Christchurch Ocean Outfall: 2018 Benthic Survey

July 2018

Consulting Biologists – Established 1972
P.O. Box 2373, Christchurch 8140. New Zealand
www.bioresearches.co.nz

Christchurch Ocean Outfall: 2018 Benthic Survey
July 2018

DOCUMENT APPROVAL

Document title:	Christchurch Ocean Outfall: 2018 Benthic Survey
Prepared for:	Christchurch City Council
Version:	Final
Date:	2 July 2018
Document name:	BRS17141 Christchurch City Council Outfall Monitoring 2018 final.docx

Authors:	Simon West M.Sc. (Hons) Senior Marine Ecologist Mark Yungnickel M.Sc. (Hons) Senior Ecologist Jessica Feickert M.Sc. (Hons) Marine and Coastal Ecologist
Reviewer:	Graham Don M.Sc. (Hons) Senior Ecology Consultant
Approved for Release:	Graham Don M.Sc. (Hons) Senior Ecology Consultant

REVISION HISTORY

Rev. No.	Date	Description	Author(s)	Reviewer	Approved
1	3 July 2018	Version 1	S. West, M. Yungnickel, J. Feickert	Graham Don	Graham Don

Reference: Bioresearches (2018). Christchurch Ocean Outfall: 2018 Benthic Survey. Report for Christchurch City Council. pp 92

Cover Illustration: Dredge tow, Christchurch Ocean Outfall (March 2018)

SUMMARY

Christchurch City Council was granted resource consents from Environment Canterbury (ECAN) for the construction, operation and maintenance of a new ocean outfall in 2006. The outfall was formally commissioned on 10 March 2010. Consent no. CRC051724 requires the monitoring of effects on the receiving environment. The 2018 survey of the ocean outfall is the second survey carried out since commissioning in 2010. Prior to construction and commissioning, surveys were conducted to obtain information about the physical and chemical properties of surface sediments and biological communities.

The 2018 survey involved collection of samples of sediment and seabed biota as required by the resource consent at sites around the outfall and at a control site near the Waimakariri River mouth. Sediment samples were examined for texture, total organic carbon, nitrogen and phosphorus and trace elements. Sediment cores were examined for infauna and the epibenthic fauna was examined using dredge tows.

Sediment quality was examined on whole sediment (<2 mm) with concentration data interpreted from whole sediment and also using parameter/mud ratios, the latter being utilised to normalise the variation that arises from the variability arising from the amount of mud in the samples. The key conclusions from the examination of the sediment quality data were:

- Whole sediment TOC, cadmium, chromium, copper, lead, nickel and zinc concentrations showed statistically significant higher concentrations in sediments collected greater than 200 m away from the outfall, than those collected within 200 m of the diffuser. Similarly the samples collected further away from the diffuser contained slightly higher percentage of mud on average than samples collected close to the diffuser. The average concentration differences between the two groups of sediments were small.
- PCA and cluster analysis of the 2018 sediment quality data showed the outfall sites were different to the control sites based on the percentage of mud being higher at the control sites. Sites to the north were identified as being different to those nearer the outfall and south as a result of elevated concentrations chromium, nickel, TOC, zinc, phosphorus and lead to the north.
- Examination of parameter / mud ratios showed the reverse of the whole sediment pattern with higher ratios close to the diffuser. For all parameters a small peak in ratios occurred close to the diffuser even though the average percentage of mud was lower close to the diffuser.
- The concentration of all parameters measured for which sediment quality limits were identified in the resource consent were lower than the identified ANZECC limits. The low concentrations of trace elements in sediments would indicate that the sediment quality should not be having any adverse effects on sediment infauna.

The examination of the benthic community in 2018 has shown:

- Increases in abundance with distance from the outfall along the North-South Transect, particularly outside the mixing zone.
- Increases in abundance and richness within distance offshore.
- Abundance and richness was typically higher with the mixing zone compared to control sites. While abundance increased outside the mixing zone boundary, richness decreased slightly.
- Analysis of the benthic communities as a whole showed the control sites were significantly different from the outfall sites and that the three northern sites (N2500, N1000 and N500) were significantly different from the other outfall sites.

- Abundance and richness varied significantly between survey years but fell within the range of baseline levels in 2018. Compared with 2012 the average faunal abundance had decreased by 2018 at all sites, controls included.
- The benthic communities between survey years were significantly different. Some of this difference could be attributed to some degree to variations in the level of resolution for some taxonomic groups which provided some limitations in the detail of benthic community structure. However it is not possible to rule out real variations in benthic community structure between surveys.

Overall the weight of evidence, both sediment quality and benthic community structure suggests that the control sites are different to the outfall sites, and that distant sites to the north of the outfall are different to those at the outfall. The changes in both sediment quality and species composition and abundance suggest the northern sites were likely affected by the outfall discharges. The increases in the numbers of the polychaete worm *Heteromastus* are a typical response to the observed outfall-derived organic enrichment at these sites.

CONTENTS

1. INTRODUCTION

1.1 Christchurch City Council Ocean Outfall

Christchurch City Council (CCC) was granted resource consent from Environment Canterbury (ECAN) for the construction, operation and maintenance of a new ocean outfall in 2006. The consent permitted the discharge of treated wastewater from the Christchurch Wastewater Treatment Plant (CWTP) into Pegasus Bay. The ocean outfall replaced the discharge of treated wastewater from the treatment plant to the Avon Heathcote estuary. Prior to that, wastewater had been discharged into the estuary since the 1950's when sewage underwent primary treatment at the 'sewage farm' on the site of the existing oxidation ponds (Knox & Kilner 1973).

The consent allows for the discharge of up to 518,000 m^3 of treated wastewater per day at a peak rate of 6 m^3 per second into the coastal marine area at no less than 2,730 m seaward of mean high water springs (MHWS). The term of the consent is for 35 years, from 30 October 2005. The outfall was formally commissioned on 10 March 2010. The wastewater discharged through the ocean outfall is treated at the CWTP. From the treatment plant, wastewater is transferred via gravity via subsurface pipeline to Jellicoe Street then to the New Brighton shore then below the seabed with the pipeline terminating in a diffuser located about 3,000 m offshore from MHWS. A pump station at the oxidation ponds is available to pump wastewater if required.

1.2 Environmental Surveys

Monitoring for effects on the receiving marine environment in relation to this discharge is required under consent no. CRC051724. Monitoring was required to occur one year after construction and initial operation of the system and thereafter at five yearly intervals. Prior to construction and commissioning surveys were conducted to obtain information about the physical and chemical properties of surface sediments and biological communities. An initial examination of the subtidal marine environment off New Brighton Beach was undertaken in April-May 2003 (Kingett Mitchell 2003). The survey design included a series of four transects (positioned near Jellicoe Street) running offshore for a distance of 3,600 m. Two further surveys of the benthic subtidal environment were undertaken prior to construction of the outfall. As these surveys were carried out at a depth and location matching the proposed outfall location, they are considered baseline surveys. The first baseline survey was conducted in November 2004 (Kingett Mitchell, 2004). The 2004 survey was designed to investigate the subtidal marine benthos in the vicinity of two proposed locations for the outfall diffuser, at approximately 2,000 m and 3,000 m offshore from New Brighton Beach. The second baseline survey was carried out in April 2007 (Kingett Mitchell, 2004; Golder Kingett Mitchell, 2007).

The first CCC outfall baseline survey coincided with the first baseline survey undertaken for the neighbouring proposed Waimakariri District Council outfall and consequently the two monitoring programmes shared the same control monitoring stations. The second baseline survey carried out in April 2007 replicated the sample locations in the 2004 survey and focussed on the confirmed diffuser location at approximately 3,000 m offshore.

1.3 Monitoring Requirements

The resource consent issued to CCC identified that the outfall diffuser design is required to ensure that wastewater has a median dilution of at least 240 times and a minimum dilution of no less than 61 times within the near-field mixing zone. The near-field mixing zone is defined as 200 m north and south of the outfall diffusers, and 200 m east of the diffuser furthest from the shore and 200 m west of the diffuser closest to the shore.

In regard to consent conditions relevant to this report, the conditions for monitoring of receiving environment marine sediments, benthic invertebrates and epibenthos are summarised below.

- Collect marine sediment, benthic invertebrate and epibenthos samples on two occasions at least 12 months apart, in either February or March prior to commissioning of the outfall; and one year after commissioning of the outfall and thereafter at five yearly intervals, during either February or March.
- Obtain marine sediment and benthic invertebrate samples at 100, 200, 500, 1,000 and 2,500 m alongshore from the centre point of the diffuser (both north and south) and at 100, 200 and 500 m inshore and offshore from the diffuser.
- Obtain no less than three replicate surface sediment samples and five replicate benthic fauna samples at each sampling location specified in the preceding point and from two sites south of Waimakariri River.
- For each replicate sediment sample, collect no less than three surface sediment samples to a depth of 50 mm and combine to form a single composite sample.
- Sampling of benthic fauna should be made using no less than 13 cm diameter cores and samples are processed using a 0.5 mm mesh sieve. The invertebrates are counted and identified to the lowest practical taxonomic level.
- All surface sediment samples collected in accordance with these conditions are analysed for the determinands presented in Table 1.
- All samples are analysed using appropriate, current and scientifically-recognised methods by an accredited laboratory according to International Accreditation New Zealand (IANZ) or equivalent.
- Epibenthic sampling is carried out one year after the discharge from the outfall commences and thereafter at five yearly intervals. Where possible, epibenthic sampling is to coincide with sediment and benthic invertebrate sampling.
- Three epibenthic tows of 200 m each (using a naturalists' dredge) are undertaken perpendicular to the shore, at control sites and at sampling locations 200 m north and south of the outfall. Epibenthic samples are analysed for species composition and abundance of epibenthic organisms, used to identify any variation in these parameters over time, identify any relationship between epibenthos and sediment quality, and noting the presence of any deformed individuals.

Table 1 Sediment sample determinands to be tested during receiving environment monitoring.

Constituent group	Constituent	Units
Physical characteristics	Sediment texture grain size - gravel, sand, mud	% dry weight
	Man-made objects	Description only in the >2 mm fraction
Organic status	Total organic carbon (TOC)	%
	Total nitrogen	mg/kg as N dry weight
	Total phosphorus	mg/kg as P dry weight
Metals	Arsenic, cadmium, chromium, copper, lead, mercury, nickel and zinc - strong acid extraction	mg/kg dry weight

CCC is required to notify ECAN within 10 working days of the detection of any exceedances in the event that the concentration of any parameter in a single marine sediment sample exceeds a trigger value as set out Table 3. Within one month of detecting any exceedances CCC is then required to provide a report to ECAN detailing the risk of the exceedances to aquatic communities in Pegasus Bay and any measures proposed by CCC to mitigate the effects of the exceedances on these communities.

1.4 Report Scope and Contents

This report has been prepared to fulfil the requirements of Resource Consent CRC051724 Conditions 23, 24 and 25 for the period prior to the operation of the ocean outfall. The relevant extract from the consent is included in Appendix 1 for completeness. The report contains three key sections following this introduction.

Section 2 describes the methodology used to collect sediment and biological samples along with the analytical methods used to examine sediment samples.

Section 3 describes the physical environment in Pegasus Bay and the nature of the seabed and sediments in the area off New Brighton and the chemistry of sediments off New Brighton Beach.

Section 4 describes the benthic ecology of the environment off New Brighton. The information includes a description of the epibenthos (i.e., the fauna present on the seabed) and the infauna (i.e., the fauna inhabiting the sediment) existing in the study area.

This report focuses on the second post commissioning sampling conducted in 2018 and compares the results with that of the first post commissioning study. **Unfortunately complete sets of raw data from the earlier three baseline reports were unavailable so statistical analysis was limited. Baseline data from the third (2007) study has been included were possible. No baseline data were available from the first (2003) and second (2004) surveys.**

2. METHODOLOGY

2.1 Survey Design

Sampling sites for 2018 were positioned based on the as-built location of the diffuser (LINZ 2010). Sediment and benthic biological sampling was carried out at 18 sites in Pegasus Bay, including 16 sites distributed around the ocean diffuser and two control sites located to the south of Waimakariri River (Figure 1).

The sampling sites in 2018 are the same sampling sites surveyed in 2004, 2007, 2012 and pre-commissioning surveys and the consent conditions identified sample locations based upon those used in earlier surveys. Sampling sites were positioned according to consent conditions at 100, 200, 500, 1000, and 2500m to the north and south (alongshore direction) from the centre point of the diffuser, and at 100, 200, and 500m to the east and west (inshore to offshore direction) from the diffuser.

At each location, replicate samples were randomly collected by SCUBA divers. In all previous sampling years replicate sample positions were determined using randomly-generated X-Y coordinates on a 10x10m grid to give distance (in metres) at a bearing between 0 and 360 from the grid centre, which was taken to represent the anchor position used by SCUBA divers onsite. Eight random sample collection positions were generated for each site including five for benthic sample collection and three for surface sediment sample collection (Figure 2).

The 2018 survey was set up to use the same approach used in all previous surveys to date, however, the first dive revealed zero visibility and pitch black conditions so compass bearings could not be used. The majority of sites revealed the same conditions thus this methodology was amended and divers used the anchor as the centre point and collected random samples at bearings within approximately 5 metres of this point. The head diver Dwayne Pool (Marinetec, Lyttelton, *pers comm*) explained these zero visibility conditions are consistent with diving conditions they regularly experience working up and down the Canterbury coast.

Epifauna dredge tows were made at roughly the same control site sampled in 2007 and 2012 and sampling sites at 200m north and 200m south of the outfall (Figure 1).

All methods used and identified in the sections below followed those in the pre-commissioning surveys and as outlined in the consent conditions.

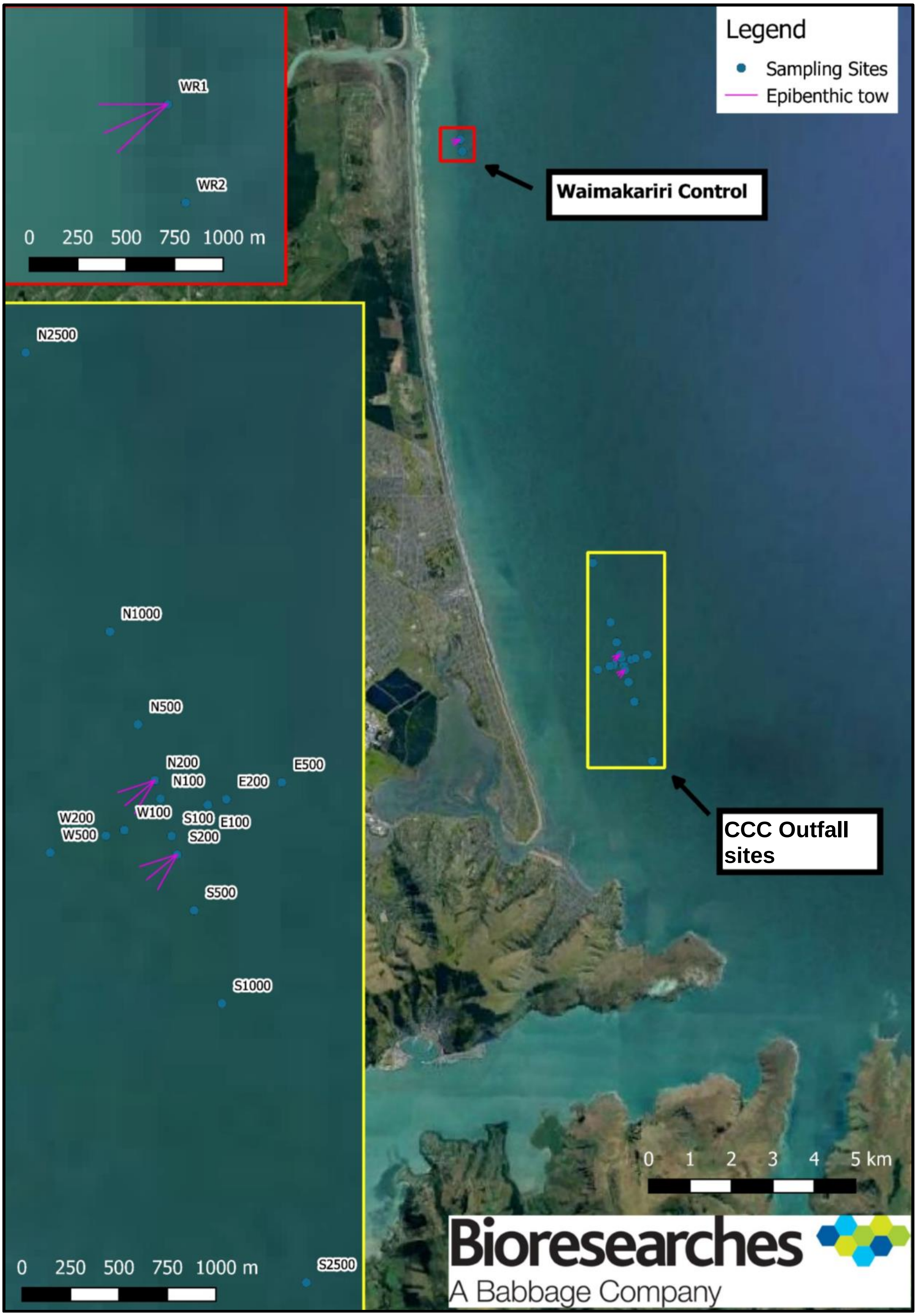


Figure 1 2018 sampling sites.

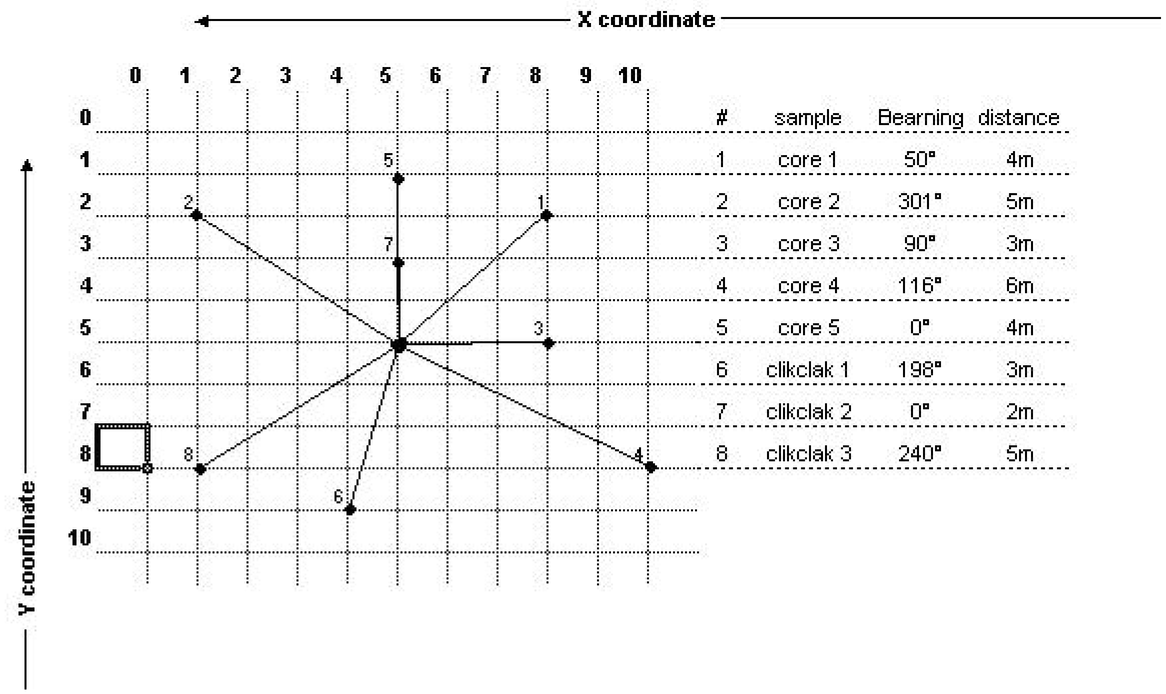


Figure 2 Method for location of samples to be collected at each sampling site.

2.2 Sample Collection, Processing and Analysis

2.2.1 Surface Sediments

Three replicate composited sediment samples were collected at each sampling site. For each replicate, at least three surface sediment samples to a depth of 50mm were collected by SCUBA divers and combined to form a composite sample. Samples were kept chilled during transport from the field then send via overnight courier to Hill Laboratories.

Sediment textural analysis

Sediment textures were measured by wet sieving the sub-sample of each replicate through 2mm and 63 µm mesh sieves. This method partitioned sediments into gravel (>2mm), sand (≤2mm, >63µm), and mud (≤63µm, silt and clay) referred hereafter as "mud" fractions. Each fraction was then dried to a constant weight at 60°C and the percentage of each fraction was calculated on a dry weight basis. Coarser fractions (gravels and sands) were also inspected for the presence of man-made objects.

Sediment chemistry analysis

In the laboratory, the sub-sample of each replicate was air dried and sieved to <2mm for the purpose of sediment quality analyses. The parameters analysed were:

- Total organic carbon (TOC)
- Total phosphorus (TP)
- Total nitrogen (TN)
- Arsenic (As)
- Cadmium (Cd)
- Chromium (Cr)
- Copper (Cu)
- Lead (Pb)
- Mercury (Hg)
- Nickel (Ni)
- Zinc (Zn)

TOC (after acid pre-treatment) and TN were analysed by combustion. All other parameters were measured by ICP-MS after digestion in aqua regia (nitric and hydrochloric acids) (refer to Appendix 3 for full laboratory reports). The results of statistical analysis of sediment quality data are provided in Appendix 4.

2.2.2 Benthic Infauna

Five replicate benthic infauna samples were collected from each site for benthic biological assessment. Benthic infauna samples were collected by SCUBA divers using cylindrical core samplers (130mm diameter, 150mm deep). Samples were washed through a 0.5mm bucket sieve using fresh seawater and all material retained in the sieve was fixed in 5% glyoxal, 70% ethanol, 25% seawater solution for further examination in the laboratory.

Benthic invertebrates were sorted, counted and identified to the lowest practical taxonomic level. Benthic infaunal data for all samples are provided in Appendix 5. The results of statistical analysis of benthic infauna data are provided in Appendix 4.

2.2.3 Epibenthos

Epibenthic species were sampled using a dredge (60cm x 20cm opening and retrofitted with 10mm mesh) that was towed in a direction perpendicular to the shore. Each tow was 200m in length and carried out at low speed (<1 kilometre/per hour). At approximately 100m the boat completely stopped for several seconds to ensure the dredge was on the bottom. Three tows were carried out at each of the epibenthic sampling sites. Epibenthic fauna and flora were fixed in 5% glyoxal, 70% ethanol, 25% seawater solution. Epibenthic organisms were counted and identified to the lowest practical taxonomic level.

3. SEDIMENTS

3.1 Environmental Overview

As described previously (Kingett Mitchell 2003, 2004), the physical marine environment of Pegasus Bay is a direct response to a rise in sea level during the Holocene period. The shoreline has been extending seawards since the maximum inland sea transgression occurred around 6,500 years BP (Allan *et al*. 1999). The seabed has a moderately steep inshore zone and a relatively gentle continental shelf. Adjacent to Jellicoe Street the seabed slopes gently with the seabed reaching only 12 m depth at 2,000 m offshore and 15 m depth by 3,000 m from the low tide mark.

The CCC Outfall lies immediately north of the mouth of the Avon Heathcote River, which is fed by the Avon and Heathcote Rivers. Within Pegasus Bay, two processes play a key role in the transport of sediment. The first is the input of sediments from rivers that enter the bay and the second is long-shore transport. A detailed sediment budget analysis carried out by Duns (1995) shows that the greater proportion of locally derived sediment (in the vicinity of the outfall) is from Waimakariri River (40 %), followed by sediment derived from long-shore currents (28 %) and onshore currents (14 %). The prevailing coastal current in Pegasus bay is in a northerly direction (Brodie, 1960).

3.2 Physical Characteristics

Spatial distributions

The sediments collected in 2018 were dominated by sands and muds, while amounts of gravel were <1 %. Gravel material >2 mm in size within the samples consisted of shell fragments of a variety of sizes. No visible man-made objects were identified in an examination of the > 2 mm fraction of all samples. Sand was the dominant sediment fraction, making up 80 % - 97 % of the sediments collected along the outfall transects, and 63 % - 84 % of the sediments from the south of the mouth of Waimakariri River. Examination of the 2018 data shows that there was no spatial pattern in the distribution of gravel sized particles (Figure 3). The 2018 data shows that the sediment within 200 m of the outfall contained on average less mud than those more than 200 m away (all directions) (5.1 % for <200 m and 10.6 % for >200 m) and the control site samples collected south of the Waimakariri River (26.6 %) ($p = <0.001$). In 2018 the percentage of sand increased statistically significantly ($p = <0.001$) towards the outfall, (94.9 % for <200 m and 89.4 % for >200 m) and in the control site samples collected south of the Waimakariri River (73.3 %).

The sediment was sandier at the CCC outfall sites than at the Waimakariri Control sites; conversely the percentage of mud was lower at the outfall sites compared to the control sites.

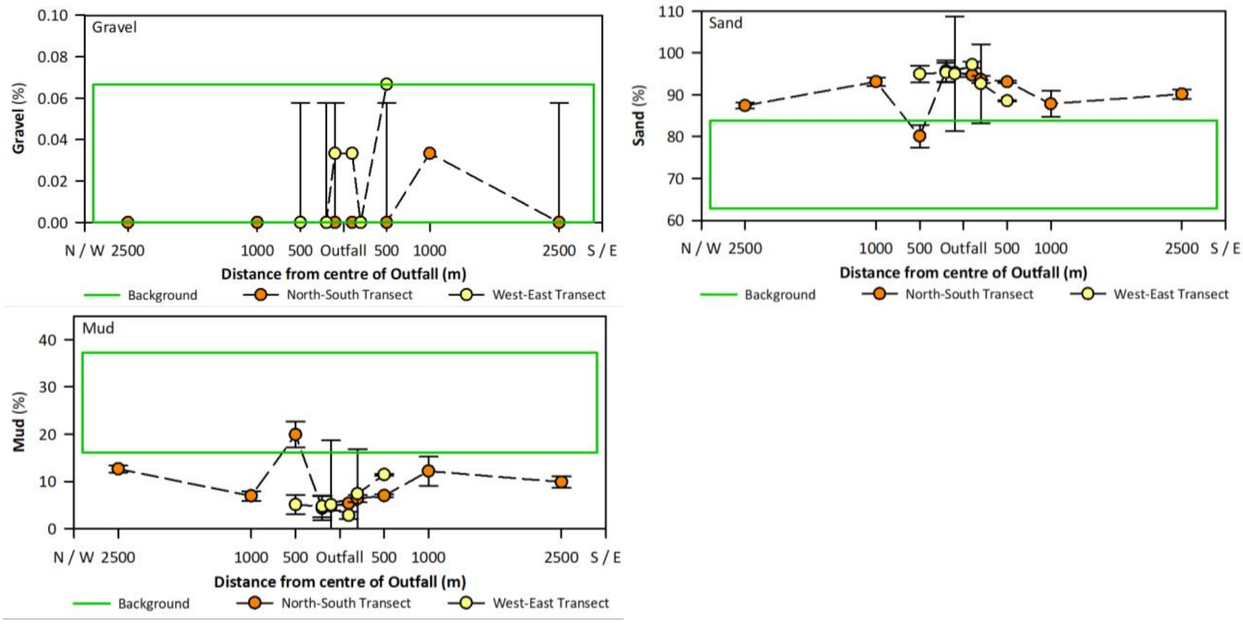


Figure 3 ***Average percentage of sediment size classes (± standard deviation) for all sites sampled near the Christchurch City Council ocean outfall and Waimakariri River control sites in 2018.***

Temporal changes

A comparison of 2018 sediment texture data with previous surveys is presented in Table 2. The average percentage of mud decreased statistically significantly between 2012 and 2018 at sites within (p=<0.001) the 200m mixing zone and beyond the mixing zone (p=<0.001) but did not increase significantly (p=0.163) at the Waimakariri Control sites. The average percentage of gravel did not vary statistically significantly between 2012 and 2018 either within the mixing zone or beyond and at the control. The average percentage of sand increased statistically significantly between 2012 and 2018 at sites within (p=<0.001) the 200m mixing zone and beyond the mixing zone (p=<0.001) but did not decrease significantly (p=0.161) at the Waimakariri Control sites.

Table 2 ***Summary of sediment texture data for CCC ocean outfall surveys.***

Location		100m from Outfall[1]	200m from Outfall[1]	>200m from Outfall[2]	Waimakariri[3]
Gravels (>2mm)	**2018**	0.02 %	0.00 %	0.01 %	0.03 %
	2012	0.00 %	0.06 %	0.47 %	0.00 %
	2007	0.19 %	0.00 %	0.00 %	0.00 %
	2004	0.14 %	0.11 %	0.06 %	0.00 %
Sands (<2mm to >63µm)	**2018**	95.50	94.31	89.36	73.32
	2012	85.85	80.70	78.02	78.16
	2007	88 %	80 %	87 %	76 %
	2004	79 %	84 %	82 %	42 %
Muds (<63µm)	**2018**	4.48	5.69	10.62	26.65
	2012	14.15	19.24	21.51	21.84
	2007	11 %	20 %	13 %	24 %
	2004	21 %	16 %	18 %	58 %

Notes: Mean values presented. These were rounded and are not necessarily equal to 100%, [1]n = 12, [2]n = 24, [3]n = 6. Current sampling is highlighted in orange and previous study in blue.

3.3 Sediment Chemistry Assessment

The purpose of post commissioning surveys, as dictated by resource consent conditions (refer Appendix 1), is to detect changes in sediment quality that may be attributable to the discharge from the outfall. However, natural sources of variation need to be understood to identify changes in concentration that may not be natural (i.e., changes that can be attributed to the outfall). Variations in sediment chemistry on a regional scale can arise as a result of changes in particle size, and mineralogy from different geological formations. At a local scale, variation occurs as a consequence of processes that transport sediment, such as fluvial deposition, seabed disturbance by waves and longshore sediment transport processes.

Detecting changes

Variability in trace element concentrations in coastal sediments studies such as this can be reduced through a number of techniques, typically grouped into five categories.

1. Mechanical size normalisation.
2. Extrapolation from regression curves.
3. Correction for the presence of inert minerals (e.g., quartz).
4. Chemical extraction of the 'mobile' component of the element of interest.
5. Comparison with a tracer element.

Of these choices, those that involve no manipulation of the sample are the simplest followed by the separation of a fine grain size fraction. The latter assumes that only the fine fraction is involved in the accumulation of anthropogenic contaminants.

Adopted approach

In the 2018, as with the pre-commissioning surveys, the direct use of mud content was utilised to compare concentrations over time. Concentrations of trace elements in sediments (whole and <2 mm) are controlled, for a significant part, by the average size of the particles in the sample. Smaller particles have greater surface areas relative to their volume and so the smaller the particle, the greater the influence of material adsorbed onto them. Adsorption is an important mechanism with respect to sediment contamination, as the process is the most likely pathway for the removal of dissolved contaminants from solution in stable environmental conditions, and their subsequent accumulation in sediments. In addition, particles from an outfall enriched in contaminants are likely to have become enriched as a function of previous adsorption or in the case of the oxidation ponds taken up by algae in the ponds, rather than being present as specific mineral particles. Therefore, the normalisation of <2 mm sediment quality data using mud proportions provides better insight into changes in sediment chemistry than does analysis of raw concentrations.

In the following sections, raw concentration data presented in Appendix 3 and summarised in Table 3 are examined for each parameter in turn. Lack of availability of complete historical data sets has limited the ability to examine changes over time beyond the last survey. Following this an examination of the mud normalised concentration data has been conducted to detect any changes either spatially or temporally. Mud normalised concentrations are achieved by multiplying the concentration by the reciprocal of the mud concentration. The purpose of this normalisation is to reduce variability with the aim of being able to compare sediment samples on a more even basis.

Table 3 Summary of average concentrations of contaminants in sediments at all sites sampled near the Christchurch City Council ocean outfall and Waimakariri River control sites in 2018.

Tests			Total		Total Recoverable								
			Organic Carbon	Nitrogen	Phosphorus	Arsenic	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Zinc
Units			g/100g dry wt.		mg/kg dry wt.								
ANZECC	ISQG	Low				20	1.5	80	65	50	0.15	21	200
		High				70	10	370	270	220	1	52	410
Site	North	N 2500	0.17	< 0.05	383.33	6.37	0.01	12.90	3.87	10.53	0.04	11.07	36.00
		N1000	0.21	< 0.06	393.33	6.10	0.02	13.17	4.17	10.93	0.04	11.43	37.67
		N500	0.15	< 0.05	386.67	5.93	0.01	13.03	3.87	10.17	0.04	11.30	36.33
		N200	0.15	< 0.05	373.33	5.43	0.01	12.53	3.77	10.27	0.04	11.03	36.33
		N100	0.15	< 0.05	356.67	5.43	0.01	12.17	3.73	9.93	0.04	10.73	35.00
	South	S100	0.12	< 0.05	360.00	4.57	0.02	10.77	2.83	8.60	0.03	9.33	32.67
		S200	0.16	< 0.05	383.33	4.67	0.02	11.27	3.17	9.10	0.04	9.67	34.00
		S500	0.13	< 0.05	366.67	4.67	0.02	11.07	2.87	8.73	0.04	9.03	33.00
		S1000	0.15	< 0.05	396.67	5.00	0.02	11.43	3.27	9.00	0.04	10.07	35.00
		S2500	0.19	< 0.05	430.00	5.13	0.02	12.50	3.60	10.40	0.04	9.97	36.33
	West	W500	0.13	< 0.05	330.00	4.60	0.01	11.60	3.50	8.50	0.03	9.90	33.67
		W200	0.11	< 0.05	310.00	4.40	0.02	11.57	3.33	8.53	0.04	9.77	32.33
		W100	0.11	< 0.05	333.33	4.33	0.02	10.90	2.73	7.87	0.04	8.80	31.67
	East	E100	0.13	< 0.05	373.33	5.07	0.02	11.53	3.17	9.13	0.04	9.20	33.67
		E200	0.22	< 0.05	413.33	5.23	0.02	12.33	3.57	10.53	0.05	9.70	37.33
		E500	0.18	< 0.05	413.33	5.23	0.02	12.20	3.33	10.03	0.04	9.57	35.67
	Control	WR1	0.08	< 0.05	330.00	3.30	0.02	10.43	3.70	7.67	0.04	8.67	30.33
		WR2	0.14	< 0.05	366.67	3.53	0.02	10.87	4.23	8.83	0.04	9.13	33.33

3.3.1 Total Organic Carbon

Table 4 provides a summary of total organic carbon (TOC) information gathered since 2003 at the CCC ocean outfall and at the control site south of the Waimakariri River. Median and mean TOC concentrations in 2018 were slightly lower than those measured in 2012 and the baseline in 2003 and 2004. Further examination of the 2018 sediment TOC data showed that all sites around the outfall (within 200 m of the diffuser and >200 m away) contained TOC within the range collected at control site (Figure 4a). The net average difference between samples collected close to the diffuser (i.e., within 200 m) and further away (>200 m) was small (± 0.02 % TOC) but statistically significant (p=0.019).

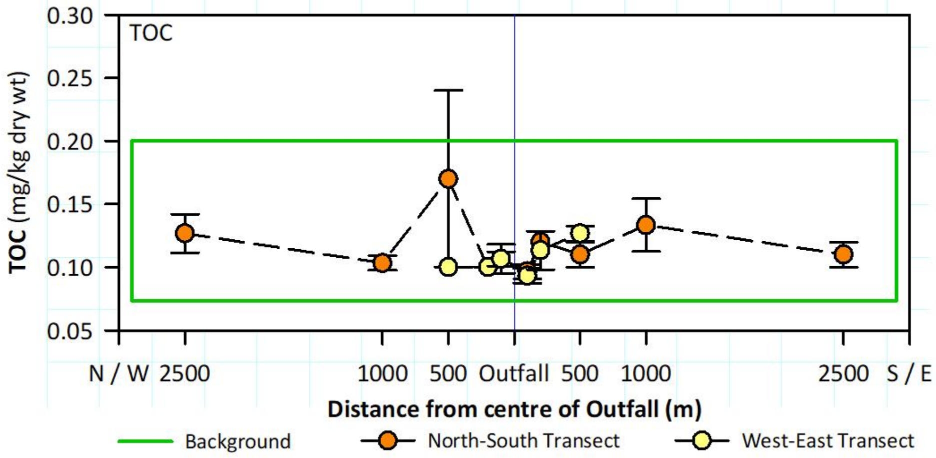
The effect of normalising the TOC to mud highlights the concentrations near the outfall suggesting TOC is enriched near the outfall, relative to surrounding sediments (Figure 4c).

Figure 4d plots the individual data against their sample mud content for 2012 and 2018. The older data were not available. The figure also shows the 95 % confidence intervals (CL) for the 2018 and 2012. When viewing the figure and the following figures for other parameters, the overlap of the area between the CL's (both vertically and horizontally in the figure) between the 2018 and 2012 survey sample data indicates there is little evidence that these datasets are distinct from each other.

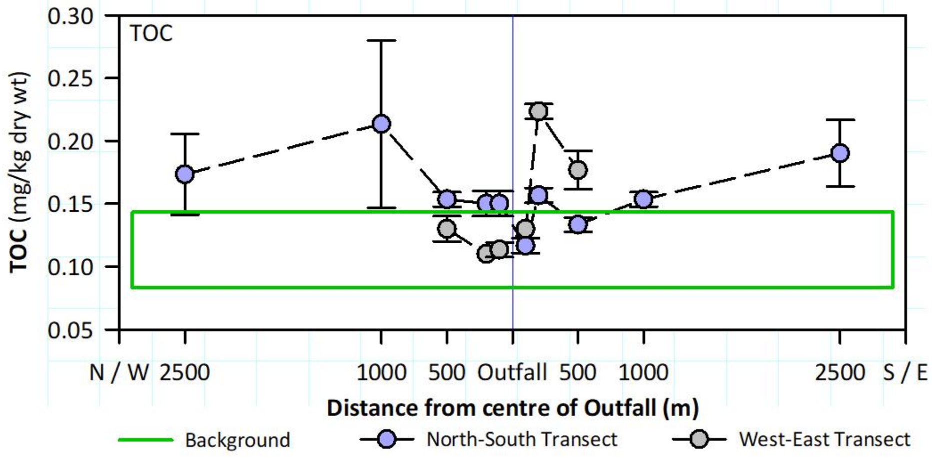
Table 4 Total organic carbon concentrations in sediments collected off New Brighton Beach in 2018, 2012, 2007, 2004 and 2003 (all data % dry weight).

Location/Survey	Median	Range	Mean ± Std Dev	CV	Number of samples
New Brighton 2018 (all samples)	0.11	0.09 – 0.25	0.11 ± 0.02	22 %	48
100-200 m subset	0.10	0.09 – 0.13	0.10 ± 0.01	10 %	24
500-2500 m subset	0.12	0.10 – 0.25	0.12 ± 0.03	26 %	24
New Brighton 2012	0.15	0.11 – 0.29	0.15 ± 0.04	24 %	48
100-200 m subset	0.135	0.11 – 0.29	0.15 ± 0.05	31 %	24
500-2500 m subset	0.15	0.12 – 0.22	0.16 ± 0.04	16 %	24
New Brighton 2007	0.16	0.14 – 0.31	0.16 ± 0.03	18 %	48
New Brighton 2004 (all samples)	0.15	0.12 – 0.40	0.17 ± 0.06	35 %	90
2000 m subset	0.15	0.12 – 0.19	0.15 ± 0.04	27 %	45
3000 m subset	0.15	0.13 – 0.29	0.17 ± 0.08	47 %	45
New Brighton 2003	0.15	0.12 – 0.19	0.15 ± 0.02	13 %	16*
Waimakariri River control 2018	0.095	0.07 – 0.25	0.14 ± 0.09	62 %	6
Waimakariri River control 2012	0.095	0.08 – 0.20	0.16 ± 0.07	60 %	6
Waimakariri River control 2007	0.14	0.13 – 0.18	0.14 ± 0.02	14 %	6
Waimakariri River control 2004	0.26	0.13 – 0.49	0.28 ± 0.14	50 %	6
Ashley River 2007	0.15	0.14 – 0.18	0.15 ± 0.02	11 %	6
Ashley River 2004	0.13	0.12 – 0.20	0.14 ± 0.03	21 %	6

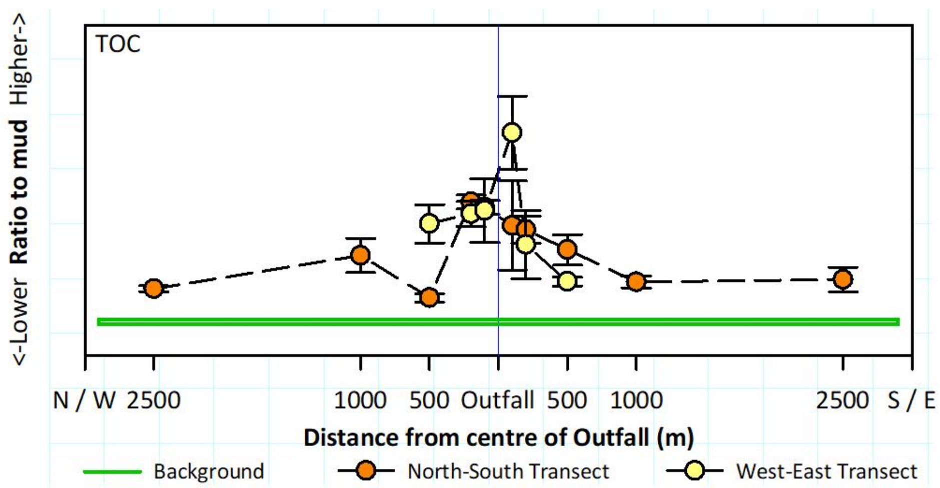
Notes: *Four samples of mud extracted from samples were also examined. Current sampling is highlighted in orange and previous study in blue.



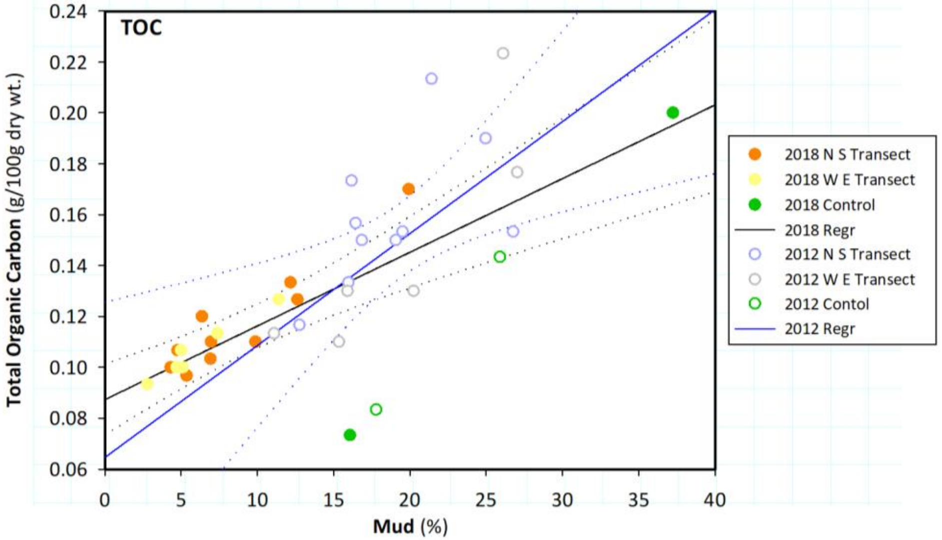
a. **2018 TOC**



b. **2012 TOC**



c. **2018 TOC mud normalised**



d. **Relationship between TOC % and mud content**

Figure 4 ***a. 2018 and b. 2012 Spatial plots of TOC sediment quality data, c. 2018 Spatial plot of normalised TOC sediment quality data, d. Relationship between TOC % and sediment mud content in outfall sediments (dotted lines denote 95% CL)***

3.3.2 Nitrogen

Table 5 provides a summary of total Nitrogen (TN) information gathered since 2003 at the CCC ocean outfall and at the control site south of the Waimakariri River. Median and mean TN concentrations in 2018 were all lower than the detection limit and similar to those recorded in 2012 and the baseline in 2003 and 2004. Further examination of the 2018 sediment TN data was not warranted given all data were below the detection limit. The net average difference between samples collected close to the diffuser (i.e., within 200 m) and further away (>200 m) was not statistically significant (p=0.280).

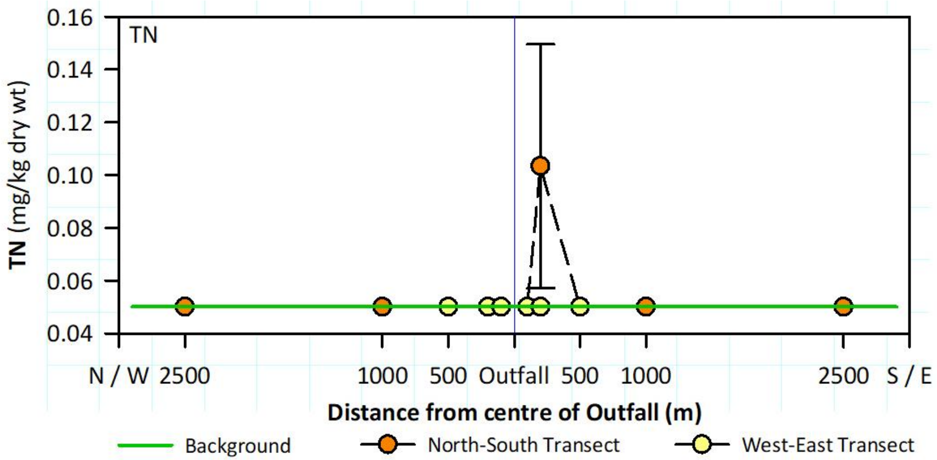
The effect of normalising the TN to mud again highlights the concentrations near the outfall suggesting TN is enriched near the outfall, relative to surrounding sediments (Figure 5c).

Figure 5d plots the individual data against their sample mud content for 2012 and 2018. The older data were not available. The overlapping data clouds as defined by 95% CL, between the 2018 and 2012 survey sample data indicates there is little evidence that these datasets are distinct from each other.

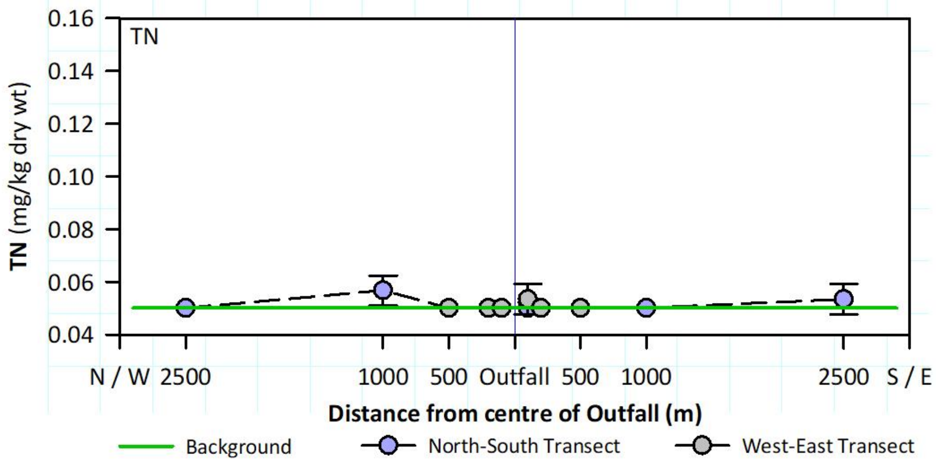
Table 5 Total nitrogen concentrations in sediments collected off New Brighton Beach in 2018, 2012, 2007, 2004 and 2003 (all data mg/kg dry weight).

Location/Survey	Median	Range	Mean ± Std Dev	Number of samples
New Brighton 2018 (all samples)	<500	<500 – <1300	<500 ± 200	48
100-200 m subset	<500	<500 – <1300	<600 ± 200	24
500-2500 m subset	<500	<500	<500	24
New Brighton 2012 (all samples)	<500	<500 – 600	<500	48
100-200 m subset	<500	<500 – 600	<500	24
500-2500 m subset	<500	<500 – 600	<500	24
New Brighton 2007	<500	<500	<500	20
New Brighton 2004	<500	<500 – 900	<500	90
2000 m subset	<500	<500 – 600	<500	45
3000 m subset	<500	<500 – 900	<500	45
Waimakariri River control 2018	<500	<500	<500	6
Waimakariri River control 2012	<500	<500 – 600	<500	6
Waimakariri River control 2007	<500	<500	<500	6
Waimakariri River control 2004	<500	<500 – 1000	<500 ± 700	6
Ashley River 2007	<500	<500	<500	6
Ashley River 2004	<500	<500 - 600	<500	6

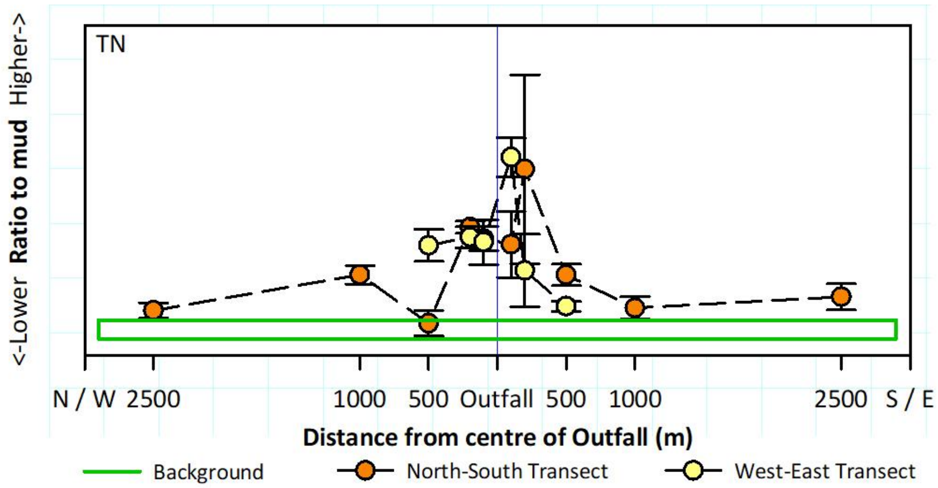
Notes: Current sampling is highlighted in orange and previous study in blue.



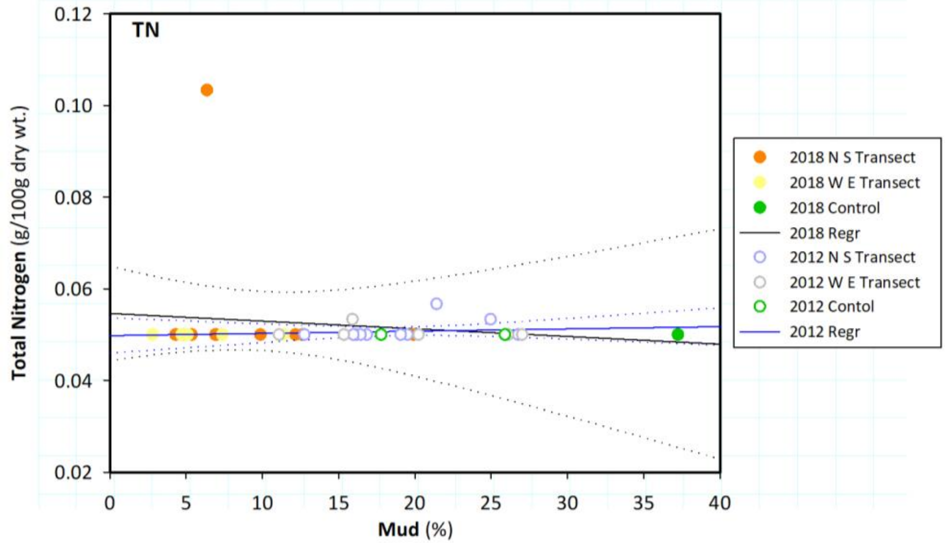
a. 2018 TN



b. 2012 TN



c. 2018 TN mud normalised



d. Relationship between TN and mud content

Figure 5 ***a. 2018 and b. 2012 Spatial plots of TN sediment quality data, c. 2018 Spatial plot of normalised TN sediment quality data, d. Relationship between TN % and sediment mud content in outfall sediments (dotted lines denote 95% CL)***

3.3.3 Phosphorus

Table 6 provides a summary of total Phosphorus (TP) information gathered since 2003 at the CCC ocean outfall and at the control site south of the Waimakariri River. Median and mean TP concentrations in 2018 were all slightly higher than those recorded in 2012, but slightly lower than the baseline values from 2003 and 2004. Further examination of the 2018 sediment TP data showed that the majority of sites away from the outfall (>200 m away) contained TP greater than the range collected at control site (Figure 6a), while those sites close to the outfall (within 200 m of the diffuser) contained TP within or below the range at the control. The net average difference between samples collected close to the diffuser (i.e., within 200 m) and further away (>200 m) was relatively small (± 17.9 mg/kg dry wt.) and not statistically significant (p=0.062).

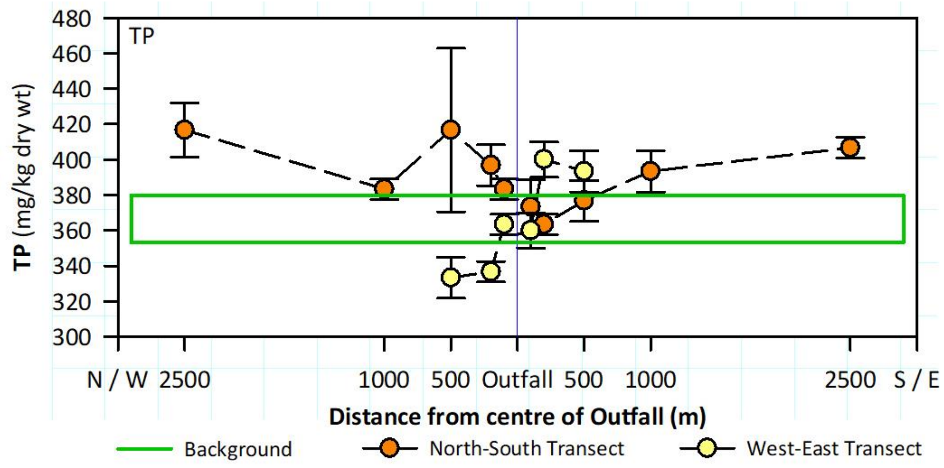
The effect of normalising the TP to mud was to sharply increase the contrast between those sites close to the outfall and those further away suggesting TP is enriched near the outfall, relative to surrounding sediments (Figure 6c).

Figure 6d plots the individual data against their sample mud content for 2012 and 2018. The older data were not available. The lack of overlap between 2018 and 2012 TP concentrations data for smaller proportions of mud suggests the 2018 concentrations were higher than in 2012 when sample sites were less muddy. Control sites did not seem to be similarly affected.

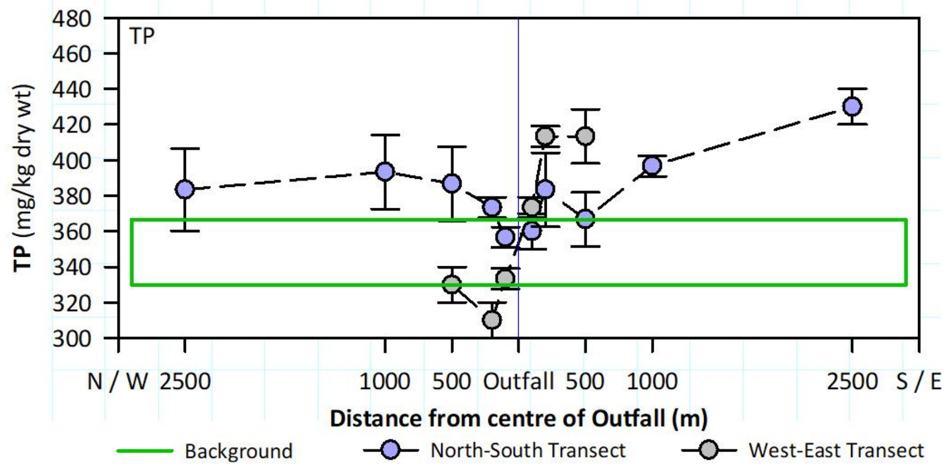
Table 6 Summary of total phosphorus concentrations in sediments collected off New Brighton Beach in 2018, 2012, 2007, 2004 and 2003 (all data mg/kg dry weight).

Location/Survey	Median	Range	Mean ± Std Dev	CV	Number of samples
New Brighton 2018 (all samples)	380	320 – 470	381 ± 27.6	7 %	48
100-200 m subset	370	330 – 410	372 ± 21.5	6 %	24
500-2500 m subset	390	320 - 470	390 ± 30.5	8 %	24
New Brighton 2012 (all samples)	320	300 – 400	375 ± 33	9 %	48
100-200 m subset	320	300 – 420	365 ± 33	9 %	24
500-2500 m subset	380	320 – 430	385 ± 32	8 %	24
New Brighton 2007	394	341 – 451	393 ± 27	7 %	48
New Brighton 2004 (all samples)	414	344 – 582	420 ± 42	10 %	90
2000 m subset	380	344 – 488	394 ± 31	8 %	45
3000 m subset	447	380 – 582	444 ± 38	9 %	45
New Brighton 2003*	735	619 – 791	720 ± 75	10 %	4
Waimakariri River control 2018	360	340 - 420	367 ± 30	8 %	6
Waimakariri River control 2012	345	320 – 400	348 ± 30	9 %	6
Waimakariri River control 2007	354	341 – 380	355 ± 14	4 %	6
Waimakariri River control 2004	480	374 – 567	475 ± 94	20 %	6
Ashley River 2007	365	349 – 372	363 ± 8	2 %	6
Ashley River 2004	343	372 – 376	346 ± 22	6 %	6

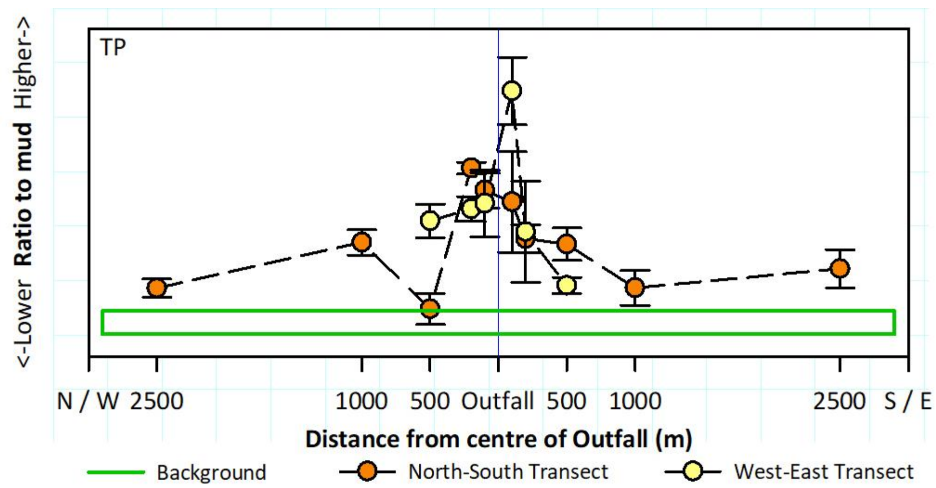
Notes: *Four samples of mud extracted from samples were also examined. Current sampling is highlighted in orange and previous study in blue.



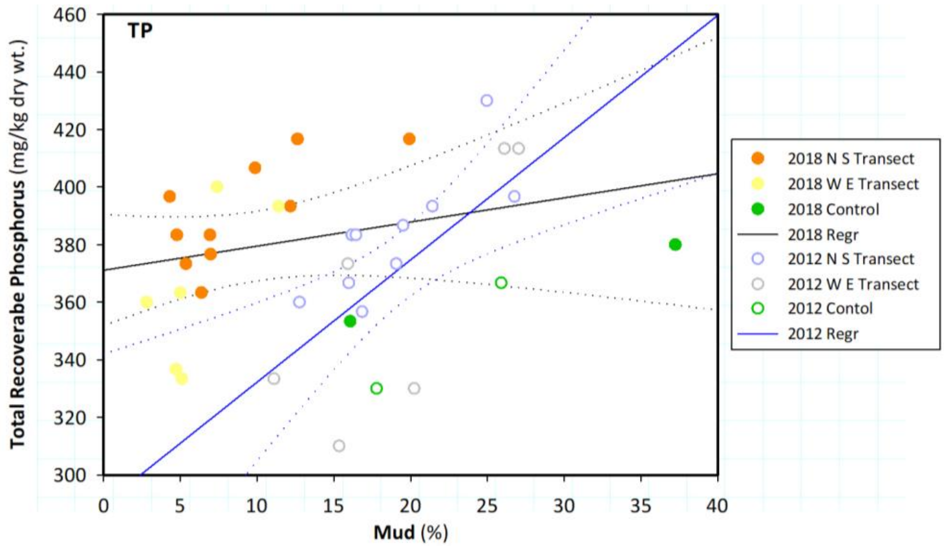
a. 2018 TP



b. 2012 TP



c. 2018 TP mud normalised



d. Relationship between TP and mud content

Figure 6 a. 2018 and b. 2012 Spatial plots of TP sediment quality data, c. 2018 Spatial plot of normalised TP sediment quality data, d. Relationship between TP concentration and sediment mud content in outfall sediments (dotted lines denote 95% CL)

3.3.4 Arsenic

Table 7 provides a summary of total recoverable arsenic information gathered since 2003 at the CCC ocean outfall and at the control site south of the Waimakariri River. In 2018, arsenic concentrations were well below the ANZECC ISQG Low trigger level of 20 mg/kg dry weight (Table 3). Median and mean arsenic concentrations in 2018 were all slightly higher than those recorded in 2012, but slightly lower than the baseline values from 2003 and 2004. Further examination of the 2018 sediment arsenic data showed that all sites around the outfall (within 200 m of the diffuser and >200 m away) contained arsenic greater than the range collected at control site (Figure 7a). The 2012 and 2018 spatial graphs (Figure 7, a and b) showed similar patterns with the nearshore samples lower in arsenic than offshore. The net average difference between samples collected close to the diffuser (i.e., within 200 m) and further away (>200 m) was small (± 0.16 mg/kg dry wt.) and not statistically significant, however the control site was statistically significantly lower than both the near outfall and distant sites.

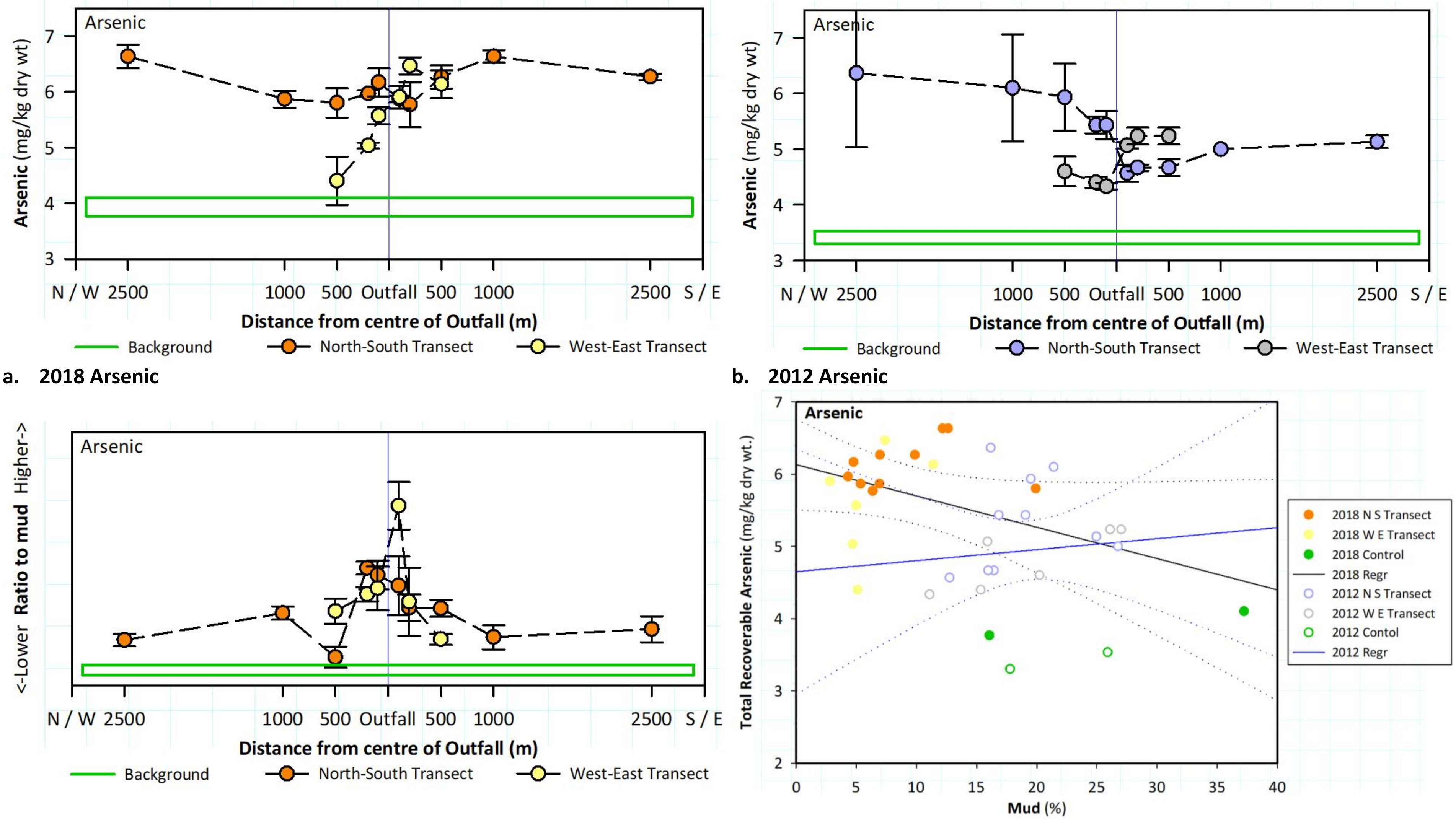
The effect of normalising the arsenic to mud was to show that fine sediments at sites close to the outfall were enriched by arsenic, relative to surrounding sediments (Figure 7c), particularly at site E100 just offshore from the outfall.

Figure 7d plots the individual data against their sample mud content for 2012 and 2018. The older data were not available. The lack of overlap between 2018 and 2012 arsenic concentrations data for smaller proportions of mud suggests the 2018 concentrations were higher than in 2012 when sample sites were less muddy. Control sites did not seem to be similarly affected.

Table 7 Summary of arsenic concentrations in sediments collected off New Brighton Beach in 2018, 2012, 2007, 2004 and 2003 (all data mg/kg dry weight).

Location/Survey	Median	Range	Mean ± Std Dev	CV	Number of samples
New Brighton 2018 (all samples)	6.0	3.9 – 6.8	5.9 ± 0.59	10 %	48
100-200 m subset	5.9	5.0 – 6.6	5.8 ± 0.44	7 %	24
500-2500 m subset	6.2	3.9 – 6.8	6.0 ± 0.71	12 %	24
New Brighton 2012 (all samples)	5.1	4.3 – 7.9	5.1 ± 0.70	14 %	48
100-200 m subset	4.9	5.3 – 7.1	5.0 ± 0.65	13 %	24
500-2500 m subset	5.2	4.3 – 7.9	5.3 ± 0.7	13 %	24
New Brighton 2007	6.3	5.3 – 7.1	6.3 ± 0.4	6 %	48
New Brighton 2004 (all samples)	6.0	5.2 – 7.2	6.0 ± 0.4	7 %	90
2000 m subset	5.7	5.2 – 6.6	5.7 ± 0.3	5 %	45
3000 m subset	6.3	5.8 – 7.1	6.3 ± 0.4	7 %	45
New Brighton 2003*	5.6	4.1 – 6.4	5.3 ± 0.7	13 %	16
Waimakariri River control 2018	3.9	3.6 – 4.5	3.9 ± 0.3	8 %	6
Waimakariri River control 2012	3.4	3.1 – 3.7	3.4 ± 0.2	6 %	6
Waimakariri River control 2007	4.1	3.9 – 4.5	4.2 ± 0.2	6 %	6
Waimakariri River control 2004	4.8	4.1 – 5.7	4.9 ± 0.1	2 %	6
Ashley River 2007	6.7	6.4 – 7.0	6.7 ± 0.2	3 %	6
Ashley River 2004	5.1	4.9 – 5.2	5.0 ± 0.6	12 %	6

Notes: *Four samples of mud extracted from samples were also examined. Current sampling is highlighted in orange and previous study in blue.



a. **2018 Arsenic**

b. **2012 Arsenic**

c. **2018 Arsenic mud normalised**

d. **Relationship between Arsenic and mud content**

Figure 7 ***a. 2018 and b. 2012 Spatial plots of Arsenic sediment quality data, c. 2018 Spatial plot of normalised Arsenic sediment quality data, d. Relationship between Arsenic concentration and sediment mud content in outfall sediments (dotted lines denote 95% CL)***

3.3.5 Cadmium

Table 8 provides a summary of total recoverable cadmium information gathered since 2003 at the CCC ocean outfall and at the control site south of the Waimakariri River. In 2018, cadmium concentrations were well below the ANZECC ISQG Low trigger level of 1.5 mg/kg dry weight (Table 3). Median and mean cadmium concentrations in 2018 were slightly lower than those measured in 2012 and the baseline in 2003 and 2004. Further examination of the 2018 sediment cadmium data showed that all sites around the outfall (within 200 m of the diffuser and >200 m away) contained cadmium below the range collected at control site (Figure 8a). The net average difference between samples collected close to the diffuser (i.e., within 200 m) and further away (>200 m) was very small (± 0.002 mg/kg dry wt.) but statistically significant (p=<0.001).

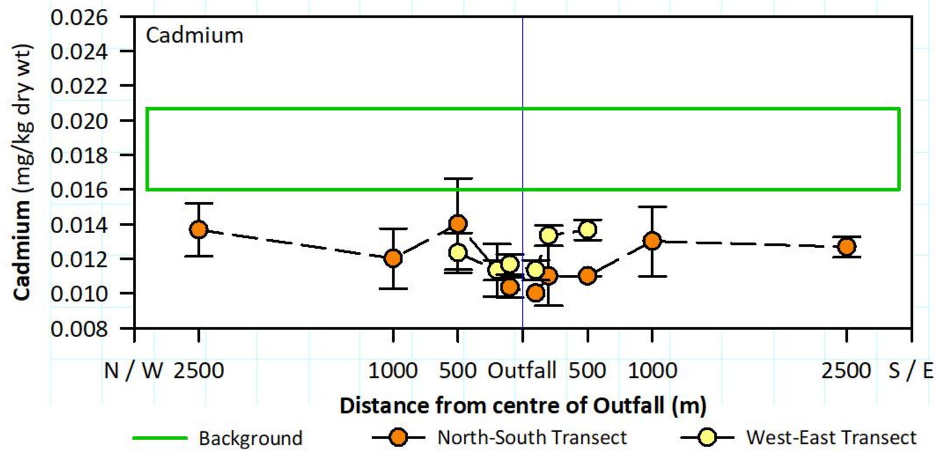
The effect of normalising the cadmium to mud was to sharply increase the contrast between those sites close to the outfall and those further away suggesting cadmium is enriched near the outfall, relative to surrounding sediments (Figure 8c).

Figure 8d plots the individual data against their sample mud content for 2012 and 2018. The older data were not available. The overlapping data clouds as defined by 95% CL, between the 2018 and 2012 survey sample data indicates there is little evidence that these datasets are distinct from each other.

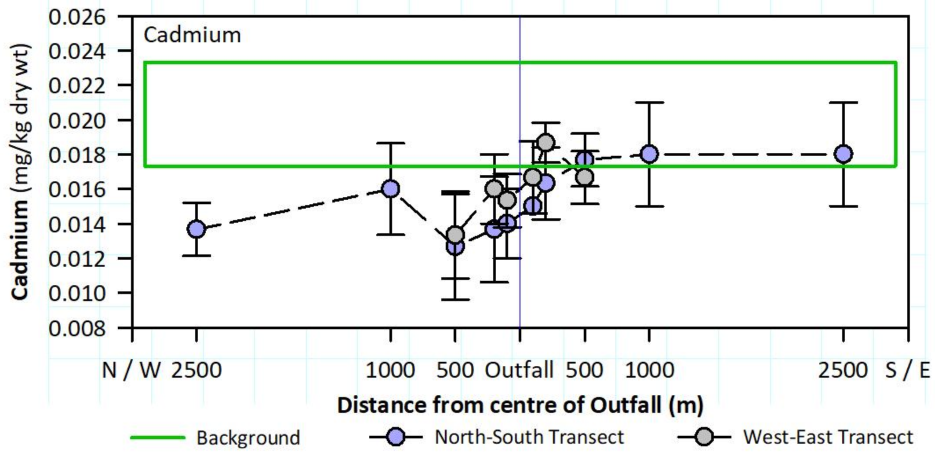
Table 8 Summary of cadmium concentrations in sediments collected off New Brighton Beach in 2018, 2012, 2007, 2004 and 2003 (all data mg/kg dry weight).

Location/Survey	Median	Range	Mean ± Std Dev	CV	Number of samples
New Brighton 2018 (all samples)	0.012	<0.01 – 0.016	0.012 ± 0.002	13 %	48
100-200 m subset	0.011	<0.01 – 0.014	0.011 ± 0.001	11 %	24
500-2500 m subset	0.013	<0.01 – 0.016	0.013 ± 0.002	12 %	24
New Brighton 2012 (all samples)	0.016	0.01 – 0.021	0.016 ± 0.003	13 %	48
100-200 m subset	0.016	0.012 – 0.020	0.016 ± 0.002	13 %	24
500-2500 m subset	0.015	0.01 – 0.021	0.015 ± 0.003	20 %	24
New Brighton 2007	0.02	0.01 – 0.03	0.02 ± <0.01	<50 %	48
New Brighton 2004 (all samples)	0.02	<0.02 – 0.03	0.02 ± <0.01	<50 %	90
2000 m subset	0.02	0.01 – 0.02	0.02 ± <0.01	<50 %	45
3000 m subset	0.02	0.01 – 0.03	0.02 ± <0.01	<50 %	45
New Brighton 2003*	0.01	-	0.01	-	16
Waimakariri River control 2018	0.019	0.014 – 0.023	0.018 ± 0.003	17 %	6
Waimakariri River control 2012	0.02	0.014 – 0.027	0.02 ± 0.004	20 %	6
Waimakariri River control 2007	0.02	0.02 – 0.03	0.02 ± 0.01	<50 %	6
Waimakariri River control 2004	0.02	0.02 – 0.02	0.02	-	6
Ashley River 2007	0.02	0.02 – 0.02	0.02 ± 0.0	-	6
Ashley River 2004	0.02	0.02 – 0.04	0.03 ± <0.1	<30 %	6

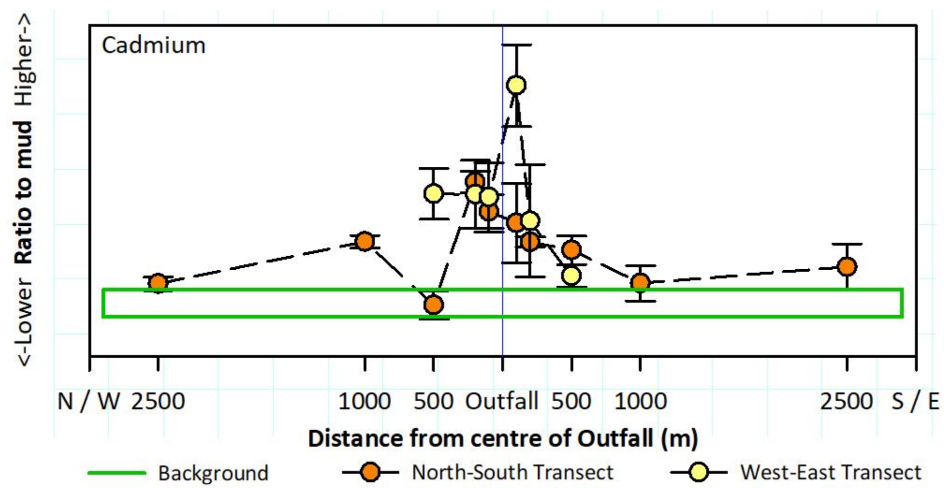
Notes: *Four samples of mud extracted from samples were also examined. Current sampling is highlighted in orange and previous study in blue.



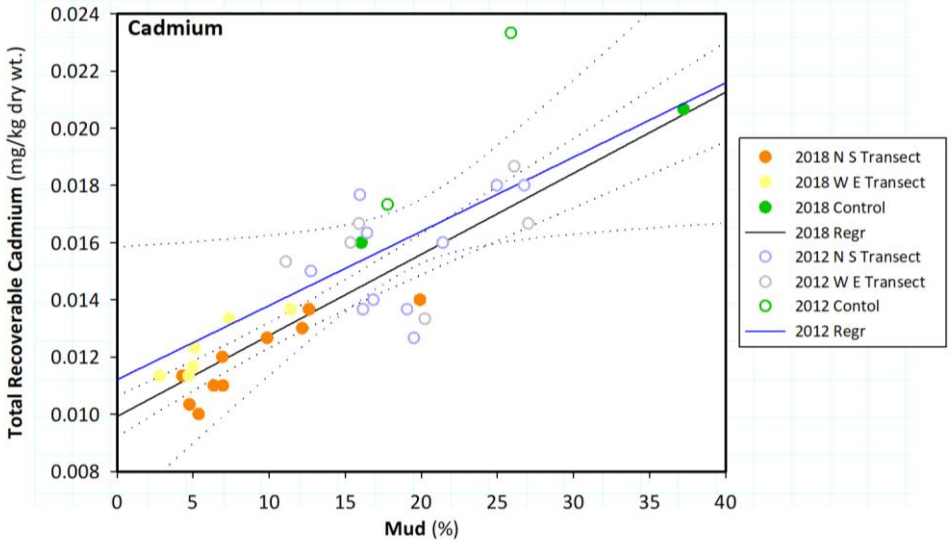
a. 2018 Cadmium



b. 2012 Cadmium



c. 2018 Cadmium mud normalised



d. Relationship between Cadmium and mud content

Figure 8 a. 2018 and b. 2012 Spatial plots of Cadmium sediment quality data, c. 2018 Spatial plot of normalised Cadmium sediment quality data, d. Relationship between Cadmium concentration and sediment mud content in outfall sediments (dotted lines denote 95% CL)

3.3.6 Chromium

Table 9 provides a summary of total recoverable chromium information gathered since 2003 at the CCC ocean outfall and at the control site south of the Waimakariri River. In 2018, chromium concentrations were well below the ANZECC ISQG Low trigger level of 80 mg/kg dry weight (Table 3). Median and mean chromium concentrations in 2018 were slightly lower than those measured in 2012 and the baseline in 2003 and 2004. Further examination of the 2018 sediment chromium data showed that all sites around the outfall (within 200 m of the diffuser and >200 m away) contained chromium generally within the range collected at control site (Figure 9a). Sites inshore from the outfall had chromium concentration below the range of the control. The net average difference between samples collected close to the diffuser (i.e., within 200 m) and further away (>200 m) was small (± 0.65 mg/kg dry wt.) but near the outfall sites were significantly (p=<0.001) lower in chromium concentration than the distant sites.

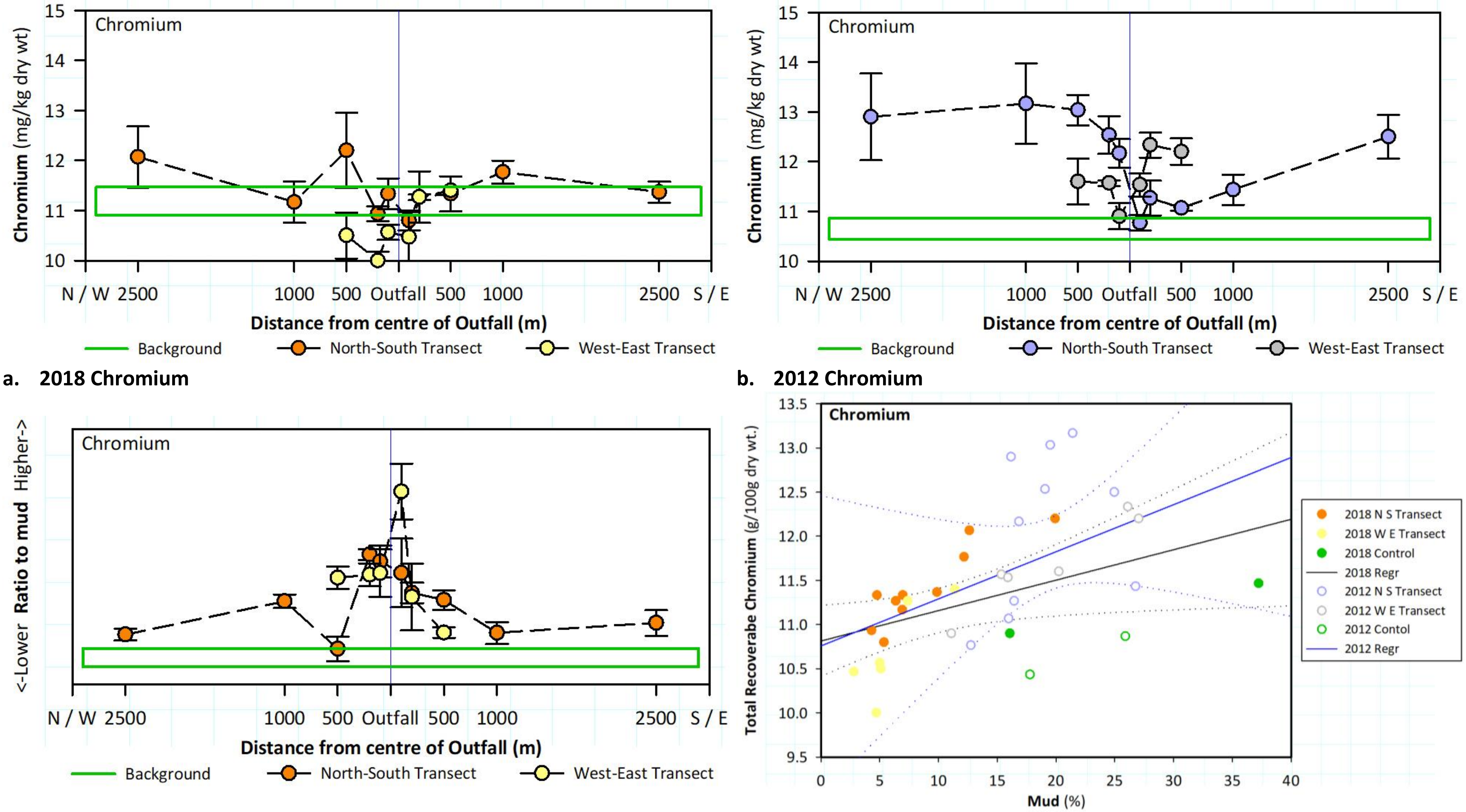
The effect of normalising the chromium to mud was to sharply increase the contrast between those sites close to the outfall and those further away suggesting chromium is enriched near the outfall, relative to surrounding sediments (Figure 9c).

Figure 9d plots the individual data against their sample mud content for 2012 and 2018. The older data were not available. The overlapping data clouds as defined by 95% CL, between the 2018 and 2012 survey sample data indicates there is little evidence that these datasets are distinct from each other.

Table 9 Summary of chromium concentrations in sediments collected off New Brighton Beach in 2018, 2012, 2007, 2004 and 2003 (all data mg/kg dry weight).

Location/Survey	Median	Range	Mean ± Std Dev	CV	Number of samples
New Brighton 2018 (all samples)	11.2	9.8 – 12.9	11.2 ± 0.7	6 %	48
100-200 m subset	10.9	9.8 – 11.7	10.8 ± 0.5	5 %	24
500-2500 m subset	11.4	10.1 – 12.9	11.5 ± 0.6	6 %	24
New Brighton 2012 (all samples)	12.0	10.6 – 14.1	11.9 ± 0.8	7 %	48
100-200 m subset	11.6	10.6 – 14.1	11.7 ± 0.8	7 %	24
500-2500 m subset	12.1	11 – 13.9	12.1 ± 0.8	7 %	24
New Brighton 2007	12.2	11.3 – 14.4	12.4 ± 0.8	6.5 %	48
New Brighton 2004 (all samples)	13.5	11.6 – 18.9	13.8 ± 1.4	10 %	90
2000 m subset	12.8	11.9 – 14.9	12.9 ± 1.2	9 %	45
3000 m subset	14.5	12.1 – 16.6	14.2 ± 1.5	11 %	45
New Brighton 2003*	12.8	11.5 – 13.5	12.7 ± 0.6	15 %	16
Waimakariri River control 2018	11.0	10.6 – 12.1	11.2 ± 0.5	5 %	6
Waimakariri River control 2012	10.5	10.0 – 11.4	10.65 ± 0.55	5 %	6
Waimakariri River control 2007	11.8	11.5 – 12.7	11.9 ± 0.5	4 %	6
Waimakariri River control 2004	15.9	13.1 – 19.7	13.8 ± 1.4	10 %	6
Ashley River 2007	12.1	11.4 – 12.2	12.0 ± 0.3	2.5 %	6
Ashley River 2004	11.4	11.0 – 12.8	13.8 ± 1.4	10 %	6

Notes: *Four samples of mud extracted from samples were also examined. Current sampling is highlighted in orange and previous study in blue.



a. **2018 Chromium**

b. **2012 Chromium**

c. **2018 Chromium mud normalised**

d. **Relationship between Chromium and mud content**

Figure 9 ***a. 2018 and b. 2012 Spatial plots of Chromium sediment quality data, c. 2018 Spatial plot of normalised Chromium sediment quality data, d. Relationship between Chromium concentration and sediment mud content in outfall sediments (dotted lines denote 95% CL)***

3.3.7 Copper

Table 10 provides a summary of total recoverable copper information gathered since 2003 at the CCC ocean outfall and at the control site south of the Waimakariri River. In 2018, copper concentrations were well below the ANZECC ISQG Low trigger level of 65 mg/kg dry weight (Table 3). Median and mean copper concentrations at the outfall sites in 2018 were slightly lower than those measured in 2012 and the baseline in 2003 and 2004. However the median and mean copper concentrations were higher at the control sites in 2018 than recorded in 2012, but lower than that found during the baseline in 2003 and 2004. Further examination of the 2018 sediment copper data showed that all sites around the outfall (within 200 m of the diffuser and >200 m away) contained copper below the range collected at control site (Figure 10a). The net average difference between samples collected close to the diffuser (i.e., within 200 m) and further away (>200 m) was small (± 0.25 mg/kg dry wt.) but the near outfall sites were significantly lower in copper concentration than the distant sites.

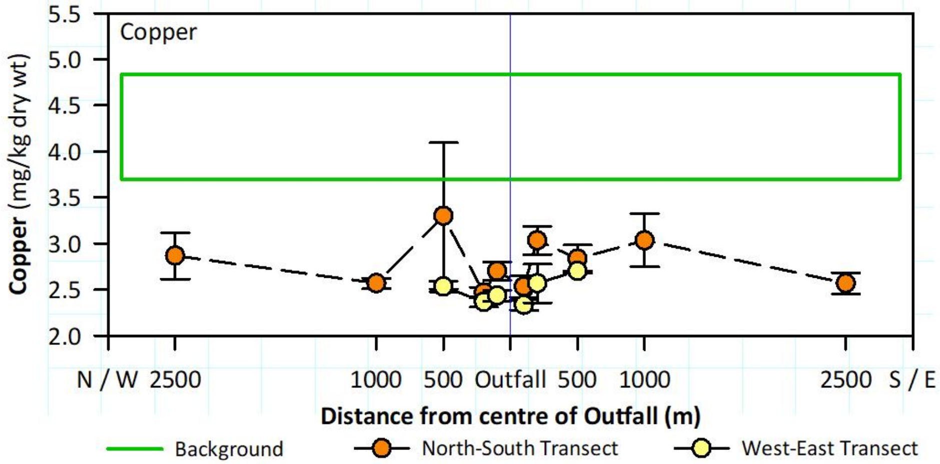
The effect of normalising the copper to mud was to sharply increase the contrast between those sites close to the outfall and those further away suggesting copper is enriched near the outfall, relative to surrounding sediments (Figure 10c).

Figure 10d plots the individual data against their sample mud content for 2012 and 2018. The older data were not available. The overlapping data clouds as defined by 95% CL, between the 2018 and 2012 survey sample data indicates there is little evidence that these datasets are distinct from each other.

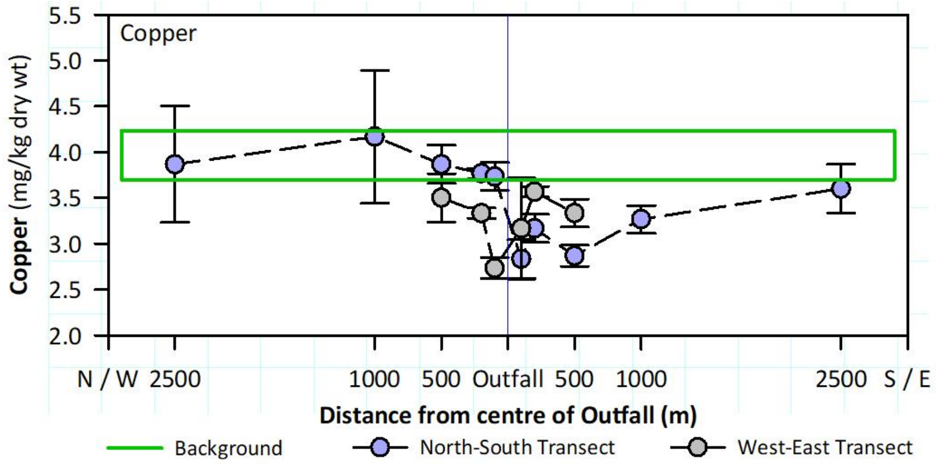
Table 10 Summary of copper concentrations in sediments collected off New Brighton Beach in 2018, 2012, 2007, 2004 and 2003 (all data mg/kg dry weight).

Location/Survey	Median	Range	Mean ± Std Dev	CV	Number of samples
New Brighton 2018 (all samples)	2.6	2.3 – 4.2	2.7 ± 0.3	12 %	48
100-200 m subset	2.5	2.3 – 3.2	2.6 ± 0.2	9 %	24
500-2500 m subset	2.7	2.5 – 4.2	2.8 ± 0.4	13 %	24
New Brighton 2012 (all samples)	3.4	2.6 – 5.0	3.4 ± 0.5	14	48
100-200 m subset	3.3	2.6 – 5.0	3.3 ± 0.5	15	24
500-2500 m subset	3.5	2.8 – 4.6	3.5 ± 0.4	12	24
New Brighton 2007	3.5	3.1 – 4.4	3.6 ± 0.3	8	48
New Brighton 2004 (all samples)	3.7	3.1 – 9.2	4.0 ± 0.9	22.5	90
2000 m subset	3.6	3.2 – 4.1	3.6 ± 0.55	15	45
3000 m subset	3.8	3.5 – 5.8	4.0 ± 0.6	15	45
New Brighton 2003*	3.6	3.2 – 3.9	3.5 ± 0.2	6	16
Waimakariri River control 2018	4.0	3.7 – 5.3	4.27 ± 0.7	17 %	6
Waimakariri River control 2012	4.0	3.6 – 4.8	4.05 ± 0.5	11	6
Waimakariri River control 2007	4.7	4.5 – 5.5	4.8 ± 0.4	8	6
Waimakariri River control 2004	6.8	4.6 – 9.3	6.9 ± 0.3	4	6
Ashley River 2007	3.8	3.5 – 4.0	3.8 ± 0.2	5	6
Ashley River 2004	3.5	3.4 – 4.2	3.6 ± 2.2	61	6

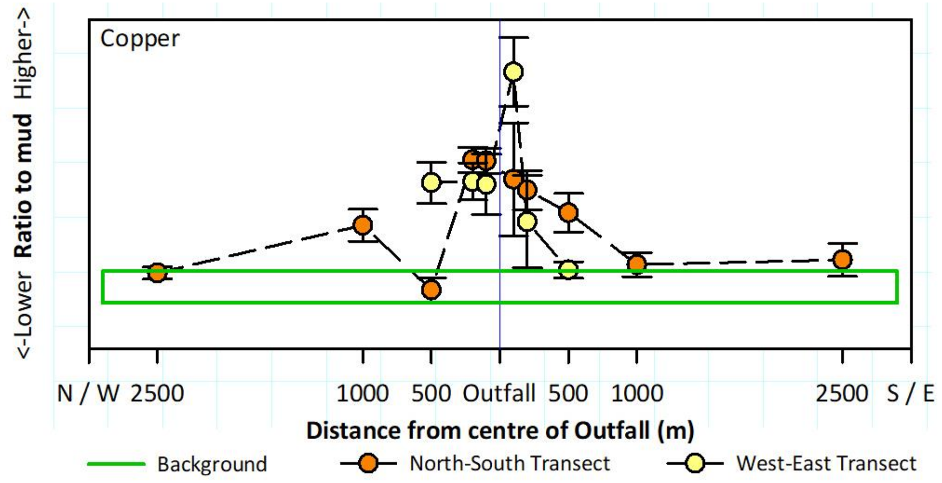
Notes: *Four samples of mud extracted from samples were also examined. Current sampling is highlighted in orange and previous study in blue.



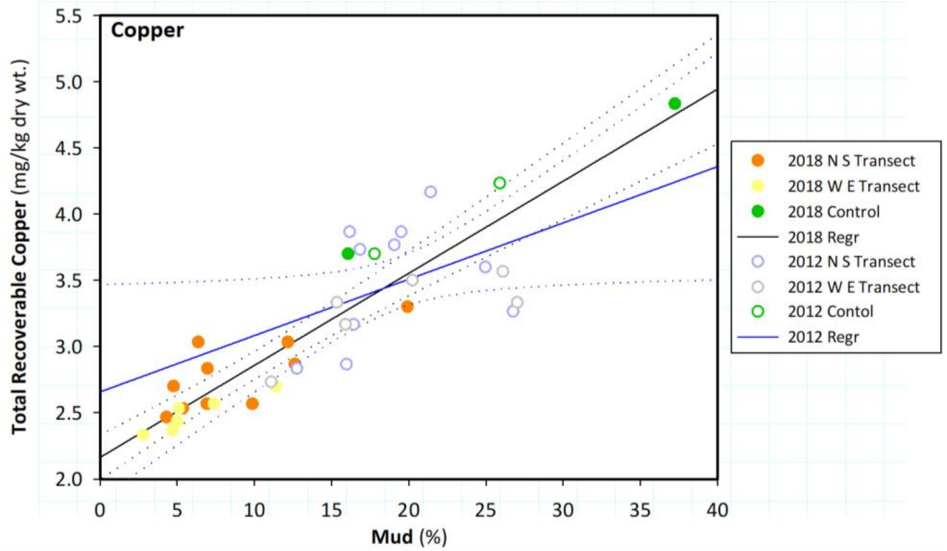
a. **2018 Copper**



b. **2012 Copper**



c. **2018 Copper mud normalised**



d. **Relationship between Copper and mud content**

Figure 10 a. 2018 and b. 2012 Spatial plots of Copper sediment quality data, c. 2018 Spatial plot of normalised Copper sediment quality data, d. Relationship between Copper concentration and sediment mud content in outfall sediments (dotted lines denote 95% CL)

3.3.8 Lead

Table 11 provides a summary of total recoverable lead information gathered since 2003 at the CCC ocean outfall and at the control site south of the Waimakariri River. In 2018, lead concentrations were well below the ANZECC ISQG Low trigger level of 50 mg/kg dry weight (Table 3). Median and mean lead concentrations near the outfall in 2018 were similar to those recorded in 2012, but slightly lower than the baseline values from 2003 and 2004. Further examination of the 2018 sediment lead data showed that sites near the outfall (within 200 m of the diffuser) contained lead within the range collected at control site (Figure 11a), while sites more distant from the outfall (> 200 m from the diffuser) contained lead at concentrations greater than the range collected at the control site. The 2012 and 2018 spatial graphs (Figure 11, a and b) showed similar patterns with the nearshore samples lower in lead than the offshore. The net average difference between samples collected close to the diffuser (i.e., within 200 m) and further away (>200 m) was small (± 0.62 mg/kg dry wt.) but the near outfall sites were significantly ($p=0.003$) lower in lead concentration than the distant sites.

The effect of normalising the lead to mud was to show that fine sediments at sites close to the outfall were enriched by lead, relative to surrounding sediments (Figure 11c), particularly at site E100 just offshore from the outfall.

Figure 11d plots the individual data against their sample mud content for 2012 and 2018. The older data were not available. The lack of overlap between 2018 and 2012 lead concentrations data for smaller proportions of mud suggests the 2018 concentrations were higher than in 2012 when sample sites were less muddy. The control sites did not seem to be similarly affected.

Table 11 Summary of lead concentrations in sediments collected off New Brighton Beach in 2018, 2012, 2007, 2004 and 2003 (all data mg/kg dry weight).

Location/Survey	Median	Range	Mean ± Std Dev	CV	Number of samples
New Brighton 2018 (all samples)	9.5	8.2 – 11.4	9.5 ± 0.7	7 %	48
100-200 m subset	9.2	8.2 – 9.8	9.2 ± 0.5	5 %	24
500-2500 m subset	9.9	8.2 – 11.4	9.8 ± 0.7	7 %	24
New Brighton 2012 (all samples)	9.6	7.7 – 11.7	9.5 ± 1.0	10.5 %	48
100-200 m subset	9.2	7.7 – 11.7	9.3 ± 1.1	12 %	24
500-2500 m subset	9.8	8.1 – 11.3	9.7 ± 0.9	9 %	24
New Brighton 2007	10.0	9.2 – 11.6	10.1 ± 0.5	5 %	28
New Brighton 2004 (all samples)	11.5	9.7 – 18.5	11.7 ± 1.4	12 %	90
2000 m subset	10.7	9.7 – 12.0	10.7 ± 1.0	9 %	45
3000 m subset	11.9	10.8 – 15.3	12.0 ± 1.5	12.5 %	45
New Brighton 2003*	10.5	9.1 – 12.2	10.3 ± 0.8	8 %	16
Waimakariri River control 2018	8.4	7.9 – 9.7	8.7 ± 0.8	10 %	6
Waimakariri River control 2012	7.8	7.2 – 9.8	8.2 ± 1.0	12 %	6
Waimakariri River control 2007	8.4	8.3 – 9.6	8.7 ± 0.5	6 %	6
Waimakariri River control 2004	12.0	9.6 – 15.3	12.3 ± 2.2	18 %	6
Ashley River 2007	9.1	8.8 – 9.3	9.1 ± 0.2	2 %	6
Ashley River 2004	8.1	7.9 – 9.3	8.3 ± 0.5	6 %	6

Notes: *Four samples of mud extracted from samples were also examined. Current sampling is highlighted in orange and previous study in blue.

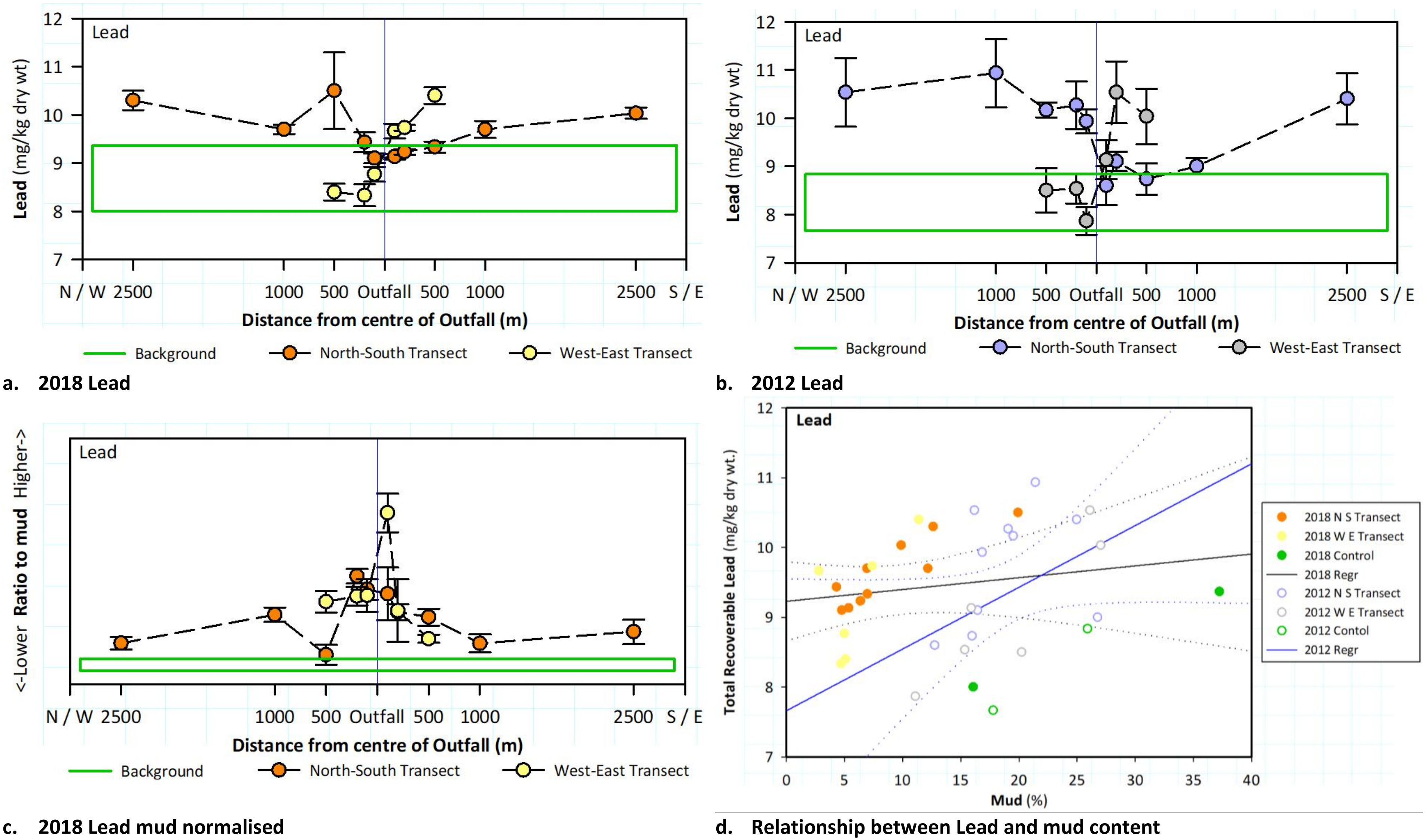


Figure 11 ***a. 2018 and b. 2012 Spatial plots of Lead sediment quality data, c. 2018 Spatial plot of normalised Lead sediment quality data, d. Relationship between Lead concentration and sediment mud content in outfall sediments (dotted lines denote 95% CL)***

3.3.9 Mercury

Table 12 provides a summary of total recoverable mercury information gathered since 2003 at the CCC ocean outfall and at the control site south of the Waimakariri River. In 2018, mercury concentrations were well below the ANZECC ISQG Low trigger level of 0.15 mg/kg dry weight (Table 3). Median and mean mercury concentrations near the outfall in 2018 were slightly higher compared to those recorded in 2012, and the baseline values from 2003 and 2004. Further examination of the 2018 sediment lead data showed that sites near the outfall (within 200 m of the diffuser) contained mercury at concentrations greater than the range collected at the control site (Figure 12a), while sites more distant and inshore from the outfall (> 200 m from the diffuser) contained mercury at concentrations more similar to the range collected at the control site. The 2012 and 2018 spatial graphs (Figure 12, a and b) showed similar patterns with the nearshore samples lower in mercury than those offshore. The net average difference between samples collected close to the diffuser (i.e., within 200 m) and further away (>200 m) was very small (± 0.001 mg/kg dry wt.) and not statistically significant (p=0.295).

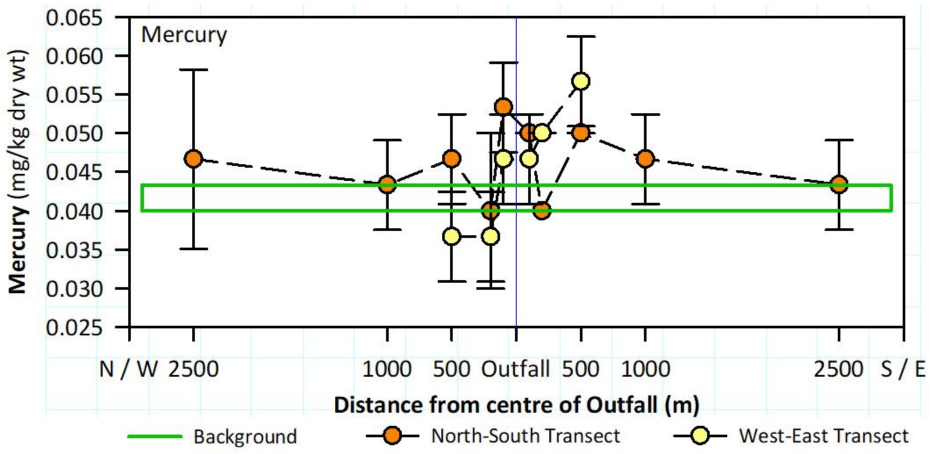
The effect of normalising the lead to mud was to show that fine sediments at sites close to the outfall were enriched by mercury, relative to surrounding sediments (Figure 12c), particularly at site E100 just offshore from the outfall.

Figure 12d plots the individual data against their sample mud content for 2012 and 2018. The older data were not available. The lack of overlap between 2018 and 2012 mercury concentrations data for smaller proportions of mud suggests the 2018 concentrations were higher than in 2012 when sample sites were less muddy. The control sites did not seem to be similarly affected.

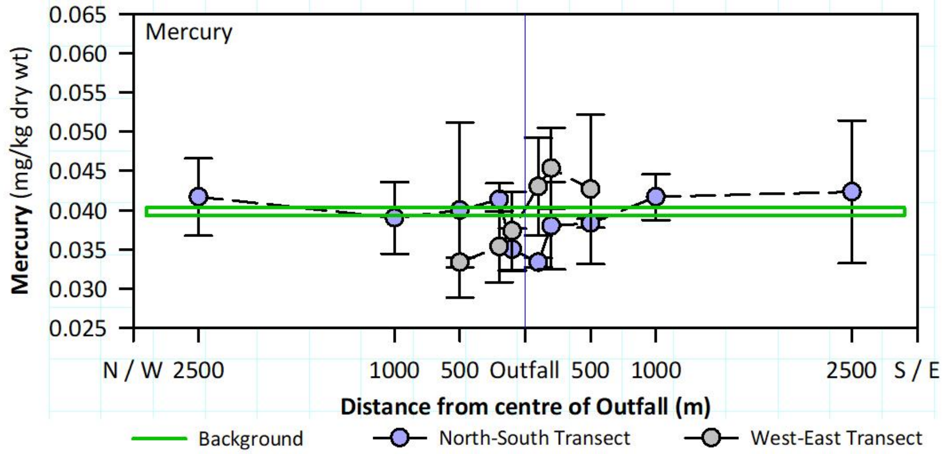
Table 12 Summary of mercury concentrations in sediments collected off New Brighton Beach in 2018, 2012, 2007, 2004 and 2003 (all data mg/kg dry weight).

Location/Survey	Median	Range	Mean ± Std Dev	CV	Number of samples
New Brighton 2018 (all samples)	0.05	0.03 – 0.06	0.05 ± 0.01	16 %	48
100-200 m subset	0.05	0.03 – 0.06	0.05 ± 0.01	16 %	24
500-2500 m subset	0.05	0.03 – 0.06	0.05 ± 0.01	17 %	24
New Brighton 2012 (all samples)	0.039	0.028 – 0.052	0.04 ± 0.006	15 %	48
100-200 m subset	0.038	0.031 – 0.051	0.04 ± 0.005	13 %	24
500-2500 m subset	0.04	0.028 – 0.052	0.04 ± 0.006	15 %	24
New Brighton 2007	0.04	0.02 – 0.08	0.04 ± 0.01	25 %	48
New Brighton 2004 (all samples)	0.04	0.03 – 0.07	0.04 ± <0.01	<25 %	90
2000 m subset	0.04	0.03 – 0.05	0.04 ± <0.01	<25 %	45
3000 m subset	0.05	0.04 – 0.06	0.05 ± <0.01	<20 %	45
New Brighton 2003*	0.03	0.02 – 0.04	0.03 ± <0.01	<33 %	16
Waimakariri River control 2018	0.04	0.04 – 0.05	0.04 ± 0.00	10 %	6
Waimakariri River control 2012	0.04	0.033 – 0.04	0.04 ± 0.006	16 %	6
Waimakariri River control 2007	0.04	0.03 – 0.04	0.04 ± 0	-	6
Waimakariri River control 2004	0.06	0.05 – 0.07	0.06 ± <0.01	<16 %	6
Ashley River 2007	0.04	0.04 – 0.05	0.04 ± 0	-	6
Ashley River 2004	0.035	0.03 – 0.05	0.04 ± <0.01	<25 %	6

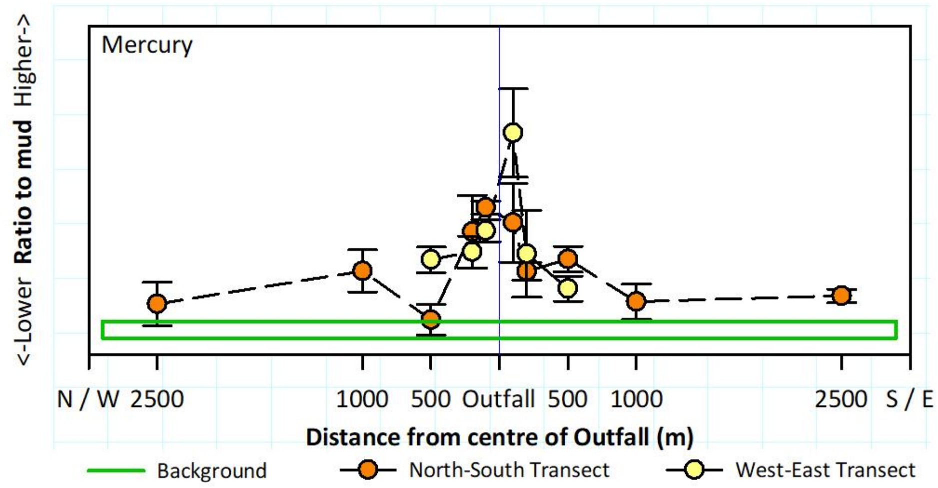
Notes: *Four samples of mud extracted from samples were also examined. Current sampling is highlighted in orange and previous study in blue.



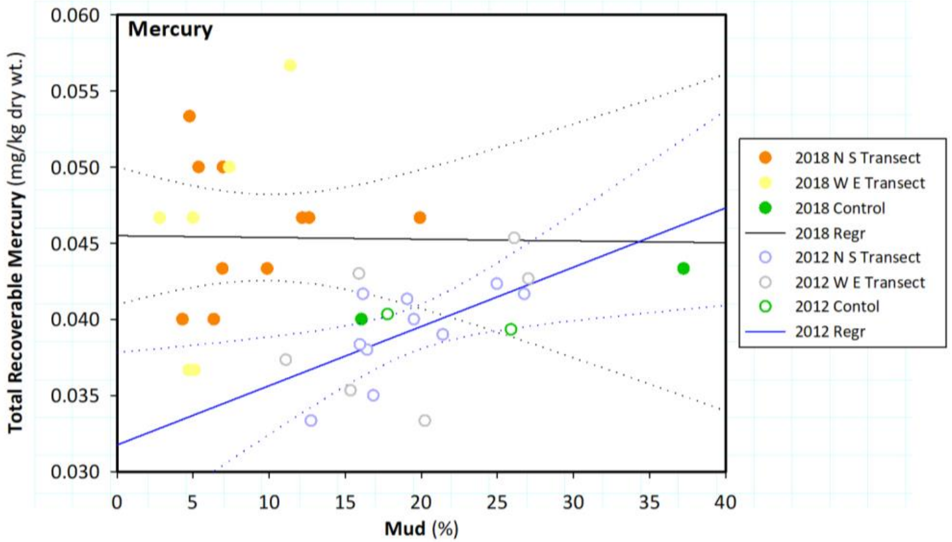
a. 2018 Mercury



b. 2012 Mercury



c. 2018 Mercury mud normalised



d. Relationship between Mercury and mud content

Figure 12 a. 2018 and b. 2012 Spatial plots of Mercury sediment quality data, c. 2018 Spatial plot of normalised Mercury sediment quality data, d. Relationship between Mercury concentration and sediment mud content in outfall sediments (dotted lines denote 95% CL)

3.3.10 Nickel

Table 13 provides a summary of total recoverable nickel information gathered since 2003 at the CCC ocean outfall and at the control site south of the Waimakariri River. In 2018, nickel concentrations were well below the ANZECC ISQG Low trigger level of 21 mg/kg dry weight (Table 3). Median and mean nickel concentrations at the outfall sites in 2018 were slightly lower than those measured in 2012 and the baseline in 2003 and 2004. However the median and mean nickel concentrations were higher at the control sites in 2018 than recorded in 2012, but lower than that found during the baseline in 2003 and 2004. Further examination of the 2018 sediment nickel data showed that sites south and inshore of the outfall contained nickel below the range collected at control site (Figure 13a), while sites north and offshore of the outfall contained nickel within the range collected at the control site. The net average difference between samples collected close to the diffuser (i.e., within 200 m) and further away (>200 m) was small (± 0.65 mg/kg dry wt.) but the near outfall sites were significantly (p=0.008) lower in nickel concentration than the distant sites.

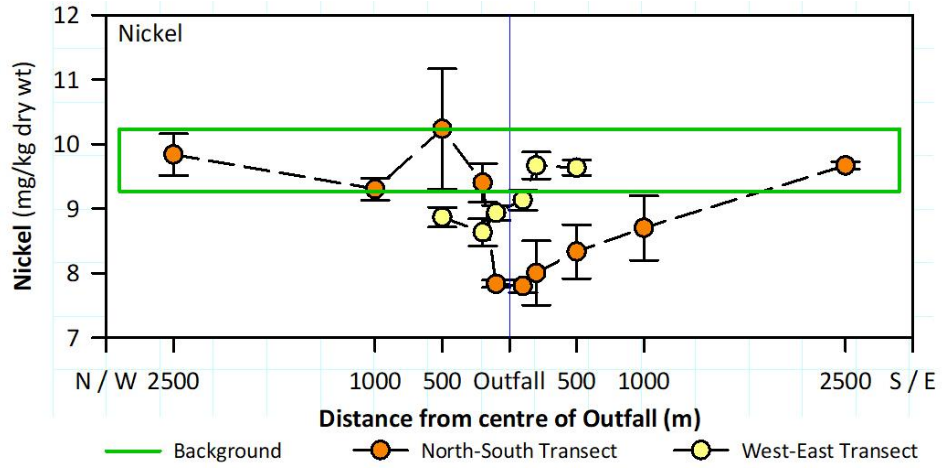
The effect of normalising the nickel to mud was to sharply increase the contrast between those sites close to the outfall and those further away suggesting nickel is enriched near the outfall, relative to surrounding sediments (Figure 13c).

Figure 13d plots the individual data against their sample mud content for 2012 and 2018. The older data were not available. The overlapping data clouds as defined by 95% CL, between the 2018 and 2012 survey sample data indicates there is little evidence that these datasets are distinct from each other.

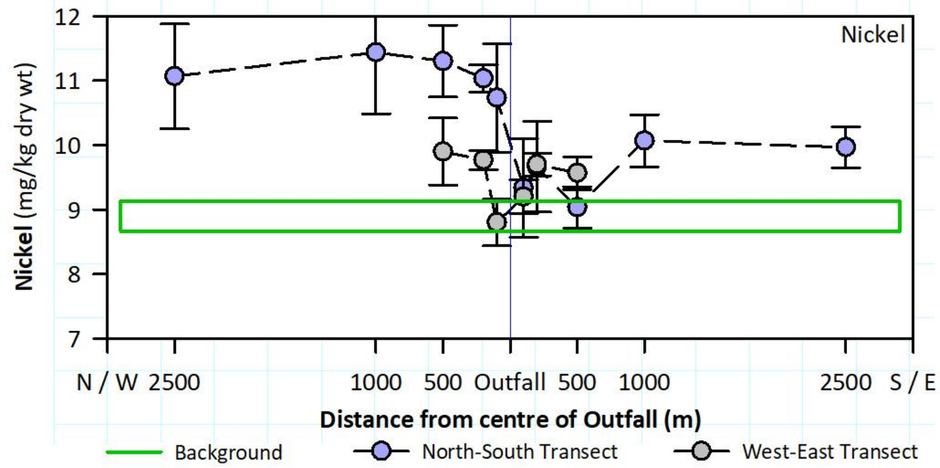
Table 13 Summary of nickel concentrations in sediments collected off New Brighton Beach in 2018, 2012, 2007, 2004 and 2003 (all data mg/kg dry weight).

Location/Survey	Median	Range	Mean ± Std Dev	CV	Number of samples
New Brighton 2018 (all samples)	9.1	7.5 – 11.3	9.0 ± 0.8	9 %	48
100-200 m subset	8.8	7.5 – 9.9	8.7 ± 0.7	8 %	24
500-2500 m subset	9.5	8.0 – 11.3	9.3 ± 0.7	7 %	24
New Brighton 2012 (all samples)	9.8	8.4 – 12.7	10.1 ± 1.0	10 %	48
100-200 m subset	9.7	8.4 – 12.5	9.8 ± 1.0	10 %	24
500-2500 m subset	10.25	8.8 – 12.7	10.3 ± 0.9	9 %	24
New Brighton 2007	9.7	8.9 – 11.2	9.8 ± 0.6	6 %	48
New Brighton 2004 (all samples)	10.7	9.4 – 15.5	10.9 ± 1.0	10 %	90
2000 m subset	10.3	9.7 – 11.5	10.4 ± 0.5	5 %	45
3000 m subset	11.2	9.7 – 13.1	11.1 ± 0.7	6 %	45
New Brighton 2003*	10.6	9.6 – 11.1	10.4 ± 2.0	19 %	16
Waimakariri River control 2018	9.5	9.1 – 10.8	9.8 ± 0.7	7 %	6
Waimakariri River control 2012	9.25	8.4 – 10.1	9.2 ± 0.9	9 %	6
Waimakariri River control 2007	9.8	9.5 – 10.4	9.8 ± 0.3	3 %	6
Waimakariri River control 2004	12.8	10.8 – 15.3	13.0 ± 2.2	17 %	6
Ashley River 2007	9.2	8.6 – 9.7	9.1 ± 0.4	4 %	6
Ashley River 2004	9.1	8.8 – 10.0	9.2 ± 0.5	5 %	6

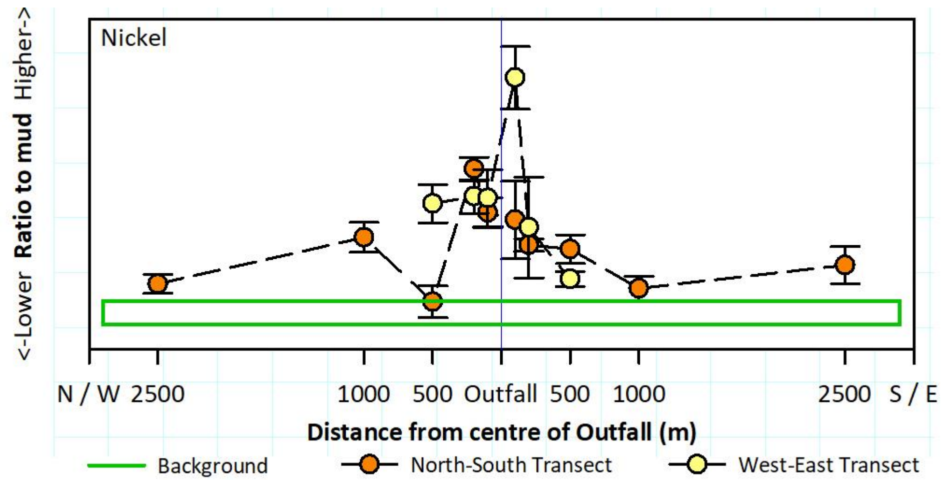
Notes: *Four samples of mud extracted from samples were also examined. Current sampling is highlighted in orange and previous study in blue.



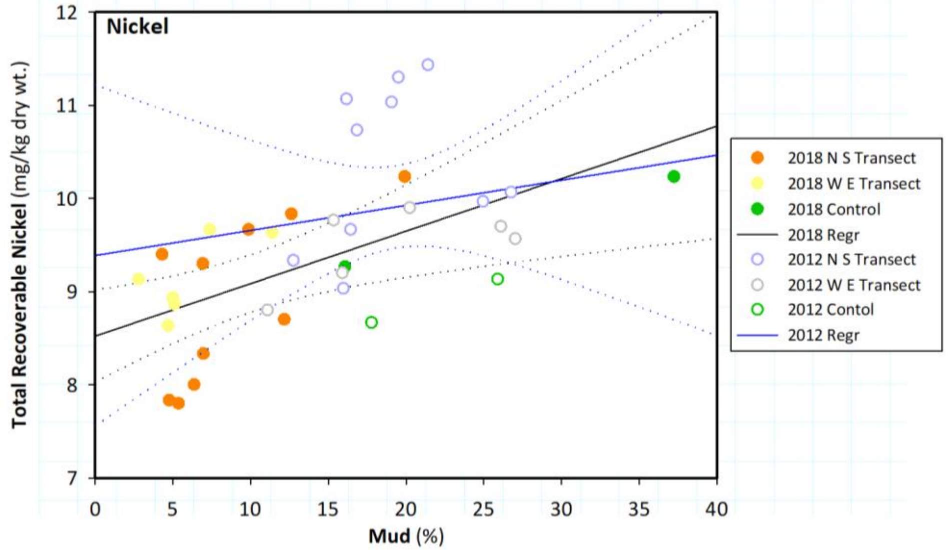
a. 2018 Nickel



b. 2012 Nickel



c. 2018 Nickel mud normalised



d. Relationship between Nickel and mud content

Figure 13 ***a. 2018 and b. 2012 Spatial plots of Nickel sediment quality data, c. 2018 Spatial plot of normalised Nickel sediment quality data, d. Relationship between Nickel concentration and sediment mud content in outfall sediments (dotted lines denote 95% CL)***

3.3.11 Zinc

Table 14 provides a summary of total recoverable zinc information gathered since 2003 at the CCC ocean outfall and at the control site south of the Waimakariri River. In 2018, zinc concentrations were well below the ANZECC ISQG Low trigger level of 200 mg/kg dry weight (Table 3). Median and mean zinc concentrations at the outfall sites in 2018 were similar to those measured in 2012 and slightly lower than the baseline in 2003 and 2004. However the median and mean zinc concentrations were higher at the control sites in 2018 than recorded in 2012, but lower than that found during the baseline in 2003 and 2004. Further examination of the 2018 sediment zinc data showed that generally sites around the outfall (within 200 m of the diffuser and >200 m away) contained zinc within the range collected at the control site (Figure 14a). The net average difference between samples collected close to the diffuser (i.e., within 200 m) and further away (>200 m) was small (± 2.8 mg/kg dry wt.) but the near outfall sites were significantly (p=<0.001) lower in zinc concentration than the distant sites.

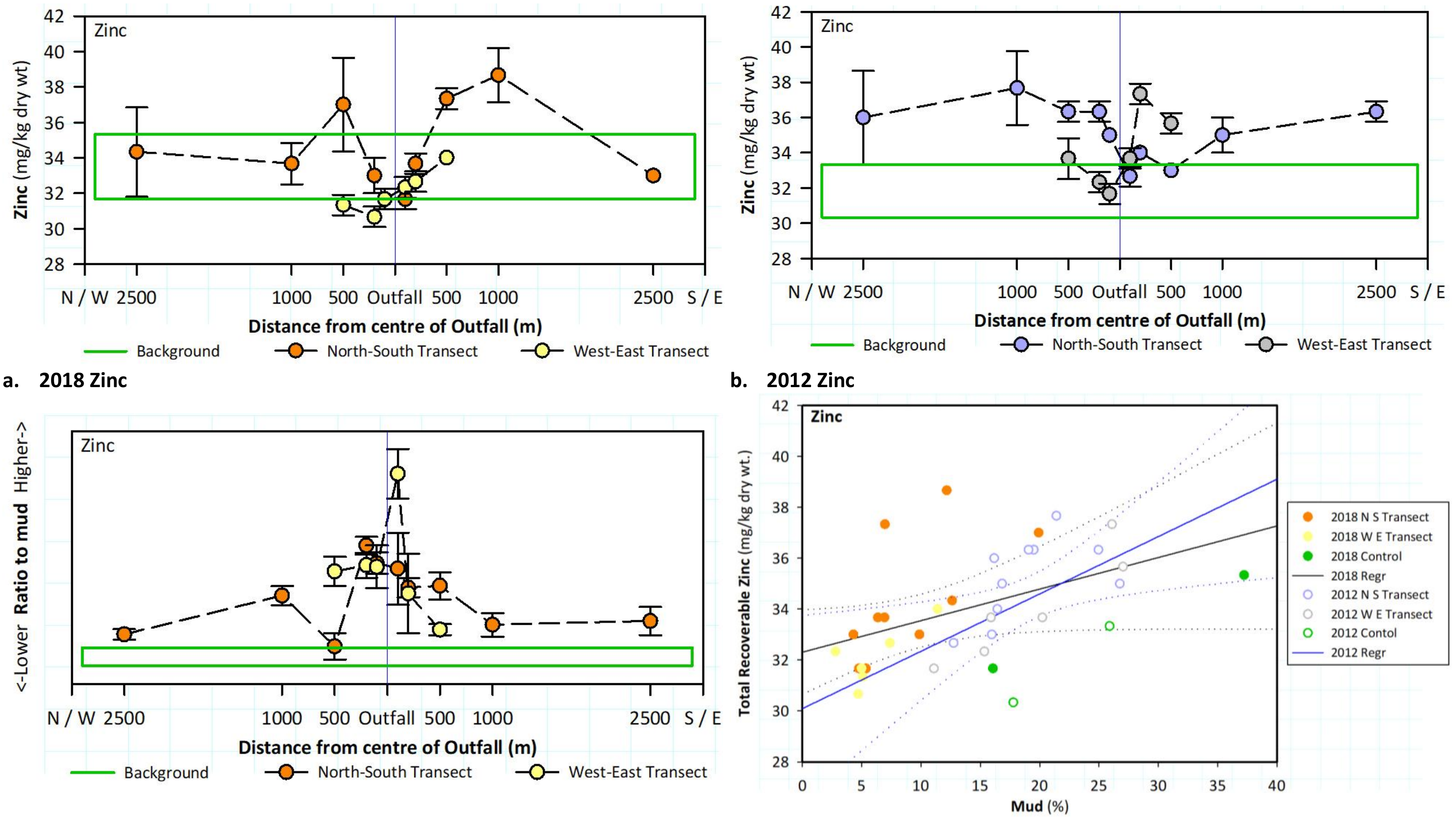
The effect of normalising the zinc to mud was to sharply increase the contrast between those sites close to the outfall and those further away suggesting zinc is enriched near the outfall, relative to surrounding sediments (Figure 14c).

Figure 14d plots the individual data against their sample mud content for 2012 and 2018. The older data were not available. The overlapping data clouds as defined by 95% CL, between the 2018 and 2012 survey sample data indicates there is little evidence that these datasets are distinct from each other.

Table 14 Summary of zinc concentrations in sediments collected off New Brighton Beach in 2018, 2012, 2007, 2004 and 2003 (all data mg/kg dry weight).

Location/Survey	Median	Range	Mean ± Std Dev	CV	Number of samples
New Brighton 2018 (all samples)	33	30 - 40	34 ± 2.5	7 %	48
100-200 m subset	32	30 - 34	32 ± 1.1	3 %	24
500-2500 m subset	34	31 - 40	35 ± 2.7	8 %	24
New Brighton 2012 (all samples)	35	31 – 40	34.8 ± 2.0	6 %	48
100-200 m subset	34	31 – 40	34.3 ± 2.3	7 %	24
500-2500 m subset	36	33 – 39	35.3 ± 1.6	5 %	24
New Brighton 2007	36.5	33.6 – 42.9	36.6 ± 2.3	6 %	48
New Brighton 2004 (all samples)	41.2	36.9 – 60.4	41.7 ± 3.9	9 %	90
2000 m subset	38.9	36.9 – 45.1	39.4 ± 2.2	6 %	45
3000 m subset	41.9	37.9 – 51.9	42.2 ± 2.9	7 %	45
New Brighton 2003*	40.4	30 – 36	40.1 ± 7.9	4 %	16
Waimakariri River control 2018	33	31 - 37	33.5 ± 2.4	7 %	6
Waimakariri River control 2012	31	8.4 – 10.1	32 ± 2.2	7 %	6
Waimakariri River control 2007	35.2	34.6 – 39.7	56.0 ± 1.9	5 %	6
Waimakariri River control 2004	50.4	41.1 – 62.0	50.4 ± 9.9	20 %	6
Ashley River 2007	33.8	33.4 – 35	34.1 ± 0.7	2 %	6
Ashley River 2004	34.7	33.9 – 39.1	35.3 ± 2.0	6 %	6

Notes: *Four samples of mud extracted from samples were also examined. Current sampling is highlighted in orange and previous study in blue.



a. 2018 Zinc

b. 2012 Zinc

c. 2018 Zinc mud normalised

d. Relationship between Zinc and mud content

Figure 14 ***a. 2018 and b. 2012 Spatial plots of Zinc sediment quality data, c. 2018 Spatial plot of normalised Zinc sediment quality data, d. Relationship between Zinc concentration and sediment mud content in outfall sediments (dotted lines denote 95% CL)***

3.4 Discussion

Constituents in the discharge behave differently when discharged from the diffuser to the sea off New Brighton. The nature of these constituents is a function of the CCC wastewater treatment plant processes. Broadly, these can be grouped as:

- **Inorganic particulates** (suspended sediment) that will be deposited to the seabed depending upon their size/density and local sea conditions.
- **Organic particulates** (e.g., algal cells) which will tend to be transported further than inorganic particles of the same size.
- **Dissolved constituents** that are conservative, stay dissolved and are transported away with local currents.
- **Dissolved constituents** that are not-conservative that are either taken up by biota (e.g., by plankton) or undergo physio-chemical changes when the freshwater they are in mixes with seawater. These may result in removal from solution and, depending upon conditions, incorporation into sediment.

All whole sediment concentrations recorded in 2018 were below the ANZECC ISQG low trigger values which suggest no adverse ecological effects would be expected.

When the 2018 whole sediment concentrations were considered the concentrations of phosphorus, arsenic, lead, mercury at the outfall sites were greater than at the control sites, while concentrations of cadmium and copper were higher at the control sites than near the outfall. Concentrations of TOC, chromium, nickel and zinc near the outfall were not greatly different from the control sites. Concentrations of phosphorus, TOC, cadmium, chromium, copper, lead and nickel were all elevated to the north, with the >200 m concentrations higher that those near the outfall. Total nitrogen was highest close to the outfall to the south. While the concentrations of arsenic and zinc were highest to the south. These results suggest a northward transportation of discharges. The concentrations were generally higher beyond 200 m from the outfall than those closer to the outfall, suggesting the majority of contaminants discharged are either attached to organic particles or dissolved.

To assess the differences between sites within the 2018 data set, all the site data were averaged, and Primer 7 was used normalise the data and a resemblance matrix calculated using Euclidean distance. The matrix was then subjected to grouped average clustering with SIMPROF testing to define statistically significantly related sites. Additionally the data were subjected to Principal Components Analysis (PCA) to graphically show the relationship between sites (Figure 15). Figure 15 shows the control sites (WR1 and WR2) are largely different from the outfall sites based on their increased percentage of mud, copper and cadmium. Sites to the north of the outfall (N500 and N2500) showed similarities and were different from other sites around the outfall (F) as a result of elevated concentrations chromium, nickel, TOC, zinc, phosphorus and lead. The sites in the inshore grouping C (W200 and W500) were also shown to be different from other outfall sites (F) in that they had less mercury and phosphorus.

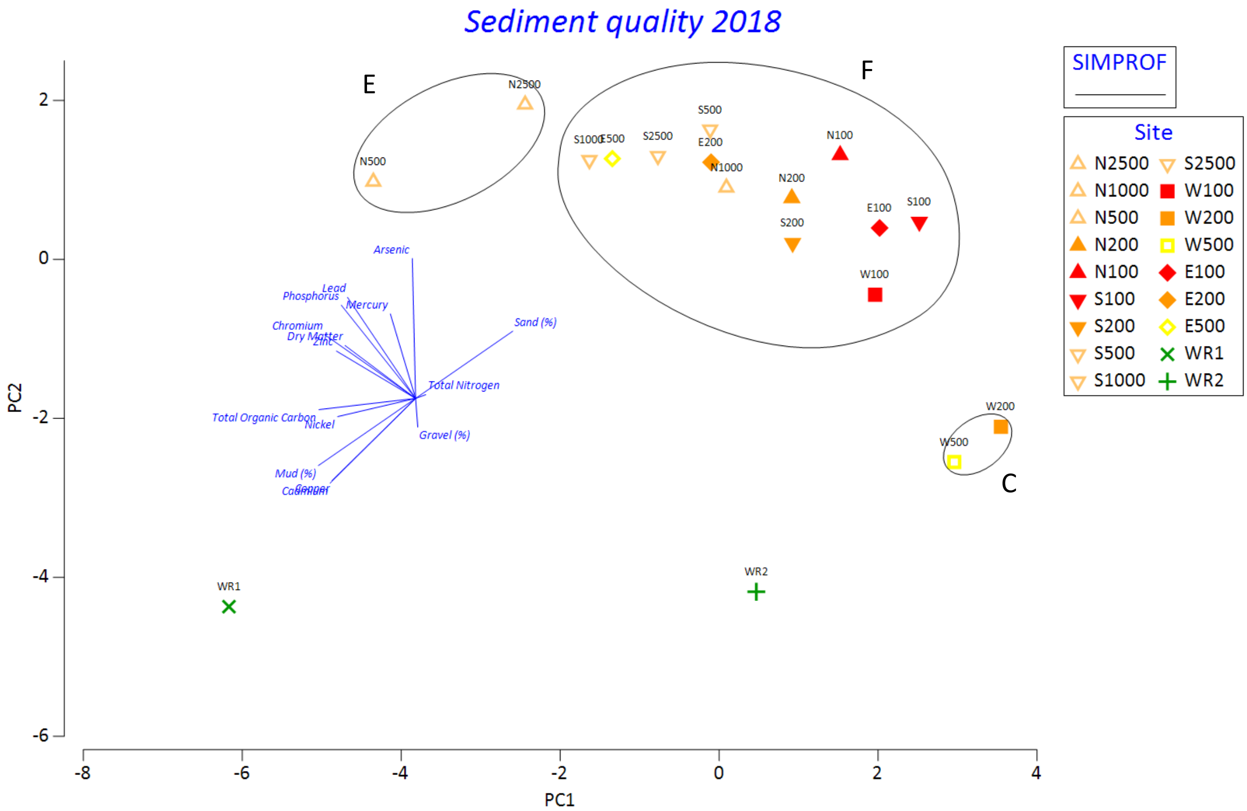


Figure 15 ***Principal Components Analysis 2018 whole sediment quality data, showing site clustering and parameter vectors.***

The whole sediment concentrations of TOC, cadmium, chromium, copper and nickel were lower in 2018 compared with 2012 while the concentrations of arsenic were greater in 2018. The concentration of mercury was greater at the outfall sites in 2018 compared to 2012 but similar at greater distance from the outfall. The concentrations of total nitrogen, total phosphorus, lead and zinc were not dissimilar between 2012 and 2018.

The differences between the 2012 and 2018 sediment quality were also compared with a PCA plot (Figure 16). Figure 16 shows the samples from the outfall area in 2018 were separated from the 2012 outfall sites based on more mercury and nitrogen in 2018 than 2012 and less nickel, chromium, mud, TOC and copper in 2018 than in 2012. The differences between the control sites in 2012 and 2018 were smaller but largely the results of greater concentration of TOC and cadmium and more mud in 2018 than in 2012.

When the whole sediment contaminant concentrations are normalised by percentage mud all contaminants show elevated levels near the outfall, in comparison to those further afield and at the control.

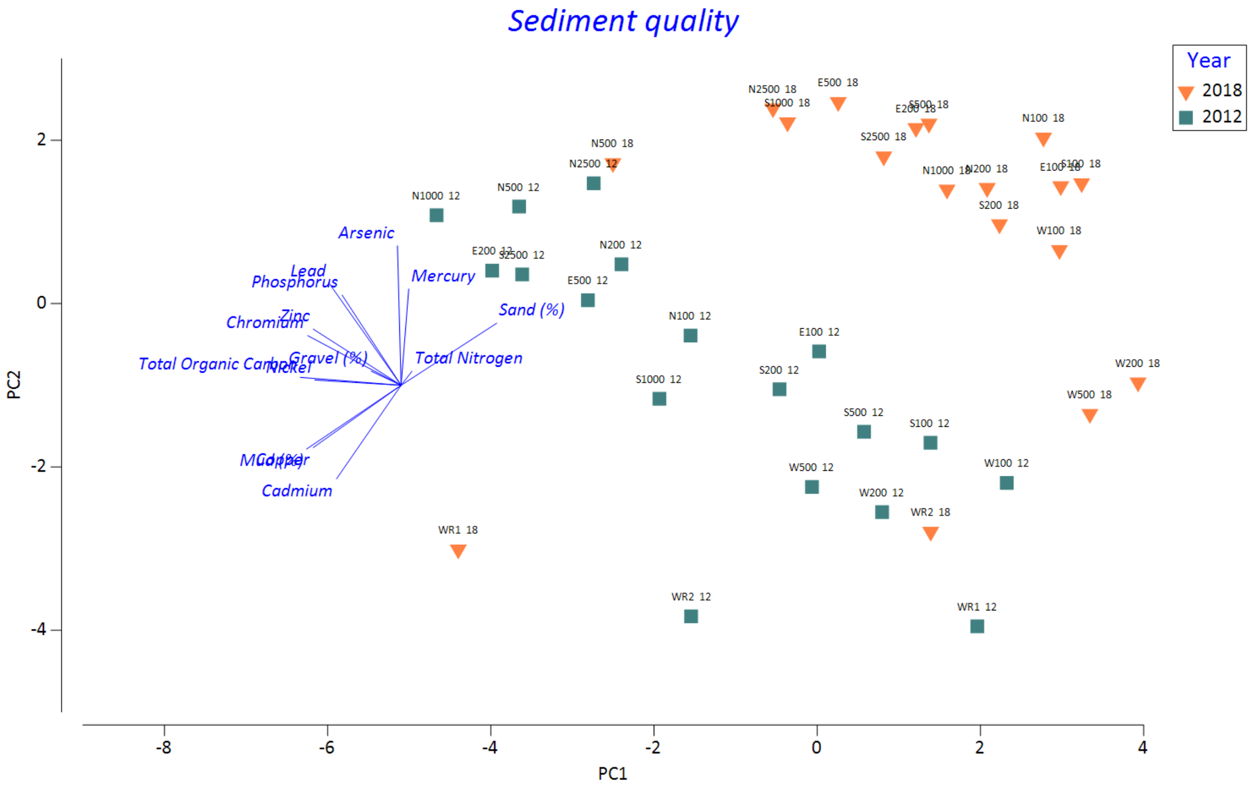


Figure 16 Principal Components Analysis 2012 and 2018 whole sediment quality data, showing parameter vectors

4. BENTHIC ECOLOGY

4.1 Introduction

The benthic faunal communities were assessed using two sampling techniques which target slightly different communities. The benthic epifauna includes those species living on the surface of the seabed; these often include larger biota that occur in patchy distributions of wide areas. The benthic epifauna were surveyed by benthic epifauna dredge tows. The benthic infauna includes those species living within the seabed sediments; the infauna biota is generally small and thus its distribution varies over a small scale. The benthic infauna was surveyed by collecting seabed core samples.

Standard descriptive parameters were used to assess the variation in benthic faunal assemblages and to examine any changes in the benthic fauna since the surveys conducted prior to commissioning. A range of univariate quantitative measures were used to describe the faunal community, including abundance (number of individuals), species richness (number of species) and species diversity (a measure of the abundance of species relative to the total species at each site). Species diversity was calculated using the Shannon-Weiner Diversity Index. Shannon-Wiener Diversity Index measures the rarity and commonness of species in a community and is calculated using the following formula.

$$H = - \Sigma (p_i \ln p_i)$$

Here p_i is the proportion of total number of species made up of the i^{th} species.

All benthic fauna data are presented in Appendix 5.

4.2 Benthic Epifauna

The epifaunal taxa present in the vicinity of the outfall and at the Waimakariri River control site consisted of common species of annelids, molluscs, crustaceans, echinoderms and fish; as well as specimens from less common phyla that typically reside on or within the sediment as infauna, including sea anemones (Cnidaria), peanut worms (Sipuncula), spoon worms (Echiura), and the worm-like priapulids (Priapulida).

4.2.1 Spatial Distribution

The abundance of epibenthic species recovered from the tows is presented in Table 32 in Appendix 5. Photographs showing the epifaunal organisms collected in each of the dredge tows are provided in Figure 29 in Appendix 5. The echinoderm *Fellaster zelandiae* (sand dollar) was the most abundant epibenthic species overall and was found in moderate numbers at both tow sites near the outfall. Sand dollars are highly mobile deposit feeders that live on the sand or are buried very shallow in the sand, often in high densities. Molluscs were the most taxonomically diverse epibenthic group of epifauna at the Waimakariri control sites, however were species poor at the outfall sites. There was a similar decrease in species richness of the taxonomic groups of crustacea and polychaetes between the Waimakariri control sites and the outfall sites.

Table 15 provides a summary of the epifauna and other species found in the tows undertaken since 2003. It was noted that the data present in Table 21 of the Golder, 2012 report were incorrect with regard to average abundance of taxa groupings and total abundance and diversity for data from 2007 and 2012, these have been corrected in Table 15. Lack of raw data prevented correction of the 2003 and 2004 data in Table 15.

In 2018 the proportions of molluscs and crustacea were lower at the CCC outfall sites compared with the Waimakariri river control sites. Conversely the proportion of echinoderms was higher at the CCC outfall New Brighton sites compared with the Waimakariri river control sites. The abundance of epibenthic fauna was greater north of the outfall compared with south; both north and south were lower in abundance of benthic epifauna when compared to the control. While the epibenthic dredge tows to the north of the outfall had slightly lower species richness than the dredge tows collected to the south of the outfall, the difference was slight. The species richness of benthic epifauna around the outfall was lower than that recorded at the Waimakariri River control sites.

Table 15 Summary of average abundance for epifaunal dredge tow taxa for all surveys of the Christchurch City Council outfall 2003- 2018.

Taxa / Site	New Brighton	New Brighton	Waimakariri River	Ashley River	New Brighton	Waimakariri River	New Brighton	Waimakariri River	New Brighton	Waimakariri River
Date	**2003**	**2004**	**2004**	**2004**	**2007**	**2007**	**2012**	**2012**	**2018**	**2018**
Mollusca	*7*	*11*	*49*	*25*	*37.2*	*56.7*	*65.8*	*119.0*	0.3	11.3
Crustacea	*49*	*16*	*26*	*28*	*10.3*	*5.7*	*72.3*	*38.0*	0.2	1.0
Annelida	*0.25*				*1.2*	*14.0*	*2.3*	*14.0*		4.0
Echinodermata	*0.25*	*5*			*6.8*	*2.3*	*317.7*	*24.3*	13.8	2.7
Fish	*2*	*7*	*8*	*8*	*1.7*	*1.0*	*6.0*	*6.7*		1.0
Priapulida						*2.7*				
Sipuncula					*0.2*	*0.7*				
Cnidaria	*1*					*0.7*	*0.3*	*0.3*		0.7
Echiura						*0.3*				
Ctenophore	*12*			*67*						
Bryozoa							*0.5*			
Total Average Abundance	***64.5***	***28***	***34***	***103***	***57***	***84***	***465***	***202***	**14**	**21**
Average Number of taxa	***9***	***10***	***12***	***10***	***11***	***17***	***19***	***20***	**2**	**8**

Note: *values in italics corrected from the 2007 and 2012 reports based on epibenthic biota data presented in those reports*. Current sampling is in blue.

4.2.2 Temporal Changes

Consistent with previous years the average number of taxa was greater at the Waimakariri Control site than the CCC outfall New Brighton sites.

The total abundance of fauna around the outfall in 2018 was less than that observed in previous sampling (2003, 2004, 2007 and 2012). Some of the variation seen between years may be due to the different dredges used between sampling events. The dredge used in 2018 was slightly smaller in size than in previous years and likely a different design which may have resulted in it moving differently across the seabed.

The proportion by abundance of molluscs and crustaceans has decreased over time 2007 to 2018 at the outfall sites, while the proportion has remained similar at the Waimakariri control site. Conversely the proportion of echinoderms has increased over time 2007 to 2018, at both the CCC outfall New Brighton sites and the Waimakariri control site, however the increases at the outfall sites are much greater (Figure 17).

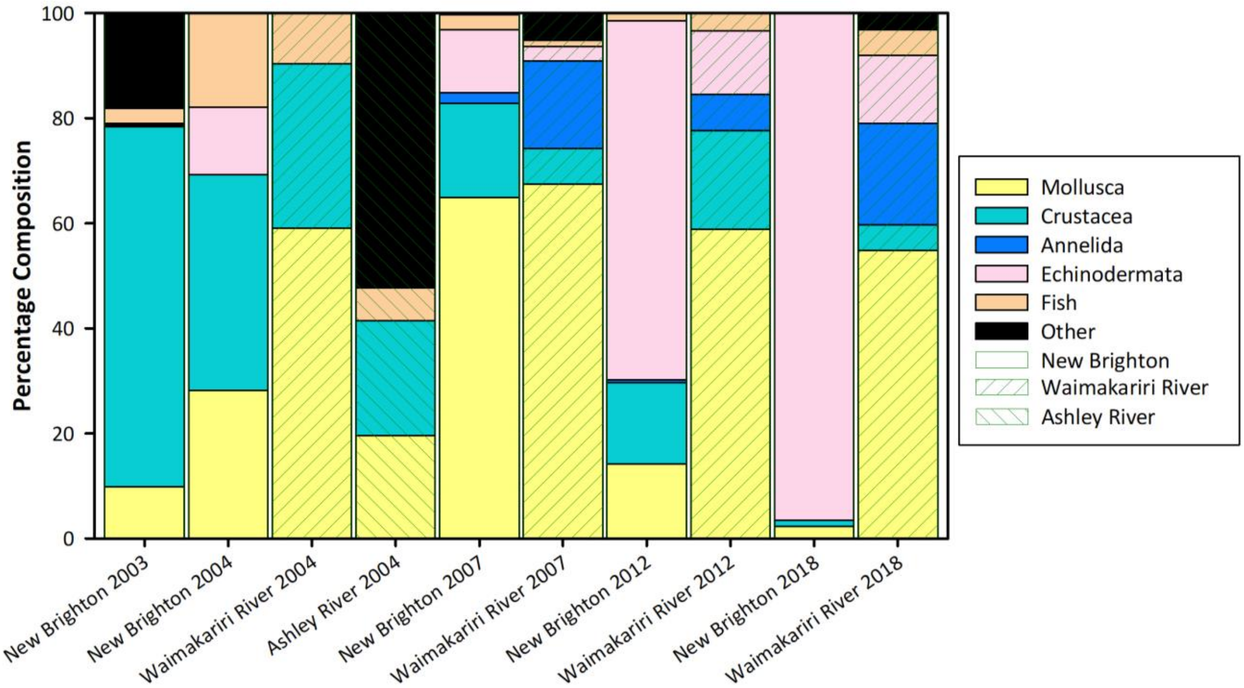


Figure 17 Percentage composition of major taxa groupings in epifauna biota

4.3 Benthic Infauna

The infaunal taxa present in the vicinity of the CCC outfall and at the Waimakariri River control site consisted of common species of annelids, molluscs, crustaceans and echinoderms; as well as specimens from less common phyla, including sea anemones (Cnidaria), nemerteans, flatworms (Platyhelminthes) and horseshoe worms (Phoronida).

In addition to the statistical analysis of the univariate summary statistics of abundance, richness and diversity, the use of multivariate analyses techniques including cluster analysis and non-metric multidimensional scaling (MDS) were used to allow the patterns in species composition and abundance data to be observed between sites and over time. These multivariate analyses, however, do not provide an indication of the statistical significance of the differences or what has changed between sites or surveys, to lead to the observed differences. Therefore, a multivariate analysis of variance (MANOVA) test is required to determine the statistical significance of the degree of difference between the species abundance and composition data for the sites. Unfortunately, the assumptions for a MANOVA will never be satisfied for typical multi-species abundance data, therefore non-parametric MANOVA has been conducted.

Ordination procedures were carried out using data averaged per site that were fourth root transformed to reduce the dominance of highly abundance species in assessing overall benthic community trends.

4.3.1 Spatial distributions

Abundance

Average abundance increased with increasing distance from the diffuser along the North-South Transect, with approximately twice the number of organisms at the sites >1 km from the diffuser compared to those at 100 m from the diffuser (Figure 18). The exceptions to this pattern were sites N1000 and S2500 where much lower abundances of fauna were recorded, which is due to a lower abundance of annelid worms at these sites compared to other locations. Sites outside of the 200 m mixing zone had a greater average abundance than those within 200 m of the diffuser. There was no clear pattern to the fluctuations in average abundance along the West-East Transect, although the deeper eastern samples were higher in abundance than the shallower western samples. The average abundance at control sites was similar to the mixing zone sites but lower than the more distant outfall sites. The variability (standard deviation) associated with average abundance was higher for some sites, particularly those with high numbers of organisms such as site N2500 (Figure 18).

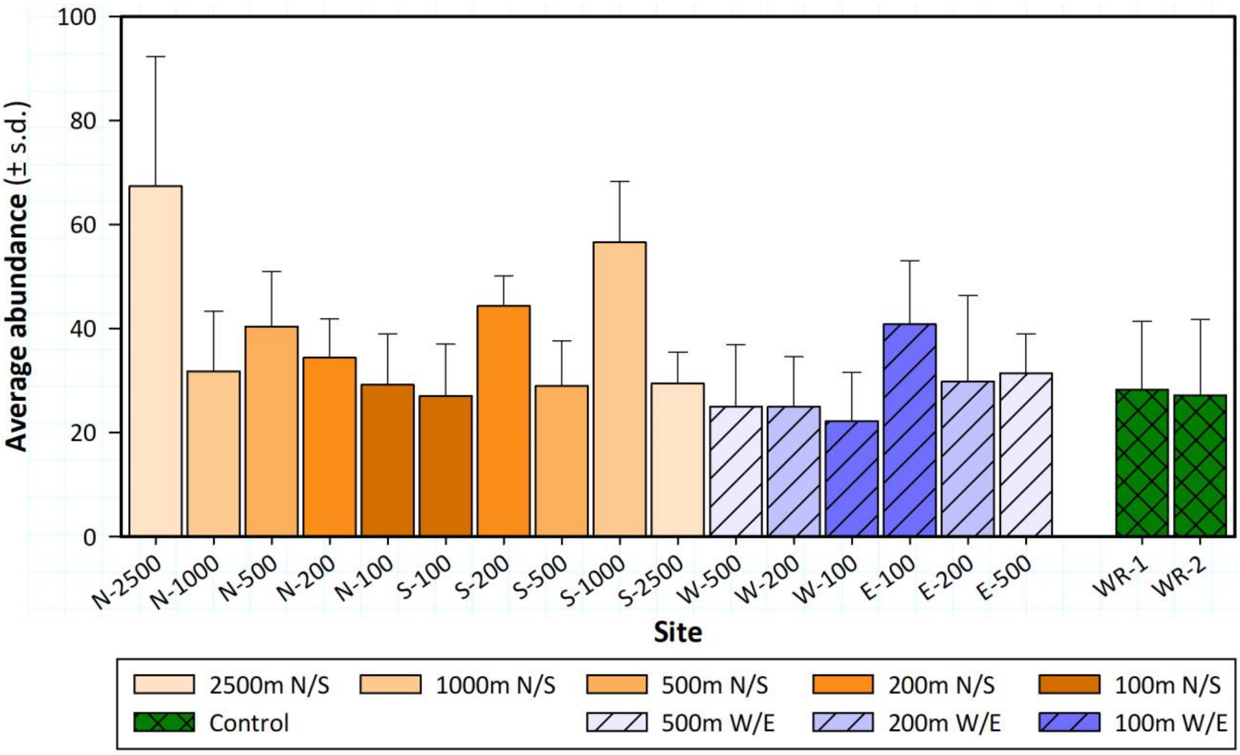


Figure 18 Average faunal abundance (± standard deviation) for all sites sampled near the Christchurch City Council ocean outfall and Waimakariri River control sites in 2018.

Sites N2500 and S1000 had the highest average abundances of all sites with an average of 67.4 and 56.6 organisms per replicate respectively. These high abundances were largely due to high numbers of annelid worms (Figure 19), in particular the polychaete *Heteromastus filiformis*. Similarly lower average abundances at sites N100, S100, W100 and W200 were partially the result of lower numbers of annelid worms in particular the polychaete *Heteromastus filiformis*. Capitellidae worms such as *Heteromastus filiformis* prefer a muddy sand habitat with mud content of up to 95%, with an optimum range of 10-40%, in estuaries and harbours where they can burrow deeply into the sediment up to about 10 cm. Capitellidae worm abundance is often high in organically enriched estuarine sediments. Mud content at sites N2500 and S1000 is approximately 12% just within the preferred range for *Heteromastus filiformis*, while at sites N100, S100, W100 and W200 the mud content was approximately 5%, below their preferred range.

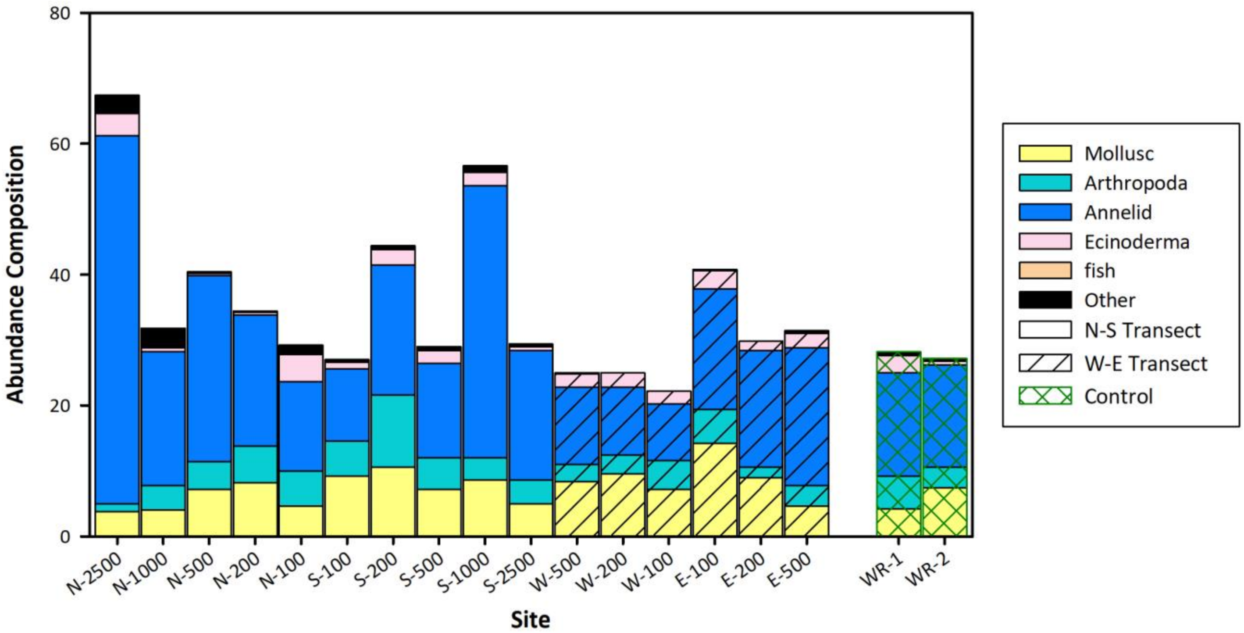


Figure 19 Average abundance for benthic fauna groups for all sites sampled near the Christchurch City Council ocean outfall and Waimakariri River control sites in 2018.

Species richness

Average species richness ranged between 12.8 and 21.0 species per site, with an overall average for all sites of 15.4 species per sample (stdev. = 4.1). There were no distinguishable differences between sites overall for average species richness, however species richness does not account for changes in species composition.

Shannon Wiener Diversity

Species diversity was generally relatively similar at all sites with the exception of N2500 which was much lower than all other sites. There was an almost imperceptible, gradual decrease in diversity with distance from the outfall along the North-South Transect and similarly away from the outfall along the West-East Transect (Figure 21). Diversity within the mixing zone sites was marginally higher than the average recorded outside the mixing zone but less than that recoded at the Waimakariri control sites.

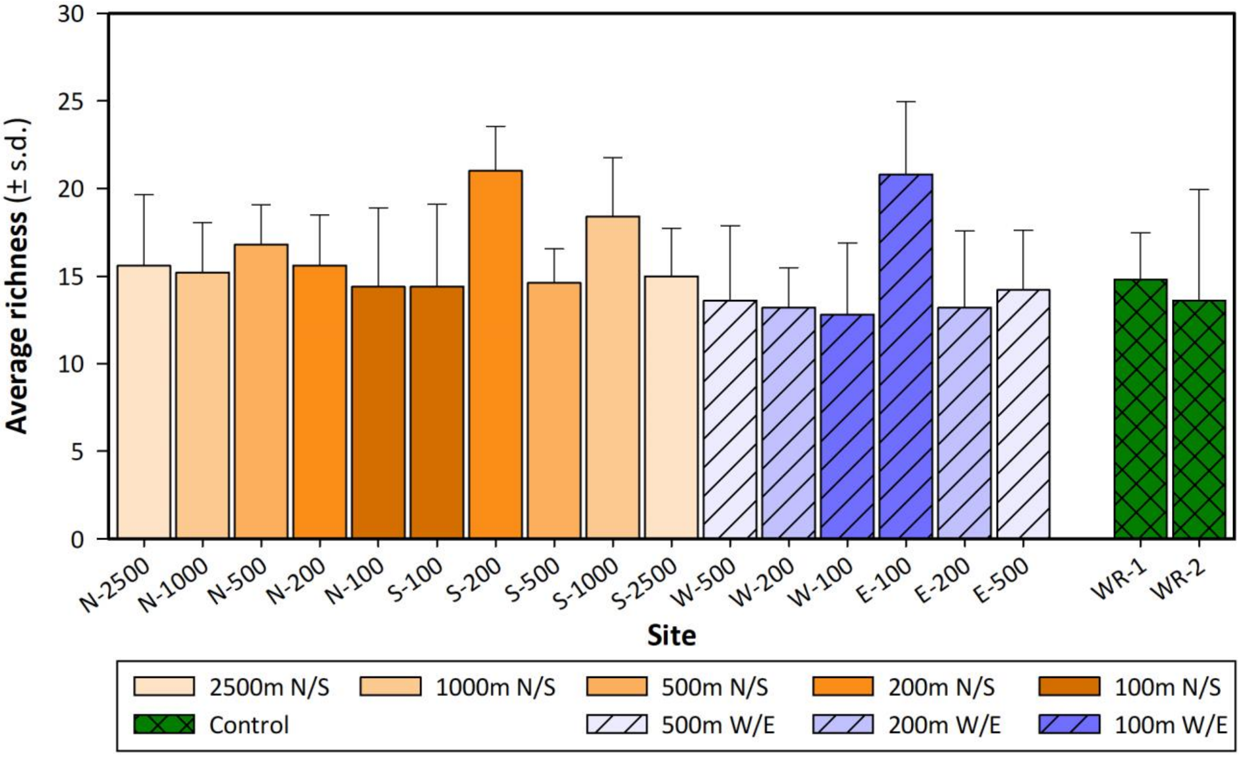


Figure 20 ***Average species richness (± standard deviation) for all sites sampled near the Christchurch City Council ocean outfall and Waimakariri River control sites in 2018.***

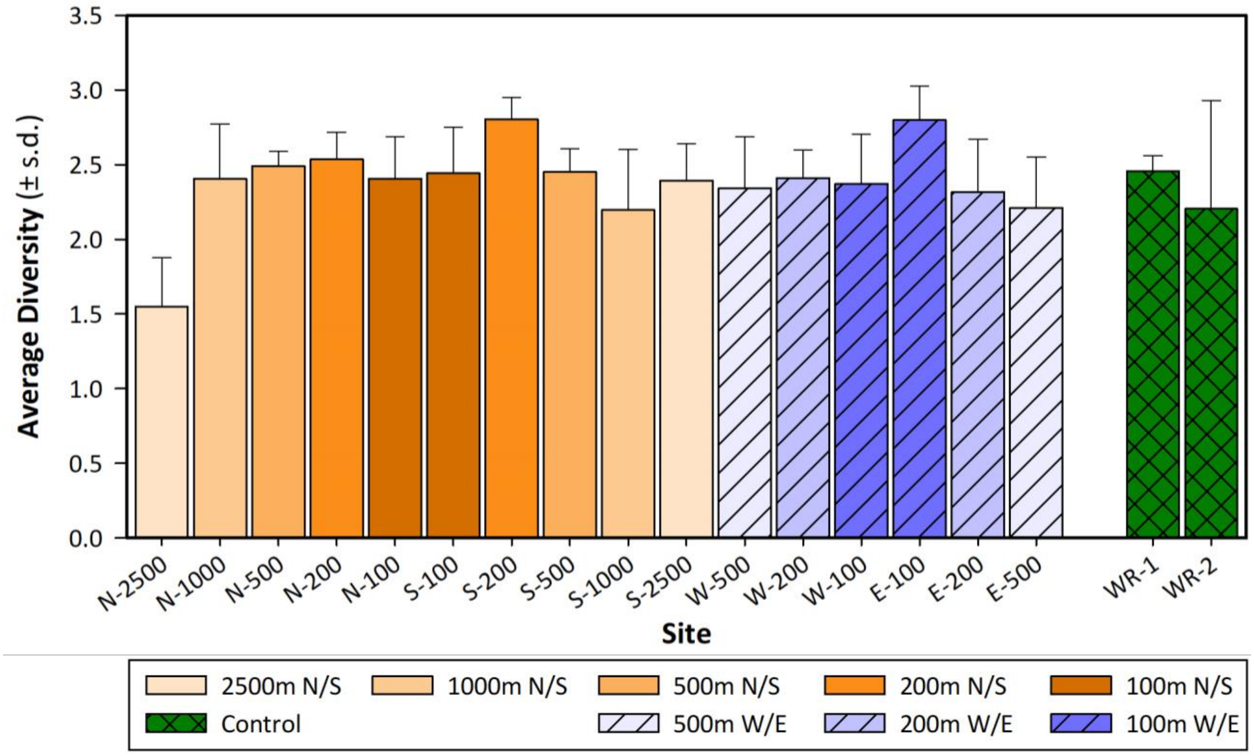


Figure 21 ***Average species diversity (± standard deviation) for all sites sampled near the Christchurch City Council ocean outfall and Waimakariri River control sites in 2018.***

Benthic community structure

To further investigate the patterns in the benthic infauna data as a whole, the data were subjected to multivariate analysis. Prior to multivariate analysis the replicate benthic infauna data were averaged at each site. The data were then transformed using a fourth root transformation to reduce the effects of the very abundant species. A resemblance matrix was then calculated using the Bray Curtis similarity measure. To determine the similarity of species composition and abundance between sites the resemblance matrix was then analysed using grouped average cluster analysis provided by the software package Primer 7. Similarity profile permutation testing was used to look for statistically significant evidence of structure between the sites. In addition the data were subjected to non-metric multiple dimensional scaling (nMDS) to provide a 2D representation of the similarities between sites. The closer together the points for each sample are, the more similar the benthic infauna community structure is between the site. The Primer nMDS analysis provides a stress value, which is an indication of how well the plots fit the real data. Stress values <0.05 provide excellent representation with no prospect of misinterpretation, <0.1 corresponds to a good ordination with no real prospect of misleading interpretation, <0.2 still gives a potentially useful 2D picture, though for values in the upper end of this range little reliance should be placed on the detail of the plot. The results of the cluster analysis are shown in Figure 22 and results of the nMDS analysis are shown in Figure 23, symbols have been used to show statistically significant cluster groups while symbol colour has been used to show further site groupings. The 2D stress value of 0.2, while on the high side, the nMDS still gives a useful representation of the differences and similarities within the species composition and abundance data.

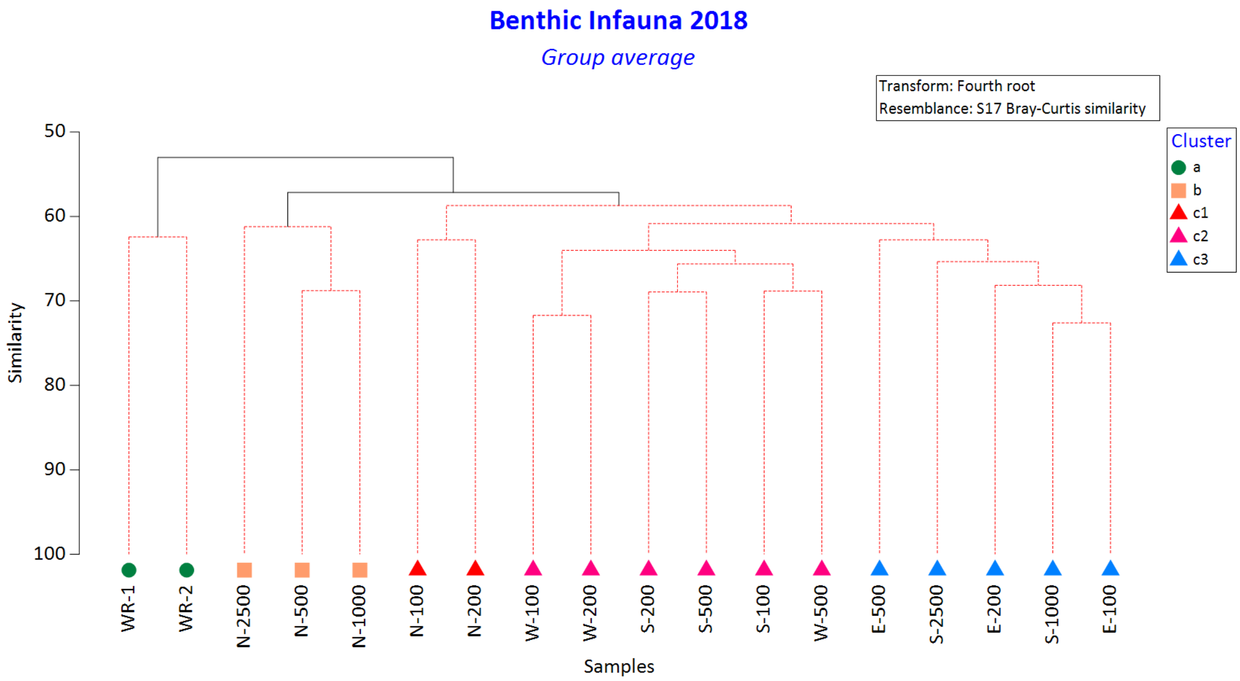


Figure 22 Dendrogram generated using Grouped average Clustering in Primer 7.

The cluster analysis determined that the Waimakariri control sites had a different species composition and abundance from those at the CCC Outfall. Within the outfall area the sites (N500, N1000 and N2500) at the northern end of the North South transect were showed significantly different structure to those to the south and across shore. Within this southern group of sites the cluster analysis shows non-significant structure splitting the sites into three groupings; C1 (sites N100 and N200), C2 (sites S100, S200, S500, W100, W200 and W500) and C3 (sites E100, E200, E500, S1000 and S2500). This grouping makes sense geographically with the groupings defining adjacent non overlapping areas.

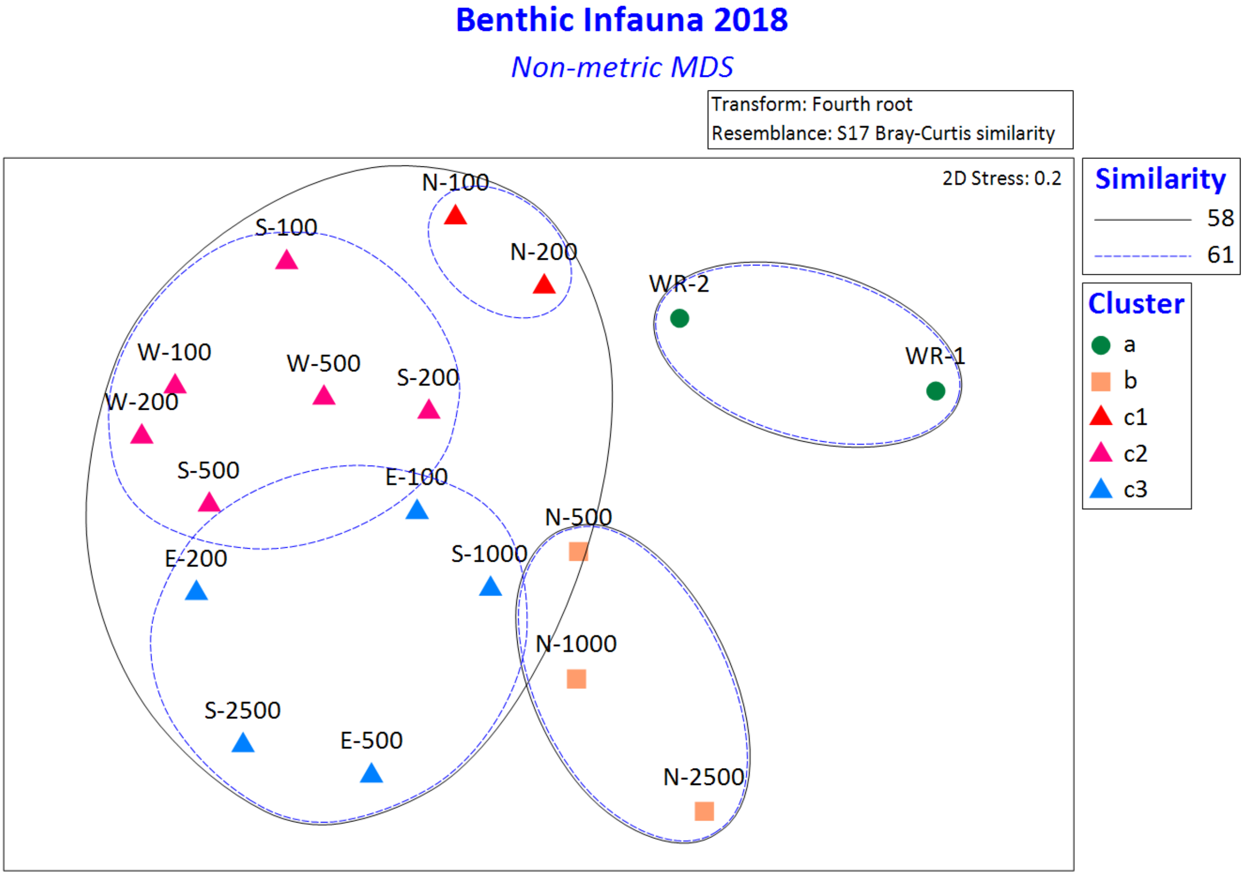


Figure 23 ***nMDS ordination plot of the benthic community in the vicinity of Christchurch City Council outfall in 2018 with site clustering outlined.*** *(Note: axis on the plots are not related to any variable and are numberless)*

To assess the species responsible for the differences between sites Primer 7 offers the SIMPER function; the results are present in Table 28 in Appendix 4. The differences in community structure are defined by dissimilarity of species between sites or site groupings contribution. Between the three site groupings defined above no individual species stands out with significantly greater contributions than others, to the dissimilarities between sites.

The Control sites showed absence of 57 taxa present at other sites including the polychaete *Aricidea* sp., the horseshoe worm *Phoronus* sp., brittle starfish (Ophiuroidea), the bivalve *Dosinia anus* and the Tanaidacea, but the presence of the polychaete *Pectinaria australis* and Hydromedusae that were absent from outfall sites. In group b which included sites N500, N1000 and N2500, 41 species recorded at other sites were absent, 33 of these were only recorded at the group c sites in low numbers. Within group b the polychaete worm *Heteromastus* were most the abundant, followed by the polychaete worms *Prionospio australiensis*, Goniadidae, *Magelona dakini*, Nephtyidae, the Phoxocephalidae amphipods, the bivalve *Myllitella vivens* and the horseshoe worm *Phoronus* sp. In group c 33 species were recorded that were not recorded at other sites albeit at very low numbers. Within group c the polychaete worm *Heteromastus* were most the abundant, followed by the polychaete worms Nephtyidae, Goniadidae and

Prionospio australiensis, the Phoxocephalidae amphipods, the bivalves *Myllitella vivens* and *Nucula nitidula.*

The differences in species composition and abundance between sites within the mixing zone out to 200m from the outfall were compared with those beyond and at the control sites and were tested by the ANOSIM (Table 29 in Appendix 4) and PERMANOVA (Table 30 in Appendix 4) functions in Primer 7. In both cases the individual site replicate data were used following the fourth root transformation and construction of a resemblance matrix based on Bray Curtis similarity. In both cases the differences between each group (mixing zone, outside mixing zone and control) were statistically significantly different from each other at the 0.05% level. The differences were further analysed with SIMPER (Table 31 in Appendix 4) to determine the contribution of each species to the dissimilarities between groups.

The differences between the mixing zone sites and those outside the mixing zone near the outfall were defined by a group of 27 species with the polychaete worms *Heteromastus filiformis*, *Prionospio australiensis*, Goniadidae, *Magelona dakini*, *Aglaophamus* sp., Ampharetidae, the crustacea Tanaidacea, the horseshoe worm *Phoronus* sp. and the bivalve *Nucula nitidula* all showing increases in abundance outside the mixing zone. The differences between the mixing zone sites and control sites were defined by a group of 25 species with the polychaete worms *Prionospio* sp., *Prionospio australiensis*, Goniadidae, *Owenia petersonae*, Sigalionidae, *Heteromastus filiformis* and *Scoloplos cylindrifer*, the bivalves *Nucula nitidula* and *Serratina charlottae*, the sea cucumber *Trochodota dendyi* and the ribbon worms Nemertea all showed higher abundance at the control sites than in the mixing zone. The differences between those sites outside the mixing zone near the outfall and control sites were defined by a group of 27 species with the polychaete worms *Prionospio* sp., *Owenia petersonae*, Sigalionidae, *Scoloplos cylindrifer*, Goniadidae and Ampharetidae, the bivalves *Serratina charlottae*, *Arthritica bifurca*, the amphipod Haustoridae, the tanaid *Diasterope grisea*, the sea cucumbers *Trochodota dendyi*, *Paracaudina chilensis* and the ribbon worms Nemertea that all showed higher abundance at the control sites than at those outside the mixing zone near the outfall. Species such as the bivalve *Myllitella vivens* the Phoxocephalidae amphipods and the sea cucumber *Heterothyone ocnoides* were all more abundant within the mixing zone sites compared with other sites.

4.3.2 Temporal changes

No numerical raw data for the 2004 baseline study was available to compare with the later survey data, or summary statistic. Were possible 2004 data has been estimated from past reports for graphs but the raw data required for statistically tests was not available.

Abundance

Compared to data collected in 2012, the average faunal abundance had decreased by 2018 at all sites along the North-South Transect and at all of the West-East Transect sites (Figure 24). Faunal abundance had also decreased at both control sites. The most notable decreases in abundance were recorded at sites N1000, N500, S2500, E200 and WR2. The pattern of general decrease in abundance suggests it is the result of factors other than the outfall, with the exception of Site E200, the sites closest to the outfall showed the least change in abundance between 2012 and 2018. By comparison to baseline data collected in 2004, (note this data was estimated from graphs in 2012 report) the average abundance of fauna in 2018 was again lower than that recorded previously (Figure 24). The patterns in fluctuating abundance were similar across all sites over time, decreased between 2004 and 2007, increased between 2007 and

2012, and decreased between 2012 and 2018. As discussed in the 2012 report (Golder, 2012) the large increases in abundance in 2012 were the result of very high numbers of juvenile echinoids.

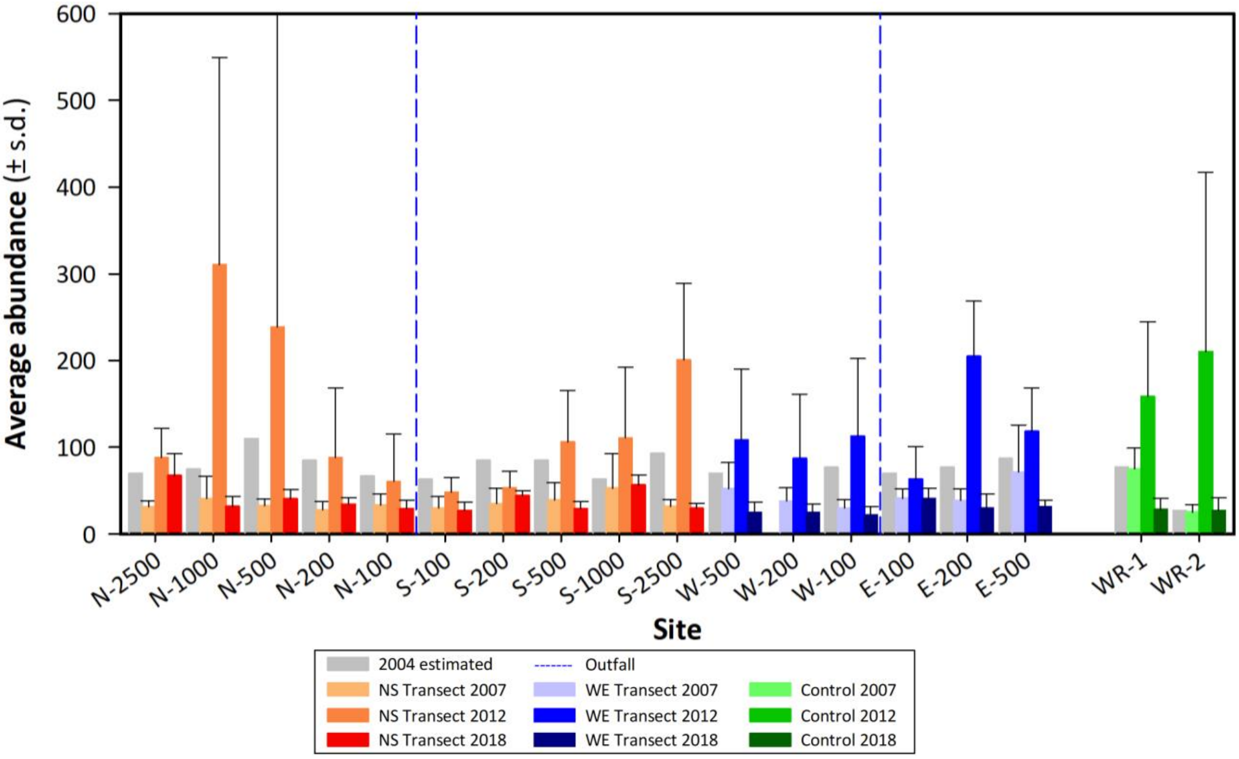


Figure 24 Average fauna abundance for all sites sampled near the Christchurch City Council ocean outfall and Waimakariri River control sites in 2004, 2007, 2012 and 2018.

Species richness

Species richness was generally lower in 2018 compared to 2012 (including the control sites), and was similarly less than that recorded in 2004 (Figure 25). The level of taxonomic resolution has varied between surveys whereby a greater number of fauna were identified to genus or species level in 2004 and 2012 but most fauna could only be identified as far as family level in 2007; the 2018 data seems to be somewhere in between 2007 and 2012. In 2012 there was a lack identification to species level with a large number of genera differentiated into multiple unknown species, and less grouping into family level. In 2018 there were less unknown species; genera usually only had a maximum of one unknown species or data were grouped into a higher taxa. The reason for this difference in resolution is not known but could reflect the improving scientific knowledge with time, type of species present (i.e., some taxonomic groups can be more difficult to identify than others based on their size and complexity of morphology), varying preservation and condition of samples for identification or experience of the taxonomist.

Putting aside the taxonomic resolution difference, the changes in species richness may be attributed to natural variation in species composition between years. There were slightly lower numbers of species recorded in close proximity to the outfall location in 2004, 2007 and 2012, however in 2018 the numbers of species were higher within the 200m mixing zone compared with those further away and at the control.

In 2004 there was a pattern of greater species richness near the outfall along the west-east transect prior to construction of the outfall pipeline. No such pattern was evident in 2007, however in 2012 the species richness was greater at the offshore end of the transect. In 2018 the species richness was greatest 100m east of the outfall, but flat along the rest of the transect. The patterns over time suggests that species richness was naturally greater mid transect and that in recent years after the installation of the outfall this peak in species richness has shifted further offshore. This provides some suggestion that the pattern of species richness could be a reflection of the impact on the benthos from installation and operation of the outfall.

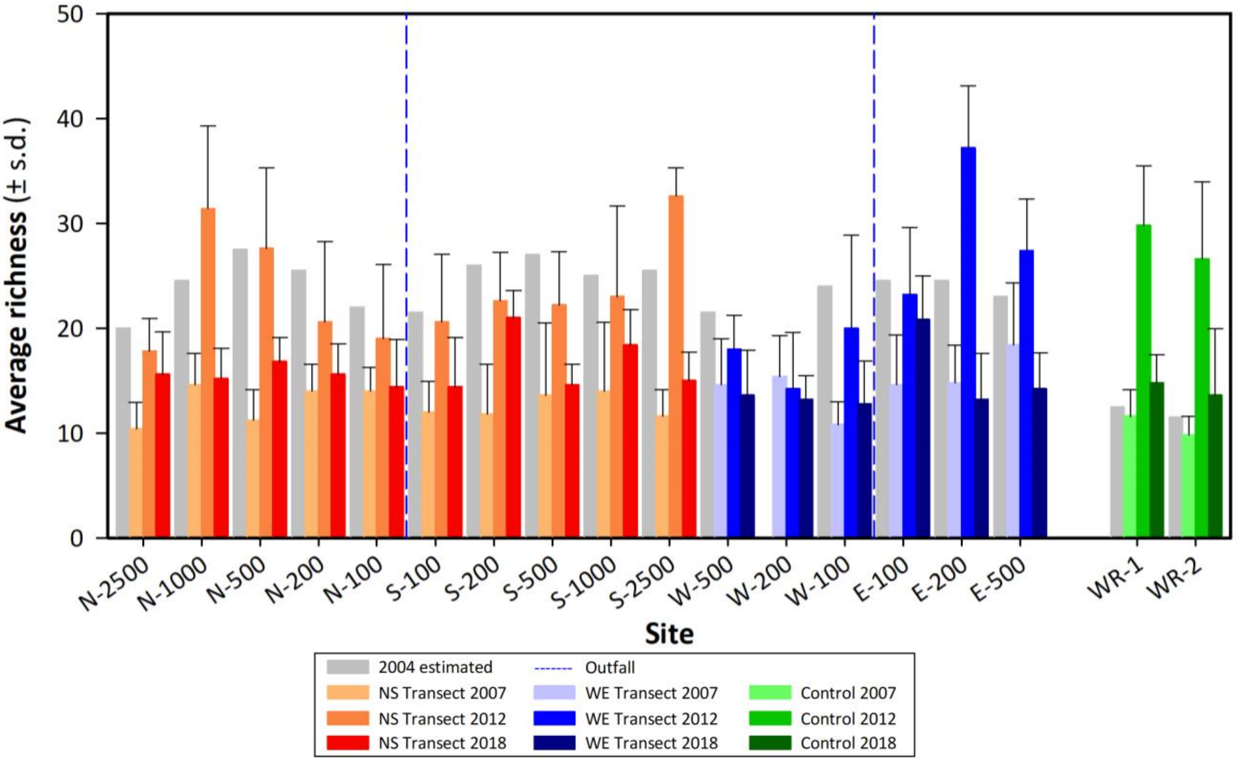


Figure 25 Average species richness for all sites sampled near the Christchurch City Council ocean outfall and Waimakariri River control sites in 2004, 2007, 2012 and 2018.

Shannon Wiener Diversity

Estimation of the 2004 Shannon wiener diversity index values was not possible from the graphs in the 2012 report. Between 2007 and 2012 the diversity on average increased within the mixing zone, but remained the same at the more distance sites, while the control showed greater increases. In 2018 the Shannon Wiener Diversity was typically slightly higher than that recorded in 2012; the exception was those sites to the east of the outfall (Figure 26). Overall the diversity has increased at between 2007 and 2018 at all sites except N2500, W200 and E500.

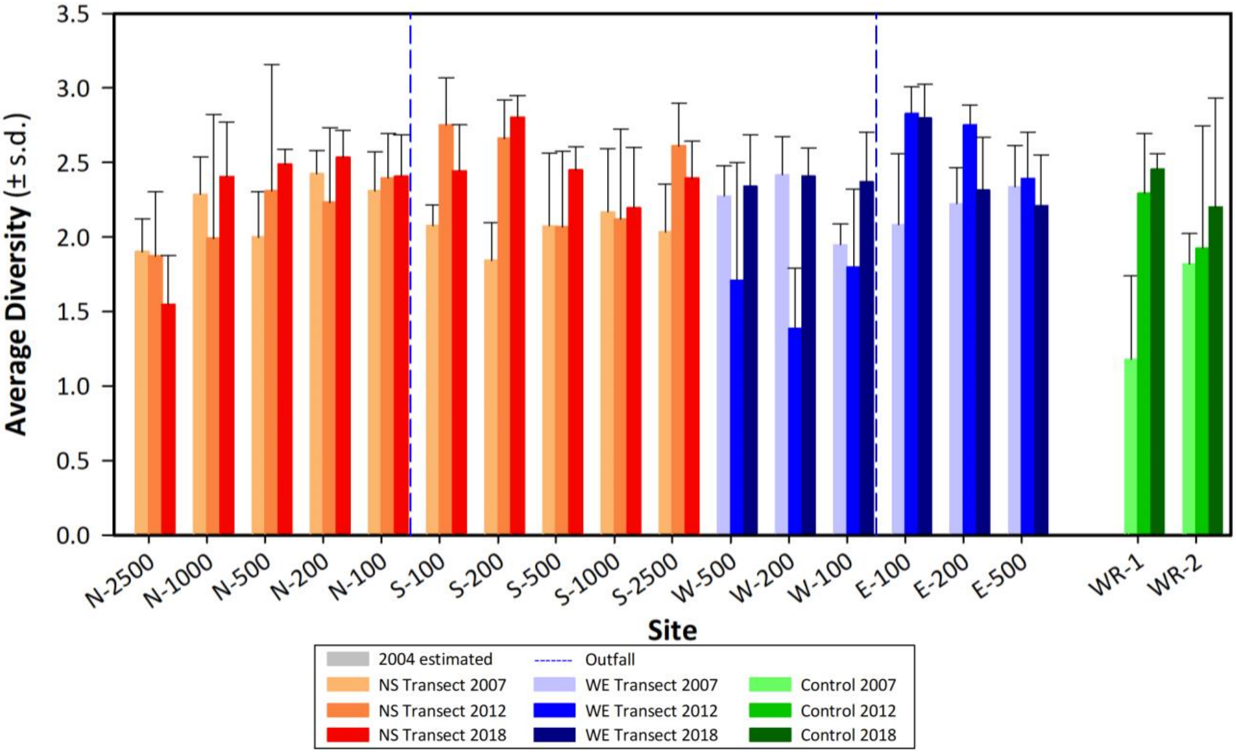


Figure 26 Average species diversity for all sites sampled near the Christchurch City Council ocean outfall and Waimakariri River control sites in 2004, 2007, 2012 and 2018.

Benthic community structure

Multivariate analysis of the three survey years 2007, 2012 and 2018 based on the taxa as reported showed differences between survey years were greater than differences between sites. For instance, mMDS ordination showed clear separation of all sites into groups based on survey years (Figure 27) with some additional grouping within years as defined by grouped average cluster analysis (Figure 28). The different symbols have been used to show direction from outfall while symbol colour has been used to show distance from outfall. The stress value 0.21, while on the high side, the mMDS still gives a useful representation of the differences and similarities within the species composition and abundance data.

The mMDS and cluster dendrogram show that community structure based on species is more similar within years than between years. However there were still statistically significant differences between sites within years. The data suggest greater, most likely natural, factors than the effects of the outfall operation influence the changes in species composition and abundance over time.

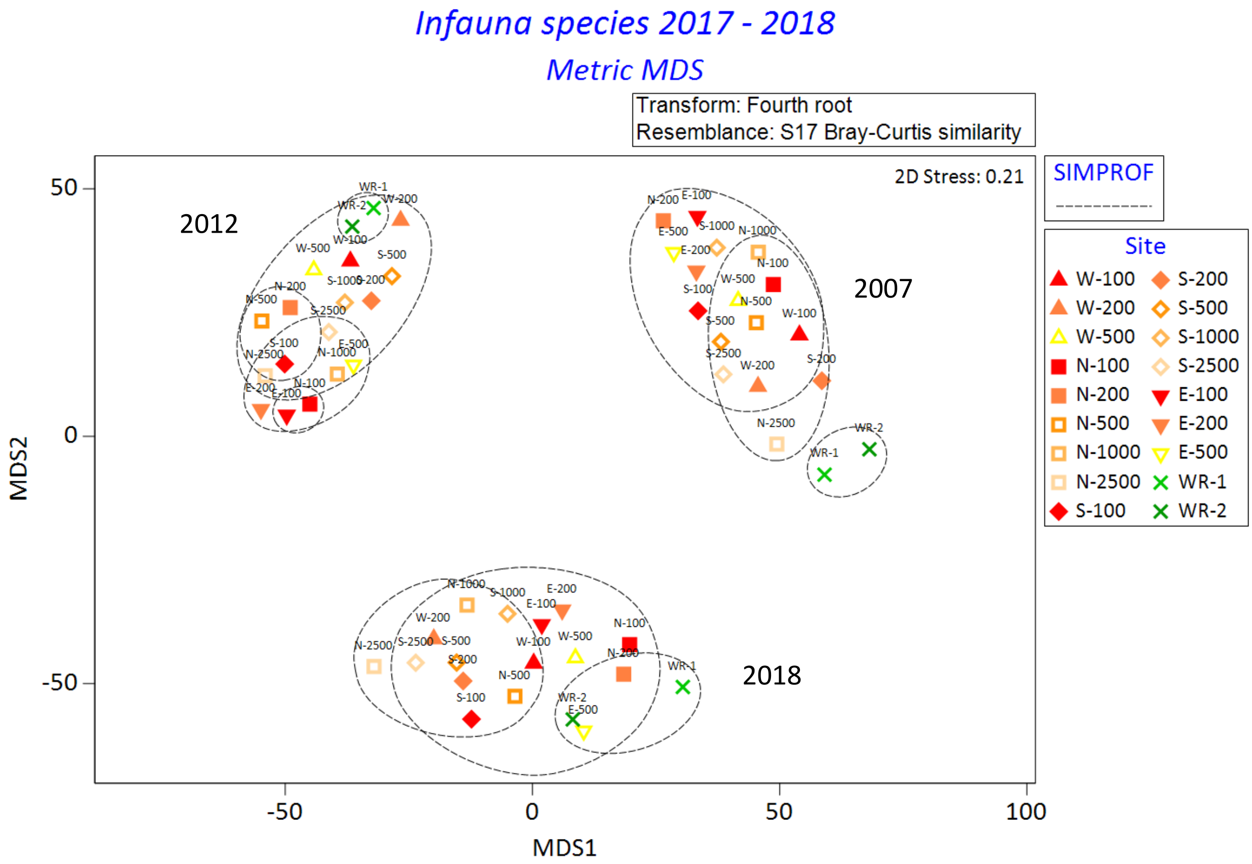


Figure 27 **mMDS ordination plot of the species level benthic community taxa in the vicinity of Christchurch City Council outfall in 2007, 2012 and 2018 with clustering outlined.**

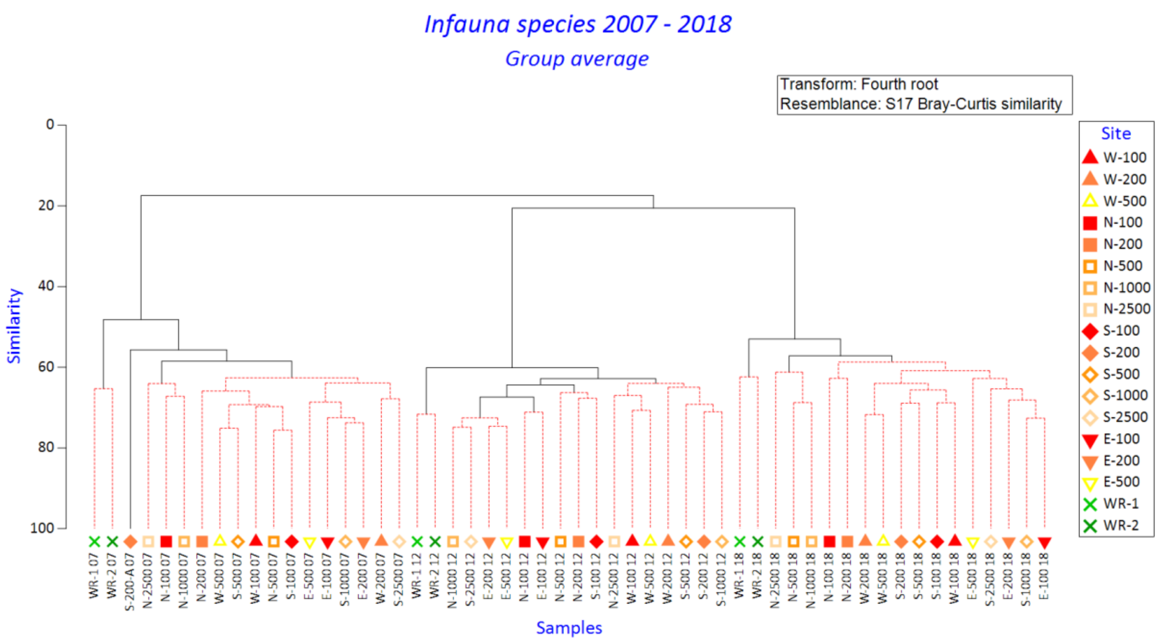


Figure 28 **Dendrogram generated using Grouped average Clustering for species data by site and years in Primer 7.**

4.4 Summary and Discussion

Abundance and species richness were lower inside the 200 m mixing zone and progressively increased with increasing distance from the outfall along the North-South Transect. Abundance and species richness were highest 100 east of the outfall; with the exception of this enriched area both parameters increased with increasing distance from that the outfall. Overall faunal abundance and species richness was lower at the control sites compared to impact sites. Diversity was relatively similar between all sites including the control sites. These findings suggest that the discharge is having some influence on the abundance and richness of benthic communities, but that the greater impact occurs within the 200 m mixing zone boundary. This impact takes the form of increased species richness and locally depressed abundance within the mixing zone. Species composition and abundance showed statistically significant geographical groupings. Rather than a few key species defining the differences between site groupings, in 2018 a large number of species each contributed small amounts to the differences.

The changes in benthic communities over time, between 2007, 2012 and 2018, included an apparent decrease in abundance and species richness between 2004 and 2007, followed by an increase between 2007 and 2012, and further decreases between 2012 and 2018. It was noted, however, that some differences in the benthic taxonomic resolution during each survey may account for some of the observed differences particularly in species richness. The mMDS and cluster dendrogram show that community structure based on species is more similar within years than between years. However there were still statistically significant differences between sites within years.

Epifauna was more abundant in 2012 compared to all other years surveyed, in particular due to the high abundance of sand dollar urchins. The epibenthic communities included typical species found in New Zealand subtidal benthic environments and echinoderms, molluscs and crustaceans were the most common epibenthic species.

Given the greater difference between the benthic communities over survey years than differences within the survey area, it is possible that the majority of these changes are the result of natural fluctuations in benthic populations. Despite this the 2018 survey data suggest the outfall may have some influence as the benthic communities are statistically significantly divisible with a pattern geographically centred on the outfall.

5. SUMMARY AND CONCLUSIONS

The 2018 survey of the CCC ocean outfall is the second survey carried out since commissioning in 2010. The survey collected samples of sediment and seabed biota as required by the resource consent issued to CCC.

The 2018 survey has reported on the concentrations of a number of key sediment quality parameters (e.g., TOC, nitrogen and phosphorus) and a range of environmentally important trace elements. The measurement of concentrations was undertaken on whole sediment (<2 mm fraction to be exact). Data were interpreted on the basis of whole sediment and also following the calculation of parameter / mud ratios, the latter being utilised to normalise the variation that arises from the variability in the amount of mud in the samples. The key conclusions are:

- Whole sediment TOC, cadmium, chromium, copper, lead, nickel and zinc concentrations showed statistically significant higher concentrations in sediments collected greater than 200 m away from the outfall, than those collected within 200 m of the diffuser. Similarly the samples collected further away from the diffuser contained a slightly higher percentage of mud on average than samples collected close to the diffuser. The average concentration differences between the two groups of sediments were small.
- PCA and cluster analysis of the 2018 sediment quality data showed the outfall sites were different to the control sites based on the percentage of mud being higher at the control sites. Sites to the north were identified as different to those nearer the outfall and south as a result of elevated concentrations chromium, nickel, TOC, zinc, phosphorus and lead to the north.
- Examination of parameter / mud ratios showed the reverse of the whole sediment pattern with higher ratios close to the diffuser. For all parameters a small peak in ratios occurred close to the diffuser even though the average percentage of mud was lower close to the diffuser.
- The concentration of all parameters measured for which sediment quality limits were identified in the resource consent were lower than the identified ANZECC limits. The low concentrations of trace elements in sediments would indicate that the sediment quality should not be having any adverse effects on sediment infauna.

The examination of the benthic community in 2018 has shown:

- Increases in abundance with distance from the outfall along the North-South Transect, particularly outside the mixing zone.
- Increases in abundance and richness within distance offshore.
- Abundance and richness were typically higher within the mixing zone compared to control sites. While abundance increased outside the mixing zone boundary, richness decreased slightly.
- Analysis of the benthic communities as a whole showed the control sites were significantly different from the outfall sites and that the three northern sites (N2500, N1000 and N500) were significantly different from the other outfall sites.
- Abundance and richness varied significantly between survey years but fell within the range of baseline levels in 2018. Compared with 2012 the average faunal abundance had decreased by 2018 at all sites, controls included.
- The benthic communities between survey years were significantly different. Some of this difference could be attributed to some degree by variations in the level of resolution for some taxonomic groups which provided some limitations in the detail of benthic community structure.

However it is not possible to rule out real variations in benthic community structure between surveys.

The weight of evidence from both sediment quality and benthic community structure suggests that the control sites are different from the outfall sites, and that distant sites to the north of the outfall are different from those at the outfall. The changes in both sediment quality and species composition and abundance suggest the northern sites were likely affected by the outfall discharge. The increase in the numbers of the polychaete worm *Heteromastus* is a typical response to the observed outfall derived organic enrichment at these sites.

6. REFERENCES

Allan, J.C., Kirk, R.M., Hemmingsen, M., Hart, D. (1999)

Coastal processes in Pegasus Bay: A Review. Report prepared for Woodward Clyde New Zealand Limited and Christchurch City Council. July 1999.

Brodie, J. W. (1960)

Coastal surface currents around New Zealand, New Zealand Journal of Geology and Geophysics, 3:2, 235-252

Duns, R.M. (1995)

A sediment budget analysis of Pegasus Bay. Unpublished MSc thesis in Geography, University of Canterbury, New Zealand. 156 pp

Kingett Mitchell (2003)

Evaluation of the benthic fauna and sediment quality off New Brighton Beach. Report prepared by Kingett Mitchell Ltd for Christchurch City Council. August 2003.

Kingett Mitchell (2004)

Results of the first Christchurch ocean outfall benthic survey. Report prepared by Kingett Mitchell Ltd for Christchurch City Council. November 2004.

Golder Kingett Mitchell (2007)

2007 Christchurch Outfall Monitoring Survey. Report prepared by Golder Associates (NZ) Limited for Christchurch City Council. October 2007.

Golder (2012)

Christchurch Ocean Outfall 2012 Marine benthic Survey. Report prepared by Golder Associates (NZ) Limited for Christchurch City Council. August 2012.

Knox, G.A. and Kilner, A.R. (1973)

The ecology of the Avon-Heathcote estuary. Unpublished report to the Christchurch Drainage Board by Estuarine Research Unit, Department of Zoology, University of Canterbury. October 1973.

Land Information New Zealand (Linz) (2010)

New Zealand Notice to Mariners. Edition 19. Notice 158/10 17 September 2010. http://www.linz.govt.nz/docs/hydro/ntm/pdf10/nz19-1709-157-161.pdf

7. APPENDICES

Appendix 1 Resource Consent Conditions CRC051724

Receiving Environment Monitoring - Marine Sediments

23

a. The consent holder shall obtain no less than three replicate surface sediment samples at locations 100, 200, 500, 1000 and 2,500 metres along shore from the centre point of the diffuser (both north and south) and 100, 200 and 500 metres inshore and offshore from the diffuser.
b. The consent holder shall obtain no less than three replicate surface sediment samples from two sites south of the Waimakariri River.
c. The collection of sediment samples in accordance with Condition 23(a) and (b) shall occur:
    a. On two occasions at least 12 months apart, in either February or March prior to commissioning of the outfall; and
    b. One year after the commissioning of the outfall and thereafter at five yearly intervals, during either February or March.
a. At each of the replicate stations identified in Condition 23(a) and (b), a series of no less than three surface sediment samples are to be collected to a depth of 50 millimetres and combined to form a single sample for each location.
b. All sediment samples collected in accordance with these conditions shall be analysed for the following determinands:

Constituent Group	Constituent	Units
Physical characteristics	Sediment texture Grain size - gravel, sand, mud	percent dry weight
	Man-made objects	Description only in the less than two millimetre fraction
Organic status	Total organic carbon (TOC)	percent
	Total nitrogen	milligrams per kilogram as Nitrogen dry weight
	Total phosphorus	milligrams per kilogram as Phosphorus dry weight
Metals	Arsenic, cadmium, chromium, copper, lead, mercury, nickel and zinc - strong acid extraction	milligrams per kilogram dry weight

24 In the event that the concentration of any parameter in a single sample analysed in accordance with Condition 23(e) exceeds a trigger value specified below, the consent holder shall:
    a. Notify the Canterbury Regional Council within 10 working days of the detection of this exceedance; and
    b. Provide to the Canterbury Regional Council within one month of detecting the exceedence a report detailing the risk of the exceedence to aquatic communities in Pegasus Bay and any measures proposed by the consent holder to mitigate the effects of the exceedence on these communities.

Trigger Levels:
Parameter Trigger Levels:
Arsenic 20 milligrams per kilogram dry weight, Cadmium 1.5 milligrams per kilogram dry weight, Chromium 80 milligrams per kilogram dry weight, Copper 65 milligrams per kilogram dry weight, Lead 50 milligrams per kilogram dry weight, Mercury 0.15 milligrams per kilogram dry weight, Nickel 21 milligrams per kilogram dry weight, Zinc 200 milligrams per kilogram dry weight.

Receiving Environment Monitoring - Benthic Invertebrates

25

a. The consent holder shall obtain five replicate sediment samples for the examination of benthic fauna at stations adjacent to the discharge point. Samples to be collected from locations 100, 200, 500, 1,000 and 2,500 metres along shore from the centre point of the diffuser (both north and south) and 100, 200 and 500 metres inshore and offshore from the diffuser (total 16 sites, 80 samples).

b. The consent holder shall obtain five replicate sediment samples for the examination of benthic fauna from two sites south of the Waimakariri River (total two sites, 10 samples).
c. The collection of sediment samples for the examination of benthic fauna in accordance with Condition 25(a) and (b) shall occur:
    a. On two occasions at least 12 months apart, in either February or March prior to commissioning of the outfall; and
    b. One year after the commissioning of the outfall and thereafter at five yearly intervals, during either February or March.
d. Sampling of benthic fauna using no less than 13 centimetre diameter cores and samples shall be processed using a 0.5 millimetre sieve and the invertebrates collected counted and identified to the lowest practical taxonomic level.

Receiving Environment Monitoring - Epibenthos

26

a. Epibenthic tows shall be undertaken perpendicular to the shore, at the control sites and at sites 200 metres north and 200 metres south of the outfall one year after the discharge from the outfall commences, and thereafter at five yearly intervals. Each tow shall include three runs of 200 metres each. All samples collected shall be analysed for species composition and species abundance of epibenthic organisms. Where possible, tows are to coincide with sediment and benthic invertebrate sampling in Conditions 23 and 25 above.
b. The information collected shall be used for the purposes of:
    a. determining the composition and abundance of epibenthic species in the vicinity of the outfall;
    b. identifying any variation in the composition and abundance of epibenthic species over time; -
    c. identifying any relationship between the composition and abundance of epibenthic species and sediment quality; and
    d. noting the presence of any deformed individuals.

Appendix 2 Sample Positions

No sample positions were recorded in the Golder, 2012 report thus sample positions were taken from the Golder, 2007 report. Some inaccuracies in these coordinates have been amended.

Sites **Benthic Sampling**	*Latitude*	*Longitude*	*NZTM (Easting)*	*NZTM (Northing)*
N100	S43 31.329	E172 46.607	1581961	5181174
N200	S43 31.278	E172 46.585	1581932	5181269
N500	S43 31.123	E172 46.521	1581844	5181556
N1000	S43 30.865	E172 46.413	1581698	5182033
N2500	S43 30.089	E172 46.091	1581259	5183468
S100	S43 31.433	E172 46.649	1582019	5180982
S200	S43 31.485	E172 46.671	1582048	5180887
S500	S43 31.640	E172 46.736	1582136	5180600
S1000	S43 31.898	E172 46.843	1582281	5180122
S2500	S43 32.674	E172 47.166	1582720	5178688
E100	S43 31.346	E172 46.789	1582205	5181143
E200	S43 31.331	E172 46.859	1582300	5181172
E500	S43 31.284	E172 47.072	1582587	5181260
W100	S43 31.417	E172 46.468	1581775	5181012
W200	S43 31.432	E172 46.398	1581680	5180983
W500	S43 31.479	E172 46.185	1581393	5180895
WR1	S43 24.560	E172 43.712	1578020	5193692
WR2	S43 24.714	E172 43.750	1578073	5193407

Sites **Epibenthic tows**	*Latitude*	*Longitude*	*NZTM (Easting)*	*NZTM (Northing)*
WR1 - tow 1 start	S43 24.560	E172 43.712	1578020	5193692
WR1 - tow 1 end	S43 24.560	E172 43.563	1577819	5193691
WR1 - tow 2 start	S43 24.560	E172 43.712	1578020	5193692
WR1 - tow 2 end	S43 24.605	E172 43.575	1577836	5193608
WR1 - tow 3 start	S43 24.560	E172 43.712	1578020	5193692
WR1 - tow 3 end	S43 24.635	E172 43.604	1577875	5193552
WR2 - tow 1 start	S43 24.714	E172 43.750	1578073	5193407
N200 - tow 1 start	S43 31.278	E172 46.585	1581932	5181269
N200 - tow 1 end	S43 31.312	E172 46.444	1581741	5181206
N200 - tow 2 start	S43 31.278	E172 46.585	1581932	5181269
N200 - tow 2 end	S43 31.348	E172 46.472	1581779	5181139
N200 - tow 3 start	S43 31.278	E172 46.585	1581932	5181269
N200 - tow 3 end	S43 31.370	E172 46.507	1581827	5181097
S200 - tow 1 start	S43 31.485	E172 46.671	1582048	5180887
S200 - tow 1 end	S43 31.518	E172 46.528	1581856	5180825
S200 - tow 2 start	S43 31.485	E172 46.671	1582048	5180887
S200 - tow 2 end	S43 31.554	E172 46.555	1581892	5180758
S200 - tow 3 start	S43 31.485	E172 46.671	1582048	5180887
S200 - tow 3 end	S43 31.582	E172 46.597	1581948	5180706

Appendix 3 Laboratory data

Hill Laboratories
TRIED, TESTED AND TRUSTED
R J Hill Laboratories Limited
28 Duke Street Frankton 3204
Private Bag 3205
Hamilton 3240 New Zealand
T 0508 HILL LAB (44 555 22)
T +64 7 858 2000
E mail@hill-labs.co.nz
W www.hill-laboratories.com

Certificate of Analysis

Page 1 of 3

Client:	Bioresearches	**Lab No:**	1940159 SPv1
Contact:	Mark Yungnickel	**Date Received:**	09-Mar-2018
	C/- Bioresearches	**Date Reported:**	04-May-2018
	PO Box 2828	**Quote No:**	87168
	Auckland 1140	**Order No:**	
		Client Reference:	Christchurch City Council Marine Outfall Monitoring
		Submitted By:	Mark Yungnickel

Sample Type: Sediment

Sample Name:		E500 A 07-Mar-2018	E500 B 07-Mar-2018	E500 C 07-Mar-2018	E200 A 07-Mar-2018	E200 B 07-Mar-2018
Lab Number:		1940159.1	1940159.2	1940159.3	1940159.4	1940159.5
Individual Tests						
Dry Matter of Sieved Sample	g/100g as rcvd	77	72	80	76	76
Total Recoverable Phosphorus	mg/kg dry wt	400	380	400	400	410
Total Nitrogen*	g/100g dry wt	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Total Organic Carbon*	g/100g dry wt	0.13	0.13	0.12	0.11	0.13
Heavy metals, trace As,Cd,Cr,Cu,Ni,Pb,Zn,Hg						
Total Recoverable Arsenic	mg/kg dry wt	5.9	6.4	6.1	6.6	6.5
Total Recoverable Cadmium	mg/kg dry wt	0.013	0.014	0.014	0.014	0.013
Total Recoverable Chromium	mg/kg dry wt	11.4	11.4	11.4	11.4	11.7
Total Recoverable Copper	mg/kg dry wt	2.7	2.7	2.7	2.5	2.8
Total Recoverable Lead	mg/kg dry wt	10.6	10.3	10.3	9.7	9.8
Total Recoverable Mercury	mg/kg dry wt	0.05	0.06	0.06	0.05	0.05
Total Recoverable Nickel	mg/kg dry wt	9.7	9.5	9.7	9.6	9.9
Total Recoverable Zinc	mg/kg dry wt	34	34	34	32	33
3 Grain Sizes Profile						
Fraction >/= 2 mm*	g/100g dry wt	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Fraction < 2 mm, >/= 63 µm*	g/100g dry wt	87.5	88.4	89.7	92.9	89.4
Fraction < 63 µm*	g/100g dry wt	12.5	11.5	10.2	7.1	10.6

Sample Name:		E200 C 07-Mar-2018	E100 A 07-Mar-2018	E100 B 07-Mar-2018	E100 C 07-Mar-2018	W100 A 07-Mar-2018
Lab Number:		1940159.6	1940159.7	1940159.8	1940159.9	1940159.10
Individual Tests						
Dry Matter of Sieved Sample	g/100g as rcvd	75	74	76	78	76
Total Recoverable Phosphorus	mg/kg dry wt	390	360	350	370	360
Total Nitrogen*	g/100g dry wt	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Total Organic Carbon*	g/100g dry wt	0.10	0.09	0.09	0.10	0.11
Heavy metals, trace As,Cd,Cr,Cu,Ni,Pb,Zn,Hg						
Total Recoverable Arsenic	mg/kg dry wt	6.3	5.9	5.7	6.1	5.4
Total Recoverable Cadmium	mg/kg dry wt	0.013	0.011	0.011	0.012	0.012
Total Recoverable Chromium	mg/kg dry wt	10.7	10	10.4	11.0	10.4
Total Recoverable Copper	mg/kg dry wt	2.4	2.3	2.3	2.4	2.5
Total Recoverable Lead	mg/kg dry wt	9.7	9.7	9.5	9.8	8.8
Total Recoverable Mercury	mg/kg dry wt	0.05	0.05	0.04	0.05	0.05
Total Recoverable Nickel	mg/kg dry wt	9.5	9.0	9.1	9.3	9.0
Total Recoverable Zinc	mg/kg dry wt	33	32	32	33	32

IANZ ACCREDITED LABORATORY

This Laboratory is accredited by International Accreditation New Zealand (IANZ), which represents New Zealand in the International Laboratory Accreditation Cooperation (ILAC). Through the ILAC Mutual Recognition Arrangement (ILAC-MRA) this accreditation is internationally recognised.
The tests reported herein have been performed in accordance with the terms of accreditation, with the exception of tests marked *, which are not accredited.

Sample Type: Sediment						
Sample Name:		E200 C 07-Mar-2018	E100 A 07-Mar-2018	E100 B 07-Mar-2018	E100 C 07-Mar-2018	W100 A 07-Mar-2018
Lab Number:		1940159.6	1940159.7	1940159.8	1940159.9	1940159.10
3 Grain Sizes Profile						
Fraction >/= 2 mm*	g/100g dry wt	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Fraction < 2 mm, >/= 63 µm*	g/100g dry wt	95.6	97.0	97.0	97.5	94.0
Fraction < 63 µm*	g/100g dry wt	4.5	2.9	3.0	2.5	5.9

Sample Name:		W100 B 07-Mar-2018	W100 C 07-Mar-2018	W200 A 07-Mar-2018	W200 B 07-Mar-2018	W200 C 07-Mar-2018
Lab Number:		1940159.11	1940159.12	1940159.13	1940159.14	1940159.15
Individual Tests						
Dry Matter of Sieved Sample	g/100g as rcvd	77	75	75	76	74
Total Recoverable Phosphorus	mg/kg dry wt	360	370	340	340	330
Total Nitrogen*	g/100g dry wt	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Total Organic Carbon*	g/100g dry wt	0.10	0.11	0.10	0.10	0.10
Heavy metals, trace As,Cd,Cr,Cu,Ni,Pb,Zn,Hg						
Total Recoverable Arsenic	mg/kg dry wt	5.6	5.7	5.0	5.1	5.0
Total Recoverable Cadmium	mg/kg dry wt	0.011	0.012	0.013	< 0.010	0.011
Total Recoverable Chromium	mg/kg dry wt	10.6	10.7	10.1	9.8	10.1
Total Recoverable Copper	mg/kg dry wt	2.4	2.4	2.4	2.3	2.4
Total Recoverable Lead	mg/kg dry wt	8.9	8.6	8.6	8.2	8.2
Total Recoverable Mercury	mg/kg dry wt	0.05	0.04	0.04	0.04	0.03
Total Recoverable Nickel	mg/kg dry wt	9.0	8.8	8.8	8.4	8.7
Total Recoverable Zinc	mg/kg dry wt	32	31	31	30	31
3 Grain Sizes Profile						
Fraction >/= 2 mm*	g/100g dry wt	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Fraction < 2 mm, >/= 63 µm*	g/100g dry wt	94.9	96.0	95.6	94.8	95.5
Fraction < 63 µm*	g/100g dry wt	5.1	4.0	4.4	5.2	4.5

Sample Name:		W500 A 07-Mar-2018	W500 B 07-Mar-2018	W500 C 07-Mar-2018	S2500 A 07-Mar-2018	S2500 B 07-Mar-2018
Lab Number:		1940159.16	1940159.17	1940159.18	1940159.19	1940159.20
Individual Tests						
Dry Matter of Sieved Sample	g/100g as rcvd	74	75	75	76	78
Total Recoverable Phosphorus	mg/kg dry wt	320	340	340	410	410
Total Nitrogen*	g/100g dry wt	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Total Organic Carbon*	g/100g dry wt	0.10	0.10	0.10	0.11	0.12
Heavy metals, trace As,Cd,Cr,Cu,Ni,Pb,Zn,Hg						
Total Recoverable Arsenic	mg/kg dry wt	4.7	4.6	3.9	6.3	6.2
Total Recoverable Cadmium	mg/kg dry wt	0.013	0.013	0.011	0.013	0.012
Total Recoverable Chromium	mg/kg dry wt	10.1	11	10.4	11.2	11.6
Total Recoverable Copper	mg/kg dry wt	2.5	2.6	2.5	2.5	2.7
Total Recoverable Lead	mg/kg dry wt	8.2	8.5	8.5	10.1	9.9
Total Recoverable Mercury	mg/kg dry wt	0.03	0.04	0.04	0.04	0.05
Total Recoverable Nickel	mg/kg dry wt	8.7	9.0	8.9	9.7	9.7
Total Recoverable Zinc	mg/kg dry wt	31	32	31	33	33
3 Grain Sizes Profile						
Fraction >/= 2 mm*	g/100g dry wt	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Fraction < 2 mm, >/= 63 µm*	g/100g dry wt	95.5	94.0	95.2	91.5	87.2
Fraction < 63 µm*	g/100g dry wt	4.5	6.0	4.8	8.5	12.8

Sample Name:		S2500 C 07-Mar-2018				
Lab Number:		1940159.21				
Individual Tests						
Dry Matter of Sieved Sample	g/100g as rcvd	78	-	-	-	-
Total Recoverable Phosphorus	mg/kg dry wt	400	-	-	-	-
Total Nitrogen*	g/100g dry wt	< 0.05	-	-	-	-
Total Organic Carbon*	g/100g dry wt	0.10	-	-	-	-

Sample Type: Sediment						
	Sample Name:	S2500 C 07-Mar-2018				
	Lab Number:	1940159.21				
Heavy metals, trace As,Cd,Cr,Cu,Ni,Pb,Zn,Hg						
Total Recoverable Arsenic	mg/kg dry wt	6.3	-	-	-	-
Total Recoverable Cadmium	mg/kg dry wt	0.013	-	-	-	-
Total Recoverable Chromium	mg/kg dry wt	11.3	-	-	-	-
Total Recoverable Copper	mg/kg dry wt	2.5	-	-	-	-
Total Recoverable Lead	mg/kg dry wt	10.1	-	-	-	-
Total Recoverable Mercury	mg/kg dry wt	0.04	-	-	-	-
Total Recoverable Nickel	mg/kg dry wt	9.6	-	-	-	-
Total Recoverable Zinc	mg/kg dry wt	33	-	-	-	-
3 Grain Sizes Profile						
Fraction >/= 2 mm*	g/100g dry wt	< 0.1	-	-	-	-
Fraction < 2 mm, >/= 63 µm*	g/100g dry wt	91.7	-	-	-	-
Fraction < 63 µm*	g/100g dry wt	8.3	-	-	-	-

Summary of Methods

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively clean matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis.

Sample Type: Sediment			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
Individual Tests			
Environmental Solids Sample Preparation	Air dried at 35°C and sieved, <2mm fraction. Used for sample preparation. May contain a residual moisture content of 2-5%.	-	1-21
Dry Matter for Grainsize samples	Drying for 16 hours at 103°C, gravimetry (Free water removed before analysis).	0.10 g/100g as rcvd	1-21
Total Recoverable digestion	Nitric / hydrochloric acid digestion. US EPA 200.2.	-	1-21
Total Recoverable Phosphorus	Dried sample, sieved as specified (if required). Nitric/Hydrochloric acid digestion, ICP-MS, screen level. US EPA 200.2.	40 mg/kg dry wt	1-21
Total Nitrogen*	Catalytic Combustion (900°C, O2), separation, Thermal Conductivity Detector [Elementar Analyser].	0.05 g/100g dry wt	1-21
Total Organic Carbon*	Acid pretreatment to remove carbonates present followed by Catalytic Combustion (900°C, O2), separation, Thermal Conductivity Detector [Elementar Analyser].	0.05 g/100g dry wt	1-21
Heavy metals, trace As,Cd,Cr,Cu,Ni,Pb,Zn,Hg	Dried sample, <2mm fraction. Nitric/Hydrochloric acid digestion, ICP-MS, trace level.	0.010 - 0.4 mg/kg dry wt	1-21
3 Grain Sizes Profile*		0.1 g/100g dry wt	1-21
3 Grain Sizes Profile			
Fraction >/= 2 mm*	Wet sieving with dispersant, 2.00 mm sieve, gravimetry.	0.1 g/100g dry wt	1-21
Fraction < 2 mm, >/= 63 µm*	Wet sieving using dispersant, 2.00 mm and 63 µm sieves, gravimetry (calculation by difference).	0.1 g/100g dry wt	1-21
Fraction < 63 µm*	Wet sieving with dispersant, 63 µm sieve, gravimetry (calculation by difference).	0.1 g/100g dry wt	1-21

These samples were collected by yourselves (or your agent) and analysed as received at the laboratory.

Samples are held at the laboratory after reporting for a length of time depending on the preservation used and the stability of the analytes being tested. Once the storage period is completed the samples are discarded unless otherwise advised by the client.

Ara Heron BSc (Tech)
Client Services Manager - Environmental

Hill Laboratories
TRIED, TESTED AND TRUSTED

R J Hill Laboratories Limited
28 Duke Street Frankton 3204
Private Bag 3205
Hamilton 3240 New Zealand

T 0508 HILL LAB (44 555 22)
T +64 7 858 2000
E mail@hill-labs.co.nz
W www.hill-laboratories.com

Certificate of Analysis

Client:	Bioresearches	**Lab No:**	1941075 SPv1
Contact:	Mark Yungnickel	**Date Received:**	10-Mar-2018
	C/- Bioresearches	**Date Reported:**	08-May-2018
	PO Box 2828	**Quote No:**	87168
	Auckland 1140	**Order No:**	
		Client Reference:	Christchurch City Council Marine Outfall Monitoring
		Submitted By:	Mark Yungnickel

Sample Type: Sediment

Sample Name:		N100A 08-Mar-2018	N100B 08-Mar-2018	N100C 08-Mar-2018	S100A 08-Mar-2018	S100B 08-Mar-2018
Lab Number:		1941075.1	1941075.2	1941075.3	1941075.4	1941075.5
Individual Tests						
Dry Matter of Sieved Sample	g/100g as rcvd	77	74	77	72	76
Total Recoverable Phosphorus	mg/kg dry wt	380	390	380	390	360
Total Nitrogen*	g/100g dry wt	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Total Organic Carbon*	g/100g dry wt	0.12	0.10	0.10	0.10	0.09
Heavy metals, trace As,Cd,Cr,Cu,Ni,Pb,Zn,Hg						
Total Recoverable Arsenic	mg/kg dry wt	5.9	6.4	6.2	5.9	5.9
Total Recoverable Cadmium	mg/kg dry wt	0.010	0.011	< 0.010	0.010	< 0.010
Total Recoverable Chromium	mg/kg dry wt	11.0	11.4	11.6	10.8	10.6
Total Recoverable Copper	mg/kg dry wt	2.8	2.7	2.6	2.6	2.4
Total Recoverable Lead	mg/kg dry wt	9.0	9.2	9.1	9.1	9.2
Total Recoverable Mercury	mg/kg dry wt	0.06	0.05	0.05	0.05	0.05
Total Recoverable Nickel	mg/kg dry wt	7.8	7.8	7.9	7.9	7.8
Total Recoverable Zinc	mg/kg dry wt	32	32	31	32	31
3 Grain Sizes Profile						
Fraction >/= 2 mm*	g/100g dry wt	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Fraction < 2 mm, >/= 63 µm*	g/100g dry wt	94.7	95.3	95.7	95.8	92.4
Fraction < 63 µm*	g/100g dry wt	5.3	4.7	4.3	4.2	7.6

Sample Name:		S100C 08-Mar-2018	S200A 08-Mar-2018	S200B 08-Mar-2018	S200C 08-Mar-2018	S500A 08-Mar-2018
Lab Number:		1941075.6	1941075.7	1941075.8	1941075.9	1941075.10
Individual Tests						
Dry Matter of Sieved Sample	g/100g as rcvd	76	79	78	75	77
Total Recoverable Phosphorus	mg/kg dry wt	370	370	360	360	390
Total Nitrogen*	g/100g dry wt	< 0.05	< 0.13	< 0.13	< 0.05	< 0.05
Total Organic Carbon*	g/100g dry wt	0.10	0.12	0.12	0.12	0.12
Heavy metals, trace As,Cd,Cr,Cu,Ni,Pb,Zn,Hg						
Total Recoverable Arsenic	mg/kg dry wt	5.8	6.2	5.7	5.4	6.1
Total Recoverable Cadmium	mg/kg dry wt	< 0.010	< 0.010	0.010	0.013	0.011
Total Recoverable Chromium	mg/kg dry wt	11.0	11.3	11.3	11.2	11.0
Total Recoverable Copper	mg/kg dry wt	2.6	2.9	3.2	3.0	3.0
Total Recoverable Lead	mg/kg dry wt	9.1	9.2	9.3	9.2	9.4
Total Recoverable Mercury	mg/kg dry wt	0.05	0.04	0.04	0.04	0.05
Total Recoverable Nickel	mg/kg dry wt	7.7	7.5	8.0	8.5	8.8
Total Recoverable Zinc	mg/kg dry wt	32	33	34	34	38

IANZ ACCREDITED LABORATORY

This Laboratory is accredited by International Accreditation New Zealand (IANZ), which represents New Zealand in the International Laboratory Accreditation Cooperation (ILAC). Through the ILAC Mutual Recognition Arrangement (ILAC-MRA) this accreditation is internationally recognised.
The tests reported herein have been performed in accordance with the terms of accreditation, with the exception of tests marked *, which are not accredited.

Sample Type: Sediment						
	Sample Name:	S100C 08-Mar-2018	S200A 08-Mar-2018	S200B 08-Mar-2018	S200C 08-Mar-2018	S500A 08-Mar-2018
	Lab Number:	1941075.6	1941075.7	1941075.8	1941075.9	1941075.10
3 Grain Sizes Profile						
Fraction >/= 2 mm*	g/100g dry wt	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Fraction < 2 mm, >/= 63 µm*	g/100g dry wt	95.7	94.1	94.0	92.8	93.4
Fraction < 63 µm*	g/100g dry wt	4.3	5.9	6.0	7.2	6.6

	Sample Name:	S500B 08-Mar-2018	S500C 08-Mar-2018	S1000A 08-Mar-2018	S1000B 08-Mar-2018	S1000C 08-Mar-2018
	Lab Number:	1941075.11	1941075.12	1941075.13	1941075.14	1941075.15
Individual Tests						
Dry Matter of Sieved Sample	g/100g as rcvd	79	77	74	76	79
Total Recoverable Phosphorus	mg/kg dry wt	370	370	400	400	380
Total Nitrogen*	g/100g dry wt	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Total Organic Carbon*	g/100g dry wt	0.11	0.10	0.15	0.11	0.14
Heavy metals, trace As,Cd,Cr,Cu,Ni,Pb,Zn,Hg						
Total Recoverable Arsenic	mg/kg dry wt	6.5	6.2	6.5	6.7	6.7
Total Recoverable Cadmium	mg/kg dry wt	0.011	0.011	0.015	0.013	0.011
Total Recoverable Chromium	mg/kg dry wt	11.7	11.3	11.9	11.5	11.9
Total Recoverable Copper	mg/kg dry wt	2.8	2.7	3.2	2.7	3.2
Total Recoverable Lead	mg/kg dry wt	9.4	9.2	9.8	9.5	9.8
Total Recoverable Mercury	mg/kg dry wt	0.05	0.05	0.04	0.05	0.05
Total Recoverable Nickel	mg/kg dry wt	8.2	8.0	8.7	8.2	9.2
Total Recoverable Zinc	mg/kg dry wt	37	37	40	37	39
3 Grain Sizes Profile						
Fraction >/= 2 mm*	g/100g dry wt	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Fraction < 2 mm, >/= 63 µm*	g/100g dry wt	91.9	93.8	85.2	90.6	87.6
Fraction < 63 µm*	g/100g dry wt	8.1	6.2	14.8	9.3	12.4

Summary of Methods

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively clean matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis.

Sample Type: Sediment

Test	Method Description	Default Detection Limit	Sample No
Individual Tests			
Environmental Solids Sample Preparation	Air dried at 35°C and sieved, <2mm fraction. Used for sample preparation. May contain a residual moisture content of 2-5%.	-	1-15
Dry Matter for Grainsize samples	Drying for 16 hours at 103°C, gravimetry (Free water removed before analysis).	0.10 g/100g as rcvd	1-15
Total Recoverable digestion	Nitric / hydrochloric acid digestion. US EPA 200.2.	-	1-15
Total Recoverable Phosphorus	Dried sample, sieved as specified (if required). Nitric/Hydrochloric acid digestion, ICP-MS, screen level. US EPA 200.2.	40 mg/kg dry wt	1-15
Total Nitrogen*	Catalytic Combustion (900°C, O2), separation, Thermal Conductivity Detector [Elementar Analyser].	0.05 g/100g dry wt	1-15
Total Organic Carbon*	Acid pretreatment to remove carbonates present followed by Catalytic Combustion (900°C, O2), separation, Thermal Conductivity Detector [Elementar Analyser].	0.05 g/100g dry wt	1-15
Heavy metals, trace As,Cd,Cr,Cu,Ni,Pb,Zn,Hg	Dried sample, <2mm fraction. Nitric/Hydrochloric acid digestion, ICP-MS, trace level.	0.010 - 0.4 mg/kg dry wt	1-15
3 Grain Sizes Profile*		0.1 g/100g dry wt	1-15
3 Grain Sizes Profile			
Fraction >/= 2 mm*	Wet sieving with dispersant, 2.00 mm sieve, gravimetry.	0.1 g/100g dry wt	1-15
Fraction < 2 mm, >/= 63 µm*	Wet sieving using dispersant, 2.00 mm and 63 µm sieves, gravimetry (calculation by difference).	0.1 g/100g dry wt	1-15
Fraction < 63 µm*	Wet sieving with dispersant, 63 µm sieve, gravimetry (calculation by difference).	0.1 g/100g dry wt	1-15

These samples were collected by yourselves (or your agent) and analysed as received at the laboratory.

Samples are held at the laboratory after reporting for a length of time depending on the preservation used and the stability of the analytes being tested. Once the storage period is completed the samples are discarded unless otherwise advised by the client.

This certificate of analysis must not be reproduced, except in full, without the written consent of the signatory.

Graham Corban MSc Tech (Hons)
Client Services Manager - Environmental

Hill Laboratories
TRIED, TESTED AND TRUSTED
R J Hill Laboratories Limited
28 Duke Street Frankton 3204
Private Bag 3205
Hamilton 3240 New Zealand
T 0508 HILL LAB (44 555 22)
T +64 7 858 2000
E mail@hill-labs.co.nz
W www.hill-laboratories.com

Certificate of Analysis

Client:	Bioresearches	**Lab No:**	1941077 SPv1
Contact:	Mark Yungnickel	**Date Received:**	10-Mar-2018
	C/- Bioresearches	**Date Reported:**	09-May-2018
	PO Box 2828	**Quote No:**	
	Auckland 1140	**Order No:**	
		Client Reference:	17141
		Submitted By:	Mark Yungnickel

Sample Type: Sediment

Sample Name:		WR1A 08-Mar-2018	WR1B 08-Mar-2018	WR1C 08-Mar-2018	WR2A 08-Mar-2018	WR2B 08-Mar-2018
Lab Number:		1941077.1	1941077.2	1941077.3	1941077.4	1941077.5
Individual Tests						
Dry Matter of Sieved Sample	g/100g as rcvd	76	79	76	75	77
Total Recoverable Phosphorus	mg/kg dry wt	420	340	380	360	340
Total Nitrogen*	g/100g dry wt	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Total Organic Carbon*	g/100g dry wt	0.25	0.11	0.24	0.07	0.08
Heavy metals, trace As,Cd,Cr,Cu,Ni,Pb,Zn,Hg						
Total Recoverable Arsenic	mg/kg dry wt	4.5	3.8	4.0	3.6	3.9
Total Recoverable Cadmium	mg/kg dry wt	0.020	0.019	0.023	0.016	0.014
Total Recoverable Chromium	mg/kg dry wt	12.1	11.0	11.3	10.6	11.1
Total Recoverable Copper	mg/kg dry wt	5.3	4.2	5.0	3.7	3.7
Total Recoverable Lead	mg/kg dry wt	9.7	8.7	9.7	8.0	8.1
Total Recoverable Mercury	mg/kg dry wt	0.05	0.04	0.04	0.04	0.04
Total Recoverable Nickel	mg/kg dry wt	10.8	9.6	10.3	9.3	9.4
Total Recoverable Zinc	mg/kg dry wt	37	33	36	32	32
3 Grain Sizes Profile						
Fraction >/= 2 mm*	g/100g dry wt	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Fraction < 2 mm, >/= 63 µm*	g/100g dry wt	64.5	75.5	48.3	82.3	86.5
Fraction < 63 µm*	g/100g dry wt	35.5	24.5	51.7	17.7	13.4

Sample Name:		WR2C 08-Mar-2018	N2500A 08-Mar-2018	N2500B 08-Mar-2018	N2500C 08-Mar-2018	N1000A 08-Mar-2018
Lab Number:		1941077.6	1941077.7	1941077.8	1941077.9	1941077.10
Individual Tests						
Dry Matter of Sieved Sample	g/100g as rcvd	76	80	79	74	77
Total Recoverable Phosphorus	mg/kg dry wt	360	420	400	430	390
Total Nitrogen*	g/100g dry wt	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Total Organic Carbon*	g/100g dry wt	0.07	0.13	0.11	0.14	0.10
Heavy metals, trace As,Cd,Cr,Cu,Ni,Pb,Zn,Hg						
Total Recoverable Arsenic	mg/kg dry wt	3.8	6.7	6.4	6.8	6.0
Total Recoverable Cadmium	mg/kg dry wt	0.018	0.015	0.012	0.014	0.013
Total Recoverable Chromium	mg/kg dry wt	11.0	12.2	11.4	12.6	11.5
Total Recoverable Copper	mg/kg dry wt	3.7	2.9	2.6	3.1	2.6
Total Recoverable Lead	mg/kg dry wt	7.9	10.3	10.1	10.5	9.7
Total Recoverable Mercury	mg/kg dry wt	0.04	0.04	0.06	0.04	0.04
Total Recoverable Nickel	mg/kg dry wt	9.1	9.7	9.6	10.2	9.2
Total Recoverable Zinc	mg/kg dry wt	31	34	32	37	35

Sample Type: Sediment						
	Sample Name:	WR2C 08-Mar-2018	N2500A 08-Mar-2018	N2500B 08-Mar-2018	N2500C 08-Mar-2018	N1000A 08-Mar-2018
	Lab Number:	1941077.6	1941077.7	1941077.8	1941077.9	1941077.10
3 Grain Sizes Profile						
Fraction >/= 2 mm*	g/100g dry wt	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Fraction < 2 mm, >/= 63 µm*	g/100g dry wt	82.8	86.9	89.6	85.6	92.9
Fraction < 63 µm*	g/100g dry wt	17.1	13.1	10.4	14.4	7.1

	Sample Name:	N1000B 08-Mar-2018	N1000C 08-Mar-2018	N500A 08-Mar-2018	N500B 08-Mar-2018	N500C 08-Mar-2018
	Lab Number:	1941077.11	1941077.12	1941077.13	1941077.14	1941077.15
Individual Tests						
Dry Matter of Sieved Sample	g/100g as rcvd	78	78	78	78	76
Total Recoverable Phosphorus	mg/kg dry wt	380	380	390	390	470
Total Nitrogen*	g/100g dry wt	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Total Organic Carbon*	g/100g dry wt	0.10	0.11	0.12	0.14	0.25
Heavy metals, trace As,Cd,Cr,Cu,Ni,Pb,Zn,Hg						
Total Recoverable Arsenic	mg/kg dry wt	5.9	5.7	5.7	5.6	6.1
Total Recoverable Cadmium	mg/kg dry wt	0.013	< 0.010	0.011	0.015	0.016
Total Recoverable Chromium	mg/kg dry wt	11.3	10.7	11.4	12.3	12.9
Total Recoverable Copper	mg/kg dry wt	2.5	2.6	2.7	3.0	4.2
Total Recoverable Lead	mg/kg dry wt	9.8	9.6	9.9	10.2	11.4
Total Recoverable Mercury	mg/kg dry wt	0.04	0.05	0.05	0.04	0.05
Total Recoverable Nickel	mg/kg dry wt	9.2	9.5	9.6	9.8	11.3
Total Recoverable Zinc	mg/kg dry wt	33	33	35	36	40
3 Grain Sizes Profile						
Fraction >/= 2 mm*	g/100g dry wt	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Fraction < 2 mm, >/= 63 µm*	g/100g dry wt	92.4	93.9	87.3	83.6	69.4
Fraction < 63 µm*	g/100g dry wt	7.6	6.1	12.8	16.4	30.6

	Sample Name:	N200A 08-Mar-2018	N200B 08-Mar-2018	N200C 08-Mar-2018		
	Lab Number:	1941077.16	1941077.17	1941077.18		
Individual Tests						
Dry Matter of Sieved Sample	g/100g as rcvd	76	75	79	-	-
Total Recoverable Phosphorus	mg/kg dry wt	410	390	390	-	-
Total Nitrogen*	g/100g dry wt	< 0.05	< 0.05	< 0.05	-	-
Total Organic Carbon*	g/100g dry wt	0.10	0.10	0.10	-	-
Heavy metals, trace As,Cd,Cr,Cu,Ni,Pb,Zn,Hg						
Total Recoverable Arsenic	mg/kg dry wt	5.9	6.0	6.0	-	-
Total Recoverable Cadmium	mg/kg dry wt	0.011	0.012	0.011	-	-
Total Recoverable Chromium	mg/kg dry wt	10.9	11.1	10.8	-	-
Total Recoverable Copper	mg/kg dry wt	2.4	2.5	2.5	-	-
Total Recoverable Lead	mg/kg dry wt	9.2	9.5	9.6	-	-
Total Recoverable Mercury	mg/kg dry wt	0.03	0.04	0.05	-	-
Total Recoverable Nickel	mg/kg dry wt	9.1	9.7	9.4	-	-
Total Recoverable Zinc	mg/kg dry wt	32	34	33	-	-
3 Grain Sizes Profile						
Fraction >/= 2 mm*	g/100g dry wt	< 0.1	< 0.1	< 0.1	-	-
Fraction < 2 mm, >/= 63 µm*	g/100g dry wt	95.5	95.7	95.9	-	-
Fraction < 63 µm*	g/100g dry wt	4.5	4.4	4.1	-	-

Summary of Methods

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively clean matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis.

Sample Type: Sediment			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
Individual Tests			
Environmental Solids Sample Preparation	Air dried at 35°C and sieved, <2mm fraction. Used for sample preparation. May contain a residual moisture content of 2-5%.	-	1-18

Sample Type: Sediment			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
Dry Matter for Grainsize samples	Drying for 16 hours at 103°C, gravimetry (Free water removed before analysis).	0.10 g/100g as rcvd	1-18
Total Recoverable digestion	Nitric / hydrochloric acid digestion. US EPA 200.2.	-	1-18
Total Recoverable Phosphorus	Dried sample, sieved as specified (if required). Nitric/Hydrochloric acid digestion, ICP-MS, screen level. US EPA 200.2.	40 mg/kg dry wt	1-18
Total Nitrogen*	Catalytic Combustion (900°C, O2), separation, Thermal Conductivity Detector [Elementar Analyser].	0.05 g/100g dry wt	1-18
Total Organic Carbon*	Acid pretreatment to remove carbonates present followed by Catalytic Combustion (900°C, O2), separation, Thermal Conductivity Detector [Elementar Analyser].	0.05 g/100g dry wt	1-18
Heavy metals, trace As,Cd,Cr,Cu,Ni,Pb,Zn,Hg	Dried sample, <2mm fraction. Nitric/Hydrochloric acid digestion, ICP-MS, trace level.	0.010 - 0.4 mg/kg dry wt	1-18
3 Grain Sizes Profile*		0.1 g/100g dry wt	1-18
3 Grain Sizes Profile			
Fraction >/= 2 mm*	Wet sieving with dispersant, 2.00 mm sieve, gravimetry.	0.1 g/100g dry wt	1-18
Fraction < 2 mm, >/= 63 µm*	Wet sieving using dispersant, 2.00 mm and 63 µm sieves, gravimetry (calculation by difference).	0.1 g/100g dry wt	1-18
Fraction < 63 µm*	Wet sieving with dispersant, 63 µm sieve, gravimetry (calculation by difference).	0.1 g/100g dry wt	1-18

These samples were collected by yourselves (or your agent) and analysed as received at the laboratory.

Samples are held at the laboratory after reporting for a length of time depending on the preservation used and the stability of the analytes being tested. Once the storage period is completed the samples are discarded unless otherwise advised by the client.

This certificate of analysis must not be reproduced, except in full, without the written consent of the signatory.

Graham Corban MSc Tech (Hons)
Client Services Manager - Environmental

Appendix 4 Statistical Analysis

Table 16 One Way Analysis of Variance Mud Percentage

Normality Test: Failed (P < 0.050)

Kruskal-Wallis One Way Analysis of Variance on Ranks

Group	N	Missing	Median	25%	75%
>200m	24	0	9.750	6.850	12.775
<200m	24	0	4.500	4.250	5.900
Control	6	0	21.100	17.100	35.500

H = 33.949 with 2 degrees of freedom. (P = <0.001)

The differences in the median values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference (P = <0.001)

To isolate the group or groups that differ from the others use a multiple comparison procedure.

All Pairwise Multiple Comparison Procedures (Dunn's Method):

Comparison	Diff of Ranks	Q	P<0.05
Control vs <200m	35.771	4.982	Yes
Control vs >200m	15.604	2.173	No
>200m vs <200m	20.167	4.441	Yes

Note: The multiple comparisons on ranks do not include an adjustment for ties.

Table 17 One Way Analysis of Variance Total Organic Carbon

Normality Test: Failed (P < 0.050)

Kruskal-Wallis One Way Analysis of Variance on Ranks

Group	N	Missing	Median	25%	75%
>200m	24	0	0.115	0.1000	0.130
<200m	24	0	0.1000	0.1000	0.110
Control	6	0	0.0950	0.0700	0.240

H = 7.958 with 2 degrees of freedom. (P = 0.019)

The differences in the median values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference (P = 0.019)

To isolate the group or groups that differ from the others use a multiple comparison procedure.

All Pairwise Multiple Comparison Procedures (Dunn's Method):

Comparison	Diff of Ranks	Q	P<0.05
>200m vs <200m	12.104	2.665	Yes
>200m vs Control	10.271	1.430	No
Control vs <200m	1.833	0.255	No

Table 18 One Way Analysis of Variance Total Nitrogen

Normality Test: Failed (P < 0.050)
Kruskal-Wallis One Way Analysis of Variance on Ranks

Group	N	Missing	Median	25%	75%
>200m	24	0	0.0500	0.0500	0.0500
<200m	24	0	0.0500	0.0500	0.0500
Control	6	0	0.0500	0.0500	0.0500

H = 2.548 with 2 degrees of freedom. (P = 0.280)

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 = 0.280)

Table 19 One Way Analysis of Variance Total Recoverable Phosphorus

Normality Test: Passed (P = 0.369)
Equal Variance Test: Passed (P = 0.772)

Group Name	N	Missing	Mean	Std Dev	SEM
>200m	24	0	390.000	30.503	6.226
<200m	24	0	372.083	21.464	4.381
Control	6	0	366.667	30.111	12.293

Source of Variation	DF	SS	MS	F	P
Between Groups	2	4954.167	2477.083	3.458	0.039
Residual	51	36529.167	716.258		
Total	53	41483.333			

The differences in the mean values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference (P = 0.039).

Power of performed test with alpha = 0.050: 0.462

All Pairwise Multiple Comparison Procedures (Tukey Test):

Comparisons for factor: **location**

Comparison	Diff of Means	p	q	P	P<0.050
>200m vs. Control	23.333	3	2.701	0.146	No
>200m vs. <200m	17.917	3	3.280	0.062	Do Not Test
<200m vs. Control	5.417	3	0.627	0.898	Do Not Test

A result of "Do Not Test" occurs for a comparison when no significant difference is found between two means that enclose that comparison. For example, if you had four means sorted in order, and found no difference between means 4 vs. 2, then you would not test 4 vs. 3 and 3 vs. 2, but still test 4 vs. 1 and 3 vs. 1 (4 vs. 3 and 3 vs. 2 are enclosed by 4 vs. 2: 4 3 2 1). Note that not testing the enclosed means is a procedural rule, and a result of Do Not Test should be treated as if there is no significant difference between the means, even though one may appear to exist.

Table 20 One Way Analysis of Variance Total Recoverable Arsenic

Normality Test: Failed (P < 0.050)
Kruskal-Wallis One Way Analysis of Variance on Ranks

Group	N	Missing	Median	25%	75%
>200m	24	0	6.150	5.800	6.450
<200m	24	0	5.900	5.650	6.150
Control	6	0	3.850	3.800	4.000

H = 17.843 with 2 degrees of freedom. (P = <0.001)

The differences in the median values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference (P = <0.001)

To isolate the group or groups that differ from the others use a multiple comparison procedure.

All Pairwise Multiple Comparison Procedures (Dunn's Method):

Comparison	Diff of Ranks	Q	P<0.05
>200m vs Control	30.187	4.204	Yes
>200m vs <200m	7.312	1.610	No
<200m vs Control	22.875	3.186	Yes

Note: The multiple comparisons on ranks do not include an adjustment for ties.

Table 21 One Way Analysis of Variance Total Recoverable Cadmium

Normality Test: Passed (P = 0.478)
Equal Variance Test: Failed (P < 0.050)
Kruskal-Wallis One Way Analysis of Variance on Ranks

Group	N	Missing	Median	25%	75%
>200m	24	0	0.0130	0.0110	0.0140
<200m	24	0	0.0110	0.01000	0.0120
Control	6	0	0.0185	0.0160	0.0200

H = 23.280 with 2 degrees of freedom. (P = <0.001)

The differences in the median values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference (P = <0.001)

To isolate the group or groups that differ from the others use a multiple comparison procedure.

All Pairwise Multiple Comparison Procedures (Dunn's Method):

Comparison	Diff of Ranks	Q	P<0.05
Control vs <200m	32.292	4.497	Yes
Control vs >200m	19.271	2.684	Yes
>200m vs <200m	13.021	2.867	Yes

Note: The multiple comparisons on ranks do not include an adjustment for ties.

Table 22 One Way Analysis of Variance Total Recoverable Chromium

Normality Test: Passed (P = 0.785)
Equal Variance Test: Passed (P = 0.804)

Group Name	N	Missing	Mean	Std Dev	SEM
>200m	24	0	11.475	0.633	0.129
<200m	24	0	10.829	0.514	0.105
Control	6	0	11.183	0.504	0.206

Source of Variation	DF	SS	MS	F	P
Between Groups	2	5.010	2.505	7.714	0.001
Residual	51	16.563	0.325		
Total	53	21.573			

The differences in the mean values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference (P = 0.001).

Power of performed test with alpha = 0.050: 0.912

All Pairwise Multiple Comparison Procedures (Tukey Test):

Comparisons for factor: **Location**

Comparison	Diff of Means	p	q	P	P<0.050
>200m vs. <200m	0.646	3	5.552	<0.001	Yes
>200m vs. Control	0.292	3	1.586	0.506	No
Control vs. <200m	0.354	3	1.926	0.369	No

Table 23 One Way Analysis of Variance Total Recoverable Copper

Normality Test: Failed (P < 0.050)
Kruskal-Wallis One Way Analysis of Variance on Ranks

Group	N	Missing	Median	25%	75%
>200m	24	0	2.700	2.600	2.950
<200m	24	0	2.500	2.400	2.650
Control	6	0	3.950	3.700	5.000

H = 23.344 with 2 degrees of freedom. (P = <0.001)

The differences in the median values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference (P = <0.001)

To isolate the group or groups that differ from the others use a multiple comparison procedure.

All Pairwise Multiple Comparison Procedures (Dunn's Method):

Comparison	Diff of Ranks	Q	P<0.05
Control vs <200m	32.792	4.567	Yes
Control vs >200m	19.896	2.771	Yes
>200m vs <200m	12.896	2.840	Yes

Note: The multiple comparisons on ranks do not include an adjustment for ties.

Table 24 One Way Analysis of Variance Total Recoverable Lead

Normality Test: Passed (P = 0.453)
Equal Variance Test: Passed (P = 0.137)

Group Name	N	Missing	Mean	Std Dev	SEM
>200m	24	0	9.796	0.712	0.145
<200m	24	0	9.175	0.459	0.0937
Control	6	0	8.683	0.835	0.341

Source of Variation	DF	SS	MS	F	P
Between Groups	2	8.056	4.028	10.281	<0.001
Residual	51	19.983	0.392		
Total	53	28.039			

The differences in the mean values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference (P = <0.001).

Power of performed test with alpha = 0.050: 0.979

All Pairwise Multiple Comparison Procedures (Tukey Test):

Comparisons for factor: **Location**

Comparison	Diff of Means	p	q	P	P<0.050
>200m vs. Control	1.113	3	5.507	<0.001	Yes
>200m vs. <200m	0.621	3	4.859	0.003	Yes
<200m vs. Control	0.492	3	2.434	0.207	No

Table 25 One Way Analysis of Variance Total Recoverable Mercury

Normality Test: Failed (P < 0.050)
Kruskal-Wallis One Way Analysis of Variance on Ranks

Group	N	Missing	Median	25%	75%
>200m	24	0	0.0500	0.0400	0.0500
<200m	24	0	0.0500	0.0400	0.0500
Control	6	0	0.0400	0.0400	0.0400

H = 2.438 with 2 degrees of freedom. (P = 0.295)

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 = 0.295)

Table 26 One Way Analysis of Variance Total Recoverable Nickel

Normality Test: Passed (P = 0.364)
Equal Variance Test: Passed (P = 0.737)

Group Name	N	Missing	Mean	Std Dev	SEM
>200m	24	0	9.321	0.709	0.145
<200m	24	0	8.675	0.725	0.148
Control	6	0	9.750	0.660	0.269

Source of Variation	DF	SS	MS	F	P
Between Groups	2	8.022	4.011	7.916	0.001
Residual	51	25.840	0.507		
Total	53	33.861			

The differences in the mean values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference (P = 0.001).

Power of performed test with alpha = 0.050: 0.921

All Pairwise Multiple Comparison Procedures (Tukey Test):

Comparisons for factor: **Location**

Comparison	Diff of Means	p	q	P	P<0.050
Control vs. <200m	1.075	3	4.679	0.005	Yes
Control vs. >200m	0.429	3	1.868	0.390	No
>200m vs. <200m	0.646	3	4.445	0.008	Yes

Table 27 One Way Analysis of Variance Total Recoverable Zinc

Normality Test: Passed (P = 0.125)
Equal Variance Test: Failed (P < 0.050)
Kruskal-Wallis One Way Analysis of Variance on Ranks

Group	N	Missing	Median	25%	75%
>200m	24	0	34.000	33.000	37.000
<200m	24	0	32.000	31.500	33.000
Control	6	0	32.500	32.000	36.000

H = 15.358 with 2 degrees of freedom. (P = <0.001)

The differences in the median values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference (P = <0.001)

To isolate the group or groups that differ from the others use a multiple comparison procedure.

All Pairwise Multiple Comparison Procedures (Dunn's Method):

Comparison	Diff of Ranks	Q	P<0.05
>200m vs <200m	17.500	3.853	Yes
>200m vs Control	9.687	1.349	No
Control vs <200m	7.813	1.088	No

Note: The multiple comparisons on ranks do not include an adjustment for ties.

Table 28 Similarity Percentages – benthic infauna species contributions between site groupings 2018

One-Way Analysis

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

Factor Groups

Sample	SFG2
N-100	c
N-200	c
S-100	c
S-200	c
S-500	c
S-1000	c
S-2500	c
W-100	c
W-200	c
W-500	c
E-100	c
E-200	c
E-500	c
N-500	b
N-1000	b
N-2500	b
WR-1	a
WR-2	a

Group c
Average similarity: 61.79

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Nephtyidae	1.27	4.01	9.15	6.49	6.49
Heteromastus filiformis	1.38	3.96	4.94	6.41	12.90
Myllitella vivens	1.17	3.50	5.18	5.66	18.55
Cirratulidae	1.04	3.24	8.06	5.24	23.79
Nucula nitidula	1.10	3.22	4.21	5.21	29.00
Magelona dakini	1.03	3.16	7.16	5.12	34.13
Heterothyone ocnoides	0.98	2.90	5.91	4.69	38.81
Diasterope grisea	0.88	2.71	8.40	4.38	43.19
Goniadidae	1.01	2.66	2.21	4.31	47.50
Phoxocephalidae	0.98	2.50	1.50	4.04	51.54
Prionospio australiensis	0.97	2.48	1.48	4.01	55.55
Rissoidae	0.87	2.44	2.21	3.95	59.50
Haustoridae	0.87	2.36	2.15	3.83	63.33
Aricidea sp.	0.81	2.20	2.11	3.56	66.89
Dosinia anus	0.76	2.15	2.00	3.47	70.36

Group b
Average similarity: 63.74

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Heteromastus filiformis	1.90	4.70	8.49	7.38	7.38
Goniadidae	1.27	3.66	8.70	5.74	13.12
Magelona dakini	1.16	3.43	13.81	5.38	18.50
Nephtyidae	1.10	3.03	5.65	4.75	23.26
Aricidea sp.	1.02	3.00	22.15	4.71	27.96
Phoxocephalidae	1.10	2.92	3.67	4.58	32.54
Prionospio australiensis	1.23	2.88	2.04	4.52	37.06
Ampharetidae	0.91	2.63	11.70	4.12	41.18
Nucula nitidula	0.99	2.56	3.00	4.01	45.20
Cirratulidae	0.92	2.42	4.40	3.79	48.99
Sigalionidae	0.81	2.30	5.65	3.61	52.60
Paraprionospio sp.	0.85	2.30	5.82	3.61	56.21
Tanaidacea	0.80	2.21	8.73	3.47	59.68
Diasterope grisea	0.75	2.21	8.73	3.47	63.15
Aglaophamus sp.	0.78	2.21	11.70	3.47	66.62
Crassula aequilatera	0.78	2.21	11.70	3.47	70.09

Group a

Average similarity: 62.42

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Prionospio sp.	1.32	4.48	SD=0!	7.18	7.18
Heteromastus filiformis	1.29	3.85	SD=0!	6.17	13.36
Nucula nitidula	1.24	3.85	SD=0!	6.17	19.53
Goniadidae	1.09	3.68	SD=0!	5.90	25.43
Haustoridae	0.95	3.48	SD=0!	5.58	31.01
Phoxocephalidae	0.97	3.48	SD=0!	5.58	36.59
Sigalionidae	0.96	3.24	SD=0!	5.19	41.78
Owenia petersenae	0.94	2.93	SD=0!	4.69	46.47
Diasterope grisea	0.99	2.93	SD=0!	4.69	51.17
Trochodota dendyi	0.87	2.93	SD=0!	4.69	55.86
Serratina charlottae	0.92	2.93	SD=0!	4.69	60.55
Ampharetidae	0.73	2.46	SD=0!	3.95	64.49
Hesionidae	0.67	2.46	SD=0!	3.95	68.44
Nephtyidae	0.93	2.46	SD=0!	3.95	72.38

Groups c & b

Average dissimilarity = 42.84

Species	Group c Av.Abund	Group b Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Phoronus sp.	0.35	0.85	1.18	1.47	2.76	2.76
Prionospio sp.	0.72	0.00	1.15	1.40	2.68	5.44
Paraprionospio sp.	0.18	0.85	1.12	2.09	2.62	8.05
Haustoridae	0.87	0.22	1.10	1.73	2.57	10.62
Dosinia sp. (Juvenile)	0.69	0.00	1.09	1.38	2.54	13.16
Ampharetidae	0.27	0.91	1.07	1.74	2.50	15.66
Heteromastus filiformis	1.38	1.90	1.02	1.37	2.38	18.04
Spiophanes modestus	0.16	0.74	0.96	1.93	2.23	20.27
Crassula aequilatera	0.23	0.78	0.94	1.78	2.20	22.48
Arthritica bifurca	0.69	0.33	0.94	1.37	2.20	24.68
Prionospio australiensis	0.97	1.23	0.85	1.42	1.98	26.66
Myllitella vivens	1.17	0.81	0.82	1.04	1.91	28.57
Owenia petersenae	0.57	0.52	0.77	1.23	1.79	30.35
Bivalvia Unid. (juv)	0.05	0.49	0.75	1.32	1.76	32.11
Tanaidacea	0.46	0.80	0.73	1.25	1.71	33.83
Mysella sp.	0.23	0.52	0.73	1.21	1.70	35.53
Rissoidae	0.87	0.49	0.73	1.22	1.70	37.23
Lumbrineridae	0.32	0.54	0.71	1.17	1.65	38.88
Aglaophamus sp.	0.37	0.78	0.69	1.17	1.61	40.49
Onuphis aucklandensis	0.11	0.45	0.68	1.28	1.60	42.09
Nemertea	0.34	0.71	0.68	1.26	1.60	43.69
Soletellina sp.	0.38	0.45	0.67	1.24	1.56	45.25
Armandia maculata	0.16	0.45	0.66	1.22	1.54	46.79
Cumacea	0.10	0.45	0.66	1.24	1.54	48.33
Hunkydora australica novozelandica	0.50	0.45	0.65	1.18	1.52	49.84
Ophiuroidea	0.71	0.45	0.64	1.20	1.49	51.34
Dosinia anus	0.76	0.45	0.63	1.11	1.48	52.82
Flabelligeridae	0.44	0.52	0.63	1.09	1.48	54.29
Leuroleberis zealandica	0.40	0.00	0.63	1.05	1.47	55.77
Serratina charlottae	0.37	0.00	0.60	0.87	1.39	57.16
Hesionidae	0.33	0.45	0.58	1.08	1.36	58.53
Trochodota dendyi	0.26	0.45	0.58	1.06	1.35	59.88
Phoxocephalidae	0.98	1.10	0.58	0.95	1.34	61.22
Maldanidae	0.23	0.27	0.55	0.88	1.29	62.51
Sigalionidae	0.51	0.81	0.55	0.96	1.28	63.79
Natatolana sp.	0.32	0.22	0.54	0.97	1.25	65.04
Goniadidae	1.01	1.27	0.53	0.91	1.23	66.27
Heterothyone ocnoides	0.98	0.88	0.52	1.82	1.22	67.49
Gastropoda Unid. Juv.	0.17	0.27	0.51	0.83	1.20	68.69
Amphipoda Unid.	0.33	0.00	0.51	0.89	1.19	69.88
Scoloplos cylindrifer	0.23	0.22	0.51	0.89	1.19	71.07

Groups c & a

Average dissimilarity = 46.93

Species	Group c Av.Abund	Group a Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Aricidea sp.	0.81	0.00	1.42	2.73	3.03	3.03
Dosinia anus	0.76	0.00	1.34	2.71	2.86	5.89
Prionospio yuriel	0.07	0.77	1.27	3.29	2.70	8.59
Paracaudina chilensis	0.07	0.77	1.27	3.29	2.70	11.29
Ophiuroidea	0.71	0.00	1.24	2.23	2.65	13.94
Prionospio australiensis	0.97	0.68	1.19	1.30	2.53	16.47
Myllitella vivens	1.17	0.58	1.15	1.21	2.45	18.92
Cirratulidae	1.04	0.40	1.12	1.52	2.39	21.31
Cumacea	0.10	0.73	1.11	2.41	2.37	23.67
Prionospio sp.	0.72	1.32	1.10	1.23	2.34	26.01
Trochodota dendyi	0.26	0.87	1.07	1.79	2.28	28.29
Magelona dakini	1.03	0.44	1.05	1.37	2.24	30.53
Spiophanes modestus	0.16	0.73	1.02	1.92	2.18	32.71
Serratina charlottae	0.37	0.92	1.02	1.47	2.17	34.87
Arthritica bifurca	0.69	0.56	1.01	1.34	2.14	37.01
Heterothyone ocnoides	0.98	0.52	1.00	1.28	2.13	39.14
Dosinia sp. (Juvenile)	0.69	0.40	0.95	1.23	2.02	41.16
Scoloplos cylindrifer	0.23	0.52	0.91	1.10	1.95	43.11
Owenia petersenae	0.57	0.94	0.88	1.18	1.88	44.99
Ampharetidae	0.27	0.73	0.87	1.38	1.85	46.83
Nemertea	0.34	0.77	0.84	1.32	1.78	48.61
Pectinaria australis	0.00	0.47	0.83	0.97	1.76	50.37
Sigalionidae	0.51	0.96	0.81	1.19	1.72	52.10
Tanaidacea	0.46	0.00	0.80	1.02	1.71	53.81
Leuroleberis zealandica	0.40	0.44	0.78	1.16	1.66	55.47
Hunkydora australica novozelandica	0.50	0.33	0.75	1.15	1.60	57.07
Flabelligeridae	0.44	0.00	0.75	1.22	1.59	58.66
Paraprionospio sp.	0.18	0.40	0.71	1.04	1.52	60.18
Copepoda	0.12	0.40	0.70	1.01	1.50	61.68
Amphipoda Unid.	0.33	0.67	0.69	1.18	1.47	63.15
Hesionidae	0.33	0.67	0.67	1.17	1.43	64.58
Soletellina sp.	0.38	0.00	0.63	0.88	1.35	65.93
Mysella sp.	0.23	0.33	0.62	1.02	1.32	67.25
Nephtyidae	1.27	0.93	0.61	1.31	1.30	68.55
Aglaophamus sp.	0.37	0.33	0.60	1.00	1.28	69.83
Natatolana sp.	0.32	0.33	0.60	1.00	1.28	71.10

Groups b & a

Average dissimilarity = 47.26

Species	Group b Av.Abund	Group a Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Prionospio sp.	0.00	1.32	2.22	11.64	4.70	4.70
Aricidea sp.	1.02	0.00	1.73	10.30	3.66	8.35
Serratina charlottae	0.00	0.92	1.55	6.76	3.29	11.64
Phoronus sp.	0.85	0.00	1.43	1.29	3.03	14.67
Tanaidacea	0.80	0.00	1.36	5.86	2.87	17.54
Crassula aequilatera	0.78	0.00	1.32	9.14	2.78	20.33
Prionospio australiensis	1.23	0.68	1.31	1.25	2.77	23.10
Haustoridae	0.22	0.95	1.22	2.08	2.59	25.69
Magelona dakini	1.16	0.44	1.21	1.48	2.56	28.25
Amphipoda Unid.	0.00	0.67	1.13	60.03	2.39	30.64
Heteromastus filiformis	1.90	1.29	1.10	1.24	2.33	32.97
Myllitella vivens	0.81	0.58	1.08	1.04	2.28	35.24
Heterothyone ocnoides	0.88	0.52	1.03	1.62	2.19	37.43
Arthritica bifurca	0.33	0.56	0.95	0.98	2.00	39.43
Cirratulidae	0.92	0.40	0.95	1.36	2.00	41.44
Paracaudina chilensis	0.22	0.77	0.93	1.51	1.98	43.41
Prionospio yuriel	0.22	0.77	0.93	1.51	1.97	45.39
Lumbrineridae	0.54	0.00	0.91	1.25	1.92	47.31
Scoloplos cylindrifer	0.22	0.52	0.88	1.09	1.86	49.17
Flabelligeridae	0.52	0.00	0.86	1.25	1.82	51.00
Paraprionospio sp.	0.85	0.40	0.83	1.22	1.77	52.76
Bivalvia Unid. (juv)	0.49	0.00	0.81	1.28	1.72	54.49
Pectinaria australis	0.00	0.47	0.80	0.91	1.68	56.17
Owenia petersenae	0.52	0.94	0.77	1.10	1.64	57.81
Onuphis aucklandensis	0.45	0.00	0.76	1.29	1.60	59.41
Armandia maculata	0.45	0.00	0.76	1.29	1.60	61.01
Soletellina sp.	0.45	0.00	0.76	1.29	1.60	62.61
Ophiuroidea	0.45	0.00	0.75	1.29	1.60	64.21
Aglaophamus sp.	0.78	0.33	0.75	1.18	1.59	65.80
Dosinia anus	0.45	0.00	0.74	1.29	1.57	67.38
Leuroleberis zealandica	0.00	0.44	0.74	0.91	1.57	68.95
Trochodota dendyi	0.45	0.87	0.71	1.21	1.50	70.46

Table 29 One-Way Analysis of Similarities

Resemblance worksheet
Name: Resem1
Data type: Similarity
Selection: All

Factors

Place	Name	Type	Levels
A	mix	Unordered	3

Mix levels
Mixing zone
Outside
Control

Tests for differences between unordered mix groups
Global Test
Sample statistic (R): 0.243
Significance level of sample statistic: 0.01%
Number of permutations: 9999 (Random sample from a large number)
Number of permuted statistics greater than or equal to R: 0

Pairwise Tests

Groups	R Statistic	Significance Level %	Possible Permutations	Actual Permutations	Number >= Observed
Mixing zone, Outside	0.144	0.01	Very large	9999	0
Mixing zone, Control	0.408	0.03	Very large	9999	2
Outside, Control	0.484	0.01	Very large	9999	0

Table 30 Permutational MANOVA

Resemblance worksheet
Name: Resem1
Data type: Similarity
Selection: All
Transform: Fourth root
Resemblance: S17 Bray-Curtis similarity

Sums of squares type: Type III (partial)
Fixed effects sum to zero for mixed terms
Permutation method: Unrestricted permutation of raw data
Number of permutations: 9999

Factors

Name	Type	Levels
Mix	Fixed	3

PAIR-WISE TESTS

Groups	t	P(perm)	Unique perms
Mixing zone, Outside	2.2137	0.0001	9929
Mixing zone, Control	2.4928	0.0001	9919
Outside, Control	2.5133	0.0001	9920

Denominators

Groups	Denominator	Den.df
Mixing zone, Outside	1*Res	78
Mixing zone, Control	1*Res	48
Outside, Control	1*Res	48

Average Similarity between/within groups

	Mixing zone	Outside	Control
Mixing zone	43.542		
Outside	41.411	44.746	
Control	33.671	34.128	40.884

Table 31 Similarity Percentages - benthic infauna species contributions between mixing zone and other site groupings 2018

One-Way Analysis

Data worksheet
Name: Data1
Data type: Abundance
Sample selection: All
Variable selection: All

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

Factor Groups

Sample	mix	Sample	mix	Sample	mix
N-100A	mixing zone	N-500A	outside	WR-1A	control
N-100B	mixing zone	N-500B	outside	WR-1B	control
N-100C	mixing zone	N-500C	outside	WR-1C	control
N-100D	mixing zone	N-500D	outside	WR-1D	control
N-100E	mixing zone	N-500E	outside	WR-1E	control
N-200A	mixing zone	N-1000A	outside	WR-2A	control
N-200B	mixing zone	N-1000B	outside	WR-2B	control
N-200C	mixing zone	N-1000C	outside	WR-2C	control
N-200D	mixing zone	N-1000D	outside	WR-2D	control
N-200E	mixing zone	N-1000E	outside	WR-2E	control
S-100A	mixing zone	N-2500A	outside		
S-100B	mixing zone	N-2500B	outside		
S-100C	mixing zone	N-2500C	outside		
S-100D	mixing zone	N-2500D	outside		
S-100E	mixing zone	N-2500E	outside		
S-200A	mixing zone	S-500A	outside		
S-200B	mixing zone	S-500B	outside		
S-200C	mixing zone	S-500C	outside		
S-200D	mixing zone	S-500D	outside		
S-200E	mixing zone	S-500E	outside		
W-100A	mixing zone	S-1000A	outside		
W-100B	mixing zone	S-1000B	outside		
W-100C	mixing zone	S-1000C	outside		
W-100D	mixing zone	S-1000D	outside		
W-100E	mixing zone	S-1000E	outside		
W-200A	mixing zone	S-2500A	outside		
W-200B	mixing zone	S-2500B	outside		
W-200C	mixing zone	S-2500C	outside		
W-200D	mixing zone	S-2500D	outside		
W-200E	mixing zone	S-2500E	outside		
E-100A	mixing zone	W-500A	outside		
E-100B	mixing zone	W-500B	outside		
E-100C	mixing zone	W-500C	outside		
E-100D	mixing zone	W-500D	outside		
E-100E	mixing zone	W-500E	outside		
E-200A	mixing zone	E-500A	outside		
E-200B	mixing zone	E-500B	outside		
E-200C	mixing zone	E-500C	outside		
E-200D	mixing zone	E-500D	outside		
E-200E	mixing zone	E-500E	outside		

Group mixing zone
Average similarity: 43.54

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Nephtyidae	1.08	4.52	1.50	10.37	10.37
Heteromastus filiformis	1.00	4.14	1.34	9.52	19.89
Myllitella vivens	1.03	3.98	1.15	9.14	29.03
Magelona dakini	0.86	3.36	1.14	7.72	36.75
Phoxocephalidae	0.88	3.12	0.99	7.17	43.92
Cirratulidae	0.79	2.85	0.86	6.55	50.48
Nucula nitidula	0.76	2.43	0.81	5.57	56.05
Goniadidae	0.79	2.28	0.76	5.24	61.29
Heterothyone ocnoides	0.68	1.91	0.65	4.38	65.67
Haustoridae	0.65	1.71	0.62	3.93	69.60
Prionospio australiensis	0.65	1.67	0.63	3.83	73.43

Group outside
Average similarity: 44.75

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Heteromastus filiformis	1.69	7.73	2.50	17.27	17.27
Nephtyidae	1.07	4.63	1.50	10.34	27.61
Magelona dakini	0.92	3.98	1.39	8.89	36.50
Nucula nitidula	0.96	3.90	1.27	8.71	45.21
Prionospio australiensis	1.00	3.88	1.17	8.67	53.88
Goniadidae	0.96	3.80	1.29	8.49	62.36
Cirratulidae	0.72	2.52	0.89	5.63	68.00
Phoxocephalidae	0.70	2.02	0.68	4.52	72.51

Group control

Average similarity: 40.88

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Goniadidae	1.00	5.73	1.70	14.00	14.00
Heteromastus filiformis	1.19	5.43	1.80	13.29	27.29
Prionospio sp.	1.18	5.43	1.90	13.28	40.57
Nucula nitidula	0.95	3.15	0.91	7.69	48.27
Serratina charlottae	0.63	2.45	0.66	6.00	54.26
Prionospio australiensis	0.66	1.89	0.49	4.63	58.89
Owenia petersenae	0.65	1.87	0.69	4.57	63.46
Haustoridae	0.63	1.82	0.69	4.46	67.92
Sigalionidae	0.65	1.80	0.69	4.40	72.32

Groups mixing zone & outside

Average dissimilarity = 58.59

	Group m	Group o				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Heteromastus filiformis	1.00	1.69	2.44	1.21	4.16	4.16
Myllitella vivens	1.03	0.64	2.10	1.22	3.58	7.74
Prionospio australiensis	0.65	1.00	2.08	1.14	3.54	11.28
Phoxocephalidae	0.88	0.70	1.93	1.16	3.29	14.58
Goniadidae	0.79	0.96	1.87	1.09	3.19	17.76
Heterothyone ocnoides	0.68	0.54	1.87	1.10	3.18	20.95
Haustoridae	0.65	0.22	1.81	1.05	3.08	24.03
Nucula nitidula	0.76	0.96	1.77	1.07	3.02	27.05
Cirratulidae	0.79	0.72	1.67	1.06	2.84	29.89
Aricidea sp.	0.53	0.42	1.66	1.02	2.83	32.72
Prionospio sp.	0.53	0.26	1.64	0.93	2.80	35.51
Rissoidae	0.55	0.45	1.63	1.03	2.78	38.30
Diasterope grisea	0.52	0.41	1.57	1.00	2.69	40.98
Dosinia sp. (Juvenile)	0.46	0.28	1.52	0.89	2.60	43.58
Arthritica bifurca	0.47	0.25	1.49	0.91	2.55	46.13
Nephtyidae	1.08	1.07	1.47	0.91	2.51	48.64
Dosinia anus	0.37	0.33	1.41	0.88	2.41	51.05
Ophiuroidea	0.41	0.38	1.38	0.92	2.36	53.41
Owenia petersenae	0.46	0.21	1.37	0.88	2.34	55.75
Magelona dakini	0.86	0.92	1.36	0.87	2.32	58.07
Tanaidacea	0.17	0.37	1.20	0.79	2.05	60.12
Hunkydora australica novozelandica	0.40	0.08	1.17	0.78	2.01	62.12
Phoronus sp.	0.06	0.39	1.16	0.69	1.97	64.10
Sigalionidae	0.25	0.23	1.02	0.74	1.73	65.83
Ampharetidae	0.08	0.29	0.93	0.65	1.59	67.42
Soletellina sp.	0.26	0.13	0.86	0.66	1.47	68.88
Aglaophamus sp.	0.10	0.25	0.84	0.64	1.43	70.31

Groups mixing zone & control

Average dissimilarity = 66.33

	Group m	Group c				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Myllitella vivens	1.03	0.38	2.70	1.29	4.07	4.07
Prionospio sp.	0.53	1.18	2.52	1.29	3.80	7.87
Cirratulidae	0.79	0.12	2.38	1.22	3.59	11.47
Nephtyidae	1.08	0.59	2.30	1.16	3.46	14.93
Magelona dakini	0.86	0.30	2.17	1.20	3.27	18.20
Nucula nitidula	0.76	0.95	2.17	1.10	3.27	21.47
Prionospio australiensis	0.65	0.66	2.17	1.03	3.27	24.74
Phoxocephalidae	0.88	0.56	2.14	1.09	3.22	27.97
Heterothyone ocnoides	0.68	0.44	1.99	1.02	3.00	30.96
Serratina charlottae	0.22	0.63	1.95	1.06	2.94	33.91
Haustoridae	0.65	0.63	1.89	1.04	2.85	36.75
Goniadidae	0.79	1.00	1.88	1.06	2.84	39.60
Diasterope grisea	0.52	0.49	1.86	0.99	2.80	42.40
Owenia petersenae	0.46	0.65	1.84	1.09	2.78	45.18
Sigalionidae	0.25	0.65	1.75	1.09	2.64	47.82
Heteromastus filiformis	1.00	1.19	1.73	0.86	2.60	50.42
Arthritica bifurca	0.47	0.26	1.70	0.90	2.57	52.99
Rissoidae	0.55	0.20	1.64	0.96	2.47	55.46
Aricidea sp.	0.53	0.00	1.58	0.88	2.38	57.84
Trochodota dendyi	0.05	0.52	1.54	0.97	2.32	60.15
Dosinia sp. (Juvenile)	0.46	0.20	1.52	0.83	2.30	62.45
Nemertea	0.13	0.40	1.30	0.83	1.96	64.41
Scoloplos cylindrifer	0.03	0.43	1.28	0.80	1.93	66.34
Hunkydora australica novozelandica	0.40	0.10	1.26	0.77	1.91	68.25
Dosinia anus	0.37	0.00	1.24	0.67	1.87	70.12

Groups outside & control

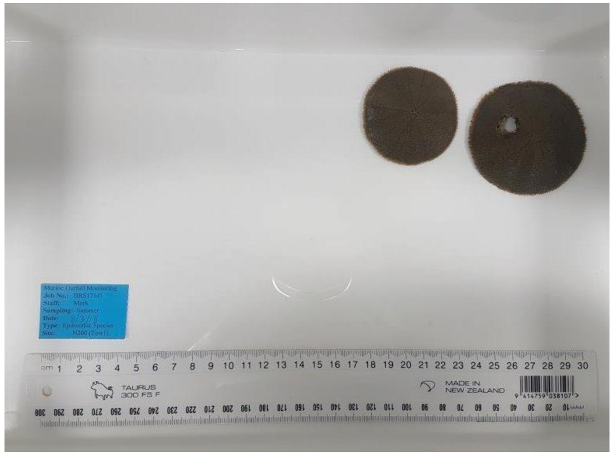
Average dissimilarity = 65.87

Species	Group o Av.Abund	Group c Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Prionospio sp.	0.26	1.18	2.91	1.72	4.42	4.42
Heteromastus filiformis	1.69	1.19	2.32	0.94	3.52	7.94
Nephtyidae	1.07	0.59	2.29	1.14	3.48	11.42
Magelona dakini	0.92	0.30	2.28	1.29	3.46	14.88
Prionospio australiensis	1.00	0.66	2.28	1.18	3.46	18.34
Cirratulidae	0.72	0.12	2.14	1.27	3.24	21.58
Myllitella vivens	0.64	0.38	2.05	1.03	3.10	24.69
Nucula nitidula	0.96	0.95	2.03	1.05	3.09	27.77
Serratina charlottae	0.05	0.63	2.01	1.11	3.05	30.83
Phoxocephalidae	0.70	0.56	2.01	1.07	3.05	33.87
Owenia petersenae	0.21	0.65	1.79	1.13	2.72	36.59
Heterothyone ocnoides	0.54	0.44	1.79	1.00	2.71	39.30
Haustoridae	0.22	0.63	1.77	1.11	2.69	42.00
Sigalionidae	0.23	0.65	1.77	1.12	2.68	44.68
Diasterope grisea	0.41	0.49	1.70	0.98	2.58	47.25
Trochodota dendyi	0.13	0.52	1.54	0.98	2.34	49.59
Rissoidae	0.45	0.20	1.50	0.87	2.27	51.86
Scoloplos cylindrifer	0.18	0.43	1.38	0.86	2.10	53.96
Nemertea	0.20	0.40	1.36	0.86	2.06	56.02
Goniadidae	0.96	1.00	1.33	0.89	2.02	58.05
Ampharetidae	0.29	0.30	1.30	0.80	1.97	60.02
Paracaudina chilensis	0.08	0.40	1.26	0.82	1.92	61.93
Aricidea sp.	0.42	0.00	1.24	0.74	1.88	63.81
Arthritica bifurca	0.25	0.26	1.20	0.70	1.82	65.62
Ophiuroidea	0.38	0.00	1.15	0.74	1.74	67.36
Phoronus sp.	0.39	0.00	1.13	0.66	1.72	69.09
Tanaidacea	0.37	0.00	1.09	0.70	1.66	70.74

Appendix 5 Benthic Infauna Data

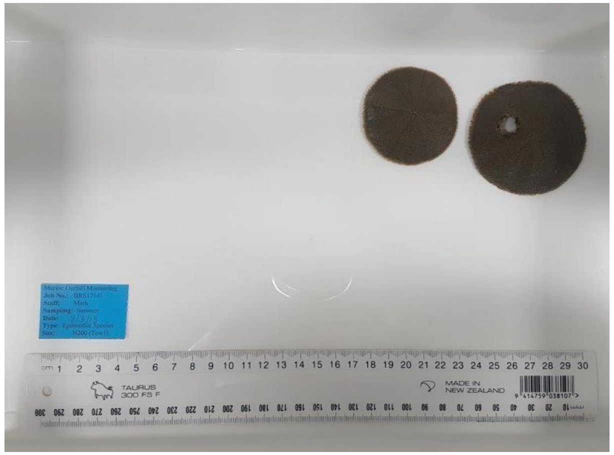
Table 32 Abundance of species in epibenthic tow samples, March 2018 (N = 200m north of outfall, S = 200m south of outfall, WR = Waimakariri River control site).

Taxon	Common Name	Species	S1	S2	S3	N1	N2	N3	WR1	WR2	WR3
Mollusca	Southern Olive	*Amalda australis*			1					1	
	Clam	*Dosinia sp.*		1							
	Green lipped mussel	*Perna canaliculus*							7	2	
	Sea snail	*Philine angasi*								1	
	Bivalvia Unid	Unid. Juvenile Bivalvia							9	12	
	Triangle shell	*Crassula aequilatera*							1	1	
Crustacea	Hermit crab	*Pagurus* spp.					1				
	Shrimp	*Philocheras australis*							1	1	
	Amphipod	Unid. Amphipoda							1		
Polychaeta		*Pectinaria australis*							8	2	
		Paraprionospio pinnata							1		
		Maldanidae								1	
Cnidaria		Hydroida							1	1	
Echinodermata	Heart urchin	*Echinocardium australe*		1							
	Sand dollar	*Fellaster zelandiae*	1	16	11	2	51	1		4	
	Sea cucumber	*Paracaudina chilensis*							2	2	
Fish	Red cod	*Pseudophycis bachus*								1	
	Sole	*Peltorhamphus* sp.							1	1	
No taxa			**1**	**3**	**2**	**1**	**2**	**1**	**10**	**13**	**0**
No Individuals			**1**	**18**	**12**	**2**	**52**	**1**	**32**	**30**	**0**

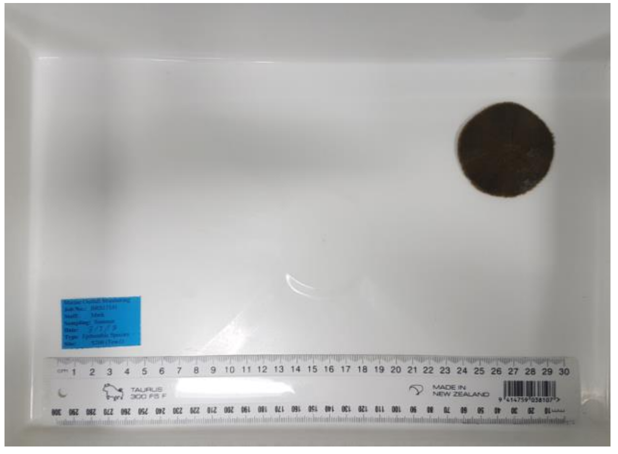


Site N200 (Tow 1)

Site N200 (Tow 2)



Site N200 (Tow 3)



Site S200 (Tow 1)

Site S200 (Tow 2)

Site S200 (Tow 3)

Site WR1 (Tow 1)

Site WR1 (Tow 2)

Site WR1 (Tow 3)

Figure 29 Species present in Epibenthic tow samples, March 2018

Table 33 Abundance of species in benthic infauna core samples, March 2018 (Number per core).

Taxa		N-100					N-200					N-500					N-1000					N-2500					S-100					S-200					S-500					S-1000					S-2500				
		A	B	C	D	E	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E
Annelida																																																			
Polychaeta																																																			
Ampharetidae										1			2	1		2	1	1						1	2	1								1											1						
Capitellidae	Capitellidae																																																		
	Heteromastus filiformis	2		1	1		1	2	2	1	2	8	8	9	6	16	2	3	7	4	3	40	74	42	24	35	3		4	1	3	1	2	1		5	4	5	5	1	15	31	14	19	40	16	5	6	9	6	15
Cirratulidae			1		1	1				1	3	1	1	1	1	1					1	1	3			3		2	1	1	2	2	3			2			1	3	4	1	2	1	1		1	1	1	1	
Flabelligeridae			1									1				2								1									1	1												1	1	1			
Glyceridae	*Glycera* sp.			1			1														1															1															
Goniadidae		4	6		3	4		4	2	6	3	3	2	3	1	8	1	1	2	2	1	6	5	3	1	2			1	1		3	3	3	5	4		3		1	2	2	2	5	4	4	1	1	1	1	
Hesionidae									1									1					1				1			1													1					1			
Lumbrineridae	Lumbrineridae										1							1					1		2	1																				1					1
	Marphysa disjuncta																																														1				
Magelonidae	*Magelona dakini*	2	2	3	2	1	1	1	2	3	1	3	1	2	3	2	1	2	1		2	4	1	3	2	1	1			1	3	4	1	3	2	1			3	2	1	2	1	1	1		1	2	1	1	2
Maldanidae																			1	1									1	1										1											
Nephtyidae	*Aglaophamus* sp.			1										1	1						1		1	1		1								1							1		1	1							
	Nephtyidae	4	4	1			1	2	5	1	4	3		4	2	4	1	1	3	1	3		2	1			3	2		4	2	3	3	4	5	6	1	4	2	1	2	2	5	3	4	3	1	1	1	1	4
Onuphidae	*Onuphis aucklandensis*															1			1																								1								
Opheliidae	*Armandia maculata*															1			1																1																
Orbiniidae	*Leitoscoloplos kerguelensis*			1																																															
	Orbiniidae																	1			1																														
	Leodamas cylindrifer											1																															1					1	1		1
Oweniidae	*Owenia petersenae*	2		2		1	3	3	1	1	4	1	1		1							1										1		1		2						2			1	2					
Paraonidae	*Aricidea* sp.			1			1	4		1	1		1	3		1	3	2	3			2			1	1	4	1			1	1			1	1		1					3			1	2				
Pectinariidae	*Lagis australis*																																																		
Pilargidae																						1																													
Scalibregmatidae	*Travisia* sp.											1																																							
Sigalionidae		1		1				1						2		1	2		1			1										1				1			1						1		1	1			
Spionidae	*Aonides oxycephala*			1																																															
	Boccardia sp.																																									1									
	Paraprionospio sp.										1	1						1	2			1	1	1	1	1																		4				1			
	Prionospio australiensis											6	1	4	5	5	6	1	7	17					1		1		1	3	3	1	5	6	2	1	1	3	2		2	4	2	2	3	3	1	3	4	4	2
	Prionospio sp.	4	3	1		3	3	3	4	9	4																																	2	4	1	3		2		2
	Prionospio yurieli									3					1																																				
	Spiophanes kroyeri																						1										1																	1	
	Spiophanes modestus			1									1				1	1	1				1				1																								
Syllidae																																			1																
Terebellidae											1																	1				1																			
Arthropoda																																																				
Hexanauplia	Copepoda																																																		
Malacostraca																																																			
Amphipoda	*Ampelisca* sp.																																			5															
	Amphipoda Unid.						1		1																				1					1											1						
	Caprellidae																1																																		
	Haustoridae			1		2			2	1	2			1													4	1	4	3	2	6		4	4	1	2			3										3	1
	Lysianassidae					2	3																					1				1			1																
	Phoxocephalidae	2	7	7	1		1	7	5	1	1	3	5	3	2	1			6		5		1		1		2	1	1	1		6	4	2	5		1	4	3	4		2		5	1						
Cumacea														1												1																			1						
Decapoda	Decapoda (larvae Unid.)																																	1																	
	Ogyrides sp																					1												1												1				1	
Isopoda	Anthuroidea																																																		
	Uromunna schauinslandi																																				1														
	Natatolana sp.														1															1				1	1		1					1									1
Leptostraca	*Nebalia* sp.																				1											1						1									1				
Tanaidacea		1										1				1	1	1	1		1	1																				1		1			1	2	2		4
Ostracoda	*Diasterope grisea*	1	1								3				1	1			1	1		1					3			1	1	1	1	2	3	1	1		2	1				1	1	1	1		1		
	Pleoschisma agilis																																																		
	Leuroleberis zealandica				1																													1	1																
	Scleroconcha sp.	1																																																	

Taxa		N-100					N-200					N-500					N-1000					N-2500					S-100					S-200					S-500					S-1000					S-2500				
		A	B	C	D	E	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E
Cnidaria																																																			
Anthozoa	Anemone Unid		2																																																
	Anthopleura hermaphroditica																													1																					
	Edwardsia sp.																																																		
Hydrozoa	Hydroida (athecate)																																			1															
	Hydromedusae																																																		
Echinodermata																																																			
Asteroidea	*Fellaster zelandiae*																																																		
Echinoidea	*Echinocardium cordatum*					1																													1				1		1										
	Echinocardium spat																																																		
Holothuroidea	*Heterothyone ocnoides*	2	5	8		5	2					1								1		3	3	2	1	6		1	1	1		1		1	1	1	2	1		1			1	1	1	5					1
	Paracaudina chilensis																					1																													
	Taeniogyrus dendyi															1					1															1		1													
Ophiuroidea																	1					1								1	1	1	1	1	2	1	1			1	1		1			1	1				1
Mollusca																																																			
Bivalvia	*Arthritica bifurca*		2	3		1																3	2				1	1	1		9	1	1	2	5				2		1			1	1	1	1				2
	Bivalvia Unid. (juv)														1							2																													
	Bassina yatei																													1																					
	Crassula aequilatera									1			1	1		1		1				1		1									4													1					
	Divalucina cumingi																																																		
	Dosinia anus					1	3				1					1								1				1		1						1	1			1	1		1					1		3	
	Dosinia lambata																																																		
	Dosinia sp. (Juvenile)		1																													1	1						1		1			2	2	2					
	Ennucula strangei	1																																																	
	Gari lineolata		1								1																												1												1
	Hunkydora novozelandica	1		1				1	1											1				1			1			1					1																
	Macomona liliana																								1																										
	Myadora striata																																																		
	Myllita vivens		1		2	3			3	3	1	5	4		2	5			6	1							6	1	2	4	9		7	4	4	3		1	4		2	1	1	1				1	1		
	Mysella sp.	1													1							2	1													2		1		1										1	
	Nucula nitidula			1			1		5	4	3	4	3	2	1		1	1	2	3	1	1					1			1		3	1		3	1		1	1	2	2	1	6	3	6	6	3	1	2	4	2
	Perna canaliculus (spat)					1																																													
	Serratina charlottae																																											1			1				
	Hiatula sp.							1		2	3	1							1								1						1	1	1											1					
	Bartschicoma edgari																																													1					
	Varinucula gallinacea								1																																										
Gastropoda	*Amalda australis*																						1																												
	Austrofusus glans																																													1			1		
	Gastropoda Unid. Juv.						1															1				1	1			1					2																
	Philine angasi															1																																			
	Philine sp																1																																		
	Rissoidae	1		1				2		2	1		1	1							1								2					1	2		1	2	2	3	3		1		1	1					
	Turbonilla sp.																																							1											
Nemertea		1		1				1				1					1							1	1					1													1	2	1						
Phoronida	*Phoronus* sp.				3													4	4	2	4	7	3	1		1										2			1		2					1	1				
Platyhelminthes																																																1			
No taxa		17	14	20	8	13	14	13	14	17	20	18	14	16	16	20	15	16	19	11	15	22	17	14	12	13	16	11	12	22	11	20	17	23	23	22	12	13	16	16	16	13	18	19	20	22	19	16	13	12	15
No Individuals		31	37	38	14	26	23	32	35	41	41	45	32	39	30	56	24	23	51	34	27	82	102	60	38	55	34	13	20	32	36	40	40	44	54	44	17	28	32	27	41	51	45	56	76	55	28	25	27	27	40
Shannon Weiner Diversity		2.67	2.38	2.63	1.97	2.38	2.50	2.36	2.45	2.53	2.84	2.60	2.33	2.51	2.53	2.48	2.48	2.63	2.66	1.77	2.50	2.11	1.30	1.35	1.52	1.46	2.55	2.35	2.30	2.91	2.09	2.73	2.59	2.92	2.94	2.85	2.34	2.36	2.62	2.62	2.30	1.60	2.40	2.42	1.97	2.59	2.76	2.55	2.20	2.24	2.22
Shannon Weiner Evenness		0.94	0.90	0.88	0.95	0.93	0.95	0.92	0.93	0.89	0.95	0.90	0.88	0.91	0.91	0.83	0.91	0.95	0.90	0.74	0.92	0.68	0.46	0.51	0.61	0.57	0.92	0.98	0.93	0.94	0.87	0.91	0.91	0.93	0.94	0.92	0.94	0.92	0.94	0.95	0.83	0.62	0.83	0.82	0.66	0.84	0.94	0.92	0.86	0.90	0.82

Table 33 Abundance of species in benthic infauna core samples, March 2018 (Number per core).

Taxa		W-100					W-200					W-500					E-100					E-200					E-500					WR-1					WR-2				
		A	B	C	D	E	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E
Annelida																																									
Polychaeta																																									
Ampharetidae																		1										1			1			1		1		1			
Capitellidae	Capitellidae																								1																
	Heteromastus filiformis		2	1	4	1	4	3	1	2	2	2		4		4		2	3	2	1	3	2	5		24	16	11	6	7	11	3	5	5	3	12		1	2	2	1
Cirratulidae		2	2		3		1		1		2	1		1	1	2	1	6	2	6	3	2	3	2		2	2			1	1										2
Flabelligeridae									1												1			1				1	1												
Glyceridae	*Glycera* sp.																				1								1				1								
Goniadidae			2			1						1		1			1	2	2	3	1	1	2			3	3		2	2		1	1	3	2	3	1	1		1	2
Hesionidae										1							1		1																	1			1		
Lumbrineridae	Lumbrineridae																		1							1		1		1											
	Marphysa disjuncta																																								
Magelonidae	*Magelona dakini*		1				1	2	1			1	1			2	2	2	2	1	1	1		1	2	1	1		2	2	1							1	1	1	
Maldanidae																			1			1	1																		
Nephtyidae	*Aglaophamus* sp.														1						1	1												1							
	Nephtyidae	1	1	3	3	4	3	8	3			1	4	8		6	1	5	1	3	3	1	3	1		3	5	3	7		4			1				2	5	2	1
Onuphidae	*Onuphis aucklandensis*																												1		1										
Opheliidae	*Armandia maculata*				1	1												1																							
Orbiniidae	*Leitoscoloplos kerguelensis*																																								
	Orbiniidae																																								
	Leodamas cylindrifer													1		1				1												3	1	1		1					
Oweniidae	*Owenia petersenae*				1													4	1	1		3					1								1	1		1	2	1	3
Paraonidae	*Aricidea* sp.					1	4		1					1		1			3			1	1	2		4															
Pectinariidae	*Lagis australis*																															1		1		2					
Pilargidae																																									
Scalibregmatidae	*Travisia* sp.																																								
Sigalionidae					1	1		1	1									1														3		1		2			1	1	1
Spionidae	*Aonides oxycephala*																																								
	Boccardia sp.																																								
	Paraprionospio sp.																																2								
	Prionospio australiensis					2	3	3	1	1	1	2		1	2	7	1	3	2	3		2	1			2		1	4	1							3	4	3	6	1
	Prionospio sp.		1	1		2						1			1		1		1		3	2				2				2		2	1	3	1	4		3	5	9	3
	Prionospio yuriel																																		1	2			1		
	Spiophanes kroyeri																																								
	Spiophanes modestus																	1			1												1						1	1	
Syllidae																																									
Terebellidae																								1																	
Arthropoda																																									
Hexanauplia	Copepoda																		2		1								1			1			1						
Malacostraca																																									
Amphipoda	*Ampelisca* sp.																																								
	Amphipoda Unid.															2			1																	1			1		
	Caprellidae																																								
	Haustoridae	2	3				2		1							1		1	1		1			1			1		1			1		1	1	1			3		1
	Lysianassidae																																								
	Phoxocephalidae	3	1	1	2	4	1	4	1			3	1		1	1		1	3	1	2						1		3		1	4	1						2	1	1
Cumacea																											1								1	1		1			
Decapoda	Decapoda (larvae Unid.)																																								
	Ogyrides sp																												1												1
Isopoda	Anthuroidea		1																																						
	Uromunna schauinslandi																																								
	Natatolana sp.															1																		1							
Leptostraca	*Nebalia* sp.																			1																					
Tanaidacea								1			1							1	2			4							2												
Ostracoda	*Diasterope grisea*	1		1	2					2		1						1	2		1				2			1		2		8				2		1	1		
	Pleoschisma agilis								1																																
	Leuroleberis zealandica		1									2					1	3								1					1							2	1		
	Scleroconcha sp.																																								

Taxa		W-100					W-200					W-500					E-100					E-200					E-500					WR-1					WR-2				
		A	B	C	D	E	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E
Cnidaria																																									
Anthozoa	Anemone Unid																																								
	Anthopleura hermaphroditica																																								
	Edwardsia sp.																												1												
Hydrozoa	Hydroida (athecate)																																								
	Hydromedusae																																								1
Echinodermata																																									
Asteroidea	*Fellaster zelandiae*					1				1		1	1															1													
Echinoidea	*Echinocardium cordatum*			1			1																																		
	Echinocardium spat					1																																			
Holothuroidea	*Heterothyone ocnoides*	3						1		6	1	4		1				4	2	1	2	1	3	2				1			1	2	1		2	1					
	Paracaudina chilensis																										2				1			1	1	1				1	
	Taeniogyrus dendyi			1											1																1		1	1		2		1			1
Ophiuroidea					1	2					1				1	1	1	1	1	1	1				1		1	1	1	1											
Mollusca																																									
Bivalvia	*Arthritica bifurca*			1		1				1							1					1		1								7			1						
	Bivalvia Unid. (juv)																			1																					
	Bassina yatei																																								
	Crassula aequilatera															1																									
	Divalucina cumingi		1																																						
	Dosinia anus	1	1		1					1	2	1	1	1	1	1					1			2	1																
	Dosinia lambata																													1											
	Dosinia sp. (Juvenile)						1	2		2	1	1		1		1	4	4		10	4	2	2	2		4			3		4								1		1
	Ennucula strangei																																								
	Gari lineolata																				1																				
	Hunkydora novozelandica		2			2	2	2	2		1			1				1		1																					1
	Macomona liliana																																								
	Myadora striata										1																														
	Myllita vivens				3	6	4	1	1	4			2	2	2	5	2	2	7	7	5	4	5	2	1	3		2	2	3								1	6		2
	Mysella sp.																																						1		
	Nucula nitidula		1	3	3	2	4	6	2	1		4	1	2	4	4	1	2			1	2	3		1	1	1		1		1	2	1			3		5	7	4	5
	Perna canaliculus (spat)																																								
	Serratina charlottae			1	1	3		2	1									1				1	2									1	1		1	3	1			1	
	Hiatula sp.														1	1	1	1	1																						
	Bartschicoma edgari																																								
	Varinucula gallinacea																																								
Gastropoda	*Amalda australis*							1												1																					
	Austrofusus glans																				1									1											
	Gastropoda Unid. Juv.																																								
	Philine angasi																																								
	Philine sp																																								
	Rissoidae			1	1	1	1		1	1		2		1	1		1		1	3	5	2				2	1			1	1	1									1
	Turbonilla sp.																									1			1												
Nemertea														1				1														1	1		1					1	
Phoronida	*Phoronus* sp.																												1												
Platyhelminthes																																									
No taxa		7	14	11	14	18	14	14	16	12	10	16	7	15	12	18	15	25	23	18	23	19	12	13	7	15	13	11	20	13	14	16	13	13	13	19	3	14	19	14	18
No Individuals		13	20	15	27	36	32	37	20	23	13	28	11	27	17	42	20	52	43	47	42	35	28	23	9	54	36	24	42	25	30	41	18	21	17	44	5	25	45	32	29
Shannon Weiner Diversity		1.84	2.55	2.27	2.50	2.69	2.48	2.39	2.69	2.25	2.25	2.62	1.77	2.37	2.34	2.60	2.58	3.01	2.96	2.53	2.92	2.81	2.38	2.42	1.89	2.09	1.96	1.88	2.74	2.32	2.15	2.50	2.37	2.35	2.48	2.60	0.95	2.43	2.67	2.25	2.72
Shannon Weiner Evenness		0.95	0.97	0.95	0.95	0.93	0.94	0.91	0.97	0.90	0.98	0.95	0.91	0.88	0.94	0.90	0.95	0.94	0.94	0.88	0.93	0.96	0.96	0.95	0.97	0.77	0.76	0.79	0.91	0.90	0.82	0.90	0.92	0.92	0.97	0.88	0.86	0.92	0.91	0.85	0.94