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Monitoring of Tūranganui Estuary: 2024

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Monitoring of Tūranganui Estuary: 2024

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Prepared for Gisborne District Council

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Executive summary

In 2023, Gisborne District Council (GDC) commissioned Cawthron Institute (Cawthron) to help design a long-term estuary monitoring programme across Tairāwhiti / Gisborne District in conjunction with mana whenua. As part of the initial implementation, Cawthron was commissioned to carry out monitoring in Tūranganui Estuary in February 2024. This tidal river mouth estuary is formed by the joining of the Taruheru and Waimatā Rivers, which flow through the city of Gisborne and combine to form Tūranganui River. The smaller Waikanae Creek flows into the mouth of Tūranganui River before draining out to the ocean.

Fine-scale and shellfish monitoring was carried out at two intertidal sites, one on the Taruheru River and another on the Waimatā River. The monitoring sampled and assessed the animal / plant communities living on and within the sediment (infaunal macroinvertebrates and epibiota), shellfish abundance and size, physical and chemical characteristics of the sediment, and woody debris. Water quality data provided by GDC was used to compliment the assessment. This report presents the results of an assessment of ecological health of Tūranganui Estuary. We also provide future recommendations for the monitoring programme.

Sediment grain size
Sediments were largely composed of fine mud at the Taruheru site (60%) and sand at the Waimatā site. Most sediment samples at both sites exceeded the fair / poor health boundary threshold for mud content.

Sediment nutrients and organic content
Total organic carbon (TOC) in the sediment was highest at the Taruheru site and indicative of moderate eutrophication. TOC levels were low at the Waimatā site, indicating minimal eutrophication. Total nitrogen (TN) values indicated moderate eutrophication for both sites (i.e. in terms of nitrogen input). Total recoverable phosphorus (TRP) was relatively low for both sites, indicating the sediments were in good condition for this parameter.

Sediment metal contamination
Overall, metal contamination within Tūranganui Estuary sediments was low according to current guidelines for sediment contaminants.

Epibiota
At both Tūranganui Estuary sites, there were low abundances of epifaunal macroinvertebrates. No seaweed or seagrass was present.

Infaunal macroinvertebrates
The composition of infaunal macroinvertebrate communities was similar within the Taruheru site and significantly distinct from the Waimatā site. Communities at the Taruheru site were characterised by more mud-tolerant species (e.g. estuarine mud snail *Potamopyrgus estuarinus* and bristle worm *Scolecolepides benhami*), an indicator of high mud and organic content. The Waimatā site was characterised by species with a higher sensitivity to mud (e.g. pipi *Paphies australis* and the worm *Microspio maori)*. The Asian date mussel (*Arcuatula senhousia*) was also found at both sites and is a non-indigenous species that is under management in some regions in Aotearoa New Zealand.

Environmental drivers of macroinvertebrate communities
At the Taruheru site, the Mud Benthic Health Model (BHM) score indicated high to very high sedimentation impact, and the Metals BHM score indicated a moderate impact from metals compared to other estuarine sites across

Aotearoa New Zealand. At the Waimatā site, both Mud and Metals BHM scores were lower than expected and outside the limits of the model. The scores were therefore not a reliable indicator of estuary health relative to other intertidal estuary sites in Aotearoa New Zealand. However, they likely can be used to track health at the Waimatā site through time. We recommend checking the fit of the BHM during future monitoring to determine how useful the BHM scores are for this site.

Of the sediment characteristics examined, differences in mud content (< 65 µm), fine sand (65–500 µm), TOC, TN, TRP and the metal lead (Pb) were most closely related to patterns in macroinvertebrate community composition.

Shellfish
There was low abundance of tuangi / cockles (*Austrovenus stutchburyi*) and pipi (*P. australis*) and no hanikura / wedge shells (*Macomona liliana*) at the sites. The Taruheru site had taungi / cockles and no pipi, and the Waimatā Site had mostly pipi. However, two hanikura / wedge shells (< 5 mm) were found in the fine-scale sampling at the Waimatā site.

Woody debris
The percent cover of existing areas of woody debris was estimated, and we found some cover of debris (10–22 %) within and nearby the sites.

Water quality
There were 19 parameters across 11 state of the environment (SOE) sites assessed for trends from 2019–24. The majority of faecal indicators were above the freshwater guidelines and exhibited degrading trends since 2019, except at Taruheru River at Tuckers Rd Bridge and Kopuawhakapata Stream at Hirini St. Although these two sites showed improving trends, the median levels for *E. coli*, enterococci and faecal coliforms still exceeded the default guideline values (DGVs). In addition, most nutrient parameters were above the freshwater guidelines, except for nitrate-N. However, nitrate-N still exhibited a degrading trend across 10 of the 11 SOE sites. Levels of total suspended solids (TSS) have also worsened over the past 5 years.

Bird and marine mammal monitoring
No bird data were available, and there were no marine mammals observed (within the last year).

Overall conclusions
From the sediment mud content, our results showed that fine mud is the key stressor even with the high expected flushing capacity of the estuary. The Taruheru site had muddier sediments (classified as poor mud content) and more mud-tolerant taxa. The Waimatā site had sandier sediments (classified as fair mud content) with more mud-sensitive taxa. The TSS levels in the water exceeded the DGVs, although water clarity values were within the recommended guidelines. Reducing sedimentation should be a key focus for estuary health management.

Nutrient enrichment in the sediments was more a risk at the Taruheru site, where the TOC and TN levels were above threshold values. Metal contaminants in the sediments were generally low at both sites.

Faecal contamination was shown to be a key issue in relation to water quality, with most faecal indicators exhibiting degrading trends and exceeding DGVs at most sites.

The next fine-scale / shellfish monitoring event for the Tūranganui Estuary sites is scheduled for February 2025 and annually thereafter for another 4 years. Bird monitoring is due to be conducted quarterly, including during the next monitoring event, and both water quality data and marine mammal data should be updated in the next results report.

1. Background and scope

A long-term estuary monitoring programme was designed for Gisborne / Tairāwhiti District, and as part of its implementation, Gisborne District Council (GDC) commissioned Cawthron Institute (Cawthron) to undertake monitoring in Tūranganui Estuary in 2024. This included four components: fine-scale, shellfish, water quality and marine mammal monitoring. Although bird monitoring is also recommended for the monitoring programme, no data were available at the time of the 2024 reporting. This report includes an assessment of the estuary condition and provides a baseline of estuary characteristics. A summary of these characteristics is provided, focusing on: epibiota abundance, macroinvertebrate abundance, sediment quality, shellfish abundance and woody debris. Trends in water quality and future recommendations for the monitoring programme are also included.

1.1 Tūranganui Estuary

Tūranganui Estuary is formed by the joining of the Taruheru and Waimatā Rivers, which flow through the city of Gisborne / Tūranganui-a-Kiwa and combine to form the Tūranganui River. The smaller Waikanae Creek enters the mouth of Tūranganui River before flowing out to the ocean at Waikanae Beach (Figure 3). The estuary is relatively small and surrounded by a large catchment (31,400 ha), mostly covered in grassland, exotic forest and native scrub / shrubland. The estuary is classified as a tidal river mouth estuary, meaning that it has a long, narrow and shallow basin that is dominated by river flows, rather than tidal circulation (Hume et al. 2016). The estuary has a narrow mouth (388 m wide), very little intertidal area (i.e. most of the estuary is submerged with water regardless of tidal height) and an average depth of only 1 m at spring high tide. Seawater can travel kilometres up these types of estuaries where there are areas of low-gradient coastal plains. In the Tūranganui River, the saltwater wedge is thought to extend 4.7–6.7 km up the Taruheru and Waimatā Rivers and 3.6 km up the Waikanae Creek (Figure 1).[1]

For this report, we define the estuary as encompassing the Tūranganui River, the mapped estuary extent, and upstream to the saltwater wedge in Waikanae Creek and the Taruheru and Waimatā Rivers (Figure 1).

[1] Based on locations of the saltwater wedge supplied by Gisborne District Council.

Figure 1. Overview of Tūranganui Estuary, including the mapped estuary extent and upstream to the saltwater wedge in Waikanae Creek and the Taruheru and Waimatā Rivers (see yellow outline). Data sources: NZ Regional Boundaries 2020 (Eagle Technology[2]) and NZ Coastal Hydrosystems: estuary extent (yellow polygon; Hume et al. 2016[3]).

A summary of the values of and threats to Tūranganui Estuary, based on the vulnerability assessment by Clark et al. 2023, is provided below. The land around the mouth of the Tūranganui River and the joining of the Taruheru and Waimatā Rivers (also known as Ngā Waiweherua – 'The Waters Split') was originally settled by people from the *Horouta, Tākitimu* and *Te Ikaroa-a-Rauru* waka (Spedding 2006; Salmond et al. 2022). The area was name Tūranga-nui-a-Kiwa, meaning 'Great Standing Place of Kiwa' (Salmond et al. 2022). It is also the location where Captain James Cook first made landfall in Aotearoa New Zealand (Spedding 2006). The estuary has many culturally and historically significant sites , and the surrounding land is an important place for recreational activities, including walking, cycling, picnicking, swimming, fishing and a range of water sports such as waka ama, boating and kayaking (Reeve 2015; Salmond et al. 2022). Located near the mouth of the estuary are a port and a marina.

The estuary is currently facing a number of high, moderate and low risk threats. It has been extensively modified from its original state, and most of the shoreline has been hardened and reclaimed, with little wetland or saltmarsh vegetation remaining. In addition to habitat modification, the estuary faces high risks of contamination, sedimentation, woody debris buildup, invasive species and pests, unsafe kai harvest and climate change effects. There are large deposits of sediment and woody debris in the

[2] https://services.arcgis.com/XTtANUDT8Va4DLwI/ArcGIS/rest/services/nz_regional_councils/FeatureServer/0
[3] https://data.mfe.govt.nz/document/12835-nz-coastal-hydrosystems-shp-poly/

estuary from frequent large-scale storms and floods (Reeve 2015). The estuary is subject to a high risk of contamination through industrial activities due to its urban location and horticultural land use in the upper parts of the catchment. While the estuary still provides habitat for birds, fishes and invertebrates, the estuary also has high microbial loads from sewage overflows, which increase the risks for recreation, and seafood harvest and consumption (Salmond et al. 2022). On the other hand, if microbial loads were to be reduced, the shellfish population could be overharvested due to the accessible location, further diminishing shellfish populations (Clark et al. 2023). Furthermore, climate change poses a high risk for the estuary through sea level rise and warming, increasing the severity and frequency of storms and droughts, and ocean acidification.

Nutrient enrichment, harmful algal blooms (HABs) and disturbance pose moderate risks to Tūranganui Estuary. Most nutrients are flushed out to the ocean, rather than remaining in the estuary, and although there are frequent blooms of the harmful planktonic diatom genus (*Pseudo-nitzschia*), other HAB species identified in the estuary are presently at low densities. While flood events regularly cause disturbance, other impacts from livestock grazing and human activities, for example, are less of an issue. Additionally, with most of the coastal shoreline hardened, there is lower risk of coastal erosion.

1.2 Overview of Tūranganui Estuary monitoring programme

The estuary monitoring programme for Tūranganui Estuary focuses on the estuary's physical characteristics and potential threats. The programme has been designed to be feasible and cost-effective, while incorporating the values and priorities of mana whenua.[4] The estuary monitoring aligns with Aotearoa New Zealand's National Estuary Monitoring Programme (NEMP; Robertson et al. 2002), which is used by many councils as a standardised approach for monitoring the ecological condition of estuaries. Two sites within Tūranganui Estuary were chosen for fine-scale and shellfish monitoring (Figure 2), and five components were recommended for the monitoring plan (Table 1):

- Fine-scale monitoring (i.e. epibiota, infaunal macroinvertebrates and sediment quality)
- Shellfish monitoring
- Water quality monitoring
- Bird monitoring
- Marine mammal monitoring.

Broadscale monitoring (e.g. habitat mapping) was not recommended because the estuary has a limited intertidal area and a restricted extent of important estuarine habitats (e.g. saltmarsh, seagrass).

It should be noted that the Tūranganui Estuary monitoring programme primarily tracks estuary health from a Western viewpoint and does not encompass all aspects of estuary health that are important to mana whenua.

[4] Mana whenua associated with this estuary include Rongowhakaata Iwi Trust, Ngāi Tāwhiri, Te Whānau a Iwi, Te Rūnanga o Ngāti Porou and Ngāti Oneone.

Table 1. Details on spatial extent, timing and frequency of data collection for each of the components of the Tūranganui Estuary monitoring programme.

Component	Number of sites	Time of year for data collection	Frequency
Fine-scale monitoring	2	February	Annually for 5 years then review
Shellfish monitoring	2 (same sites as fine-scale monitoring)	February	Annually for 5 years then review
Water quality monitoring	11	Year-round	Monthly
Bird monitoring	2 (same sites as fine-scale monitoring)	Quarterly intervals, with one survey occurring within 1 month of fine-scale monitoring	Quarterly intervals
Marine mammal monitoring	Within the estuary and within a 1 km radius of the estuary mouth	Year-round	Data collated every time fine-scale / shellfish reporting is undertaken

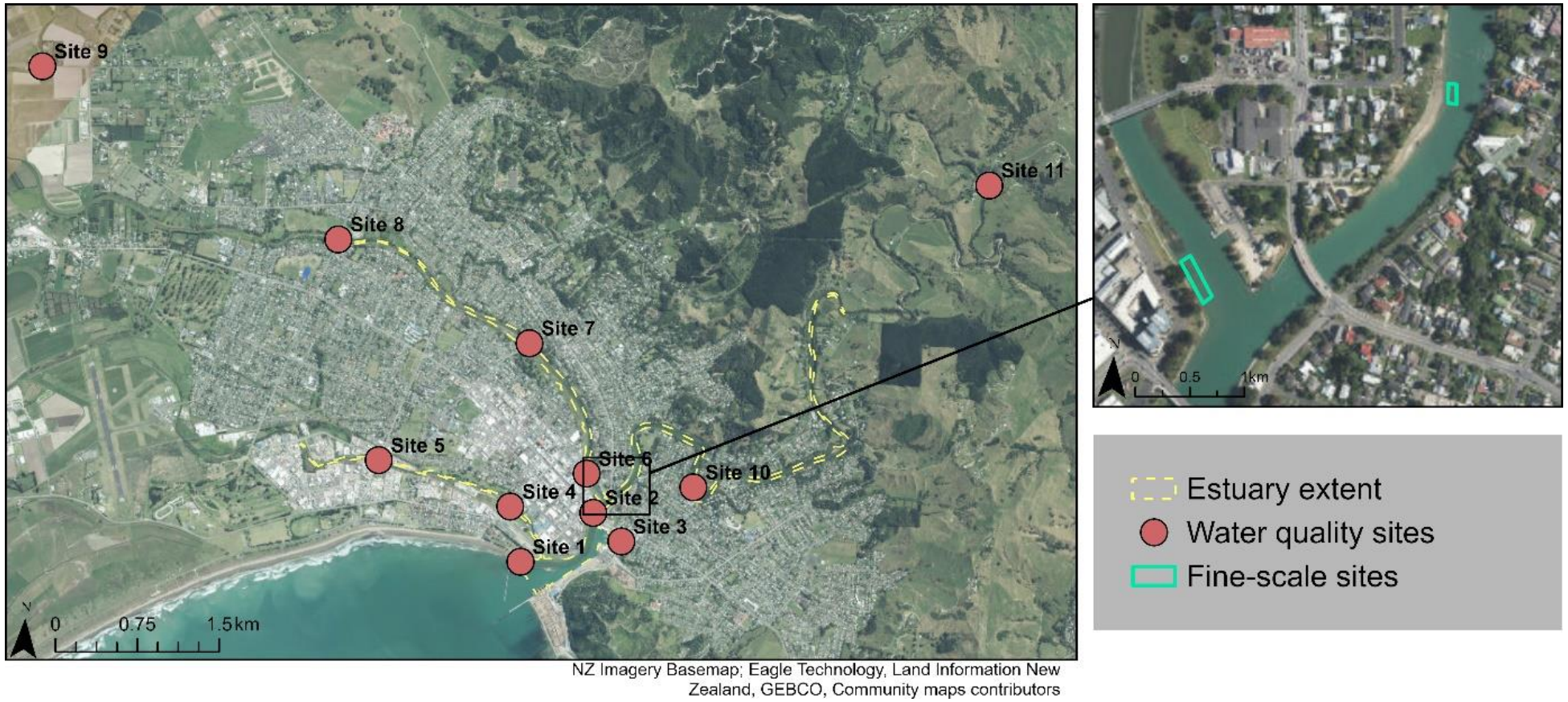


Figure 2. Fine-scale / shellfish sites and water quality monitoring sites in the Tūranganui Estuary monitoring programme. Data sources: NZ Imagery Basemap (see figure for credits), NZ Coastal Hydrosystems (Hume et al. 2016) and state of the environment sites (Gisborne District Council Hub).

1.3 Report scope and objective

This report describes the 2024 monitoring for Tūranganui Estuary as outlined in the monitoring protocol (Clark et al. 2024). It is the first round of monitoring and encompasses fine-scale and shellfish monitoring at two sites within the estuary and provides a summary of the estuary condition, including the epibiota, infaunal macroinvertebrates, sediment quality, shellfish abundance and woody debris found at each site. Our report also encompasses the available data from the other types of monitoring (water quality, birds and marine mammals) identified in the monitoring protocol. Ultimately, we aim to establish a baseline of estuary characteristics for Tūranganui Estuary and provide an assessment of the current environmental conditions and ecological health.

2. Fine-scale and shellfish monitoring methods

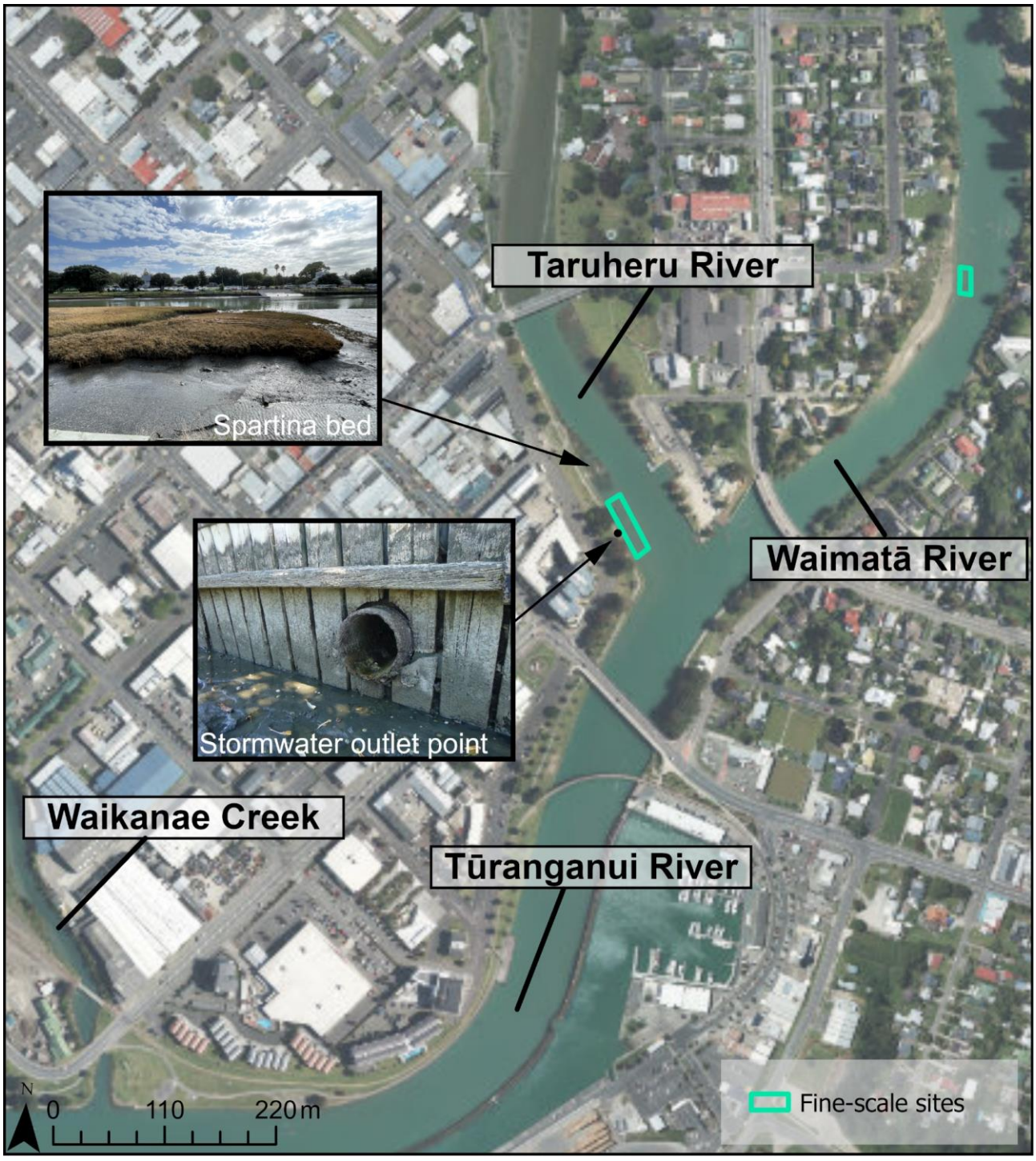
The fine-scale monitoring involved collecting detailed data at two sites considered representative of Tūranganui Estuary. A suite of physical, chemical and biological indicators were measured to assess the health of sediments and biological communities. Additionally, shellfish monitoring was conducted at the same sites and times as the fine-scale monitoring, which involved quantifying the abundance and size structure of shellfish populations. However, assessing the safety of shellfish for human consumption was not included in the programme. The fine-scale and shellfish monitoring methods for 2024 are described below, and these followed the monitoring protocol outlined by Clark et al. (2024). Gisborne District Council were responsible for communicating and engaging with mana whenua around the monitoring programme (Clark et al. 2024).

2.1 Site locations and set-up

The two Tūranganui Estuary fine-scale / shellfish monitoring sites were located on two areas of unvegetated, soft sediment intertidal substrates (Figure 3). One site was across from the Marine Park boat ramp on Taruheru River, close to the recreation reserve. The other site was on the Waimatā River near 31 Fitzherbert Street, on the corner of Fitzherbert and Clifford Streets (Figure 4). Both sites were positioned between the estuary margin and the channel, with their location and size[5] restricted due to the limited intertidal area present in Tūranganui Estuary. Other key site characteristics and differences include:

- At the Taruheru site, the shoreline is hardened by a wall, while at the Waimatā site the shoreline slopes gradually upwards.
- There is an outlet pipe, likely for stormwater, at approximately the midpoint of the landward side, which exits directly onto the Taruheru site (pers. comm. GDC).
- A small stream enters the estuary near the edge of the Waimatā site.
- *Spartina* (cordgrass) habitat is present just upstream of the Taruheru site. We understand that *Spartina* at the site area (i.e. the fine-scale site) had previously been eradicated.

[5] The Tūranganui Estuary fine-scale / shellfish site size was smaller than that outlined in the GDC estuary monitoring protocols for other Gisborne estuaries.



NZ Imagery Base Map; Eagle Technology, Land Information New Zealand, GEBCO, Community maps contributors

Figure 3. Close-up of the two fine-scale / shellfish monitoring sites (solid boxes) in Tūranganui Estuary. The *Spartina* bed (upstream of the site) and the stormwater outlet point (located on the landward edge of the site) are shown in the inserts. The location of the stormwater outlet (black dot) is shown relative to the fine-scale site on Taruheru River. Data sources: NZ Imagery Basemap (see figure for credits). Photo credits: Cawthron Institute.

Figure 4. The Taruheru (top) and Waimatā (bottom) fine-scale / shellfish monitoring sites. Photo credits: Cawthron Institute.

Areas at the two river sites were measured out to the following dimensions: 60 m × 15 m for the Taruheru site and 24 m × 10 m for the Waimatā site. Every site corner was marked with a wooden stake (Table 2 provides the GPS coordinates for each corner of each site). A measuring tape was then used to divide the site into a grid of equal size plots , with smaller stakes marking the plot corners. The site on Taruheru River (hereafter Taruheru site) was divided into nine plots, each measuring 20 m × 5 m, and the site on Waimatā River (hereafter Waimatā site) was divided into six plots, each measuring 8 m × 5 m (Figure 5; Figure 6). In accordance with the monitoring protocol, the two sites were positioned between the estuary margin and the channel. Due to the relatively limited intertidal area, the size of the sites was smaller than that outlined in the monitoring protocols for the other Gisborne estuaries and the NEMP (Clark et al. 2023; Berthelsen et al. 2024a; Berthelsen et al. 2024b). The Waimatā site had even less intertidal area than Taruheru and, as a result, was divided into six plots (rather than nine). This meant that only six macroinvertebrate replicate samples (epifaunal and infaunal) were collected for the Waimatā site. Six replicates were still considered suitable for analysis relative to other monitoring programmes in Aotearoa New Zealand (Anderson et al. 2007; Hewitt and McCartain 2017) but, due to the different total number of replicates between the two Tūranganui Estuary sites, only the average infaunal macroinvertebrate and epibiota taxa metrics (e.g. abundance and richness) per replicate were compared and not the overall values (i.e. all replicates combined). The whole of each site was photographed along with each individual plot with a label of its site name and plot number.

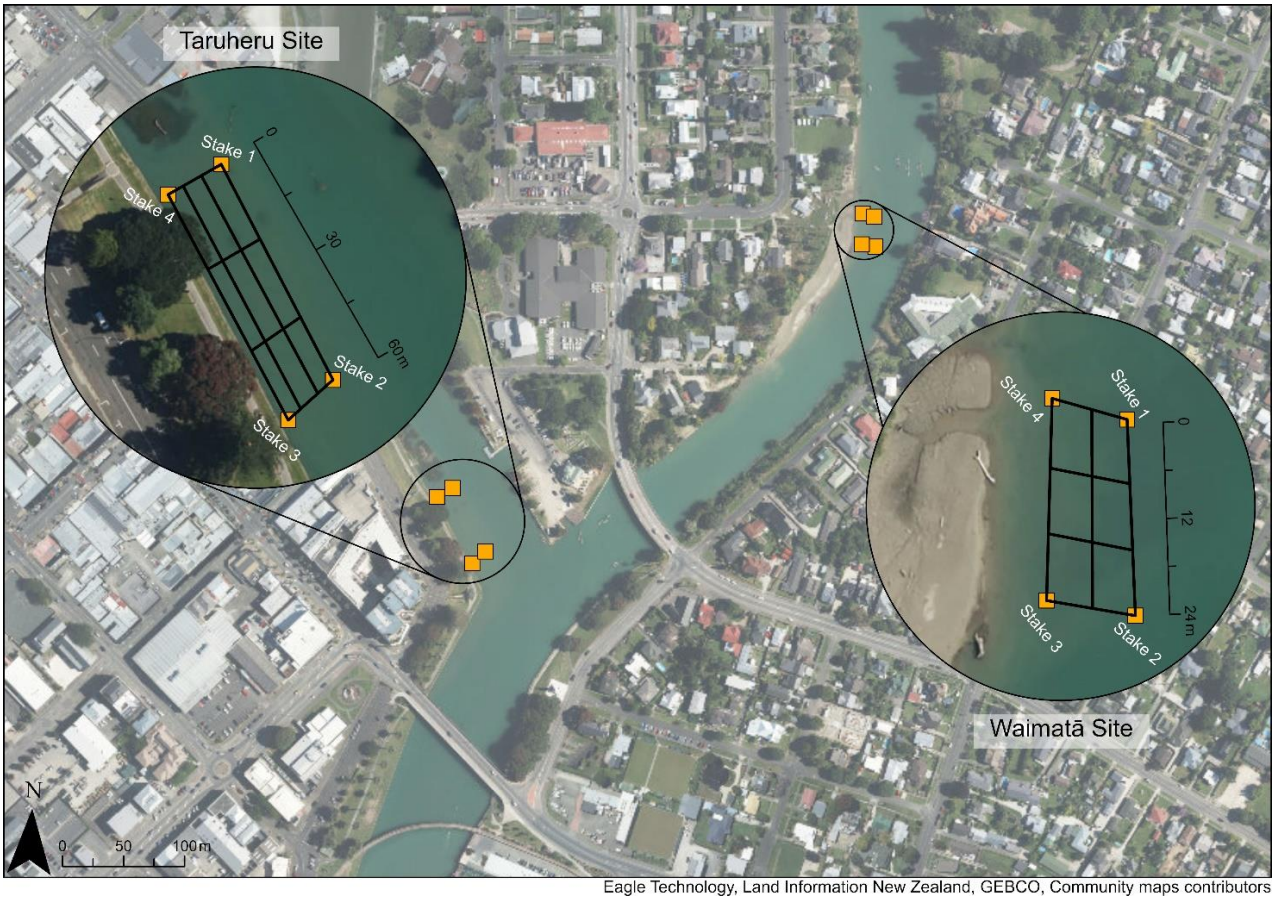


Figure 5. The fine-scale / shellfish monitoring sites at Taruheru and Waimatā Rivers measured to 60 m × 15 m and 24 m × 10 m, respectively. The inserts show a close-up of the Taruheru and Waimatā sites, divided into nine and six plots respectively, and the marking of the four corner stakes (orange squares) for each site. Note the differences in scale between the two inserts. Data sources: NZ Imagery Basemap (see figure for credits).

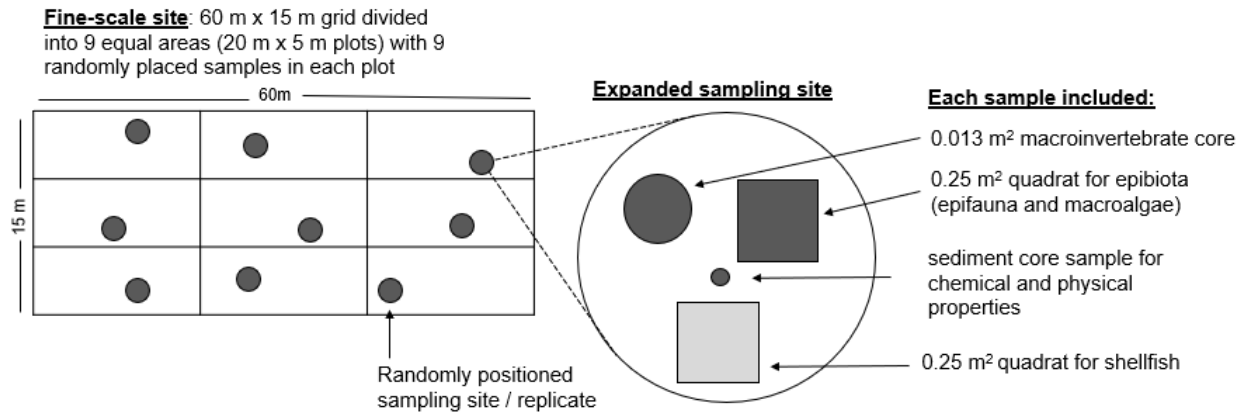


Figure 6. The sampling layout of the fine-scale monitoring site at Taruheru River illustrating a 60 m × 15 m grid divided into nine equal plots (each 20 m × 5 m), with a randomly placed sampling site in each plot. The expanded sampling site image illustrates the samples collected. *Note that the Waimatā site measured 24 m × 10 m with six equal plots.

Table 2. GPS coordinates for each corner of the Taruheru and Waimatā fine-scale / shellfish monitoring sites in Tūranganui Estuary.

Site	NZTME	NZTMN
Taruheru		
Northeast corner	38.666827°S	178.028842°E
Northwest corner	38.666899°S	178.0287°E
Southeast corner	38.66728°S	178.029183°E
Southwest corner	38.667372°S	178.029066°E
Waimatā		
Northeast corner	38.664662°S	178.032654°E
Northwest corner	38.664881°S	178.032681°E
Southeast corner	38.66487°S	178.032553°E
Southwest corner	38.664643°S	178.032545°E

2.2 Sediment quality

To monitor sediment physical and chemical parameters, a sediment core (6 cm diameter, at least 15 cm depth) was taken from each fine-scale site plot, within 30 cm of where the macroinvertebrate core was collected. The cored sediment was extruded onto a white tray and split vertically into two halves using a plastic ruler (Figure 7). The ruler was then placed next to the sediment core, and the sediment colour, texture, stratification and any occurrence of black (anoxic[6]) zones were recorded. If black zones were present, the average apparent depth of the transition between the lighter coloured surface layer and the darker deeper layer known as the redox potential discontinuity (RPD[7]) was measured. Poor oxygenation is indicated if the core consistently has a RPD < 10 mm deep and shows grey or black profiles, and emits a strong rotten egg smell of hydrogen sulphide (Forrest and Stevens 2023). The sediment core was then photographed with a site name and plot number label, and any sulphide odours were recorded.

Figure 7. Example of an extruded and split sediment core.

6 Devoid of dissolved oxygen, as opposed to oxic, which indicates sufficient dissolved oxygen availability for animal life.
7 Transitional zone between aerobic (oxygenated) sediments and anaerobic (deoxygenated) sediments.

Following the sediment core observations (described above), the top 2 cm of the whole sediment core was collected. Samples from multiple plots were combined into three composite samples. Samples were analysed for grain size, nutrients, metals and organic content.

The composite samples from Taruheru site were:

- sample 1: from plots 1–3
- sample 2: from plots 4–6
- sample 3: from plots 7–9.

The composite samples from Waimatā site were:

- sample 1: from plots 1–2
- sample 2: from plots 3–4
- sample 3: from plots 5–6.

An additional sediment core was sampled from each plot within 30 cm of the macroinvertebrate core. This sample comprised approximately equal amounts of sediment from the top 2 cm of the core from all plots per site. This sample was analysed for semi-volatile organic compounds (SVOCs), polycyclic aromatic hydrocarbons (PAHs), total petroleum hydrocarbons (TPHs) and organochlorine pesticides. All collected sediment samples were transported in a chilly bin with ice and refrigerated until sent for analyses to Hill Labs. Analytical methods are outlined in Table 3.

Table 3. Parameters analysed in sediment samples and their analytical methods and detection limits. The environmental threat evaluated by each parameter is also provided.

Threat	Parameter	Method	Level of detection limit
Sedimentation	Sediment grain size (Seven Grain Sizes profile)	Drying for 16 hours at 103 °C, gravimetry (free water removed before analysis). Wet sieving with dispersant, as received	0.1 g/100 g dry wt
Nutrient enrichment	Total organic carbon (TOC)	Acid pre-treatment to remove carbonates present, followed by catalytic combustion (O_2), separation, thermal conductivity detector [Elementar Analyser]	0.05 g/100 g dry wt
	Total nitrogen (TN)	Catalytic combustion (900 °C, O_2), separation, thermal conductivity detector [Elementar Analyser]	0.02 g/100 g dry wt
	Total recoverable phosphorous (TPR)	Dried sample, sieved as specified (if required). Nitric / hydrochloric acid digestion, ICP-MS, screen level. US EPA 200.2	40 mg/kg dry wt
Contamination	Heavy metals (trace) As, Cd, Cr, Cu, Ni, Pb, Zn, Hg	Dried sample, sieved as specified (if required). Nitric / hydrochloric acid digestion, ICP-MS, trace level. US EPA 200.2	0.01–0.8 mg/kg dry wt depending on the metal
	Semi-volatile organic compounds (SVOCs) trace in soil by GC-MS*	Sonication extraction, GC-MS analysis. In-house based on US EPA 8270	0.1–6.0 mg/kg dry wt depending on the SVOC
	Total petroleum hydrocarbons (TPHs) in solids*	Solvent extraction, GC-FID analysis. In-house based on US EPA 8015	20–70 mg/kg dry wt depending on the TPH
	Organochlorine pesticides trace in soil*	Sonication extraction, GC-ECD analysis. In-house based on US EPA 8081	0.0010 mg/kg dry wt
	Polycyclic aromatic hydrocarbons (PAHs) trace in soil*	Sonication extraction, GC-MS/MS analysis. In-house based on US EPA 8270	0.002–0.03 mg/kg dry wt depending on the PAH

***** Measured only in the first year of the sampling programme, unless levels are close to, or above, guideline limits during the previous round of sampling, or GDC or mana whenua are concerned that new sources of contamination are present.

Data analyses for sediment parameters and comparisons against guidelines

We investigated similarities and differences in sediment grain size composition among sites using a principal components analysis (PCA). Sediment contaminants and nutrients were plotted for visualisation against guideline values. Sediment quality was assessed using a range of existing guidelines: Land, Air, Water Aotearoa (LAWA), the Estuary Trophic Index (ETI; Robertson et al. 2016b), Robertson and Stevens (2010), ANZG (2018), Environmental Response Criteria (ERC; ARC 2004) and Effect Concentration Values (Hewitt et al. 2009). The Canadian Environmental Guidelines (CCME 2014) were used if there was no national guideline available (See Table 4–12).

Note that various guidelines exist for assessing the effects of sediment metal contamination on coastal environments. Where possible, metal concentrations were compared to guidelines derived from field-based studies of species sensitivity distributions (Hewitt et al. 2019). For metals not covered in Hewitt et al. (2009), ANZG (2018) guidelines or the more conservative sediment quality ERC used by Auckland Regional Council (ARC 2004) were used. Note that the above guidelines (ANZG and ERC) are limited to certain individual analytes, and do not take into account the synergistic effects of contaminants within sediments. In addition, the nutrient and mud sediment thresholds used in this report were not specifically designed for tidal river estuaries, so the results should be interpreted with caution.

Table 4. Guidelines for sediment mud content in estuarine sediments from Land, Air, Water Aotearoa (LAWA). Colours are used to indicate values that are suggestive of good (green), fair (yellow) or poor (red) health.

Rating	Mud (%)	Rationale
Good	≤ 3%	A small amount of mud is beneficial because the fine particles contain organic matter, which some macrofauna feed on. This means that the most diverse macroinvertebrate communities are often found when there is around 3% mud content, but diversity starts to decline beyond this (Douglas 2019)
	> 3–10%	Macroinvertebrate communities are most resilient when mud content is < 10% (Rodil et al. 2013)
Fair	> 10–30%	There are major declines in the resilience of macroinvertebrate communities between 10% and 25% mud content (Rodil et al. 2013), and communities are described as impoverished at around 30%
Poor	> 30–60%	Macroinvertebrate communities are unbalanced when mud content is > 30% (Robertson et al. 2016b)
	> 60%	Macroinvertebrate communities are degraded beyond 60% mud content (Rodil et al. 2013)

Table 5. Guidelines (interim) for sediment total nitrogen (TN) and total organic carbon (TOC) from the Estuary Trophic Index (Robertson et al. 2016b). Colours are used to indicate values that are suggestive of good (green), fair (yellow) or poor (red) health.

Rating	TN (mg/kg)	TOC (%)
Minimal eutrophication	< 250	< 0.5
Moderate eutrophication	250–1,000	0.5–1
High eutrophication	> 1,000–2,000	> 1–2
Very high eutrophication	> 2,000	> 2

Table 6. Guidelines (interim) for total recoverable phosphorus (TRP) from Robertson and Stevens (2010). Colours are used to indicate values that are suggestive of good (green), fair (yellow) or poor (red) health.

Rating	TRP (mg/kg)
Very good	< 200
Good	200–500
Fair	> 500–1,000
Poor	> 1,000

Table 7. Guidelines for metal contamination. Colours are used to indicate values that are suggestive of good (green), fair (yellow) or poor (health).

Rating (mg/kg)	As	Cd	Cr	Cu	Pb	Ni	Zn	Hg	Source
FEC lower (adjusted)				5.3	10.4		113.0		Hewitt et al. (2009)
***Austrovenus* EC50**				11.2					
FEC upper				9.3	19.4		118.0		
ERC – green/amber boundary				19.0	30.0		124.0		ARC (2004)
ERC – amber/red boundary				34.0	50.0		150.0		
DGV	20.0	1.5	80.0	65.0	50.0	21.0	200.0	0.15	ANZG (2018)
GV-high	70.0	10.0	370.0	270.0	220.0	52.0	410.0	1.0	

Table abbreviations: FEC = effect concentration values, EC50 = effective concentration in producing 50% decline in abundance, ERC = environmental response criteria, DGV = default guideline value, GV-high = upper guideline value (see footnote to Table 10), As = Arsenic, Cd = cadmium, Cr = chromium, Cu = copper, Pb = lead, Ni = nickel, Zn = zinc.

Table 8. Guideline values for additional sediment contaminants. DGV = default guideline value.

Stressor		Value		Source
		DGV	GV-high*	
Semi-volatile organic compounds (SVOCs)		**		ANZG (2018)
Total petroleum hydrocarbons (mg/kg dry weight)		280	550	
Polycyclic aromatic hydrocarbons (µg/kg dry weight, 1% organic carbon (OC)		10,000	50,000	
Organochlorine pesticides (µg/kg dry weight, 1% OC)	**DDT**	1.2	5	
	p.p'-DDE	1.4	7	
	o,p'- + p,p'-DDD	3.5	9	
	Dieldrin	2.8	7	
	Chlordane	4.5	9	
	Lindane	0.9	1.4	
	Total PCBs	34	280	

* 'Upper' guideline values (GV-high) provide an indication of concentrations at which you might already expect to observe toxicity-related adverse effects. The GV-high value should only be used as an indicator of potential high-level toxicity problems, not as a guideline value to ensure protection of ecosystems.

** SVOCs encompass many different parameters. If measured values are above detection limits, then specific guideline values can be obtained for comparison from ANZG (2018).

2.3 Epibiota

To monitor epibiota macroinvertebrates at each fine-scale site, a 0.25 m^2 quadrat was randomly placed in each plot and the epifauna (animals on the sediment surface) and the number of crab burrows were quantified and identified. The placed quadrat was photographed with a site name and plot number label, and observations of number of individuals for each animal taxon and number of crab burrows (and those under any seaweed) were recorded. Observations of the colour, coverage and thickness of any microalgae growing on the sediment surface were also recorded. If seaweed (macroalgae) or seagrass was present, percent cover was estimated, but no seaweed or seagrass was found at either fine-scale site during sampling in 2024.

Data analysis for epibiota

For community metrics

To assess epifaunal macroinvertebrate communities, the following univariate community metrics were used: species richness (*S*), total abundance (*N*), diversity (*H'*), and evenness (*J'*). These indices are useful for making comparisons between sites and years and any significant differences or trends (if data over time is available) may then be interpreted with respect to key environmental parameters. Additionally, macroinvertebrate community metrics can, to some extent, indicate the level of impact of stressors such as organic enrichment and sedimentation.

2.4 Infaunal macroinvertebrates

To monitor infaunal macroinvertebrates (animals living in the sediment) at each fine-scale site, a macroinvertebrate core (13 cm diameter, 15 cm depth) was collected from each plot. The sediment was passed through a 0.5 mm sieve by washing using a squeezy bottle with seawater from the nearby channel / river. Some sediment was retained to help protect delicate macroinvertebrate species from damage, and each sample retained on the sieve was transferred into 1.5 L plastic pottles (also using a squeezy bottle with seawater). Each pottle had seawater that covered just the surface of the sample before preservation. Once in the pottle, the sample was left for approximately 10 minutes so the sediment could settle, and the excess seawater was carefully decanted (to avoid ethanol dilution) using a 0.5 mm sieve again to avoid losing specimens. Any specimens retained on the sieve were transferred back into the pottle using a squeezy bottle with 80% ethanol. Additional ethanol solution was then added to each pottle to preserve the samples.

Preserved infaunal macroinvertebrate samples were sent to a taxonomist (MacLean Marine Identifiers[8]) and processed, identified and checked for quality assurance according to the protocols for Aotearoa New Zealand marine benthic invertebrate samples (Hewitt et al. 2014). The taxonomic resolution was identified to at least the lowest practicable level required for the application of the National Benthic Health Models (BHMs; Clark 2022). The accuracy and consistency in identifying benthic macroinvertebrates of soft sediment estuarine intertidal zones across Aotearoa New Zealand was checked using the web-based CSIG Species Key.[9] The taxonomist also created a photo library of the collected macroinvertebrate specimens, which was not identified in the estuary monitoring protocol requirements but was useful for reporting our results.

Data analyses for macroinvertebrates

Community composition and links to environmental variables

To analyse macroinvertebrate communities, we used a non-metric, multi-dimensional scaling (nMDS) ordination procedure and average cluster analysis based on Bray-Curtis similarities. Macroinvertebrate data were square-root transformed to reduce the effect of numerically dominant species. Differences in

[8] https://www.maclean-id.com/

[9] Species Key – Coastal Taxonomic Resource Tool | NIWA: https://niwa.co.nz/coasts/species-key-coastal-taxonomic-resource-tool

community structure among sites were further quantified using a permutational multivariate analysis of variance (PERMANOVA; one-way design with site as a fixed factor). A similarity percentage analysis (SIMPER) was used to identify the contributions of individual species to variation in community structure among sites. All multivariate analyses were performed in PRIMER 7 (v7.0.23) software.

A biota and environmental (BEST) routine using a biological environmental (BIOENV) method based on 9999 permutations was used to identify which environmental variable might be contributing to variations in the community structure.

Community metrics

To assess infaunal macroinvertebrate communities, the same univariate community metrics were used: species richness (*S*), total abundance (*N*), diversity (*H'*), and evenness (*J'*). These indices are useful for making comparisons between sites and years (i.e. significant differences or trends if data over time is available) relative to key environmental parameters.

Table 9. Descriptions of univariate measures for epifaunal and macroinvertebrate communities.

Index	Equation	Description
No. species (*S*)	Count (taxa)	Total number of species in a sample
No. individuals (*N*)	Sum (n)	Total number of individual organisms in a sample
Diversity (*H'* $\log_e$)	$H' = -SUM(P_i*\log_e(P_i)$	Shannon–Wiener diversity index ($\log_e$ base). A diversity index that describes, in a single number, the different types and amounts of animals present in a collection. Varies with both the number of species and the relative distribution of individual organisms among the species. The index ranges from 0 for communities containing a single species to high values for communities containing many species with each represented by a small number of individuals. P_i is the number of individuals of the *i*th species as a proportion of the total number of individuals in the sample
Evenness (*J'*)	$J' = H'/Log_e(S)$	Pielou's evenness. A measure of equitability, or how evenly the individuals are distributed among the different species. Values can theoretically range from 0.00 to 1.00, where a high value indicates an even distribution, and a low value indicates an uneven distribution or dominance by a few taxa

Benthic Health Models

The National Benthic Health Models (BHMs) were developed in 2020 as a standardised measure of the relative impact of two key coastal stressors – sedimentation and heavy metal contamination – on benthic (seafloor) macroinvertebrate communities in Aotearoa New Zealand's estuaries (Clark et al. 2020). There are two separate models: the Mud BHM and the Metals BHM. The Mud BHM assesses the impact of mud in surface sediments on macrofaunal communities and can be used as a surrogate for sediment accumulation rates. The Metals BHM assesses the impact of copper, lead and zinc in surface sediments on faunal communities. These metals are generally the key metals of concern produced by stormwater discharges in Aotearoa New Zealand estuaries (ARC 2004).

The BHM approach uses information about animals living within the seafloor sediments to assign a score that indicates the relative health of an estuarine site. The output from each model is a BHM score between 1 and 6, with 1 indicating the lowest impact of the stressor(s) on macrofaunal communities, and 6 indicating the highest impact, relative to other estuarine sites across Aotearoa New Zealand. The BHM scores can be expressed in five categories (Table 10). For the Metals BHM, additional guidance based on existing sediment quality guidelines has been developed to indicate the absolute health (poor, fair, good) of estuarine communities in an Aotearoa New Zealand context (Table 11). These scores facilitate the tracking of the relative health of sites through time. Further details about the BHMs can be found in Clark et al. (2020) and Clark (2022).

BHM scores for the two Tūranganui sites were calculated from the macroinvertebrate data collected during the fine-scale sampling. The taxa names and resolution were checked using the World Register of Marine Species (WoRMS) and standardised following Clark (2022); replicates were then averaged by site. BHM scores were calculated using PRIMER 7 (v 7.0.21) with the PERMANOVA+ add-on (Anderson et al. 2008; Clarke and Gorley 2015), and the fit of the calculated BHM scores were checked against the national dataset used to develop the models. None of the sites assessed were included in the original BHMs.

Table 10. Descriptive names and boundaries for Benthic Health Model (BHM) score categories.

BHM group	Level of impact relative to other estuarine sites in Aotearoa New Zealand*	BHM score
1	Very low	1.0 to < 2.0
2	Low	2.0 to < 3.0
3	Moderate	3.0 to < 4.0
4	High	4.0 to < 5.0
5	Very high	≥ 5.0

* This is a relative measure of impact rather than an absolute measure of health.

Table 11. Absolute health boundaries for the National Metals Benthic Health Model (BHM).

Absolute health	Metals BHM score
Good	Less than 3.6
Fair	3.6 to < 4.8
Poor	4.8 or greater

Indicator taxa

Key indicator taxa from fine-scale and shellfish monitoring data were used to indicate the presence of certain human-caused stressors (See Table 12 for examples). Infaunal macroinvertebrates are commonly used as indicators to assess the ecological condition of estuarine ecosystems, as these taxa exhibit characteristic responses to environmental changes or disturbances. Monitoring their abundance at individual sites and across time can be helpful to detect shifts in environmental conditions such as pollution or habitat degradation.

Infaunal species were assigned indicators based on Table 12 and summed for both sites. Indicator taxa abundance based on a Pearson correlation among sampling locations was overlaid and plotted for visualisation. Shellfish abundance and size data were also plotted for visualisation. Given seagrass was not present at either fine-scale site, it was not used as an indicator for the estuary in this report.

Table 12. Examples of indicator taxa and relationships with stressors.

Stressor	Taxon	Relationship with stressor	Sources
Nutrient / organic enrichment	**Polychaetes** Capitellidae*	Dominance of this taxon may indicate high levels of nutrient enrichment	AZTI (2022)
	Algae	Nuisance macroalgae, such as *Ulva* spp. and *Agarophyton chilense*, form blooms under enriched conditions	Sutula et al. (2014)
Sedimentation	**Polychaetes** Aonides sp., Microspio maori	Highly sensitive to mud; presence may indicate low mud levels	Norkko et al. (2002); Thrush et al. (2003); Gibbs and Hewitt (2004); Anderson (2008); Robertson et al. (2015)
	Nemertia spp., *Nicon aestuariensis*	Widely tolerant of sediment mud content; presence may indicate high mud levels	
	Scolecolepides benhami	Somewhat associated with elevated mud; presence may indicate moderately high mud levels	
	Snails *Amphibola crenata*, *Potamopyrgus estuarinus*	Widely tolerant of sediment mud content; presence may indicate high mud levels	
	Shellfish Tuangi / cockle, pipi, *Macomona liliana*	Sensitive to terrestrial sediment and different levels of suspended sediment; presence may indicate tolerable (e.g. low to intermediate) mud levels	Norkko et al. (2002); Nicholls et al. (2003); Thrush et al. (2003); Hewitt and Norkko (2007); Anderson (2008); Robertson et al. (2015)
	Arthritica bifurca	Somewhat associated with elevated mud; presence may indicate moderately high mud levels	
Metal contamination	**Polychaetes** *Aonides trifida*	Sensitive to copper contamination	Thrush et al. (2008); Hewitt et al. (2009)
	Snails *Amphibola crenata*	Shell length has been positively correlated with sediment cadmium and zinc concentration	Thrush et al. (2008); De Silva et al. (2022)
	Shellfish Tuangi / cockle	Moderately sensitive to stormwater contaminants	Hewitt et al. (2009)
		Sensitive to Cu or Cu/Pb/Zn	Anderson et al. (2002); Thrush et al. (2008); Tremblay et al. (2017)
		Sensitive to metals	De Luca Abbot (2001); Townsend et al. (2009)
	Macomona liliana	Sensitive to Cu or Cu / Pb / Zn	Anderson et al. (2002); Thrush et al. (2008)
		Sensitive to metals	Roper and Hickey (1994); Fukunaga et al. (2010)

*Capitellidae (*Heteromastus filiformis* and genus *Capitella*) is generally considered tolerant of organic enrichment overseas; however, taxa tolerances can vary in different locations (Berthelsen et al. 2022).

2.5 Shellfish sampling and analysis

To sample shellfish at each fine-scale site, a 0.25 m^2 quadrat was randomly placed in each plot. The sediment within the quadrat was dug up to a depth of 15 cm using a trowel or spade. The sediment was passed through a 4 mm mesh size sieve using the seawater from the nearby channel / river. Any tuangi / cockles (*Austrovenus stutchburyi*), pipi (*Paphies australis*) or hanikura / wedge shells (*Macomona liliana*) remaining on the sieve were picked out and placed apart on a white tray, separated into the different species. A ruler was also placed at the top of the tray, and a photograph was taken of the tray of shellfish with a label of the site name and plot number. Caution was taken during photographing to ensure lighting conditions were consistent and the ruler measurements could be clearly seen for photo image analyses. During fine-scale sampling in 2024, we observed very low numbers of tuangi / cockles and pipi at both survey sites. To avoid impacting existing populations, no shellfish were collected for the shellfish condition assessment described in the monitoring protocol.

After field sampling, the numbers of tuangi / cockles, pipi and hanikura / wedge shells collected from each quadrat were counted from the photographs. The photo analysis software, ImageJ, was also used to measure the size of each shellfish by measuring the distance across the widest part of each individual's shell.

2.6 Woody debris sampling and analysis

To estimate the percent cover of existing areas of woody debris within a fine-scale site, a 0.25 m^2 gridded quadrat (gridded into 36 squares) was randomly placed on top of the woody debris. This was also repeated if woody debris was found outside of the fine-scale sites (i.e. up to 20 m away). The percent cover of woody debris in the quadrat was estimated by counting the number of grid intersections (including those on the outer frame) that overlapped the woody debris. The quadrat was photographed, and the process was repeated up to 12 times each, for both within and outside of the fine-scale site. The percent cover of woody debris in the quadrats were broadly categorised as: 0% = none (i.e. no woody debris found), 0–50% = some, 50%+ = lots.

3. Additional monitoring data (water quality, bird and marine mammals)

3.1 Water quality data and analysis

The GDC currently monitors water quality parameters at 11 sites within the estuary extent for state of the environment (SOE) monitoring purposes (Figure 8). These sites are representative of the rivers rather than associated with particular sources of contamination (e.g. stormwater outfalls), and most parameters are measured monthly (Clark et al. 2023). The SOE sites closest to the fine-scale monitoring sites were Taruheru River at Peel St Bridge (Site 6; upstream of the Taruheru site), Tūranganui River at Gladstone Rd Bridge (Site 2; downstream of both fine-scale sites) and Waimatā River at Grand Rd (Site 10; upstream of the Waimatā site).

As this was the first year of fine-scale monitoring for Tūranganui Estuary, we analysed water quality data (provided by GDC) for the previous 5 years (i.e. from 2019 onwards) across all 11 SOE sites. The provided data were categorised by routine, non-routine and resampled data. Data were considered resampled if a measurement exceeded higher than expected values, which only occurred in one instance, and thus the value was retained in our analysed dataset. Dates categorised as non-routine were removed from our dataset, as these measurements were triggered from a storm event, i.e. heavy rainfall, which can disproportionately affect the trend.

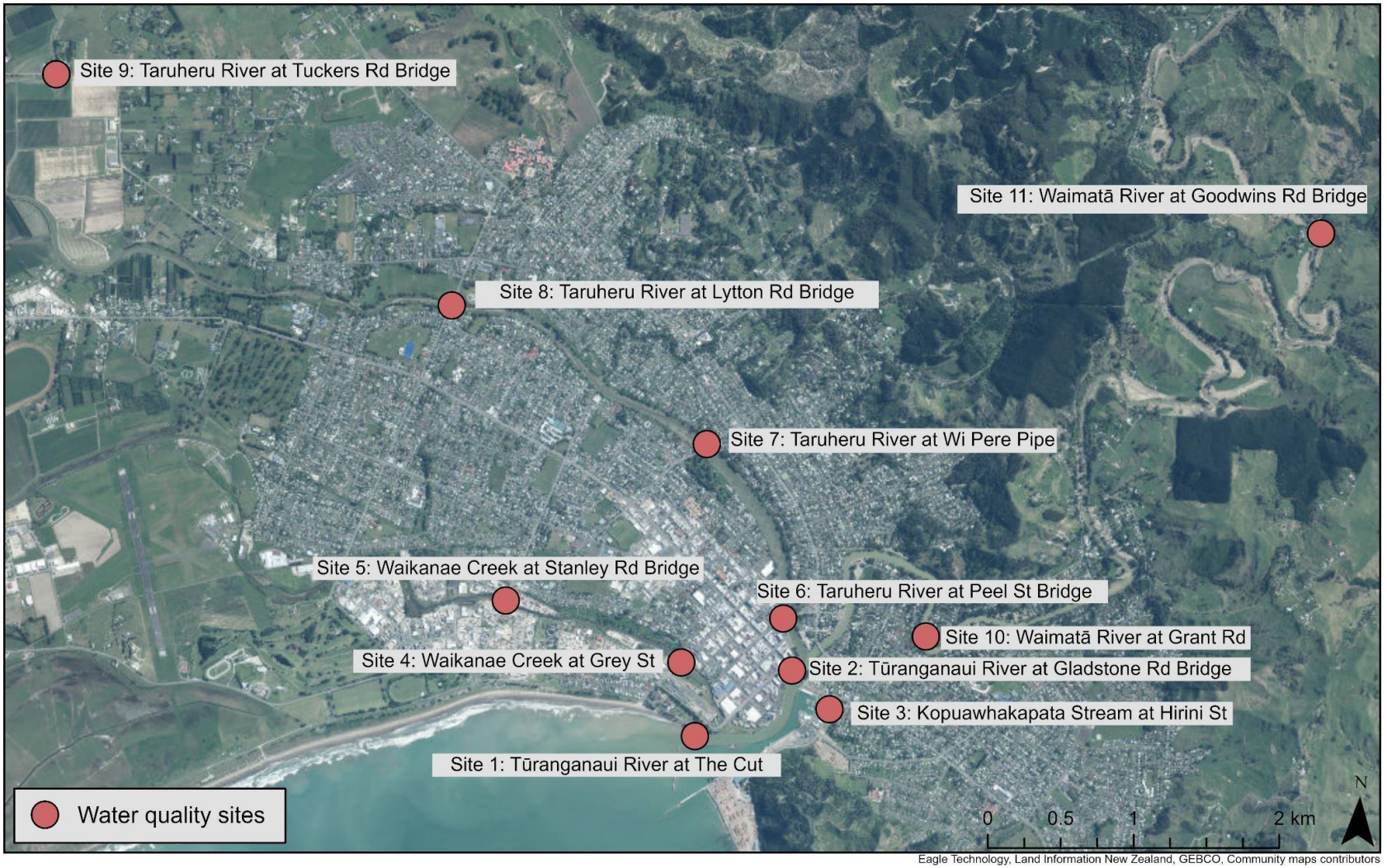


Figure 8. State of the environment (SOE) water quality monitoring sites in Tūranganui Estuary. Data sources: NZ Imagery Basemap (see figure for credits) and SOE sites (Gisborne District Council Hub).

From the list of provided parameters, we selected 19 parameter variables as the most biologically relevant to assess coastal and estuarine water quality (Table 13; further details in Dudley et al. 2017; ANZECC 2000; Fraser et al. 2021). These parameters provided useful information for assessing physico-chemical parameters (including nutrient enrichment), microbial contaminants, metal contaminants and water clarity (sedimentation).

Table 13. List of biological parameters to assess coastal and estuarine water quality.

	Parameter
Physical parameters	pH
	Salinity
	Water temperature
Chemical parameters	Ammoniacal nitrogen (ammonia-N / NH_4-N)
	Nitrate nitrogen (NO_3-N)
	Total nitrogen (TN)
	Dissolved reactive phosphorus (DRP)
	Total phosphorus (TP)
	Dissolved oxygen (DO)
Microbial contaminants	*E. coli*
	Enterococci
	Faecal coliforms
Metal contaminants	Copper (Cu)
	Lead (Pb)
	Zinc (Zn)
Water clarity	Clarity tube
	Total suspended solids (TSS)
	Turbidity
Additional contaminants	Total petroleum hydrocarbon (TPHs)

Water quality can show gradual changes over time, and the change in overall direction of a parameter over a selected time period is referred to as a trend. For this study, we analysed the water quality data from the previous 5 years (i.e. from 2019 onwards) for trends. We then assessed the results against the ANZG (2018) guidelines developed for Australia and Aotearoa New Zealand for most water quality parameters (Table 14). Microbial contamination was assessed using guidance provided by the Ministry for the Environment and Ministry of Health (MfE and MoH 2002).

To assess water quality trends, we followed the methods of Larned et al. (2015) and Snelder et al. (2021) using the LWP Trends Package R functions (R Core Team) provided by LandWaterPeople[10] (LWP; v2102; Snelder and Fraser 2019). We applied the filtering rules for each water quality variable; the site and parameter combinations had observations for at least 90% of the years and at least 90% of seasons within the 5-year time period. We checked the data for monitoring frequency, which in this case, equated to at least 60 observations over 5 years.

For some water quality parameters, measurement values were above or below a detection limit (e.g. < 0.200) and these values are known as censored values. The LWP Trends Package recognises censored values (denoted with symbols '<' or '>' in the dataset), which are substituted with absolute values imputed by the LWP Trends Package and simultaneously categorised as censored. Following LAWA,[11] if there were fewer than five total and three unique, non-censored observations, the trends were reported as 'not assessed' because too many censored data can lead to unreliable analyses. If parameters did not have enough measurements over the 5-year period, the trends also were not calculated and resulted in 'not assessed.'

To assess the direction of the trend (improving, degrading or indeterminate), the LWP Trends Package tested each site / parameter combination against a seasonal or non-seasonal version of the Mann-Kendall slope test (Snelder and Fraser 2021). This test assessed all pairwise combinations of the data. Following LAWA's trend categories,[12] the trends are differentiated into the same five classes: very likely degrading, likely degrading, indeterminate, likely improving and very likely improving.

[10] https://landwaterpeople.co.nz/pdf_report/water-quality-trend-analysis-functions-for-r/
[11] https://www.lawa.org.nz/learn/factsheets/calculating-water-quality-trends-in-rivers-and-lakes
[12] https://www.lawa.org.nz/learn/factsheets/calculating-water-quality-trends-in-rivers-and-lakes

Table 14. The default guideline values (DGVs) for water quality parameters for physico-chemical parameters, microbial contamination, metal contaminants and water clarity for freshwater and marine environments. There are no DGVs for TPH and pH.

		Stressor	Value		Source
			Freshwater	Marine	
Physico-chemical parameters	Nutrient enrichment (chemical)	Total nitrogen (TN; mg/L)	0.281	–	ANZG (2018) freshwater physical and chemical stressor DGVs for slightly to moderately disturbed systems
		Ammoniacal nitrogen (NH_4-N; mg/L)	0.017	2	
		Nitrate nitrogen (NO_3^-N; mg/L)	3.8	–	
		Dissolved reactive phosphorous (DRP; mg/L)	0.007	–	
		Total phosphorus (TP; mg/L)	0.023	–	
		Dissolved oxygen (DO; %)	82 %–100 %	–	
	Physical parameters	Salinity (mg/L)	< 5% from background levels		For estuarine and coastal waters, ANZECC (2000)
		Temperature (Temp.; °C)	21	–	Davies-Colley et al. (2013)
Microbial contamination		*E. coli* (n/100 mL)	550	–	MfE and MoH (2002)
		Enterococci (n/100 mL)	280	–	
		Faecal coliforms (n/100 mL)	200	–	
Metal contaminants		Dissolved copper (Cu; mg/L)	0.0018	0.003	Recommended ANZG (2018) freshwater and marine DGVs for 99% level of species protection of moderately disturbed systems
		Dissolved lead (Pb; mg/L)	0.0056	0.0066	
		Dissolved zinc (Zn; mg/L)	0.015	0.023	
Water clarity (Sedimentation)		Clarity (m)	0.7	–	Recommended ANZG (2018) freshwater and marine DGVs for 99% level of species protection of moderately disturbed systems
		Total suspended solids (TSS; mg/L)	4.6 mg/L	–	
		Turbidity (NTU or FNU)	5.6	–	ANZECC (2000) trigger value for lowland NZ rivers

3.2 Bird monitoring data

Bird monitoring data were not available at the time of the 2024 fine-scale reporting and therefore are not included in our report.

3.3 Marine mammal data

We obtained the Marine Mammal Sighting Database from DOC, which records public sightings and strandings of whales, dolphins, seals and rāpoka / New Zealand sea lions.[13] Our focus was to determine whether there were any records of marine mammals sighted or stranded within the estuary or within a 1 km radius of the Tūranganui Estuary mouth over the year preceding the fine-scale / shellfish monitoring. The data were filtered by location (i.e. Gisborne) and while sightings had been documented, these were from earlier years (2019 and earlier) and were not within the 1 km radius of the estuary mouth. However, these sightings are included in this report to provide information on marine mammals that have previously been observed near the study sites.

[13] Email marinemammals@doc.govt.nz to request these data.

4. Results and discussion

4.1 Sediment quality

No strong sulphide odour was detected in the sediment cores from either of the two Tūranganui Estuary fine-scale sites. The cores from the Taruheru site were generally lighter brown grey within 3 cm of the surface and commonly grey / darker grey at deeper depths (> 9 cm). One core from the Taruheru site contained vegetation material at > 9 cm depth, but no distinct *Spartina* was found in any of the cores. The sediment in the cores at the Taruheru site was relatively fine. The cores from the Waimatā site were generally grey / brown for the whole core, except in plots 5 and 6 where the cores were brown. The sediment in the cores at the Waimatā Site was relatively coarse. No distinct apparent RPD was observed in any of the cores for either site (Appendix 1). Shell hash was usually present deeper than 14 cm at both sites.

Grain size

Sediment grain size composition differed between the Taruheru and Waimatā monitoring sites. The sediment mud content exceeded the LAWA fair / poor boundary for most samples at both monitoring sites (Figure 9). The Taruheru site had higher proportions of mud in the samples, with two of the three sediment samples characterised by high proportions of mud (> 60 %). At the Waimatā site, the mud proportions in sediment samples were < 32 % (Figure 10). Besides mud, the remaining sediment in samples at both sites was composed of sand of varying grain sizes. Our recorded sediment mud values in 2024 indicated that macroinvertebrate communities are likely to be degraded because they are above the LAWA guidelines. The 2024 sediment mud content values were also well above a value previously reported for tidal river mouth estuaries in Aotearoa New Zealand (median mud = 28%; Berthelsen et al. 2019). In 2019, Kelly and Sim-Smith (2020) found high sediment mud content, ranging from 60 %–69%, at various sites in the Tūranganui River and 40%–66% in the Waimatā River. Two of their 2019 study sites, Tūranganui 1 and Waimatā 3, were relatively close in proximity to our 2024 Taruheru and Waimatā fine-scale sites, respectively. In the study, Tūranganui 1 had a similarly high (~60%) mud content compared to our 2024 values; however, the sediment mud content values for Waimatā 3 were much higher (~66%) than those recorded at our 2024 Waimatā monitoring site.

In terms of overall sediment grain size composition (i.e. all grain sizes considered together), samples from the same site clustered together on the similarity plot, indicating a degree of within-site consistency (Figure 11). Variation in sediment composition was observed among the fine-scale samples at each site, which was likely due to the position of plots within the sites (e.g. higher or lower tidal height on the shore). For example, the Taruheru 1 sample had the lowest mud content at the Taruheru site and was a composite from the three plots closest to the river. In comparison, the Taruheru 2 and 3 samples had much higher mud content and were composited from three plots in the middle and farthest from the river (closest to landward side), respectively.

Sediment composition and grain size can be affected by several factors, including sediment sources (e.g. run-off from land, presence of liquefaction sediment), site hydrodynamics or the presence of

vegetation. Both the Taruheru and Waimatā Rivers flow through Gisborne City, i.e. areas of urban development, which may contribute to sediment inputs. For example, it is possible that sediment enters the sites through the nearby stormwater outlet at the Taruheru site or a stream at the Waimatā site. Further upstream, the Taruheru catchment is predominantly cropland, comprising cropping, orchards and grasslands (Kelly and Sim-Smith 2020; Clark et al. 2024). The Waimatā catchment is predominantly exotic forest and grassland (Kelly and Sim-Smith 2020; Clark et al. 2024). The surrounding land uses include forestry and agricultural activities, which have adversely contributed to the sediment inputs into rivers (Kelly and Sim-Smith 2020). In addition, at the site level, areas that are well flushed or have higher wave movement generally have low mud content and higher sandy sediments due to resuspension (Robertson and Stevens 2013). The Taruheru site is located alongside a hardened shoreline, which might influence sediment dynamics. Furthermore, the higher mud content at the Taruheru site could be attributed to the previous presence of vegetation. Historically, this site had *Spartina* spp. (cordgrasses), and currently, *Spartina* can still be seen in close proximity to the site. Vegetation can trap finer sediment and organic matter and reduce water flow, enhancing sediment deposition and contributing to finer sediment accumulation (Clark et al. 2024). Conversely, the Waimatā site had a softer shoreline and no nearby *Spartina*.

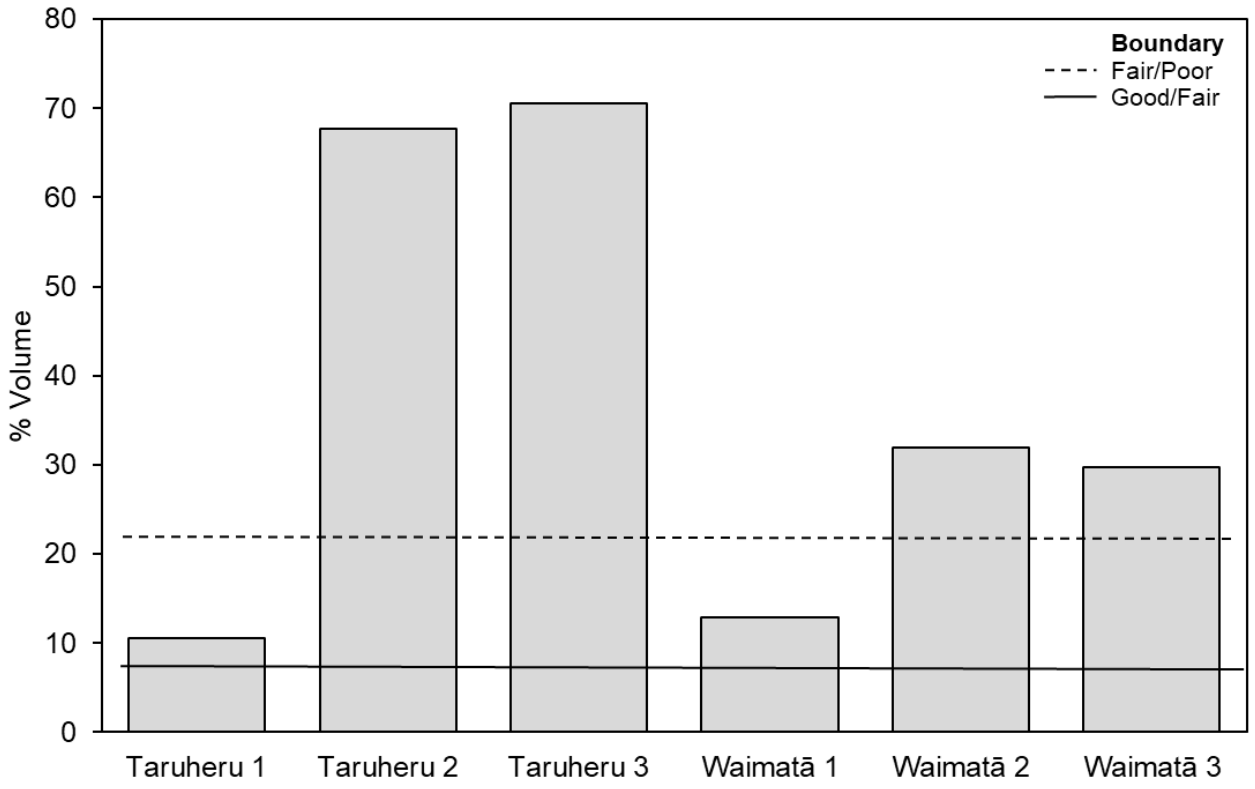


Figure 9. Sediment mud (< 63 µm) content (% volume) at the Taruheru and Waimatā sites in Tūranganui Estuary. Horizontal lines indicate poor, fair and good health based on LAWA guidelines.

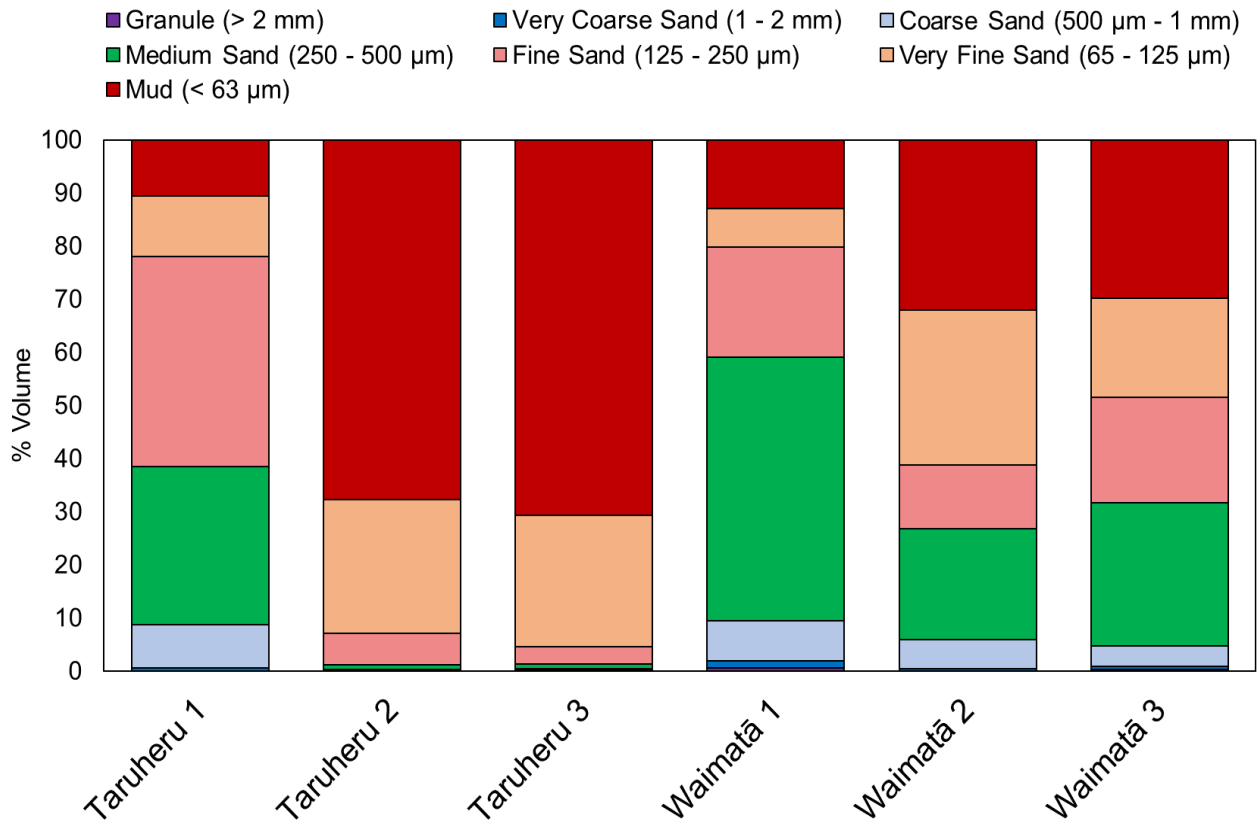


Figure 10. Sediment grain size categories (% volume) from composite samples at the Taruheru and Waimatā sites in Tūranganui Estuary.

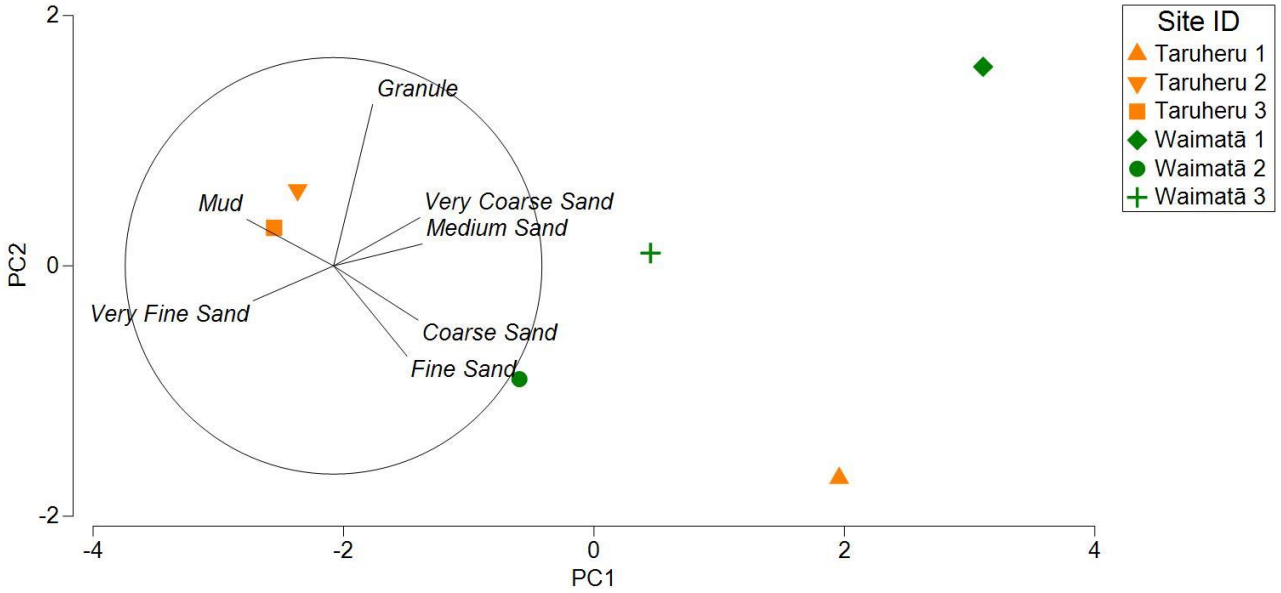


Figure 11. Differences in sediment grain size composition (based on Euclidean distance) among and between sediment composites from the two fine-scale sites (Taruheru and Waimatā) in Tūranganui Estuary illustrated using a principal components analysis (PCA). Each symbol represents the sediment grain size data (for one composite sample) from the fine-scale sites. Symbols that are closer together indicate that composite samples are more similar than those spread farther apart.

Organic carbon and nutrients

Total organic carbon (TOC) in the sediment was highest at the Taruheru site and indicative of moderate eutrophication according to the ETI interim guidelines (Figure 12). Waimatā TOC levels were below the minimal / moderate ETI eutrophication boundary, indicating that this location was not eutrophic. Total nitrogen (TN) values at both sites indicated moderate eutrophication (i.e. in terms of nitrogen input) when compared to the ETI interim guidelines. Total recoverable phosphorus (TRP) was relatively low for both sites, indicating the sites were in good condition (i.e. in terms of phosphorus input) according to the ETI. A 2019[14] study (Kelly and Sim-Smith 2020) sampled sediment cores at 12 sites in Tūranganui Estuary, and two sampling points that were relatively close to our Taruheru and Waimatā sites. The TOC levels at the Taruheru site were higher in 2024 compared to 2019, and were in the range considered to cause minor stress (0.5–1%). However, the Waimatā site TOC levels had decreased in 2024 (< 0.3%) compared to 2019. Similarly, the 2024 TN levels at the Taruheru site had increased to 600–800 mg/kg and the Waimatā site had decreased to 300–400 mg/kg compared to the 2019 study (Figure 12). For baseline comparison to our 2024 results, the 2019 study found low levels of TOC (< 0.5%) that were in the 'good' range and thus caused no stress to aquatic organisms. The 2019 study also found lower levels of TN (450–600 mg/kg) at both sites, but these were still at a level considered to cause moderate stress on aquatic organisms. The levels of TRP (301–325 mg/kg) at both sites in 2019 were similar to the 2024 levels and were within the 'good' range. However, these results suggest that there is still a risk to macroinvertebrate communities from nutrient enrichment, especially for the

[14] The 2019 study collected sediment samples at 12 sites, comprising two composites (made up of three sub-samples) at each site for sediment quality analysis

Taruheru site, as TOC and TN levels were nearly all above the average levels for estuaries across Aotearoa New Zealand (mean TOC = 0.6%, mean TN = 602 mg/kg; Berthelsen et al. 2019).

For both sites, nutrients and organic matter could originate from an upstream source such as human wastewater and agriculture run-off. Catchment land use and human activities can heavily impact the rivers. For the Taruheru site, the moderate eutrophication detected could potentially be due to the presence of a secondary sewage outfall approximately 150 m upstream of the site by Palmerston Rd / Peel St. Overflows at this outfall are only expected to occur following large events; however, the overflows discharge directly into the estuarine area, and this can increase or produce a spike in local nutrient levels (Kelly and Sim-Smith 2020). Differences in organic carbon and nutrients found at the Taruheru and Waimatā sites could therefore potentially be explained by differences in the land-use activities (e.g. agriculture vs forestry) along the catchments of each river.

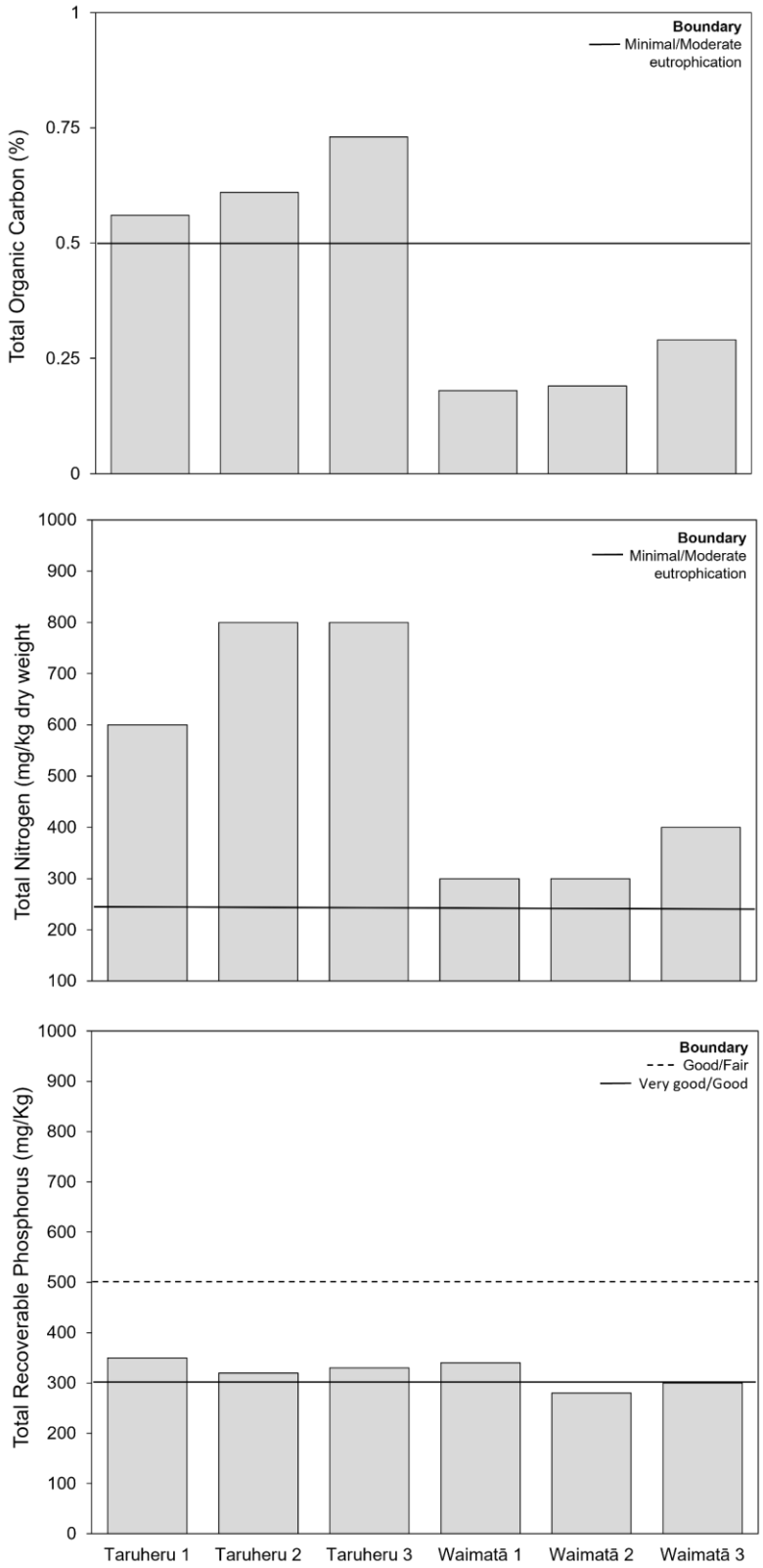


Figure 12. Sediment total organic carbon (TOC), total nitrogen (TN), and total recoverable phosphorus (TRP) content at the Taruheru and Waimatā sites. Top and middle: Horizontal lines indicate TOC and TN levels for minimal to moderate eutrophication based on the Estuary Trophic Index (Robertson et al. 2016b). Bottom: Guidelines for good / fair health are based on Robertson and Stevens (2010).

Metal contamination

Sediment metal (arsenic [As], chromium [Cr], cadmium [Cd], copper [Cu], lead [Pb], zinc [Zi], nickel [Ni], mercury [Hg]) values were generally the same across both sites and were all below default guideline values (DGVs) and / or threshold limits (Table 11; Figure 13). While values were low, negative effects can occur below these limits (Hewitt et al. 2009). Overall, metal contamination within the sampled Tūranganui Estuary sediments was low in relation to current guidelines for sediment contaminants. Aligning with this result, our Metals BHM score at the Taruheru site was in fair health and indicated moderate metals impact compared to other estuarine sites across Aotearoa New Zealand (refer to Section 4.3). However, the role of Pb in driving some patterns in infaunal macroinvertebrate community composition, discussed below, suggests that this may be a contaminant to pay particular attention to over time (i.e. included in future fine-scale sampling; Figure 21). When considering water quality at the three SOE sites closest to the benthic fine-scale monitoring sites, Pb levels in water quality data indicated Taruheru River at Peel St Bridge had a very likely degrading trend (i.e. increasing; Pb trends at the other two SOE sites could not be assessed / indeterminate) (refer to Section 4.6). Metal contaminants can enter estuaries through rivers, stormwater and other legal and illegal discharges, as well as from diffuse sources. Lead, for example, was once widely used in plumbing, paints and fuel and remains a key contaminant for urban waterways.

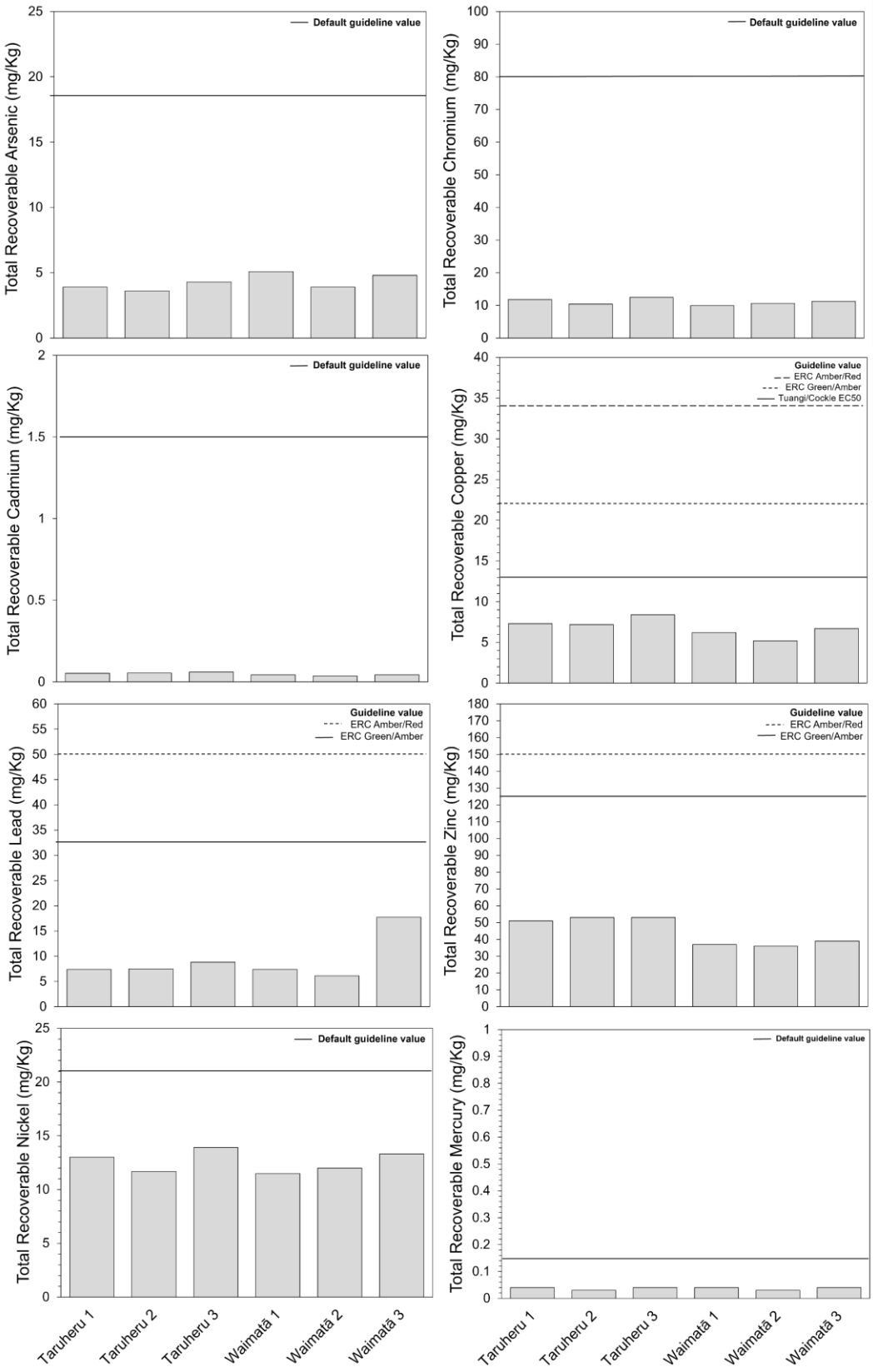


Figure 13. Metal contaminants (arsenic, chromium, cadmium, copper, lead, zinc, nickel and mercury) in the sediments at the Taruheru and Waimatā sites in Tūranganui Estuary. Metal concentrations were compared against guidelines developed by ANZG, ERC and Hewitt et al. (2009; for tuangi / cockles).

Additional contaminants

Additional contaminant (e.g. semi-volatile organic compounds [SVOC], total petroleum hydrocarbons [TPHs], and organochlorine pesticides) values at both Tūranganui sites were below the laboratory detection limits. Polycyclic aromatic hydrocarbons (PAHs) were below laboratory detection limits at the Taruheru site. At the Waimatā site, PAHs were detected but total PAHs were collectively lower than guideline values (Table 12; Figure 14). Low PAH levels detected in 2024 were not considered a threat to ecological health. However, if levels increase in the future, we recommend monitoring for PAHs at the Waimatā site during the next fine-scale survey. PAHs are one of the typical estuarine contaminants that can persist in the marine environment (Clark et al 2024). They are released into the environment from both natural sources (e.g. forest fires, natural oil seeps) and human activities (e.g. aluminium or steel production, municipal or industrial waste incineration, charcoal grilling). PAHs are also persistent organic pollutants, meaning they break down slowly and can accumulate in the food chain, which can be toxic if levels are too high (e.g. Balcıoğlu 2016).

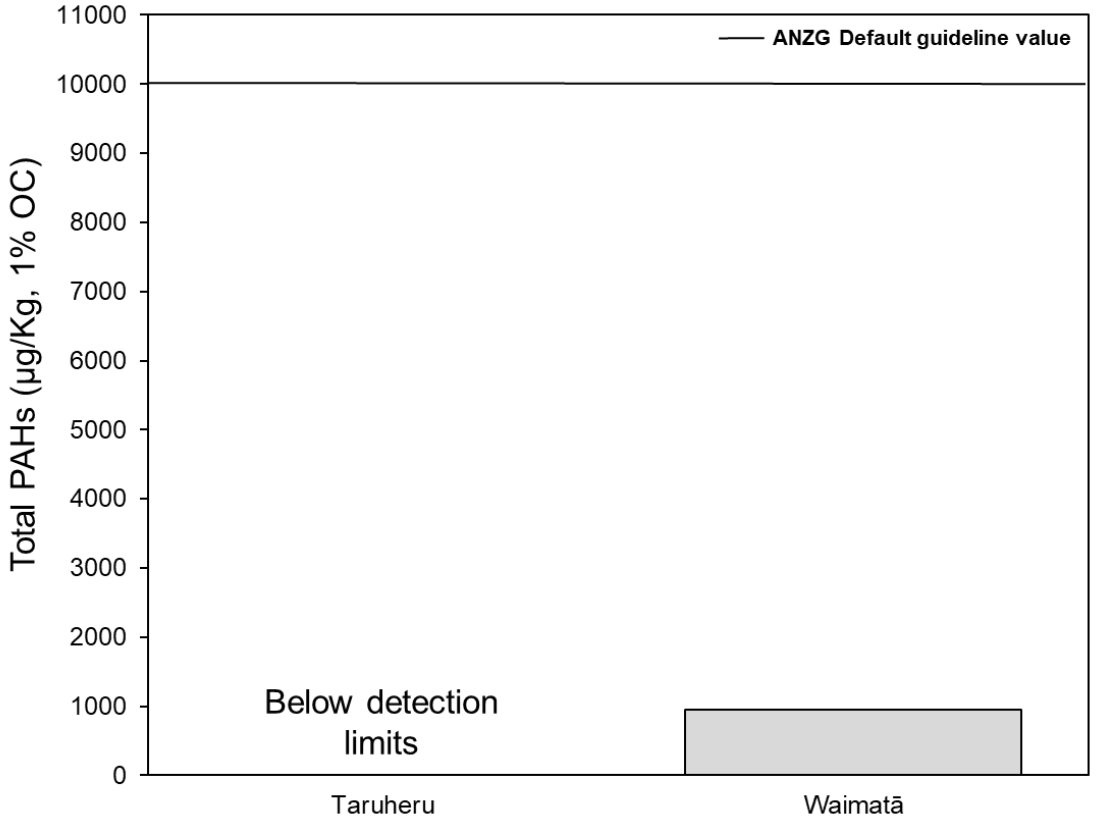


Figure 14. Polycyclic aromatic hydrocarbons (PAHs) at the Taruheru and Waimatā sites in Tūranganui Estuary. Total PAHs at the Taruheru site was below the detection limit. The horizontal line is the ANZG default guideline value.

4.2 Epibiota

At both Tūranganui Estuary sites, there was a low abundance of epifaunal macroinvertebrates. Crab holes were observed at both sites whereas estuarine snails (*Potamopyrgus estuarinus*) and mud snails (*Amphibola crenata*) were found only at the Taruheru site. At the Taruheru site, there was an average of 29 ± 7 (± SE) crab burrows compared to only one observation of a crab burrow at the Waimatā site. At the Taruheru site overall (all replicates combined), there also were three observations of the estuarine snail (*P. estuarinus*) and 22 observations of the mud snail (*A. crenata*), and no observations of either of these taxa at the Waimatā site. There were also two very small burrows observed at Waimatā site; however, we could not identify the species of animal that had created them. No seaweed or plants (e.g. saltmarsh vegetation or seagrass) were recorded within the quadrats.

4.3 Infaunal macroinvertebrates

Community composition and metrics

The composition of infaunal macroinvertebrate communities within the Taruheru site was similar and significantly distinct from those at Waimatā site (nMDS and PERMANOVA). In general, infaunal communities had higher similarity (i.e. tighter clustering; SIMPER, 56% within-site similarity; Appendix 3) among plots at the Taruheru site than those at the Waimatā site (i.e. higher spread; SIMPER, 29% within-site similarity; Figure 15, Figure 26; Appendix 3).

The average Shannon–Wiener diversity (*H'*), species richness (*S*) and abundance (*N*) were higher at the Taruheru site. The Taruheru site had an average of 1.46 (*H'*), 7.2 taxa (*S*) and 57 (*N*) per core, and the Waimatā site had an average of 0.696 (*H'*), 3.2 (*S*) and 20 (*N*) per core. There was little difference in the average evenness at the two sites. However, due to higher replicate plots at the Taruheru site, this location is expected to have higher species richness, abundance and diversity. The differing numbers of replicates will affect the community metric results, and we would expect slightly lower values for the Waimatā site due to lower number of replicates.

Both sites had fewer taxa (Taruheru, S = 7.2; Waimatā, S = 3.2 per core) than an average value reported for soft sediments across estuaries in Aotearoa New Zealand (S = 10.4 per 0.0133 m^2; Berthelsen et al. 2019). Similarly, both sites had far fewer individuals (Taruheru, N = 57; Waimatā, N = 20 per core) than the average value reported nationally (N = 115.8 per 0.0133 m^2; Berthelsen et al. 2019). However, for tidal river estuaries in Aotearoa New Zealand, the Taruheru site had comparable number of taxa to what has been reported nationally (N = 6; Berthelsen et al. 2019). However, both Tūranganui Estuary sites still had lower number of individuals than an average value reported nationally for tidal river mouth estuaries in Aotearoa New Zealand (mean N = 196; Berthelsen et al. 2019), noting the national data was for 13 sites across seven tidal river estuaries. Tidal river estuaries can have comparatively low species diversity relative to other estuary types (Berthelsen et al. 2019), but they may still support high macrofaunal abundances. For example, at another tidal river estuary, Waikanae Estuary, mean species richness in 2022 was also considered low (7–10 taxa per core), but the estuary had higher mean abundances (70–703 individuals per core; Forrest and Stevens 2023). However, having high abundances

in a community is not an indicator of better health, and in fact, it can be a sign of poor health depending on what species are present in high numbers (Berthelsen et al. 2019).

Overall, there were 14 infauna taxa at the Taruheru site and eight taxa at the Waimatā site. The Taruheru site had mostly estuarine snails (*P. estuarinus*), tuangi / cockles (*A. stutchburyi*), polychaetes (juvenile Nereidae and *Scolecolepides benhami*) and small bivalves (*Arthritica bifurca)*, and the Waimatā site had mostly bristle worms (*M. maori*) and pipi (*P. australis)* (Figure 17, Figure 18). Of note was that the Asian date mussel (*Arcuatula senhousia*) was found at both sites. This is considered a non-indigenous species that is under management in some regions of Aotearoa New Zealand.

Site characteristics (e.g. sediment grain size composition) differed between the sites and may have driven community composition patterns (refer to Section 4.1). We note that the higher number of taxa recorded at the Taruheru site overall (compared to Waimatā site) could have been influenced by the higher number of replicate plots sampled at this site; however, the average taxa numbers per core at the Taruheru site were higher than the Waimatā site, supporting the result that Taruheru was associated with higher taxa numbers. For baseline comparison to our 2024 study, in 2019, Kelly and Sim-Smith (2020) found 17 taxa and 20 taxa at their nearby Tūranganui and Waimatā sites, respectively. The majority of macroinvertebrates recorded in 2019[15] were from the same seven taxa: polychaete (*Heteroastus filiformis*), the small bivalve (*A. bifurca*), tuangi / cockles (*Austrovenus stutchburyi*), hanikura / wedge shells (*Macomona liliana*) and the polychaetes (*Prionospio aucklandica*, juvenile Nereidae and *S. benhami*). In 2019, *A. bifurca* was most abundant at their Waimatā site. While Peacock (1997) found polychaetes *S. benhami* and *Nicon aestuariensis* and the mud snail *A. crenata* predominantly at their Waimatā site (~2 km upstream of the confluence). Interestingly, the taxa most abundant in both previous studies (2019 and 1997) were only found in the sediment at the Taruheru site and not Waimatā site (except one polychaete).

[15] The 2019 study collected five core samples (13 cm × 15 cm deep) from each of the six sites for infaunal macroinvertebrates composition analysis

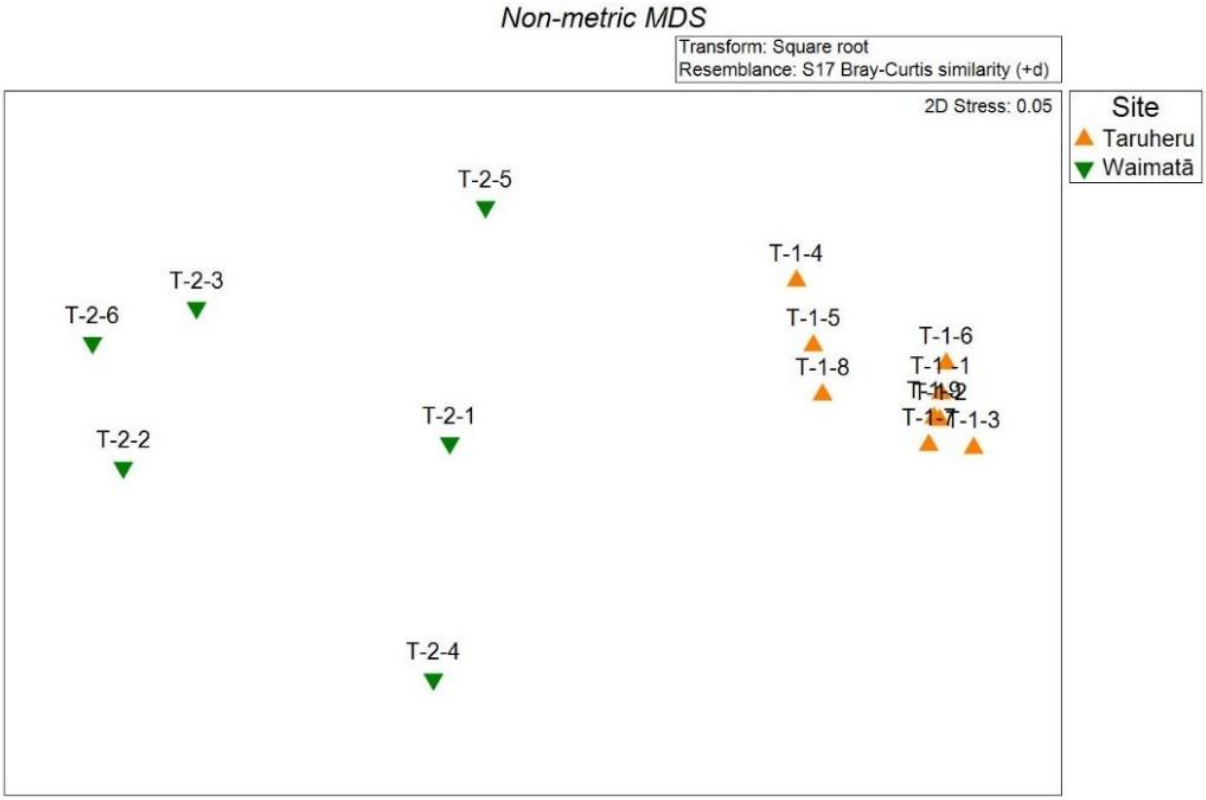


Figure 15. Differences in infaunal macroinvertebrate community composition (based on Bray-Curtis similarity using square-root transformed macroinvertebrate count data) between the Taruheru and Waimatā fine-scale sites in Tūranganui Estuary. The T-1 labels represent the Taruheru site (orange triangles) and T-2 labels represent the Waimatā site (green triangles). The number following the label T-1 or T-2 indicates each plot number for that respective site. Each symbol represents an infaunal macroinvertebrate community sampled from each plot of the monitoring site. Note that the communities represented by symbols that appear closer together are more similar than those spread farther apart.

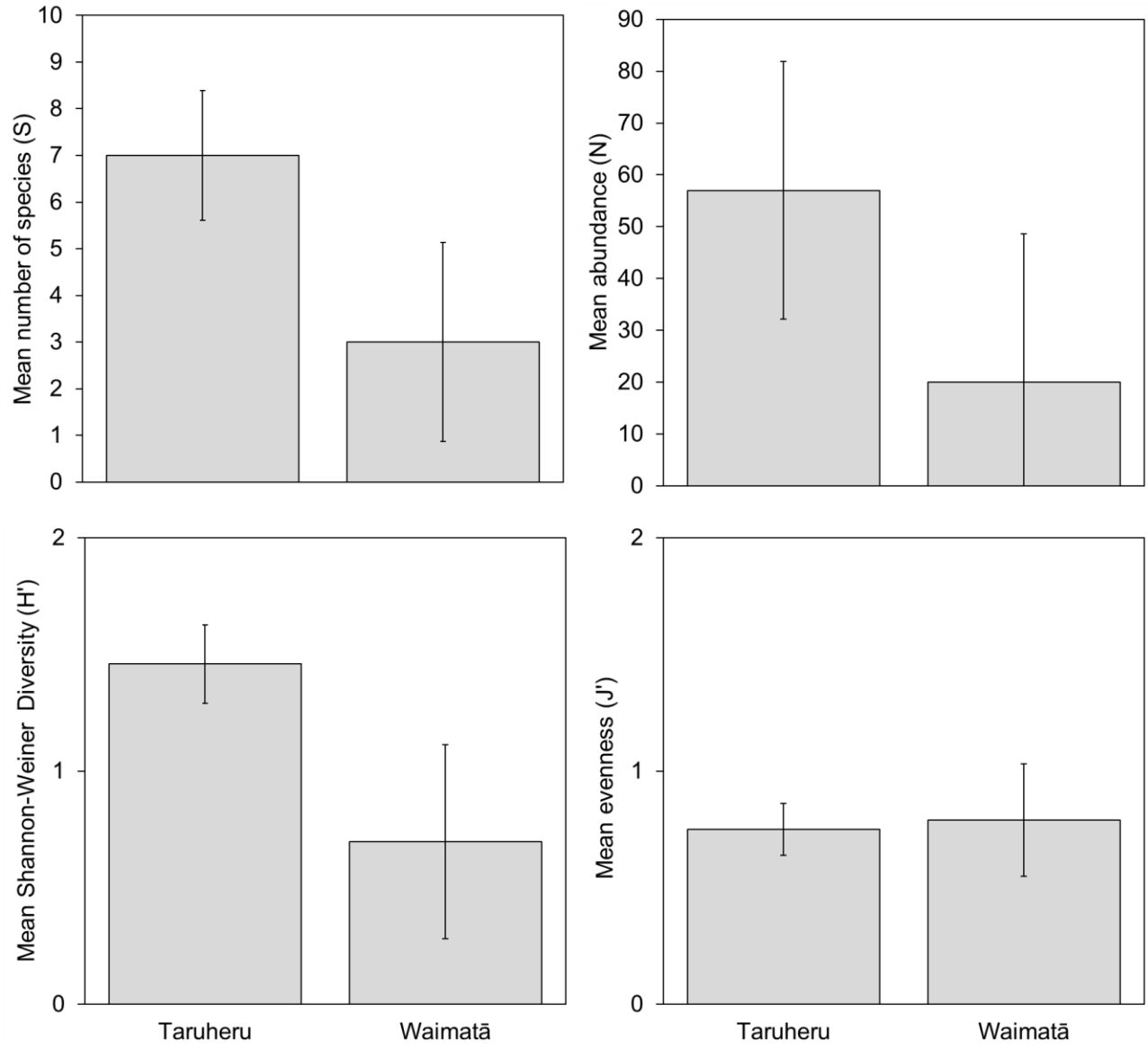


Figure 16. Community indices for the Taruheru and Waimatā fine-scale sites in Tūranganui Estuary. Number of macroinvertebrate species (S) and diversity(H'; left) and infauna abundance (N) and evenness (J'; right).

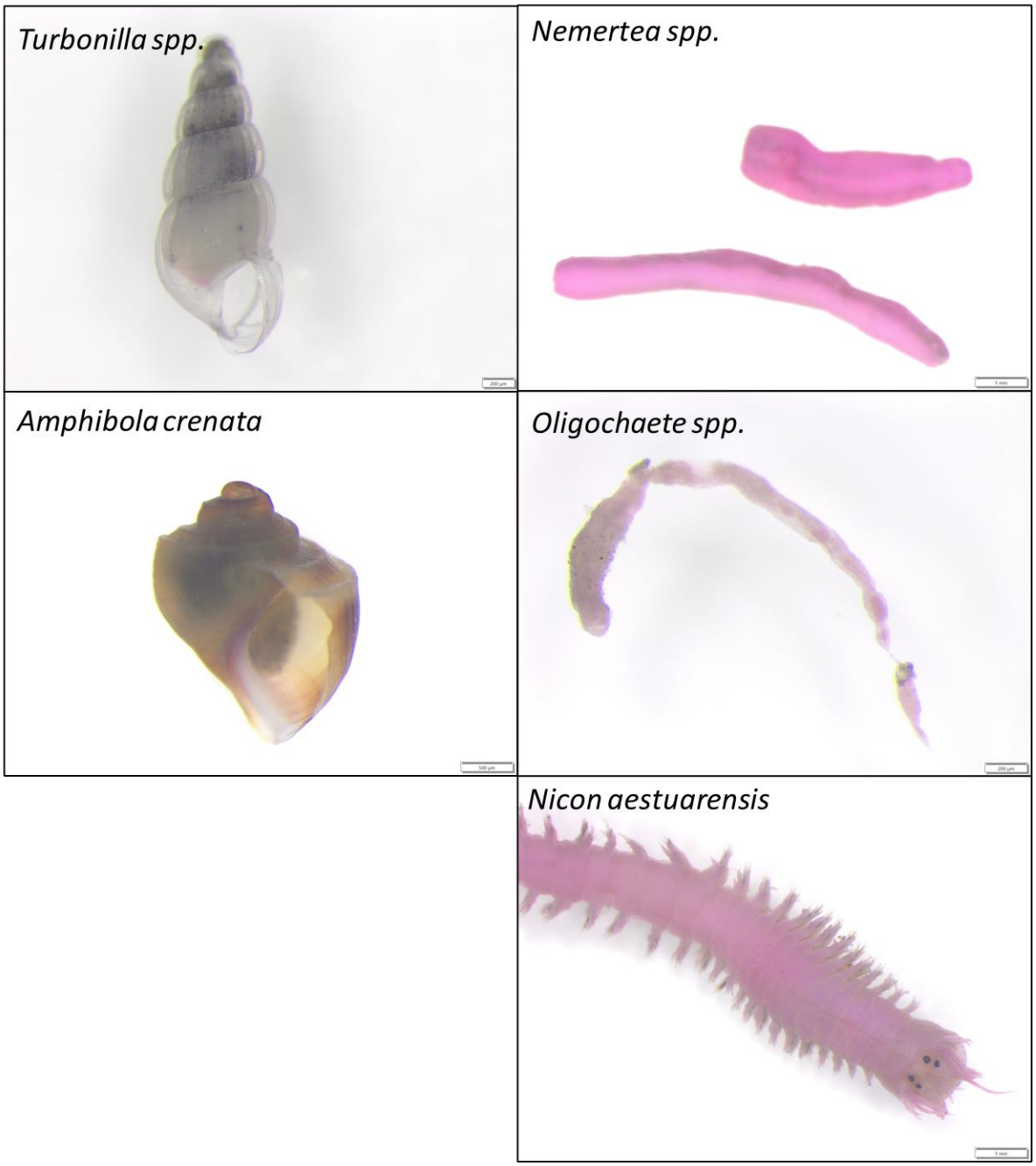


Figure 17. Macroinvertebrate species (bivalves and crabs) observed at the Taruheru and / or Waimatā fine-scale sites in Tūranganui Estuary. Image credits: MacLean Marine Identifiers.

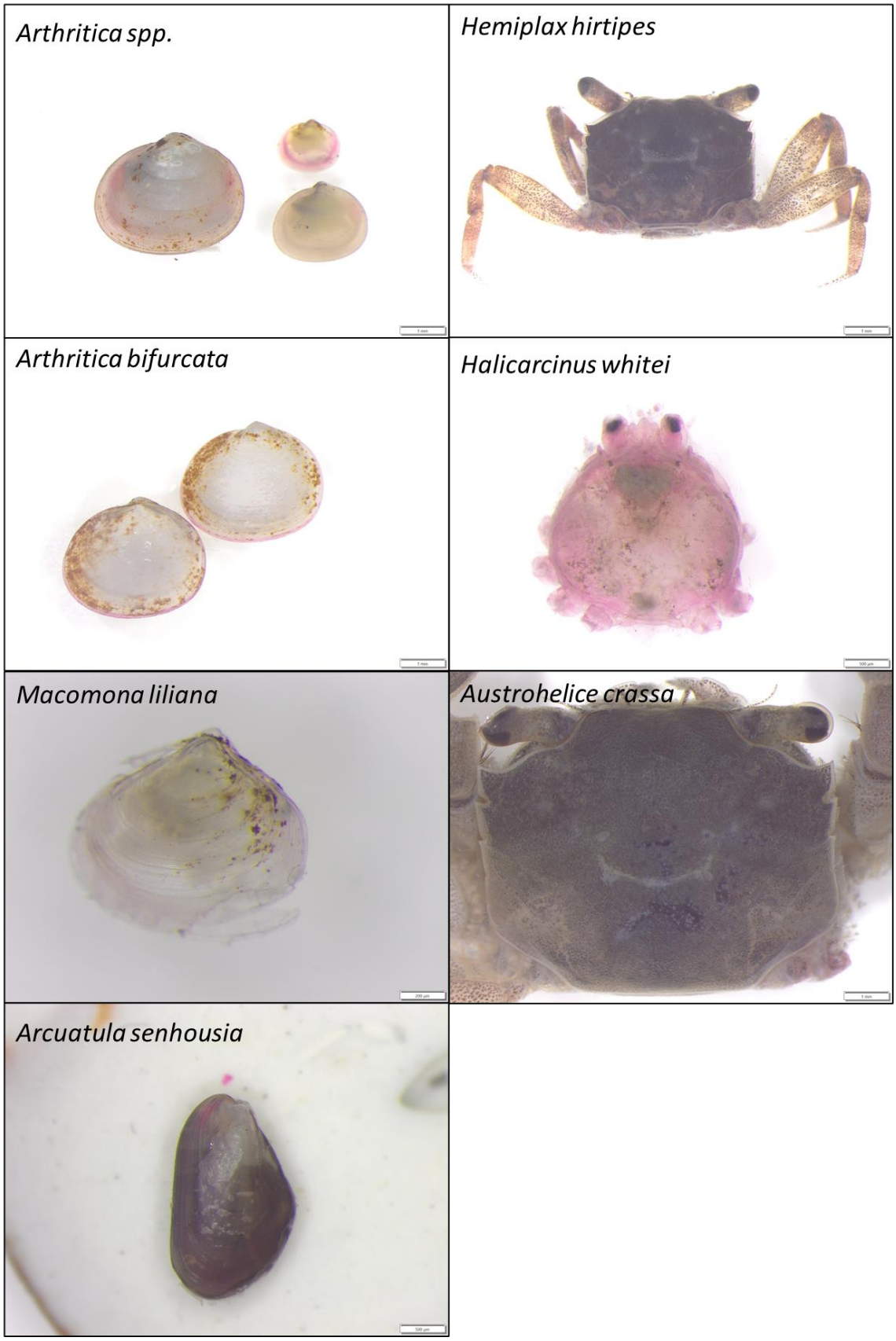


Figure 18. Additional macroinvertebrate species (snails and polychaetes) observed at the Taruheru and / or Waimatā fine-scale sites in Tūranganui Estuary. Image credits: MacLean Marine Identifiers.

Benthic Health Models

The fit of the BHMs was tested for both sites (Taruheru and Waimatā). One taxon was removed before modelling according to the procedures outlined in Clark et al. (2022) (Appendix 5). The Taruheru site had a good fit with the BHMs, indicating that both the Mud BHM and Metals BHM can be reliably used to assess the health of this site relative to other estuarine sites across Aotearoa New Zealand. The Mud BHM score (5.11) at the Taruheru site indicated high to very high impact from sedimentation compared to other estuarine sites across Aotearoa New Zealand. The Metals BHM score (3.72) indicated moderate impact from metals compared to other estuarine sites, although this score was still indicative of fair health (Figure 19, Figure 20). Conversely, the Mud BHM and Metals BHM scores (2.12 and 2.11, respectively) for the Waimatā site were lower than expected given the mud and metals content at the site, and they were outside the limits of the model. The scores for the Waimatā site were therefore not a reliable indicator of estuary health at this site relative to other estuarine sites across Aotearoa New Zealand. Given there is currently only one sampling time point, data collected during future monitoring events at the Waimatā site should be rechecked for fit to assess whether the sample is representative of estuary health. Although the current BHM score for the Waimatā site cannot be compared for health to other sites across Aotearoa New Zealand, it can likely be used to track health at the site through time.

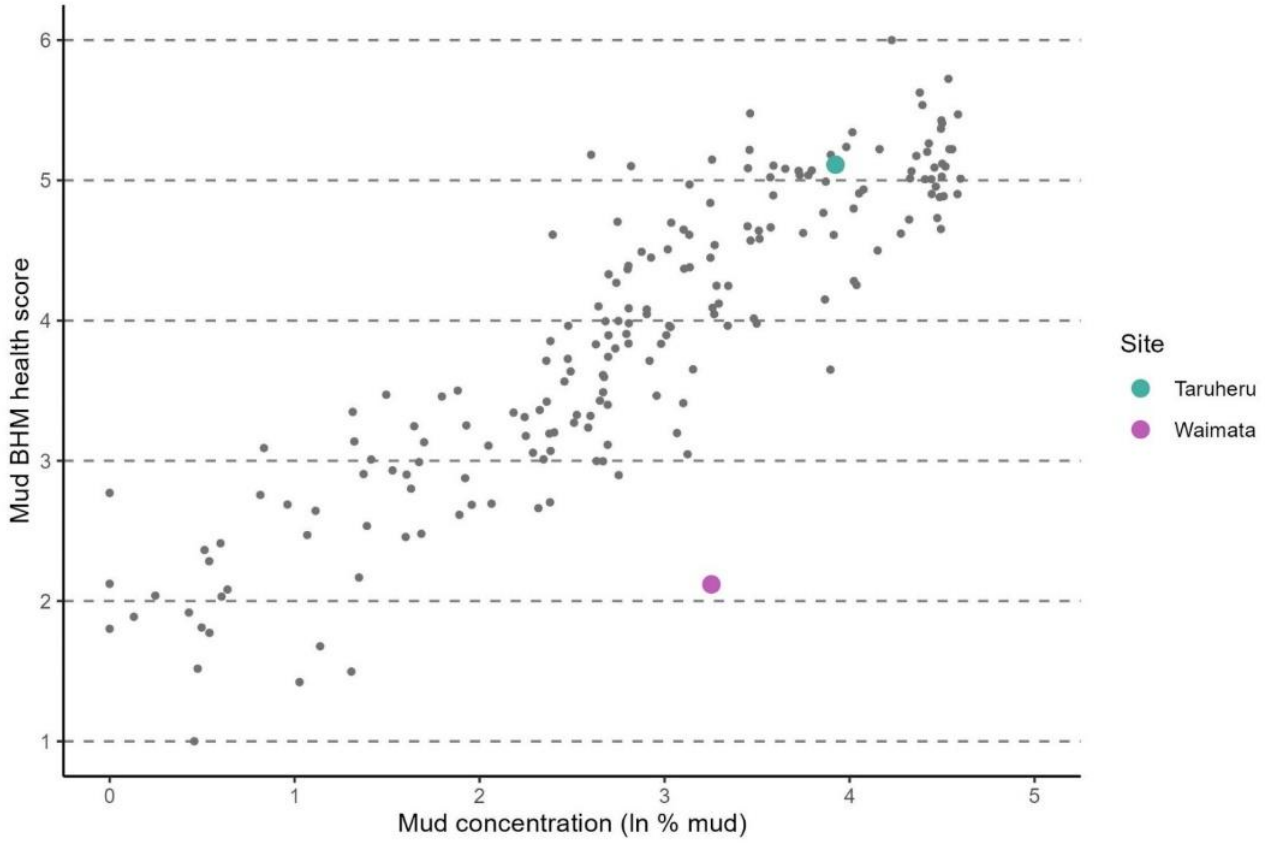


Figure 19. Mud Benthic Health Model (BHM) scores for the Taruheru and Waimatā fine-scale sites in Tūranganui Estuary (coloured circles) compared with those from sites used to develop the model (grey circles). BHM scores range from 1 (least impacted) to 6 (most impacted) relative to other estuarine sites across Aotearoa New Zealand.

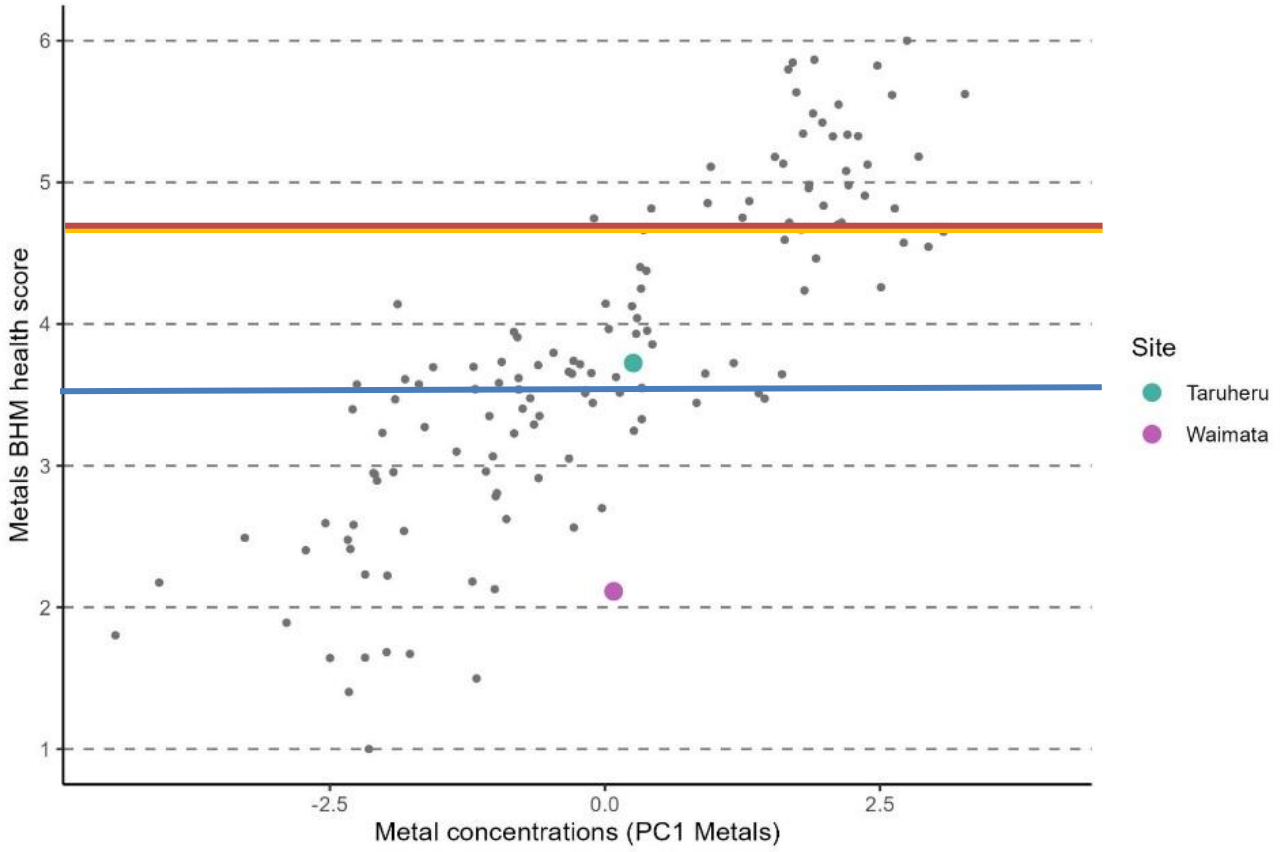


Figure 20. Comparison of Metals Benthic Health Model (BHM) scores for the Taruheru and Waimatā fine-scale sites in Tūranganui Estuary (coloured circles) compared with those from sites used to develop the model (grey circles). BHM scores range from 1 (least impacted) to 6 (most impacted) relative to other estuarine sites across Aotearoa New Zealand. The absolute health boundaries for Metals BHM scores are indicated with the coloured solid lines: blue is good (< 3.6), yellow is fair (3.6 – < 4.8) and red is poor (> 4.8).

Community links to sediment characteristics

Overall, sediment characteristics explained a high percentage (89.6%) of the total variation observed in macroinvertebrate species counts among all samples (BEST). Of the sediment characteristics examined for the Tūranganui Estuary sites, differences in fine sand (65–500 µm) content, mud (< 65 µm), nutrients (TOC, TN, TRP) and the metal Pb were most closely related to patterns in macroinvertebrate community composition for each monitoring site (BEST correlation = 0.896; Figure 21). In Aotearoa New Zealand, sediment grain size, nutrients and Pb are known to influence macroinvertebrate community composition (Rodil et al. 2013; Robertson et al. 2015).

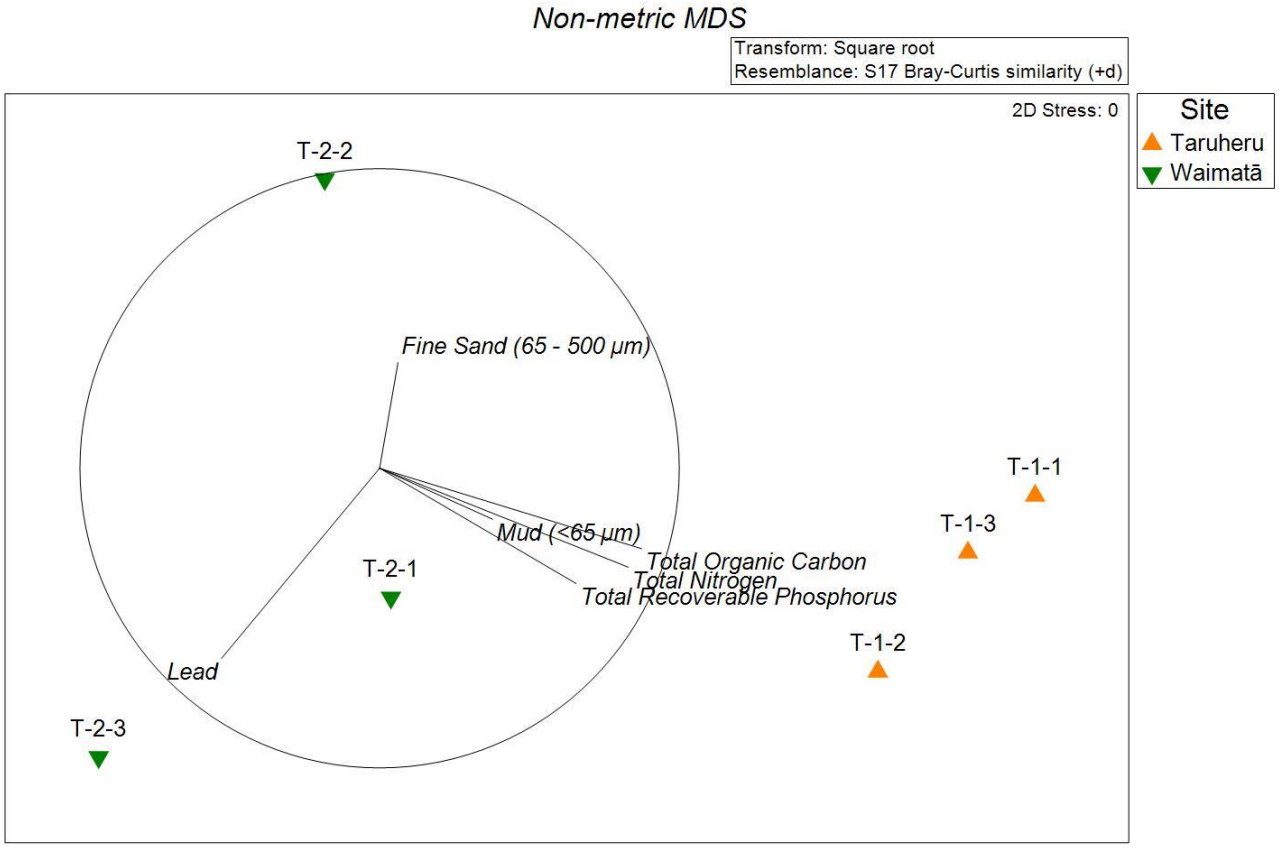


Figure 21. Differences in macroinvertebrate communities are typically explained by variations in sediment composition (sand and fine sand), nutrient content and lead content. Each symbol represents a macroinvertebrate community sampled from each plot of the Taruheru and Waimatā sites in Tūranganui Estuary. Note that symbols that appear closer together represent communities that are more similar than those spread farther apart.

4.4 Shellfish and other indicator taxa

Shellfish abundance

A small number of the taxa targeted for shellfish sampling (e.g. tuangi / cockles and pipi, > 4 mm in size) were found at both the Taruheru and Waimatā sites. For both sites, an average of 1 ± 1 SD tuangi / cockle was found across the quadrats (Figure 22). Only one pipi specimen in total was found at the Taruheru site, and an average of 4 ± 4 SD pipi (per quadrat) was observed at the Waimatā site (Figure 22). The tuangi / cockles at the Taruheru site were mostly juveniles (< 5 mm) and adults (> 10 mm), and only juveniles[16] were found at the Waimatā site (Figure 23). No larger (i.e. > 35 mm) tuangi / cockles were observed at either site. In the infaunal macroinvertebrate samples (collected from cores, 0.5 mm sieve size), the majority of tuangi / cockles were < 5 mm at both sites. The Taruheru site had an average of 18 tuangi / cockle individuals per core and no pipi, and the Waimatā site, on average,

[16] We separated juveniles into two size classes, recruits (< 5 mm) and juveniles (5–10 mm), however, both are within the juvenile size class of < 10 mm (Michael and Lyon 2000).

had one tuangi / cockle per core and six pipi per core. For baseline comparison, the two sampling points in 2019 (Kelly and Sim-Smith 2020) that were relatively close to our Taruheru and Waimatā sites were found to have an average of 12 and 16 tuangi / cockles, respectively. Similar to the 2024 results, the majority of tuangi / cockles and hanikura / wedge shells in 2019 were small in size (< 5 mm shell length). The 2019 study also identified hanikura / wedge shells at both sites, with more found at the Waimatā site (average = 11) than the Taruheru site (average = 2). The 2024 shellfish monitoring found no hanikura / wedge shells at either site, but there were two hanikura / wedge shells (< 5 mm) in the fine-scale sampling at the Waimatā site. The decrease in tuangi / cockles and hanikura / wedge shells since 2019 indicates a potential degradation in suitable conditions. Both species of shellfish are known to be sensitive to fine sediment and contaminants (Gibbs and Hewitt 2004; Hewitt et al. 2009); however, we recorded low contaminants in 2024 and mud levels were similar or lower than those recorded at nearby sites in 2019. The cause of the decline in shellfish is currently unknown.

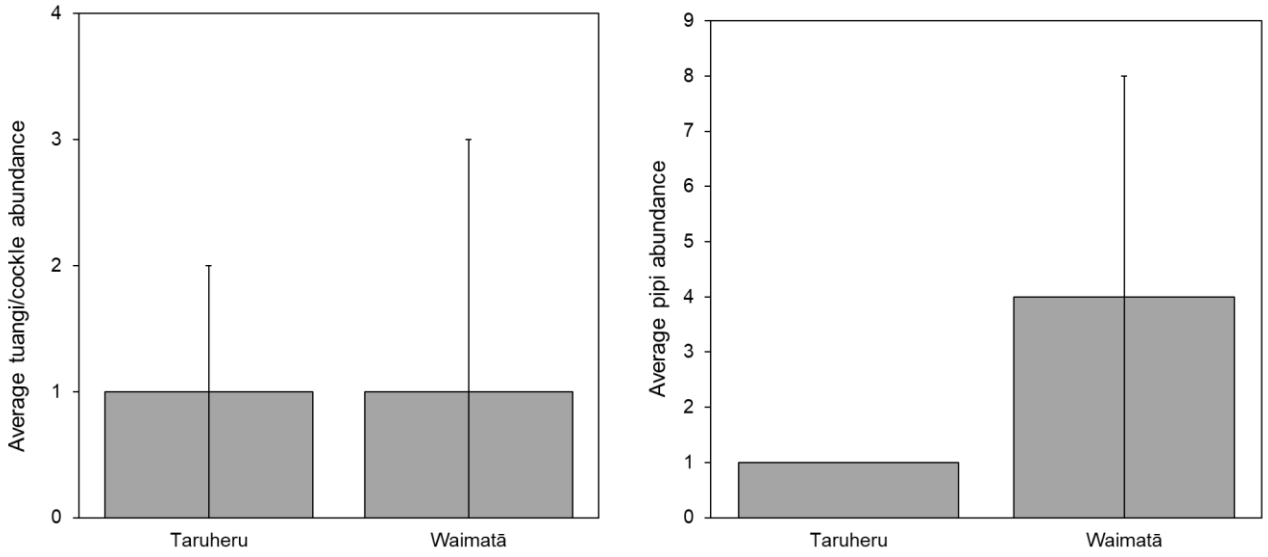


Figure 22. Average tuangi / cockle (left) and pipi abundances (right) per sampling site from shellfish sampling at the Taruheru and Waimatā sites in Tūranganui Estuary.

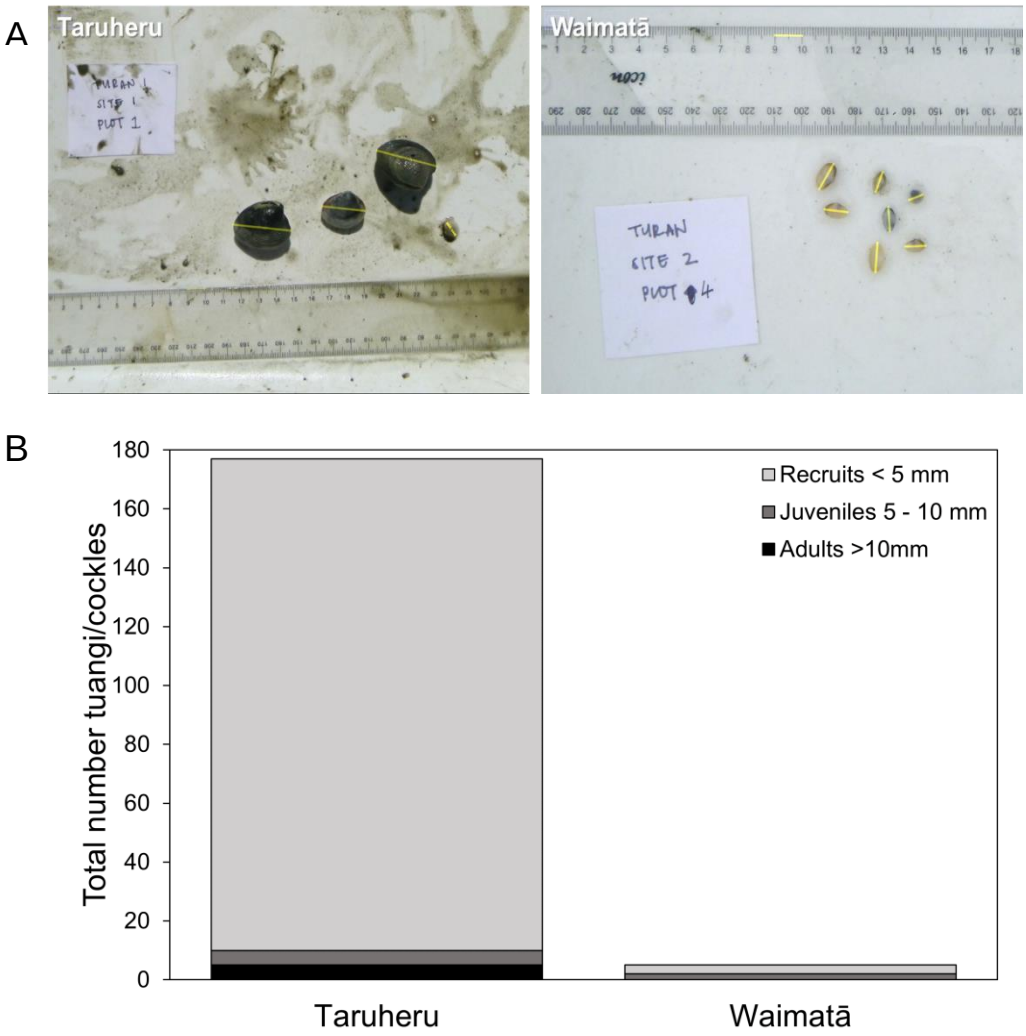


Figure 23. (A) Tuangi / cockles and pipi specimens found during shellfish sampling at the Taruheru and Waimatā sites in Tūranganui Estuary. Yellow lines were superimposed on images to measure in ImageJ. (B) Tuangi / cockle size classes in total (i.e. from all plots) from the Taruheru and Waimatā sites.

Indicator taxa in relation to mud and nutrient content

Infaunal macroinvertebrate communities can indicate the environmental conditions present at a site in relation to key parameters, e.g. sediments, nutrients and contaminants. The shellfish (e.g. tuangi / cockles, pipi, hanikura / wedge shells), snails (e.g. estuarine snail), and worm species (in particular *M. maori*) identified during the 2024 fine-scale sampling for Tūranganui Estuary indicated patterns for the presence of mud and / or nutrients (Figure 24). Based on the highest average similarity, communities at the Taruheru site were characterised by more mud-tolerant species (e.g. estuarine mud snail, bristle worm *S. benhami*), while communities at the Waimatā site were characterised by species that have a higher sensitivity to mud (e.g. pipi, *M. maori*; Figure 25, Figure 26). High population densities of mud snails can also indicate both high mud, nutrient / organic content and metals (De Silva et al. 2022). The highest abundances of mud snails were present at the muddier Taruheru site and may also reflect the high organic carbon present at this location (among other environmental drivers; Figure 12).

A number of tuangi / cockles were observed at both sites despite the high mud content, suggesting that both locations can still support these shellfish to some extent. The Waimatā site was sandier and had higher abundance of pipi, which are more sensitive to mud and prefer sandy sediments. *Microspio maori* is highly mud sensitive and was also observed at the Waimatā site, again suggesting this location is in better condition (in relation to mud content; Figure 9) than the Taruheru site. A metal contaminants plot was not included, as there were low levels of metals across all sites and no distinct patterns or variations were observed among the sites. No nutrient indicator taxa were found, and therefore, these taxa were not plotted.

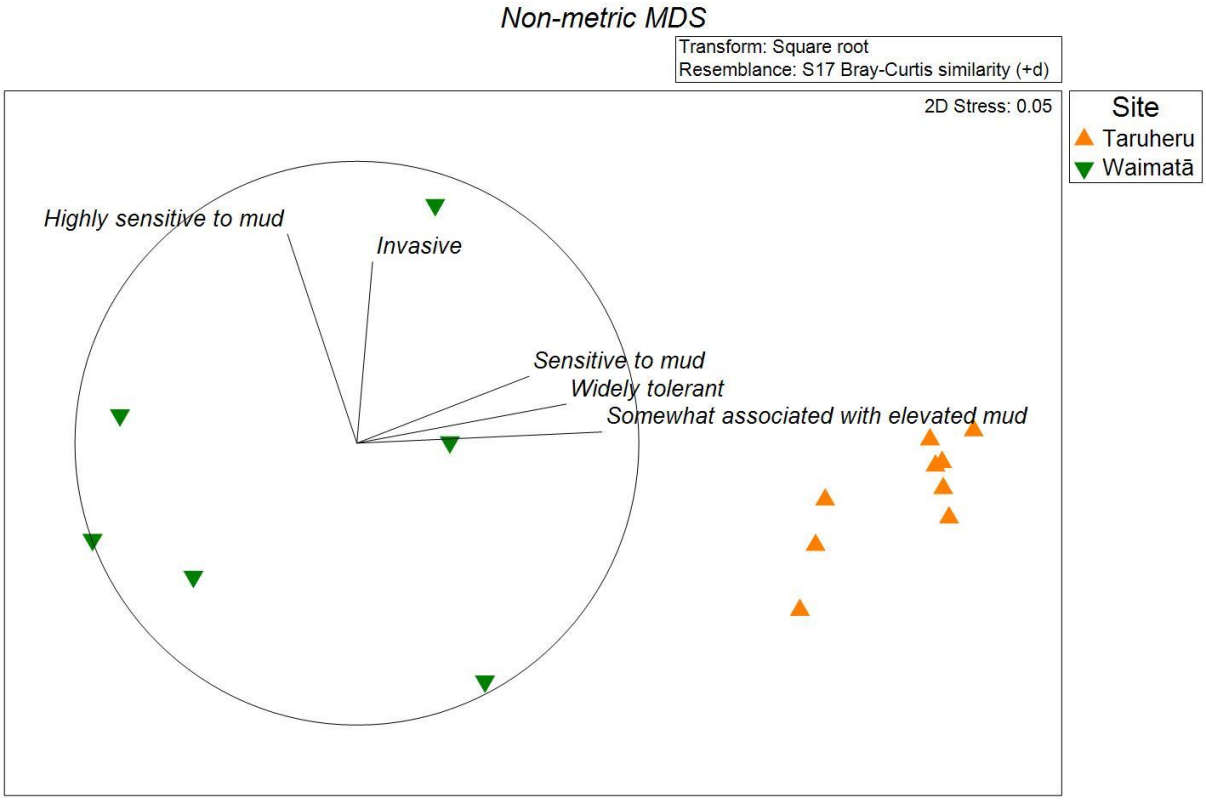


Figure 24. Differences in indicator species communities for mud among and between the Taruheru and Waimatā fine-scale sites in Tūranganui Estuary. Each symbol represents an indicator species community sampled from each plot of the sampling site. The species highly sensitive to mud include *Microspio maori*; the species sensitive to mud include tuangi / cockles (*Austrovenus stutchburyi*), hanikura / wedge shells (*Macomona liliana*) and pipi (*Paphies australis*); the species widely tolerant include proboscis worms (*Nemertia spp.*), mud snails (*Amphibola crenata*), estuarine snails (*Potamopyrgus estuarinus*) and *Nicon aestuariensis*; the species somewhat associated with elevated mud include *Arthritica bifurca* and *Scolecolepides benhami*; and the invasive species include Asian date mussel (*Arcuatula senhousia*). Note that symbols that appear closer together reflect indicator species communities that are more similar than those spread further apart.

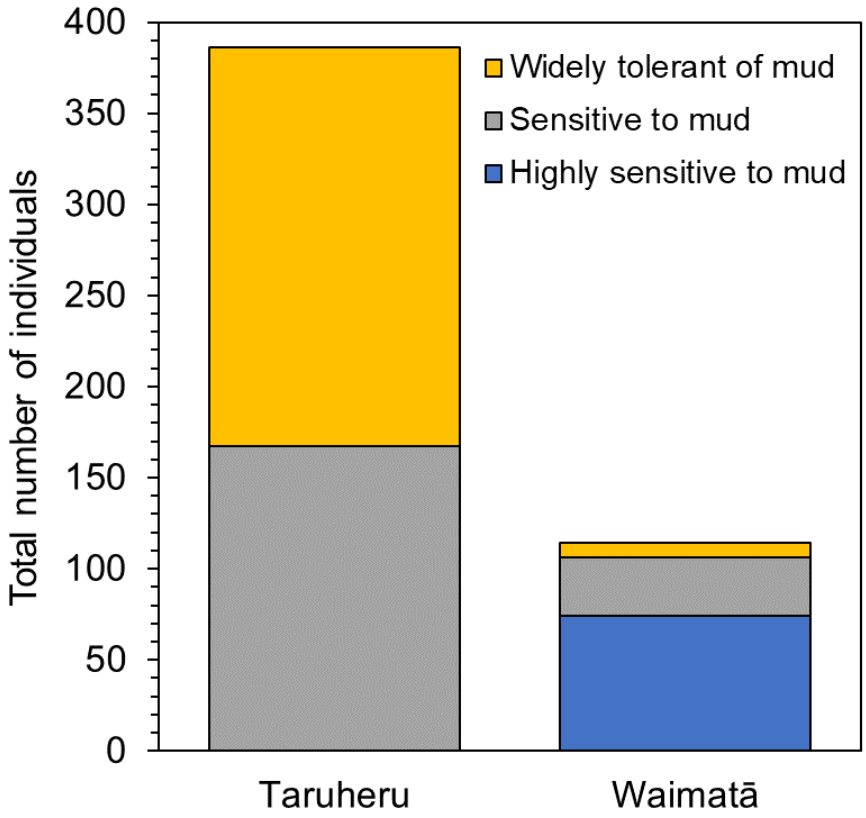


Figure 25. The average abundance of indicator species (corrected for different sample sizes) for mud found at the Taruheru and Waimatā sites in Tūranganui Estuary. The species highly sensitive to mud include *Microspio maori*; the species sensitive to mud includes tuangi / cockles (*Austrovenus stutchburyi*), hanikura / wedge shells (*Macomona liliana*) and pipi (*Paphies australis*); and the species widely tolerant include proboscis worms (*Nemertia spp.*), mud snails (*Amphibola crenata*), estuarine snails (*Potamopyrgus estuarinus*) and *Nicon aestuariensis*.

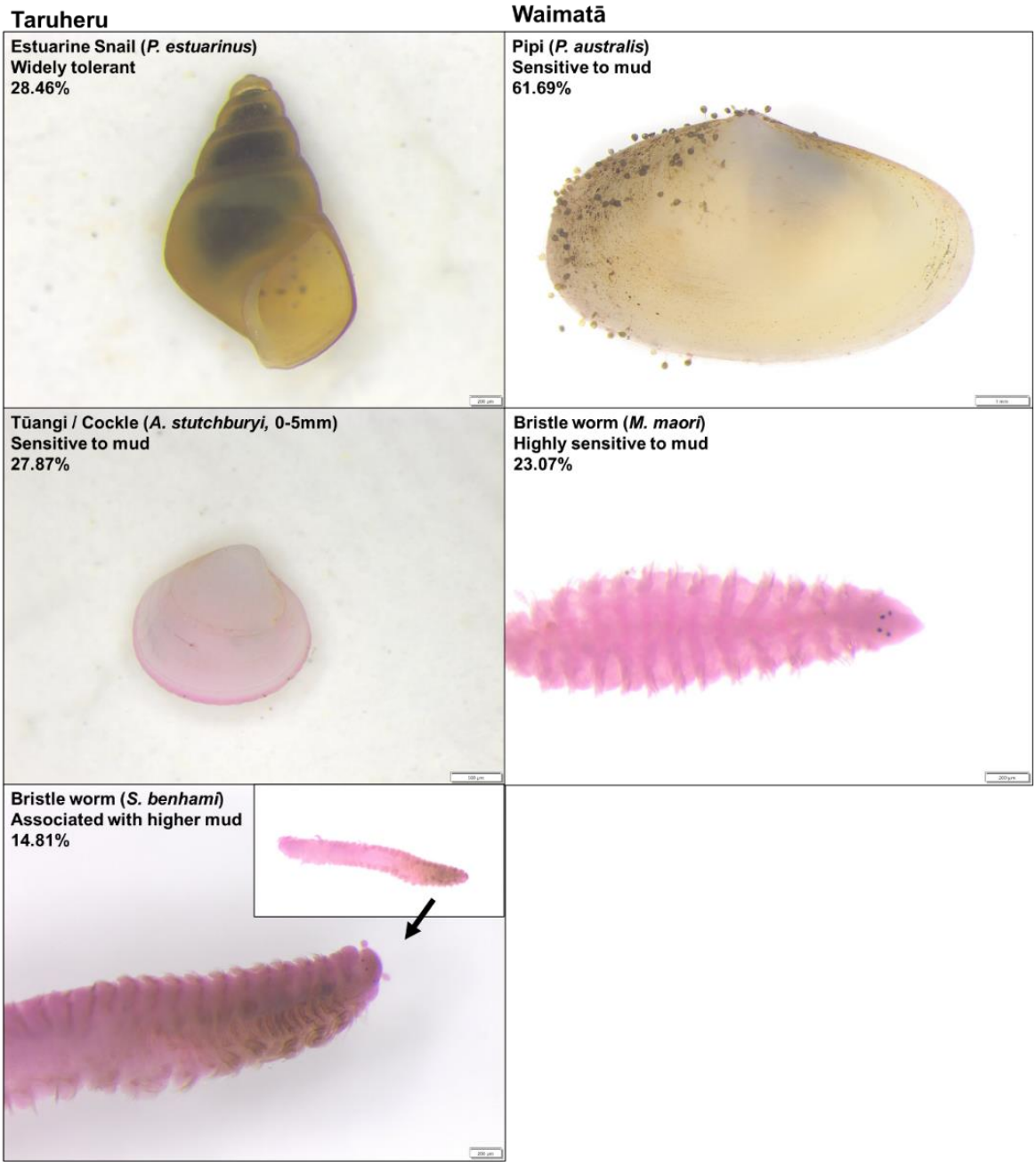


Figure 26. Indicator species contributing to similarity (%; SIMPER) among samples within the Taruheru and Waimatā sites in Tūranganui Estuary (refer to Table 12). Infauna at the Taruheru site were dominated by more mud-tolerant species, whereas infauna at the Waimatā site were dominated by mud-sensitive species. Image credits: MacLean Marine Identifiers.

4.5 Woody debris

Although woody debris was found within and outside both sites, neither the Taruheru nor Waimatā site had high amounts of woody debris present based on general field observations. Woody debris cover within quadrats placed on top of areas of debris was, on average, between 10–22 % (i.e. classified as 'some cover', 0–50%; Figure 27) for both the Taruheru and Waimatā sites. A small number of logs and a range of other woody debris (e.g. branches, bark, sticks) were found both inside and outside the two fine-scale sampling sites (Figure 28, Figure 29). The accumulation of woody debris can have ramifications, such as lowering the area's aesthetic appeal, limiting accessibility for recreational and cultural activities, and potentially causing damage to bridges (Clark et al. 2023). Landslips and deposition of woody debris have occurred almost annually since 2010 in some locations of the Tairāwhiti region, and it will likely be an ongoing issue (Johnston et al. 2022). The buildup of woody debris due to frequent large flood events is therefore expected to continue to pose a high risk to Tūranganui Estuary (Clark et al. 2023).

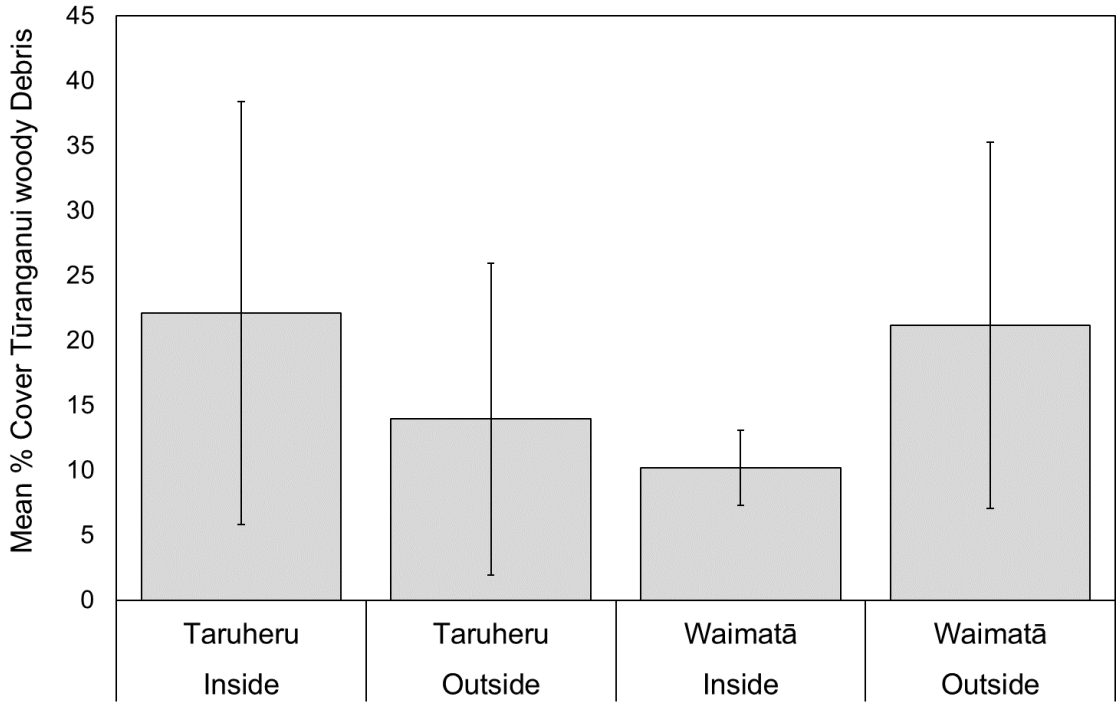


Figure 27. The mean percent cover of woody debris within quadrats placed on top of the debris inside and outside of the Taruheru and Waimatā fine-scale sampling sites in Tūranganui Estuary.

Figure 28. Larger pieces of woody debris (marked by yellow arrows) at the Waimatā site in Tūranganui Estuary.

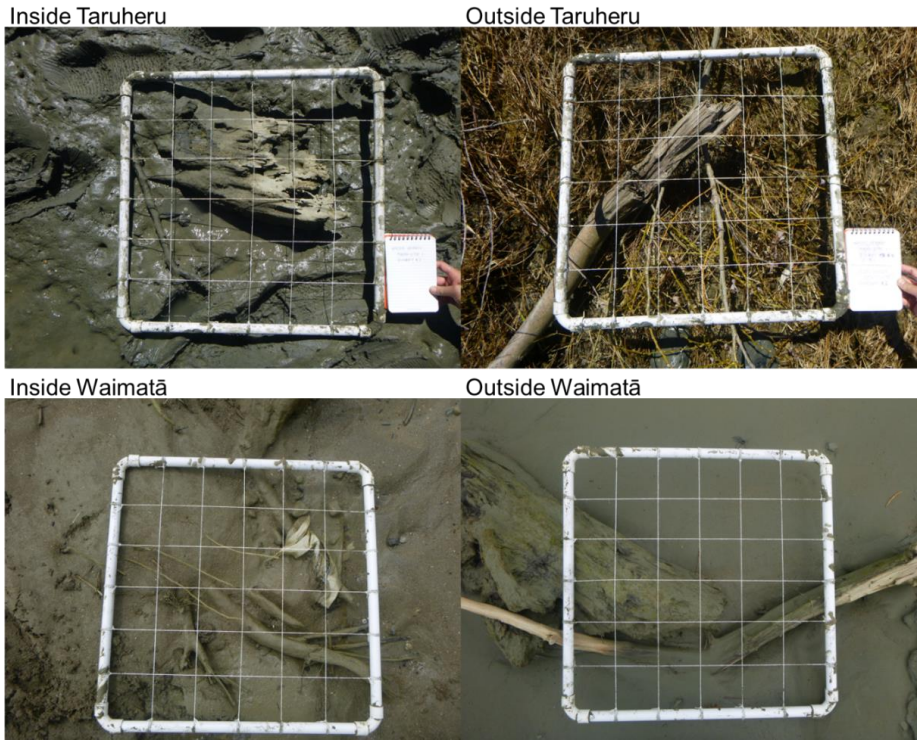


Figure 29. Examples of woody debris quadrats inside and outside of the Taruheru and Waimatā fine-scale sites in Tūranganui Estuary. Inside refers to woody debris quadrats placed within the fine-scale site, and outside refers to woody debris found outside the fine-scale site (i.e. within 20 m). Note that invasive grass (*Spartina* sp.) is present in the quadrat for 'outside of Taruheru'; however, only the woody debris in the foreground was assessed.

4.6 Water quality

The trend directions of the selected water quality parameters for assessing estuary health for all 11 SOE sites over the 5-year period (2019 to 2024) are summarised in Table 15. The trend categories do not reflect the rate of change but can indicate whether the parameter at a site is improving or degrading. In general, an improvement in a trend is a decrease in the parameter levels / concentrations for nutrients, microbial contaminants, water clarity and metals. The selected parameters are also plotted as boxplots to show the median and overall distribution of concentrations of each parameter over the 5-year period (Appendix 6). Where available, the freshwater and / or marine default guideline value was plotted in respect to the parameter.

The majority of nutrients (ammonia-N, total nitrogen [TN], dissolved reactive phosphorus [DRP] and total phosphorus [TP]) were found to have exceeded the freshwater DGVs across the SOE sites, except TN levels at four sites. Total suspended solid (TSS) levels across all SOE sites also exceeded the freshwater DGVs. The trends for TSS exhibited degrading trends across all SOE sites, with the exception of Waikanae Creek at Stanley Rd Bridge and Kopuawhakapata Stream at Hirini St. This finding suggest that water clarity has not been improving.

The faecal coliforms levels for seven of the SOE sites exceeded the freshwater DGV (200 n/100 mL). The majority of faecal indicators across the sites have exhibited degrading trends (i.e. increasing levels) since 2019, except at Taruheru River at Tuckers Rd Bridge and Kopuawhakapata Stream at Hirini St. Although these two sites have shown improving trends, the median levels for *E. coli*, enterococci and faecal coliforms still exceeded the DGVs (550 CFU/100 mL, 280 CFU/100 mL and 200 CFU/100 mL, respectively). In a water quality report by Keenan (2023), 5-year trends from 2017–2022 were assessed for various parameters including *E. coli*. The report observed degrading trends in *E. coli*, except at the same two sites as above: Taruheru River at Tuckers Rd Bridge (likely improving) and Kopuawhakapata Stream at Hirini St (very likely improving).

Of the SOE sites, Taruheru River at Tuckers Rd Bridge had more trends recorded as likely improving or very likely improving across parameters, except for TSS (very likely degrading). In contrast, Taruheru River at Peel St Bridge had more trends with either likely degrading or very likely degrading. The site at Tuckers Rd Bridge was the farthest site from the township, while the site at Peel St Bridge is more central to the township. Taruheru River at Peel St Bridge is also one of the three SOE sites near the fine-scale sites, and the other two are Tūranganui River at Gladstone Rd Bridge and Waimatā River at Grand Rd. Similarly, Tūranganui River at Gladstone Rd Bridge is also more central to the township and had more 'likely to very likely degrading' trends, rather than trends of improvement. At Waimatā River at Grand Rd, the nutrients were mostly improving.

Further results for each water quality parameter for Tūranganui Estuary monitoring (2019–2024) are described below under the following themes: physico-chemical, water clarity and microbial and metal contaminants.

Physico-chemical parameters

Chemical parameters

Ammonia-N is an important plant fertiliser and usually enters waterways primarily through point source discharge (e.g. via pipes or drains) and sewage[17] (Gadd et al. 2020). At high concentrations, ammonia-N can be toxic. For Tūranganui Estuary monitoring (2019–2024), the median levels of ammonia-N at all SOE sites exceeded the freshwater DGV (0.017 mg/L; ANZG 2018), except Waimatā River at Goodwins Rd Bridge (median = 0.016 mg/L). However, all sites were below the marine DGV (value = 2; Appendix A6.1). Ammonia-N was highest at Waikanae Creek at Stanley Rd Bridge (median = 0.124 mg/L). For a baseline comparison, in 2019, Kelly and Sim-Smith (2020) also found that ammonia-N concentrations in water at two Waikanae sites exceeded the ANZECC (2000) trigger value. When the 11 SOE sites were assessed for our report, two sites showed very likely improving trends (Tūranganui River at Gladstone Rd Bridge and Waimatā River at Grant Rd), and two sites showed trends of likely improving (Tūranganui River at The Cut and Taruheru River at Tuckers Rd Bridge). Four of the sites were indeterminate, two sites were likely degrading and one site, Waikanae Creek at Grey St Bridge, showed that it was very likely degrading.

Nitrate-N (NO_3-N) is one of the most common contaminants in waterways and easily leaches through soils after heavy rainfall. Once in groundwater, it can persist for many years and travel long distances. If nitrate-N enters drinking water in high concentrations, it can be harmful for humans and livestock.[18] All SOE sites were below the freshwater DGV for NO_3-N, except Taruheru River at Tuckers Rd Bridge, which exceeded this guideline value on occasion (Appendix A6.1). Taruheru River at Tuckers Rd Bridge also had the highest NO_3-N level (median = 1.1 mg/L). In the study by Kelly and Sim-Smith (2020), Taruheru River at Lytton Rd Bridge had the highest NO_3-N concentrations of the sites. Across the 11 SOE sites in our report, only one site, Taruheru River at Tuckers Rd Bridge, showed a very likely improving trend. The remaining 10 sites had either likely degrading (at two sites) or very likely degrading (at eight sites) trends over the past 5 years.

Total nitrogen (TN) is comprised of all nitrogen species (i.e. NH_4-N, NO_3-N and nitrite). The highest TN level was at Taruheru River at Tuckers Rd Bridge (median =1.9 mg/L). Four of the SOE sites, Waimatā River at Goodwins Rd Bridge and at Grant Rd, and Tūranganui River at Gladstone Rd Bridge and at The Cut had TN levels under the DGV. The six other sites (median range: 0.52–1.45 mg/L) exceeded the freshwater DGV (0.281 mg/L; Appendix 6.1). Across the 11 SOE sites, trends of TN levels for eight of the sites were either likely degrading or very likely degrading. One site, Waikanae Creek at Stanley Rd Bridge showed a likely improving trend and the site at Taruheru River at Tuckers Rd Bridge shows a very likely improving trend. The TN trend for Waimatā River at Goodwins Rd Bridge was indeterminate.

Dissolved reactive phosphorus (DRP) is a form of phosphorus that through dissolution of sediments is available for uptake for plant and algae growth. DRP is commonly transferred through groundwater, and high concentrations are indicative of human influence[19] (e.g. wastewater or land-use activities). DRP levels were highest at Waikanae Creek at Stanely Rd Bridge (median = 0.151 mg/L) and exceeded the DGV at all SOE sites (0.007 mg/L; Appendix 6.1). Two sites, Tūranganui River at Tuckers Rd Bridge

[17] https://www.lawa.org.nz/learn/factsheets/nitrogen
[18] https://www.lawa.org.nz/learn/factsheets/nitrogen
[19] https://www.lawa.org.nz/learn/factsheets/phosphorus

and Waimatā River at Grand Rd, showed trends of very likely improving, and three sites, Waikanae Creek at Stanley Rd Bridge, Taruheru River at Lytton Rd Bridge and Waimatā River at Goodwins Rd Bridge, showed likely improving trends. Tūranganui River at Gladstone Rd Bridge was indeterminate, and the remaining sites were likely degrading.

Total phosphorus (TP) occurs naturally in rocks and minerals and commonly sticks to soil. Over time through weathering, the sediment can dissolve and become DRP. Both forms are important nutrients for plant life.[20] TP levels were highest at Waikanae Creek at Stanley Bridge (median = 0.327 mg/L), and TP levels at all sites exceeded the DGV (0.023 mg/L). Taruheru River at Peel St Bridge show a very likely degrading trend, and two sites, Waikanae Creek at Stanley Rd Bridge and Tūranganui River at Tuckers Rd Bridge, showed very likely improving trends. Waimatā River at Grand Rd and at Goodwins Rd Bridge were likely improving. Tūranganui River at The Cut and at Gladstone Rd Bridge, and Taruheru River at Wi Pere Pipe were likely degrading. TP levels at the remaining sites were indeterminate. High DRP and TP levels can indicate nutrient pollution or eutrophication, as well as human activities; for example, urban land cover in the catchment area that drains into the estuary can significantly increase these nutrient concentrations (Dudley et al. 2020).

Dissolved oxygen (DO; in % saturation) provides the measurement of oxygen concentration in the water. The oxygen is derived from the photosynthesis and respiration of plants and organisms. DO saturation was lowest at Waikanae Creek at Stanley Rd Bridge (median = 81.1%) and highest at Tūranganui River at The Cut (median = 99.4%), although all SOE sites were within the 82–100 % recommended DGV; Appendix A6.1). However, a reduction in DO can potentially be due to overflows, and this situation would need to be monitored if it occurred during the sampling period. Across the 11 SOE sites in this report, three sites indicated DO concentrations as very likely degrading. Two sites, Waikanae Creek at Grey St Bridge and Taruheru River at Wi Pere Pipe, showed very likely improving trends, and the remaining six sites had indeterminate DO trends (Table 14).

Physical parameters

The physical water quality parameters (pH, salinity, water temperature) were not classified into trends because we could not provide the direction of a trend (i.e. confidence) that reflects whether there was an improvement – or not – in ecosystem health (Gadd et al. 2020).

pH measurements can be used to show how acidic or basic / alkaline the water is. In estuaries, pH levels are often affected by microbial or plant activity associated with their photosynthesis (for algae) and respiration (both algae and microbes) rates (Gadd et al. 2020). The median pH (8.2) was highest at Waimatā Rd at Goodwins Bridge (Appendix A6.2).

Salinity indicates how much fresh and salt water is mixing, and it is an important parameter to assess sources of contaminants (Gadd et al. 2020). Salinity measurements indicated that three sites were fresh water (< 0.5 ppt; Taruheru River at Tuckers Rd Bridge, Waimatā River at Goodwins Rd Bridge and Kopuawhakapata Stream at Hirini St), while the other eight sites were estuarine (salinity range: 1.7–22 ppt; Appendix A6.2).

[20] https://www.lawa.org.nz/learn/factsheets/phosphorus

Water temperatures for all sites were below the freshwater DGV (21 °C). The temperature at Tūranganui River at Gladstone Rd Bridge had the highest median temperature of 18 °C.

Water clarity parameters

The two water clarity parameters assessed were **clarity tube** and **total suspended solids** (TSS). Clarity tube readings across all SOE sites were below the freshwater DGV (0.7 m). Waimatā River at Goodwins Rd Bridge had the highest reading (median = 53.5 cm). TSS levels exceeded the freshwater DGVs (4.6 mg/L). The highest level of TSS was at Waikanae Creek at Stanley Rd Bridge (median = 31.4 mg/L; Appendix A6.3). There were several outlier TSS levels at three sites: Tūranganui River at The Cut and Waimatā River at Goodwins Rd Bridge in 2020, and Waimatā River at Grant Rd in 2023; however, it was out of our scope to interpret and extrapolate the high value (> 2,000 mg/L). TSS trends were mostly very likely degrading (eight sites). One site was indeterminate, two sites were likely degrading, and one site, Kopuawhakapata Stream at Hirini St, showed a likely improving trend. Clarity tube trends were indeterminate at two sites, but the remaining nine sites showed trends of very likely improving. **Turbidity** data from both the field and lab (NTU) were not assessed in our report, as data were only collected between 2019–2022 and did not meet the frequency criteria of > 90% observations over a period of time.

Microbial contaminants

The parameters assessed for microbial contaminants (faecal indicator bacteria) were *E. Coli*, enterococci and faecal coliforms. Faecal indicators can indicate high risks of gastrointestinal illness (Gadd et al. 2020). ***E. coli*** is a preferred indicator for fresh water and can show that faecal matter has contaminated a waterbody.[21] **Enterococci** is the preferred indicator of faecal contamination in coastal waters,[22] while **faecal coliform** concentrations are used as an indicator for suitability to gather shellfish (Gadd et al. 2020).

The highest median level for *E. coli* was recorded at Kopuawhakapata Stream at Hirini St (960 CFU/100 mL) and nearly 9 times higher than the DGVs for enterococci and faecal coliforms (2,500 CFU/100 mL and 2050 CFU/100 mL, respectively) over the 5-year period (Appendix A6.4). All three microbial contaminants at Kopuawhakapata Stream at Hirini St, Taruheru River at Lytton Rd Bridge and Tuckers Rd Bridge, and Waikanae Creek at Stanley Rd Bridge exceeded the freshwater DGVs.

For all three parameters, the majority of the SOE sites showed trends of likely degrading and very likely degrading. The exceptions were: Kopuawhakapata Stream at Hirini St showed trends of very likely improving for *E. coli* and likely improving for enterococci and faecal coliform; Taruheru River at Tuckers Rd Bridge showed trends of very likely improving for both *E. coli* and enterococci, but faecal coliform could not be assessed; and at Waimatā River at Grand Rd, enterococci concentration was likely improving, faecal coliform was likely degrading and *E. coli* was indeterminate (Table 14). The vulnerability assessment by Clark et al. (2023) found that both industrial pollution and sewage overflows can increase concentrations of microbial contaminants, which overall pose risks to human health. It should be noted that *E. coli* and enterococci parameters at Tūranganui River at Gladstone Rd Bridge

[21] https://www.lawa.org.nz/learn/factsheets/faecal-indicators
[22] https://www.lawa.org.nz/learn/factsheets/faecal-indicators

were measured > 200 times over the 5-year period, with an increased frequency between November and April of each year (5–6 times per month). As we could not identify the reason for the increase in sampling frequency, or separate the data by a particular occasion, caution should be taken around the trends for *E. coli* (enterococci trends were indeterminate).

Metal and other contaminants

The metal contaminants assessed were copper (Cu), lead (Pb) and zinc (Zn). The highest median Cu level (0.0023 mg/L), Pb level (0.001 mg/L) and Zn level (0.021 mg/L) were at Waikanae Creek at Stanley Rd Bridge. The median Cu and Zn level exceeded the freshwater DGV (Cu = 0.0018 mg/L) and Zn = 0.015 mg/L). In addition to Waikanae Creek at Stanley Rd Bridge, Cu levels at Kopuawhakapata Stream at Hirini St and Waikanae Creek at Grey St Bridge exceeded the freshwater DGV. All 11 SOE sites had Cu levels under the marine DGV, and all Pb levels were under both the freshwater and marine DGVs (Appendix A6.5). Kopuawhakapata Stream at Hirini St exceeded the freshwater but not the marine DGV for Zn (0.023 mg/L), although various sites had occasional Zn levels that exceeded the marine DGVs (Appendix A6.5). The metal concentrations in rivers, particularly for Cu and Zn, are likely related to stormwater inputs and due to sediments below urban stormwater outfalls (Kelly and Sim-Smith 2020). Elevated Zn concentrations can be caused by stormwater discharges, as it originated from roofing materials, tyre wear and atmospheric deposition (Clark et al. 2023). Metal contaminants can be toxic to organisms at high levels and some can accumulate in shellfish (Gadd et al 2020).

The trends of metal contaminants could not be assessed at three sites: Tūranganui River at Gladstone Rd Bridge, Taruheru River at Tuckers Rd Bridge and Waimatā River at Goodwins Rd Bridge. At most other sites, at least one metal was either indeterminate or could not be assessed. This indicated that values were below the detection limit or there were not enough measurements taken over the 5-year period. Trends for all three metals were only found at two sites: the site at Taruheru River at Peel St Bridge had a likely degrading trend for Cu, very likely degrading trend for Pb and likely improving trend for Zn; the site at Kopuawhakapata Stream at Hirini St had a very likely improving trend for both Pb and Zn and a likely improving trend for Cu.

TPHs were not assessed, as too many data were below the detection limit, which can result in an unreliable trend. Similarly, TPHs in the sediment analyses were also below the detection limit (see Section 4.1 – Sediment quality: Additional contaminants).

Table 15. The summary of the water quality trend results from 2019–2024 for the 11 SOE sites in the Tūranganui Estuary. The five trend classes, very likely improving, likely improving, indeterminate (i.d), likely degrading and very likely degrading are denoted with coloured arrows. TPH and turbidity could not be assessed and were not included in the summary table. NA indicates 'not assessed' due to too many censored values or too few observations over the 5-year period. Asterisk indicates the SOE sites closest to the monitoring sites.

Very likely improving	Likely improving	I.d - Indeterminate	Likely degrading	Very likely degrading

	Tūranganui River at The Cut	Tūranganui River at Gladstone Rd Bridge*	Waikanae Creek at Grey St Bridge	Waikanae Creek at Stanley Rd Bridge	Taruheru River at Peel St Bridge*	Taruheru River at Lytton Rd Bridge	Taruheru River at Wi Pere Pipe	Taruheru River at Tuckers Rd Bridge	Kopuawhakapata Stream at Hirini St	Waimatā River at Grand Rd*	Waimatā River at Goodwins Rd Bridge
NH_4-N (mg/L)	↑	↑↑	↓↓	↓	I.d	I.d	↓	↑	I.d	↑↑	I.d
NO_3-N (mg/L)	↓↓	↓↓	↓↓	↓↓	↓↓	↓↓	↓↓	↑↑	↓↓	↓	↓
TN (mg/L)	↓	↓↓	↓	↑	↓↓	↓	↓↓	↑↑	↓↓	↓↓	I.d.
DRP (mg/L)	↓	I.d	↓	↑	↓	↑	↓	↑↑	↓	↑↑	↑
TP (mg/L)	↓	↓	I.d	↑↑	↓↓	I.d	↓	↑↑	I.d	↑	↑
DO (%)	I.d	I.d	↑↑	I.d	I.d	I.d	↑↑	↓↓	↓↓	I.d	↓↓
Clarity Tube (cm)	NA	↑↑	↑↑	↑↑	↑↑	↑↑	↑↑	↑↑	NA	↑↑	↑↑
TSS (mg/L)	↓↓	↓↓	↓	I.d	↓↓	↓↓	↓↓	↓↓	↑	↓	↓↓
Faecal Coliforms (CFU/100 mL)	↓↓	↓↓	↓↓	↓	↓↓	↓↓	↓↓	NA	↑	↓	NA
Enterococci (CFU/100 mL)	↓↓	I.d	↓	I.d	↓↓	I.d	↓↓	↑↑	↑	↑	NA
***E. coli* (CFU/100 mL)**	↓↓	↓	↓	↓	↓↓	↓↓	↓↓	↑↑	↑↑	I.d	↓
Cu (mg/L)	I.d	NA	↓	I.d	↓	NA	I.d	NA	↑	↓	NA
Pb (mg/L)	I.d	NA	I.d	↑	↓↓	↓↓	I.d	NA	↑↑	I.d	NA
Zn (mg/L)	↑	NA	I.d	↓	↑	↓	I.d	NA	↑↑	↓	NA

4.7 Marine mammal sightings

The marine mammal sightings were outside the time period (i.e. 2023) and / or spatial radius (i.e. 1 km from the estuary mouth) of interest for Tūranganui Estuary. However, these data still provide a baseline of marine mammal sightings in Gisborne. There were historical sightings of Hector's dolphins within and outside the 1 km spatial radius from 2011 and prior. There were five sightings (one popoiangore / leopard seal and four ihu koropuku / southern elephant seal) in 2017 and 2019 combined: one sighting in Tokomaru Bay, two sightings in Hicks Bay and two sightings at Wainui Beach. We acknowledge that many sightings and strandings are not reported, and therefore, these data can only provide an indication on the marine mammals that were present in the region.

5. Overall summary of ecological health

This report presents and discusses the results of monitoring carried out at two sites in Tūranganui Estuary in 2024. Bird monitoring data were not available for assessment, and no marine mammal sightings had been recorded in the last year. Some woody debris was found within and nearby both sites, but neither site had high amounts of woody debris. Although assessing microbial contamination on human health was outside the scope of this report, water quality data results indicated that the majority of faecal indicators were above the freshwater guidelines and microbial contamination is increasing at most sites. Table 16 presents a summary of our conclusions for sedimentation, nutrient enrichment, metal contaminants and additional contaminants / stressors.

Taruheru site

Sedimentation was a problem at the Taruheru site, as evidenced by the very high mud content in sediments, the absence of mud-sensitive species and the very high Mud Benthic Health Model (BHM) score. Water quality data showed the effects of sedimentation were widespread across the estuary, with median total suspended solid (TSS) levels above the freshwater guideline values, although the water clarity values were within the recommended guidelines. Over the past 5 years, TSS levels have worsened, and the slightly higher mud content observed in 2024, compared to a 2019 study, also indicated that sedimentation may be getting worse in the Taruheru River (Kelly and Sim-Smith 2020).

The Taruheru site had moderate **eutrophication**, with levels of phosphorus in the sediment in the 'good' range. These results are considered to cause minor to moderate stress to aquatic organisms. Based on the sediment redox potential discontinuity (RPD) assessment, there was no indication of poor oxygenation through colour profile or a hydrogen sulphuric smell. However, nutrient enrichment can still pose a risk to macroinvertebrate communities at this site. Total organic carbon (TOC) and total nitrogen (TN) levels were higher in 2024 compared to those in 2019 (Kelly and Sim-Smith 2020) and the levels were above threshold values, with nearly all values above the average levels for estuaries across Aotearoa New Zealand (Berthelsen et al. 2019). For water quality, the closest two state of the environment (SOE) sites, one upstream and one downstream of the Taruheru site, also indicated a worsening of almost all levels of nutrients over the past 5 years.

Metal contaminants were generally low at the Taruheru site, and this was evidenced by the Metals BHM score in fair health with a moderate metals impact compared to other estuarine sites across Aotearoa New Zealand. However, lead (Pb) appears to be influencing the community composition patterns, and the water quality data showed that the Pb levels at the SOE site closest to the Taruheru site had degraded over the past 5 years. **Additional contaminants** in sediments were below detection limits at the Taruheru site.

Overall, **shellfish** sampling had low abundances at the Taruheru site, with low tuangi / cockles and no pipi. When compared to a study undertaken in 2019, the numbers of tuangi / cockles and hanikura / wedge shells have decreased (we found no hanikura / wedge shells), suggesting the Taruheru site is less suited for these shellfish, as both species are sensitive to fine sediment and the site has very high mud content (Kelly and Sim-Smith 2020).

Waimatā site

Sedimentation was also identified as a problem at the Waimatā site (although to a lesser extent than at the Taruheru site). Although the site had more sand and mud-sensitive species, the majority of sediment mud content values at Waimatā were still above guideline values. Interestingly, the mud content at this site has decreased since a 2019 study by Kelly and Sim-Smith (2020).

The Waimatā site had minimal to moderate **eutrophication**, with levels of phosphorus in the 'good' range. There was also no indication of poor oxygenation through colour profile or a hydrogen sulphuric smell from the sediment RPD assessment. TOC levels in the sediment were below the thresholds, while TN levels exceeded the thresholds. However, the Waimatā site is considered in good to fair ecological health, with minimal nutrients and low organic carbon content. In 2024, both TOC and TN levels had decreased at the Waimatā site compared to 2019, with values below the average levels for estuaries across Aotearoa New Zealand (Berthelsen et al. 2019). This was also evident in the water quality data at an SOE site upstream of the Waimatā site, where some nutrient levels, – ammonia-N, dissolved reactive phosphorus (DRP) and total phosphorus (TP) – were improving; however, nitrate-N and TN levels were degrading.

Generally, **metal contaminants** in sediments were low at the Waimatā site. The water quality data results indicated both copper (Cu) and zinc (Zn) at the SOE site closest to the Waimatā site had degraded over the past 5 years. Both the Mud and Metals BHM scores were not reliable indicators of estuary health relative to other estuarine sites across Aotearoa New Zealand.

Additional contaminant in sediments also were below detection limits at the Waimatā site, except for polycyclic aromatic hydrocarbons (PAHs). Although PAHs were detected, the values were below guideline values and thus are not considered a threat to ecological health.

Shellfish abundances were also low at the Waimatā site. There were low numbers of pipi and no tuangi / cockles, thus no samples were collected for shellfish condition. Compared to the results of a study in 2019, the numbers of tuangi / cockles and hanikura / wedge shells have decreased (we only found two hanikura / wedge shells in the 2024 fine-scale sampling and none in the shellfish monitoring). Since 2019, the Waimatā site has improved in mud content, indicating a potentially healthier site for highly mud-sensitive taxa such as pipi.

Table 16: Indicators of nutrient enrichment, sedimentation, metal and additional contaminants at the Taruheru and Waimatā sites in Tūranganui Estuary. For sedimentation, colours indicate if the state of the site showed minimal sedimentation (green), moderate sedimentation (yellow) or high sedimentation (red). For nutrients, colours are indicative of minimal eutrophication (green), moderate eutrophication (yellow) or high eutrophication (red) based on the most recent sampling for that indicator. Refer to Tables 8–12 for details on indicator thresholds for mud, sediment organic carbon, nitrogen and phosphorus. The state for other parameters was assigned based on indicator values (e.g. low [green], moderate [yellow] or high [red]) using best professional judgement of the authors.

	Indicator	Taruheru	Waimatā
Sedimentation	**Sediment mud content**	Poor	Fair
	Infaunal communities	Mud-tolerant	Mud-sensitive
	Tuangi / cockles (Sensitive to mud)	Present (Low abundance)	Present (Low abundance)
	Pipi (Sensitive to mud)	Present (Low abundance)	Present (Low abundance)
	***Microspio maori* (Highly sensitive to mud)**	Not present	Present (Low abundance)
	***Aonides species* (Sensitive to mud)**	Not present	Not present
	Mud snails (Widely tolerant of mud)	Low abundance	High abundance
	Mud BHM		N/A
Nutrients	**Total organic carbon**	Moderate eutrophication	Minimal eutrophication
	Total nitrogen	Moderate eutrophication	Moderate eutrophication
	Total recoverable phosphorus	Good	Good
Metal contaminants	**As**	Below DGV	Below DGV
	Cd	Below DGV	Below DGV
	Cr	Below DGV	Below DGV
	Cu	Below DGV	Below DGV
	Pb	Below DGV	Below DGV
	Ni	Below DGV	Below DGV
	Zi	Below DGV	Below DGV
	Hg	Below DGV	Below DGV
	Metals BHM		N/A
Additional contaminants / stressors	**Semi-volatile organic compounds (SVOCs)**	Below DL	Below DL
	Total petroleum hydrocarbons (TPHs)	Below DL	Below DL
	Polycyclic aromatic hydrocarbons (PAHs)	Below DL	Below DGV
	Organochlorine pesticides	Below DL	Below DL
	Woody debris	Some cover	Some cover

6. Monitoring recommendations

Overall, we recommend that monitoring for Tūranganui Estuary (fine-scale, shellfish, water quality, bird and marine mammal) is continued following the monitoring protocol by Clark et al. (2024). In terms of fine-scale and shellfish sampling, this should be carried out at the Taruheru and Waimatā sites in one year's time (due 2025). Future monitoring should ideally be undertaken within the same month (i.e. February) for comparison of any changes and to reduce the influence of seasonal variation on macroinvertebrate communities. Our recommendations for future monitoring at Tūranganui Estuary are as follows (see Clark et al. 2024 for further details on points noted below):

- Prior to future monitoring, the project team should consult with mana whenua and offer them the opportunity to be involved in fine-scale sampling (see section 4 in Clark et al. 2024). We also recommended discussions with mana whenua about the expression of mauri[23] in the context of this estuary and its current state. These conversations should also address the future state of mauri ora and the potential to incorporate other indicators of estuary health into the programme.
- Semi-volatile organic compounds (SVOCs), total petroleum hydrocarbons (TPHs) and organochlorine pesticides were below detection limits at the Taruheru site. Therefore, we recommend these are not sampled routinely as part of the future monitoring programme. However, if an upstream or nearby downstream contamination source is identified, we recommend reconsidering their inclusion in routine monitoring to understand the potential impacts on shellfish and infaunal macroinvertebrate communities.
- Polycyclic aromatic hydrocarbons (PAHs) were detected at the Waimatā site and the levels fell well below current ANZG (2018) default guideline values. Therefore, we recommend analysing PAHs at the next fine-scale sampling for the Waimatā site. However, if no change in levels is detected, then PAHs could be removed from subsequent analysis pending any activities that might increase levels.
- To assist with interpretation of fine-scale ecological results, data collection for additional environmental parameters such as light and temperature levels is recommended. There are various examples of loggers that can be used (see section 5.2.7 in Clark et al. 2024).
- We suggest rechecking the BHM scores and fit of the Waimatā site when this site is next sampled to assess whether the BHM scores are representative of estuary health relative to other sites across Aotearoa New Zealand.
- As the monitoring programme progresses, reducing the infaunal macroinvertebrate replicates at the Taruheru site from nine to six replicates (i.e. plots) should be considered based on the analysis of the data. The nine plots overall should remain, but six of the plots could be randomly sampled for epibiota and infaunal macroinvertebrates. This aligns with other estuary monitoring approaches (e.g. Anderson et al. 2007; Hewitt and McCartain 2017), and it would ensure equal replicates for both Tūranganui sites, making overall comparison of results easier and reducing monitoring costs.

[23] Mauri means the essential quality and vitality of a being – the life force or essence. Mauri ora is freedom of cultural expression and identity.

- We recommend conducting trend analyses on fine-scale ecological data (e.g. sediment characteristics, macroinvertebrate metrics and indicator species abundances) once a suitable amount of data have been collected over time.
- As the monitoring programme progresses, we recommend using a distance-based linear model (DistLM) with a BEST function to examine the degree of variation that each environmental variable contributes to patterns in species composition. Data from DistLMs should be visualised using a multi-dimensional scaling plot based on a distance-based redundancy analysis (dbRDA) to explore the relationship between macroinvertebrate communities and environmental metrics. (see section 5.5.4 in Clark et al. 2024).
- We recommend collating any information on rainfall, river flow and climatic indices (e.g. the Southern Oscillation Index, MZ1) to aid interpretation of ecological health.
- In relation to fine-scale sampling, additional information for future analysis could include documenting changes in animal activity (e.g. evidence of shellfish, worm or crustacean bioturbation) on the sediment surface to monitor changes in key macroinvertebrates and their behaviour. The epifauna quadrat photos could be reviewed to determine useful measures for future monitoring.
- In general, we recommend that National Estuary Monitoring Programme (NEMP) revisions are incorporated into the monitoring programme, if possible, based on data consistency over time. The monitoring protocol can also be updated as new technology and tools become available. For example, Cawthron is currently developing eDNA-based estuary health indicators, which, once complete, could be incorporated into the fine-scale monitoring programme.
- For future monitoring, we recommend Gisborne District Council (GDC) implement Cawthron's monitoring recommendations on harmful algal blooms (HABs) once they have been developed. This information can be used to supplement / interpret fine-scale and other ecological results (see section 3 in Clark et al. 2024).
- GDC is currently conducting an eradication project of *Spartina* spp. in the Taruheru River (including locations near the fine-scale site). Although details of the project were not available for the current report, we recommend GDC monitor and track the changes in the extent of the invasive plant *Spartina* (if not already included in other programmes administered by DOC or GDC) and provide this information for future fine-scale reporting. Recording and monitoring sediment types, especially mud content, could also be carried out concurrently.
- We recommend continued monitoring of shellfish abundance and size of tuangi / cockles, pipi and hanikura / wedge shells. These data can help track changes in population size structure over time. In the future, for each survey, mana whenua can consider whether it is suitable to collect tuangi / cockles to assess shellfish condition (through ash-free dry weight analysis). If so, we recommend collecting a minimum of five tuangi / cockle individuals and up to a maximum of 30. However, if the next monitoring results in the same or lower shellfish abundance and sizes, we recommend GDC establish another shellfish site. From the 12 sites sampled by Kelly and Sim-Smith (2020), two sites, one near Peel St Bridge (Taruheru 6) and one near Gladstone Rd Bridge (Tūranganui 2), had the highest numbers of tuangi / cockles per core in 2019 and could offer good alternative locations.
- For the woody debris survey, we also recommend completing an overall site assessment on the amount of woody debris covering the fine-scale site. This could be done by roughly estimating

the percent cover (to around the nearest 10%) of woody debris covering the fine-scale site and by counting the number of fine-scale plots where woody debris is present. While both estimate methods are not expected to fully quantify the overall cover, they can still compliment the information on the percent cover measurements of debris from quadrats.

- We recommend conducting bird monitoring surveys during the next monitoring event following the methods outlined in the protocol. If interest in community-based bird monitoring is high, the additional monitoring effort can expand to include community groups that have localised knowledge and expertise. This approach can increase the monitoring coverage of an estuary both in terms of time and space. We encourage GDC to also consider establishing Tūranganui Estuary as a site in the National Wader Count Scheme.[24]

[24] This scheme is part of a wider set of monitoring programmes that engage with local communities to promote archiving of bird observations throughout Aotearoa New Zealand to assist with species conservation and management. https://www.birdsnz.org.nz/schemes/national-wader-count

7. Contributors

Maureen Ho: Fine-scale monitoring, report writing and data analyses

Al Alder: Report writing and data analyses

Isabella Clere: Fine-scale shellfish sampling

Taylor Hills: Fine-scale shellfish sampling

8. Acknowledgements

We would like to thank Anna Berthelsen (Cawthron) who assisted with the monitoring fieldwork and provided a helpful review of this report. We also thank Dana Clark (Cawthron) and Judie Hewitt (Tidal Research Ltd, Auckland) for their helpful reviews, and Louisa Fisher for editing and finalising the report.

9. Appendices

Appendix 1. Sediment cores in Tūranganui Estuary

Figure A1.1. Sediment cores from the nine plots at the Taruheru site. For composited samples: sample 1 was from plots 1–3, sample 2 was from plots 4–6 and sample 3 was from plots 7–9.

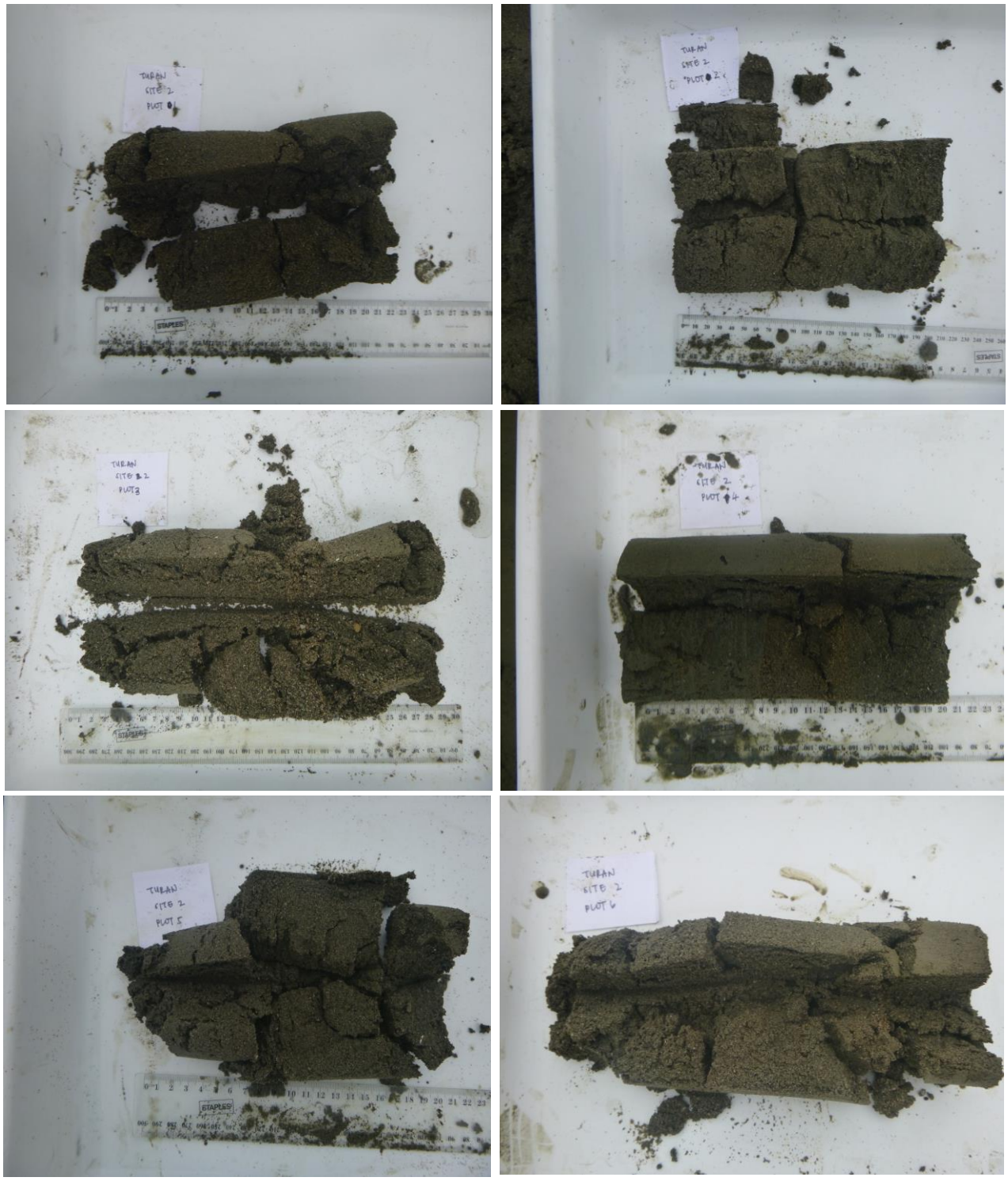


Figure A1.2. Sediment cores from the six plots at the Waimatā site. For composited samples, sample 1 was from plots 1–2, sample 2 was from plots 3–4 and sample 3 was from plots 5–6.

Appendix 2. Epibiota abundance in Tūranganui Estuary

Site	ID	Common name	Species ID	plot1	plot 2	plot3	plot4	plot5	plot6	plot7	plot8	plot9
Taruheru	T1	crab holes		14	12	16	24	24	17	38	45	72
Taruheru	T1	estuarine snail (small grastropod)	*Potamopyrgus estuarinus*	3	0	0	0	0	0	0	0	0
Taruheru	T1	mud snail	*Amphibola crenata*	0	2	4	4	2	7	3	0	0
Waimata	T2	crab holes		0	0	0	1	0	0	NA	NA	NA
Waimata	T2	unknown animal (very small hole)	no ID	0	2	0	0	0	0	NA	NA	NA

Appendix 3. SIMPER analyses table for macroinvertebrate communities

Taruheru					
Average similarity: 56.13					
Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Estuarine snail	21.67	20.82	1.88	37.1	37.1
Cockle (0–5 mm)	18.44	19.48	2.39	34.71	71.81
Bristle worm (*S. benhami*)	4.44	6.22	1.21	11.08	82.89

Waimatā					
Average similarity: 28.69					
Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Pipi	4.67	19.54	0.81	68.1	68.1
Bristle worm (*M. maori*)	12.33	5.68	0.66	19.79	87.9

Taruheru & Waimatā						
Average dissimilarity = 92.68						
	Taruheru	**Waimatā**				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Estuarine snail	21.67	1.33	26.01	1.66	28.07	28.07
Cockle (0–5mm)	18.44	0.5	24.21	1.87	26.13	54.19
Bristle worm (*M. maori*)	0	12.33	11.1	0.63	11.98	66.17
Bristle worm (*S. benhami*)	4.44	0.17	7.52	1.32	8.11	74.28
Pipi	0	4.67	6.48	1.32	6.99	81.27

Appendix 4. Macroinvertebrate abundance in Tūranganui Estuary

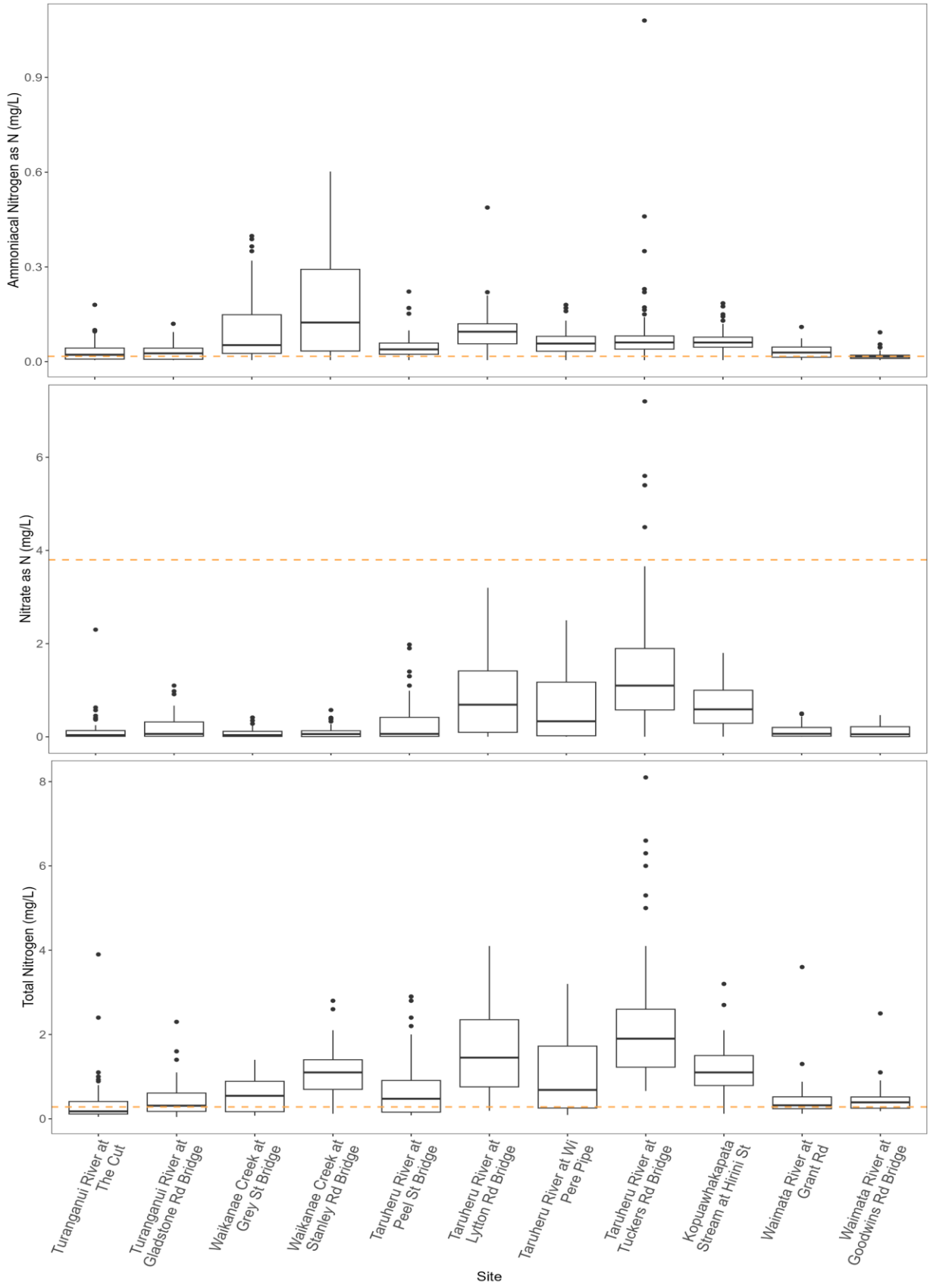
Site	Year	ID	Replicate	*Nemertea*	*Amphibola crenata*	*Potamopyrgus estuarinus*	*Turbonilla sp.*	*Arcuatula senhousia*	*Arthritica bifurca*	*Austrovenus stutchburyi* (0-5mm)	*Austrovenus stutchburyi (06-10mm)*	*Macomona liliana (0-5mm)*	*Paphies australis*	*Oligochaeta*	*Microspio maori*	*Scolecolepides benhami*	*Nereididae (juvenile)*	*Nicon aestuariensis*	*Hemiplax hirtipes*	*Austrohelice crassa*	*Halicarcinus whitei*
Taruheru	2024	T1	1	0	3	37	0	0	3	21	0	0	0	0	0	4	3	0	0	0	1
Taruheru	2024	T1	2	0	1	23	0	0	5	20	0	0	0	0	0	1	9	4	0	0	0
Taruheru	2024	T1	3	0	2	32	0	1	8	47	1	0	0	0	0	1	7	2	2	0	0
Taruheru	2024	T1	4	0	0	8	0	0	0	5	0	0	0	2	0	6	8	0	0	1	0
Taruheru	2024	T1	5	0	0	11	1	0	0	12	0	0	0	0	0	6	2	0	0	0	0
Taruheru	2024	T1	6	0	1	8	0	0	7	31	0	0	0	0	0	5	1	0	2	0	0
Taruheru	2024	T1	7	0	1	48	0	0	2	8	0	0	0	0	0	9	4	1	1	0	0
Taruheru	2024	T1	8	1	2	4	0	0	0	10	0	0	0	0	0	5	3	2	0	0	0
Taruheru	2024	T1	9	0	1	24	0	0	10	12	0	0	0	1	0	3	3	3	0	0	0
Waimata	2024	T2	1	0	0	5	0	0	0	0	0	0	10	0	3	0	2	0	0	0	0
Waimata	2024	T2	2	0	0	0	0	0	0	0	0	0	4	0	6	0	0	0	0	0	0
Waimata	2024	T2	3	0	0	0	0	0	0	1	0	0	3	0	0	0	0	0	0	0	0
Waimata	2024	T2	4	0	0	0	0	1	0	1	0	1	8	0	63	1	2	0	0	0	0
Waimata	2024	T2	5	0	0	3	0	0	0	1	0	0	0	0	2	0	0	0	0	0	0
Waimata	2024	T2	6	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0

Appendix 5. Benthic Health Models

Taxa that were removed before BHM modelling for both Tūranganui Estuary fine-scale sites following Clark et al. (2022), as well as the average abundance and number of occurrences summed across every site / time.

Reason removed	Taxon	Average abundance	Number of occurrences
Juvenile	Nereididae	5.11	2

Appendix 6. Water quality parameters plotted from 2019-2024 in Tūranganui Estuary



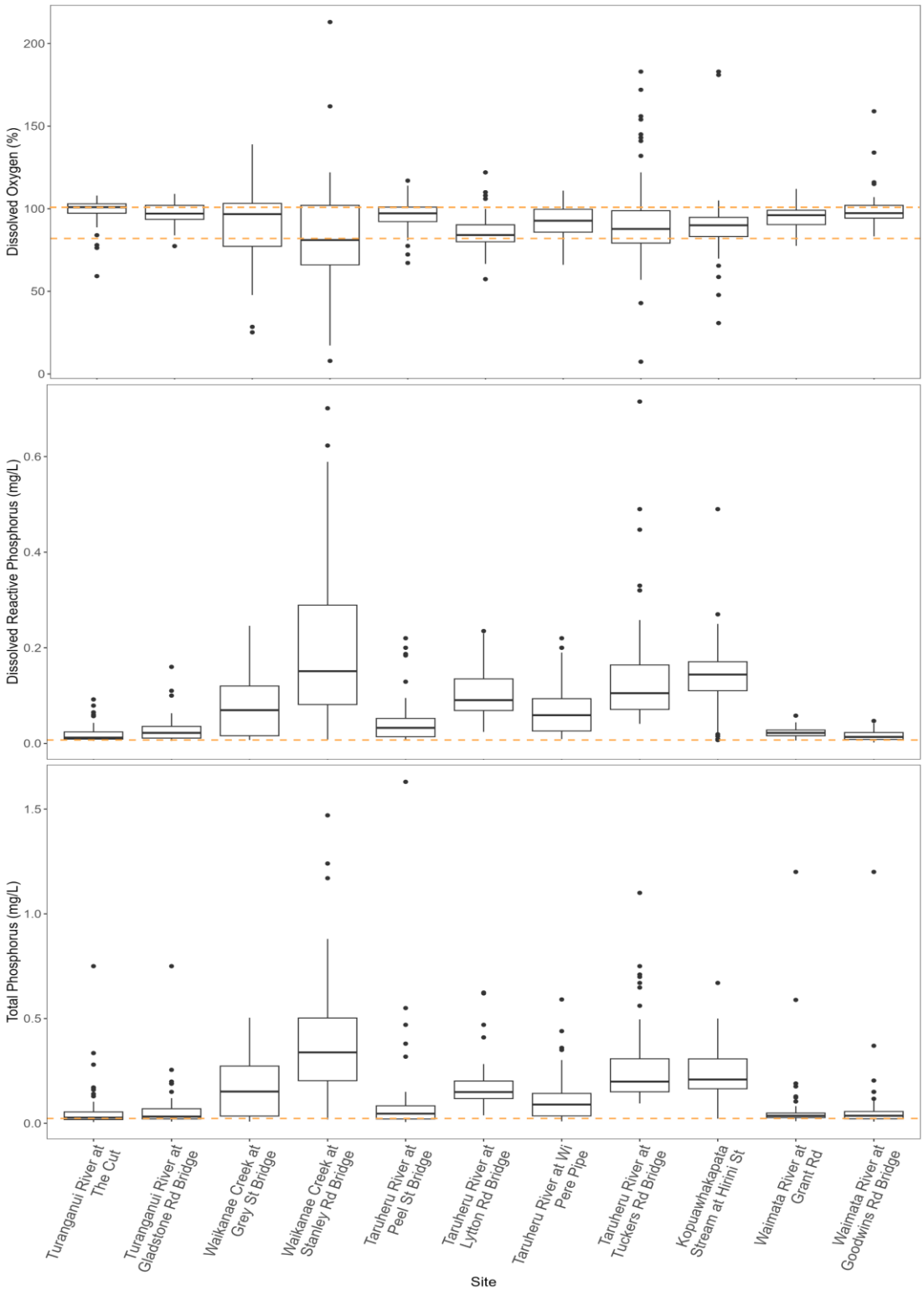


Figure A6.1. The nutrient concentrations relative to the freshwater default guideline values (orange dashed line) for the 11 state of the environment sites. The boxplots show the distribution of measurements for ammonia-N, nitrate-N, total nitrogen, dissolved oxygen, dissolved reactive phosphorus and total phosphorus from January 2019–February 2024. Ammonia-N has a marine DGV of 2 that was not plotted, as it exceeded the limit of the plot distribution and all values were below the marine DGV.

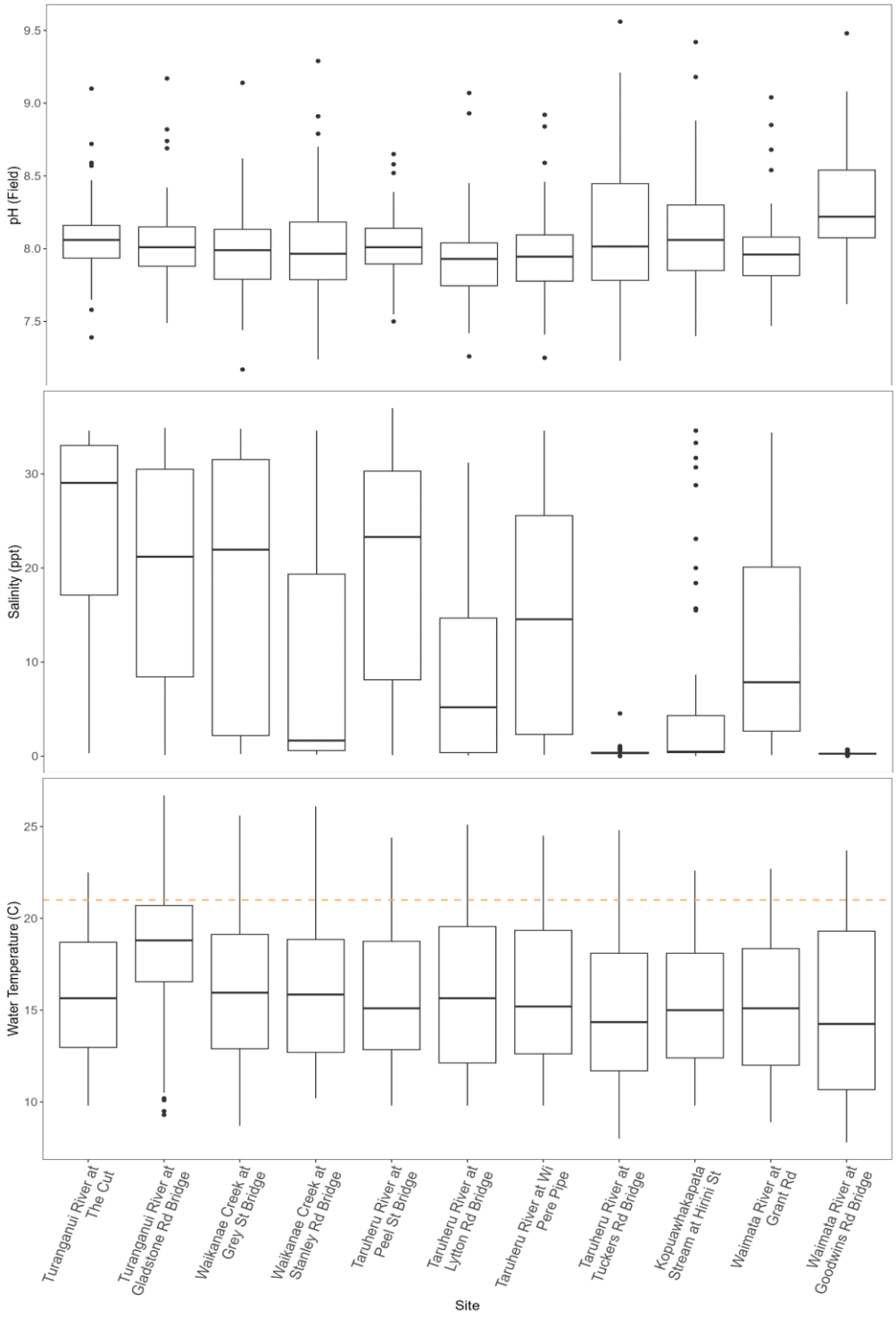


Figure A6.2. The physical parameters at the 11 state of the environment sites. The boxplots show the distribution of the measurements for pH, salinity and water temperature from January 2019–February 2024. The freshwater default guideline value (orange dashed line) was only available for water temperature. Note that for salinity it was < 5 % background values.

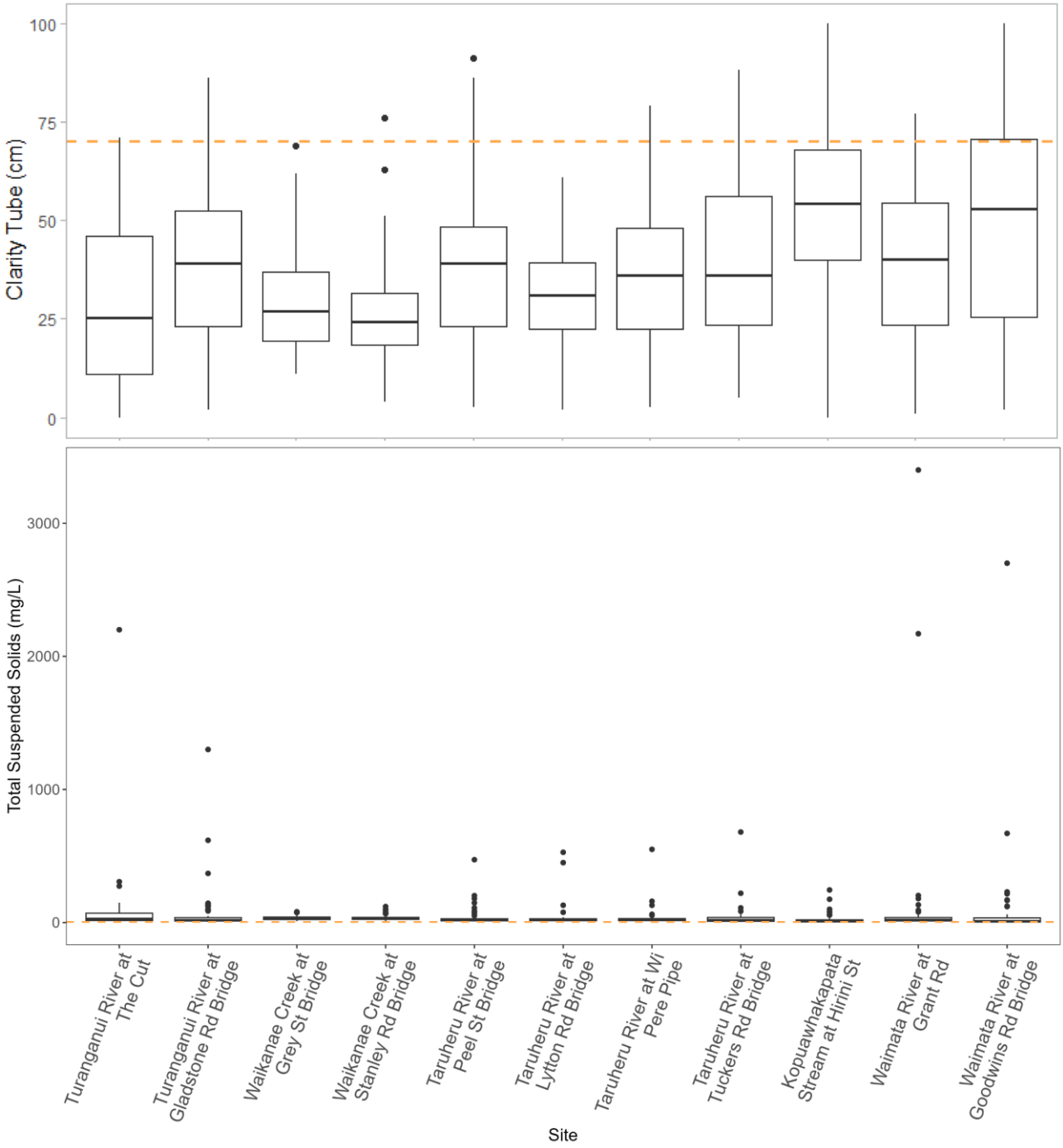


Figure A6.3. Water clarity parameters relative to the freshwater default guideline values (orange dashed line) for the 11 state of the environment sites. The boxplots show the distribution of measurements for total suspended solids and clarity tube from January 2019–February 2024. Turbidity was not assessed and therefore not included.

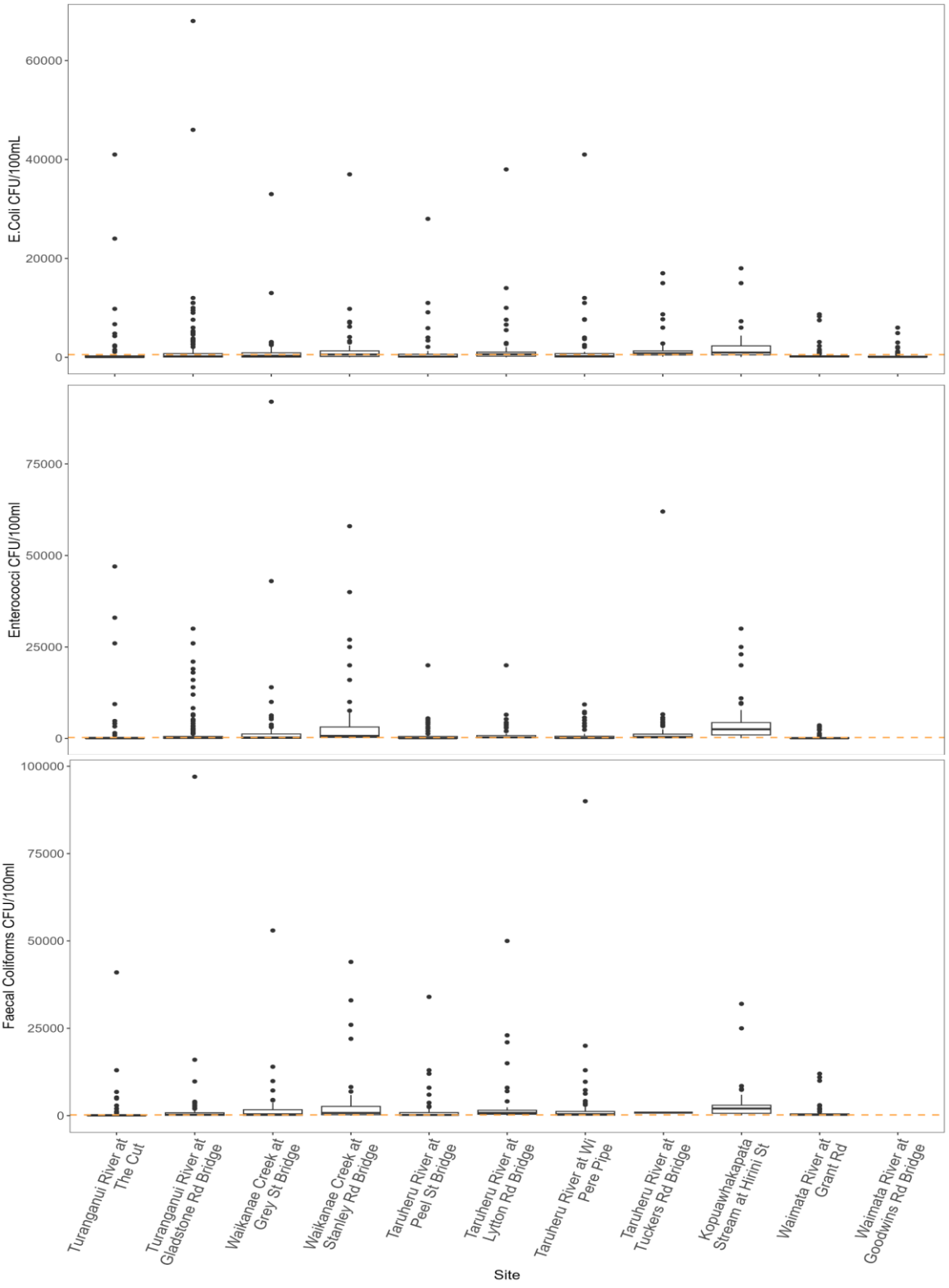


Figure A6.4. The microbial concentrations relative to the freshwater default guideline values (orange dashed line) for the 11 state of the environment sites. The boxplots show the distribution of measurements for *E. coli*, enterococci and faecal coliforms from January 2019–February 2024.

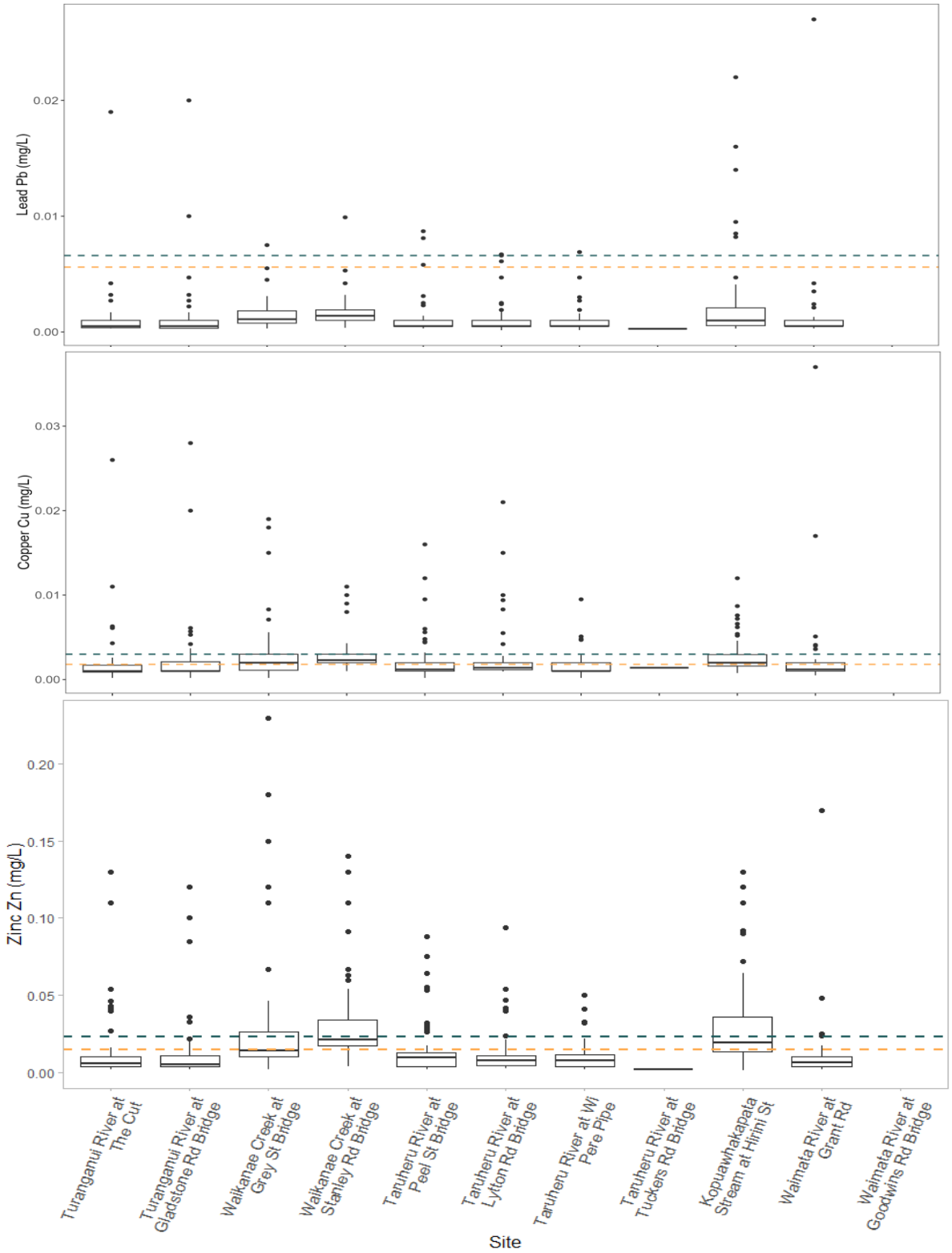


Figure A6.5. The metal parameters relative to the freshwater (orange dashed line) and marine (blue dashed line) default guideline values for the 11 state of the environment sites. The boxplots show the distribution of measurements for copper (Cu), zinc (Zn) and lead (Pb) from January 2019–February 2024.

Appendix 7. Laboratory results

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Certificate of Analysis

Client:	Cawthron Institute (Nelson)	**Lab No:**	3479171	SPv1
Contact:	Maureen Ho	**Date Received:**	27-Feb-2024	
	C/- Cawthron Institute (Nelson)	**Date Reported:**	16-Apr-2024	
	Private Bag 2	**Quote No:**	126565	
	Nelson Mail Centre	**Order No:**	66775	
	Nelson 7042	**Client Reference:**		
		Submitted By:	Maureen Ho	

Sample Type: Sediment

Sample Name:		T-1-1 24-Feb-2024	T-1-2 24-Feb-2024	T-1-3 24-Feb-2024	T-1-1-C 24-Feb-2024	T-2-1 25-Feb-2024
Lab Number:		3479171.1	3479171.2	3479171.3	3479171.4	3479171.5
Individual Tests						
Dry Matter	g/100g as rcvd	-	-	-	68	-
Total Recoverable Phosphorus	mg/kg dry wt	350	320	330	-	340
Total Nitrogen*	g/100g dry wt	0.06	0.08	0.08	-	0.03
Total Organic Carbon*	g/100g dry wt	0.56	0.61	0.73	-	0.18
Heavy metals, trace As,Cd,Cr,Cu,Ni,Pb,Zn,Hg						
Total Recoverable Arsenic	mg/kg dry wt	3.9	3.6	4.3	-	5.1
Total Recoverable Cadmium	mg/kg dry wt	0.053	0.054	0.060	-	0.043
Total Recoverable Chromium	mg/kg dry wt	11.8	10.4	12.5	-	9.9
Total Recoverable Copper	mg/kg dry wt	7.3	7.2	8.4	-	6.2
Total Recoverable Lead	mg/kg dry wt	7.4	7.5	8.8	-	7.4
Total Recoverable Mercury	mg/kg dry wt	0.04	0.03	0.04	-	0.04
Total Recoverable Nickel	mg/kg dry wt	13.0	11.7	13.9	-	11.5
Total Recoverable Zinc	mg/kg dry wt	51	53	53	-	37
7 Grain Sizes Profile as received*						
Dry Matter of Sieved Sample*	g/100g as rcvd	71	66	69	-	71
Fraction >/= 2 mm*	g/100g dry wt	0.1	0.3	0.2	-	0.6
Fraction < 2 mm, >/= 1 mm*	g/100g dry wt	0.6	< 0.1	< 0.1	-	1.3
Fraction < 1 mm, >/= 500 µm*	g/100g dry wt	8.1	0.1	0.2	-	7.6
Fraction < 500 µm, >/= 250 µm*	g/100g dry wt	29.8	0.8	0.9	-	49.7
Fraction < 250 µm, >/= 125 µm*	g/100g dry wt	39.5	6.0	3.3	-	20.8
Fraction < 125 µm, >/= 63 µm*	g/100g dry wt	11.4	25.1	24.7	-	7.2
Fraction < 63 µm*	g/100g dry wt	10.5	67.7	70.6	-	12.9
Organochlorine Pesticides Trace in Soil						
Aldrin	mg/kg dry wt	-	-	-	< 0.002	-
alpha-BHC	mg/kg dry wt	-	-	-	< 0.002	-
beta-BHC	mg/kg dry wt	-	-	-	< 0.002	-
delta-BHC	mg/kg dry wt	-	-	-	< 0.002	-
gamma-BHC (Lindane)	mg/kg dry wt	-	-	-	< 0.002	-
cis-Chlordane	mg/kg dry wt	-	-	-	< 0.002	-
trans-Chlordane	mg/kg dry wt	-	-	-	< 0.002	-
2,4'-DDD	mg/kg dry wt	-	-	-	< 0.002	-
4,4'-DDD	mg/kg dry wt	-	-	-	< 0.002	-
2,4'-DDE	mg/kg dry wt	-	-	-	< 0.002	-
4,4'-DDE	mg/kg dry wt	-	-	-	< 0.002	-
2,4'-DDT	mg/kg dry wt	-	-	-	< 0.002	-
4,4'-DDT	mg/kg dry wt	-	-	-	< 0.002	-
Total DDT Isomers	mg/kg dry wt	-	-	-	< 0.012	-

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

Sample Type: Sediment						
Sample Name:		T-1-1 24-Feb-2024	T-1-2 24-Feb-2024	T-1-3 24-Feb-2024	T-1-1-C 24-Feb-2024	T-2-1 25-Feb-2024
Lab Number:		3479171.1	3479171.2	3479171.3	3479171.4	3479171.5
Organochlorine Pesticides Trace in Soil						
Dieldrin	mg/kg dry wt	-	-	-	< 0.002	-
Endosulfan I	mg/kg dry wt	-	-	-	< 0.002	-
Endosulfan II	mg/kg dry wt	-	-	-	< 0.002	-
Endosulfan sulphate	mg/kg dry wt	-	-	-	< 0.002	-
Endrin	mg/kg dry wt	-	-	-	< 0.002	-
Endrin aldehyde	mg/kg dry wt	-	-	-	< 0.002	-
Endrin ketone	mg/kg dry wt	-	-	-	< 0.002	-
Heptachlor	mg/kg dry wt	-	-	-	< 0.002	-
Heptachlor epoxide	mg/kg dry wt	-	-	-	< 0.002	-
Hexachlorobenzene	mg/kg dry wt	-	-	-	< 0.002	-
Methoxychlor	mg/kg dry wt	-	-	-	< 0.002	-
Polycyclic Aromatic Hydrocarbons Trace in Soil*						
Total of Reported PAHs in Soil	mg/kg dry wt	-	-	-	< 0.05	-
1-Methylnaphthalene	mg/kg dry wt	-	-	-	< 0.002	-
2-Methylnaphthalene	mg/kg dry wt	-	-	-	< 0.002	-
Acenaphthene	mg/kg dry wt	-	-	-	< 0.002	-
Acenaphthylene	mg/kg dry wt	-	-	-	< 0.002	-
Anthracene	mg/kg dry wt	-	-	-	< 0.002	-
Benzo[a]anthracene	mg/kg dry wt	-	-	-	< 0.002	-
Benzo[a]pyrene (BAP)	mg/kg dry wt	-	-	-	< 0.002	-
Benzo[b]fluoranthene + Benzo[j] fluoranthene	mg/kg dry wt	-	-	-	< 0.002	-
Benzo[e]pyrene	mg/kg dry wt	-	-	-	< 0.002	-
Benzo[g,h,i]perylene	mg/kg dry wt	-	-	-	< 0.002	-
Benzo[k]fluoranthene	mg/kg dry wt	-	-	-	< 0.002	-
Chrysene	mg/kg dry wt	-	-	-	< 0.002	-
Dibenzo[a,h]anthracene	mg/kg dry wt	-	-	-	< 0.002	-
Fluoranthene	mg/kg dry wt	-	-	-	< 0.002	-
Fluorene	mg/kg dry wt	-	-	-	< 0.002	-
Indeno(1,2,3-c,d)pyrene	mg/kg dry wt	-	-	-	< 0.002	-
Naphthalene	mg/kg dry wt	-	-	-	< 0.010	-
Perylene	mg/kg dry wt	-	-	-	0.011	-
Phenanthrene	mg/kg dry wt	-	-	-	< 0.003	-
Pyrene	mg/kg dry wt	-	-	-	< 0.002	-
Benzo[a]pyrene Potency Equivalency Factor (PEF) NES*	mg/kg dry wt	-	-	-	< 0.0049	-
Benzo[a]pyrene Toxic Equivalence (TEF)*	mg/kg dry wt	-	-	-	< 0.0049	-
Haloethers Trace in SVOC Soil Samples by GC-MS						
Bis(2-chloroethoxy) methane	mg/kg dry wt	-	-	-	< 0.10	-
Bis(2-chloroethyl)ether	mg/kg dry wt	-	-	-	< 0.10	-
Bis(2-chloroisopropyl)ether	mg/kg dry wt	-	-	-	< 0.10	-
4-Bromophenyl phenyl ether	mg/kg dry wt	-	-	-	< 0.10	-
4-Chlorophenyl phenyl ether	mg/kg dry wt	-	-	-	< 0.10	-
Nitrogen containing compounds Trace in SVOC Soil Samples, GC-MS						
N-Nitrosodiphenylamine + Diphenylamine	mg/kg dry wt	-	-	-	< 0.16	-
2,4-Dinitrotoluene	mg/kg dry wt	-	-	-	< 0.2	-
2,6-Dinitrotoluene	mg/kg dry wt	-	-	-	< 0.2	-
Nitrobenzene	mg/kg dry wt	-	-	-	< 0.10	-
N-Nitrosodi-n-propylamine	mg/kg dry wt	-	-	-	< 0.16	-
Organochlorine Pesticides Trace in SVOC Soil Samples by GC-MS						
Aldrin	mg/kg dry wt	-	-	-	< 0.8	-
alpha-BHC	mg/kg dry wt	-	-	-	< 0.10	-
beta-BHC	mg/kg dry wt	-	-	-	< 0.10	-
delta-BHC	mg/kg dry wt	-	-	-	< 0.10	-

Sample Type: Sediment						
Sample Name:		T-1-1 24-Feb-2024	T-1-2 24-Feb-2024	T-1-3 24-Feb-2024	T-1-1-C 24-Feb-2024	T-2-1 25-Feb-2024
Lab Number:		3479171.1	3479171.2	3479171.3	3479171.4	3479171.5
Organochlorine Pesticides Trace in SVOC Soil Samples by GC-MS						
gamma-BHC (Lindane)	mg/kg dry wt	-	-	-	< 0.10	-
4,4'-DDD	mg/kg dry wt	-	-	-	< 0.10	-
4,4'-DDE	mg/kg dry wt	-	-	-	< 0.10	-
4,4'-DDT	mg/kg dry wt	-	-	-	< 0.2	-
Dieldrin	mg/kg dry wt	-	-	-	< 0.10	-
Endosulfan I	mg/kg dry wt	-	-	-	< 0.2	-
Endosulfan II	mg/kg dry wt	-	-	-	< 0.5	-
Endosulfan sulphate	mg/kg dry wt	-	-	-	< 0.2	-
Endrin	mg/kg dry wt	-	-	-	< 0.16	-
Endrin ketone	mg/kg dry wt	-	-	-	< 0.2	-
Heptachlor	mg/kg dry wt	-	-	-	< 0.10	-
Heptachlor epoxide	mg/kg dry wt	-	-	-	< 0.10	-
Hexachlorobenzene	mg/kg dry wt	-	-	-	< 0.10	-
Polycyclic Aromatic Hydrocarbons Trace in SVOC Soil Samples*						
Acenaphthene	mg/kg dry wt	-	-	-	< 0.10	-
Acenaphthylene	mg/kg dry wt	-	-	-	< 0.10	-
Anthracene	mg/kg dry wt	-	-	-	< 0.10	-
Benzo[a]anthracene	mg/kg dry wt	-	-	-	< 0.10	-
Benzo[a]pyrene (BAP)	mg/kg dry wt	-	-	-	< 0.10	-
Benzo[b]fluoranthene + Benzo[j] fluoranthene	mg/kg dry wt	-	-	-	< 0.10	-
Benzo[g,h,i]perylene	mg/kg dry wt	-	-	-	< 0.10	-
Benzo[k]fluoranthene	mg/kg dry wt	-	-	-	< 0.10	-
1&2-Chloronaphthalene	mg/kg dry wt	-	-	-	< 0.10	-
Chrysene	mg/kg dry wt	-	-	-	< 0.10	-
Dibenzo[a,h]anthracene	mg/kg dry wt	-	-	-	< 0.10	-
Fluoranthene	mg/kg dry wt	-	-	-	< 0.10	-
Fluorene	mg/kg dry wt	-	-	-	< 0.10	-
Indeno(1,2,3-c,d)pyrene	mg/kg dry wt	-	-	-	< 0.10	-
2-Methylnaphthalene	mg/kg dry wt	-	-	-	< 0.10	-
Naphthalene	mg/kg dry wt	-	-	-	< 0.10	-
Phenanthrene	mg/kg dry wt	-	-	-	< 0.10	-
Pyrene	mg/kg dry wt	-	-	-	< 0.10	-
Benzo[a]pyrene Potency Equivalency Factor (PEF) NES*	mg/kg dry wt	-	-	-	< 0.25	-
Benzo[a]pyrene Toxic Equivalence (TEF)*	mg/kg dry wt	-	-	-	< 0.25	-
Phenols Trace in SVOC Soil Samples by GC-MS						
4-Chloro-3-methylphenol	mg/kg dry wt	-	-	-	< 0.5	-
2-Chlorophenol	mg/kg dry wt	-	-	-	< 0.2	-
2,4-Dichlorophenol	mg/kg dry wt	-	-	-	< 0.2	-
2,4-Dimethylphenol	mg/kg dry wt	-	-	-	< 0.4	-
3 & 4-Methylphenol (m- + p-cresol)	mg/kg dry wt	-	-	-	< 0.4	-
2-Methylphenol (o-cresol)	mg/kg dry wt	-	-	-	< 0.2	-
2-Nitrophenol	mg/kg dry wt	-	-	-	< 0.4	-
Pentachlorophenol (PCP)	mg/kg dry wt	-	-	-	< 6	-
Phenol	mg/kg dry wt	-	-	-	< 0.2	-
2,4,5-Trichlorophenol	mg/kg dry wt	-	-	-	< 0.2	-
2,4,6-Trichlorophenol	mg/kg dry wt	-	-	-	< 0.2	-
Plasticisers Trace in SVOC Soil Samples by GC-MS						
Bis(2-ethylhexyl)phthalate	mg/kg dry wt	-	-	-	< 0.5	-
Butylbenzylphthalate	mg/kg dry wt	-	-	-	< 0.2	-
Di(2-ethylhexyl)adipate	mg/kg dry wt	-	-	-	< 0.2	-
Diethylphthalate	mg/kg dry wt	-	-	-	< 0.2	-
Dimethylphthalate	mg/kg dry wt	-	-	-	< 0.2	-

Sample Type: Sediment						
Sample Name:		T-1-1 24-Feb-2024	T-1-2 24-Feb-2024	T-1-3 24-Feb-2024	T-1-1-C 24-Feb-2024	T-2-1 25-Feb-2024
Lab Number:		3479171.1	3479171.2	3479171.3	3479171.4	3479171.5
Plasticisers Trace in SVOC Soil Samples by GC-MS						
Di-n-butylphthalate	mg/kg dry wt	-	-	-	< 0.2	-
Di-n-octylphthalate	mg/kg dry wt	-	-	-	< 0.2	-
Other Halogenated compounds Trace in SVOC Soil Samples by GC-MS						
1,2-Dichlorobenzene	mg/kg dry wt	-	-	-	< 0.16	-
1,3-Dichlorobenzene	mg/kg dry wt	-	-	-	< 0.16	-
1,4-Dichlorobenzene	mg/kg dry wt	-	-	-	< 0.16	-
Hexachlorobutadiene	mg/kg dry wt	-	-	-	< 0.16	-
Hexachloroethane	mg/kg dry wt	-	-	-	< 0.16	-
1,2,4-Trichlorobenzene	mg/kg dry wt	-	-	-	< 0.10	-
Other SVOC Trace in SVOC Soil Samples by GC-MS						
Benzyl alcohol	mg/kg dry wt	-	-	-	< 1.0	-
Carbazole	mg/kg dry wt	-	-	-	< 0.10	-
Dibenzofuran	mg/kg dry wt	-	-	-	< 0.10	-
Isophorone	mg/kg dry wt	-	-	-	< 0.10	-
Total Petroleum Hydrocarbons in Solids						
C7 - C9	mg/kg dry wt	-	-	-	< 30	-
C10 - C14	mg/kg dry wt	-	-	-	< 20	-
C15 - C36	mg/kg dry wt	-	-	-	47	-
Total hydrocarbons (C7 - C36)	mg/kg dry wt	-	-	-	< 90	-

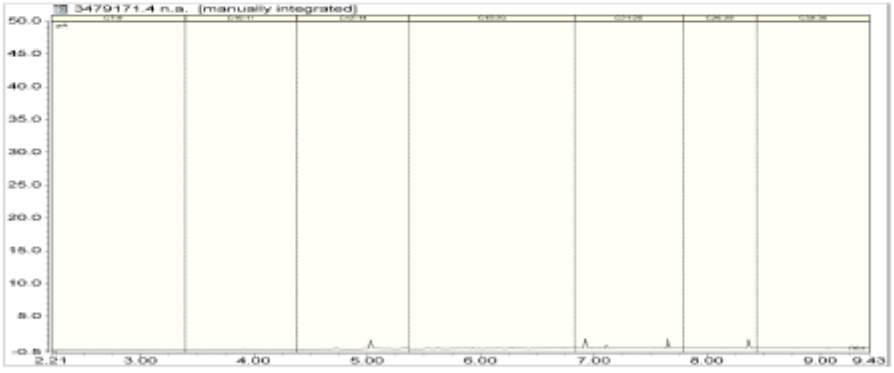
Sample Name:		T-2-2 25-Feb-2024	T-2-3 25-Feb-2024	T-2-1-C 25-Feb-2024
Lab Number:		3479171.6	3479171.7	3479171.8
Individual Tests				
Dry Matter	g/100g as rcvd	-	-	65
Total Recoverable Phosphorus	mg/kg dry wt	280	300	-
Total Nitrogen*	g/100g dry wt	0.03	0.04	-
Total Organic Carbon*	g/100g dry wt	0.19	0.29	-
Heavy metals, trace As,Cd,Cr,Cu,Ni,Pb,Zn,Hg				
Total Recoverable Arsenic	mg/kg dry wt	3.9	4.8	-
Total Recoverable Cadmium	mg/kg dry wt	0.036	0.043	-
Total Recoverable Chromium	mg/kg dry wt	10.6	11.2	-
Total Recoverable Copper	mg/kg dry wt	5.2	6.7	-
Total Recoverable Lead	mg/kg dry wt	6.1	17.7	-
Total Recoverable Mercury	mg/kg dry wt	0.03	0.04	-
Total Recoverable Nickel	mg/kg dry wt	12.0	13.3	-
Total Recoverable Zinc	mg/kg dry wt	36	39	-
7 Grain Sizes Profile as received*				
Dry Matter of Sieved Sample*	g/100g as rcvd	74	71	-
Fraction >/= 2 mm*	g/100g dry wt	0.1	0.3	-
Fraction < 2 mm, >/= 1 mm*	g/100g dry wt	0.4	0.6	-
Fraction < 1 mm, >/= 500 µm*	g/100g dry wt	5.5	3.9	-
Fraction < 500 µm, >/= 250 µm*	g/100g dry wt	20.8	26.9	-
Fraction < 250 µm, >/= 125 µm*	g/100g dry wt	12.0	19.9	-
Fraction < 125 µm, >/= 63 µm*	g/100g dry wt	29.1	18.6	-
Fraction < 63 µm*	g/100g dry wt	32.0	29.7	-
Organochlorine Pesticides Trace in Soil				
Aldrin	mg/kg dry wt	-	-	< 0.002
alpha-BHC	mg/kg dry wt	-	-	< 0.002
beta-BHC	mg/kg dry wt	-	-	< 0.002
delta-BHC	mg/kg dry wt	-	-	< 0.002
gamma-BHC (Lindane)	mg/kg dry wt	-	-	< 0.002
cis-Chlordane	mg/kg dry wt	-	-	< 0.002
trans-Chlordane	mg/kg dry wt	-	-	< 0.002
2,4'-DDD	mg/kg dry wt	-	-	< 0.002
4,4'-DDD	mg/kg dry wt	-	-	< 0.002

Sample Type: Sediment				
Sample Name:		T-2-2 25-Feb-2024	T-2-3 25-Feb-2024	T-2-1-C 25-Feb-2024
Lab Number:		3479171.6	3479171.7	3479171.8
Organochlorine Pesticides Trace in Soil				
2,4'-DDE	mg/kg dry wt	-	-	< 0.002
4,4'-DDE	mg/kg dry wt	-	-	< 0.002
2,4'-DDT	mg/kg dry wt	-	-	< 0.002
4,4'-DDT	mg/kg dry wt	-	-	< 0.002
Total DDT Isomers	mg/kg dry wt	-	-	< 0.012
Dieldrin	mg/kg dry wt	-	-	< 0.002
Endosulfan I	mg/kg dry wt	-	-	< 0.002
Endosulfan II	mg/kg dry wt	-	-	< 0.002
Endosulfan sulphate	mg/kg dry wt	-	-	< 0.002
Endrin	mg/kg dry wt	-	-	< 0.002
Endrin aldehyde	mg/kg dry wt	-	-	< 0.002
Endrin ketone	mg/kg dry wt	-	-	< 0.002
Heptachlor	mg/kg dry wt	-	-	< 0.002
Heptachlor epoxide	mg/kg dry wt	-	-	< 0.002
Hexachlorobenzene	mg/kg dry wt	-	-	< 0.002
Methoxychlor	mg/kg dry wt	-	-	< 0.002
Polycyclic Aromatic Hydrocarbons Trace in Soil*				
Total of Reported PAHs in Soil	mg/kg dry wt	-	-	0.17
1-Methylnaphthalene	mg/kg dry wt	-	-	< 0.003
2-Methylnaphthalene	mg/kg dry wt	-	-	0.002
Acenaphthene	mg/kg dry wt	-	-	< 0.003
Acenaphthylene	mg/kg dry wt	-	-	< 0.003
Anthracene	mg/kg dry wt	-	-	0.003
Benzo[a]anthracene	mg/kg dry wt	-	-	0.011
Benzo[a]pyrene (BAP)	mg/kg dry wt	-	-	0.016
Benzo[b]fluoranthene + Benzo[j] fluoranthene	mg/kg dry wt	-	-	0.017
Benzo[e]pyrene	mg/kg dry wt	-	-	0.009
Benzo[g,h,i]perylene	mg/kg dry wt	-	-	0.011
Benzo[k]fluoranthene	mg/kg dry wt	-	-	0.006
Chrysene	mg/kg dry wt	-	-	0.010
Dibenzo[a,h]anthracene	mg/kg dry wt	-	-	0.002
Fluoranthene	mg/kg dry wt	-	-	0.019
Fluorene	mg/kg dry wt	-	-	< 0.003
Indeno(1,2,3-c,d)pyrene	mg/kg dry wt	-	-	0.010
Naphthalene	mg/kg dry wt	-	-	< 0.011
Perylene	mg/kg dry wt	-	-	0.013
Phenanthrene	mg/kg dry wt	-	-	0.009
Pyrene	mg/kg dry wt	-	-	0.026
Benzo[a]pyrene Potency Equivalency Factor (PEF) NES*	mg/kg dry wt	-	-	0.023
Benzo[a]pyrene Toxic Equivalence (TEF)*	mg/kg dry wt	-	-	0.023
Haloethers Trace in SVOC Soil Samples by GC-MS				
Bis(2-chloroethoxy) methane	mg/kg dry wt	-	-	< 0.10
Bis(2-chloroethyl)ether	mg/kg dry wt	-	-	< 0.10
Bis(2-chloroisopropyl)ether	mg/kg dry wt	-	-	< 0.10
4-Bromophenyl phenyl ether	mg/kg dry wt	-	-	< 0.10
4-Chlorophenyl phenyl ether	mg/kg dry wt	-	-	< 0.10
Nitrogen containing compounds Trace in SVOC Soil Samples, GC-MS				
N-Nitrosodiphenylamine + Diphenylamine	mg/kg dry wt	-	-	< 0.17
2,4-Dinitrotoluene	mg/kg dry wt	-	-	< 0.2
2,6-Dinitrotoluene	mg/kg dry wt	-	-	< 0.2
Nitrobenzene	mg/kg dry wt	-	-	< 0.10
N-Nitrosodi-n-propylamine	mg/kg dry wt	-	-	< 0.17

Sample Type: Sediment				
Sample Name:		T-2-2 25-Feb-2024	T-2-3 25-Feb-2024	T-2-1-C 25-Feb-2024
Lab Number:		3479171.6	3479171.7	3479171.8
Organochlorine Pesticides Trace in SVOC Soil Samples by GC-MS				
Aldrin	mg/kg dry wt	-	-	< 0.9
alpha-BHC	mg/kg dry wt	-	-	< 0.10
beta-BHC	mg/kg dry wt	-	-	< 0.10
delta-BHC	mg/kg dry wt	-	-	< 0.10
gamma-BHC (Lindane)	mg/kg dry wt	-	-	< 0.10
4,4'-DDD	mg/kg dry wt	-	-	< 0.10
4,4'-DDE	mg/kg dry wt	-	-	< 0.10
4,4'-DDT	mg/kg dry wt	-	-	< 0.2
Dieldrin	mg/kg dry wt	-	-	< 0.10
Endosulfan I	mg/kg dry wt	-	-	< 0.2
Endosulfan II	mg/kg dry wt	-	-	< 0.5
Endosulfan sulphate	mg/kg dry wt	-	-	< 0.2
Endrin	mg/kg dry wt	-	-	< 0.17
Endrin ketone	mg/kg dry wt	-	-	< 0.2
Heptachlor	mg/kg dry wt	-	-	< 0.10
Heptachlor epoxide	mg/kg dry wt	-	-	< 0.10
Hexachlorobenzene	mg/kg dry wt	-	-	< 0.10
Polycyclic Aromatic Hydrocarbons Trace in SVOC Soil Samples*				
Acenaphthene	mg/kg dry wt	-	-	< 0.10
Acenaphthylene	mg/kg dry wt	-	-	< 0.10
Anthracene	mg/kg dry wt	-	-	< 0.10
Benzo[a]anthracene	mg/kg dry wt	-	-	< 0.10
Benzo[a]pyrene (BAP)	mg/kg dry wt	-	-	< 0.10
Benzo[b]fluoranthene + Benzo[j] fluoranthene	mg/kg dry wt	-	-	< 0.10
Benzo[g,h,i]perylene	mg/kg dry wt	-	-	< 0.10
Benzo[k]fluoranthene	mg/kg dry wt	-	-	< 0.10
1&2-Chloronaphthalene	mg/kg dry wt	-	-	< 0.10
Chrysene	mg/kg dry wt	-	-	< 0.10
Dibenzo[a,h]anthracene	mg/kg dry wt	-	-	< 0.10
Fluoranthene	mg/kg dry wt	-	-	< 0.10
Fluorene	mg/kg dry wt	-	-	< 0.10
Indeno(1,2,3-c,d)pyrene	mg/kg dry wt	-	-	< 0.10
2-Methylnaphthalene	mg/kg dry wt	-	-	< 0.10
Naphthalene	mg/kg dry wt	-	-	< 0.10
Phenanthrene	mg/kg dry wt	-	-	< 0.10
Pyrene	mg/kg dry wt	-	-	< 0.10
Benzo[a]pyrene Potency Equivalency Factor (PEF) NES*	mg/kg dry wt	-	-	< 0.25
Benzo[a]pyrene Toxic Equivalence (TEF)*	mg/kg dry wt	-	-	< 0.25
Phenols Trace in SVOC Soil Samples by GC-MS				
4-Chloro-3-methylphenol	mg/kg dry wt	-	-	< 0.5
2-Chlorophenol	mg/kg dry wt	-	-	< 0.2
2,4-Dichlorophenol	mg/kg dry wt	-	-	< 0.2
2,4-Dimethylphenol	mg/kg dry wt	-	-	< 0.4
3 & 4-Methylphenol (m- + p-cresol)	mg/kg dry wt	-	-	< 0.4
2-Methylphenol (o-cresol)	mg/kg dry wt	-	-	< 0.2
2-Nitrophenol	mg/kg dry wt	-	-	< 0.4
Pentachlorophenol (PCP)	mg/kg dry wt	-	-	< 6
Phenol	mg/kg dry wt	-	-	< 0.2
2,4,5-Trichlorophenol	mg/kg dry wt	-	-	< 0.2
2,4,6-Trichlorophenol	mg/kg dry wt	-	-	< 0.2
Plasticisers Trace in SVOC Soil Samples by GC-MS				
Bis(2-ethylhexyl)phthalate	mg/kg dry wt	-	-	< 0.5

Sample Type: Sediment				
Sample Name:		T-2-2 25-Feb-2024	T-2-3 25-Feb-2024	T-2-1-C 25-Feb-2024
Lab Number:		3479171.6	3479171.7	3479171.8
Plasticisers Trace in SVOC Soil Samples by GC-MS				
Butylbenzylphthalate	mg/kg dry wt	-	-	< 0.2
Di(2-ethylhexyl)adipate	mg/kg dry wt	-	-	< 0.2
Diethylphthalate	mg/kg dry wt	-	-	< 0.2
Dimethylphthalate	mg/kg dry wt	-	-	< 0.2
Di-n-butylphthalate	mg/kg dry wt	-	-	< 0.2
Di-n-octylphthalate	mg/kg dry wt	-	-	< 0.2
Other Halogenated compounds Trace in SVOC Soil Samples by GC-MS				
1,2-Dichlorobenzene	mg/kg dry wt	-	-	< 0.17
1,3-Dichlorobenzene	mg/kg dry wt	-	-	< 0.17
1,4-Dichlorobenzene	mg/kg dry wt	-	-	< 0.17
Hexachlorobutadiene	mg/kg dry wt	-	-	< 0.17
Hexachloroethane	mg/kg dry wt	-	-	< 0.17
1,2,4-Trichlorobenzene	mg/kg dry wt	-	-	< 0.10
Other SVOC Trace in SVOC Soil Samples by GC-MS				
Benzyl alcohol	mg/kg dry wt	-	-	< 1.0
Carbazole	mg/kg dry wt	-	-	< 0.10
Dibenzofuran	mg/kg dry wt	-	-	< 0.10
Isophorone	mg/kg dry wt	-	-	< 0.10
Total Petroleum Hydrocarbons in Solids				
C7 - C9	mg/kg dry wt	-	-	< 30
C10 - C14	mg/kg dry wt	-	-	< 20
C15 - C36	mg/kg dry wt	-	-	< 40
Total hydrocarbons (C7 - C36)	mg/kg dry wt	-	-	< 90

3479171.4
T-1-1-C 24-Feb-2024
Client Chromatogram for TPH by FID



Summary of Methods

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively simple matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis. A detection limit range indicates the lowest and highest detection limits in the associated suite of analytes. A full listing of compounds and detection limits are available from the laboratory upon request. Unless otherwise indicated, analyses were performed at Hill Labs, 28 Duke Street, Frankton, Hamilton 3204.

Sample Type: Sediment			
Test	Method Description	Default Detection Limit	Sample No
Individual Tests			
Environmental Solids Sample Drying*	Air dried at 35°C Used for sample preparation. May contain a residual moisture content of 2-5%.	-	1-3, 5-7
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%.	-	1-3, 5-7

Sample Type: Sediment			
Test	Method Description	Default Detection Limit	Sample No
Soil Prep Dry for Organics,Trace*	Air dried at 35°C Used for sample preparation. May contain a residual moisture content of 2-5%.	-	4, 8
Dry Matter	Dried at 103°C for 4-22hr (removes 3-5% more water than air dry) , gravimetry. (Free water removed before analysis, non-soil objects such as sticks, leaves, grass and stones also removed). US EPA 3550.	0.10 g/100g as rcvd	4, 8
Total Recoverable digestion	Nitric / hydrochloric acid digestion. US EPA 200.2.	-	1-3, 5-7
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	1-3, 5-7
Total Nitrogen*	Catalytic Combustion (900°C, O2), separation, Thermal Conductivity Detector [Elementar Analyser].	0.02 g/100g dry wt	1-3, 5-7
Total Organic Carbon*	Acid pretreatment to remove carbonates present followed by Catalytic Combustion (O2), separation, Thermal Conductivity Detector [Elementar Analyser].	0.05 g/100g dry wt	1-3, 5-7
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	1-3, 5-7
Organochlorine Pesticides Trace in Soil	Sonication extraction, GC-ECD analysis. In-house based on US EPA 8081.	0.0010 - 0.006 mg/kg dry wt	4, 8
Polycyclic Aromatic Hydrocarbons Trace in Soil*	Sonication extraction, GC-MS/MS analysis. Tested on as received sample. In-house based on US EPA 8270.	0.002 - 0.03 mg/kg dry wt	4, 8
Semivolatile Organic Compounds Trace in Soil by GC-MS	Sonication extraction, GC-MS analysis. Tested on as received sample. In-house based on US EPA 8270.	0.10 - 6 mg/kg dry wt	4, 8
7 Grain Sizes Profile as received			
Dry Matter for Grainsize samples (sieved as received)*	Drying for 16 hours at 103°C, gravimetry (Free water removed before analysis).	0.10 g/100g as rcvd	1-3, 5-7
Fraction >/= 2 mm*	Wet sieving with dispersant, as received, 2.00 mm sieve, gravimetry.	0.1 g/100g dry wt	1-3, 5-7
Fraction < 2 mm, >/= 1 mm*	Wet sieving using dispersant, as received, 2.00 mm and 1.00 mm sieves, gravimetry (calculation by difference).	0.1 g/100g dry wt	1-3, 5-7
Fraction < 1 mm, >/= 500 µm*	Wet sieving using dispersant, as received, 1.00 mm and 500 µm sieves, gravimetry (calculation by difference).	0.1 g/100g dry wt	1-3, 5-7
Fraction < 500 µm, >/= 250 µm*	Wet sieving using dispersant, as received, 500 µm and 250 µm sieves, gravimetry (calculation by difference).	0.1 g/100g dry wt	1-3, 5-7
Fraction < 250 µm, >/= 125 µm*	Wet sieving using dispersant, as received, 250 µm and 125 µm sieves, gravimetry (calculation by difference).	0.1 g/100g dry wt	1-3, 5-7
Fraction < 125 µm, >/= 63 µm*	Wet sieving using dispersant, as received, 125 µm and 63 µm sieves, gravimetry (calculation by difference).	0.1 g/100g dry wt	1-3, 5-7
Fraction < 63 µm*	Wet sieving with dispersant, as received, 63 µm sieve, gravimetry (calculation by difference).	0.1 g/100g dry wt	1-3, 5-7
Total Petroleum Hydrocarbons in Solids			
Client Chromatogram for TPH by FID	Small peaks associated with QC compounds may be visible in chromatograms with low TPH concentrations. QC peaks are as follows: one peak in the C12 - 14 band, the C21 - 25 band and the C30 - 36 band. All QC peaks are corrected for in the reported TPH concentrations.	-	4
C7 - C9	Solvent extraction, GC-FID analysis. In-house based on US EPA 8015.	20 mg/kg dry wt	4, 8
C10 - C14	Solvent extraction, GC-FID analysis. Tested on as received sample. In-house based on US EPA 8015.	20 mg/kg dry wt	4, 8
C15 - C36	Solvent extraction, GC-FID analysis. Tested on as received sample. In-house based on US EPA 8015.	40 mg/kg dry wt	4, 8
Total hydrocarbons (C7 - C36)	Calculation: Sum of carbon bands from C7 to C36. In-house based on US EPA 8015.	70 mg/kg dry wt	4, 8

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

Testing was completed between 26-Feb-2024 and 16-Apr-2024. For completion dates of individual analyses please contact the laboratory.

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

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