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Working with water

# Harwich Haven Disposal Site TH027

## 2020 Annual Monitoring Report

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March 2021

# Document information

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# Executive summary

## During the course of a typical year five to six maintenance dredging campaigns at approximately 10 week intervals to remove mud from Harwich Harbour are undertaken by trailing suction hopper dredger. The dredged material is placed at an offshore disposal site.

The duration of the campaigns are typically between one and two weeks, with between 40 and 80 trips being sailed. The volume of material dredged from Harwich Harbour is typically between 200,000 $m^3$ and 600,000 $m^3$, approximately equivalent to 100,000 to 300,000 tonnes dry solids (TDS). Since June 2018 the placement has been to the new offshore disposal site (Harwich Haven – TH027). There were two campaigns of trial placements to TH027 in June and August 2016.

A Marine License granted by the Marine Management Organisation (MMO) permits Harwich Haven Authority (HHA) to dispose of material arising from their maintenance dredging of Harwich Harbour to the new TH027 disposal site. A condition of the licence is that HHA will undertake a disposal site monitoring programme that will run for a minimum of three years and that a monitoring report will be supplied to the MMO annually so that it can assess, together with its advisors, whether any statistically significant negative impacts have been identified that can be attributed to disposal activities.

The 2018 monitoring report (HR Wallingford, 2019) was related to disposal activity at TH027 in 2018. As only one dredging campaign had placed material at the site during this period this was not deemed by the MMO to be an "Annual" report (MMO, 2019) in terms of meeting the licence condition. In a typical year there are five to six disposal campaigns at approximately 10 week intervals. The 2019 monitoring report (HR Wallingford, 2020) was therefore deemed to be the first Annual monitoring report. This report is the second Annual monitoring report and presents information relating to disposal activity at TH027 in 2020 and the results of the associated monitoring.

Multibeam echo sounder surveys of the TH027 disposal site undertaken in 2017, 2018, 2019 and 2020 show that since disposal activities commenced at TH027 there is no measurable change (i.e. ±0.2 m) in seabed elevation within the outer areas of disposal site TH027. In the central north-south area accretion of between 0.2 m and 0.8 m was measured between the 2017 and 2020 surveys. This accretion, which is apparent both within the boundary of the disposal site and in an area to the south west of the boundary, can likely be linked to the disposal activities that have taken place at the site since June 2018. The volume of accretion that has taken place within the boundary of TH027 during the period between the 2017 and 2020 surveys has been calculated to be about 121,750 $m^3$, equivalent to about 2.6% of the mass placed at the site during the period.

To better capture the changes in bathymetry that are being observed to the south west of the disposal site boundary, the southern extent of the MBES survey area was extended by a further 200 m to the south in 2020.

A programme of seabed sampling has been undertaken over the disposal site and in the vicinity of the site. The sampling stations were grouped into the following treatment areas:

- Central area (within the boundary of TH027);
- Disposal area (area of potential effect outside of TH027);
- Crab area (suitable crab/lobster site);
- Inner area (inner reference area);

- Outer area (outer reference area).

The seabed sediment surveys carried out in 2016, 2017, 2018, 2019 and 2020 demonstrated that, between 2017 and 2018 the particle size distribution within the Central and Disposal treatment areas became finer at a number of sampling stations. Between 2018 and 2019 an increase in the proportion of fine material was seen at most stations in the Outer reference area indicating that there was a trend for an increase in fine material over the entire survey area. Since 2019, changes in sediment composition have been less pronounced but reflected a reduction in silt and an increase in sandy sediment across all areas.

Seabed benthic surveys carried out in 2017, 2018, 2019 and 2020 demonstrated that the faunal communities observed in the vicinity of the TH027 disposal site were diverse and heterogeneous in nature. Since 2017 benthic faunal communities have demonstrated considerable temporal change in the Central treatment area, i.e., within the boundary of the TH027 disposal site. Whilst a large increase in abundance was recorded in the Crab area in 2020 (this was heavily influenced by an abnormally high count of individuals at one station) temporal changes in treatment areas more distant from the Central area show only small changes in species diversity. The distribution of gravel and coarse and fine sand was found to correlate most strongly with faunal patterns, confirming that the presence of these sediments has the greatest control on the faunal communities present in terms of the variables measured during the surveys.

Whilst HHA has liaised with representatives of local fishermen regarding the establishment of a monthly voluntary shellfish catch returns scheme for crab and lobster, to date it has not been possible to establish such a voluntary scheme.

Shellfish catch and returns data provided by the MMO for ICES rectangle 32F1 has demonstrated crab landings of up to 14 tonnes per year between 2015 and 2019 for all vessels (up to 12.5 tonnes per year for vessels greater than 10 m in length and up to 1.5 tonnes per year for vessels less than 10 m in length). For the period 2015 to 2018, the Eastern IFCA report landings of up to 4.6 tonnes per year for vessels of less than 10 m in length. MMO returns data for 2020 has demonstrated an annual landing of about 49 tonnes for all vessels (22.4 tonnes for vessels greater than 10 m in length and 22.5 tonnes for vessels less than 10 m in length). Eastern IFCA landings data for 2019 has not yet been published.

# Contents

## Figures



## Tables

# 1. Introduction

The Marine Management Organisation (MMO) has granted Harwich Haven Authority (HHA) a Marine License (L/2013/00392/4, issued on 28 February 2018) that permits HHA to dispose of material arising from their maintenance dredging of Harwich Harbour to the new TH027 disposal site. A condition of the license is that HHA will undertake a disposal site monitoring programme that will run for a minimum of three years and that a monitoring report will be supplied to the MMO annually so that it can assess, together with its advisors, whether any statistically significant negative impacts have been identified that can be attributed to disposal activities.

The specific aims of the monitoring programme, as stated in Schedule 6 of the Marine Licence, are as follows:

> The aim of the multi-beam survey is to verify that there is no build-up of dredged material on the seabed compared to baseline conditions.
>
> The aim of the sediment surveys is to verify that there is no permanent change to the seabed substrate compared to baseline conditions (outside of the disposal site); and,
>
> the aim of the benthic surveys is to verify the prediction that there will be no significant changes to the benthic community composition (outside of the disposal site) as a result of disposal activities.
>
> *Marine License L/2013/00392/4, Schedule 6*

The 2018 monitoring report (HR Wallingford, 2019) was related to disposal activity at TH027 in 2018. As only one dredging campaign had placed material at the site during this period this was not deemed by the MMO to be an “Annual” report (MMO, 2019) in terms of meeting the licence condition. In a typical year there are five to six disposal campaigns at approximately 10 week intervals. The 2019 monitoring report (HR Wallingford, 2020) was therefore deemed to be the first Annual monitoring report. This report is the second Annual monitoring report and presents information relating to disposal activity at TH027 in 2020 and the results of the associated monitoring. Where appropriate, comparison is made with data presented in the 2018 and 2019 monitoring reports.

The monitoring report presents results from the following 2020 activities:

- Dredging and disposal records;
- Comment on any abnormal metocean conditions;
- Annual multi-beam hydrographic survey;
- Annual sediment and benthic surveys;
- Information regarding voluntary shellfish catch returns scheme;
- Available MMO catch and returns data from ICES rectangle 32F1 of area IVc (Southern North Sea).

Results from each of these activities are provided respectively in Sections 2 to 7 and a discussion of the results is presented in Section 8.

# 2. Dredging and disposal records for TH027

## 2.1. Disposal records

Dredging and disposal records for maintenance dredging campaigns undertaken at Harwich and using the TH027 disposal site during the period 2016 to 2020 are provided in Table 2.1. The location of the Harwich Haven (TH027) disposal site is shown in Figure 2.1.

Figure 2.1 also shows the relative locations of the Inner Gabbard East (TH056) and the Inner Gabbard (TH052) disposal sites within the ICES Rectangle 32F1 (see Section 7). Material dredged from the Harbour is disposed of at the Harwich Haven site. Material dredged from the Inner Channel (west of No.1 Buoy) which is very silty is disposed of at the Inner Gabbard site. Material dredged from the Outer Channel (east of No. 1 Buoy) which is more granular is disposed of at the Inner Gabbard East site.

Table 2.1: Dredging and disposal records for TH027 (2016 – 2020)

| | Vessel | Dredging area | Tonnes dry solids (TDS) | Disposal site |
|---|---|---|---|---|
| **2016** | | | | |
| 09 Jun – 17 Jun | Barent Zanen | Harbour | 246,912 | Harwich Haven |
| 21 Aug – 30 Aug | HAM 316 | Harbour | 161,839 | Harwich Haven |
| **2017** | | | | |
| None in 2017 | | | | |
| **2018** | | | | |
| 07 Jun – 15 Jun | Uilenspiegel | Harbour | 214,999 | Harwich Haven |
| 24 Aug – 05 Sep | Barent Zaren | Harbour | 301,116 | Harwich Haven |
| 14 Nov – 26 Nov | Barent Zaren | Harbour | 231,536 | Harwich Haven |
| **2019** | | | | |
| 08 Feb – 19 Feb | HAM 316 | Harbour | 274,647 | Harwich Haven |
| 25 Apr – 05 May | HAM 316 | Harbour | 275,662 | Harwich Haven |
| 17 Jul – 25 Jul | HAM 316 | Harbour | 212,558 | Harwich Haven |
| 01 Nov – 21 Nov | HAM 316 | Harbour | 262,880 | Harwich Haven |
| **2020** | | | | |
| 01 Feb – 08 Feb | James Cook | Harbour | 226,162 | Harwich Haven |
| 11 Apr – 18 Apr | Alexander von Humboldt | Harbour | 151,089 | Harwich Haven |
| 14 Jun – 23 Jun | Alexander von Humboldt | Harbour | 231,125 | Harwich Haven |
| 23 Aug – 01 Sep | Shoreway | Harbour | 115,034 | Harwich Haven |
| 26 Nov – 09 Dec | Medway | Harbour | 224,796 | Harwich Haven |

*Source: Harwich Haven Authority*
*Note: Tonnes Dry Solids (TDS) = Dry Tonnes*

Disposal at the Harwich Haven site is undertaken in a manner to promote dispersion of the muddy material released at the site. The dredger slowly steams across the site releasing material through the bottom doors. This process of dispersive release of fines was also adopted at the Inner Gabbard site.

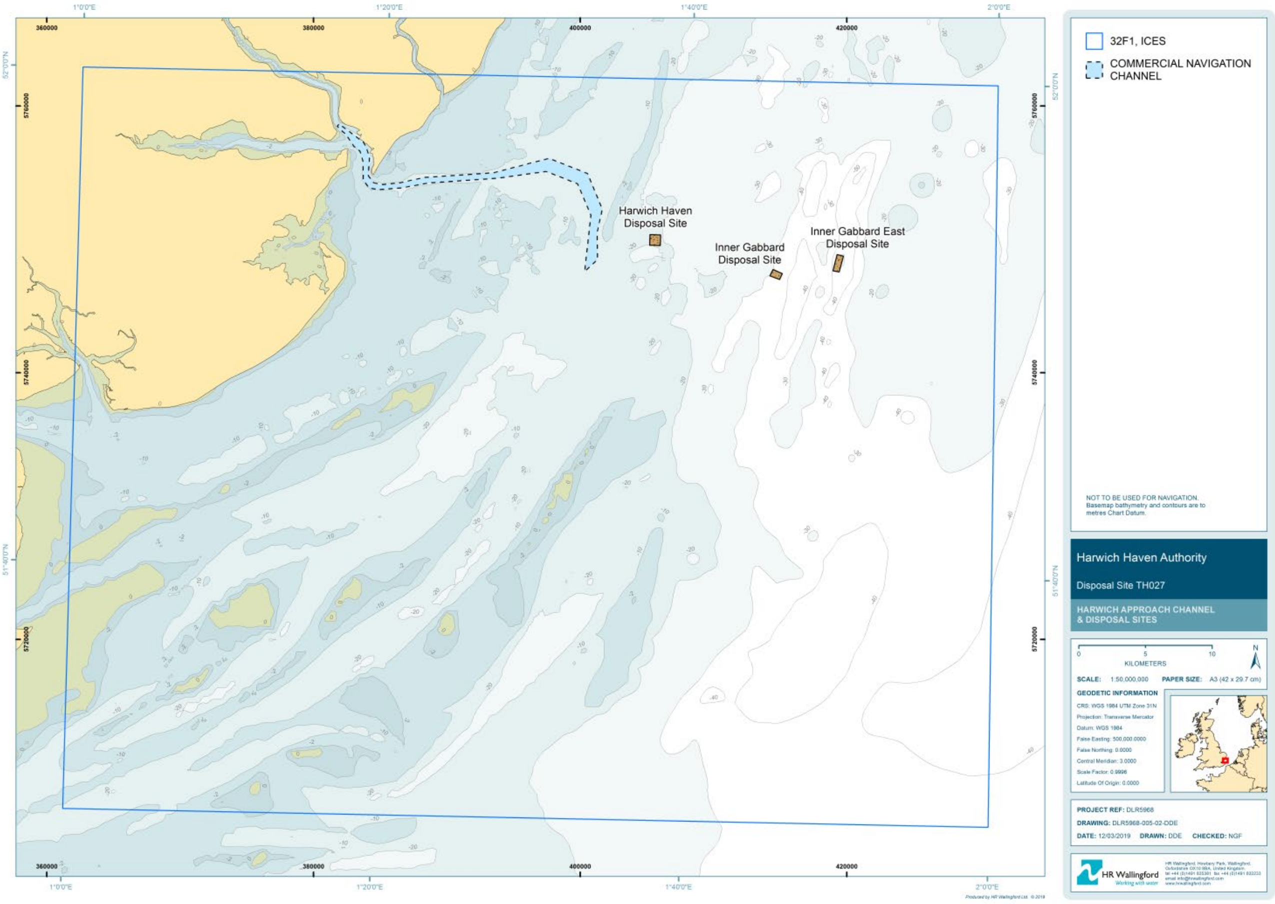


Figure 2.1: Location of Inner Gabbard East, Inner Gabbard and Harwich Haven disposal sites within ICES Rectangle 32F1

*Source: HR Wallingford*

## 2.2. Timing of disposal relative to stage of tide

For the case of the disposal activities undertaken in 2020, an assessment of the timing of the disposals relative to the stage of tide at Harwich Harbour has been undertaken. The results of this assessment are shown as a histogram in Figure 2.2, where flood tide disposals are indicated in hours before the nearest high water (i.e., negative values) and ebb tide disposals are indicated in hours after the nearest high water (i.e., positive values).

The histogram demonstrates that overall, there is no bias towards disposals taking place during either the flood or ebb tide and that disposals are fairly evenly spread over the full tidal cycle with 49% taking place on the ebb tide and 51% on the flood tide.

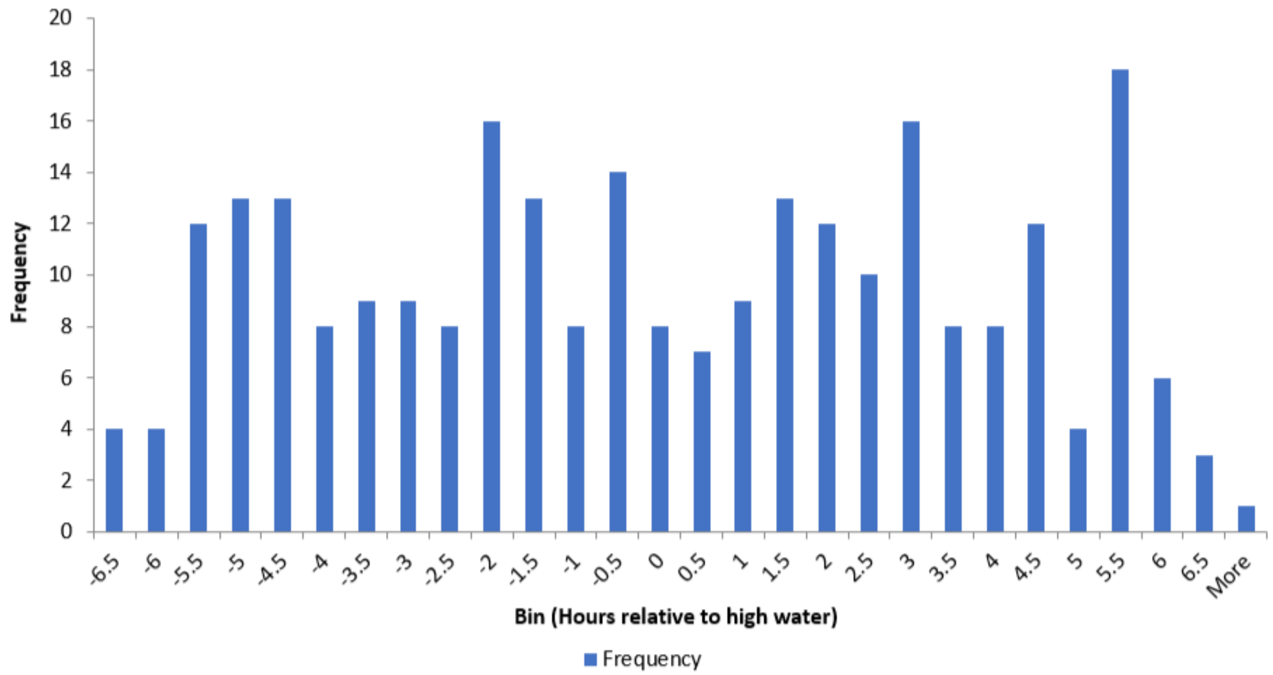


Figure 2.2: Histogram of disposal time relative to high water at Harwich Harbour

*Source: HR Wallingford*

## 2.3. Dredged sediment particle size

During the Harwich Harbour maintenance dredging campaign undertaken in November and December 2020 (so after the 2020 monitoring surveys) two samples of dredged material were retrieved from the hopper of the dredger *Medway*. The samples were collected during trip 34 of the campaign on 2 December 2020. Sample *Hopper01* was taken from about mid-depth in the hopper and sample *Hopper02* was taken from close to the bottom of the hopper.

The two hopper samples were analysed by Thomson Unicomarine for particle size distribution (PSD), the results of which are presented graphically in Figure 2.3.

Figure 2.3 shows that the two samples collected from the hopper of the dredger had very similar PSD's. The material comprised about 85% fine particles (<63 µm diameter) and about 15% fine to medium sand size particles. No coarse sand or gravel size particles were present in the samples.

Figure 2.4 shows the PSD of four grab samples collected from the bed of the harbour in September 2016. Figure 2.3 and Figure 2.4 demonstrate the broad similarity in the PSD of the samples collected from in-situ and from the hopper of the dredger.

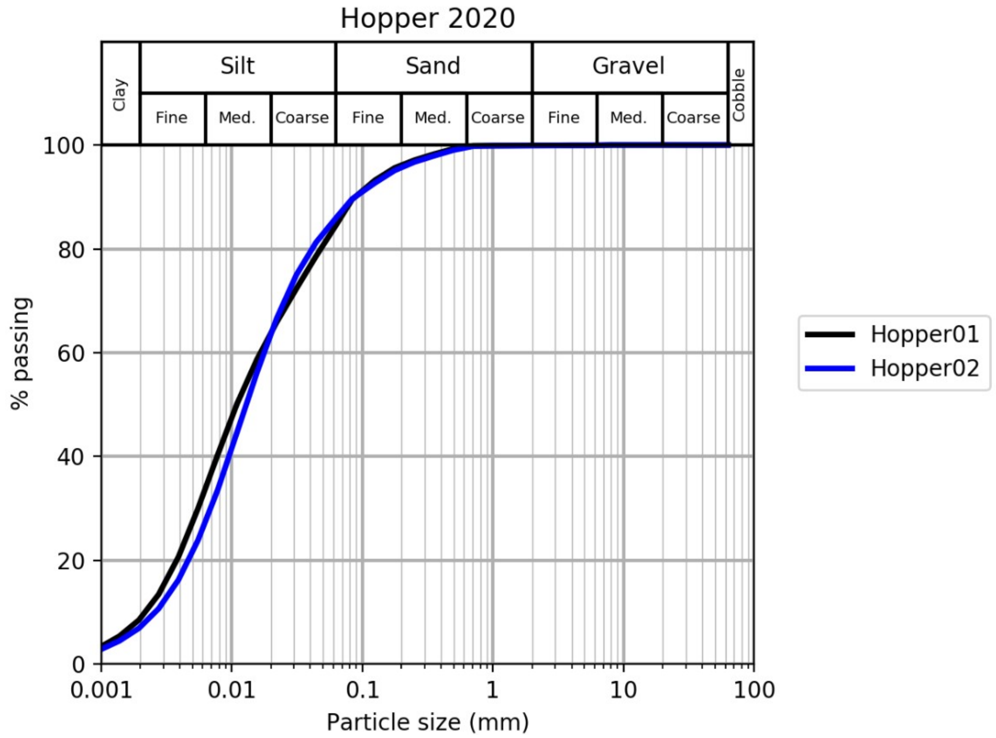


Figure 2.3: Particle size distribution of hopper samples

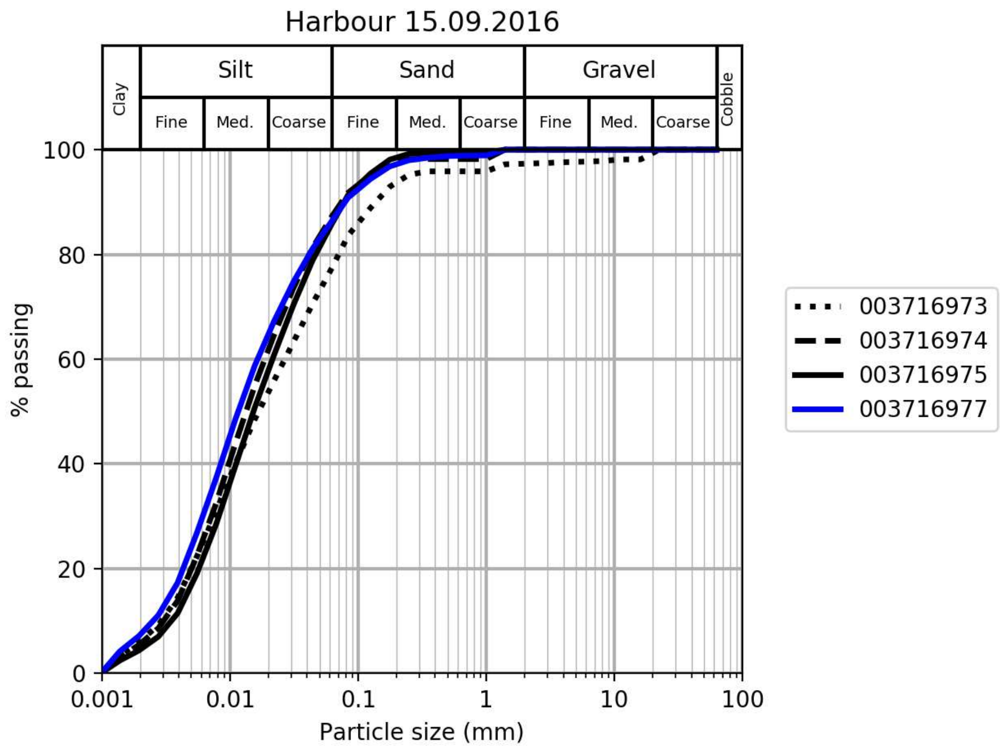


Figure 2.4: Particle size distribution of harbour samples

# 3. Abnormal metocean conditions

Large tidal surges (i.e. the difference between the predicted and actual water level), whether positive or negative, can result in near-bed tidal current speeds being higher or lower than those experienced under normal tidal conditions, depending on the phasing of the surge during the tidal cycle.

Predicted and measured water level data for Harwich Harbour between 2015 and 2020 has been analysed and the number of positive and negative surge tides of a) between 1.0 m and 1.5 m and b) above 1.5 m are summarised on an annual basis in Table 3.1.

Table 3.1 demonstrates that in the period 2015 to 2020 these large tidal surges have only occurred over the winter period between October and March. The benthic sampling has taken place between May and September. Any influence of surges on the movement of seabed material will not have directly impacted the seabed substrate in the immediate months preceding the benthic sampling. Over time these more extreme sediment transport events in combination with wave and tidal action will contribute to variations in the distribution of sediment type on the seabed.

Table 3.1: Occurrences of surge tides in excess of 1 m in Harwich Harbour

| Year | + surges 1 m to 1.5 m | + surges over 1.5 m | - surges 1 m to 1.5 m | - surges over 1.5 m |
|---|---|---|---|---|
| 2015 | 1 (Jan), 1 (Oct), 2 (Nov) | 1 (Jan) | 1 (Jan), 1 (Feb), 1 (Dec) | 0 |
| 2016 | 2 (Dec) | 0 | 1 (Jan), 1 (Dec) | 0 |
| 2017 | 2 (Jan), 1 (Feb), 1 (Oct), 1 (Dec) | 1 (Jan), 1 (Oct) | 0 | 0 |
| 2018 | 0 | 0 | 1 (Feb), 1 (Dec) | 0 |
| 2019 | 2 (Jan), 1 (Mar), 2 (Dec) | 1 (Jan) | 1 (Mar) | 1 (Dec) |
| 2020 | 1 (Jan), 1 (Feb), 1 (Nov), 1 (Dec) | 0 | 2 (Feb) | 0 |

*Source: Harwich Haven Authority*

# 4. TH027 multi-beam hydrographic surveys

## 4.1. Multi-beam echo sounders surveys

Multi-beam echo sounder (MBES) surveys of the TH027 disposal site have been carried out since June 2012 by HHA and Cefas as shown in Table 4.1.

The June 2012 survey was carried out by HHA as part of a site selection exercise seeking to identify a new disposal site for HHA's maintenance dredging material which was closer to the shore than the (then) existing disposal site TH052 at Inner Gabbard (HR Wallingford, 2013).

The May, June and October 2016 surveys were carried out to meet a condition of a MMO Marine Licence (L/2013/00392/3, issued on 6 May 2016) which permitted two trial campaigns of disposal of dredged material at TH027. These monitoring surveys (HR Wallingford, 2017) were followed by HHA's annual survey of July 2017. The extent of the 800 m x 800 m disposal site TH027 was surveyed by covering a 1 km by 1 km area of the seabed.

A condition of the current MMO Marine Licence (L/2013/00392/4, issued on 28 February 2018) is that an annual multi-beam echo sounder (MBES) survey of the TH027 disposal site is carried out once per year (for a minimum of three years), between July and September and in between disposal campaigns. The condition proposes a minimum period of 4 weeks between the end of a disposal campaign and the survey commencing.

Annual MBES monitoring surveys of TH027 have previously been carried out by HHA in June 2018 and September 2019. The most recent HHA survey was undertaken on 3 August 2020, i.e. 41 days (or 5 weeks and 6 days) after the 14 June – 23 June 2020 dredging and disposal campaign was completed (see Table 2.1).

The purpose of the annual MBES surveys is to verify that there is no long-term build-up of dredged material from one year to the next and compared to the 2017 baseline conditions.

In addition to the above HHA surveys, Cefas undertook a survey of the TH027 disposal site in July 2017 as part of their MMO Coast of England Dredged Material Disposal Site Monitoring project (Cefas, 2018).

Table 4.1: TH027 multi-beam hydrographic surveys

| Survey date | Surveyor | Days after last disposal |
|---|---|---|
| 27 Jun 2012 | HHA | N/A |
| 23 / 25 May 2016 | HHA | N/A |
| 18 / 28 July 2016 | HHA | 31/41 |
| 31 Oct / 1 Nov 2016 | HHA | 62/63 |
| Jul 2017 | Cefas | >300* |
| 14 Jul 2017 | HHA | 318 |
| 26 Jun 2018 | HHA | 11 |
| 10 Sept 2019 | HHA | 47 |
| 3 Aug 2020 | HHA | 41 |

*Source: Harwich Haven Authority / Cefas*
** Note: Precise date of Cefas survey not known*

Comparison of the three 2016 HHA surveys has previously been undertaken on behalf of HHA by HR Wallingford (HR Wallingford, 2017) and a comparison of the October 2016 HHA and July 2017 Cefas surveys has been carried out by Cefas on behalf of the MMO (Cefas, 2018). The Cefas analysis confirmed similarity between the 2016 HHA and 2017 Cefas surveys. On behalf of HHA, HR Wallingford has previously undertaken comparisons of the July 2017 and June 2018 surveys (HR Wallingford, 2019) and the June 2018 and September 2019 surveys (HR Wallingford, 2020).

The 2017, 2018, 2019 and 2020 HHA MBES survey data was provided to HR Wallingford in x, y, z format at 1 m horizontal resolution. The data provided was a “median selection” rather than being “raw” or “shoal biased” data. The survey data sets were processed and 3D surface models of the surveyed area created at 1 m horizontal resolution.

The 3D surfaces generated from the July 2017, June 2018, September 2019 and August 2020 surveys of disposal site TH027 are shown in Figure 4.1, Figure 4.2, Figure 4.3 and Figure 4.4.

The figures show that the seafloor within the footprint of disposal site TH027 has remained very flat with seabed elevations varying between -21 mCD in the north-west of the area to about -22.5 mCD in the south-east of the area. This range of bed levels is consistent with that measured during the 2016 HHA surveys.

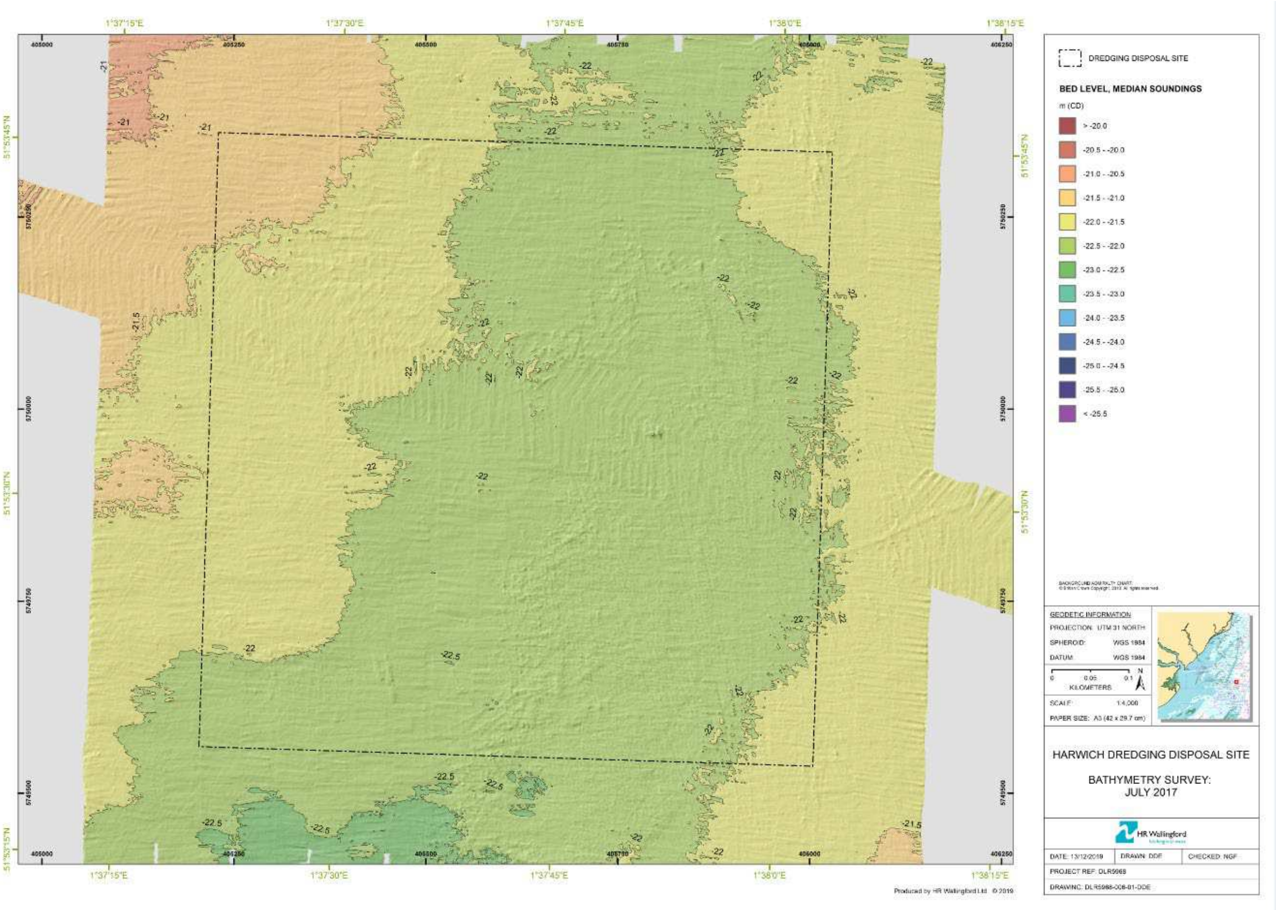


Figure 4.1: HHA July 2017 bathymetry survey of disposal site TH027

*Source: Harwich Haven Authority*

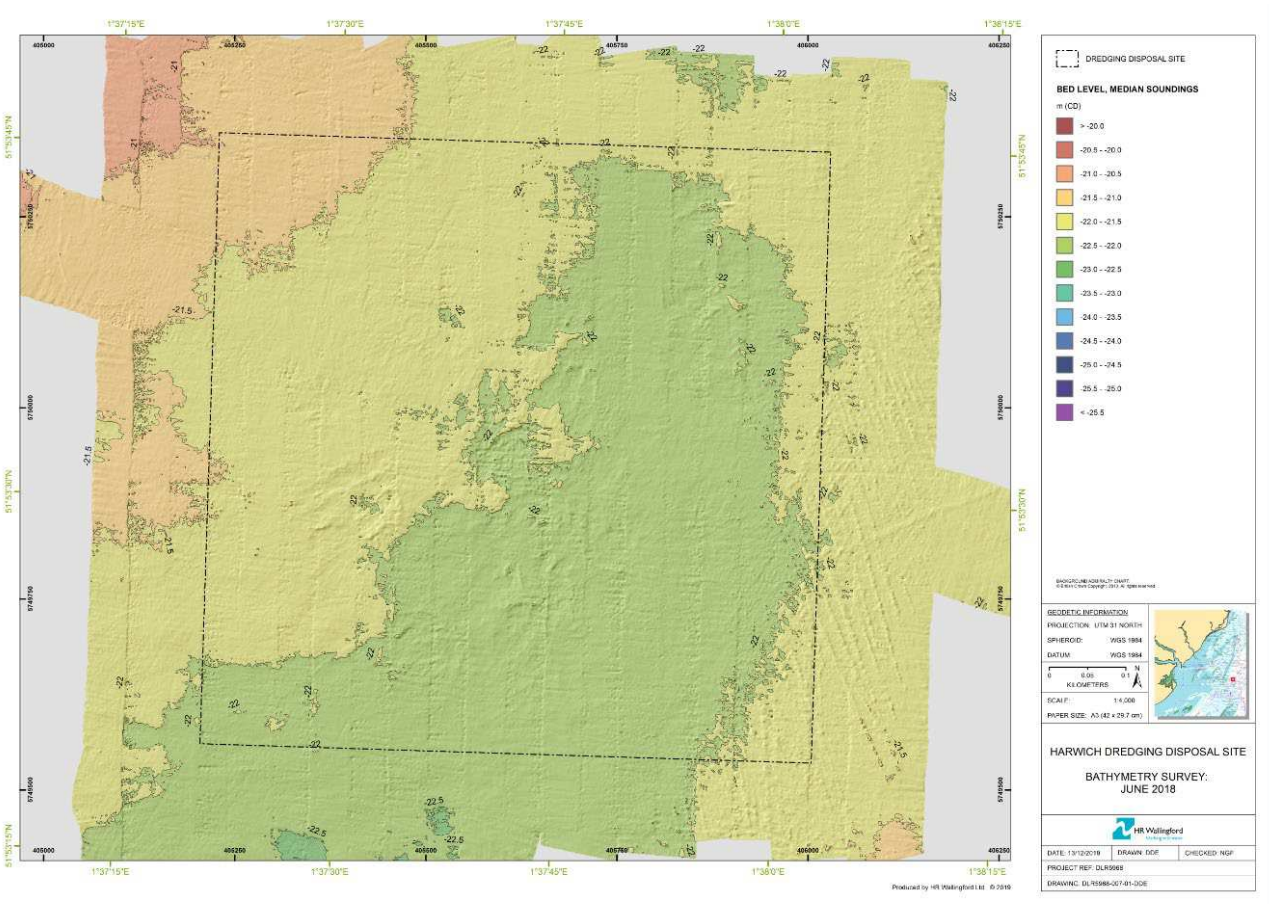


Figure 4.2: HHA June 2018 bathymetry survey of disposal site TH027

*Source: Harwich Haven Authority*

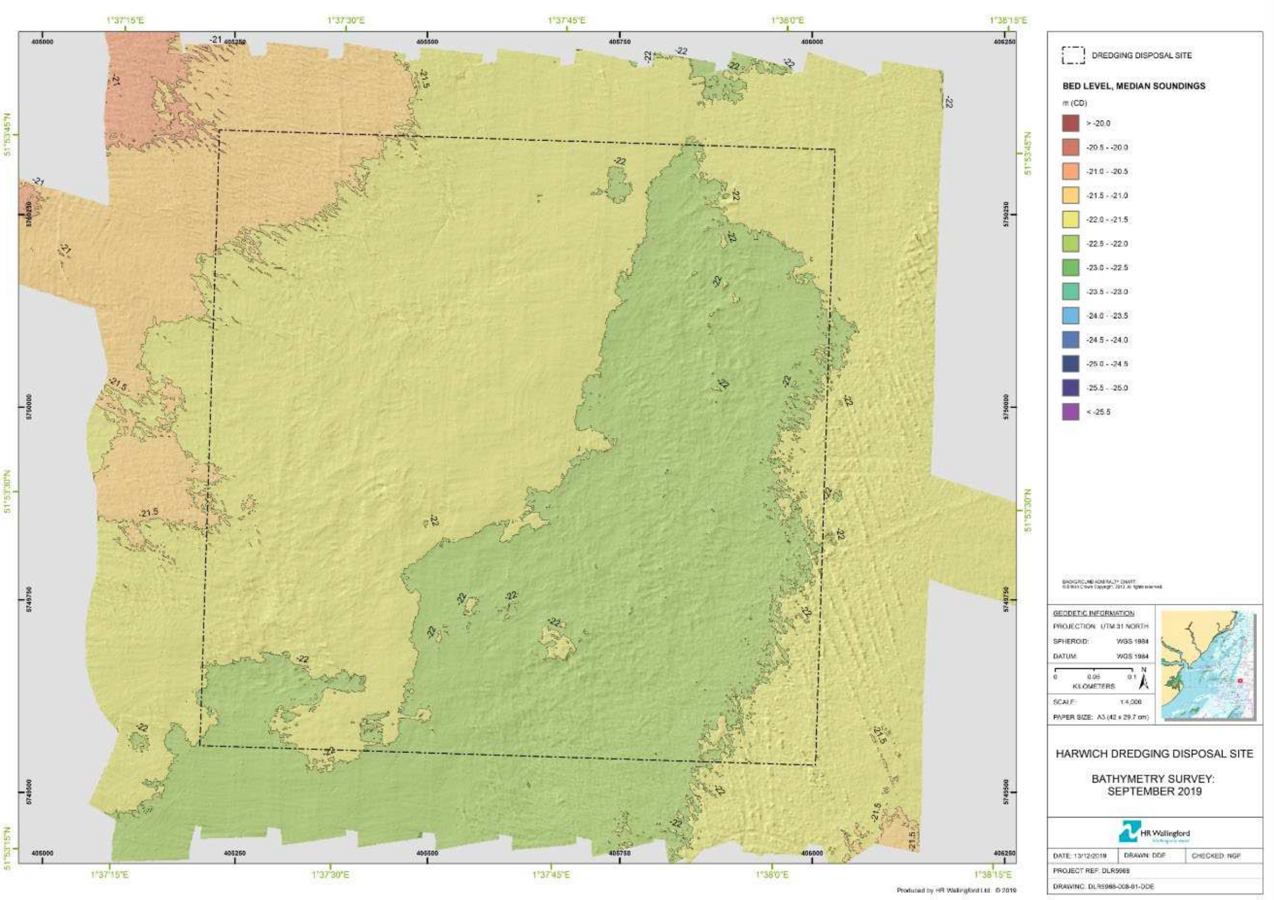


Figure 4.3: HHA September 2019 bathymetry survey of disposal site TH027

*Source: Harwich Haven Authority*

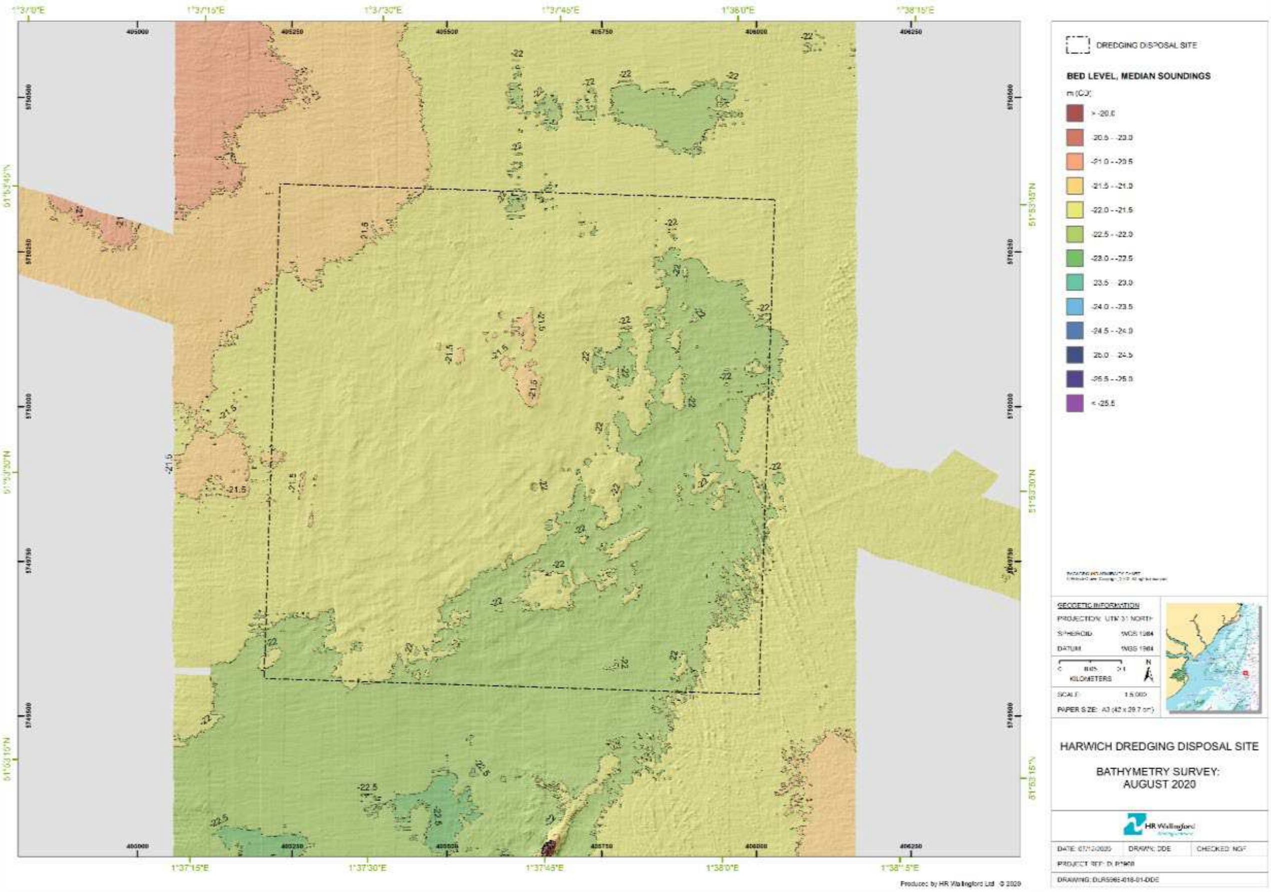


Figure 4.4: HHA August 2020 bathymetry survey of disposal site TH027

*Source: Harwich Haven Authority*

## 4.2. Changes in bathymetry

To identify areas of the seabed where changes in seabed elevation had occurred during the period between the July 2017 and August 2020 surveys difference models were generated by subtracting one surface from the other. As the quoted vertical repeatability / accuracy of MBES surveys is ±0.2 m, only changes in seabed level of greater than 0.2 m (accretion or erosion) are shown in the difference model. Any changes smaller than this are coloured in white in the difference models.

Figure 4.5 shows the changes in seabed elevation that occurred during the period between the July 2017 baseline survey and the June 2018 survey (i.e. June 2018 minus July 2017).

Figure 4.6 shows the changes in seabed elevation that occurred during the period between the June 2018 survey and the September 2019 survey (i.e. September 2019 minus June 2018).

Figure 4.7shows the changes in seabed elevation that occurred during the period between the August 2020 survey and the September 2019 survey (i.e. August 2020 minus September 2019).

Figure 4.8 shows the changes in seabed elevation that occurred during the period between the July 2017 baseline survey and the August 2020 survey (i.e. August 2020 minus July 2017).

Where accretion volumes are reported in the following sections, these include changes in seabed level of less than 0.2 m.

### 4.2.1. July 2017 to June 2018

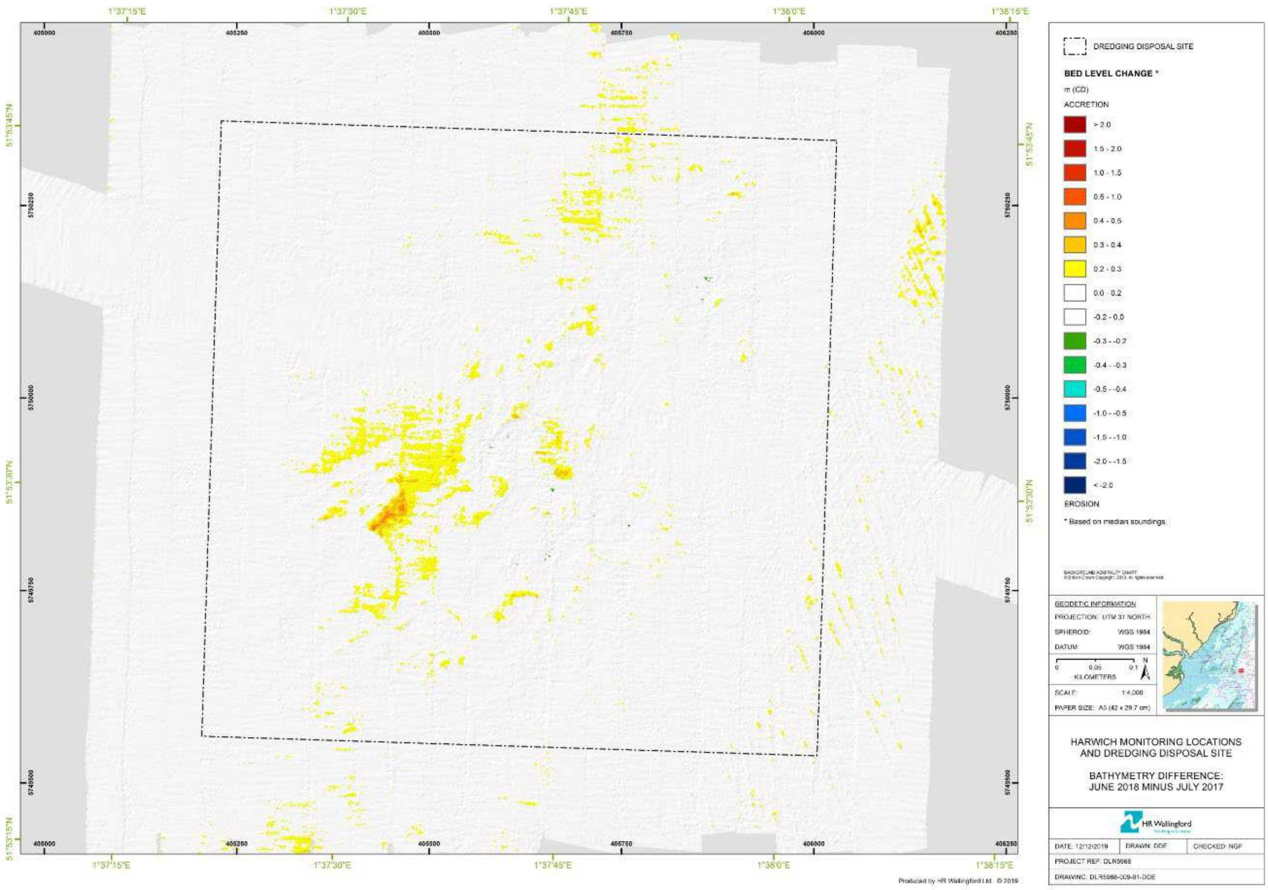


Figure 4.5: Disposal site TH027 bathymetry difference June 2018 minus July 2017 at a minimum resolution of ±0.2 m

*Source: Harwich Haven Authority*

The changes in bathymetry that occurred between 14 July 2017 and 26 June 2018 are shown in Figure 4.5 and described in detail in HR Wallingford (2019). During this period one maintenance dredging campaign took place in June 2018 where about 215,000 Tonnes Dry Solids (TDS) of material was disposed of at disposal site TH027 (Table 2.1).

Within the outer areas of disposal site TH027 there is generally no measurable change (i.e. ±0.2 m) in seabed elevation (shown as white in Figure 4.5). In the central north-south area patches of accretion of between 0.2 m and 0.4 m (shown as yellow and orange) can be seen over relatively small areas of the seabed. The volume of accretion within the boundary of TH027 between the 2017 and 2018 surveys has been calculated to be about 57,500 $m^3$. This accretion can likely be linked to the June 2018 disposal campaign during which the last loads of material were placed over the site 11 days prior to the June 2018 MBES survey having been undertaken. Assuming an in-situ dry density of about 500 $kg/m^3$ for the settled material arising from the placement this volume of measurable accretion represents a mass of about

28,750 TDS, equivalent to about 13.4% of the mass placed at the site during June 2018. Bed level changes of this magnitude are similar to those observed between consecutive MBES surveys during the monitoring of the trial placements (HR Wallingford, 2017).

### 4.2.2. June 2018 to September 2019

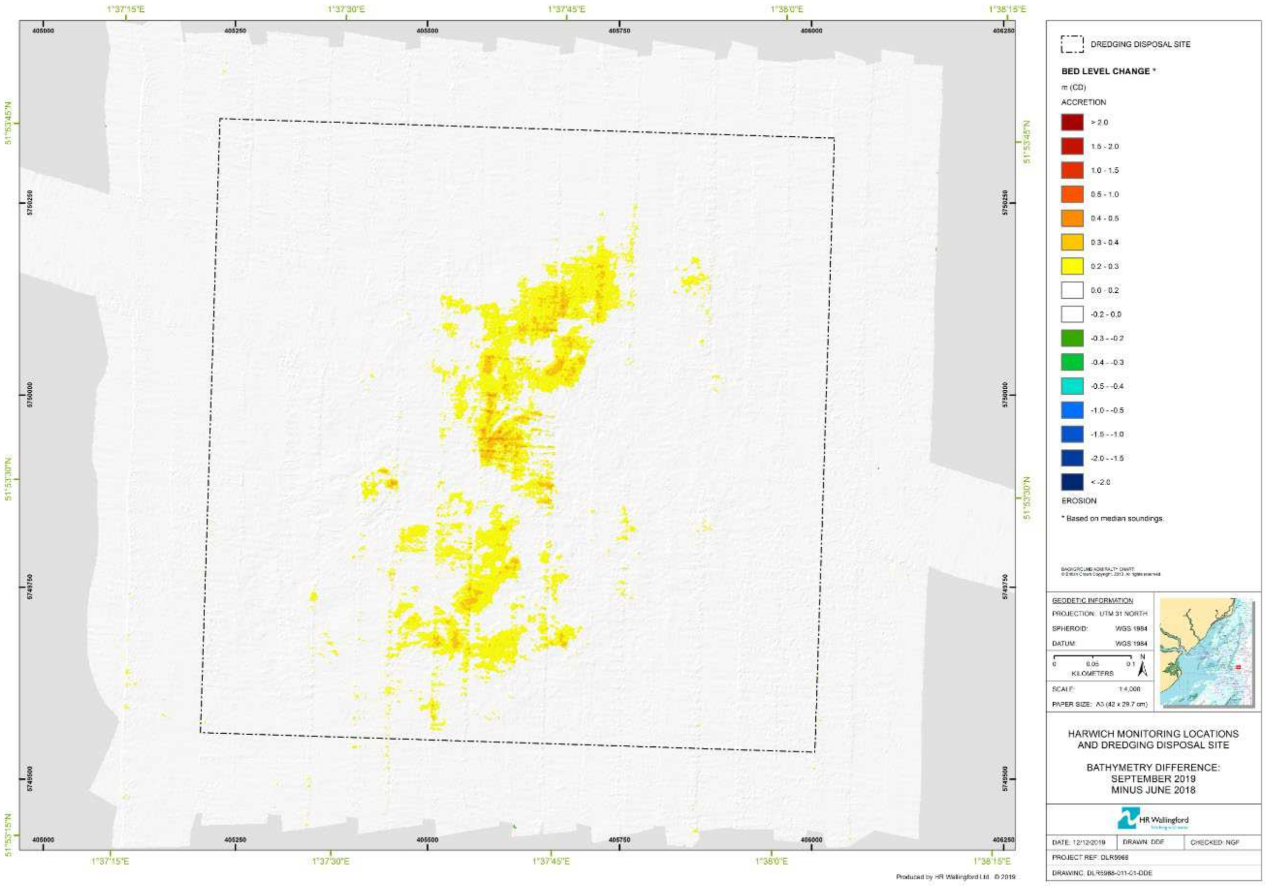


Figure 4.6: Disposal site TH027 bathymetry difference September 2019 minus June 2018 at a minimum resolution of ±0.2 m

*Source: Harwich Haven Authority*

The changes in bathymetry that occurred between 26 June 2018 and 10 September 2019 are shown in Figure 4.6. During this period (since August 2018) five maintenance dredging campaigns had taken place where a total of about 1,295,500 TDS of material was disposed of at disposal site TH027 (Table 2.1).

Within the outer areas of disposal site TH027 there is generally no measurable change (i.e. ±0.2 m) in seabed elevation (shown as white in Figure 4.6). In the central north-south area patches of accretion of between 0.2 m and 0.4 m (shown as yellow and orange) can be seen on the seabed. The volume of accretion within the boundary of TH027 between the 2018 and 2019 surveys has been calculated to be about 40,000 m$^3$. This measured accretion can likely be linked to the disposal activities that have taken place at the site during this period. Assuming an in-situ dry density of 500 kg/m$^3$ this volume represents mass of about 20,000 TDS, equivalent to about 1.5% of the mass placed at the site during the period.

## 4.2.3. September 2019 to August 2020

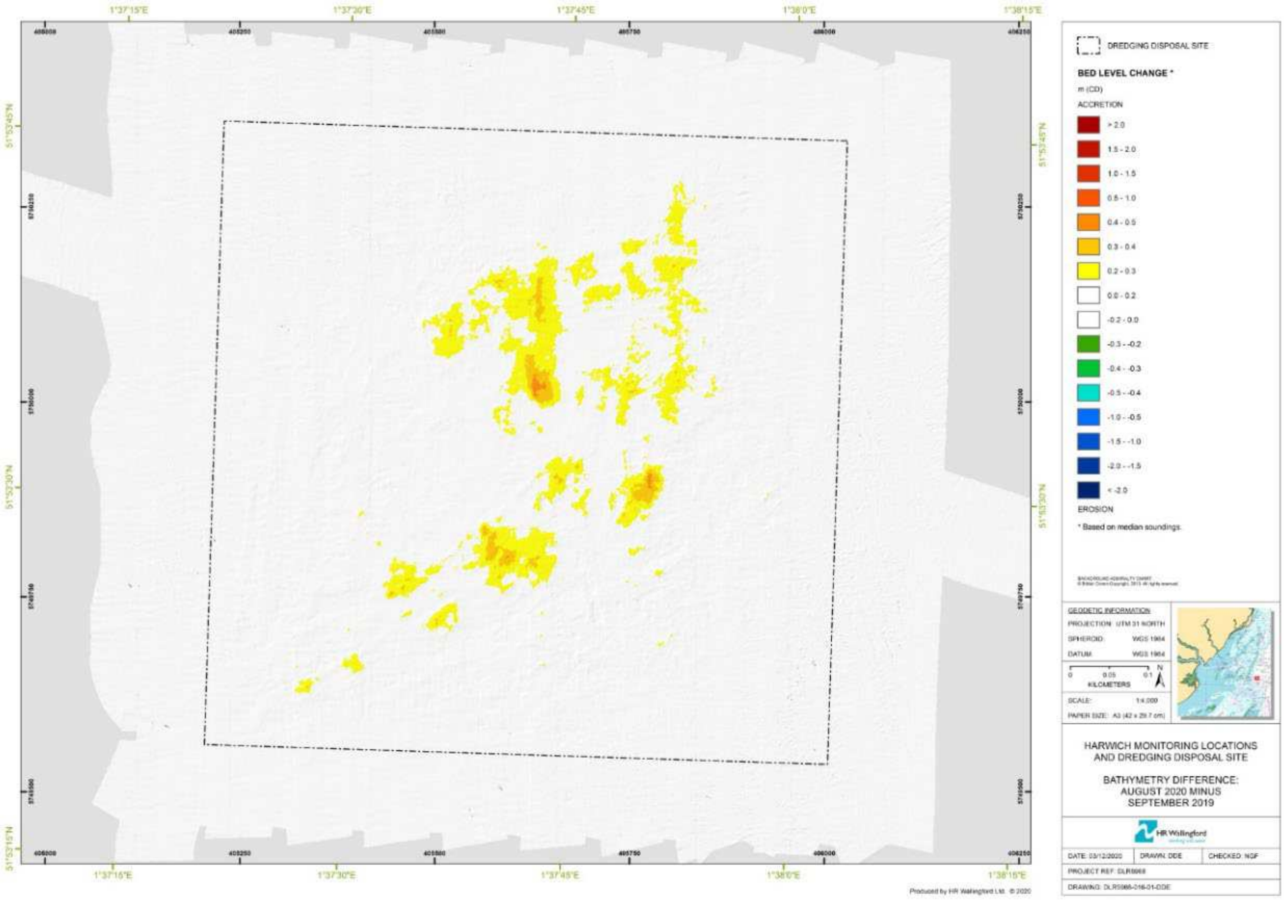


Figure 4.7: Disposal site TH027 bathymetry difference August 2020 minus September 2019 at a minimum resolution of ±0.2 m

*Source: Harwich Haven Authority*

The changes in bathymetry that occurred between 10 September 2019 and 3 August 2020 are shown in Figure 4.7. During this period (since November 2019) four maintenance dredging campaigns had taken place where a total of about 871,250 TDS of material was disposed of at disposal site TH027 (Table 2.1).

Within the outer areas of disposal site TH027 there is generally no measurable change (i.e. ±0.2 m) in seabed elevation (shown as white in Figure 4.7). In the central north-south area patches of accretion of between 0.2 m and 0.5 m (shown as yellow and orange) can be seen on the seabed. The volume of accretion within the boundary of TH027 between the 2019 and 2020 surveys has been calculated to be about 40,500 $m^3$. This measured accretion can likely be linked to the disposal activities that have taken place at the site during this period. Assuming an in-situ dry density of 500 $kg/m^3$ this volume represents mass of about 20,250 TDS, equivalent to about 2.3% of the mass placed at the site during the period.

### 4.2.4. July 2017 to August 2020

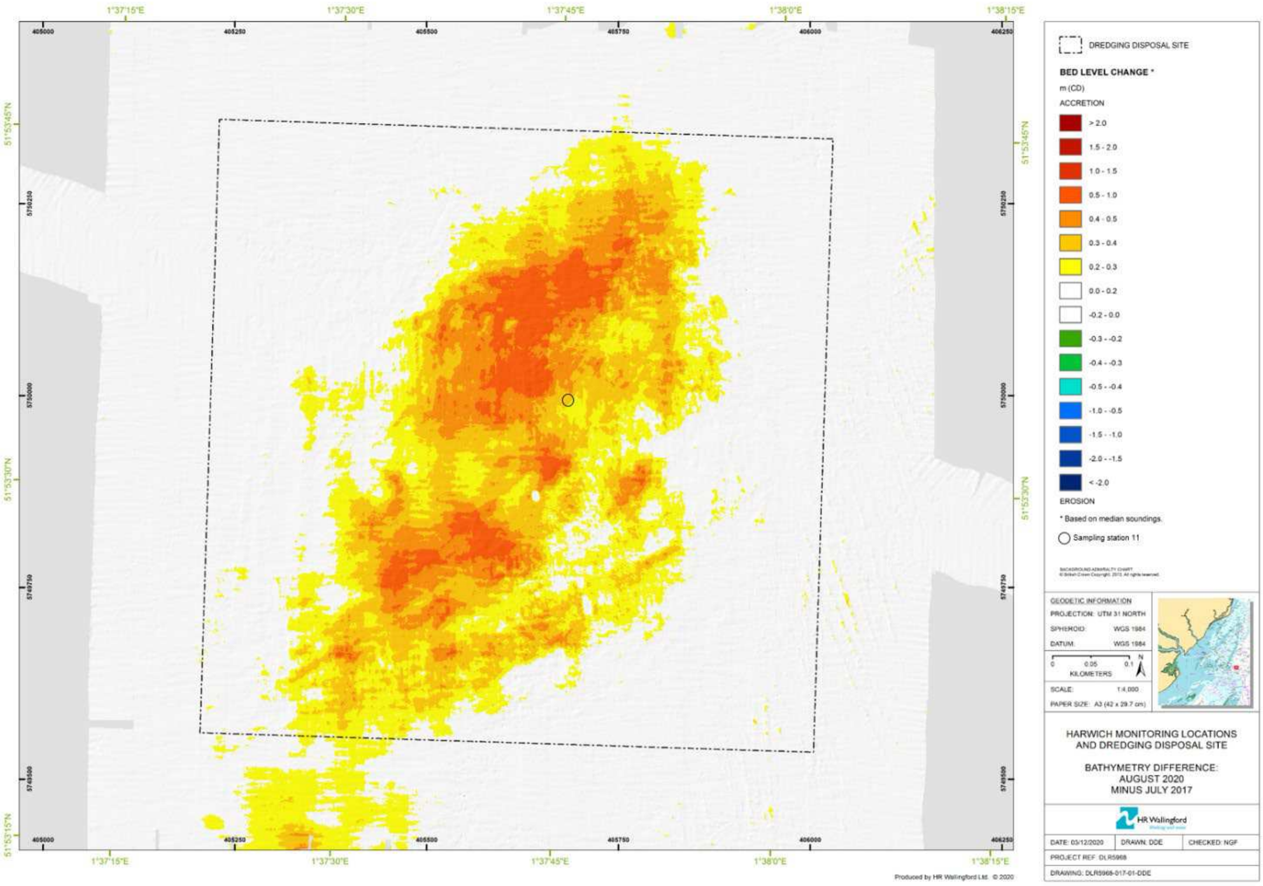


Figure 4.8: Disposal site TH027 bathymetry difference August 2020 minus July 2017 at a minimum resolution of ±0.2 m

*Source: Harwich Haven Authority*

The changes in bathymetry that occurred between the baseline survey of 14 July 2017 and the annual monitoring survey of 3 August 2020 are shown in Figure 4.8. During this period a total of about 2,381,750 TDS of material was disposed of at disposal site TH027 (Table 2.1).

Figure 4.8 shows that since disposal activities commenced at TH027 there is no measurable change (i.e. ±0.2 m) in seabed elevation within the west, and east outer areas of disposal site TH027. In the central north-south area accretion of between 0.2 m and 0.8 m (shown as yellow, orange and red) can be seen on the seabed. This measured accretion, which is apparent both within the boundary of the disposal site and, to a lesser extent, in an area to the south west of the disposal site boundary, can likely be linked to the disposal activities that have taken place at the site since June 2018. The extent of accretion seen over this 3 year period is greater than that seen during each of the three 1 year periods July 2017 to June 2018 (Figure 4.5), June 2018 to September 2019 (Figure 4.6) and September 2019 to August 2020 (Figure 4.7).

To better capture the changes in bathymetry that are being observed to the south west of the disposal site boundary, southern extent of the MBES survey area was extended by a further 200 m to the south in 2020 (as shown in Figure 4.4). This extended survey area, which also includes a 200 m extension to the north of the disposal site boundary, area will be adopted for future annual MBES surveys to allow changes in bathymetry in these areas to also be monitored.

In Figure 4.9 the extent of the accretion observed between 2017 and 2020 (Figure 4.8) is plotted as an overlay on the July 2017 bathymetry (Figure 4.1). Figure 4.9 demonstrates that, in general, the accretion has occurred in depressions on the seabed i.e. the seabed is becoming flatter as a result of this infilling.

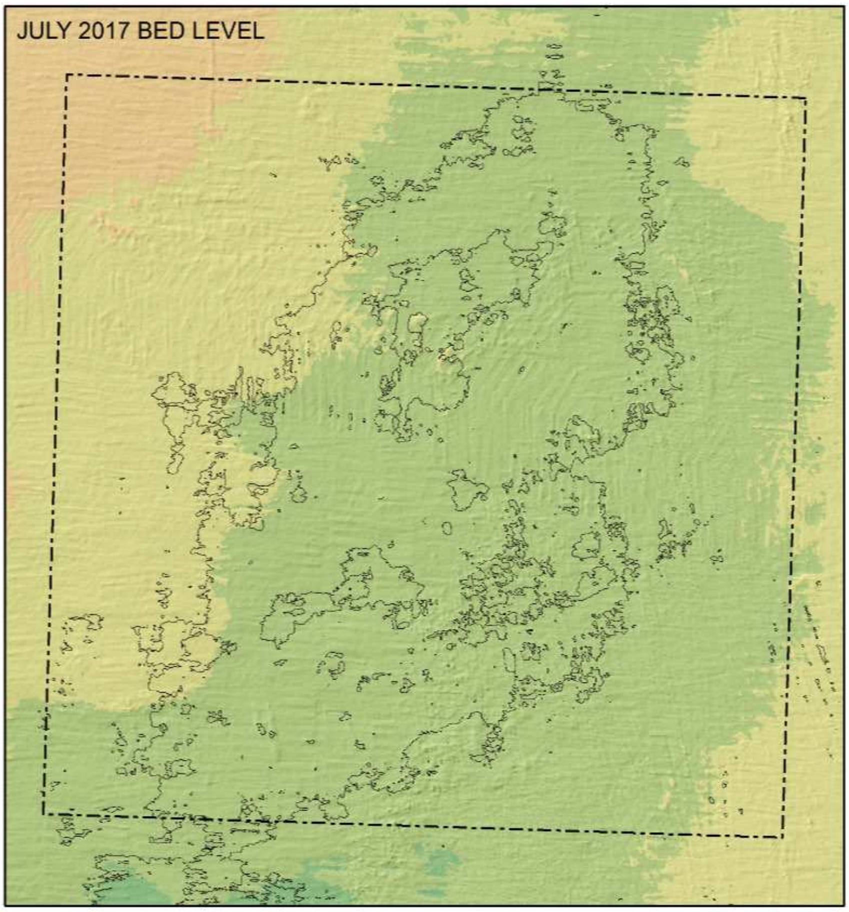


Figure 4.9: Extent of the accretion observed between 2017 and 2020 as an overlay on the July 2017 bathymetry

*Source: Harwich Haven Authority*

The volume of accretion that has taken place within the boundary of TH027 during the period between the 2017 and 2020 surveys has been calculated to be about 121,750 m$^3$. Assuming an in-situ dry density of 500 kg/m$^3$ this volume represents mass of about 60,900 TDS, equivalent to about 2.6% of the mass placed at the site during the period. It can be confirmed that the disposal site is behaving as a dispersive site with almost all the material disposed at the site dispersing away from the site following disposal.

# 5. Annual sediment and benthic surveys

## 5.1. Introduction

Sediment and benthic surveys of the TH027 disposal site have been carried out since August 2012 by Thomson Unicomarine (on behalf of HHA) and Cefas as shown in Table 5.1.

Table 5.1: TH027 sediment and benthic surveys

| Survey date | Surveyor | No. sampling stations visited | No. stations at which samples recovered | Days after last disposal |
|---|---|---|---|---|
| 8-10 Aug 2012 | Thomson Unicomarine | 59 | 59 | N/A |
| 18 May 2016 | Thomson Unicomarine | 21 | 20 | N/A |
| 19 July 2016 | Thomson Unicomarine | 21 | 20 | 32 |
| 13 Sep 2016 | Thomson Unicomarine | 21 | 17 | 12 |
| Jul 2017 | Cefas | 20 | 20 | >300* |
| 15-16 Aug 2017 | Thomson Unicomarine | 21 | 21 | 350 |
| 1-2 Aug 2018 | Thomson Unicomarine | 24 | 23 | 47 |
| 28-29 Aug 2019 | Thomson Unicomarine | 26 | 26 | 34 |
| 6-7 Aug 2020 | Thomson Unicomarine | 26 | 25 | 44 |

** Note: Precise date of Cefas survey not known*

The August 2012 survey was carried out by Thomson Unicomarine as part of the site selection exercise (HR Wallingford, 2013). During this initial site characterisation survey 59 sampling stations were identified in the vicinity of the TH027 disposal site (HR Wallingford, 2013).

The May, July and September 2016 surveys were carried out to meet a condition of an MMO Marine Licence (L/2013/00392/3, issued on 6 May 2016) which permitted two trial disposals of dredged material at TH027. These monitoring surveys (HR Wallingford, 2017) were followed by HHA's annual survey of August 2017. During these four surveys 21 sampling stations were visited on each occasion (these stations being an agreed sub-set of the August 2012 survey sampling stations). The August 2018, August 2019 and August 2020 surveys were undertaken to meet a condition of the current MMO Marine Licence. During these surveys the sampling stations visited comprised the 21 stations visited in 2016 and 2017 plus a number of additional stations appointed by an on-board Harwich Fishermen's representative. During the 2018 survey an additional 3 stations were visited (Stations 100, 101 and 102) and during the 2019 and 2020 surveys a further 2 stations were visited (Stations 103 and 104).

Note that, as shown in Table 5.1, samples were not successfully recovered from all stations due to a rocky substrate being encountered at some locations. The stations successfully sampled during the 2016, 2017, 2018, 2019 and 2020 Thomson Unicomarine surveys are shown in Table 5.2.

Table 5.2: Stations at which samples were successfully recovered during the 2016, 2017, 2018, 2019 and 2020 surveys

| Station | May-16 | Jul-16 | Sep-16 | Aug 17 | Aug 18 | Aug 2019 | Aug 2020 |
|---|---|---|---|---|---|---|---|
| 1 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 11 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 21 | ✓ | ✓ | × | ✓ | ✓ | ✓ | ✓ |
| 22 | × | × | ✓ | ✓ | × | ✓ | ✓ |
| 24 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 25 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 27 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 28 | ✓ | ✓ | × | ✓ | ✓ | ✓ | ✓ |
| 36 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 37 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 39 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 40 | ✓ | ✓ | × | ✓ | ✓ | ✓ | ✓ |
| 42 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 43 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 45 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 46 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 49 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 51 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 52 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 55 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 59 | ✓ | ✓ | × | ✓ | ✓ | ✓ | ✓ |
| 100 | N/A | N/A | N/A | N/A | ✓ | ✓ | ✓ |
| 101 | N/A | N/A | N/A | N/A | ✓ | ✓ | ✓ |
| 102 | N/A | N/A | N/A | N/A | ✓ | ✓ | × |
| 103 | N/A | N/A | N/A | N/A | N/A | ✓ | ✓ |
| 104 | N/A | N/A | N/A | N/A | N/A | ✓ | ✓ |

*Source: Thomson Unicomarine*

The locations of the 21 sampling stations visited in 2016 and 2017 are shown in Figure 5.1. One of the objectives of the benthic monitoring undertaken in 2016 was to determine if there were any differences in the community composition before and after the trial disposals. The sampling stations from the 2016 and 2017 surveys were therefore grouped into treatment areas so that comparisons of the species community could be carried out to understand if there were:

- Any differences in community composition across the survey area;
- Any differences in community composition between surveys.

The treatment areas defined in 2017 are as follows and as shown in Figure 5.1:

- Central area (the disposal site itself) – Station 11;
- Disposal area (area of potential effect around the disposal site) – Stations 1, 21, 25 and 28;

- Crab area (suitable crab/lobster site to the west of the disposal site) – Stations 27, 22 and 24;
- Inner area – Stations 36, 27, 52, 55, 39 and 40;
- Outer reference area – Stations 45, 46, 59, 49, 42, 43 and 51.

N.B. Sampling Station 11 was not included in the Disposal treatment area as this was the proposed location of disposal and therefore likely to be affected by the actual sediment disposal. As such any data from this station may have skewed the results of any analysis of the treatment area in which is it included, therefore it formed the Central treatment area on its own.

For the purpose of analysing the 2018, 2019 and 2020 benthic data, Stations 100 to 104 were included and assigned to the treatment areas defined in 2017 as shown in Figure 5.1.

- Central area – Station 100;
- Disposal area (area of potential effect) – Stations 101, 103, and 104;
- Crab area (suitable crab/lobster site) – Station 102.

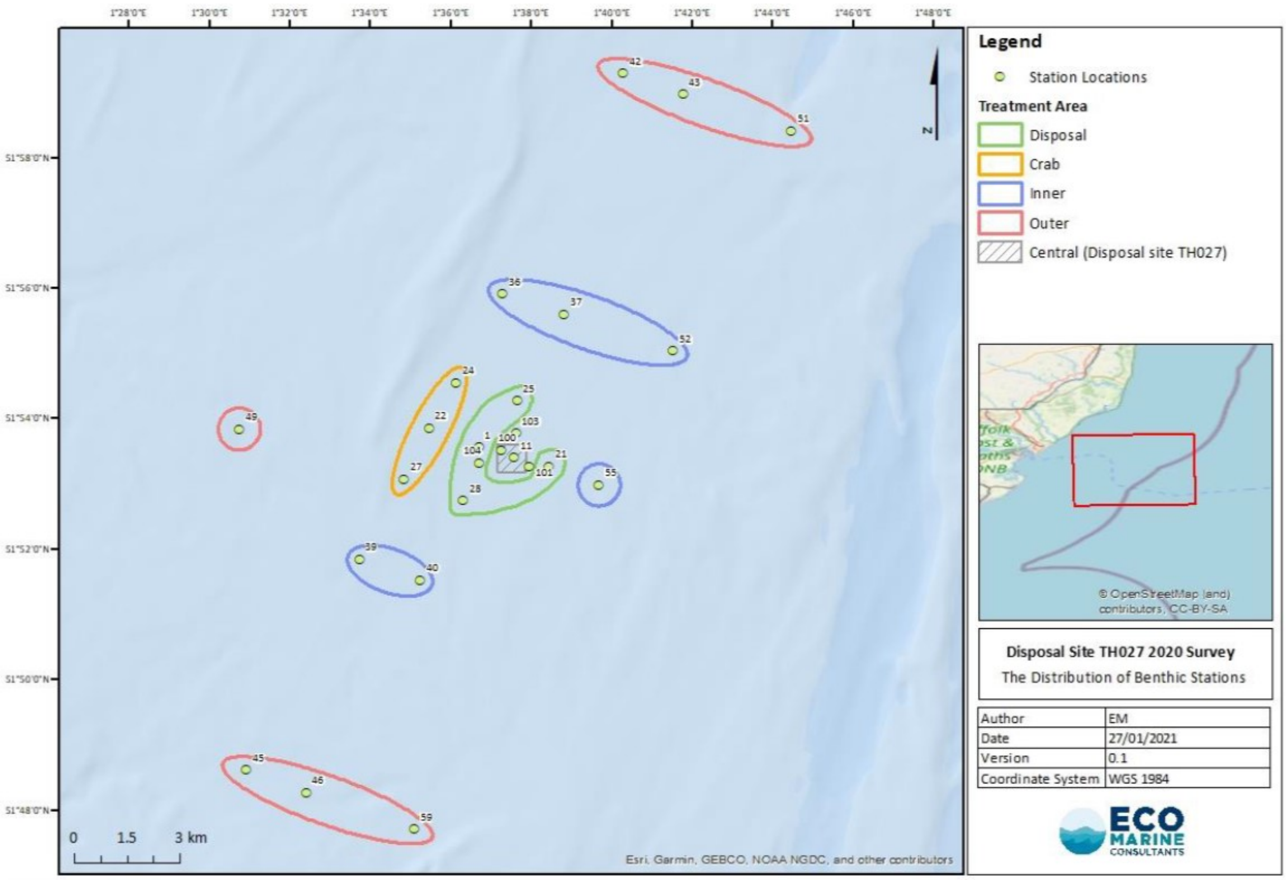


Figure 5.1: Sampling stations showing group treatment areas used for statistical analysis

*Source: ECO Marine*

Statistical analyses of the benthic community composition undertaken in 2016 (HR Wallingford, 2017) suggested that there were no significant differences between the groups for any single survey or between the three surveys. There were no clear trends in the faunal assemblage in terms of species and abundance that could be directly related to the trial placement activities that had taken place at disposal site TH027.

These results suggested that the observed minor variations in number of species and individual abundances were due to natural variation and not related to the trial disposal activities.

A condition of the current MMO Marine Licence (L/2013/00392/4, issued on 28 February 2018) is that an annual sediment and benthic survey of the TH027 disposal site is carried out once per year (for a minimum of three years), between July and September and in between disposal campaigns. The condition proposes a minimum period of 4 weeks between the end of a disposal campaign and the survey commencing.

The most recent survey was undertaken by Thomson Unicomarine on behalf of HHA commencing 6 August 2020, i.e. 44 days (or 6 weeks and 2 days) after the 14 June – 23 June 2020 dredging and disposal campaign was completed (see Table 2.1). The sampling stations visited during the 2018 survey (24 stations) and the 2019 and 2020 surveys (26 stations) are shown in Figure 5.1. These stations comprised the 21 stations visited in 2016 and 2017 plus the additional stations appointed by an on-board Harwich Fishermen's representative during the 2018 and 2019 surveys, within a predetermined area (see Figure 5.2) agreed in consultation with CEFAS, Eastern IFCA and local fishermen.

As indicated in Table 5.2, no samples were acquired from Station 22 in 2018 due to a rocky substrate being encountered, samples were successfully recovered from 23 of the 24 stations visited. In 2019 samples were recovered from all 26 sampling stations as shown in Figure 5.2. In 2020, no samples were acquired from Station 102 due to a rocky substrate being encountered, samples were successfully recovered from 25 of the 26 stations visited.

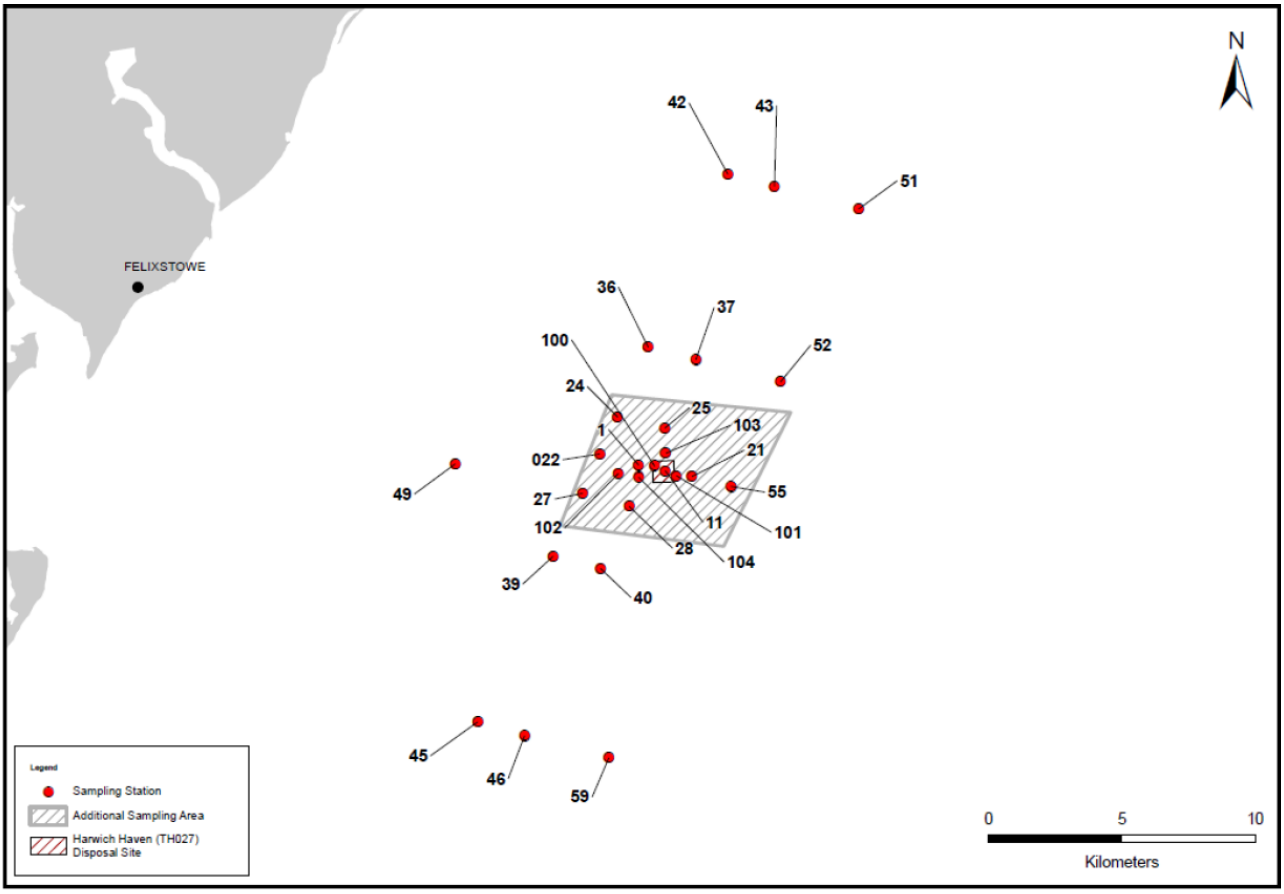


Figure 5.2: 2018, 2019 and 2020 sampling stations

*Source: Thomson Unicomarine, 2019*

*Notes: Sample recovery from Station 22 was unsuccessful in 2018 due to a rocky substrate being encountered*
*Sample recovery from Station 102 was unsuccessful in 2020 due to a rocky substrate being encountered*

The purpose of the annual sediment and benthic surveys is to verify that there is no permanent change to the seabed substrate and benthic community composition compared to the 2017 baseline conditions (outside of the disposal site).

In addition to the above Thomson Unicomarine surveys, Cefas undertook a survey of the TH027 disposal site in July 2017 as part of their MMO Coast of England Dredged Material Disposal Site Monitoring project (Cefas, 2018). During this survey 20 sampling stations were visited which comprised a further subset of the 59 stations visited by Thomson Unicomarine in 2012. The Cefas analyses of the benthic sample data concluded that there was no indication of any clear effects of the disposal of dredged material on the benthic communities in the survey area and were consistent with the findings of previous surveys of the site undertaken by Thomson Unicomarine in 2016.

## 5.2. Sediment particle size

During the 2016 and 2017 surveys 21 sediment sampling stations were visited. During the 2018 survey 24 stations were visited and in 2019 and 2020 a total of 26 stations were visited. Due to a rocky substrate being encountered at some sampling stations samples were not successfully recovered from all locations during all surveys (see Table 5.2). The samples obtained were analysed by Thomson Unicomarine for particle size distribution (PSD), the results of which have been presented graphically as shown in the Station 1 example provided in Figure 5.3.

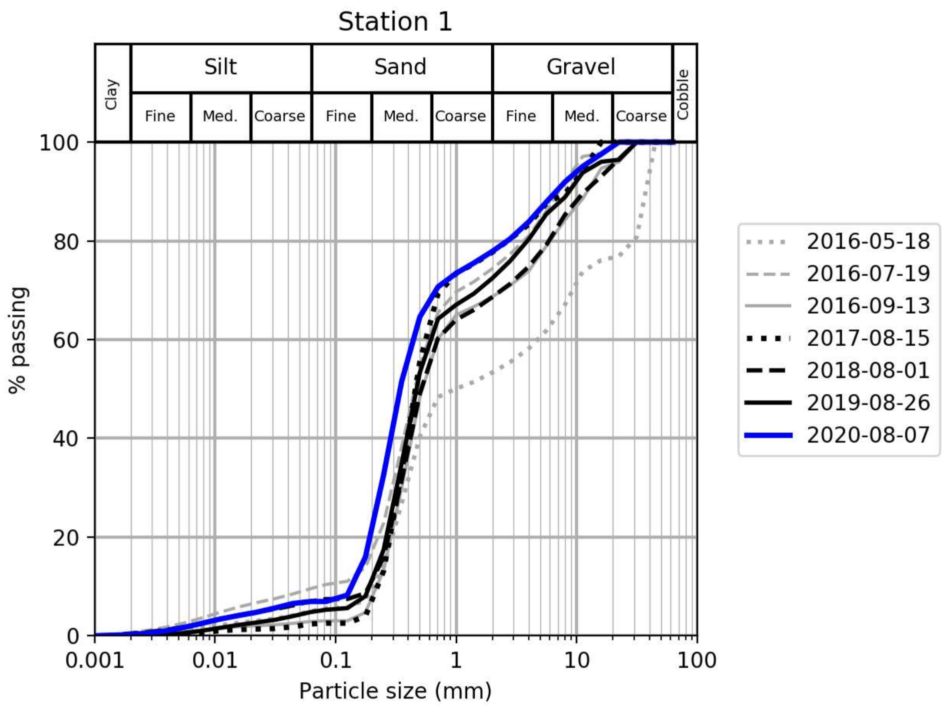


Figure 5.3: Example particle size distribution envelope (Station 1)

*Source: Thomson Unicomarine data*

The PSD envelopes for all sampling stations are provided in Appendix A. The figures are presented such that the most recent PSD is plotted as a solid blue line, the preceding PSD as a solid black line and earlier PSDs are plotted in dashed black and solid and dashed grey lines.

The figures in Appendix A demonstrate that whilst there is a degree of variability in particle size distribution at each of the sampling stations between 2016 and 2020, there is a general trend in the 2020 PSD data for the composition of the bed material over the entire survey area to have become coarser when compared to the 2019 PSD data, whilst remaining in the envelope of variability seen between 2016 and 2019.

During the 2018 survey the largest shift in particle size distribution compared to the 2017 PSD data was seen at sampling Station 11 (Figure 4.8 and Figure 5.4). As Station 11 was previously the only sampling station located within the Central treatment area (i.e. within the footprint of disposal site TH027) it was therefore expected that this station was most likely to be affected by the actual sediment disposal which finished 47 days prior to the stations being sampled (see Section 5.1). The 2019 PSD data showed that at Station 11 there had been some coarsening of the bed material since the 2018 survey such that the bed composition at this station is not too dissimilar to that seen in July 2016. The 2020 PSD data shows that the composition of the material at Station 11 to be finer than that seen in 2019, whilst remaining within the envelope of variability seen between 2016 and 2019. In 2020 the stations were sampled 44 days after the disposal activities finished.

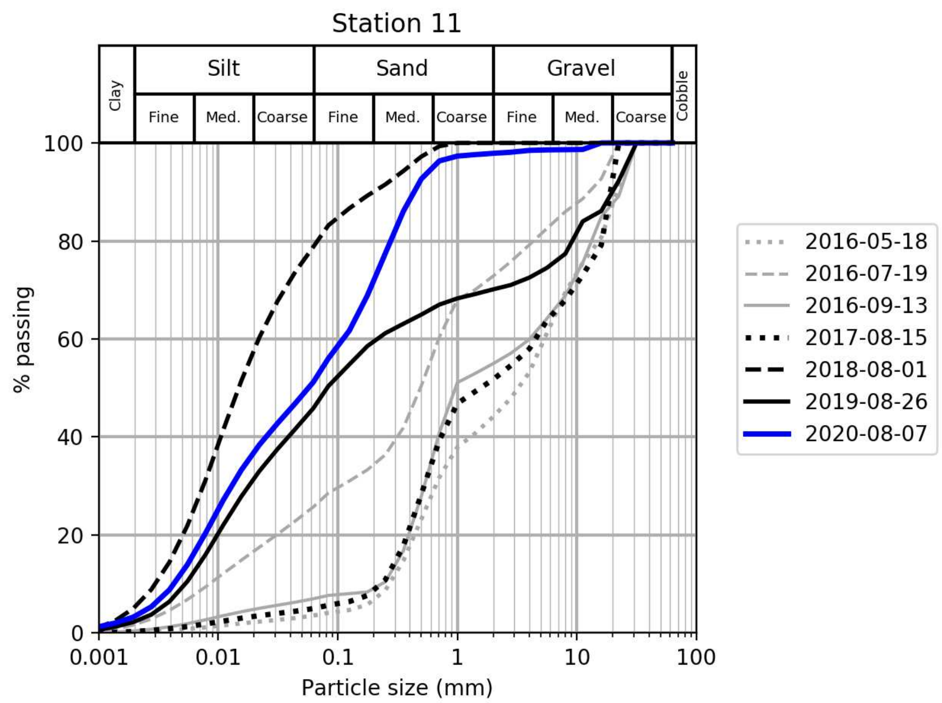


Figure 5.4: Particle size distribution envelope at Station 11

*Source: Thomson Unicomarine data*

Station 100, which is also located in the Central treatment area in the north-west corner of disposal site TH027 and Station 101, which is located in the Disposal treatment area close to the south-east corner of the disposal site (Figure 5.2), were selected by the on-board Harwich Fishermen's representative during the 2018 survey. In contrast to the fining of the bed material seen at Station 11, the bed composition at Station 100 (Figure 5.5) and Station 101 (Figure 5.6) was coarser in 2020 when compared to the 2019 PSD data.

The largest change in bed composition between the 2019 and 2020 surveys is seen at Station 21 in the Disposal treatment area and Station 22 in the Crab treatment area. At both of these sampling stations there has been a coarsening of the bed material between the 2019 and 2020 surveys such that the 2020 PSD is similar to that shown by the 2016-2018 PSD data.

In summary, most sampling stations over the entire survey area show the composition of bed material to have become coarser since 2019, so a reversal of the fining trend seen between 2018 and 2019.

Sampling stations within the Outer treatment areas (Figure 5.1), which are located some 11 km from the boundary of the disposal site, do not show any consistent trend. At 11 km to the south of the disposal site, Stations 45 and 46 show the material to be coarser in 2020 when compared to 2019 whereas Station 59 shows it to be finer. This is a reversal of the trend seen between 2018 and 2019. At 11 km to the north of the disposal site, Stations 42, 43 and 51 all show the material to be coarser in 2020 when compared to 2019.

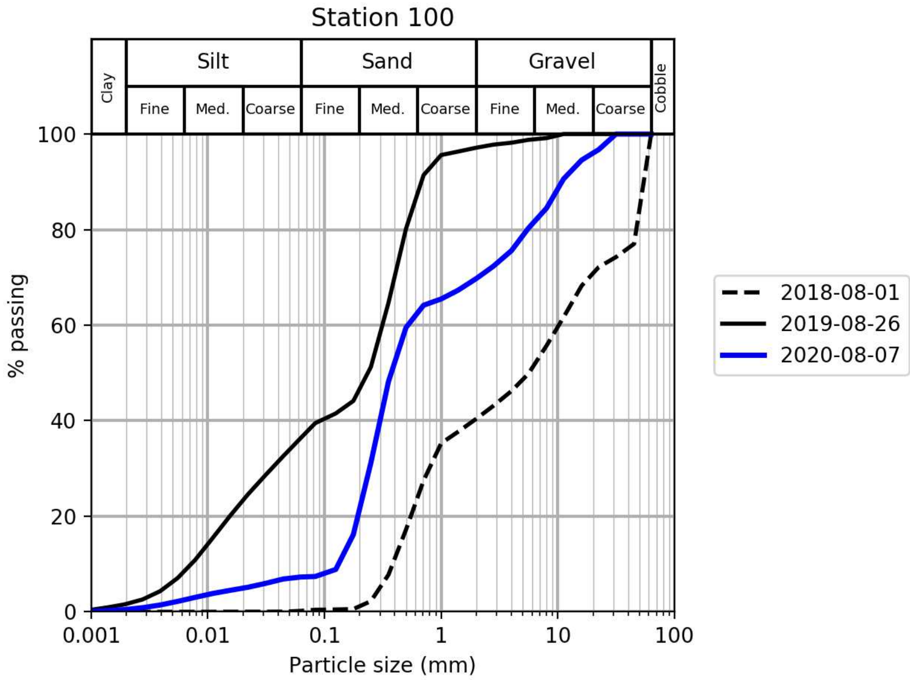


Figure 5.5: Particle size distribution envelope at Station 100

*Source: Thomson Unicomarine data*

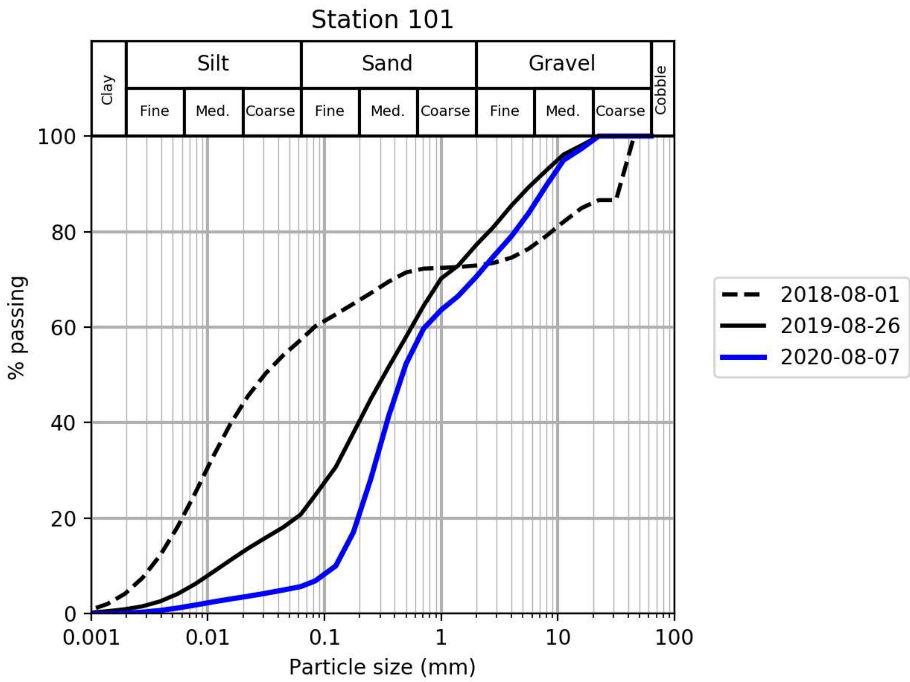


Figure 5.6: Particle size distribution envelope at Station 101

*Source: Thomson Unicomarine data*

## 5.3. Benthic surveys

Two replicate benthic samples were collected from 21 stations during the 2017 survey (Figure 5.1) and from 24 stations during the 2018 survey (Figure 5.2), noting that sample recovery from Station 22 was unsuccessful in 2018 due to a rocky substrate being encountered (Table 5.2).

During the 2019 and 2020 surveys, five replicate benthic samples were to be collected from 26 stations which comprised the same 24 stations visited during the 2018 survey plus two additional stations appointed by an on-board Harwich Fishermen's representative. One replicate was to be used for PSA analysis (Section 5.2), two for benthic biological analysis and two were to be stored for benthic biological analysis at a later date should this be deemed necessary. As indicated in Table 5.2, samples were collected from all 26 stations in 2019 and in 2020, no samples were recovered from Station 102 due to a rocky substrate being encountered. Replicate samples for storage were not successfully recovered from Stations 22, 100, 103 and 104 during the 2020 survey.

The samples were analysed by Thomson Unicomarine who also undertook a univariate analysis of the data. The results of the 2020 analyses are presented in the Thomson Unicomarine factual report (Thomson Unicomarine 2020) provided in Appendix B. The results of the 2017, 2018 and 2019 analyses are provided in previously issued factual reports (Thomson Unicomarine 2018a, 2018b and 2019).

Further, more detailed statistical analyses of the 2017, 2018, 2019 and 2020 macrofauna and PSD data have been carried out by Eco Marine Consultants using PRIMER. To understand the degree of similarity between the communities present cluster analysis has been carried out and to better understand the similarity relationships the data have been presented as a non-metric Multi-Dimensional Scaling (nMDS) ordination. The results of the statistical analyses for the data from 2017, 2018, 2019 and 2020 are summarised in Sections 5.3.1, 5.3.2, 5.3.3 and 5.3.4.

The detailed results of the statistical analyses for the data from 2020 are presented in the Eco Marine Consultants report (Eco Marine Consultants 2021) provided in Appendix C. The results of the 2017, 2018 and 2019 detailed analyses are provided in previously issued reports (Eco Marine Consultants 2019a, 2019b and 2020).

### 5.3.1. 2017 benthic and sediment data

For the August 2017 survey sediment samples were collected from the 21 stations shown in Figure 5.1. This survey was undertaken 350 days after the last placement at the TH027 disposal site in August 2016.

The analyses of the data indicated that the faunal communities observed in the vicinity of the TH027 disposal site in August 2017 were diverse and heterogeneous in nature. No strong patterns or zonation was apparent within either the sediment or faunal data.

The faunal communities within the survey area were found to be relatively homogeneous on a spatial scale. Communities documented within each reference area (see Figure 5.1) showed a high degree of overlap in terms of composition, and limited multivariate clustering was observed. Statistical testing confirmed a high degree of overlap in community composition between all station treatments, although the result was not significant. Those faunal communities found within the Central treatment area were found to be statistically similar to those found at some stations within both the Disposal and Inner treatment areas.

Analysis of sediment data indicated a similar pattern in results to the faunal data; a high degree of overlap in sediment composition between all station treatments was revealed through statistical testing, although the result was not significant.  Sediment types were well dispersed across the survey area.  The same sediment group that was observed within the centre of the disposal site was also recorded across every reference area, including those located to the far north and south of the survey array.

A significant relationship between sediment composition and faunal community composition was observed. The distribution of medium sand, fine sand and fine gravel was found to correlate most strongly with faunal patterns thus it can be said that the presence of these sediments has the greatest control on the faunal communities present in terms of the variables measured as part of the survey.

### 5.3.2. 2018 benthic and sediment data

The August 2018 survey represents the first monitoring survey for the disposal site as required under the new licence (note that this was deemed by the MMO to not be an "Annual" survey, see Section 1).  Sediment samples were collected from the 23 stations shown in Figure 5.2 (noting that sample recovery from Station 22 was unsuccessful in 2018 due to a rocky substrate being encountered).  This survey was undertaken 47 days after the placement at the TH027 disposal site in June 2018.

The data analyses indicated that the faunal communities documented in the 2018 survey of the TH027 disposal site were diverse and largely heterogeneous in nature.  No clear patterns were evident within the datasets, and a strong degree of similarity was recorded across communities dispersed across the survey array.

Statistical testing indicated that the communities documented within each reference area (see Figure 5.1) showed a high degree of overlap in terms of composition, and limited multivariate clustering was observed. Importantly the Central treatment area was not found to be unique across the survey area in terms of the faunal communities recorded, and displayed a statistical similarity to some stations found in the Disposal, Crab and Inner treatment areas.

Analysis of sediment data indicated a similar pattern in results to the faunal data; a high degree of overlap in sediment composition between all station treatments was revealed through statistical testing, although the result was not significant.  The same sediment group that was observed within the centre of the TH027 disposal site was also recorded across every reference area, including those located to the far north and south of the array.

A moderate significant relationship between sediment composition and faunal community composition was observed.  The distribution of gravel and coarse and fine sand was found to correlate most strongly with faunal patterns thus it can be said that the presence of these sediments has the greatest control on the faunal communities present in terms of the variables measured as part of the survey.

### 5.3.3. 2019 benthic and sediment data

The September 2019 survey represents the second monitoring survey (and the first "Annual" survey, see Section 1) for the disposal site as required under the new licence.  Sediment samples were collected from the 26 stations shown in Figure 5.2.  This survey was undertaken 34 days after the placement at the TH027 disposal site in July 2019.

The data analyses indicated that the mean faunal abundance and species diversity in 2019 was greatest in the Outer reference area. All other areas recorded considerably lower mean abundance and species diversity, including the Central treatment area, i.e. within the boundary of the TH027 disposal site.

Macrofaunal communities within the study area were found to be relatively heterogenous on a spatial scale. Limited clustering of stations was evident, and most treatment areas displayed a wide degree of overlap.

Statistical testing confirmed a high degree of overlap in community composition between all station treatments at a significant level, although pairwise testing between individual zones showed moderate-high dissimilarity between the Central and Outer treatment areas in terms of faunal community composition. These differences were principally accounted for by the relative contribution of *Pectinaria koreni*, *Abra spp.* and *Notomastus spp.* in the Central treatment area compared to a lack of these taxa in the Outer reference area.

The data analysed indicated that faunal communities found within the survey area were diverse and subject to a high level of spatial variance. Faunal communities found within the Central treatment area displayed a statistical similarity to some stations found in the Disposal, Crab and Inner treatment areas.

Sediment composition across the survey area was found to be relatively homogeneous and dominated by Gravelly Muddy Sand in all areas except the Outer reference area which was classified on average as Muddy Sandy Gravel. The greatest silt proportion was observed in the Central treatment area and the least in the Outer reference area. A high degree of overlap in sediment composition between all station treatments was revealed through statistical testing, although the result was not significant. Testing between individual treatment areas likewise indicated no significant differences in sediment composition.

A moderate significant relationship between sediment composition and faunal community composition was observed in the 2019 data. The distribution of gravel and coarse and fine sand was found to correlate most strongly with faunal patterns thus it can be said that the presence of these sediments has the greatest control on the faunal communities present in terms of the variables measured as part of the survey. This is in common with previous years.

### 5.3.4. 2020 benthic and sediment data

The August 2020 survey represents the third monitoring survey (and the second “Annual” survey, see Section 1) for the disposal site as required under the new licence. Sediment samples were collected from the 26 stations shown in Figure 5.2, (noting that sample recovery from Station 102 was unsuccessful in 2020 due to a rocky substrate being encountered). This survey was undertaken 44 days after the placement at the TH027 disposal site in June 2020.

The data analyses indicated that the mean faunal abundance and species diversity in 2020 was greatest in the Crab area, though there was considerable variation between stations in this area with one station having an abnormally high count of individuals. The Central area (i.e., within the boundary of the TH027 disposal site) contained the second lowest mean faunal abundance and the lowest species diversity.

Macrofaunal communities within the study area were found to be relatively heterogenous on a spatial scale. Limited clustering of stations was evident, and most treatment areas displayed a wide degree of overlap.

Statistical testing confirmed a high degree of overlap in community composition between all station treatments at a significant level, although pairwise testing between individual areas showed moderate-high dissimilarity between some areas in terms of faunal community composition. These differences were principally accounted for by the relative contribution of *Lagis koreni, Abra spp.* and *Notomastus spp*. in the Central area compared to a lack of these taxa in the Outer reference area.

The data analysed indicated that faunal communities found within the survey area were diverse and subject to a high level of spatial variance, though three faunal groups were found at only one station.

Sediment composition across the survey area was less homogeneous than in previous years and showed some spatial variation. Gravelly Muddy Sand was the most prominent mean sediment type across the survey area, recorded in the Central, Disposal and Inner areas. A high silt content was noted in the Central area compared to other areas, especially the Outer area which was dominated by coarse gravelly deposits. A moderate degree of overlap in sediment composition between all station treatments was revealed through statistical testing, testing between individual treatment areas indicated some considerable differences in sediment composition.

A moderate significant relationship between sediment composition and faunal community composition was observed in the 2020 data. The distribution of gravel and coarse and fine sand was found to correlate most strongly with faunal patterns thus it can be said that the presence of these sediments has the greatest control on the faunal communities present in terms of the variables measured as part of the survey. This is in common with previous years.

### 5.3.5. Temporal comparison of benthic and sediment data

Temporal analysis of sediment composition data indicated that that the greatest changes in sediment composition between the 2017 baseline and 2020 were within the Central treatment area, i.e., within the boundary of the TH027 disposal site. During this period, average percentages of gravel decreased by nearly a third, whilst the relative proportion of silt increased by approximately a quarter. This caused the mean Folk category for this area to change from Sandy Gravel in 2017 to Gravelly Muddy Sand in 2020. Sediment composition in other treatment areas was also variable between years, notably in areas with close proximity to the Central area, with each recording an increase in the proportion of silty sediment present and a decrease in the relative proportion of gravel. The exception to this was in the Outer reference area, where sediment composition remained relatively stable between the baseline and 2020 surveys, suggesting low natural variation across the site.

Changes in sediment composition in the past year were less pronounced but reflected a reduction in silt and an increase in sandy sediment across all areas. Statistical testing indicated moderate levels of similarity between years, although due to the small number of common replicates, a figure for similarity in the Central area over time could not be generated.

A decrease in mean faunal abundance and species diversity in the Central treatment area was observed between 2017 and 2020, though these indices increased between 2019 and 2020. Other treatment areas indicated variable positive trends in mean abundance and species diversity over time. A large increase in abundance was recorded in the Crab area in 2020; this was heavily influenced by an abnormally high count of individuals at one station. Change in the Outer reference area over time was low, suggesting that natural variation in faunal communities across the site is minimal.

Statistical testing revealed that faunal community composition between all years was moderately similar at a significant level. A high degree of overlap in faunal community composition was apparent when year and treatment were considered as factors in all areas except for the Central and Crab areas which showed considerable changes over time (noting the above comment relating to the Crab area).

The changes in faunal community composition observed in the Central area since the start of disposals were largely accounted for by a decrease in species associated with an established, coarse sediment habitat and an increase in taxa tolerant of, or having a high recoverability to, smothering and increased sedimentation. A considerable increase in the relative abundance of the noted disposal indicator species *Abra alba* and *Lagis koreni* were recorded.

Differences related to faunal community composition in other treatment areas followed a similar pattern though were less distinct. In the short term, moderate increases in taxa known to be indicators of disposal activity or tolerant to the impacts were all observed to increase between 2019 and 2020 in the Central, Disposal and Inner areas. It can be said that whilst impacts of disposal have been observed on faunal communities within the Central area, impacts outside of the footprint of TH027 are much reduced. Any impacts observed outside of TH027 are likely to be tied to changes in sediment composition, the presence of these sediments having the greatest control on the faunal communities present in terms of the variables measured as part of the survey.

### 5.3.6. Sabellaria

Sabellaria reefs are listed as a UKBAP Priority Habitat; OSPAR List of Threatened and/or Declining Species; and are also listed as an Annex 1 habitat under the EC Habitats Directive.

In 2017 *Sabellaria spinulosa* was the most abundant species found in the survey and was present at 10 of the 21 sampling stations.

In the 2018 survey *Sabellaria spinulosa* was the second most abundant species and was present at 12 of the 23 sampling stations.

In the 2019 survey *Sabellaria spinulosa* was the most abundant species and was present at 12 of the 26 sampling stations.

In the 2020 survey *Sabellaria spinulosa* was the third most abundant species and was present at 10 of the 25 sampling stations. Note that the most abundant species found in the 2020 survey was heavily influenced by an abnormally high count of individuals at one station in the Crab area.

# 6. Voluntary shellfish catch returns scheme

HHA has liaised with representatives of local fishermen regarding the establishment of a monthly voluntary shellfish catch returns scheme for crab and lobster fishermen who work in the vicinity of the new disposal site (TH027). The aim of such a scheme is to allow an assessment of catch relative to fishing effort to be made.

To date it has not been possible to establish such a voluntary scheme.

# 7. Available MMO catch and returns data.

## 7.1. Introduction

To provide a context for any information arising from the implementation of a voluntary shellfish catch returns scheme available reported data has been obtained and presented. There are two sources for the data: MMO data derived from the national data sets and data from the Eastern IFCA Crab and Lobster Stock Assessment from the local Monthly Shellfish Activity Returns to the Eastern IFCA. The Eastern IFCA data should be a subset of the MMO data.

## 7.2. MMO data

Monthly shellfish fishing effort and landings data has been obtained from the MMO for ICES rectangle 32F1 of area IVc (Southern North Sea). The monthly shellfish returns data are provided by national datasets for vessels greater than 10 m in length and by the Monthly Shellfish Activity Return (MSAR) scheme for vessels less than 10 m in length.

The crab landings data as provided by the MMO for ICES rectangle 32F1 are presented in Table 7.1 and Table 7.2 for the years 2015, 2016, 2017, 2018, 2019 and 2020[1]. The data are presented for UK vessels less than 10 m in length in Table 7.1 and for vessels greater than 10 m in length in Table 7.2.

The shellfish catch and returns data presented in Table 7.1 and Table 7.2 demonstrate crab landings of up to 14 tonnes per year between 2015 and 2019 for all vessels (up to 12.5 tonnes per year for vessels greater than 10 m in length and up to 1.5 tonnes per year for vessels less than 10 m in length). MMO returns data for 2020 has demonstrated an annual landing of about 49 tonnes for all vessels (22.4 tonnes for vessels greater than 10 m in length and 22.5 tonnes for vessels less than 10 m in length).

Table 7.1: ICES rectangle 32F1 crab landings (tonnes) – Vessels less than 10 m in length

| Month | 2015 | 2016 | 2017 | 2018 | 2019 | 2020[1] |
|---|---|---|---|---|---|---|
| January | | 0.036 | 0.055 | 0.0241 | | |
| February | | | | | | |
| March | | | 0.0166 | | 0.045 | 0.0638 |
| April | 0.019 | | 0.1029 | 0.0766 | 0.027 | |
| May | 0.0563 | | 0.0797 | 0.2733 | 0.092 | 0.009 |
| June | 0.077 | 0.0015 | 0.2454 | 0.252 | 0.0019 | 1.9039 |
| July | 0.0929 | | 0.1997 | 0.1251 | 0.0145 | 5.8437 |
| August | 0.1405 | 0.0017 | 0.2418 | 0.256 | 0.0045 | 4.8815 |
| September | 0.0461 | 0.003 | 0.1508 | 0.0012 | 0.001 | 5.7633 |
| October | 0.051 | 0.0235 | 0.1719 | 0.1432 | 0.0325 | 2.4267 |
| November | 0.053 | 0.0175 | 0.122 | 0.0972 | 0.183 | 5.0238 |
| December | 0.0124 | 0.015 | 0.1156 | | 0.1164 | 0.5701 |
| **TOTAL** | **0.5482** | **0.0982** | **1.5014** | **1.2487** | **0.5178** | **26.4858** |

*Source: MMO for ICES rectangle 32F1 of area IVc (Southern North Sea)*

Table 7.2: ICES rectangle 32F1 crab landings (tonnes) – Vessels greater than 10 m in length

| Month | 2015 | 2016 | 2017 | 2018 | 2019 | 2020[1] |
|---|---|---|---|---|---|---|
| January | | 0.024 | 0.012 | | | |
| February | 0.0063 | 0.036 | 0.005 | 0.012 | 0.0064 | |
| March | 0.0129 | 0.039 | 0.01 | 0.0944 | 0.012 | 0.0149 |
| April | 0.034 | 0.025 | 0.01 | 0.4668 | 0.01 | 5.8559 |
| May | 0.012 | 0.033 | 0.031 | 0.135 | 0.014 | 0.05 |

[1] Note that the 2020 data is currently in draft format and will not be in final quality checked form until after formal publication by the MMO in September 2021.

| Month | 2015 | 2016 | 2017 | 2018 | 2019 | 2020[1] |
|---|---|---|---|---|---|---|
| June | 0.003 | 0.018 | 0.664 | 0.005 | | 0.045 |
| July | 0.022 | 0.043 | 0.8365 | 0.007 | 0.004 | 1.208 |
| August | 0.005 | | 0.01 | 0.912 | 0.16 | 6.62 |
| September | 0.0439 | 0.018 | 4.285 | 0.01 | | |
| October | 0.021 | | 3.888 | 0.02 | 0.015 | 4.454 |
| November | 6.01 | | 2.664 | 0.026 | 0.958 | 3.754 |
| December | 0.01 | | | | | 0.342 |
| **TOTAL** | **6.1801** | **0.236** | **12.4155** | **1.6822** | **1.1794** | **22.3438** |

*Source: MMO for ICES rectangle 32F1 of area IVc (Southern North Sea)*

The MMO data presented in Table 7.1 and Table 7.2 represent the landings of crab resulting from fishing in ICES rectangle 32F1. It should be noted this data may include landings outside of the Eastern IFCA area.

## 7.3. Eastern IFCA data

The fishing effort and landings data for the Eastern IFCA Crab and Lobster Stock Assessment are provided monthly to the MMO under the Monthly Shellfish Activity Return (MSAR) scheme by all masters of under 10 metre fishing vessels with a shellfish entitlement.

Summary shellfish fishing effort and landings statistics for the years 2015, 2016, 2017 and 2018 have been extracted from Bridges (2019) for landings within ICES rectangle 32F1 and are presented in Table 7.3. The table includes both crab and lobster landings because the recorded effort relates to combined landings.

Table 7.3: Eastern IFCA summary data for ICES rectangle 32F1 - Vessels less than 10 m in length

| Year | Ports Fishing | Vessels Fishing | Effort (pot hauls) | Crab Landings (kg) | Lobster Landings (kg) |
|---|---|---|---|---|---|
| 2015 | 2 | 6 | 5,942 | 4,558 | 1,093 |
| 2016 | 5 | 6 | 743 | 430 | 192 |
| 2017 | 5 | 7 | 5,921 | 939 | 664 |
| 2018 | n/a | n/a | 1,528 | 453 | 147 |

*Source: Bridges (2019)*

The data for 2018 may be revised as final MSAR's are made available to the Eastern IFCA and published in the Crab & Lobster Stock Assessment for 2019.

At the time of writing, the Crab & Lobster Stock Assessment for 2019 had not been published by the Eastern IFCA for ICES rectangle 32F1 and as such data is not provided for 2019 in Table 7.3. If further information becomes available this will be incorporated in the 2021 Annual monitoring report.

It should be noted that ICES rectangle 32F1, located at the southern extremity of the Eastern IFCA district, overlaps considerably with Kent and Essex IFCA (Figure 7.1). For vessels less than 10 m in length, the Eastern IFCA crab landings data for ICES rectangle 32F1 (Table 7.3) would therefore be expected to be a subset of the MMO data for ICES rectangle 32F1 (Table 7.1). There is clearly a degree of inconsistency between the two datasets as, for example, in 2016 the reported crab landings within the segment of ICES rectangle 32F1 that falls within the Eastern IFCA district (Table 7.3) is greater than the total for ICES rectangle 32F1 (Table 7.1) as reported by the MMO based on the national data set (0.43 tonnes c.f. 0.0982 tonnes).

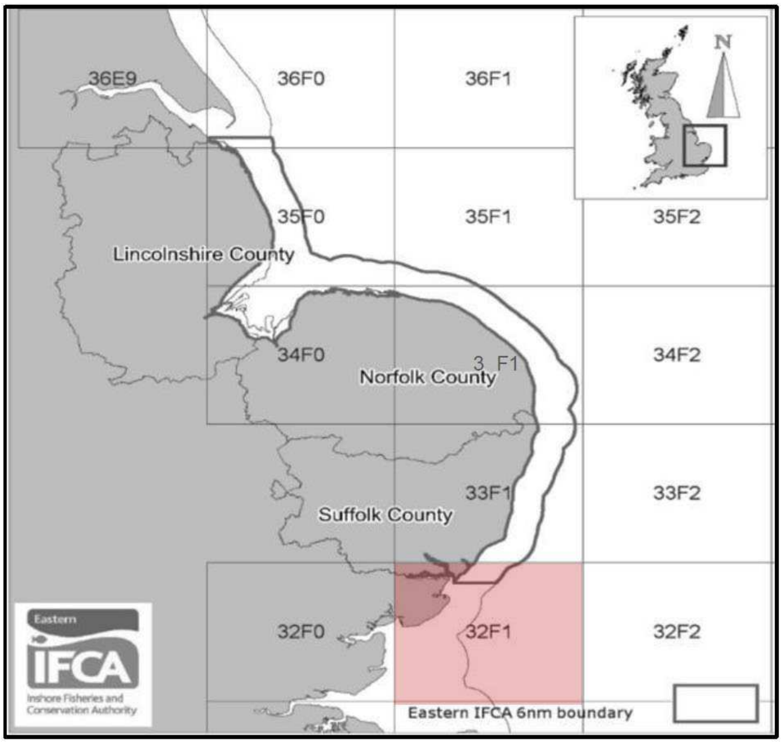


Figure 7.1: ICES rectangle 32F1 and Eastern IFCA 6nm boundary

*Source: Bridges (2018)*

# 8. Conclusions

During the course of a typical year five to six maintenance dredging campaigns at approximately 10 week intervals to remove mud from Harwich Harbour are undertaken by trailing suction hopper dredger. The dredged material is placed at a dispersive offshore disposal site. The duration of the campaigns are typically between one and two weeks, with between 40 and 80 trips being sailed. The volume of material dredged from Harwich Harbour during a campaign is typically between 200,000 $m^3$ and 600,000 $m^3$, approximately equivalent to 100,000 to 300,000 tonnes dry solids (TDS). Since June 2018 the placement has been to the new offshore disposal site (Harwich Haven – TH027). There were two trial placements to TH027 in the summer of 2016.

Multibeam echo sounder surveys of the TH027 disposal site undertaken in 2017, 2018, 2019 and 2020 show that since disposal activities commenced at TH027 there is no measurable change (i.e. ±0.2 m) in seabed elevation within the outer areas of disposal site TH027. In the central north-south area accretion of between 0.2 m and 0.8 m was measured between the 2017 and 2020 surveys. This accretion, which is apparent both within the boundary of the disposal site and in an area to the south west of the boundary, can likely be linked to the disposal activities that have taken place at the site since June 2018. The volume of accretion that has taken place within the boundary of TH027 during the period between the 2017 and 2020 surveys has been calculated to be about 121,750 $m^3$, equivalent to about 2.6% of the mass placed at the site during the period.

To better capture the changes in bathymetry that are being observed to the south west of the disposal site boundary, the southern extent of the MBES survey area was extended by a further 200 m to the south in 2020.

The seabed sediment surveys carried out in 2016, 2017, 2018, 2019 and 2020 demonstrated that, between 2017 and 2018 the particle size distribution within the Central and Disposal treatment areas became finer at a number of sampling stations. Between 2018 and 2019 an increase in the proportion of fine material was seen at most stations in the Outer reference area indicating that there was a trend for an increase in fine material over the entire survey area. Since 2019, changes in sediment composition have been less pronounced but reflected a reduction in silt and an increase in sandy sediment across all areas.

Seabed benthic surveys carried out in 2017, 2018, 2019 and 2020 demonstrated that the faunal communities observed in the vicinity of the TH027 disposal site were diverse and heterogeneous in nature. Since 2017 benthic faunal communities have demonstrated considerable temporal change in the Central treatment area, i.e. within the boundary of the TH027 disposal site. Whilst a large increase in abundance was recorded in the Crab area in 2020 (this was heavily influenced by an abnormally high count of individuals at one station) temporal changes in treatment areas more distant from the Central area show only small changes in species diversity. The distribution of gravel and coarse and fine sand was found to correlate most strongly with faunal patterns, confirming that the presence of these sediments has the greatest control on the faunal communities present in terms of the variables measured during the surveys.

Whilst HHA has liaised with representatives of local fishermen regarding the establishment of a monthly voluntary shellfish catch returns scheme for crab and lobster, to date it has not been possible to establish such a voluntary scheme.

Shellfish catch and returns data provided by the MMO for ICES rectangle 32F1 has demonstrated crab landings of up to 14 tonnes per year between 2015 and 2019 for all vessels (up to 12.5 tonnes per year for vessels greater than 10 m in length and up to 1.5 tonnes per year for vessels less than 10 m in length). MMO returns data for 2020 has demonstrated an annual landing of about 49 tonnes for all vessels (22.4 tonnes for vessels greater than 10 m in length and 22.5 tonnes for vessels less than 10 m in length).

# 9. References

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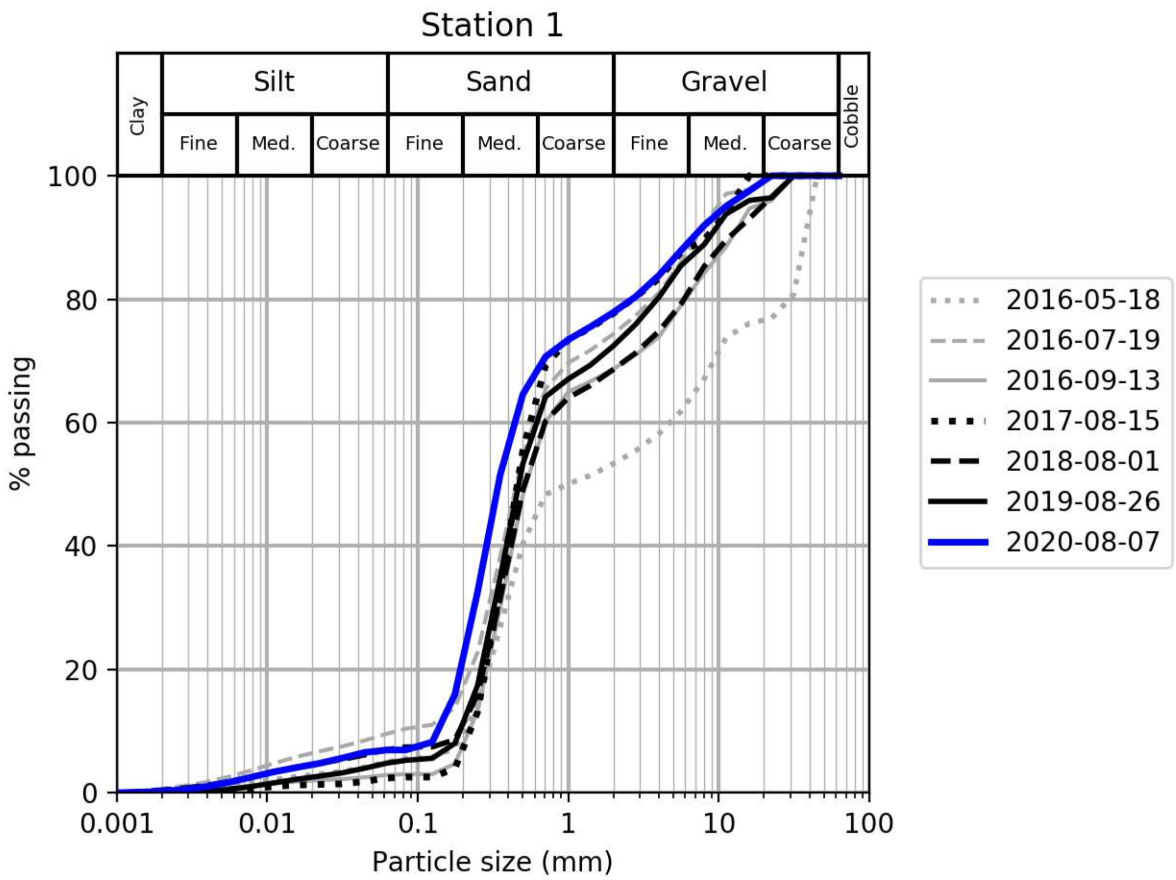
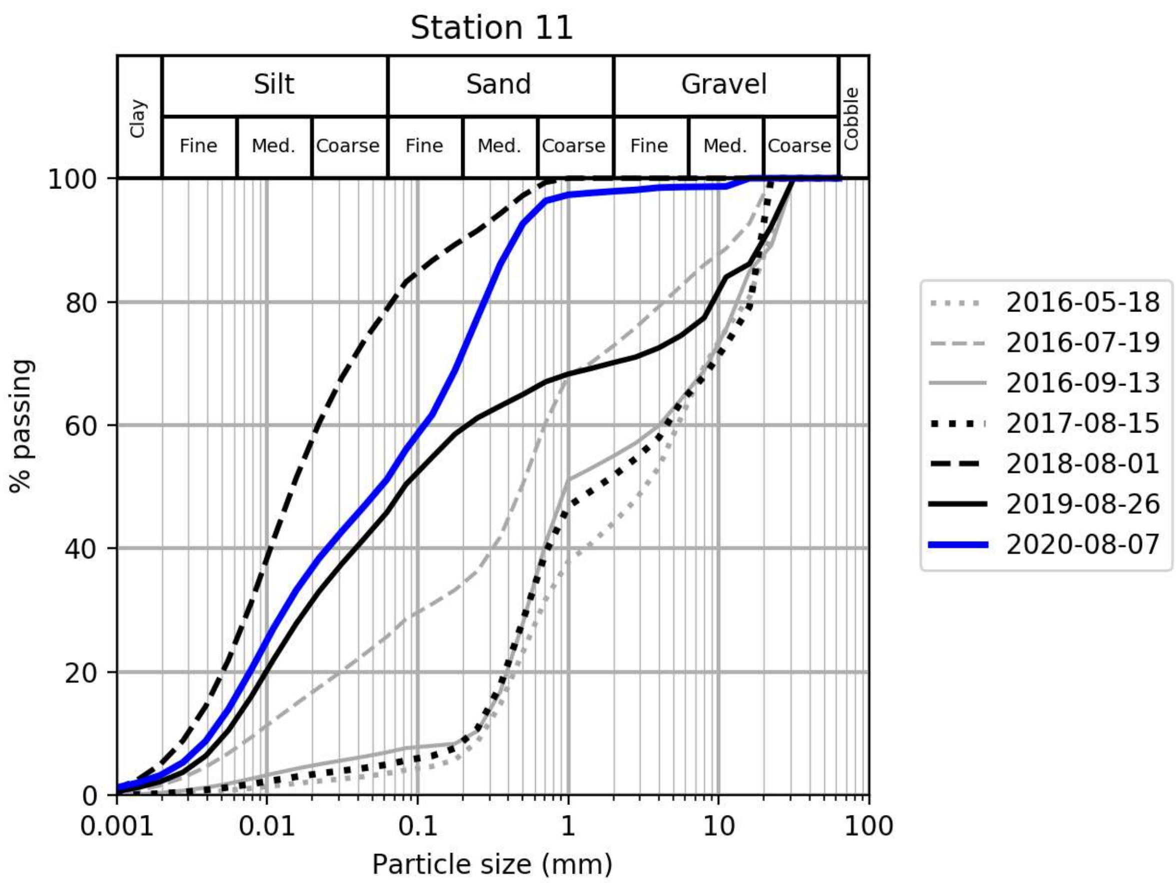
# Appendices

## A. Particle size distribution envelopes 2016 to 2020



Station 1
Clay
Silt
Sand
Gravel
Cobble
Fine
Med.
Coarse
Fine
Med.
Coarse
Fine
Med.
Coarse
% passing
Particle size (mm)
0.001
0.01
0.1
1
10
100
0
20
40
60
80
100
2016-05-18
2016-07-19
2016-09-13
2017-08-15
2018-08-01
2019-08-26
2020-08-07

Station 11
Clay
Silt
Sand
Gravel
Cobble
Fine
Med.
Coarse
Fine
Med.
Coarse
Fine
Med.
Coarse
% passing
Particle size (mm)
0.001
0.01
0.1
1
10
100
0
20
40
60
80
100
2016-05-18
2016-07-19
2016-09-13
2017-08-15
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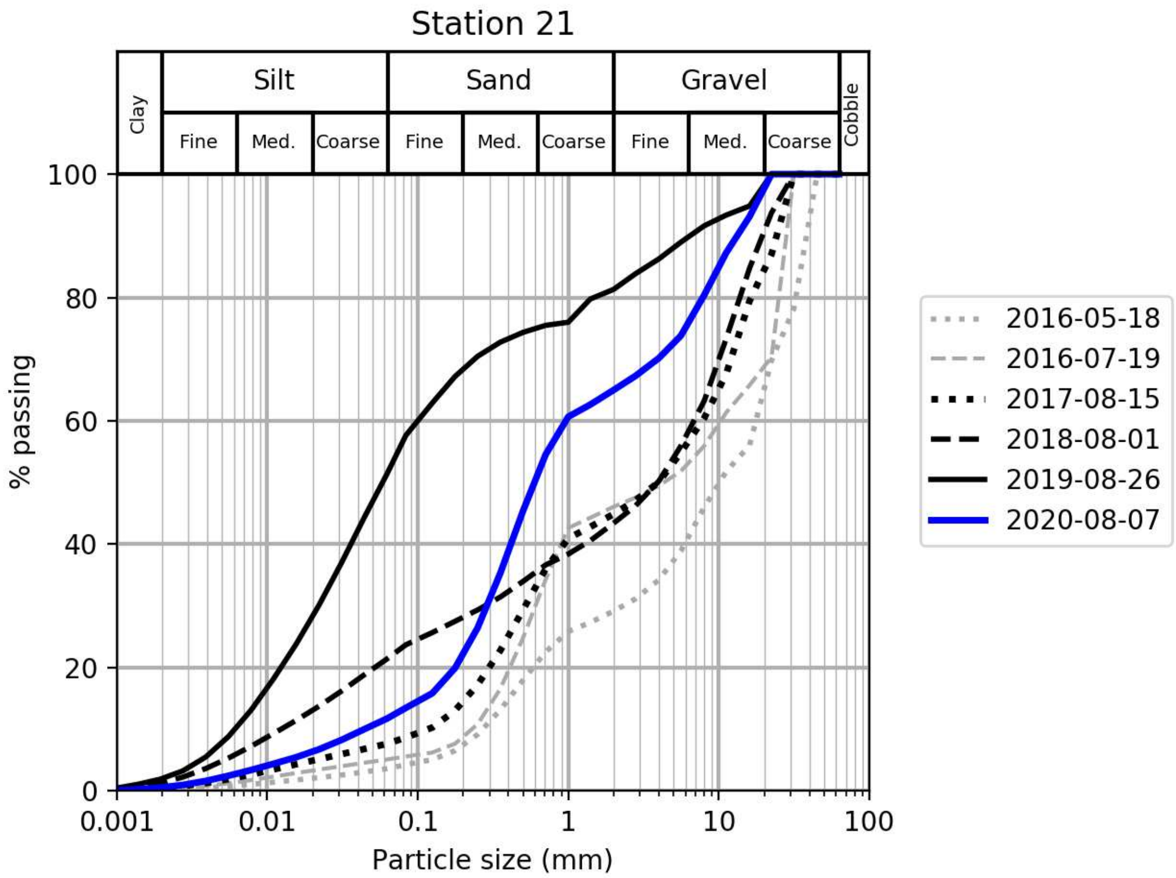
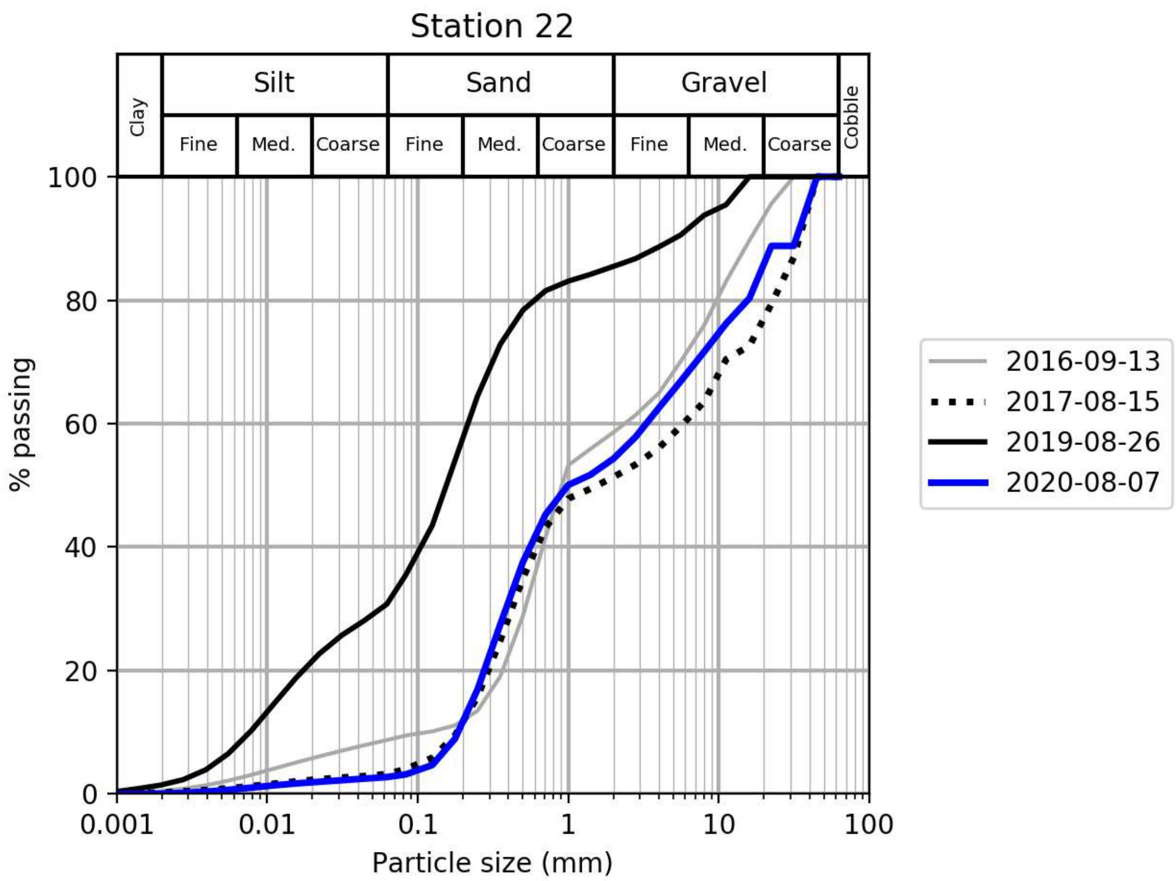
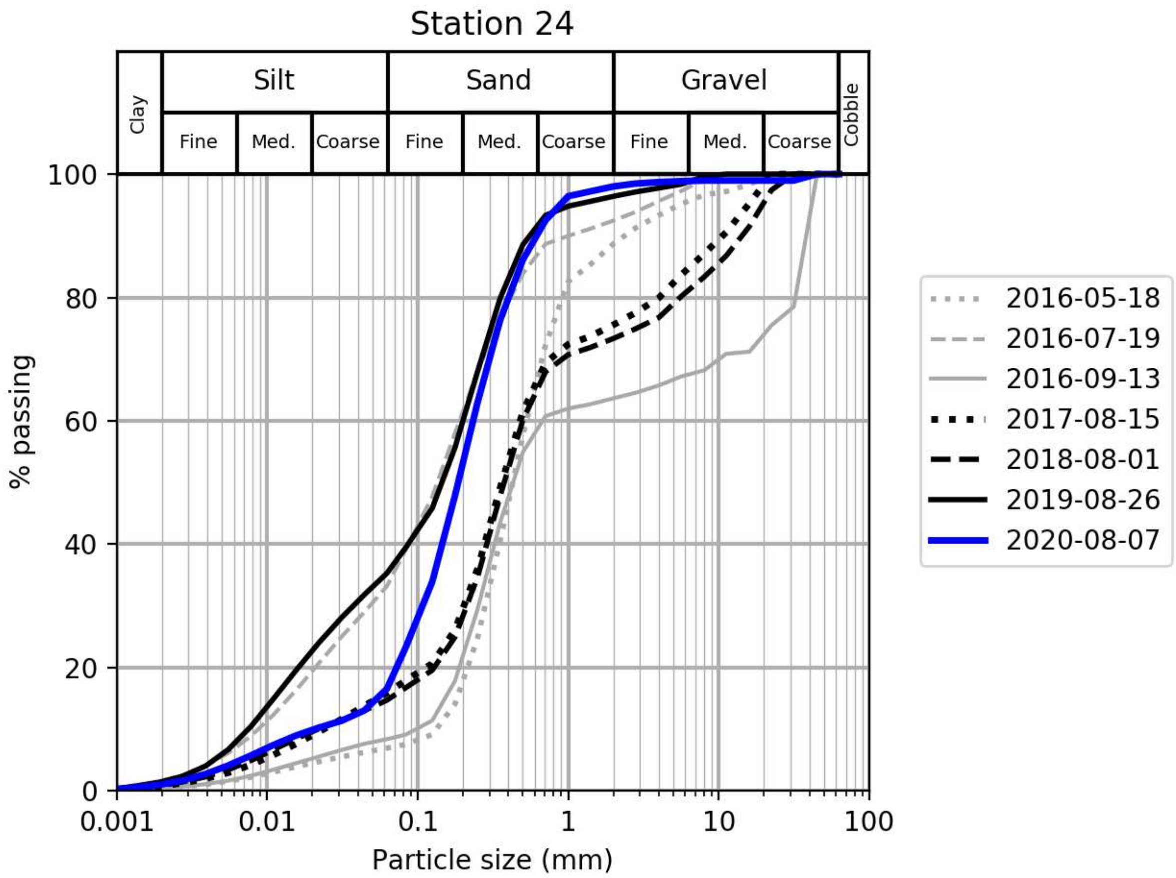
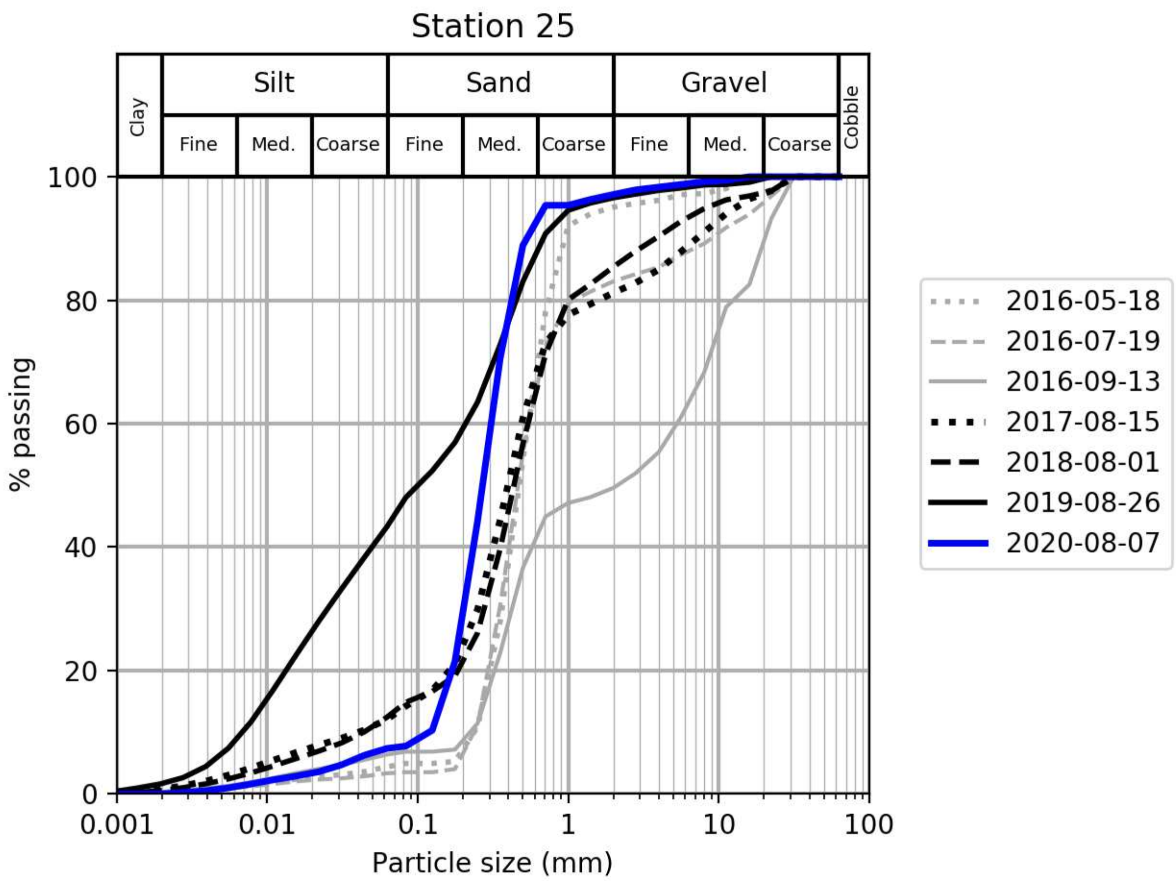
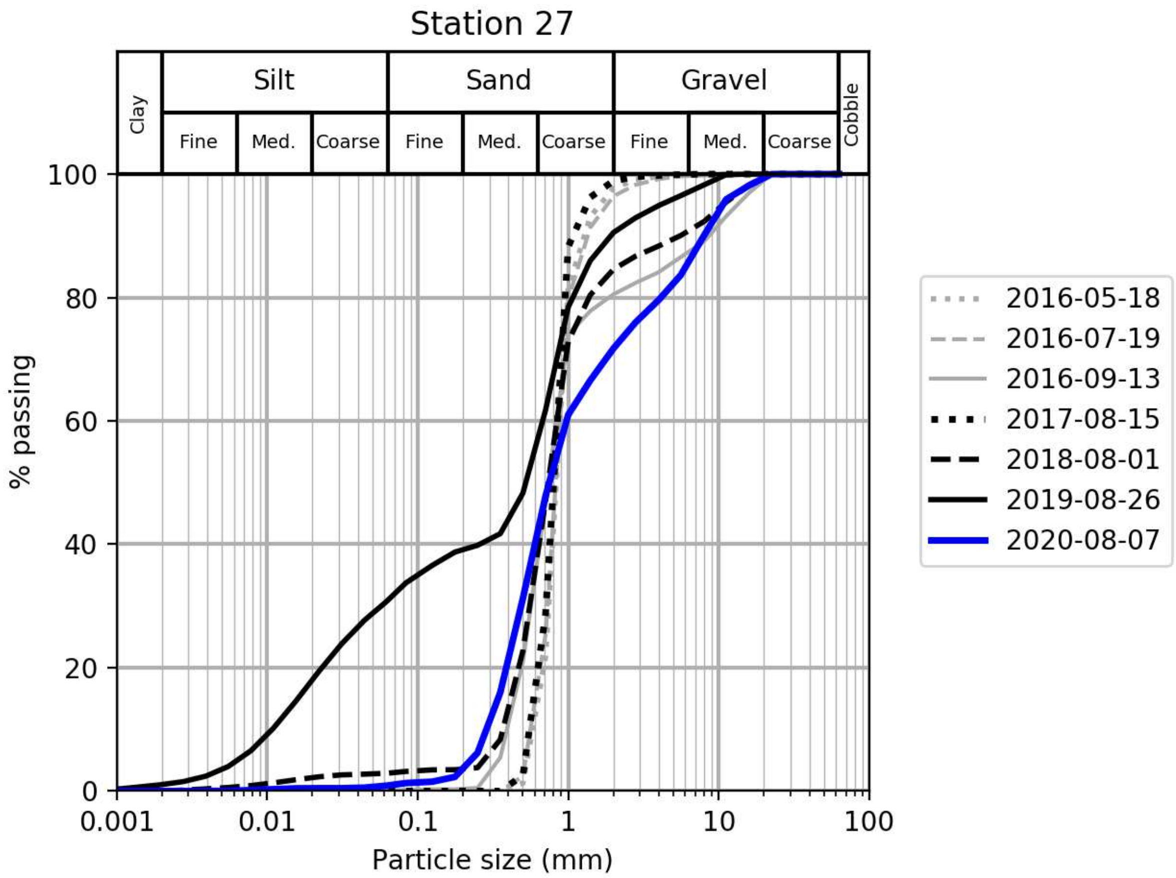
2019-08-26
2020-08-07


Station 21
Clay
Silt
Sand
Gravel
Cobble
Fine
Med.
Coarse
Fine
Med.
Coarse
Fine
Med.
Coarse
100
80
60
40
20
0
% passing
0.001
0.01
0.1
1
10
100
Particle size (mm)
2016-05-18
2016-07-19
2017-08-15
2018-08-01
2019-08-26
2020-08-07

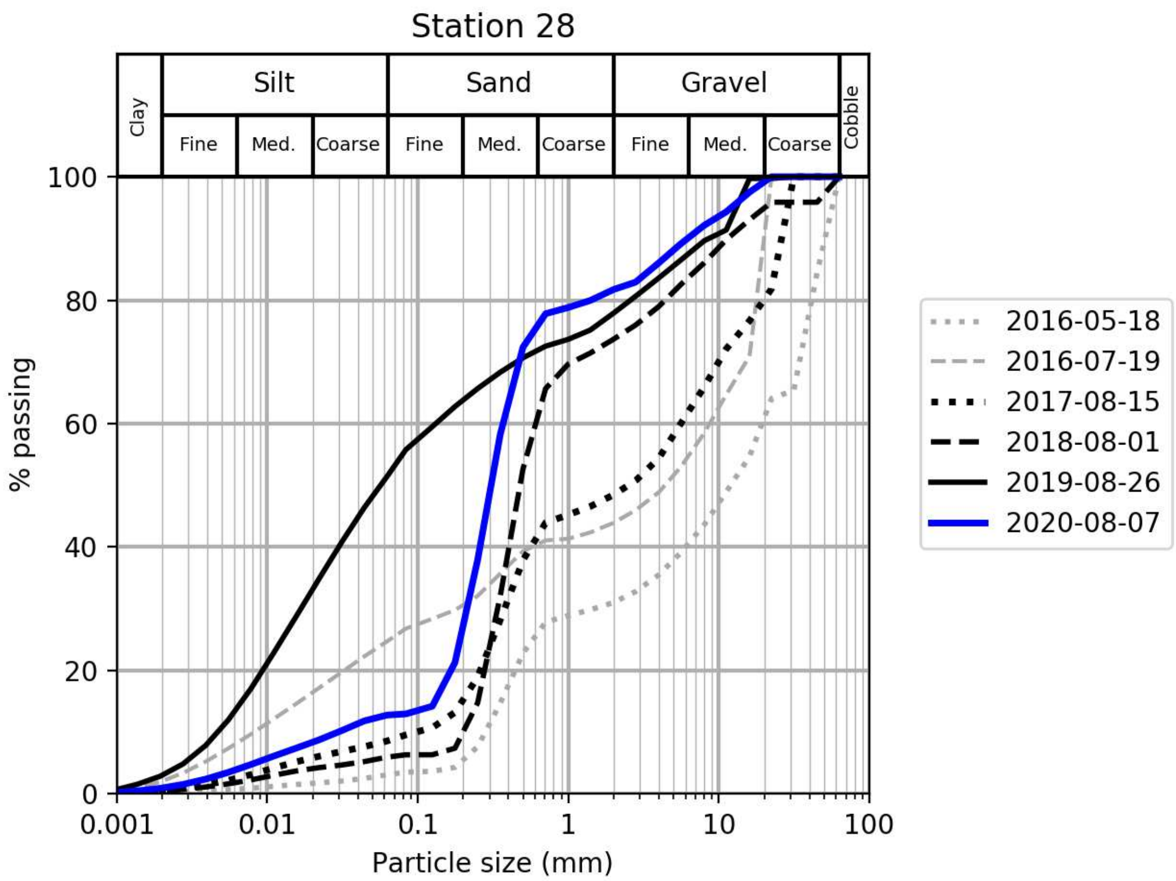

Station 22
Clay
Silt
Sand
Gravel
Cobble
Fine
Med.
Coarse
Fine
Med.
Coarse
Fine
Med.
Coarse
100
80
60
40
20
0
% passing
0.001
0.01
0.1
1
10
100
Particle size (mm)
2016-09-13
2017-08-15
2019-08-26
2020-08-07


Station 24
Clay
Silt
Sand
Gravel
Cobble
Fine
Med.
Coarse
Fine
Med.
Coarse
Fine
Med.
Coarse
% passing
Particle size (mm)
0
20
40
60
80
100
0.001
0.01
0.1
1
10
100
2016-05-18
2016-07-19
2016-09-13
2017-08-15
2018-08-01
2019-08-26
2020-08-07

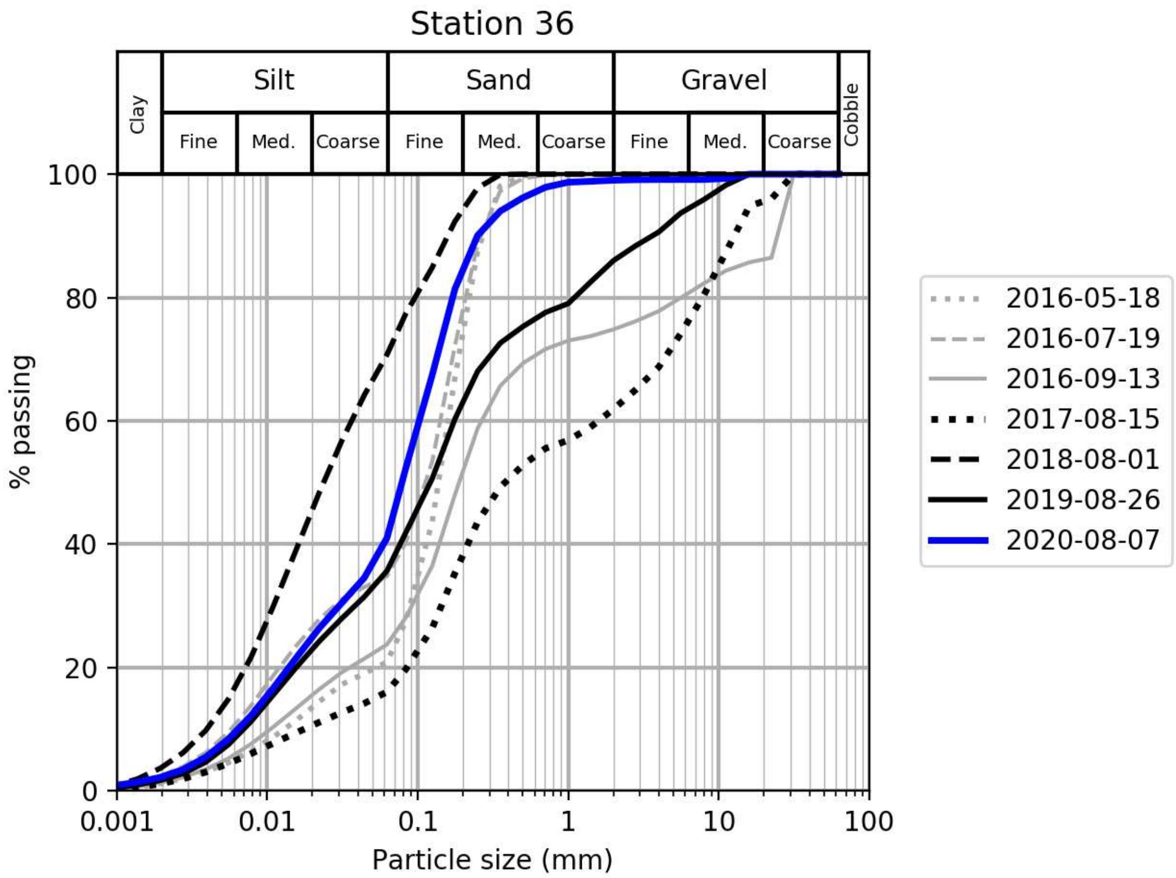

Station 25
Clay
Silt
Sand
Gravel
Cobble
Fine
Med.
Coarse
Fine
Med.
Coarse
Fine
Med.
Coarse
% passing
Particle size (mm)
0
20
40
60
80
100
0.001
0.01
0.1
1
10
100
2016-05-18
2016-07-19
2016-09-13
2017-08-15
2018-08-01
2019-08-26
2020-08-07

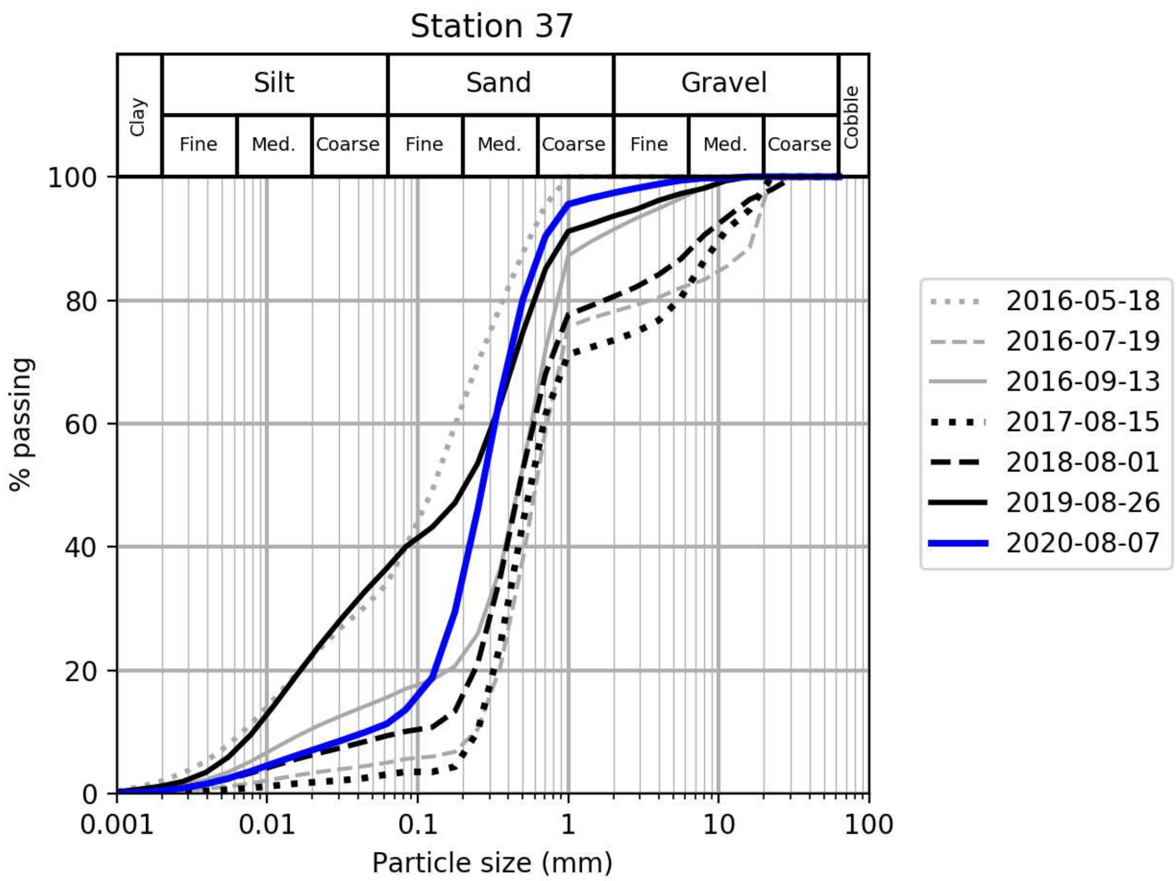


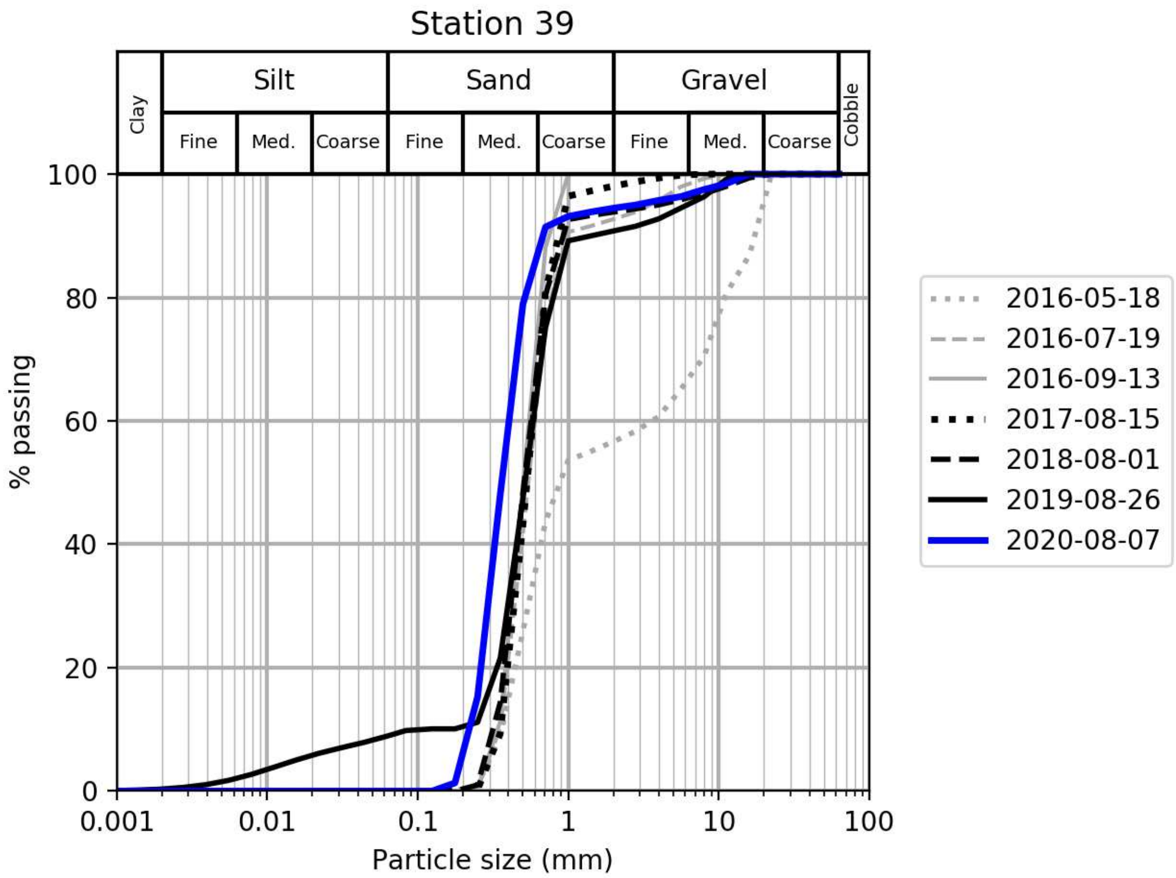
Station 27
Clay
Silt
Sand
Gravel
Cobble
Fine
Med.
Coarse
Fine
Med.
Coarse
Fine
Med.
Coarse
% passing
Particle size (mm)
0.001
0.01
0.1
1
10
100
0
20
40
60
80
100
2016-05-18
2016-07-19
2016-09-13
2017-08-15
2018-08-01
2019-08-26
2020-08-07

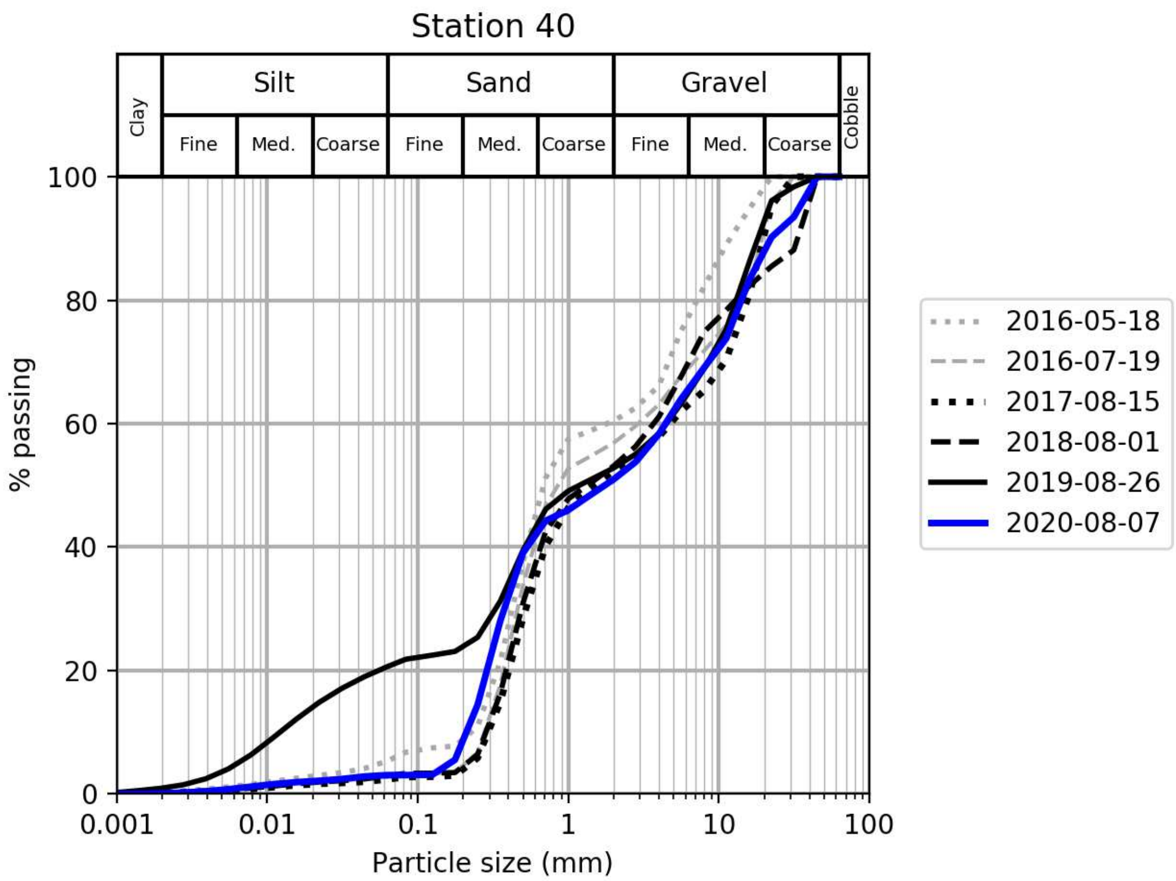



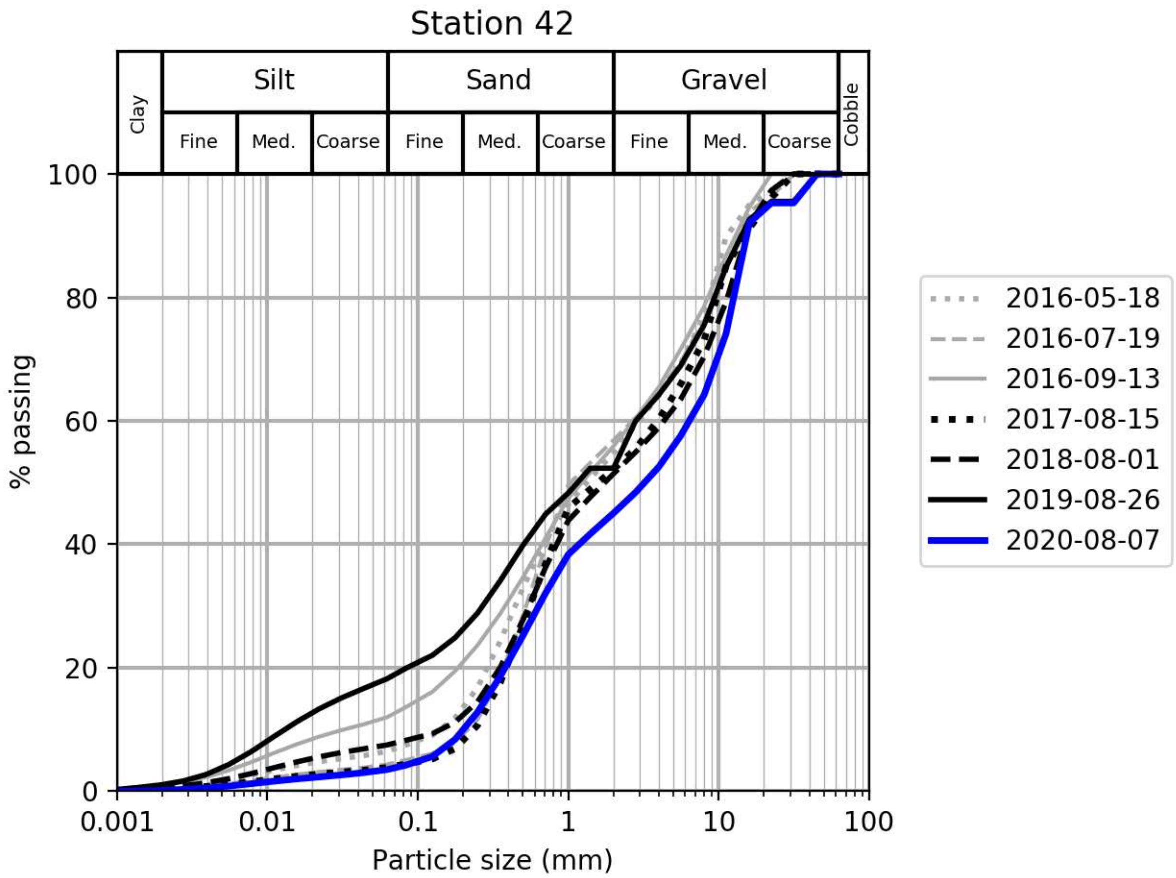
Station 28
Clay
Silt
Sand
Gravel
Cobble
Fine
Med.
Coarse
Fine
Med.
Coarse
Fine
Med.
Coarse
% passing
Particle size (mm)
0.001
0.01
0.1
1
10
100
0
20
40
60
80
100
2016-05-18
2016-07-19
2017-08-15
2018-08-01
2019-08-26
2020-08-07


Station 36
Clay
Silt
Sand
Gravel
Cobble
Fine
Med.
Coarse
Fine
Med.
Coarse
Fine
Med.
Coarse
% passing
Particle size (mm)
2016-05-18
2016-07-19
2016-09-13
2017-08-15
2018-08-01
2019-08-26
2020-08-07

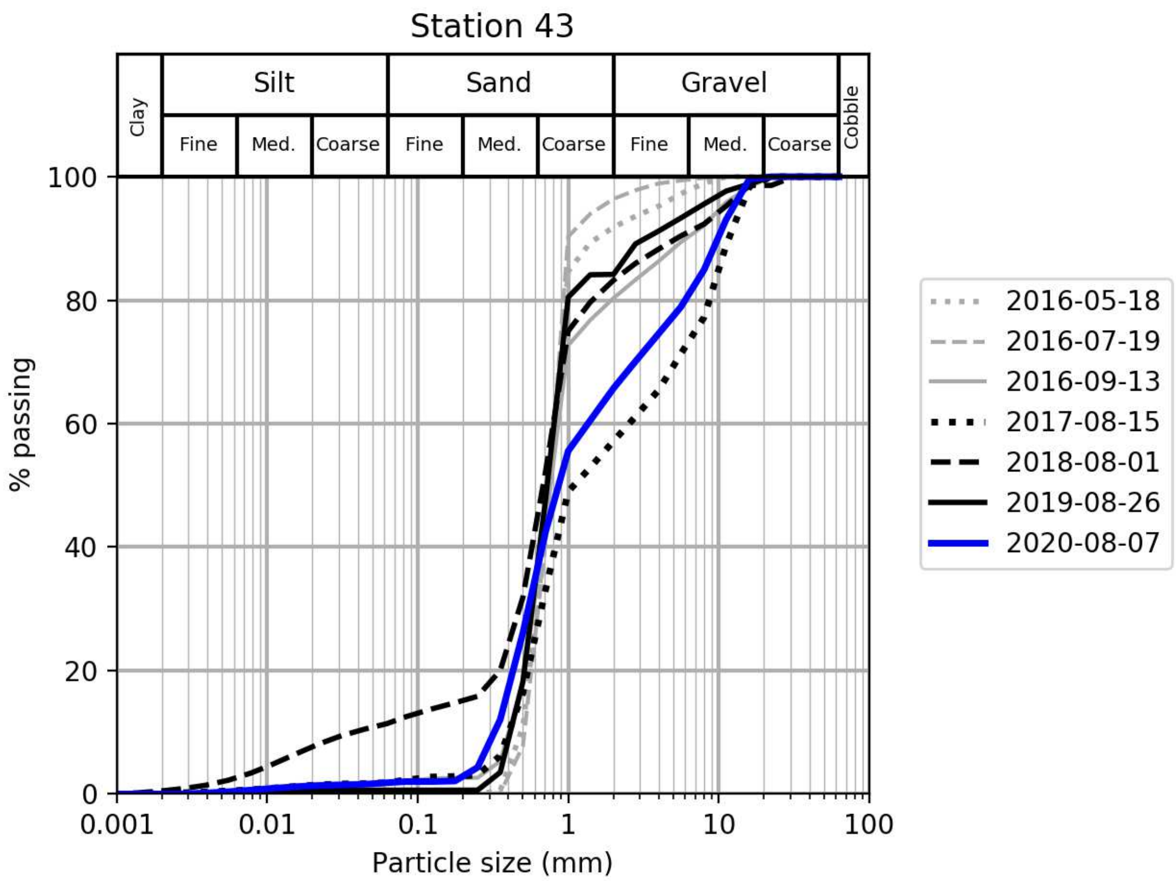

Station 37
Clay
Silt
Sand
Gravel
Cobble
Fine
Med.
Coarse
Fine
Med.
Coarse
Fine
Med.
Coarse
% passing
Particle size (mm)
2016-05-18
2016-07-19
2016-09-13
2017-08-15
2018-08-01
2019-08-26
2020-08-07


Station 39
Clay
Silt
Sand
Gravel
Cobble
Fine
Med.
Coarse
Fine
Med.
Coarse
Fine
Med.
Coarse
100
80
60
40
20
0
% passing
0.001
0.01
0.1
1
10
100
Particle size (mm)
2016-05-18
2016-07-19
2016-09-13
2017-08-15
2018-08-01
2019-08-26
2020-08-07

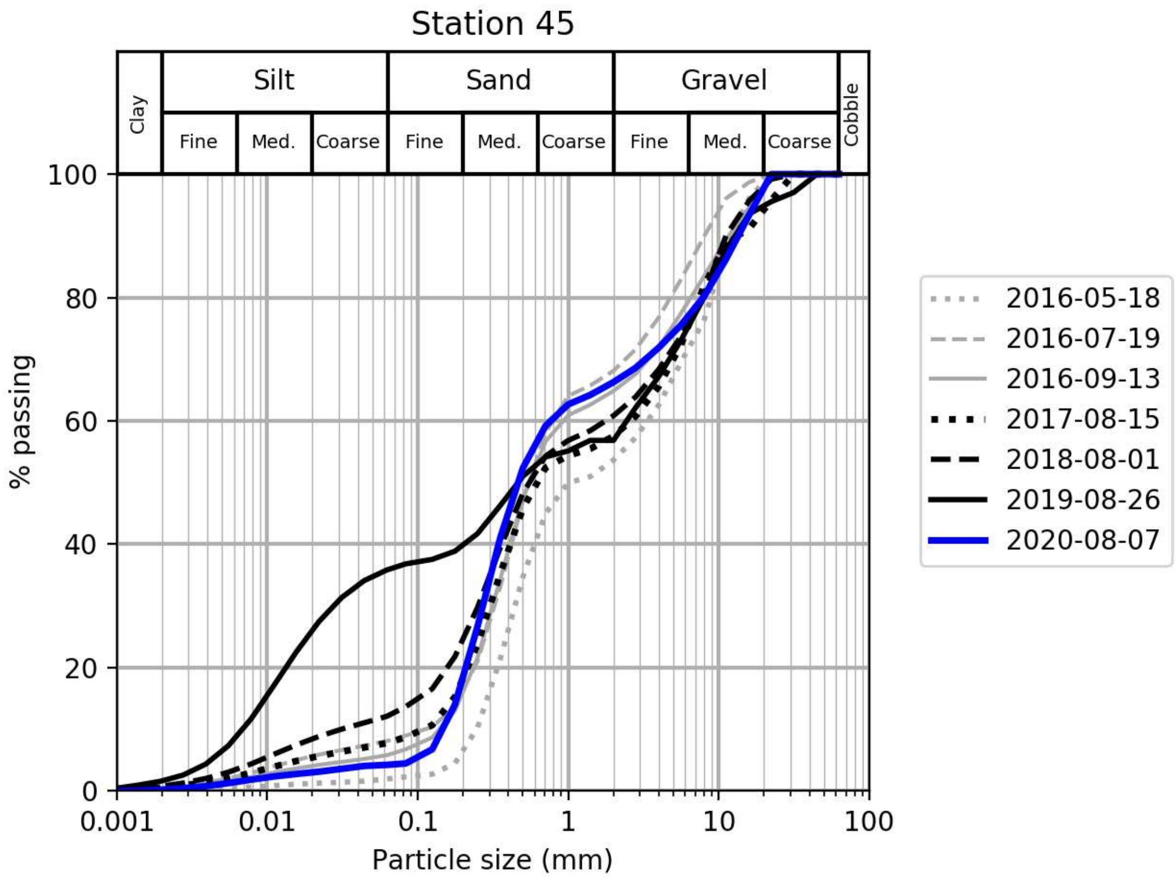

Station 40
Clay
Silt
Sand
Gravel
Cobble
Fine
Med.
Coarse
Fine
Med.
Coarse
Fine
Med.
Coarse
100
80
60
40
20
0
% passing
0.001
0.01
0.1
1
10
100
Particle size (mm)
2016-05-18
2016-07-19
2017-08-15
2018-08-01
2019-08-26
2020-08-07

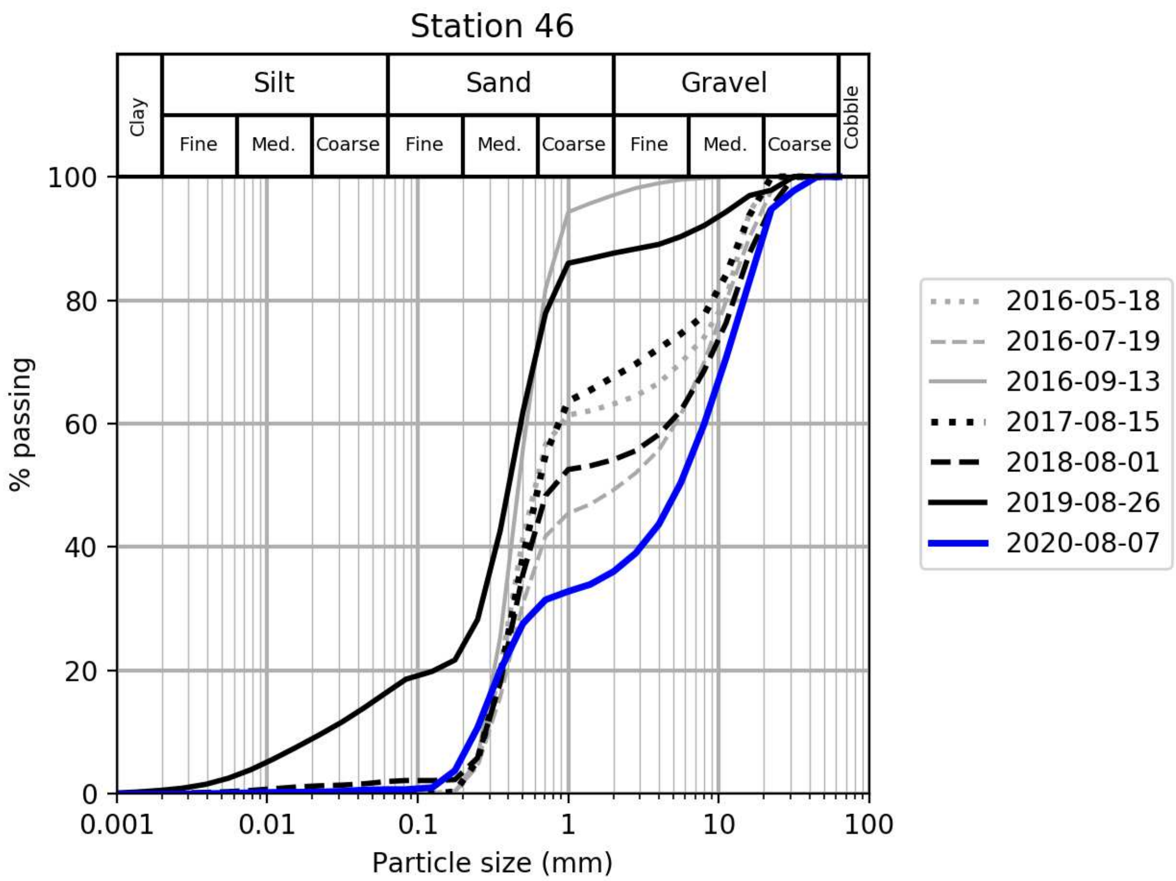


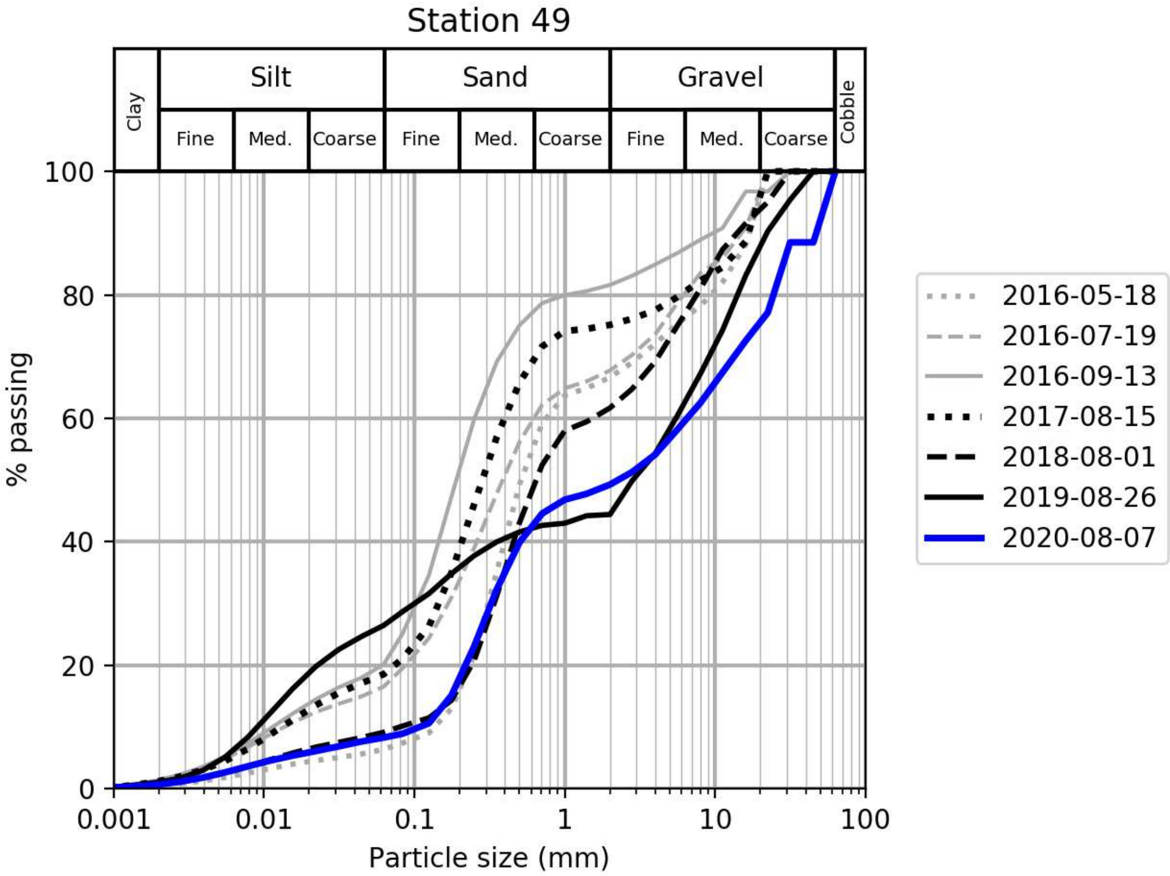
Station 42
Clay
Silt
Sand
Gravel
Cobble
Fine
Med.
Coarse
Fine
Med.
Coarse
Fine
Med.
Coarse
% passing
Particle size (mm)
2016-05-18
2016-07-19
2016-09-13
2017-08-15
2018-08-01
2019-08-26
2020-08-07

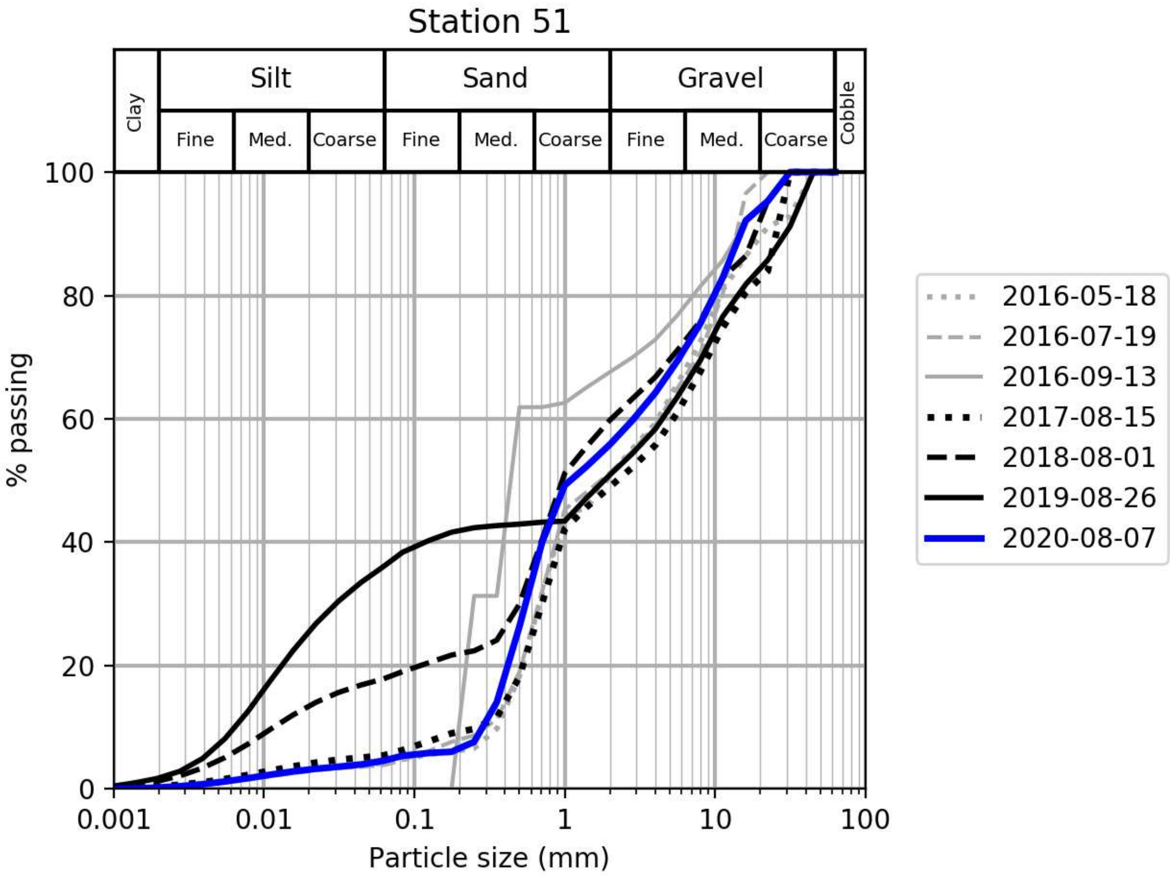
Station 43
Clay
Silt
Sand
Gravel
Cobble
Fine
Med.
Coarse
Fine
Med.
Coarse
Fine
Med.
Coarse
% passing
Particle size (mm)
2016-05-18
2016-07-19
2016-09-13
2017-08-15
2018-08-01
2019-08-26
2020-08-07


Station 45
Clay
Silt
Sand
Gravel
Cobble
Fine
Med.
Coarse
Fine
Med.
Coarse
Fine
Med.
Coarse
% passing
Particle size (mm)
0.001
0.01
0.1
1
10
100
0
20
40
60
80
100
2016-05-18
2016-07-19
2016-09-13
2017-08-15
2018-08-01
2019-08-26
2020-08-07

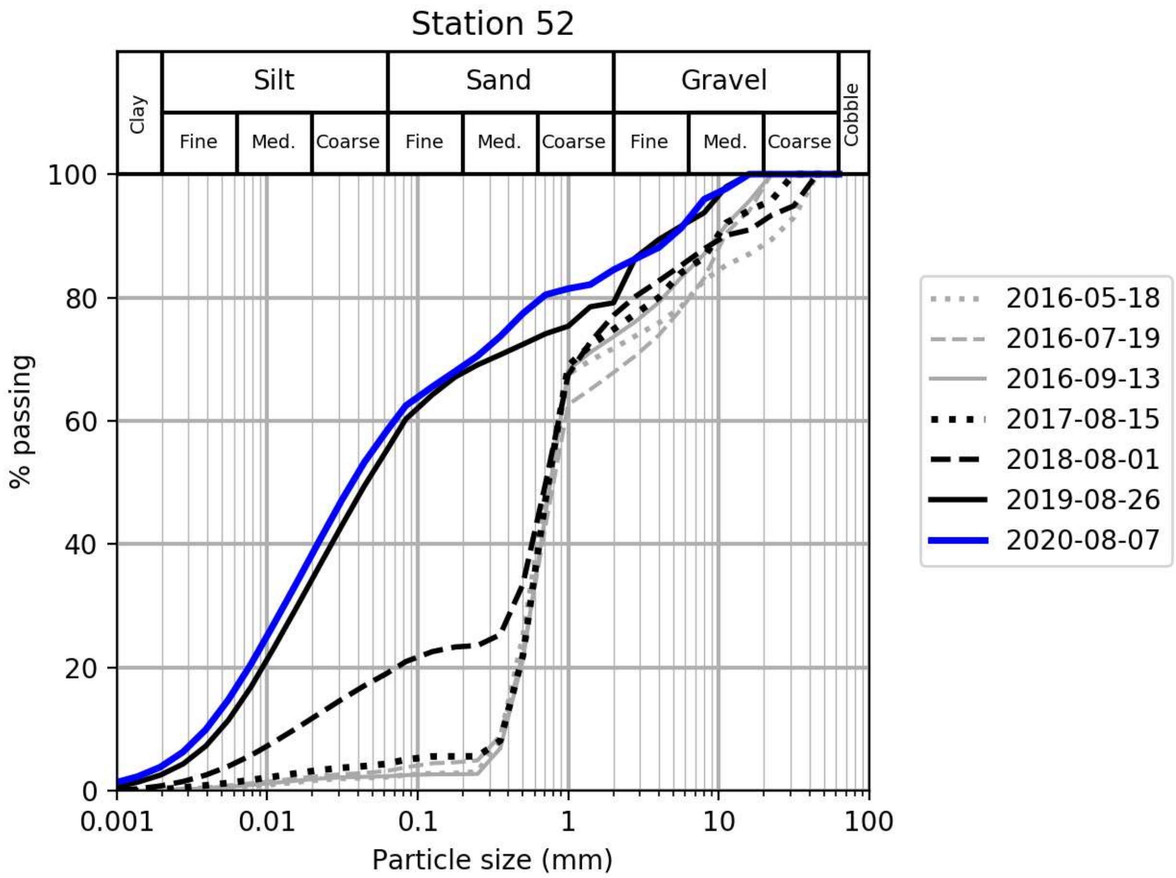

Station 46
Clay
Silt
Sand
Gravel
Cobble
Fine
Med.
Coarse
Fine
Med.
Coarse
Fine
Med.
Coarse
% passing
Particle size (mm)
0.001
0.01
0.1
1
10
100
0
20
40
60
80
100
2016-05-18
2016-07-19
2016-09-13
2017-08-15
2018-08-01
2019-08-26
2020-08-07

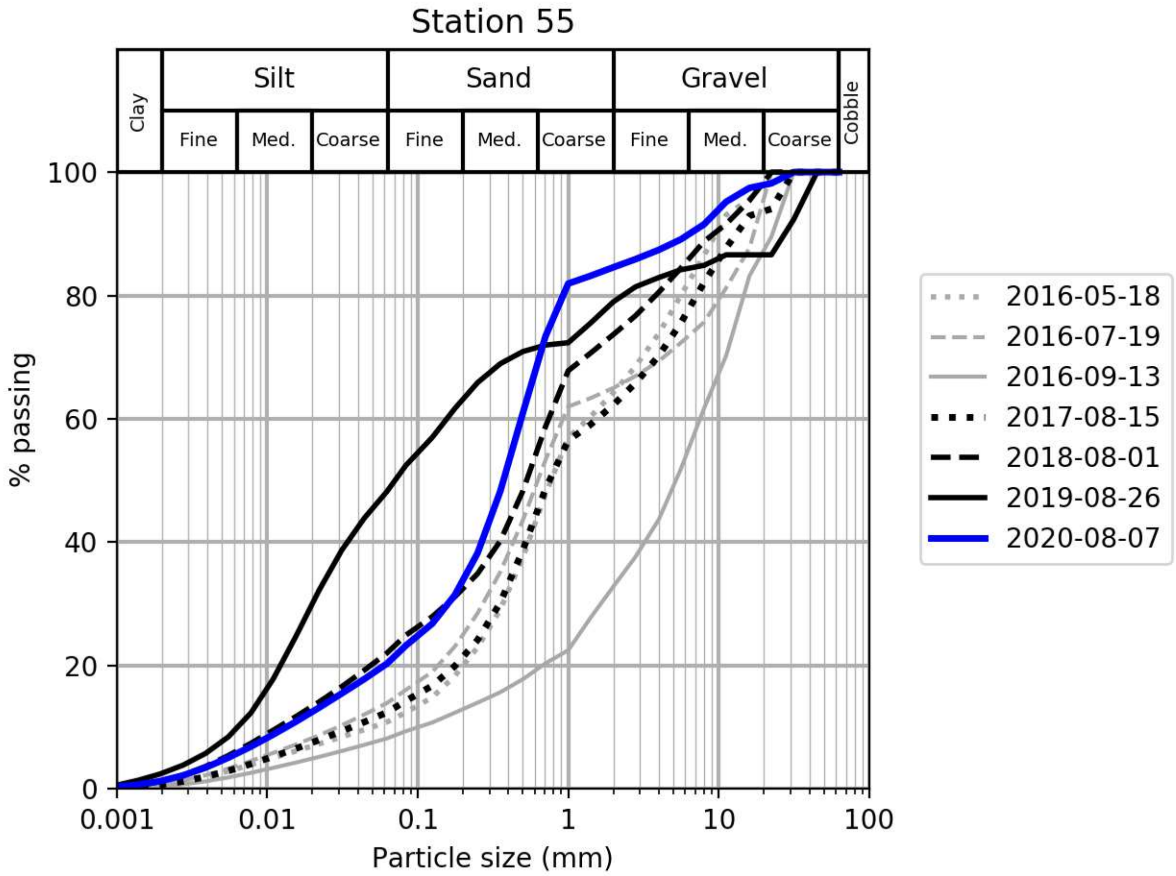


Station 49
Clay
Silt
Sand
Gravel
Cobble
Fine
Med.
Coarse
Fine
Med.
Coarse
Fine
Med.
Coarse
% passing
Particle size (mm)
0
20
40
60
80
100
0.001
0.01
0.1
1
10
100
2016-05-18
2016-07-19
2016-09-13
2017-08-15
2018-08-01
2019-08-26
2020-08-07

Station 51
Clay
Silt
Sand
Gravel
Cobble
Fine
Med.
Coarse
Fine
Med.
Coarse
Fine
Med.
Coarse
% passing
Particle size (mm)
0
20
40
60
80
100
0.001
0.01
0.1
1
10
100
2016-05-18
2016-07-19
2016-09-13
2017-08-15
2018-08-01
2019-08-26
2020-08-07


Station 52
Clay
Silt
Sand
Gravel
Cobble
Fine
Med.
Coarse
Fine
Med.
Coarse
Fine
Med.
Coarse
% passing
Particle size (mm)
0
20
40
60
80
100
0.001
0.01
0.1
1
10
100
2016-05-18
2016-07-19
2016-09-13
2017-08-15
2018-08-01
2019-08-26
2020-08-07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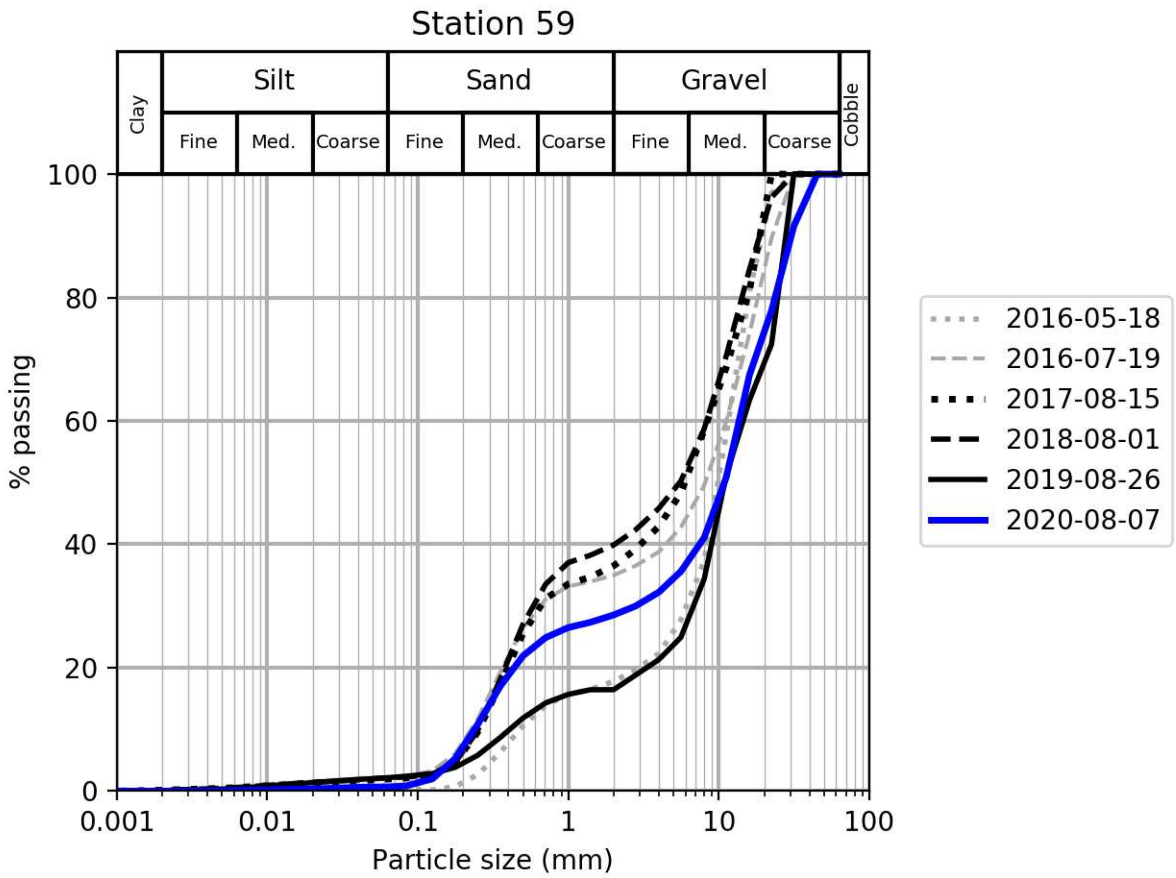
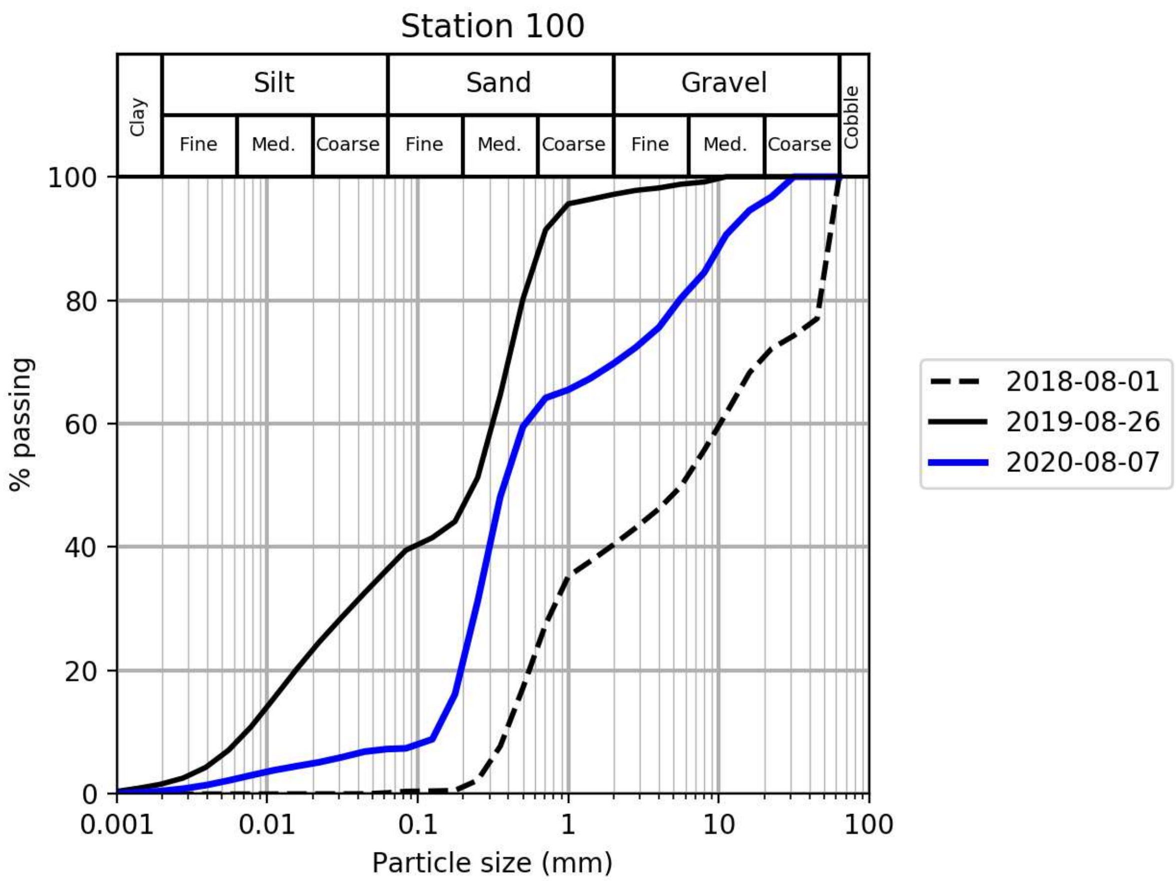
Clay
Silt
Sand
Gravel
Cobble
Fine
Med.
Coarse
Fine
Med.
Coarse
Fine
Med.
Coarse
% passing
Particle size (mm)
0
20
40
60
80
100
0.001
0.01
0.1
1
10
100
2016-05-18
2016-07-19
2016-09-13
2017-08-15
2018-08-01
2019-08-26
2020-08-07


Station 59
Silt
Sand
Gravel
Clay
Cobble
Fine
Med.
Coarse
Fine
Med.
Coarse
Fine
Med.
Coarse
% passing
Particle size (mm)
0
20
40
60
80
100
0.001
0.01
0.1
1
10
100
2016-05-18
2016-07-19
2017-08-15
2018-08-01
2019-08-26
2020-08-07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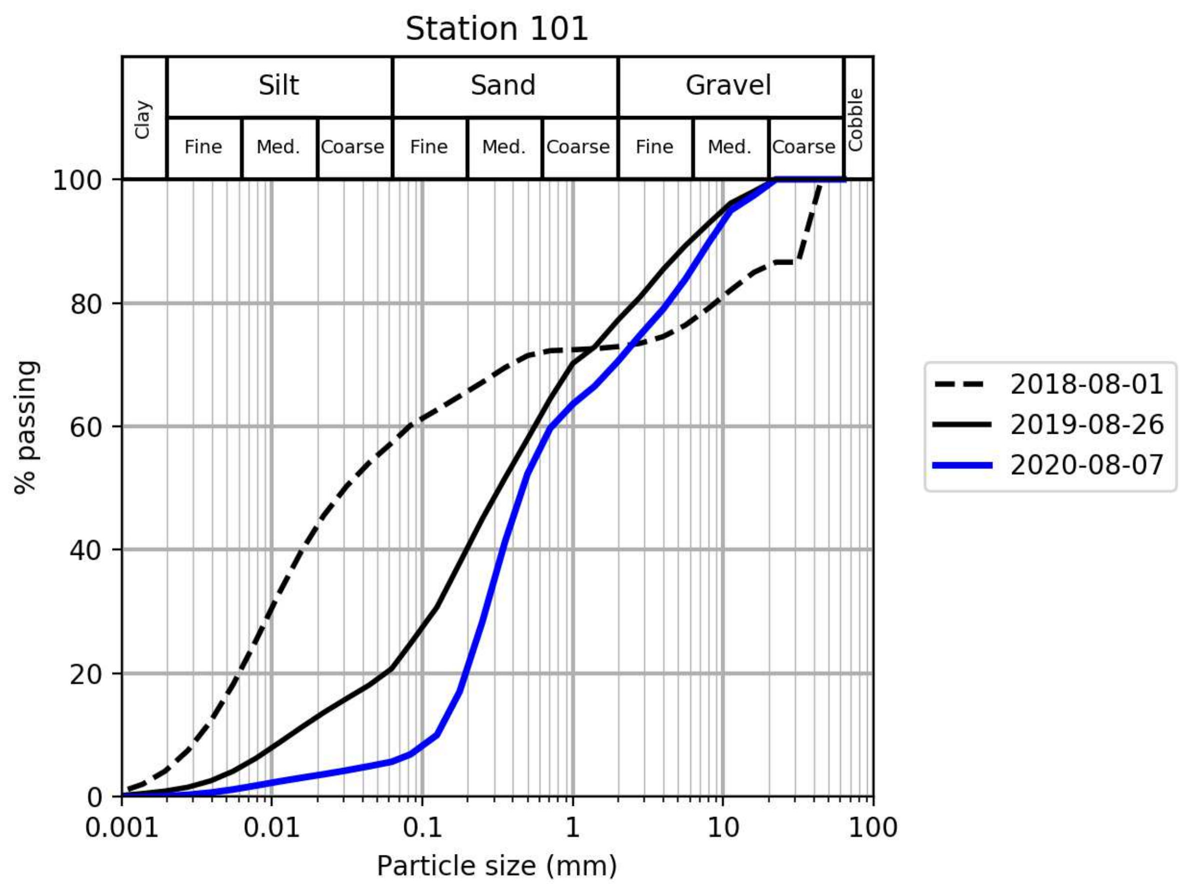
Sand
Gravel
Clay
Cobble
Fine
Med.
Coarse
Fine
Med.
Coarse
Fine
Med.
Coarse
% passing
Particle size (mm)
0
20
40
60
80
100
0.001
0.01
0.1
1
10
100
2018-08-01
2019-08-26
2020-08-07


Station 101
Clay
Silt
Sand
Gravel
Cobble
Fine
Med.
Coarse
Fine
Med.
Coarse
Fine
Med.
Coarse
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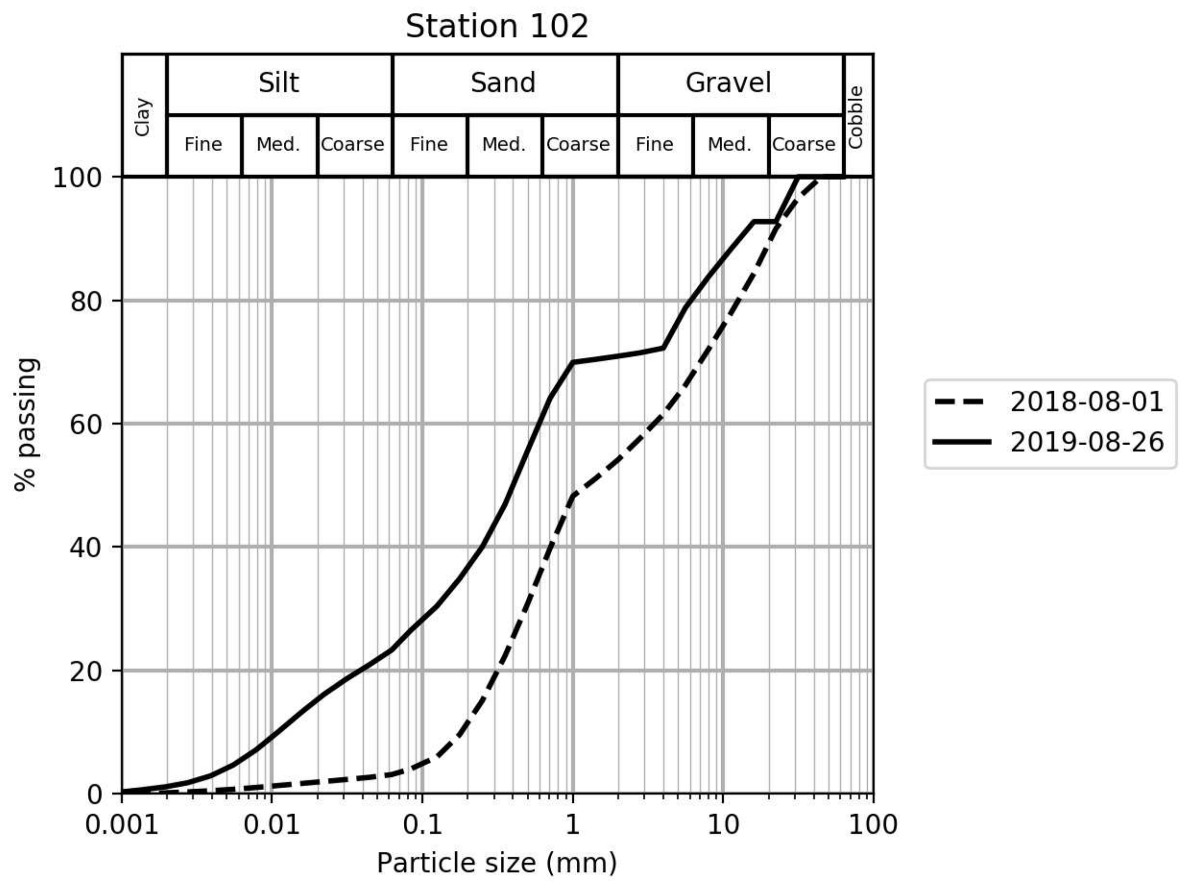
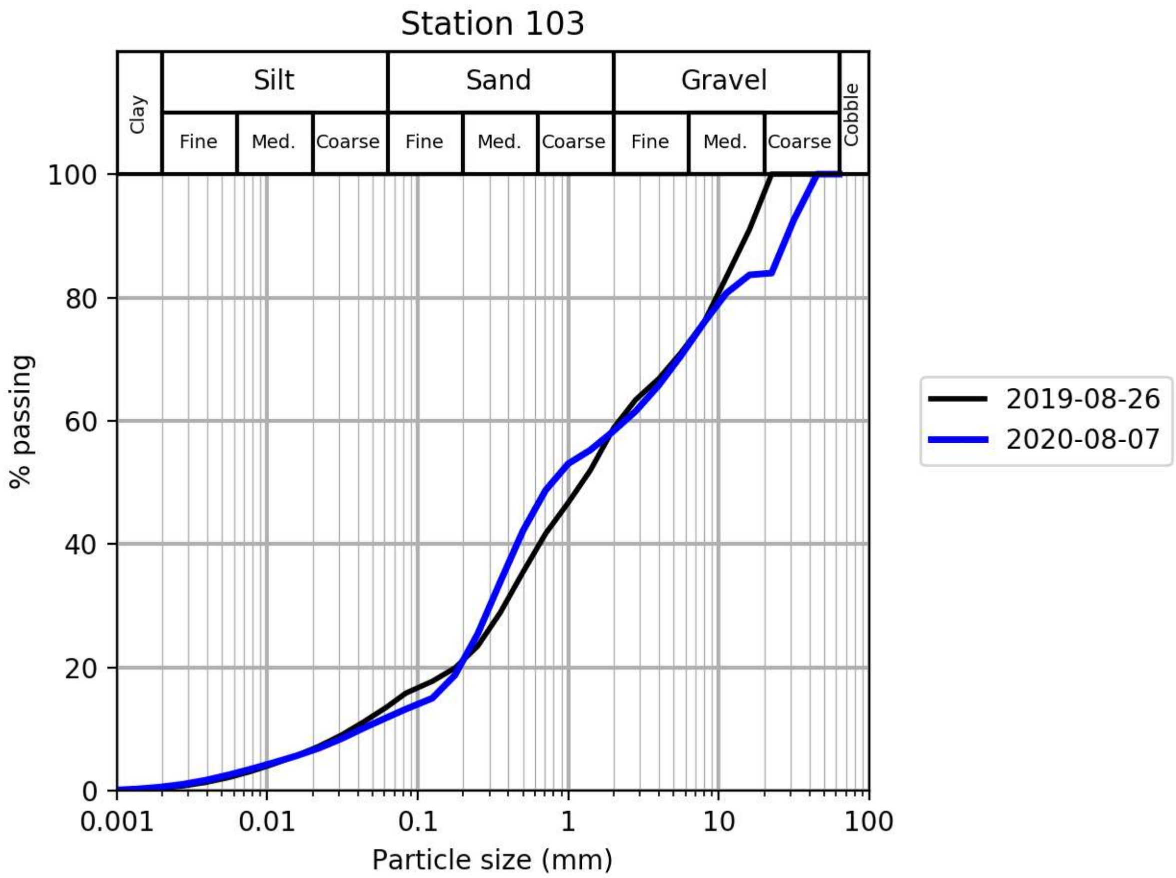
Particle size (mm)
2018-08-01
2019-08-26
2020-08-07


Station 102
Clay
Silt
Sand
Gravel
Cobble
Fine
Med.
Coarse
Fine
Med.
Coarse
Fine
Med.
Coarse
% passing
Particle size (mm)
2018-08-01
2019-08-26



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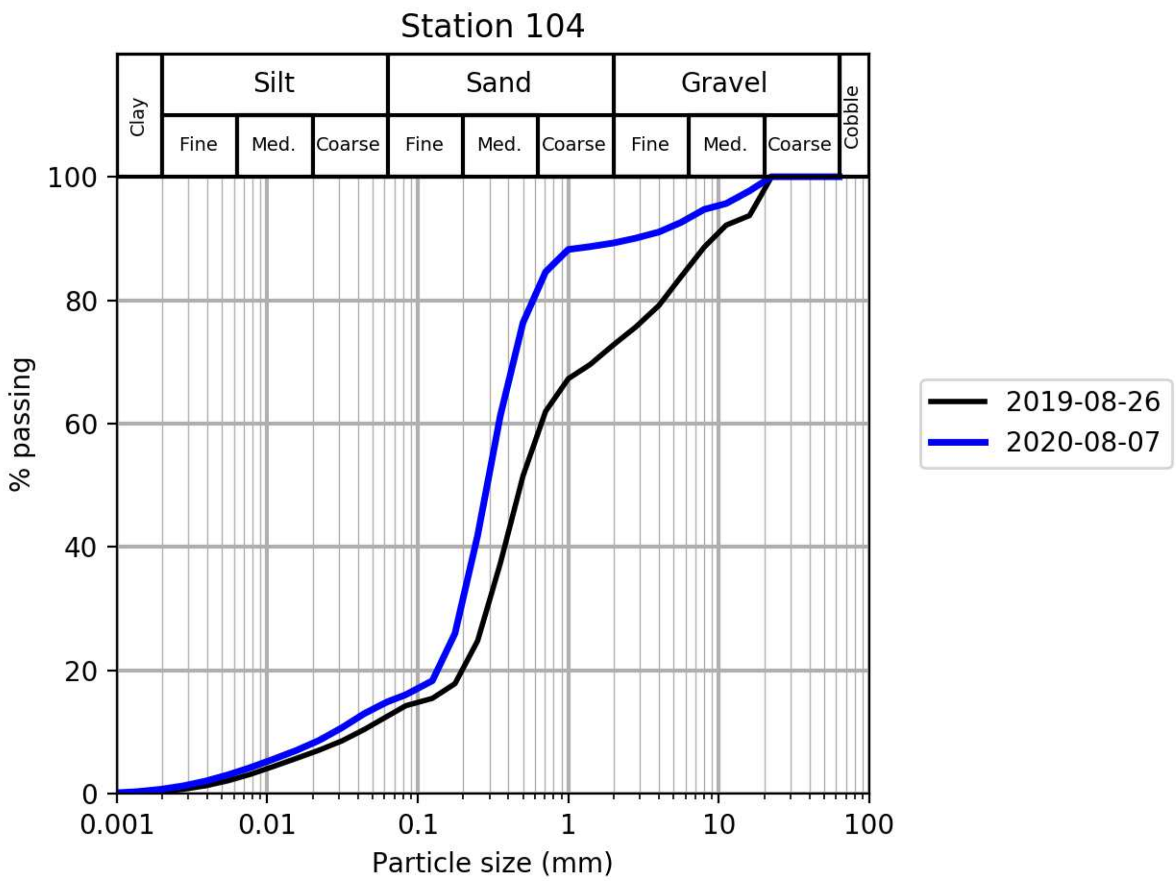
Clay
Silt
Sand
Gravel
Cobble
Fine
Med.
Coarse
% passing
Particle size (mm)
2019-08-26
2020-08-07

Station 104
Clay
Silt
Sand
Gravel
Cobble
Fine
Med.
Coarse
% passing
Particle size (mm)
2019-08-26
2020-08-07

# B. Thomson 2020 factual report

Thomson
environmental
consultants

Harwich Haven Disposal Site (TH027) Report: 2020 Survey

For

Harwich Haven Authority

Project No.: I-HHA-119

October 2020

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| Project Number | Report No. | Revision No. | Date of Issue |
|---|---|---|---|
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## Figures

## Summary

In February 2018, Harwich Haven Authority (HHA) was granted a licence to undertake disposal of dredged sediment at the disposal site TH027. As part of the licence consent requirement, annual summer monitoring aims to verify that there is no permanent change to the seabed substrate or significant changes to the benthic community composition around the disposal site.

In August 2020, a survey was undertaken of the area surrounding the TH027 disposal site. Grab samples were collected for macrofaunal and particle size analysis. Sampling was conducted at 21 stations which have been sampled since 2012, as well as an additional 5 stations chosen by a Harwich Fisherman's representative in 2018 and 2019, within a predetermined area agreed in consultation with CEFAS, Eastern IFCA and local fishermen.

Analysis of the samples collected during this 2020 monitoring survey show that there is a high variability in sediment types within the survey area. All samples consisted of some proportion of coarse sediment, with the majority being classified as gravels and sands. Only 2 stations had mud as the dominant sediment size fraction.

A total of 256 taxa were identified across the survey area, the majority being polychaetes (39% of species) with crustaceans (18%), molluscs (15%) and other fauna (28%), accounting for the rest. The most abundant taxon was the bivalve *Abra alba,* with 2,408 individuals recorded across 18 stations, although the majority (1908 individuals) were recorded at station 024. The next most abundant species were the tube-building polychaetes, Lagis koreni (Trumpet worms) and Sabellaria spinulosa (Ross worms). High levels of heterogeneity were observed across the survey area, with large variation in the abundance and diversity of benthic species between sampling stations.

5 biotopes were identified across the survey area. The most dominant biotope was '*Sabellaria spinulosa* on stable circalittoral mixed sediment', which was assigned to 18 samples, closely followed by 'Circalittoral course sediment', identified for 15 samples.

# 1. Introduction

## 1.1 Background

The Marine Management Organisation (MMO) granted HHA a Marine Licence that permitted two trial disposals of 500,000 $m^3$ of dredged material in June and August 2016. The trial disposal site, known as Harwich Haven Disposal Site (Cefas Site Code: TH027), is located to the east of the Shipwash Sand (Figure 1). The dredged material disposed at this site arose from maintenance dredging at Harwich and Felixstowe Harbour.

An initial characterisation survey was carried out in August 2012 (Unicomarine, 2012) to provide background data for the future monitoring of the proposed disposal ground. A total of 59 stations were sampled during this initial survey.

It was identified that the deposition of dredge material onto the seabed at TH027 could affect the sediment particle size and benthic ecology in and around the new disposal site. To measure potential changes to benthic communities between pre-disposal and post-disposal events, benthic surveys of the disposal site and surrounding area were undertaken. From the 59 initial sampling stations, 21 were selected and agreed with CEFAS for inclusion in the monitoring programme.

Three monitoring surveys were conducted during May, July and September 2016 to gather data on the potential changes to the sediment particle size, the benthic community and overall ecological condition following two trial disposal events. The first survey took place before the trial disposals (to provide data on baseline conditions), the second survey was undertaken after the Trial 1 disposal event and the third survey was undertaken after the completion of the Trial 2 disposal (Unicomarine, 2016). A survey was also carried out in 2017, however this was not part of any licence requirement and no disposals took place that year (Wallingford, 2017)

The disposal licence was reviewed in February 2018 and now allows for disposal of all silt material to the TH027 disposal site, with annual monitoring as part of the consent requirement. The proposed monitoring program will be continued on an annual basis, surveying between July and September, for a minimum period of 3 years (2018-2020)

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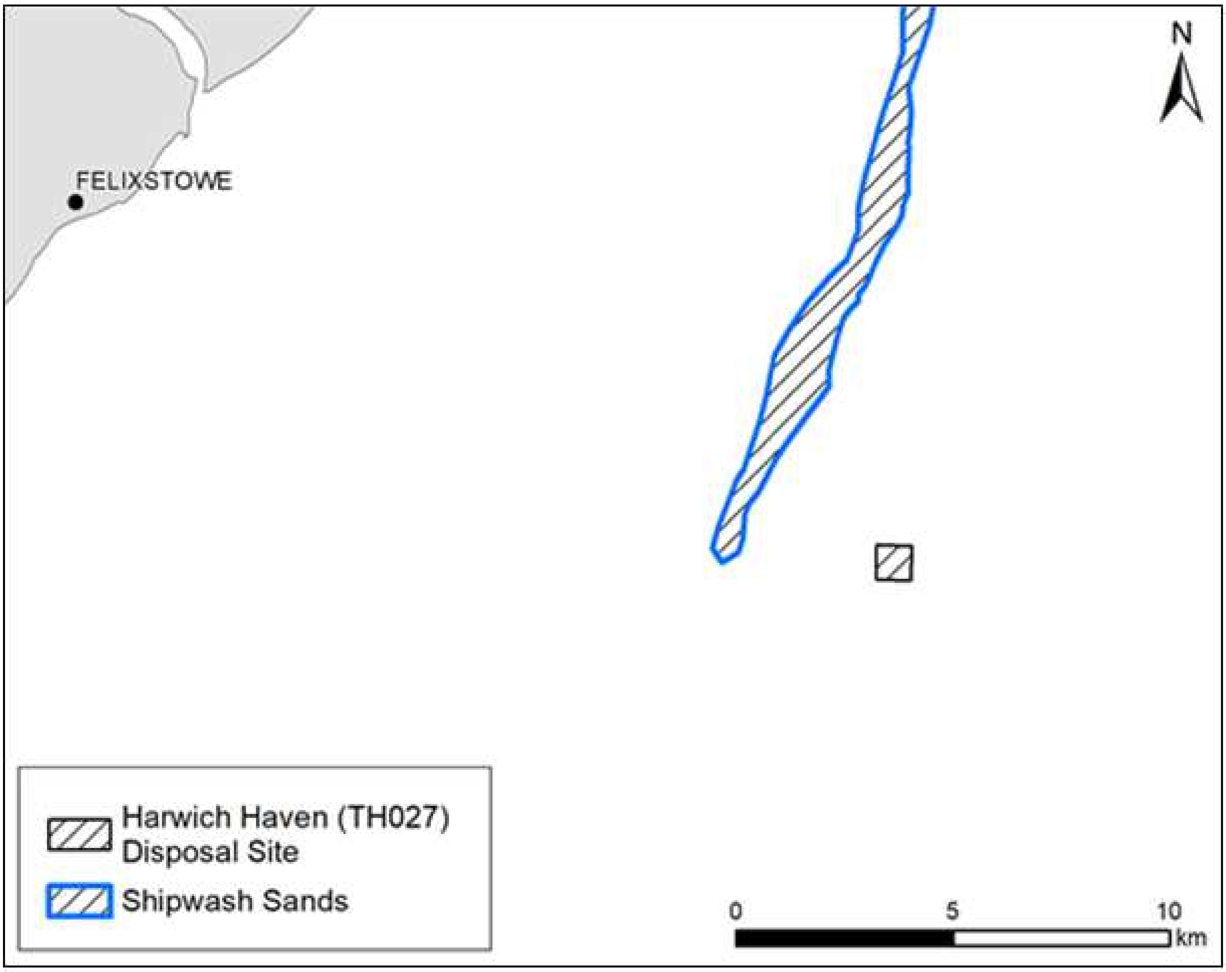


**Figure 1 - Location of disposal ground TH027**

## 1.2 The Brief and Objectives

Thomson Environmental Consultants (previously Unicomarine and hereafter referred to as Thomson) was commissioned by HHA to carry out the planned benthic survey of the disposal ground in 2020. The objectives of the 2020 survey and this report are to:

1. Collect grab samples at 21 previously adopted monitoring stations as well as an additional 5 stations appointed by Harwich's fisherman.
2. Sample analysis to determine particle size distributions, identify macrofauna species and measure abundance for all taxa.
3. Undertake multi-variate analysis to determine differences in macrofaunal communities between sampling stations.
4. Identify biotopes associated with each sampling station.

# 2. Methodology

## 2.1 Design of survey programme

Following the successful monitoring of disposal site TH027 from 2016 to 2019, Thomson were commissioned by HHA to undertake further monitoring during 2020.

It was proposed that samples would be collected from the 21 stations which have been sampled since 2012. In addition, 5 stations appointed by a Harwich Fisherman's representative during the 2018 and 2019 surveys would also be surveyed. These stations are located within a predetermined area agreed in consultation with CEFAS, Eastern IFCA and local fishermen. Sampling stations are shown in Figure 2 and the coordinates of sampling points are presented in Appendix 1 – Sampling Log. It was planned for a total of 5 grab samples to be taken at each station, using a 0.1m² Hamon grab. 4 of these grabs would be taken for biological samples, 2 for analysis and 2 to be stored and, if deemed necessary, analysed at a later date. The remaining grab taken at each station would be for PSA.

## 2.2 Field work

Sampling was undertaken by experienced and qualified Thomson and HHA staff on the 6th and 7th of August 2020. PSA samples and A & B biological replicates were successfully collected from 25 of the planned stations. Grabbing was unsuccessful for the collection of C & D biological replicates from stations 022, 100, 103 and 104 and no samples were taken from station 102 after multiple failed attempts.

Sample collection was logged with a visual assessment of each sample (Appendix 1 – Sampling Log). The biological samples were sieved over a 1.0mm mesh and preserved in a 4% formaldehyde solution on the day of sampling. For PSA samples, the sediment from the grab was homogenized with a clean spoon and a representative subsample (minimum 500 g) was placed into a clean labelled sample bag. PSA samples were kept cool until they were returned to the laboratory, where they were refrigerated prior to analysis.

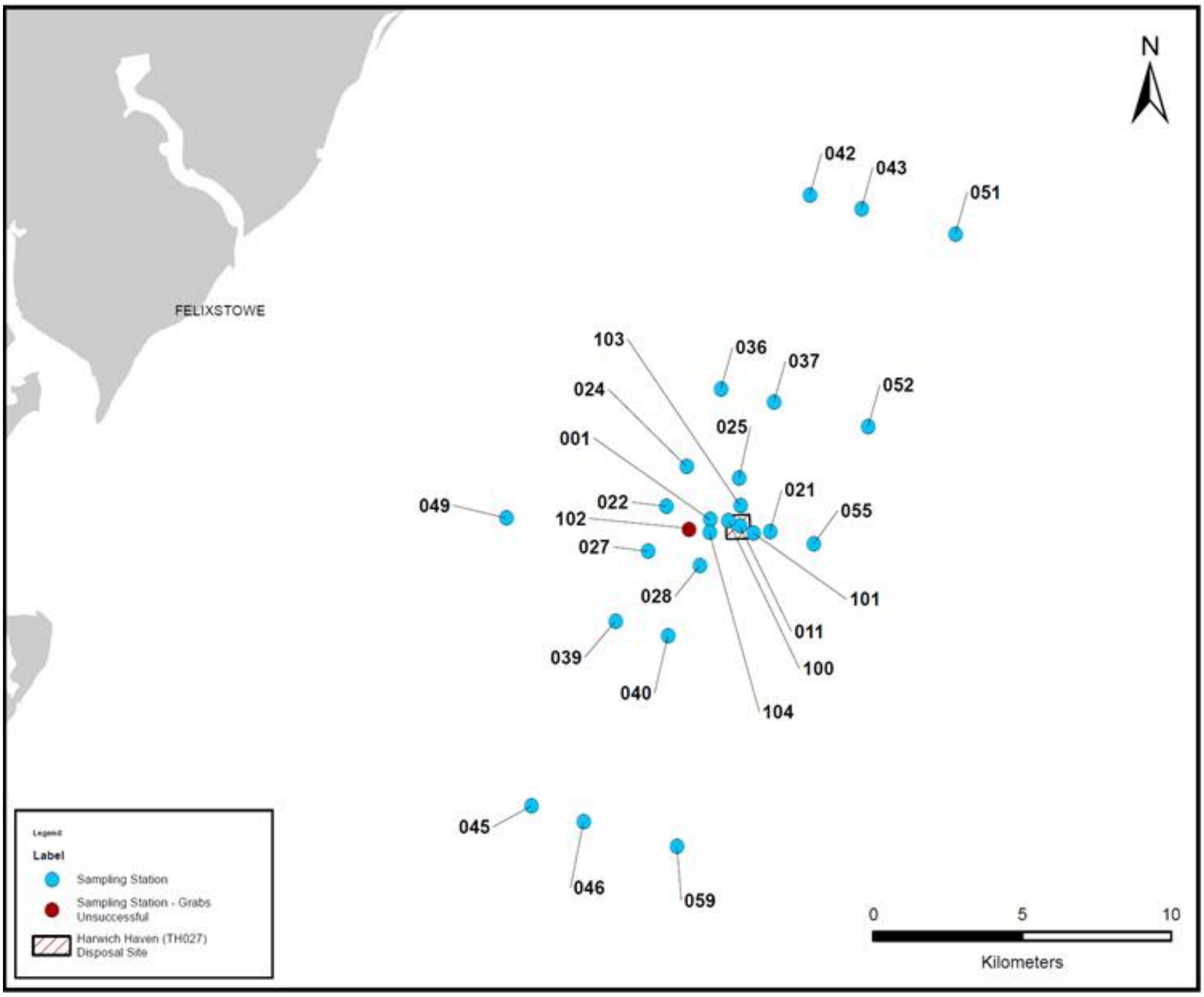


Figure 2 - Location of sampling stations

## 2.3 Laboratory work

Sample analysis was conducted at Thomson's Marine Sciences Laboratory. Particle Size and macrofauna analyses were conducted following agreed specifications, using Thomson's Standard Operating Procedures (Chamberlain, 2016; Gordon et al., 2020). These follow the National Marine Biological Analytical Quality Control (NMBAQC) Scheme's best practice guidelines (Worsfold et al., 2010; Mason, 2016)

### 2.3.1 PSA

A subsample was taken from each homogenised sample and washed over a 1 mm sieve in order to determine analysis methodology. All the samples were determined to be diamictons (mixed sediment including gravel, sand and mud content), meaning both sieve and laser diffraction methods were used for all samples.

The Particle Size Distribution (PSD) of the <1 mm sediment was measured by laser diffraction using Thomson Environmental Consultant's Mastersizer 2000. The >1 mm sediment was oven dried and sieved at 0.5 φ intervals using a Retsch sieve shaker (amplitude: 5, duration: 20 minutes); the weights of the sediment retained on each sieve were recorded to two decimal places.

### 2.3.2 Macrofauna

The biological samples were sieved over a clean stack of sieves (4 mm, 2 mm and 1 mm) in a ventilated washroom. Once divided into these size fractions, the benthic macroinvertebrates were extracted from the sediment using low power stereo microscopes. After fauna were extracted from the sediment of each sample, over 40% of sample residues were checked by a second analyst. This included the first two samples completed by each analyst, randomly selected samples and any samples where low abundances were found. With an acceptable extraction level of 95%, these in-house quality control procedures helped to ensure biota was not missed.

The extracted biota was preserved in 70% Industrial Denatured Alcohol (IDA). Countable specimens were identified to the lowest taxonomic level practicable (usually species) and enumerated, to give a species abundance matrix. Non-countable animals, such as colonial species, were recorded as present "P". High power compound microscopes were used to confirm the identity of some taxa.

All identification analysts used approved literature and keys, as well as reliably identified reference material from the in-house reference collection. Taxonomic identifications were quality assured by a Thomson Principal Taxonomist. At least 10% of species identifications and enumerations from each sample underwent quality control and specimens with difficult taxonomic characters were routinely checked. For quality control purposes and to allow future taxonomic comparisons, the extracted fauna will be kept at Thomson for a minimum of 2 years after analysis.

## 2.4 Data Analysis

### 2.4.1 PSA

After internal QC of the sieve and laser data, the data from the two analysis methods were merged to produce a continuous PSD for each sample. GRADISTAT, an Excel based software package (Blott & Pye, 2001), was used to calculate standard sedimentological statistical parameters. PSD data were converted into simplified proportions of eight size categories (Wentworth, 1922).

Sediment classifications were assigned, based on the proportion of sediment in three size categories: mud (up to 0.03125 mm), sand (>0.03125 and <2 mm) and gravel (>2 mm). As a quality control measure, these classifications were checked against the original sample descriptions.

### 2.4.2 Macrobenthic data

All statistical analyses outlined below were carried out using the PRIMER (Plymouth Routines in Multivariate Ecological Research) suite of applications version 7.0.17 (Clarke & Warwick, 1994; Clarke & Gorley, 2015). Non-countable taxa were excluded from univariate and multivariate analyses, except when calculating the total number of taxa.

#### Univariate analysis

Species richness and diversity indices were calculated for each sample using the DIVERSE component of PRIMER. The following diversity indices were calculated:

- Total numbers of taxa (S) and individuals (N).
- Margalef's index (d, species richness) which accounts for the number of different species within a dataset (community).
- Pielou's index (J', evenness) which is a measure of the relative abundance of the different species making up the richness of an area.
- Shannon-Wiener ($H'(\log_e)$, diversity) is a quantitative measure that reflects how many different species there are in a dataset, and simultaneously takes into account how evenly individuals are distributed among those species.

### Multivariate analysis

#### *Cluster analysis*

Cluster analysis was undertaken to compare the abundance of each taxon in each sample with its abundance in each of the other samples. The analysis used Bray-Curtis similarity on fourth root transformed data and the group averaging cluster algorithm (Clarke & Gorley, 2015).

This resulting similarity matrix is represented diagrammatically as a dendrogram, with similar samples linking towards the bottom of the figure and less similar samples linking towards the top of the diagram. The scale is an index from 0% to 100% and should be viewed as a relative indicator of similarity. It does not indicate the proportion of species in common.

A similarity profile (SIMPROF) test was carried out as part of the cluster analysis. This permutational test identifies clusters of samples that cannot be statistically separated at the 5% significance level and marks them on the dendrogram using red lines. Black branches on the cluster denote samples that are statistically different from one another at the 5% significance level.

#### *Multi-Dimensional Scaling (MDS)*

Non-metric multidimensional scaling (MDS) was used to further examine the grouping of samples described above by employing relevant statistical considerations (Clarke & Warwick, 1994). This technique uses the same Bray-Curtis similarity matrix used for the cluster analysis. An iterative process places sample points onto a 2-dimensional plane in a configuration where the inter-sample similarities are most closely represented. Although the MDS plot is bounded by a box, this does not represent either axes or scale. Two samples with a high similarity index will appear close together while those less similar will appear further apart. The technique should be viewed as complementary to cluster analysis, offering a different perspective of the same information.

### 2.4.3 Biotope Assignment

The determined PSD and faunal assemblage of each sampling site was used to inform the characterisation of the benthic environment through biotope classification. Following the definition of Connor et al. (2004), a biotope is a combination of an abiotic habitat and its associated community of species. Abiotic characteristics of an environment include physical and chemical properties, such as sediment type, hydrodynamic regime, turbidity, dissolved oxygen and salinity. In the marine environment, there is a strong relationship between the abiotic characteristics of habitats and the biological composition of the communities which they support (Conner et al., 2004).

The data were examined to determine the characteristic fauna of the communities recognised by the cluster groupings of samples, described above. The mean number of individuals of each recorded taxon in the samples assigned to each of the cluster groups was calculated.

Comparative tables produced by Connor et al. (2004) were used to assign biotopes to the cluster groups. These allowed the characteristic biota of each cluster group to be listed, producing percentage values of core biotope records within which the given species is recorded. These percentages were totalled for each biotope, which enabled a rapid comparison of biotopes with comparable faunal assemblages. This was used with an assessment of the principal physical characteristics of the habitats to assign the biotope that best represented that cluster group.

### 2.4.4 Data Mapping

Sampling points from the 2020 survey were plotted onto maps using ESRI ArcGIS. Sediment classifications, numbers of taxa and individuals, SIMPROF cluster groups and biotopes were also mapped.

# 3. Results

## 3.1 PSA

Results from the PSA are presented on the Wentworth Scale in Appendix 2 - PSA Results, and graphed in Figure 3 below. The analysis showed that all the samples contained gravel. For 12 out of 25 samples, gravel was the dominant size fraction, with 8 of these being classified as sandy gravel and 4 being classified as muddy sandy gravel. A further 11 samples were sands with various gravel and silt components. Of these, stations 01, 25, 27, 39 and 101 contained low levels of silt (<9%), being classified as gravelly sand or slightly gravelly sand. The remaining 6 of the samples which were classified as sand contained moderate levels of silt. Stations 11 and 52 contained high levels of silt (>50%) and were classified as 'slightly gravelly sandy mud' and 'gravelly mud', respectively.

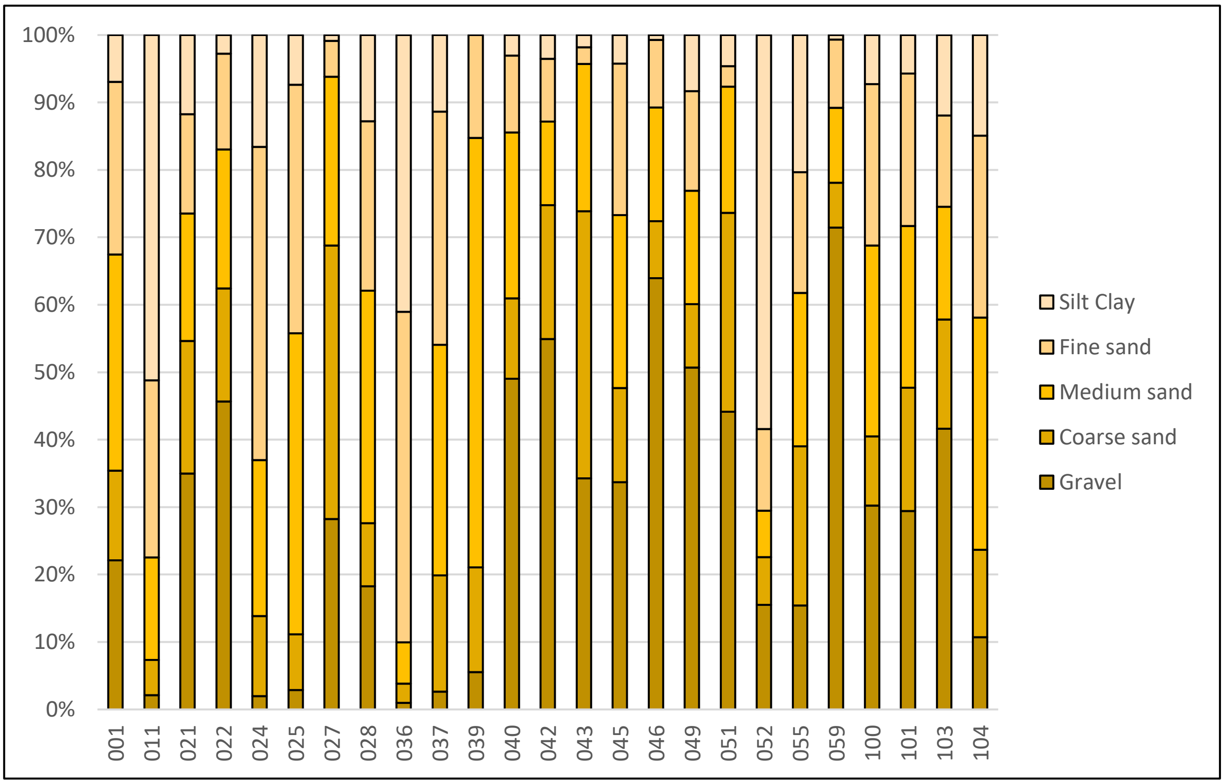


**Figure 3 - Proportion of sediment in different size classes per sampling station**

The sediment classifications assigned through PSA are mapped in Figure 4, showing the spatial distribution of the groups.

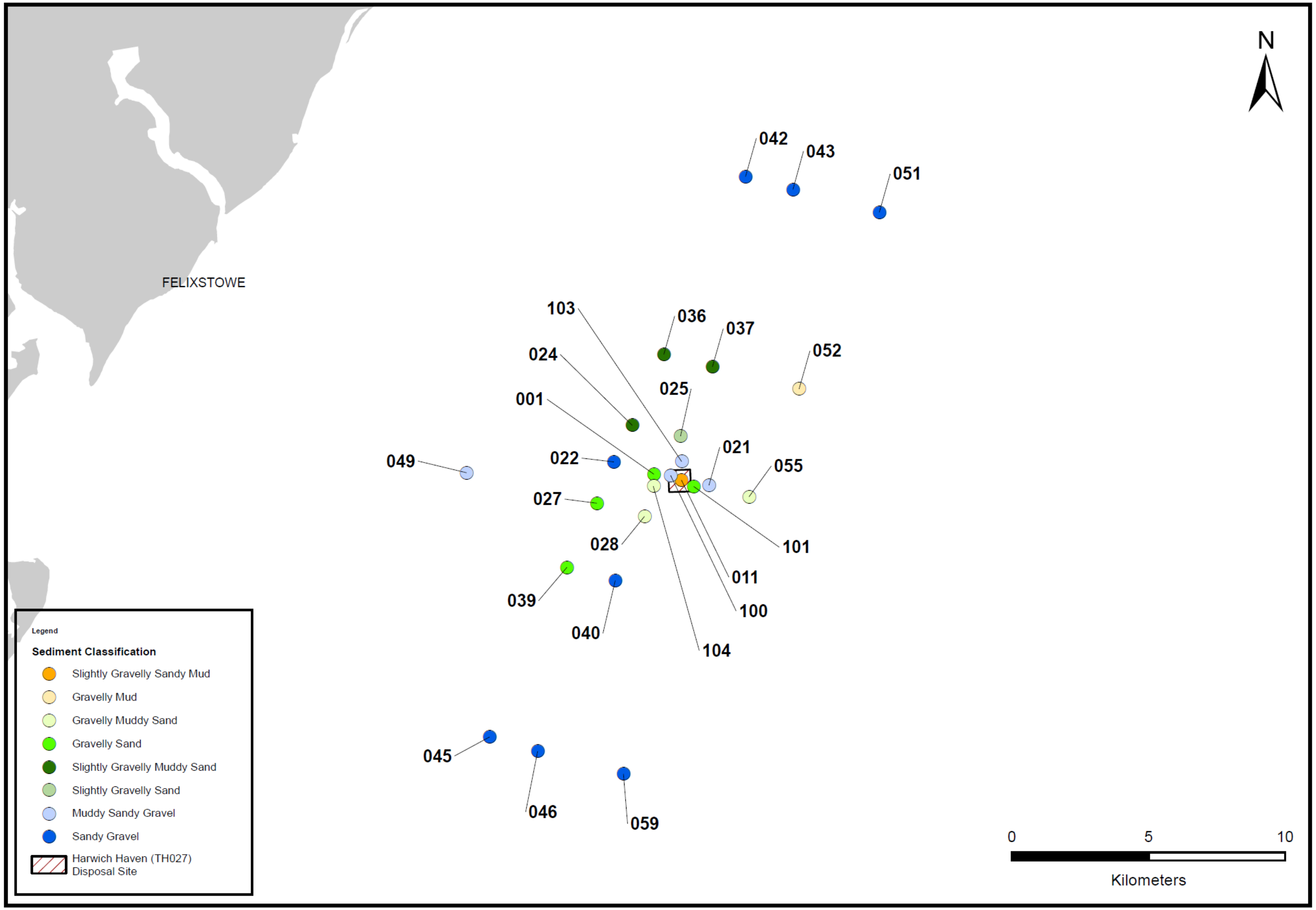


Figure 4 - Particle Size Analysis sediment classifications

## 3.2 Macrobenthic data

The raw species data matrix is presented in Appendix 3 – Macrofauna Matrix.

### Univariate analysis

The diversity indices calculated from the univariate analyses are summarised in Table 1, with the results per station presented in Appendix 4 – Diversity Indices, Table 6.

A total of 256 taxa were identified across the survey area. 42 of these were non-countable, colonial taxa and were recorded as present. Diversity across the samples ranged from between 6 and 80 taxa (including taxa recorded as present). The number of taxa for each sampling station (average of replicate samples A & B) is mapped in Figure 5. Diversity across the survey area appears to be heterogenous, with the most diverse station, 022, and the least diverse station, 027, situated next to each other.

Abundance per sample ranged from only 2 individuals per sample (027A and 027B) to 1,870 individuals (024A). Excluding 24A, which was dominated by the bivalve *Abra sp.* (1,715 individuals), all samples had abundances ≤500 individuals and only 9 of the 50 samples had abundances above 160 individuals. The average number of individuals across the survey area was therefore towards the lower end of this large range in abundance, at 145 individuals per sample. The number of individuals for each sampling station is mapped in Figure 6.

**Table 1 - Univariate analysis results summary. Showing highest and lowest values for the diversity indices calculated by the DIVERSE component of PRIMER. The stations to which the values relate are displayed in brackets.**

| Index Parameter | Maximum (Sample) | Minimum (Sample) | Mean |
|---|---|---|---|
| **Number of taxa (including colonial)** | 80 (022A) | 6 (027A & 039A) | 27 |
| **Number of taxa (excluding colonial)** | 54 (022A) | 2 (027A & 027B) | 21 |
| **Number of individuals** | 1870 (024A) | 2 (027A & 027B) | 145 |
| **Margalef's species richness (d)** | 9.15 (022A) | 1.44 (027A & 027B) | 4.39 |
| **Pielou's eveness (J)** | 1 (027A & 027B) | 0.23 (024A) | 0.74 |
| **Shannon-Weiner ($log_e$) (H')** | 3.29 (051A) | 0.69 (027A & 027B) | 2.06 |

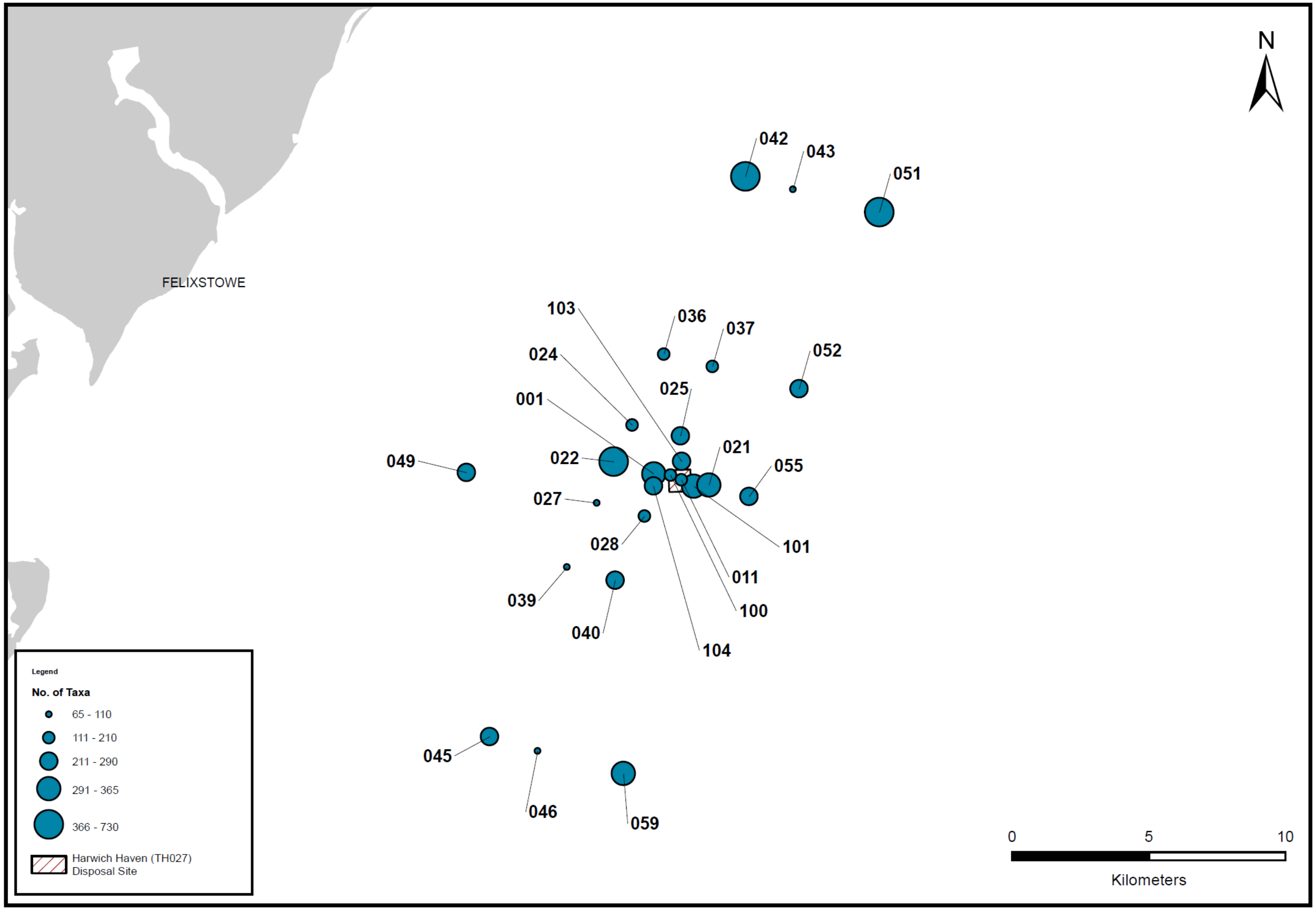


Figure 5 - Average number of taxa per square metre (colonial taxa included) from A & B replicate samples at each station

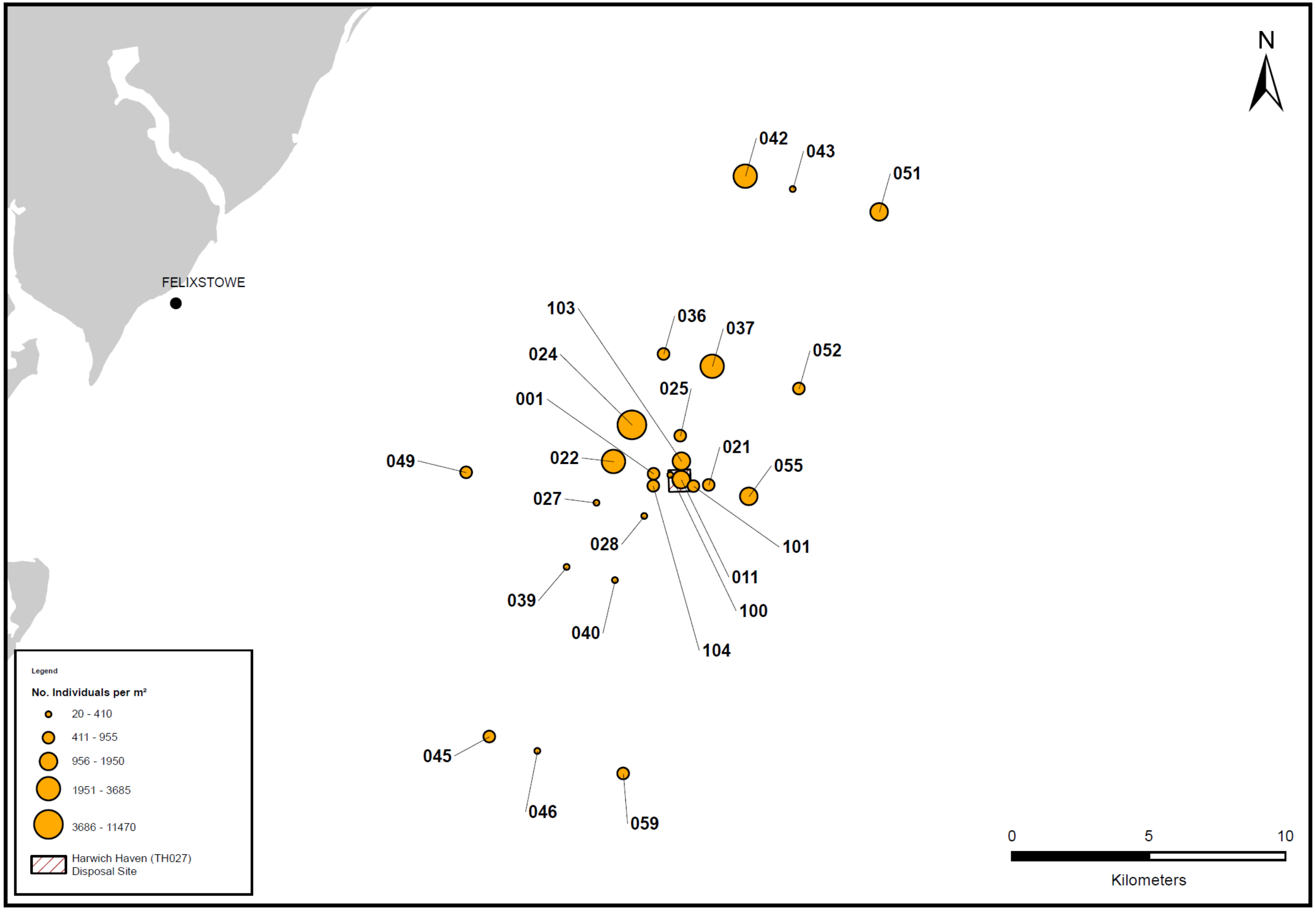


Figure 6 - Average number of individuals per square metre from A & B replicate samples at each station

The benthic community recorded over the survey area was dominated by polychaetes (39% of species) with crustaceans (18%), molluscs (15%) and other fauna (28%), accounting for the rest.

The most abundant taxon was the bivalve *Abra alba,* totalling 2,408 individuals from all samples. This species was found at 18 stations (recorded in 33 samples) however station 024 accounts for 79% of the species' abundance. The next most abundant species were the tube-building polychaetes, *Lagis koreni* (Trumpet worms) and *Sabellaria spinulosa* (Ross worms). *L. koreni* was recorded at 21 stations (in 37 samples), with notable abundances from station 037 (594 individuals). *S. spinulosa* was abundant at station 042 (215 individuals) and present in low numbers (<20 individuals per sample) at an additional 9 stations.

Also present in relatively high numbers (>150 individuals) were the polychaete *Spiophanes bombyx,* the brittle star *Ophiura albida*, the bivalve *Kurtiella bidentata,* the barnacle *Verucca stroemia*, and anemones.

Margalef's species richness (d) index, the measure of the total number of species for the number of individuals present, ranged from 1.44 (samples 027A & 027B) to 9.15. Of the 9 samples with abundances above 160 individuals, samples 024A, 024B, 037A, 037B and 103A had relatively low Margalef's indicies (<3.5), indicating that these samples were dominated by a few taxa. This was confirmed by Pielou's evenness index (J), a measure of the relative abundance of the different species within a sample. This index is constrained between 0 and 1, where less variation in the abundance of different species, corresponds to a higher index. Pielou's evenness index was lowest (0.23) for sample 024A, owing to the abundance of *Abra alba.* Due to the low abundances recorded from station 027, Pielou's evenness index was highest for these samples, with a value of 1. The mean for this index across all samples was 0.74, suggesting that, on average, there was relatively little variation in species abundance within samples.

The value of the Shannon-Weiner species diversity index (H') usually lies from 1.5 for systems with low species diversity to 3.5 for systems with high species diversity. The Shannon-Weiner index value ranged from its lowest at station 027 (0.69 for both A & B samples) to its highest at station 051 (3.29 for 051A, 3.19 for 051B). This shows that species diversity ranged from low to high within the survey area.

### Multivariate analysis

Multivariate analyses were carried out to explore the relationships between stations and investigate similarities in the species assemblage found at each station.

Cluster analysis, including a similarity profile (SIMPROF) test, groups the samples into 15 clusters, where samples that cannot be statistically separated at the 5% significance level (Figure 7). The fact the samples were assigned to such a high number of groups indicates that there was high variability in community structure between samples.

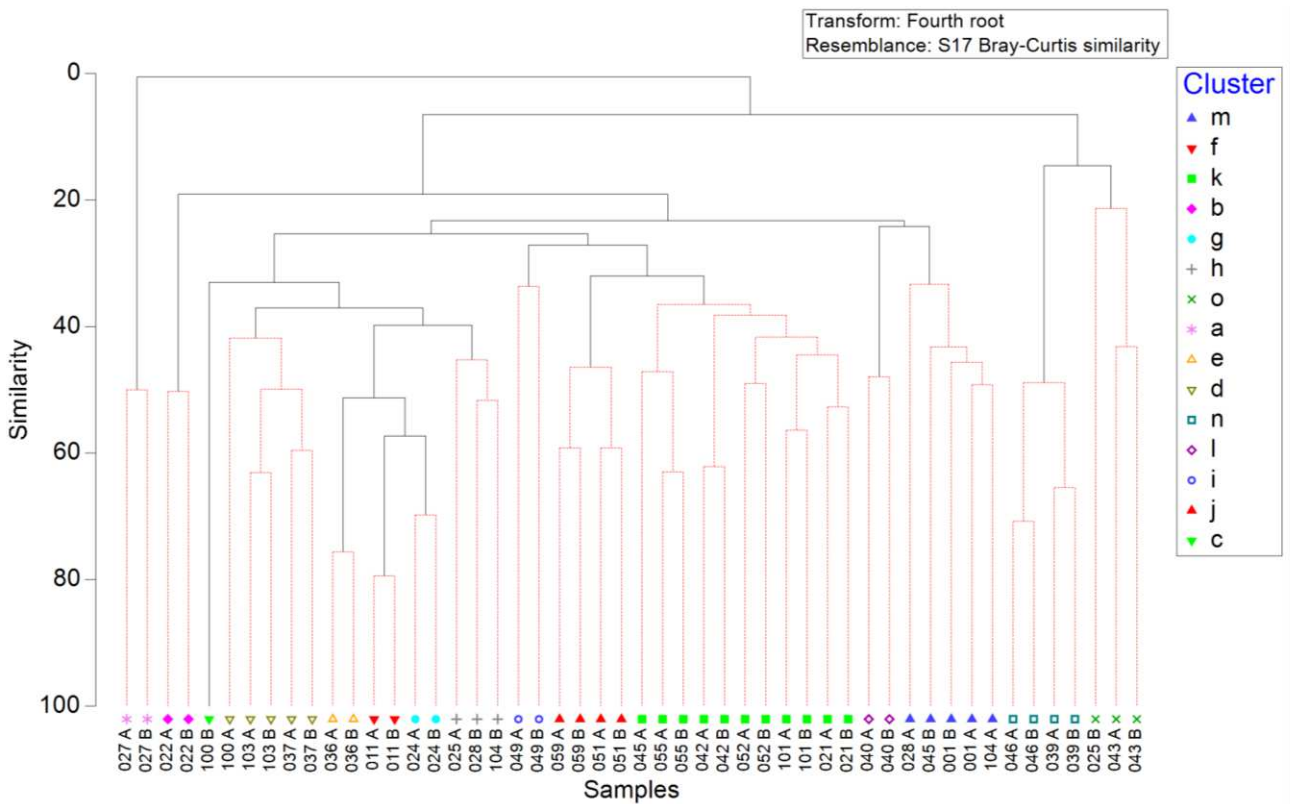


**Figure 7 - SIMPROF hierarchical cluster dendrogram of macrofaunal community structure of each sampling station. Samples connected by red dotted lines are significantly similar in terms community structure and form SIMPROF cluster groups a – o (P=0.05)**

Multi-Dimensional Scaling (MDS) indicates that the community structure was different in groups ‘a, ‘n’ and ‘o’ compared to the rest of the groups, which cluster close together (Figure 8). Groups ‘a’ and ‘o’ also had more variation between samples within their groups than the other groups.

The cluster groups identified for each station are mapped in Figure 9, showing the spatial distribution of the groups. There was little correlation between the PSA results and the cluster groups.

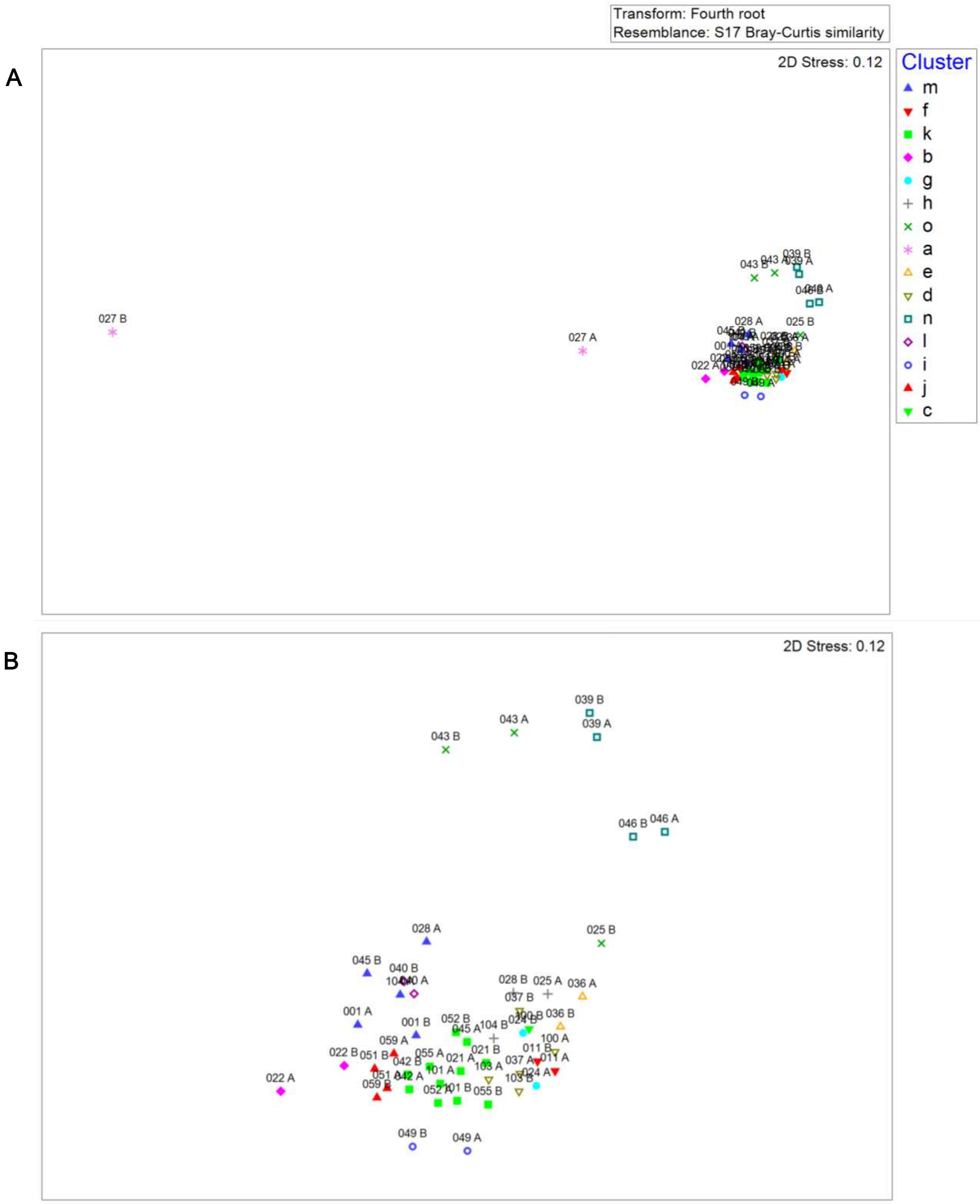


Figure 8 - Multidimensional scaling (MDS) plots of the macrofaunal community structures of samples. Symbols indicate SIMPROF cluster groupings. A includes all samples, B excludes samples 027 A & B to show a clearer comparison of the remaining samples.

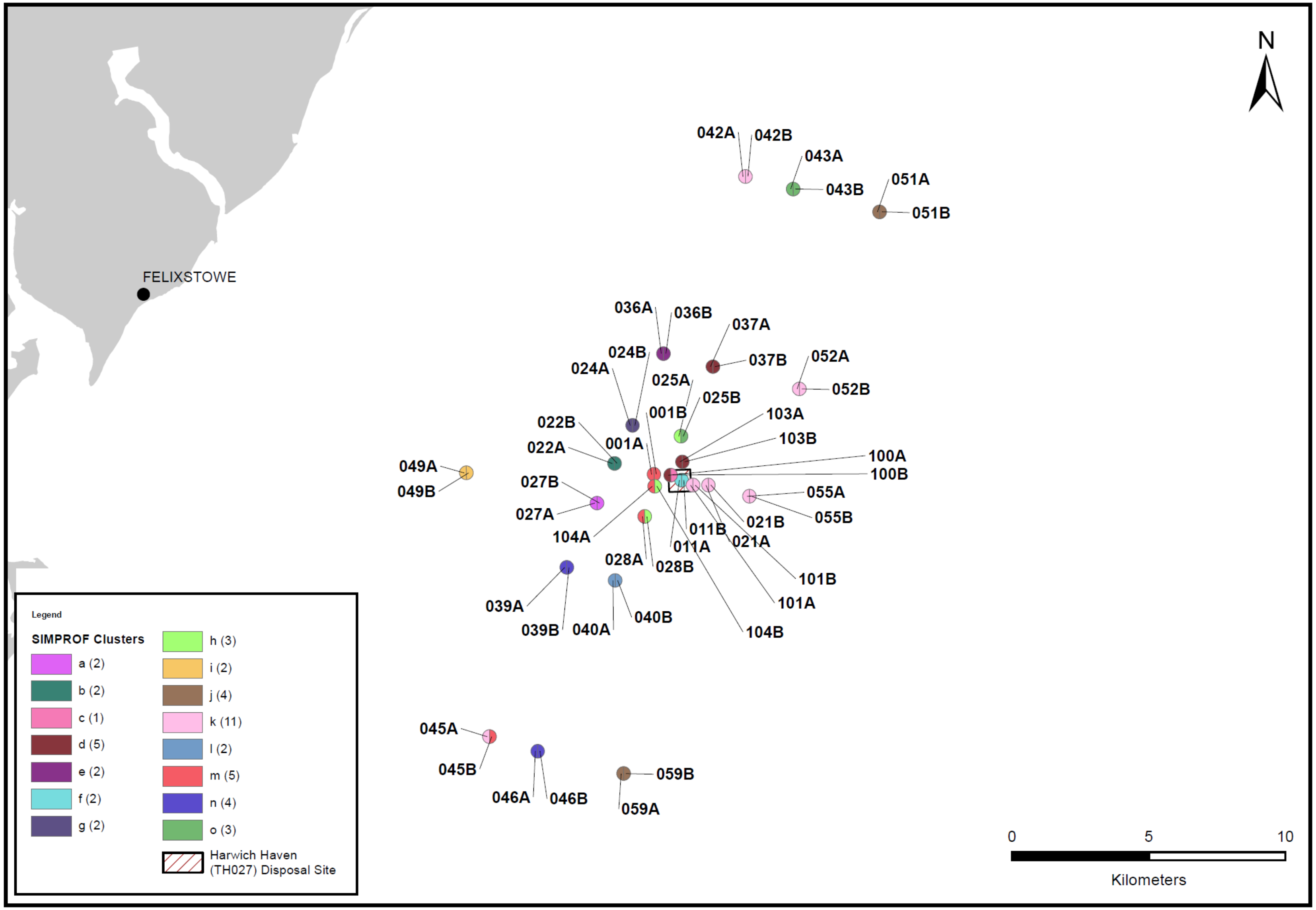


Figure 9 - Sampling stations and the assigned cluster groups

### 3.3 Biotope Assessment

Biotopes were mapped across the survey area by identifying the most abundant species for each cluster group (Appendix 5 - Cluster Group Dominant Species) and the dominant particle size fractions for each sample station with each cluster group.

5 biotopes were identified across the 15 cluster groups (Table 2). The full biotope descriptions are presented in Appendix 6 - Biotope Descriptions. The locations of sample stations and their biotopes are displayed in Figure 10.

| Biotope name | Biotope code | EUNIS code | Cluster group | Station (Sample) |
|---|---|---|---|---|
| Circalittoral course sediment | SS.SCS.CCS | A5.13 | a, j, l, n, o | 027, 059, 051, 040, 046, 039, 025(B), 043 |
| *Sabellaria spinulosa* on stable circalittoral mixed sediment | SS.SBR.PoR.SspiMx | A5.611 | b, k, m | 022, 045(A), 055, 042,052, 101, 021, 028(A), 045(B), 001, 104(A) |
| Circalittoral muddy sand | SS.SSa.CMuSa | A5.26 | c, d, h | 100, 103, 037, 025(A), 028(B), 104(B) |
| *Abra alba* and *Nucula nitidosa* in circalittoral muddy sand or slightly mixed sediment | SS.SSa.CMuSa.Aalb Nuc | A5.261 | e, f, g | 036, 011, 024 |
| *Molgula manhattensis* with a hydroid and bryozoan turf on tide-swept moderately wave-exposed circalittoral rock | CR.HCR.XFa.Mol | A4.138 | i | 049 |

The most dominant biotope was '*Sabellaria spinulosa* on stable circalittoral mixed sediment', which was assigned to 18 samples. 2 other level 5 biotopes were identified, with 6 samples (3 stations) being identified as '*Abra alba* and *Nucula nitidosa* in circalittoral muddy sand or slightly mixed sediment' and the 2 samples at station 049 assigned the biotope '*Molgula manhattensis* with a hydroid and bryozoan turf on tide-swept moderately wave-exposed circalittoral rock'.

,

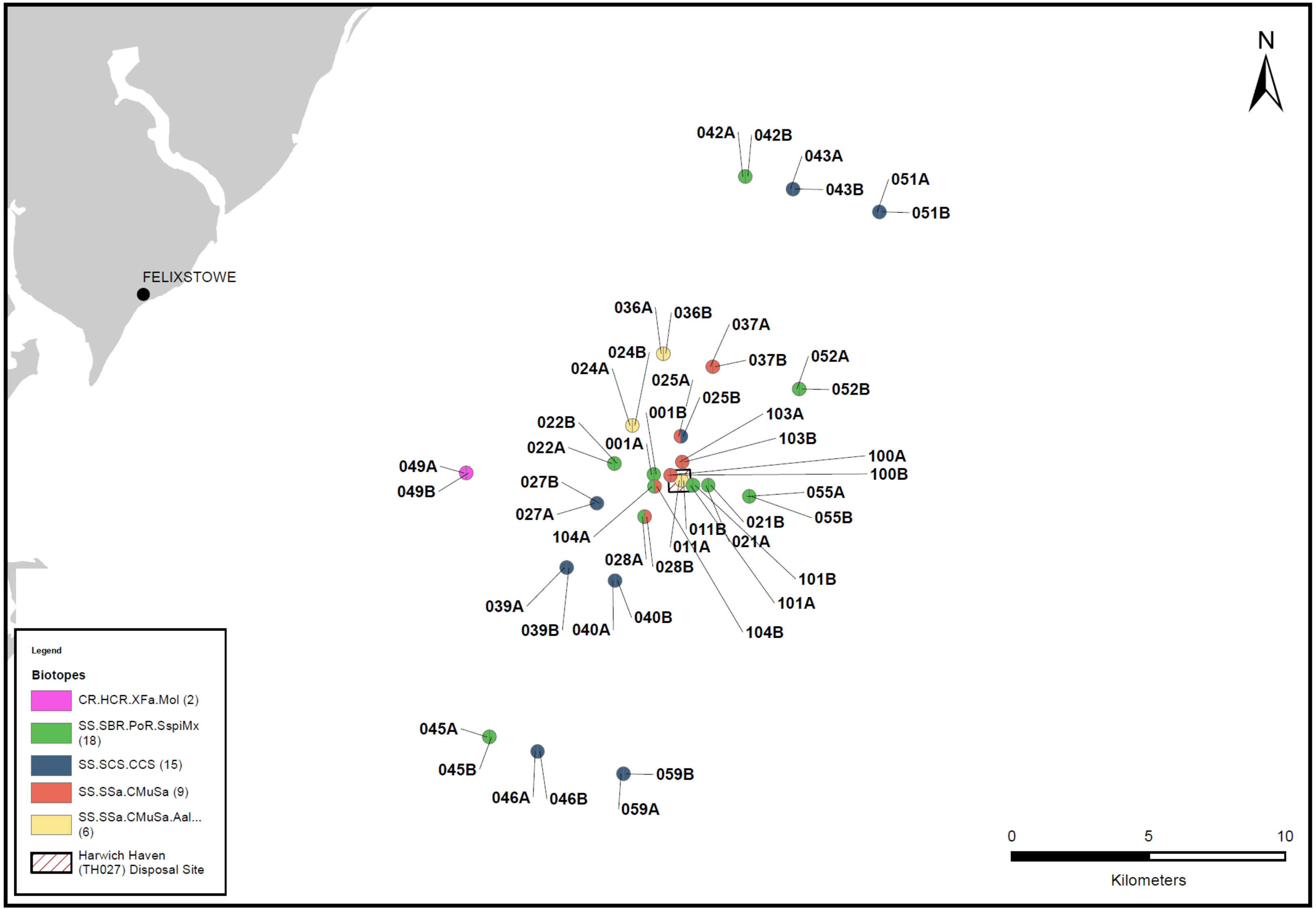


Figure 10 -Sampling stations and the identified biotopes

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# Appendix 1 - Sampling Log

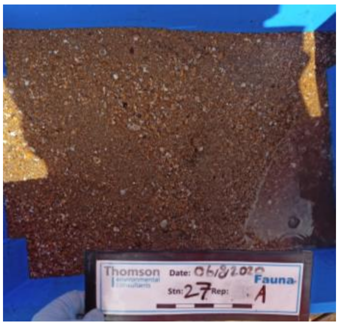
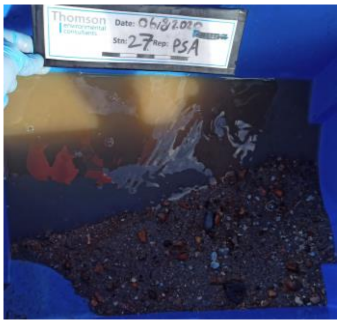
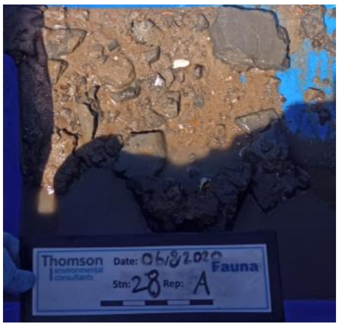
Table 2 - Coordinates for PSA and fauna replicate A & B samples

| Station | Replicate | Date | Time (BST) | Coordinates WGS84 | |
|---|---|---|---|---|---|
| | | | | Latitude | Longitude |
| 001 | A | 06/08/2020 | 12:42 | 51 53.694552 N | 001 36.899616 E |
| | B | 06/08/2020 | 12:44 | 51 53.697077 N | 001 36.898392 E |
| | PSA | 06/08/2020 | 12:53 | 51 53.692198 N | 001 36.900313 E |
| 011 | A | 07/08/2020 | 12:01 | 51 53.546934 N | 001 37.768649 E |
| | B | 07/08/2020 | 12:03 | 51 53.545519 N | 001 37.765946 E |
| | PSA | 07/08/2020 | 12:13 | 51 53.548186 N | 001 37.766269 E |
| 021 | A | 07/08/2020 | 12:41 | 51 53.417783 N | 001 38.626584 E |
| | B | 07/08/2020 | 12:44 | 51 53.417258 N | 001 38.628716 E |
| | PSA | 07/08/2020 | 12:52 | 51 53.417809 N | 001 38.630785 E |
| 022 | A | 06/08/2020 | 12:21 | 51 53.974118 N | 001 35.640027 E |
| | B | 06/08/2020 | 12:27 | 51 53.971999 N | 001 35.646069 E |
| | PSA | 06/08/2020 | 12:30 | 51 53.971898 N | 001 35.645234 E |
| 024 | A | 07/08/2020 | 10:36 | 51 54.672413 N | 001 36.288004 E |
| | B | 07/08/2020 | 10:39 | 51 54.680763 N | 001 36.287837 E |
| | PSA | 07/08/2020 | 10:49 | 51 54.677519 N | 001 36.281595 E |
| 025 | A | 07/08/2020 | 11:07 | 51 54.412751 N | 001 37.808841 E |
| | B | 07/08/2020 | 11:10 | 51 54.415758 N | 001 37.80595 E |
| | PSA | 07/08/2020 | 11:19 | 51 54.414892 N | 001 37.810312 E |
| 027 | A | 06/08/2020 | 10:16 | 51 53.181607 N | 001 35.033574 E |
| | B | 06/08/2020 | 10:18 | 51 53.180941 N | 001 35.038552 E |
| | PSA | 06/08/2020 | 10:24 | 51 53.180277 N | 001 35.038467 E |
| 028 | A | 06/08/2020 | 10:46 | 51 52.868648 N | 001 36.527314 E |
| | B | 06/08/2020 | 10:51 | 51 52.868182 N | 001 36.528692 E |
| | PSA | 06/08/2020 | 10:59 | 51 52.871148 N | 001 36.528614 E |
| 036 | A | 07/08/2020 | 09:58 | 51 56.04891 N | 001 37.407271 E |
| | B | 07/08/2020 | 10:00 | 51 56.05061 N | 001 37.40232 E |
| | PSA | 07/08/2020 | 10:18 | 51 56.044375 N | 001 37.405456 E |
| 037 | A | 07/08/2020 | 09:15 | 51 55.751276 N | 001 38.932133 E |
| | B | 07/08/2020 | 09:17 | 51 55.75084 N | 001 38.935333 E |
| | PSA | 07/08/2020 | 09:24 | 51 55.749292 N | 001 38.933715 E |
| 039 | A | 06/08/2020 | 09:48 | 51 51.944152 N | 001 33.976829 E |
| | B | 06/08/2020 | 09:51 | 51 51.94105 N | 001 33.98099 E |
| | PSA | 06/08/2020 | 09:57 | 51 51.941067 N | 001 33.986183 E |
| 040 | A | 06/08/2020 | 09:20 | 51 51.641172 N | 001 35.492539 E |
| | B | 06/08/2020 | 09:26 | 51 51.637952 N | 001 35.502126 E |
| | PSA | 06/08/2020 | 09:35 | 51 51.638512 N | 001 35.498013 E |
| 042 | A | 07/08/2020 | 07:10 | 51 59.460892 N | 001 40.290346 E |
| | B | 07/08/2020 | 07:13 | 51 59.459482 N | 001 40.293385 E |
| | PSA | 07/08/2020 | 07:19 | 51 59.459521 N | 001 40.292902 E |
| 043 | A | 07/08/2020 | 07:37 | 51 59.160785 N | 001 41.783289 E |
| | B | 07/08/2020 | 07:39 | 51 59.163439 N | 001 41.77712 E |
| | PSA | 07/08/2020 | 07:46 | 51 59.160036 N | 001 41.780781 E |
| 045 | A | 06/08/2020 | 07:51 | 51 48.677963 N | 001 31.276671 E |
| | B | 06/08/2020 | 07:53 | 51 48.678626 N | 001 31.272953 E |
| | PSA | 06/08/2020 | 07:59 | 51 48.679197 N | 001 31.263776 E |

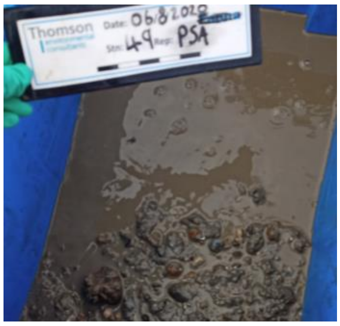
| | | | | | |
|---|---|---|---|---|---|
| 046 | A | 06/08/2020 | 08:12 | 51 48.349108 N | 001 32.767978 E |
| | B | 06/08/2020 | 08:15 | 51 48.350673 N | 001 32.767482 E |
| | PSA | 06/08/2020 | 08:21 | 51 48.350779 N | 001 32.766374 E |
| 049 | A | 06/08/2020 | 06:55 | 51 53.9012 N | 001 30.9301 E |
| | B | 06/08/2020 | 06:57 | 51 53.9019 N | 001 30.9418 E |
| | PSA | 06/08/2020 | 07:04 | 51 53.9029 N | 001 30.9316 E |
| 051 | A | 07/08/2020 | 08:07 | 51 58.627988 N | 001 44.499077 E |
| | B | 07/08/2020 | 08:09 | 51 58.628344 N | 001 44.500405 E |
| | PSA | 07/08/2020 | 08:16 | 51 58.624975 N | 001 44.502792 E |
| 052 | A | 07/08/2020 | 08:47 | 51 55.228359 N | 001 41.653593 E |
| | B | 07/08/2020 | 08:49 | 51 55.226886 N | 001 41.656829 E |
| | PSA | 07/08/2020 | 08:56 | 51 55.225018 N | 001 41.656688 E |
| 055 | A | 07/08/2020 | 13:04 | 51 53.152023 N | 001 39.885676 E |
| | B | 07/08/2020 | 13:07 | 51 53.152215 N | 001 39.890098 E |
| | PSA | 07/08/2020 | 13:15 | 51 53.153843 N | 001 39.891749 E |
| 059 | A | 06/08/2020 | 08:39 | 51 47.824162 N | 001 35.462754 E |
| | B | 06/08/2020 | 08:41 | 51 47.826552 N | 001 35.463418 E |
| | PSA | 06/08/2020 | 08:47 | 51 47.825289 N | 001 35.462868 E |
| 100 | A | 06/08/2020 | 13:02 | 51 53.657157 N | 001 37.435221 E |
| | B | 06/08/2020 | 13:04 | 51 53.659545 N | 001 37.432176 E |
| | PSA | 07/08/2020 | 11:52 | 51 53.656097 N | 001 37.429932 E |
| 101 | A | 07/08/2020 | 12:33 | 51 53.418537 N | 001 38.142538 E |
| | B | 07/08/2020 | 12:26 | 51 53.416185 N | 001 38.149553 E |
| | PSA | 07/08/2020 | 12:33 | 51 53.414059 N | 001 38.147817 E |
| 103 | A | 07/08/2020 | 11:36 | 51 53.917165 N | 001 37.808162 E |
| | B | 07/08/2020 | 11:41 | 51 53.914233 N | 001 37.804551 E |
| | PSA | 07/08/2020 | 11:44 | 51 53.915596 N | 001 37.804449 E |
| 104 | A | 06/08/2020 | 11:26 | 51 53.449616 N | 001 36.909406 E |
| | B | 06/08/2020 | 11:34 | 51 53.458941 N | 001 36.865527 E |
| | PSA | 06/08/2020 | 11:34 | 51 53.458941 N | 001 36.865527 E |

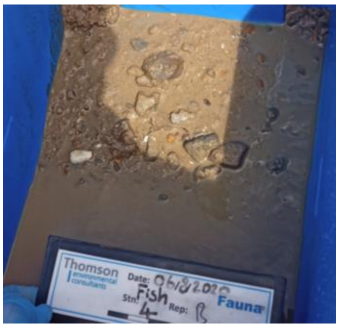
Table 3 - Fauna replicate A & B and PSA sample photographs

| Station | Visual Assessment of Sediment type | Photo | | |
|---|---|---|---|---|
| | | Fauna A | Fauna B | PSA |
| 001 | Muddy Gravelly Sand |  |  |  |
| 011 | Sandy Mud |  |  |  |
| 021 | Sandy Muddy Gravel |  |  |  |
| 022 | Gravelly Muddy Sand |  |  |  |
| 024 | Gravelly Muddy Sand (A) Gravelly Sandy Mud (B & PSA) |  |  |  |

| | | | | |
|---|---|---|---|---|
| 025 | Gravelly Sandy Mud (A)<br>Muddy Sand (B)<br>Gravelly Muddy Sand (PSA) |  |  |  |
| 027 | Slightly Gravelly Sand (A & B)<br>Gravelly Sand (PSA) |  |  |  |
| 028 | Gravelly Sandy Mud |  |  |  |
| 036 | Muddy Sand |  |  |  |
| 037 | Muddy Sand |  |  |  |

| | | | | |
|---|---|---|---|---|
| 039 | Gravelly Muddy Sand |  |  |  |
| 040 | Sandy Gravel |  |  |  |
| 042 | Sandy Gravel |  |  |  |
| 043 | Sand (A) Gravelly Sand (B & PSA) |  |  |  |
| 045 | Gravelly Sand |  |  |  |

| | | | | |
|---|---|---|---|---|
| 046 | Sand (A)<br>Gravelly Sand<br>(B & PSA) |  |  |  |
| 049 | Sandy Muddy<br>Gravel |  |  |  |
| 051 | Gravelly Sand |  |  |  |
| 052 | Gravelly Mud |  |  |  |
| 055 | Gravelly<br>Sandy Mud |  |  |  |

| | | | | |
|---|---|---|---|---|
| 059 | Gravelly Sand (A)<br>Sandy Gravel (B & PSA) |  |  |  |
| 100 (FISH01) | Muddy Gravelly Sand |  |  |  |
| 101 (FISH03) | Gravelly Muddy Sand |  |  |  |
| 103 (FISH02) | Muddy Gravelly Sand |  |  |  |
| 104 (FISH04) | Gravelly Muddy Sand |  |  |  |

# Appendix 2 - PSA Results

**Table 4 - Particle Size Distribution (%) using Wentworth Scale and Textural Group**

| Station | Silt Clay <0.063 mm | V. fine sand >0.063<0.125 mm | Fine sand >0.125<0.25 mm | Medium sand >0.25<0.5 mm | Coarse sand >0.5<1 mm | V. coarse sand >1<2 mm | Granule >2<4 mm | Pebble >4<64 mm | Textural Group |
|---|---|---|---|---|---|---|---|---|---|
| **001** | 6.97 | 1.30 | 24.29 | 32.05 | 8.82 | 4.45 | 5.97 | 16.15 | Gravelly Sand |
| **011** | 51.22 | 10.49 | 15.77 | 15.19 | 4.66 | 0.57 | 0.60 | 1.52 | Slightly Gravelly Sandy Mud |
| **021** | 11.75 | 4.11 | 10.61 | 18.92 | 15.29 | 4.33 | 5.18 | 29.82 | Muddy Sandy Gravel |
| **022** | 2.74 | 1.94 | 12.27 | 20.62 | 12.48 | 4.27 | 8.22 | 37.45 | Sandy Gravel |
| **024** | 16.58 | 17.37 | 29.07 | 23.11 | 10.29 | 1.58 | 0.70 | 1.29 | Slightly Gravelly Muddy Sand |
| **025** | 7.38 | 2.94 | 33.92 | 44.64 | 6.50 | 1.75 | 1.19 | 1.68 | Slightly Gravelly Sand |
| **027** | 0.88 | 0.64 | 4.68 | 25.02 | 29.77 | 10.77 | 7.86 | 20.38 | Gravelly Sand |
| **028** | 12.78 | 1.44 | 23.71 | 34.44 | 6.45 | 2.91 | 4.33 | 13.94 | Gravelly Muddy Sand |
| **036** | 41.02 | 26.46 | 22.57 | 6.12 | 2.51 | 0.32 | 0.12 | 0.88 | Slightly Gravelly Muddy Sand |
| **037** | 11.38 | 7.49 | 27.07 | 34.20 | 15.40 | 1.84 | 1.44 | 1.18 | Slightly Gravelly Muddy Sand |
| **039** | 0.00 | 0.00 | 15.27 | 63.65 | 14.23 | 1.34 | 1.27 | 4.25 | Gravelly Sand |
| **040** | 3.06 | 0.06 | 11.36 | 24.57 | 6.96 | 4.96 | 7.36 | 41.68 | Sandy Gravel |
| **042** | 3.51 | 2.13 | 7.20 | 12.39 | 13.12 | 6.71 | 7.49 | 47.45 | Sandy Gravel |
| **043** | 1.82 | 0.19 | 2.29 | 21.80 | 29.46 | 10.15 | 8.89 | 25.38 | Sandy Gravel |
| **045** | 4.25 | 2.53 | 19.94 | 25.65 | 10.30 | 3.61 | 5.61 | 28.11 | Sandy Gravel |
| **046** | 0.72 | 0.31 | 9.72 | 16.86 | 5.22 | 3.21 | 7.65 | 56.31 | Sandy Gravel |
| **049** | 8.32 | 2.31 | 12.48 | 16.80 | 6.93 | 2.44 | 4.87 | 45.85 | Muddy Sandy Gravel |
| **051** | 4.60 | 1.24 | 1.81 | 18.70 | 22.87 | 6.65 | 8.35 | 35.77 | Sandy Gravel |
| **052** | 58.43 | 7.10 | 5.00 | 6.89 | 4.03 | 3.05 | 3.62 | 11.89 | Gravelly Mud |
| **055** | 20.34 | 6.48 | 11.44 | 22.73 | 20.95 | 2.65 | 2.82 | 12.60 | Gravelly Muddy Sand |
| **059** | 0.68 | 1.29 | 8.81 | 11.12 | 4.60 | 2.03 | 3.71 | 67.75 | Sandy Gravel |
| **100** | 7.28 | 1.58 | 22.33 | 28.31 | 5.98 | 4.27 | 5.83 | 24.41 | Muddy Sandy Gravel |
| **101** | 5.69 | 4.33 | 18.27 | 24.01 | 11.29 | 6.97 | 8.46 | 20.98 | Gravelly Sand |
| **103** | 11.92 | 3.13 | 10.40 | 16.73 | 10.89 | 5.30 | 7.43 | 34.20 | Muddy Sandy Gravel |
| **104** | 14.90 | 3.44 | 23.55 | 34.44 | 11.88 | 1.06 | 1.77 | 8.96 | Gravelly Muddy Sand |

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# Appendix 3 – Macrofauna Matrix

## Table 5 – Species Abundance Matrix

| Taxon name | Qualifiers | 001 A | 001 B | 011 A | 011 B | 021 A | 021 B | 022 A | 022 B | 024 A | 024 B | 025 A | 025 B | 027 A | 027 B | 028 A | 028 B | 036 A | 036 B | 037 A | 037 B | 039 A | 039 B | 040 A | 040 B | 042 A | 042 B | 043 A | 043 B | 045 A | 045 B | 046 A | 046 B | 049 A | 049 B | 051 A | 051 B | 052 A | 052 B | 055 A | 055 B | 059 A | 059 B | 100 A | 100 B | 101 A | 101 B | 103 A | 103 B | 104 A | 104 B |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ANIMALIA | Eggs | - | - | - | - | - | - | P | P | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| PORIFERA | | - | - | - | - | - | - | P | P | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| CNIDARIA | | - | - | - | - | 1 | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| ACTINIARIA | | 2 | 3 | - | - | 3 | - | 49 | 106 | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | 2 | - | 1 | - | - | - | 1 | - | - | 2 | 1 | - | - | 1 | 1 | - | - | 8 | 4 | - | - | 2 | 2 | - | - | 5 | - |
| Alcyonium digitatum | | - | - | - | - | - | - | P | P | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Cerianthus lloydii | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| HYDROZOA | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | P | P | - | - | - | P | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| ANTHOATHECATA | | - | - | - | - | - | - | P | P | - | - | - | P | - | - | - | P | - | - | - | - | - | - | - | - | - | P | - | - | - | - | - | - | - | P | - | - | P | - | - | - | - | - | P | P | - | - | - | - | - | - |
| Hydractiniidae | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | P | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| LEPTOTHECATA | | - | P | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | P | P | - | - | - | - | - | P | - | - | - | - | - | - | - | - | - |
| Campanulariidae | | P | P | - | - | P | P | P | P | P | P | P | P | - | - | P | P | P | - | P | P | P | P | P | P | P | P | P | P | P | P | P | P | P | P | - | P | P | P | P | P | - | - | P | - | P | P | P | - | P | P |
| Halecium | | - | - | - | - | - | - | P | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | P | - | - | - | - | - | - | - | - | - | - | P | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
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| Taxon name | Qualifiers | 001 A | 001 B | 011 A | 011 B | 021 A | 021 B | 022 A | 022 B | 024 A | 024 B | 025 A | 025 B | 027 A | 027 B | 028 A | 028 B | 036 A | 036 B | 037 A | 037 B | 039 A | 039 B | 040 A | 040 B | 042 A | 042 B | 043 A | 043 B | 045 A | 045 B | 046 A | 046 B | 049 A | 049 B | 051 A | 051 B | 052 A | 052 B | 055 A | 055 B | 059 A | 059 B | 100 A | 100 B | 101 A | 101 B | 103 A | 103 B | 104 A | 104 B |
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| Taxon name | Qualifiers | 001 A | 001 B | 011 A | 011 B | 021 A | 021 B | 022 A | 022 B | 024 A | 024 B | 025 A | 025 B | 027 A | 027 B | 028 A | 028 B | 036 A | 036 B | 037 A | 037 B | 039 A | 039 B | 040 A | 040 B | 042 A | 042 B | 043 A | 043 B | 045 A | 045 B | 046 A | 046 B | 049 A | 049 B | 051 A | 051 B | 052 A | 052 B | 055 A | 055 B | 059 A | 059 B | 100 A | 100 B | 101 A | 101 B | 103 A | 103 B | 104 A | 104 B |
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| Scolelepis (Parascolelepis) tridentata | | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
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| Chaetozone zetlandica | | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 2 | 3 | - | - | - | - | 1 | - | - | - | - | - | 1 | - | 2 | 2 | 3 | 1 | - | 1 | - | - | - | - | 2 | 1 | - | - |
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| Sabellaria spinulosa | | 5 | 7 | - | - | - | 1 | 19 | 16 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 82 | 133 | - | - | 1 | 1 | - | - | 1 | 13 | - | - | 9 | 6 | 2 | - | - | - | - | - | 5 | 6 | - | - | 15 | - |
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| Ammothella longipes | | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
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| Callipallene | Eggs | - | - | - | - | - | - | P | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Nymphon brevirostre | | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - |

| Taxon name | Qualifiers | 001 A | 001 B | 011 A | 011 B | 021 A | 021 B | 022 A | 022 B | 024 A | 024 B | 025 A | 025 B | 027 A | 027 B | 028 A | 028 B | 036 A | 036 B | 037 A | 037 B | 039 A | 039 B | 040 A | 040 B | 042 A | 042 B | 043 A | 043 B | 045 A | 045 B | 046 A | 046 B | 049 A | 049 B | 051 A | 051 B | 052 A | 052 B | 055 A | 055 B | 059 A | 059 B | 100 A | 100 B | 101 A | 101 B | 103 A | 103 B | 104 A | 104 B |
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| Ampelisca spinipes | | - | - | - | - | 1 | - | - | 3 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 21 | 25 | - | - | 3 | - | - | - | - | 2 | 11 | 11 | 2 | 6 | 2 | 2 | 3 | 6 | - | - | - | - | - | - | - | - |
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Thomson environmental consultants

| Taxon name | Qualifiers | 001 A | 001 B | 011 A | 011 B | 021 A | 021 B | 022 A | 022 B | 024 A | 024 B | 025 A | 025 B | 027 A | 027 B | 028 A | 028 B | 036 A | 036 B | 037 A | 037 B | 039 A | 039 B | 040 A | 040 B | 042 A | 042 B | 043 A | 043 B | 045 A | 045 B | 046 A | 046 B | 049 A | 049 B | 051 A | 051 B | 052 A | 052 B | 055 A | 055 B | 059 A | 059 B | 100 A | 100 B | 101 A | 101 B | 103 A | 103 B | 104 A | 104 B |
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| Nucula nitidosa | | - | - | 3 | 10 | - | - | - | - | 4 | 1 | - | - | - | - | - | - | 2 | 3 | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - |
| Heteranomia squamula | | - | - | - | - | - | - | 2 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Mactridae | | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | 2 | - | - |
| Spisula | | - | - | - | - | - | - | - | - | - | - | - | 4 | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | 1 | 1 | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - |

| Taxon name | Qualifiers | 001 A | 001 B | 011 A | 011 B | 021 A | 021 B | 022 A | 022 B | 024 A | 024 B | 025 A | 025 B | 027 A | 027 B | 028 A | 028 B | 036 A | 036 B | 037 A | 037 B | 039 A | 039 B | 040 A | 040 B | 042 A | 042 B | 043 A | 043 B | 045 A | 045 B | 046 A | 046 B | 049 A | 049 B | 051 A | 051 B | 052 A | 052 B | 055 A | 055 B | 059 A | 059 B | 100 A | 100 B | 101 A | 101 B | 103 A | 103 B | 104 A | 104 B |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Thracia | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| CHEILOSTOMATIDA | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | P | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | P | P | - | - |
| Schizomavella | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | P | P | P | - | - | - | - | P | - | - | - | - | - | - | - | - | - |
| Schizomavella (Schizomavella) linearis | | - | - | - | - | - | - | P | P | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Bugulidae | | - | - | - | - | - | - | P | - | - | - | P | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | P | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Bicellariella ciliata | | - | - | - | - | - | - | P | P | P | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | P | P | - | - | - | - | - | - | - | - | P | - | - | - | - | - | - | - |
| Amphiblestrum auritum | | - | - | - | - | - | - | - | P | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Callopora dumerilii | | - | - | - | - | - | - | P | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Candidae | | - | P | P | P | - | - | - | - | - | - | P | P | - | - | - | - | - | - | - | - | - | - | P | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Aspidelectra melolontha | | - | - | - | - | - | - | P | P | - | - | - | - | P | P | - | - | P | P | - | - | - | - | - | - | - | - | P | P | P | - | P | P | - | - | - | - | P | P | P | - | - | - | P | - | - | - | P | - | P | - |
| Conopeum reticulum | | - | - | - | - | P | - | P | P | - | - | - | P | - | P | P | - | P | P | - | - | - | - | P | P | - | - | - | - | P | - | - | - | - | P | - | - | - | - | - | - | - | - | P | - | - | - | P | - | - | - |
| Electra monostachys | | P | P | - | - | P | P | P | P | - | - | - | - | - | - | P | P | P | P | - | - | - | - | P | P | - | - | - | P | P | P | P | P | P | P | - | - | P | P | - | - | - | - | P | P | - | - | - | - | P | - |
| Electra pilosa | | P | P | - | - | P | - | P | P | - | - | - | P | P | P | - | - | - | - | - | P | - | - | P | P | P | P | - | - | - | - | - | P | - | - | P | P | - | - | P | - | - | - | P | P | - | P | - | - | P | - |
| Eucratea loricata | | - | - | P | - | P | - | - | - | - | P | - | - | - | - | - | - | - | P | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | P | - |
| Chartella papyracea | | - | - | - | - | - | - | P | P | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Flustra foliacea | | P | - | - | - | - | - | P | P | - | - | - | P | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | P | - |
| Escharella | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | P | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Escharella immersa | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | P | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Alcyonidioides mytili | | - | - | - | - | - | - | P | P | - | - | - | - | - | - | P | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Alcyonidium parasiticum | | - | - | - | - | - | - | P | P | - | - | - | - | - | - | P | - | - | - | - | - | - | - | P | P | - | - | - | - | - | - | - | - | - | - | - | - | - | P | - | - | - | - | - | - | P | P | P | - | P | - |
| Anguinella palmata | | P | P | - | - | P | - | P | P | - | - | P | P | P | P | - | P | - | P | - | P | - | P | - | P | - | - | - | - | - | - | - | - | - | P | - | - | - | - | - | - | - | - | - | - | - | P | P | - | P | - |
| Penetrantia | | - | - | - | - | - | - | - | - | - | P | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | P | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | P | P | P | - | - |
| Amathia | | - | - | - | - | - | - | P | P | - | - | - | - | - | - | - | - | - | - | - | - | - | - | P | P | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Vesicularia spinosa | | - | - | - | - | - | - | - | - | - | - | - | P | - | - | - | - | - | P | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | P | - | - | - | P | - | P | - |
| CYCLOSTOMATIDA | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | P | P | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Crisia | | - | P | - | - | - | - | P | P | - | - | - | P | - | - | - | - | - | - | - | - | - | - | P | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | P | - | - |
| Phoronis | | - | - | - | - | - | - | 1 | 8 | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | 1 | - | - | 1 | - | - | 2 | - | - | 2 | - | 3 | - | - | 1 |
| ECHINIDEA | Juvenile | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Psammechinus miliaris | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 2 | 1 | - | - | - | - | 2 | 2 | - | - | - | - | - | - | - | - |
| Echinocyamus pusillus | | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | 7 | 5 | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Amphiuridae | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 2 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 1 | - | - |
| Acrocnida brachiata | | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Amphipholis squamata | | 5 | 1 | - | - | - | - | 6 | 4 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 4 | - | - | - | - | - | - | - | 2 | 1 | 1 | - | - | - | - | 1 | 6 | - | - | 2 | 1 | 3 | - | - | - |
| Ophiothrix fragilis | | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Ophiuridae | | - | - | - | - | - | - | - | - | 2 | - | - | - | - | - | - | - | - | 2 | - | 2 | - | - | - | - | 6 | 4 | - | - | - | - | - | - | - | - | 2 | 4 | 1 | 1 | 3 | 3 | - | 1 | - | - | 1 | 2 | - | - | - | - |
| Ophiura | | - | - | - | - | - | - | - | - | 3 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Ophiura albida | | - | - | - | - | 2 | 5 | - | - | 4 | 2 | - | - | - | - | - | - | 12 | 8 | - | - | - | - | - | - | 22 | 25 | - | - | 19 | - | - | - | 1 | - | 19 | 18 | 2 | 5 | 3 | - | 3 | 6 | - | - | 1 | 3 | - | - | - | - |
| Ophiura ophiura | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - |
| ENTEROPNEUSTA | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| ASCIDIACEA | | 3 | 1 | - | - | - | - | P | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Molgula | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 53 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Polycarpa fibrosa | | 1 | 2 | - | - | - | - | 6 | 18 | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 4 | - |
| Araceae | | - | - | P | P | - | - | - | - | P | P | P | P | - | - | - | - | - | - | - | - | P | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Folliculinidae | | - | - | P | P | - | - | P | P | - | P | P | P | P | P | - | - | - | - | P | P | - | - | - | - | - | P | P | - | P | - | - | - | - | - | - | P | - | P | - | - | - | - | - | - | - | - | - | - | - | - |

# Appendix 4 – Diversity Indices

Table 6 – Diversity indices from PRIMER's univariate analysis

| Sample | No. of Taxa (inc. colonial) | No. of Taxa (exc. colonial) | No. of Individuals | Margalef's index | Pielou's index | Shannon-Wiener ($log_e$) |
|---|---|---|---|---|---|---|
| 001A | 37 | 31 | 65 | 7.187 | 0.8813 | 3.027 |
| 001B | 36 | 28 | 78 | 6.197 | 0.8894 | 2.964 |
| 011A | 18 | 12 | 157 | 2.176 | 0.5857 | 1.455 |
| 011B | 17 | 13 | 111 | 2.548 | 0.7317 | 1.877 |
| 021A | 39 | 33 | 79 | 7.324 | 0.9014 | 3.152 |
| 021B | 22 | 19 | 71 | 4.223 | 0.7439 | 2.191 |
| 022A | 80 | 54 | 328 | 9.149 | 0.6949 | 2.772 |
| 022B | 66 | 45 | 355 | 7.493 | 0.6499 | 2.474 |
| 024A | 23 | 20 | 1870 | 2.522 | 0.2307 | 0.6911 |
| 024B | 19 | 13 | 424 | 1.984 | 0.344 | 0.8824 |
| 025A | 20 | 13 | 72 | 2.806 | 0.4764 | 1.222 |
| 025B | 27 | 14 | 83 | 2.942 | 0.5329 | 1.406 |
| 027A | 6 | 2 | 2 | 1.443 | 1 | 0.6931 |
| 027B | 7 | 2 | 2 | 1.443 | 1 | 0.6931 |
| 028A | 21 | 16 | 27 | 4.551 | 0.9146 | 2.536 |
| 028B | 21 | 16 | 55 | 3.743 | 0.6955 | 1.928 |
| 036A | 14 | 9 | 56 | 1.987 | 0.5558 | 1.221 |
| 036B | 20 | 12 | 87 | 2.463 | 0.472 | 1.173 |
| 037A | 20 | 17 | 237 | 2.926 | 0.4279 | 1.212 |
| 037B | 21 | 17 | 500 | 2.975 | 0.2479 | 0.7074 |
| 039A | 9 | 7 | 25 | 1.864 | 0.8095 | 1.575 |
| 039B | 6 | 4 | 6 | 1.674 | 0.9591 | 1.33 |
| 040A | 33 | 20 | 49 | 4.882 | 0.8798 | 2.636 |
| 040B | 20 | 11 | 22 | 3.235 | 0.9327 | 2.237 |
| 042A | 47 | 42 | 261 | 7.368 | 0.7004 | 2.618 |
| 042B | 55 | 47 | 344 | 7.876 | 0.6641 | 2.557 |
| 043A | 9 | 5 | 13 | 1.559 | 0.8245 | 1.327 |
| 043B | 12 | 5 | 10 | 1.737 | 0.7627 | 1.228 |
| 045A | 32 | 27 | 79 | 5.95 | 0.7794 | 2.569 |
| 045B | 24 | 21 | 29 | 5.939 | 0.9203 | 2.802 |
| 046A | 12 | 9 | 55 | 1.996 | 0.6634 | 1.458 |
| 046B | 10 | 6 | 19 | 1.698 | 0.9403 | 1.685 |
| 049A | 17 | 13 | 21 | 3.942 | 0.9456 | 2.425 |
| 049B | 31 | 19 | 95 | 3.953 | 0.607 | 1.787 |
| 051A | 54 | 47 | 152 | 9.156 | 0.8551 | 3.292 |
| 051B | 54 | 46 | 146 | 9.03 | 0.8324 | 3.187 |
| 052A | 27 | 23 | 51 | 5.595 | 0.9195 | 2.883 |
| 052B | 28 | 23 | 55 | 5.49 | 0.9158 | 2.871 |
| 055A | 30 | 27 | 116 | 5.47 | 0.7796 | 2.57 |
| 055B | 16 | 15 | 112 | 2.967 | 0.5938 | 1.608 |
| 059A | 35 | 33 | 99 | 6.964 | 0.8564 | 2.994 |
| 059B | 30 | 30 | 92 | 6.413 | 0.903 | 3.071 |
| 100A | 21 | 12 | 30 | 3.234 | 0.8393 | 2.086 |
| 100B | 16 | 12 | 47 | 2.857 | 0.6598 | 1.64 |
| 101A | 28 | 26 | 57 | 6.183 | 0.9312 | 3.034 |
| 101B | 35 | 27 | 66 | 6.206 | 0.8861 | 2.92 |
| 103A | 28 | 20 | 238 | 3.472 | 0.5313 | 1.592 |
| 103B | 26 | 23 | 152 | 4.379 | 0.6093 | 1.911 |
| 104A | 40 | 30 | 65 | 6.947 | 0.8744 | 2.974 |
| 104B | 18 | 16 | 73 | 3.496 | 0.7137 | 1.979 |

# Appendix 5 - Cluster Group Dominant Species

**Table 7 - Taxa with highest mean abundance within each cluster group (showing ~80% cumulative mean abundance for each group)**

| Cluster Group | Samples | Taxon name | Mean Abundance (per m$^2$) | Mean Abundance (%) | Cumulative Mean Abundance (%) |
|---|---|---|---|---|---|
| a | 027A 027B | Capitellidae | 10 | 50.00 | 50.00 |
| | | Hesionura elongata | 5 | 25.00 | 75.00 |
| | | Mytilidae | 5 | 25.00 | 100.00 |
| b | 022A 022B | Verruca stroemia | 785 | 22.99 | 22.99 |
| | | ACTINIARIA | 775 | 22.69 | 45.68 |
| | | Mytilus edulis | 560 | 16.40 | 62.08 |
| | | Sabellaria spinulosa | 175 | 5.12 | 67.20 |
| | | Polycarpa fibrosa | 120 | 3.51 | 70.72 |
| | | Pisidia longicornis | 60 | 1.76 | 72.47 |
| | | Amphipholis squamata | 50 | 1.46 | 73.94 |
| | | Harmothoe | 45 | 1.32 | 75.26 |
| | | Phoronis | 45 | 1.32 | 76.57 |
| | | Gammaropsis maculata | 40 | 1.17 | 77.75 |
| | | Lagis koreni | 35 | 1.02 | 78.77 |
| | | NEMERTEA | 30 | 0.88 | 79.65 |
| | | Syllis armillaris | 30 | 0.88 | 80.53 |
| | | Lumbrineris aniara agg. | 30 | 0.88 | 81.41 |
| c | 100B | Spiophanes bombyx | 270 | 57.45 | 57.45 |
| | | Lagis koreni | 40 | 8.51 | 65.96 |
| | | Balanus crenatus | 30 | 6.38 | 72.34 |
| | | Nuculidae | 30 | 6.38 | 78.72 |
| d | 100B 103A 103B 037A 037B | Lagis koreni | 1532 | 66.21 | 66.21 |
| | | Spiophanes bombyx | 308 | 13.31 | 79.52 |
| | | Kurtiella bidentata | 134 | 5.79 | 85.31 |
| e | 036A 036B | Abra alba | 490 | 68.53 | 68.53 |
| | | Ophiura albida | 100 | 13.99 | 82.52 |
| f | 011A 011B | Abra alba | 645 | 48.13 | 48.13 |
| | | Lagis koreni | 260 | 19.40 | 67.54 |
| | | Notomastus | 135 | 10.07 | 77.61 |
| | | Nucula | 95 | 7.09 | 84.70 |
| g | 024A 024B | Abra alba | 9540 | 83.17 | 83.17 |
| h | 025A 028B 104B | Abra alba | 347 | 52.00 | 52.00 |
| | | Lagis koreni | 110 | 16.50 | 68.50 |
| | | Spiophanes bombyx | 43 | 6.50 | 75.00 |
| | | Kurtiella bidentata | 20 | 3.00 | 78.00 |
| | | Goniada maculata | 13 | 2.00 | 80.00 |
| i | 049A 049B | Molgula | 265 | 45.69 | 45.69 |
| | | Sabellaria spinulosa | 70 | 12.07 | 57.76 |
| | | NEMERTEA | 30 | 5.17 | 62.93 |

| | | | | | |
|---|---|---|---|---|---|
| | | Notomastus | 30 | 5.17 | 68.10 |
| | | ACTINIARIA | 15 | 2.59 | 70.69 |
| | | Goniada maculata | 15 | 2.59 | 73.28 |
| | | Lumbrineris aniara agg. | 15 | 2.59 | 75.86 |
| | | Pseudopolydora pulchra | 15 | 2.59 | 78.45 |
| | | Owenia | 15 | 2.59 | 81.03 |
| | | Abra alba | 15 | 2.59 | 83.62 |
| j | 059A 059B 051A 051B | Abra alba | 120 | 9.82 | 9.82 |
| | | Ophiura albida | 115 | 9.41 | 19.22 |
| | | Abra | 105 | 8.59 | 27.81 |
| | | Spirobranchus lamarcki | 78 | 6.34 | 34.15 |
| | | Ampelisca spinipes | 78 | 6.34 | 40.49 |
| | | Lumbrineris aniara agg. | 70 | 5.73 | 46.22 |
| | | Kurtiella bidentata | 33 | 2.66 | 48.88 |
| | | ACTINIARIA | 30 | 2.45 | 51.33 |
| | | Echinocyamus pusillus | 30 | 2.45 | 53.78 |
| | | Photis longicaudata | 28 | 2.25 | 56.03 |
| | | Pisidia longicornis | 28 | 2.25 | 58.28 |
| | | NEMERTEA | 25 | 2.04 | 60.33 |
| | | Trochidae | 25 | 2.04 | 62.37 |
| | | Glycera lapidum | 23 | 1.84 | 64.21 |
| | | Paucibranchia bellii | 23 | 1.84 | 66.05 |
| | | Leiochone | 23 | 1.84 | 67.89 |
| | | Amphipholis squamata | 23 | 1.84 | 69.73 |
| | | Owenia | 20 | 1.64 | 71.37 |
| | | Aonides paucibranchiata | 18 | 1.43 | 72.80 |
| | | Lagis koreni | 18 | 1.43 | 74.23 |
| | | Psammechinus miliaris | 18 | 1.43 | 75.66 |
| | | Ophiuridae | 18 | 1.43 | 77.10 |
| | | Notomastus | 15 | 1.23 | 78.32 |
| | | Polycirrinae | 13 | 1.02 | 79.35 |
| | | Leptochiton asellus | 13 | 1.02 | 80.37 |
| k | 045A 055A 055B 042A 042B 052A 052B 101A 101B 021A 021B | Sabellaria spinulosa | 223 | 18.98 | 18.98 |
| | | Lagis koreni | 180 | 15.34 | 34.31 |
| | | Kurtiella bidentata | 90 | 7.67 | 41.98 |
| | | Ophiura albida | 79 | 6.74 | 48.72 |
| | | Ampelisca spinipes | 56 | 4.80 | 53.52 |
| | | Ampharete lindstroemi | 54 | 4.57 | 58.09 |
| | | Spiophanes bombyx | 45 | 3.80 | 61.89 |
| | | Abra alba | 39 | 3.33 | 65.22 |
| | | Lumbrineris aniara agg. | 29 | 2.48 | 67.70 |
| | | NEMERTEA | 25 | 2.17 | 69.87 |
| | | Abra | 22 | 1.86 | 71.73 |
| | | Anoplodactylus | 20 | 1.70 | 73.43 |
| | | Ophiuridae | 19 | 1.63 | 75.06 |
| | | Ampharete | 16 | 1.39 | 76.45 |
| | | Barnea candida | 16 | 1.39 | 77.85 |
| | | Photis longicaudata | 12 | 1.08 | 78.93 |

| | | | | | |
|---|---|---|---|---|---|
| | | Glycera alba | 11 | 0.93 | 79.86 |
| | | Euclymene oerstedii agg. | 11 | 0.93 | 80.79 |
| | | Scalibregma inflatum | 11 | 0.93 | 81.72 |
| l | 040A 040B | Abra alba | 85 | 23.94 | 23.94 |
| | | Myrianida | 30 | 8.45 | 32.39 |
| | | Chaetozone zetlandica | 25 | 7.04 | 39.44 |
| | | Achelia echinata agg. | 20 | 5.63 | 45.07 |
| | | Goniada maculata | 15 | 4.23 | 49.30 |
| | | Lumbrineris aniara agg. | 15 | 4.23 | 53.52 |
| | | Lanice conchilega | 15 | 4.23 | 57.75 |
| | | Anoplodactylus | 15 | 4.23 | 61.97 |
| | | Macropodia | 15 | 4.23 | 66.20 |
| | | Mytilidae | 15 | 4.23 | 70.42 |
| | | Mytilus edulis | 15 | 4.23 | 74.65 |
| m | 028A 045B 001A 001B 104A | Sabellaria spinulosa | 56 | 10.61 | 10.61 |
| | | Anoplodactylus | 54 | 10.23 | 20.83 |
| | | Spiophanes bombyx | 52 | 9.85 | 30.68 |
| | | NEMERTEA | 30 | 5.68 | 36.36 |
| | | ACTINIARIA | 24 | 4.55 | 40.91 |
| | | Abra | 22 | 4.17 | 45.08 |
| | | Paucibranchia bellii | 18 | 3.41 | 48.48 |
| | | Leiochone | 18 | 3.41 | 51.89 |
| | | Polycarpa fibrosa | 18 | 3.41 | 55.30 |
| | | Mytilidae | 16 | 3.03 | 58.33 |
| | | Kurtiella bidentata | 14 | 2.65 | 60.98 |
| | | Lagis koreni | 12 | 2.27 | 63.26 |
| | | Amphipholis squamata | 12 | 2.27 | 65.53 |
| | | Paradoneis lyra | 8 | 1.52 | 67.05 |
| | | THORACICA | 8 | 1.52 | 68.56 |
| | | ASCIDIACEA | 8 | 1.52 | 70.08 |
| | | NEMATODA | 6 | 1.14 | 71.21 |
| | | Glycera alba | 6 | 1.14 | 72.35 |
| | | Caulleriella alata | 6 | 1.14 | 73.48 |
| | | Achelia echinata agg. | 6 | 1.14 | 74.62 |
| | | Unciola crenatipalma | 6 | 1.14 | 75.76 |
| | | Nucula | 6 | 1.14 | 76.89 |
| n | 046A 046B 039A 039B | Bathyporeia elegans | 85 | 32.38 | 32.38 |
| | | Ophelia borealis | 58 | 21.90 | 54.29 |
| | | Bathyporeia | 43 | 16.19 | 70.48 |
| | | Glycera oxycephala | 20 | 7.62 | 78.10 |
| o | 025B 034A 043B | Goodallia triangularis | 183 | 51.89 | 51.89 |
| | | Polycirrinae | 37 | 10.38 | 62.26 |
| | | Abra alba | 37 | 10.38 | 72.64 |
| | | Gastrosaccus spinifer | 20 | 5.66 | 78.30 |
| | | Spisula | 20 | 5.66 | 83.96 |

# Appendix 6 – Biotope Descriptions

***SS.SBR.PoR.SspiMx* – *Sabellaria spinulosa* on stable circalittoral mixed sediment**

Biotope description

The tube-building polychaete *Sabellaria spinulosa* at high abundances on mixed sediment. These species typically forms loose agglomerations of tubes forming a low lying matrix of sand, gravel, mud and tubes on the seabed. The infauna comprises typical sublittoral polychaete species such as *Protodorvillea kefersteini, Pholoe synophthalmica, Harmothoe spp, Scoloplos armiger, Mediomastus fragilis, Lanice conchilega* and cirratulids, together with the bivalve *Abra alba*, and tube building amphipods such as *Ampelisca spp*. The epifauna comprise a variety of bryozoans including *Flustra foliacea, Alcyonidium diaphanum* and *Cellepora pumicosa*, in addition to calcareous tubeworms, pycnogonids, hermit crabs and amphipods. The reefs formed by *Sabellaria* consolidate the sediment and allow the settlement of other species not found in adjacent habitats leading to a diverse community of epifaunal and infauna species. The development of such reefs is assisted by the settlement behaviour of larval *Sabellaria* which are known to selectively settle in areas of suitable sediment and particularly on existing *Sabellaria* tubes (Tait and Dipper, 1997; Wilson 1929). These reefs are particularly affected by dredging or trawling and in heavily dredged or disturbed areas an impoverished community may be left (e.g. Pkef) particularly if the activity or disturbance is prolonged. However, it is likely that reefs of S. spinulosa can recover quite quickly from short term or intermediate levels of disturbance as found by Vorberg (2000) in the case of disturbance from shrimp fisheries and recovery will be accelerated if some of the reef is left intact following disturbance as this will assist larval settlement of the species.

Situation

S. spinulosa reefs are often found in areas with quite high levels of natural sediment disturbance

Temporal variation

In some areas the reefs are periodically destroyed by storm events leading to a cyclical shift in biotopes from SspiMx to other biotopes e.g. Pkef or AalbNuc with re-establishment of the Sabellaria colonies in the following year.

From: https://mhc.jncc.gov.uk/biotopes/jnccmncr00001112

**CR.HCR.Xfa.Mol – *Molgula manhattensis* with a hydroids and bryozoan turf on tide-swept moderately wave-exposed circalittoral rock**

Biotope description

This biotope is typically found on slightly sand-scoured, tide-swept, moderately exposed circalittoral bedrock and cobbles. It is commonly recorded from the shallower reaches of the circalittoral around depths from 5m to 15m BCD, as it occurs mostly in very turbid waters. From afar, the physical characteristics are usually silted bedrock reefs and cobble, interspersed with patches of clean sand, causing a scour effect on the rock. Dense aggregations of the ascidian *Molgula manhattensis* form a silty mat on the rock and there is a sparse hydroid and bryozoan turf. A hydroid turf, composed of *Nemertesia antennina, Halecium beanii, Hydrallmania falcata, Sertularella gaudichaudi, Tubularia indivisa* and *Alcyonium digitatum*, in varying amounts, occurs at most sites on the tops of boulders and ridges. A bryozoan turf is also present, but not usually dense and includes *Flustra foliacea, Alcyonidium diaphanum, Electra pilosa* and the crust-forming bryozoan *Conopeum reticulum*. The polychaete *Lanice conchilega* thrives in the sandy patches which often occur between the rock ridges. The scour effect tends to reduce the diversity of sponges present with only *Halichondria panicea* occasionally present. Isolated clumps of the polychaete *Sabellaria spinulosa* may be present but they do not occur in dense aggregations as in the Sspi.ByB biotope. The anemones *Urticina felina* and *Sagartia troglodytes* may occur in cracks between cobbles or on stones buried in the sandy substratum. The anemone *Sagartia elegans* is more commonly found attached to crevices in the bedrock. Other species such as the hermit crab *Pagurus bernhardus*, the barnacle *Balanus crenatus*, the polychaete *Sabella pavonia* and *Pomatoceros triqueter* may all be present whilst the crab *Pisidia longicornis* may be found under cobbles and stones. Records of this biotope are distributed along the south coast of England and the north Wales coast as well as Pembrokeshire near the entrance to Milford Haven.

Situation

As this biotope is often recorded on soft rock (chalk), soft rock communities (SfR biotope complex) would be observed in close proximity with species of the genus *Polydora* and piddocks (*Pholas spp*. and *Barnea spp*). Moderately exposed kelp forests may be found within the shallow infralittoral zone.

Temporal variation

Not known.

From: https://mhc.jncc.gov.uk/biotopes/jnccmncr00002144

**_SS.SSa.CMuSa.AalbNuc_ - _Abra alba_ and _Nucula nitidosa_ in circalittoral muddy sand or slightly mixed sediment**

Biotope description

Non-cohesive muddy sands or slightly shelly/gravelly muddy sand characterised by the bivalves *Abra alba* and *Nucula nitidosa*. Other important taxa include *Nephtys spp*., *Chaetozone setosa* and Spiophanes bombyx with Fabulina fabula also common in many areas. The echinoderms *Ophiura albida* and *Asterias rubens* may also be present. The epibiotic biotope EcorEns may overlap this biotope. This biotope is part of the *Abra* community defined by Thorson (1957) and the infralittoral etage described by Glemarec (1973).

Situation

No situation data available.

Temporal variation

Numbers of adult *Abra alba* can exceed 1000 m-

From: https://mhc.jncc.gov.uk/biotopes/jnccmncr00000356

**_SS.SCS.CCS_ - Cicalittoral coarse sediment**

Biotope description

Tide-swept circalittoral coarse sands, gravel and shingle generally in depths of over 15-20m. This habitat may be found in tidal channels of marine inlets, along exposed coasts and offshore. This habitat, as with shallower coarse sediments, may be characterised by robust infaunal polychaetes, mobile crustacea and bivalves. Certain species of sea cucumber (e.g. Neopentadactyla) may also be prevalent in these areas along with the lancelet Branchiostoma lanceolatum.

Situation

No situation data available.

Temporal variation

No temporal data available.

From: https://mhc.jncc.gov.uk/biotopes/jnccmncr00002088

***SS.SSa.CMuSa*** **– Circalittoral muddy sand**

Biotope description

Circalittoral non-cohesive muddy sands with the silt content of the substratum typically ranging from 5% to 20%. This habitat is generally found in water depths of over 15-20m and supports animal-dominated communities characterised by a wide variety of polychaetes, bivalves such as *Abra alba* and *Nucula nitidosa*, and echinoderms such as *Amphiura spp* and *Ophiura spp*., and *Astropecten irregularis*. These circalittoral habitats tend to be more stable than their infralittoral counterparts and as such support a richer infaunal community.

Situation

No situation data available.

Temporal variation

No temporal data available.

From: https://mhc.jncc.gov.uk/biotopes/jnccmncr00001203

# C. Eco Marine Consultants 2020 analysis report

# Disposal Site TH027 2020 Data Analysis Report

Report produced for HR Wallingford

by Eco Marine Consultants Limited

*February 2021*

Report no. HRWHAR0221

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This report has been prepared with due care and diligence and with the skill reasonably expected of a reputable consultant experienced in the types of work carried out under the contract and as such the findings in this report are based on an interpretation of data which is a matter of opinion on which professionals may differ and unless clearly stated is not a recommendation of any course of action.

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# Contents

## Executive Summary

Eco Marine Consultants Ltd was commissioned by HR Wallingford to undertake detailed analysis of benthic environmental and ecological data gathered in 2020 relating to the offshore dredge-spoil disposal site utilised by the Harwich Haven Authority and known as 'Harwich Haven Disposal Site TH027' located in the southern North Sea. Specifically, the previously gathered data were analysed with consideration to geographic 'treatment areas' distributed around TH027. The 2020 survey year represents the third year of monitoring following commencement of regular disposal of dredged material at the site under the new MMO licence, and the second following regular use. Data from 2020 were compared to survey data from the 2017 baseline to assess longer term trends at the site, in addition to data from the last year of monitoring in 2019 to look at shorter term changes.

The analysis undertaken indicated that the faunal communities documented in the 2020 survey of Disposal Site TH027 and the surrounding area were diverse and largely heterogeneous in nature. Some faunal communities found within the Central area, i.e., within the boundary of the TH027 disposal site, were statistically similar to those found in all other treatment areas, whilst others displayed a greater degree of difference. The Central area showed the lowest species richness and diversity and a low abundance compared to other areas and was typically characterised by fauna associated with the impacts of dredge disposal or those tolerant of sedimentation. A combination of taxa not observed in high numbers at other sites was recorded in the Reference area, though some similarity of taxa in this area to other parts of the survey array was apparent. Mean faunal abundance and species diversity in 2020 was greatest in the Crab area to the west of TH027, though there was considerable variation between stations in this area. Statistical testing confirmed a high degree of overlap in community composition between all station treatments at a significant level, though pairwise testing between individual areas showed moderate-high dissimilarity between some areas in terms of faunal community composition.

Sediment composition across the survey area was less homogeneous in 2020 than in previous years and showed some spatial variation, reflecting a reduction in silt and an increase in sandy sediment across all areas. Gravelly Muddy Sand was the most prominent mean sediment type across the survey area, recorded in the Central, Disposal and Inner areas. A high silt content was noted in the Central area compared to other treatment areas, especially the Outer area which was dominated by coarse gravelly deposits. A moderate degree of overlap in sediment composition between all station treatments was revealed through statistical testing; testing between individual treatment areas indicated some considerable differences in sediment composition.

Temporal analysis of sediment composition data indicated that considerable increases in silty material, coupled with a relative decrease in gravel, occurred within the Central area between the baseline and 2020, though this is not unexpected. Sediment composition in other treatment areas was also variable between years, notably in areas with close proximity to TH027, where patterns were similar to those observed across the Central area but less pronounced. Changes in sediment composition in the Outer area were moderately low, suggesting that natural variation across the site is likewise low. Statistical testing indicated moderate levels of similarity between years, although due

to the small number of common replicates, a figure for similarity in the Central area over time could not be generated.

A decrease in mean faunal abundance and species diversity in the Central treatment area was observed between the baseline and 2020, though it is apparent that there have been some increases in each index over the last year. Outside of the Central area, increases in faunal abundance and species diversity have generally been observed over time. A large increase in abundance was recorded in the Crab area in 2020; this is heavily influenced by an abnormally high count of individuals at one station. Change in the Outer reference area over time was low, suggesting that natural variation in faunal communities across the site is minimal. Statistical testing revealed that faunal community composition between all years was moderately similar at a significant level. A high degree of overlap in faunal community composition was apparent when year and treatment were considered as factors in all areas except for the Central and Crab areas.

The changes in community composition observed in the Central area since the start of disposals were largely accounted for by a decrease in species associated with an established, coarse sediment habitat and an increase in taxa tolerant of, or having a high recoverability to, smothering and increased sedimentation. This is not unexpected following the start of disposal activity. The evidence has shown that major changes in faunal community composition has principally occurred in the Central area where an increase in these taxa has occurred over time. These species have also increased in other areas, though not to the same degree as within the boundary of TH027.

# 1. Introduction

Eco Marine Consultants Ltd (Eco Marine) was commissioned by HR Wallingford to undertake the analysis of benthic environmental and ecological data gathered in 2020 and a comparison with previous data relating to an offshore dredge-spoil disposal site utilised by the Harwich Haven Authority and known as 'Harwich Haven Disposal Site TH027'.

The samples were previously collected and the macrobenthic and sediment particle size distribution data were analysed by Thomson Unicomarine before being made available to Eco Marine for further analysis and interpretation.

This report sets out the methods applied to the data analysis and includes the outputs of the analyses. Basic factual technical reports have already been prepared by Thomson Unicomarine describing the results of the 2017, 2018, 2019 and 2020 data, followed by in-depth analysis reports by Eco Marine for the 2017, 2018 and 2019 survey years.

This report therefore aims to conduct a more detailed analysis of the 2020 data, examine the distribution of faunal communities and the effect of treatment types, plot the results spatially, and to conduct a temporal comparison of data between the survey years.

## 1.1. Background

Site TH027 is located approximately 20 Km offshore from Felixstowe in the southern North Sea. Use of the site is principally to accommodate the disposal of material arising from maintenance dredging undertaken by the Harwich Haven Authority (HHA) in Harwich Harbour. The disposal site was first licensed for use in 2016. Disposal under the new licence commenced in June 2018 following one campaign of disposal at the site prior to the 2018 sampling undertaken by Thomson Unicomarine. The first major disposal year was therefore 2019. In a typical year there will be five to six disposal campaigns at approximately 10-week intervals. The location of Site TH027 is shown in Figure 1.

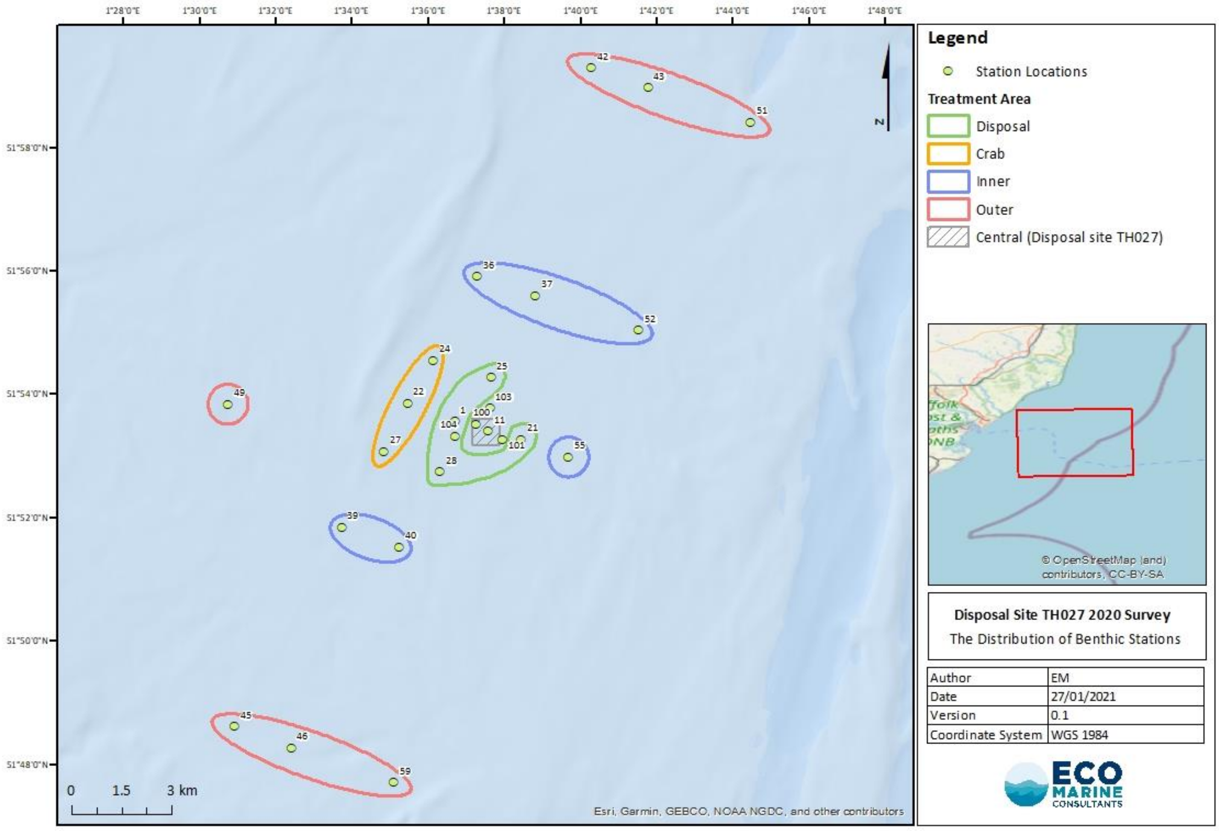


**Figure 1.** The location of the sampling stations used in the 2020 Disposal Site TH027 monitoring survey.

A trial study was initially conducted at the disposal site in 2016 during which material arising from the June and August maintenance dredging campaigns at Harwich was disposed at the site (HR Wallingford, 2017). Following this an annual monitoring survey programme commenced in 2017 to allow the effects of future disposal of dredged material to be monitored. No dredged material was disposed at the site between August 2016 and June 2018. Data from the August 2018 survey represented the first year of monitoring after the new MMO licence was provided. At this time only 215,000 tonnes of material arising from the June 2018 dredging campaign had been disposed at the site. A further 1,295,000 tonnes of material was placed at the site prior to the August 2019 survey being undertaken, followed by another 871,250 tonnes by August 2020. HR Wallingford have calculated the volume of accretion within the boundary of TH027 between the 2019 and 2020 monitoring surveys to be approximately 40,500m$^3$. Assuming an in-situ mass of 500kg/m$^3$ this volume represents a mass of approximately 20,250 tonnes dry solids, equivalent to 2.3% of the mass placed at the site during this period and suggesting that nearly all of the disposed material has dispersed outside of the licence area. In December 2020 (after the 2020 monitoring surveys), two dredged sediment samples were collected from the hopper of a dredger undertaking maintenance dredging in Harwich Harbour. These samples were analysed for particle size distribution (PSD) which indicated that the dredged material comprised approximately 85% fine particles (<63 µm diameter) and approximately 15% fine to medium sand size particles. No coarse sand or gravel size particles were present in the samples. The disposal figures are summarised in Table 1.

**Table 1.** Volume of dredged material disposed of at TH027 between monitoring surveys, showing years split according to survey timings.

| Monitoring Year | Approximate Tonnes Dry Solids |
|---|---|
| 2016 (trial dredge) | 408,750 |
| 2017-2018 | 215,000 |
| 2018-2019 | 1,295,000 |
| 2019-2020 | 871,250 |

The 2020 survey was undertaken by Thomson Unicomarine in August 2020, 44 days after the last disposal campaign was completed. The survey targeted 26 stations which had been sampled as part of previous monitoring campaigns. Samples were recovered from all stations except for Station 102 which did not yield a sample due to a rocky substrate being encountered. A sample was obtained from Station 22 which has proven difficult to sample in the past due to the physical nature of the seabed at this site.

The 2020 survey array included the five additional stations that were sampled for the 2019 monitoring campaign (Stations 100 to 104, noting that no sample was recovered from Station 102), the locations of which were originally determined by a fisheries-observer who participated in the 2018 and 2019 surveys. Note that different combinations of stations have been sampled over the years as part of the TH027 surveys, as additional stations have been added to the survey array and samples have not been possible to collect at other stations due to the nature of the seabed in those locations.

Five replicate grab samples were collected during the 2020 survey. Two replicate samples were collected for macrofaunal analysis at each station, with a third collected to provide a PSA sample. The remaining two replicates were stored for benthic biological analysis at a later date should this be deemed necessary. Macrofaunal analysis was conducted in-line with the National Marine Biological Analytical Quality Control (NMBAQC) Scheme's best practice guidelines. Samples were sieved over a 1 mm mesh sieve prior to analysis. PSA data were processed in-line with Thomson Unicomarine's in-house SOP.

A summary of the data from the 2020 survey and a basic statistical analysis of the data is presented in Thomson Unicomarine (2020).

## 1.2. Aims and Objectives

The aim of this report is to present a detailed analysis of the 2020 data collected by Thomson Unicomarine and to present a temporal comparison of the 2020 data against those collected in 2019, as well as a comparison against the baseline years of 2017 and 2018. Specifically:

- The aim of the sediment surveys is to verify that there is no permanent change to the seabed substrate compared to baseline conditions (outside of the disposal site) as a result of the disposal activities.
- The aim of the benthic surveys is to verify the prediction that there will be no significant changes to the benthic community composition (outside of the disposal site) as a result of the disposal activities.

To address these aims, the objectives are as follows:

- To analyse the 2020 macrofauna and PSA data using PRIMER to undertake cluster analysis and MDS plots. Stations in the analyses will be assigned 'treatments' based on their geographic locations to enable a spatial analysis of the results.
- To produce associated GIS plots indicating spatial patterns.
- To conduct a temporal time-series comparison of faunal and sediment data to assess changes in benthic communities and sediment distribution against 2019 data and baseline data.
- To prepare a short technical report detailing the results.

# 2. Methods

Details of the survey and laboratory methodologies are presented in Thomson Unicomarine (2020), along with univariate analysis of the data.

Multivariate statistical Analysis was conducted using the PRIMER V6 software package (with reference to Anderson *et al*. (2008), Clarke & Gorley (2006) and Clarke and Warwick (2001)), MS Excel and R. Routines employed included the following:

**Hierarchical Cluster Analysis**

Cluster analysis aims to find “natural groupings” such that samples within a group are more similar to each other than samples in different groups. The results of hierarchical clustering are represented by a tree diagram or dendrogram, with the x-axis representing the full set of samples and the y-axis representing the similarity level at which the groups are considered to have fused.

**The SIMPROF Test**

A similarity profile permutation test (SIMPROF) looks for statistically significant evidence of genuine clusters in samples. Tests are performed at every node of a completed dendrogram, testing whether the group that has been subdivided has ‘significant’ internal structure.

**Multidimensional Scaling (MDS) Ordination**

This technique allows the construction of a configuration of the samples in multidimensional space to position the samples as accurately as possible to reflect their similarity. For example, if sample 1 has a greater similarity to sample 2 than it does to sample 3 then sample 1 will be positioned more closely to sample 2 than it is to sample 3. This “map” of the relative similarities between samples is then plotted in two dimensions.

**The SIMPER routine**

The SIMPER routine allows comparisons between groups of samples to be made. Following the comparison of similarities between groups the taxa (or particle size fractions) responsible for the dissimilarities between sites are sub-listed in decreasing order of importance in order to facilitate the discrimination of the groups. This routine also provides information on the species responsible for within-site similarities and their contribution to the internal similarity of the group.

**Analysis of Similarity (ANOSIM)**

This test was used to test the null hypothesis ($H_0$) that there are no differences in community (or sediment) composition between the pooled sample categories featured in the present investigation. The test returns an R statistic and a significance level (displayed as %, equivalent to a p-value in other tests. Significance is taken at the $p = <0.05$ level, or 5%). The value of the R statistic demonstrates the overlap between datasets as follows:

- R Statistic approaching zero: very slight differences & therefore a high degree of overlap between the groups
- R Statistic of 0.2 - 0.3: some difference but still with some degree of overlap between the groups

- R Statistic approaching 1 (>0.5): large differences & therefore only slight overlap between the groups

However, it is important to remember the importance of the statistical significance of the R Statistic. This value assists in the determination of whether the R statistic returned by the test is a 'real' result, which was unlikely to be achieved by chance, or whether the R value is in fact coincidental biproduct of the sample data.

In utilising the above routines, stations were assigned a 'treatment area' based on their geographic location and proximity to the TH027 site and the range of potential secondary impacts. The station-by-station breakdown of treatments utilised for the 2020 data analysis is shown in Table 2 and are plotted in Figure 1. Impact treatments were based upon those assigned in the initial 2016 monitoring survey report (HR Wallingford, 2017) and those assigned in the 2018 and 2019 reports by Eco Marine (Eco Marine, 2019; 2020). For the purpose of these studies the Central treatment area was defined by the boundary of the TH027 site and the Disposal treatment area was defined as being the area of potential effect outside of TH027. The Crab treatment area was defined to include sampling stations within an area considered suitable for crab/lobster. It was also assumed that stations located in the Outer treatment area are 'reference' stations outside the zone of influence from any activity within the TH027 site. As such these stations will be used to gauge the level of natural variation across the wider monitoring site free from any disposal related impacts.

**Table 2.** Station treatments used in the analysis of the 2020 Disposal Site TH027 monitoring data. Note that Station 102, located in the Crab area, was not collected in 2020.

| Station | Treatment | Station | Treatment |
|---|---|---|---|
| 1 | Disposal | 43 | Outer |
| 11 | Central | 45 | Outer |
| 21 | Disposal | 46 | Outer |
| 22 | Crab | 49 | Outer |
| 24 | Crab | 51 | Outer |
| 25 | Disposal | 52 | Inner |
| 27 | Crab | 55 | Inner |
| 28 | Disposal | 59 | Outer |
| 36 | Inner | 100 | Central |
| 37 | Inner | 101 | Disposal |
| 39 | Inner | 103 | Disposal |
| 40 | Inner | 104 | Disposal |
| 42 | Outer | | |

Replicate samples in the data have been left as individuals and have not been pooled or averaged unless stated.

# 3. Results: 2020 Data

## 3.1. Macrofaunal Analysis

A summary of the mean abundance and mean species diversity recorded in 2020 split by treatment areas is shown in Table 3.

**Table 3.** Mean faunal abundance and mean species diversity per station grouped according to impact area for the 2020 Disposal Site TH027 monitoring data.

| Treatment Area | Mean Abundance (±SD) | Mean Species Diversity (±SD) | Number of stations (inc. replicates) |
|---|---|---|---|
| Central | 91.75 (±57.50) | 17.75 (±2.22) | 4 |
| Disposal | 90.57 (±52.09) | 28.43 (±7.64) | 14 |
| Crab | 507.50 (±694.79) | 33.17 (±31.11) | 6 |
| Inner | 114.50 (±136.83) | 20.25 (±8.16) | 12 |
| Outer | 106.14 (±99.53) | 30.00 (±16.96) | 14 |

Table 3 shows that the greatest mean abundance of individuals per station and the greatest mean species diversity was recorded in the Crab treatment area, by some margin. The lowest mean abundance was observed in the Disposal treatment area (closely followed by the Central area) and the lowest mean species diversity in the Central area. The Inner treatment area recorded moderate values in each index.

It should be noted that the mean abundance and diversity values observed in the Crab area are subject to a high standard deviation, and considerable variance was recorded between the samples in this area, with some stations recording values as low as six individuals per station from six taxa, and others recording abundance figures of over 1,870 individuals per station and nearly 80 taxa. The faunal complement in the more diverse samples are reflective of the presence of boulders and coarse gravel in the samples which provide seabed heterogeneity conducive to the establishment of complex benthic communities, which are not necessarily indicative of the wider survey area.

Cluster analysis has initially been undertaken to explore the data and to ascertain the similarity between faunal communities located in different treatment areas. Figure 2 shows a group average sorting dendrogram (based on Bray-Curtis similarity of square-root transformed abundance data), with the accompanying non-metric multidimensional scaling (MDS) plot shown in Figure 3.

Figures 2 and 3 indicate that macrofaunal communities within the study area are relatively heterogeneous on a spatial scale. Though some clustering of stations is evident from the MDS plot and the cluster analysis, all treatment types display a degree of overlap with at least one other treatment area, though the Crab area is the most isolated.

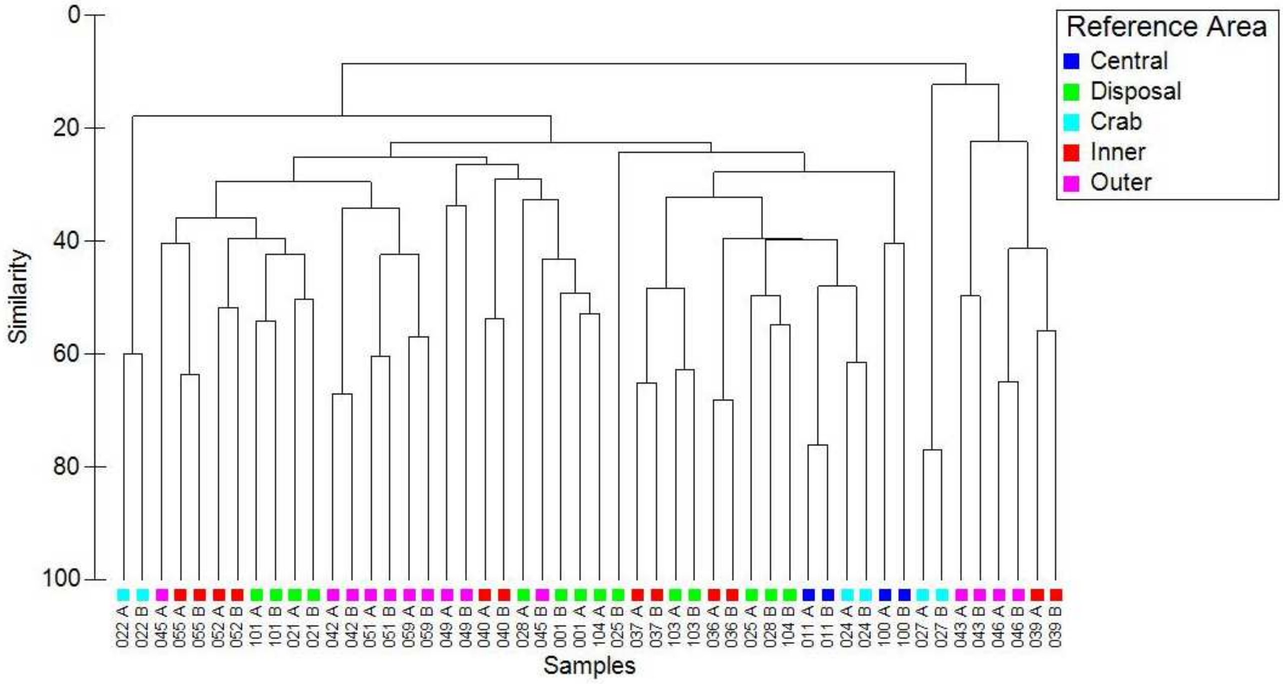


**Figure 2.** Group average sorting cluster dendrogram based on the square root transformed benthic abundance data (Bray-Curtis similarity) from the 2020 TH027 monitoring survey, showing station treatments.

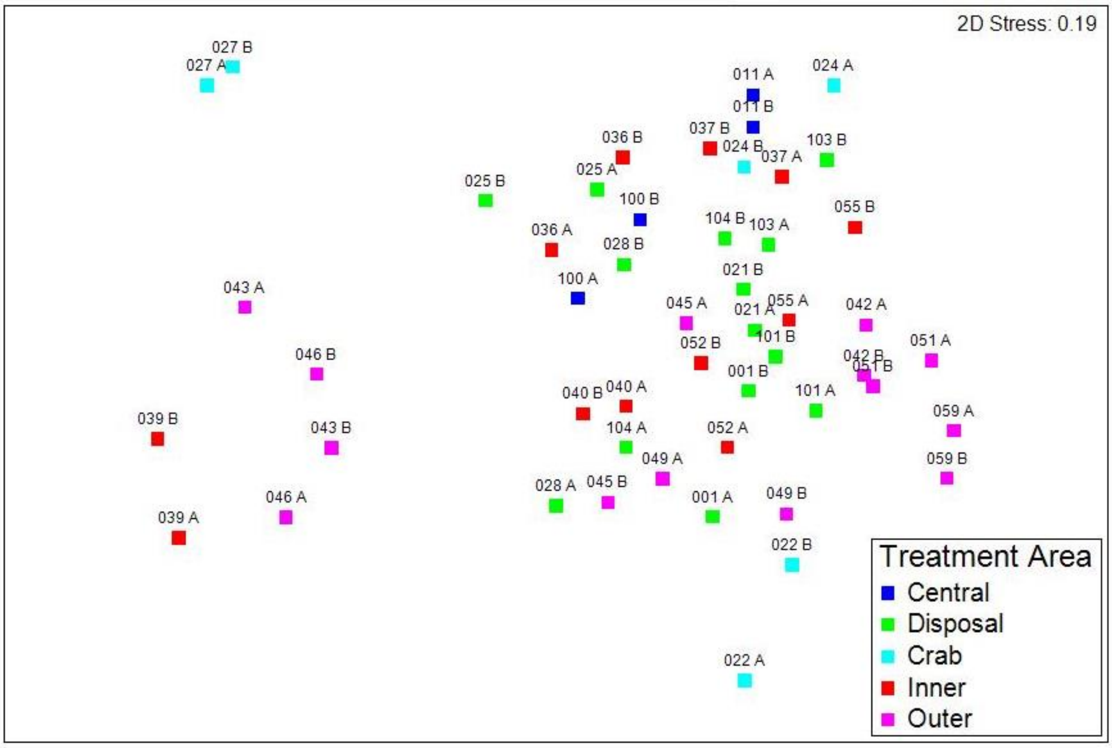


**Figure 3.** Non-metric multidimensional scaling (MDS) plot, presented in 2D format, based on the square root transformed benthic abundance data (Bray-Curtis similarity) from the 2020 TH027 monitoring survey, showing station treatments.

The results of a one-way ANOSIM test on the 2020 macrofaunal data corroborate the findings of the above by indicating a moderately high degree of overlap in community composition between all station treatments at a significant level (R = 0.169, sig level = 0.1%). When individual treatment areas were assessed, greatest differences in faunal community composition were observed between the Disposal and Crab areas (R = 0.500, sig level = 0.2%), though differences were also noted between the Disposal and Outer areas (R = 0.236, sig level = 0.1%) and the Crab and Outer areas (R = 0.247, sig level = 3.7%).

A SIMPER analysis was also conducted to highlight the similarities/differences in terms of faunal community composition between the treatment areas. The top characterising taxa of each treatment area are shown in Table 4.

Table 4 indicates that a mix of characterising taxa were found across the various treatment areas. The small bivalve *Abra alba* was noted as being an important characterising taxon in four of the five treatment areas. Similarly, the annelid *Lagis koreni* was likewise noted as important in three of the five areas.

Notably the top characterising taxa in each treatment area were similar in terms of their contribution to group similarity, with the exception of the Outer area, suggesting that species dominance across the study area was low. The Central treatment area in 2020 was typically characterised by the bivalve *Abra alba* and the polychaetes *Lagis koreni* and *Spiophanes bombyx* which most accounted for the group similarity. This was highly similar to the composition of this area in 2019 (See Section 4.2).

The presence of *Lagis koreni* and *Abra* spp. is considered an indicator of the presence of muddy dredged material arising from disposal activities (Rees *et al*., 1992; Whormersley *et al*., 2008). These taxa were observed in the Central treatment area in high proportions in 2020.

**Table 4.** Top characterising taxa in each treatment area in the 2020 Disposal Site TH027 survey data.

| Treatment Area | Characterising taxa | Contribution to Group Similarity |
|---|---|---|
| Central | *Abra alba* | 16.92% |
| | *Lagis koreni* | 15.97% |
| | *Spiophanes bombyx* | 14.63% |
| Disposal | *Lagis koreni* | 14.51% |
| | *Spiophanes bombyx* | 13.08% |
| | *Abra alba* | 11.04% |
| Crab | Folliculinidae | 11.82% |
| | *Abra alba* | 11.31% |
| | *Aspidelectra melolontha* | 8.33% |
| Inner | *Abra alba* | 13.40% |
| | *Lagis koreni* | 12.67% |
| | Campanulariidae | 12.29% |
| Outer | Campanulariidae | 9.20% |
| | *Ophiura albida* | 5.82% |
| | Nemertea | 5.64% |

Diversity indices for each station in the 2020 TH027 survey have also been calculated. These are shown grouped by treatment area in Table 5. The table shows that the Outer reference area has the greatest species richness and the Central treatment area the lowest, in common with previous years. Evenness was relatively uniform across the survey area, further suggesting that the abundance of all taxa was relatively comparable in all treatment areas and that dominance of any one taxon was low. The minor exception to this was in the Crab area, which indicated the lowest evenness index; one sample from this area contained a very high number of *Abra alba*, likely influencing the figure observed. The Disposal area had the highest Shannon-Weiner value, suggesting that this treatment area was the most diverse overall, closely followed by the Outer area.

**Table 5.** Mean diversity indices for stations sampled during the 2020 Disposal Site TH027 monitoring survey, grouped by treatment area.

| Treatment Area | Mean Margalef's Species Richness (d) | Mean Pielou's evenness (J') | Mean Shannon-Weiner (H'(loge)) |
|---|---|---|---|
| Central | 4.95 | 0.93 | 2.67 |
| Disposal | 7.37 | 0.95 | 3.16 |
| Crab | 7.51 | 0.90 | 2.72 |
| Inner | 5.51 | 0.93 | 2.71 |
| Outer | 7.49 | 0.96 | 3.10 |

A further Cluster analysis exercise has been undertaken to determine statistically similar groupings of faunal communities within the data, which can subsequently be linked back to station treatments. A SIMPROF routine was initially utilised to identify statistically similar groupings within the faunal data, however the test returned a very large number of small groups, thus instead a manual cut-off of 25% similarity has been used to identify groups of similar fauna (which yielded highly similar groupings to the SIMPROF test). The cluster analysis showing the resulting faunal groups is shown in Figure 4 and the accompanying MDS plot in Figure 5.

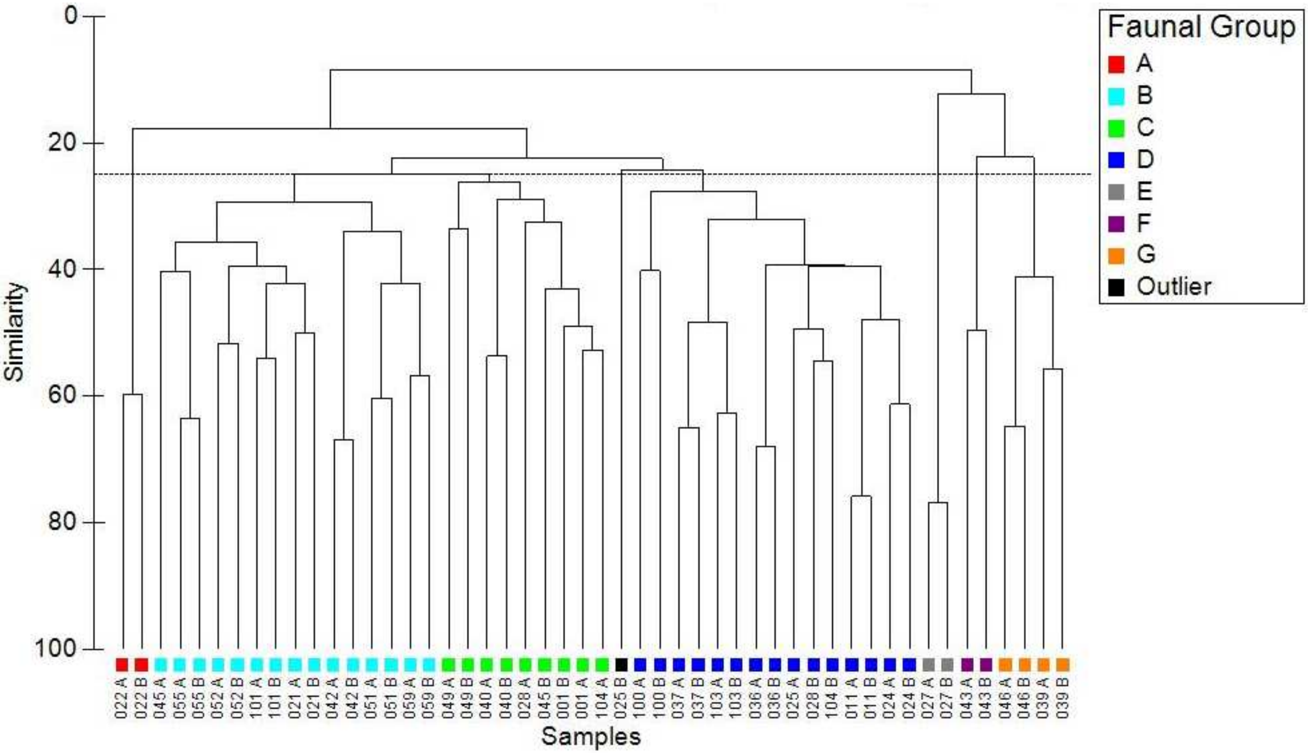


**Figure 4.** Group average sorting cluster dendrogram based on the square root transformed benthic abundance data (Bray-Curtis similarity) from the 2020 TH027 monitoring survey, showing faunal groups.

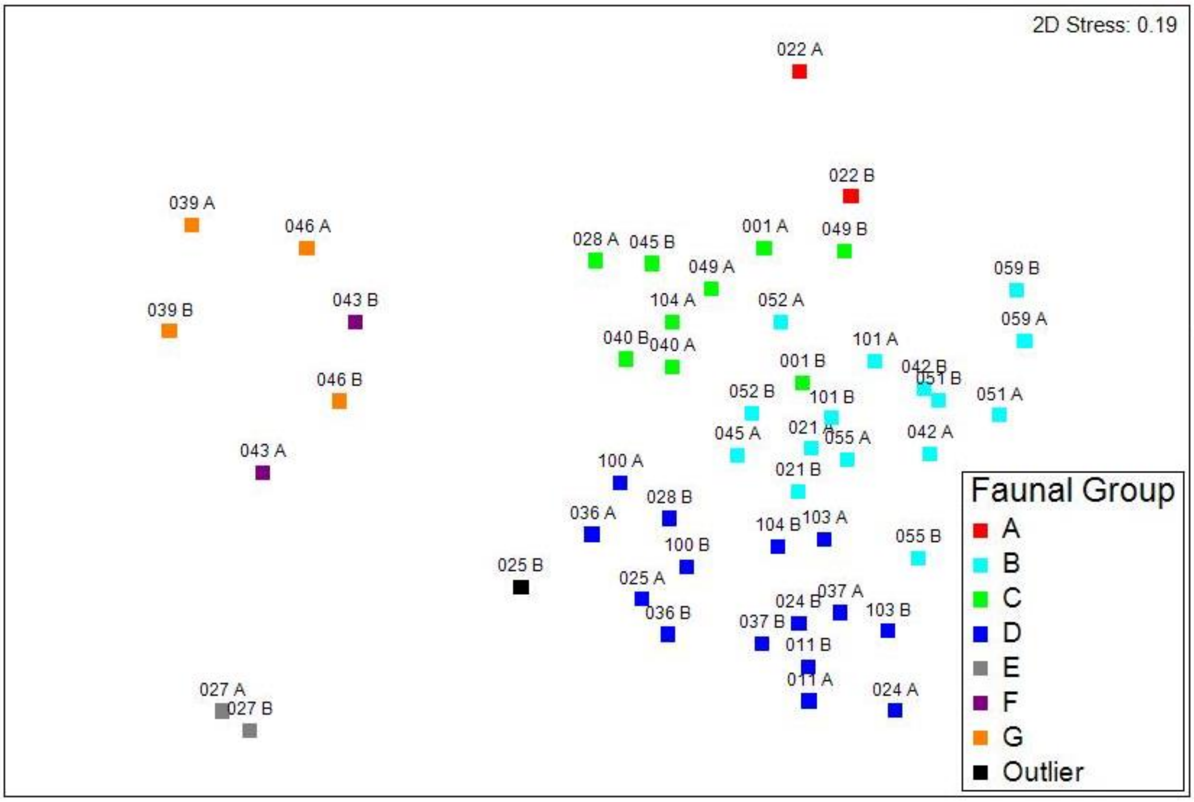


**Figure 5.** Non-metric multidimensional scaling (MDS) plot, presented in 2D format, based on the square root transformed benthic abundance data (Bray-Curtis similarity) from the 2020 TH027 monitoring survey, showing faunal groups.

The cluster analysis and MDS plot show seven distinct faunal groups in the 2020 data, in addition to one station which did not group with any others and has been labelled as an 'Outlier' (Station 25B). A spatial plot of the identified faunal groups with reference to the station treatment areas is shown in Figure 6.

A summary of the faunal groups is shown below.

**Faunal Group A**

Group A was located at one station (two replicates) in the Crab treatment area to the west of TH027 (Station 22). The group contained the highest mean abundance and species diversity recorded by some margin and was characterised by taxa associated with coarse material or harder substrata such as the barnacle *Verruca stroemia*, anenomes of the Order Actinaria, the mussel *Mytilus edulis* and *Sabellaria spinulosa.* Both replicates from this station grouped together, which coupled with the high abundance and species diversity observed, reinforces the different nature of this station compared to the others sampled as part of the survey. This station has proved difficult to sample in the past due to the nature of the seabed in this location.

**Faunal Group B**

Group B was recorded at eight stations (15 replicates) across the Disposal, Inner and Outer treatment areas across the full spread of the survey array and was the second largest group observed. The group displayed a moderate mean abundance and species diversity. Faunal community composition was characterised by a small contribution from a number of taxa including *Lagis koreni*, *Ophiura albida* and Nemertea, though there was little dominance by any one species.

**Faunal Group C**

Group C was recorded at six stations (nine replicates) located across the Disposal, Inner and Outer areas, typically to the west and south of TH027. Mean abundance and species diversity within the group was moderate-low compared to other groups. Similar to Faunal Group B, community composition was characterised by a low contribution from a number of taxa, principally Campanulariidae, *Electra monostachys* and Nemertea.

**Faunal Group D**

Faunal Group D was located at nine stations (15 replicates in total) across all treatment areas apart from the Outer area, making this the most numerous and most widespread group. Mean abundance within this group was second greatest, though species diversity was somewhat low. The faunal community was dominated by *Abra alba*, *Lagis koreni* and *Spiophanes bombyx*, with these three taxa alone contributing for over 60% of the group similarity.

**Faunal Group E**

Faunal Group E, similar to Group A, was recorded at only one station (two replicates) to the west of TH027. The group was located in the Crab treatment area was characterised by very low mean faunal abundance and species diversity. The faunal complement included Capitellidae, *Aspidelectra melolontha*, *Electra Pilosa* and *Anguinella palmata*.

**Faunal Group F**

Group F was likewise recorded at just two replicates from one station. The group was located in the Outer reference area to the far north of the survey array, and was dominated by Polycirrinae, with other taxa such as Campanulariidae, Sertulariidae and *Spisula* spp. also present. Mean abundance and species diversity were low for this group.

**Faunal Group G**

Another small group, Faunal Group G was recorded at four replicates across two stations distributed across the Inner and Outer treatment areas to the south of TH027. Mean faunal abundance and species diversity was low within the group, though not as low as documented for Groups E and F. Faunal community composition within the group was dominated *Ophelia borealis*, *Bathyporeia* spp., *Glycera oxycephala* and Campanulariidae; the contributions from these four taxa accounted for nearly 80% of the group similarity.

**Outlier**

One replicate (25B) did not group with any other samples and was classified as an outlier. This was located in the Disposal treatment area to the north of TH027. Moderate faunal abundance and species diversity was recorded at this station. The faunal complement was dominated by the presence of high numbers of *Goodallia triangularis*, a bivalve not recorded in large numbers at any other station. Also characterising this station was the presence of *Bathyporeia gracilis*, an amphipod not recorded at many other stations, and a notable absence of any annelid taxa in high numbers as typically recorded elsewhere in the survey.

**Summary: Macrofaunal Analysis 2020**

The information presented above indicates that faunal communities in 2020 were diverse and variable in nature. Some faunal communities found within the Central area were statistically similar to those found in all other treatment areas, whilst others displayed a greater degree of difference. Despite this, the Central area showed the lowest species richness and diversity and a low abundance compared to other areas. The Outer reference area was typically characterised by a combination of taxa not observed in high numbers at other sites, though some similarity between the taxa from this area and other areas was apparent. Fauna associated with the impacts of dredge disposal were documented in high numbers in the Central area.

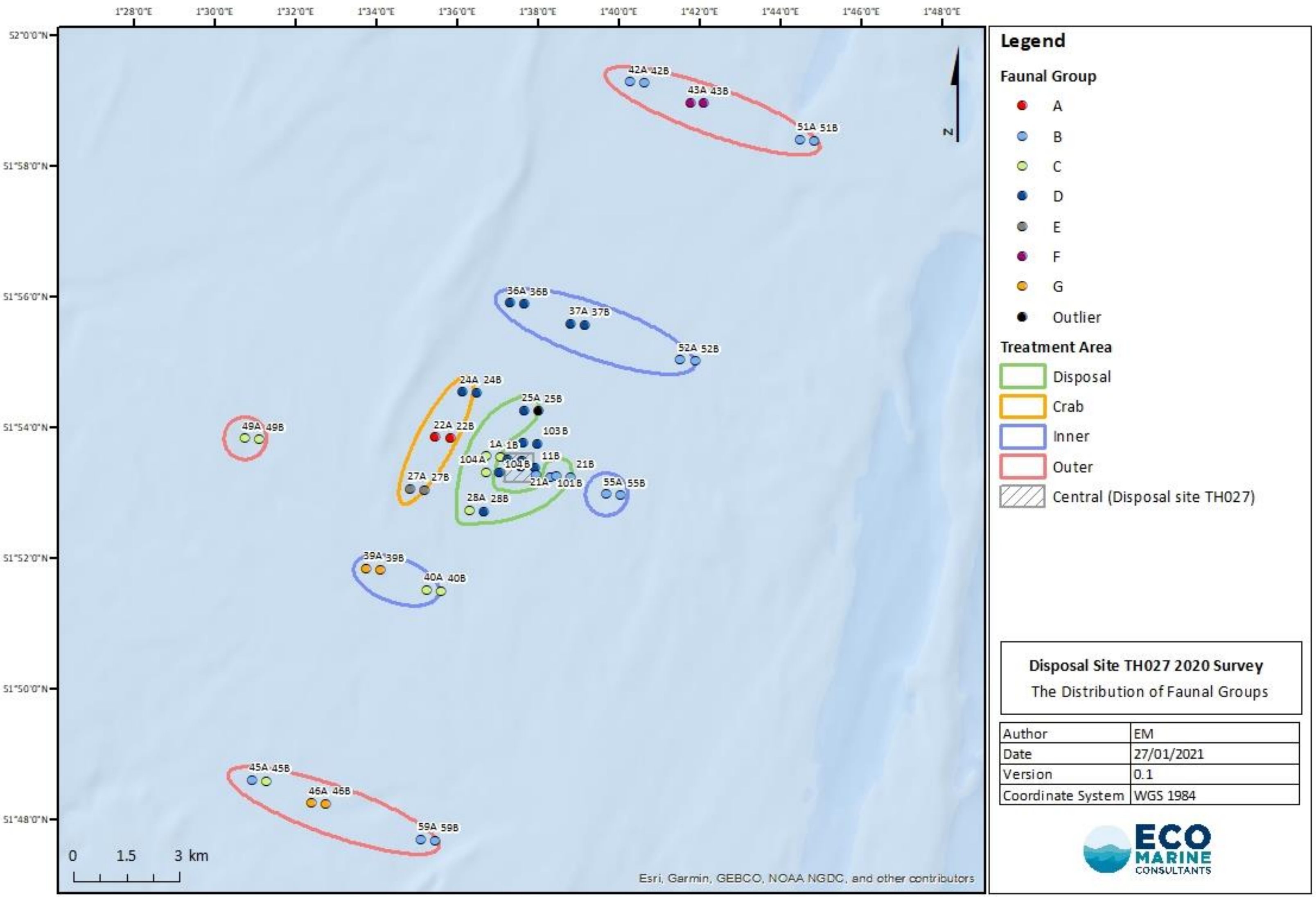


**Figure 6.** The distribution of faunal groups identified in the macrofaunal data from the 2020 monitoring survey of Disposal Site TH027.

## 3.2. Sediment Analysis

A summary of the mean sediment particle size distribution split by treatment areas is shown in Table 6. It can be seen that sediment composition across the majority of the treatment areas is somewhat similar, though the proportion of silt and gravel does vary between some treatment areas. The Central area contained the greatest proportion of fine silty sediments, whilst the greatest gravel proportion was noted in the Outer reference area which also contained a very low proportion of silt and less sand than other areas. The Central, Disposal and Inner treatment areas were all classified as the same Folk category, Gravelly Muddy Sand. As discussed above, there was considerable disparity within the Crab area in 2020, with the individual stations present in this area (Stations 22, 44 and 27) classified as Sandy Gravel, Slightly Gravelly Muddy Sand and Gravelly Sand respectively.

**Table 6.** Mean sediment particle size distribution grouped according to impact treatments for the 2020 Disposal Site TH027 monitoring data. Data are summarised as mean gravel proportion (≥2mm), mean sand proportion (0.063mm to <2mm) and mean silt proportion (<0.063mm) within the sample. The Folk category has been assigned to the mean values for each treatment area after Folk (1954).

| Treatment Area | Gravel % | Sand % | Silt % | Folk Category |
|---|---|---|---|---|
| Central | 16.18 | 54.57 | 29.25 | Gravelly Muddy Sand |
| Disposal | 22.87 | 66.93 | 10.20 | Gravelly Muddy Sand |
| Crab | 25.30 | 67.96 | 6.73 | Gravelly Sand |
| Inner | 14.85 | 62.78 | 22.37 | Gravelly Muddy Sand |
| Outer | 50.46 | 46.13 | 3.41 | Sandy Gravel |

Cluster analysis of sediment particle size data has been undertaken to explore the similarities between habitats in the different treatment areas. Figure 7 shows a group average sorting dendrogram with the accompanying non-metric multidimensional scaling plot shown in Figure 8.

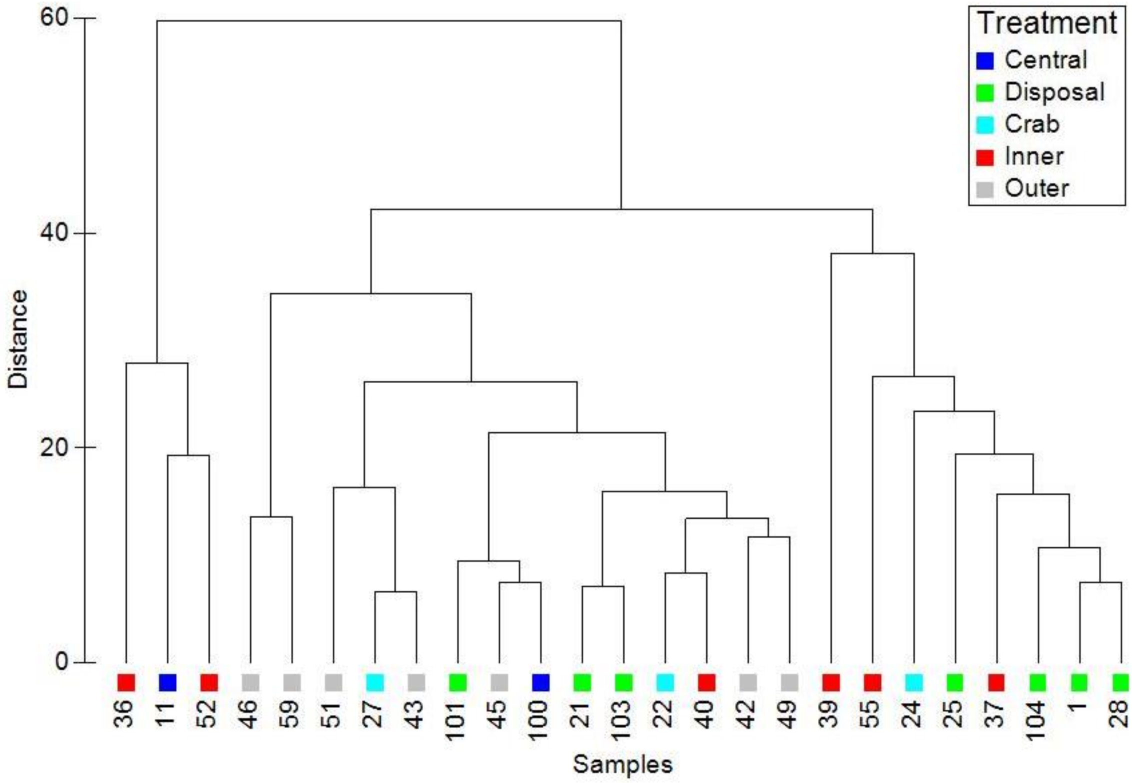


**Figure 7.** Group average sorting cluster dendrogram based on sediment particle size distribution data (Euclidian distance) from the 2020 TH027 monitoring survey, showing station treatments.

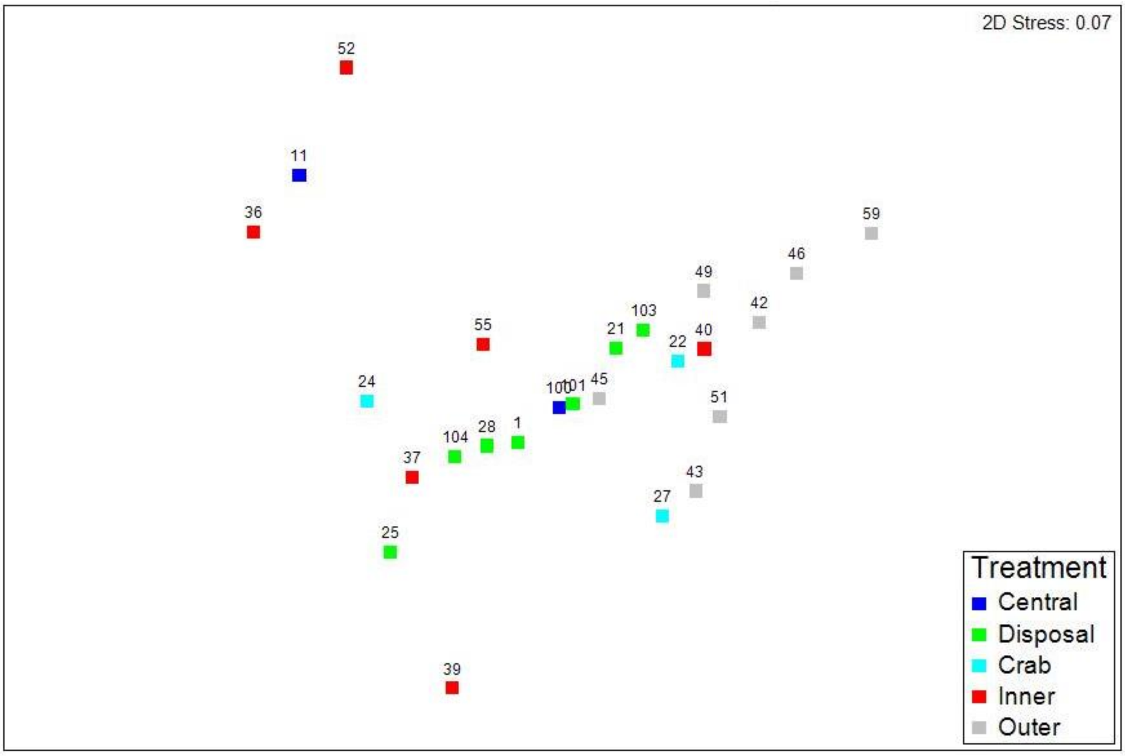


**Figure 8.** Non-metric multidimensional scaling (MDS) plot, presented in 2D format, based on sediment particle size composition data (Euclidian distance) from the 2020 TH027 monitoring survey, showing station treatments.

Figures 7 and 8 indicate that sediments found across the survey area are relatively heterogenous on a spatial scale due to the limited clustering observed and the wide degree of overlap found within the data from different stations.

The results of a one-way ANOSIM test on the 2020 sediment data corroborate the findings of the above by indicating a moderately high degree of overlap in sediment composition between all station treatments at a significant level (R = 0.26, sig level = 0.2%). Pair-wise testing between different individual treatment areas indicated large differences between the Outer reference area and the Disposal and Inner areas at significant levels (Disposal and Outer areas, R = 0.436, sig level = 0.6%; Inner and Outer areas, R = 0.434, sig level = 0.5%). The largest difference was observed between the Central area and the Outer area, though this was not at a significant level (R = 0.617, sig level = 8.3%). Other areas indicated higher degrees of similarity to one another, though these were not significant results.

A further Cluster analysis exercise has been undertaken to determine statistically similar groupings of sediment distribution across the survey array, which can subsequently be linked back to station treatments. The SIMPROF routine has been utilised to identify statistically similar groupings at the 5% significance level (p = <0.05). The cluster analysis showing the resulting sediment groups is shown in Figure 9 and the accompanying MDS plot in Figure 10.

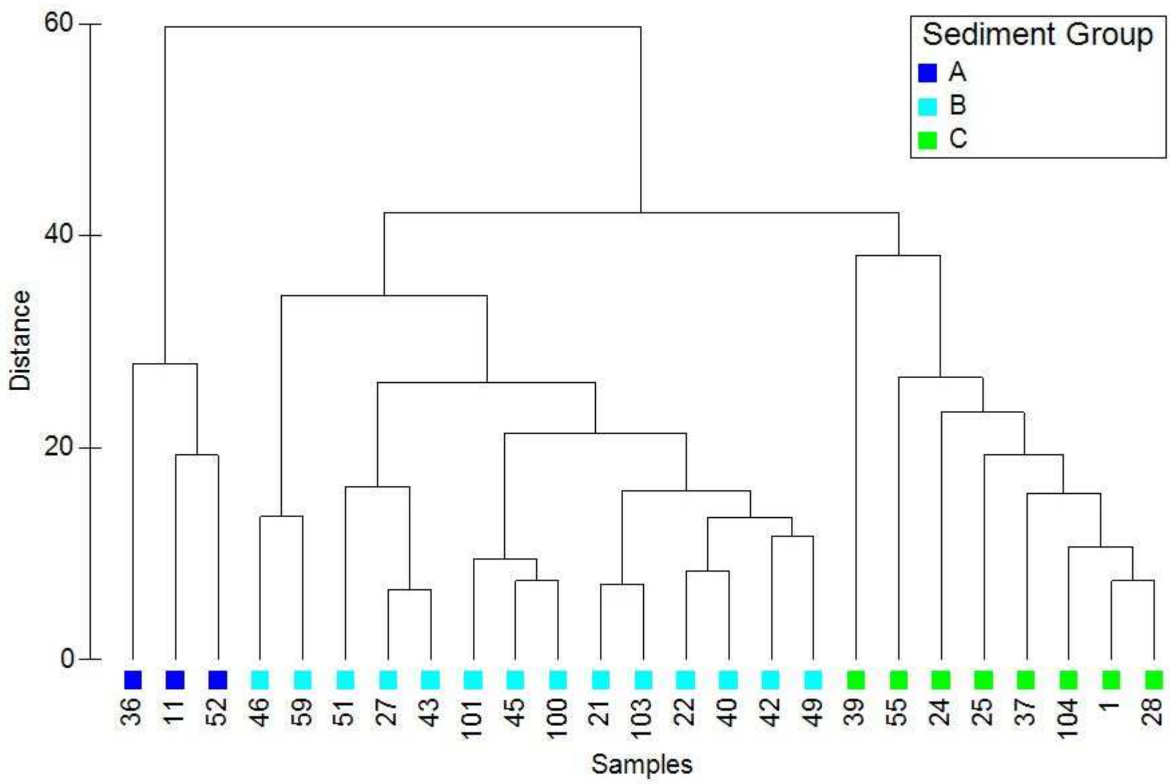


**Figure 9.** Group average sorting cluster dendrogram based on sediment particle size distribution data (Euclidian distance) from the 2020 TH027 monitoring survey, showing sediment groups identified through the SIMPROF routine.

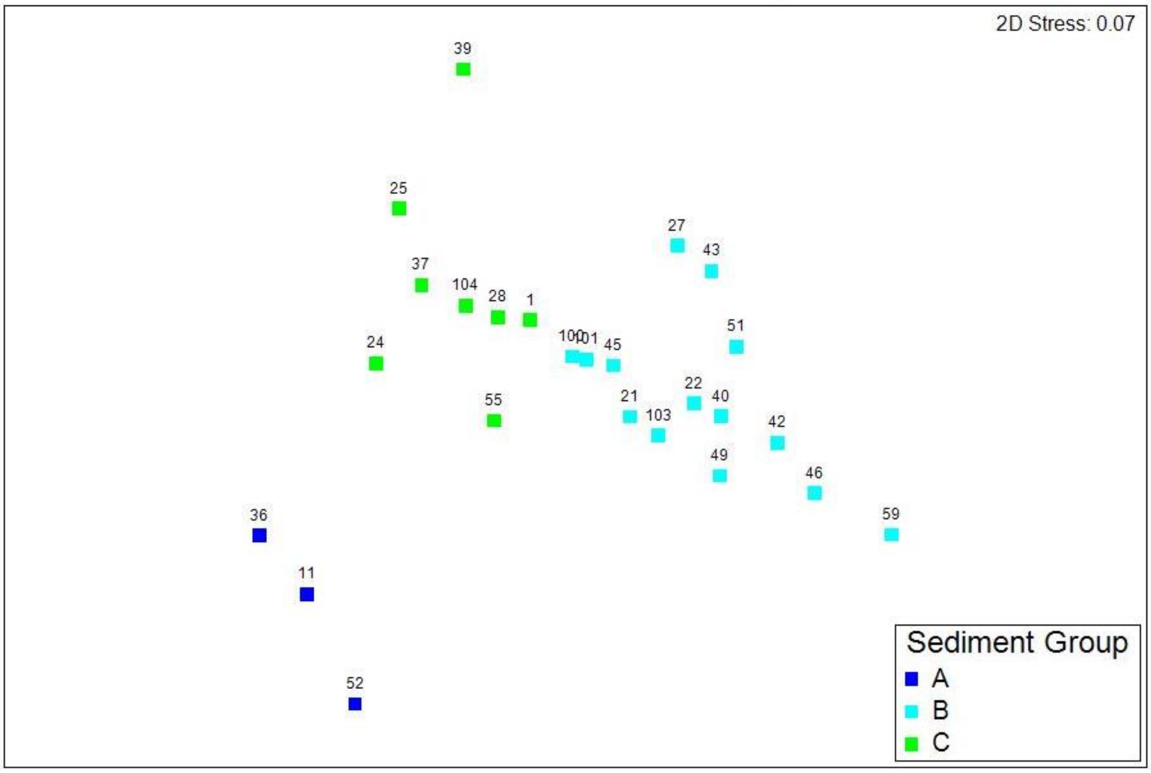


**Figure 10.** Non-metric multidimensional scaling (MDS) plot, presented in 2D format, based on sediment particle size distribution data (Euclidian distance) from the 2020 TH027 monitoring survey, showing sediment groups identified through the SIMPROF routine.

The cluster analysis and MDS plot show three statistically significant sediment groups. A spatial plot of the identified sediment groups with treatment to the station treatment areas is shown in Figure 11.

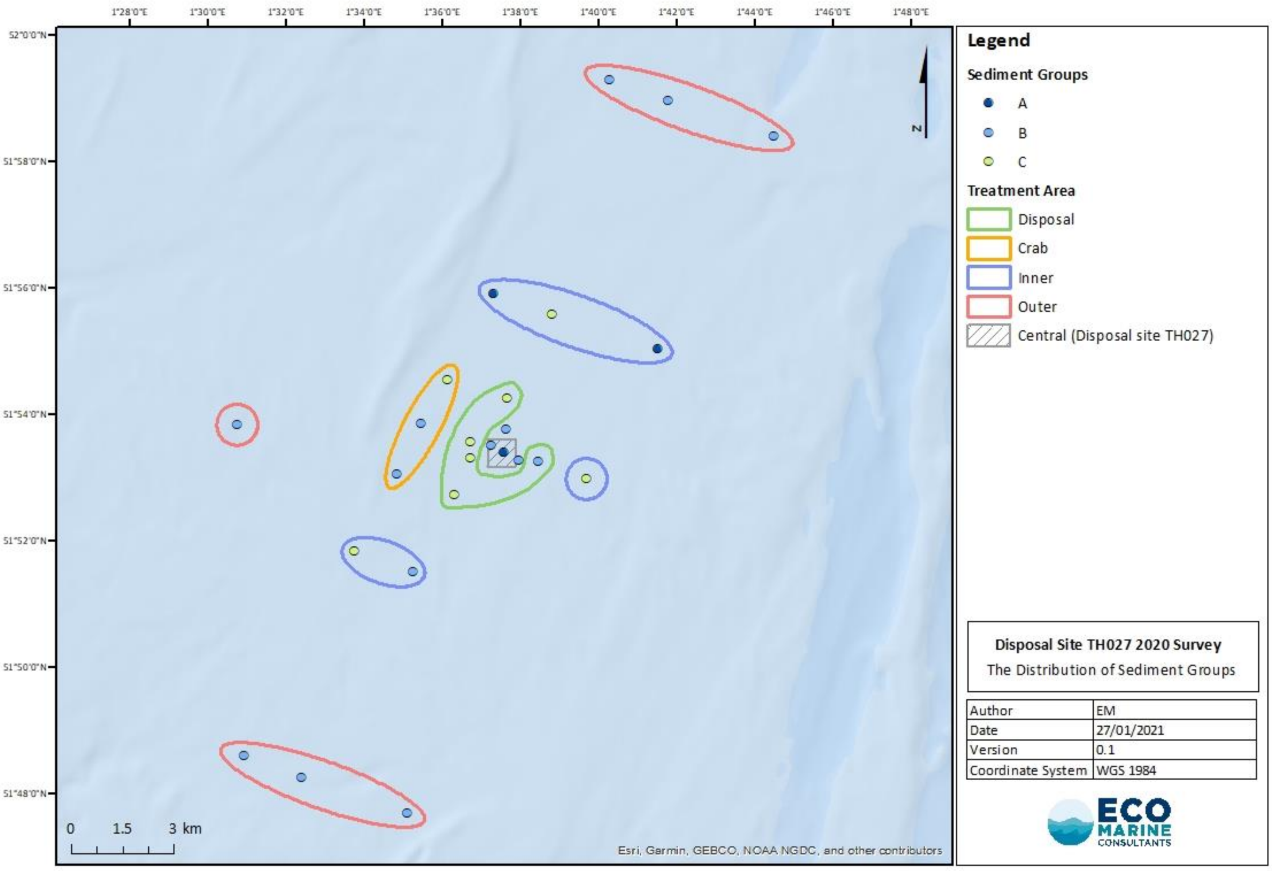


**Figure 11.** The distribution of sediment groups identified in the macrofaunal data from the 2020 monitoring survey of Disposal Site TH027.

A summary of the sediment groups is shown in Table 7 below.

**Table 7.** Summary of the sediment groups identified from the 2020 Disposal Site TH027 monitoring data.

| Group | Gravel % | Sand % | Silt % | Folk Category | Number of stations | Treatment Areas |
|---|---|---|---|---|---|---|
| A | 6.21 | 43.57 | 50.22 | Gravelly Mud | 3 | Central, Inner |
| B | 43.75 | 51.45 | 4.80 | Sandy Gravel | 14 | Central, Disposal, Crab, Inner, Outer |
| C | 9.94 | 78.76 | 11.29 | Gravelly Muddy Sand | 8 | Disposal, Crab, Inner |

Figure 11 and Table 7 show the variation and distribution of sediment types across the survey area in 2020. It can be seen that the majority of stations were classified as Sandy Gravel, and that this sediment type was located across all treatment areas.

**Summary: Sediment Analysis 2020**

The information presented above indicates that sediment types were well dispersed across the survey area. The same sediment groups that were observed within parts of the Central treatment area were also recorded across every treatment area, including those located to the far north and south of the array in the Outer area. Muddy fractions were present in all treatment areas, including within Outer treatment area, though were more common in the Central area.

### 3.3. Driving Factors of Community Composition

The data relating to sediment and faunal groupings, seen in Figures 2 to 11 suggest some correspondence between the benthic communities present and the composition of the substrate.

It is well documented that sediment composition is an important factor for determining the distribution of infaunal communities (e.g. Cooper *et al.,* 2011). For example, the presence of coarse sediments provides attachment sites for a diverse assemblage of epifauna including bryozoans and hydroids, which may not otherwise have suitable attachment surfaces in more muddy substrates.

In order to establish the robustness of this relationship for the 2020 Disposal Site TH027 survey, the faunal data were compared with the sediment data using the BIO-ENV and RELATE multivariate statistical routines.

The RELATE routine provides a means for testing correlations between two multivariate patterns, which in this case was a test for relationships between the distribution of biological communities and the distribution of sediment types. The results of this test demonstrates that there is a moderate overall significant relationship (Rho = 0.236, Significance Level = 3.1%) between the multivariate patterns observed in the 2020 sediment data and in the corresponding faunal communities. This value indicates marginally less of a relationship between the sediment and the faunal data in 2020 compared to the 2019 dataset.

In order to establish which particle sizes correlate most strongly with the patterns observed within the faunal communities, the faunal and sediment data were tested using the BIO-ENV routine. The results indicate that the strongest correlation between the multivariate patterns in the sediment and faunal data correspond most strongly with the distribution of gravel and coarse and fine sand, thus it can be said that the presence of these sediments has the greatest control on the faunal communities present in terms of the variables measured.

Natural processes are also likely to be considerable controlling factors in the patterns of faunal community composition observed.

# 4. Results: Temporal Analysis

In order to assess changes in sediment composition and faunal communities at disposal site TH027 and the surrounding vicinity over time, data from each past survey has been compared and analysed. Principally, data from 2019 and 2020 are compared to assess short-term changes at the site, whilst the 2020 data are also compared to the baseline period in order to assess longer-term changes since the start of disposals.

For the purposes of this analysis it is assumed that data from 2017 represent the baseline year. It must be noted that the 2017 survey is, however, not a true baseline/pre-disposal survey, given that limited disposals had occurred at TH027 prior to this as part of a trial study.

Data in this section are taken from stations common to all surveys being compared in order to avoid skewing the results, unless otherwise stated.

## 4.1. Sediment Distribution

Table 8 shows the mean percentage of gravel, sand and silt sampled in each treatment area surrounding and within TH027 in 2017 as the baseline year, and in 2019 and 2020. A summary of the changes in each treatment area between the baseline and 2020 is shown in Table 9, and between 2019 and 2020 in Table 10.

**Table 8.** Mean sediment particle size distribution grouped according to impact treatments for the 2017, 2019 and 2020 Disposal Site TH027 monitoring data. Data are summarised as mean gravel proportion (≥2mm), mean sand proportion (0.063mm to <2mm) and mean silt proportion (<0.063mm). The Folk category has been assigned to the mean values for each treatment area after Folk (1954).

| Treatment Area | Year | Gravel % | Sand % | Silt % | Folk Category |
|---|---|---|---|---|---|
| Central | 2017 | 48.23 | 46.78 | 4.99 | Sandy Gravel |
| | 2019 | 16.36 | 42.52 | 41.12 | Gravelly Muddy Sand |
| | 2020 | 16.18 | 54.57 | 29.25 | Gravelly Muddy Sand |
| Disposal | 2017 | 36.93 | 54.89 | 8.18 | Muddy Sandy Gravel |
| | 2019 | 24.17 | 47.18 | 28.65 | Gravelly Muddy Sand |
| | 2020 | 22.87 | 66.93 | 10.20 | Gravelly Muddy Sand |
| Crab | 2017 | 24.72 | 68.92 | 6.36 | Gravelly Sand |
| | 2019 | 12.59 | 57.99 | 29.42 | Gravelly Muddy Sand |
| | 2020 | 25.30 | 67.96 | 6.73 | Gravelly sand |
| Inner | 2017 | 29.50 | 64.11 | 6.39 | Gravelly Sand |
| | 2019 | 19.78 | 46.00 | 34.22 | Gravelly Muddy Sand |
| | 2020 | 14.85 | 62.78 | 22.37 | Gravelly Muddy Sand |
| Outer | 2017 | 43.56 | 50.82 | 5.62 | Sandy Gravel |
| | 2019 | 43.89 | 36.70 | 19.41 | Muddy Sandy Gravel |
| | 2020 | 50.46 | 46.13 | 3.41 | Sandy Gravel |

**Table 9.** Change in percentage points of mean sediment composition sampled as part of the TH027 monitoring surveys between 2017 and 2020, split by treatment areas.

| Treatment Area | Gravel % change | Sand % change | Silt % change |
|---|---|---|---|
| Central | -32.05 | 7.79 | 24.26 |
| Disposal | -14.06 | 12.04 | 2.02 |
| Crab | 0.58 | -0.96 | 0.37 |
| Inner | -14.65 | -1.33 | 15.98 |
| Outer | 6.90 | -4.69 | -2.21 |

**Table 10.** Change in percentage points of mean sediment composition sampled as part of the TH027 monitoring surveys between 2019 and 2020, split by treatment areas.

| Treatment Area | Gravel % change | Sand % change | Silt % change |
|---|---|---|---|
| Central | -0.18 | 12.05 | -11.87 |
| Disposal | -1.30 | 19.75 | -18.45 |
| Crab | 12.71 | 9.97 | -22.69 |
| Inner | -4.93 | 16.78 | -11.85 |
| Outer | 6.57 | 9.43 | -16.00 |

Tables 8 and 9 indicate that sediment composition between the baseline period and 2020 was variable in most treatment areas. Considerable change was especially noted in the Central treatment area, where a large decrease in the relative proportion of gravel present and corresponding increase in silt and sands was observed, changing the average Folk category between 2017 and 2020 from Sandy Gravel to Gravelly Muddy Sand. This same effect was observed in the Disposal and Inner treatment areas, though to a lesser degree.

Notably, very little change in sediment composition was observed in the Crab area when comparing the baseline data to the 2020 data, though it should be noted that larger changes were recorded in this area in the 2018 and 2019 datasets (see Eco Marine, 2020 for further details).

A small-moderate degree of change in sediment composition between the baseline and 2020 can be seen in the Outer reference area. This area is outside the range of any secondary impacts arising from disposal activity at TH027, and thus it can be assumed that any changes here are reflective of natural variation over time. In this instance it can be said that natural trends in the area point to a small increase in the relative proportion of gravel and decrease in the relative proportions of sand and silt.

When assessing shorter term change in sediment composition between 2019 and 2020 (Table 10), it can be seen that the differences observed are somewhat aligned with the longer-term trends, albeit on a reduced scale. Within the Central area very little change in the proportion of gravel present was recorded between the years, though an increase in sandy sediment and decrease in silt was observed. Similar patterns were observed in the Disposal, Crab and Inner treatment areas, though the Crab area recorded a larger increase in the relative proportion of gravels, in part reflective of the differing nature of the seabed sampled here in 2018 and 2019 (Eco Marine, 2020).

A greater degree of change in the Outer reference area is apparent in the short-term data compared to the longer-term dataset, with changes over the past year principally being a greater decrease in the relative proportion of silt present and increase in the proportions of sandy sediments.

Multivariate statistical techniques have been applied to the sediment data in order to assess in detail the temporal changes in sediment composition over the course of the disposal period.

ANOSIM tests were carried out on the baseline vs 2020 dataset and the 2019 vs the 2020 datasets. The results of the baseline vs 2020 data tests indicated that statistically there was a high degree of similarity and overlap in the proportion of gravel, sand, and silt between the yearly datasets, though the result was not significant (R = 0.041, sig = 7.1%). A similar result was achieved when treatment area and year were considered, though the results in this case were at a significant level (R = 0.183, sig = 0.8%).

The results of the 2019 vs 2020 ANOSIM tests showed a high-moderate level of similarity between years at a significant level (R = 0.178, sig = 0.1%). The level of similarity decreased when year and treatment area were considered between 2019 and 2020, though results remained at a significant level (R = 0.219, sig = 0.1%).

Pairwise ANOSIM tests (presented in Table 11) indicate some dissimilarity within treatment areas between years. It can be seen that whilst there are some similarities in sediment composition between 2020 and the baseline, none of the results obtained are at a statistically significant level. Comparing the 2019 dataset against 2020 indicates that sediment composition in the Disposal and Outer treatment areas was moderately comparable between years in the short-term at a significant level, though some differences were apparent. All other results were at an insignificant level.

**Table 11.** Results of the pairwise ANOSIM tests on year and treatment area on sediment data from comparable stations across the TH027 survey array for 2017 vs 2020 and 2019 vs 2020. Significant results are taken at the P = <0.05 level (5%).

| Group | R Statistic | Significance Level (%) |
|---|---|---|
| Central (2017 vs 2020) | Too few replicates for analysis | |
| Disposal (2017 vs 2020) | 0.083 | 22.9 |
| Crab (2017 vs 2020) | -0.25 | 100 |
| Inner (2017 vs 2020) | 0.174 | 7.4 |
| Outer (2017 vs 2020) | -0.083 | 78.9 |
| | | |
| Central (2019 vs 2020) | -0.5 | 100 |
| Disposal (2019 vs 2020) | 0.252 | 2.6 |
| Crab (2019 vs 2020) | 0.407 | 20 |
| Inner (2019 vs 2020) | -0.024 | 51.7 |
| Outer (2019 vs 2020) | 0.211 | 3.4 |

The results presented in this section indicate slight-moderate statistically significant changes in sediment particle size composition between 2019 and 2020 in the Disposal and Outer treatment areas. A degree of change in sediment composition in other areas over the long and short term were noted, however these results were statistically insignificant. Too few common replicates were available in the Central area during the baseline survey to apply statistical testing to this treatment area for this period, however the results of testing indicated considerable change albeit at an insignificant level.

**Summary: Temporal Sediment Analysis**

The results of the analysis suggest that sediment composition in the Central treatment area has changed considerably since the baseline period, with the relative proportion of gravel decreasing and the silt component increasing, as is to be expected. Changes in other areas were similar though less pronounced. Over the past year there has been a reduction in the relative proportion of silt and an associated increase in sandy sediment present across all areas. Changes in sediment composition in the Outer area were moderately low, suggesting that natural variation across the site is likewise low. The Crab area shows considerable variation in sediment composition over the last year, though this is thought to be influenced by sediment composition at one station alone.

## 4.2. Benthic Fauna

The results of the 2020 survey have similarly been compared with faunal data from the baseline survey in 2017 and the previous year's data from 2019 in order to determine the changes which have occurred following the start of disposals and in the more recent short-term.

Mean faunal abundance and species diversity during the surveys undertaken in 2017, 2019 and 2020 by treatment area are presented in Table 12 and in Figures 12 and 13.

**Table 12.** Mean faunal abundance and species diversity per sample grouped according to impact treatments for the 2017, 2019 and 2020 Disposal Site TH027 monitoring data.

| Treatment Area | Year | Mean Abundance | Mean Species Diversity |
|---|---|---|---|
| Central | 2017 | 248.5 | 32.0 |
| | 2019 | 44.0 | 10.5 |
| | 2020 | 138.5 | 17.0 |
| Disposal | 2017 | 29.3 | 15.1 |
| | 2019 | 38.4 | 19.5 |
| | 2020 | 72.9 | 27.9 |
| Crab | 2017 | 10.3 | 6.8 |
| | 2019 | 21.8 | 7.5 |
| | 2020 | 579.0 | 13.8 |
| Inner | 2017 | 34.9 | 12.0 |
| | 2019 | 27.0 | 14.0 |
| | 2020 | 114.5 | 20.3 |
| Outer | 2017 | 118.4 | 27.5 |
| | 2019 | 133.4 | 33.6 |
| | 2020 | 106.1 | 30.0 |

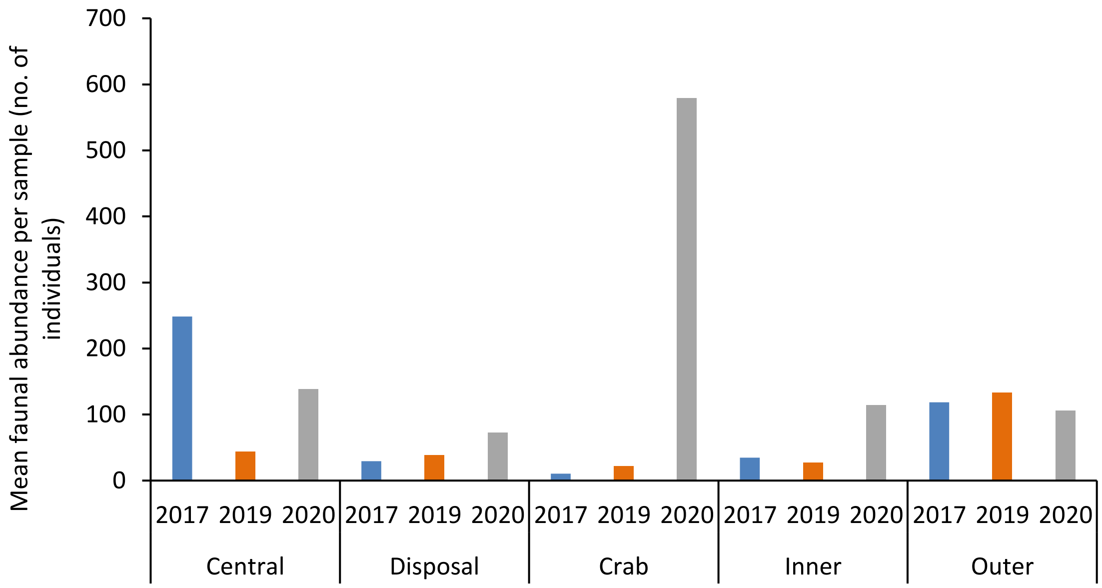


**Figure 12.** Mean infaunal abundance (no. of individuals) per sample in and adjacent to TH027 in 2017, 2019 and 2020.

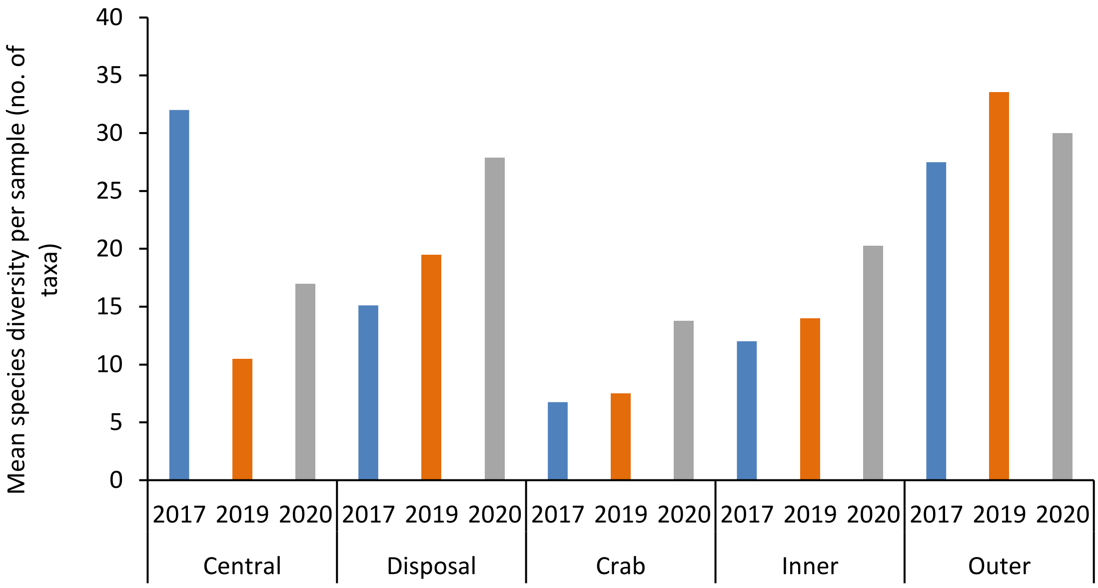


**Figure 13.** Mean species diversity (no. of taxa) per sample in and adjacent to TH027 in 2017, 2019 and 2020.

The above figures indicate variable temporal trends across the study area. A decline in mean faunal abundance and species diversity from the baseline 2017 data to the 2020 dataset can be observed, though these indices have recovered since 2019. A large increase in mean faunal abundance is evident in the Crab treatment area in 2020 compared to both the baseline and the 2019 data, coupled with an increase in species diversity. It should though be noted that variability between stations in the Crab area in 2020 was uncommonly high; a replicate from one station in this area recorded 1,873 individuals from 23 taxa, whilst another replicate from another station recorded just six individuals from six taxa.

Trends observed in the Disposal and Inner treatment areas were similar, with both areas showing an increase in faunal abundance and species from the baseline to 2020 and across the short term from 2019 to 2020.

Both mean abundance and species diversity in the Outer reference area remained relatively stable across the long- and shorter-term datasets, indicating that levels of natural faunal variation across the area are likely to be low. However, when assessing natural variation across the survey array consideration should be given to the fact that sediment type in the baseline survey was somewhat different in the Outer area compared to that across the Central area and some other areas likely to be impacted by disposal activity at TH027 (Eco Marine, 2019). As sediment type is a major influencer of faunal community composition, it cannot therefore be supposed that the degree of change observed in the Outer reference area will be common to all other areas that may have a different sediment composition and therefore support a different array of fauna.

It should also be noted that the number of comparable stations in the Central treatment area between years is low (limited to two replicates from one station), thus trends shown are more likely to be adversely affected by any changes. Additionally, faunal heterogeneity across the site was found to be high, and several stations in the Central, Crab and Disposal treatment areas have at certain times been found to contain a much higher or much lower than average abundance and species diversity than surrounding stations, further affecting the trends shown.

To investigate the impacts of the disposal of dredged material over time, data gathered during the 2017 baseline and 2020 were compared and analysed in relation to year and treatment area using an ANOSIM test. A separate analysis was conducted on data gathered in 2019 and 2020 to assess short term changes at the site. Only data from stations present in both sets of years being compared have been included in the analyses.

The ANOSIM test revealed that faunal community composition between the baseline and 2020 was moderately similar at a significant level (R = 0.236, significance level = 0.1%). A comparable, though marginally more similar result was achieved when treatment area and year were considered (R = 0.196, sig = 0.1%).

The same tests computed for the short term 2019 to 2020 datasets indicated comparable results, with moderately similar faunal community composition between years (R = 0.18, sig = 0.1%), decreasing in similarity when treatment area was also factored in (R = 0.247, sig = 0.1%).

Pairwise ANOSIM tests (presented in Table 13) indicate some dissimilarity within treatments areas between years.

**Table 13.** Results of the pairwise ANOSIM tests on year and treatment area on faunal community composition data from comparable stations across the TH027 survey array for 2017 vs 2020, and 2019 vs 2020. Significant results are taken at the P = <0.05 level (5%).

| Group | R Statistic | Significance Level (%) |
|---|---|---|
| Central (2017 vs 2020) | 0.99 | 33.3 |
| Disposal (2017 vs 2020) | 0.428 | 0.1 |
| Crab (2017 vs 2020) | -0.135 | 77.1 |
| Inner (2017 vs 2020) | 0.154 | 0.7 |
| Outer (2017 vs 2020) | 0.189 | 0.7 |
| | | |
| Central (2019 vs 2020) | 0.375 | 0.1 |
| Disposal (2019 vs 2020) | 0.244 | 5.7 |
| Crab (2019 vs 2020) | 0.096 | 14.3 |
| Inner (2019 vs 2020) | 0.198 | 0.9 |
| Outer (2019 vs 2020) | 0.131 | 1.3 |

The MDS plots shown in Figure 14 illustrates the multivariate differences between years in terms of faunal community composition.

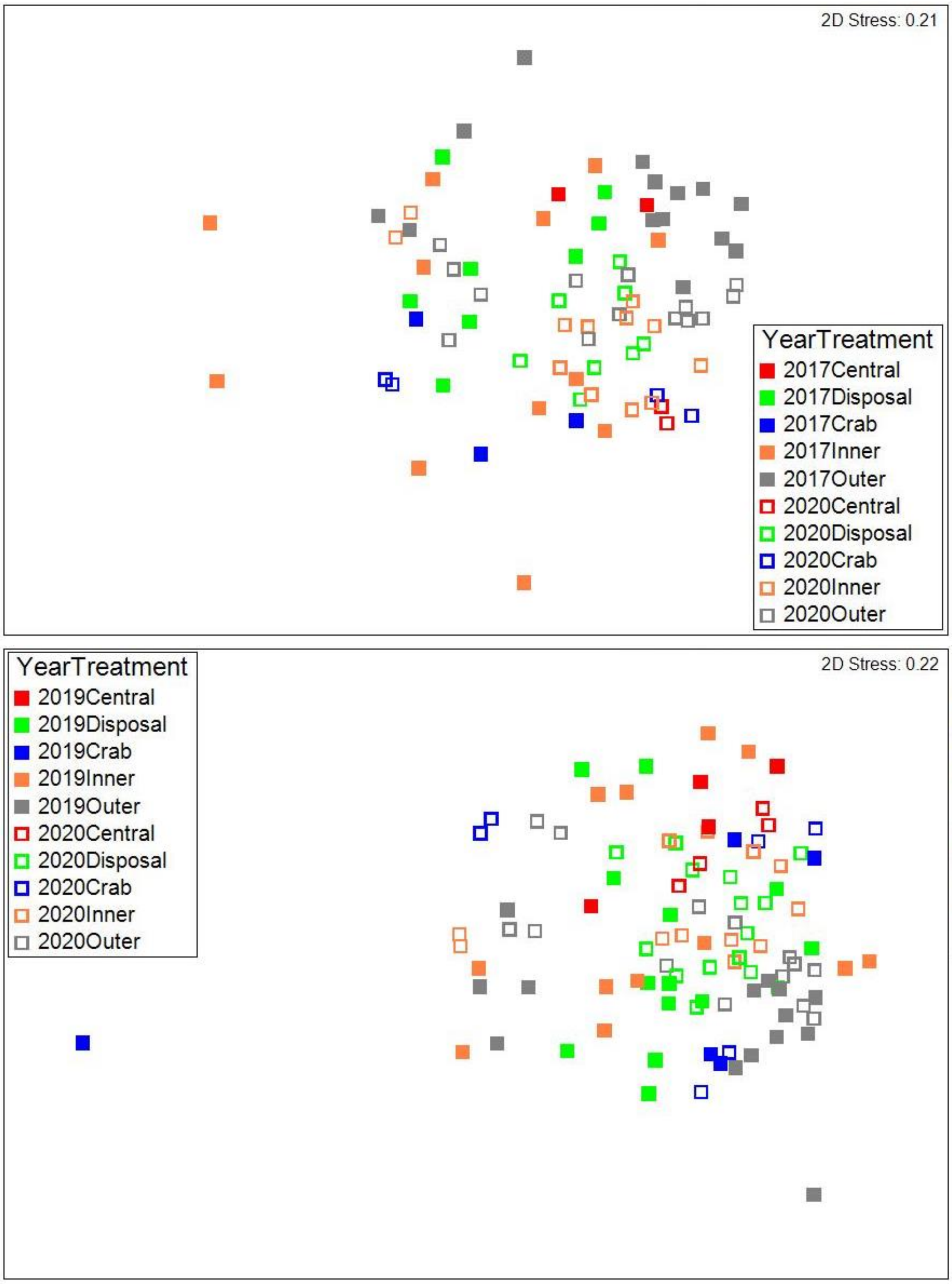


**Figure 14.** 2D multidimensional scaling ordinations based on faunal community composition data sampled in and adjacent to disposal site TH027 in 2017 and 2020 (top) and in 2019 and 2020 (bottom), showing year and treatment areas.

The plots in Figure 14 indicate that since the baseline survey, considerable changes have occurred in faunal community composition in the Central area, though the results of the ANOSIM tests in Table 13 shows that these were not at a significant level (likely due to the low number of replicates available for testing). Changes in fauna have also occurred in the Disposal area, and to a lesser extent in the Inner area, both at a significant level. The large differences in abundance over time recorded in the Crab area (as shown in Figure 12) are not indicated as significant by the results of the ANOSIM test.

Comparing shorter term data from 2019 to 2020, it can be seen that faunal community composition exhibited a low-moderate degree of similarity at a significant level in the Central area, suggesting that some changes have occurred in the last year. Results from the Disposal and Crab areas were insignificant, though a good degree of overlap was observed between faunal communities in the Inner area.

Results from both the baseline to 2020 and 2019 to 2020 analyses indicated that faunal communities in the Outer reference area were similar over time, further reinforcing the principle of low levels of natural variation across the site (noting the comments above regarding variation in sediment type across other areas).

Changes in faunal community composition in the Disposal area since the baseline and in the Central area since 2019 can be said to be outside of any changes expected as part of natural variation. The differences observed in the Inner area across both the long and short term are comparable to those changes observed in the Outer reference area.

Further testing using SIMPER analysis revealed that the key differences in the Central area between the 2017 baseline and 2020 were principally accounted for by the absence of *Balanus crenatus*, *Sabellaria spinulosa* and Thoracica in 2020 compared to 2017, as well the introduction of *Abra alba*, *Lagis koreni* and *Notomastus* spp. between years. These changes are reflective of what would be expected following the regular disposal of dredged material at sea; a change from an established coarse sediment-based faunal community to one more adapted to a more silt dominated habitat which is tolerant of sedimentation or else has a high recoverability from such impacts.

The increase in *Lagis koreni* and *Abra alba* between 2017 and 2020 in the Central area in particular is indicative of the impacts of the regular disposal of dredged material. *L. koreni* is known to be an indicator species for such activity (e.g. Rowlatt *et al*., 1990; Rees *et al*., 1992) and is thought to dominate in disturbed areas due to its opportunistic life cycle which enables it to colonise recently deposited material (Whormersley *et al*., 2008). The marked increase in the abundance of this species following the start of disposal is therefore indicative of the impacts observed. Increases in the abundance of other taxa such as *Abra alba* which are regarded as tolerant of increases in suspended sediment and smothering, and equally have a high colonisation rate and high recoverability from disturbance (Budd, 2007) further support the evidence that faunal community composition has shifted in the Central treatment area as a result of the regular disposal of dredged material.

An increase in *Lagis koreni* and *Abra* spp. between 2017 and 2020 was also observed in the Disposal and Inner areas, however the change in relative abundance was not as prominent as in the Central area. A very large increase in *Abra alba* was recorded in the Crab area in 2020 compared to the baseline; this is reflective of one station where a total of over 1,580 *Abra alba* individuals were recorded, and is not thought to be representative of the wider treatment area given that as low as one individual was recorded at other stations in this area at the same time.

Natural changes in community composition that have occurred in the Outer reference area since the baseline appear to have been driven by small changes in the relative abundance of a large number of taxa such as *Sabellaria spinulosa*, *Ampelisca spinipes* and *Ophiura albida.* These taxa are generally not those which have exhibited considerable change in treatment areas closer to TH027, underlining that the changes that have occurred in close proximity to the disposal site are likely outside of the range of natural variation.

Other differences related to community composition across the Disposal, Inner and Outer treatment areas as noted through SIMPER analysis were less distinct and less driven by the presence or absence of any obvious indicator species. Small shifts in community composition may have occurred in these areas, however the taxa which contribute most to group similarities observed in these areas has remained somewhat similar over time, as evidenced by the results of the ANOSIM tests. It can thus be said that whilst considerable impacts of disposal have been observed on faunal communities within the Central area, i.e., within the boundary of the TH027 disposal site, impacts outside of TH027 are much reduced. Any impacts observed outside of TH027 are likely to be tied to changes in sediment composition, and potentially affected by natural variation. Changes in sediment composition are known to be a major driver of change in faunal community composition (e.g. Cooper *et al.,* 2011; Desprez, 2000).

Drivers of change in faunal community composition in the shorter term between 2019 and 2020 follow a similar pattern to those that have occurred since the baseline period, though are less distinct. Moderate increases in *Abra alba*, *Lagis koreni* and *Spiophanes bombyx* were all observed between 2019 and 2020 in the Central, Disposal and Inner areas. A large increase in *Abra alba* was also documented in the Crab area between these years as discussed above. The Outer area saw a decrease in a number of species between 2019 and 2020, mirroring those changes observed over the longer period since the baseline, and setting this area apart from the others in terms of changes observed.

**Summary: Temporal Faunal Analysis**

Benthic faunal communities have demonstrated temporal change in the Central area, i.e., within the boundary of the TH027 disposal site. Overall, there has been a decrease in faunal abundance and species diversity in this area between 2020 and the baseline period, though some recovery has taken place since 2019. Outside of the Central area, increases in faunal abundance and species diversity have generally been observed over time. A large increase in abundance was recorded in the Crab area in 2020; this is heavily influenced by an abnormally high count of individuals at one station. Change in the Outer reference area over time is low, suggesting that natural variation in faunal communities across the site is minimal.

Major changes in faunal community composition are therefore mainly limited to the Central area where an increase in species regarded as indicators of disposal of dredge material have shown a considerable increase over time. These species have also increased in other areas, though not to the same degree as within the boundary of TH027.

# 5. Conclusions

The results presented in this report indicate that faunal communities observed in the vicinity of Disposal Site TH027 in 2020 remain diverse and heterogeneous in nature. Impacts of increased sedimentation have been observed upon sediment and faunal community composition within the study area since the baseline period, as is to be expected.

The key conclusions from the analyses conducted are as follows:

- Mean faunal abundance and species diversity in 2020 was greatest in the Crab area, though there was considerable variation between stations in this area. The Central area contained the second lowest mean faunal abundance and the lowest species diversity.
- Macrofaunal communities within the study area were found to be relatively heterogenous on a spatial scale. Limited clustering of stations was evident from the MDS plots and the cluster analysis, and most treatment areas displayed a wide degree of overlap. Statistical testing confirmed a high degree of overlap in community composition between all station treatments at a significant level, though pairwise testing between individual areas showed moderate-high dissimilarity between some areas in terms of faunal community composition. These differences were principally accounted for by the relative contribution of *Lagis koreni, Abra spp. and Notomastus* spp. in the Central area compared to a lack of these taxa in the Outer reference area; these species are considered indicators of the impacts of disposal at sea.
- A total of seven distinct groups were identified within the 2020 faunal data; there was limited evidence of the identified groups clustering with different treatment areas, with one faunal group identified in every treatment area, including the Central and Outer areas.
- Faunal communities found within the survey area were diverse and subject to a high level of spatial variance, though three faunal groups were found at only one station.
- Sediment composition across the survey area was less homogeneous than in previous years and showed some spatial variation. Gravelly Muddy Sand was the most prominent mean sediment type across the survey area, recorded in the Central, Disposal and Inner areas. A high silt content was noted in the Central area compared to other areas, especially the Outer area which was dominated by coarse gravelly deposits. A moderate degree of overlap in sediment composition between all station treatments was revealed through statistical testing, testing between individual treatment areas indicated some considerable differences in sediment composition.
- A total of three statistically significant groups were identified within the 2020 sediment data; there was limited evidence of the identified groups clustering with different treatment areas.
- A moderate significant relationship between sediment composition and faunal community composition was observed. The distribution of gravel and coarse and fine sand was found to correlate most strongly with faunal patterns thus it can be said that the presence of these sediments has the greatest control on the faunal communities present in terms of the variables measured as part of the survey. This is in common with previous years.
- Temporal analysis of sediment composition data indicated that that the greatest changes in sediment composition between the 2017 baseline and 2020 were within the Central treatment area, i.e., within the boundary of the TH027 disposal site. During this period, average percentages of gravel decreased by a nearly a third, whilst the relative proportion of

silt increased by approximately a quarter. This caused the mean Folk category for this area to change from Sandy Gravel in 2017 to Gravelly Muddy Sand in 2020. Sediment composition in other treatment areas was also variable between years, notably in areas with close proximity to the Central area, with each recording an increase in the proportion of silty sediment present and a decrease in the relative proportion of gravel. The exception to this was in the Outer reference area, where sediment composition remained relatively stable between the baseline and 2020 surveys, suggesting low natural variation across the site. Changes in sediment composition in the past year were less pronounced but reflected a reduction in silt and an increase in sandy sediment across all areas. Statistical testing indicated moderate levels of similarity between years, although due to the small number of common replicates, a figure for similarity in the Central area over time could not be generated.

- A decrease in mean faunal abundance and species diversity in the Central treatment area was observed between 2017 and 2020, though these indices increased between 2019 and 2020. Other treatment areas indicated variable positive trends in mean abundance and species diversity over time. A large increase in abundance was recorded in the Crab area in 2020; this was heavily influenced by an abnormally high count of individuals at one station. Change in the Outer reference area over time was low, suggesting that natural variation in faunal communities across the site is likewise low.
- Statistical testing revealed that faunal community composition between all years was moderately similar at a significant level. A high degree of overlap in faunal community composition was apparent when year and treatment were considered as factors in all areas except for the Central and Crab areas which showed considerable changes over time (noting the above comment relating to the Crab area).
- The changes in community composition observed in the Central area since the start of disposals were largely accounted for by a decrease in species associated with an established, coarse sediment habitat and an increase in taxa tolerant of or having a high recoverability to smothering and increased sedimentation. A considerable increase in the relative abundance of the noted disposal indicator species *Abra alba* and *Lagis koreni* were recorded.
- Differences related to community composition in other treatment areas followed a similar pattern though were less distinct. In the short term, moderate increases in taxa known to be indicators of disposal activity or tolerant to the impacts were all observed to increase between 2019 and 2020 in the Central, Disposal and Inner areas.
- Natural changes in community composition that have occurred in the Outer reference area since the baseline and since 2019 appear to have been driven by small changes in the relative abundance of a large number of taxa which are generally not those which have exhibited considerable change in treatment areas closer to TH027. This underlines that the changes that have occurred in close proximity to the disposal site are likely outside of the range of natural variation.
- Despite this, it can be said that whilst impacts of disposal have been observed on faunal communities within the Central area, impacts outside of TH027 are much reduced. Any impacts observed outside of TH027 are likely to be tied to changes in sediment composition, which is known to be a major driver of change in faunal community composition.

To make statistically valid comparisons between sediment composition and community composition in future surveys it is important to ensure that surveys continue to be undertaken at comparable times of the year and utilise the same sampling locations.

**Summary: Concluding Points**

- The biological community within and surrounding TH027 remains diverse in terms of species diversity and abundance.
- The sediments are equally diverse, the proportion of gravel being of dominant importance in controlling community composition.
- Over time, there is clear evidence of an increase in the proportion of silt in the deposits since the commencement of regular disposal of dredged material (though this trend has reversed in all areas since 2019). This has principally affected the Central treatment area, though changes in sediment composition have been observed within other areas close to TH027 to a lesser degree. Change in sediment composition within the Outer Reference area is minor, suggesting that natural variation in sediments across the site is low.
- The increase in silt content is associated with a change in community composition over time, especially in the Central area. Within the boundary of TH027, a considerable decrease in the abundance of species associated with an established, coarse sediment habitat has been observed, coupled with an increase in taxa tolerant of or having a high recoverability to smothering and increased sedimentation. Similar changes have been observed in other areas close to the licence area, though to a lesser degree. Natural variation in faunal community composition is deemed to be low given the small scale changes apparent in the Outer reference area.
- It is necessary to carry out strictly compatible surveys at standardised times to reduce the well-known seasonal variations in population density that can occur over time in coastal deposits.

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