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Dredged Material Disposal Site Monitoring Round the Coast of England: Results of Sampling (2018-19)

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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 1.2) project (C6794 hereafter) round the coast of England during 2018-19.
- 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 predictions; 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.
- Six disposal sites were targeted for assessment during 2018-19; North Tyne, Sunderland and Whitby off the northeast coast of England, Nab Tower off the Isle of Wight, and Sprey Point and Plymouth Deep along the southwest coast.

Table of Contents

Tables

Figures

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 suitability of the dredged material for aquatic disposal 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' Science for Sustainable Marine Management (SSMM) 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 currently approximately 109 open sites (numerous sites are opened and closed every year) 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).

Although total quantities vary year to year, approximately 40 Mt (wet weight) are annually disposed to coastal sites around England. 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 project C6794 'Monitoring of dredged material disposal sites'

The dredged material disposal site monitoring project C6794, funded by the MMO, falls under a 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 around 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' SSMM team and the licensing team within the MMO. The scientific outcomes of the work undertaken within C6794 are circulated to the Cefas SSMM 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 2018-19, constitutes the 10th in the series. The previous reports 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 around 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 2018-19 are listed in Table 1.1. These sites were identified following consultation between Cefas' SSMM 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 2018-19.

Disposal site	Geographical location off English coast	Code
North Tyne	Northeast	TY070
Sunderland	Northeast	TY090
Whitby	Northeast	TY180
Nab Tower	South	WI060
Sprey Point	Southwest	PO070
Plymouth Deep	Southwest	PL035

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' SSMM 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., 2016a). The aims of this report are:

- to present the results of sampling undertaken during 2018-19 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 2018-19 results with those of previous years to provide a temporal assessment (see Bolam et al., 2009; 2011a; 2012a; 2012b; 2014b; 2015a; 2015b; 2016b; 2017 and 2018 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; 2015a; 2015b; 2016b; 2017; 2018), the main conclusions regarding each site are presented within Section 2 (below). More detailed scientific data (e.g., acoustic, sediment particle size, organic carbon, macrofauna, contaminants) for each site, together with their interpretation, are described in Appendix 1. For background information regarding each disposal site monitored, the reader is directed towards this appendix. The section pertaining to the Sprey Point disposal site represents a distillation of an advice minute submitted to the MMO earlier during the reporting year (December 2018) and, as such, its format slightly deviates from that of the other sites.

2 Conclusions and implications for further monitoring

The main findings of the monitoring undertaken during 2018-19 are presented within this section, 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 stakeholder concerns are all embraced within, and have a direct bearing on, the selection process for disposal site monitoring under this project. Thus, the recommendations for monitoring presented here for each site, although representing an important component of the decision-making process, may or may not be altered by other factors.

2.1 North Tyne (TY070)

The North Tyne dredged material disposal site has, over the years, received capital and maintenance dredgings, minestone mine-tailings and fly-ash from power stations. The material

destined for this site has occasionally been relatively contaminated in nature compared to pristine marine sediments; this is a legacy of the region's industrial background. Because of this, sampling at this site has been conducted under the auspices of C6794 for a number of years to provide intelligence of the contaminant concentrations, and that these remain within acceptable limits. This allows an assessment as to whether the screening process for determining the material's suitability for sea disposal functions as an appropriate barrier to excessive contamination of the disposal site.

The results of sampling during 2018 revealed that the sediments within and surrounding the North Tyne site are predominantly slightly gravelly muddy sands, and some mixed muddy sandy gravels, with organic carbon values (in the <63 µm fraction) from 3.6 to 4.7 % m/m. Total polycyclic aromatic hydrocarbons (PAHs), although considered to be 'elevated', showed a moderate decrease at eight of the 12 stations sampled compared with concentrations observed in 2013. All samples collected during 2018 exceeded the effects range low (ERL) for low molecular weight (LMW) PAHs, and those of eight stations exceeded the effects range median (ERM) for the LMW PAHs and the ERL high molecular weight (HMW) PAHs. This represents an increase from 2013 when three stations exceeded these latter two benchmarks.

Chlorobenzenes (CBs), brominated diphenyl ethers (BDEs) (including BDE209) and organochlorine pesticides (OCPs) hexachlorobenzene (HCB), plus dichlorodiphenyltrichloroethane (DDT) and metabolites were detected at all stations sampled. Concentrations of CBs at all stations were all below Cefas action level 1, as was dieldrin. Total DDT concentrations were above action level 1 at all but three stations. According to the OSPAR guidelines, all stations had 'good' environmental status for all ICES 7 CBs and 'good' status overall. Using the new OSPAR guidelines for BDEs, with the exception of BDE209, all stations were below the environmental assessment concentrations (EACs) for most congeners.

The metals concentrations observed at North Tyne were generally much higher than the OSPAR background assessment concentrations (BACs) especially for mercury and lead and, to a lesser extent, zinc. When assessed against the regional baseline values - which were derived considering regional variability - enrichment was still evident, but to a reduced level. Cadmium had a noticeably higher concentration inside the disposal site compared to outside, but no other elements display noticeably increased concentrations inside the site.

Based on the data acquired during 2018, and in conjunction with data previously obtained for North Tyne, Cefas would recommend that future sampling of contaminants concentrations be conducted in three- or four-years' time. The inclusion of sampling of the macrofaunal assemblages would also be recommended. This endorsement assumes that no significant changes to either the amount or nature of the material destined for North Tyne occurs. The data here imply that PAHs at the site remain a concern due to the exceedances of ERMs at a number of stations, thus, these contaminants should continually be monitored in dredged material testing during the licensing process.

2.2 Sunderland (TY090)

Sunderland dredged material disposal site is a small (0.8 km^2) area located approximately 4 km east off the northeast coast of England, off the coast of Sunderland, and in approximately 25 m water depth. The site receives material from the River Wear catchment, primarily *via* maintenance dredging activities of the Port of Sunderland. Routine sediment sampling for dredge applications has shown hydrocarbons (PAHs in particular) to be elevated beyond effects ranges (i.e. ERL, ERM) and, recently, shown evidence of high levels of lead (Pb). The site, and the areas of seabed within its immediate vicinity, has never been assessed for contaminants concentrations under C6794. Sampling at this site during 2018, therefore, aimed to provide a contemporary assessment of the sediment concentrations of PAHs, trace metals and organohalogens (OHs). These data allow an assessment of whether the current screening process and dredging and disposal practices result in acceptable concentrations at the receiving environment.

Sampling conducted at ten stations (four of which were inside the disposal site) revealed variable sediment types including sandy muds, with mixed sediments including gravels and sand. Organic carbon values ranged from 3.2 to 5.9 % m/m in the <63 µm fraction. Total PAH concentrations were observed to be elevated (in the tens of thousands of µg kg^{-1} dry weight (dw)) at all but one station. All samples collected at Sunderland during 2018 exceeded the ERL for LMW PAHs, and all but one station exceeded the ERM for the LMW PAHs. Furthermore, concentrations at six of the ten stations sampled exceeded the ERL for HMW PAHs.

All the stations sampled for OHs had sum ICES 7 CB concentrations above limit of detections (LODs), while BDEs, BDE209, the OCPs HCB, dieldrin, plus DDT and metabolites were also

detected at all stations. Concentrations of CBs and dieldrin were below Cefas action level 1. Total DDT concentrations were above Cefas action level 1 at all stations except one. According to the OSPAR guidelines, all stations had 'good' environmental status for all sum ICES 7 CBs, and 'good' status overall. According to the new OSPAR guidelines for BDEs, all stations were below the EACs for all congeners, although concentrations at two stations within the disposal site were close to the EAC for BDE209.

Metals concentrations at Sunderland tended to be much higher than those of the OSPAR BAC values, especially for mercury and lead. When assessed against the regional baseline concentrations, enrichment was still observed for lead (especially within the disposal site) but to a reduced level. Mercury displayed no enrichment against these regional baseline values. Cadmium and lead displayed a noticeably higher concentration inside the disposal site compared to outside.

Based on the data acquired during 2018, Cefas would recommend that future sampling of sediments within and surrounding the Sunderland site for contaminants concentrations be conducted in approximately five years' time. Particularly, the assessment of PAH concentrations, which have been witnessed to be elevated during 2018 and during subsequent survey efforts, should remain a priority. This recommendation assumes that no significant changes to either the amount or nature of the material destined for Sunderland arises. The data acquired for Sunderland imply that contaminants, notably PAHs, should continually be monitored in dredged material testing during the licensing process.

2.3 Whitby (TY180)

Whitby is a small (0.62 km^2) disposal site, located in approximately 40 m of water, 2.4 km off the northeast coast adjacent to the town of Whitby. This disposal site receives material dredged from the River Esk in Whitby, in particular from the Whitby Harbour maintenance dredging regime. Routine testing of the *in-situ* dredge material has shown a persistent presence of elevated hydrocarbon compounds in Whitby Harbour, particularly oil or coal derived PAHs (napthalenes and phenathrenes).

Akin to the situation for Sunderland, the sediment chemistry at the disposal site has not previously been ascertained and, therefore, it is not currently possible to evaluate any potential

impacts of disposal on sediment chemistry at the site. In view of this, sampling in 2018 targeted sediments within (four stations) and surrounding (seven stations) the disposal site which were analysed for PAHs and trace metals concentrations.

The resulting data revealed that the Whitby sediments were composed predominantly of muddy sands (slightly gravelly and gravelly), with slightly gravelly sands and muddy sandy gravels, with organic carbon values (<63 µm fraction) between 2.9 and 4.3 % m/m. PAHs were mostly in the thousands of µg kg $^{-1}$ dw, although two stations (one inside the disposal site) harboured concentrations in the tens of thousands of µg kg $^{-1}$ dw. All but one sample collected at Whitby exceeded the ERL for LMW PAHs, while two stations exceeded the ERM for LMW PAHs and the ERL for HMW PAHs.

Trace metals concentrations at Whitby tended to be noticeably higher than the OSPAR BAC values especially for mercury and lead. The station generally showing the greatest enrichments was to the northwest of the disposal site. When assessed against the regional baseline values, enrichment was still observed but to a reduced level relative to that for OSPAR BACs.

Based on the data acquired during 2018, Cefas would recommend that future sampling of sediments within and surrounding the Whitby site for contaminants concentrations be conducted in approximately five years' time. Particularly, the assessment of PAH concentrations during subsequent survey efforts should remain a priority, and the inclusion of organohalogens, which were not evaluated in 2018, would also be prudent. This recommendation assumes that no significant changes to either the amount or nature of the material destined for Whitby transpires. The data acquired for Whitby imply that contaminants, notably PAHs, should continually be monitored in dredged material testing during the licensing process.

2.4 Nab Tower (WI060)

Nab Tower is a heavily-used disposal site, located in 30 to 40 m of water and approximately 13 km southeast of Bembridge, Isle of Wight. 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.

Following a small number of large capital disposal campaigns, in 2017 the MMO commissioned ecological sampling under the auspices of C6794 (Bolam et al., 2018); the acquired data described the ecological conditions at the end of a recent large disposal. Sampling conducted during 2018 aimed to provide an assessment of the early ecological recovery from this large placement.

The sediment particle size data from the 16 stations sampled (four within the disposal site) revealed mixed and coarse sediment types, being predominantly muddy sandy gravel and sandy gravel. Organic carbon values ranged from 0.7 to 3.0 % m/m in the <63 µm fraction.

The acquired macrofaunal data contained several notable species including three non-native species (i.e. the amphipod *Monocorophium sextonae*, the Tufty-buff bryozoan *Tricellaria inopinata* and the Slipper limpet *Crepidula fornicata*) and four species which have not been formally recorded from the UK. The reef-building Ross worm *Sabellaria spinulosa* was also found although no conclusions can be made on the potential presence of reef around Nab Tower as this would require the additional collection of video and acoustic data.

There was a general trend of lower number of taxa, abundance and biomass at the stations within and close to the disposal site. Furthermore, the macrofaunal assemblages within the disposal site in 2018 were significantly different from those of the reference stations; a situation that is consistent with the situation previously observed in 2014 and 2017. The data imply that dredged material disposal is having an adverse effect on the benthic communities within the site.

The assessment of the macrofaunal data from 2018, in conjunction with data acquired from the same stations in 2014 and 2017, implies that the assemblages within the Nab Tower disposal site are consistently different from those outside the disposal site. No recovery from recent disposal activity is apparent. The altered assemblage structure inside the site is likely to result from the combined impacts of sporadic large, capital disposal campaigns and the ongoing, not insubstantial amounts of maintenance material placed. In view of this, Cefas would consider that sampling at this site in the near future is not warranted, and that the site be considered for the assessment of macrofaunal assemblages in *circa* five years' time.

2.5 Sprey Point (PO070)

Sprey Point is a small (approximately 100 m in diameter) disposal site located just northeast of the mouth of the Teign Estuary in South Devon. During 2017, the MMO licenced material from Exmouth Marina (licence L/2017/00034/1) to be disposed of to Sprey Point. However, concerns were later raised that the disposed material may potentially be responsible for oily sediments on the neighbouring beach. In response to this, the Exmouth Marina disposal licence was suspended, and work conducted under the auspices of C6794 during July 2018 focussed on assessing the sediment granulometry (particle size), contaminant concentration (focussing on PAHs) and visual appearance of the sediments along the intertidal foreshore.

The survey at Teignmouth Beach revealed no evidence of sediments that may be regarded as fine, black nor of an oily appearance. This conclusion is based on a full walk-over survey together with an analytical assessment of sediments taken from 10 stations across the foreshore. All sampled sediments were coarse (very low silt/clay), with very low organic carbon and PAH concentrations. Cefas recommend that repeat surveys are undertaken following any resumption of disposal of material from Exmouth Marina to Sprey Point.

2.6 Plymouth Deep (PL035)

Plymouth Deep is a recently-designated dredged material disposal site that was characterised to provide a sustainable site for receiving material resulting from dredging operations within the River Tamar and Plymouth Sound area. The licenced site, measuring 1.5 km by 1 km, is located in approximately 49 to 50 m water depth. The Western Channel Observatory L4 station, which represents a scientifically-important station providing one of the few examples where robust time-series data of both the pelagic and, increasingly benthic systems, is located near to Plymouth Deep. Thus, it is important to acquire empirical data to allow an assessment as to whether disposal at Plymouth Deep is affecting the ecological characteristics of the L4 site.

Replicated L4 benthic macrofaunal data from 2016 and 2017, acquired through sampling conducted by the Plymouth Marine Laboratory, were previously analysed under C6974. These data implied that no changes to either the univariate or multivariate taxonomic structure resulting from the disposal activity to date could be discerned (Bolam et al., 2018). However, the disposal regime at that time did not replicate the full disposal campaign licenced for

Plymouth Deep, and the amount of material placed represented a minor proportion of that licenced for the site during any one year. Thus, under this project, the L4 macrofaunal data from 2014 and 2016-2018 are assessed to evaluate whether the continued disposal of material during 2017-18 has resulted in any detectable change in macrofauna at L4.

The data from these four years present no evidence of a change in macrofaunal univariate metrics (e.g. abundance, biomass and number of taxa per sample, diversity) following the commencement of disposal activity. Values remain high from June 2017 (following the May disposal) for the remainder of that year, and metric values for 2018 appear to reproduce the seasonal changes observed during the two baseline years (2014 and 2016). Additionally, multivariate taxonomic structure of the L4 assemblages during 2018 does not appear to show any change from previous years, and no indication to any alteration to seasonal variability following the commencement of disposal activity is apparent. The composition of the assemblages during 2018 is comparable with those sampled during 2016 and 2017.

While the L4 data analysed to date under C6794 do not infer any impacts, Cefas consider that the data analysed hitherto offer a short-term assessment, representing only one year of full disposal activities (i.e. 2018). An analysis based on the inclusion of additional empirical data from 2019-20 would provide a more informed assessment as to the potential impacts of disposal on the macrofaunal assemblages at L4.

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Appendix 1: Results

1 North Tyne (TY070)

1.1 Background

Material disposed of to North Tyne is made up of predominantly silt and sand. In the past, the site has received capital and maintenance dredgings, minestone mine-tailings and fly-ash from power stations. An application for the disposal of significant quantities of capital material (up to 1.3 million wet tonnes) from the Tyne navigational channel and deepening of berths was licensed with disposal activity undertaken during 2011. Some material under this application was excluded from sea disposal; some used for land reclamation while the portion accepted for sea disposal was used to top up the cap at Souter Point (Bolam et al., 2014). A total of approximately 650, 000 t of material was disposed during that year which represented the largest annual amount since almost 900,000 t was disposed of in 2006 (Figure A1.1.1).

The relatively contaminated nature of the dredged material potentially destined for the North Tyne site is a result of the region's industrial background. For example, the mining industry has resulted in elevated levels of heavy metals, and historical ship-building on the Tyne, together with large volumes of shipping traffic in and out of the wharves, have contributed to a legacy of TBT and hydrocarbon contamination.

North Tyne was last sampled and assessed for sediment contaminants under C6794 (then SLAB5) in 2013 whereupon it was found that all samples exceeded the (effects range low) ERL for low molecular weight (LMW) PAHs, and samples from three stations exceeded the effects range median (ERM) for the LMW PAHs and the ERL high molecular weight (HMW) PAHs (Bolam et al., 2014). Regarding trace metals, enrichment relative to regional baseline concentrations was observed for a number of metals, especially for mercury, cadmium and zinc. The study concluded that future monitoring at North Tyne should continue, focussing primarily on assessing concentrations of PAHs, OHs and trace metals.

Sampling at this site under C6794 during 2018 aimed, in accordance with such guidance, to provide a contemporary assessment of the concentrations of these chemicals within and surrounding the disposal site. Sampling was conducted at stations previously sampled allowing

an assessment of temporal trends in chemical concentrations (Figure A1.1.2). Samples were collected at 12 stations with NT3, NT4, NT12 and NT13 located within the disposal site.

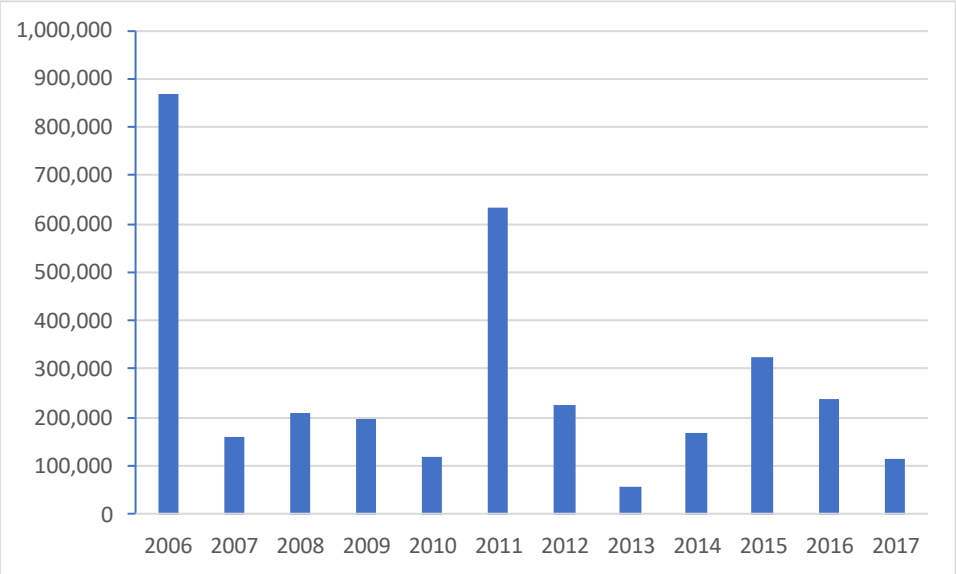


Figure A1.1.1: Annual tonnages of dredged material (in t wet weight) disposed to TY070 in recent years. Average annual tonnage disposed during this period is 275,792 t.

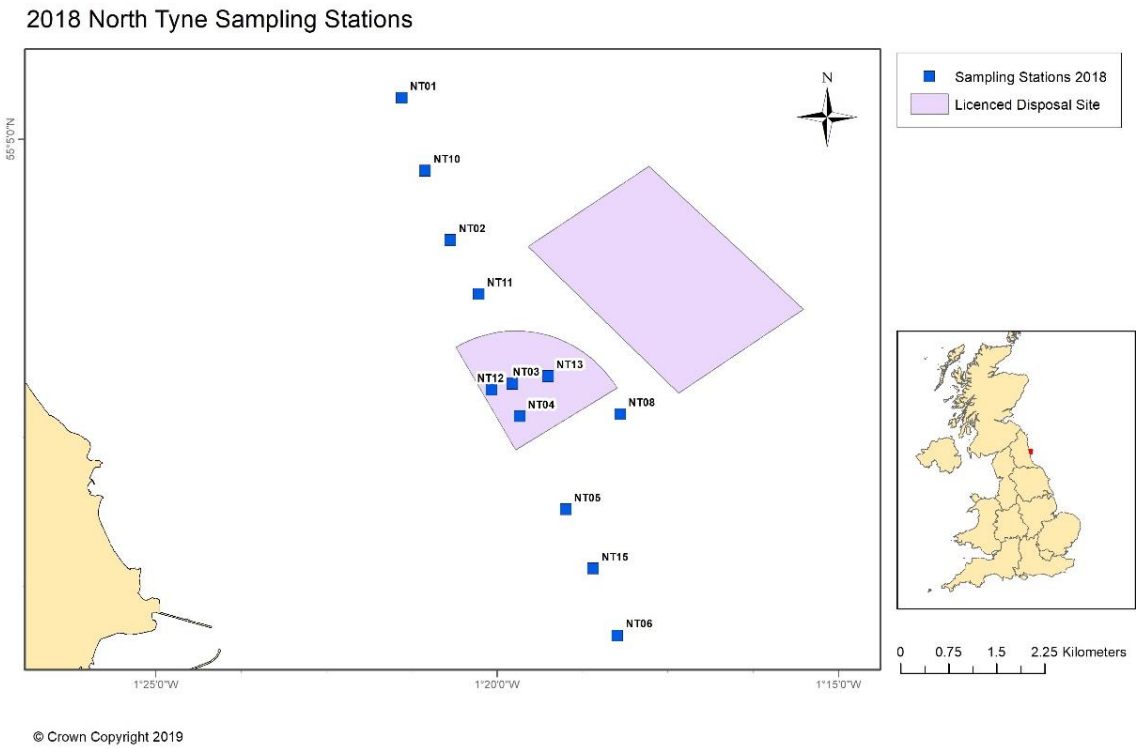


Figure A1.1.2: Stations sampled at North Tyne (cone-shaped), 2018. The site to the immediate northeast of North Tyne is the closed Howden Area disposal site.

1.2 Results

1.2.1 Sediment Particle Size

North Tyne sediments are predominantly slightly gravelly muddy sands, and some mixed muddy sandy gravels (Table A1.1.1). In order to conduct temporal comparisons, the sediment particle size data (PSD) for all the results collected at each station were grouped using Entropy, a non-hierarchal clustering method that groups sediments based on their full distribution. EntropyMax is a Windows-based software that groups large matrices of PSD data sets into a finite number of groups. It is described in more detail by Stewart et al. (2009). Four sediment groups were derived based on the 2018 data, using a comparable methodology, which while similar to those in previous years, have one less sediment group overall. Sediment group NT1 contains sediments with the highest levels of mud, while NT2, NT3 and NT4 have similar amounts of mud, but being dominated by different sediment types (NT2 – fine/very fine sand; NT3 – fine/medium sand; and NT4 -gravel) (Table A1.1.1).

Table A1.1.1: Average sediment descriptions (top) and sediment statistics (bottom) for each sediment group at North Tyne.

Sediment group	Number of samples	Sample Type	Sediment description
NT1	7	Unimodal, Very Poorly Sorted	Slightly Gravelly Sandy Mud
NT2	21	Unimodal, Poorly Sorted	Slightly Gravelly Muddy Sand
NT3	30	Unimodal, Poorly Sorted	Slightly Gravelly Muddy Sand
NT4	18	Polymodal, Very Poorly Sorted	Muddy Sandy Gravel

Sediment group	Gravel (%)	Sand (%)	Silt/clay (%)	Very coarse sand (%)	Coarse sand (%)	Medium sand (%)	Fine sand (%)	Very fine sand (%)
NT1	1.93	41.90	56.18	1.27	1.99	6.78	13.37	18.48
NT2	4.06	76.21	19.74	2.74	5.18	12.44	29.01	26.83
NT3	2.90	84.42	12.68	1.80	4.97	30.23	34.18	13.24
NT4	36.55	52.16	11.29	10.73	8.05	10.83	12.81	9.75

The temporal changes in sediment groups for stations sampled at North Tyne since 2006 are minimal for some stations, particularly for NT01, NT06, NT07, NT10, NT12 and NT15, which have been ascribed to the same group each year (Table A1.1.2). NT03, NT08 and NT13 have each been ascribed two sediment groups. The greatest temporal variability is observed at NT05 (each sediment group present) to the south of the disposal site, followed by NT02, NT04 and NT11 (three sediment groups present). In 2018, no station was represented by sediment group NT1

(the muddiest group), which may indicate that the large volume of dredge disposal that occurred in 2011 has dispersed across this area.

Table A1.1.2: Sediment groups for each sample code between 2006 and 2013 inclusive at North Tyne. Blanks indicate no samples were collected/measured. NT03, NT04, NT12 and NT13 are located within the disposal site boundary.

	Year								
Sample code	2006	2007	2008	2009	2010	2011	2012	2013	2018
NT01	NT2	NT2	NT2	NT2	NT2	NT2	NT2	NT2	NT2
NT02	NT2	n	n	NT4	NT2	NT2	NT2	NT1	NT2
NT03	NT3	NT3	NT3	NT3	NT3	NT3	NT3	NT1	NT3
NT04	NT1	NT3	NT3	NT3	NT1	NT3	NT3	NT2	NT3
NT05	NT4	NT2	NT2	NT2	NT2	NT3	NT1	NT3	NT3
NT06	NT4	NT4	NT4		NT4			NT4	NT4
NT07	NT4	NT4			NT4		NT4		
NT08	NT3	NT3	NT3	NT3	NT3	NT3	NT4	NT3	NT3
NT10							NT4	NT4	NT4
NT11							NT1	NT2	NT3
NT12							NT3	NT3	NT3
NT13							NT3	NT1	NT3
NT15								NT4	NT4

While the above temporal variation of sediment groups was completed on sieve particle size methodology, the assessment of spatial variation of silt/clay, sand and gravel content is based on laser particle size methodology results as these are then comparable with other sites within this report. The spatial variation in the proportional representation of these sediment classes for each sampling station in 2018 is shown in Figure A1.1.3. NT04 and NT05, within and south of the disposal site respectively, have the highest silt/clay content (~50 % laser based). Silt/clay content was less variable than in previous years. NT05 is on the tidal axis from the disposal area and is therefore expected to be within the main sediment transport pathway of sediment from the disposal site.

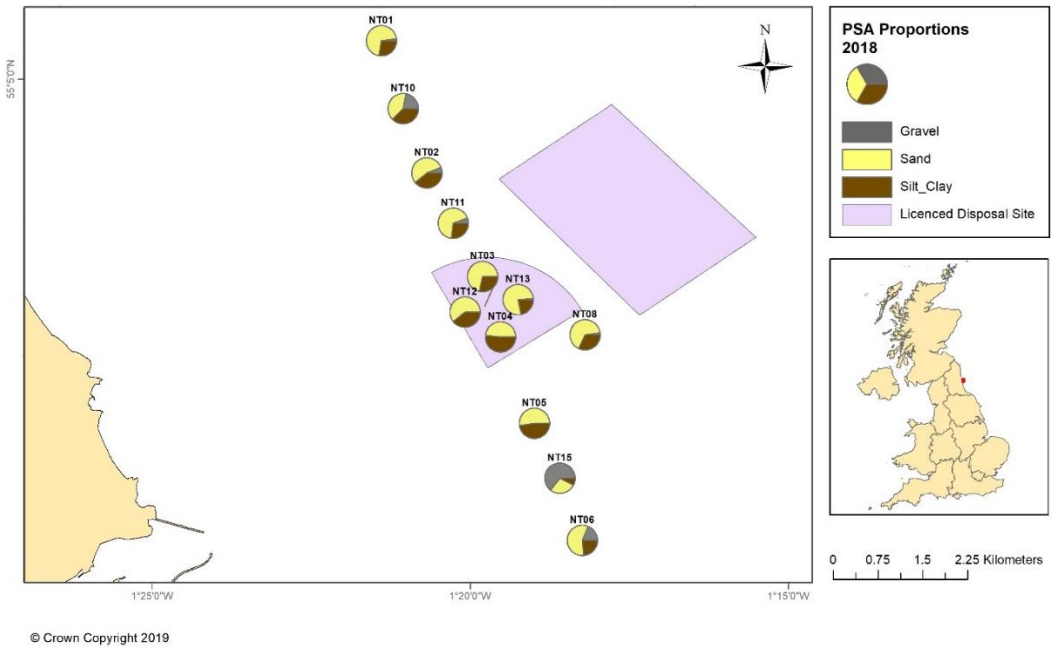


Figure A1.1.3: Pie charts of sediment gravel, sand and silt/clay at North Tyne (cone-shaped), 2018. The site to the immediate northeast of North Tyne is the closed Howden Area disposal site.

1.2.2 Sediment organic carbon (POC)

Organic carbon values ranged from 1.8 to 7.3 % m/m in the <2mm sediment fraction (Figure A1.1.4), and from 3.6 to 4.7 % m/m in the <63 µm fraction (Figure A1.1.5). These are similar to those observed between 2006 and 2013.

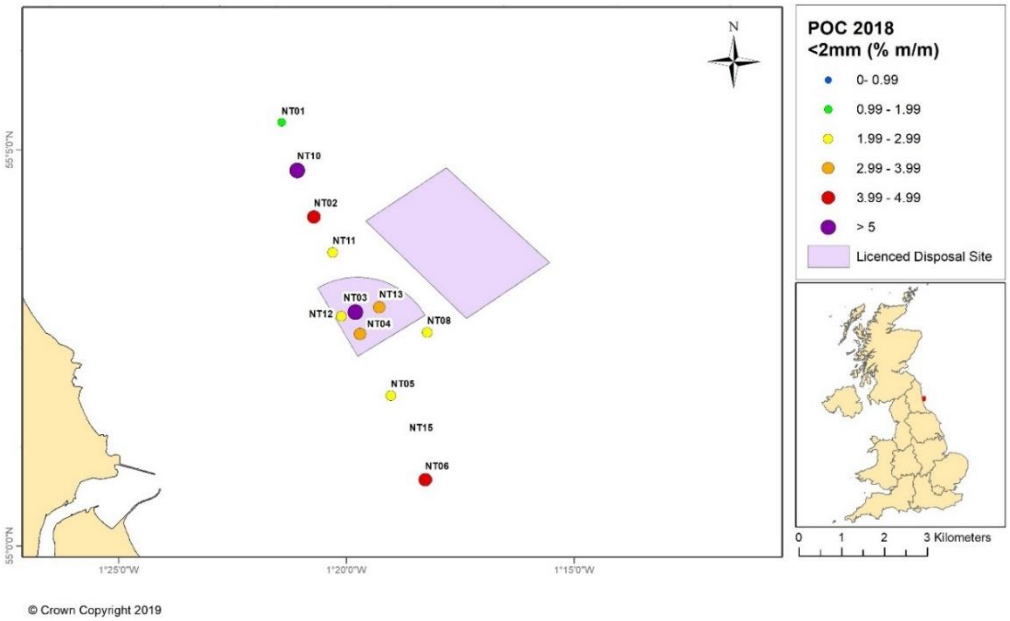


Figure A1.1.4: Organic carbon (% m/m) in the <2mm fraction at North Tyne (cone-shaped), 2018. The site to the immediate northeast of North Tyne is the closed Howden Area disposal site.

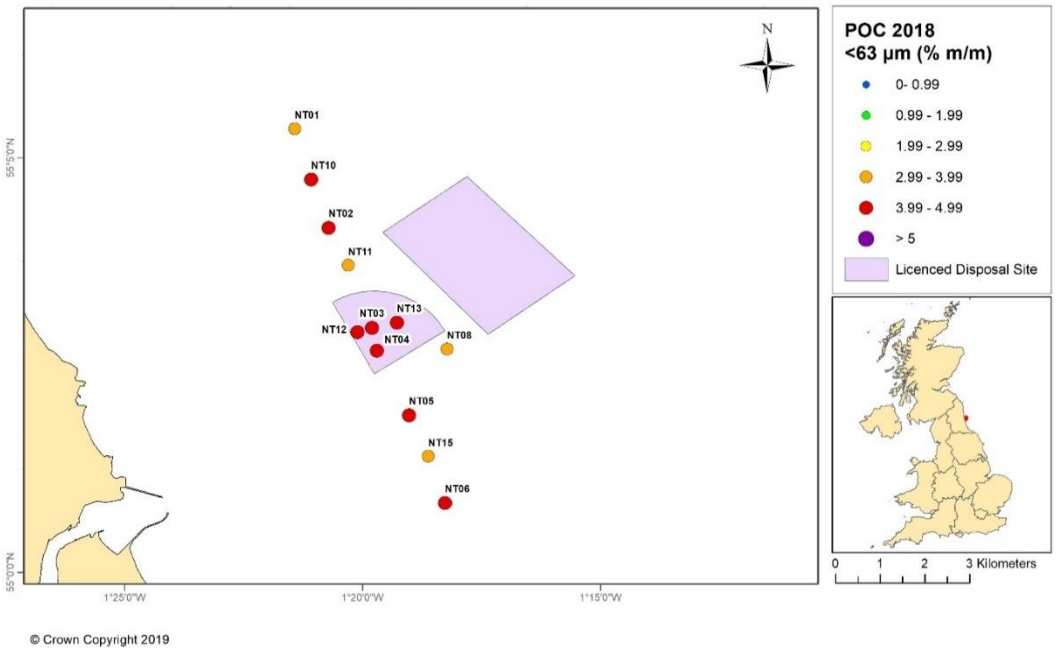
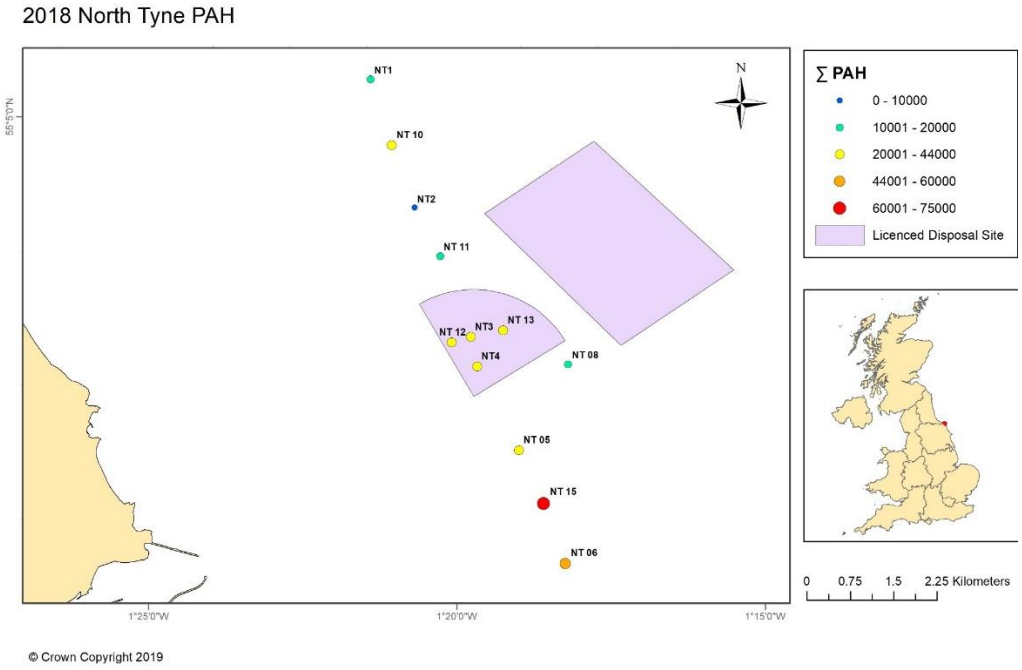


Figure A1.1.5: Organic carbon (% m/m) in the <63 µm fraction at North Tyne (cone-shaped), 2018. The site to the immediate northeast of North Tyne is the closed Howden Area disposal site.

1.2.3 Sediment Chemistry

1.2.3.1 Polycyclic aromatic hydrocarbons (PAHs)

The highest summed PAH concentration at North Tyne in 2018 was 66,100 µg kg^{-1} dry weight (dw) found at NT15, approximately 2 km south-southeast of the disposal site (Figure A1.1.6). This is a similar concentration to the highest concentration found in 2013 (61,600 µg kg^{-1} dw at NT13 within the disposal site). The summed PAH concentration at NT13 in 2018 was 25,116 µg kg^{-1} dw, indicating a substantial decline in PAH concentration at this station since it was last sampled in 2013. The second highest summed PAH concentration (44,100 µg kg-^{1} dw) found during the 2018 survey was at NT6, located at the southern limit of the survey (Figure A1.1.6), sampled for the first time in 2013 (52,000 µg kg-^{1} dw).



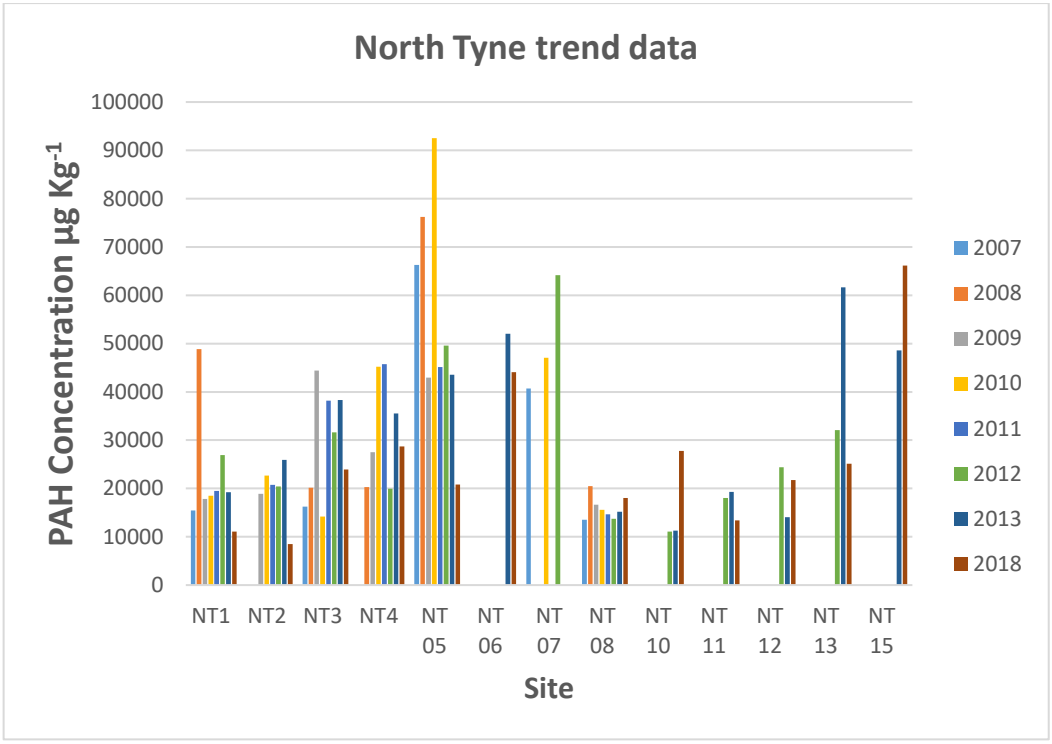


Figure A1.1.6: Summed PAH concentrations (µg kg^{-1} dry weight) for stations sampled at North Tyne (cone-shaped), 2018 (top) and concentrations observed during 2007 to 2018 (bottom). The site to the immediate northeast of North Tyne in the top pane is the closed Howden Area disposal site.

The lowest summed PAH concentration in 2018 was 8,500 µg kg^{-1} dw, at NT2, approximately 2 km north-northwest of the disposal site. This represents a decline compared with the concentration at NT2 in 2013 (25,900 µg kg^{-1} dw) (Figure A1.1.6). The lowest summed PAH concentration in 2013 was 11,300 µg kg^{-1} dw, at NT10, approximately 3 km north-northwest of

the disposal site. In 2018 the summed PAH concentration at NT10 had increased to 27, 800 µg kg $^{-1}$ dw. However, the generally lower total PAH concentrations observed north of the disposal site relative to those to the south remains and is consistent with previous observations (Bolam et al., 2009; 2012).

Summed PAH concentrations found in 2018 at stations NT1 to NT6, and NT11 to NT12, showed reduced levels compared with 2013. Whereas, in 2018 stations NT8, NT10, NT12, and NT15 all had elevated concentrations compared with 2013. Stations NT10 - NT13 were sampled in 2018 for the third time, and for station NT15 the second time, and the data obtained continues to allow us to improve our understanding of the spatial variability of PAH concentrations in this area.

All sediment samples collected at North Tyne during 2018, in harmony with the situation in 2013, exceeded the ERL for low molecular weight (LMW) PAHs. In 2018, sediments from NT3, NT4, NT5, NT6, NT10, NT12, NT13 and NT15 all additionally exceeded the ERM for the LMW PAHs. Whereas, in 2013 only three sediments (NT13, NT3 and NT2) exceeded the ERM for LMW PAHs. In 2018 sediments from eight stations (NT3, NT4, NT06, NT08, NT10, NT12, NT13 and NT15) exceeded the ERL for the high molecular weight (HMW) PAHs, whilst in 2013 only three stations (NT13, NT3 and NT2) exceeded the ERL for HMW PAHs. Similar to 2013, no stations exceeded the ERM for the HMW PAHs in 2018. Evaluation of the PAH data indicated that the source in all the sediment samples was predominantly petrogenic, generally with >74 % of the PAH content arising from oil rather than combustion sources, except for station NT3 where >68 % of the PAH content arose from oil rather than combustion sources.

1.2.3.2 *Organohalogens (OHs)*

Chlorobenzenes (CBs) at North Tyne were detected at all stations (∑ICES7 CBs range 1.2-6.1 µg kg^{-1} dw). Concentrations of CBs were lowest at NT13 inside the disposal site with similar concentrations also at NT01 and NT08. The highest CB concentration was found inside the disposal site at NT03 (∑ICES7 CBs 6.1 µg kg^{-1} dw) with the next highest concentrations found at NT15 (∑ICES7 CBs 4.2 µg kg^{-1} dw) and NT10 (∑ICES7 CBs 3.2 µg kg^{-1} dw), to the south and north of the disposal site respectively (Figure A1.1.7).

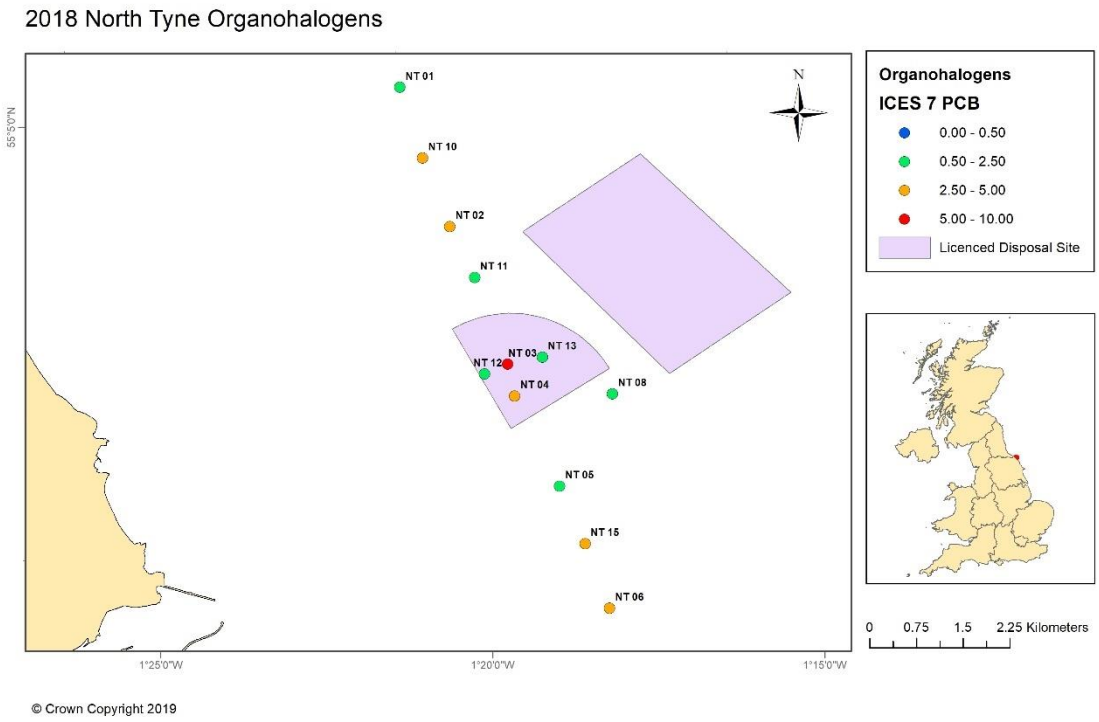


Figure A1.1.7: ∑ ICES7 CB concentrations (µg kg^{-1} dw) for the North Tyne Stations (cone-shaped), 2018. The site to the immediate northeast of North Tyne is the closed Howden Area disposal site.

Brominated diphenyl ethers (BDEs) were detected at all stations (∑11 BDEs range 0.68-5.3 µg kg^{-1} dw). Similar to CBs, the lowest concentrations were at NT13 and NT01. The highest concentrations of 5.3 and 3.2 µg kg^{-1} dw were found at NT02 and NT10 to the north of the disposal site (Figure A1.1.8). 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.

BDE209 was detected at all stations and was at higher concentrations than the other measured organohalogens (range 8.6-87.4 µg kg^{-1} dw; Figure A1.1.9). When included with the other BDEs, BDE209 made up >72 % of the BDEs present (range 72-93 %). BDE209 is indicative of the decaBDE technical mixture, which has been in use more recently than the other technical mixtures, although it's use too has now been restricted in the EU since 2008. High concentrations of 87, 49 and 47 µg kg^{-1} dw were found at NT04, NT03 and NT12, respectively, which are all within the disposal site. The next highest concentration of 26 µg kg^{-1} dw was found to the north of the disposal site at NT10.

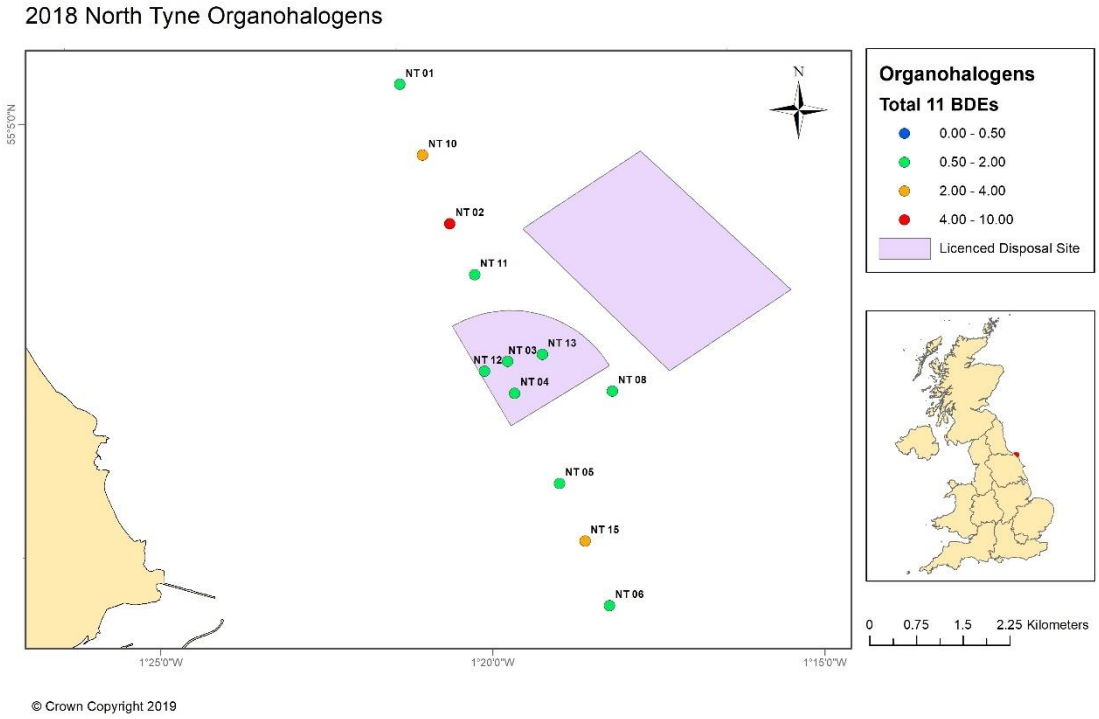


Figure A1.1.8: ∑ 11 BDEs concentrations (µg kg^{-1} dw) for the stations sampled at North Tyne (cone-shaped), 2018. The site to the immediate northeast of North Tyne is the closed Howden Area disposal site.

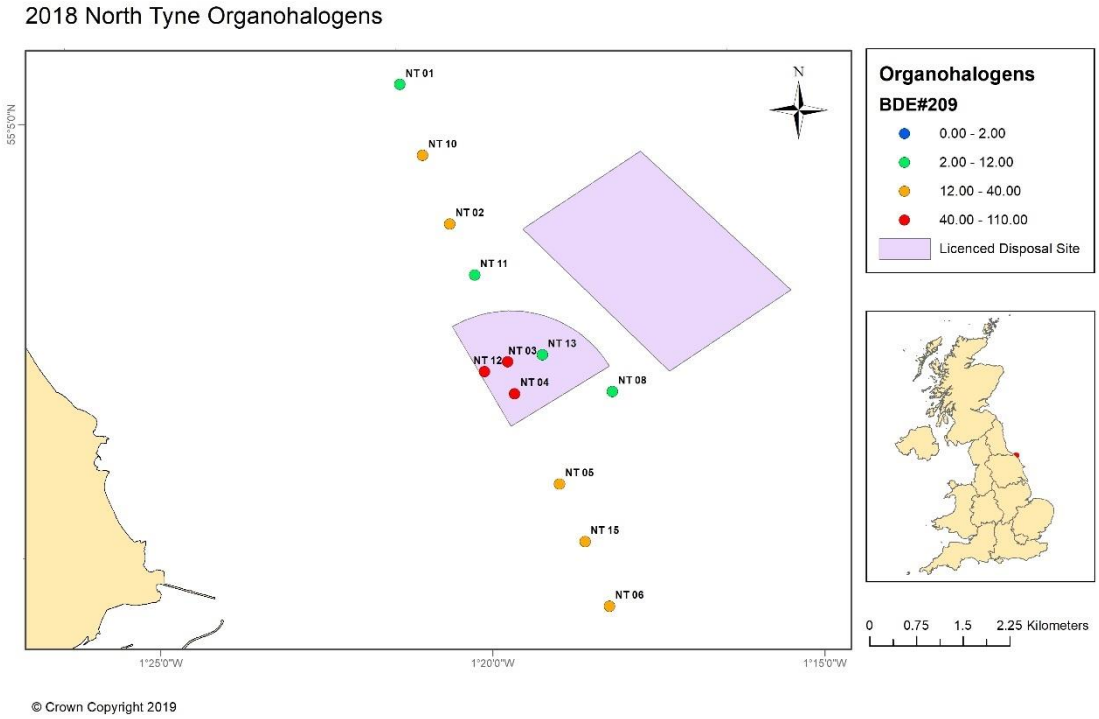


Figure A1.1.9: BDE209 concentrations (µg kg^{-1} dw) for the stations sampled at North Tyne (cone-shaped), 2018. The site to the immediate northeast of North Tyne is the closed Howden Area disposal site.

The organochlorine pesticides (OCPs) hexachlorobenzene (HCB), plus Dichlorodiphenyltrichloroethane (DDT) and metabolites were detected at all stations. $\sum_6$DDTs concentrations ranged from 0.71-84 µg kg^{-1} dw, with the highest values at NT06 (84 µg kg^{-1} dw) and NT15 (5.4 µg kg^{-1} dw; Figure A1.1.10). The ratio of DDT:metabolites at NT06 is greater than 1, suggesting that this sediment has received a fresh input of DDT. HCB concentrations ranged from 0.26 – 5.9 µg kg^{-1} dw, with the highest values at NT04 (5.9 µg kg^{-1} dw) and NT06 (1.8 µg kg^{-1} dw). Dieldrin was detected at 10 out of 12 stations (range <0.1-0.76 µg kg^{-1} dw), with the highest values at NT15 (0.76 µg kg^{-1} dw), NT12 (0.54 µg kg^{-1} dw) and NT06 (0.45 µg kg^{-1} dw).

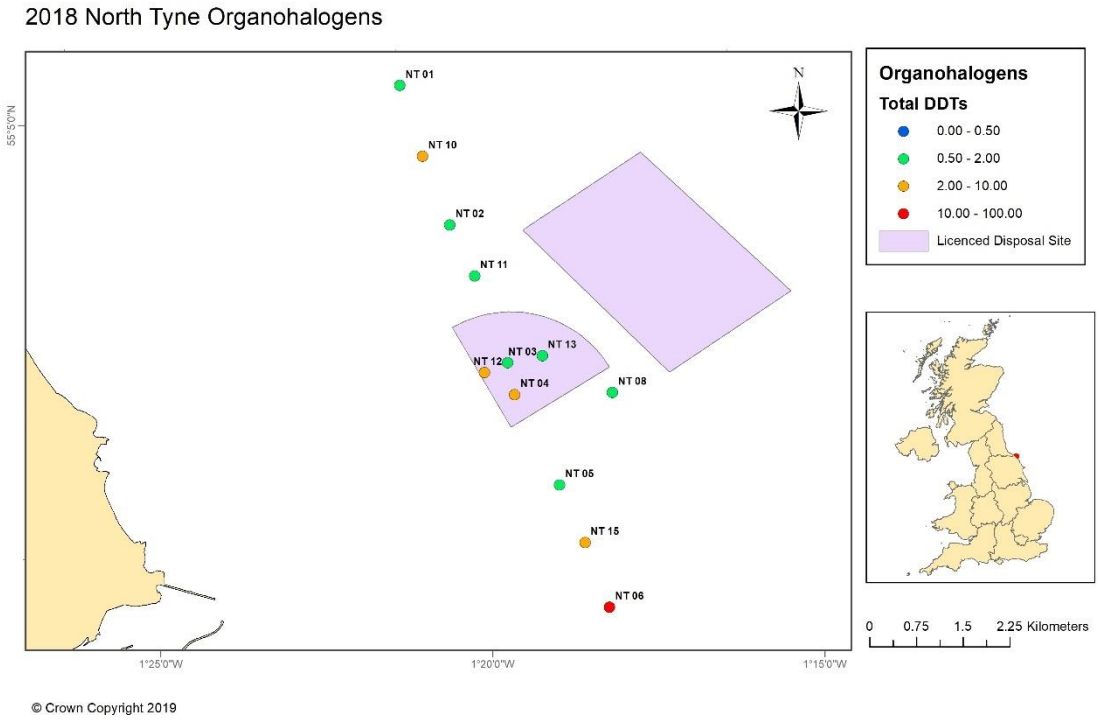


Figure A1.1.10: Total DDT concentrations (µg kg^{-1} dw) for the stations sampled at North Tyne (cone-shaped), 2018. The site to the immediate northeast of North Tyne is the closed Howden Area disposal site.

Concentrations of CBs at all stations were all below Cefas action level 1, as was dieldrin. Total DDT concentrations were above action level 1 at all stations except NT01, NT08 and NT13. No FEPA action levels exist for BDEs including BDE209 (Appendix 2.2). According to the OSPAR guidelines, all stations had 'good' environmental status for all ICES 7 CBs and 'good' status overall. Using the new OSPAR guidelines for BDEs, with the exception of BDE209, all stations were below the EACs for most congeners. However, station NT04 exceeded the EAC for BDE209, and NT09 was close to the EAC. Both these stations are within the disposal site. Station NT02 was close to the EAC for BDE99.

There are OH data available to assess temporal trends from 2006 to 2018 (Table A1.1.3 to Table A1.1.6). For CBs, most stations have shown a decrease in concentration since the last survey in 2013. The exceptions were NT12, NT08 and NT05, which increased slightly. Trends for ∑11 BDEs were similar, with most stations lower than in 2013, with the exception of NT12 and NT05, which increased. No discernible temporal trend can be observed for BDE209. However, concentrations at NT10, NT12, NT15 and NT06 in 2018 were the highest that have been recorded at these stations. No clear trend can be observed for total DDT, with some stations lower and some higher than when last measured. However, the increase at NT06 was very significant and was the highest concentration observed in the North Tyne area by an order of magnitude.

Table A1.1.3: Temporal trends (2006-2018) of ∑ICES 7 CBs concentration (in µg kg^{-1} dw) at the stations sampled at North Tyne in 2018.

Station code	**∑ICES 7 CBs concentration (in µg kg^{-1} dw)**								
	2006	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2018**
NT1	1.54	0.97	2.11	0.93	0.98	1.13	1.37	1.34	1.18
NT10							2.63	6.62	3.23
NT2				1.69	1.63	2.66	2.67	4.72	2.96
NT11							2.89	11.0	1.72
NT12							17.0	*0.7	2.20
NT3	1.48	2.03	1.79	4.12	1.63	11.9	3.39	7.8	6.08
NT4	7.21		*0.7	4.58	11.0	5.84	2.63	4.63	2.88
NT13							1.61	10.4	1.15
NT8	5.21	2.03	0.81	*0.7	1.12	1.10	1.13	*0.7	1.31
NT5	2.7	7.59	6.05	3.24	11.9	2.72	3.88	1.37	2.31
NT15								5.47	4.20
NT6	2.44	2.54	3.88		2.09			3.36	2.71
NT7		1.55			1.76		2.24		

*estimates of concentrations for samples where all ICES 7 congener concentrations were below LODs

Table A1.1.4: Temporal trends (2006-2018) of ∑11 BDEs concentration (in µg kg^{-1} dw) at the stations sampled at North Tyne in 2018.

Station code	∑11 BDEs concentration (in µg kg^{-1} dw)								
	2006	2007	2008	2009	2010	2011	2012	2013	2018
NT1	1.56	1.68	1.27	0.95	0.93	1.92	2.45	2.27	0.79
NT10							2.61	5.09	3.24
NT2	5.28			1.27	1.84	2.12	2.30	5.74	5.27
NT11							2.99	1.58	0.99
NT12							0.67	0.40	1.41
NT3	1.72	1.54	0.49	2.55	0.52	1.84	1.60	6.80	1.36
NT4	13.2		0.28	1.27	4.18	7.10	1.48	4.12	1.36
NT13							0.92	9.54	0.68
NT8	1.86	2.84	1.42	0.74	1.65	1.40	3.98	1.78	1.19
NT5	2.18	4.49	0.96	5.89	1.31	2.10	2.45	1.23	1.50
NT15								4.49	2.12
NT6	7.69	4.12	1.18		1.34			1.61	1.62
NT7		1.77			0.84		1.98		

Limits of detection for BDEs improved between 2007 and 2008 and therefore values assigned to congeners below LOD are lower from 2008 onwards, resulting in a step decrease in ∑11 BDEs concentration for samples with congeners below LODs.

Table A1.1.5: Temporal trends (2008-2018) of BDE209 concentration (in µg kg^{-1} dw) at the stations sampled at North Tyne in 2018.

Station	BDE209 concentration (in µg kg^{-1} dw)						
	2008	2009	2010	2011	2012	2013	2018
NT1	104.2	11.46	3.93	7.33	5.56	12.8	8.59
NT10					16.5	15.7	26.0
NT2		12.23	12.2	42.9	11.9	69.5	22.9
NT11					12.5	12.5	10.6
NT12					7.7	2.43	47.2
NT3	2.72	48.54	7.91	21.6	35.4	185	49.3
NT4	0.78	36.11	95.5	108	38.1	152	87.4
NT13					45.3	206	10.2
NT8	8.03	8.95	20.1	7.21	4.91	14.4	10.4
NT5	6.21	11.94	6.64	10.6	273	6.28	22.1
NT15						12.6	23.0
NT6	6.15		8.69			12.8	15.8
NT7			17.5		8.46		

Table A1.1.6: Temporal trends (2006-2018) of ∑DDTs concentration (in µg kg^{-1} dw) at the stations sampled at North Tyne in 2018.

Station code	∑DDTs concentration (in µg kg^{-1} dw)				
	2006	2007	2008	2010	2018
NT1	0.97	1.54	1.44	0.83	0.71
NT10					2.16
NT2	1.56			1.38	1.79
NT11					1.36
NT12					2.15
NT3	0.89	1.83	3.17	1.27	1.03
NT4	7.2		1.12	6.92	2.25
NT13					0.84
NT8	0.84	1.59	0.88	1.36	0.96
NT5	1.12	3.41	3.48	1.25	1.52
NT15					5.39
NT6	1.25	2.25	1.84	0.91	83.8
NT7	1.12	1.66		0.95	

1.2.3.3 *Trace metals*

Levels of enrichment for North Tyne stations based on the OSPAR background assessment concentrations (BACs) and regional baseline values are represented in Figure A1.1.11. Arsenic concentrations at three of the four stations inside the disposal site are lower than the regional baseline assessment concentrations. Three of the stations surrounding the site are also low using this assessment method; the remaining stations show only slight enrichment. A comparable picture of either no enrichment or slight enrichment is also seen using the OSPAR method. No clear temporal trend was observed from 2006-2018 dataset for arsenic for both stations within and outside the disposal site (Figure A1.1.11).

Chromium and nickel showed comparable patterns, being slightly enriched at all stations based on the OSPAR assessment. Since the baseline values for this region are higher than the OSPAR BAC values (Table A2.3.1) for these two metals, all sampling stations show no enrichment using the baseline approach, except for several stations showing slight enrichment. No clear temporal trend was observed for these two metals from 2006-2018 for stations within and outside the disposal site.

Both assessment methods depict the same observations for cadmium, showing moderate enrichment only within the boundary of the disposal site (NT4, NT12 and NT3). NT13 has decreased to slight enrichment and overall there has been a decrease in enrichment within the

disposal site (with the exception of the increase from slight to moderate at NT12). Previously, in 2013, stations located north of the disposal sites were not enriched for cadmium, whereas those located south of the disposal site were slightly enriched. In 2018, however, the two stations immediately north of the disposal site (NT02 and NT11) display slight enrichment while all southern stations of the disposal site continue to be enriched.

Copper is moderately enriched at NT2 (north of the disposal site) and slightly enriched at all other stations (except NT15, south of the site, which only just has moderate enrichment with the OSPAR assessment). NT3, NT4 and NT13, all within the disposal site, have all decreased from moderate to slight enrichment since the last assessment in 2013. There is an overall slight decrease in copper concentrations inside the disposal site.

Mercury is moderately enriched according to the OSPAR BAC assessment method for all stations, except NT02 (north of the disposal site), NT04 (within) and NT15 (south of the disposal site) which display high enrichment. There is a decrease in enrichment ratio values across all sample stations compared to the 2013 survey and a baseline analysis reveals no trends comparable to those found in the 2013 – 14 report (previously a site slight enrichment to the south of the disposal site was evidenced; Bolam et al., 2015).

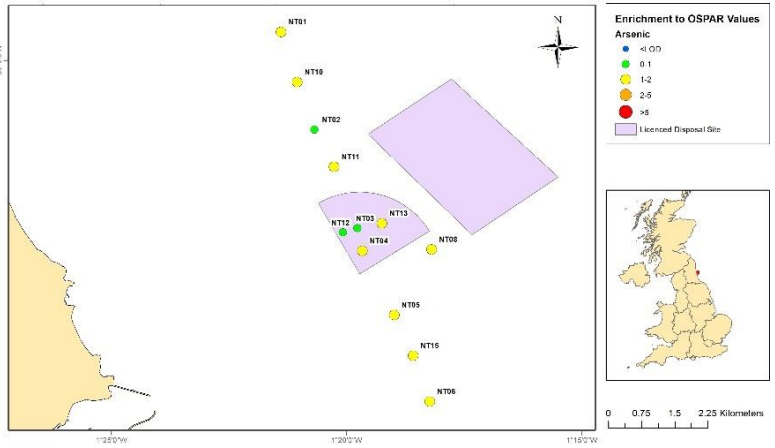
Lead enrichment is found to be moderate for all stations based on the OSPAR approach. This is, however, a general decrease compared with 2013 survey, and inside the disposal site, stations have decreased from high enrichment (for NT03, NT04 and NT12) to moderate enrichment. The regional baseline approach depicts either slight or no enrichment in lead, again a general trend of decreasing enrichment ratio values compared with 2013 survey. In general, concentrations inside the disposal site are not noticeable higher than those outside the disposal site.

Moderate enrichment is observed for zinc at stations within the disposal site for the OSPAR BAC assessment (except for just slight enrichment at NT13) while all but the two most southerly stations (moderate enrichment) show slight enrichment. There is a less pronounced enrichment when using the regional baseline approach and, except for the moderate enrichment at NT04 inside the disposal site, all stations display only slight enrichment.

In conclusion, the metals concentrations at North Tyne in 2018 tend to be much higher than the OSPAR BAC values especially for mercury and lead and, to a lesser extent, zinc. When assessing

concentrations against the proposed baseline values which were derived by taking into account regional variability, enrichment is still observed, but to a reduced level. Cadmium has a noticeably higher concentration inside the disposal site compared to outside, but no other elements display noticeably increased concentrations inside the site (Figure A1.1.12).

2018 North Tyne Metals to OSPAR



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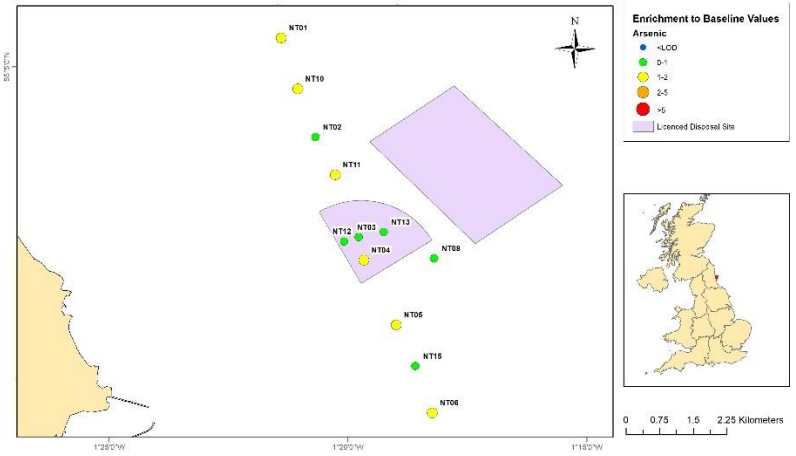
2018 North Tyne Metals to Baseline



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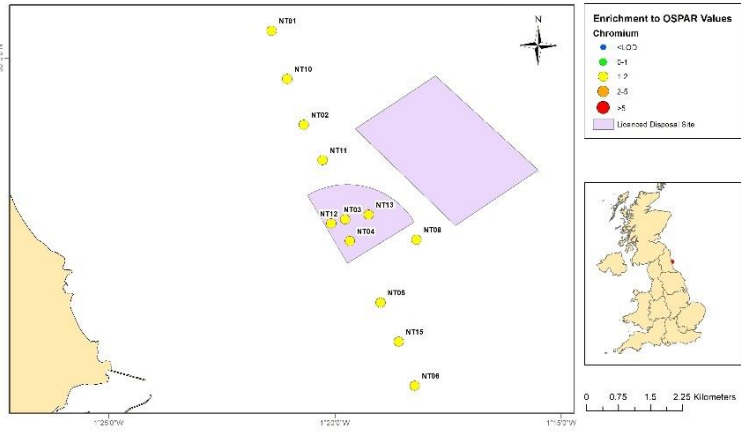
2018North Tyne Metals to OSPAR



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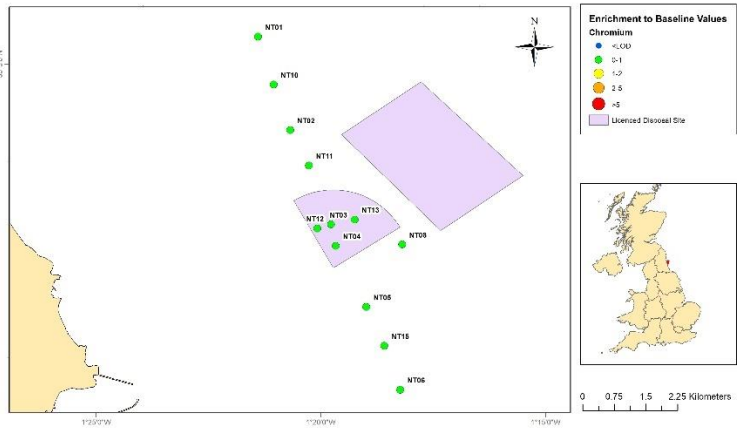
2018 North Tyne Metals to Baseline



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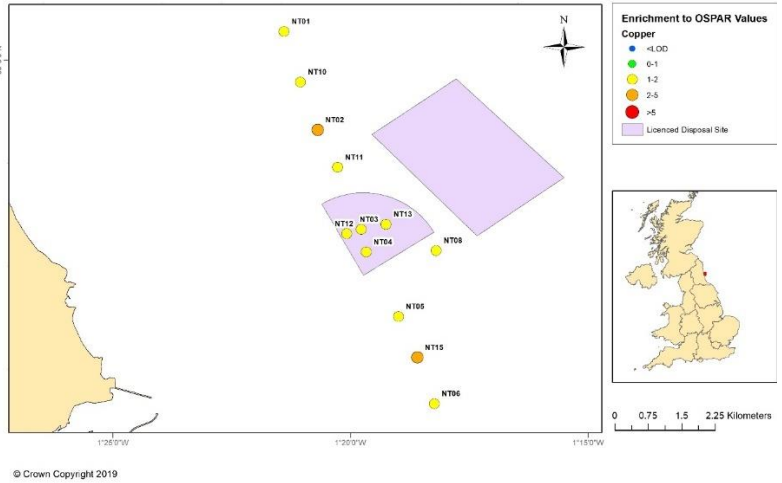
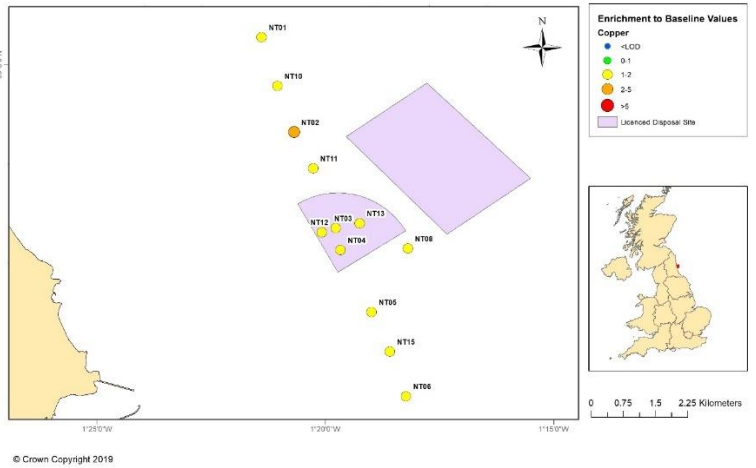
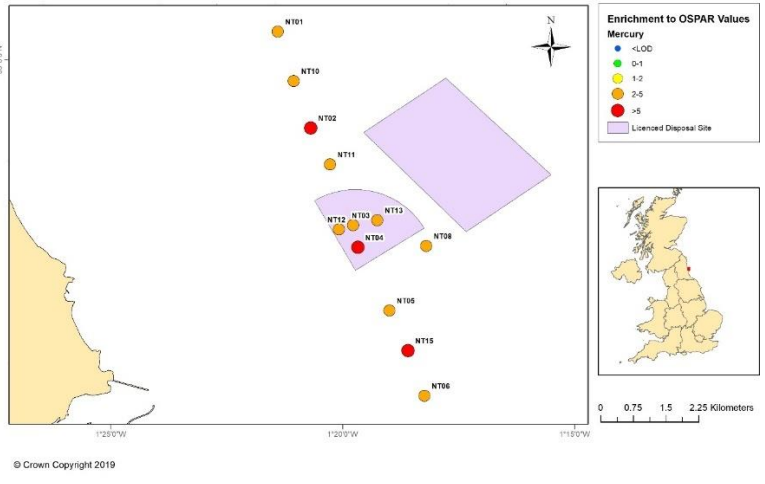
2018 North Tyne Metals to OSPAR



2018 North Tyne Metals to Baseline



2018 North Tyne Metals to OSPAR



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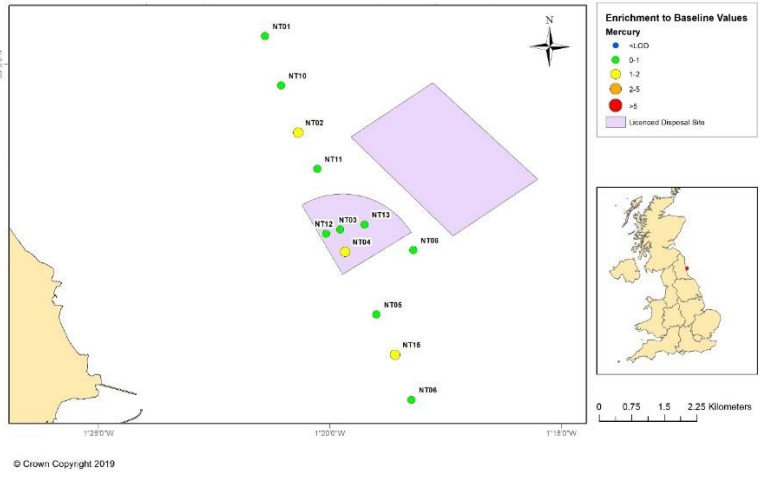
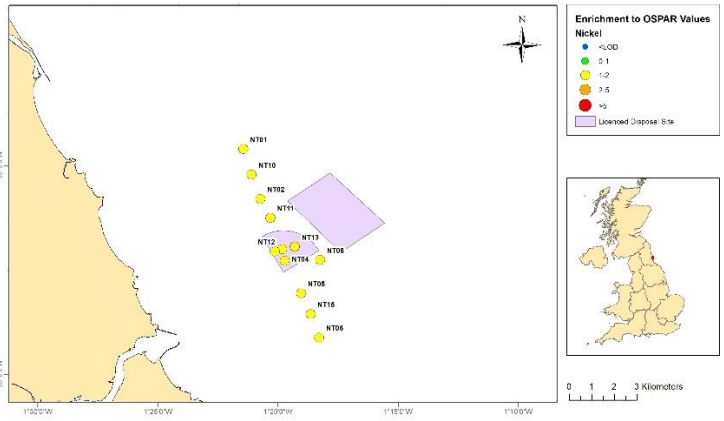
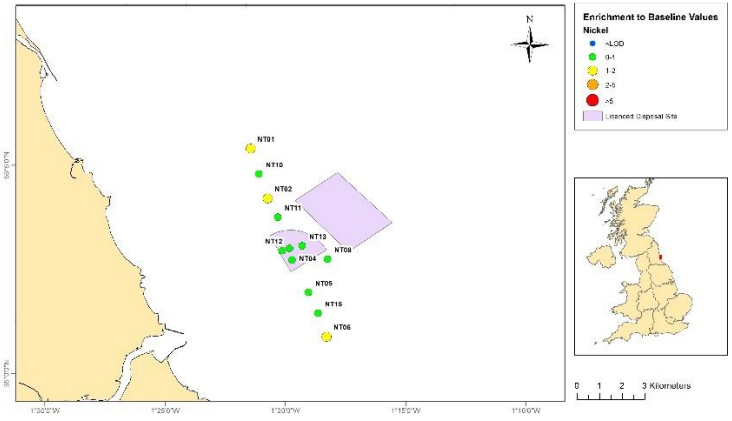


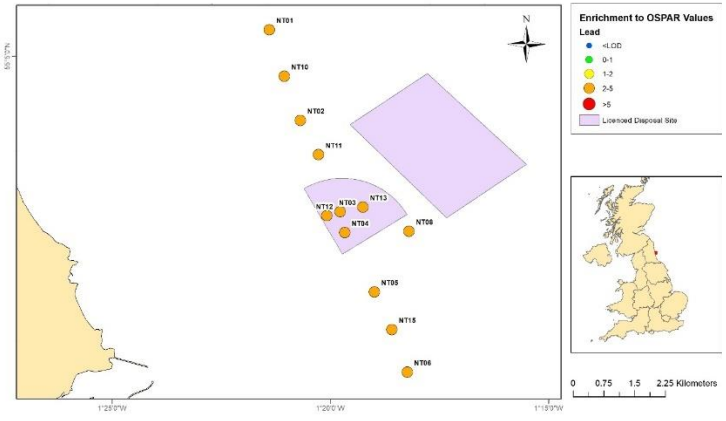
2018 North Tyne Metals to OSPAR



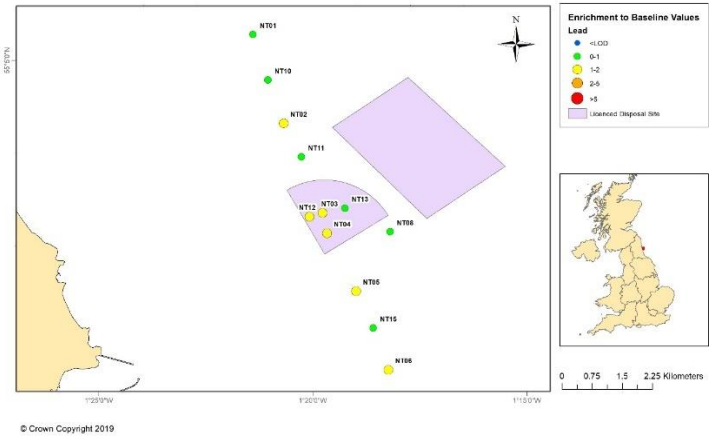
2018 North Tyne Metals to Baseline



2018 North Tyne Metals to OSPAR



2018 North Tyne Metals to Baseline



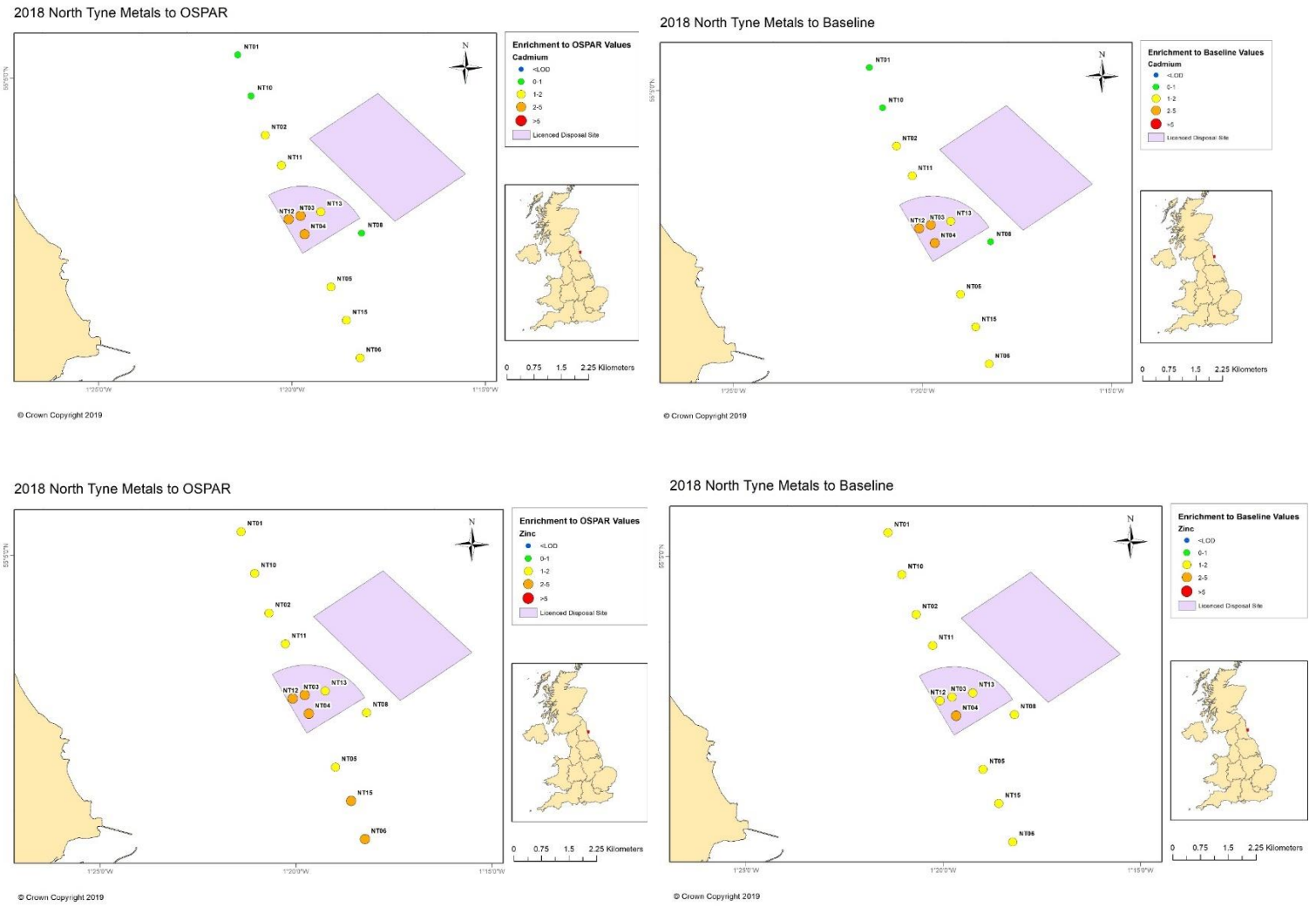


Figure A1.1.11: Enrichment to OSPAR BACs (left) and regional baseline values (right) for stations sampled at North Tyne (cone-shaped site) for As, Cr, Cu, Hg, Ni, Pb, Cd and Zn. The site to the immediate northeast of North Tyne is the closed Howden Area disposal site.

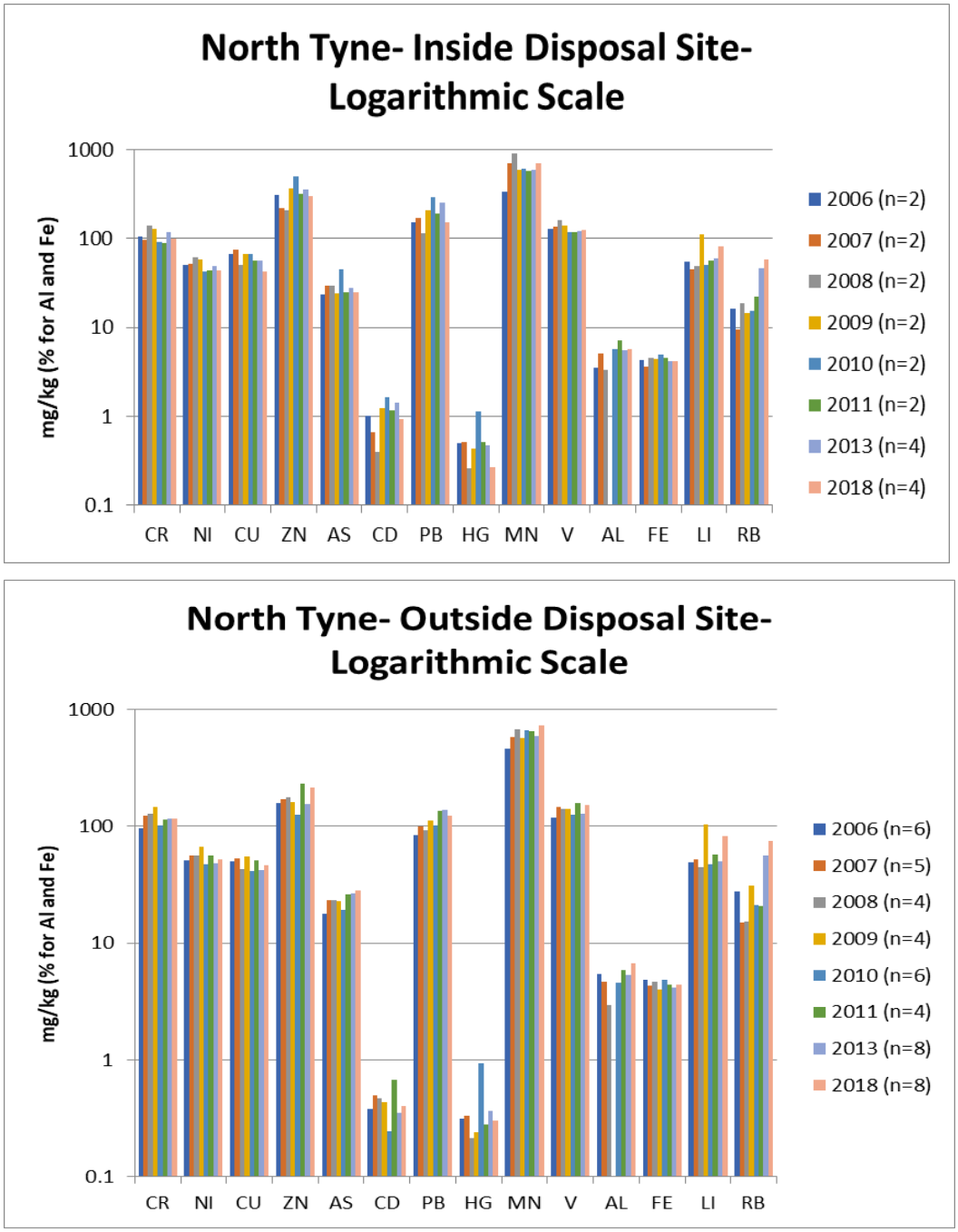


Figure A1.1.12: Trace metals concentrations for stations sampled inside (top) and outside (bottom) the North Tyne disposal site, 2018.

2 Sunderland (TY090)

2.1 Background

A small (0.8 km^2) disposal site located approximately 4 km east off the northeast coast of England, off the coast of Sunderland, and in approximately 25 m water depth. Disposal returns data for this site date back to 1984 demonstrating it to be an historic site with a long and continuous history of use. Annual tonnages recently disposed approximates 202,000 t, with a peak of 450,000 t in 2011 (Figure A1.2.1). TY090 receives material from the River Wear catchment, primarily from the Port of Sunderland maintenance dredging activities. Although the majority of material is of maintenance dredge origin, some capital dredge projects have disposed at this site over the years. Routine sampling for dredge applications has shown hydrocarbons (PAHs in particular) to be elevated beyond effects ranges (i.e. ERL, ERM) and has recently shown evidence of high levels of lead (Pb). Although exclusion zones for areas considered contaminated with lead are enforced, it is not known if there are any effects/impacts at the disposal site from elevated PAHs in the disposed material and the potential for high levels of lead from unsampled dredging areas.

In view of this, and the fact that the receiving environment within and surrounding the disposal site has never been assessed for contaminants concentrations, sampling at this site under C6794 during 2018 aimed to provide a contemporary assessment of the sediment concentrations of trace metals, PAHs and hydrocarbons. These data will allow an assessment of whether the current screening process and dredging and disposal practices are resulting in acceptable concentrations at the receiving environment.

A total of 10 stations were successfully sampled, four of which (SUND01, SUND02, SUND03 and SUND04) were located within the disposal site (Figure A1.2.2). The remaining six stations were principally positioned to the north and south of the disposal site along the main tidal axis.

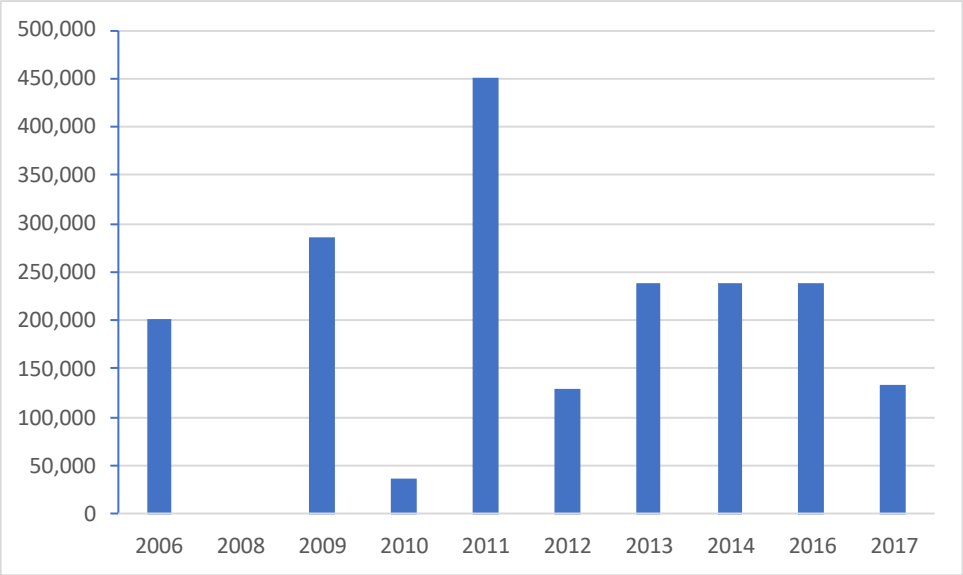


Figure A1.2.1: Annual tonnages of dredged material (in t wet weight) disposed to TY090 in recent years. Average annual tonnage disposed during this period is 195,195 t.

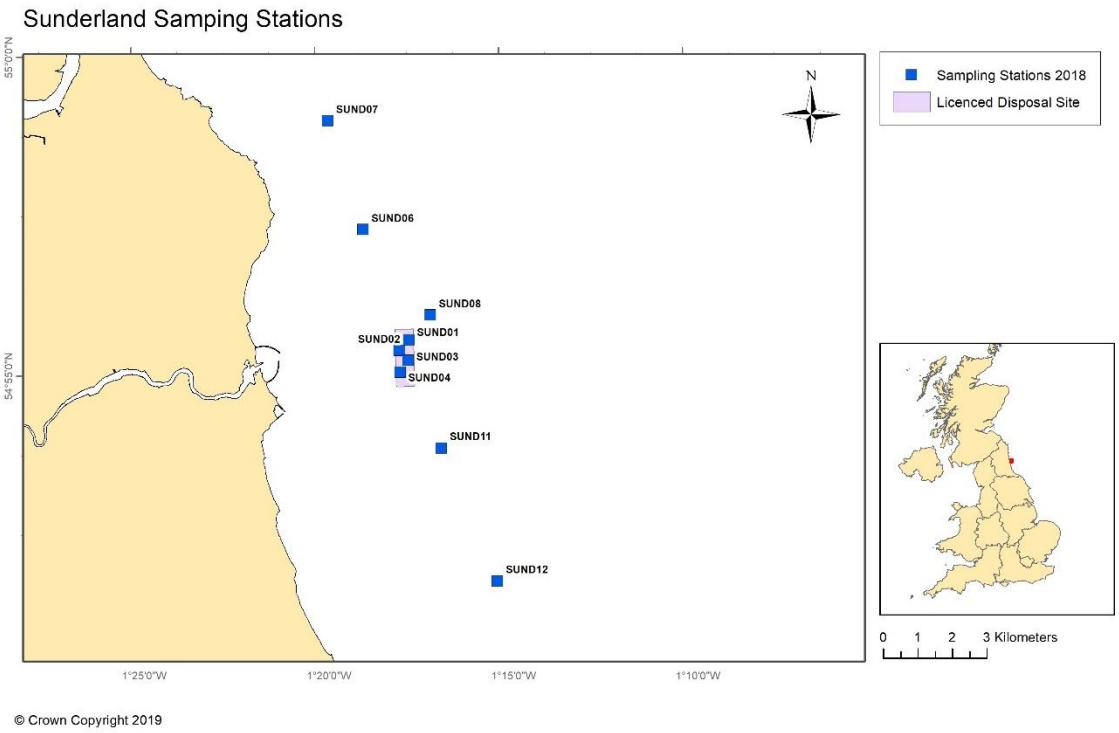


Figure A1.2.2: Stations successfully sampled within and surrounding the Sunderland dredged material disposal site, 2018. One further station, SUD10, was successfully sampled for contaminants only.

2.2 Results

2.2.1 Sediment particle size

Sediments from Sunderland in 2018 are composed of variable sediment types, including sandy muds, with mixed sediments as well as gravels and sand, as shown in the sediment summary in Table A1.2.1. No sample was successfully obtained for particle size assessment for SUD10.

Table A1.2.1: Sediment descriptions (top) and statistics (bottom) for each station sampled at Sunderland, 2018.

Sample code	Sample type	Sediment description
SUD01	Unimodal, Poorly Sorted	Slightly Gravelly Muddy Sand
SUD02	Trimodal, Very Poorly Sorted	Sandy Gravel
SUD03	Trimodal, Very Poorly Sorted	Muddy Sandy Gravel
SUD04	Trimodal, Very Poorly Sorted	Gravelly Mud
SUD06	Polymodal, Very Poorly Sorted	Gravelly Muddy Sand
SUD07	Bimodal, Very Poorly Sorted	Slightly Gravelly Sandy Mud
SUD08	Unimodal, Very Poorly Sorted	Slightly Gravelly Sandy Mud
SUD11	Unimodal, Poorly Sorted	Slightly Gravelly Sandy Mud
SUD12	Bimodal, Very Poorly Sorted	Sandy Mud

Sample code	Gravel (%)	Sand (%)	Silt/clay (%)	Very coarse sand (%)	Coarse sand (%)	Medium sand (%)	Fine sand (%)	Very fine sand (%)
SUD01	0.27	81.69	18.04	0.41	2.23	10.28	54.35	14.41
SUD02	51.83	43.78	4.39	20.66	10.10	5.36	6.44	1.22
SUD03	45.60	34.91	19.49	14.85	5.24	4.01	5.32	5.49
SUD04	12.74	20.56	66.70	2.10	0.00	0.14	5.29	13.03
SUD06	27.56	53.65	18.79	16.55	17.66	10.93	4.33	4.17
SUD07	0.64	20.36	79.00	0.66	0.48	1.60	6.46	11.17
SUD08	0.03	24.68	75.29	0.23	0.00	0.30	6.00	18.15
SUD11	0.16	39.16	60.68	0.58	3.01	1.73	9.18	24.66
SUD12	0.00	28.76	71.24	0.37	1.00	3.40	8.90	15.09

The spatial variation of gravel, sand and silt/clay for each station is shown in Figure A1.2.3. High concentrations of silt/clay content (>60 %) are present at most stations, particularly for SUD04, SUD07, SUD08, SUD11 and SUD12 which extend across the entire transect.

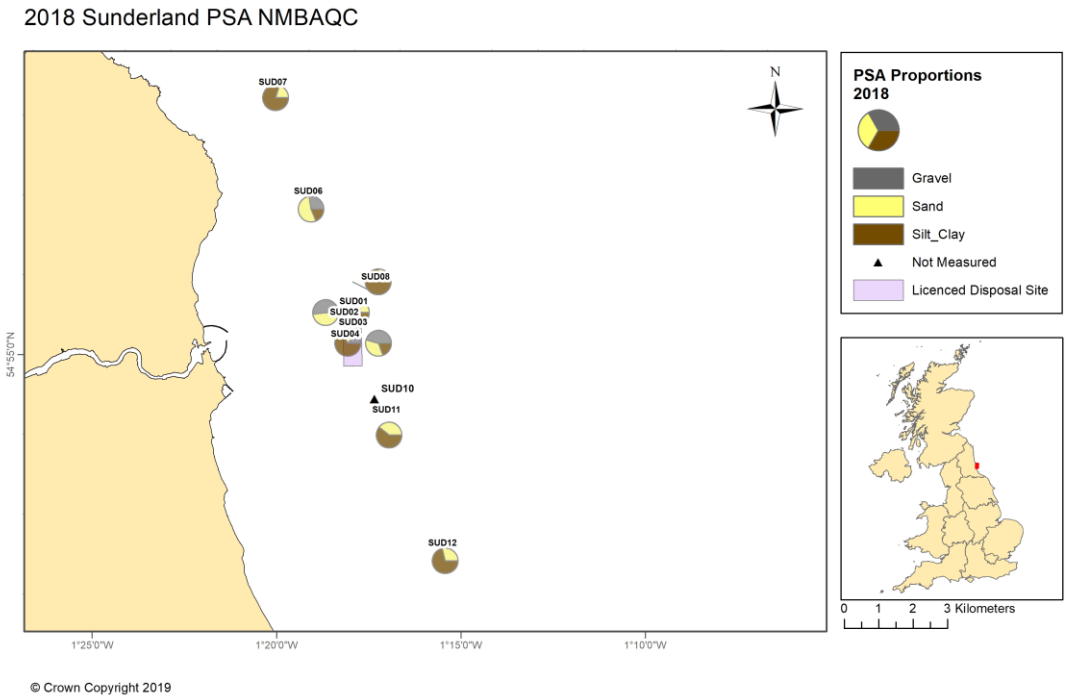


Figure A1.2.3: Pie charts of gravel, sand and silt/clay at Sunderland, 2018.

2.2.2 Sediment organic carbon

Organic carbon values range from 3.0 to 5.0 % m/m in the <2 mm sediment fraction (Figure A1.2.4), and from 3.2 to 5.9 % m/m in the <63 µm fraction (Figure A1.2.5). No assessment of sediment organic carbon was made on the <2 mm fraction for SUD10.

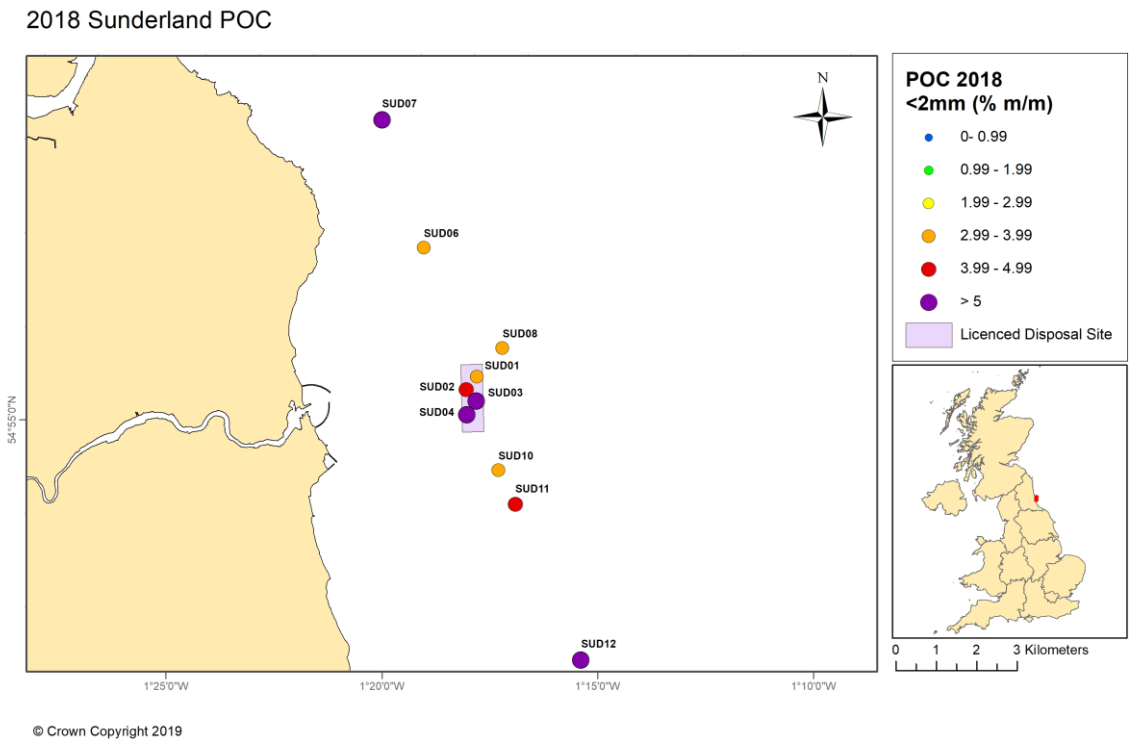


Figure A1.2.4: Organic carbon (% m/m) in the <2 mm fraction at Sunderland, 2018.

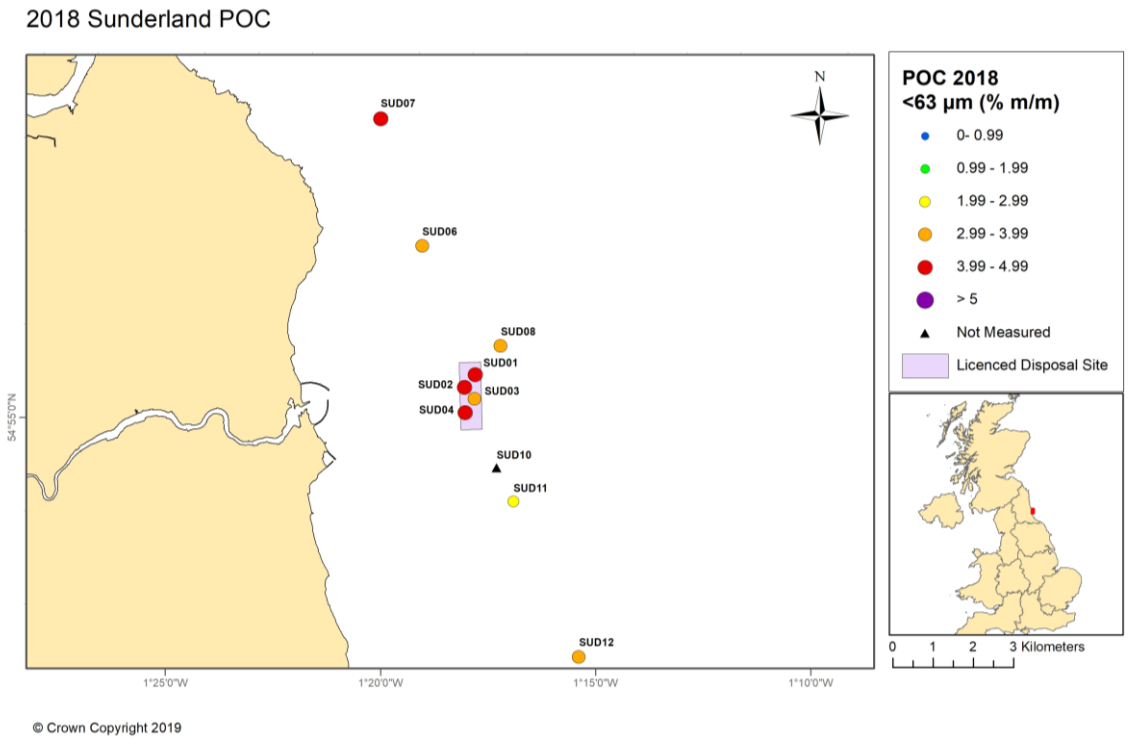


Figure A1.2.5: Organic carbon (% m/m) in the <63 µm fraction at Sunderland, 2018.

2.2.3 Sediment Chemistry

2.2.3.1 Polycyclic aromatic hydrocarbons (PAHs)

The highest summed PAH concentration at Sunderland in 2018 was 73,700 µg kg^{-1} dw, at SUD02 within the disposal site, whilst the second highest concentration was 68,100 µg kg^{-1} dw at SUD12 at the southern limit of the survey (Figure A1.2.6). Intermediate concentrations where found at SUD04 (50,100 µg kg^{-1} dw) within the disposal site, SUD11 (46,900 µg kg^{-1} dw) approximately 2 km south-southeast of the disposal site, and SUD07 (55,400 µg kg^{-1} dw) at the northern limits of the survey.

The lowest summed PAH concentration in 2018 was 7,000 µg kg^{-1} dw at SUD10, approximately 1 km south-southeast of the disposal site, whilst the second lowest concentration was 27,000 µg kg^{-1} dw, at SUD06, approximately 3 km north-northwest of the disposal site (Figure A1.2.6).

All sediment samples collected at Sunderland during 2018 exceeded the ERL for low molecular weight (LMW) PAHs, and all but one station (SUD10, which had the lowest summed PAH concentration) exceeded the ERM for the LMW PAHs. Sediments from six stations (SUD01, SUD03 and SUD04 within the disposal site, SUD07 at the northern limits of survey, and SUD11 and SUD12 south-southeast and at the southern limits of survey respectively) exceeded the ERL for the high molecular weight (HMW) PAHs, but no station exceeded the ERM for the HMW PAHs. Evaluation of the PAH data indicated that the source in all the sediment samples was predominantly petrogenic, generally with >80 % of the PAH content arising from oil rather than combustion sources.

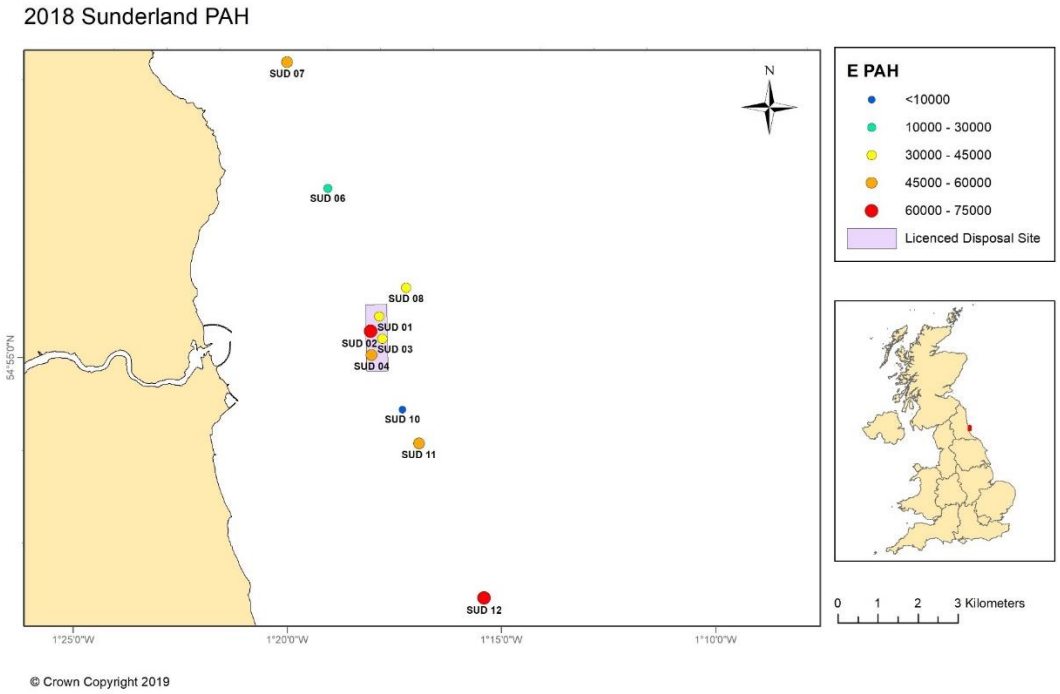


Figure A1.2.6: Summed PAH concentrations (µg kg $^{-1}$ dry weight) for stations sampled at Sunderland, 2018.

2.2.3.2 *Organohalogens (OHs)*

∑ICES 7 CB concentrations for the Sunderland stations range from 0.70-4.2 µg kg^{-1} dw. All of the 10 stations sampled for OHs had ∑ICES 7 CB concentrations above LODs (Figure A1.2.7). The highest concentration (4.2 µg kg^{-1} dw) was measured at station SUD07 to the north of the disposal site. The next highest result, 3.6 µg kg^{-1} dw, was observed at SUD04 within the disposal site. The lowest ∑ICES 7 CB result of 0.70 µg kg^{-1} dw was found at SUD02 inside the disposal site. The remaining stations were within a narrow concentration range of 1.8-2.4 µg kg^{-1} dw (Figure A1.2.7).

BDEs were detected at all stations (∑11 BDEs range 0.22-4.9 µg kg^{-1} dw). Three out of the four highest values were found at stations within the disposal site (4.9, 3.8 and 3.3 µg kg^{-1} dw at SUD04, SUD03 and SUD01, respectively), with a high value, 4.3 µg kg^{-1} dw, also witnessed at SUD07 to the north (Figure A1.2.8). Like PCBs, the lowest value was found at SUD02, 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. Penta and octa technical mixtures are no longer in use, having been banned in the EU since 2004.

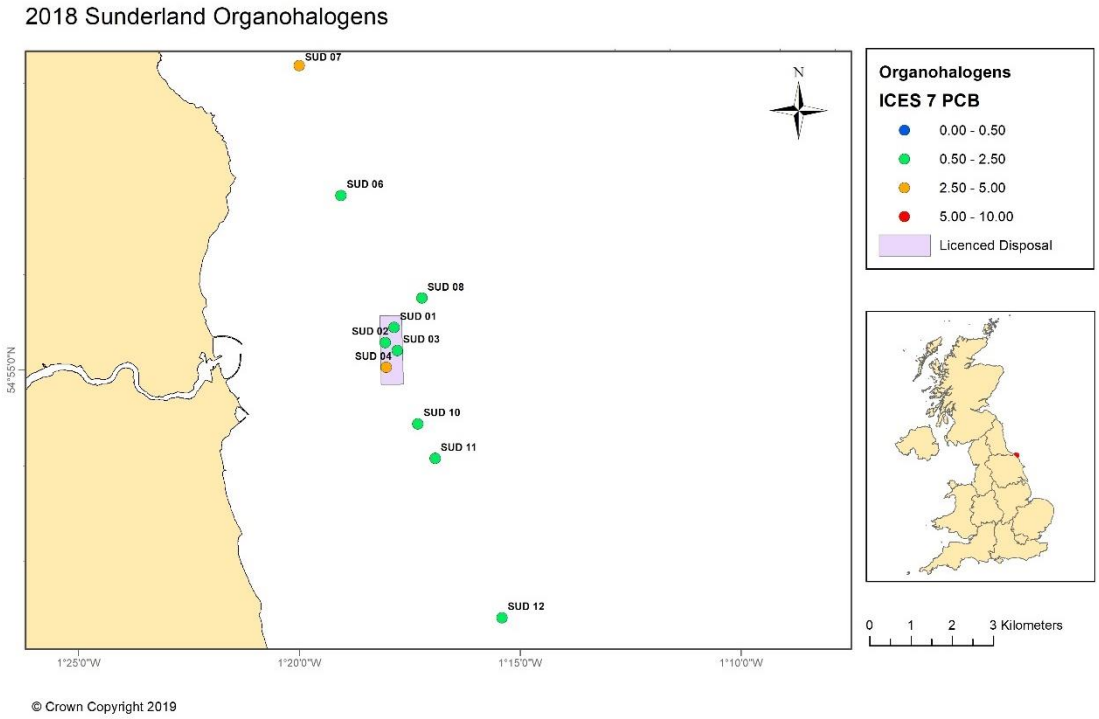


Figure A1.2.7: Summed ICES7 CB concentrations (µg kg^{-1} dw) for the Sunderland stations, 2018.

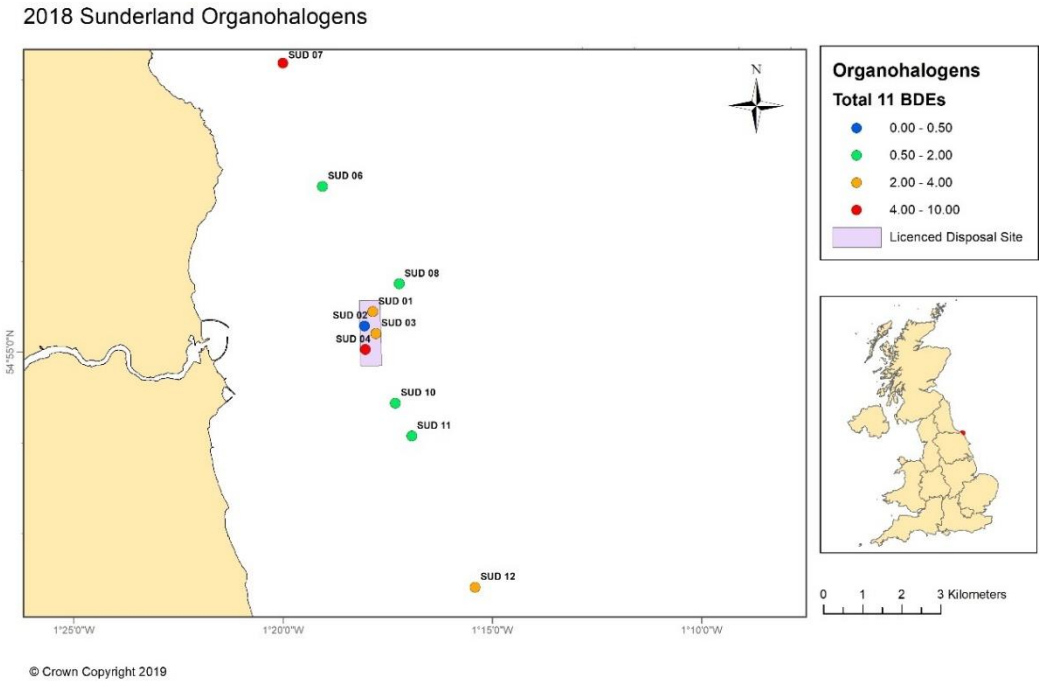


Figure A1.2.8: Summed 11 BDEs concentrations (µg kg^{-1} dw) for the Sunderland stations, 2018.

BDE209 was detected at all 10 stations and was at higher concentrations than the other measured organohalogens (range 1.6-101 µg kg^{-1} dw). When included with the other BDEs, BDE209 made up >68 % of the BDEs present (range 68-88 %). 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. Three out of the four highest values were found at stations within the disposal site (101, 86 and 39 µg kg^{-1} dw at SUD03, SUD04 and SUD01, respectively; Figure A1.2.9), with an additional high value of 51 µg kg^{-1} dw at SUD07 to the north. Once again, the lowest value was found at SUD02, within the disposal site.

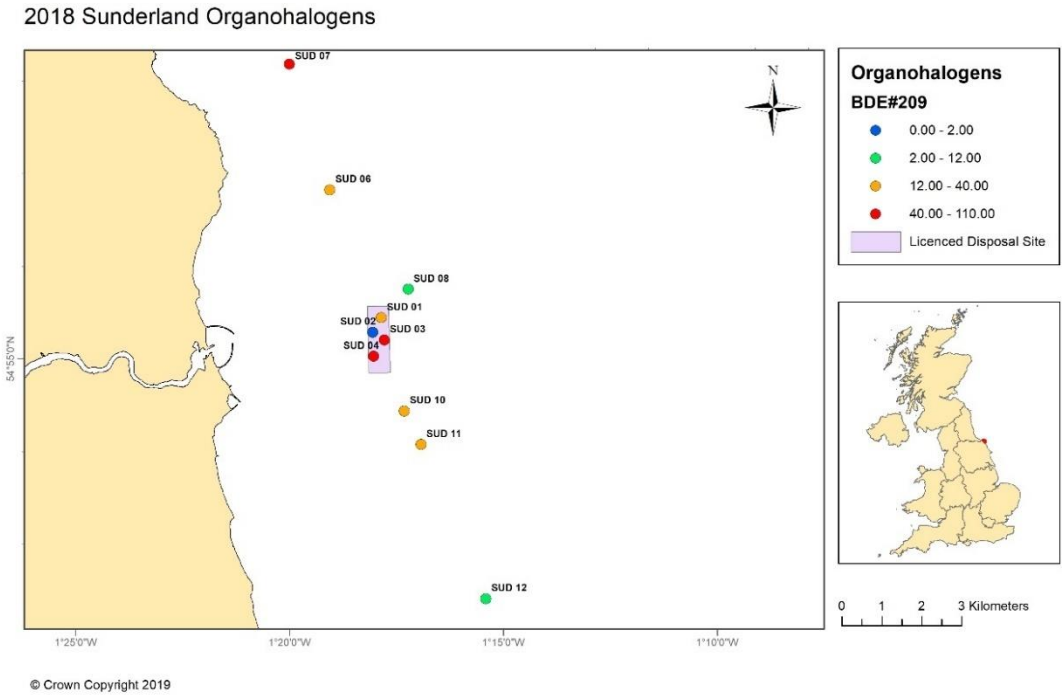


Figure A1.2.9: BDE209 concentrations (µg kg^{-1} dw) for the Sunderland Stations, 2018.

The OCPs HCB, dieldrin, plus DDT and metabolites were detected at all stations (Figure A1.2.10). $\sum_6$DDTs concentrations ranged from 0.24-3.1 µg kg^{-1} dw, with the highest values at SUD04 (3.1 µg kg^{-1} dw) and SUD07 (3.0 µg kg^{-1} dw). HCB concentrations ranged from 0.29 – 1.1 µg kg^{-1} dw, with the highest values at SUD07 (1.1 µg kg^{-1} dw) and SUD12 (0.52 µg kg^{-1} dw). Dieldrin was detected at all stations (range 0.15-0.80 µg kg^{-1} dw), with the highest values at SUD04 (0.80 µg kg^{-1} dw) and SUD07 (0.62 µg kg^{-1} dw).

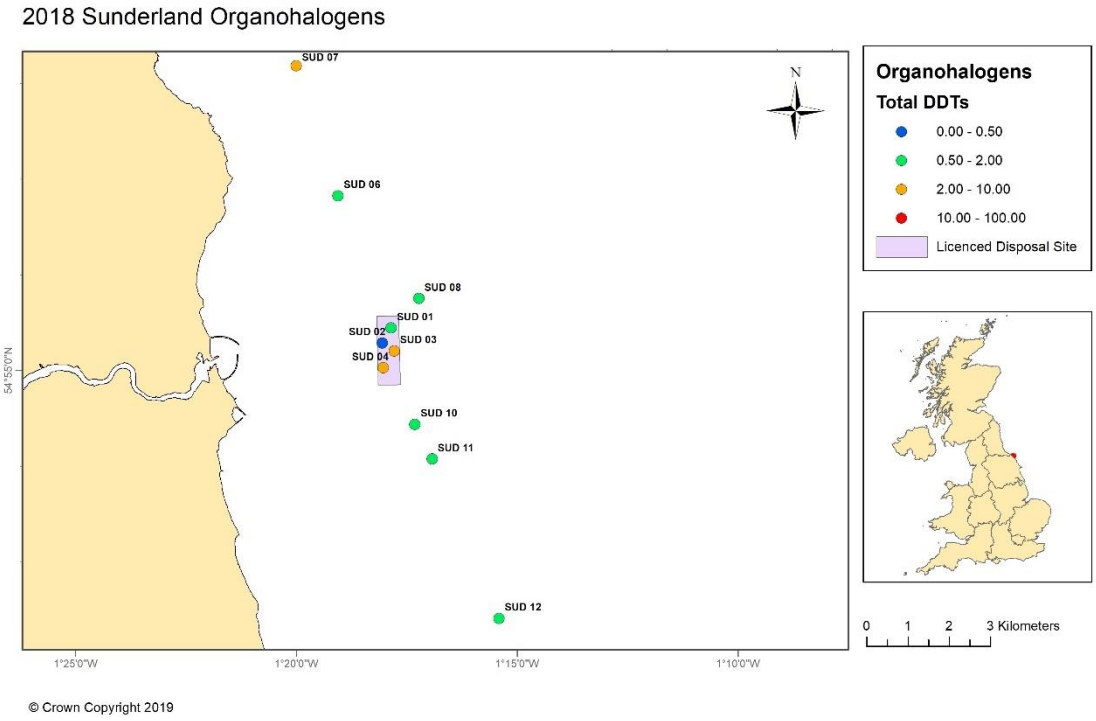


Figure A1.2.10: Total DDT concentrations (µg kg^{-1} dw) for the Sunderland Stations, 2018.

Concentrations of CBs and dieldrin at all stations were below Cefas action level 1. Total DDT concentrations were above Cefas action level 1 at all stations except SUD02. No Cefas action levels exist for BDEs and BDE209 (Appendix 2.2). According to the OSPAR guidelines, all stations had 'good' environmental status for all ICES 7 CBs, and 'good' status overall. Using the new OSPAR guidelines for BDEs (Appendix 2.2), all stations were below the EACs for all congeners, although SUD03 and SUD04 were close to the EAC for BDE209. Both these stations are within the disposal site.

There are no previous sediment OH data from Sunderland with which to compare the 2018 results for temporal trends. In this respect, the data acquired here represent an important data gap for this disposal site. In comparison with the nearby North Tyne dredge disposal area (Section 1.2.3.2), Sunderland has similar concentrations.

2.2.3.3 *Trace metals*

Assessment of arsenic concentrations shows either no or slight enrichment at Sunderland. Both OSPAR BAC and regional baseline methods inferred no enrichment within the disposal site. In

general, both methods (OSPAR BAC and regional baseline values) show comparable observations. There are no previous data upon which temporal comparisons for Sunderland disposal site could be evaluated.

Chromium and nickel are both slightly enriched with the OSPAR assessment at all stations (except SUND08 and SUND11 which have no enrichment) but since the baseline values for this region are higher than the OSPAR BAC value (Table A2.3.1), all sampling stations display no enrichment using the baseline approach (except for SUND02 which shows slight enrichment; Figure A1.2.11).

Both assessment methods depict the same observations for cadmium of moderate enrichment at stations within the disposal site boundary (SUND01, SUND03 and SUND04). SUND02, the other station inside the site, has a slight enrichment. All stations outside the site display either no or very low slight enrichments. Cadmium concentrations within the disposal site were, therefore, greater than those outside. Copper showed a similar pattern to cadmium, being slightly elevated outside and moderately enriched at stations inside the disposal site.

Mercury is moderately enriched according to the OSPAR map for all stations, except SUND02 and SUND11 which display slight enrichment. In contrast, mercury was not enriched at all when assessed in accordance with the regional baseline values. There are no dispersion trends and the disposal site does not display greater concentrations compared with stations outside the site (Figure A1.2.12).

Lead enrichment is high for all stations within the confines of the disposal site with the OSPAR assessment method (except SUND02 which is moderate). Stations outside the site are slight or moderately enriched displaying a trend for higher concentration of lead within the disposal site with no dispersal of lead along the north-south transect. Using the baseline approach, lead values are less enriched, although the stations inside the site are still either slight (one station) or moderately enriched (three stations)

Moderate zinc enrichment is observed at stations within the disposal site based on the OSPAR BAC assessment (except for slight enrichment at SUND02; Figure A1.2.11). Outside the site, the OSPAR assessment shows only slight enrichment with no dispersion trend. There is a reduced enrichment according to the regional baseline approach with only one station (SUND04)

moderately enriched. All other stations within the disposal site are slightly enriched and all outer stations show have no or low enrichment.

In conclusion, the metals concentrations at Sunderland tend to be much higher than the OSPAR BAC values especially for mercury and lead. This is generally due to the legacy from the historical and current industrial activities of the area. When assessing those concentrations against the proposed baseline values, which were derived by taking regional variability into account, enrichment is still observed for lead (especially within the disposal site) but to a reduced level. Mercury displays no enrichment against baseline assessments. Cadmium has a noticeably higher concentration inside the disposal site compared to outside, as does lead, but no other elements displays a noticeably increased concentration inside the site (based on either OSPAR BAC or regional assessment methods; Figure A1.2.12).

Although there have been no previous surveys with historical data to refer to for temporal trend analysis, recent dredging disposal application results (based on partial digestion of sediment rather than total digestion) reveal that there were potentially high levels of lead (exceeded Cefas action level 1 but below Cefas action level 2) in sediment from Sunderland Harbour that have been disposed at sea in recent years. There was sediment exceeding action level 2 for lead; while excluded from sea disposal, this highlights the high level of this metal in Sunderland Harbour sediment. This is evidenced by the elevated levels of this element, especially within the Sunderland disposal site, compared to those within North Tyne and Whitby.

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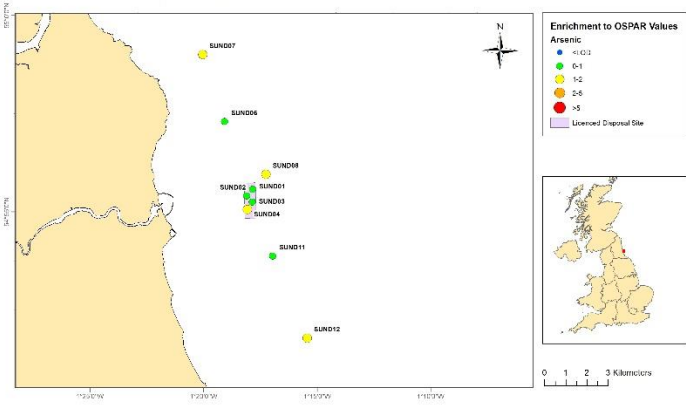

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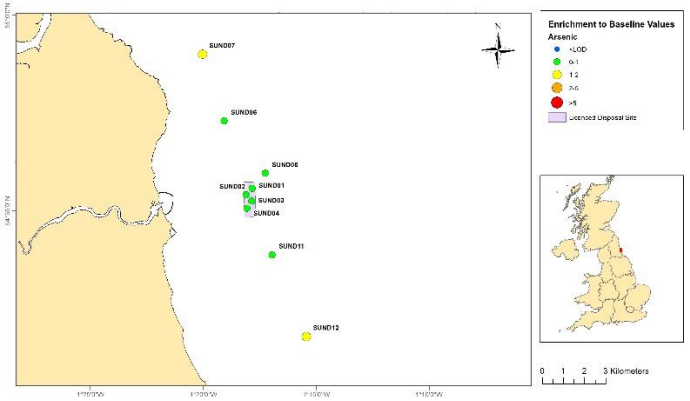

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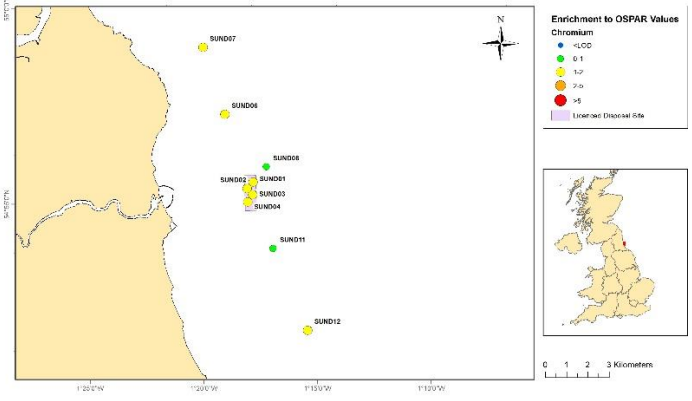

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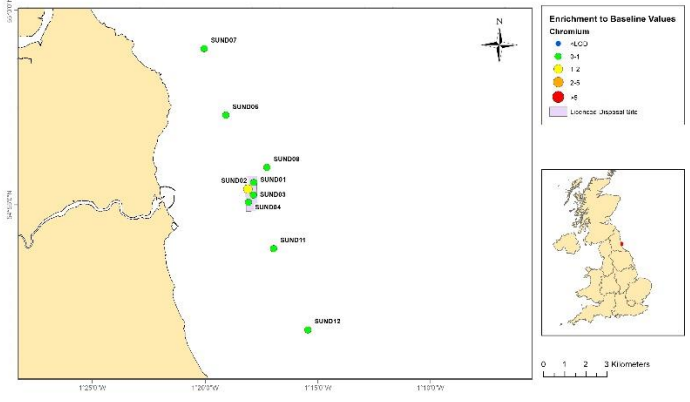

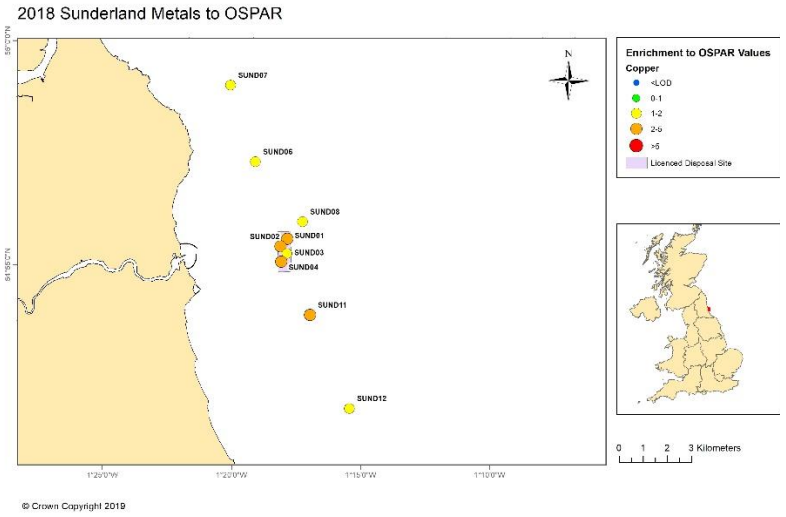
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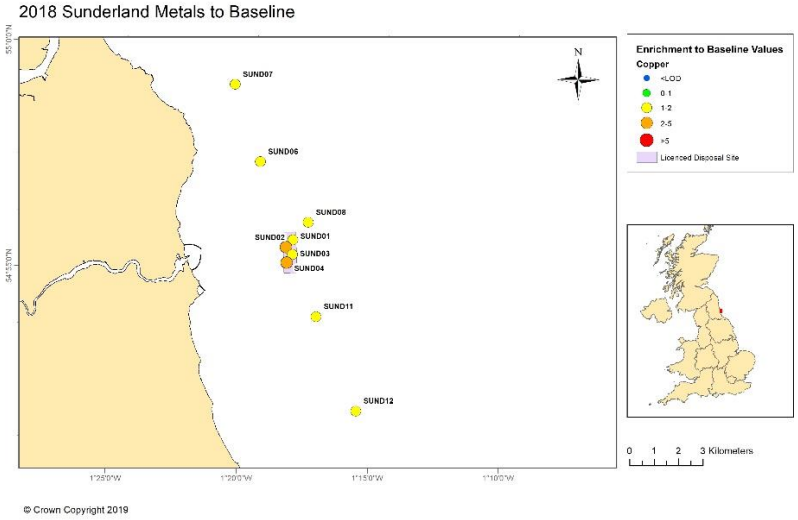
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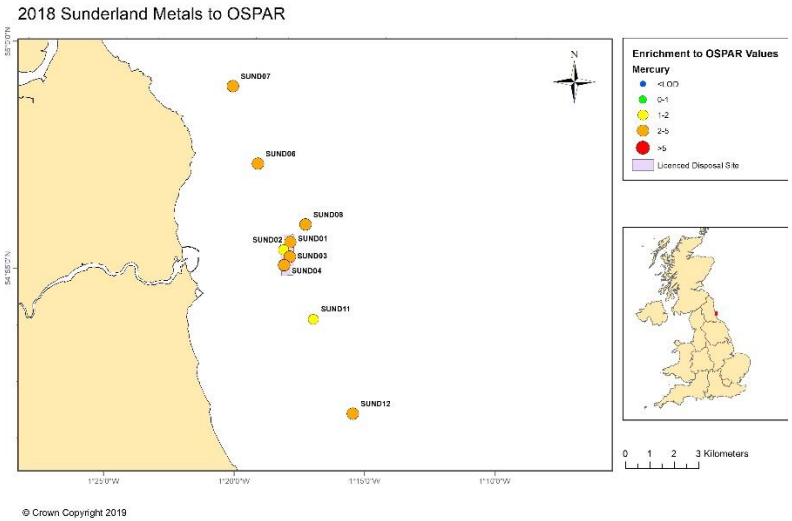
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Enrichment to OSPAR Values
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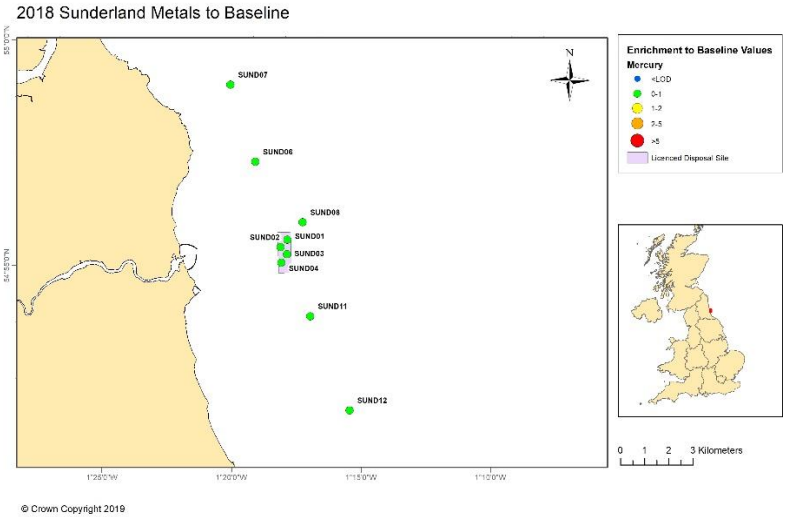
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Enrichment to Baseline Values
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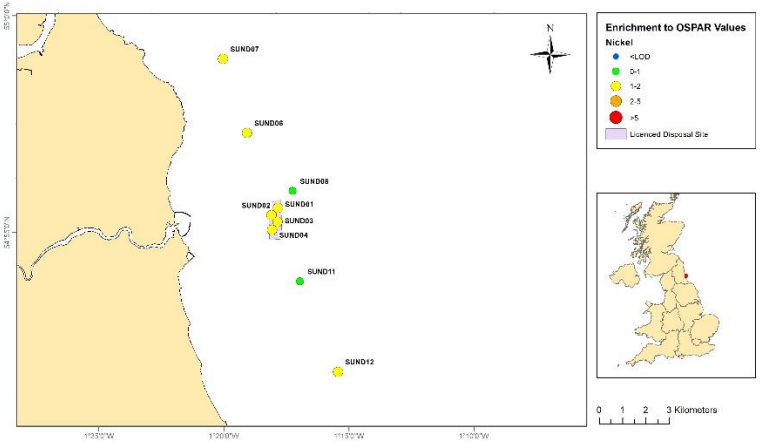
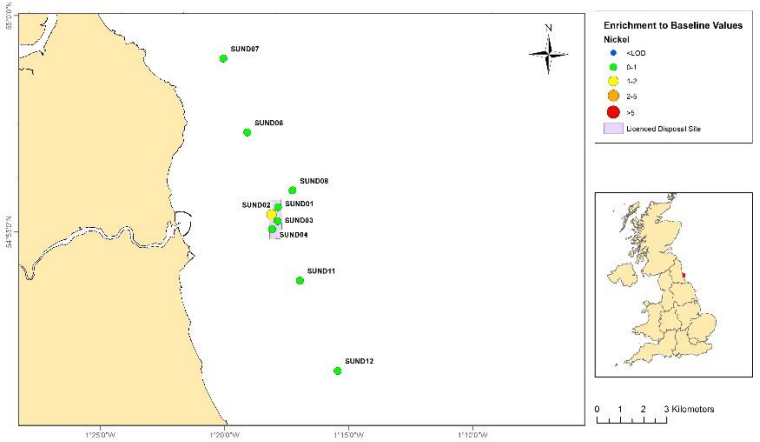
2018 Sunderland Metals to OSPAR



2018 Sunderland Metals to Baseline



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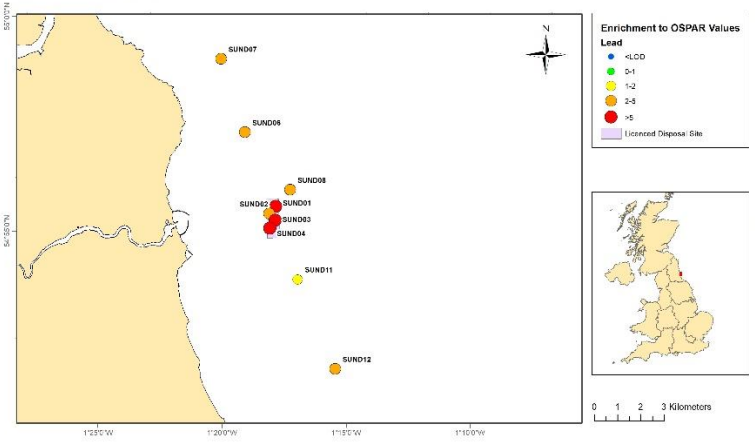

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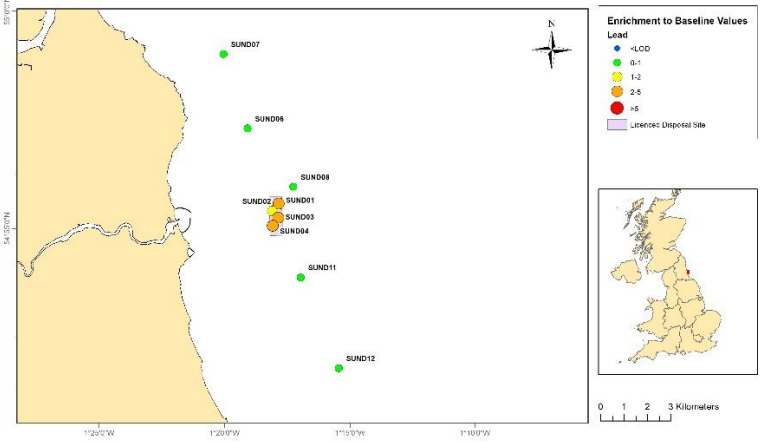

Figure A1.2.11: Enrichment to OSPAR BACs (left) and regional baseline values (right) at Sunderland for As, Cr, Cu, Hg, Ni, Pb, Cd and Zn.

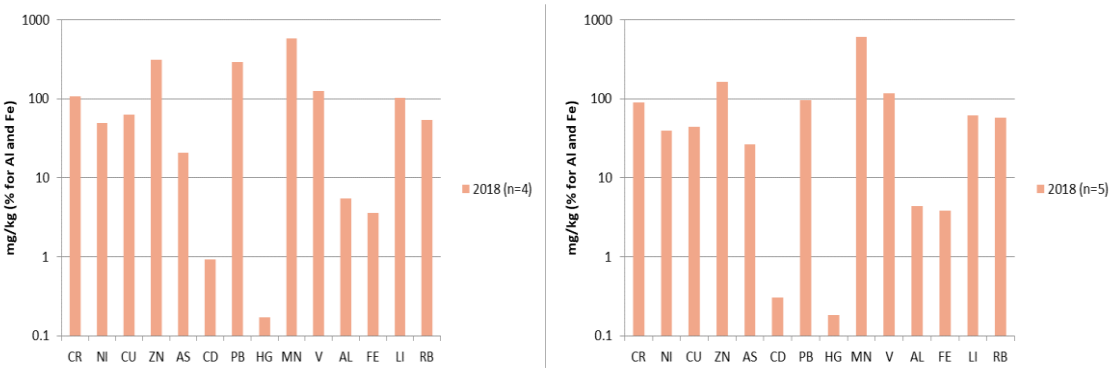

Figure A1.2.12: Trace metals concentrations for stations sampled inside (left) and outside (right) the Sunderland disposal site, 2018.

3 Whitby (TY180)

3.1 Background

A small (0.62 km^2) disposal site, located in approximately 40 m water depth, situated 2.4 km off the northeast coast adjacent to the town of Whitby. Although there is no readily available information on the designation of this site, 'returns' data for this site date from 1984 demonstrating it to be a historic site with a long history of use. This disposal site receives material dredged from the River Esk in Whitby, in particular from the Whitby Harbour maintenance dredging which currently licences up to 49,000 wet tonnes of material for disposal per annum. Average annual tonnage disposed to TY180 during the past decade is 32,750 t, although no material was disposed during 2013 and 2014 (Figure A1.3.1).

Routine testing of the dredge material has shown a persistent presence of elevated hydrocarbon compounds in Whitby Harbour, particularly oil/coal derived PAHs (napthalenes and phenathrenes). Whilst disposal has been licenced to continue, there is currently annual sampling for PAHs to determine either a downward trend or investigate the origins of the contamination in Whitby. Akin to the situation for Sunderland, the sediment chemistry at the disposal site is not known and, therefore, it is not currently possible to evaluate any potential impacts of disposal on the sediment chemistry at the site. In view of this, sampling in 2018 targeted sediments within and surrounding the site and assessed them for PAHs and hydrocarbon concentrations.

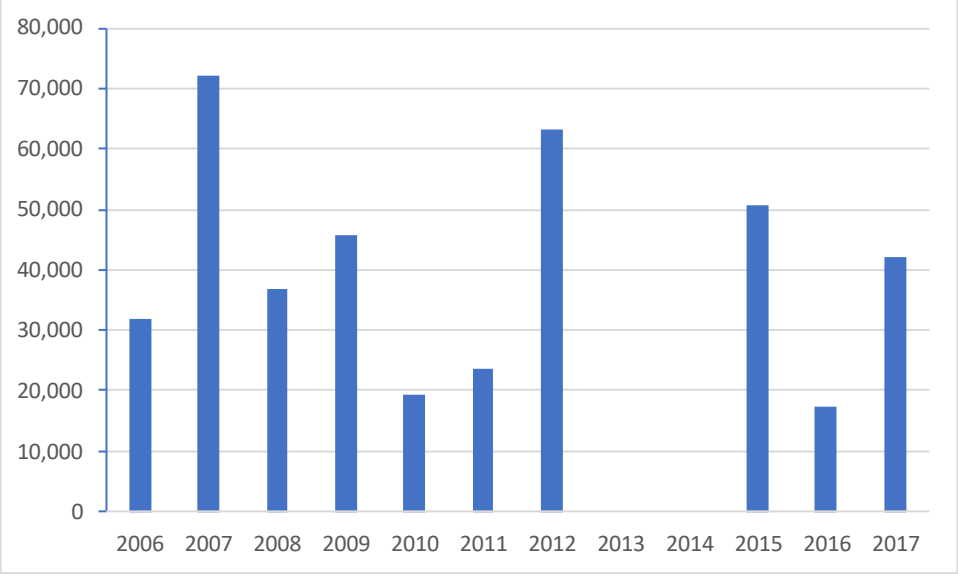

Figure A1.3.1: Annual tonnages of dredged material (in t wet weight) disposed to Whitby in recent years. Average annual tonnage disposed during this period is 33,540 t.

During the 2018 survey, sediment samples were collected at 11 stations, four of which (WHYT01, WHYT02, WHYT03 and WHYT04) were located within the disposal site (Figure A1.3.2).

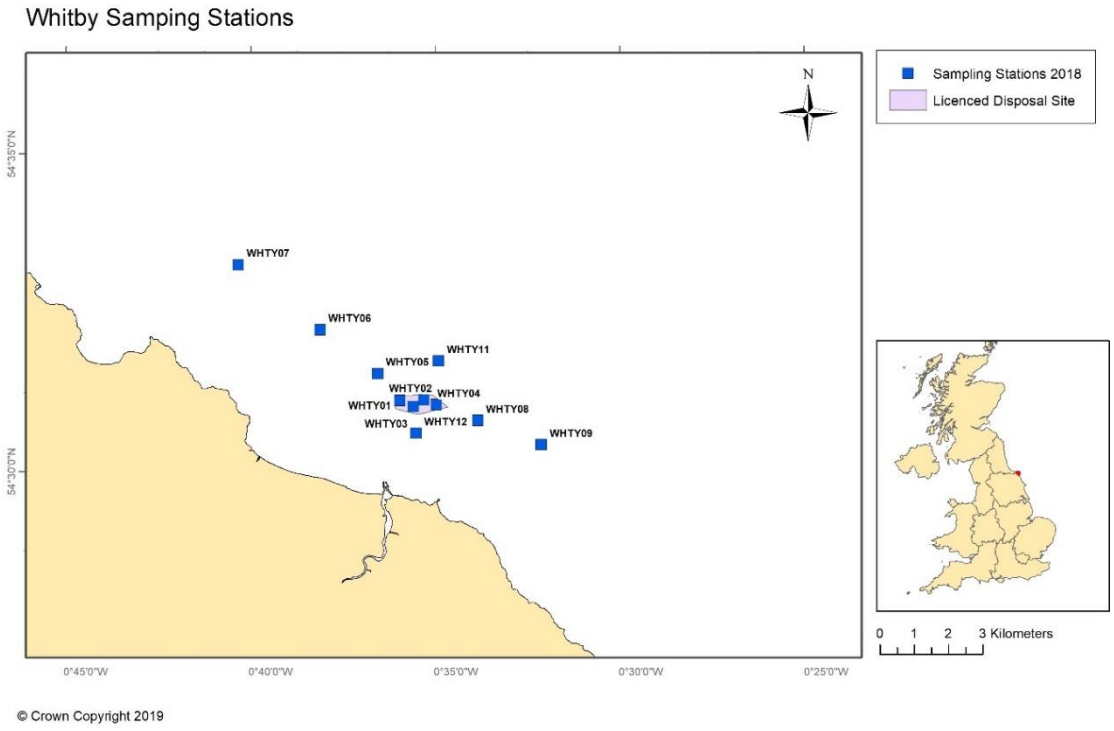

Figure A1.3.2: Stations sampled at Whitby disposal site for sediment and contaminant concentration assessment, 2018.

3.2 Results

3.2.1 Sediment Particle Size

Sediments from Whitby in 2018 were composed predominantly of muddy sands (slightly gravelly and gravelly), with slightly gravelly sands and muddy sandy gravels, as shown by sediment summary in Table A1.3.1.

The spatial variation of gravel, sand and silt/clay for each sampling station in 2018 is shown in Figure A1.3.3. There are variable concentrations of silt/clay content present, with the lowest (~5 %) at WHTY01 and highest (~30 %) at WHTY03 within the disposal site.

Table A1.3.1: Sediment descriptions (top) and statistics (bottom) for each station sampled at Whitby, 2018.

Sample code	Sample type	Sediment description
WHTY01	Unimodal, Very Poorly Sorted	Slightly Gravelly Muddy Sand
WHTY02	Unimodal, Poorly Sorted	Slightly Gravelly Sand
WHTY03	Bimodal, Very Poorly Sorted	Slightly Gravelly Muddy Sand
WHTY04	Polymodal, Very Poorly Sorted	Gravelly Muddy Sand
WHTY05	Unimodal, Poorly Sorted	Slightly Gravelly Muddy Sand
WHTY06	Unimodal, Poorly Sorted	Slightly Gravelly Sand
WHTY07	Polymodal, Very Poorly Sorted	Gravelly Muddy Sand
WHTY08	Polymodal, Very Poorly Sorted	Gravelly Muddy Sand
WHTY09	Polymodal, Very Poorly Sorted	Muddy Sandy Gravel
WHTY11	Trimodal, Very Poorly Sorted	Gravelly Muddy Sand
WHTY12	Polymodal, Very Poorly Sorted	Muddy Sandy Gravel

Sample code	Gravel (%)	Sand (%)	Silt/clay (%)	Very coarse sand (%)	Coarse sand (%)	Medium sand (%)	Fine sand (%)	Very fine sand (%)
WHTY01	2.27	78.10	19.63	1.34	11.93	36.70	23.47	4.66
WHTY02	2.96	91.87	5.17	16.61	52.95	16.53	4.35	1.44
WHTY03	2.18	64.60	33.22	1.27	10.55	31.14	16.31	5.33
WHTY04	14.36	71.77	13.86	18.60	18.32	17.71	10.53	6.62
WHTY05	0.44	87.01	12.54	0.86	10.28	35.49	36.80	3.59
WHTY06	0.07	93.09	6.84	0.15	4.92	38.98	46.47	2.57
WHTY07	17.33	62.37	20.31	16.26	16.79	7.05	11.02	11.24
WHTY08	7.46	63.76	28.77	9.57	14.80	16.04	12.55	10.79
WHTY09	36.09	50.52	13.39	10.53	17.09	12.64	5.49	4.77
WHTY11	14.30	62.22	23.48	27.75	13.70	8.08	5.51	7.18
WHTY12	34.29	55.29	10.42	10.44	12.16	13.97	13.72	5.00

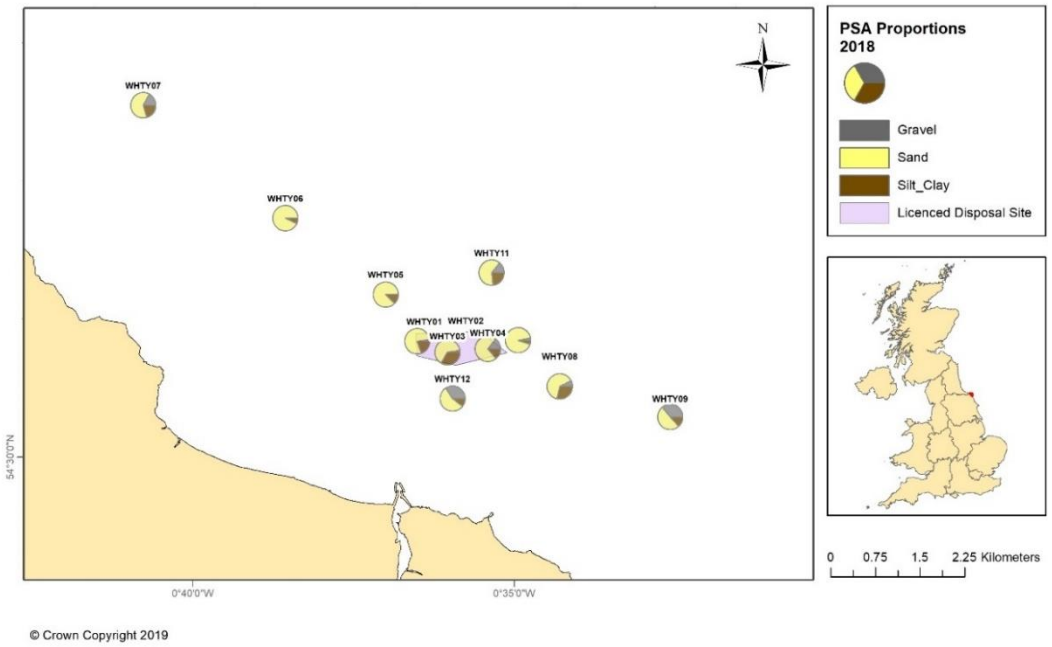

Figure A1.3.3: Pie charts of gravel, sand and silt/clay at Whitby, 2018.

3.2.2 Sediment organic carbon (POC)

Organic carbon values range from 0.8 to 4.4 % m/m in the <2 mm sediment fraction (Figure A1.3.4), and from 2.9 to 4.3 % m/m in the <63 µm fraction (Figure A1.3.5). Sediment organic carbon was not analysed on the <2 mm fraction for WHTY11 and WHTY12.

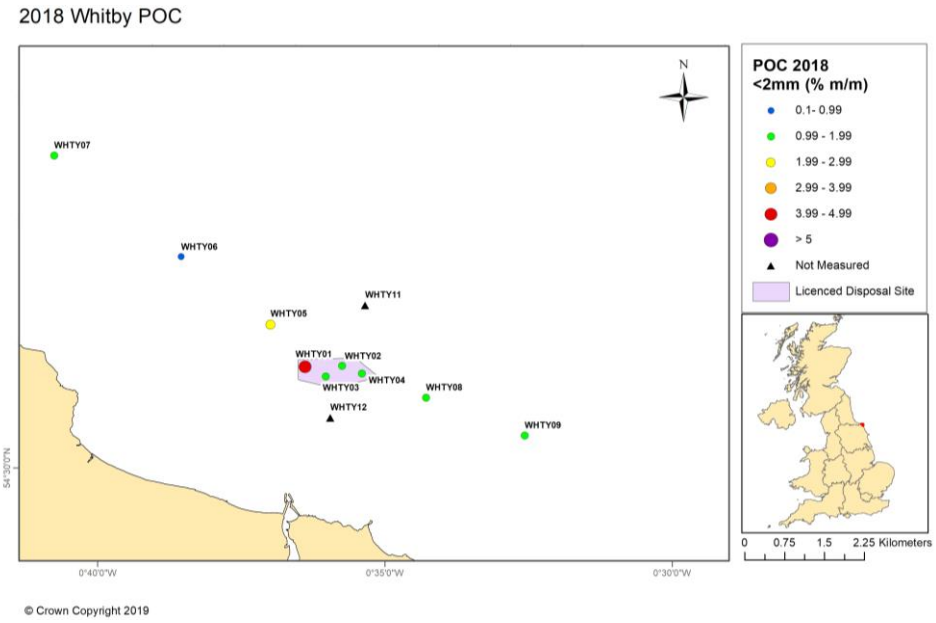

Figure A1.3.4: Organic carbon (% m/m) in the <2mm fraction at Whitby in 2018.

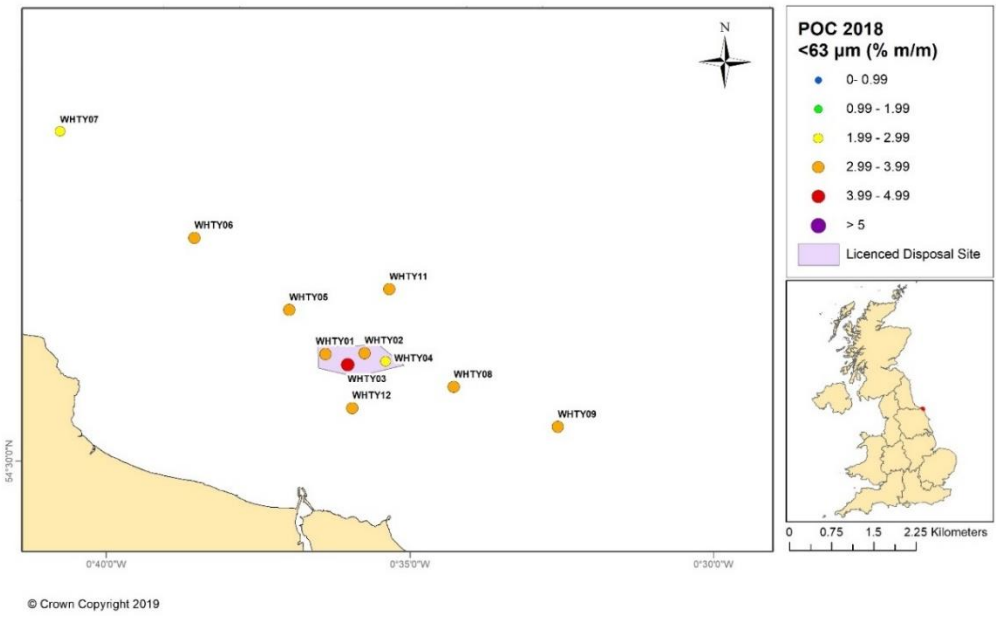

Figure A1.3.5: Organic carbon (% m/m) in the <63 µm fraction at Whitby in 2018.

3.2.3 Sediment Chemistry

3.2.3.1 Polycyclic aromatic hydrocarbons (PAHs)

The highest summed PAH concentration observed at Whitby in 2018 was 57,500 µg kg^{-1} dw at WHTY01 within the disposal site, whilst the second highest concentration was 23,800 µg kg^{-1} dw found at WHTY05 approximately 1 km northwest of the disposal site (Figure A1.3.6). Intermediate concentrations where found at WHTY02, WHTY03 and WHTY04 (range 6,100 – 6,700 µg kg^{-1} dw) within the disposal site, as well as at WHTY06 (5,600 µg kg^{-1} dw) approximately 4 km northwest of the disposal site and at WHTY08 (8,000 µg kg^{-1} dw) approximately 1 km east-southeast of the disposal site (Figure A1.3.6). Meanwhile, the lowest summed PAH concentration was 2,500 µg kg^{-1} dw at WHTY10 at the eastern limits of the survey, whilst the next lowest concentrations were at WHTY09 (3,800 µg kg^{-1} dw) approximately 4 km east-southeast of the disposal site and WHTY07 (4,800 µg kg^{-1} dw) at the northwest limits of the survey.

All but one sediment sample collected at Whitby exceeded the ERL for low molecular weight (LMW) PAHs, the exception being WHTY10 (lowest summed PAH concentration). Two stations

WHTY01 (highest summed PAH concentration) and WHTY05 (second highest summed PAH concentration) also exceeded the ERM for the LMW PAHs. Sediments from these same stations, WHTY01 and WHTY05, exceeded the ERL for the high molecular weight (HMW) but no station exceeded the ERM for the HMW PAHs. Evaluation of the PAH data indicated that the source in all the sediment samples was predominantly petrogenic, generally with >80 % of the PAH content arising from oil rather than combustion sources.

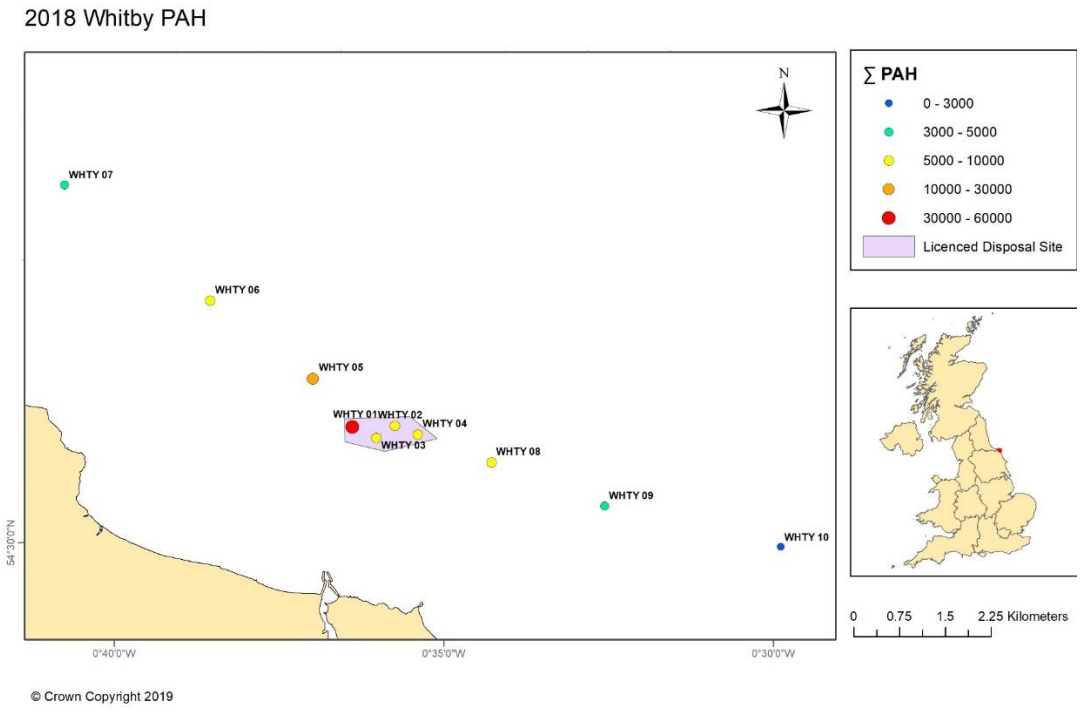

Figure A1.3.6: Summed PAH concentrations (µg kg $^{-1}$ dry weight) for stations sampled at Whitby, 2018.

3.2.3.2 *Trace metals*

Assessment of the metals enrichment for the Whitby stations sampled shows either no or slight enrichment for arsenic, except for WHTY06 (northwest of the disposal site) which is moderately enriched (see Figure A1.3.7). This was consistent for both the OSPAR BAC and the regional baseline assessment methods (Appendix 2.3). There are no previous data to refer to for temporal comparisons for the Whitby disposal site.

Chromium and nickel show comparable enrichments which are spatially consistent. While the OSPAR approach reveals slight enrichment at all stations, both in and outside the disposal site, all stations are below the regional assessment method.

Meanwhile, for cadmium, both assessment methods depict comparable observations, showing either slight or no enrichment across all stations. Furthermore, no within or outside disposal distinction is observable for cadmium. Three stations, one of which is inside the disposal site, possessed cadmium concentrations below limit of detection.

Copper is slightly or moderately enriched at all stations, except for no enrichment at two stations when assessed according to the regional baseline method. No spatial trends could be discerned for copper concentrations.

The biggest difference between the two assessment methods is observed for mercury. While most stations are moderately enriched according to the OSPAR approach (two stations being slightly enriched), all stations reveal no enrichment by the regional approach. A similar disparity between the two methods is observed for lead; all stations (except WHTY06 which is highly enriched) show moderate enrichment using the OSPAR method, but this is reduced to most stations showing no enrichment using the regional method (except two stations showing slight enrichment and WHTY06 being moderate).

Enrichment is slight for zinc at stations using the OSPAR assessment with values being similar for stations inside and outside the disposal site. The regional baseline approach gives either no or slight enrichment with no discernible trends.

In conclusion, the metals concentrations at Whitby tend to be noticeably higher than the OSPAR BAC values especially for mercury and lead. Other OSPAR assessed values tend toward slight enrichment. This is generally due to the legacy from the historical and current industrial activities of the area. When assessing those concentrations against the proposed baseline values which were derived accounting for regional variability, enrichment is still observed but to a reduced level. No element has a noticeably higher concentration in the disposal site compared to stations outside (Figure A1.3.8).

Although there have been no previous surveys producing historical data with which to refer for temporal trend analysis, recent disposal application results (based on partial digestion of sediment rather than total digestion) reveal that there were no significant levels of metals in sediment from Whitby harbour that have been disposed at sea in recent years.

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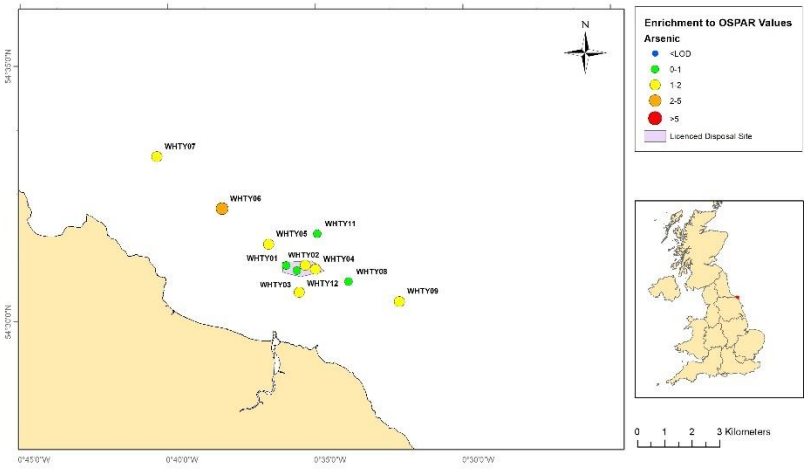

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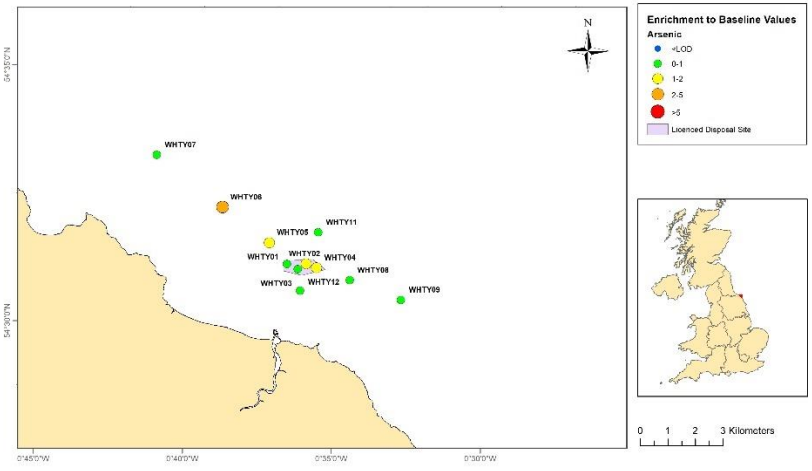

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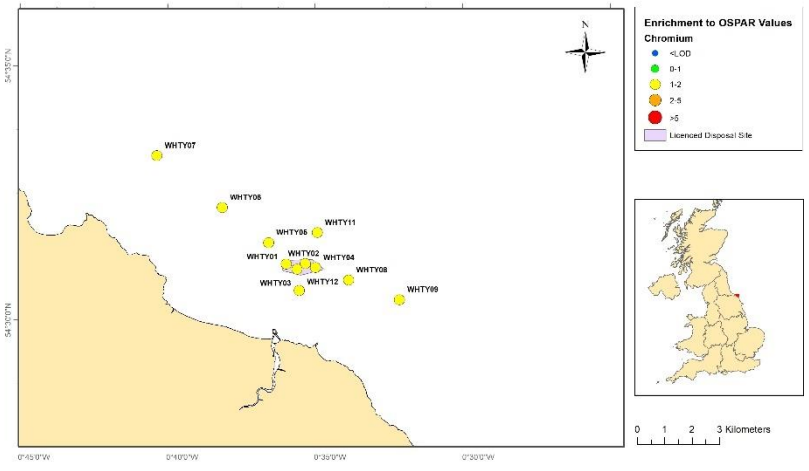

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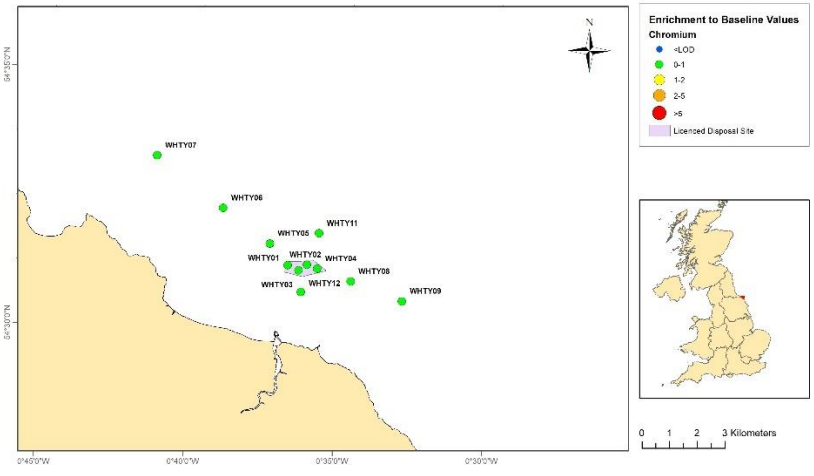

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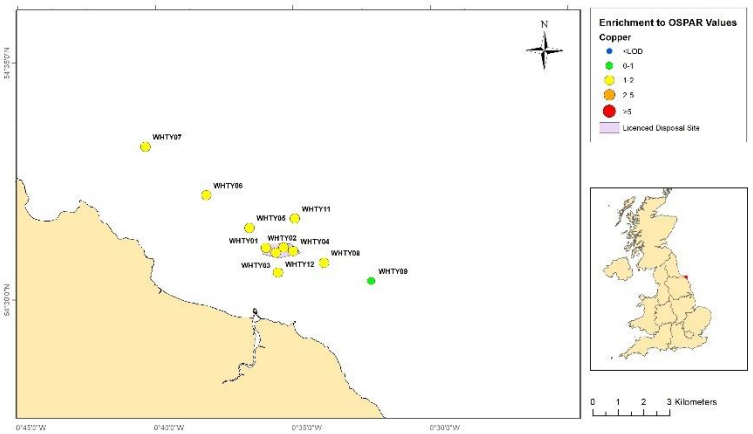

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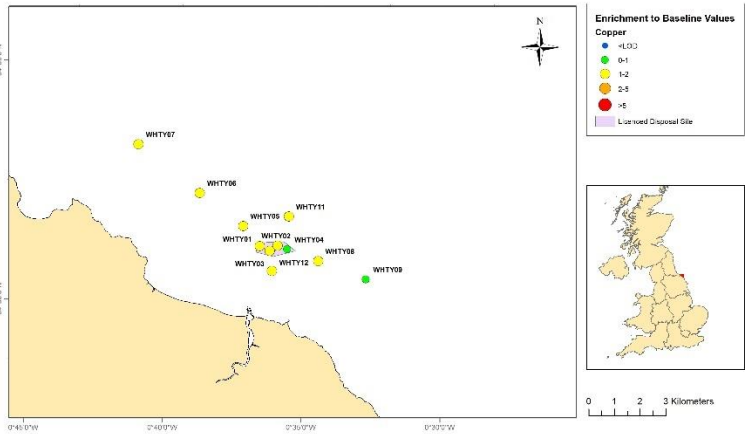

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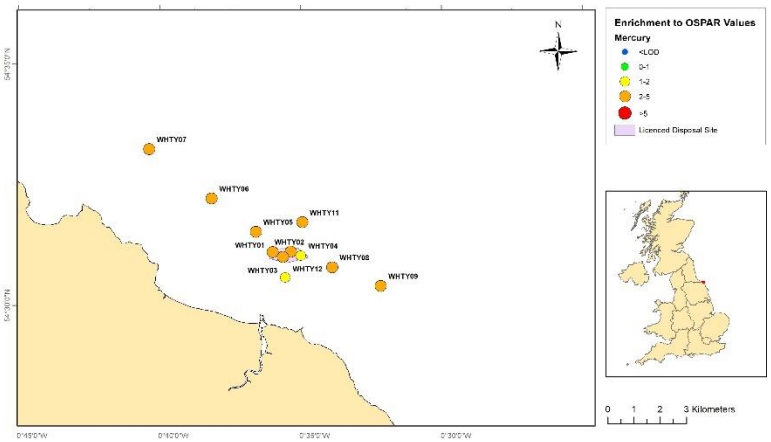

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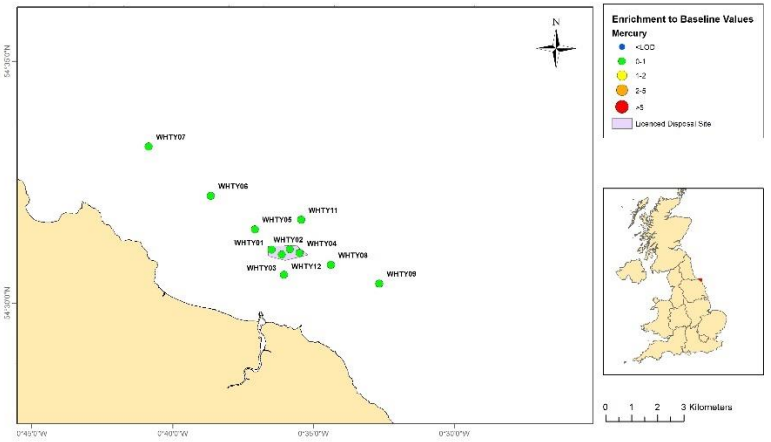

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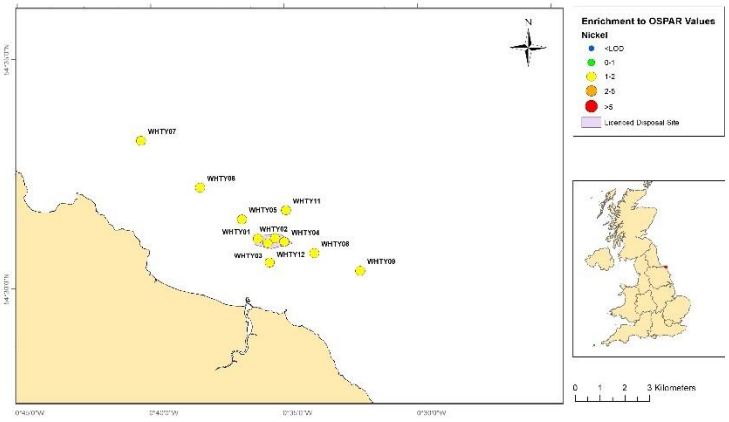

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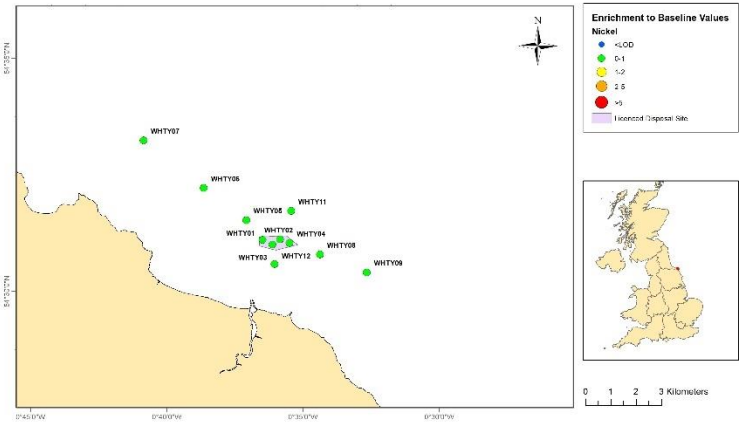

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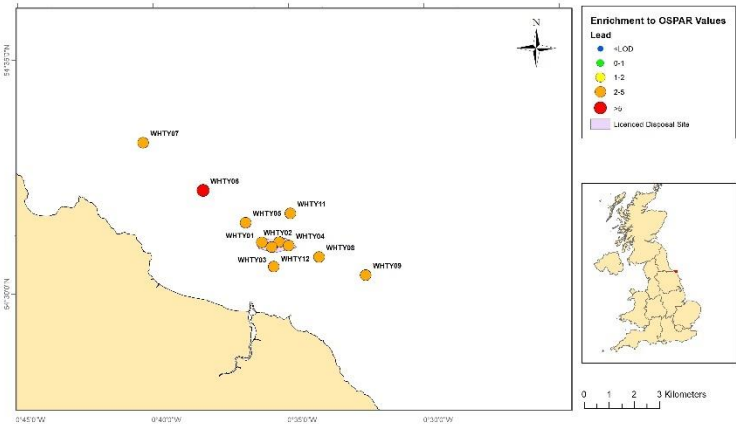
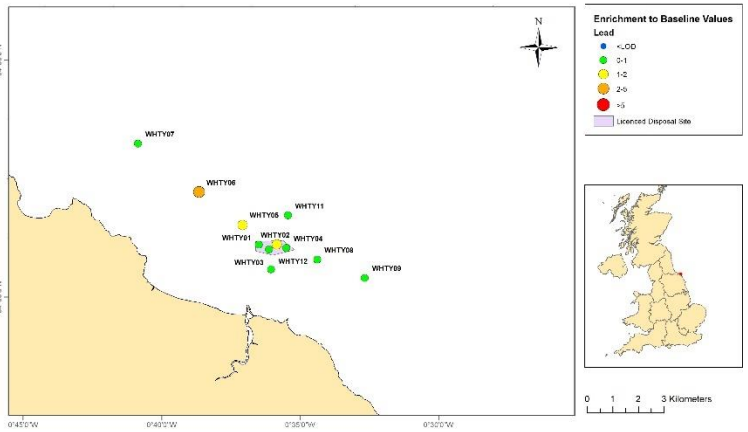


2018 Whitby Metals to Baseline



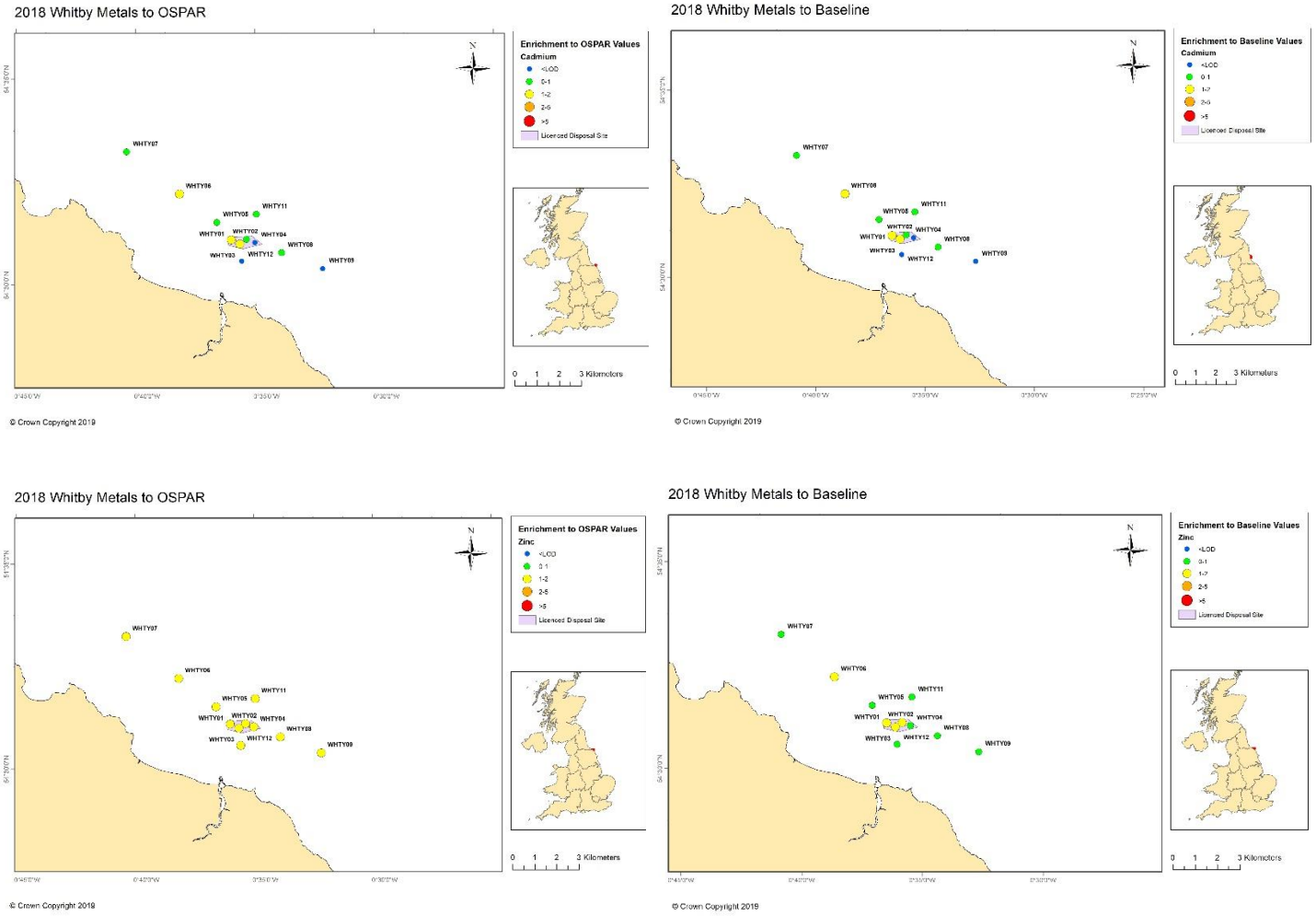


Figure A1.3.7: Enrichment to OSPAR BACs (left) and regional baseline values (right) at Whitby in 2018 for As, Cr, Cu, Hg, Ni, Pb, Cd and Zn.

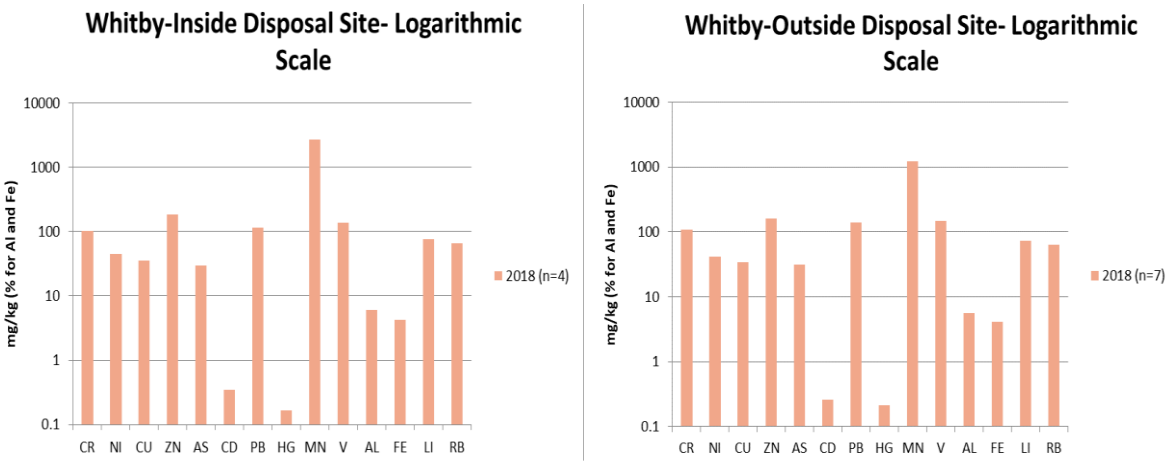


Figure A1.3.8: Concentrations of trace metals in sediments sampled inside (left) and outside (right) the Whitby disposal site, 2018.

4 Nab Tower (WI060)

4.1 Background

Nab Tower is a well-used disposal site, 30-40 m in depth and approximately 13 km southeast of Bembridge, Isle of Wight. 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 Mt (wet weight) 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 in 1995 and 1996 when 5.3 and 6.3 Mt wet weight (respectively) were disposed, and, more recently in 2014 with the placement of almost 5 Mt of material (Figure A1.4.1).

In recent years, there has 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 the potential increased usage of the 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 the physical (Figure A1.4.2) and biological changes to the seabed to be conducted (Bolam et al., 2015b).

Recently, the MMO granted a marine licence (from April 2015 to July 2017) for the disposal of a large amount of material to the site from a large capital dredge to deepen the Portsmouth approach channel to accommodate the new Queen Elizabeth aircraft carriers. Approximately 6 Mt (wet weight) of clay, gravel, sand and silt material was licenced to be disposed to the site during this dredging campaign. To provide data to allow an assessment of the ecological implications of this large deposit, the MMO sanctioned ecological sampling under the auspices of C6794 during 2017 (Bolam et al., 2018); the acquired data described the ecological conditions at the end of this large disposal. Sampling subsequently conducted during 2018 was aimed to allow an assessment of the early recovery from this large placement. The stations sampled during 2017 for macrofaunal and sediment particle size was revisited to facilitate this temporal assessment. Moreover, the conclusions reached regarding recovery from the large capital

campaign may be compared with the few analogous studies (e.g., Roughs Tower, Barrow-in-Furness; Ware et al., 2010) focussing on capital campaigns across the coast of England.

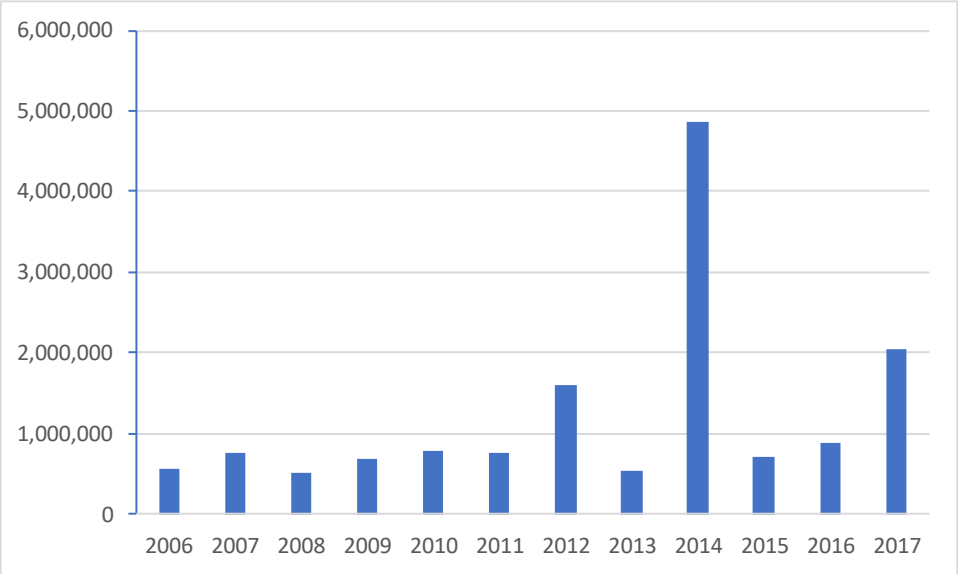


Figure A1.4.1: Annual tonnages of dredged material (in t wet weight) disposed to WI060 in recent years. Average annual tonnage disposed during this period is 1,223,658 t.

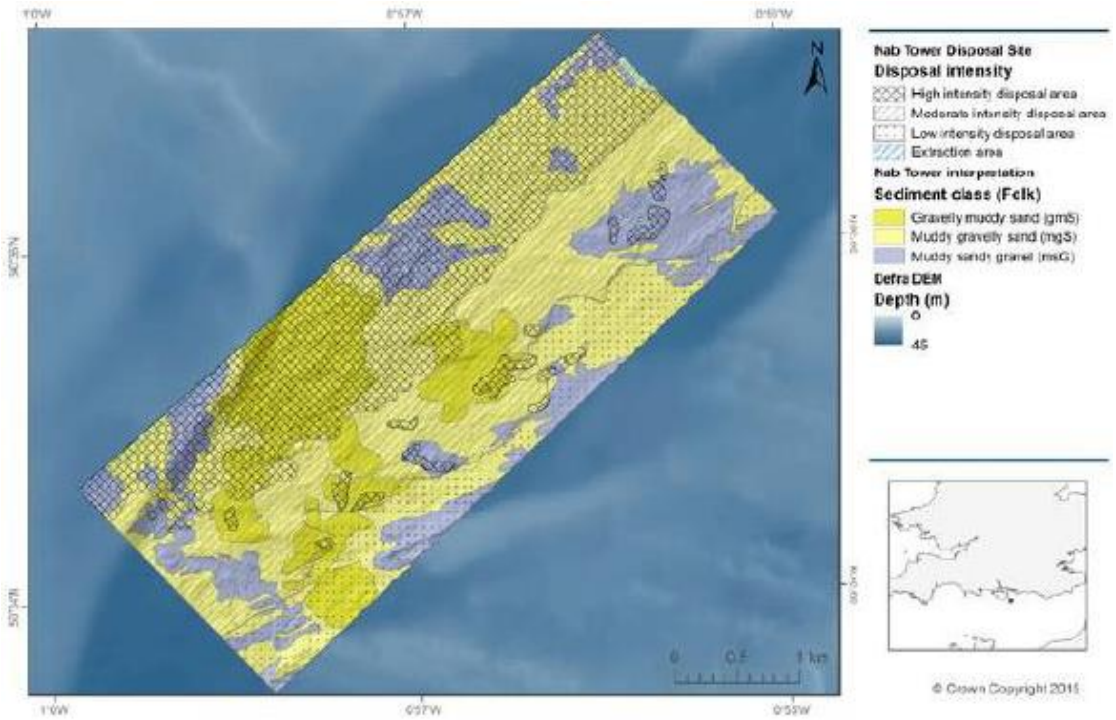


Figure A1.4.2: Relative intensity of disposed dredged material on the seabed at Nab Tower, November 2014. Data collected under the auspices of SLAB5 (Bolam et al., 2015b).

4.2 Results

4.2.1 Sediment Particle Size

Sediments from Nab Tower during 2018, analogous to that observed in 2014, were composed of mixed and coarse sediment types, being predominantly muddy sandy gravels, sandy gravels, gravelly sands and gravelly muddy sands with slightly gravelly sandy mud and gravel, as shown by sediment summary in Table A1.4.1. There were insufficient samples overall to create sediment groups and so temporal comparisons have been completed by comparing these sample pairs where present (Table A1.4.2).

Table A1.4.1: Sediment descriptions for each sample at Nab Tower in 2014 and 2018.

Sample code	Year	Sample type	Sediment description
ADD02	2018	Trimodal, Very Poorly Sorted	Muddy Sandy Gravel
G08	2014	Bimodal, Poorly Sorted	Muddy Sandy Gravel
	2018	Trimodal, Extremely Poorly Sorted	Muddy Sandy Gravel
G10	2014	Trimodal, Very Poorly Sorted	Muddy Sandy Gravel
	2018	Trimodal, Very Poorly Sorted	Gravelly Muddy Sand
G17	2014	Polymodal, Very Poorly Sorted	Sandy Gravel
	2018	Polymodal, Very Poorly Sorted	Sandy Gravel
G18	2014	Trimodal, Very Poorly Sorted	Gravel
	2018	Bimodal, Very Poorly Sorted	Sandy Gravel
G19	2014	Bimodal, Very Poorly Sorted	Muddy Sandy Gravel
	2018	Bimodal, Very Poorly Sorted	Gravelly Sand
G21	2014	Polymodal, Very Poorly Sorted	Sandy Gravel
	2018	Trimodal, Very Poorly Sorted	Muddy Sandy Gravel
G37	2018	Trimodal, Very Poorly Sorted	Sandy Gravel
Nab02	2014	Trimodal, Very Poorly Sorted	Gravelly Muddy Sand
	2018	Unimodal, Poorly Sorted	Gravelly Sand
Nab03	2014	Trimodal, Very Poorly Sorted	Muddy Sandy Gravel
	2018	Bimodal, Very Poorly Sorted	Slightly Gravelly Sandy Mud
Nab04	2014	Trimodal, Very Poorly Sorted	Gravelly Sand
	2018	Unimodal, Poorly Sorted	Gravelly Sand
Nab05	2018	Bimodal, Very Poorly Sorted	Sandy Gravel
Nab06	2014	Bimodal, Very Poorly Sorted	Muddy Sandy Gravel
	2018	Trimodal, Very Poorly Sorted	Muddy Sandy Gravel
Nab07	2014	Trimodal, Very Poorly Sorted	Gravelly Muddy Sand
	2018	Unimodal, Moderately Sorted	Gravelly Sand
Nab08	2014	Trimodal, Very Poorly Sorted	Gravelly Muddy Sand
	2018	Polymodal, Very Poorly Sorted	Muddy Sandy Gravel
Nab09	2014	Trimodal, Very Poorly Sorted	Muddy Sandy Gravel
	2018	Polymodal, Extremely Poorly Sorted	Muddy Sandy Gravel

Table A1.4.2: Sediment statistics for each sample at Nab Tower in 2014 and 2018.

Sample code	Gravel (%)	Sand (%)	Silt/clay (%)	Very coarse sand (%)	Coarse sand (%)	Medium sand (%)	Fine sand (%)	Very fine sand (%)
ADD02	53.83	40.87	5.30	2.27	9.80	14.77	12.44	1.58
G08	77.15	19.24	3.61	2.10	4.95	5.13	5.76	1.29
	41.54	35.03	23.44	3.54	6.93	7.74	12.15	4.67
G10	32.57	60.19	7.24	3.46	7.77	26.46	19.24	3.26
	29.39	54.94	15.67	2.09	5.13	21.46	20.93	5.32
G17	46.38	50.04	3.58	4.44	5.96	24.16	14.13	1.35
	35.85	60.27	3.88	3.50	7.88	30.92	16.68	1.29
G18	81.49	17.91	0.60	1.70	3.63	8.43	3.90	0.25
	57.21	38.68	4.11	2.15	4.72	20.45	10.03	1.33
G19	50.28	40.00	9.72	3.13	4.35	21.14	10.20	1.17
	20.02	72.74	7.24	0.83	4.86	47.84	18.05	1.15
G21	55.00	41.30	3.70	6.84	11.21	11.50	10.27	1.47
	63.96	31.66	4.38	3.75	8.09	8.92	9.55	1.34
G37	63.20	34.17	2.64	1.58	13.63	16.76	1.75	0.44
Nab02	12.09	61.61	26.30	7.00	18.74	24.61	9.27	2.00
	5.66	87.76	6.58	3.75	36.72	42.44	4.21	0.63
Nab03	37.58	46.17	16.25	6.87	12.05	13.81	9.84	3.59
	0.42	12.45	87.13	0.32	0.00	0.42	5.41	6.31
Nab04	27.44	66.79	5.77	5.46	17.98	25.67	15.82	1.85
	7.15	88.96	3.89	5.21	40.67	37.80	4.71	0.58
Nab05	62.18	35.22	2.61	6.68	19.95	7.17	0.83	0.60
Nab06	51.56	42.73	5.71	2.84	6.62	11.79	19.06	2.42
	57.10	35.90	7.00	2.12	7.09	9.04	15.28	2.37
Nab07	21.34	65.02	13.65	3.55	11.31	30.25	16.65	3.26
	5.13	91.17	3.70	4.79	40.55	41.39	3.84	0.60
Nab08	19.03	71.86	9.12	5.09	10.12	28.13	25.75	2.77
	33.99	54.00	12.01	3.53	10.15	21.21	16.99	2.12
Nab09	50.60	41.28	8.12	5.64	8.68	12.81	11.29	2.86
	48.75	30.51	20.74	4.50	5.81	6.83	8.74	4.62

The spatial variation of gravel, sand and silt/clay for each sampling station in 2018 is shown in Figure A1.4.3. The highest concentration of silt/clay was observed at Nab03 (~90 % silt/clay), within the northern limit of the disposal boundary. Sediments within the disposal site generally contain lower gravel content to those outside of the site, which is likely to be related to the sediment types being disposed here. Variable temporal changes in silt/clay content for sampling stations from 2014 and 2018 are observed (Figure A1.4.4). The significant increase in silt/clay content from 2014 (~16 %) to 2018 (~90 %) at Nab03 within the disposal site is likely to relate to a recent disposal operation. There are smaller increases in silt/clay content at G08 (also inside the site), G10, G18 and Nab09 (all outside site). There are, in contrast, small decreases in silt/clay content from 2014 to 2018 at Nab02 and Nab07 (both within the disposal site). Silt/clay

content at other stations have remained temporally consistent. ADD02, G37 and Nab05 were only sampled in 2018. The sediment types being disposed of at this disposal site are mixed, and therefore temporal changes are complex and difficult to assess.

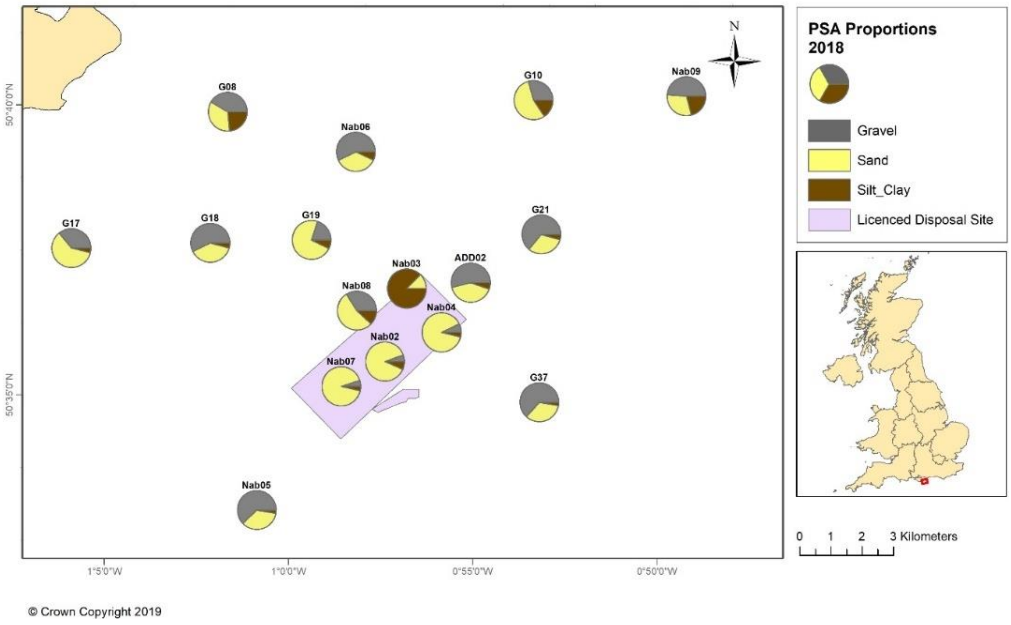


Figure A1.4.3: Pie charts of gravel, sand and silt/clay at Nab Tower (rectangular site), 2018. The small disposal site alongside the southeastern boundary of Nab Tower is the closed Area 451 Temporary Storage Site.

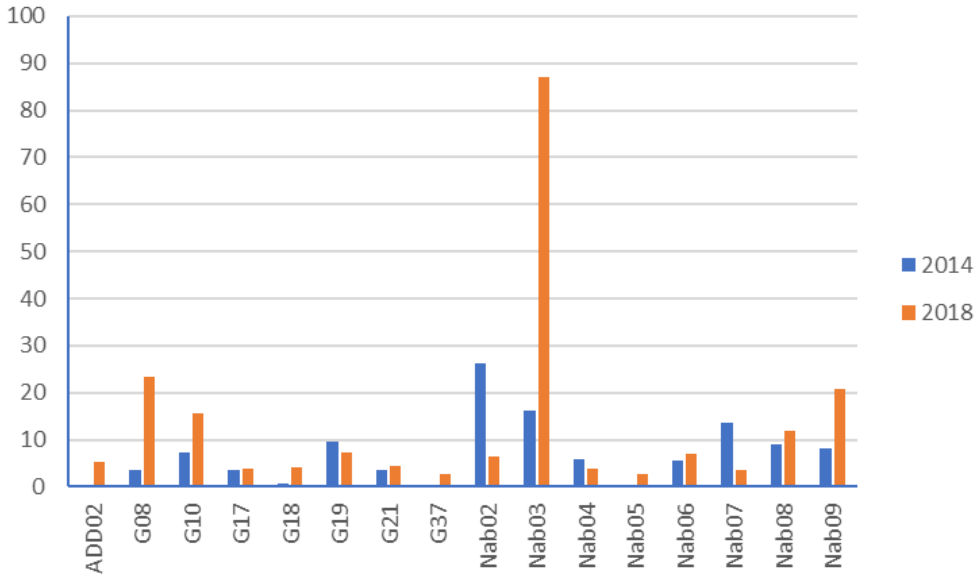


Figure A1.4.4: Sediment silt/clay content of the stations sampled at Nab Tower in 2014 and 2018.

4.2.2 Sediment organic carbon (POC)

Organic carbon values range from 0.7 to 3.0 % m/m in the <63 µm fraction (Figure A1.4.5). No measurements were taken in 2014. As the samples of sediment were not assessed for contaminants (as undertaken for North Tyne, Sunderland and Whitby), organic carbon was not evaluated on the <2 mm fraction for Nab Tower.

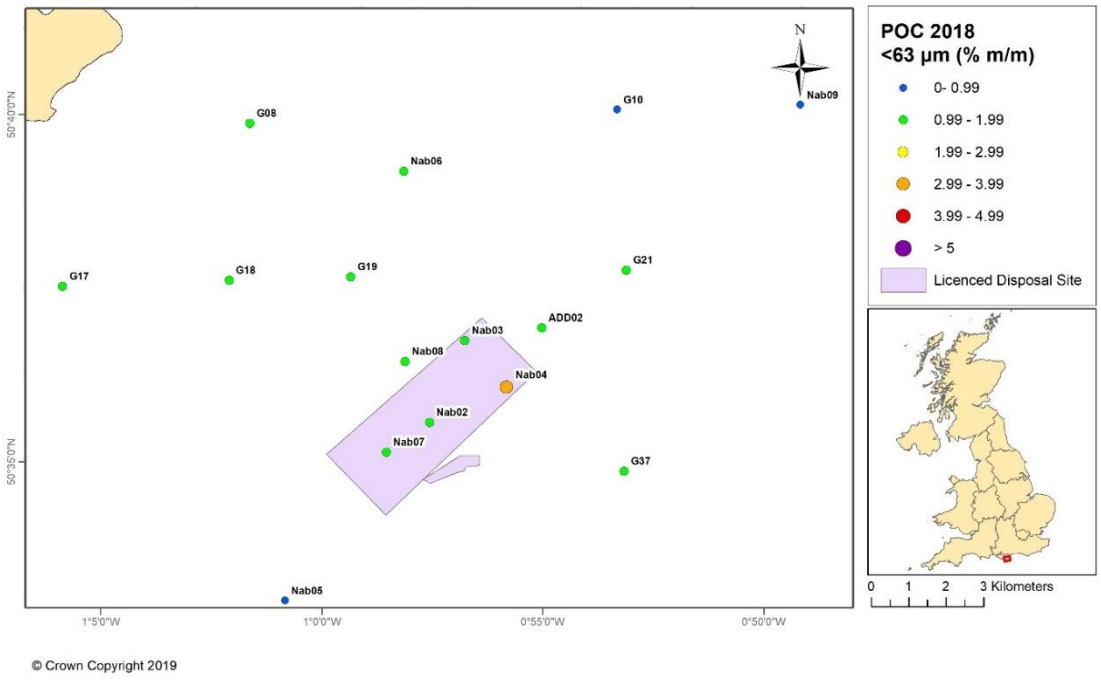


Figure A1.4.5: Sediment organic carbon (% m/m) in the <63 µm fraction of the stations sampled at Nab Tower (rectangular site), 2018. The small disposal site alongside the southeastern boundary of Nab Tower is the closed Area 451 Temporary Storage Site.

4.2.3 Sediment macrofauna

The 2018 survey of Nab Tower disposal site successfully collected 41 samples from the 16 stations (0.1 m^2 mini Hamon Grab); three replicates at 10 stations, two replicates at five stations and one station with a single replicate (G37). All macrofauna individuals from the samples were identified and enumerated and the biomass per taxon was recorded. All macrofauna individuals from the samples were identified and enumerated and the biomass per taxon was recorded. The data from the analysis were rationalised (or 'truncated') to remove or combine; duplicate records, high level identifications and fragments. Colonial taxa were included in taxa counts, but not abundance totals. For multivariate analysis colonial taxa were given an abundance value of 1.

A total of 6,508 macrofaunal individuals were sampled from 345 taxa (including colonials) from the 41 samples. Simple univariate metrics of the number of taxa, abundance and biomass are shown in Figure A1.4.6. The number of taxa ranged from four per 0.1 m^2 (NAB03_C2) to 114 taxa per 0.1 m^2 (G18_B3). Total abundance ranged from five individuals per 0.1 m^2 (samples NAB03_A1 and NAB03_C2) to 1,314 individuals per 0.1 m^2 (sample G17_B3). Macrofaunal biomass ranged from 0.014 g (wet weight) per 0.1 m^2 (sample NAB03_C2) to 25.007 g per 0.1 m^2 (sample G10_C2). When averaged per station, a general trend of lower number of taxa, abundance and biomass at the stations within and close to the disposal site can be discerned (Figure A1.4.6).

The most well-represented phylum was annelids, or segmented worms (146 taxa sampled), followed by molluscs (54 taxa), crustaceans (45 taxa) and bryozoans (40 taxa). The most abundant taxon sampled was the Porcelain crab *Pisidia longicornis* with 1,221 individuals from all samples. *P. longicornis* was present in 14 samples from 8 stations across the survey but 1,111 were found in a single sample, G17_B3. The most commonly found taxa were the bryozoan *Schizomavella* sp., identified at 30 stations, and the polychaete worm *Lumbrineris cingulata*, identified at 29 stations.

Several notable species were identified from the macrofaunal analysis (Table A1.4.3). The list includes three non-native species; the amphipod crustacean *Monocorophium sextonae*, the Tufty-buff bryozoan *Tricellaria inopinata* and the Slipper limpet *Crepidula fornicata,* as well as four species which have not been formally recorded from the UK. The presence of the reef-building Ross worm *Sabellaria spinulosa* was also noted with 689 individuals found in 20 samples from 9 stations (Figure A1.4.7). No *S. spinulosa* were present in samples taken from within the disposal site; higher abundances were witnessed from the stations furthest away from the site. This same pattern was observed in the 2017 Nab Tower data (Bolam et al., 2018). Biogenic reefs are potentially qualifying features of the EC Habitats Directive (92/43/EEC), although the taxon itself is not afforded conservation protection. No firm conclusions can be made on the potential presence of reef around Nab Tower as this would require the additional collection of video and acoustic data to conduct a 'reefiness' assessment.

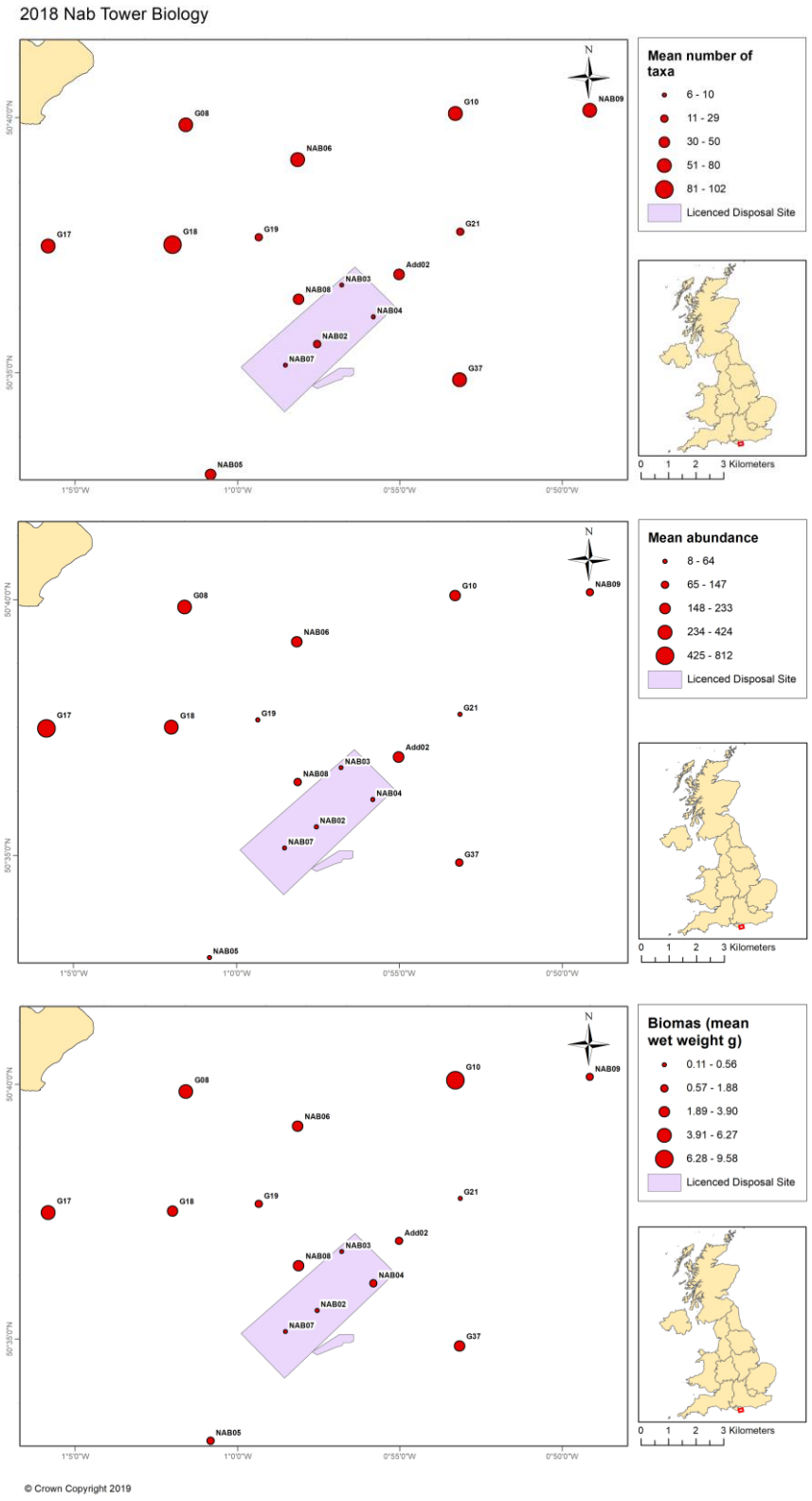


Figure A1.4.6: Mean number of taxa (top), mean abundance (centre) and mean biomass (wet weight g) (bottom) per grab (0.1 m^2) from Nab Tower (rectangular site), 2018. The small disposal site alongside the southeastern boundary of Nab Tower is the closed Area 451 Temporary Storage Site.

Table A1.4.3: Notable species identified from the 2018 Nab Tower macrofaunal samples.

Species	Notes
Syllis garciai	Not formally recorded from UK
Syllis pontxioi	Not formally recorded from UK
Rullierinereis ancornunezi	Only recently published as a UK species
Paradoneis ilvana	(Previously recorded as *Paradoneis* type B) Not formally recorded from UK
Spio symphyta	(Previously recorded as *Spio filicornis* agg.) Not formally recorded from UK
Sabellaria spinulosa	Represents priority habitat, if reef-forming
Monocorophium sextonae	Listed as non-native
Crepidula fornicata	Non-native in the UK
Thecacera pennigera	Cryptogenic; Nationally scarce
Hincksina flustroides	Nationally rare
Tricellaria inopinata	Non-native in the UK

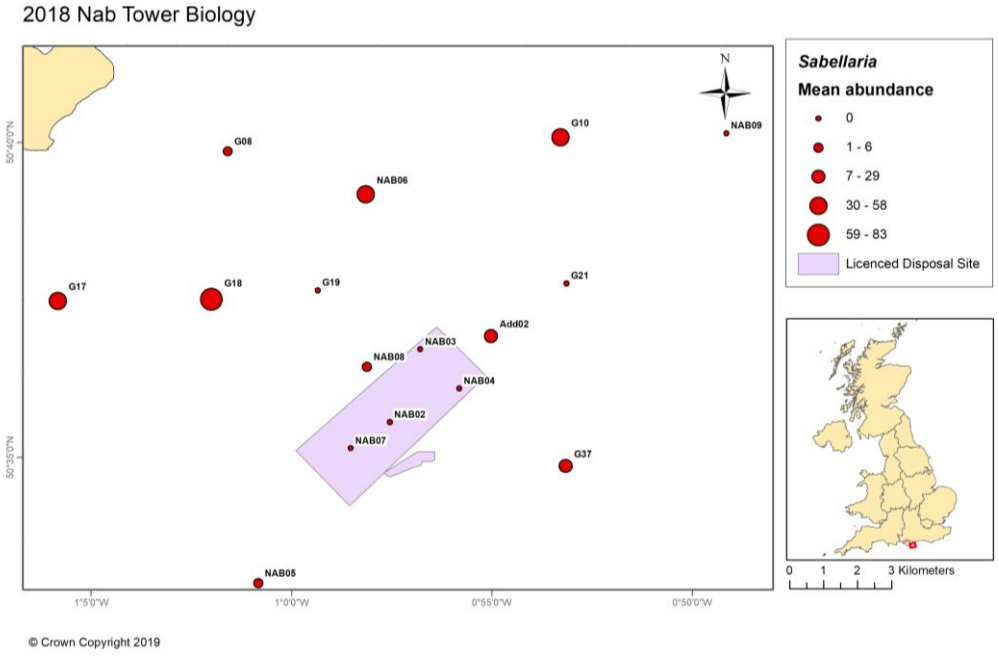


Figure A1.4.7: Mean abundance of *Sabellaria spinulosa* per grab (0.1 m^2) sampled at Nab Tower (rectangular site), 2018. Note there is no evidence of reef formation at any station from the current data. The small disposal site alongside the southeastern boundary of Nab Tower is the closed Area 451 Temporary Storage Site.

Multivariate numerical analyses were conducted on the taxonomic structure of the faunal abundance 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) were 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' groups (Bolam et al., 2018). Following a square root-transformation and Bray-Curtis similarity resemblance, Figure A1.4.8 presents an nMDS ordination of the samples, illustrating the similarity (closeness of the points) of the overall community assemblages. This figure indicates there are structural differences between the samples in the different test groups. For example, the 'Disposal' samples are generally projected on the ordination towards the bottom right, while, in general, the 'Reference' group samples are towards the middle left. Exceptions to this can be seen, with the reference station G19 sitting closer to the disposal stations, and two of the samples from the disposal station NAB03 transposed separately on their own.

The apparent differences between the samples within and outside of the disposal site was tested for statistical significance with a one-way ANOSIM test on PRIMER which tests the pairwise relationships between *a priori* groups. The test shows there is an overall significant difference between the groups (global R=0.369, P=0.001) with a larger difference seen between the 'Reference' and 'Disposal' groups (R=0.607, P=0.001).

Groups of samples with similar assemblage structures can also be identified without *a priori* groups using clustering and the SIMPROF routine on PRIMER. To aid spatial interpretation samples were averaged per station. This routine resulted in five clusters of stations with statistically similar (within-cluster) assemblages (5 % significance) (Figure A1.4.9). All four of the 'Disposal' stations were grouped within the same cluster (cluster e) alongside the 'Reference' station G19. The 'Far' station and most of the 'Reference' stations were grouped together in cluster d, with the remaining 'Reference' station clustered on its own (cluster c). The four 'Near' stations cluster into two groups (clusters a and b); Figure A1.4.10 shows how these cluster groups are related spatially. Table A1.4.4 presents the main characterising taxa (from the SIMPER routine on PRIMER) of each cluster, the abundance of each taxa, and averaged univariate metrics for each cluster. This shows that the cluster containing the 'Disposal' stations (cluster e) has lower number of species, abundance and biomass, when compared to the other

clusters, which suggests the dredge disposal is having an adverse effect on the benthic communities within the site. The 'Far' and all but one of the 'Reference' stations and some 'Near' stations display high levels of abundance, number of taxa and biomass indicating that the effects of disposal on the benthic communities does not extend considerably outside the disposal area. It is uncertain why the 'Reference' station G19 displays the same pattern as the 'Disposal' stations other than only small volume samples (3-4 L) were able to be successfully collected.

Abundance data from the 2014, 2017 and 2018 surveys were further analysed by merging the datasets together. To avoid duplicating taxa identified to different taxonomic levels a degree of standardisation (or truncation) was performed to remove or merge data entries. Figure Figure A1.4.11 shows an nMDS ordination of the station averaged data and SIMPROF clusters (at 5 % significance) from the combined data. These nMDS plots illustrate that the benthic assemblages observed in the three survey years are generally similar and the stations from the disposal site group close to each other within two clusters. This implies that the benthic assemblages present within the disposal site are structurally different from those outside, and that this has remained consistent between 2014 and 2018 (i.e. all are located on left hand side of the plot). This implies that there is no evidence of any macrofaunal recovery within the disposal site boundary.

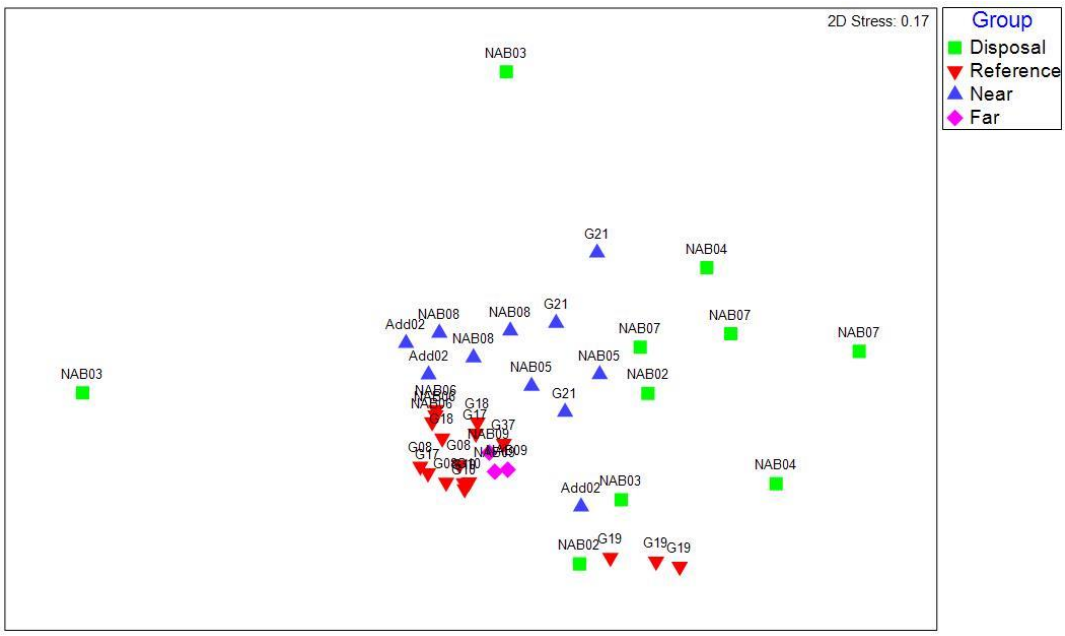


Figure A1.4.8: 2-D non-metric multidimensional scaling (nMDS) ordination of macrofaunal assemblages in samples from Nab Tower 2018 following square root-transformation and Bray-Curtis similarity.

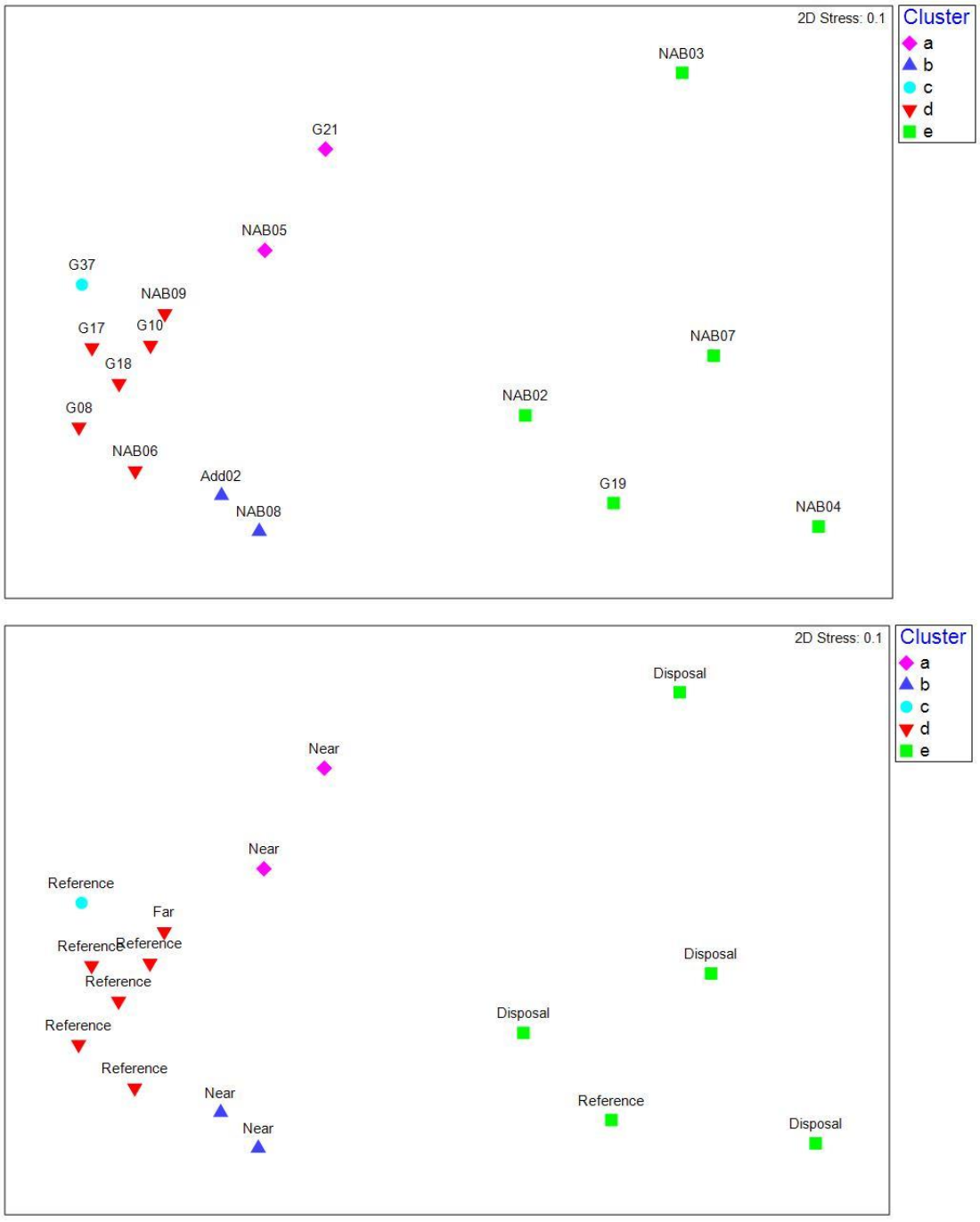


Figure A1.4.9: 2-D nMDS ordination of macrofaunal assemblages at stations (samples averaged) from Nab Tower 2018 following square root-transformation and Bray-Curtis similarity. Top pane shows station names, bottom pane shows disposal zone groups with symbols showing SIMPROF clusters on both.

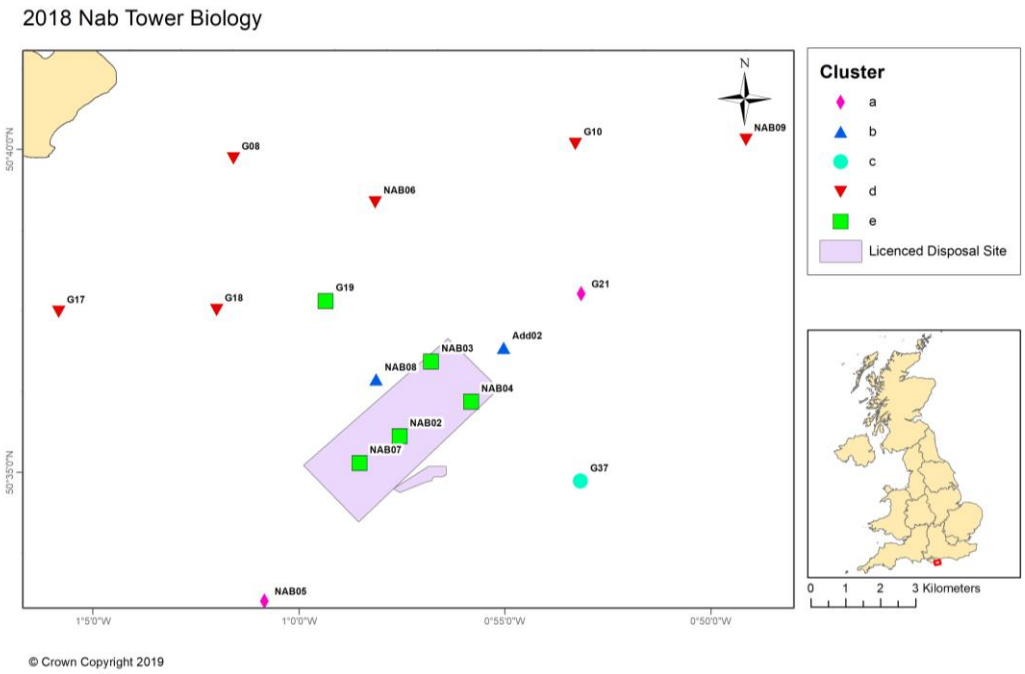


Figure A1.4.10: Map of macrofaunal assemblage clusters from the stations sampled at Nab Tower (rectangular site), 2018. The small disposal site alongside the southeastern boundary of Nab Tower is the closed Area 451 Temporary Storage Site.

Table A1.4.4: Characterising taxa (SIMPER) of SIMPROF-derived assemblage clusters from the 2018 Nab Tower survey with average univariate metrics per cluster.

Cluster	Station (group)	Taxa	Average Abundance (ind 0.1m²)	Average number of species (0.1m²)	Average abundance (0.1m²)	Average Biomass (g wet weight) (0.1m²)
a	G21, NAB05 (Near)	*Aonides paucibranchiata*	5	61	62	0.6398
		Glycera lapidum	3			
		Eulalia mustela	2			
		Laonice bahusiensis	2			
		Nematoda	4			
b	Add02 NAB08 (Near)	*Spiophanes bombyx*	16	97	145	2.1317
		Mediomastus fragilis	11			
		Unciola crenatipalma	4			
		Lumbrineris cingulata	6			
		Sabellaria spinulosa	10			
c	G37 (Reference)	*Sabellaria spinulosa*	29	64	132	3.4742
		Syllis armillaris	9			
		Spirobranchus lamarcki	6			
		Spisula sp.	5			
		Proceraea sp.	4			
d	G08 G10 G17 G18 NAB06 (Reference) NAB09 (Far)	*Sabellaria spinulosa*	41	120	368	4.7094
		Spirobranchus lamarcki	38			
		Ascidiacea	9			
		Lumbrineris cingulata	4			
		Serpulidae	7			
e	NAB02 NAB03 NAB04 NAB07 (Disposal) G19 (Reference)	*Lumbrineris cingulata*	2	26	19	0.6327
		Schizomavella sp.	P			
		Spisula elliptica	<1			
		Paucibranchia sp.	<1			
		Escharella immersa	P			

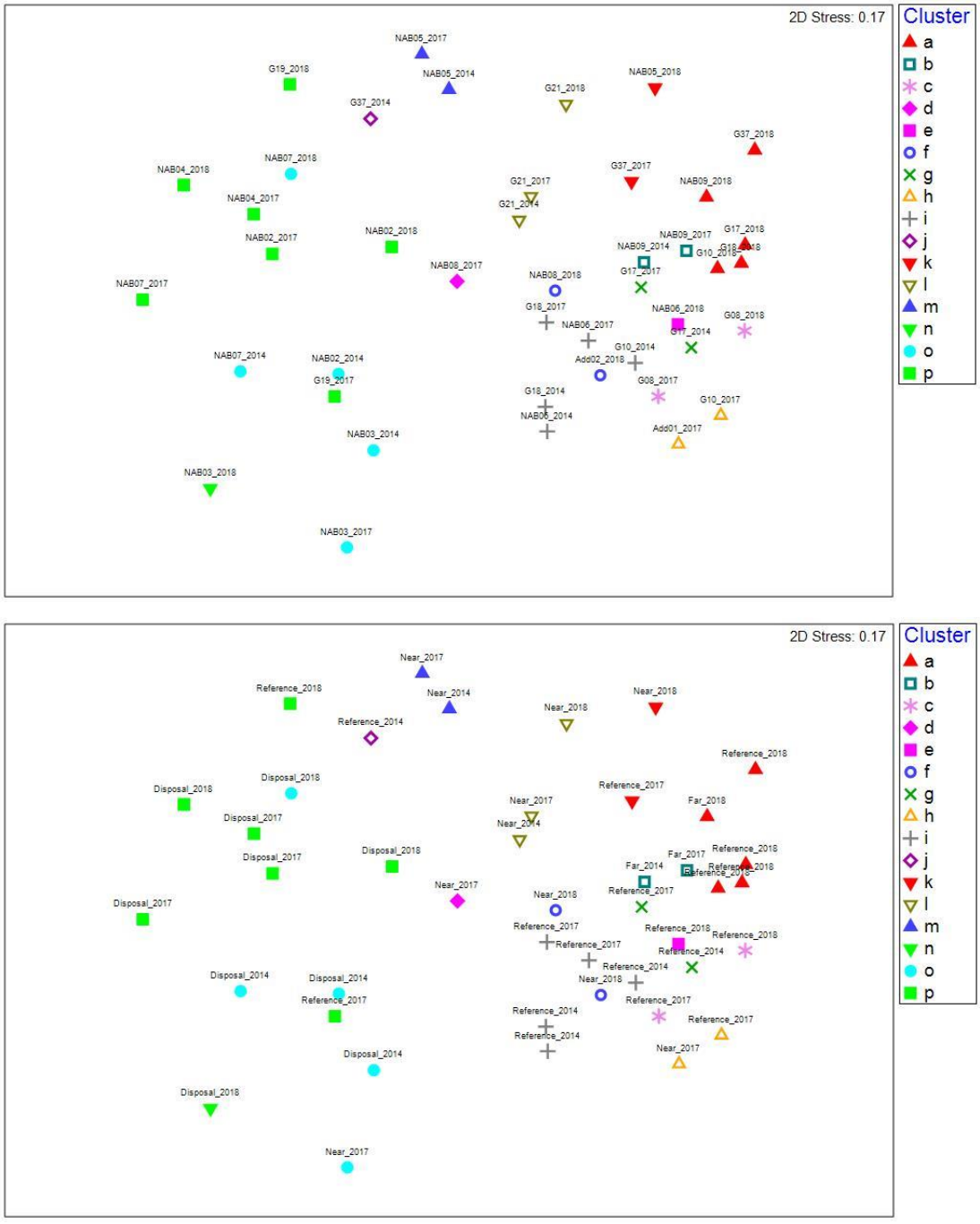


Figure A1.4.11: 2-D nMDS ordination of macrofaunal assemblages at stations (samples averaged) from Nab Tower in 2014, 2017 and 2018 (combined datasets) following square root-transformation and Bray-Curtis similarity. Top pane shows station names bottom pane shows disposal zone groups with symbols showing SIMPROF clusters on both.

5 Sprey Point (PO070)

5.1 Background

Sprey Point is a small (approximately 100 m in diameter) disposal site located just northeast of the mouth of the Teign Estuary in South Devon. The site may be regarded as receiving only modest amounts of material, with an average of just over 36,000 t (wet weight) over the period 2006 to 2016 (Figure A1.5.1). However, the amount disposed in 2016 (140,000 t wet weight) represented a notable increase above the average. The site lies both in shallow water and on the intertidal area, off a sandy beach popular with walkers as it forms part of the South West Coast Path.

Sprey Point has been identified as lying at a potential "bed parting zone" where, on average, sediment to the north will tend to be transported north and that to south to migrate southward. However, this parting zone reflects the long-term situation and at any one point in time, sediment may be moving along the coastline in a northward or southward direction.

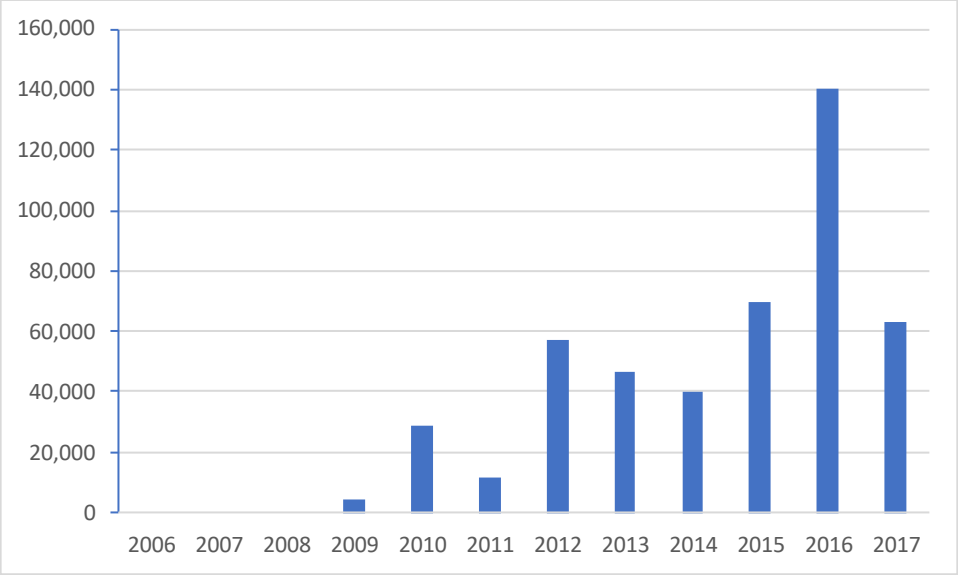


Figure A1.5.1: Annual tonnages of dredged material (in t wet weight) disposed to PO070 in recent years. Average tonnage for 2006-17 is 38,589 t per annum.

Cefas holds disposal records for PO070 disposal site dating back to 1983. However, the site is a historical site; it predates current designation records and thus its actual commencement date is likely to predate the early 1980s. The site receives dredged material from both Exmouth Marina and Teignmouth Harbour. Due to the high silt content of its material, licences for Exmouth Marina stipulate a condition that no more than 10,000 tonnes (wet weight) may be disposed of at PO070 per annum. This condition aims to ensure that acceptable volumes of material can be accommodated within the capacity of the disposal site. Licences for the coarser material originating from Teignmouth Harbour have no such condition.

The contaminant concentrations of the material dredged from both Teignmouth Harbour and Exmouth Marina have recently been reviewed. The trace metal results from Exmouth Marina show the material (86 % silt/clay and 14 % sand) to contain slightly elevated levels (above Cefas action level 1) of chromium, copper and zinc. Being below Cefas action level 2, these metals concentrations deem the material suitable for marine disposal following the formal screening process. The organotin (TBT, DBT) results showed concentrations to be below limits of detection. Similarly, levels of PAHs were elevated but at sufficiently low concentrations that the material is considered suitable for marine disposal. Similar assessments of the coarser material from Teignmouth Harbour have demonstrated the material to be very low in contaminants (owing to its coarse characteristic) with concentrations of a range of chemicals below limit of detection.

During 2017, the MMO licenced material from Exmouth Marina (licence L/2017/00034/1) to be disposed of to Sprey Point. However, concerns were later raised that disposal of material to Sprey Point may potentially be responsible for oily sediments on the neighbouring beach. As such, the MMO suspended this licence pending the outcomes of investigative work by Cefas to ascertain whether material disposed of to Sprey Point may be the cause of such material. Based on a basic sediment transport model, the Cefas study concluded that high proportions of fine-grained material placed at P0070 are likely to migrate onto the local intertidal area.

Work planned under the auspices of C6794 during 2018 at this site focussed on assessing the sediment granulometry (particle size), contaminant concentration (focussing on PAHs) and visual appearance of the sediments along the intertidal foreshore. The first of such surveys was conducted during July 2018 with an aim to sample the areas where this oily sediment was observed; ascertaining the characteristics of these sediments would facilitate knowledge of

their provenance. In the absence of intelligence regarding the location of the black, oily sediment on the intertidal, no *a priori* stations were planned; the survey comprised an initial walk-over survey followed by samples being acquired from 10 stations across the entire beach. It was anticipated that repeated surveys would be conducted under C6794 following further disposal of material from Exmouth, however, no such disposal activity took place during 2018-19.

In December 2018, a brief advice minute was submitted to the MMO based on the outcomes of the July survey (Bolam et al., 2018b). A distillation of this minute is included below and represents the reporting for this site under this technical report.

5.2 Distillation of Minute submitted to the MMO, December 2017 (Bolam et al., 2018b).

5.2.1 Methods

The intertidal beach survey at Teignmouth was conducted at low (neap) tide on the afternoon of 2nd July, 2018. Weather was warm and sunny and the sea condition was very calm. The survey was initiated by a walk-over visual survey of the whole beach (from high water to low water) to observe the sediment types, particularly for the presence of finer material and/or sediments that appeared darker in colour. Sampling was then conducted at 10 stations (TM1-TM10), starting from the south-western extent of the beach near the mouth of the Teign Estuary (TM1) and ending at the north-eastern part of the beach at Holbrooke (TM10) (Figure A1.5.2). Stations were located to ensure a wide coverage of the beach, ensuring that any areas where surficial sediments appeared finer were sampled, together with a greater density of stations near the disposal site.

At each station, surface sediments were extracted using a hexane-rinsed, stainless steel sampler, the sediments then being placed in either a plastic bag (for particle size assessment, 'PSA' hereafter, and carbon and nitrogen) or a hexane-rinsed glass jar for total hydrocarbon concentrations ('THCs' hereafter) and polycyclic aromatic hydrocarbons ('PAHs' hereafter). These samples were kept cool and then frozen within 24 hr on return to the laboratory.

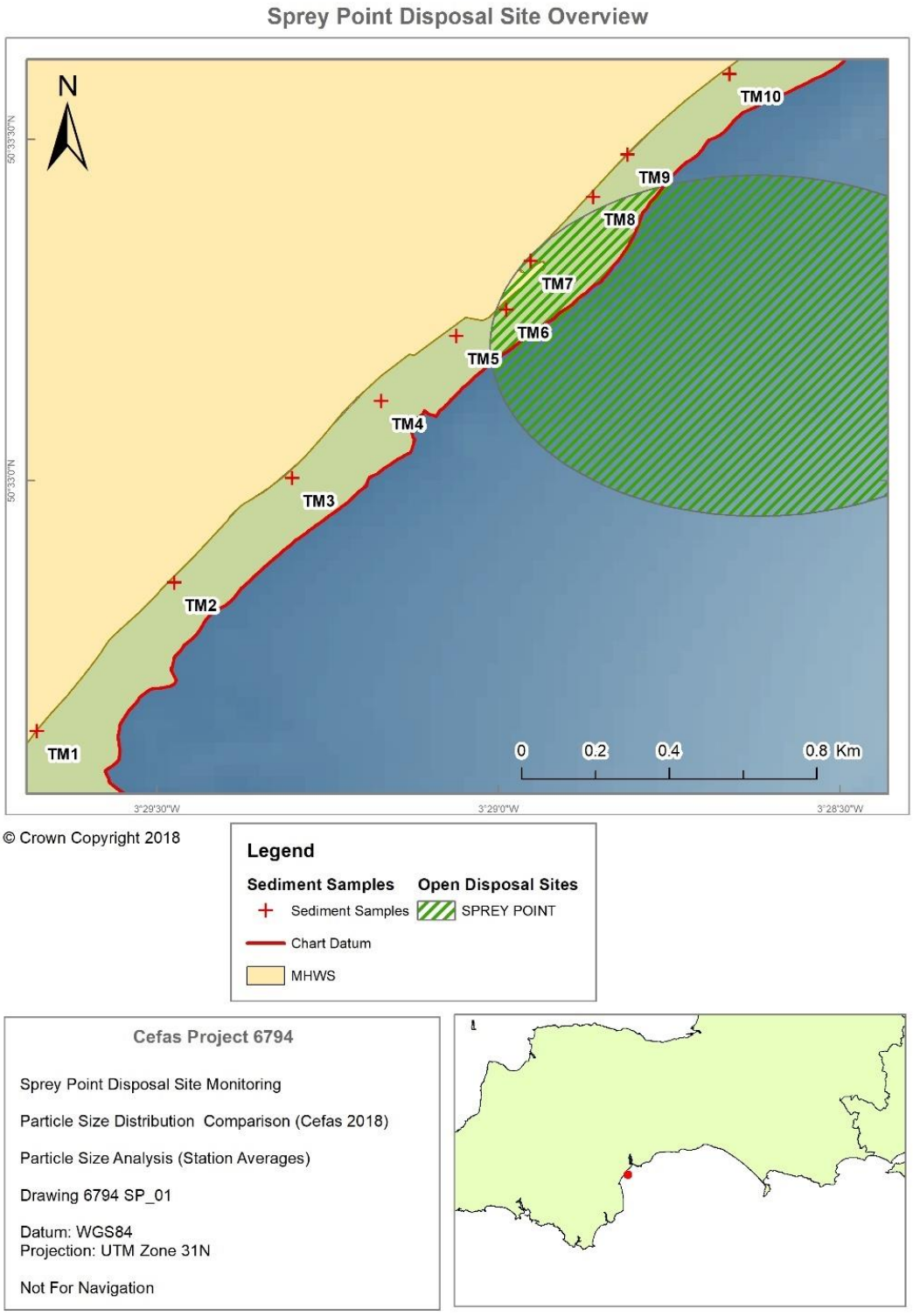


Figure A1.5.2: Sprey Point disposal site (PO070) and the locations of the 10 stations (TM1-TM10) sampled for sediments at Teignmouth Beach, July 2018.

5.2.2 Results

The visual survey of the sediments along the foreshore at Teignmouth Beach revealed no areas of fine sediments nor areas where sediments appeared black. This observation is supported by the PSA results from the sediments taken at TM1-TM10 (Table A1.5.1; Figure A1.5.3). Sediments sampled at Teignmouth Beach during July 2018 were coarse, composed of predominantly gravelly sands, with slightly gravelly sands and sandy gravel. Very low concentrations of silt/clay were present in all samples (all <1.5 % silt/clay).

Total organic carbon and nitrogen content concentrations were very low for all sediments sampled at Teignmouth Beach. Sediment organic carbon values (in the <2 mm sediment fraction) range from 0.03 to 0.06 % while those of nitrogen range between 0.02 to 0.06 %.

Table A1.5.1: Sediment descriptions (top) and statistics (bottom) for the 10 stations sampled at Teignmouth Beach, July 2018.

Sample code	Sample type	Sediment description
TM1	Trimodal, Poorly Sorted	Sandy Gravel
TM2	Bimodal, Poorly Sorted	Gravelly Sand
TM3	Bimodal, Poorly Sorted	Gravelly Sand
TM4	Trimodal, Poorly Sorted	Gravelly Sand
TM5	Bimodal, Poorly Sorted	Gravelly Sand
TM6	Unimodal, Poorly Sorted	Gravelly Sand
TM7	Unimodal, Poorly Sorted	Gravelly Sand
TM8	Unimodal, Moderately Well Sorted	Slightly Gravelly Sand
TM9	Unimodal, Moderately Well Sorted	Slightly Gravelly Sand
TM10	Trimodal, Poorly Sorted	Gravelly Sand

Sample code	Gravel (%)	Sand (%)	Silt/clay (%)	Very coarse sand (%)	Coarse sand (%)	Medium sand (%)	Fine sand (%)	Very fine sand (%)
TM1	48.91	50.44	0.65	20.19	14.04	7.99	7.65	0.57
TM2	15.13	83.98	0.89	6.78	16.41	30.22	29.73	0.84
TM3	29.21	69.78	1.02	5.85	10.85	22.17	29.65	1.27
TM4	9.02	89.89	1.10	9.99	19.61	28.23	30.95	1.11
TM5	12.64	86.43	0.92	9.69	18.74	27.86	28.97	1.17
TM6	14.18	84.92	0.90	15.91	46.32	14.29	7.94	0.46
TM7	16.70	82.68	0.61	17.52	44.91	17.59	2.46	0.21
TM8	0.06	99.94	0.00	0.27	5.64	41.74	51.80	0.49
TM9	0.44	98.20	1.36	0.93	6.04	32.63	56.19	2.41
TM10	10.29	88.69	1.02	16.06	23.72	19.01	28.43	1.47

PAHs and THCs in the sediments were very low across all 10 stations sampled. Summed PAH concentrations (∑PAH) for all 10 sediment samples (17.7 – 84.7 µg kg^{-1} dw) were well below the background levels (i.e. <200 µg kg^{-1} dw) for this area along the southwest coast of England. None of the sediments collected exceeded the ERL (effects range low) or ERM (effects range median) for low molecular weight (LMW) or high molecular weight (HMW) PAHs. Additionally, all THCs for samples from Teignmouth Beach (<0.1 – 2.62 mg kg^{-1} dw) were well below the action level 1 guidance of 100 mg kg^{-1} dw in dredged material, and concentrations of all PAHs were well below the action level 1 guidance of 0.1 mg kg^{-1} for individual PAHs in dredged material. The lowest concentrations of THCs and PAHs were generally observed at TM1, the most southwesterly station located near the mouth of the Teign Estuary.

5.3 Conclusions

The survey at Teignmouth Beach during July 2018 revealed no evidence of sediments that may be regarded as fine, black nor of an oily appearance. This conclusion is based on a full walk-over survey together with an analytical assessment of sediments taken from 10 stations across the foreshore. All sampled sediments were coarse (very low silt/clay), with very low organic carbon, THCs and PAH concentrations.

Cefas recommend that repeat surveys are undertaken following any resumption of disposal of material from Exmouth to Sprey Point.

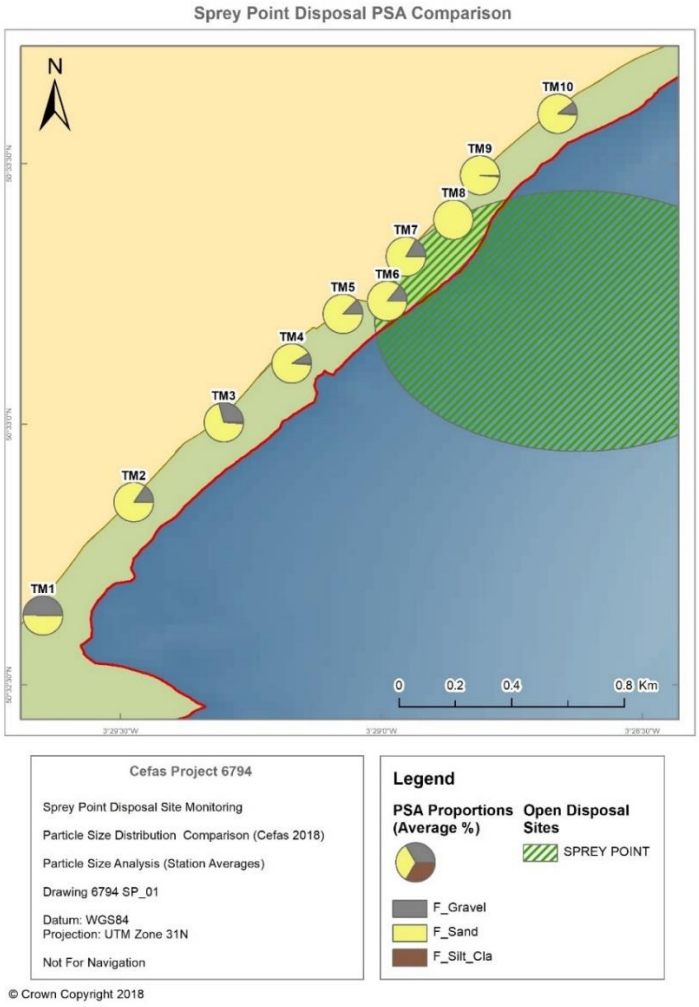


Figure A1.5.3: Proportional representation of gravel, sand and silt/clay content (%) of the sediments sampled at the 10 stations along Teignmouth Beach, July 2018. The location of Sprey Point (PO070) is also displayed.

6 Plymouth Deep (PL035)

6.1 Background

Plymouth Deep is a recently-designated dredged material disposal site that was characterised to provide a sustainable site for receiving material resulting from dredging operations within the River Tamar and Plymouth Sound area. The site is located south of Plymouth and the entrance to the Tamar Estuary, around 9 km southwest of the Plymouth breakwater. The site is 1.5 km by 1 km in size and located in approximately 49 to 50 m water depth below Ordnance Datum Newlyn (ODN).

The L4 sampling station (50° 013.300' N, 04° 011.400' W), located approximately ten nautical miles southwest of Plymouth, represents one of the main sites of the Western Channel Observatory (WCO). The station constitutes an oceanographic time-series and marine biodiversity reference site and is arguably one of the best-studied marine regions in Europe (http://www.westernchannelobservatory.org.uk) (Zhang et al., 2015). Water depth at the station is approximately 50 m and the seabed is comprised of fine sand. The sediment is also fairly impoverished in terms of organic material with a total carbon content of around 2.5 % of which over 84 % is inorganic carbon. Thus, only 0.4 % of the total sediment mass is made up of organic carbon. Intermittent observations have been made at L4 for more than 100 years, while for the past 25 years the station has been visited between 40 and 45 times per year, resulting in a rich dataset of both environmental and biological variables sampled at fine temporal resolution (Harris, 2010). These observations have shown that, typically, L4 is seasonally stratified from late-April until September with environmental or biological responses and patterns being largely regulated by subtle variations in temperature, light, nutrients and meteorology (Smyth et al., 2010). More recent remote sensing and modelling approaches have allowed the L4 station to be placed in the wider regional context (Harris, 2010; Smyth et al., 2010).

Studies and data acquisition at L4 have, until relatively recently, been largely focused on pelagic sampling. However, regular observations of the benthic system commenced in 2007. At more-or-less monthly intervals, the seabed sediments are sampled using a 0.1 m^2 box corer and the macrofaunal individuals assessed following sieving on a 0.5 mm mesh sieve. The number of replicates sampled and/or processed each month since 2007 varies. The data have been used

to provide new insights regarding benthic-pelagic coupling and functional responses of various macrofaunal groups to short-term seasonal changes in food supply from the water column (Zhang et al., 2015; Navarro-Barranco et al., 2017).

The L4 station represents a scientifically-important station, providing one of the few examples where robust time-series data of both the pelagic and, increasingly benthic, systems and the interactions between them have been, and continue to be, assessed. The key importance of the site is to represent a 'natural' example where both short-term, seasonal, and long-term temporal trends may be studied. In view of this, it is important to acquire empirical data to allow an assessment as to whether disposal at Plymouth Deep is affecting the ecological characteristics at the site. Plymouth Marine Laboratory routinely processes one of the four replicate samples acquired during each survey, and these data are submitted to the Western Channel Observatory. In 2017-18, under the auspices of C6794, the three remaining replicates sampled at L4 were processed for six (excl. the single rep in Dec.) surveys during 2016 and seven surveys during 2017. These data were used to assess whether the initial disposal episode to Plymouth Deep during May 2017 resulted in any detectable change to the benthic assemblage at L4. The data implied that no changes to either the univariate or multivariate taxonomic structure could be discerned (Bolam et al., 2018). However, the May 2017 disposal event did not reflect the full disposal campaign licenced for Plymouth Deep, and the amount of material placed represented a minor proportion of that licenced for the site during any one year. Thus, the study concluded that this assessment should be continued to capture any potential changes occurring over a longer period. Furthermore, it stated that additional data should be acquired to provide a more robust assessment of the seasonal variability in macrofaunal assemblages prior to the opening of Plymouth Deep. Thus, under C6794 during 2018-19, further data from 2018, together with those from 2014, were acquired through collaboration with Plymouth Marine Laboratory (Table A1.6.1). Here, we present the outcomes of analyses of the data from 2014 and 2016-2018 to assess whether the continued disposal of material during 2017-18 have resulted in any detectable change in macrofauna at L4.

We seek to demonstrate if assemblage shifts were evident following the disposal, and if these are potentially in response to, or a result from, the disposal activity. As was reported in Bolam et al. (2018), there are several inherent limitations to this approach, namely:

- the assessment focusses solely on the benthic assemblage at a single site (L4), it does not make any reference to benthic changes at any other area that may or may not be affected by disposal activity;
- the assessment is based on data solely from four years and relies on the assumption that
    - seasonal variability prior to disposal (as represented by the data 2014 and 2016 data analysed herein) suitably represents natural seasonal variability for the site, and;
    - the environmental conditions prevalent during 2017 and 2018 were not atypical;
- the approach is limited to assessing the potential short-term effects of disposal. Further data would be needed to address the possibility of long-term changes associated with the disposal campaign; and
- this assessment focuses solely on the macrofaunal component of the sediments. Potential impacts on other biological groups associated with the seabed (e.g., epifauna, meiofauna) and physical sediment characteristics (e.g., particle size distribution, total organic carbon) are outside the scope of this assessment.

6.2 Methods

The abundance data were truncated to remove non-marine taxa, a polychaete fragment (*Nephtys* species), 'Decapoda' records, pelagic taxa (*Sagitta* species), meiofauna (copepods and nematodes) and 'biomass' only records. Records of the same species, but with different size qualifiers (e.g. *Upogebia deltaura* 'large' and 'small') were included in the dataset as separate entries to determine any fine scale changes in the assemblage structure and univariate metrics investigated.

Records assigned a 'juv' (juvenile) qualifier were combined with records of the same binomial name (e.g., *Acanthocardia echinata* 'juv') as the definition of this qualifier is not defined and the morphological characters to determine a species level identification are present. Taxa indicated with a 'P' in the original dataset (colonials) are not enumerated during processing. These records were included as a numerical value of one during analysis to ensure colonial taxa are represented in the total number of taxa (*S*) metric.

Meteorological season and the month in which the sampling took place were used to group the replicates and mean values and the 95 % confidence interval plotted for each sampling event in

R. The non-parametric Wilcoxon test was performed in R to compare the median value of each of the univariate metrics pre- and post- disposal to Plymouth Deep. Multivariate analyses were then performed in Primer v7. Highly variable species in the abundance data were down-weighted using a dispersion factor of one. Consistently highly abundant species were then down-weighted using a square root transformation (Clarke et al., 2006). A Bray-Curtis similarity measure was performed on the replicate-averaged transformed abundance values to give a resemblance matrix of the percentage similarity between sampling events. A non-metric multi-dimensional scaling ordination (nMDS) analysis was carried out on the resulting resemblance matrix and a trajectory showing the survey event for each year analysed was added.

Two cyclic model resemblance matrices were generated using the Model Matrix tool in Primer V7. A monthly model was created whereby each month was given a numerical value ranging from $\frac{1}{12}$ – 1 (January – December) to determine an estimate of predicted similarity between sampling events. That is, Jan. and Dec. are expected to be more similar than Jan. and March. A cyclic seasonal model was also created with values ranging from $\frac{1}{4}$-1. The resultant resemblance matrices contain reasonable estimates for the expected similarity among the months in which surveys took place, and likewise among seasons.

Each ranked modelled resemblance matrix (month and season) was then compared with the ranked similarities from the Bray-Curtis resemblance matrix using the RELATE test for each year in turn to determine the Spearman coefficient ρ and a probability value (Veale et al., 2014). Higher values of ρ indicate measured similarities are correlated with those modelled and imply annual cycles in the benthic assemblage.

Diversity metrics (number of taxa (*S*), abundance (*N*), diversity (Shannon H'), evenness (Pielou's J')) were calculated for each sample replicate using the DIVERSE routine. The total biomass (*g*) was generated for each replicate by summing the biomass records for all taxa in the abundance data matrix. Mean values for monthly (i.e. per survey event) and seasonally-averaged replicates, with associated 95 % confidence intervals, were plotted in R to assess temporal trends.

Table A1.6.1: Sampling dates in 2014, 2016, 2017 and 2018 from which replicate (four) macrofaunal data were analysed under C6794. All sampling was undertaken by PLM. Dates in yellow are prior to any disposal at Plymouth Deep, those in green are post-disposal. A single replicate was processed from the December 2016 sampling event but the data are not presented herein.

Season	Month	2014	2016	2017	2018
Winter	December	-	*2nd (single replicate)*		
	January	-	-	-	-
	February	-	-	-	7th
Spring	March	13th	15th	16th	-
	April	-	-	28th	-
	May	20th	5th	10th	3rd
Summer	June	18th	16th	15th	6th
	July	-	21st	15th	31st
	August	20th	25th	11th	-
Autumn	September	-	-	-	-
	October	1st	14th	4th	3rd
	November	-	-	-	-

6.3 Results

6.3.1 Faunal description and univariate measures

In total, 463 taxon records were present in the truncated abundance data matrix. This included 188 annelid (segmented worms) taxa, 141 arthropod taxa, 86 molluscan taxa and 23 echinoderm taxa. Other phyla accounted for the remaining 5 % (23 taxa). The most abundant taxa overall were the polychaete *Lumbrineris cingulata* (occurring in all 93 samples at an average abundance of 30 ind. per sample), the amphipod crustacean *Ampelisca tenuicornis* (occurring in 87 of the samples, average abundance of 12 ind. per sample) and the echinoderm Pea urchin *Echinocyamus pusillus* (in 87 of the samples, average abundance of 11 ind. per sample). Other common taxa occurring in >80 % samples were the polychaetes *Podarkeopsis capensis*, *Poecilochaetus serpens*, *Peresiella clymenoides*, *Magelona minuta*, *Polycirrus* sp., *Magelona alleni*, *Nephtys* sp. (juveniles) and *Spiophanes bombyx*, and Nemerteans. Actiniaria (most typically anemones) accounted for the largest proportion of the biomass (23 % of the total). Of the top ten taxa ranked by biomass, the most commonly occurring and abundant was

the capitellid polychaete *Notomastus* sp. (occurring in 71 samples, at an average abundance of two ind. per replicate, with a total biomass of 20.81 g).

Univariate metrics of replicate-averaged number of taxa (*S*), abundance (*N*) and diversity (Shannon H') at L4 were found to be significantly higher after the commencement of sediment placement (May, 2017; see Table A1.6.1). No such significant differences were observed for total biomass (*g*) and evenness value (Pielou's J'). Descriptive statistics showing the mean, median, standard deviation (and error) and range are provided in Table A1.6.2.

Table A1.6.2: Mean, standard deviation, median and range of the five univariate metrics of community structure of L4 assemblages. Values are given for surveys before and after the May 2017 disposal event for each year. Metrics in **bold** significantly increased post disposal.

		mean	**standard deviation**	**median**	**min**	**max**
Number of taxa (S)	Post	71	12	70.5	48	90
	Pre	57	15	59	28	87
Abundance (N)	Post	280	70	268.5	177	441
	Pre	221	98	210	68	511
Evenness (Pielou's J')	Post	0.85	0.03	0.85	0.76	0.89
	Pre	0.84	0.05	0.85	0.63	0.93
Diversity (Shannon Loge)	Post	3.60	0.22	3.62	3.02	3.98
	Pre	3.36	0.33	3.44	2.10	3.82
Biomass (g)	Post	14.92	9.78	11.40	1.64	45.35
	Pre	13.96	9.21	11.01	2.69	43.73

The number of taxa (*S*) is variable within a survey event but generally increases throughout the course of the year in 2014 (Figure A1.6.1). The average number of taxa in the summers of 2017 and 2018 appear higher than the 2014 and 2016 values. Similarly, the total abundance (*N*) generally increases as the year progresses with notably high summer 2018 mean values. Diversity and evenness values are also variable. The mean evenness and diversity values appear to dip between the April and May sampling events in 2017, a period when the average total abundance increases, and the average number of taxa decreases. The mean evenness values for a similar period in 2014 (20th May) and 2016 (5th May) appear much higher but all years demonstrate similar mean evenness values and overlapping error bars from the summer and autumn survey events. The mean biomass is highly variable yet appears stable for all sampling events with no discernible upward or downward trend evident (Figure A1.6.1). In summary,

these plots present no evidence of a change in macrofaunal univariate metrics following the commencement of disposal activity. Values remain high from June 2017 (following the May disposal) for the remainder of that year, and metric values for 2018 appear to reproduce the seasonal changes observed during the two baseline years (2014 and 2016).

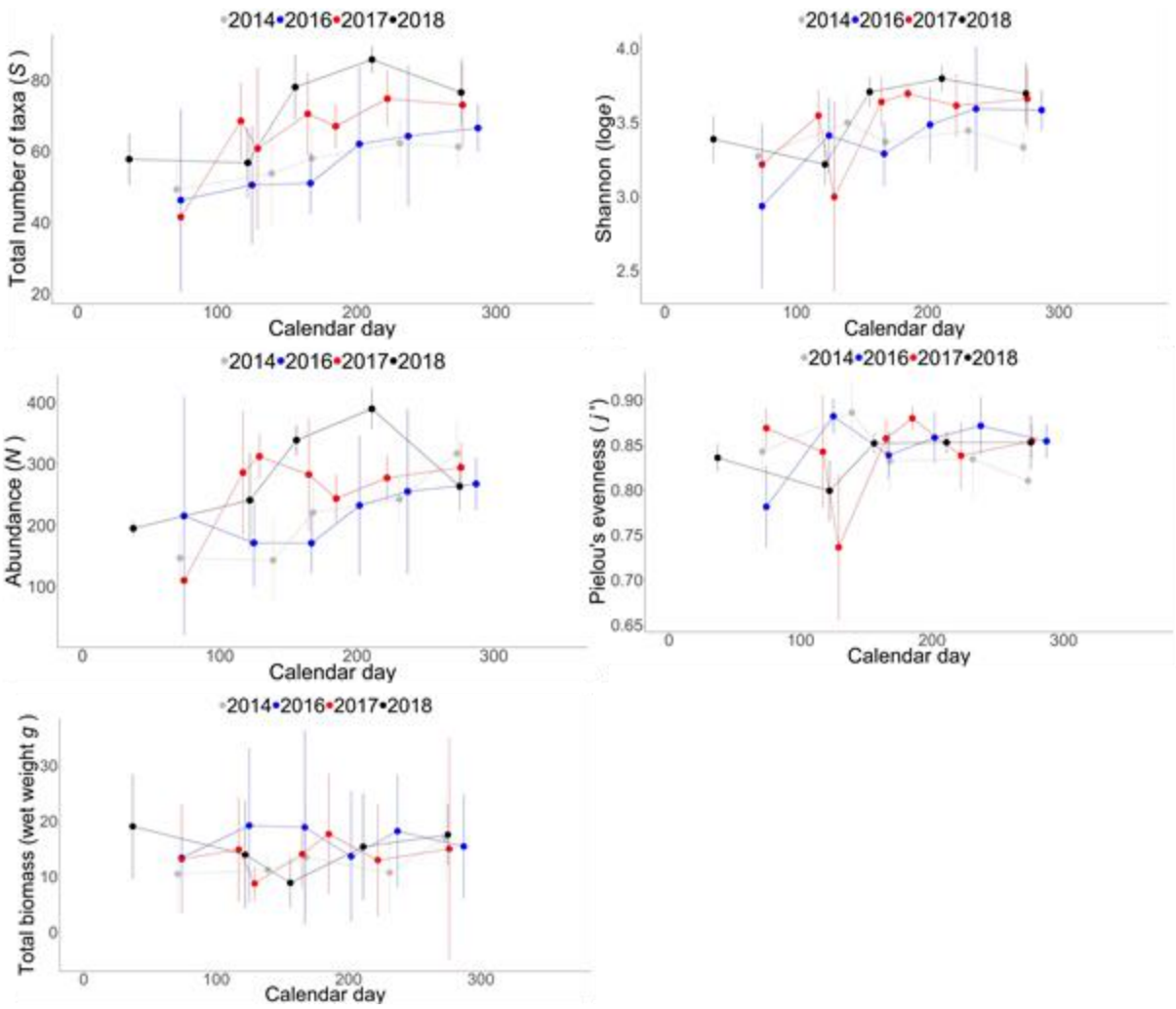


Figure A1.6.1: Averaged univariate metrics (±95 confidence intervals) of the benthic macrofaunal assemblages at L4 from 2014, 2016, 2017 and 2018.

6.3.2 Multivariate analysis

6.3.2.1 Abundance

The similarities between replicates for all surveys are presented in the nMDS ordination in Figure A1.6.2. This reveals macrofaunal dissimilarity in spring is high between years, although assemblage structure in spring 2018 was less variable and less distinct from previous years. Assemblages during autumn appear more similar between years. Assemblage structure during 2018 does not appear to show any change from previous years.

The transition of the benthic assemblage structure over the course of each year is indicated by the chronological trajectory ordination plot in Figure A1.6.3. One can see that there is inherent seasonal variability in the structure of the macrofaunal assemblages at L4, as evidenced during the two baseline years of 2014 and 2016. The natural seasonal progression in structure appears to be common across years, although the structure of the initial assemblage varies between years. Notably, the first sampling event incorporated into the analysis for 2017, prior to any disposal, appears to show the greatest separation from other years for a comparable time of year. The assemblage structures of the final surveys in each year appear to show the highest similarity, indicating that the assemblages each year converge to a relatively similar structure despite high dissimilarity earlier in the year. Overall, there is no indication to any alteration to seasonal variability following the commencement of disposal activity. The composition of the assemblages during 2018 appears somewhat mid-way between those sampled during 2016 and 2017.

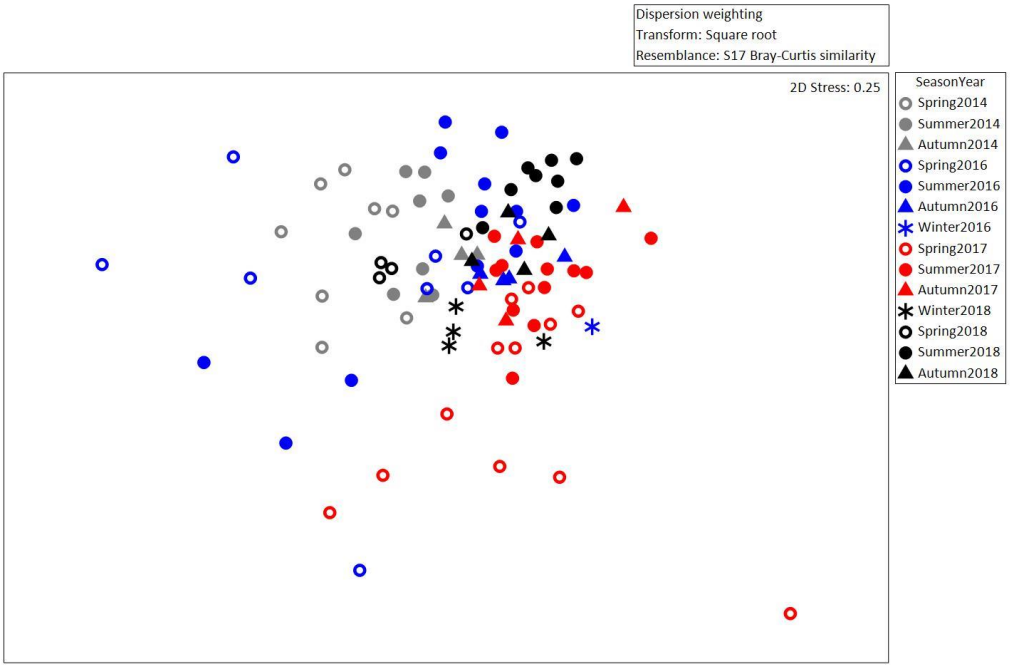


Figure A1.6.2: Non-metric multi-dimensional scaling (nMDS) ordination showing the similarity among dispersion weighted and square root-transformed infaunal abundance data sample replicates.

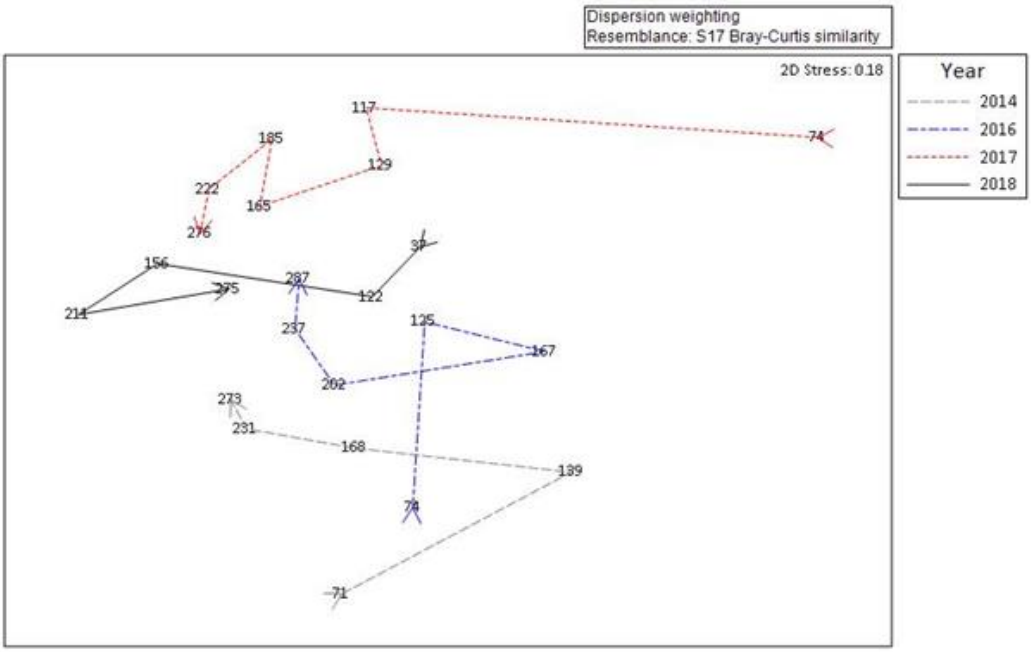


Figure A1.6.3: Non-metric multi-dimensional scaling (nMDS) ordination showing survey event averaged values for each year. Bray-Curtis similarity matrices based on square root-transformed and dispersion weighted abundance values.

6.3.2.2 *Biomass*

The untransformed infaunal biomass values, expressed as replicate averages for each survey event, is presented as an nMDS ordination in Figure A1.6.4. Seasonal variability appears greater than any annual variability as the location of the trajectories on the plot closely overlap. However, the seasonal variability does not appear cyclical (Table A1.6.3). Evidence of a seasonal cycle is limited for 2014 (Spearmans co-efficient ρ = 0.164) and absent from 2016, 2017 and 2018. Akin to the conclusion based on abundance-based taxonomic structure, there is no evidence of a shift in biomass-based structure following the commencement of disposal activity.

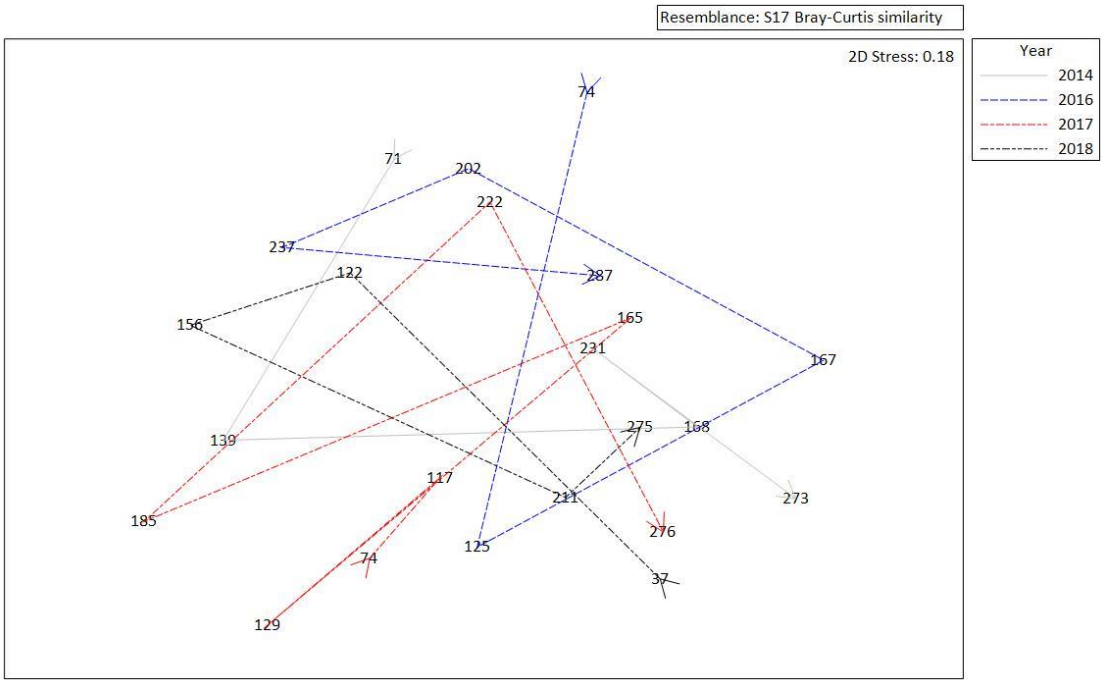


Figure A1.6.4: Non-metric multi-dimensional scaling (nMDS) ordination showing survey event averaged data for each year. Bray-Curtis similarity matrix based on untransformed biomass data.

6.4 Conclusions

- Biomass is variable at the L4 site, yet the mean value appears consistent over time and is not different before or after the commencement of disposal activity at Plymouth Deep.
- The number of taxa, abundance and Shannon diversity are significantly different pre and post disposal, with increased mean values in samples collected after May 2017.

- There is no evidence of changes to seasonal variations of macrofaunal univariate metrics following the commencement of disposal activity over the course of 2014, 2016, 2017 and 2018.
- There is no evidence in the multivariate analysis of abundance or biomass values of significantly different assemblages pre and post disposal.
- Variability in the L4 benthic assemblage at the Plymouth Deep site may be linked to, and as a result of, natural variability e.g., food availability and primary production, which are not reported here and are outside of this study.
- The results and conclusions obtained here must be considered with respect to the limitations of this assessment as outlined in Section 6.1.

Table A1.6.3: Results of the RELATE test for each survey year showing the correlation co-efficient (Rho) and probability value (p) for the comparison of the Bray-Curtis untransformed abundance similarity resemblance matrix with the modelled (cyclic) resemblance matrix for monthly and seasonally averaged replicates.

Year	a) Monthly cycle Spearman coefficient ρ	*p*	b) Seasonal cycle Spearman coefficient ρ	*p*
2014	0.082	0.15	**0.164**	0.02
2016	-0.089	0.91	-0.141	0.98
2017	0.021	0.34	0.036	0.27
2018	0.114	0.09	0.082	0.13

Appendix 2: Assessment methods of contaminants

1 PAHs

1.1 Sample extraction

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).

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 routinely determined 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 Organohalogens

2.1 Sample extraction

Sediment samples were air dried and sieved (<2 mm) 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 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).

2.3 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.

2.4 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 1.00 min, 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 were 340°C and 230°C, respectively. A 2-µl extract was injected in pulsed-splitless mode with a purge time of 2 min.

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 1.00 min, 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 were 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.

2.6 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.

2.7 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.

2.8 Method used for assessment

PCB, OC 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. Where individual congener concentrations were below the limit of detection (LOD) of 0.02 µg kg^{-1}, a value of half the LOD was inserted for calculation of summed concentrations. The ∑DDTs (*p,p'*-DDE, *p,p'*-TDE, *p,p'*-DDT, *o,p'*-DDE, *o,p'*-TDE, *o,p'*-DDT) were calculated. The ∑11 BDEs were calculated. Where individual congener concentrations were below the LOD of 0.02 µg kg^{-1}, a value of half the LOD was inserted for calculation of summed concentrations. For samples analysed prior to 2008, a different LOD of 0.125 µg kg^{-1} 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^{-1}, 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 (dw) basis unless otherwise stated.

The current Cefas action limits for dredge disposal are: Action level 1 if ∑ICES7 CBs > 10 µg kg^{-1}, ∑25CBs > 20 µg kg^{-1}, ∑DDT > 1 µg kg^{-1}, dieldrin > 1 µg kg^{-1}, and action level 2 if ∑25CBs > 200 µg kg^{-1}. Concentrations are expressed on a dry weight (dw) 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^{-1} 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^{-1} 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

OSPAR MIME have recently adopted the Canadian FEQG (Federal Environmental Quality Guidelines) levels as EAC results for PBDEs, and also calculated BAC values. These thresholds are shown in Table A2.2.2.

Table A2.2.2: Canadian FEQG (Federal Environmental Quality Guidelines) levels adopted by OSPAR MIME as EACs thresholds for PBDEs, together with calculated BAC values.

Sediment (µg kg^{-1} dry weight, normalised to 2.5 % TOC)		
Compound	**BAC**	**EAC**
BDE28	0.04	110
BDE47	0.04	97.5
BDE66	0.04	97.5
BDE85	0.04	1
BDE99	0.04	1
BDE100	0.04	1
BDE153	0.04	1100
BDE154	0.04	1100
BDE183	0.04	14000
BDE209	0.04	47.5

Concentrations in the samples collected in 2018 for this report were compared with those collected on previous sampling campaigns from 2002-2012, to investigate temporal trends in sediments at the sampling stations.

3 Trace Metals

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 <63 µm fraction. Details on obtaining the <63 µm 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 (<63 µm) 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.

3.2 Numerical assessments

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.

3.2.1.1 *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.

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

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).

3.2.1.1.1 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 (<63 µm), normalisation to some extent has already been completed, therefore all enrichment calculations were based on the raw data.

3.2.1.1.2 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).

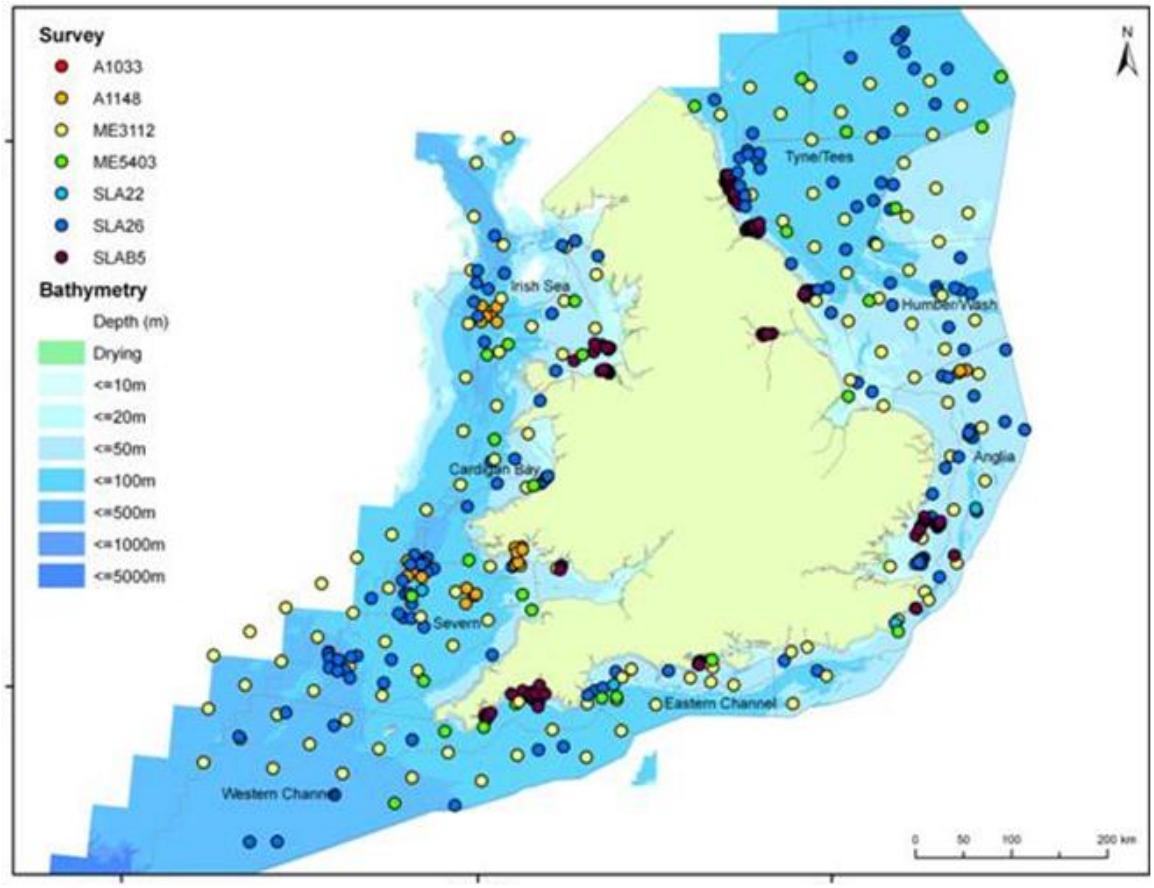


Figure A2.3.1: Location of stations sampled to provide metals data as part of the regional baseline approach.

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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