

Army Bay Wastewater Treatment Plant

Environmental Monitoring of the Benthos in the Whangaparāoa Passage (Autumn 2025)

for: Watercare Services Ltd.




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Cover Illustration: Reef at the drop camera station C61, Army Bay, June 2025. Young *Ecklonia* seaweed with the sponge *Ecionemia alata*.

EXECUTIVE SUMMARY

A renewed discharge consent (DIS60331146) was granted in December 2019 that includes a receiving environment monitoring plan (REMP), detailing protocols for a long-term environmental monitoring programme in the Whangaparāoa Passage to detect adverse effects caused by the discharge from the wastewater treatment plant on habitat quality, marine life, and shellfish beds.

This report presents the sixth annual monitoring of the subtidal benthic ecology, and the sediment quality in the vicinity of the new outfall since its first use (April 2019). Data were collected in autumn and winter between 6th of May and the 24th of July 2025. Stations for sediment quality and benthic sampling were located at 100m, 250m and 1000m to the north, east and south of the discharge outfall, and 100m, 250m to the west (11 stations in total) to provide information of the spatial extent of any impact of the discharge on the benthic ecosystem.

Sediment quality

This sixth year of monitoring shows good sediment quality: all contaminants were well below guideline levels, so adverse effects on benthic life are not expected. Cadmium was generally undetectable. Mud content has shown an increasing trend at the Control sites (1000m distance from the outfall) since the first year of monitoring. Nitrogen and phosphorus were lower than last year; the spikes seen in 2024 were not repeated, and current values align with the pre-2023 record. There was no clear pattern with distance from the outfall, indicating no measurable enrichment from the discharge; the earlier nutrient peaks likely reflected storm-driven runoff and coastal erosion rather than outfall effects.

Overall, results are consistent with previous years, some mild, system-wide lifts occurred in 2021 and 2024 but still stayed within thresholds. Compared with the pre-outfall baseline, concentrations are modestly higher as expected in a receiving environment yet remain below levels linked to effects; far-field sites tracked with the rest, suggesting broadscale variability rather than distance-driven change. In sum, the system appears stable, the outfall is not causing measurable seabed enrichment, and occasional nutrient spikes are more plausibly tied to catchment inputs during major rain events.

Biogenic habitat

A combination of drop camera photographs and video footage were deployed at different distances and directions around the new outfall in order to map the biogenic features of the Whangaparāoa Passage.

Biogenic features detected by drop camera and video transects were the sediment texture, and the presence of horse mussels, sponges, and fan worms. Scallops are easily missed when buried in substrate and were not determined with the current methodology. Substrate with shell can be found west of a north-south line that passes through the outfall position, towards the Whangaparāoa shore. East of this line, in deeper waters (> 25m deep), the sediment has rarely any shell and is mostly devoid of any epibiota.

The most important biogenic habitat reported in the passage in previous studies was horse mussel beds around the outfall. Video transects of the south and south-west in 2025 revealed a degraded habitat for horse mussels, like in the previous year. The typical epibiota assemblage of horse mussels, colonial ascidians, finger sponges, and fan worms was covered by a layer of silt. The smothering of epibiota by

sediment was observed in the whole monitored area. This phenomenon is likely to occur at a larger scale in the Hauraki Gulf.

Benthic biota

Overall, a total of 119 taxa were identified from the benthic samples with a total of 3,569 sorted invertebrates. Polychaetes dominated (~52%) with notable taxa *Myriochele* sp., *Aglaophamus* sp., *Prionospio yuriei*, Cirratulidae; crustaceans included Tanaids (~11%). The invasive bivalve *Theora lubrica* occurred (~4%). Significant regional differences were identified. West had the highest richness and density (but patchy). South had the lowest richness/abundance yet the most even assemblages. East/North were intermediate and more consistent. Overall, distance effects were weaker than regional effects.

Multivariate analyses showed moderate separation by region and weak by distance. BIO-ENV correlations (testing link between contaminants and biota distributions) were low to moderate (max ~0.48). Best matches involved the combination of As, Zn, P, N (by region) and Cr, Zn, P or %mud (by distance). This indicates sediment chemistry explained only a small fraction of biological pattern.

There was a marked interannual variability in the polychaete species without a consistent direction. North–East was dominated early by tube-builders (*Myriochele* sp., Ampharetidae), shifting later toward small deposit feeders (e.g., *Cossura consimilis*, Paraonidae, Cirratulidae). South–West showed larger swings with pulses of *Polydora* sp. and strong peaks of *Heteromastus filiformis* in 2023. Across all six years, contaminants were below effects guidelines; with consistent methods/season/taxonomy, observed changes most likely reflect natural variability, not contaminant pressure.

In conclusion, because regional differences exceed distance-from-outfall effects, and sediment chemistry explains little variation, there is no clear, consistent footprint of the discharge on infaunal communities to date. Benthic composition is dynamic and may be a low-signal indicator at this site without long time series; continued, standardised monitoring is warranted to define natural variability and detect subtle shifts.

Intertidal macroalgae

To assess the potential effect of the outfall effluent onto the closest intertidal habitat (Outfall Bay), macroalgal communities were identified and mapped by photography drone survey and ground survey in March 2025.

The algae patches recorded during the intertidal survey (possible *Ulva* and *Lyngbya*) were very localised in rock pools and depressions, as previously observed during the 2021 and 2023 intertidal surveys. Opportunistic algae bloom rapidly when conditions of temperature, nutrients and light are optimal. The blooms disappear when the water temperature drops in autumn.

The consecutive series of mapped macroalgae (and green-blue algae) data could be used to show changes in the extent of natural and nuisance macroalgae beds around the outfall site over time. Nonetheless, due to the emplacement of the outfall in the Passage and the strong currents North-South, it is unlikely that the nutrients from the outfall would influence Outfall Bay.

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1 INTRODUCTION

1.1 Background

The Army Bay wastewater treatment plant (WWTP) is Watercare’s third largest WWTP and services Whangaparāoa Peninsula, Orewa, Hatfields Beach and Silverdale. To allow for the expansion of the WWTP needed to service the population growth in the area, a new discharge outfall was completed in April 2019 in the Whangaparāoa Passage next to the previous outfall, approximately 1 km out into the Passage (Figure 1). A discharge consent (DIS60331146) was granted in December 2019 that includes a receiving environment monitoring plan (REMP, Condition 34), detailing protocols for a long-term environmental monitoring programme in the Whangaparāoa Passage to detect any adverse effects caused by the discharge from the WWTP on habitat quality, marine life, and shellfish beds.



Figure 1. Map representing the route of the old (labelled existing) and new pipeline and outfall. From Watercare Services.

This report presents the sixth annual monitoring of the subtidal benthic ecology, and the sediment quality in the vicinity of the new outfall since its first use (April 2019). Data were collected in autumn and winter between the 6th of May and the 24th of July 2025.

The assessment of effects from a discharge point is typically based on comparison of potentially affected samples and samples representing an ecosystem out of reach of the contaminants (geographical variation with control) or before and after discharges started (temporal variation with control). The environment surrounding the outfall has been under the influence of treated wastewater from the WWTP since 1982. Therefore, the comparison of samples over time with the new outfall aims to detect the influence of the new flow regime of discharge on the environment rather than the influence of the discharge itself (this requires a temporal control that is not available).

1.2 Previous data collected in the area

The subtidal benthic communities within 2 km of the outfall were surveyed in 2018 (Kelly et al., 2018). The drop camera and video survey showed that the Whangaparāoa Passage supported a diverse range of species and habitats, including a variety of species that form sensitive biogenic habitats (macroalgae, sponges, scallops and horse mussels). Grain size, total organic carbon, nutrients and heavy metals were reported for samples taken near the outfall and for samples approximately 1.5 km away. This survey formed the principal background information used to design the REMP.

The first monitoring of the new outfall was carried out in May-June 2020 (Bioresearches 2020). The sediment collected in the Whangaparāoa passage showed contaminant concentrations well below the guideline concentrations and a significant variation with distance from the outfall and regions in the Whangaparāoa Passage. Benthic habitat and infauna assessments showed only a sporadic horse mussel distribution. The variation in the infauna distribution at the sampling sites was higher between regions in the Passage than with distance from outfall, and it was hypothesized that the main factors of influence were physical parameters (i.e. substrate, current, depth), and not chemical (from effluent effect).

The second monitoring of the new outfall was carried out in April-June 2021 (Bioresearches 2021). The conclusions from this study were similar to the first monitoring with sediment contaminant concentration well below the guideline concentrations and no clear pattern among the different contaminants loads. Benthic habitat assessment showed a larger horse mussel bed than in the previous year, likely due to a better video quality, thus a higher detection on the video image. Infauna distribution was likely influenced by the sediment grain size composition and other physical parameters.

The third monitoring and the fourth monitoring of the new outfall were carried out in April-May 2022 (Bioresearches 2022) and in May-July 2023 (Bioresearches 2023) respectively. Similar to previous results, contaminant concentrations were below the guidelines and there was no indication of an effluent effect on the environment. Horse mussel beds persisted around the outfall and to the west and south. Benthic biota showed strong differences between regions with East and North on one hand, and West and South on the other. This was likely influenced by physical parameters such as depth, grain size and current.

The fifth monitoring was carried out in April-July 2024 (Bioresearches 2025). Sediment contaminant concentrations remained low, with elevated nitrogen and phosphorus compared to earlier years (except 2023), but no evidence of effluent-related enrichment. Metal levels varied by site, being lower in the West and North and higher at 100 m from the outfall. Video transects showed degraded horse mussel habitat in the South and Southwest, while epibiota assemblages were covered by silt and/or a red alga. Benthic biota again differed strongly between East-North and West-South, with a weaker gradient between 100 m and 250 m, reflecting underlying physical factors such as depth, grain size, and current.

Results of the past five monitoring surveys were compared with the 2025 monitoring in each section. As in previous years, Bioresearches aimed to restrict sampling to the autumn months in line with the REMP. However, unfavourable weather and poor underwater visibility during autumn 2025 prevented fieldwork at-sea. As a result, photographic and video surveys were undertaken later than the required sampling period, anticipating better weather conditions at the start of winter.

1.3 Overview of adverse effects of wastewater discharge.

As per section 3.2 (Subtidal benthic ecology) of the REMP, wastewater discharges have the potential to affect benthic communities through:

- the organic enrichment of sediments that increases diversity and abundance of benthic infauna (low levels of enrichment) or reduces diversity and abundance (high levels of enrichment).
- increasing benthic algal productivity by adding nutrients.
- altering the benthic light regime with increasing water turbidity due to particulate substances in wastewater.
- the effects of toxic contaminants (REMP 2019).

To assess the extent of potential effects highlighted above, monitoring of benthic communities affected by wastewater outfalls involves the measurement of, as stated in the REMP:

- **epibiota**—abundance and diversity of animals and plants that live on top of the seabed, particularly biogenic habitat forming species such as macroalgae, horse mussels and sponges.
- **benthic infauna**—abundance and diversity of animals that live in the sediment.
- **sediment quality parameters**—grain size, total phosphorus, total nitrogen, total organic carbon, total organic matter; and,
- **toxic contaminants**—e.g. heavy metals.

In the intertidal zone, macroalgae's growth and species composition can change with the influence of high levels of nutrients. This can come from discharged wastewater that is not properly treated. Blooms of nuisance macroalgae (*Ulva and Gracilaria*) and cyanobacteria (*Lyngbya*) may appear on the shore. Monitoring of algae and cyanobacteria on the closest shore from the outfall is also assessed in this report, as described in section 3.3 (Intertidal macroalgae) of the REMP.

1.4 Structure of the report

The REMP details the requirements of the environmental monitoring of the benthos which are defined in points II and IV of the objectives such as:

“ II. Subtidal benthic ecology, including the mapping of biogenic habitats, abundance, and diversity of the benthic community and the spatial and temporal extent of macroalgae (including any potential nuisance macroalgal blooms detected);

IV. Sediment quality (texture, total organic carbon, total nitrogen, and total phosphorus annually, and metals biennially); ”

Chapter 2 describes the subtidal **sediment quality** (grain size, organic content and pollutant concentrations) from grab samples. Chapter 3 describes the subtidal **biogenic habitat** recorded from photographs and videos of the benthos. Chapter 4 describes the composition and abundance of the subtidal **benthic infauna** from grab samples. The subtidal monitoring occurred between the 6th of May and the 24th of July 2025. Chapter 5 of the report describes the assessment of **algae distribution on the intertidal zone** of Whangaparāoa Bay in March 2025.

2 SUBTIDAL SEDIMENT QUALITY MONITORING

2.1 Surveys prior to the new outfall

Kelly and colleagues (2018) collected sediment in November 2017 with a 2 L Van Veen grab sampler at four sites.

- within 100 m of the old outfall,
- 1.5 km north of the old outfall,
- 1.5 km east of the old outfall,
- 1.5 km south of the old outfall.

At each of the four sites, 10 samples were taken and analysed for grain size, total organic matter and total organic carbon. Five samples were analysed for total nitrogen, total phosphorus, and heavy metals (recoverable cadmium, chromium, copper, lead, mercury, nickel, and zinc) on the total sediment fraction.

They found that sediment grain size around the outfall had a high percentage of mud with approximately 50% by mass, similar to the east and south remote sites. The northern remote site had higher mud content with 80% average. The total organic carbon in the east of the outfall was more than double that at the outfall. Most of the concentrations of nutrients and heavy metals were higher at the north site than at the other sites, probably due to a higher mud percentage in the sediment. The outfall did not show higher concentrations of contaminants than the east and the south. Heavy metals were well below the threshold effects levels (TEL) (MacDonald et al. 1996). From these results, Kelly et al. (2018) concluded that the discharge from the old outfall had no influence on the contaminants found at the sampled sites.

2.2 Methodology

2.2.1 Sampling protocol

The REMP specified four radii from the outfall with sampling stations for surficial sediment samples located at 100m, 250m and 1000m to the north, east, south and west of the discharge outfall, except 1000m in the west as rocky substrate (11 stations in total), to provide information on the spatial extent of any impact of the discharge on the sediment quality (Figure 1, coordinates in Appendix A). At each station the REMP specified that three replicate grabs were taken with a Petite Ponar grab sampler. The Petite Ponar grab samples a surface area of 0.023 m² (152 x 152 mm) with a bite depth of 70mm. An additional 4 kg of weights were added to the sides of the Petite Ponar to aid bite depth along with an additional 2 kg of weights to the top of the Petite Ponar to aid grab triggering due to strong currents in the Passage. ORP (Oxidation-reduction potential in mV) was not measured as the previous surveys showed the inadequacy of the methodology (see Appendix 3 in Bioresearches 2022).

The petite Ponar was lowered down to the seafloor from a boat. When the Ponar was retrieved on the boat, the sediment sample was transferred into a clean bucket. The content was mixed with an untreated clean wooden stick. A sub-sample of 100 g was retained for the analysis of grain particle size. A second sub-sample of 500 g was retained for the analysis of % dry weight, total organic carbon, total nitrogen, total phosphorus, total recoverable metals (arsenic, cadmium, chromium, copper, lead, nickel and zinc) on the whole sediment fraction, and bioavailable metals on the mud fraction.

The sediment samples were placed in a clean polyethylene ‘zip lock’ bag, then placed in a chilly bin. Sediment chemistry samples were frozen prior to transportation to the laboratory, while grain size samples were chilled. Metal testing was conducted by Watercare Services Laboratories, and grain size testing was conducted by Hill Laboratories using accredited testing methods.

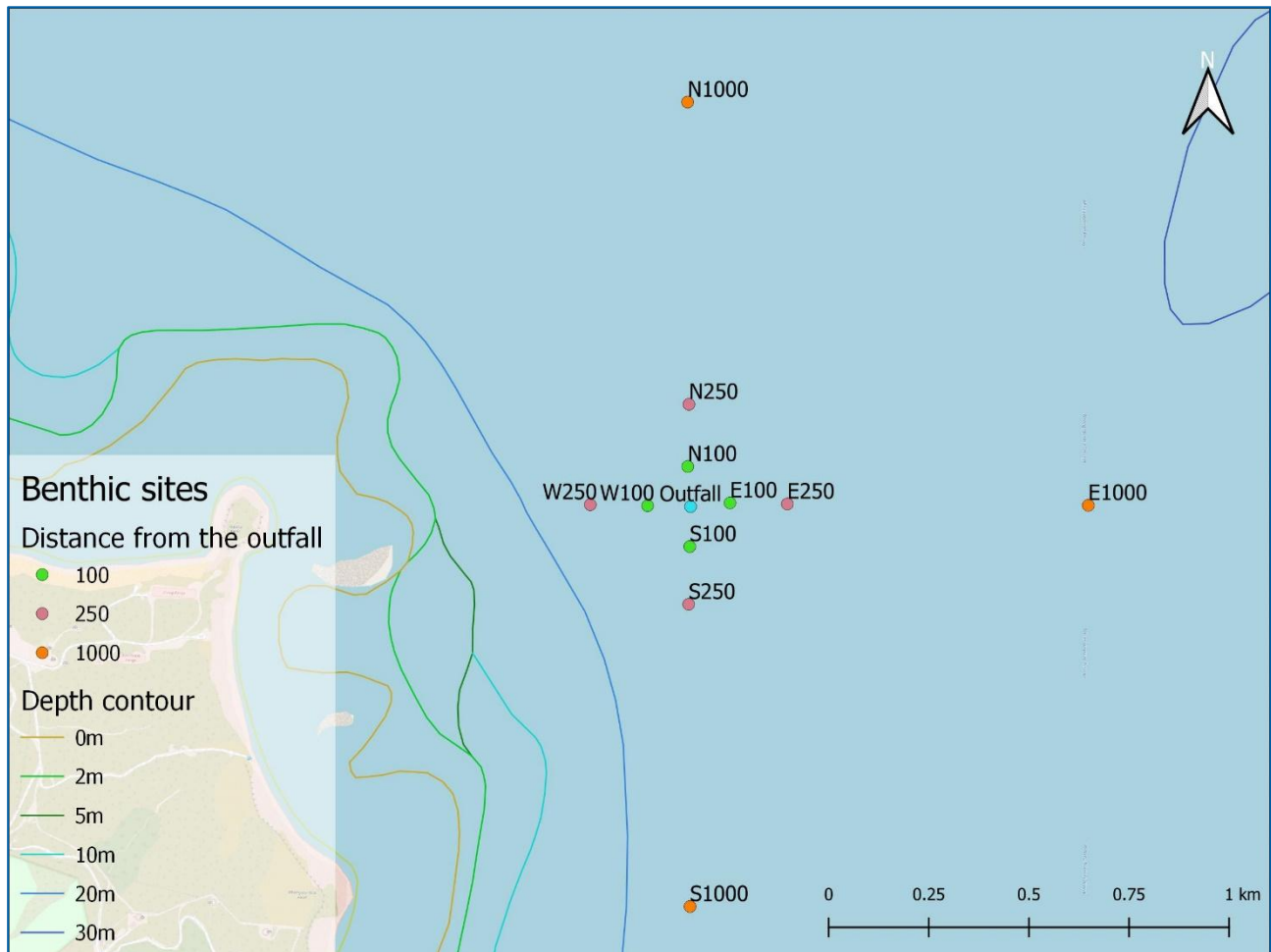


Figure 2. Benthic biota sampling locations in the Whangaparāoa Passage compared to the outfall (coordinates in Appendix A).

2.2.2 Analytical procedures

The analytical methods are described in the REMP as follows:

- Grain size method: determined by wet sieving, 5 fractions (> 2, 2 – 0.5, 0.5 – 0.25, 0.25 – 0.063 and < 0.063 mm).
- total organic carbon (TOC)—determined from the 500 µm sieved fraction on a dry weight basis using non-dispersive infrared detection (modified USEPA NCEA-C-1282)
- total nitrogen—determined in accordance with the Soil Sampling and Methods of Analysis by Colorimetry/Discrete Analyser (Carter & Gregorich, 2008)
- total phosphorus—determined using method US EPA 200.2 digestion ICP-MS

- total recoverable metals/metalloids (arsenic, cadmium, chromium, copper, lead, nickel and zinc) using HNO₃/HCl extraction from the <500 µm fraction followed by ICP-MS (modified US EPA Method 200.2 or 200.8).

The bioavailable metals/metalloids (arsenic, cadmium, chromium, copper, lead, nickel and zinc) were added to the array of tests from the second survey to dissociate the influence of the sediment texture from the potential discharge effect on the contaminant loads. The tests used weak acid extraction (2M HCl for 24h) from the <63 µm fraction followed by ICP-MS (ARC 2004).

2.2.3 Sediment Quality Guidelines

There are three main sediment quality guidelines (SQGs) providing threshold values for a range of contaminants:

- the US NOAA guidelines presented in Long *et al.* (1995),
- the Canadian guidelines presented in CCME (2007), and
- the Australian and New Zealand guidelines presented in ANZECC (2000), revised in 2013 (Simpson *et al.* 2013) which were adopted in 2018 (ANZG 2018). These guidelines combine threshold values from the first two references, with additional data.

The National Oceanic and Atmospheric Administration (NOAA) developed the Effects Range Low **ERL**, and the Effects Range Median **ERM** concentrations based on toxicity tests (Long *et al.* 1995). ERL indicates the concentrations below which adverse effects are unlikely to occur, and ERM indicates the concentrations above which adverse effects are likely to occur (Table 1).


The Canadian guidelines use another set of threshold values, namely the Threshold Effect Level (**TEL**) below which adverse effects rarely occur, and the Probable Effect Level (**PEL**) above which adverse effects frequently occur (Table 1). Concentrations ranging between PEL and TEL indicate values where there are possible adverse effects (MacDonald *et al.* 1996, CCME 2007).

The Auckland Council developed the Environmental Response Criteria based on the NOAA and the Canadian thresholds with a three-color system: green (healthy), amber and red (polluted) (ARC 2004). Contaminant levels in the “green” are below the TEL. Contaminant levels in the “amber” are between the TEL and the ERL. Contaminant levels in the “Red” are above the ERL (Table 1). The heavy metal results from the 2024 survey were compared with the Auckland Council guidelines (ARC 2004).

2.2.4 Normalisation procedures

To assess the anthropogenic effects from a potential pollution source such as a WWTP outfall, understanding the importance of natural variability is fundamental to differentiate contaminants originating from natural processes and contaminants originating from anthropogenic processes.

Table 1. Sediment quality guidelines (SQG).

Types of SQG	Acronym	Description	Auckland Council categories	Level of contamination
Threshold effect level	TEL	No adverse effects below	Green	Low 
Effect range-low	ERL	Rare adverse effects below	Amber	
Probable effect level	PEL	Possible adverse effects below	Red	
Effect range-median	ERM	Expected adverse effects below, Frequent adverse effects above		

Contaminant loads in sediment are highly dependent on the grain size distribution and the geological origin of the substrate (Clark et al. 2008). Normalisation of contaminant concentrations allows to compensate for some natural processes and gives a better visibility of anthropogenic effects. Metals tend to concentrate in the mud fraction of sediments; therefore, a common normalisation is based on the consideration of the mud fraction (granulometry approach; Ho et al. 2012). Two procedures can be followed: The first relies on the separation of the mud fraction (particle size $<63\mu\text{m}$) prior to chemical analysis (weak-acid extractable fraction). The second normalises total recoverable metal concentrations by the percentage of the mud fraction. This last procedure assumes that there is a linear relationship between the total metal contents and the mud percentage (Ho et al. 2012).

The mud fraction showed good relationships with metals (Pearson correlation coefficients $R > 0.7$) except for copper ($R = 0.59$) (Appendix C; Figure 26), therefore this method was retained for the assessment of effects along with the total metal loads (also called the recoverable concentrations) and the weak-acid extractable loads (also called bioavailable concentrations).

2.2.5 Statistical procedures

Statistical differences on percentages are commonly tested with a chi-square test of homogeneity. This is however not recommended with a small sample size; therefore, no statistical test was run on the grain size percentages. Instead, notable percentage differences between sites were visually assessed from the figures.

An exploratory analysis was performed with a Principal Component Analysis (PCA) on PRIMER-E (version 8 beta 2.0 36, Quest Research Ltd). It allowed to visualise in a multivariable space (all contaminants at once) the similarity between sites based on the concentration of metals/metalloids (environmental variables). Metal values were normalised beforehand to have them on a common scale (the mean is subtracted from each metal value, and the result is divided by the standard deviation). One-way analysis of similarities ANOSIM (maximum permutations = 999) were performed on the Euclidean distance similarity matrix to test the null hypothesis “no difference between groups”. The ANOSIM test is the multivariate analogue of the univariate ANOVA test.

Concentrations of metals and nutrients were compared among regions (west, north, east, and south of the outfall) and distances (100, 250, and 1000 m from the outfall) using ANOVA tests, followed by pairwise Tukey tests. Data normality (Shapiro–Wilk test) and homogeneity of variance (Levene’s test) were assessed for total metals, bioavailable fractions, and mud-adjusted datasets, but assumptions were met only for some metals and nutrients. To ensure consistency across contaminants, the non-parametric Kruskal–Wallis test was applied to all datasets, with subsequent pairwise comparison Dunn’s tests. All univariate tests were performed in R (version R 4.4.1, R Core Team 2024) with an alpha value of 0.05.

2.3 Results and Interpretation

Sediment samples were collected during two boat trips: the 6th of May and the 24th of July 2025. Samples collected at site W250 contained a large quantity of shell with little sediment content. There was not enough material for testing both total metals and the bioavailable fraction, therefore, priority was given to the total metal analyses.

2.3.1 Grain size

Three replicates of substrates for each of the 11 sites around the outfall were collected for grain size. The grain size percentages are summarised in Table 2 and compared visually between regions and distances from the outfall in Figure 3. Raw results are available in Appendix B and show seven fractions as this is the standard procedure by Hill laboratories. Fractions [$<2\text{mm}$, $\geq 1\text{mm}$] and [$<1\text{mm}$, $\geq 500\mu\text{m}$] were pulled together as well as fractions [$<250\mu\text{m}$, $\geq 125\mu\text{m}$] and [$<125\mu\text{m}$, $\geq 63\mu\text{m}$] to match the five fractions in the REMP.

Table 2. Grain size summary percentages by mass in 2025 (means \pm 95%CI).

Grain size		North			East			South			West	
(mm)	Class	N1000	N250	N100	E1000	E250	E100	S1000	S250	S100	W250	W100
> 2.000	Gravel and Granules	1 \pm 2	8 \pm 23	23 \pm 14	12 \pm 8	1 \pm 2	21 \pm 25	27 \pm 33	36 \pm 27	21 \pm 2	50 \pm 13	31 \pm 13
2.000 - 0.500	Coarse Sand	1 \pm 0	3 \pm 6	6 \pm 2	6 \pm 7	1 \pm 1	6 \pm 6	6 \pm 4	9 \pm 2	8 \pm 1	15 \pm 6	11 \pm 4
0.500 - 0.250	Medium Sand	0.3 \pm 0	1 \pm 1	1 \pm 1	3 \pm 5	1 \pm 0.2	1 \pm 1	1 \pm 0	2 \pm 0	2 \pm 1	3 \pm 1	2 \pm 1
0.250 - 0.063	Fine Sand	15 \pm 4	10 \pm 3	8 \pm 1	13 \pm 6	7 \pm 3	11 \pm 11	9 \pm 4	8 \pm 4	9 \pm 0.4	7 \pm 2	10 \pm 4
< 0.063	Silt and Clay	83 \pm 6	78 \pm 31	62 \pm 16	66 \pm 10	90 \pm 3	61 \pm 22	57 \pm 34	45 \pm 26	60 \pm 2	26 \pm 15	47 \pm 23
Sample size		3	3	3	3	3	3	3	3	3	3	3

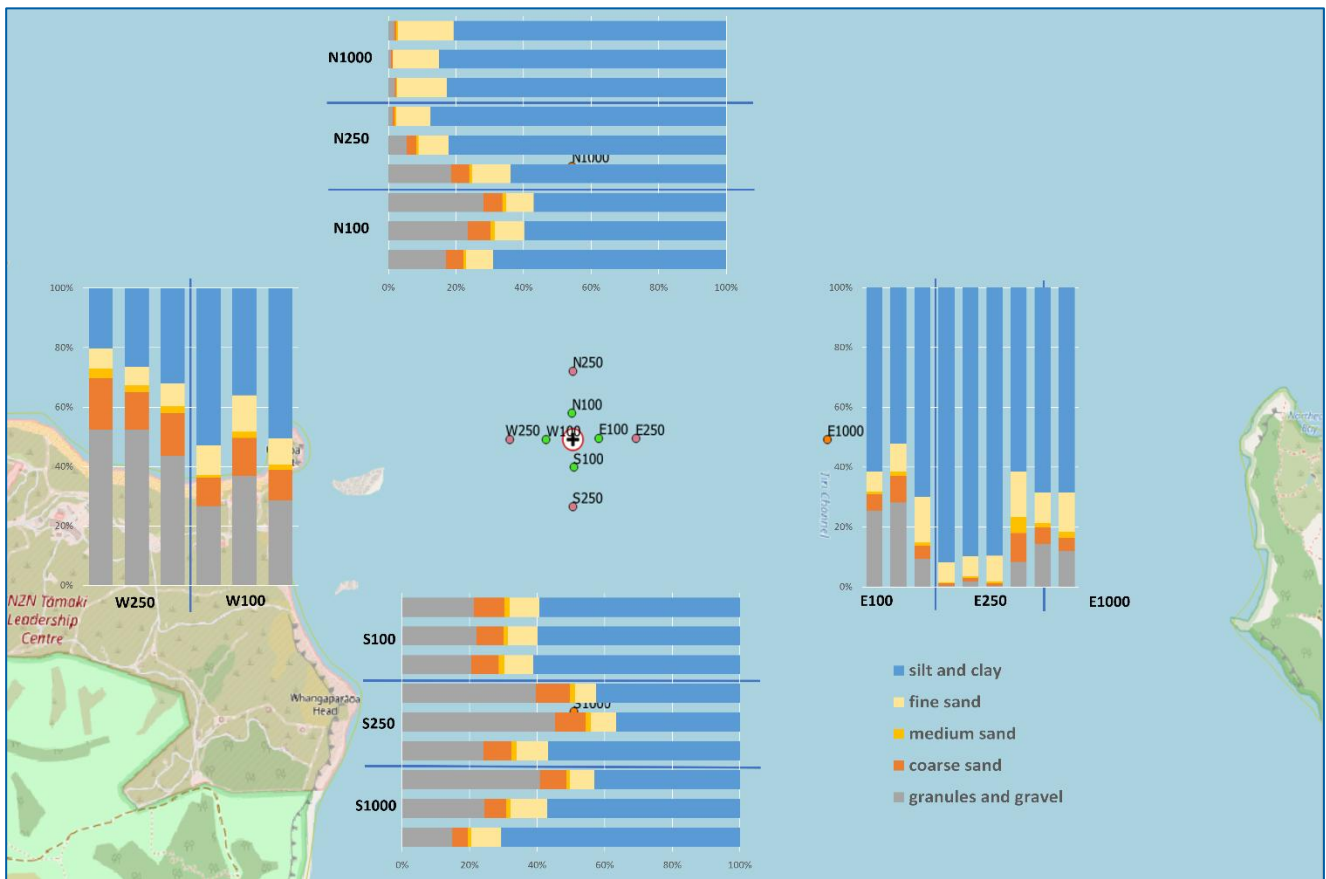


Figure 3. Comparison of grain size percentages between sampled sites - 2025.

Silt and clay (mud) and granules and gravel were the dominant substrate components across the study area. At 100 m from the outfall, the grain size profile was generally consistent, with 60–62% silt and clay and 21–23% granules and gravel, except in the west where gravel dominated the substrate (Figure 3, Appendix B). Elevated proportions of granules and gravel were also recorded at S1000 (21–36%). In contrast, mud comprised more than 80% of the substrate in the North (N250 and N1000) and at E250.

Mud percentages were compared between years to observe any potential grain size change over the years (Figure 4). In the north, N250 mud percentage remained high and stable, while N1000 was moderately high with a steady increase. N100 revealed lower mud percentage and more variable, with a marked reduction in 2024. In the south, S100 showed the greatest fluctuations, while S250 and S1000 remained moderate with limited variability. In the west, W250 mud percentage stayed consistently low, and W100 was similarly low without a clear trend. In the east, E250 remained the highest and most stable, E100 was lower and variable with a decrease in 2024, and E1000 was mid-high and steady.

Over the last five monitoring surveys, the percentage of mud content has increased at the 1000m sites (South, East and North), and at E250.

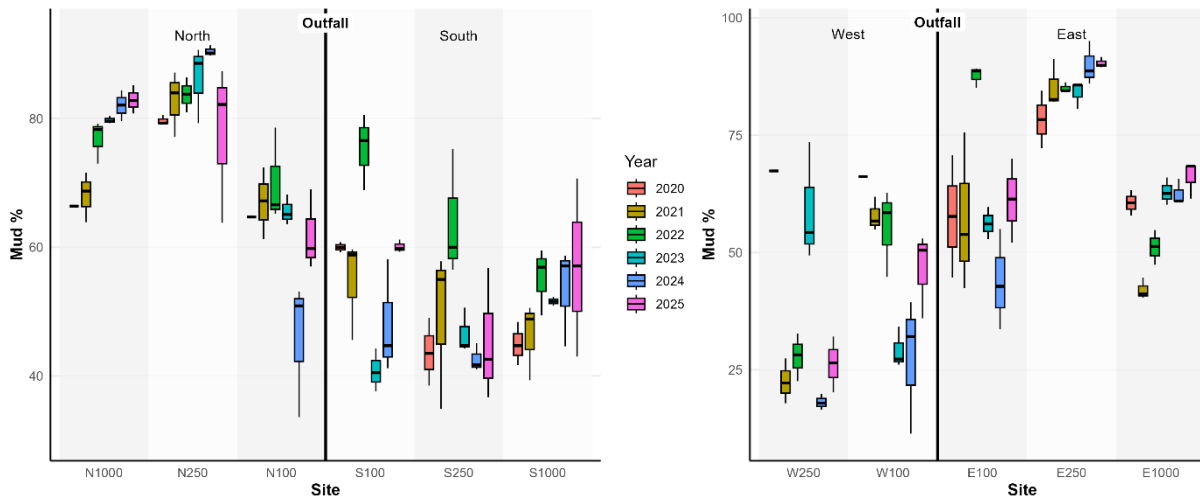


Figure 4. Mud content (% dry weight) box plots per site compared between monitoring surveys.

2.3.2 Total organic carbon and nutrients in sediments

The Total Organic Carbon (TOC) and nutrients levels were analysed from three sample replicates for each of the 11 sites, and are summarised in Table 3 with raw data presented in Appendix C (Table 14, Table 16).

The TOC % showed low values across the sites with less than 2% dry weight (Table 3).

Table 3. Means (\pm 95%CI) of Total Organic Carbon (% d. w.) and Nutrients (mg/kg d. w.) 2025

Region	Samples	% dry weight	TOC (% d. w.)	Nitrogen (mg/kg d. w.)	Phosphorus (mg/kg d. w.)
East	E100	49.8 \pm 10.4	1.44 \pm 0.0	1433 \pm 236	467 \pm 148
	E250	40.0 \pm 1.5	1.60 \pm 0.0	1767 \pm 364	597 \pm 17.3
	E1000	39.1 \pm 7.1	1.45 \pm 0.2	2133 \pm 346	707 \pm 64.3
North	N100	33.1 \pm 1.8	1.46 \pm 0.0	2267 \pm 131	643 \pm 69.0
	N250	35.6 \pm 4.3	1.43 \pm 0.1	2267 \pm 173	577 \pm 193
	N1000	34.0 \pm 5.8	1.25 \pm 0.0	2500 \pm 299	733 \pm 157
South	S100	53.9 \pm 2.1	1.50 \pm 0.0	1263 \pm 462	407 \pm 23.6
	S250	51.9 \pm 5.8	1.50 \pm 0.1	1280 \pm 431	353 \pm 157
	S1000	53.0 \pm 6.3	1.44 \pm 0.0	1273 \pm 545	430 \pm 129
West	W100	44.6 \pm 9.3	1.40 \pm 0.1	1733 \pm 261	457 \pm 141
	W250	60.2 \pm 8.8	1.14 \pm 0.2	983 \pm 213	347 \pm 42.8
	Min	33.1	1.1	983	347
	Max	60.2	1.6	2500	733

Total Nitrogen concentrations in the sediment ranged from 720 to 2800 mg/kg (Appendix C; Table 14), with significant variation of nitrogen between regions (Appendix D; Table 23). The northern sites recorded the highest nitrogen concentrations overall, forming a uniformly nitrogen-rich area, with N1000 showing the highest values (median \sim 2,450–2,600). Southern sites had lower concentrations, with a clear increase with distance from the outfall. On the western sites, the pattern was reversed: W100 was enriched relative to W250, which in 2025 had the lowest concentrations (median \sim 900–1,000). Eastern sites consistently

showed high nitrogen concentrations that increased with distance, with E1000 among the highest overall (median ~2,150–2,300).

When comparing among years, across most sites, nitrogen concentrations in 2025 were lower than in 2024, except at the northern sites (Appendix C; Figure 27). In 2024, localised high-nitrogen events occurred at E250, E1000, S250, and S1000; in 2025 these sites showed lower and steadier concentrations. 2024 peaks >3,000 mg/kg at E250, S250, and S1000 and remain the highest records in the area (Bioresearches 2020, 2021, 2022, 2023, 2025).

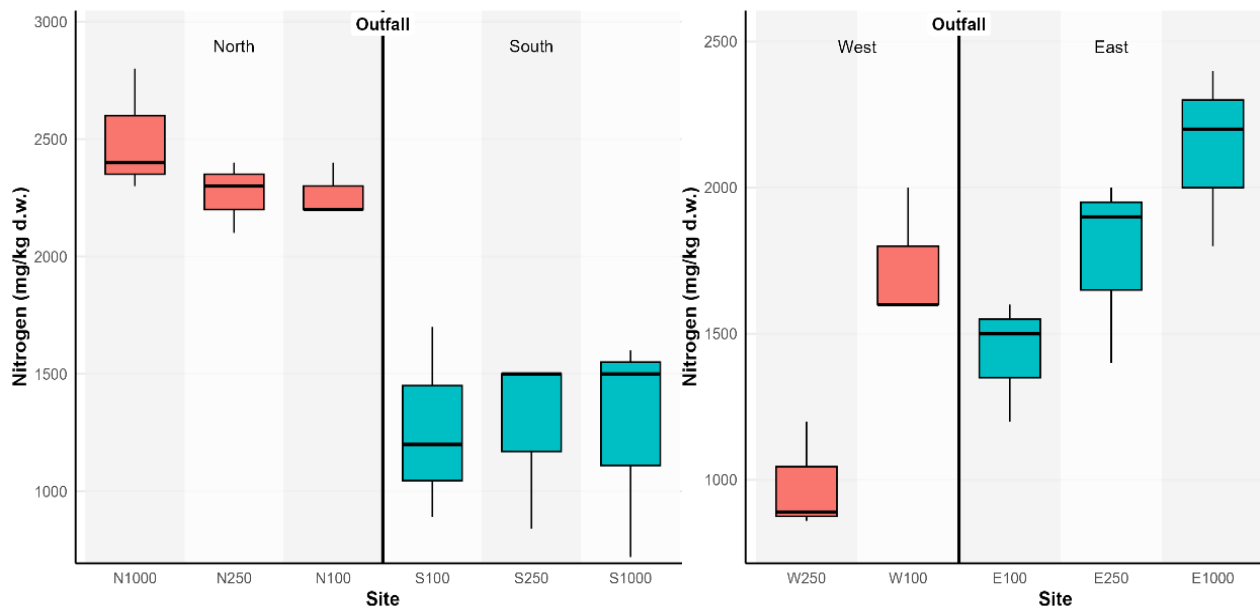


Figure 5. Nitrogen (mg/kg dry weight) boxplots for each site.

Total Phosphorus concentrations in the sediment ranged from 200 to 850 mg/kg (Appendix C; Table 14), with significant variation between regions (Appendix D, Table 23). Phosphorus concentrations were highest in the North and East (especially at 1000 m) and lowest in the South and West. Near-outfall sites (100 m) had lower, more variable values than the 1000 m sites (Figure 6), consistent with a mixing zone at the discharge and preferential deposition to the East and North.

The phosphorus values in 2025 were significantly lower than the 2024 loads in most of the sites except in the north where similar values were measured between the last two monitoring surveys (Figure 28 in Appendix C). In the North, levels remained high, with N1000 increasing from about 700 mg/kg in 2024 to nearly 800 mg/kg in 2025. By contrast, the southern sites dropped markedly in 2025, with medians falling to ~400–500 mg/kg compared to ~600 mg/kg the previous year. The western sites also declined, most notably W250, which dropped from ~600 to ~350 mg/kg. The eastern sites remained the strongest phosphorus sinks, with consistently high concentrations at E250 and E1000, though slightly reduced in 2025 compared to 2024. Overall, 2025 reinforced the long-term pattern with North and East accumulating the most phosphorus, while South and West remain relatively depleted, with the South showing the sharpest declines in the last five years (Bioresearches 2020, 2021, 2022, 2023, 2025).

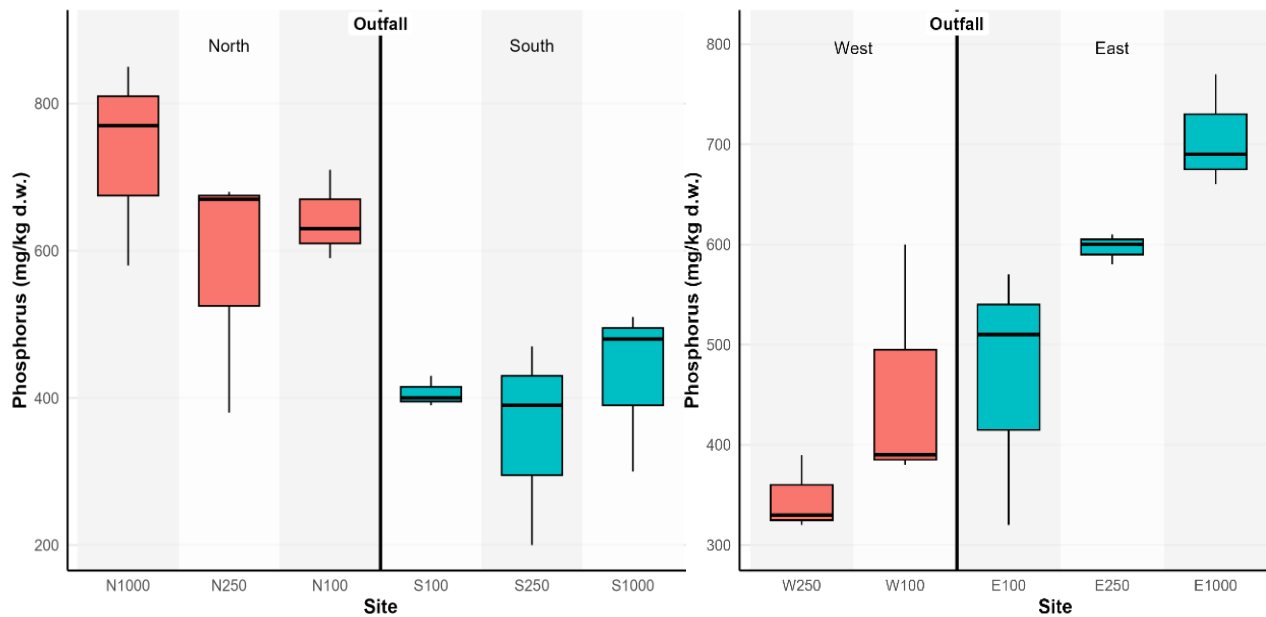


Figure 6. Phosphorus (mg/kg dry weight) boxplots for each site.

2.3.3 Heavy metals and metalloid in sediments

The total recoverable heavy metals and arsenic were analysed from three sample replicates for each of the 11 sites and are summarised in Table 4 (raw data are presented in Appendix C). Concentrations were compared with the previous surveys and Kelly *et al.* (2018) in Table 5. Since the 2021 survey, the weak acid extractable heavy metals from the mud fraction (bioavailable metal concentrations) were measured from the same site locations to complement the interpretation of the differences between sites with distinct grain size composition. In addition, the normalised metal concentrations called “mud-adjusted concentrations” were examined, following the condition that mud concentrations were, for the most part, correlated with the contaminants (Appendix C, Figure 26).

2.3.3.1 2025 metal/metalloid pattern in sediment

All heavy metals and Arsenic concentrations measured in the sediments in the Whangaparāoa Passage were well below the standard thresholds for adverse effects (Table 4).

The PCAs integrated the variation of five heavy metals and arsenic (Figure 7). Cadmium was excluded from the analyses as levels were under the detection limit of the laboratory method (Table 4). When metal total recoverable concentrations were assessed with PCA (Figure 7 top), the West region showed markedly higher values compared to North, South, and East (ANOSIM $R = 0.274$ $p = 0.0002$; Appendix D; Table 17). The analysis clearly distinguished a subset of West 250 m samples from the others. These samples were strongly aligned with the contaminant vectors, indicating overall enrichment, particularly for arsenic, lead, chromium, and nickel (Figure 7 top). Most North, South, and East sites grouped on the positive side of PC1, reflecting lower concentrations. Variation between distance groups was present but less pronounced than the regional effect.

When the extractable fraction was considered (Figure 7 middle), regional patterns were less distinct, with samples from North, South, East, and West largely overlapping (ANOSIM $R = 0.051$, $p = 0.1673$; Appendix D, Table 19). The PCA did not clearly separate sites by region, although some 100 m samples plotted closer to the contaminant vectors, suggesting a weak association with higher extractable metals (arsenic, chromium, nickel, lead, copper). Most sites at 250 m and 1000 m clustered toward the positive side of PC1, reflecting lower metal influence. Variation between regions was therefore minor, and differences with distance groups were even less pronounced.

In the mud fraction (Figure 7 bottom), regional and distance patterns were more clearly separated than in the REC and EXT fractions. The PCA explained 95% of variation on PC1, with South and West sites (notably at 100 m and 250 m) plotting on the positive side of the axis and strongly distinguished from North and East (ANOSIM $R = 0.334$, $p = 0.0001$; Appendix D, Table 21). These South and West samples were aligned with the contaminant vectors, indicating greater enrichment in arsenic, lead, and associated metals. In contrast, most North and East sites grouped negatively on PC1, reflecting comparatively lower concentrations. Variation between distance groups was also significant but less pronounced (ANOSIM $R = 0.090$, $p = 0.0494$), with 100 m and 250 m sites more closely associated with contaminant vectors than the 1000 m group.

Elevated contaminant loads were observed at sites closest to the outfall (100 m) and, to a lesser extent, at 250 m in the South and West, particularly when recoverable concentrations were normalised by mud content. PCA highlighted stronger enrichment in South and West compared to North and East, with the clearest separation observed in the mud fraction and a subset of enriched West 250 m samples in the recoverable fraction. In contrast, regional patterns were weak in the extractable fraction, although some 100 m sites showed a minor association with contaminant vectors. Together, these results indicate that fine sediments act as a key sink for contaminants, with localized accumulation strongest near the outfall. Despite these spatial differences, overall concentrations remained below guideline thresholds, suggesting limited risk to biota.

Across all three fractions, the PCA showed weaker separation in the total recoverable and extractable fraction phases, where most regions overlapped, but a clear spatial pattern in the MUD fraction. The mud results revealed stronger regional structuring, with South and West sites enriched in metals, while North and East remained comparatively lower.

Table 4. Means (\pm 95%CI) of heavy metals in sediments (mg/kg dry weight) 2025

Region	Samples	Arsenic	Cadmium	Chromium	Copper	Lead	Nickel	Zinc	
East	E100	Total	5.9 \pm 0.7	<0.11	33 \pm 2.4	9.1 \pm 0.7	13 \pm 1.3	12 \pm 0.7	66 \pm 5.3
		Bio	2.7 \pm 0.2	<0.064	21 \pm 1.1	6.3 \pm 0.2	16 \pm 0.7	7.1 \pm 0.2	63 \pm 1.7
	E250	Total	7.3 \pm 0.2	<0.11	38 \pm 1.1	10 \pm 0.0	16 \pm 0.0	13 \pm 0.0	75 \pm 2.4
		Bio	2.6 \pm 0.2	<0.063	19 \pm 1.3	5.6 \pm 0.2	14 \pm 0.0	6.3 \pm 0.5	56 \pm 1.7
	E1000	Total	7.2 \pm 1.3	<0.070	31 \pm 7.7	6.9 \pm 2.0	13 \pm 3.6	10 \pm 2.7	58 \pm 15.4
		Bio	2.2 \pm 0.3	<0.055	18 \pm 0.7	4.6 \pm 0.7	13 \pm 0.7	5.5 \pm 0.2	52 \pm 2.0
North	N100	Total	6.0 \pm 0.9	<0.068	30 \pm 3.0	8.5 \pm 1.0	14 \pm 2.0	11 \pm 1.1	62 \pm 7.5
		Bio	2.1 \pm 0.4	<0.054	19 \pm 2.0	5.9 \pm 0.8	14 \pm 1.1	6.1 \pm 0.8	57 \pm 6.2
	N250	Total	6.2 \pm 0.6	<0.068	30 \pm 2.6	8.7 \pm 0.7	14 \pm 0.7	11 \pm 0.7	65 \pm 5.3
		Bio	2.2 \pm 0.3	<0.056	19 \pm 1.3	5.7 \pm 0.5	15 \pm 0.7	6.0 \pm 0.6	57 \pm 4.1
	N1000	Total	8.0 \pm 0.5	<0.062	34 \pm 2.6	9.2 \pm 0.8	17 \pm 1.3	13 \pm 1.1	72 \pm 6.2
		Bio	2.2 \pm 0.6	<0.048	18 \pm 2.4	5.0 \pm 0.6	13 \pm 1.7	5.7 \pm 0.9	52 \pm 5.8
South	S100	Total	6.2 \pm 0.4	<0.10	34 \pm 1.1	9.5 \pm 0.4	14 \pm 0.0	12 \pm 0.0	75 \pm 16.7
		Bio	2.5 \pm 0.2	<0.056	21 \pm 1.7	6.5 \pm 0.6	15 \pm 1.7	6.9 \pm 0.6	62 \pm 6.9
	S250	Total	6.0 \pm 0.5	<0.1	34 \pm 0.0	9.3 \pm 0.1	14 \pm 0.7	12 \pm 0.0	67 \pm 1.1
		Bio	2.1 \pm 0.1	<0.050	19 \pm 1.3	6.0 \pm 0.3	15 \pm 0.7	6.1 \pm 0.5	59 \pm 4.0
	S1000	Total	6.5 \pm 0.3	<0.098	34 \pm 1.7	9.2 \pm 0.5	13 \pm 1.3	12 \pm 1.1	67 \pm 3.5
		Bio	2.3 \pm 0.3	<0.050	19 \pm 1.3	6.0 \pm 0.4	15 \pm 1.1	6.2 \pm 0.4	60 \pm 3.6
West	W100	Total	5.7 \pm 0.9	<0.0674	26 \pm 3.5	7.8 \pm 1.1	13 \pm 1.7	9.9 \pm 1.4	56 \pm 8.6
		Bio	2.2 \pm 0.3	<0.049	19 \pm 1.3	6.0 \pm 0.5	15 \pm 0.7	6.1 \pm 0.6	57 \pm 4.0
	W250	Total	4.2 \pm 1.0	<0.061	17 \pm 4.9	5.3 \pm 1.4	8.6 \pm 2.3	6.7 \pm 1.7	37 \pm 9.8
		Bio	-	-	-	-	-	-	-
Standard thresholds	ER-L	8.2	1.5	80	65	50	21	200	
	ER-M	70	10	370	270	220	52	410	
	ARC green	<7.2	<0.7	<52	<19	<30	-	<124	
	ARC Amber	-	0.7<x<1.2	52<x<80	19<x<34	30<x<50	-	124<x<150	
	ARC Red	-	>1.2	>80	>34	>50	-	>150	
	ANZECC Low	20	1.5	80	65	50	21	200	
ANZECC High	70	10	370	270	220	52	410		

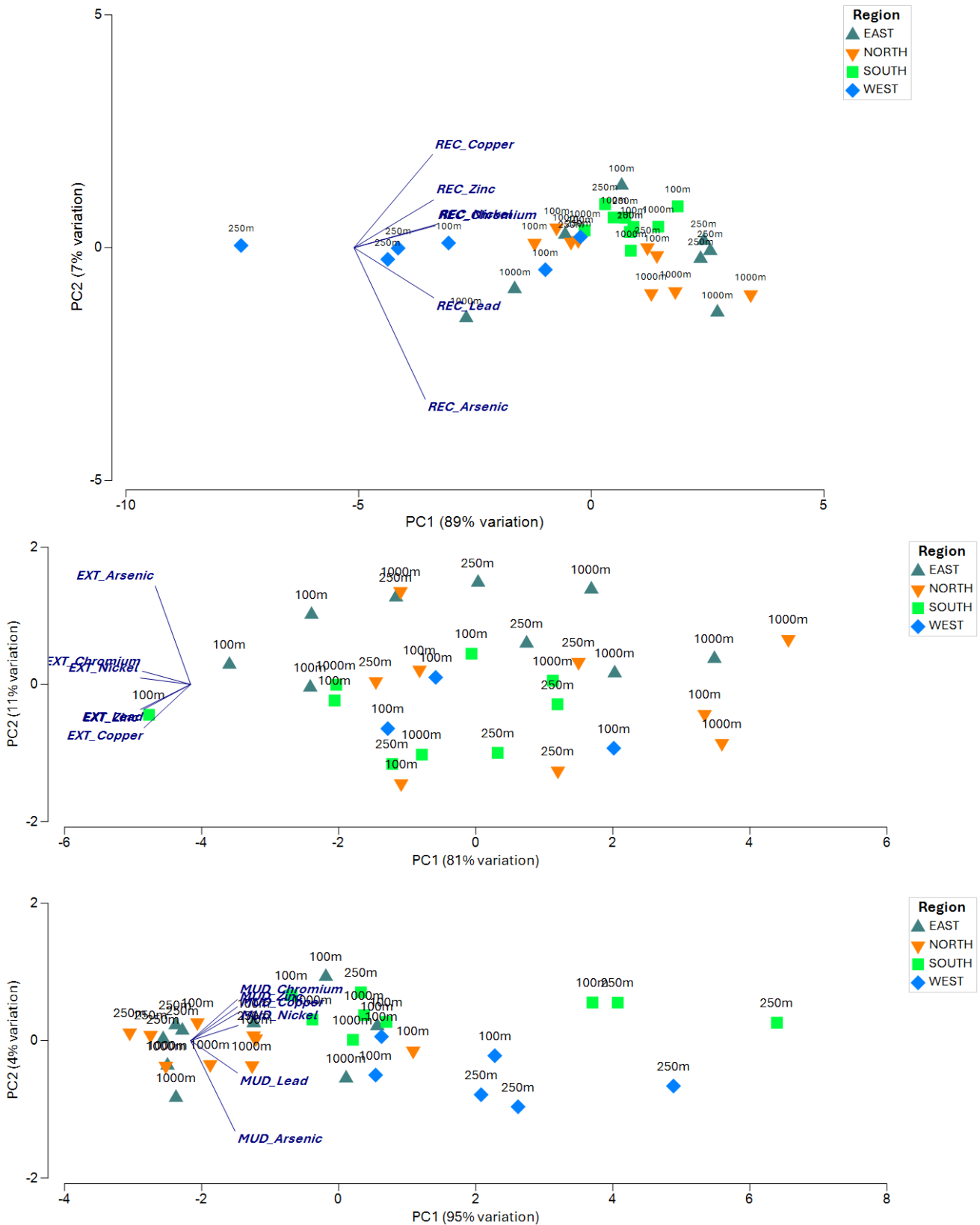


Figure 7. Principal Component Analyses based on metal concentrations. REC for total recoverable (top), EXT for weak acid extractable (middle) and Mud-adjusted metals (bottom).

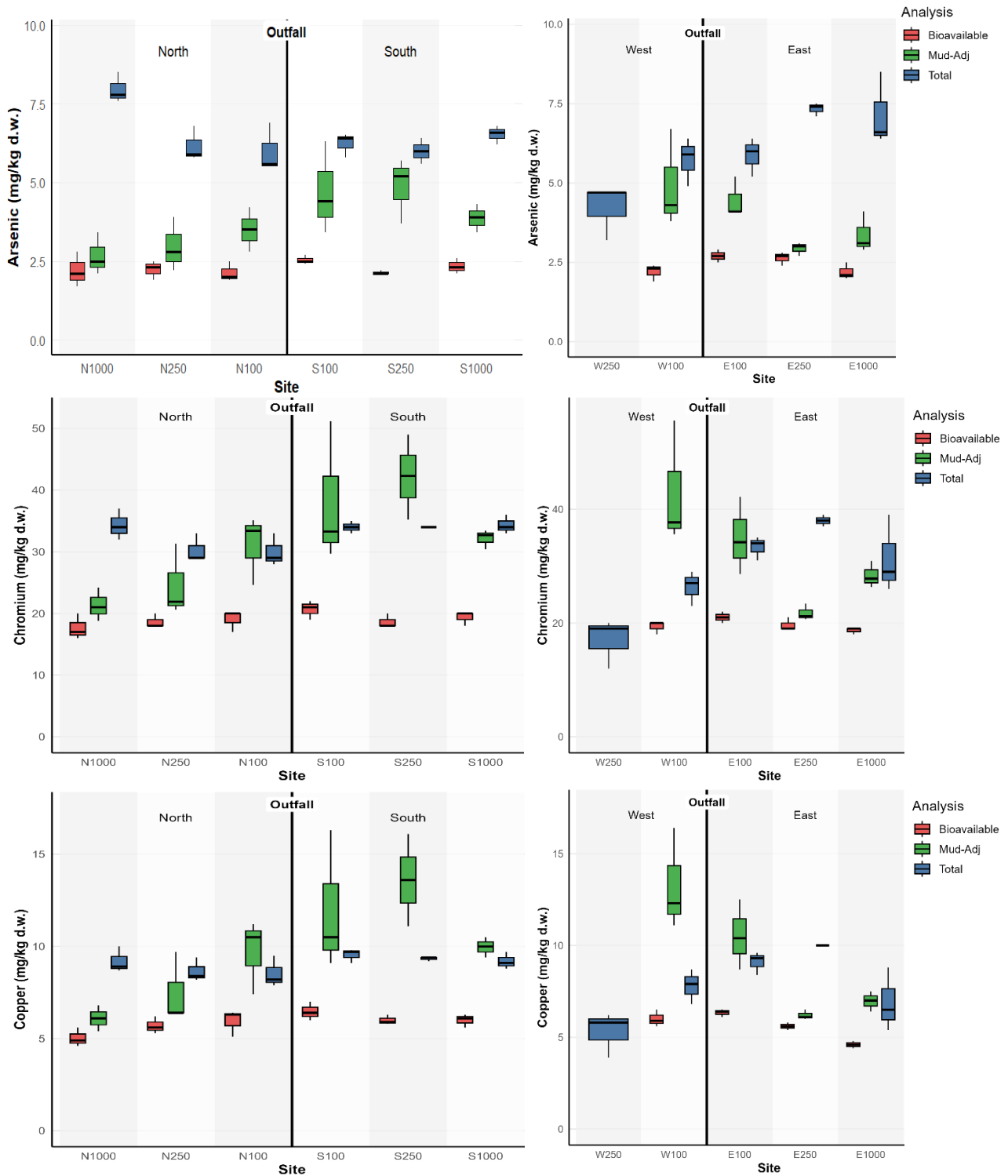


Figure 8. Arsenic, chromium, and copper concentrations (boxplot mg/kg dry weight) per site in 2025. Red = bioavailable fraction, Green = Mud-adjusted fraction, Blue = total recoverable fraction.

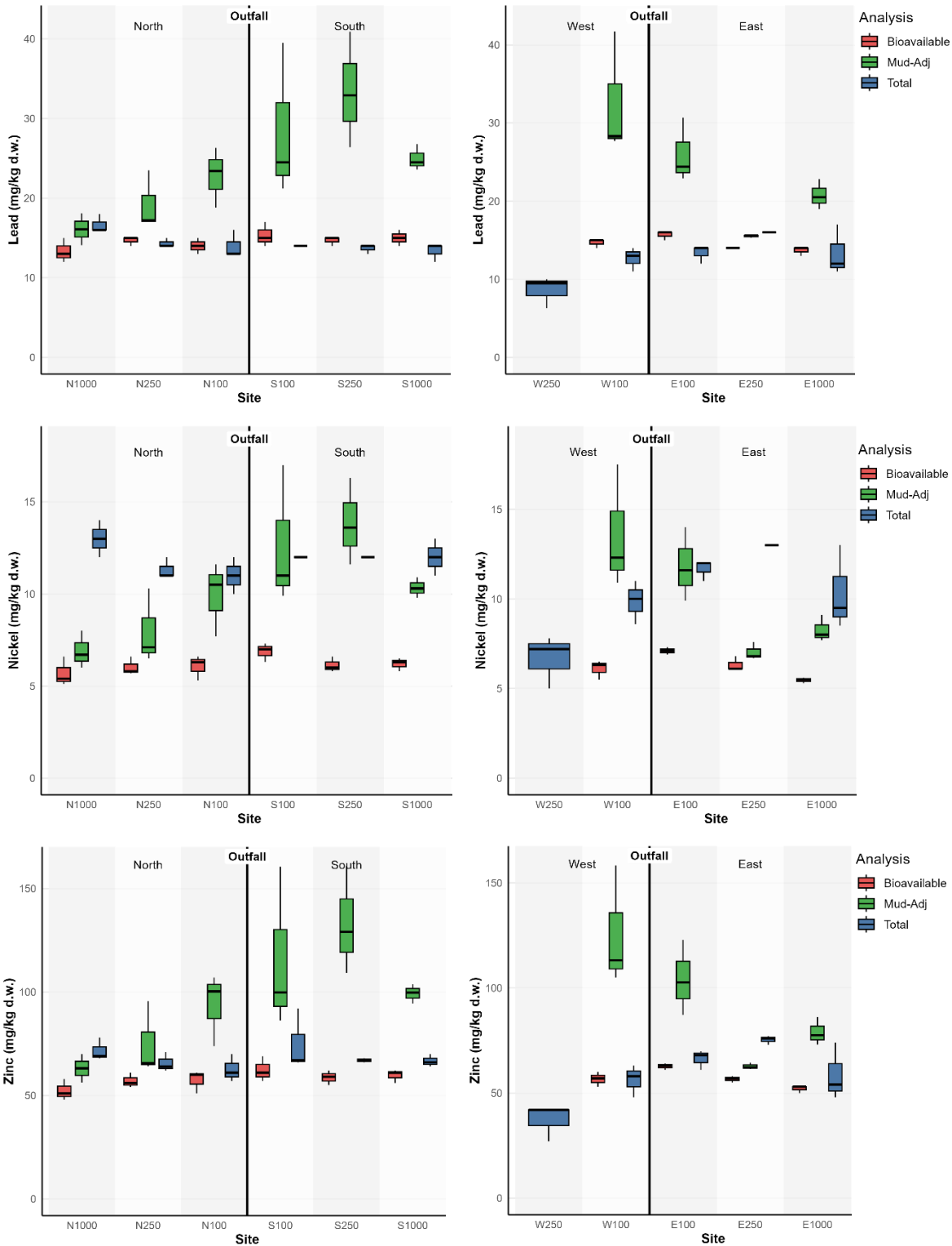


Figure 9. Lead, nickel, and zinc concentrations (boxplot mg/kg dry weight) per site in 2025. Red = bio-available fraction, Green = Mud-adjusted fraction Blue = total recoverable fraction.

2.3.3.2 Comparison of metal concentrations between monitoring surveys

The 2025 survey matched the same range of concentrations to that of the previous monitoring surveys since the installation of the new outfall (Table 5) but are higher than the levels of contaminants found in the preliminary study by Kelly and colleagues (2018).

Table 5. Comparison of levels of total heavy metals in sediments (mean mg/kg dry weight with range) between surveys in the Whangaparāoa Passage

	2025	2024	2023	2022	2021	2020	Kelly et al. (2018)
As	6 (4.9 – 6.9)	5.4 (4.6 – 6.3)	5.5 (4.8 – 6.5)	5.5 (3.7 – 8.3)	5.3 (3.7 – 7.9)	5.1 (4.5 – 5.7)	-
Cd	<0.10	<0.10	<0.10	<0.10	<0.17	<0.11	<0.09
Cr	31 (23 – 35)	29 (25 – 32)	28 (24 – 31)	30 (26 – 34)	31 (26 – 34)	29 (28 – 30)	18 (12 – 24)
Cu	9 (6.8 – 9.8)	9 (8 – 11)	8 (7 – 9)	9 (6 – 15)	9 (7 – 11)	9 (8 – 11)	5.3 (3.5 – 7.1)
Pb	14 (11 – 16)	14 (11 – 19)	14 (12 – 15)	15 (12 – 25)	15 (12 – 25)	14 (13 – 14)	9 (6 – 12.5)
Ni	11 (8.6 – 12)	11 (9.7 – 12)	11 (10 – 11)	12 (10 – 14)	12 (10 – 14)	11	7 (4 – 9)
Zn	65 (48 – 92)	63 (58 – 70)	61 (52 – 66)	64 (54 – 72)	64 (54 – 72)	62 (60 – 64)	41 (26 – 56)

Note: mean values calculated from 3 samples during the monitoring surveys, and from 5 samples in Kelly et al.'s study. Data from 2020 to 2025 were collected at 100 m from the outfall. Data from Kelly et al. (2018) was collected within 100m from the outfall.

A principal component analysis of yearly mean metals shows a broad **overlap among years** with most points forming a single cloud (Figure 10). Scores to the right on PC1 align with higher metal concentrations of Arsenic and Chromium (and some Copper), and these are dominated by East sites, whereas West sites lie mainly to the left (lower metal concentrations). Year-to-year, the colour clouds intermingle: some 2025 points extend far right (strong Arsenic/Chromium signal) while several 2022 points occur on the left, but no year forms a distinct cluster. Along PC2, Copper separates upward from Arsenic/Chromium downward, indicating changes in metal mix rather than discrete temporal shifts. The 1000 m sites (filled circles) are dispersed within the main cloud rather than forming a separate group, indicating no clear distance-driven separation at this scale. Overall, the pattern is stable through time, shows an east-west gradient in total metals, and indicates mix differences (Copper vs Arsenic/Chromium) along the vertical axis.

2.4 Summary of Subtidal Sediment Quality

This sixth year of monitoring shows good sediment quality: all contaminants were well below guideline levels, so adverse effects on benthic life are not expected. Cadmium was generally undetectable. Mud content has shown an increasing trend at the Control sites (1000m distance from the outfall) since the first year of monitoring. Nitrogen and phosphorus were lower than last year; the spikes seen in 2024 were not repeated, and current values align with the pre-2023 record. There was no clear pattern with distance from the outfall, indicating no measurable enrichment from the discharge; the earlier nutrient peaks likely reflected storm-driven runoff and coastal erosion rather than outfall effects.

Overall, results are consistent with previous years, some mild, system-wide lifts occurred in 2021 and 2024 but still stayed within thresholds. Compared with the pre-outfall baseline, concentrations are modestly higher as expected in a receiving environment yet remain below levels linked to effects; far-field sites tracked with the rest, suggesting broadscale variability rather than distance-driven change. In sum, the system appears stable, the outfall is not causing measurable seabed enrichment, and occasional nutrient spikes are more plausibly tied to catchment inputs during major rain events.

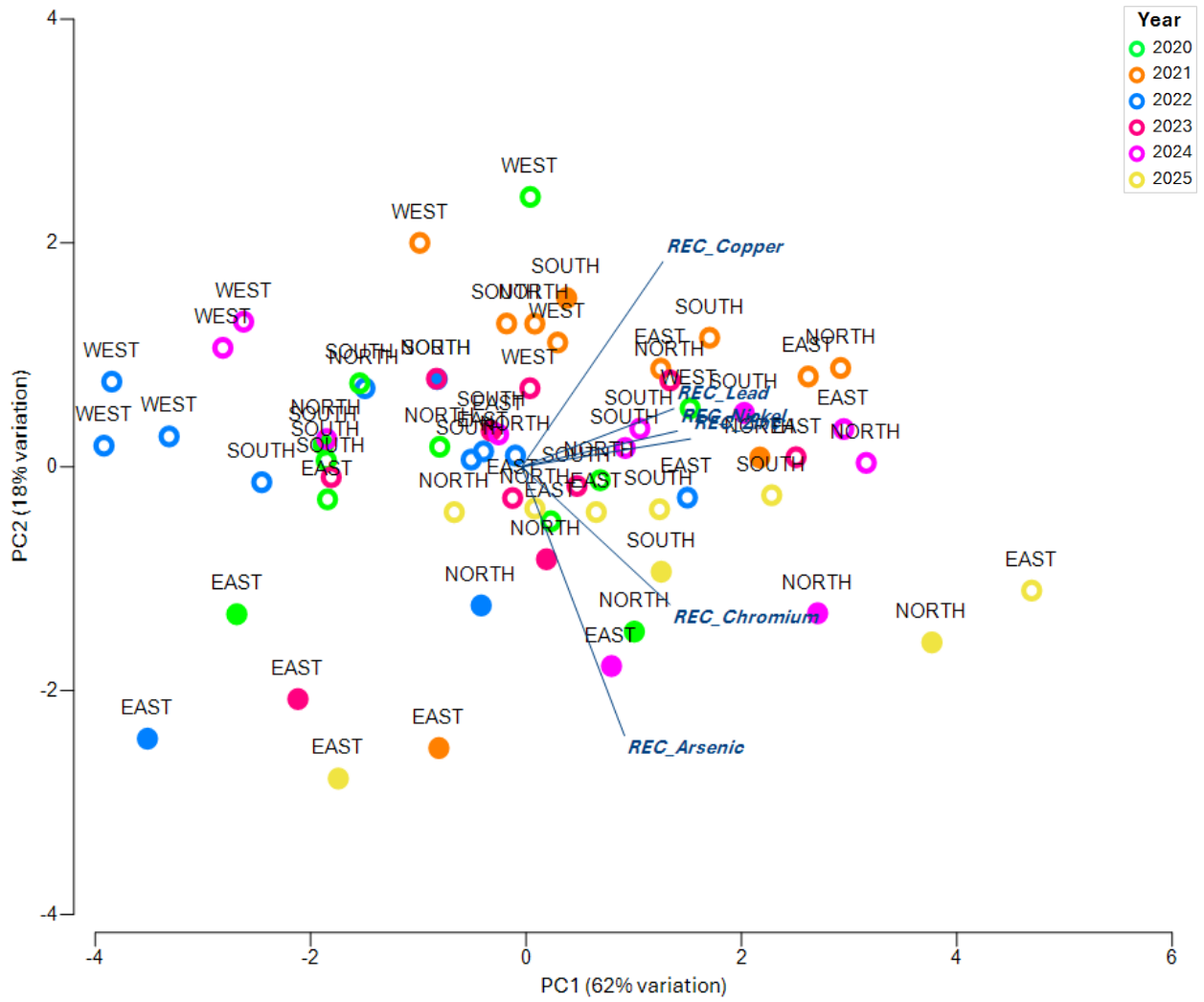


Figure 10. Principal Component Analysis on the average metal concentrations (recoverable total) per year. Filled circles represent the sites 1000 m away from the outfall.

3 SUBTIDAL BIOGENIC HABITAT MONITORING

3.1 Definition of biogenic habitat

Morrison et al. (2014) defined biogenic habitats as:

- a) those living species that form emergent three-dimensional structure on the seabed, and
- b) non-living structure generated by living organisms, such as infaunal tubes and burrows.

Examples of these habitats include shellfish beds (e.g. horse mussels, scallops, and oysters), kelp forests, sponge gardens, rhodolith beds (free-living red calcareous algae), stony coral thickets or reefs, and calcareous tubeworms (MacDiarmid et al. 2013; Morrison et al. 2009, 2014). They provide three dimensional habitats for a high diversity of benthic species, and in some cases, provide nursery for shellfish larvae, crabs and fish.

MacDiarmid et al. (2013) defined some of the biogenic habitats found in New Zealand North Island with details in the percentage of cover for each type, such as:

Beds of large bivalves: Living or dead clams covering 30% or more of a seabed surface of 100m² or contributing 30% or more by volume in a single grab sample.

Sponge gardens: sponges covering 25% or more of a seabed surface of 100m² or contributing 25% or more by volume in a single grab sample.

3.2 Survey prior to the new outfall

Sjardin (2015) had identified two broad subtidal habitats between Tiritiri Island and Whangaparāoa Peninsula: the sandstone reef which extends from the intertidal reef system, becoming patchier offshore; and the channel with a mixture of sand, shells and mud.

Kelly et al. (2018) characterised the biogenic habitat within a 2 km radius of the outfall with a combination of photographs and video transects recorded in November 2017 and January 2018 respectively. Photographs of the bottom sediment were taken at fifty locations within 1 km from the outfall with a drop camera system. Video transects were 2 km long, extending from the outfall to the north, south, east, northwest and southwest. They found that the central passage and north had little visible shell. Horse mussel beds were present north of the outfall to about 500m, south of the outfall to about 200m and southwest of the outfall to about 300m. South of the outfall, from 200m distance, horse mussels were recorded but in sparse distribution. Sponges were found all along the southern video transect and going southwest from the outfall. Scallops were marked as probably present along the southern transect.

3.3 Methodology

Subtidal biogenic habitats and large epibiota were monitored using a combination of underwater videos and photographs. Video tows allow the spatial extent of biogenic habitats to be mapped, while photographs allow the abundance of epifauna to be assessed in more details (REMP 2019). The REMP specifies this is to be repeated annually in April-May.

3.3.1 Photography methodology

The REMP stipulates that 75 randomly located georeferenced underwater photographs should be recorded, such that 25 samples are to be located within a radius of 250m from the outfall, 25 are to be located between 250m and 500m radius from the outfall and 25 are to be located between 500m and 750m radius of the outfall. In addition, the 25 samples from each distance zone were equally distributed in five 72° arcs to ensure even distribution of sample points in the study area. Seventy-five locations were generated randomly following these criteria.

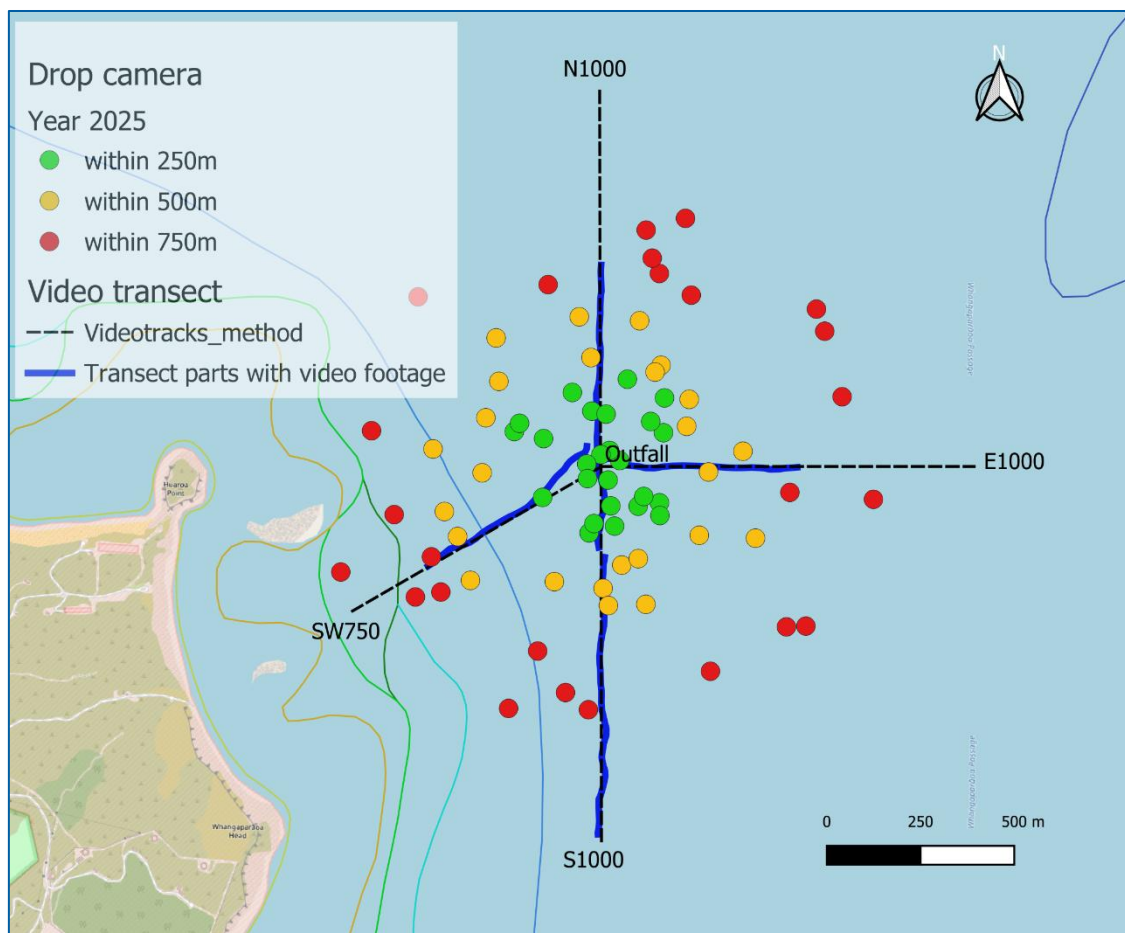


Figure 11. Drop camera sites coloured with the radius from the outfall (coordinates in Appendix 5). Coloured lines represent isobaths.

The camera system was mounted on a pyramid-shaped stainless-steel frame with a 1 m² surface square at the frame base. One camera was attached on top of the frame approximately one meter above the base to have a field of view large enough to cover the 1 m frame on the sea bottom. The second camera was

attached on the side of the frame approximately 30 cm above the base to photograph a side view (Figure 12 left photo). Side photographs allow to identify benthic features missed by the top view camera (Bioresearches 2022).

Each camera was a Go Pro Hero12 model set on a time lapse of 2 seconds at 12MP resolution. A light was attached next to the top camera to improve image quality of the seafloor. The camera frame system was lowered by hand from the side of the boat at each predetermined photograph location. It was left on the seafloor for 20 – 30 seconds before being pulled back into the boat.

Photographs were analysed for substrate type, and the presence of any identifiable epibiota (e.g. sponges, macroalgae, horse mussels *Atrina zelandica*, scallops *Pecten novaezelandiae*, ascidians (like *Synoicum kuranui*), macroalgae (like *Ecklonia radiata*, algal mat) were recorded. Maps were created in QGIS 3.34.9. For the substrate type, we follow Kelly et al. (2018) who defined 5 types: Sediments, Sediments-low shell content, Sediments-high shell content, Shell hash, and Reef.



Figure 12. Left: Drop camera frame with the dual camera system in position to drop to the seafloor. Right: sled used for the video transects in surveys prior to 2023.

3.3.2 Video methodology

Four video transects were originally conducted using an underwater camera attached to a bottom contact towed sled (Figure 12 right photo). However, to avoid the damage of horse mussels by the sled, a non-impact video method was used with a towed board (the “manta board”) manoeuvred by a diver (Figure 13). Despite ideal weather conditions during several fieldwork attempts, the visibility at the seabed was always poor, limiting the identification of biota on the deepest parts of the transects, i.e. the northern part of the North transect, and the eastern part of the East transect (Figure 11).

3.3.2.1 Manta board/diver methodology

The GoPro camera was mounted on a wooden board attached to a rope towed by a boat (Figure 13). Holes on the board acted as handles for the professional diver who was able to adjust the distance to the sea-floor by tilting the board up or down during towing. A one-hundred-metre rope was deployed behind the boat and towing was at a maximum speed of 3km/h. One diver can survey approximately 750m at that speed before reaching the maximum safe dive time of 20min without decompression stops (based on the maximum depth of 27m).

3.3.2.2 Video settings

The videos were recorded with a GoPro Hero12, with a 4k resolution and a frame rate of 30 f/s, with the addition of a light for the low visibility. The video camera and portable GPS data were synced with the free software Dashware 1.7.37 to georeference the video footage by linking the gpx file (track) recorded by the GPS.

3.3.2.3 Video analysis

The video footage was analysed for the presence and type of biota dwelling on the seabed (particularly sponge gardens, horse mussel beds, macroalgae forests, and nuisance macroalgae), and general habitat characteristics. The substrate type categories described for the photographs were also used for the videos. The coordinates of major habitat features/transitions observed in the video were recorded using Dashware and mapped using GIS. In addition to recording epibenthic features, the substrate was categorised every 10 m along transects, and georeferenced.

3.4 Results and Interpretation

3.4.1 Limitations of the methodology: poor visibility

The photographs of the seabed were taken on the 19th of June, and the video footage on the 24th of July. The REMP specifies that monitoring should be conducted in April-May. Since 2023, the total monthly rainfall in April and May at Army Bay has been higher than the average historical data (230mm vs. 76mm in April and 150mm vs. 129mm in May) which affected the visibility in the Whangaparāoa Passage and reduced the available time for fieldwork. Therefore, the photo and video monitoring were delayed to June and July 2025. Furthermore, it was observed that the water column in the Whangaparāoa Passage was full of plankton resulting in poor visibility even without rain events occurring in the days prior to sampling. Considering these factors, the 2026 photo and video monitoring could be trialled at an earlier period, *i.e.* March.

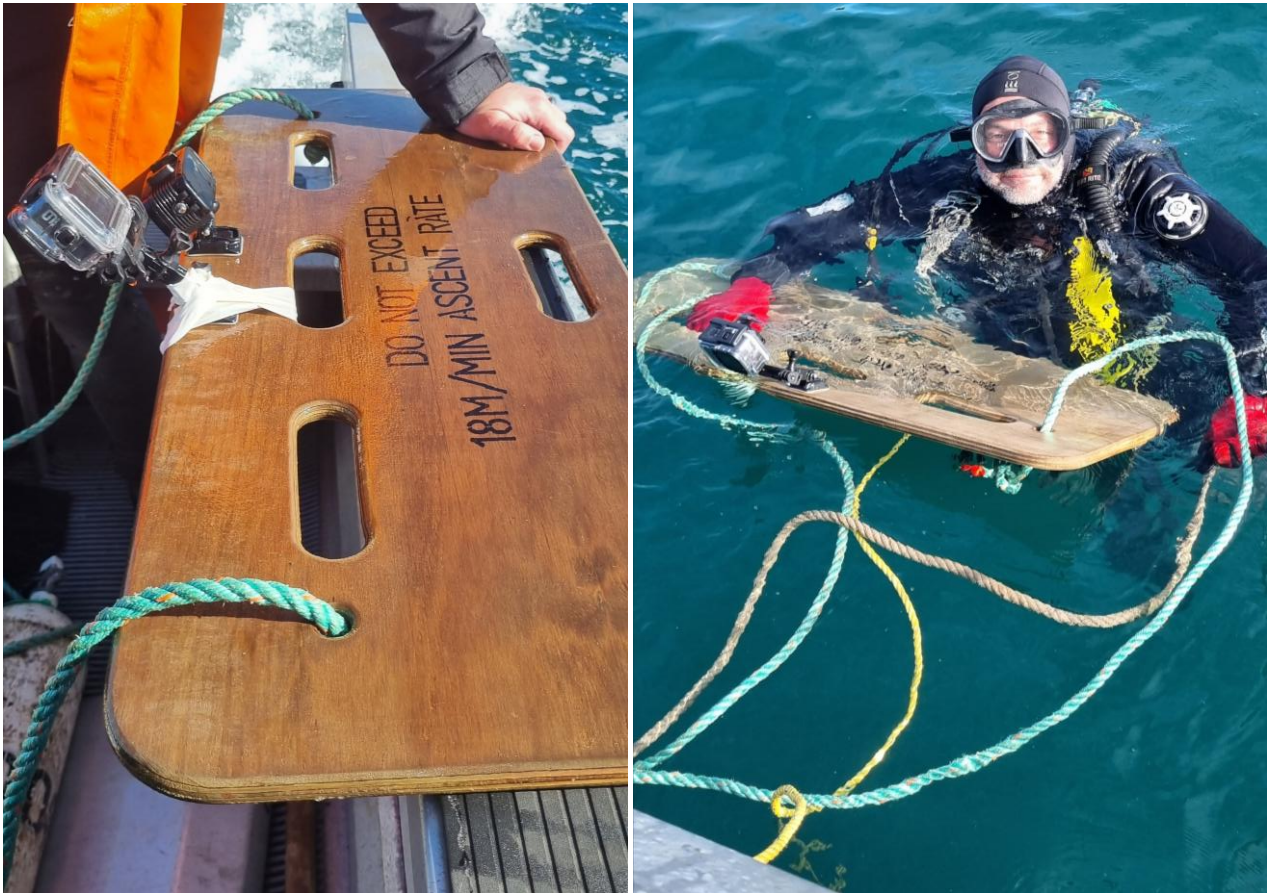


Figure 13. Left: Manta board with GoPro camera and light; Right: Diver getting ready for the descent.

3.4.2 Habitat quality around the outfall

The records of the epibiota features are listed in Appendix E Table 29 and Table 30, with photographs of the seabed.

The substrate recorded in 2025 were consistent with the previous surveys: visual analysis of the photographs and video footage indicated that most of the locations around the outfall contained sediment with no visible shell or with low shell (Figure 14). High shell content was present in the west towards the coast of the peninsula. The reef was observed after 550m south-west from the outfall. The South transect was mostly classified into the “sediment – low shell” category. The parts of the North and East transects surveyed in 2025 were entirely in the “sediment” category.

Kelly *et al.* (2018) described horse mussel (*Atrina zelandica*) beds around the outfall to a distance of 200m to 500m in all directions except east of the outfall. The monitoring surveys between 2020 and 2024 revealed a similar distribution along the video transects to that described by the 2018 study (BioResearches 2020, 2021, 2022, 2023, 2025). However, the 2025 survey showed a reduction in the density of horse mussels, especially along the south transect (Figure 15). As before, horse mussels were associated with other epibiota such as ascidians (*Synoicum kuranui*), finger sponges (*Raspailia*), and the Mediterranean fan worm (*Sabella spallanzanii*) (Figure 16). With horse mussels covered with these biota assemblages combined with the low visibility, it was not possible to identify live from dead specimens which are still up right in the sediment. Moreover, the drop camera sites did not show any horse mussel.

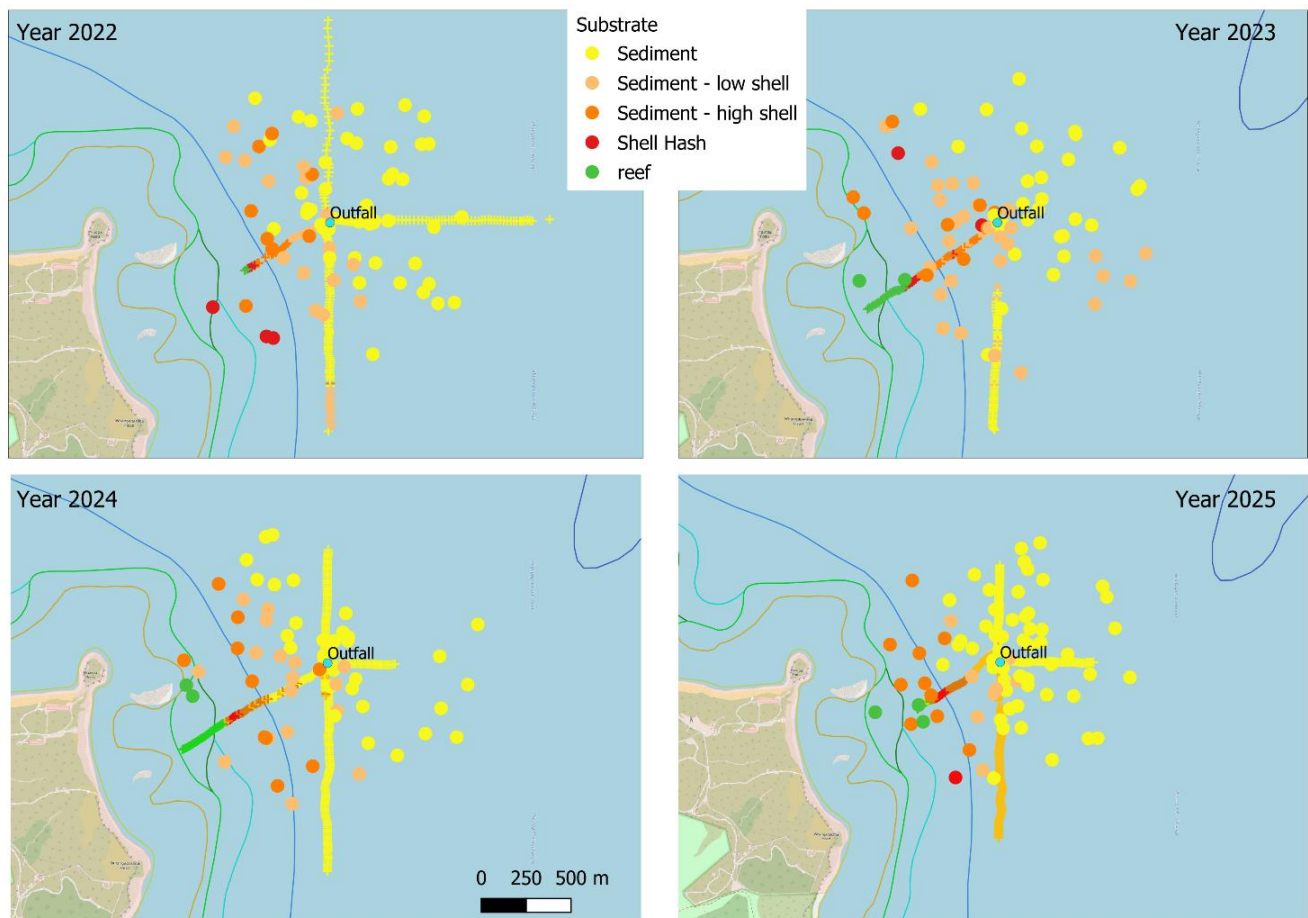


Figure 14 Substrate recorded from drop camera and towed video footage during the past 4 surveys

The high turbidity at the seabed and the layer of silt covering epibiota were observed at all drop camera sites and along the video transects, suggesting an impact of sedimentation over the whole Whangaparāoa Passage. In addition, the high plankton concentration in the water column in the Whangaparāoa Passage is likely to have detrimental effects on the benthic biota, limiting light penetration in the water column. The origin of high suspended particles is not known, but the consistency of high TSS in all sampling and the visible effect on the whole monitored benthic area suggest an impact at a larger scale, possibly from the erosion of the Hauraki Gulf coastline. There is no indication that the effluent plays a role.

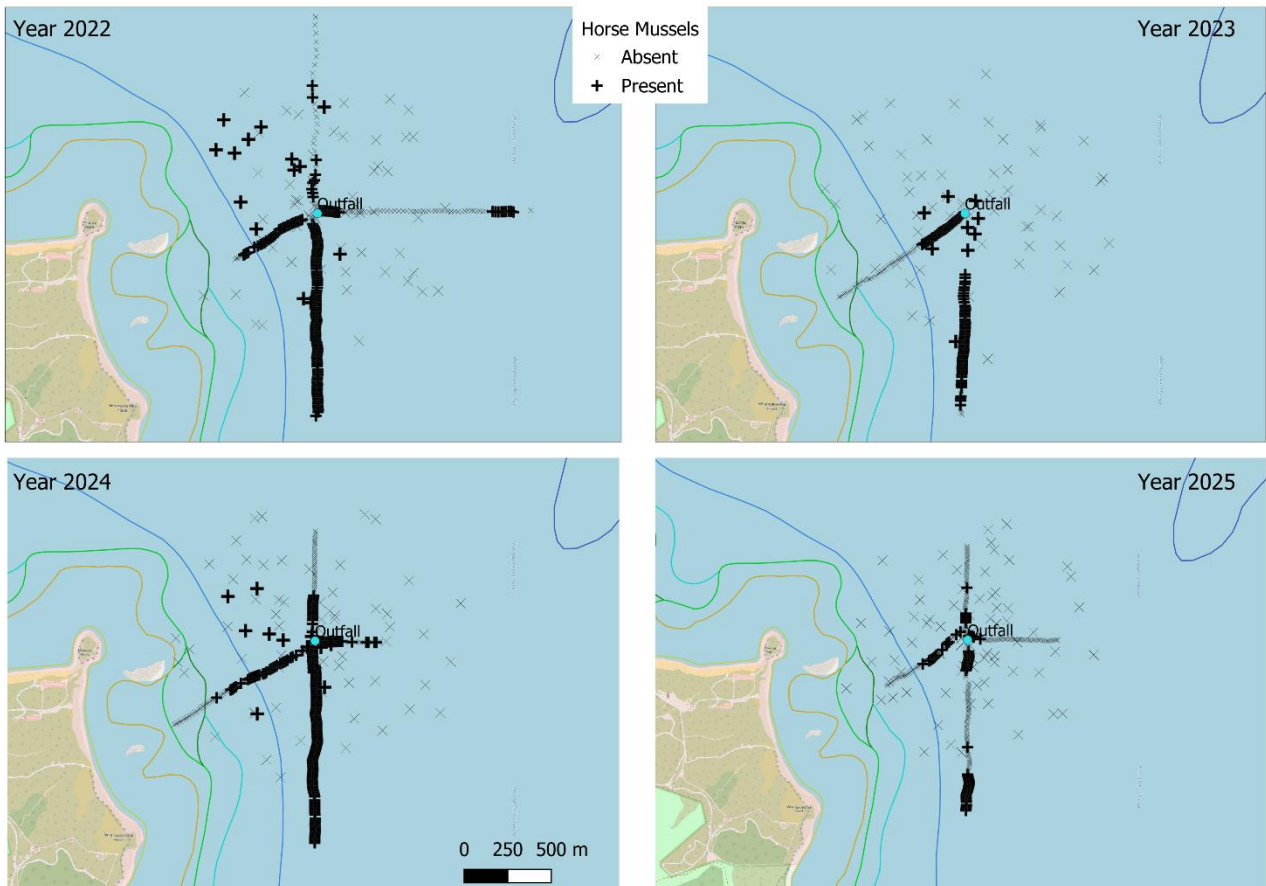


Figure 15 Horse Mussels' distribution from drop camera and towed video footage during the past 4 surveys

3.5 Summary of Subtidal Biogenic Habitat

A combination of drop camera photographs and video footage were deployed at different distances and directions around the new outfall in order to map the biogenic features of the Whangaparāoa Passage.

Biogenic features detected by drop camera and video transects were the sediment texture, and the presence of horse mussels, sponges, and fan worms. Scallops are easily missed when buried in substrate and were not determined with the current methodology. Substrate with shell can be found west of a north-south line that passes through the outfall position, towards the Whangaparāoa shore. East of this line, in deeper waters (> 25m deep), the sediment has rarely any shell and is mostly devoid of any epibiota.

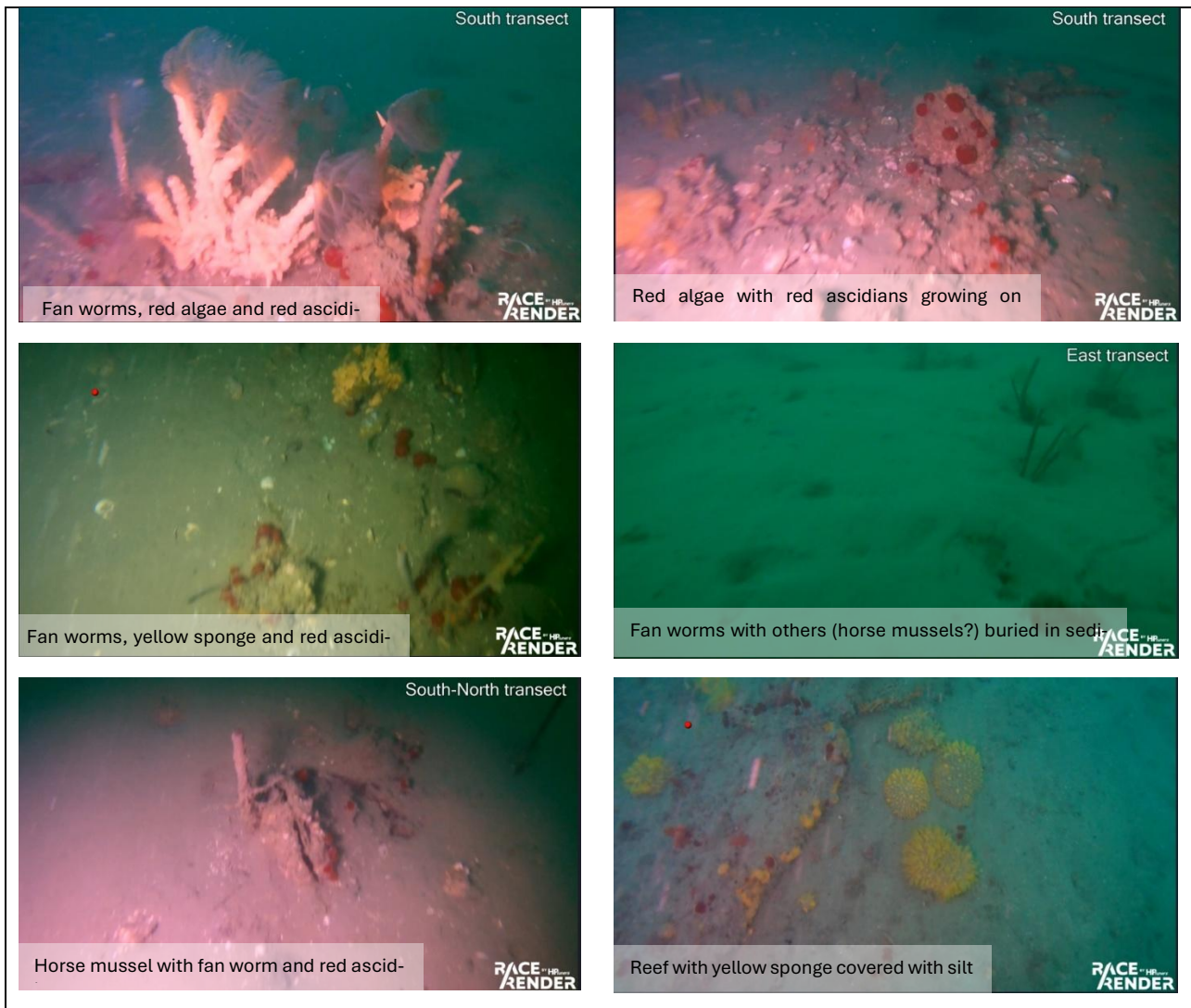


Figure 16 Examples of snapshots taken during the video footage with typical epibiota. More examples are displayed in Appendix E.

The most important biogenic habitat reported in the passage in previous studies was horse mussel beds around the outfall. Video transects of the south and south-west in 2025 revealed a degraded habitat for horse mussels, like in the previous year. The typical epibiota assemblage of horse mussels, colonial ascidians, finger sponges, and fan worms was covered by a layer of silt. The smothering of epibiota by sediment was observed in the whole monitored area. This phenomenon is likely to occur at a larger scale in the Hauraki Gulf.

4 SUBTIDAL BENTHIC ECOLOGY MONITORING

4.1 Surveys prior to the new outfall

An inspection of the old outfall in February 2000 gave some indication of the biota at the time (White 2003). Horse mussels (*Atrina zelandica*), scallops (*Pecten novaezealandiae*), dog cockles (*Glycymeris* sp.), sponge and macroalgae beds were recorded. Sjardin (2015) found that Maldanidae (bamboo worms) were the most abundant taxa in sediments next to the outfall.

Kelly and colleagues (2018) collected sediment in November 2017 with a 2 L Van Veen grab sampler within 100m of the outfall, and 1.5 km north, east and south. At each of the four sites, 10 samples were analysed for species composition. They found that polychaetes were the most diverse and abundant phylum. Near the outfall, the most abundant taxa were the 3 polychaete taxa *Cossura*, *Cirratulidae* and *Onuphis*. The *Phoxocephalidae* amphipods and echinoderms Ophiuroidea were also in more than 5% of individuals counts.

4.2 Methodology

Stations for benthic sampling were located at 100, 250 and 1000m to the north, east and south of the discharge outfall, and at 100 and 250m to the west (11 stations in total) to provide information of the spatial extent of any impact of the discharge on the infauna (Figure 2). At each station, six replicate grabs were taken with a Petite Ponar grab sampler. The sampler has a surface bite of 0.023 m² producing a theoretical sample volume of up to 2.4 L. An additional 4 kg of weights were added to the sides of the Petite Ponar to aid bite depth along with an additional 2 kg of weights to the top of the Petite Ponar to aid grab triggering due to strong currents in the Passage.

Sediment from the sampler was sieved through 0.5 mm mesh sieves with seawater on the boat. The material retained on the sieves was transferred to a zip lock bag, and preserved with a 5% glyoxal, 70% ethanol and seawater solution to fix the animal tissues. For each sample, the bag was placed into another zip-lock bag and stored in a plastic container to avoid any leak. In the laboratory, samples were rinsed after a minimum of one week of fixing in glyoxal and sorted for biota. Individuals were identified to the lowest practicable level, and enumerated, by an experienced benthic taxonomist (Rod Asher, Biolive, Nelson).

The ecological data were analysed using a mix of data plots, univariate and multivariate statistical methods to identify spatial trends in key species and indices of biodiversity and abundance. The biota matrix was examined in relation to the sediment quality matrix, to determine if contaminants or grain size influenced the benthic biota community around the outfall.

Four species diversity indices were considered: number of taxa S, number of individuals N, Margalef's richness d , and Pielou's evenness J' (calculated from the Shannon index H'). Margalef's diversity index d is calculated from S (number of taxa) and N (number of individuals).

$$d = \frac{S - 1}{\ln N}$$

Pielou's index is an evenness index considering dominance or rarity of species and is calculated from Shannon index H' and S . If taxa are in equal numbers, J' is 1. If one species strongly dominates, J' is close to zero.

$$J' = \frac{H'}{\ln S}$$

The Shannon index is calculated from the proportion number of a taxon i over the total number across all taxa (p_i).

$$H' = - \sum_{i=1}^S p_i \ln p_i$$

The diversity indices were compared between regions (west, north, east, and south of outfall) and distance (100, 250, 1000m from outfall) with ANOVA tests followed by pairwise comparison Tukey tests in R (version R 4.1.1, R Core Team 2023). When normality of data was not reached, Kruskal-Wallis tests were used with subsequent pairwise comparison Dunn's tests. All univariate tests were performed with an alpha value of 0.05.

A multivariate approach provides the ability to test differences in species assemblages between groups (distances from outfall and regions). Multivariate tests were conducted with the software PRIMER-E (version 8 beta 2.0 36, Quest Research Ltd). Bray-Curtis (B-C) similarity matrices were created on square-root transformed density data. The data transformation down-weights the importance of abundant species and gives more influence of the rare taxa. Non-metric multidimensional scaling (nMDS) was used to visualise the degree of similarity among samples of different groups on a two-dimensional plot. One-way analysis of similarities ANOSIM (maximum permutations = 999) were performed on the B-C similarity matrices to test the null hypothesis "no difference between groups". The ANOSIM test is the multivariate analogue of the univariate ANOVA test. In the case of significant differences between groups, a one-way similarity percentage analysis SIMPER is needed to determine the taxa responsible for the differences between the groups. The multivariate procedure "data transform – Bray-Curtis – nMDS – ANOSIM – SIMPER" has become a common statistical methodology for communities' structure in the past 15 years (Clarke *et al.*, 2014).

The role of sediment quality on the benthic community composition was investigated by linking biological variables on the nMDS plot with the physicochemical variables in the contaminant matrix. BIO-ENV routine in PRIMER assesses the "match" between the biota similarity matrix and the environmental variables by calculating Spearman's rank correlations with different subsets of environmental data.

4.3 Results and Interpretation

4.3.1 General Biota composition

Taxa composition of benthic biota at the 11 sites around the new outfall is summarised in Table 6 for the main taxa. All taxa are listed with densities for each sample in Appendix F. A total of 119 taxa were identified from the benthic samples with a total of 3,569 sorted invertebrates. Overall, the taxa with the highest densities were polychaetes with 52% of the total number of counted individuals in the sediment samples, and the Tanaid shrimp (11%). Polychaetes consisted of 20 species/group with *Myriochele* sp. (13%) being the most abundant followed by *Aglaophamus* sp. (7%), *Prionospio yuriei* (6%) and from the *Cirratulidae* (4%) family. The other significant taxon was the invasive mollusc *Theora lubrica* (4%) (Table 6).

Table 6. Summary of densities (number/0.023 m²) and percentage densities for the main biota taxa.

Phylum	Taxa group	Name	All samples		% by region				% by distance (m)		
			Total No.	% Total	East	North	South	West	100	250	1000
Nemertea	Nemertea	Nemertea	32	0.9	0.3	0.9	2.2	0.9	1.5	0.9	0.4
Scaphopoda	Scaphopoda	<i>Cadulus teliger</i>	38	1.1	2.5	0.7	0.8	0.0	0.9	1.2	1.2
Mollusca	Bivalvia	<i>Arthritica bifurca</i>	20	0.6	0.4	1.3	0.0	0.0	1.1	0.3	0.4
		<i>Mysella</i> sp.	25	0.7	0.9	0.9	1.0	0.0	0.0	0.8	1.2
		<i>Theora lubrica</i>	151	4.3	6.4	6.1	1.8	0.3	6.3	3.5	3.3
Annelida	Oligochaeta	Oligochaeta	54	1.5	2.2	1.5	1.6	0.8	3.2	1.1	0.5
	Polychaeta	Paraonidae	41	1.2	0.2	1.0	1.0	2.8	1.5	1.7	0.2
		<i>Cossura consimilis</i>	135	3.8	3.7	4.5	7.6	0.5	5.7	1.8	4.5
		<i>Polydora</i> sp.	17	0.5	0.6	0.2	0.0	1.1	0.7	0.7	0.0
		<i>Prionospio multicristata</i>	50	1.4	0.3	0.4	0.8	4.8	1.3	2.6	0.1
		<i>Prionospio</i> sp.	11	0.3	0.0	0.9	0.0	0.0	1.1	0.0	0.0
		<i>Prionospio yuriei</i>	206	5.8	10.9	4.0	7.4	1.1	3.9	9.0	3.7
		<i>Barantolla lepte</i>	67	1.9	0.6	0.0	3.4	5.5	3.4	1.7	0.7
		<i>Heteromastus filiformis</i>	78	2.2	0.1	1.2	0.6	7.4	1.6	4.5	0.0
		<i>Armandia maculata</i>	102	2.9	0.2	0.8	0.2	11.2	5.4	3.3	0.0
		Sigalionidae	51	1.4	1.7	2.1	1.2	0.3	1.4	1.4	1.5
		Hesionidae	18	0.5	0.4	0.2	1.2	0.6	0.9	0.3	0.4
		Syllidae	16	0.5	0.0	0.1	0.4	1.6	1.0	0.4	0.0
		Exogoninae	62	1.7	1.3	0.9	1.8	3.6	1.5	2.9	0.6
		<i>Aglaophamus</i> sp.	252	7.1	5.5	10.9	9.4	1.9	8.0	5.0	8.8
		<i>Onuphis pectinata</i>	40	1.1	1.0	0.7	3.0	0.9	2.3	1.0	0.3
		Dorvilleidae	65	1.8	0.0	3.1	0.6	3.0	2.2	3.1	0.0
		<i>Myriochele</i> sp.	451	12.7	32.7	9.0	1.2	0.3	0.0	7.0	31.4
		Cirratulidae	155	4.4	2.8	4.6	11.0	1.9	4.8	3.1	5.6
		Flabelligeridae	20	0.6	0.2	0.2	1.2	1.1	1.0	0.6	0.2
<i>Terebellides stroemi</i>	10	0.3	0.2	0.1	0.8	0.4	0.6	0.3	0.0		
Arthropoda	Cumacea	Cumacea	96	0.7	0.1	0.1	2.4	1.5	1.9	0.4	0.0
	Crustacea	<i>Nebalia</i> sp.	26	2.7	1.3	1.4	0.6	7.9	3.4	3.7	0.8
	Tanaidacea	<i>Tanaid</i> sp.	383	10.8	4.2	25.8	3.8	0.6	5.1	6.0	22.0
	Isopoda	Anthuridea	15	0.4	0.0	0.1	0.0	1.8	0.1	1.0	0.0
	Amphipoda	Phoxocephalidae	84	2.4	1.4	0.7	1.8	6.5	4.6	2.1	0.6
		Amphipoda Unid.	125	3.5	0.2	1.5	5.4	9.8	6.9	3.9	0.0
	Decapoda	<i>Pilumnus novaezelandiae</i>	24	0.7	0.0	0.5	1.2	1.5	1.0	1.0	0.0
		Decapoda (larvae Unid.)	14	0.4	0.1	0.6	0.4	0.5	0.5	0.5	0.2
	Ostracoda	<i>Cypridinoides</i> sp.	52	1.5	1.8	2.1	1.2	0.3	0.9	1.5	2.0
		<i>Trachyleberis lytteltonsis</i>	116	3.3	7.3	3.0	0.8	0.1	1.2	4.8	3.4
	Cirripedia	<i>Balanus decorus</i>	84	2.4	0.7	0.7	11.4	1.4	1.1	5.3	0.0
Echinodermata	Echinoidea	<i>Echinocardium cordatum</i>	34	1.0	1.3	1.1	1.6	0.0	0.3	0.9	1.7
	Ophiuroidea	Ophiuroidea	60	1.7	1.4	1.5	1.2	2.6	1.2	2.0	1.8
Chaetognatha	Chaetognatha	Chaetognatha	28	0.8	1.4	0.5	1.2	0.3	1.1	0.9	0.4
OTHER TAXA (Nb <15 over total of samples)			175	4.9	3.7	3.1	5.8	8.8	7.7	5.5	1.7

Note: light blue for 150<x<250 total individuals and light orange for 250<x<500 total individuals

4.3.2 Benthic community distribution with distance and region in 2024

4.3.2.1 Diversity measures

Table 7 and Figure 17 present the diversity measures between regions and distances. The results of the statistical tests are detailed in Appendix G. There were significant differences in taxa richness S, number of individuals N, diversity *d* and evenness *J'* between regions (Table 7, Figure 17). Variation between distances from the outfall was significant for *d* and *J'* only.

Table 7. Mean diversity measures (\pm 95% CI) by region and distance from outfall

Diversity measures	Region				Distance from outfall		
	East	North	South	West	100m	250m	1000m
S – No. of taxa	14.7 \pm 2.5	17.4 \pm 3.5	12.8 \pm 3.0	23.7 \pm 6.2	16.7 \pm 3.8	18.5 \pm 3.5	13.7 \pm 1.6
N – No. of individuals	56.9 \pm 17.4	68.6 \pm 17.0	28.1 \pm 13.0	67.0 \pm 31.4	44.0 \pm 15.7	57.5 \pm 15.3	62.9 \pm 21.1
<i>d</i> – Margalef’s index	3.5 \pm 0.5	3.9 \pm 0.7	3.7 \pm 0.6	5.5 \pm 1.0	4.2 \pm 0.7	4.5 \pm 0.6	3.2 \pm 0.3
<i>J'</i> – Pielou’s index	0.8 \pm 0.1	0.8	0.9	0.9	0.9	0.9	0.7 \pm 0.1

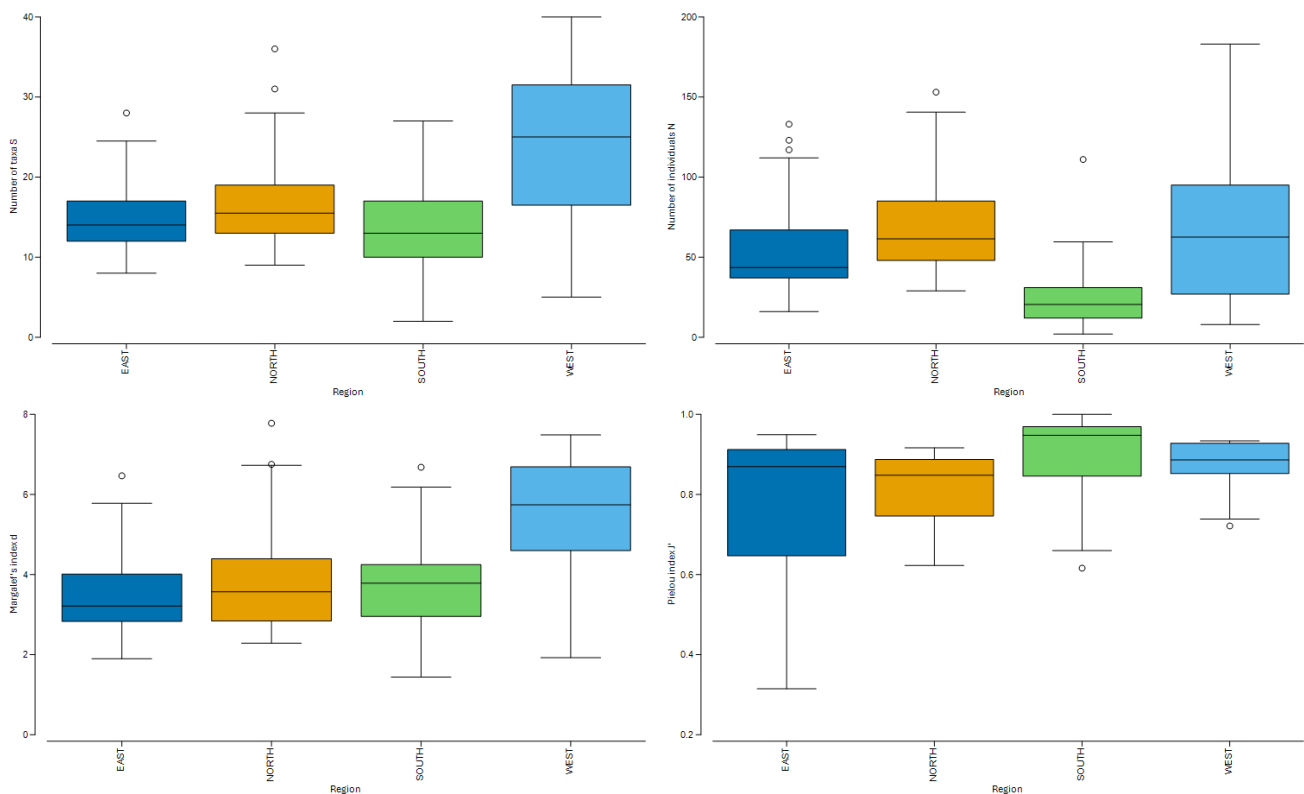


Figure 17. Diversity measures (box plots) for benthic locations grouped by region.

Across regions, benthic diversity shows clear but moderate contrasts. West sites generally had the highest richness and densities, more taxa and more individuals overall, and also the widest spread, indicating patchier conditions with a few very rich sites. East and North showed mid-values for both richness and abundance, with relatively tight boxes suggesting more consistent communities. South had the lowest counts of taxa and individuals, but it showed the most even communities (species were shared more evenly across samples, high Pielou’s *J'*). Margalef’s index followed the same pattern as richness, highest in the West, intermediate in East and North, and lower in the South, reinforcing these differences. A few

outliers are present (e.g., very high richness in the West and a single low-evenness East sample), but they do not change the overall pattern that West supports the richest, most variable assemblages, while South is poorer in taxa and numbers but comparatively well balanced in species composition (Appendix G, Table 35).

Regarding the distance factor, taxon richness (S) and Margalef's index were highest at 100–250 m (peaking at 250 m) and lowest at 1000 m, indicating fewer species at the far-field sites. Total abundance (N) tended to be lower at 100 m and higher at 250–1000 m, although a few spikes occurred at both the near and far distances. Evenness (Pielou's J') was high and consistent at 100–250 m but dropped and became more variable at 1000 m, suggesting that some far-field samples were dominated by a few taxa (Appendix G, Figure 35). Overall, communities close to the outfall were more diverse and even but contained fewer individuals, whereas farther away there were more animals overall but fewer species and, at times, uneven assemblages (Appendix G, Table 35).

4.3.2.2 Multivariate analysis

Species represented by only one individual in the whole dataset create noise in multivariate statistical analysis. Therefore, out of the 119 taxa, the 26 taxa which occurred only once were grouped with a higher taxon. The nMDS plot showed that benthic communities were different between regions and distances in the Passage, with two distinct groups, South and West, along the horizontal axis (Figure 8). The distance plot showed two loose groups, where most 1000 m samples cluster together on the left, while 100 m and 250 m samples overlap on the right. The 100 m samples are also the most scattered, suggesting higher variability close to the discharge. The ANOSIM tests showed a stronger differentiation between regions ($R = 0.38$, $p = 0.0001$) than between distances ($R = 0.13$, $p = 0.0003$) (Appendix G, Table 36 and Table 37).

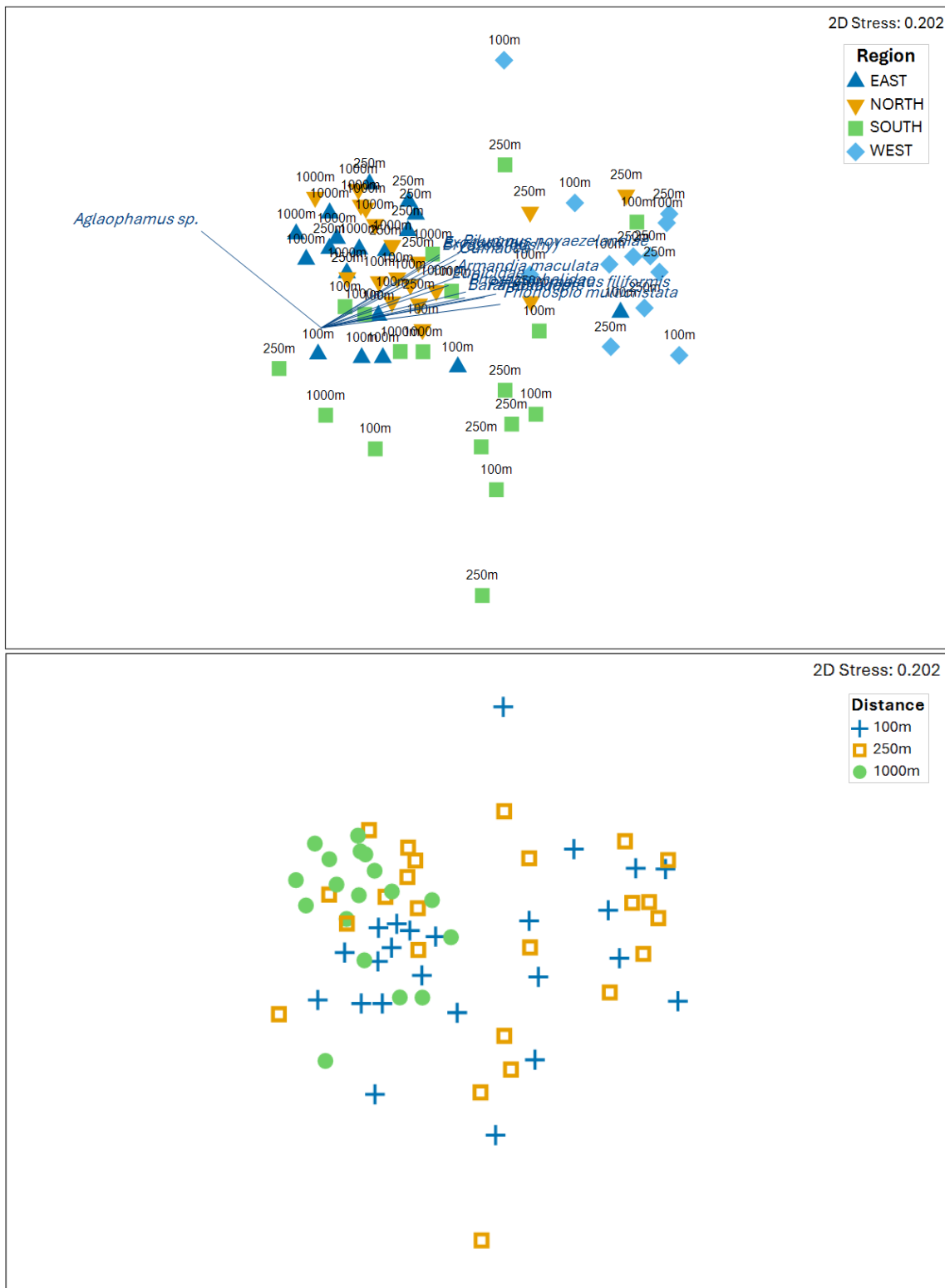


Figure 18. Non-metric Multi-Dimensional Scaling (nMDS) on benthic biota numbers (square-rooted) color-coded to represent the two factors (Region and Distance). Vectors represented are the most relevant to variation (correlation of 0.5).

Note: Species/groups in the top nMDS are *Aglaophamus sp.*, *Armandia maculata*, *Barantolla lepte*, Bryozoa (Bushy), Cumacea, Eunicidae, Exogoninae, Glyceridae, *Heteromastus filiformis*, Paraonidae, Phoxocephalidae, *Pilumnus novaezealandiae*, and *Prionospio multicristata*.

Although there was a substantial overlap among regions, there was a weak spatial signal in the species mix. Samples from South tend to lie to the left of the plot, where the only strong vector pointing that way is *Aglaophamus* sp., indicating this taxon is more characteristic of South sites. Most other vectors point toward the centre-right of the ordination, where East, North and some West samples are more common, suggesting relatively higher occurrences there of *Heteromastus filiformis*, *Prionospio multicristata*, Paraoonidae, Exogoninae, Eunicidae, Glyceridae, *Armandia maculata*, *Barantolla lepte*, the crustacean groups Cumacea and Phoxocephalidae, the crab *Pilumnus novaezelandiae*, and bushy Bryozoa. Overall, species associations with region are moderate, with South distinguished mainly by *Aglaophamus* sp. and the other regions sharing a similar suite of common polychaetes and small crustaceans (Figure 18, Appendix G).

The Primer BIO-ENV routine aims to find the best match between the multivariate among-sample patterns of biota assemblage and that from environmental variables associated with those samples. The extent to which these two patterns match reflects the degree to which the chosen environmental data ‘explains’ the biotic pattern. BIO-ENV carries out a complete search of all possible combinations of variables from the data. BIO-ENV analyses showed weak associations between contaminants and benthic assemblages. For total recoverable metals, the highest Spearman rank correlation was 0.483 (Table 8). By region, the best subset included three or four variables: Arsenic, Zinc, Phosphorus, and Nitrogen (Range of 0.330); by distance, Chromium, Zinc, and Phosphorus (Range of 0.483). For bioavailable metals, maxima were also low (Range of 0.384; Table 9). By region, Lead and Arsenic performed best (Range of 0.384); by distance, Zinc alone (Range of 0.279). Overall, contaminants and % mud showed poor correspondence with benthic community patterns across regions and distances, consistent with generally low contaminant levels unlikely to affect organisms (Table 4). Therefore, the distribution of benthic biota was likely influenced by physical parameters such as current, depth, and grain size.

Table 8. Results from the BIO-ENV routines with the total recoverable metals, nutrients and mud percentage (best correlations highlighted)

Number of variables	Correlation (Spearman’s rank)	Variable combination
Between REGIONS (general rank 0.330)		
1	0.320	Phosphorus
2	0.320	Arsenic, Phosphorus
3	0.330	Arsenic, Zinc, Phosphorus
4	0.330	Arsenic, Zinc, Phosphorus, Nitrogen
5	0.311	Arsenic, Chromium, Phosphorus, Nitrogen, %mud
Between DISTANCES (general rank = 0.483)		
1	0.451	%mud
2	0.464	Arsenic, %mud
3	0.483	Chromium, Zinc, Phosphorus
4	0.468	Chromium, Zinc, Phosphorus, %mud
5	0.469	Chromium, Nickel, Zinc, Phosphorus, %mud

Note: The variables are REC_Arsenic, REC_Chromium, REC_Copper, REC_Lead, REC_Nickel, REC_Zinc, Phosphorus, Nitrogen, and percentage mud.

Table 9. Results from the BIO-ENV routines with the bioavailable metals, nutrients and mud percentage (best correlations highlighted)

Number of variables	Correlation (Spearman's rank)	Variable combination
Between REGIONS (general rank = 0.384)		
1	0.384	Lead
2	0.384	Arsenic, Lead
3	0.375	Arsenic, Chromium, Lead
4	0.375	Arsenic, Chromium, Copper, Lead
5	0.375	Arsenic, Chromium, Copper, Lead, Nickel
Between DISTANCES (general rank = 0.279)		
1	0.279	Zinc
2	0.272	Copper, Zinc
3	0.247	Copper, Nickel, Zinc
4	0.221	Chromium, Lead, Nickel, Zinc
5	0.221	Chromium, Copper, Lead, Nickel, Zinc

Note: The variables are BIO_Arsenic, BIO_Chromium, BIO_Copper, BIO_Lead, BIO_Nickel, BIO_Zinc, Phosphorus, Nitrogen, and percentage mud.

4.4 Changes over time in benthic community

The most obvious change between the six years of monitoring was the total number of individuals found in the sediment. In 2020 during the first monitoring, 7840 benthic invertebrates were found in the samples. During the subsequent monitoring surveys, the number of biota found in the sediment was largely reduced, with 4688 and 2981 individuals in 2021 and 2022 respectively. The abundance has increased to 3779 during 2023 and to 5163 in 2024, dropping again to 3569 in 2025.

Changes in biota present in the sediment does not give any indication on the health of the habitat, as invasive species tolerant to pollution could settle and thrive in a degraded environment. Moreover, the polychaete communities which dominate the benthic communities by number, vary in composition between years. For instance, in the North–East sites, communities were dominated in 2020–2021 by tube-building taxa, *Myriochele* sp. and Ampharetidae together accounting for roughly half of individuals each year. Their contribution decreased in later years, with moderate increases in small surface-deposit feeders such as *Cossura consimilis*, Paraonidae, *Prionospio* sp., and a marked rise of Cirratulidae in 2024; 2025 appears more evenly shared among several groups. In the South–West sites the mix was more variable, and opportunistic taxa were more prominent. *Polydora* sp. was among the main contributors in 2020–2021, *Heteromastus filiformis* peaked strongly in 2023, becoming the dominant taxon that year, and Ampharetidae/Cirratulidae increased in 2024–2025. Overall, North–East was characterised by sustained dominance of *Myriochele* sp./Ampharetidae early on, whereas South–West showed larger year-to-year swings with pulses of *Polydora* sp. and *H. filiformis*.

The same sampling methods, seasonal timing, and identification experts were used during all five years, eliminating the sampling methods, seasonality, or identification expertise level as potential sources of variation. The changes in benthic composition overall highlight the high variation of composition in the benthos with no clear factors of influence. Contaminants in all five years were found in concentrations less than the effects guidelines. This dynamic variation without the influence of a contaminant source questions the validity of the benthic composition to assess a potential effect from contaminants. Only a

long-term monitoring over several years will allow to clarify the amplitude of natural variation, and the sensitivity of the benthic communities to potential contaminant factors.

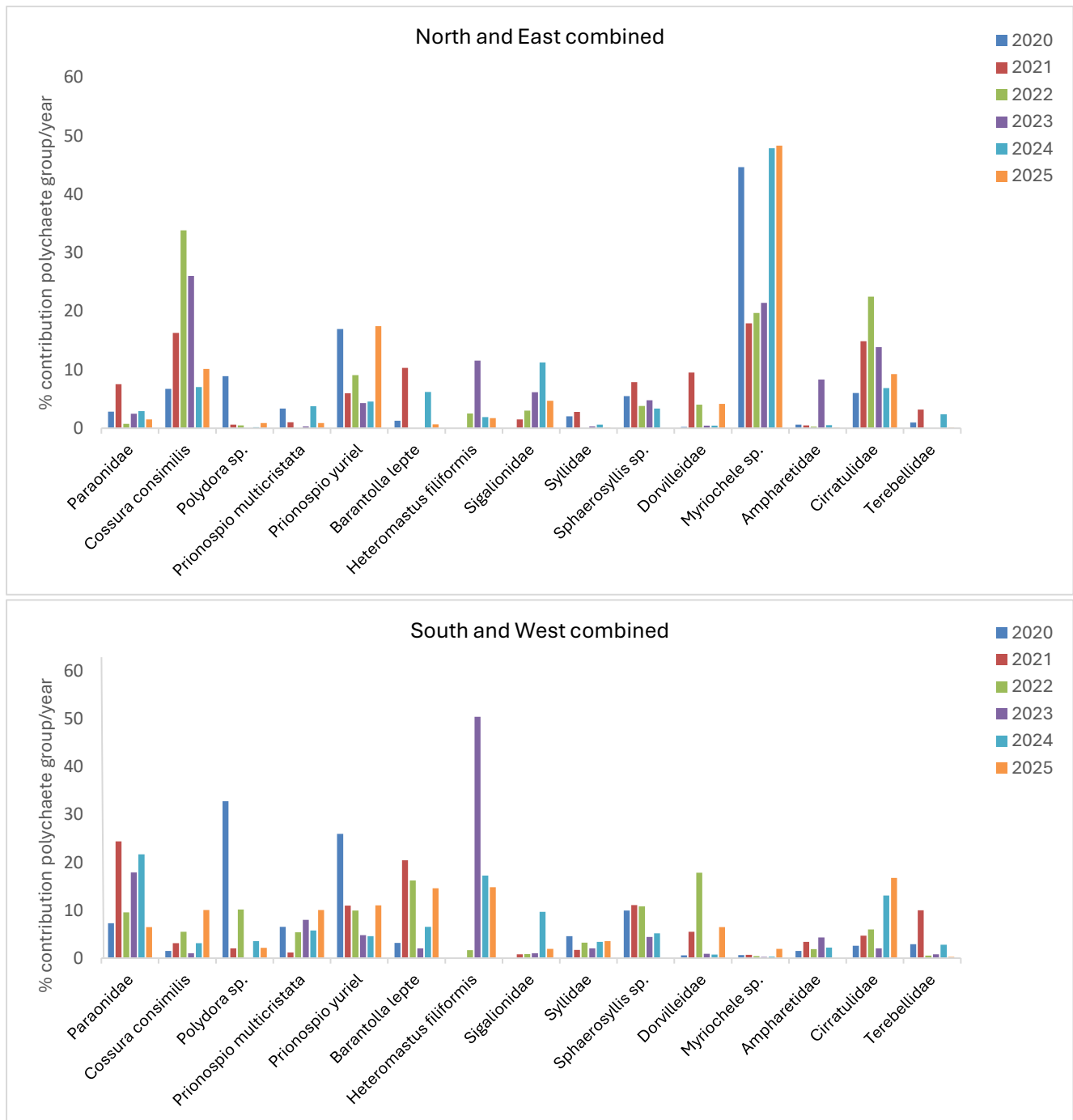


Figure 19. Contribution of polychaete species (% number) per monitoring year combined between North and East, and between South and West.

4.5 Summary of Subtidal Benthic biota composition

Overall, a total of 119 taxa were identified from the benthic samples with a total of 3,569 sorted invertebrates. Polychaetes dominated (~52%) with notable taxa *Myriochele* sp., *Aglaophamus* sp., *Prionospio yuriei*, Cirratulidae; crustaceans included Tanaids (~11%). The invasive bivalve *Theora lubrica* occurred

(~4%). Significant regional differences were identified. West had the highest richness and density (but patchy). South had the lowest richness/abundance yet the most even assemblages. East/North were intermediate and more consistent. Overall, distance effects were weaker than regional effects.

Multivariate analyses showed moderate separation by region and weak by distance. BIO-ENV correlations (testing link between contaminants and biota distributions) were low to moderate (max ~0.48). Best matches involved the combination of As, Zn, P, N (by region) and Cr, Zn, P or %mud (by distance). This indicates sediment chemistry explained only a small fraction of biological pattern.

There was a marked interannual variability in the polychaete species without a consistent direction. North–East was dominated early by tube-builders (*Myriochele* sp., Ampharetidae), shifting later toward small deposit feeders (e.g., *Cossura consimilis*, Paraonidae, Cirratulidae). South–West showed larger swings with pulses of *Polydora* sp. and strong peaks of *Heteromastus filiformis* in 2023. Across all six years, contaminants were below effects guidelines; with consistent methods/season/taxonomy, observed changes most likely reflect natural variability, not contaminant pressure.

In conclusion, because regional differences exceed distance-from-outfall effects, and sediment chemistry explains little variation, there is no clear, consistent footprint of the discharge on infaunal communities to date. Benthic composition is dynamic and may be a low-signal indicator at this site without long time series; continued, standardised monitoring is warranted to define natural variability and detect subtle shifts.

5 INTERTIDAL MACROALGAE DISTRIBUTION

5.1 Macroalgal surveys prior to the new outfall

Previous surveys were carried out during the monitoring of the old outfall's discharge (White, 1999), for the upgrade of the old outfall (Sjardin, 2015), and for the renewal of the discharge consent (Kelly, 2018). Here, only the last study from Kelly (2018) is detailed regarding the macroalgal communities found in the "Outfall Bay". Outfall Bay was identified in Kelly et al. (2018) as the Bay between Whangaparāoa Head and Huaroa Point where the outfall pipe goes out to sea (Figure 1). The same name was used in this section for consistency. Outfall Bay has an extensive intertidal zone formed by sandstone platforms extending up to 200 m east at each extremity of the Bay (Figure 20). The macroalgae (including cyanobacteria *Lyngbya* sp) identified by Kelly et al. (2018) were listed in Table 10.

Table 10. List of algae species found during the intertidal survey by Kelly et al. (2018)

Algae species	Occurrence
High Shore splash zone	
<i>Bostrychia arbuscula</i> - encrusting	Common - patches
Upper and mid- shore	
<i>Corallina officinalis</i> - turf	Abundant
<i>Hormosira banksia</i>	Abundant
<i>Codium convolutum</i>	Occasionally
<i>Lyngbya</i> sp. (depressions)	Common
Mid to lower shore	
<i>Colpomenia sinuosa</i>	Abundant
<i>Corallina officinalis</i> - turf	Abundant
<i>Hormosira banksia</i>	Abundant
<i>Lyngbya</i> sp. (depressions)	Occasionally
<i>Splachnidium rugosum</i>	Occasionally
<i>Scytothamnus australis</i>	Occasionally
Low tide limit	
<i>Jania verrucosa</i>	Common
<i>Ecklonia radiata</i>	Common
<i>Carpophyllum</i> spp.	Common
<i>Sargassum sinclairii</i>	Common
<i>Cystophora torulosa</i>	Common

5.2 Methodology

The REMP described how discharged wastewater could affect macroalgae by:

- “increasing growth and abundance due to increased nutrients.
- changing the species composition, due to the different nutrient requirements of different species.
- decreasing growth and abundance due to increased turbidity and total suspended solids.

Of particular concern are blooms of nuisance macroalgae or cyanobacteria (blue-green algae), such as those from the genus *Ulva*, *Gracilaria* and *Lyngbya*.”

To assess the potential effect of the outfall effluent onto the closest intertidal habitat (Outfall Bay), macroalgal communities were identified and mapped by photography drone survey and ground survey the 11th of March 2025. The best conditions for algal blooms are during the warmest months, i.e. January to March. The last survey since the new outfall was conducted in March 2023 (Bioresearches 2023).



Figure 20. Area to be surveyed by drone for aerial photography.

A DJI Phantom 4 Pro V2 model drone with a one-inch CMOS camera sensor was used for the survey (Figure 21). Several different altitudes were trialled to identify the optimal one: Flight altitude was set to 80 m above ground level, producing a ground sampling distance of 2.18 cm/pixel which provided a high level of accuracy while maintaining efficient speed of coverage. The flight path was programmed with Pix4D Capture to stop at each image capture location; this was done to eliminate motion blur in the captured images. Image overlap was set to 65% to allow more precise stitching of the orthomosaic.

The survey area was divided into two parts: south of Huaroa Point (Outfall Bay) and north of Huaroa Point, to be able to keep visual contact with the drone during its flight. The flight plans and distribution of photographs are presented in Figure 22.

After the survey, georeferenced photographs were combined using the “stitching” processing tool Agisoft Metashape Pro. Once Processed, the two survey areas were combined and stitched together inside Agisoft Metashape Pro to produce one overall orthomosaic, showing the full extent of the survey. The algal blooms were mapped by tracing the outlines of visible beds/patches.



Figure 21. The DJI Phantom 4 pro ready for deployment.



Figure 22. Flight paths and geo-centre of each photograph taken. Whole Outfall Bay on the left; around Huaroa Point on the right.

The areas of the shore accessible by foot were ground-truthed by visual inspection and identification just after the drone survey. The locations of algal communities identified directly by visual identification were matched with the composite photograph. The description of the intertidal zone was limited to algae. Invertebrates were not assessed.

5.3 Results and interpretation

The drone survey was carried out in the morning of the 11 March 2023 on a sunny day, with no wind and flat sea, two hours on either side of the low tide.

As described in previous surveys of the area (Kelly 2018, Bioresearches 2021), the Outfall Bay mid to lower shore sandstone platform was dominated by Coralline turf (*Corallina officinalis*), and Neptune's necklace (*Hormosira banksia*), with occasional *Codium fragile*. The sublittoral fringe was bordered with brown seaweed *Carpophyllum* spp., *Sargassum sinclairii* and *Cystophora retroflexa* (vvvv). Rock depressions where water accumulates had a more diverse algae community with the Coralline *Corallina officinalis* commonly dominating.



Ridged platform south of the Bay covered with Neptune necklace and Coralline turf



Sublittoral fringe with brown seaweed *Carphophyllum*, and *Cystophora*

Figure 23 Examples of typical seaweed communities of the Outfall Bay intertidal shore

Small patches of green algae, possibly *Ulva compressa*, were covering the coralline turf in rock pools all along the Bay (). Cyanobacteria *Lyngbya* was present in the same areas in depressions along the ridges. These patches were not dense and colour-contrasted enough to be visible on the aerial photographs. The Neptune's necklace has a green-brown colour, similar to the cyanobacteria bloom (). However, we are confident that significant algae blooms would be visible by aerial photography.

The algae patches noticed during the survey were very localised. Opportunistic algae bloom rapidly when conditions of temperature, nutrients and light are optimal. Nuisance macroalgal blooms are common in estuaries and coastal waters all over New Zealand (Nelson *et al.*, 2015). The blooms disappear when conditions change (Bioresearches 2021). Due to the emplacement of the outfall in the Passage and the strong currents North-South, it is unlikely that the nutrients from the outfall would influence Outfall Bay.

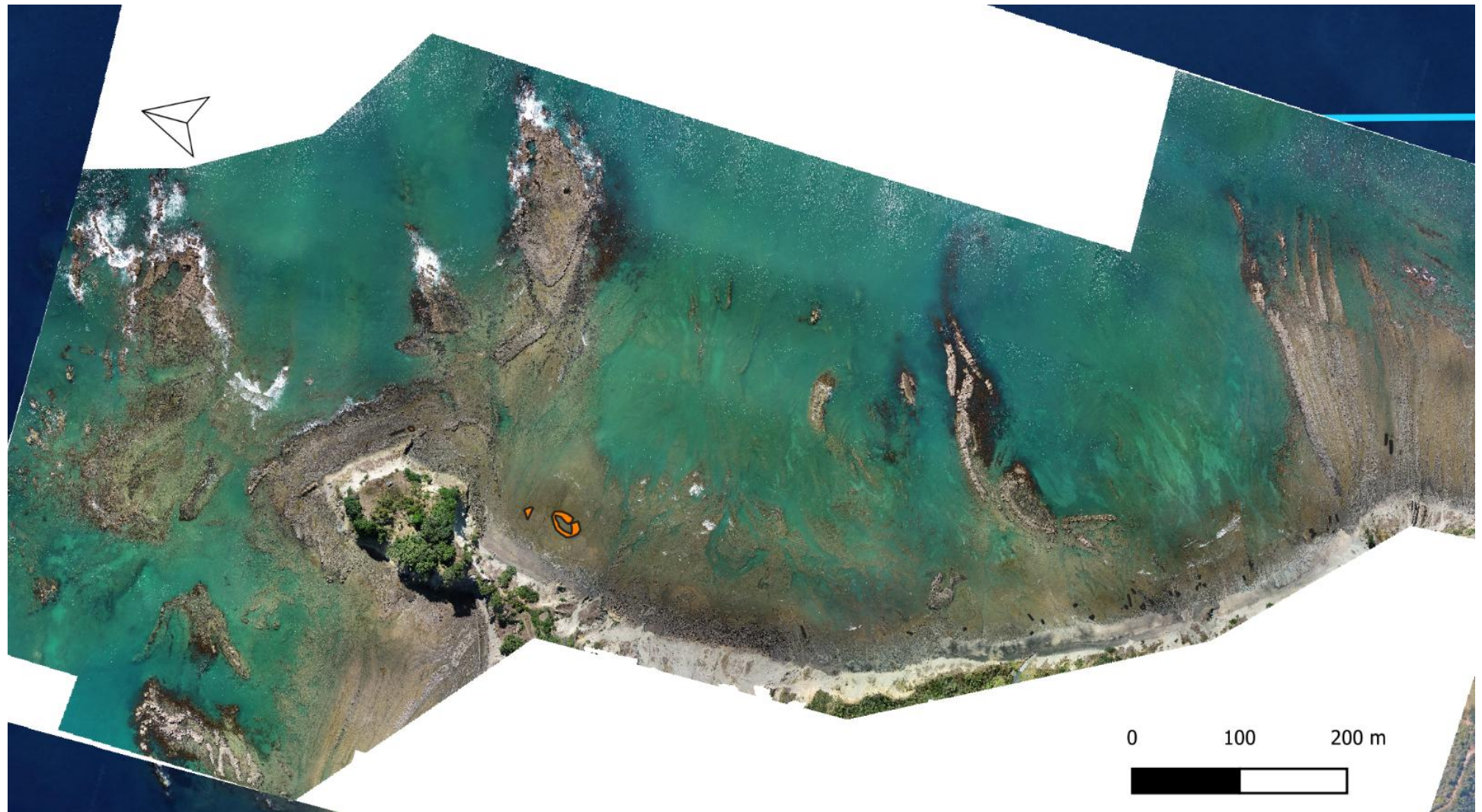


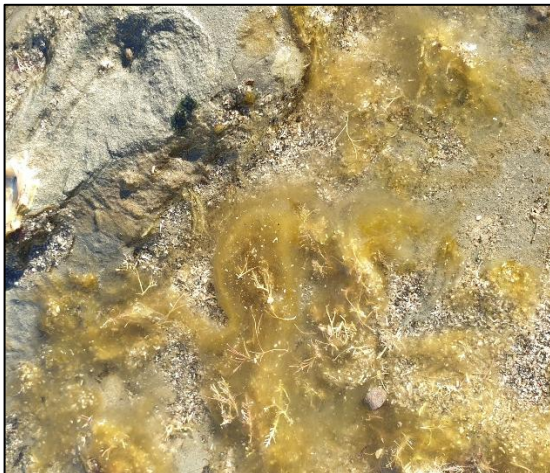
Figure 24 Composite image of aerial photographs of Outfall Bay. Algal blooms are represented by the orange patches: green algae in rock pools and *Lyngbya* in depressions along ridges



Green Algae growing on coralline turf



Lyngbya patch



Close up – green algae



Close up –*Lyngbya*

Figure 25 *Examples of algal blooms identified at the Outfall Bay, March 2025*

5.4 Summary of intertidal macroalgal cover

To assess the potential effect of the outfall effluent onto the closest intertidal habitat (Outfall Bay), macroalgal communities were identified and mapped by photography drone survey and ground survey in March 2025.

The algae patches recorded during the intertidal survey (possible *Ulva* and *Lyngbya*) were very localised in rock pools and depressions, as previously observed during the 2021 and 2023 intertidal surveys. Opportunistic algae bloom rapidly when conditions of temperature, nutrients and light are optimal. The blooms disappear when the water temperature drops in autumn.

The consecutive series of mapped macroalgae (and green-blue algae) data could be used to show changes in the extent of natural and nuisance macroalgae beds around the outfall site over time. Nonetheless, due to the emplacement of the outfall in the Passage and the strong currents North-South, it is unlikely that the nutrients from the outfall would influence Outfall Bay.

6 CONCLUSIONS

This report presents the sixth annual monitoring of the **subtidal benthic ecology**, and the **sediment quality** in the vicinity of the new outfall since its first use (April 2019). Data were collected in autumn and winter 2025 between the 6th of May and the 24th of July 2025. In addition, an intertidal algae survey was conducted in the Bay west of the outfall, “Outfall Bay”.

The sixth annual monitoring indicates that the discharge is not showing measurable adverse effects on the marine environment to date. Sediment quality remains good with contaminant levels below guideline thresholds, and no clear enrichment from the outfall discharge is evident. Biogenic habitats such as horse mussel beds show signs of smothering by sediment, likely reflecting broader environmental processes rather than localized impacts. Benthic community composition exhibits natural variability with regional differences exceeding any distance-related effects from the outfall. Intertidal macroalgal communities near Outfall Bay remain localized and typical, suggesting minimal influence from the outfall's nutrients due to strong ambient currents. Continued standardized monitoring is recommended to delineate natural ecological fluctuations from potential future changes related to the discharge, ensuring long-term protection of the receiving environment.

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APPLICABILITY AND LIMITATIONS

Restrictions of Intended Purpose

This report has been prepared solely for the benefit of Watercare Services Ltd. as our client with respect to the brief. The reliance by other parties on the information or opinions contained in the report shall, without our prior review and agreement in writing, be at such party's sole risk.

Legal Interpretation

Opinions and judgements expressed herein are based on our understanding and interpretation of current regulatory standards and should not be construed as legal opinions. Where opinions or judgements are to be relied on, they should be independently verified with appropriate legal advice.

Maps and Images

All maps, plans, and figures included in this report are indicative only and are not to be used or interpreted as engineering drafts. Do not scale any of the maps, plans or figures in this report. Any information shown here on maps, plans and figures should be independently verified on site before taking any action. Sources for map and plan compositions include LINZ Data and Map Services and local council GIS services. For further details regarding any maps, plans or figures in this report, please contact BioResearches.

Appendix A Coordinates of benthic samples (Sediment quality and biota)

Table 11. Coordinates of benthic samples

Benthic Samples	Latitude	Longitude
Outfall	-36.5929	174.8502
N100	-36.592	174.8501
N250	-36.5906	174.8501
N1000	-36.5838	174.8499
E100	-36.5928	174.8513
E250	-36.5928	174.8529
E1000	-36.5927	174.8613
S100	-36.5938	174.8502
S250	-36.5951	174.8502
S1000	-36.6019	174.8504
W100	-36.5929	174.849
W250	-36.5929	174.8474

Appendix B Grain Size data and analysis

Table 12. 2025 Grain size data (%) on dry weight basis, Hill Laboratories.

Sample	Granules and gravel	Coarse sand	Medium sand	Fine sand	Silt and Clay (mud)
	> 2 mm	0.5 – 2.0 mm	0.25 – 0.5 mm	0.063 – 0.25 mm	< 0.063 mm
N100 A	17.1	5.1	0.7	8.1	69
N100 B	23.6	6.7	1.2	8.7	59.8
N100 C	28.2	5.5	1.1	8.2	57
E100 A	25.5	5.5	0.7	6.9	61.4
E100 B	28.2	8.9	1.4	9.5	52.1
E100 C	9.4	4.3	1.1	15.3	70
S100 A	14.9	4.6	0.9	9	70.7
S100 B	24.3	6.5	1.2	10.9	57.1
S100 C	40.8	7.9	0.9	7.4	43
W100 A	26.7	9.5	1.1	9.8	53
W100 B	36.8	12.8	2.1	12.3	36
W100 C	28.6	10.4	1.6	8.9	50.5
N250 A	18.6	5.3	0.8	11.4	63.8
N250 B	5.5	2.8	0.6	8.9	82.2
N250 C	1.2	0.7	0.4	10.2	87.4
E250 A	0.4	0.7	0.4	6.8	91.7
E250 B	1.8	1.2	0.5	6.7	89.9
E250 C	0.4	0.9	0.6	8.5	89.5
S250 A	24.1	8.2	1.7	9.2	56.8
S250 B	45.3	9	1.6	7.4	36.7
S250 C	39.6	10	1.6	6.2	42.6
W250 A	52.5	17.3	3.3	6.7	20.2
W250 B	52.5	12.5	2.3	6.2	26.5
W250 C	43.6	14.4	2.4	7.5	32.1
N1000 A	1.9	0.3	0.3	14.7	82.8
N1000 B	0.7	0.5	0.2	13.5	85.2
N1000 A	1.7	0.6	0.5	16.5	80.8
E1000 A	8.4	9.6	5.3	15.3	61.5
E1000 B	14.4	5.4	1.5	10.3	68.4
E1000 C	12	4.3	2.2	13	68.4
S1000 A	20.5	8.1	1.8	8.5	61.2
S1000 B	22	8	1.4	8.8	59.8
S1000 C	21.3	8.9	1.6	8.8	59.3

Table 13. Certificate of Analysis for 2025 grain size.



R J Hill Laboratories Limited
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mail@hill-labs.co.nz
www.hill-labs.co.nz

Certificate of Analysis		Page 1 of 3				
Client: Bioresearches Contact: Laureline Meynier C/- Bioresearches PO Box 2828 Auckland 1140	Lab No: 3907829 Date Received: 04-Jun-2025 Date Reported: 14-Jul-2025 Quote No: Order No: Client Reference: 68022 Submitted By: Laureline Meynier	SPv1				
Sample Type: Sediment						
Sample Name:	Sed-N100 a	Sed-N100 b	Sed-N100 c	Sed-E100 a	Sed-E100 b	
Lab Number:	3907829.1	3907829.2	3907829.3	3907829.4	3907829.5	
7 Grain Sizes Profile as received						
Dry Matter of Sieved Sample	g/100g as rcvd	45	40	46	42	54
Fraction >= 2 mm	g/100g dry wt	17.1	23.6	26.2	25.5	26.2
Fraction < 2 mm, >= 1 mm	g/100g dry wt	3.3	4.2	3.3	3.4	5.9
Fraction < 1 mm, >= 500 µm	g/100g dry wt	1.6	2.5	2.2	2.1	3.0
Fraction < 500 µm, >= 250 µm	g/100g dry wt	0.7	1.2	1.1	0.7	1.4
Fraction < 250 µm, >= 125 µm	g/100g dry wt	3.7	4.1	3.6	3.9	5.6
Fraction < 125 µm, >= 63 µm	g/100g dry wt	4.4	4.6	4.6	3.0	3.9
Fraction < 63 µm	g/100g dry wt	69.0	59.6	57.0	61.4	52.1
Sample Name:	Sed-E100 c	Sed-S100 a	Sed-S100 b	Sed-S100 c	Sed-W100 a	
Lab Number:	3907829.6	3907829.7	3907829.8	3907829.9	3907829.10	
7 Grain Sizes Profile as received						
Dry Matter of Sieved Sample	g/100g as rcvd	42	43	44	51	50
Fraction >= 2 mm	g/100g dry wt	9.4	14.9	24.3	40.6	26.7
Fraction < 2 mm, >= 1 mm	g/100g dry wt	2.6	3.2	4.1	5.1	6.6
Fraction < 1 mm, >= 500 µm	g/100g dry wt	1.7	1.4	2.4	2.6	2.9
Fraction < 500 µm, >= 250 µm	g/100g dry wt	1.1	0.9	1.2	0.9	1.1
Fraction < 250 µm, >= 125 µm	g/100g dry wt	6.5	3.6	5.1	3.3	3.6
Fraction < 125 µm, >= 63 µm	g/100g dry wt	6.6	5.2	5.6	4.1	6.0
Fraction < 63 µm	g/100g dry wt	70.0	70.7	57.1	43.0	53.0
Sample Name:	Sed-W100 b	Sed-W100 c	Sed-N250 a	Sed-N250 b	Sed-N250 c	
Lab Number:	3907829.11	3907829.12	3907829.13	3907829.14	3907829.15	
7 Grain Sizes Profile as received						
Dry Matter of Sieved Sample	g/100g as rcvd	56	46	45	37	41
Fraction >= 2 mm	g/100g dry wt	36.6	28.6	16.6	5.5	1.2
Fraction < 2 mm, >= 1 mm	g/100g dry wt	6.9	7.6	3.3	1.6	0.3
Fraction < 1 mm, >= 500 µm	g/100g dry wt	3.9	2.6	2.0	1.2	0.4
Fraction < 500 µm, >= 250 µm	g/100g dry wt	2.1	1.6	0.6	0.6	0.4
Fraction < 250 µm, >= 125 µm	g/100g dry wt	5.0	2.7	4.8	2.6	2.7
Fraction < 125 µm, >= 63 µm	g/100g dry wt	7.3	6.2	6.6	6.3	7.5
Fraction < 63 µm	g/100g dry wt	36.0	50.5	63.6	62.2	67.4
Sample Name:	Sed-E250 a	Sed-E250 b	Sed-E250 c	Sed-S250 a	Sed-S250 b	
Lab Number:	3907829.16	3907829.17	3907829.18	3907829.19	3907829.20	
7 Grain Sizes Profile as received						
Dry Matter of Sieved Sample	g/100g as rcvd	37	34	37	45	49
Fraction >= 2 mm	g/100g dry wt	0.4	1.6	0.4	24.1	45.3
Fraction < 2 mm, >= 1 mm	g/100g dry wt	0.3	0.7	0.4	5.0	6.2
Fraction < 1 mm, >= 500 µm	g/100g dry wt	0.4	0.5	0.5	3.2	2.6

Sample Type: Sediment						
Sample Name:	Sed-E250 a	Sed-E250 b	Sed-E250 c	Sed-S250 a	Sed-S250 b	
Lab Number:	3907829.16	3907829.17	3907829.18	3907829.19	3907829.20	
7 Grain Sizes Profile as received						
Fraction < 500 µm, >= 250 µm	g/100g dry wt	0.4	0.5	0.6	1.7	1.6
Fraction < 250 µm, >= 125 µm	g/100g dry wt	2.1	2.6	3.1	4.7	3.0
Fraction < 125 µm, >= 63 µm	g/100g dry wt	4.7	4.1	5.4	4.5	4.4
Fraction < 63 µm	g/100g dry wt	91.7	89.9	89.5	56.6	36.7
Sample Name:	Sed-S250 c	Sed-W250 a	Sed-W250 b	Sed-W250 c	Sed-N1000 a	
Lab Number:	3907829.21	3907829.22	3907829.23	3907829.24	3907829.25	
7 Grain Sizes Profile as received						
Dry Matter of Sieved Sample	g/100g as rcvd	50	67	59	65	39
Fraction >= 2 mm	g/100g dry wt	39.6	52.5	52.5	43.6	1.9
Fraction < 2 mm, >= 1 mm	g/100g dry wt	7.1	10.7	6.1	9.0	0.2
Fraction < 1 mm, >= 500 µm	g/100g dry wt	2.9	6.6	4.4	5.4	0.1
Fraction < 500 µm, >= 250 µm	g/100g dry wt	1.6	3.3	2.3	2.4	0.3
Fraction < 250 µm, >= 125 µm	g/100g dry wt	2.5	2.9	2.6	2.9	2.1
Fraction < 125 µm, >= 63 µm	g/100g dry wt	3.7	3.6	3.6	4.6	12.6
Fraction < 63 µm	g/100g dry wt	42.6	20.2	26.5	32.1	62.6
Sample Name:	Sed-N1000 b	Sed-N1000 c	Sed-E1000 a	Sed-E1000 b	Sed-E1000 c	
Lab Number:	3907829.26	3907829.27	3907829.28	3907829.29	3907829.30	
7 Grain Sizes Profile as received						
Dry Matter of Sieved Sample	g/100g as rcvd	36	41	46	44	36
Fraction >= 2 mm	g/100g dry wt	0.7	1.7	6.4	14.4	12.0
Fraction < 2 mm, >= 1 mm	g/100g dry wt	0.2	0.3	4.5	3.9	2.9
Fraction < 1 mm, >= 500 µm	g/100g dry wt	0.3	0.3	5.1	1.5	1.4
Fraction < 500 µm, >= 250 µm	g/100g dry wt	0.2	0.5	5.3	1.5	2.2
Fraction < 250 µm, >= 125 µm	g/100g dry wt	1.7	2.6	11.6	6.5	9.2
Fraction < 125 µm, >= 63 µm	g/100g dry wt	11.6	13.7	3.7	3.6	3.6
Fraction < 63 µm	g/100g dry wt	66.2	66.6	61.5	66.4	66.4
Sample Name:	Sed-S1000 a	Sed-S1000 b	Sed-S1000 c			
Lab Number:	3907829.31	3907829.32	3907829.33			
7 Grain Sizes Profile as received						
Dry Matter of Sieved Sample	g/100g as rcvd	50	46	46		
Fraction >= 2 mm	g/100g dry wt	20.5	22.0	21.3		
Fraction < 2 mm, >= 1 mm	g/100g dry wt	4.9	5.1	5.6		
Fraction < 1 mm, >= 500 µm	g/100g dry wt	3.2	2.9	3.3		
Fraction < 500 µm, >= 250 µm	g/100g dry wt	1.6	1.4	1.6		
Fraction < 250 µm, >= 125 µm	g/100g dry wt	4.2	4.3	4.7		
Fraction < 125 µm, >= 63 µm	g/100g dry wt	4.3	4.5	4.1		
Fraction < 63 µm	g/100g dry wt	61.2	59.6	59.3		

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 simple 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. A detection limit range indicates the lowest and highest detection limits in the associated suite of analytes. A full listing of compounds and detection limits are available from the laboratory upon request. Unless otherwise indicated, analyses were performed at Hill Labs, 28 Duke Street, Frankton, Hamilton 3204.

Sample Type: Sediment			
Test	Method Description	Default Detection Limit	Sample No
7 Grain Sizes Profile as received			
Dry Matter for Grainsize samples (sieved as received)	Drying for 16 hours at 103°C, gravimetry (Free water removed before analysis).	0.10 g/100g as rcvd	1-33
Fraction >= 2 mm	Wet sieving with dispersant, as received, 2.00 mm sieve, gravimetry.	0.1 g/100g dry wt	1-33
Fraction < 2 mm, >= 1 mm	Wet sieving using dispersant, as received, 2.00 mm and 1.00 mm sieves, gravimetry (calculation by difference).	0.1 g/100g dry wt	1-33
Fraction < 1 mm, >= 500 µm	Wet sieving using dispersant, as received, 1.00 mm and 500 µm sieves, gravimetry (calculation by difference).	0.1 g/100g dry wt	1-33

Sample Type: Sediment			
Test	Method Description	Default Detection Limit	Sample No
Fraction < 500 µm, ≥/≈ 250 µm	Wet sieving using dispersant, as received, 500 µm and 250 µm sieves, gravimetry (calculation by difference).	0.1 g/100g dry wt	1-33
Fraction < 250 µm, ≥/≈ 125 µm	Wet sieving using dispersant, as received, 250 µm and 125 µm sieves, gravimetry (calculation by difference).	0.1 g/100g dry wt	1-33
Fraction < 125 µm, ≥/≈ 63 µm	Wet sieving using dispersant, as received, 125 µm and 63 µm sieves, gravimetry (calculation by difference).	0.1 g/100g dry wt	1-33
Fraction < 63 µm	Wet sieving with dispersant, as received, 63 µm sieve, gravimetry (calculation by difference).	0.1 g/100g dry wt	1-33

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

Testing was completed between 30-Jun-2025 and 14-Jul-2025. For completion dates of individual analyses please contact the laboratory.

Samples are held at the laboratory after reporting for a length of time based on the stability of the samples and analytes being tested (considering any preservation used), and the storage space available. Once the storage period is completed, the samples are discarded unless otherwise agreed with the customer. Extended storage times may incur additional charges.

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Certificate of Analysis

Client: Bioresearches Contact: Laureline Meynier C/- Bioresearches PO Box 2828 Auckland 1140	Lab No: 3907829 Date Received: 04-Jun-2025 Date Reported: 14-Jul-2025 Quote No: Order No: Client Reference: 68022 Submitted By: Laureline Meynier	SUPV1
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Sample Type: Sediment					
Sample Name:	Sed-N100 a 21-May-2025	Sed-N100 b 21-May-2025	Sed-N100 c 21-May-2025	Sed-E100 a 06-May-2025	
Lab Number:	3907829.1	3907829.2	3907829.3	3907829.4	
7 Grain Sizes Profile as received					
Dry Matter of Sieved Sample	g/100g as rcvd	45	40	46	42
Fraction ≥/≈ 2 mm	g/100g dry wt	17.1	23.6	26.2	25.5
Fraction < 2 mm, ≥/≈ 1 mm	g/100g dry wt	3.3	4.2	3.3	3.4
Fraction < 1 mm, ≥/≈ 500 µm	g/100g dry wt	1.8	2.5	2.2	2.1
Fraction < 500 µm, ≥/≈ 250 µm	g/100g dry wt	0.7	1.2	1.1	0.7
Fraction < 250 µm, ≥/≈ 125 µm	g/100g dry wt	3.7	4.1	3.6	3.9
Fraction < 125 µm, ≥/≈ 63 µm	g/100g dry wt	4.4	4.6	4.6	3.0
Fraction < 63 µm	g/100g dry wt	69.0	59.6	57.0	61.4
Sample Name:	Sed-E100 b 06-May-2025	Sed-E100 c 06-May-2025	Sed-S100 a 06-May-2025	Sed-S100 b 06-May-2025	
Lab Number:	3907829.5	3907829.6	3907829.7	3907829.8	
7 Grain Sizes Profile as received					
Dry Matter of Sieved Sample	g/100g as rcvd	54	42	43	44
Fraction ≥/≈ 2 mm	g/100g dry wt	26.2	9.4	14.9	24.3
Fraction < 2 mm, ≥/≈ 1 mm	g/100g dry wt	5.9	2.6	3.2	4.1
Fraction < 1 mm, ≥/≈ 500 µm	g/100g dry wt	3.0	1.7	1.4	2.4
Fraction < 500 µm, ≥/≈ 250 µm	g/100g dry wt	1.4	1.1	0.9	1.2
Fraction < 250 µm, ≥/≈ 125 µm	g/100g dry wt	5.6	6.5	3.6	5.1
Fraction < 125 µm, ≥/≈ 63 µm	g/100g dry wt	3.9	6.6	5.2	5.6
Fraction < 63 µm	g/100g dry wt	52.1	70.0	70.7	57.1
Sample Name:	Sed-S100 c 06-May-2025	Sed-W100 a 21-May-2025	Sed-W100 b 21-May-2025	Sed-W100 c 21-May-2025	
Lab Number:	3907829.9	3907829.10	3907829.11	3907829.12	
7 Grain Sizes Profile as received					
Dry Matter of Sieved Sample	g/100g as rcvd	51	50	56	48
Fraction ≥/≈ 2 mm	g/100g dry wt	40.8	26.7	36.6	26.6
Fraction < 2 mm, ≥/≈ 1 mm	g/100g dry wt	5.1	6.6	6.9	7.6
Fraction < 1 mm, ≥/≈ 500 µm	g/100g dry wt	2.6	2.9	3.9	2.6
Fraction < 500 µm, ≥/≈ 250 µm	g/100g dry wt	0.9	1.1	2.1	1.6
Fraction < 250 µm, ≥/≈ 125 µm	g/100g dry wt	3.3	3.6	5.0	2.7
Fraction < 125 µm, ≥/≈ 63 µm	g/100g dry wt	4.1	6.0	7.3	6.2
Fraction < 63 µm	g/100g dry wt	43.0	53.0	36.0	50.5
Sample Name:	Sed-N250 a 21-May-2025	Sed-N250 b 21-May-2025	Sed-N250 c 21-May-2025	Sed-E250 a 06-May-2025	
Lab Number:	3907829.13	3907829.14	3907829.15	3907829.16	
7 Grain Sizes Profile as received					
Dry Matter of Sieved Sample	g/100g as rcvd	45	37	41	37
Fraction ≥/≈ 2 mm	g/100g dry wt	16.6	5.5	1.2	0.4
Fraction < 2 mm, ≥/≈ 1 mm	g/100g dry wt	3.3	1.6	0.3	0.3
Fraction < 1 mm, ≥/≈ 500 µm	g/100g dry wt	2.0	1.2	0.4	0.4

Sample Type: Sediment					
Sample Name:	Sed-N250 a 21-May-2025	Sed-N250 b 21-May-2025	Sed-N250 c 21-May-2025	Sed-E250 a 06-May-2025	
Lab Number:	3907829.13	3907829.14	3907829.15	3907829.16	
7 Grain Sizes Profile as received					
Fraction < 500 µm, >= 250 µm	g/100g dry wt	0.8	0.6	0.4	0.4
Fraction < 250 µm, >= 125 µm	g/100g dry wt	4.8	2.6	2.7	2.1
Fraction < 125 µm, >= 63 µm	g/100g dry wt	6.6	6.3	7.5	4.7
Fraction < 63 µm	g/100g dry wt	63.8	62.2	67.4	91.7
Sample Name:	Sed-E250 b 06-May-2025	Sed-E250 c 06-May-2025	Sed-S250 a 06-May-2025	Sed-S250 b 06-May-2025	
Lab Number:	3907829.17	3907829.18	3907829.19	3907829.20	
7 Grain Sizes Profile as received					
Dry Matter of Sieved Sample	g/100g as rcvd	34	37	45	49
Fraction >= 2 mm	g/100g dry wt	1.8	0.4	24.1	45.3
Fraction < 2 mm, >= 1 mm	g/100g dry wt	0.7	0.4	5.0	6.2
Fraction < 1 mm, >= 500 µm	g/100g dry wt	0.5	0.5	3.2	2.8
Fraction < 500 µm, >= 250 µm	g/100g dry wt	0.5	0.6	1.7	1.6
Fraction < 250 µm, >= 125 µm	g/100g dry wt	2.6	3.1	4.7	3.0
Fraction < 125 µm, >= 63 µm	g/100g dry wt	4.1	5.4	4.5	4.4
Fraction < 63 µm	g/100g dry wt	59.9	59.5	56.5	36.7
Sample Name:	Sed-S250 c 06-May-2025	Sed-W250 a 21-May-2025	Sed-W250 b 21-May-2025	Sed-W250 c 21-May-2025	
Lab Number:	3907829.21	3907829.22	3907829.23	3907829.24	
7 Grain Sizes Profile as received					
Dry Matter of Sieved Sample	g/100g as rcvd	50	67	59	65
Fraction >= 2 mm	g/100g dry wt	39.6	32.5	32.5	43.6
Fraction < 2 mm, >= 1 mm	g/100g dry wt	7.1	10.7	6.1	9.0
Fraction < 1 mm, >= 500 µm	g/100g dry wt	2.9	6.6	4.4	5.4
Fraction < 500 µm, >= 250 µm	g/100g dry wt	1.6	3.3	2.3	2.4
Fraction < 250 µm, >= 125 µm	g/100g dry wt	2.5	2.9	2.6	2.9
Fraction < 125 µm, >= 63 µm	g/100g dry wt	3.7	3.8	3.6	4.6
Fraction < 63 µm	g/100g dry wt	42.6	20.2	26.5	32.1
Sample Name:	Sed-N1000 a 21-May-2025	Sed-N1000 b 21-May-2025	Sed-N1000 c 21-May-2025	Sed-E1000 a 21-May-2025	
Lab Number:	3907829.25	3907829.26	3907829.27	3907829.28	
7 Grain Sizes Profile as received					
Dry Matter of Sieved Sample	g/100g as rcvd	39	38	41	48
Fraction >= 2 mm	g/100g dry wt	1.9	0.7	1.7	6.4
Fraction < 2 mm, >= 1 mm	g/100g dry wt	0.2	0.2	0.3	4.5
Fraction < 1 mm, >= 500 µm	g/100g dry wt	0.1	0.3	0.3	5.1
Fraction < 500 µm, >= 250 µm	g/100g dry wt	0.3	0.2	0.5	5.3
Fraction < 250 µm, >= 125 µm	g/100g dry wt	2.1	1.7	2.8	11.6
Fraction < 125 µm, >= 63 µm	g/100g dry wt	12.6	11.8	13.7	3.7
Fraction < 63 µm	g/100g dry wt	62.8	65.2	60.6	61.5
Sample Name:	Sed-E1000 b 21-May-2025	Sed-E1000 c 21-May-2025	Sed-S1000 a 06-May-2025	Sed-S1000 b 06-May-2025	
Lab Number:	3907829.29	3907829.30	3907829.31	3907829.32	
7 Grain Sizes Profile as received					
Dry Matter of Sieved Sample	g/100g as rcvd	44	38	50	46
Fraction >= 2 mm	g/100g dry wt	14.4	12.0	20.5	22.0
Fraction < 2 mm, >= 1 mm	g/100g dry wt	3.9	2.4	4.9	5.1
Fraction < 1 mm, >= 500 µm	g/100g dry wt	1.5	1.9	3.2	2.9
Fraction < 500 µm, >= 250 µm	g/100g dry wt	1.5	2.2	1.5	1.4
Fraction < 250 µm, >= 125 µm	g/100g dry wt	6.5	9.2	4.2	4.3
Fraction < 125 µm, >= 63 µm	g/100g dry wt	3.8	3.8	4.3	4.5
Fraction < 63 µm	g/100g dry wt	66.4	66.4	61.2	59.8

Sample Type: Sediment		
Sample Name:	Sed-S1000 c 06-May-2025	
Lab Number:	3907829.33	
7 Grain Sizes Profile as received		
Dry Matter of Sieved Sample	g/100g as rcvd	46
Fraction >= 2 mm	g/100g dry wt	21.3
Fraction < 2 mm, >= 1 mm	g/100g dry wt	5.6
Fraction < 1 mm, >= 500 µm	g/100g dry wt	3.3
Fraction < 500 µm, >= 250 µm	g/100g dry wt	1.6
Fraction < 250 µm, >= 125 µm	g/100g dry wt	4.7
Fraction < 125 µm, >= 63 µm	g/100g dry wt	4.1
Fraction < 63 µm	g/100g dry wt	59.3

The reported uncertainty is an expanded uncertainty with a level of confidence of approximately 95 percent (i.e. two standard deviations, calculated using a coverage factor of 2). Reported uncertainties are calculated from the performance of typical matrices, and do not include variation due to sampling.

For further information on uncertainty of measurement at Hill Laboratories, refer to the technical note on our website: www.hill-laboratories.com/files/intro_To_UOM.pdf, or contact the laboratory.

Summary of Methods

The following table(s) give 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 simple 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. A detection limit range indicates the lowest and highest detection limits in the associated suite of analyses. A full listing of compounds and detection limits are available from the laboratory upon request. Unless otherwise indicated, analyses were performed at Hill Labs, 26 Duke Street, Franklin, Hamilton 3204.

Sample Type: Sediment	Test	Method Description	Default Detection Limit	Sample No
7 Grain Sizes Profile as received				
	Dry Matter for Grainsize samples (sieved as received)	Drying for 16 hours at 103°C, gravimetry (Free water removed before analysis).	0.10 g/100g as rcvd	1-33
	Fraction >= 2 mm	Wet sieving with dispersant, as received, 2.00 mm sieve, gravimetry.	0.1 g/100g dry wt	1-33
	Fraction < 2 mm, >= 1 mm	Wet sieving using dispersant, as received, 2.00 mm and 1.00 mm sieves, gravimetry (calculation by difference).	0.1 g/100g dry wt	1-33
	Fraction < 1 mm, >= 500 µm	Wet sieving using dispersant, as received, 1.00 mm and 500 µm sieves, gravimetry (calculation by difference).	0.1 g/100g dry wt	1-33
	Fraction < 500 µm, >= 250 µm	Wet sieving using dispersant, as received, 500 µm and 250 µm sieves, gravimetry (calculation by difference).	0.1 g/100g dry wt	1-33
	Fraction < 250 µm, >= 125 µm	Wet sieving using dispersant, as received, 250 µm and 125 µm sieves, gravimetry (calculation by difference).	0.1 g/100g dry wt	1-33
	Fraction < 125 µm, >= 63 µm	Wet sieving using dispersant, as received, 125 µm and 63 µm sieves, gravimetry (calculation by difference).	0.1 g/100g dry wt	1-33
	Fraction < 63 µm	Wet sieving with dispersant, as received, 63 µm sieve, gravimetry (calculation by difference).	0.1 g/100g dry wt	1-33

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

Testing was completed between 30-Jun-2025 and 14-Jul-2025. For completion dates of individual analyses please contact the laboratory.

Samples are held at the laboratory after reporting for a length of time based on the stability of the samples and analytes being tested (considering any preservation used), and the storage space available. Once the storage period is completed, the samples are discarded unless otherwise agreed with the customer. Extended storage times may incur additional charges.

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Appendix C Sediment quality data and analysis

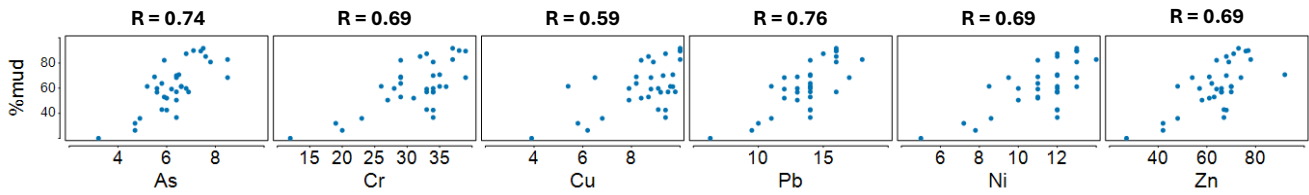


Figure 26. Mud content (%) correlations with total metal concentrations.

Table 14. 2025 Contaminant data (mg/kg dry weight) for the total recoverable fraction (<500 µm).

Stations	% dry weight	TOC %d.w.	Nitrogen	Phosphorus	Total Arsenic	Total Cadmium	Total Chromium	Total Copper	Total Lead	Total Nickel	Total Zinc
E100 A	45.9	1.5	1200	510	5.2	<0.12	35	10	14	12	70
E100 B	60.3	1.4	1500	320	6.0	<0.11	31	8	12	11	61
E100 C	43.1	1.4	1600	570	6.4	<0.11	34	9	14	12	68
E100	49.8	1.4	1433	467	5.9	<0.11	33	9	13	12	66
95%CI	10.4	0.0	236	148	0.7	-	2	1	1	1	5
E250 A	40.9	1.6	2000	580	7.5	<0.11	37	10	16	13	73
E250 B	38.4	1.7	1400	600	7.1	<0.12	38	10	16	13	77
E250 C	40.6	1.6	1900	610	7.4	<0.1	39	10	16	13	76
E250	40.0	1.6	1767	597	7.3	<0.11	38	10	16	13	75
95%CI	1.5	0.0	364	17	0.2	-	1	0	0	0	2
E1000 A	46.3	1.3	1800	690	6.6	<0.059	26	5	11	9	48
E1000 B	35.5	1.5	2200	770	6.4	<0.068	29	7	12	10	54
E1000 C	35.4	1.6	2400	660	8.5	<0.082	39	9	17	13	74
E1000	39.1	1.4	2133	707	7.2	<0.070	31	7	13	10	59
95%CI	7.1	0.2	346	64	1.3	-	8	2	4	3	15
N100 A	32.0	1.4	2400	710	5.5	<0.081	29	8	13	11	61
N100 B	32.4	1.5	2200	630	5.6	<0.059	28	8	13	10	57
N100 C	34.9	1.5	2200	590	6.9	<0.063	33	10	16	12	70
N100	33.1	1.5	2267	643	6.0	<0.068	30	9	14	11	63
95%CI	1.8	0.0	131	69	0.9	-	3	1	2	1	8
N250 A	35.2	1.4	2300	680	5.8	<0.063	29	8	14	11	62
N250 B	39.6	1.5	2100	380	5.9	<0.063	29	8	14	11	64
N250 C	32.0	1.5	2400	670	6.8	<0.078	33	9	15	12	71
N250	35.6	1.4	2267	577	6.2	<0.068	30	9	14	11	66
95%CI	4.3	0.1	173	193	0.6	-	3	1	1	1	5
N1000 A	28.4	1.3	2800	850	8.5	<0.064	37	10	18	14	78
N1000 B	38.5	1.2	2300	580	7.6	<0.064	32	9	16	12	68
N1000 C	35.1	1.3	2400	770	7.8	<0.057	34	9	16	13	69
N1000	34.0	1.3	2500	733	8.0	<0.062	34	9	17	13	72
95%CI	5.8	0.0	299	157	0.5	-	3	1	1	1	6
S100 A	55.5	1.5	1200	400	6.5	<0.11	35	10	14	12	92
S100 B	51.8	1.5	890	390	6.4	<0.097	34	10	14	12	66
S100 C	54.3	1.5	1700	430	5.8	<0.094	33	9	14	12	67
S100	53.9	1.5	1263	407	6.2	<0.10	34	10	14	12	75
95%CI	2.1	0.0	462	24	0.4	-	1	0	0	0	17
S250 A	46.0	1.5	1500	470	5.6	<0.09	34	9	13	12	66
S250 B	54.9	1.4	1500	390	6.4	<0.1	34	9	14	12	67
S250 C	54.8	1.6	840	200	6.0	<0.1	34	9	14	12	68
S250	51.9	1.5	1280	353	6.0	<0.1	34	9	14	12	67
95%CI	5.8	0.1	431	157	0.5	-	0	0	1	0	1
S1000 A	59.2	1.4	720	300	6.6	<0.098	36	10	14	13	70
S1000 B	51.1	1.5	1500	480	6.8	<0.096	34	9	14	12	66
S1000 C	48.6	1.4	1600	510	6.2	<0.1	33	9	12	11	64

Environmental Monitoring of the Benthos in the Whangaparāoa Passage (Autumn 2025)

S1000	53.0	1.4	1273	430	6.5	<0.098	34	9	13	12	67
95%CI	6.3	0.0	545	129	0.3	-	2	1	1	1	3
W100 A	49.5	1.4	1600	390	5.9	<0.069	29	9	14	11	63
W100 B	49.2	1.3	1600	380	4.9	<0.055	23	7	11	9	48
W100 C	35.1	1.4	2000	600	6.4	<0.067	27	8	13	10	58
W100	44.6	1.4	1733	457	5.7	<0.067	26	8	13	10	56
95%CI	9.3	0.1	261	141	0.9	-	3	1	2	1	9
W250 A	68.0	1.0	860	320	3.2	<0.057	12	4	6	5	27
W250 B	60.3	1.2	890	330	4.7	<0.065	20	6	10	8	42
W250 C	52.4	1.2	1200	390	4.7	<0.061	19	6	10	7	42
W250	60.2	1.1	983	347	4.2	<0.061	17	5	9	7	37
95%CI	8.8	0.2	213	43	1.0	-	5	1	2	2	10

Table 15. 2025 Contaminant data (mg/kg dry weight) for the weak acid extractable fraction (<63 µm).

Stations	% dry weight	Extractable Arsenic	Extractable Cadmium	Extractable Chromium	Extractable Copper	Extractable Lead	Extractable Nickel	Extractable Zinc
E100 A	28.1	2.5	<0.061	21	6.4	15	7.1	63
E100 B	25.6	2.7	<0.083	22	6.5	16	7.3	64
E100 C	33.9	2.9	<0.049	20	6.1	16	6.9	61
E100	29.2	2.7	<0.064	21	6.3	16	7.1	63
95%CI	4.8	0.2	-	1.1	0.2	0.7	0.2	1.7
E250 A	26.1	2.8	<0.069	19	5.6	14	6.1	57
E250 B	25.3	2.7	<0.06	21	5.8	14	6.8	58
E250 C	24.6	2.4	<0.061	19	5.4	14	6.1	55
E250	25.3	2.6	<0.063	20	5.6	14	6.3	57
95%CI	0.8	0.2	-	1.3	0.2	0.0	0.5	1.7
E1000 A	21.4	2.5	<0.057	19	4.6	14	5.6	53
E1000 B	24.1	2	<0.056	18	4.4	13	5.3	50
E1000 C	22	2.1	<0.052	19	4.8	14	5.5	53
E1000	22.5	2.2	<0.055	19	4.6	14	5.5	52
95%CI	1.6	0.3	-	0.7	0.2	0.7	0.2	2.0
N100 A	25.6	1.9	<0.054	17	5.1	13	5.3	51
N100 B	22.4	2.5	<0.062	20	6.3	14	6.3	60
N100 C	26.6	2	<0.045	20	6.4	15	6.6	61
N100	24.9	2.1	<0.054	19	5.9	14	6.1	57
95%CI	2.5	0.4	-	2.0	0.8	1.1	0.8	6.2
N250 A	20.9	2.5	<0.061	20	6.2	15	6.6	61
N250 B	23	2.3	<0.056	18	5.3	14	5.8	54
N250 C	24.5	1.9	<0.052	18	5.6	15	5.7	56
N250	22.8	2.2	<0.056	19	5.7	15	6.0	57
95%CI	2.0	0.3	-	1.3	0.5	0.7	0.6	4.1
N1000 A	23.6	2.8	<0.052	20	5.6	15	6.6	58
N1000 B	25.7	2.1	<0.047	16	4.6	12	5.1	48
N1000 C	27.4	1.7	<0.046	17	4.9	13	5.4	51
N1000	25.6	2.2	<0.048	18	5.0	13	5.7	52
95%CI	2.2	0.6	-	2.4	0.6	1.7	0.9	5.8
S100 A	26.3	2.4	<0.049	21	6.4	15	7	61
S100 B	24.4	2.5	<0.05	19	6	14	6.3	57
S100 C	26.5	2.7	<0.07	22	7	17	7.3	69
S100	25.7	2.5	<0.056	21	6.5	15	6.9	62
95%CI	1.3	0.2	-	1.7	0.6	1.7	0.6	6.9
S250 A	25	2.1	<0.066	20	6.3	15	6.6	62
S250 B	23.8	2.1	<0.048	18	5.9	15	6	59
S250 C	33.7	2.2	<0.035	18	5.8	14	5.8	55
S250	27.5	2.1	<0.050	19	6.0	15	6.1	59
95%CI	6.1	0.1	-	1.3	0.3	0.7	0.5	4.0
S1000 A	27.3	2.1	<0.043	20	6.1	15	6.3	61
S1000 B	27.1	2.6	<0.052	20	6.3	16	6.5	62

Environmental Monitoring of the Benthos in the Whangaparāoa Passage (Autumn 2025)

S1000 C	26.9	2.3	<0.053	18	5.6	14	5.8	56
S1000	27.1	2.3	<0.050	19	6.0	15	6.2	60
95%CI	0.2	0.3	-	1.3	0.4	1.1	0.4	3.6
W100 A	25.5	2.3	<0.052	20	6.5	15	6.5	60
W100 B	26.4	2.4	<0.048	20	5.9	15	6.3	57
W100 C	25.2	1.9	<0.048	18	5.6	14	5.5	53
W100	25.7	2.2	<0.049	19.3	6.0	14.7	6.1	56.7
95%CI	0.7	0.3	-	1.3	0.5	0.7	0.6	4.0
W250 A	-	-	-	-	-	-	-	-
W250 B	-	-	-	-	-	-	-	-
W250 C	-	-	-	-	-	-	-	-
W250	-	-	-	-	-	-	-	-
95%CI	-	-	-	-	-	-	-	-

Note: W250 were not analysed due to limited sediment material available, which was prioritised for Total recoverable metal analyses.

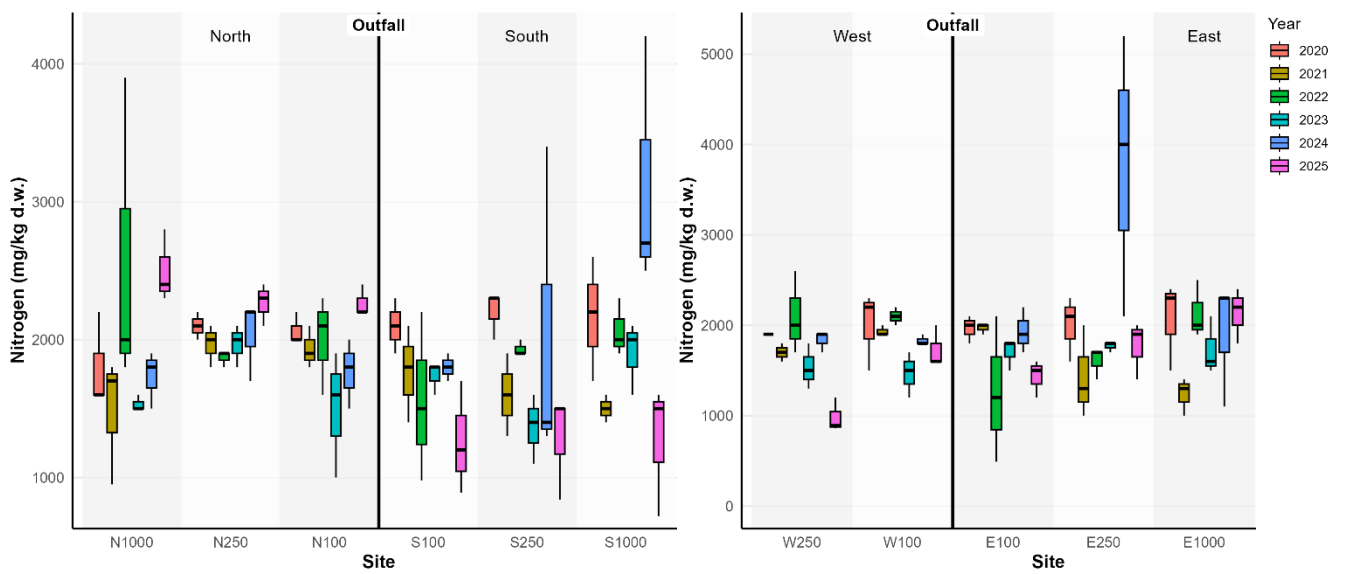


Figure 27. Nitrogen (mg/kg dry weight) box plots per site compared between monitoring surveys.

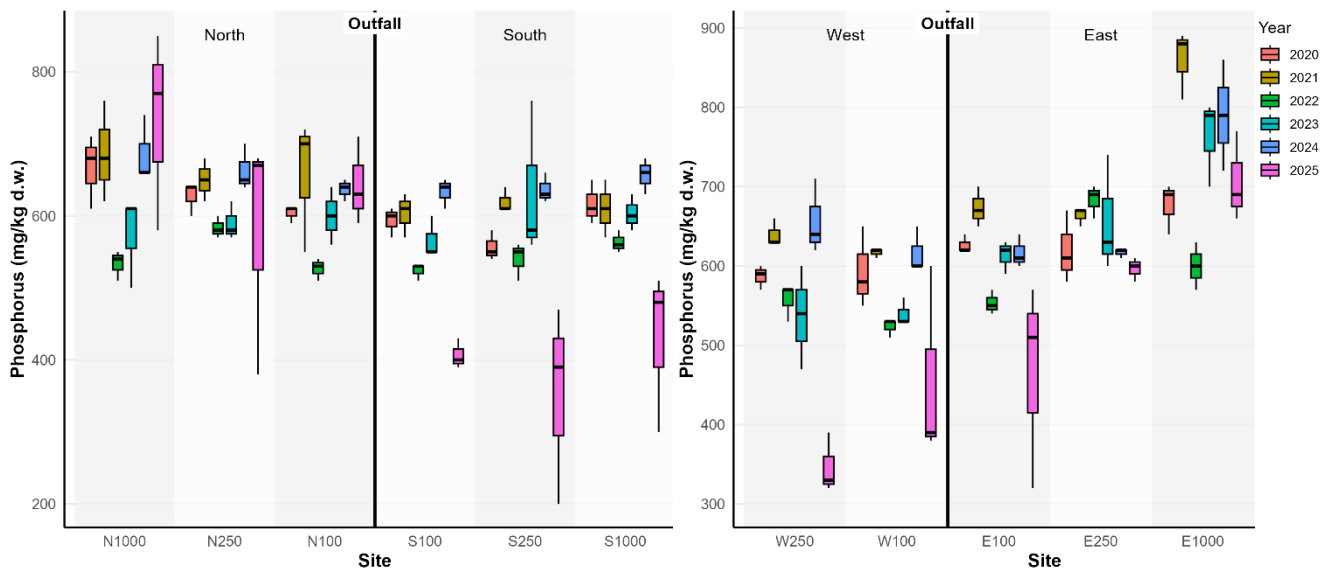


Figure 28. Phosphorus (mg/kg dry weight) box plots per site compared between monitoring surveys.

Table 16. Certificate of analysis for the contaminant concentrations.



Watercare Services Limited
52 Aintree Ave, Māngere, Auckland, 2022
PO Box 107028, Auckland, 2150
T: 0800 522 365
clientsupport@water.co.nz
www.watercarelabs.co.nz

Certificate of Analysis			
Laboratory Reference: 250526-075			
Attention:	Laureline Moynier	Final Report:	592718-0
Client:	WATERCARE SERVICES LTD	Report Issue Date:	13-Jun-2025
Address:	500 Island Road, Māngere, Auckland, 2022	Received Date:	26-May-2025
Client Reference:	Army Bay Wastewater Monitoring - Sediment Quality	Laboratory Activity Dates:	27-May-2025 - 13-Jun-2025
Purchase Order:	460012842	Quote Reference:	17524

Sample Details				
Lab Sample ID:	250526-075-1	250526-075-2	250526-075-3	250526-075-4
Client Sample ID:				
Sample Date/Time	06/05/2025	06/05/2025	06/05/2025	06/05/2025
Description:	Sed-E100a <63	Sed-E100b <63	Sed-E100c <63	Sed-S100a <63
General Testing				
Total Solids	%	28.1 *	25.6 *	33.9 *
Weak Acid Extraction		Completed *	Completed *	Completed *
Metals				
Weak Acid Extractable Metals by ICP-MS—Trace (Dry Wt. Basis)				
Arsenic (Weak Acid Extractable)	mg/kg	2.5 *	2.7 *	2.9 *
Cadmium (Weak Acid Extractable)	mg/kg	<0.061 *	<0.063 *	<0.049 *
Chromium (Weak Acid Extractable)	mg/kg	21 *	22 *	20 *
Copper (Weak Acid Extractable)	mg/kg	6.4 *	6.5 *	6.1 *
Lead (Weak Acid Extractable)	mg/kg	15 *	16 *	16 *
Nickel (Weak Acid Extractable)	mg/kg	7.1 *	7.3 *	6.9 *
Zinc (Weak Acid Extractable)	mg/kg	63 *	64 *	61 *

Sample Details				
Lab Sample ID:	250526-075-5	250526-075-6	250526-075-7	250526-075-8
Client Sample ID:				
Sample Date/Time	06/05/2025	06/05/2025	06/05/2025	06/05/2025
Description:	Sed-S100b <63	Sed-S100c <63	Sed-E250a <63	Sed-E250b <63
General Testing				
Total Solids	%	24.4 *	26.5 *	26.1 *
Weak Acid Extraction		Completed *	Completed *	Completed *
Metals				
Weak Acid Extractable Metals by ICP-MS—Trace (Dry Wt. Basis)				
Arsenic (Weak Acid Extractable)	mg/kg	2.5 *	2.7 *	2.8 *
Cadmium (Weak Acid Extractable)	mg/kg	<0.05 *	<0.07 *	<0.069 *
Chromium (Weak Acid Extractable)	mg/kg	19 *	22 *	19 *
Copper (Weak Acid Extractable)	mg/kg	6.0 *	7.0 *	5.6 *
Lead (Weak Acid Extractable)	mg/kg	14 *	17 *	14 *
Nickel (Weak Acid Extractable)	mg/kg	6.3 *	7.3 *	6.1 *
Zinc (Weak Acid Extractable)	mg/kg	57 *	69 *	57 *

Sample Details				
Lab Sample ID:	250526-075-9	250526-075-10	250526-075-11	250526-075-12
Client Sample ID:				
Sample Date/Time	06/05/2025	06/05/2025	06/05/2025	06/05/2025
Description:	Sed-E250c <63	Sed-S250a <63	Sed-S250b <63	Sed-S250c <63
General Testing				
Total Solids	%	24.6 *	25.0 *	23.8 *
Weak Acid Extraction		Completed *	Completed *	Completed *
Metals				
Weak Acid Extractable Metals by ICP-MS—Trace (Dry Wt. Basis)				

Sample Details (continued)	SOLIDS	SOLIDS	SOLIDS	SOLIDS
Lab Sample ID:	250526-075-9	250526-075-10	250526-075-11	250526-075-12
Client Sample ID:				
Sample Date/Time:	06/05/2025	06/05/2025	06/05/2025	06/05/2025
Description:	Sed-E250c <63	Sed-S250a <63	Sed-S250b <63	Sed-S250c <63
Metals				
Weak Acid Extractable Metals by ICP-MS—Trace (Dry Wt. Basis)				
Arsenic (Weak Acid Extractable)	mg/kg	2.4 *	2.1 *	2.1 *
Cadmium (Weak Acid Extractable)	mg/kg	<0.061 *	<0.066 *	<0.048 *
Chromium (Weak Acid Extractable)	mg/kg	19 *	20 *	18 *
Copper (Weak Acid Extractable)	mg/kg	5.4 *	6.3 *	5.9 *
Lead (Weak Acid Extractable)	mg/kg	14 *	15 *	15 *
Nickel (Weak Acid Extractable)	mg/kg	6.1 *	6.6 *	6.0 *
Zinc (Weak Acid Extractable)	mg/kg	55 *	62 *	59 *

Sample Details				
Lab Sample ID:	250526-075-13	250526-075-14	250526-075-15	250526-075-16
Client Sample ID:				
Sample Date/Time	06/05/2025	06/05/2025	06/05/2025	06/05/2025
Description:	Sed-S1000a <63	Sed-S1000b <63	Sed-S1000c <63	Sed-E100a <500
General Testing				
Total Nitrogen (as N, Dry Weight Basis)	mg/kg	-	-	1200 *
Total Solids	%	27.3 *	27.1 *	26.9 *
Weak Acid Extraction		Completed *	Completed *	Completed *
Metals				
Recoverable Metals by ICP-MS (<500 µm fraction)—Trace				
Arsenic (Recoverable Dry Wt.)	mg/kg	-	-	5.2 *
Cadmium (Recoverable Dry Wt.)	mg/kg	-	-	<0.12 *
Chromium (Recoverable Dry Wt.)	mg/kg	-	-	35 *
Copper (Recoverable Dry Wt.)	mg/kg	-	-	9.6 *
Lead (Recoverable Dry Wt.)	mg/kg	-	-	14 *
Nickel (Recoverable Dry Wt.)	mg/kg	-	-	12 *
Zinc (Recoverable Dry Wt.)	mg/kg	-	-	70 *
Recoverable Metals by ICP-MS—Trace				
Phosphorus (Recoverable Dry Wt.)	mg/kg	-	-	510
Weak Acid Extractable Metals by ICP-MS—Trace (Dry Wt. Basis)				
Arsenic (Weak Acid Extractable)	mg/kg	2.1 *	2.6 *	2.3 *
Cadmium (Weak Acid Extractable)	mg/kg	<0.043 *	<0.052 *	<0.053 *
Chromium (Weak Acid Extractable)	mg/kg	20 *	20 *	18 *
Copper (Weak Acid Extractable)	mg/kg	6.1 *	6.3 *	5.6 *
Lead (Weak Acid Extractable)	mg/kg	15 *	16 *	14 *
Nickel (Weak Acid Extractable)	mg/kg	6.3 *	6.5 *	5.8 *
Zinc (Weak Acid Extractable)	mg/kg	61 *	62 *	56 *

Subcontracting				
Hill Laboratories Miscellaneous Test		-	-	Report attached *
Sample Details				
Lab Sample ID:	250526-075-17	250526-075-18	250526-075-19	250526-075-20
Client Sample ID:				
Sample Date/Time	06/05/2025	06/05/2025	06/05/2025	06/05/2025
Description:	Sed-E100b <500	Sed-E100c <500	Sed-S100a <500	Sed-S100b <500
General Testing				
Total Nitrogen (as N, Dry Weight Basis)	mg/kg	1500 *	1600 *	1200 *
Total Solids	%	60.3	43.1	55.5
Metals				
Recoverable Metals by ICP-MS (<500 µm fraction)—Trace				
Arsenic (Recoverable Dry Wt.)	mg/kg	6.0 *	6.4 *	6.5 *
Cadmium (Recoverable Dry Wt.)	mg/kg	<0.11 *	<0.11 *	<0.11 *
Chromium (Recoverable Dry Wt.)	mg/kg	31 *	34 *	35 *
Copper (Recoverable Dry Wt.)	mg/kg	8.4 *	9.3 *	9.7 *
Lead (Recoverable Dry Wt.)	mg/kg	12 *	14 *	14 *
Nickel (Recoverable Dry Wt.)	mg/kg	11 *	12 *	12 *
Zinc (Recoverable Dry Wt.)	mg/kg	61 *	68 *	92 *

Sample Details				
Lab Sample ID:	250526-075-17	250526-075-18	250526-075-19	250526-075-20
Client Sample ID:				
Sample Date/Time	06/05/2025	06/05/2025	06/05/2025	06/05/2025
Description:	Sed-E100b <500	Sed-E100c <500	Sed-S100a <500	Sed-S100b <500
General Testing				
Total Nitrogen (as N, Dry Weight Basis)	mg/kg	1500 *	1600 *	1200 *
Total Solids	%	60.3	43.1	55.5
Metals				
Recoverable Metals by ICP-MS (<500 µm fraction)—Trace				
Arsenic (Recoverable Dry Wt.)	mg/kg	6.0 *	6.4 *	6.5 *
Cadmium (Recoverable Dry Wt.)	mg/kg	<0.11 *	<0.11 *	<0.11 *
Chromium (Recoverable Dry Wt.)	mg/kg	31 *	34 *	35 *
Copper (Recoverable Dry Wt.)	mg/kg	8.4 *	9.3 *	9.7 *
Lead (Recoverable Dry Wt.)	mg/kg	12 *	14 *	14 *
Nickel (Recoverable Dry Wt.)	mg/kg	11 *	12 *	12 *
Zinc (Recoverable Dry Wt.)	mg/kg	61 *	68 *	92 *

Sample Details (continued)				
	SOLIDS	SOLIDS	SOLIDS	SOLIDS
Lab Sample ID:	250526-075-17	250526-075-18	250526-075-19	250526-075-20
Client Sample ID:				
Sample Date/Time:	06/05/2025	06/05/2025	06/05/2025	06/05/2025
Description:	Sed-E100b <500	Sed-E100c <500	Sed-S100a <500	Sed-S100b <500
Metals				
Recoverable Metals by ICP-MS—Trace				
Phosphorus (Recoverable Dry Wt.)	mg/kg	320	570	400
Subcontracting				
Hill Laboratories Miscellaneous Test		Report attached *	Report attached *	Report attached *
Sample Details				
Lab Sample ID:	250526-075-21	250526-075-22	250526-075-23	250526-075-24
Client Sample ID:				
Sample Date/Time:	06/05/2025	06/05/2025	06/05/2025	06/05/2025
Description:	Sed-S100c <500	Sed-E250a <500	Sed-E250b <500	Sed-E250c <500
General Testing				
Total Nitrogen (as N, Dry Weight Basis)	mg/kg	1700 *	2000 *	1400 *
Total Solids	%	54.3	40.9	38.4
Metals				
Recoverable Metals by ICP-MS (<500 µm fraction)—Trace				
Arsenic (Recoverable Dry Wt.)	mg/kg	5.8 *	7.5 *	7.1 *
Cadmium (Recoverable Dry Wt.)	mg/kg	<0.094 *	<0.11 *	<0.12 *
Chromium (Recoverable Dry Wt.)	mg/kg	33 *	37 *	38 *
Copper (Recoverable Dry Wt.)	mg/kg	9.1 *	10 *	10 *
Lead (Recoverable Dry Wt.)	mg/kg	14 *	16 *	16 *
Nickel (Recoverable Dry Wt.)	mg/kg	12 *	13 *	13 *
Zinc (Recoverable Dry Wt.)	mg/kg	67 *	73 *	77 *
Recoverable Metals by ICP-MS—Trace				
Phosphorus (Recoverable Dry Wt.)	mg/kg	430	580	600
Subcontracting				
Hill Laboratories Miscellaneous Test		Report attached *	Report attached *	Report attached *
Sample Details				
Lab Sample ID:	250526-075-25	250526-075-26	250526-075-27	250526-075-28
Client Sample ID:				
Sample Date/Time:	06/05/2025	06/05/2025	06/05/2025	06/05/2025
Description:	Sed-S250a <500	Sed-S250b <500	Sed-S250c <500	Sed-S1000a <500
General Testing				
Total Nitrogen (as N, Dry Weight Basis)	mg/kg	1500 *	1500 *	840 *
Total Solids	%	46.0	54.9	54.8
Metals				
Recoverable Metals by ICP-MS (<500 µm fraction)—Trace				
Arsenic (Recoverable Dry Wt.)	mg/kg	5.6 *	6.4 *	6.0 *
Cadmium (Recoverable Dry Wt.)	mg/kg	<0.09 *	<0.1 *	<0.1 *
Chromium (Recoverable Dry Wt.)	mg/kg	34 *	34 *	34 *
Copper (Recoverable Dry Wt.)	mg/kg	9.2 *	9.4 *	9.4 *
Lead (Recoverable Dry Wt.)	mg/kg	13 *	14 *	14 *
Nickel (Recoverable Dry Wt.)	mg/kg	12 *	12 *	12 *
Zinc (Recoverable Dry Wt.)	mg/kg	66 *	67 *	68 *
Recoverable Metals by ICP-MS—Trace				
Phosphorus (Recoverable Dry Wt.)	mg/kg	470	390	200
Subcontracting				
Hill Laboratories Miscellaneous Test		Report attached *	Report attached *	Report attached *
Sample Details				
Lab Sample ID:	250526-075-29	250526-075-30		
Client Sample ID:				
Sample Date/Time:	06/05/2025	06/05/2025		
Description:	Sed-S1000b <500	Sed-S1000c <500		
General Testing				
Total Nitrogen (as N, Dry Weight Basis)	mg/kg	1500 *	1600 *	

Sample Details (continued)			
	SOLIDS	SOLIDS	
Lab Sample ID:	250526-075-29	250526-075-30	
Client Sample ID:			
Sample Date/Time:	06/05/2025	06/05/2025	
Description:	Sed-S1000b <500	Sed-S1000c <500	
General Testing			
Total Solids	%	51.1	48.6
Metals			
Recoverable Metals by ICP-MS (<500 µm fraction)—Trace			
Arsenic (Recoverable Dry Wt.)	mg/kg	6.8 *	6.2 *
Cadmium (Recoverable Dry Wt.)	mg/kg	<0.096 *	<0.1 *
Chromium (Recoverable Dry Wt.)	mg/kg	34 *	33 *
Copper (Recoverable Dry Wt.)	mg/kg	9.1 *	8.8 *
Lead (Recoverable Dry Wt.)	mg/kg	14 *	12 *
Nickel (Recoverable Dry Wt.)	mg/kg	12 *	11 *
Zinc (Recoverable Dry Wt.)	mg/kg	66 *	64 *
Recoverable Metals by ICP-MS—Trace			
Phosphorus (Recoverable Dry Wt.)	mg/kg	480	510
Subcontracting			
Hill Laboratories Miscellaneous Test		Report attached *	Report attached *
<p>Results marked with * are not accredited to International Accreditation New Zealand. A dash indicates no test performed.</p> <p>Where samples have been supplied by the client, they are tested as received.</p> <p>The results of analysis contained in this report relate only to the sample(s) tested. Where sample collection was performed by the laboratory, the results of analysis contained in this report relate only to the sample(s) collected.</p>			
Reference Methods			
The sample(s) referred to in this report were analysed by the following method(s)			
Analyte	Method Reference	MDL	Samples Location
General Testing			
Total Nitrogen (as N, Dry Weight Basis) by Colorimetry/Discrite Analyser	Soil Sampling and Methods of Analysis. Can. Soc. Soil Sci. (2008)	20 mg/kg	16, 17, 18, 19, 20, Auckland 21, 22, 23, 24, 25, 26, 27, 28, 29, 30
Total Solids by Gravimetry	APHA (online edition) 2540 G	0.1 %	16, 17, 18, 19, 20, Auckland 21, 22, 23, 24, 25, 26, 27, 28, 29, 30
Total Solids by Gravimetry	APHA (online edition) 2540 G		1, 2, 3, 4, 5, 6, 7, Auckland 8, 9, 10, 11, 12, 13, 14, 15
Metals			
Recoverable Metals by ICP-MS (<500 µm fraction)—Trace			
Arsenic (Recoverable Dry Wt.)	APHA (online edition) 3125 B by ICPMS	0.02 mg/kg	16, 17, 18, 19, 20, Auckland 21, 22, 23, 24, 25, 26, 27, 28, 29, 30
Cadmium (Recoverable Dry Wt.)	APHA (online edition) 3125 B by ICPMS	0.01 mg/kg	16, 17, 18, 19, 20, Auckland 21, 22, 23, 24, 25, 26, 27, 28, 29, 30
Chromium (Recoverable Dry Wt.)	APHA (online edition) 3125 B by ICPMS	0.02 mg/kg	16, 17, 18, 19, 20, Auckland 21, 22, 23, 24, 25, 26, 27, 28, 29, 30
Copper (Recoverable Dry Wt.)	APHA (online edition) 3125 B by ICPMS	0.05 mg/kg	16, 17, 18, 19, 20, Auckland 21, 22, 23, 24, 25, 26, 27, 28, 29, 30
Lead (Recoverable Dry Wt.)	APHA (online edition) 3125 B by ICPMS	0.03 mg/kg	16, 17, 18, 19, 20, Auckland 21, 22, 23, 24, 25, 26, 27, 28, 29, 30
Nickel (Recoverable Dry Wt.)	APHA (online edition) 3125 B by ICPMS	0.05 mg/kg	16, 17, 18, 19, 20, Auckland 21, 22, 23, 24, 25, 26, 27, 28, 29, 30
Zinc (Recoverable Dry Wt.)	APHA (online edition) 3125 B by ICPMS	0.75 mg/kg	16, 17, 18, 19, 20, Auckland 21, 22, 23, 24, 25, 26, 27, 28, 29, 30
Recoverable Metals by ICP-MS—Trace			
Phosphorus (Recoverable Dry Wt.)	APHA (online edition) 3125 B by ICPMS	2 mg/kg	16, 17, 18, 19, 20, Auckland 21, 22, 23, 24, 25, 26, 27, 28, 29, 30
Weak Acid Extractable Metals by ICP-MS—Trace (Dry Wt. Basis)			
Arsenic (Weak Acid Extractable)	APHA (online edition) 3125 B by ICPMS	0.02 mg/kg	1, 2, 3, 4, 5, 6, 7, Auckland 8, 9, 10, 11, 12, 13, 14, 15
Cadmium (Weak Acid Extractable)	APHA (online edition) 3125 B by ICPMS	0.01 mg/kg	1, 2, 3, 4, 5, 6, 7, Auckland 8, 9, 10, 11, 12, 13, 14, 15

Metals			
Weak Acid Extractable Metals by ICP-MS—Trace (Dry Wt. Basis)			
Chromium (Weak Acid Extractable)	APHA (online edition) 3125 B by ICPMS	0.02 mg/kg	1, 2, 3, 4, 5, 6, 7, Auckland 8, 9, 10, 11, 12, 13, 14, 15
Copper (Weak Acid Extractable)	APHA (online edition) 3125 B by ICPMS	0.05 mg/kg	1, 2, 3, 4, 5, 6, 7, Auckland 8, 9, 10, 11, 12, 13, 14, 15
Lead (Weak Acid Extractable)	APHA (online edition) 3125 B by ICPMS	0.03 mg/kg	1, 2, 3, 4, 5, 6, 7, Auckland 8, 9, 10, 11, 12, 13, 14, 15
Nickel (Weak Acid Extractable)	APHA (online edition) 3125 B by ICPMS	0.05 mg/kg	1, 2, 3, 4, 5, 6, 7, Auckland 8, 9, 10, 11, 12, 13, 14, 15
Zinc (Weak Acid Extractable)	APHA (online edition) 3125 B by ICPMS	0.75 mg/kg	1, 2, 3, 4, 5, 6, 7, Auckland 8, 9, 10, 11, 12, 13, 14, 15
Subcontracting			
Hill Laboratories Miscellaneous Test	As per Subcontractor Method		16, 17, 18, 19, 20, See attached 21, 22, 23, 24, 25, 26, 27, 28, 29, 30
Preps - Do not report			
Complete	APHA (online edition) 2540 G		16, 17, 18, 19, 20, Auckland 21, 22, 23, 24, 25, 26, 27, 28, 29, 30
Preparations			
Digest for Recoverable Metals in Solids	US EPA 200.8 (1:1 Nitric:Hydrochloric Acid)		16, 17, 18, 19, 20, Auckland 21, 22, 23, 24, 25, 26, 27, 28, 29, 30
Digest for Recoverable Metals in Solids	US EPA 200.8 (1:1 Nitric:Hydrochloric Acid)		16, 17, 18, 19, 20, Auckland 21, 22, 23, 24, 25, 26, 27, 28, 29, 30
Sieve to <500 µm	In House		16, 17, 18, 19, 20, Auckland 21, 22, 23, 24, 25, 26, 27, 28, 29, 30
Sieve to <63 Micron	In House		1, 2, 3, 4, 5, 6, 7, Auckland 8, 9, 10, 11, 12, 13, 14, 15
Weak Acid Extraction for Solids	Auckland Regional Council Technical Publication 168 (2 M Hydrochloric Acid, 24 hours)		1, 2, 3, 4, 5, 6, 7, Auckland 8, 9, 10, 11, 12, 13, 14, 15
<i>The method detection limit (MDL) listed is the limit attainable in a relatively clean matrix. If dilutions are required for analysis the detection limit may be higher. For more information please contact the Compliance and Projects Manager.</i>			

Samples, with suitable preservation and stability of analytes, will be held by the laboratory for a period of two weeks after results have been reported, unless otherwise advised by the submitter.

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Robyn Abernethy
Compliance and Projects Manager



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Certificate of Analysis			
Laboratory Reference: 250529-103			
Attention:	Laureline Meynier	Final Report:	593116-0 Replaces Report 592811-0
Client:	WATERCARE SERVICES LTD	Report Issue Date:	17-Jun-2025
Address:	500 Island Road, Māngere, Auckland, 2022	Received Date:	03-Jun-2025
		Sampled By:	Laureline Meynier
Client Reference:	Army Bay Wastewater Monitoring - Sediment Quality	Laboratory Activity Dates:	03-Jun-2025 - 16-Jun-2025
Purchase Order:	460012842	Quote Reference:	17524

Sample Details				
Lab Sample ID:	250529-103-1	250529-103-2	250529-103-3	250529-103-4
Client Sample ID:				
Sample Date/Time	21/05/2025	21/05/2025	21/05/2025	21/05/2025
Description:	Sed-N100 a <500	Sed-N100 b <500	Sed-N100 c <500	Sed-W100 a <500
General Testing				
Total Nitrogen (as N, Dry Weight Basis)	mg/kg	2400 *	2200 *	2200 *
Total Solids	%	32.0	32.4	34.9
Metals				
Recoverable Metals by ICP-MS (<500 µm fraction)—Trace				
Arsenic (Recoverable Dry Wt.)	mg/kg	5.5 *	5.6 *	6.9 *
Cadmium (Recoverable Dry Wt.)	mg/kg	<0.081 *	<0.059 *	<0.063 *
Chromium (Recoverable Dry Wt.)	mg/kg	29 *	28 *	33 *
Copper (Recoverable Dry Wt.)	mg/kg	8.2 *	7.9 *	9.5 *
Lead (Recoverable Dry Wt.)	mg/kg	13 *	13 *	16 *
Nickel (Recoverable Dry Wt.)	mg/kg	11 *	10 *	12 *
Zinc (Recoverable Dry Wt.)	mg/kg	61 *	57 *	70 *
Recoverable Metals by ICP-MS—Trace				
Phosphorus (Recoverable Dry Wt.)	mg/kg	710	630	590
Subcontracting				
Hill Laboratories Miscellaneous Test		Report attached *	Report attached *	Report attached *

Sample Details				
Lab Sample ID:	250529-103-5	250529-103-6	250529-103-7	250529-103-8
Client Sample ID:				
Sample Date/Time	21/05/2025	21/05/2025	21/05/2025	21/05/2025
Description:	Sed-W100 b <500	Sed-W100 C <500	Sed-N250 a <500	Sed-N250 b <500
General Testing				
Total Nitrogen (as N, Dry Weight Basis)	mg/kg	1600 *	2200 *	2300 *
Total Solids	%	49.2	35.1	35.2
Metals				
Recoverable Metals by ICP-MS (<500 µm fraction)—Trace				
Arsenic (Recoverable Dry Wt.)	mg/kg	4.9 *	6.4 *	5.8 *
Cadmium (Recoverable Dry Wt.)	mg/kg	<0.055 *	<0.067 *	<0.063 *
Chromium (Recoverable Dry Wt.)	mg/kg	23 *	27 *	29 *
Copper (Recoverable Dry Wt.)	mg/kg	6.8 *	7.9 *	8.2 *
Lead (Recoverable Dry Wt.)	mg/kg	11 *	13 *	14 *
Nickel (Recoverable Dry Wt.)	mg/kg	8.6 *	10 *	11 *
Zinc (Recoverable Dry Wt.)	mg/kg	48 *	58 *	62 *
Recoverable Metals by ICP-MS—Trace				
Phosphorus (Recoverable Dry Wt.)	mg/kg	380	600	680
Subcontracting				
Hill Laboratories Miscellaneous Test		Report attached *	Report attached *	Report attached *

Sample Details				
Lab Sample ID:	250529-103-9	250529-103-10	250529-103-11	250529-103-12
Client Sample ID:				
Sample Date/Time	21/05/2025	21/05/2025	21/05/2025	21/05/2025
Description:	Sed-N250 c <500	Sed-W250 a <500	Sed-W250 b <500	Sed-W250 c <500
General Testing				
Total Nitrogen (as N, Dry Weight Basis)	mg/kg	2400 *	860 *	890 *
Total Solids	%	32.0	68.0	60.3
Metals				
Recoverable Metals by ICP-MS (<500 µm fraction)—Trace				
Arsenic (Recoverable Dry Wt.)	mg/kg	6.8 *	3.2 *	4.7 *
Cadmium (Recoverable Dry Wt.)	mg/kg	<0.078 *	<0.057 *	<0.065 *
Chromium (Recoverable Dry Wt.)	mg/kg	33 *	12 *	20 *
Copper (Recoverable Dry Wt.)	mg/kg	9.4 *	3.9 *	6.2 *
Lead (Recoverable Dry Wt.)	mg/kg	15 *	6.3 *	9.5 *
Nickel (Recoverable Dry Wt.)	mg/kg	12 *	5.0 *	7.8 *
Zinc (Recoverable Dry Wt.)	mg/kg	71 *	27 *	42 *
Recoverable Metals by ICP-MS—Trace				
Phosphorus (Recoverable Dry Wt.)	mg/kg	670	320	330
Subcontracting				
Hill Laboratories Miscellaneous Test		Report attached *	Report attached *	Report attached *
Sample Details				
Lab Sample ID:	250529-103-13	250529-103-14	250529-103-15	250529-103-16
Client Sample ID:				
Sample Date/Time	21/05/2025	21/05/2025	21/05/2025	21/05/2025
Description:	Sed-N1000 a <500	Sed-N1000 b <500	Sed-N1000 c <500	Sed-E1000 a <500
General Testing				
Total Nitrogen (as N, Dry Weight Basis)	mg/kg	2800 *	2300 *	2400 *
Total Solids	%	28.4	38.5	35.1
Metals				
Recoverable Metals by ICP-MS (<500 µm fraction)—Trace				
Arsenic (Recoverable Dry Wt.)	mg/kg	8.5 *	7.6 *	7.8 *
Cadmium (Recoverable Dry Wt.)	mg/kg	<0.064 *	<0.064 *	<0.057 *
Chromium (Recoverable Dry Wt.)	mg/kg	37 *	32 *	34 *
Copper (Recoverable Dry Wt.)	mg/kg	10 *	8.7 *	8.9 *
Lead (Recoverable Dry Wt.)	mg/kg	18 *	16 *	16 *
Nickel (Recoverable Dry Wt.)	mg/kg	14 *	12 *	13 *
Zinc (Recoverable Dry Wt.)	mg/kg	78 *	68 *	69 *
Recoverable Metals by ICP-MS—Trace				
Phosphorus (Recoverable Dry Wt.)	mg/kg	850	580	770
Subcontracting				
Hill Laboratories Miscellaneous Test		Report attached *	Report attached *	Report attached *
Sample Details				
Lab Sample ID:	250529-103-17	250529-103-18	250529-103-19	250529-103-20
Client Sample ID:				
Sample Date/Time	21/05/2025	21/05/2025	21/05/2025	21/05/2025
Description:	Sed-E1000 b <500	Sed-E1000 c <500	Sed-N100 a <63	Sed-N100 b <63
General Testing				
Total Nitrogen (as N, Dry Weight Basis)	mg/kg	2200 *	2400 *	-
Total Solids	%	35.5	35.4	25.6 *
Weak Acid Extraction		-	-	Completed *
Metals				
Recoverable Metals by ICP-MS (<500 µm fraction)—Trace				
Arsenic (Recoverable Dry Wt.)	mg/kg	6.4 *	8.5 *	-
Cadmium (Recoverable Dry Wt.)	mg/kg	<0.068 *	<0.082 *	-
Chromium (Recoverable Dry Wt.)	mg/kg	29 *	39 *	-
Copper (Recoverable Dry Wt.)	mg/kg	6.5 *	8.8 *	-
Lead (Recoverable Dry Wt.)	mg/kg	12 *	17 *	-
Nickel (Recoverable Dry Wt.)	mg/kg	9.5 *	13 *	-
Zinc (Recoverable Dry Wt.)	mg/kg	54 *	74 *	-
Recoverable Metals by ICP-MS—Trace				

Sample Details (continued)		SOLIDS	SOLIDS	SOLIDS	SOLIDS
Lab Sample ID:	250529-103-17	250529-103-18	250529-103-19	250529-103-20	
Client Sample ID:					
Sample Date/Time:	21/05/2025	21/05/2025	21/05/2025	21/05/2025	
Description:	Sed-E1000 b <500	Sed-E1000 c <500	Sed-N1100 a <63	Sed-N1100 b <63	
Metals					
Recoverable Metals by ICP-MS—Trace					
Phosphorus (Recoverable Dry Wt.)	mg/kg	770	660	-	-
Weak Acid Extractable Metals by ICP-MS—Trace (Dry Wt. Basis)					
Arsenic (Weak Acid Extractable)	mg/kg	-	-	1.9 *	2.5 *
Cadmium (Weak Acid Extractable)	mg/kg	-	-	<0.054 *	<0.062 *
Chromium (Weak Acid Extractable)	mg/kg	-	-	17 *	20 *
Copper (Weak Acid Extractable)	mg/kg	-	-	5.1 *	6.3 *
Lead (Weak Acid Extractable)	mg/kg	-	-	13 *	14 *
Nickel (Weak Acid Extractable)	mg/kg	-	-	5.3 *	6.7 *
Zinc (Weak Acid Extractable)	mg/kg	-	-	51 *	60 *
Subcontracting					
Hill Laboratories Miscellaneous Test		Report attached *	Report attached *	-	-
Sample Details					
Lab Sample ID:	250529-103-21	250529-103-22	250529-103-23	250529-103-24	
Client Sample ID:					
Sample Date/Time:	21/05/2025	21/05/2025	21/05/2025	21/05/2025	
Description:	Sed-N1100 c <63	Sed-W100 a <63	Sed-W100 b <63	Sed-W100 C <63	
General Testing					
Total Solids	%	26.6 *	25.5 *	26.4 *	25.2 *
Weak Acid Extraction		Completed *	Completed *	Completed *	Completed *
Metals					
Weak Acid Extractable Metals by ICP-MS—Trace (Dry Wt. Basis)					
Arsenic (Weak Acid Extractable)	mg/kg	2.0 *	2.3 *	2.4 *	1.9 *
Cadmium (Weak Acid Extractable)	mg/kg	<0.045 *	<0.052 *	<0.048 *	<0.048 *
Chromium (Weak Acid Extractable)	mg/kg	20 *	20 *	20 *	18 *
Copper (Weak Acid Extractable)	mg/kg	6.4 *	6.5 *	5.9 *	5.6 *
Lead (Weak Acid Extractable)	mg/kg	15 *	15 *	15 *	14 *
Nickel (Weak Acid Extractable)	mg/kg	6.6 *	6.5 *	6.3 *	5.5 *
Zinc (Weak Acid Extractable)	mg/kg	61 *	60 *	57 *	53 *
Sample Details					
Lab Sample ID:	250529-103-25	250529-103-26	250529-103-27	250529-103-28	
Client Sample ID:					
Sample Date/Time:	21/05/2025	21/05/2025	21/05/2025	21/05/2025	
Description:	Sed-N1250 a <63	Sed-N1250 b <63	Sed-N1250 c <63	Sed-N1000 a <63	
General Testing					
Total Solids	%	20.9 *	23.0 *	24.5 *	23.6 *
Weak Acid Extraction		Completed *	Completed *	Completed *	Completed *
Metals					
Weak Acid Extractable Metals by ICP-MS—Trace (Dry Wt. Basis)					
Arsenic (Weak Acid Extractable)	mg/kg	2.5 *	2.3 *	1.9 *	2.8 *
Cadmium (Weak Acid Extractable)	mg/kg	<0.061 *	<0.056 *	<0.052 *	<0.052 *
Chromium (Weak Acid Extractable)	mg/kg	20 *	18 *	18 *	20 *
Copper (Weak Acid Extractable)	mg/kg	6.2 *	5.3 *	5.6 *	5.6 *
Lead (Weak Acid Extractable)	mg/kg	15 *	14 *	15 *	15 *
Nickel (Weak Acid Extractable)	mg/kg	6.6 *	5.8 *	5.7 *	6.6 *
Zinc (Weak Acid Extractable)	mg/kg	61 *	54 *	56 *	58 *
Sample Details					
Lab Sample ID:	250529-103-29	250529-103-30	250529-103-31	250529-103-32	
Client Sample ID:					
Sample Date/Time:	21/05/2025	21/05/2025	21/05/2025	21/05/2025	
Description:	Sed-N1000 b <63	Sed-N1000 c <63	Sed-E1000 a <63	Sed-E1000 b <63	
General Testing					
Total Solids	%	25.7 *	27.4 *	21.4 *	24.1 *
Weak Acid Extraction		Completed *	Completed *	Completed *	Completed *

Sample Details (continued)		SOLIDS	SOLIDS	SOLIDS	SOLIDS
Lab Sample ID:	250529-103-29	250529-103-30	250529-103-31	250529-103-32	
Client Sample ID:					
Sample Date/Time:	21/05/2025	21/05/2025	21/05/2025	21/05/2025	
Description:	Sed-N1000 b <63	Sed-N1000 c <63	Sed-E1000 a <63	Sed-E1000 b <63	
Metals					
Weak Acid Extractable Metals by ICP-MS—Trace (Dry Wt. Basis)					
Arsenic (Weak Acid Extractable)	mg/kg	2.1 *	1.7 *	2.5 *	2.0 *
Cadmium (Weak Acid Extractable)	mg/kg	<0.047 *	<0.046 *	<0.057 *	<0.056 *
Chromium (Weak Acid Extractable)	mg/kg	16 *	17 *	19 *	18 *
Copper (Weak Acid Extractable)	mg/kg	4.6 *	4.9 *	4.6 *	4.4 *
Lead (Weak Acid Extractable)	mg/kg	12 *	13 *	14 *	13 *
Nickel (Weak Acid Extractable)	mg/kg	5.1 *	5.4 *	5.6 *	5.3 *
Zinc (Weak Acid Extractable)	mg/kg	48 *	51 *	53 *	50 *
Sample Details					
Lab Sample ID:	250529-103-33				
Client Sample ID:					
Sample Date/Time:	21/05/2025				
Description:	Sed-E1000 c <63				
General Testing					
Total Solids	%	22.0 *			
Weak Acid Extraction		Completed *			
Metals					
Weak Acid Extractable Metals by ICP-MS—Trace (Dry Wt. Basis)					
Arsenic (Weak Acid Extractable)	mg/kg	2.1 *			
Cadmium (Weak Acid Extractable)	mg/kg	<0.052 *			
Chromium (Weak Acid Extractable)	mg/kg	19 *			
Copper (Weak Acid Extractable)	mg/kg	4.8 *			
Lead (Weak Acid Extractable)	mg/kg	14 *			
Nickel (Weak Acid Extractable)	mg/kg	5.5 *			
Zinc (Weak Acid Extractable)	mg/kg	53 *			
<p>Results marked with * are not accredited to International Accreditation New Zealand. A dash indicates no test performed.</p> <p>Where samples have been supplied by the client, they are tested as received.</p> <p>The results of analysis contained in this report relate only to the sample(s) tested. Where sample collection was performed by the laboratory, the results of analysis contained in this report relate only to the sample(s) collected.</p>					
Reference Methods					
The sample(s) referred to in this report were analysed by the following method(s)					
Analyte	Method Reference	MDL	Samples	Location	
General Testing					
Total Nitrogen (as N, Dry Weight Basis) by Colorimetry/Discrite Analyser	Soil Sampling and Methods of Analysis. Can. Soc. Soil Sci. (2008)	20 mg/kg	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18	Auckland	
Total Solids by Gravimetry	APHA (online edition) 2540 G	0.1 %	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18	Auckland	
Total Solids by Gravimetry	APHA (online edition) 2540 G		19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33	Auckland	
Metals					
Recoverable Metals by ICP-MS (<500 µm fraction)—Trace					
Arsenic (Recoverable Dry Wt.)	APHA (online edition) 3125 B by ICPMS	0.02 mg/kg	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18	Auckland	
Cadmium (Recoverable Dry Wt.)	APHA (online edition) 3125 B by ICPMS	0.01 mg/kg	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18	Auckland	
Chromium (Recoverable Dry Wt.)	APHA (online edition) 3125 B by ICPMS	0.02 mg/kg	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18	Auckland	
Copper (Recoverable Dry Wt.)	APHA (online edition) 3125 B by ICPMS	0.05 mg/kg	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18	Auckland	

Metals				
Recoverable Metals by ICP-MS (<500 µm fraction)—Trace				
Lead (Recoverable Dry Wt.)	APHA (online edition) 3125 B by ICPMS	0.03 mg/kg	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18	Auckland
Nickel (Recoverable Dry Wt.)	APHA (online edition) 3125 B by ICPMS	0.05 mg/kg	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18	Auckland
Zinc (Recoverable Dry Wt.)	APHA (online edition) 3125 B by ICPMS	0.75 mg/kg	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18	Auckland
Recoverable Metals by ICP-MS—Trace				
Phosphorus (Recoverable Dry Wt.)	APHA (online edition) 3125 B by ICPMS	2 mg/kg	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18	Auckland
Weak Acid Extractable Metals by ICP-MS—Trace (Dry Wt. Basis)				
Arsenic (Weak Acid Extractable)	APHA (online edition) 3125 B by ICPMS	0.02 mg/kg	19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33	Auckland
Cadmium (Weak Acid Extractable)	APHA (online edition) 3125 B by ICPMS	0.01 mg/kg	19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33	Auckland
Chromium (Weak Acid Extractable)	APHA (online edition) 3125 B by ICPMS	0.02 mg/kg	19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33	Auckland
Copper (Weak Acid Extractable)	APHA (online edition) 3125 B by ICPMS	0.05 mg/kg	19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33	Auckland
Lead (Weak Acid Extractable)	APHA (online edition) 3125 B by ICPMS	0.03 mg/kg	19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33	Auckland
Nickel (Weak Acid Extractable)	APHA (online edition) 3125 B by ICPMS	0.05 mg/kg	19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33	Auckland
Zinc (Weak Acid Extractable)	APHA (online edition) 3125 B by ICPMS	0.75 mg/kg	19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33	Auckland
Subcontracting				
Hill Laboratories Miscellaneous Test	As per Subcontractor Method		1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18	See attached
Preps - Do not report				
Complete	APHA (online edition) 2540 G		1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18	Auckland
Preparations				
Digest for Recoverable Metals in Solids	US EPA 200.8 (1:1 Nitric-Hydrochloric Acid)		1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18	Auckland
Digest for Recoverable Metals in Solids	US EPA 200.8 (1:1 Nitric-Hydrochloric Acid)		1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18	Auckland
Sieve to <500 µm	In House		1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18	Auckland
Sieve to <63 Micron	In House		19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33	Auckland
Weak Acid Extraction for Solids	Auckland Regional Council Technical Publication 168 (2 M Hydrochloric Acid, 24 hours)		19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33	Auckland
<i>The method detection limit (MDL) listed is the limit attainable in a relatively clean matrix. If dilutions are required for analysis the detection limit may be higher. For more information please contact the Compliance and Projects Manager.</i>				

Samples, with suitable preservation and stability of analytes, will be held by the laboratory for a period of two weeks after results have been reported, unless otherwise advised by the submitter.

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Robyn Abernethy
Compliance and Projects Manager

Appendix D Statistical tests on 2025 contaminant concentrations

Total metals – Multivariate statistical tests results for region and distance

ANOSIM test for differences between unordered **Region** groups

Sample statistic (R): 0.274

Significance level of sample statistic: 0.02% (p-value: 0.0002)

Table 17. Total metals - Pairwise Tests for differences between unordered REGION groups

Groups	R Statistic	Significance level %	p-value	Possible permutations	Actual Permutations	Number ≥ Observed
EAST, NORTH	0.017	30.9	0.3088	24310	9999	3087
EAST, SOUTH	0.157	2.5	0.025	24310	9999	249
EAST, WEST	0.383	0.8	0.008	5005	5005	40
NORTH, SOUTH	0.255	0.4	0.0043	24310	9999	42
NORTH, WEST	0.445	0.5	0.0046	5005	5005	23
SOUTH, WEST	0.697	0.04	0.0004	5005	5005	2

Highlighted p values are statistically significant at alpha = 0.05.

ANOSIM test for differences between unordered **Distance** groups

Sample statistic (R): 0.058

Significance level of sample statistic: 10.1% (p-value: 0.1014)

Table 18. Total metals - Pairwise Tests for differences between unordered DISTANCE groups.

Groups	R Statistic	Significance level %	p-value	Possible permutations	Actual permutations	Number ≥ Observed
100m, 250m	0.017	28.6	0.2857	1352078	9999	2856
100m, 1000m	0.188	2.2	0.0219	293930	9999	218
250m, 1000m	0.002	37.9	0.3793	293930	9999	3792

Highlighted p values are statistically significant at alpha = 0.05.

Bioavailable metals – Multivariate statistical tests results for region and distance

ANOSIM test for differences between unordered **Region** groups

Sample statistic (R): 0.051

Significance level of sample statistic: 16.7% (P-Value: 0.1673)

Table 19. Bioavailable metals - Pairwise Tests for differences between unordered REGION groups.

Groups	R Statistic	Significance level %	p-value	Possible permutations	Actual permutations	Number ≥ Observed
EAST, NORTH	0.018	30.6	0.3055	24310	9999	3054
EAST, SOUTH	0.099	11.1	0.1113	24310	9999	1112
NORTH, SOUTH	0.041	22.7	0.2267	24310	9999	2266

Note: West was excluded from analysis (single sample) to avoid bias.

ANOSIM test for differences between unordered **Distance** groups

Sample statistic (R): 0.108

Significance level of sample statistic: 4.4% (p-value: 0.0435)

Table 20. Bioavailable metals - Pairwise Tests for differences between unordered DISTANCE groups.

Groups	R Statistic	Significance level %	p-value	Possible permutations	Actual permutations	Number ≥ Observed
100m, 250m	0.064	17	0.1702	293930	9999	1701
100m, 1000m	0.182	3.1	0.0308	293930	9999	307
250m, 1000m	0.099	11.4	0.1138	24310	9999	1137

Highlighted p values are statistically significant at alpha = 0.05.

Mud-adjusted metals – Multivariate statistical tests results for region and distance

ANOSIM test for differences between unordered **Region** groups

Sample statistic (R): 0.334

Significance level of sample statistic: 0.01% (p-value: 0.0001)

Table 21. Mud-adjusted metals - Pairwise Tests for differences between unordered REGION groups.

Groups	R Statistic	Significance level %	p-value	Possible permutations	Actual permutations	Number ≥ Observed
EAST, NORTH	-0.007	42.9	0.4292	24310	9999	4291
EAST, SOUTH	0.269	0.5	0.005	24310	9999	49
EAST, WEST	0.678	0.04	0.0004	5005	5005	2
NORTH, SOUTH	0.419	0.03	0.0003	24310	9999	2
NORTH, WEST	0.731	0.06	0.0006	5005	5005	3
SOUTH, WEST	0.078	18.5	0.1846	5005	5005	924

Highlighted p values are statistically significant at alpha = 0.05.

ANOSIM test for differences between unordered **Distance** groups

Sample statistic (R): 0.09

Significance level of sample statistic: statistic: 4.9% (p-value: 0.0494)

Table 22. Mud-adjusted metals - Pairwise Tests for differences between unordered DISTANCE groups.

Groups	R Statistic	Significance level %	p-value	Possible permutations	Actual permutations	Number ≥ Observed
100m, 250m	0.112	5.4	0.0541	1352078	9999	540
100m, 1000m	0.098	10	0.0997	293930	9999	996
250m, 1000m	0.033	23.1	0.2311	293930	9999	2310

Highlighted p values are statistically significant at alpha = 0.05.

Table 23. Total metals & nutrients – UNIVARIATE statistical tests results for region and distance.

Factor	REGION (4 groups)				DISTANCE (3 groups)			
	General test	Post-hoc test	Statistic value (H)	p-value	General test	Post-hoc test	Statistic value (H)	p-value
Nitrogen	Kruskal-Wallis	Dunn	20.03	0.000	Kruskal-Wallis	-	2.990	0.224
Phosphorus	Kruskal-Wallis	Dunn	15.33	0.002	Kruskal-Wallis	-	4.391	0.111
Arsenic	Kruskal-Wallis	Dunn	9.745	0.021	Kruskal-Wallis	Dunn	9.480	0.009
Chromium	Kruskal-Wallis	Dunn	16.11	0.001	Kruskal-Wallis	-	1.374	0.503
Copper	Kruskal-Wallis	Dunn	11.59	0.009	Kruskal-Wallis	-	0.125	0.939
Lead	Kruskal-Wallis	Dunn	10.89	0.012	Kruskal-Wallis	-	1.201	0.549
Nickel	Kruskal-Wallis	Dunn	12.25	0.007	Kruskal-Wallis	-	1.899	0.387
Zinc	Kruskal-Wallis	Dunn	11.30	0.010	Kruskal-Wallis	-	0.549	0.760

Highlighted p values are statistically significant at alpha = 0.05.

Table 24. Total metals & nutrients - Post hoc tests detailed differences.

Factor	REGION (4 groups)	DISTANCE (3 groups)
Nitrogen	North > East, South, West	
Phosphorus	East, North > South, West	
Arsenic	West < East, North	100 m, 250 m < 1000 m
Chromium	West < East, South	
Copper	West < East, South	
Lead	West < East, North	
Nickel	West < East, North, South	
Zinc	West < East, North, South	

Table 25. Bioavailable metals – UNIVARIATE statistical tests results for region and distance.

Factor	REGION (4 groups)				DISTANCE (3 groups)			
	General test	Post-hoc test	Statistic value (H)	p-value	General test	Post-hoc test	Statistic value (H)	p-value
Arsenic	Kruskal-Wallis	-	5.190	0.158	Kruskal-Wallis	-	0.870	0.647
Chromium	Kruskal-Wallis	-	3.218	0.359	Kruskal-Wallis	-	5.347	0.069
Copper	Kruskal-Wallis	-	4.857	0.182	Kruskal-Wallis	Dunn	11.21	0.004
Lead	Kruskal-Wallis	-	3.264	0.353	Kruskal-Wallis	-	3.455	0.178
Nickel	Kruskal-Wallis	-	2.413	0.491	Kruskal-Wallis	Dunn	6.860	0.032
Zinc	Kruskal-Wallis	-	4.166	0.244	Kruskal-Wallis	-	5.089	0.078

Highlighted p values are statistically significant at alpha = 0.05.

Table 26. Bioavailable metals - Post hoc test detailed differences.

Factor	REGION (4 groups)	DISTANCE (3 groups)
Arsenic		
Chromium		
Copper		100 m > 1000 m
Lead		
Nickel		100 m > 1000 m
Zinc		

Table 27. Mud-adjusted metals – UNIVARIATE statistical tests results for region and distance.

Factor	REGION (4 groups)				DISTANCE (3 groups)			
	General test	Post-hoc test	Statistic value (H)	p-value	General test	Post-hoc test	Statistic value (H)	p-value
Arsenic	Kruskal-Wallis	Dunn	10.73	0.013	Kruskal-Wallis	Dunn	6.022	0.049
Chromium	Kruskal-Wallis	Dunn	13.11	0.004	Kruskal-Wallis	Dunn	7.221	0.027
Copper	Kruskal-Wallis	Dunn	13.25	0.004	Kruskal-Wallis	Dunn	8.410	0.014
Lead	Kruskal-Wallis	Dunn	15.22	0.001	Kruskal-Wallis	-	5.574	0.062
Nickel	Kruskal-Wallis	Dunn	11.95	0.007	Kruskal-Wallis	Dunn	8.410	0.015
Zinc	Kruskal-Wallis	Dunn	12.76	0.005	Kruskal-Wallis	Dunn	7.015	0.030

Highlighted p values are statistically significant at alpha = 0.05.

Table 28. Mud-adjusted metals - Post hoc tests detailed differences.

Factor	REGION (4 groups)	DISTANCE (3 groups)
Arsenic	North < South, West	100 m > 1000 m
Chromium	East, North < South, West	100 m > 1000 m
Copper	East, North < South, West	100 m > 1000 m
Lead	East, North < South, West	
Nickel	East, North < South, West	100 m > 1000 m
Zinc	East, North < South, West	100 m > 1000m

Appendix E Drop camera and Video transect analyses

Table 29. Coordinates of drop camera photographs with substrate and epibiota presence – 19 June 2025.

Site	Latitude (South)	Longitude (West)	Dominant Substrate	Complexity	Horse Mussel	Med. Fan worm	Scallops	Algae	Sponges	Ascidian Synoicum	Polychaete burrows
A01	36.59119458	174.8520275	Sediment	1	Absent	Absent	Absent	Absent	Absent	Absent	Absent
A02	36.59272229	174.8507268	Sed - low shell	1	Absent	Present	Absent	Absent	Absent	Absent	Absent
A03	36.59248425	174.8504187	Sediment	1	Absent	Absent	Absent	Absent	Absent	Absent	Absent
A04	36.59203302	174.8520163	Sediment	1	Absent	Absent	Absent	Absent	Absent	Absent	Absent
A05	36.5917693	174.8516292	Sediment	1	Absent	Absent	Absent	Absent	Absent	Absent	Absent
A06	36.59076323	174.8509095	Sediment	1	Absent	Absent	Absent	Absent	Absent	Absent	Absent
A07	36.59154735	174.8498685	Sediment	1	Absent	Absent	Absent	Absent	Absent	Absent	Absent
A08	36.59161209	174.8502949	Sediment	1	Absent	Absent	Absent	Absent	Absent	Absent	Absent
A09	36.59258779	174.8501644	Sediment	1	Absent	Absent	Absent	Absent	Absent	Absent	Absent
A10	36.59110692	174.8492756	Sediment	1	Absent	Present	Absent	Absent	Absent	Absent	Absent
A11	36.59207376	174.8475687	Sediment	1	Absent	Absent	Absent	Absent	Absent	Absent	Absent
A12	36.59282035	174.8497458	Sediment	1	Absent	Absent	Absent	Absent	Absent	Absent	Absent
A13	36.59187286	174.8477199	Sediment	1	Absent	Absent	Absent	Absent	Absent	Absent	Absent
A14	36.59364492	174.8484487	Sed - low shell	2	Absent	Absent	Absent	Absent	Absent	Absent	Absent
A15	36.5922299	174.8484447	Sediment	1	Absent	Absent	Absent	Absent	Absent	Absent	Absent
A16	36.59317132	174.8497775	Sediment	1	Absent	Absent	Absent	Absent	Absent	Absent	Absent
A17	36.5943016	174.8506123	Sediment	1	Absent	Absent	Absent	Absent	Absent	Absent	Absent
A18	36.59447689	174.8498568	Sed - low shell	3	Absent	Present	Absent	Absent	Present	Present	Absent
A19	36.59381703	174.8504876	Sediment	1	Absent	Absent	Absent	Absent	Absent	Absent	Absent
A20	36.59424915	174.8499961	Sed - low shell	3	Absent	Present	Absent	Absent	Absent	Present	Absent
A21	36.59371986	174.8519382	Sediment	1	Absent	Absent	Absent	Absent	Absent	Absent	Absent
A22	36.59319675	174.8503929	Sediment	1	Absent	Present	Absent	Absent	Absent	Absent	Absent
A23	36.59381195	174.8513035	Sed - low shell	2	Absent	Present	Absent	Absent	Present	Absent	Absent
A24	36.59357482	174.8514648	Sediment	1	Absent	Absent	Absent	Absent	Absent	Absent	Absent
A25	36.59402598	174.8519575	Sediment	1	Absent	Absent	Absent	Absent	Absent	Absent	Absent
B26	36.59121787	174.8527658	Sediment	1	Absent	Absent	Absent	Absent	Absent	Absent	Present
B27	36.59041252	174.8519061	Sediment	1	Absent	Absent	Absent	Absent	Absent	Absent	Present
B28	36.59244251	174.8543968	Sediment	1	Absent	Absent	Absent	Absent	Absent	Absent	Present
B29	36.59186788	174.8527049	Sediment	1	Absent	Absent	Absent	Absent	Absent	Absent	Present
B30	36.59057777	174.8517317	Sediment	1	Absent	Absent	Absent	Absent	Absent	Absent	Present
B31	36.5898339	174.8494395	Sediment	1	Absent	Absent	Absent	Absent	Absent	Absent	Present
B32	36.59025942	174.8498119	Sediment	1	Absent	Absent	Absent	Absent	Absent	Absent	Absent
B33	36.59087442	174.8470786	Sed - low shell	2	Absent	Absent	Absent	Absent	Absent	Absent	Absent
B34	36.58935143	174.8512408	Sediment	1	Absent	Absent	Absent	Absent	Absent	Absent	Present
B35	36.5898307	174.8469727	Sediment	1	Absent	Absent	Absent	Absent	Absent	Absent	Absent
B36	36.5915506	174.8467108	Sed - high shell	3	Absent	Absent	Absent	Absent	Present	Present	Absent
B37	36.59462562	174.8459374	Sed - high shell	3	Absent	Absent	Absent	Absent	Absent	Absent	Absent
B38	36.59252997	174.8451553	Sed - high shell	3	Absent	Absent	Absent	Absent	Absent	Absent	Absent
B39	36.59402874	174.8455303	Sed - high shell	3	Absent	Absent	Absent	Absent	Absent	Absent	Absent
B40	36.59308134	174.8466342	Sediment	1	Absent	Absent	Absent	Absent	Absent	Absent	Present
B41	36.59567315	174.8463452	Sed - high shell	3	Absent	Absent	Absent	Absent	Absent	Present	Absent
B42	36.59580311	174.8503057	Sediment	2	Absent	Present	Absent	Present	Absent	Present	Absent
B43	36.59621483	174.8504731	Sediment	1	Absent	Absent	Absent	Absent	Absent	Absent	Absent
B44	36.59566602	174.8488489	Sed - low shell	2	Absent	Present	Absent	Absent	Present	Present	Absent
B45	36.59523489	174.8508495	Sediment	1	Absent	Absent	Absent	Absent	Absent	Absent	Absent
B46	36.5961685	174.8515897	Sediment	1	Absent	Absent	Absent	Absent	Absent	Absent	Absent
B47	36.59507324	174.851337	Sediment	1	Absent	Absent	Absent	Absent	Absent	Absent	Absent
B48	36.5929558	174.8533821	Sediment	1	Absent	Absent	Absent	Absent	Absent	Absent	Present
B49	36.59452626	174.8548211	Sediment	1	Absent	Absent	Absent	Absent	Absent	Absent	Present
B50	36.59448319	174.8531433	Sediment	1	Absent	Absent	Absent	Absent	Absent	Absent	Absent

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C51	36.58686816	174.8525496	Sediment	1	Absent	Absent	Absent	Absent	Absent	Absent	Present
C52	36.58898991	174.8565068	Sediment	1	Absent	Absent	Absent	Absent	Absent	Absent	Absent
C53	36.5910849	174.8573226	Sediment	1	Absent	Absent	Absent	Absent	Absent	Absent	Present
C54	36.58871215	174.8527663	Sediment	1	Absent	Absent	Absent	Absent	Absent	Absent	Present
C55	36.5895172	174.8567667	Sediment	1	Absent	Absent	Absent	Absent	Absent	Absent	Present
C56	36.58820603	174.8518028	Sediment	1	Absent	Absent	Absent	Absent	Absent	Absent	Absent
C57	36.58784032	174.8515807	Sediment	1	Absent	Absent	Absent	Absent	Absent	Absent	Absent
C58	36.5885246	174.8484917	Sediment	1	Absent	Absent	Absent	Absent	Absent	Absent	Present
C59	36.58887973	174.8446227	Sed - high shell	3	Absent	Absent	Absent	Absent	Absent	Absent	Absent
C60	36.58716772	174.851384	Sediment	1	Absent	Absent	Absent	Absent	Absent	Absent	Present
C61	36.59553251	174.8424739	Reef	5	Absent	Absent	Absent	Present	Present	Absent	Absent
C62	36.59212007	174.8433113	Sed - high shell	3	Absent	Absent	Absent	Absent	Absent	Absent	Absent
C63	36.5941266	174.8440351	Sed - high shell	3	Absent	Absent	Absent	Absent	Absent	Absent	Absent
C64	36.59512559	174.8451682	Reef	5	Absent	Absent	Absent	Absent	Present	Present	Absent
C65	36.59609785	174.8447133	Sed - high shell	3	Absent	Absent	Absent	Absent	Absent	Absent	Absent
C66	36.5973414	174.8483903	Sed - high shell	3	Absent	Present	Absent	Absent	Absent	Present	Absent
C67	36.59873484	174.8475554	Shell Hash	3	Absent	Absent	Absent	Absent	Absent	Absent	Absent
C68	36.59872981	174.8499363	Sediment	1	Absent	Absent	Absent	Absent	Absent	Absent	Absent
C69	36.59832716	174.8492437	Sed - low shell	2	Absent	Present	Absent	Absent	Absent	Present	Absent
C70	36.59596765	174.8454699	Reef	5	Absent	Absent	Absent	Absent	Present	Present	Absent
C71	36.59774792	174.8535543	Sediment	1	Absent	Absent	Absent	Absent	Absent	Absent	Absent
C72	36.59353735	174.8583158	Sediment	1	Absent	Absent	Absent	Absent	Absent	Absent	Present
C73	36.59664558	174.8557941	Sediment	1	Absent	Absent	Absent	Absent	Absent	Absent	Present
C74	36.59340935	174.8558197	Sediment	1	Absent	Absent	Absent	Absent	Absent	Absent	Present
C75	36.5966175	174.8563747	Sediment	1	Absent	Absent	Absent	Absent	Absent	Absent	Present

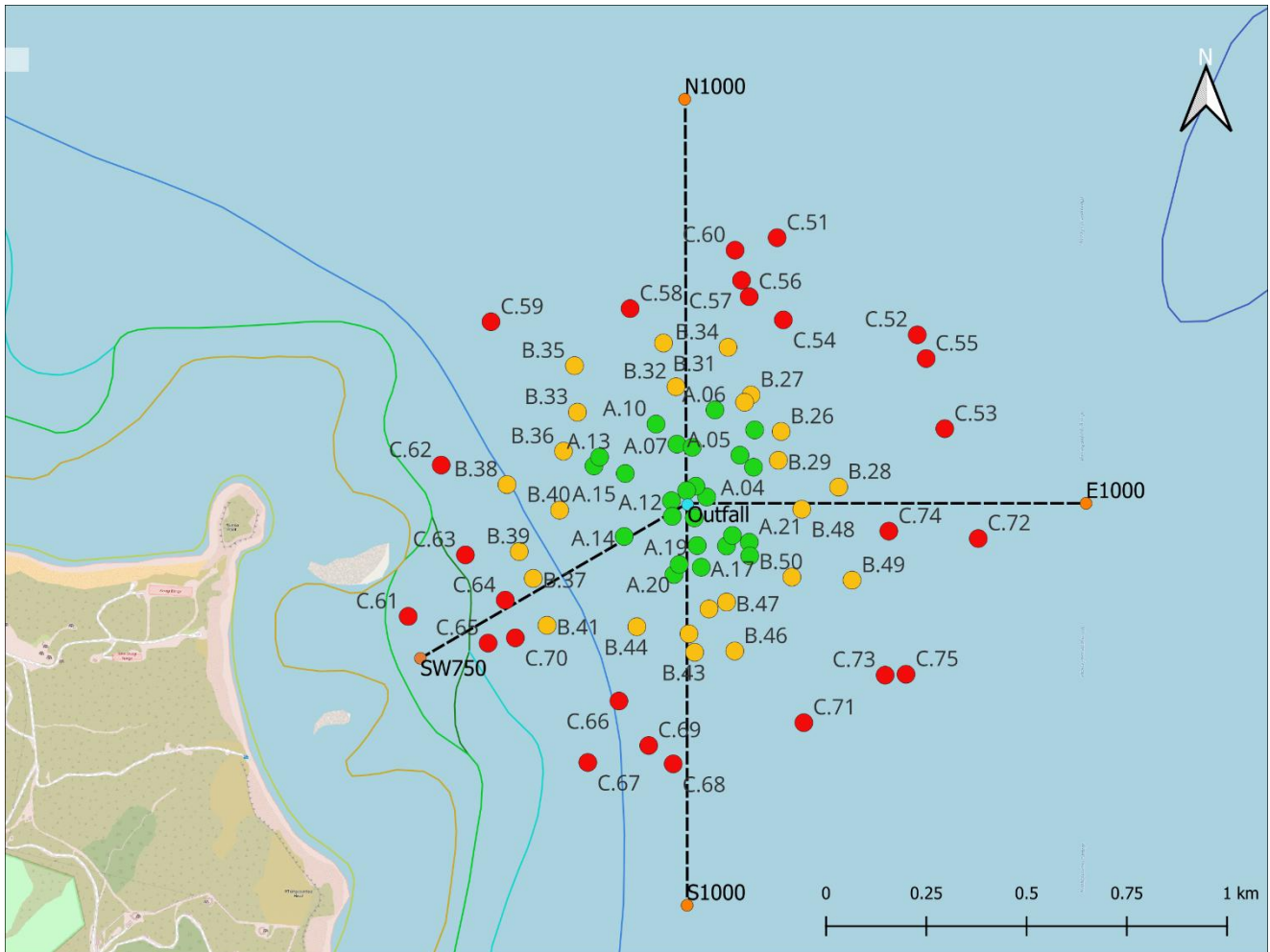


Figure 29. Location of 2025 drop camera stations.

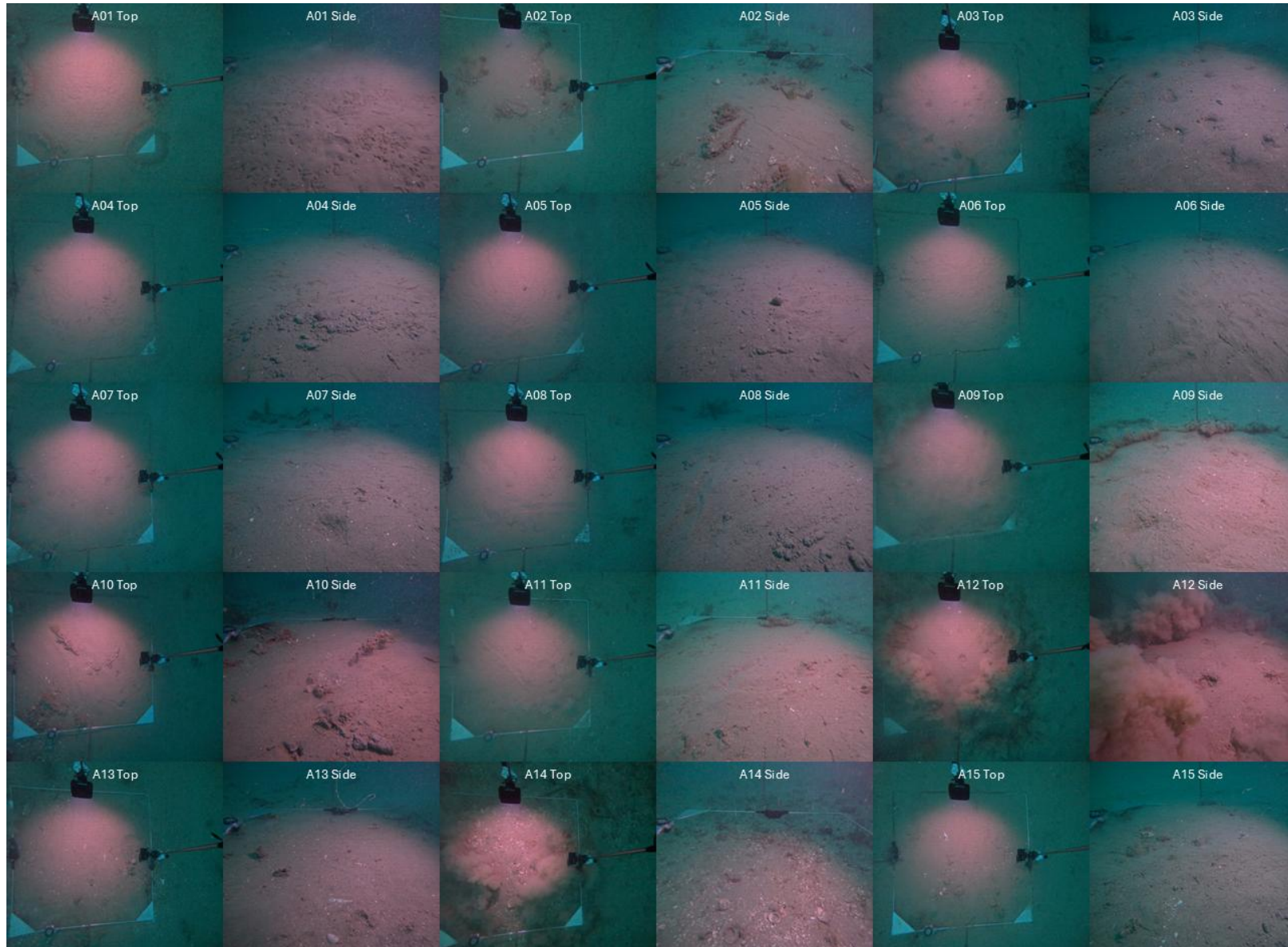


Figure 30. Photographs of the seabed at the drop camera stations A01 to A15.

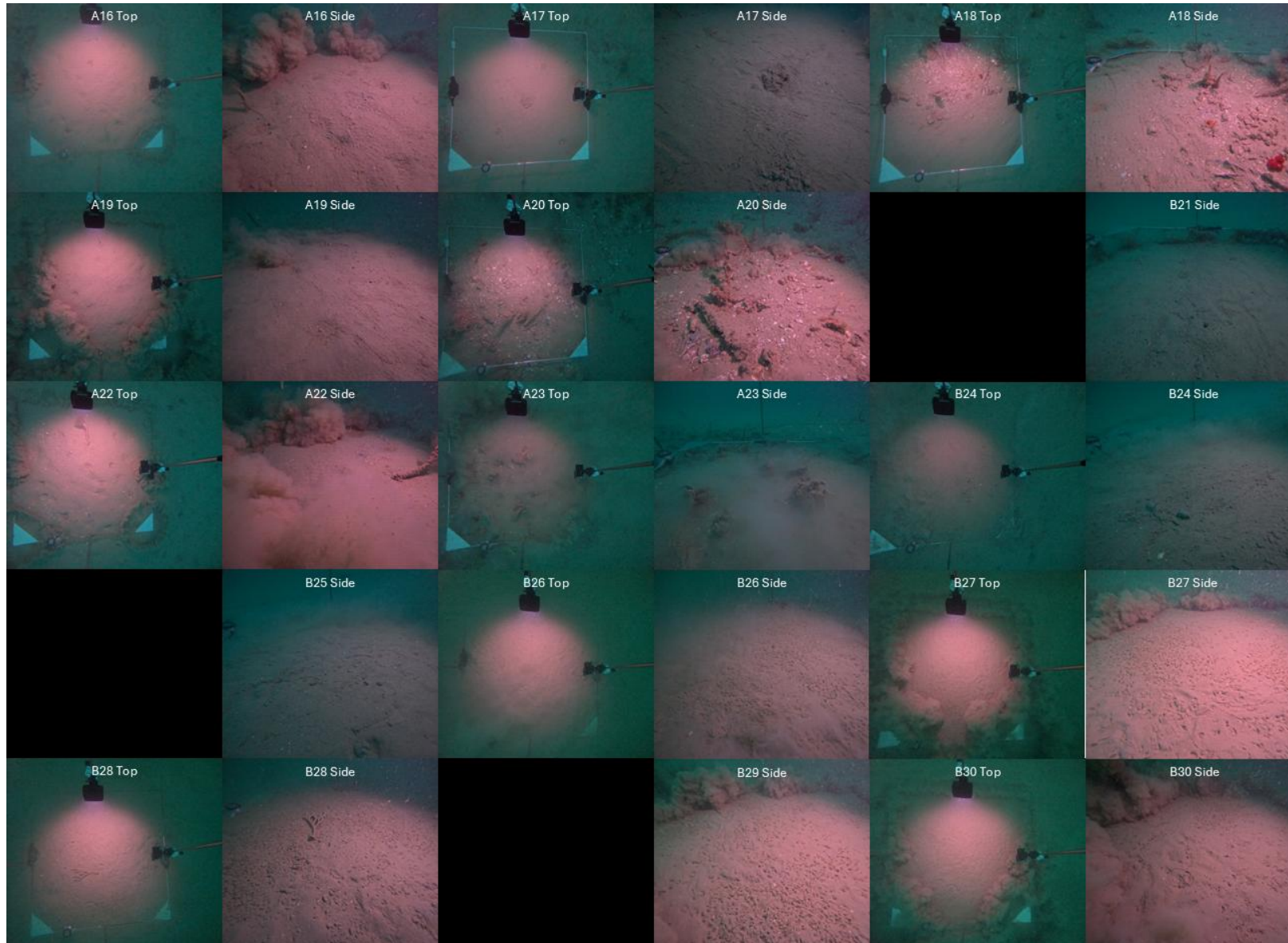


Figure 31. Photographs of the seabed at the drop camera stations A16 to B30.

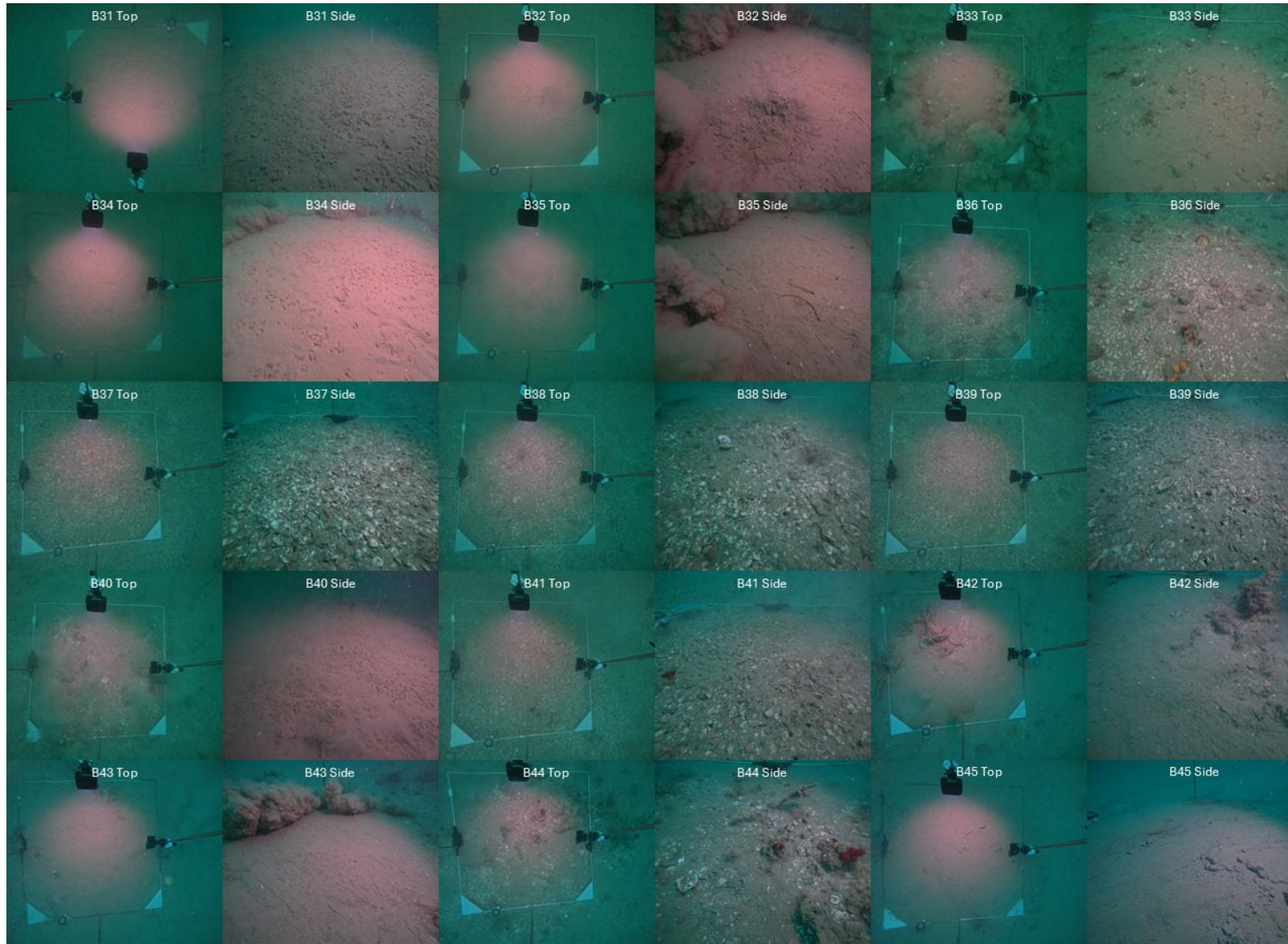


Figure 32. Photographs of the seabed at the drop camera stations B31 to B45.

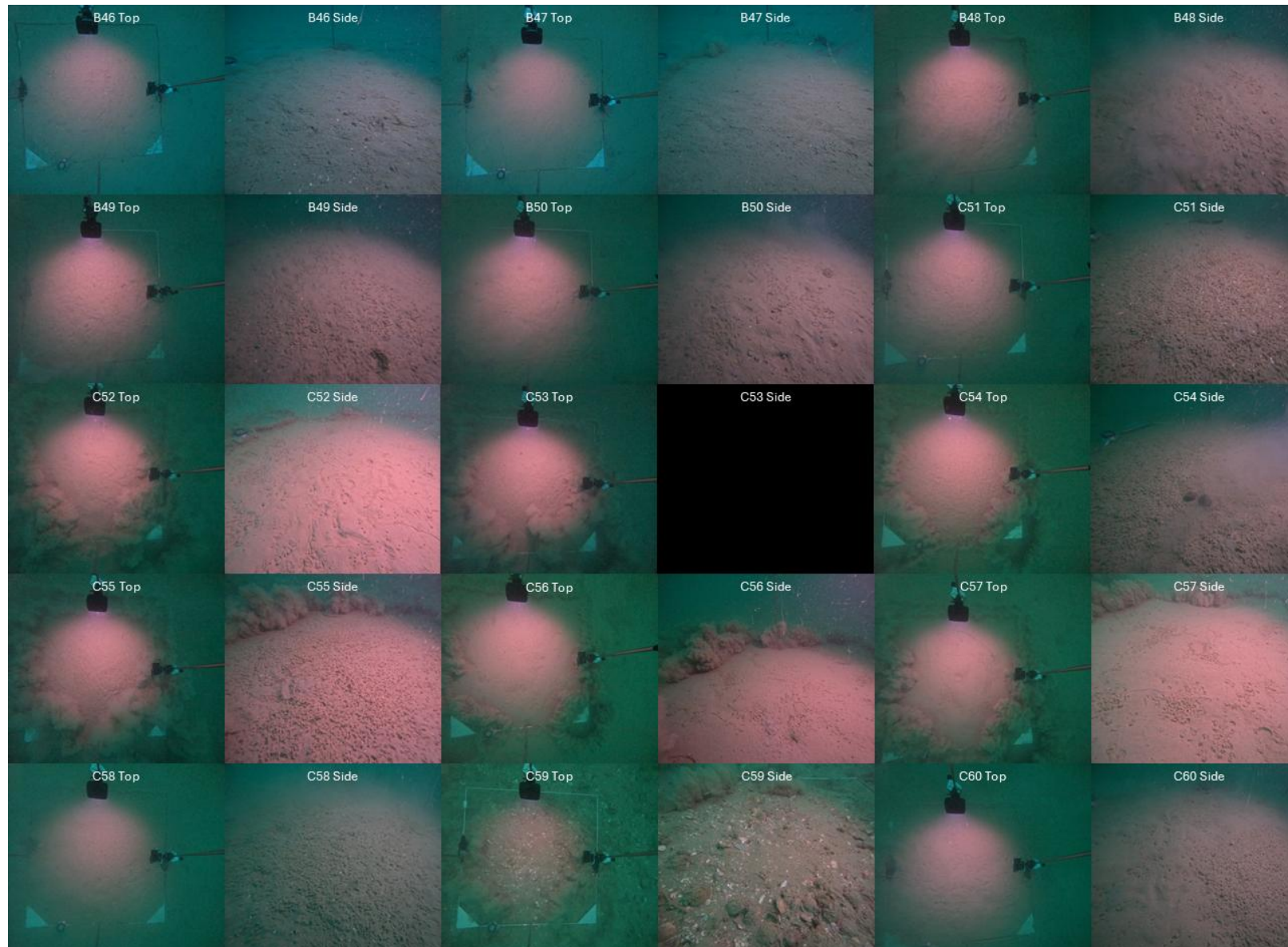


Figure 33. Photographs of the seabed at the drop camera stations B46 to C60.

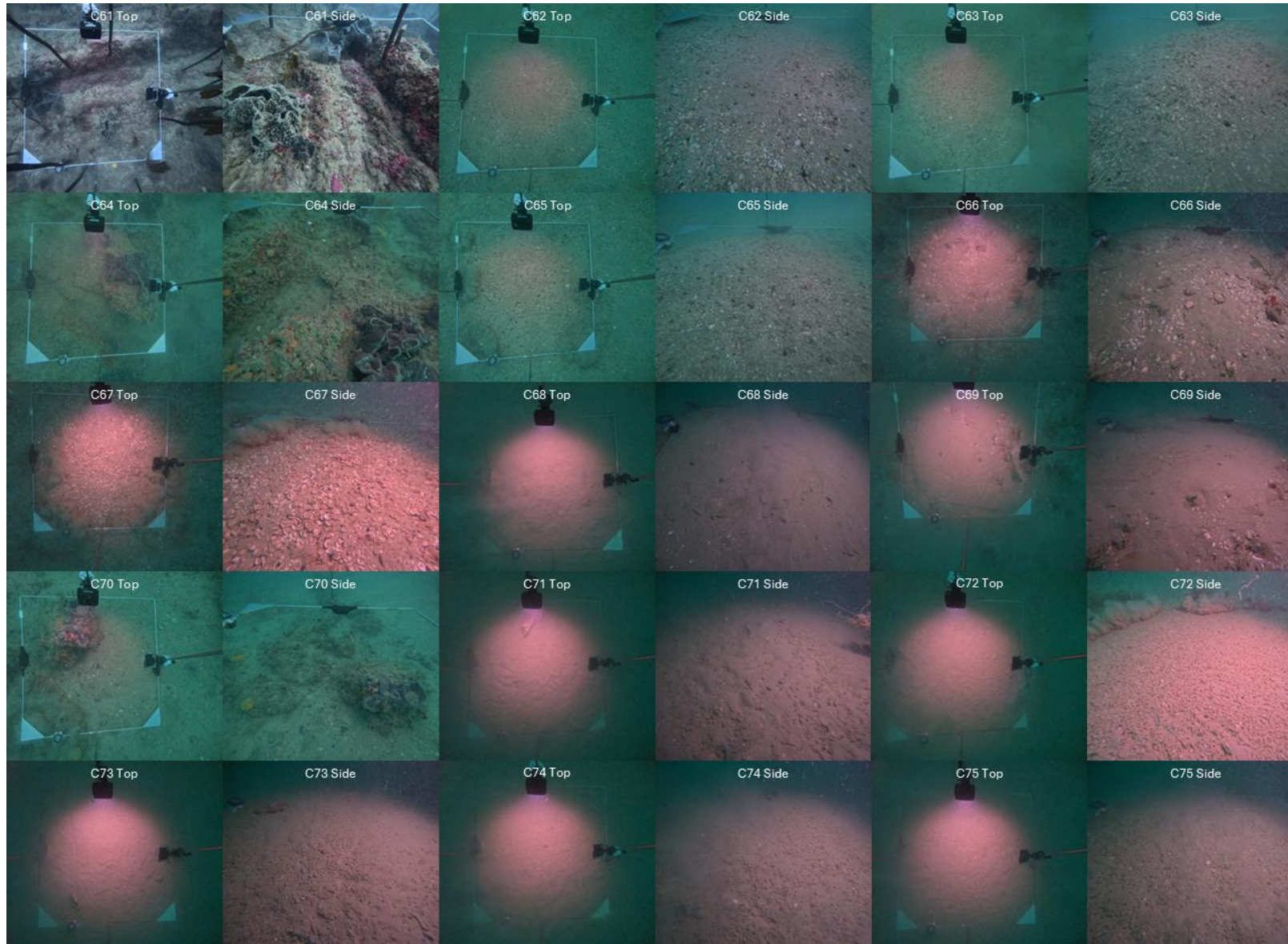


Figure 34. Photographs of the seabed at the drop camera stations C60 to C75.

Table 30 *Coordinates of epibiota detected during the video transects. Epibiota were recorded every 10m.*

Dive #	Diving Track	distance for each dive	Lat_DMS	Long_DMS	Substrate	Horse_Mussel	Sabella	Sponge	Polychaete
1	SW-track25	0	-36°35'32.624"	174°50'59.066"	Sediment	Absent	Absent	Absent	Absent
1	SW-track25	10	-36°35'32.940"	174°50'58.994"	Sediment	Present	Present	Absent	Absent
1	SW-track25	20	-36°35'33.207"	174°50'58.790"	Sed - low shell	Absent	Present	Absent	Absent
1	SW-track25	30	-36°35'33.356"	174°50'58.433"	Sed - low shell	Absent	Present	Absent	Absent
1	SW-track25	40	-36°35'33.493"	174°50'58.068"	Sed - low shell	Present	Present	Absent	Absent
1	SW-track25	50	-36°35'33.676"	174°50'57.738"	Sed - low shell	Absent	Present	Absent	Absent
1	SW-track25	60	-36°35'33.876"	174°50'57.422"	Sed - low shell	Absent	Present	Absent	Absent
1	SW-track25	70	-36°35'34.107"	174°50'57.142"	Sed - low shell	Absent	Present	Absent	Absent
1	SW-track25	80	-36°35'34.369"	174°50'56.907"	Sed - low shell	Absent	Present	Absent	Absent
1	SW-track25	90	-36°35'34.645"	174°50'56.697"	Sed - low shell	Absent	Present	Absent	Absent
1	SW-track25	100	-36°35'34.872"	174°50'56.410"	Sed - low shell	Present	Present	Present	Absent
1	SW-track25	110	-36°35'35.097"	174°50'56.120"	Sed - low shell	Present	Present	Absent	Absent
1	SW-track25	120	-36°35'35.323"	174°50'55.832"	Sed - low shell	Present	Present	Absent	Absent
1	SW-track25	130	-36°35'35.582"	174°50'55.588"	Sed - low shell	Absent	Present	Absent	Absent
1	SW-track25	140	-36°35'35.844"	174°50'55.352"	Sed - low shell	Absent	Present	Absent	Absent
1	SW-track25	150	-36°35'36.109"	174°50'55.121"	Sed - low shell	Absent	Present	Present	Absent
1	SW-track25	160	-36°35'36.364"	174°50'54.872"	Sed - low shell	Present	Present	Present	Absent
1	SW-track25	170	-36°35'36.609"	174°50'54.609"	Sed - low shell	Absent	Present	Absent	Absent
1	SW-track25	180	-36°35'36.828"	174°50'54.316"	Sed - high shell	Absent	Present	Present	Absent
1	SW-track25	190	-36°35'37.009"	174°50'53.983"	Sed - high shell	Absent	Present	Present	Absent
1	SW-track25	200	-36°35'37.238"	174°50'53.701"	Sed - high shell	Absent	Absent	Present	Absent
1	SW-track25	210	-36°35'37.484"	174°50'53.438"	Sed - low shell	Present	Present	Absent	Absent
1	SW-track25	220	-36°35'37.721"	174°50'53.164"	Sed - high shell	Present	Present	Absent	Absent
1	SW-track25	230	-36°35'37.950"	174°50'52.879"	Sed - high shell	Present	Present	Absent	Absent
1	SW-track25	240	-36°35'38.136"	174°50'52.552"	Sed - high shell	Present	Present	Absent	Absent
1	SW-track25	250	-36°35'38.307"	174°50'52.209"	Sed - high shell	Present	Present	Absent	Absent
1	SW-track25	260	-36°35'38.465"	174°50'51.858"	Sed - high shell	Present	Present	Absent	Absent
1	SW-track25	270	-36°35'38.622"	174°50'51.506"	Sed - high shell	Absent	Present	Present	Absent
1	SW-track25	280	-36°35'38.761"	174°50'51.143"	Sed - high shell	Absent	Present	Present	Absent
1	SW-track25	290	-36°35'38.902"	174°50'50.780"	Sed - high shell	Absent	Present	Absent	Absent
1	SW-track25	300	-36°35'39.066"	174°50'50.433"	Sed - high shell	Present	Present	Present	Absent
1	SW-track25	310	-36°35'39.231"	174°50'50.087"	Sed - high shell	Absent	Present	Present	Absent
1	SW-track25	320	-36°35'39.405"	174°50'49.747"	Sed - high shell	Absent	Present	Present	Absent
1	SW-track25	330	-36°35'39.574"	174°50'49.404"	Sed - high shell	Absent	Present	Present	Absent
1	SW-track25	340	-36°35'39.741"	174°50'49.059"	Sed - high shell	Absent	Present	Absent	Absent
1	SW-track25	350	-36°35'39.907"	174°50'48.713"	Sed - high shell	Absent	Present	Present	Absent
1	SW-track25	360	-36°35'40.089"	174°50'48.381"	Shell hash	Absent	Absent	Absent	Absent
1	SW-track25	370	-36°35'40.280"	174°50'48.055"	Shell hash	Absent	Absent	Absent	Absent
1	SW-track25	380	-36°35'40.487"	174°50'47.747"	Shell hash	Absent	Present	Present	Absent
1	SW-track25	390	-36°35'40.708"	174°50'47.452"	Shell hash	Absent	Present	Absent	Absent
1	SW-track25	400	-36°35'40.904"	174°50'47.133"	Shell hash	Absent	Present	Absent	Absent
1	SW-track25	410	-36°35'41.084"	174°50'46.799"	Shell hash	Absent	Present	Absent	Absent
1	SW-track25	420	-36°35'41.230"	174°50'46.441"	Shell hash	Absent	Absent	Present	Absent
1	SW-track25	430	-36°35'41.351"	174°50'46.068"	Sed - high shell	Absent	Absent	Present	Absent
1	SW-track25	440	-36°35'41.435"	174°50'45.680"	Sed - high shell	Absent	Absent	Present	Absent
1	SW-track25	450	-36°35'41.532"	174°50'45.296"	Reef	Absent	Absent	Present	Absent
1	SW-track25	460	-36°35'41.635"	174°50'44.915"	Sed - low shell	Absent	Absent	Absent	Absent
1	SW-track25	470	-36°35'41.751"	174°50'44.541"	Reef	Absent	Absent	Present	Absent
1	SW-track25	480	-36°35'41.963"	174°50'44.237"	Reef	Absent	Absent	Present	Absent
1	SW-track25	490	-36°35'42.176"	174°50'43.933"	Sed - low shell	Absent	Absent	Absent	Absent

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1	SW-track25	500	-36°35'42.375"	174°50'43.615"	Sed - low shell	Absent	Absent	Absent	Absent
1	SW-track25	510	-36°35'42.574"	174°50'43.298"	Reef	Absent	Absent	Present	Absent
1	SW-track25	520	-36°35'42.799"	174°50'43.007"	Reef	Absent	Present	Present	Absent
1	SW-track25	530	-36°35'43.015"	174°50'42.708"	Sed - low shell	Absent	Absent	Absent	Absent
1	SW-track25	540	-36°35'43.198"	174°50'42.376"	Reef	Absent	Present	Present	Absent
2	South-track25	0	-36°36'6.187"	174°51'1.066"	Sed - low shell	Present	Present	Absent	Absent
2	South-track25	10	-36°36'5.865"	174°51'1.090"	Sed - low shell	Present	Present	Absent	Absent
2	South-track25	20	-36°36'5.543"	174°51'1.131"	Sed - low shell	Present	Present	Absent	Absent
2	South-track25	30	-36°36'5.220"	174°51'1.168"	Sed - low shell	Present	Present	Absent	Absent
2	South-track25	40	-36°36'4.896"	174°51'1.163"	Sed - low shell	Absent	Absent	Absent	Absent
2	South-track25	50	-36°36'4.573"	174°51'1.136"	Sed - low shell	Present	Present	Absent	Absent
2	South-track25	60	-36°36'4.249"	174°51'1.108"	Sed - low shell	Present	Present	Absent	Absent
2	South-track25	70	-36°36'3.925"	174°51'1.080"	Sed - low shell	Present	Present	Absent	Absent
2	South-track25	80	-36°36'3.601"	174°51'1.069"	Sed - low shell	Present	Present	Absent	Absent
2	South-track25	90	-36°36'3.277"	174°51'1.062"	Sed - low shell	Present	Present	Absent	Absent
2	South-track25	100	-36°36'2.973"	174°51'1.179"	Sed - low shell	Present	Present	Absent	Absent
2	South-track25	110	-36°36'2.667"	174°51'1.308"	Sed - low shell	Present	Present	Absent	Absent
2	South-track25	120	-36°36'2.354"	174°51'1.414"	Sed - low shell	Present	Present	Absent	Absent
2	South-track25	130	-36°36'2.039"	174°51'1.510"	Sed - low shell	Present	Present	Absent	Absent
2	South-track25	140	-36°36'1.722"	174°51'1.597"	Sed - low shell	Present	Present	Absent	Absent
2	South-track25	150	-36°36'1.403"	174°51'1.668"	Sed - low shell	Present	Present	Absent	Absent
2	South-track25	160	-36°36'1.083"	174°51'1.717"	Sed - low shell	Present	Present	Absent	Absent
2	South-track25	170	-36°36'0.759"	174°51'1.687"	Sed - low shell	Present	Present	Absent	Absent
2	South-track25	180	-36°36'0.448"	174°51'1.583"	Sed - low shell	Present	Present	Absent	Absent
2	South-track25	190	-36°36'0.140"	174°51'1.456"	Sed - low shell	Present	Present	Absent	Absent
2	South-track25	200	-36°35'59.821"	174°51'1.378"	Sed - low shell	Present	Present	Absent	Absent
2	South-track25	210	-36°35'59.503"	174°51'1.300"	Sed - low shell	Present	Present	Absent	Absent
2	South-track25	220	-36°35'59.181"	174°51'1.347"	Sed - low shell	Absent	Present	Absent	Absent
2	South-track25	230	-36°35'58.859"	174°51'1.396"	Sed - low shell	Absent	Present	Absent	Absent
2	South-track25	240	-36°35'58.538"	174°51'1.453"	Sed - low shell	Absent	Present	Absent	Absent
2	South-track25	250	-36°35'58.217"	174°51'1.512"	Sed - low shell	Absent	Present	Absent	Absent
2	South-track25	260	-36°35'57.906"	174°51'1.629"	Sed - low shell	Absent	Present	Absent	Absent
2	South-track25	270	-36°35'57.596"	174°51'1.746"	Sed - low shell	Absent	Present	Absent	Absent
2	South-track25	280	-36°35'57.272"	174°51'1.743"	Sed - low shell	Absent	Present	Absent	Absent
2	South-track25	290	-36°35'56.951"	174°51'1.709"	Sed - low shell	Absent	Present	Absent	Absent
2	South-track25	300	-36°35'56.639"	174°51'1.599"	Sed - low shell	Absent	Present	Absent	Absent
2	South-track25	310	-36°35'56.325"	174°51'1.497"	Sed - low shell	Absent	Present	Absent	Absent
2	South-track25	320	-36°35'56.009"	174°51'1.406"	Sed - low shell	Absent	Present	Absent	Absent
2	South-track25	330	-36°35'55.695"	174°51'1.307"	Sed - low shell	Absent	Present	Absent	Absent
2	South-track25	340	-36°35'55.379"	174°51'1.214"	Sed - low shell	Absent	Present	Absent	Absent
2	South-track25	350	-36°35'55.057"	174°51'1.172"	Sed - low shell	Absent	Present	Absent	Absent
2	South-track25	360	-36°35'54.733"	174°51'1.143"	Sed - low shell	Absent	Present	Present	Absent
2	South-track25	370	-36°35'54.409"	174°51'1.143"	Sed - low shell	Present	Present	Present	Absent
2	South-track25	380	-36°35'54.085"	174°51'1.138"	Sed - low shell	Absent	Present	Absent	Absent
2	South-track25	390	-36°35'53.760"	174°51'1.126"	Sed - low shell	Absent	Present	Absent	Absent
2	South-track25	400	-36°35'53.438"	174°51'1.089"	Sed - low shell	Absent	Present	Absent	Absent
2	South-track25	410	-36°35'53.115"	174°51'1.042"	Sed - low shell	Absent	Present	Absent	Absent
2	South-track25	420	-36°35'52.792"	174°51'1.017"	Sed - low shell	Absent	Present	Absent	Absent
2	South-track25	430	-36°35'52.468"	174°51'0.993"	Sed - low shell	Absent	Present	Absent	Absent
2	South-track25	440	-36°35'52.144"	174°51'0.975"	Sed - low shell	Absent	Present	Absent	Absent
2	South-track25	450	-36°35'51.820"	174°51'0.946"	Sed - low shell	Absent	Present	Absent	Absent
2	South-track25	460	-36°35'51.498"	174°51'0.902"	Sed - low shell	Absent	Present	Absent	Absent
2	South-track25	470	-36°35'51.174"	174°51'0.879"	Sed - low shell	Absent	Present	Absent	Absent
2	South-track25	480	-36°35'50.850"	174°51'0.861"	Sed - low shell	Absent	Present	Absent	Absent
2	South-track25	490	-36°35'50.526"	174°51'0.877"	Sed - low shell	Absent	Present	Absent	Absent
2	South-track25	500	-36°35'50.202"	174°51'0.903"	Sed - low shell	Absent	Present	Absent	Absent
2	South-track25	510	-36°35'49.879"	174°51'0.937"	Sed - low shell	Absent	Present	Absent	Absent
2	South-track25	520	-36°35'49.556"	174°51'0.974"	Sed - low shell	Absent	Present	Absent	Absent
2	South-track25	530	-36°35'49.234"	174°51'1.027"	Sed - low shell	Absent	Present	Absent	Absent
2	South-track25	540	-36°35'48.913"	174°51'1.083"	Sed - low shell	Absent	Present	Absent	Absent

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2	South-track25	550	-36°35'48.595"	174°51'1.161"	Sed - low shell	Absent	Present	Absent	Absent
2	South-track25	560	-36°35'48.277"	174°51'1.240"	Sed - low shell	Absent	Present	Absent	Absent
2	South-track25	570	-36°35'47.954"	174°51'1.268"	Sed - low shell	Absent	Present	Absent	Absent
2	South-track25	580	-36°35'47.630"	174°51'1.270"	Sed - low shell	Absent	Present	Absent	Absent
2	South-track25	590	-36°35'47.305"	174°51'1.263"	Sed - low shell	Absent	Present	Absent	Absent
2	South-track25	600	-36°35'46.981"	174°51'1.252"	Sed - low shell	Absent	Present	Absent	Absent
2	South-track25	610	-36°35'46.657"	174°51'1.238"	Sed - low shell	Absent	Present	Absent	Absent
2	South-track25	620	-36°35'46.335"	174°51'1.190"	Sed - low shell	Absent	Present	Absent	Absent
2	South-track25	630	-36°35'46.013"	174°51'1.142"	Sed - low shell	Absent	Present	Absent	Absent
2	South-track25	640	-36°35'45.691"	174°51'1.088"	Sed - low shell	Absent	Present	Absent	Absent
2	South-track25	650	-36°35'45.370"	174°51'1.034"	Sed - low shell	Absent	Present	Absent	Absent
2	South-track25	660	-36°35'45.046"	174°51'1.018"	Sed - low shell	Absent	Present	Absent	Absent
2	South-track25	670	-36°35'44.721"	174°51'1.010"	Sed - low shell	Absent	Present	Absent	Absent
2	South-track25	680	-36°35'44.397"	174°51'1.015"	Sed - low shell	Absent	Present	Absent	Absent
2	South-track25	690	-36°35'44.073"	174°51'1.023"	Sed - low shell	Absent	Present	Absent	Absent
2	South-track25	700	-36°35'43.750"	174°51'1.059"	Sed - low shell	Absent	Present	Present	Absent
2	South-track25	710	-36°35'43.426"	174°51'1.087"	Sed - low shell	Absent	Present	Absent	Absent
2	South-track25	720	-36°35'43.102"	174°51'1.093"	Sed - low shell	Absent	Present	Absent	Absent
2	South-track25	730	-36°35'42.778"	174°51'1.109"	Sed - low shell	Absent	Present	Absent	Absent
2	South-track25	740	-36°35'42.456"	174°51'1.164"	Sed - low shell	Absent	Present	Absent	Absent
3	SNorth-track25	0	-36°35'41.362"	174°51'0.557"	Sed - low shell	Absent	Present	Absent	Absent
3	SNorth-track25	10	-36°35'41.044"	174°51'0.486"	Sed - low shell	Absent	Present	Absent	Absent
3	SNorth-track25	20	-36°35'40.721"	174°51'0.444"	Sed - low shell	Absent	Present	Absent	Absent
3	SNorth-track25	30	-36°35'40.397"	174°51'0.431"	Sed - low shell	Absent	Present	Absent	Absent
3	SNorth-track25	40	-36°35'40.080"	174°51'0.494"	Sed - low shell	Present	Present	Absent	Absent
3	SNorth-track25	50	-36°35'39.769"	174°51'0.607"	Sed - low shell	Present	Present	Absent	Absent
3	SNorth-track25	60	-36°35'39.452"	174°51'0.682"	Sed - low shell	Present	Present	Absent	Absent
3	SNorth-track25	70	-36°35'39.128"	174°51'0.705"	Sed - low shell	Present	Present	Absent	Absent
3	SNorth-track25	80	-36°35'38.804"	174°51'0.728"	Sed - low shell	Present	Present	Absent	Absent
3	SNorth-track25	90	-36°35'38.501"	174°51'0.867"	Sed - low shell	Present	Present	Absent	Absent
3	SNorth-track25	100	-36°35'38.196"	174°51'1.000"	Sed - low shell	Present	Present	Absent	Absent
3	SNorth-track25	110	-36°35'37.877"	174°51'1.069"	Sed - low shell	Present	Present	Absent	Absent
3	SNorth-track25	120	-36°35'37.556"	174°51'1.107"	Sed - low shell	Present	Present	Absent	Absent
3	SNorth-track25	130	-36°35'37.233"	174°51'1.071"	Sed - low shell	Present	Present	Absent	Absent
3	SNorth-track25	140	-36°35'36.910"	174°51'1.034"	Sed - low shell	Present	Present	Absent	Absent
3	SNorth-track25	150	-36°35'36.588"	174°51'0.985"	Sed - low shell	Present	Present	Absent	Absent
3	SNorth-track25	160	-36°35'36.266"	174°51'0.936"	Sed - low shell	Absent	Present	Absent	Absent
3	SNorth-track25	170	-36°35'35.952"	174°51'0.839"	Sed - low shell	Absent	Present	Absent	Absent
3	SNorth-track25	180	-36°35'35.640"	174°51'0.726"	Sed - low shell	Absent	Present	Absent	Absent
3	SNorth-track25	190	-36°35'35.329"	174°51'0.613"	Sed - low shell	Absent	Present	Absent	Absent
3	SNorth-track25	200	-36°35'35.019"	174°51'0.493"	Sed - low shell	Absent	Present	Absent	Absent
3	SNorth-track25	210	-36°35'34.710"	174°51'0.373"	Sed - low shell	Absent	Present	Absent	Absent
3	SNorth-track25	220	-36°35'34.396"	174°51'0.287"	Sed - high shell	Absent	Present	Absent	Absent
3	SNorth-track25	230	-36°35'34.071"	174°51'0.280"	Sed - high shell	Absent	Present	Absent	Absent
3	SNorth-track25	240	-36°35'33.747"	174°51'0.269"	Sed - low shell	Absent	Present	Absent	Absent
3	SNorth-track25	250	-36°35'33.425"	174°51'0.221"	Sediment	Absent	Present	Absent	Absent
3	SNorth-track25	260	-36°35'33.102"	174°51'0.187"	Sediment	Absent	Absent	Present	Absent
3	SNorth-track25	270	-36°35'32.778"	174°51'0.174"	Sediment	Absent	Absent	Absent	Absent
3	SNorth-track25	280	-36°35'32.453"	174°51'0.161"	Sediment	Absent	Absent	Absent	Absent
3	SNorth-track25	290	-36°35'32.129"	174°51'0.146"	Sediment	Absent	Absent	Absent	Absent
3	SNorth-track25	300	-36°35'31.805"	174°51'0.131"	Sediment	Absent	Absent	Absent	Absent
3	SNorth-track25	310	-36°35'31.481"	174°51'0.149"	Sediment	Absent	Absent	Absent	Absent
3	SNorth-track25	320	-36°35'31.157"	174°51'0.170"	Sediment	Present	Absent	Absent	Absent
3	SNorth-track25	330	-36°35'30.833"	174°51'0.191"	Sediment	Present	Absent	Absent	Absent
3	SNorth-track25	340	-36°35'30.509"	174°51'0.212"	Sed - low shell	Present	Present	Absent	Absent
3	SNorth-track25	350	-36°35'30.185"	174°51'0.204"	Sed - low shell	Present	Present	Absent	Absent
3	SNorth-track25	360	-36°35'29.862"	174°51'0.168"	Sediment	Present	Present	Absent	Absent
3	SNorth-track25	370	-36°35'29.540"	174°51'0.126"	Sediment	Present	Present	Absent	Absent
3	SNorth-track25	380	-36°35'29.218"	174°51'0.074"	Sediment	Absent	Present	Absent	Absent
3	SNorth-track25	390	-36°35'28.896"	174°51'0.022"	Sediment	Absent	Present	Absent	Absent

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3	SNorth-track25	400	-36°35'28.572"	174°51'0.000"	Sediment	Absent	Present	Absent	Absent
3	SNorth-track25	410	-36°35'28.248"	174°50'59.979"	Sediment	Absent	Present	Absent	Absent
3	SNorth-track25	420	-36°35'27.928"	174°51'0.007"	Sediment	Absent	Present	Absent	Absent
3	SNorth-track25	430	-36°35'27.611"	174°51'0.095"	Sediment	Absent	Present	Absent	Absent
3	SNorth-track25	440	-36°35'27.292"	174°51'0.170"	Sediment	Absent	Absent	Absent	Absent
3	SNorth-track25	450	-36°35'26.972"	174°51'0.232"	Sediment	Absent	Absent	Absent	Absent
3	SNorth-track25	460	-36°35'26.650"	174°51'0.275"	Sediment	Absent	Absent	Absent	Absent
3	SNorth-track25	470	-36°35'26.326"	174°51'0.294"	Sediment	Absent	Absent	Absent	Absent
3	SNorth-track25	480	-36°35'26.002"	174°51'0.303"	Sediment	Absent	Present	Absent	Absent
3	SNorth-track25	490	-36°35'25.677"	174°51'0.294"	Sediment	Absent	Absent	Absent	Absent
3	SNorth-track25	500	-36°35'25.353"	174°51'0.291"	Sediment	Absent	Absent	Absent	Absent
3	SNorth-track25	510	-36°35'25.029"	174°51'0.312"	Sediment	Absent	Present	Absent	Absent
3	SNorth-track25	520	-36°35'24.705"	174°51'0.325"	Sediment	Present	Present	Absent	Absent
3	SNorth-track25	530	-36°35'24.380"	174°51'0.318"	Sediment	Absent	Present	Absent	Absent
3	SNorth-track25	540	-36°35'24.056"	174°51'0.305"	Sediment	Absent	Present	Absent	Absent
3	SNorth-track25	550	-36°35'23.736"	174°51'0.245"	Sediment	Absent	Absent	Absent	Absent
3	SNorth-track25	560	-36°35'23.415"	174°51'0.185"	Sediment	Absent	Absent	Absent	Absent
3	SNorth-track25	570	-36°35'23.091"	174°51'0.165"	Sediment	Absent	Absent	Absent	Absent
3	SNorth-track25	580	-36°35'22.767"	174°51'0.158"	Sediment	Absent	Absent	Absent	Absent
3	SNorth-track25	590	-36°35'22.442"	174°51'0.155"	Sediment	Absent	Absent	Absent	Absent
3	SNorth-track25	600	-36°35'22.118"	174°51'0.167"	Sediment	Absent	Absent	Absent	Present
3	SNorth-track25	610	-36°35'21.794"	174°51'0.187"	Sediment	Absent	Absent	Absent	Present
3	SNorth-track25	620	-36°35'21.470"	174°51'0.203"	Sediment	Absent	Absent	Absent	Present
3	SNorth-track25	630	-36°35'21.146"	174°51'0.219"	Sediment	Absent	Absent	Absent	Present
3	SNorth-track25	640	-36°35'20.822"	174°51'0.208"	Sediment	Absent	Absent	Absent	Present
3	SNorth-track25	650	-36°35'20.497"	174°51'0.199"	Sediment	Absent	Present	Absent	Present
3	SNorth-track25	660	-36°35'20.173"	174°51'0.213"	Sediment	Absent	Absent	Absent	Present
3	SNorth-track25	670	-36°35'19.849"	174°51'0.226"	Sediment	Absent	Absent	Absent	Present
3	SNorth-track25	680	-36°35'19.526"	174°51'0.259"	Sediment	Absent	Absent	Absent	Present
3	SNorth-track25	690	-36°35'19.203"	174°51'0.296"	Sediment	Absent	Absent	Absent	Present
3	SNorth-track25	700	-36°35'18.879"	174°51'0.283"	Sediment	Absent	Absent	Absent	Present
3	SNorth-track25	710	-36°35'18.555"	174°51'0.263"	Sediment	Absent	Absent	Absent	Present
3	SNorth-track25	720	-36°35'18.231"	174°51'0.244"	Sediment	Absent	Absent	Absent	Present
3	SNorth-track25	730	-36°35'17.907"	174°51'0.226"	Sediment	Absent	Absent	Absent	Present
3	SNorth-track25	740	-36°35'17.582"	174°51'0.206"	Sediment	Absent	Absent	Absent	Present
3	SNorth-track25	750	-36°35'17.258"	174°51'0.207"	Sediment	Absent	Absent	Absent	Present
3	SNorth-track25	760	-36°35'16.934"	174°51'0.220"	Sediment	Absent	Absent	Absent	Present
4	East-track25	0	-36°35'33.891"	174°51'0.297"	Sed - high shell	Absent	Absent	Present	Absent
4	East-track25	10	-36°35'33.908"	174°51'0.697"	Sed - high shell	Absent	Present	Absent	Absent
4	East-track25	20	-36°35'33.730"	174°51'0.974"	Sed - low shell	Present	Present	Present	Absent
4	East-track25	30	-36°35'33.672"	174°51'1.369"	Sediment	Present	Present	Present	Absent
4	East-track25	40	-36°35'33.705"	174°51'1.749"	Sediment	Present	Present	Present	Absent
4	East-track25	50	-36°35'33.848"	174°51'2.110"	Sediment	Present	Present	Present	Absent
4	East-track25	60	-36°35'33.992"	174°51'2.471"	Sediment	Absent	Absent	Absent	Absent
4	East-track25	70	-36°35'34.135"	174°51'2.832"	Sediment	Absent	Absent	Absent	Absent
4	East-track25	80	-36°35'34.197"	174°51'3.220"	Sediment	Absent	Present	Absent	Absent
4	East-track25	90	-36°35'34.218"	174°51'3.621"	Sediment	Present	Present	Present	Absent
4	East-track25	100	-36°35'34.239"	174°51'4.023"	Sediment	Absent	Absent	Absent	Absent
4	East-track25	110	-36°35'34.260"	174°51'4.424"	Sediment	Absent	Absent	Absent	Absent
4	East-track25	120	-36°35'34.304"	174°51'4.822"	Sediment	Absent	Absent	Absent	Absent
4	East-track25	130	-36°35'34.369"	174°51'5.216"	Sediment	Absent	Absent	Absent	Absent
4	East-track25	140	-36°35'34.401"	174°51'5.614"	Sediment	Absent	Absent	Absent	Absent
4	East-track25	150	-36°35'34.404"	174°51'6.017"	Sediment	Absent	Absent	Absent	Absent
4	East-track25	160	-36°35'34.391"	174°51'6.417"	Sediment	Absent	Absent	Absent	Absent
4	East-track25	170	-36°35'34.333"	174°51'6.813"	Sediment	Absent	Absent	Absent	Absent
4	East-track25	180	-36°35'34.275"	174°51'7.209"	Sediment	Absent	Absent	Absent	Absent
4	East-track25	190	-36°35'34.232"	174°51'7.607"	Sediment	Absent	Absent	Absent	Present
4	East-track25	200	-36°35'34.194"	174°51'8.007"	Sediment	Absent	Absent	Absent	Present
4	East-track25	210	-36°35'34.170"	174°51'8.408"	Sediment	Absent	Absent	Absent	Present
4	East-track25	220	-36°35'34.157"	174°51'8.810"	Sediment	Absent	Absent	Absent	Present

Environmental Monitoring of the Benthos in the Whangaparāoa Passage (Autumn 2025)

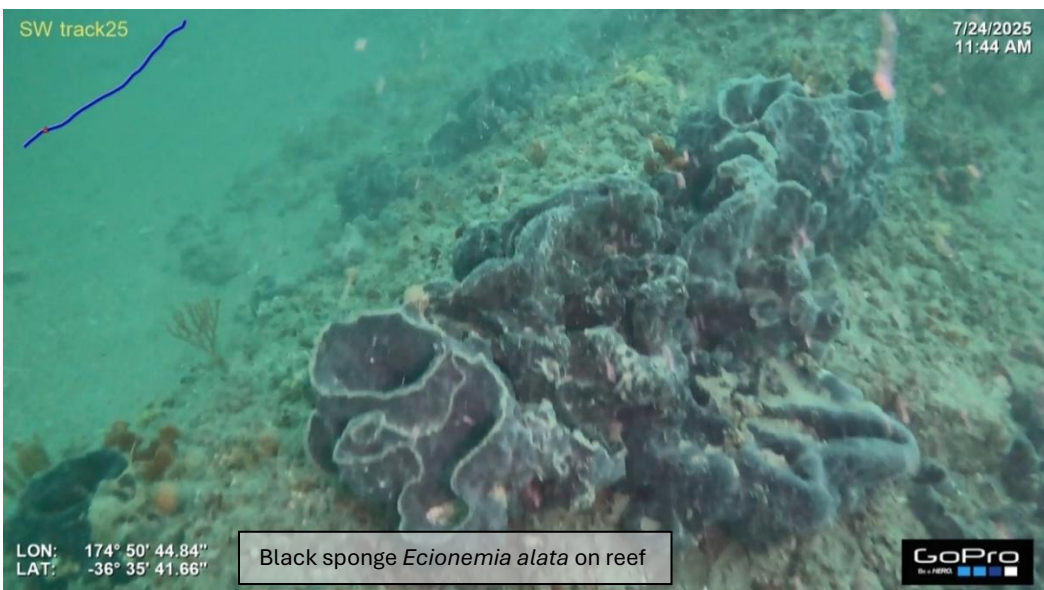
4	East-track25	230	-36°35'34.145"	174°51'9.212"	Sediment	Absent	Absent	Absent	Present
4	East-track25	240	-36°35'34.139"	174°51'9.614"	Sediment	Absent	Absent	Absent	Present
4	East-track25	250	-36°35'34.138"	174°51'10.017"	Sediment	Absent	Present	Absent	Present
4	East-track25	260	-36°35'34.137"	174°51'10.419"	Sediment	Absent	Absent	Absent	Present
4	East-track25	270	-36°35'34.139"	174°51'10.821"	Sediment	Absent	Present	Absent	Present
4	East-track25	280	-36°35'34.141"	174°51'11.224"	Sediment	Absent	Present	Absent	Present
4	East-track25	290	-36°35'34.141"	174°51'11.626"	Sediment	Absent	Absent	Absent	Present
4	East-track25	300	-36°35'34.141"	174°51'12.028"	Sediment	Absent	Absent	Absent	Present
4	East-track25	310	-36°35'34.155"	174°51'12.430"	Sediment	Absent	Absent	Absent	Present
4	East-track25	320	-36°35'34.173"	174°51'12.832"	Sediment	Absent	Absent	Absent	Present
4	East-track25	330	-36°35'34.191"	174°51'13.233"	Sediment	Absent	Absent	Absent	Present
4	East-track25	340	-36°35'34.208"	174°51'13.635"	Sediment	Absent	Absent	Absent	Present
4	East-track25	350	-36°35'34.224"	174°51'14.037"	Sediment	Absent	Absent	Absent	Present
4	East-track25	360	-36°35'34.234"	174°51'14.439"	Sediment	Absent	Present	Absent	Present
4	East-track25	370	-36°35'34.244"	174°51'14.841"	Sediment	Absent	Absent	Absent	Present
4	East-track25	380	-36°35'34.239"	174°51'15.244"	Sediment	Absent	Absent	Absent	Present
4	East-track25	390	-36°35'34.231"	174°51'15.646"	Sediment	Absent	Absent	Absent	Present
4	East-track25	400	-36°35'34.217"	174°51'16.048"	Sediment	Absent	Present	Absent	Present
4	East-track25	410	-36°35'34.197"	174°51'16.449"	Sediment	Absent	Absent	Absent	Present
4	East-track25	420	-36°35'34.179"	174°51'16.851"	Sediment	Absent	Absent	Absent	Present
4	East-track25	430	-36°35'34.189"	174°51'17.253"	Sediment	Absent	Absent	Absent	Present
4	East-track25	440	-36°35'34.200"	174°51'17.655"	Sediment	Absent	Present	Absent	Present
4	East-track25	450	-36°35'34.222"	174°51'18.056"	Sediment	Absent	Absent	Absent	Present
4	East-track25	460	-36°35'34.269"	174°51'18.454"	Sediment	Absent	Absent	Absent	Present
4	East-track25	470	-36°35'34.315"	174°51'18.852"	Sediment	Absent	Absent	Absent	Present
4	East-track25	480	-36°35'34.300"	174°51'19.253"	Sediment	Absent	Absent	Absent	Present
4	East-track25	490	-36°35'34.279"	174°51'19.655"	Sediment	Absent	Absent	Absent	Present
4	East-track25	500	-36°35'34.238"	174°51'20.054"	Sediment	Absent	Absent	Absent	Present
4	East-track25	510	-36°35'34.193"	174°51'20.452"	Sediment	Absent	Absent	Absent	Present
4	East-track25	520	-36°35'34.155"	174°51'20.852"	Sediment	Absent	Absent	Absent	Present
4	East-track25	530	-36°35'34.123"	174°51'21.252"	Sediment	Absent	Absent	Absent	Present
4	East-track25	540	-36°35'34.091"	174°51'21.652"	Sediment	Absent	Absent	Absent	Present

Note: The transects were recorded in this order: 1. SW transect from the outfall to 540m (reef starting); 2. Southern transect from S1000 going north towards the outfall for 740m (dive time limitation); 3. South-North transect going north from the end point of transect 2, passing the outfall, towards N1000 for 760m (dive time limitation); 4. Eastern track from the outfall going East towards E1000 for 540m (depth limitation of 27m).

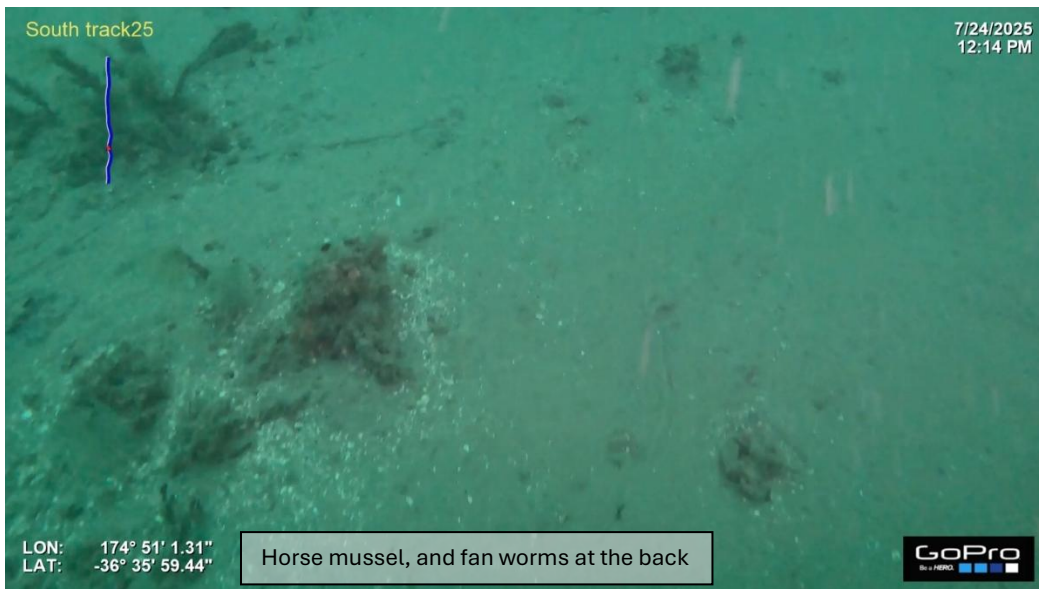
Table 31 Snapshots of video footage showing some examples of epibiota features – July 2025

1. SW track

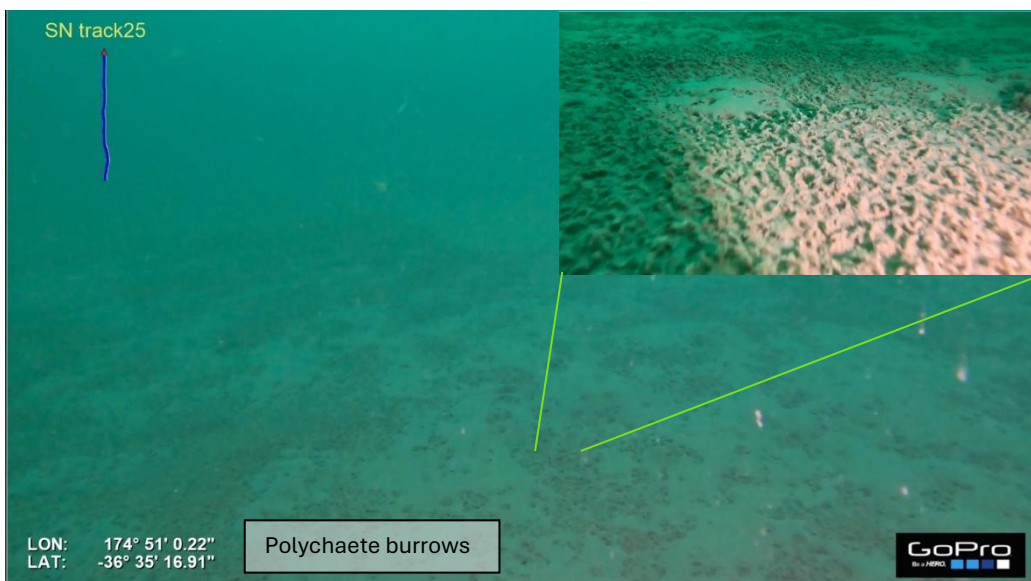
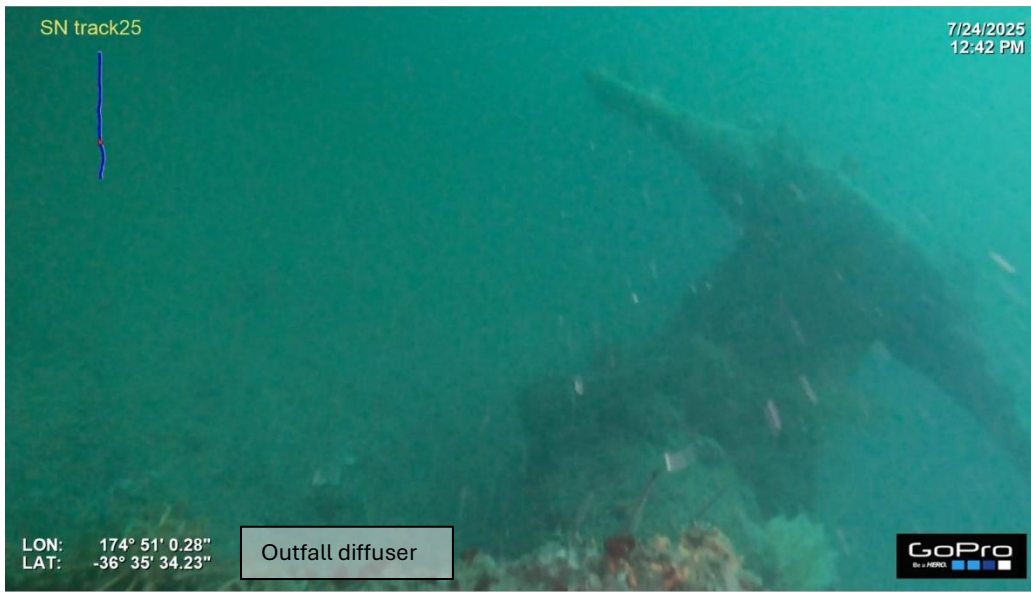




2. South track



3. South-North track



Appendix G Statistical tests on benthic biota

Table 34. Univariate statistical tests results on diversity measures for region and distance.

Factor	REGION (4 groups)				DISTANCE (3 groups)			
	General test	Post-hoc test	Statistic value (H)	p-value	General test	Post-hoc test	Statistic value (H)	p-value
S	Kruskal-Wallis	Dunn	13.20	0.004	Kruskal-Wallis	-	4.207	0.122
N	Kruskal-Wallis	Dunn	18.23	0.0004	Kruskal-Wallis	-	3.561	0.169
d	Kruskal-Wallis	Dunn	13.52	0.004	Kruskal-Wallis	Dunn	8.975	0.011
J'	Kruskal-Wallis	Dunn	13.34	0.004	Kruskal-Wallis	Dunn	10.22	0.006

Highlighted p values are statistically significant at alpha = 0.05.

Table 35. Post hoc tests on diversity measures.

Factor	REGION (4 groups)	DISTANCE (3 groups)
S	West > East, South	-
N	South < East, North, West	-
d	West > East, North, South	250 m > 1000 m
J'	South > East, North	100 m, 250 m > 1000 m

Benthic biota matrix – Multivariate statistical tests results for region and distance

ANOSIM test for differences between unordered **Region** groups

Sample statistic (R): 0.385

Significance level of sample statistic: 0.01% (p-value: 0.0001)

Table 36. Benthic biota - Pairwise Tests for differences between unordered REGION groups.

Groups	R Statistic	Significance level %	p-value	Possible permutations	Actual permutations	Number ≥ observed
EAST, NORTH	0.129	0.2	0.0023	Very large	9999	22
EAST, SOUTH	0.236	0.01	0.0001	Very large	9999	0
EAST, WEST	0.832	0.01	0.0001	86493225	9999	0
NORTH, SOUTH	0.218	0.03	0.0003	Very large	9999	2
NORTH, WEST	0.724	0.01	0.0001	86493225	9999	0
SOUTH, WEST	0.442	0.01	0.0001	86493225	9999	0

Highlighted p values are statistically significant at alpha = 0.05.

ANOSIM test for differences between unordered **Distance** groups

Sample statistic (R): 0.127

Significance level of sample statistic: 0.03% (p-value: 0.0003)

Table 37. Benthic biota - Pairwise Tests for differences between unordered DISTANCE groups.

Groups	R Statistic	Significance level %	p-value	Possible permutations	Actual permutations	Number ≥ observed
100m, 250m	0.022	16.7	0.1674	Very large	9999	1673
100m, 1000m	0.228	0.05	0.0005	Very large	9999	4
250m, 1000m	0.155	0.4	0.0037	Very large	9999	36

Highlighted p values are statistically significant at alpha = 0.05.

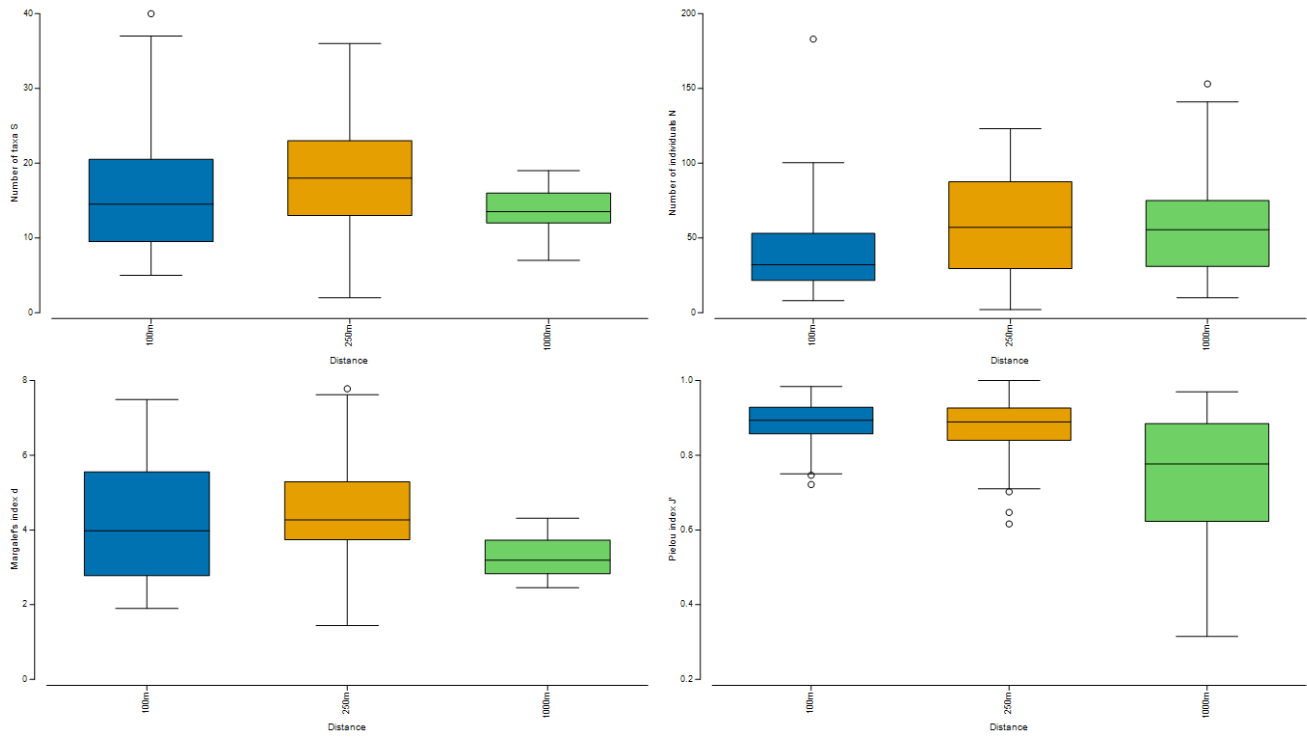
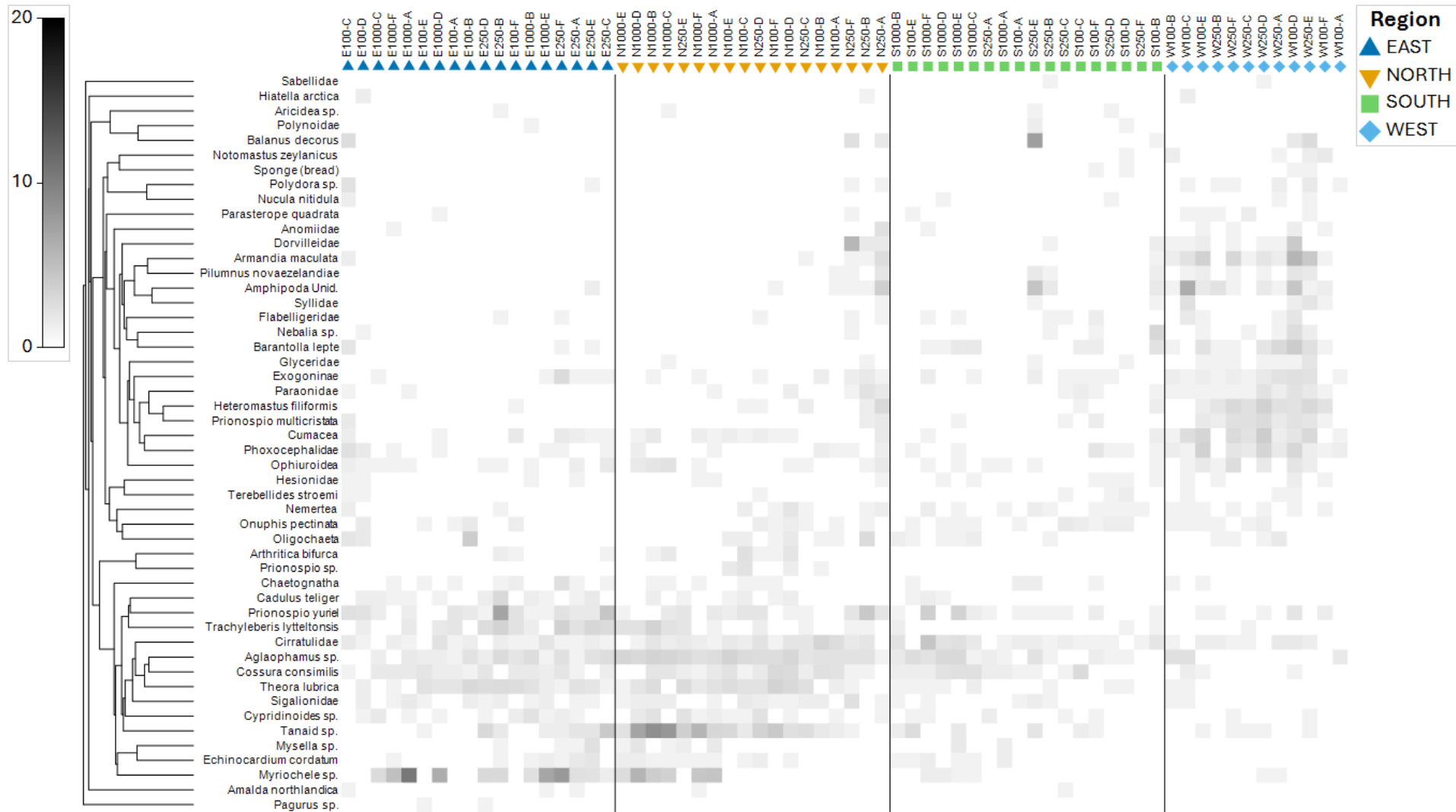


Figure 35. Diversity measures (box plots) for benthic locations grouped by distance.

Appendix H Benthic biota matrix organised by taxa similarities



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