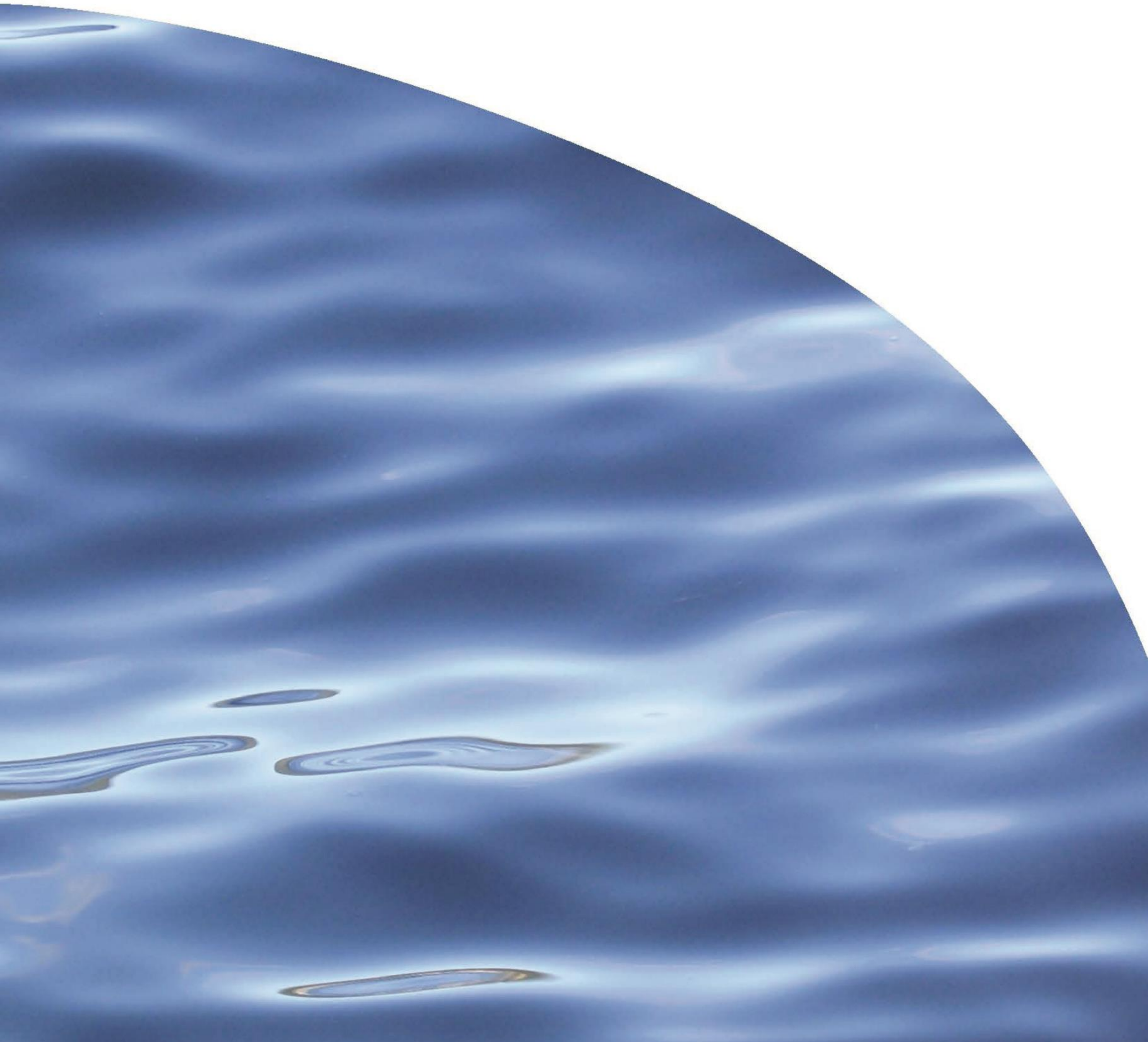
REPORT NO. 3363

BASELINE SAMPLING SURVEY OF PORT OF NAPIER OFFSHORE SPOIL GROUND



BASELINE SAMPLING SURVEY OF PORT OF NAPIER OFFSHORE SPOIL GROUND

ROSS SNEDDON

Prepared for Port of Napier Ltd

CAWTHRON INSTITUTE
98 Halifax Street East, Nelson 7010 | Private Bag 2, Nelson 7042 | New Zealand
Ph. +64 3 548 2319 | Fax. +64 3 546 9464
www.cawthron.org.nz

REVIEWED BY:
Don Morrisey

APPROVED FOR RELEASE BY:
Grant Hopkins

ISSUE DATE: 15 August 2019

RECOMMENDED CITATION: Sneddon R 2019. Baseline sampling survey of Port of Napier offshore spoil ground. Prepared for Port of Napier Ltd. Cawthron Report No. 3363. 32 p. plus appendices.

EXECUTIVE SUMMARY

This report describes the implementation and findings of a benthic survey to meet the requirements of conditions 11-16 of Resource Consent CD180012W. This consent covers the establishment and use of an offshore spoil ground to accept dredged material generated by capital works to deepen access to the Port of Napier.

The survey, conducted 25–26 April 2019, used a spatial gradient design with the following elements:

- 28 benthic stations for the sampling of sediments and seabed macrofaunal communities. These were spread across the following three zone categories along an approximate 20 m isobath:
  - Spoil ground
  - Spreading zone
  - Far-field sites
- Side-scan sonar transects
- Epifaunal dredge trawls
- Benthic video sled transects.

The key aims of the design were that it would establish a sound baseline of benthic conditions and ecology and facilitate future investigation of possible changes from use of the spoil ground.

Benthic conditions were found to be effectively uniform across the full extent of the survey area. The substrate consisted of fine unconsolidated sands raised into wave-induced ripples indicating mobilisation by long-period swell waves.

The diversity and composition of benthic communities reflect the dynamic nature of the seabed. Although a range of faunal phyla and classes were represented with moderate diversity, the community was sparse, with limited complexity compared to more stable benthic habitats. As with substrate, no clear spatial trends in these communities were identified.

Although some larger bivalve molluscs were collected by the sampling methods, numbers and observations were not consistent with the existence of high-density or extensive shellfish beds in the vicinity. Neither was there any indication of other habitats of special ecological or conservation value.

Comparison of the results of the current survey with those of a similar survey conducted in 2005 indicated no changes in benthic substrate, habitats and communities beyond those from expected natural variability.

The current survey data set represents a suitable baseline to which the results of future surveys may be compared to identify and investigate any changes to the benthic environment.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

GLOSSARY

Item	Description	Type
µm	Micron	Unit
AFDW	Ash Free Dry Weight	Acronym
ANOSIM	Analysis of Similarity	Abbreviation
aRPD	Apparent redox potential discontinuity	Acronym
As	Arsenic	Abbreviation
Cd	Cadmium	Abbreviation
cm	Centimetre	Unit
Cr	Chromium	Abbreviation
Cu	Copper	Abbreviation
E	East	Acronym
FF	Far-field	Acronym
g	Grams	Unit
GPS	Global Positioning System	Acronym
H’	Shannon-Weiner diversity index	Index
ha	Hectare	Unit
Hg	Mercury	Abbreviation
ICP-MS	Inductively Coupled Plasma Mass Spectrometry	Acronym
J'	Pielou’s evenness index	Index
kHz	kiloherz (cycles per second)	Unit
km	Kilometre	Unit
LOI	Loss On Ignition	Acronym
LOS	Level Of Similarity	Acronym
m	Metre or metres	Unit
MBES	Multibeam echo-sounder	Acronym
MDS	Multi-dimensional scaling	Acronym
mm	Millimetres	Unit
MSL	Mean Sea Level	Acronym
N	No. of individuals (index)	Abbreviation
n	Number of replicates in a sample	Variable
Ni	Nickel	Abbreviation
nMDS	Non-metric multidimensional scaling	Acronym
Pb	Lead	Abbreviation
PONL	Port of Napier Ltd	Acronym
PVC	Polyvinyl chloride	Acronym
R2	Coefficient of determination	Coefficient
S	Number of species (species richness)	Index
SG	Spoil ground	Acronym
SIMPER	Similarity percentage	Abbreviation
SZ	Spreading zone	Acronym
TOC	Total organic carbon	Acronym
USEPA	United States Environmental Protection Agency	Acronym
Zn	Zinc	Abbreviation

1. INTRODUCTION

1.1. Background

Port of Napier Limited (PONL) plans to deepen its existing approach channel to accept deeper draft vessels and establish a new berth (No.6 berth) on the northern face of the main Port reclamation. This entails widening the current dredged channel and extending it seaward by approximately 1.3 km. The swing basin at the Port entrance will also be extended approximately 120 m westwards and 220 m south and deepened to serve the new berth. Over multiple stages, the dredging project will generate approximately 3.2 million m^3 of dredge spoil and this will be deposited in a consented 346 ha disposal area located approximately 3.3 km south-east of Pania Reef and 4 km offshore in water depths of 20–23 m. The spatial footprint for the dredging work and the proposed disposal area for the dredge spoil, in relation to the principal features of the coastline, are depicted in Figure 1.

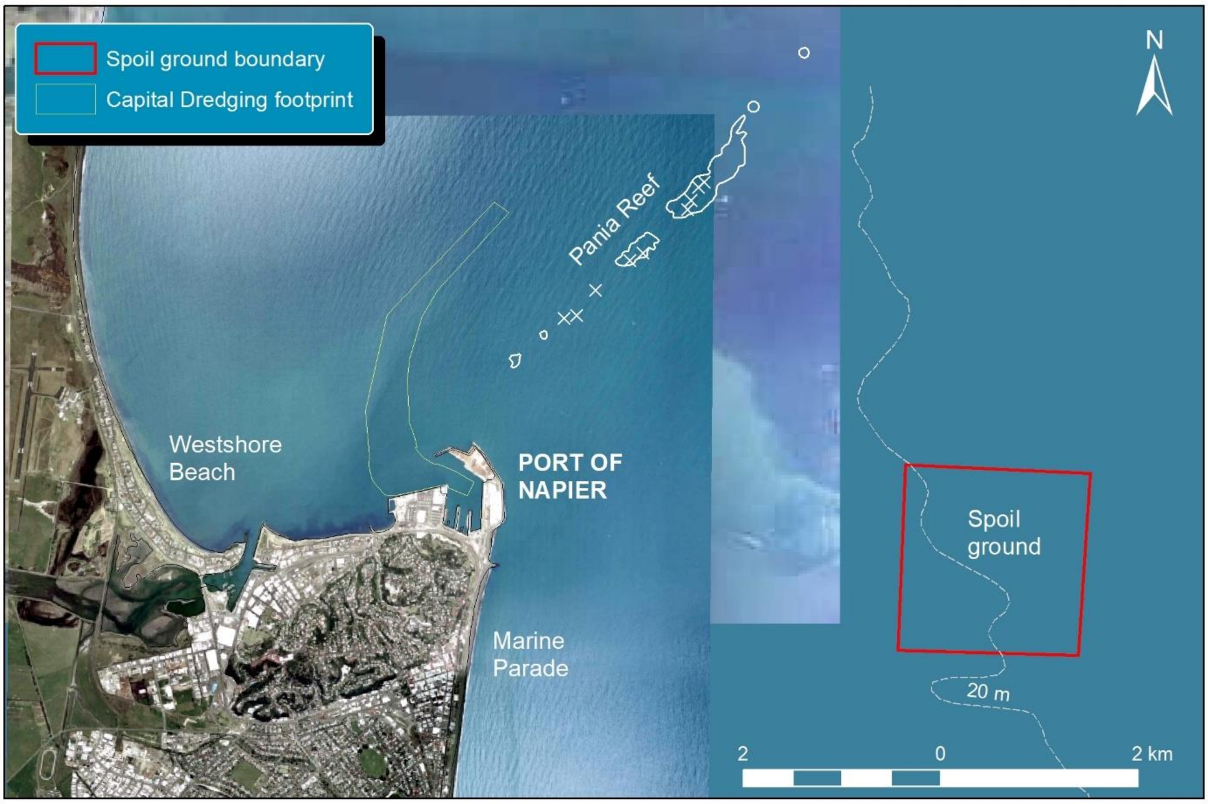


Figure 1. Composite image showing the location of the offshore spoil ground in relation to the Port of Napier, Pania Reef and the planned capital dredging footprint.

The disposal area was the subject of a sampling survey conducted in 2005 (Cawthron, unpublished data) but, due to the age of these data and the need for a larger spatial scope for seabed characterisation, the associated resource consent (CD180012W) requires a new baseline benthic survey of the vicinity. Cawthron institute were contracted by PONL to conduct the survey, the fieldwork for which was completed over 25–26 April 2019. This report presents the results, data analysis and interpretation. It also provides a comparison with the 2005 data to establish the nature and scale of any changes that may have occurred between the two surveys.

1.2. Scope

The scope of this work is set by the requirements of conditions 11–16 of Resource Consent CD180012W.

The primary aim of the survey work is to better establish the nature and spatial distribution of benthic habitat and communities within the vicinity of the spoil ground. Establishing such a baseline enables:

a) Validation of the 2017 assessment findings (Sneddon et al. (2017), based on analysis of the 2005 data) upon which the consent is based.
b) Determination of the nature and scale of any changes to benthic conditions identified from subsequent survey iterations required by the consent.

2. METHODS

The survey employed both direct sampling and seabed imaging methods to establish the nature and relative uniformity of benthic conditions and communities in the vicinity of the spoil ground.

Survey elements were structured around 28 benthic sample stations (Figure 2). Since all available information[1] indicated a flat and relatively unvarying seabed, the principal considerations for layout were bathymetry and coverage of the area of interest.

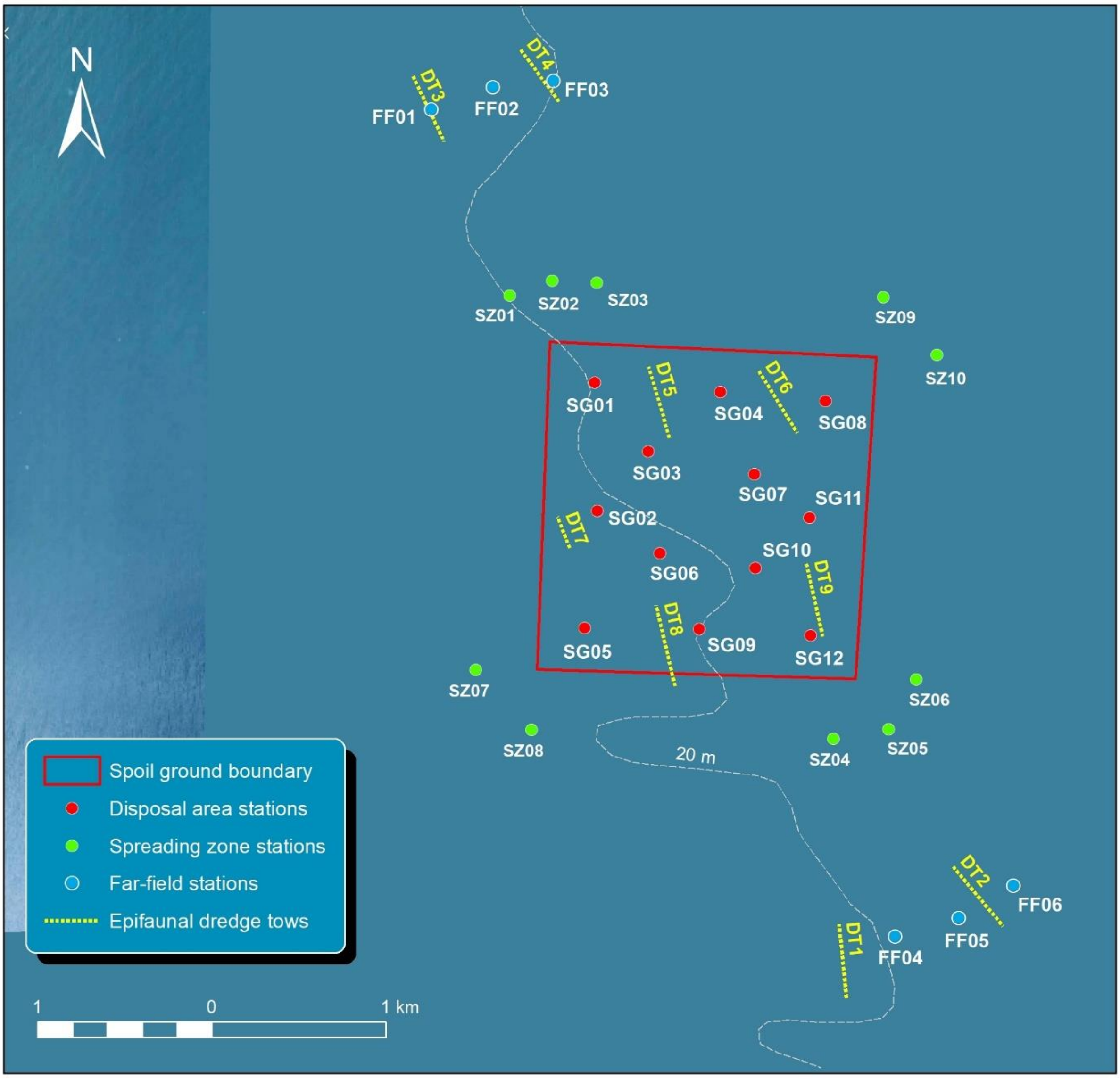


Figure 2. Spatial layout of principal sampling elements; benthic grab stations and epifaunal dredge trawls. The 20 m depth contour from hydrographic chart NZ571 has been overlaid.

[1] As well as indications from nautical charts and the 2005 Cawthron survey, this included a multi-beam echo sounder (MBES) survey of the spoil ground carried out by Port of Napier in February 2019 (Appendix 1).

The stations were arranged spatially according to three area or zone classifications:

- **Spoil ground (SG):** Twelve stations within the consented spoil ground boundary.
- **Spreading zone (SZ):** Ten stations at 350 m from the spoil ground boundary, including:
    - Three stations (300–400 m apart) at each end of an approximate isobath running through the spoil ground centre
    - Two stations (400–500 m apart) at each of locations inshore and offshore from the NE and SW vertices of the spoil ground
- **Far-field (FF):** Three stations (300–400 m apart) at each end of an approximate isobath running through the spoil ground centre, and located 1500 m from its closest boundary.

2.1. Benthic sampling

Sediments were collected using a 0.1 m^2 stainless steel van Veen grab mounted in a weighted frame to assist with penetration in dense fine sand substrates (Figure 3). This method collects a relatively undisturbed section of surficial sediment down to a depth of 10-12 cm in the profile. Upon retrieval, the grab contents can be sub-sampled using standardised corers to provide material for sediment and infauna analyses.

On the basis that previous sampling work (2005) and the general bathymetry indicated a highly uniform seabed habitat, the approach sought to balance sample replication with site coverage, opting for single grab deployments at stations grouped according to area and bathymetry (Figure 2). There was potential, during the field survey, to revise this approach according to the results of direct observation (including sonar and video of the seabed); however, such changes were not found to be necessary.

2.1.1. Sediment core samples

At each station, three 62-mm diameter cores were collected from the contents of the grab. These were photographed and their colour and any noticeable odour noted, along with the depth to any apparent redox potential discontinuity (aRPD) layer[2]. The top 5 cm from each of the three cores was combined to provide a single composite sample for analysis of grain size distribution, organic content and trace metals. All samples were chilled for transport to the laboratory. A summary of sediment analyses and analytical methods is listed in Table 1.

[2] The aRPD refers to the often-distinct colour change, between surface and underlying sediments, brought about by the changing redox environment with depth in the profile. This gradient of colour change is in reality continuous but may be reduced to an average transition point (sediment depth) for descriptive purposes.

Figure 3. **Top left:** The van Veen grab sampler. **Bottom left:** The research dredge used to sample epifauna. **Right:** The grab sampler mounted in its frame.

Table 1. Summary of analytical methods used for sediment characterisation.

Analyte	Method Number	Description
Particle grain size distribution (sediment texture)	Hill Laboratories in-house method	Wet sieved through screen sizes: > 2 mm = Gravel < 2 mm to > 1 mm = Coarse Sand < 1 mm to > 500 µm = Medium Sand < 500 µm to > 250 µm = Medium/Fine Sand < 250 µm to > 125 µm = Fine Sand < 125 µm to > 63 µm = Very Fine Sand < 63 µm = Mud (Silt & Clay) Size classes from Udden-Wentworth scale
Trace metals (As, Cd, Cu, Pb, Hg, Ni, Cr, Zn)	USEPA 200.2	Detected by ICP-MS (inductively coupled plasma mass spectrometry) following nitric/hydrochloric acid digestion
Total organic carbon	Hill Laboratories in-house method	Acid pre-treatment to remove carbonates if present, neutralisation, [Elementar combustion analyser].

The analysis of sediment texture (particle grain size distribution) defines the coarseness of sediments and provides an important measure of the physical characteristics of a site that can be used to investigate and interpret differences between sites in other environmental parameters. Chemical contaminants are primarily retained within fine sediments (e.g. Förstner 1995). Metals, especially, can adsorb to particulates and may accumulate over long time periods. Both sediment texture and organic content play an important role in determining the capacity for adsorption and retention of contaminants and allow the assessment of associations between substrate type and the associated sediment faunal communities.

2.1.2. Benthic macrofauna

The ecological assemblage of small invertebrate animals (larger than 0.5 mm) living in the upper 100 mm of the sediment profile is generally referred to as macrofauna or infauna[3]. Infauna have been used for several decades to assess the effects of human impacts in marine environments and various studies have demonstrated that they respond relatively rapidly to anthropogenic and natural stress (Pearson & Rosenberg 1978; Dauer et al. 1993; Borja et al. 2000).

Sample collection

At each sample station, one macrofauna sediment core was extracted from the contents of the grab. The corer consisted of an elliptical section made from PVC pipe with cross-sectional area equivalent to a circular section 130 mm in diameter (133 cm^2). Each corer was manually driven into the contents of the grab then withdrawn and the core emptied into a 0.5 mm mesh sieve where it was gently rinsed with seawater to remove the majority of the fine sediment matrix. The residue was transferred to a sample container for preservation in a solution comprising 3% glyoxal and 70% ethanol.

Sample analysis

In the Cawthron taxonomy laboratory, macrofauna within the preserved samples were identified and counted with the aid of a binocular microscope. Identifications were made to the lowest practicable taxonomic level. For some groups of macrofauna, species level identification is very difficult and, in such instances, macrofauna were grouped into recognisable taxa (morphologically similar groups). In this manner, a list of taxa and their abundance was compiled for each station.

Community data analysis

The macrofauna count data was compiled and analysed to ascertain levels of abundance (individual species density), species richness and standardised indices of community diversity and evenness for each station (Table 2). These values were

[3] While the infauna are technically the subset of macrofauna that lives within the sediment matrix, core samples invariably also include those which are principally surface-dwelling.

compared among stations and significant differences interpreted with respect to key factors such as water depth and substrate characteristics.

Table 2. Descriptions of standard community indices.

Index	Equation	Description
No. species (S)	$\sum s$	Total number of species (s) in a sample.
No. abundance (N)	$\sum n$	Total number of organisms (n). This comprised the sum of percentage cover of colonial organisms and solitary individuals.
Evenness (*J'*)	$J' = \frac{H'}{log_e S}$	Pielou's evenness. A measure of equitability, or how evenly the individuals are distributed among the different species. Values can theoretically range from 0.00 to 1.00, where a high value indicates an even distribution and a low value indicates an uneven distribution or dominance by a few taxa.
Diversity (*H'*)	$H' = -\sum P_i \, log_e \, (P_i)$ P_i is the proportion of N comprised of the *i*th species.	Shannon-Wiener diversity index describes, in a single number, the different types and amounts of taxa present in a sample. The index ranges from 0 for communities containing a single species to high values for communities containing many species each represented by a similar number of individuals.

The infaunal assemblages recorded at each site were contrasted using non-metric multidimensional scaling (nMDS; Kruskal & Wish 1978) ordination and cluster diagrams using Bray-Curtis similarities between samples. Abundances were square-root transformed to de-emphasise the influence of the numerically dominant species. The significance of differences between survey events was tested using analysis of similarities (ANOSIM) and the principal taxa contributing to the dissimilarities of each grouping were identified using SIMPER (Clarke et al. 2014). All statistical analyses were conducted using PRIMER v7 (Clarke & Gorley 2015; Anderson et al*.* 2008).

To enable comparison of the community data from the current survey with that from the 2005 investigation, the two macrofaunal data sets were compiled with necessary adjustments to taxonomic resolution. This unavoidably resulted in the loss of some detail from the current data set.

2.1.3. Epifaunal communities

Epifauna refers to the organisms living on the sediment surface. Epifaunal communities were sampled using a small research dredge or epibenthic sled. This had a 250 mm x 500 mm throat and was fitted with a 500 mm deep stainless-steel wire mesh basket of mesh size 10 mm (Figure 3). Dredge trawls were carried out at vessel idle speed (1.5–2 knots) along approximate isobaths, with the track and depths logged for each one. Upon retrieval, the dredge contents were photographed, identified, and the number of individuals of each faunal taxon counted.

Nine epifaunal dredge trawls were completed, all except one covering a distance of approximately 400 m. Five trawls were distributed across the spoil ground; the remaining four comprised two at each of the far-field sites (Figure 2).

2.2. Benthic imaging

Benthic imaging techniques were used to gain a better indication of the homogeneity of the seabed in the vicinity of the spoil ground. By using the macrofaunal and epifaunal samples to ground-truth the images, the spatial extent of any distinctive habitats can be ascertained.

While the available information indicated that the seabed was fairly homogenous across the survey area, there is a small area of slightly raised bathymetry marked on the nautical charts approximately 200 m north of the spoil ground boundary and 50 m outside the extent of the February 2019 multi-beam echo sounder (MBES) survey (Appendix 1). Due to the possibility that this patch represented a more substantial hard substrate or biogenic feature[4], it was investigated specifically using imaging methods.

2.2.1. Side-scan sonar

Side-scan sonar images of the seabed were collected using a Lowrance Structurescan HD® system (455 kHz frequency) with a vessel-mounted transducer. This gave a swathe width of 100 m within which changes in seabed relief and reflectivity could be identified if present. Side-scan recordings were made at a vessel speed of 2-3 kn during the five epifaunal dredge tows through the spoil ground, as well as for those at the north-western far-field site. Additionally, side-scan images were recorded on two passes over the chart-indicated shallow patch adjacent to the spoil ground northern boundary (Figure 2).

During the side-scan transects, GPS position tracks were logged simultaneously with bathymetric data and the sonar output to the vessel’s chart plotter. The start and endpoints of tracks, and any features of interest, were marked as waypoints. This enabled the relocation of such areas for subsequent inspection and verification using video or other methods.

The sonar imagery was processed using the Reefmaster 2.0 software package to convert the sonar files to geo-referenced .kml files.

[4] Of biological origin. Such features may include structures such as sponge gardens or rhodolith beds, or emergent sessile shellfish beds such as horse mussels (*Atrina zelandica*).

2.2.2. Benthic video

While side-scan sonar will show distinct changes in surface relief, it will not necessarily be able to resolve low relief changes in seabed features, especially when they are unaccompanied by associated changes in sonar reflectance. To cover this possibility and better establish the nature of the seabed, direct video observation was performed using a towed video sled. However, the efficacy of video is sometimes significantly constrained by low underwater visibility above fine sediment substrates and hence cannot always be relied upon to provide useful information.

The camera was positioned on the towed sled looking forward from a height of 400 mm above the seabed, giving a useful field of view approximately 0.6 m wide directly in front of the runners. Battery-powered lights were mounted on either side of the sled to minimise reflection from particulates suspended in the water column. The sled was towed by the camera's power and communications cable.

The start and endpoint of each transect were marked as the vessel locations where the video sled was lowered to, and lifted from, the seabed. The distance or layback of the sled behind the vessel makes it difficult to pinpoint the exact position of the camera at any point, but this limitation is of concern mostly to mapping rather than characterisation surveys[5].

Four video transects were run, three within the spoil ground and one at the patch indicated as a high point on chart NZ5721a (Figure 4). Two of these coincided with areas covered by side-scan sonar and one with a site targeted by epifaunal dredge trawl. Transects varied in length from 100 m to 300 m.

The entire transect was viewed in real-time via live feed to the vessel and recorded to the vessel's computer. In this way, notes could be taken, and the vessel's heading adjusted to react to anything observed on the seabed.

[5] It is possible to overcome this limitation and exactly locate underwater instruments using an Ultra-Short BaseLine (USBL) acoustic positioning system.

3. RESULTS AND DISCUSSION

3.1. Field observations and benthic imaging

Field notes from grab sampling recorded sediments as being comprised predominantly of fine unconsolidated sands. Little variation was noted across the entire survey area; although, there was some patchiness observed in the apparent silt content of the samples. Two of the spreading zone samples, SZ06 and SZ10 were described as being noticeably siltier. Samples from SZ10 were the only cores described as featuring a discernible aRPD (at ~6 cm depth in the profile, see Appendix 2). Both these stations were in slightly greater water depths, on the seaward side of the survey area (Figure 2). Heavier mobile sands were noted for stations at the southern far-field site (FF04-6) and for SZ09, resulting in poorer grab penetration.

Some variability in the substrate was also noted during epifaunal trawls, with the dredge bogging in softer sediments during tows DT07 and DT08 (Figure 2), the former requiring retrieval of the dredge after only 200 m. Although some consistency with greater water depths was apparent, the distribution of siltier substrates appears to have been generally patchy.

3.1.1. Side scan sonar

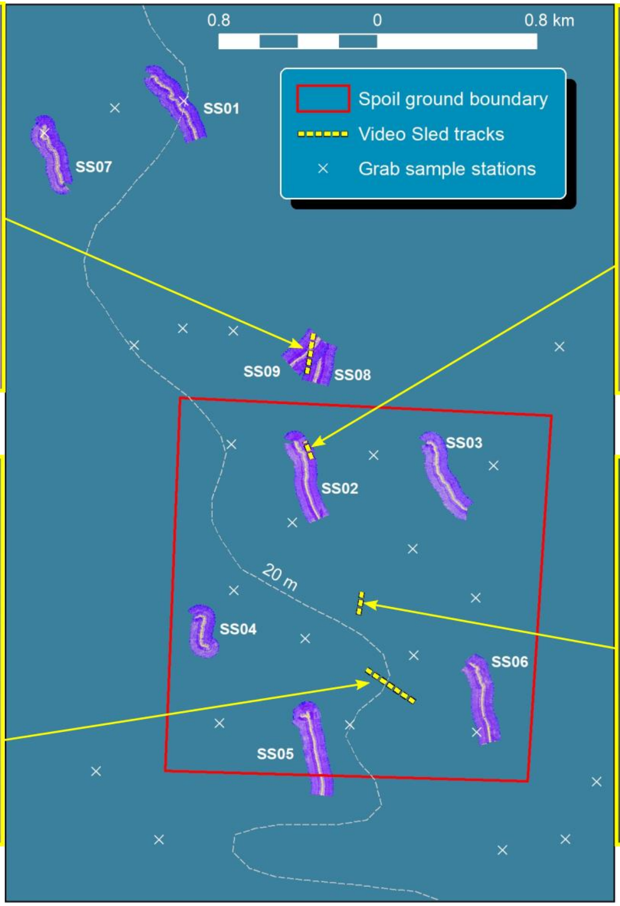
Side-scan sonar recording was operated during all epifaunal trawls except those at the southern far-field site. As noted, it was also employed to examine the patch north of the spoil ground indicated as shallower on the charts (SS08 and SS09, Figure 4). Notes taken during real-time display on the vessel’s chart plotter recorded no discernible features of interest. The sonar imagery was consistent with a uniform seabed of fine mobile sands with no significant biogenic structures. The locations of the sonar images derived from side-scan outputs are shown in Figure 4 and presented in detail in Appendix 3.

3.1.2. Video sled recordings

Very calm conditions in the days preceding and during the survey resulted in acceptable underwater visibility at the seabed and the video sled proved useful in ground-truthing the side-scan sonar imagery. The video recordings were in agreement with all other survey data, indicating the ubiquitous presence of mobile sand substrate and very few other features. They revealed that the substrate was raised into prominent sand ripples of wave-length 100-150 mm (Figure 4). This, and the unconsolidated nature of the sands retrieved by the grab, indicates that the seabed is regularly mobilised by shear forces from oceanic swells. The rippled sand patterns were aligned with the general orientation of depth contours (NNW to SSE) and mostly unchanging, although there were two instances where the regular pattern was disrupted, possibly due to localised changes in sediment texture.

Video 4: Sand ripples (wavelength 100-150 mm) and burrow entrance.

Video 1: Sand ripples and sand tube casings (bottom left and center).



Video 2: Sand ripples and gastropod shell (*Struthiolaria papulosa*)

Video 5: Sand ripples, sand tube casing (center foreground) and large burrow entrance with associated ejected material.

Figure 4. Spatial layout of side-scan sonar swathes and benthic video sled tracks in relation to the spoil ground boundaries and benthic grab stations (white crosses). Still images captured from the video highlight features identified from the otherwise highly uniform soft-sediment substrate. Individual sonar swathe images are provided in Appendix 3.

Review of the video recordings provided little information on epifaunal communities. Only in two instances were small whelk gastropods visible (probably *Austrofusus glans*). Occasionally, emergent sand tubes and larger burrow entrances were visible, but the animals responsible for these could not be identified and neither of these features were observed in densities that would be judged unusual or ecologically significant. Visible shell material was also occasionally visible, usually the fragments of small bivalves and once the gastropod *Struthiolaria papulosa* (Figure 4). Both *A. glans* and *S. papulosa* were collected live in epifaunal trawls (Section 3.4).

3.2. Sediment physico-chemical characteristics

3.2.1. Grain size distribution and organic enrichment

Most of the sediment samples collected from the 28 benthic stations were dominated by very fine sands (average 70%) with the majority of the balance made up by the silt/clay fraction. There was some variability between stations (Figure 5, Figure 6) and, although spatial patterns were not strong, the silt/clay component tended to be smaller at the southern far-field site (FF04-6; ranging 13-19%) and greater at the spreading zone stations to the east and south of the spoil ground (SZ04-6, SZ09-10; ranging 36-58%). These patterns did not, however, represent clear gradients on a wider scale, either along isobaths (Figure 6) or with water depth (Figure 7).

Ranging from 0.12 to 0.22%, the organic carbon content of the sediments was generally very low, reflecting the mobile nature of the substrate. Spatial trends in the organic carbon component were weak but tended to follow those of the silt fraction (Figure 5; $R^2 = 0.62$), with greater values at the spreading zone stations to the east and south of the spoil ground.

3.2.2. Trace metals

None of the trace metals analysed in the sediment samples was elevated relative to national guideline levels (ANZG 2018) and there was minimal variation across stations (Figure 8). However, some metals were moderately well correlated with the sediment silt/clay and organic components, especially chromium, copper, nickel and zinc (Table 3).

Table 3. Coefficients of determination (R^2) between the silt/clay and organic carbon (TOC) components of sediments and their trace metal concentrations across all survey samples.

Metal/metalloid	As	Cd	Cr	Cu	Pb	Hg	Ni	Zn
Silt/clay	0.24	0.09	0.79	0.81	0.42	0.03	0.70	0.8
TOC	0.34	0.07	0.61	0.71	0.49	0.04	0.65	0.75

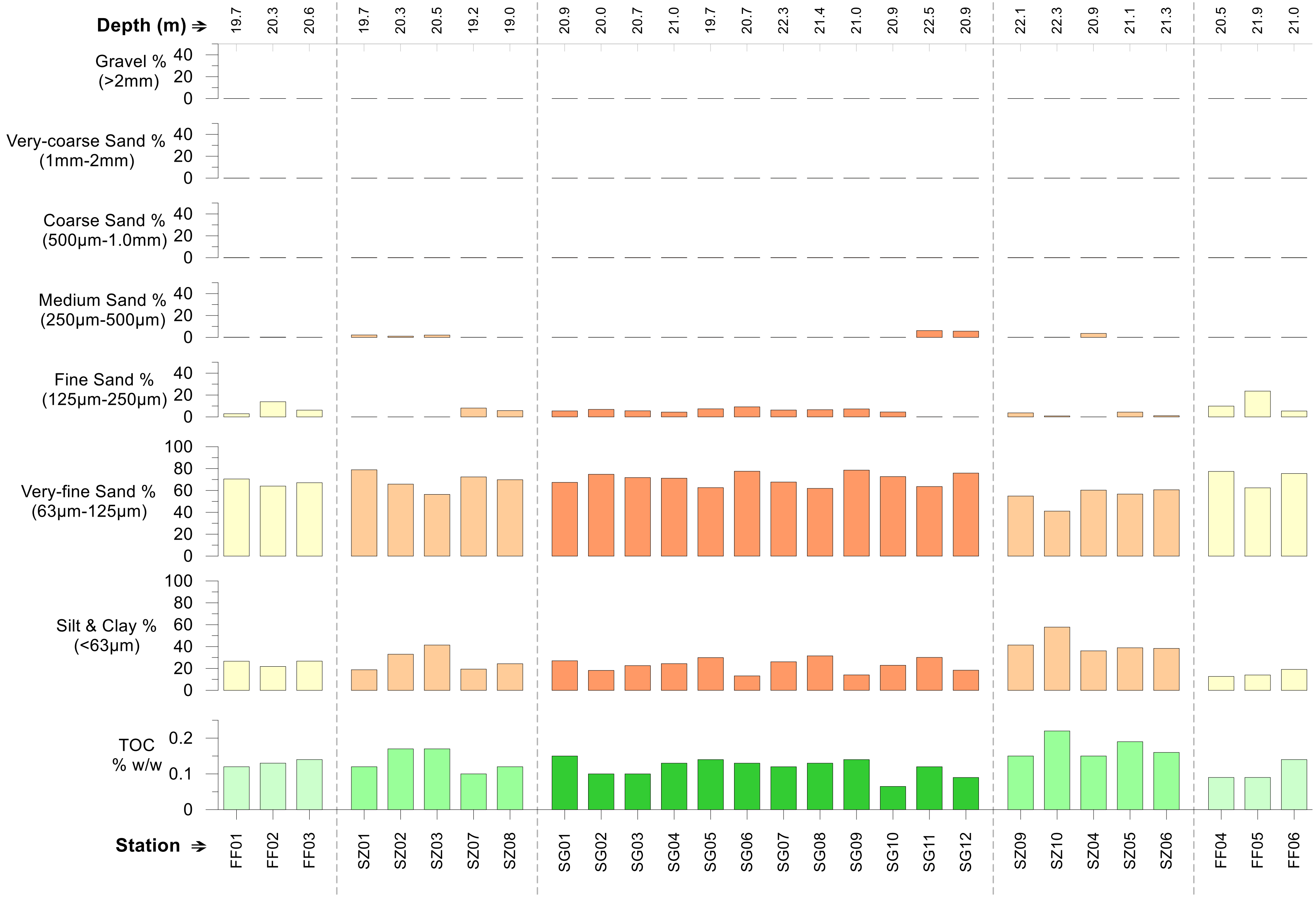


Figure 5. Grain-size distribution and organic content of sediments sampled from the vicinity of the spoil ground. Divisions and colour-shadings depict the three station zones of spoil ground (SG), spreading zone (SZ) and far-field (FF).

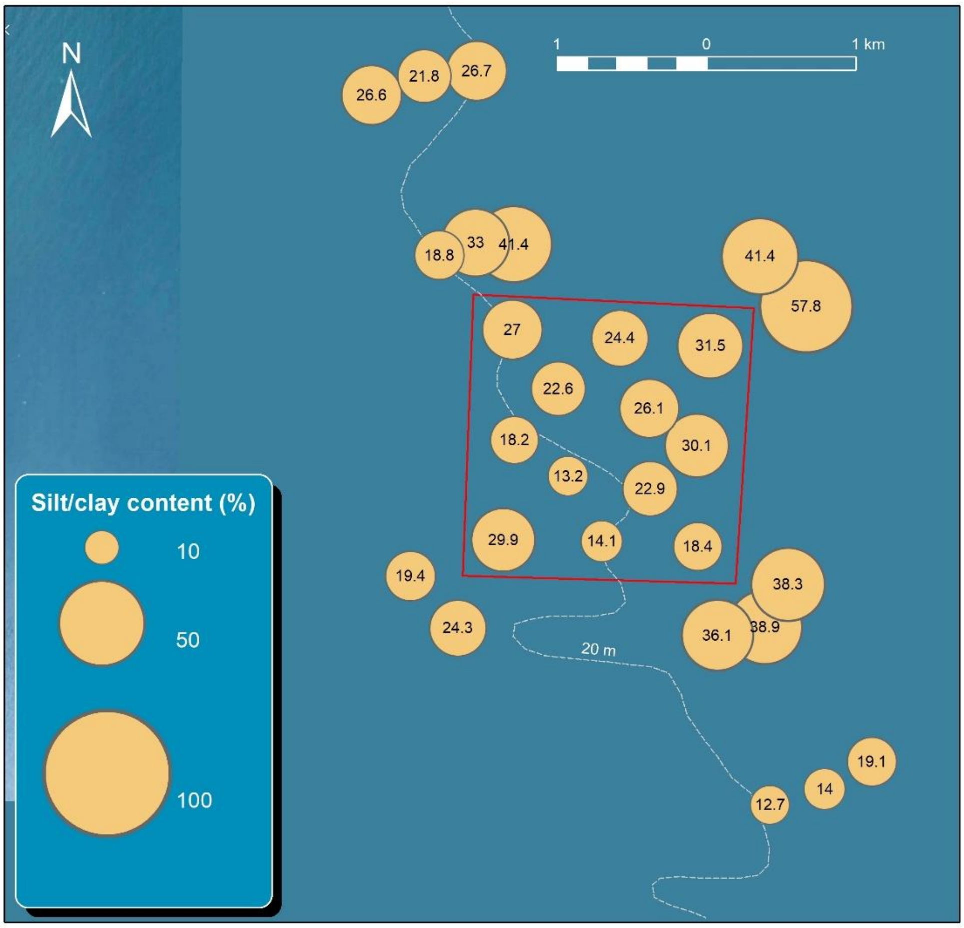


Figure 6. Spatial variability of sediment silt/clay content (% < 63 µm) across the benthic sample stations. Proportional symbols adjusted with Flannery compensation to allow for viewer perception.

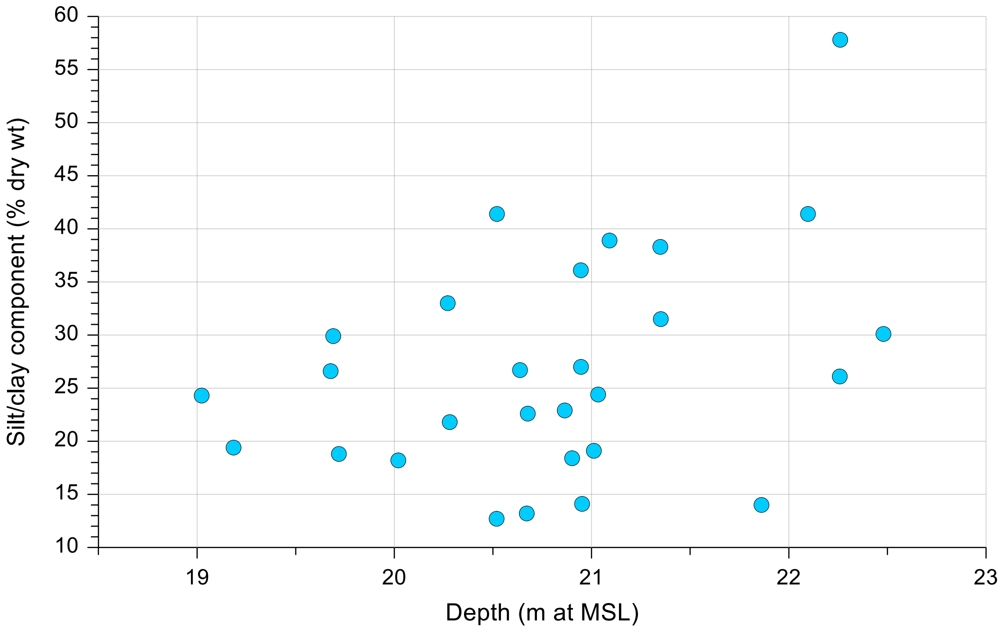


Figure 7. Variation of the silt/clay fraction (% < 63 µm) of sediments with water depth (MSL) across all sample stations.

Figure 8. Trace metal concentrations in sediments sampled from the vicinity of the spoil ground. Divisions and colour-shadings depict the three station zones of spoil ground (SG), spreading zone (SZ) and far-field (FF).

3.3. Macrofaunal communities

3.3.1. Patterns in community indices

Typical of mobile sediments, the macrofaunal core samples yielded only moderate numbers of organisms (ranging 34 to 157 individuals per 133 cm^2 sample). Across all stations, 78 macrofaunal taxa were identified, including 34 polychaete worms and 15 bivalve molluscs as well as crustaceans of the classes Ostracoda and Malacostraca (orders Amphipoda, Decapoda, Isopoda and Cumacea) and two holothurians (sea cucumbers). Table 4 lists the 15 most abundant taxa overall, showing numerical dominance by the capitellid polychaete *Heteromastus filiformis* and the small bivalve *Nucula nitidula*.

Total abundance of macrofauna (N) varied across stations but there was no consistent spatial pattern, reflecting the typical patchiness of such communities (Figure 9). The number of taxa per core (S) also varied (from 14 to 32) and tended to mirror the pattern of total abundance. Derived as it is from both N and S, Shannon-Weiner diversity (H') also followed this pattern. Values of H' varied from 2.0 to 2.9, these levels being fairly typical of mobile sand environments. Community evenness values (P') were consistently moderate to high, indicating that the more abundant taxa did not generally dominate to the exclusion of other species.

Table 4. The 15 most abundant macrofaunal taxa identified across all stations. Means of 28 samples across all three zone categories.

Group	Taxa	Mean*
Polychaeta: Capitellidae	*Heteromastus filiformis*	19.1
Bivalvia	*Nucula nitidula*	11.8
Amphipoda	Phoxocephalidae	7.3
Polychaeta: Spionidae	*Prionospio* sp.	4.6
Bivalvia	*Dosinia* sp. (Juvenile)	3.5
Holothuroidea	*Heterothyone ocnoides*	3.5
Polychaeta: Goniadidae	Goniadidae	2.8
Polychaeta: Nephtyidae	*Aglaophamus* sp.	2.5
Amphipoda	Haustoriidae	2.3
Bivalvia	*Myllitella vivens vivens*	1.9
Polychaeta: Spionidae	*Prionospio australiensis*	1.9
Polychaeta: Ampharetidae	Ampharetidae	1.7
Polychaeta: Spionidae	*Spiophanes modestus*	1.7
Polychaeta: Paraonidae	*Aricidea* sp.	1.5
Holothuroidea	*Paracaudina chilensis*	1.1

* Average number of individuals occurring per 133 cm^2 core sample (n = 28).

Figure 9. Benthic macrofaunal community indices for each of the 0.013 m^2 core samples from the 28 stations. H' Diversity = Shannon-Weiner Diversity index. Divisions and colour-shadings depict the three station zones of spoil ground (SG), spreading zone (SZ) and far-field (FF).

3.3.2. Multivariate statistical analysis

It is important for a baseline survey to establish whether there exist any significant differences between the areas that will later form the basis of investigations of temporal change. In terms of macrofaunal community variability, such underlying patterns can be identified using multivariate statistics.

The dendrogram from cluster analysis in PRIMER (Figure 10) shows no consistent grouping of benthic stations on the basis of spatial proximity or area category. At 40% and greater, the level of similarity (LOS) at which station groups resolve from each other is furthermore quite high, reflecting an overall uniformity of communities across the survey area.

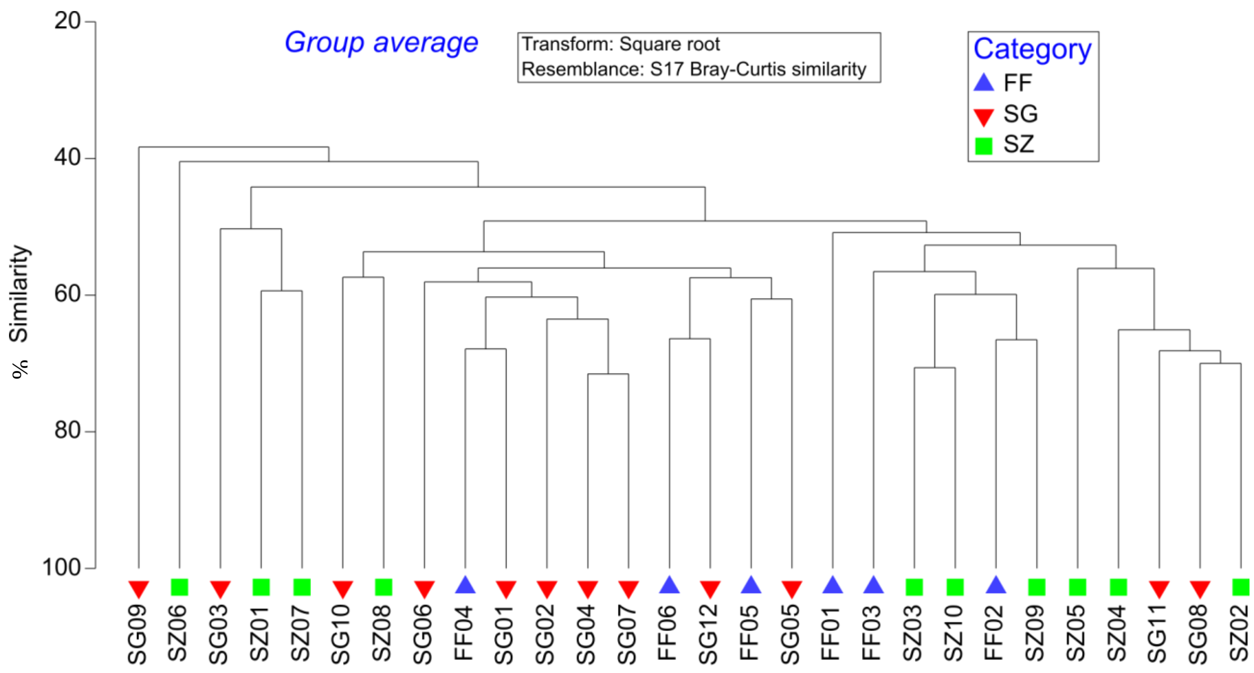


Figure 10. Dendrogram of square-root-transformed macrofaunal abundance data across station categories, showing clustering of individual benthic samples according to Bray-Curtis similarity.

The absence of strong patterns related to the three area categories is supported by the non-metric MDS plot for the macrofaunal data set (Figure 11). While there is a suggestion of an underlying difference between spoil ground (SG) and spreading zone (SZ) stations, it is important to note that the moderate associated stress value[6] of 0.20

[6] Distances on the nMDS plot have only relative, not absolute, meaning. The stress value is a dimensionless quantity and is a measure of the difficulty involved in compressing the sample relationships into two dimensions. A stress value of < 0.1 corresponds to a good ordination with no real prospect of a misleading interpretation, while a stress value of < 0.2 still gives a potentially useful 2-D picture. Stress values within the range of 0.2 to 0.3 should be treated with caution, particularly if in the upper half of this range and for sample sizes of < 50.

means that there is a limit to how accurately distances between individual points on the nMDS plot reflect the real magnitude of differences in community composition.

While the outlying SZ stations in Figure 11 tend to be those further offshore, the bubble plots suggest that silt/clay content plays a slightly greater role in community differences than water depth (although, as has been noted, there is some evidence that the two parameters may be weakly correlated). Nonetheless, the southern far-field stations (FF04–06), which were notable for low silt/clay content, are not observed to separate from the spoil ground samples on the basis of community structure, indicating that the influence of localised sediment texture is not strong.

The vector overlay of taxa correlated with the principal axes of the nMDS plot in Figure 11 does not necessarily show all of the organisms contributing significantly to dissimilarity across samples. This is because the correlation assumes linearity in the change in (transformed) abundances across the space represented. However, this property is useful in pre-impact baseline studies to indicate the presence of spatial gradients across the area of interest. Although such correlations are present for several of the dominant species, the sample points fit only weakly a pattern consistent with geographical aspects (principally inshore-offshore). This suggests that spatial gradients unrelated to depth were effectively absent from the survey site.

SIMPER analysis in PRIMER indicated that the taxon with the greatest influence on differences between SG and SZ stations was the polychaete *H. filiformis*, with greater numbers generally occurring in SZ. Since this species is most often associated with silty environments, it supports the role of silt/clay content in the observed trends. Therefore, there is a logical consistency to some SZ stations supporting an altered community structure, but the magnitude of these differences is in reality quite subtle.

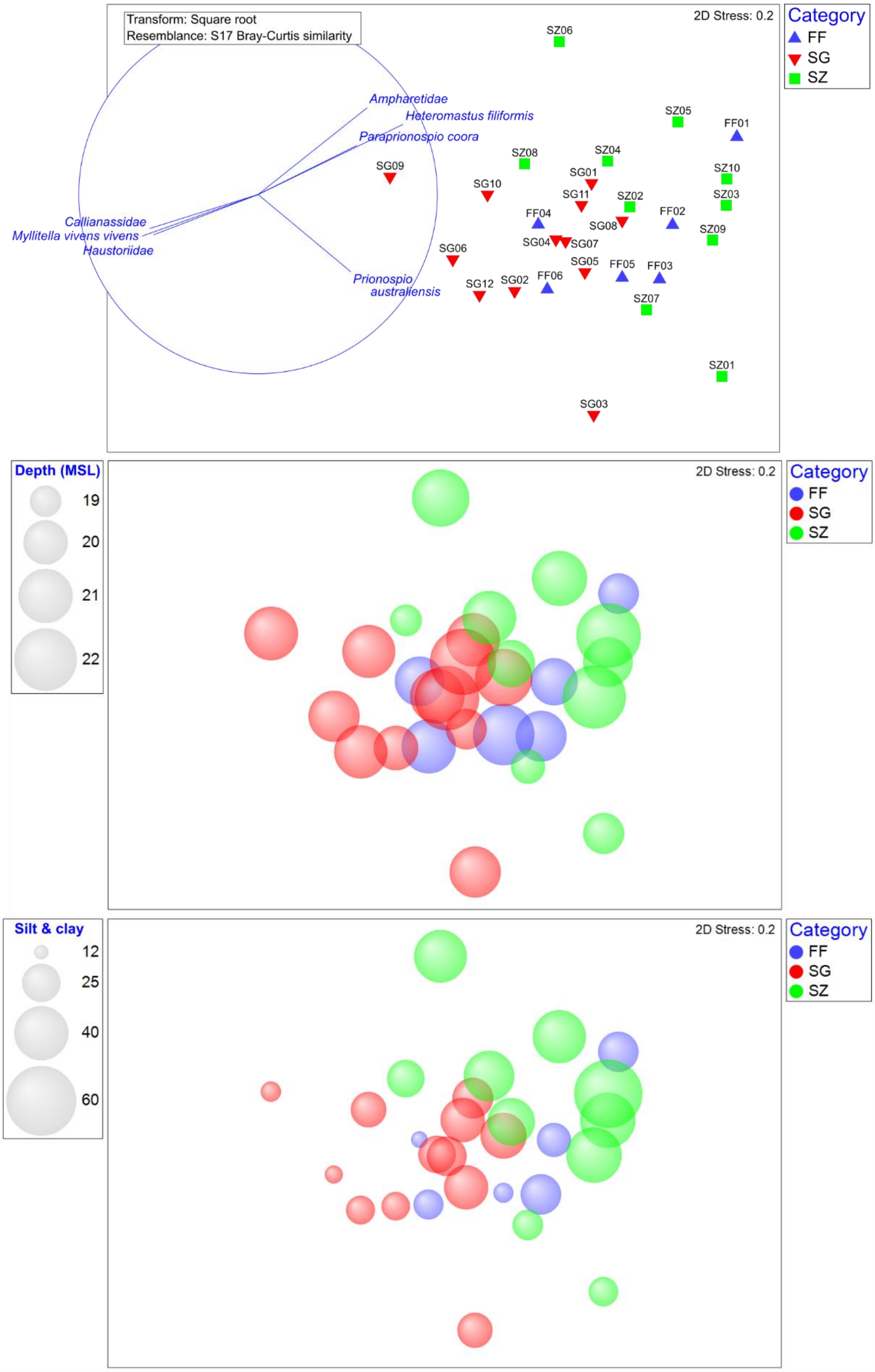


Figure 11. Non-metric multidimensional scaling (nMDS) plot for the benthic samples according to station category Vectors for taxa correlated > 0.6 (Pearson). (FF = far-field; SG = spoil ground; SZ = spreading zone). Bubble plot representations of the same figure showing variation in water depth (middle) and silt/clay content (bottom) at each station.

3.4. Epifauna

A list of the biota identified from the epifaunal dredge trawls is provided in Table 5, including comparative data from the 2005 survey. Photographs of the trawl contents are provided in Appendix 4. Of the 13 taxa in total identified from the current survey, only the gastropods *Austrofusus glans* and *Amalda australis*, the crabs *Pyromaia tuberculata* and Paguridae, ophiuroids (brittle stars) and horse mussels are likely to be truly surface-dwelling fauna. The other taxa present live mostly buried within the sediments and would have been picked up from the bite of the dredge down into the sediment profile. Nonetheless, the community of larger organisms collected by the dredge is indicated to be quite sparse, the notable exceptions being the small sea cucumber *Heterothyone ocnoides*, the knobbed whelk *A. glans* and hermit crabs (Paguridae). *Heterothyone ocnoides* was especially abundant, although its distribution appeared to have been quite patchy (from 0 to 137 per dredge sample). These species are relatively common to sandy coastal areas and have been collected from other locations in the wider Napier area (Sneddon et al. 2017, Sneddon & Atalah 2018).

Very little debris was collected along with the biota in these trawls, although sparsely occurring shell fragments suggested that additional bivalve mollusc species may either live deeper in the sediments than reached by the dredge or have populations occurring within the wider vicinity of the survey area. However, the mobile nature of the sediments also supports the possibility that these fragments may have originated from quite distant populations.

It is worth noting that the size of biota collected by the dredge was generally small. For example, it was the shape rather than the size of *H. ocnoides* that resulted in its not passing through the 10 mm mesh. This, together with the evidence for a variable dredge bite depth (Section 3.1), means that the results should be interpreted as semi-quantitative at best.

Table 5. Biota identified within epifaunal dredge trawls. Data from the 2005 survey are included for comparison.

Survey		**2019**	**2019**	**2019**	**2019**	**2019**	**2019**	**2019**	**2019**	**2019**	**2005**	**2005**	**2005**	**2005**
Trawl no.		**DT1**	**DT2**	**DT3**	**DT4**	**DT5**	**DT6**	**DT7**	**DT8**	**DT9**	**T1**	**T2**	**T3**	**T4**
Trawl distance (m)		430	450	420	390	430	430	200	480	430	380	500	480	560
Trawl depth (MSL, m)		20.4	21.5	19.7	20.6	20.9	21.2	20.0	20.8	21.2	20.8	21.0	21.5	21.1
Taxa	**Common name**													
Struthiolaria papulosa	Ostrich foot snail					1					13			
Austrofusus glans	Knobbed whelk		14	9	18	7	6	4	4	3		20	3	12
Amalda australis	Olive shell				1									1
Spisula aequilatera	Triangle shell											5		1
Bassina yatei	Frilled cockle								1					
Atrina zelandica	Horse mussel									1				
Pyromaia tuberculata	Spider crab						2							
Paguridae	Hermit crabs		4	9	17	1	4	1	1	2			10	5
Hymenosoma depressum	Sea spider											1	1	
Ophiuroid	Brittle star						1			1				
Paracaudina chilensis	Sea cucumber		2						2			4	1	1
Heterothyone ocnoides	Sea cucumber	1	61	137	79	20		66	30	8	216	131	70	70
Nemertea	Ribbon worms											1		
Aphrodita australis	Sea mouse (polychaete)		1											
Aglaophamus macroura	Polychaete worm									1		1		
Prionospio sp.	Polychaete worm										1			
Maldanidae	Polychaete worm		2											
Shell fragments (excl. those associated with pagurids)														
Atrina zelandica	Horse mussel			1			1							
Dosinia sp.				3	1		5							
Serratina charlottae	Wedge shell			1		1	1							
Gari strangeri					1									
Mactra sp.							2							

4. COMPARISON WITH THE 2005 SURVEY RESULTS

4.1. Side-scan sonar and sampling observations

The layout of the key elements of the 2005 survey, overlaid with the current spoil ground outline, are shown in Figure 12. Consistent with the results of the current survey, side-scan sonar imagery indicated a flat and very uniform soft sediment habitat with no significant high-relief features or structures. Sampling observations from 2005 also noted homogenous core profiles, indicating that sediments were well mixed with no near-surface hypoxic conditions.

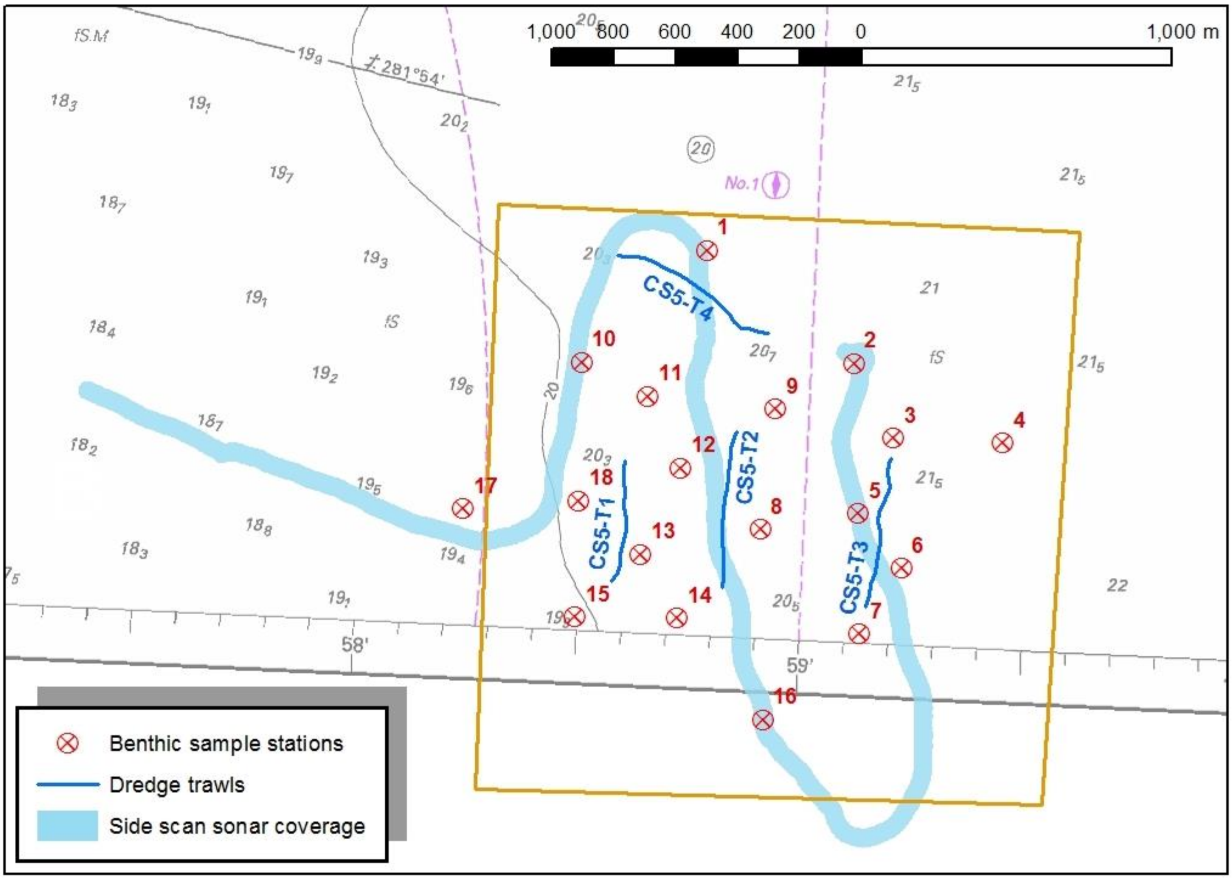


Figure 12. Layout of the 2005 survey elements in relation to the current consented offshore spoil ground (gold outline), overlaid on part chart NZ5712a. The side-scan swathe width was 60 m.

4.2. Sediment physico-chemical characteristics

All core samples collected from within the spoil disposal area in 2005 were comprised primarily of fine and very fine sands (greater than 75% of the dry weight) with a smaller silt/clay component (23%). A comparison of summary statistics between the 18 samples collected in 2005 and the 12 'SG' samples from the current survey (Table 6) suggests that there has been a shift from a fine sand dominated texture to that of very fine sand. However, this is more likely to be a methodological artefact. Where the modal peak in grain size occurs very close to the division between the two sieve sizes (125 µm) apparently large differences may arise from a very small shift in actual texture. Considering the analysis was carried out by different laboratories, this may be compounded by small methodological or laboratory equipment differences. There are three aspects that support such an explanation:

- the combined fine and very fine sand components were almost identical between surveys (77% and 76% in 2005 and 2019, respectively)
- the silt/clay content (23%) was identical between the two surveys
- there were, overall, similar levels of variability between samples.

Table 6. Summary table of mean grain-size distribution and organic content (as ash free dry weight or total organic carbon) for the two surveys of the offshore spoil disposal area.

	2005 (n = 18)		2019 (SG; n = 12)	
	Mean	**Stdev**	**Mean**	**Stdev**
Depth	20.80	0.34	20.99	0.79
Grain size distribution				
Gravel	0.05	0.01	0.05	0.00
Very coarse sand	0.10	0.07	0.05	0.00
Coarse sand	0.09	0.04	0.05	0.00
Medium sand	0.28	0.22	1.04	2.30
Fine sand	46.20	11.72	5.32	2.78
Very fine sand	30.41	4.09	70.48	5.82
Silt/clay	23.00	9.63	23.20	6.16
Organic enrichment				
Ash free dry weight	2.18	0.66	-	-
Total organic carbon	-	-	0.12	0.02

Different measures of organic content were used in the two surveys, so direct comparison is not possible. The Ash-Free Dry Weight (AFDW) used in 2005 is a gravimetric, loss-on-ignition (LOI) method and a direct conversion to TOC is generally unreliable due to multiple variables of influence. However, the AFDW of around 2%

indicated low overall levels of sediment enrichment and the measures are likely to reflect similar conditions.

No trace metals or other contaminants were tested for in the 2005 sediment samples.

4.3. Macrofaunal communities

4.3.1. Community indices

The infaunal corers used in 2005 to sub-sample the contents of the van Veen grab were 20% smaller in cross-sectional area than those employed for the current survey. So, in order to make meaningful comparisons, the 2005 abundance data were adjusted upwards by a factor of 1.25. There were also differences in taxonomic resolution between the two data sets, with identification to genus or species level achieved more frequently for the current survey. A combined data set was generated, at the lower level of resolution, to allow comparison of the summary statistics for the principal community indices from the two surveys (Table 7). Bar plots for individual samples from the two surveys are compared in Figure 13.

Table 7. Summary of community index averages for spoil ground samples from the two surveys. N = number of individuals, S = species richness, J' = Pielou's evenness, H' = Shannon-Weiner diversity. Values in parentheses are standard deviations.

Survey	N	S	J'	H'
2019	74 (28)	19.8 (3.9)	0.84 (0.05)	2.47 (0.17)
2005	70 (29)	14.7 (4.7)	0.82 (0.07)	2.15 (0.27)

In general, the indices recorded from the two surveys were comparable, especially those of abundance (N) and evenness (J'). While average values for taxa richness (S) and diversity (H') were lower in 2005, it should be noted that the smaller size of the infaunal cores used in 2005 is also likely to have limited the number of taxa sampled per core, which will in turn affect the derived diversity value. However, this introduces a potential difference for which a straightforward correction is not possible.

Figure 13. Comparison of infauna community indices for data from the 2019 (left) and 2005 (right) surveys. The combined data set was adjusted to balance differences in core area and taxonomic resolution between the two surveys.

In 2005, the van Veen grab was deployed without a weighted frame and encountered problems with penetration of the sediments, resulting in lower retrieved sediment volumes (this constraint was the reason for utilising a grab frame in 2019). This would, in turn, have limited the depth of the subsequent cores, resulting in lower infaunal sample volumes that may have under-sampled deeper-burrowing organisms. In consideration of these limitations, it is likely that differences in the indices from the two sampling surveys do not reflect any substantive difference in community structure.

Even with adjustments to taxonomic resolution, more taxa were identified from the current survey (48) than in 2005 (41), an effect that also may derive from the increased sample size. However, the mix of characteristic macrofaunal taxa was very similar between surveys, with all five of the most abundant taxa in 2019 (*H. filiformis*, *N. nitidula*, Amphipoda, *Prionospio* sp. and *Dosinia* sp.) also recorded as numerically dominant in 2005.

4.3.2. Multivariate statistical analysis

A non-metric MDS plot of the combined two-survey macrofaunal data set is shown in Figure 14. The plot indicates separation of the samples from the two surveys at the 51% level of similarity (LOS), with just one sample from the current survey (SG11) grouped with those from 2005. But a level of similarity of 51% is high for macrofaunal data sets[7], indicating that the overall differences between the sample groups were small. Apart from sample S513 (2005 survey), all samples were grouped at the 48% level of similarity.

SIMPER analysis showed that the taxa contributing most to the dissimilarity between surveys were *N. nitidula* and *H. filiformis* (both more abundant in 2005) and Amphipoda and the bivalve *Myllitella vivens vivens* (both more abundant in 2019). Also contributing was the decapod shrimp Callianassidae (mean abundance 2.1 /sample in 2019), which was not recorded in 2005.

However, as with the indices, these small changes in composition do not amount to more than the shifts that would be expected from seasonal and inter-annual cycles driven by a range of natural environmental factors. The overall similarity of the two community data sets is further illustrated by the shade plot[8] in Figure 15. All of the characteristic taxa (those occurring consistently within the samples of each survey) are seen to exhibit a similar level of variability between samples as that occurring between surveys.

---

[7] The lower the level of similarity at which a group of samples resolves from the rest of the samples, the more fundamentally different the macrofaunal community is. (i.e. at very high LOS, all samples will become distinct from one another).

[8] The shade plot is simply an image of the data matrix, in which the (transformed) abundance for each species is represented by a grey scale, from white (absent) to black (the largest count in the worksheet). The most important contributing taxa are based on those that account for the highest proportion of total individuals in any sample (Clarke & Gorley 2015).

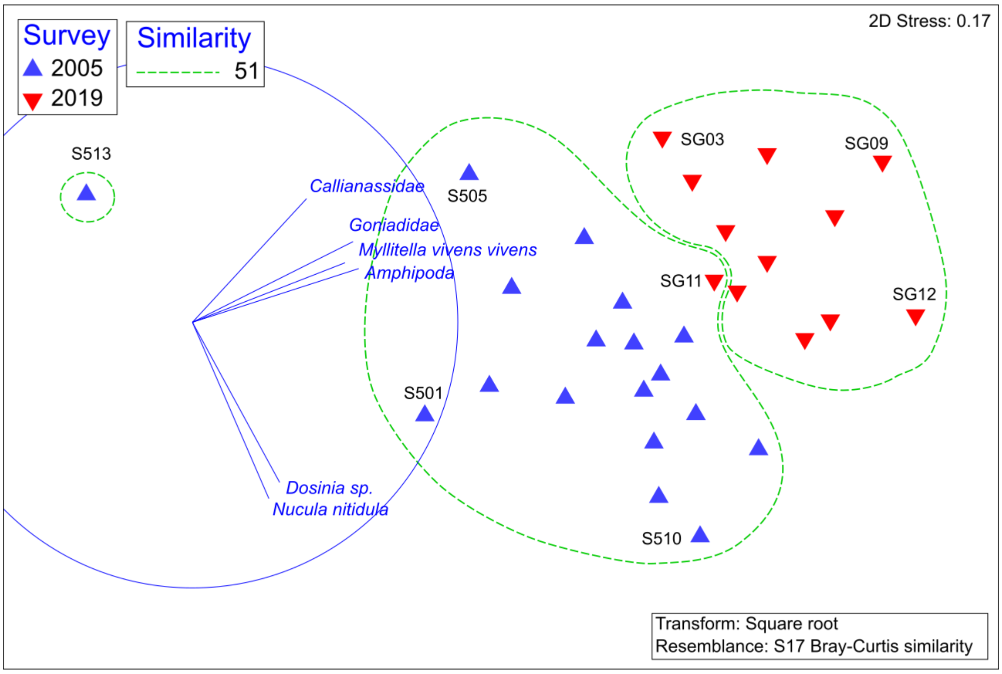


Figure 14. nMDS plot showing clustering within the combined 2005 and 2019 infauna data set. Of the 2019 samples, only those collected from within the spoil ground boundaries (code SG) are included. Vector overlay shows taxa correlated to plot coordinates (r > 0.6). Note: Only selected samples are labelled.

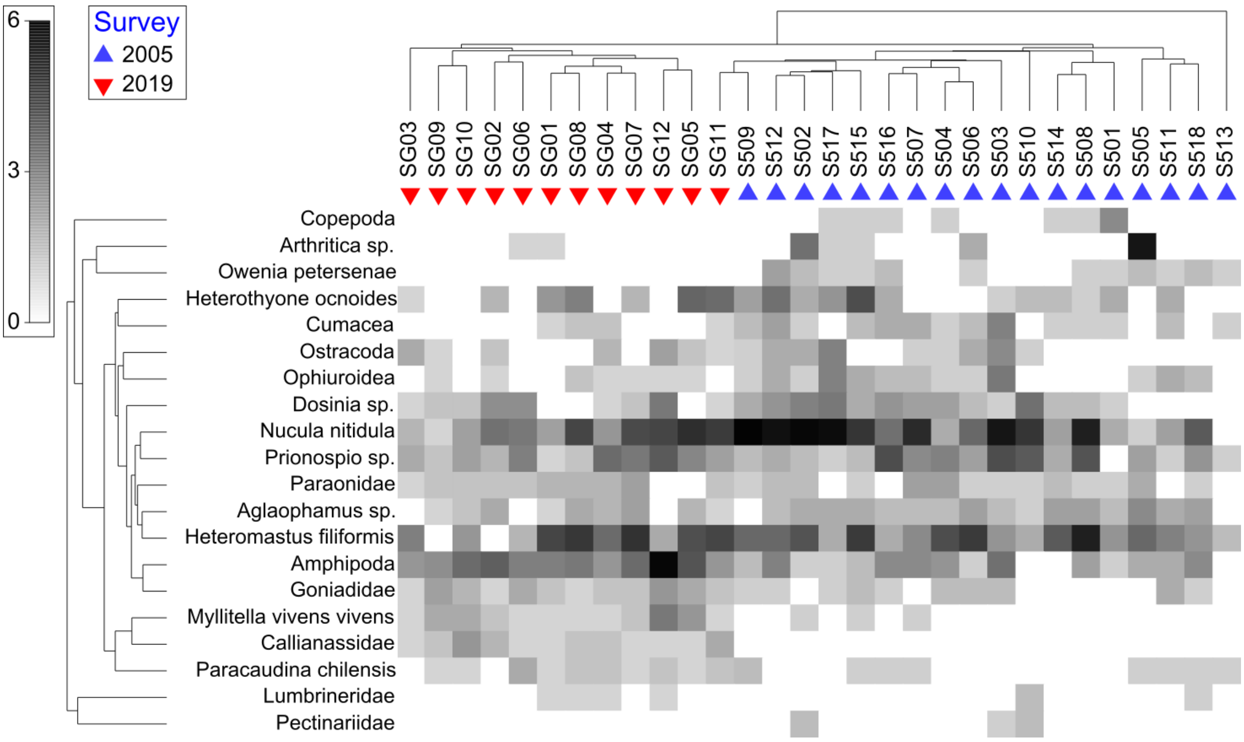


Figure 15. Shade plot showing the 20 most important contributing taxa overall, based on the square-root transformed data set.

4.4. Epifauna

The epifaunal count data from the four dredge trawls conducted within the spoil ground area in 2005 is listed alongside those of the current survey in Table 5. The same dredge was used in both surveys and field notes show that conditions were near-identical;

- The dredge occasionally bogged down in what appeared to be softer areas of sediment.
- The sediment sieved through the mesh so that the dredge was retrieved clean.
- Very little biomass and generally low numbers of organisms were collected.
- The only species to be collected at the site in any abundance was the small holothurian *Heterothyone ocnoides*.
- The only other species that were present as more than single individuals in two or more trawls were knobbed whelk (*Austrofusus glans*), hermit crabs, another small holothurian (*Paracaudina chilensis*) and the clam *Spisula aequilatera.*

Only *S. aequilatera* (recorded as 6 individuals in 2005) was absent from the 2019 trawl data. The only taxon collected from more than a single trawl in 2019 but absent from the 2005 record were ophiuroids (brittle stars; two individuals). On this basis, the epifaunal data from the two surveys are generally consistent.

5. CONCLUSIONS

From direct observations and analysis of the survey data, the following conclusions are drawn regarding the status of the benthic environment in the vicinity of the spoil ground.

The substrate is unconsolidated fine and very fine sands with a significant silt component. This material is regularly mobilised by shear from long-period swell waves, resulting in a dynamic sediment habitat that is effectively uniform out to the furthest extent of the survey coverage. The hydrodynamic drivers that bring about these benthic conditions nonetheless appear to maintain it in a steady state, with minimal change discernible between surveys in 2005 and 2019.

Although there was an indication of silt content varying slightly with depth, spatial variability was in general limited to small-scale patchiness in substrate. These localised changes did not appear to be great enough to cause an observable change in benthic community structure.

Benthic communities reflected the dynamic nature of the seabed, with a limited and relatively sparse macrofauna that exhibited little spatial variability. Diversity, however, was moderate, with a range of phyla and classes represented.

Slow-moving epifauna appear to have been very sparse, with most taxa collected by a dredge with 10 mm mesh being inhabitants of the near-surface sediment matrix (and therefore technically part of the infauna).

Comparison of the results of the current survey with those of the survey conducted in 2005 indicated that no more than very small changes have occurred in benthic substrate, habitats and communities. Such changes are well within what could be expected from natural variability and cycles.

The current survey data set represents a suitable baseline to which the results of future surveys may be compared to identify and investigate any changes to the benthic environment.

The current survey design is suitable to use in subsequent iterations to investigate possible changes arising from the use of the spoil ground, although it should be acknowledged that direct video of the seabed may be precluded by turbid near-bed conditions. While sampling intensity outside the spoil ground boundary should be retained for any future surveys, it is considered that the number of sample stations within the boundary could be reduced.

6. ACKNOWLEDGEMENTS

The author of this study would like to acknowledge Scott Edhouse (Cawthron) for his assistance in the field; Fiona Gower and Bill Nikkel (Cawthron) for macrofaunal taxonomy; Lisa Floerl (Cawthron) for GIS and side-scan imagery technical assistance, Don Morissey (Cawthron) for report review and Gretchen Rasch for editorial guidance.

7. REFERENCES

Anderson M, Gorley RN, Clarke KR 2008. Permanova+ for Primer: Guide to Software and Statistical Methods.

ANZG 2018. Australian and New Zealand guidelines for fresh and marine water quality. Toxicant default guideline values for sediment quality. http://www.waterquality.gov.au/anz-guidelines/guideline-values/default/sediment-quality-toxicants.

Borja A, Franco J, Perez V 2000. A marine biotic index to establish the ecological quality of soft-bottom benthos within European estuarine and coastal environments. Marine Pollution Bulletin 40(12): 1100-1114.

Clarke KR, Gorley RN 2015. PRIMER v7: User manual/tutorial. PRIMER-E: Plymouth, UK. 296 p.

Clarke KR, Gorley RN, Somerfield PJ, Warwick RM 2014. Change in marine communities: an approach to statistical analysis and interpretation, 3rd edition. PRIMER-E: Plymouth, UK.

Dauer DM, Luckenback MW, Rodi Jr AJ 1993. Abundance biomass comparison (ABC method): effects of an estuarine gradient, anoxic/hypoxic events and contaminated sediments. Marine Biology 116: 511-518

Förstner U 1995. Risk assessment and technological options for contaminated sediments - a geochemical perspective. Marine and Freshwater Research 46: 113-127.

Kruskal JB, Wish M 1978. Multidimensional scaling. Sage Publications, Beverley Hills, California.

Pearson TH, Rosenburg R 1978. Macrobenthic succession in relation to organic enrichment and pollution of the marine environment. Oceanography and Marine Biology: An Annual Review 16: 229-311.

Sneddon R, Dunmore R, Berthelsen A, Barter P 2017. Assessment of effects on benthic ecology and fisheries resources from proposed capital dredging and spoil disposal for the Port of Napier. Prepared for Port of Napier Ltd. Cawthron Report No. 2895. 154 p. plus appendices.

Sneddon R, Atalah J 2018. Monitoring of benthic effects from dredge spoil disposal at sites offshore from Napier Port: 2018 survey. Prepared for Port of Napier Ltd. Cawthron Report No. 3141. 62 p. plus appendices.

8. APPENDICES

Appendix 1. Background information contributing to the field survey approach.

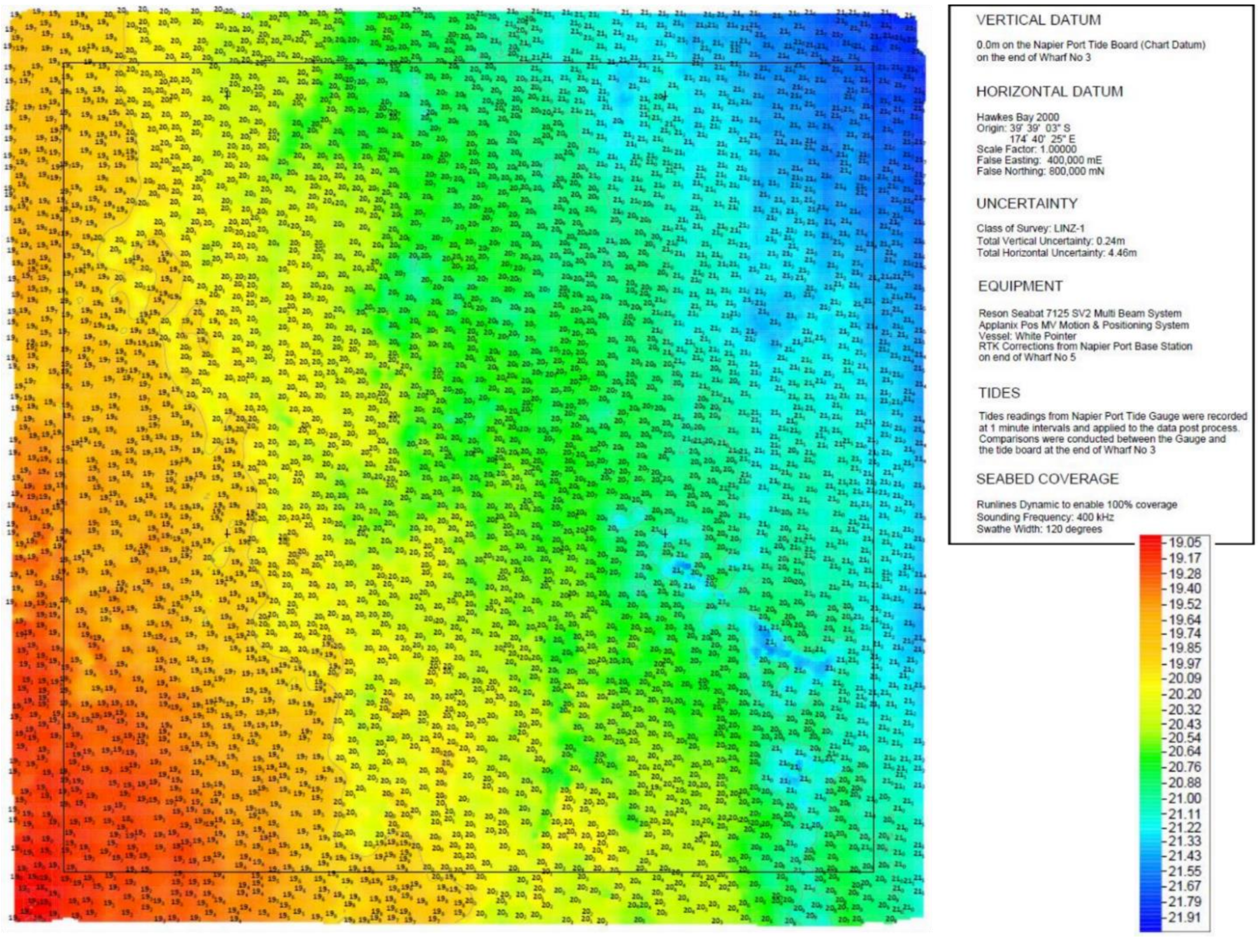


Figure A1.1 Multi-beam echo sounder (MBES) image of the spoil ground out to 100 m beyond its boundary (black square outline). Heron Construction Co Ltd. 7 February 2019. DRG No. HERON_NZ19.001_NAPIER_20190207_2. Colours denote depth range.

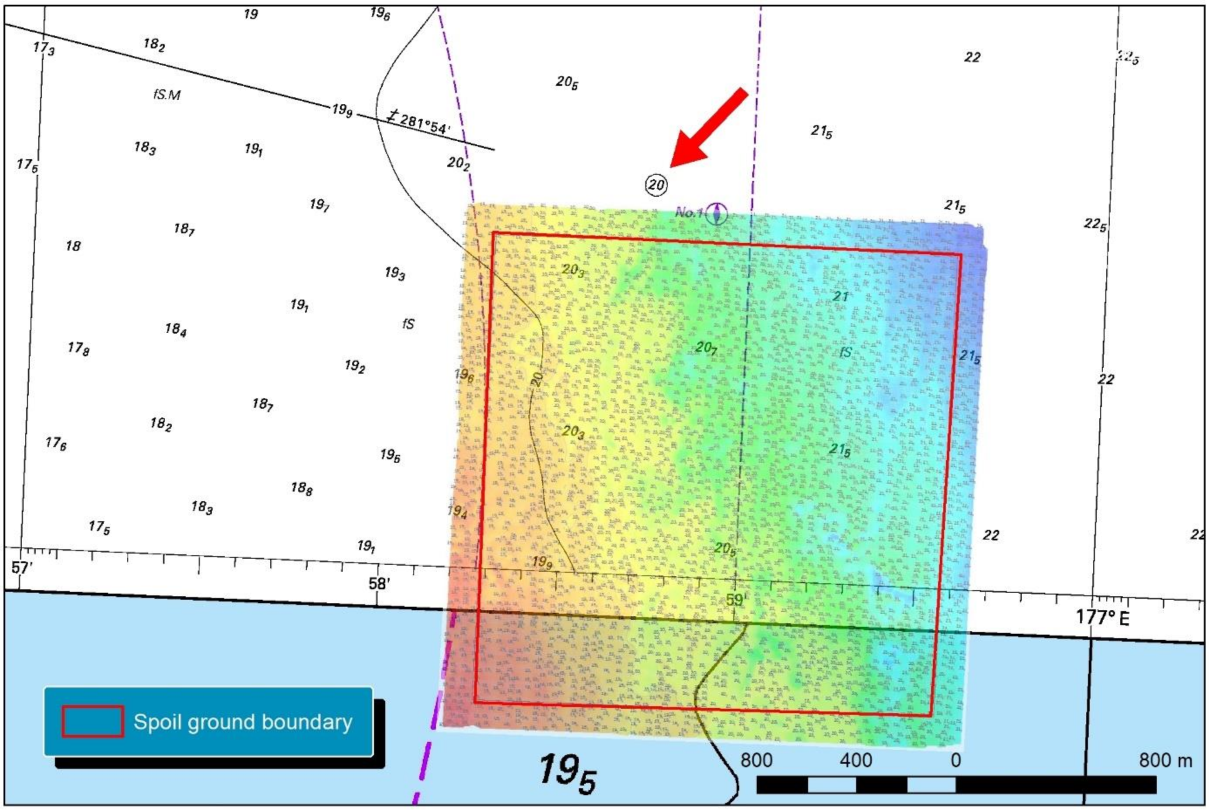


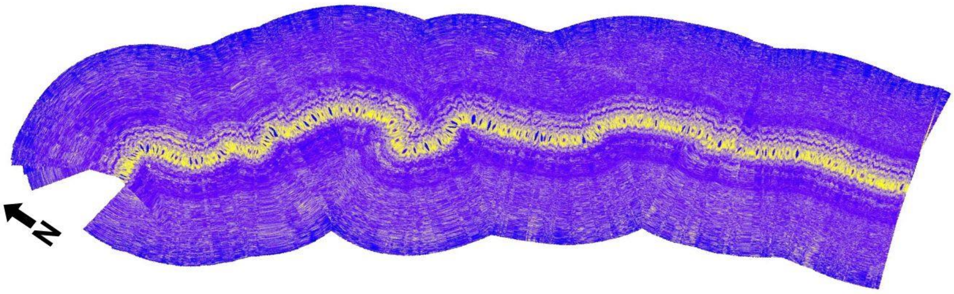
Figure A1.2 MBES image overlaid on part Charts NZ5712a and NZ571, showing indicated shallow patch approximately 100 m north of the survey coverage.

Appendix 2. Photographs of benthic sediment core samples.

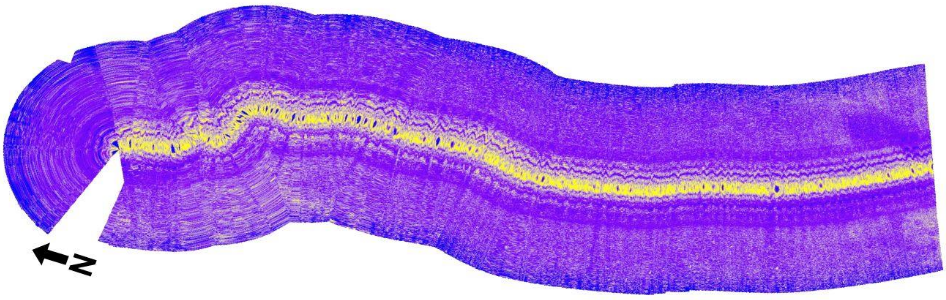

SZ04
SZ05
SZ06
SZ07
SZ08
SZ09
SZ10
FF01
FF02
FF03
FF04
FF05
FF06

Appendix 3. Side-scan sonar swathe images. The central portion of these images (in yellow along the swathe axis) is sonar shadow and hence can contain no detail. Geographic locations for these images are shown in Figure 4.

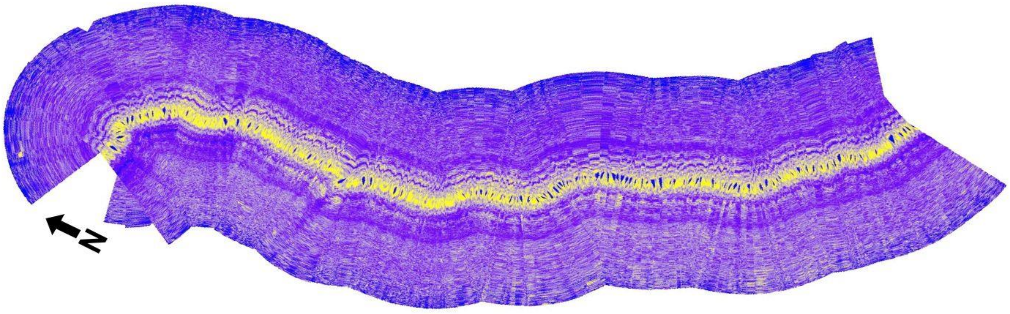
Side-scan sonar image for track SS01 (through benthic station FF03)



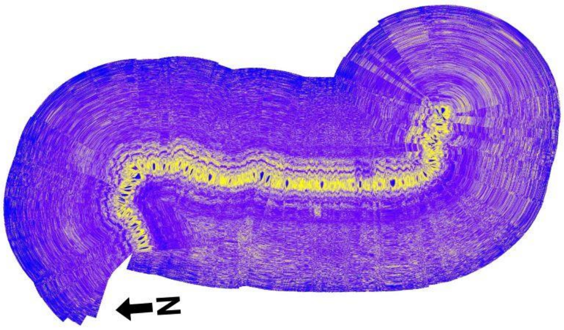
Side-scan sonar image for track SS02 (running N from adjacent station SG03)



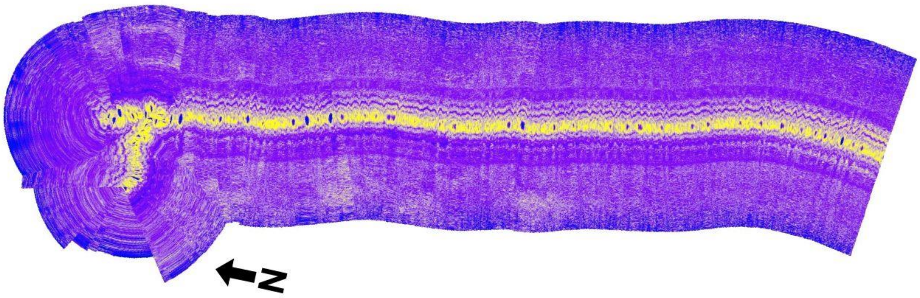
Side-scan sonar image for track SS03 (E of benthic stations SG07 and SG04)



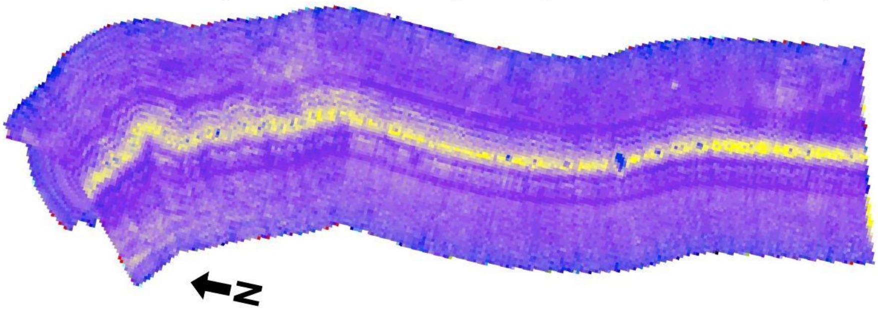
Side-scan sonar image for track SS04 (SW of benthic station SG02)



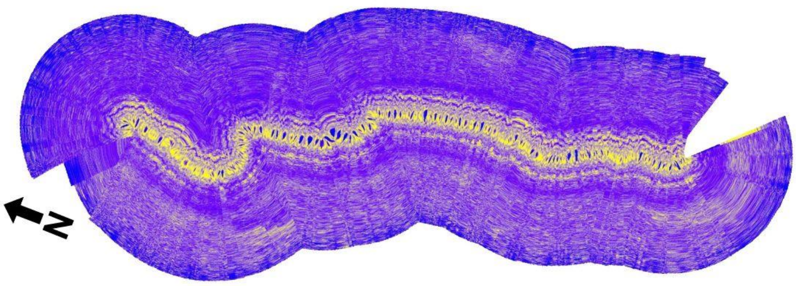
Side-scan sonar image for track SS05 (running N from station SG12)



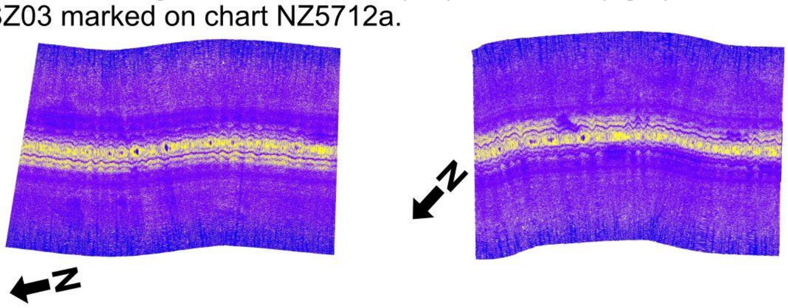
Side-scan sonar image for track SS06 (running N from station SG12)



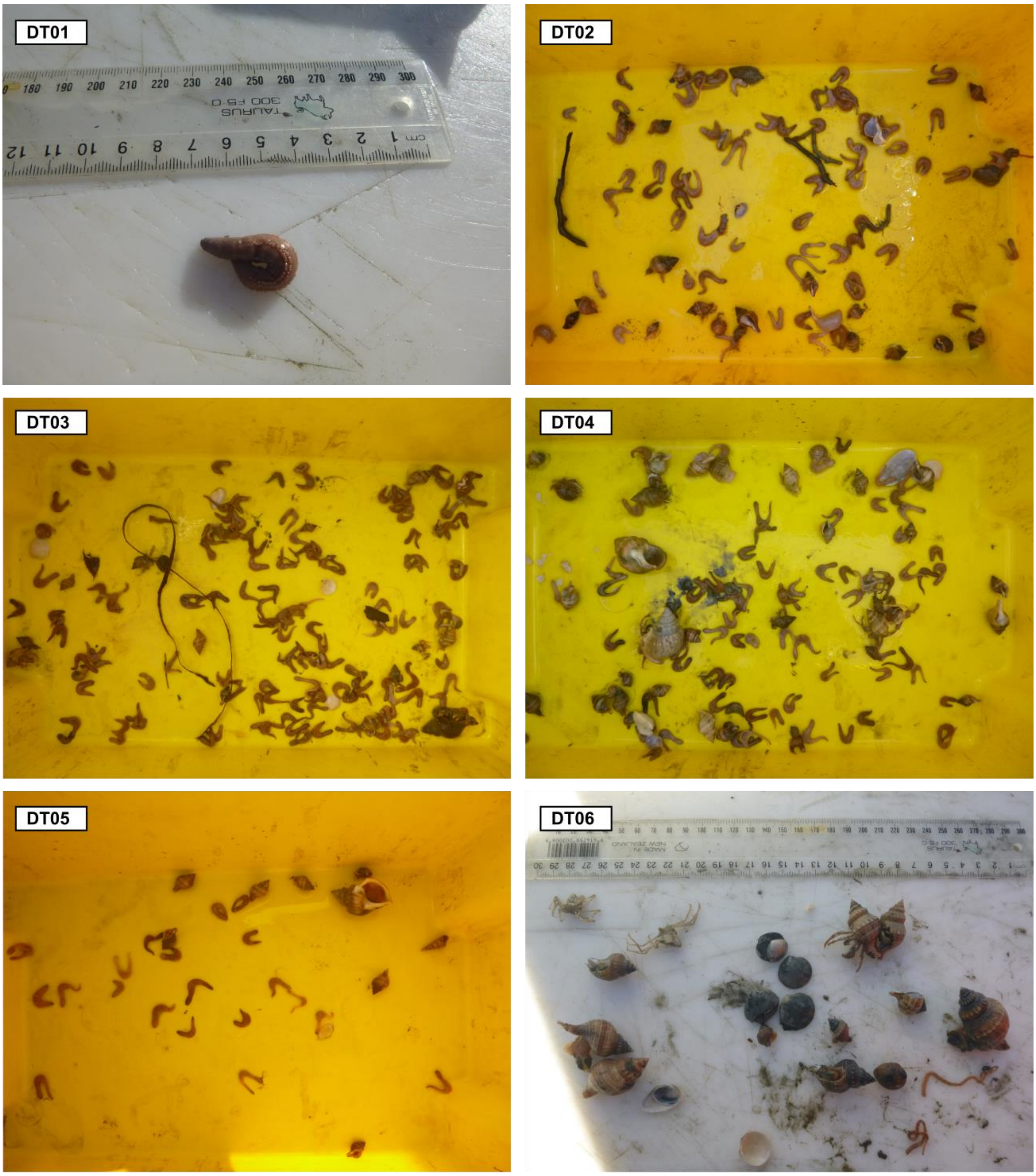
Side-scan sonar image for track SS07 (through far-field benthic station FF01)

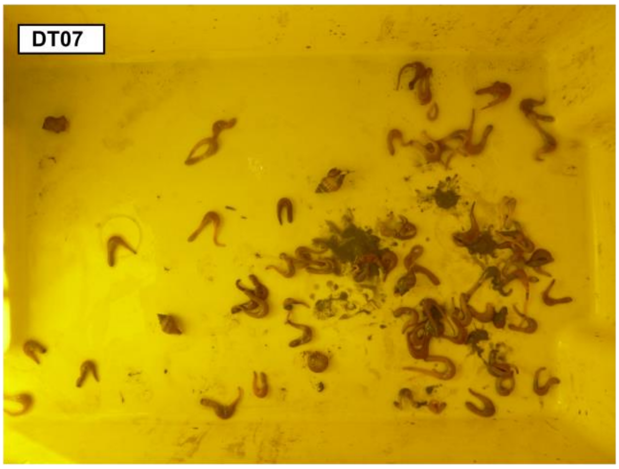


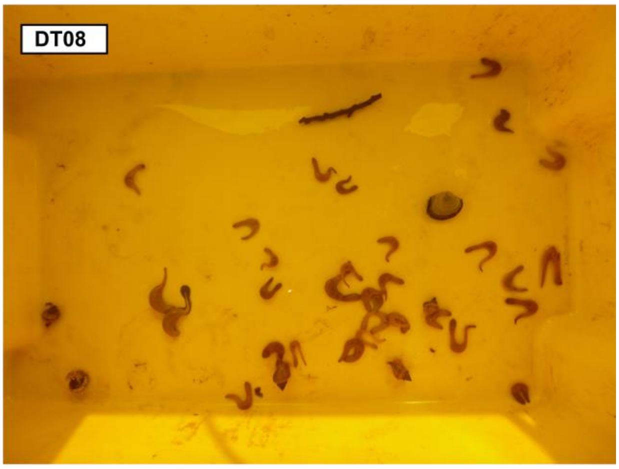
Side-scan sonar image for tracks SS08 (left) and SS09 (right). Shallow patch E of station SZ03 marked on chart NZ5712a.



Appendix 4. Photographs of the contents of epifaunal dredge trawls.




DT07


DT08


DT09

Appendix 5. Grain size distribution and organic content (as ash-free dry weight) of sediments collected from the 18 stations sampled in the 2005 survey. Sample station locations are shown in Figure 12. All parameters expressed as % dry weight.