Harbour and Estuary Ecology State and Trends in Tāmaki Makaurau / Auckland to 2023

State of the Environment Reporting

Tarn P. Drylie

August 2025 Technical Report 2025/15

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Cover image credit

Mahurangi Harbour sandflat inhabitants (photograph by Tarn Drylie) and arriving on site to sample in Manukau Harbour (photograph by Jonathan De Villiers).

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The author wishes to acknowledge the many people that have contributed to collecting and analysing field samples for this programme over the decades, and the peer reviewers (Dr Michael Townsend and Sage Vernall) for their time and feedback which improved this report.

Executive summary

Tāmaki Makaurau / Auckland is predominantly marine, with varied seascapes making up roughly 70 per cent (11,117 km^2) of the region's territorial area. Estuaries (ranging from large, traversable harbours to small estuaries and inlets) make up two thirds of the coastline and are the focus of this report.

Population growth and the intensification of land use puts pressure on the natural environment. In estuaries, these pressures mostly occur in the form of pollution from excess sediment, nutrients and contaminants (like metals and organic chemicals), and modification of the natural coastline. This report presents technical information describing the current ecological state (or 'health') of the estuaries in Tāmaki Makaurau and how this has changed over time, making connections to the influence of land-derived pressures.

Monitoring focused on benthic ecosystems (those associated with the seafloor rather than the water column) in the intertidal zone (the area that is periodically covered and uncovered by the tides) because of their high ecological value and because their physical and biological components are responsive to land-derived pressures. We sampled sandflat characteristics (such as the proportion of mud and organic content) and sediment-dwelling invertebrates (i.e. macrofauna), which have limited mobility and known preferences and sensitivities that make them useful as indicator species.

A total of 172 monitoring sites from across 15 estuaries had benthic ecology data available for assessment of current state (drawing from Auckland Council's Harbour Ecology, East Coast Estuaries Ecology and Regional Sediment Contaminant Monitoring Programmes). According to the Combined Health Score, only 2 per cent of the monitored sites were in 'Excellent' overall health and 22 per cent were 'Good'. Sites most commonly had 'Fair' (34 per cent) or 'Marginal' (30 per cent) health and 12 per cent of sites were 'Poor'.

Excess land-derived sediment (silts and clays which are referred to as 'mud' in the estuary) continued to be the most prevalent and severe pressure on benthic environments across Tāmaki Makaurau. All sites that had 'Excellent' overall health also had less than 3 per cent sediment mud content, and all sites that were in 'Poor' health had at least 30 per cent mud content. Every monitored estuary exhibited at least moderate impacts from sediment and long-term degrading conditions at one monitoring site or more. Fewer estuaries (eight out of 14) were impacted by metal contamination and in several locations (namely Māngere Inlet, Waitematā Harbour tidal creeks and Tāmaki Estuary) the impact of metals on the health of the benthic community had decreased over the long-term. Ecological health may have been impacted by excess nutrient concentrations at sites in seven of the monitored estuaries (up from three in the last state and trends report), though this requires further investigation given limitations of the (indirect) indicators used to identify nutrient impacts.

Health state and trends varied by location. It was most common for ecological condition to have degraded and for overall health to be poor (as was the case for Mahurangi Harbour, Pūhoi River and Mangemangeroa Creek, for example). Management interventions need to focus on reducing the pressures on these estuaries, such as minimising the input of pollutants from land-based activities. The main basin of Manukau Harbour, Whangateau Harbour and sites beyond the estuary mouth in Tūranga Creek had limited degrading trends and were in largely good ecological health. For these locations, management efforts should focus on protection and conservation. A similar approach might be recommended for estuaries where ecological health was mostly poor but improving trends were detected (like Tāmaki Estuary and the tidal creeks of Manukau Harbour), though active restoration may increase their recovery rate.

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1 Introduction

Tāmaki Makaurau / Auckland is a predominantly marine region with roughly 70 per cent (11,117 km^2) of our territorial area being made up of estuaries, bays and coastal seas (Auckland Regional Council, 2010). This vast marine environment is characterised by varied seascapes including large shallow harbours, small winding estuaries, black sand surf beaches and offshore islands, split between the sheltered east and rugged west coasts. This variety provides the setting for a great diversity of marine ecosystems, though estuaries and small inlets make up two thirds of the Tāmaki Makaurau coastline and are the focus of this report.

Many Aucklanders value biodiversity and feel a sense of connectedness with nature (Ovenden & Roberts, 2021), and the Auckland Plan 2050 identifies our marine environments as taonga to be protected. However, Tāmaki Makaurau houses the largest population of people in the country; 1.7 million people resided in the region in 2023, equivalent to 33 per cent of Aotearoa / New Zealand's population (Stats NZ, 2024). Such a large population challenges the protection and enhancement of marine environments as population growth is a major driver of the pressures placed on the environment, particularly via the intensification of land use (including urbanisation) (Ministry for the Environment and Stats NZ, 2025). In estuaries, these pressures are mostly felt in the form of pollution (from excess land-derived sediment, contaminants like metals and organic chemicals, and excess nutrients from food production) and modification of the natural coastline (for land reclamation, construction of roads, building of flood barriers, etc.).

Pollution and habitat modifications impact the ecological health of estuaries, reducing their capacity to provide ecosystem services such as climate regulation, food production, nutrient and water cycling, and provision of cultural and recreational opportunities (Snelgrove et al., 2014; Thrush et al., 2013). An unhealthy estuary is also less resilient to disturbances, whether natural or anthropogenic (i.e., man-made) (Drylie et al., 2020; Thrush et al., 2003). This is important in the context of global climate change, another important driver of environmental change that can amplify the effects of other drivers and pressures (Ministry for the Environment and Stats NZ, 2025). Expected climate-driven changes in Tāmaki Makaurau include an increase in annual and seasonal mean temperatures with more hot days (greater than 25°C) per year, and increases in annual heavy rainfall (Macara et al., 2024). Evidence of such change already seems apparent, with frequent and persistent marine heat waves since 2017 (Shears et al., 2024) and record-breaking extreme weather events in early 2023 (Lorrey et al., 2025).

The multitude of pressures that estuaries face can interact and accumulate (resulting in what are often referred to as 'cumulative impacts') such that predicting the consequences for ecosystem health is very difficult. Research increasingly teaches us that surprising ecological responses are likely, and that when looking for management solutions, a location-specific focus rather than broadscale, one-size-fits-all approaches are necessary (Gladstone-Gallagher et al., 2023; Ministry for the Environment, 2024; Rullens et al., 2022). Monitoring is an essential part of taking care of our estuarine environments, particularly long-term monitoring that provides an understanding of the state of our estuaries, how they are changing, why, and whether management responses have been effective in minimising impacts (Hewitt et al., 2016; Hewitt & Thrush, 2019).

1.1 Report purpose and objectives

The primary objective of this report is to provide technical information describing the current state of ecological health and how this has changed over the monitoring period in estuaries across Tāmaki Makaurau / Auckland. This forms part of a series of technical reports collectively addressing marine sediment contaminants (Allen, 2025) and coastal water quality (Kamke & Gadd, 2025) to comprehensively assess the state of Auckland's marine environment.

Te Kaunihera ō Tāmaki Makaurau / Auckland Council's estuary ecology monitoring programmes support the following national and regional objectives:

- Satisfy council's obligations under section 35a of the Resource Management Act 1991 (as amended) to monitor and report on the state of the environment.
- Help monitor the effectiveness of regional policy initiatives and strategies (as required under section 35b of the Resource Management Act).
- Provide evidence of how the council is protecting and enhancing the coastal environment (Local Government (Auckland Council) Act 2009) and specifically, evidence for the Environment and Cultural Heritage component of the Auckland Plan 2050.
- Support Māori in their role as kaitiaki to protect and enhance te mauri o te wai (the life supporting capacity of water).
- Assist with the identification of large scale and/or cumulative impacts of land use activities on estuary health.
- Provide baseline and regionally representative data to support sustainable management through the resource consent process and associated compliance monitoring for coastal environments.
- Provide robust data on estuary health to national environmental reporting initiatives.
- Continuously increase the availability of information for Aucklanders and promote awareness of estuary health issues in the region.

These objectives are enabled by the Auckland Unitary Plan (AUP) (Operative in Part) which provides direction to guide Auckland's growth and development while addressing challenges of population growth and environmental degradation. The main challenges and directions were unchanged following a revision of the Plan in 2022, though greater emphasis was placed on the impacts from and strategic approach to climate change, among other narrative changes.

1.2 Supporting information

This report is one of a series of technical publications prepared in support of *Te oranga o te taiao o Tāmaki Makaurau – The health of Tāmaki Makaurau Auckland's Natural Environment in 2025: a synthesis of Auckland Council State of the Environment reporting*.

All related reports (past and present) are published on the Knowledge Auckland website.

All data supporting this report can be requested through our Environment Auckland Data Portal and interactive dashboards of various regional council monitoring data, including estuary health data, can be found at the Land, Air, Water Aotearoa website.

Reports pertaining to the coastal environment include:

- *Beach change in the Auckland region: current state and trends,* TR2025/13
- *Coastal and estuarine water quality state and trends in Tāmaki Makaurau / Auckland 2024.* TR2025/19
- *East coast estuaries ecology state and trends in Tāmaki Makaurau / Auckland to 2023,* TR2025/10
    - the present report.
- *Harbour and estuary ecology state and trends in Tāmaki Makaurau / Auckland to 2023,* TR2025/15
    - this report contains a regional summary of all marine ecology monitoring including the East Coast Estuaries and Regional Sediment Contaminants programmes.
- *Marine sediment contaminant state and trends in Tāmaki Makaurau / Auckland 2004-2023,* TR2025/12
- *Tāmaki Makaurau / Auckland east coast subtidal reef monitoring report: 2007 to 2024*, TR2025/24
- *Tāmaki Makaurau / Auckland intertidal reef monitoring report: 2011 to 2024,* TR2025/25

2 Methods

2.1 Programme overview

The Harbour Ecology monitoring programme was initiated with Manukau Harbour in 1987 and progressively increased in response to information needs to include five sub-programmes covering the Mahurangi, Central Waitematā, Upper Waitematā and Kaipara Harbours (see Appendix 1: Monitored sites for details of site and harbour monitoring periods). The programme aims to provide a long-term, baseline understanding of the condition of regionally representative coastal habitats. A temporally nested sampling design is employed to monitor 'core' sites continuously (three to four times per year) and 'rotational' sites periodically (for two years every five years) allowing a robust and cost-effective way of monitoring temporal changes without sacrificing spatial representativeness (Table 1; Hewitt, 2000).

Monitoring focuses on benthic ecosystems (those associated with the seafloor rather than the water column) in the intertidal zone (the area that is periodically covered and uncovered by the tides) because of their high ecological value and because their physical and biological components are responsive to land-derived pressures. Sediment characteristics can be directly and indirectly influenced by anthropogenic activities (via sediment deposition or nutrient enrichment, for example) and affect the distribution of sediment-dwelling invertebrates (i.e. macrofauna). The macrofauna themselves translate information about the broader environment as they bridge seafloor and water column processes, they reflect local conditions thanks to their generally limited mobility, and in many cases, they have known preferences and sensitivities that make them useful as indicator species.

Estuary ecology data are also collected in the East Coast Estuaries Ecology programme and the Regional Sediment Contaminant Monitoring Programme (RSCMP). The East Coast Estuaries Ecology programme was initiated in 2001 in response to the growing human population and recognition of the potential threat associated with increased inputs of sediment to the smaller estuaries along the east coast. Sampling takes place twice per year at three core sites per estuary, and rotational sites are sampled roughly every five to 10 years as required (Table 1). A comprehensive analysis and assessment of sites monitored under this programme is presented in Drylie (2025) and an overview of the findings are included in this report to facilitate a regional summary.

The RSCMP monitors the quality of marine sediments against established guidelines and focuses on sheltered tidal creeks to complement and increase the coverage of the Harbour Ecology programme. Sites are concentrated in estuaries close to Auckland's urban centre (Manukau Harbour, Waitematā Harbour and Tāmaki Estuary) as the programme aims to detect contaminants largely derived from urban sources (such as metals like copper, lead and zinc). Sampling occurs every three to six years as contaminant concentrations usually exhibit a slow rate of change and the often-muddy sites need time to recover from the disturbance of sampling. The state of RSCMP sites according to benthic health indices are presented and reference is made to metal contaminant concentrations where relevant, though a detailed assessment of sediment contaminant state and trends can be found in Allen (2025).

Sites in the Harbour Ecology programme are largely sandy and located in the main bodies of the harbours and are therefore referred to as ‘sandflat’ sites, while the RSCMP sites are referred to as ‘tidal creek’ sites. This naming approach is less effective for the Upper Waitematā Harbour where most of the Harbour Ecology sites are also in sheltered, muddy creeks, though the distinction is still used because the RSCMP sites are further upstream and have slightly different monitoring objectives. In total, 172 sites spread across 15 estuaries had ecological data available for assessments of current state (Figure 1).

Table 1. Summary of the timing and frequency of sampling for monitored estuaries each year. Blue shaded cells indicate sampling occurs in that month. The East Coast Estuaries include Ōkura, Pūhoi, Waiwera, Ōrewa, Mangemangeroa, Tūranga, Waikōpua and Whangateau. RSCMP = Regional Sediment Contaminants Monitoring Programme.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Manukau		■				■				■		
Central Waitematā		■				■				■		
Kaipara	■			■			■			■		
Mahurangi	■			■			■			■		
Upper Waitematā		■			■			■			■	
East Coast Estuaries				■						■		
RSCMP*											■	

*Sampling only occurs every three to six years for RSCMP sites, not annually.

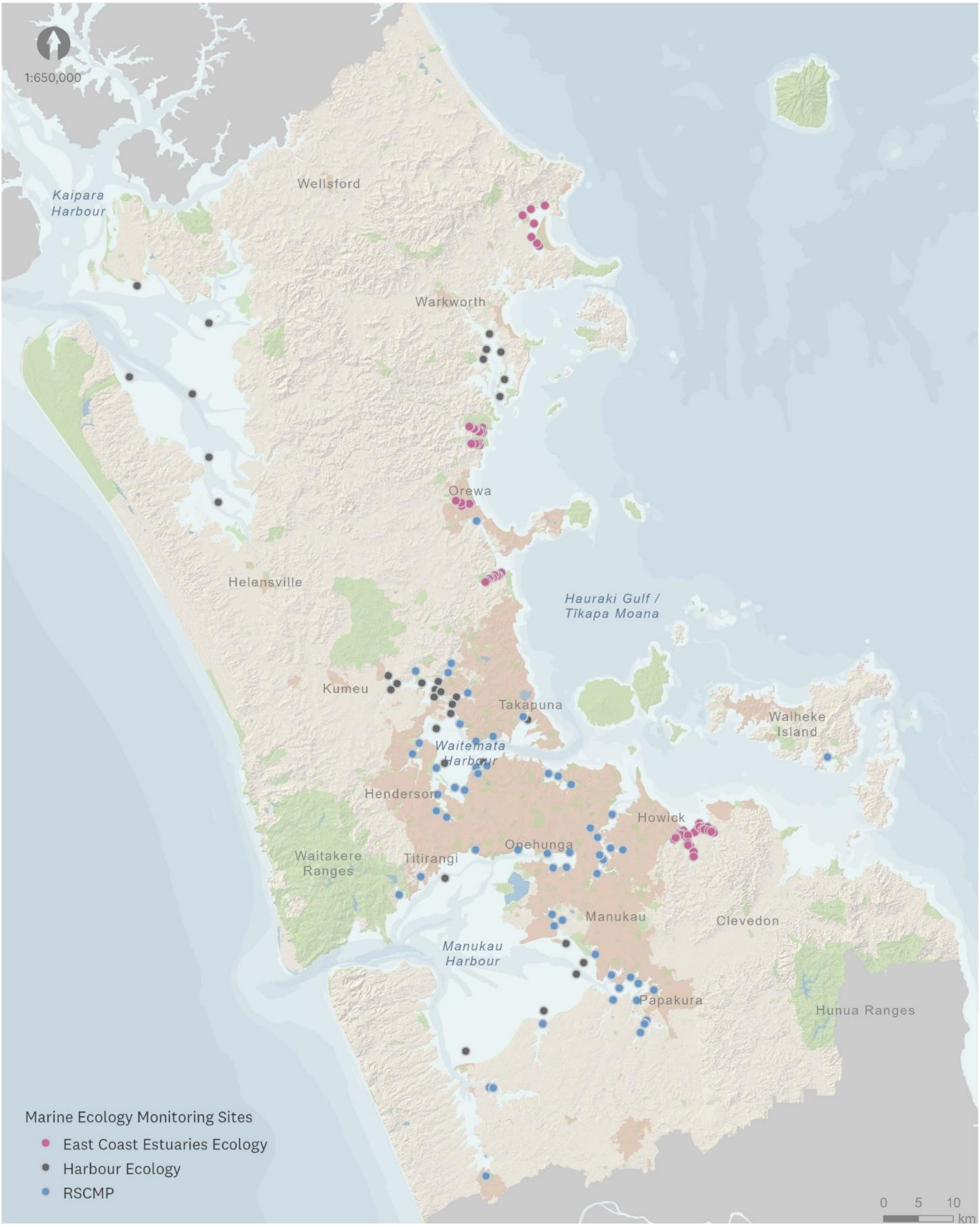

Figure 1. Location of sites featured in this report.

2.2 Data collection and analysis

2.2.1 Surface sediment characteristics

Composite samples of surface sediments were collected to characterise sites according to sediment grain size, organic content and chlorophyll *a* concentration (a proxy for the abundance of benthic microalgae). Six small cores (2 cm diameter, 2 cm deep) were collected randomly from across each site (adjacent to cores collected for macrofauna) and split into two sample jars (one for grain size and organic content analyses, the other for chlorophyll *a*). Samples were then stored frozen in the dark prior to the following laboratory analyses.

Grain size

Samples were homogenised before taking a 5 g subsample and digesting in 6 per cent hydrogen peroxide to remove organic matter. Wet sieving and pipette analysis were used to separate size fractions (Gatehouse, 1971), before drying at 60 °C until a constant weight. The results are presented as percentage composition of gravel/shell hash (>2 mm), coarse sand (500-2,000 μm), medium sand (250-500 μm), fine sand (125-250 μm), very fine sand (62.5-125 μm), silt (3.9-62.5 μm) and clay (<3.9 μm). Mud content is the sum of the silt and clay fractions.

Organic content

Approximately 5 g of sediment was placed in a dry, pre-weighed foil tray and dried at 60 °C until a constant weight was reached. The sample was then combusted at 400 °C for 5.5 h and reweighed (Mook & Hoskin, 1982). The results are presented as a percentage composition.

Chlorophyll a

Within one month of sampling, the full sample was freeze-dried, weighed, then homogenised and a roughly 0.5 g subsample taken for analysis. The pigments were extracted by boiling the sediment in 90 per cent ethanol (using an acidification step to separate chlorophyll *a* from degradation products) and the extracts were processed using a spectrophotometer (Sartory & Grobbelaar, 1984). The results are presented as the concentration of chlorophyll *a* per gram of dry weight sediment: μg/g dw sediment.

Assessing the state of sediment characteristics

The relationship between sediment mud content and macrofauna has been well researched in Aotearoa / New Zealand and empirically derived thresholds were used to assess the state of sediment quality relative to this regional indicator (Table 2). The thresholds in this report differ slightly from those in Drylie (2021) and were revised to match the categories used in the Land, Air, Water Aotearoa website's Estuary Health topic. The LAWA categories were more conservative (for instance the poorest category in Drylie (2021) was >80 per cent mud content and this was lowered to >60 per cent) which could result in an apparent decline in sediment quality.

Table 2. Thresholds for assessing state in relation to sediment mud content (as per Land, Air, Water Aotearoa).

Threshold	Rationale
≤3%	A small amount of mud is beneficial because the fine particles contain organic matter, which some macrofauna feed on. This means the most diverse macrofaunal communities are often found when there is around 3% mud content, but diversity starts to decline beyond this (Douglas et al., 2019).
3–10%	Macrofaunal communities are most resilient when mud content is less than 10% (Rodil et al., 2013).
10–30%	There are major declines in the resilience of macrofaunal communities between 10 and 25% mud content (Rodil et al., 2013), and communities are described as impoverished around 30% (Robertson et al., 2016).
30–60%	Macrofaunal communities are "unbalanced" (characterised by a reduced abundance of sensitive species and an increased abundance of tolerant species) when mud content is greater than 30% (Robertson et al., 2016).
>60%	Macrofaunal communities are degraded beyond 60% mud content (Rodil et al., 2013).

Suitable thresholds for assessing state according to sediment organic content (measured via loss on ignition techniques) or chlorophyll *a* concentrations were not available (Stevens et al., 2024), though these indicators provide useful information about the availability of food for the macrofaunal community and changes in their quantities can provide an indication of excess nutrients. A simultaneous increase in organic content and chlorophyll *a* may be caused by excess nutrients (provided light is not limiting) as nutrients fuel primary production and increase the amount of plant and algal material in the sediment.

Where available and relevant, reference is made to the sediment metal contaminant concentrations measured in samples taken for the RSCMP. Several sediment quality guidelines were available to assess the state of a site according to metal concentrations and are discussed thoroughly in Allen (2025). The Environmental Response Criteria (ERC) are conservative guidelines that were developed specifically for the Auckland region to interpret the likely ecological impact of copper, lead, and zinc concentrations (Auckland Regional Council, 2004) and are the only guidelines referenced in this report[1]. The ERC use a traffic light approach where the colours have the following interpretations:

- 'Green' – concentrations of the metal are low and not expected to impact the ecology of the site
- 'Amber' – concentrations of the metal are above the level at which adverse effects on benthic ecology may start to appear
- 'Red' – concentrations of the metal are elevated and adverse effects on benthic ecology are likely.

[1] The ERC are underpinned by international guidelines (such as the Thresholds Effect Level (MacDonald et al., 1996)). The Australian and New Zealand Guidelines for fresh and marine water quality (ANZG, 2018) are commonly used nationally, though these were not derived in New Zealand and do not represent conservative guidelines for early detection of degradation.

2.2.2 Macrofauna

For analysis of macrofauna, 12 large cores (13 cm in diameter x 15 cm deep) were collected at each site and sieved *in situ* over a 500 µm mesh. The material remaining on the sieve was washed into sample jars, stored in 70 per cent isopropyl alcohol, and stained with Rose of Bengal solution prior to sorting, identification and enumeration. A random sampling approach was used to ensure samples were not within a 5 m radius of each other or any samples from the preceding 12 months. The entire community was identified and enumerated from the samples collected during the October/November sampling to enable full community analyses (including assessment of species richness) and calculation of benthic health indices (see Section 2.2.3).

Macrofaunal community data were plotted using non-metric multi-dimensional scaling (nMDS) ordinations to visualise the (dis)similarities in community composition between sites. Data from the last ten years were plotted to identify recent changes in the composition of the community and highlight whether sites had become more alike (thus indicating an estuary-wide driver of change). Ordinations were based on square root-transformed data to reduce the influence of dominant species and Bray-Curtis similarity matrices. Trajectories showing the direction of change through time were overlaid for each site. When large shifts in community composition were apparent from the nMDS plots, a Similarity Percentage (SIMPER) analysis was performed to measure the contribution of individual species to the difference between years and identify those driving the shift. All plots and analyses were produced using the software PRIMER (v7) following Anderson et al., (2008).

For all other sampling occasions (other than October/November), a specific set of species were monitored in each harbour as they respond to relevant stressors, are important for biodiversity or ecosystem functioning, and occur in sufficient abundances to monitor change (hereafter "monitored species", see Appendix 2: Monitored species). Seven species with known sediment preferences (based on Norkko et al., (2001) and Gibbs and Hewitt (2004)) were common across all ecology programmes (including the East Coast Estuaries) and are referred to as "common species"; analysis of trends in the abundance of these species enabled regionwide trends in biodiversity (which may be driven by regionwide stressors) to be assessed. The common species were:

- the bivalves *Austrovenus stutchburyi*, *Macomona liliana* and *Linucula hartvigiana* (all prefer sand)
- the polychaetes *Aonides trifida* (strongly prefers sand), *Aricidea* sp. and *Prionospio aucklandica* (both prefer some mud)
- the gastropod *Notoacmea scapha* (strongly prefers sand).

Trends in the abundance of monitored species were only analysed for a site if there was a change in benthic health status or degrading health score trends that were to be investigated. Trends in the abundance of regionally common species were analysed for all sites (see Section 2.2.4).

2.2.3 Health indices

Benthic Health Models

Regional Benthic Health Models (BHMs) were developed to assess the health of macrofaunal communities relative to stormwater contaminants (total sediment copper, lead and zinc; BHMmetals) and sediment mud content (BHMmud) (see Anderson et al. (2006) and Hewitt and Ellis (2010)). The models are based on data from 95 unvegetated intertidal sites across the Auckland region encompassing tidal creeks, estuaries and harbours (but not exposed beaches) with a range of contaminant concentrations and mud content. Multivariate analyses of the variation in macrofaunal community composition related to each environmental variable were used to define scores relative to that variable. The composition of new samples is compared to the model data to obtain a score which is then allocated to one of five groups related to health. An increase in BHM score represents a degradation of health. As the BHMs were developed based on data from unvegetated sites, they are not suitable for assessing the health of sites dominated by seagrass or other vegetation.

Traits-Based Index

The functioning of benthic ecosystems is directly affected by benthic biodiversity (Belley & Snelgrove, 2016; Snelgrove et al., 2014; Thrush et al., 2006). To help understand these interactions, macrofauna can be categorised according to characteristics (traits) that are likely to influence function, e.g. their feeding mode (such as deposit or suspension feeding), mobility, size, living habit (such as free-living or tube dwelling), and so on. The Traits-Based Index (TBI) was developed based on the richness (count) of species exhibiting seven particular traits important for benthic ecosystem function: living in the top 2 cm of sediment, having an erect structure or tube, moving sediment around within the top 2 cm of the sediment column, being sedentary or only moving within a fixed tube, being a suspension feeder, being of medium size, or being worm shaped (Hewitt et al., 2012; Lohrer & Rodil, 2011; van Houte-Howes & Lohrer, 2010). Index values range from zero to one, with TBI scores less than 0.3 indicating low levels of functional redundancy and highly degraded sites, scores of 0.3 to 0.4 indicating intermediate conditions, and scores greater than 0.4 indicating high levels of functional redundancy. A site with a high level of functional redundancy is considered ‘healthy’ as environmental changes that affect the macrofaunal community tend to have a lesser impact on ecosystem function than a site with low functional redundancy.

Combined Health Score

The BHMs and TBI were combined into a single index, the Combined Health Score, to provide a complementary assessment of health (see Hewitt et al. (2012) for details). This index ranges from zero to one and an increase in score represents a degradation in health. While this score provides a helpful overview of site health, it loses some of the detail from the BHMs and TBI and can smooth over interesting dynamics between the indices. Scores assigned to the monitoring sites (whether BHM, TBI or the Combined Health Score) cannot be generalised to the whole estuary, which may have locations with better or worse health.

2.2.4 Identifying changes over time

Trend analysis

Changes in sediment characteristics, health indices and species abundances were analysed for each site to identify statistically significant trends. Details of the statistical approaches are given in Appendix 3: Trend analysis method and outlined briefly here. Trends were analysed for time series containing five or more data points only, as trends based on any fewer observations are likely to be unreliable. A total of 97 sites had sufficient data for trend analyses (see Appendix 1: Monitored sites) and there were 1475 unique site–variable combinations for analysis. In all cases, the complete time series was analysed to maximise our ability to detect patterns in the data that may influence trends.

Initially, scatterplots were inspected to identify suspected linear or non-linear trends, step changes, or other patterns. Only monotonic trends were investigated to focus on continuous, long-term change. Ordinary least squares (OLS) regression was used to analyse trends in datasets where the assumptions of OLS were met, whereas generalised least squares (GLS) regression was used if the assumption of homoscedasticity was violated. The slope of the regression indicated the trend magnitude (expressed in the units of the given variable), and the associated p-value was used to determine whether this was statistically significant ($p < 0.15$). For statistically significant trends, plots of residuals were inspected for any bias that might indicate multi-year cycles rather than long-term change and, in combination with scatterplots, used to identify the start and end of trends that occurred over only a portion of the time series. All trend analysis steps were performed in R Studio v4.3.1 (R Core Team, 2021).

Statistically significant trends were assigned a certainty score based on the regression p-value and the presence of multi-year cycles as follows:

- If $p < 0.05$ and no multi-year cycles are observed, the trend is considered "certain" and is assigned a score of 1.
- If p is between 0.05 and 0.1 OR $p < 0.05$ but multi-year cycles are observed, the trend is "less certain" and assigned a score of 0.5.
- If p is between 0.1 and 0.15 the trend is "uncertain" and assigned a score of 0.25.

This approach allows potential emerging trends to be highlighted while at the same time acknowledging there is a lack of confidence associated with them. As with all statistical analyses, there is some potential for Type 1 errors (or 'false positives', where the null hypothesis (of no significant trend) is incorrectly rejected). The likelihood of a Type 1 error occurring increases with higher p-values, such that applying a p-value of 0.15 is more likely to result in false positives than a p-value of 0.05. It is important to be cognizant of this when interpreting the emerging trend findings.

Recent changes

To identify recent changes that may represent an early warning of environmental degradation, qualitative comparisons are made to the results of Drylie (2021) and changes in the abundance of indicator species within the last five years are highlighted.

3 Results and Discussion

Results are first presented for each of the Harbour Ecology sub-programmes individually in Section 3.1 with an overview of the findings from the East Coast Estuaries Ecology programme in Section 3.2 (see Drylie (2025) for a comprehensive assessment of these estuaries). A regional summary of all results is then presented in Section 3.3.

3.1 Harbour Ecology

3.1.1 Kaipara

Kaipara Harbour is the largest estuary in Aotearoa / New Zealand and one of the biggest in the Southern Hemisphere. Roughly half of its 743 km^2 area falls under the jurisdiction of Auckland Council (the southern Kaipara Harbour) and has a catchment area of 1409 km^2 (according to Auckland Council's Consolidated Receiving Environment classification). Most of the freshwater discharge received by the harbour comes from the Wairoa River in Northland, which drains a much larger catchment area (Reeve et al., 2008).

The southern Kaipara catchment is rural and dominated by high producing exotic grassland with substantial areas of exotic forest (Auckland Council, 2025). Areas of cropland adjacent to the Te Ngaio Point monitoring site are notable, and the most significant urban area is associated with the Helensville settlement near the head of the Kaipara River. There were many instances of land use change since the last report, though these tended to be small scale and scattered evenly throughout the catchment. The most common changes were from exotic forest to harvested forest (and less frequently from harvested forest to exotic forest) and high producing exotic grassland to indigenous scrub/shrubland. There were some instances of exotic grassland becoming cropland (particularly in Tapora) or built-up areas, though these were relatively small in area.

The core monitoring sites in Kaipara Harbour are Kakaraia Flats, Ngapuke Creek, Kaipara Bank and Te Ngaio Point. Haratahi Creek and Kaipara Flats are rotational sites and were last sampled in 2021. There was significant encroachment and colonisation of Kakaraia Flats and Te Ngaio Point by the seagrass *Zostera muelleri* in the years since the previous state and trends report (Figure 2 and Figure 3).

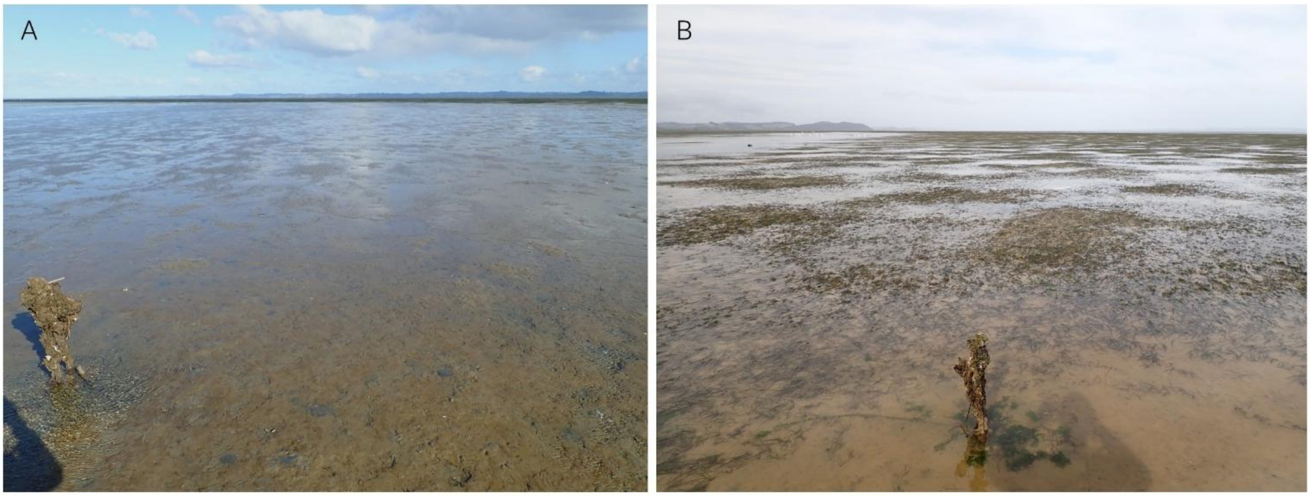

Figure 2. Kakaraia Flats in A) July 2020 (seagrass is visible in the distance) and B) July 2022 (seagrass covers the entire site).

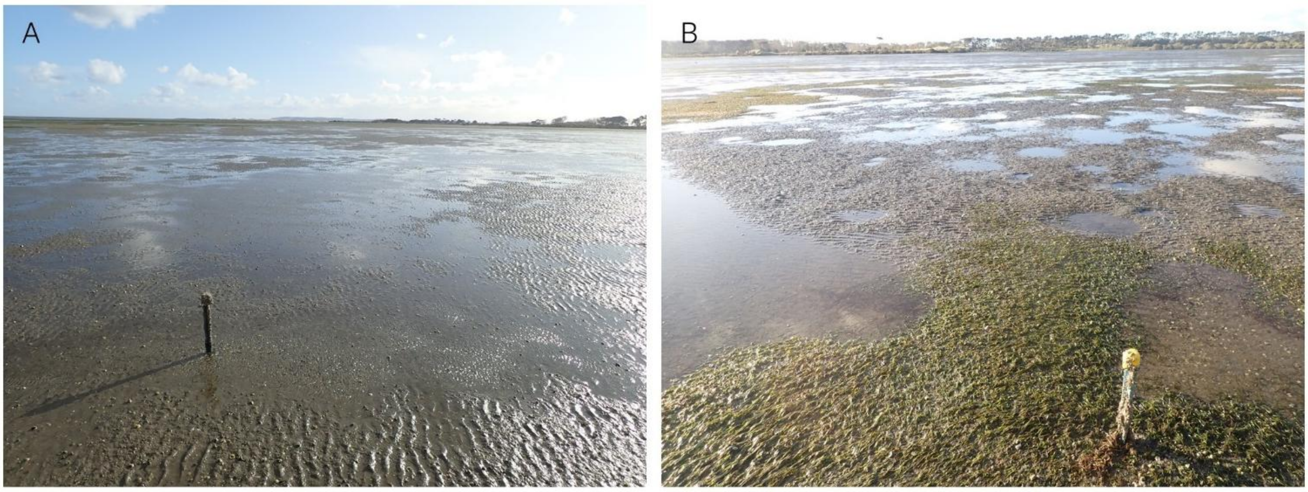

Figure 3. Te Ngaio Point in A) July 2020 (small patches of seagrass occurred at the edge of the site) and B) April 2023 (patches of seagrass cover the entire site).

Sediment characteristics

In 2021 and 2023, sediment mud content was less than 3 per cent at Haratahi Creek, Kaipara Flats and Ngapuke Creek and at such levels is unlikely to negatively impact ecological health (Figure 4). Sediment mud content was elevated at all other sites and was particularly high at Kaipara Bank; at levels such as these, mud content is likely to reduce the diversity and resilience of the macrofaunal community (Table 2). At several sites these results represented an increase in sediment mud content since the last report based on data up to 2019. For instance, mud content at Kaipara Bank increased from 27 per cent in 2019 to 43 per cent in 2023 and was much higher in 2023 than the median of the time series (Table 3). Interestingly, mud content had declined steadily at this site between 2019 and 2022 and the increases occurred in the months after the extreme weather events of early 2023 (Appendix 4: Figure A1); this suggests the increase in mud content was due to increased sediment loads from Kaipara River following the heavy rainfall events.

Notable increases in mud content also occurred between 2019 and 2023 at Kakaraia Flats (from 5 per cent to 13 per cent) and Te Ngaio Point (0.6 per cent to 3.7 per cent). There was some evidence of the 2023 weather events driving changes in mud content at Kakaraia Flats (Appendix 4: Figure A1 and Figure 5), though there was no abrupt increase in mud content at Te Ngaio Point and instead, the encroachment and increase in density of seagrass (*Zostera muelleri*) at both of these sites over the last few years likely contributed to the mud content increases. Metal contaminant concentrations (copper, lead, zinc, arsenic and mercury) were measured in 2019 and found to be well below sediment quality guidelines and notably, some of the lowest contaminant concentrations in the region were recorded in Kaipara Harbour.

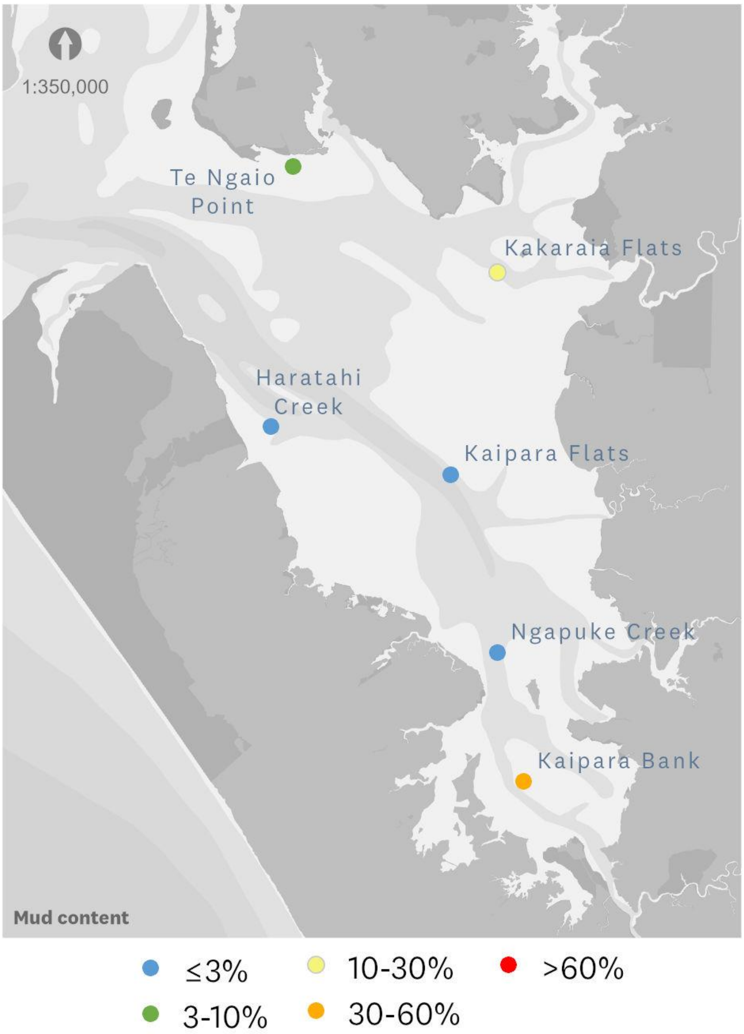

Figure 4. Sediment mud content at Kaipara Harbour monitoring sites in 2021 (rotational sites) and 2023 (core sites).

Table 3. Median values and temporal variation (standard deviation) of surface sediment characteristics at Kaipara monitoring sites between 2009 and 2023 (except Te Ngaio Point which is 2014–2019).

	Mud content (%)		Organic content (%)		Chl *a* (µg g^{-1} dw sediment)	
	Med	SD	Med	SD	Med	SD
Kakaraia Flats	3.69	3.83	1.09	0.6	8.54	2.22
Ngapuke Creek	2.18	2.54	0.79	0.48	5.68	1.51
Kaipara Bank	15.75	7.79	1.66	0.84	7.66	1.64
Te Ngaio Point	1.01	0.9	0.63	0.29	5.95	1.2
Haratahi Creek	0.52	0.43	0.72	0.35	8.71	2.1
Kaipara Flats	0.33	0.18	0.6	0.27	7.74	2.93

Figure 5. Sediment deposition at Kakaraia Flats in April 2023 (roughly two months after the Auckland Anniversary and Cyclone Gabrielle extreme weather events).

Significant long-term increases in sediment mud content occurred at all sites except Haratahi Creek and Kaipara Flats (Table 4 and Appendix 4: Figure A1). Organic content also increased over the monitoring period at several sites, though is only likely to be of concern at Kaipara Bank where chlorophyll *a* also increased and may reflect an excess nutrients issue. Large blooms of algae were observed in and around Kaipara Bank in 2022, providing further evidence of potential nutrient enrichment; in January, blooms of an unknown algae occurred in the subtidal channels approaching the site and in October, large quantities of the red seaweed *Gracilaria chilensis* were found on site (Figure 6). At Kakaraia Flats and Ngapuke Creek increasing organic content was likely caused by increases in terrestrial sediments (indicated by increasing mud content), and although this was not the case at Haratahi Creek, chlorophyll *a* was found to decrease over the same period that organic content increased so is unlikely to reflect excess nutrients.

Table 4. Direction of statistically significant trends in sediment characteristics at Kaipara monitoring sites between 2009 and 2023: ▲ represents an increase and ▼ a decrease. Grey cells indicate trends that are less certain or uncertain. New = this trend was not previously detected in Drylie (2021), Maintained = this trend was previously detected, Lost = a previously detected trend no longer occurs.

	Mud content (%)	Organic content (%)	Chl *a* ($\mu g\ g^{-1}$ dw sediment)
Kakaraia Flats	▲ New	▲ New	▼ Maintained
Ngapuke Creek	▲ Maintained	▲ Maintained	
Kaipara Bank	▲ Maintained	▲ Maintained	▲ New
Te Ngaio Point	▲ Maintained		Lost - previously ▲
Haratahi Creek		▲ Maintained	▼ Maintained
Kaipara Flats	Lost - previously ▲		▼ Maintained

Figure 6. Large blooms of the red seaweed, *Gracilaria chilensis*, at Kaipara Bank in October 2022.

Benthic health

Overall health according to the Combined Health Score was mostly 'Good', although two sites had 'Fair' health; Ngapuke Creek which is in the southern compartment of the harbour and Kakaraia Flats which is downstream of Hōteo River (Figure 7). The Kakaraia Flats site is now completely covered by seagrass and Benthic Health Models (BHMs) are unlikely to accurately assess health in such habitats. This may be the cause of the comparatively low Combined Health Score at Kakaraia Flats and as such, BHM state and trends are not presented or discussed any further for this site.

Most sites had 'Good' health in relation to mud (BHMmud), except Ngapuke Creek which was 'Fair'. Health degraded significantly at all sites except Kaipara Flats over the long term, with the new trend at Haratahi Creek being of particular concern (Table 5). The gradual degrading trends resulted in a decline in health group at Ngapuke Creek between 2019 ('Good') and 2023 ('Fair'), despite the low mud content measured at this site in 2023 (Figure 4).

Health with respect to metals (BHMmetals) was 'Good' at all sites, although there were several significant degrading trends over the long term (the new degrading trend at Te Ngaio Point might reflect the increasing coverage of seagrass across the site) (Table 5). Concerning recent changes occurred at Haratahi Creek and Kaipara Flats where health declined from 'Excellent' in 2019 to 'Good' in 2023. The BHMmetals health group oscillated between 'Excellent' and 'Good' at these sites since 2009 despite the low, stable concentrations of metal contaminants across the harbour (Mills and Allen (2021) and Allen (2025)). Functional resilience (as indicated by the Traits-Based Index (TBI)) was 'High' at all sites and had increased significantly over the monitoring period everywhere except Kaipara Flats. Most of the long-term trends were not previously detected (Table 5).

Figure 7. Combined Health Scores for Kaipara Harbour monitoring sites in 2021 (rotational sites) and 2023 (core sites).

Table 5. Benthic health groups at Kaipara Harbour monitoring sites in 2021 (rotational sites) and 2023 (core sites). Benthic Health Models (BHM): Excellent, Good, Fair, Marginal, Poor; Traits-Based Index (TBI): High, Intermediate, Low. Arrows show significant trends in index scores between 2009 and 2023: ▲ = health improved; ▼ = health degraded. New = this trend was not previously detected in Drylie (2021), Maintained = this trend was previously detected. An asterisk (*) indicates a degradation in benthic health group since the last report.

	BHMmud	BHMmetals	TBI
Kakaraia Flats	N/A	N/A	▲ New
Ngapuke Creek	▼* Maintained	▼ Maintained	▲ New
Kaipara Bank	▼ Maintained	▼ Maintained	▲ New
Te Ngaio Point	▼ Maintained	▼ New	▲ New
Haratahi Creek	▼ New	*	▲ Maintained
Kaipara Flats		*	

Macrofaunal community

Species richness was highest at Kakaraia Flats and Te Ngaio Point (and markedly higher than the average across the monitored harbours) (Figure 8). This was not unexpected given the colonisation of sandflats by seagrass has been shown to increase macrofaunal species diversity (Lundquist et al., 2018). At all other sites, species richness was close to the regional average and had increased over the monitoring period at Ngapuke Creek, Kaipara Bank and Haratahi Creek (Figure 8 and Appendix 5: Figure A6).

The non-metric multi-dimensional scaling (nMDS) plot had moderate to high stress and was useful for identifying patterns but not detailed interpretation. Te Ngaio Point was most dissimilar to the other sites in terms of macrofaunal community composition, and Kaipara Flats and Haratahi Creek were also distinct from the other sites (Figure 9). The remaining sites (Ngapuke Creek, Kakaraia Flats and Kaipara Bank) had quite similar communities, though over the last ten years directional shifts occurred at Kakaraia Flats such that it became less like Ngapuke Creek and more like Kaipara Bank in 2023, possibly due to the increase in sediment mud content.

There was little evidence of a shift in community composition at Ngapuke Creek between 2019 and 2023 that aligned with the change observed in BHMmud group (Figure 9). As the change in BHMmud group was caused by a gradual linear decline in BHMmud scores, as opposed to an abrupt change, it is likely the underpinning shifts in community composition were similarly subtle and incremental and difficult to detect. Slight shifts in community composition occurred between 2019 and 2020 at Haratahi Creek and Kaipara Flats, coinciding with degrading BHMmetals groups. Increases in the abundance of the opossum shrimp, Mysida, contributed to the community shifts at both sites, as well as decreases in the abundance of *Heteromastus filiformis* (which prefers some mud) at Haratahi Creek and Urothoidae at Kaipara Flats. As Mysids are reported to be sensitive to chemical contaminants and environmental perturbations (Oliveira et al., 2023) and increased in abundance at both sites, it is unlikely the change in community composition and decline in BHMmetals health group was caused by an increase in sediment contaminants. Despite this assurance, close monitoring of the BHMmetals is advised in the coming years.

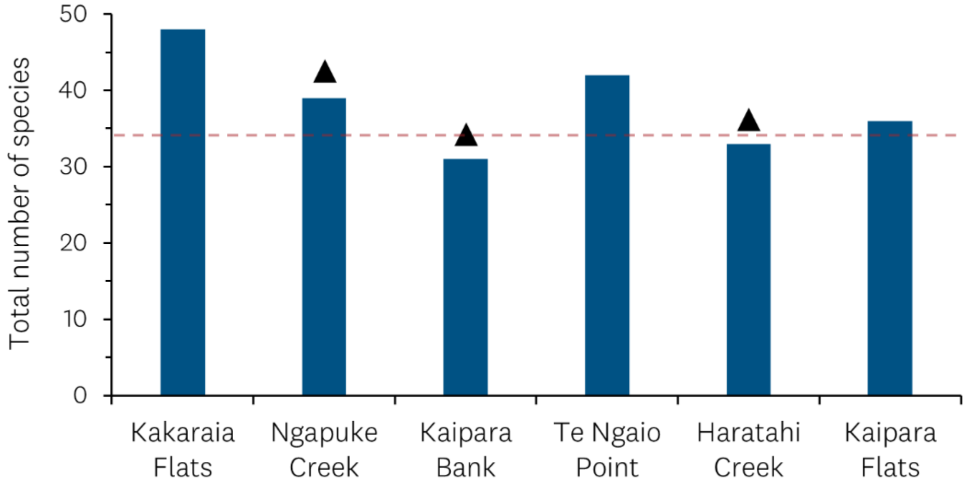

Figure 8. Species richness at Kaipara Harbour monitoring sites in 2021 (rotational sites) and 2023 (core sites). The dashed line shows the median species richness across all Harbour Ecology sites based on the latest available data. The direction of statistically significant trends between 2009 and 2023 are shown: ▲ represents an increase and ▼ a decrease.

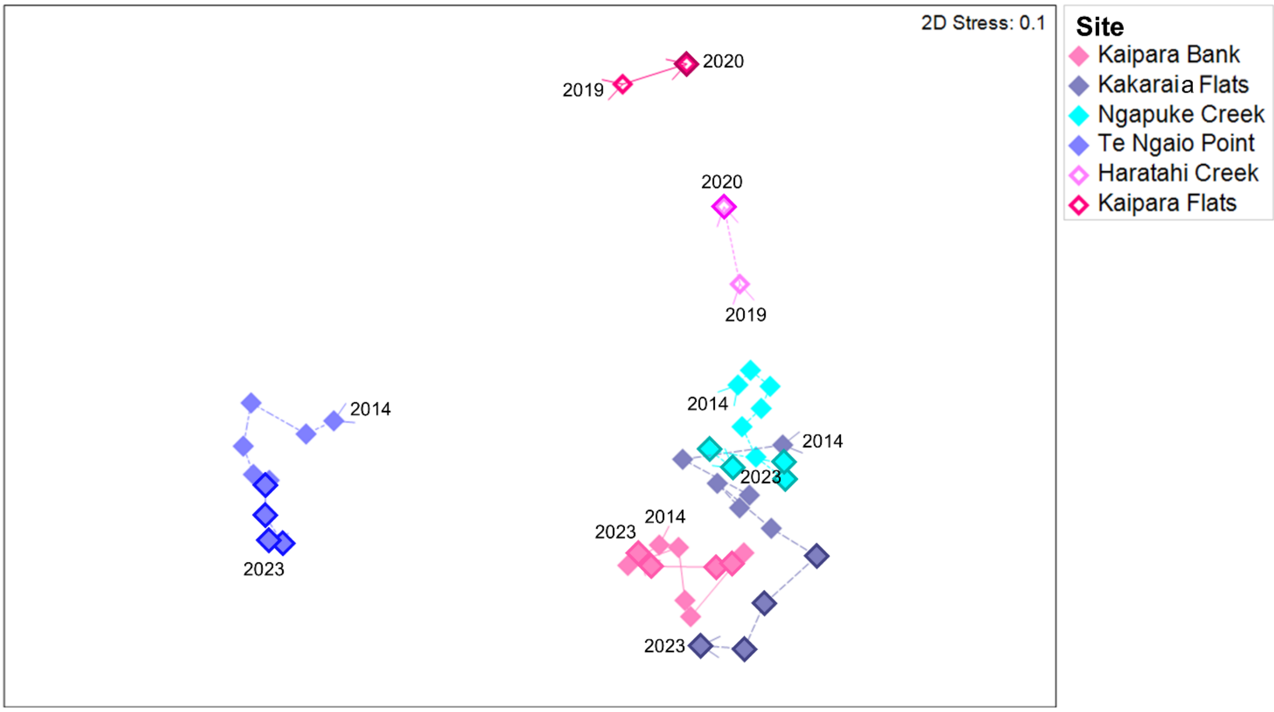

Figure 9. The similarity in macrofaunal community composition between Kaipara monitoring sites and changes over the last 10 years (2014 to 2023). Symbols are outlined to highlight new data since Drylie (2021).

Indicator species

Trend analysis was performed for indicator species at all sites given the widespread changes in sediment quality and benthic health indices. *Exosphaeroma planulum* did not occur frequently enough at any site to be suitable for trend analysis, and *Exosphaeroma waitemata* was only present frequently enough at Te Ngaio Point. These species should be removed from the monitored species list.

A high number of long-term trends consistent with sedimentation were found at Ngapuke Creek (Table 6), coinciding with increases in sediment mud content (Table 4). A moderate number of trends consistent with both sedimentation and metal contamination were found at Te Ngaio Point, supporting the degrading BHMmud and BHMmetals trends. Of the five metal-sensitive species that decreased significantly in abundance, four are known to be sensitive to lead (*Boccardia syrtis*, *Waitangi brevirostris*, *Magelona dakini* and *Macomona liliana*). Although sampling in 2019 did not find any evidence of elevated lead concentrations (Allen, 2025), this ecological response should be investigated further including considering activities in the surrounding catchment (which contains notable areas of cropland).

Recent changes in the abundance of several indicator species occurred at Kakaraia Flats and Kaipara Bank, mostly suggesting an improvement in environmental conditions. For example, since 2019 several species with a preference for sand increased in abundance at Kakaraia Flats (*Torridoharpinia hurleyi*, *Scoloplos cylindrifer* and *Notoacmea scapha*) and at Kaipara Bank, the sand-preferring *Torridoharpinia hurleyi* increased in abundance and the mud-preferring *Nicon aestuariensis* decreased (though this may later prove to be part of a multi-year cycle).

Table 6. Trends in the abundance of monitored and regionally common species at Kaipara monitoring sites between Oct. 2009 and Oct. 2023: ▲ = significant increase; ▼ = significant decrease. Arrows are coloured to highlight trends consistent with a particular stressor: sedimentation, metal contamination, or both. Grey cells indicate trends that are less certain or uncertain and sites exhibiting multi-year cycles (MY) are shown. An asterisk (*) indicates a recent change in abundance. Pref = sediment preference; SS = strong sand preference, S = prefers sand, M = prefers some mud, MM = strong mud preference, - = unknown. N/A = not assessed (occurrence and/or abundance too low).

Monitored species	Pref	Kakaraia Flats	Ngapuke Creek	Kaipara Bank	Te Ngaio Point	Haratahi Creek	Kaipara Flats
Boccardia syrtis	M	▲ MY	▲	▲ MY	▼ MY	N/A	N/A
Cossura consimilis	M	N/A	▲	▼	N/A	N/A	N/A
Clymenella stewartensis	M		▲			▲	
Nicon aestuariensis	M	▲	▲	▲ *	▲	N/A	N/A
Torridoharpinia hurleyi	S	*	N/A	*	▲ MY		N/A
Scoloplos cylindrifer	S	▲ *	N/A	N/A	N/A	N/A	N/A
Anthopleura hermaphroditica	S	N/A	▼ MY	▲	▲ MY		N/A
Orbinia papillosa	S		▲	N/A	▼ MY	N/A	
Owenia petersenae	S			N/A	N/A	N/A	N/A
Colurostylis lemurum	SS		▲ MY				
Waitangi brevirostris	SS	N/A	▼	N/A	▼		
Travisia novaezealandiae	SS	N/A	N/A	N/A			▲
Aglaophamus macroura	-	*	▲	▲	▼ MY	▲	
Euchone sp.	-	▼	N/A	N/A	N/A	N/A	N/A
Magelona dakini	-				▼		
Exosphaeroma waitemata	-	N/A	N/A	N/A		N/A	N/A
Taeniogyrus dendyi	-	▼	▼	N/A		▼ MY	▼
Hiatula siliquens	-	▼	▼ MY	▼	▼ MY	▼ MY	▼
Arcuatula senhousia	-	▲	▲ MY	▼ MY			N/A
Regionally common species							
Aricidea sp.	M	▲ MY	▲ MY	▲ MY			
Prionospio aucklandica	M		▲	▲ MY	▲ MY		N/A
Austrovenus stutchburyi	S		▼ MY		▲ MY		N/A
Linucula hartvigiana	S		▲	▲ MY	▲ MY		N/A
Macomona liliana	S			▼ MY	▼		
Aonides trifida	SS				▲ * MY		N/A
Notoacmea scapha	SS	▲ *	▼		▲		N/A
Trends consistent with sedimentation		3	10	4	5	1	0
Trends consistent with metals		1	2	1	5	0	0

Summary

In 2020 and 2023, health was ‘Good’ to ‘Fair’ in Kaipara Harbour. Health had degraded at most sites since 2009 (all except Kaipara Flats and Kakaraia Flats), yet species richness and functional resilience remained ‘High’.

Declines in sediment quality and macrofaunal community health at Kaipara Bank were of particular concern, even though some recent changes in indicator species suggested possible reductions in sedimentation stress. Evidence of potential nutrient enrichment was also detected at this site. Similarly, the steady increase in mud and decline in abundance of sediment-sensitive species at Ngapuke Creek resulted in a degradation in BHMmud group since the last report and may be a warning signal of a spreading impact from the Kaipara River.

Decreases in sediment quality and benthic health at Kakaraia Flats likely reflect the effect of seagrass colonisation that has occurred since 2019, given seagrass can stabilise and accumulate mud and the BHMs cannot reliably assess the health of vegetated sites. Alternative methods for assessing health at this site should be explored. There was some evidence of metal contamination impacting the macrofaunal community at Te Ngaio Point (despite very low sediment metal concentrations in 2019) which requires further investigation.

3.1.2 Manukau

Manukau Harbour is the second largest estuary in Aotearoa / New Zealand (with a surface area of 366 km^2) and drains a comparatively small catchment (916 km^2). The dominant catchment land use varies considerably around the harbour, with indigenous forest and scrub/shrubland to the north (part of the Waitākere Ranges), urban areas (including industry) to the east and exotic grassland and cropland to the south (including the Āwhitu peninsula) (Auckland Council, 2025). Since the last report, small pockets of change occurred throughout the east and south-east of the catchment with very little change to the north and west. Notably, there were several instances of exotic grassland becoming urban (built-up) area around Drury.

The core Harbour Ecology monitoring sites are Auckland Airport and Clarks Beach, with Cape Horn, Puhinui Stream, Karaka Point and Elletts Beach monitored on a rotational basis (and last sampled in 2021). In addition to the sandflat sites, data were available for 27 RSCMP tidal creek sites; results of the ecology sampling (sediment mud content and benthic health indices) are presented here, and Allen (2025) provides a detailed assessment of metal contaminant state and trends.

Sediment characteristics

Between 2020 and 2023, sediment mud content was less than 10 per cent at all sandflat sites and less than 3 per cent at Auckland Airport, Karaka Point, Puhinui Stream and Cape Horn (Figure 10). Sediment mud content state had not changed since last reported in Drylie (2021), nor had the long-term median or temporal variation (Table 7). Sediment mud content in the tidal creeks and transitional reaches of Manukau Harbour was at least 10 per cent and often greater than 60 per cent.

Sediment mud content decreased over the monitoring period at Karaka Point and Cape Horn (trends that were identified previously), and a new but uncertain decreasing trend with low magnitude was also detected at Clarks Beach (Table 8 and Appendix 4: Figure A2). The lack of any increasing trends suggests sedimentation has not been a notable stressor of any of the sandflat sites. See Allen (2025) for assessment of trends for the tidal creek sites.

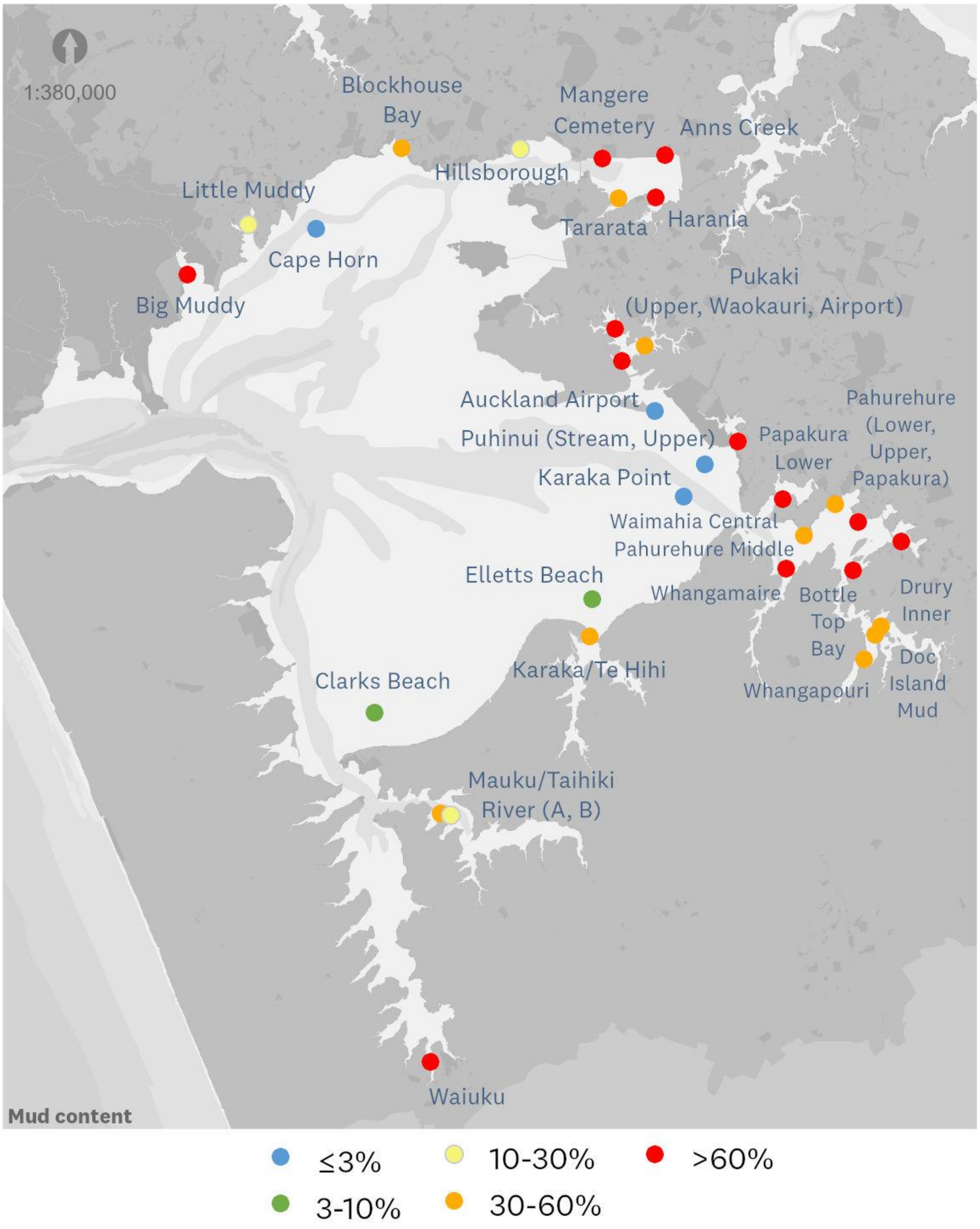

Figure 10. Sediment mud content at Manukau Harbour monitoring sites in 2020 (rotational sites) and 2023 (core sites).

The sandflat sites were organically poor over the monitoring period (median organic content was less than one per cent for all except Clarks Beach) (Table 7). However, several previously identified decreasing trends could no longer be detected due to increases in organic content between 2020 and 2022 (at all sites except Cape Horn) (Table 8 and Figure 11). Chlorophyll *a* concentrations decreased over the monitoring period at all sandflat sites except Auckland Airport and there were no recent changes that coincided with the increases in organic content. As such, further investigation is needed to determine whether the harbour-wide increases in organic matter were a symptom of excess nutrients or other broadscale drivers, such as climatic variability (Hailes & Hewitt (2009) showed that ecological variables in Manukau Harbour exhibit long-term cycles that are strongly correlated with the El Niño–Southern Oscillation, for instance).

Table 7. Median values and temporal variation (standard deviation) of surface sediment characteristics at Manukau monitoring sites between 1987 and 2023.

	Mud content (%)		Organic content (%)		Chl *a* (µg g^{-1} dw sediment)	
	Med	SD	Med	SD	Med	SD
Auckland Airport	0.87	1.42	0.61	0.24	9.83	2.62
Clarks Beach	4.79	4.72	1.19	0.52	11.01	4.49
Elletts Beach	6.22	6.98	1.01	0.66	11.55	3.4
Cape Horn	0.89	3.15	0.7	0.45	7.79	4.25
Karaka Point	2.55	3.46	0.8	0.3	6.99	3.04
Puhinui Stream	1.14	1.75	0.59	0.24	9.1	3.41

Table 8. Direction of statistically significant trends in sediment characteristics at Manukau monitoring sites between 1987 and 2023: ▲ represents an increase and ▼ a decrease. Grey cells indicate trends that are less certain or uncertain. New = this trend was not previously detected in Drylie (2021), Maintained = this trend was previously detected, Lost = a previously detected trend no longer occurs.

	Mud content (%)	Organic content (%)	Chl *a* (µg g^{-1} dw sediment)
Auckland Airport		Lost - previously ▼	
Clarks Beach	▼ New		▼ Maintained
Karaka Point	▼ Maintained	Lost - previously ▼	▼ Maintained
Puhinui Stream		Lost - previously ▼	▼ New
Elletts Beach		Lost - previously ▼	▼ Maintained
Cape Horn	▼ Maintained	▼ Maintained	▼ Maintained

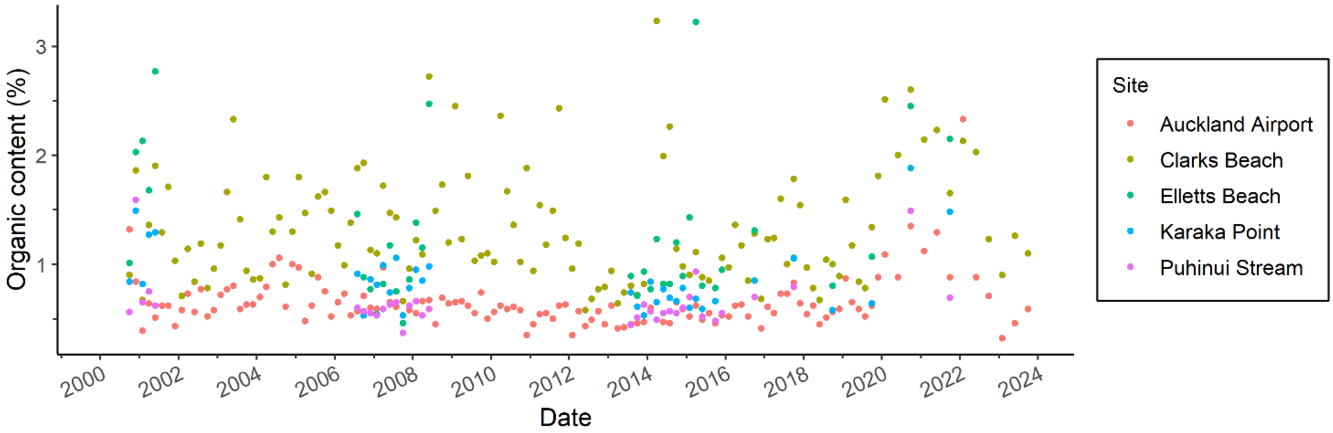

Figure 11. Sediment organic content in Manukau monitoring sites.

Metal contaminant concentrations were low at the tidal creek sites in 2021 (93 per cent of sites were in the green Environmental Response Criteria (ERC) category). Exceptions were Harania and Anns Creek in Māngere Inlet where zinc was elevated (triggering the amber ERC category), however long-term decreases in copper and lead concentrations were also detected at all four sites in Māngere Inlet. See Allen (2025) for more information.

Benthic health

Between 2020 and 2021, overall health at the sandflat sites ranged from 'Excellent' (at Auckland Airport) to 'Fair' (at Clarks Beach) and was most commonly 'Good' (Figure 12). Clarks Beach is now persistently dominated by seagrass and the BHMs, which contribute to the Combined Health Score, may not accurately reflect ecological health in these circumstances. As such, there will be no further discussion of state or trends according to BHMs for this site. Of the tidal creek sites assessed in 2021, most (65 per cent) had 'Marginal' or 'Poor' overall health and only two (7 per cent) were in 'Good' health. This spatial pattern of mostly good ecological health on the open sandflats and poor health in the tidal creeks is typical of Manukau Harbour (see Drylie (2021)).

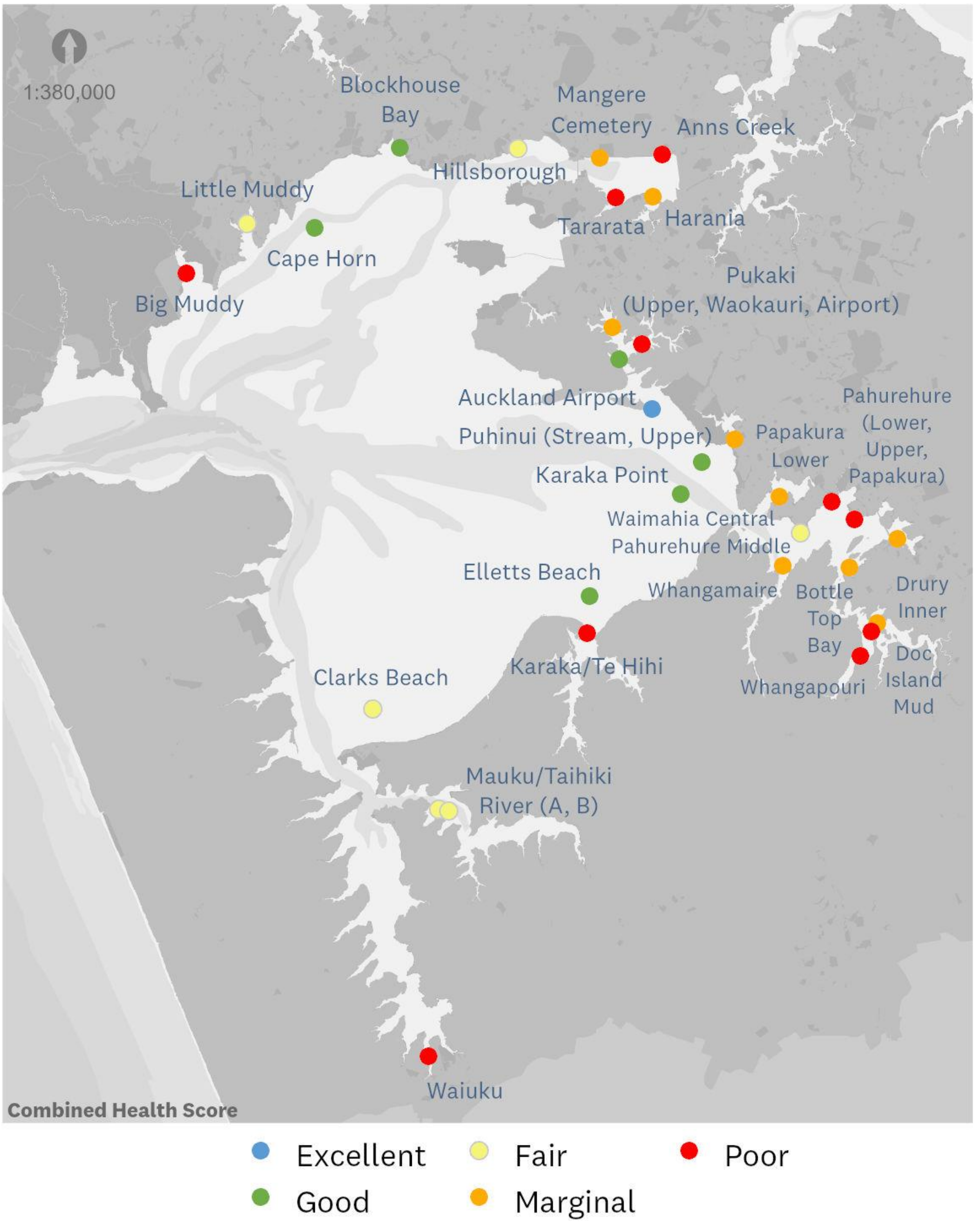

Figure 12. Combined Health Scores for Manukau Harbour monitoring sites in 2020 (rotational sites) and 2023 (core sites).

Health with respect to mud (BHMmud) and metals (BHMmetals) was 'Excellent' or 'Good' at the sandflat sites, and functional resilience (TBI) was 'High'. In contrast, the tidal creek sites with sufficient data for trend analysis scored 'Marginal' (Māngere Cemetery) or 'Poor' (Anns Creek) according to the BHMs and had 'Intermediate' or 'Low' functional resilience (Table 9). Several sites exhibited long-term changes in benthic health indices, though there was no harbour-wide pattern in these trends. Most represented an improvement in health, except for the long-term, low magnitude degrading trends in both BHMs at Auckland Airport (maintained from Drylie (2021)) and a newly detected degrading trend in BHMmetals at Elletts Beach (which started around 2015). Despite this, Auckland Airport remained in the 'Excellent' health category for both BHMs in 2023 and improving trends in BHMmud and TBI were detected for Elletts Beach.

Table 9. Benthic health groups at Manukau Harbour monitoring sites in 2020 (rotational sites) and 2023 (core sites). Benthic Health Models (BHM): Excellent, Good, Fair, Marginal, Poor; Traits-Based Index (TBI): High, Intermediate, Low. Arrows show significant trends in index scores over the monitoring period (Appendix 1: Monitored sites): ▲ = health improved; ▼ = health degraded. New = this trend was not previously detected in Drylie (2021), Maintained = this trend was previously detected. An asterisk (*) indicates a degradation in benthic health group since the last report.

Sandflat sites	BHMmud	BHMmetals	TBI
Auckland Airport	▼ Maintained	▼ Maintained	▲ Maintained
Clarks Beach	N/A	N/A	▲ New
Karaka Point	▲ Maintained	▲ New	
Puhinui Stream			▲ Maintained
Elletts Beach	▲ Maintained	▼ New	▲ Maintained
Cape Horn	▲ Maintained	▲ Maintained	
Tidal creek sites			
Anns Creek			
Māngere Cemetery	▲ Maintained	▲ New	

Macrofaunal community

Species richness was very high at Clarks Beach in 2023 (67 species, the greatest number of any site in the region) and above the regional average at Karaka Point and Elletts Beach (Figure 13). The high diversity at Clarks Beach was likely due to the presence of seagrass, which covered most of the monitoring site. Species richness increased significantly at all sites except Cape Horn over the monitoring period (Appendix 5: Figure A7), underpinning the numerous improving TBI trends (Table 9).

The non-metric multi-dimensional scaling (nMDS) plot had moderate to high stress and was useful for identifying patterns but not detailed interpretation. There were no large shifts in macrofaunal community composition at Auckland Airport over the last ten years, but a gradual transition from the right of the nMDS plot to the left was apparent and aligned with the degrading BHM trends (Figure 14). Contrastingly, community composition shifted considerably at Elletts Beach in recent years, though SIMPER analysis revealed that the species responsible for the differences in composition had contrasting preferences and did not indicate a clear environmental stressor. The composition of the macrofaunal community at Cape Horn was distinct from all other sites and was the most variable over the last ten years. However, in 2020 the community returned to a composition more like that observed in 2017 and 2018, ending several years of directional shifts.

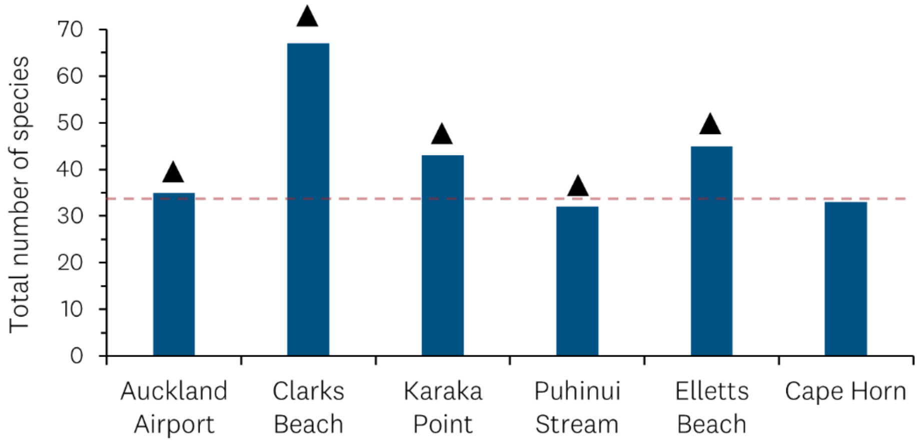

Figure 13. Species richness at Manukau Harbour monitoring sites in 2020 (rotational sites) and 2023 (core sites). The dashed line shows the median species richness across all Harbour Ecology sites based on the latest available data. The direction of statistically significant trends between 1987 and 2023 are shown: ▲ represents an increase and ▼ a decrease.

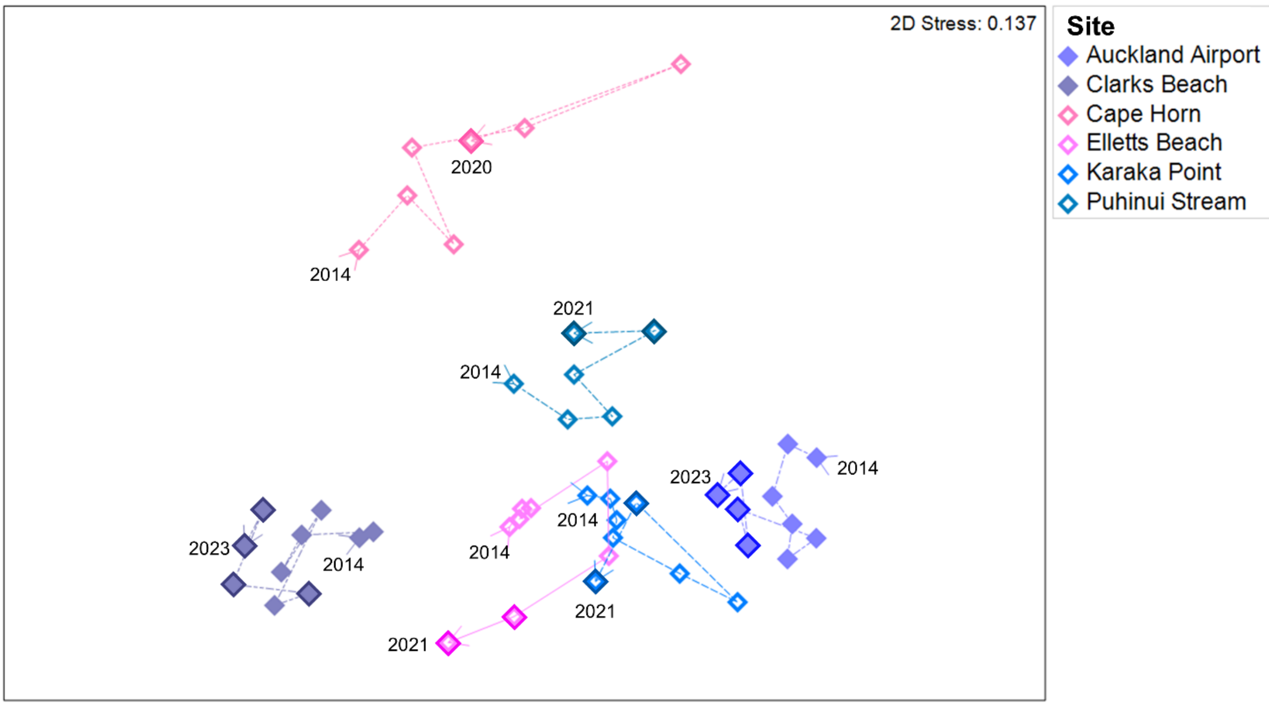

Figure 14. The similarity in macrofaunal community composition between Manukau monitoring sites and changes over the last 10 years (2014 to 2023). Symbols are outlined to highlight new data since Drylie (2021).

Indicator species

Trends in indicator species were analysed for Auckland Airport and Clarks Beach because these sites had more than one degrading benthic health trend (although not presented in Table 9, both BHMs degraded at Clarks Beach). Despite this, very few concerning trends in indicator species occurred at either site over the monitoring period (Table 10). The deep-burrowing bivalve *Macomona liliana* (which prefers sand and is sensitive to stormwater contaminants) declined at Clarks Beach recently (since 2018) but may be in response to the displacement or sediment stabilisation associated with increases in seagrass extent and density.

Table 10. Trends in the abundance of monitored and regionally common species at Manukau monitoring sites between Oct. 1987 and Oct. 2023: ▲ = significant increase; ▼ = significant decrease. Arrows are coloured to highlight trends consistent with a particular stressor: sedimentation, metal contamination, or both. Grey cells indicate trends that are less certain or uncertain and sites exhibiting multi-year cycles (MY) are shown. An asterisk (*) indicates a recent change in abundance. Pref = sediment preference; SS = strong sand preference, S = prefers sand, M = prefers some mud, MM = strong mud preference, - = unknown. N/A = not assessed (occurrence and/or abundance too low).

Monitored species	Pref	Auckland Airport	Clarks Beach
Boccardia syrtis	M		
Clymenella stewartensis	M	N/A	
Anthopleura hermaphroditica	S		▲
Orbinia papillosa	S	▲	
Owenia petersenae	S	N/A	▲ MY
Torridoharpinia hurleyi	S	▲ MY	▲ MY
Colurostylis lemurum	SS	▲ MY	
Travisia novaezealandiae	SS		N/A
Waitangi brevirostris	SS		N/A
Aglaophamus macroura	-	▼	▼
Exosphaeroma planulum	-	N/A	▲
Exosphaeroma waitemata	-		▼
Glycinde trifida	-	▼	▼
Hiatula siliquens	-	▲ MY	▲
Magelona dakini	-		
Methalimedon sp.		▼	
Taeniogyrus dendyi	-		
Regionally common species			
Aricidea sp.	M		▲ MY
Prionospio aucklandica	M	▲	
Austrovenus stutchburyi	S	▲ MY	▲ MY
Linucula hartvigiana	S	▼ MY	▲ MY
Macomona liliana	S		▼ *
Aonides trifida	SS	▲	
Notoacmea scapha	SS		▲
Trends consistent with sedimentation		2	2
Trends consistent with metals		1	1

Summary

The health of the Manukau Harbour sandflat sites was mostly ‘Good’ or even ‘Excellent’, while in the tidal creeks and transitional reaches ecological health was most often ‘Marginal’ or ‘Poor’. There were a small number of degrading health trends that are not currently of concern as they were not supported by trends in indicator species or sediment characteristics. However, continued interrogation of the Auckland Airport data is recommended to better understand the declining health indices at this important site (for instance, characterising the species driving the subtle shifts in community in more detail and investigating correlations with a broader suite of environmental variables). Increases in sediment organic content that occurred at most sandflat sites since 2015 requires further investigation (such as sampling of sediment nutrient concentrations) to confirm whether this was indicative of an excess nutrients issue.

3.1.3 Mahurangi

Mahurangi Harbour is the smallest harbour in the region (with a surface area of 25 km^2) though is quite large relative to its 128 km^2 catchment. The catchment is dominated by exotic grassland and has large sections of indigenous forest, with notable patches of exotic forest and a built-up urban area associated with the Warkworth settlement (Auckland Council, 2025). There was a slight areal increase in urban land uses since the last report due to construction of the Ara Tūhono – Pūhoi to Warkworth project on State Highway 1, which converted exotic grassland to transport infrastructure along the western length of the harbour, and some conversion of exotic grassland to urban area around Warkworth.

The core monitoring sites in Mahurangi Harbour are Dyers Creek, Jamieson Bay, Mid Harbour, Te Kapa Inlet and Hamilton Landing (though the latter is only sampled once per year as opposed to quarterly). Cowans Bay is the only rotational site and was last sampled in 2022. Sediment accretion monitoring was initiated at several sites in 2023 and once a baseline is developed (in roughly five years), should provide additional understanding of sediment dynamics in the harbour to support interpretation of the ecological data.

Sediment characteristics

In 2021 and 2023, sediment mud content was at least slightly elevated at all sites in Mahurangi Harbour and particularly high at Hamilton Landing (Figure 15). Notable improvements occurred at Te Kapa Inlet since the last assessment (sediment mud content decreased from 23 per cent in 2019 to 17 per cent in 2023 (Appendix 4: Figure A3)) and over the long-term (sediment mud content decreased at both the sandy and muddy sub-sites (Table 11)). Previously reported trends at Dyers Creek (increasing) and Cowans Bay (decreasing) could no longer be detected with the addition of four more years of largely stable observations (Appendix 4: Figure A3). As such, increasing sediment mud content trends could not be detected at any site.

Organic content was high at Hamilton Landing and Te Kapa Inlet (muddy) over the monitoring period (reflecting the high sediment mud content at these sites) but decreased significantly at Hamilton Landing (Table 12). Previously reported decreasing trends could no longer be detected at Te Kapa Inlet or Mid Harbour and significant increases were observed at Dyers Creek and Jamieson Bay due to abrupt increases in organic content between 2019 and 2022, although values returned to more typical concentrations in 2023 (Table 12 and Figure 16). The increase in both organic content and chlorophyll *a* (which increased significantly at all sites) at Dyers Creek, Jamieson Bay, Mid Harbour and Te Kapa Inlet indicates potential nutrient enrichment, as do observations of a filamentous brown alga at Te Kapa Inlet in April 2023. This requires further specific investigation.

In 2022, metal contaminant concentrations were low at all sites and in the case of cadmium (a common chemical found in phosphate fertilizers) below detection limits at Cowans Bay and Dyers Creek. No sites triggered the ERC (see Allen (2023) for further detail).

Figure 15. Sediment mud content at Mahurangi Harbour monitoring sites in 2022 (rotational sites) and 2023 (core sites).

Table 11. Median values and temporal variation (standard deviation) of surface sediment characteristics at Mahurangi monitoring sites between 1995 and 2023.

	Mud content (%)		Organic content (%)		Chl *a* (µg g^{-1} dw sediment)	
	Med	SD	Med	SD	Med	SD
Dyers Creek	9.6	2.61	1.29	0.38	8.14	2.12
Hamilton Landing	44.92	8.36	3.88	0.93	11.47	3.26
Jamieson Bay	7.74	4.7	1.72	0.61	4.53	1.43
Mid Harbour	14.27	5.77	1.86	0.66	9.04	2.48
Te Kapa Inlet (muddy)	31.79	6.85	2.41	0.62	12.65	3.48
Te Kapa Inlet (sandy)	12.45	8.1	1.79	1.19	8.02	3.06
Cowans Bay	26.31	6.07	2.13	0.48	14.67	2.63

Table 12. Direction of statistically significant trends in sediment characteristics at Mahurangi monitoring sites between 1995 and 2023: ▲ represents an increase and ▼ a decrease. Grey cells indicate trends that are less certain or uncertain. New = this trend was not previously detected in Drylie (2021), Maintained = this trend was previously detected, Lost = a previously detected trend no longer occurs.

	Mud content (%)	Organic content (%)	Chl *a* (µg g^{-1} dw sediment)
Dyers Creek	Lost - previously ▲	▲ Maintained	▲ Maintained
Hamilton Landing		▼ Maintained	▲ Maintained
Jamieson Bay		▲ New	▲ New
Mid Harbour		Lost - previously ▼	▲ Maintained
Te Kapa Inlet	▼ Maintained	Lost - previously ▼	▲ Maintained
Cowans Bay	Lost - previously ▼		▲ New

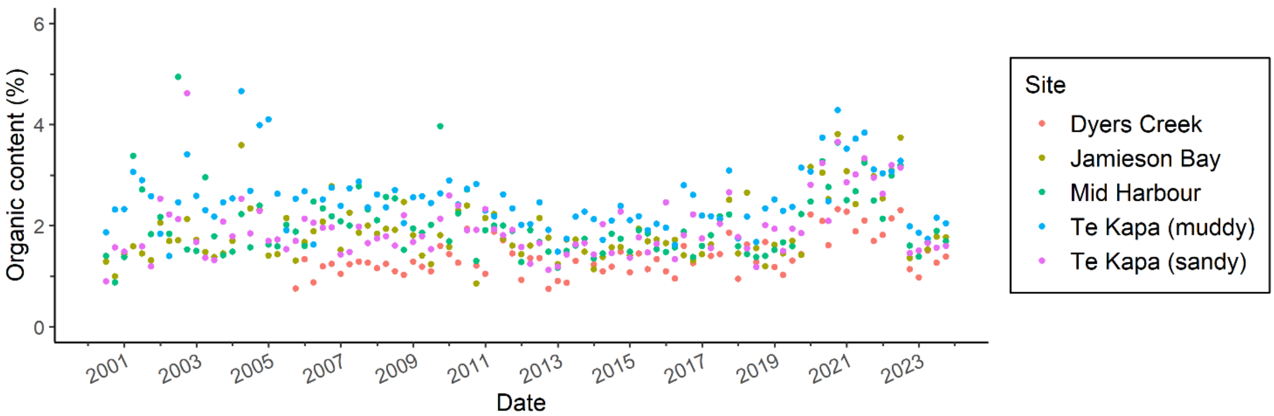

Figure 16. Sediment organic content in Mahurangi monitoring sites.

Benthic health

Overall health according to the Combined Health Score was mostly 'Fair', although two sites had 'Good' health; Hamilton Landing and Cowans Bay. This is counterintuitive as environmental conditions at these sites were poor (sediment mud content was high and organic content was elevated), and health in relation to mud and metals was 'Marginal' (Table 13). The method for calculating the Combined Health Score requires that when a site is allocated to the 'Marginal' or 'Poor' BHMmetals group, the Combined Health Score is equivalent to the TBI. Both Hamilton Landing and Cowans Bay had 'High' TBI scores despite their otherwise unhealthy state. This phenomenon highlights the importance of considering the individual indices contributing to the Combined Health Score rather than relying solely on this summary metric.

Figure 17. Combined Health Scores for Mahurangi Harbour monitoring sites in 2022 (rotational sites) and 2023 (core sites).

Health in relation to mud (BHMmud) was 'Good' at Dyers Creek (an improvement from 'Fair' in 2019) but 'Fair' or 'Marginal' at all other sites and had degraded at most sites over the monitoring period (Table 13). Health with respect to metals (BHMmetals) was 'Fair' or 'Marginal' at all sites, and degrading trends occurred at all except Mid Harbour and Cowans Bay. There was no change in state for either of the BHMs at any site since the last report.

Functional resilience (according to TBI) was 'High' at all sites and increased everywhere except Dyers Creek. This represented an improvement since the last report for Hamilton Landing, Mid Harbour and Dyers Creek. The change at Dyers Creek was most pronounced with a shift from 'Low' in 2019 to 'High' in 2023.

Table 13. Benthic health groups at Mahurangi Harbour monitoring sites in 2022 (rotational sites) and 2023 (core sites). Benthic Health Models (BHM): Excellent, Good, Fair, Marginal, Poor; Traits-Based Index (TBI): High, Intermediate, Low. Arrows show significant trends in index scores between 1995 and 2023: ▲ = health improved; ▼ = health degraded. New = this trend was not previously detected in Drylie (2021), Maintained = this trend was previously detected. An asterisk (*) indicates a degradation in benthic health group since the last report.

	BHMmud	BHMmetals	TBI
Dyers Creek	▼ New	▼ Maintained	
Hamilton Landing	▼ Maintained	▼ Maintained	▲ New
Jamieson Bay	▼ Maintained	▼ Maintained	▲ New
Mid Harbour	▼ New		▲ Maintained
Te Kapa Inlet	▼ New	▼ Maintained	▲ New
Cowans Bay			▲ Maintained

Macrofaunal community

Species richness was very high at Jamieson Bay (66 species) and close to the regional median (34 species) at all other sites (Figure 18). Significant long-term increases in species richness occurred at most sites (Appendix 5: Figure A8), including those with the poorest health according to the BHMs (Hamilton Landing and Cowans Bay) and despite degrading health trends (at Hamilton Landing, Jamieson Bay and Mid Harbour) (Table 13).

The nMDS plot had moderate to high stress, so should only be interpreted for broad patterns. The monitoring sites were characterised by distinct macrofaunal communities (evidenced by the lack of overlapping points in the nMDS plot) with reasonable variability over the last ten years at all sites (Figure 19). The direction of change was similar throughout the harbour, with sites shifting towards the top left of the nMDS plot over time; this suggests a common environmental driver of change. Only Mid Harbour exhibited notable change in the last four years (since last reported in 2019). Oscillations in the abundance of *Aricidea* sp., *Arthritica bifurca*, *Cossura consimilis* (all of which prefer some mud) and *Linucula hartvigiana* (which prefers sand) were responsible for the dissimilarity in community composition pre- versus post-2019, though the changes were not consistent with a specific stressor (i.e. in some instances, the abundance of mud and sand preferring species increased simultaneously).

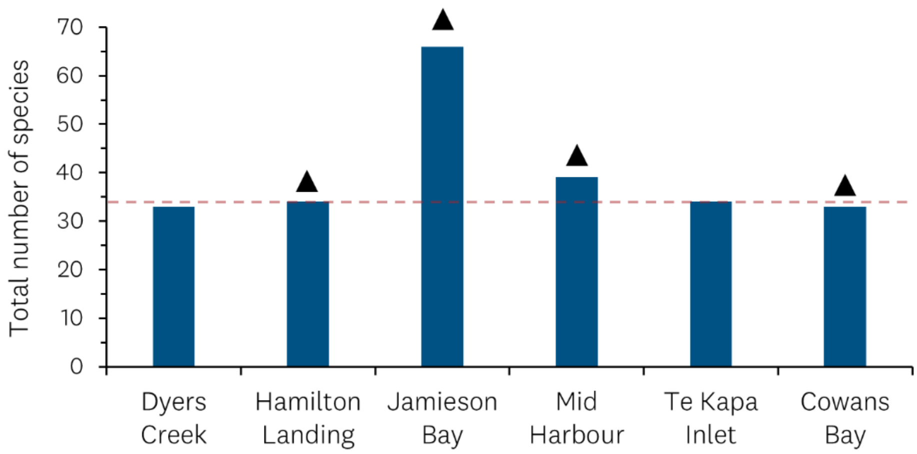

Figure 18. Species richness at Mahurangi Harbour monitoring sites in 2022 (rotational sites) and 2023 (core sites). The dashed line shows the median species richness across all Harbour Ecology sites based on the latest available data. The direction of statistically significant trends between 1995 and 2023 are shown: ▲ represents an increase and ▼ a decrease.

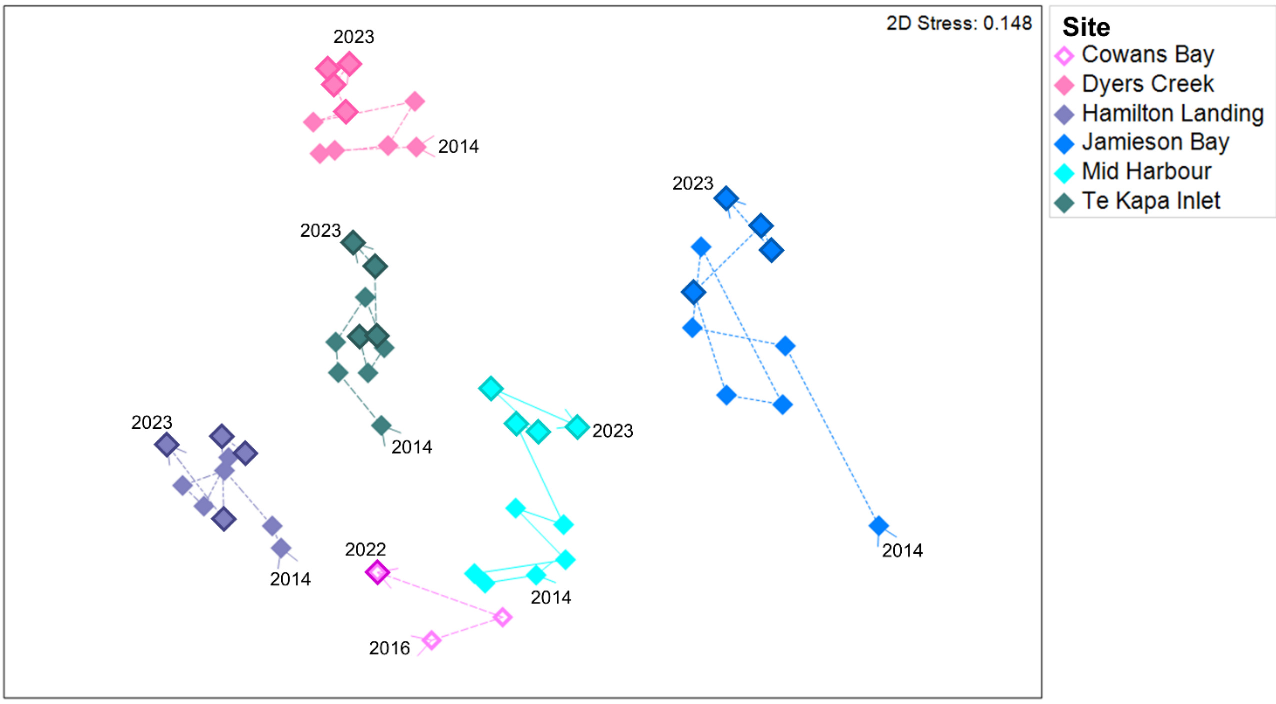

Figure 19. The similarity in macrofaunal community composition between Mahurangi monitoring sites and changes over the last 10 years (2014 to 2023). Symbols are outlined to highlight new data since Drylie (2021).

Indicator species

Trends in indicator species were analysed for all sites except Cowans Bay because there had been no degradation in benthic health indicators at this site. There was a very high number of trends indicative of sedimentation at all analysed sites and especially Jamieson Bay (Table 14). This was despite the relatively low median sediment mud content at Jamieson Bay and no evidence of increases over the long-term (Table 12). There were comparatively fewer trends consistent with metal contamination, and it is notable that the metal-sensitive species that exhibited significant decreasing trends were also sensitive to sedimentation so may have been responding to sediment rather than metal contaminants.

Recent decreases in the abundance of several mud-preferring species indicated improving environmental conditions at Dyers Creek, for instance Oligochaeta and Polydorids decreased since 2020 and *Hemiplax hirtipes* since 2019. Similarly, recent changes at Mid Harbour signalled improving conditions; the mud-preferring Nemertea decreased in abundance since 2020, while the sand-preferring *Torridoharpinia hurleyi* increased since 2018 and *Austrovenus stutchburyi* since 2020.

Table 14. Trends in the abundance of monitored and regionally common species at Mahurangi monitoring sites between Oct. 1995 and Oct. 2023: ▲ = significant increase; ▼ = significant decrease. Arrows are coloured to highlight trends consistent with a particular stressor: sedimentation, metal contamination, or both. Grey cells indicate trends that are less certain or uncertain and sites exhibiting multi-year cycles (MY) are shown. An asterisk (*) indicates a recent change in abundance. Pref = sediment preference; SS = strong sand preference, S = prefers sand, M = prefers some mud, MM = strong mud preference, - = unknown. N/A = not assessed (occurrence and/or abundance too low).

Monitored species	Pref	Dyers Creek	Hamilton Landing	Jamieson Bay	Mid Harbour	Te Kapa Inlet
Oligochaeta	MM	▲ * MY	▲	▲ MY	▲	▲
Arthritica bifurca	M	▲ MY		▲ MY	▲ MY	▲
Cossura consimilis	M		▲	▲	▲ MY	▲
Hemiplax hirtipes	M	▲ * MY	▲	▲ MY	▲	▲
Heteromastus filiformis	M	▼ MY		▲ MY		▼
Nemertea	M			▲ MY	▲ *	
Perinereis vallata	M		▼ MY		N/A	
Polydorids	M	*	▼			▼ MY
Owenia petersenae	S	N/A	N/A	▼ MY	N/A	
Paracalliope novizealandiae	S		▲ MY	▲ MY	▲ MY	
Scoloplos cylindrifer	S	▲ MY	▼	▲	N/A	▲
Torridoharpinia hurleyi	S	▼ MY		▲	▲ *	▲ MY
Regionally common species						
Aricidea sp.	M	▲ MY	▲ MY	▲ MY	▲ MY	▲
Prionospio aucklandica	M		▲	▲	▲ MY	
Austrovenus stutchburyi	S	▲ MY	▼ MY	▲ MY	▲ *	
Linucula hartvigiana	S	▼ MY	▼ MY	▼ MY	▼	▼ MY
Macomona liliana	S	▼ MY	▼ MY	▼ MY	▼ MY	▼
Aonides trifida	SS	▼		▼	▲	
Notoacmea scapha	SS	▼	N/A		N/A	▼
Trends consistent with sedimentation		9	9	12	9	8
Trends consistent with metals		4	2	3	2	2

Summary

Overall health was mostly 'Fair' in Mahurangi Harbour in 2023, though there were some interesting contradictions between health indices generally and at specific sites. Health according to the BHMs was mostly 'Fair' or 'Marginal' and had degraded over the monitoring period, while functional resilience according to the TBI was 'High' and had increased (alongside species richness). For the

Hamilton Landing and Cowans Bay sites, health according to both BHMs was 'Marginal' but as the TBI was 'High', the assessment from the Combined Health Score identified these sites as having 'Good' overall health. The apparent contradictions in these states and trends may be explained by closer interrogation of macrofaunal community dynamics that were beyond the scope of this report, though such analyses would be worthwhile to clarify the nature of the interactions between the health indices.

Sediment mud content was elevated at most sites and negatively impacted ecological health. However, the lack of increasing sediment mud content trends, recent changes in BHMmud groups or indicator species suggested most sedimentation stress in Mahurangi Harbour was due to legacy rather than contemporary inputs. Given the extreme weather events in early 2023, which resulted in large sedimentation events across the country, the lack of a recent sedimentation spike in Mahurangi Harbour is surprising yet reassuring. Similarly, metal contamination seemingly impacted the macrofaunal community at all sites (according to the BHMmetals health groups) and caused a decline in health over the long term, however there were few indications of recent increases in contamination stress and metal contaminant concentrations were low at all sites in 2022. There were some concerning indications of potential nutrient enrichment at Dyers Creek, Jamieson Bay, Mid Harbour and Te Kapa Inlet that requires further investigation.

3.1.4 Waitematā

Waitematā Harbour forms the coastline of Tāmaki Makaurau / Auckland's Central Business District and also the narrow Auckland isthmus with Manukau Harbour. The harbour has a surface area of 80 km^2 and drains a 451 km^2 catchment which houses a variety of land use types. Due to differences in the dominant land use and physical characteristics of the harbour, monitoring and reporting is split into the Upper Waitematā and the Central Waitematā.

Sediment accretion monitoring was initiated at several sites in 2024 (Herald Island Waiarohia in Upper Waitematā and the three core sites in Central Waitematā). Once a baseline is developed (in roughly five years), this data should provide additional understanding of sediment dynamics in the harbour to support interpretation of the ecological data.

3.1.4.1 Upper

The dominant land uses in Upper Waitematā are urban (to the east and around Riverhead, Whenuapai and Hobsonville) and exotic grassland (to the north and west) (Auckland Council, 2025). Large areas of exotic forest occur at the head of Rangitōpuni Creek (Riverhead Forest) and there is a reasonable area of cropland around Riverhead and dotted through the catchment. The biggest areas of land use change were associated with forestry activities in Riverhead (both harvesting and regrowth) and there were many small instances of exotic grassland becoming urban (whether built-up area, parkland or transport infrastructure).

The core monitoring sites are Herald Island North, Herald Island Waiarohia, Lucas Creek, Hellyers Creek and Rangitōpuni Creek (though the latter is only sampled once per year, as opposed to quarterly). The rotational sites are Brigham Creek, Upper Main, Central Main, Outer Main and Opposite Hobsonville and were last sampled in 2022. In addition to the sandflat sites, data were available for five RSCMP tidal creek sites (metal contaminant concentrations and ecological indicators). Tidal creek sites were last sampled in 2020 or 2022. Results of the ecology sampling (sediment mud content and benthic health indices) are presented here, and Allen (2025) provides a detailed assessment of contaminant state and trends. Despite the naming conventions, the 'sandflat' sites are mostly in sheltered, muddy tidal creeks similar to the RSCMP 'tidal creek' sites, with only Herald Island North, Herald Island Waiarohia and Central Main being located on what could truly be described as sandflats.

Sediment characteristics

In 2022 and 2023, sediment mud content was high throughout Upper Waitematā and frequently greater than 60 per cent (Figure 20). Rangitōpuni Creek, Upper Main and Brigham Creek (the most sheltered sites farthest from the sub-estuary mouth) had very high sediment mud content over the monitoring period (median of roughly 90 per cent) (Table 15). Sites with the lowest mud content were in the main channel towards the sub-estuary mouth where tidal energy is likely to be higher (for example, both Herald Island sites and Outer Main). Notable fine sediment depositions (roughly 10 mm deep) were observed at all sites during sampling in February 2023 (following the Auckland Anniversary floods and Cyclone Gabrielle) and were still evident in May 2023.

Sediment mud content increased significantly at four sandflat sites over the monitoring period, including the two sites with the lowest long-term median values (Herald Island North and Herald Island Waiarohia). The increasing trends at Herald Island North and Hellyers Creek were not detected in Drylie (2021), and the decreasing trend previously identified for Rangitōpuni Creek could no longer be detected. See Allen (2025) for the latest trends for the tidal creek sites.

Most sandflat sites were organically enriched and particularly so where sediment mud content was highest (Table 15). Long-term increases in organic content occurred at four sites and three of these trends were not previously detected (Table 16). Chlorophyll *a* concentrations were also elevated at most sites and increased at 50 per cent of sites over the monitoring period. Simultaneous increases in organic content and chlorophyll *a* occurred at Hellyers Creek, Herald Island Waiarohia and Lucas Creek and may indicate a nutrient enrichment issue. There have been multiple observations of large, dense mats of benthic microalgae since February 2021 at Herald Island Waiarohia and Lucas Creek (as well as Herald Island North) which is also a sign of excess nutrients (Figure 21). Benthic microalgae were not recorded during sampling in 2023, possibly because they were smothered by sediment that was deposited following the weather events of early 2023.

Sampling of metal contaminant concentrations across Upper Waitematā between 2020 and 2022 found that concentrations of most metals at most sites were low, but copper and mercury exceeded sediment quality thresholds at Brigham Creek, Rangitōpuni Creek, Upper Main, Pāremoremo, Hellyers Upper and Opposite Hobsonville (all sites with very high sediment mud content). At Herald

Island Waiarohia, copper, lead and zinc had increased meaningfully (by more than 2 per cent per year) over the monitoring period, while lead decreased at Outer Main and copper decreased at Lucas Te Wharau. See Allen (2025) for more information.

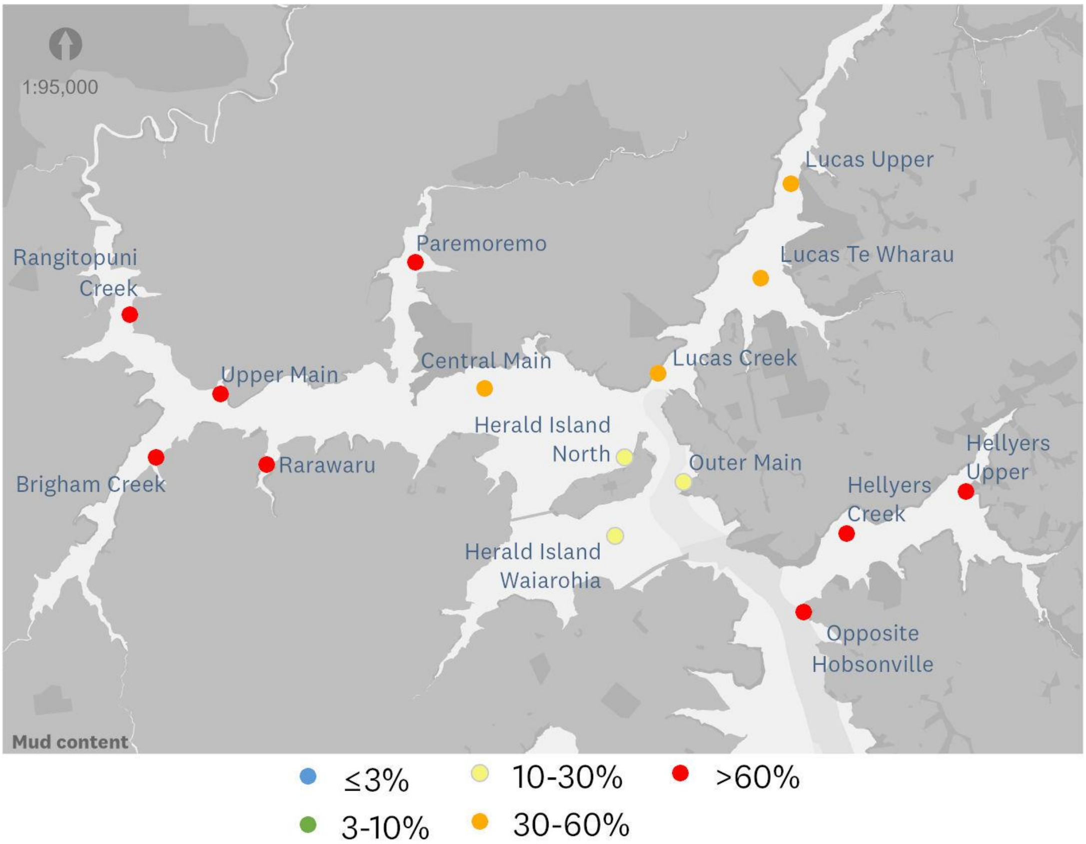

Figure 20. Sediment mud content at Upper Waitematā Harbour monitoring sites in 2020 (rotational sites) and 2023 (core sites).

Table 15. Median values and temporal variation (standard deviation) of surface sediment characteristics at Upper Waitematā sandflat sites between 2005 and 2023.

	Mud content (%)		Organic content (%)		Chl *a* (µg g^{-1} dw sediment)	
	Med	SD	Med	SD	Med	SD
Hellyers Creek	53.88	10.98	3.91	1.31	18.88	4.13
Herald Island North	13.6	6.72	2.15	0.85	16.71	6.5
Herald Island Waiarohia	18.7	5.5	1.7	0.73	16.27	5.36
Lucas Creek	31.05	13.1	4.02	1.32	13.99	5.96
Rangitōpuni Creek	96.24	1.64	8.97	1.83	12.62	6.28
Brigham Creek	89.27	4.99	7.36	1.54	9.4	3.36
Opposite Hobsonville	66.79	8.51	4.99	1.15	10.09	2.94
Central Main	27.3	4.25	4.55	0.99	11.58	1.93
Upper Main	89.57	3.97	7.41	1.65	12.84	4.17
Outer Main (muddy)	23.14	6.21	2.95	0.95	12.63	3.64
Outer Main (sandy)	12.92	4.64	2.13	0.67	11.7	4.14

Table 16. Direction of statistically significant trends in sediment characteristics at Upper Waitematā monitoring sites between 2005 and 2023: ▲ represents an increase and ▼ a decrease. Grey cells indicate trends that are less certain or uncertain. New = this trend was not previously detected in Drylie (2021), Maintained = this trend was previously detected, Lost = a previously detected trend no longer occurs.

	Mud content (%)	Organic content (%)	Chl *a* (µg g^{-1} dw sediment)
Hellyers Creek	▲ New	▲ New	▲ Maintained
Herald Island North	▲ New	▲ New	▼ Maintained
Herald Island Waiarohia	▲ Maintained	▲ Maintained	▲ Maintained
Lucas Creek		▲ New	▲ New
Rangitōpuni Creek	Lost - previously ▼		
Brigham Creek			▲ Maintained
Opposite Hobsonville	▼ New		
Central Main	▲ Maintained		
Upper Main			
Outer Main			▲ Maintained

Figure 21. Conspicuous patches of benthic microalgae at A) and B) Herald Island Waiarohia in February 2021 and C) Lucas Creek in May 2022.

Benthic health

Four tidal creek sites had sufficient data for trend analyses (Hellyer's Upper, Lucas Upper, Lucas Te Wharau and Pāremoremo) and the current state of an additional site (Rarawaru) is shown in the map of Combined Health Scores. Between 2020 and 2023, overall health in Upper Waitematā ranged from 'Good' to 'Poor' and was most commonly 'Marginal' (Figure 22). Sites with the poorest health tended to be in the upper reaches of the tidal creeks and sites with better health were around the main drainage channel, though there were exceptions to this (for example, Opposite Hobsonville and Herald Island Waiarohia had 'Marginal' health despite being close to the main channel).

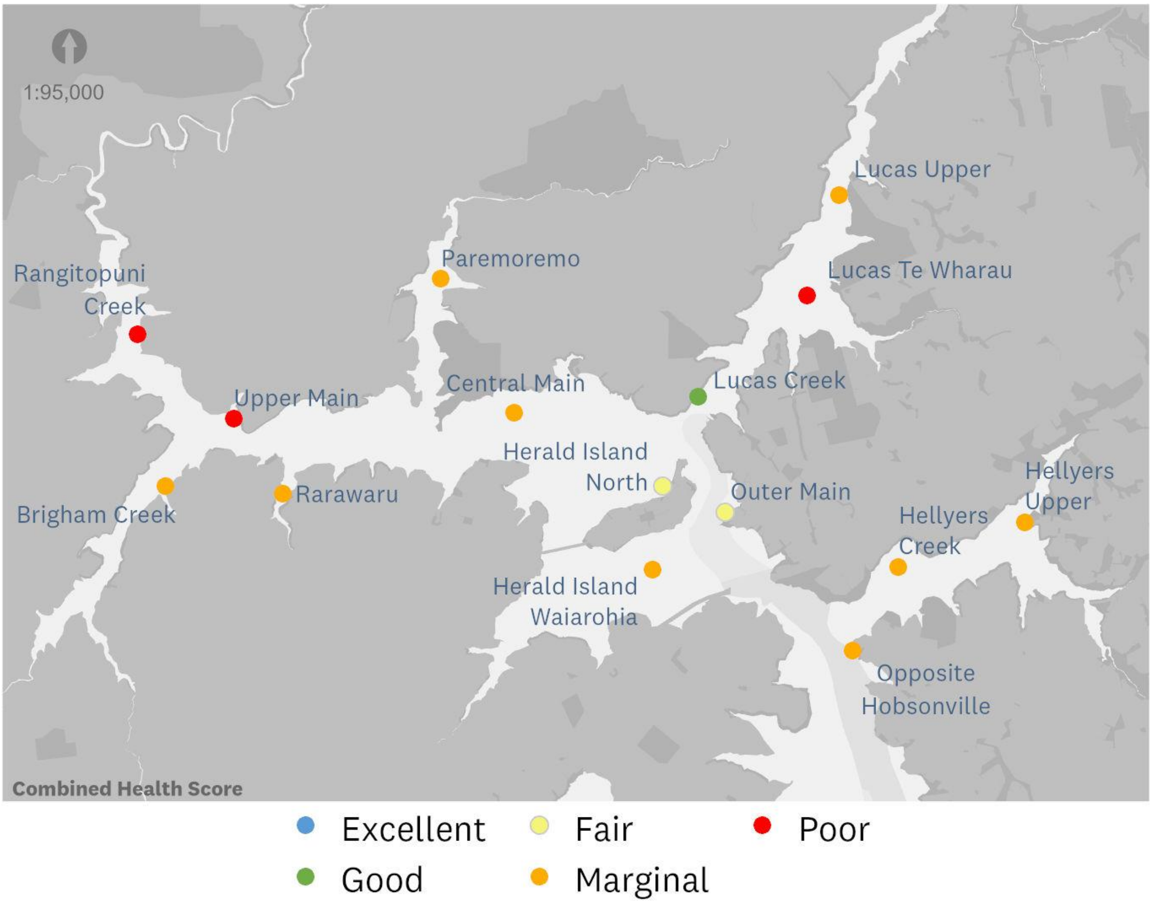

Figure 22. Combined Health Scores for Upper Waitematā Harbour monitoring sites in 2020 (rotational sites) and 2023 (core sites).

Health in relation to mud was 'Marginal' or 'Fair', even at sites with very high sediment mud content (such as Rangitōpuni Creek, Upper Main and Brigham Creek) (Table 17). Health degraded at six of the sandflat sites over the monitoring period and the trends at Hellyers Creek and Herald Island Waiarohia were not previously detected. In most cases, sites with degrading BHMmud trends had increasing sediment mud content trends, though this was not the case for Lucas Creek (where no trend was found) or Opposite Hobsonville (where mud content had decreased) (Table 16). The only change in health group since the last report was an improvement at Herald Island Waiarohia from 'Marginal' to 'Fair', though this was caused by recovery from unusually low health scores in 2019 (across all benthic health indices) and does not meaningfully contradict the degrading BHMmud trend at this site.

Health in relation to metals was also ‘Marginal’ or ‘Fair’ at all monitored sites, and there were numerous significant trends over the monitoring period (Table 17). Health degraded at six of the sandflat sites (and improved at three) and the new degrading trends detected at Herald Island Waiarohia, Opposite Hobsonville and Central Main are of particular concern. At Upper Main, health in relation to metals worsened from ‘Fair’ in 2019 to ‘Marginal’ in 2022 despite a long-term improving health trend. This site currently sits close to the boundary between the ‘Fair’ and ‘Marginal’ groups and the change between 2019 and 2022 was caused by a minor shift in BHMmetals score; ongoing fluctuations between health groups are likely for this site and may not reflect meaningful ecological change. All the trends occurring at tidal creek sites were improvements in health.

Functional resilience ranged from ‘High’ (at sites around the channel near the sub-estuary mouth) to ‘Low’ and mostly increased over the long term, though a decreasing trend was identified at Herald Island Waiarohia. Concerning changes also occurred at Lucas Te Wharau (‘High’ in 2018 to ‘Low’ in 2020) and Lucas Upper (‘Intermediate’ in 2018 to ‘Low’ in 2022), despite reductions in metal contamination at Lucas Te Wharau (Allen, 2025). Six sites exhibited very concerning health trends (i.e., more than one index was degrading): Hellyers Creek, Herald Island North, Herald Island Waiarohia, Lucas Creek, Opposite Hobsonville and Central Main. Every index had degraded at Herald Island Waiarohia.

The ’High’ functional resilience (TBI) recorded at Herald Island North, Lucas Creek and Outer Main is quite surprising given the elevated mud content at these sites and ‘Fair’ and ‘Marginal’ BHM assessments. Given TBI scores are positively correlated with species richness, one explanation could be spatial heterogeneity in the macrofaunal community which increases species richness (compared to a homogeneous site, which the TBI was developed for). Spatial heterogeneity in the macrofaunal community is reasonably likely at these sites because they are known to encompass varying sediment conditions that may support different macrofaunal assemblages. For instance, the Outer Main site has two distinct halves in terms of sediment conditions, with one half being notably muddier than the other (25 per cent mud content versus 14 per cent, on average over the monitoring period). Herald Island North has been dominated by soft mud with contrasting areas of firmer, raised muddy sand in recent years, and Lucas Creek is a long, rectangular site that can have quite variable sediment conditions along its length. Analyses of the variance across replicate macrofaunal cores (beta-diversity) would help improve our understanding of the potential role of heterogeneity in driving the ‘High’ TBI scores at these sites (Legendre & De Cáceres, 2013).

Table 17. Benthic health groups at Upper Waitematā Harbour monitoring sites in 2020 (rotational sites) and 2023 (core sites). Benthic Health Models (BHM): Excellent, Good, Fair, Marginal, Poor; Traits-Based Index (TBI): High, Intermediate, Low. Arrows show significant trends in index scores over the monitoring period (see Appendix 1: Monitored sites): ▲ = health improved; ▼ = health degraded. New = this trend was not previously detected in Drylie (2021), Maintained = this trend was previously detected. An asterisk (*) indicates a degradation in benthic health group since the last report.

Sandflat sites	BHMmud	BHMmetals	TBI
Hellyers Creek	▼ New	▼ Maintained	▲ New
Herald Island North	▼ Maintained	▼ Maintained	▲ New
Herald Island Waiarohia	▼ New	▼ New	▼ Maintained
Lucas Creek	▼ Maintained	▼ Maintained	▲ New
Rangitopuni Creek	▲ New	▲ New	
Brigham Creek		▲ Maintained	
Opposite Hobsonville	▼ Maintained	▼ New	▲ New
Central Main	▼ Maintained	▼ New	▲ New
Upper Main	▲ Maintained	▲ * New	
Outer Main			▲ New
Tidal creek sites			
Hellyers Upper		▲ New	
Lucas Te Wharau			*
Lucas Upper		▲ Maintained	*
Pāremoremo		▲ Maintained	

Macrofaunal community

Species richness was below the regional average of 34 species at all sites and was particularly low (less than 20) at Hellyers Creek, Rangitōpuni Creek, Brigham Creek, Opposite Hobsonville, Central Main and Upper Main (Figure 23); this aligns with the 'Low' functional resilience at most of these sites (Table 17). Significant decreases occurred at Herald Island Waiarohia and Central Main over the monitoring period, while species richness increased at Lucas Creek and Outer Main (alongside increases in TBI score) (Appendix 5: Figure A9).

The nMDS plot for Upper Waitematā had moderate stress and an acceptable fit for interpretation. Sites separated into three main clusters that reflected their sediment mud content values: Rangitōpuni Creek, Brigham Creek and Upper Main (very high mud content); Hellyers Creek, Central Main and Opposite Hobsonville (high mud content); Herald Island North, Herald Island Waiarohia and

Outer Main (moderate mud content) (Figure 24). Lucas Creek occupied the space between the high and moderate mud content sites over the last 10 years but in 2023 was more like those with high mud content. Community composition was especially variable at Brigham Creek, Upper Main, Rangitōpuni Creek, Lucas Creek and Herald Island Waiarohia over the last 10 years, however there was no consistency in the direction that sites have shifted. For example, the recent trajectory of the Brigham Creek and Upper Main sites was in opposing directions in the nMDS plot space. This suggests the variability may be natural rather than being caused by a consistent environmental driver.

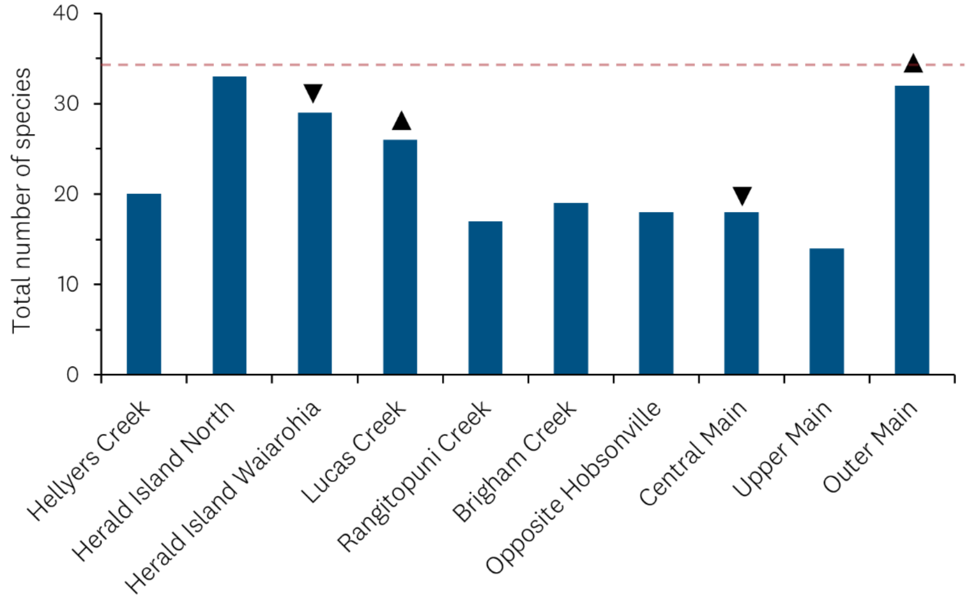

Figure 23. Species richness at Upper Waitematā monitoring sites in 2020 (rotational sites) and 2023 (core sites). The dashed line shows the median species richness across all Harbour Ecology sites based on the latest available data. The direction of statistically significant trends between 2005 and 2023 are shown: ▲ represents an increase and ▼ a decrease.

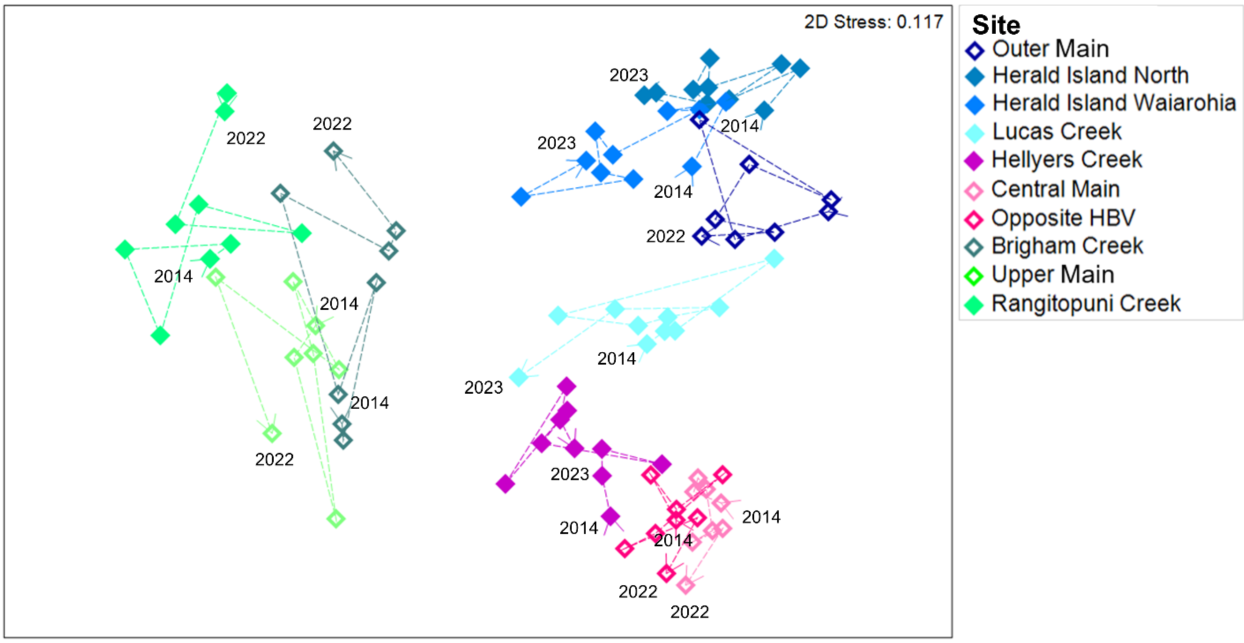

Figure 24. The similarity in macrofaunal community composition between Upper Waitematā monitoring sites and changes over the last 10 years (2014 to 2023). Symbols are outlined to highlight new data since Drylie (2021).

Indicator species

The occurrence of *Pseudopotamilla* sp. was too low to perform trend analysis at any site and should be removed from the suite of monitored species for Upper Waitematā. The strongly sand-preferring species *Aonides trifida* and *Notoacmea scapha* did not occur frequently enough at most sites to perform trend analyses but should be retained as indicator species as they exhibited trends at some less impacted sites where monitoring any degradation in ecological condition is crucial.

Trends in indicator species were analysed for the seven sites that had degrading benthic health indices (either long-term or since the last state assessment based on 2019 data). A very high number of trends indicative of sedimentation occurred at both Herald Island sites and slightly fewer were detected at Hellyers Creek, Central Main, Lucas Creek and Opposite Hobsonville (Table 18). These trends likely explain the degrading BHMmud scores observed at Lucas Creek and Opposite Hobsonville, despite no trend in sediment mud content being found at Lucas Creek and a decrease occurring at Opposite Hobsonville (mud content increased at all other sites with a high number of indicator species trends) (Table 16). There were far fewer trends consistent with metal contamination, though again the greatest number occurred at the Herald Island sites. This likely reflects the increased concentrations of copper, lead and zinc that were identified at Herald Island Waiarohia (Allen, 2025) and explains the degrading BHMmetals scores (Table 17).

Changes in indicator species abundances at Herald Island Waiarohia and Herald Island North may be an indication of recent sedimentation stress, in addition to the long-term pressures evident at these sites. For example, at Herald Island Waiarohia, Oligochaeta (which have a strong preference for mud) increased since 2021 and *Austrovenus stutchburyi* (which prefers sand) decreased since 2017 and at Herald Island North, *Arthritica bifurca* (which prefers some mud) increased since 2020 (Table 18). Likewise, *Paradoneis lyra* and *Levinsenia gracilis* increased in abundance at Central Main since 2018; the preferences and sensitivities of these species have not been empirically tested in New Zealand, however international research suggests they may prefer fine, muddy sediments (JNCC, 2022; Martínez, 2019). There was some evidence that sedimentation stress may have decreased in recent years at Lucas Creek despite the long-term degrading trend in BHMmud at this site, as Nereididae and *Aricidea* sp. (both prefer some mud) decreased since 2017/2016 and the limpet *Notoacmea scapha* (which has a strong preference for sand) was mostly absent until 2015.

Table 18. Trends in the abundance of monitored and regionally common species at Upper Waitematā monitoring sites between Oct. 2005 and Oct. 2023: ▲ = significant increase; ▼ = significant decrease. Arrows are coloured to highlight trends consistent with a particular stressor: sedimentation, metal contamination, or both. Grey cells indicate trends that are less certain or uncertain and sites exhibiting multi-year cycles (MY) are shown. An asterisk (*) indicates a recent change in abundance. Pref = sediment preference; SS = strong sand preference, S = prefers sand, M = prefers some mud, MM = strong mud preference, - = unknown. N/A = not assessed (occurrence and/or abundance too low).

Monitored species	Pref	Hellyers Creek	Herald Island North	Herald Island Waiarohia	Lucas Creek	Opposite Hobsonville	Central Main	Upper Main
Oligochaeta	MM	▲	▲	▲ *				
Arthritica bifurca	M	▲	▲ * MY					N/A
Austrohelice crassa	M	N/A	▲ MY	▼		N/A	N/A	
Capitellidae	M	N/A	N/A	▲ MY	▲ MY	N/A	N/A	▲
Cossura consimilis	M	▼	N/A	N/A	▼	▲	▲	
Heteromastus filiformis	M		▼ MY			▲	▲	
Nereididae	M	▲	▲ MY		▼ *		▲ MY	▼
Polydoridae	M		▲	▲	▲ MY	N/A	▼	
Corophiidae	-	▼ MY	N/A	N/A	▼	▼	▼	▼ MY
Phoxocephalidae	-	▼	N/A	N/A	▼	▲	▼	N/A
Paradoneis lyra	-		N/A	N/A		▲ * MY	▲ *	
Levinsenia gracilis	-	▲	N/A	N/A	▼	*	*	N/A
Pseudopotamilla sp.	-	N/A	N/A	N/A	N/A	N/A	N/A	
Arcuatula senhousia	-	N/A	▲ MY	▲		N/A	N/A	N/A
Tritia burchardi	-	N/A		▲	▲ *	N/A	N/A	N/A
Regionally common species								
Aricidea sp.	M	▼ * MY	▼ MY		▼ * MY	*		
Prionospio aucklandica	M	▲	▲ MY		▲	▲ MY	▲ MY	▲
Austrovenus stutchburyi	S		▲ MY	▼ *	▲ MY	N/A		N/A
Linucula hartvigiana	S	▼ MY	▼ MY	▼ MY	▼ MY	▼ MY	▼	N/A
Macomona liliana	S	▼ MY	▼ MY	▼	▼ MY	▼ MY	▼	N/A
Aonides trifida	SS	N/A	▼ MY	▼	N/A	N/A	N/A	N/A
Notoacmea scapha	SS	N/A	▼ MY	▼ MY	▲	N/A	N/A	N/A
Trends consistent with sedimentation		6	10	8	5	5	6	1
Trends consistent with metals		2	3	3	2	2	2	0

Summary

Between 2020 and 2023, overall health in Upper Waitematā was most commonly 'Marginal' and species richness was below the regional average at all sites. Health in the upper reaches of the tidal creeks improved in several instances yet remained low (for instance at Rangitōpuni Creek and Upper Main), whereas health in the lower parts of the sub-estuary tended to be better yet had degraded over the monitoring period (such as Lucas Creek and Herald Island North). At six of the sandflat sites, more than one benthic health index had degraded over the monitoring period.

Impacts from excess sediment were apparent throughout Upper Waitematā: sediment mud content was high at all sites (and greater than 60 per cent at more than half of the sites) and had increased at many, health according to the BHMmud was 'Fair' at best, and there were numerous trends in indicator species that were consistent with sedimentation impacts at most sites. Concerningly, new trends and recent changes in indicator species were detected (for instance at Herald Island North, Herald Island Waiarohia and Hellyers Creek) that suggested sedimentation continued to be a stressor of the sub-estuary in 2023.

Metal contaminants also appeared to impact ecological health; although sediment quality thresholds were only exceeded in the muddy upper reaches of the sub-estuary (for copper and mercury), all sites had 'Fair' or 'Marginal' health according to the BHMmetals. Degrading trends in BHMmetals scores occurred at six of the sandflat sites, despite few trends in indicator species that were consistent with metal contamination. Nonetheless, new degrading trends detected at Herald Island Waiarohia, Opposite Hobsonville and Central Main are of concern and at Herald Island Waiarohia these reflect meaningful long-term increases in copper, lead and zinc over the monitoring period. The only changes observed at the tidal creek sites in relation to metal contaminant impacts were improvements. Sediments in Upper Waitematā were organically enriched and chlorophyll *a* concentrations tended to be high. Simultaneous increases in organic content and chlorophyll *a* occurred at Hellyers Creek, Herald Island Waiarohia and Lucas Creek and may be indicative of excess nutrients.

A very concerning number of changes occurred at Herald Island Waiarohia that represent serious declines in ecological condition. All three benthic health indices degraded since 2005, sediment mud content and metal contaminant concentrations increased, there was evidence of potential excess nutrients, species richness decreased, and there were a very high number of trends in indicator species consistent with sedimentation. Similar though slightly less severe results were observed at Herald Island North. These sites represent the best ecological health in Upper Waitematā, so protecting them from further decline is important.

3.1.4.2 Central

The vast majority of the Central Waitematā catchment is urban, with a relatively small area of exotic grassland (interspersed with some cropland) and indigenous vegetation to the west (Auckland Council, 2025). Very little change in land use occurred since the last report, given the intensively urbanised catchment.

The core monitoring sites are Hobsonville, Whau River and Upper Shoal Bay and the rotational sites are Meola Reef and Henderson Creek; all sites were sampled in 2023. In addition to the sandflat sites, 19 RSCMP tidal creek sites had data available on metal contaminant concentrations and ecological indicators. Results of the ecology sampling (sediment mud content and benthic health indices) are presented here, and Allen (2025) provides a detailed assessment of contaminant state and trends.

Sediment characteristics

In 2023, sediment mud content was at least 3 per cent at all sites and often greater than 60 per cent (Figure 25). The highest concentrations regularly occurred in the upper reaches of tidal creeks such as Whau Estuary, Henderson Creek and Shoal Bay, and the lowest concentrations were generally observed at the more exposed sandflat sites (where long-term median values were all less than 10 per cent (Table 19)). Notable increases in sediment mud content occurred at Henderson Creek (from 6 per cent in 2019 to 16 per cent in 2023) and Whau Upper (from 58 per cent in 2018 to 76 per cent in 2023) since Drylie (2021). While less extreme, increases at Coxs Bay (from 8 per cent in 2019 to 12 per cent in 2023) and Chelsea (from 7 per cent in 2019 to 11 per cent in 2023) crossed the ecological threshold of 10 per cent mud content, beyond which macrofaunal diversity and resilience may be reduced (Rodil et al., 2013). At the sandflat sites, long-term increasing sediment mud content trends remained at Whau River, Henderson Creek and Meola Reef (

Table 20). See Allen (2025) for the most up-to-date trends for the tidal creek sites.

Increasing trends in organic content were detected at Shoal Bay Upper and Whau River (

Table 20). These were matched by an increasing trend in chlorophyll *a* at Whau River, and a previously reported decreasing trend at Shoal Bay Upper could no longer be detected due to large increases since 2020 (Appendix 4: Figure A5). These trends may suggest nutrient enrichment at these sites. Median organic content and chlorophyll *a* concentrations were high at Henderson Creek and there was a maintained increasing trend in chlorophyll *a*, so it may also be beneficial to investigate the potential for excess nutrients at this site, despite the lack of a trend in organic content (Table 19 and

Table 20). Very small patches of opportunistic algae (*Ulva intestinalis* and *Gracilaria chilensis*) have been recorded at all three of these sites regularly since 2018, though never in bloom proportions (always covering less than 1 per cent of the site).

Metal contaminant concentrations were sampled at Central Waitematā tidal creek sites in 2023 and were found to be some of the most heavily impacted sites in the region (Allen, 2025). Elevated zinc concentrations placed seven sites in the red ERC category (in Whau Estuary, Henderson Creek, Meola Reef and Hobson Bay) and a total of 11 sites had at least one metal that triggered the amber category (of the ERC or other relevant guideline). The Whau Upper site was in particularly poor condition with copper, lead and zinc concentrations in the red ERC category. Three sites had meaningful increases in contaminant concentrations over the monitoring period: Coxs Bay (copper, lead and zinc), Kendall Bay (copper) and Whau Entrance (copper and zinc). The sandflat sites have been sampled more sporadically but have had consistently low metal concentrations.

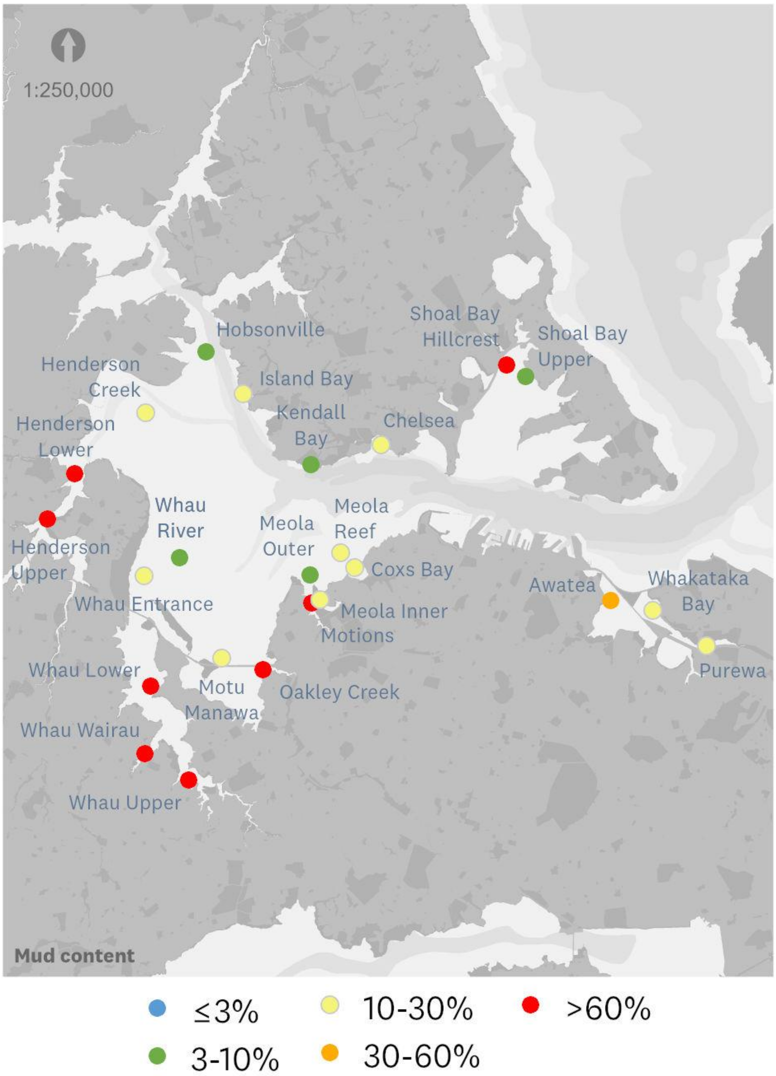

Figure 25. Sediment mud content at Central Waitematā Harbour monitoring sites in 2023.

Table 19. Median values and temporal variation (standard deviation) of surface sediment characteristics at Central Waitematā sandflat sites between 2000 and 2023.

	Mud content (%)		Organic content (%)		Chl *a* (µg g^{-1} dw sediment)	
	Med	SD	Med	SD	Med	SD
Hobsonville	3.24	1.47	1.29	0.7	13.84	2.77
Shoal Bay Upper	6.25	4.63	1.08	0.75	12.93	4.92
Whau River	2.88	1.3	0.98	0.42	12.73	4.07
Henderson Creek	6.39	3.02	2.2	0.65	25.77	6.05
Meola Reef	7.96	3.87	1.48	0.79	8.19	2.93

Table 20. Direction of statistically significant trends in sediment characteristics at Central Waitematā monitoring sites between 2000 and 2023: ▲ represents an increase and ▼ a decrease. Grey cells indicate trends that are less certain or uncertain. New = this trend was not previously detected in Drylie (2021), Maintained = this trend was previously detected, Lost = a previously detected trend no longer occurs.

	Mud content (%)	Organic content (%)	Chl *a* (µg g⁻¹ dw sediment)
Hobsonville			
Shoal Bay Upper		▲ New	Lost - previously ▼
Whau River	▲ Maintained	▲ New	▲ Maintained
Henderson Creek	▲ Maintained		▲ Maintained
Meola Reef	▲ Maintained		▼ Maintained

Benthic health

There were 18 tidal creek sites with sufficient data for trend analyses, and the current state of an additional site (Island Bay) is shown in the map of Combined Health Scores. The Meola Reef sandflat site is now completely covered by seagrass and BHMs are unlikely to accurately assess health in such habitats. As such, BHM state and trends are not presented for this site. In 2023, overall health in Central Waitematā ranged from 'Good' to 'Poor' with a largely balanced spread of sites between health groups (Figure 26). Sites with the poorest health tended to be in the upper reaches of the tidal creeks and sites with better health were closer to the main basin of the harbour.

Health with respect to mud (BHMmud) was 'Excellent' to 'Fair' at the sandflat sites and degraded at all except Upper Shoal Bay over the monitoring period (Table 21). The degrading trends were new at Whau River and Henderson Creek (and matched trends of increasing mud content) and resulted in a change in health status for Hobsonville (from 'Excellent' in 2019 to 'Good' in 2023) (Drylie, 2021). At the tidal creek sites, BHMmud ranged from 'Good' to 'Poor' and had degraded significantly at five sites (including at two Whau Estuary sites and both Meola sites) resulting in a shift at Meola Inner and Whau Wairau from 'Marginal' to 'Poor' since 2019. Although not driven by a long-term degrading trend, changes in benthic health group also occurred since the last report at Chelsea and Shoal Bay Hillcrest. Overall, five sites were in a worse BHMmud group in 2023 than they were in 2019.

Health with respect to metals (BHMmetals) was 'Good' at all sandflat sites, although a new uncertain degrading trend was identified at Whau River (Table 21). BHMmetals scores were variable at Whau River over the monitoring period and had been improving since 2020, so additional data will be helpful in revealing whether the trend persists and should be investigated further. Health with respect to metals was 'Good' or 'Fair' at most (71 per cent) of the tidal creek sites and only one site (Whau Wairau) scored 'Poor' (Table 21). Improving long-term trends were detected at eight sites and a degrading trend was found at only one (Coxs Bay), though previous improving trends were no longer detected at Meola Inner and Motu Manawa due to degrading scores at both sites since 2018. Since the last report, declines in health group occurred at Oakley Creek, Chelsea and Whau Wairau;

this contradicts the improving long-term trend at Whau Wairau but was caused by degrading scores since 2018.

Functional resilience (TBI) was 'High' at all sandflat sites and had increased at all but Shoal Bay Upper over the monitoring period (Table 21). There was more variation in functional resilience at the tidal creek sites, though again the only significant long-term trends were improvements. In the short term, decreases in TBI group occurred at Whau Upper and Motu Manawa (from 'Intermediate' in 2018 to 'Low' in 2023). Changes in more than one health index at Chelsea (BHMmud and BHMmetals) and Motu Manawa (BHMmetals and TBI) are of particular concern and coincide with sediment mud content surpassing 10 per cent at Chelsea.

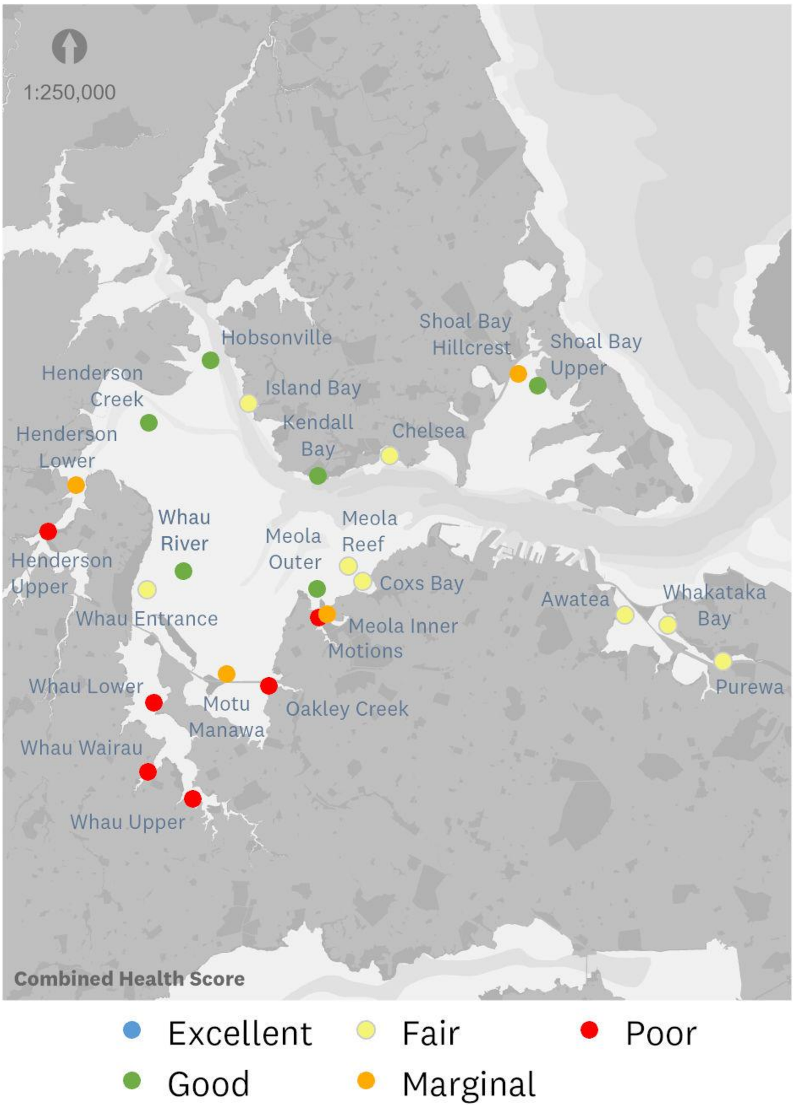

Figure 26. Combined Health Scores for Central Waitematā Harbour monitoring sites in 2023.

Table 21. Benthic health groups at Central Waitematā Harbour monitoring sites in 2023. Benthic Health Models (BHM): Excellent, Good, Fair, Marginal, Poor; Traits-Based Index (TBI): High, Intermediate, Low. Arrows show significant trends in index scores over the monitoring period (see Appendix 1: Monitored sites): ▲ = health improved; ▼ = health degraded. New = this trend was not previously detected in Drylie (2021), Maintained = this trend was previously detected. An asterisk (*) indicates a degradation in benthic health group since the last report.

Sandflat sites	BHMmud	BHMmetals	TBI
Hobsonville	Good ▼ * Maintained	Good	High ▲ Maintained
Shoal Bay Upper	Excellent	Good	High
Whau River	Good ▼ New	Good ▼ New	High ▲ Maintained
Henderson Creek	Good ▼ New	Good ▲ Maintained	High ▲ Maintained
Meola Reef	N/A	N/A	High ▲ New
Tidal creek sites			
Awatea	Fair	Fair	High ▲ New
Chelsea	Fair *	Fair *	High ▲ New
Coxs Bay	Fair ▼ Maintained	Fair ▼ Maintained	High ▲ New
Henderson Lower	Marginal	Marginal ▲ New	Intermediate ▲ New
Henderson Upper	Marginal	Marginal ▲ New	Low
Kendall Bay	Good	Good	High
Meola Inner	Poor ▼ * New	Marginal Lost - previously ▲	Low
Meola Outer	Good ▼ Maintained	Good	High ▲ New
Motions	Marginal	Fair ▲ Maintained	Intermediate
Motu Manawa	Good	Fair Lost - previously ▲	Low *
Oakley Creek	Marginal	Marginal *	Low
Pourewa	Fair	Fair ▲ New	High ▲ New
Shoal Bay Hillcrest	Marginal *	Fair ▲ Maintained	Intermediate ▲ New
Whakatakataka Bay	Fair	Good	High
Whau Entrance	Fair ▼ New	Fair	High
Whau Lower	Marginal	Fair ▲ Maintained	Low
Whau Upper	Marginal	Marginal ▲ Maintained	Low *
Whau Wairau	Poor ▼ * New	Poor ▲ * Maintained	Low ▲ Maintained

Macrofaunal community

Species richness was high at Meola Reef (a seagrass-dominated site), Whau River and Hobsonville and close to the regional average at Shoal Bay Upper and Henderson Creek (Figure 27). Species richness increased significantly over the monitoring period at all sites except Shoal Bay Upper (Appendix 5: Figure A10).

The non-metric multi-dimensional scaling (nMDS) plot had moderate to high stress and was useful for identifying patterns but not detailed interpretation. The sandflat sites had quite distinct macrofaunal communities and Meola Reef was the most dissimilar to the other sites (owing to the seagrass habitat at this site), evidenced by the separation between sites in Figure 28. Large shifts in community composition occurred at Meola Reef each time it was monitored in the last 10 years (monitoring took place in 2015, 2016, 2022 and 2023). Results of SIMPER analysis suggest these changes in community composition were mostly caused by fluctuations in the abundance of mud-tolerant species (*Heteromastus filiformis*, *Aricidea* sp., *Boccardia syrtis* and Oligochaeta) and likely reflect short-term variability in sediment mud content. Some minor directional change was evident at Whau River which coincided with the increasing trends in sediment mud content, organic content and chlorophyll *a* and the degrading BHMmud trend.

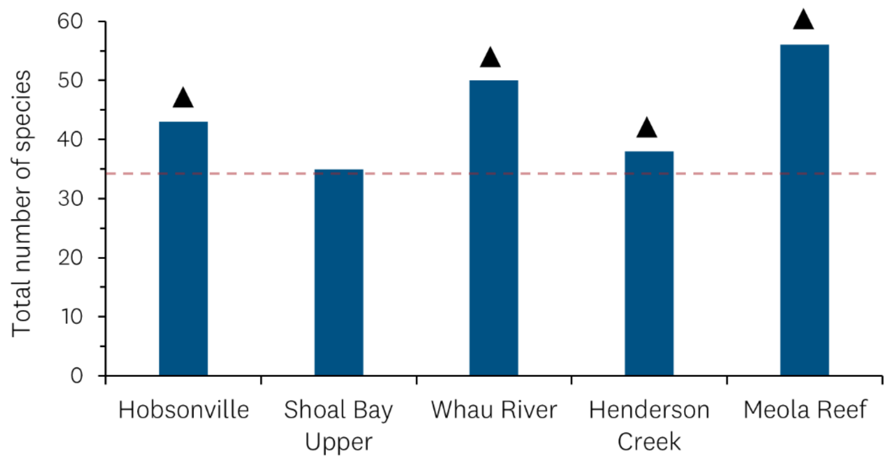

Figure 27. Species richness at Central Waitematā monitoring sites in 2020 (rotational sites) and 2023 (core sites). The dashed line shows the median species richness across all Harbour Ecology sites based on the latest available data. The direction of statistically significant trends between 2000 and 2023 are shown: ▲ represents an increase and ▼ a decrease.

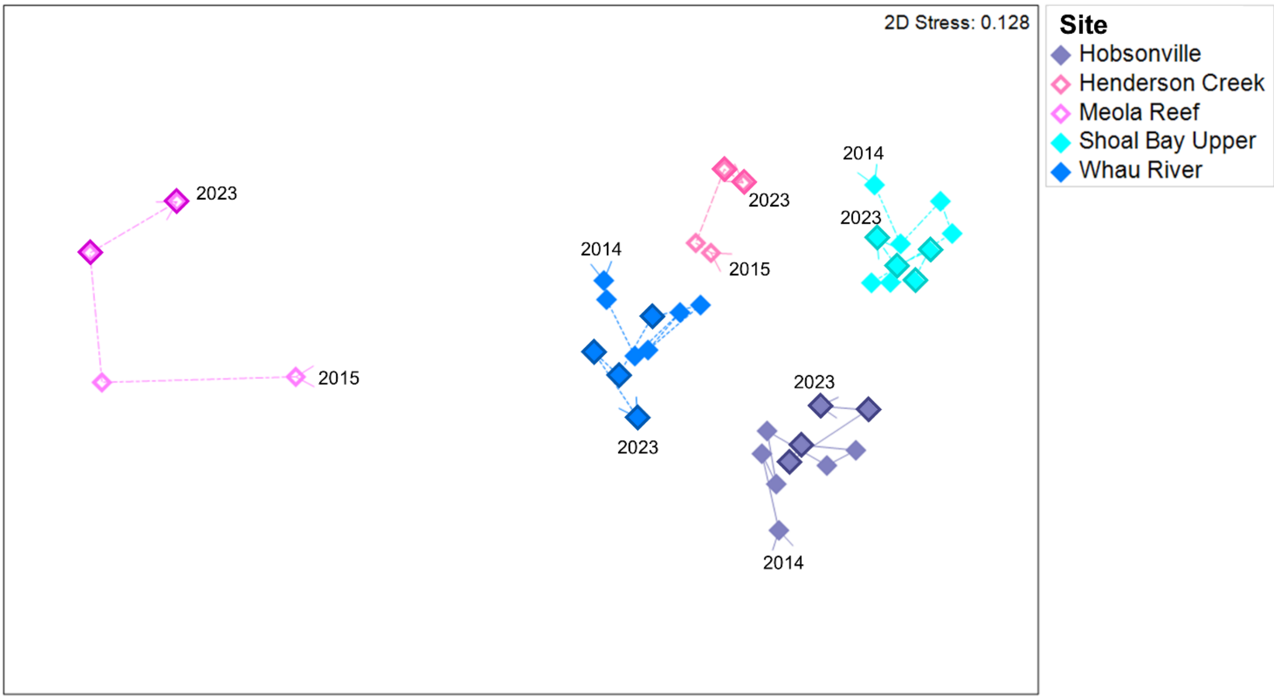

Figure 28. The similarity in macrofaunal community composition between Central Waitematā monitoring sites and changes over the last 10 years (2014 to 2023). Symbols are outlined to highlight new data since Drylie (2021).

Indicator species

Except for Upper Shoal Bay, trends in the abundance of indicator species were analysed for all sandflat sites due to concerning benthic health trends and group changes. *Papawera zelandiae* was absent from all analysed sites in 2023; the final occurrence of this gastropod was at Whau River in 2018, but it first disappeared from Henderson Creek as long ago as 2011. It may not be appropriate to retain this as an indicator species for Central Waitematā, and this should be reviewed in the next reporting round.

There was a high number of trends consistent with sedimentation at all the analysed sites; especially Hobsonville and Meola Reef (Table 22). Several new trends were detected at Hobsonville including decreases in the abundance of *Paphies australis* and *Aonides trifida* (both have a strong preference for sand) and *Macomona liliana* (which prefers sand). Some observations also suggested more recent sedimentation stress as, since 2017, *Anthopleura hermaphroditica* and *Macomona liliana* abundances decreased at Hobsonville (both species prefer sandy habitats).

The greatest number of trends consistent with metal contamination occurred at Meola Reef, though there were no changes to suggest recent contamination stress and metal concentrations were low when sampled in 2019. Each of the metal-sensitive species that exhibited significant trends were also sensitive to sedimentation, so it is likely the significant increase in sediment mud content (Table 20) was the main driver of these changes.

Table 22. Trends in the abundance of monitored and regionally common species at Central Waitematā monitoring sites between Oct. 2000 and Oct. 2023: ▲ = significant increase; ▼ = significant decrease. Arrows are coloured to highlight trends consistent with a particular stressor: sedimentation, metal contamination, or both. Grey cells indicate trends that are less certain or uncertain and sites exhibiting multi-year cycles (MY) are shown. An asterisk (*) indicates a recent change in abundance. Pref = sediment preference; SS = strong sand preference, S = prefers sand, M = prefers some mud, MM = strong mud preference, - = unknown. N/A = not assessed (occurrence and/or abundance too low).

Monitored species	Pref	Hobsonville	Whau River	Henderson Creek	Meola Reef
Arthritica bifurca	M	▲ MY	▲ MY	▲ MY	▲ MY
Boccardia syrtis	M	▲ MY	▲	▲	▲ MY
Clymenella stewartensis	M				
Glycera americana	M				
Heteromastus filiformis	M			▲	▲ *
Zeacumantus lutulentus	M				▼
Anthopleura hermaphroditica	S	▲ *	▲ MY	*	N/A
Diloma subrostratum	S		▲		N/A
Colurostylis lemurum	SS	▲ MY	▲		▼ MY
Paphies australis	SS	▼	N/A	N/A	N/A
Euchone sp.	-	N/A	N/A	N/A	▼
Exosphaeroma spp.	-	▼ MY	▼	▼	N/A
Papawera zelandiae	-		▼	▼	▼ MY
Regionally common species					
Aricidea sp.	M	▲ *	▲	▲ MY	▲ MY
Prionospio aucklandica	M	▲ MY			▲ MY
Austrovenus stutchburyi	S	▲ MY		▲ * MY	
Linucula hartvigiana	S	▼ MY	▼ MY	▼ MY	▼
Macomona liliana	S	▼ * MY	▼ MY		▼ MY
Aonides trifida	SS	▼	▼ MY	▲ MY	
Notoacmea scapha	SS		▲ MY	▲ MY	▲ MY
Trends consistent with sedimentation		8	6	5	8
Trends consistent with metals		3	3	1	4

Summary

The overall health of monitoring sites in Central Waitematā ranged from 'Good' to 'Poor' in 2023. Sites with the poorest health tended to be in the upper reaches of the tidal creeks, where sediment mud content was very high and metal contaminant concentrations were often elevated. The sandflat sites tended to have better health and lower sediment mud content (always less than 10 per cent), and metal contaminant concentrations were low.

Long-term increases in sediment mud content and declines in BHMmud scores occurred at three of the sandflat sites, and numerous trends in indicator species that were consistent with sedimentation were detected at all analysed sites. Concerningly, several changes at Hobsonville indicated ongoing sedimentation stress (degraded BHMmud group and new indicator species trends) despite no sediment mud content trend, and a total of five sites (across the sandflats and tidal creeks) were in a poorer BHMmud health category in 2023 compared to 2019.

Metal contaminants also impacted the health of most tidal creek sites, and degrading BHMmetals scores since 2018 at Meola Inner, Motu Manawa and Whau Wairau are of concern. However, health in relation to metals had improved at eight tidal creek sites over the long-term. All the sandflat sites were in 'Good' health according to the BHMmetals, which was expected given the low metal contaminant concentrations at these sites.

Evidence of potential nutrient enrichment was found at three of the sandflat sites (Upper Shoal Bay, Whau River and Henderson Creek) and warrants further investigation. Likewise, changes in more than one benthic health index at the Chelsea and Motu Manawa tidal creek sites is of concern and should be monitored closely in the coming years.

3.1.5 Tāmaki

Tāmaki Estuary has a surface area of 17 km^2 and drains an almost exclusively urban catchment of 102 km^2 (Auckland Council, 2025). There was minimal change in catchment land use since the last report except for small areas of exotic grassland and urban parkland becoming built-up urban areas in the Otara Creek/Flat Bush and Pakuranga Creek sub-catchments.

Ecological data for Tāmaki Estuary is collected under the Regional Sediment Contaminant Monitoring Programme (i.e. the estuary is not part of the Harbour Ecology monitoring programme). Due to the differences in variables and sampling frequencies between these programmes, the data available for ecological analysis were more limited than for the other estuaries. However, eight sites had sufficient benthic health data for trend analyses, and the current state of an additional site (Roberta Reserve) was available. Analysis of sediment contaminant data is available in Allen (2025).

Sediment characteristics

The most recent data for sites in Tāmaki Estuary showed sediment mud content was high (greater than 10 per cent) everywhere except Roberta Reserve, which is located near the estuary mouth

(Figure 29). All sites in the upper reaches of the tidal creeks (Panmure, Pakuranga Upper, Ōtāhuhu and Middlemore) had mud content greater than 60 per cent. According to Allen (2025), sediment mud content increased ('worsened') at four sites and decreased ('improved') at two over the monitoring period (Table 23).

Concentrations of metal contaminants were sampled in 2022 and were highly variable among sites, with levels of contamination tending to decrease towards the estuary mouth (Allen, 2025). Concentrations of copper and lead decreased meaningfully (by more than 2 per cent per year) at Pakuranga Upper over the monitoring period, yet zinc concentrations increased at Benghazi and Middlemore and were elevated at several sites in the upper estuary (triggering the red ERC category). Copper, lead and mercury were also elevated at several sites such that Benghazi and Roberta Reserve were the only sites not triggering any sediment quality guidelines.

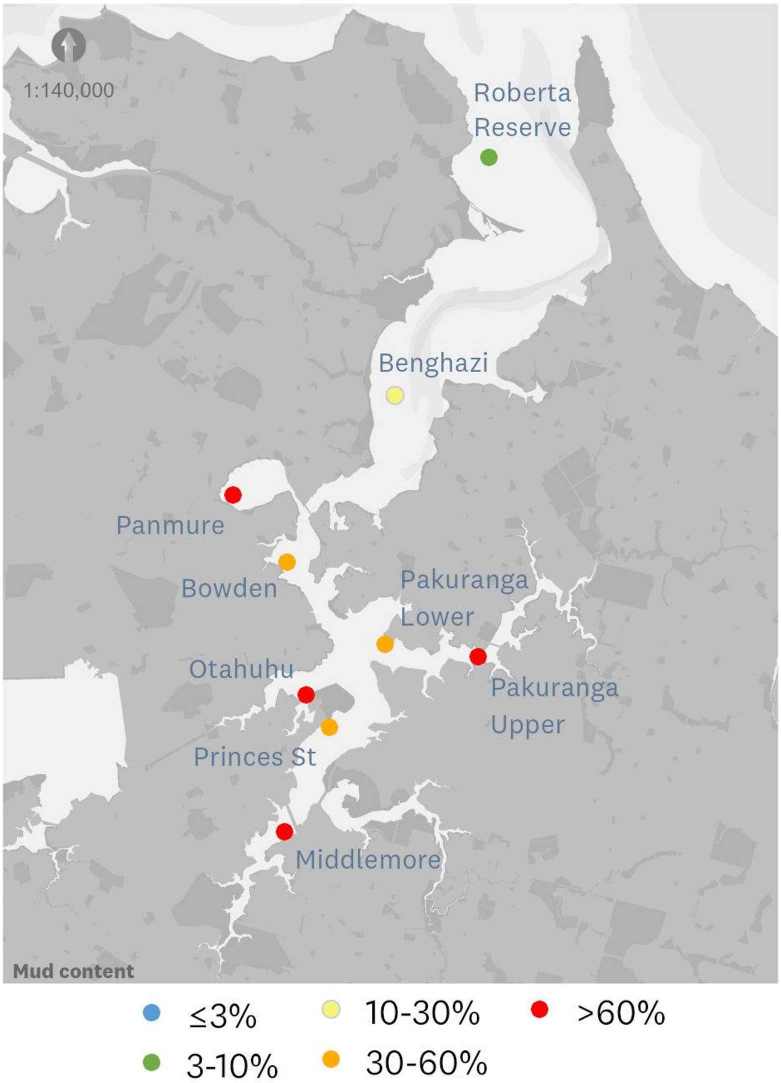

Figure 29. Sediment mud content at Tāmaki Estuary monitoring sites between 2017 and 2022.

Table 23. Significant trends in sediment mud content at Tāmaki Estuary sites (adapted from Allen, 2025). Linear trends assessed with Mann-Kendall test, trend likelihood based on Sen Slope probabilities following LAWA categories ('very likely' (>90%), 'likely' (67-90%), and 'indeterminate' (<67%)).

Site	Mud content (%) trend likelihood
Benghazi	Indeterminate
Bowden	Likely improving
Middlemore	Likely worsening
Ōtāhuhu	Very likely worsening
Pakuranga Lower	Likely worsening
Pakuranga Upper	Very likely improving
Panmure	Indeterminate
Princes St	Likely worsening

Benthic health

Between 2017 and 2022, overall health according to the Combined Health Score ranged from 'Fair' to 'Poor' and was most commonly 'Marginal' (Figure 30). Sites with the poorest health tended to be in the upper reaches of the estuary and health improved towards the estuary mouth, largely mirroring the pattern in sediment mud content. Functional resilience (according to the TBI) ranged from 'High' to 'Low' and increased significantly at Benghazi and Ōtāhuhu over the long-term (Table 24).

Figure 30. Combined Health Scores for Tāmaki Estuary sites between 2017 and 2022.

Health in relation to mud was 'Marginal' at all sites and no significant long-term trends were detected, however the health status at Benghazi and Panmure degraded between 2019 and 2022 (Table 24). This shift does not seem immediately concerning for Panmure and may simply reflect natural variability, given health at this site was 'Marginal' every year except 2019 (since monitoring began in 2004). At Benghazi, health in relation to mud was mostly 'Fair' since 2004 so the shift to 'Marginal' in 2022 might signal a more concerning decline in condition that should be monitored closely. Both sites had 'indeterminate' trends for sediment mud content (Table 23).

Health in relation to metals was 'Fair' at most sites and 'Marginal' at Bowden, Middlemore and Pakuranga Upper (Table 24). However, significant improving health trends occurred at most sites and new trends were detected at Ōtāhuhu, Pakuranga Lower and Princes St which lead to improvements in the BHMmetals group at all three of these sites (from 'Marginal' in 2017/2018 to 'Fair' in 2022).

The monitored sites in Tāmaki Estuary were in a generally poor ecological condition and show evidence of impacts from sedimentation and, to a slightly lesser degree, metal contamination. Some recent changes in health groups may be of concern, but in contrast the only long-term trends detected were improvements in health.

Table 24. Benthic health groups at Tāmaki Estuary monitoring sites between 2017 and 2022. Benthic Health Models (BHM): Excellent, Good, Fair, Marginal, Poor; Traits-Based Index (TBI): High, Intermediate, Low. Arrows show significant trends in index scores over the monitoring period (see Appendix 1: Monitored sites): ▲ = health improved; ▼ = health degraded. New = this trend was not previously detected in Drylie (2021), Maintained = this trend was previously detected. An asterisk (*) indicates a degradation in benthic health group since the last report, Lost = a previously detected trend no longer occurs.

	BHMmud	BHMmetals	TBI
Benghazi	*		▲ Maintained
Bowden		*	
Middlemore	Lost - previously ▼	▲ Maintained	Lost - previously ▼
Ōtāhuhu		▲ New	▲ New
Pakuranga Lower		▲ New	
Pakuranga Upper		▲ Maintained	
Panmure	*	▲ Maintained	
Princes St		▲ New	

3.2 East Coast Estuaries summary

A comprehensive assessment of state and trends in ecological health in the small east coast estuaries has been undertaken in Drylie (2025); a summary of the findings is presented here to facilitate a regional synthesis of estuary ecology data.

According to the Combined Health Score, 28 per cent of the intertidal sandflat sites were in 'Excellent' or 'Good' health and 71 per cent were 'Fair' or 'Marginal' between 2021 and 2023. Only one site had 'Poor' overall health (equivalent to 1 per cent). On average, 23 species of macrofauna were found at each site and most sites (56 per cent) had 'High' functional resilience according to the TBI. The ecological health of monitoring sites tended to be better in the lower estuary close to the estuary mouth and poorer in the upper estuary close to freshwater inflows. The health of the monitoring sites seemingly degraded since the last report (based on data to 2019), as fewer sites were in 'Excellent' health (3 per cent in 2023 compared to 11 per cent in 2019) or 'Good' health (25 per cent in 2023 compared to 34 per cent in 2019) and more had 'Poor' health (one site in 2023 compared to no sites in 2019).

Sedimentation was the most prevalent stressor of ecological health, impacting every estuary to some degree. Whangateau Harbour exhibited the fewest long-term trends consistent with sedimentation while Mangemangeroa, Ōkura and Waikōpua exhibited the most. Some recent changes in indicators that might suggest ongoing impacts from sedimentation were also found in most estuaries. For instance, an increase in the concentration of very fine sediments, a degradation in the health group assigned by the BHMmud, or a change in the abundance of indicator species that occurred within the last five years. Notably, potential recovery from sedimentation impacts was evident at sites in Tūranga and Waikōpua (in the form of improving health indices and increasing abundances of sediment-sensitive species).

Metal contamination may have caused stress to benthic communities over the monitoring period, though this was often difficult to separate from the impacts of sedimentation and there was little evidence to suggest that metals impacted ecological health in any estuary within the last five years. Despite the focus of the East Coast Estuaries monitoring programme on terrestrial sediment impacts, at more than one site in Ōrewa and Waikōpua there was an indication of potential nutrient enrichment, namely co-occurring increases in the concentration of organic content and chlorophyll *a*.

3.3 Regional summary

The current ecological state of 172 monitoring sites was assessed from across Tāmaki Makaurau / Auckland (see Figure 1). Some of these sites (36 per cent) were part of the Regional Sediment Contaminant Monitoring Programme (RSCMP) and are predisposed to being in polluted locations close to urban and industrial centres. The Harbour Ecology sites, contrastingly, are intentionally located in less polluted areas to increase our ability to detect degradation (and are often close to transitional boundaries between sandy and muddy conditions) and contributed 19 per cent of the assessed sites. Sites monitored in the East Coast Estuaries Ecology programme are spread from the upper to the lower estuary and represent a gradient of impacts (decreasing with distance from freshwater inflows) and made up 45 per cent of the assessed sites. Combined, these sites provide a largely balanced representation of intertidal benthic ecology across the region but may tend to over-represent locations that are at least somewhat degraded, given the high proportion of RSCMP sites.

Sediment mud content was at least somewhat elevated (greater than 3 per cent) and likely to affect the benthic community at 88 per cent of the monitored sites (Appendix 6: Figure A11). At 21 per cent of sites, sediment mud content was very high (greater than 60 per cent) and likely to cause degraded macrofaunal communities. Only 2 per cent of the monitored sites were in 'Excellent' overall health and 22 per cent were 'Good'. Sites most commonly had 'Fair' (34 per cent) or 'Marginal' (30 per cent) health and 12 per cent of sites were 'Poor' (Appendix 6: Figure A12).

All sites that had 'Excellent' overall health also had less than 3 per cent mud content, and all sites that were in 'Poor' health had at least 30 per cent mud content (Figure 31). Sediment mud content tended to be below 10 per cent at sites with 'Good' overall health and greater than 10 per cent at sites with 'Fair' or 'Marginal' health. There were some unusual instances where a site with more than 60 per cent mud content had 'Good' health (Pukaki Airport in Manukau Harbour) and where sites with less than 3 per cent mud content had 'Marginal' health (PUH1 in Pūhoi and WWR3 in Waiwera) (Figure 31). In the case of Pukaki Airport, excess sediment clearly impacted the site as the BHMmud group was 'Marginal' (and BHMmetals was 'Poor') yet a 'High' TBI score pulled the overall health assessment up. At PUH1, Drylie (2025) hypothesised that a high rate of disturbance from shifting coarse sands in the estuary (evidenced by high sediment accretion rates yet low sediment mud content) resulted in an impoverished macrofaunal community, and it is suspected a similar situation occurred at WWR3.

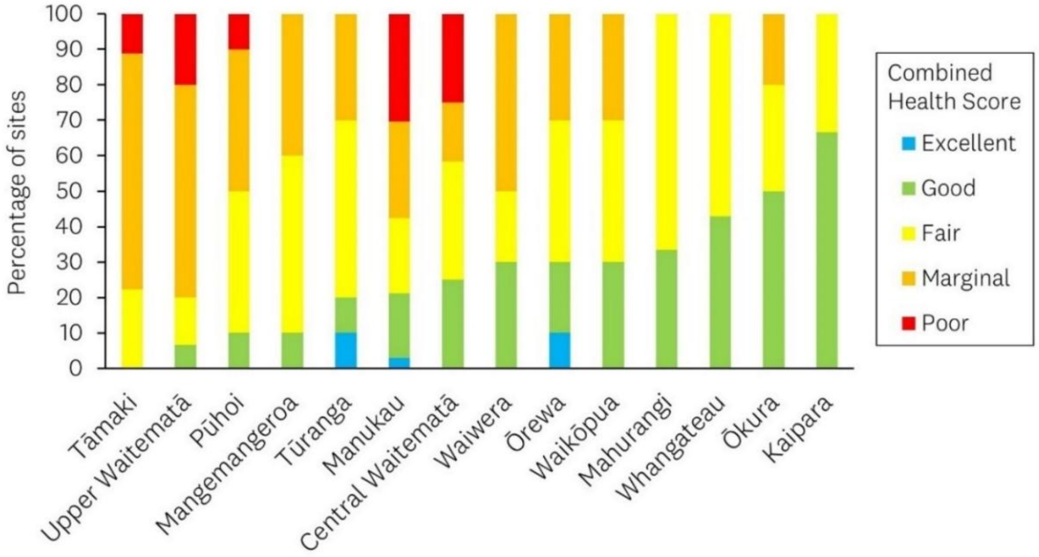

Figure 31. Relationship between sediment mud content and Combined Health Score among all sites.

There was a tendency for mud content to be high and ecological health to be low in the upper reaches of estuaries, and especially those closest to the intensely urbanised Auckland isthmus; sites with 'Poor' health mostly occurred in Manukau, Waitematā and Tāmaki (Figure 32, Appendix 6: Figure A11 and Figure A12). The catchments of these estuaries have the longest history of land use change and the highest urban densities in the region (Fredrickson, 2014). The estuaries with the greatest proportion of sites in 'Good' health (50 per cent or more) were Kaipara and Ōkura, where the dominant catchment land uses were rural (Figure 32).

The only estuaries with examples of sites in 'Excellent' health were Tūranga (TRN2), Ōrewa (ORW3) and Manukau (Auckland Airport). These sites are far away from freshwater inflows and are positioned on exposed sandflats where tidal energy is high, resulting in low exposure to pollutants (such as mud and metal contaminants) and a high flushing potential when exposure does occur. These conditions only occurred at one site in each estuary, however, and just a short distance from these 'Excellent' sites were others that were stressed and scored 'Fair' and 'Marginal' (especially in the case of Tūranga and Ōrewa, see Drylie (2025)) (Figure 32).

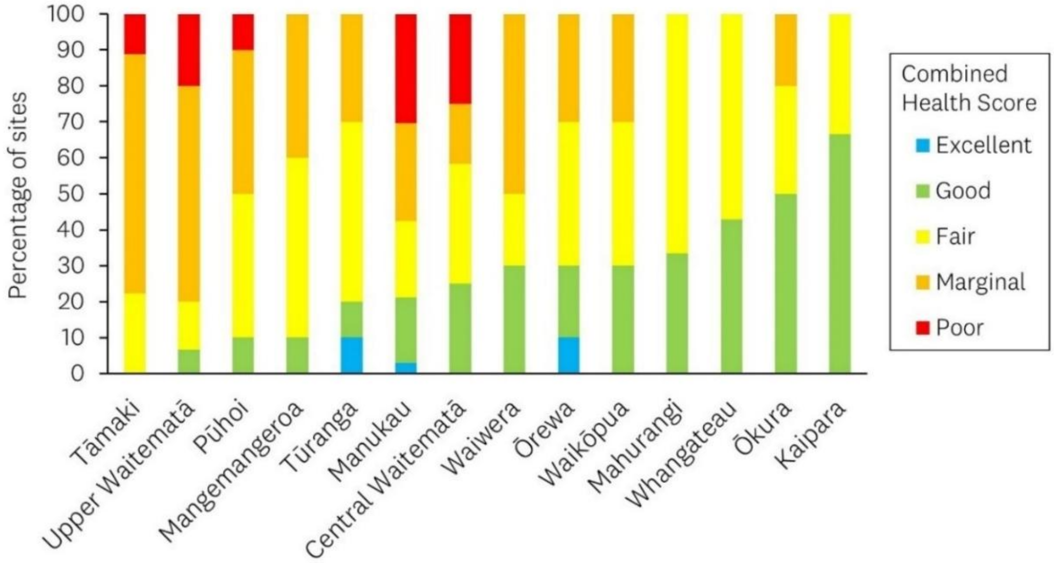

Figure 32. Distribution of monitoring sites between Combined Health Scores by estuary.

The only regionally common indicator species that changed consistently across all estuaries was the shellfish *Austrovenus stutchburyi*, which increased significantly in abundance in at least one site per estuary (Figure 33). This species prefers sandy habitats and is functionally important. Similarly, the limpet *Notoacmea scapha* strongly prefers sand habitats and increased in abundance in more estuaries than it decreased (and often lives on cockles and shell hash, so unsurprisingly showed a similar pattern to *Austrovenus stutchburyi*). However, other sand-preferring shellfish such as *Macomona liliana* (which is also sensitive to stormwater contaminants) decreased in abundance in all estuaries except Whangateau and *Linucula hartvigiana* (which is also sensitive to copper) decreased everywhere except Kaipara and Ōrewa (Figure 33 and Appendix 7: Table A3). It was also more common for the mud-preferring polychaetes *Aricidea* sp. and *Prionospio aucklandica* to increase in abundance than to decrease (*P. aucklandica* increased everywhere except Waiwera and Whangateau), and the strongly sand-preferring *Aonides trifida* more commonly decreased in abundance.

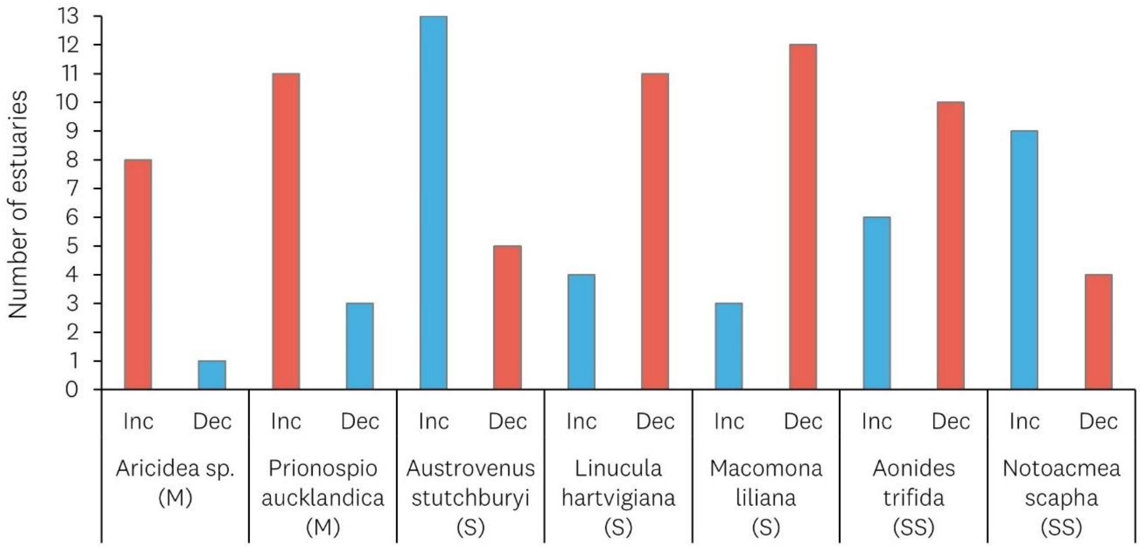

Figure 33. Frequency of trends in the abundance of regionally common species. Inc = increase, Dec = decrease. Bars are coloured to identify trends indicative of degrading or improving environmental conditions and the sediment preferences of species are shown in brackets (M = prefers some mud; S = prefers sand; SS = strong sand preference).

Information on state and trends are most insightful when interpreted holistically, for instance by identifying locations where health might be poor yet improving, or where health might be in a good state but degrading. There were few generalisable patterns when considering the estuary ecology monitoring results through this lens, as state and trend combinations were highly variable across the region and even within estuaries (Figure 34). Nonetheless, the main basin of Manukau, Whangateau and sites beyond the estuary mouth in Tūranga had limited degrading trends and were in largely good ecological health. For these estuaries, management efforts should focus on protection and conservation. A similar approach might be recommended for the estuaries where ecological health was mostly poor but improving trends were detected, such as the tidal creeks of Manukau Harbour and Tāmaki Estuary. Active restoration (as opposed to passive restoration) could potentially increase the rate of recovery in these locations (Elliott et al., 2007; Handley, 2022).

Concerningly, more estuaries fell into the 'poor and degrading' category than any other, and there were several examples of estuaries (or parts of estuaries) that remained in good health yet had degraded over the monitoring period (including Kaipara, Ōkura and sites within Upper and Central Waitematā) (Figure 34). Management interventions are needed to reduce the pressures on these estuaries, such as minimising the input of sediments and nutrients from land-based activities. Only once the delivery of pollutants to the estuaries is reduced can we expect to see effective restoration interventions and improvements in health.

Good and stable	Good yet degrading
Manukau Whangateau Tūranga (beyond estuary mouth)	Kaipara Central Waitematā Ōkura
Poor and degrading	**Poor yet improving**
Mahurangi Upper Waitematā Central Waitematā Pūhoi Waiwera Ōrewa Mangemangeroa Waikōpua	Manukau Upper Waitematā Central Waitematā Tāmaki Tūranga (in-estuary) Waikōpua

Figure 34. Summary of state and trends in estuaries across Tāmaki Makaurau / Auckland.

Excess land-derived sediment continued to be the most prevalent and severe pressure on benthic environments across Tāmaki Makaurau / Auckland (Table 25). Every estuary exhibited at least moderate impacts from sediment and long-term degrading conditions at one monitoring site or more. Signs of recent sedimentation impacts were also apparent in several estuaries. The ecological health of sites in far fewer estuaries (eight out of 14) were impacted by contamination from metals, although the effects could be large where they did occur. Health in relation to metal contamination (BHMmetals) had improved in several locations, especially estuaries with the longest history of catchment modification, though there were also signs of recent impacts in some small east coast estuaries. Excess nutrient concentrations may have impacted the ecological health of sites in seven (50 per cent) of the monitored estuaries across both urban and rural catchments (Table 25). As the indicators used to identify impacts from nutrient enrichment are limited, these findings act as a trigger for further investigation.

Table 25. Summary of the ecological health of monitored estuaries in Tāmaki Makaurau / Auckland in relation to land-derived pressures.

	Sedimentation	Metal contamination	Nutrient enrichment	Ecological Health
Kaipara	Impacts from sedimentation were minor at most sites despite several degrading health trends.	Impacts from metals were minimal despite some degrading trends.	Some evidence of nutrient impacts at Kaipara Bank.	Predominantly 'Good' though numerous degrading trends
Manukau	Impacts were minor at sandflat sites and severe in tidal creeks. Several improving trends were found.	Contamination impacts occurred at tidal creek sites and were minimal at sandflat sites. Several improving trends were found.	Recent harbour-wide increases in organic content that could be related to excess nutrients.	'Excellent' to 'Fair' at sandflat sites and 'Good' to 'Poor' at tidal creek sites. Very few concerning trends and some improving.
Mahurangi	Excess sediment impacted the health of all sites and caused degrading trends at most.	Health was moderately impacted by metals at all sites and had degraded at four.	Potential enrichment at most sites.	Predominantly 'Fair' and numerous degrading trends
Upper Waitematā	Sedimentation had large impacts on sandflat and tidal creek health which were often worsening.	Metals had a large impact on all sites and a mixture of improving and degrading trends occurred.	Evidence of excess nutrients at several sites near the sub-estuary mouth.	'Good' to 'Poor' (predominantly 'Marginal') with both improving and degrading trends.
Central Waitematā	Impacts were moderate at sandflat sites and more severe in tidal creeks. Degrading trends occurred throughout.	Impacts were minor at sandflat sites and more severe in tidal creeks. Several improving trends occurred.	Evidence of excess nutrients at several sites throughout.	'Good' to 'Poor' (often better at the sandflat sites) with both improving and degrading trends.
Tāmaki	Excess sediment severely impacted the health of all but one site and recent impacts were evident.	Metals had a large impact on health at all sites, though many improving trends occurred.	*No data available to assess this stressor*	'Fair' to 'Poor' and mostly 'Marginal' with many improving trends.
Whangateau	Excess sediment impacted the health of sites close to freshwater inflows.	Minimal evidence of metal contamination impacts.	Minimal evidence of excess nutrients.	'Good' or 'Fair' with few changes of concern.

	Sedimentation	Metal contamination	Nutrient enrichment	Ecological Health
Pūhoi	All sites were impacted, especially in the upper estuary. Recent impacts were evident.	Minimal evidence of metal contamination impacts.	Minimal evidence of excess nutrients.	'Good' to 'Poor' and mostly 'Fair' or 'Marginal'. Several health declines.
Waiwera	Impacts were widespread. Recent impacts were evident.	Some indication of recent impacts from metals.	Minimal evidence of excess nutrients.	Predominantly 'Marginal' though instances of 'Good'. Several health declines.
Ōrewa	Impacts were severe in the upper estuary and reduced near the mouth. Recent impacts were evident.	Minimal evidence of metal contamination impacts.	Evidence of nutrient impacts at more than one site.	Mostly 'Fair' or 'Marginal' and numerous declines in health.
Ōkura	Impacts were severe in the upper estuary and reduced near the mouth. Recent impacts were evident.	Metals (copper and lead) may impact health in the upper estuary.	Minimal evidence of excess nutrients.	Mostly 'Good' with instances of 'Fair' and 'Marginal' and some declines in health.
Mangemangeroa	Most sites were heavily impacted by sediment, and recent impacts were evident at some core sites.	Metals (copper and lead) may impact health in the mid and upper estuary.	Minimal evidence of excess nutrients.	Predominantly 'Fair' or 'Marginal' with several declines in health.
Tūranga	Health was heavily impacted in the mid and upper estuary.	Minimal evidence of metal contamination impacts.	Minimal evidence of excess nutrients.	'Fair' or 'Marginal' in-estuary and 'Excellent' or 'Good' beyond the estuary mouth, with some improvements in-estuary.
Waikōpua	Health was heavily impacted in the mid and upper estuary.	Minimal evidence of metal contamination impacts.	Evidence of nutrient impacts at more than one site.	'Good' to 'Marginal' (most commonly 'Fair') with both improvements and declines in health.

4 Conclusions

The ecological health of every monitored estuary in Tāmaki Makaurau / Auckland was degraded to some extent by historic and current land use. Estuaries with catchments dominated by indigenous vegetation and rural land uses, or with a short history of urbanisation, tended to be in better condition (such as Kaipara and Whangateau Harbours). By contrast, estuaries with predominantly urban catchments and a long history of land use change had predictably poor health (such as Central Waitematā Harbour and Tāmaki Estuary). Impacts from excess land-derived sediment were apparent in every estuary. Spatial patterns occurred within estuaries with clear improvements in health as the distance from stream and river mouths increased, unless modifications to the coastline (such as causeways) interfered with the natural dynamics of the ecosystem.

It was not possible to identify a regionally consistent pattern when considering information on state and trends holistically; the condition of some estuaries had degraded yet they remained in good health, for some there had been improvements though they remained in poor health. Most commonly, ecological health had degraded and resulted in poor health. These estuary-specific dynamics highlight the need for location-specific management approaches. By categorising estuaries according to their combination of state and trends it was possible to identify broad environmental management approaches that might be most appropriate for each estuary (or part of an estuary), such as where active restoration might be most effective or where more work needs to be done to reduce the input of pollutants first.

In this report, more estuaries were identified as having potential excess nutrient issues than in Drylie (2021). Sites in only three estuaries (the Mahurangi, Upper Waitematā and Central Waitematā Harbours) had symptoms of nutrient enrichment previously, whereas sites in seven estuaries did based on the present analysis (those listed plus Manukau Harbour, Kaipara Harbour, Ōrewa River estuary and Waikōpua Creek estuary). There was some alignment between these findings and the results of Dudley et al. (2024), who modelled nutrient inputs to estuaries in Tāmaki Makaurau / Auckland and assessed their susceptibility to eutrophication. For instance, Ōrewa and zones of the Kaipara and Waitematā Harbours were predicted to have moderate to high susceptibility by Dudley et al. (2024). However, the other estuaries where nutrient enrichment symptoms were detected had low predicted susceptibility. The variables used to identify excess nutrients are indirect indicators, i.e. organic content and chlorophyll *a* respond to an increase in nutrient availability and are interpreted as a proxy of previously elevated nutrient concentrations; analysing sediment nutrient concentrations directly and continuing to contextualise the monitoring data with broadscale symptoms of nutrient enrichment (such as algal blooms) would help confirm the occurrence and assess the severity of any nutrient enrichment issues.

The sensitivity of indicator species to both metals and sediment occasionally limited our ability to identify impacts from metal contamination. Of the macrofaunal species where information about their habitat preferences and pollutant sensitivities are known, very few are exclusively sensitive to metal contaminants and not to sediment. This makes disentangling the true driver of population trends difficult, especially as metal concentrations tend to increase with sediment mud content (Mills & Allen, 2021) and the Benthic Health Models (BHMs) for metals and mud are positively correlated (Hewitt & Ellis, 2010). A weight of evidence approach is helpful, for instance considering the BHMmetals, trends in indicator species and sediment metal contaminant concentration data, where available. This helped to distinguish between genuine metal contamination effects and those likely confounded by sedimentation, though where metal contaminant data are not available, additional exploration of the BHM scores data might prove useful. Bivariate plots (i.e. where the BHMmud and BHMmetals scores are plotted against one another) may help assess site changes as the movement of a site along the BHMmetals axis would suggest contaminants are the main factor driving species responses (and vice versa if the site moves along the BHMmud axis) (Hewitt & Ellis, 2010). The utility of such manipulations for identifying metal contamination effects should be explored at sites where there is uncertainty about drivers of change.

Some counter-intuitive interactions occurred between benthic health indices that require further investigation. At several sites, health according to the BHMs declined, while functional resilience according to the Traits-Based Index (TBI) improved. These indices are designed to reflect different aspects of the macrofaunal community and their opposing responses are not necessarily contradictory; degrading BHM scores are usually associated with decreases in the abundance (and eventual loss) of species that are sensitive to mud or metals, whereas the TBI is strongly related to species richness and an increase in TBI is often caused by an increase in the number of species in the community, irrespective of abundance (Hewitt & Ellis, 2010; van Houte-Howes & Lohrer, 2010). As a macrofaunal community transitions from one state to another, even if that is from a healthy state to a less healthy one, there may be a period where species richness increases as individuals representing both community states are present. For example, mud-tolerant species may migrate into a location affected by sedimentation before all the mud-sensitive species have been excluded if there is some overlap in the range of mud content they can tolerate (Thrush et al., 2003). In such cases, the TBI would increase on account of the greater species diversity, while the BHMmud might degrade as the abundance of mud-sensitive species decrease and mud-tolerant species increase. Further interrogation of the changes in community that underly the BHM and TBI trends could shed light on whether these kinds of dynamics occurred at the monitoring sites.

Similarly, several sites had 'High' functional resilience scores that were counter-intuitive, given they also had high sediment mud content and degraded health according to the BHMs (namely Herald Island North, Lucas Creek and Outer Main in Upper Waitematā and Pukaki Airport in Manukau Harbour). It is suggested that spatial heterogeneity in the macrofaunal community might play a role and should be investigated with analyses of the variance among replicate macrofaunal samples (beta-diversity). If such heterogeneity is confirmed, consideration should be given to whether it is still appropriate to apply this index at these sites.

Increases in the extent and density of seagrass beds were identified in several estuaries, providing some insight into the regional state of this habitat. The data presented in this report originate from Tier 1 estuary ecology monitoring programmes which are designed to meet temporal objectives of identifying change in benthic ecology, rather than providing spatial habitat assessments (Carbines et al., 2013; Hewitt, 2000). Nevertheless, the gradual expansion and infilling of seagrass meadows at permanent monitoring sites in the Manukau, Kaipara and Central Waitematā Harbours was tracked over the last five years. The colonisation of bare sediment by seagrass lead to increases in macrofaunal diversity at each of the affected sites (an effect that has been demonstrated elsewhere in Aotearoa / New Zealand (Lundquist et al., 2003)) and seagrass habitats are associated with numerous ecological functions, including high rates of primary production, provision of habitat structure and nutrient cycling (Turner & Schwarz, 2006). The factors influencing seagrass dynamics are complex, though pollution (whether from fine sediments, excess nutrients or contaminants) has a negative effect on seagrass, such that it would be unlikely for expansion to occur into areas where these stressors are high (Matheson & Schwarz, 2007; Morrison et al., 2009). This suggests environmental conditions are favourable in the recently colonised sites, though it is also possible that seagrass growth may be enhanced in the early stages of nutrient pollution (Matheson & Schwarz, 2007); surveying sediment nutrient concentrations across the region will provide useful information to help better understand recent seagrass dynamics.

The expansion of seagrass into the Tier 1 monitoring plots does present a challenge in terms of monitoring, as the variables sampled in the estuary ecology programme were designed for unvegetated sandflat habitats. In particular, the BHMs cannot be applied to seagrass-dominated sites as they assess health by comparing the composition of the macrofaunal community at monitoring sites to the model data, which were derived from unvegetated sites. Similarly, sediment mud content tends to be higher in seagrass habitats due to the stabilising and trapping effect of the seagrass roots and blades, and assessment of this variable according to thresholds developed for unvegetated sites may not be appropriate. Alternative approaches to assessing ecological state should be considered at these sites, drawing on guidance documents such as the Coastal Special Interest Group seagrass monitoring guidelines (Shanahan et al., 2023) and the Ministry for the Environment's assessment of estuary indicators (Stevens et al., 2024).

4.1 Recommendations

Several specific recommendations have been made for future monitoring and further investigation in the Harbour and East Coast Estuaries Ecology programmes and are summarised here (see Drylie (2025) for additional details relating to the latter).

Harbour Ecology monitoring programme

- Kaipara Harbour – remove *Exosphaeroma planulum* and *Exosphaeroma waitemata* from the monitored species list as they did not occur frequently enough to be suitable for trend analysis.

- Upper Waitematā Harbour – remove *Pseudopotamilla* sp. from the monitored species list as its occurrence was too low to perform trend analysis at any site.
- Central Waitematā Harbour – review the suitability of *Papawera zelandiae* as an indicator species in the next reporting round. This species was absent from all analysed sites in 2023 and had not been observed at any site since 2018.
- Consider alternative approaches to assessing ecological state at sites now dominated by seagrass, drawing on guidance documents such as the Coastal Special Interest Group seagrass monitoring guidelines (Shanahan et al., 2023) and the Ministry for the Environment's assessment of estuary indicators (Stevens et al., 2024).

East Coast Estuaries Ecology monitoring programme

- Whangateau Harbour – include site WNG5 as a core site to improve spatial coverage and better capture the influence of Ōmaha River on the estuary.
- Mangemangeroa Creek – investigate the potential to include site MNG7 or MNG9 as a core site to improve spatial coverage across the estuary.

Further investigations

- Measure sediment nutrient concentrations to improve knowledge of the occurrence and severity of any benthic nutrient enrichment issues across the region (focusing on areas with suspected pollution, see Table 25).
- Continue to interrogate the degrading BHM trends at Auckland Airport to better understand their cause, given this is an ecologically valuable site and the only example of 'Excellent' overall health in the Harbours programme.
- Explore the utility of bivariate plots for disentangling the influence of sediment versus metals in driving species responses.
- Interrogate macrofaunal community composition dynamics to explain the unexpectedly 'High' TBI scores (for some Upper Waitematā Harbour sites) and contradictory BHM and TBI trends (at several locations) which may be caused by spatial heterogeneity or transitioning ecological communities.

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Appendix 1: Monitored sites

Table A1. Sites with sufficient data for trend analysis and the length of the time series. RSCMP = Regional Sediment Contaminant Monitoring Programme.

	Programme	Site	Location	Time series
1	Harbour Ecology	Haratahi Creek	Kaipara	2009–2021
2	Harbour Ecology	Kaipara Bank	Kaipara	2009–2023
3	Harbour Ecology	Kaipara Flats	Kaipara	2009–2021
4	Harbour Ecology	Kakaraia Flats	Kaipara	2009–2023
5	Harbour Ecology	Ngāpuke Creek	Kaipara	2009–2023
6	Harbour Ecology	Te Ngaio Point	Kaipara	2014–2023
7	Harbour Ecology	Auckland Airport	Manukau	1987–2023
8	Harbour Ecology	Clarks Beach	Manukau	1987–2023
9	Harbour Ecology	Karaka Point	Manukau	1987–2021
10	Harbour Ecology	Puhinui Stream	Manukau	1987–2021
11	Harbour Ecology	Elletts Beach	Manukau	1987–2021
12	Harbour Ecology	Cape Horn	Manukau	1987–2020
13	RSCMP	Anns Creek	Manukau (Māngere Inlet)	2005–2021
14	RSCMP	Māngere Cemetery	Manukau (Māngere Inlet)	2005–2021
15	Harbour Ecology	Dyers Creek	Mahurangi	2005–2023
16	Harbour Ecology	Hamilton Landing	Mahurangi	1995–2023
17	Harbour Ecology	Jamieson Bay	Mahurangi	1995–2023
18	Harbour Ecology	Mid Harbour	Mahurangi	1995–2023
19	Harbour Ecology	Te Kapa Inlet	Mahurangi	1995–2023
20	Harbour Ecology	Cowans Bay	Mahurangi	1995–2022
21	Harbour Ecology	Hellyers Creek	Upper Waitematā	2005–2023
22	Harbour Ecology	Herald Island North	Upper Waitematā	2005–2023
23	Harbour Ecology	Herald Island Waiarohia	Upper Waitematā	2005–2023
24	Harbour Ecology	Lucas Creek	Upper Waitematā	2005–2023

	Programme	Site	Location	Time series
25	Harbour Ecology	Rangitōpuni Creek	Upper Waitematā	2005–2022
26	Harbour Ecology	Brigham Creek	Upper Waitematā	2005–2022
27	Harbour Ecology	Opposite Hobsonville	Upper Waitematā	2005–2022
28	Harbour Ecology	Central Main	Upper Waitematā	2005–2022
29	Harbour Ecology	Upper Main	Upper Waitematā	2005–2022
30	Harbour Ecology	Outer Main	Upper Waitematā	2005–2022
31	RSCMP	Hellyers Upper	Upper Waitematā	2007–2020
32	RSCMP	Lucas Te Wharau	Upper Waitematā	2004–2020
33	RSCMP	Lucas Upper	Upper Waitematā	2005–2022
34	RSCMP	Pāremoremo	Upper Waitematā	2005–2022
35	Harbour Ecology	Hobsonville	Central Waitematā	2000–2023
36	Harbour Ecology	Shoal Bay Upper	Central Waitematā	2014–2023
37	Harbour Ecology	Whau River	Central Waitematā	2000–2023
38	Harbour Ecology	Henderson Creek	Central Waitematā	2000–2023
39	Harbour Ecology	Meola Reef	Central Waitematā	2000–2023
40	RSCMP	Awatea	Central Waitematā (Hobson Bay)	2006–2023
41	RSCMP	Chelsea	Central Waitematā	2004–2023
42	RSCMP	Coxs Bay	Central Waitematā	2004–2023
43	RSCMP	Henderson Lower	Central Waitematā	2004–2023
44	RSCMP	Henderson Upper	Central Waitematā	2005–2020
45	RSCMP	Kendall Bay	Central Waitematā	2004–2023
46	RSCMP	Meola Inner	Central Waitematā	2005–2023
47	RSCMP	Meola Outer	Central Waitematā	2004–2023
48	RSCMP	Motions	Central Waitematā	2005–2023
49	RSCMP	Motu Manawa (Pollen Island)	Central Waitematā	2005–2023
50	RSCMP	Oakley Creek	Central Waitematā	2005–2023
51	RSCMP	Pourewa	Central Waitematā (Hobson Bay)	2004–2023
52	RSCMP	Shoal Bay Hillcrest	Central Waitematā	2004–2023
53	RSCMP	Whakatakataka Bay	Central Waitematā (Hobson Bay)	2005–2023

	Programme	Site	Location	Time series
54	RSCMP	Whau Entrance	Central Waitematā	2006–2023
55	RSCMP	Whau Lower	Central Waitematā	2005–2023
56	RSCMP	Whau Upper	Central Waitematā	2005–2023
57	RSCMP	Whau Wairau	Central Waitematā	2005–2023
58	RSCMP	Benghazi	Tāmaki	2004–2022
59	RSCMP	Bowden	Tāmaki	2004–2022
60	RSCMP	Middlemore	Tāmaki	2005–2022
61	RSCMP	Ōtāhuhu	Tāmaki	2004–2022
62	RSCMP	Pakuranga Lower	Tāmaki	2011–2022
63	RSCMP	Pakuranga Upper	Tāmaki	2005–2022
64	RSCMP	Panmure	Tāmaki	2004–2022
65	RSCMP	Princes St	Tāmaki	2004–2022

Appendix 2: Monitored species

Table A2. Routinely monitored species in each Harbour Ecology sub-programme, their sediment preferences (SS = strong sand preference, S = prefers sand, M = prefers some mud but not in high percentages, MM = strong mud preference) and sensitivity to metal contaminants, if known (based on Norkko et al., (2001) and Gibbs & Hewitt (2004)). KAI = Kaipara, MAN = Manukau, MAHU = Mahurangi, CWH = Central Waitematā, UWH = Upper Waitematā.

Order	Species	Pref	Metal	KAI	MAN	MAHU	CWH	UWH
Polychaete	*Aglaophamus macroura*	-		X	X			
Anthozoa	*Anthopleura hermaphroditica* (was *A. aureoradiata*)	S	✓	X	X		X	
Polychaete	*Aonides trifida*	SS	✓	X	X	X	X	
Bivalve	*Arcuatula senhousia*	-		X				X
Polychaete	*Aricidea* sp.	M		X		X	X	X
Bivalve	*Arthritica bifurca*	M				X	X	X
Decapod	*Austrohelice crassa*	M						X
Bivalve	*Austrovenus stutchburyi*	S		X	X	X	X	X
Polychaete	*Boccardia syrtis*	M	✓	X	X		X	
Polychaete	Capitellidae	M						X
Cumacea	*Colurostylis lemurum*	SS	✓	X	X		X	
Amphipod	Corophiidae	-						X
Polychaete	*Cossura consimilis*	M		X		X		X
Gastropod	*Diloma subrostratum*	S					X	
Polychaete	*Euchone* sp.	-	✓	X			X	
Isopod	*Exosphaeroma planulum*	-		X	X			
Isopod	*Exosphaeroma waitemata*	-		X	X			
Isopod	*Exosphaeroma* spp.	-					X	
Polychaete	*Glycera americana*	M					X	
Polychaete	*Glycinde trifida*	-			X			
Gastropod	*Papawera zelandiae* (was *Haminoea zelandiae*)	-					X	
Decapod	*Hemiplax hirtipes*	M				X		
Polychaete	*Heteromastus filiformis*	M				X	X	X
Bivalve	*Hiatula siliquens*	-		X	X			
Polychaete	*Levinsenia gracilis*	-						X
Bivalve	*Linucula hartvigiana*	S	✓	X	X	X	X	X

Order	Species	Pref	Metal	KAI	MAN	MAHU	CWH	UWH
Bivalve	*Macomona liliana*	S	✓	X	X	X	X	
Polychaete	*Clymenella stewartensis* (was *Macroclymenella stewartensis*)	M	✓	X	X		X	
Polychaete	*Magelona dakini*	-	✓	X	X			
Amphipod	*Methalimedon* sp.	-			X			
Polychaete	Nemertea	M				X		
Polychaete	Nereididae	M						X
Polychaete	*Nicon aestuariensis*	M		X				
Gastropod	*Notoacmea scapha*	SS		X	X	X	X	
Polychaete	Oligochaeta	MM				X		X
Polychaete	*Orbinia papillosa*	S	✓	X	X			
Polychaete	*Owenia petersenae*	S		X	X	X		
Bivalve	*Paphies australis*	SS					X	
Amphipod	*Paracalliope novizealandiae*	S				X		
Polychaete	*Paradoneis lyra*	-						X
Polychaete	*Perinereis vallata*	M				X		
Amphipod	Phoxocephalidae	-						X
Polychaete	Polydorids (Spionidae)	M				X		X
Polychaete	*Prionospio aucklandica*	M	✓	X	X	X	X	X
Polychaete	*Pseudopotamilla* sp.	-						X
Polychaete	*Scoloplos cylindrifer*	S		X		X		
Holothuria	*Taeniogyrus dendyi*	-		X	X			
Amphipod	*Torridoharpinia hurleyi*	S	✓	X	X	X		
Polychaete	*Travisia novaezealandiae*	SS		X	X			
Gastropod	*Tritia burchardi*	-						X
Amphipod	*Waitangi brevirostris*	SS	✓	X	X			
Gastropod	*Zeacumantus lutulentus*	M					X	

Appendix 3: Trend analysis method

Data

Due to changes in laboratory techniques and evolution of the Harbour Ecology programme, data on sediment characteristics are available from the following dates:

- Sediment mud content – since the start of monitoring for each Harbour
- Organic content and chlorophyll *a* – October 2000

Macrofauna abundance data are available from the start of the monitoring period for all sites (see Appendix 1: Monitored sites).

Trends were only analysed for variables with five or more data points, as results based on fewer observations are likely to be unreliable. Climatic variables may also be important predictors of trends based on less than ten years of data (Hewitt et al., 2016), so any such trends should be treated with caution unless supported by similar trends within the estuary.

Trend analysis

The statistical approaches largely follow those outlined by Drylie (2021) and Hewitt et al. (2015) and all trend analyses were performed in RStudio (v4.3.1). As a first step, visual assessment of scatterplots was used to determine whether step changes, multi-year cycles, linear or non-linear patterns could be seen. Then, for datasets with a within-year sampling frequency less than or equal to two (i.e. RSCMP sites):

- If a step change was indicated, analysis was conducted using a t-test with data grouped before and after the suspected step.
- Otherwise, an ordinary least squares (OLS) regression with time was run, using log transformations to include monotonic non-linear responses. Polynomial non-linear responses were not investigated to maintain a focus on continuous, long-term trends.
- If the OLS assumption of homoscedasticity was violated, then a generalised least squares (GLS) regression was run instead.
- Where a statistically significant trend was observed ($p < 0.15$), residuals were examined for indications of multi-year cycles; where these indicated significant bias, the trend was considered a multi-year cycle. Inspection of residual plots also indicated whether trends occurred over the entire monitoring period or shorter time frames and enabled detection of their start and end points.

For datasets with a within-year sampling frequency greater than two (i.e. Harbour Ecology sites) and with more than 30 data points:

- Temporal autocorrelation was investigated using Durban-Watson statistics (up to six time lags was within-year for Manukau and Central Waitematā, but this varied according to the frequency of sampling for the given harbour) to check assumptions on the number of independent samples. The power to detect autocorrelation is low with fewer than 30 samples (Chatfield, 1980).
- If there was no autocorrelation the same OLS regression steps were followed as above, and where autocorrelation was indicated:
    - Trends were investigated with generalised least squares regression, utilising autoregressive correlation structures (Choudhury et al., 1999).
    - Step trends were determined based on the significance of Yule-Walker parameter estimates on time series data points grouped before and after a suspected change.
- Plots of residuals were examined for significant trends as outlined above.

Appendix 4: Sediment trends scatterplots

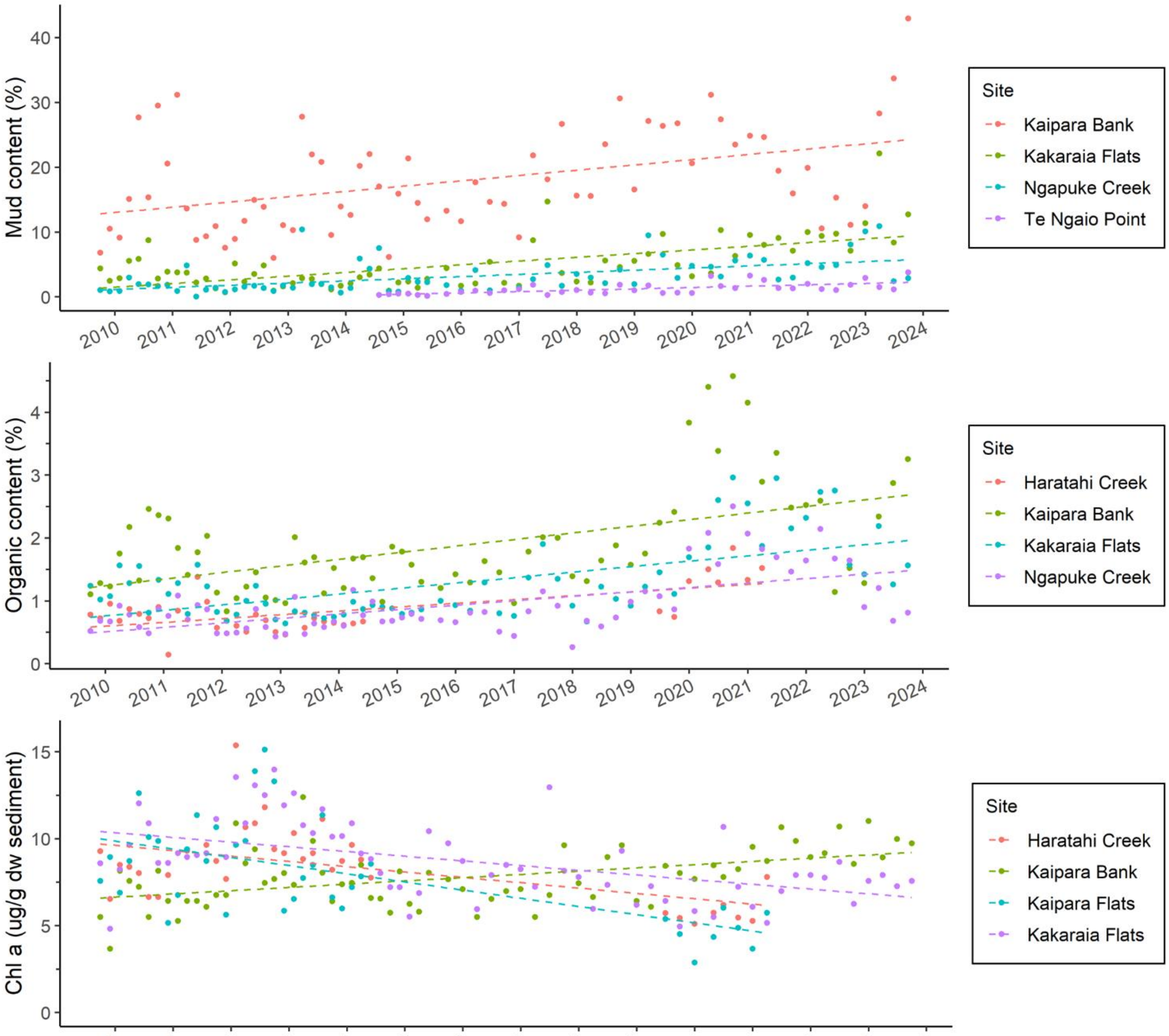

Figure A1. Surface sediment characteristics with significant trends (2009 to 2023) at Kaipara sites.

Figure A2. Surface sediment characteristics with significant trends (1987 to 2023) at Manukau sites.

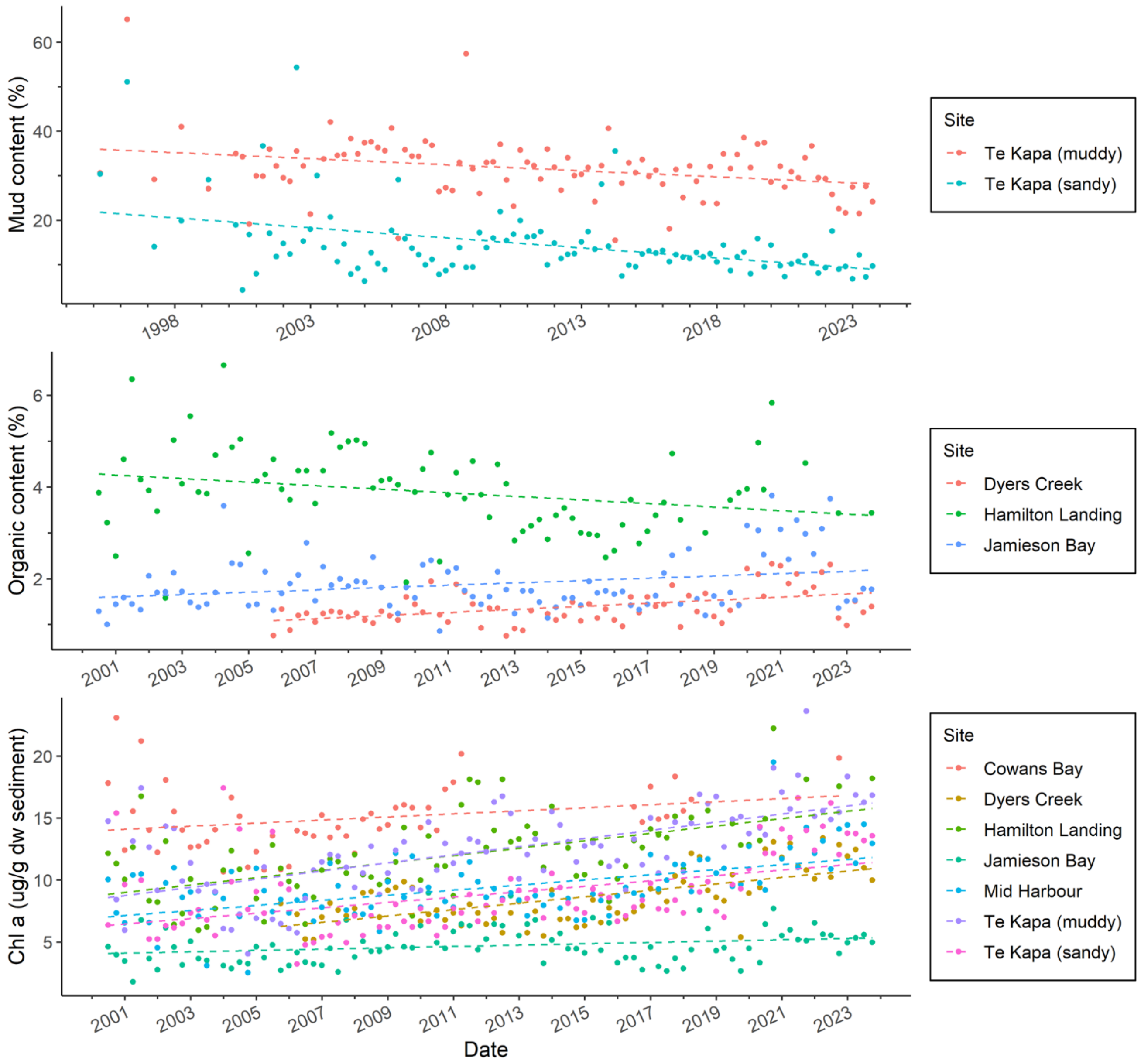

Figure A3. Surface sediment characteristics with significant trends (1995 to 2023) at Mahurangi sites.

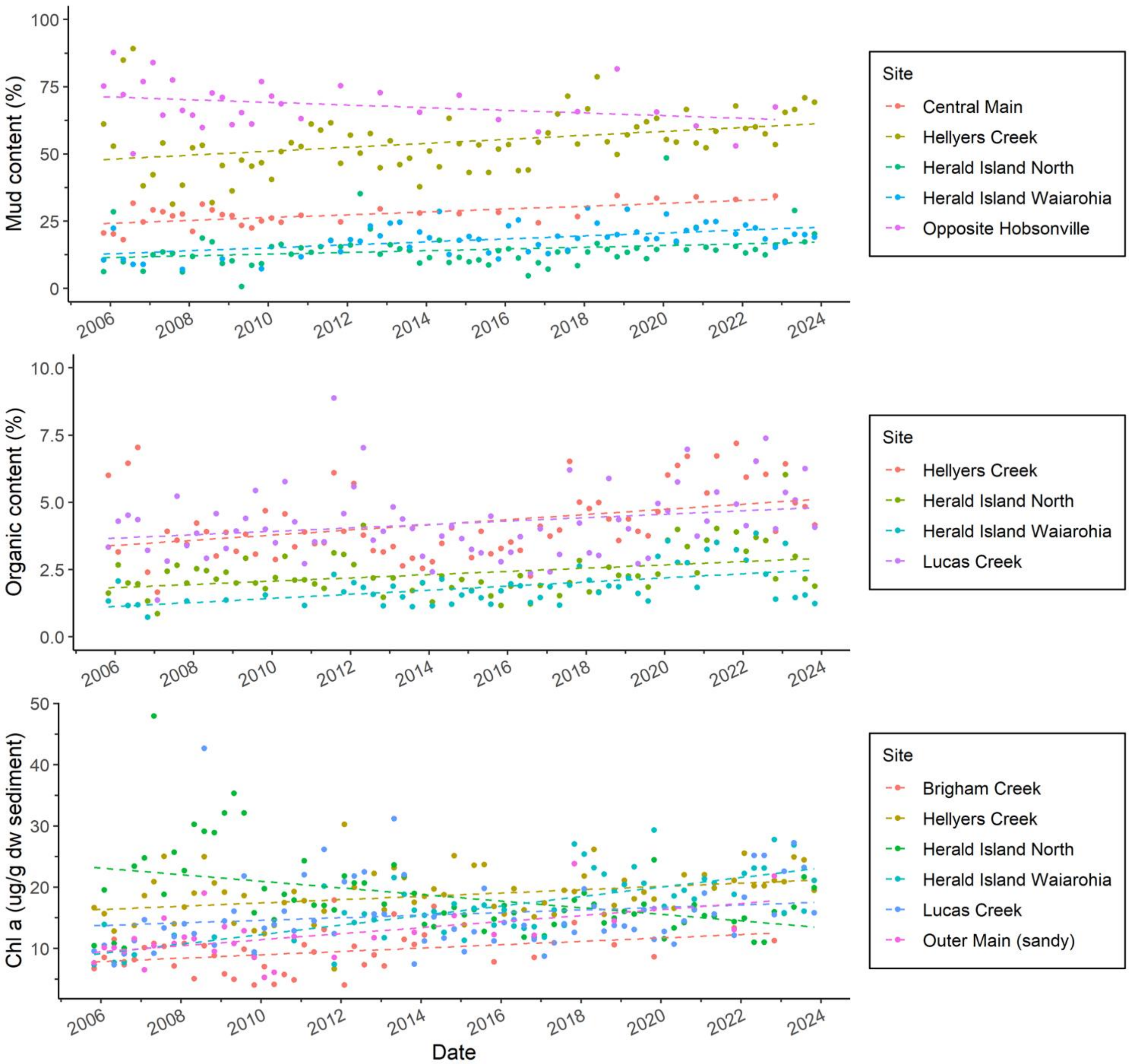

Figure A4. Surface sediment characteristics with significant trends (2005 to 2023) at Upper Waitematā sites.

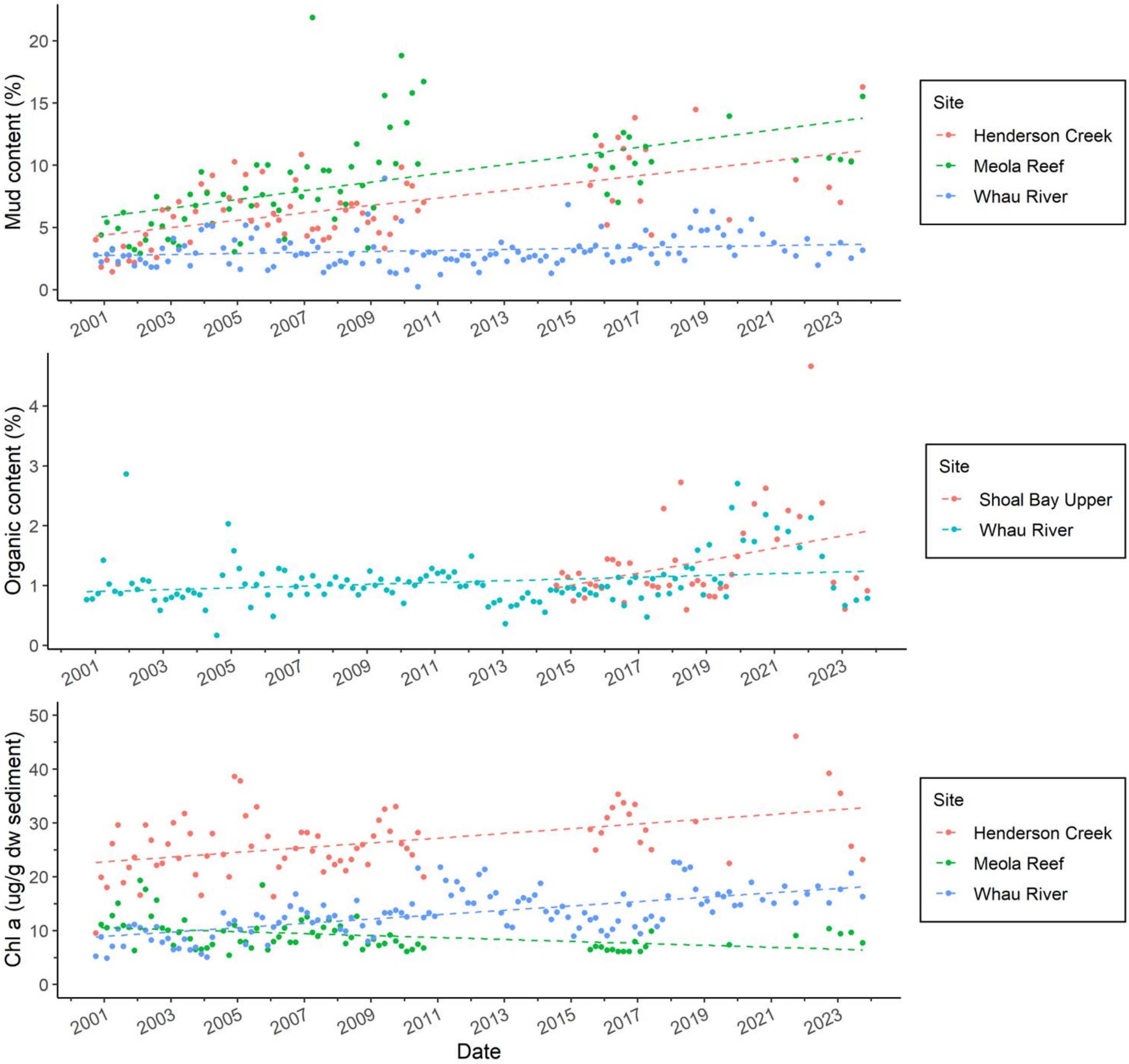

Figure A5. Surface sediment characteristics with significant trends (2005 to 2023) at Central Waitematā sites.

Appendix 5: Species richness trends scatterplots

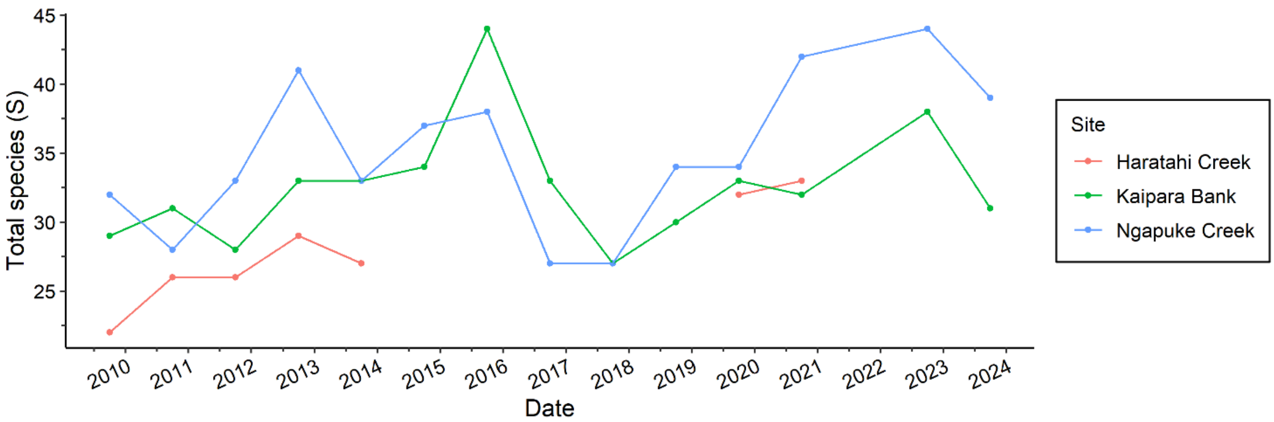

Figure A6. Species richness time series for Kaipara sites with significant trends (2009 to 2023).

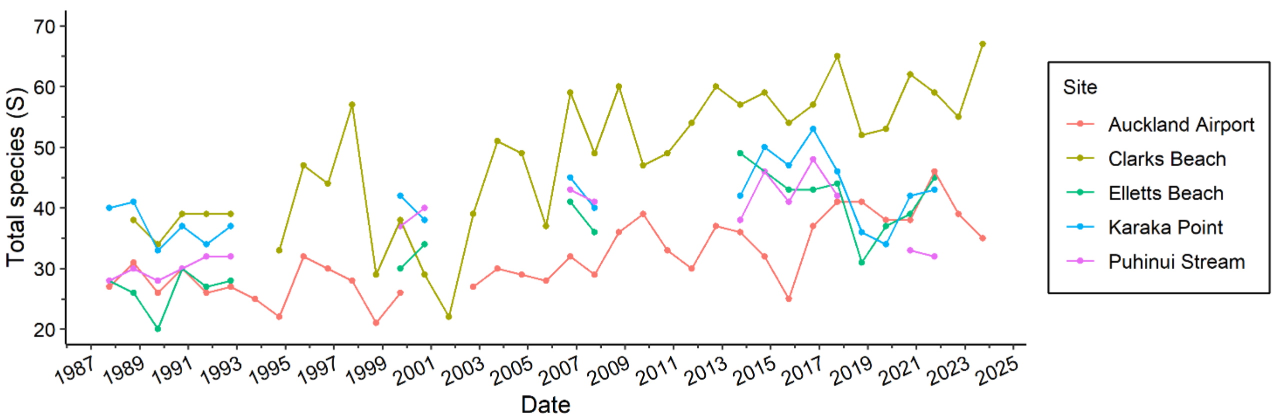

Figure A7. Species richness time series for Manukau sites with significant trends (1987 to 2023).

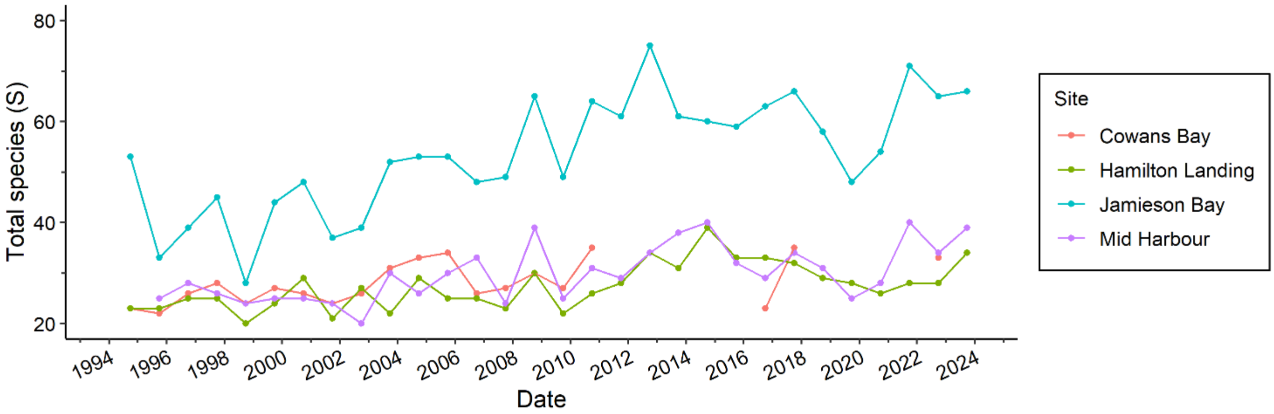

Figure A8. Species richness time series for Mahurangi sites with significant trends (1995 to 2023).

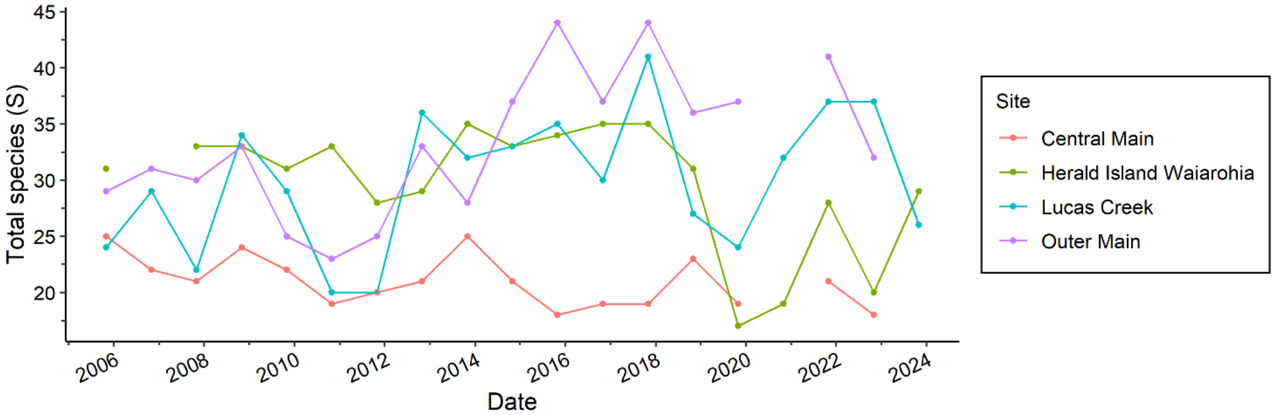

Figure A9. Species richness time series for Upper Waitematā sites with significant trends (2005 to 2023).

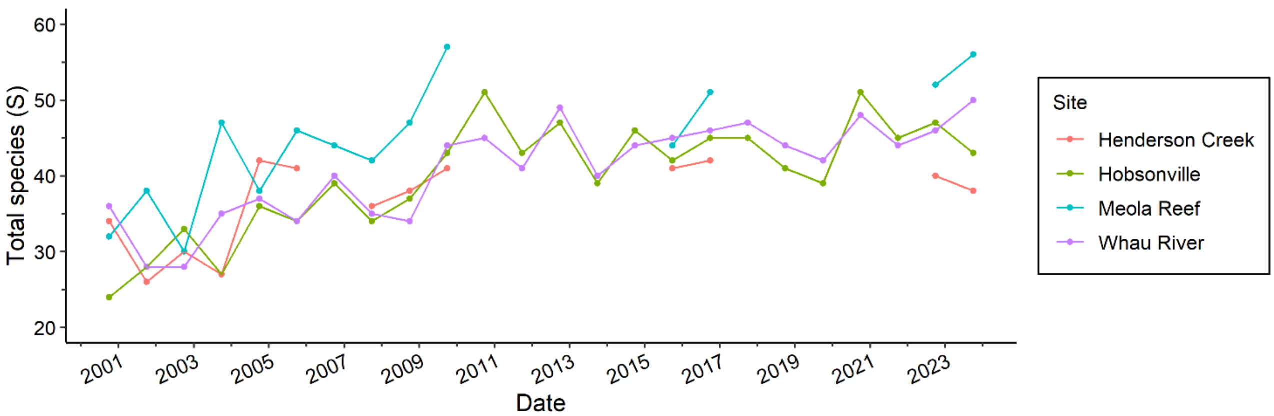

Figure A10. Species richness time series for Central Waitematā sites with significant trends (2000 to 2023).

Appendix 6: Regional state maps

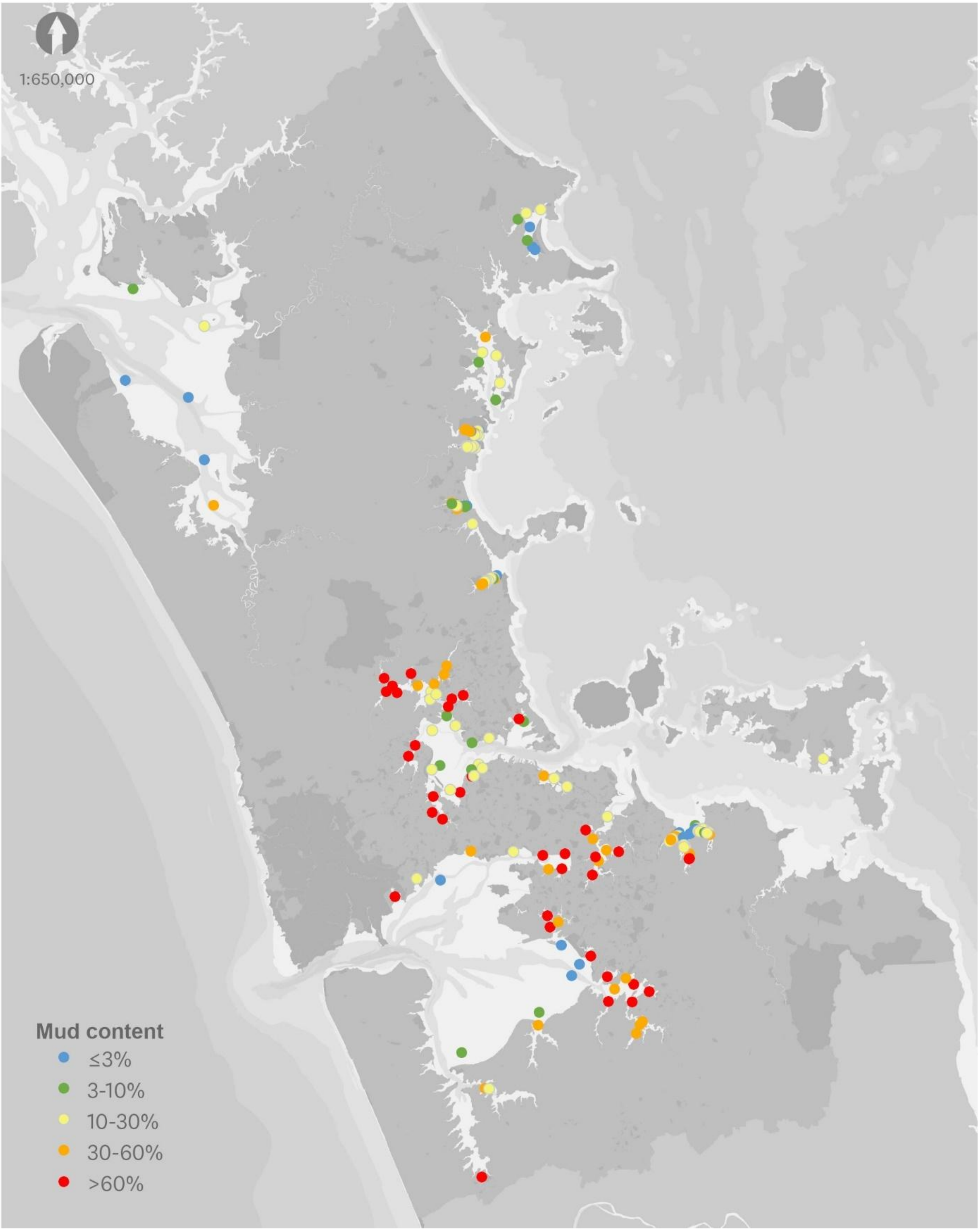

Figure A11. Sediment mud content at benthic ecology monitoring sites in Tāmaki Makaurau / Auckland in 2023.

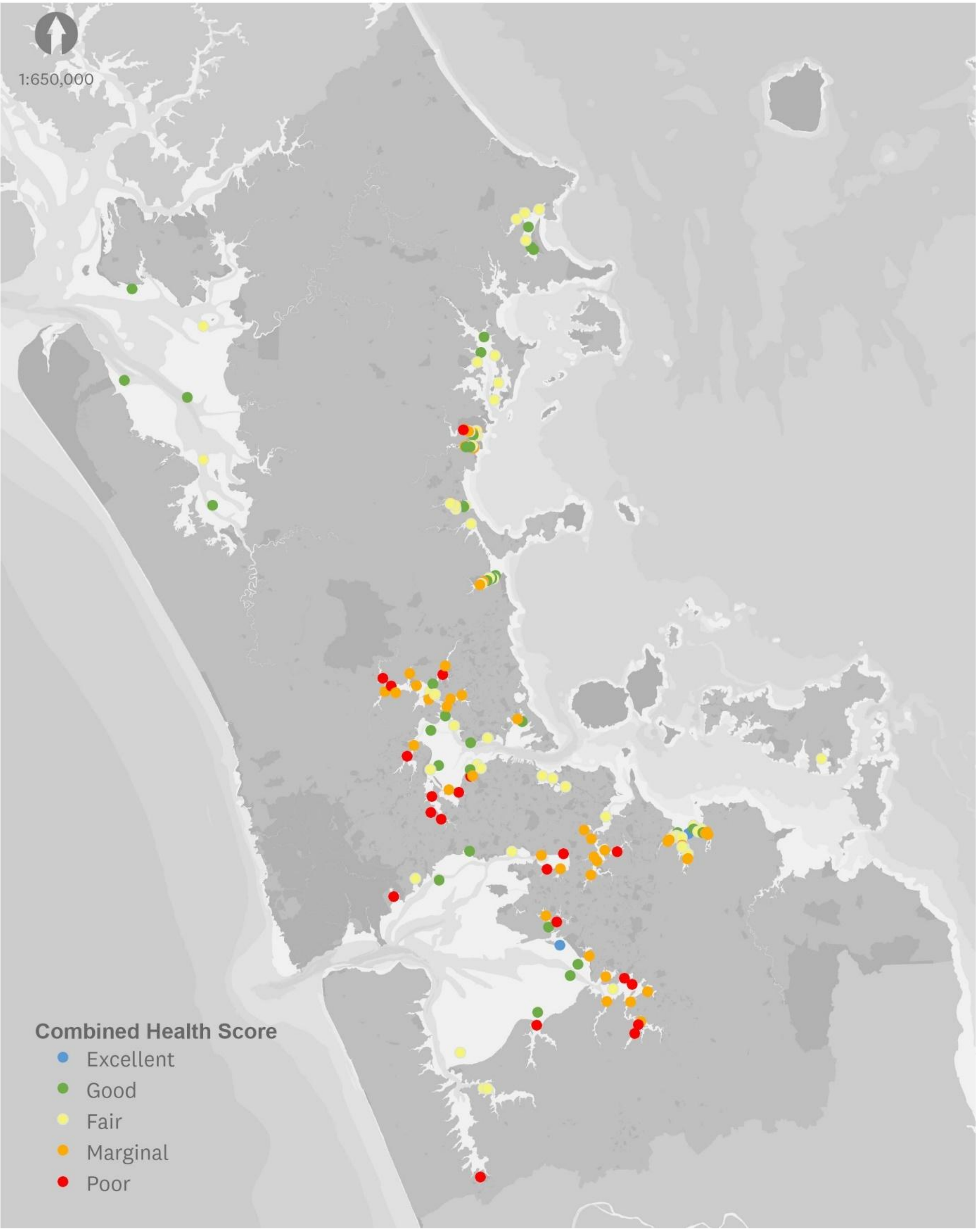

Figure A12. Combined Health Score at benthic ecology monitoring sites in Tāmaki Makaurau / Auckland in 2023.

Appendix 7: Common species trends

Table A3. The number of sandflat sites in each estuary with significant trends (increasing or decreasing) in the abundance of regionally common species. Cells are coloured to reflect trends consistent with sedimentation or sedimentation + metal contamination. Pref = sediment preference; SS = strong sand preference, S = prefers sand, M = prefers some mud, MM = strong mud preference.

		Aricidea sp.	*Prionospio aucklandica*	*Austrovenus stutchburyi*	*Linucula hartvigiana*	*Macomona liliana*	*Aonides trifida*	*Notoacmea scapha*
	Pref	M	M	S	S	S	SS	SS
Kaipara	Inc	3	3	1	3	0	1	2
	Dec	0	0	1	0	2	0	1
Manukau	Inc	3	2	5	2	2	1	2
	Dec	0	1	0	2	2	1	0
Mahurangi	Inc	6	4	4	0	0	1	0
	Dec	0	0	1	6	5	2	2
Upper Waitematā	Inc	0	9	3	0	0	0	2
	Dec	3	0	1	6	7	2	2
Central Waitematā	Inc	4	2	2	0	0	1	4
	Dec	0	0	0	4	3	2	0
Whangateau	Inc	1	0	2	0	0	0	0
	Dec	0	0	0	3	0	1	0
Puhoi	Inc	1	2	2	0	0	1	0
	Dec	0	0	0	2	1	1	0
Waiwera	Inc	1	0	1	0	0	0	1
	Dec	0	0	0	1	1	0	1
Ōrewa	Inc	0	1	2	1	1	1	1
	Dec	0	2	0	0	2	1	0
Ōkura	Inc	0	2	2	0	0	0	1
	Dec	0	0	1	2	1	3	0
Mangemangeroa	Inc	0	3	1	0	0	0	0
	Dec	0	0	1	3	3	2	0
Tūranga	Inc	0	2	3	0	0	0	1
	Dec	0	1	0	2	1	0	0
Waikopua	Inc	1	3	3	1	1	0	2
	Dec	0	0	0	2	2	2	0

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