Cefas contract report: SLAB5

Dredged Material Disposal Site Monitoring Around the Coast of England: Results of Sampling (2009)

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Issue date: April 2011

This work was carried out under the Cefas/Marine and Fisheries Agency (MFA) MoU B, contract SLAB5.

Cefas Document Control

Title: Dredged Material Disposal Site Monitoring Around the Coast of England: Results of Sampling (2009)

Submitted to:	MMO
Date submitted:	May 2011
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Approved by & date:	Chris Vivian, May 2011
Version:	4.0

Version Control History			
Author	**Date**	**Comment**	**Version**
Draft (submitted to co-authors)	1.0	S Bolam	21 February 2011
Draft (edits addressed)	2.0	S Bolam	4 March 2011
Draft (sent to C. Vivian and S. Rogers)	3.0	S Bolam	7 March 2011
Revised version	4.0	S Bolam	28 April 2011

Executive Summary

- The scientific findings following dredged material disposal site monitoring around the coast of England during 2009 are presented.
- The main aims of this report are to aid the dissemination of the monitoring results, to indicate whether the results obtained are in line with those expected, to compare the results with those of previous years (where possible) and to facilitate our improved understanding of the impacts of dredged material disposal at both a site-specific level and a national level.
- Parameters monitored varied across sites but included multibeam and sidescan sonar acoustic techniques, sediment particle size assessments, sediment organic carbon and nitrogen, macrofaunal communities, Sediment Profile Imagery (SPI), and the assessment of a range of sediment contaminants including Tri-Butyl Tin (TBT), polycyclic aromatic hydrocarbons (PAHs), organohalogens (e.g., pesticides, flame retardants) and trace metals.
- While biological impacts (where assessed) were similar across all disposal sites (i.e., an altered community structure within, and in the immediate vicinity of, the disposal site), elevations in the concentrations of the various contaminant types were somewhat site-specific.
- Based on the data obtained, five of the seven disposal sites monitored in 2009 are recommended for further monitoring; the focus of four of these should be primarily on assessing contaminant concentrations within, and in the vicinity of, the disposal site.

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1. Introduction

1.1 Regulation of disposal activity in England

Around the coast of England, licences for the disposal of dredged material to sea during the period covered by this report were issued by the Marine and Fisheries Agency (MFA) under the Food and Environment Protection Act (FEPA) (Great Britain Parliament, 1985). Under FEPA, there is a requirement for the consideration of alternative uses and, while sea disposal continues to account for the bulk of dredged material generated in the UK, an increasing quantity is being directed elsewhere to serve a variety of purposes, e.g., sediment cell maintenance, habitat creation and/or enhancement (Murray, 1994; Bolam *et al*., 2003). From April 2010 the licensing role was taken on by the Marine Management Organisation.

In licensing the disposal of dredged material at sea, numerous conditions associated with the relevant national and international agreements (e.g., the London Convention 1972 (LC72) and London Protocol of 1996 (LP96), the OSPAR Convention, the Environmental Impact Assessment Directive (97/11/EEC), the Habitats and Species Directive (92/43/EEC), the Wild Birds Directive (79/409/EEC), and the Water Framework Directive (WFD, 2000/60/EC)), must be considered to determine whether likely impacts arising from the dredging and disposal are acceptable (MEMG, 2003). Criteria considered under the various conventions and directives include the presence and levels of contaminants in the materials to be disposed of, along with perceived impacts on any sites of conservation value in the vicinity of disposal. Additional potential beneficial usage of the materials must be considered prior to a disposal consent being issued (MEMG, 2003).

One of the roles of Cefas is to provide scientific advice to the MFA and now the MMO on the suitability of the dredged material for sea disposal at the application stage and, once a licence is granted, to check that licence conditions are met and that no unexpected effects occur. Advice on the licensing of dredged material disposal at sea is provided by Cefas' Regulatory Assessment Team (RAT), work conducted under SLAB5 helps underpin the scientific rationale for such advice (see Section 1.3).

1.2 Disposal sites around England

There are currently 136 sites designated for dredgings disposal around the coast of England, not all of which are used in any one year. While the many of these are located on the coast of the mainland, generally within a few miles of a major port or estuary entrance, a significant number are positioned within estuaries (e.g., Humber) or on intertidal mudflats as part of beneficial use schemes (Bolam *et al*., 2006).

In total, approximately 40 million wet tonnes are disposed of annually but can vary from 26 to 57 million wet tonnes. Individual quantities licensed may range from a few hundred to several million tonnes, and the nature may vary from soft silts to boulders or even crushed rock according to origin, although the majority consists of finer material (Bolam *et al*., 2006).

1.3 Overview of Cefas/MFA MOU B contract No. SLAB5 'Monitoring of dredged material disposal sites'

In England, SLAB5 was one of several contracts funded by the MFA under the non-R&D MoU B. The project provides field evaluations ('baseline', monitoring and 'trouble-shooting' surveys) at dredged material disposal sites in support of FEPA II (1985).

1.1.1 A major component of the project is, therefore, the commissioning of sea-going surveys at targeted disposal sites. Such field evaluations under SLAB5 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 contribute directly to the licensing/enforcement process, by ensuring that any evidence of unacceptable changes or practices is rapidly communicated and acted upon. 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' RAT. One of the key roles of the latter is to advise the FEPA licensing authority of the appropriateness of current licences and the suitability of any new licence applications. The scientific outcomes of work undertaken within SLAB5 are circulated to the Cefas RAT via a number of routes including peer-reviewed publications (including both activity-specific and site-specific findings), internal documents, direct discussions and internal and external presentations. The production of this report, within which a summary of the annual findings is presented, forms an important element of such scientific communication. It is not the purpose of this report to present a detailed appraisal of the processes giving rise to impacts at a particular site (this is more the role of, for example, peer-review outcomes) but to encapsulate the essence of the impacts associated with this activity in its entirety across the coast of England (see Section 1.5).

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 aimed that this approach should increase the transparency of the decision-making process regarding disposal site selection, i.e., establishes a model for site-specific decisions regarding sampling.

A tiered survey design and site assessment system, therefore, facilitates the prioritisation of dredge 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 2009 are listed in Table 1.1. These sites were identified following consultation between Cefas case officers within the RAT and scientists in a number of key disciplines (e.g., benthic ecology, sediment contaminants). These sites were selected based on information from dredged material licence applications, consultation with MMO and through concerns identified by stakeholders including conservation agencies and the general public.

Disposal Site	Code	Prioritisation assessment: Tier
North Tyne	TY070	1
Souter Point	TY081	1
Tees Bay (inner)	TY160	1
Tees Bay (outer)	TY150	1
Bridlington	HU015	1
Inner Gabbard East	TH056	2
Rame Head South	PL031	1

1.5 Aims 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 case officers, presentations and subsequent publications at national and international conferences, and via papers in peer-reviewed journals. The aims of this report are:

- To present the findings of the results of sampling undertaken during 2009 under SLAB5, thereby aiding the dissemination of the findings under this project;

- To indicate whether the results obtained are in line with those expected, or whether subsequent investigations should be conducted;
- Where possible, assess the 2009 results in line with those of previous years to provide a temporal assessment;
- 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 SLAB5.

Section 2 of this report presents the findings of the 2009 sampling programme under SLAB5. Methods, both field, laboratory and numerical, are not described but such information can be obtained either via those references cited (where appropriate) or by contacting Cefas (Stefan.bolam@cefas.co.uk, or www.cefas.defra.gov.uk). Information regarding the processing of samples for TBT, PAHs, organohalogens and trace metals, together with some background to the numerical approaches and derivation of action levels, is briefly given in Appendices 1 – 4 respectively.

2. Results

2.1 North Tyne (TY070)

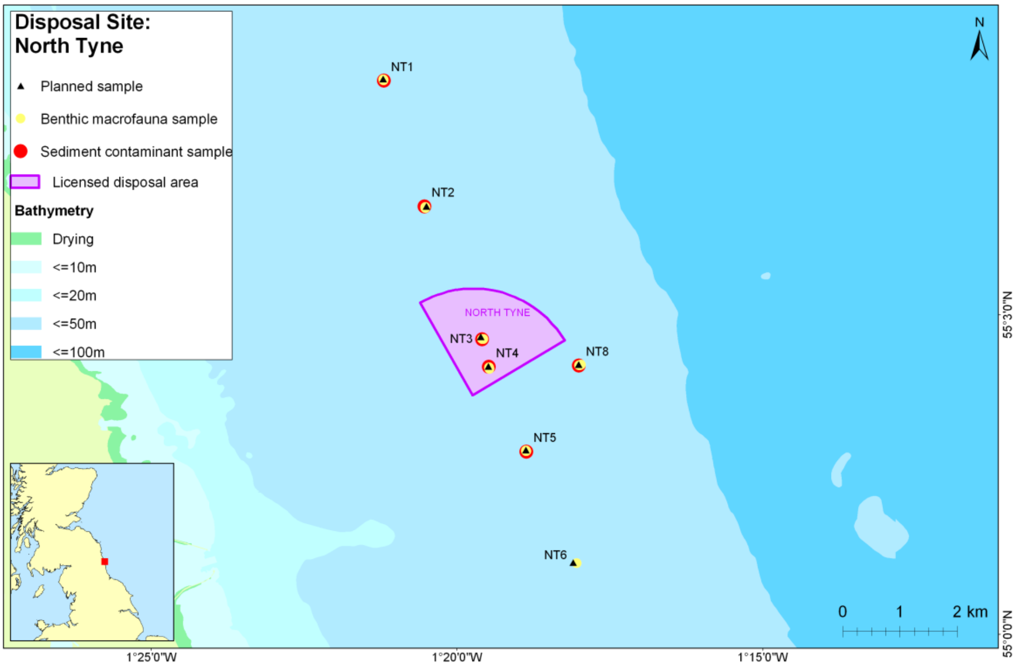


Figure 2.1.1. Locations of monitoring stations at North Tyne disposal site during 2009.

2.1.1 Background

Material disposed of to North Tyne is made up of predominantly silt and sand. In the past the site was used for capital and maintenance dredgings, minestone, mine tailings and fly ash from power stations.

The contaminated nature of the dredged material is a result of metal mineralisation, mining activity and industrial activities more generally in the catchment area. This has resulted in very high levels of heavy metals redundant from the historic mining industry and hydrocarbons from industrial activities. Recently material around Action Level (AL) 2 for Zinc has been disposed of from Walker Technology Park to this disposal site.

Currently, elevated levels of hydrocarbons and heavy metals are regularly disposed of to this site compared to levels seen at some other disposal sites. Historically, relatively high levels of TBT in dredged material going to this site were not unusual.

2.1.2 Impact hypotheses

- Any elevations in the concentrations of chemical contaminants directly attributable to dredged material disposal will be confined to within and the near vicinity of the disposal site, principally along the tidal axis

- Any elevations in the concentrations of chemical contaminants directly attributable to dredgings disposal will be within acceptable limits
- Any changes to the physical habitat will be confined to within and the near vicinity of the disposal site, principally along the tidal axis
- Any adverse effects on the benthic biota will be confined to within and the near vicinity of the disposal site, principally along the tidal axis
- Effects on benthos within the disposal site will be limited to periodic and localised reductions in the densities/diversity of the benthos, *i.e.*, the disposal site will at no time be characterised as azoic
- The wider dispersal of fine particulates arising from dredgings disposal, including any wave-induced shoreward transport, will have no adverse consequences for the marine biota or for recreational/amenity interests

2.1.3 Parameters monitored

Sediment particle size distribution
Sediment organic carbon and nitrogen
Macrofaunal communities
Sediment contaminants (TBT, PAHs, organohalogens, trace metals).

2.1.4 Results

2.1.4.1 Sediment particle size

Seven sediment groups were defined for North Tyne (Table 2.1.1). Sediments in sediment groups NoT1, NoT3 and NoT6 are all described as slightly gravelly, muddy sand, with NoT1 and NoT3 containing less silt/clay than NoT6 (16%/18% compared with 40% respectively). Sediments in NoT3 are dominated by fine sand (49%) compared with NoT1 where the sand is more mixed, split between fine sand and very fine sand. Both NoT1 and NoT3 are unimodal (152.5µm). Sediments in NoT2 are described as muddy, sandy gravel. Sediments in NoT4 are described as slightly gravelly sand (medium). Sediments in NoT5 and NoT7 are described as gravelly muddy sand, with NoT5 containing less gravel than NoT7 (6% compared with 20% respectively).

Sediment group	Number of samples	% number of samples	Sample Type	Sediment description	MODE 1 (µm):	MODE 2 (µm):	MODE 3 (µm):
NoT1	7	26	Unimodal, poorly sorted	Slightly gravelly muddy sand (lower silt/clay% than NoT6)	152.5		
NoT2	5	19	Polymodal, very poorly sorted	Muddy sandy gravel	26950.0	215.0	1700.0
NoT3	3	11	Unimodal, poorly sorted	Slightly gravelly muddy Sand (fine)	152.5		
NoT4	4	15	Unimodal, moderately sorted	Slightly gravelly sand (medium)	302.5		
NoT5	4	15	Unimodal, poorly sorted	Gravelly muddy sand (lower gravel% than NoT7)	302.5		
NoT6	2	7	Bimodal, very poorly sorted	Slightly gravelly muddy sand (higher silt/clay% than NoT1)	152.5	26.7	
NoT7	2	7	Polymodal, very poorly sorted	Gravelly muddy sand (higher gravel% than NoT5)	605.0	215.0	107.5

Sediment group	Gravel (%)	Sand (%)	Silt/clay (%)	Very coarse sand (%)	Coarse sand (%)	Medium sand (%)	Fine sand (%)	Very fine sand (%)
NoT1	3.45	80.04	16.52	2.58	4.67	10.94	31.57	30.28
NoT2	40.01	49.93	10.07	11.00	7.91	10.12	12.94	7.95
NoT3	0.46	81.22	18.32	0.96	3.30	14.82	49.95	12.19
NoT4	1.46	94.50	4.04	0.93	3.35	47.42	36.73	6.06
NoT5	6.04	82.13	11.83	3.37	4.91	29.36	29.79	14.69
NoT6	1.83	54.94	43.23	1.66	2.94	10.82	22.43	17.10
NoT7	20.10	66.45	13.45	9.82	14.75	15.50	14.41	11.98

Table 2.1.1. Sediment descriptions and summary statistics, based on the average sediment distribution, calculated using Gradistat (Blott and Pye, 2001) for each sediment group defined at North Tyne.

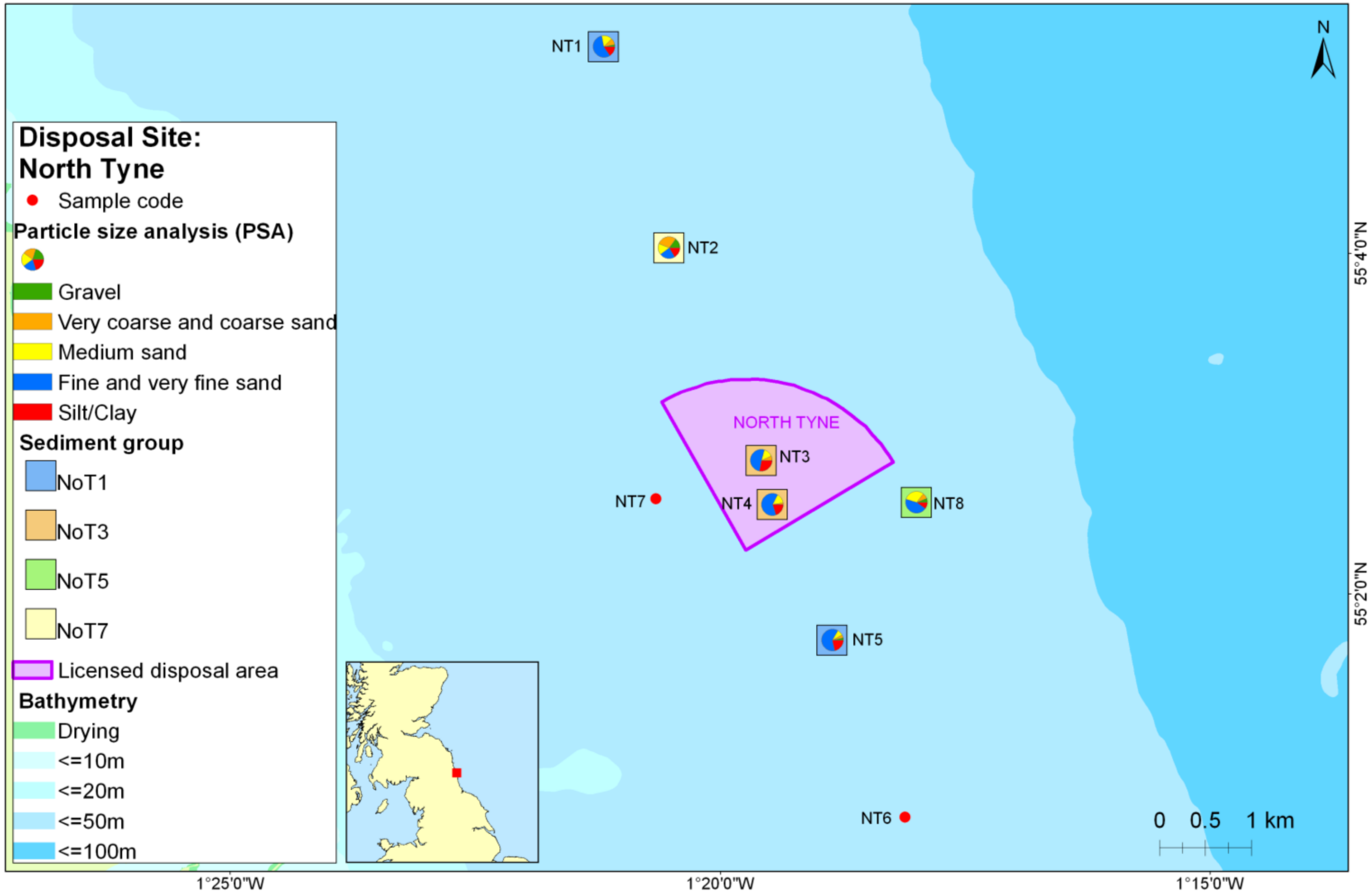


Figure 2.1.2. Sediment groups (coloured squares) overlain with pie charts showing proportions of gravel, very coarse sand and coarse sand, medium sand, fine and very fine sand and silt/clay at each station (labelled with sample code) in 2009.

Station code	2006	2007	2008	2009
NT1	NoT1	NoT1	NoT1	NoT1
NT2	NoT1	ns	ns	NoT7
NT3	NoT3	NoT4	NoT4	NoT3
NT4	NoT6	NoT4	NoT4	NoT3
NT5	NoT2	NoT6	NoT1	NoT1
NT6	NoT2	NoT7	NoT2	ns
NT7	NoT2	NoT2	ns	ns
NT8	NoT5	NoT5	NoT5	NoT5

Table 2.1.2. Sediment group at each station between 2006 and 2009 inclusive (ns = no sample).

The spatial distribution of the various sediment groups is shown in Figure 2.1.2. One can see that the sediments within the disposal site (stations NT3 and NT4) are both in sediment group NoT3 (dominated by fine sand). These stations have shown some change each year since 2006 (Table 2.1.2), more recently due to increased proportions of mud. North, and immediately south, of the site of the licensed disposal site, at NT1 and NT5 respectively, the sediments are in sediment group NoT1 (dominated by sand). Immediately north of the site, at NT2, the sediment is more mixed (NoT7, gravelly muddy sand, mixed sediment), while east of the site, at NT8, the sediment is in sediment group NoT5 (gravelly muddy sand, unimodal). NT1, NT7 and NT8 have remained consistent since 2006 while all the other stations have shown some temporal variability (Table 2.1.2). NT6 and NT7, not sampled in 2009, were previously muddy sandy gravels: this relatively coarse substrate may explain the difficultly in sampling there in 2009.

2.1.4.2 Sediment organic carbon & nitrogen

Sediment organic carbon (on the <63µm sediment fraction), organic carbon (on the <2mm sediment fraction) and silt/clay contents for the North Tyne survey stations are shown in Figure 2.1.3. Organic carbon values (on the <63µm sediment fraction) range from 3.12 (at NT1) to 5.26 % m/m (within the disposal site); these values are similar to those observed during 2006, 2007 and 2008 (data not shown). At NT5, higher levels of organic carbon are present in the <2mm fraction than the <63µm indicating that the organic carbon for this area is present in the coarser sediment, probably as coal, which is locally in the sediment in this area.

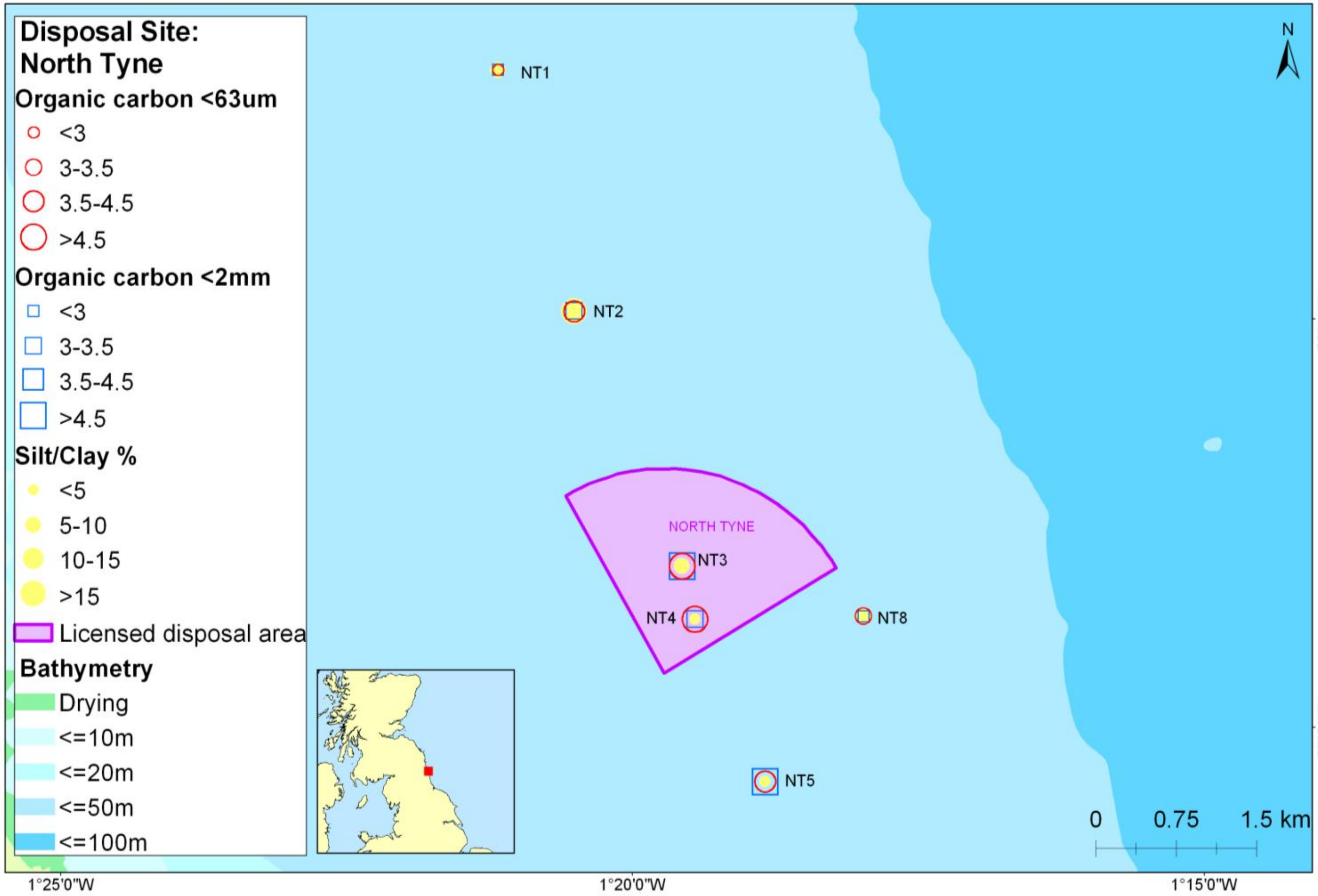


Figure 2.1.3. Organic carbon (<63µm), organic carbon (<2mm) and silt/clay at North Tyne

2.1.4.3 Macrofaunal communities

The macrofaunal analysis identified a total of 2076 individuals and 55 taxa from the samples collected during 2009. The main taxonomic groups were represented by Annelida (77% of total abundance), Mollusca (13%), Miscellanea (3%), Echinodermata (4%), and Crustaceans (3%).

The total abundance of individuals varied from 109 to 440 per 0.1 m^2 across the study area. Overall, the lowest densities observed were 109 to 144 individuals per 0.1 m^2 at NT3 and NT4 respectively (both within the disposal site). Higher values were observed at the stations located outside the disposal site at stations NT1 and NT6 located north and south of the centre respectively (Figure 2.1.4A). Total number of species per 0.1 m^2 grab ranged from 40 to 65: the higher values being encountered in NT8 and NT1 (64 and 61 species respectively) to the north and west of the licensed disposal site (Figure 2.1.4B).

Total macrofaunal biomass ranged from 2.43 to 9.61 g / 0.1 m^2 (Figure 2.1.4C). Higher biomass values were recorded at stations NT4, NT3 and NT2 (9.61, 5.02 and 4.84 g / 0.1 m^2 respectively) which are within, and to the north of, the disposal site. The species responsible for the higher biomasses at these stations were *Dosinia lupinus*, *Echinocardium cordatum* and *Atelecyclus rotundatus.*

Multivariate analyses showed a clear separation of stations located in the centre of the disposal site (NT3 and NT4) with those to the north and south reference stations (NT1 and NT5 respectively) (Figure 2.1.5). Macrofaunal community structure of the replicates from station NT8 (east of the disposal site) resembled those of these reference stations which is in contrast to previous monitoring assessments (see 2008-09 monitoring report in Bolam *et al*., 2009).

SIMPER analysis showed the species that were causing the dissimilarity between the disposal site and reference stations. The average dissimilarity between the disposal site and northern reference was 54.62 %, the species primarily responsible for which were *Peresiella clymenoides*, *Galathowenia oculata*, *Rhodine gracilior*, Phoronis sp., *Dosinia* sp. (juv), and *Chamelea striatula (juv)* (these species contributed to 10.34 % of overall group dissimilarity).

The average dissimilarity between the north and south reference was 45.08 %, the main responsible species causing this dissimilarity were *Abra nitida*, *Phoronis* sp., *Trichobranchus roseus*, *Ampharete baltica*, *Ophelina acuminata*, Amphiuridae (juv) and *Mysella bidentata* (these species contributed to 10.08 % of the overall group dissimilarity).

Comparisons between the dissimilarity observed between the disposal site and south reference (54.27%) indicated that the species responsible were *Abra nitida*, *Peresiella* *clymenoides*, *Chamelea striatula*, *Dosinia* sp. (juv)and *Galathowenia oculata* (these species contributed to 10.59 % of the overall group dissimilarity).

Overall, these data show that numbers of individuals and total number of species are reduced within the disposal site stations (i.e. NT3 and NT4) when compared with the north and south reference, resembling a similar situation to previous monitoring assessments at this disposal site. In contrast, macrofaunal biomass in the disposal site is comparable to the reference areas: the observed increase at station NT4 was caused by 10 individuals of *Echinocardium cordatum*. North and south reference stations cluster with the stations located at the periphery of the disposal site.

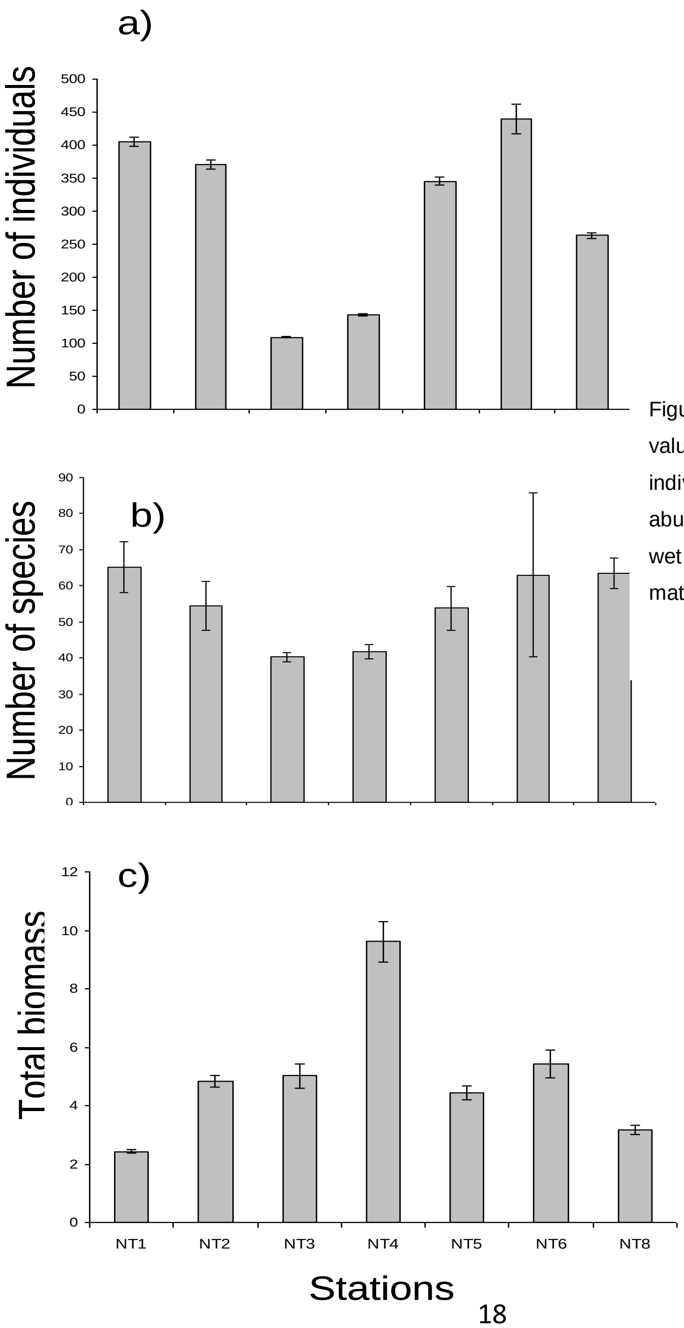


Figure 2.1.4. Univariate trends, mean values (+/- SE) for A) total number of individuals per 0.1m-2 grab, B) total abundance of taxa per grab, and C) total wet biomass per grab at TY070 dredged material disposal site.

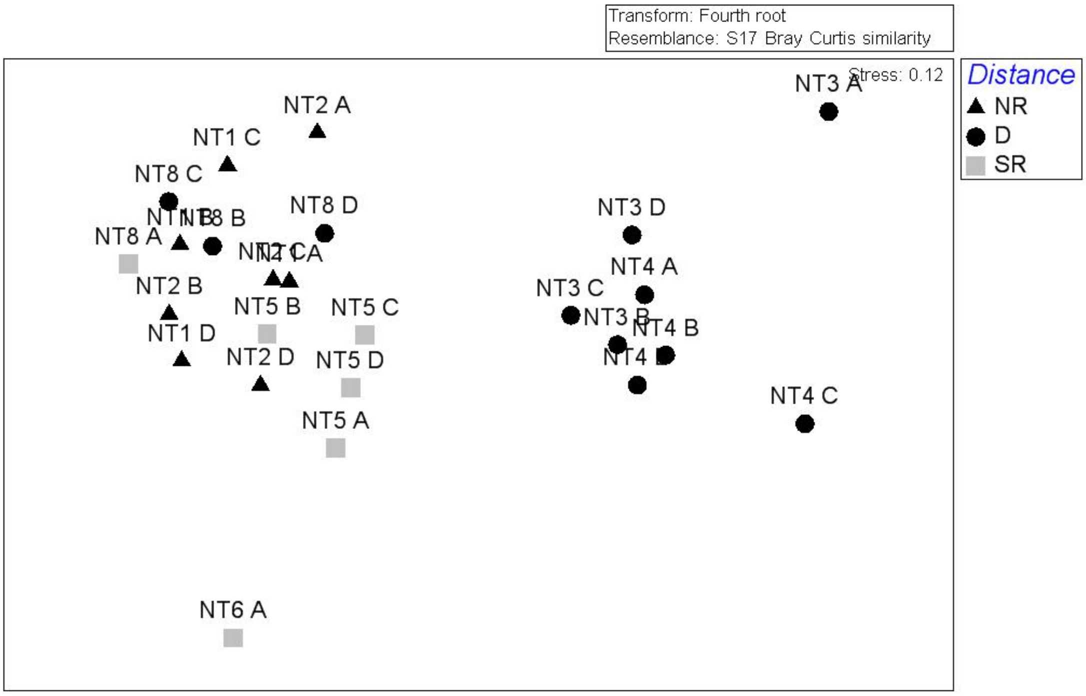


Figure 2.1.5. Multidimensional scaling ordination based on Bray-Curtis similarity for infauna samples at TY070 dredged material disposal site. Symbols refer to north reference (triangles), south reference (squares) and stations within the disposal site (circles).

2.1.4.4 Sediment contaminants

2.1.4.4.1 TBT

Within the disposal site, NT3 and NT4 both exhibited detectable levels of TBT: 0.05 mg/kg and 0.12 mg/kg respectively. The latter concentration has fluctuated between 0.05 mg/g and 0.1 mg/kg during the last 4 years. TBT concentrations were below the method limit of detection (or LOD, 0.002 mg/kg) for all stations outside the disposal site (i.e., NT1, NT2, NT5 and NT8). Both NT1 and NT8 have consistently been below the method LOD for the last 4 years and TBT concentrations at station NT5 have continually decreased since 2007.

The overall loading of TBT disposed of at North Tyne (from either capital or maintenance dredging) has halved from 2007 to 2008. The dispersive nature of this site, together with the decrease in disposal quantities, is likely to explain the observed decline in TBT values in these sediments.

Overall, the general findings are very similar to previous years' observation regarding levels of TBT at targeted stations.

2.1.4.4.2 PAHs

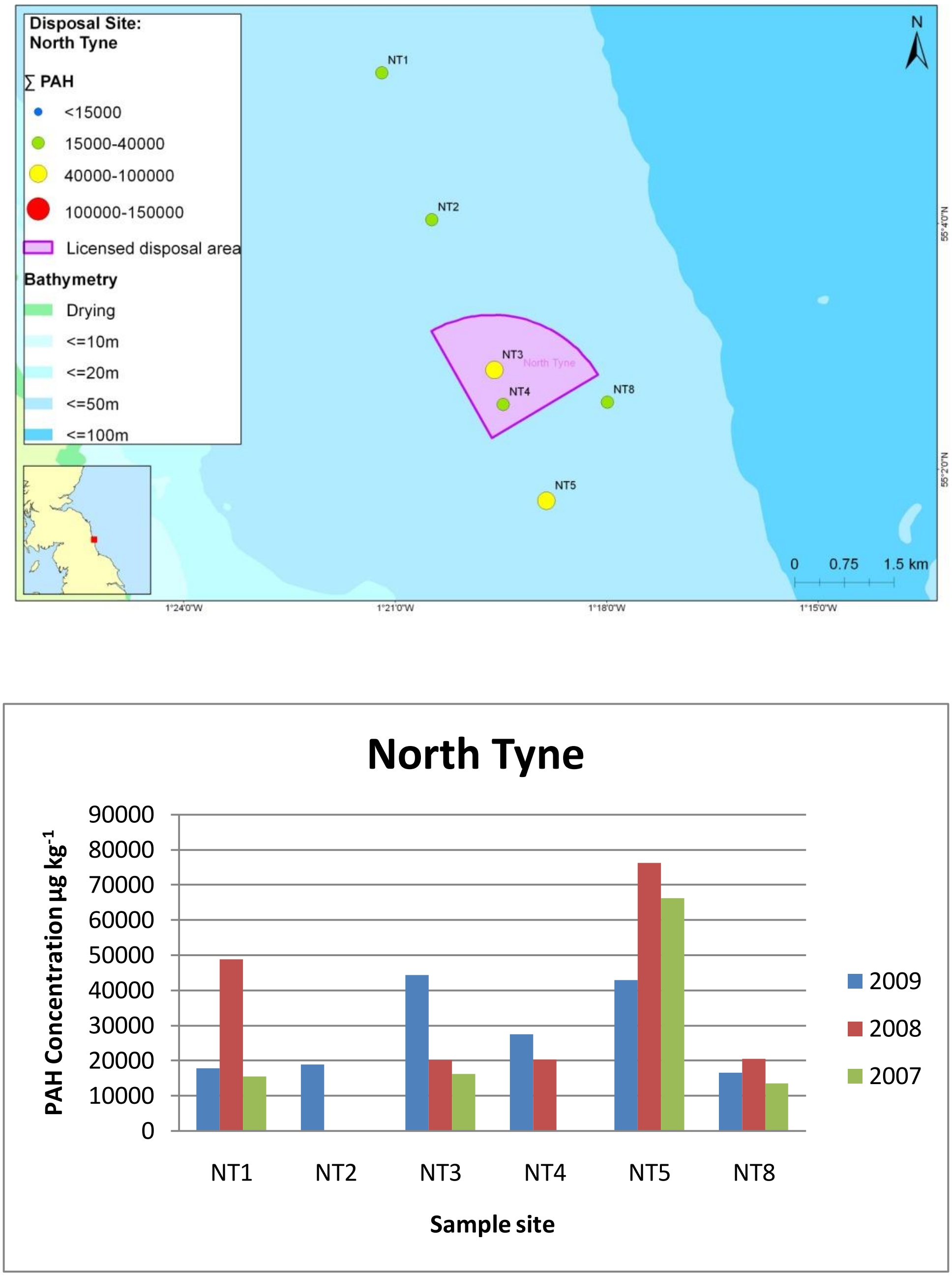


Figure 2.1.6. Summed PAH concentrations (µg kg^{-1}) for stations sampled in 2009 at North Tyne (top) and concentrations observed during 2007, 2008 and 2009 (bottom).

The highest summed PAH concentration observed at North Tyne during 2009 was 44,400 µg kg^{-1} at NT3, situated at the centre of the disposal site, which is much higher than that sampled there in 2008 (20,100 µg kg^{-1}, Figure 2.1.6). The next highest concentration observed in 2009 was at NT5 (i.e., 43,000 µg kg^{-1}, Figure 2.1.6) which, in contrast to the situation at NT3, is lower than in previous years (e.g., 76,200 µg kg^{-1} in 2008). NT6, the station where the highest summed PAH concentration was observed in 2008, was not sampled in 2009. NT2 was not sampled in the previous two years but its summed PAH concentration of 18,800 µg kg^{-1} is typical of values found at NT1 and NT8 outside of the disposal site area.

From the derived sediment quality guidelines using the Effects Range Low/Effects Range Median (ERL/ERM) methodology all sediment samples taken at North Tyne exceeded the ERL for low molecular weight (LMW) PAHs. Three stations (i.e., NT3, NT4 and NT5) display summed PAH concentrations that exceed the ERM for the LMW PAHs: these three stations also exceeded the ERL for the high molecular weight (HMW) PAHs.

2.1.4.4.3 Organohalogens

At North Tyne, CBs were detected at all stations apart from NT8 (∑ICES7 CBs range <0.7-4.6 µg/kg dw). Concentrations of CBs were low to the north and east of the disposal site, generally below or close to LODs (Figure 2.1.7). Concentrations of CBs within and south of the disposal site were higher, with ∑ ICES 7 concentrations ranging from 3.2 to 4.6 µg/kg dw (Figure 2.1.7).

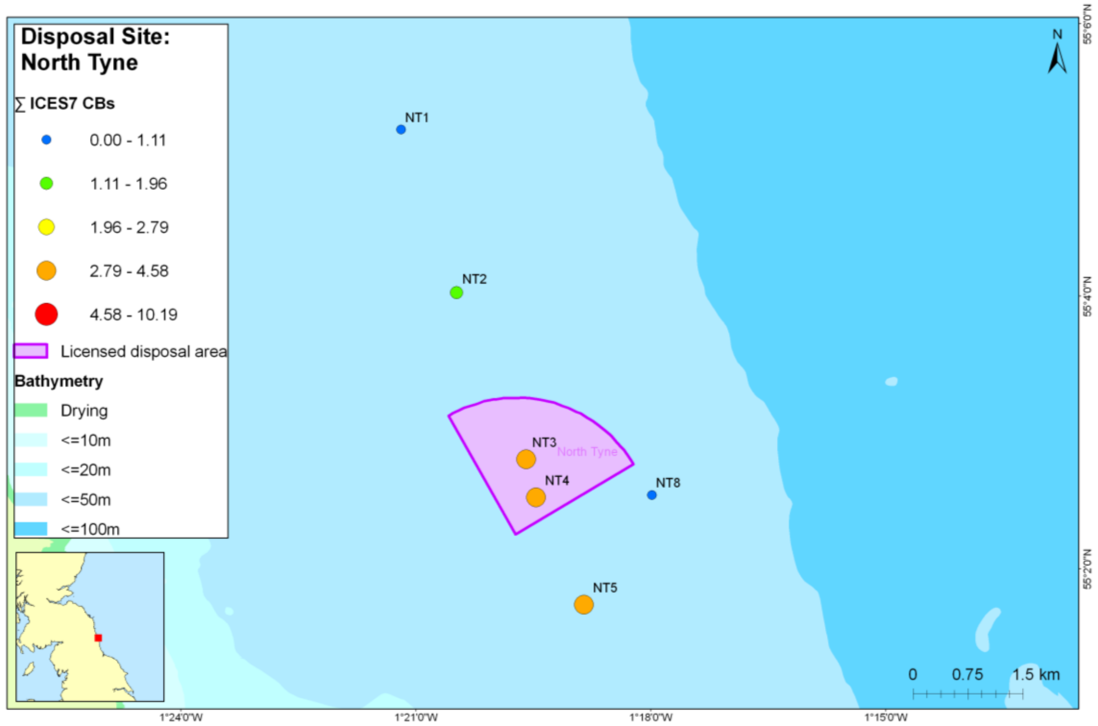


Figure 2.1.7. Summed ICES7 CB concentrations (in µg/kg) for the North Tyne Stations, 2009.

BDEs were detected at all stations (∑11 BDEs range 0.74-5.9 µg/kg dw; Figure 2.1.8). Such concentrations were lowest to the north and east of the disposal site; similar to the situation for CBs. Concentrations of BDEs within the disposal site were higher, with ∑11 BDEs concentrations of 1.3 and 2.5 µg/kg dw. The highest concentration of 5.9 µg/kg dw was found to the south of the disposal site. In general, therefore, there were apparent similarities in the concentration gradients for both these organohalogen groups in 2009.

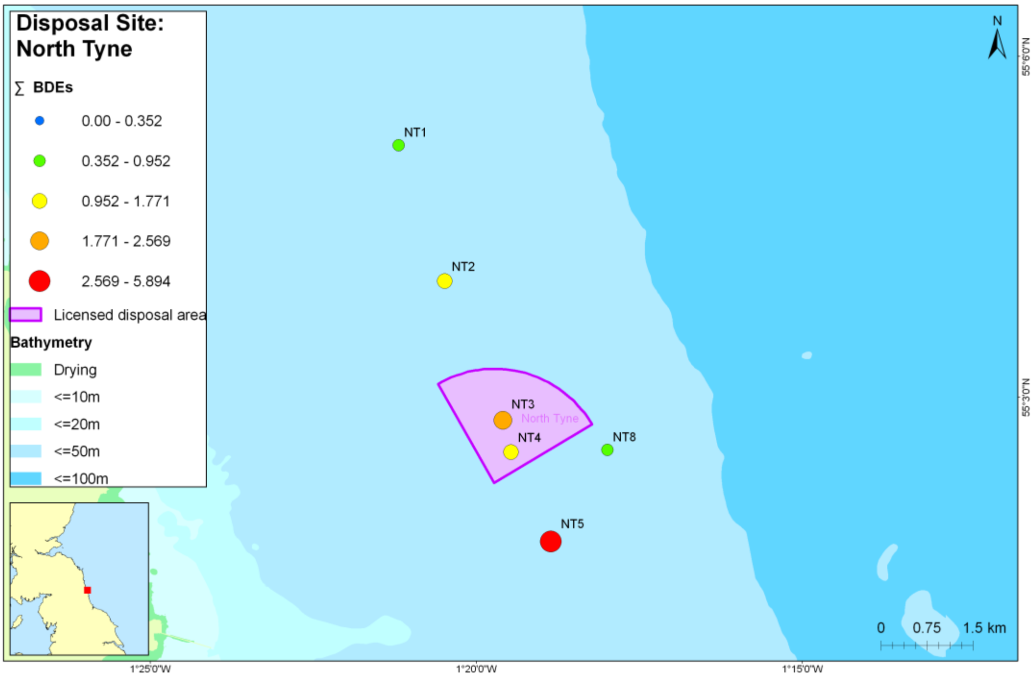


Figure 2.1.8. Summed 11 BDEs concentrations (in µg/kg) for the North Tyne Stations, 2009.

Concentrations of CBs at all stations were below Cefas Action (AL) Level 1, while no ALs currently exist for BDEs. According to the OSPAR guidelines, all stations had ‘good’ environmental status for all ICES 7 CBs and ‘good’ status overall; this is in agreement with the observations made the previous year for this site (Bolam *et al*., 2009). No OSPAR guidelines exist for BDEs at present.

Concentrations of CBs at NT3 and NT4 (within the disposal site) in 2009 were more than double to those reported in 2008 while, in contrast, the concentration at NT5 (to the south) has almost halved (Table 2.1.3). BDE concentrations at NT3, NT4 and NT5 in 2009 were all 5 times higher than observed in 2008 (Table 2.1.4). Concentrations of CBs and BDEs in the sites to the north and east continue to show a trend of decreasing concentrations over the period 2006 - 2009.

Station code	∑ICES 7 CBs concentration (in µg/kg)			
	2006	2007	2008	2009
NT1	1.54	0.97	2.11	0.93
NT2				1.69
NT3	1.48	2	1.79	4.12
NT4	7.21		*0.7*	4.58
NT8	5.21	2	0.81	*0.7*
NT5	2.7	7.59	6.05	3.24
NT6	2.44	2.54	3.88	

Table 2.1.3. Temporal trends (2006-2009) of ∑ICES 7 CBs concentration (in µg/kg) at North Tyne in the stations sampled during 2009.(Note, concentrations in italic represent estimates of concentrations for samples where all ICES 7 congener concentrations were below LODs)

Station code	∑11 BDEs concentration (in µg/kg)			
	2006	2007	2008	2009
NT1	1.56	1.68	1.27	0.95
NT2	5.28			1.27
NT3	1.72	1.54	0.49	2.55
NT4	13.2		0.28	1.27
NT8	1.86	2.84	1.42	0.74
NT5	2.18	4.49	0.96	5.89
NT6	7.69	4.12	1.18	

Table 2.1.4. Temporal trends (2006-2009) of ∑11 BDEs concentration (in µg/kg) at North Tyne in the stations sampled during 2009. (Note, limits of detection for BDEs improved between 2007 and 2008 and therefore values assigned to congeners below LOD are lower in 2008 and 2009, resulting in a step decrease in ∑11 BDEs concentration for samples with congeners below LODs)

2.1.4.4.4 Trace metals

Figure 2.1.9 indicates that average metals concentrations (over the period 2006 to 2009 inclusive) inside the disposal site and outside do not generally differ. Although average concentrations for one or two metals (e.g., Zn, Mn) are slightly higher inside, these were not significantly elevated and are within observed temporal and/or spatial variability.

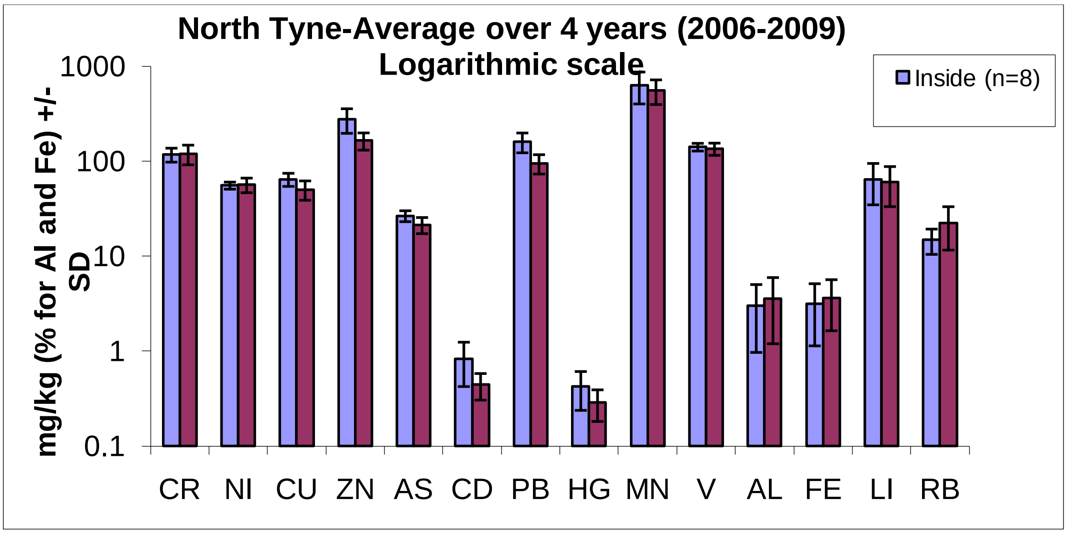


Figure 2.1.9. Average metal concentrations at North Tyne inside and outside between 2006 and 2009 inclusive.

Looking at the year-by-year concentrations for stations inside and outside the disposal site (Figures 2.1.10 and 2.1.11 respectively) we can see that there is no overall trend in the concentrations of metals over the past 4 years. Although the concentrations of some metals species appear elevated in 2009, e.g. Pb, Zn and Li, these are generally not significantly above those levels found in previous years (except perhaps for Li). Therefore, the increase in total metals loading disposed of to this site over the past 2 years (by about 10%) for some metals species (e.g., As, Cd, Cr, Cu, Ni, Pb, Zn) do not appear to result in significant increases within or outside of the disposal site.

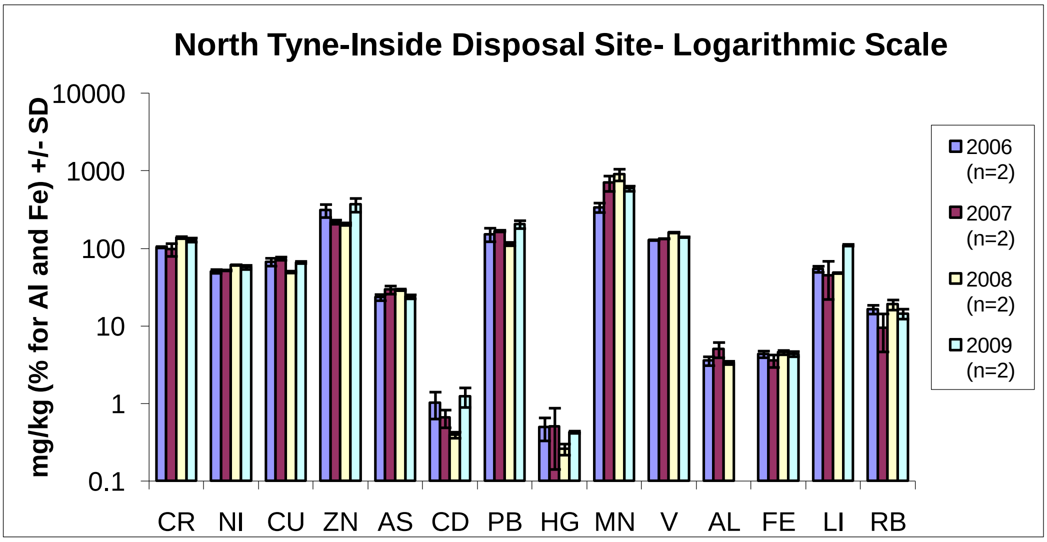


Figure 2.1.10 Average metal concentrations inside the North Tyne disposal site from 2006-2009.

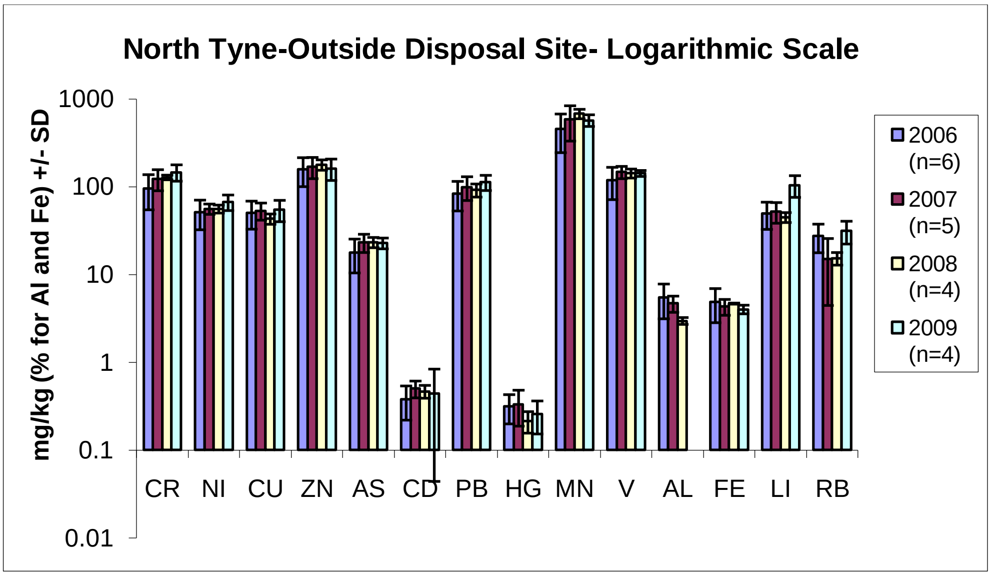


Figure 2.1.11 Average metal concentrations outside the North Tyne disposal site from 2006-2009.

When comparing the Tyne preliminary baseline with OSPAR BACs (see Appendix 4), Hg and Pb enrichment is expected and this is confirmed across the whole area (Appendix Table A4), but they are more enriched (>2X) within the site. Within the site there is also clear enrichment in As, Cd, Cu and Zn, which as indicated above, may relate to higher dredge material input at this site. Enrichment is mapped for Cd, Cu, Ni and Zn in Figure 2.1.12. There is also increased enrichment in many trace metals at NT5 (south of the disposal site) in 2009.

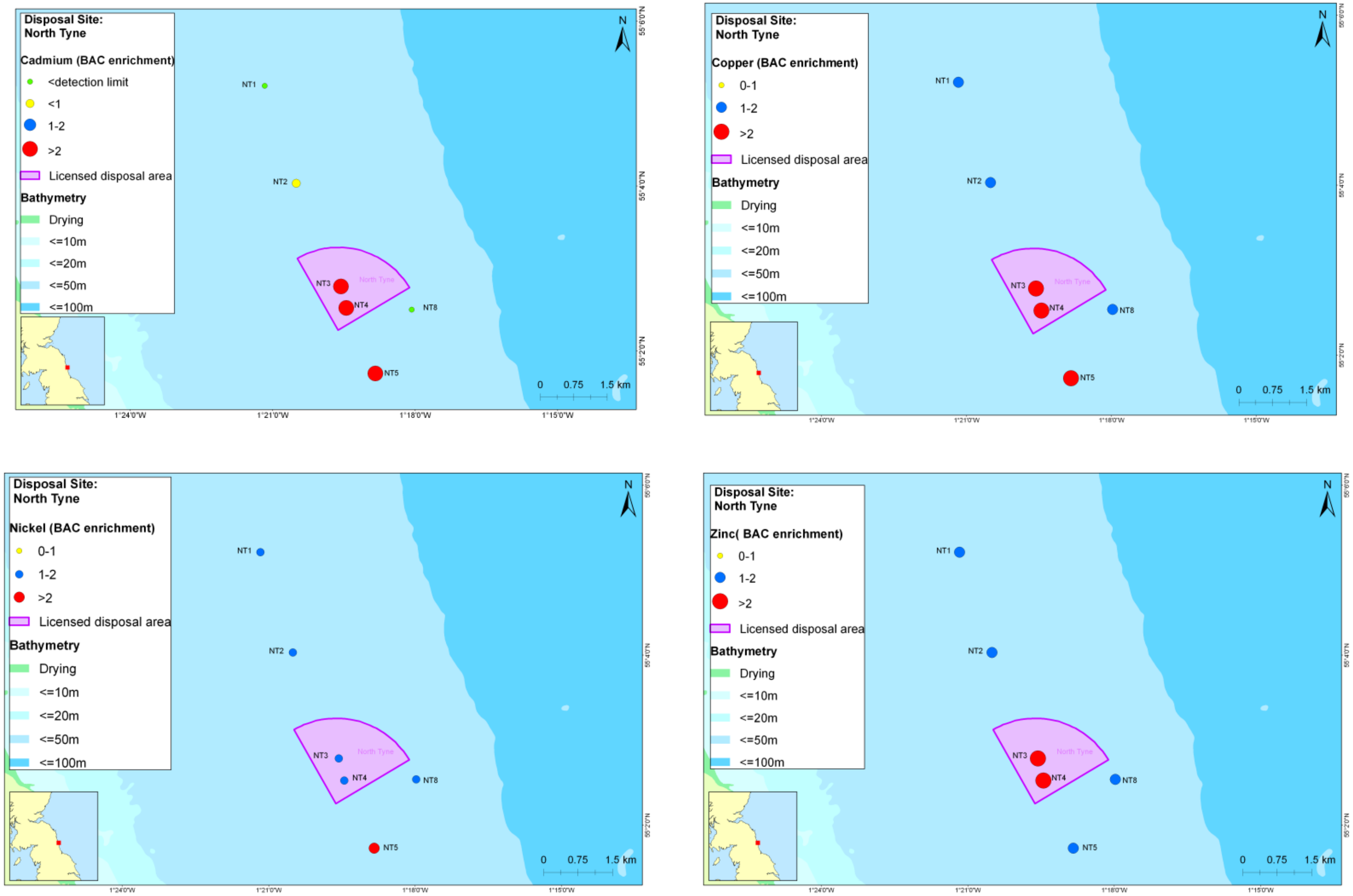


Figure 2.1.12. Enrichment to OSPAR BACs (raw/OSPAR BAC) at North Tyne (Cd, Cu, Ni, and Zn).

2.1.5 Conclusions

Monitoring at the North Tyne dredged material disposal site has been conducted under SLAB5 for a number of consecutive years. As such, a good understanding of the spatial variation in the biology, sediments and contaminants following disposal activity at this site has been acquired. The 2009 monitoring data show that infaunal communities within the licensed boundary of the disposal site display decreased number of species and abundance, and exhibit distinctly altered community structures. However, these changes appear to be restricted to within the disposal site: all stations outside appear to have similar (unimpacted) benthic community assemblages.

TBT concentrations outside the disposal site were all below Limit of Detection (LOD), with detectable concentrations within the disposal site of up to 0.12 mg/kg. Although these concentrations inside the site are somewhat high (at a national level) for dredged material disposal sites, they are somewhat lower than those reported a number of years back (e.g., 1999). Importantly, these elevated concentrations appear to be restricted to within the licensed boundary of the site. PAH concentrations at North Tyne are high, with the Effects Range Low (ERL) for Low Molecular Weight (LMW) PAHs being exceeded at all station sampled, even those furthest from the disposal site. Increased concentrations in 2009 were observed relative to those in 2008. Organohalogen concentrations at North Tyne do not appear to present a concern. For example, although Chlorinated Biphenyls (CBs) and Brominated Diphenylethers (BDEs) were detected at almost all stations sampled in 2009, these were at somewhat low levels (all stations were below Cefas AL1 and 'good' status under OSPAR guidelines for CBs). CB concentrations are showing, however, increased concentrations within the site compared to previous years.

Although some trace metals were enriched relative to OSPAR Background Assessment Concentrations (BACs) due the metal mineralisation in the catchment and the results of mining activity, metals in general are not showing any trend of increasing or decreasing at North Tyne.

These data indicate that monitoring at the North Tyne should be conducted in 2010 with special attention to ensuring that concentrations of certain contaminant groups, TBT, PAHs and organohalogens in particular, do not show increasing levels outside the disposal site boundary. The nature of subsequent monitoring at North Tyne should also be based on additional insights regarding changes to the amount, frequency and nature (e.g., contaminant loading) of the material licensed for disposal.

2.2 Souter Point (TY081)

2.2.1 Background

The Souter Point disposal site is located at a depth of approx. 40-50 m, shallowing by up to 5 m at the inshore end due to historical accumulations of minestone and fly-ash depositions. Tidal currents in the vicinity of the disposal site are moderate in strength and run generally parallel with the coastline, with a southerly net residual drift. The sediments within the vicinity of this disposal site are muddy sands. However, sediments may vary to a large extent from this following dredged material disposal and in response to its earlier history of solid industrial wastes or other discharges inshore.

Between December 2004 and April 2005, a trial bottom-capping project was undertaken within the centre of the site. The Port of Tyne disposed 60,000 m^3 of contaminated dredged material (CDM), which was to be covered with 100,000 m^3 of silt and around 60,000 m^3 of sand. However, on placement of the silt around 80% was was widely dispersed, so an increased quantity of 90,000 m^3 of sand was later placed to try to achieve a 1.5m thick cap. Further material was deposited in 2006 and 2007 to attempt to ensure isolation of the CDM. During this time the maintenance dredged material from the Tyne was disposed of to the North Tyne TY070.

Following the trial capping project undertaken at this site, there are current concerns regarding the integrity of the cap, specifically related to cap thickness. Consequently, SLAB5 monitoring in 2009, as in previous years, has focussed on monitoring techniques that provide data to assess cap thickness, temporal changes to cap thickness, together with assessments of the contaminant and biological impacts associated with ongoing disposal activities at the site.

2.2.2 Impact hypotheses

- No migration of cap material outside original disposal footprint, measurable using acoustic data (SSS,SPI and Multibeam) to show no long-term movement of the cap
- Cap integrity is maintained with no leakage of CDM to surrounding area
- Any adverse effects on the benthic biota will be confined to within and the near vicinity of the disposal site, principally along the tidal axis
- Effects on benthos within the disposal site will be limited to periodic and localised reductions in the densities/diversity of the benthos (*i.e.*, the disposal site will at no time be characterised as azoic)
- The wider dispersal of fine particulates arising from dredgings disposal, including any wave-induced shoreward transport, will have no adverse consequences for the marine biota or for recreational/amenity interests

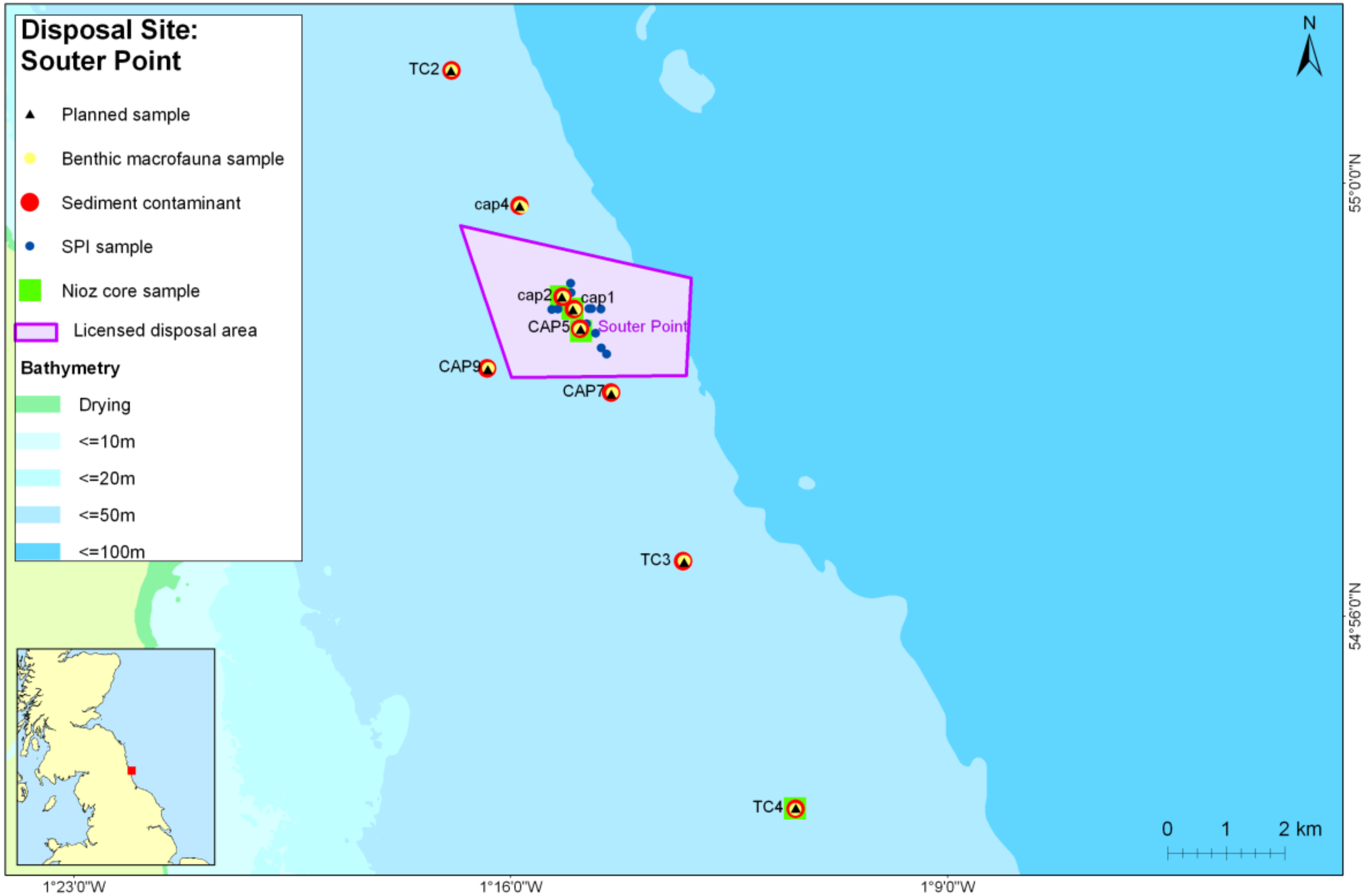


Figure 2.2.1. Locations of sampling stations at Souter Point, 2009.

2.2.3 Parameters monitored

Sidescan and multibeam
Sediment particle size distribution
Sediment organic carbon and nitrogen
Macrofaunal communities
Sediment Profile Imagery (SPI)
Sediment contaminants (TBT, PAHs, organohalogens, trace metals).

2.2.4 Results

2.2.4.1 Sidescan and multibeam

The Souter Point acoustic survey was conducted using a Kongsberg EM3002D SIS multibeam data acquisition system. The previous surveys carried out at Souter Point revealed a site of predominantly muddy sands, with disposal material constituting a cap of fine sand to the centre of the site. The locality reaches a depth of approx. 50m (Figure 2.2.2) with moderate tidal currents in the area running parallel with the coastline.

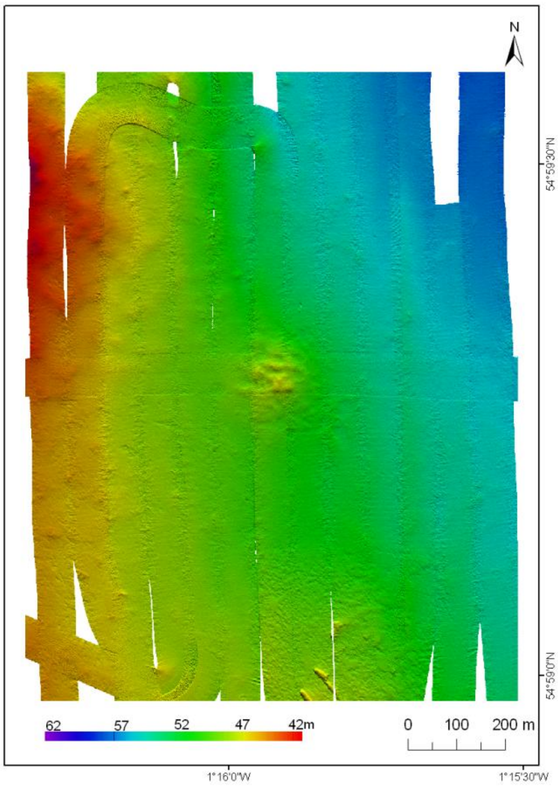


Figure 2.2.2. Souter Point seabed bathymetry from the 2009 multibeam survey.

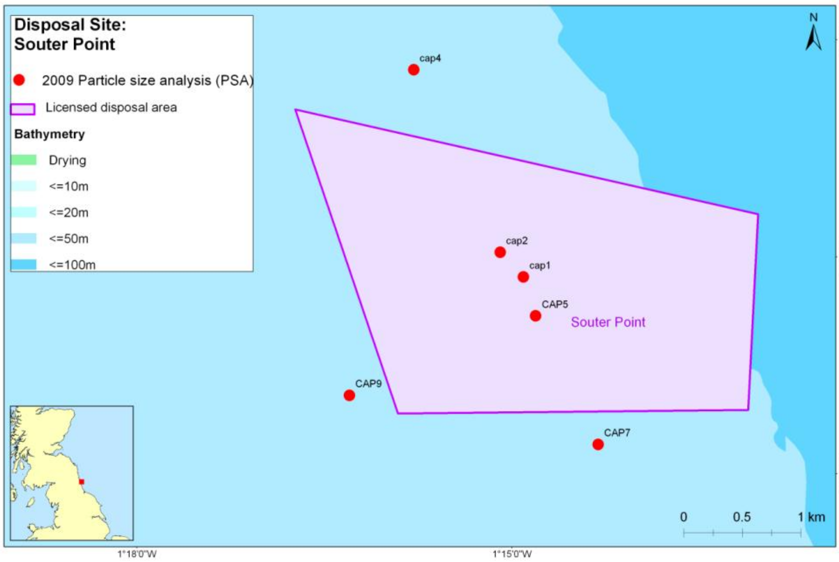


Figure 2.2.3. Location of particle size analyses sampling stations at Souter Point.

The interpretation of the acoustic data collected at Souter Point was aided by sediment particle size data from samples collected *via* a Day grab (Figure 2.2.3). The acoustic survey data show increased backscatter strength where the capping area is located (Figure 2.2.4). The central, highest area of the survey has an identifiably stronger backscatter return associated with the sandy cap and its low mud and gravel content. The area surrounding the cap with a slightly lower backscatter return shows increased gravel and mud content. These two regions are distinct from the surrounding areas and are likely to be associated with Souter Point disposal cap.

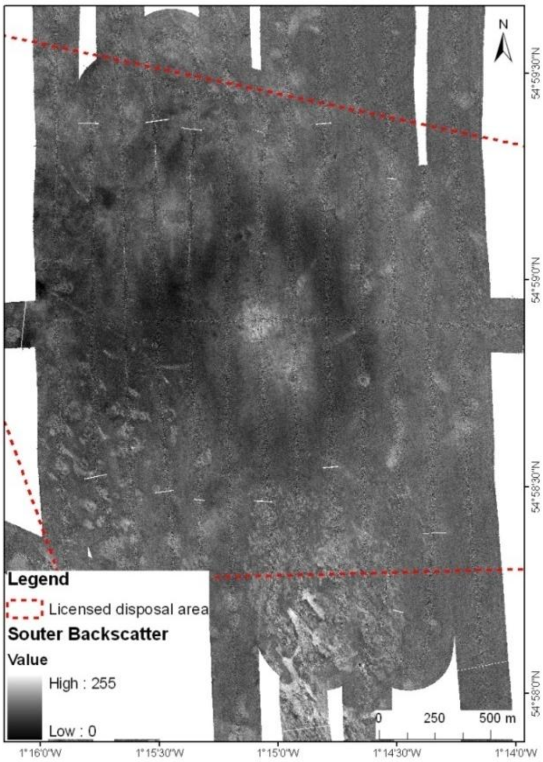


Figure 2.2.4. Multibeam backscatter from the 2009 Souter Point survey

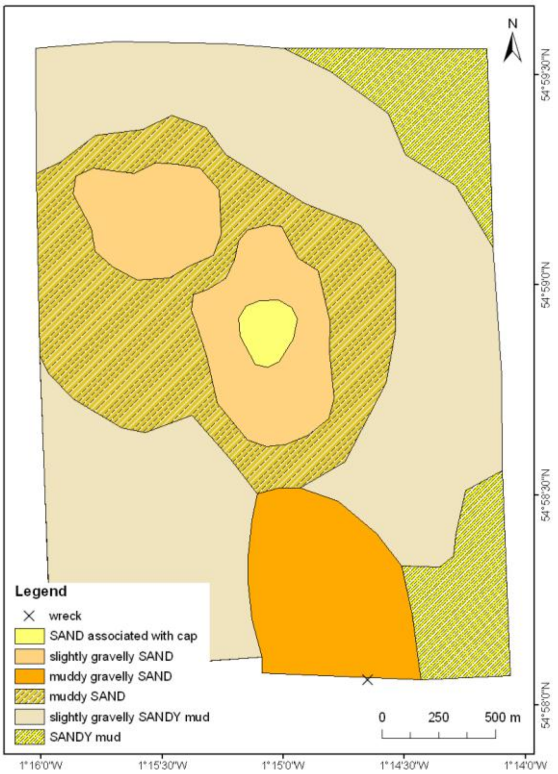


Figure 2.2.5. Interpretation from the 2009 Souter Point survey

Figure 2.2.5 presents the interpretation of the 2009 Souter Point multibeam backscatter (i.e., Figure 2.2.4) using particle size distribution data collected from the Day grabs. The sediment samples in the area show an increased gravel and mud content. The areas to the north and east of the cap show slightly higher returns indicating areas of harder or coarser substrate, this is therefore likely to have higher gravel content. To the south of the cap, there are linear raised areas that have a high backscatter return indicating coarse sediments associated with muddy gravel. The remaining areas to the south and west are identified as muddy gravelly sands through the sediment sample analysis. There are also additional features in the vicinity likely to be associated with the disposal of material to the seabed.

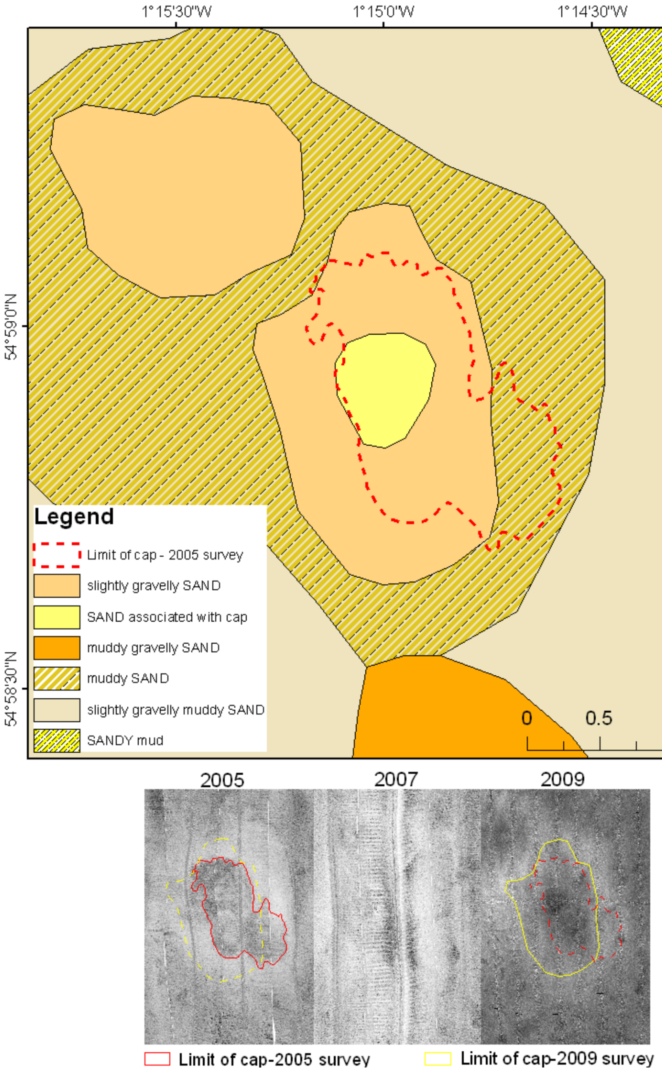


Figure 2.2.6. Interpretation of the multibeam backscatter with results from the 2005 survey showing the limit of cap as a red line (top), and backscatter results for 2005, 2007 and 2009 surveys (bottom).

Figure 2.2.6 presents the 2009 multibeam backscatter interpretation with the outline of the cap limit from the 2005 interpretation. Direct comparisons of these images are somewhat subjective, as the different environmental conditions and requisition systems from year to year can impact on the final image. With this caveat in mind, a comparison of the survey results from 2005 to 2009 indicates that the capping material, consisting mostly of sand, has migrated west and changed shape and size. The 2005 outline was smaller in size with a narrow centre, whereas the 2009 cap has extended to the west and expanded its footprint.

2.2.4.2 Sediment particle size

Eight sediment groups were defined for the stations sampled Souter Point during 2009 (Table 2.2.1). Sediment group SoP1 contains one sample from CAP9 (muddy, sandy gravel), SoP2 and SoP5 are all described as gravelly sand, with SoP2 containing less gravel than SoP5 (7% compared with 17% respectively). Sediments in SoP3 are described as slightly gravelly sand, dominated by fine sand. Sediments in SoP8 are described as gravelly muddy sand, mixed sediment. Sediments in sediment groups SoP4, SoP6 and SoP7 are all described as slightly gravelly, muddy sand, with SoP4, dominated with fine sand, and SoP6, dominated with very fine sand, both containing less silt/clay than SoP7 (12%, 20% and 33% respectively).

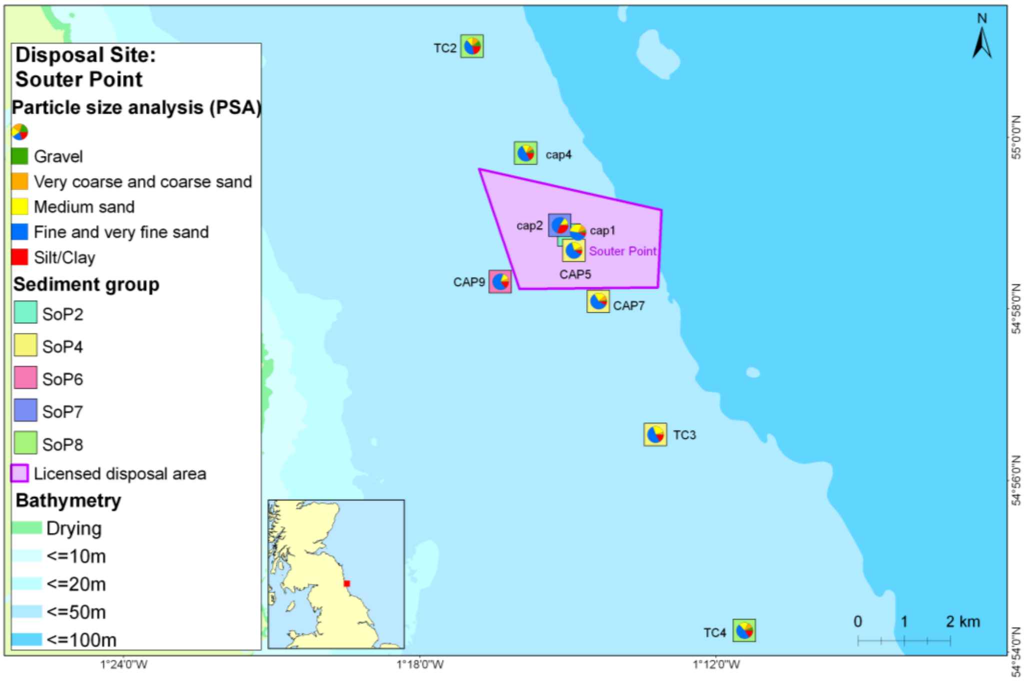


Figure 2.2.7. Sediment groups (coloured squares) overlain with pie charts showing proportions of gravel, very coarse sand and coarse sand, medium sand, fine and very fine sand and silt/clay at each station in 2009.

Sediment group	Number of samples	% number of samples	Sample Type	Sediment description	MODE 1 (µm):	MODE 2 (µm):	MODE 3 (µm):
SoP1	1	3	Trimodal, very poorly sorted	Muddy sandy gravel	1700.0	107.5	37.8
SoP2	4	10	Unimodal,poorly sorted	Gravelly sand	215.0		
SoP3	5	13	Unimodal, moderately well sorted	Slightly gravelly sand	152.5		
SoP4	10	26	Unimodal, poorly sorted	Slightly gravelly muddy sand (lower silt/clay% than SoP6)	215.0		
SoP5	2	5	Bimodal, very poorly sorted	Gravelly sand (more gravelly than SoP2)	215.0	26950.0	
SoP6	3	8	Unimodal, poorly sorted	Slightly gravelly muddy sand	107.5		
SoP7	5	13	Bimodal, poorly sorted	Slightly gravelly muddy sand (higher silt/clay% than SoP6)	152.5	26.7	
SoP8	9	23	Bimodal, very poorly sorted	Gravelly muddy sand	107.5	26.7	

Sediment group	Gravel (%)	Sand (%)	Silt/clay (%)	Very coarse sand (%)	Coarse sand (%)	Medium sand (%)	Fine sand (%)	Very fine sand (%)
SoP1	32.39	57.39	10.22	21.74	13.22	5.68	4.66	12.10
SoP2	7.55	88.52	3.93	4.23	9.53	34.94	34.27	5.56
SoP3	0.34	96.94	2.71	0.47	2.78	15.96	66.06	11.68
SoP4	1.61	86.83	11.56	1.42	5.30	22.80	38.30	19.01
SoP5	17.25	77.00	5.75	2.70	5.12	18.02	40.21	10.95
SoP6	1.17	79.38	19.44	1.40	4.97	12.44	26.12	34.46
SoP7	0.56	66.34	33.10	0.83	2.39	9.40	32.42	21.30
SoP8	7.90	74.18	17.92	3.90	7.96	16.13	19.97	26.22

Table 2.2.1. Sediment descriptions and summary statistics, based on the average sediment distribution, calculated using Gradistat (Blott and Pye, 2001) for each sediment group defined at Souter Point

Station code	2006	2007	2008	2009
CAP 1	SoP3	SoP2	SoP2	SoP2
CAP 2	SoP3/SoP7	SoP3	SoP3	SoP7
CAP 4	SoP4	SoP4	SoP5	SoP8
CAP 5	SoP3	SoP5	SoP2	SoP4
CAP 7	SoP4	SoP7	SoP8	SoP4
CAP 9	SoP6	SoP6	SoP1	SoP6
CEF 2	ns	ns	SoP4	ns
POT 6	ns	ns	SoP7	ns
SPI 10	ns	ns	SoP7	ns
TC2	SoP8	SoP8	ns	SoP8
TC3	SoP4	SoP4	SoP4	SoP4
TC4	SoP8	SoP8	SoP8	SoP8

Table 2.2.2. Sediment group at each station between 2006 and 2009 inclusive (ns = no sample).

The spatial location of these eight sediment groups is displayed in Figure 2.2.7. The sediments within and on the periphery of the disposal site are variable. Within the disposal site, for example, CAP1 (SoP2) is gravelly sand, CAP2 (SoP7) is slightly gravelly sand dominated by silt/clay, and CAP5 (SoP4) is classed as slightly gravelly muddy sand, dominated by fine sand. Silt/clay content at each of these sites has increased since the previous year, particularly at CAP2 (4%in 2008, 31% in 2009; Table 2.2.2). At CAP4, immediately north of the disposal site, the sediments (SoP8) are described as gravelly muddy sand, reflecting an increase in silt/clay and gravel from previous years. At CAP7, immediately south of the disposal site, the sediment group (SoP4) described as slightly gravelly muddy sand, reflecting a decrease in silt/clay and gravel from previous years. At CAP9, immediately west of the disposal site, the sediment group (SoP6) described as slightly gravelly muddy sand, as for CAP 7, reflecting a decrease in silt/clay and gravel from previous year, to the same sediment group recorded in 2006 and 2007. Sediment groups are consistent with previous years at reference stations (TC2, TC3 and TC4) outside of the disposal site (Table 2.2.2).

2.2.4.3 Sediment organic carbon and nitrogen

The sediment organic carbon (<63µm sediment fraction), organic carbon (<2mm sediment fraction) and silt/clay contents of the stations sampled at Souter Point in 2009 are shown in Figure 2.2.8. Organic carbon values (<63µm sediment fraction) range from 2.89 to 4.86 %m/m; the highest values being found within and adjacent to (at CAP9 and CAP4) the disposal site boundary. In general, these values are similar to those observed during 2006, 2007 and 2008 at this site (see Bolam *et al*., 2009).

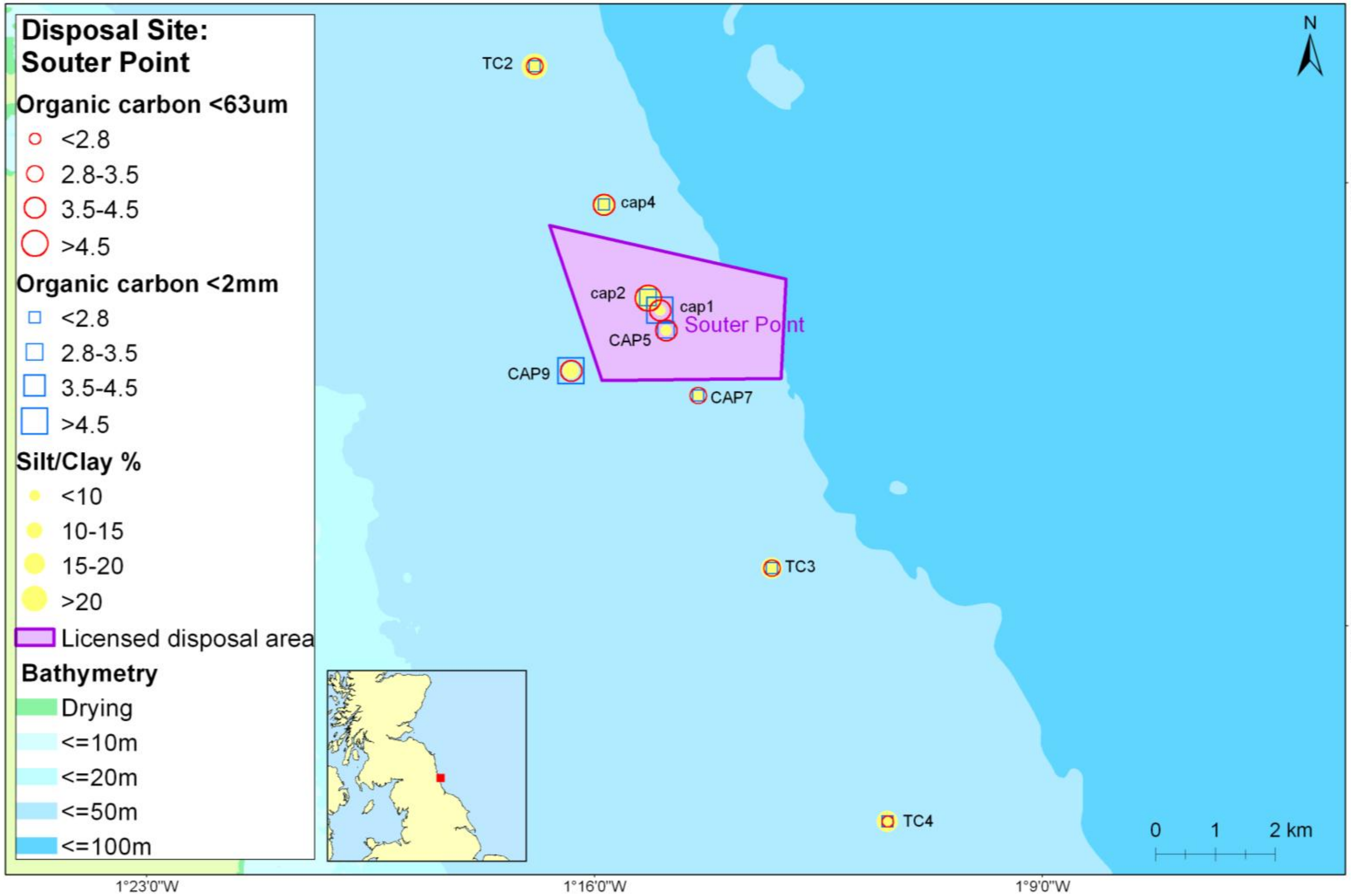


Figure 2.2.8. Organic carbon (<63µm), organic carbon (<2mm) and silt/clay contents of sediments sampled at Souter Point, 2009.

2.2.4.4 Macrofaunal communities

Macrofaunal analysis identified a total of 1778 individuals and 56 taxa from the grab samples taken at Souter Point. The main taxonomic groups were represented by Annelida (66 % of the total numbers), Mollusca (19%), Echinodermata (6%), Crustacea (5%) and miscellania (4%).

The total abundance of individuals fluctuated from 73 to 296 per 0.1 m^2 across the study area. The stations exhibiting the lowest total density were Cap1 and Cap2 (73 and 133 individuals per 0.1 m^2 respectively; Figure 2.2.9A) in the capping area. Higher values were observed at stations located immediately outside the disposal site at stations Cap9 and TC2 (Figure 2.2.9A). Total number of species ranged from 35 to 64 species per 0.1 m^2 (Figure 2.2.9B): higher values of which were observed at TC2 and TC4 the stations furthest north and south respectively while lower species numbers were sampled at the two stations within the capping area (i.e., Cap1 and Cap2). Total macrofaunal biomass ranged from 2.4 to 11.09 g / 0.1 m^2 (ww); the higher values being obtained at Cap4, TC3 and Cap5 (11.09, 10.51 and 6.42 g / 0.1 m^2 (ww) respectively) (Figure 2.2.9C). The species responsible for the higher biomass were *Dosinia lupinus* and *Echinocardium cordatum.*

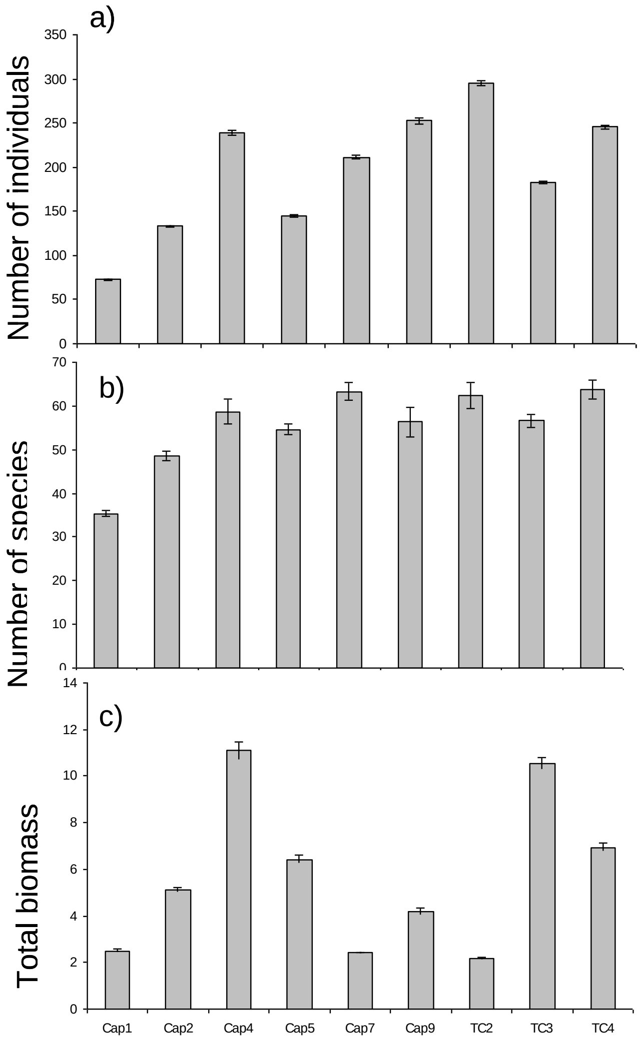


Figure 2.2.9. Univariate mean values (± S.E., n = 3) for, A) total number of individuals (per 0.1m-2 grab), B) total number of taxa (per grab) and C) total wet biomass (per grab) at Souter Point dredged material disposal site.

Multivariate analyses showed a clear separation of stations located in the centre of the disposal site (i.e., Cap1, Cap2 and Cap5) with those located on the periphery of the disposal site (Cap4, Cap 7 and Cap9) and north-south reference stations (TC2, TC3 and TC4) (Figure 2.2.10). Within and between station variability was greater within the disposal site compared to the reference areas. The average dissimilarity between the disposal site and the northern reference accounted for 54.4 %, from which the species responsible were *Peresiella clymenoides*, *Terebellides stroemi, Rhodine gracilior*, *Trichobranchus roseus, Harpinia antennaria,* and *Phoronis* sp. (these species contributed to 19.12 % of overall group dissimilarity).

The average dissimilarity between the north and south reference was 49.1 %, the main responsible species causing this dissimilarity were *Ophelina borealis*, *Polydora caeca*, *Peresiella clymenoides*, *Mediomastus fragilis*, *Mysella bidentata* and *Scalibregma inflatum* (these species contributed to 8.7 % of the overall group dissimilarity). Comparisons between the dissimilarity observed between the disposal site and south reference showed the highest group dissimilarity with 55.16 %, the species responsible were *Peresiella clymenoides*, *Polydora caeca*, *Terebellides stroemi*, *Trichobranchus roseus*, *Mediomastus fragilis* and *Rhodine gracilior* (these species contributed to 8.42 % of the overall group dissimilarity).

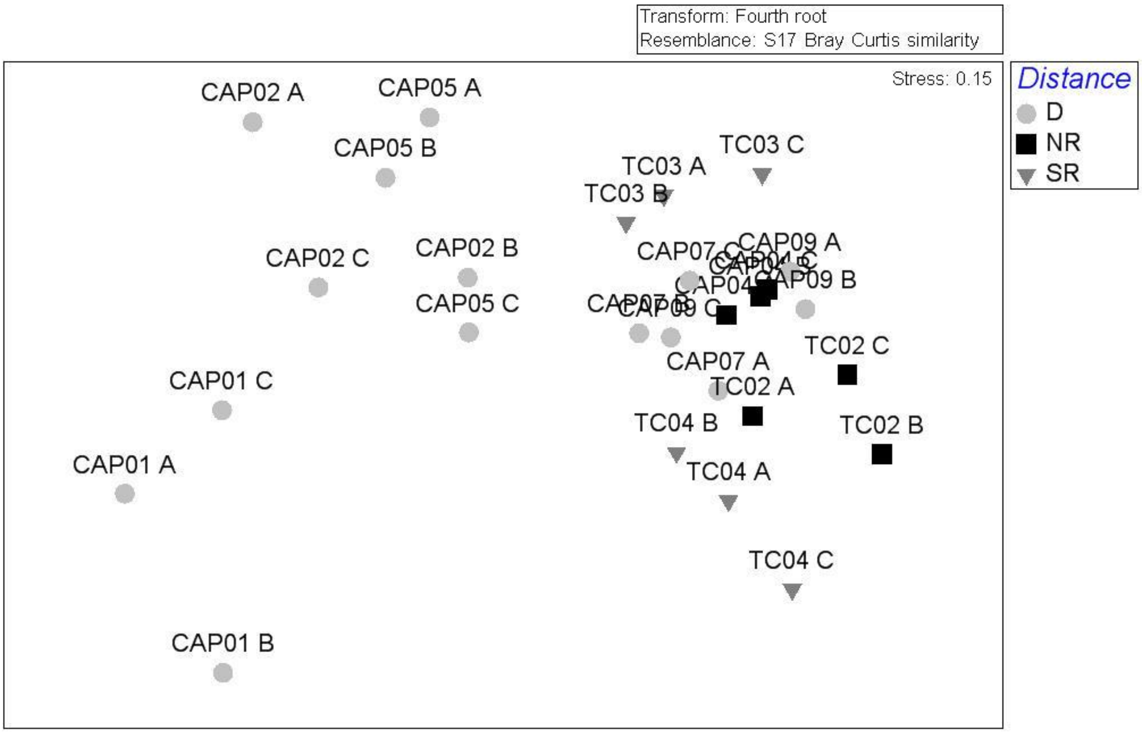


Figure 2.2.10. Multidimensional scaling ordination based on Bray-Curtis similarity for infauna samples at Souter Point, 2009.

2.2.4.5 Sediment Profile Imagery (SPI)

The Sediment Profile Imagery (SPI) survey was conducted in two stages, the first set of images was obtained during the June survey with the remainder collected during October 2009. There are clear differences in the clarity of the SPI images collected; this is mainly due to the presence of artefacts in the images rather than the local conditions.

From the SPI images, it is possible to discern the presence of the contaminated dredged material (CDM) inside of the proposed capped area (e.g., at CAP5). The CDM visually appears as fine-grained material with some black, cohesive mud (Figure 2.2.11a&b). The surface sand layer observed in the images corresponds with the material deposited to isolate the CDM. There is no clear evidence of the presence of benthic organisms and hence it is not possible to identify successional stages (Figure 2.2.11a). Data collected at stations further away from the centre (SPI10 and Cef4) showed the presence of historical dredge material deposition from previous disposal activity and also fine sediments, some broken shells and deep-burrowing polychaetes (Figure 2.2.11c&d). Overall, some of the images collected in the vicinity of the disposal site (Cap5 and SPI7) also showed deep layers of CDM and also a series of clean sediment layer, which can be indication of added material to the cap layers. Benthic species were not observed in the centre of the capped area (Figure 2.2.11a). Stations located further east from the disposal site (e.g. Cef4, Figure 2.2.11d) showed the presence of small voids, which are indicative of infaunal activity at the site. At SPI10 (Figures 2.2.11c), the presence of deep burrowing polychaetes represented a mature benthic community (stage II - III) (Rhoads & Germano, 1990). Similar changes were observed at the site during earlier assessments (Birchenough *et al*., 2007).

2.2.4.6 Sediment contaminants

2.2.4.6.1 TBT

Samples for TBT determination were collected at 9 grab stations, as well as from the NIOZ cores. Cap 1 and Cap 2 both exhibited detectable levels of TBT (0.02 and 0.03 mg/kg respectively), a slight increase from the last 3 years. The organotins results were below AL1 for all of the nine stations that were sampled and analysed in the 2009 survey.

Temporal trends show consistent results below LOD for Cap 5, Cap 7, Cap 9, TC2, TC3 and TC4 from 2005 to 2009. Results for Cap 4 peaked in 2008 survey and decreased in 2009 while consistently remaining below AL1.

In addition to the (above) grab survey data, NIOZ cores were used to ascertain the depth profiles of TBT at a number of stations within and outside the capping area; the 2008 and 2009 results for CAP2 and CAP5 are displayed in Figures 2.2.12 and 2.2.13 respectively. Although a detailed study of particle size analysis of these cores is yet to be completed, we can observe from the preliminary photos that the visually-discernible layers of the cores tend to correspond to the TBT depth profile, i.e., lower TBT concentrations for coarser layers and more elevated TBT for fine-sediment layers.

At CAP2, concentrations throughout the core profile remained below 0.25 mg/kg, with peak concentrations in 2008 and 2009 at the same depths (approximately 15 cm and 24 cm sediment depth). This observation may indicate no net sediment erosion or deposition at this station between these two sampling dates. However, the situation at CAP5 is somewhat different; TBT levels for 2009 at CAP5 are noticeably more elevated compared to the previous year for all analysed depth samples. Moreover, whereas the levels of TBT remain below AL2 (but exceeding AL1) from –15cm depth for CAP2 station, CAP5 station exhibits concentration of TBT above AL2 at the bottom layer of the core (i.e., below 20cm depth), with TBT 1.01 mg/kg for 2008 and 4.85mg/kg for 2009. This TBT concentration would indicate that CDM is being sampled, implying that the thickness of the cap at CAP5 is approximately 20cm. Previous data (2005 - 2007) from cores at CAP2 and CAP5 indicate TBT concentrations above AL1 but none above AL2 at all depths. For CAP5, therefore, this would indicate a thinning of the cap between 2008 and 2009.

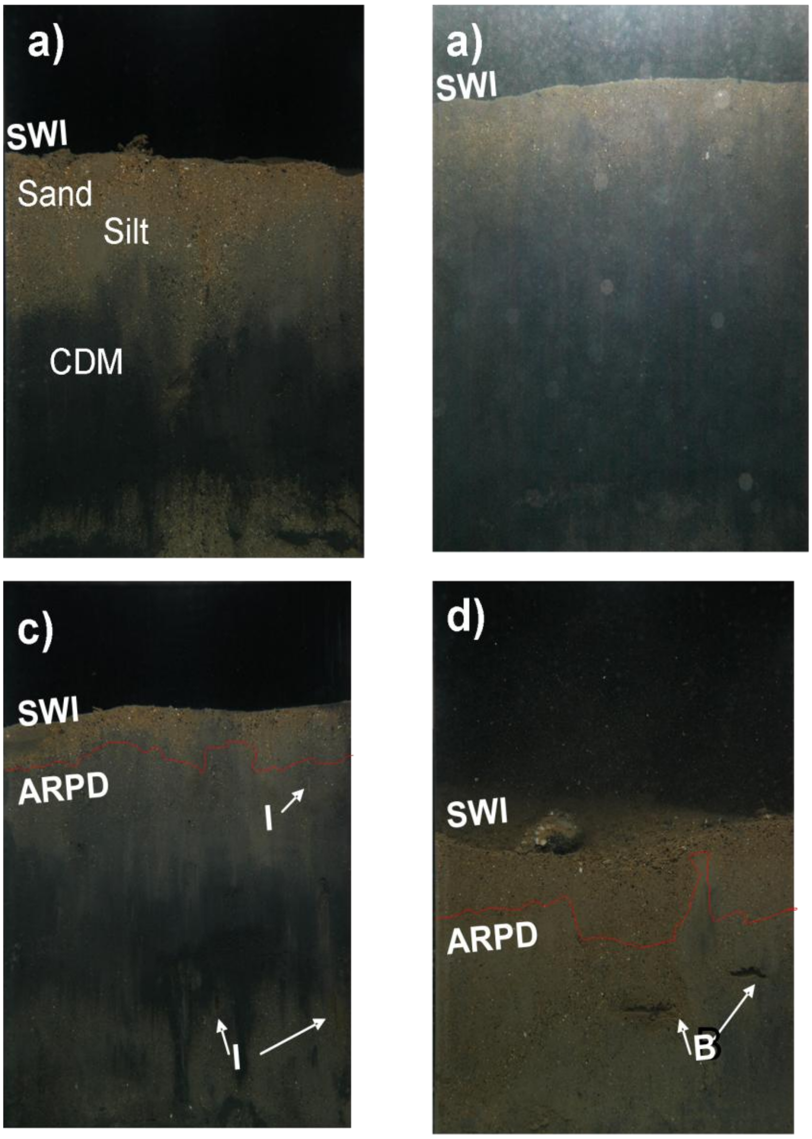


Figure 2.2.11. Sediment profile images (SPI) collected at Souter point disposal site, stations; a) Cap5, b) SPI7, c) SPI 10, and d) Cef4. SWI=sediment water interface, CDM=contaminated dredged material, I=infaunal polychaete, ARPD=apparent redox discontinuity layer, v=void and B= burrows.

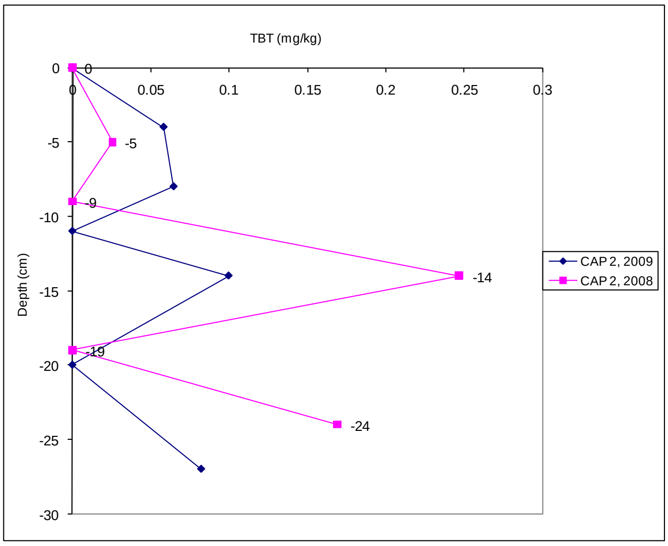
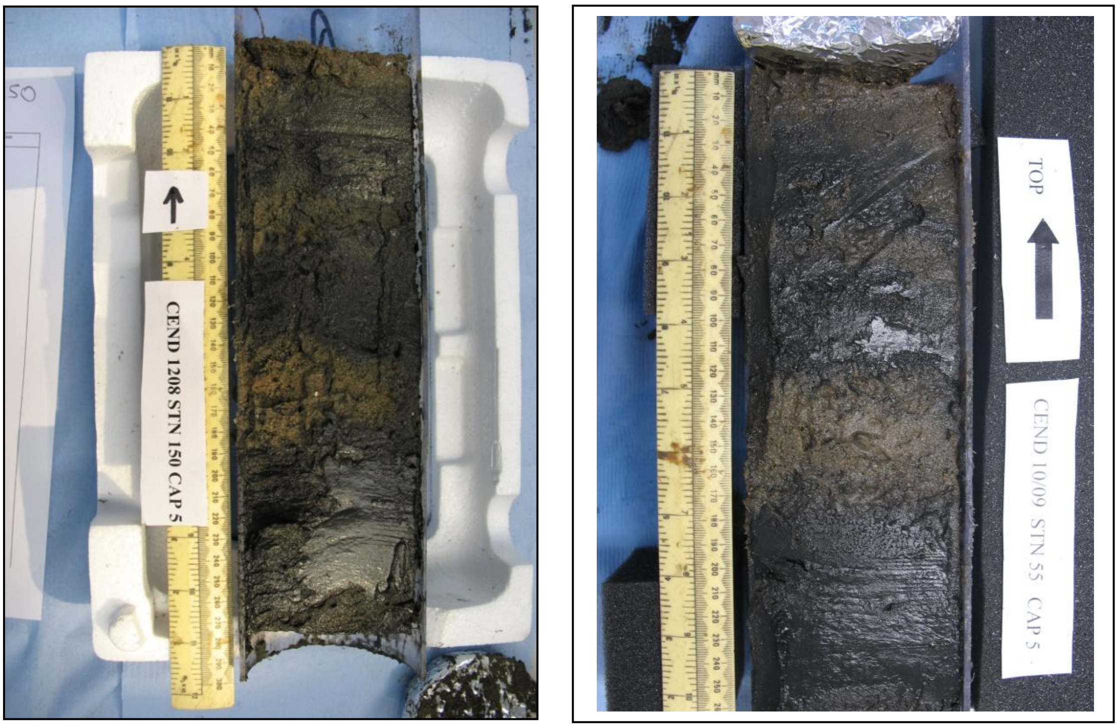


Figure 2.2.12. Photos of vertical slices of cores taken at CAP2 during 2008 and 2009 (above) and TBT concentration profiles



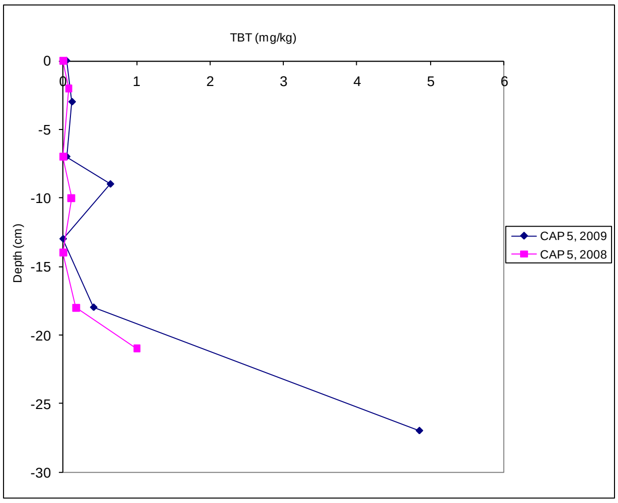


Figure 2.2.13. Photos of vertical slices of cores taken at CAP5 during 2008 and 2009 (above) and TBT concentration profiles

2.2.4.6.2 PAHs

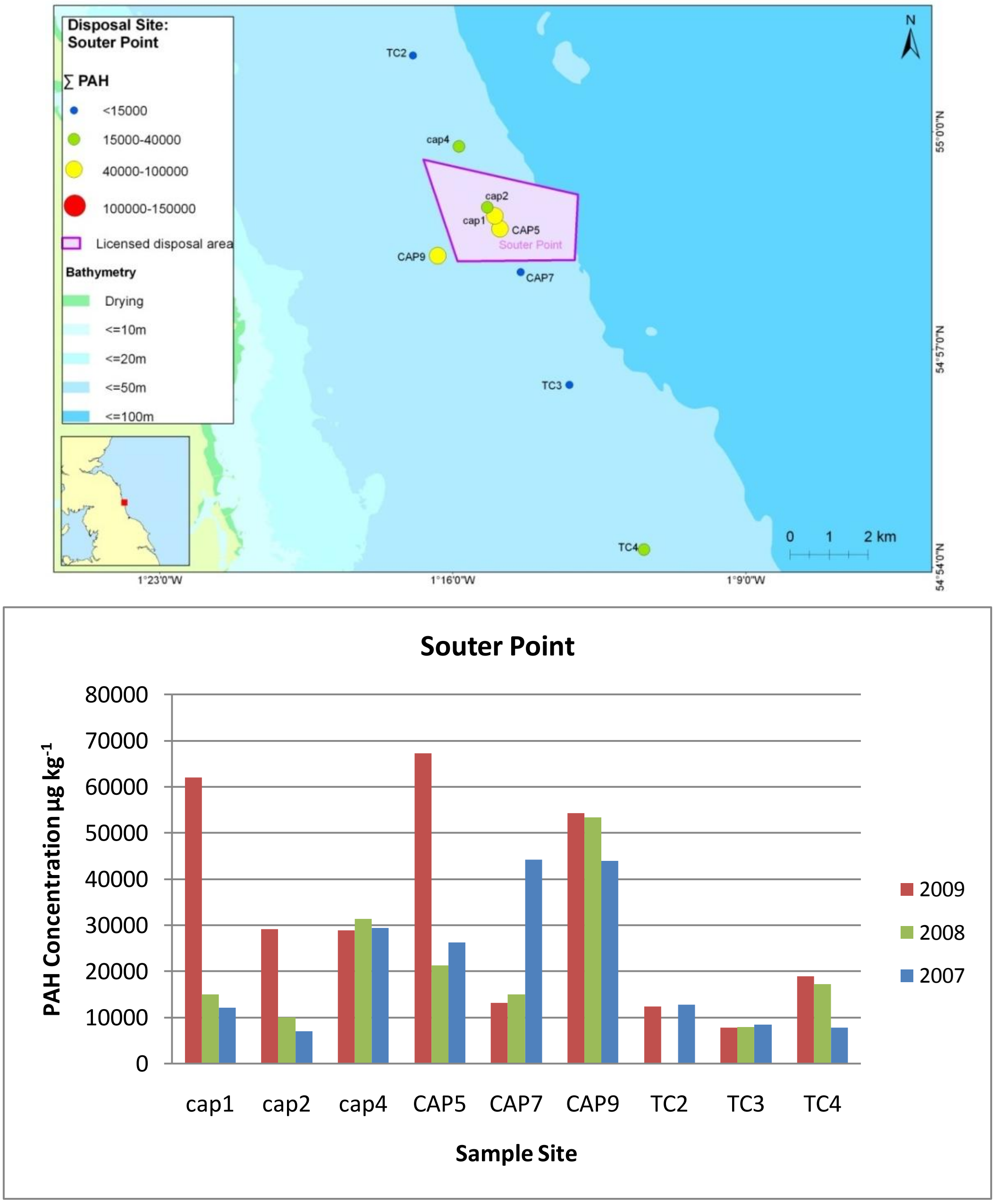


Figure 2.2.14. Summed PAH concentrations (µg kg^{-1}) for stations sampled in 2009 at Souter Point (top) and concentrations observed during 2007, 2008 and 2009 (bottom).

The highest summed PAH concentrations for Souter Point during 2009 were found at CAP5 (67,200 µg kg^{-1}) and CAP1 (62,000 µg kg^{-1}), both within the disposal site (Figure 2.2.14). In 2008 the highest concentrations were found at CAP9 just outside the SW boundary of the disposal ground, a station which has shown little change in summed PAH concentration in

2009 (at 54,300 µg kg^{-1}). Summed PAH concentrations in 2009 have remained similar to 2008 levels at the other sampling station with the lowest values found at TC3 (7,700 µg kg^{-1}).

All sampling stations were found to exceed the ERL for LMW PAHs with the ERM being exceeded at all stations except for CAP7, TC2 and TC3 which are all situated to the south of the disposal site. The ERL for the HMW PAH was exceeded at CAP1, CAP2, CAP4, CAP5 and CAP9 which are all situated on or close to the disposal ground. Of these stations only CAP5 exceeded the ERM for the HMW PAHs. The Tyne Estuary has been shown to have high levels of PAH in its sediments during an earlier survey (Woodhead *et al*., 1999).

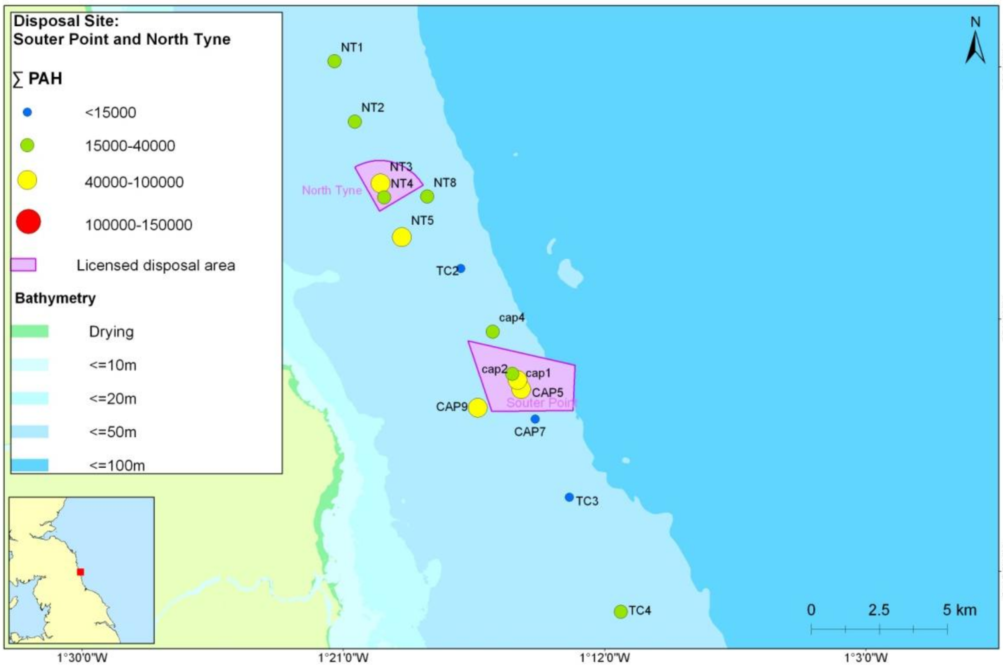


Figure 2.2.15. Summed PAH concentrations (µg kg^{-1}) of stations sampled in 2009 at North Tyne and Souter Point.

To compare summed PAH concentrations over the Souter Point disposal site it is interesting to look at the data from both the North Tyne and Souter Point surveys together (Figure 2.2.15). It is apparent that the highest concentrations occur within or in the immediate vicinity of the two disposal sites. In 2008, the highest concentration (115,000 µg kg^{-1}) was sampled at NT6 (not sampled in 2009) between the two disposal sites: in 2009, TC2 (slightly further to the west of NT6) was found to have summed PAH concentrations of only 12,400 µg kg^{-1}.

2.2.4.6.3 Organohalogens

At Souter Point, CBs were detected at all stations (∑ICES7 CBs range 0.96-7.2 µg/kg dw) (Figures 2.2.16 and 2.2.17). Concentrations of CBs were lowest to the south of the disposal site and levels were also low at stations CAP1 and CAP5 within the disposal site. Slightly higher ∑ICES 7 concentrations of 3.1 and 3.5 µg/kg dw were found at CAP4 and CAP9 to the north and west of the disposal site respectively. The highest ∑ICES 7 CBs concentration of 7.2 µg/kg dw was found at CAP2 within the disposal site. Looking at the PCB congener profiles, CAP2 had a much higher proportion of hepta-PCBs than the other stations, suggesting a different source.

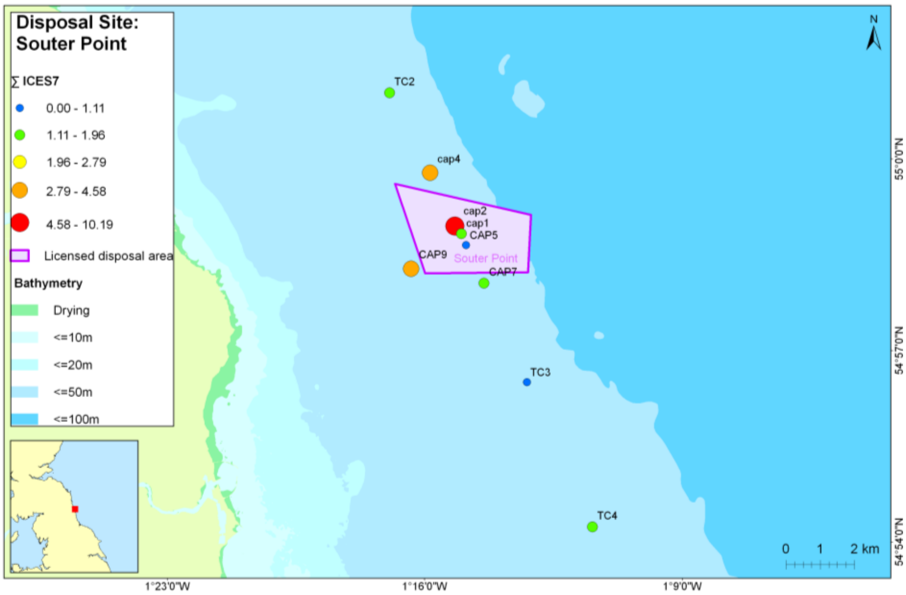


Figure 2.2.16. Summed ICES7 CB concentrations for the Souter Point Stations, 2009.

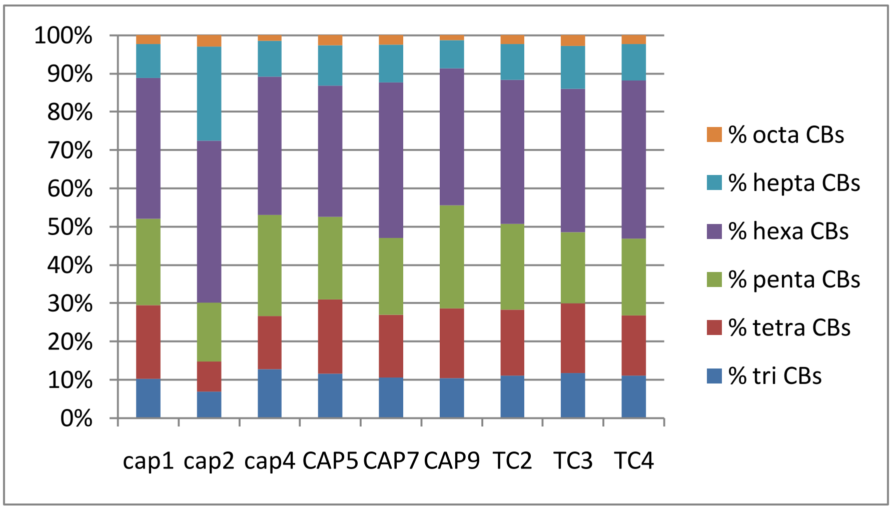


Figure 2.2.17. CB congener profiles for the Souter Point stations, 2009.

BDEs were detected at all stations (∑11 BDEs range 0.62-1.9 µg/kg dw). Concentrations of BDEs were also lowest to the south of the disposal site and at stations CAP1 and CAP5 within the disposal site (Figure 2.2.18). Higher ∑11 BDE concentrations of 1.2 and 1.4 µg/kg dw were found at CAP4 and TC2 to the north of the disposal site respectively and of 1.6 µg/kg dw at CAP2 within the disposal site. It is possible that there is a drift of organohalogens from the North Tyne disposal site which is located north of Souter Point. Slightly higher ∑11 BDE concentrations of 1.9 µg/kg dw were found at CAP9 to the west of the disposal site. Additionally, there was only factor of 3 differences in BDE concentration between all of the stations, in contrast to CBs which had factor of 8 differences between highest and lowest concentrations. This suggests that background contamination has a higher impact than the disposal site for BDEs, compared with CBs where the disposal site has a higher impact.

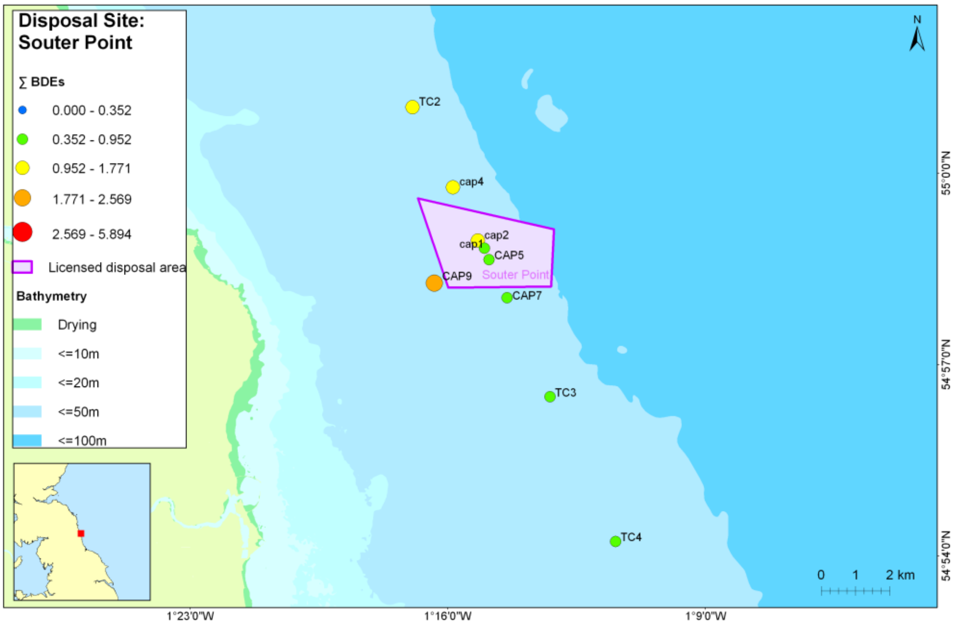


Figure 2.2.18. Summed 11 BDEs concentrations for the Souter Point Stations, 2009.

Concentrations of CBs at all stations were below Cefas AL1; no ALs currently exist for BDEs. According to the OSPAR guidelines, all stations had ‘good’ environmental status for all ICES 7 CBs and ‘good’ status overall. No OSPAR guidelines exist for BDEs at present.

Looking at temporal trends in organohalogen levels (Tables 2.2.3 and 2.2.4 for CBs and BDEs respectively), concentrations of CBs at CAP2 within the disposal zone in 2009 showed a large increase in comparison with 2008, with levels being 10 times higher. At CAP1, CB concentrations doubled between 2008 and 2009. In contrast, at CAP5 CB concentrations in 2009 were a third of those measured in 2008. To the immediate west of the disposal site at CAP9, CB concentrations increased slightly, continuing an upwards trend from 2007 onwards.

Slightly to the north and south of the disposal site, at CAP4, CAP7 and TC3, concentrations either stayed the same or decreased slightly, whereas further to the north and south at TC2 and TC4 a more marked decline was observed.

Station code	∑ICES 7 CBs concentration (in µg/kg)				
	2005	2006	2007	2008	2009
TC2		6.2	2.58		1.54
CAP4	3.7	3.6	2.35	3.39	3.11
CAP2	0.83	1.01	*0.7*	*0.7*	7.23
CAP2 (subsurface mud)	8.24	10.1			
CAP2 (0-5.5 cm, sand)			2.67		
CAP2 (5.5-11.5 cm, muddy sand)			5.22		
CAP2 (11.5-17.5 cm, sand)			27.4		
CAP2 (17.5-21.5 cm, black mud)			22.1		
CAP1	1.1	0.84	*0.7*	0.96	1.88
CAP1 (0-7 cm, sand)			*0.7*		
CAP1 (7-14 cm, sand)			11.2		
CAP1 (14-21 cm, sand)			25.3		
CAP5	1.1	0.86	0.7	3.22	1.11
CAP5 (surface)			5.15		
CAP5 (middle)			2.91		
CAP5 (bottom)			8.82		
CAP9	4.97	2.91	2	2.84	3.25
CAP7	1.34	1.12	2.23	1.51	1.24
TC3	0.96	1.19	*0.7*	*0.7*	0.96
TC4	1.17	1.14	*0.7*	2.62	1.3

Table 2.2.3. Temporal trends (2005-2009) of ∑ICES 7 CBs concentration (in µg/kg) at Souter Point in the stations sampled during 2009. Note, concentrations in italic represent estimates of concentrations for samples where all ICES 7 congener concentrations were below LODs)

Within the disposal site, the depth profile of CBs at some of the ‘CAP’ stations has previously been investigated. In 2005 and 2006 the subsurface mud layer at CAP2, which may be contaminated disposal material, was found to be 10 times more contaminated than the surface sand. A core collected at CAP2 in 2007 found even higher CB concentrations below a muddy sand layer, which were 40 times higher than at the surface. Similarly, cores collected at CAP1 and CAP5 showed much higher CB concentrations with increasing depth.

Concentrations of BDEs at CAP2 within the disposal site in 2009 also showed a large increase in comparison with 2008, with levels being 4 times higher (although only 50% higher than the concentration sampled in 2005), and at CAP1 BDE concentrations tripled between 2008 and 2009. These observations for BDEs at these stations mirror the trend seen for the CBs. At CAP5 BDE concentrations increased slightly between from 2008-2009, but remained lower than the three years prior to this. Just to the west of the disposal site at CAP9, BDE concentrations almost doubled between 2008 and 2009 but also remained lower than the three years prior to this. To the north of the disposal site at CAP4 and TC2, concentrations of BDEs decreased slightly, whereas to the south of the disposal site at CAP7, TC3 and TC4 concentrations either stayed the same or increased slightly. Therefore, the station-specific changes in BDEs between 2008 and 2009 were similar to those observed for CBs.

Station code	∑11 BDEs concentration (in µg/kg)				
	2005	2006	2007	2008	2009
TC2	3.95	8.30	2.94		1.36
CAP4	5.84	2.15	2.57	1.37	1.18
CAP2	1.11	1.01	0.79	0.41	1.55
CAP2 (subsurface mud)	9.76	16.7			
CAP2 (0-5.5 cm, sand)			4.18		
CAP2 (5.5-11.5 cm, muddy sand)			7.30		
CAP2 (11.5-17.5 cm, sand)			4.71		
CAP2 (17.5-21.5 cm, black mud)			1.48		
CAP1	0.83	0.80	0.96	0.26	0.62
CAP1 (0-7 cm, sand)			*0.69*		
CAP1 (7-14 cm, sand)			*0.69*		
CAP1 (14-21 cm, sand)			*0.69*		
CAP5	1.13	1.07	0.91	0.41	0.54
CAP5 (surface)			4.08		
CAP5 (middle)			59.6		
CAP5 (bottom)			14.1		
CAP9	3.77	12.6	5.92	1.02	1.92
CAP7	1.94	2.37	3.96	0.85	0.80
TC3	1.45	5.96	1.36	0.55	0.73
TC4	1.78	8.59	1.51	0.82	0.86

Table 2.2.4. Temporal trends (2005-2009) of ∑11 BDEs concentration (in µg/kg) at Souter Point in the stations sampled during 2009. Note, concentrations in italic represent estimates of concentrations for samples where all 11 BDE congener concentrations were below LODs. Limits of detection for BDEs improved between 2007 and 2008 and therefore values assigned to congeners below LOD are lower in 2008 and 2009, resulting in a step decrease in ∑11 BDEs concentration for samples with congeners below LODs)

Within the disposal zone, the depth profile of BDEs at CAP stations has also previously been investigated. In 2005 and 2006 the subsurface mud layer at CAP2 was found to be 9 and 16 times more contaminated than the surface sand, respectively. A core collected in 2007 found a decreasing trend of BDE concentrations below this muddy sand layer. A core collected at CAP5 showed even greater BDE contamination at depth, where levels were up to 65 times higher than at the surface. In contrast, at CAP1 BDEs were below LODs in core slices below the surface.

The sharp increase in contaminants at CAP2 may have originated from 2 sources, either from disposal of dredged material or from the erosion of the cap exposing more-contaminated underlying sediment. There was an increase in the amount of material disposed of at Souter Point from the Tyne between the 2008 and 2009 sampling periods. However, this could be expected to impact stations CAP5 and CAP1 to a similar extent, and this was not the case. The CB congener profile at CAP2 was enriched in higher chlorinated congeners, which could be indicative of ‘aged’ subsurface sediment, resulting from selected leaching of the lower chlorinated congeners over time. Alternatively it might match the pattern of recently disposed sediment from the Tees. Elevated concentrations of CBs and BDEs at CAP2 are similar to those found at depth in 2007, which could suggest that erosion of the sandy cap is occurring. Analysis of a new set of core samples should shed more light onto the cause of this observed phenomenon.

2.2.4.6.4 Trace metals

Although the average concentrations of some trace metals are higher inside the disposal site relative to those outside (e.g., Zn, Pb), when averaged over the past 4 years none of these were significantly elevated (Figure 2.2.19). Although there was an increase in the metals loading from 2007 to 2008, the direct input of heavy metals from dredged material disposed of at this site may have been masked by the existing elevated concentrations derived from a combination of a mineralised catchment with extensive residues of mining activities together with industrial activity around the Tyne Estuary particularly shipbuilding, ship repairing and smelting resulting in a legacy of high levels of heavy metals in the sediments.

Average concentrations of trace metals inside and outside the disposal site over each of the past 4 years are shown in Figures 2.2.20 and 2.2.21 respectively. Although there is some temporal variation in concentrations for some metals, there does not appear to be any significantly elevated or reduced levels for any metals, either inside or outside the disposal site. 2009 saw the highest concentrations inside the disposal site for Mn, V and Li, but these were not significant increases.

When comparing the Tyne preliminary baseline with OSPAR BACs (Table A4, Appendix 4), Hg and Pb enrichment is expected (Table A5, Appendix 4) and this is confirmed across the whole area, but they are more enriched (>2X) within the site. It is worth noting that for all samples measured at Souter Point in 2009, Cd is below detection limits. Enrichment is mapped for Cu, Ni, Pb and Zn in Figure 2.2.22. There is also increased enrichment in Cu measured at CAP4, north of site and at CAP9, west of site, in 2009.

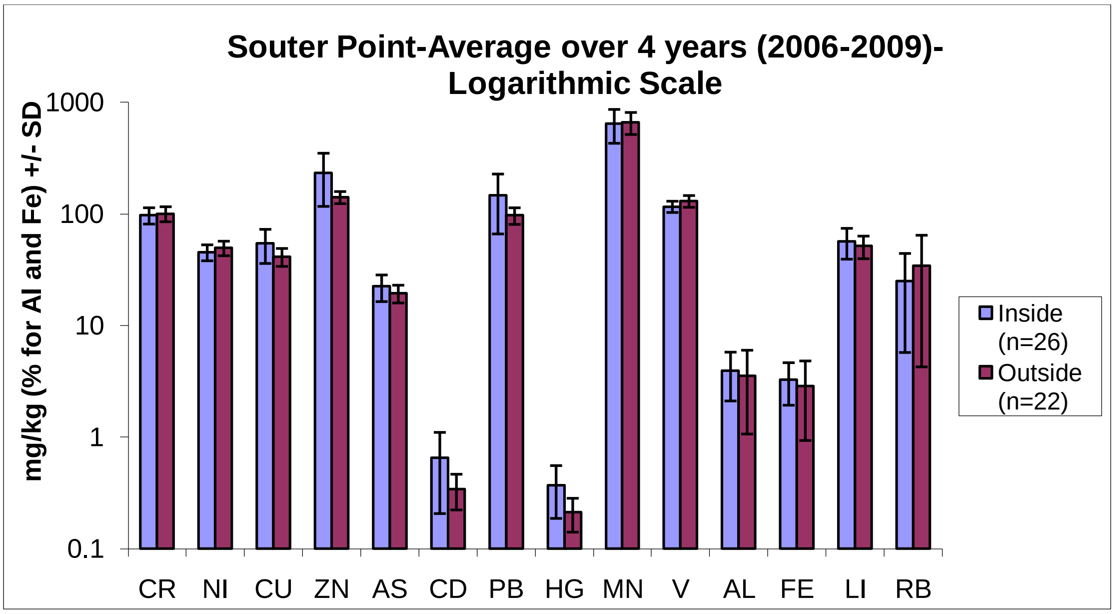


Figure 2.2.19. Average metal concentrations inside and outside for metal concentrations at Souter Point between 2006 and 2009 inclusive

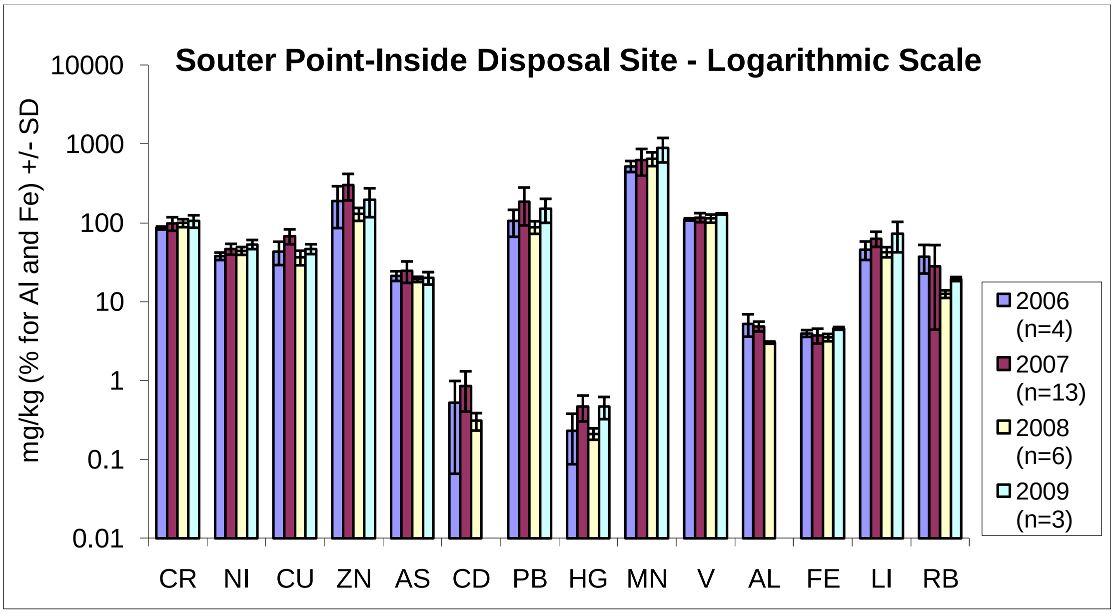


Figure 2.2.20. Average metal concentrations inside the Souter Point disposal site from 2006-2009

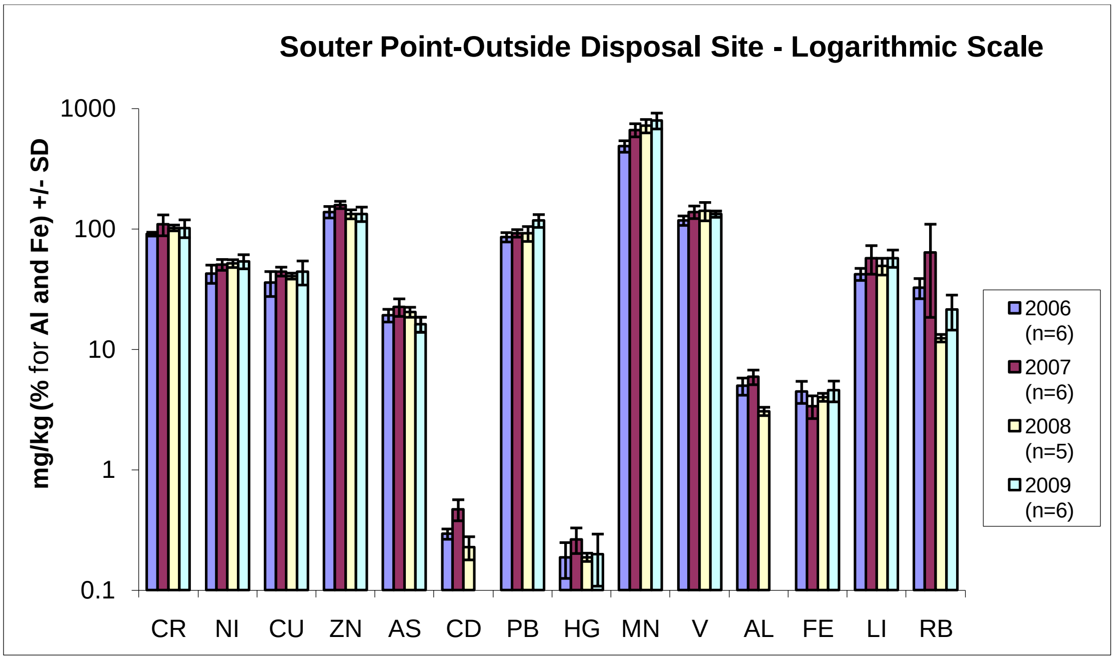


Figure 2.2.21. Average metal concentrations outside the Souter Point disposal site between 2006, 2007 and 2008.

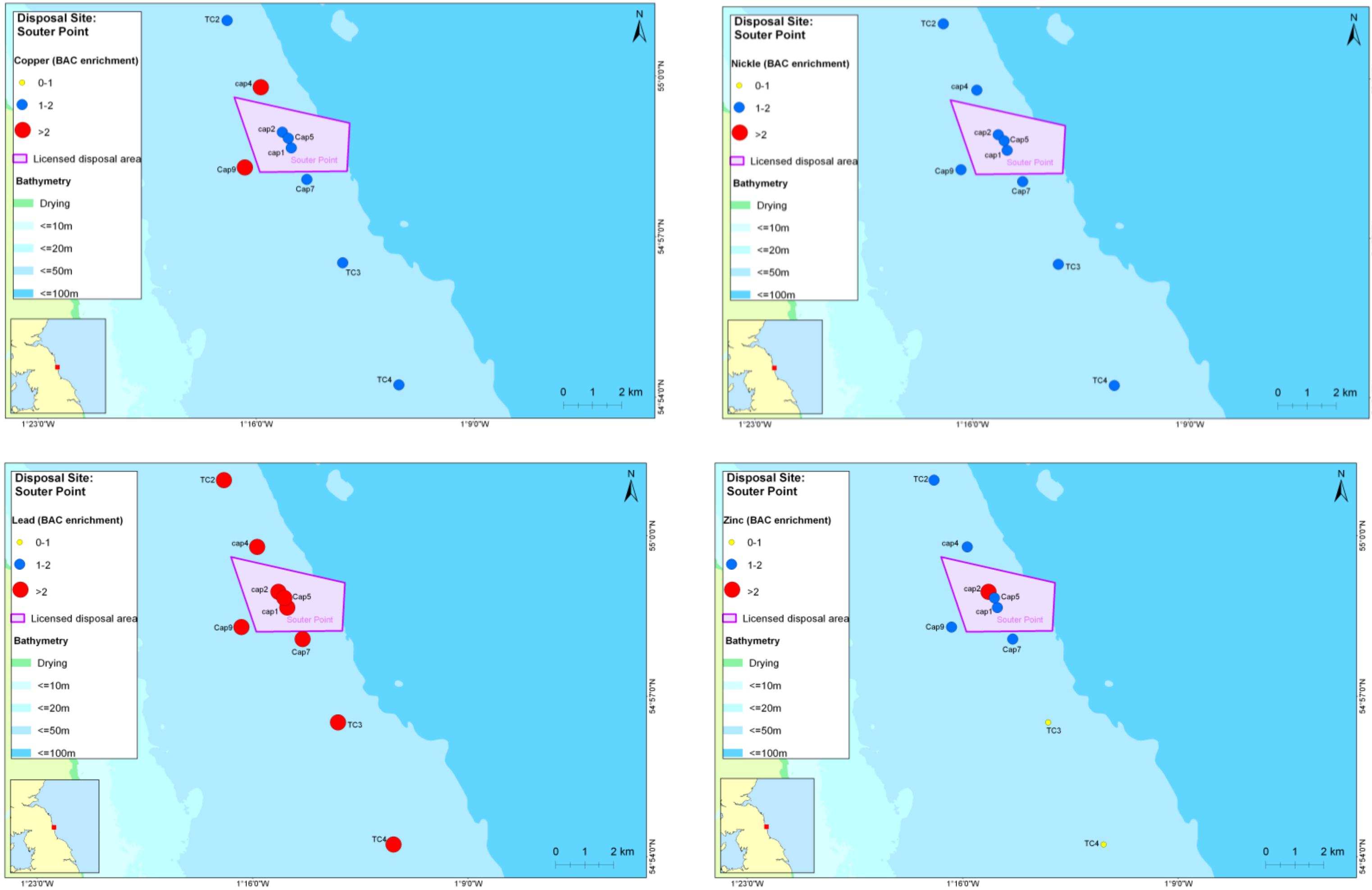


Figure 2.2.22 Enrichment to OSPAR BACs (raw/OSPAR BAC) at Souter Point (Cu, Ni, Pb, and Zn), 2009.

2.2.5 Conclusions

Monitoring at Souter Point dredged material disposal site has been conducted annually for a number of years, aiming primarily to determine the physical integrity of the cap and ensure that impacts of ongoing disposals are limited to within the vicinity of the disposal site. A number of complementary approaches (e.g., grabbing, coring, acoustics, SPI) have been applied at this site to achieve these aims. The 2009 data indicate that accumulations of deposited material have, relative to 2005, migrated further west and occupy a larger footprint on the bed.

Macrofaunal communities inside the disposal site show signs of decreased abundances, species richness and altered community structure relative to those outside the licensed boundary. Macrofaunal biomass was generally spatially variable, with some stations furthest away from the disposal site displaying lower biomass than those inside the capping area.

TBT concentrations from the grab stations were all low. PAH concentrations, however, are generally high at this site; stations within and to the north of the disposal site exceeded the ERL for both LMW and HMW PAHs (station CAP5 also exceeded the ERM for HMW PAHs). Organohalogens were spatially variable, with low values being found south of the site and higher values within (although not always) and north of the disposal site. However, CB concentrations were below FEPA action levels for all sites.

The approaches used to provide data regarding the vertical profiling of sediments gave useful insights, particularly in relation to cap thickness. The Contaminated Dredged Material (CDM) layer below the cap could clearly be discerned at (for example) station CAP5. TBT concentrations at various sediment depths, when compared with those from 2008, indicated that there may have been no net sediment erosion or deposition at stations CAP2 and CAP5 within the last 12 months, although some erosion appears to have taken place prior to then.

Future monitoring at Souter Point needs to be conducted under SLAB5, the details of which must be drafted following an appraisal of the various data already obtained for this site. Monitoring at this site has, and must continue to have, two aims; to ensure spatial impacts of ongoing disposal events are in line with expectations, and to ensure cap integrity. Under the former, the spatial assessment of contaminant levels should be a priority.

2.3 Tees (inner and outer, TY160 & TY150)

2.3.1 Background

Inner Tees receives most of the approximately 2,800,000 tonnes of maintenance dredged material licensed per year for the Tees Estuary, Seaton Channel and Hartlepool. Historic shoaling of disposed material at the eastern edge of the site was managed by the introduction in 2006 of a disposal regime involving the rotation of disposal in differing sectors of the site.

Over recent years there have been a number of high profile construction and dredging applications made under FEPA with regard to the Tees. In addition to the approximately 2.8 million tonnes of maintenance material licensed, there are ongoing capital operations also currently licensed for disposal to the two Tees Bay sites, including deepening of the Seaton Channel which, due to the physical nature of the material arising, is divided for disposal between the two sites. The extent of disposal undertaken to date under current licences for capital material has been variable, determined by progress on the proposed projects with which the dredging requirement is associated, however significant quantities for disposal at both sites may arise from proposed future infrastructure development activities within the Tees Estuary.

The Tees Estuary is associated with a significant historic and ongoing chemical industry which has resulted in the observation of contaminants within dredge sediments. ICI, Tioxide factories and brominated flame retardant producers have all discharged into the Tees. The eroding mud flat within the Tees Estuary, which had previously been observed to be a potential source of ongoing contamination due to high levels of Lead and Zinc, is now undergoing remediation utilising ‘geobag’ technology to construct a retaining bund. Significant Lead contamination of sediments is widespread throughout the Tees Estuary and in some areas results in arising dredge material being considered unacceptable for disposal at sea. Additionally, some of the highest levels of hydrocarbons found in England and Wales have been observed in sediment samples analysed from this area.

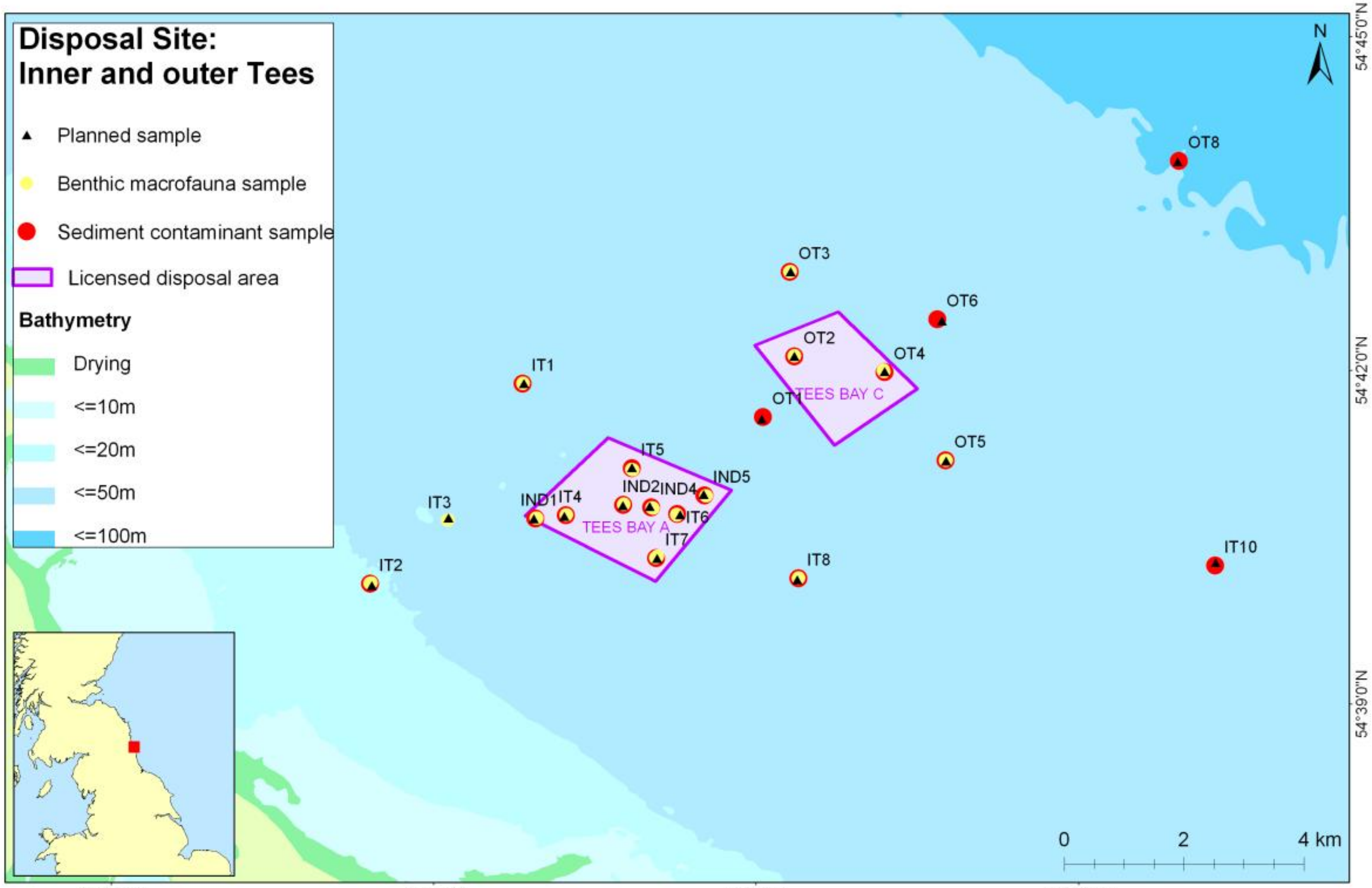


Figure 2.3.1. Locations of sampling stations at Inner and Outer Tees, 2009.

2.3.2 Impact hypotheses

- Any elevations in the concentrations of chemical contaminants directly attributable to dredged material disposal will be confined to within and the near vicinity of the disposal site, principally along the tidal axis
- Any elevations in the concentrations of chemical contaminants directly attributable to dredgings disposal will be within acceptable limits
- Any changes to the physical habitat will be confined to within and the near vicinity of the disposal site, principally along the tidal axis
- Any adverse effects on the benthic biota will be confined to within and the near vicinity of the disposal site, principally along the tidal axis
- Effects on benthos within the disposal site will be limited to periodic and localised reductions in the densities/diversity of the benthos, *i.e.*, the disposal site will at no time be characterised as azoic
- The wider dispersal of fine particulates arising from dredgings disposal, including any wave-induced shoreward transport, will have no adverse consequences for the marine biota or for recreational/amenity interests

2.3.3. Parameters monitored

Sidescan and multibeam (Inner Tees only)
Sediment particle size distribution
Sediment organic carbon and nitrogen
Macrofaunal communities
Sediment contaminants (TBT, PAHs, organohalogens, trace metals).

2.3.4 Results

2.3.4.1 Sidescan and multibeam

The Inner Tees dredged material disposal site covers approximately 4.6 square kilometres. The acoustic survey at Inner Tees used a Kongsberg EM3002D SIS multibeam data acquisition system. The seabed bathymetry is characterised by a raised mound in the south western part of the disposal site believed to be the result of the accumulation of dredged material in the area. The height of the raised feature is approximately 5m above the surrounding seabed. The seafloor topography slopes to the north east and east reaching around 40m deep (Figure 2.3.2).

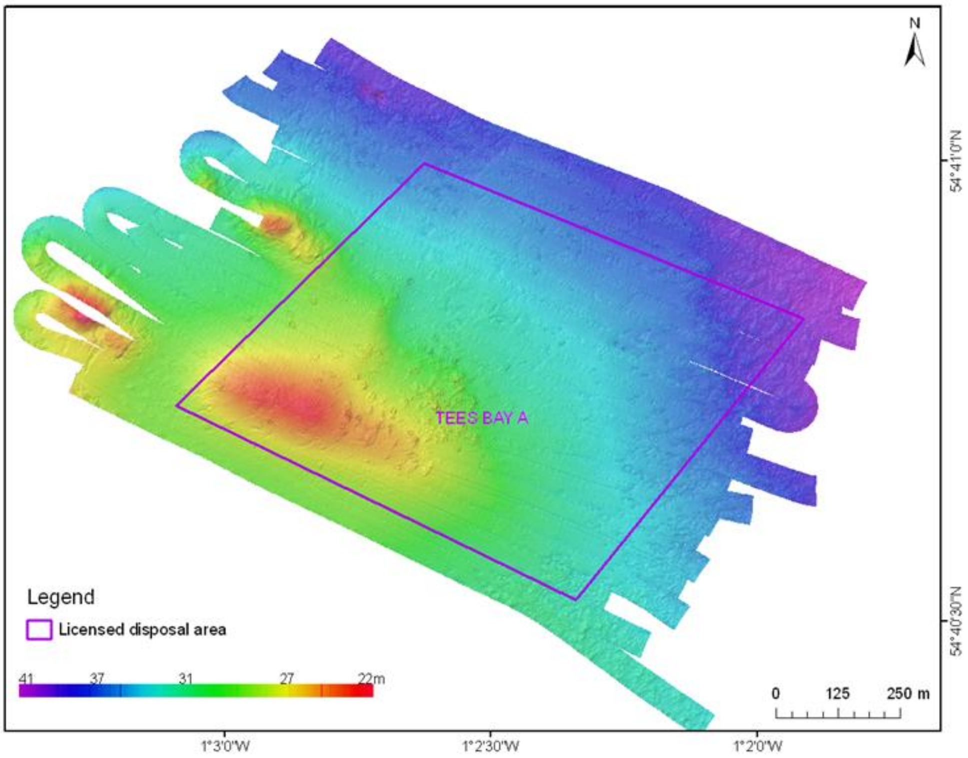


Figure 2.3.2. Inner Tees seabed bathymetry from the 2009 multibeam survey.

Eight particle size analysis (PSA) samples were collected from the site using a Hamon grab, the positions for which can be seen in Figure 2.3.3. The disposal site consists mostly of muddy sandy sediments as indicated by the low backscatter return observed (Figure 2.3.3). High backscatter returns suggest coarser or harder substrates in the area, predominantly this can be found in the south east of the site. The observed coarser sediments are more heterogeneous in nature and likely to be associated with gravelly sands. Temporal comparison of the data shows that there was little change in the broad distribution of sediments across the site; however the 2009 data show more widespread backscatter patches across the site compared to that of the 2008 results, suggesting the disposal activity is more widespread, rather than concentrating in one area.

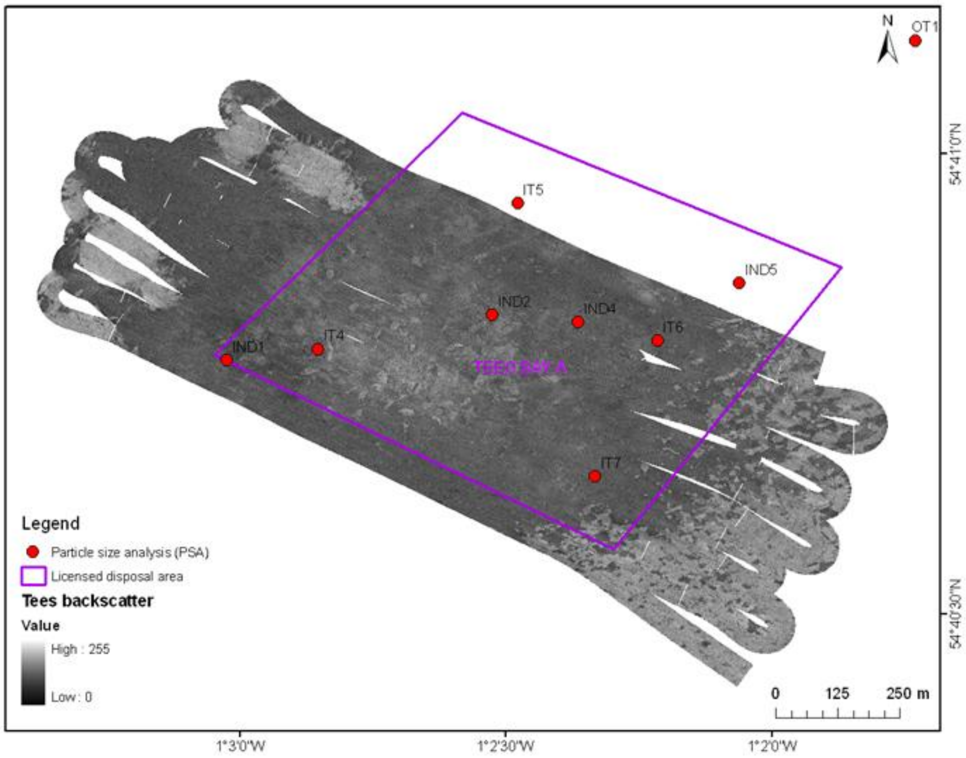


Figure 2.3.3. Tees disposal site backscatter from 2009 survey with licensed disposal area and PSA sample positions

Figure 2.3.4 presents the interpretation of the 2008 versus 2009 survey results within the disposal site. The red line identifies the extent of the main impacted area from the 2008 survey (Bolam *et al*., 2009). The area receiving the majority of dredged material has not moved location significantly between 2008 and 2009 although the overall shape has changed, causing the surrounding sediments to adapt to this alteration. The majority of the slightly gravelly muddy sand that constitutes the disposal area has redistributed to the north east in comparison to the 2008 interpretation. Such change is likely to be caused by environmental conditions, such as tidal currents in the area.

Comparison of the multibeam backscatter from the 2008 and 2009 datasets show that some changes in the nature of the seabed have occurred. The extent of the sediments consisting solely of mud has reduced and thus the area has become relatively featureless homogeneous gravelly sand.

A plot showing the difference in meters between the 2008 and 2009 bathymetric surveys is shown in Figure 2.3.5. The results show a substantial build up of sediment in the site with a change in accretion occurring in the eastern side of the disposal area. The scale on this Figure represents the removal of sediments from the 2009 layer to that of the 2008. i.e. the 2008 data is removed from the 2009 layer producing a minus output. The surface statistics indicate a mean build up of 0.38m at the site overall.

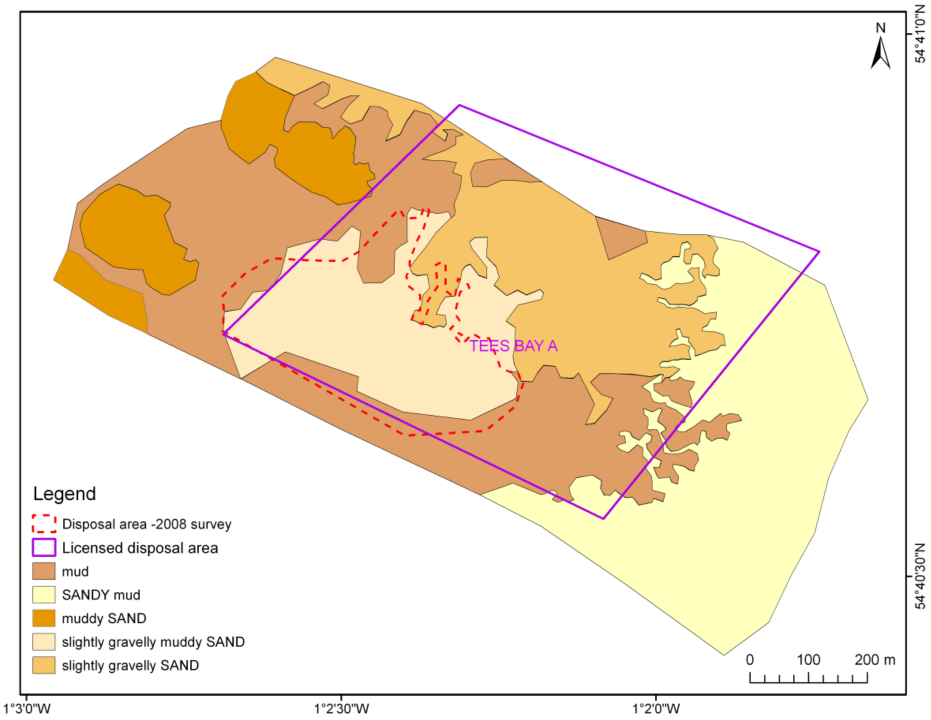


Figure 2.3.4. Interpretation of the Tees 2009 multibeam survey showing region of disposal from the 2008 acoustic survey superimposed.

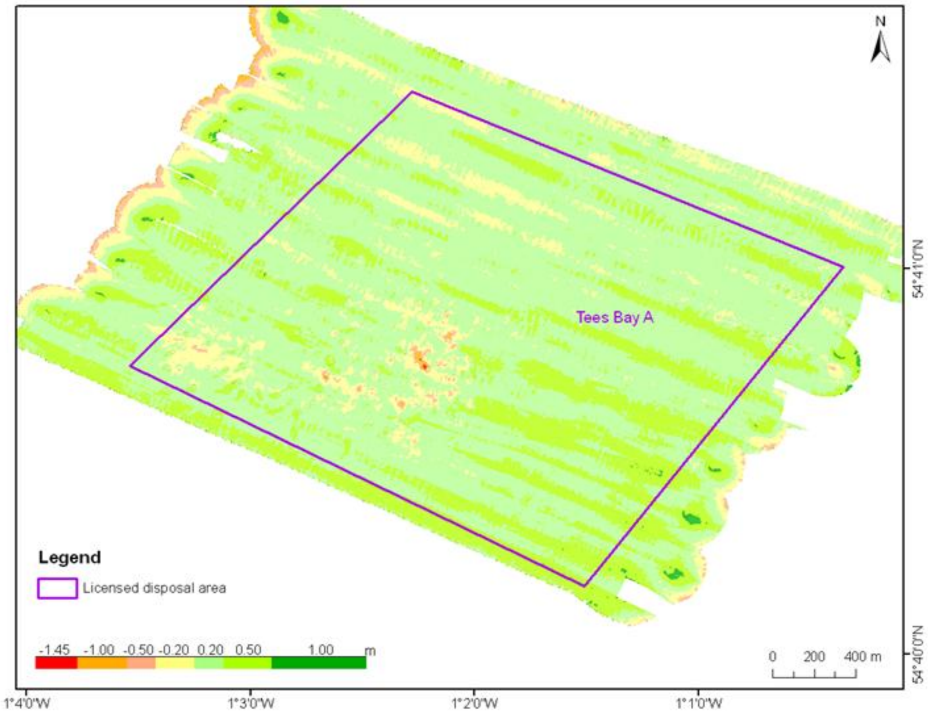


Figure 2.3.5. Bathymetric differences between 2008 and 2009 multibeam surveys

Due to the nature of bathymetric surveys it is often difficult to determine whether the changes noted are natural temporal changes or if they are indeed the result of a change in the regime of sediment disposal at the site. Comparison of the previous year's surveys to the 2009 bathymetric survey suggest that there is a definite increase in the disposal of material to the south eastern part of the licensed area, especially near to where the raised feature is present.

2.3.4.2 Sediment particle size

Five sediment groups were defined for Inner Tees (Table 2.3.1). Sediment group Inner Tees 1 contains one sample from IND2 in 2009 that is described as mud. Sediments in Inner Tees 2 are described as slightly gravelly sand, dominated by fine sand. Sediments in Inner Tees 3 are described as gravelly muddy sand, mixed sediment. Sediments in sediment groups Inner Tees 4 and Inner Tees 5 are both described as slightly gravelly, muddy sand, with the sand in Inner Tees 5 dominated by very fine sand.

At the Outer Tees, eight sediment groups were defined (Table 2.3.2). Sediment group Outer Tees 1 is described as slightly gravelly sand. Outer Tees 2 contains one sample from OT2 in 2006 is described as sandy gravel. Sediments in Outer Tees 3 are described as gravelly sand. Sediments in Outer Tees 4 are described as gravelly muddy sand, mixed sediment. Sediments in Outer Tees 5 are described as slightly gravelly sandy mud. Sediments in sediment groups Outer Tees 6, Outer Tees 7 and Outer Tees 8 are all described as slightly gravelly, muddy sand. Sediment in sediment group Outer Tees 7 contain the most silt/clay, with fine sand dominating in Outer Tees 6 and Outer Tees 8 (50% of sand present in Outer Tees 6, and 66% of the sand present in Outer Tees 8).

The spatial distribution of these sediment groups for Inner Tees is shown in Figure 2.3.6 and how these groups at each station have varied between 2006 and 2009 is presented in Table 2.3.3. In 2009, the sediments both within and outside of the Inner Tees disposal site varied. In the centre of the Inner Tees disposal site at IND2, the sediments comprised 99%mud, previously being slightly gravelly sand in all previous years measured. Stations in the eastern side of the site (IND4 and IT6) and in the southern corner (IT7) are in 'Inner Tees 4' (slightly gravelly muddy sand) which is consistent with previous year, although there is a slight increase in silt clay content in 2008 and 2009 at IND4. At IND5, in the eastern corner of the site, and at IT4 and IND1, both in the western corner of the site, sediments are in 'Inner Tees 2' (slightly gravelly sand), which is consistent with previous surveys. At IT5, in the northern corner of the site, the sediment is also in sediment group Inner Tees 2, but this shows a decrease in silt/clay compared with previous two years, while being similar to 2006. IT1, to the north of the Inner Tees disposal site, and IT8 to the south-east, are represented by 'Inner Tees 5' (slightly gravelly muddy sand); consistent with previous years. At IT2, outside of the site to the west, closest to shore, and at IT10, east of the site, sediments are in ‘Inner Tees 2’ (slightly gravelly sand).

The spatial distribution of the sediment groups at Outer Tees is also presented in Figure 2.3.6 and how such groups have varied between 2006 and 2009 is displayed in Table 2.3.4. In 2009, the sediments both within and outside of the disposal site were spatially very variable. At OT2 (at the western edge of the Outer site), sediments showed notable temporal variability, being represented by a different sediment group each year (Table 2.3.4). At OT4 (on the eastern perimeter of the site) however, sediments have consistently been classed as Outer Tees 6 (slightly gravelly muddy sand), except in 2008 when it is more mixed falling in sediment group Outer Tees 4.

At OT1, outside on the western edge of the site, the sediment is in sediment group Outer Tees 3 (gravelly sand), which is different to previous years, when sediments were in sediment group Outer Tees 1, slightly gravelly sand. There is, therefore, a slight increase in gravel content (2009: 7%, 2006-2008: <1%) at this site in 2009. At OT3 (north of the site) the sediment is temporally highly variable and in 2009 it is in ‘Outer Tees 4’ (gravelly muddy sand). At OT5, southeast of the site, and at OT6, northeast of the site, sediments are in ‘Outer Tees 7’ for all years sampled, except at OT6 2007 (Outer Tees 8), containing more fine sand, and OT5 2008 (Outer Tees 5), containing more silt/clay. At OT8, furthest offshore, outside and to the east of the disposal site, sediments for each year sampled are all in sediment group Outer Tees 8, described as slightly gravelly muddy sand.

Sediment group	Number of samples	% number of samples	Sample Type	Sediment description	MODE 1 (µm):	MODE 2 (µm):	MODE 3 (µm):
Inner Tees 1	1	2	Unimodal, Poorly Sorted	Slightly Gravelly Mud	6.7		
Inner Tees 2	15	33	Unimodal, Moderately Sorted	Slightly Gravelly Sand	152.5		
Inner Tees 3	4	9	Polymodal, Very Poorly Sorted	Gravelly Muddy Sand	76.5	152.5	605.0
Inner Tees 4	16	36	Unimodal, Poorly Sorted	Slightly Gravelly Muddy Sand	107.5		
Inner Tees 5	9	20	Unimodal, Moderately Sorted	Slightly Gravelly Muddy Sand	107.5		

Sediment group	Gravel (%)	Sand (%)	Silt/clay (%)	Very coarse sand (%)	Coarse sand (%)	Medium sand (%)	Fine sand (%)	Very fine sand (%)
Inner Tees 1	0.04	0.35	99.61	0.03	0.02	0.03	0.13	0.14
Inner Tees 2	0.79	95.57	3.63	1.34	3.95	13.85	56.34	20.10
Inner Tees 3	7.51	60.28	32.21	4.40	9.50	11.63	15.72	19.04
Inner Tees 4	0.62	84.11	15.27	0.93	2.71	6.80	37.37	36.30
Inner Tees 5	0.51	86.03	13.46	0.49	1.21	3.33	19.51	61.49

Table 2.3.1. Sediment descriptions and summary statistics, based on the average sediment distribution, calculated using Gradistat (Blott and Pye, 2001) for each sediment group defined at Inner Tees.

Sediment group	Number of samples	% number of samples	Sample Type	Sediment description	MODE 1 (µm):	MODE 2 (µm):	MODE 3 (µm):
Outer Tees 1	4	13	Unimodal, moderately sorted	Slightly gravelly sand	215.0		
Outer Tees 2	1	3	Bimodal, very poorly sorted	Sandy gravel	215.0	38250.0	
Outer Tees 3	2	7	Unimodal, poorly sorted	Gravelly sand	215.0		
Outer Tees 4	4	13	Polymodal, very poorly sorted	Gravelly muddy sand	855.0	215.0	19200.0
Outer Tees 5	3	10	Bimodal, very poorly sorted	Slightly gravelly sandy mud	76.5	26.7	
Outer Tees 6	5	17	Unimodal, poorly sorted	Slightly gravelly muddy sand	152.5		
Outer Tees 7	6	20	Unimodal, poorly sorted	Slightly gravelly muddy sand	152.5		
Outer Tees 8	5	17	Unimodal, moderately sorted	Slightly gravelly sand	152.5		

Sediment group	Gravel (%)	Sand (%)	Silt/clay (%)	Very coarse sand (%)	Coarse sand (%)	Medium sand (%)	Fine sand (%)	Very fine sand (%)
Outer Tees 1	0.90	94.62	4.48	1.74	5.13	19.94	60.79	7.02
Outer Tees 2	32.74	62.83	4.43	4.08	6.66	11.08	35.80	5.21
Outer Tees 3	6.10	89.73	4.17	8.83	16.55	24.46	34.28	5.61
Outer Tees 4	16.14	70.46	13.40	17.17	17.93	12.02	13.61	9.74
Outer Tees 5	3.37	44.85	51.79	1.31	2.97	5.49	12.85	22.23
Outer Tees 6	2.02	84.62	13.36	2.91	5.00	11.38	44.30	21.04
Outer Tees 7	0.24	81.49	18.27	0.37	1.17	4.26	37.53	38.16
Outer Tees 8	0.26	92.05	7.69	0.47	1.95	7.42	62.96	19.26

Table 2.3.2. Sediment descriptions and summary statistics, based on the average sediment distribution, calculated using Gradistat (Blott and Pye, 2001) for each sediment group defined at Outer Tees.

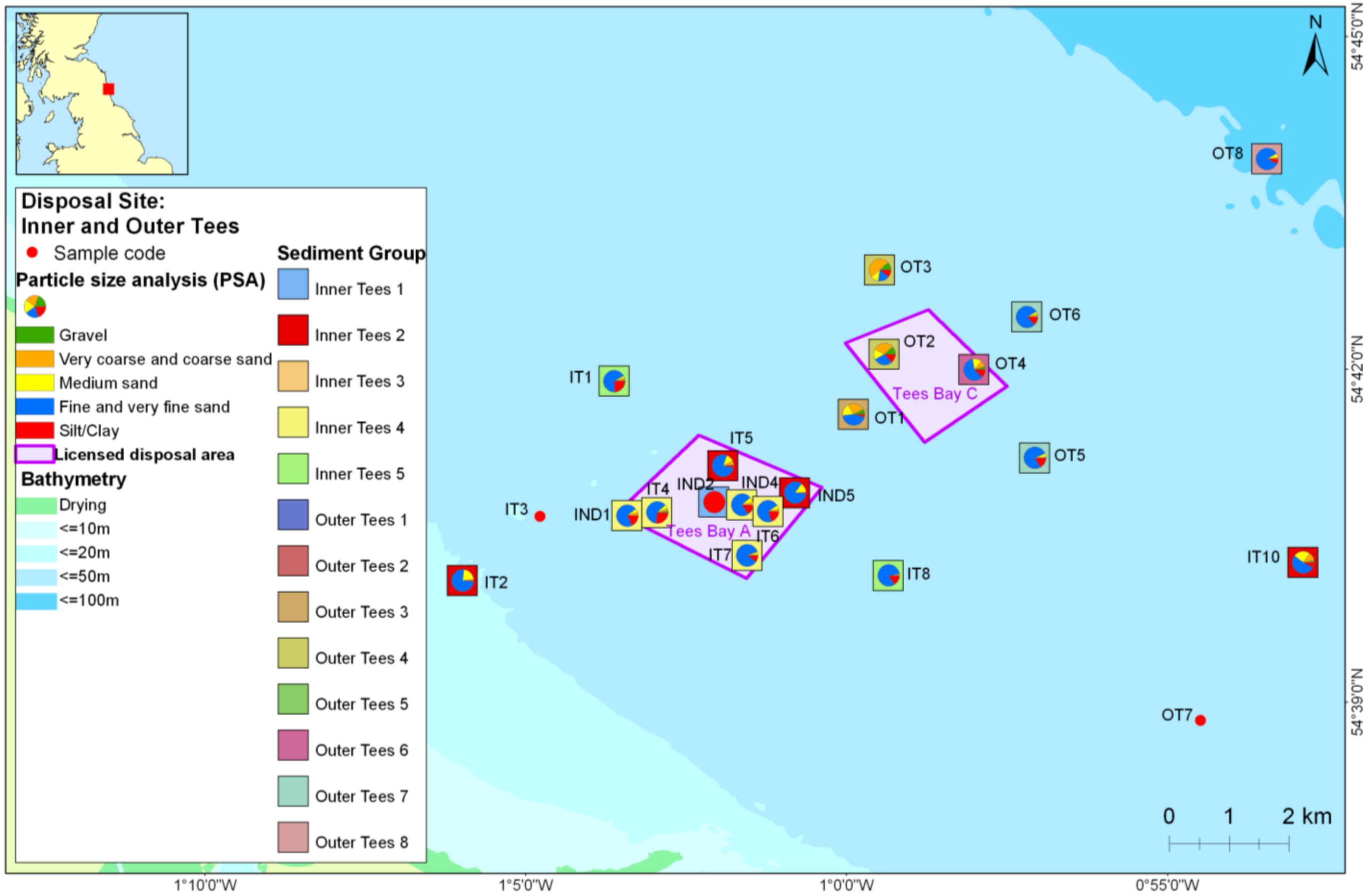


Figure 2.3.6. Sediment groups (coloured squares) overlain with pie charts showing proportions of gravel, very coarse sand and coarse sand, medium sand, fine and very fine sand and silt/clay at each station in 2009.

Station code	2006	2007	2008	2009
IND 1	Inner Tees 5	Inner Tees 5	Inner Tees 2	Inner Tees 4
IND 2	Inner Tees 2	Inner Tees 2	Inner Tees 2	Inner Tees 1
IND 4	ns	Inner Tees 2	Inner Tees 4	Inner Tees 4
IND 5	ns	Inner Tees 2	Inner Tees 2	Inner Tees 2
IT1	Inner Tees 5	Inner Tees 4	ns	Inner Tees 5
IT2	ns	ns	ns	Inner Tees 2
IT3	Inner Tees 2	Inner Tees 3	Inner Tees 2	ns
IT4	Inner Tees 5	Inner Tees 4	Inner Tees 4	Inner Tees 4
IT5	Inner Tees 2	Inner Tees 4	Inner Tees 4	Inner Tees 2
IT6	Inner Tees 4	Inner Tees 3	Inner Tees 4	Inner Tees 4
IT7	Inner Tees 4	Inner Tees 2	Inner Tees 4	Inner Tees 4
IT8	Inner Tees 5	Inner Tees 5	Inner Tees 5	Inner Tees 5
IT10	Inner Tees 3	Inner Tees 4	Inner Tees 3	Inner Tees 2

Table 2.3.3. Sediment group at each Inner Tees station between 2006 and 2009 inclusive (ns = no sample).

Station code	2006	2007	2008	2009
OT1	Outer Tees 1	Outer Tees 1	Outer Tees 1	Outer Tees 3
OT2	Outer Tees 2	Outer Tees 5	Outer Tees 6	Outer Tees 4
OT3	Outer Tees 6	Outer Tees 3	Outer Tees 1	Outer Tees 4
OT4	Outer Tees 6	Outer Tees 6	Outer Tees 4	Outer Tees 6
OT5	Outer Tees 7	Outer Tees 7	Outer Tees 5	Outer Tees 7
OT6	Outer Tees 7	Outer Tees 8	Outer Tees 7	Outer Tees 7
OT7	ns	Outer Tees 4	Outer Tees 5	ns
OT8	Outer Tees 8	Outer Tees 8	Outer Tees 8	Outer Tees 8

Table 2.3.4. Sediment group at each Outer Tees station between 2006 and 2009 inclusive (ns = no sample).

2.3.4.3 Sediment organic carbon and nitrogen

Sediment organic carbon (on the <63µm sediment fraction), organic carbon (on the <2mm sediment fraction) and silt/clay contents for both Inner and Outer Tees sites during 2009 are shown in Figure 2.3.7. Organic carbon values (on the <63 µm sediment fraction) at Inner Tees range from 1.54 to 5.45 %m/m. These are similar to 2006, 2007 and 2008 (data not presented). IND1, IND4, IT5, IT6 and IT7 contained higher levels of organic carbon for the <2mm fraction than in the <63µm, indicating there is a source of organic carbon in the coarser sediment in this area (possibly coal).

In 2009, organic carbon values (on the <63µm sediment fraction) at Outer Tees range from 2.62 to 3.8 %m/m. These are similar to concentrations found in 2006, 2007 and 2008.

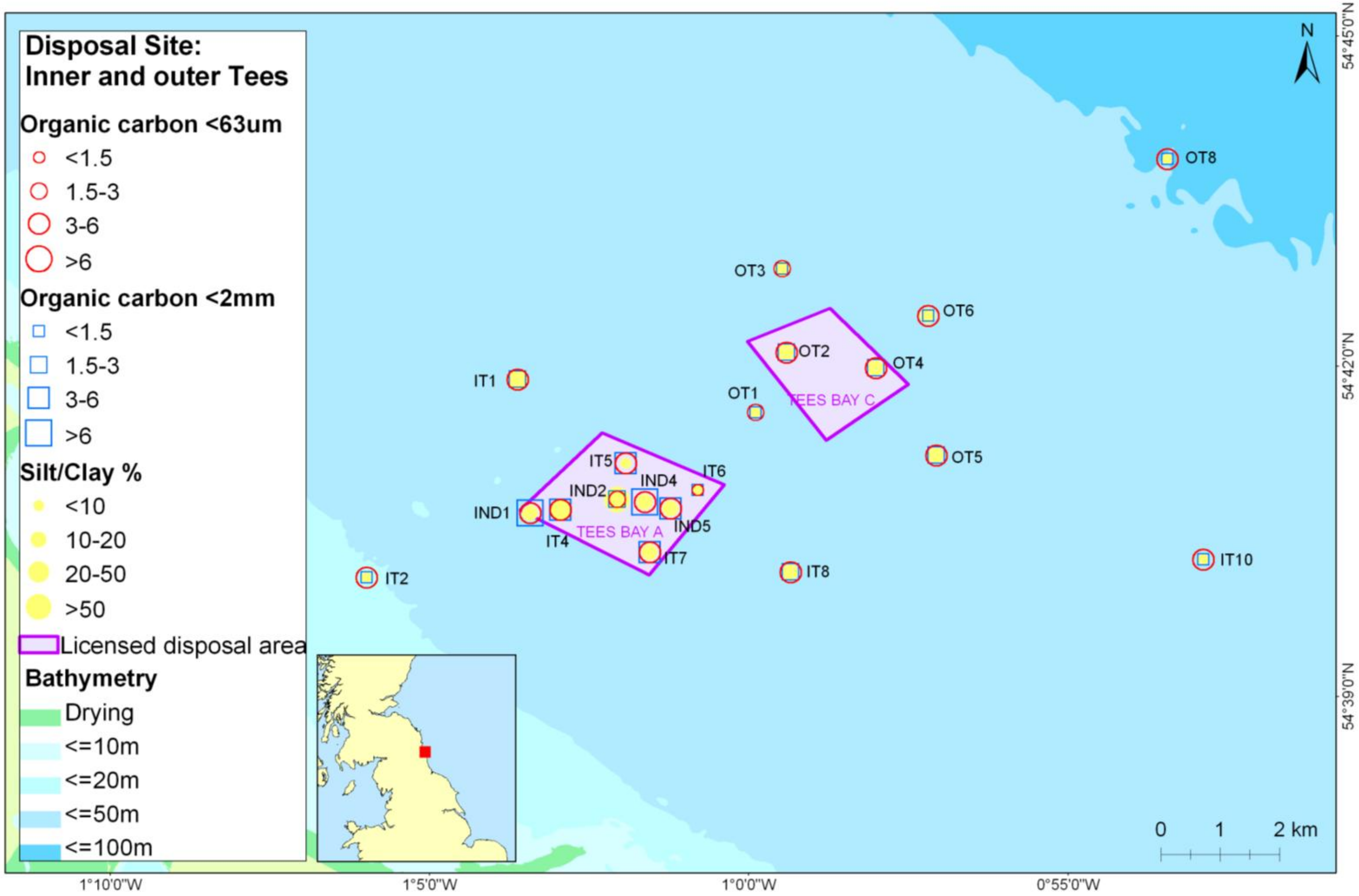


Figure 2.3.7. Organic carbon (<63µm), organic carbon (<2mm) and silt/clay at Inner and Outer Tees.

2.3.4.4 Macrofaunal communities

At the Inner Tees disposal site, 171 taxa were identified from the 12 stations sampled, 40 of which occurred in only one grab. Bivalves and echinoderms dominated in terms of species numbers and abundance. *Nucula nitidosa*, *Amphiura filiformis* and *Abra alba* were the most abundant species (917, 405 and 306 individuals respectively) and *Echinocardium cordatum* had the greatest biomass.

The mean number of species per grab inside the disposal ground was 27, compared to 36 outside (Figure 2.3.8A). The highest mean number of species was observed from outside the disposal ground (57 per grab at IT1; 54 per grab at IT8), whereas the lowest were from inside it at IND2 (30 species per grab) and IT4 (31 species per grab) (Figure 2.3.8A). It is evident, however, that species numbers were also comparatively low at IT2 and IT3 outside the disposal ground; 6 out of 8 stations from inside the disposal site show a higher mean number of species than that found at IT2 and IT3; west of the disposal site (Figure 2.3.8A). IT2 and IT3 also show relatively low mean numbers of individuals (47 and 53 per grab respectively) (Figure 2.3.8B); these numbers were lower than those found at the other stations outside the disposal ground and at IT5, IT6 and IT7 inside it. The highest mean number of individuals (305 per grab) came from IT5 (inside disposal ground), although replicate variability was quite high at this station, followed by IT8 (245 individuals; outside disposal ground) (Figure 1B). Mean biomass was highest at IT8 (>16g wet mass per grab) and lowest at IND2 (0.2g per grab) (Figure 2.3.8C).

From the four stations sampled as part of the Outer Tees survey 167 taxa were identified; 53 of these occurred once only. The polychaetes *Lumbrineris gracilis*, *Galathowenia oculata* and *Mediomastus fragilis* were the most abundant species (308, 140 and 137 individuals per grab respectively) and the bivalve *Dosinia lupinus* exhibited the highest biomass. One-way ANOVA showed that the differences in mean number of species and biomass weren't significant ($P>0.05$) between stations in the Outer Tees area. The differences in mean number of individuals were significant (ANOVA: $P<0.05$). The highest mean number of individuals was 234 per grab at OT3 (outside disposal ground), followed by 191 individuals for OT4 (inside); the lowest was 156 from OT2 (inside) and 181 (OT5, outside).

Multi-dimensional scaling analysis was performed on the Inner Tees species abundance data using PRIMER v.6 (Clarke & Gorley, 2006) (Figure 2.3.9A). Replicates from stations outside the disposal ground were clustered into two distinct groups: IT1 and IT8 are tightly clustered, indicating a high degree of similarity between replicates from both these stations; replicates from IT2 and IT3 are slightly less tightly clustered, though still similar to each other (Figure 2A). Inside the Inner Tees disposal ground there appears to be a high level of similarity between replicates from IT5, IT6 and IT7 and IND1; station IT4 shows strong similarity between its replicates but not the other stations inside the disposal site. Replicates from

IND2, IND4 and IND5 exhibit the greatest variability within stations and are less similar to other stations from inside the disposal ground (Figure 2A). For the Outer Tees sites, there is some indication of separation in community structure between stations inside and outside the disposal site (although one replicate for OT4 appears more similar to those of OT3 outside the site) (Figure 2.3.9B).

Hierarchical cluster analysis with a similarity profile test (SIMPROF, significance level 5 %) was performed with PRIMER v.6 (Clarke & Gorley, 2006) to look for statistically significant evidence of multivariate pattern in the samples from Inner and Outer Tees (Figure 2.3.10A&B). Samples from the Inner Tees show evidence of several genuine clusters. Samples from IT8 show the greatest similarity within a station; samples from IND5 the greatest dissimilarity. Overall, the communities from inside the disposal site do not vary as much as those found outside the disposal site; stations from the latter cluster into two significant groups, i.e. IT2 / IT3 and IT1 / IT8. Samples from the Outer Tees are more similar as a group than those from the Inner Tees. There are three clusters of samples that cannot be significantly differentiated, i.e. OT5; OT2 and two samples from OT4; OT3 and one sample from OT4.

One-way ANOSIM (PRIMER v.6., Clarke & Gorley, 2006) was used to test the null hypothesis that there are no assemblage differences between groups of samples specified by position inside or outside the disposal ground. For the Inner Tees an overall observed R statistic of 0.472, significance level $p < 0.1$ %, means that the probability of the patterns in the data being produced by chance is low and that there is a relationship between patterns in the macrofaunal communities and position inside or outside the disposal ground. There was so significant differences between the macrofaunal communities inside and outside the disposal ground for the Outer Tees ($p = 0.74$; $R = 0.244$).

The similarity percentages program SIMPER (PRIMER v.6., Clarke & Gorley, 2006) was used to indicate which taxa contributed the most towards dissimilarity between stations. The average abundance of the bivalve *Abra alba* made the greatest contribution to dissimilarities between IND2 and IT4 and other stations, whereas for IND4 the polychaete *Euchone rubrocincta* contributed the most. The average abundance of the amphipod *Bathyporeia elegans* made the biggest contribution to dissimilarity between IT2 and IT3 with other stations. For IT1 and IT8 dissimilarity to other stations was primarily due to average abundances of the brittle star *Amphiura filiformis* and the Capitellid *Peresiella clymenoides*.

Inner and Outer Tees Bays were similar in the number of taxa identified. The Inner Tees supports a bivalve and echinoderm-dominated macrofaunal community, whereas polychaetes are most abundant in the Outer Tees. These are all typical fauna in muddy sand and what would be expected for the area. The differences in mean number of species, individuals and biomass were all significant between stations in the Inner Tees. Mean number of species, individuals and biomass were lowest at IND2 and IT4 (inside the disposal ground); species numbers were generally greater outside the disposal ground. Samples from IND5 showed the greatest variability within a station. The Inner Tees showed significant internal structure in its macofaunal communities. Some stations within the disposal ground are similar in their macrofaunal abundance (i.e. IND1, IT5-7) and others are not (IND2, IND4&5, IT4). Outside the disposal ground stations IT1and IT8 show strong similarity to each, but not to other Inner Tees stations; IT2&3 exhibit similarity to each other and to one of the samples from IND5 (inside the disposal ground). In the Outer Tees differences in the mean number of individuals between stations were significant, but there was no clear pattern or significant differences between the macrofaunal communities in regard to the disposal ground.

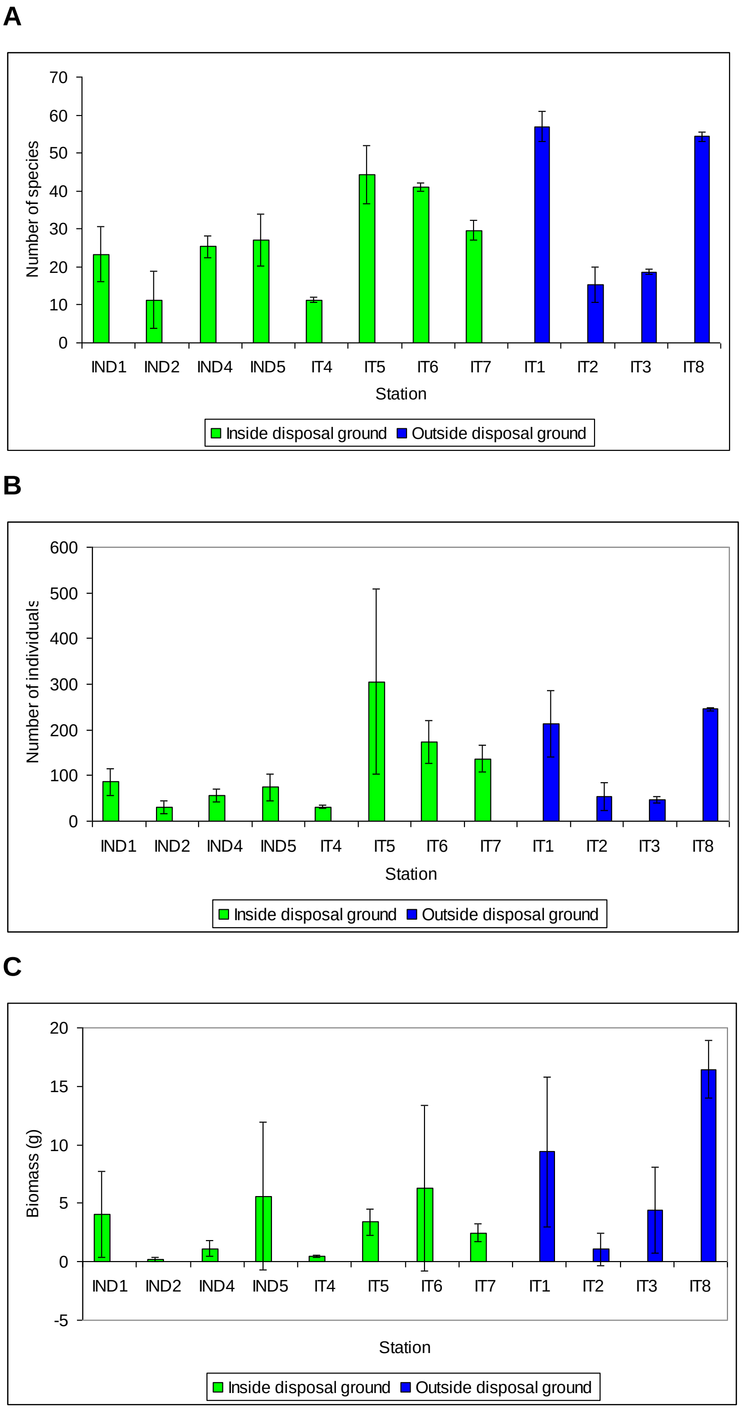


Figure 2.3.8. A: Mean number of species (+/- standard deviation), B: Mean number of individuals (+/- standard deviation), and C: Mean biomass (+/- standard deviation) for Inner Tees, 2009. Values presented per 0.1m-2 grab.

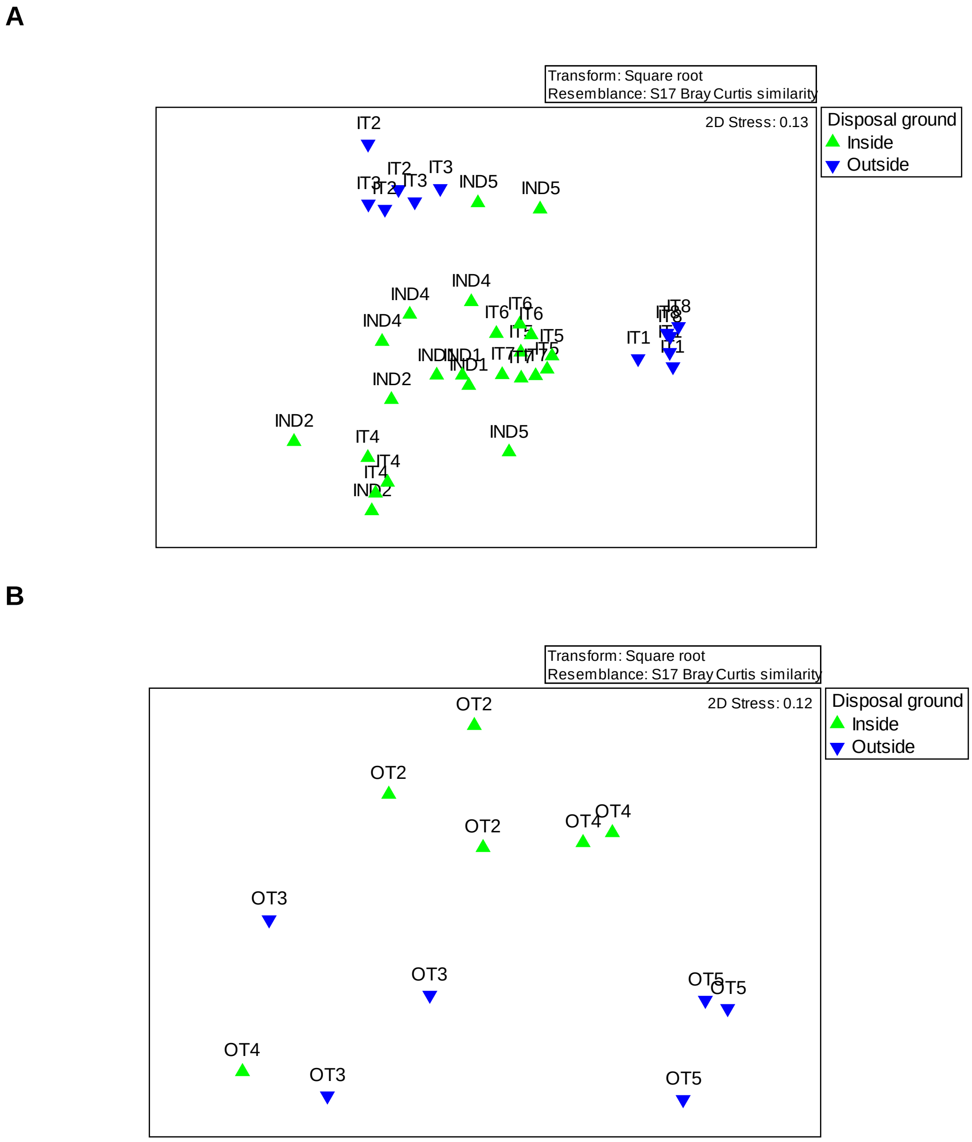


Figure 2.3.9. MDS plot of species abundance. A. Inner Tees Bay. B. Outer Tees Bay.

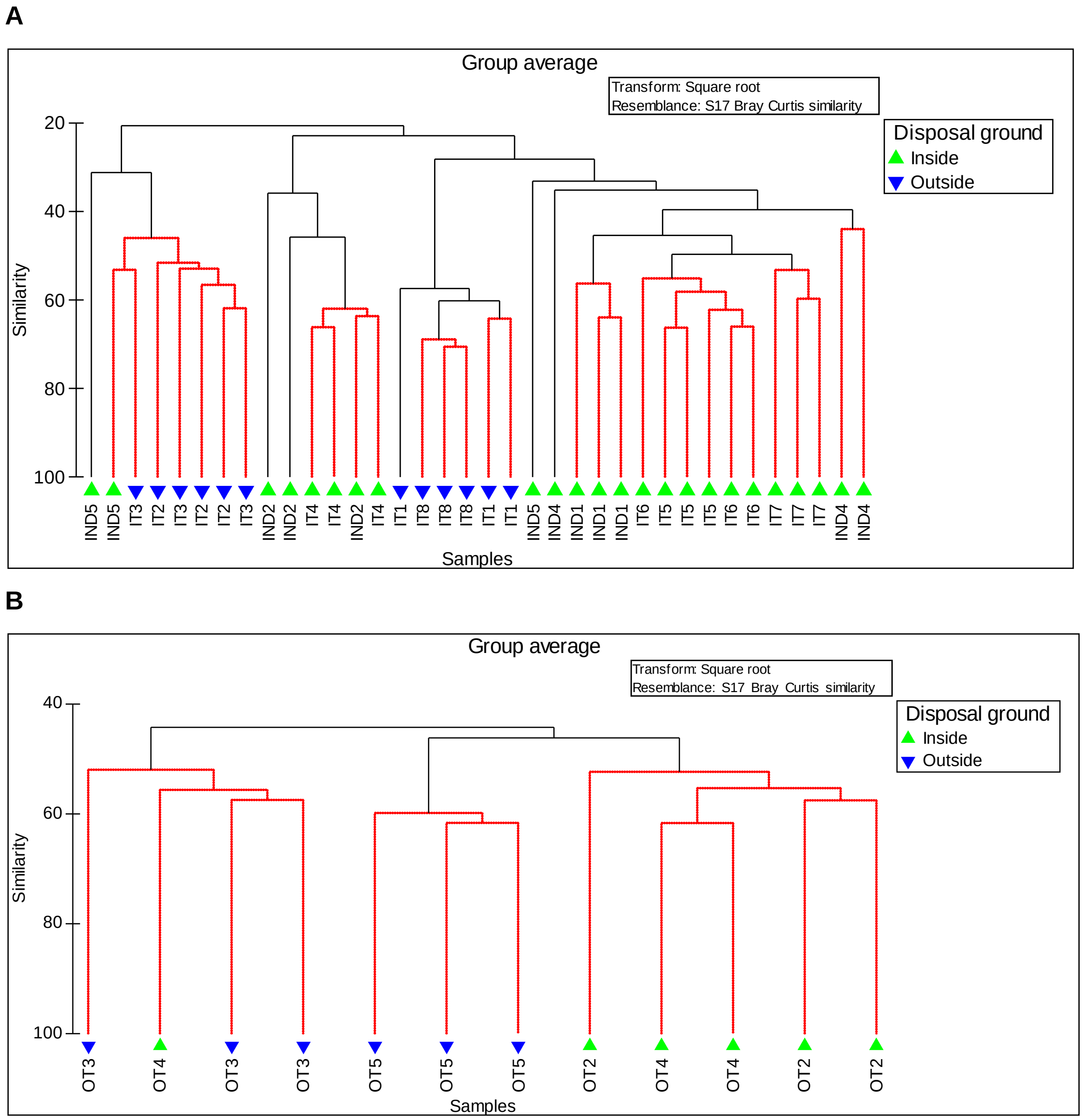


Figure 2.3.10. Hierarchical cluster analysis with a SIMPROF test (significance level 5%) of abundance data. A. Inner Tees Bay. B. Outer Tees Bay.

2.3.4.5 Contaminants

2.3.4.5.1 TBT

Samples from the Inner Tees at station IND4 (within the disposal site) had a TBT concentration of 0.04 mg/kg, a slight increase from 2007 and 2008 surveys, however this result remains below AL1. All other samples taken at the Inner Tees stations were below the detection limit. This is probably due to the fact that Inner Tees is a highly dispersive area, thus an increase of TBT loading does not necessarily result in accumulation of TBT within the disposal site. Additionally, the oxic nature of the environment probably promotes the degradation of TBT.

All the seven stations sampled at the Outer Tees recorded results below the detection limit. This observation is consistent with those for the last three years. There has been no dredged material disposal activity at the Outer Tees disposal site for the last 3 years, which may explain the continual low level of organotins.

2.3.4.5.2 PAHs

The Tees area displayed the highest concentrations of summed PAHs compared to all disposal sites surveyed during 2009 with the highest value found at IND1 (on the western perimeter of Inner Tees) with a summed PAH concentration of 156,000 µg kg^{-1} (Figure 2.3.11). In 2008 the maximum concentration was 179,600 µg kg^{-1} at sampling point IT6 which in 2009 was found to be 63,700 µg kg^{-1}.

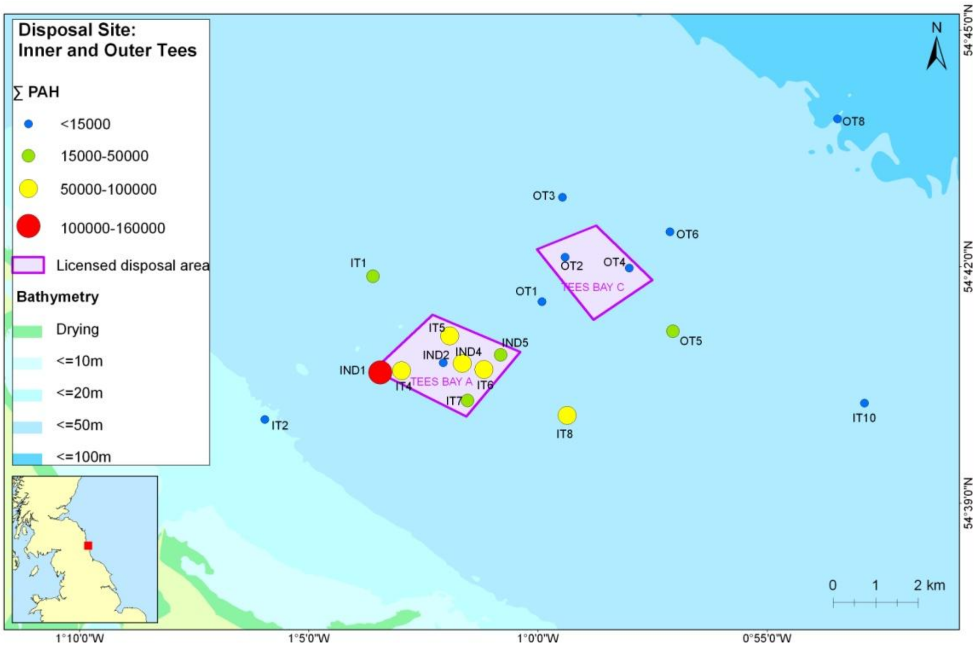
Generally concentrations are much lower at the Outer Tees disposal ground with a maximum summed PAH concentration of 13,000 µg kg^{-1} at both OT2 and OT4 (previously 16,000 µg kg^{-1} at both in 2008). At OT5, to the south-east of the disposal site, summed PAH concentration was 17,200 µg kg^{-1}, a noticeable reduction from that sampled in 2008 (i.e., 44,500 µg kg^{-1}).

Disposal activity at Inner Tees increased from 2007 to 2008 by nearly 17% which could account for the increase in concentration found in this area whereas no disposal activity has occurred at the outer disposal area which would account for the lower values found in these samples.

Studies of specific PAHs within the samples taken from the disposal sites indicate primarily petrogenic (fossil fuel based) sources.

Only two sites, IT2 and OT8 (the two stations furthest away from the disposal sites at the western and eastern extremes of the survey respectively) did not exceed the ERL for the LMW PAHs whereas the ERM for LMW PAHs was exceeded at IND1, IND4, IND5, IT1 and IT4, IT5. IT6, IT7, IT8, OT4 and OT5. The ERL for the HMW PAHs was exceeded at IND1, IND5, IT1, IT4, IT5 and IT6 but no sites exceeded the ERM for HMW PAHs.

As for the Tyne, the Tees Estuary is known to exhibit elevated PAH concentrations in sediments (Woodhead *et al*., 1999).



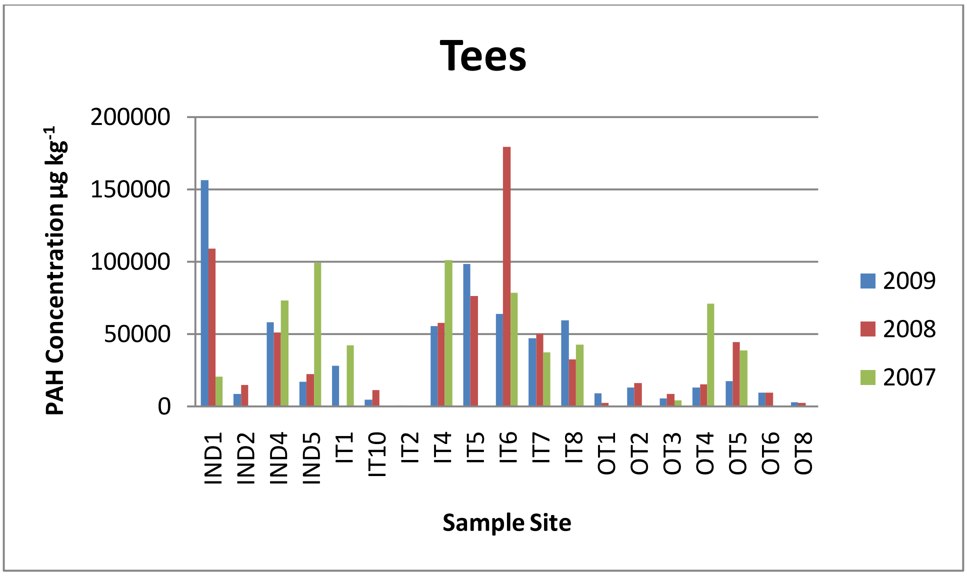


Figure 2.3.11. Summed PAH concentrations (µg kg^{-1}) for stations sampled in 2009 at Inner and Outer Tees (top) and concentrations observed during 2007, 2008 and 2009 (bottom).

2.3.4.5.3 Organohalogens

At Tees, CBs were detected at 11 of the 19 stations, with highest concentrations in the Inner Tees area (∑ICES7 CBs range <0.7-2.7 µg/kg dw) (Figure 2.3.12). Highest ∑ICES 7 CB concentrations in the Inner Tees disposal area were 2.7, 2.4 and 2.1 µg/kg dw for IT4, IT6 and IND4 respectively, with 2.1 µg/kg dw also found at IT1 north of the disposal area. Highest ∑ICES 7 CB concentrations in the Outer Tees area were 1.6 µg/kg dw at OT4 within the disposal site and 1.2 µg/kg dw at OT5 to the south of the disposal site. All CBs were below limits of detection at 3 of the Inner Tees stations (IT2, IT5 and IND5) and 5 of the Outer Tees stations (OT1, OT2, OT3, OT6 and OT8).

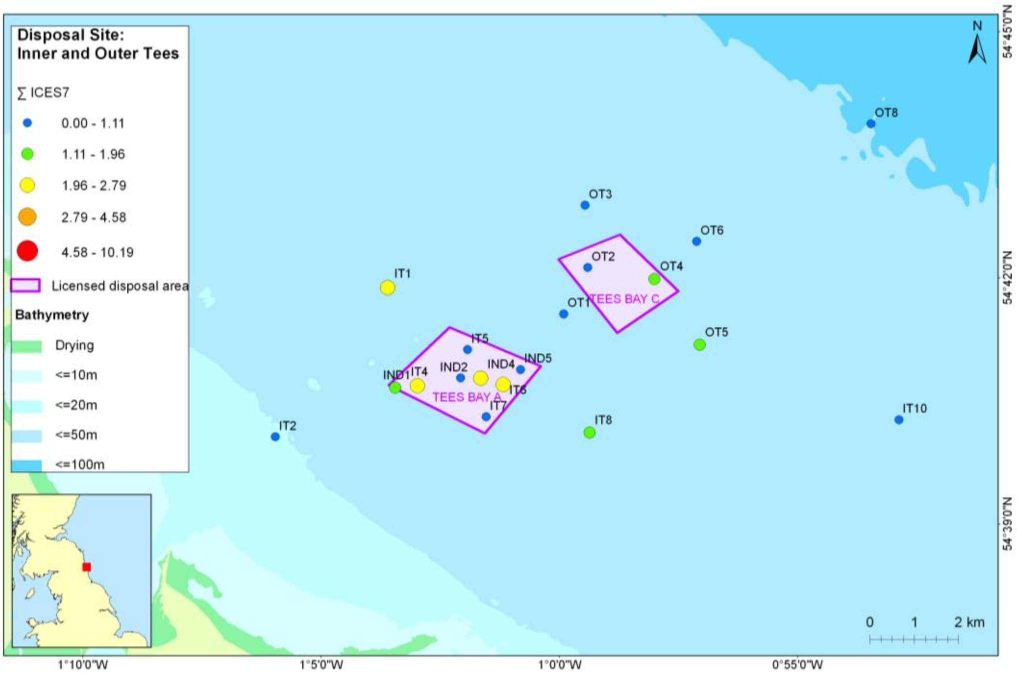


Figure 2.3.12. Summed ICES7 CB concentrations for the Inner and Outer Tees stations, 2009.

BDEs were detected in 18 of the 19 stations (∑11 BDEs range <0.11-4.1 µg/kg dw), with at least BDEs 47 and 99 detected at all stations apart from IND2. Concentrations were again higher in the Inner Tees area compared to the Outer Tees area (Figure 2.3.13). Highest ∑11 BDEs concentrations in the Inner Tees disposal area were 4.1, 3.7 and 2.6 µg/kg dw for IT4, IT6 and IND4 respectively, with 2.0 µg/kg dw also found at IND1 just west of the disposal area. Concentrations of 1.8 and 1.7 µg/kg dw at IT1 and IT8 north and south of the Inner Tees disposal zone were higher than in the Outer Tees disposal site. Highest ∑11 BDEs concentrations in the Outer Tees area were 1.3 µg/kg dw at OT4 within the disposal site and 0.9 µg/kg dw at OT5 to the south of the disposal site. Two congeners, BDEs 99 and 47, were responsible for > 50% of the ∑11 BDEs concentrations. BDE 183 was detected at 8 of the 19 stations which is indicative of widespread use of the octa or deca BDE technical mixes.

Concentrations of CBs at all stations were below Cefas AL1; no such ALs exist for BDEs. According to the OSPAR guidelines, all stations had 'good' environmental status for all ICES 7 CBs and 'good' status overall. No OSPAR guidelines exist for BDEs at present.

Concentrations of CBs have increased between 2008 and 2009 in most of the Inner Tees stations, whereas a decrease has occurred for most of the Outer Tees stations (Tables 2.3.5 and 2.3.6). This is probably a reflection of the fact that that the Outer Tees disposal site received no dredged material in 2008 and 2009 while the Inner Tees station received material in both years. However, it is important to note that concentrations in the Inner Tees disposal site at IT4 and IT7 remain 10-20 times lower than maxima observed in 2003. Trends in BDE concentrations at Inner Tees were more variable. Most stations in the Inner Tees disposal site, such as IND1, IT4, IT6 and IT7, had similar increases to CBs, but others such as IT5 and IND4 had decreased between 2008 and 2009. In the Outer Tees disposal site, BDE concentrations either decreased or stayed the same since 2008 and were up to ten times lower than observed in 2007.

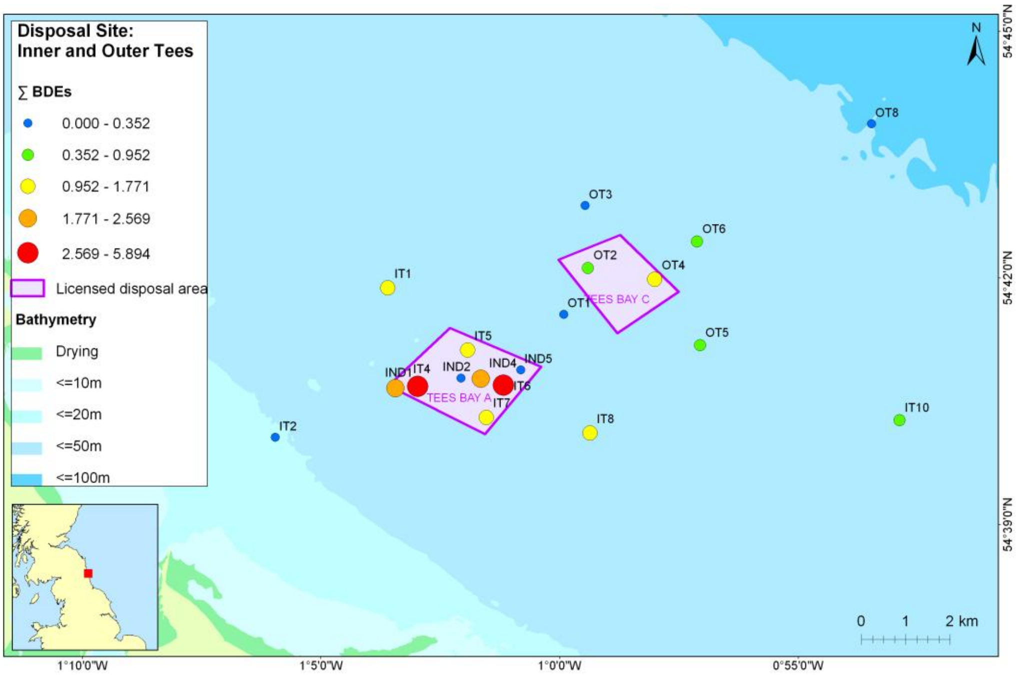


Figure 2.3.13. Summed 11 BDEs concentrations for the Inner and Outer Tees Stations, 2009.

2.3.4.5.4 Trace metals

2.3.4.5.4.1 Inner Tees

Based on average concentrations from the last 4 years of sampling (i.e., 2006 to 2009 incl.), there does not appear to be any difference in the concentrations of any metal species inside and outside the disposal site (Figure 2.3.14). Although the concentrations of some metals are slightly raised inside (Zn, Cr, Cu), these are not significant. To place the metals loading at Inner Tees into a more national context, the loading at this site during 2009 represented over 80% of the total loading of all the disposal sites featured in this report. The conclusion obtained based on Figure 2.3.14, therefore, presumably results from the highly dispersive nature of this area.

Station code	∑ICES 7 CBs concentration (in µg/kg)							
	2002	2003	2004	2005	2006	2007	2008	2009
IT2		*0.7*						*0.7*
IT1					0.83	1.54		2.13
IND1					*0.7*	*0.7*	*0.7*	1.96
IT4		26.4			*0.7*	2.8	*0.7*	2.75
IND2					*0.7*		*0.7*	*0.7*
IT5		*0.7*			*0.7*		0.92	*0.7*
IND4						4.62	1.76	2.15
IT7		24.1			*0.7*	1.7	*0.7*	1.04
IT6		*0.7*			*0.7*	0.82	2.2	2.39
IND 5						0.95	*0.7*	*0.7*
IT8		*0.7*			*0.7*	1.5	1.64	1.79
OT1					*0.7*		*0.7*	*0.7*
OT2					*0.7*		*0.7*	*0.7*
OT3					0.9	*0.7*	*0.7*	*0.7*
OT4					1.28	5.8	1.5	1.61
OT6					0.83		1.81	*0.7*
OT5					0.83	3.49	4.19	1.25
IT10		*0.7*					1.08	0.93
OT8					*0.7*		*0.7*	*0.7*

Table 2.3.5. Temporal trends (2003-2009) of ∑ICES 7 CBs concentration (in µg/kg) at Tees in the stations sampled during 2009. Note, concentrations in italic represent estimates of concentrations for samples where all ICES 7 congener concentrations were below LODs)

Station code	∑11 BDEs concentration (in µg/kg)			
	2006	2007	2008	2009
IT2				0.30
IT1	3.75	2.43		1.75
IND1	2.85	0.92	0.50	2.10
IT4	3.17	6.19	1.99	4.13
IND2	1.02		0.22	*0.11*
IT5	1.04		1.84	1.45
IND4		3.31	2.99	2.57
IT7	1.32	1.20	0.64	1.40
IT6	1.61	1.46	2.80	3.67
IND 5		1.19	0.20	0.20
IT8	1.22	2.51	0.95	1.66
OT1	0.84		0.18	0.23
OT2	1.06		0.38	0.43
OT3	1.71	1.04	0.73	0.26
OT4	2.04	9.91	0.82	1.26
OT6	1.55		0.87	0.63
OT5	1.56	8.21	3.41	0.89
IT10			0.60	0.68
OT8	0.96		0.79	0.35

Table 2.3.6. Temporal trends (2003-2009) of ∑11 BDEs concentration (in µg/kg) at Tees in the stations sampled during 2009. Note, concentrations in italic represent estimates of concentrations for samples where all 11 BDE congener concentrations were below LODs. Limits of detection for BDEs improved between 2007 and 2008 and therefore values assigned to congeners below LOD are lower in 2008 and 2009, resulting in a step decrease in ∑11 BDEs concentration for samples with congeners below LODs)

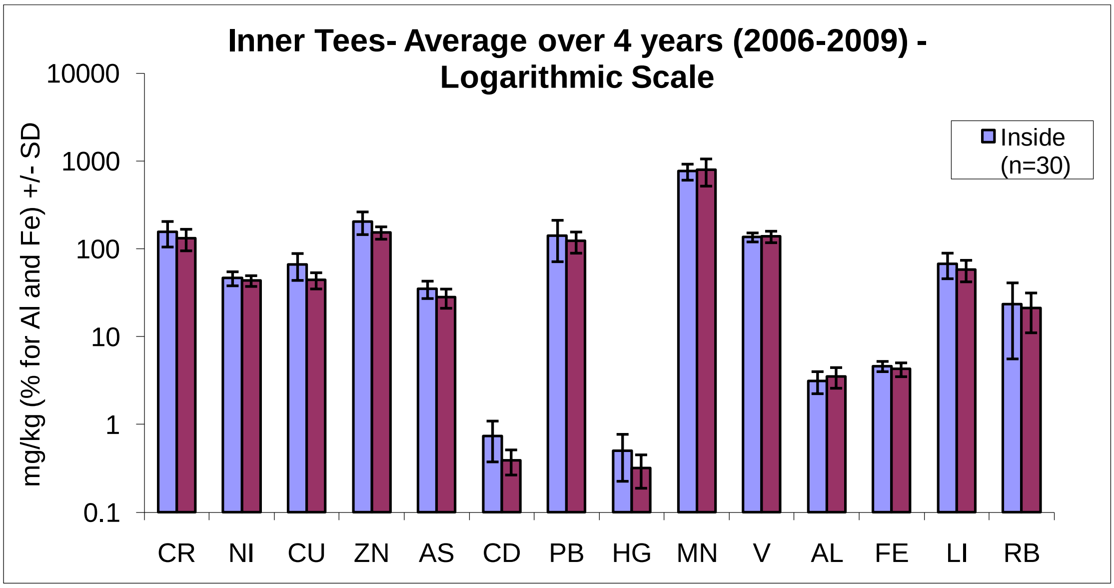


Figure 2.3.14 Average metal concentrations inside and outside for metal concentrations at the Inner Tees between 2006 and 2009 inclusive

The temporal changes in the metals concentrations between 2006 and 2009 for stations inside and outside the disposal site are presented in Figures 2.3.15 and 2.3.16 respectively. These data indicate that there does not appear to be any increase in metals concentrations over this time period, either with or outside the disposal site. Within the disposal site, peak concentrations for many metals (e.g., Cr, Cu, Zn, As, Pb, Mn, V) appear to have been in 2007 (although none were significantly higher relative to the other three years) with 2009 values being somewhat typical for most (except Rb and Li where the highest concentrations found inside the disposal site was in 2009). For stations outside the disposal site, the maximum average concentrations for many metals (e.g., Cr, Pb, Mn, V, Li) appear to have occurred in 2009, although none of these increases appear statistically significant.

When comparing the Tyne preliminary baseline with OSPAR BACs (Table A4, Appendix 4), Pb enrichment is expected and this is confirmed across the whole area (Table A5, Appendix 4), but more enriched (>2X) within the Inner Tees disposal site (Figure 2.3.17). In 2009, there is distinct enrichment within the Inner Tees disposal site, in Cd and Cu, decreasing towards the eastern edge of the disposal site. However, at IND2, in the centre of the disposal site, there is no enrichment for the majority of trace metals, except Ni, and in addition this site was very high in silt/clay content (99%). Outside of the site, at IT2, there is relatively high Cr enrichment (>2X).

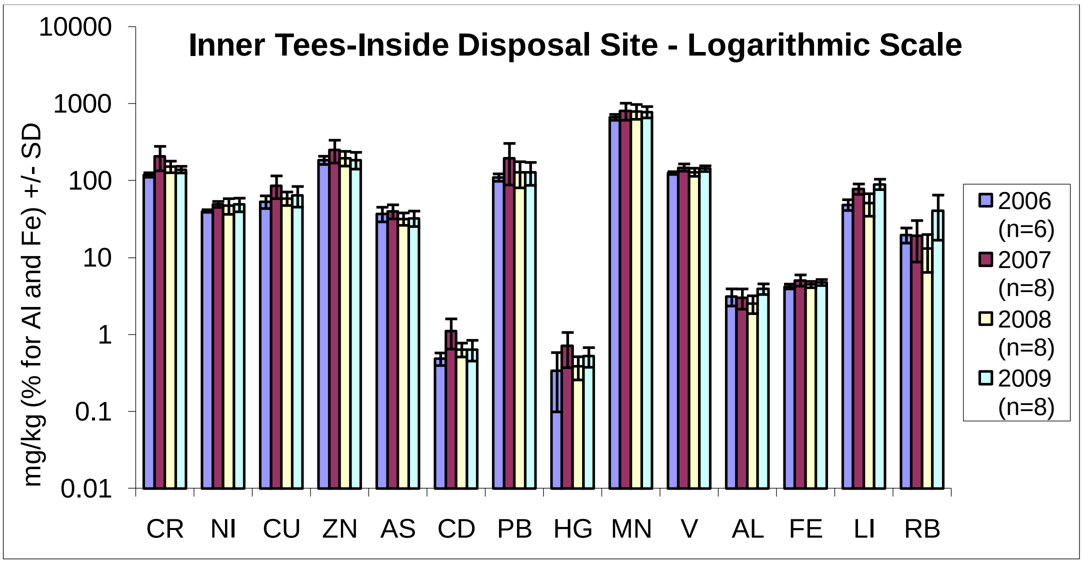


Figure 2.3.15. Average metal concentrations inside the Inner Tees disposal site from 2006-2009

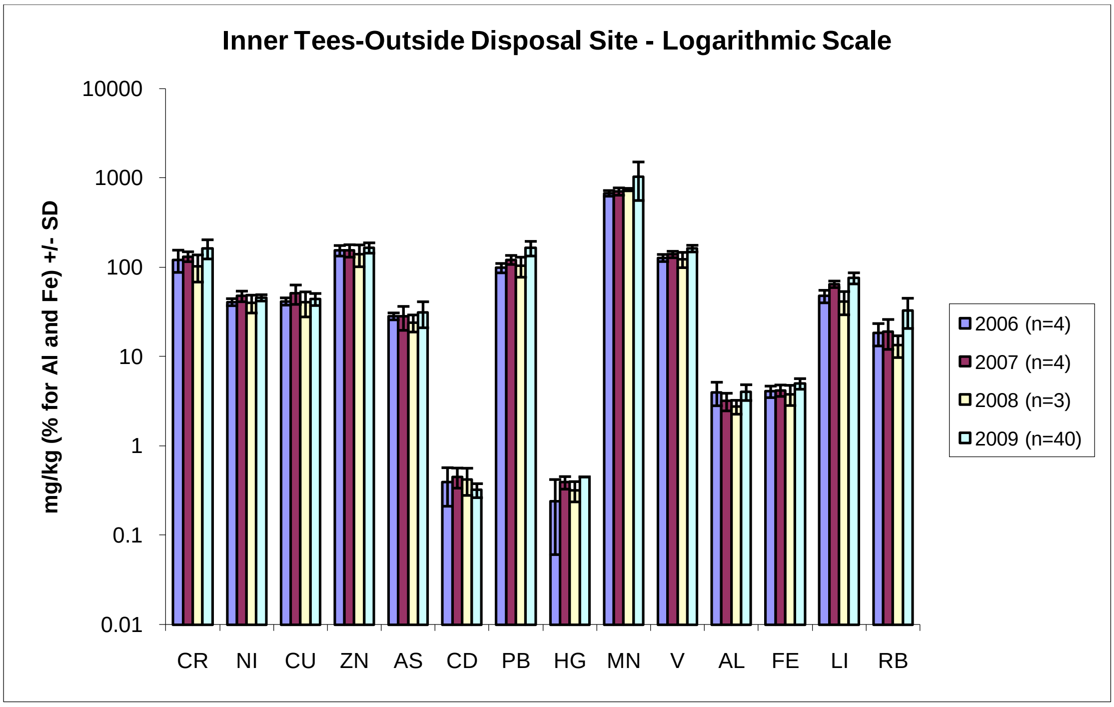


Figure 2.3.16. Average metal concentrations outside the Inner Tees disposal site from 2006-2009.

2.3.4.5.4.2 Outer Tees

Based on average concentrations from the last 4 years of sampling, there does not appear to be any significant difference between the concentrations found inside the Outer Tees disposal site and outside for any metal species (Figure 2.3.18).

In contrast to the observation at Inner Tees where the highest concentration inside the disposal site for many metals were found during 2007, at the Outer Tees this appears to be 2009 (Figure 2.3.19). However, although such values were relatively high in 2009 for Cr, Zn, Pb, Mn, V and Li, they were not significantly higher from all the previous 4 years of surveying. Outside the Outer Tees disposal site, concentrations of metals were not noticeably elevated during 2009 and they appear somewhat in line with previous years for all metals (Figure 2.3.20). Of note is that while a large decrease in the total amount of material disposed to Outer Tees this year resulted in decreased concentrations in some contaminants, PAHs and organohalogens for example, concentrations of trace metals did not show this decline.

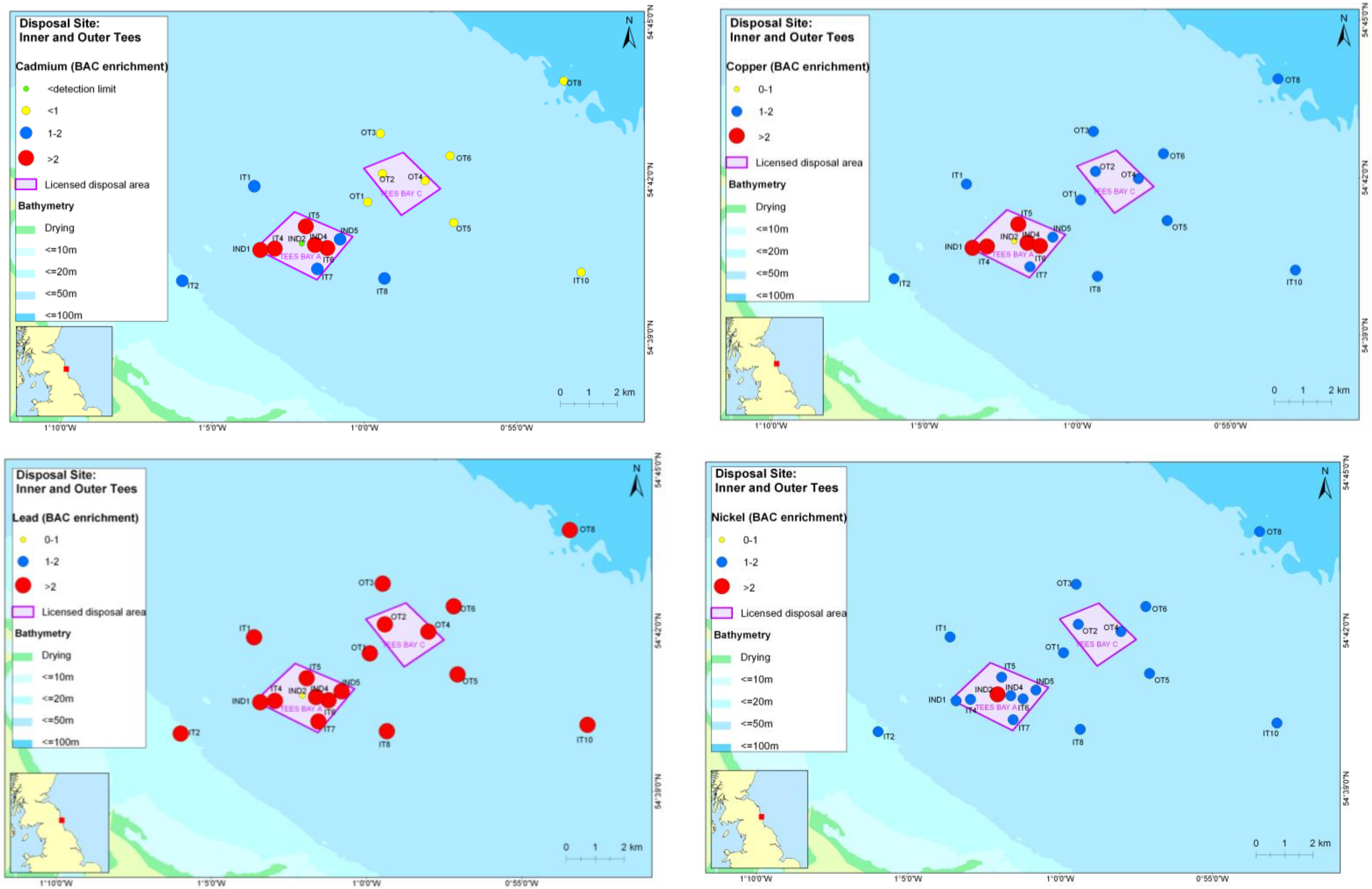


Figure 2.3.17 Enrichment to OSPAR BACs (raw/OSPAR BAC) at Tees (Inner and Outer) in 2009 for Cd, Cu, Pb and Ni.

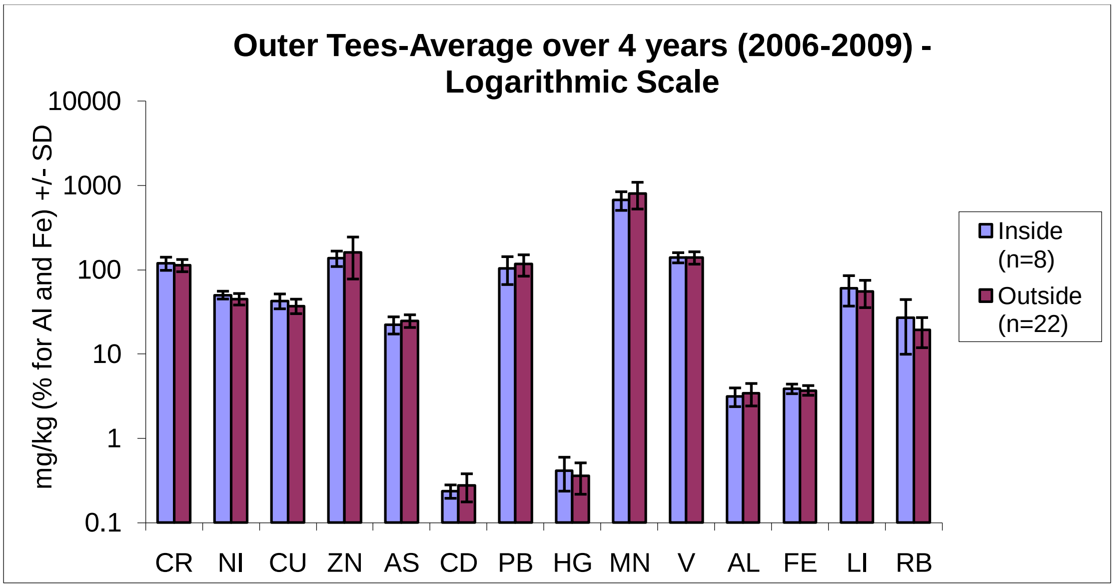


Figure 2.3.18. Average metal concentrations inside and outside for metal concentrations at the Outer Tees between 2006 and 2009 inclusive.

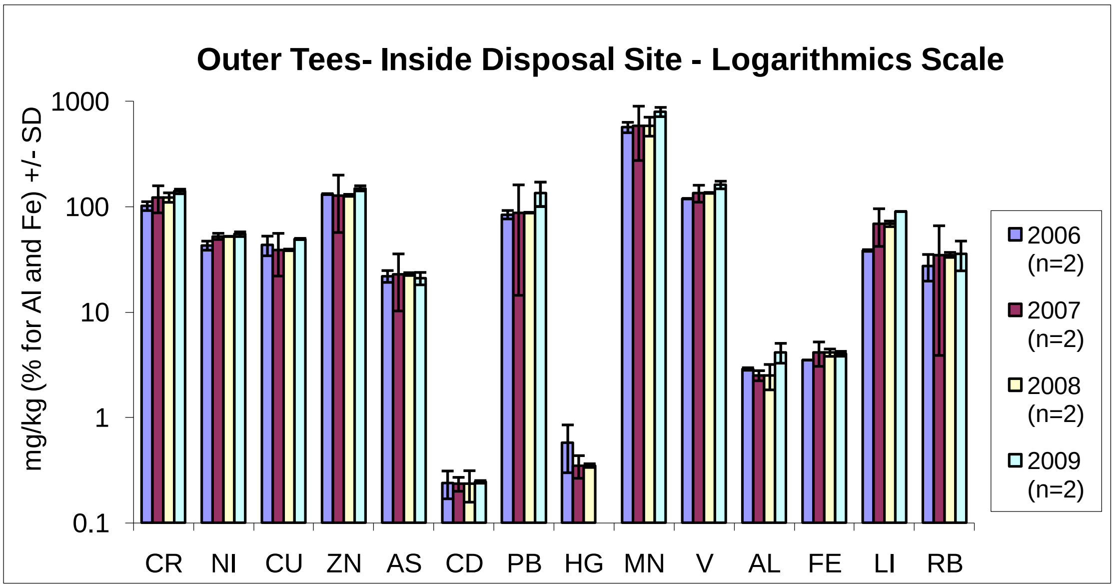


Figure 2.3.19. Average metal concentrations inside the Outer Tees disposal site from 2006-2009.

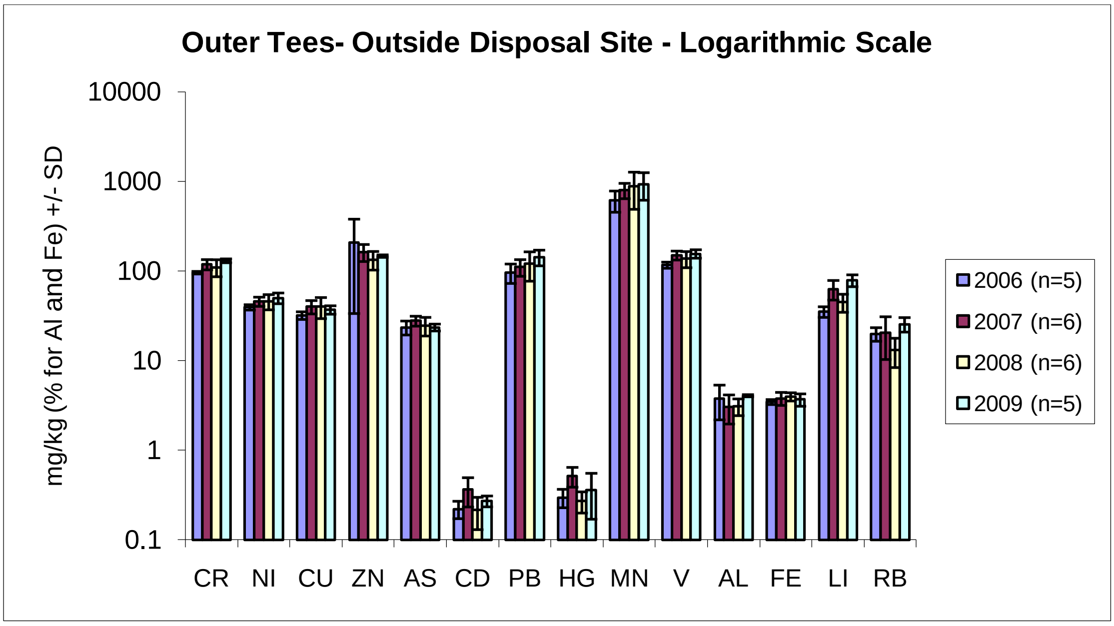


Figure 2.3.20. Average metal concentrations outside the Outer Tees disposal site from 2006-2009.

There has been no dredged materials disposal activity over the last 2 years, hence no trends are observed for this disposal site.

When comparing the Tyne preliminary baseline with OSPAR BACs (Table A4, Appendix 4), Hg and Pb enrichment is expected and this is confirmed across the whole area for Pb (Table A5, Appendix 4), with Hg most enriched (>X2) to the east offshore (Figure 2.3.17) but it is below detection for the rest of the survey. Enrichment is mapped for Cd, Cu, Pb and Ni in Figure 2.3.17. In 2009, there are no differences in enrichment in and outside the site, with the exception of Hg which is more enriched to the east, outside of the site. Interestingly, the elevated Cd values above OSPAR BACs observed for all stations associated with the Inner Tees survey was not observed for any stations sampled under the Outer Tees survey where all concentrations were below OSPAR BACs (Figure 2.3.17).

2.3.5 Conclusions

Analogous to the situation for North Tyne and Souter Point, monitoring at the Tees disposal sites has been conducted annually for a number of years and, as such, we have a good temporal dataset to draw upon when making contemporary assessments. While there have been no deposits at Outer Tees during the year subsequent to the 2009 survey, ongoing deposits at Inner Tees have been conducted using a sequencing approach whereupon deposits are placed at varying sections within the licensed boundary.

The macrofaunal communities within both disposal sites appear altered (relative to those outside), but show little sign of reductions in total abundance and biomass. TBT concentrations at these two sites remain very low, below LOD for most stations and a maximum concentration of only 0.04 mg/kg within the Inner Tees disposal site (this is despite a relatively high total TBT loading). PAHs remain very high within this region with most stations exceeding the ERM for LMW PAHs; the ERL for HMW PAHs was also exceeded at a number of stations. PAH concentrations continue to decline at the Outer Tees site as a consequence of the cessation of disposal activity. Organohalogens, while present at most sampling stations, are found at somewhat low concentrations; all stations sampled at Tees exhibited organohalogen concentrations below Cefas AL1 for CBs. Concentrations were, however, slightly increased relative to those found in 2008. A number of metals are enriched relative to OSPAR BACs (particularly at the Inner site)) due the metal mineralisation in the catchment and the results of mining activity, however, concentrations do not appear to have increased over the last four years.

These data imply that subsequent monitoring at Tees should continue, but effort should focus predominantly at determining the spatial extent of increased concentrations of PAHs and organohalogens. While it might be prudent to continue to sample for the macrofaunal communities, decisions regarding the processing of such samples should perhaps rest upon the outcomes of the contaminant assessments. Naturally, decisions regarding the precise nature of subsequent monitoring must embrace all intelligence relating to any specific changes to the nature and type of the disposal activity at these two sites.

2.4 Bridlington

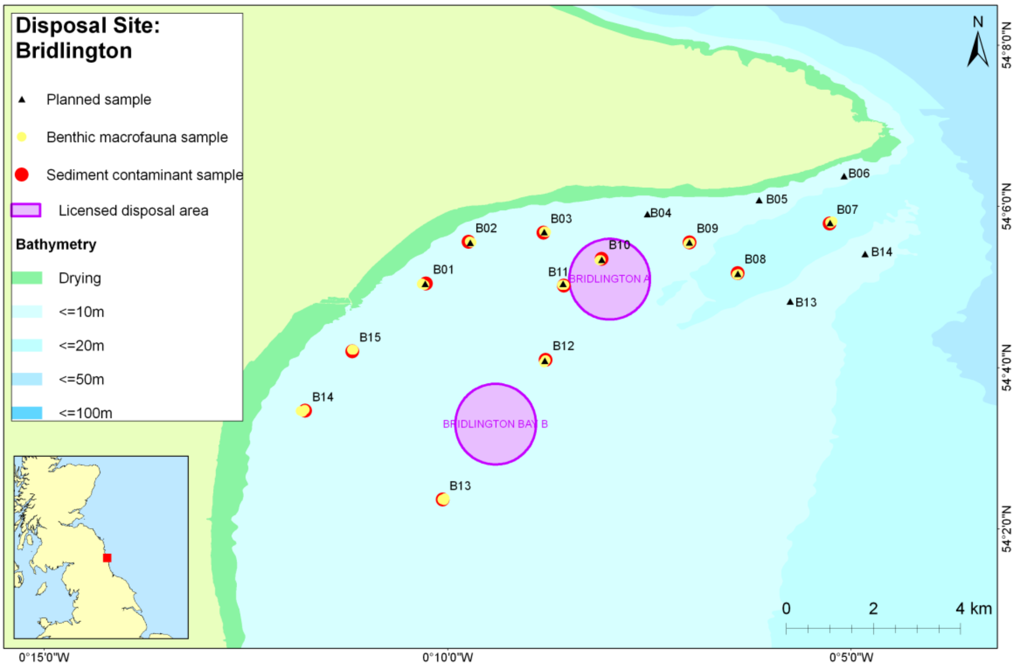


Figure 2.4.1. Bridlington Bay disposal site showing the locations of the stations sampled in 2009.

2.4.1 Background:

Disposal site HU015 is located in Bridlington Bay, to the northwest of the South Smithic sandbank. Charted water depth is approximately 7m. The site has been in use since the inception of the Food and Environment Protection Act in 1985. There is little site-specific information on hydrography etc. available, other than that from the Admiralty Charts for the area and the data presented in Hydraulics Research (2000). Prior to the mid-1980's, site HU010 'Bridlington Bay B' was used for the disposal of dredged material, located 3.5km to the southwest of the current site (Figure 2.4.1). Activity was shifted to HU015 to accommodate concerns of the fishing industry that HU010 was accumulating silty material.

Currently, HU015 is used for the disposal of maintenance dredged material from the port of Bridlington. The maximum quantity that is currently authorised for disposal in any one year is 30,000 tonnes. Material deposited at HU015 varies in composition but is generally a mixture of fine sands and silts, and can therefore be expected to move by both wave and tidal currents.

The Conservation Regulations 1994 required Defra (then MAFF) to review those existing disposal licences which it is considered are likely to have a significant effect on European sites such as SACs and SPAs. Disposal site HU015 Bridlington falls just within the Flamborough Head SAC. The site has been in use for many years and there is no direct evidence for an adverse effect on the marine habitats for which the SAC is identified. However, English Nature (now Natural England) advised that disposal could have the potential to impact the SAC. It was therefore agreed that a review be undertaken to help determine the likely effects of disposal on the SAC based on the available information at that time. Cefas undertook a desk-based review, which culminated in a report on disposal activity dated June 1999. In response to that review, EN advised that it had not been demonstrated sufficiently that there would not be a likely significant effect on the features for which the SAC had been identified.

During 2008/09, the MFA contacted Cefas to enquire what monitoring had been undertaken at Bridlington disposal site HU015. This was partly in response to the fact that the disposal licence for the Port of Bridlington has a condition stating that the Appropriate Assessment should be reviewed in 2005. The condition was placed on the licence at Natural England's request and to date the review has not been undertaken. NE concerns relate to the fate of the material once placed at the disposal ground and the risk of deposited material affecting features of the SAC which would be sensitive to such material. SLAB5 monitoring in 2009 involved a spatial assessment of the sediments (and contaminants) and infaunal communities in the area upon which to make an assessment for the potential of any impacts resulting from the disposal activity.

2.4.2 Impact hypotheses:

- Any changes to the physical habitat will be confined to within and the near vicinity of the disposal site, principally along the tidal axis
- Any adverse effects on the benthic biota will be confined to within and the near vicinity of the disposal site, principally along the tidal axis
- Effects on benthos within the disposal site will be limited to periodic and localised reductions in the densities/diversity of the benthos, *i.e.*, the disposal site will at no time be characterised as azoic
- The wider dispersal of fine particulates arising from dredgings disposal, including any wave-induced shoreward transport, will have no adverse consequences for the marine biota or for recreational/amenity interests

2.4.3 Parameters monitored (via non-Cefas charter vessel):

Sediment particle size
Sediment organic carbon and nitrogen
Macrofauna (video data at some stations)
Sediment contaminants

2.4.4 Results

A separate report has been produced for the MMO regarding the results of the 2009 survey at Bridlington, with special reference to their implications for the determination of impacts on the Flamborough Head SAC (please see Bolam *et al*., 2010)

2.4.4.1 Sediment particle size

Three sediment groups were identified for the 12 stations sampled at Bridlington Bay. Overall, sediments in sediment group BR1 are described as gravelly mud dominated by silt/clay (all >29 % silt/clay), while sediments in sediment group BR2 are described as gravelly muddy sands (all >14 % gravel). Sediments in sediment group BR3 are described as slightly gravelly sand, dominated by fine sand (all >59 % fine sand) (Table 2.4.1).

The distribution of these sediment groups is presented in Figure 2.4.2. The five BR3 stations generally comprise the south-eastern section of the survey area; BR07 & BR08 to the east of the disposal site and BR12, BR13 & BR14 to the south and southwest of the disposal site. These stations were well-sorted and comprised predominately fine sand (>90 %; Table 2.4.1). The stations within and those inshore of the disposal site were relatively poorly-sorted showing varying components of silt and gravel mixed with the sand. Within the disposal site, BR10 contained the highest proportion of gravel (44 %) and relatively low silt/clay content (2 %), while BR11 contained 36 % silt/clay. Similarly, sediments of those stations inshore of the disposal sites were predominantly sandy with varying proportions of silt and gravel.

Station	Sediment group	Sample Type	Sediment description	Gravel (%)	Sand (%)	Silt/clay (%)
B01	BR1	Unimodal, poorly sorted	Slightly gravelly muddy sand	1.7	69.1	29.2
B02	BR2	Polymodal, very poorly sorted	Muddy sandy gravel	30.6	54.3	15.1
B03	BR1	Bimodal, very poorly sorted	Gravelly Mud	6.1	41.6	52.3
B07	BR3	Unimodal, moderately sorted	Slightly gravelly sand (fine)	1.4	91.9	6.7
B08	BR3	Unimodal, well sorted	Slightly gravelly sand (fine)	0.2	99.3	0.5
B09	BR2	Polymodal, very poorly sorted	Gravelly muddy sand	23.3	57.0	19.7
B10	BR2	Polymodal, very poorly sorted	Sandy gravel	43.8	53.9	2.3
B11	BR1	Trimodal, very poorly sorted	Gravelly Muddy Sand	7.0	56.8	36.2
B12	BR3	Unimodal, well sorted	Slightly gravelly sand (fine)	0.0	99.4	0.6
B13	BR3	Unimodal, very well sorted	Sand (fine)	0.0	99.7	0.3
B14	BR3	Unimodal, moderately well sorted	Slightly gravelly sand (fine)	0.0	95.5	4.4
B15	BR2	Polymodal, very poorly sorted	Gravelly muddy sand	14.5	62.0	23.5

Table 2.4.1. Sediment descriptions and summary statistics, for each sample, calculated using Gradistat (Blott and Pye, 2001) for each sediment group defined at Bridlington.

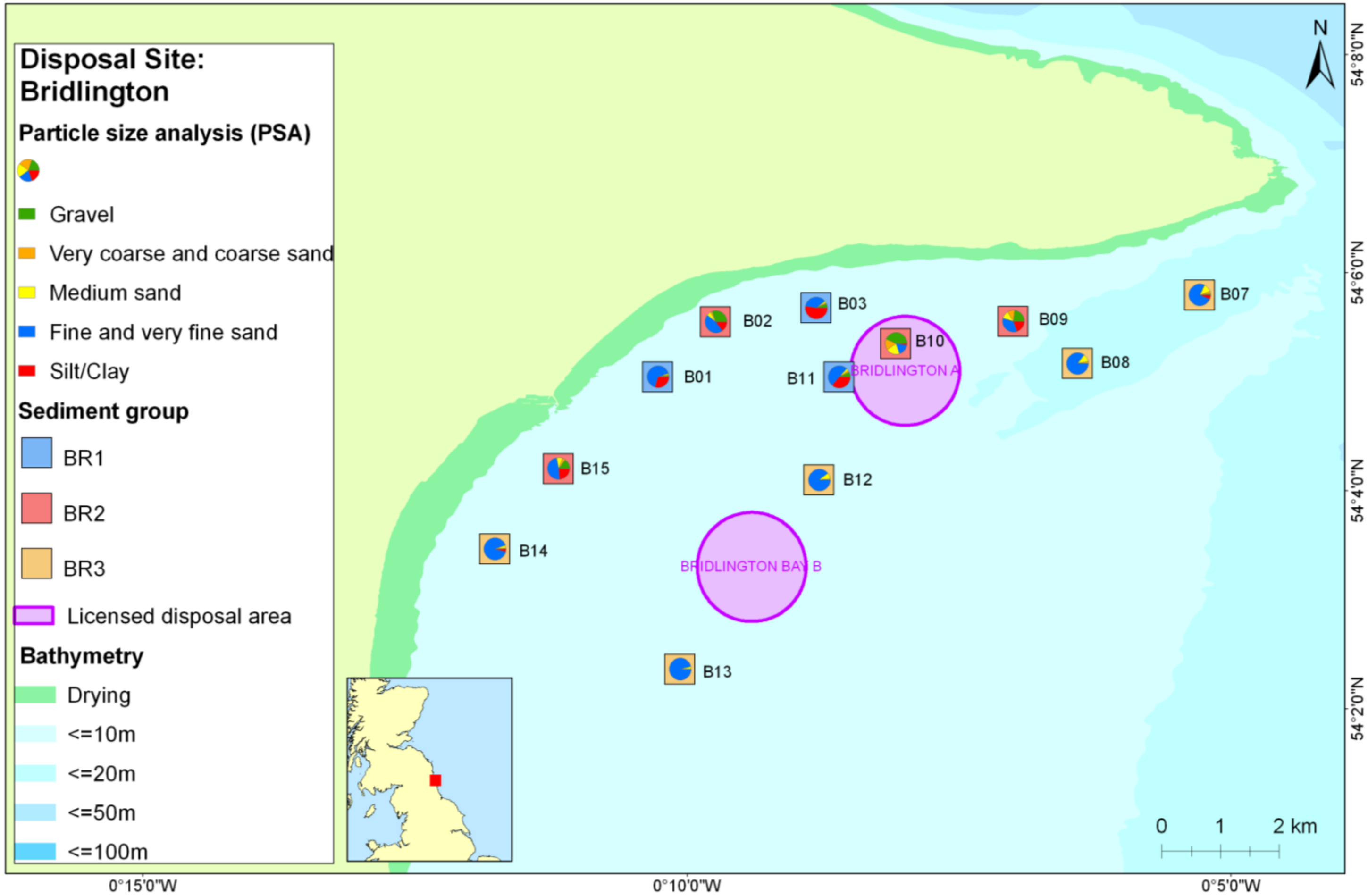


Figure 2.4.2. Sediment groups (coloured squares) overlain with pie charts showing proportions of gravel, very coarse sand and coarse sand, medium sand, fine and very fine sand and silt/clay at each station.

2.4.4.2 Sediment organic carbon and nitrogen

The sediment organic carbon and nitrogen contents of the samples from Bridlington are presented in Table 2.4.2, and mapped in Figure 2.4.3. Organic carbon values (on the <63 µm sediment fraction) were generally between 2 – 3 %, except for B14 south of the disposal site (0.99 %) and B07 at the northeast limit of the survey (3.54 %). Sediment nitrogen contents were all below 0.5 % (<63 µm sediment fraction), the lowest being 0.07 % at B14, the most south-westerly station sampled.

Sample code	Silt/clay (%)	<63um: Organic carbon (%m/m)	<63um: Nitrogen (%m/m)	<2mm: Organic carbon (%m/m)	<2mm: Nitrogen (%m/m)
B01	29.25	2.00	0.16	1.3	0.1
B02	15.13	2.97	0.48	0.31	<0.03
B03	52.40	2.34	0.19	2.03	0.15
B07	6.70	3.54	0.31	1.99	0.12
B08	0.55	n	n	0.22	<0.03
B09	19.79	3.04	0.25	1.55	0.12
B10	2.36	n	n	0.25	0.04
B11	36.23	2.93	0.23	n	n
B12	0.57	n	n	0.1	<0.03
B13	0.31	n	n	0.09	<0.03
B14	4.45	0.99	0.07	0.14	<0.03
B15	24.06	2.00	0.19	0.63	0.1

Table 2.4.2. Organic carbon and nitrogen (% m/m) on <63 µm sediment fraction and <2 mm sediment fraction. ‘n’ is used to represent not measured.

2.4.4.3 Macrofauna

2.4.4.3.1 Video analyses

Due to the small size of the vessel, the camera equipment available and the turbidity of the water at the time of survey, the quality of the underwater video was not optimal. For the majority of the stations (i.e., B01-03; B07-15) video data was obtained at the point where the grab sample was collected. For stations B04 and B05, the camera was held just above the seabed while the survey vessel slowly drifted.

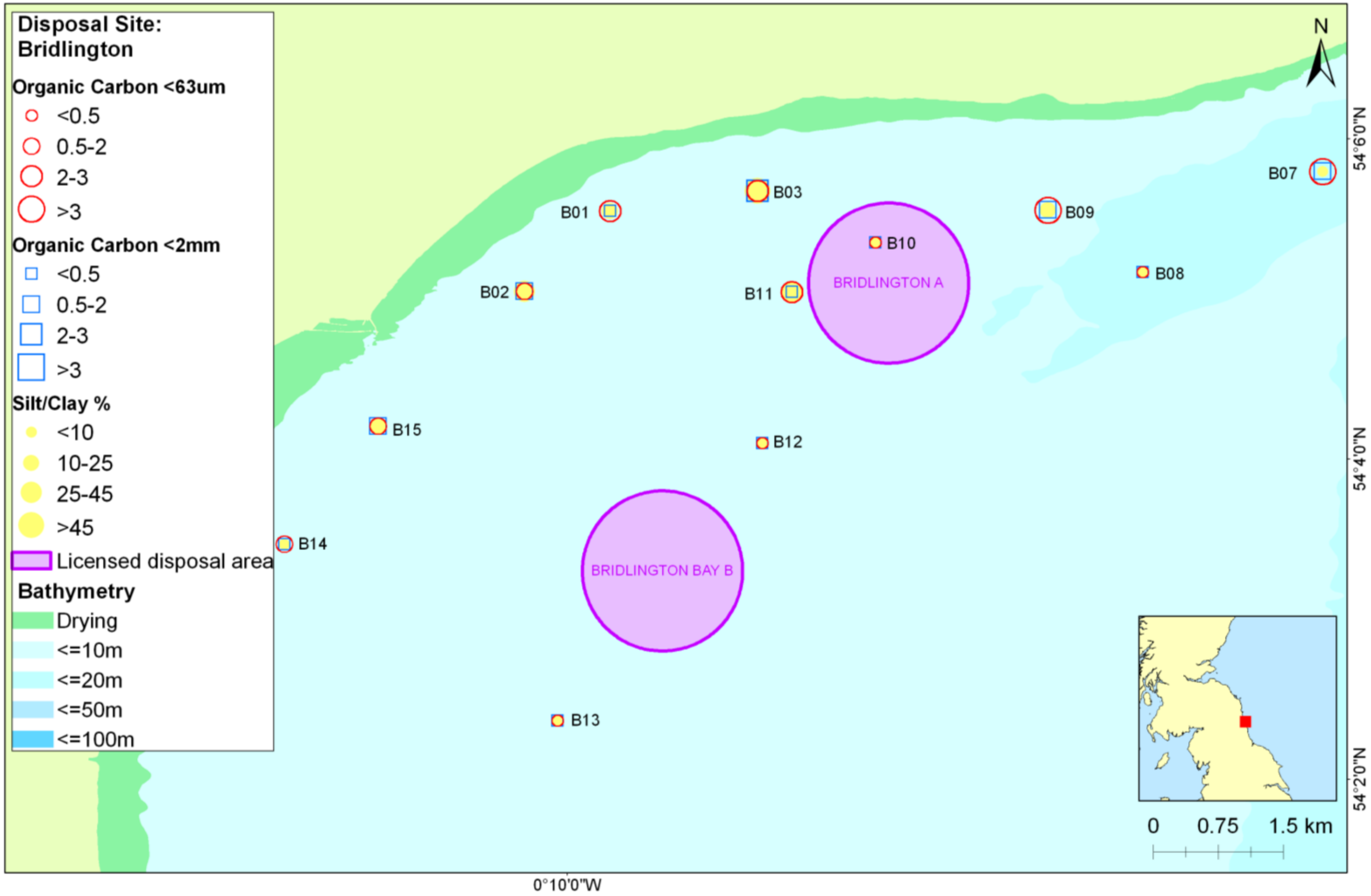


Figure 2.4.3. Organic carbon and nitrogen (% m/m) on <63 µm and <2 mm sediment fractions for all stations.

Analyses of the video data allowed an assessment of the visual characteristics/features of each station as summarised in Table 2.4.3. The two stations within the disposal site (B10 and B11) comprised mixed sediment types (mud, sand, gravel, cobbles) and mussels. The stations inshore of the disposal site (B01 – B05) were visually dominated by kelp, and while the more southerly inshore stations (B01 – B03) were muddy sand/gravel in nature and exhibited significant mussel densities, the two more northerly stations (B04 and B05) were coarser, comprising sand and cobbles. The stations to the north-east of the disposal site (B07 – B09) were visually described as muddy sand with mussels apparent at the sediment surface. The stations further south of the disposal site (B12 to B15) were predominantly sandy in nature and mussels observed at only one of these stations.

Station	Lat	Lon	Depth (m)	Description
B01	54.084	-0.1713	7.2	Gravelly muddy sand with mussels and brown algae (kelp?)
B02	54.0925	-0.162	6.1	Muddy sand with mussels and brown algae
B03	54.0947	-0.1467	6.7	Gravelly muddy sand with mussels and kelp
B04	54.0984	-0.1254	n/a	Cobble reef, heavily encrusted with red algae and kelp. Sand between cobbles
B05	54.1013	-0.1023	n/a	Cobble reef, heavily encrusted with red algae and kelp. Sand between cobbles
B07	54.0966	-0.0877	14.6	Mussels on sandy mud
B08	54.0861	-0.1067	14.3	Gravelly muddy sand
B09	54.0926	-0.1167	10.0	Mussels on muddy sand
B10	54.089	-0.1348	n/a	Mussels on gravelly muddy sand
B11	54.084	-0.1428	8.4	Mussels on muddy sand with pebbles and
B12	54.0681	-0.1466	11.2	Sand
B13	54.0394	-0.1674	13.4	Sand
B14	54.0577	-0.1964	10.9	Sand with worm tubes
B15	54.0704	-0.1864	9.6	Mussels on gravelly sand

Table 2.4.3. Results of the underwater video analyses.

2.4.4.3.1 Macro-infaunal communities

2.4.4.3.1.1 Univariate analyses

One replicate from each of the twelve Hamon grab stations was processed and analysed for macrofauna (the other replicates can subsequently be processed to allow within-station variability to be determined if required). A total of 167 taxa were identified from the twelve grabs, including 23 colonial species and 47 species that occurred only once. The mussel *Mytilus edulis* was by far the most abundant species present (2,205 individuals in total), exceeding other species in abundance by an order of magnitude and accounting for 97% of the total biomass. The bivalve *Abra alba*, the crab *Pisidia longicornis* and the capitellid worm *Mediomastus fragilis* were the next most abundant species (239, 220 and 150 individuals present respectively).

Figure 2.4.4A indicates that the total number of species was highest (95 species) at station B11 (inside the disposal ground), and lowest at those stations south of the disposal site (B13, B12 and B14; 4, 9 and 14 species per grab respectively). These latter stations also exhibited the lowest number of individuals (Figure 2.4.4B). The highest number of individuals were recorded from station B07 (1,214 per grab) and B11 (989 per grab). Figure 2.4.4C shows that total biomass (ash-free dry weight) ranged from <0.07 g (stations B12, B13 and B14) to >49 g per grab at B07.

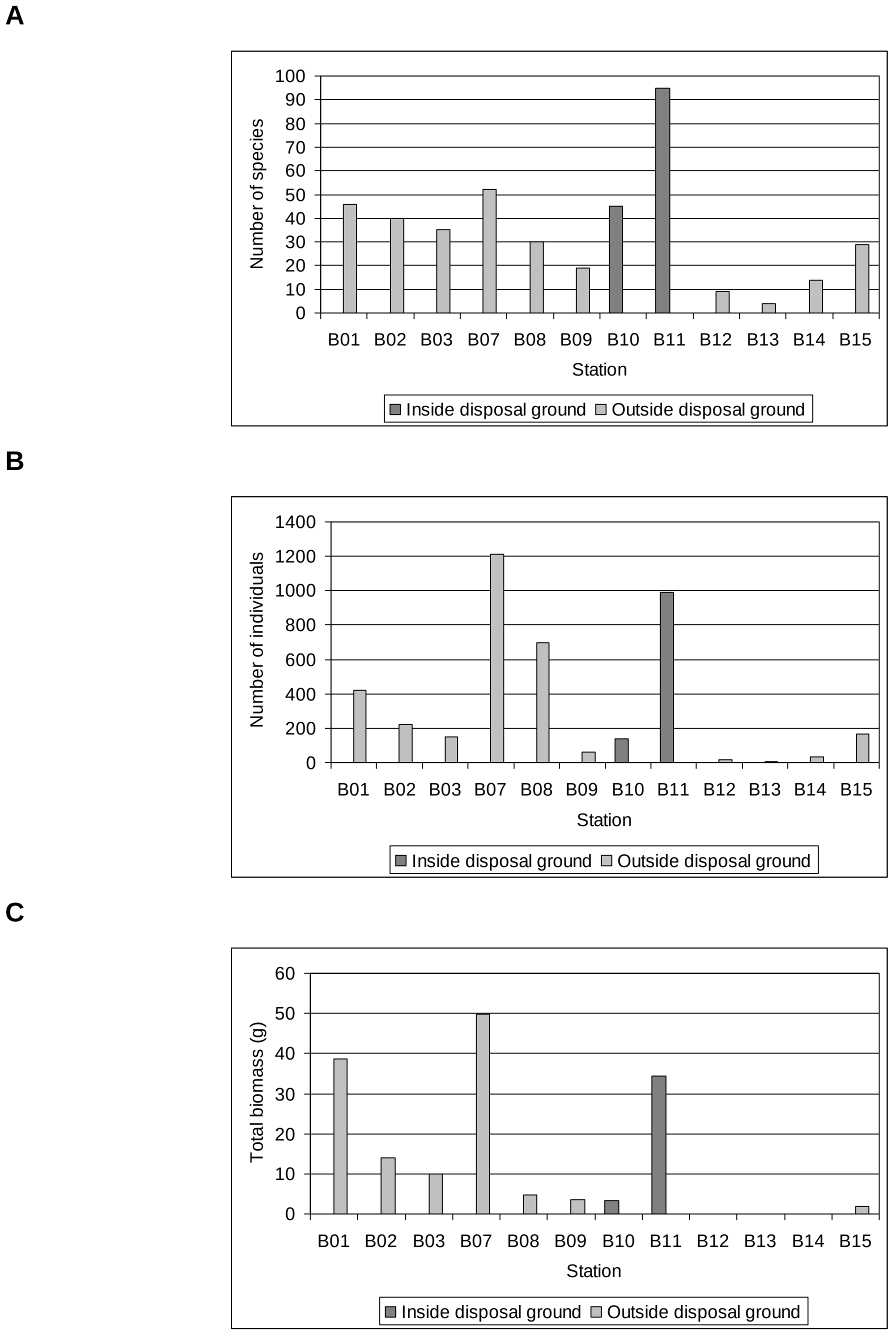


Figure 2.4.4. A. Total number of species. B. Total number of individuals. C. Total biomass (g ash-free dry weight) of the macrofauna at Bridlington 2009 (values per 0.1 m-2 grab).

2.4.4.3.1.2 Multivariate analyses

Non-metric multi-dimensional scaling analysis was performed on the species abundance and biomass data, the resulting 2-dimensional ordination plots are presented in Figure 2.4.5A-D. As *M. edulis* was so numerically and biomass dominant at the majority of the stations, this numerical approach was also performed with *M. edulis* excluded. Apart from the stations south of the disposal site, the communities of all stations clustered quite closely together, indicating a high degree of similarity in macrofaunal species abundance (Figure 2.4.5A) and biomass (Figure 2.4.5B). Station position relative to the disposal ground (inside or outside it) did not produce any patterns in the abundance or biomass data. Stations B12, B13 and B14 did not exhibit a strong similarity in abundance or biomass with the other stations; neither do they show a strong similarity to each other, except in biomass between B12 and B13. Generally, the same observations were apparent following the removal of *M. edulis* from the data (Figure 2.4.5C&D) except B08 shows increased similarity to B12-14. This indicates that these results do not simply reflect the variability of *M. edulis*, and that community structure where *M. edulis* is present differs from that where *M. edulis* is more-or-less absent.

Hierarchical cluster analysis (PRIMER v.6, Clarke & Gorley, 2006) with a similarity profile test (SIMPROF, significance level 5%) shows that stations B12, B13 and B14 cannot be significantly differentiated from each other in terms of macrofaunal abundance (Figure 2.4.6). These 3 stations show very little similarity in abundance to the other stations (<10 % similarity). The similarity percentages program SIMPER (PRIMER v.6, Clarke & Gorley, 2006) indicated that this dissimilarity is primarily caused by differences in the abundance of *M. edulis*, present in very low numbers at B12 and B14 and absent from B13.

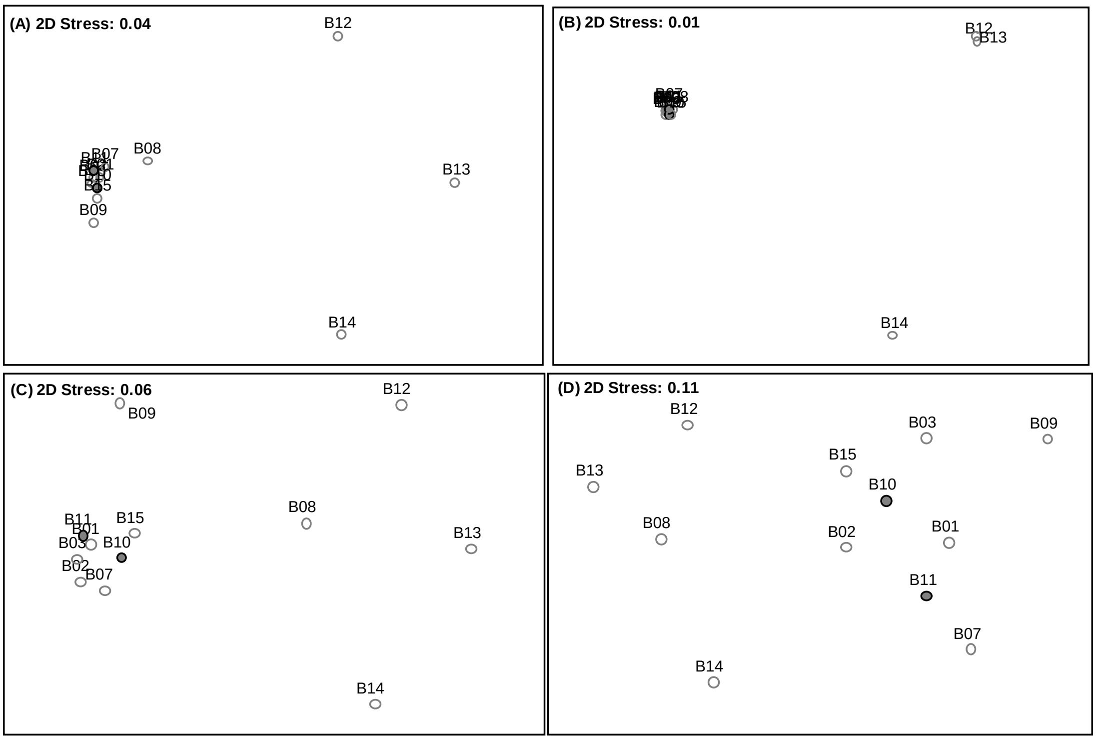


Figure 2.4.5A-D. MDS plots of Bridlington macrofauna, 2009. (A) abundance and (B) biomass including *M. edulis*; (C) abundance and (D) biomass excluding *M. edulis*. Shaded circles represent stations inside the disposal site (i.e., B10 & B11) while open circles represent those outside.

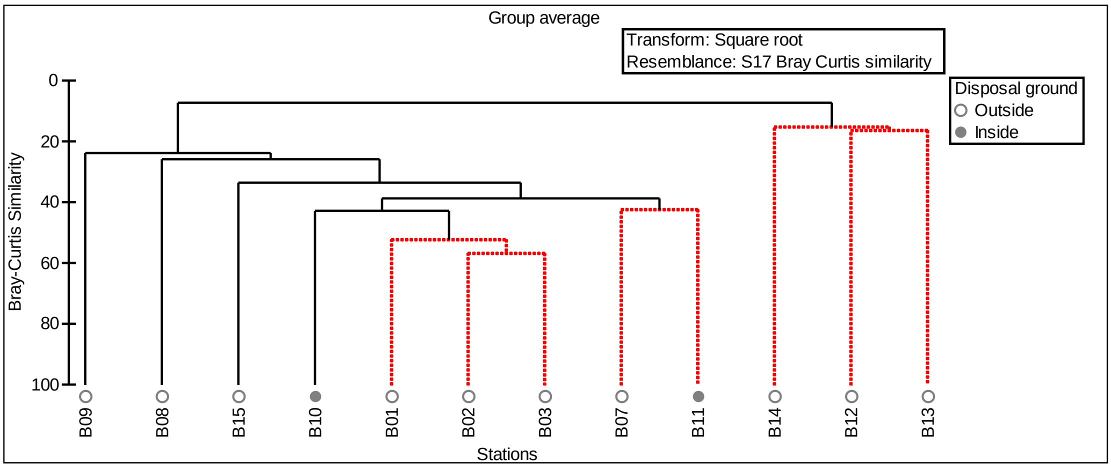


Figure 2.4.6. Hierarchical cluster analysis with a SIMPROF test (significance level 5%) of macofaunal abundance, Bridlington 2009. Stations connected by red lines cannot be significantly differentiated.

2.4.4.3.1.3 Mussels

Figure 2.4.7 shows the density of *M. edulis* sampled at each station. Taken together, the grab data and video data indicate that *M. edulis* reefs are potentially extensive within the disposal ground and within large areas of the southern part of Flamborough Head SAC.

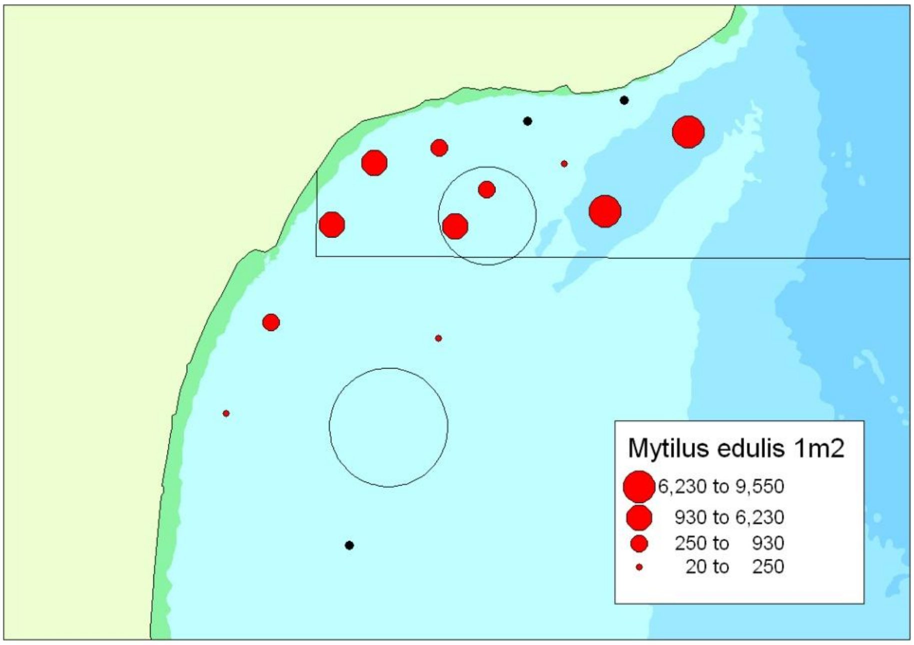


Figure 2.4.7. *Mytilus edulis* densities (m^{-2}) at the Bridlington 2009 stations. The straight lines on the map indicate the limit of the southern section of the Flamorough Head SAC.

2.4.4.4 Sediment contaminants

2.4.4.4.1 TBT

Primarily as a result of the comparably small quantities of dredged material disposed of at this site, the TBT loading at Bridlington Bay was relatively low compared with other sites monitored under SLAB5 during 2009. All 12 stations sampled at Bridlington were below limit of detection (including B10 and B11 that are located within the disposal site).

2.4.4.4.2 PAHs

The highest concentration of summed PAHs was 20,900 µg kg^{-1} at B07, the most north-easterly station sampled (Figure 2.4.8). Relatively high concentrations (19,200 µg kg^{-1} at B03 and 13,300 µg kg^{-1} at B09) were also exhibited by stations inshore of the licensed disposal site. Samples taken along a northeast to southwest transect through the disposal site (i.e., B10 – B14) all display low levels of summed PAH concentrations (all <1000 µg kg^{-1}). Samples taken at B01, B02, B09 and B15 exceed the ERL for LMW PAHs, while those from B07 and B03 exceed the ERM for LMW PAHs and the ERL for HMW PAHs.

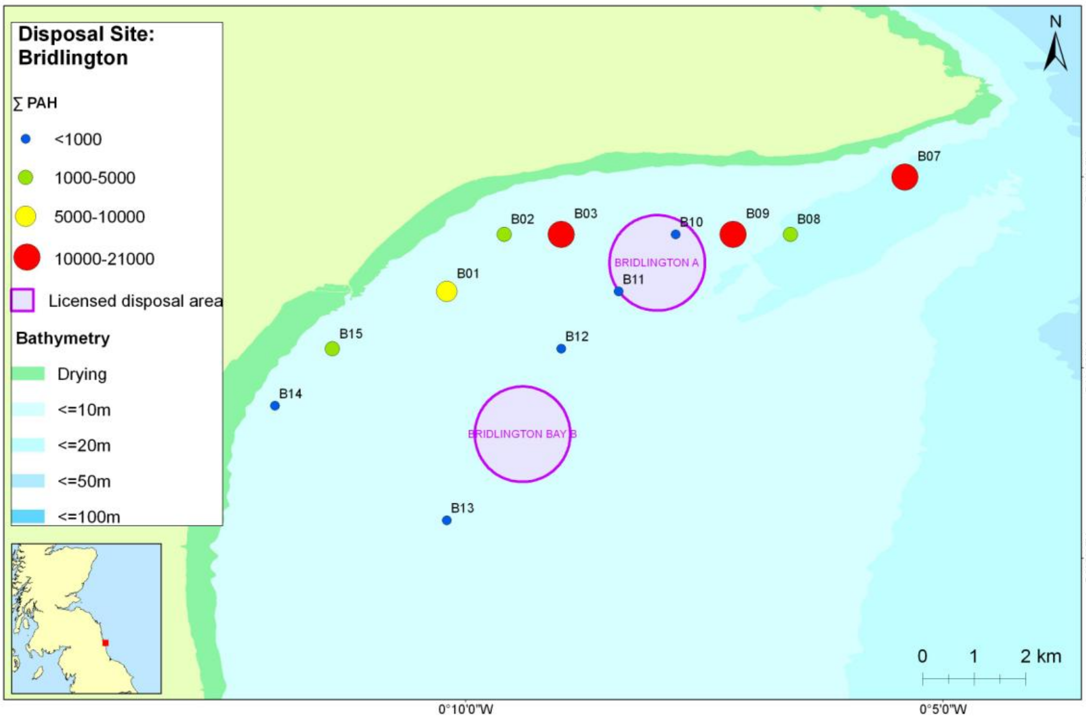


Figure 2.4.8. Summed PAH concentrations (µg kg^{-1}) for all stations at Bridlington 2009.

2.4.4.4.3 Organohalogens

At Bridlington, CBs concentrations were low at all stations, either close to or below the LODs (Figure 2.4.9). Indeed, ICES 7 CBs concentrations were below LODs at all stations and all

CBs were below LODs for 6 stations (B07, B08, B12, B13, B14 & B15). For the remaining 6 stations, only a few congeners were detected. These latter stations are inshore and to the east of Bridlington. CB concentrations can be considered to be at the lower end of those found in the northeast of England.

BDE concentrations were low at most stations, either at or below the LODs (Figure 2.4.10). There were a few exceptions, with highest BDE concentrations found at the inshore stations south of Flamborough Head (B03, B01 and B09 with ∑11 BDEs concentration of 1.8, 1.2 and 1.1 µg / kg dw respectively). In contrast, all BDE congeners were below LODs detected at stations B08, B12, B13 and B14. Intermediate values of 0.25 and 0.29 µg / kg dw were observed at stations B07 and B11. Generally, these concentrations can be considered as typical for the northeast of England. BDEs 47 and 99 were the largest contributors to ∑11 BDEs, reflecting the penta BDE mix as the source of contamination, although BDE183 was detected at B03 which is indicative of octa or deca BDE mix.

While there are currently no FEPA action levels for BDEs, concentrations of CBs at all stations were below Cefas AL1. According to the OSPAR guidelines, all stations had ‘good’ environmental status for all ICES 7 CBs and ‘good’ status overall.

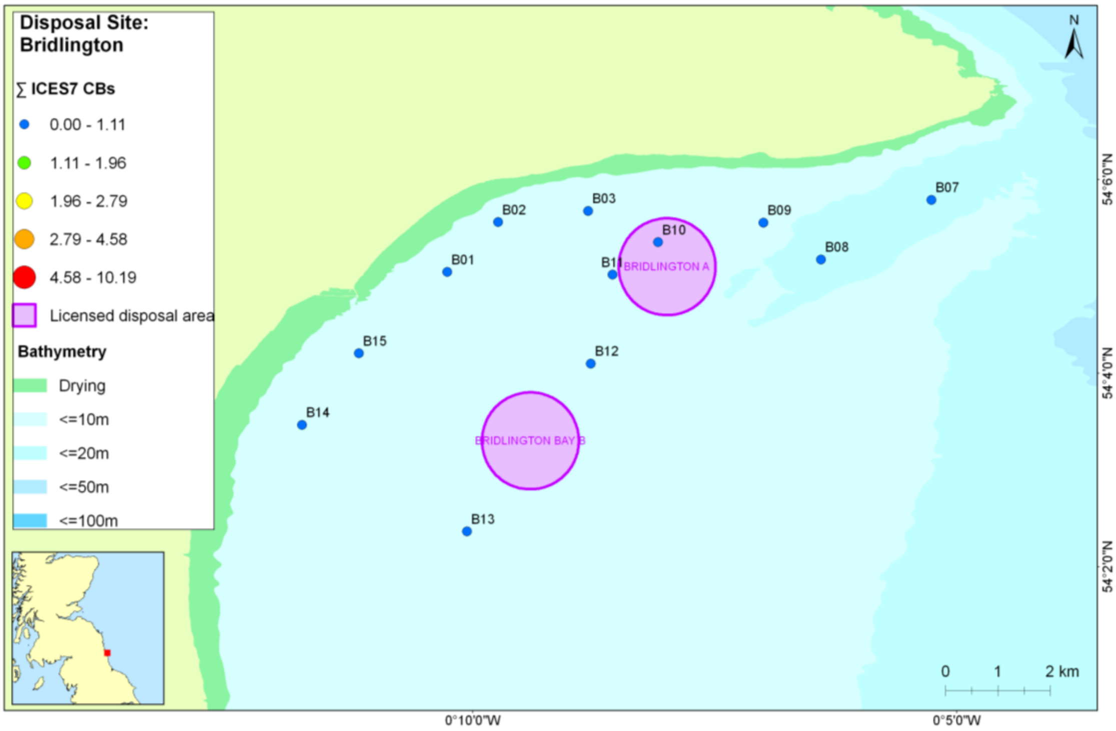


Figure 2.4.9. Summed ICES7 CB concentrations for Bridlington, 2009

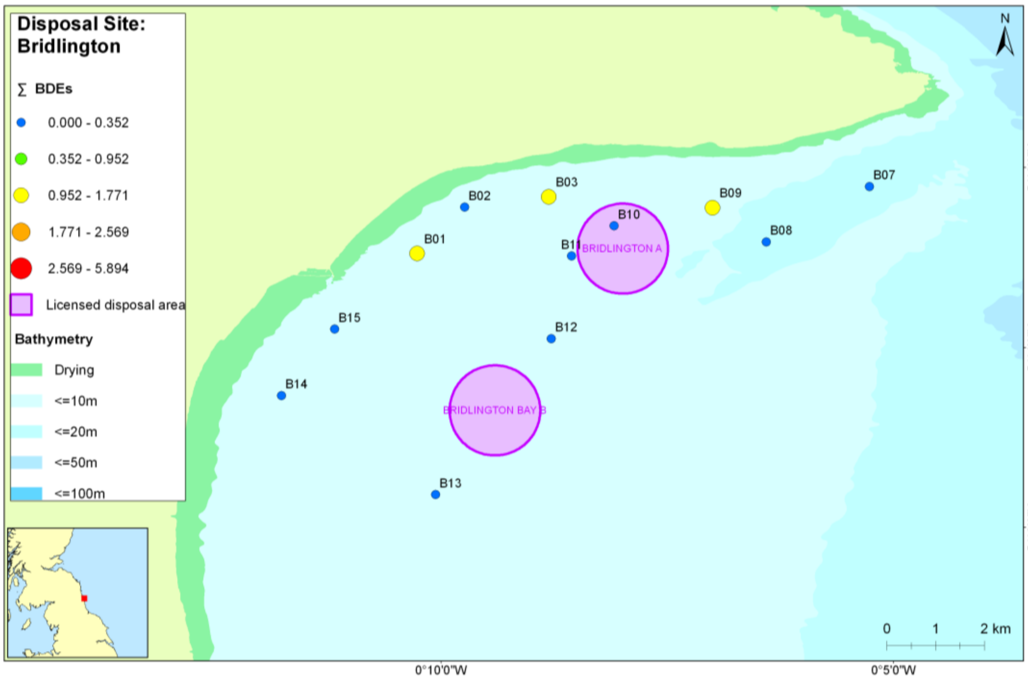


Figure 2.4.10. Summed 11 BDE concentrations for Bridlington, 2009.

2.4.4.4.4 Trace metals

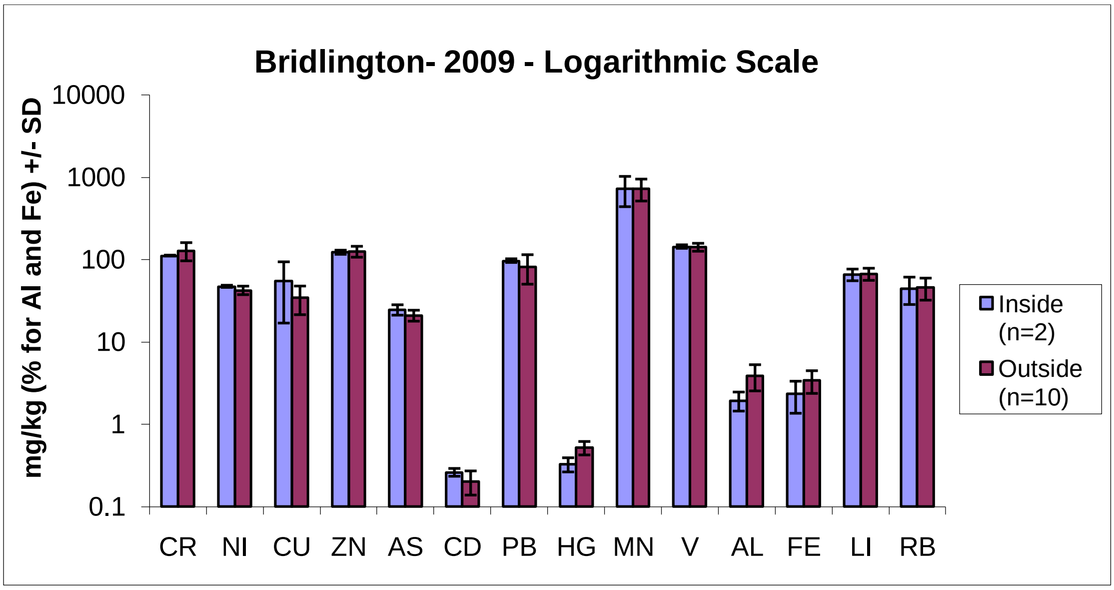


Figure 2.4.11. Average metal concentrations inside and outside for metal concentrations at the Bridlington in 2009.

There appears to be little difference in the concentrations of metals inside and outside the disposal site at Bridlington (Figure 2.4.11). Although Cr was slightly more concentrated outside, and Cu and Zn elevated inside relative to outside, none of these average differences were statistically significant.

When comparing the Humber preliminary baseline with OSPAR BACs (Table A4, Appendix 4) Cr, Cu, Hg, Ni and Pb enrichment is expected and this is apparent across the area, although Hg was below detection for most samples outside of the disposal site. Enrichment is mapped for As, Cr, Pb and Zn in Figure 2.4.12; there is relatively more enrichment within the disposal site and at B08, east of the site, for As and Cu. Pb and Zn are also relatively enriched within the site as well as offshore and east of the site. Cr is relatively enriched at two sites (B12 and B14), west of the disposal site.

2.4.5 Conclusions

The survey conducted at Bridlington was the first such survey conducted at this site under SLAB5. As such, the data provided present spatial assessments of the variability of measured variables in an attempt to determine the nature and extent of impacts associated with disposal activity.

High densities of mussels (*Mytilus edulis*) were sampled at the majority of stations inside the disposal site and at other stations within the SAC; these were associated with increased species diversity relative to more southerly stations where mussels were either absent or far less abundant. Video data confirm the presence of kelp forests (and other macroalgae) within the inshore regions of the SAC.

TBT concentrations at all stations were below limits of detection. PAHs were elevated at some inshore stations within the SAC; concentrations found exceed the ERM for LMW PAHs and the ERL for HMW PAHs. CB concentrations were low at all stations, either close to or below the limit of detection, indicating lower concentrations than expected for the northeast coast of England. BDE concentrations were low at most stations, either at or below the limit of detection; these concentrations being typical for the northeast coast of England. There were no observable differences between the concentrations of trace metals in sediments within and outside the disposal site. Trace metals concentrations of sediments in the inshore regions were between 1 and 2 times those of OSPAR BACs. These concentrations probably reflect natural mineralogical properties of the sediments and are unlikely to present any biological concern.

The data acquired have indicated that there is currently little evidence that the disposal operation at Bridlington is affecting the integrity of the ecological features of the Flamborough Head SAC; no further monitoring under SLAB5 appears warranted at this site unless significant changes to the disposal activities are anticipated.

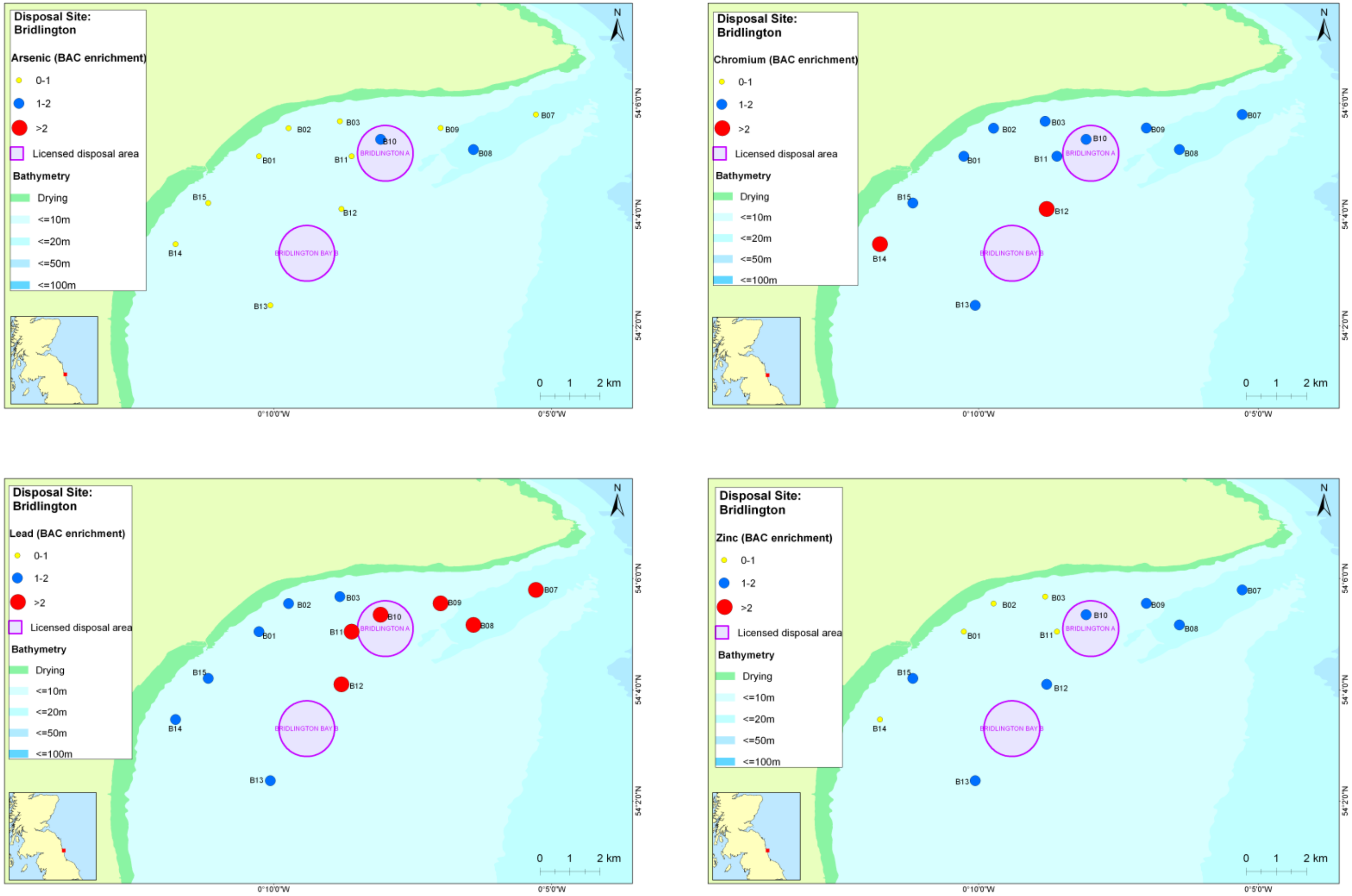


Figure 2.4.12. Enrichment to OSPAR BACs (raw/OSPAR BAC) at Bridlington in 2009 -As, Cr, Pb, and Zn.

2.5 Inner Gabbard East (TH056)

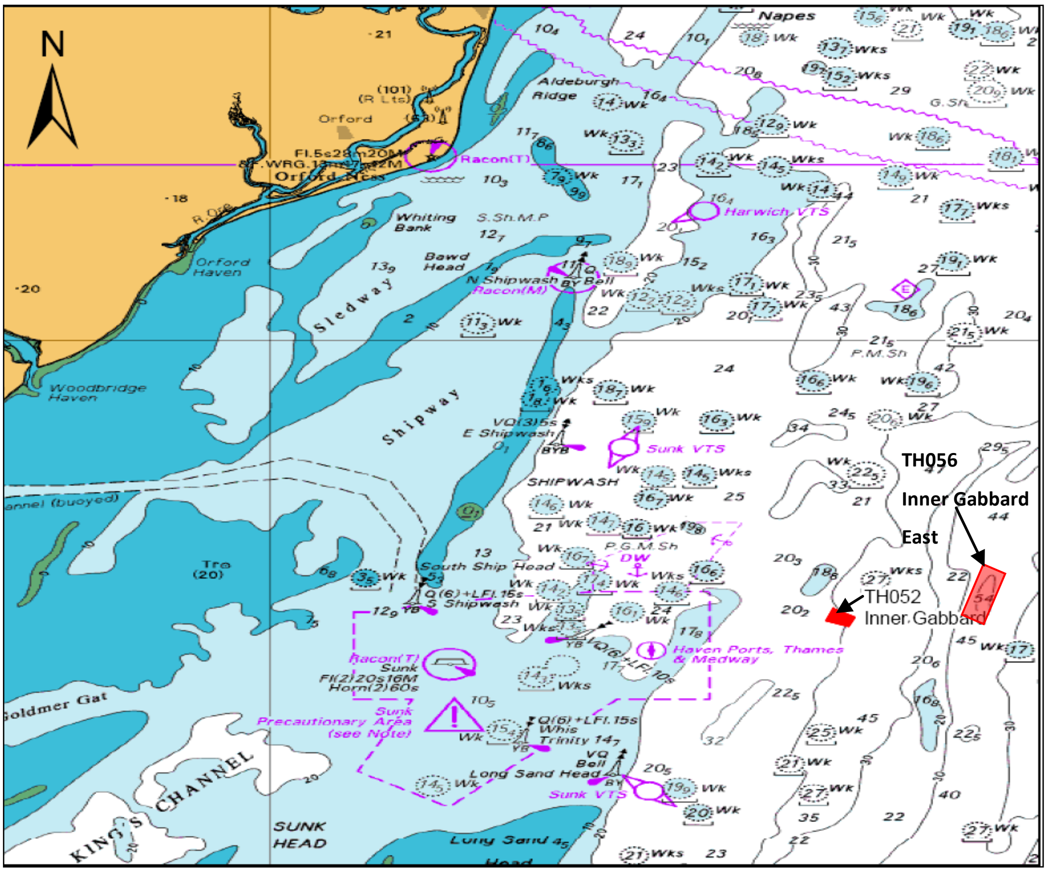


Figure 2.5.1. Map of the Harwich approach Channel, greater Thames Estuary, showing the position of the Inner Gabbard and Inner Gabbard East disposal sites. Note, the actual licensed boundary of Inner Gabbard East (TH056) is only approximately delineated on this figure, located east of TH052, in the deep trough approximately 55 m deep.

2.5.1 Background

Inner Gabbard East (TH056) is a new site characterised by Harwich Haven Authority (HHA) to take consolidated capital dredged material from the proposed container port development at Bathside Bay and from the recently-consented Felixstowe South Redevelopment (FSR). Inner Gabbard East is broadly similar in terms of wave and tidal flow climates and bed conditions to the existing Inner Gabbard (TH052) disposal site, being characterised as fairly featureless, flat sand and gravel beds. The main difference is depth, TH056 is in an elongated depression in the seabed approximately 55m deep.

The FSR was the first development to be realised and TH056 began to receive material from that project in March 2009. Although dispersion of material from the IGE site was not seen as a major issue, it was proposed it could be minimised by making a series of placements at one location creating localised mounds and effectively trapping material in the lower layers. As the location of the disposal site is in an elongated depression north to south, it was also proposed to form bunds to the northern and southern ends at the start of the disposal operations. These consist of more consolidated material and would form less ‘erodable’ ends to the deposit, providing some shelter from the prevailing currents and a measure of constraint to what would be more mixed material (sand/ clay/ stone) which would be placed between. The bunds would also prevent possible downslope movement of clay subsequently placed. Conditions were placed on the licence to ensure that the disposal was carried out as described.

However during the FSR project, it has become apparent that more of the dredged material was usable for use in the reclamation than previously thought, leading to a reduced import of new material to the disposal site. In addition, as a result of changes to the dredging methodology, more of the material destined for the IGE site, and particularly most of that dredged at first, was likely to be finer material containing a mixture of sands and clays. Therefore it was not possible to form initial bunds at the ends of the site. As a result MFA agreed to amend the licence conditions. The nature of the disposal operation has therefore changed to that originally assessed and agreed so that now material would initially be placed evenly over the site with more consolidated material deposited at the ends later in the operation, as described below.

- Material for disposal from trailer dredgers is to be placed by bottom dumping when stationary, located initially no closer than 250 m from the northern or southern limits of the site and no closer than 50 m from the eastern or western limits of the site. (The whole licensed disposal site is approximately 1,250m by 500m.) Material is to be placed evenly over this reduced area using a system of targeted and recorded locations for each disposal
- Rock and stiff clay is to be placed in the areas at the northern and southern ends of the site, in targeted loads to produce an even distribution. Barges, when dumping this material, are to be located no closer than 50 m from the disposal site limits

As a result of these changes, Cefas is required to identify this disposal site as a priority for monitoring to ensure that the disposal operation has been carried out as agreed, and to determine if the deposited material is remaining or being eroded.

2.5.2 Impact hypothesis

- to ensure deposited material is being maintained within the confines of the licensed disposal site

2.5.3 Parameters monitored

Macrofauna (for retention only)

Sediment particle size
Sidescan and multibeam

2.5.4 Results

2.5.4.1 Sidescan and multibeam

The multibeam bathymetry and backscatter data gathered at Inner Gabbard East dredged material disposal site was used to interpret the nature of the seabed within the licensed site. The survey was conducted using a Kongsberg EM3002D SIS multibeam echosounder.

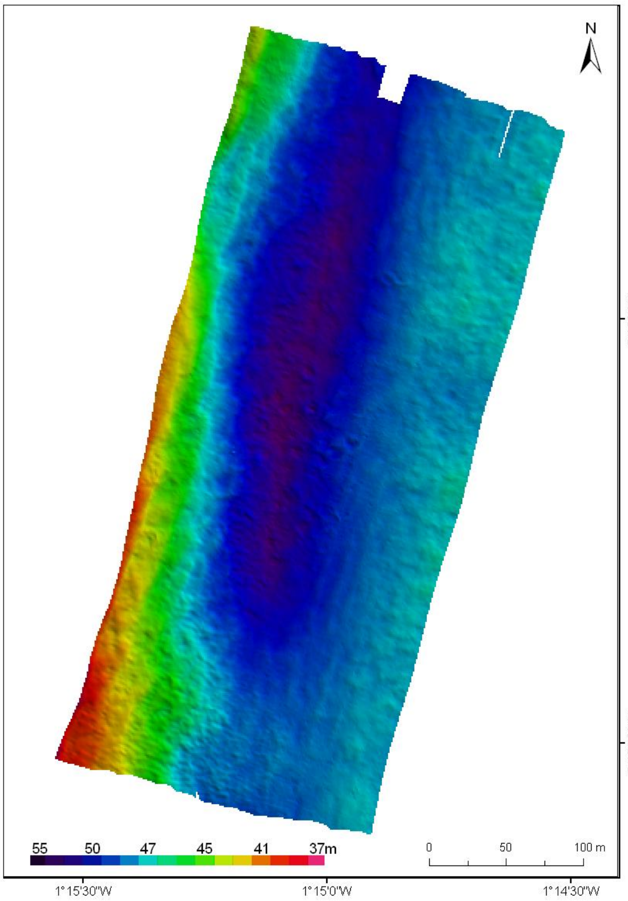


Figure 2.5.2. Inner Gabbard East seabed bathymetry from the 2009 multibeam survey.

The Inner Gabbard East disposal area has a seabed with an average water depth of 50m (Figure 2.5.2). The area has a central trench running in a north-northeast to south-southwest orientation reaching approximately 55m at its deepest. The trench gently gets shallower to the east levelling out to approx. 45m. The western edge has a sharper incline, increasing from 50m water depth to 35m within a 50m range.

Additional data were collected from particle size analysis (PSA) samples taken during the survey to ground-truth the acoustic data. Fifteen samples were gathered employing a Hamon grab in three replicates from five locations across the disposal area (Figure 2.5.3). The multibeam backscatter data indicate that the centre of the disposal site has a lower backscatter return indicating areas of finer sediments with pockets of higher backscatter returns of gravelly muddy sands being present (Figure 2.5.3). The PSA data indicated that these sediments were generally classified as muddy sands.

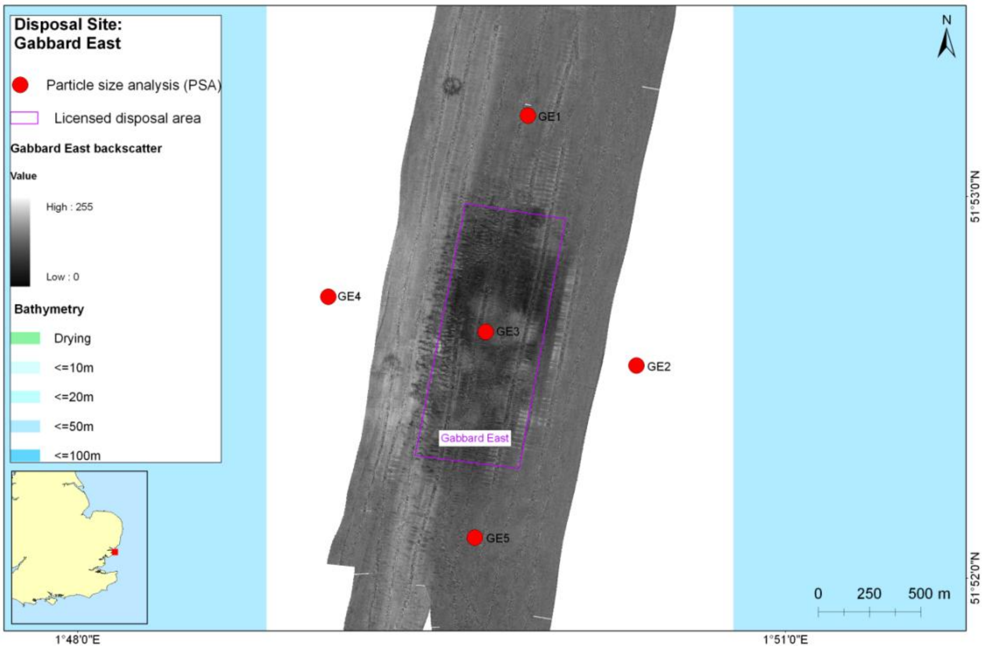


Figure 2.5.3. PSA sample positions overlaid on multibeam backscatter data collected from the 2009 Inner Gabbard East survey.

The area adjacent to this has a stronger backscatter return indicating the seabed to be largely characterised by coarser sediments, with PSA data suggesting muddy gravelly sediments. The multibeam backscatter imagery portrays patches of coarser gravelly sediments in a homogeneous muddy substrate. There are also small patches of slightly gravelly sand identifiable to the west of the site.

Figure 2.5.4 presents an interpretation of the multibeam backscatter gathered at Inner Gabbard East integrated with information from the sediment particle size analysis. There is a distinct boundary running from the north east to the south west of the site separating the sandier sediments in the west of the site from the muddier ones to the east. The centre of the site consists predominantly of muddy sand with small areas of higher backscatter returns of gravelly muddy sands. This is likely the result of the dredged material disposal activity in this area, as demonstrated by the presence of disposal features on the multibeam bathymetry in this area. There are also small patches of slightly gravelly sand identifiable to the west of the site, outside of the licensed boundary area; these are also possibly associated with dredged material disposal events.

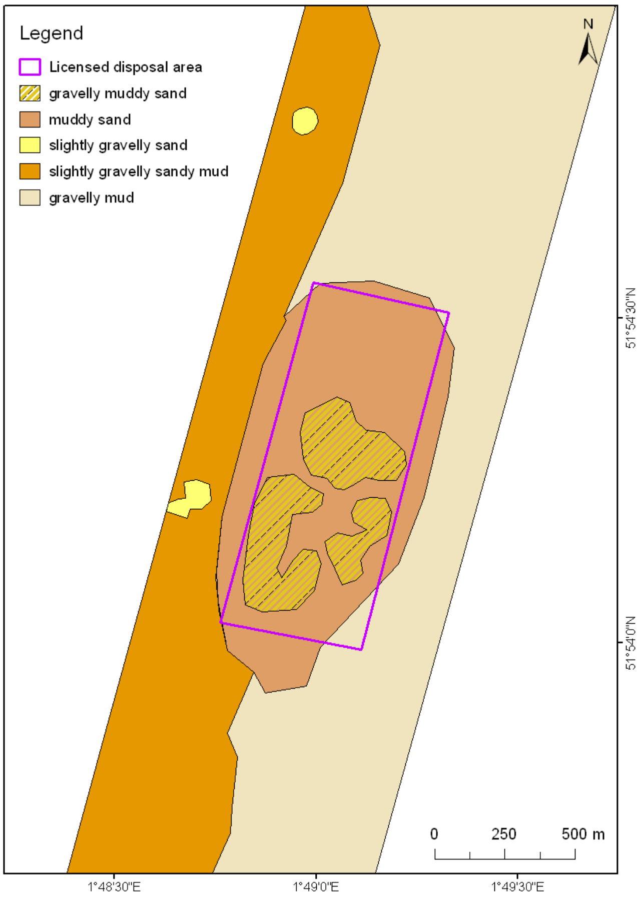


Figure 2.5.4. Interpretation of the multibeam backscatter from the 2009 Inner Gabbard East survey.

The available data suggests the impact on the physical nature of the seabed is limited within the licensed area and up to 200m from the licensed area (based on site outline). Since this was the first acoustic survey at this site, it is not possible to discuss changes to the seabed at this site. Future acoustic surveys will help to identify any change for the Inner Gabbard East disposal site.

2.5.4.2 Sediment particle size

Three sediment groups were defined for Inner Gabbard East (Table 2.5.1). In general, the sediments at this site are very mixed. Sediments in sediment group GaE1 are described as gravelly mud, dominated by silt/clay (all >46% silt/clay), while sediments in sediment group GaE2 are described as gravelly muddy sands (>19% fine sand). Sediments in sediment group GaE3 are described as muddy sandy gravel, dominated by medium and fine sand.

The spatial distribution of these three sediment groups is shown in Figure 2.5.5. GE3, within the disposal site, comprises sediments that are classed as gravelly muddy sands (GaE2) for 2 replicates and muddy sandy gravel (GaE3) for one replicate; all samples at this station however, contained >15% fine sand. To the north (GE1), east (GE2) and south (GE5) of the licensed disposal site the dominant sediment group is gravelly mud (GaE1). West of the site, at GE4, the dominant sediment group is described as muddy sandy gravel (GaE3).

2.5.5 Conclusions

The 2009 survey approach for Inner Gabbard East, and the resulting data acquired, aims to provide an assessment regarding the fate of the material deposited at this site. As disposal activity at this site from the FSR project commenced several months before the present acoustic survey, the data can only be used to indicate whether the disposal activity is being conducted as agreed. Indeed, the multibeam data indicated regions within the centre of the disposal area that resembled recently deposited material. The data also serves as a baseline to assess future disposal operations. Further monitoring at this site will, therefore, be conducted in future years and the results compared for temporal changes.

Site code	Sediment group	Sample Type	Sediment description	MODE 1 (µm):	MODE 2 (µm):	MODE 3 (µm):	Gravel (%)	Sand (%)	Silt/clay (%)	Very coarse sand (%)	Coarse sand (%)	Medium sand (%)	Fine sand (%)	Very fine sand (%)
GE1A	GaE1	Polymodal, very poorly sorted	Gravelly mud	9.4	215.0	605.0	7.04	20.87	72.09	3.90	6.15	3.50	5.71	1.61
GE1B	GaE1	Polymodal, extremely poorly sorted	Gravelly mud	9.4	9600.0	215.0	17.03	19.07	63.90	3.41	4.64	2.90	6.59	1.52
GE1C	GaE3	Polymodal, extremely poorly sorted	Muddy gravel	9600.0	215.0	9.4	42.66	26.45	30.89	5.31	7.00	4.34	8.26	1.53
GE2A	GaE1	Trimodal, very poorly sorted	Gravelly mud	6.7	9600.0	3400.0	10.74	9.12	80.14	3.77	2.73	1.06	1.04	0.52
GE2B	GaE1	Polymodal, extremely poorly sorted	Gravelly mud	6.7	1700.0	855.0	20.96	32.49	46.55	9.68	9.46	4.62	6.93	1.79
GE2C	GaE3	Polymodal, extremely poorly sorted	Muddy sandy gravel	2400.0	215.0	605.0	38.45	36.53	25.02	11.40	9.13	4.61	7.97	3.42
GE3A	GaE2	Bimodal, very poorly sorted	Gravelly muddy sand	215.0	26950.0		14.56	65.59	19.85	1.78	3.13	19.90	36.53	4.26
GE3B	GaE3	Polymodal, extremely poorly sorted	Muddy sandy gravel	302.5	26950.0	4800.0	37.19	41.81	21.00	4.93	5.71	15.27	13.35	2.54
GE3C	GaE2	Polymodal, extremely poorly sorted	Gravelly muddy sand	215.0	38250.0	9.4	22.79	50.16	27.05	3.31	4.95	19.85	20.23	1.81
GE4A	GaE3	Trimodal, very poorly sorted	Muddy sandy gravel	13600.0	605.0	215.0	64.42	25.47	10.11	5.15	10.03	5.40	3.86	1.04
GE4B	GaE3	Polymodal, extremely poorly sorted	Gravelly muddy sand	605.0	26950.0	9600.0	27.31	38.78	33.92	5.53	16.20	9.46	6.38	1.21
GE4C	GaE3	Polymodal, extremely poorly sorted	Gravelly muddy sand	605.0	13600.0	215.0	20.62	45.60	33.78	8.70	19.56	9.38	6.02	1.93
GE5A	GaE1	Polymodal, extremely poorly sorted	Gravelly mud	9.4	9600.0	215.0	20.26	20.36	59.38	5.08	4.11	2.30	7.57	1.30
GE5B	GaE1	Polymodal, very poorly sorted	Gravelly mud	6.7	215.0	605.0	11.22	27.16	61.62	4.82	6.16	3.49	10.44	2.24
GE5C	GaE3	Polymodal, very poorly sorted	Muddy sandy gravel	9600.0	215.0	605.0	35.01	44.98	20.01	9.80	11.77	6.60	13.82	2.99

Table 2.5.1. Sediment descriptions and summary statistics, for each sample, calculated using Gradistat (Blott and Pye, 2001) for each sediment group defined at Inner Gabbard East.

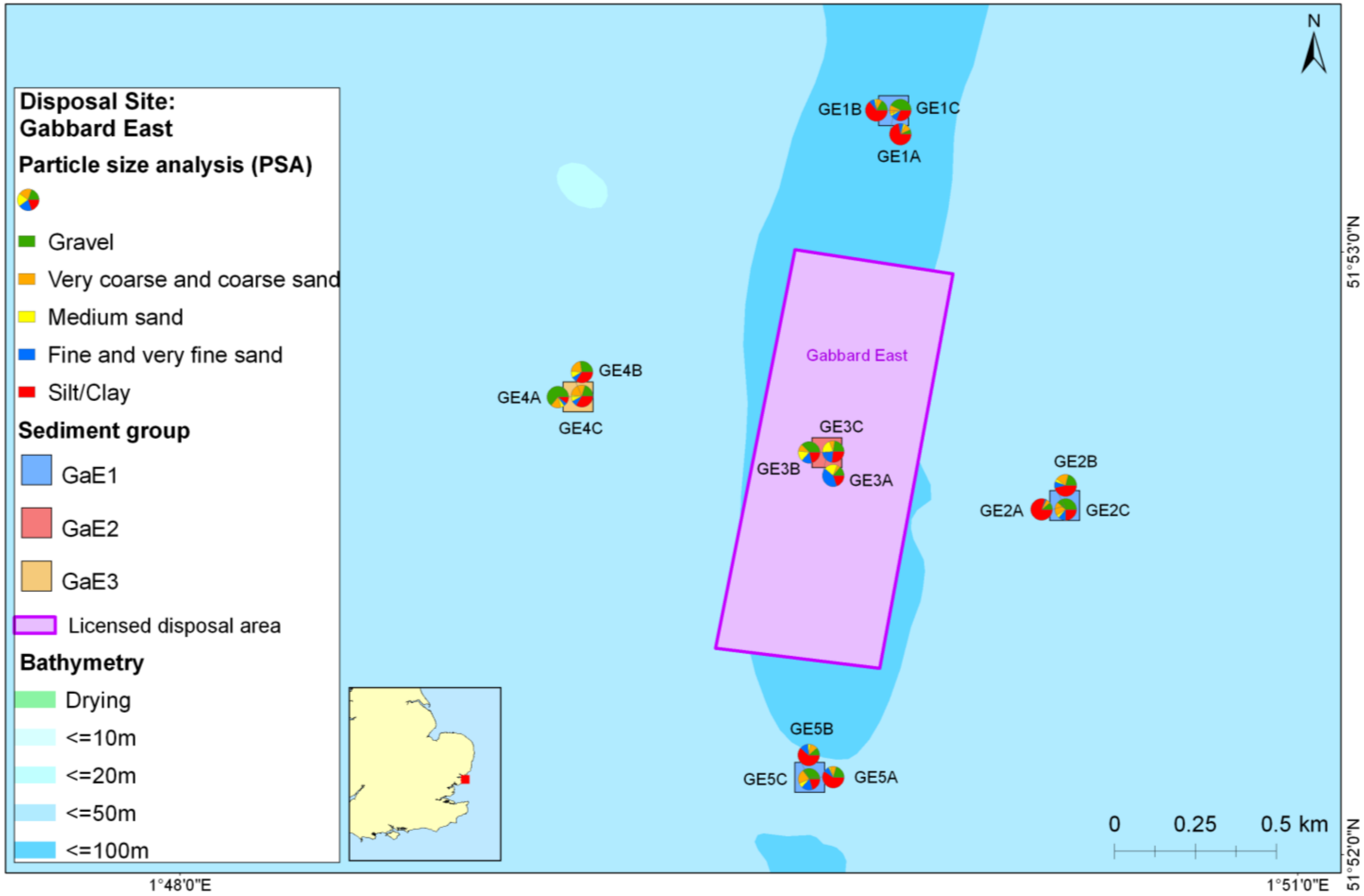


Figure 2.5.5. Sediment groups (coloured squares) overlain with pie charts showing proportions of gravel, very coarse sand and coarse sand, medium sand, fine and very fine sand and silt/clay at each station

2.6 Rame Head (PL031)

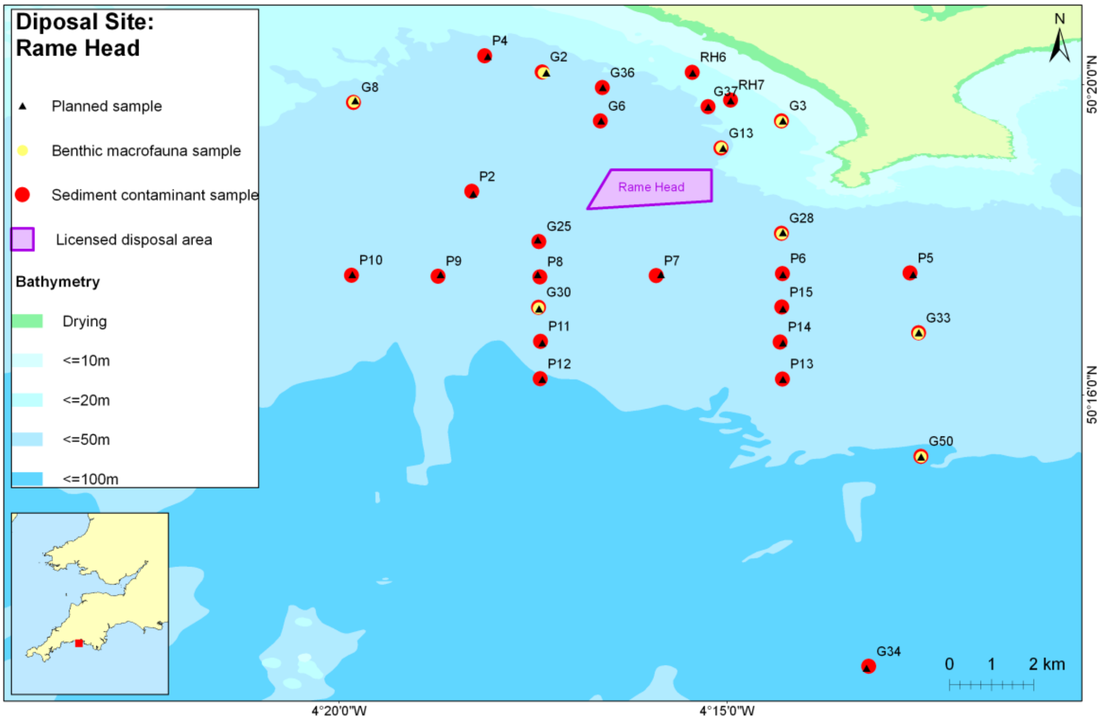


Figure 2.6.1. Locations of all monitoring stations for Rame Head 2009.

2.6.1 Background

Rame Head is an open and active disposal site with a depth of 18-38m below CD. The site, located approximately 2 km west of Rame Head and 6 km west of the entrance to Plymouth Sound, is used for dredged material disposal mostly during the winter months.

The site has been used for almost 100 years although during the early part of this period it was primarily used for munitions disposal. Dredged material disposed comes from the ports, harbours, berths and navigation channels in and alongside the rivers Tamar and Plym and the Sound, with principle locations being Devonport Dockyard and associated Ministry of Defence (MoD) areas. The site thus receives material from a variety of sources. Between 1976 and 2005, over 5 million tonnes of material was disposed of, being composed typically of sandy mud, with > 70% silt/clay fraction.

Over the last 30 years, the amount of material being disposed of at this disposal site has slowly declined with exception of two peaks in 1986 and 2001. The 2001 disposal activity was subject to specific licence conditions requiring the licence holder to take all reasonable precautions to remove anthropogenic debris from the material.

The coastal region within which the disposal site is located is important for a wide range of stakeholders including those associated with diving, fisheries and shellfisheries. There are also a large number of sewage and storm-water discharges in the locality.

There has been a large public and media interest regarding the impacts associated with dredged material disposal at Rame Head. Concerns have primarily been based around the potential of the disposed material as a source of contamination at Polhawn Cove and of the dive sites (e.g., HMS Scylla) in Whitsand Bay. A large amount of litter being found along the intertidal areas of the disposal site has also been alleged to be derived from the disposal activity.

2.6.2 Impact hypotheses

- Any elevations in the concentrations of chemical contaminants directly attributable to dredged material disposal will be confined to the near vicinity of the disposal site, principally along the tidal axis
- Any elevations in the concentrations of chemical contaminants directly attributable to dredgings disposal will be within acceptable limits
- Any changes to the physical habitat will be confined to the near vicinity of the disposal site, principally along the tidal axis
- Any adverse effects on the benthic biota will be confined to the near vicinity of the disposal site, principally along the tidal axis
- The wider dispersal of fine particulates arising from dredgings disposal, including any wave-induced shoreward transport, will have no adverse consequences for the marine biota or for recreational/amenity interests

The 2009 survey design planned for Rame Head encompassed sampling stations within and at increasing distances from the disposal site, forming primarily an extension to previous surveys for the site. However, RV *Cefas Endeavour* during the July survey was, at the last minute, unable to deploy grabs within the licensed disposal site. It was subsequently decided that, rather than to return to the area and sample stations within the disposal site boundary, the data obtained from sampling stations outside were sufficient to provide the ongoing assessment of impacts associated with this site (i.e., monitoring is principally concerned with ensuring impacts outside the site are within acceptable limits).

2.6.3 Parameters monitored

Sediment particle size distribution
Sediment organic carbon and nitrogen
Macrofaunal communities

Sediment contaminants (TBT, PAHs, organohalogens, trace metals).

2.6.4 Results

2.6.4.1 Sediment particle size

Six sediment groups were defined for the stations sampled at Rame Head in 2009 (Table 2.6.1). Sediments in sediment group RaH1 are described as sandy gravel. Sediments in sediment group RaH2 are described as slightly gravelly, muddy sand and this group contains the highest silt/clay content overall. Sediments in sediment group RaH4 are described as gravelly muddy sand. Sediments in sediment groups RaH3 and RaH5 are both described as slightly gravelly sand, dominated by fine sand in RaH3, and medium sand in RaH5.

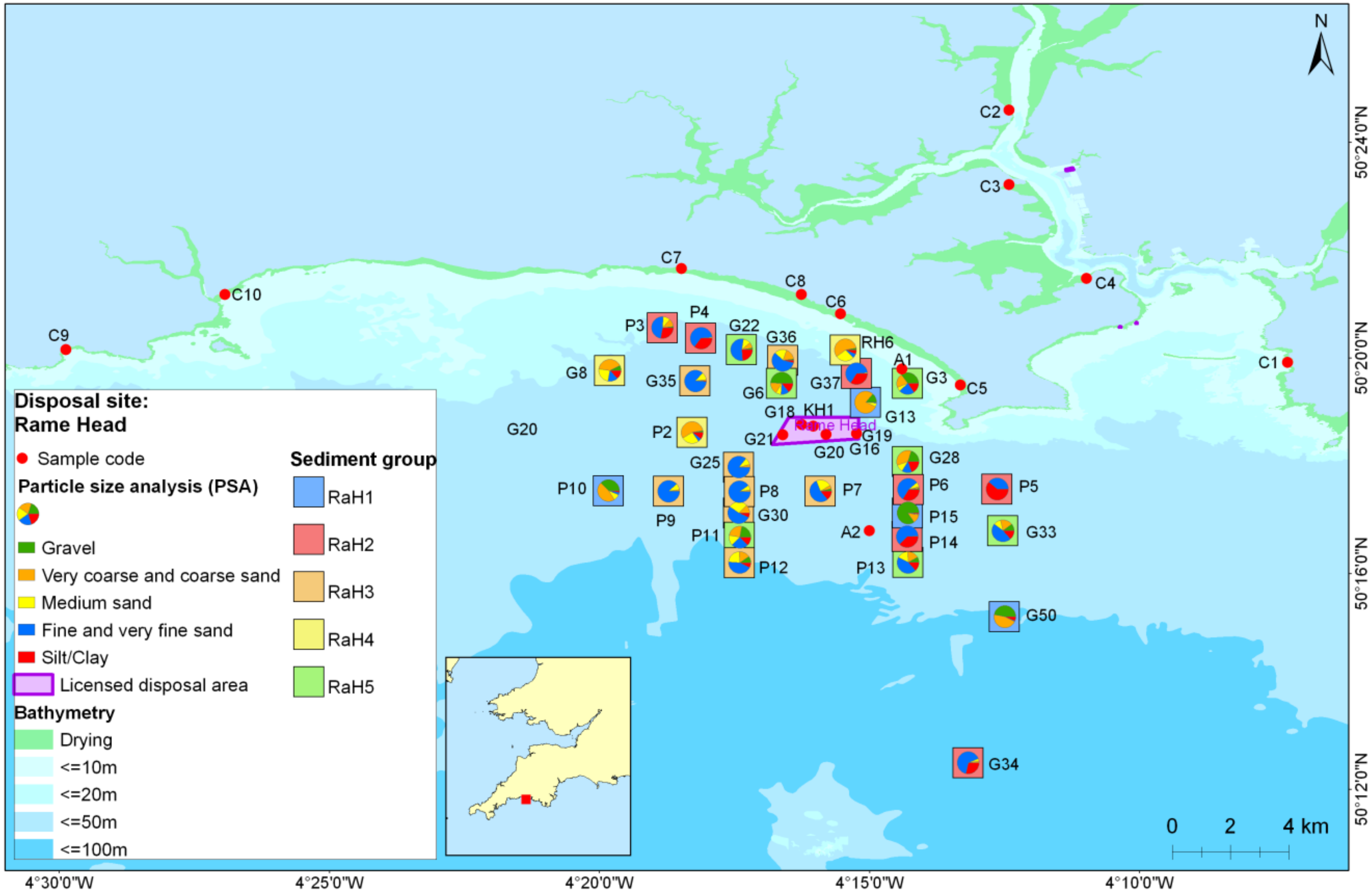


Figure 2.6.2. Sediment groups (coloured squares) overlain with pie charts showing proportions of gravel, very coarse sand and coarse sand, medium sand, fine and very fine sand and silt/clay at each station. The positions of stations sampled between 2006 and 2008 are also included (see Table 2.6.2).

Sediment group	Number of samples	% number of samples	Sample Type	Sediment description	MODE 1 (µm):	MODE 2 (µm):	MODE 3 (µm):
RaH1	13	12	Bimodal, poorly sorted	Sandy gravel	1200.0	9600.0	
RaH2	23	22	Bimodal, poorly sorted	Slightly gravelly muddy sand	76.5	37.8	
RaH3	27	26	Unimodal, moderately sorted	Slightly gravelly sand	152.5		
RaH4	8	8	Bimodal, very poorly sorted	Gravelly sand	605.0	38250.0	
RaH5	28	27	Polymodal, very poorly sorted	Gravelly muddy sand	107.5	605.0	9600.0
RaH6	6	6	Unimodal, moderately well sorted	Slightly gravelly sand	302.5		

Sediment group	Gravel (%)	Sand (%)	Silt/clay (%)	Very coarse sand (%)	Coarse sand (%)	Medium sand (%)	Fine sand (%)	Very fine sand (%)
RaH1	42.51	55.22	2.27	29.36	17.96	4.81	2.03	1.06
RaH2	1.07	62.49	36.44	0.91	2.51	3.84	9.03	46.20
RaH3	1.64	94.83	3.53	1.58	5.72	15.30	57.79	14.45
RaH4	12.12	82.17	5.71	15.91	38.92	18.51	6.08	2.75
RaH5	20.84	56.67	22.49	7.43	8.51	8.16	12.13	20.44
RaH6	0.45	97.43	2.12	0.88	10.14	63.05	22.69	0.67

Table 2.6.1. Sediment descriptions and summary statistics, based on the average sediment distribution, calculated using Gradistat (Blott and Pye, 2001) for each sediment group defined at Rame Head.

Station code	2006	2007	2008	2009	2009A
A1	RaH3	ns	ns	ns	ns
A2	RaH5	ns	ns	ns	ns
C1	ns	RaH2	ns	ns	ns
C2	ns	RaH5	ns	ns	ns
C3	ns	RaH5	ns	ns	ns
C4	ns	RaH6	ns	ns	ns
C5	ns	RaH6	ns	ns	ns
C6	ns	RaH6	ns	ns	ns
C7	ns	RaH6	ns	ns	ns
C8	ns	RaH6	ns	ns	ns
C9	ns	RaH1	ns	ns	ns
C10	ns	RaH3	ns	ns	ns
G2	ns	RaH2	RaH2	RaH5	ns
G3	RaH3	RaH3	RaH3	RaH5	RaH3
G6	RaH2	RaH2	RaH2	RaH5	ns
G8	RaH1	RaH1	RaH1	RaH4	RaH1
G13	RaH1	RaH1	RaH1	RaH1	RaH4
G16	RaH1	ns	ns	ns	ns
G18	RaH5	ns	RaH5	ns	ns
G19	RaH3	RaH4	RaH4	ns	ns
G20	ns	RaH5	RaH5	ns	ns
G21	ns	RaH4	RaH5	ns	ns
G22	ns	ns	ns	ns	RaH2
G25	RaH2	RaH2	RaH2	RaH3	ns
G28	RaH2	RaH5	RaH5	RaH5	RaH5
G30	ns	RaH6	RaH3	RaH3	RaH5
G33	RaH5	RaH5	RaH5	RaH5	RaH5
G34	RaH3	RaH3	RaH3	RaH2	ns
G35	ns	RaH5	ns	RaH3	ns
G36	ns	RaH2	RaH2	RaH3	ns
G37	RaH5	RaH2	RaH3	RaH2	ns
G50	ns	RaH3	RaH3	RaH1	RaH3
KH1	ns	RaH5	RaH5	ns	ns
P2	ns	ns	ns	RaH4	ns
P3	ns	ns	ns	RaH2	ns
P4	ns	ns	ns	RaH2	ns
P5	ns	ns	ns	RaH2	ns
P6	ns	ns	ns	RaH2	ns
P7	ns	ns	ns	RaH3	ns
P8	ns	ns	ns	RaH3	ns
P9	ns	ns	ns	RaH3	ns
P10	ns	ns	ns	RaH1	ns
P11	ns	ns	ns	RaH5	ns
P12	ns	ns	ns	RaH3	ns
P13	ns	ns	ns	RaH5	ns
P14	ns	ns	ns	RaH2	ns
P15	ns	ns	ns	RaH1	ns
RH4	ns	RaH3	ns	ns	ns
RH6	ns	RaH3	RaH3	RaH4	ns
RH7	ns	RaH4	RaH3	RaH5	ns

Table 2.6.2. Sediment group at each station between 2006 and 2009 (2009A represent sediment groups measured from Hamon grabs in 2009) inclusive (ns = no sample).

Sediment groups for 2009 are shown in Figure 2.6.2 and those for each station sampled between 2006 and 2009 are presented in Table 2.6.2. In 2009, sediment groups were measured for surface sediments ('2009' column in Table 2.6.2) and for 9 mixed sediments collected using a Hamon grab in support of biological samples ('2009A' column). Most of these are in different sediment groups to those measured in the surface sediment, probably indicative of layering of the sediments near the surface.

Sediments northwest of the disposal site are described as muddy sand (RaH2) at P3 and P4, gravelly muddy sand (RaH4) at P2 and G8 to the south of these, with fine sand (RaH3) at G35 and G36 and medium sand (RaH5) at G6 and G22. Sediments south west of the site are described as fine sand (RaH3) at P7, P8, P9, P12, G25 and G30, medium sand (RaH5) at P11, and sandy gravel (RaH1) at P10. Sediments southeast of the site include sandy gravel (RaH1) at P15, surrounded by muddy sand (RaH2) at P5, P6 and P14. North, G28, and south, P13 and G33, of this muddy zone, there is medium sand (RaH5). Further offshore, at G50, the sediment is described as sandy gravel (RaH1) (fine sand from the Hamon Grab (HG)), and further offshore, at G34, the sediment is muddy sand (RaH2). Sediments, northeast of the site, include sandy gravel (RaH1) at the corner of the disposal site at G13 (gravelly muddy sand from HG), and closer to shore muddy sand at G37, medium sand (RaH5) at G3 (fine sand from HG), and gravelly muddy sand (RaH4) at RH6. RaH6 was only found at intertidal stations C4 to C8.

2.6.4.2 Sediment organic carbon and nitrogen

The sediment organic carbon (on the <63µm sediment fraction), organic carbon (on the <2mm sediment fraction) and silt/clay contents are shown for 2009 at Rame Head in Figure 2.6.3. Sediment organic carbon values (on the <63µm sediment fraction) range from 0.81 to 2.62 %m/m. These are similar to those observed during 2006, 2007 and 2008 (see Bolam *et al*., 2009).

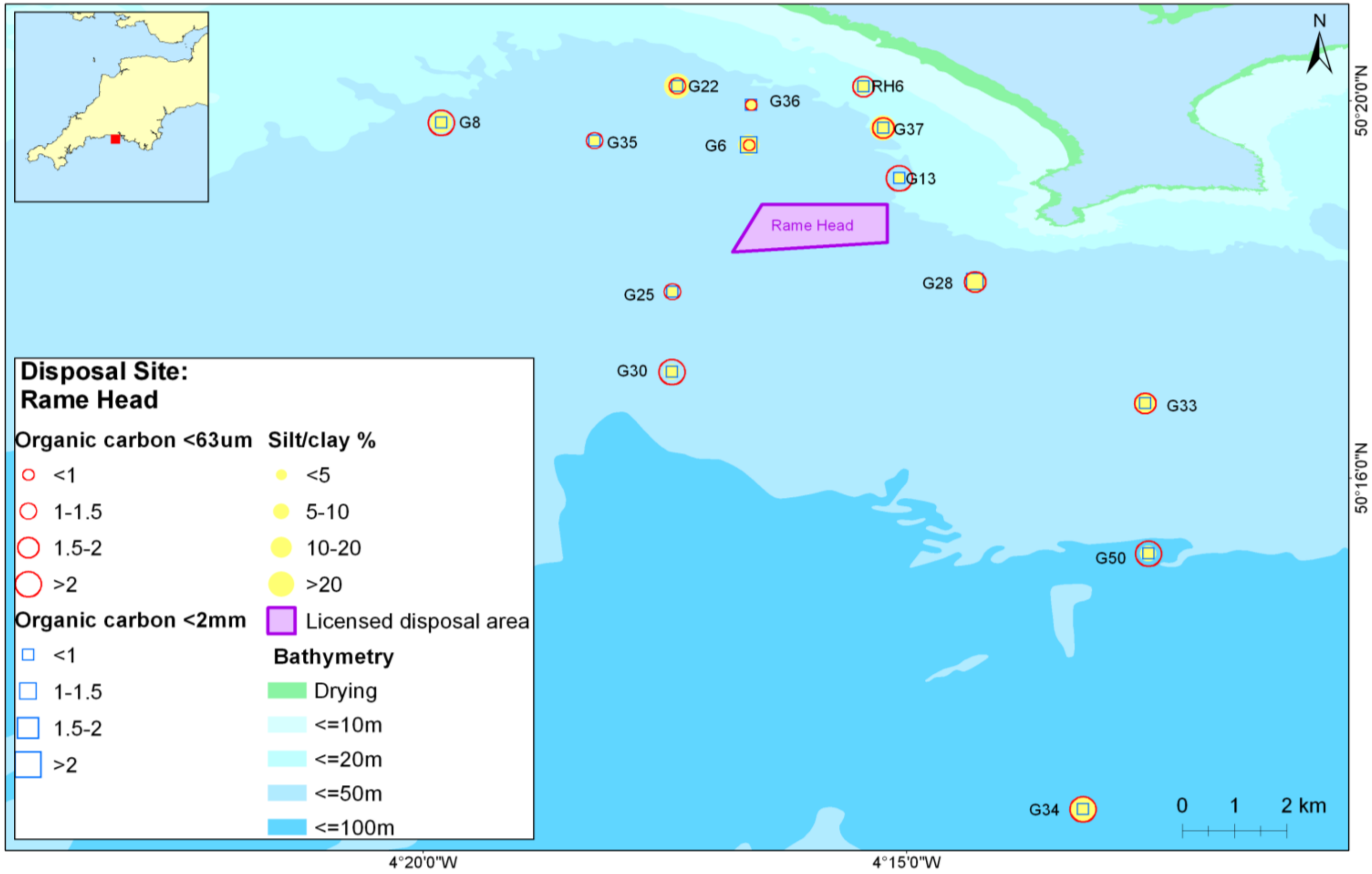


Figure 2.6.3. Organic carbon (<63µm), organic carbon (<2mm) and silt/clay contents of the sediments at Rame Head, 2009.

2.6.4.3 Macrofaunal communities

A total of 374 taxa were identified from the eight stations sampled for macrofauna at Rame Head during 2009; the average number of species at a single station, however, was always <120. The most diverse taxonomic group was annelids which accounted for 44% of the species identified. Crustaceans accounted for a further 20% and molluscs 18%. The average number of species (mean of three replicates) for each station is shown in Figure 2.6.4. There is high variability in the number of species between the sites, from a maximum of 119 $0.1m^{-2}$ (G28, southeast of the disposal site) to a minimum of 20 $0.1m^{-2}$ at G03 (inshore, northeast of the disposal site). There does not appear to be any pattern in the number of species with distance from the disposal site.

The average number of individuals and total biomass for each station are shown in Figures 2.6.5 and 2.6.6 respectively. Both vary considerably between the stations with no visually-discernible relationship with distance from the disposal site. The maximum number of individuals recorded at a station was 1097 (highest mean per $0.1m^{-2}$) at G28. Reference back to the raw data showed that one sample from this station contained 1616 specimens of the barnacle *Verruca stroemia*, the other two replicates at this station contained only 2 and 4 individuals of this species. This suggests that *V. stroemia* occurs in small patches and was probably recorded in large numbers in a single sample because a cobble was retained in the grab with many individuals attached.

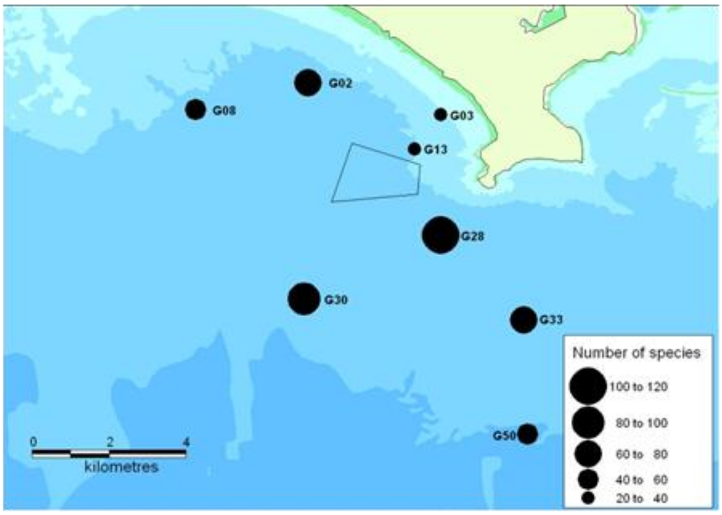


Figure 2.6.4. Average number of benthic macrofauna species collected from three grab samples.

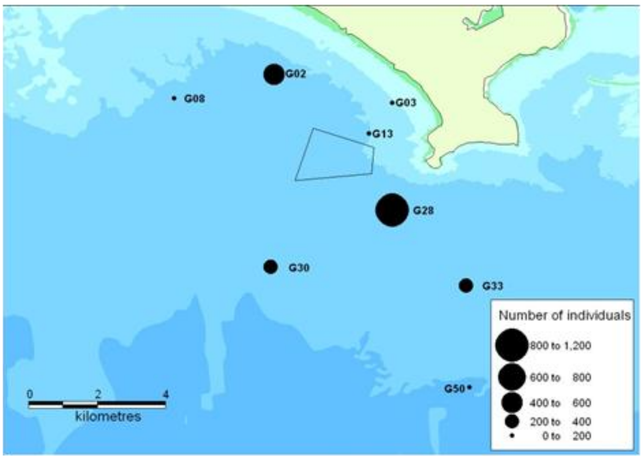


Figure 2.6.5. Average total number of individuals (per 0.1m-^{2}) counted from three replicate samples.

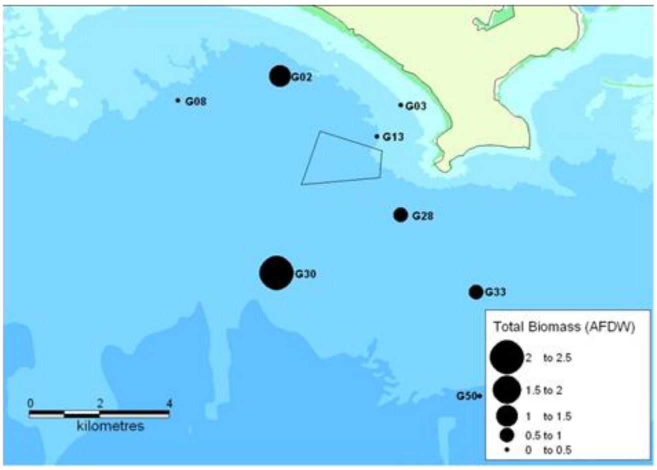


Figure 2.6.6. Average total benthic biomass (AFDW, per 0.1m-^{2}) from three replicates.

Univariate measures of diversity (Shannon H') and evenness (Pielou's J') were calculated for each sample and averaged by station (Figures 2.6.7 and 2.6.8 respectively). Values are similar between stations. Shannon-Wiener Diversity is typically high, on average 3, suggesting that there is a high number of species and that dominance is low. This assessment is supported by the evenness indicator values which show most stations have a Pielou's evenness value between 0.7 and 0.8 demonstrating low dominance.

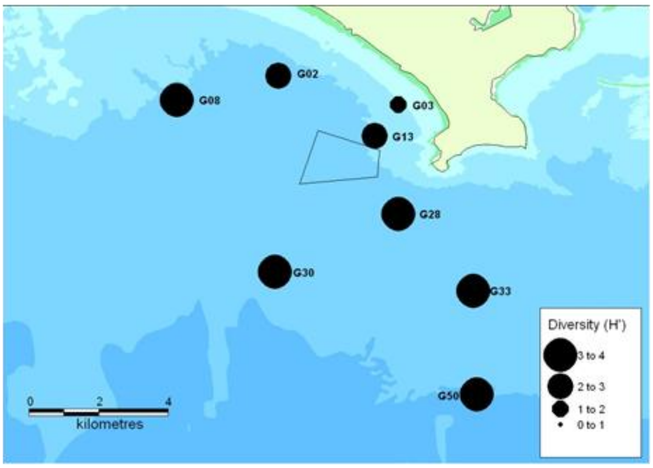


Figure 2.6.7. Average diversity (Shannon H') from three replicates.

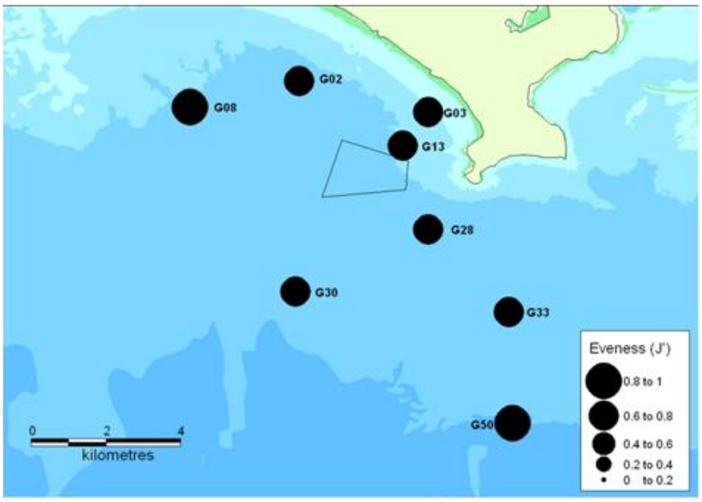


Figure 2.6.8. Average evenness (Pielou's J') from three replicates.

The 2009 data were further explored using multivariate techniques. Multivariate statistical tests were performed using the PRIMER software (Clarke & Gorley, 2006). Data were pre-treated with a square-root transformation to remove the influence of highly abundant species. Clustering with SIMPROF testing produced nine clusters at P=0.05 (Figure 2.6.9). It can be seen that each station is more-or-less clustered with its replicates separately from the other stations (except for G03) indicating there is generally high within-station similarity relative to between-station similarity. A 2-dimensional MDS ordination of the data points with SIMPROF clusters is shown in Figure 2.6.10. This plot generally supports the notion that replicates for each station are typically very similar. This plot also infers that the community structures of G30, G33 and G28 (all south of the disposal site) probably share many of the same characteristics. These results show that there is very strong spatial variability in the benthic communities in the sampling area. There is no evidence to suggest that any of the sampling stations are being impacted by the disposal activities nearby; the spatial variability observed in the benthic communities is probably linked to variability in sediment characteristics between the sites and/or depth.

The disposal site at Rame Head has been monitored annually for the last nine years which provides an ideal time series of data which can be used to identify any temporal changes in benthic communities. A full analysis of this data is not within the scope of this report (see Bolam *et al*., in prep) however preliminary results are presented here. Figures 2.6.11 and 2.6.12 show the number of species and abundance of benthic invertebrates (for the stations that were sampled in 2009) over this time period. The plots show that there has been no decline in either the number of species or abundance at any of the stations over the last nine years. On the contrary, total abundance and number of species per grab have tended to slightly increase over this period, particularly for some stations. Evenness at each of the stations also remained consistent over time (Figure 2.6.13).

Multivariate analysis of the time series data also showed evidence that there has been no continuous decline in the state of the benthic communities at any of the locations sampled regularly at Rame Head. ANOSIM tests, which are used to identify structuring in the data based on predefined groups, showed that there was a very strong relationship with stations over time (global R=0.653 P=0.01) while there was no apparent structuring of the data based on the year. This demonstrates that there is a consistent spatial pattern, but no strong temporal patterns. A 2-dimensional MDS ordination for station data from 2001 through to 2009 (Figure 2.6.14) shows that station points are generally tightly grouped together, although it can be seen that G13 shows greater variation between years than the other stations. This station, located just north of the disposal site, has exhibited slight increases in numbers of species and total abundance during this period (Figures 2.6.11 and 2.6.12). Thus, the temporal changes in multivariate community structure identified in Figure 2.6.14 at G13 reflect changes in, and additions to, the species present in the community as opposed to a decline in community integrity.

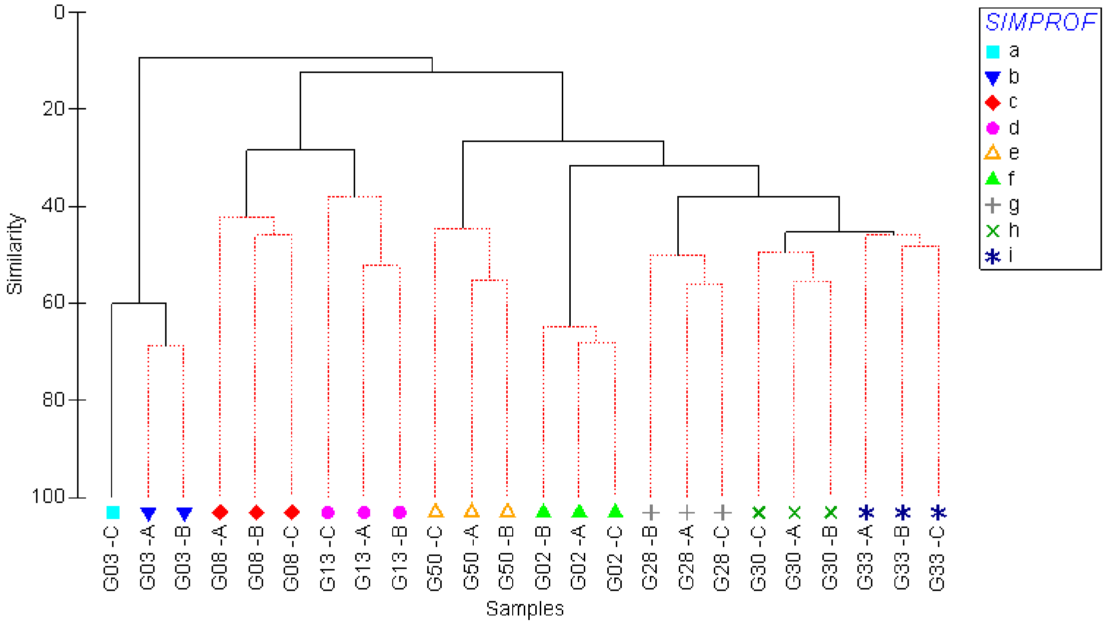


Figure2.6.9. Dendrogram showing clustering of the 2009 macrofauna data. Red lines indicate no significance difference at P=0.05.

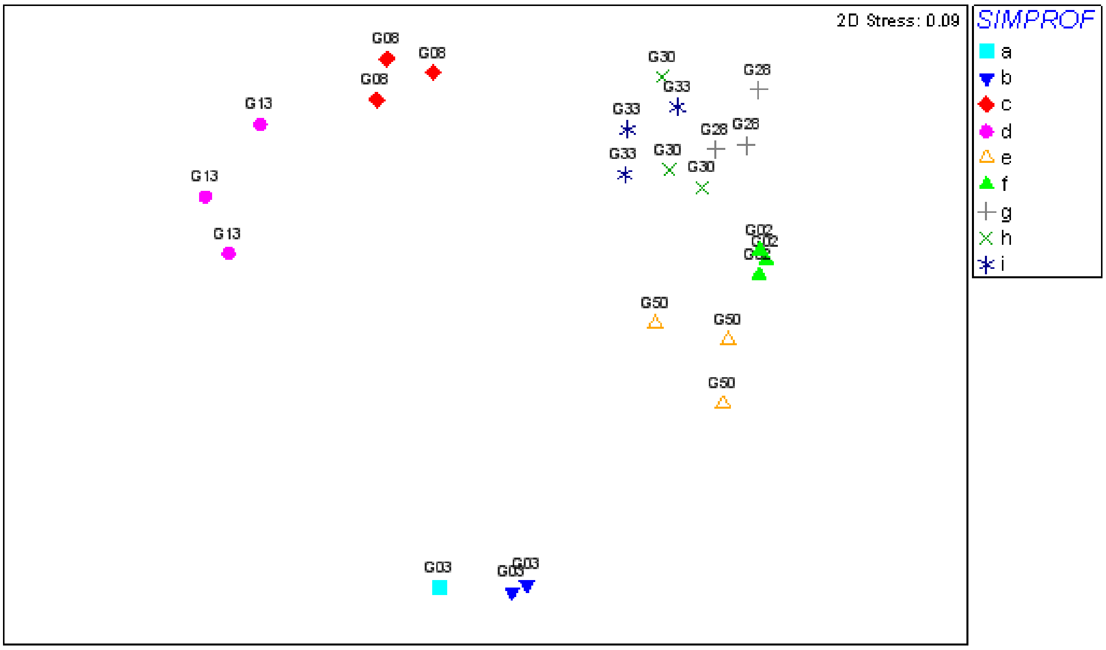


Figure 2.6.10. 2D MDS ordination of the 2009 macrofauna data.

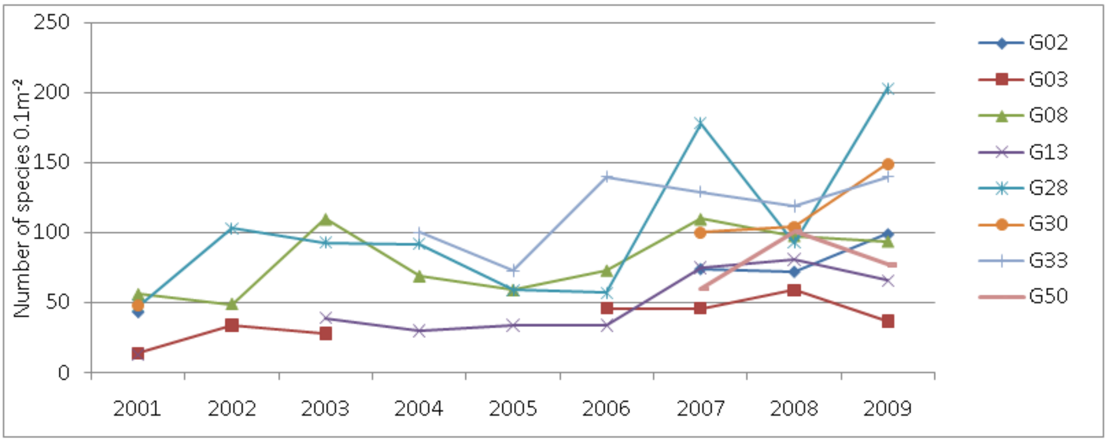


Figure 2.6.11. Temporal changes in the number of benthic macrofauna species at eight stations around the Rame Head disposal site from 2001-2009.

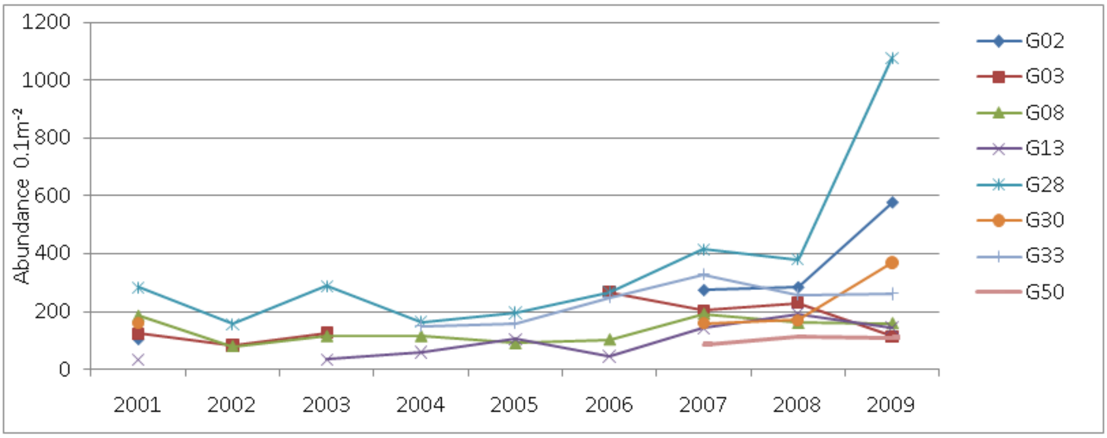


Figure 2.6.12. Temporal changes in the total abundance of macrofauna at eight stations around the Rame Head disposal site from 2001-2009.

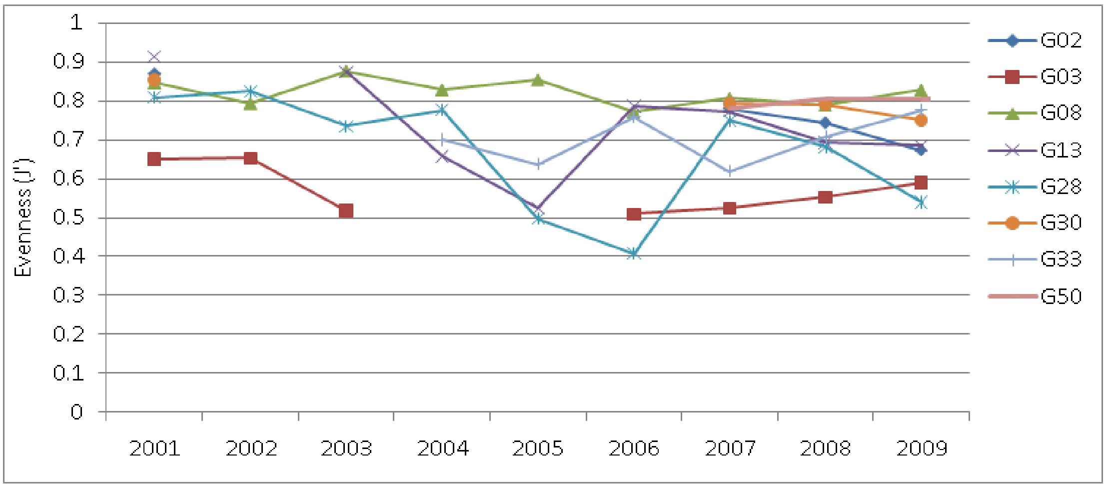


Figure 2.6.13. Temporal changes in the evenness (J') of benthic macrofauna at eight stations around the Rame Head disposal site from 2001-2009.

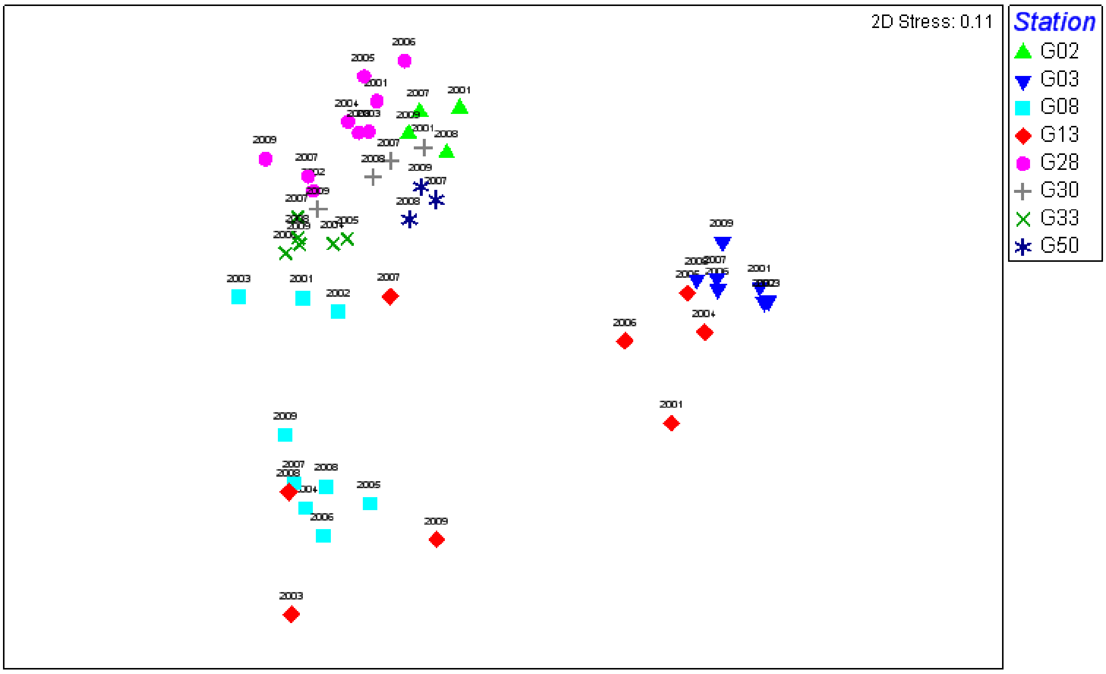


Figure 2.6.14. 2D MDS ordination of benthic macrofauna data from stations surrounding the Rame Head disposal site from 2001-2009.

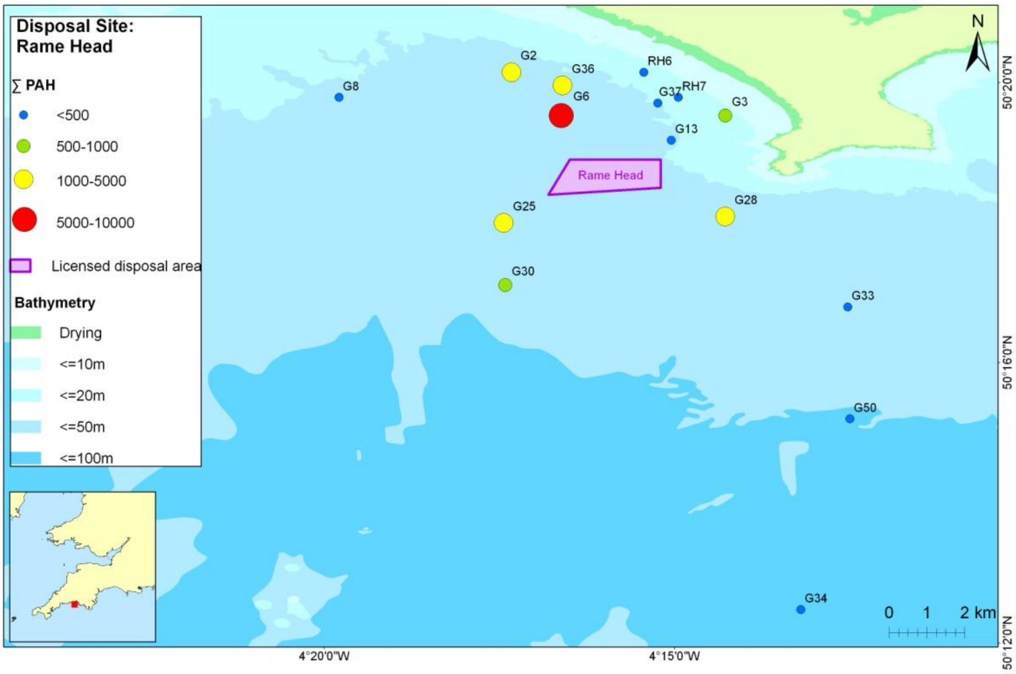
2.6.4.4 Contaminants

2.6.4.4.1 TBT

All the 15 samples located outside the disposal site were below the detection limit. This is consistent with what has been observed for the last five consecutive years at Rame Head. The overall TBT loading in the material disposed of to this site has halved from 2007 to 2008. This decrease in TBT loading, together with the dispersive nature of Rame Head, most likely contributes to the low levels of TBT found within this area.

2.6.4.4.2 PAHs

In 2009 the highest concentration of summed PAHs in the sampled Rame Head area (i.e. outside the disposal site) was 5,940 µg kg^{-1} found at G6 to the NW of the disposal site which in 2008 was found to be 4,830 µg kg^{-1} (Figure 2.6.15). The next highest summed PAH concentration found was at G28 with 4,250 µg kg^{-1}, a slight decrease from that found in 2008 (5,260 µg kg^{-1}), followed by concentrations of < 3,000 µg kg^{-1} at G36 and < 2,000 µg kg^{-1} at G25 and G2. Concentrations found in the inshore area are generally found to be relatively very low, < 200 µg kg^{-1}, with the exception of G3 which has a summed PAH concentration of 942 µg kg^{-1} . These low concentrations are directly comparable with those found in deeper offshore sites at G34 and G50. Levels at RH6 RH7 G37 and G13 are less than those found in 2008.



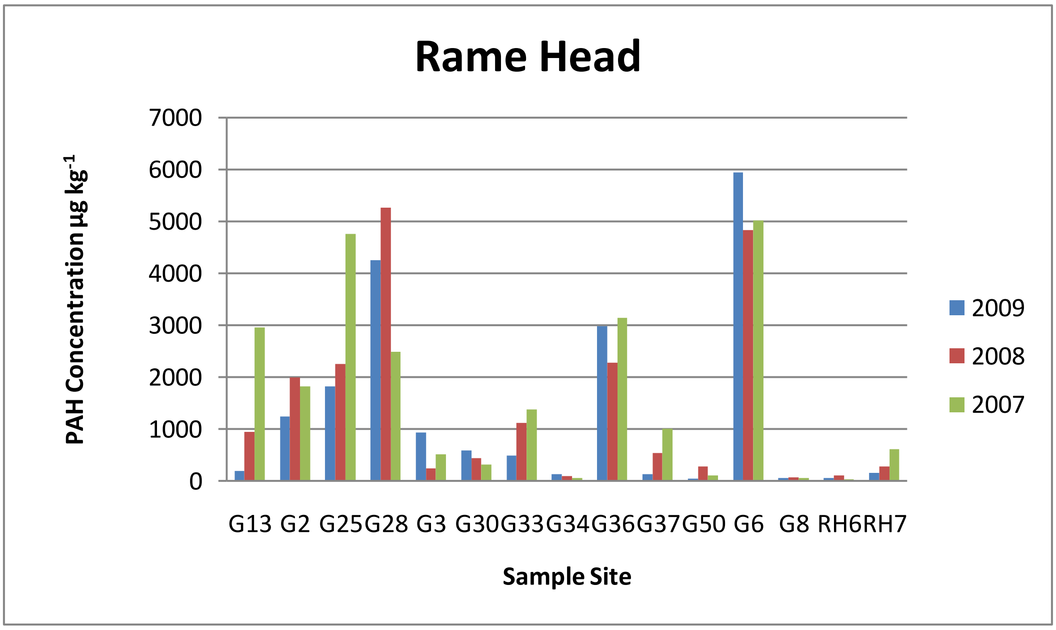


Figure 2.6.15. Map showing concentrations of summed PAHs at Rame Head during 2009 (top) and bar chart of concentrations for 2007, 2008 and 2009.

Disposal at the Rame Head site has decreased from 2007 to 2008 by 74,345 wet tonnes of dredged material from 98,883 to 24,538 tonnes. At only one station, G28, was the ERL for LMW PAHs exceeded, whilst at G6 the ERL was exceeded for HMW PAHs.

2.6.4.4.3 Organohalogens

At Rame Head, CB concentrations were highly variable, with a factor of 15 difference between highest and lowest values (∑ICES7 CBs range <0.7-10.2 µg/kg dw). A total of 9 stations had ∑ICES 7 CB concentrations below LODs, and these were the stations to the northwest and northeast of the disposal site, and to the extreme south of the sampling area (Figure 2.6.16). The highest ∑ICES 7 CB concentration of 10.2 µg/kg dw was measured at station G28 to the southeast of the disposal site, along the main tidal axis through the site. The concentration at G28 in 2009 is similar to that obtained at stations within the disposal site in 2008. Station G33 further along the axis of dispersal had a lower ∑ICES 7 CB concentration of 2.5 µg/kg dw. Other stations where CBs were detected were G6 and G36 to the north of the disposal site (3.3 and 2.8 µg/kg dw respectively) and G25 and G30 to the southwest of the disposal site (1.8 and 1.3 µg/kg dw respectively).

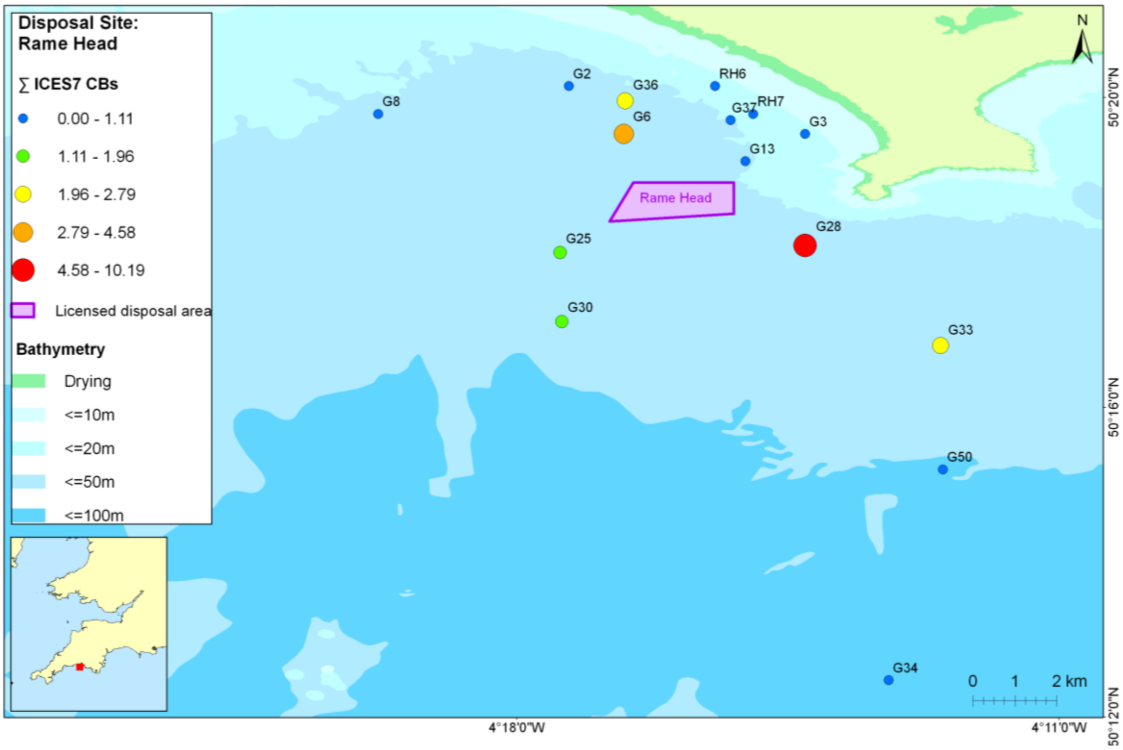


Figure 2.6.16. Summed ICES7 CB concentrations for the Rame Head Stations, 2009.

BDE concentrations at Rame Head are low, generally at or below limits of detection (∑11 BDEs range <0.11-0.49 µg/kg dw). All BDE congeners were below LODs at 7 of the 15 stations and for another 7 only BDE47 was detected, just above LODs. The only significant ∑11 BDEs concentration of 0.49 µg/kg dw was found at G2 (Figure 2.6.17), northwest of the disposal site, although this concentration can also be considered to be low. A similar value was found at this station in 2008. Samples collected from stations within the disposal site in 2008, e.g. G18, G19, G20, G21 and KH1, also had BDE levels below or close to LODs, indicating that dredge disposal is not introducing BDEs to the local environment.

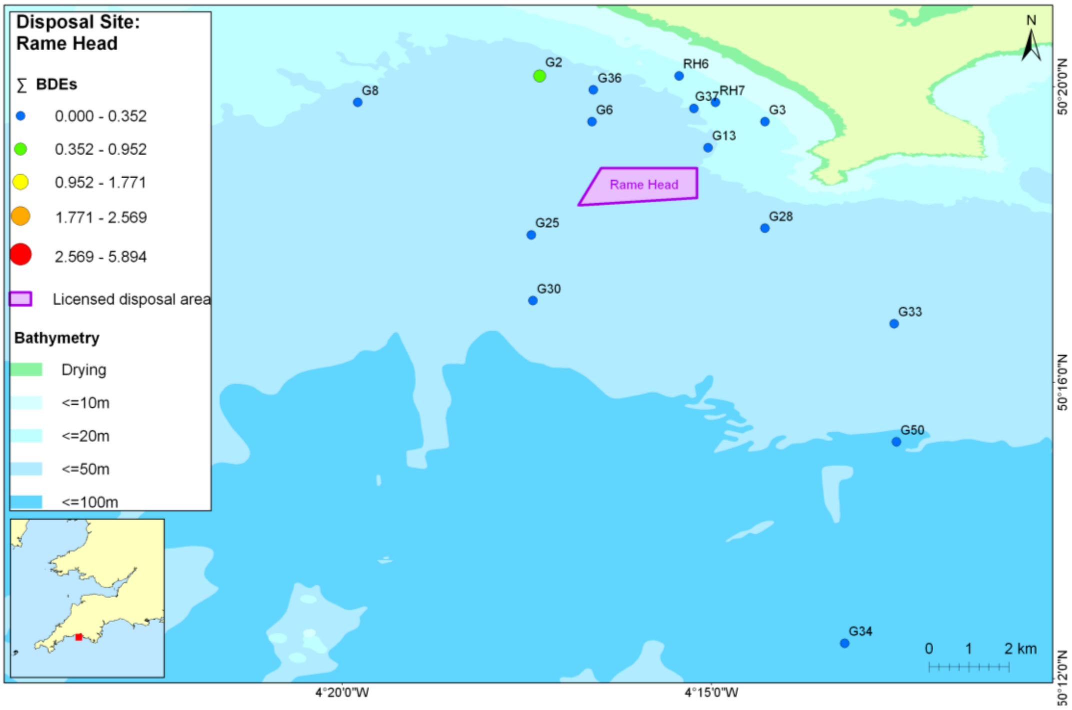


Figure 2.6.17. Summed 11 BDEs concentrations for the Rame Head Stations, 2009.

Concentrations of CBs at all stations except for G28 were below Cefas AL1. Station G28 was just above warning limits for ∑ICES7 CBs but just below for ∑25 CBs. No Cefas action levels exist for BDEs. According to the OSPAR guidelines, stations G13, G2, G3, G34, G37, G50, G8, RH6 and RH7 had ‘good’ environmental status for all ICES 7 CBs, and ‘good’ status overall. Stations G25, G30, G33, G36 and G6 had ‘bad’ environmental status for CB118, but ‘good’ status overall. The one exception was station G28 which had ‘bad’ environmental status for CB118 and CB101, and therefore ‘bad’ status overall. No OSPAR guidelines exist for BDEs at present.

Looking at temporal trends in contaminant levels (See Tables 2.6.3 and 2.6.4), ∑ICES7 CB concentrations at G28 in 2009 were 7 times lower than measured in 2008, and similar to concentrations measured between 2005-07. Similarly, ∑ICES7 CB concentrations at G33 were 3 times lower than in 2008, and lower than anything measured since 2005. ∑ICES7 CB concentrations at G36 and G3 to the north of the disposal site were higher than measured in 2008, whereas the levels at G25 to the southwest is the lowest measured to date. Concentrations of ∑11 BDEs at Rame Head have always been close to limits of detection over the period 2003-2009.

Station code	∑ICES 7 CBs concentration (in µg/kg)							
	2002	2003	2004	2005	2006	2007	2008	2009
G34		*0.7*		*0.7*	*0.7*	2.1	*0.7*	*0.7*
G50							*0.7*	*0.7*
G33	*0.7*	14.2	7.67	2.37	4.08	4.26	7.87	2.46
G28	64.6	57.9	4.78	8.55	10.2	9.86	71.9	10.2
G30						3.69	*0.7*	1.27
G25	23.9	19.7			2.07		2.6	1.83
G21	28.4	12.3				5.42	4.76	
G18	81.9	90.8	62.5	6.7	7.11		18.8	
KH1						40.6	1.37	
G20						1.8	6.6	
G19	194	15.9	202	24.7	1.43	1.34	13.1	
G13	*0.7*	*0.7*	1.47	*0.7*	*0.7*	384	1.83	*0.7*
G3	*0.7*	*0.7*			*0.7*	0.95	*0.7*	*0.7*
RH7		*0.7*		*0.7*		*0.7*	*0.7*	*0.7*
G37		*0.7*			1.33	0.89	*0.7*	*0.7*
RH6		*0.7*		*0.7*		*0.7*	*0.7*	*0.7*
G6					2.75	3.85	0.82	3.26
G36		*0.7*				1.8	1.82	2.79
G2	*0.7*	5.1				1.19	1.58	*0.7*
G8	5.2	7.4	0.86	*0.7*	*0.7*	*0.7*	*0.7*	*0.7*

Table 2.6.3. Temporal trends (2002-2009) of ∑ICES 7 CBs concentration (in µg/kg) at Rame Head in the stations sampled during 2009. Note, concentrations in italic represent estimates of concentrations for samples where all ICES 7 congener concentrations were below LODs.

Station code	∑11 BDEs concentration (in µg/kg)							
	2002	2003	2004	2005	2006	2007	2008	2009
G34		*0.69*		*0.69*	*0.69*	*0.69*	*0.11*	*0.11*
G50						*0.69*	0.13	*0.11*
G33				*0.69*	*0.69*	*0.69*	*0.11*	0.12
G28		*0.69*		*0.69*	*0.69*	*0.69*	0.18	0.12
G30						*0.69*	*0.11*	0.12
G25		0.79			0.88		*0.11*	0.13
G21		0.80				*0.69*	0.12	
G18		1.18		*0.69*	0.84		*0.11*	
KH1						*0.69*	*0.11*	
G20						*0.69*	*0.11*	
G19		0.74		*0.69*	0.78	*0.69*	0.12	
G13		0.81		*0.69*	0.77	*0.69*	*0.11*	*0.11*
G3		0.79			0.82	*0.69*	*0.11*	*0.11*
RH7		0.73		*0.69*		*0.69*	0.12	*0.11*
G37		0.75			0.76	*0.69*		*0.11*
RH6		*0.69*		*0.69*		*0.69*	0.13	*0.11*
G6					0.96	*0.69*	0.53	0.12
G36		1.27				*0.69*	*0.11*	0.12
G2		0.72				*0.69*	0.51	0.49
G8		0.79		*0.69*	0.94	*0.69*	0.23	0.12

Table 2.6.4. Temporal trends (2002-2009) of ∑11 BDEs concentration (in µg/kg) at Rame Head in the stations sampled during 2009. Note, concentrations in italic represent estimates of concentrations for samples where all 11 BDE congener concentrations were below LODs. Limits of detection for BDEs improved between 2007 and 2008 and therefore values assigned to congeners below LOD are lower in 2008 and 2009, resulting in a step decrease in ∑11 BDEs concentration for samples with congeners below LODs.

2.6.4.4.4 Trace metals

Since stations inside the disposal site were not sampled in 2009, temporal data based on stations outside the disposal site only are presented (see Bolam *et al*., 2009 for data regarding temporal variability in trace metals inside the disposal site at Rame Head). Figure 2.5.18 presents the average metals concentrations for stations outside the disposal site sampled in 2009 compared to previous years. There is no indication of a general increase or decrease in metals concentrations in 2009. Although the maximum average concentration of Li and Cr is found in 2009, these are not statistically higher than concentrations of the metals found in one or more previous years. Spatial variability was high for some metals, particularly for Zn, Pb and Mn in 2006 and Pb in 2007; this was due to elevated values at G13 for Zn and Pb, at G16 for Mn in 2006, and for Pb at G13 in 2007.

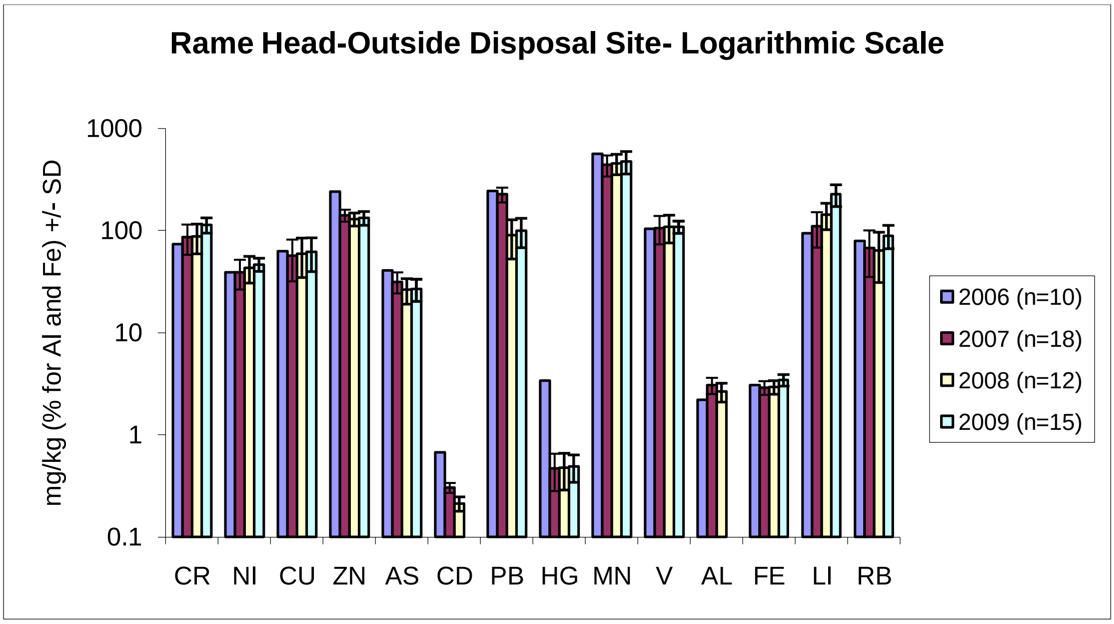


Figure 2.6.18. Average metal concentrations outside Rame Head disposal site from 2006-2009. Stations sampled in 2009 with a prefix 'P' were not included in this assessment.

When comparing the West Channel preliminary baseline with OSPAR BACs (Table A4, Appendix 4) many trace metals values are lower: perhaps because there is limited reference data (n=23) in the West Channel from which the baselines are derived. Enrichment is mapped for As, Cu, Pb and Cr in Figure 2.6.19. No samples were collected in 2009 from within the disposal site. However, samples from extra transects situated south and northwest of the site (pre-fixed P) were completed to validate proposed sites where resuspended dredge sediment from the disposal site may be deposited (Okada *et al*., 2009). In 2009, most stations were enriched, except for the more offshore stations with respect to Pb (Figure 2.6.19). Cu, and to a lesser extent As, showed relative enrichment towards the southeast and northwest of the area surveyed. The enrichment compared to OSPAR BACs observed are unlikely to be the direct result of disposal activity, although it may be possible that the disposal activity is enhancing already high concentrations, related to the natural environment in this area, as well as resultant from historic mining activity (Rowlatt and Lovell, 1994; Langston *et al*., 2003).

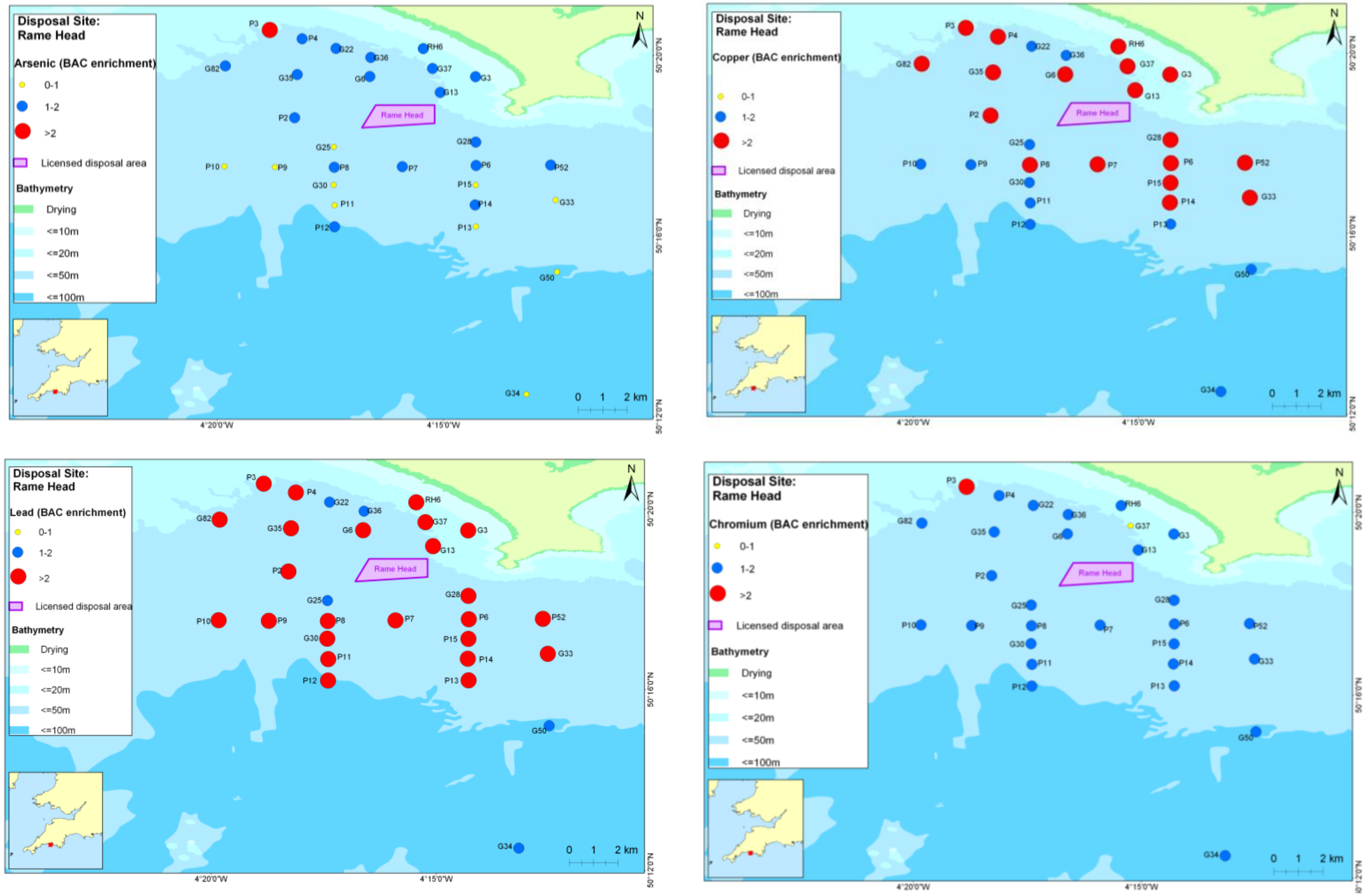


Figure 2.6.19. Enrichment to OSPAR BACs (raw/OSPAR BAC) at Rame Head in 2009 for As, Cu, Pb, and Cr.

2.6.5 Conclusions

Monitoring at the Rame Head disposal site has been conducted annually since 2001 using a variety of approaches (camera tows, grabs, acoustics, intertidal contaminant assessments, turbidity loggers). The outcomes of such monitoring have been reported at various times (e.g., Cefas, 2005; Bolam *et al*., 2009; Bolam *et al*., in press). Although sampling was not conducted within the licensed boundary of the disposal site in 2009, the results from stations outside the site support the conclusions of previous years. Biological changes are small and reflect an alteration in community structure as opposed to a marked decrease in numbers of individuals or species. Indeed, total secondary productivity of the benthos appears to show little relationship with distance form the disposal site (Bolam *et al*., in press).

TBT concentrations continue to be below the limit of detection at all stations around Rame Head. PAH concentrations do not appear to present any concern; of all the stations sampled only one station exceeded the ERL for LMW PAHs and one for HMW PAHs. These stations lie just outside the disposal site boundary, along the main sediment transport pathway. Similarly, organohalogen concentrations observed in 2009 indicate that disposal activity is not resulting in levels to raise concern. For BDEs for example, concentrations are below, or just above, LODs for almost all stations while for CBs, 9 stations were below LOD. The only station to show notable concentrations of organohalogens was G28, southeast of the disposal site and along the main transport pathway. The more-or-less isolated cases of raised concentrations of PAHs and organohalogens in 2009 to the immediate southeast and northwest of the disposal site supports our expectation that raised contaminants should be restricted to the immediate vicinity of the site along the main transport pathway. Observed trace metals concentrations were not elevated from previous years: the general enrichment across the survey area (relative to OSPAR BACs) is likely to reflect natural mineralogical characteristics of the region. Further work is currently being conducted to address the latter issue for the whole of the UK under a separate project.

The 2009 data for Rame Head indicate that, unless any changes to the disposal regime are anticipated, no further monitoring appears warranted in the short term. However, an assessment of contaminant concentrations (particularly metals, once metals data can be assessed with potentially more appropriate regional background concentrations) should be conducted within a few years, together with actions to respond to any issues that may arise regarding the site.

3. Acknowledgements

A large number of Cefas staff has helped contribute to the work which has been conducted to produce this report. Such staff have been involved in all aspects of the work from an early stage, e.g., during discussions of the specific issues regarding dredged material disposal sites around the England and Wales coast (Cefas’ RAT), through to the field sampling and the laboratory processing of the various biological, physical and chemical parameters; such staff are far too numerous to name here.

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Appendix 1. TBT methods and concentration assessment.

1. Methodology

The sediment samples were collected in hexane-rinsed glass jars and were frozen immediately after collection. The samples were collected for organics analyses, mainly organotins (TBT and DBT), organohalogens and hydrocarbons analyses. The whole (wet) sediment sample is homogenised then sub-sampled for the determination of the total solid content and for organotins analysis.

Sample extraction is initially carried out by alkaline saponification, the organotins compounds are then converted into their hydrides forms with the addition of sodium borohydride. The organotins hydrides are finally extracted back in hexane by liquid-liquid extraction. Analysis is undertaken using a Gas Chromatography-Flame Photometric Detector (GC-FPD) and quantification is done using external calibration. A certified reference material is run within each sample batch for quality control. Results are reported in mg kg^{-1} (ppm) dry weight.

2. Method used for assessment

In this report, since the method is similar to that used for the dredged materials analysis, direct comparison can be made and therefore we assess the organotins data against the actions levels used by the Regulatory Assessment Team (Table A1). In general, contaminant levels in dredged material below Action Level 1 are of no concern and are unlikely to influence the licensing decision. However, dredged material with contaminant levels above Action Level 2 is generally considered unsuitable for sea disposal. The latter situation most often applies only to a part of a proposed dredging area and so that area can be excluded from disposal at sea and disposed of by other routes e.g. landfill. Dredged material with contaminant levels between Action Levels 1 and 2 requires further consideration and testing before a decision can be made.

ACTION LEVELS	Action Level 1 (mg/kg)	Action Level 2 (mg/kg)
Organotins; TBT/ DBT/ MBT	0.1	1

Table A1. Actions levels for Organotins compounds.

Appendix 2. Methods for PAH assessment and concentration assessments.

1. Methodology

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

2. 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 10th and 50th 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 PAH includes the 2- and 3-ring PAH compounds naphthalene, monomethyl naphthalenes, acenaphthene, acenaphthylene, fluorene, phenanthrene and anthracene; HMW PAH includes the 4- and 5-ring PAH compounds fluoranthene, pyrene, benz[*a*]anthracene, chrysene, benzo[*a*]pyrene and dibenz[*a,h*]anthracene. Although a wider suite of PAH is determined routinely for both licensing and monitoring purposes, these can be considered as toxicity markers for the PAH as a whole. The ERL and ERM concentrations applied are given in Table A2.

PAH compounds	**ERL**	**ERM**
LMW PAH	552	3,160
HMW PAH	1,700	9,600

Table A2. ERL and ERM concentrations for LMW and HMW PAHs in sediments (µg kg^{-1} dry weight).The limits for LMW PAH are lower than those for HMW PAH as they carry a higher acute toxicity.

Appendix 3. Organohalogens methods and concentration assessment.

Full details of the analytical methodology are given in Allchin *et al*. (1989) and de Boer *et al*. (2001).

1. Sample extraction

Sediment samples were air dried and sieved (<2mm) in a controlled environment. 10 g of dried sediment were mixed with sodium sulphate, transferred to a glass Soxhlet thimble and topped with 1 cm of sodium sulphate. Samples were extracted over a 6 h period using 50:50 hexane:acetone, with an average of 9 - 10 cycles h^{-1}. Sulphur residues were removed at this stage with copper filings.

2. Sample extract clean-up

An aliquot of the Soxhlet extract was cleaned up and fractionated using alumina (5% deactivated) and silica (3% deactivated) columns, respectively. The silica column fractionation results in two fractions, the first fraction containing polychlorinated biphenyls (PCBs) and the second fraction containing polybrominated diphenylethers (PBDEs).

3. Analysis of PCBs by GC-ECD

After addition of internal standard CB#53, PCB concentrations were determined with an Agilent 6890 GC with µECD. The separation of analytes was performed on a 50.0 m × 200 µm, 0.33-µm-film-thickness DB-5 capillary column (J&W). The carrier and ECD make-up gas were hydrogen (32.2 psi constant pressure, initial velocity 50 cm/s) and argon/methane (95:5), 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, and finally held for 23 min. The injector temperature and detector temperature was 270°C and 300°C, respectively. A 1-µl extract was injected in splitless mode with a purge time of 2 min.

4. Analysis of PBDEs by GC-MS

After addition of internal standard CB#200, PBDE concentrations were determined with an Agilent 6890 GC with 5973 MS. The separation of analytes was performed on a 30.0 m × 250 µm, 0.25-µm-film-thickness DB-5 capillary column (J&W). The carrier gas was helium (30 psi constant pressure, average velocity 40 cm/s). The initial oven temperature was 90°C, held for 2.00min, then increased to 200°C at 30°C/min, to 295°C at 2.5°C/min, and finally held for 31.33 min. The injector temperature and detector temperature was 270°C and 200°C, respectively. A 2-µl extract was injected in splitless mode with a purge time of 2 min.

5. Quantitation methods

The identification of PCBs and PBDEs was based on the retention time of individual standards in the calibration mixtures.

Quantitation for PCBs was performed using internal standards and 7 calibration levels (range 0.5 – 100 ng/ml). The PCB standard solutions contained the following 25 compounds in iso-octane: 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; together with the internal standard IUPAC CB53.

Quantitation for PBDEs was performed using internal standards and 8 calibration levels (range 0.1 – 50 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; together with the internal standard IUPAC CB200.

6. Quality assurance/ quality control procedures

AQC procedures included reagents purification, method blanks, and use of control charts created from repeated analysis of the SETOC 770 Certified Reference Material (CRM).

PCB and OCP concentrations were determined in the sediments and reported on a dry weight basis. The ∑ICES 7 CBs (CB28, CB52, CB118, CB153, CB138, CB 170, CB183), and the sum of all 25 measured CBs (∑CBs) were calculated. Where individual congener concentrations were below the limit of detection (LOD) of 0.2 µg/kg, a value of half the LOD was inserted for calculation of summed concentrations. The CB congener distribution was calculated from the proportion of the sum of ∑CBs that contained 3 chlorines (CB18, CB28, CB31), 4 chlorines (CB44, CB47, CB49, CB52, CB66), 5 chlorines (CB105, CB110, CB101, CB118), 6 chlorines (CB128, CB158, CB141, CB149, CB153, CB138, CB151, CB156), 7 chlorines (CB170, CB180, CB183, CB187), and 8 chlorines (CB194), respectively. Congener profiles at different stations were compared to identify stations with different sources.

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 in the sediment were compared with various action limits, to investigate whether any adverse effects in benthic biota were likely to be expected as a consequence of their presence. The current Cefas action levels for dredge disposal are: warning levels if ∑ICES7 CBs > 10 µg/kg, ∑CBs > 20 µg/kg, and action levels if ∑CBs > 200 µg/kg. Concentrations are expressed on a dry weight basis. According to the work of McDonald *et al.*; (2000), consensus-based TECs (Threshold effect concentrations), i.e. below which harmful effects are unlikely to be observed, are: ∑CBs <59.8 µg/kg; and consensus-based PECs (Predicted effect concentrations), i.e. above which harmful effects are likely to be observed (∑CBs >277 µg/kg). Concentrations are expressed on a dry weight basis. OSPAR have set criteria for Background Assessment Concentrations (BAC) and Environmental Assessment Concentrations (EAC) for the ICES7 CBs in sediments (see Table A3). Concentrations are expressed in µg/kg dry weight normalised to 2.5% organic carbon. Concentrations below BACs would be considered to have high environmental status. Concentrations significantly below EACs could be considered to have good environmental status and those above, bad environmental status. The station is deemed to have 'bad' environmental status if 'bad' status occurs for more than one ICES7 CB congener.

Sediment (µg/kg dry weight, normalised to 2.5% TOC)

Compound	BAC	EAC
CB28	0.22	1.7
CB52	0.12	2.7
CB101	0.14	3.0
CB118	0.17	0.6
CB138	0.15	7.9
CB153	0.19	40
CB180	0.10	12

Table A3. OSPAR assessment criteria for CBs in sediment from CP2.

Appendix 4. Metals methods and assessment of concentrations.

1. Methodology

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

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

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

2. Method used for assessment

Two studies, looking at general trends, and not individual stations, are 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.

In order to assess relative level of trace metal contamination, enrichment to a baseline is required. OSPAR Background Assessment Concentrations (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. 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, J *et al*, 2003; Rowlatt, S and Lovell, D, 1994). Therefore, for assessing enrichments at disposal sites, it is proposed to develop regional baselines utilising various spatial datasets around England and Wales. Preliminary baselines for the areas are defined in Table A4, along with OSPAR BACs (OSPAR, 2006). These are presented to give an indication of the relative differences to the OSPAR BACs. So far these regional baselines concentrations are similar to OSPAR BACs, and several are lower. However in this report, they are purely presented to show there is regional variation, but have not been used to calculate enrichment as they are still in the developmental stage.

In the previous annual monitoring report (Bolam *et al*., 2009), Effects Range Low (ERLs) were also used in an attempt to determine whether concentrations measured were likely to affect biological communities. ERLs are based on 10th percentile of the distribution of contaminant concentrations associated with adverse biological effects. These values have been produced using large US datasets produced using a wide range of methodologies. They are based on the co-occurrence of bulk chemical concentrations and toxicity measured in bioassays of sediment samples and do not demonstrate cause and effect. They do not take account of sediment type and it is advisable only to consider them in conjunction with other environmental data types, such as sediment type (Hubner, *et al*., 2009). The amount of uncertainty associated with the ERLs in relation to the methodology used in this assessment (total digest on <63µm, and wide range of sediment types covered) means the degree and extent of contamination indicated by them was unlikely to be realistic and so they have not been used in this year's assessment.

Normalisation of metal concentrations is required to account for differences caused by different sediment types present in the area surveyed. As trace metal concentrations were measured on the fine fraction of sediment (<63µm), normalisation to some extent has already been completed. However, 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, as well as rubidium, organic carbon and silt/clay (%). 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 either aluminium or lithium. Lithium was the better of the two tested, but the relationship between lithium and trace metals was not strong enough to confirm the use of lithium for normalisation definitively. At North Tyne and Bridlington, there was a clear relationship between organic carbon and trace metal concentrations, and this should be further investigated for reporting next year.

Preliminary regional baselines	Number of samples	Li	As	Cd	Cu	Cr	Hg	Ni	Pb	Zn
Tyne (median value of 25 percentile for 'reference' concentrations, in relation to lithium)	76	41	17	0.17	18	90	0.08	35	67	101
West Channel (median value of 25 percentile for 'reference' concentrations, in relation to lithium)	56	56	12	0.19	17	51	0.05	25	28	95
Humber (median value of 25 percentile for 'reference' concentrations, in relation to lithium)	23	49	24	0.16	21	97	0.09	40	50	110
OSPAR BAC (normalised to 5%Al or 50mg Li)	-	50	25	0.31	81	27	0.07	36	38	122

Table A4. Comparison of OSPAR BACs (OSPAR, 2006) with preliminary baselines for regions covered in disposal site assessment in 2010.

To further confirm inferences above, for each site, the trace metals data was normalised to 5%Al with pivot point, and to 50mg Li with pivot point. Enrichment to OSPAR BACs for normalised data 5%Al (calculation 1), 50mg Li (calculation 2) and with no normalisation (calculation 3) was completed using the following calculation:

Enrichment = Metal (calculation 1: normalised to 5%Al with pivot point)

(mg kg-1) (calculation 2:normalised to 50mg Li with pivot point)

(calculation 3:no normalisation)

OSPAR BAC

The relationship between each dataset was tested using the multivariate test, within PRIMER software, called RELATE (Clarke and Gorley, 2006). This test compares the similarity matrix produced for each enrichment type (Al, Li or raw) against each other. The closer the R value is to 1, the more similar the enrichment patterns produced. It was clear for each dataset that for each site the lithium enrichment factors were closest to the raw data enrichment factors (coloured pink in Table A5).

RELATE results	Site	R	Significance (%)
Al enrich v Li enrich	North Tyne	0.42	0.1
Li enrich v RAW enrich	North Tyne	0.57	0.1
Al enrich v RAW enrich	North Tyne	0.22	2.6
Al enrich v Li enrich	Bridlington	0.07	31.8
Li enrich v RAW enrich	Bridlington	0.70	0.1
Al enrich v RAW enrich	Bridlington	0.08	34.8
Al enrich v Li enrich	Tees	0.28	0.1
Li enrich v RAW enrich	Tees	0.42	0.1
Al enrich v RAW enrich	Tees	0.38	0.1
Al enrich v Li enrich	Souter Point	-0.05	71.2
Li enrich v RAW enrich	Souter Point	0.24	0.1
Al enrich v RAW enrich	Souter Point	-0.01	51.1
Al enrich v Li enrich	Rame Head	0.42	0.2
Li enrich v RAW enrich	Rame Head	0.62	0.1
Al enrich v RAW enrich	Rame Head	0.28	0.2

Table A5. Comparison of enrichment factors (Al, Li and raw) at each site: RELATE results.

Therefore, as the trace metal concentrations were already normalised by measuring on the <63µm sediment fraction, and there were no significant relationships in the trace metals data with the normalisers tested, enrichment to OSPAR BACs using no further normalisation is completed at each site, even though the OSPAR BACs are produced using data normalised to 5%Al with a pivot point. These enrichment values, for each site, for all years will be used for discussion in this report under each site. The values are presented in Table A5.

About us

Cefas is a multi-disciplinary scientific research and consultancy centre providing a comprehensive range of services in fisheries management, environmental monitoring and assessment, and aquaculture to a large number of clients worldwide.

We have more than 500 staff based in 2 laboratories, our own ocean-going research vessel, and over 100 years of fisheries experience.

We have a long and successful track record in delivering high-quality services to clients in a confidential and impartial manner.
(www.cefas.defra.gov.uk)

Cefas Technology Limited (CTL) is a wholly owned subsidiary of Cefas specialising in the application of Cefas technology to specific customer needs in a cost-effective and focussed manner.

CTL systems and services are developed by teams that are experienced in fisheries, environmental management and aquaculture, and in working closely with clients to ensure that their needs are fully met.
(www.cefastechnology.co.uk)

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Customer focus

With our unique facilities and our breadth of expertise in environmental and fisheries management, we can rapidly put together a multi-disciplinary team of experienced specialists, fully supported by our comprehensive in-house resources.

Our existing customers are drawn from a broad spectrum with wide ranging interests. Clients include:

- international and UK government departments
- the European Commission
- the World Bank
- Food and Agriculture Organisation of the United Nations (FAO)
- oil, water, chemical, pharmaceutical, agro-chemical, aggregate and marine industries
- non-governmental and environmental organisations
- regulators and enforcement agencies
- local authorities and other public bodies

We also work successfully in partnership with other organisations, operate in international consortia and have several joint ventures commercialising our intellectual property

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