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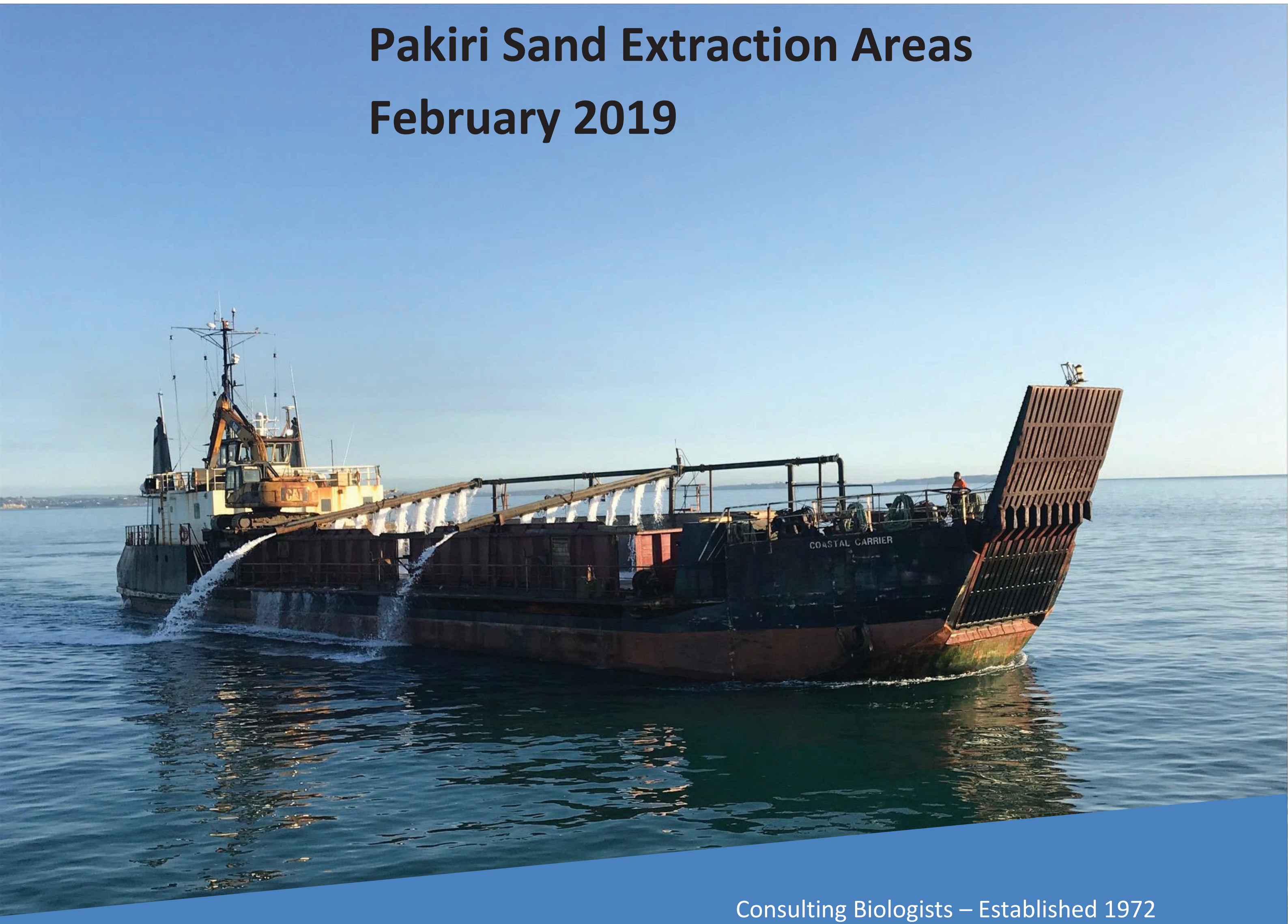
Assessment of Ecological Effects: Following Sand Extraction from the Pakiri Sand Extraction Areas February 2019



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Cover Illustration: Sand dredge in operation off Pakiri beach (May 2019)

CONTENTS

1. Introduction ... 1
1.1 Previous Surveys ... 1

2. Methods ... 3
2.1.1 Benthic Fauna Sampling ... 3
2.1.2 Surficial Sediment Particle Size ... 4
2.1.3 Seabed Photographs ... 5
2.1.4 Epibenthic Macrofauna Sampling ... 6
2.1.5 Macrofauna Survivorship Sampling ... 7
2.2 Ecological Impact Assessment Methodology ... 7

3. Results ... 10
3.1 Benthic Fauna ... 10
3.1.1 3.15 mm Screened Data ... 11
3.1.2 1 mm Screened Data ... 13
3.2 Surficial Sediment Particle Size ... 15
3.3 Drop Camera Survey ... 16
3.4 Dredge Tow Macrobenthic Biota ... 16
3.5 Macrofauna Survivorship ... 17
3.5.1 Numbers of Individuals ... 17
3.5.2 Size of Individuals ... 18

4. Discussion ... 20
4.1 Seabed Morphology ... 20
4.2 Seabed Particle Size ... 20
4.3 Turbidity ... 21
4.4 Benthic biota ... 21
4.5 Macrobenthic biota ... 22
4.6 Macrofauna Survivorship ... 22
4.7 Fin fish ... 23
4.8 General Implications of Findings ... 24

5. Ecological Values ... 26
5.1 Benthic Habitat and Fauna ... 26
5.2 Fish ... 26
5.3 Summary of Ecological Values ... 26

6. Assessment Of Effects of Sand Extraction on Ecology ... 28
6.1 Benthic Biota and Macrobenthic Epifauna ... 28
6.2 Fish, Marine Mammals and Birds ... 29
6.3 Effects of the Continuation of Sand Extraction ... 31
6.4 Summary of Ecological Effects ... 33
6.5 Level of Ecological Effects ... 33

7. References 34

8. Appendices 36

Appendix 1 Sampling Area Positions 36
Appendix 2 Particle Size Results 37
Appendix 3 Drop Camera Images 38
Appendix 4 Benthic Biota results 46
Appendix 5 Macrofauna Survivorship 52
Appendix 6 Statistical Results 58

1. INTRODUCTION

In 2006 McCallum Brothers Limited® (MBL) was granted the Coastal Permits (ARC28165, ARC28172, ARC28173 & ARC28174), under which they are permitted to remove up to 76,000 m³/year of sand from the nearshore area between the 5 m and 10 m water depths located between the Auckland/Northland regional boundary and the Poutawa Stream as shown in Figure 1.1. This extraction regime was consented by the Environment Court in May 2006 for a 14-year period, expiring on the 6th September 2020.

In preparation for an application to renew this consent it was identified that before and after comparative data, on benthic biota and sediment particle size characteristics from the sand extraction area was not available with which to assess any potential effects. The composition of the benthic fauna is influenced by the particle size composition of the seabed sands, therefore understanding any changes in sediment particle size composition is important for understanding changes in the abundance and/or composition of the benthic fauna. This report presents a comparative analysis of the benthic biota data from the dredging areas against an adjacent control area. The samples were collected using an MBL vessel in 2019 in accordance with a sampling plan devised by MBL and Dr Roger Grace.

1.1 Previous Surveys

Dr Grace undertook biological investigations in 1990 and 2005 in the current operational extraction area (Grace, 1991; Grace, 2005). Benthic fauna in the extraction area has been noted as extremely sparse as the environment is naturally harsh and there are no shellfish of any consequence. Grace's 1990 studies in the near-shore bar found species known for their tolerance of heavy surf just off the beach (Grace, 1991). Species such as wheel shell *(Zethalia zelandica)*, scale worms *(Sigalion)*, mantis shrimp *(Pterygosquilla armata)*, and large pink siphon worm (*Sipunculus maoricus)* showed a consistent occurrence and association with the dominant sand dollar *(Fellaster).* A small number of surf clams *(Dosinia anus & Dosinia subrosea)* were also found in the samples. The study noted that wheel shells were at lower densities than that of the Hilton (1990) study. In 2005 Dr Grace's investigations found no wheel shells or surf clams. However, there was the presence of stink worms and paddle crab (Grace, 2005). The main changes that were identified between the 1990 and 2005 studies was the decrease in species diversity and decrease in abundance in some species. Dr Grace attributed these changes to natural variations in recruitment of biota and the naturally harsh environment and that they were not the result of sand extraction. There was also an observation that variations in sampling technique can also lead to variations in biota detected.

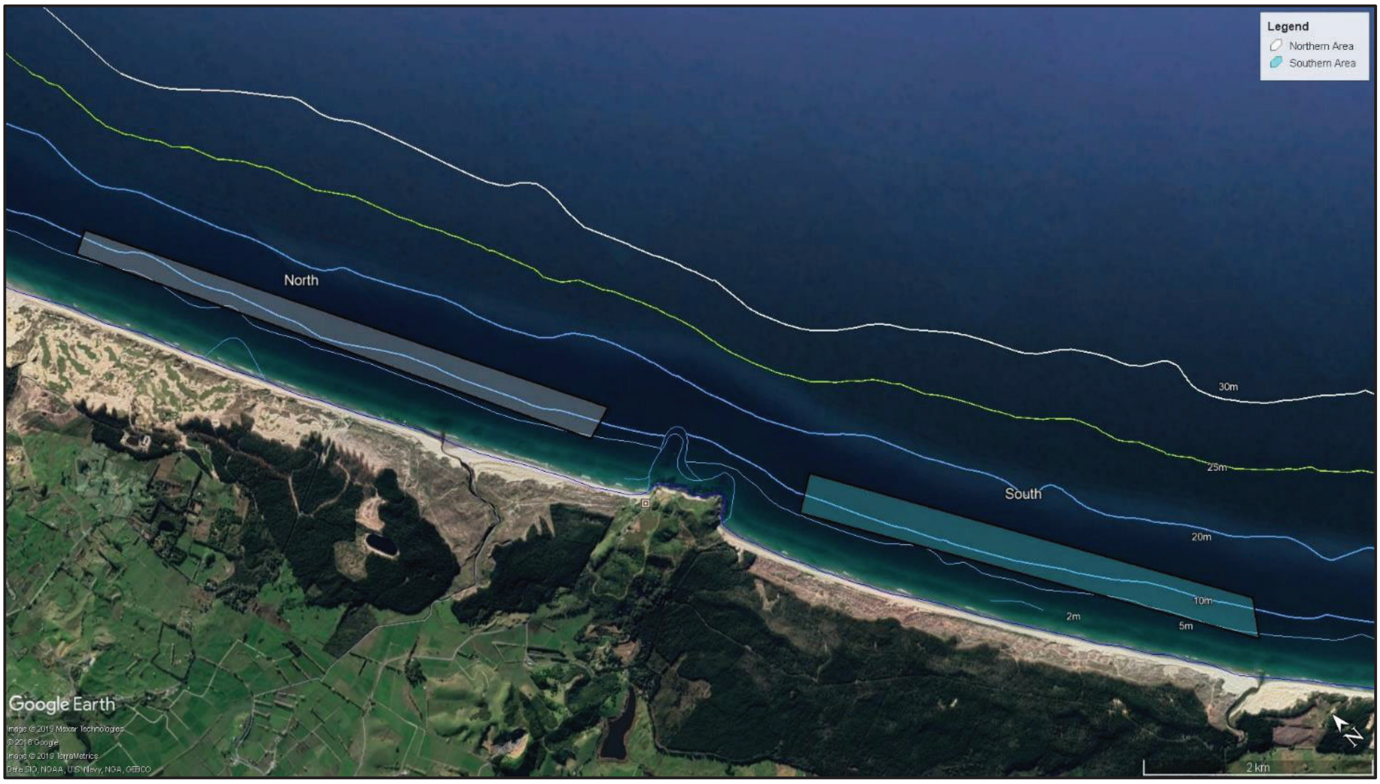

Figure 1.1 Existing Inshore Sand Extraction Areas at Pakiri Beach

2. METHODS

MBL in combination with Dr Grace devised the sampling methodologies as outlined below, to assess the actual or potential effects on the nearshore benthic ecology in the Pakiri – Mangawhai embayment, affected by the sand extraction from the inshore extraction areas (Figure 1.1) operated by MBL. The sampling was largely conducted by McCallum Bros. Ltd® using their own vessel but with Dr Mathew Jones present to ensure the methodology was followed. Potential effects on marine mammals and on marine water quality are not part of this assessment.

2.1.1 Benthic Fauna Sampling

To determine the potential effects of sand extraction on the relative abundance and diversity of the benthic communities in the consented area and a nearby control area were assessed. A total of 30 box dredge samples were collected in early 2019, 10 within or directly adjacent to the northern consented Area, 10 within or directly adjacent to the southern consented Area and 10 within a Control Area to the south which covered a similar depth range and distance offshore. Each sampling site is shown in (Figure 2.2) and the GPS locations are listed in Appendix 1.

The samples were collected with a box dredge sampler, with a sample width of 180 mm, and a bite depth of about 75 mm, producing sample volumes of up to 4.5 L. The dredge was lowered to the seabed, towed to full and bought to surface for processing. If the sample volume was less than 3.75 L the sample was discarded and repeated. Diver observation of the box dredge in operation (Figure 2.1) determined that the drag length to fill the box was in the order of 0.9 m.

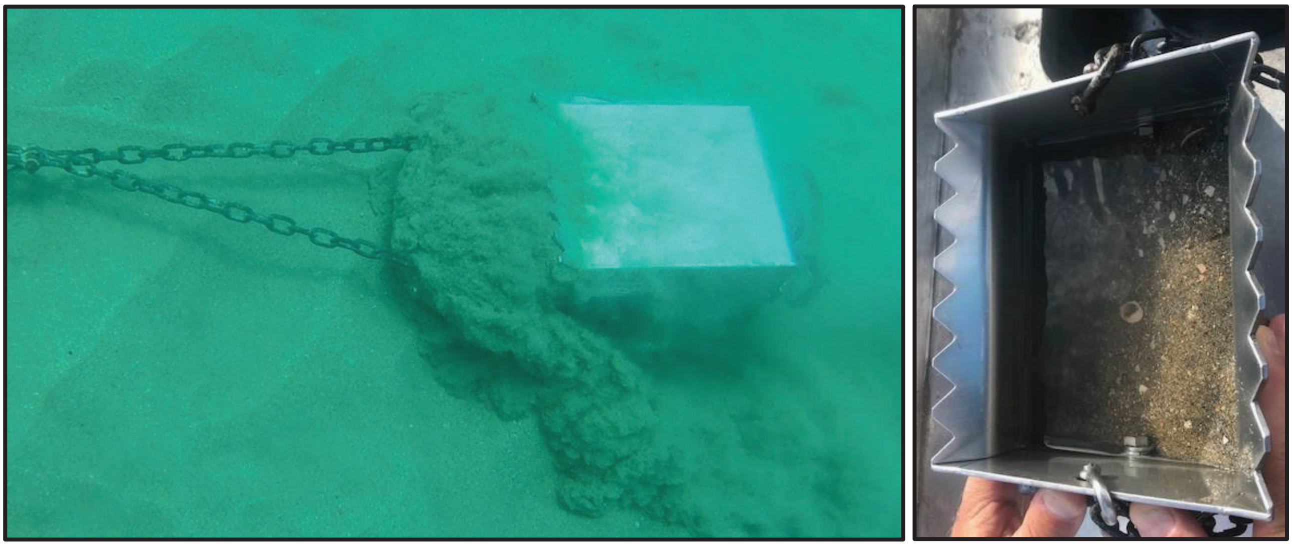

Figure 2.1 Box dredge in operation and full retrieved sample

Sieving large volumes of sandy material through 1 mm mesh sieves is time consuming and produces large numbers of biota to identify and count, for little gain in understanding. Increasing the mesh size reduces the sample processing time and number of biota, but at the expense of not retaining some of the smaller species. Therefore, a combined approach has been adopted. Two subsamples of 100 mL were taken from each sample and the material was screened over a 1 mm mesh screen and all material retained was transferred to a zip lock plastic bag, labelled and preserved in methylated spirits prior to later identification. The remainder of the box dredge sample was screened over a 3.15 mm mesh screen and all material retained was transferred to a zip lock plastic bag, labelled and preserved in methylated spirits prior to later identification. In both samples all animals were identified to the lowest possible taxonomic level and counted, by Dr M. Jones.

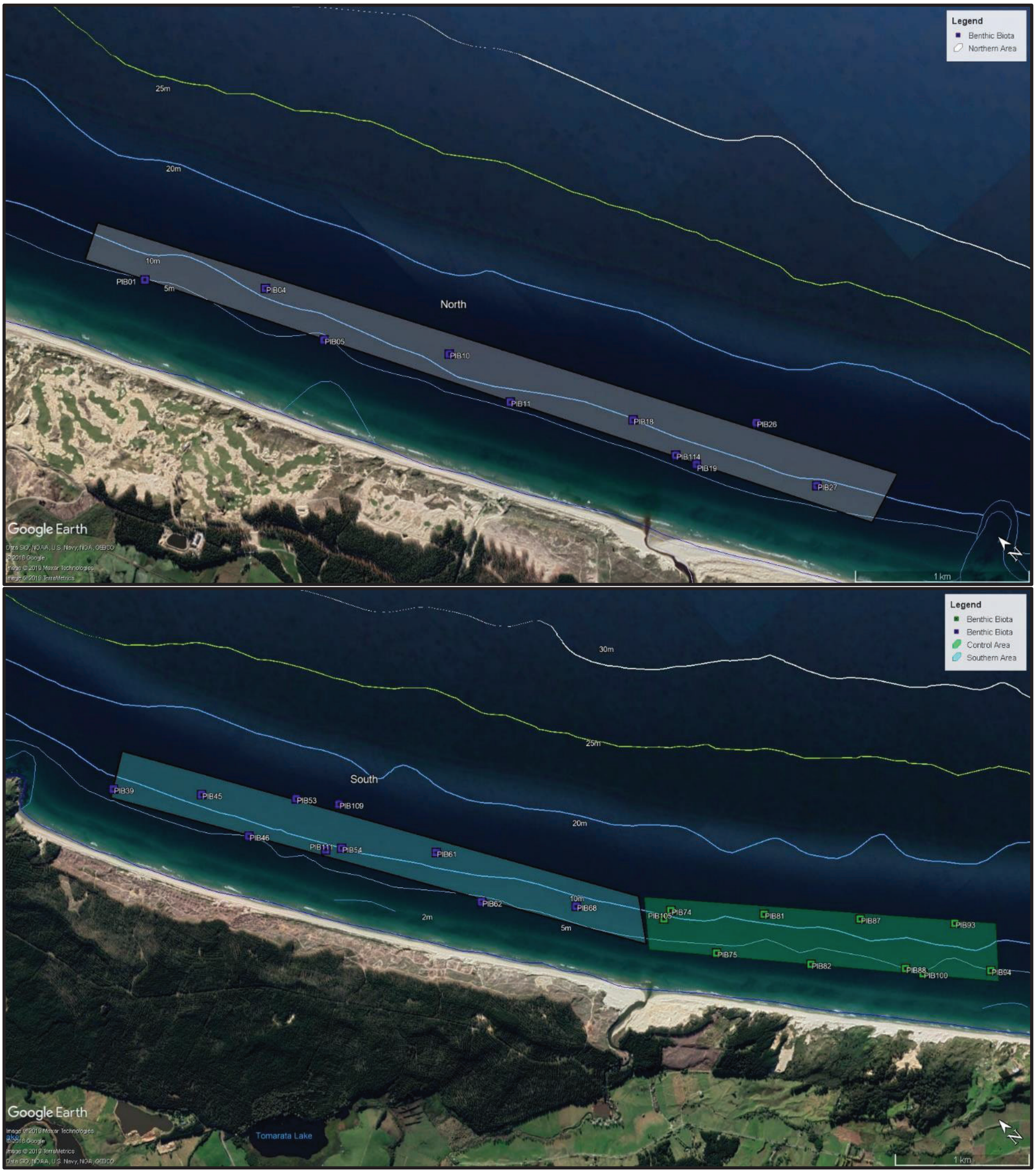

Figure 2.2 Location of benthic box dredge samples, 2019.

2.1.2 Surficial Sediment Particle Size

Changes in the particle size composition of the seabed has the potential to influence benthic biota community composition. Samples were collected to determine the potential effects of sand extraction on sediment particle size, and therefore on the benthic biota community, in the consented area. The results were compared to a nearby control area. A one kilogram subsample of sediment was retained from the sediment passing through the 3.15 mm sieve from the 30 box dredge samples collected for benthic fauna and the sediment grain size analysed. Sand was dried and processed to the concrete industry standard - NZS 3111: 1986 Methods of Test for Water and Aggregate for Concrete.

2.1.3 Seabed Photographs

Seabed photographs were taken at approximately 1 m depth intervals aligned along four transects from 5 m depth to 1 m depth outside of the consented sand extraction areas. At each site a single drop camera photograph of a 1 m² of seabed was recorded with a compass reference. The cameras were set to record images at 2 second intervals with the clearest images selected. Photographic sample locations are shown in Figure 2.3. GPS coordinates, water depth and time were recorded at each site. Details of the substrate and presence of any conspicuous species were recorded.

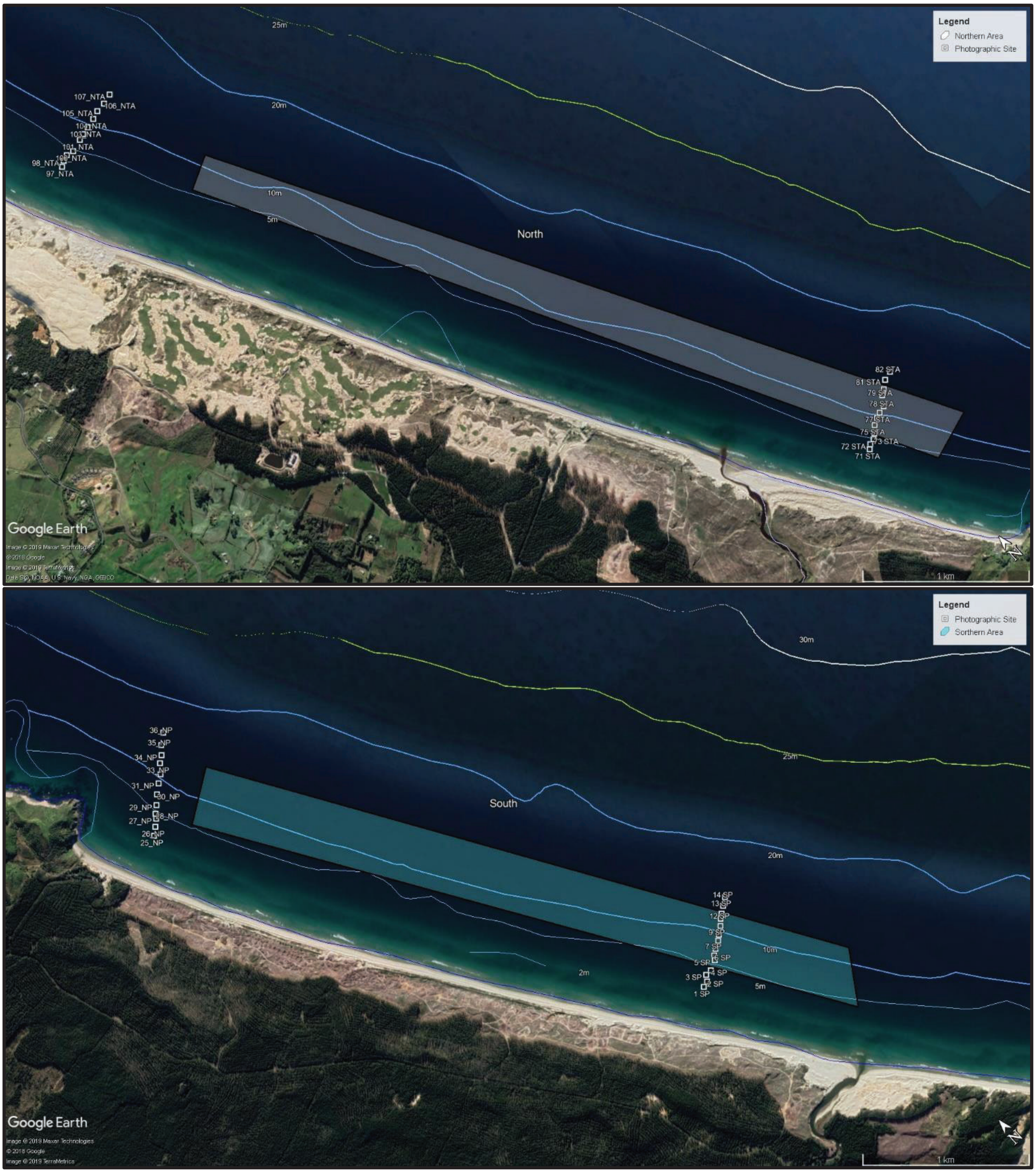

Figure 2.3 Location of seabed photographic samples, 2019.

2.1.4 Epibenthic Macrofauna Sampling

Larger epibenthic macrofauna can occur at low densities and are not adequately sampled by the small box dredge tow samples or seabed photographs. Thus approximately 300 m long dredge tows, using a 650 mm wide dredge fitted with a 15 mm square mesh bag, were conducted approximately along the 5 and 10 m bathymetric contours. Three tows per extraction area were conducted at each depth contour plus one tow at each contour in the control area to the south, the locations of each tow including the start location are shown in Figure 2.4 and the GPS locations are listed in Appendix 1. All species captured during each tow were removed and immediately sorted, photographed, identified, measured and then returned to the sea alive.

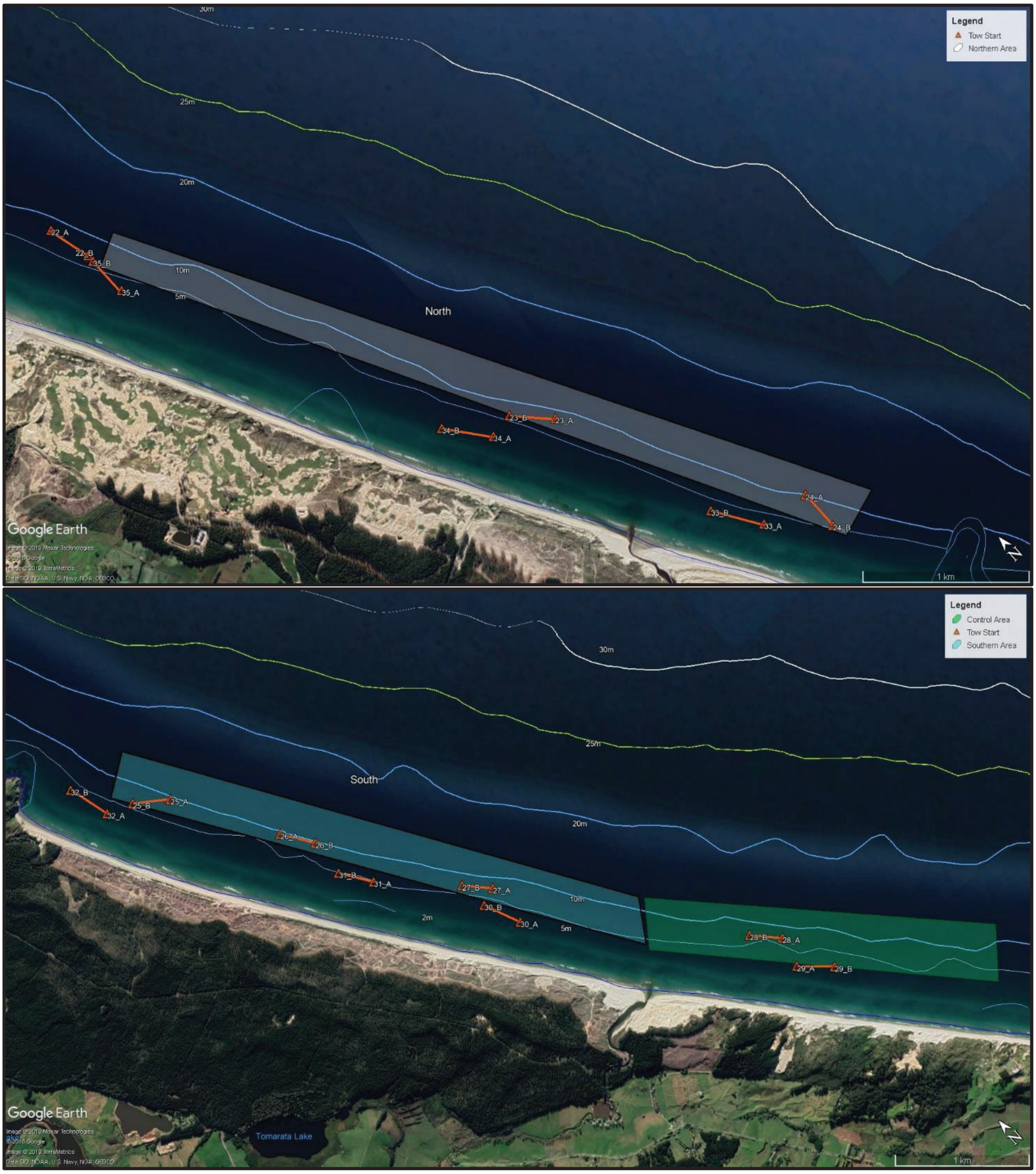

Figure 2.4 Location of epibenthic macrofauna dredge tows, 2019

2.1.5 Macrofauna Survivorship Sampling

The aim of the assessment was to determine to what extent, if any, the larger macrofauna such as shellfish, starfish and urchins were damaged by passage through the dredge system. The sampling method borrows from the experience reported in Grace, 2016. However rather than using the sampling method to survey benthic biota present on the seabed, it has been used to collect a sample of larger macrofauna with which to assess the biota for damage as a result of the activity of dredging.

Five replicate samples were collected with the sand extraction dredge operating along the inshore edge of the south area and five replicate samples were collected with the sand extraction dredge operating along the offshore edge of the south area. GPS coordinates, water depth and time were recorded at each site. Sample sites are shown in Figure 2.5 and GPS points presented in Table 8.3 of Appendix 1.

The sand extraction intake pump was run at a normal stable operating speed as per standard extraction, and all wastewater was discharge via a single pipe. A 2 m diameter net with a 9 mm square mesh, was inserted under the discharge at water level, for approximately 5 to 10 seconds, in order to collect sufficient sample. Sampling from water level was to ensure that as much as possible the shellfish collected represented those discharged during normal operation. The material collected on each net set was retrieved, photographed, sorted and all macrofauna were collected, bagged with site labels and chilled prior to later assessment on shore. Each sample was sorted by species and level of damage, the size of individuals was recorded or estimated. Each individual was assigned a damage level following criterion based on Moschino *et al.,* 2003.

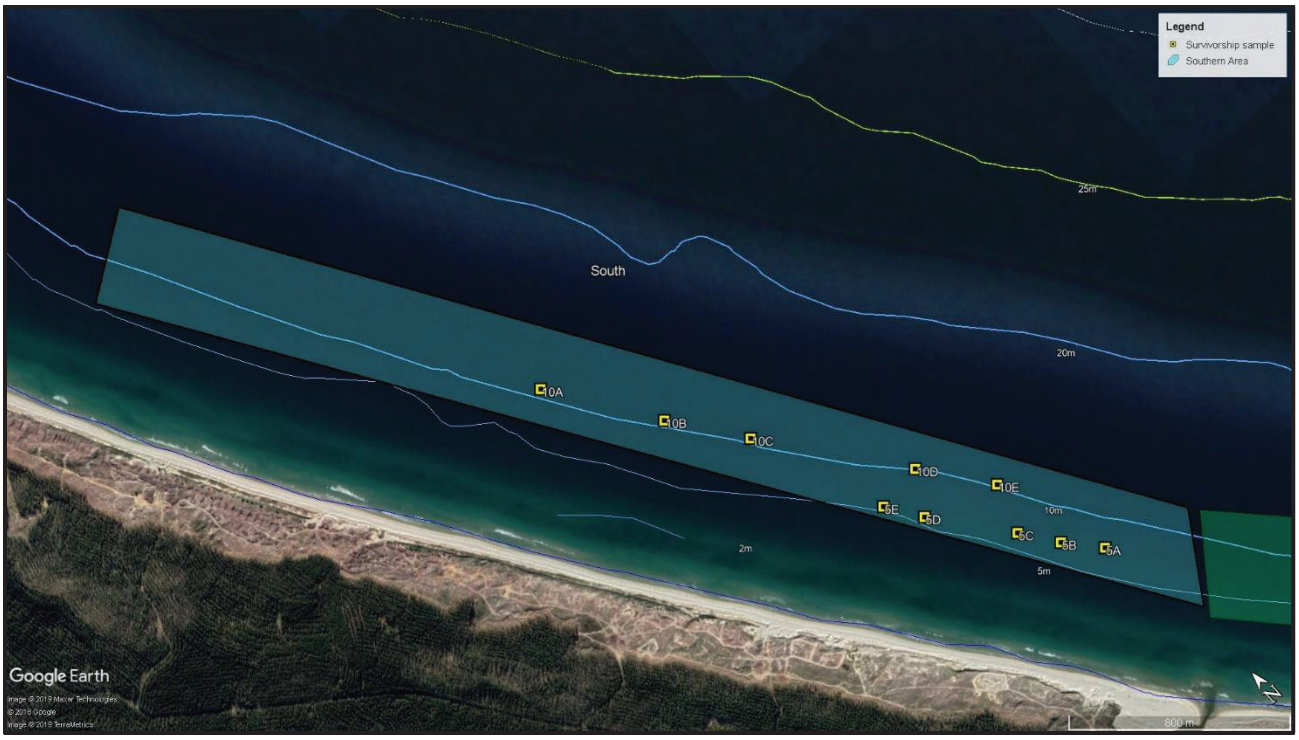

Figure 2.5 Location of Macrofauna Survivorship sample collection

2.2 Ecological Impact Assessment Methodology

Guidelines for undertaking the Ecological Impact Assessments have been published by the Environment Institute of Australia and New Zealand (EIANZ, 2018). These guidelines have been designed specifically for terrestrial and freshwater habitats. There are no standard guidelines on how to assess the ecological value of marine habitats. With the lack of current EIANZ New Zealand guidelines for determining value and level of effect in the marine environment, the following methods to determine values for marine environments have been applied.

Ecological values of sites, species, habitats, communities or ecosystems are ranked – the range "very high" to "negligible". Full listing of the factors considered behind any rankings is provided in Table 2.1, but generally consider the four factors.

- representativeness,
- rarity/distinctiveness,
- diversity and pattern, and
- ecological context.

While the criteria for determining the magnitude of the effect to the marine environment are given in Table 2.2. The level of effect was determined through combining the value of the ecological feature, and the rating for the magnitude of effect (Table 2.3). The cells in bold red italics in Table 2.3 represent a 'significant' effect.

Table 2.1 Method for assigning ecological values.

Ecological Value	Characteristics and Determining Factors
Very High	• Benthic invertebrate community typically has very high diversity, species richness and abundance. • Nationally Threatened species present either permanently or seasonally. • Likely to be nationally important and recognised as such. • Surface sediment oxygenated. • Contaminant concentrations in surface sediment at background concentrations. • Invasive, opportunistic or disturbance tolerant species absent. • Habitat unmodified, pristine.
High	• Benthic invertebrate community typically has high diversity, species richness and abundance. • At Risk – Declining species present either permanently or seasonally. • Marine sediments typically comprise <50% silt and clay particle sizes. • Surface sediment oxygenated. • Contaminant concentrations in surface sediment rarely exceed low effects threshold concentrations. • Invasive, opportunistic or disturbance tolerant species largely absent. • Habitat largely unmodified
Medium	• Benthic invertebrate community typically has moderate species richness, diversity and abundance. • At Risk – Relict, Naturally Uncommon, Recovering species present either permanently or seasonally; and or Locally uncommon or distinctive species present. • Benthic invertebrate community has both (organic enrichment and mud) tolerant and sensitive taxa present. • Marine sediments typically comprise less than 50-70% silt and clay particle sizes. • Shallow depth of oxygenated surface sediment. • Contaminant concentrations in surface sediment generally below ISQG-high or ARC-red effects threshold concentrations. • Few invasive, opportunistic or disturbance tolerant species present. • Habitat modification limited.

Ecological Value	Characteristics and Determining Factors
Low	• Benthic invertebrate community degraded with low species richness, diversity and abundance. • Nationally and locally common indigenous species. • Benthic invertebrate community dominated by organic enrichment tolerant and mud tolerant organisms with few/no sensitive taxa present. • Marine sediments dominated by silt and clay particle sizes. • Surface sediment predominantly anoxic (lacking oxygen). • Elevated contaminant concentrations in surface sediment, above ISQG-high or ARC-red effects threshold concentrations. • Invasive, opportunistic or disturbance tolerant species dominant. • Habitat highly modified.
Negligible	• Benthic invertebrate community highly degraded with very low species richness, diversity and abundance. • Invasive, opportunistic or disturbance tolerant species dominant. Exotic species including pests, species having recreational value. • High contaminant concentrations in surface sediment, above ISQG-high or ARC-red effects threshold concentrations. • Habitat entirely artificial.

Table 2.2 Criteria for describing the magnitude of effects

Magnitude	Description
Very High	Total loss of, or a very major alteration to, key elements/features of the existing baseline conditions, such that the post-development character, composition and/or attributes will be fundamentally changed and may be lost form the site altogether; AND/OR Loss of a very high proportion of the known population or range of the element/feature.
High	Major loss of major alteration to key elements/features of the existing baseline conditions such that the post-development character, composition and/or attributes will be fundamentally changed; AND/OR Loss of a high proportion of the known population or range of the element/feature.
Moderate	Loss or alteration to one or more key elements/features of the existing baseline conditions, such that the post-development character, composition and/or attributes will be partially changed; AND/OR Loss of a moderate proportion of the known population or range of the element/feature.
Minor	Minor shift away from existing baseline conditions. Change arising from the loss/alteration will be discernible, but underlying character, composition and/or attributes of the existing baseline condition will be similar to pre-development circumstances and patterns; AND/OR Having minor effect on the known population or range of the element/feature.
Negligible	Very slight change from the existing baseline condition. Change barely distinguishable, approximating to the 'no change' situation; AND/OR Having negligible effect on the known population or range of the element/feature.

Table 2.3 Criteria for describing the level of effects

		Ecological Value				
		Very High	High	Moderate	Low	Negligible
Magnitude of Effect	Very High	*Very High*	*Very High*	*High*	*Moderate*	Minor
	High	*Very High*	*Very High*	*Moderate*	Minor	Negligible
	Moderate	*High*	*High*	*Moderate*	Minor	Negligible
	Minor	*Moderate*	Minor	Minor	Negligible	Negligible
	Negligible	Minor	Negligible	Negligible	Negligible	Negligible
	Positive	Net Gain	Net Gain	Net Gain	Net Gain	Net Gain

3. RESULTS

3.1 Benthic Fauna

The raw benthic biota data from each screen size are presented in Table 8.6 and Table 8.7 in Appendix 4. With the 3.15 mm screen method, 61 species/taxa were identified and a total of 564 individuals counted. With the 1 mm screen, 41 species/taxa were identified and a total of 178 individuals counted. When data from both sieves were combined a total of 75 species/taxa were identified.

Diversity measures (species richness and the Shannon index) were calculated for each station and screen size these are summarised in Table 3.1. The differences in diversity measures between areas (North, South and Control) were statistically compared by ANOVA when data satisfied the assumptions of normality and equal variance but were compared by the non-parametric equivalent Kruskal-Wallis when otherwise, using Sigmaplot 11.0. The statistical test results are presented in Appendix 6. All tests showed no statistical difference between the areas.

Table 3.1 Summary of Benthic Biota Population Statistics by Area and Screen Size

Area	Control		North		South	
3.15 mm Screen	Average	Standard Deviation	Average	Standard Deviation	Average	Standard Deviation
Number of Species / taxa	**5.30**	3.43	**5.40**	2.80	**5.20**	2.74
Number of Individuals	**10.20**	10.81	**35.40**	61.67	**10.80**	7.131
Shannon-Weiner Diversity Index	**1.313**	0.514	**1.212**	0.799	**1.247**	0.649
Shannon Evenness Index	**0.898**	0.135	**0.727**	0.362	**0.856**	0.136
1 mm Screen	Average	Standard Deviation	Average	Standard Deviation	Average	Standard Deviation
Number of Species / taxa	**4.00**	3.43	**3.10**	3.03	**3.20**	3.65
Number of Individuals	**6.40**	7.23	**6.60**	6.022	**4.80**	6.07
Shannon-Weiner Diversity Index	**1.030**	0.803	**0.753**	0.891	**0.748**	0.904
Shannon Evenness Index	**0.959**	0.064	**0.971**	0.058	**0.972**	0.032

The comparison of summary population statistics does not describe any changes in composition of benthic biota communities. A multivariate approach is required to describe and test differences in species composition between the northern, southern sand extraction areas and the control area.

The benthic biota data sets for both the 1 mm and the 3.15 mm screen contain species/taxa where only one individual was recorded from a single sample site. This has an adverse effect on the multivariate statistical analysis; thus, data sets were created where taxa with 2 or more individuals were present. Where only a single taxa was present, they were grouped into higher taxa groupings and re-included in the data set if providing more than 2 individuals were present. This data reduction resulted in data sets of 28 and 40 taxa and taxa groups from the 1 mm and 3.15 mm screened samples respectively.

To assess community differences between the sand extraction areas and the control area, Bray-Curtis (B-C) similarity matrices were created on 4th root transformed data (both 1 mm and 3.15 mm screened). The data transformation down-weights the importance of abundant species such as the wheel shell and gives more influence of the rare taxa. Non-metric multidimensional scaling (nMDS) was used to visualise the degree of similarity among samples of different areas on a two-dimensional plot. One-way analysis of similarities ANOSIM tests (maximum permutations = 999) were performed on the B-C similarity matrices to test the null hypothesis “no difference between the areas”. A test statistic R is calculated and is constrained between the values −1 to 1, where positive numbers suggest more similarity within sites, and values close to zero represent no difference between within sites and within sites similarities. Negative R values suggest more similarity between sites than within sites. The ANOSIM test is the multivariate analogue of the univariate ANOVA test. If a global statistical significance is determined at the 0.05 level, then pairwise comparisons between each group should be completed. This will determine which groups are different from each other but not what is responsible for the difference. In the case of significance between groups, a one-way similarity percentage analysis SIMPER was needed to determine the taxa responsible for the differences between the groups. The multivariate procedure "data transform – Bray-Curtis – nMDS – ANOSIM – SIMPER" has become a common statistical methodology for communities' structure in the past 10 years (Clarke *et al.*, 2014). All analyses were performed with the software PRIMER-E (version 7.0.13, Quest Research Ltd).

In addition to grouping the samples per area (North, South, and Control), depth was considered as a factor for differentiating the samples. Stations shallower than 10 m were labelled "shallow", and stations deeper than 10 m were labelled "deeper".

3.1.1 3.15 mm Screened Data

Sixty-one species/taxa were identified with a total of 564 individuals. Species richness did not vary between the control area and the sand extraction areas (average of 5.3 per area), nor did the Shannon-Weiner Diversity index (average of 1.25) (Table 3.1). Statistical comparisons between the northern, southern and Control area samples showed no statistical difference between the areas for species richness, number of individuals, Shannon-Weiner diversity or evenness.

Once the less common species were removed or grouped to higher taxa, the dataset was reduced to 40 taxa. The nMDS on the 40 grouped species/taxa showed the data points from each area were overlapping suggesting no difference between the sand extraction areas and the control area (Figure 3.1). The ANOSIM statistical test (Table 8.20 in Appendix 6) gave a global R close to zero (R = 0.024) and a P value of 0.315, meaning there was no statistical difference between the Northern, Southern extraction areas and the Control area.

When samples were labelled by water depth category on the nMDS plot (Figure 3.2), a distinction between deep (>10 m) and shallow (<10 m) samples was visible, however the groups still overlapped. When the differences were tested, the ANOSIM (Table 8.21 in Appendix 6) showed a statistically significant community difference between the shallow stations and the deep ones (R = 0.267, P = 0.002). A SIMPER test (Table 8.22 in Appendix 6) revealed that dissimilarities between the shallow and deep groups were driven by the wheel shell (*Zethalia*) and echinoderms (*Fellaster* and *Amphiura*), which were more abundant in shallow stations; and the clams (*Myadora* and *Dosinia*), polychaetes (Maldanidae and others), and the lancelets (*Epigonichthys*), which were more abundant in deeper stations (Table 3.2).

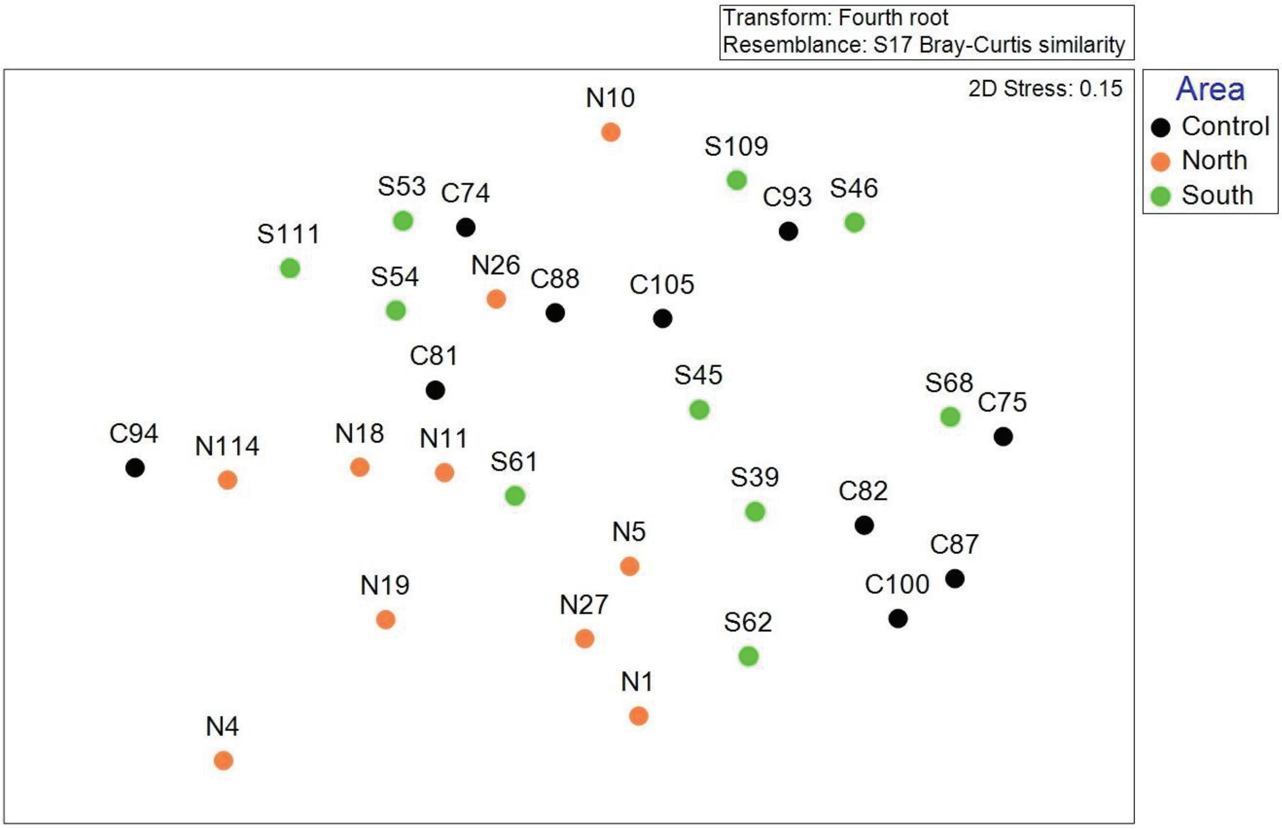

Figure 3.1 ***Non Metric multidimensional scaling (nMDS) of samples (3.15 mm screen) of benthic biota (40 taxa) classified by the area of sampling. North and South represent sand extraction areas.***

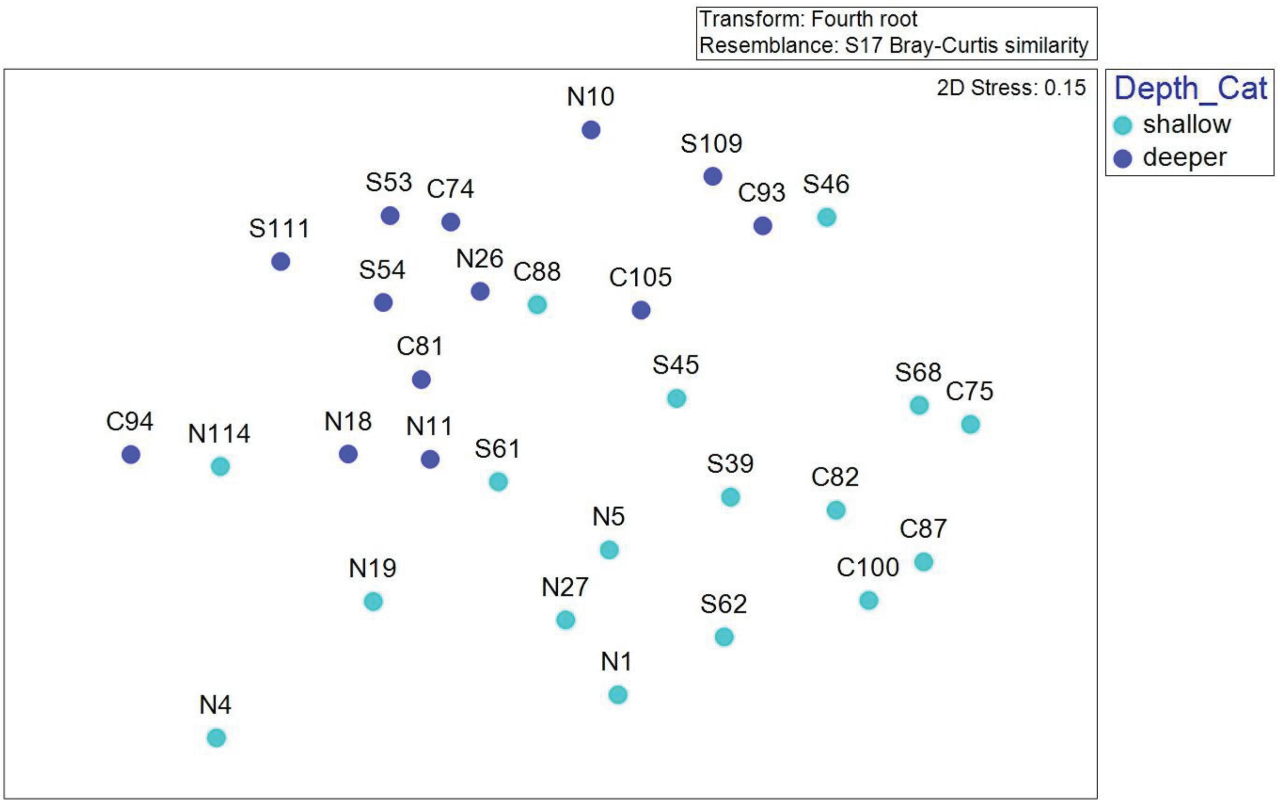

Figure 3.2 ***Non Metric multidimensional scaling (nMDS) of samples (3.15 mm screen) of benthic biota (40 taxa) classified by depth (shallow is < 10 m and deep is > 10 m).***

Table 3.2 SIMPER results between the shallow (<10 m) and the deeper (>10 m) groups (3.15 mm screen).

Species	Average Abundance		Average	Dissimilarity	Percentage	Cumulative
	Group deeper	Group shallow	Dissimilarity	SD	Contribution	percentage
Myadora boltoni	0.88	0.06	7.02	1.25	7.70	7.70
Zethalia zelandica	0.00	0.77	6.40	0.62	7.01	14.71
Maldanidae	0.56	0.07	5.33	0.82	5.85	20.56
Fellaster zelandiae	0.00	0.48	4.90	0.74	5.36	25.92
Epigonichthys hectori	0.59	0.22	4.76	0.92	5.22	31.14
Polychaeta Other	0.38	0.24	4.26	0.76	4.67	35.81
Myadora striata	0.49	0.13	3.96	0.80	4.34	40.15
Dosinia subrosea	0.31	0.19	3.71	0.65	4.07	44.21
Anomura	0.31	0.06	3.36	0.59	3.68	47.89
Amphiura aster	0.08	0.31	3.08	0.63	3.38	51.27

Note:
Only the top contributing taxa up to a cumulative dissimilarity of 50% are shown. The blue-shaded cells represent the highest number between the depth categories. Numbers are fourth root transformed abundance.

3.1.2 1 mm Screened Data

While the 3.15 mm screened samples included the full (approx. 3 L) sample, the 1 mm screened samples were only from a 200 mL sub sample. Thus, predictably the 1 mm screened samples, contained a lot less biota, 178 individuals, compared with the 3.15 mm screened samples with 559 individuals. The 1 mm screen samples were included to specifically target smaller biota such as amphipods and small polychaetes. The smaller sample volume also resulted in a smaller number of species/taxa with only 41 recorded from all the samples. Species richness showed higher average numbers at the control area (4.00) compare with the sand extraction areas (3.15), similarly the Shannon-Weiner Diversity index was higher at the control area (1.03) than the sand extraction areas (average of 0.75) (Table 3.1). Statistical comparisons between the northern, southern and Control area samples showed no statistical difference between the areas for species richness, number of individuals, Shannon-Weiner diversity or evenness. At station 27, numbers of *Zethalia* were higher than in other stations with 20 individuals. Amphipods were found in higher numbers than with the 3.15 mm screen (45 individuals *versus* 7 individuals).

Once the less common species were removed or grouped to higher taxa, the dataset was reduced to 28 taxa. Samples from five sites did not include any biota in the 1 mm screens. The nMDS on the 28 grouped species/taxa showed the data points from each area were overlapping suggesting no difference between the sand extraction areas and the control area (Figure 3.3). The ANOSIM statistical test (Table 8.23 in Appendix 6) gave a global R close to zero (R = 0.059) and a P value of 0.116, meaning there was no statistical difference. However pairwise testing between the Northern and Southern extraction areas revealed a weak difference (P = 0.073), similarly there was a weak difference between the control and northern (P = 0.073), but no difference between the control and southern (P = 0.703) areas. A SIMPER test (Table 8.24 in Appendix 6) was used to reveal that dissimilarities between the northern and southern groups were driven by the wheel shell (*Zethalia*) which were more abundant in northern stations.

When samples were labelled by depth category on the nMDS plot (Figure 3.4), a distinction between deep (>10 m) and shallow (<10 m) samples was visible, however there was no spatial segregation among the groups in the nMDS. When the differences were tested, the ANOSIM (Table 8.25 in Appendix 6) showed a statistically significant community difference between the shallow stations and the deep ones (R = 0.304, P = 0.001). The shallow samples were highly variable in their species structure, while the deeper samples were more homogeneous. A SIMPER test (Table 8.26 in Appendix 6) was used to revealed that dissimilarities between the shallow and deep groups were driven by the wheel shell (*Zethalia*), which were more abundant in shallow stations; and the amphipods (Phoxocephalidae and Haustoriidae) and polychaetes (*Armandia*, Maldanidae and other), which were more abundant (e.g. Phoxocephalidae) or absent in deeper stations (Table 3.3).

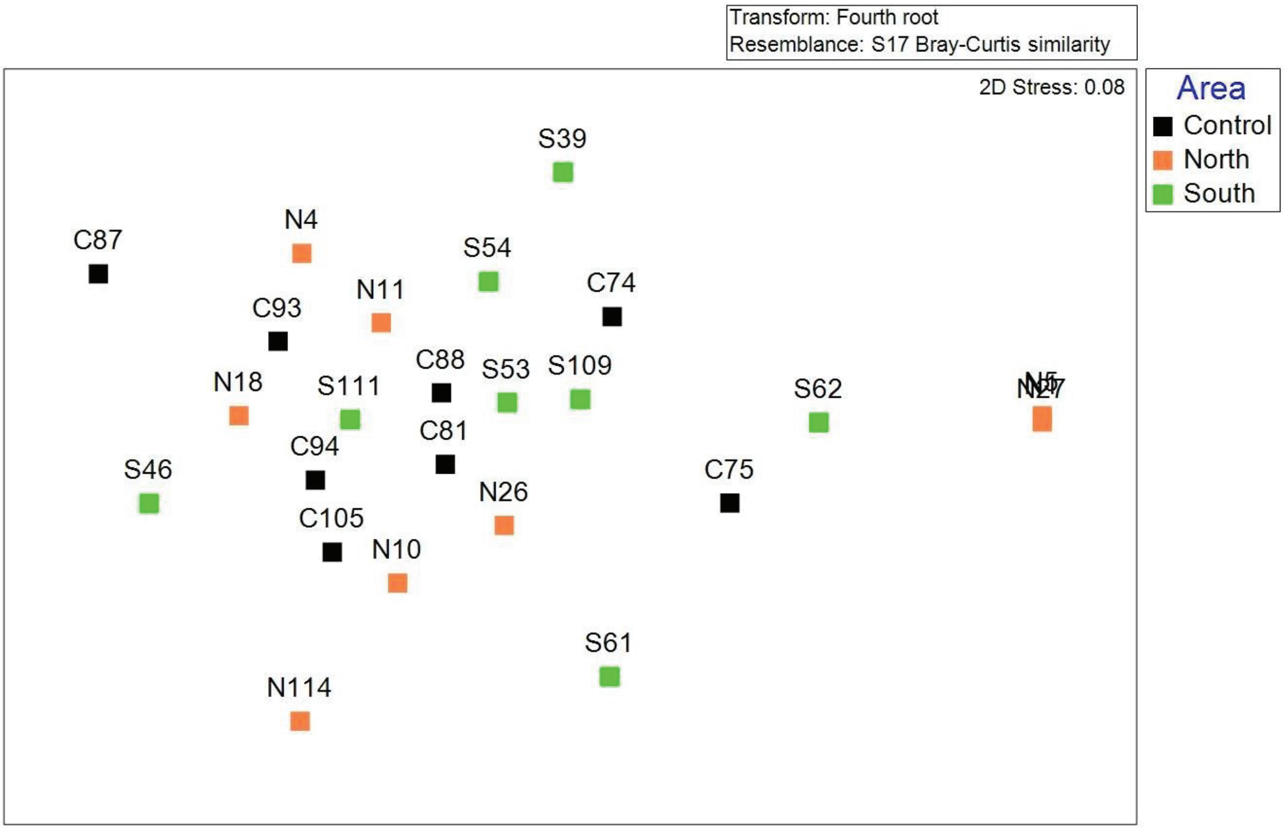

Figure 3.3 ***Non Metric multidimensional scaling (nMDS) of samples (1 mm screen) of benthic biota (28 taxa) classified by the area of sampling. North and South represent sand extraction areas.***

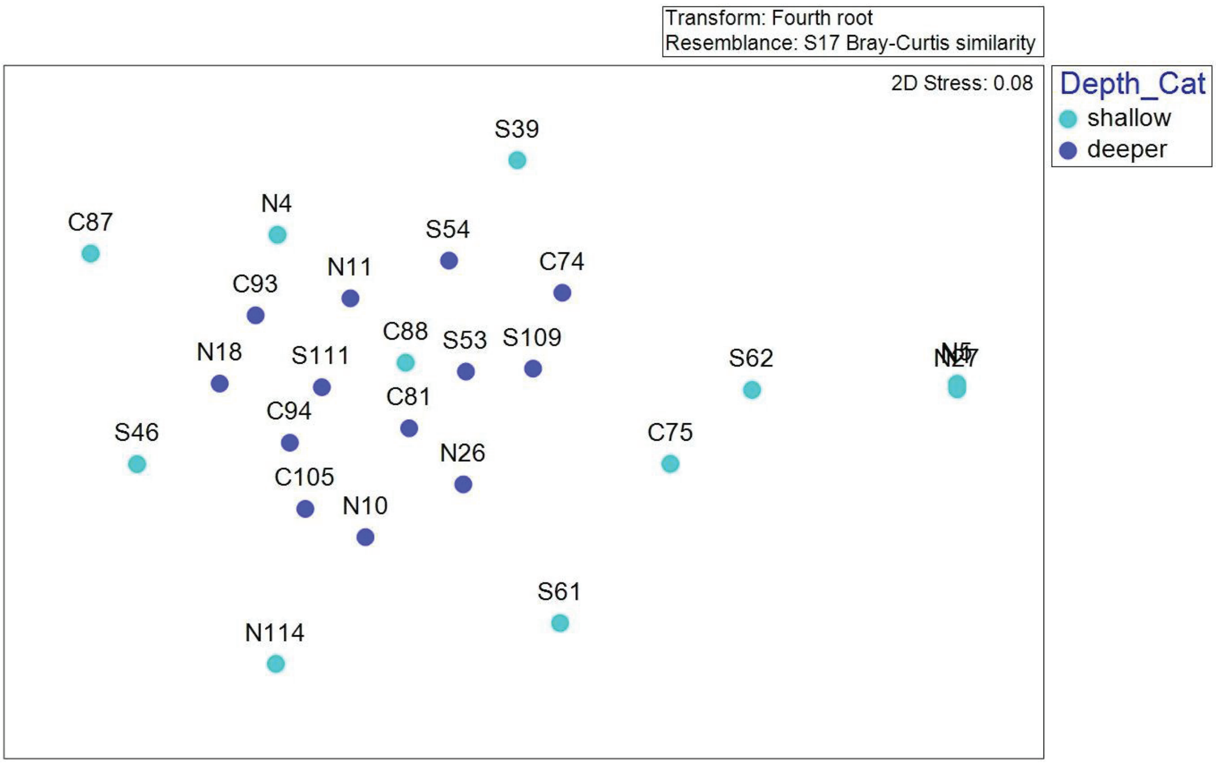

Figure 3.4 ***Non Metric multidimensional scaling (nMDS) of samples (1 mm screen) of benthic biota (28 taxa) classified by depth (shallow is < 10 m and deep is > 10 m).***

Table 3.3 SIMPER results between the shallow (<10 m) and the deeper (>10 m) (1 mm screen).

Species	Average Abundance		Average	Dissimilarity	Percentage	Cumulative
	Group deeper	Group shallow	Dissimilarity	SD	Contribution	percentage
Phoxocephalidae sp. 1	0.61	0.20	7.74	0.95	8.23	8.23
Zethalia zelandica	0.00	0.50	6.77	0.63	7.19	15.43
Cirolanidae sp. 1	0.56	0.00	6.52	0.94	6.93	22.36
Armandia cf. maculata	0.43	0.00	5.93	0.68	6.30	28.66
Maldanidae	0.44	0.00	5.66	0.66	6.02	34.68
Haustoriidae	0.51	0.00	5.36	0.87	5.70	40.38
Polychaeta Other	0.38	0.00	4.62	0.69	4.91	45.29
Epigonichthys hectori	0.43	0.14	4.51	0.82	4.79	50.08

Notes:
Only the top contributing taxa up to a cumulative dissimilarity of 50% are shown. The blue-shaded cells represent the highest number between the depth categories. Numbers are fourth root transformed abundance.

3.2 Surficial Sediment Particle Size

The 2019 particle size samples were analysed by MBL. The samples were processed to the concrete industry standard NZS 3111: 1986 Methods of Test for Water and Aggregate for Concrete, which results in percentage composition based on the weight of particles. The NZS 3111 method uses different sieve sizes to samples normally processed for environmental samples but the results are still comparable. The particle size data for each of the 30 sites sampled are presented in Table 8.4 of Appendix 2. The concrete method rather than the environmental method was used so that the data generated can be used to demonstrate suitability of the product to the industry requirements.

Where possible the raw particle size data has been grouped into the following standard size fractions.

Class	Gravel	Sand	Silt and Clay
Particle Size (mm)	> 2.00	2.00 – 0.063	< 0.063

According to the methodology defined in Folk (1980) the sediments were assigned a description based on the principle particle size fraction with modifiers based on the next important particle sizes. These descriptions are given as letter codes. For example,

- A sample which consisted of mostly sand with a significant proportion of silt and clay would be described as muddy sand. This would be denoted **mS**.
- If the sample had a gravel component, it would be described as slightly gravelly muddy sand. This would be denoted **(g)mS**.

The descriptions of the sediments are based on criteria illustrated in Figure 3.5.

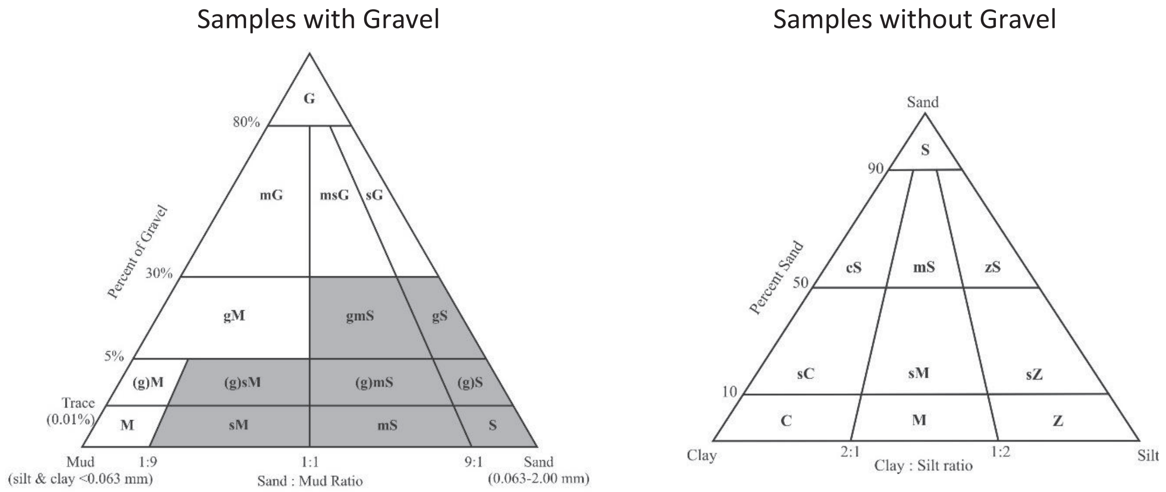

***Figure 3.5	Sediment Particle Size Description.*** *(C=clay, M=mud, Z=silt, S=sand, G=gravel)*

## 3.3	Drop Camera Survey

Drop camera images from each of the photographic sites sampled in March 2019 are presented in Figure 8.1 and Figure 8.2 in Appendix 3.

The GPS locations and depths of each photographic site together with comments on sediment composition, topography and biota are presented in Table 8.5 in Appendix 3.

## 3.4	Dredge Tow Macrobenthic Biota

The detailed dredge tow data, including sizes of shellfish and densities per 100 m^2, are presented in Table 8.8 in Appendix 4. The species and abundance within each area and depth are summarised in Table 3.4.

A total of 18 different taxa (113 individuals) were identified over 14 tows. The samples were identified and measured on capture and released alive, thus some small taxa such as polychaetes were not identified to the species level. One tow did not contain any specimens (tow 24 in North area at a 10 m depth).

Species diversity was higher in the shallow near shore (5 m deep) tows than in the deeper (10 m deep) tows. Crustaceans, gastropods, bivalves, and echinoderms were found in shallow dredge tows for each sand extraction area, and the control area. Bivalves were absent from the deeper dredge tows, while the starfish *Astropecten* was present. The sand dollar *Fellaster* was the most abundant taxa and 37 out of 38 individuals were recorded from the 5 m tows.

There were no apparent major differences in composition between sand extraction areas and the control area, and this was confirmed by an ANOSIM statistical test (Global test R = 0.084, P = 0.267) (Table 8.27 in Appendix 6). However, water depth was a significant factor to explain differences in species distribution (R = 0.493, P = 0.001) (Table 8.28 in Appendix 6).

Table 3.4 Abundance of species collected with the dredged tows in the inshore zone. North and South are sand-extraction areas.

Area	North						South						Control	
Bathymetry	**5 m**			**10 m**			**5 m**			**10 m**			**5 m**	**10 m**
Tow #	35	34	33	22	23	24	32	31	30	25	26	27	29	28
Polychaeta: Maldanidae							1			1				
Polychaeta other								1					2	
Nemertea				1										
Amphipoda: Gammaridea		5					2							
Decapoda: *Ovalipes catharus*	1		1		1					3			1	
Decapoda: Paguridae		2	1				2			1	6			
Isopoda: *Euidotea peronii*		1					1							
Gastropoda: *Dicathais orbita*		1												
Gastropoda: *Sigapatella tenuis*					1									
Gastropoda: *Cominella adspersa*							2			1	1		1	
Gastropoda: *Amalda australis*			1				1							
Gastropoda: *Zethalia zelandica*			7											
Bivalvia: *Myadora striata*								1					1	
Bivalvia: *Dosinia subrosea*			1				2	2	2				1	
Echinodermata: *Fellaster zelandiae*	1	19	8				1	1	4			1	3	
Echinodermata: ophiuroids							1	1					1	
Echinodermata: *Astropecten polyacanthus*				1							7	1		1
Ulva Branches							2							
Number of taxa	**9**			**4**			**12**			**6**			**7**	**1**
Number of individuals	**16.3**			**1.3**			**9.0**			**7.3**			**10.0**	**1.0**

3.5 Macrofauna Survivorship

The larger macrofauna collected from the dredge oversize outlet were sorted per species and per state of damage (no damage, sub lethal and lethal), counted (Table 8.9), measured (Table 8.10) and photographed (Table 8.11). Individuals classified as having “no” and “sub lethal” damage were defined as having survived passage through the dredge. There is still a possibility that they could suffer predation by fish on their descent to the seabed and prior to their reburial in the seabed sediments. However, the extent of this is not measurable. Individuals classified as suffering “lethal” damage had broken shells, or parts of the body missing, were either already dead or were unlikely to survive.

3.5.1 Numbers of Individuals

The five samples collected at a 10 m bathymetry contained more than three times the number of individuals found at a 5 m bathymetry (56 individuals at 5 m, Table 3.5; 179 individuals at 10 m, Table 3.6), this is reflective of the abundance of the macrofauna rather than any dredge related effects. The most abundant species represented in the dredge discharge at both bathymetries was the surf clam *Dosinia subrosea* with more than 70% of total number. The other species found were gastropods, a few crabs and shrimps, and some echinoderms (5 m only).

Table 3.5 Total Numbers of Individuals per State of Damage found in 5 m bathymetry samples

Class	Species	No Damage	Sub Lethal	Lethal	Total	%
Gastropod	*Amalda australis*	1			**1**	2
	Zethalia zelandica	2			**2**	4
Bivalve	*Dosinia anus*	6	1		**7**	13
	Dosinia subrosea	21	5	13	**39**	70
Crustacean	*Ovalipes catharus*	1			**1**	2
	shrimp	2			**2**	4
Echinoderm	*Amphiura*			1	**1**	2
	Fellaster zelandiae	2	1		**3**	5
	Total Damage	**35**	**7**	**14**	**56**	
	%	63	13	25		

Table 3.6 Total Numbers of Individuals per State of Damage found in 10 m bathymetry samples

Class	Species	No Damage	Sub Lethal	Lethal	Total	%
Gastropod	*Amalda australis*	2			**2**	1
	Cominella adspersa	10	2		**12**	7
	Xymene plebeius	2			**2**	1
Bivalve	*Dosinia anus*	4	1	1	**6**	3
	Dosinia subrosea	37	24	79	**140**	78
	Myadora striata	14	1		**15**	8
Crustacean	*Ovalipes catharus*	1			**1**	1
	Shrimp		1		**1**	1
	Total Damage	**70**	**29**	**80**	**179**	
	%	39	16	45		

With both sets of bathymetry data combined, 60% of individuals recorded no damaged or survivable damage (Table 3.7), the majority of these individuals are likely to survive the passage to the seabed and rebury themselves. When the numbers of individuals were divided by taxa into bivalves and gastropods, differences were notable with the gastropods suffering no lethal damage thus were all likely to survive the dredging process. By contrast, 45% of the bivalves showed lethal damage and thus the survivorship was estimated to be 55%. With only 12 other individuals, the other taxa were not recorded in sufficient numbers to determine trends. Based on the difference between bivalves and gastropods it is suggested that shape of the macrofauna has an influence on the damage caused by the dredge, with the generally flat bivalves more susceptible to damage than the rounder gastropods. Similarly, more fragile macrofauna such as Ophiuroid starfish are likely to suffer more damage than more robust biota such as molluscs.

Table 3.7 Total Numbers of Individuals per State of Damage

	No Damage	Sub Lethal	Lethal	Total
Total Number of Individuals	105	36	94	**235**
% Total	45	15	40	
Bivalves	82	32	93	**207**
% Bivalves	40	15	45	
Gastropods	14	2	0	**16**
% Gastropods	88	13	0	

3.5.2 Size of Individuals

The average length and ranges of measured individuals are reported in Table 8.10. For species similar between the different depths such as the southern olive *Amalda australis* and the two species of *Dosinia*, there was little or no difference in the size ranges.

Dosinia subrosea was the only species collected in enough numbers to be informative of the damage caused by the dredging system relative to size. Since the length distributions of *D. subrosea* at each bathymetry were similar, the data from both depths were combined and presented in Figure 3.6.

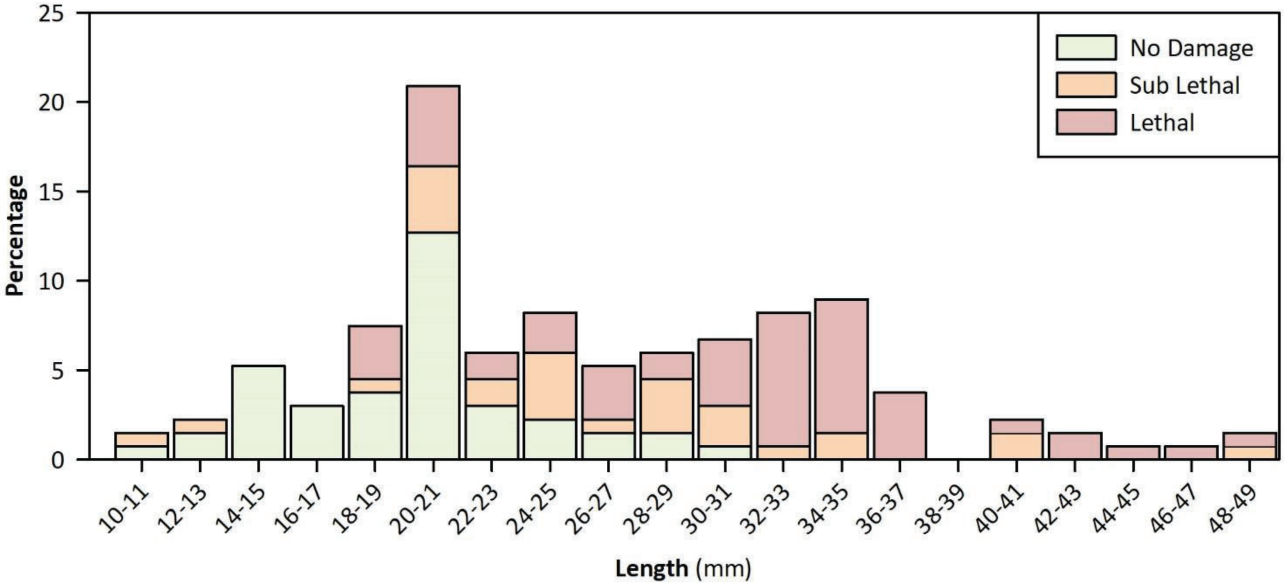

Figure 3.6 Length Distribution (mm) of Dosinia subrosea by State of Damage.

The undamaged clams ranged in size from 10 to 30 mm with an average size of 19.6 mm and a mode of 20 mm. Those clams with sub lethal damage ranged from 10 to 49 mm averaging 26.6 mm and mode of 20 mm. However clams which had lethal damage were larger ranging from 18 to 48 mm and averaging 30.5 mm with a mode of 35 mm (Figure 3.6). While the size ranges of clams in the three classes of damage overlapped, the lethal effects appear to be more prevalent in clams of larger sizes. All clams smaller than 18mm survived passage through the dredge but clams larger than 31 mm almost all did not survive passage through the dredge. For clams smaller than 31 mm approximately 73% survived, whereas for clams larger 31 mm approximately 84% did not survive passage through the dredge.

4. DISCUSSION

In the absence of standardised monitoring studies over time, the 2019 studies have concentrated on comparing data from the sand extraction areas with that collected in an adjacent control area, with the aim of determining effects.

4.1 Seabed Morphology

The descriptive nature of the photographic data (Table 8.5) precludes statistical analysis. In general, the seabed micro topography and condition shows a pattern that varies with increased depth and distance from shore, of;

- fine sand with irregular small or no ripples inshore of the sand extraction areas,
- increasing sand size with shell debris and ripple size with depth, across extraction area,
- larger ripples but low or flat shape in area beyond extraction area.

Both the southern extraction area off Pakiri Beach and northern extraction area off Te Arai beach were surveyed by two photographic transects each, one (southern) passed through the extraction area and the other (northern) passed to the north of the extraction area. In Table 8.5 the black shaded cells indicate sand extraction and the grey shaded cells highlight the sites similar but with no sand extraction.

In the southern area the extraction samples show greater amounts of shell debris compared to the no extraction areas. The ripples appear to be larger and flatter in the no extraction area compared with the extraction area. No difference was seen in the fauna observed.

In the northern extraction area, the extraction samples do not show any increased shell debris and the ripples are largely similar in size to those in the no extraction area. No difference was seen in the fauna observed.

Based on the photographic evidence collected, there is no consistent obvious visual differences between the sand extraction seabed and that of similar areas of no extraction.

4.2 Seabed Particle Size

All sediments in and adjacent to the consented sand extraction areas were described as Sand (S). None of the samples recorded the presence of gravel sized particles or silt and clay sized particles, this is a function of the way in which the samples were collected, having first been processed for benthic fauna. Pre sieving the sample through a 3.15 mm sieve will have removed any gravel sized particles. Any silt and clay sized particles may have been washed out of the sample in the process of washing the sample through the 3.15 mm sieve. While the seabed photographs suggest the presence of shell fragments in the gravel size range there is no evidence of silt and clay sized particle being present.

When the sediment particle size data were divided into extraction area, the northern area showed slightly higher proportions of very fine sand (12.8%), very coarse sand (2.4%) and coarse sand(4.5%) than recorded at the southern area (9.2, 1.0 and 2.8%) and was more similar to the Control area (11.2, 1.5 and 3.5%). In the southern area (29.4%) the proportion of medium sand was greater than recorded at the northern (21.4%) and control (24.9%) areas. There was very little difference between the areas in terms of the most abundant particle size fraction of fine sand with the proportions ranging from 59.1% at the Control area to 57.6% at the Southern area.

The data do not provide any evidence of a consistent difference between the Northern and Southern sand extraction areas and the Control area, as a result of sand extraction.

When the proximity to shore was considered the three areas show differing patterns of particle size distribution. For particles larger than medium sand the Northern area is similar to the Control area with a greater proportion recorded from samples closer to shore. Medium sand sized particles showed a consistent pattern across all three areas recording greater proportions in the offshore samples. For particles smaller than medium sand the Southern area is similar to the Control area with a greater proportion recorded from samples further offshore. However, the variations in proportions are not considered great enough to be ecologically significant, i.e. not expected to result in differences in biota composition and abundance.

4.3 Turbidity

Water clarity can be important for the healthy functioning of marine ecosystems. Increased suspended solid loads that reduce water clarity, through increased turbidity, can affect the amount of photosynthesis (primary production) of aquatic plants. Reduced water clarity can also affect the feeding efficiency of visual predators like fish and sea birds.

ANZECC (2000) list default trigger values for turbidity in slightly disturbed marine waters and estuaries of 0.5 to 10 NTU but acknowledge that these values are of little practical use. Values of 0.5 NTU are expected for offshore waters, while values of up to 10 NTU can naturally occur in estuaries (ANZECC, 2000). The Environmental Response Criteria (ERC) report (ARC, 2002) was unable to define clarity guidelines. It concluded that observed clarity and turbidity is highly location and weather dependent, and the present clarity/turbidity criteria (MfE or ANZECC) is of doubtful relevance for shallow and muddy Auckland estuaries, which can become naturally quite turbid on windy days, irrespective of catchment discharges. Therefore, Auckland Council does not currently have any guideline values for turbidity in the marine environment.

The water quality results presented in Gibbs and Kubale (2019) show increased turbidity in the wake of the Coastal Carrier dredge vessel, which was predictably highest adjacent to the discharge from the Coastal Carrier, but rapidly reduced to ambient background levels 800m following the Coastal Carrier dredge vessel. Based on a dredging speed of 1.5kn this equates to a plume of elevated turbidity that lasts for less than 22 minutes in any one area on a day assuming that the dredge does not dredge the same area more than once in a day.

4.4 Benthic biota

Both screening methods (1 mm and 3.15 mm) did not reveal any statistically significant differences in benthic biota between stations that have had sand extraction and the control stations. Differences in benthic communities were present across the zones as shown by depth. This is consistent with what was expected based on previous studies in the area such as the Bioresearches, 2016 report. The 1 mm screening method is complementary to the 3.15 mm screening method by representing different communities. Indeed, amphipods, isopods and several polychaete species were only present when the 1 mm sieve was used. The 1 mm screening method seems less robust than the 3.15 mm with species composition in the 1 mm samples highly variable between samples within the same area, this is mostly due to the small sand volume sampled.

Overall, sediments shallower than 10 m were characterised by the wheel shell, sand dollars *Fellaster* and *Amphiura,* while sediments deeper than 10 m were characterised by a variety of clams, polychaetes, amphipods and the lancelets.

4.5 Macrobenthic biota

The range of species caught with the dredge is limited to large individuals such as molluscs, crabs and echinoderms. The small individuals like amphipods and polychaetes were only recorded because they were "trapped" in larger micro habitat forming biota such as kelp or sponge. Therefore, this method should not be used to quantify the relative importance of these taxa. Only five individual polychaetes were recorded, that were assigned to only two taxa, this is in contrast with the large diversity of species of polychaetes recorded with the dredge box (21 taxa and 121 individuals). The dredge tow data showed a larger abundance of echinoderms compared to the dredge box. For instance, *Fellaster* was well represented here (total of 38), whereas only 6 were collected in the sand extraction areas with the dredge box. This highlights the necessity to use a range of methods to quantify species presence/absence and abundance when surveying soft sediment habitats.

Both sampling techniques showed statistically significant differences in species distribution by depth, but no statistically significant differences between the extraction areas and the control area.

4.6 Macrofauna Survivorship

The study recorded four species of gastropods, three species of bivalves, two species of crustaceans, and two species of echinoderms, all in varying sizes. Based on the survivorship data collected approximately 60 % of the macro biota passing through the sand extraction dredge, pump, weir and discharge pipes survives with little or no damage, to be returned to the sea surface. There will likely be some predation by fish and birds during the passage from the sea surface to the seabed and prior to reburial in the seabed.

No lethal effects were recorded for gastropods, however some of the larger *Cominella adspersa* showed minor damage. Only the bivalve *Dosinia subrosea* was recorded in sufficient numbers to assess differences in sizes. While the size ranges of clams in the three classes of damage overlapped, the lethal effects appear to be more prevalent in clams of larger sizes. All clams smaller than 18mm survived passage through the dredge but of the clams smaller than 31 mm approximately 73% survived, whereas for clams larger than 31 mm approximately 84% did not survive passage through the dredge. Thus, larger biota was deemed more likely to suffer damage.

More fragile biota such as crustacea and echinoderms were not recorded in sufficient numbers to determine effects, however it is predicted that fragile species like brittle stars will suffer greater rates of damage than hard shell molluscs by passage through the dredge. Similarly, it is expected that fragile species will be more readily predated upon during their return to the seabed.

4.7 Fin fish

Very few surveys have been undertaken in the region of the sand extraction areas. Snapper (*Pagrus auratus*), Red gurnard (*Chelidonichthys kumu*) and Blue cod (*Parapercis colias*) are known to be present further offshore (Bioresearches, 2019) and are likely to occur in the sand extraction area. Grace (2005) reported the presence of Sole (*Peltorhamphus novaezeelandiae*) and Sand divers (*Tewara cranwellae*) in samples passing through the dredge. Pelagic species such as Kahawai (*Arripis trutta*), Kingfish (*Seriola ialandi*), Trevally (*Pseudocaranx dentex*), Skipjack tuna (*Katsuwonus pelamis*) as well as other bottom feeding species such as John dory (*Zeus faber*), Red gurnard (*Chelidonichthys kumu*) and Tarakihi (*Nemadactylus macropterus*) are either known, from fish reported catch or expected to be present all or at some of the time in the sand extraction area at varying abundances. A school of Kingfish were recorded offshore in a depth 27 m along the line of the south Pakiri beach photographic transect. A number of species of sharks are also expected to be present in the sand extraction area at times throughout the year. Bronze whaler (*Carcharhinus brachyurus*) are one such species that can be found from the surf zone to slightly beyond the continental shelf in the open ocean, diving to depths of 100 m or more. This species commonly enters very shallow habitats, including bays, shoals, and harbours, and also inhabits rocky areas such as Te Arai point.

Most fished coastal marine teleost finfish have life histories that can be divided up into spawning/reproduction, eggs and larval periods, a juvenile phase, and an adult phase, when reproductive maturity is reached. The level of knowledge varies greatly across species with snapper and blue cod most heavily studied. The sensitivity to the effects of sand extraction is likely to vary between life stages and fish species. It is also known that many fish species spend their juvenile life stage in more sheltered estuarine habitats meaning juvenile fish are not abundant in the sand extraction area.

Fin fish may be affected by a number of factors related to the operation of the sand dredge; these include;

- noise effects
- entrainment
- sub lethal effects from suspended sediment
- food source reduction.

Underwater noise levels from the dredge are discussed in a separate report (Pine, 2019) and the effects were considered to be less than those for marine mammals. The operation of the sand dredge is not expected to cause injury either permanent or temporary beyond 1 m from the dredge. There is a risk of auditory masking and behavioural effects occurring at a limited range from the sand dredge for fish; however, ranges are substantially smaller than for the marine mammals.

It is not expected that mobile commercial fish will be entrained into the dredge as the water flow will be targeted at sucking sediment up from the seabed and the drag head is designed to sit on the seabed. It is expected that the mobile fish species present will avoid the sand dredged during operation and thus avoid entrainment.

Recent studies have identified that increased suspended solids in the water column is detrimental to juvenile snapper health in estuarine environments (Lowe, 2013). While the research was aimed at the effects of increased terrestrial sediment inputs, the discharge of fine marine sediments could have similar effects. The percentage of fine sediments in the seabed of the sand extraction area is and has been low ranging from 0 – 3 percent. Discharge to the ocean from the dredge vessel occurs in the following two ways:

1. **Discharge of by-wash containing oversized material that is too large to pass through the sand screens to the hopper.** From sampling undertaken as part of the consent investigations, the indicative Total Suspended Sediment (TSS) in this discharge is in the order of 200 mg/L or less. Once discharged the concentration quickly reduces back to ambient conditions in both depth and distance from the discharge point, this is further defined in Gibbs and Kubale (2019).
2. **Discharge over the weir boards as the hopper fills with sand.** Water sampling of the weir board discharge indicated Total Suspended Sediment values of 107 – 196 mg/L, to form part of the overall plume with the by-wash discharge as noted above.

The extent and duration of plumes of elevated suspended solids and turbidity created by the Coastal Carrier are unlikely to adversely affect the fish present.

Benthic biota forms the basis of many fish diets a reduction as a result of sand dredging could potentially impact bottom feeding fish species. The benthic biota collected in sand extraction and control areas does not suggest a decrease in abundance of biota, therefore fish are not expected to be adversely affected through loss of prey. Species present in the benthic biota may have changed over time (Grace, 1991, 2005) but this was not attributed to sand extraction. The discharge of oversized material from the sand dredge, including damaged biota acts as a food source and attracts fish.

While the fish species present or likely to be present are ecologically and economically important the effects of the sand extraction will be no more than minor.

4.8 General Implications of Findings

The combined weight of evidence approach of multiple survey techniques (grab samples, dredge tows and photographic survey) while not sufficient to detect small changes in benthic community structure, has provided sufficient data to assess the broad scale effects of sand extraction. Based on the data collected in and near the sand extraction areas the abundance of benthic biota was low, while diversity was high. There was little difference in diversity and abundance between the sand extraction areas and the Control area, suggesting that the diversity and abundance of benthic biota has not been adversely affected by sand extraction at the scale consented.

Generally, dredging of any kind results in the direct removal of benthic habitat along with infaunal and epifaunal organisms with limited mobility, and results in a reduction in the number of individuals, number of species, and biomass. Observations of the current dredge currently operating have shown that a number of the burrowing animals in the dredge path are not removed through the activity. The depth of sediment removal is not enough to completely excavate the larger burrowing polychaetes, which were observed immediately post dredging actively reburying themselves and within 8 hours those animals resume normal activity and can be found in the dredge track (Figure 4.1).

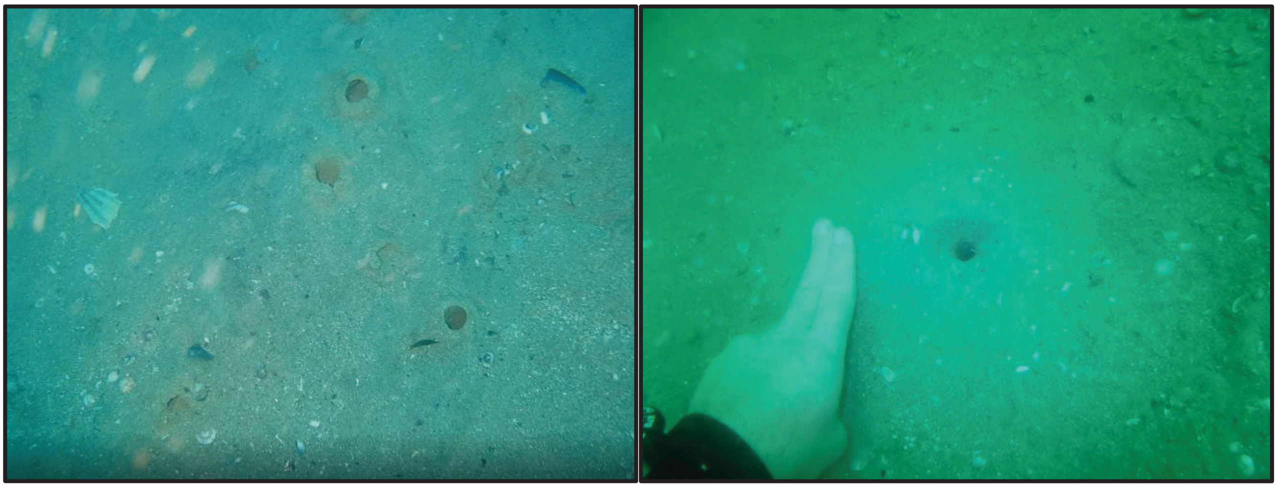

Figure 4.1 Burrowing animals in the dredge path, left immediately following dredge, right 2 days later showing active burrowing.

The benthic community in the sand extraction area is seasonally subjected to the settlement of juvenile biota from planktonic larvae and constantly subjected to the migration of biota from adjacent habitats. The initial step towards recovery of local bottom topography and benthos occurs through slumping and slope re-equilibration of the sides of the dredge depressions (Cooper, *et al*. 2007). Lateral migration of juvenile and adult benthic organisms into the dredged depression may help accelerate recolonisation (Brooks, *et al*. 2004, 2006). The majority of benthic biological recovery occurs through subsequent larval settlement and interactive community development, analogous to recovery from other mass perturbations of seafloor sediments and benthos at these depths where sand extraction occurs.

The balance between the extent and frequency of dredging and the extent and frequency of recolonization will determine the level of effects observed. Since no adverse effects were observed in the abundance and diversity of benthic biota, the current level of sand extraction is within the capacity of the benthic community.

Larger scale natural disturbance events such as extreme storms can result in significant changes in seabed topography, sedimentation, changes in sediment particles size, and loss of species. These events more often than not affect large areas of the seabed making recolonization by lateral spread almost non-existent. Thus, the time taken to recolonise is often much longer. In addition, if larval supply is affected through loss of parent populations or is naturally variable, then the benthic community that re-establishes itself can have a different composition. Historical studies in the general sand extraction area by Hilton (1990) and Grace (1991 and 2005) have shown that some species come and go from the area. The wheel shell is one such example, present in 1990 and 1991, absent in 2005 and present again in 2019.

The very short term and localised turbidity plume associated with the dredging is not likely to have any detectable effects on the phytoplankton production in the dredging areas or adjacent coastal habitat. The duration of the plume not likely to adversely affect fish or seabird populations through reduced feeding efficiency of visual predators like fish and sea birds.

Provided that the sand extraction operation or other factors do not result in an ecologically significant physical change of depth or particle size, then it is expected that continued operation of the dredge at its current rate of sand extraction is not likely to cause ecological effects beyond those observed to date, which are less than minor.

5. ECOLOGICAL VALUES

5.1 Benthic Habitat and Fauna

The seabed habitat in the nearshore of the Pakiri embayment is subject to wave activity and the sandy seabed results in a highly mobile substrate. This habitat is typical of many of the northern New Zealand exposed east coast beaches. The exposed nature of the habitat does not provide protection for sensitive life stages.

The benthic biota data collected in 2019 from the sand extraction area and an adjacent control area recorded the presence of a total of 742 individual animals, from a total of 75 species/taxa identified. The most abundant taxa found in the samples collected were the wheel shell (*Zethalia*), the lancelets (*Epigonichthys*), the clams (*Myadora*), polychaete worms (Maldanidae), the amphipods (Phoxocephalidae and Cirolanidae) and the echinoderm (*Fellaster*).

A multivariate analysis revealed little differences in species composition and abundance along shore, however there were dissimilarities between the shallow and deep groups of samples. These differences were driven by the wheel shell (*Zethalia*) and echinoderms (*Fellaster* and *Amphiura*), which were more abundant in shallow stations; and the clams (*Myadora* and *Dosinia*), polychaetes (Maldanidae and others), and the lancelets (*Epigonichthys*), which were more abundant in deeper stations.

The benthic fauna community in the extraction area is sparse, and there were no shellfish of any ecological or economical consequence in 2019. The biota recorded are typical of the biota found in similar habitat along the coast to the north and south. No invasive species were recorded as present. Based on the sparse populations of biota of nationally and locally common species, with no At Risk species, the benthic biota faunal community is ascribed a classification of low to moderate ecological value. The low ecological value is due to low abundance of nationally and locally common species. While the moderate diversity of 105 taxa and lack of invasive species suggests an ecological value of moderate.

5.2 Fish

Fish are more mobile than the benthic biota therefore a wider area was considered. The fish identified as present within the Pakiri embayment were all typical of the region. These include a number of economically important species such as Snapper, Red gurnard and Blue cod, Kahawai, Kingfish, Trevally, John dory and Tarakihi. None of these species are likely to be directly killed or negatively impacted by the sand extraction process. Many of these species can be found around the dredge while it is in operation and are clearly taking advantage of the opportunity for an easy meal. Therefore, the dredge has a potentially positive affect on fish present in the area providing easier access to food. Based on the sparse populations of fish of nationally and locally common species the fish community is ascribed a classification of low ecological value.

5.3 Summary of Ecological Values

The sand extraction area represents habitat typical of the wider outer Hauraki Gulf and north eastern New Zealand. That is, dynamic, mobile sediments supporting common, opportunistic benthic fauna; and a fish community containing common nearshore species. Less common fish species may pass through the area. However, they are considered to be vagrant and therefore not part of the fish community.

Table 5.1 provides a summary of ecological values for the marine environment using the criteria described in Table 2.1. The values of Birds and Marine Mammals are covered by separate reports.

Table 5.1 Summary of ecological values within the sand extraction area and surrounding areas

Component	Value	Comments
Benthic Fauna	Low - Moderate	Species adapted to the high energy environment. Benthic fauna was sparse but moderately diverse. Benthic community has an ecological function as a food resources for the fish community.
Benthic Habitat	Low	Benthic habitat dominated by mobile substrates typical of the shallow outer Hauraki Gulf area as well as wider north east coast of North Island. The habitat does not provide protection for sensitive life stages.
Fish	Low	Species that frequent the area are locally common, present within the Hauraki Gulf area. Most species widely distributed around New Zealand.

6. ASSESSMENT OF EFFECTS OF SAND EXTRACTION ON ECOLOGY

Jacobs (2019) summarises the sand extraction over the period of the consent. Sand has been extracted from the nearshore of the Mangawhai-Pakiri embayment since post World War 2 to supply Northland-Auckland region with a high-quality sand product that requires minimum processing for use in the concrete industry. The quantities recovered under the Coastal Permits (ARC28165, ARC28172, ARC28173 & ARC28174) between 2003 and 2019 have been supplied by MBL. The data shows a combined total of 677,500 m³ has been from both the inshore areas, with annual volumes extracted ranging from 13,406 m³ in 2014 to 79,250 m³ in 2005.

The comments presented below are based on comparisons of data obtained as part of monitoring of the consented areas and as far as can be deduced from background information available. These effects include:

- changes to benthic biota
- changes in fish community

Marine mammals and birds are addressed in separate reports (Clement & Johnston, 2019).

6.1 Benthic Biota and Macrobenthic Epifauna

Benthic fauna in the extraction area has been noted as sparse as the environment is naturally harsh and there are no shellfish of any consequence.

Grace's 1990 studies and this study, in the near-shore bar found species known for their tolerance of heavy surf just off the beach (Grace, 1991). Species such as; wheel shell *(Zethalia zelandica)*, scale worms *(Sigalion)*, mantis shrimp *(Pterygosquilla armata)*, large pink siphon worm (*Sipunculus maoricus)* showed a consistent occurrence and association with the dominant sand dollar *(Fellaster).* The study (Grace, 1991) noted that wheel shells were at lower densities than that of the Hilton (1990) study.

In 2005 Dr Grace's investigations found no wheel shells or surf clams *(Dosinia anus & Dosinia subrosea)*. However, the sand dollar *Fellaster*, and siphon worm *Sipunculus*, the mantis shrimp *Squilla*, and the scale worm *Sigalion* were still present. In addition, the stink worms (*Travisia olens*) and paddle crab (*Ovalipes catharus*) had increased in numbers (Grace, 2005). The main changes that were identified between the 1990 and 2005 studies was the decrease in species diversity and decrease in abundance in some species. These changes have been attributed to natural variations in recruitment of biota and the naturally harsh environment and were not the result of sand extraction.

In 2019 wheel shells were again found in the shallows, with higher densities inshore of the northern extraction area. The surf clams *Dosina subrosea* were also recorded along the full length of shore. Mantis shrimps (Stomatopoda) have been recorded from the area in all three studies but identified as three different species in the studies.

Unfortunately, the detailed data from the 1990 and 2005 studies, with which statistical analysis may have been possible, were not able to be sourced. However, the main changes between the 2005 and 2019 studies were the reestablishment or redetection, of species perceived to have been absent in 2005 that were previously present in 1990. The biota are likely to suffer from significant inter annual variation in recruitment of juveniles meaning the populations of shellfish such as wheel shells may come and go over time, irrespective of the sand extraction.

Macrofauna survivorship studies showed that as the sand is extracted and macrofauna pass through the dredge prior to return to the seabed via the oversize waste pipe, bivalves are more likely to suffer some shell damage and potential mortality than gastropods. Gastropods are generally more robust and compact than bivalves and by observation suffer less damage by the passage through the dredge. Their abundance was not great enough to determine if it had been greatly affected by the sand extraction activity. Similarly, more fragile species such as echinoderms and polychaete worms will likely be more greatly affected than more robust species such as molluscs. Additionally, predation will have an impact on the survivorship of macrofauna returning to the seabed, the softer bodied polychaetes will likely suffer greater predation on their descent to the seabed by birds and fish than molluscs due to speed of descent.

The generally small crustacea are for the most part short lived and are either predatory or opportunistic feeders. The passage of the smaller crustacea such as amphipods through the sand dredge is not expected to result in significant mortality, given their smaller size and robustness. The disturbance caused by the sand dredge is likely to have created advantageous conditions, through deposition of food in the form of damaged animals like bivalves, echinoderms, polychaetes etc, for such species to thrive on, however no such increased abundance or diversity is seen in the benthic biota data from 2019.

6.2 Fish, Marine Mammals and Birds

No direct assessment has been made of the populations of fish populations prior to and following sand dredging, or in comparison between areas dredged and not dredged. Marine mammals and birds have been the subject of additional reports (Clement & Johnston, 2019). The operation of the sand extraction dredge results in the discharge of oversized material and fine material passing over the sand screen. The discharge of this material creates a plume behind the sand barge, which increases turbidity over a short timescale (Gibbs and Kubale, 2019) and contains whole or fragments of benthic biota (Figure 6.1). During daytime operation it has been observed that birds (Red billed gulls, *Chroicocephalus novaehollandiae scopulinus*) frequent the area of the plume close to the barge foraging for biota fragments (Figure 6.1).

Figure 6.1 Sand barge in operation showing discharge of material, turbid plume and birds foraging.

If the sand extraction operation is to occur during the hours of darkness, then the positive effect to opportunistic visual predators such as the red billed gulls will not occur.

Light is well known to attract a variety of marine birds (Montevecchi, 2016). The adverse attraction to vessel lights by seabirds is considered to be more likely on nights without natural light sources such as the moon and in areas remote from land-based lights (Whitehead *et al*., 2019). That is because the degree of ambient night lighting will be lower. Therefore, the vessel should follow appropriate light minimisation protocols to limit possible pelagic seabird impacts.

Fish may be affected by a number of factors related to the operation of the sand dredge; these include;

- noise effects;
- entrainment;
- sub lethal effects from suspended sediment;
- food source reduction.

Underwater noise levels from the dredge are discussed in a separate report (Pine, 2019) and are not enough to result in significant effects to biota present. It is not expected that mobile fish will be entrained into the dredge as the water flow will be targeted at sucking sediment up from the seabed. The sand dredge moves over the seabed at a speed of 1 – 1.5 knots, thus it is expected that the mobile fish species present will be able to avoid the sand dredged during operation and thus avoid entrainment. Fish species that are slow moving or have behaviours that limit escape or avoidance such as sole (*Peltorhamphus novaezeelandiae*), or live within the sediment such as Sand divers, (*Tewara cranwellae*), both of which have been reported in samples passing through the dredge, and Opalfish, (*Hemerocoetes monopterygius*) or short finned worm eels (*Scolecenchelys australis*) which have been recorded further north and off shore from the sand extraction area may be entrained (Bioresearches, 2016).

Recent studies have identified that increased suspended solids in the water column is detrimental to juvenile snapper health in estuarine environments (Lowe, 2013). While the research was aimed at the effects of increased terrestrial sediment inputs, the discharge of fine marine sediments from the sand barge could have similar effects. However the percentage of fine sediments in the seabed of the sand extraction area is and has been low ranging from 0 – 3 percent meaning the amount of fine discharged from the sand dredge that remains suspended for any significant length of time, will be small and unlikely to adversely affect fish present. Additionally, the Coastal Carrier is currently only operational in the area for periods of approximately 5 hours, after which time the Coastal Carrier under normal operation reaches its load capacity and must return to port for unloading. The William Fraser is expected to be operational in early November 2019 and is expected reduce the time on site to about 2.5 hours. It is expected that the William Fraser will have significantly greater sand extraction efficiency than the Coastal Carrier and retain up to 90% of the sand extracted. Due to the larger capacity of the William Fraser fewer trips per month will be required than with the Coastal Carrier.

As benthic biota forms the basis of many fish diets, a reduction in abundance or a change in species present as a result of sand dredging could potentially impact bottom feeding fish species. The benthic biota collected in the sand extraction area does not show any statistically significant differences in species composition or abundance between the extraction areas and the control site. Therefore, there is not likely to be an adverse effect to bottom feeding fish.

While the fish species present or likely to be present are ecologically and economically important the effects of the sand extraction are expected be no more than minor.

6.3 Effects of the Continuation of Sand Extraction

The effects of sand extraction dredging are summarised in Figure 6.2. Benthic biota will be entrained from the seabed in the path of the dredge head, (Figure 6.3) travel through the dredge head, pump and pipe potentially suffering damage, smaller biota may pass through the screens and be removed with the sand, while larger biota will be returned to the sea via the oversized discharge. This larger biota will likely be in a damaged state and suffer further impact through predation on its return to the seabed. Biota left on the seabed from the path of the dredge head could potentially suffer predation if only partially entrained. Biota in the seabed areas adjacent to the dredge path could suffer temporary minor smothering from the settlement of discharges. The significance of the impact depends on the value or uniqueness of the local community, the susceptibility of the community, the composition of the surficial seabed sediments, the dimensions of the area and the recovery rate of the benthic community.

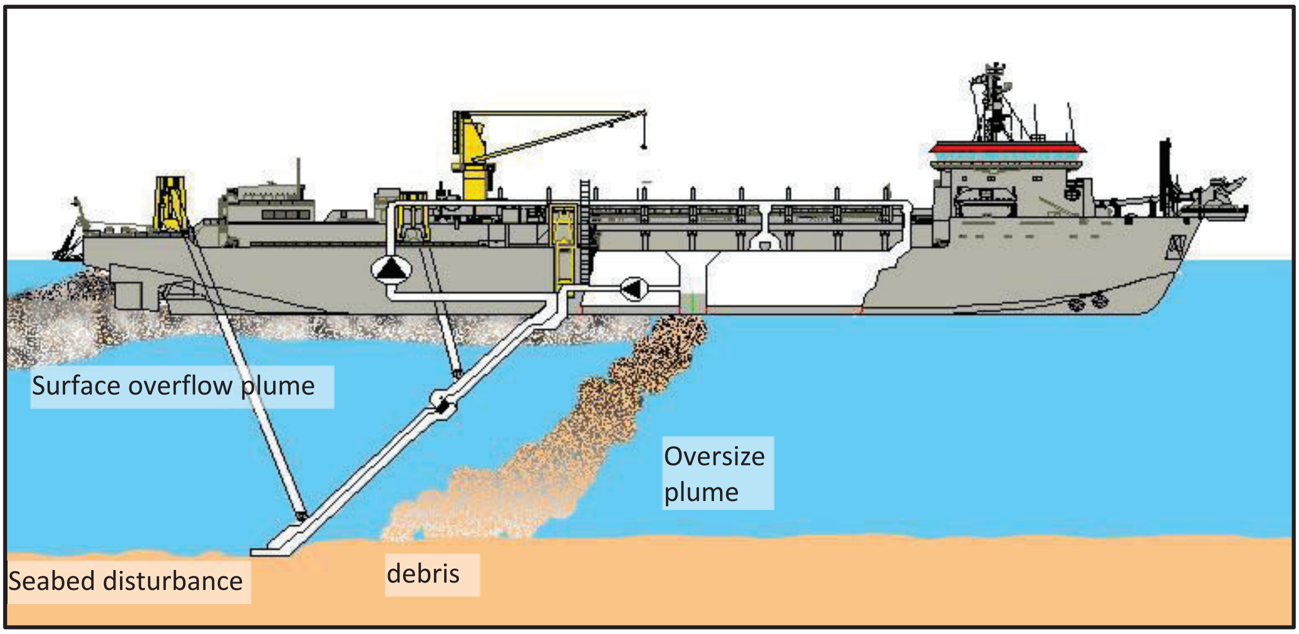

Figure 6.2 Summary of the effects of sand dredging

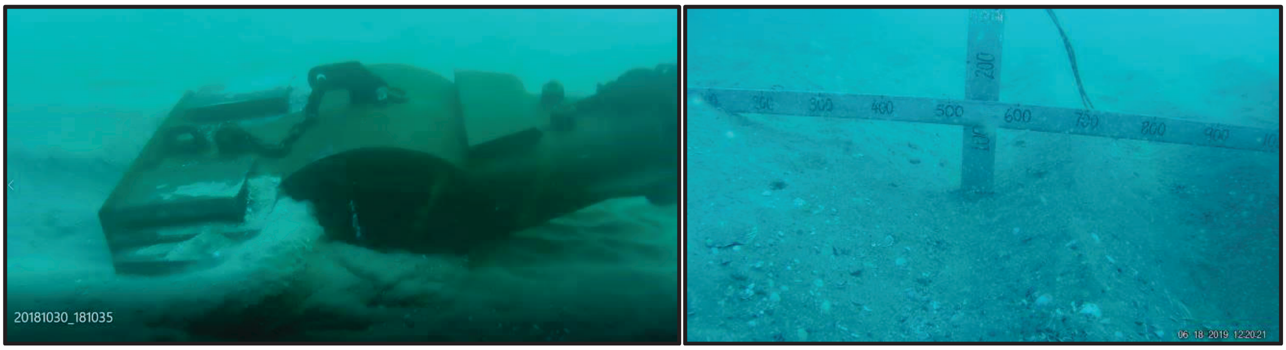

Figure 6.3 Path of dredge head through seabed at Pakiri.

The benthic and near benthic communities of the sand extraction area have been described and are not unique, in that they are common along much of the north eastern coast of the north island. While they have value in that they provide the basis for significant fisheries, the effects to date do not indicate that the benthic communities will be altered to the extent that these fin fisheries will be affected.

The seabed sediment is mostly medium to fine sand with very little silt and clay as shown by the particle size analysis (Table 8.4). There are no sources of chemical contamination in or near the sand extraction area. The sediment quality has been assessed in Gibbs and Kubale (2019) and shown to be devoid of contaminants. Thus, the composition of the seabed sediments will not result in adverse effects if disturbed.

Estimates of the time taken for a benthic community to recover from a disturbance event of the scale of sand dredging is between 6 months to several years (Michel, *et al.*, 2013). This is based on smaller biota with general short life spans re-establishing first from adjacent habitats and those larger species following but taking longer to grow to adult sizes. However, it is noted that not all species inhabiting the seabed are removed by the dredge head. Larger burrowing polychaete worm species have been observed to remain on the seabed after passage of the dredge head and actively rebury themselves. Seasonal timing will also influence the speed of recovery, initially recovery will be by survival and migration from adjacent habitats, and then by reproductive settlement which will be seasonal.

Based on the dimensions of the extraction areas and assuming that dredge trenches are spaced at least 10m apart, the total volume able to be extracted by the 'William Fraser' without re-dredging the same 10m wide trench strip is in the order of 44,500m³ from the northern area and 47,500m³ from the southern area. Therefore, there is capacity within the extraction areas for a trench strip to be dredged no more than once per year. The position fixing and dredge tracking technology of the 'William Fraser' will allow this to be monitored to ensure that trenches have the maximum time to infill by natural sediment transport processes. By comparison, applying the same calculations for the 'Coastal Carrier' results in only a net volume of 20,500m³ being able to be extracted from a single pass over the whole extraction area, hence each trench strip would have to be dredged three or four times each year if the maximum annual extraction volume of 76,000m³ was taken.

Based on this predicted frequency of dredging of once per year it is expected that the benthic communities will have the ability to at least partially recover between dredging events assuming the dredging is spread out over the entire sand extraction area. The wide spacing between dredge runs will ensure maximum recovery is achieved by lateral spread as only 12% of the dredge path as defined above, will actually be dredged.

The dredging strategy of a deeper layer of sediment extracted rather than shallow one will result in a smaller surface area being affected and thus fewer biota will be affected. This is the preferred approach assuming the dredging technology is available and economical. There are also benefits to be gained in increasing the efficiency of sand retention in the barge, thus a smaller area would need to be dredged to obtain the same volume of sand. This would also have the added benefit of increasing the period between re-dredging allowing greater recovery and also likely reduce any water turbidity issues.

6.4 Summary of Ecological Effects

Table 6.1 summarises the magnitude of potential effects associated with the continued sand extraction from the current consented areas.

Table 6.1 Magnitude of potential ecological effects from sand extraction

Effect	Magnitude of Effect	Comments
Water Quality	Minor	The discharge from the current sand vessel increases turbidity in the wake of the vessel for approximately 800 metres during operation. The increased turbidity is short term in duration lasting approximately 22 minutes in any one location. The current dredge operation averages 3-4 hours per barge load.
Fish	Minor	There is potential for minor displacement of fish from the extraction zone, however this is estimated to be within 50 metres of the path of the dredge. The effect is temporary and will reverse with the passing of the dredge as fish will be attracted to the food source created by the oversized discharges. Adjacent non affected habitat is plentiful, sparsely populated and of the same nature as the sand extraction area. The sand extraction area does not represent a large area of important habitat for fish.
Commercial Fishing	Negligible	The continued operation is not expected to impact Commercial fishing above current levels.
Benthic Fauna	Minor	There is potential for minor changes in benthic community structure due to removal of seabed sediments and biota, however the area disturbed is small and narrow allowing spread from adjacent unaffected habitat. Changes in community composition are not expected to be directly attributable to the sand extraction, rather, result from natural phenomena.

6.5 Level of Ecological Effects

Table 6.2 presents the overall assessment of the potential level of ecological effects, based on the matrix shown in Table 2.3. The level of ecological effects are determined by combining the ecological values present in Table 5.1 and the magnitude of potential ecological effects presented in Table 6.1. There is a minor to negligible likelihood of detrimental ecological impacts of the operation of the sand dredge, generally due to the minor magnitude of recorded and potential effects.

Table 6.2 Level of effect incorporating the ecology value and magnitude of effect for the project.

Component	Value	Magnitude	Level
Water Quality	High	Minor	Minor
Benthic Biota	Moderate	Minor	Minor
Fish	Low	Minor	Minor
Commercial Fishing	Low	Negligible	Negligible

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8. APPENDICES

Appendix 1 Sampling Area Positions

Table 8.1 Consented Sand Extraction and Control Area 2019 Benthic Biota, Drop Camera and Sediment particle size Sampling Points (WGS 84 datum)

Longshore Area	Site	World Geodetic System 1984		Depth
		Latitude	Longitude	m
North	PIB01	-36.11882	174.62399	4.9
	PIB04	-36.12337	174.62927	8.5
	PIB05	-36.12737	174.62977	5.8
	PIB10	-36.13230	174.63501	15.9
	PIB11	-36.13625	174.63578	10.1
	PIB18	-36.14124	174.64075	11
	PIB19	-36.14514	174.64179	7.9
	PIB26	-36.14567	174.64640	13.1
	PIB27	-36.15017	174.64649	4.5
	PIB114	-36.14407	174.64122	9.1
South	PIB39	-36.16827	174.65844	2.7
	PIB45	-36.17247	174.66364	7
	PIB46	-36.17667	174.66429	7.7
	PIB53	-36.17690	174.66929	21.1
	PIB54	-36.18141	174.66939	18.7
	PIB61	-36.18584	174.67504	9.7
	PIB62	-36.19034	174.67514	4.8
	PIB67	-36.19026	174.68070	11.3
	PIB68	-36.19477	174.68079	5.8
	PIB109	-36.17907	174.67165	17.2
	PIB111	-36.18078	174.66830	11.8

Longshore Area	Site	World Geodetic System 1984		Depth
		Latitude	Longitude	m
Control	PIB74	-36.19920	174.68645	15
	PIB75	-36.20336	174.68695	6.7
	PIB81	-36.20353	174.69204	11.2
	PIB82	-36.20813	174.69220	6.2
	PIB87	-36.20805	174.69776	11
	PIB88	-36.21256	174.69786	5.5
	PIB93	-36.21248	174.70342	17.5
	PIB94	-36.21646	174.70305	10.7
	PIB100	-36.21360	174.69867	5.7
	PIB105	-36.19930	174.68555	12.2

Table 8.2 Consented Sand Extraction and Control Area 2019 dredge tow sampling points (WGS 84 datum)

Longshore Area	Site	Date	Depth	World Geodetic System 1984				Distance
				Beginning		End		
			(m)	Latitude	Longitude	Latitude	Longitude	(m)
North	22_A	31-Jan-19	10	-36.11272	174.62122	-36.11515	174.62205	281
	23_A	31-Jan-19	10	-36.13835	174.63808	-36.13657	174.63595	277
	24_A	31-Jan-19	10	-36.15038	174.64718	-36.15248	174.64718	233
	35_A	31-Jan-19	5	-36.11767	174.62208	-36.11555	174.62205	234
	34_A	15-Apr-19	5	-36.13685	174.63420	-36.13467	174.63202	315
	33_A	15-Apr-19	5	-36.15007	174.64383	-36.14755	174.64177	336
South	25_A	31-Jan-19	10	-36.17133	174.66140	-36.16993	174.65892	272
	26_A	14-Feb-19	10	-36.17795	174.66632	-36.18002	174.66807	279
	27_A	14-Feb-19	10	-36.19013	174.67655	-36.18863	174.67482	228
	32_A	15-Apr-19	5	-36.16922	174.65668	-36.16652	174.65580	319
	31_A	15-Apr-19	5	-36.18452	174.66947	-36.18245	174.66780	270
	30_A	15-Apr-19	5	-36.19305	174.67640	-36.19060	174.67510	296
Control	28_A	14-Feb-19	10	-36.20552	174.69183	-36.20387	174.68990	254
	29_A	15-Apr-19	5	-36.20757	174.69118	-36.20920	174.69345	274

Table 8.3 Consented Sand Extraction Area 2019 Macrofauna Survivorship sampling points (WGS 84 datum)

Depth	Site	World Geodetic System 1984	
		Latitude	Longitude
5 m	5A	-36.19624	174.68164
	5B	-36.19516	174.68046
	5C	-36.19400	174.67941
	5D	-36.19161	174.67703
	5E	-36.19048	174.67608

Depth	Site	World Geodetic System 1984	
		Latitude	Longitude
10 m	10A	-36.18026	174.66890
	10B	-36.18368	174.67178
	10C	-36.18597	174.67390
	10D	-36.19025	174.67804
	10E	-36.19239	174.68008

Appendix 2 Particle Size Results

Table 8.4 Summary Sediment Particle Size Data 2019 (Percentage by Weight)

Area	Site	Depth (m)	Size class (mm)									Fineness Modulus	Characterization
			Gravel		Very Coarse sand	Coarse sand	Medium sand		Fine sand	Very fine sand	Silt and Clay		
			>4.75	4.75 - 2.36	2.36 - 1.18	1.18 - 0.6	0.6 - 0.43	0.43 - 0.3	0.3 - 0.15	0.15 - 0.08	<0.075		
Control	BD75	6.7	0	0	2	5	7	14	59	13	0	1.26	S
	BD82	6.2	0	0	3	9	8	20	54	6	0	1.51	S
	BD88	5.5	0	0	2	1	2	10	71	14	0	1.07	S
	BD94	10.7	0	0	1	1	4	22	59	13	0	1.15	S
	BD100	5.7	0	0	2	5	7	16	60	10	0	1.27	S
	BD74	15.0	0	0	2	6	23	33	32	4	0	1.54	S
	BD81	11.2	0	0	2	2	2	13	62	19	0	1.07	S
	BD87	11.0	0	0	0	1	1	7	80	11	0	0.98	S
	BD93	17.5	0	0	0	2	11	35	48	4	0	1.36	S
	BD105	12.2	0	0	1	1	4	10	66	18	0	1.01	S
Inshore average		**7.0**	**0**	**0**	**2.0**	**4.2**	**5.6**	**16.4**	**60.6**	**11.2**	**0**	**1.25**	**S**
Offshore average		**13.4**	**0**	**0**	**1.0**	**2.4**	**8.2**	**19.6**	**57.6**	**11.2**	**0**	**1.19**	**S**
Northern	BD1	4.9	0	0	0	1	2	7	77	13	0	0.98	S
	BD5	5.8	0	0	8	21	10	10	43	8	0	1.99	S
	BD11	10.1	0	0	2	1	4	10	63	20	0	1.01	S
	BD19	7.9	0	0	5	10	16	20	42	7	0	1.64	S
	BD27	4.5	0	0	1	1	3	7	73	15	0	1.00	S
	BD114	9.1	0	0	2	3	5	17	59	14	0	1.20	S
	BD4	8.5	0	0	4	6	6	18	55	11	0	1.40	S
	BD10	15.9	0	0	0	1	9	47	38	5	0	1.44	S
	BD18	11.0	0	0	1	1	2	10	69	17	0	0.98	S
	BD26	13.1	0	0	1	0	3	8	70	18	0	0.95	S
Inshore average		**7.1**	**0**	**0**	**3.8**	**8.3**	**8.0**	**11.8**	**56.3**	**12.0**	**0**	**1.41**	**S**
Offshore average		**12.1**	**0**	**0**	**1.5**	**2.0**	**4.7**	**17.8**	**60.7**	**13.3**	**0**	**1.16**	**S**
Southern	BD39	2.7	0	0	0	1	3	25	67	4	0	1.23	S
	BD46	7.7	0	0	2	5	7	23	55	8	0	1.37	S
	BD54	18.7	0	0	0	1	2	23	64	10	0	1.16	S
	BD62	4.8	0	0	0	1	4	19	68	8	0	1.15	S
	BD68	5.8	0	0	1	2	7	22	58	10	0	1.21	S
	BD111	11.8	0	0	2	2	3	12	64	17	0	1.09	S
	BD45	7.0	0	0	3	12	15	21	43	6	0	1.65	S
	BD53	21.1	0	0	0	3	19	47	29	2	0	1.55	S
	BD61	9.7	0	0	1	1	2	9	69	18	0	0.98	S
	BD109	17.2	0	0	1	0	6	25	59	9	0	1.21	S
Inshore average		**8.6**	**0**	**0**	**0.8**	**2.0**	**4.3**	**20.7**	**62.7**	**9.5**	**0**	**1.20**	**S**
Offshore average		**13.8**	**0**	**0**	**1.3**	**4.0**	**10.5**	**25.5**	**50.0**	**8.8**	**0**	**1.35**	**S**

Appendix 3 Drop Camera Images

Northern Boundary Pakiri Beach

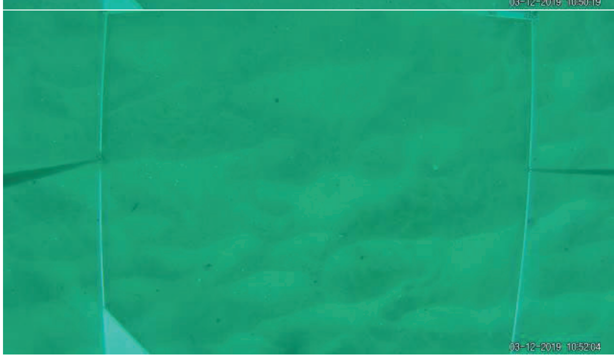
25 NP 5.1m

26 SP 6.1m

27 SP 7.3m

28 SP 8.2m

29 SP 9.0 m



Southern Boundary Pakiri Beach

1 SP 5.1m

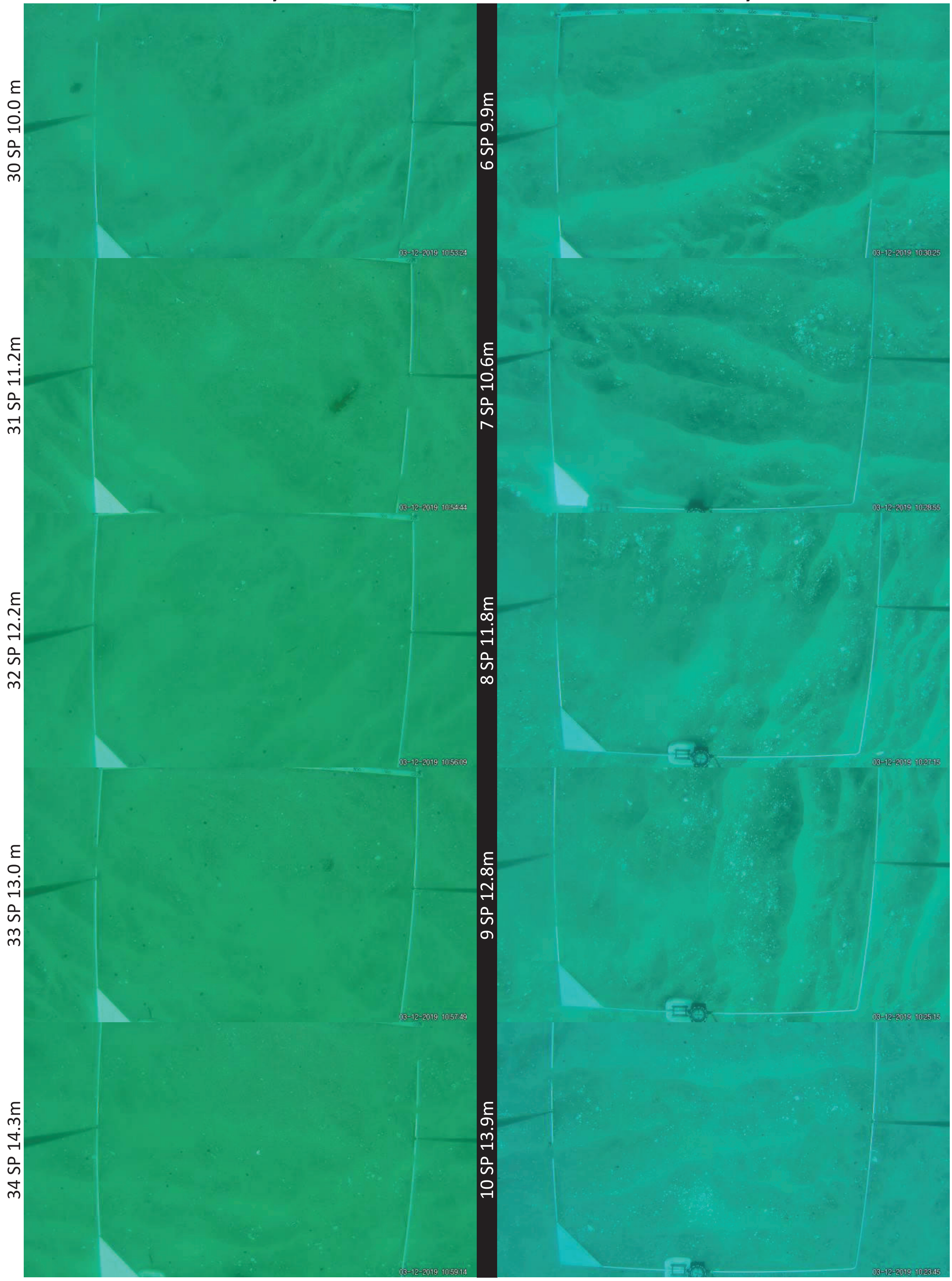
2 SP 5.9m

3 SP 6.9m

4 SP 8.0 m

5 SP 9.0 m

Northern Boundary Pakiri Beach | **Southern Boundary Pakiri Beach**



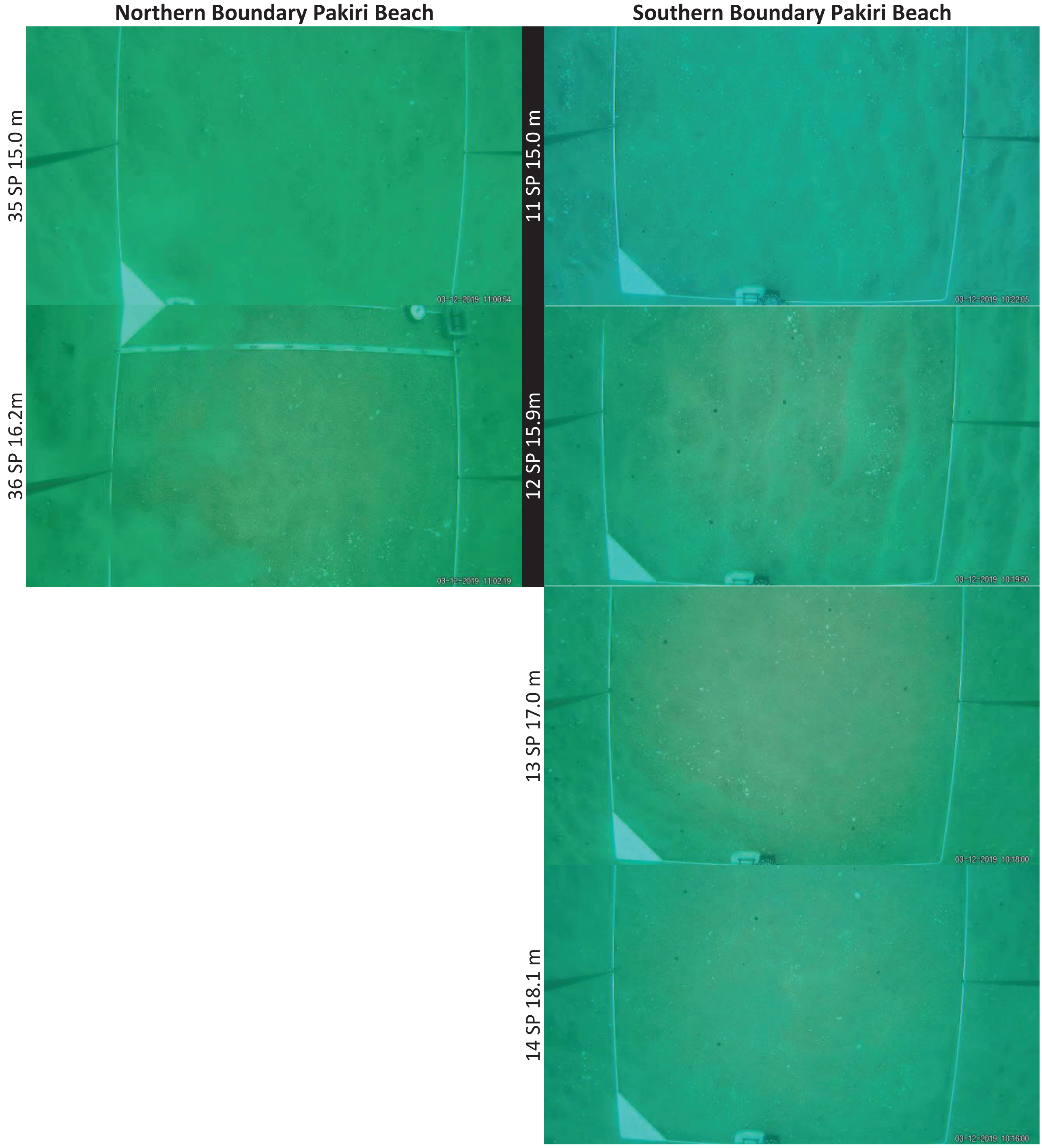


Figure 8.1 Drop Camera images from Southern area Pakiri Beach, March 2019. *(white photo Id indicates inside consented sand extraction area)*

Northern Boundary Te Arai Beach

97 NTA 5.3m

98 NTA 6.2m

99 NTA 7.0 m

100 NTA 8.0 m

101 NTA 9.0 m

Southern Boundary Te Arai Beach

71 STA 5.0 m

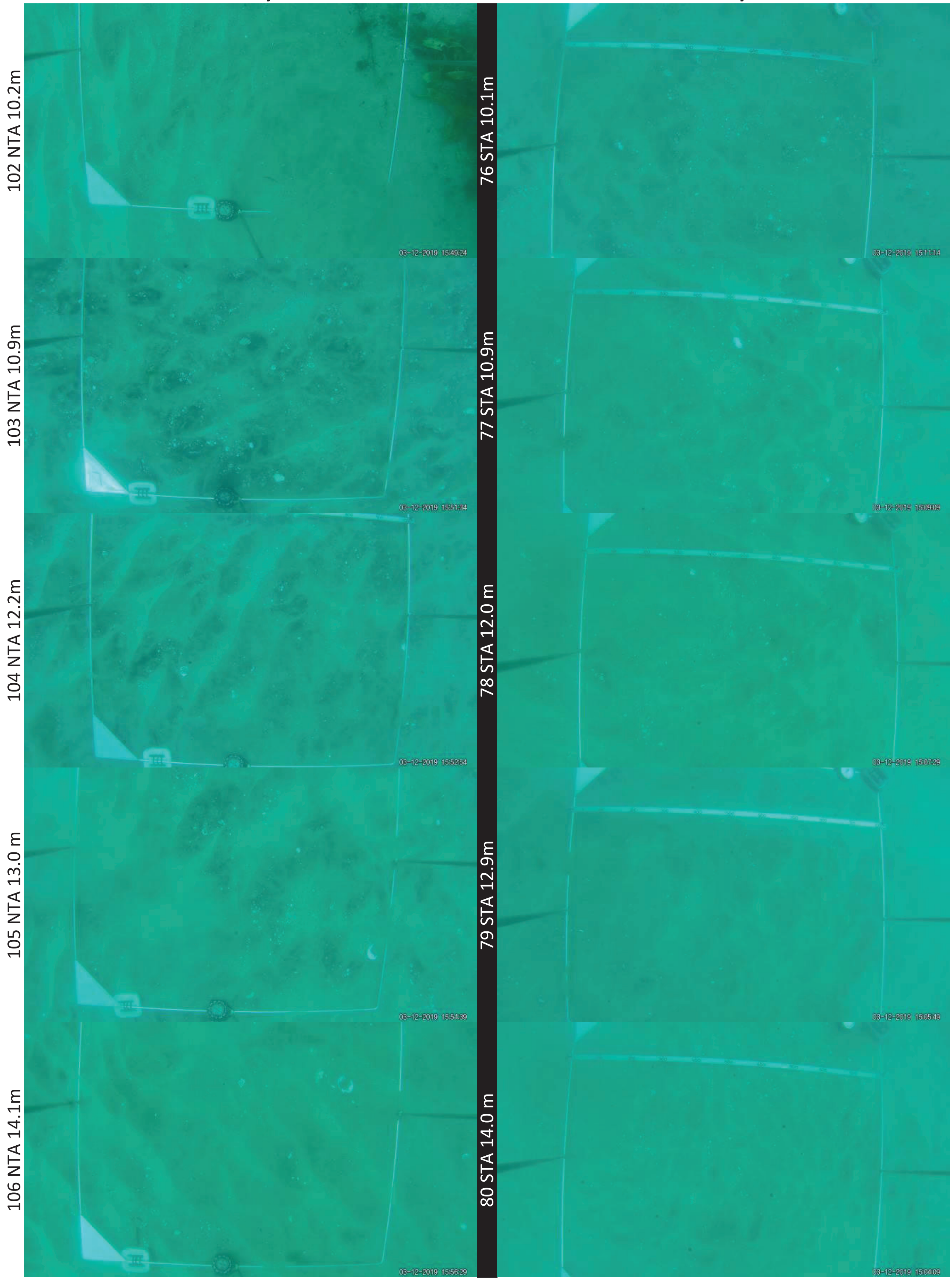
72 STA 6.1m

73 STA 7.2m

74 STA 7.8m

75 STA 9.1m

Northern Boundary Te Arai Beach | **Southern Boundary Te Arai Beach**



Northern Boundary Te Arai Beach | **Southern Boundary Te Arai Beach**

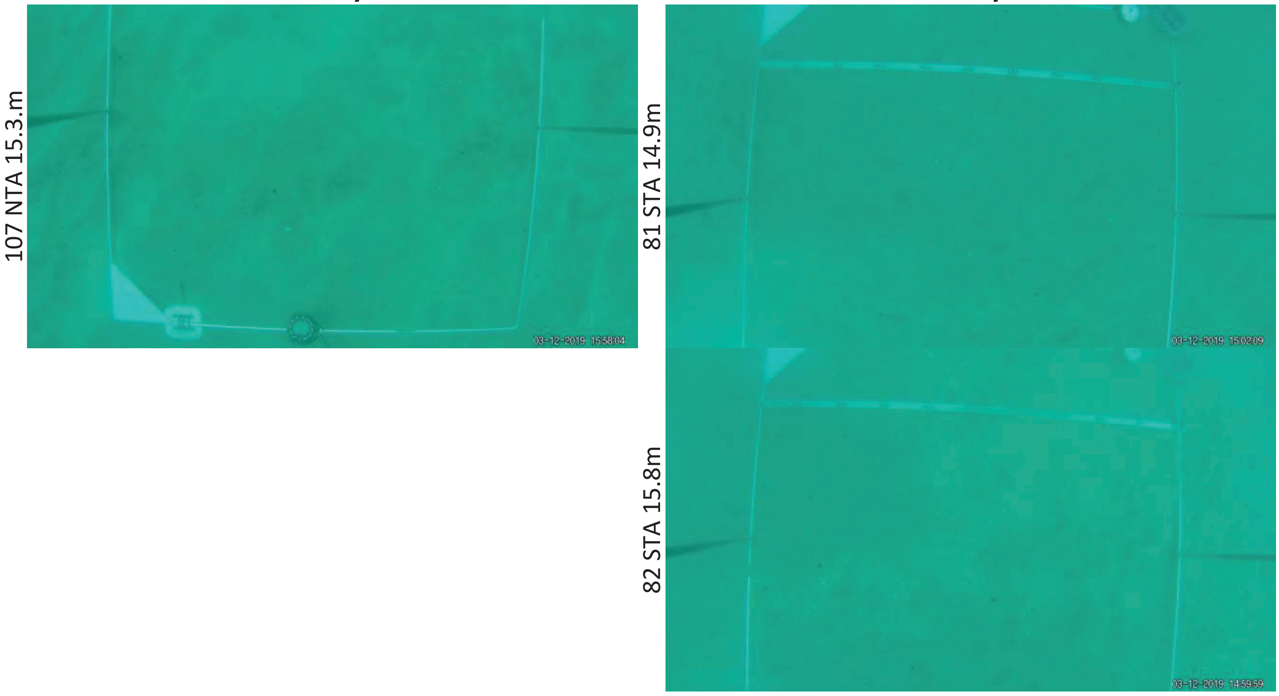


Figure 8.2 Drop Camera images from Northern Area Te Arai Beach, March 2019. *(white photo Id indicates inside consented sand extraction area)*

***Table 8.5 Seabed photography summary descriptions, 2019.** (white indicates inside consented sand extraction area, grey indicates similar area but not dredged)*

Photo ID	World Geodetic System 1984		Depth	Date	Comments		
	Latitude	Longitude	(m)		Substrate	Ripples	Biota
South Pakiri Beach							
1 SP 5.1	-36.193467	174.676167	5.1	12 Mar 19	sand 100%	irregular small	burrows
2 SP 5.9	-36.193367	174.676567	5.9	12 Mar 19	sand 100%	small aligned	
3 SP 6.9	-36.193067	174.676817	6.9	12 Mar 19	sand 98%, shell debris 2%	medium aligned	burrows
4 SP 8	-36.193050	174.677250	8.0	12 Mar 19	sand 95%, shell debris 5%	medium aligned	burrows
5 SP 9	-36.192783	174.677900	9.0	12 Mar 19	sand 90%, shell debris 10%	medium aligned	
6 SP 9.9	-36.192567	174.678083	9.9	12 Mar 19	sand 95%, shell debris 5%	large with small sub-ripples	
7 SP 10.6	-36.192350	174.678433	10.6	12 Mar 19	sand 95%, shell debris 5%	large	
8 SP 11.8	-36.192117	174.678933	11.8	12 Mar 19	sand 90%, shell debris 10%	medium aligned	burrows
9 SP 12.8	-36.191900	174.679233	12.8	12 Mar 19	sand 90%, shell debris 10%	large aligned	burrows
10 SP 13.9	-36.191600	174.679700	13.9	12 Mar 19	sand 95%, shell debris 5%	large smooth	burrows common, C. adspersa
11 SP 15	-36.191317	174.680033	15.0	12 Mar 19	sand 95%, shell debris 5%	medium flat	burrows
12 SP 15.9	-36.191150	174.680300	15.9	12 Mar 19	sand 95%, shell debris 5%	medium flat	burrows large
13 SP 17	-36.190883	174.680733	17.0	12 Mar 19	sand 98%, shell debris 2%	none	burrows large
14 SP 18.1	-36.190600	174.681200	18.1	12 Mar 19	sand 98%, shell debris 2%	none	burrows large
North Pakiri Beach							
25 NP 5.1	-36.167683	174.655367	5.1	12 Mar 19	sand 100%	irregular small	
26 NP 6.1	-36.167367	174.655833	6.1	12 Mar 19	sand 100%	small aligned	
27 NP 7.3	-36.167067	174.656233	7.3	12 Mar 19	sand 100%	medium aligned	
28 NP 8.2	-36.166850	174.656417	8.2	12 Mar 19	sand 100%	medium irregular	
29 NP 9.0	-36.166533	174.656850	9.0	12 Mar 19	sand 100%	medium irregular	burrows
30 NP 10.0	-36.166117	174.657350	10.0	12 Mar 19	sand 98%, shell debris 2%	large with small sub-ripples	burrows
31 NP 11.2	-36.165733	174.657917	11.2	12 Mar 19	sand 98%, shell debris 2%	large flat	
32 NP 12.2	-36.165433	174.658417	12.2	12 Mar 19	sand 98%, shell debris 2%	large flat	burrows
33 NP 13.0	-36.164967	174.658883	13.0	12 Mar 19	sand 98%, shell debris 2%	large flat	burrows large
34 NP 14.3	-36.164700	174.659317	14.3	12 Mar 19	sand 98%, shell debris 2%	large flat	burrows
35 NP 15.0	-36.164283	174.659750	15.0	12 Mar 19	sand 98%, shell debris 2%	large flat	burrows
36 NP 16.2	-36.163850	174.660400	16.2	12 Mar 19	sand 95%, shell debris 5%	none	burrows

Photo ID	World Geodetic System 1984		Depth	Date	Comments		
	Latitude	Longitude	(m)		Substrate	Ripples	Biota
South Te Arai Beach							
71 STA 5	-36.150683	174.644383	5.0	12 Mar 19	sand 98%, shell debris 2%	irregular	
72 STA 6.1	-36.150500	174.644633	6.1	12 Mar 19	sand 100%	irregular	
73 STA 7.2	-36.150417	174.645017	7.2	12 Mar 19	sand 100%	irregular medium	
74 STA 7.8	-36.150217	174.645317	7.8	12 Mar 19	sand 98%, shell debris 2%	irregular medium	
75 STA 9.1	-36.149883	174.645700	9.1	12 Mar 19	sand 98%, shell debris 2%	irregular medium	
76 STA 10.1	-36.149683	174.646133	10.1	12 Mar 19	sand 95%, shell debris 5%	irregular medium flat	
77 STA 10.9	-36.149567	174.646500	10.9	12 Mar 19	sand 98%, shell debris 2%	irregular medium flat	burrows
78 STA 12	-36.149450	174.646983	12.0	12 Mar 19	sand 98%, shell debris 2%	irregular medium flat	burrows
79 STA 12.9	-36.148950	174.647400	12.9	12 Mar 19	sand 100%	large flat	burrows
80 STA 14	-36.148767	174.647750	14.0	12 Mar 19	sand 98%, shell debris 2%	irregular small flat	burrows large
81 STA 14.9	-36.148433	174.648233	14.9	12 Mar 19	sand 100%	none	burrows
82 STA 15.8	-36.148283	174.648833	15.8	12 Mar 19	sand 100%	none	burrows
North Te Arai Beach							
97 NTA 5.3	-36.110350	174.616550	5.3	12 Mar 19	sand 100%	irregular small	
98 NTA 6.2	-36.110167	174.616900	6.2	12 Mar 19	sand 100%	irregular small	
99 NTA 7.0	-36.110050	174.617300	7.0	12 Mar 19	sand 100%	irregular small	
100 NTA 8.0	-36.110117	174.617800	8.0	12 Mar 19	Sand 85%, Shell debris 5%, rock 10%	medium	
101 NTA 9.0	-36.109900	174.618633	9.0	12 Mar 19	sand 100%	medium irregular	
102 NTA 10.2	-36.109783	174.619050	10.2	12 Mar 19	sand 100%	medium irregular	
103 NTA 10.9	-36.109667	174.619583	10.9	12 Mar 19	sand 90%, shell debris 10%	medium	burrows
104 NTA 12.2	-36.109533	174.620233	12.2	12 Mar 19	sand 98%, shell debris 2%	medium	burrows
105 NTA 13.0	-36.109367	174.620783	13.0	12 Mar 19	sand 95%, shell debris 5%	medium	burrows
106 NTA 14.1	-36.109300	174.621450	14.1	12 Mar 19	sand 95%, shell debris 5%	medium	burrows
107 NTA 15.3	-36.109133	174.622133	15.3	12 Mar 19	sand 100%	medium flat	burrows

Appendix 4 Benthic Biota results

Table 8.6 Benthic Biota Retained in 1 mm screen samples, 2019 (Number per sample).

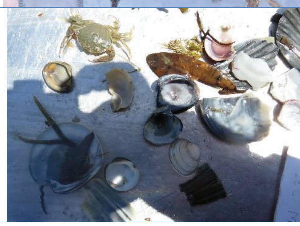
Taxa / Area	Control										North										South									
Site number	75	82	88	94	100	74	81	87	93	105	1	5	11	19	27	114	4	10	18	26	39	46	54	62	68	111	45	53	61	109
Depth (m)	7	6	5	11	6	15	11	11	17	12	5	6	10	8	4	9	8	16	11	13	3	8	19	5	6	12	7	21	10	17
Phylum Annelida																														
Class Polychaeta																														
Paraprionospio pinnata							7																1							
Cirratulidae																		2												
? *Aglaophamus/Nephtys*										1																				
Phyllodocidae																														1
Magelona cf. *dakini*																							2			1				
Capitellidae																		1												
Armandia cf. maculata							1						2										2					2		1
Maldanidae						1	1													2								3		2
? *Aricidea* sp.																										1				
Scalibregmatidae							1																							
Polychaeta undet.	1		1																	2				1				1		
Phylum Nemertea																														
Nemertea										1																1				
Phylum Arthropoda																														
Class Malacostraca																														
Order Amphipoda																														
Gammaridea undet.			1			1															2		1					1		
Lysianassidae																												4		
Phoxocephalidae sp. 1			4	1			2		2				2				1		1							3		1		
Phoxocephalidae sp. 2								1	2																					
Phoxocephalidae sp. 3							1											1		1										
Haustoriidae				1			3		1									2								1		2		
Liljeborgiidae										1									1											
Order Cumacea																														
Cyclaspis elegans																		2		1										
Cyclaspis cf. levis				1												1		1		1										
Order Decapoda																														
Paguridae			1																											
Order Isopoda																														
Sphaeromatidae sp. 1																	3			2										
Paranthura sp.																			1											
Cirolanidae sp. 1				1			1			3			1					1		1						1				
Cirolanidae sp. 2			1																											
Order Mysida																														
Tenagomysis spp.			1	1															1							1				
Phylum Mollusca																														
Class Gastropoda																														
Zethalia zelandica											6	2			20									2						
Antisolarium egenum									1																					
Maoricolpus roseus			1																											
Epitonium jukesianum				1																										
Amalda depressa										1																				
Turbonilla sp.																						1								
Class Bivalvia																														
Nucula nitidula						1				1																		1		
Hiatula nitida																													1	
Tawera spissa							1																							
Myadora boltoni																			1	1										
Myadora striata																												1		
Phylum Echinodermata																														
Class Ophiuroidea																														
Amphiura aster								1																		1				
Phylum Chordata																														
Class Leptocardii																														
Epigonichthys hectori			7				3													1			1			1		3		
Class Actinopterygii																														
Limnichthys polyactis													1																	
Number of Species / taxa	1	0	8	6	0	3	10	2	4	6	1	1	4	0	1	1	2	7	5	9	1	1	5	2	0	9	0	10	1	3
Number of Individuals	1	0	17	6	0	3	21	2	6	8	6	2	6	0	20	1	4	10	5	12	2	1	7	3	0	11	0	19	1	4
Shannon - Wiener Diversity Index	0.00	0.00	1.71	1.79	0.00	1.10	2.02	0.69	1.33	1.67	0.00	0.00	1.33	0.00	0.00	0.00	0.56	1.89	1.61	2.14	0.00	0.00	1.55	0.64	0.00	2.10	0.00	2.16	0.00	1.04

Table 8.7 Benthic Biota Retained in 3.15 mm screen samples, 2019 (Number per sample).

Taxa / Area	Control										North										South									
Sample number	75	82	88	94	100	74	81	87	93	105	1	5	11	19	27	114	4	10	18	26	39	46	54	62	68	111	45	53	61	109
Depth (m)	7	6	5	11	6	15	11	11	17	12	5	6	10	8	4	9	8	16	11	13	3	8	19	5	6	12	7	21	10	17
Phylum Annelida																														
Class Polychaeta																														
? *Prionospio* sp.												1																		
Paraprionospio pinnata							4					1	1																	
Cirratulidae																				1				1						
Lumbrineris sp.										2																1			1	
Onuphidae							1																					1		
Nephtyidae	1																	1												
? *Aglaophamus/Nephtys*									1																					
Nereididae																						1								
Phyllodocidae																				1										
Polynoidae																					1									
Sigalionidae					1									1																
Magelona cf. *dakini*													1						1										1	
Capitellidae						1																								
Armandia cf. maculata			1																											
Maldanidae						1	4		1									5										1	2	3
Travisia olens										1																				
Polychaeta undet.																														1
Polychaeta undet.						3							1							7							1			
Annelida undet.														2												2				
Phylum Nemertea																														
Nemertea																										1				1
Phylum Arthropoda																														
Order Amphipoda																														
Gammaridea sp. 5																			1											
Phoxocephalidae sp. 1							1					3																	1	
Haustoriidae							1																							
Order Cumacea																														
Cyclaspis cf. levis														1													1			
Order Decapoda																														
Ovalipes catharus			1																								1			
Anomura				1		1									1								1					1		
Paguridae			1				1																							
Paguristes setosus						1																				1		1		
Order Isopoda																														
Sphaeromatidae sp. 1																			1											
Cirolanidae sp. 1							2					3	1				1		2										1	
Order Mysida																														
Tenagomysis spp.														2			1													
Tenagomysis producta							1																							
Order Stomatopoda																														
Pariliacantha georgeorum																1			1								1		1	
Phylum Mollusca																														
Class Gastropoda																														
Zethalia zelandica											30	42		1	204						4			15						
Maoricolpus roseus			1																											
Striacolpus pagoda																											1			
Sigapatella tenuis																				3										
Semicassis pyrum (juvenile)									1																					
Cominella adspersa			1															1												
Cominella quoyana																														1
Amalda australis										2			2											1						
Amalda depressa								1																			1			
Amalda novaezelandiae																									1					
Class Bivalvia																														
Nucula nitidula						5														1								2		
Athritica bifurca						1																								
Gari stangeri																		1												
Hiatula nitida											1								1	1										
Zemysina globus																		1												
Tawera spissa																							1			1				
Dosinia subrosea				1		1								1		2			1							1			1	
Myadora boltoni			1				2			1			1					3	1	4			11			2		6		
Myadora striata			1				4												1	2			5					3	2	
Myadora subrostrata										1																				
Bivalvia undet.										1																				
Phylum Echinodermata																														
Class Ophiuroidea																														
Amphiura aster		1			2			1		1					1														1	
Class Echinoidea																														
Fellaster zelandiae	1	1			1			7													1			3	2					
Phylum Nematoda																													1	
Phylum Foraminifera							3																							
Phylum Chordata																														
Class Thaliacea																														
Salpida				1																										
Class Leptocardii																														
Epigonichthys hectori			10			1	13						1	1		1				1			1			9				
Class Actinopterygii																														
Limnichthys polyactis		1											1								1		1							
Number of Species / taxa	2	3	8	3	3	9	12	3	3	7	2	5	8	7	3	3	2	6	9	9	4	1	6	4	2	8	6	7	10	4
Number of Individuals	2	3	17	3	4	15	37	9	3	9	31	50	9	9	206	4	2	12	10	21	7	1	20	20	3	18	6	15	12	6
Shannon - Wiener Diversity Index	0.69	1.10	1.48	1.10	1.04	1.95	2.10	0.68	1.10	1.89	0.14	0.64	2.04	1.89	0.06	1.04	0.69	1.54	2.16	1.91	1.15	0.00	1.27	0.80	0.64	1.64	1.79	1.68	2.25	1.24

Table 8.8 Epibenthic Macrofauna Retrieved in Dredge Tows, 2019.

Area	Depth	Tow Number	Date	Distance m	Area m²	Common Name	Scientific Name	Size mm				Density x	/100 m²	Comments	Photo
Control	5 m	29	15 Apr 2019	274	178.1	Polychaete		30 to 65				2	1.12		
						Paddle Crab	*Ovalipes catharus*	15				1	0.56		
						Silky Dosinia	*Dosinia subrosea*	40				1	0.56		
						Myadora	*Myadora striata*	20				1	0.56		
						Speckled Whelk	*Cominella adspersa*	35				1	0.56		
						Sand Dollar	*Fellaster zelandiae*	15	20	20		3	1.68		
						Brittle Star - arms	Ophiuroidea	80				1	0.56		
	10 m	28	14 Feb 2019	254	165.1	Spiny Starfish	*Astropecten polyacanthus*	130				1	0.61		
North	5 m	35	31 Jan 2019	234	152.1	Paddle Crab	*Ovalipes catharus*	30				1	0.66		
						Sand Dollar	*Fellaster zelandiae*	60				1	0.66		
		34	15 Apr 2019	315	204.75	Isopod (with Kelp)	*Euidotea peronii*					1	0.49	Kelp dweller	
						Amphipod (with kelp)	Gammaridea	5 to 10				5	2.44	Kelp dweller	
						Hermit Crab	Paguridae	15	25			2	0.98		
						Cartwright Shell	*Dicathais orbita*	15				1	0.49		
						Sand Dollar	*Fellaster zelandiae*	35 to 70				19	9.28	Lots of Seaweed present	
		33	15 Apr 2019	336	218.4	Paddle Crab	*Ovalipes catharus*	30				1	0.46		

Area	Depth	Tow Number	Date	Distance	Area	Common Name	Scientific Name	Size				Density		Comments	Photo
				m	m²			mm				x	/100 m²		
						Hermit Crab	Paguridae	15				1	0.46		
						Dosinia	*Dosinia subrosea*	25				1	0.46	Lots of Shell Hash	
						Olive Shell	*Amalda (B.) australis*	30				1	0.46		
						Wheel shell	*Zethalia zelandica*	5 to 15				7	3.21		
						Sand Dollar	*Fellaster zelandiae*	50 to 60				8	3.66		
		22	31 Jan 2019	281	182.65	Nemertean (black)	Nemertea	70				1	0.55		
						Spiny Starfish (arm)	*Astropecten polyacanthus*					1	0.55	Shell Hash	
	10 m	23	31 Jan 2019	277	180.05	Paddle Crab	*Ovalipes catharus*	20				1	0.56		
						Limpet (on shell)	*Sigapatella tenuis*	5				1	0.56		
		24	31 Jan 2019	233	151.45	Nothing in Tow									
South	5 m	32	15 Apr 2019	319	207.35	Bamboo Worm	*Maldanidae*	40				1	0.48		
						Isopod (with Kelp)	*Euidotea peronii*	25				1	0.48		
						Amphipod (with kelp)	Gammaridea	10				2	0.96		
						Hermit Crab	Paguridae	20	20			2	0.96		
						Dosinia	*Dosinia subrosea*	20	25			2	0.96		
						Olive Shell	*Amalda (B.) australis*	30				1	0.48		
						Speckled Whelk	*Cominella adspersa*	35	45			2	0.96		
						Sand Dollar	*Fellaster zelandiae*	15				1	0.48		
						Brittle Star	Ophiuroidea	60				1	0.48		
						Ulva Branches						2	0.96	Seaweed	
		31	15 Apr 2019	270	175.5	Polychaete Tube		70				1	0.57	Empty tube	

Area	Depth	Tow Number	Date	Distance m	Area m²	Common Name	Scientific Name	Size mm				Density x	/100 m²	Comments	Photo
						Hermit Crab	Paguridae	10				1	0.57		
						Silky Dosinia	*Dosinia subrosea*	35	45			2	1.14		
						Myadora	*Myadora striata*	35				1	0.57		
						Sand Dollar	*Fellaster zelandiae*	15				1	0.57		
						Brittle Star	Ophiuroidea	100				1	0.57		
		30	15 Apr 2019	296	192.4	Dosinia	*Dosinia subrosea*	30	30			2	1.04		
						Sand Dollar	*Fellaster zelandiae*	20	20	70	70	4	2.08		
		25	31 Jan 2019	272	176.8	Bamboo Worm	Maldanidae	30	60			1	0.57		
						Paddle Crab	*Ovalipes catharus*	20	20	30		3	1.70		
						Hermit Crab	Paguridae	10				1	0.57		
						Speckled Whelk	*Cominella adspersa*	30				1	0.57		
		26	14 Feb 2019	279	181.35	Hermit Crab	Paguridae	30				6	3.31		
	10 m					Speckled Whelk	*Cominella adspersa*	30				1	0.55		
						Spiny Starfish	*Astropecten polyacanthus*	100 to 200				7	3.86		

Area	Depth	Tow Number	Date	Distance	Area	Common Name	Scientific Name	Size	Density		Comments	Photo
				m	m²			mm	x	/100 m²		
		27	14 Feb 2019	228	148.2	Spiny Starfish	*Astropecten polyacanthus*	10	1	0.67		
						Sand Dollar	*Fellaster zelandiae*	50	1	0.67		

Appendix 5 Macrofauna Survivorship

Table 8.9 Numbers of Macrofauna passing through the dredge sorted by site and degree of damage, May 2019.

Depth	Site	Species	Damage		
			None	Sub Lethal	Lethal
5 m	5A	*Dosinia subrosea*	8		5
		Zethalia zelandica	2		
		Dosinia anus	1		
	5B	*Dosinia subrosea*	6	3	3
		Ovalipes catharus	1		
	5C	*Dosinia subrosea*	2		4
		shrimp	1		
	5D	*Amalda australis*	1		
		Dosinia subrosea	2		
		Dosinia anus	3	1	
		Fellaster zelandiae	2	1	
		Amphiura			1
	5E	*Dosinia anus*	2		
		Dosinia subrosea	3	2	1
		Shrimp	1		
10 m	10A	*Cominella adspersa*	2		
		Amalda australis	2		
		Xymene plebeius	2		
		Dosinia subrosea	9	5	19
		Dosinia anus	3		1
		Myadora striata	4		
	10B	*Myadora striata*	3	1	
		Dosinia subrosea	10	3	15
		Ovalipes catharus	1		
	10C	*Cominella adspersa*	3		
		Dosinia subrosea	7	3	19
		Myadora striata	1		
	10D	*Dosinia anus*	1	1	
		Dosinia subrosea	8	7	14
		Myadora striata	1		
	10E	*Cominella adspersa*	5	2	
		Dosinia subrosea	3	6	12
		Myadora striata	5		
		Shrimp		1	

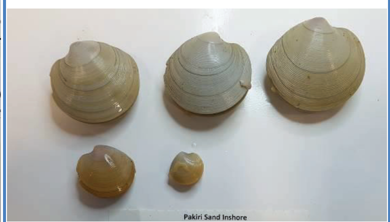
Table 8.10 Sizes of Macrofauna passing through the dredge sorted by site and degree of damage, May 2019.

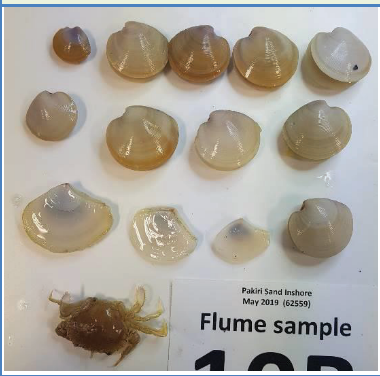
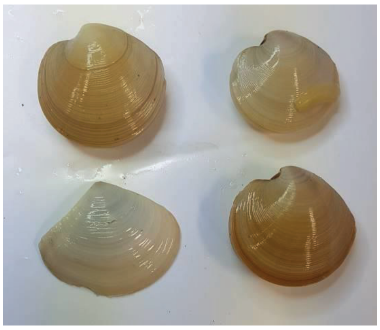
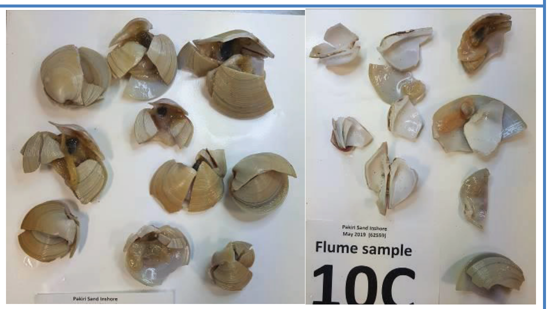
Depth	Class	Species	Average size (mm)			Range (mm)		
			Damage			Damage		
			None	Sub Lethal	Lethal	None	Sub Lethal	Lethal
5 m	Gastropod	*Amalda australis*	17			17		
		Zethalia zelandica	6			[4 - 7]		
	Bivalve	*Dosinia anus*	22	17		[16-27]	17	
		Dosinia subrosea	20	26	31	[13-38]	[20-32]	[20-48]
	Crustacean	*Ovalipes catharus*	no size					
		Shrimp	no size					
	Echinoderm	Amphiura	no size					
		Fellaster zelandiae	15	21		[12-18]	21	
10 m	Gastropod	*Amalda australis*	19			[18-20]		
		Cominella adspersa	36	33		[32-42]	[30-35]	
		Xymene plebeius	22			[17-27]		
	Bivalve	*Dosinia anus*	25	44	53	[11-42]	44	53
		Dosinia subrosea	20	27	31	[11-29]	[10-30]	[18-46]
		Myadora striata	24	29		[21-30]	29	
	Crustacean	*Ovalipes catharus*	19			19		
		Shrimp	no size					

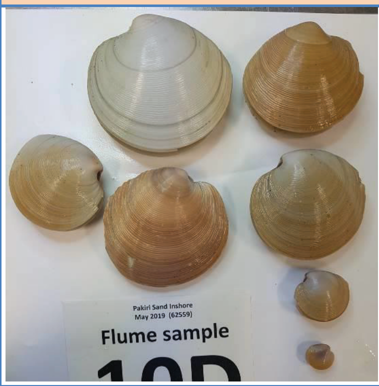
Table 8.11 Photographic record of Macrofauna after passing through the dredge sorted by site and degree of damage, May 2019.

Site	No Damaged	Sub Lethal Damage	Lethal Damage
5A			
5B			

Site	No Damaged	Sub Lethal Damage	Lethal Damage
5C			 
5D			

Site	No Damaged	Sub Lethal Damage	Lethal Damage
5E			
10A			

Site	No Damaged	Sub Lethal Damage	Lethal Damage
10B			
10C			

Site	No Damaged	Sub Lethal Damage	Lethal Damage
10D			 
10E			 

Appendix 6 Statistical Results

Univariate Statistics

Table 8.12 One Way Analysis of Variance of Number of Taxa for 1mm Screen

Dependent Variable: Number of Taxa
Normality Test: Failed (P < 0.050)

Kruskal-Wallis One Way Analysis of Variance on Ranks

Group	N	Missing	Median	25%	75%
PI Con	10	0	3.500	1.000	6.000
PI N	10	0	1.500	1.000	5.000
PI S	10	0	1.500	1.000	5.000

H = 0.457 with 2 degrees of freedom. (P = 0.796)

The differences in the median values among the treatment groups are not great enough to exclude the possibility that the difference is due to random sampling variability; there is not a statistically significant difference (P = 0.796).

Table 8.13 One Way Analysis of Variance of Number of Individuals for 1mm Screen

Dependent Variable: Number of individuals
Normality Test: Failed (P < 0.050)

Kruskal-Wallis One Way Analysis of Variance on Ranks

Group	N	Missing	Median	25%	75%
PI Con	10	0	4.500	1.000	8.000
PI N	10	0	5.500	2.000	10.000
PI S	10	0	2.500	1.000	7.000

H = 0.853 with 2 degrees of freedom. (P = 0.653)

The differences in the median values among the treatment groups are not great enough to exclude the possibility that the difference is due to random sampling variability; there is not a statistically significant difference (P = 0.653).

Table 8.14 One Way Analysis of Variance of Shannon- Weiner Diversity for 1mm Screen

Dependent Variable: Shannon-Weiner Diversity index
Normality Test: Failed (P < 0.050)

Kruskal-Wallis One Way Analysis of Variance on Ranks

Group	N	Missing	Median	25%	75%
PI Con	10	0	1.214	0.000	1.706
PI N	10	0	0.281	0.000	1.609
PI S	10	0	0.318	0.000	1.550

H = 0.721 with 2 degrees of freedom. (P = 0.697)

The differences in the median values among the treatment groups are not great enough to exclude the possibility that the difference is due to random sampling variability; there is not a statistically significant difference (P = 0.697).

Table 8.15 One Way Analysis of Variance of Shannon Evenness for 1mm Screen

Dependent Variable: Shannon Evenness
Normality Test: Failed (P < 0.050)

Kruskal-Wallis One Way Analysis of Variance on Ranks

Group	N	Missing	Median	25%	75%
PI Con	10	0	1.000	0.931	1.000
PI N	10	0	1.000	0.970	1.000
PI S	10	0	0.981	0.946	1.000

H = 0.393 with 2 degrees of freedom. (P = 0.821)

The differences in the median values among the treatment groups are not great enough to exclude the possibility that the difference is due to random sampling variability; there is not a statistically significant difference (P = 0.821).

Table 8.16 One Way Analysis of Variance of Number of Taxa for 3.15 mm Screen

Dependent Variable: Number of Taxa
Normality Test: Passed (P = 0.058)
Equal Variance Test: Passed (P = 0.952)

Group Name	N	Missing	Mean	Std Dev	SEM
Control	10	0	5.300	3.433	1.086
North	10	0	5.400	2.797	0.884
South	10	0	5.200	2.741	0.867

Source of Variation	DF	SS	MS	F	P
Between Groups	2	0.200	0.1000	0.0111	0.989
Residual	27	244.100	9.041		
Total	29	244.300			

The differences in the mean values among the treatment groups are not great enough to exclude the possibility that the difference is due to random sampling variability; there is not a statistically significant difference (P = 0.989).

Power of performed test with alpha = 0.050: 0.049
The power of the performed test (0.049) is below the desired power of 0.800.
Less than desired power indicates you are less likely to detect a difference when one actually exists. Negative results should be interpreted cautiously.

All Pairwise Multiple Comparison Procedures (Holm-Sidak method): Overall significance level = 0.05
Comparisons for factor: Area

Comparison	Diff of Means	t	Unadjusted P	Critical Level	Significant?
PI N vs. PI S	0.200	0.149	0.883	0.017	No
PI N vs. PI Con	0.100	0.0744	0.941	0.025	No
PI Con vs. PI S	0.1000	0.0744	0.941	0.050	No

Table 8.17 One Way Analysis of Variance of Number of Individuals for 3.15 mm Screen

Dependent Variable: Number of individuals
Normality Test: Failed (P < 0.050)

Kruskal-Wallis One Way Analysis of Variance on Ranks

Group	N	Missing	Median	25%	75%
PI Con	10	0	6.500	3.000	15.000
PI N	10	0	11.000	9.000	31.000
PI S	10	0	9.500	6.000	18.000

H = 2.415 with 2 degrees of freedom. (P = 0.299)

The differences in the median values among the treatment groups are not great enough to exclude the possibility that the difference is due to random sampling variability; there is not a statistically significant difference (P = 0.299)

Table 8.18 One Way Analysis of Variance of Shannon- Weiner Diversity for 3.15 mm Screen

Dependent Variable: Shannon-Weiner Diversity index
Normality Test: Passed (P = 0.276)
Equal Variance Test: Passed (P = 0.186)

Group Name	N	Missing	Mean	Std Dev	SEM
PI Con	10	0	1.313	0.514	0.162
PI N	10	0	1.212	0.799	0.253
PI S	10	0	1.247	0.649	0.205

Source of Variation	DF	SS	MS	F	P
Between Groups	2	0.0522	0.0261	0.0592	0.943
Residual	27	11.902	0.441		
Total	29	11.955			

The differences in the mean values among the treatment groups are not great enough to exclude the possibility that the difference is due to random sampling variability; there is not a statistically significant difference (P = 0.943).

Power of performed test with alpha = 0.050: 0.049
The power of the performed test (0.049) is below the desired power of 0.800.
Less than desired power indicates you are less likely to detect a difference when one actually exists. Negative results should be interpreted cautiously.

All Pairwise Multiple Comparison Procedures (Holm-Sidak method): Overall significance level = 0.05
Comparisons for factor: Area

Comparison	Diff of Means	t	Unadjusted P	Critical Level	Significant?
PI Con vs. PI N	0.101	0.339	0.737	0.017	No
PI Con vs. PI S	0.0659	0.222	0.826	0.025	No
PI S vs. PI N	0.0348	0.117	0.908	0.050	No

Table 8.19 One Way Analysis of Variance of Shannon Evenness for 3.15 mm Screen

Dependent Variable: Shannon Evenness
Normality Test: Failed (P < 0.050)

Kruskal-Wallis One Way Analysis of Variance on Ranks

Group	N	Missing	Median	25%	75%
PI Con	10	0	0.959	0.844	1.000
PI N	10	0	0.908	0.398	0.983
PI S	10	0	0.880	0.788	0.979

H = 1.258 with 2 degrees of freedom. (P = 0.533)

The differences in the median values among the treatment groups are not great enough to exclude the possibility that the difference is due to random sampling variability; there is not a statistically significant difference (P = 0.533).

Multivariate Statistics

Table 8.20 ANOSIM - Analysis of Similarities by Area, 3.15 mm Screen

Area levels
Control
North
South

Tests for differences between unordered Area groups
Global Test
Sample statistic (R): 0.024
Significance level of sample statistic: 31.5%
Number of permutations: 999 (Random sample from a large number)
Number of permuted statistics greater than or equal to R: 314

Pairwise Tests

Groups	R Statistic	Significance Level %	Possible Permutations	Actual Permutations	Number >= Observed
Control, North	0.133	3.7	92378	999	36
Control, South	-0.106	95.6	92378	999	955
North, South	0.059	18.1	92378	999	180

Table 8.21 ANOSIM - Analysis of Similarities by Depth, 3.15 mm Screen

Depth levels
deeper
shallow

Tests for differences between unordered Depth groups
Global Test
Sample statistic (R): 0.267
Significance level of sample statistic: 0.2%
Number of permutations: 999 (Random sample from 119759850)
Number of permuted statistics greater than or equal to R: 1

Table 8.22 SIMPER - One-Way Analysis of Similarity Percentages - species contributions, 3.15 mm Screen

Parameters
Resemblance: S17 Bray-Curtis similarity
Cut off for low contributions: 70.00%

Group deeper Average similarity: 21.28

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Myadora boltoni	0.88	6.09	0.89	28.61	28.61
Maldanidae	0.56	3.02	0.45	14.18	42.78
Epigonichthys hectori	0.59	2.08	0.48	9.77	52.55
Polychaeta Other	0.38	2.03	0.36	9.54	62.09
Myadora striata	0.49	1.58	0.37	7.43	69.51
Anomura	0.31	1.21	0.28	5.67	75.18

Group shallow Average similarity: 13.61

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Fellaster zelandiae	0.48	4.91	0.42	36.03	36.03
Zethalia zelandica	0.77	3.28	0.32	24.09	60.12
Amphiura aster	0.31	1.61	0.27	11.82	71.94

Groups deeper & shallow Average dissimilarity = 91.26

Species	Group Deeper Av.Abund	Shallow Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Myadora boltoni	0.88	0.06	7.02	1.25	7.70	7.70
Zethalia zelandica	0.00	0.77	6.40	0.62	7.01	14.71
Maldanidae	0.56	0.07	5.33	0.82	5.85	20.56
Fellaster zelandiae	0.00	0.48	4.90	0.74	5.36	25.92
Epigonichthys hectori	0.59	0.22	4.76	0.92	5.22	31.14
Polychaeta Other	0.38	0.24	4.26	0.76	4.67	35.81
Myadora striata	0.49	0.13	3.96	0.80	4.34	40.15
Dosinia subrosea	0.31	0.19	3.71	0.65	4.07	44.21
Anomura	0.31	0.06	3.36	0.59	3.68	47.89
Amphiura aster	0.08	0.31	3.08	0.63	3.38	51.27
Cirolanidae sp. 1	0.26	0.20	2.94	0.65	3.22	54.49
Gastropoda Other	0.15	0.18	2.94	0.55	3.22	57.71
Polychaeta undet.	0.30	0.06	2.48	0.58	2.72	60.43
Bivalvia Other	0.26	0.00	2.32	0.52	2.54	62.97
Limnichthys polyactis	0.15	0.12	2.14	0.52	2.34	65.31
Nucula nitidula	0.28	0.00	2.09	0.53	2.29	67.61
Amalda australis	0.18	0.06	1.95	0.48	2.14	69.74
Pariliacantha georgeorum	0.08	0.18	1.86	0.50	2.04	71.79

Bioresearches
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Table 8.23 ANOSIM - Analysis of Similarities by Area, 1 mm Screen

Area levels
Control
North
South

Tests for differences between unordered Area groups
Global Test
Sample statistic (R): 0.059
Significance level of sample statistic: 11.6%
Number of permutations: 999 (Random sample from a large number)
Number of permuted statistics greater than or equal to R: 115

Pairwise Tests

Groups	R Statistic	Significance Level %	Possible Permutations	Actual Permutations	Number >= Observed
Control, North	0.102	7.1	24310	999	70
Control, South	-0.047	70.3	6435	999	702
North, South	0.102	7.3	24310	999	72

Table 8.24 SIMPER - One-Way Analysis of Similarity Percentages - species contributions, 1 mm Screen

Parameters
Resemblance: S17 Bray-Curtis similarity
Cut off for low contributions: 70.00%

Group Control Average similarity: 14.93

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Gastropoda Other	0.50	3.52	0.51	23.56	23.56
Phoxocephalidae sp. 1	0.60	3.26	0.50	21.85	45.41
Haustoriidae	0.41	1.55	0.33	10.37	55.78
Cirolanidae sp. 1	0.41	1.39	0.33	9.32	65.10
Phoxocephalidae sp. 2	0.27	1.12	0.19	7.50	72.60

Group North Average similarity: 13.50

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Zethalia zelandica	0.54	6.76	0.30	50.07	50.07
Phoxocephalidae sp. 1	0.35	2.40	0.29	17.76	67.82
Cyclaspis cf. levis	0.33	1.50	0.29	11.10	78.92

Group South Average similarity: 8.59

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Gammaridea undet.	0.40	2.08	0.31	24.20	24.20
Armandia cf. maculata	0.42	1.83	0.33	21.28	45.49
Epigonichthys hectori	0.41	1.26	0.34	14.62	60.10
Maldanidae	0.31	0.58	0.19	6.77	66.87
Bivalvia Other	0.25	0.57	0.19	6.69	73.56

Groups Control & North Average dissimilarity = 90.62

Species	Group Control Av.Abund	Group North Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Zethalia zelandica	0.00	0.54	9.88	0.59	10.90	10.90
Phoxocephalidae sp. 1	0.60	0.35	7.33	0.90	8.09	18.99
Gastropoda Other	0.50	0.00	5.53	0.91	6.10	25.10
Cirolanidae sp. 1	0.41	0.33	5.35	0.84	5.91	31.00
Polychaeta undet.	0.25	0.13	5.20	0.49	5.74	36.75
Cyclaspis cf. levis	0.13	0.33	4.72	0.56	5.21	41.95
Phoxocephalidae sp. 2	0.27	0.00	4.70	0.52	5.18	47.14
Haustoriidae	0.41	0.13	4.68	0.78	5.17	52.31
Maldanidae	0.25	0.13	3.58	0.56	3.95	56.25
Nucula nitidula	0.25	0.00	3.48	0.52	3.84	60.09
Epigonichthys hectori	0.37	0.11	3.42	0.63	3.78	63.87
Gammaridea undet.	0.25	0.00	3.26	0.51	3.60	67.47
Sphaeromatidae sp. 1	0.00	0.28	3.26	0.43	3.60	71.08

Groups Control & South Average dissimilarity = 85.73

Species	Group Control Av.Abund	Group South Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Gastropoda Other	0.50	0.13	6.35	0.71	7.41	7.41
Phoxocephalidae sp. 1	0.60	0.29	6.28	0.92	7.32	14.73
Gammaridea undet.	0.25	0.40	6.28	0.63	7.32	22.05
Polychaeta undet.	0.25	0.25	5.88	0.52	6.86	28.91
Maldanidae	0.25	0.31	4.95	0.65	5.77	34.68
Epigonichthys hectori	0.37	0.41	4.94	0.86	5.76	40.44
Haustoriidae	0.41	0.27	4.83	0.82	5.63	46.07
Phoxocephalidae sp. 2	0.27	0.00	4.67	0.51	5.45	51.52
Armandia cf. maculata	0.13	0.42	4.46	0.73	5.20	56.72
Cirolanidae sp. 1	0.41	0.13	4.25	0.74	4.95	61.67
Bivalvia Other	0.13	0.25	3.94	0.46	4.59	66.27
Polychaeta Other	0.25	0.25	3.86	0.67	4.50	70.76

Groups North & South Average dissimilarity = 92.36

Species	Group North Av.Abund	Group South Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Zethalia zelandica	0.54	0.15	13.09	0.64	14.18	14.18
Phoxocephalidae sp. 1	0.35	0.29	6.57	0.72	7.11	21.29
Gammaridea undet.	0.00	0.40	6.33	0.53	6.85	28.14
Armandia cf. maculata	0.13	0.42	5.93	0.71	6.42	34.55
Cyclaspis cf. levis	0.33	0.00	5.12	0.47	5.55	40.10
Bivalvia Other	0.00	0.25	4.43	0.41	4.79	44.89
Maldanidae	0.13	0.31	4.18	0.57	4.53	49.42
Cirolanidae sp. 1	0.33	0.13	4.10	0.67	4.44	53.86
Polychaeta undet.	0.13	0.25	4.04	0.54	4.38	58.24
Epigonichthys hectori	0.11	0.41	3.99	0.78	4.32	62.56
Sphaeromatidae sp. 1	0.28	0.00	3.90	0.42	4.22	66.78
Polychaeta Other	0.11	0.25	3.67	0.58	3.97	70.75

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Table 8.25 ANOSIM - Analysis of Similarities by Depth, 1 mm Screen

Depth levels
deeper
shallow

Tests for differences between unordered Depth groups
Global Test
Sample statistic (R): 0.304
Significance level of sample statistic: 0.1%
Number of permutations: 999 (Random sample from 5200300)
Number of permuted statistics greater than or equal to R: 0

Table 8.26 SIMPER - One-Way Analysis of Similarity Percentages - species contributions, 1 mm Screen

Parameters
Resemblance: S17 Bray-Curtis similarity
Cut off for low contributions: 70.00%

Group deeper Average similarity: 22.53

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Phoxocephalidae sp. 1	0.61	4.26	0.56	18.90	18.90
Cirolanidae sp. 1	0.56	3.69	0.58	16.39	35.29
Haustoriidae	0.51	2.48	0.47	10.99	46.29
Armandia cf. maculata	0.43	2.21	0.35	9.82	56.11
Maldanidae	0.44	1.98	0.35	8.77	64.88
Polychaeta Other	0.38	1.79	0.37	7.95	72.83

Group shallow Average similarity: 9.09

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Zethalia zelandica	0.50	6.55	0.31	72.08	72.08

Groups deeper & shallow Average dissimilarity = 94.06

	Group deeper	Group shallow				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Phoxocephalidae sp. 1	0.61	0.20	7.74	0.95	8.23	8.23
Zethalia zelandica	0.00	0.50	6.77	0.63	7.19	15.43
Cirolanidae sp. 1	0.56	0.00	6.52	0.94	6.93	22.36
Armandia cf. maculata	0.43	0.00	5.93	0.68	6.30	28.66
Maldanidae	0.44	0.00	5.66	0.66	6.02	34.68
Haustoriidae	0.51	0.00	5.36	0.87	5.70	40.38
Polychaeta Other	0.38	0.00	4.62	0.69	4.91	45.29
Epigonichthys hectori	0.43	0.14	4.51	0.82	4.79	50.08
Gammaridea undet.	0.23	0.18	4.47	0.60	4.75	54.83
Gastropoda Other	0.23	0.17	4.17	0.63	4.44	59.27
Polychaeta undet.	0.17	0.25	3.72	0.63	3.96	63.23
Cyclaspis cf. levis	0.23	0.08	3.30	0.57	3.50	66.73
Nucula nitidula	0.23	0.00	3.17	0.48	3.37	70.11

Table 8.27 ANOSIM - Analysis of Similarities by Extraction Area, dredge tow

Area levels
Control
North
South
Tests for differences between unordered Area groups
Global Test
Sample statistic (R): 0.084
Significance level of sample statistic: 26.7%
Number of permutations: 999 (Random sample from 36036)
Number of permuted statistics greater than or equal to R: 266

Pairwise Tests

Groups	R Statistic	Significance Level %	Possible Permutations	Actual Permutations	Number >= Observed
North, South	0.092	26	462	462	120
North, Control	0.291	23.8	21	21	5
South, Control	-0.052	60.7	28	28	17

Table 8.28 ANOSIM - Analysis of Similarities by Depth, dredge tow

Depth levels
deeper
shallow

Tests for differences between unordered Bathymetry groups
Global Test
Sample statistic (R): 0.493
Significance level of sample statistic: 0.1%
Number of permutations: 999 (Random sample from 1716)
Number of permuted statistics greater than or equal to R: 0