

Catlins/Pounaweia Estuary
Intertidal Fine-Scale Monitoring
Data Summary

Prepared for
Otago Regional Council
February 2024

Salt Ecology
Report 130

RECOMMENDED CITATION

Morrisey D, Forrest BM. 2023. Catlins/Pounawea Estuary Intertidal Fine-Scale Monitoring Data Summary. Salt Ecology Report 130, prepared for Otago Regional Council, February 2024. 13p.

Catlins/Pounaweia Estuary Intertidal Fine-Scale Monitoring Data Summary

Prepared by

Don Morrisey
and Barrie Forrest

for

Otago Regional Council
February 2024

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

www.saltecolgy.co.nz

GLOSSARY

AMBI	AZTI Marine Biotic Index
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
NEMP	National Estuary Monitoring Protocol
Ni	Nickel
ORC	Otago Regional Council
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

ACKNOWLEDGEMENTS

Many thanks to Sam Thomas (ORC) for his support in undertaking this work and peer review of the report. Thanks also to Keryn Roberts (Salt Ecology) for comments on the report draft.

TABLE OF CONTENTS

1.	INTRODUCTION.....	1
2.	METHODS.....	1
3.	KEY FINDINGS.....	2
3.1	Sediment quality.....	2
3.2	Biota.....	5
4.	MONITORING AND MANAGEMENT IMPLICATIONS.....	8
5.	RECOMMENDATIONS.....	9
6.	REFERENCES.....	9
	Appendix 1. Summary of NEMP fine-scale indicators.....	10
	Appendix 2. Condition ratings for assessing estuary health.....	11
	Appendix 3. Sediment quality data.....	12
	Appendix 4. Macrofauna core data summed across ten replicates for each survey and site.....	13

FIGURES

Fig. 1.	Location of the two fine-scale monitoring sites in Catlins Estuary.....	1
Fig. 2.	Sediment particle grain size analysis.....	2
Fig. 3.	Mean (\pm SE, n=3-10) aRPD depth relative to condition ratings.....	3
Fig. 4.	Mean (\pm SE, n=3) sediment total organic carbon and total nitrogen in composite samples, relative to condition ratings.....	4
Fig. 5.	Mean (\pm SE, n=3) trace metal concentrations in composite samples, relative to condition ratings.....	4
Fig. 6.	Mean (\pm SE, n=10) macrofauna taxon richness and abundance per core.....	5
Fig. 7.	Mean (\pm SE, n=10) AMBI scores relative to condition ratings.....	5
Fig. 8.	Contribution to site richness and abundances of macrofauna species in eco-groups ranging from sensitive (EG-I) to resilient (EG-V).....	6
Fig. 9.	Non-metric MDS ordination of macrofaunal core samples for each site-zone and survey.....	7

TABLES

Table 1.	Summary of mean values of key indicators at fine-scale monitoring sites in Catlins Estuary.....	3
----------	---	---

1. INTRODUCTION

Between December 2016 and February 2019, Otago Regional Council (ORC) undertook three ecological and sediment quality surveys in Catlins/Pounaweia (hereafter Catlins) Estuary. A report was produced on the first survey (Robertson et al. 2017) but data from the two subsequent surveys were archived. This report provides a high-level summary of the data for all three surveys, to support a planned review of ORC's estuary State of the Environment (SOE) monitoring programme.

2. METHODS

The survey methods are described in Robertson et al. (2017) and were based on the 'fine-scale' approach in New Zealand's National Estuary Monitoring Protocol (NEMP; Robertson et al. 2002). Monitoring was

conducted at two sites (Fig. 1). Different providers have undertaken the surveys, namely Wriggle Coastal Management (December 2016), Ryder Associates (December 2017) and Salt Ecology (February 2019). Monitoring indicators and methods are described in Appendix 1, and were as follows:

- Sediment quality indicators: Included sediment mud content, oxygenation status (measured as the apparent Redox Potential Discontinuity depth; aRPD), nutrients and organic content, and selected trace contaminants. Sediment aRPD was measured in the field. For the other variables, three samples (each composited from 3-4 sub-samples of the surface 20mm of sediment) were collected and sent to Hill Laboratories for analysis.
- Biotic indicators: Included surface-dwelling snails and macroalgae, and benthic macrofauna. Macrofauna sampling was undertaken using cores (130mm diameter, 150mm deep, ~2L volume,

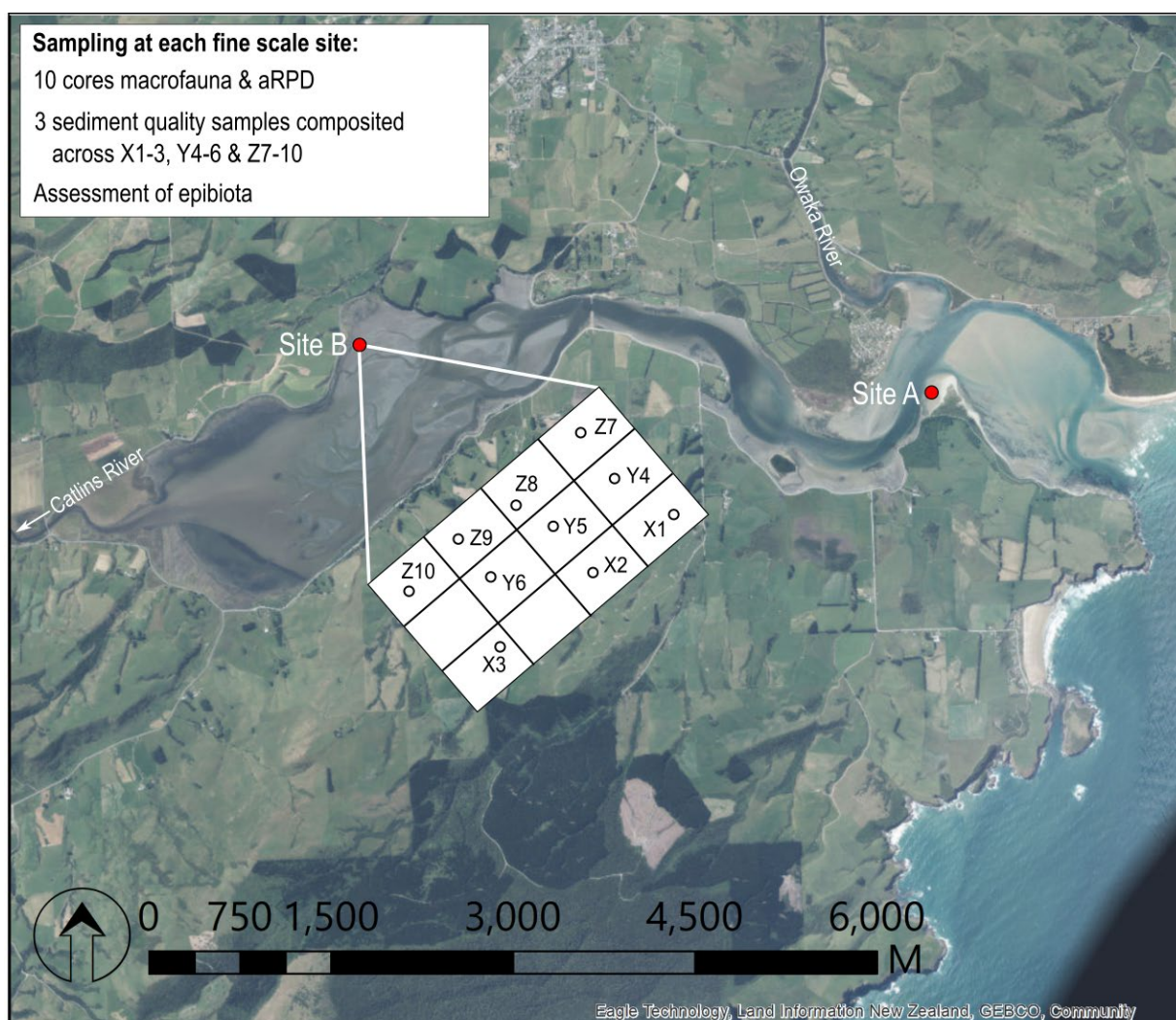


Fig. 1. Location of the two fine-scale monitoring sites in Catlins Estuary. The schematic depicts the sediment sample and macrofauna core collection. Information on site GPS positions and other location information is provided in Robertson et al. (2017).

sieved to 0.5mm). Macrofauna species taxonomy and counts were made by Ryder Associates in December 2017, and by Coastal Marine Ecology Consultants for the other two surveys. For reporting purposes, macrofauna naming differences among surveys have been standardised to the extent feasible.

The data analysis methods are described in recent ORC reports (e.g., Forrest et al. 2022a). Macrofauna assessment included calculation of scores for the international biotic health index 'AMBI'. To assess estuary health, results for most indicators are evaluated against 'condition ratings' described in Appendix 2.

3. KEY FINDINGS

An overall summary of results, with condition ratings applied where available, is provided in Table 1.

3.1 SEDIMENT QUALITY

Sediment quality data are collated in Appendix 3. Sediments consisted of sand at Site A and muddy sand at Site B (Fig. 2, see photos opposite). There was an increase in the amount of mud in the sediment at Site B in consecutive years, from 24.7% in 2016 to 42.9% in 2019. This corresponds to a change in status from 'fair' to 'poor' (Table 1). Site A is on the edge of the channel in the lower estuary, and is likely strongly influenced by the physical effects of water movement (e.g., tide, wind and flood-related water movement), leading to habitat instability. The muddier sediments at Site B appear more stable, which reflects the more sheltered location of this site in the upper estuary.

These site characteristics are reflected in data from annual sedimentation monitoring between 2016 and 2022 (Forrest 2023). That monitoring shows a steady sediment accrual at Site B (average rate of 5.8mm/yr). By contrast, Site A experienced periods of sand erosion prior to 2020, with accrual measured thereafter (Forrest 2023). This pattern at Site A is likely to reflect movement of sand by water currents rather than input of fine sediment from the catchment, while the latter is a likely explanation for the steady build-up of muddy sediment at Site B.

Data from December 2019 to November 2022 (i.e., subsequent to the fine scale surveys) show that the percentage of mud in sediments at Site B has decreased since the February 2019 peak in Fig. 2 (from 42.9% to 29.4%). These changes may reflect specific events in the catchment, such as periods of

intense rainfall that have led to variable inputs of muddy sediment. In addition, beds of macroalgae (mainly *Gracilaria* spp., which has previously been called *Agarophyton* spp.) are present in the upper estuary margins, including in the area adjacent to Site B (Stevens & Roberts 2022), and may enhance the deposition and accumulation of fine sediment.

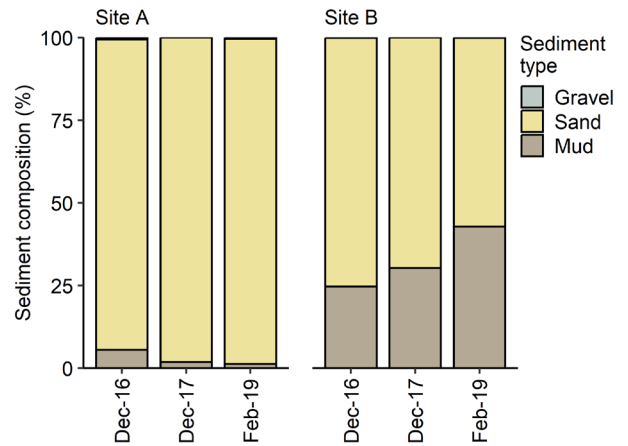
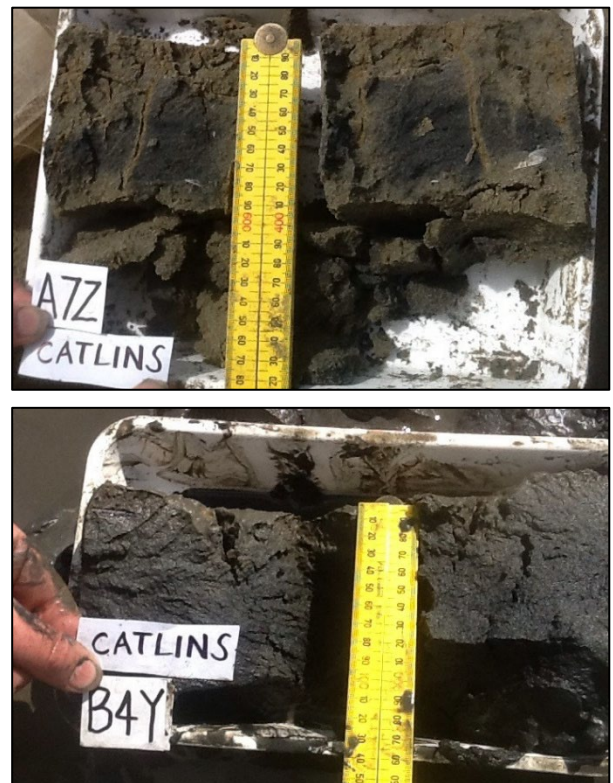


Fig. 2. Sediment particle grain size analysis showing percentage composition of mud (<63µm), sand (<2mm to ≥63µm) and gravel (≥2mm) from composite samples (n=3) at fine-scale sites.



Sediment core profiles from Site A (top, sand) and B (bottom, muddy sand) in 2019. Faunal burrows are visible at Site A and oxygen-depleted sediment is the deeper grey/black colouring.

Table 1. Summary of mean values of key indicators at fine-scale monitoring sites in Catlins Estuary. Values are rated against condition scores of ecological health, where available (Appendix 2). No rating criteria exist for Total Phosphorus (TP), macrofauna richness (Rich) or macrofauna abundance (Abun). See Glossary for definition of indicators.

Site	Year	Mud %	aRPD mm	TN mg/kg	TP mg/kg	TOC %	As mg/kg	Cd mg/kg	Cr mg/kg	Cu mg/kg	Pb mg/kg	Hg mg/kg	Ni mg/kg	Zn mg/kg	Rich na	Abun na	AMBI na
A	Dec-16	5.5	30	<500	217	<0.05	5.3	0.013	6.0	2.3	1.3	<0.01	4.1	11.1	5	17	1.3
	Dec-17	1.9	-	<1300	440	<0.13	6.1	0.013	5.7	2.3	1.2	<0.02	3.5	12.4	9	176	2.3
	Feb-19	1.3	45	<500	211	<0.13	5.4	0.009*	5.7	1.9	1.1	<0.02	3.0	11.1	9	149	2.7
B	Dec-16	24.7	20	367*	263	0.27	2.9	0.019	8.6	4.5	2.2	0.01*	5.7	24.3	8	274	4.4
	Dec-17	30.4	-	<500	387	0.36	3.6	0.018	9.3	4.9	2.5	<0.02	6.0	30.0	6	280	4.5
	Feb-19	42.9	20	<500	337	0.35	3.3	0.016	8.8	4.2	2.4	0.02	5.2	27.0	8	386	4.4

* Sample mean includes values below lab detection limits

< All values below lab detection limit

Very Good	Good	Fair	Poor
-----------	------	------	------

Sediment oxygenation assessed by the aRPD method, was rated 'fair' to 'good' in both surveys where it was recorded (Table 1, Fig. 3). The core photos on the previous page illustrate the change in aRPD transition between brown surface sediment and deeper oxygen-depleted sediment. There were no signs of excessive sediment enrichment, such as an intense black colour throughout the depth profile or a strong sulphide ('rotten egg') odour when the sediment was disturbed.

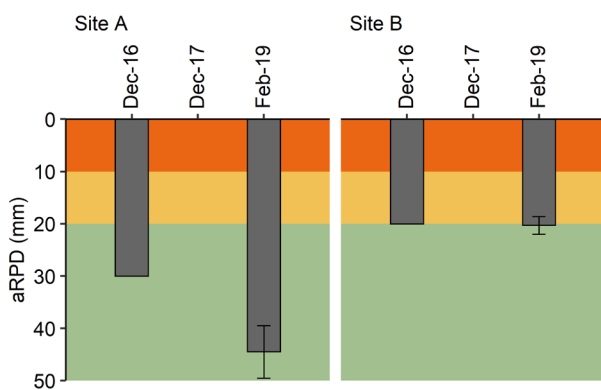


Fig. 3. Mean (\pm SE, n=3-10) aRPD depth relative to condition ratings. The aRPD depth was not recorded in December 2017.

Very Good	Good	Fair	Poor
-----------	------	------	------



Intertidal flats at Site A looking towards lower estuary.



Site B in upper estuary.

Laboratory sediment analyses revealed low levels of organic matter and nutrients, corresponding to ratings of 'very good' (Table 1, Fig. 4). TOC values at Site A, and TN values at both sites, were often less than routine laboratory method detection limits.

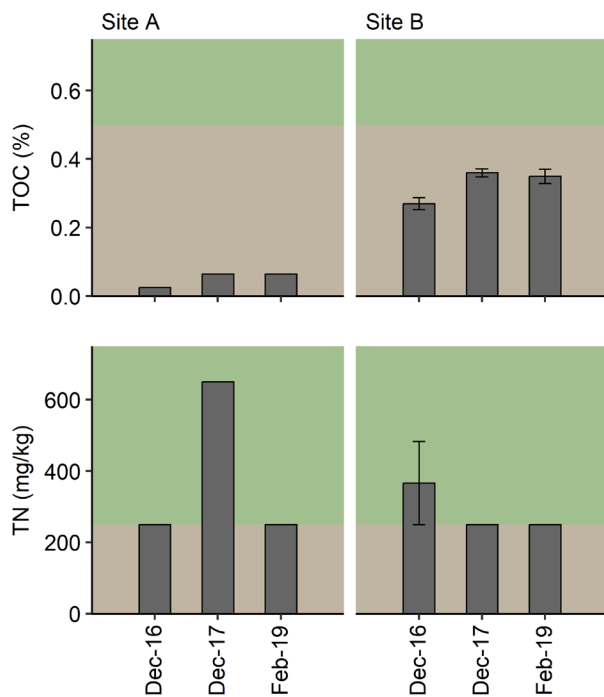


Fig. 4. Mean (\pm SE, n=3) sediment total organic carbon (TOC) and total nitrogen (TN) in composite samples, relative to condition ratings. TOC and TN values at Site A in all years, and TN values at Site B in December 2017 and 2019, were less than routine laboratory method detection limits. Values plotted are 50% of the detection limit.



Sediment trace metal contaminants were at very low concentrations in all three surveys, and less than half of the national sediment quality Default Guideline Value (DGV; Table 1, Fig. 5). DGVs indicate "...the concentrations below which there is a low risk of unacceptable effects occurring" (ANZG 2018). Overall, therefore, these results suggest that there are no significant chemical contaminant inputs from the catchment that are accumulating in the estuary, and no trends in concentrations over time.

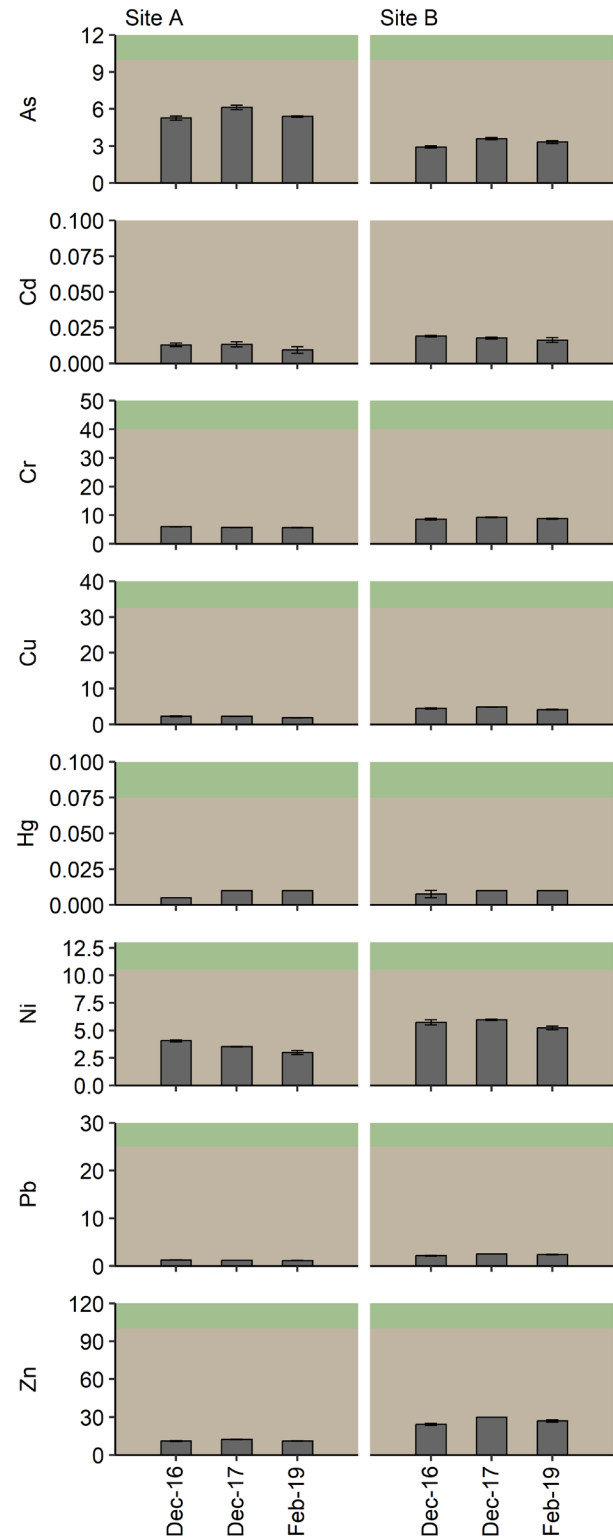


Fig. 5. Mean (\pm SE, n=3) trace metal concentrations in composite samples, relative to condition ratings. The boundary between 'very good' and 'good' represents 50% of the ANZG (2018) sediment quality Default Guideline Value (DGV). Below the DGV there is a 'low risk' of unacceptable effects.



3.2 BIOTA

Surface dwelling epibiota

Epibiota were sparse at both sites, except for mud snails (*Amphibola crenata*), which were relatively common at Site B (e.g., 10-20/m² in 2019). Mudflat top shells (*Diloma subrostratum*) and whelks (*Cominella glandiformis*) were also present at Site B in 2019, but described as 'rare' (<0.1/m²). The seaweeds *Gracilaria* spp. and *Ulva* spp. ('sea lettuce') have also been described from both sites, but are not consistently present and, when recorded, have been at a low prevalence (<1% cover).

Sediment-dwelling macrofauna

Macrofauna species and abundances are summarised in Appendix 4. Core sampling revealed the macrofauna to be moderately impoverished in terms of the range of species present, and dominated by hardy species. Key points are as follows:

- A total of 34 species or higher macrofauna taxa have been recorded from the two sites. Eleven main taxonomic groups are present, but shrimp-like amphipods, bivalves and polychaete worms are by far the most abundant (Appendix 4).
- Mean species richness at both sites was low (range ~5-9 taxa per core at Site A, ~6-8 at Site B). At Site A, more species were present in 2017 and 2019 than in 2016 (Fig. 6, top). Fewer species were present at Site B in 2017 than in 2016 or 2019, which had similar numbers.
- Similarly, the greatest abundances occurred in 2017 and 2019 at Site A, with means of 176 and 149 organisms per core, respectively (Fig. 6, bottom). Abundances were similar in 2016 and 2017 but increased in 2019 at Site B. This temporal fluctuation likely reflects natural variability. While it is possible that the use of different providers in each of the three survey years resulted in variability, the observed consistency between consecutive surveys (2017 and 2019 at Site A, 2016 and 2017 at Site B) suggests that the abundance increases over time are unlikely to be an artefact.
- Mean values of the biotic index AMBI corresponded to a condition rating of 'good' at Site A and 'poor' at Site B (Table 1, Fig. 7). These ratings reflect that the macrofauna at Site B was consistently dominated by hardy species in eco-group IV while eco groups I-III were predominant at Site A, but their relative proportions varied among surveys (Fig. 8). For example, mean AMBI

values at Site A have increased (i.e., deteriorated) over time, which appears due mainly to increased densities of the hardy (EG-IV) tube-building amphipod *Paracorophium excavatum*. This result conceivably reflects natural processes such as physical disturbance from sand movement and migration of the main estuary channel.

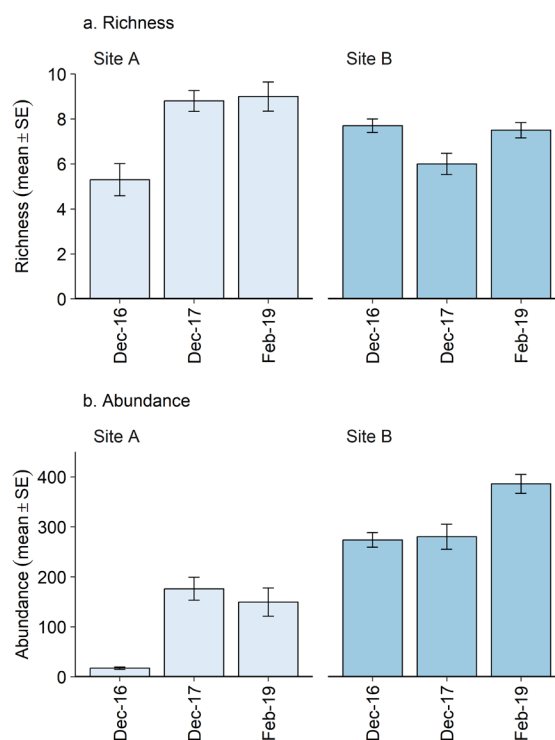


Fig. 6. Mean (\pm SE, n=10) macrofauna taxon richness and abundance per core.

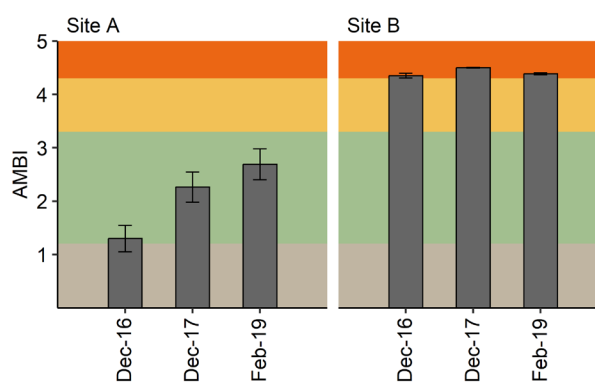


Fig. 7. Mean (\pm SE, n=10) AMBI scores relative to condition ratings.



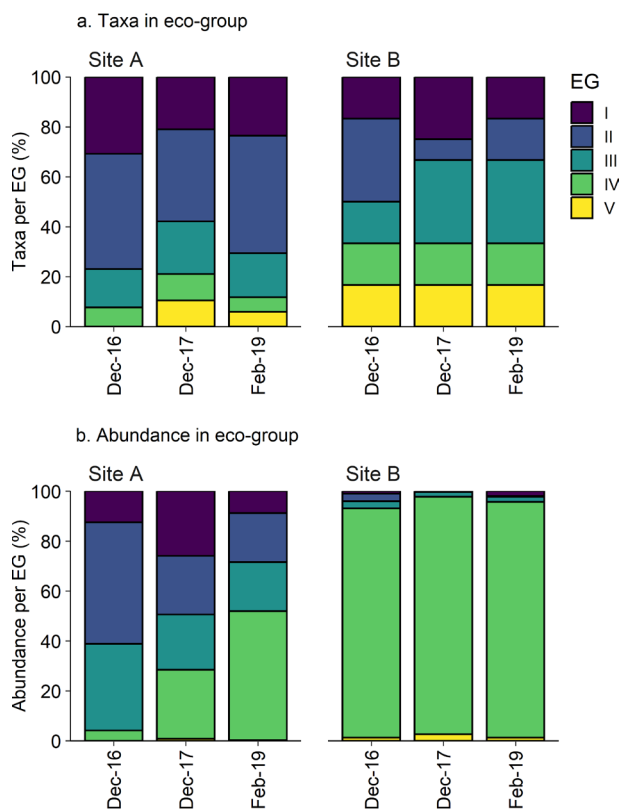


Fig. 8. Contribution to site richness and abundances of macrofauna species in eco-groups ranging from sensitive (EG-I) to resilient (EG-V). The graphs illustrate that the macrofauna was dominated by hardy (EG-IV) organisms at Site B in all years, and at Site A in 2019.

- The small bivalve *Legrandina turneri* was the most abundant species at Site A in 2017 and 2019 but was present in much smaller numbers in 2016 (Appendix 4, photo opposite). This species has a southern New Zealand distribution, and is considered to be intolerant of mud and organic material (Robertson et al. 2017). Note that this species does not have an AMBI eco-group designation, hence these high abundances are not reflected in the AMBI data in Figs 7 and 8.
- In addition to *Legrandina turneri*, two amphipod species, *Torridoharpinia hurleyi* and *Waitangi* sp. 1, were consistently common at Site A but absent from Site B.
- By far the most abundant of the hardy species at Site B was the amphipod *Paracorophium excavatum* noted above (Appendix 4, photo opposite). This species is common in disturbed environments, especially in river-dominated estuaries subject to highly variable flows and salinities. Also present at Site B were oligochaete and polychaete worm species that are commonly

found in estuaries nationally, in particular *Scolecopides benhami*. The small and nationally-common estuarine bivalve *Arthritica* sp. 5 was also common at Site B.

- Cockles were recorded in both sites in most surveys but were not abundant (1-2 individuals per core). The few cockles present were smaller at Site A (4-15mm shell length) than Site B (mainly 26-34mm shell length).



The small bivalve *Legrandina turneri* was the most dominant of the macrofauna at Site A. This is a little-known species whose distribution appears to be restricted to southern New Zealand.



The tube-building amphipod *Paracorophium excavatum* was by far the most dominant of the macrofauna at Site B. This species is common in physically disturbed environments, especially in river-dominated estuaries where water flows and salinities are highly variable (image from NIWA Otago estuaries collection).

A cursory analysis of macrofauna community composition differences among sites and surveys was undertaken. A multivariate method was used to 'group' sites according to their similarity in macrofauna composition (Fig. 9). The analysis revealed the following macrofauna composition patterns:

- Macrofauna differences between the two sites were quite pronounced, reflecting the species differences described above, as well as more subtle differences in the occurrence of sub-dominant species (Appendix 6).
- The tight grouping of Site B samples in all years reflects the strong dominance in all three surveys of the amphipod *Paracorophium excavatum*, and to a lesser degree oligochaete worms and the polychaete worm *Scolecopides benhami*.
- At Site A, the analysis revealed differences in 2016 relative to the two other surveys, which reflect the relatively species-poor nature and low abundance of macrofauna in that year (see Fig. 6).

A limited analysis was undertaken to determine whether macrofauna differences among sites/surveys could be 'explained' by any of the sediment quality variables. Sediment mud appears likely to be a potential explanatory variable for the difference between sites. Macrofauna composition differences were correlated with higher values of mud at Site B

(and at Site A in 2016), and with a higher TOC and shallower aRPD (Spearman rank correlation coefficient $\rho = 0.713$ for sediment %mud; see also Fig. 9). However, absolute TOC values were low and aRPD values reasonably high (corresponding to 'fair' and 'good' condition ratings; see Table 1). In this respect, of the variables measured, the amount of mud in the sediment is likely to have the most plausible influence on macrofaunal composition. For example, a mud content of around 25% or greater (i.e., as evident at Site B) is often considered as the level at which macrofaunal composition changes can occur relatively to sandier sediments (Robertson et al. 2015; Ward & Roberts 2021). In general, muddy sediment is regarded as one of the key drivers of ecological health degradation in New Zealand estuaries (Cummings et al. 2003; Robertson et al. 2015; Berthelsen et al. 2018; Clark et al. 2021).

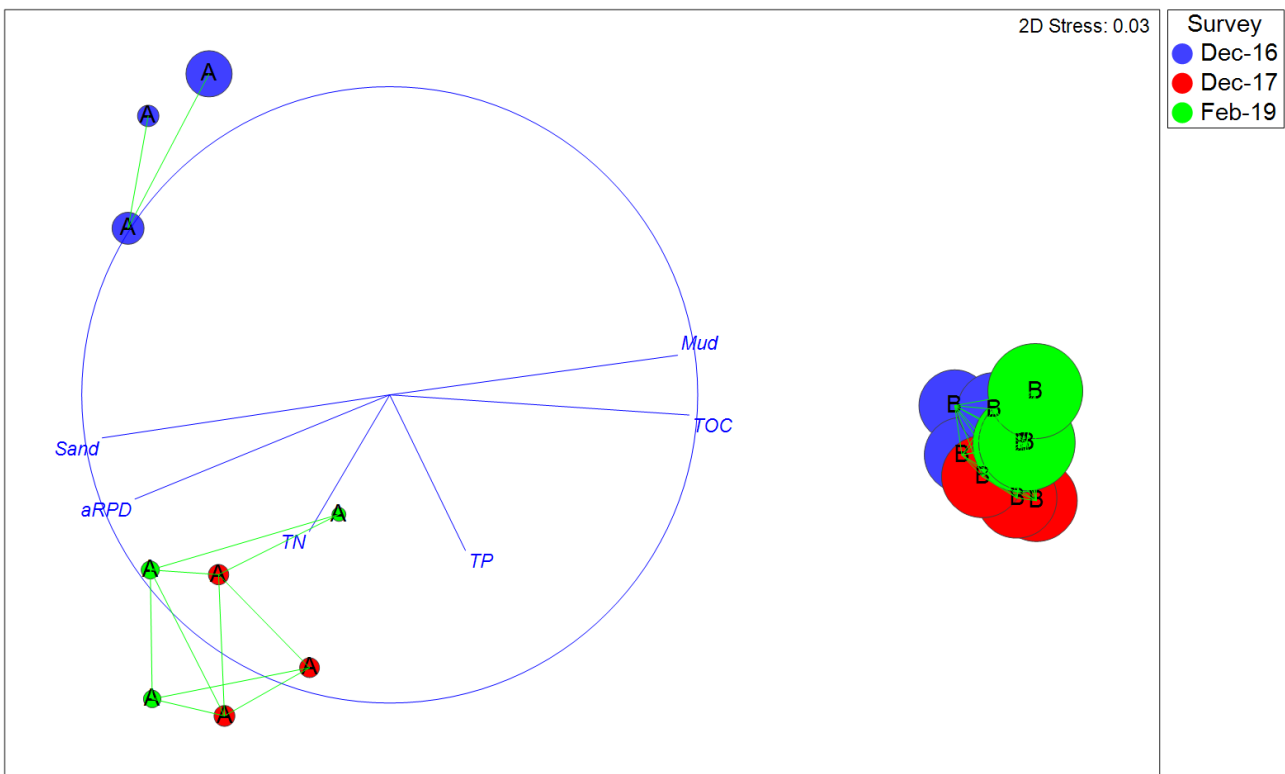


Fig. 9. Non-metric MDS ordination of macrofaunal core samples for data aggregated within each site-zone and survey.

Sample groups closer to each other are more similar than distant ones in terms of macrofaunal composition. A 'stress' value of 0.03 indicates that a 2-dimensional plot provides a reliable representation of differences. The green lines connect sample groups with a high similarity (65%) based on the Bray-Curtis measure. The vectors show the direction and strength of association (length of line relative to circle) of the measured environmental variables that were most strongly correlated with the pattern of differences. Bubble sizes are scaled to sediment mud content, which was highly correlated with TOC.

4. MONITORING AND MANAGEMENT IMPLICATIONS

ORC began broad-scale habitat monitoring of the Catlins Estuary in 2008 with repeat surveys in 2012, 2017, 2022 and 2024. To complement broad-scale monitoring comprehensive baseline fine-scale monitoring was undertaken in 2016, 2017 and 2019. One of the reasons for compiling the present summary report was to better understand the utility of the current monitoring approach. Once data for all Otago estuaries have been collated in a similar way, ORC will be in a better position to review the programme and determine monitoring priorities. In this broader context, Catlins Estuary presents some features that will need to be accounted for in the review. These include the following:

- The upper estuary (including Site B) appears susceptible to catchment influences, with land uses being predominantly pasture for sheep and beef farming (61% of catchment area; Robertson et al. 2017). ORC will need to consider priorities for managing these sources in the context of other regional catchment management priorities.
- Monitoring of macroalgal cover and biomass in the estuary (Stevens & Roberts 2022) has shown a marked degradation in ecological quality in the upper estuary margins, due to nuisance growths of *Gracilaria* spp. Between 2016 and late 2021, the area of the estuary affected by nuisance macroalgae had increased from 54ha to 127ha, and the biomass had tripled. Some areas show widespread degradation of sediment quality (shallow aRPD, high mud content and high organic content). Site B is immediately adjacent to one of these areas, hence provides a potentially useful baseline site against which to quantify the effects of any future expansion of the *Gracilaria* beds. That said, note that the macrofaunal species present at Site B are generally tolerant of mud and organic enrichment, and may be reasonably resilient to future changes.
- Previous sedimentation and macroalgal monitoring, combined with the analysis of fine scale data in this report, suggest that sediment and nutrient loads to Catlins Estuary from the catchment are exceeding the estuary's assimilative capacity. At present these problems are mainly confined to the upper estuary (and also the Ōwaka Arm; see Fig 1), reflecting their

more sheltered and less well-flushed hydrodynamic environments.

- The lower estuary, in contrast, is physically more dynamic, with a higher level of tidal flushing and variable patterns of sediment deposition and erosion at Site A (Forrest 2023). Nevertheless, macroalgal beds are also present just upstream of Site A and could expand in the future (Stevens & Roberts 2022). While Site A provides a potentially useful baseline site for quantifying the effects of such an expansion, the positioning of the site near the channel means that it is subject to physical stresses relating to hydrological conditions and sand movement. These conditions mean that physical disturbance at the site may have an over-riding influence on macrofauna, and make future ecological changes difficult to detect.

In terms of future monitoring, the above discussion suggests that neither site is ideal in terms of being sensitive to a change in direct catchment pressures (e.g., ongoing muddy sediment inputs). That said, if future changes include proliferation of nuisance algae, this type of habitat has its own characteristics that set it apart ecologically from 'barren' sand/mud habitats (Forrest et al. 2022b). As such, continued fine-scale monitoring, particularly at Site B, provides a means of characterising this type of ecological effect.

A question for ORCs programme review will be the merits of investigating alternative Catlins fine scale sites that may be more sensitive to long term changes in direct catchment pressures such as sedimentation. For this purpose, there will be additional macrofauna core data available over the next few months from a broad scale habitat survey conducted over the current summer. These data can be used to inform potential site selection. There are also limited data available from four mid-lower estuary sites that were sampled historically (Stewart & Bywater 2009; Stewart 2012), although these appear no more species-rich than Sites A and B described in the present report. Decisions regarding future monitoring sites should form part of ORC's review of the regional estuary SOE programme. That review should consider the specific type of monitoring that is needed in the context of management goals in Catlins Estuary, and the priorities for monitoring relative to other estuary systems in Otago.

5. RECOMMENDATIONS

Although there is merit in continued fine scale monitoring in Catlins Estuary, it is recommended that the scheduled monitoring in the present (2023/24) summer be deferred, with a decision on future fine-scale and other monitoring needs for Catlins Estuary determined as part of ORC's planned review of the regional estuary SOE programme. The results of ongoing annual sedimentation monitoring, and a NEMP broad-scale habitat mapping survey undertaken in the current summer, will contribute to a broader understanding of estuary state and monitoring needs.

6. REFERENCES

- ANZG 2018. Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Australian and New Zealand Governments and Australian State and Territory Governments, Canberra ACT, Australia. Available at <https://www.waterquality.gov.au/anz-guidelines/guideline-values/default/sediment-quality-toxicants>.
- Berthelsen A, Atalah J, Clark D, Goodwin E, Patterson M, Sinner J 2018. Relationships between biotic indices, multiple stressors and natural variability in New Zealand estuaries. *Ecological Indicators* 85: 634-643.
- Clark DE, Stephenson F, Hewitt JE, Ellis JI, Zaiko A, Berthelsen A, Bulmer RH, Pilditch CA 2021. Influence of land-derived stressors and environmental variability on compositional turnover and diversity of estuarine benthic communities. *Marine Ecology Progress Series* 666: 1-18.
- Cummings V, Thrush S, Hewitt J, Norkko A, Pickmere S 2003. Terrestrial deposits on intertidal sandflats: sediment characteristics as indicators of habitat suitability for recolonising macrofauna. *Marine Ecology Progress Series* 253: 39-54.
- FGDC 2012. Coastal and Marine Ecological Classification Standard. Standard FGDC-STD-018-2012, Marine and Coastal Spatial Data Subcommittee, Federal Geographic Data Committee, June 2012. 343p. Available at: https://www.fgdc.gov/standards/projects/cme/cs-folder/CMECS_Version_06-2012_FINAL.pdf.
- Forrest BM 2023. Catlins Estuary: 2022/2023 Intertidal Sediment Monitoring Summary. *Salt Ecology Short Report 025*, prepared for Otago Regional Council, March 2023. 2p.
- Forrest BM, Roberts KL, Stevens LM 2022a. Fine scale intertidal monitoring of Pleasant River (Te Hakapupu) Estuary. *Salt Ecology Report 093*, prepared for Otago Regional Council, June 2022. 29p.
- Forrest BM, Roberts KL, Stevens LM, Rabel H 2022b. Fine Scale Intertidal Monitoring of New River Estuary: Synthesis of Survey Data 2001-2022. *Salt Ecology Report 100*, prepared for Environment Southland, September 2022. 47p.
- Robertson B, Gillespie P, Asher R, et al. 2002. *Estuarine Environmental Assessment and Monitoring: A National Protocol. Part A, Development; Part B, Appendices; and Part C, Application*. Prepared for supporting Councils and the Ministry for the Environment, Sustainable Management Fund Contract No. 5096. Part A, 93p; Part B, 159p; Part C, 40p plus field sheets.
- Robertson BM, Robertson BP, Stevens LM 2017. *Catlins Estuary: Fine Scale Monitoring 2016/17*. Prepared for Otago Regional Council. 32p.
- Robertson BM, Stevens L, Robertson B, et al. 2016. NZ Estuary Trophic Index Screening Tool 2: determining monitoring indicators and assessing estuary trophic state. Prepared for Envirolink Tools Project: Estuarine Trophic Index MBIE/NIWA Contract No: C01X1420. 68p.
- Robertson BP, Gardner JPA, Savage C 2015. Macro-benthic–mud relations strengthen the foundation for benthic index development: A case study from shallow, temperate New Zealand estuaries. *Ecological Indicators* 58: 161-174.
- Stevens LM, Roberts KL 2022. *Macroalgae Monitoring of Catlins/Pounaweia Estuary 2021/22*. *Salt Ecology Report 089*, prepared for Otago Regional Council, June 2022. 28p.
- Stewart B 2012. *Habitat Mapping of the Owaka Estuary*. Otago Regional Council State of the Environment Report, prepared by Ryder Consulting, November 2012. 37p.
- Stewart B, Bywater C 2009. *Habitat Mapping of the Catlins Estuary*. Otago Regional Council State of the Environment Report, prepared by Ryder Consulting, January 2009. 36p.
- Ward N, Roberts K 2021. *Estuaries and Coast: Classification and Attributes for Southland*. Environment Southland publication number 2020-03, Environment Southland: Invercargill. 107p. ISBN 978-0-909043-63-6.

APPENDIX 1. SUMMARY OF NEMP FINE-SCALE INDICATORS

The rationale for each indicator and sampling method is provided. The main departures from the NEMP are described in footnotes.

Indicator	General rationale	Sampling method
Physical and chemical		
Sediment grain size	Indicates the relative proportion of fine-grained sediments that have accumulated.	Three composited (3-4 sub-samples) surface scrapes to 20mm sediment depth per site. Samples sent to Hill Laboratories for analysis.
Nutrients (nitrogen and phosphorus), and organic matter	Reflects the enrichment status of the estuary and potential for algal blooms and other symptoms of enrichment.	Three composited (3-4 sub-samples) surface scrapes to 20mm sediment depth per site. Organic matter measured as Total Organic Carbon (TOC) (note 1). Samples sent to Hill Laboratories for analysis.
Trace elements (arsenic, copper, chromium, cadmium, lead, mercury, nickel, zinc)	Common toxic contaminants generally associated with human activities. High concentrations may indicate a need to investigate other anthropogenic inputs, e.g., pesticides, hydrocarbons.	Three composited (3-4 sub-samples) surface scrapes to 20mm sediment depth per site (note 2). Samples sent to Hill Laboratories for analysis.
Substrate oxygenation (apparent Redox Potential Discontinuity depth; aRPD)	Measures the enrichment/trophic state of sediments according to the depth of the aRPD. This is the visual transition between brown oxygenated surface sediments and deeper less oxygenated black sediments. The aRPD can occur closer to the sediment surface as organic matter loading or sediment mud content increase.	Ten sediment cores per site, split vertically, with average depth of aRPD (for each core) recorded in the field where visible.
Biological		
Macrofauna	Abundance, composition and diversity of infauna living with the sediment are commonly-used indicators of estuarine health.	Ten sediment cores per site (130mm diameter, 150mm depth, 0.013m ² sample area, 2L core volume), sieved to 0.5mm to retain macrofauna.
Epibiota (epifauna)	Abundance, composition and diversity of epifauna are commonly-used indicators of estuarine health.	Abundance based on SACFOR (note 3).
Epibiota (macroalgae)	The composition and prevalence of macroalgae are indicators of nutrient enrichment.	Percent cover based on SACFOR (note 3).
Epibiota (microalgae)	The prevalence of microalgae is an indicator of nutrient enrichment.	Visual assessment of conspicuous growths based on SACFOR (notes 3, 4).

¹ Since the NEMP was published, Total Organic Carbon (TOC) has become available as a routine low-cost analysis which provides a more direct and reliable measure than the NEMP recommendation of converting Ash Free Dry Weight (AFDW) to TOC.

² Arsenic and mercury are not specified in the NEMP, but can be included in the trace element suite by the analytical laboratory.

³ Assessment of epifauna, macroalgae and microalgae used quadrat sampling in the first two surveys, but for the last survey used the 'SACFOR' approach: S = super abundant, A = abundant, C = common, F = frequent, O = occasional, R = rare. SACFOR was used instead of the quadrat sampling, which is subject to considerable within-site variation for epibiota that have clumped or patchy distributions (see Forrest et al. 2022 for further detail).

⁴ NEMP recommends taxonomic composition assessment for microalgae but this is not typically undertaken due to clumped or patchy distributions and the lack of demonstrated utility of microalgae as a routine indicator.

APPENDIX 2. CONDITION RATINGS FOR ASSESSING ESTUARY HEALTH

No rating criteria exist for Total Phosphorus (TP), or macrofauna variables other than AMBI. See Glossary for definition of indicators.

Indicator	Unit	Very good	Good	Fair	Poor
Sediment quality and macrofauna					
Mud content ¹	%	<5	5 to <10	10 to <25	≥25
aRPD depth ²	mm	≥50	20 to <50	10 to <20	<10
TN ¹	mg/kg	<250	250 to <1000	1000 to <2000	≥2000
TP		Requires development			
TOC ¹	%	<0.5	0.5 to <1	1 to <2	≥2
Macrofauna AMBI ¹	na	0 to 1.2	>1.2 to 3.3	>3.3 to 4.3	≥4.3
Sediment trace contaminants ³					
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 from Robertson et al. (2016).

2. aRPD based on FGDC (2012).

3. 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.

APPENDIX 3. SEDIMENT QUALITY DATA

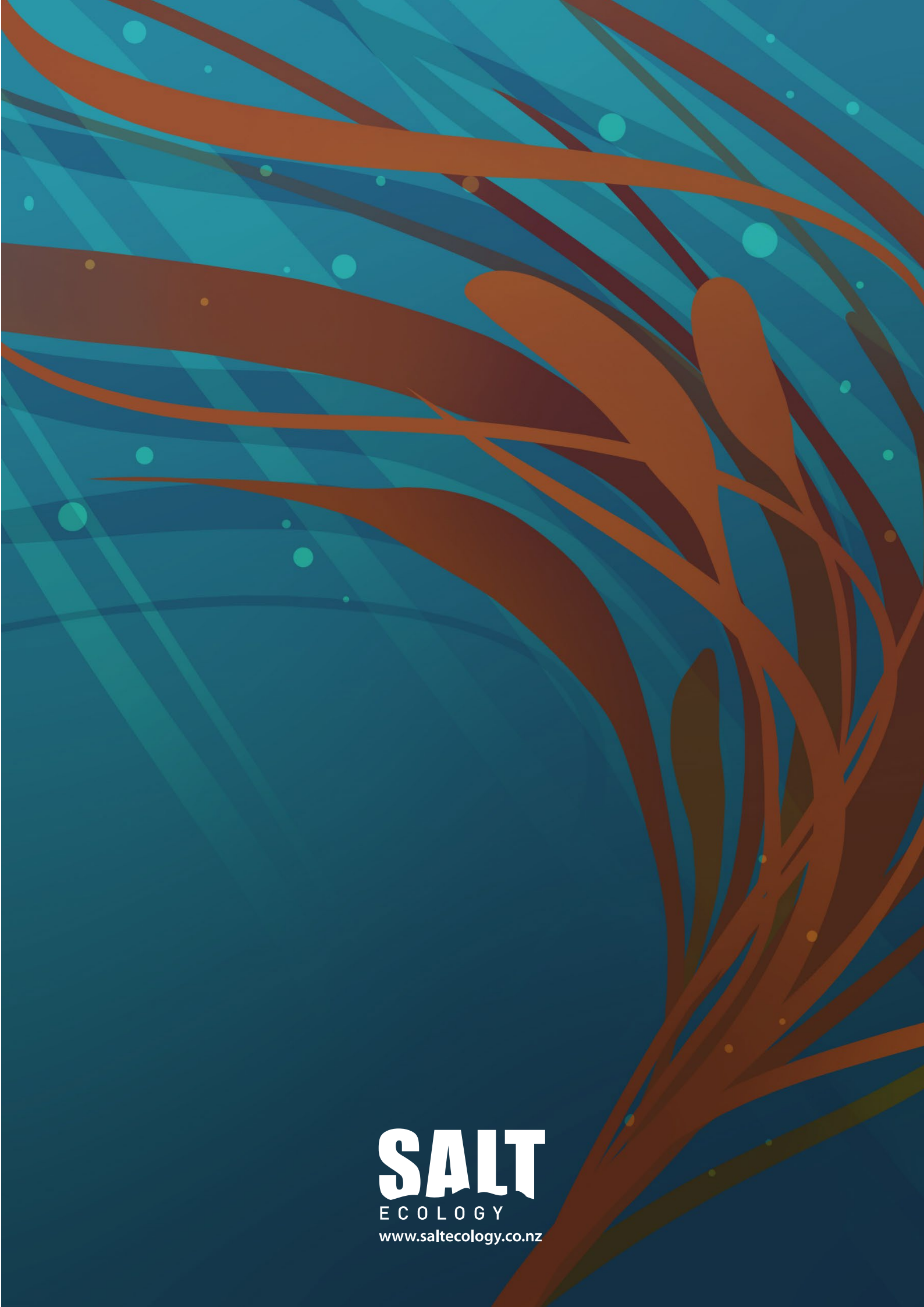
Values based on a composite sample within each of Zone X (reps X1-3), Y (reps Y4-6) and Z (reps Z7-10), except for aRPD in February 2019 for which the mean and range is shown for 10 replicates. The aRPD depth was not reported in December 2017. DGV = Default guideline value for sediment quality (ANZG 2018); GV-High = Guideline Value High.

Site	Survey	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	Dec-16	X	0.6	97.3	2.1	<0.05	<500	220	30	5.1	0.015	6.1	2.2	<0.01	4.2	1.3	12	
		Y	0.6	89.6	9.8	<0.05	<500	210	30	5.1	0.013	5.9	2.1	<0.01	3.9	1.2	10	
		Z	0.4	94.8	4.7	<0.05	<500	220	30	5.6	0.011	6	2.5	<0.01	4.1	1.3	11	
	Dec-17	X	<0.1	98.1	1.9	<0.13	<1300	240	-	6.4	0.011	5.7	2.2	<0.02	3.5	1.2	12	
		Y	<0.1	98	2	<0.13	<1300	540	-	5.8	0.012	5.7	2.3	<0.02	3.5	1.2	12	
		Z	<0.1	98.2	1.8	<0.13	<1300	540	-	6.2	0.017	5.8	2.3	<0.02	3.6	1.2	13	
	Feb-19	X	0.9	98.2	0.9	<0.13	<500	193	41.7 (30 to 60)	5.5	0.01	5.5	1.8	<0.02	2.7	1.1	11	
		Y	<0.1	98.5	1.5	<0.13	<500	220	48.3 (40 to 65)	5.4	0.013	5.8	1.9	<0.02	3.3	1.2	11	
		Z	<0.1	98.6	1.4	<0.13	<500	220	43.8 (25 to 70)	5.3	<0.010	5.7	1.9	<0.02	3	1.1	11	
	B	Dec-16	X	<0.1	76.5	23.5	0.24	600	270	20	2.9	0.019	8.5	4.3	<0.01	5.5	2.1	23
			Y	<0.1	73.8	26	0.27	<500	260	20	2.8	0.018	8.2	4.2	0.01	5.5	2.1	24
			Z	<0.1	75.3	24.7	0.3	<500	260	20	3.1	0.02	9.2	4.9	<0.01	6.2	2.3	26
Dec-17		X	<0.1	69.3	30.7	0.36	<500	390	-	3.5	0.017	9.5	4.9	<0.02	5.9	2.5	30	
		Y	<0.1	70.5	29.5	0.34	<500	380	-	3.5	0.017	9.3	4.9	<0.02	6.1	2.5	30	
		Z	<0.1	69.1	30.9	0.38	<500	390	-	3.8	0.019	9.1	4.8	<0.02	5.9	2.5	30	
Feb-19		X	<0.1	55.6	44.4	0.38	<500	350	19.0 (10 to 25)	3.5	0.018	9	4.3	<0.02	5.5	2.5	28	
		Y	<0.1	57.3	42.7	0.36	<500	340	21.7 (15 to 30)	3.4	0.018	8.9	4.3	<0.02	5.3	2.4	28	
		Z	<0.1	58.4	41.5	0.31	<500	320	20.3 (20 to 21)	3.1	0.013	8.5	3.9	<0.02	4.9	2.3	25	
									DGV	20	1.5	80	65	0.15	21	50	200	
									GV-high	70	10	370	270	1	52	220	410	

APPENDIX 4. MACROFAUNA CORE DATA SUMMED ACROSS TEN REPLICATES FOR EACH SURVEY AND SITE

Minor macrofauna renaming or aggregation to genus has been undertaken to standardise (to the extent feasible) across the different provider in December 2017 vs the other two surveys.

Main group	Taxa	EG	Dec-16 A	Dec-17 A	Feb-19 A	Dec-16 B	Dec-17 B	Feb-19 B
Amphipoda	Paracalliope novizealandiae	I		3		10	2	28
Amphipoda	Paracorophium excavatum	IV	3	65	176	2455	2570	3597
Amphipoda	Torridoharpinia hurleyi	I	3	54	15		2	
Amphipoda	Waitangi sp. 1	II	17	20	8			
Anthozoa	Anthopleura hermaphroditica	III					1	
Anthozoa	Edwardsia sp. 1	II		12	11			
Bivalvia	Arthritica sp. 5	III		9		76	50	77
Bivalvia	Austrovenus stutchburyi	II	1	1	1	2		2
Bivalvia	Hiatula sp. 1	I	1					
Bivalvia	Legrandina turneri	na	97	1521	1151		2	
Bivalvia	Paphies australis	II		1	3			
Bivalvia	Paphies subtriangulata	na			1			
Copepoda	Copepoda	II				8		
Cumacea	Colurostylis lemurum	II	7	16	8	17		
Decapoda	Hemiplax hirtipes	III				2	2	1
Isopoda	Eurylana arcuata	na		1				
Isopoda	Pseudaega punctata	na			1			
Mysida	Mysida	II	1			57	3	6
Oligochaeta	Oligochaeta	V		1		21	63	24
Polychaeta	Aonides trifida	I		2				
Polychaeta	Boccardia syrtis	II	7	5	20			
Polychaeta	Capitella spp.	V		1	1	14	10	25
Polychaeta	Macroclymenella stewartensis	II	2	1	15			
Polychaeta	Microspio maori	I	4	3	3	16	2	49
Polychaeta	Nereididae (juv)	III	24		24			1
Polychaeta	Nicon aestuariensis	III					1	3
Polychaeta	Orbinia papillosa	I	1		10			
Polychaeta	Paradoneis lyra	III		8				
Polychaeta	Perinereis vallata	III	1	28	33			
Polychaeta	Phyllodocidae sp. 1	II			1			
Polychaeta	Prionospio aucklandica	III		8	10			
Polychaeta	Scolecopelides benhami	IV		1		59	94	47
Polychaeta	Thoracophelia otagoensis	I			2			
Stomatopoda	Heterosquilla	na	3	1				
Site richness			15	22	20	12	13	12
Site abundance			172	1762	1494	2737	2802	3860



SALT
ECOLOGY
www.saltecoology.co.nz