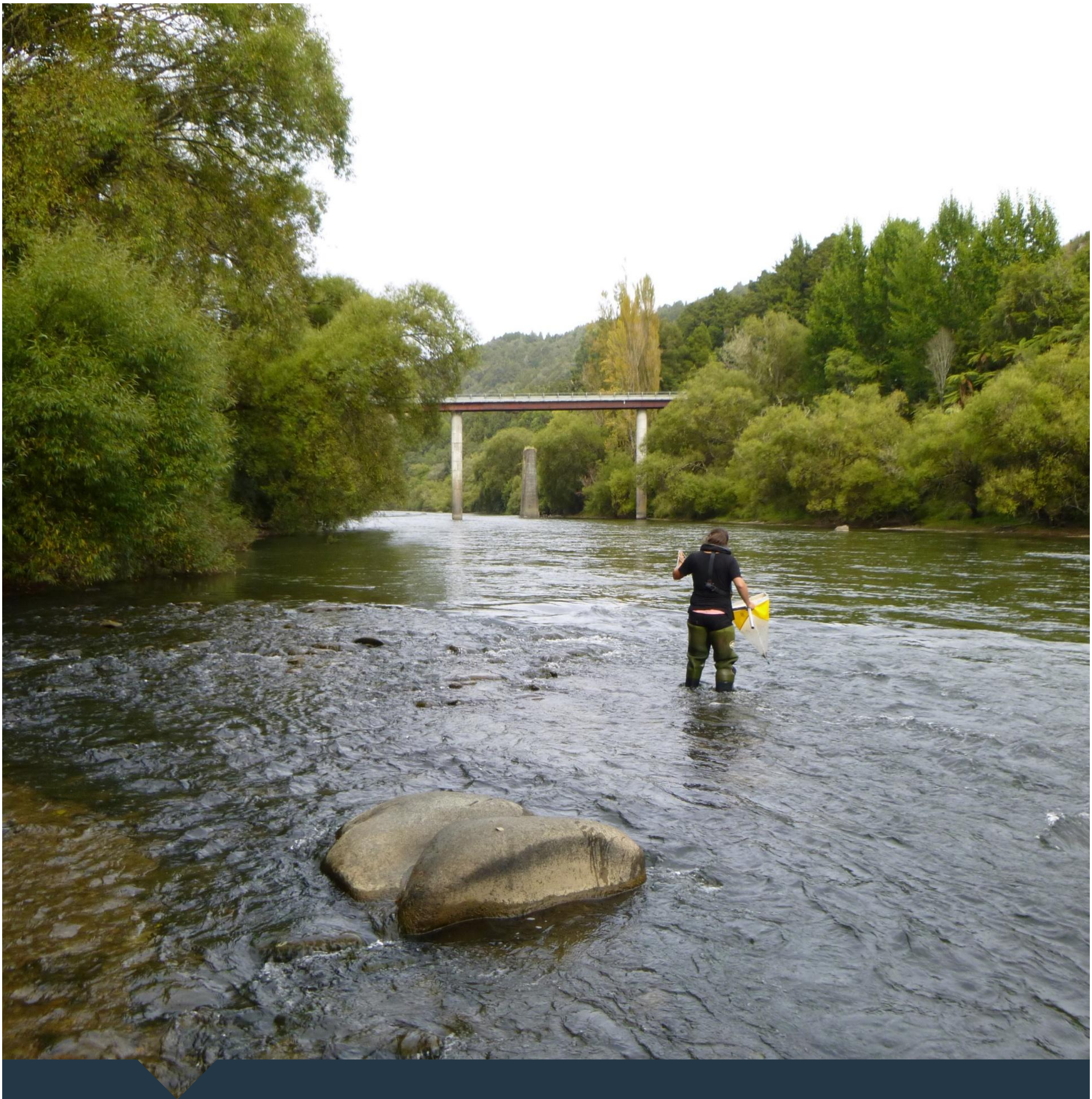

Manawatū Estuary

2026 intertidal fine-scale monitoring

June 2026

horizons
REGIONAL COUNCIL

Prepared for:

Mike Patterson
Science Manager

June 2026
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Manawatū Estuary: 2026 intertidal fine-scale monitoring

Prepared for

Horizons Regional Council

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Report 170

Cover photo: Site A Manawatū Estuary, January 2026.

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For the People
Mō ngā tāngata

Manawatū Estuary:
2026 intertidal fine-scale monitoring

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for

Horizons Regional Council

June 2026

www.saltecology.co.nz

For the environment
Mō te taiao

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
CMEC	Coastal Marine Ecology Consultants
Cr	Chromium
Cu	Copper
DGV	Default Guideline Value
EG	Eco-group (used in the AMBI)
ESNZ	Earth Sciences New Zealand (formerly NIWA)
Hg	Mercury
HRC	Horizons 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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Many thanks to Caitlin Wheeler of Horizons Regional Council (HRC) for support in undertaking this work, assistance in the field (along with Pearl Ruston and Marc Hassenbank) and review of the report. Thanks also to Thomas Scott-Simmonds (TC Environmental) for field assistance, and Gary Stephenson (Coastal Marine Ecology Consultants) for taxonomic identification of macrofauna.

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SUMMARY

BACKGROUND

As part of its State of the Environment programme, Horizons Regional Council (HRC) monitors the ecological condition of selected estuaries in its region. This report describes ecological monitoring conducted in January 2026 at two sites in Manawatū Estuary, following the 'fine-scale' methodology described in New Zealand's National Estuary Monitoring Protocol (NEMP). Results are compared to three earlier surveys undertaken between 2017 and 2019, assessed against ecological condition ratings, and discussed in the context of potential drivers of estuary condition and future monitoring needs.

KEY FINDINGS

A summary of monitoring indicators, and comparison to condition rating thresholds, is provided in the table below. Overall, the estuary monitoring sites are in a reasonable ecological state, with features typical of river-dominated environments.

- The sites are situated in a relatively uniform area of intertidal flats, consisting of unvegetated soft, muddy-sand sediments. Sediment trophic state indicators (nutrients, organic matter, oxygenation) show no signs of excessive enrichment, and levels of toxicants are very low.
- The macrofaunal assemblage is species-poor, and dominated by disturbance-tolerant organisms, suggesting that both sites are exposed to reasonably harsh physical conditions such as brackish (low-salinity) water, and physical disturbance from strong river or tidal flows, as well as from wind-induced waves and currents.
- The effects of a harsh physical environment are likely to mask the effects of catchment pressures (e.g., changing sediment loads). This situation means that monitoring is likely to have limited value in the short-term, and is better suited for tracking changes that occur over the long-term (e.g., over decades).
- Despite its limitations, there is value in continuing a low frequency of fine-scale monitoring, and in re-establishing the annual sedimentation monitoring programme that was implemented over 2017-2022.

RECOMMENDATIONS

HRC should consider the following:

- Continue fine-scale monitoring every 5-years, based on the same NEMP approach described in this report.
- Relocate or reinstall 'sediment plates' at fine-scale sites and monitor annually, along with collection of sediment samples to track changes in mud content.

Mean values of fine-scale monitoring indicators in Manawatū Estuary. Values are rated against condition scores of ecological health, as available. See Glossary for abbreviations of indicators.

Site	Survey	Mud	aRPD	TN	TP	TOC	As	Cd	Cr	Cu	Pb	Hg	Ni	Zn	AMBI	Abun	Rich
		%	mm	mg/kg	mg/kg	%	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	na	#	#
A	2017	19.0	20	<500	367	0.30	3.4	0.02	10.5	4.7	5.5	0.04	8.8	32.3	4.6	6.3	196
	2018	23.3	40	333*	357	0.25	3.3	0.01	10.3	4.1	5.4	0.01*	8.2	33.3	4.5	9.2	222
	2019	31.6	26	<500	410	0.34	3.8	0.02	11.7	4.7	5.9	0.12	9.9	40.7	4.5	7.8	225
	2026	30.4	32	433	387	0.35	3.5	0.02	11.0	4.8	6.2	0.03	9.5	38.3	4.5	8.2	275
B	2017	22.9	20	<500	370	0.26	3.1	0.02	9.8	4.5	5.4	0.02	8.7	32.7	4.5	6.8	298
	2018	36.4	25	333*	390	0.33	2.9	0.02	10.5	4.3	5.5	0.02*	8.6	33.7	4.6	7	109
	2019	37.3	18	<500	413	0.37	3.4	0.02	11.3	5.1	6.2	0.03	10.0	43.3	4.5	7.2	260
	2026	28.8	34	367	410	0.28	3.0	0.02	10.7	4.3	5.6	0.03	9.1	36.7	4.5	7.9	331

** Sample mean includes values below lab detection limits, < All values below lab detection limit.*

 # Mean species richness (Rich) and abundance (Abun) per core (n=10) are reported for each site.

Very Good	Good	Fair	Poor	Very Poor

1. INTRODUCTION

Since 2016, Horizons Regional Council (HRC) has undertaken State of Environment (SOE) monitoring in Manawatū Estuary (hereafter Manawatū) following methods outlined in a National Estuary Monitoring Protocol (NEMP; Stevens et al. 2025).

The NEMP approach involves two main types of survey:

- Estuary-wide 'broad-scale' mapping of intertidal habitats (Roberts et al. 2025).
- Site-specific 'fine-scale' monitoring of estuarine biota, sediment quality, and sedimentation rate (Forrest et al. 2025a).

Broad-scale monitoring is typically undertaken every 5 to 10 years (Roberts et al. 2025), following an initial baseline survey undertaken in January 2016 (Stevens & Robertson 2016). Fine-scale monitoring is conducted by most councils at intervals ranging from annually, to every 5-years after initially establishing a baseline (Forrest et al. 2025a). The Manawatū baseline was established at two sites (A & B; Fig. 1) over three consecutive annual surveys conducted during 2017-2019 (Forrest & Stevens 2019). Sedimentation monitoring is typically conducted annually (Hunt 2019). In the Manawatū, annual sedimentation monitoring was undertaken between January 2017 and January 2022 (Stevens 2022), but has not been conducted since.

Salt Ecology was contracted by HRC in late 2025 to repeat broad- and fine-scale NEMP monitoring surveys, with field work undertaken in January 2026 with assistance from HRC staff. The present report provides a summary of the fine-scale monitoring component conducted over 23-24 January 2026, and compares findings with the baseline monitoring. Note that the current report focuses on the sediment quality and biota monitoring components. Although the intention was to also repeat the sedimentation monitoring, the measurement points (marked with wooden pegs) could not be relocated (e.g., likely buried or washed away). As such, sedimentation data are not included in the present report, but the merits of re-establishing that monitoring component are addressed in Section 4.2.

Background information on the key features of Manawatū Estuary, and the studies that led to the development of the SOE monitoring programme, were described by Forrest and Stevens (2019) and are not repeated here.

Lower Manawatū Estuary looking downstream across the main tidal flats next to Foxton Beach township.

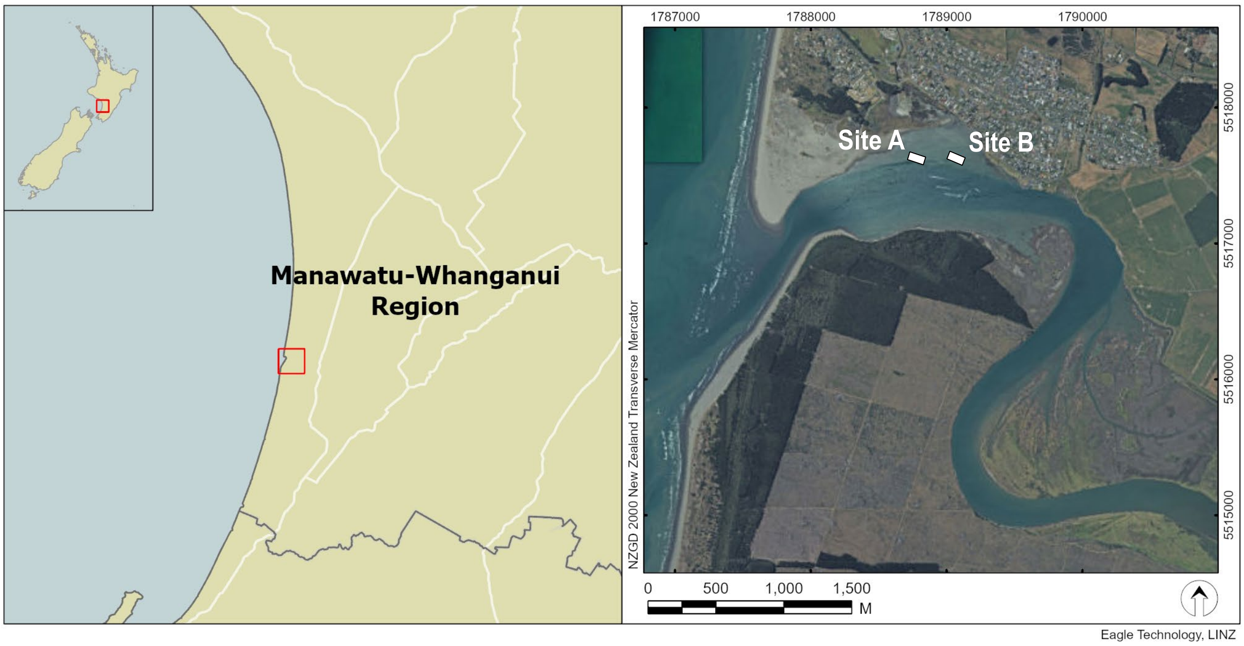


Fig. 1. Manawatū Estuary at Foxton Beach, showing the location of two fine-scale monitoring sites.

2. METHODS

2.1 SITES

The two sampling sites are positioned ~350m apart on the main mud/sand flats next to Foxton Beach township. Site positions are provided in Appendix 1. A schematic of the sampling approach is provided in Fig. 2, with methods described below.

2.2 INDICATORS AND SAMPLING

A summary of the NEMP indicators is provided in Table 1. As depicted in Fig. 2, each fine-scale site was divided into a 3 x 4 grid of 12 plots, with sampling conducted in 10 of these plots. The key sampling elements are summarised below.

Sediment quality: NEMP Indicators included sediment mud content, oxygenation status (measured as the apparent Redox Potential Discontinuity depth; aRPD), nutrients, organic content, and selected trace contaminants. Sediment aRPD was measured in the field. For the other variables, three composite sediment samples (each consisting of 3-4 sub-samples) were collected to 20mm depth using a trowel or corer, and sent to Hill Labs for analysis. Lab methods are provided in Appendix 1. If Hill Labs results included values less than laboratory method detection limits, half of the detection limit value was used for data averaging, according to standard convention.

Biota: To characterise the dominant ecological features of the fine-scale sites, a qualitative field method ('SACFOR'; Appendix 1) was used to estimate the abundance or percent cover of conspicuous surface-dwelling snails, macroalgae, microalgae and seagrass, when present. In addition, quantitative sampling was undertaken of macrofauna, which are small organisms that live within or on the sediment matrix.

Macrofauna were sampled using sediment cores (130mm diameter, 150mm deep, ~2L volume), which were sieved through a 0.5mm mesh to remove mud, sand and other larger material. The composition of the sieved core samples in terms of macrofauna species (or higher taxa) and their abundances, was determined by Gary Stephenson at Coastal Marine Ecology Consultants (CMEC). CMEC has been used for all Manawatū fine-scale surveys, with quality assurance checks on voucher specimens previously made by expert taxonomists at Earth Sciences New Zealand (formerly NIWA).

Macrofauna analyses included the following:

- Derivation of richness and abundance, which are simple measures that describe the number of different species present in a sample (i.e., richness), and total organism abundances, respectively.
- Calculation of 'AMBI' scores (Appendix 1). The AMBI is an international biotic health index (Borja et al. 2000) whose calculation is based on the proportion of macrofauna falling into one of five eco-groups (EG) ranging from relatively sensitive species (EG-I) to relatively hardy ones (EG-V).
- Multivariate analysis methods based on PRIMER v7 (Clarke & Gorley 2015) were used to assess changes macrofauna community composition. Correlation-based approaches were used to relate macrofaunal composition to changes in sediment quality characteristics.

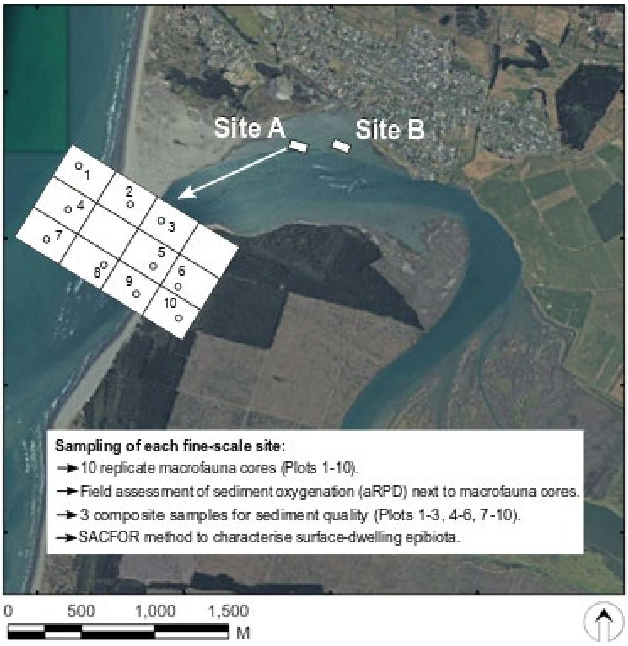


Fig. 2. Schematic of fine-scale approach showing a 3x4 grid (30x60m) of 12 plots, in which 10 are sampled. The main methods applied in each of Plots 1-10 are indicated.

2.3 ASSESSMENT OF ESTUARY CONDITION

In addition to the authors' expert interpretation of the data, results are assessed against 'condition rating' thresholds for ecological health in New Zealand estuaries. These metrics assign different indicators to one of five colour-coded 'health status' bands shown in Table 2. Note that these rating thresholds differ slightly to those reported in Forrest and Stevens (2019) as they were updated in 2024 as part of a Ministry for the Environment project (Stevens et al. 2024).

Table 1. Summary of NEMP fine-scale indicators and sampling methods.

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/cores to 20mm sediment depth per site.
Nutrients (nitrogen and phosphorus), and organic matter (TOC)	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/cores to 20mm sediment depth per site.
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/cores to 20mm sediment depth per site.
Substrate oxygenation (apparent Redox Potential Discontinuity depth; aRPD)	The aRPD is the visual transition between brown oxygenated surface sediments and deeper less oxygenated black sediments. It can occur closer to the sediment surface if organic matter loading or mud content increase sediment enrichment.	Ten sediment cores per site, split vertically, with average depth of aRPD (for each core) recorded in the field, where an aRPD is visible
Biological		
Macrofauna	Abundance, composition and diversity of infauna living within 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 (Appendix 1).
Epibiota (macroalgae)	The composition and prevalence of macroalgae are indicators of nutrient enrichment.	Percent cover based on SACFOR (Appendix 1).
Epibiota (microalgae)	The prevalence of microalgae is an indicator of nutrient enrichment.	Visual assessment for conspicuous growths.

Table 2. Condition ratings for assessing estuary health*. See Glossary for definitions.

Indicator	Unit	Very Good	Good	Fair	Poor	Very Poor
Sediment quality and macrofauna						
Sedimentation	mm/yr	<0.5	≥0.5 to <1	≥1 to <2	≥2 to <10	≥10
Mud content	%	<5	≥5 to <10	≥10 to <25	≥25 to <50	≥50
aRPD depth[1]	mm	>40	≤40 to >25	≤25 to 10	<10 to 5	<5
TN	mg/kg	<250	≥250 to <800	≥800 to <1200	≥1200 to <2000	≥2000
TOC[2]	%	<0.5	≥0.5 to 1.2	>1.2 to 2	>2 to 3.5	>3.5
AMBI	na	0 to 1.2	>1.2 to 3.3	>3.3 to 4.3	>4.3 to 5	>5 to 7
Trace elements						
As	mg/kg	<5	5 to 10	10 to <20	20 to <70	≥70
Cd	mg/kg	<0.38	0.38 to 0.75	0.75 to <1.5	1.5 to <10	≥10
Cr	mg/kg	<20	20 to 40	40 to <80	80 to <370	≥370
Cu	mg/kg	<16	16 to 32.5	32.5 to <65	65 to <270	≥270
Hg	mg/kg	<0.038	0.038 to 0.075	0.075 to <0.15	0.15 to <1	≥1
Ni	mg/kg	<5.2	5.2 to 10.5	10.5 to <21	21 to <52	≥52
Pb	mg/kg	<12.5	12.5 to 25	25 to <50	50 to <220	≥220
Zn	mg/kg	<50	50 to 100	100 to <200	200 to <410	≥410

* Ratings taken from Stevens et al. (2024) with aRPD and TOC modified by addition of a 'Very Poor' category to discriminate situations of low oxygenation or very high enrichment, respectively.

3. KEY FINDINGS

3.1 GENERAL SITE FEATURES

Sampling was undertaken on 23 and 24 January, when predicted low tide heights ranged from 0.35-0.38m (https://tides.niwa.co.nz/). Site A did not fully uncover at low tide, with a shallow (~50-100mm) layer of surface water remaining along the channel side. This situation reflected a combination of high-flow conditions in the Manawatū River, and a low-pressure weather system.

The intertidal sampling sites are positioned within an extensive area of uniform muddy-sand flats. Both sites were relatively featureless, with mud snails (*Amphibola crenata*) present on the surface, as described in earlier surveys. Neither site had visible biological growths such as macroalgae or microalgal mats, or other obvious symptoms that might indicate enriched or otherwise degraded conditions. No seagrass was recorded. There was very little detritus or terrestrial debris apparent, and the sediments generally had a low shell content, except for weathered shell litter at the bottom of some of the cores. This material is thought to be from historical shellfish beds (predominantly surf clams *Cyclomactra*) that appear to have been previously widespread across the intertidal area.

3.2 SEDIMENT QUALITY

Sediment quality data for all survey years are in Appendix 2. Laboratory analyses revealed that the sand fraction was dominant at both sites (Fig. 3). Sediment mud content exceeded the 25% threshold (rated as 'Poor') at both sites in most surveys, and was slightly greater at Site B than Site A. Values in 2026 (Table 3) were within the range measured in earlier years.

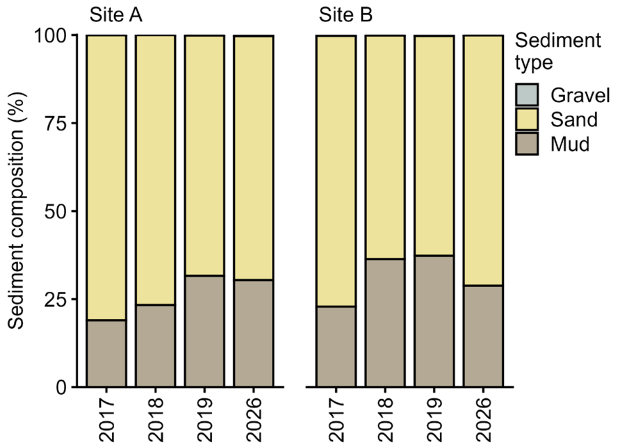


Fig. 3. Sediment grain size composition classes at fine-scale sites over 2017-2026 (n=3 composite samples).

The aRPD transition between brown oxygenated surface sediments and deeper grey/black sediments (indicating reduced oxygenation) was typically between 18-40mm sediment depth over all surveys (Table 3, Fig. 4, see photo on next page). Small differences among sites and years are of no ecological significance. These are commonly due to processes such as bioturbation by macrofauna, or variability in observer differences in judgements as to the exact depth of the aRPD transition. Of most importance is that there was no evidence of the aRPD occurring at, or close to (i.e., within a few millimetres of), the sediment surface, as would commonly occur under highly depositional and/or enriched conditions.

Table 3. Summary of mean values of key indicators at fine-scale monitoring sites in Manawatū Estuary. Values are rated against condition thresholds of ecological health, where available (see Table 2). See Glossary for abbreviations.

Site	Survey	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	AMBI na	Abun #	Rich #
A	2017	19.0	20	<500	367	0.30	3.4	0.02	10.5	4.7	5.5	0.04	8.8	32.3	4.6	6.3	196
	2018	23.3	40	333*	357	0.25	3.3	0.01	10.3	4.1	5.4	0.01*	8.2	33.3	4.5	9.2	222
	2019	31.6	26	<500	410	0.34	3.8	0.02	11.7	4.7	5.9	0.12	9.9	40.7	4.5	7.8	225
	2026	30.4	32	433	387	0.35	3.5	0.02	11.0	4.8	6.2	0.03	9.5	38.3	4.5	8.2	275
B	2017	22.9	20	<500	370	0.26	3.1	0.02	9.8	4.5	5.4	0.02	8.7	32.7	4.5	6.8	298
	2018	36.4	25	333*	390	0.33	2.9	0.02	10.5	4.3	5.5	0.02*	8.6	33.7	4.6	7	109
	2019	37.3	18	<500	413	0.37	3.4	0.02	11.3	5.1	6.2	0.03	10.0	43.3	4.5	7.2	260
	2026	28.8	34	367	410	0.28	3.0	0.02	10.7	4.3	5.6	0.03	9.1	36.7	4.5	7.9	331

** Sample mean includes values below lab detection limits, < All values below lab detection limit.*

 # Mean species richness (Rich) and abundance (Abun) per core (n=10) are reported for each site.

Very Good	Good	Fair	Poor	Very Poor

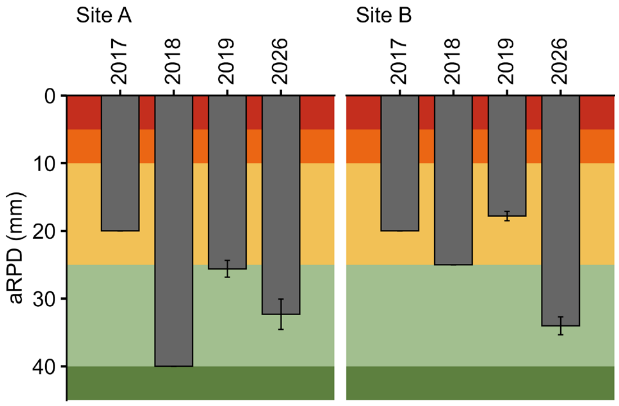


Fig. 4. Mean aRPD depth (±SE, n=10). Colour bands reflect condition ratings.

Very Good	Good	Fair	Poor	Very Poor

Sampling the tidally-covered channel side of Site A in 2026.

Site A

Site B

Examples of sediment cores from Sites A and B, illustrating well-oxygenated surface sediments. The aRPD is measured as the average depth of transition between brown surface sediment to the grey/black deeper sediment beneath.

Fig. 5 shows the mean percentage total organic carbon (TOC), and total nitrogen (TN) from composite samples, relative to condition ratings. TOC values were very low (rated 'Very Good') and were generally slightly higher in muddier sediments. TN values were at, or less than, method detection limits at both sites in 2017 and 2019, and otherwise low (rated 'Good'). Total phosphorous (TP) concentrations were low and similar among sites and years (Appendix 2).

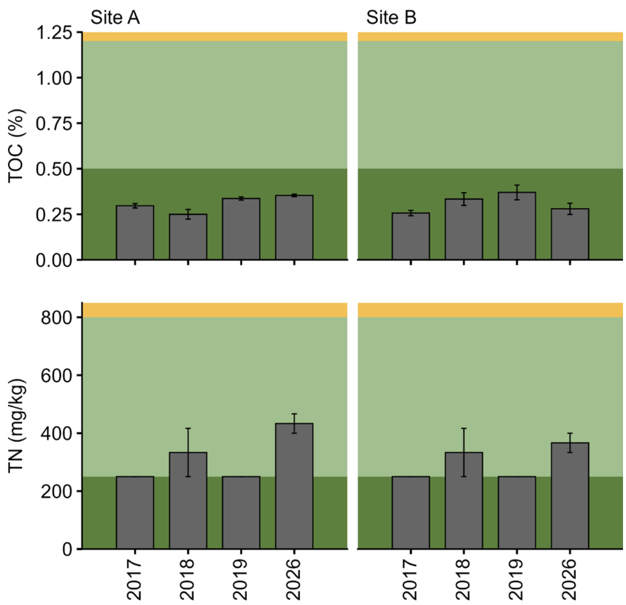


Fig. 5. Mean (±SE, n=3) sediment total organic carbon (TOC), and total nitrogen (TN) in composite samples. Colour bands reflect condition ratings. TN method detection limits (MDL) in 2017 to 2019 were 500mg/kg with plotted values representing half the MDL in most replicates (see Table 3 & Appendix 2).

Very Good	Good	Fair	Poor	Very Poor

Trace contaminant concentrations at all sites were well below ANZG (2018) Default Guideline Values (DGV) for sediment quality (Fig. 6), with the single exception of mercury (Hg) at Site A in 2019, when the mean concentration of 0.31 mg/kg was twice the DGV. The reason for this result is unknown, but it is clearly an aberration given that none of the other samples (or contaminants) were at elevated concentrations.

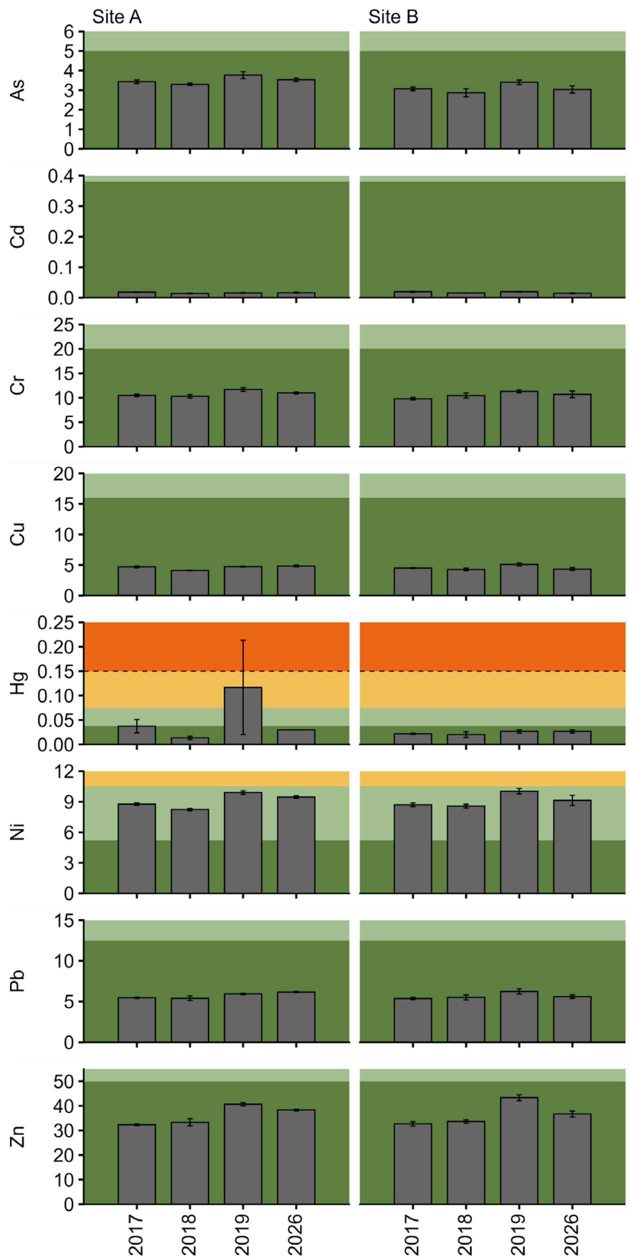


Fig. 6. Mean (±SE, n=3) trace contaminant concentrations (mg/kg) in composite samples. See glossary for abbreviations. Colour bands reflect condition ratings.

3.3 BIOTA

Surface-dwelling epibiota

SACFOR ratings for epibiota are summarised in Table 4 for the mud snail *Amphibola crenata*, which was the only conspicuous species on the sediment surface. Mud snail density scores have been rated as 'Occasional' (Site A) or 'Common' (Site B) in the last two surveys. Mud snails are endemic to New Zealand and are common in muddy sediments, especially in the mid-upper tidal zone. This species feeds by ingesting surface sediment and extracting bacteria, diatoms, and organic matter, typically leaving spiral coils of faecal matter on the sediment surface. The seaweed *Gracilaria* spp. was also noted at Site A, but was sparse (<0.01% cover).

As per the footnote to Table 4, SACFOR ratings for the brackish water estuarine snail *Potamopyrgus estuarinus* were reported by Forrest and Stevens (2019) but were not assessed in 2026. Densities of this snail cannot be easily estimated in the field as it is very small and cryptic, and does not meet the revised criteria for SACFOR assessment in the updated NEMP guidance (Forrest et al. 2025).

Table 4. SACFOR ratings for the mud snail *Amphibola crenata* for the two sites and four surveys, based on the ordinal scale in Appendix 1*.

Year	Site A	Site B
2017	Few	Common
2018	Rare	Common
2019	Occasional	Common
2026	Occasional	Common

* *Potamopyrgus estuarinus* was also reported by Forrest and Stevens (2019), but this species does not meet the criteria for SACFOR assessment in the latest NEMP guidance (Forrest et al. 2025).

Manawatū fine-scale Site B, 2026.

Sediment-dwelling macrofauna

The macrofaunal assemblages at the two sites were relatively impoverished. Only 23 species or higher taxa have been recorded over the four surveys, representing 10 main groups of organisms (Table 5). Species richness has been consistently very low, with mean values ranging from ~6-9 taxa per core (Fig. 7a). Organism abundances were low in 2018 at Site B, but mean values per core have otherwise been consistently high (Fig. 7b).

Abundances have been consistently dominated by a few hardy species, notably shrimp-like corophioid amphipods *Paracorophium* spp. and estuarine snails *Potamopyrgus estuarinus* (Table 5). Subdominant species have included small bivalves *Arthritica* sp. 5, amphipods *Josephosella awa*, and nereid polychaete worms. All of these taxa are in resilient eco-groups (EG-III to EG-V). Illustrative photos are shown on the next page beneath Table 5.

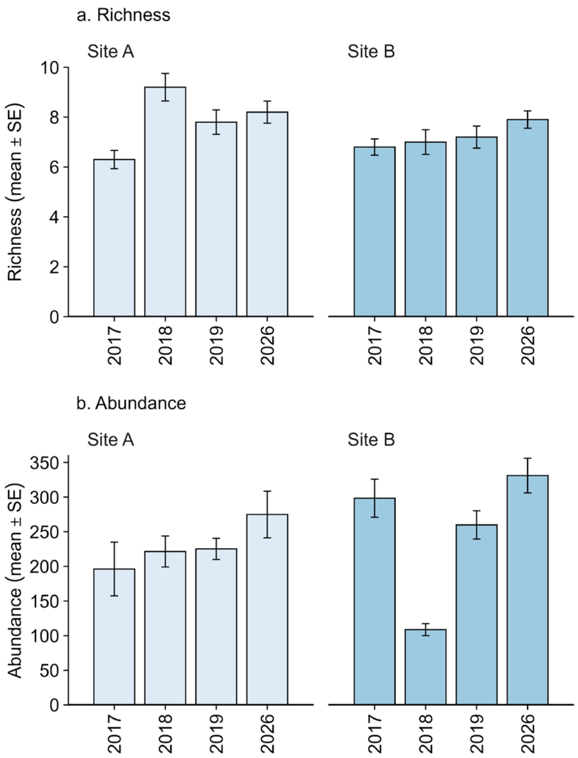


Fig. 7. Mean (±SE, n=5-10) sediment macrofauna taxon richness and abundance per core.

Table 5 shows that, despite the dominance of hardy species, a few relatively sensitive species have also been recorded, but only in low abundances. For example, low numbers of small-to-medium size) surf clams *Cyclomactra tristis* (EG-I) have been recorded in most surveys. In terms of overall patterns, Fig. 8 illustrates that the species assemblage was represented by most eco-groups, but EG-IV species dominated abundances, due mostly to the two species noted above; i.e., *Paracorophium* spp. and *Potamopyrgus estuarinus*. As a consequence, AMBI scores were uniformly high, with values of ~4.5 at both sites across all surveys (Fig. 9), which correspond to a condition rating of 'Poor'.

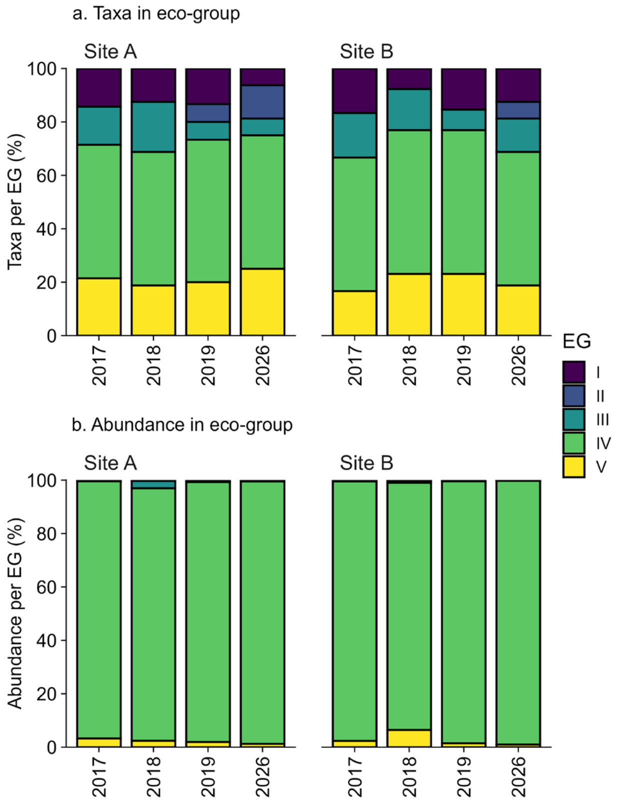


Fig. 8. Contribution of eco-groups ranging from sensitive (EG-I) to resilient (EG-V) to total macrofauna richness and abundance.

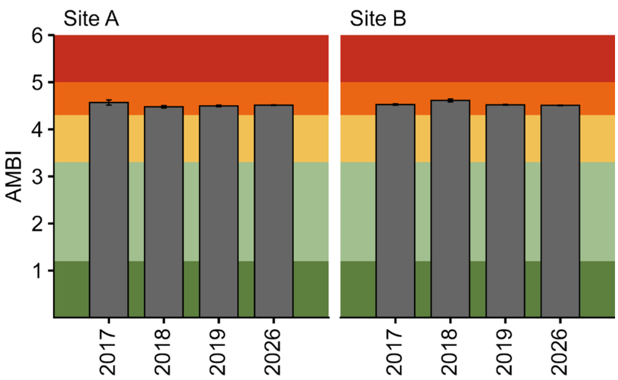
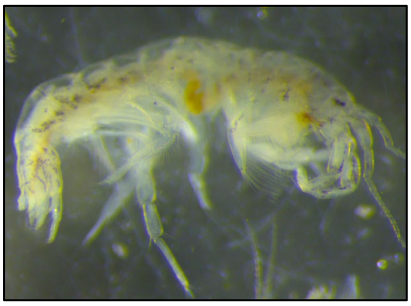
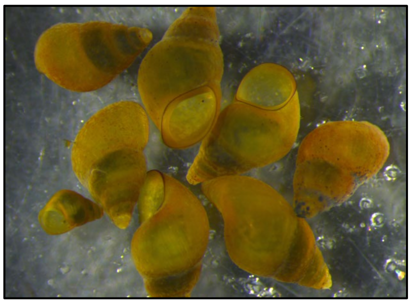


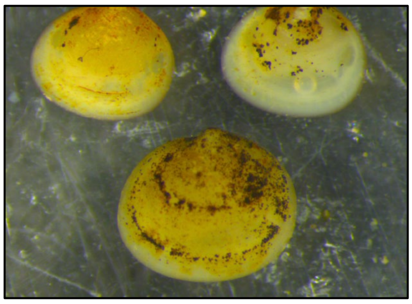
Fig. 9. Patterns in mean (±SE, n=5-10) AMBI scores. Colour bands reflect condition ratings.

Table 5. Complete list of sediment-dwelling macrofauna and their abundances (summed across cores) for each site and survey. Common names or descriptors of main groups are shown alongside eco-groups (EG) from sensitive (EG-I) to resilient (EG-V), with examples of the different macrofauna species in the photos (photos from ESNZ).

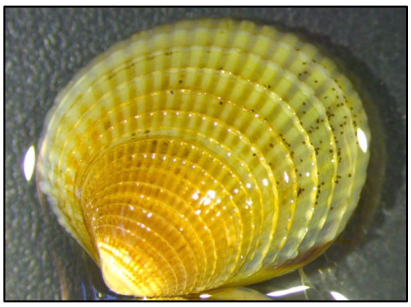
Main group (common name)	Taxa	EG	Site A				Site B			
			2017	2018	2019	2026	2017	2018	2019	2026
Amphipods (small crustaceans)	*Josephosella awa*	IV	39	41	20	19	49	12	13	15
	Paracorophium spp.	IV	1553	1801	1499	2138	2303	646	1848	2627
Bivalves (shellfish)	*Arthritica* sp. 5	V	60	29	33	22	67	57	26	9
	Austrovenus stutchburyi	III	1	4						
	Cyclomactra tristis	I	6	5	12	5	2		4	3
	Paphies australis	III	1	54		6	1	5		2
Copepods (very small crustaceans)	Copepoda sp. 1	II			1					
Decapods (crabs)	*Austrohelice crassa*	V				2				
	Decapod megalopa	II				2				
	Halicarcinus whitei	IV	1		1					2
	Hemiplax hirtipes	V	1	11	1	5	3	10	4	7
Gastropods (snails)	*Amphibola crenata*	III		3	1		5	2	6	1
	Potamopyrgus estuarinus	IV	265	209	616	478	510	320	605	589
Isopods (sea slaters)	*Eurylana* sp. 1	II								1
	Exosphaeroma sp.	IV		1		3		1		1
	Anthuroidea	I	1	2	3		7	4	2	2
Mysids (mysid shrimps)	*Tenagomysis* sp. 1	II				1				
Nemerteans (ribbon worms)	Nemertea sp. 1	IV		1	2	1	1	2	2	3
Oligochaetes (segmented worms)	Oligochaeta sp. 1	IV				1			1	
Polychaetes (bristle worms)	Nereididae (juveniles)	IV	25	17	33	32	30	8	69	16
	Nicon aestuariensis	IV	4	23	19	29	6	17	11	17
	Perinereis vallata	IV	2	1	1					
	Scolecolepides benhami	V	3	13	10	5		3	8	17


Paracorophium spp.


Potamopyrgus estuarinus


Arthritica sp. 5


Nicon aestuariensis


Austrovenus stutchburyi (cockle)


Hemiplax hirtipes (stalked eyed crab)

Analysis of community composition did not discern any strong differences between sites or surveys (Fig. 10), consistent with the patterns evident from the data in Table 5. When data from individual cores were analysed, there was considerable spatial interspersion of sites and years in the nMDS plot, suggesting no strong grouping patterns. Nonetheless, overall tests of site and year differences using an Analysis of Similarities (ANOSIM) procedure (Clarke 1993), revealed weak but statistically significant differences between sites (ANOSIM, $R = 0.19$, $p = 0.001$), while assemblage composition differed more strongly among years (ANOSIM, $R = 0.34$, $p = 0.001$). In other words, samples from the same year were considerably more similar to each other than samples from different years, whereas the spatial differences in composition across the intertidal flats are less pronounced. The latter finding in consistent with the relatively homogeneous soft sediment environment.

Despite differences highlighted by the ANOSIM test, drilling further into Fig. 10 shows that site-averaged composition differences are minor in ecological terms. The top plot in Fig. 10 shows that sites/surveys were compositionally similarly to each other at a 75% similarity threshold (based on the Bray-Curtis index of association). In fact, site/survey separation does not emerge until a similarity of ~85%, which is unusually high for macrofaunal data. Even at that threshold, the composition differences are small; they reflect minor shifts in species abundances (e.g., higher densities of *Paracorophium* spp. in 2026), and chance sampling of the less abundant species, rather than ecologically significant composition changes.

The bottom plot in Fig. 10 explores the association between community composition and the sediment quality variables described above. The plot illustrates no strong associations, meaning that the relatively small changes in composition cannot be clearly 'explained' by any of the measured sediment quality variables. This result is supported by a statistical analysis of association using the BIO-ENV procedure in Primer (Clarke & Ainsworth 1993), which revealed no significant associations between composition patterns and sediment quality variables (Spearman correlation, rho ≤ 0.11).

The latter result is not surprising, as Manawatū Estuary is strongly river-dominated. In this type of system, macrofaunal composition is strongly influenced by the prevailing harsh physical conditions, i.e., low salinity and current disturbance, to an extent that likely masks the influence of other potential drivers of spatial or temporal change, such as sediment mud content (Forrest et al. 2024).

4. SUMMARY AND IMPLICATIONS

4.1 OVERVIEW OF KEY FINDINGS

This report has described the findings of four surveys conducted at two sites in the Manawatū Estuary, following NEMP 'fine-scale' survey methods.

The sites are situated in a relatively uniform area of intertidal flats, consisting of soft, muddy-sand sediments. Sediment trophic state indicators (nutrients, TOC, aRPD) show no signs of excessive enrichment, and levels of toxicants were very low.

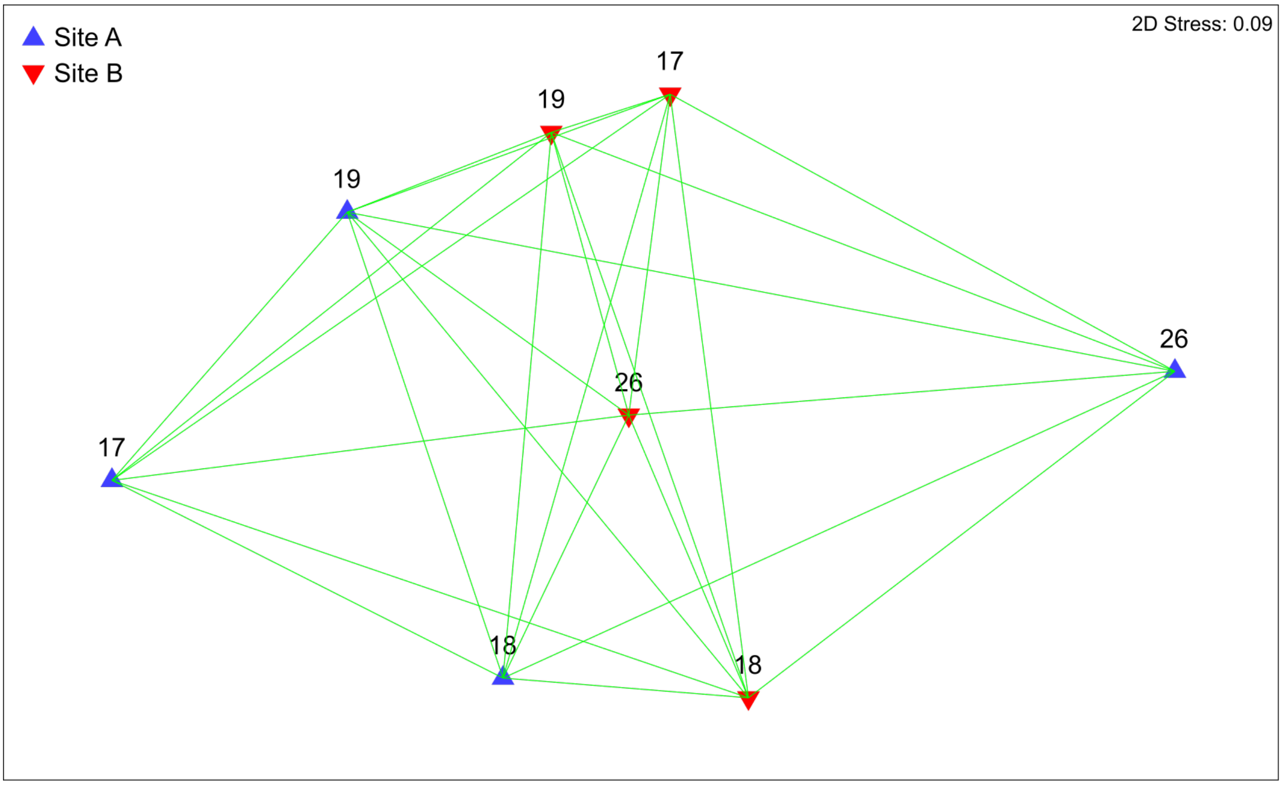
The macrofaunal assemblage has been consistently species-poor in all surveys, and dominated by a few disturbance-tolerant species, especially corophioid amphipods *Paracorophium* spp. and brackish water snails *Potamopyrgus estuarinus*. These results suggest that the macrofauna at both sites is exposed to reasonably harsh physical conditions. One of the major contributing factors is likely to be the effect of low-salinity water inundating the tidal flats each day, reflecting mixing of Manawatū River water with incoming tidal seawater. Low-salinity effects would be exacerbated during flood events.

Similarly, physical disturbance likely plays a role in shaping the macrofaunal assemblage. Strong river or tidal flows, as well as wind-induced wave and water current disturbance are both likely to move sediments around the estuary by processes of erosion, resuspension and deposition. Flood conditions potentially contribute significantly to sediment movement and deposition, with Fig. 11 illustrating some significant flood events preceding and during the 2026 survey, with implications further discussed in the next section.

4.2 IMPLICATIONS FOR FUTURE MONITORING

Fine-scale programme

Across all indicators, there were no ecologically meaningful or directional temporal trends, and little meaningful difference between the two sites. As the sites are already relatively muddy, and the harsh physical environment has an overriding influence on the associated biota, the monitoring approach is unlikely to be sensitive to 'upstream' changes that could occur in coming years (e.g., increased sediment or nutrient loads from the catchment, or changes in land management practices).



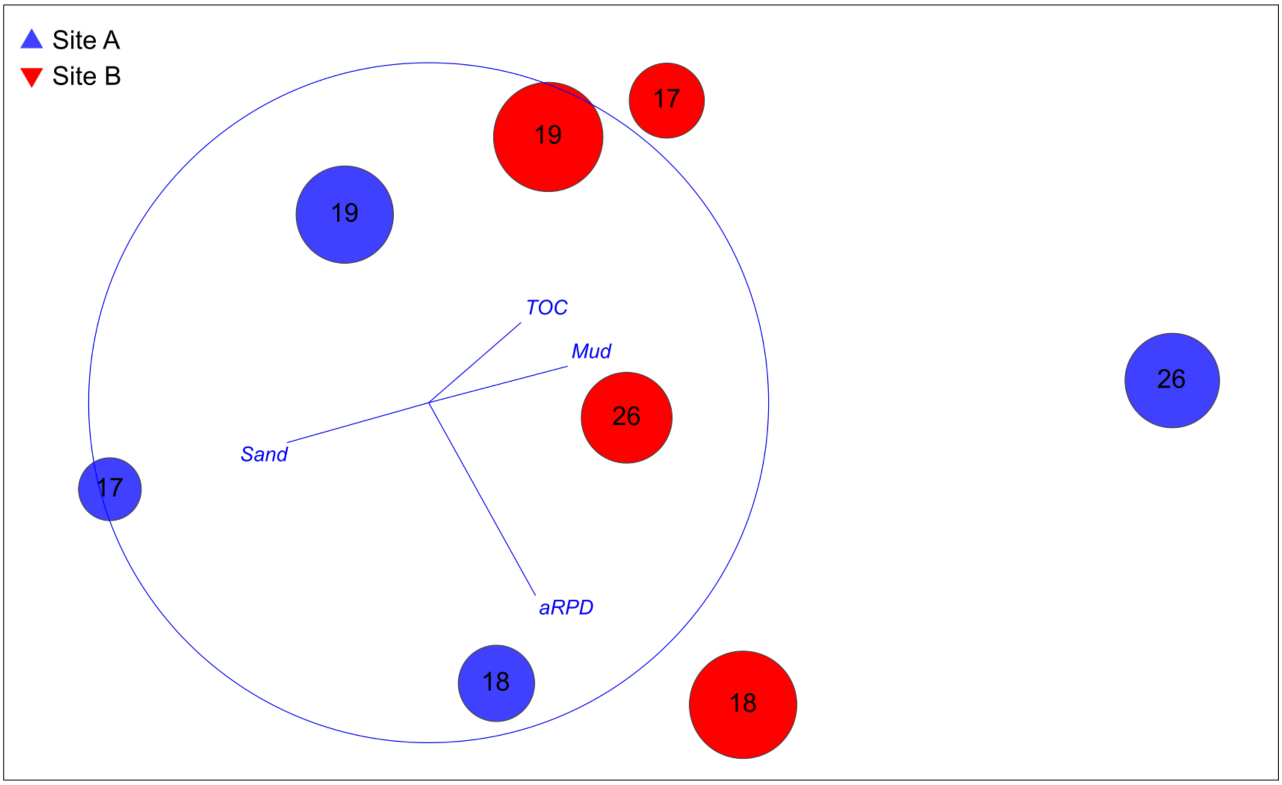


Fig. 10. Non-metric MDS ordination of macrofaunal core samples for data aggregated within each site and survey (year indicated by the two digits).

Sites and surveys closer to each other are more similar than distant ones in terms of macrofaunal composition. A 'stress' value of 0.09 indicates that a 2-dimensional plot provides a good representation of differences. In the top plot, the green lines connect sites with a 75% composition similarity (based on the Bray-Curtis index), illustrating that there are no ecologically important compositional differences among sites and surveys. In the bottom plot, the vectors show the direction and strength of association (length of line relative to circle) of key sediment quality variables, with bubble sizes scaled to sediment percent mud. The patterns suggests that sediment quality is not strongly associated with community composition changes.

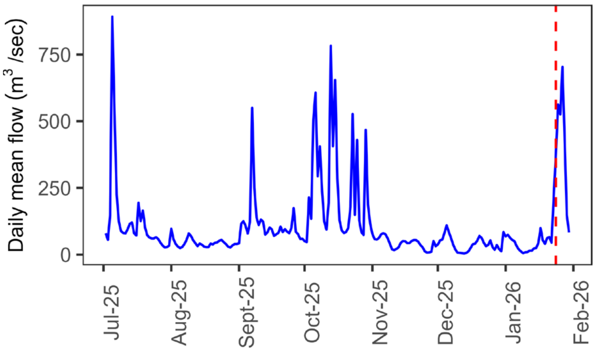


Fig. 11. Manawatū River daily mean flows in the 6-months before the fine-scale survey. The timing of the survey (23 & 24 Jan.) relative to a developing flood event is indicated by the dashed red line.

Based on the results and discussion above, ongoing monitoring will enable detection of any major shifts in ecology and potential drivers of change (e.g., sediment mud content, nutrients, contaminants), but in the short-term, monitoring is likely to be of limited direct value regarding the implementation or assessment of management actions. However, in the long-term (decades) the programme may provide insight into large-scale catchment changes (e.g., in sediment or nutrient loads), and the influence of broader scale phenomena such as climate change, i.e., sea level rise, global warming.

Given limitations of the NEMP methodology in river-dominated environments (Forrest et al. 2024), repeat monitoring every 5-years would be a reasonable approach for Manawatū Estuary, as indicators can be assessed against condition rating thresholds such as used in the present report, noting it will be many years before meaningful long-term trend analyses can be undertaken.

Sedimentation monitoring

An additional consideration for HRC is whether to re-establish the sedimentation monitoring programme. Previously, four 'sediment plates' were buried along the downstream margin of each fine-scale site, and sediment depth above the plates was monitored annually from 2017 to 2022. The pegs that marked the location of these plates were not present in 2026, hence sedimentation measurements could not be made. It is unclear whether the pegs were buried in sediment, washed away by scouring, or removed by someone.

When last reported by Stevens (2022), both sites had experienced net sediment erosion over a 5-year monitoring period. This was attributed to scouring processes, which is a view supported by field observations at the time whereby surf clam shell hash had been uncovered by scouring and was visible on the sediment surface (see photo).

Surf clam shell beds exposed by sediment scouring in 2022. By 2026, these beds were buried beneath muddy-sand and only encountered at the bottom of some of the 150mm deep macrofauna cores.

The fact that this shell material was encountered buried deeper in the sediment in 2026 (at the bottom of a few macrofauna cores) suggests that the estuary intertidal flats are quite dynamic in terms of their physical processes, showing considerable movement of bed sediments that likely leads to periods of sediment inundation as well as erosion. In this respect, sedimentation monitoring is likely to reveal more about the dynamic nature of the environment, than it is about the accumulation of catchment-derived sediment. Nonetheless, having information on sedimentation patterns helps to understand the nature and resilience of the macrofaunal community. As such, there would be value in reinstalling sediment plates and starting annual monitoring again. Annual monitoring is reasonably quick to do, and a field visit for that purpose provides the opportunity to walk over the tidal flats to gain a broader impression of estuary state.

5. RECOMMENDATIONS

It is recommended that HRC consider the following:

- Continue fine-scale monitoring every 5-years based on the NEMP approach described in this report.
- Reinstall sediment plates at fine-scale sites and monitor annually. At the same time, collect sediment samples for grain size analysis, to track changes in sediment mud content.

Note that, as well as marking sediment plates with pegs, it is suggested that differential GPS (accurate to 1-5cm) be used to log each plate location, to enable relocation if pegs are lost.

6. REFERENCES

Borja A, Franco J, Pérez V 2000. A Marine Biotic Index to Establish the Ecological Quality of Soft-Bottom Benthos Within European Estuarine and Coastal Environments. Marine Pollution Bulletin 40(12): 1100-1114.

Borja Á, Mader J, Muxika I 2012. Instructions for the use of the AMBI index software (Version 5.0). Revista de Investigación Marina, AZTI-Tecnalia 19(3): 71-82.

Clarke KN, Gorley RN 2015. PRIMER v7: User Manual/Tutorial. PRIMER-E, Plymouth.

Clarke KR 1993. Non-parametric multivariate analyses of changes in community structure. Australian Journal of Ecology 18: 117-143.

Clarke KR, Ainsworth M 1993. A method of linking multivariate community structure to environmental variables. Marine Ecology Progress Series 2: 205-219.

Forrest BM, Stevens LM 2019. Fine-scale intertidal monitoring of Manawatū Estuary. Salt Ecology Report 016, prepared for Horizons Regional Council. 26p.

Forrest BM, Stevens LM, Roberts KL 2025a. National Estuary Monitoring Protocol for Aotearoa New Zealand: Site-specific (fine-scale) intertidal monitoring methods. Salt Ecology Report 153, prepared for Ministry for the Environment, June 2025. 33p.

Forrest BM, Roberts KL, Stevens LM, O'Connell-Milne S 2025b. Otago regional intertidal fine-scale monitoring programme review. Salt Ecology Report 165, prepared for Otago Regional Council, June 2025. 62p.

Forrest BM, Roberts KL, Plew DR, Dudley BD, Stevens LM 2024. Guidance for assessment and monitoring of tidal river estuaries. Salt Ecology Report 133, prepared for Ministry for the Environment, June 2024. 53p.

Hunt S 2019. Regional Estuary Monitoring Programme (REMP) intertidal sedimentation measurements, results and review of methodologies. Waikato Regional Council technical report 2019/04, Waikato Regional Council, Hamilton, June 2019. 57p.

Roberts KL, Stevens LM, Forrest BM 2025. National Estuary Monitoring Protocol for Aotearoa New Zealand: Estuary-wide (broad-scale) intertidal monitoring methods. Salt Ecology Report 152, prepared for Ministry for the Environment, June 2025. 49p.

Robertson BP, Gardner JPA, Savage C 2015. Macrobenthic–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 2022. Manawatū Estuary: 2021/2022 intertidal sediment monitoring summary. Salt Ecology Short Report 011, prepared for Horizons Regional Council, April 2022. 2p.

Stevens LM, Robertson BP 2016. Manawatū Estuary 2016: Broad-scale habitat mapping. Prepared by Wriggle Coastal Management for Horizons Regional Council. 28p.

Stevens LM, Forrest BM, Roberts KL 2025. National Estuary Monitoring Protocol for Aotearoa New Zealand: Overarching Guidance. Salt Ecology Report 151, prepared for Ministry for the Environment, June 2025. 42p.

Stevens LM, Roberts KL, Forrest BM, Morrisey D, Zeldis JR, Dudley BD, Mangan S, Lam-Gordillo O, Lundquist C, Lohrer AM, Plew DR 2024. Advice on indicators, thresholds and bands for estuaries in Aotearoa New Zealand. Salt Ecology Report 141, prepared for Ministry for the Environment, June 2024. 182p.

APPENDIX 1. SITE AND METHOD INFORMATION

Site positions

In 2017, sites were marked with wooden pegs, and GPS positions recorded (±5m accuracy).

In 2026, most of the site pegs were missing, with sediment plates unable to be relocated.

Fine Scale Site Pegs

Site	Peg	NZTM East	NZTM North
A	1	1788727	5517648
A	2	1788725	5517619
A	3	1788787	5517620
A	4	1788787	5517650
B	1	1789082	5517639
B	2	1789069	5517612
B	3	1789127	5517598
B	4	1789140	5517623

Sediment Plates

Site	Plate	NZTM East	NZTM North
A	1	1788726	5517643
A	2	1788727	5517639
A	3	1788726	5517629
A	4	1788727	5517623
B	1	1789080	5517636
B	2	1789078	5517631
B	3	1789074	5517621
B	4	1789072	5517617

Analytical methods used by Hill Labs

Note that for total nitrogen, a trace detection limit of 0.02% (200mg/kg) was achieved in 2026.

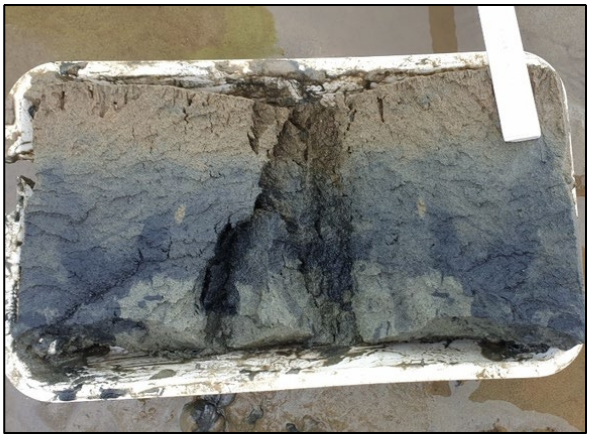
Summary of Methods

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively clean matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis.
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	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 - 0.4 mg/kg dry wt	1-6
3 Grain Sizes Profile			
Fraction >/= 2 mm*	Wet sieving with dispersant, 2.00 mm sieve, gravimetry.	0.1 g/100g dry wt	1-6
Fraction < 2 mm, >/= 63 µm*	Wet sieving using dispersant, 2.00 mm and 63 µm sieves, gravimetry (calculation by difference).	0.1 g/100g dry wt	1-6
Fraction < 63 µm*	Wet sieving with dispersant, 63 µm sieve, gravimetry (calculation by difference).	0.1 g/100g dry wt	1-6

Field method for sediment oxygenation



The aRPD depth (see photo inset) provides an easily measured, time-integrated, and relatively stable indicator of sediment enrichment and oxygenation. It is assessed in sediment cores, which are split vertically, and the mean aRPD depth is recorded to the nearest mm. Representative cores are photographed.

Sediments are considered to have poor oxygenation if the aRPD is consistently <10mm deep and clear signs of organic enrichment are indicated by a distinct colour change to grey or black. Extremely enriched sediments typically have an intense black sediment profile with the aRPD at or near the surface, emit a rotten-egg smell of hydrogen sulfide, and may have surface growths of sulfur oxidising bacteria.

SACFOR methods for epifauna (density) and algae (percent cover)

Epibiota (seagrass, macroalgae, microalgae, and conspicuous surface-dwelling estuarine snails nominally >5mm body size) visible on the sediment surface at each site are semi-quantitatively categorised using 'SACFOR' abundance (animals) or percentage cover (seagrass, macroalgae, microalgae) ratings shown in the Table inset.

The SACFOR method is ideally suited to characterise intertidal epibiota with patchy or clumped distributions. It can be used in preference to quantitative quadrat sampling which is known to poorly characterise scarce or clumped species.

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

Note that the SACFOR epibiota assessment does 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). Nor does it include very small organisms such as the estuarine snail *Potamopyrgus* spp.

AMBI calculation

Scores for the international biotic health index AMBI were calculated using the method of Borja et al. (2000). AMBI scores reflect the proportion of taxa falling into one of five eco-groups (EG) that reflect sensitivity to stress, ranging from sensitive (EG-I) to resilient (EG-V). The AMBI scores in this report differ to those presented in the previous fine-scale report for the Manawatū, due to modifications to some of the EGs, which were implemented following an analysis of New Zealand data by Forrest et al. (2025b). That analysis was based on organism distributions in relation to mud (a proxy for total organic carbon), following a method used previously for determining New Zealand-specific EGs (Robertson et al. 2015). The approach taken in the present report was to calculate AMBI using the revised EGs determined by Forrest et al. (2025b), but defaulting to international EGs where New Zealand-specific EGs were unavailable. AMBI scores were not calculated for macrofauna cores that did not meet operational limits defined by Borja et al. (2012) in terms of the percentage of unassigned taxa (>20%), low sample richness (<3 taxa) or low abundances (<6 individuals).

APPENDIX 2. SEDIMENT QUALITY DATA 2017-2026

Site	Year	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	2017	X	0.1	80.2	19.8	0.32	<500	380	20	3.6	0.02	11	5	0.02	9	5.6	33
		Y	0.2	79.8	20	0.29	<500	370	20	3.3	0.02	10.3	4.5	0.07	8.6	5.4	32
		Z	0.1	82.8	17.2	0.28	<500	350	20	3.4	0.02	10.2	4.6	0.02	8.7	5.4	32
	2018	X	<0.1	73.3	26.7	0.3	500	380	40	3.4	0.01	10.9	4.2	<0.02	8.4	5.9	33
		Y	<0.1	76.6	23.3	0.24	<500	360	40	3.3	0.02	10.3	4.1	0.02	8.3	5.4	31
		Z	<0.1	80.1	19.9	0.21	<500	330	40	3.2	0.01	9.7	4	<0.02	8	4.9	36
	2019	X	0.1	66.6	33.3	0.35	<500	430	29 (27 to 30)	4.1	0.02	12.4	4.9	0.31	10.2	6.1	42
		Y	0.1	68.4	31.4	0.32	<500	400	24 (20 to 27)	3.7	0.01	11.6	4.6	0.02	9.6	5.8	40
		Z	<0.1	69.8	30.1	0.34	<500	400	24 (20 to 30)	3.5	0.02	11.1	4.7	0.02	9.9	5.9	40
	2026	X	0.1	68.1	31.7	0.34	500	410	38 (30 to 50)	3.5	0.02	10.9	4.7	0.03	9.3	6.1	38
		Y	0.3	69	30.7	0.36	400	390	29 (23 to 35)	3.4	0.01	10.7	4.7	0.03	9.4	6.1	38
		Z	0.5	70.7	28.8	0.36	400	360	30 (28 to 32)	3.7	0.02	11.4	5.1	0.03	9.7	6.3	39
B	2017	X	0.4	72.7	26.9	0.28	<500	380	20	3.2	0.02	10.2	4.6	0.02	9	5.6	34
		Y	0.2	77.4	22.5	0.26	<500	380	20	3.1	0.02	9.9	4.5	0.02	8.7	5.4	33
		Z	0.2	80.7	19.2	0.23	<500	350	20	2.9	0.02	9.3	4.4	0.02	8.4	5.1	31
	2018	X	0.1	55.7	44.1	0.39	500	420	25	3.2	0.02	11.4	4.7	0.03	8.9	6.1	35
		Y	<0.1	65.1	34.8	0.34	<500	390	25	2.9	0.02	10.3	4	<0.02	8.5	5.3	33
		Z	<0.1	69.7	30.2	0.27	<500	360	25	2.5	0.02	9.7	4.1	0.02	8.3	5.1	33
	2019	X	0.5	58.2	41.3	0.42	<500	450	17 (16 to 18)	3.6	0.02	11.3	5.4	0.03	10.2	6.7	45
		Y	0.1	62.2	37.7	0.4	<500	410	18 (15 to 22)	3.2	0.02	11.8	5.3	0.03	10.4	6.4	44
		Z	0.3	66.8	32.9	0.29	<500	380	18 (15 to 20)	3.4	0.02	10.8	4.6	0.02	9.5	5.6	41
	2026	X	<0.1	66.3	33.6	0.26	300	400	35	3.3	0.02	10.3	4.2	0.03	8.8	5.7	36
		Y	<0.1	70.1	29.8	0.34	400	430	33 (25 to 38)	3.1	0.02	12	4.8	0.03	10.1	5.9	39
		Z	0.2	76.8	23.1	0.24	400	400	34 (30 to 40)	2.7	0.01	9.8	4	0.02	8.5	5.2	35
									Default Guideline Value (DGV; ANZG 2018)	20	1.5	80	65	0.15	21	50	200
									Guideline Value high (GV-High; ANZG 2018)	70	10	370	270	1	52	220	410

[#]aRPD range based on replicates within each zone indicated (n=3-4). No range for 2017 and 2018 data indicates no variability between measures.

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