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Fine Scale Intertidal Monitoring of Blueskin Bay

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Prepared by

Barrie Forrest,
Keryn Roberts
and Leigh Stevens

for

Otago Regional Council

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barrie@saltecology.co.nz, +64 (0)27 627 4631

www.saltecology.co.nz

GLOSSARY

AMBI	AZTI Marine Biotic Index
ANZECC	Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2000)
ANZG	Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2018)
aRPD	Apparent Redox Potential Discontinuity
As	Arsenic
Cd	Cadmium
Cr	Chromium
Cu	Copper
DGV	Default Guideline Value
ETI	Estuary Trophic Index
Hg	Mercury
NCC	Otago Regional Council
NEMP	National Estuary Monitoring Protocol
Ni	Nickel
Pb	Lead
SACFOR	Epibiota categories of Super abundant, Abundant, Common, Frequent, Occasional, Rare
SOE	State of Environment (monitoring)
TN	Total nitrogen
TOC	Total Organic Carbon
TP	Total phosphorus
Zn	Zinc

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BACKGROUND

As part of its State of the Environment (SOE) programme, Otago Regional Council monitors the ecological condition of significant estuaries in its region. This report describes the first of three planned annual baseline ecological monitoring and sedimentation surveys in Blueskin Bay, which was conducted in January 2021. The survey largely followed the 'fine scale' approach described in New Zealand's National Estuary Monitoring Protocol (NEMP), with 'sediment plates' installed at the time of the survey to enable future sedimentation monitoring. Results are assessed against condition rating criteria for estuary heath in the Table below.

KEY FINDINGS

- Sediment quality for most variables was rated as 'good' or 'very good' (see Table). The survey revealed that both sites consisted of sand-dominated sediments with very low concentrations of organic carbon, total nitrogen, and contaminants.
- Site B (to the south of the estuary) was more enriched than the centrally located Site A (see aRPD in Table below), and had elevated phosphorus concentrations. However, there were no symptoms of eutrophication, such as a black, anoxic and sulphide-smelling sediment, and no excessive surface growths of opportunistic macroalgae.
- The high sediment quality at the fine scale sites was reflected in the diverse and abundant macrofauna present. Compared to other estuaries in the Otago SOE programme, Blueskin Bay stands out as clearly having the greatest macrofaunal richness and some of the highest abundances.
- In other Otago SOE estuaries, high macrofaunal abundances tend to be a symptom of a degraded or harsh physical environment, with hardier disturbance-tolerant species proliferating in what are typically species-poor assemblages. By contrast, the species-rich assemblages in Blueskin Bay are dominated by a variety of taxa, and both sites were characterised by a range of organisms generally considered to be sensitive to displacement due to habitat disturbance.

Overall, the main tidal flats of Blueskin Bay are in a healthy condition. This situation has persisted despite historic modification of estuary's margins, loss of salt marsh, and catchment land-use changes that have increased the threat from muddy sediment inputs. Future threats should be managed so that the current healthy state of the estuary is maintained.

RECOMMENDATIONS

It is recommended that the two further surveys are completed. Together with data gathered from changes in sediment plate depth, the work will provide a comprehensive baseline for the long-term monitoring of ecological health in Blueskin Bay.

Summary of scores of estuary condition based on values of key indicators

Site	Zone	Mud %	TOC %	TN mg/kg	aRPD mm	As mg/kg	Cd mg/kg	Cr mg/kg	Cu mg/kg	Hg mg/kg	Ni mg/kg	Pb mg/kg	Zn mg/kg	AMBI na
A	X	5.6	0.11	< 500	11	1.9	< 0.010	4.1	0.9	< 0.02	2.6	0.9	9.0	2.1
	Y	5.1	0.15	< 500	14	2.1	< 0.010	4.2	1.0	< 0.02	2.5	1.4	8.5	1.7
	Z	4.2	0.14	< 500	13	2.1	< 0.010	4.1	0.8	< 0.02	2.4	1.0	7.8	1.9
B	X	5.0	0.11	< 500	22	2.9	< 0.010	6.9	1.0	< 0.02	5.8	1.2	11.4	2.1
	Y	5.6	0.11	< 500	28	3.0	< 0.010	7.0	1.0	< 0.02	5.3	1.2	11.5	2.2
	Z	6.5	0.13	< 500	28	3.2	< 0.010	7.5	1.2	< 0.02	6.2	1.4	12.1	2.3

< All values below lab detection limit

Condition rating key:

Very Good	Good	Fair	Poor

1. INTRODUCTION

Monitoring the ecological condition of estuarine habitats is critical to their management. Estuary monitoring is undertaken by most councils in New Zealand as part of their State of the Environment (SOE) programmes. The most widely-used monitoring framework is that outlined in New Zealand's National Estuary Monitoring Protocol (NEMP; Robertson et al. 2002). The NEMP is intended to provide resource managers nationally with a scientifically defensible, cost-effective and standardised approach for monitoring the ecological status of estuaries in their region. The results establish a benchmark of estuarine health in order to better understand human influences, and against which future comparisons can be made. The NEMP approach involves two main types of survey:

- Broad scale mapping of estuarine intertidal habitats. This type of monitoring is typically undertaken every 5 to 10 years.
- Fine scale monitoring of estuarine biota and sediment quality. This type of monitoring is typically conducted at intervals of 5 years after initially establishing a baseline.

One of the key additional methods that has been put in place subsequent to the NEMP being developed is 'sediment plate' monitoring. This component typically involves an annual assessment of patterns of sediment accretion and erosion in estuaries, based on changes in sediment depth over buried concrete pavers. Sediment plate monitoring stations are often established at NEMP fine scale sites, or nearby. In addition to providing information on patterns of sediment accretion and erosion, sediment plate monitoring aids interpretation of physical and biological changes at fine scale sites.

Monitoring of selected estuaries in the Otago region has been undertaken using the above methods for several years, with locations including Shag River, Waikouaiti, Kaikorai, Tokomairiro and Catlins estuaries. ORC is expanding its estuary monitoring programme and in January 2021 added Blueskin Bay, a large estuary to the north of Dunedin (Fig. 1). For this purpose, Salt Ecology undertook a NEMP broad scale habitat mapping and fine scale survey in parallel in January 2021, and installed sediment plates for future sedimentation monitoring.

This report describes the methods and results of the fine scale and sediment plate components, with the broad scale work described by Roberts et al. (2021). Results of the present survey are discussed in the context of existing knowledge of Blueskin Bay (e.g. from Otago University studies) and in relation to various criteria for assessing estuary health. The current survey is intended as the first of three consecutive annual baseline surveys of Blueskin Bay using the fine scale and sediment plate approach.

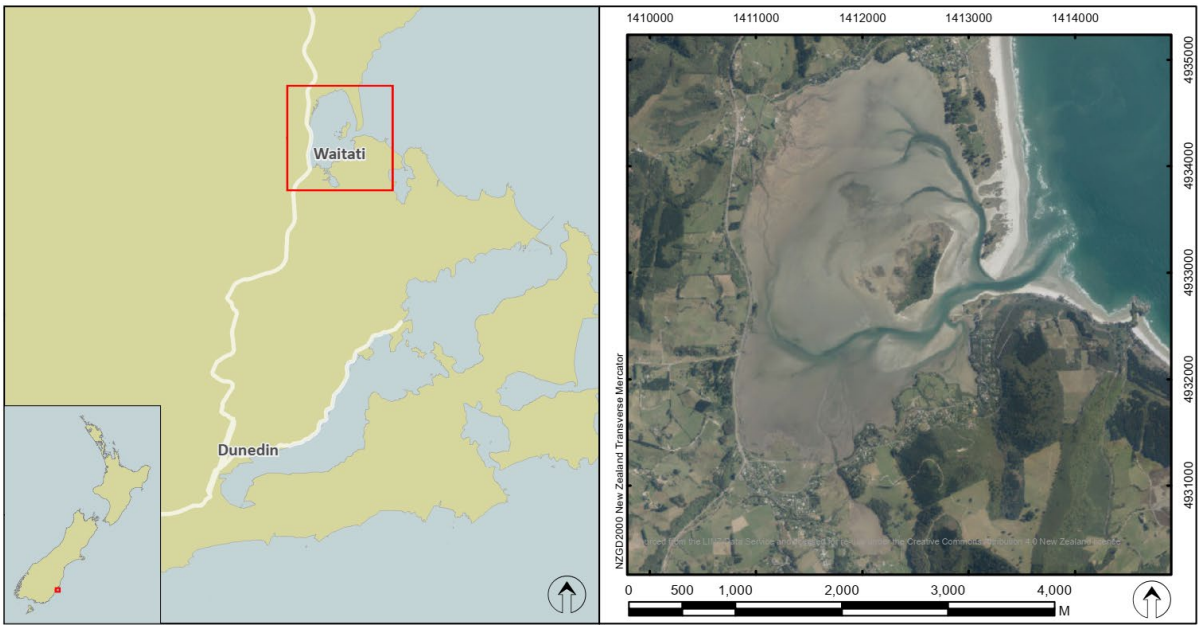


Fig. 1. Location of Blueskin Bay.

2. BACKGROUND TO BLUESKIN BAY

The following background information on Blueskin Bay has been updated from Roberts et al. (2021) and incorporates the findings of the broad scale habitat mapping survey described in that report.

Blueskin Bay is a large (690ha) shallow, intertidally dominated, tidal lagoon type estuary (SIDE) located approximately 25km north of Dunedin. The estuary mouth at the south end is permanently open to the sea and the main body is protected from the open ocean by a sandspit (see Fig. 1). The estuary is well flushed with the majority of tidal water exchanged with the ocean on each tidal cycle (Zhang 2018; O'Connell-Milne et al. 2020).

At low tide, 91% of the estuary is exposed, revealing habitats consisting of firm sand-dominated sediments (437ha). Mud-dominated sediments (>50% mud) are a minor component, with only 25.2ha (3.7% of the intertidal area) mapped by Roberts et al. (2021), which were recorded in localised areas of freshwater inflow, salt marsh, and in Orokonui Inlet at the south end.

Macroalgae are widespread across parts of Blueskin Bay but, to our knowledge, nuisance blooms of opportunistic species have not been reported. Roberts et al. (2021) recorded two localised patches (0.6ha or 0.1% of the intertidal area) of sediment-entrained *Agarophyton chilense* (formerly known as *Gracilaria chilensis*) near channels in the north-west corner of the estuary. These areas comprised patches of >90% cover, a high biomass (>1kg/m^2), and associated eutrophic sediments (high mud content and low sediment oxygenation).

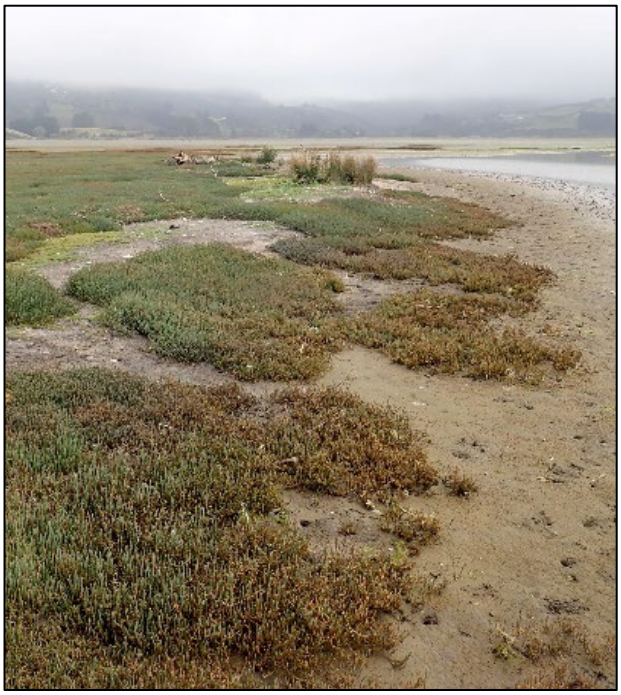
Extensive seagrass (*Zostera muelleri*) beds are a dominant feature of the central intertidal flats, with 33.5ha (5.2% of the intertidal area) mapped by Roberts et al. (2021). That report attributed the extensive seagrass to the low sediment and nutrient input to the estuary, strong flushing, and high water clarity.

The lower estuary supports occasional dredge oysters (*Tiostrea chilensis*) and a healthy supply of cockles (*Austrovenus stutchburyi*). Roberts et al. (2021) mapped a total of 30.8ha (4.9% of the intertidal area) of cockle beds and shell banks, and there is recreational, customary and commercial fishing of cockles in the Bay. Several studies have demonstrated that coastal phytoplankton is a primary food source for these filter feeders, highlighting the important interaction between estuaries and open coastal waters (Kainamu 2010; Zhang 2018; O'Connell-Milne et al. 2020).

Around the margins of the estuary, the area of salt marsh measured in 2021 was 35.4ha, representing 5.7% of the intertidal area and comprising 54.1% herbfield. Historically salt marsh would have been more extensive, with losses resulting from urban and infrastructure development on the estuary margins for rail, roading and the settlements of Warrington and Waitati.

Like many estuaries, Blueskin Bay is regarded as an important habitat for nesting birds and a nursery for fish. Overall, Blueskin Bay is considered to have high ecological, cultural and social values. As such, both Blueskin Bay and Orokonui Inlet are within coastal protection areas in the 'Otago Regional Plan: Coast', for their Kai Tahu cultural and spiritual values, in addition to their estuarine values.

The high values of Blueskin Bay can be attributed, in part, to ~62% of the catchment being densely vegetated (Fig. 2), and having low freshwater inputs with flows from Waitati River (south) and Careys Creek (northwest) (mean freshwater flow 0.8m^3/s) contributing only a small portion of the total estuary volume. However, the lower catchment is dominated by high-producing pasture (28% of the catchment area), which is a potential source of muddy sediment and nutrients.



Salt marsh herbfield, Blueskin Bay

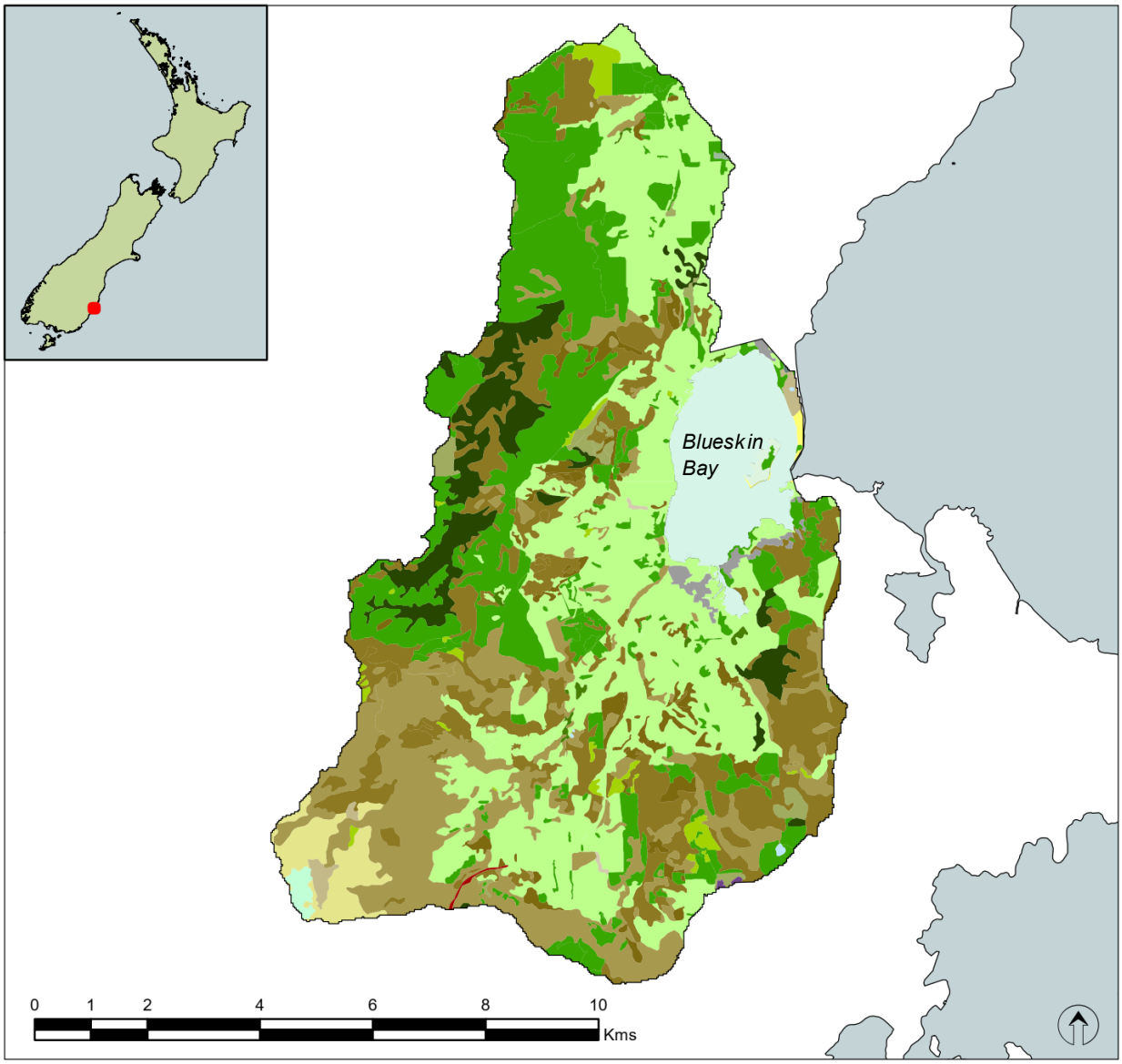


Fig. 2. Blueskin Bay and surrounding catchment land use classifications from LCDB5 (2017/18) database.

3. FINE SCALE METHODS

3.1 OVERVIEW OF NEMP FINE SCALE APPROACH

Mapping the main habitats in an estuary using the NEMP broad scale approach provides a good basis for identifying representative areas to establish fine scale and sediment plate sites. The NEMP advocates that fine scale monitoring is undertaken in soft sediment (sand/mud) habitat in the mid to low tidal range of priority estuaries, although seagrass habitats or areas with high enrichment conditions are sometimes included.

The environmental characteristics assessed in fine scale surveys incorporate a suite of common benthic indicators, including biological attributes such as the 'macrofaunal' assemblage and various physico-chemical characteristics (e.g. sediment mud content, trace metals, nutrients).

Extensions to the NEMP methodology that support the fine scale approach include the development of various metrics for assessing ecological condition according to prescribed criteria, and inclusion of sediment plate monitoring as noted in Section 1. These additional components are included in the present report and are described in the subsections below.

3.2 BLUESKIN BAY FINE SCALE AND SEDIMENT PLATE SITES

Blueskin Bay consists of an extensive area of relatively uniform intertidal flat comprising firm muddy sand, that is largely uncovered at mid-tide. Due to the uniformity across a large area, it was considered that monitoring at only two sites would likely be sufficiently representative of the wider estuary.

Accordingly, Site A was positioned near the center of Blueskin Bay and Site B toward the south, both sites having surface macroalgae but no seagrass. Each fine scale site was set up as a 30 x 60m rectangle, and sediment plates were installed along the landward 30m margin (Appendix 1). The sites were positioned at approximately mid-tide, although Site B was at a slightly lower tidal height than Site A.

To assist relocation, fine scale site corners and the locations of sediment plates were marked with wooden pegs. Coordinates for each of these features are provided in Appendix 1. A map showing the site locations, and a schematic of the sampling approach described below, is provided in Fig. 3.

Plate installation and fine scale site set-up and sampling was undertaken on 15 Jan 2021. On that day there was a 0.32m low tide at 11:35 (NIWA tide forecast, Blueskin Bay), with conditions suitable for sampling until ~14:30.

3.3 SEDIMENT PLATES

Concrete 'plates' (pavers, 19cm x 23cm) for sediment plate monitoring were installed at the two sites. Four plates were installed along the 30m length of each fine scale site boundary, spaced at 5, 10, 20 and 25m. As well as the fine scale site corner pegs, an additional relocation peg was placed at the 15m mid-point (see Fig. 3).

Plates were buried and leveled at ~50mm depth in the sediment. Actual baseline depths (from the sediment surface to each buried plate) were then measured. For this purpose, a 2m straight edge was placed over each plate position to average out any small-scale irregularities in surface topography. The depth to each plate was measured in triplicate by vertically inserting a probe into the sediment until the plate was located. Depth was measured to the nearest millimeter.

At each site, a single sediment sample (composited from 20mm deep sub-samples taken next to each plate) was collected and retained for laboratory analysis of grain size, using the methods described for fine scale monitoring (see next section). As the sediment plate measurements are expected to be undertaken annually, the grain size data can be used to assess ongoing changes in sediment muddiness.

Installing sediment plates at Site B, Jan 2021

3.4 FINE SCALE SAMPLING AND BENTHIC INDICATORS

Each fine scale site was divided into a 3 x 4 grid of 12 plots (see Fig. 3). Fine scale sampling for sediment indicators was conducted in 10 of these plots, with Fig. 3 showing the standard numbering sequence for replicates at both sites, and the designation of zones X, Y and Z (for compositing sediment samples; see below).

A summary of the benthic indicators, the rationale for their inclusion, and the field sampling methods, is provided in Table 1. Although the baseline sampling approach generally adhered to the NEMP, a review undertaken for Marlborough District Council (Forrest & Stevens 2019) highlighted that alterations and additions to early NEMP methods have been introduced in most surveys conducted over the last 10 or more years. For present purposes we adopted these modifications as indicated in Table 1.

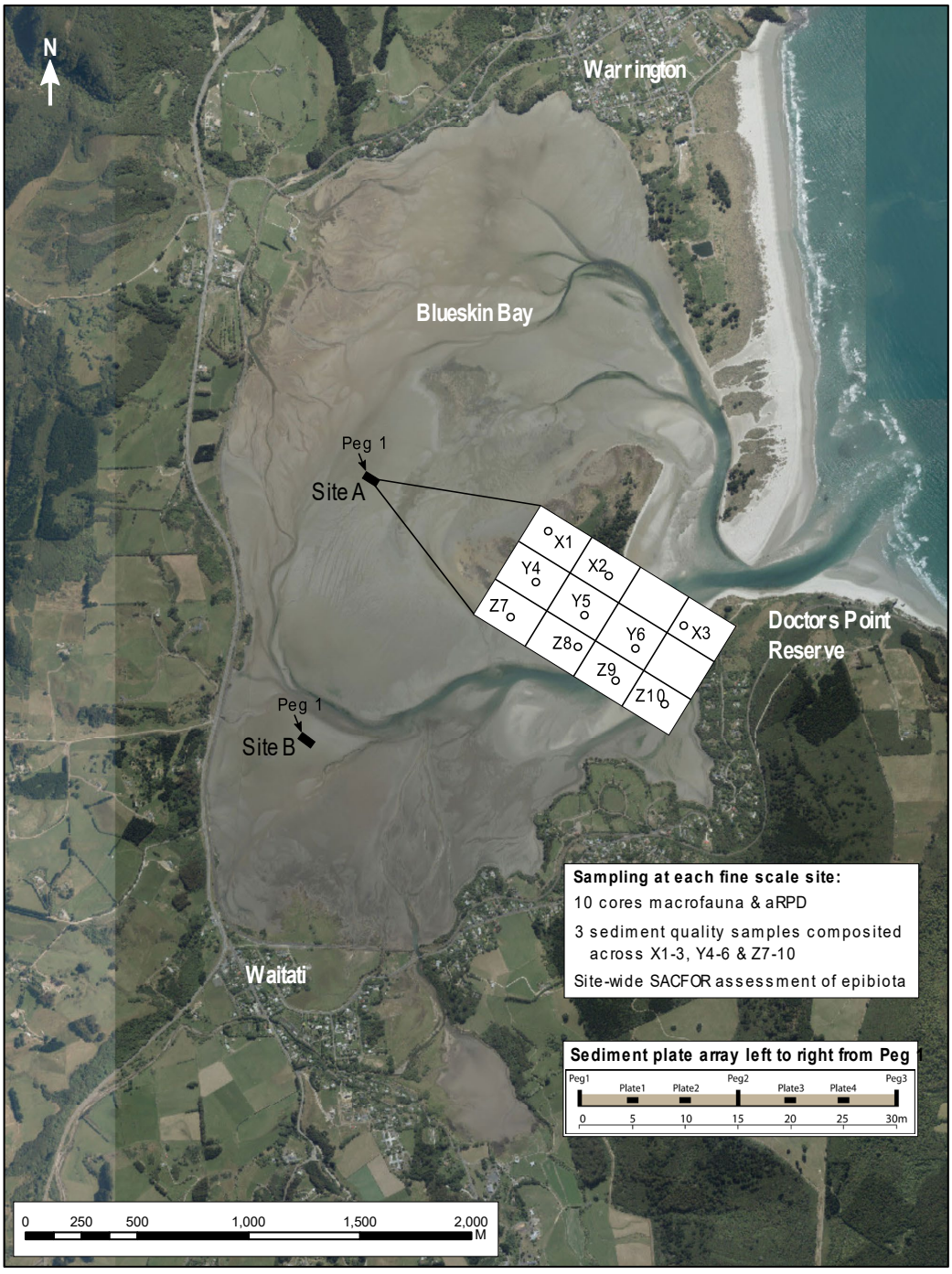


Fig. 3. Locations of the sites in Blueskin Bay, and schematics illustrating fine scale and sediment plate methods.

Table 1. Summary of NEMP fine scale benthic indicators, rationale for their use, and sampling method. Any meaningful departures from NEMP are described in footnotes.

NEMP benthic indicators	General rationale	Sampling method
Physical and chemical		
Sediment grain size	Indicates the relative proportion of fine-grained sediments that have accumulated.	1 x surface scrape to 20mm sediment depth, with 3 composited samples taken across the 10 plots (see note 1).
Nutrients (nitrogen and phosphorus) and organic matter	Reflects the enrichment status of the estuary and potential for algal blooms and other symptoms of enrichment.	1 x surface scrape to 20mm sediment depth, with 3 composited samples taken across the 10 plots (see note 1).
Trace metals (copper, chromium, cadmium, lead, nickel, zinc)	Common toxic contaminants generally associated with human activities.	1 x surface scrape to 20mm sediment depth, with 3 composited samples taken across the 10 plots (see notes 1, 2).
Depth of apparent redox potential discontinuity layer (aRPD)	Subjective time-integrated measure of the enrichment state of sediments according to the visual transition between oxygenated surface sediments and deeper deoxygenated black sediments. The aRPD can occur closer to the sediment surface as organic matter loading increases.	1 x 130mm diameter sediment core to 150mm deep for each of 10 plots, split vertically, with depth of aRPD recorded in the field where visible.
Biological		
Macrofauna	The abundance, composition and diversity of macrofauna, especially the infauna living with the sediment, are commonly-used indicators of estuarine health.	1 x 130mm diameter sediment core to 150mm deep (0.013m^2 sample area, 2L core volume) for each of 10 plots, sieved to 0.5mm to retain macrofauna.
Epibiota (epifauna)	Abundance, composition and diversity of epifauna are commonly-used indicators of estuarine health.	Abundance score based on ordinal SACFOR scale in Table 2 (see note 3).
Epibiota (macroalgae)	The composition and prevalence of macroalgae are indicators of nutrient enrichment.	Percent cover score based on ordinal SACFOR scale in Table 2 (see note 3).
Epibiota (microalgae)	The composition and prevalence of microalgae are indicators of nutrient enrichment.	Visual assessment of conspicuous growths based on ordinal SACFOR scale in Table 2 (see notes 3, 4).

Notes:

[1] For cost reasons, sediment quality is assessed in 3 composite samples rather than 10 discrete samples as specified in the NEMP.

[2] Arsenic and mercury are not required by NEMP, but were included in the trace element suite.

[3] Assessment of epifauna, macroalgae and microalgae used SACFOR in favour of quadrat sampling outlined in NEMP. Quadrat sampling is subject to considerable within-site variation for epibiota that have clumped or patchy distributions.

[4] NEMP recommends taxonomic composition assessment for microalgae but this is not typically undertaken due to unavailability of expertise and lack of demonstrated utility of microalgae as a routine indicator.

3.4.1 Sediment quality assessment

At each fine scale site, three composite sediment samples (each ~250g) were pooled from sub-samples (to 20mm depth) collected across each of zones X, Y and Z (replicates 1-3, 4-6 and 7-10, respectively; see Fig. 3). Samples were stored on ice and sent to RJ Hill Laboratories for analysis of: particle grain size in three categories (%mud <63µm, sand <2mm to ≥63µm, gravel ≥2mm); organic matter (total organic carbon, TOC); nutrients (total nitrogen, TN; total phosphorus, TP); and trace contaminants (arsenic, As; cadmium, Cd; chromium, Cr; copper, Cu; mercury, Hg; lead, Pb; nickel, Ni; zinc, Zn). Details of laboratory methods and detection limits are provided in Appendix 2.

3.4.2 Field sediment oxygenation assessment

To assess sediment oxygenation, the apparent redox potential discontinuity (aRPD) depth (Table 1.) was measured. The aRPD depth is a subjective measure of the enrichment state of sediments according to the depth of visible transition between oxygenated surface sediments (typically brown in colour) and deeper less oxygenated sediments (typically dark grey or black in colour). The aRPD depth in all surveys was measured (to the nearest mm) after extracting a large sediment core (130mm diameter, 150mm deep) from each of the 10 plots, placing it on a tray, and splitting it vertically. Representative split cores (X1, Y4 and Z7) were also photographed.

3.4.3 Biological sampling

Sediment-dwelling macrofauna

To sample sediment-dwelling macrofauna, each of the large sediment cores used for assessment of aRPD was placed in a separate 0.5mm sieve bag, which was gently washed in seawater to remove fine sediment. The retained animals were preserved in a mixture of 75% isopropyl alcohol and 25% seawater for later sorting and taxonomic identification by Cawthron Institute. The types of animals present in each sample, as well as the range of different species (i.e. richness) and their abundance, are well-established indicators of ecological health in estuarine and marine soft sediments.

Surface-dwelling epibiota

In addition to macrofaunal core sampling, epibiota (macroalgae, and conspicuous surface-dwelling animals nominally >5mm body size) visible on the sediment surface at each site were semi-quantitatively categorised using 'SACFOR' abundance (animals) or percentage cover (macroalgae) ratings shown in Table 2. These ratings represent a scoring scheme simplified from established monitoring methods (MNCR 1990; Blyth-Skyrme et al. 2008).

The SACFOR method is ideally suited to characterise intertidal epibiota with patchy or clumped distributions. It was conducted as an alternative to the quantitative quadrat sampling specified in the NEMP, which is known to poorly characterise scarce or clumped species. Note that our epibiota assessment did not include infaunal species that may be visible on the sediment surface, but whose abundance cannot be reliably determined from surface observation (e.g. cockles).

Table 2. SACFOR ratings for site-scale abundance, and percent cover of epibiota and algae, respectively.

SACFOR category	Code	Density per m^2	Percent cover
Super abundant	S	> 1000	> 50
Abundant	A	100 - 999	20 - 50
Common	C	10 - 99	10 - 19
Frequent	F	2 - 9	5 - 9
Occasional	O	0.1 - 1	1 - 4
Rare	R	< 0.1	< 1

Collecting sediment cores for macrofauna and aRPD assessment

3.5 DATA RECORDING, QA/QC AND ANALYSIS

All sediment and macrofaunal samples were tracked using standard Chain of Custody forms, and results were transferred electronically to avoid transcription errors. Field measurements from the fine scale and sediment plate surveys were recorded electronically in templates that were custom-built using software available at www.fulcrumapp.com. Pre-specified constraints on data entry (e.g. with respect to data type, minimum or maximum values) ensured that the risk of erroneous data recording was minimised. Each sampling record created in Fulcrum generated a GPS position for that record (e.g. a sediment core). Field data were exported to Excel, together with data from the sediment and macrofaunal analyses.

Excel sheets for the different data types and survey years were imported into the software R 4.0.5 (R Core Team 2021) and merged by common sample identification codes. All summaries of univariate responses (e.g. totals, means ± 1 standard error) were produced in R, including tabulated or graphical representations of data from sediment plates, laboratory sediment quality analyses, and macrofauna. Where results for sediment quality parameters were below analytical detection limits, averaging (if undertaken) used half of the detection limit value, according to convention.

Before macrofaunal analyses, the data were screened to remove species that were not regarded as a true part of the macrofaunal assemblage; these were planktonic life-stages and non-marine organisms (e.g. terrestrial beetles). To facilitate comparisons with future surveys, and other Otago estuaries, cross-checks were made to ensure consistent naming of species and higher taxa. For this purpose, the adopted name was that accepted by the World Register of Marine Species (WoRMS, www.marinespecies.org/). Taxonomy QA cross-checks were undertaken by sending samples from four macrofauna cores (2 samples per site) to Gary Stephenson, Coastal Marine Ecology Consultants (CMEC) for taxonomic verification.

Macrofaunal response variables included richness and abundance by species and higher taxonomic groupings. In addition, scores for the biotic health index AMBI (Borja et al. 2000) were derived. AMBI scores reflect the proportion of taxa falling into one of five eco-groups (EG) that reflect sensitivity to pollution (in particular eutrophication), ranging from relatively sensitive (EG-I) to relatively resilient (EG-V).

To meet the criteria for AMBI calculation, macrofauna data were reduced to a subset that included only adult 'infauna' (those organisms living within the sediment matrix), which involved removing surface dwelling epibiota and any juvenile organisms. AMBI scores were calculated based on standard international eco-group classifications where possible (http://ambi.azti.es).

However, to reduce the number of taxa with unassigned eco-groups, international data were supplemented with more recent eco-group classifications for New Zealand (Keeley et al. 2012; Robertson et al. 2015; Robertson et al. 2016c; Robertson 2018). Note that AMBI scores were not calculated for macrofaunal cores that did not meet operational limits defined by Borja et al. (2012), in terms of the percentage of unassigned taxa (>20%), or low sample richness (<3 taxa) or abundances (<6 individuals).

Multivariate representation of the macrofaunal community data used the software package Primer v7.0.13 (Clarke et al. 2014). Patterns in site similarity as a function of macrofaunal composition and abundance were assessed using an 'unconstrained' non-metric multidimensional scaling (nMDS) ordination plot, based on pairwise Bray-Curtis similarity index scores among samples aggregated within each site and zone (see Fig. 3). The purpose of aggregation was to smooth over the 'noise' associated with a core-level analysis and enable the relationship to patterns in sediment quality variables to be determined.

Prior to the multivariate analysis, macrofaunal abundance data were either square-root or presence-absence transformed to down-weight the influence on the ordination pattern of the dominant species or higher taxa. The purpose of the presence-absence transformation was to explore site differences that were attributable to species occurrences irrespective of their relative abundances. The procedure PERMANOVA was used to test for compositional differences among sites and zones, based on both types of transformed data.

Overlay vectors and bubble plots on the nMDS were used to visualise relationships between multivariate biological patterns and sediment quality data, which were log(x+1)-transformed and normalised to a standard scale. Additionally, the Primer procedure Bio-Env was used to evaluate the suite of sediment quality variables that best explained the biological ordination pattern.

3.6 ASSESSMENT OF ESTUARY CONDITION

To supplement our analyses and interpretation of the data, results were assessed within the context of established or developing estuarine health metrics ('condition ratings'), drawing on approaches from

New Zealand and overseas. These metrics assign different indicators to one of four rating bands, colour-coded as shown in Table 3. Most of the condition ratings in Table 3 were derived from those described in a New Zealand Estuary Trophic Index (Robertson et al. 2016b, a), which includes purpose-developed criteria for eutrophication, and also draws on wider national and international environmental quality guidelines. Key elements of this approach are as follows:

- *New Zealand Estuary Trophic Index (ETI):* The ETI provides screening guidance for assessing where an estuary is positioned on a eutrophication gradient. While many of the constituent metrics are intended to be applied to the estuary as a whole (i.e. in a broad scale context), site-specific thresholds for %mud, TOC, TN, aRPD and AMBI are described by Robertson et al. (2016a). We adopted those thresholds for present purposes, except: (i) for %mud we adopted the refinement to the ETI thresholds described by Robertson et al. (2016c); and (ii) for aRPD we modified the ETI ratings based on the US Coastal and Marine Ecological Classification Standard Catalog of Units (FGDC 2012).
- *ANZG (2018) sediment quality guidelines*: The condition rating categories for trace contaminants were benchmarked to ANZG (2018) sediment quality guidelines as described in Table 3. The Default Guideline Value (DGV) and Guideline Value-High (GV-high) specified in ANZG are thresholds that can be interpreted as reflecting the potential for 'possible' or 'probable' ecological effects, respectively. Until recently, these thresholds were referred to as ANZECC (2000) Interim Sediment Quality Guideline low (ISQG-low) and Interim Sediment Quality Guideline high (ISQG-high) values, respectively.

In addition, for assessing and managing sedimentation effects, two guidelines are available at a national level that will be applied in subsequent surveys in Blueskin Bay.

- Townsend and Lohrer (2015) propose a DGV of 2mm of sediment accumulation per year above natural deposition rates. Where unknown, natural deposition rates are conservatively assumed to be

Table 3. Condition ratings used to characterise estuarine health for key indicators. See footnotes and main text for explanation of the origin or derivation of the different metrics. Note that sediment plates were installed in January 2021, hence the sedimentation rate indicator will be relevant to future surveys.

Indicator	Unit	Very good	Good	Fair	Poor
General indicators [1]					
Sedimentation rate[a]	mm/yr	< 0.5	≥0.5 to < 1	≥1 to < 2	≥ 2
Mud content[b]	%	< 5	5 to < 10	10 to < 25	≥ 25
aRPD depth[c]	mm	≥ 50	20 to < 50	10 to < 20	< 10
TN[b]	mg/kg	< 250	250 to < 1000	1000 to < 2000	≥ 2000
TOC[b]	%	< 0.5	0.5 to < 1	1 to < 2	≥ 2
AMBI[b]	na	0 to 1.2	> 1.2 to 3.3	> 3.3 to 4.3	≥ 4.3
Trace elements [2]					
As	mg/kg	< 10	10 to < 20	20 to < 70	≥ 70
Cd	mg/kg	< 0.75	0.75 to <1.5	1.5 to < 10	≥ 10
Cr	mg/kg	< 40	40 to <80	80 to < 370	≥ 370
Cu	mg/kg	< 32.5	32.5 to <65	65 to < 270	≥ 270
Hg	mg/kg	< 0.075	0.075 to <0.15	0.15 to < 1	≥ 1
Ni	mg/kg	< 10.5	10.5 to <21	21 to < 52	≥ 52
Pb	mg/kg	< 25	25 to <50	50 to < 220	≥ 220
Zn	mg/kg	< 100	100 to <200	200 to < 410	≥ 410

1. Ratings derived or modified from: [a]Townsend and Lohrer (2015), [b]Robertson et al. (2016) with modification for mud content described in text, [c]FGDC (2012).

2. Trace element thresholds scaled in relation to ANZG (2018) as follows: Very good = < 0.5 x DGV; Good = 0.5 x DGV to < DGV; Fair = DGV to < GV-high; Poor = > GV-high. DGV = Default Guideline Value, GV-high = Guideline Value-high. These were formerly the ANZECC (2000) sediment quality guidelines whose exceedance roughly equates to the occurrence of 'possible' and 'probable' ecological effects, respectively.

0mm/yr. The 2mm/yr value has been used as the threshold between the 'fair' and 'poor' bands in Table 3 on the basis that exceeding the DGV is expected to result in an increased likelihood of adverse ecological effects.

- The ETI recommends using the ratio of estimated current to natural (pre-human) sedimentation rates, with increasing values considered to be associated with increasing ecological stress (Robertson et al. 2016b). These parameters were calculated by Roberts et al. (2021) based on NIWA's estuary sediment load estimator (Hicks et al. 2019).

Note that the scoring categories described above and in Table 3 should be regarded only as a general guide to assist with interpretation of estuary condition. Accordingly, it is major spatio-temporal changes in the categories that are of most interest, rather than their subjective condition descriptors; i.e. descriptors such as 'poor' condition should be regarded more as a relative rather than absolute rating.

4. KEY FINDINGS

4.1 GENERAL FEATURES OF FINE SCALE SITES

The selected sites were typical of the intertidal flats across the estuary. Within each site the sediment textural characteristics were uniform. The photos below show the similarity in the general appearance of the two sites, with both having a conspicuous cover of macroalgae. Shell hash was common within the sediment and on the surface.

Firm muddy sand sediments at Site A (top) and Site B (bottom), both with a conspicuous cover of macroalgae

4.2 SEDIMENT PLATES

Sediment plate data are provided in Appendix 3. These data provide the baseline measurements against which future changes in plate depth can be determined, and annual or longer-term sediment accrual or erosion evaluated.

4.3 SEDIMENT QUALITY

4.3.1 Sediment grain size, TOC and nutrients

Composite sediment sample raw data are tabulated in Appendix 4. Laboratory analyses of sediment grain size confirmed the field observations of sand-dominated sediments; the mud component was only 5% at Site A and 6% at Site B Fig. 4.

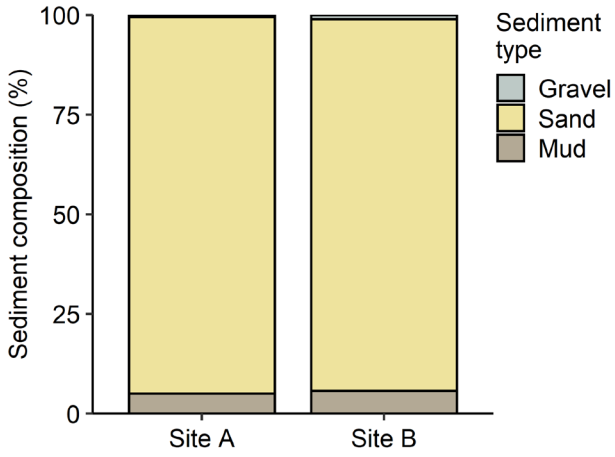


Fig. 4. Mean (n=3) sediment particle grain size based on composite samples. Grain size fractions are mud (<63µm), sand (≥63µm to <2mm) and gravel (≥2mm).

To provide a visual impression of sediment quality relative to the Table 3 condition ratings, Fig. 5 compares the mean percentage mud, total organic carbon (TOC) and total nitrogen (TN) from composite samples against the rating thresholds. The low values of all analytes placed them in rating categories of 'good' or 'very good'.

Note that TN levels in all samples were less than the laboratory detection limit and are presented as 50% of the detection limit. Levels of the nutrient total phosphorus (TP) were elevated at Site B (250-270mg/kg) relative to Site A (172-179mg/kg), although values at both sites are not especially high (Appendix 4).

4.3.2 Sediment oxygenation

No signs of excessive sediment enrichment were evident in the sediment core profiles at either site – see Fig. 6 and photos in Fig. 7. Baseline aRPD values ranged from a mean of ~10-15mm sediment depth at Site A and ~25-30mm at Site B; condition ratings of 'fair' and 'good' respectively (Fig. 6).

The aRPD was at times indistinct, for example due to sediment mixing by invertebrates (e.g. Fig. 7, Site A-Z). Also, while measurements were carried out by experienced field staff, it should be acknowledged that there is inherent subjectivity in the aRPD assessment, hence some variability due to interpretation can be expected. However, the approach aims to assess gross meaningful shifts in aRPD which indicate changes in sediment condition. Importantly, neither site provided evidence of black anoxic (and sulphide-smelling) sediments at (or within a few millimetres of) the sediment surface, as would occur under strongly enriched conditions.

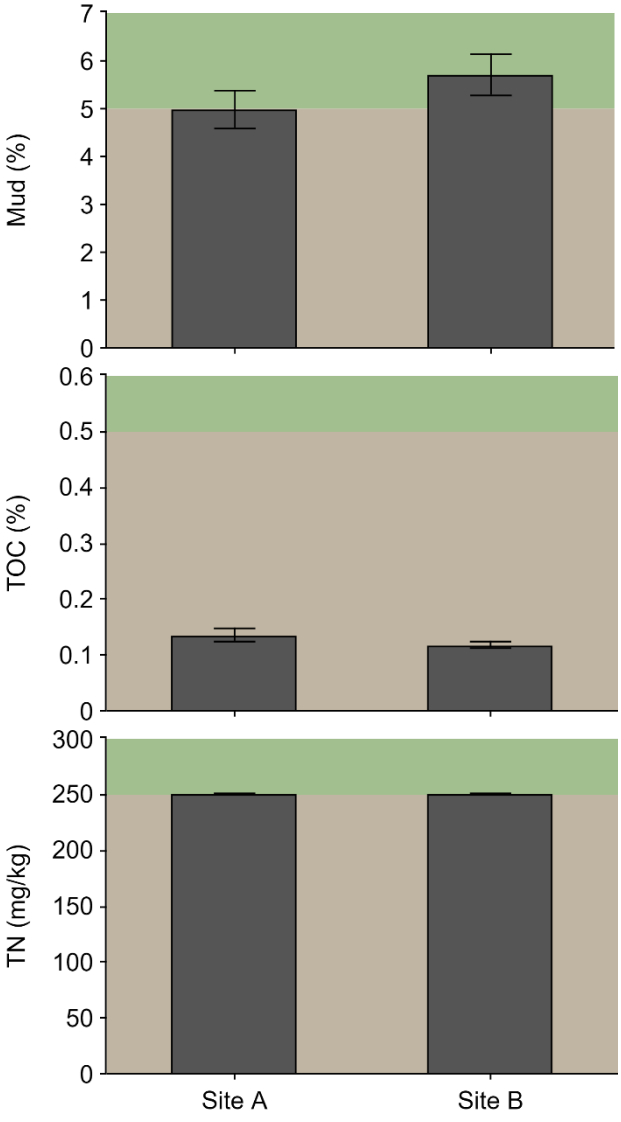


Fig. 5. Mean (±SE, n=3) sediment %mud, total organic carbon, and total nitrogen relative to condition ratings. TN values 50% of detection limit.

Condition rating key:

Very Good	Good	Fair	Poor

The absence of excessive enrichment likely reflects that the sandy sediments at both sites are sufficiently coarse-grained to enable water penetration into the sediment matrix, maintaining well-oxygenated conditions.

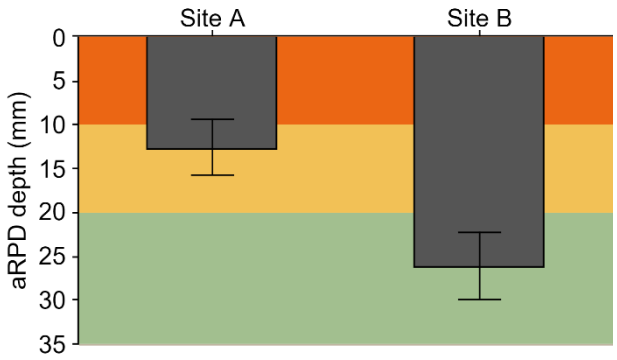


Fig. 6. Mean (±SE, n=3) aRPD relative to condition ratings. Rating key as per Fig. 5.

as 'very good', reflecting that the concentrations are less than half of the ANZG (2018) Default Guideline Value (DGV) for 'possible' ecological effects. The results in part reflect the sandy nature of the sediments, as sand particles have a reduced capacity for adsorption of trace contaminants than is the case for muddy sediment particles (i.e. due to a reduced surface area). For this reason, marginally higher concentrations evident at Site B may be related to a slightly higher mud content at that site (see Fig. 5).

Land uses such as agriculture and horticulture can lead to soil contamination with these analytes due to practices such as fertiliser application (Gaw et al. 2006; Lebrun et al. 2019). As such, current results suggest there are no sources of widespread significance to Blueskin Bay. Although we did not measure a wide suite of other contaminants, as there is no extensive urbanisation or industrial development in the catchment (see Fig. 2), there is also no reason to expect that any would be present at significant concentrations.

4.3.3 Trace contaminants

Plots of trace contaminants in relation to condition ratings are provided in Fig. 8 (see also Appendix 4). Trace contaminant levels were very low, and all rated

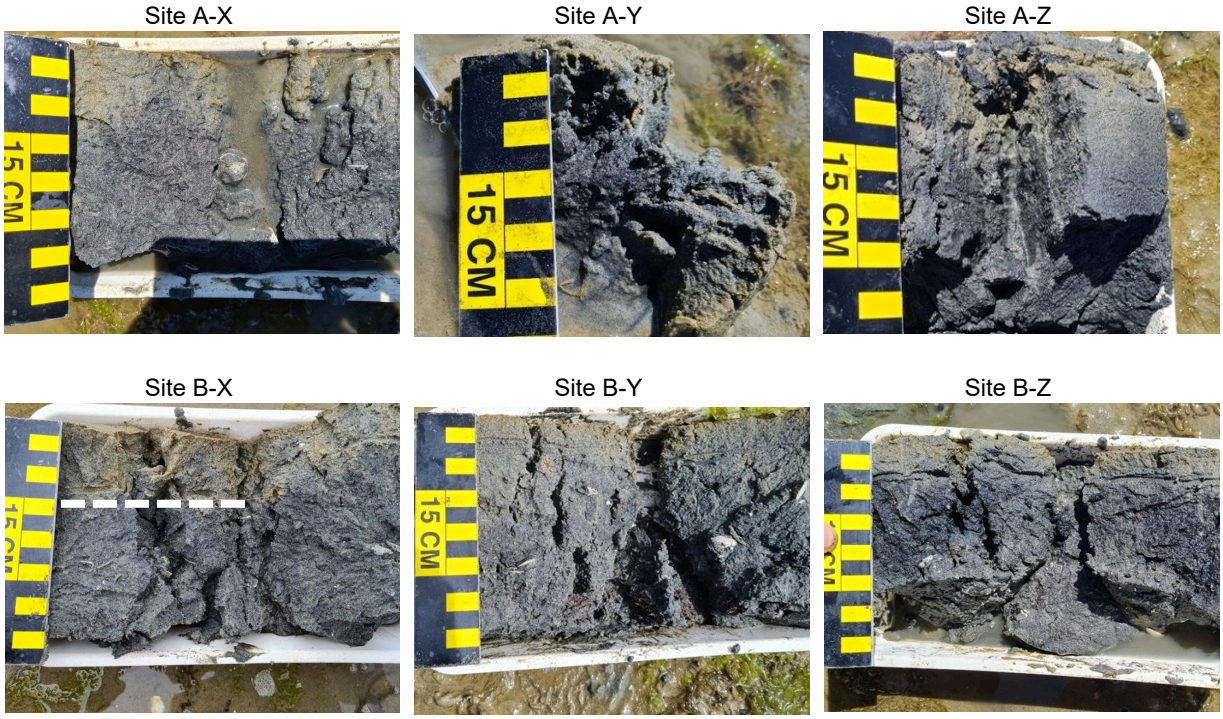


Fig. 7. Example sediment cores from the fine scale sites. To illustrate the approximate depth of the aRPD, a dashed white line is shown on the zone X core from Site B.

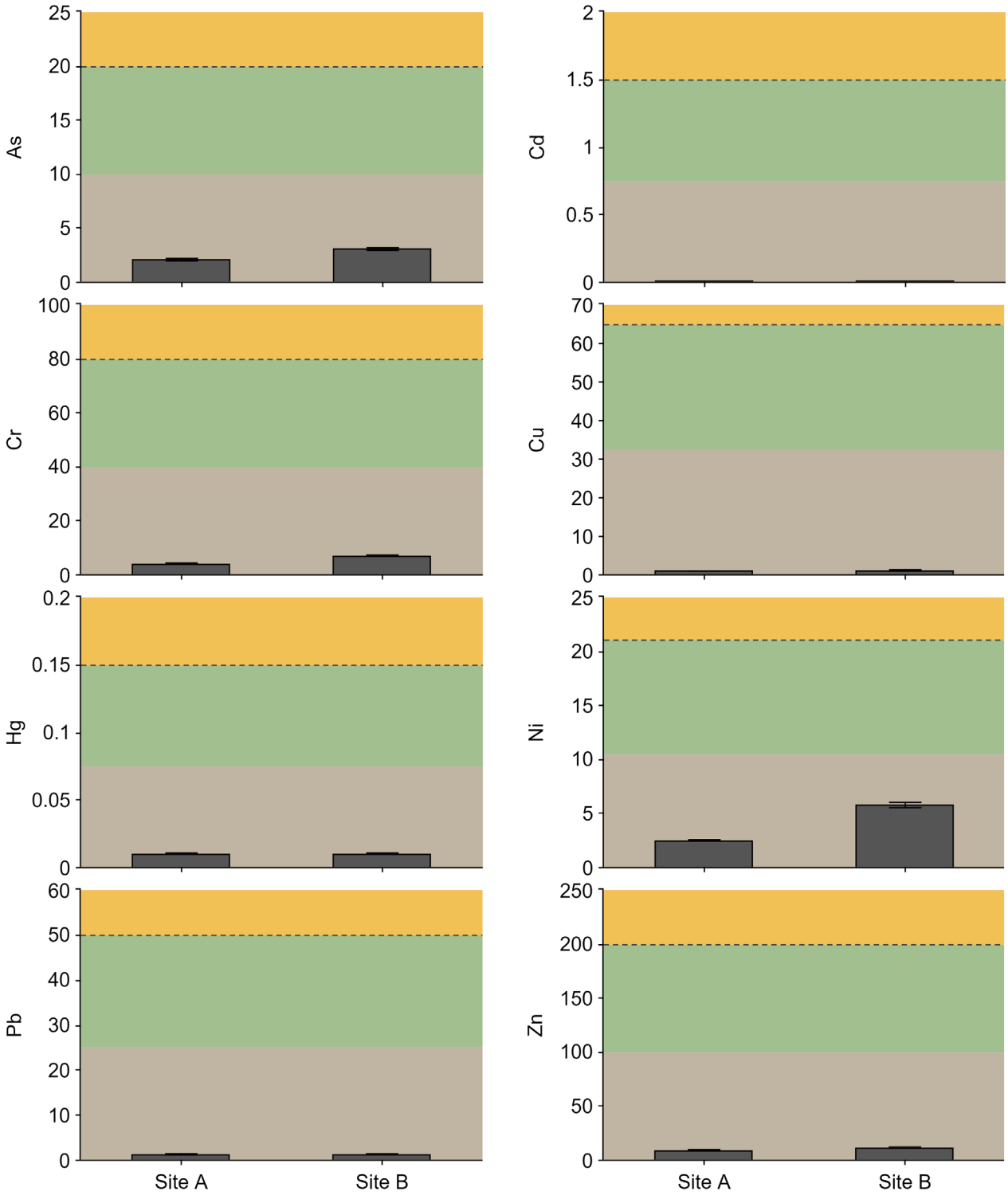


Fig. 8. Mean (±SE, n=3) trace contaminant concentrations relative to condition ratings. ANZG (2018) sediment quality Default Guideline Values are represented by the boundary (dotted line) between 'good' and 'fair' condition. Note that concentrations of cadmium (Cd) and mercury (Hg) were all less than laboratory detection limits.

Condition rating key:

Very Good	Good	Fair	Poor

4.4 MACROFAUNA

4.4.1 Conspicuous surface epibiota

Results from the January 2021 site-level assessment of surface-dwelling invertebrates and macroalgae are shown in Table 4. The epibiota in Blueskin Bay was diverse and abundant compared with that described from other estuaries in Otago where NEMP monitoring has been undertaken (e.g. Robertson et al. 2017a, b; Forrest et al. 2020a, b).

Macroalgae were visually conspicuous at both sites, usually attached to shell. The total algal cover was estimated as 60% at Site A and 35% at Site B. Most prevalent at both sites were sea lettuce *Ulva* spp. and the red seaweed *Agarophyton chilense*, which had SACFOR scores of common (C) or abundant (A). Also conspicuous at Site A were various species of filamentous red seaweed (SACFOR rating 'A'), of which the most commonly occurring was *Ceramium* spp.

Another species that was conspicuous at Site B but less so at Site A was the brown seaweed *Tinocladia novae-zelandiae*, which is characterised by its very slippery spaghetti-like texture. Although distributed New Zealand-wide, we have not encountered this species in other New Zealand estuaries, as it is more typically associated with rock and cobble habitats (Nelson 2013).

Spaghetti-like *Tinocladia novae-zelandiae*

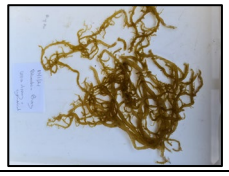
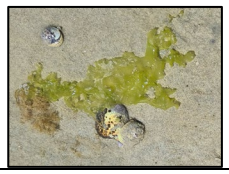
The invertebrates consisted mainly of four species of mud snail, with the mud whelk *Cominella glandiformis* occurring frequently (SACFOR 'F') at both sites, typically aggregated in clumps of individuals feeding on prey items. Abundant at Site B but less so at Site A was the mudflat topshell *Diloma subrostratum*. The horn snail *Zeacumantus lutulentus*, a typical estuarine species, was recorded at Site B but not at Site A despite being generally widespread across the estuary. Of interest at Site B were single records of *Ostrea chilensis* (aka Bluff oyster) and cat's eye (*Lunella smaragda*), the latter being a common species of rocky shorelines that is not typically found in estuaries.

Site A with macroalgae estimated to be 60% total cover

Site B with macroalgae estimated to be 35% total cover

A cluster of mud whelks *Cominella glandiformis* at Site B, among green sea lettuce *Ulva* spp. and red seaweeds including *Agarophyton chilense* and *Ceramium* spp.

Table 4. SACFOR scores for epibiota based on the scale in Table 2. Dash = not recorded. Mollusc images courtesy of Andrew Spurgeon (www.mollusca.co.nz).

Species	Common name	Functional description	Image	Site A	Site B
Invertebrates					
Cominella glandiformis	Mud whelk	Carnivore and scavenger		F	F
Diloma subrostratum	Mudflat topshell	Grazer and deposit feeder		F	C
Ostrea chilensis	Flat oyster	Filter feeder		-	R
Lunella smaragda	Cat's eye	Grazer		-	F
Zeacumantus subcarinatus	Horn snail	Microalgal and detrital grazer		-	F
Macroalgae					
Agarophyton chilense *	Red seaweed	Primary producer		C	C
Filamentous reds (mainly *Ceramium* spp.)	Red seaweed	Primary producer		A	O
Tinocladia novae-zelandiae	Brown seaweed	Primary producer		O	O
Ulva spp.	Green seaweed/ Sea lettuce	Primary producer		A	C

* *Agarophyton chilense* is the revised name for *Gracilaria chilensis*

4.4.2 Macrofauna cores

Richness, abundance and AMBI

Raw data for sediment-dwelling macrofauna are provided in Appendix 5, with QA data in Appendix 6. The QA process showed some unresolved taxonomic differences which will need to be accounted for in future analyses if the provider changes.

A total of 71 macrofaunal taxa were sampled in the 2021 survey, 49 from Site A and 57 from Site B (see Appendix 6). Table 5 describes the main species and higher taxa that were recorded. Mean species richness ranged from 24 to 27 taxa per core sample, being marginally greater at Site B (Fig9a). Mean organism abundances were also marginally greater at Site B (357/core) than Site A (325/core) (Fig9b).

Mean values of the biological index AMBI ranged from 1.89 (Site A) to 2.23 (Site B); a condition rating of 'good' (Fig. 10). This result is consistent with the high sediment quality. The low AMBI values reflect a very high prevalence of eco-group II (EG-II) species (Fig. 11), as well as a range of EG-I species. Species in EG-I and EG-II are indicative of more sensitive species that thrive in relatively healthy and undisturbed conditions (Appendix 5, Table 5).

Main taxonomic groups and species

The species present represented 15 main taxonomic groups (Fig. 12). Polychaete worms were by far the most species-rich and numerically abundant group. As evident in Table 5, half of the most abundant taxa were polychaetes, with five of the six dominant polychaetes classified as EG-I or EG-II. Especially abundant at Site A were the small spionid worm *Microspio maori*, and 'bamboo' worm *Macroclymenella stewartensis*. At Site B, syllids and *Paradoneis* sp. were particularly abundant; for example, the mean density of *Paradoneis* exceeded 150/core sample.

Bivalves and gastropods (collectively known as molluscs) were also reasonably species-rich, with two bivalves being notably abundant. These were the little-known *Lasaea parengaensis* at Site A, and the nutshell *Nucula nitidula* at Site B (EG-II). Subdominant bivalves included low densities of small cockles (*Austrovenus stutchburyi*) and wedge shells (*Macomona liliana*).

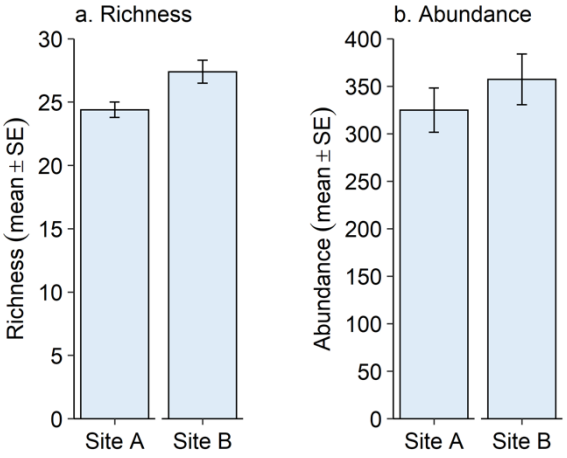


Fig. 9. Mean (± SE, n=10) taxon richness and abundance per core sample.

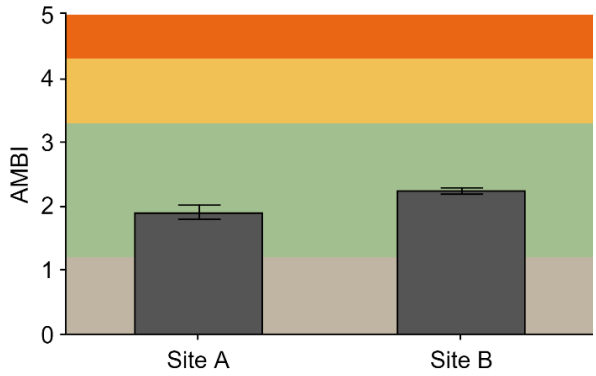


Fig. 10. Mean (± SE, n=10) AMBI scores compared with condition rating criteria.

Condition rating key:

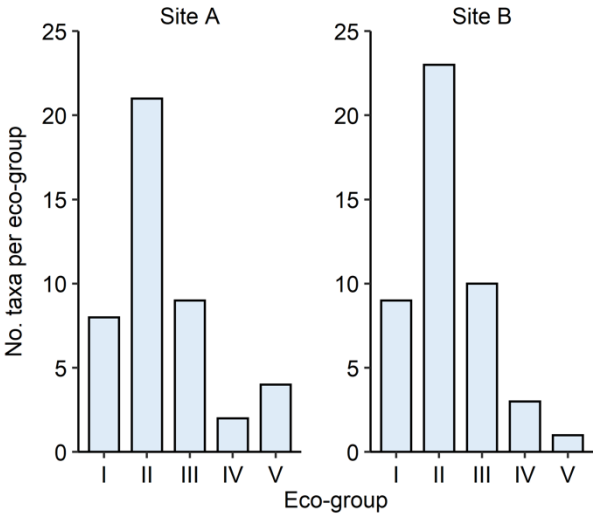
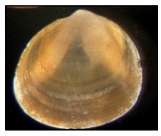
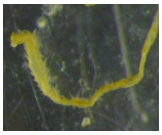


Fig. 11. Site-level data showing the number of taxa within eco-groups ranging from sensitive (EG-I) to resilient (EG-V).

Table 5. Description and site-aggregated abundances of the most commonly occurring sediment-dwelling macrofauna.

Main group, species & eco-group	Site A	Site B	Description	Image
Amphipoda, EG II	150	136	Shrimp-like crustaceans dominated by *Paracalliope novizealandiae* and *Torridoharpinia hurleyi*. Considered to be tolerant of sedimentation and mud, although *T. hurleyi* regarded as sensitive to enrichment. Probably important prey for birds and small fish.	
Bivalvia, *Lasaea parengaensis* EG unknown	580	67	Small and little-known bivalve, not widely distributed in New Zealand. Probably a prey item in the diet of birds and fish.	
Bivalvia, *Nucula nitidula* EG-II	53	397	Small estuarine bivalve mollusc, commonly called a nutshell. Considered to prefer sandy habitats, and sensitive to excess sedimentation. Probably a prey item in the diet of birds and fish.	
Oligochaeta, Oligochaete worm EG III	30	517	Segmented worms in the same group as earthworms. Deposit feeders that are generally considered pollution or disturbance tolerant.	
Ostracoda, Ostracod EG I	28	91	Class of crustaceans, sometimes known as seed shrimps because of their appearance. Poorly understood group. Considered to be omnivorous scavengers.	
Polychaeta, *Boccardia* spp. EG II	93	20	Spionid worms comprising common species *B. syrtis* and *B. acus*. Tube-building surface deposit and suspension feeders. Sensitive to excessive sedimentation. Variable tolerance to organic enrichment.	
Polychaeta, Exogoninae EG II	103	42	Small syllid polychaete worm. Common but poorly understood. Considered to be free-burrowing or epifaunal omnivores.	
Polychaeta, *Macroclymenella stewartensis* EG II	248	102	A sub-surface, deposit-feeding maldanid 'bamboo' worm that is usually found in tubes of fine sand or mud. This species may have a key role in turn-over of sediment. Tolerant of mud, but optimum range 10-15%. Intolerant of anoxic conditions.	
Polychaeta, *Microspio maori* EG I	400	63	Common paraonid worm considered to be sensitive to muddy sediment but tolerant of organic enrichment, despite EG I classification.	
Polychaeta, *Paradoneis* sp. EG III	1099	1523	Common paraonid worm considered to be reasonably tolerant of muddy sediment and organic enrichment. Paraonids are considered to be deposit feeders, possibly selectively feeding on microscopic diatoms and protozoans.	
Polychaeta, Syllidae EG II	31	124	Free-burrowing or epifaunal predators. Classified as EG II, but there appears to be little known about environmental tolerances.	
Tanaidacea, *Zeuxoides* sp. EG I	131	184	Shrimp-like tanaid. Little known species. Tanaids reported to inhabit all sediment types but have a mud optimum <15%.	

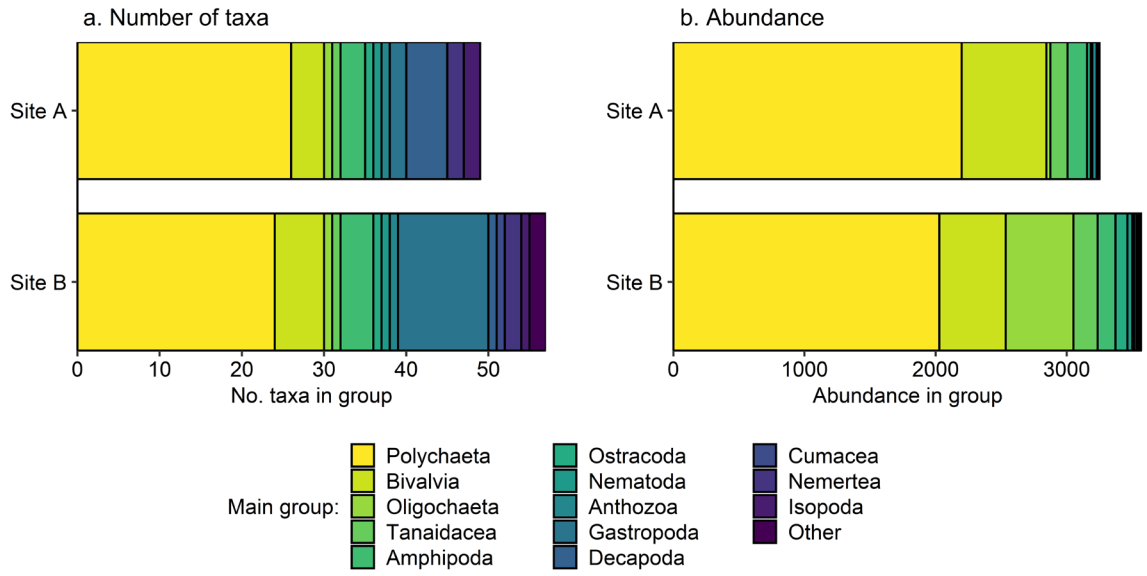


Fig. 12. Pooled data showing the contribution of main taxonomic groups to site-level richness and abundance values.

Other main taxa of interest included:

- Shrimp-like Tanaids, *Zeuxoides* sp., an EG-I species common at both sites.
- Oligochaete worms, which were notably abundant at Site B. Oligochaetes are an EG-III group often associated with enriched conditions.
- A range of amphipods, most dominant being the nationally common *Paracalliope novizealandiae* and the phoxocephalidae group, which QA suggested were likely to be *Torridoharpinia hurleyi* (Appendix 6).

Multivariate patterns and association with sediment quality variables

In order to further explore the differences and similarities among sites and surveys in terms of the macrofaunal assemblage, the nMDS ordination in Fig. 13 places zone aggregated samples of similar composition close to each other in a 2-dimensional plot, with less similar samples being further apart.

Fig. 13a further illustrates the dominant species that characterised each site that were noted above and in Table 5, and also highlights that a range of other sub-dominant taxa characterised each site or discriminated the sites from each other.

The plot emphasises that, despite being selected to be in superficially similar habitats, the two sites had some fundamental differences in species composition. Part of this difference was driven by species dominance patterns (revealed by Table 5 for the most dominant taxa), but also reflects a subset of species recorded at one site but not the other. Of the 49 taxa from Site A and 57 from Site B, there were only 35 taxa that the two sites shared in common. As such, when the nMDS was based on species presence or absence (i.e. relative abundance was not taken into account) the ordination pattern was similar to that shown in Fig. 13a. Significance tests based on the PERMANOVA procedure indicated highly significant ($p<0.001$) compositional differences between sites in the case of both relative abundance (i.e. square-root transformed) data (Pseudo-F=13.64) and presence-absence data (Pseudo-F=4.84).

Some of the presence-absence differences are probably a reflection of sampling variation. For example, in the case of a rare species (e.g. mean density <1/core), the apparent absence from a given site could reflect that it was missed purely by chance. In fact, we undertook a cursory analysis using different species richness estimators, which suggested that 10 macrofauna cores did not capture the entire species assemblage at each site. For example, whereas 49 taxa were observed at Site A, the 'true' species richness based on different estimation methods ranged from 49 to 61 taxa (mean 55 taxa). Similarly, for Site B where 57 taxa were recorded, the 'true' species richness was estimated to range from 57 to 78 taxa (mean 68 taxa). As such, a greater sampling effort may have revealed a greater site similarity than suggested in the present analysis.

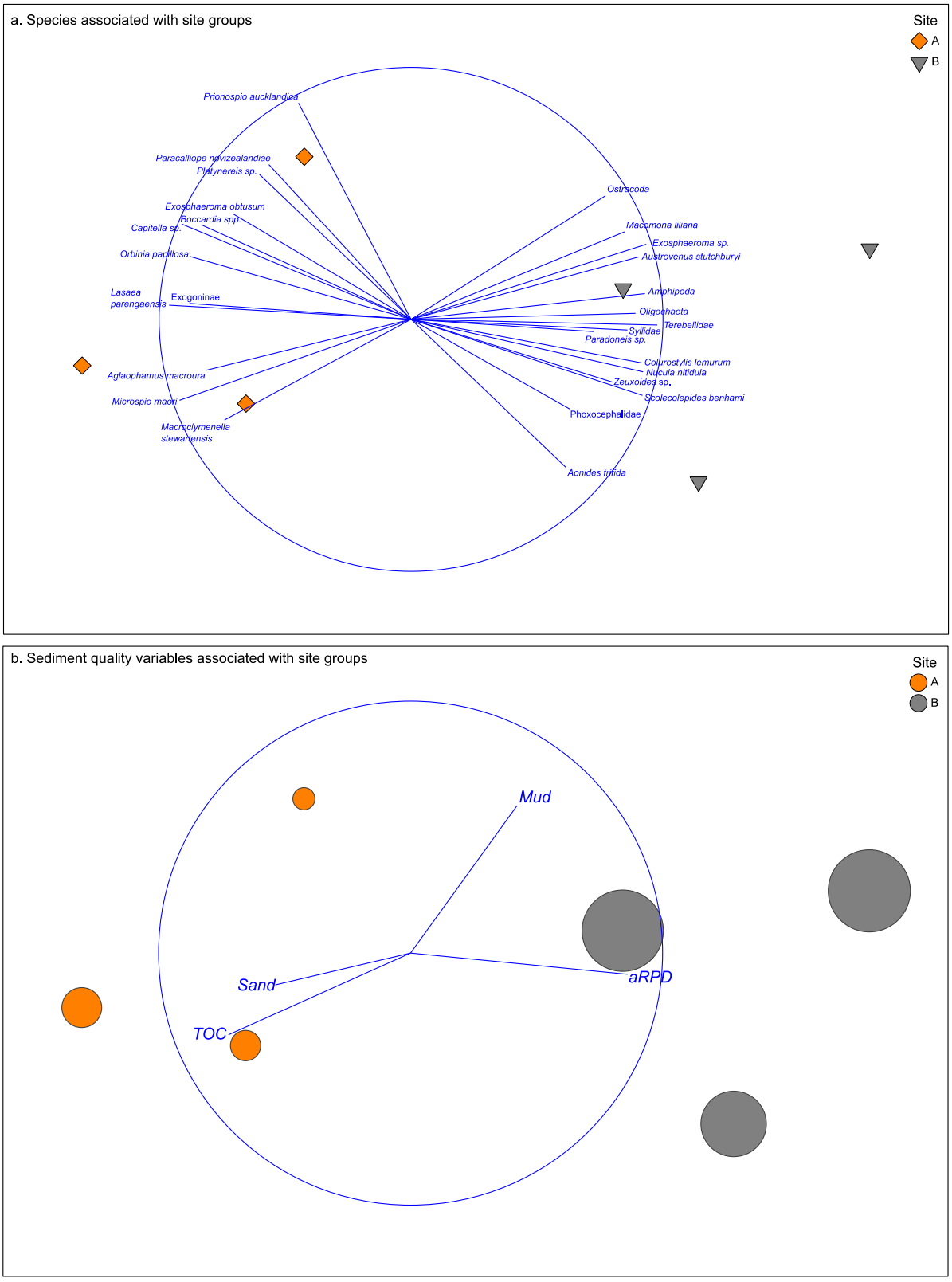


Fig. 13. Non-metric MDS ordination of macrofaunal core samples aggregated within sampling zones at each site.

The three zones at each site are placed such that closer ones are more similar than distant ones in terms of macrofaunal composition. A 'stress' value of zero for the nMDS indicated that a 2-dimensional plot provided an accurate representation of zone differences. Sites within each zone were ~79% similar in terms of their Bray-Curtis macrofaunal composition index. Vector overlays indicate the direction and strength of association (length of line relative to circle) of grouping patterns in terms of: a) the most correlated macrofauna species and b) key sediment quality variables. Bubble sizes in the bottom pane are scaled to sediment aRPD (oxygenation), which was the sediment quality variable most closely correlated with macrofaunal composition differences.

Exploration of the relationship between macrofauna patterns and sediment quality was based on a subset of uncorrelated variables. Trace contaminants were excluded, as any influence on sediment biota was not considered plausible given their very low concentrations relative to ANZG (2018) guidelines. Nutrients were also excluded as levels were very low or less than laboratory detection limits.

Of the remaining variables, the vector overlays in Fig. 13a, and associated correlation analysis, reveal that the left-to-right separation along the x-axis of the nMDS was strongly associated with a deepening of the aRPD (Pearson r2 = 0.86), suggesting Site A was slightly more organically enriched than Site B. The bottom-to-top shift along the y-axis of the nMDS was not closely correlated with any of the measured variables.

The BIO-ENV analysis of overall relationships between macrofauna and sediment quality similarly revealed that aRPD best explained the association (Spearman rank correlation $\rho = 0.70$). Of interest is that sediment mud content, which is typically among the strongest drivers of macrofaunal composition in New Zealand estuaries (Cummings et al. 2003; Robertson et al. 2015; Berthelsen et al. 2018; Clark et al. 2021), was unimportant in this instance ($\rho = 0.37$). This result is probably a reflection of the mud content at both sites being below the thresholds typically associated with ecological change.

5. SYNTHESIS AND RECOMMENDATIONS

5.1 SYNTHESIS OF KEY FINDINGS

This report has described the findings of an ecological monitoring survey conducted at two sites in Blueskin Bay, largely following the fine scale methods described in New Zealand's National Estuary Monitoring Protocol (NEMP). Sediment plates installed at the time of the survey will be monitored in the future to determine sedimentation rates.

In Table 6, key physical and biological indicators are compared against the condition rating criteria in Table 3. The survey revealed sand-dominated sediments with very low concentrations of organic carbon, nutrients, and trace contaminants. Accordingly, sediment quality for most variables was rated 'good' or 'very good' (see Table 6).

The 'fair' ratings for aRPD at Site A indicate slightly greater sediment enrichment than at Site B. This result conceivably reflects increased microbial activity in the sediment. Although TOC was only marginally elevated at Site A relative to Site B (see Fig. 6), it is plausible that the outflow at Carey's Creek, or the greater macroalgal extent at that site (see Section 4.4.1), nourish the underlying sediment with organic matter and lead to enhanced microbial decomposition relative to Site B. Despite this result, there were no symptoms of excessive enrichment, such as a black, anoxic and sulphide-smelling sediments.

Table 6. Summary of scores of estuary condition based on values of key indicators in each zone, compared to rating criteria in Table 3. AMBI values are zone averages.

Site	Zone	Mud %	TOC %	TN mg/kg	aRPD mm	As mg/kg	Cd mg/kg	Cr mg/kg	Cu mg/kg	Hg mg/kg	Ni mg/kg	Pb mg/kg	Zn mg/kg	AMBI na
A	X	5.6	0.11	< 500	11	1.9	< 0.010	4.1	0.9	< 0.02	2.6	0.9	9.0	2.1
	Y	5.1	0.15	< 500	14	2.1	< 0.010	4.2	1.0	< 0.02	2.5	1.4	8.5	1.7
	Z	4.2	0.14	< 500	13	2.1	< 0.010	4.1	0.8	< 0.02	2.4	1.0	7.8	1.9
B	X	5.0	0.11	< 500	22	2.9	< 0.010	6.9	1.0	< 0.02	5.8	1.2	11.4	2.1
	Y	5.6	0.11	< 500	28	3.0	< 0.010	7.0	1.0	< 0.02	5.3	1.2	11.5	2.2
	Z	6.5	0.13	< 500	28	3.2	< 0.010	7.5	1.2	< 0.02	6.2	1.4	12.1	2.3

< All values below lab detection limit

Condition rating key:

Very Good	Good	Fair	Poor

Although the macroalgal coverage was particularly high at Site A (~60%), and included opportunistic species such as *Agarophyton chilense*, the macroalgae were attached to shell and other hard surfaces rather than entrained within the sediment as is characteristic of nuisance macroalgal problems (e.g. Stevens et al. 2020; Roberts et al. 2021). As nutrient loads to Blueskin Bay are not particularly high (Roberts et al. 2021), the occurrence of the macroalgal beds is unlikely to be enrichment-related. Rather, they are likely maintained by the plentiful stable shell habitat for algal attachment, high water clarity, and the very flat profile of the sites, which enables water to be retained after the tide has receded.

The high sediment quality at the fine scale sites was reflected in the diverse and abundant macrofauna present. The macrofaunal patterns were correlated with the shallower aRPD at Site A. Although Site B had higher abundances of certain enrichment or disturbance-tolerant groups such as Oligochaete worms, Site A in fact had a greater prevalence and/or abundance of hardy EG-IV and EG-V taxa (see Fig. 11 & Appendix 5), which may be responding to the mild enrichment present (i.e. shallower aRPD). The planned future surveys will elucidate whether these site differences remain consistent.

Compared to other estuaries in the Otago region, Blueskin Bay stands out as clearly having the greatest macrofaunal richness and some of the highest abundances (Fig. 14). In other regional estuaries, high macrofaunal abundances tend to be a symptom of a degraded environment, where hardier disturbance-tolerant species proliferate in what are otherwise typically species-poor assemblages (e.g. Forrest et al. 2020c, d). By contrast, the species-rich assemblages in Blueskin Bay are dominated by a variety of taxa,

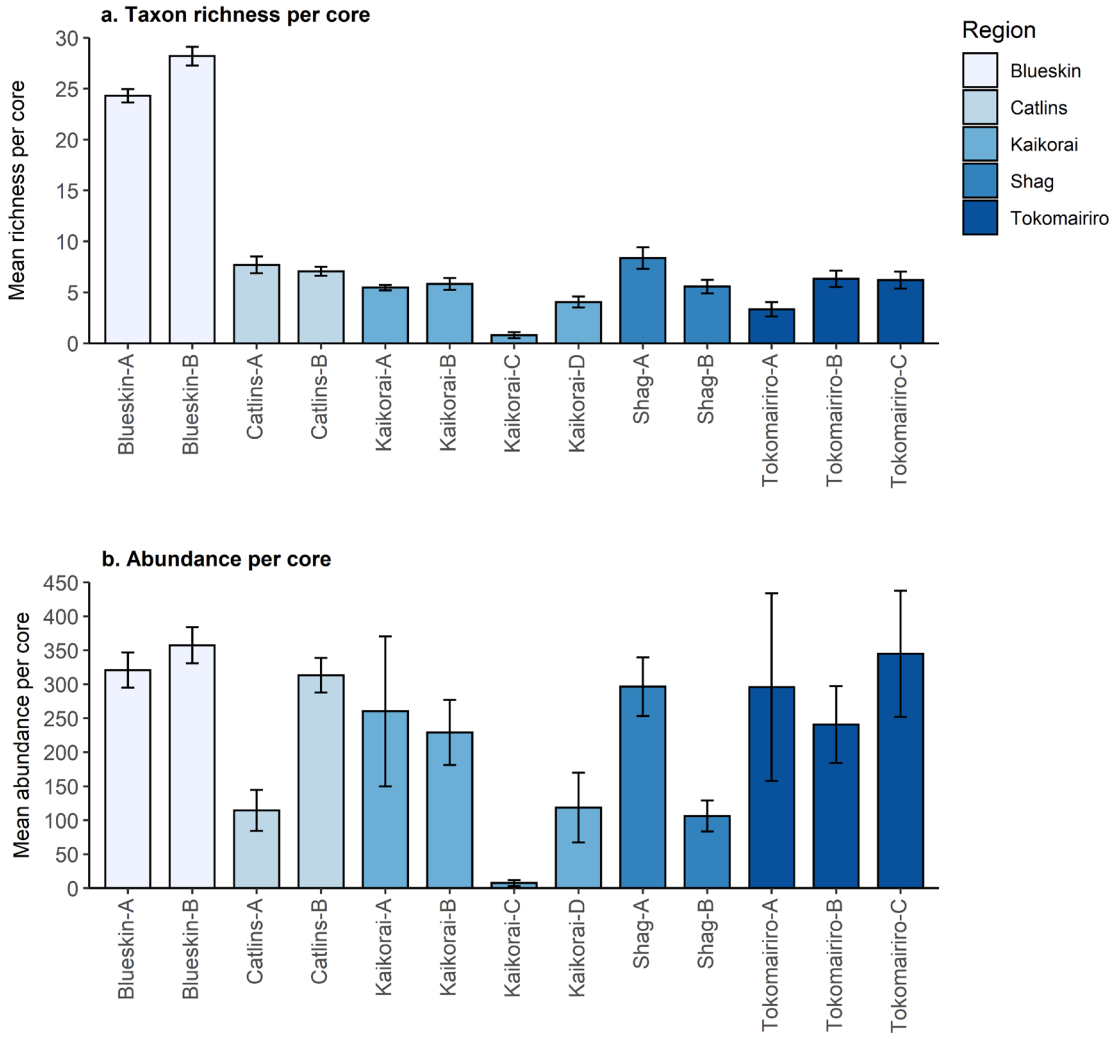


Fig. 14. Macrofauna richness and abundance summary (mean ±SE) based on NEMP monitoring in Otago estuaries over the last five years. For illustrative purposes, site-level data are averaged across multiple survey years in each estuary.

with both sites characterised by a range of organisms considered to be sensitive to displacement due to habitat disturbance.

Overall, the main tidal flats of Blueskin Bay are in a healthy condition, especially relative to other Otago estuaries that have been monitored to date. This situation has persisted in Blueskin Bay despite historic modification of estuary margins, loss of salt marsh, and catchment land-use changes that have increased the threat from muddy sediment inputs (Roberts et al. 2021). Future threats should be managed so that the current healthy state of the estuary is maintained.

5.2 RECOMMENDATIONS

It is recommended that the baseline years (two further surveys) are completed. Together with data gathered from changes in sediment plate depth, the work will provide a comprehensive baseline for the long-term monitoring of ecological health. The monitoring sites, methods and indicators described in this report are all appropriate for that purpose.

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APPENDICES

Appendix 1. GPS coordinates and for fine scale sites (corners) and sediment plates

FINE SCALE SITE A

Site	NZTM EAST	NZTM NORTH
C1	1411507	4933343
C2	1411565	4933333
C3	1411560	4933303
C4	1411500	4933313

FINE SCALE SITE B

Site	NZTM EAST	NZTM NORTH
C1	1411184	4932115
C2	1411242	4932132
C3	1411252	4932104
C4	1411193	4932088

SEDIMENT PLATES SITE A

Estuary	Site	Plate	NZTM East	NZTM North	Dist (m)
Blue	A	1	1411506	4933338	5
Blue	A	2	1411505	4933333	10
Blue	A	3	1411503	4933324	20
Blue	A	4	1411501	4933318	25

SEDIMENT PLATES SITE B

Estuary	Site	Plate	NZTM East	NZTM North	Dist (m)
Blue	B	1	1411187	4932112	5
Blue	B	2	1411188	4932107	10
Blue	B	3	1411191	4932096	20
Blue	B	4	1411192	4932092	25

Appendix 2. RJ Hill analytical methods for sediments

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 Laboratories, 28 Duke Street, Frankton, Hamilton 3204.

Sample Type: Sediment			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
Individual Tests			
Environmental Solids Sample Drying*	Air dried at 35°C Used for sample preparation. May contain a residual moisture content of 2-5%.	-	1-6
Environmental Solids Sample Preparation	Air dried at 35°C and sieved, <2mm fraction. Used for sample preparation May contain a residual moisture content of 2-5%.	-	1-6
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	1-6
Total Recoverable digestion	Nitric / hydrochloric acid digestion. US EPA 200.2.	-	1-6
Total Recoverable Phosphorus	Dried sample, sieved as specified (if required). Nitric/Hydrochloric acid digestion, ICP-MS, screen level. US EPA 200.2.	40 mg/kg dry wt	1-6
Total Nitrogen*	Catalytic Combustion (900°C, O2), separation, Thermal Conductivity Detector [Elementar Analyser].	0.05 g/100g dry wt	1-6
Total Organic Carbon*	Acid pretreatment to remove carbonates present followed by Catalytic Combustion (900°C, O2), separation, Thermal Conductivity Detector [Elementar Analyser].	0.05 g/100g dry wt	1-6
Heavy metals, trace As,Cd,Cr,Cu,Ni,Pb,Zn,Hg	Dried sample, <2mm fraction. Nitric/Hydrochloric acid digestion, ICP-MS, trace level.	0.010 - 0.8 mg/kg dry wt	1-6
3 Grain Sizes Profile as received			
Fraction >/= 2 mm*	Wet sieving with dispersant, as received, 2.00 mm sieve, gravimetry.	0.1 g/100g dry wt	1-6
Fraction < 2 mm, >/= 63 µm*	Wet sieving using dispersant, as received, 2.00 mm and 63 µm sieves, gravimetry (calculation by difference).	0.1 g/100g dry wt	1-6
Fraction < 63 µm*	Wet sieving with dispersant, as received, 63 µm sieve, gravimetry (calculation by difference).	0.1 g/100g dry wt	1-6

Appendix 3. Sediment plate raw data

Date	Site	Sediment Texture	Sediment Type*	Mud (%)	Sand (%)	Gravel (%)	aRPD (mm)	Plate	Depth (mm)
15/01/2021	A	firm	S0_10	5.0	94.5	0.6	45	p1	44
15/01/2021	A	firm	S0_10					p2	60
15/01/2021	A	firm	S0_10					p3	42
15/01/2021	A	firm	S0_10					p4	47
15/01/2021	B	firm	S0_10	5.7	93.2	1.1	35	p1	50
15/01/2021	B	firm	S0_10					p2	60
15/01/2021	B	firm	S0_10					p3	44
15/01/2021	B	firm	S0_10					p4	46

* S0_10 = sand with <10% mud

Appendix 4. Sediment quality raw data

Value for aRPD show zone mean and range. Data are otherwise based on composite samples in each zone.

Site	Zone	Gravel	Sand	Mud	TOC	TN	TP	aRPD	As	Cd	Cr	Cu	Hg	Ni	Pb	Zn
		%	%	%	%	mg/kg	mg/kg	mm	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
A	X	<0.1	94.4	5.6	0.11	<500	179	11.3 (6 to 25)	1.9	<0.010	4.1	0.9	<0.02	2.6	0.94	9
	Y	1.6	93.3	5.1	0.15	<500	172	14.3 (8 to 30	2.1	<0.010	4.2	1	<0.02	2.5	1.44	9
	Z	<0.1	95.8	4.2	0.14	<500	179	12.5 (5 to 20)	2.1	<0.010	4.1	0.8	<0.02	2.4	1	8
B	X	1.4	93.5	5	0.11	<500	250	21.7 (10 to 35)	2.9	<0.010	6.9	1	<0.02	5.8	1.22	11
	Y	1.6	92.8	5.6	0.11	<500	260	28.3 (10 to 45)	3	<0.010	7	1	<0.02	5.3	1.21	12
	Z	0.2	93.4	6.5	0.13	<500	270	28.0 (12 to 35)	3.2	<0.010	7.5	1.2	<0.02	6.2	1.41	12
								DGV	20	1.5	80	65	0.15	21	50	200
								GV-high	70	10	370	270	1	52	220	410

Appendix 5. Macrofauna core raw data

Main group	Taxa	Habitat	EG	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10
Amphipoda	Amphipoda indet.	Infauna	II													1		5		1		1	
Amphipoda	Lysianassidae	Infauna	II	1	14	7	1	1	1	1	5	4	2	2	1		11	4	3	1		1	
Amphipoda	Paracalliope novizealandiae	Infauna	II	1	29	8	2	11		4	14	4	13	1	1	1	6	5	2	7		1	2
Amphipoda	Phoxocephalidae	Infauna	II	7	1	1	6	1		2	4	2	3	9	12	8	1	8	1	9	12	12	7
Anthozoa	Anthozoa	Epibiota	II	5			1	6	6	9	2	4	1		1	1		2	5	2		1	2
Bivalvia	Arthritica sp. 5	Infauna	IV												1								
Bivalvia	Austrovenus stutchburyi	Infauna	II	3				1	1		1			3	2	1	3	3	6	1	3	1	6
Bivalvia	Lasaea parengaensis	Infauna	-	54	41	51	68	105	44	97	56	40	24	1	12	9	5	11	5	16	5	1	2
Bivalvia	Macomona liliana	Infauna	II	1	1	1			1	1	1		1	1	2		1	3		1	1	1	1
Bivalvia	Nucula nitidula	Infauna	II	8		3	14	9	3	6	5	2	3	39	52	41	49	56	45	33	21	22	39
Bivalvia	Offadesma angasi	Infauna	-																				1
Copepoda	Copepoda	Infauna	II																1				
Cumacea	Colurostylis lemurum	Infauna	I											1	1	3		1	3			3	4
Decapoda	Austrohelice crassa	Infauna	V				1																
Decapoda	Brachyura (juv.)	Infauna	-				1																
Decapoda	Halicarcinus sp. (juv)	Infauna	III						1														
Decapoda	Halicarcinus whitei	Infauna	III		2	1		1			1					1	3			1		1	
Decapoda	Hemiplax hirtipes	Infauna	V			2																	
Gastropoda	Austrolittorina cincta	Epibiota	-														1						
Gastropoda	Cominella glandiformis	Epibiota	III	1			1							2					2				
Gastropoda	Diloma sp.	Epibiota	II																	1			
Gastropoda	Diloma subrostratum	Epibiota	II																		1		
Gastropoda	Gastropoda unid. (juv)	Epibiota	-															2					
Gastropoda	Micrelenchus huttonii	Epibiota	-														3						
Gastropoda	Neguraleus sp.	Epibiota	-														1						
Gastropoda	Notoacmea sp.	Epibiota	II			1															1		
Gastropoda	Retusa striata	Epibiota	-																		1		
Gastropoda	Turbonilla sp.	Epibiota	I												1						1		
Gastropoda	Zeacumantus subcarinatus	Epibiota	I														1			1			
Isopoda	Exosphaeroma obtusum	Infauna	V		1		1																
Isopoda	Exosphaeroma sp.	Infauna	V			1									1	1			4		1	1	
Nematoda	Nematoda	Infauna	II		1			1	6	2		1		1	1	3	4	8	6	8	5	2	
Nemertea	Nemertea	Infauna	III												2								1
Nemertea	Nemertea sp. 1	Infauna	III									1											
Nemertea	Nemertea sp. 2	Infauna	III		2					1		1			3	1	1						
Oligochaeta	Oligochaeta	Infauna	III		1	1		4	4			19	1	44	8	20	31	91	115	41	26	101	40
Ostracoda	Ostracoda	Infauna	I	2	7	6	1	1	1	3	1	3	3	2	5	3	23	18	18	19		3	
Polychaeta	Aglaophamus macroura	Infauna	II	4			3	3		5	4	2	2	1	1		1	1		1			1
Polychaeta	Ampharetidae	Infauna	II	3																			
Polychaeta	Aonides trifida	Infauna	I			4		5	2	2	1	1	7	5	4	6	6		3	7	3	6	4
Polychaeta	Aricidea sp.	Infauna	II			1		1	1														
Polychaeta	Barantolla lepte	Infauna	IV		4									1	1	1			2	1		1	
Polychaeta	Boccardia spp.	Infauna	II	9	10	13	9	10	8	2	14	10	8		2			2	3	5	5	2	1
Polychaeta	Capitella sp.	Infauna	IV		44	3		17		5		18	1										
Polychaeta	Disconatis accolus	Infauna	I																	1	1		
Polychaeta	Dorvilleidae	Infauna	II					1	1									1	1	2		1	1
Polychaeta	Exogoninae	Infauna	II	5	4	10	3	24	3	15	15	9	15	5		1	4	6	5	2	2	11	6
Polychaeta	Hemipodia simplex	Infauna	II												1								
Polychaeta	Hesionidae	Infauna	I								1	1											1
Polychaeta	Heteromastus filiformis	Infauna	III	3	2					1				1	1	3			3	3	1	2	1
Polychaeta	Leodamas cylindrifer	Infauna	I		8	1					1	1											
Polychaeta	Macroclymenella stewartensis	Infauna	II	20	7	17	17	22	20	48	34	28	35	8	7	24	8	8	6	6	14	9	12
Polychaeta	Microspio maori	Infauna	I	18	5	17	34	59	70	76	59	11	51		5	16		4	1	6	13	9	9
Polychaeta	Nainereis sp.	Infauna	-	1			1							1	2					2			
Polychaeta	Nereididae (juv)	Infauna Juv	-		4					1									2		1		
Polychaeta	Nicon aestuariensis	Infauna	III	1			2		1	3	1		1					1					1
Polychaeta	Orbinia papillosa	Infauna	I	1		1		1			2												
Polychaeta	Paradoneis sp.	Infauna	III	55	136	120	42	109	97	106	68	156	210	171	93	131	105	150	171	223	131	199	149
Polychaeta	Perinereis sp.	Infauna	III																1		1		
Polychaeta	Platynereis sp.	Infauna	I		1	2	1																
Polychaeta	Polychaete larvae	Larva	-																				1
Polychaeta	Prionospio aucklandica	Infauna	II	1	14			3	1		1		2						2	7		1	
Polychaeta	Prionospio sp.	Infauna	II			2		1	1		1	1		4	3	3				2			
Polychaeta	Scolecolepides benhami	Infauna	IV											4		1		1	2	1		2	
Polychaeta	Sphaerodoridae	Infauna	-							1	1	2											
Polychaeta	Sphaerosyllis sp.	Infauna	II						1														
Polychaeta	Spionidae	Infauna	III																				1
Polychaeta	Syllidae	Infauna	II		3	2	2	7	3	6	3	1	4	14	6	6	8	7	48	6	8	15	6
Polychaeta	Terebellidae	Infauna	II		2							1		7	3		2	2	6			2	4
Porifera	Porifera	Epibiota	-														1						
Tanaidacea	Zeuxoides sp.	Infauna	I	12	11	15	4	12	5	6	32	15	19	40	16	8	23	19	21	25	10	20	2

Appendix 6. Macrofauna QA

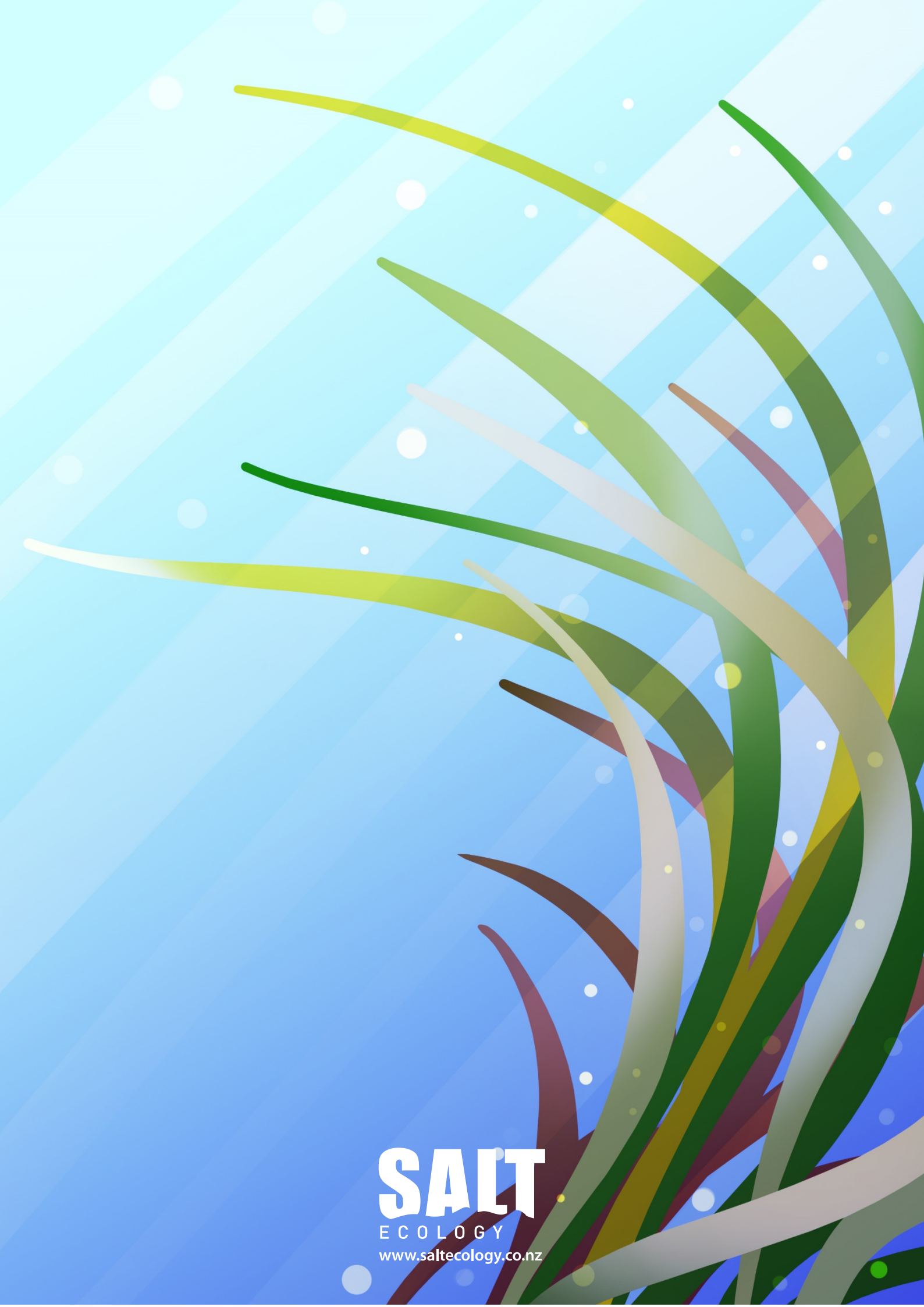
QA was undertaken on 2 core samples from each site, by Gary Stephenson, Coastal Marine Ecology Consultants (CMEC).

Cawthron Species in Blueskin Bay A-02	Cawthron Count	CMEC Count	CMEC Species in Blueskin Bay A-02	Comments
NEMERTEA			NEMERTEA	
Nemertea sp.2	2	2	Nemertea sp.#2	
NEMATODA				
Nematoda	1			
POLYCHAETA			POLYCHAETA	
Barantolla lepte	4			None of the capitellids in this sample have enough thoracic setigers with capillary setae to be identified as a *Barantolla*
Boccardia spp.	10	8	*Boccardia (Paraboccardia) syrtis*	
Capitella sp.	44	42	*Capitella* sp.	
Exogoninae	4			Included in Syllidae by CMEC
Heteromastus filiformis	2	6	*Heteromastus filiformis*	
Leodamas cylindrifer	8	8	*Leodamas cylindrifer*	
Macroclymenella stewartensis	7	8	*Macroclymenella stewartensis*	
Microspio maori	5	7	*Microspio maori*	
Nereididae juvenile	4	1	Nereididae juvenile	
		1	*Orbinia papillosa*	
Paradoneis sp.	136	140	*Paradoneis* sp.	
Platynereis australis	1	1	*Platynereis* sp.	*P. australis sensu lato* contains several species
Prionospio aucklandica	14	16	*Prionospio aucklandica*	
		1	Sabellidae	
Syllidae	3	3	Syllidae	
Terebellidae	2			Terebellid feeding tentacles cannot be fully withdrawn, yet none are visible on the specimens. Referred to Sabellidae by CMEC
OLIGOCHAETA			OLIGOCHAETA	
Oligochaeta	1	1	Oligochaeta	
BIVALVIA			BIVALVIA	
Lasaea parengaensis	41	34	?	Cannot verify as I am not familiar with this species
Macomona liliana	1	1	*Macomona liliana*	
		3	*Nucula nitidula*	
CRUSTACEA			CRUSTACEA	
Exosphaeroma obtusum	1	1	*Exosphaeroma obtusum*	
Halicarcinus whitei	2	2	*Halicarcinus whitei*	
Lyssianassidae	14	12	*Parawaldeckia* sp.	
Ostracoda	7	6	Ostracoda sp.#1	
Paracalliope novizealandiae	29	29	*Paracalliope novizealandiae*	
Phoxocephalidae	1			
Zeuxoides sp.	11	11	Tanaidacea sp.#1	Similar specimens from Waikawa Bay were identified by NIWA as *Zeuxo* sp. However, it should be noted that species from both genera have been described from NZ so until this difference is resolved I recommend listing the Otago specimens as Tanaidacea sp.#1.

Cawthron Species in Blueskin Bay A-04	Cawthron Count	CMEC Count	CMEC Species in Blueskin Bay A-04	Comments
ANTHOZOA			ANTHOZOA	
Anthozoa	1	1	*Edwardsia* sp.#1	
POLYCHAETA			POLYCHAETA	
Aglaophamus macroura	3	3	*Aglaophamus macroura*	
Boccardia spp.	9	9	*Boccardia (Paraboccardia) syrtis*	
Exogoninae	3			Included in Syllidae by CMEC
Macroclymenella stewartensis	17	12	*Macroclymenella stewartensis*	
Microspio maori	34	30	*Microspio maori*	
Naineris sp.	1	1	*Naineris* sp.	
Nicon aestuariensis	2	2	*Nicon aestuariensis*	
Paradoneis sp.	42	40	*Paradoneis* sp.	
Platynereis australis	1	1	*Platynereis* sp.	*P. australis sensu lato* contains several species
Syllidae	2	4	Syllidae	
GASTROPODA			GASTROPODA	
Cominella glandiformis	1	1	*Cominella glandiformis*	
BIVALVIA			BIVALVIA	
Lasaea parengaensis	68	82	?	Cannot verify as I am not familiar with this species
Nucula nitidula	14			
CRUSTACEA			CRUSTACEA	
Austrohelice crassa	1	1	*Austrohelice crassa*	
Brachyura juv.	1	1	*Halicarcinus whitei* juv.	
Exosphaeroma obtusum	1	1	*Exosphaeroma obtusum*	
Lyssianassidae	1	1	*Parawaldeckia* sp.	
Ostracoda	1	1	Ostracoda sp.#1	
Paracalliope novizealandiae	2	2	*Paracalliope novizealandiae*	
Phoxocephalidae	6	6	*Torridoharpinia hurleyi*	
Zeuxoides sp.	4	4	Tanaidacea sp.#1	Similar specimens from Waikawa Bay were identified by NIWA as *Zeuxo* sp. However, it should be noted that species from both genera have been described from NZ so until this difference is resolved I recommend listing the Otago specimens as Tanaidacea sp.#1.

Cawthron Species in Blueskin Bay B-02	Cawthron Count	CMEC Count	CMEC Species in Blueskin Bay B-02	Comments
ANTHOZOA			ANTHOZOA	
Anthozoa	1	1	*Edwardsia* sp.#1	
NEMERTEA			NEMERTEA	
Nemertea	2			Assigned to Nemertea sp.#2 by CMEC
Nemertea sp.2	3	5	Nemertea sp.#2	
NEMATODA			NEMATODA	
Nematoda	1	1	Nematoda	
POLYCHAETA			POLYCHAETA	
Aglaophamus macroura	1	1	*Aglaophamus macroura*	
		1	Ampharetidae	
Aonides trifida	4	4	*Aonides trifida*	
Barantolla lepte	1			Neither of the capitellids in this sample have enough thoracic setigers with capillary setae to be identified as a *Barantolla*
Boccardia spp.	2	2	*Boccardia (Paraboccardia) syrtis*	
Glyceridae	1	1	*Hemipodus simplex*	
Heteromastus filiformis	1	2	*Heteromastus filiformis*	
Macroclymenella stewartensis	7	5	*Macroclymenella stewartensis*	
Microspio maori	5	3	*Microspio maori*	
Naineris sp.	1	2	*Naineris* sp.	
Paradoneis sp.	93	88	*Paradoneis* sp.	
Prionospio sp.	3	3	*Prionospio aucklandica*	
		2	Sabellidae	
Syllidae	6	5	Syllidae	
Terebellidae	3			Terebellid feeding tentacles cannot be fully withdrawn, yet none are visible on these specimens. Referred to Ampharetidae (1) and Sabellidae (2) by CMEC
OLIGOCHAETA			OLIGOCHAETA	
Oligochaeta	8	4	Oligochaeta	
GASTROPODA			GASTROPODA	
Turbonilla sp.	1	1	*Turbonilla* sp.	
BIVALVIA			BIVALVIA	
Arthritica sp.#5	1	1	*Arthritica* sp.#1	*Arthritica* sp.#1 in Otago regional list is the same as Bruce Marshall's un-named *Arthritica* sp.#5
Austrovenus stutchburyi	2	2	*Austrovenus stutchburyi*	
Lasaea parengaensis	12			
Macomona liliana	2	2	*Macomona liliana*	
Nucula nitidula	52	63	*Nucula nitidula*	
CRUSTACEA			CRUSTACEA	
Colurostylis lemurum	1	1	*Colurostylis lemurum*	
Exosphaeroma sp.	1	1	*Exosphaeroma obtusum*	
Lyssianassidae	1	1	*Parawaldeckia* sp.	
Ostracoda	5	5	Ostracoda sp.#1	
Paracalliope novizealandiae	1	1	*Paracalliope novizealandiae*	
Phoxocephalidae	12	12	*Torridoharpinia hurleyi*	
Zeuxoides sp.	16	15	Tanaidacea sp.#1	Similar specimens from Waikawa Bay were identified by NIWA as *Zeuxo* sp. However, it should be noted that species from both genera have been described from NZ so until this difference is resolved I recommend listing the Otago specimens as Tanaidacea sp.#1.

Cawthron Species in Blueskin Bay B-10	Cawthron Count	CMEC Count	CMEC Species in Blueskin Bay B-10	Comments
ANTHOZOA			ANTHOZOA	
Anthozoa	2	2	*Edwardsia* sp.#1	
NEMERTEA			NEMERTEA	
Nemertea	1			Assigned to Nemertea sp.#2 by CMEC
		1	Nemertea sp.#2	
			NEMATODA	
		1	Nematoda	
POLYCHAETA			POLYCHAETA	
Aglaophamus macroura	1	1	*Aglaophamus macroura*	
		4	Ampharetidae	
Aonides trifida	4	4	*Aonides trifida*	
Boccardia spp.	1	1	*Boccardia (Paraboccardia) syrtis*	
Dorvilleidae	1			
Exogoninae	6			Included in Syllidae by CMEC
Hesionidae	1			
Heteromastus filiformis	1	1	*Heteromastus filiformis*	
Macroclymenella stewartensis	12	10	*Macroclymenella stewartensis*	
Microspio maori	9	11	*Microspio maori*	
Nicon aestuariensis	1	1	*Nicon aestuariensis*	
Paradoneis sp.	149	142	*Paradoneis* sp.	
Syllidae	6	13	Syllidae	
Terebellidae	4			Terebellid feeding tentacles cannot be fully withdrawn, yet none are visible on these specimens. Referred to Ampharetidae by CMEC
Unidentified polychaete	1	1	Spionidae	Specimen not suffiently complete for generic diagnosis
OLIGOCHAETA			OLIGOCHAETA	
Oligochaeta	40	15	Oligochaeta	
BIVALVIA			BIVALVIA	
Austrovenus stutchburyi	6	6	*Austrovenus stutchburyi*	
Lasaea parengaensis	2	3	?	Cannot verify as I am not familiar with this species
Macomona liliana	1	1	*Macomona liliana*	
Nucula nitidula	39	37	*Nucula nitidula*	
Offadesma angasi	1	1	*Offadesma angasi*	
CRUSTACEA			CRUSTACEA	
Colurostylis lemurum	4	4	*Colurostylis lemurum*	
Paracalliope novizealandiae	2	2	*Paracalliope novizealandiae*	
Phoxocephalidae	7	7	*Torridoharpinia hurleyi*	
Zeuxoides sp.	2	2	Tanaidacea sp.#1	Similar specimens from Waikawa Bay were identified by NIWA as *Zeuxo* sp. However, it should be noted that species from both genera have been described from NZ so until this difference is resolved I recommend listing the Otago specimens as Tanaidacea sp.#1.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