Cefas

Cefas contract report SLAB5

Dredged material disposal site monitoring across England and Wales: results of sampling under SLAB5 (2008-09)

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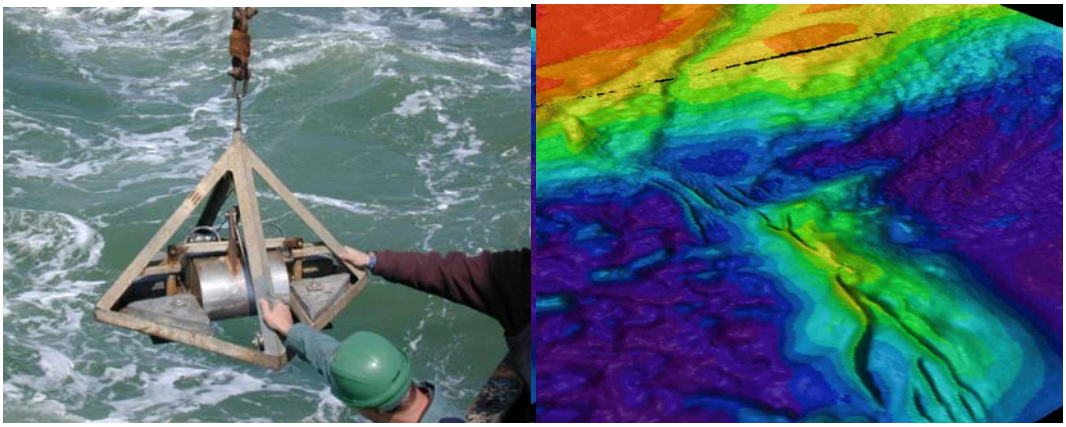
Commercial in confidence

DREDGED MATERIAL DISPOSAL SITE MONITORING ACROSS ENGLAND AND WALES: RESULTS OF SAMPLING UNDER SLAB5 (2008-09)

Bolam, S.G., Mason, C., Bolam, T., Whomersley, P., Birchenough, S.N.R, Curtis, M., Birchenough, A., Vanstaen, K., Rumney, H., Barber, J., Law, R., Aldridge, J, Nye, V. and Griffith, A.



Summary

The data and scientific findings of the dredged material disposal site sampling around the England and Wales coast during 2008 under SLAB5 are presented. The background, issues and impact hypotheses pertaining to each site are also detailed.

During 2008, a total of 8 disposal sites were sampled with a further site investigated by modelling the likely fate of disposed material at different tidal states. Parameters monitored varied across sites (governed by the specific issues and subsequent impact hypotheses for each) 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.

The results of such sampling and analyses are presented in this report in terms of whether observations are aligned with those expected for that particular site, and, where possible, temporal comparisons are made to give an indication of whether changes are showing positive or negative trends with respect to the parameters monitored. This report, therefore, helps provide an insight as to whether a particular site should be the subject of sampling in successive years.

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1. Introduction

1.1 Regulation of disposal activity in England and Wales

Around the England and Wales coastline, licences for the disposal of dredged material to sea are 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 (Murray, 1994; Bolam et al., 2003).

In licensing the disposal of dredged material at sea numerous, conditions associated with the relevant national and international agreements (e.g., the London Convention and Protocol of 1972 (LC72), 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), the Strategic Environmental Assessment Directive (85/337/EEC) and the Water Framework Directive (WFD, 2000/60/EC)), must be considered to determine whether likely impacts arising from the 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 on the suitability of the 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 and Wales

There are over 150 sites designated for dredgings disposal around the UK, not all of which are used in any one year. While the majority of these are located on the coast of the mainland, generally within a few miles of a major port or estuary entrance, a small 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. Individual quantities 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 SLAB5

In the UK, SLAB5 is one of several contracts funded by MFA under non-R&D MoU B. The project provides:

- field evaluations ('baseline', monitoring and 'trouble-shooting' surveys) principally at dredged material disposal sites in support of FEPA II (1985)
- the scientific underpinning for Cefas benthic ecologists (and others) to deliver application-related advice to Cefas' RAT (but it is not itself an advisory contract)

A major component of the project is the commissioning of sea-going activities 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 government 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 peer-review outcomes) but to encapsulate the essence of the impacts associated with this activity in its entirety across the England and Wales coast (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. 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 2008-09 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 have been selected based on information from dredged material licence applications, consultation with MFA 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
Scarborough Rock	TY190	1
Goole, Humber	HU040/041	1
Hurst Fort	WI080	2
Rame Head South	PL031	1
Falmouth Bay (B)	PL075	1

Table 1.1. Disposal sites selected for investigation during 2008-09.

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 England and Wales coastline. Such appraisals are given 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 2008 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 2008 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 aid promote the development of scientific (or other) outputs under SLAB5.

Section 2 of this report presents the findings of the 2008 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.co.uk). Information regarding the processing of samples for organohalogens, together with some background to the numerical approaches and derivation of action levels, is briefly given in Appendix 1. Appendix 2 provides an overview of the criteria used to assess trace metals concentrations in marine sediments.

2. Results

2.1 North Tyne (TY070)

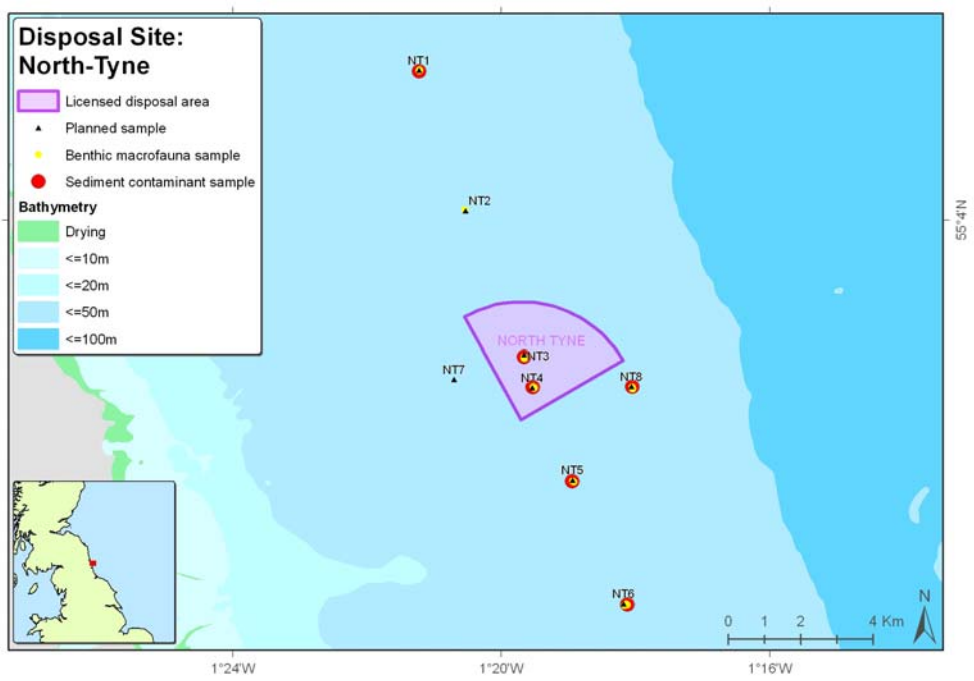


Figure 2.1. Locations of monitoring stations at North Tyne disposal site during 2008.

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, rock mine tailings and fly ash from power stations. Instructions of the current maintenance licence is restricting material going to Souter Point disposal site to the south (see Section 2.2) and therefore an increase in tonnage being disposed of at this site is expected.

The contaminated nature of the dredge material is a result of the industrial background of the area. This has resulted in very high levels of heavy metals and hydrocarbons from the mining industry. Recently material around Action Level (AL) 2 for Zinc has been disposed of from Walker Technology Park to this disposal site. The large amount of shipping in and out of the wharfs has also contributed to a historic legacy of TBT contamination.

Currently, elevated levels of hydrocarbons and heavy metals are routinely disposed of to this site compared to levels seen at other disposal sites. High levels of TBT in dredge material going to this site are 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 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

Station code	2006	2007	2008
NT1	3	3	3
NT2	3	n	n
NT3	3	7b	7b
NT4	6	7b	3
NT5	2B	6	3
NT6	2B	2C	2B
NT7	2B	2B	n
NT8	3	3	3

Table 2.1: Sediment groups for the North Tyne stations, 2006-08 (n = no sample). Key: 2B = muddy sandy gravel, 2C = gravelly muddy sand, 3 = slightly gravelly sand, 6 = gravelly muddy sand (most muddy group), and 7B = slightly gravelly sand.

In 2008, the main sediment type surrounding the disposal site is group 3, characterised by mixed slightly gravelly sands with coarser sediment of muddy sandy gravel (group 2B) south

of the site at NT6. Within the site, slightly gravelly sand (group 7B) is found at NT3 and mixed, slightly gravelly sand (group 3) at NT4, and are, therefore, quite similar to those found surrounding the site.

Temporally, the most change in sediment types is observed within the disposal site (NT3 and NT4), and at NT5, south of the disposal site. NT3 changes from mixed slightly gravelly sand to unimodal slightly gravelly sand in 2007 and 2008. The sediment type at NT4 changes from muddy, to unimodal slightly gravelly sand to mixed slightly gravelly sand. The sediment types at NT5 change from muddy sandy gravel in 2006 to muddy gravelly sand, with increased mud content (2007) to mixed slightly gravelly sand (2008). At NT6, in 2007, the sediment type measured was slightly less gravelly (group 2C) than in 2006 and 2008 (group 2B). Therefore the main changes observed are in the disposal site and at NT5, just south of the disposal site.

2.1.4.2 Sediment organic carbon & nitrogen

In 2008, organic carbon values range from 3.0 to 4.1 % m/m and for nitrogen 0.24 to 0.36 % m/m. These are similar to 2006 and 2007. NT1 and NT6 and contain higher levels of organic carbon for the <2mm fraction (4.16 compared with 2.99 at NT1, and 6.47 compared with 4.12 at NT6) than the <63µm showing that the organic carbon for this area is in the coarser sediment, probably as coal, which is naturally present in the sediment in this region (both these stations are outside of the disposal site).

2.1.4.3 Macrofaunal communities

The macrofaunal analysis identified a total of 4983 individuals and 49 taxa from the samples taken at North Tyne during 2008. The main taxonomic groups were represented by Annelida, Mollusca, Miscellania, Echinodermata, and Crustaceans (Figure 2.2)

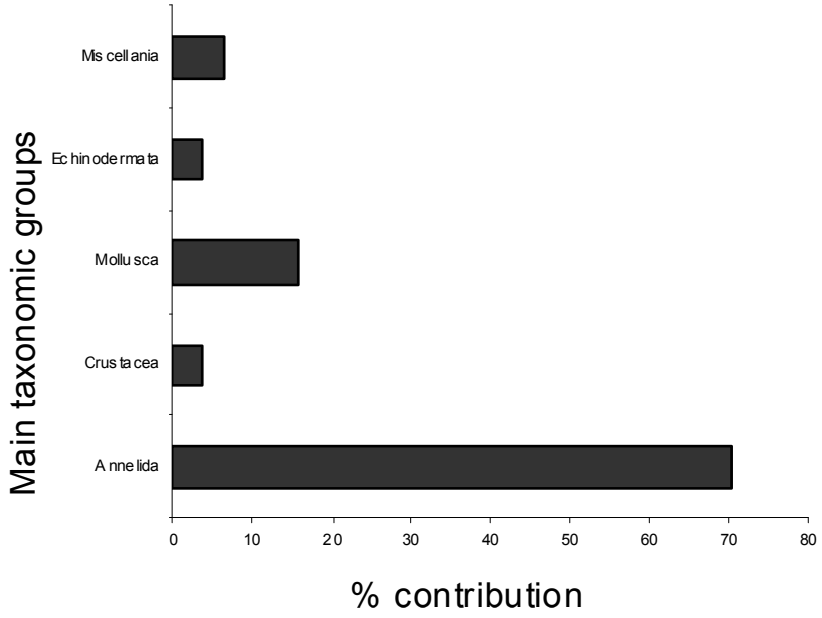


Figure 2.2. Contribution of main taxonomic groups sampled in 2008 at North Tyne.

The total abundance of individuals varied from 95 to 282 per 0.1 m^2 across the study area in 2008. Overall, the lowest values ranged from 95 to 116 individuals per 0.1 m^2 at NT4 and NT3 respectively. Higher values were observed at the stations located outside the disposal site at stations NT1 and NT8 located north and west of the centre respectively (Figure 2.3A). Total number of species ranged from 38 to 64 species per 0.1 m^2 in area. Higher values for number of species were encountered in NT8 and NT1 (64 and 61 species respectively) located north and west from the licensed disposal site (Figure 2.3B).

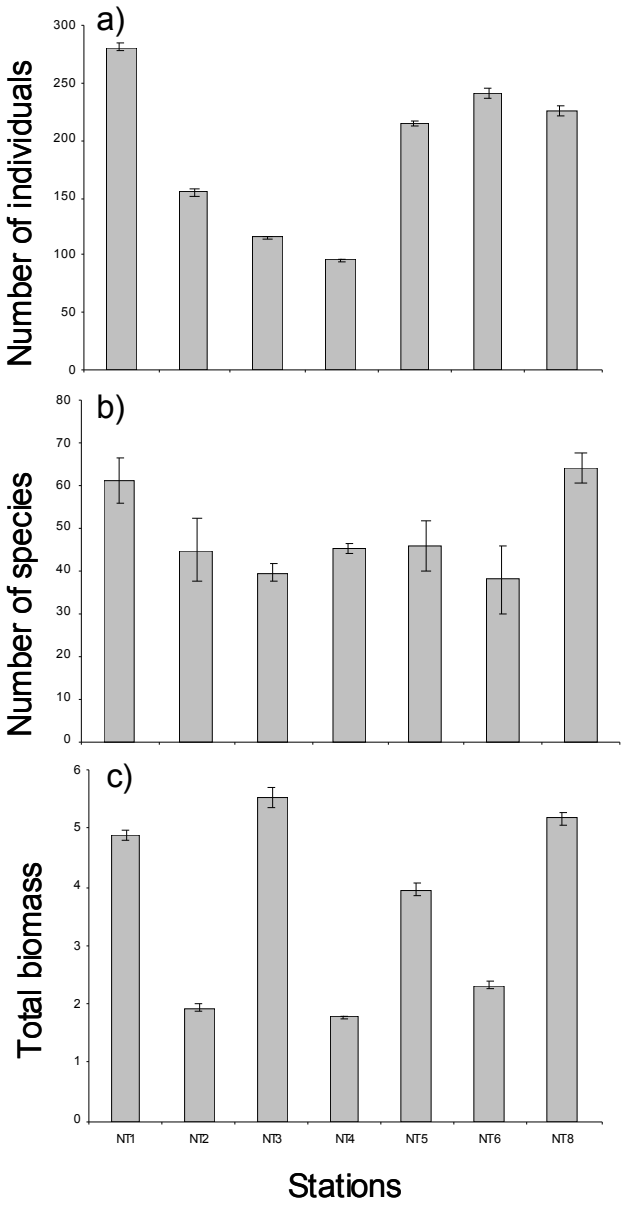


Figure 2.3. Univariate trends, mean values for: A) total number of individuals, B) total abundance of taxa and C) total biomass over 2008 at North Tyne.

Total biomass was observed to be in the order of 1.77 to 5.51 g / 0.1 m^2 in the area. Higher biomass values were recorded at stations NT1, NT3 and NT8 (4.87, 5.51 and 5.17 g / 0.1 m^2 respectively) (Figure 2.3C). The species responsible for the higher biomass were *Dosinia lupinus*, *Echinocardium cordatum*, *Aporrhais pespelecani* and the holoturian *Leptopentacta elongate*.

Multivariate analyses showed a clear separation of stations located in the centre of the disposal site (NT3 and NT4) when compared with the north and south reference stations (NT1 and NT5 respectively) (Figure 2.4).

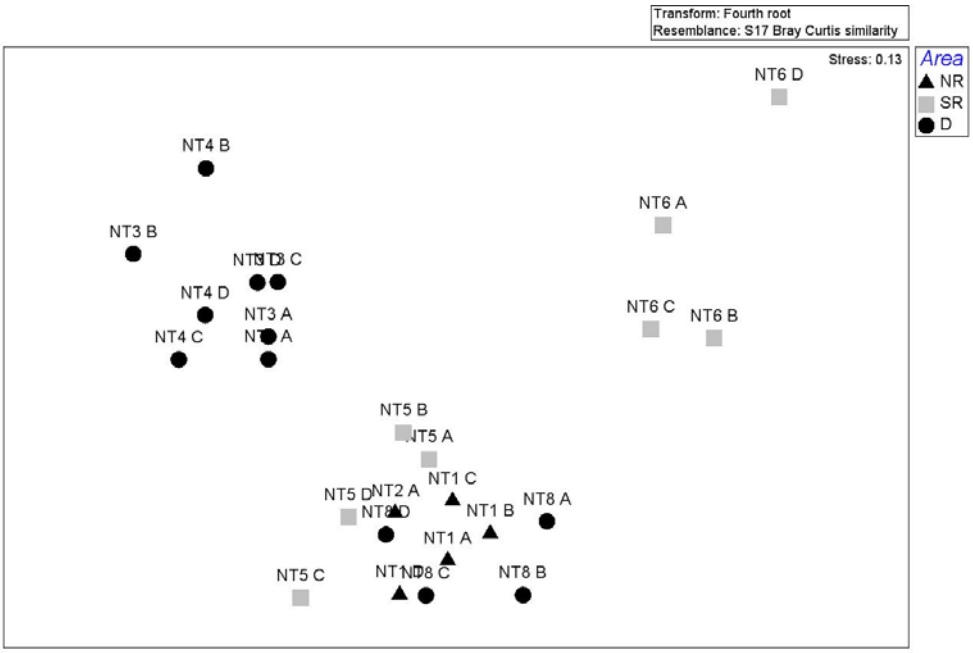


Figure 2.4. Multidimensional scaling ordination based on Bray-Curtis similarity for infauna samples over 2008 at North Tyne.

SIMPER analysis also evidenced the species that were causing the dissimilarity over the disposal site and reference stations during 2008. The average dissimilarity between the disposal site and northern reference accounted for 57.40 %, from which the species responsible were *Peresiella clymenoides*, *Phoronis* sp., *Dosinia* sp. (juv), *Phascolion strombus*, *Paradoneis lyra* and *Chaetozone setosa* (these species contributed to 10.66 % of overall group dissimilarity).

The average dissimilarity between the north and south reference was 58.18 %, the main responsible species causing this dissimilarity were Ophiuridae (juv), *Peresiella clymenoides*, *Phoronis* sp., *Mediomastus fragilis*, *Chaetozone setosa*, Amphiuridae (juv) and *Magelona alleni* (these species contributed to 10.42 % of the overall group dissimilarity). Comparisons between the dissimilarity observed between the disposal site and south reference showed the highest group dissimilarity with 64.10 %, the species responsible were *Peresiella clymenoides*, *Dosinia* sp. (juv), Ophiuridae (juv), *Mediomastus fragilis*, *Nuculoma tenuis*, *Scalibregma inflatum* and *Spiophanes bombyx* (these species contributed to 10.73 % of the overall group dissimilarity).

In conclusion, therefore, these results indicate that numbers of individuals are lowest at the disposal stations (i.e. NT3 and NT4) when compared with the north and south reference. Furthermore, numbers of species and biomass values are similar to the reference conditions.

Previous assessments of the disposal site have shown the presence of a resilient benthic community at this site (Birchenough et al., 2006).

2.1.4.4 Sediment contaminants

2.1.4.4.1 TBT

In the 2008 monitoring survey, the organotins data for the majority of the North Tyne samples were below the current limit of detection (i.e. 0.002 mg/kg) with a few positive results of TBT for sites NT5 and NT4. Both results (0.025 and 0.047 mg/kg respectively) are below AL1. Interestingly, TBT concentration was above AL2 in 2006 but has decreased to 0.047 mg/kg in 2007 and remained the same for this year. There was a slight decrease in TBT and DBT concentrations for both NT5 and NT3 from 2007.

Overall, there was a small decrease in TBT and DBT concentrations, however, the findings are very similar to previous year's in terms of their general concentrations.

2.1.4.4.2 PAHs

The North Tyne disposal site had the second highest summed PAH concentrations of the areas sampled during 2008 (after Tees). This reflects the high levels of PAH contamination previously found in the surrounding estuaries (Woodhead et al., 1999). The highest summed PAH concentration found was 115,400 µg kg^{-1} at site NT6, midway between the North Tyne and Souter Point Disposal Sites (Figure 2.5). The highest concentration observed in the 2007 survey, 292,000 µg kg^{-1}, was at this same station. Typically, summed concentrations within the disposal site, at sites NT3 and NT4, were ca. 10,000µg kg^{-1}. In 2007, the concentration at NT3 was 16,000 µg kg^{-1}.

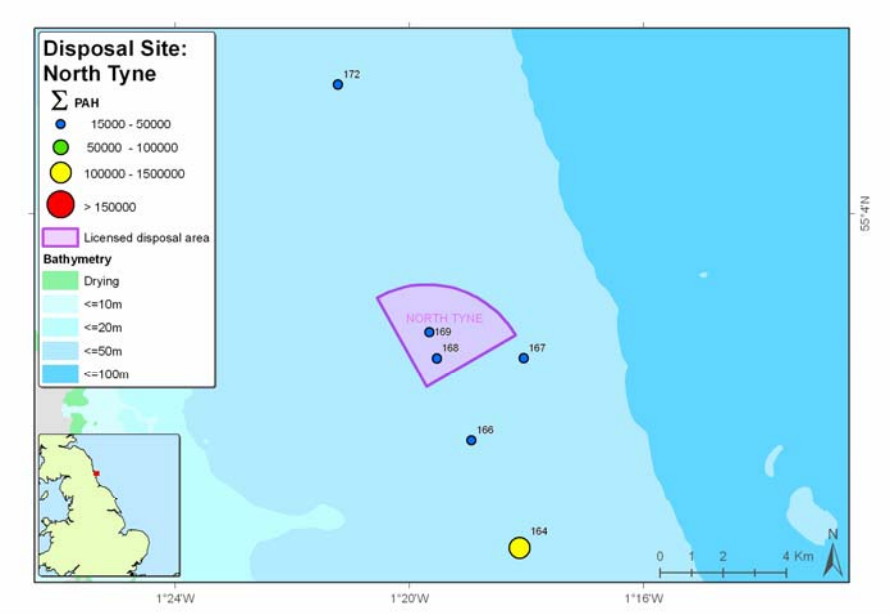


Figure 2.5. Summed PAH concentrations around the North Tyne disposal area, 2008.

2.1.4.4.3 Organohalogens

At North Tyne, concentrations of organohalogens were generally low, below or close to LODs, with the highest concentrations for chlorinated biphenyl (CB) observed south of the disposal site at stations NT5 and NT6 (Figures 2.6 – 2.8), although these were still low. Station NT5 had high dieldrin levels of 13.8 µg / kg. Most stations were below FEPA warning levels and TECs for CBs and organochlorines (OCs), except for station NT5 which was above FEPA warning limits and TEC for dieldrin. According to the OSPAR guidelines, all stations had 'good' environmental status for all ICES7 CBs, and 'good' status overall.

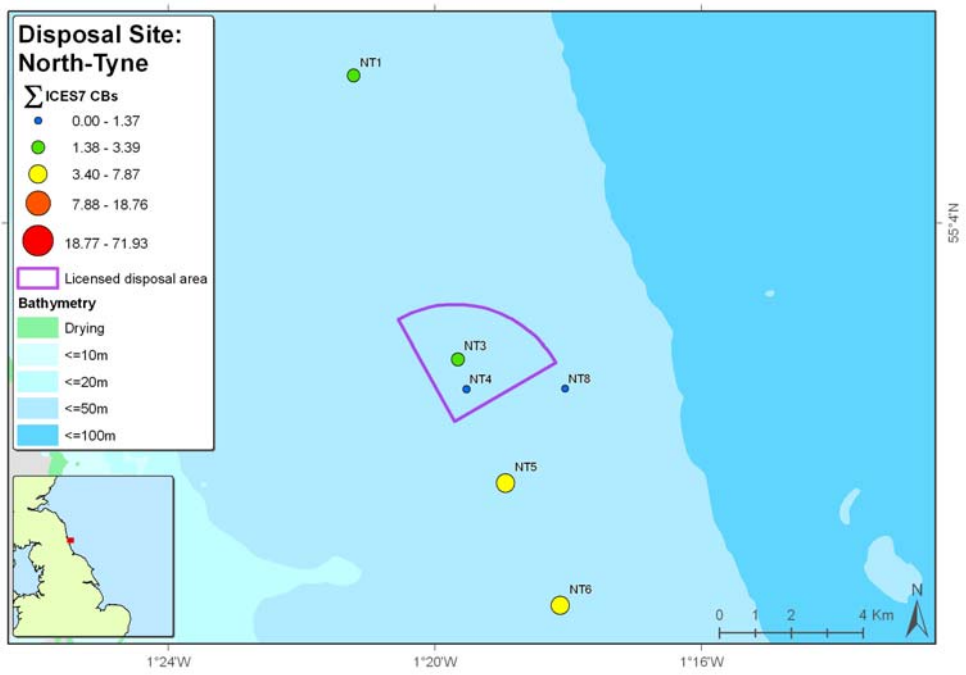


Figure 2.6. Summed ICES7 CB concentrations around the North Tyne disposal site, 2008.

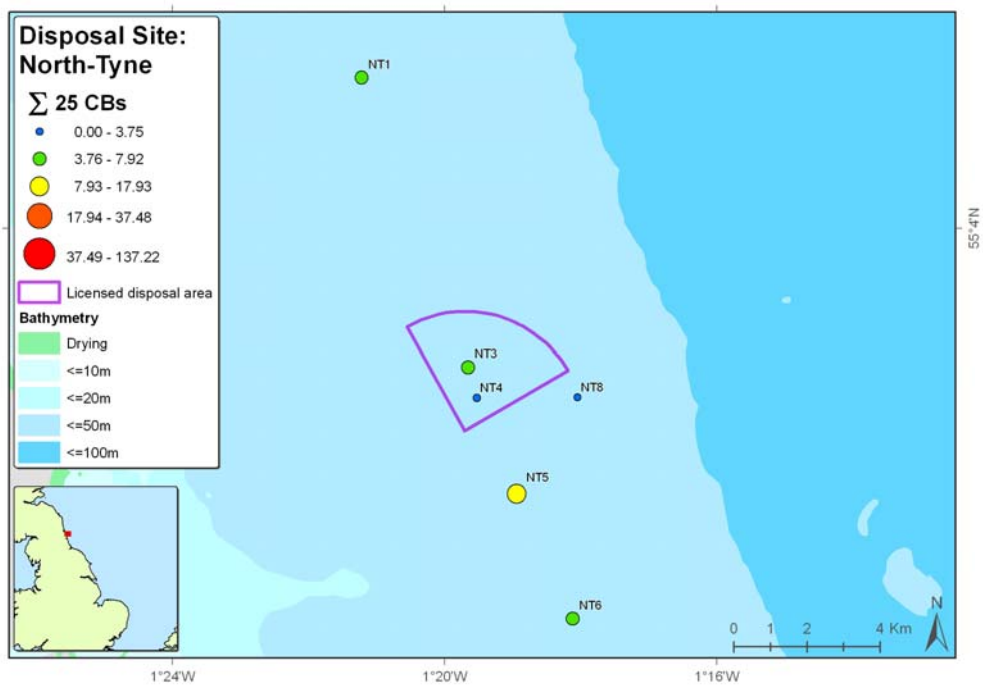


Figure 2.7. Summed 25 CB concentrations around the North Tyne disposal site, 2008.

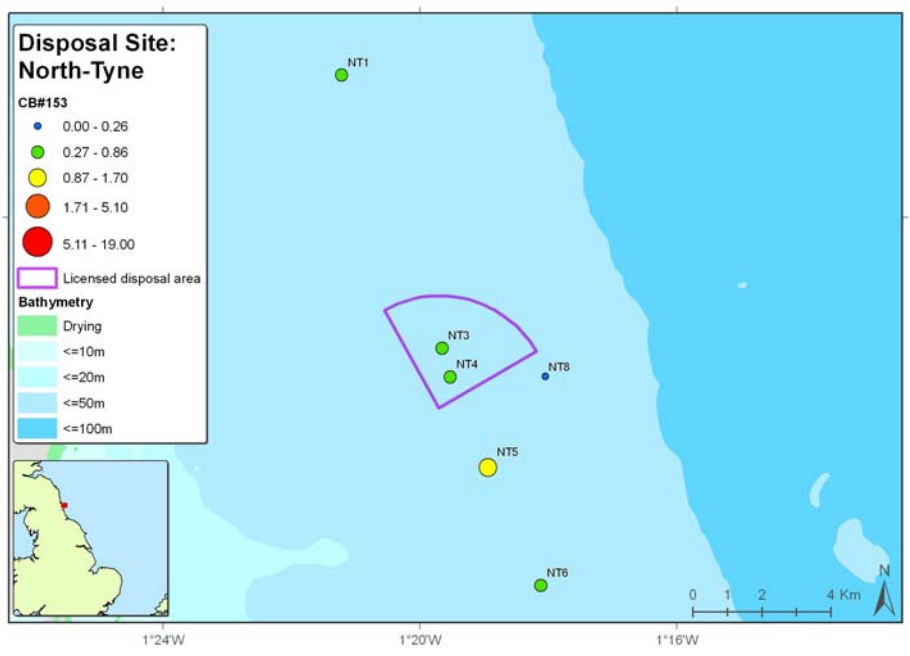


Figure 2.8. CB#153 concentrations around the North Tyne disposal site, 2008.

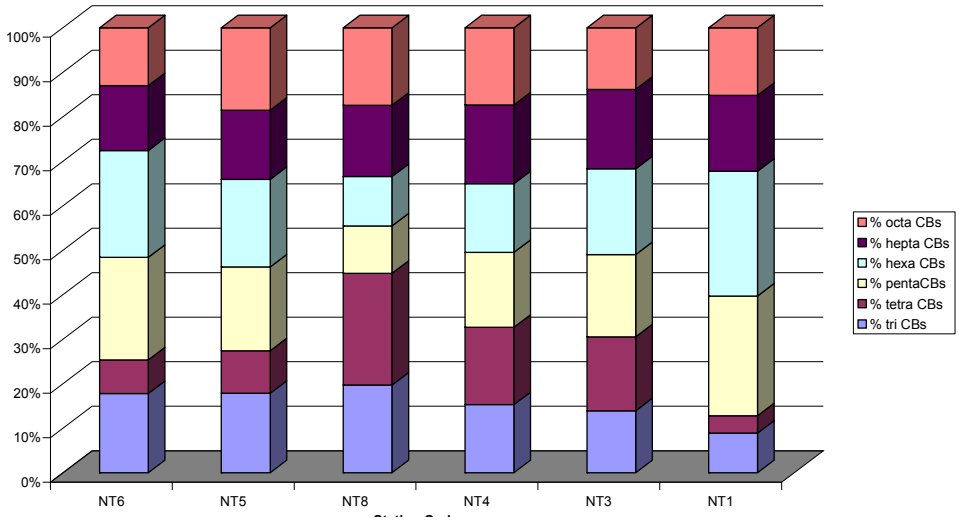


Figure 2.9. CB congener profiles for the North Tyne sampling stations, 2008.

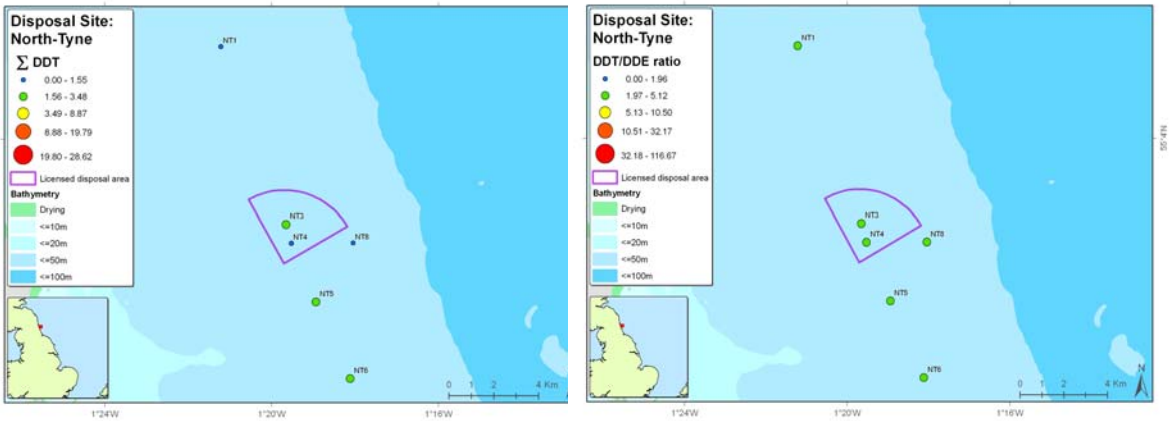


Figure 2.10. DDT concentrations (left) and DDT/DDE ratios (right) for the North Tyne stations, 2008.

Station code	∑ICES 7 CBs concentration (in µg/kg)		
	2006	2007	2008
NT6	2.44	2.54	3.88
NT5	2.7	7.59	6.05
NT8	5.21	2	0.81
NT4	7.21	n/a	0.7
NT3	1.48	2	1.79
NT1	1.54	0.97	2.11

Table 2.2. Temporal trends (2006-2008) of ∑ICES 7 CB concentrations (µg / kg) at North Tyne in the stations sampled during 2008.

Data was available for North Tyne for the years 2006, 2007 and 2008. Concentrations of CBs showed marked declines between 2006 and 2008 at stations NT4 and NT8. In contrast, an

increasing trend was observed at station NT6. The remaining stations had lower concentrations in 2008 than in 2007.

2.1.4.4.4 Trace metals

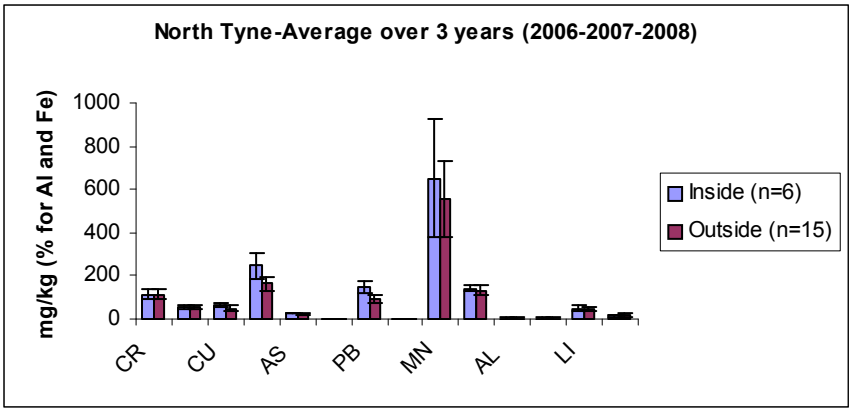


Figure 2.11. Average metal concentrations within and outside the disposal site between 2006-08 at North Tyne.

In Figure 2.11, there is no significant difference between the metals concentrations within and outside the disposal site at North Tyne. Figure 2.12 indicates that there is a slight increase in most metal concentrations between 2006 and 2008, and this is observed for both inside and outside the disposal site.

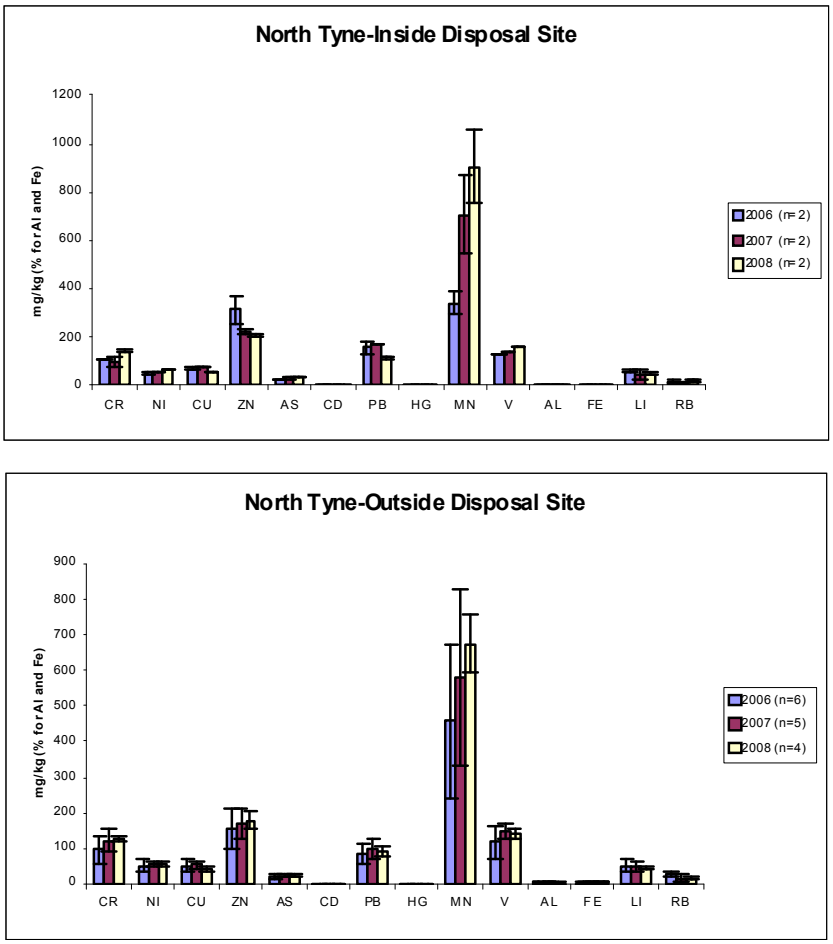


Figure 2.12. Average metal concentrations inside (top) and outside (bottom) the North Tyne disposal site between 2006, 2007 and 2008.

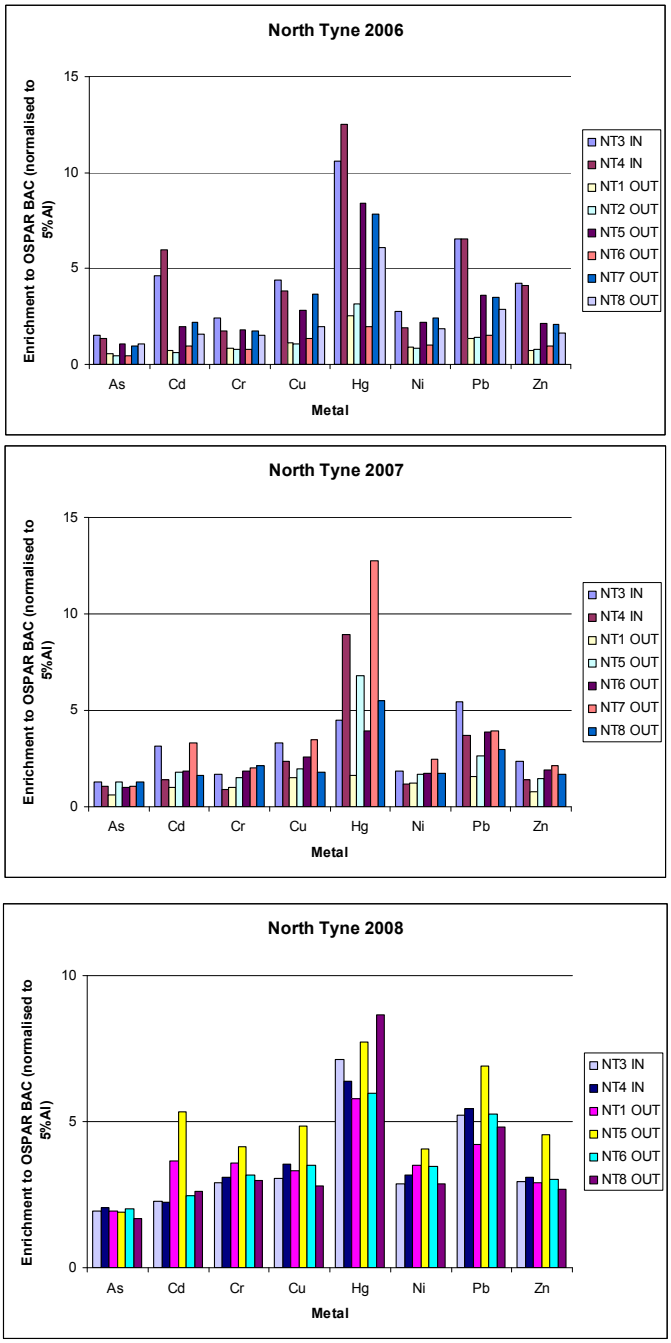


Figure 2.13. Enrichment to OSPAR BACs for metal concentrations measured at Souter Point in 2006 (top), 2007 (middle), and 2008 (bottom).

In 2006, inside the disposal site there is enrichment of Pb, Zn, Cd, Cu and Hg (>3X more than for enrichment at outside sites) (Figure 2.13). In 2007, there is still slightly increased enrichment within the disposal site, but this is not as clear as in 2006. In 2008 there is no difference in enrichment between metal concentrations inside and outside of the site. Therefore there is a general pattern of decreasing metal enrichment between 2006, 2007 and 2008.

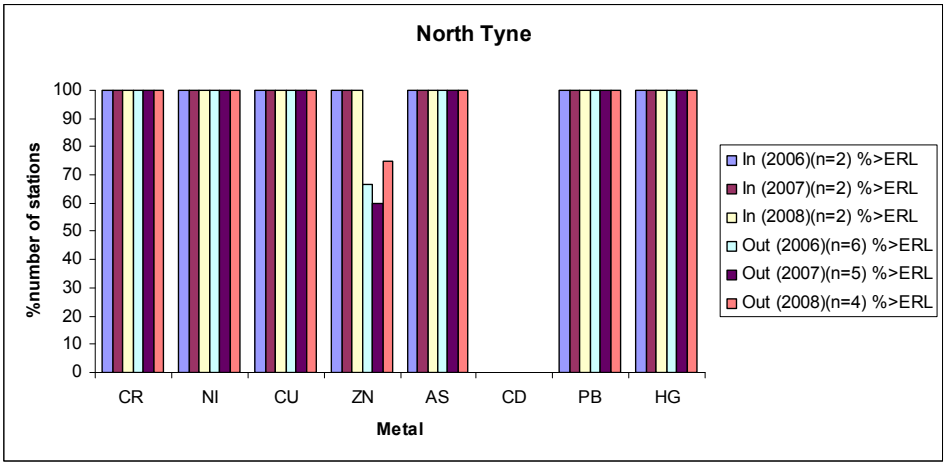


Figure 2.14. Average percentage number of stations inside and outside North Tyne disposal site with concentrations >ERL for 2006, 2007 and 2008. ERLs are calculated from raw data rather than normalised data.

All stations at North Tyne have higher average metal concentrations than Effects Range Low (ERL) except Cd (inside and outside, all years); and Zn (2006 (~65%), 2007 (~60%), 2008 (~75%)) (Figure 2.14). While there is evidence of decreasing enrichment within the disposal site between 2006 to 2008, all stations have concentrations >ERL. It is expected metal concentrations in this area have high concentrations related to the natural geology as well as historic mining activity completed here. While a trend of decreasing enrichment has been observed, most metal concentrations for all stations measured are elevated above background, when comparing to BACs values.

In summary, metal concentrations measured at North Tyne are mostly above OSPAR Background Assessment Concentrations (BACs). This is not unexpected as this area has enriched concentrations related to the natural geology as well as historic mining activity. Furthermore, metal concentrations measured at North Tyne are mostly above ERL. However, care should be taken when assessing the implications of these results, as metal concentrations were measured on the <63µm fraction using a total digest and so are in a more concentrated form than would be available for uptake within the whole sediment here. Most samples have <15% silt/clay.

2.1.5 Conclusions

Results from 2008 showed clear changes in sediment composition around and in the disposal site, evidencing a localised footprint of the disposal activity. Organic carbon values remained similar over time, showing higher concentrations at coarser fraction (i.e. <2mm) containing large coal particles in the samples. Results on the faunal composition, as expected seem to be lower values in number of individuals at the disposal site when compared with outer stations. In contrast, the number of species and biomass were higher at stations located

outside the disposal site, which were not exposed to the disposal activity. Results on sediments contaminants indicated that the concentrations on TBT/DBT were low when compared with concentrations over previous years (i.e. 2006 and 2007 respectively).

Furthermore, PAH's concentrations were observed to be the second highest values when compared across national disposal sites, clearly the station located south of the centre of the disposal site seem to be a clear example of this condition. In contrast, the concentrations from halogens showed lower values, which were classified under the OSPAR guidelines as 'good environmental status' for the site. There are some expected localised changes occurring at TY070 resulting from the disposal activity. Ongoing monitoring is scheduled for 2009, which will contribute with more information to elucidate some of observed changes resulting from the disposal activity at this site.

2.2 Souter Point (TY081)

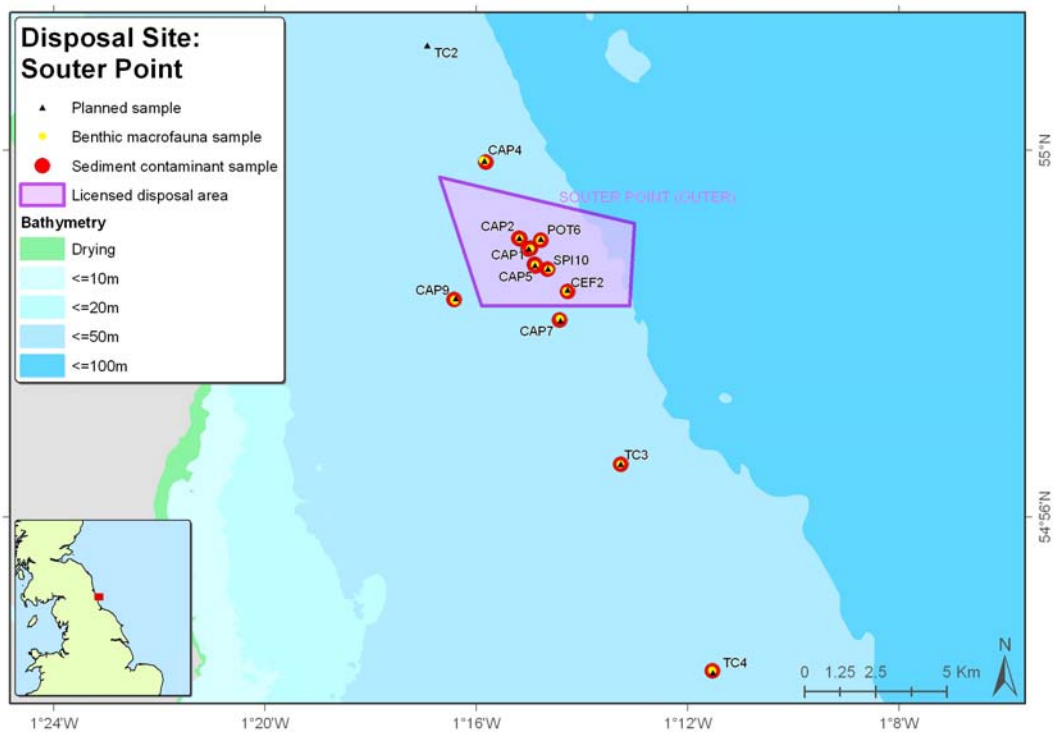


Figure 2.15. Locations of monitoring stations around the Souter Point disposal site, 2008.

2.2.1 Background

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 (unregulated) discharges inshore. The disposal site is located at a depth of approx. 40m, but this shallows by up to 5 m at the inshore end due to historical accumulations of minestone and fly-ash concretions. Tidal currents in the vicinity of the disposal site are moderate in strength and run generally parallel with the coastline, with a net residual drift, at least in surface waters, southwards.

Between December 2004 and April 2005, a trial level 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. On placement of the silt around 80% was siphoned off, thus, to leave a 1.5m cap, 90,000 m^3 of sand was later placed. 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 (see above), there are current concerns regarding the integrity of the cap, specifically related to cap thickness.

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 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

2.2.3 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 capping area is situated in the centre of the acoustic survey area, and shows an increased backscatter compared to the surrounding area (Figure 2.16). A central highest backscatter area can be recognised, with uneven seabed morphology and associated with a sandy sample with low gravel and mud content. Surrounding this area is a slightly lower backscatter area, characterised by an increased mud and gravel content in the sediment samples. It is expected that these two regions are associated with the cap.

Surrounding the immediate capping area, a low backscatter area can be observed from the sidescan sonar mosaic (Figure 2.16). Samples in this area showed an increased mud content. To the north and east of the cap area, the sidescan sonar mosaic show darker grey tones, suggesting a coarser or harder seabed substrate. Sediment samples from this area revealed slightly gravelly and gravelly sand. The increased gravel content of samples within this area explains the increased backscatter. In the south and west of the survey area, the sidescan sonar record shows numerous features associated with the disposal of material to the seabed. Samples obtained from within this area are generally muddy, gravelly sands.

The extent of the area believed to be associated with the capping material was compared with sidescan sonar survey results from 2005, 2006 and 2007. Figure 2.17 presents the 2008 data interpretation results and the outline of the cap from the 2005 data interpretation, as well as sidescan sonar results for the capping area, from annual surveys between 2005 and 2008. Comparison of these sidescan sonar mosaics is subjective, as the different environmental conditions and sidescan sonar systems will impact the look of the final mosaiced image. The sidescan sonar results show how different the data looks each year, with the capping material being easier to distinguish in 2005 and 2008.

Comparison of the interpretation results from 2005 and 2008 suggest that the extent of the capping material has changed shape and slightly reduced in size. The area occupied by the capping material was estimated at 0.28 km² in 2005, whereas this was reduced to 0.24 km² in 2008, or a reduction of 15%. The overall shape of the area occupied by the capping material also changed between 2005 and 2008. The 2008 outline is narrower in an east-west direction, but has extended further to the north. Spreading of the material further to the north could already be observed as early as 2006.

Whereas the sidescan data suggest limited change has occurred to the extent of the capping material, using sidescan sonar it was not possible to look at changes in the volume of capping material.

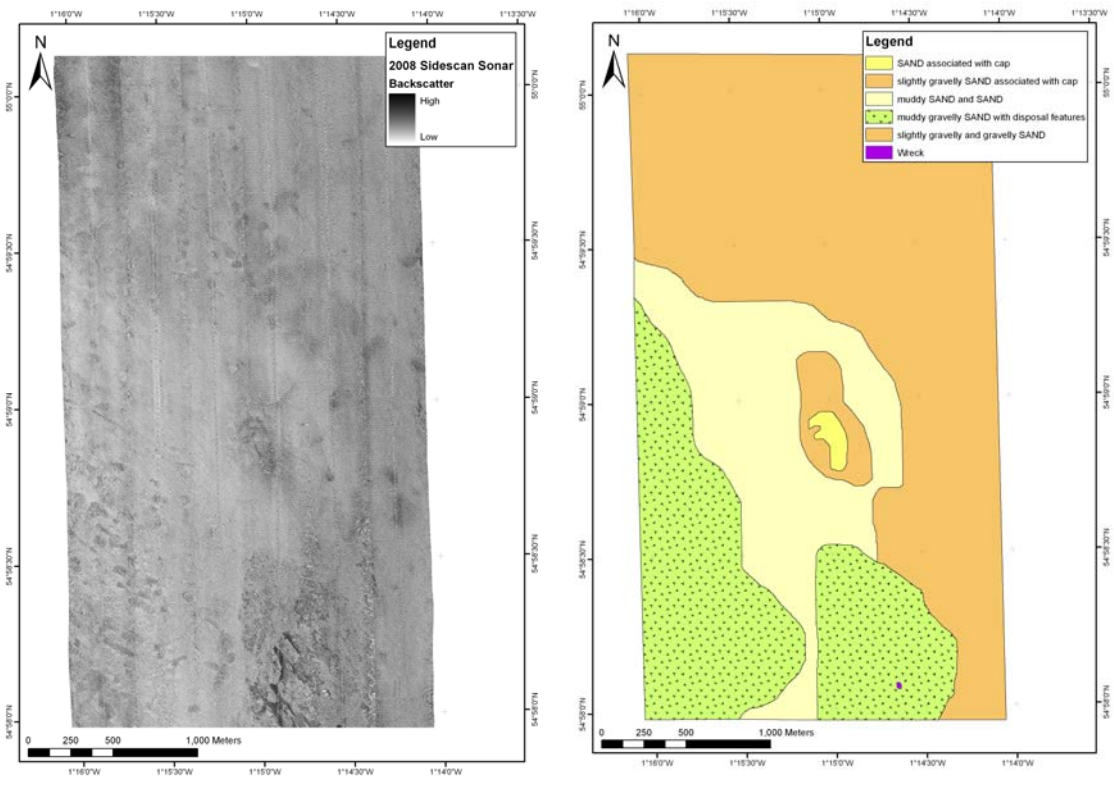


Figure 2.16. Sidescan sonar mosaic (left) and an interpretation (right) from the 2008 survey at Souter Point.

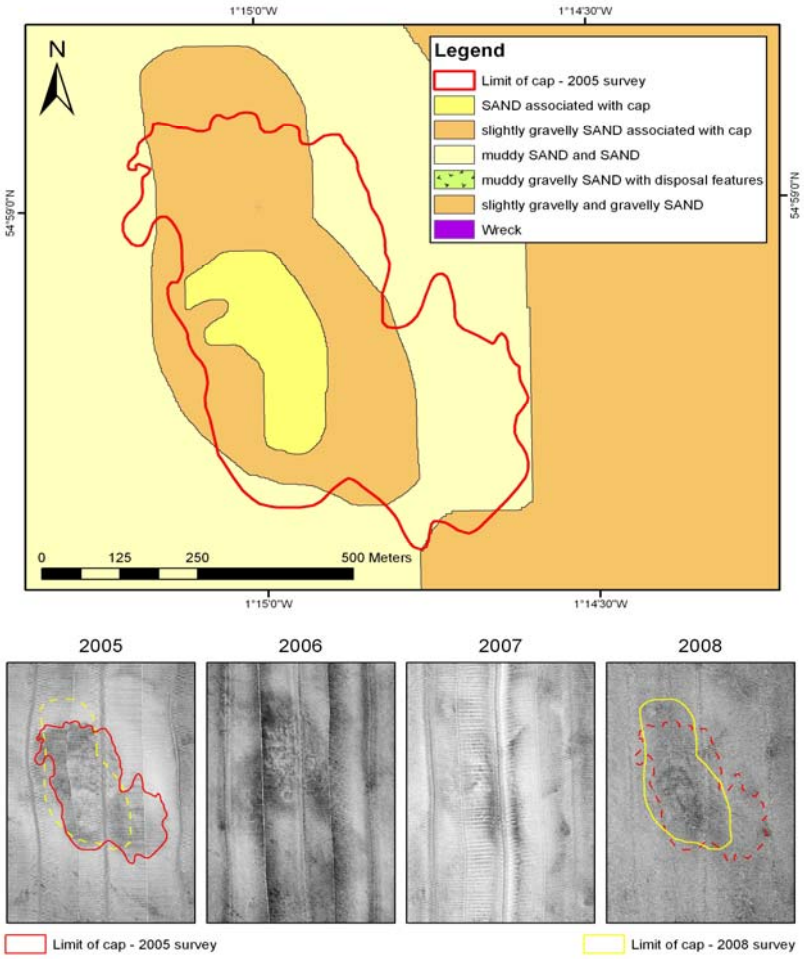


Figure 2.17. Interpretation of the sidescan sonar mosaic, with result from the 2005 sidescan sonar interpretation of the capping material shown as a red polygon (top), and sidescan sonar results for 2005 to 2008 (bottom).

2.2.4.2 Sediment particle size

The dominant sediment group at Souter Point is group 3, slightly gravelly sand (mixed and poorly-sorted). In 2008, all the samples measured are in group 3, except CAP1, CAP9 and TC2. The sediment group at CAP 1 is 7b, slightly gravelly sand (unimodal and well-sorted). This is expected to be the sand used as capping material. The sediment group at CAP 9 is 2A, gravelly sand and this profile is unusual for this site. The sediment group at TC4 is gravelly / slightly gravelly muddy sand (mixed and poorly-sorted).

Temporally, the main difference in sediment type is observed within the site at CAP1. Sediments at this station have changed from sediment group 3 in 2006, to sediment group 7a in 2007; more gravelly to sediment group 7b (unimodal sand) in 2008. TC4 has changed from a gravelly sand to a slightly gravelly muddy sand; this increased mud perhaps reflects a local heterogeneity rather than an effect of the disposal activity. CAP7 has changed from sediment

group 3 in 2006, to sediment group 6 in 2007; more muddy, back to sediment group 3 in 2008. CAP 7 is outside the disposal site, on the south side and is close to the site boundary.

Station code	2006	2007	2008
CAP1	3	7a	7b
CAP2	3	3	3
CAP4	3	3	3
CAP5	3	3	3
CAP7	3	6	3
CAP9	3	3	2A
CEF2	n	n	3
POT6	n	n	3
SPI10	n	n	3
TC2	3	3	n
TC3	3	3	3
TC4	3	3	6

Table 2.3. Sediment groups for samples analysed from the Souter Point monitoring surveys between 2006 and 2008. Key: 2a = gravelly sand (gravel being main component) – mixed, poorly sorted, 3 = slightly gravelly sand – mixed, poorly sorted, 6 = gravelly / slightly gravelly muddy sand – mixed, poorly sorted – most muddy group, 7a = slightly gravelly, muddy sand / muddy gravelly sand (more gravelly than 7b), and 7b = slightly gravelly sand – unimodal, well sorted.

2.2.4.3 Sediment organic carbon and nitrogen

In 2008, organic carbon values range from 2.7 to 4.1 % m/m and for nitrogen 0.2 to 0.35 % m/m for surface samples. The surface organic carbon content is similar to 2006 and 2007.

2.2.4.4 Macrofaunal communities

Macrofaunal analysis identified a total of 6101 individuals and 55 taxa at Souter Point from the samples taken during 2008. The main taxonomic groups were represented by Annelida, Mollusca, Miscellania, Echinodermata, and Crustaceans (Figure 2.18).

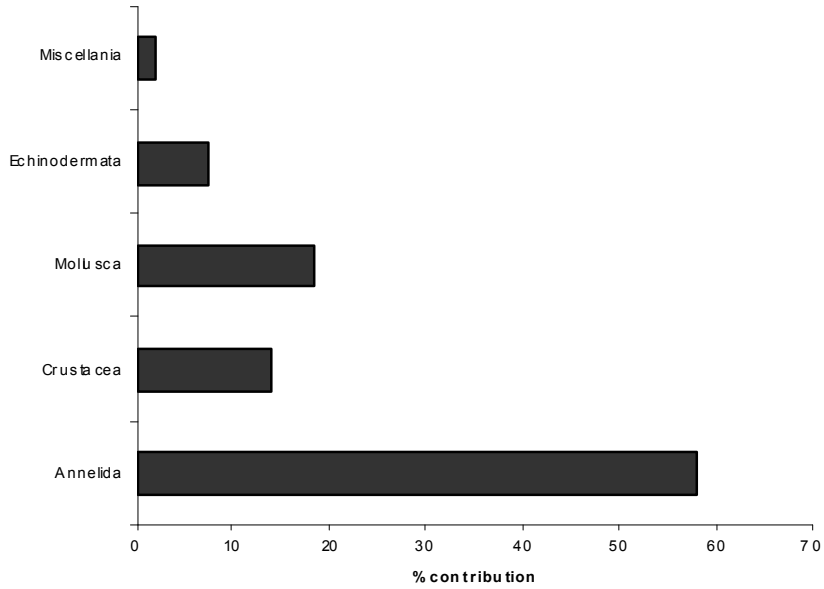


Figure 2.18. Contribution percentages of the main taxonomic groups sampled in 2008 at Souter Point.

The total abundance of individuals fluctuated from 114 to 262 per 0.1 m^2 across the study area in 2008. Overall, the lowest values ranged from 114 to 151 individuals per 0.1 m^2 at Cap1 and Cap2 respectively. Higher values were observed at the stations located outside the disposal site at stations Cap7 and TC4, these stations were located immediately outside and south of the disposal site (Figure 2.19A). Total number of species ranged from 45 to 63 species per 0.1 m^2 in area. Higher values for number of species were encountered in TC4 and Cap7 (61 and 63 species respectively) (Figure 2.19B). Total biomass was observed to be in the order of 1.6 to 6.99 g / 0.1 m^2 (ww) in the area. Higher biomass values were recorded at stations SPI10, TC3 and TC4 (22.16, 6.15 and 6.99 g / 0.1 m^2 (ww) respectively) (Figure 2.19C). The species responsible for the higher biomass were *Dosinia lupinus*, *Neptunea antigua* and *Echinocardium cordatum.*

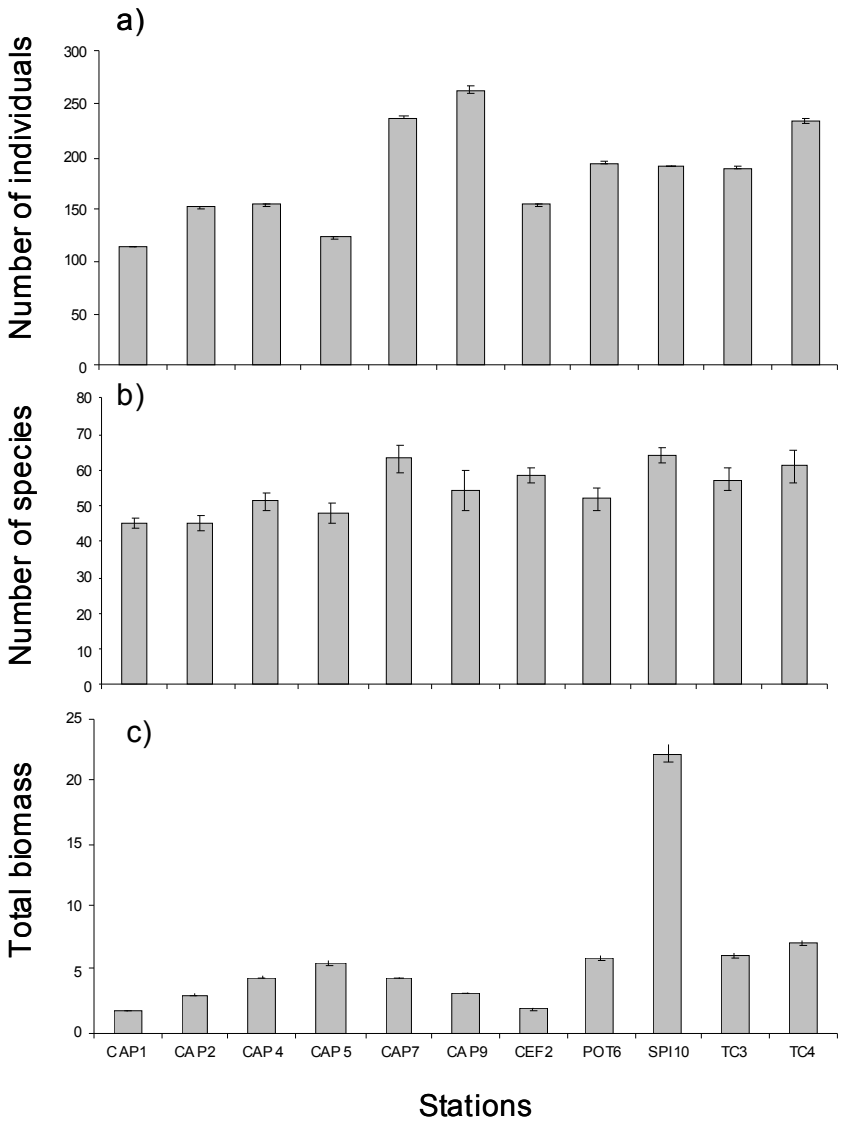


Figure 2.19A-C. Univariate trends, mean values for: A) total number of individuals, B) total abundance of taxa and C) total biomass over 2008 at Souter Point.

Multivariate analyses showed a clear separation of stations located in the centre of the disposal site (Cap1 and Cap2) from the north and some of the south reference stations (Cap7, Cap4, Cap9 and TC3). A third cluster containing stations TC4 (the most southern reference station) was also observed in the ordination (Figure 2.20). SIMPER analysis also evidenced the species that were causing the dissimilarity over the disposal site and reference stations during 2008. The average dissimilarity between the disposal site and northern reference accounted for 54.78 %, from which the species responsible were *Peresiella clymenoides*, *Abra prismatica*, *Dosinia lupinus, Lumbrineris gracilis*, *Rhodine gracilior*,

Nuculoma tenuis and *Abra nitida* (these species contributed to 10.13 % of overall group dissimilarity).

The average dissimilarity between the north and south reference was 48.41 %, the main responsible species causing this dissimilarity were *Peresiella clymenoides*, *Nuculoma tenuis, Abra alba, Lumbrineris gracilis, Abra nitida*, *Sthenelais limicola* and *Dosinia lupinus* (these species contributed to 10.42 % of the overall group dissimilarity). Comparisons between the dissimilarity observed between the disposal site and south reference showed the highest group dissimilarity with 54.21%, the species responsible were *Peresiella clymenoides*, *Abra nitida*, *Abra prismatica*, *Terebellides stroemi*, *Diastylis lucifera*, *Cylichna cylindracea*, *Spiophanes bombyx* and *Abra alba* (these species contributed to 10.12 % of the overall group dissimilarity).

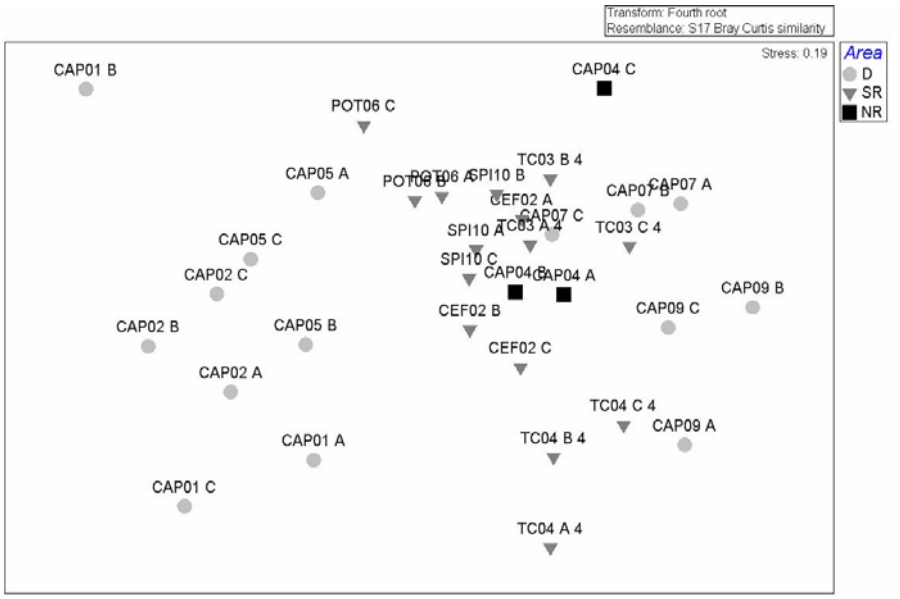


Figure 2.20. Multidimensional scaling ordination based on Bray-Curtis similarity for infauna samples over 2008 at Souter Point.

2.2.4.5 Sediment Profile Imagery (SPI)

The images obtained during the May 2008 survey confirmed the presence of the contaminated dredged material (CDM) inside of the proposed capped area. The CDM was generally fine-grained, including black cohesive mud. Images evidenced the reduced thickness of the silt layer (< 1m) present at the site (Figure 2.21a&d). 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 2.21a). Data collected at stations further away from the centre (SPI4, Cef5 and SPI11) showed the presence of fine sediments, broken pieces of shells and deep-burrowing polychaetes (Figure 2.21c,d &f). Overall, some of the images collected in the

vicinity of the disposal site (SPI2) also showed deep layers of CMD 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 2.21a). Stations located further east from the disposal site (e.g. SPI4, Figure 2.21c) showed the presence of small voids and broken shells, which are indicative of infaunal activity at the site. At stations CEF5 and SPI11 (Figures 2.21e&f), the presence of deep burrowing polychaetes and feeding voids 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).

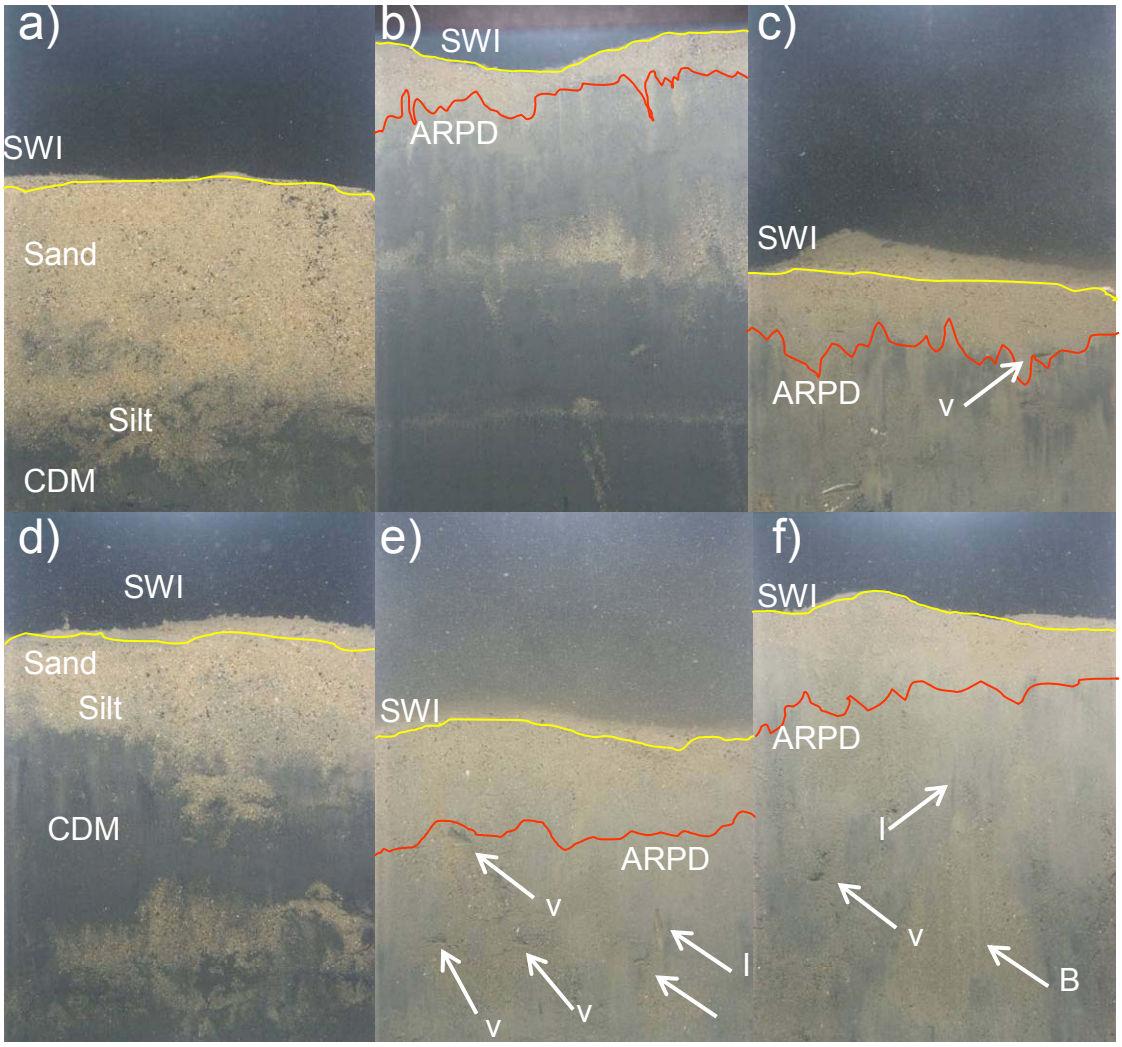


Figure 2.21. Sediment profile images (SPI) collected at Souter point disposal site, stations; a) Cap1, b) SPI 2, c) SPI4, d) SPI5, e) CEF5 and f) SPI11. SWI=sediment water interface, CDM=contaminated dredged material, I=infaunal polychaete, ARPD=apparent redox discontinuity layer, v=void and B= burrows.

2.2.4.6 Sediment contaminants

2.2.4.6.1 TBT

All the results for TBT and DBT were below the limit of detection (i.e. 0.002 mg / kg) except for site CAP4 where TBT was found at 0.066 mg / kg and DBT at 0.012 mg / kg. This has showed a slight increase in both concentrations from last year, however they remain below AL1. For other sites inside and outside of the disposal site, TBT and DBT concentrations have remained similar from 2005 to 2008.

In 2007, CAP1, CAP2 and CAP5 recorded increasing level of TBT with the sediment depth. This observation is not unusual as the sample depth profile cuts through the cap into the contaminated dredge material. The results obtained above are based on analysis of the surface samples only, depth samples collected with NIOZ cores will be analysed in due course, these data sets will be complemented with the SPI images.

2.2.4.6.2 PAHs

The highest summed PAH concentration was just outside the SW boundary of the disposal ground at CAP9, 53,400µg kg^{-1}. In 2007, the concentration at this location was 43,900 µg kg^{-1} whilst the highest concentration (71,800 µg kg^{-1}) was seen at CAP5, in the centre of the disposal ground. In 2008, the concentration at CAP5 was 21,200µg kg^{-1}. The second highest concentration, 31,400µg kg^{-1}, was observed at CAP4, just to the north of the disposal ground. In 2007, this concentration was 29,400 µg kg^{-1}.

To compare the distribution of concentrations found in the whole of the Tyne disposal area, the North Tyne and Souter Point surveys have been mapped together in the figure above. From this, it is apparent that the highest summed PAH concentration is found between the two disposal sites, directly to the east of the Tyne estuary.

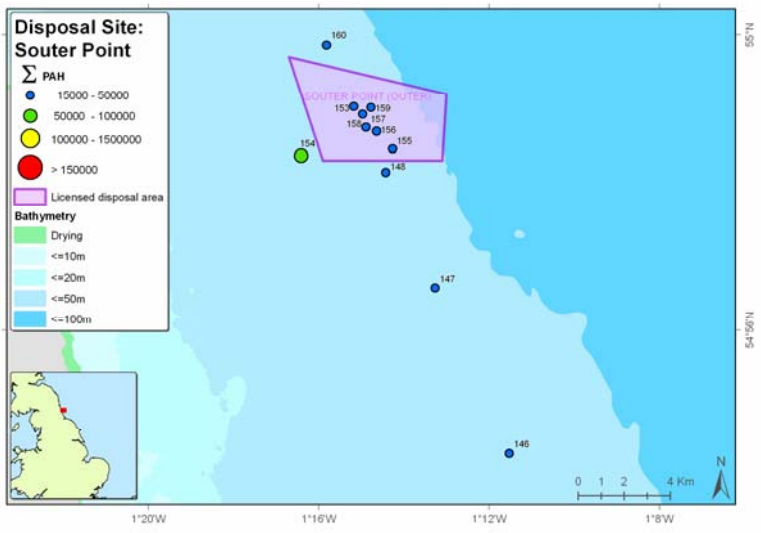


Figure 2.22. Summed PAH concentrations for the Souter Point stations, 2008.

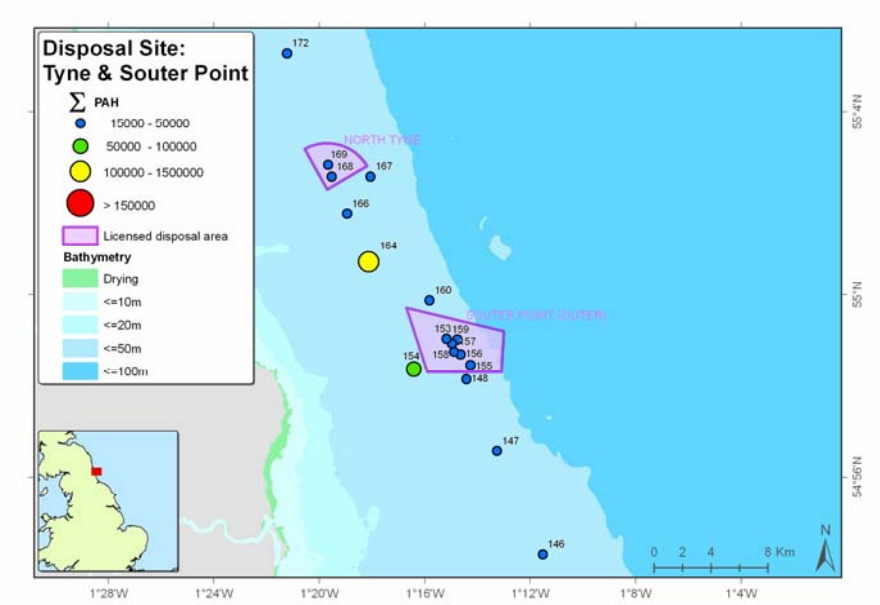


Figure 2.23. Summed PAH concentrations for the North Tyne and Souter Point stations, 2008.

2.2.4.6.3 Organohalogens

At Souter Point, concentrations of organohalogen contaminants were generally low, below or close to LODs, with the highest concentrations for CBs observed at station POT 6 inside the disposal site (Figures 2.24 – 2.26). Station CAP 5 had a slightly higher proportion and station CAP 4 a slightly lower proportion of hexachlorinated CBs than the other stations. Station CAP 4, just north of the disposal site, had elevated levels of p,p'-DDT of 28 µg/kg, and a high DDT/DDE ratio suggesting a recent input (Figure 2.28). Most stations were below FEPA warning levels and TECs for CBs and OCs, except for station CAP 4 which was above FEPA warning limits and TEC for DDT. According to the OSPAR guidelines, most stations had 'good' environmental status for all ICES7 CBs, except for CAP 4, CAP 5 and POT 6 which had 'bad' environmental status for CB118, i.e. all stations had 'good' status overall.

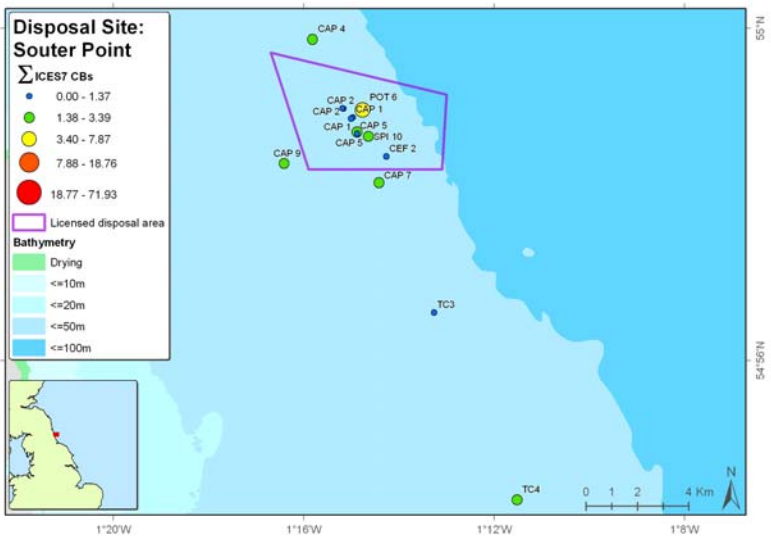


Figure 2.24. Summed ICES7 CB concentrations for the Souter Point stations, 2008.

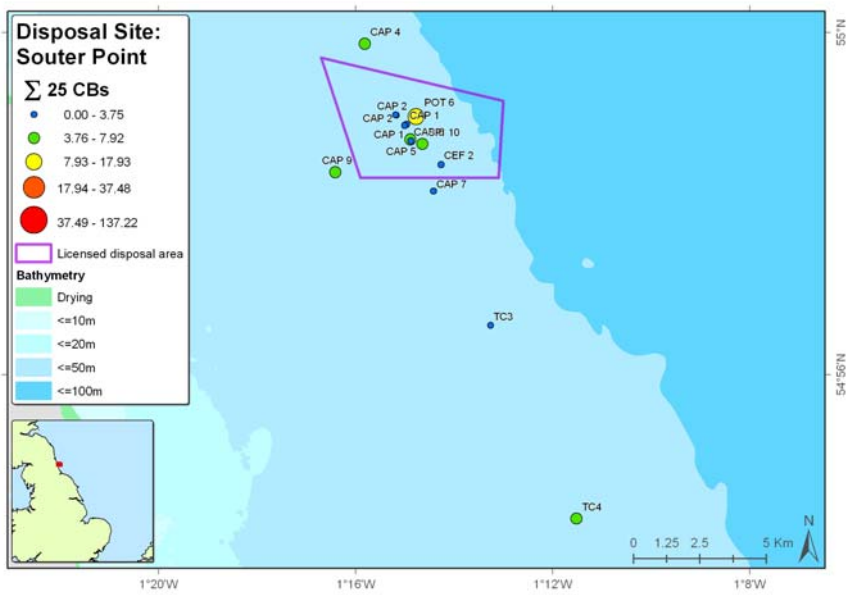


Figure 2.25. Summed 25 CB concentrations for the Souter Point stations, 2008.

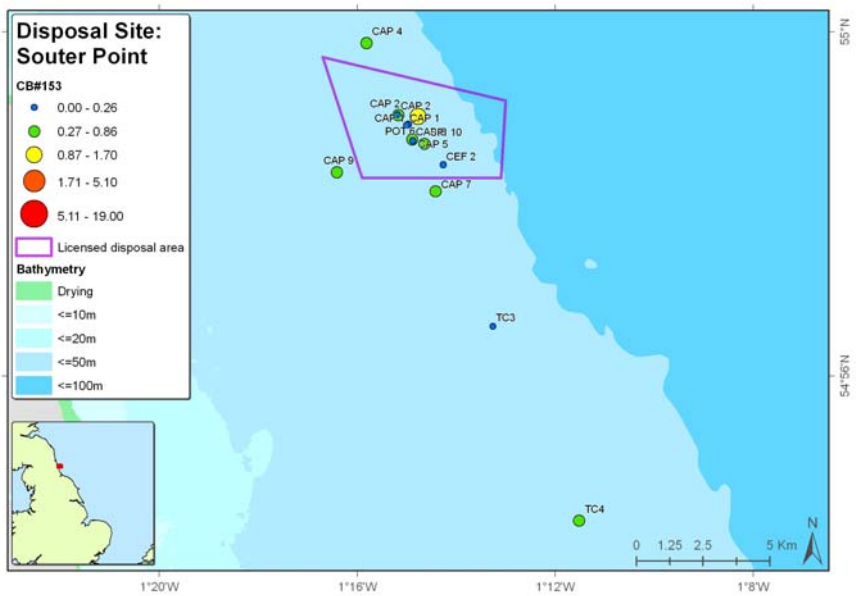


Figure 2.26. CB#153 concentrations for the Souter Point stations, 2008.

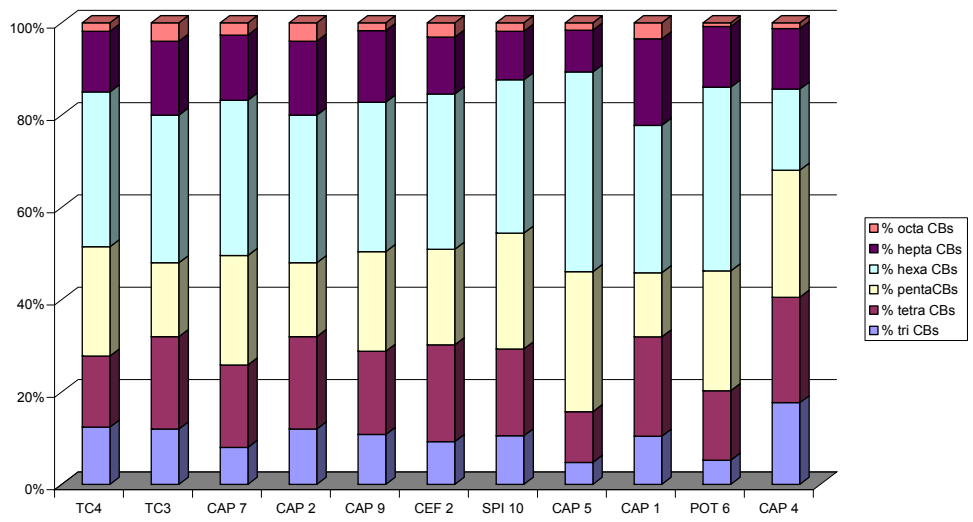


Figure 2.27. CB congener profiles for the Souter Point stations, 2008.

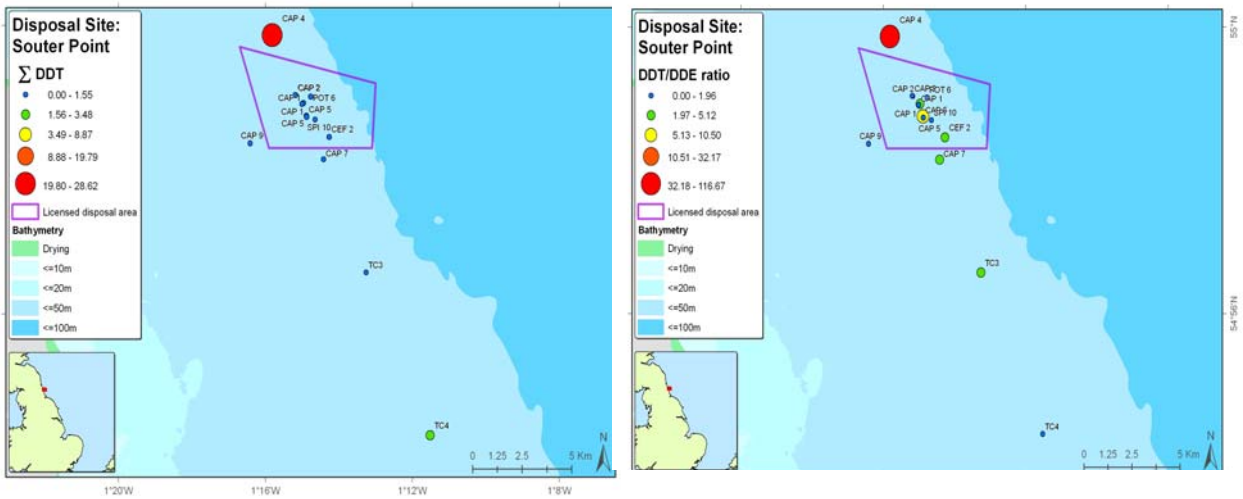


Figure 2.28. Summed DDT concentration (left) and DDT / DDE ratios (right) for the Souter Point stations, 2008.

Station	∑ICES 7 CBs concentration (in µg/kg)			
	2005	2006	2007	2008
TC4	1.17	1.14	0.7	2.62
TC3	0.96	1.19	0.7	0.7
CAP 7	1.34	1.12	2.23	1.51
CAP 2	8.24	10.1	11.6	0.7
CAP 9	4.97	2.91	2	2.84
CEF 2	n/a	n/a	n/a	1.14
SPI 10	n/a	n/a	n/a	2.53
CAP 5	1.1	0.86	4.39	3.22
CAP 1	1.1	0.84	9.48	0.96
POT 6	n/a	n/a	n/a	6.26
CAP 4	3.7	3.6	2.35	3.39

Table 2.4. Temporal trends (2005-2008) of ∑ICES 7 CB concentrations (µg / kg) at Souter Point stations (n/a = not assessed).

Data was available for Souter Point for the years 2005, 2006, 2007 and 2008. Concentrations of CBs at station CAP 2 in 2008 were much lower than in the previous years. Most other stations had concentrations in 2008 that were in a similar range to those between 2005-07, except for CAP 1 and CAP 5 which had lower concentrations in 2008 than in 2007.

2.2.4.6.4 Trace metals

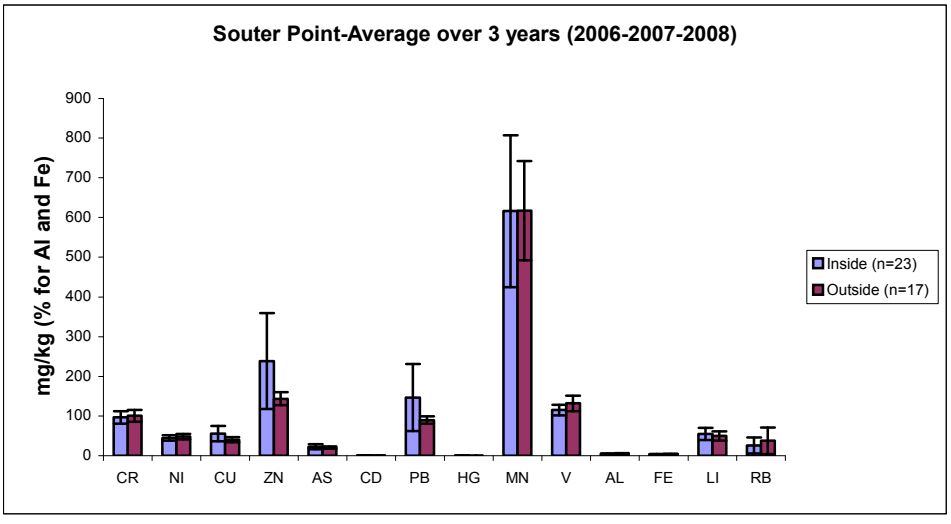


Figure 2.29. Average metal concentrations within and outside the disposal site between 2006-08 at Souter Point.

Figure 2.29 indicates that the concentrations of trace metals within the disposal site are generally the same as those observed at stations outside the disposal site, although the

concentrations of Zn in stations inside the disposal site show a relatively high spatial and/or temporal variability. Temporally, Figure 2.30 implies that, in general, there appears to be no significant increase or decrease in the levels of any trace metals at Souter Point, either inside or outside the disposal site.

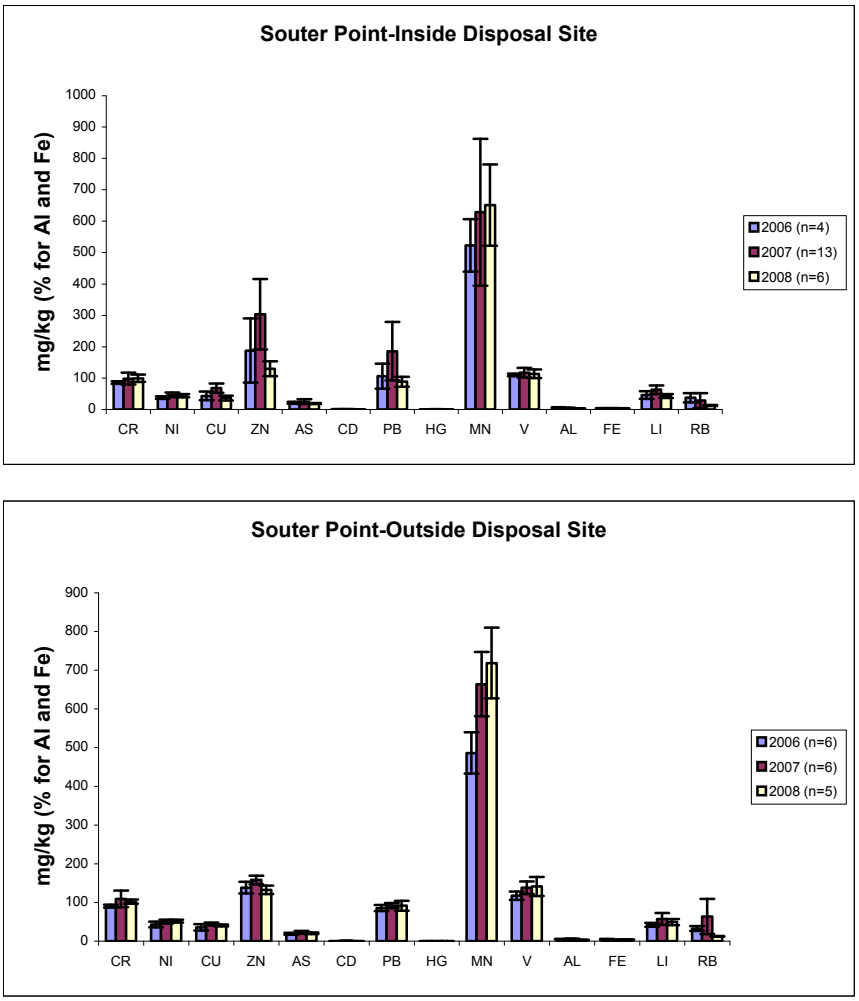


Figure 2.30. Average metal concentrations inside (top) and outside (bottom) the Souter Point disposal site between 2006, 2007 and 2008.

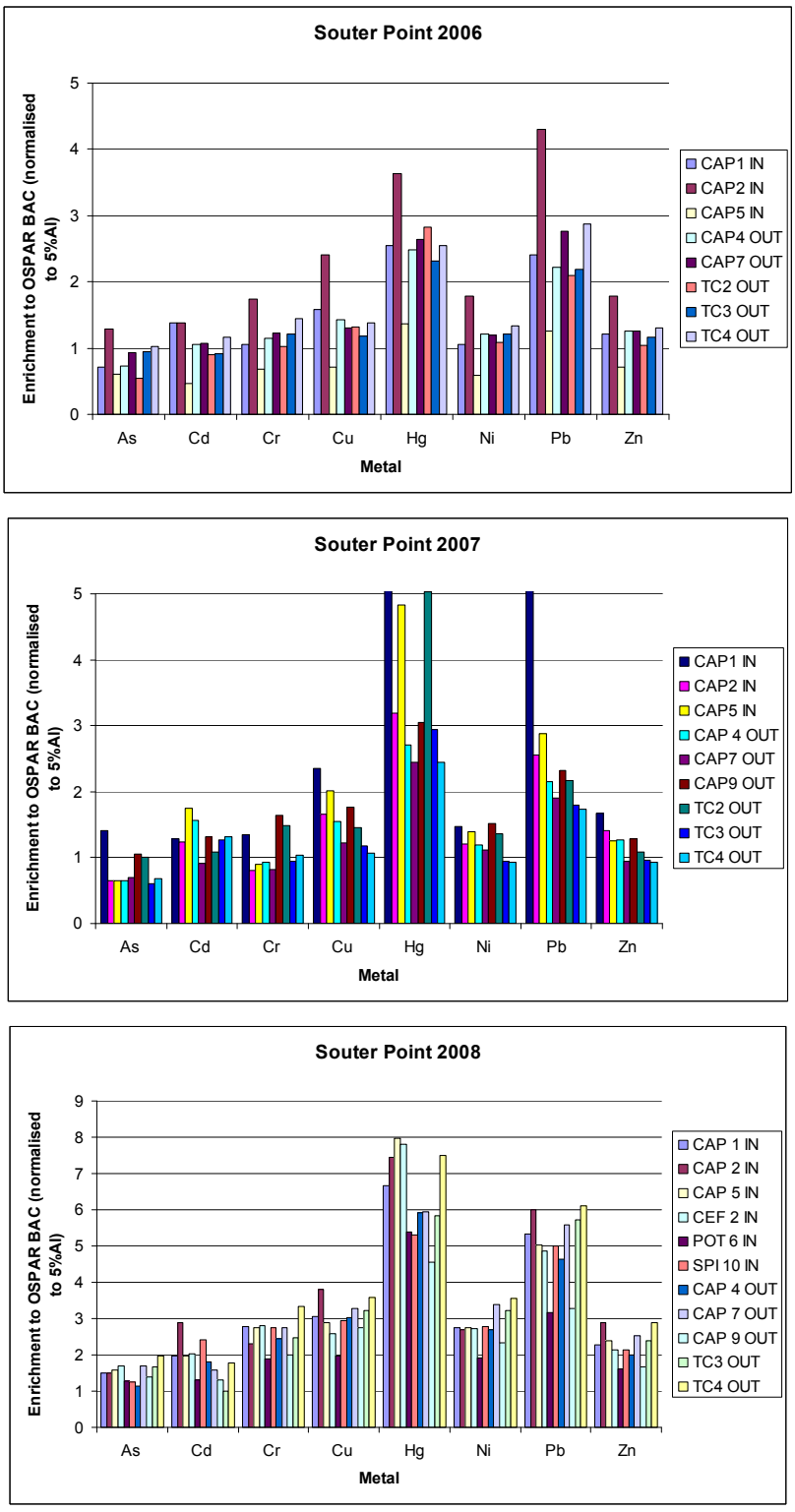


Figure 2.31. Enrichment to OSPAR BACs for metal concentrations measured at Souter Point in 2006 (top), 2007 (middle), and 2008 (bottom).

Enrichment to BACs at Souter Point is shown in Figure 2.31 which reveals that predominantly all metal species are generally enriched above OSPAR BACs (i.e., above 1 on the vertical axis), both inside and outside the disposal site. The only possible exceptions perhaps are As

and Cd which did not appear enriched outside the disposal site in 2006 and 2007, but were enriched in 2008. By 2008, all metals are generally notably enriched, being 3 or above times the OSPAR BACs. Further work on core samples for Cap 1, Cap 2 and Cap 5 is planned alongside core samples collected in 2009 to assist in determining cap integrity at Souter Point.

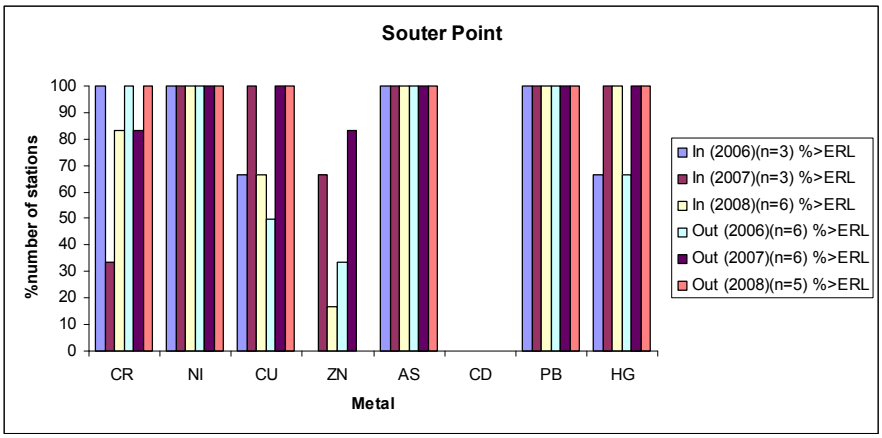


Figure 2.32. Average percentage number of stations inside and outside Souter Point disposal site with concentrations >ERL for 2006, 2007 and 2008.

All stations at Souter Point have higher average metal concentrations than ERLs except Cd (inside and outside, all years); Cr (inside 2007 (~33%), 2008 (~80%) and 2007 (80%); Zn (none inside for 2006, 2007 (70%), 2008 (20%) and outside 2006 (30%), 2007 (80%) and 2008 (none)), Cu (inside 2006 and 2008 (~70%), and outside 2006 ((~50%) and Hg (inside 2006 (~70%) and outside 2006 (~70%) (Figure 2.32). To assess the significance of these results, this data will be examined in combination with other parameters (e.g., SPI) which allow us to delineate the actual boundary of the cap.

In summary, metal concentrations measured at Souter Point are mostly above OSPAR BACs. This is not unexpected as this area has enriched concentrations related to the natural geology as well as historic mining activity. Furthermore, metal concentrations measured at Souter Point are mostly above ERL. However, care should be taken when assessing the implications of these results, as metal concentrations were measured on the <63µm fraction using a total digest and so are in a more concentrated form than would be available for uptake within the whole sediment here. Most samples have <15% average silt/clay content.

2.2.5 Conclusions

Sampling at Souter Point has been conducted annually since 2003 under SALB5 auspices. Therefore, we hold a good long-term time series datasets for biological, sediments and chemical information of this site. Acoustic results collected during 2005-2008 with sidescan

only suggests that extent of the capping material has changed shape and slightly reduced in size. Furthermore, the 2008 outline is narrower in an east-west direction, but has extended further to the north, this was also observed in 2006. Whilst sidescan sonar information is useful to assess changes over large areas of Souter point, the limitations of this technique are mainly that there is not indication of detecting change in volume of material in the area. Therefore, these changes have been analysed with multibeam information collected also in the area over time. Results on this technique will be reported in the next 2010 technical report

As expected changes in macrofaunal and granulometric composition in the centre of the disposal site are clear with low number of species and changes in sediment composition. These observed changes are directly related to the capping trial activity. Results from SPI images also showed the varying thickness of the layers at station in the centre of the capping area and outside stations, indications of the presence of CMD, slit and sand material at the stations locate din the centre and near periphery of the disposal site. Faunal composition was also determined by analysing SPI images, which concords with stages II-III of stable communities at reference stations. TBT results also showed similar concentrations to previous years, with an exception of one station, located north of the centre of the disposal activity. Results form the overall monitoring conducted in 2008 showed a series of stations at TY081 that are classified under 'good and bad environmental status' under OSPAR guidelines. Results at TY081 indicated the clear need to continue with the ongoing monitoring during 2009. Further information will enable understanding on the long-term changes on benthic fauna, sediments and contaminant levels of the area following the first capping trial in this area.

2.3 Tees (inner and outer, TY160 & TY150)

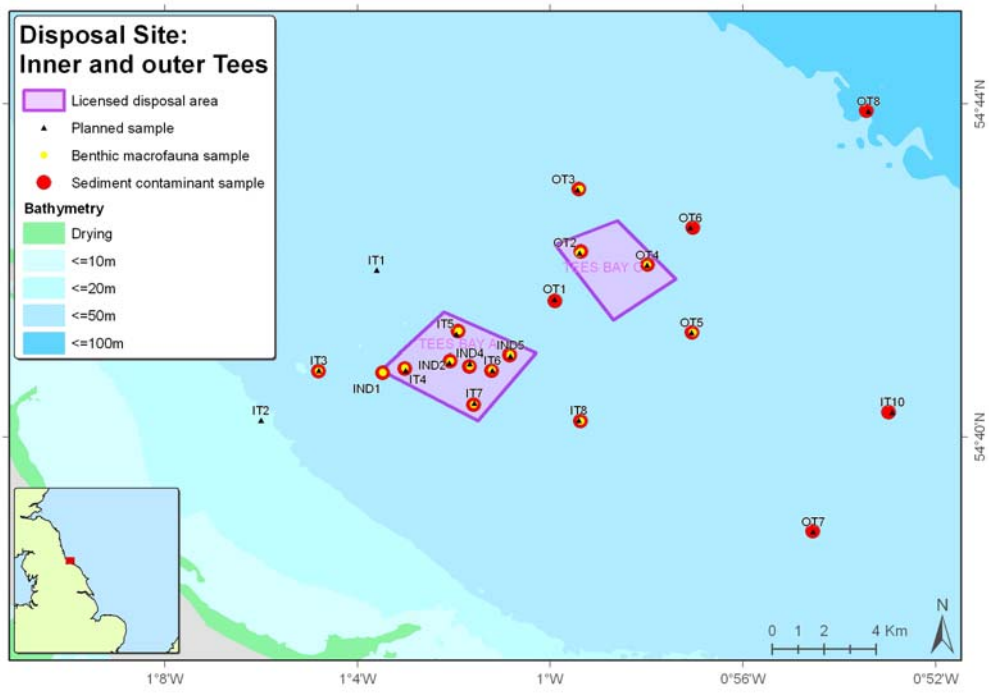


Figure 2.33. Locations of monitoring stations at Inner and Outer Tees, 2008.

2.3.1 Background

Previous surveys of the Inner Tees disposal site showed the area to have a very homogeneous substrate of muddy sand. Some of the sites sampled within the disposal area showed evidence of previous spoil disposal with small lumps of black mud and black flecks present which were probably coal.

Inner Tees receives most of the 2,715,000 tonnes of maintenance dredged material per year for the Tees Estuary, Seaton Channel and Hartlepool. In recent years the material to this site was seen to shoal at the eastern edge, probably a result of the dredgers disposing at the nearest point to the port. Therefore, in 2006, the port offered to divide the disposal area into twelve and dispose of to each on a monthly basis.

There have been a number of high profile construction and dredging applications made under the FEPA with regard to the Tees. It is anticipated that in addition to the 2.7 million tonnes of maintenance dredge there are currently three major disposal operations proposed for disposal to these two sites. The dredging of sand from a turning circle and silt/sand from a berth by the Conoco Phillips LNG terminal would result in 400 000 tonnes of material to be placed at the inner disposal site. If this is licensed this will be undertaken during summer 2008. Permission has been given for the construction works to allow Able UK to dismantle

ships within a cofferdam. To allow larger draft vessels Seaton Channel will be dredged and 2 million tonnes will be placed over both disposal sites starting 2009. Also, the proposal for the Northern Gateway container terminal is anticipated to receive permission, this would include dredging of turning circles and berth pockets in the Tees resulting in a 2 million tonne dredge. Due to the physical nature of some of the material it is anticipated that this material would be divided between the two disposal sites. Therefore in 2009 up to 4 million tonnes could be deposited over both sites.

The Tees has a large quantity of chemical industries which have resulted in contaminants within dredge sediments. ICI, Tioxzide factories and brominated flame retardant producers have all discharged into the Tees. Currently within the Tees there is an eroding mud flat, which is contaminated with high levels of Lead and Zinc. A bund in front of the area is required but over the last three years agreement has not been reached with the EA regarding the structure of this bund. As a result a large area of the Tees has levels of lead that are no longer acceptable for disposal to sea and levels within the material still acceptable are increasing. Also the analysis of dredge material from the Tees has resulted in some of the highest levels hydrocarbons found in England and Wales.

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 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 disposal site covers and area of approximately 4.6 square kilometres. The seabed bathymetry (Figure 2.34) is characterised by raised area in the western part of the site, believed to be the result of the disposal of dredged material, raised about 5 metres above the surrounding seabed area. The shallowest part of this feature is found to be 22m below mean sea level (or approximately 19m below Chart Datum). The site gently slopes towards the east, reaching a maximum of 40m in the eastern part of the licensed area.

The seabed generally consists of muddy sands and is represented by low backscatter return from the multibeam echosounder (Figure 2.35). Locally, high backscatter patches can be observed, largely associated with negative bathymetric features. High backscatter suggests a coarser or harder substrate, however, no samples are available from within these areas to characterise the nature of the sediment in these areas.

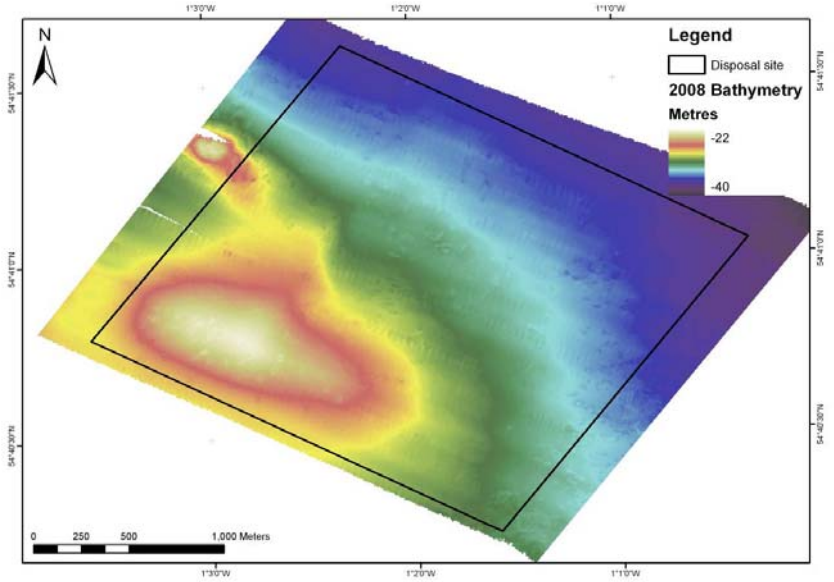


Figure 2.34. Inner Tees seabed bathymetry from the 2008 multibeam echosounder survey.

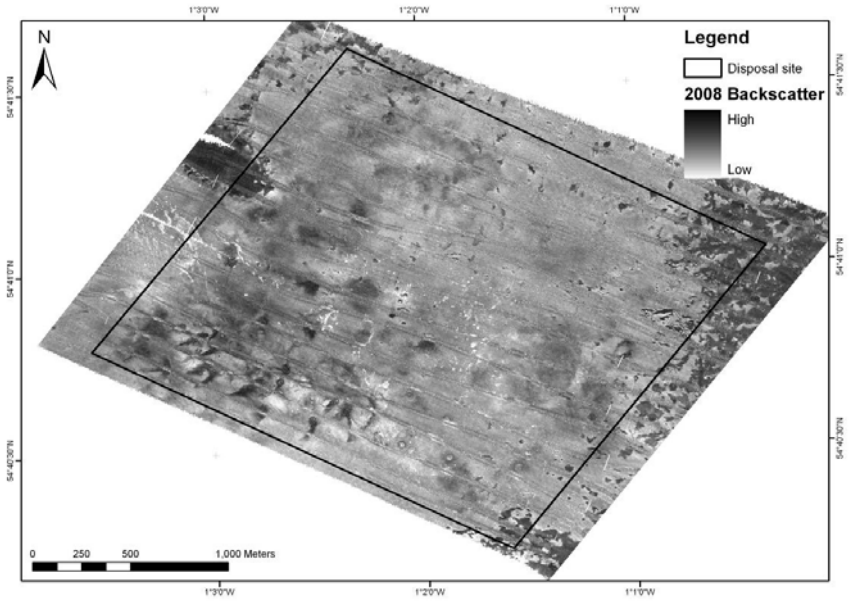


Figure 2.35. Inner Tees seabed backscatter from the 2008 multibeam echosounder survey.

Difference plots between the 2007 and 2006, as well as the 2008 and 2006 data are presented in Figure 2.36. Although these difference plots suggest substantial accretion of sediment at the site, it is believed that this is partly the result of the tidal correction models applied to the data. This is illustrated in the 2007 - 2006 difference plot where the orientation of the features is parallel to the orientation of survey lines. The 2008 - 2006 difference plot shows some accretion which is not parallel to the survey line orientation, which suggests a real accumulation of sediment in the area. The difference plot between the 2008 and 2007 multibeam survey data also suggests an accumulation of sediment in the western part of the disposal area.

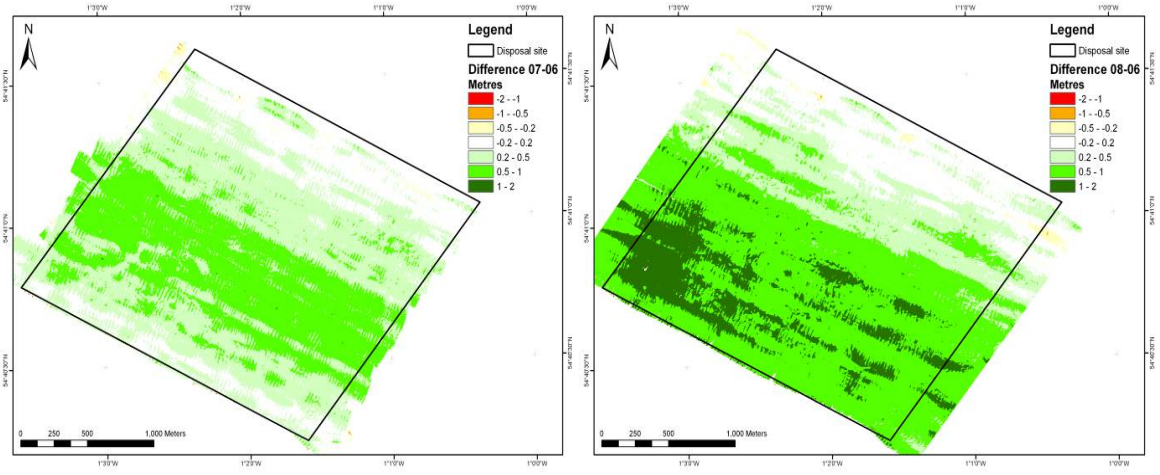


Figure 2.36. (Left) Bathymetry difference between 2007 and 2006 multibeam surveys. (Right) Bathymetry difference between 2008 and 2006 multibeam surveys.

Due to the significance of data artefacts, it is difficult to identify any changes in the disposal regime before and after 2007. Even if any changes had been possible to observe, the annual nature of the survey would not have been able to resolve whether changes are natural temporal changes or whether they were indeed the result of changes in the disposal regime at the site.

Visual comparison of the 2006, 2007 and 2008 datasets indicated some changes in the multibeam seabed backscatter across the disposal site. The 2006 dataset reveals a slightly increased backscatter on top of the raised feature in the western part of the disposal site, whereas the remaining area has a relatively low backscatter, with localised patches of higher backscatter. The 2007 data shows slightly increased backscatter patches across the site. It is believed that this slightly increased backscatter patches may be the results of dredged material disposal. Similarly, the 2008 data show more widespread occurrence of slightly increased backscatter patches across the site compared to the 2006 data.

This observation is also confirmed by difference calculations between the median backscatter strength plots, expressed in decibel. The 2007 - 2006 difference plot is shown in Figure 2.37. Where there is a positive difference, there has been an increased in backscatter from 2006 to 2007. As slightly increased backscatter values are believed to be associated with dredged material disposal, positive differences suggest the change may be a result of the disposal of dredged material. The 2007 - 2006 comparison suggests that disposal is more widespread across the site in 2007 compared to 2006. Spatial analysis of this change indicates that 71.8 % of the disposal area showed an increased backscatter between 2006 and 2007. This is likely the result of the introduction of a grid pattern for disposal which changes on a monthly basis.

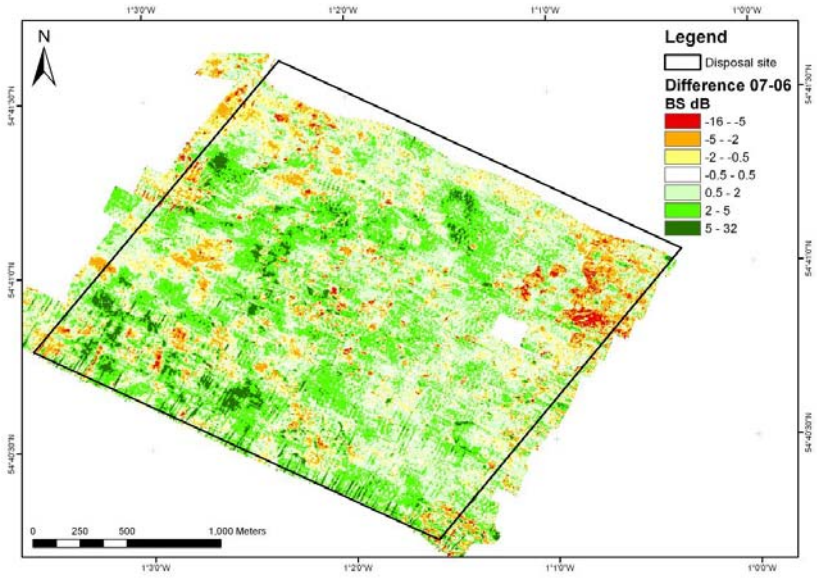


Figure 2.37. Backscatter strength difference between the 2007 and 2006 multibeam surveys.

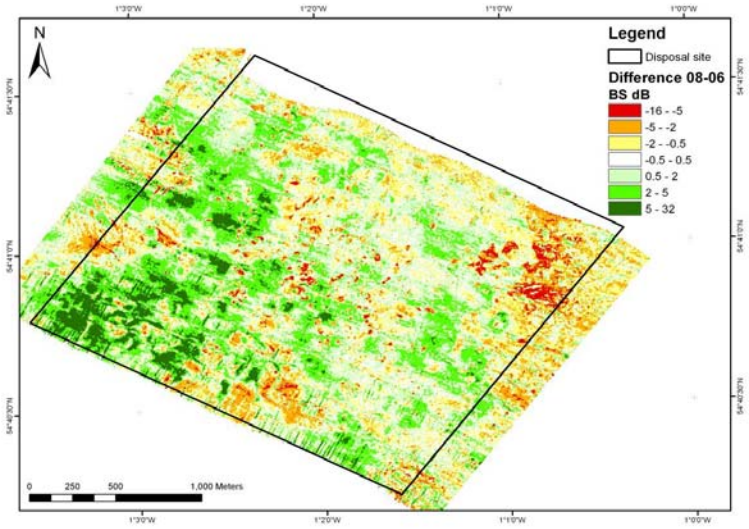


Figure 2.38. Backscatter strength difference between the 2008 and 2006 multibeam surveys.

A difference plot between the 2008 and 2006 multibeam backscatter data is presented in Figure 2.38. The majority of the disposal site is characterised by slightly increased backscatter strength. Locally there are changes in backscatter, which suggest a reduction in backscatter strength between 2006 and 2008. These seem to be mainly associated with the infill of localised high backscatter patches, which were significantly more widespread during 2006 compared to 2008. Spatial analysis of the changes in backscatter strength indicates 62.3 % of the area has shown an increase between 2006 and 2008.

A backscatter difference plot between 2007 and 2008 is presented in Figure 2.39. The result is different from the results presented in Figure 2.38 as there is no overall increase in seabed backscatter. It is expected that due to the introduction of the disposal grid with monthly changes, the backscatter increased from 2006 to 2007 and from 2006 to 2008, but that this

did not significantly change between 2007 and 2008. Overall 57.9 % of the area shows a decrease in backscatter strength, with the main increase in backscatter on the positive feature in the western part of the disposal site. This may suggest increased disposal activity in this part of the site in 2008 compared to 2007.

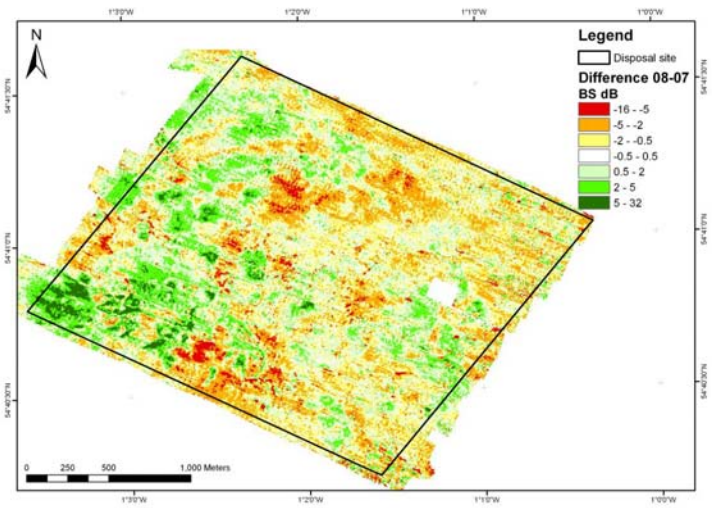


Figure 2.39. Backscatter strength difference between the 2007 and 2008 multibeam surveys.

Annual surveys were undertaken at the Inner Tees dredged material disposal site in 2006, 2007 and 2008. From 2007 onwards a monthly changing grid approach was adopted for the disposal of dredged material, in order to reduce further significant accumulation in the shallowest parts of the licensed site (see Section 2.3.1). Multibeam bathymetry and backscatter data was collected to place samples into a wider environmental context and to investigate methods to assess the performance of the grid approach for disposal of the dredged material.

Bathymetry difference plots were produced from the annual multibeam surveys, but it was found that data artefacts were overriding any actual depth changes. Therefore it is not possible to assess how the newly introduced disposal regime has changed the local seabed bathymetry or assess the effectiveness of the new disposal regime. The tidal corrections applied to the data are the likely source of these artefacts. More successful study of small changes in seabed bathymetry as a result of dredged material disposal would require the use of more sophisticated techniques to apply tidal corrections to the data. Real Time Kinematic (RTK) GPS techniques could provide such a solution, but would require land-based equipment to be installed.

Backscatter mosaics and backscatter difference plots on the other hand were more successful in identifying changes as a result of the new dredged material disposal regime. The data suggests that since 2007 disposal is more widespread over the licensed area, suggesting the grid approach with monthly changes has been adopted by the port dredging

contractors. Comparison of 2007 and 2008 data suggested increased disposal activity may have occurred more intensively in the western part of the licensed area, where the raised feature is present. It is unknown at present whether this increased activity is the result of the disposal taking place within the grid cell at the time of survey.

2.3.4.2 Sediment particle size

Station code	2006	2007	2008
IND1	5	5	3
IND2	3	3	3
IND4	n	3	5
IND5	n	3	3
IT1	5	5	n
IT3	3	6	3
IT4	5	3	5
IT5	3	5	3
IT6	5	6	3
IT7	3	5	5
IT8	5	5	5
IT10	3	3	2C
OT1	3	3	3
OT2	8	6	3
OT3	3	7a	3
OT4	3	3	2C
OT5	5	3	6
OT6	5	3	5
OT7	n	2B	6
OT8	3	3	3

Table 2.5. Sediment groups for the Tees stations, 2006-08 (n = no sample). Key: 2c = gravelly muddy sand (more muddy than 2b), 3 = slightly gravelly sand (mixed, poorly sorted), 5 = slightly gravelly muddy sand (mixed, poorly sorted, more muddy than group 3), 6 = gravelly / slightly gravelly muddy sand (mixed, poorly sorted (most muddy group)), 7a = slightly gravelly, muddy sand / muddy gravelly sand (more gravelly than 7b), and 8 = muddy sand / sandy gravel (mixed sediment).

The dominant sediment type at the Inner Tees disposal site is group 3, slightly gravelly sand (mixed and poorly sorted), and group 5, similar to group 3 generally but with higher concentrations of finer sediment. In 2008, all stations sampled revealed sediment group 3, except IND4, IT4, IT7 (all within the disposal site) which were group 5, IT8 (outside the site) which was also group 5, as well as IT10 (outside the site) which is in group 2C (gravelly muddy sand).

Within the disposal site, there is a general trend between 2006 and 2008 showing reduction in finer sediment on the east side of the site (particularly at the edge IND1), with some sites showing increase in fines towards the centre and west side of the site (IT6, IT7, and IND4). Outside of the site, IT8 and IT1 have a similar sediment type each year in group 5. IT10 had a

more gravelly sediment type (within group 2C) in 2008 than in previous years. At IT3, in 2007 the sediment type contains a higher proportion of finer sediment and falls within group 6, compared with 2006 and 2008 when the sediment type fell within group 3. The sediment description demonstrates that there was a layer of mud over sand at IT3, which has not been noted in previous years. It is expected that this results from a natural phenomena and not associated with disposal activity (this will need to be assessed along with the contaminant data).

The sediment types associated with the Outer Tees disposal site are more variable than for the Inner Tees, with sediments characterised within 8 different groups. In 2008, the sediment is slightly gravelly sand, mixed and poorly sorted (group 3) at OT2 (in the disposal site), OT1 and OT3 (both outside). The sediment at OT5 and OT7 is gravelly / slightly gravelly muddy sand (group 6) and slightly gravelly sand, with higher fines content than group 3 (group 5) at OT6. At OT4 it is gravelly / muddy sand (2C).

Generally, within the Outer Tees disposal site sediments are becoming increasingly coarse, while those outside of the site are becoming finer. This possibly results from natural changes over time, however, this would need a longer time series to allow this to be tested.

2.3.4.3 Sediment organic carbon and nitrogen

In 2008, organic carbon was measured on all samples except IND2, IND5 and OT1 (these samples did not have sufficient <63 µm sediment) for the Inner and Outer Tees monitoring survey. In 2008, at the Inner Tees disposal site, organic carbon values range from 3.6 to 5.2 % m/m and for nitrogen 0.16 to 0.28 % m/m. At the Outer Tees disposal site, organic carbon values range from 2.8 to 5.0 % m/m and for nitrogen 0.13 to 0.34 % m/m. OT7 contained very high levels of organic carbon for the <2mm fraction (10.22 % m/m compared with 3.08 % m/m) than the <63µm showing there is a source of organic carbon (probably coal) in the coarser sediment.

Generally organic carbon content for 2008 is similar to 2006 and 2007 for both the Inner and Outer Tees.

2.3.4.4 Macrofaunal communities

A total of 163 taxa were identified from the 10 stations sampled in the Inner Tees Bay during 2008, 46 of which occurred only once. Bivalves and echinoderms dominated species abundance and biomass. *Nucula nitidosa*, *Abra alba*, *Chamelea striatula* and *Amphiura filiformis* were the most abundant species. *Echinocardium cordatum* contributed a high proportion of the biomass at stations IND1, IT6 and IT8, although only 7 individuals were identified. *Amphiura filiformis* also contributed significantly to the biomass at station IT8,

where it was the most abundant species and found in its highest numbers. The crab *Corystes cassivelaunus* made the largest contribution to biomass at IND1.

From the Outer Tees Bay stations (i.e., four in total) 152 taxa were identified; 50 occurring only once. Bivalves and polychaetes (*Lumbrineris gracilis*, *Abra nitida*, *Ophelina acuminata*, *Galowthowenia oculata* and *Nuculoma tenuis*) were the most abundant species. Bivalves, polychaetes and echinoderms contributed significantly to biomass (e.g. *Echinocardium cordatum* at stations OT4 and OT5). The bivalve *Dosinia lupinis* accounted for a high share of the biomass at stations OT2-OT4, but was not recorded at OT5. The gastropod *Turritella communis* made the largest contribution to biomass at IT5, where 10 of the 12 identified individuals were found.

The mean number of species, individuals and biomass were lower inside the disposal ground (compared to outside) for the Inner Tees. For example, the mean number of individuals inside the disposal ground was 107, compared to 264 outside. Station IT8 (outside the disposal ground) had the highest mean number of species and individuals, while IT4 (inside the disposal ground) had the lowest average numbers of species and individuals (Figure 2.40A&B). One-way ANOVA showed that the differences in average number of species and individuals were significant ($P < 0.05$), but there are no significant differences in the average biomass between stations in the Inner Tees area ($P > 0.05$).

Data from the Outer Tees Bay demonstrated no significant variation between stations in the average number of species, number of individuals and biomass (one-way ANOVA, $P > 0.05$).

Multi-dimensional scaling analysis was performed on the species abundance data using PRIMER v.6 (Clarke & Gorley, 2006) (Figure 2.41). With the exception of IT4, replicates from Inner Tees stations were closely grouped together (Figure 2.41A), indicating a high degree of similarity within these stations. Excluding IT4, stations within the disposal ground are similar (clustered together). Station IT8 (outside the disposal ground) is more similar to these stations within the disposal ground than it is to IT3. Both IT8 and IT3 show greater similarity to stations within the disposal ground than IT4 does. Replicates from the Outer Tees are not closely grouped together, indicating a low degree of similarity within stations. There is no clear grouping of stations within the disposal ground, or outside it.

Hierarchical cluster analysis with a similarity profile test (SIMPROF, significance level 5%) performed with PRIMER v.6 (Clarke & Gorley, 2006) confirms that IT4 differs from all other Inner Tees stations in macrofaunal abundance structure. Stations outside the disposal ground showed a low degree of similarity to each other and to stations within the disposal ground (Figure 2.42A). The Outer Tees shows no distinct difference between stations inside and

outside the disposal ground. All replicates, except OT5A, fall into the same cluster and are broadly similar in macrofaunal abundance (Figure 2.42B).

One-way ANOSIM (PRIMER v.6, Clarke & Gorley, 2006) was used to compare abundance data inside and outside the disposal ground for the Inner and Outer Tees. This analysis showed a significant difference between the macrofaunal community assemblage inside and outside the disposal ground and that the probability of the observed data for the Inner Tees being produced by chance is low (R = 0.554). There was no significant difference between the macrofaunal communities inside and outside the disposal ground for the Outer Tees (R = 0.244).

The similarity percentages program SIMPER (PRIMER v.6, Clarke & Gorley, 2006) was used to indicate which taxa contributed the most towards similarity/dissimilarity within stations, between stations and between locations inside / outside the disposal ground. For the Inner Tees, station IT4 showed the lowest average similarity between replicates (29 average similarity). Bivalves (*Nucula nitidosa* and *Abra alba*) and polychaetes (*Euchone* Type A) and *Capitella*) contributed most to the similarity between IT4 replicates (cumulatively 92 %). Station IT8 replicates were the most similar (68 % average similarity). Echinoderms, polychaetes and bivalves contributed the greatest to this similarity. The dissimilarity (average 76) between IT8 and IT3 (both outside the disposal ground) was contributed to by echinoderms, bivalves and polychaetes at low percentages (< 7 %). Station IT4 exhibited high average dissimilarity to all other stations within the Inner Tees Bay (> 83 % average dissimilarity for each station). Stations IT4 and IT8 were the least similar pair of stations (93 % average dissimilarity), primarily due to differences in echinoderm abundances. Stations inside the disposal ground had the same average similarity (39 %) as those outside it. The average dissimilarity between stations located inside versus outside the disposal site was 76 %. *Nucula nitidosa* and *Abra alba* were the greatest contributors to the dissimilarity (but at < 5 % contribution).

SIMPER analyses showed a smaller range of average similarities within stations for the Outer Tees than that shown by Inner Tees stations. OT4 was the station with the most similar replicates (51 % average similarity), polychaetes and bivalves contributing the most to this similarity. OT5 had the least similar replicates (42 % average similarity), also mainly due to the contributions of polychaetes and bivalves. The Outer Tees demonstrated a smaller range of similarity between stations than that shown for the Inner Tees. OT2 and OT5 had the greatest average dissimilarity between stations; OT3 and OT4 were the most similar (52 % average dissimilarity). Stations inside the disposal ground were more similar (49 % average similarity) than those outside it (42 % average similarity). Polychaetes and bivalves contributed most to both these similarities. The average dissimilarity between stations located

inside versus outside the disposal site was 56 %; bivalves and echinoderms were the greatest contributors to the dissimilarity, but at low percentages (< 5 % contribution).

Inner and Outer Tees Bays are similar in the number of taxa identified. The Inner Tees supports a bivalve and echinoderm-dominated macrofaunal community, whereas bivalves and polychaetes are most dominant in the Outer Tees. These are all typical fauna in muddy sands and are what would be expected for the area. The Outer Tees showed no significant difference in the number of individuals, number of species or biomass between inside and outside the disposal ground. The number of species and individuals in the Inner Tees disposal ground were significantly reduced compared to stations outside the disposal ground. Station IT4 (inside the disposal ground) was distinct from all other Inner Tees stations in its macrofaunal abundance. It exhibited significantly reduced numbers of species and individuals and a low level of similarity between replicates. Bivalves and polychaetes contributed most to the similarity within the station. The two stations outside the disposal ground have dissimilar communities, although they are both consistent with the expected macrofauna of the area. IT8 lies south-east of the disposal ground and is potentially more vulnerable to the dispersal of disposed material by the north-to-south tidal influence than IT3 (north-west of the disposal site), while IT8 showed significantly higher numbers of species and individuals than the rest of the Inner Tees stations.

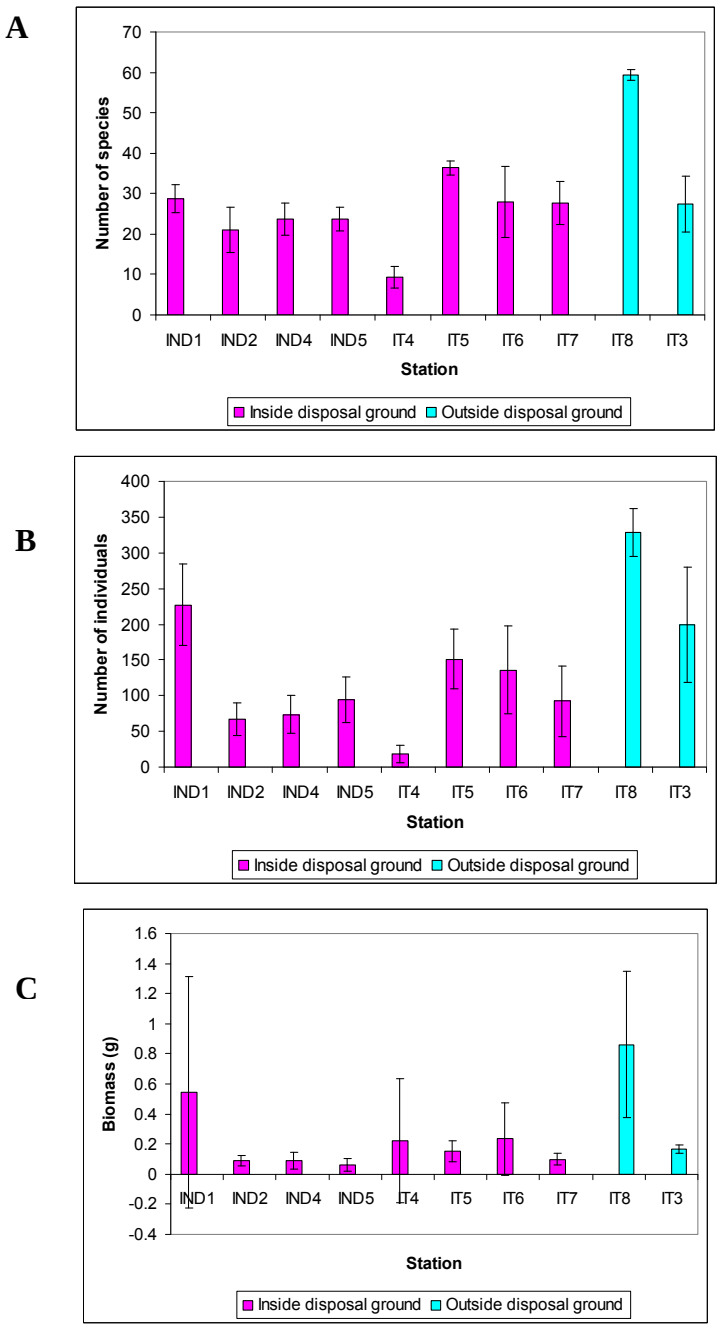
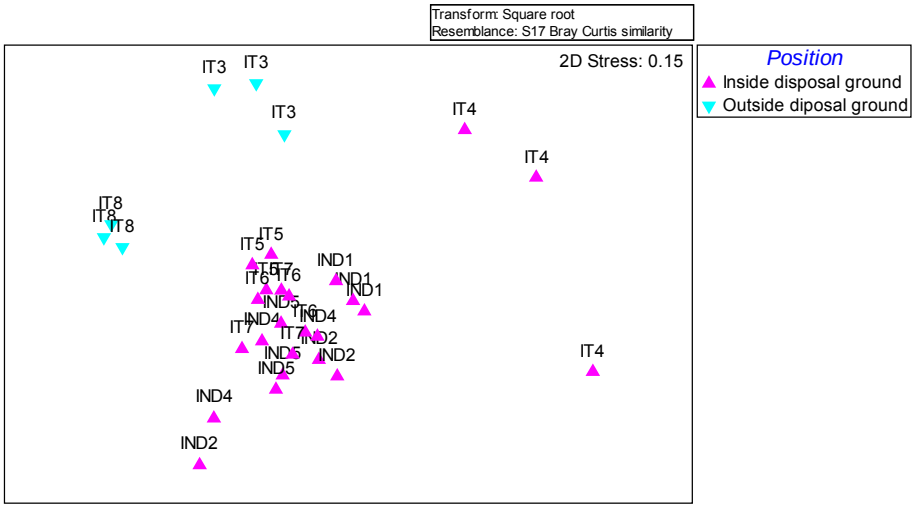


Figure 2.40A-C. Inner Tees Bay. A. Mean number of species (+/- standard deviation). B. Mean number of individuals (+/- standard deviation). C. Mean biomass (+/- standard deviation).

A



B

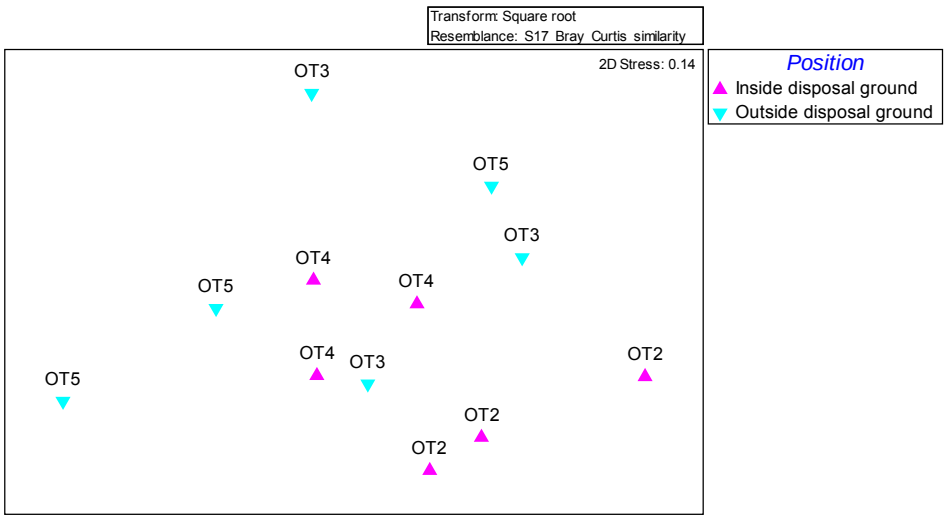


Figure 2.41. MDS plot of species abundance: A) Inner Tees Bay, and B) Outer Tees Bay.

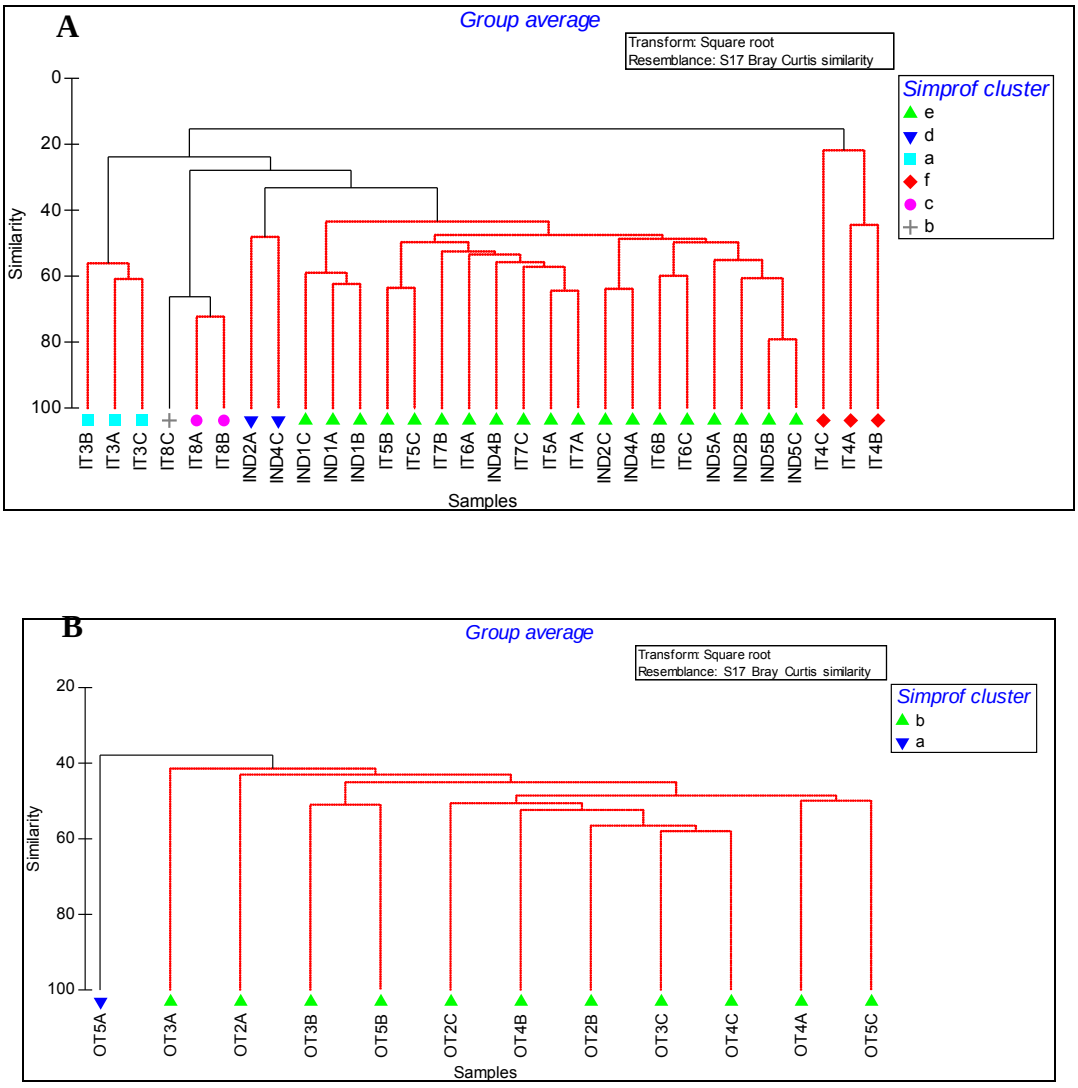


Figure 2.42. Hierarchical cluster analysis with a SIMPROF test (significance level 5%) of abundance data for A) Inner Tees Bay, and B) Outer Tees Bay.

2.3.4.5 Contaminants

2.3.4.5.1 TBT

Most of the samples analysed for TBT and DBT were below the current detection limit. There is a general slight decrease in organotins concentrations compared to the previous year's samples, mainly for stations IND4 and IT4 (both inside the disposal site) and OT3, which recorded presence of TBT and DBT below the AL1 concentration.

Sample from OT7 were analysed for organotins in 2008 and the result indicated a presence of TBT in this sample. Its concentration is still below the AL1, however, it is relatively high compared to the general findings in this report (0.045 mg/kg). There were insufficient data from the previous years (no sample collection or no analysis required) to make a temporal comparison for this site.

2.3.4.5.2 PAHs

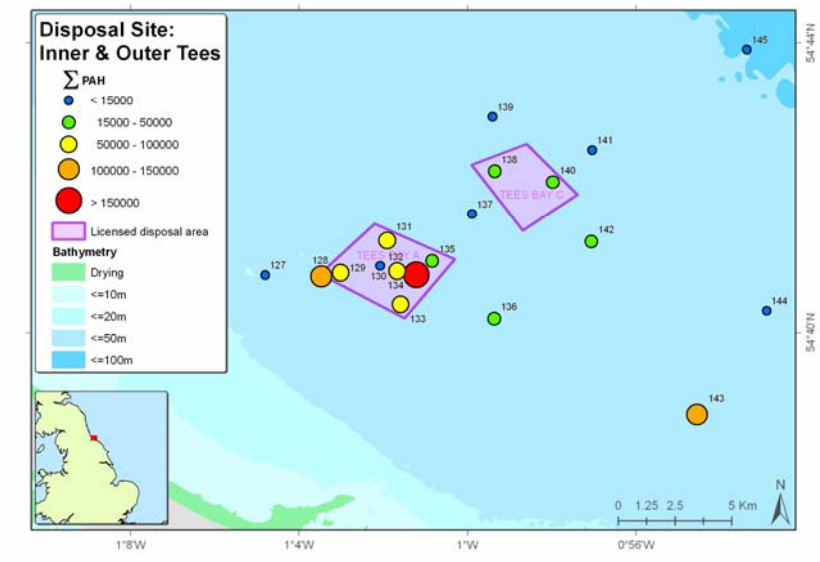


Figure 2.43. Summed PAH concentrations for the Inner and Outer Tees stations, 2008.

The Tees area displayed the highest PAH concentrations compared to all the sites sampled during 2008. The highest concentrations were seen within the Inner Tees Disposal Site (IT6) with a maximum summed PAH concentration of 179,600µg kg^{-1} compared to a maximum concentration at OT2 within the Outer Tees Disposal Site of 16,000µg kg^{-1}. In 2007 the maximum concentrations were 148,000 and 71,000 µg kg^{-1}, respectively. The differences in the concentration at the two disposal areas could be attributable to the fact that there has been no disposal activity during 2007/8 at the Outer Tees Disposal Site whilst the amount of disposal to the Inner Tees Disposal Site has increased during this period.

Study of specific PAH within the sample from IT6 within the inner disposal site indicated a primarily petrogenic (fossil-fuel based) source. However, the profile of the sample from OT7 (Stn143), which had a summed PAH concentration of 135,300 µg kg^{-1}, did not suggest a similar source.

2.3.4.5.3 Organohalogens

At Inner and Outer Tees, concentrations of organohalogen contaminants were generally low, below or close to LODs (Figures 2.44-2.46). The highest concentrations for CBs were observed south east of the disposal site at stations OT5 and OT7. All stations were below FEPA warning levels and TECs for CBs and OCs. According to the OSPAR guidelines, most stations had 'good' environmental status for all ICES7 CBs, except for IT6, IT8, OT5 and OT8 which had 'bad' environmental status for CB118, i.e. all stations had 'good' status overall.

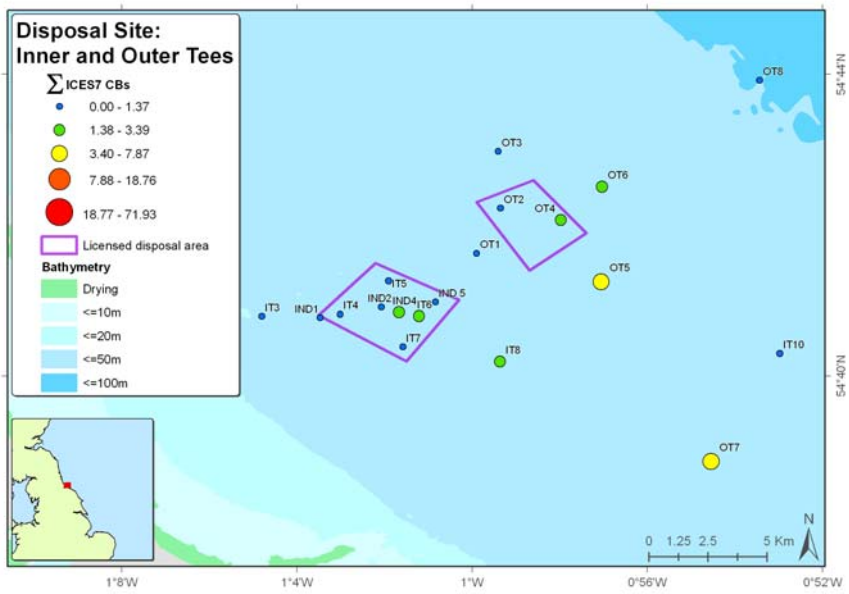


Figure 2.44. Summed ICES7 CB concentrations for the Inner and Outer Tees stations, 2008.

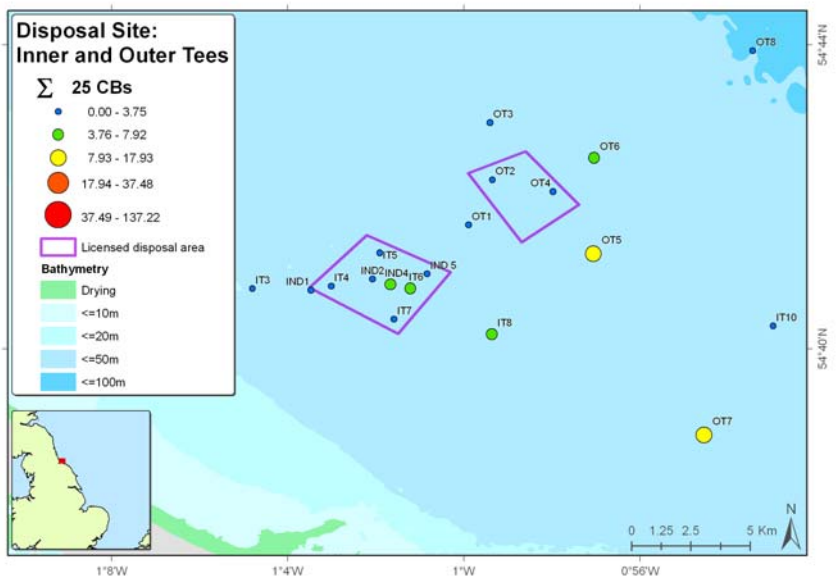


Figure 2.45. Summed 25 CB concentrations for the Inner and Outer Tees stations, 2008.

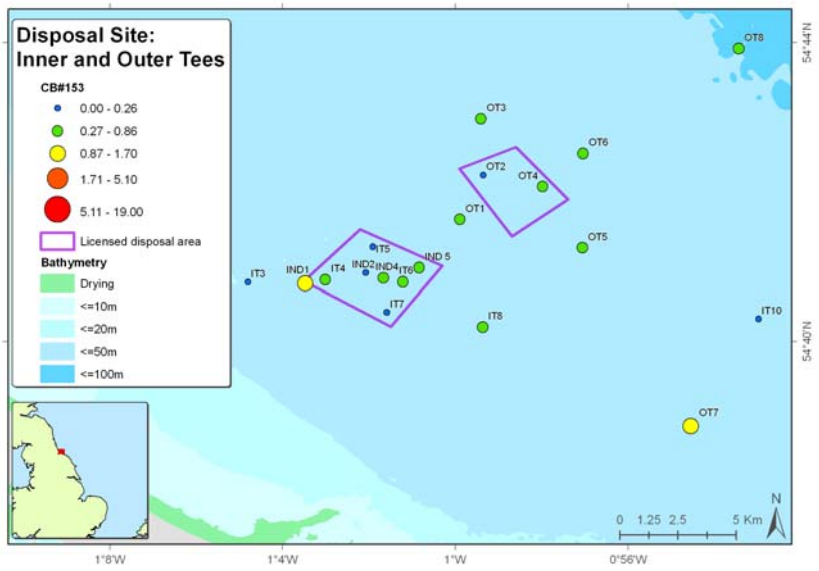


Figure 2.46. CB#153 concentrations for the Inner and Outer Tees stations, 2008.

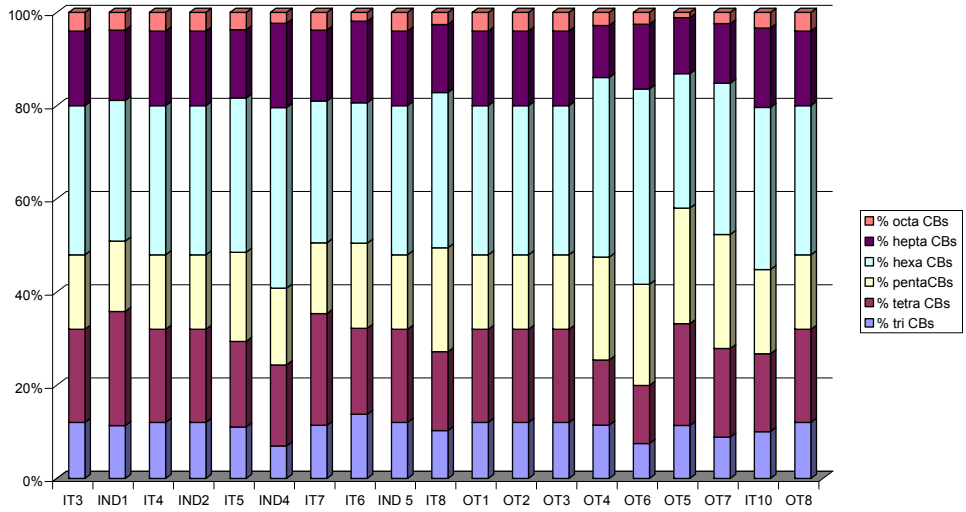


Figure 2.47. CB congener profiles for the Inner and Outer Tees stations, 2008.

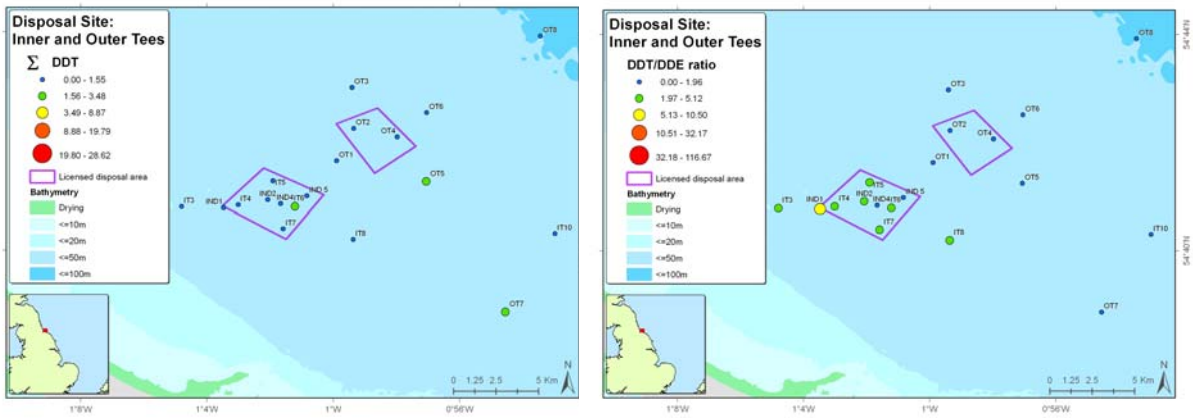


Figure 2.48. Summed DDT concentration (left) and DDT / DDE ratios (right) for the Inner and Outer Tees stations, 2008.

Station	∑ICES 7 CBs concentration (in µg/kg)						
	2002	2003	2004	2005	2006	2007	2008
IT3		0.7			0.7	5.09	0.7
IND1					0.7	0.7	0.7
IT4		26.4			0.7	2.8	0.7
IND2					0.7		0.7
IT5		0.7			0.7		0.92
IND4						4.62	1.76
IT7		24.1			0.7	1.7	0.7
IT6		0.7			0.7	0.82	2.2
IND 5						0.95	0.7
IT8		0.7			0.7	1.5	1.64
OT1					0.7		0.7
OT2					0.7		0.7
OT3					0.9	0.7	0.7
OT4					1.28	5.8	1.5
OT6					0.83		1.81
OT5					0.83	3.49	4.19
OT7							6.12
IT10		0.7					1.08
OT8					0.7		0.7

Table 2.6. Temporal trends (2003-2008) of ∑ICES 7 CB concentrations (µg / kg) at Tees stations.

Data was available for Tees for the years 2003, 2006, 2007 and 2008 (Table 2.6). Concentrations of CBs were much lower at stations IT4 and IT7 in 2008 than in 2004. Concentrations were also lower at stations IT3, IND4 and OT4 in 2008 than in 2007. Possible increasing trends were observed at stations IT6, IT8, OT5 and OT6 in 2008 compared with 2007.

2.3.4.5.4 Trace metals

2.3.4.5.4.1 Outer Tees

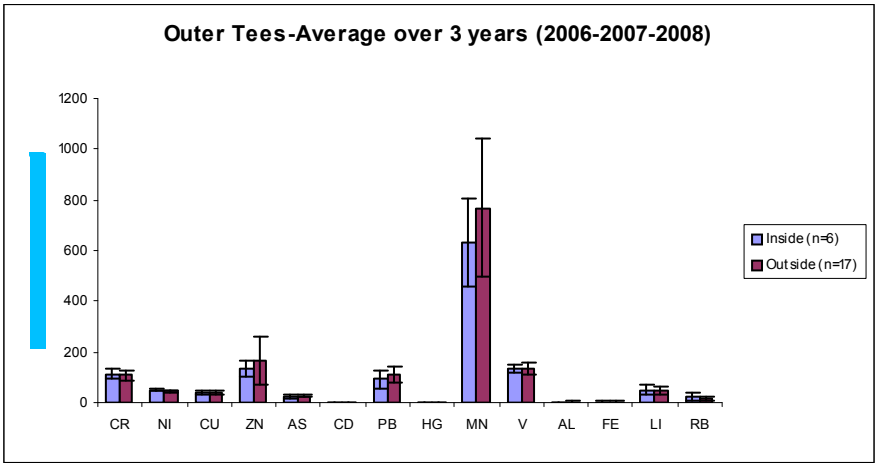


Figure 2.49. Average metal concentrations within and outside the disposal site between 2006-08 at Outer Tees.

The metals concentrations at stations outside and inside the disposal sites at Outer Tees, averaged across 2006 and 2008, were very similar (Figure 2.49). When this is temporally assessed (Figure 2.50), metals concentrations have remained somewhat similar between 2006 and 2008, for stations both inside and outside the disposal site.

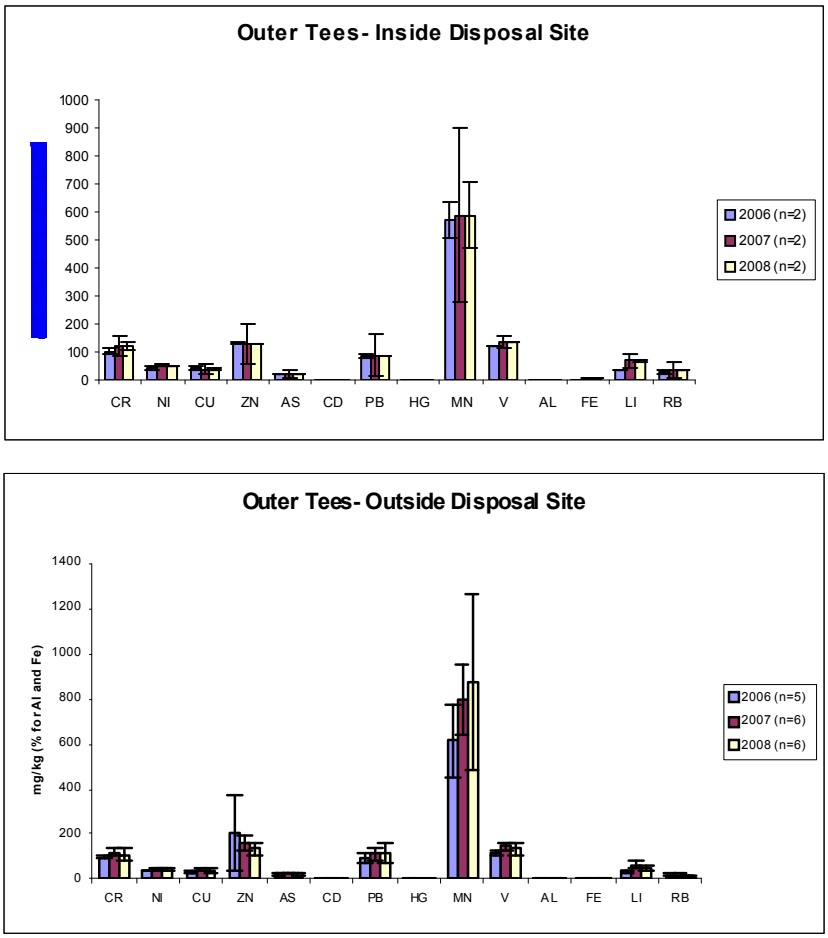


Figure 2.50. Metals concentrations inside (top) and outside (bottom) the disposal site at Outer Tees between 2006 and 2008.

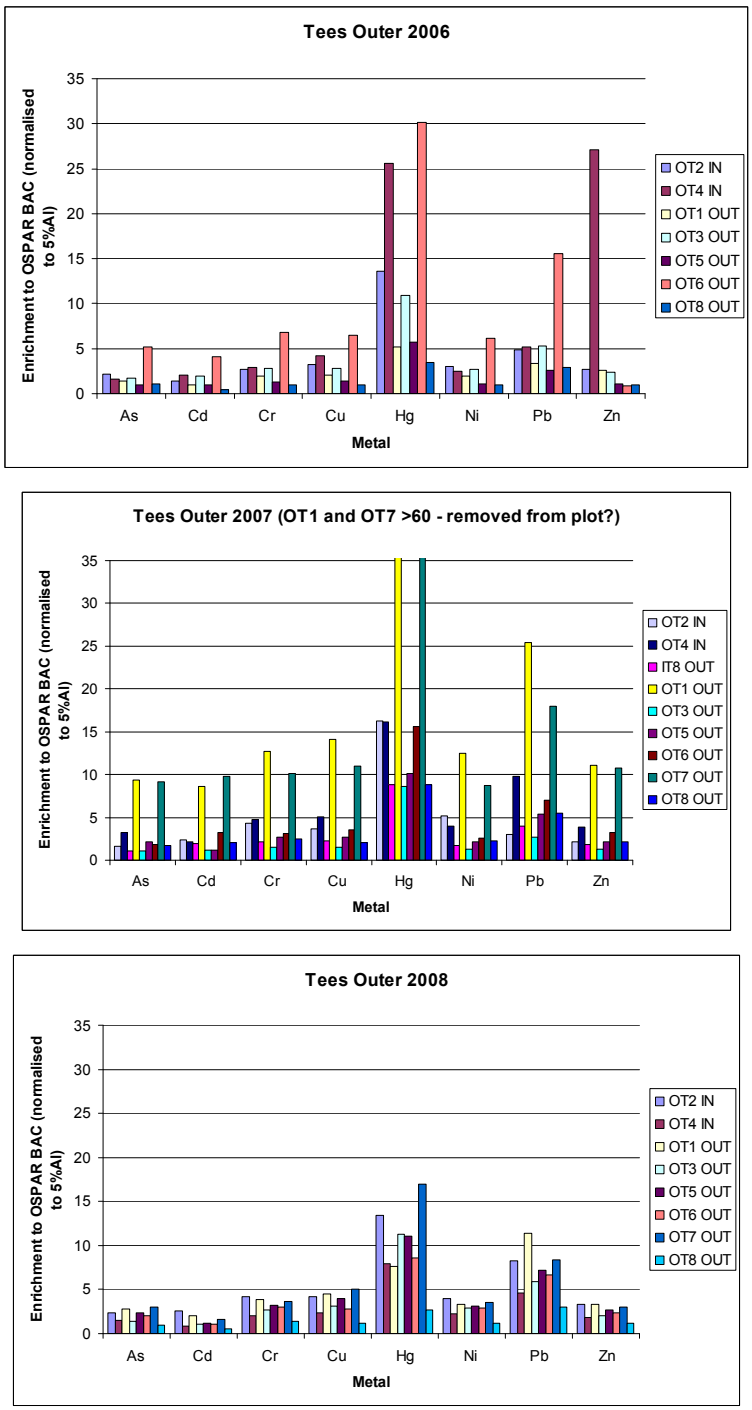


Figure 2.51. Enrichment to OSPAR BACs for metal concentrations measured at Outer Tees in 2006 (top), 2007 (middle), and 2008 (bottom).

In 2006, inside the site, Hg and Zn (both >20X enriched) are enriched relative to the other concentrations measured (Figure 2.51). OT6, outside of the site, is relatively enriched (>5X more than other sample measured) for all metals shown except Zn. In 2007, inside the site, Hg and Pb (>15X enriched) are most enriched. OT1 and OT7, outside of the site are relatively elevated (enrichments >5X more than the other samples measured) for all metals outside the site. In 2008, there are no differences in metal enrichments measured inside the site and outside the site, except for Hg (>5X enrichment than other samples) at OT7.

OT1 and OT6 are close to the site boundary, and enrichments observed here may be result of dredge material being dispersed out to these areas, whereas OT7 is a long way south of the site, and enrichments observed here are unlikely to be related to the disposal activity at the Outer Tees, especially as concentrations measured at OT5, positioned between the disposal site and OT7, do not show a pattern of decreased enrichment that would be expected if the Outer Tees was the source, and these are in general lower for OT5 than OT7 for 2007 and 2008. No measurements were made at OT7 in 2006.

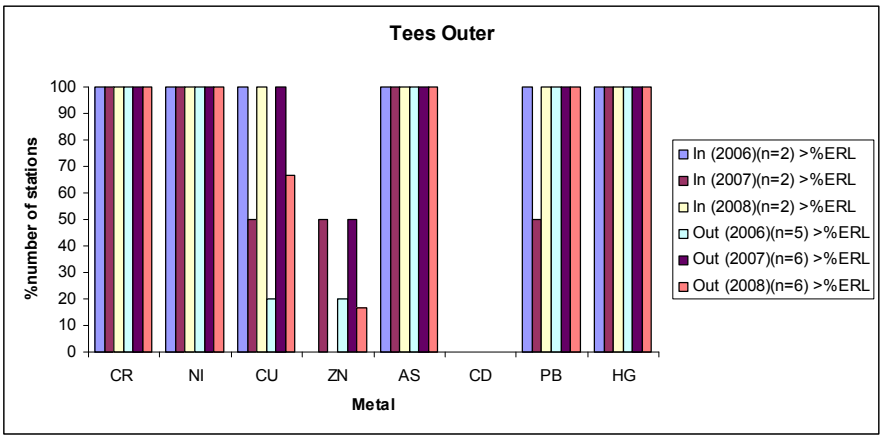


Figure 2.52. Average percentage number of stations inside and outside Outer Tees disposal site with concentrations >ERL for 2006, 2007 and 2008.

All stations at the Outer Tees have higher metal concentrations than ERLs except Cd (inside and outside, all years), Zn (none inside for 2006 and 2008, the same average percentage number of stations (50%) in 2007, and similar average percentage of stations (20%) outside for 2006 and 2008), Cu (inside 2007 (50%), and outside 2006 (20%)) and Pb (inside 2007) (Figure 2.52). Generally therefore, there is little difference (based on evidence from averaged metals concentrations, enrichment compared to BACs, and comparison of averaged percentage of stations >ERLs) in concentrations measured inside and outside of the Outer Tees in 2008. This is less clear for 2006 and 2007.

In summary, metal concentrations measured at Outer Tees are mostly above OSPAR BACs. This is not unexpected as this area has enriched concentrations related to the natural geology as well as historic mining activity. Additionally, metal concentrations are mostly above ERL. However, care should be taken when assessing the implications of these results, as metal concentrations were measured on the <63µm fraction using a total digest and so are in a more concentrated form than would be available for uptake within the whole sediment here. Most samples have <20% average silt/clay content.

2.3.4.5.4.2 Inner Tees

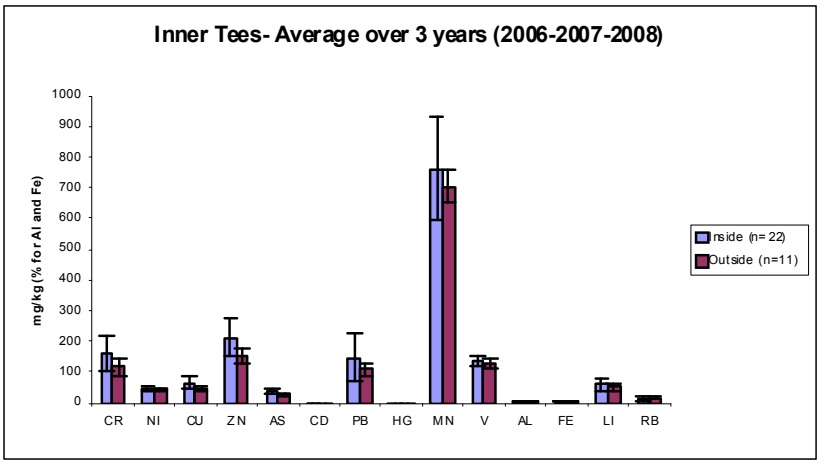


Figure 2.53. Average metal concentrations inside and outside the Inner Tees disposal site between 2006 and 2008

Figure 2.53 implies that, on average between 2006 and 2008, the concentrations of some metal species (e.g., Cr, Zn, Pb, Mn) were slightly higher inside the disposal site relative to outside, although these differences were not significant. Figure 2.54 shows the annual metal concentrations for each year. This suggests there was an increase in metal concentrations during 2007 within some stations in the disposal site.

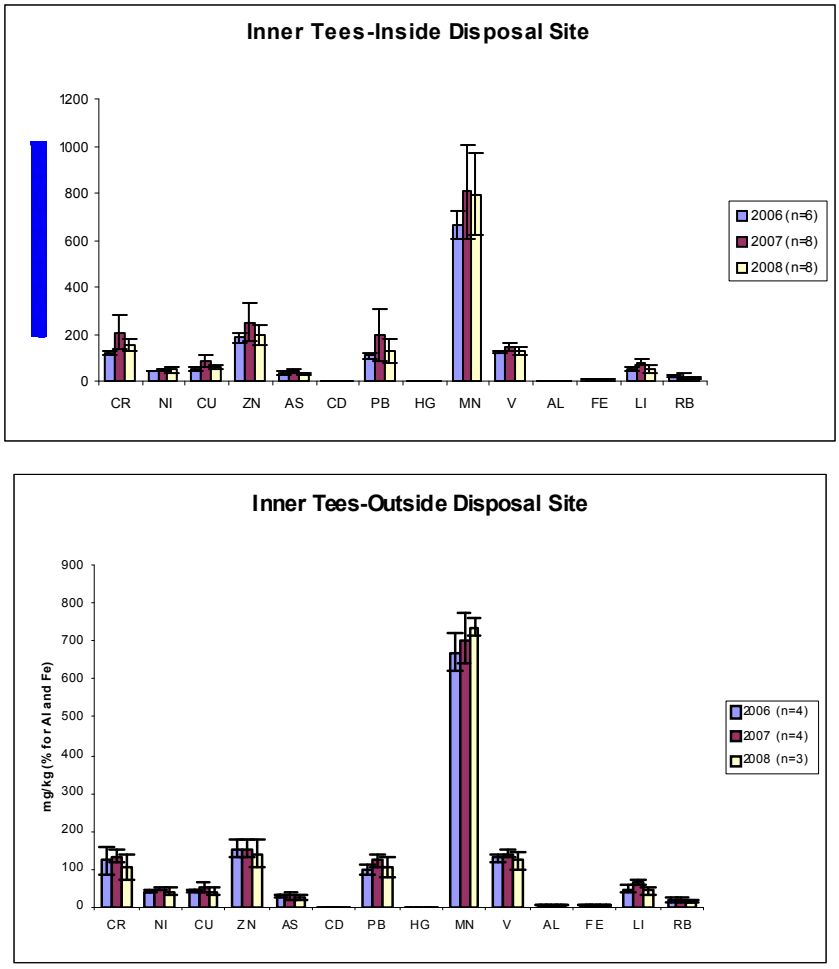


Figure 2.54. Concentrations of metals for stations inside (top) and outside (bottom) the Inner Tees disposal site between 2006 and 2008.

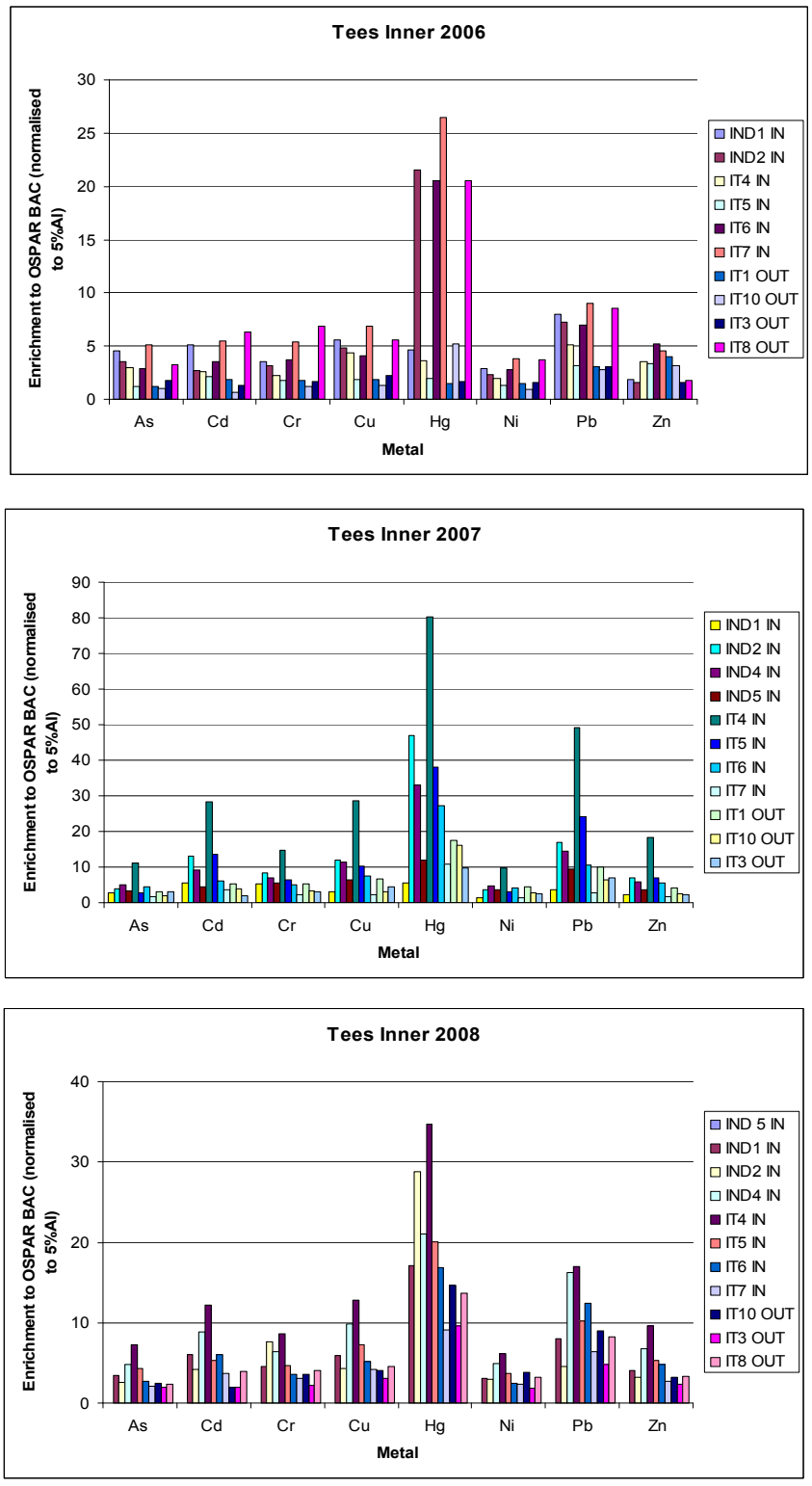


Figure 2.55. Enrichment to OSPAR BACs for metal concentrations measured at Inner Tees in 2006 (top), 2007 (middle), and 2008 (bottom).

In 2006, enrichment levels at IT8 (outside) are similar to those measured within the site, and generally these are more enriched than outside site samples (Figure 2.55). In 2007, IT4 is more enriched (5X more) than other sites within the disposal site. Metal concentrations are generally more enriched within the disposal site than outside the disposal site. In 2008, some

samples are more enriched in the site than outside for all metals, with highest enrichments at IT4. IND5 inside the disposal site showed no enrichment for any metals (the most easterly point measured in the disposal site).

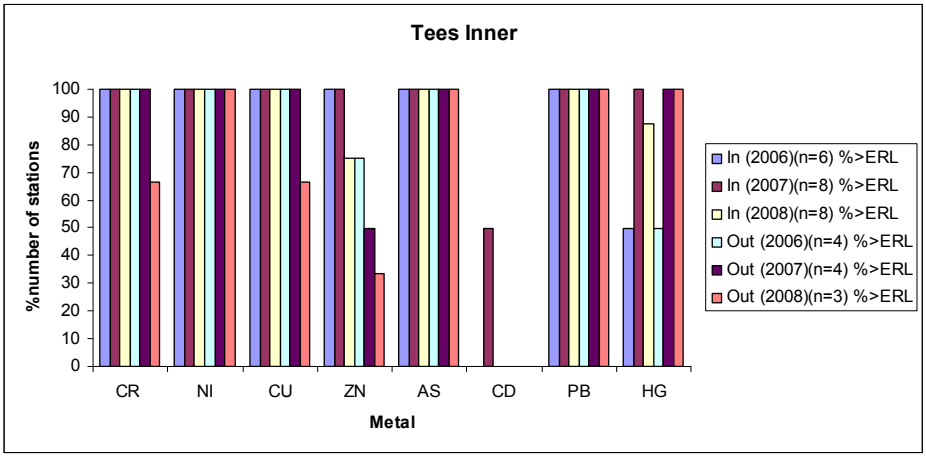


Figure 2.56. Average percentage number of stations inside and outside Outer Tees disposal site with concentrations >ERL for 2006, 2007 and 2008.

Averaged stations at the Inner Tees have higher metal concentrations than ERLs except Cd (inside and outside, all years, except In 2007 – 50%), Zn (inside 2008 (75%), and outside 2006(75%), 2007(50%) and 2008 (33%)), Cu (outside 2008 (65%)) and Hg (inside 2006 (50%), 2008 (85%) and outside 2006 (50%)) (Figure 2.56). Generally there is a slight decrease in average concentrations for some metals inside the site compared to outside the site in 2008, but compared to background there is enrichment within the site at IT4.

In summary, metal concentrations measured at Inner Tees are mostly above OSPAR BACs. This is not unexpected as this area has enriched concentrations related to the natural geology as well as historic mining activity. Additionally, metal concentrations measured at Inner Tees are mostly above ERL. However, care should be taken when assessing the implications of these results as metal concentrations were measured on the <63µm fraction using a total digest and so are in a more concentrated form than would be available for uptake within the whole sediment here. Most samples have <20% average silt/clay content. The enrichment at IT4 in 2007/2008 is noteworthy as this area should be away from the impacts of the disposal activity in an attempt to level the ground.

2.3.5 Conclusions

The Tees survey (both Inner and Outer disposal sites) represents an important component under SLAB5 primarily due to the amount of material which is annually disposed and its contaminant loading. Faunal communities inside the disposal site remain impacted relative to those outside and continued sampling should be undertaken here to ensure that those

outside do not start showing signs of impacts due to the disposal activity. TBT levels are shown to be higher here than for most disposal sites, and while organohalogens do not show significant elevations PAHs are high. Some metal species are also shown to be very enriched as a result of the disposal activity (e.g., Hg and Pb). The time-series acoustic data is proving to be a useful aid in assessing the fate of the material and in the effectiveness of the recently-imposed management practices. Sampling at this site should be continued during 2009.

2.4 Scarborough Rock (TY190)

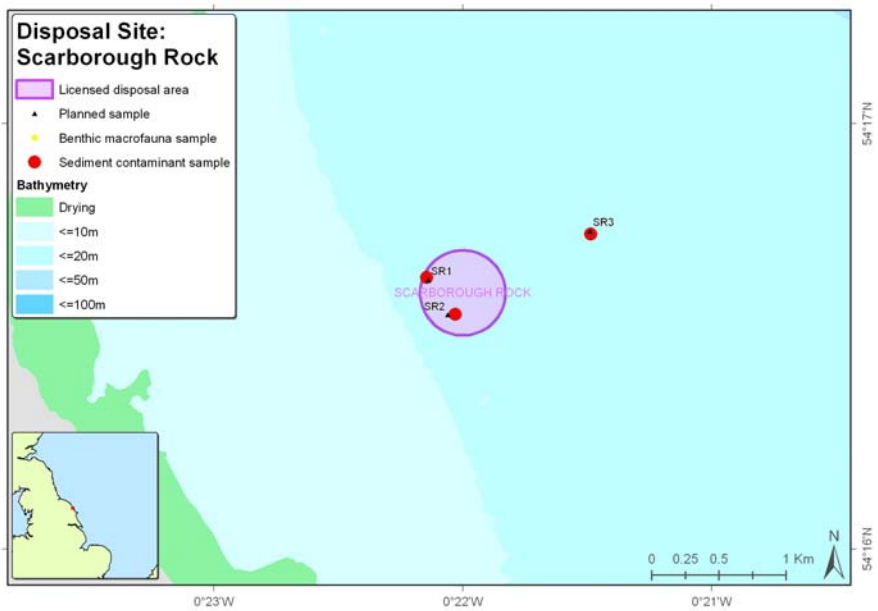


Figure 2.57. Location of Scarborough Rock monitoring stations, 2008.

2.4.1 Background

Scarborough Rock disposal site receives maintenance dredged material from Scarborough outer harbour, approach channel and inner harbour. The site receives typically 10,000 tonnes (5,819 m^3) per annum, although in 2006 a licence was granted for the disposal of 47,000 tonnes of capital material, comprising mainly sand and silt.

The inner harbour area at Scarborough Harbour has had a history of contamination with TBT and as a result some of the contaminated material was removed to landfill. However samples analysed from the inner harbour showed elevated levels of PAHs in 2006, and elevated mercury (Hg) in 2007. Monitoring during 2008, therefore, aimed primarily to assess the concentrations of these contaminants within and around the disposal site.

2.4.2 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

2.4.3 Parameters monitored

Sediment particle size distribution

Sediment organic carbon and nitrogen

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

2.4.4 Results

2.4.4.1 Sediment particle size

Station code	Sediment group
SR1	3
SR2	3
SR3	3

Table 2.7. Sediment groups for samples analysed from the Scarborough Rock monitoring survey in 2008. Key: 3 = slightly gravelly sand (mixed, poorly sorted).

All the samples had the same sediment type within group 3, and show similar sediment profiles. SR3 (outside the disposal site) contains slightly higher concentrations of muddy sediment, but still falls in the same sediment group.

2.4.4.2 Sediment organic carbon and nitrogen

Organic carbon at this site was only measured at SR3 (insufficient <63 µm fractions in the sediments at SR1 and SR2). The organic carbon value at SR3 was 3.43 % m/m and for nitrogen 0.22 % m/m. Organic carbon for the <2mm fraction for SR3 was 3.17 % m/m and 0.13 % m/m for nitrogen.

2.4.4.3 Contaminants

2.4.4.3.1 TBT

Scarborough Rock samples were collected and analysed this year and all the results were below the detection limit. This is the first set of data from this particular disposal site and therefore no data trend interpretation could be made at this point.

2.4.4.3.2 PAHs

The highest concentration of summed PAHs of 39,400 µg kg^{-1} was found at SR3, to the east of the disposal site. Concentrations at SR1 and SR2 on the disposal site were 880 and 540 µg kg^{-1}, respectively. The high concentration at SR3 may represent dispersal from the disposal site. Summed PAH concentrations of ca. 5,000 µg kg^{-1} were observed at CSEMP station 295, the outermost (about 10 miles offshore) of the two stations off the Tees Estuary, in 2008. This site was not sampled in 2007 so temporal comparisons are not possible.

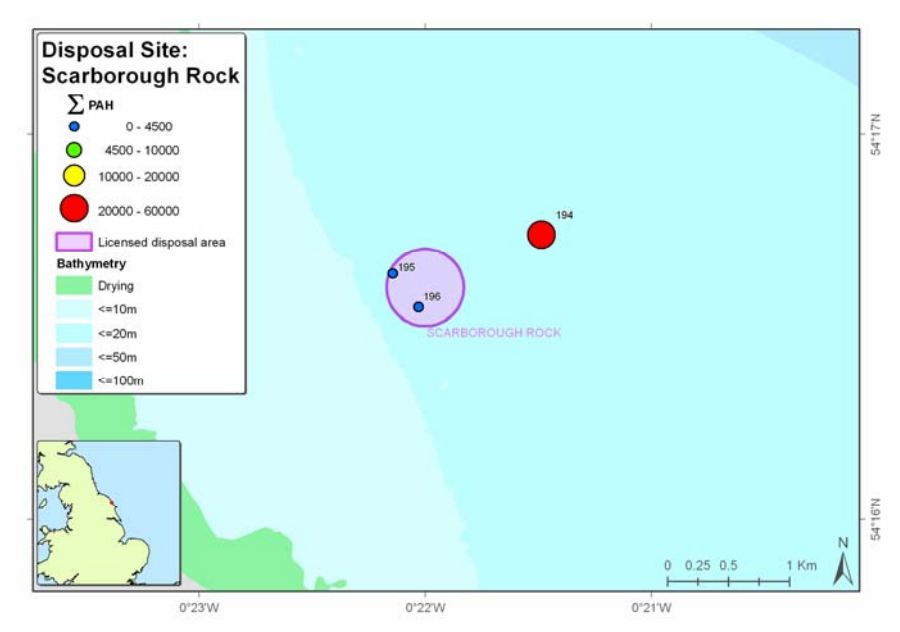


Figure 2.58. Summed PAH concentrations for the Scarborough Rock stations, 2008.

2.4.4.3.3 Organohalogens

At Scarborough Rock concentrations of organohalogen contaminants were generally low, below or close to LODs (Figures 2.59-2.61). The highest concentrations for CBs were observed outside the disposal site at SR3, but these were still low. Station SR3 had a slightly higher proportion of pentachlorinated PCBs than the other stations. All stations were below FEPA warning levels and TECs for CBs and OCs, and had 'good' environmental status for all ICES7 CBs, except for CB118 which was 'bad' at stations SR1 and SR2, i.e. all stations had 'good' status overall. No previous data was collected at this site to allow temporal comparisons.

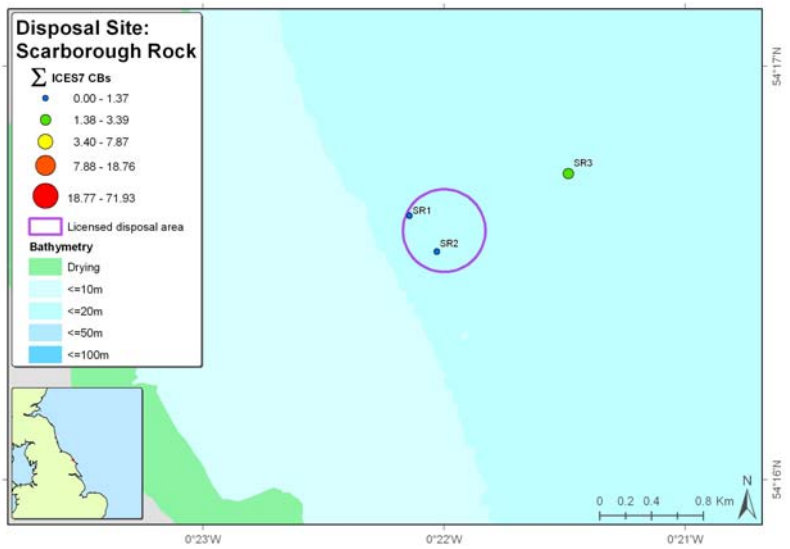


Figure 2.59. Summed ICES7 CB concentrations at Scarborough Rock stations, 2008.

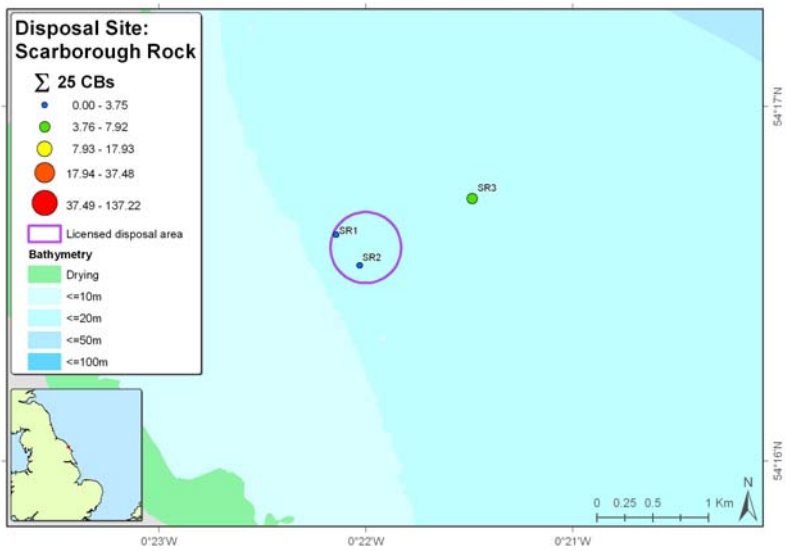


Figure 2.60. Summed 25 CB concentrations at Scarborough Rock stations, 2008.

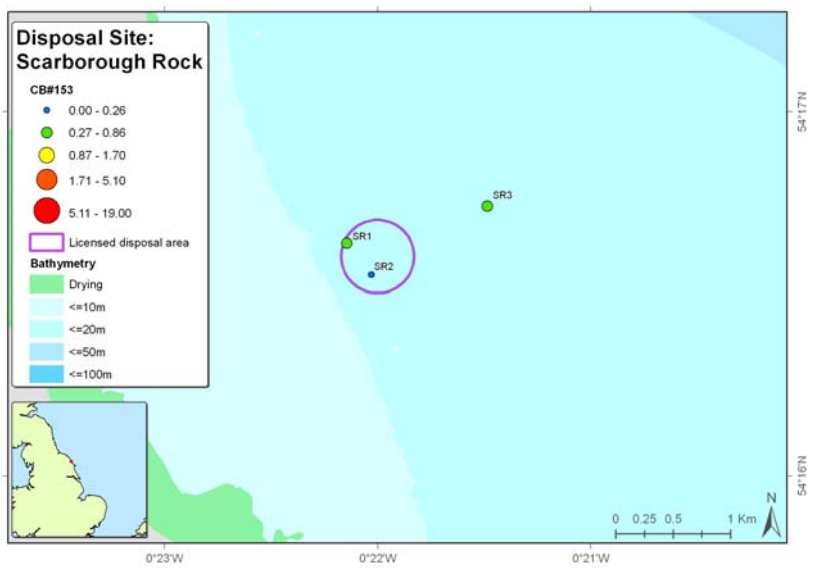


Figure 2.61. CB#153 concentrations for Scarborough Rock stations, 2008.

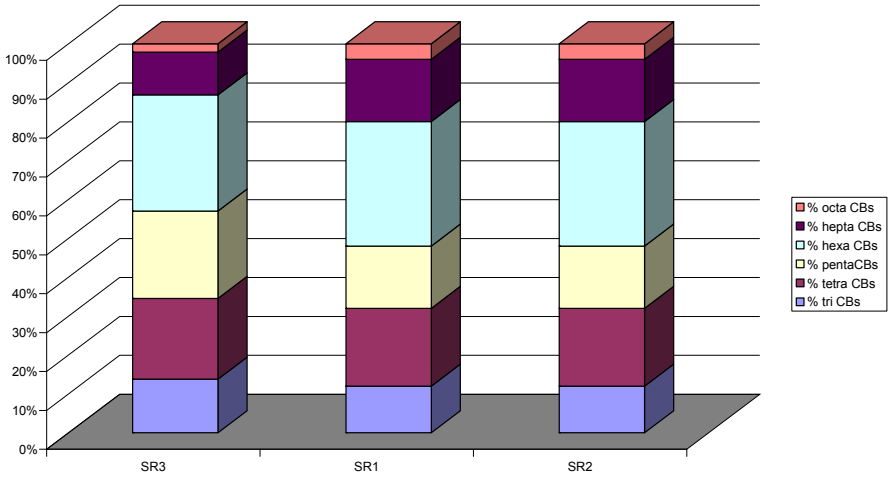


Figure 2.62. CB congener profiles for the Scarborough Rock stations, 2008.

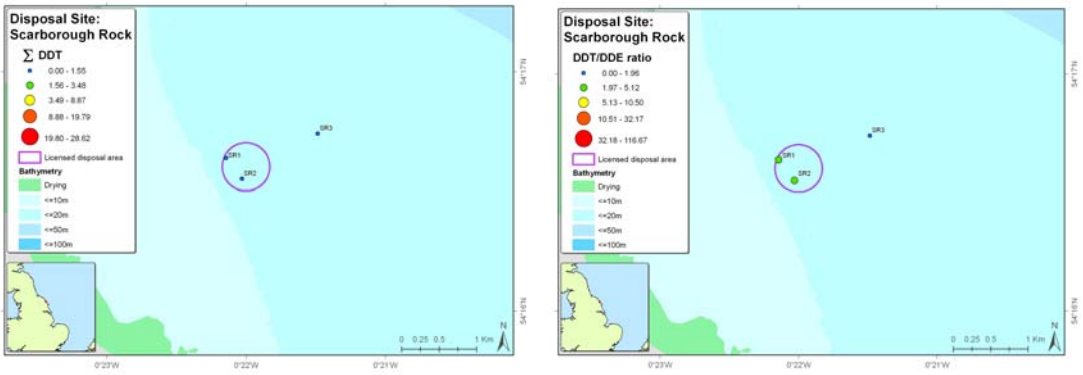


Figure 2.63. Summed DDT concentrations (left) and DDT / DDE ratios (right) for the Scarborough Rock stations, 2008.

2.4.4.3.4 Trace metals

Only SR3 (16% silt/clay) was analysed for metals because there was insufficient <63um material from SR1 and SR2 (<1%). Therefore no inside and outside comparison of concentrations could be made at this site.

		As	Cd	Cr	Cu	Hg	Ni	Pb	Zn
SR3	OUT	2	2	3	4	9	3	7	3

Table 2.8. Enrichment of metal concentrations to OSPAR BACs for Scarborough Rock

	CR	NI	CU	ZN	AS	CD	PB	HG
SR3	>ERL<ERM	>ERM	>ERL<ERM	>ERL<ERM	>ERL<ERM	<ERL	>ERL<ERM	>ERL<ERM

Table 2.9. Assessment of metal concentrations against ERLs and ERMs for Scarborough Rock.

Metals concentrations measured at Scarborough Rock are above background, as well as having concentrations >ERL (except for Cd) (Tables 2.8 & 2.9). However, further work would be required to investigate the reasons for these observations. Note, care should be taken when assessing the implication of these results, as metal concentrations were measured on the <63µm fraction using a total digest and so are in a more concentrated form than would be available for uptake within the whole sediment here.

2.4.5 Conclusions

TBT concentrations were low at this site, as were organohalogens. However, PAH concentrations to the east of the disposal site (which may or may not have originated from the disposal activity) were very high, and metals concentrations were seen to be elevated. The 2008 survey was the first sampling undertaken here under the auspices of SLAB5 and the results of this survey will be used as part of the licensing process. As such, no further sampling is required in the immediate future, but future sampling, particularly for PAHs, may be undertaken.

2.5 Goole (HU041 and HU040)

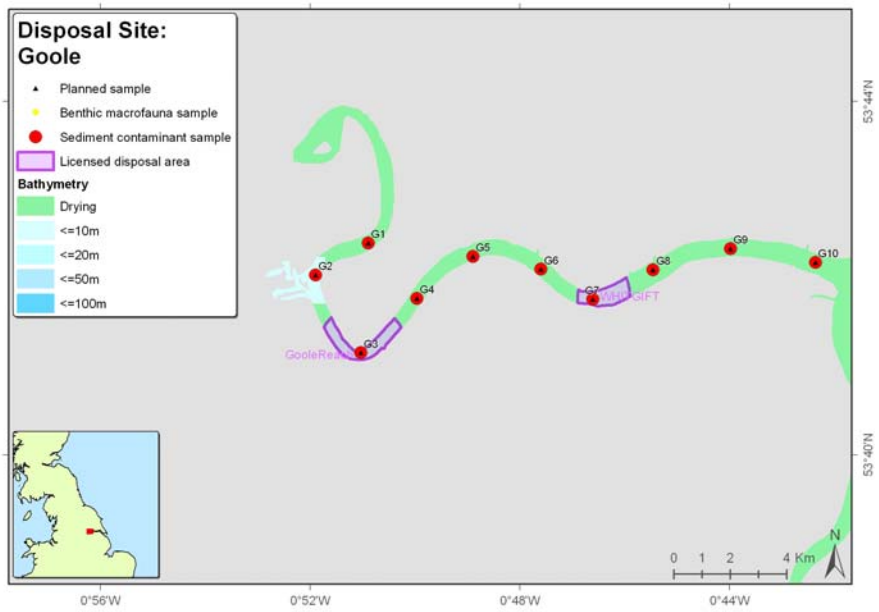


Figure 2.64. Locations of the monitoring stations at Goole, 2008.

2.5.1 Background

Goole Reach (HU041) and Whitgift Bight (HU040) are both located on the River Ouse, Humber Estuary. This is a dynamic area and material is rapidly dispersed and diluted within the estuary.

HU040 was opened in 1982 with disposal commencing in 1984, while HU041 was subsequently opened in 1990. Only maintenance dredged material from Goole docks is disposed to these sites, and is generally silt/sand material with an approximate SG of 1.3. Goole Docks have a current FEPA licence for the annual disposal of 49,000 tonnes (37,690 m^3) of maintenance dredged material. Disposal takes place around high water during which approximately 1100 tonnes are disposed of per tide.

Sediments within Goole docks have recently been highlighted as containing elevated levels of PAHs. Sampling during 2008 was conducted to assess the levels of contaminants within and surrounding the disposal sites, with a particular focus on PAHs.

2.5.2 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

2.5.3 Parameters monitored

Sediment particle size distribution

Sediment organic carbon and nitrogen

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

2.5.4 Results

2.5.4.1 Sediment particle size distribution

Station code	Sediment Group
G1	3
G2	5
G3	5
G4	1
G5	5
G6	7b
G7	5
G8	1
G9	1
G10	5

Table 2.10. Sediment groups for samples analysed from the Goole monitoring survey in 2008. Key: 1 = slightly gravelly sand (unimodal, well sorted), 3 = slightly gravelly sand (mixed, poorly sorted), 5 = slightly gravelly muddy sand (mixed, poorly sorted (more muddy than group 3), and 7b = slightly gravelly sand (unimodal, well sorted).

Sediment types measured from the Goole monitoring survey in 2008 fall into 4 sediment groups. G2, G3 (within HU041), G5, G7 (within HU040) and G10 are slightly gravelly muddy sands, mixed and poorly sorted containing more finer sediment than group 3. G4, G8 and G9 are slightly gravelly sands, unimodal and well sorted with very minimal fine sediment. G1 is defined as slightly gravelly, muddy sand, mixed and poorly sorted. G6 is defined as slightly gravelly sand, unimodal and well sorted.

2.5.4.2 Sediment organic carbon and nitrogen

In 2008, organic carbon was measured on all samples except G4, G8 and G9 (insufficient <63 µm sediment fractions) for the Goole site. Organic carbon values range from 0.4 to 2.3 % m/m and for nitrogen 0.03 to 0.16 % m/m. G1, G3 and G10 contained slightly higher levels of organic carbon for the <2mm fraction (G1: 2 % m/m compared with 0.6 % m/m; G3: 2 % m/m compared with 1.5 % m/m; and G10: 1.3 % m/m compared with 1.1 % m/m) than the <63µm showing there may be a source of organic carbon (possibly coal) in the coarser sediment here.

2.5.4.3 Contaminants

2.5.4.3.1 TBT

Both TBT and DBT results were below the current limits of detection for all Goole stations during 2008.

2.5.4.3.2 PAHs

The highest concentration of summed PAHs of 21,100 µg kg^{-1} was found at G2 upstream of the disposal site, which is located at G3, and directly outside the locks of the Port of Goole (Figure 2.65). The river is still tidal at this point despite being ca. 40 miles from the sea, and so high concentrations upstream of the disposal site do not imply an upstream source. Relatively high concentrations of 15,700-17,000µg kg^{-1} were also found at G1 further upstream of the disposal site and G10 approx 5 Km downstream of HU040. It is possible that the high concentrations seen represent redistribution of both bed sediments and disposed material in the strong tidal currents seen in the River Ouse at Goole. This site was not sampled in 2007 so temporal comparisons are not possible.

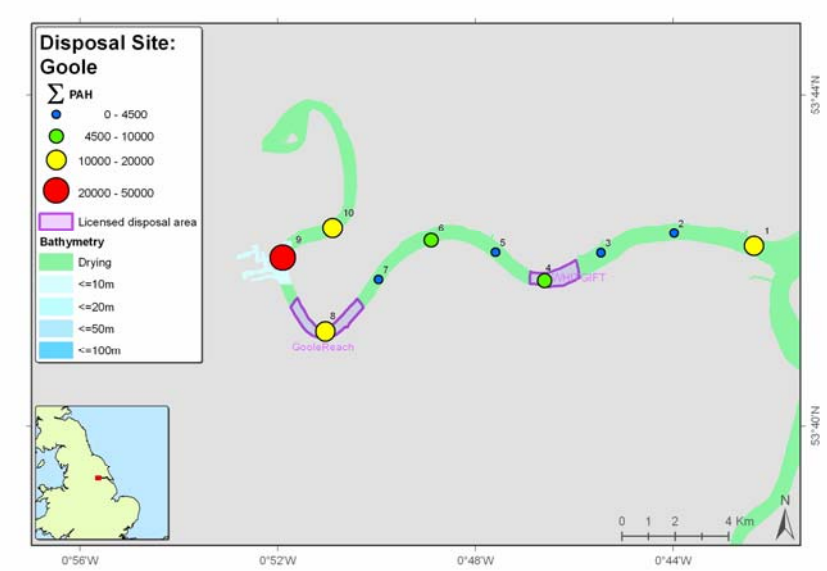


Figure 2.65. Summed PAH concentrations for the Goole stations, 2008.

2.5.4.3.3 Organohalogens

At Goole, concentrations of PCBs were generally around LODs except for at stations G1, G2 and G3 furthest upstream, and station G10 furthest downstream, where slightly higher PCB concentrations occurred (Figures 2.66 – 2.68). Only one of these stations (G3) was located within a disposal site. All stations had a significantly higher proportion of tetrachlorinated PCBs than at any of the other sites, largely caused by elevated CB47 concentrations (Figure 2.69). This profile is not consistent with any of the Aroclor mixtures, but has been reported for

sediments containing anaerobically degraded Aroclor 1260 (Johnson et al, 2006). Alternatively, it may be caused by interference on the CB47 peak giving artificially high values. OC concentrations were high compared with other sites, with stations G1, G2 and G5 having p,p-DDT levels in excess of 10 µg/kg. Highest concentrations were upstream of the disposal sites in the harbour area, and the source of these is not known. All stations were below FEPA warning levels and TECs for CBs, and had 'good' environmental status for all ICES7 CBs except for CB118 at stations G3 and G10, i.e. all stations had 'good' status overall. In contrast, all stations except for G9 were above FEPA warning limits and TECs for DDT. The source of this DDT requires investigation. No previous data was collected at this site to allow temporal comparisons.

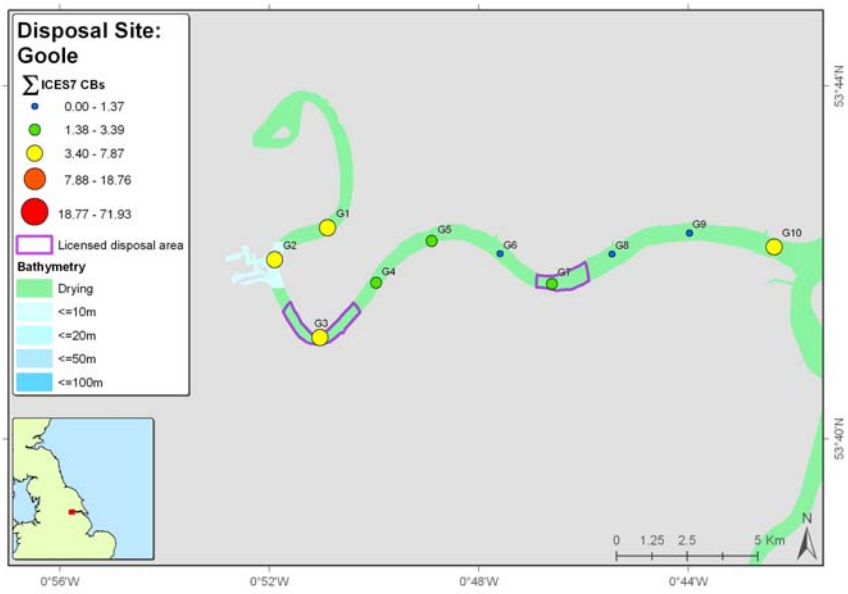


Figure 2.66. Summed ICES7 CBs for the Goole stations, 2008.

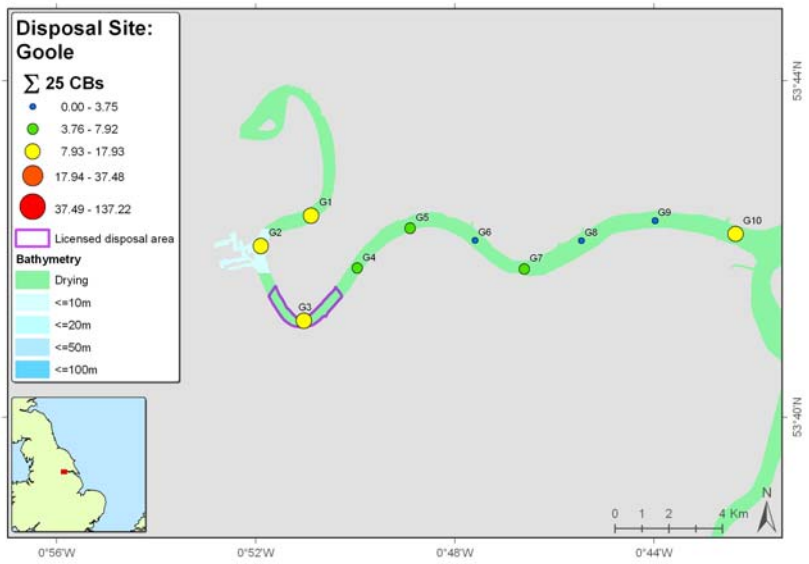


Figure 2.67. Summed 25 CB concentrations for the Goole stations, 2008.

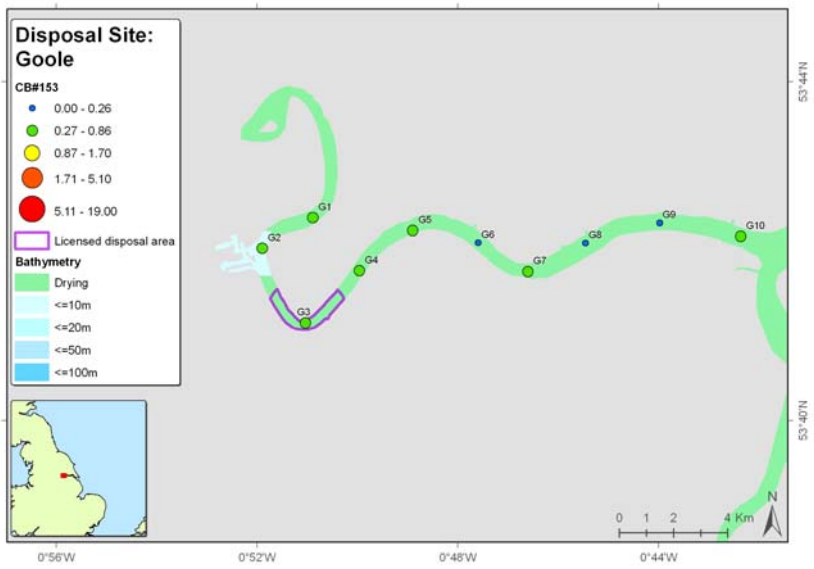


Figure 2.68. CB#153 concentrations for the Goole stations, 2008.

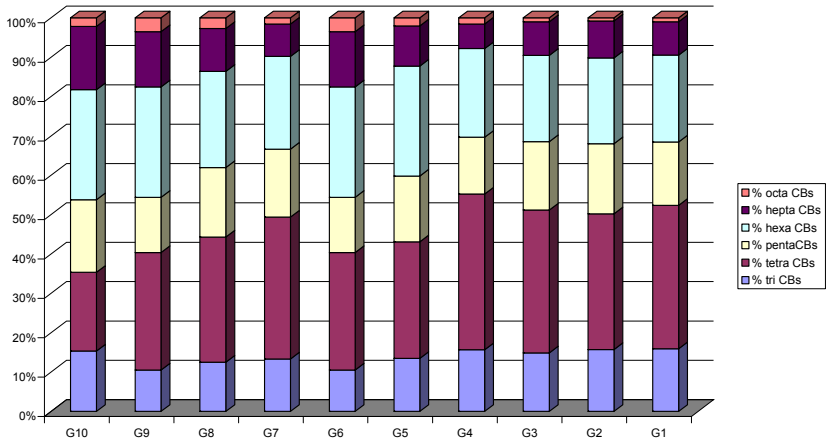


Figure 2.69. CB congener profiles for the Goole stations, 2008.

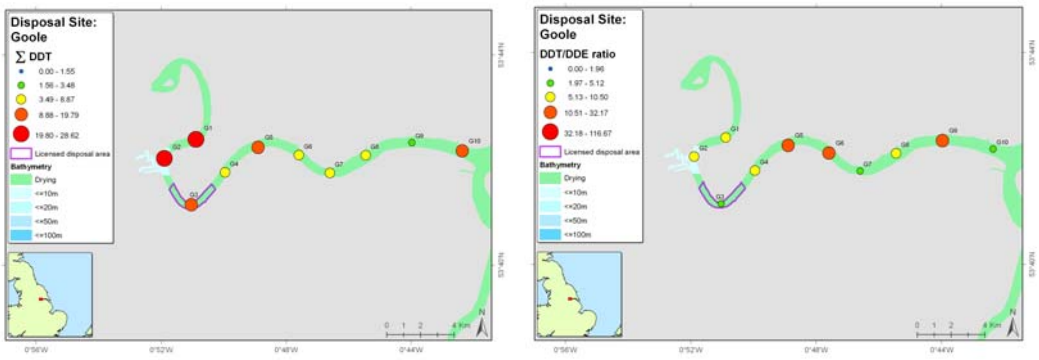


Figure 2.70. Summed DDT concentrations (left) and DDT / DDE ratios (right) for the Goole stations, 2008.

2.5.4.3.4 Trace metals

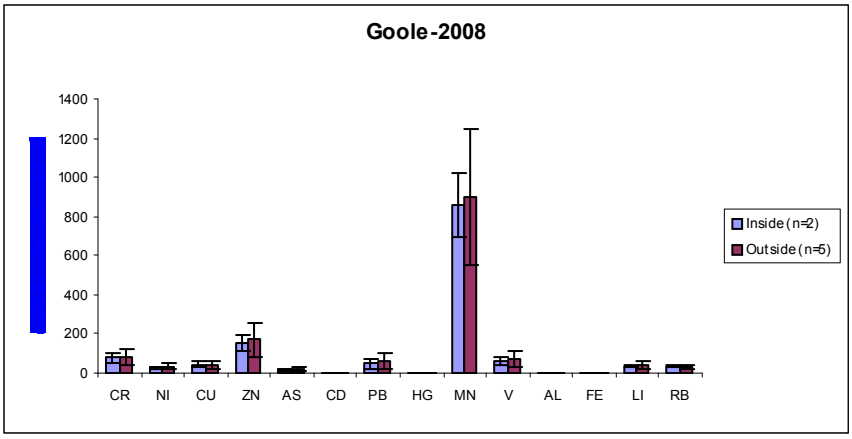


Figure 2.71. Average metal concentrations inside and outside the dredged material disposal sites at Goole for 2008. Note: the two stations were located in different disposal sites, HU040 and HU041.

Average metal concentrations of stations outside the two disposal sites are broadly comparables with those stations inside (Figure 2.71). Although there is some variability, both spatially and in the levels for different metals, metals concentrations are consistently enriched above OSPAR BACs (i.e., > 1, Figure 2.72). The station with lower enrichments relative to the other stations is G1, the most upstream sampling point during 2008, while those generally showing the highest enrichment levels across the metals were G5 and G3, the latter being located within HU041.

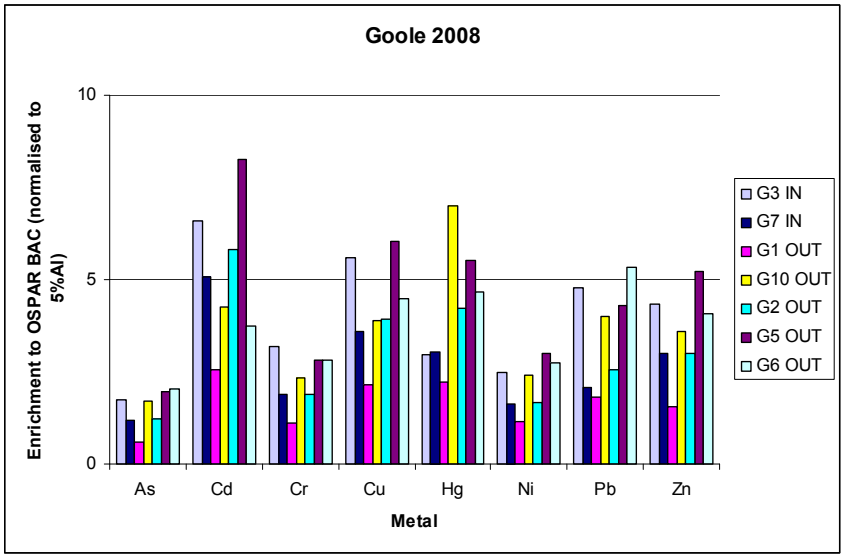


Figure 2.72. Enrichment to OSPAR BACs for metal concentrations measured at Goole in 2008. G4, G8 and G9 were not analysed for metals due to insufficient fine fractions.

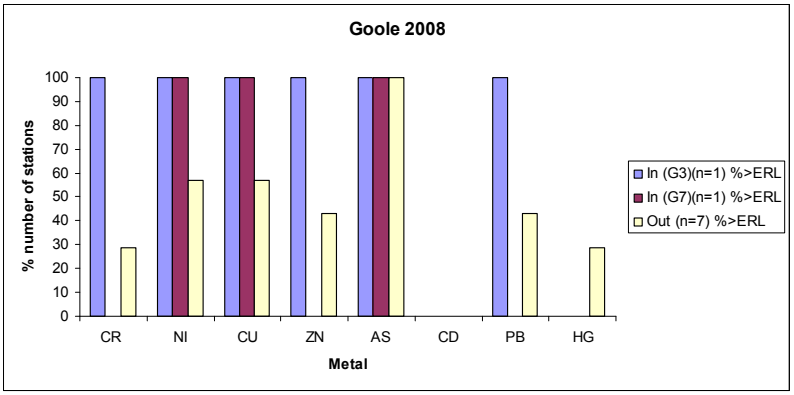


Figure 2.73. Average percentage number of stations inside and outside disposal sites at Goole with concentrations >ERL for 2008.

Within the disposal sites, average metal concentrations >ERLs for Ni, and Cu are observed for both disposal sites and also with Cr and Pb for disposal site 'G3' (Figure 2.73). Arsenic (As) concentrations measured outside and within the site are all >ERL. Cd concentrations within and outside the disposal sites are <ERLs. Hg concentrations are >ERLs outside the disposal sites, with no concentrations >ERLs present within the disposal sites. Lower numbers of stations >ERL outside of the disposal sites are observed for Cr, Cu, Ni, Pb and Zn.

In summary, metal concentrations measured at Goole are mostly above OSPAR BACs. This is not unexpected as this area has enriched concentrations related to historic industrial activity in this area. Additionally, metal concentrations measured at Goole are mostly above ERL. Care should be taken when assessing the implications of these results, as metal concentrations were measured on the <63µm fraction using a total digest and so are in a more concentrated form than would be available for uptake within the whole sediment here.

2.5.5 Conclusions

During 2008 was the first sampling undertaken under the auspices of SLAB5 at Goole. This survey therefore aimed at providing an initial assessment as to the levels of contaminants within the receiving environment at this site, although due to its location along the upper reaches of the Humber, determining exact sources of any contaminants is likely to be very difficult. Organohalogens were generally low (except for DDT) while metals and PAHs were generally elevated. The concentrations observed will be used as part of the licensing process within Cefas.

2.6 Hurst Fort (WI080)

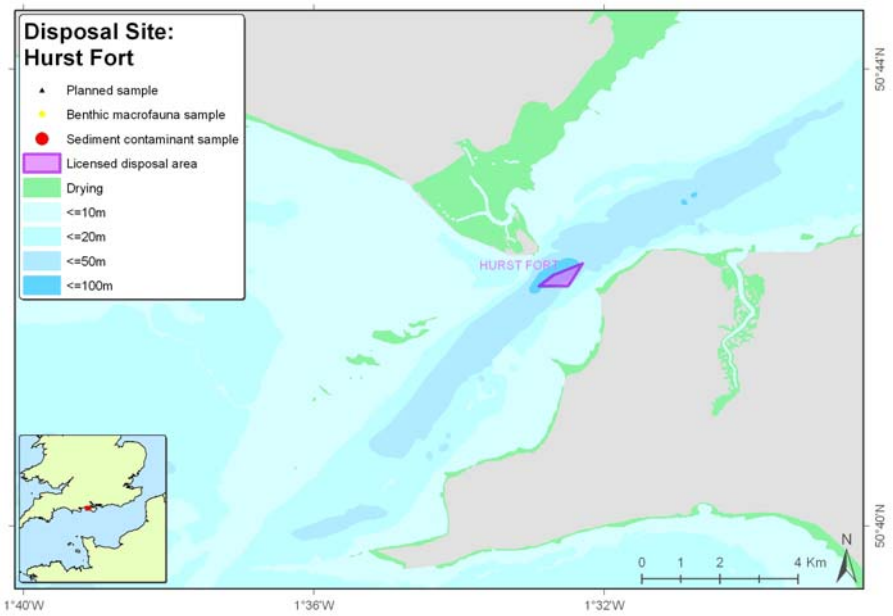


Figure 2.74. Location of the Hurst Fort dredged material disposal site.

2.6.1 Background

The Hurst Fort disposal site is located at the western entrance to the Solent, a narrow corridor of high navigational importance. Tidal velocities are high around this site and the bed here is composed of rock and gravel. The local tidal regime is highly complex and current licensing conditions require that material is disposed only on the ebb tide.

This disposal site has been used since 1952 for the disposal of sewage sludge and dredged material. Currently, it is used solely for the disposal of maintenance dredged material from the smaller ports and harbours; material from the larger ports which are capable of employing larger dredgers is disposed of at the more offshore disposal site at Nab Tower.

There have been many concerns raised regarding the impacts associated with the disposal activities at Hurst Fort. These concerns initially focussed on the physical impacts on local oyster beds and shellfish pots, deposition of finer material onto sandy beaches and the increased presence of small dredgers within the narrow navigation channel. The site has remained open, however, primarily due to the safety concerns associated with such small dredgers having to dispose at the more offshore Nab Tower.

More recently, the intertidal habitats within this location have become highly designated and without sufficient knowledge of the behaviour of the dredged material following disposal, we are not able to unequicocally conclude that the disposal activity here does not impact the integrity of the designated features. To exacerbate this, applications have been made to

increase the tonnage being disposed here. A recent desk-based review of SACs and disposal sites undertaken for the area did not find any evidence that the disposal operation was impacting the SACs. However, this was based on a somewhat very limited understanding of the behaviour and fate of the deposited material.

The aim of 2008 study at this site is to review and improve upon our predictive capability of the fate of the fine material placed at Hurst Fort disposal site and, if necessary, provide a basis for further modelling and/or sampling during 2009.

2.6.2 Impact hypotheses

- The majority of the disposed material is predicted to settle away from the intertidal SACs.

2.6.3 Methods

Indirect impacts from disposal of dredge spoil can occur as fine material is carried during the disposal process or by subsequent resuspension of settled bed material at the disposal site. In order to investigate potential areas of impact associated with the Hurst Fort disposal site a Lagrangian particle-tracking model was applied. The model (EUROSPILL) was originally designed for simulating oil spills (Elliott 1991) but has been modified subsequently to deal with more general transport problems (Defra 2001; Perianez and Elliott, 2002) including sediment plumes.

An assessment of the region of initial impact was made assuming particles did not settle at the disposal site but were immediately dispersed with the tidal flow. Given the very strong tides flows in the region this is likely to be the case if the material contains fine unconsolidated sediments. For this study relatively fine, slowly settling particles (fall velocity of 1.5 mm s^{-1}, nominal 40 micron particle diameter) were simulated. Particles were released at the Hurst Fort site location and tracked in the model for 48 hours. Particles were subject to movement by tidal currents, vertical settling and diffusion and were assumed to behave non-cohesively. Settled particles were allowed to resuspend when tidal bed stress exceeded an empirical threshold value. The resuspension rate was controlled to give a balance between particles remaining on the bed and moving back into suspension. The true proportion of particles that would be resuspended is not presently predictable due to uncertainties in modelling the interaction of particles with the bed substrate. However, the option of keeping some particles on the bed is useful when visually assessing impact as it shows locations where particles may have settled, even if only temporarily.

Two sets of runs were conducted. One simulated a continuous release over a 12.4-hour tidal cycle to give a representative distribution of particle movement starting from all possible tidal states. These calculations were undertaken for both spring and neap tides and used 4000 particles to represent the sediment cloud. Another set of simulations considered the impact if release took place only at specific tidal states. These were: 1) 1 hour either side of high water slack; 2) 1 hour either side of low water slack; 3) 1 hour either side of peak ebb; 4) 1 hour either side of peak flood. For these simulations 1000 particles were tracked.

2.6.4 Results

It must be appreciated that each of the plots presented in this section represent snapshots of a dynamic situation. The choice to plot results after 48 hours is somewhat arbitrary and different distributions will be seen at different times. Nevertheless, the plots give a good intuitive indication of where fine slowly settling particles may reach within a short period of release.

2.6.4.1 Continuous 12-hour release.

The distribution of particles after 48 hours arising from a 12.4 hours continuous release during a spring tide is shown in Figure 2.75. The tidal excursion in the Solent is large and fine sediments are predicted to travel the entire length of the Solent in a single tide with some reaching the area just outside Portsmouth harbour within a few tidal cycles. Currents in Christchurch bay to the west are lower and transport to the west covers less distance. The corresponding result at neap tides (Figure 2.76) is similar but shows a more restricted region of impact as would be expected.

2.6.4.2 Release at specific tidal states.

1. Single 2-hour release around high water slack (Figure 2.77) shows a predominance of particles to the west in Christchurch Bay after 48 hours.
2. Single 2-hour release around low water slack (Figure 2.78) shows a predominance of particles in the Solent after 48 hours.
3. Single 2-hour release around peak ebb currents (Figure 2.79) shows, after 48 hours, particles both to the west and east with a slight predominance to the west.
4. Single 2-hour release around peak flood currents (Figure 2.80) shows, after 48 hours, particles both to the west and east with a slight predominance in the Solent to the east.

The tidal residual movement in the region (Figure 2.81) can give some indication of the path material might follow over the longer term. However in this region the movement is likely to be highly influenced by the Lagrangian transport (because of the large tidal gradients at the entrance to the Solent) and also by the influence of wind driven currents.

It should be borne in mind that these results show only where particles may move. The concentrations associated with the plume may be undetectable against background levels at distances more than a few kilometres from the source. Measurable impacts might only arise due to long-term accumulation at specific locations or if particles are highly contaminated. Neither of these issues is addressed by this preliminary study.

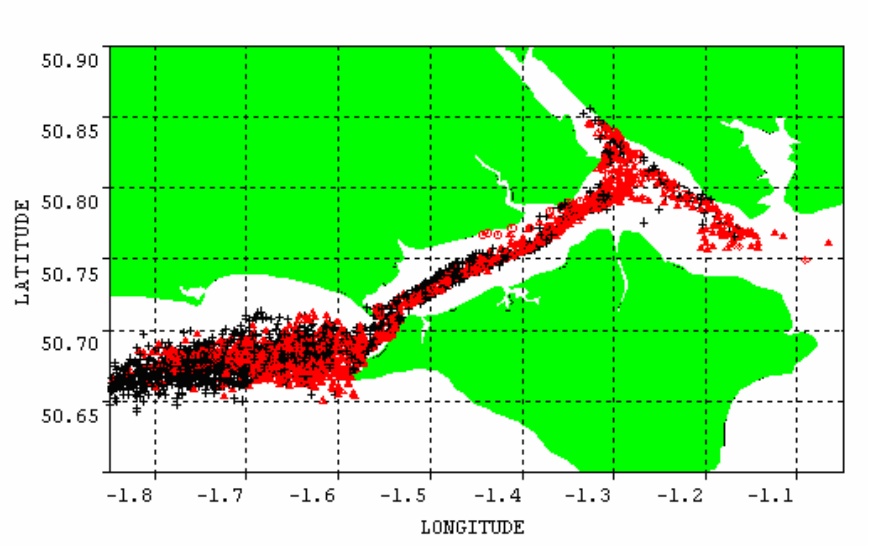


Figure 2.75. Spring tide distribution after 24 hours for twelve-hour release starting at HW slack. Black crosses indicate particles settled at the bed, red symbols indicate particles in suspension.

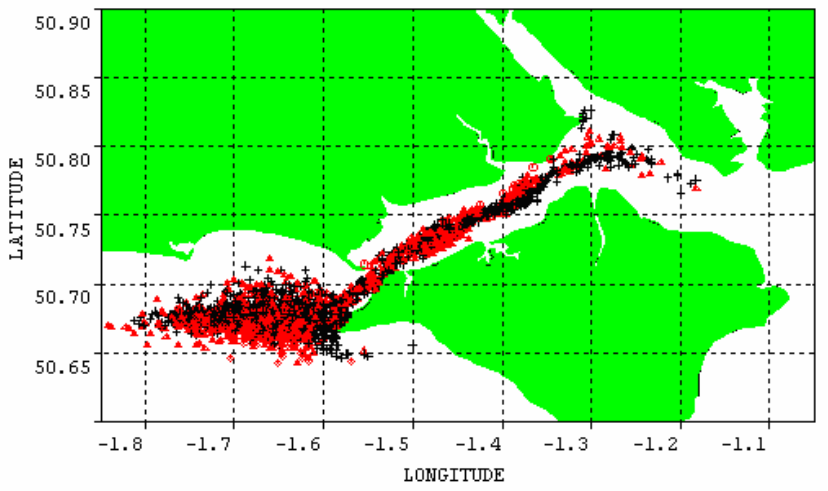


Figure 2.76. Neap tide distribution after 24 hours for twelve-hour release starting at HW slack. Black crosses indicate particles settled at the bed, red symbols indicate particles in suspension.

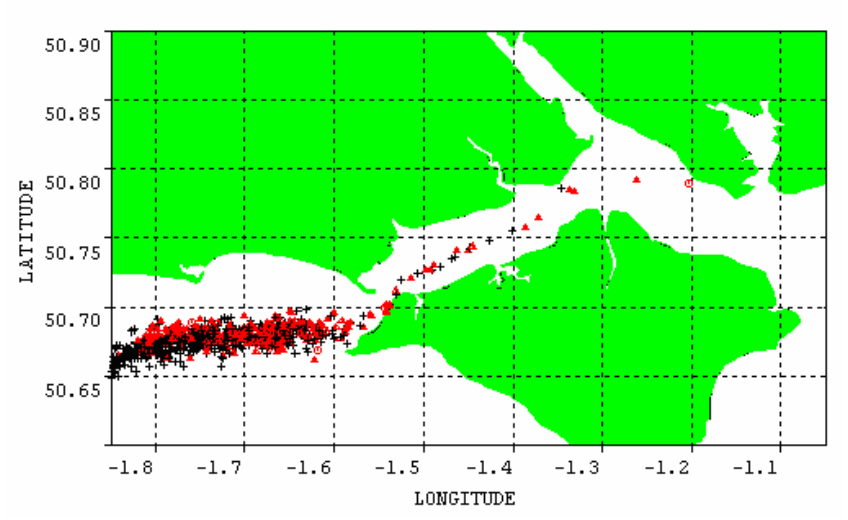


Figure 2.77. Distribution after 24 hours for three-hour release around HW slack. Spring tide. Black crosses indicate particles settled at the bed, red symbols indicate particles in suspension.

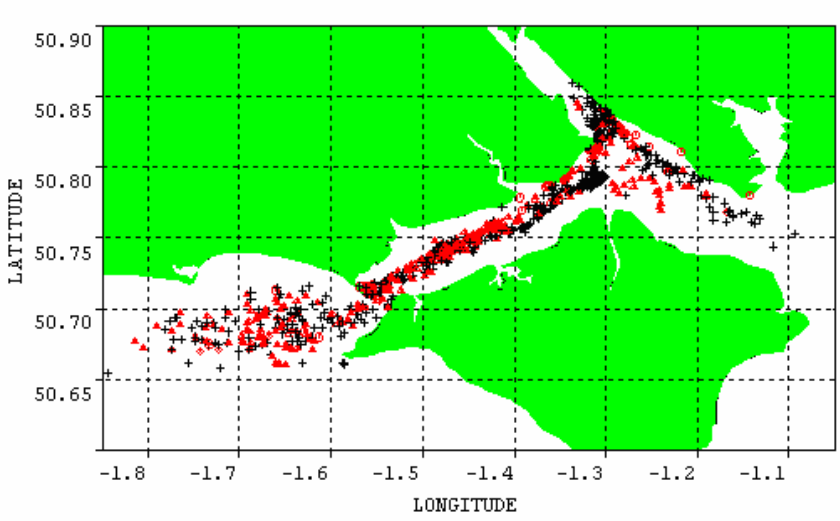


Figure 2.78. Distribution after 24 hours for three-hour release around LW slack. Spring tide. Black crosses indicate particles settled at the bed, red symbols indicate particles in suspension.

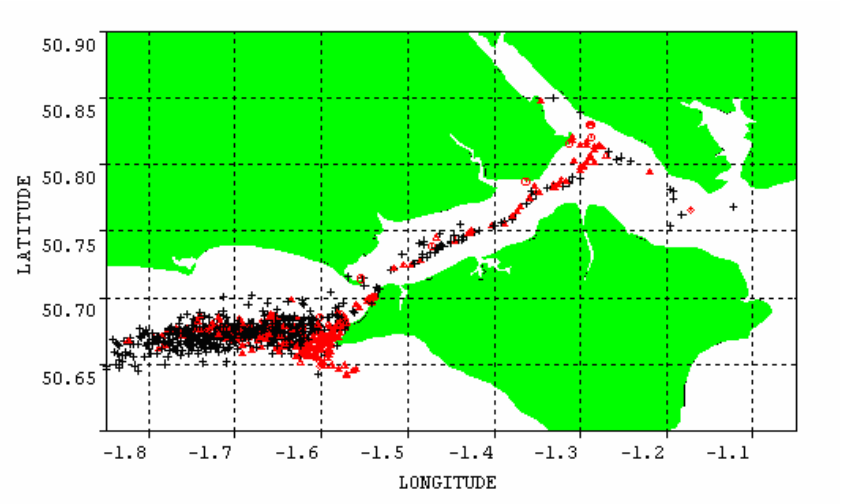


Figure 2.79. Distribution after 24 hours for three-hour release around peak flood. Spring tide. Black crosses indicate particles settled at the bed, red symbols indicate particles in suspension.

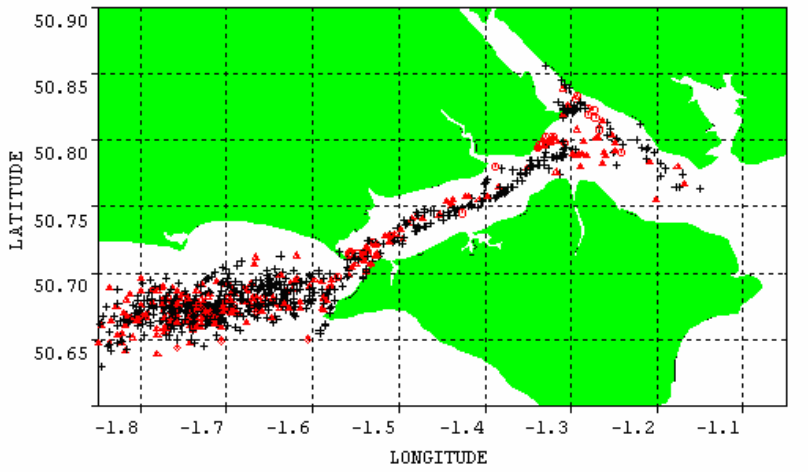


Figure 2.80. Distribution after 24 hours for three-hour release around peak ebb. Spring tide. Black crosses indicate particles settled at the bed, red symbols indicate particles in suspension.

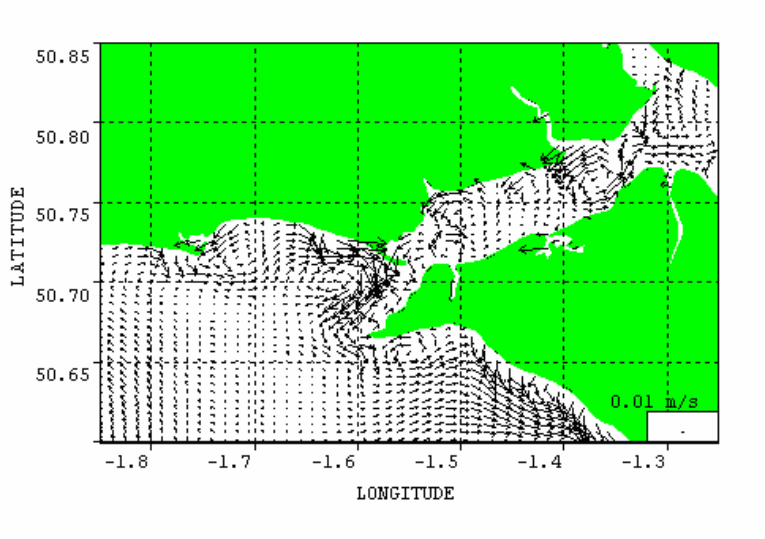


Figure 2.81. Residual flow for the region.

2.6.5 Conclusions

This desk-based study has allowed an initial assessment as to the likely fate of dredged material deposited at the Hurst Fort dredged material disposal site under a number of scenarios. The results will now be available to be used by the Cefas case officers to be used to aid the licensing process. Whether sampling will be required at this site in future will ultimately depend upon the outcomes of this process.

2.7 Rame Head (PL031)

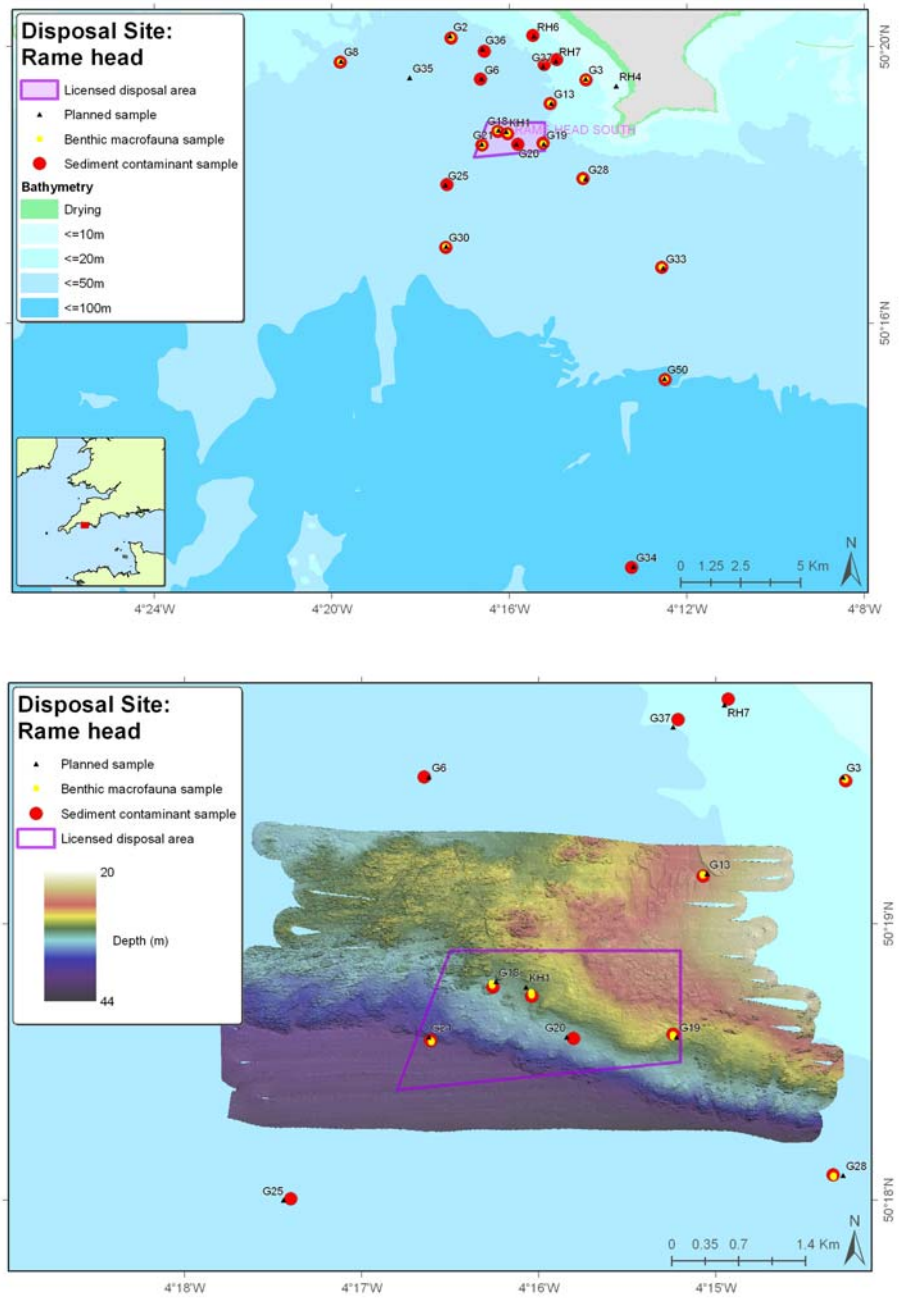


Figure 2.82. Locations of all monitoring stations for Rame Head, 2008 (top), and stations closer to the disposal site with the multibeam image from 2007 superimposed (bottom).

2.7.1 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 River Tamar and River Plym as well as from the Sound, with principle locations being Devonport Dockyard and associated Ministry of Defence (MoD) areas. The site thus receives materials 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 being a source of contamination of the nearby SAC 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 connected with the disposal activity.

2.7.2 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 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

- Any contemporary inputs of litter will be commensurate with the application of all reasonable means for their exclusion prior to disposal, and will have no far-field consequences for recreational/amenity interests.

2.7.3 Parameters monitored

Sediment particle size distribution

Sediment organic carbon and nitrogen

Macrofaunal communities

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

2.7.4 Results

2.7.4.1 Sediment particle size distribution

Station code	2006	2007	2008
G2	n	6	5
G3	2A	1	3
G6	5	5	5
G8	2A	2A	2A
G13	2C	1	2A
G16	2B	n	n
G18	6	n	6
G19	3	1	9
G20	n	6	6
G21	n	8	6
G25	5	5	5
G28	6	3	3
G30	n	7b	3
G33	2C	2C	2C
G34	3	3	3
G35	n	2C	n
G36	n	5	5
G37	6	5	3
G50	n	3	3
KH1	n	6	5
RH4	n	5	n
RH6	n	1	3
RH7	n	1	3

Table 2.11. Sediment groups for samples analysed from the Rame Head monitoring surveys between 2006 and 2008 (n – no sample). Key: 1 = slightly gravelly sand (unimodal, well sorted), 2a = gravelly sand/ gravel main component (mixed, poorly sorted), 2b = muddy sandy gravel (more muddy than 2a and coarser gravel), 2c = gravelly muddy sand (more muddy than 2b and coarser gravel, 3 = slightly gravelly sand (mixed, poorly sorted), 5 = slightly gravelly muddy sand (mixed, poorly sorted, more muddy than group 3), 6 = gravelly / slightly gravelly muddy sand (mixed, poorly sorted (most muddy group)), 7a = slightly gravelly, muddy sand / muddy gravelly sand (more gravelly than 7b), 7b = slightly gravelly sand (unimodal, well sorted), 8 = muddy sand /sandy gravel mixed sediment, and 9 = slightly gravelly sand, unimodal.

Every sediment group is represented by the samples taken at Rame Head, indicating a high degree of spatial and temporal variability in sediment types. In 2008, within the disposal site the sediments are gravelly / slightly gravelly muddy sand, mixed and poorly sorted (Group 6) except at G19, which is slightly gravelly sand, unimodal (Group 9). North-west, outside of the disposal site towards the coast, at G8 the sediment is gravelly sand (group 2A). Between G8 and the disposal site, at G35, G2, G36 and G6, sediments are slightly gravelly, muddy sands, mixed and poorly sorted (Group 5). Further inshore, north of the disposal site, at G37, RH6, RH7 and G3, the sediments are slightly gravelly sand, mixed and poorly sorted (Group 3). At G13, between the northern edge of the disposal site and the shore, the sediment is gravelly sand gravel, mixed and poorly sorted (Group 2A).

South of the disposal site, at G25 the sediment is slightly gravelly, muddy sand, mixed and poorly sorted (Group 5), while at G33, the sediment is gravelly muddy sand (Group 2C). All the other sites south of the disposal site, G50,G34, G30 and G28, are slightly gravelly sand, mixed and poorly sorted (Group 3).

The diversity of sediment types present shows the dynamic nature of this area. Within the disposal site there are some differences in sediment types between years, ranging from finer sediment types to coarser gravels. This is expected to be linked to dredge disposal activity at the site. Sediment types to the northwest of the site vary shown by the different sediment groups between years at the individual sites. The variability is site specific and there does not seem to be a general trend at all sites each year. The variability is less marked than within the disposal site. Sediment types to the south of the disposal site show less temporal variability.

2.7.4.2 Sediment organic carbon and nitrogen

In 2008, organic carbon is measured on all samples except G19, G3, RH7, RH6, G8, and G34 (these samples had insufficient <63 µm sediment fractions) for Rame Head. Organic carbon values range from 1.0 to 2.3 % m/m and for nitrogen 0.1 to 0.27 % m/m. The organic carbon content is similar to levels recorded in 2006 and 2007.

2.7.4.3 Macrofaunal communities

In total 367 different species were identified in the analysis, of these 35 % occurred in only one sample and 85 % were found in less than 10 samples. No single species occurred in every sample although some were common to many, for example, Nemertea were found in 32 out of the 36 samples, *Mediomastus fragilis* were found in 29 out of the 36 as were *Owenia fusiformis* and *Phoronis* spp. The most abundant species found was *Scalibregma inflatum* found a total of 526 times in 27 samples. Other highly abundant species were *Melinna palmata, Lumbrineris gracilis* and *Abra nitida*. These species were all common across the sampling area.

On average a single sample contained 49 (±SD 12) different species. The highest mean species number (S) by station was 68 species at station G33 (southeast of the disposal site), the lowest was 35 at station G3 (towards Polhawn Cove) (Figure 2.83). ANOVA between sites inside the disposal site, nearby and distant showed that there was no significant difference in the number of species found between these areas ($F_{2,33} = 2.80$, $P = 0.075$). The abundance of individuals at each station is shown in Figure 2.84. The graph shows that there is variation in the number of individuals between sites but that the variation does not appear to be linked to the distance from the disposal site. An ANOVA test between the sites within, nearby and distant from the disposal site shows that there was no significant variation ($F_{2,33} = 1.37$, $P = 0.267$) based on these factors. The biomass of the total biota found in each sample also varied greatly within and between sites (Figure 2.85). An ANOVA on the averaged biomass for stations within, nearby and distant from the disposal site showed that there was no significant variation ($F_{2,33} = 2.06$, $P = 0.143$). Other univarate measures of species diversity were also tested (e.g. Shannon diversity, Evenness) and showed no significant variation based on distance from the disposal site.

To analyse any potential affect of the disposal site on the abundance/biomass relationship abundance biomass curves for each sample were plotted (not shown) and the W statistic calculated. W ranges from -1 to +1 with -1 showing a sample were abundance is greater than biomass (i.e. dominated by many small bodied individuals) and 1 representing a sample where biomass is greater than abundance (i.e. a few large bodied individuals dominate the biomass). It is generally accepted that an undisturbed benthic community will have W values approaching 1. Figure 2.86 shows the average W value for each station. All values are >0 suggesting that there is no serious disturbance effect. Analysis of the variation in the W statistic between sites inside, nearby and distant from the disposal site shows that there is no signification variation based on these factors ($F_{2,33} = 2.13$, $P = 0.135$).

Multivariate analysis on the species abundance data was performed using PRIMER V6. Data were transformed with a global square root transform. Figure 2.87 shows a MDS plot of all the samples labelled as either inside the disposal site nearby or distant. An ANOSIM test on the station replicates showed that there is significant similarity between the samples from the same station ($R = 0.835$, $P = 0.1$ %). Another ANOSIM test between samples inside, nearby and distant from the disposal site showed no significant variation ($R = 0.171$, $P = 0.7$ %) based on the distance from the disposal site. This suggests that sites within or nearby the disposal area show no difference in their communities compared to sites further away.

A SIMPROF analysis in PRIMER produced 13 distinct clusters from the data. These clusters are not correlated with distance from the disposal site. It is possible that the variation in the

communities at Rame Head is driven by variation in the sediment characteristics or other abiotic factors not currently tested.

In conclusion, species diversity at Rame Head is typically high with on average 49 species and 229 individuals being found in each 10cm^2 sample. The species composition and diversity did vary between the sites (results of ANOVA and SIMPROF) but variation was not linked to distance from the disposal site.

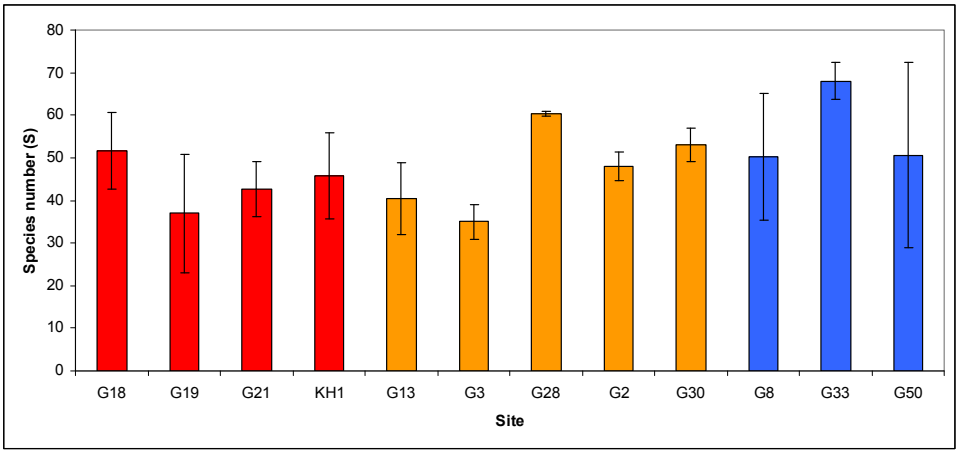


Figure 2.83. Mean number of species found per station. Stations are organised in distance from disposal site. Red= inside disposal site, orange= nearby disposal site and blue= distant from disposal site.

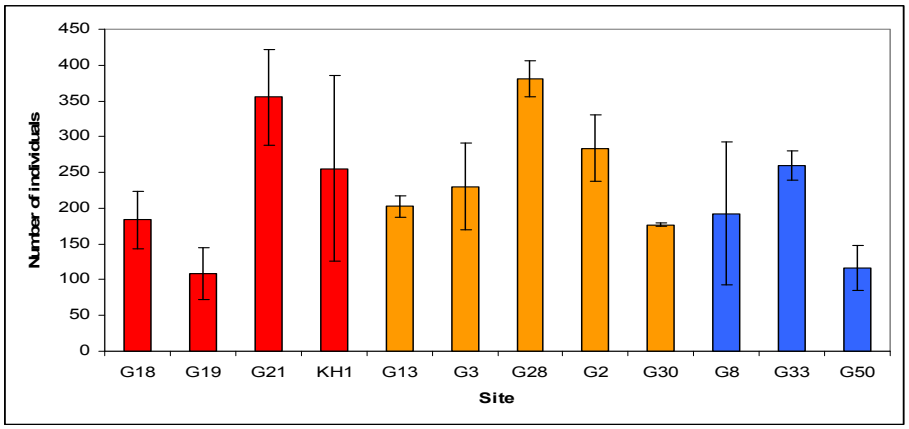


Figure 2.84. Mean number of individuals found per station. Stations are organised in distance from disposal site. Red= inside disposal site, orange= nearby disposal site and blue= distant from disposal site.

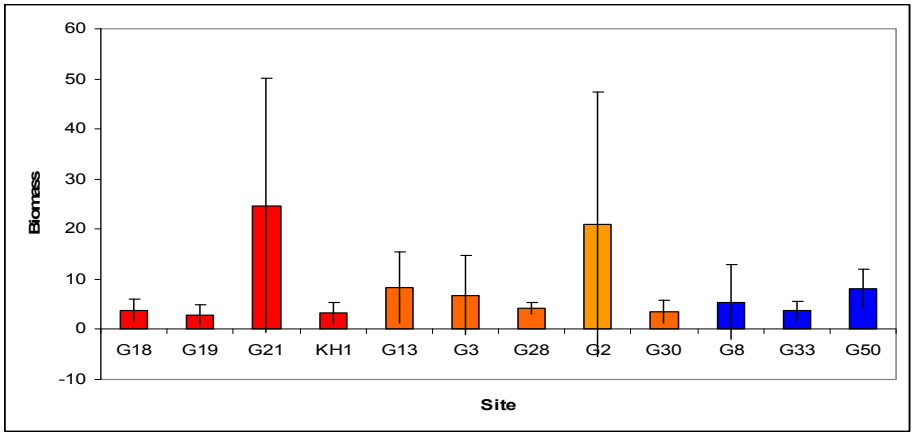


Figure 2.85. Mean total biomass per station. Stations are organised in distance from disposal site. Red= inside disposal site, orange= nearby disposal site and blue= distant from disposal site.

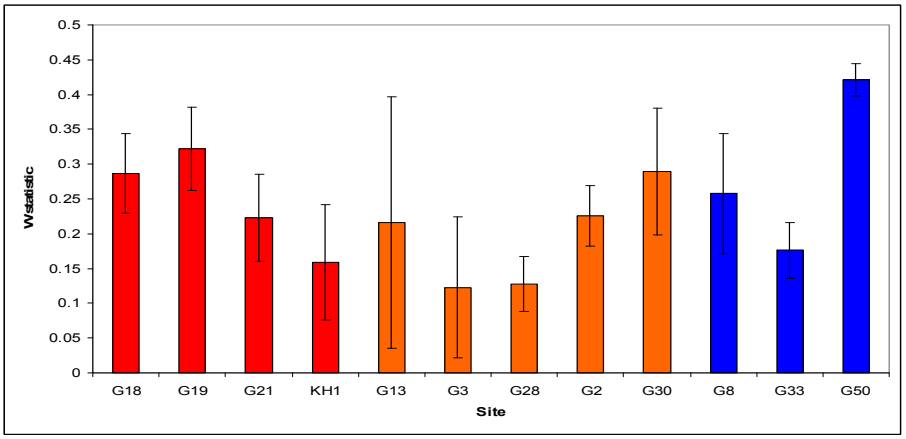


Figure 2.86. Mean W statistic from abundance biomass analysis for each station. Stations are organised in distance from disposal site. Red= inside disposal site, orange= nearby disposal site and blue= distant from disposal site.

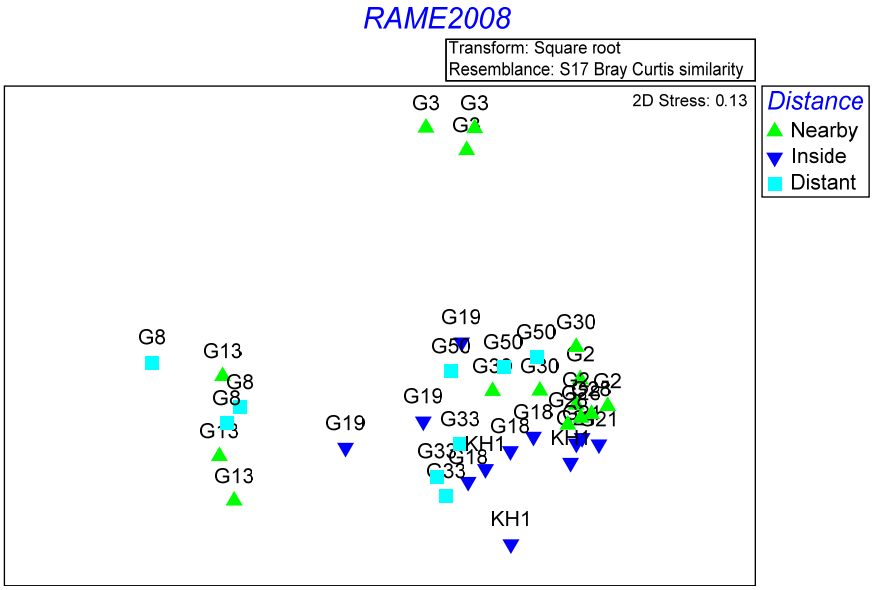


Figure 2.87. MDS plot of samples (labels) and distance from disposal site (symbols). ANOSIM results show that samples from the same site are similar (R=0.835 P=0.1%) but that the variation is not a factor of distance (R=0.171 P=0.7%).

2.7.4.4 Contaminants

2.7.4.4.1 TBT

A detectable level of TBT was recorded at stations G20 and G21 (0.010 and 0.016 mg/kg), both within the disposal site. Although this is a slight increase in concentration from the previous years, the levels of TBT are relatively well below AL1.

2.7.4.4.2 PAHs

The highest concentration of summed PAHs of 5,260 µg kg^{-1} at Rame Head was found at G28 to the SE of the disposal site (Figure 2.88). The second highest concentration was found at G6 with a summed PAH concentration of 4,830 µg kg^{-1} to the NW of the disposal site followed by G18, G20 and G21 within the disposal ground with summed PAH concentrations of approx 15,000 µg kg^{-1} at each site. In 2007, the highest concentration observed in the disposal site was much higher, 14,600 µg kg^{-1} which may be explained by the increased maintenance dredging disposal observed in 2007 compared to 2008. The high concentrations observed at G6 and G28 are in line with the axis of tidal directional flow in this area, to the NW and SE of the disposal site, and may represent transport of disposed material. There has been some concern in this area relating to possible transport of pollutants from this disposal site inshore to areas such as Polhawn Cove. It is possible to see that the lowest concentrations are found in this area at G3, RH7 and RH6 with summed PAH concentrations below 300µg kg^{-1} which are directly comparable with the low concentrations found in deeper offshore waters at sites G34 and G50, and so there is no evidence for landward transport of material from this site. At other stations outside the disposal site intermediate concentrations are observed.

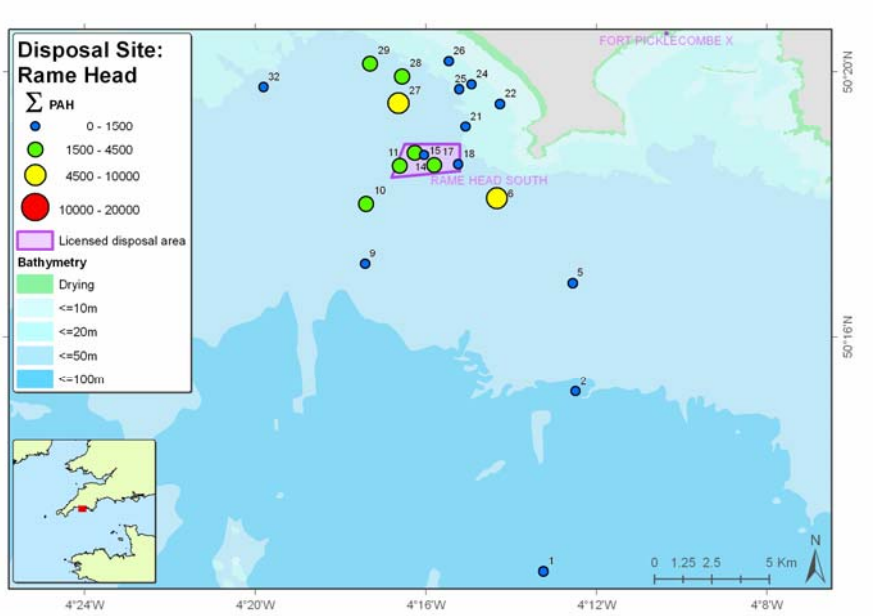


Figure 2.88. Summed PAH concentrations for the Rame Head stations, 2008.

2.7.4.4.3 Organohalogens

At Rame Head, concentrations of organohalogen contaminants were generally lower north and west of the disposal site (Figures 2.89 – 2.91). Higher concentrations were observed at the stations within the disposal site, but the highest concentrations of CBs were found at station G28, south east of the disposal site, with values of 72 µg/kg for ∑ICES7 CBs and 137 µg/kg for ∑CBs. This is down current from the disposal site and may represent drifted, more contaminated, sediments that were disposed at the site historically. Stations G18 and G28 had a slightly higher proportion of penta- and hexachlorinated CBs than the other stations, whilst G19 had much higher proportions of heptachlorinated CBs (Figure 2.92). OC levels were generally low, below or close to LOD except for stations G25 and G33, which had levels of p,p-DDT in excess of 1 µg/kg. Stations G25 and G28 had high DDT / DDE ratios, possibly suggesting a more recent DDT source (Figure 2.93).

In comparison with the FEPA action limits, stations G28, G18 and G19 were above warning limits but below action limits for both ∑ICES7 CBs and ∑CBs, as were G33 and G25 for DDT. Station G28 was also above the TEC for ∑CBs. According to the OSPAR guidelines, all stations except G50 and KH1 had 'bad' environmental status for CB118. Stations G33, G28, G18, G13, G36 and G32 also had 'bad' environmental status for CB101 and CB153, whilst G20 and G19 had 'bad' environmental status for CB 153 and G6 had 'bad' environmental status for CB28. Consequently, stations G28, G33, G18, G19, G20, G13, G6, G36 and G2 can all be considered to have 'bad' environmental status.

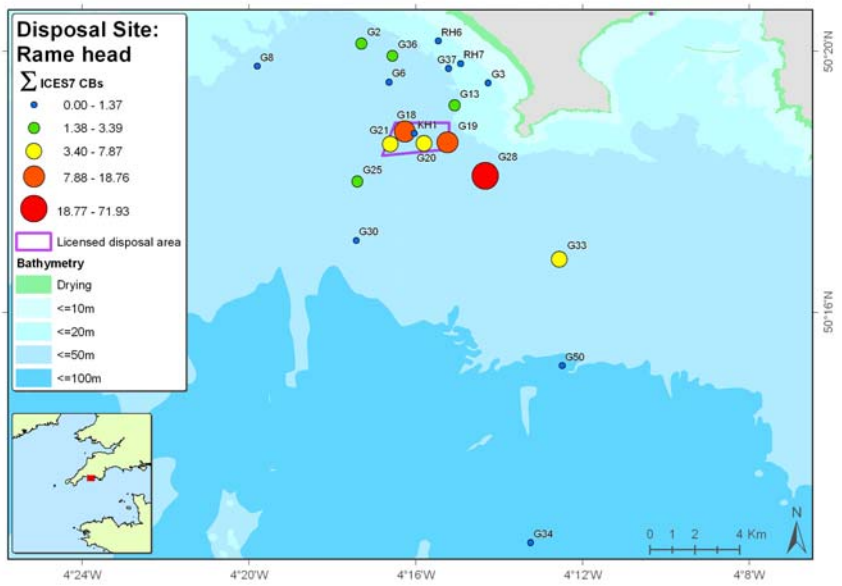


Figure 2.89. Summed ICES7 CB concentrations at Rame Head stations, 2008.

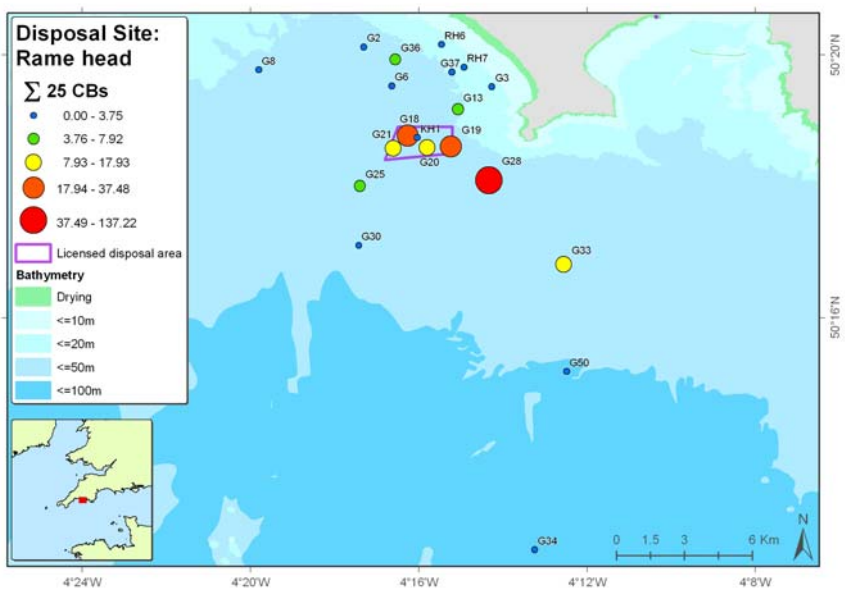


Figure 2.90. Summed 25 CB concentrations at Rame Head stations, 2008.

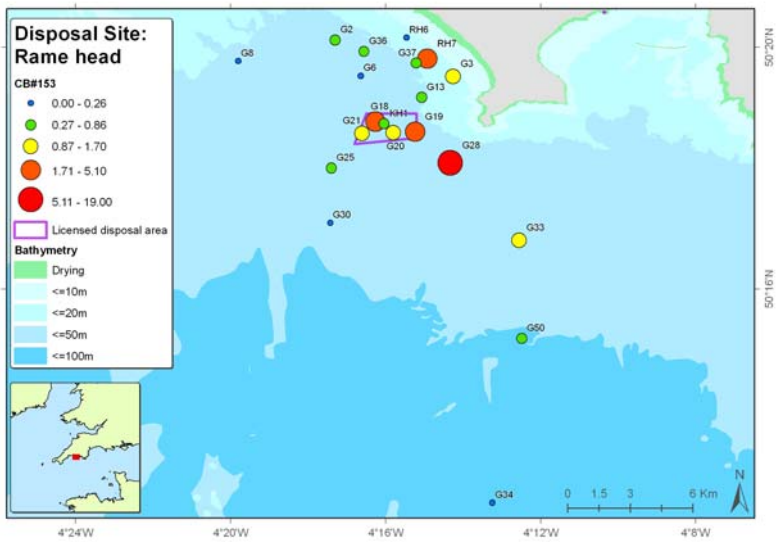


Figure 2.91. Summed CB#153 concentrations at Rame Head stations, 2008.

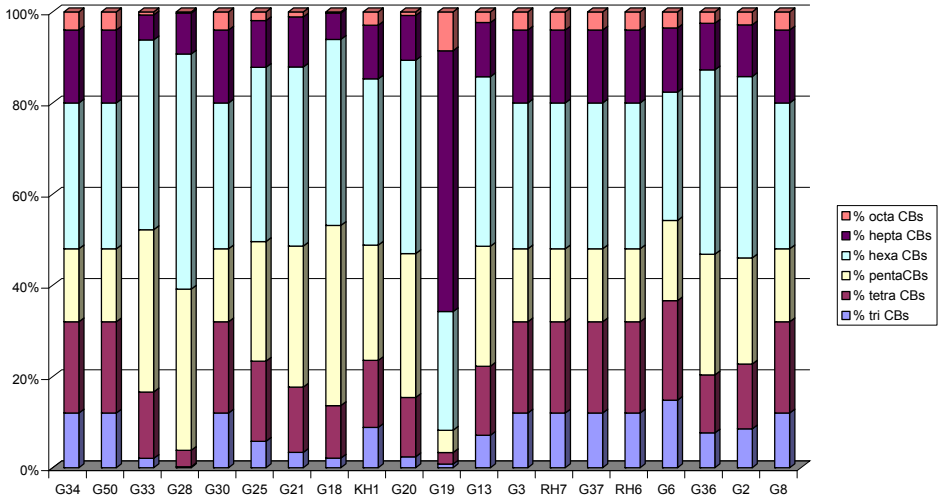


Figure 2.92. CB congener profiles for the Rame Head stations, 2008.

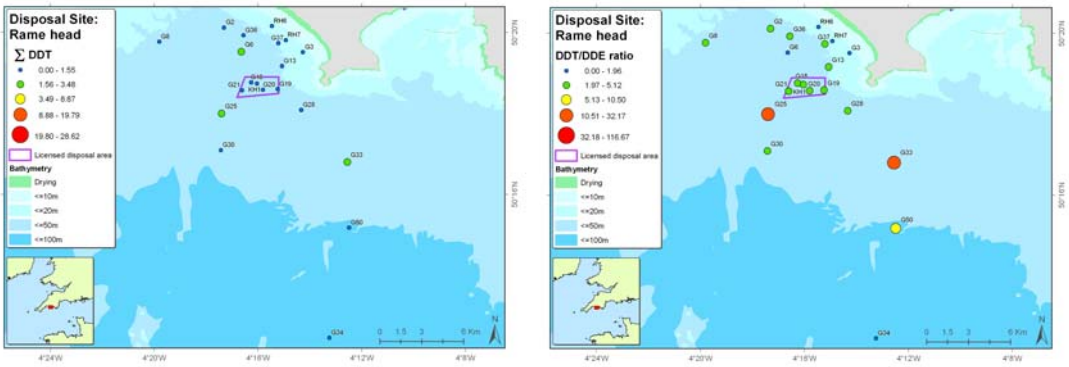


Figure 2.93. DDT concentrations (left) and DDT / DDE ratios (right) for the Rame Head stations, 2008.

Station	∑ICES 7 CBs concentration (in µg/kg)						
	2002	2003	2004	2005	2006	2007	2008
G34		0.7		0.7	0.7	2.1	0.7
G50							0.7
G33	0.7	14.2	7.67	2.37	4.08	4.26	7.87
G28	64.6	57.9	4.78	8.55	10.2	9.86	71.9
G30						3.69	0.7
G25	23.9	19.7			2.07		2.6
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
G3	0.7	0.7			0.7	0.95	0.7
RH7		0.7		0.7		0.7	0.7
G37		0.7			1.33	0.89	0.7
RH6		0.7		0.7		0.7	0.7
G6					2.75	3.85	0.82
G36		0.7				1.8	1.82
G2	0.7	5.1				1.19	1.58
G8	5.2	7.4	0.86	0.7	0.7	0.7	0.7

Table 2.12. Temporal trends (2002-2008) of ∑ICES 7 CB concentrations (µg/kg) at Rame Head in the stations sampled during 2008.

Data was available for Rame Head for all years from 2002 and 2008 (Table 2.12). Concentrations of CBs were much lower at stations G20 and G18 in 2008 than in 2002-04, but showed a big increase from 2007 to 2008. A steady decline was observed at stations G21 and G25 over the period 2002 - 2008. Concentrations were also lower at stations G30 and G6 in 2008 than in 2007. The high values recorded at stations G13 and KH1 in 2007 were markedly lower in 2008. Concentrations were higher at stations G33 and G20 in 2008 than in 2007.

2.7.4.4.4 Trace metals

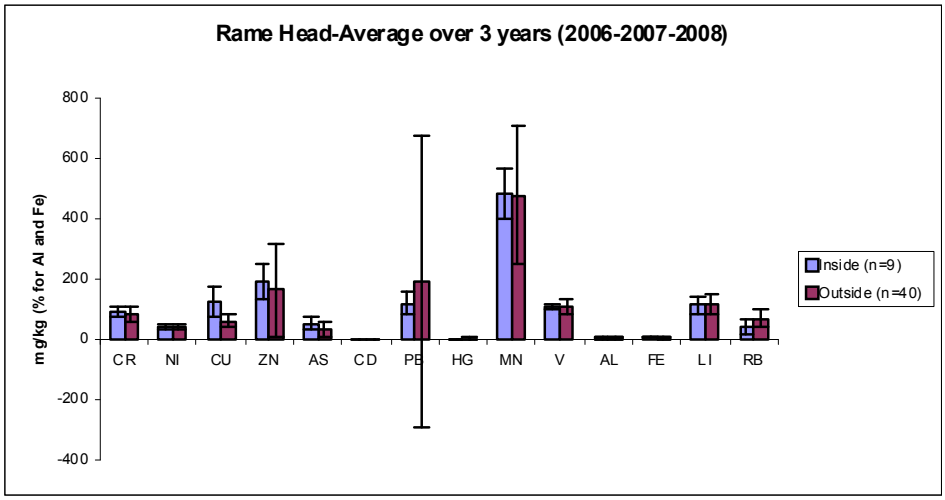


Figure 2.94. Average metal concentrations outside and inside Rame Head disposal site between 2006, 2007 and 2008.

The metals concentrations for stations inside and outside the Rame Head disposal site were, on average between 2006-08, very similar (Figure 2.94). During this time period, metals concentrations both within and outside the site have remained fairly constant from year to year (Figure 2.95).

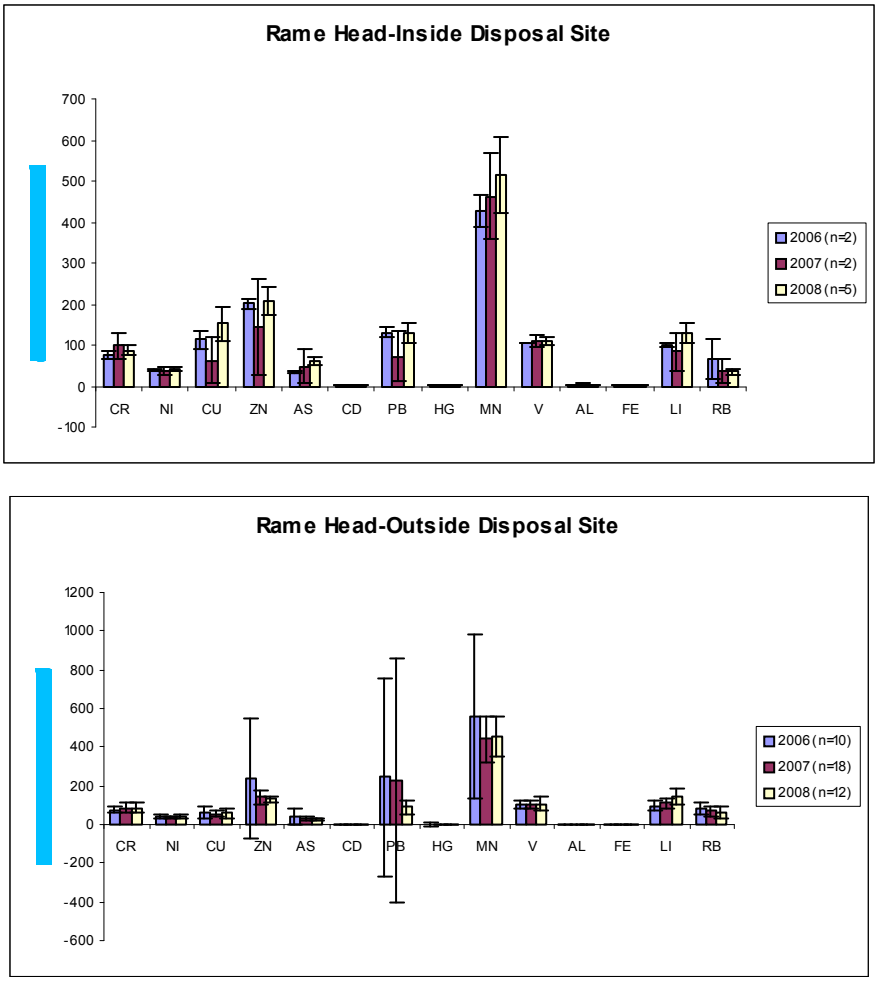
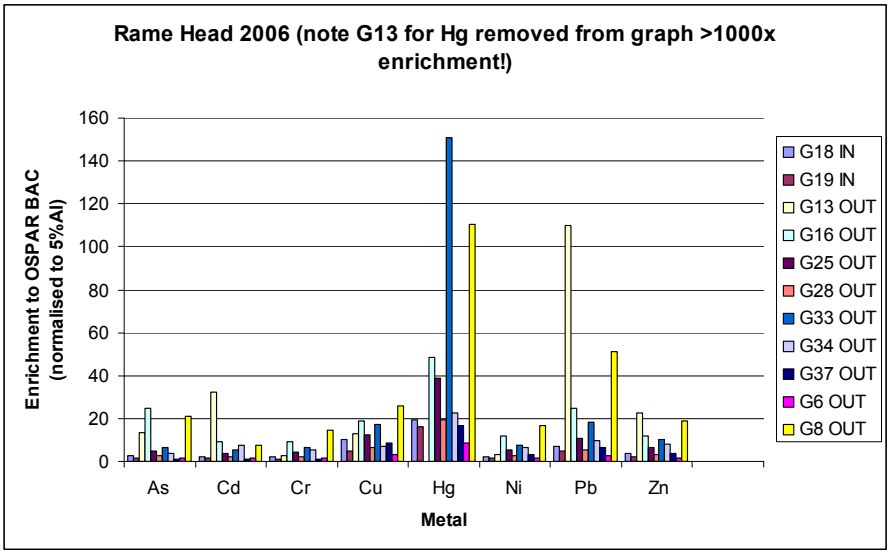
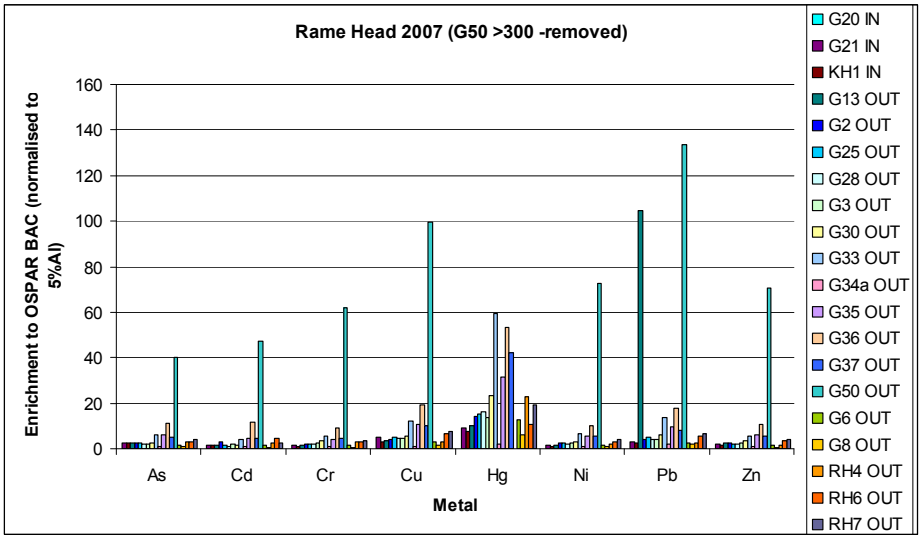


Figure 2.95. Average metal concentrations measured within (top) and outside (bottom) the Rame Head disposal site in 2006, 2007 and 2008.





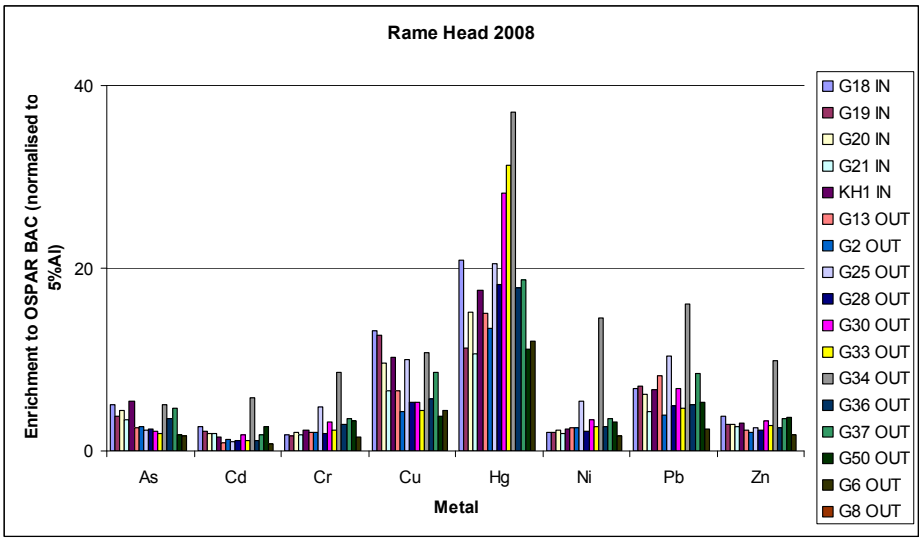


Figure 2.96. Enrichment to OSPAR BACs for metal concentrations measured at Rame Head in 2006 (top), 2007 (middle) and 2008 (bottom).

Enrichment to OSPAR BACs at Rame Head is shown for stations inside and outside of the disposal site in Figure 2.96. Care should be taken with these values as further work is being completed to ensure regional accuracy for the normalisation procedure used to produce BACs. Generally, there are high levels of enrichment to the OSPAR BACS for metal concentrations and enrichment for all metals is generally greater outside the site than inside the site. Enrichment observed for some stations (e.g., G28 and G34 in 2008, G50 in 2007) is surprising since these stations serve as offshore reference sites. Enrichment at these and perhaps all the stations at Rame Head may indeed be an artefact associated with the normalisation procedure used and therefore care should be taken when interpreting this data. Further work to better resolve normalisation at this site will be completed this year under a separate project. In addition, further sampling stations are planned at Rame Head during 2009 to determine a possible sink for the disposal site material after it is dispersed from the disposal site.

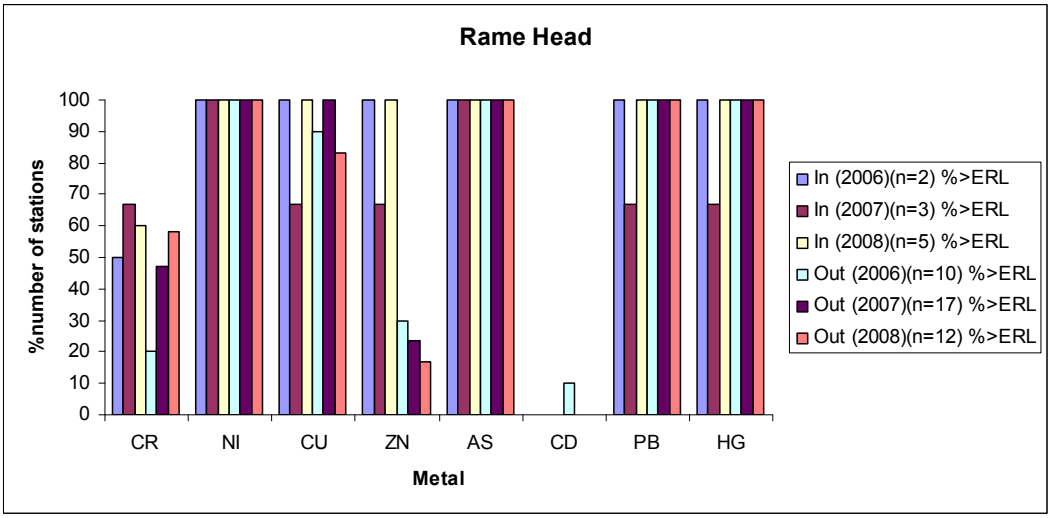


Figure 2.97. Average percentage number of stations inside and outside Rame Head disposal site with concentrations >ERL for 2006, 2007 and 2008.

The percentage of stations with metals concentrations above ERLs, both within and outside the disposal site (Figure 2.97) supports the conclusions reached regarding enrichment to BACs. There is no clear pattern between concentrations inside and outside of the site and it is not easy to determine a clear pattern of elevations, so therefore the elevations 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, which are expected to be mainly related to the natural environment in this area, as well as resultant from historic mining activity.

In summary, metal concentrations measured at Rame Head are mostly above OSPAR BACs. Care should be taken in this area with regard to derivation of BACs and such a finding is

perhaps not unexpected given the historic industrial activity in this area. Additionally, metal concentrations measured at Rame Head are mostly above ERL. Care should be taken when assessing the implications of these results, as metal concentrations were measured on the <63µm fraction using a total digest and so are in a more concentrated form than would be available for uptake within the whole sediment here. Further work linking sediment source sediment types with sediment types found from the monitoring survey is planned in 2009, and metal concentrations will be used to further validate this work.

2.7.5 Conclusions

Sampling at Rame Head has been undertaken annually since 2001 under SLAB5 and consequently, we have a relatively good time series dataset for both biological and chemical parameters. Macrofaunal variability is high at this site and predominantly reflects the variation in sediment granulomtric distributions and bathymetry. Species diversity over this area is high and variations reflect sediment differences rather than proximity to the disposal site. TBT is detectable, although in low levels and the PAH concentrations observed are low relative to those observed around other disposal sites around the UK. The low levels observed in the more inshore stations are of particular interest. While the metals concentrations are elevated, the highest levels are observed in those further away from the disposal activity and may, in fact, result from a lack of appropriate data available for the normalisation procedure. Further work is currently being undertaken to resolve this issue. The results from the 2008 survey indicate that further sampling at Rame Head should be conducted, particularly to assess contaminant levels and distributions.

2.8 Falmouth Bay (PL075)

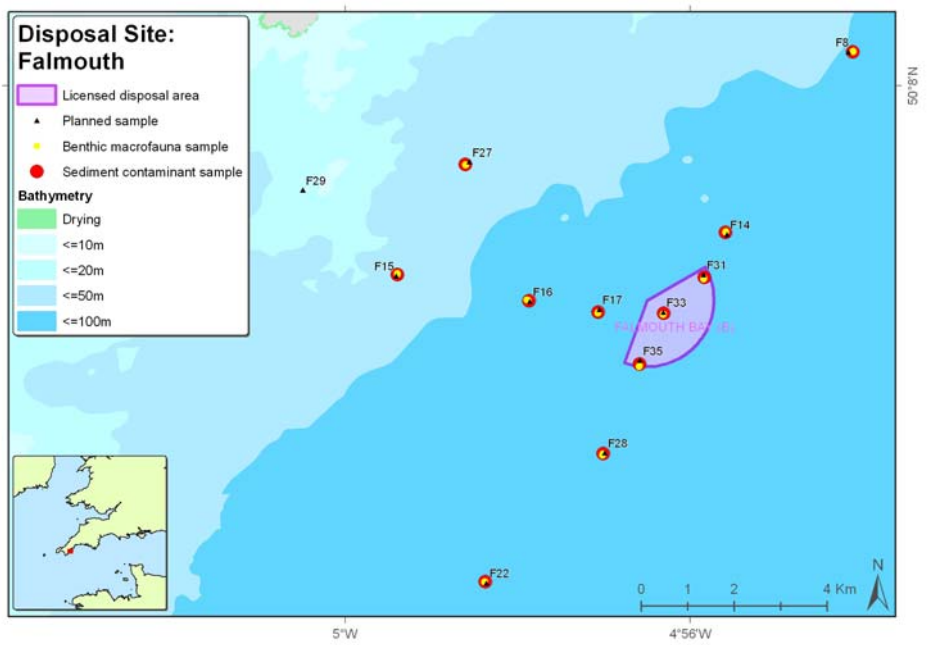


Figure 2.98. Location of monitoring stations at Falmouth Bay, 2008.

2.8.1 Background

Since 2000, 98,531 tonnes of dredged material has been disposed of to Falmouth Bay, three-quarters of this comprising capital dredge material. The material has been fairly mixed, consisting of boulders, cobbles, pebbles, sand and silt/clay.

Falmouth Harbour Commissioners (FHC) and Falmouth Docks and Engineering Company Limited (FDEC) are currently proposing to improve the cruise terminal facilities and navigation at Falmouth. As part of this development, 140,000 tonnes (100,000m^3) of capital material will be dredged with the aim of disposing it to Falmouth Bay. Furthermore, 560,000 tonnes (400,000m^3) of maerl will be dredged which, if not deemed appropriate for placing onto existing maerl beds, may have to be disposed of to the disposal site.

Consequently, it is possible that Falmouth Bay may be expected to receive, over the next few years, quantities far in excess of the total for the last 10 years. Additionally, as Falmouth Bay is being considered as an experimental Marine Protected Area for scallops there is an increased need to improve our understanding of the current conditions of this site and assess the possible impacts of such a large future deposit.

2.8.2 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 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

2.8.3 Parameters monitored

Sidescan and multibeam acoustics
Sediment particle size distribution
Sediment organic carbon and nitrogen
Macrofaunal communities (for retention of samples)
Sediment contaminants (TBT, PAHs, organohalogens, trace metals).

2.8.4 Results

2.8.4.1 Acoustics

The multibeam and sidescan sonar data provided bathymetric and granulometric data for the disposal site and the surrounding seabed to the north-east and south-west. The multibeam image shows the disposal site to be located at a depth of approximately 60 m, being slightly shallower at its north-western point and gradually shelving towards the south-east (Figure 2.99). Apart from a small number of areas where bare rock was exposed at the surface, the sidescan data indicated three distinct sedimentary regions could be discerned (Figures 2.100 & 2.101). An area of lower backscatter to the west of the disposal site indicated predominantly muddy surface sediments, high backscatter to the east signalled shelly-sand predominated, while the disposal site comprised of, and was located within a region of, gravelly, muddy-sand. The latter appeared to run in a region in a southwest to north east direction, largely following the bathymetric gradient.

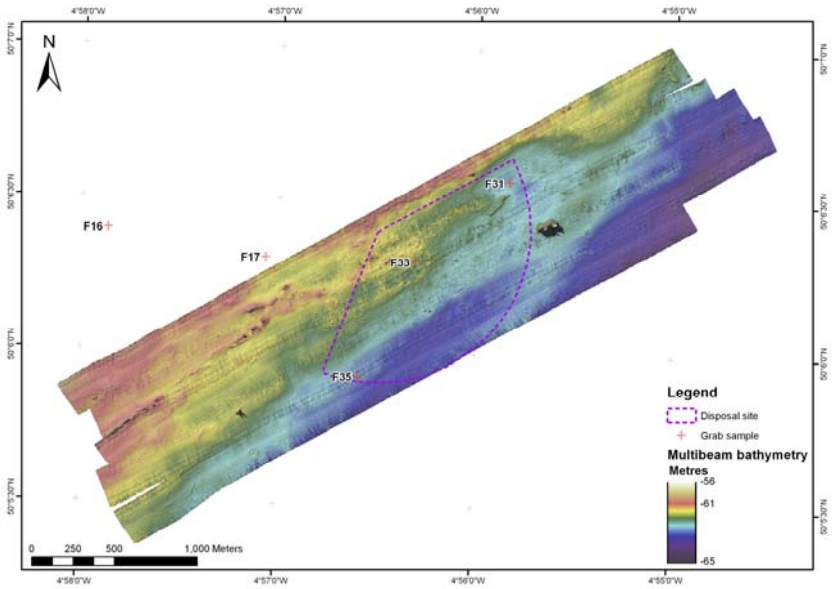


Figure 2.99. Miultibeam bathymetry image of the Falmouth Bay disposal site, 2008.

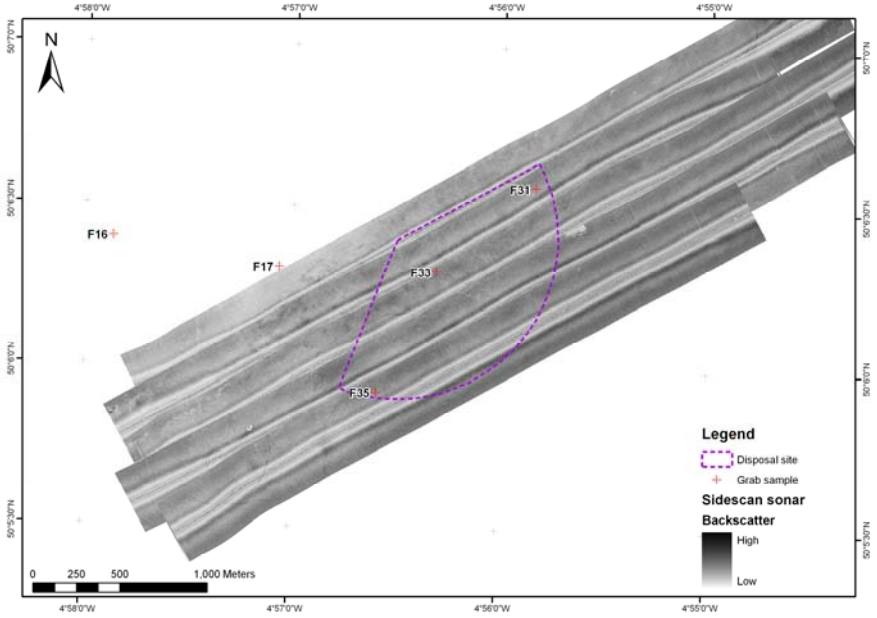


Figure 2.100. Sidescan sonar backscatter images for the Falmouth Bay disposal site, 2008.

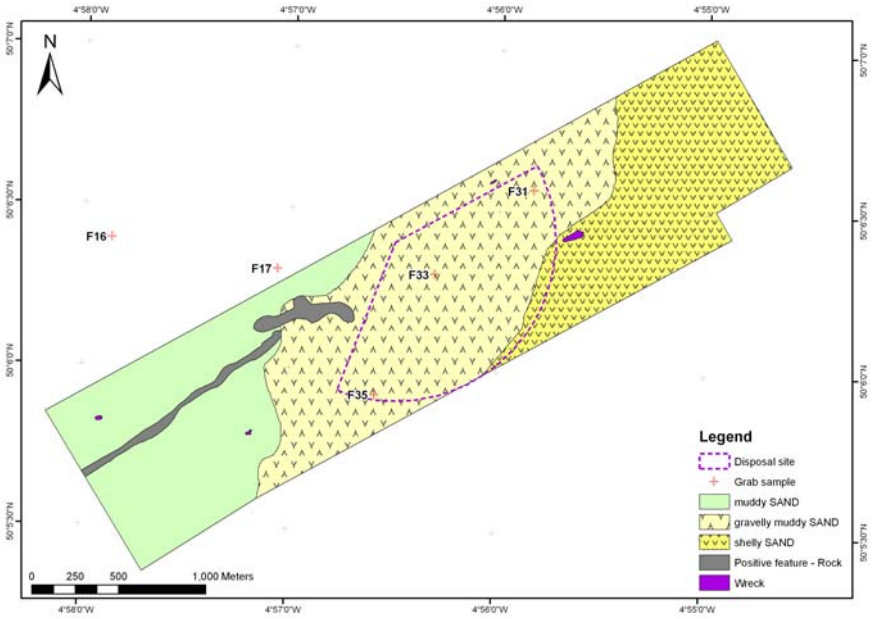


Figure 2.101. Interpretation of the sediments based on backscatter images for Falmouth Bay, 2008.

2.8.4.2 Sediment particle size

Station code	Sediment Group
F15	2A
F27	2A
F14	2C
F22	2C
F28	2C
F31	2C
F33	2C
F35	2C
F8	2C
F16	3
F17	3

Table 2.13. Sediment groups for samples analysed from the Falmouth monitoring survey in 2008. Key: 2a = gravelly sand (gravel main component, mixed, poorly sorted), 2c = gravelly muddy sand (more muddy than 2b and coarser gravel), and 3 = slightly gravelly sand (mixed, poorly sorted).

Sediment groups for each sample are given in Table 2.13 and, in general, they reveal that sediments vary along bathymetric changes. The coarser samples are closest to the coast with lower depth, and there is a grading of sediment with increased finer sediment found in sediments further offshore. The sediment present in the disposal site (F33) is in the same group as those sediments parallel with it, and from a similar depth.

2.8.4.3 Sediment organic carbon and nitrogen

In 2008, organic carbon values range from 2.2 to 2.5 % m/m and for nitrogen 0.26 to 0.32 % m/m.

2.8.4.4 Contaminants

2.8.4.4.1 TBT

Samples from all Falmouth stations were analysed and the results indicated the levels of TBT and DBT were below 0.002 mg/kg. This trend has been observed for the last 4 years.

2.8.4.4.2 PAHs

The highest concentrations of summed PAHs at Falmouth were observed within and to the west of the disposal site. The highest concentration, 4,500 µg kg^{-1}, was found at F16, the furthest inshore of these 3 locations (Figure 2.102). Within and closer to the disposal site, summed PAH concentrations were 2,200µg kg^{-1} at F33 (within the site) and 1850µg kg^{-1} at F17, between F16 and F33. Further inshore (F15 and F27), concentrations were < 1,500µg kg^{-1}, whilst at the stations to the SW of the disposal site, concentrations were similar to the low levels (<1,500 µg kg^{-1}) observed in the deeper offshore waters (e.g., F28 and F22).

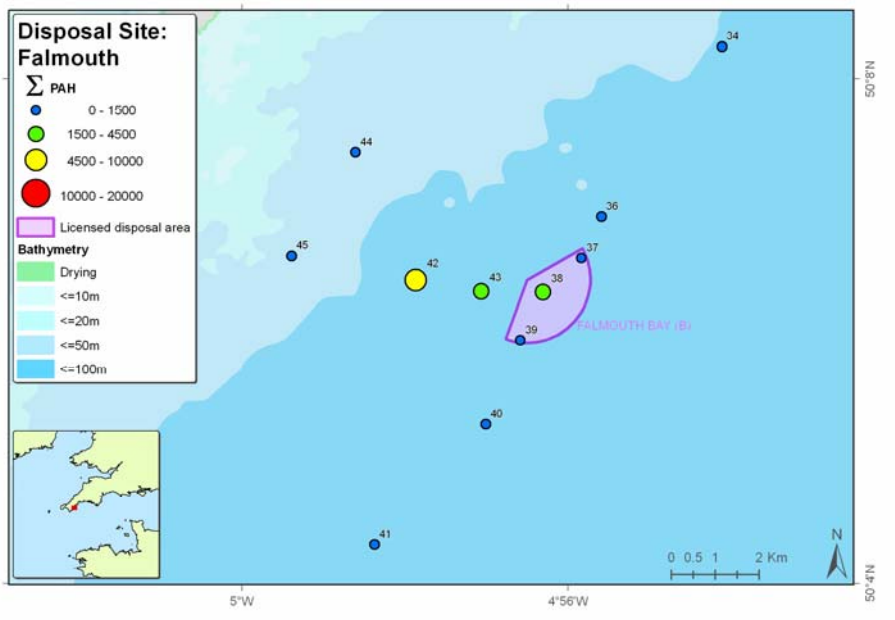


Figure 2.102. Summed PAH concentrations at Falmouth Bay, 2008.

2.8.4.4.3 Organohalogens

At Falmouth, concentrations of organohalogen contaminants were generally low, below or close to LODs (Figures 2.103 – 2.105). The highest concentrations were observed at station F33 within the disposal site for both CBs and DDT, but these were still generally low. Station F33 had a slightly higher proportion of penta- and hexachlorinated CBs than the other stations. Station F33 had a higher DDT / DDE ratio (Figure 2.107), possibly suggesting a

more recent DDT source. All stations were below FEPA warning levels and TECs, and had 'good' environmental status for all ICES7 CBs. No previous data was collected between 2002-07 that would have enabled a comparison of temporal trends.

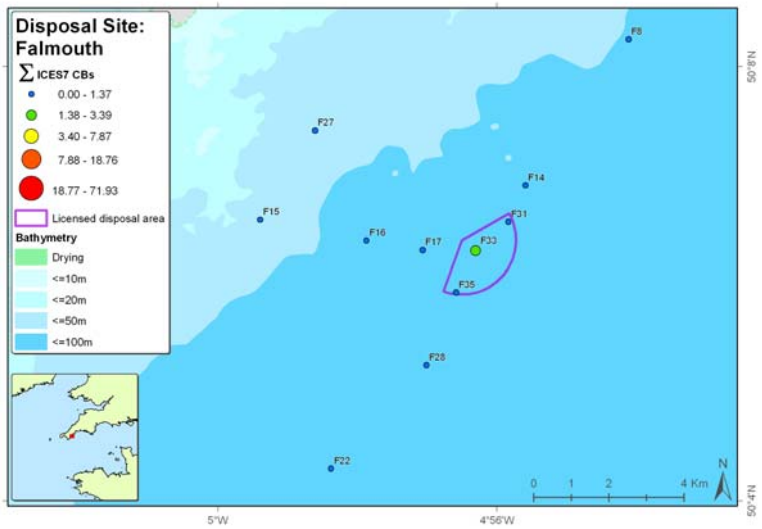


Figure 2.103. Summed ICES7 CB concentrations for stations at Falmouth Bay, 2008.

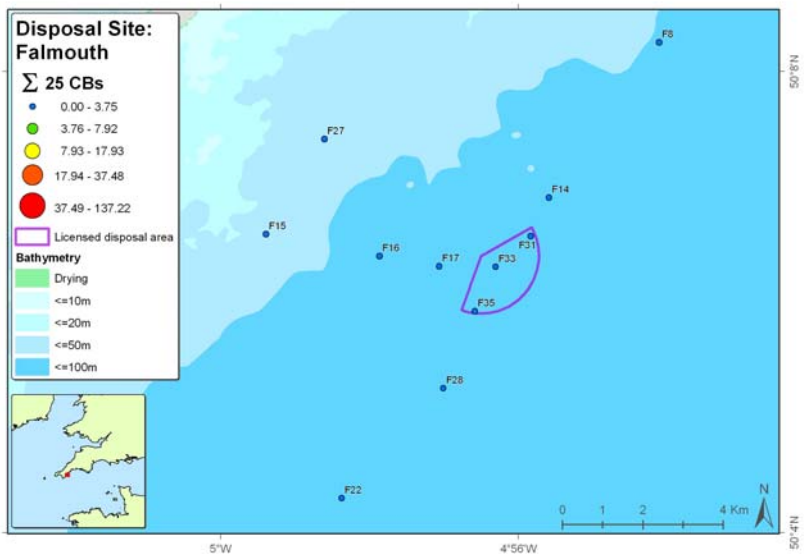


Figure 2.104. Summed 25 CB concentrations for stations at Falmouth Bay, 2008.

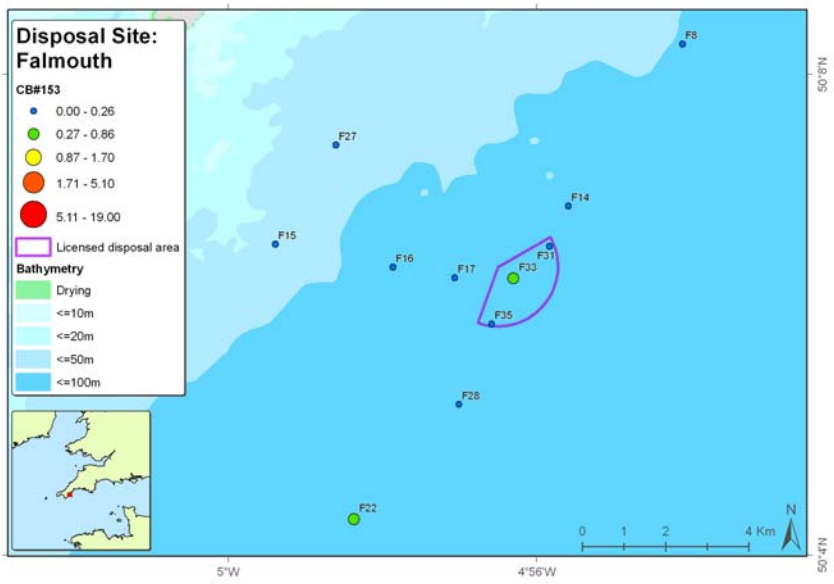


Figure 2.105. Summed CB#153 concentrations for stations at Falmouth Bay, 2008.

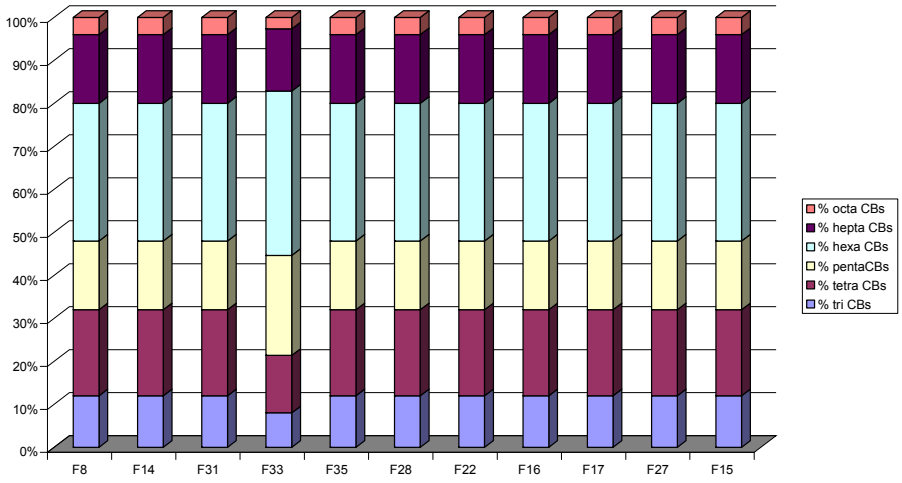


Figure 2.106. CB congener profiles for stations at Falmouth Bay, 2008.

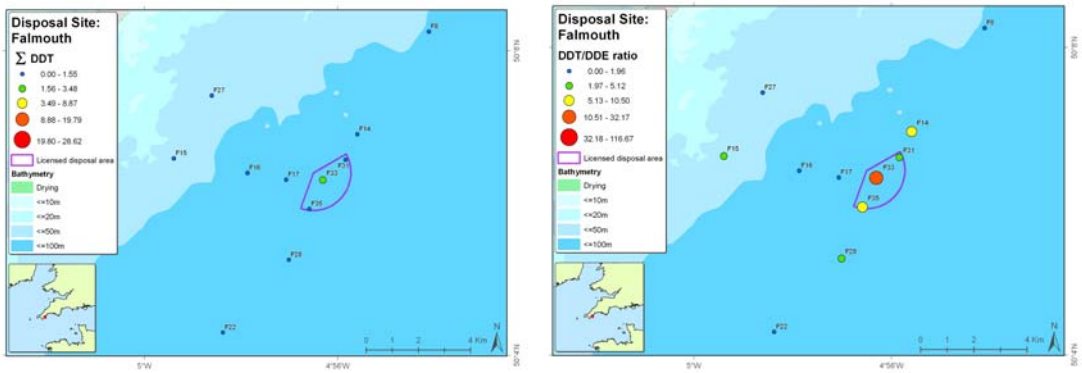


Figure 2.107. DDT concentrations (left) and DDT / DDE ratios (right) for stations at Falmouth Bay, 2008.

2.8.4.4.4 Trace metals

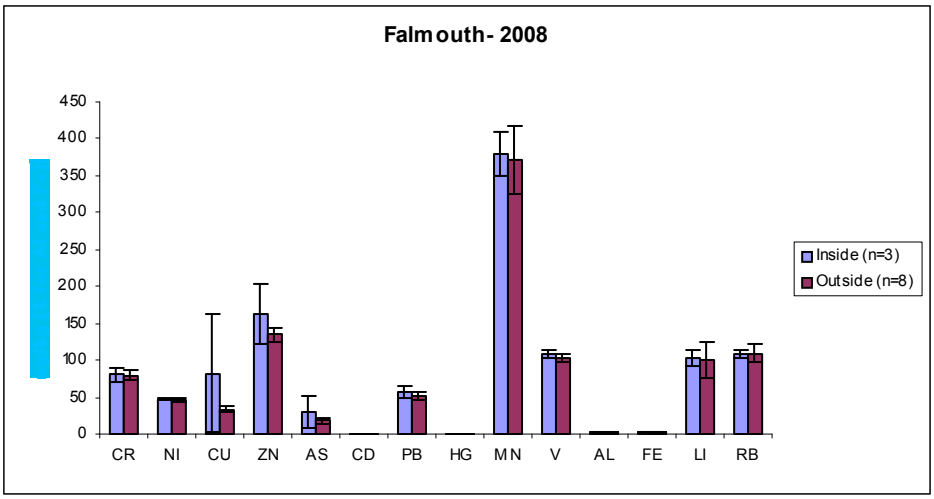


Figure 2.108. Average metals concentrations for stations inside and outside the disposal site at Falmouth Bay, 2008.

Generally, average metal concentrations are similar outside and within the disposal site (Figure 2.108), although slight increases in Cu and Zn are observed within the disposal site.

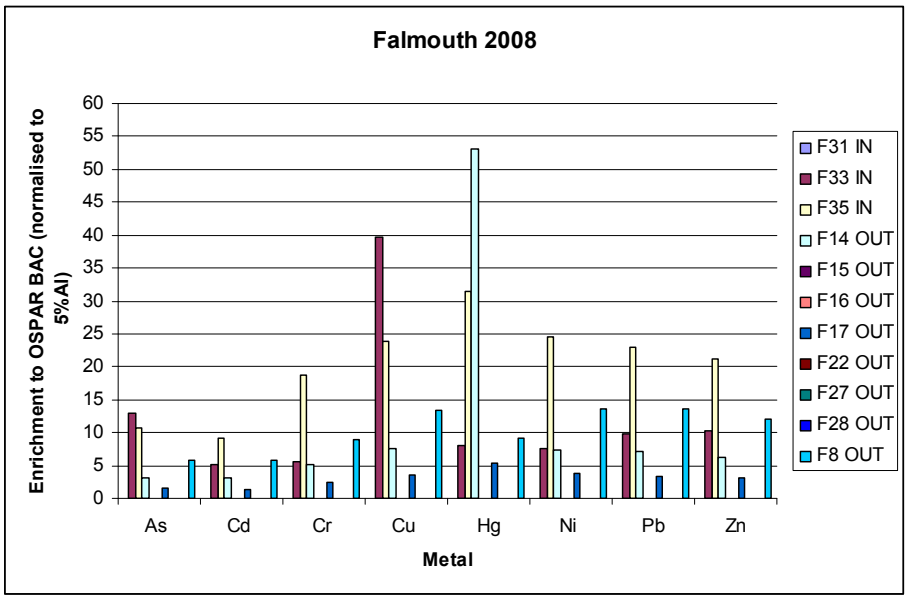


Figure 2.109. Enrichment to OSPAR BACs for each station at Falmouth Bay sampled in 2008.

Enrichment to OSPAR BACs at Falmouth is shown for stations inside and outside of the disposal site in Figure 2.109. Care should be taken with these values as further work is being completed to ensure regional accuracy for the normalisation procedure used to produce BACs. The results show some enrichment in the site for all metals for 2 stations (F33 and

F35), and particularly for Hg and Cu, (>25X enrichment to the OSPAR BAC) compared with outside the disposal site where 3 samples (F8, F14 and F17) of the 8 have any enrichment.

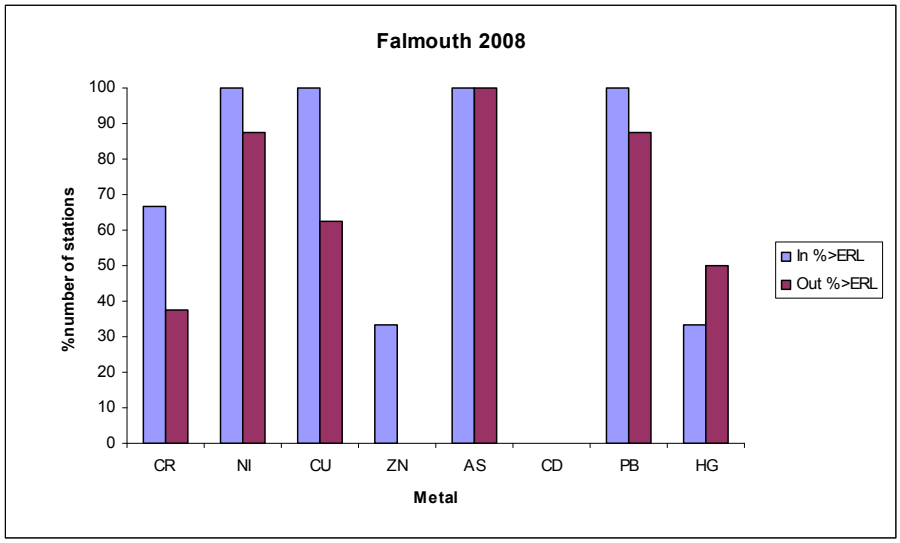


Figure 2.110. Percentage number of stations inside and outside Falmouth disposal site with concentrations >ERL

With respect to ERLs, stations inside Falmouth disposal site have elevations of Cr, Ni, Cu, Zn and Pb, relative to stations outside of the site (Figure 2.110). As and Cd both show the same pattern inside and outside of the site, with As being elevated inside and outside, and Cd showing levels below the ERL (ERL for Cd = 1.2 mg). Hg is elevated outside the site compared with inside. Enrichment to BAC values show that the main enrichment is in the site and while results for stations here may have values greater than ERLs they are below background in relation to BACs. As already stressed there are regional variations in the BACs which are currently not accounted for.

In summary, metal concentrations measured at Falmouth are mostly below OSPAR BACs. Enrichment is present within the disposal site, as well as for 3 sites outside of the disposal site. Care should be taken in this area with regard to derivation of BACs and enrichments are not unexpected as this area has enriched concentrations related to historic industrial activity as well as naturally high concentrations related to the geology. Additionally, some metal concentrations measured at Falmouth are above ERL. Care should be taken when assessing the implication of these results, as metal concentrations were measured on the <63µm fraction using a total digest and so are in a more concentrated form than would be available for uptake within the whole sediment here.

2.8.5 Conclusions

Sampling at Falmouth Bay during 2008 was primarily undertaken in view of the proposed large increase in tonnage which this site may potentially receive over the next coming years. As such, the 2008 sampling was mainly to provide a current assessment of the site from which to assess the impacts associated with the large deposits expected. In this respect the acoustics and particle size data acquired are of particular interest, and the contaminant data will be used to determine whether such parameters are notably altered over the coming years. It is anticipated that future sampling will be undertaken under SLAB5, but only after the majority of the increased tonnage (following the capital operation) has been disposed. Should the large volumes of maerl need to be disposed of at Falmouth Bay (see Section 2.8.1), this dataset should provide a unique baseline upon which to assess recolonisation of deposited maerl.

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. Thanks also go to Sonia Kirby, Manuel Nicholaus and David Stephens for their contribution to producing the finished report.

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APPENDIX 1: Background to organohalogen assessments.

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 ratio of p,p-DDT to p,p-DDE concentrations was calculated to identify whether the DDT contamination in the sediment was likely to be recent (DDT/DDE significantly >1) or historical (DDT/DDE <1).

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

Concentrations of PCBs and OCPs in the sediment were compared with various action limits, to investigate whether any adverse effects in benthic biota were likely to be expected as a consequence of their presence. The current FEPA action limits for dredge disposal are: warning levels if ∑ICES7 CBs > 10 µg/kg, ∑CBs > 20 µg/kg, DDT > 1 µg/kg, dieldrin > 1 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, DDT <4.16, ∑DDTs <5.28 µg/kg and dieldrin <1.90 µg/kg; and consensus-based PECs (Predicted effect concentrations), i.e. above which harmful effects are likely to be observed, are: ∑CBs >277 µg/kg, DDT >62.9 µg/kg**,** ∑DDTs >572 µg/kg**,** and dieldrin >61.8 µg/kg. Concentrations are expressed on a dry weight basis. OSPAR in Charting Progress2 (CP2) have set criteria for Background Assessment Concentrations (BAC) and Environmental Assessment Concentrations (EAC) for the ICES7 CBs in sediments (see Table A1). 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 A1. OSPAR assessment criteria for CBs in sediment from CP2.

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Appendix 2: Background to trace metals assessments

OSPAR Background Assessment Concentrations (BACs) have been produced to provide a means of assessing the degree of contamination of environmental samples. OSPAR BACS, (OSPAR, 2005) are defined as the typical range of values found in uncontaminated sediments. Table A2 contains BACs for trace metals, based on monitoring data from the OSPAR area (the North-East Atlantic). These values are internationally agreed by OSPAR. Each metal concentration is normalised to 5% aluminium, using a 'pivot point' (the concentration of these metals in uncontaminated sand - ideally close to the area of interest; OSPAR, 2005). Normalisation allows trace metal concentrations from different sediment types to be compared. As trace metals have a higher affinity to clay, concentrations will be higher from sediment containing a lot of clay, than sediment made up mostly of sand. The concentration of aluminium is indicative of the amount of clay in a sample, and can therefore be used a normaliser for trace metal concentrations (Rowlatt & Lovell, 1994).

Table A2: OSPAR BACs for trace metals normalised to 5%Al using pivot point data. (OSPAR, 2005).

	OSPAR (BAC) normalised to 5%Al (mg kg-1 dw)
As (5%Al)	25
Cd (5%Al)	0.31
Cr (5%Al)	81
Cu (5%Al)	27
Hg (5%Al)	0.07
Ni (5%Al)	36
Pb (5%Al)	38
Zn (5%Al)	122

BACs provide a convenient means of assessing the degree of potential contamination. However, they should be used with some care, particularly in UK waters as the natural background can be very variable, due to a diverse geological coastline and drainage basins. For example, normalised metal concentrations for the recent broad spatial survey around the UK had unexpectedly high values in some regions, most notably off the south-west coast (Anon, 2009). We consider that this may have been due to the selection of 'pivot points' in the assessment. The only published pivot point data available from the OSPAR region for completing the normalisation were taken from the *Assessment manual for contaminants in sediment and biota* (OSPAR, 2008). The ICES Working Group for Marine Sediments in pollution (WGMS) has recommended that OSPAR allow Contracting Parties to nominate their

own normaliser, ‘pivot point’ concentration and background concentrations for each OSPAR region. Work is currently being carried out within Cefas (under a Defra-funded project ME5403) to produce regional pivot points and BACs for disposal site assessment around England and Wales to account for these differences so that comparison between sites can be completed.

Enrichment relative to the OSPAR BAC has been calculated, using OSPAR BAC concentrations as defined in Table A2:

$$\frac{\text{Normalised metal concentration (to 5\%Al using pivot point)}}{\text{OSPAR BAC}}$$

The graphs presented for each disposal site have level of enrichment presented on the y axis. For this assessment no definition relating level of enrichment to level of impact has been set. This is partly due to the uncertainty in the normalisation procedure, and also because further investigation into how to set these needs to be completed as their potential significance could be misleading.

The Working Group on Monitoring (MON) has used Effects Range Low (ERL) concentrations in the Quality Status Report (QSR 2010) as well as Charting Progress (CP2) to assess trace metal concentrations in sediment. ERLs are sediment chemistry screening values based on a biological effects correlation approach. ERL is based on 10th percentile of the distribution of contaminant concentrations associated with adverse biological effects. The sediment quality guidelines derived by NOAA under the NS&T Programme uses this approach (Long et al., 1995) (Table A3). Refer to Rowlatt et al. (2002) for the derivation of the sediment quality guidelines. These values have been produced using large datasets using data produced using a wide range of methodologies. 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). Results from this assessment are on the <63 µm fraction using a total digest (HF) and in principal these should be the worst case scenario (i.e. yield highest concentration). The sediment types vary in this report (refer to sediment characterisation section for each disposal site assessment). Most results were >ERLs and while this may imply some kind of adverse biological effect, one should bear in mind this does not represent the contamination status of the whole sediment sample; i.e. the > 63 µm is likely to have a lower metal concentration (assuming most of the metal concentration is found in the <63µm fraction). In addition, there are expected to be regional differences in metal concentrations reflecting regional differences in geological and human activity (e.g. mining and industrial activity) which mean that certain areas have high concentrations unrelated to disposal operations. Interestingly, ERLs levels for As and Ni are even lower than the defined

OSPAR BACs levels – this illustrates why ERLs are at best a crude representation of biological impact, requiring further investigation before being used as a management tool.

Table A3: ERL guideline values for trace metals (from Long et al., 1995).

Trace metal	ERL (mg kg-1 dw)
Arsenic	8.2
Cadmium	1.2
Chromium	81
Copper	34
Lead	46.7
Mercury	0.15
Nickel	20.9
Zinc	150

ERLs are broadly analogous to the Action Levels used by the RAT to assess dredge material before disposal at sea. However, it has already been proven that the different analytical methods used for trace metal determination for dredge samples as opposed to monitoring samples mean the same levels can not be applied to both when trying to link source and impact at the disposal site (Cefas, unpubl. 2008). Trace metal concentrations are measured on the whole sample using a partial digest for dredge samples, compared with total digest (HF) on the <63µm fraction for monitoring samples. Such different methods yield different results and it is not sensible to assume that if there are elevations in one area using one method, these elevations will be replicated using another method in the same area. The biggest difference in measured concentrations is thought to be caused by the different size fractions analysed (Cefas, unpubl. 2008).

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Pakefield Road, Lowestoft,
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Tel +44 (0) 1502 56 2244
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