants such as trace elements and PCBs but none currently exist for PAHs. Reviews of what has been investigated in other countries has indicated that the most promising of the currently available co-occurrence methods is the Effects Range Low/Effects Range Median (ERL/ERM) methodology which is founded on a large database of sediment toxicity and benthic community information (Long et al., 1998).

The ERL/ERM methodology derives SQGs representing, respectively, the 10^{th} and 50^{th} percentiles of the effects dataset and can be derived for individual PAH compounds. In a regulatory context, where SQGs are to be used as informal (non-regulatory) benchmarks to aid in the interpretation of sediment chemistry (Long et al., 1998), this becomes complicated where a large number for individual PAH are determined, as is usually the case. This has led to separate ERL/ERM derived SQGs being set for “Low molecular weight PAHs” and “High molecular weight PAHs”. In this context;

LMW PAHs include 2- and 3-ring PAH compounds;

- Naphthalene
- monomethyl naphthalenes
- acenaphthene
- acenaphthylene
- fluorine
- phenanthrene
- anthracene

HMW PAHs include the 4- and 5-ring PAH compounds;

- fluoranthene
- pyrene

- benz[*a*]anthracene
- chrysene
- benzo[*a*]pyrene
- dibenz[*a,h*]anthracene

Although a wider suite of PAH is determined routinely for both licensing and monitoring purposes, these can be considered as toxicity markers for the PAH as a whole. The ERL and ERM concentrations applied are given in Table A2.1.1.

Table A2.1.1. ERL and ERM concentrations for LMW and HMW PAHs in sediments. The limits for LMW PAH are lower than those for HMW PAH as they carry a higher acute toxicity.

PAH compounds	**ERL** (μg kg^{-1} DW)	**ERM** (μg kg^{-1} DW)
LMW PAH	552	3,160
HMW PAH	1,700	9,600

2.2 Organohalogens

2.2.1 Sample extraction

Sediment samples were air dried and sieved (<2mm) in a controlled environment. 10 g of dried sediment were mixed with sodium sulphate, transferred to a glass Soxhlet thimble and topped with 1 cm of sodium sulphate. $^{13}C_{12}$-labelled BDE209, HCB, alpha-HCH, gamma-HCH, *p,p'*-DDT, CB28, CB52, CB101, CB118, CB138, CB153 and CB180 was added as internal recovery standard to all samples prior to the extraction step. Samples were extracted over a 6 h period using 50:50 iso-hexane:acetone, with an average of 9 - 10 cycles h^{-1}. Sulphur residues were removed at this stage with copper filings.

2.2.2 Sample extract clean-up

An aliquot of the Soxhlet extract was cleaned up and using alumina (5% deactivated) columns. The elute contained polychlorinated biphenyls (PCBs), organochlorine pesticides (OCPs) and polybrominated diphenylethers (PBDEs).

2.2.3 Analysis of PCBs and OCPs by GC-MS/MS

After addition of internal standard CB53 and CB112, PCB and OCP concentrations were determined with an Agilent 7890A GC coupled with 7000 QQQ-MS/MS in positive electron impact mode (ESI+). The separation of analytes was performed using two 25.0 m × 200 μm, 0.33-μm-film-thickness DB-5 capillary columns (J&W) with a backflush system installed. The carrier gas and collision gas were helium (1.4ml/min) and nitrogen (1.5ml/min), respectively. The initial oven temperature was 90°C, held for 2.00min, then increased to 165°C at 15°C/min, to 285°C at 2°C/min, to 310°C at 40°C/min and finally held for 10 min, with the column backflush instigated when

the oven reached 285°C (total run time 71.7 mins). The injector temperature, ion source and quadrupole temperatures were 270°C, 280°C and 150°C, respectively. A 1-µl extract was injected in pulsed-splitless mode with a purge time of 2 min.

2.2.4 Analysis of PBDEs by GC-MS/MS

After addition of internal standard CB200, PBDE concentrations were determined with a Shimadzu 2010plus GC with TQ8030 QQQ-MS/MS in positive electron impact mode (ESI+). The separation of analytes was performed on a 15.0 m × 250 µm, 0.15-µm-film-thickness Rtx-1614 capillary column (Restek). The carrier gas was helium (1.28ml/min) and the collision gas was argon. The initial oven temperature was 120°C, held for 1.00min, then increased to 275°C at 15°C/min, to 300°C at 50°C/min, and finally held for 5 min. The injector temperature and source temperature was 340°C and 230°C, respectively. A 2-µl extract was injected in pulsed-splitless mode with a purge time of 2 min.

2.2.5 Analysis of BDE209 by GC-MS

BDE209 concentrations were determined with an Agilent 6890 GC with 5973 MS in NCI mode. The separation of analytes was performed on a 15.0 m x 250 µm, 0.1-µm-film-thickness DB-1 capillary column (J&W). The carrier gas was helium (1.3ml/min constant flow, average velocity 59 cm/s) and the reagent gas was methane (40 psi). The initial oven temperature was 90°C, held for 1.00min, then increased to 200°C at 25°C/min, to 295°C at 10°C/min, and finally held for 20 min. The injector temperature and detector temperature was 250°C and 200°C, respectively. A 2-µl extract was injected in pulsed splitless mode with a 20psi pulse until 1 min and a purge time of 2 min.

2.2.6 Quantitation methods

The identification of PCBs and OCPs was based on the retention time of individual standards in the calibration mixtures. Quantitation was performed using internal standards and 9 calibration levels (range 0.1 – 200 ng/ml). The combined PCB and OCP standard solutions contained the following 41 compounds in iso-octane: Hexachlorobenzene; hexachlorobutadiene, alpha-HCH, beta-HCH, gamma-HCH, *p,p'*-DDE, *p,p'*-TDE, *p,p'*-DDT, *o,p'*-DDE, *o,p'*-TDE, *o,p'*-DDT, dieldrin, heptachlor, heptachlor epoxide, endosulfan-I, endosulfan-II, endosulfan sulfate; IUPAC CB101; IUPAC CB105; IUPAC CB110; IUPAC CB118; IUPAC CB128; IUPAC CB138; IUPAC CB141; IUPAC CB149; IUPAC CB151; IUPAC CB153; IUPAC CB156; IUPAC CB158; IUPAC CB170; IUPAC CB18; IUPAC CB180; IUPAC CB183; IUPAC CB187; IUPAC CB194; IUPAC CB28; IUPAC CB31; IUPAC CB44; IUPAC CB47; IUPAC CB49; IUPAC CB52; IUPAC CB66. Concentrations were corrected for the recovery of the $^{13}C_{12}$ labelled recovery standards.

Quantitation for PBDEs was performed using internal standards and 10 calibration levels (range 0.05 – 100 ng/ml). The PBDE standard solutions contained the following 11 compounds in iso-octane: IUPAC BDE17; IUPAC BDE28; IUPAC BDE47; IUPAC BDE66; IUPAC BDE100; IUPAC BDE99; IUPAC BDE85; IUPAC BDE154; IUPAC BDE153; IUPAC BDE138; IUPAC BDE183; plus an additional 13 compounds: IUPAC BDE3; IUPAC BDE7; IUPAC BDE15; IUPAC

BDE49; IUPAC BDE71; IUPAC BDE77; IUPAC BDE119; IUPAC BDE126; IUPAC BDE156; IUPAC BDE184; IUPAC BDE191; IUPAC BDE196; IUPAC BDE197; together with the internal standard IUPAC CB200 and recovery standards F-BDE69 and F-BDE-160. Concentrations were corrected for the recovery of the F-BDE recovery standards.

Quantitation of BDE209 was performed using an internal standard and 7 calibration levels (range 0.5 – 500 ng/ml). The BDE209 standard solutions contained IUPAC BDE209 in iso-octane, plus an additional 3 compounds IUPAC BDE206; IUPAC BDE207; IUPAC BDE208; together with the internal standard $^{13}C_{12}$- labelled IUPAC BDE209.

2.2.7 Quality assurance/ quality control procedures

AQC procedures included reagents purification, method blanks, and use of control charts created from repeated analysis of the NIST-1944 Certified Reference Material (CRM) and Quasimeme CEMP-245 materials.

2.2.8 Method used for assessment

PCB, OCP and BDE concentrations were determined in the sediments and reported on a dry weight basis. The ∑ICES 7 CBs (CB28, CB52, CB118, CB153, CB138, CB170, CB183), and the sum of all 25 measured CBs (∑CBs) were calculated, together with ∑DDTs (*p,p'*-DDE, *p,p'*-TDE, *p,p'*-DDT, *o,p'*-DDE, *o,p'*-TDE, *o,p'*-DDT). Where individual congener concentrations were below the limit of detection (LOD) of 0.01 µg/kg, a value of half the LOD was inserted for calculation of summed concentrations. The ∑11 BDEs were calculated. Where individual congener concentrations were below the LOD of 0.02 µg/kg, a value of half the LOD was inserted for calculation of summed concentrations. For samples analysed prior to 2015, a different LOD applied, resulting in higher values substituted for congeners below LODs. The congener patterns were evaluated, with BDE183 a marker constituent of the octa-BDE technical mix, and the other BDEs constituents of the penta-BDE technical mix. Additionally, BDE209 ("Deca BDE") concentrations were calculated. Where BDE209 concentrations were below the LOD of 0.1 µg/kg, a value of half the LOD was inserted.

The Total Organic Carbon (TOC) content in the <2 mm fraction determined at a number of representative sampling stations was used to additionally calculate the contaminant concentration normalised to 2.5% TOC content. The TOC data from the representative stations was used to estimate the TOC content at adjacent stations for which this value was lacking.

Concentrations of PCBs and OCPs in the sediment were compared with various action limits, to investigate whether any adverse effects in benthic biota were likely to expected as a consequence of their presence. There are no action limits available to compare PBDE concentrations with at the present. Concentrations are expressed on a dry weight basis unless otherwise stated.

The current Cefas action limits for dredge disposal are: PCBs Action level 1 if ∑ICES7 CBs > 10 µg/kg or ∑CBs > 20 µg/kg and action levels 2 if ∑CBs > 200 µg/kg; OCPs Action level 1 if ∑DDTs > 1 µg/kg, dieldrin > 1 µg/kg, no Action level 2 for either ∑DDTs or dieldrin. Concentrations are expressed on a dry weight basis.

OSPAR in Charting Progress2 (CP2) have set criteria for Background Assessment Concentrations (BAC) and Environmental Assessment Concentrations (EAC) for the ICES7 CBs in sediments (see Table A2.2.1). Concentrations are expressed in µg/kg dry weight normalised to 2.5% organic carbon. Concentrations below BACs would be considered to have high environmental status. Concentrations significantly below EACs could be considered to have good environmental status and those above, bad environmental status. The station is deemed to have 'bad' environmental status if 'bad' status occurs for more than one ICES7 CB congener.

Table A2.2.1. OSPAR assessment criteria for CBs in sediment from CP2.

Sediment (µg/kg dry weight, normalised to 2.5% TOC)		
Compound	**BAC**	**EAC**
CB28	0.22	1.7
CB52	0.12	2.7
CB101	0.14	3.0
CB118	0.17	0.6
CB138	0.15	7.9
CB153	0.19	40
CB180	0.10	12

2.3 Trace Metals

2.3.1 Methodology

The sediment samples were collected in plastic bags and were frozen immediately after collection. The samples were collected for PSA and metal analyses on the <63µm fraction. Details on obtaining the <63µm sediment fraction can be found in the Particle Size Analysis technical report.

The sample is digested in a mixture of hydrofluoric, hydrochloric and nitric acids using enclosed vessel microwave, the digest is made up in 1% nitric acid and further diluted prior to analysis by Inductively Coupled Plasma-Mass Spectrometry (ICP-MS) and Inductively Coupled Plasma-Mass Spectroscopy (ICP-AES). Quantification of Al, As, Cd, Cr, Cu, Fe, Li, Mn, Ni, Pb, Rb and Zn is done using external calibration with Indium as internal standard. A certified reference material is run within each sample batch for quality control. Results are reported in mg kg^{-1} (ppm).

Some samples contained insufficient silt/clay (<63µm) for trace metals determination. Values lower than the detection limits were omitted from the dataset. This is because several detection limits were higher than real values, causing spurious elevations.

2.3.2 Numerical assessments

2.3.2.1 Raw data

Two approaches were carried out on the raw data:

1. Data comparison between the stations located inside the disposal sites and those that are situated outside the disposal site. The average concentration is obtained over a number of years and sites to allow data comparison. This data is averaged and so might not reflect the true observed trend for individual stations.
2. Temporal trend is also assessed for stations within the disposal sites and outside the disposal site. The average concentration is calculated for each year to carry out temporal trend analysis.

2.3.2.2 Enrichment factors

In order to assess relative level of trace metal contamination for a sampled station, enrichment to a baseline is required. This report presents two assessment methods; (i) comparisons with OSPAR Background Assessment Concentrations (BACs) as in previous reports, and (ii) comparisons with regional baseline concentrations.

Enrichment ratio is defined as:

$$\frac{\text{Metal raw value}}{\text{OSPAR BAC or proposed baseline value}}$$

Enrichment is arbitrary defined in 4 levels:

0-1: no enrichment

1-2: slight enrichment

2-5: moderate enrichment

>5: high enrichment

The two assessment methods are detailed below (but refer to Cefas (2011) for a fuller explanation).

2.3.2.2.1 OSPAR BACs

OSPAR (BACs) are defined for Clean Seas Environment Monitoring Programme (CSEMP) assessment to determine temporal trends in concentrations (OSPAR, 2008). They are derived from Background Concentrations (BCs) which are based on concentrations recorded in 'pristine' areas.

Normalisation of metal concentrations is required to account for differences caused by different sediment types present in the area surveyed. Normalisation of the metal concentrations to 5% aluminium using a pivot point is completed to derive the OSPAR BACs, using pivot point data defined in the assessment manual for contaminants in sediment and biota (OSPAR, 2008). Aluminium and lithium are both commonly used to normalise metal concentrations. Correlations between all trace metals, at each site, were completed to determine the best normaliser to use.

For most sites, there were no clear correlations between the trace metals and correlations values of aluminium and lithium indicate that the relationship between the normaliser and trace metals was not strong enough to endorse the use of Al or Li for normalisation.

As trace metal concentrations used for in this study were measured on the fine fraction of sediment (<63µm), normalisation to some extent has already been completed, therefore all enrichment calculation were based on the raw data.

2.3.2.2.2 Regional baselines

The above-mentioned Background Concentrations (BCs) are based on concentrations recorded in 'pristine' areas. There is only one set of values assigned by OSPAR for the whole North Atlantic (http://www.ospar.org). However, trace metal concentrations are known to show regional variation in the UK, largely related to the variable geology around the coast and historical industrial activity in the early 19th Century which has caused localised elevated levels (Ridgeway et al, 2003; Rowlatt and Lovell, 1994; Cefas, 2005). Therefore, for assessing enrichments at disposal sites, Cefas have developed regional baselines utilising various spatial datasets around England and Wales. Recently, an extensive study was carried out on 8 regions defined in the Clean Seas and Environment Programme (CSEMP) (Figure A2.3.1) and the proposed metals baselines concentration derived from this study have additionally been used in this report as a validation tool to i/ compare with OSPAR BACs

values and ii/ to assess the credibility of using those proposed baselines values instead of the OSPAR BACs values when studying for metals enrichment. The proposed baselines for the areas are given in Table A2.3.1, along with the corresponding OSPAR BACs values for each metal (OSPAR, 2006).

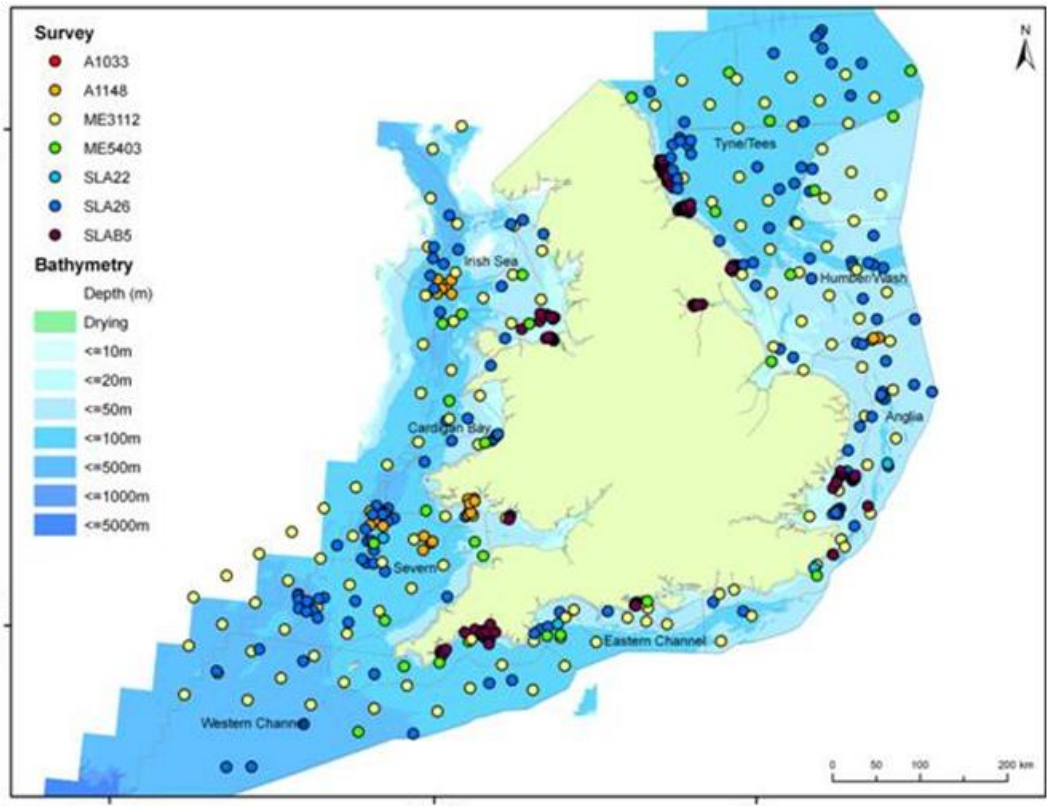

Figure A2.3.1. Location of stations sampled to provide metals data as part of the regional baseline approach.

Table A2.3.1. OSPAR BACs (in red) with proposed baselines for regions covered in disposal site assessment under C6794.

	As (mg/kg)	Cd (mg/kg)	Cr (mg/kg)	Cu (mg/kg)	Hg (mg/kg)	Ni (mg/kg)	Pb (mg/kg)	Zn (mg/kg)
Anglia	33	0.2	115	40	0.16	56	46	130
Cardigan Bay	26	0.29	103	26	0.12	44	73	145
Eastern Channel	23	0.18	90	26	0.12	31	45	107
Humber Wash	30	0.17	109	31	0.21	44	67	129
Irish Sea	21	0.29	115	38	0.43	47	77	240
Severn	21	0.2	81	27	0.1	36	47	135
Tyne/Tees	27	0.31	135	29	0.35	55	131	171
West Channel	34	0.19	105	72	0.77	50	108	153
OSPAC BAC	25	0.31	81	27	0.07	36	38	122

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