HAWKE'S BAY
REGIONAL COUNCIL

The State of the Hawke's Bay Coastal Environment:
2004-2013

June 2016
HBRC Report No. RM16-16 – 4800

Resource Management Group

ISSN 2324-4127 (PRINT)
ISSN 2324-4135 (ONLINE)

Environmental Science - Water Quality and Ecology

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Executive summary

Hawke's Bay has an extensive and varied coastal area that provides for a range of social, cultural, economic and environmental values. Hawke's Bay Regional Council (HBRC) is responsible for promoting the sustainable management of the coastal marine environment. HBRC monitors the state of the environment to provide council with the information required to underpin decision making.

HBRC monitors water quality, sediment quality and ecology in a range of coastal environments.

1. Nearshore Coastal Water Quality (Section 2)

Nearshore coastal water quality in Hawke's Bay generally appears good when compared to monitoring sites in other regions. Land-based sediment delivery to the coast is generally high and variable, highlighting periods of sediment-laden river inputs and nearshore resuspension.

Nutrient levels are similar to or lower than other sites around the country. Relatively high levels of dissolved nutrients at Ocean Beach demonstrate that rivers are not the only inputs of nutrients and highlight the role of oceanic contributions.

2. Recreational Water Quality (Section 3)

The susceptibility of Hawke's Bay's recreational waters to faecal indicator bacteria is variable. Marine beaches tend to have a high level of compliance with Ministry for the Environment and Ministry of Health national guidelines and can be considered suitable for swimming most, if not all, of the time.

Rivers tend to have more variable recreational water quality, with heavy rainfall rendering some rivers unsuitable for swimming some of the time. Lagoons, at the bottom of the catchment, can exceed guidelines more frequently. This can be due to generally slower flows, with higher temperatures and extensive bird-life.

Faecal source tracking has highlighted the role of avian and ruminant sources when guidelines are exceeded.

3. Coastal Sediment Quality (Section 4)

Coastal sediments form the basis for the habitats that support diverse benthic communities. The quality of this sediment is integral to the health of the larger ecosystem. In general nearshore sediments away from point source discharges are well sorted, with low levels of trace metal contaminants. However sediments adjacent to boat maintenance and repair facilities, and stormwater outlets, have ongoing contamination issues. Concentrations of trace metal and organic contaminants exceed sediment quality guidelines at some of the sites within the Inner Harbour and Ahuriri Estuary.

4. Estuaries (Section 5)

Infauna (sediment-dwelling organisms) sensitive to elevated mud concentrations indicate that Hawke's Bay estuaries may be experiencing moderate to high levels of sediment stress, with some sites also showing increasing trends in mud concentrations. Increasing mud concentrations are impacting on the benthic communities at monitoring sites with species intolerant to higher mud fractions being largely absent from sites where mud concentration exceeds 25%.

In general nutrient and trace metal contaminant concentrations appear below guideline values for most of sites with significant contamination confined to areas adjacent to point sources and stormwater discharges.

A Traits Based Index (TBI) was applied to the estuarine macroinvertebrate data, and corresponded well to 'muddiness'. Overall scores were low, although further work needs to verify the TBI fit to Hawke's Bay data.

An overall reduction in sediment volumes entering the estuaries would increase the health of Hawke's Bay estuary systems.

5. <u>Sandy Beaches</u> (Section 6)

Sandy beach ecosystems include a vast array of tiny organisms in the infauna that support coastal fisheries, cycle nutrients and filter large volumes of seawater. In Hawke's Bay the infaunal community composition is highly variable, with relatively low numbers of species and individuals. The highest abundance species are amphipod crustaceans, which are likely to be a key food source for coastal ecosystems. Vehicle usage of Hawke's Bay's beaches is high, and vehicles can have a deleterious effect on infaunal communities. The designation of many beaches as roads remains a resource conflict for much of New Zealand.

<u>6. Intertidal Reefs</u> (Section 7)

Similarly to sandy beaches, intertidal reefs provide both physical protection to the land from the effects of the sea, and areas of high biomass and diversity, supporting a range of ecosystem services and functions. Hawke's Bay's reef structures vary in character, and are largely dependent on the underlying geology.

The absence of the common algae *Hormosira banksii* from Hardinge road reef is currently not understood, and further work is required to explain this. Blooms of the cyanobacteria *Lyngbya sp.* at Te Mahia reef may also require investigation.

In general, many areas of the Hawke's Bay coastal environment are currently in a state that supports the values and objectives of these systems. However some areas are currently showing signs of stress, and further work is required to ensure that the services and functions that underpin these values are retained.

1 Introduction

1.1 Description of the Hawke's Bay Coastal and Marine Environment

The Hawke's Bay coastline stretches 353 km from Mahanga on the Mahia Peninsula in the north, to Whangaehu beach in the south. The coastal and marine environment (CME) includes a diverse range of habitats that are a function, in part, of the geology and geomorphology of the region. The CME can be divided into three distinct areas (Figure 1-1):

- The southern coast: Characterised by coastal cliffs, sandy beaches, extensive dune systems and rock platforms between Cape Turnagain and Cape Kidnappers.
- Hawke Bay: This area extends from Cape Kidnappers in the south to the Mahia Peninsula in the north. River mouths, estuaries, gravel beaches and herb fields typify coastal habitats between Te Awanga and Tangoio. To the north of Tangoio steep cliffs and associated rocky reefs extend up to the Waikari river mouth. Between the Waikari river mouth and the Nuhaka River mouth the coastline is typified by low-lying dunes and sand and gravel beaches.
- The Mahia Peninsula: Characterised by large sandy beaches, extensive dune systems and expansive rock platforms (Stevens and Robertson 2005).

The most dominant habitat type in the intertidal area is firm sand (48%) followed by rock field/ reef (35%). Gravel fields (8%) dominate the coastline around Napier.

The most common features of the coastal terrestrial margins (to 20 m above MHWS) are cliffs (35%) and duneland (22%). Field observations of the coastal terrestrial margin indicate that most of the land adjacent to the HBRC coastline has been modified from its native state.

There are a number of large estuaries in Hawke's Bay, including the Porangahau, Waitangi, Ahuriri, Wairoa and Maungawhio, and many smaller systems. Although these contribute a small proportion of the overall coastal area, they make an important ecological contribution in terms of production, biomass and species diversity.

The subtidal part of the CME covers an area of 701,372 ha., encompassing a range of habitats. Most of Hawke Bay (Figure 1-1) is characterised by sand and mud substrate. There are 2 areas of cobble reef, the 'Wairoa Hard' between the Mohaka river mouth and Ridgemount and the 'Clive Hard' between the Waitangi Estuary mouth and Cape Kidnappers. There are also shallow and deep rocky reef areas. The closest area of hard substrate to Napier is Pania Reef, which is a popular diving and fishing spot. The Mahia Peninsula and the coastline south of Cape Kidnappers are also characterised by large areas of rocky reef. Further offshore there are deeper reef and sandbank habitats at the Lachlan Ridge southwest of Mahia.

The Hawke's Bay Regional Council (HBRC) is responsible for promoting the sustainable management of the CME. The framework for the protection, management and use of coastal resources is set in the Regional Coastal Environment Plan (RCEP). This plan gives effect to the Resource Management Act 1991 (RMA) and the New Zealand Coastal Policy Statement 2010 (NZCPS) at a regional level. The RCEP requires HBRC to monitor specific aspects of the CME. The information is used to assess how effectively HBRC is managing resource use.

Figure 1-1: Map showing the main features, locations and areas of the Hawke's Bay CME.

For the purpose of this document the extent of the CME is as described in the Regional Coastal Environment Plan. It includes:

- The coastal marine area (CMA) out to 12 nautical miles
- Any areas identified as being affected by, or potentially affected by, coastal flooding or coastal erosion, and

- Any of the following:
  - Tidal waters and the foreshore above mean high water springs (MHWS)
  - Dunes
  - Beaches
  - Areas of coastal vegetation and coastal associated fauna
  - Coastal cliffs
  - Salt marshes
  - Coastal wetlands, including estuaries and
  - Areas where activities occur or may occur which have a direct physical connection with, or impact on, the coast.

1.2 Biogeography

The waters of Hawke's Bay are influenced by two oceanic currents. The Wairarapa Coastal Current (WCC) transports relatively cool and fresh water northwards along the coast inshore of the relatively warmer and the more saline southward flowing East Cape Current (ECC). Water temperatures north of the Mahia Peninsula can be several degrees warmer than the south of the region, because this area is beyond the effect of the WCC. This affects marine species found in these areas. Water temperatures can vary widely between approximately 12^{o}C in winter and 22^{o}C in summer (Section 2.1.4).

The highly erodible geology of Hawke's Bay has defined, and continues to influence, the Hawke's Bay marine environment. The influence of geology is seen in the generally high turbidity of the water, the predominance of muddy substrate, the relatively scarcity of areas of rocky reef and the cobble characteristics of the reefs at the Wairoa and Clive 'hards'. The water within Hawke Bay itself is heavily influenced by river inputs and is often stratified and turbid. This high degree of turbidity is caused by a combination of silt-laden river inputs and coastal sediment re-suspension.

1.3 Threats and pressures

The coastal environment receives contamination from land activities which affect river water quality. This includes increased sediment loads, increased nutrient and metal concentrations and changes in flow regimes. Different areas of the CME are at different levels of risk from these threats. For example, estuaries with long residence times are more at risk from increased nutrient loadings than the near-shore marine environment, where dilution reduces many of the potential impacts.

One of the most significant threats to marine habitats is sedimentation. Hawke's Bay is particularly susceptible to high levels of sedimentation in rivers, because of highly erodible geology, loss of land cover and localised and heavy rainfall. Many of Hawke's Bay's rivers are channelized and the natural barriers to sediment (meanders and wetlands) have been removed. The main Hawke's Bay rivers contribute about 11 million tonnes of sediment each year to the CME (Hicks 2011). High levels of sedimentation can smother habitats, kill fish and invertebrates through gill abrasion and kill plants where light levels are reduced.

Hawke's Bay's rivers also transport large volumes of nutrients to the CME. At certain times of year these nutrients can augment nutrients naturally available in coastal waters, and promote blooms of phytoplankton and diatoms. Although these algal blooms are natural processes which produce oxygen and sequester carbon, large-scale blooms can smother organisms and deplete oxygen in the water column as they die off and decompose. In extreme cases oxygen depletion can kill marine organisms (Diaz 2008).

The focal point of coastal urban development in Hawke's Bay is around Napier. This development has had an associated impact on the CME through sewage and storm-water discharges, increased runoff from impermeable surfaces, destruction of habitat through land development, disturbance of shore species and the potential for incursions of introduced species from the port.

Most Hawke's Bay land has been converted from native vegetation to pasture. Where livestock are in the CME, they can have a negative impact on coastal ecosystems through grazing and trampling of coastal vegetation as well as impacts on the quality of coastal waters.

Sandy beaches are likely to be the most widely visited coastal habitat for recreational activities. Many of Hawke's Bay's beaches have vehicular access and the beaches in Southern Hawke's Bay are used as roads at low tide. Vehicles are considered a significant threat to beach ecosystems, particularly the backshore and dunes (Stephenson 1999) and vehicles can adversely affect intertidal tuatua (*Paphies subtriangulata*) communities (Taylor G; Marsden I.D; Hart 2012). Increasing sedimentation, overharvesting, physical modification, habitat reduction and alteration associated with coastal development can also adversely affect sandy beach ecosystems.

Globally, industrial-scale fishing removes significant biomass from marine ecosystems. The trawl industry began in Hawke's Bay in 1885 (Tai-Perspectives 1996). The present impact of fishing activities on the Hawke's Bay CME are currently unquantified. However, trawl fisheries in comparable inshore mixed fisheries are associated with high numbers of discards and fish mortality (Kelleher 2005), and towed gear is reported to have deleterious impacts on benthic communities (Lokkeborg 2005). Previously, fears that pair trawling was adversely impacting Hawke Bay snapper (*Pagrus auratus*) led to the closure of the 'Wairoa Hard' to all forms of netting in 1981 (Tai-Perspectives 1996).

There are more than 150 exotic marine species already present in New Zealand coastal waters (NIWA 2002). Many of these species compete with and displace native species. Exotic species are often introduced and transported as biofouling on, or in the ballast water of, marine vessels. With a large and active commercial port at Napier, Hawke's Bay is a potential invasion pathway for any new marine species entering New Zealand. A survey of the Port of Napier (Inglis 2006) found 10 non-indigenous species, most thought to have arrived as hull fouling, and 14 cryptogenic species (those of indeterminate origin). One species, the invasive kelp Wakame (*Undaria pinnatifida),* is now widespread through nearby reef areas at Hardinge Road and Westshore.

The Hawke's Bay CME is also threatened by environmental shifts associated with climate change. Ocean acidification, sea level rise and increased storminess may each detrimentally affect the marine environment. This is particularly pertinent for areas where coastal edges are engineered and may prevent the landward migration of marine habitats in response to climate change.

1.4 Significant conservation areas

The RCEP (HBRC 2012) identifies a number of Significant Conservation Areas. These include:

- Inter-tidal reefs (Southern Hawke's Bay; Mahia)
- Estuaries and lagoons (Porangahau; Tukituki; Waitangi; Ahuriri; Wairoa; Maungawhio).
- Dune systems (Rangaiika)
- Islands (Bare Island; Portland Island)
- Subtidal reefs (Pania; Mahia)
- Subtidal cobble/ pebble habitat (Wairoa Hard; Clive Hard)

Also of significance in the RCEP are those 'Historically Rare' coastal terrestrial ecosystems that are present in Hawke's Bay. These include:

- Active sand dunes
- Shingle beaches
- Coastal rock stacks
- Coastal cliffs on acidic rocks
- Calcareous coastal cliffs
- Seabird burrowed soils
- Marine mammal haul-outs
- Estuaries
- Lagoons

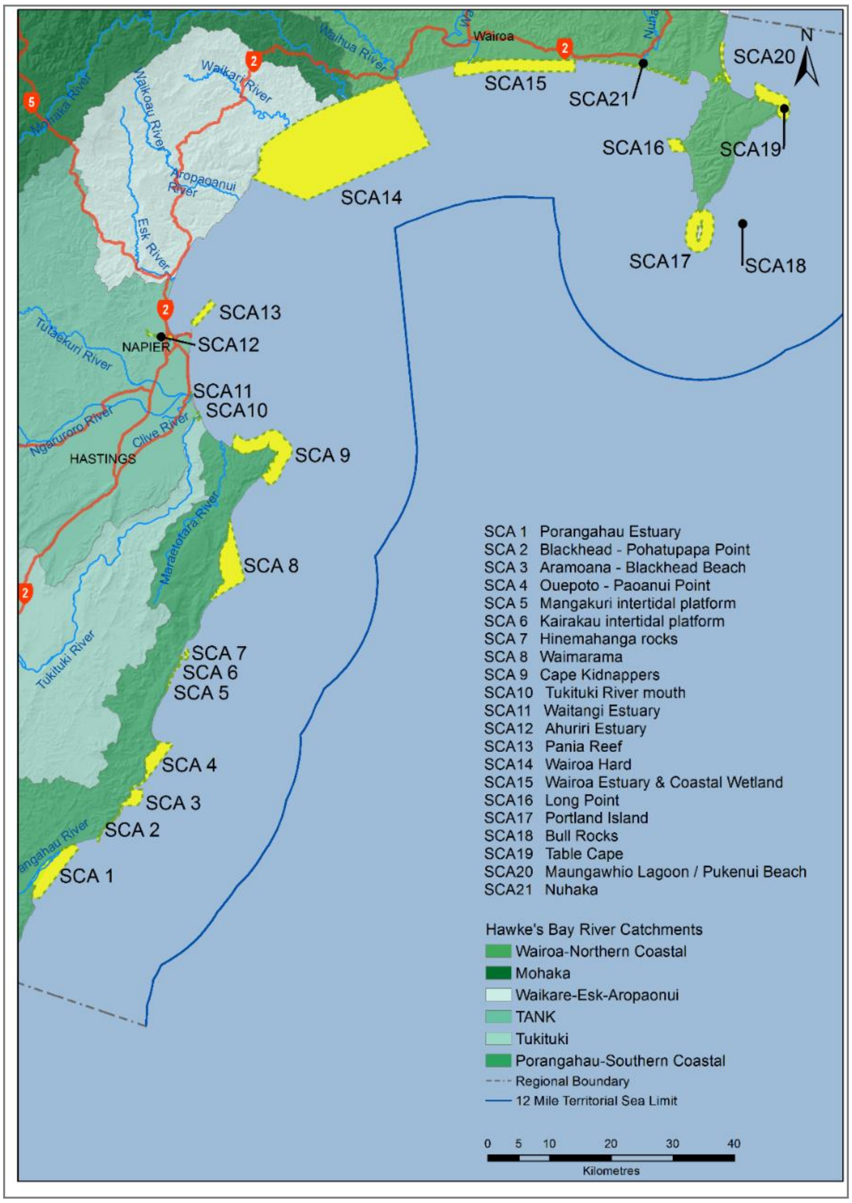

Figure 1-2: Significant conservation areas listed under the Hawke's Bay Regional Coastal Environment Plan.

2 Water quality of the Nearshore Coastal Area

2.1 Long-term SoE monitoring data

Coastal inshore waters of Hawke's Bay are used for a range of biological, social, economic and recreational activities. However these areas are also the receiving environment for runoff from almost all land-based activities through the freshwater drainage network, and are therefore susceptible to water quality issues. In Hawke Bay, large river systems contribute to the direct transport of pollutants to the nearshore coastal environment. Monitoring coastal water quality is important to ensure that key ecosystem functions and services remain intact.

Water quality monitoring in the nearshore coastal area has been carried out by HBRC since 2006 as part of the State of the Environment (SoE) programme. This SoE monitoring programme is undertaken on a 6 weekly basis, with 2 samples collected in each season.

Seven sites have been sampled between Ocean Beach and Mohaka since November, 2006. In October, 2012 an additional 4 sites in northern Hawke Bay were added to the monitoring network (Figure 2-1).

All samples are collected by boat using a van Dorn water sampler from the surface layer (0.5 m deep). Samples are collected within 1 km of shore, and in less than 10 m of well-mixed water.

The following field water quality parameters are routinely measured at the SoE monitoring sites:

- Turbidity (NTU)
- Dissolved oxygen (mg/l)
- Dissolved oxygen saturation (%)
- Conductivity (μS/cm)
- pH
- Water temperature (^{o}C)

Samples collected are also analysed at Hill laboratories for nitrogen and phosphorus species, faecal coliforms and chlorophyll *a* concentrations.

This long-term SoE monitoring data has been augmented by continuous data collected by the **HA**wke's Bay **W**ater **Q**uality **i**nformation buoy (HAWQi) since December 2012. The HAWQi buoy is situated approximately five miles east of Whirinaki (Figure 2-1).

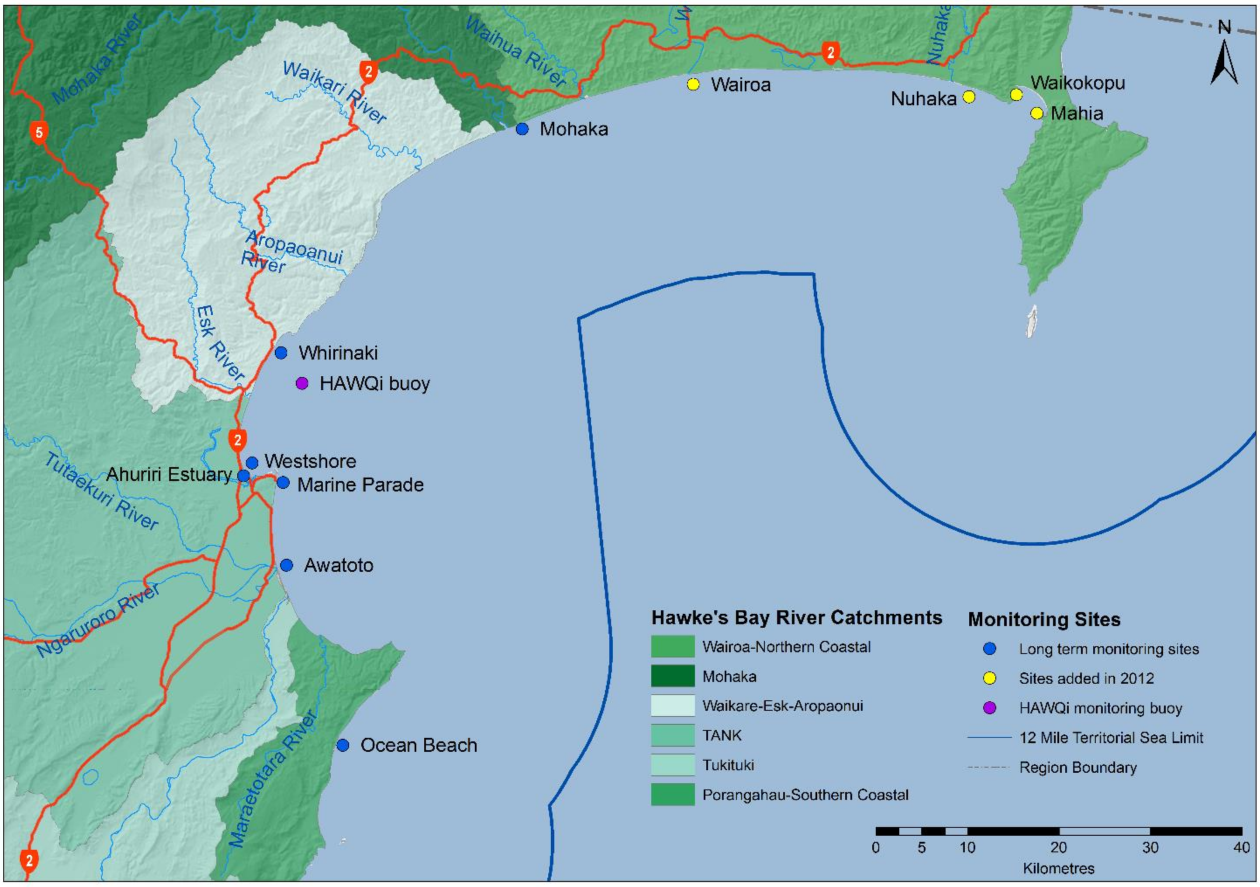

Figure 2-1: Nearshore water quality monitoring sites in Hawke's Bay

2.1.1 Water quality guidelines relevant to the Nearshore Coastal Area

Environmental guidelines are often used to describe the general state of a natural resource, even though they may not be directly applicable in a regulatory context. In the following analysis the guidelines are discussed to provide context for the observations made in the nearshore coastal area.

New Zealand water quality measurements are typically compared to guideline values presented in the ANZECC guidelines (ANZECC 2000). However, ANZECC does not include any water quality guideline values for marine waters in New Zealand. Instead ANZECC recommend using the guideline values for south-east Australia taking a precautionary approach. It is problematic to apply guidelines from one region to another. Applying the south-east Australian ANZECC guidelines is not considered appropriate in this study since the guidelines are based on estuaries in south-east Australia which are hydrodynamically and ecologically different to those found in Hawke's Bay. The use of appropriate guidelines is necessary for effectively assessing the condition of coastal waters.

The United States Environmental Protection Agency (USEPA) recommend developing a reference condition in degraded waters by identifying 'the best existing estuarine or marine waters within a watershed or coastal area, or as commonly stated, 'the best of what's left' (EPA 2002). This reference condition uses the 80th percentile of the 'best' existing site, however it is not always straight forward assessing what this means (see Section 2.1.7).

For the purposes of this report it was decided to compare water quality at monitoring sites within Hawke's Bay with the water quality found at comparable sites in other regions of New Zealand (see section 2.1.2).

The MfE/MoH (2003) 'microbiological water quality guidelines for marine and freshwater areas' are used extensively to assess 'risk' in relation to contact recreation and exposure to bacteria present in aquatic environments (3.1.1 Faecal indicator bacteria).

2.1.2 Data summaries and visualisation

Box plots have been used throughout Section 2 to summarise water quality data for the dataset between January 2009 and December 2013. Box plots present data as a box representing statistical values. The lower boundary of each box indicates the 25th percentile, a horizontal line within the box marks the median, and the higher boundary of each box indicates the 75th percentile. The horizontal line at the end of the whiskers (error bars) above and below the box indicate the 90th and 10th percentiles respectively.

The sites are ordered from left to right in order from the most southerly to the most northerly site. The Ahuriri estuary site and appropriate comparison sites from the Auckland region (Orewa and Brown's Bay) and the Canterbury region (Ashley and Waimakariri) are plotted in different colours on the right hand side of the plot.

2.1.3 Trend analyses

Trend analysis of environmental monitoring data is important because environmental characteristics may exhibit trends which indicate particular issues are changing in significance. For example, if nitrate concentrations are increasing or decreasing at a particular site, the cause and significance of these changes may need to be identified.

Trend analyses in this section use non-parametric statistical approaches similar to those used in recent nationwide water quality analyses undertaken for the LAWA project (Ballantine 2012), which involved seasonal Kendall trend tests. Sites have been sampled approximately 6 weekly. A quarterly sampling interval was applied to the entire time period using median quarterly values, to avoid biasing the trend analyses with any variation within the period. January was used as the 'start' month, i.e. the seasons were: Jan-Mar; Apr-Jun, Jul-Sep; Oct-Dec, to be consistent with the LAWA project.

The seasonal Kendall tests help to identify whether variability in the data is randomly distributed, or whether a significant trend exists over time. For example, did most of the higher ranked values occur in the last few years, or did higher values occur randomly over time? A 'significant' trend was assumed to exist where there was a less than 5% probability that the observed data was obtained by chance.

To estimate the strength of trends over time, a Theil-Sen slope estimator was used. The non-parametric Theil-Sen slope estimator estimates the median slope amongst lines through all pairs of points in the dataset. This approach is effective at estimating the true slope in water quality data series because it is less sensitive to outliers.

The values derived from the Theil-Sen slope estimator are referred to as 'Percent Annual Change' (PAC). A trend in PAC was considered meaningful if the PAC was greater than 1% per year. For most variables an increase in observed values represents a deterioration (i.e. there is more contaminant in the water).

In all tables that present trend results, the changes are represented in bold when they are significant (i.e., p value is less than 0.05). Given a significant trend for a particular variable, the PAC is highlighted in blue if there was a significant improvement in the water quality variable, and highlighted in red if there was a significant deterioration in the water quality variable.

The discussion around improvement and deterioration does not relate to natural enrichment of coastal waters through large scale processes, but instead to short-term site-specific increase or decrease in a water quality variable. These are is likely to be anthropogenically driven.

A summary of trend results is presented in the sections on water quality variables that follow. Only trend results for sites with 5 or more years of data are presented in the body of the report.

2.1.4 Temperature

The coastal waters of Hawke's Bay are temperate, with temperatures generally around 12°C in winter and as high as 22°C in summer (Figure 2-2). The lowest temperature recorded was 9.6°C at Westshore (10/07/2009) and the highest was 25.5°C at the mouth of the Ahuriri Estuary (16/01/2009).

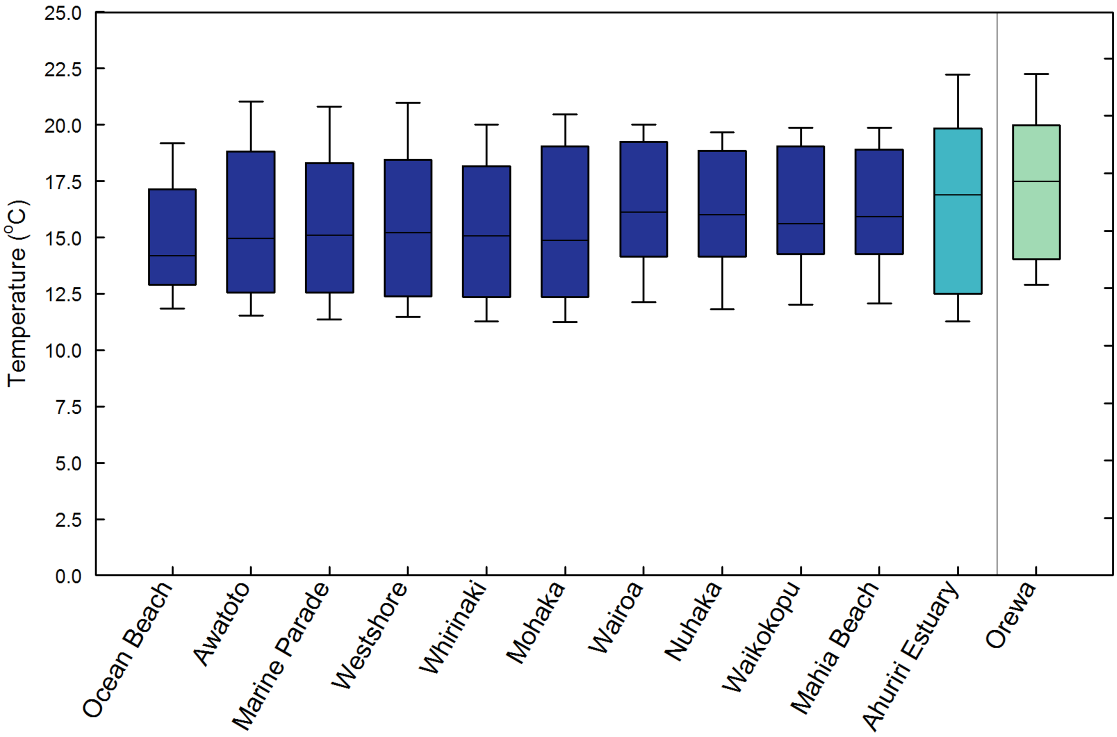

Figure 2-2: Water temperature at nearshore water quality monitoring sites (2009-2013). Statistically significant trends are indicated in bold. BLUE highlight for PAC indicates an improving trend, RED indicates a deterioration.

Seasonal variation of water temperature at sites can be wide ranging (Figure 2-3). The highest generally occur in the summer months between January and March and these months correspond with the peaks on Figure 2-3. Variations are dependent not only on climatic variation but are also influenced by river inputs and the degree of influence from either the cool Wairarapa Coastal Current or the warmer East Coast Current (Section 1.2).

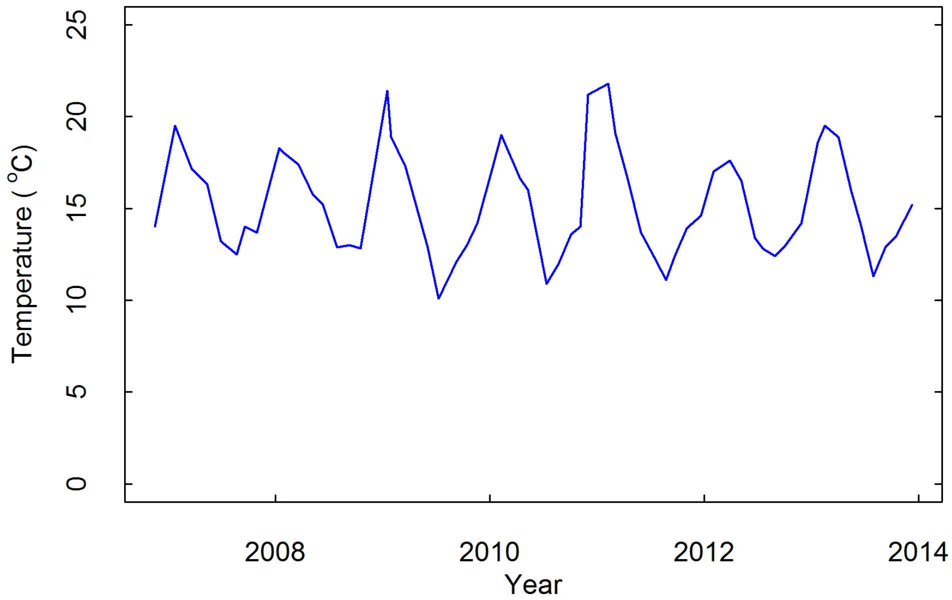

Figure 2-3: Seasonal variation in water temperatures at Ocean Beach site.

There was 1 significant trend in temperature at Westshore, where there was a small increase (1.3% annual change) which equates to an annual increase of approximately 0.19°C.

Table 2-1: Trend analysis of water temperature at nearshore water quality monitoring sites (2006-2013). Statistically significant trends are indicated in bold. BLUE highlight for PAC indicates an improving trend, RED indicates a deterioration.

Site	Temperature (°C)		
	Median	Trend p value	Percent Annual Change
Ocean Beach	14.27	0.568	0.35
Awatoto	14.94	0.670	0.44
Marine Parade	14.70	0.669	0.34
Westshore	15.00	0.225	0.73
Whirinaki	**14.96**	**0.046**	**1.30**
Mohaka	14.85	0.135	0.91
Ahuriri Estuary	15.50	0.670	-0.59

2.1.5 Turbidity and suspended sediment

Turbidity and suspended sediment concentrations are measures of water clarity. Turbidity is a measure of the passage of light through the water. The higher the turbidity the more fine particles there are in the water and the harder it is for light to pass through. Turbidity can be increased by phytoplankton and microbes as well as suspended sediment. Suspended sediment concentration is a measure of the actual weight of suspended sediment in a particular water sample.

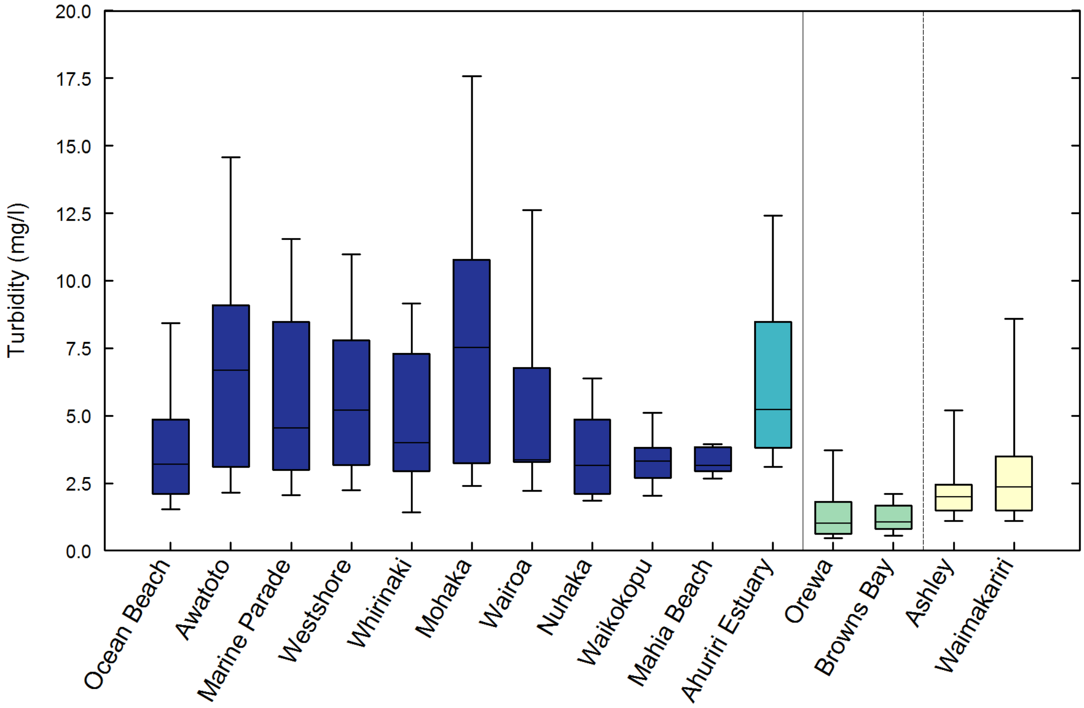

Figure 2-4: Turbidity (NTUs) at nearshore water quality monitoring sites (2009-2013)

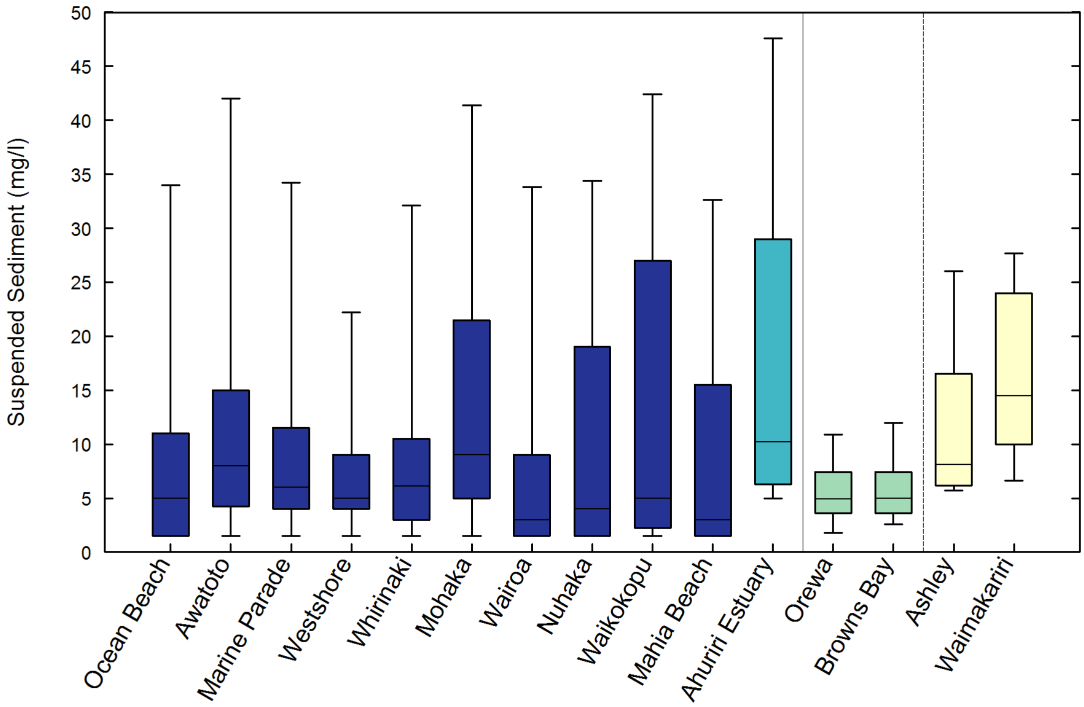

Figure 2-5: Suspended sediment concentrations at nearshore water quality monitoring sites (2009-2013).

Turbidity and suspended sediment are not necessarily directly related. Turbidity is a measure of the fine sediment particles whereas suspended sediment concentrations can be influenced by larger particles such as sand, but not dissolved coloured materials. The figures above show that turbidity is higher at the southern sites between Awatoto and Mohaka (Figure 2-4), these sites are influenced by river inputs and the resuspension of fine muddy sediments leading to higher turbidity readings. Suspended sediment concentrations are generally higher at sites near the Mahia Peninsula (Figure 2-5), these measurements reflect the sediment inputs into those areas. The sites around Mahia are close to sandy beaches and are more influenced by the resuspension of this sand. The long whiskers on the boxes indicate the sporadic periods of very high turbidity and suspended sediments characteristic of episodic events like high rainfall and heavy swells.

The only significant trend in turbidity or suspended sediment was a significant increase in turbidity at Marine Parade (Table 2-2).

Table 2-2: Trend analysis of turbidity and suspended sediment concentrations at nearshore water quality monitoring sites (2006-2013). Statistically significant trends are indicated in bold. BLUE highlight for PAC indicates an improving trend, RED indicates a deterioration.

Site	Turbidity (NTU)			Suspended sediment (mg/l)		
	Median	Trend p value	Percent Annual Change	Median	Trend p value	Percent Annual Change
Ocean Beach	3.05	0.438	5.62	4.95	0.171	11.78
Awatoto	5.90	0.642	-2.48	8.25	0.320	8.79
Marine Parade	**4.15**	**0.031**	**7.47**	5.00	0.102	10.01
Westshore	4.94	0.561	5.71	5.75	0.116	12.89
Whirinaki	3.99	0.729	-3.38	6.90	0.355	4.83
Mohaka	5.84	0.270	6.25	8.55	0.053	13.42
Ahuriri Estuary	5.05	0.438	-6.75	13.00	0.776	-3.46

The two satellite images below from before and after (Figure 2-6) Cyclone Pam in 2015 give a good example of the resuspension of sediments. Cyclone Pam generated a large 5 m easterly swell but was not accompanied by much rain. The energy of these swells can lift sediments from the seafloor, and erode estuary banks, and the coastline.

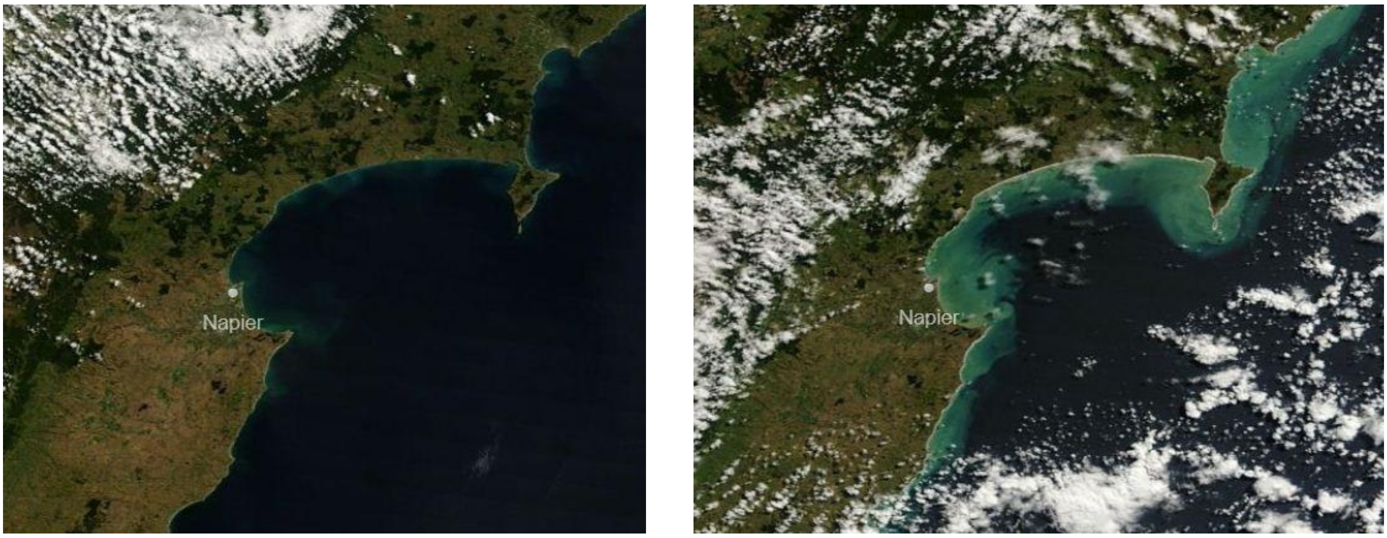

Figure 2-6: The Hawke's Bay region prior to Cyclone Pam with clear waters (left), and after Cyclone Pam (right) showing a band of turbid water along the coast.

2.1.6 Total nutrients

Total nutrient data is presented for total phosphorus only. Variable laboratory detection limits for total nitrogen do not allow meaningful analysis.

Nitrogen (N) and phosphorus (P) are key 'growth limiting' nutrients that influence the growth rate and biomass of algae and phytoplankton. A deficit in the supply of one of these two nutrients often limits algal biomass development.

Eutrophication is the term used to describe the enrichment of water bodies by inorganic plant nutrients such as nitrate or phosphate. Eutrophication may occur naturally, but is often exacerbated by human activity. Land-use change and intensification often give rise to elevated levels of nitrogen and phosphorus in river waters which discharge to estuaries and the sea. There can also be direct inputs of nutrients such as storm-water and sewage outfalls. Nuisance macroalgal growth and phytoplankton blooms can be managed by reducing or eliminating inputs of N and P from point-source discharges and/or river sources.

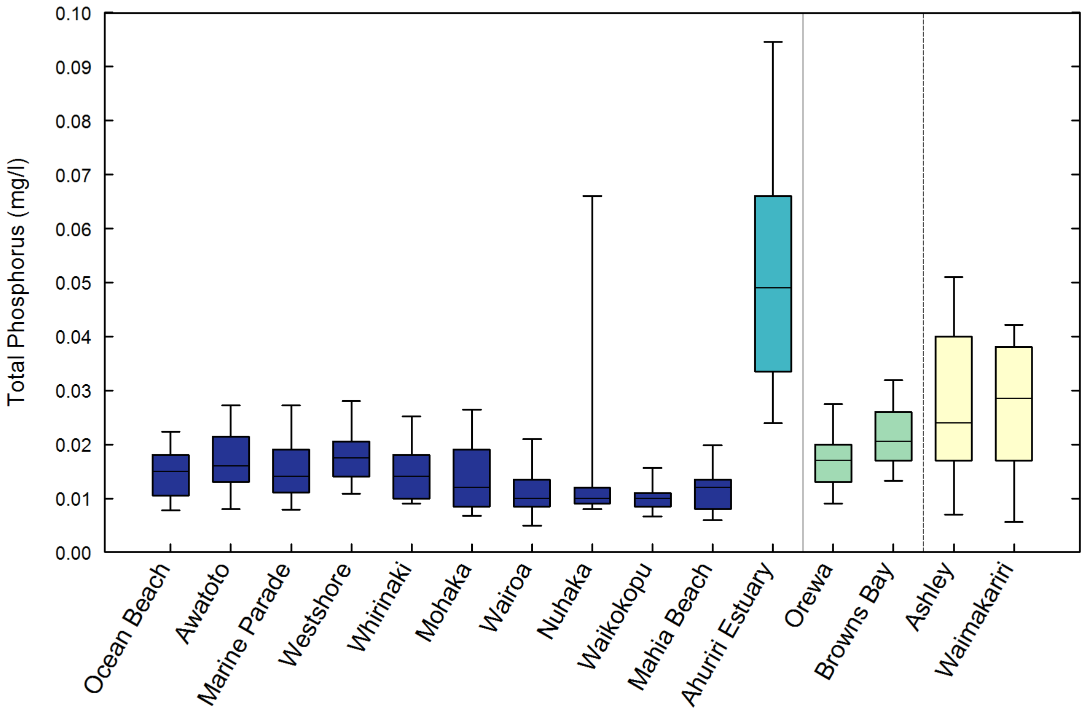

Figure 2-7: Total Phosphorus concentrations at nearshore water quality monitoring sites (2009-2013).

Total phosphorus (TP) concentrations are relatively low at all open water sites compared to the comparable sites in the Auckland and Canterbury regions (Figure 2-7).

Concentrations at the Ahuriri Estuary site are elevated as is typical in estuaries when compared to open waters. The Ahuriri Estuary site also has a significant improving trend in TP (Table 2-3). This is a 9.7% annual decrease in TP concentration.

Table 2-3: Trend analysis of Total Phosphorus concentrations at nearshore water quality monitoring sites (2006-2013). Statistically significant trends are indicated in bold. BLUE highlight for PAC indicates an improving trend, RED indicates a deterioration.

Site	Total phosphorus (mg/l)		
	Median	Trend p value	Percent Annual Change
Ocean Beach	0.015	1.000	0.00
Awatoto	0.020	0.284	-4.16
Marine Parade	0.016	0.430	-2.07
Westshore	0.019	0.226	-2.61
Whirinaki	0.015	0.721	-0.89
Mohaka	0.015	0.520	-2.26
Ahuriri Estuary	**0.056**	**0.023**	**-9.78**

2.1.7 Dissolved nutrients

Dissolved inorganic nitrogen (DIN) and dissolved reactive phosphorus (DRP) are the 2 most significant nutrient forms that stimulate or limit algal growth, since they are immediately 'bioavailable' to algae and plants and fuel biological growth. By comparison, some forms of nitrogen and phosphorus, such as organic nitrogen and particulate phosphorus, are not immediately available to algae and plants and need to go through decomposition processes such as re-mineralisation to be turned into bio-available forms.

While the input of dissolved nutrients into Hawke's Bay from rivers is an important element of marine algal growth, there are many other complex processes occurring that are not well understood. These processes can limit or promote algal growth. For example, silica can also be a limiting factor in marine phytoplankton growth. Nitrogen and phosphorus can also enter the marine environment from other sources such as atmospheric deposition, groundwater sources (Paerl 1997) and from deep water upwelling.

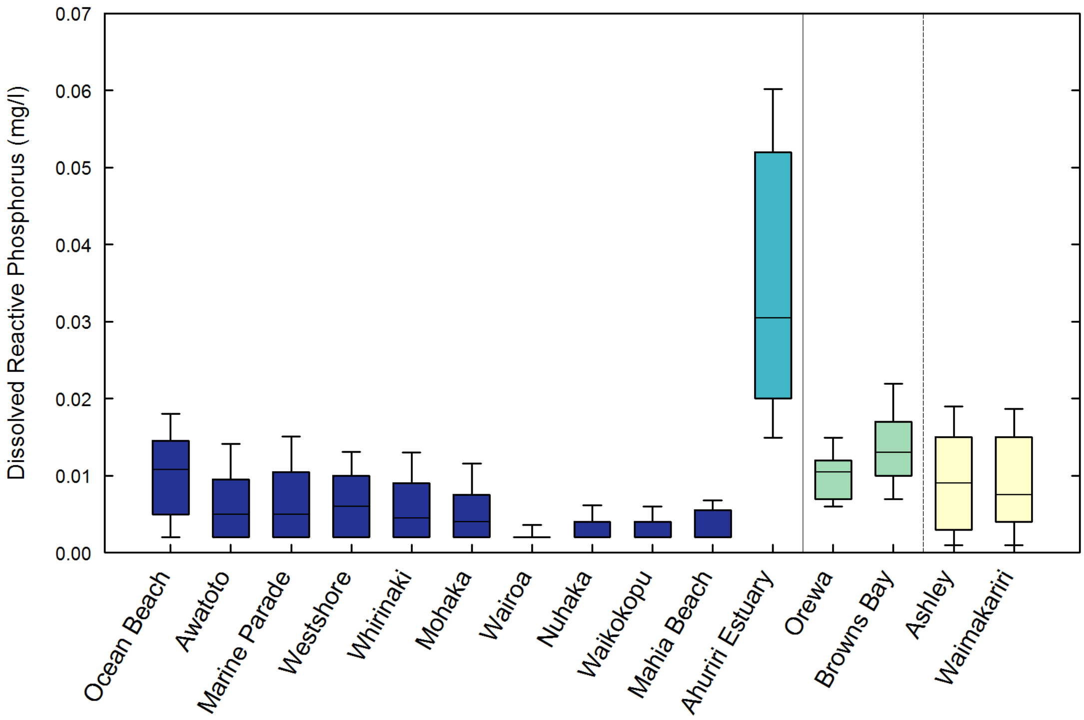

Figure 2-8: Dissolved Reactive Phosphorus concentrations at nearshore water quality monitoring sites (2009-2013).

Dissolved reactive phosphorus concentrations in Hawke's Bay are comparable, or lower, than at sites in other regions (Figure 2-8). Estuaries generally have higher nutrient concentrations than open water sites and the Ahuriri Estuary site follows this pattern. Ocean Beach also has a much higher median concentration than other sites even though this site is not located close to potential river sources of nutrients. Oceanic upwelling of nutrient-rich waters is a possible explanation for the higher median DRP concentrations at Ocean Beach than at other coastal water quality sites.

DIN concentrations in Hawke's Bay are also comparable to those at sites in other regions (Figure 2-9). Besides the Ahuriri Estuary, Ocean Beach has the highest median DIN concentration. This may confirm the likelihood of upwelling effects on the southern Hawke's Bay coast.

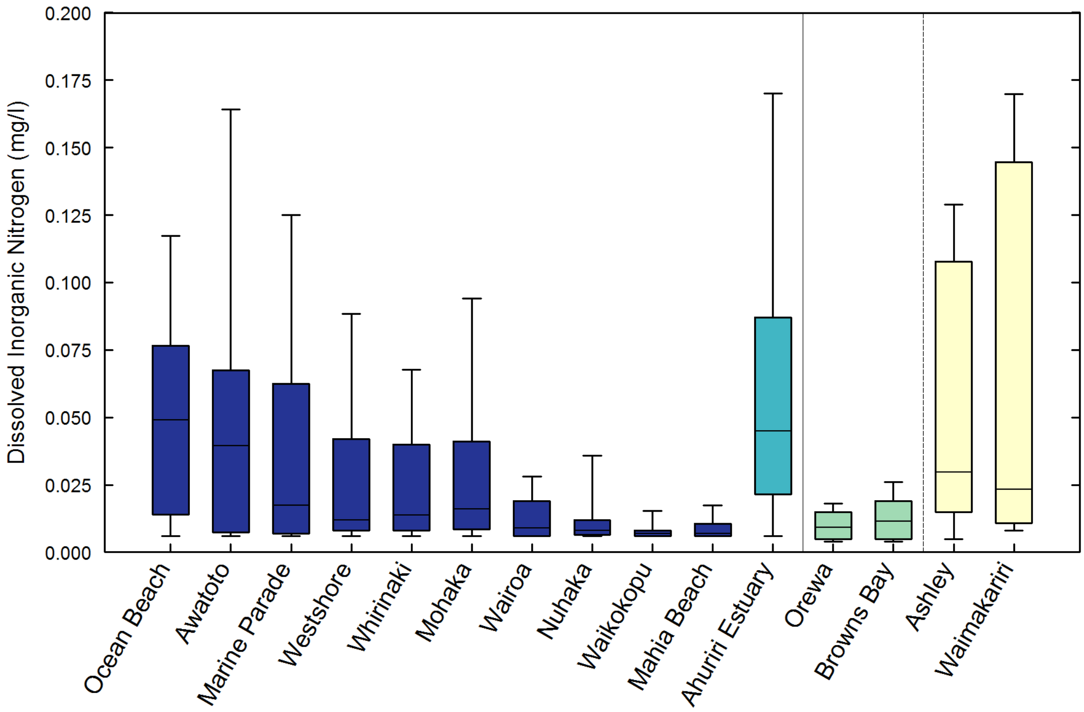

Figure 2-9: Boxplot depicting Dissolved Inorganic Nitrogen concentrations at nearshore water quality monitoring site (2009-2013).

There are no significant trends forDRP or DIN for the long term monitoring sites (Table 2-4).

Table 2-4: Trend analysis of dissolved nutrient concentrations at nearshore water quality monitoring sites (2006-2013). Statistically significant trends are indicated in bold. BLUE highlight for PAC indicates an improving trend, RED indicates a deterioration.

Site	Dissolved reactive phosphorus (mg/l)			Dissolved inorganic nitrogen (mg/l)		
	Median	Trend p value	Percent Annual Change	Median	Trend p value	Percent Annual Change
Ocean Beach	0.010	0.148	3.47	0.044	1.000	-0.37
Awatoto	0.006	0.941	0.00	0.040	0.319	-6.20
Marine Parade	0.007	0.411	0.00	0.033	0.597	-1.57
Westshore	0.006	0.886	0.00	0.015	0.520	2.45
Whirinaki	0.006	0.884	0.00	0.019	0.434	-5.26
Mohaka	0.006	0.766	0.00	0.020	0.135	-5.10
Ahuriri Estuary	0.038	0.201	-6.65	0.051	0.880	-2.68

2.1.8 Chlorophyll *a*

Chlorophyll *a* concentrations are an indication of the amount of phytoplankton (productivity) in the water column. In coastal waters, increasing concentrations of phytoplankton are commonly found when nutrient levels are high, sometimes taking the form of large algal blooms as observed in Hawke's Bay in 2012 (Figure 2-10).

Figure 2-10: Part of a large bloom of the dinoflagellate *Akashiwo sanguinea* in Hawke Bay in August 2012.

Chlorophyll *a* concentrations vary significantly between sites (Figure 2-11). Despite the elevated nutrients at Ocean Beach (see Section 2.1.7), chlorophyll *a* concentrations at this site are low, suggesting these elevated background concentrations of nutrients do not increase levels of productivity.

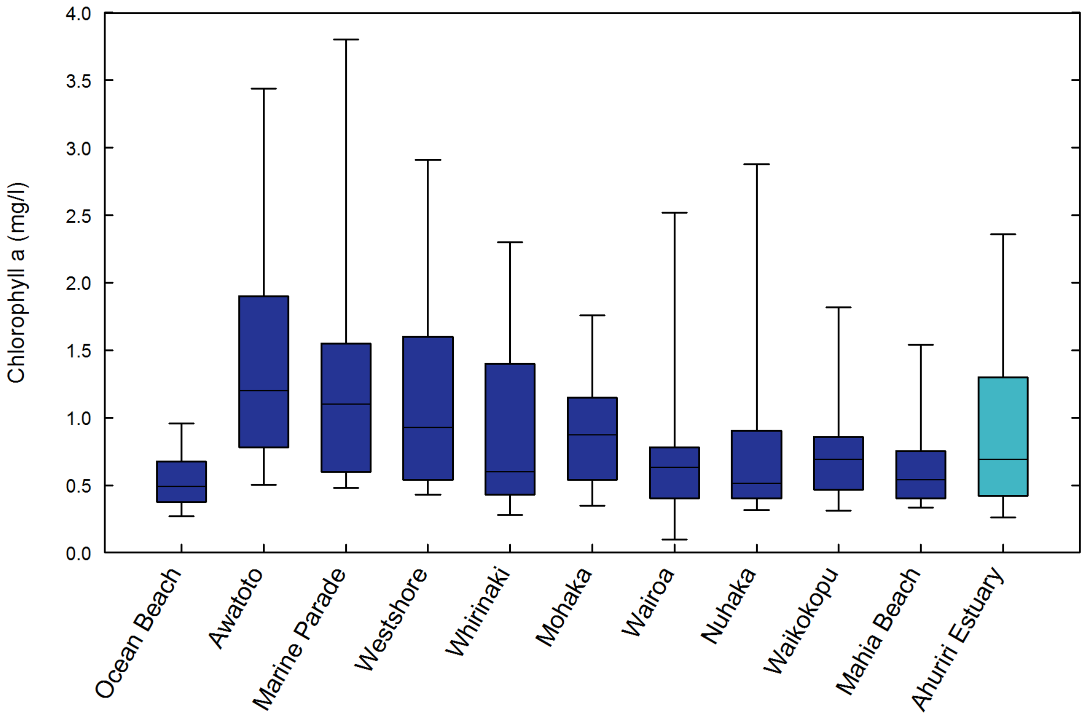

Figure 2-11: Boxplot depicting chlorophyll a concentrations at nearshore water quality monitoring sites (2009-2013.

There was no significant trend in chlorophyll *a* concentrations at the long term monitoring sites (Table 2-5).

Table 2-5: Trend analysis of chlorophyll a concentrations at nearshore water quality monitoring sites (2006-2013). Statistically significant trends are indicated in bold. BLUE highlight for PAC indicates an improving trend, RED indicates a deterioration.

Site	Chlorophyll *a* (mg/l)		
	Median	Trend p value	Percent Annual Change
Ocean Beach	0.54	0.118	-5.56
Awatoto	1.54	0.088	-8.95
Marine Parade	1.30	0.887	-1.65
Westshore	1.18	1.000	0.00
Whirinaki	0.76	0.776	-3.09
Mohaka	0.87	0.670	1.72
Ahuriri Estuary	0.86	1.000	0.87

2.1.9 Faecal coliforms

Faecal coliforms are a group of micro-organisms monitored as an indicator of faecal contamination. These bacteria are associated with the gut of many warm blooded animals. Faecal coliforms are used as an indicator of human health risk from contact recreation such as swimming (see section 3). The most common illnesses associated with swimming include gastroenteritis, respiratory illnesses, and skin and ear infections. These illnesses can be caused by a wide range of pathogenic organisms including viruses, bacteria and protozoan species, including *Salmonella, Campylobacter, Cryptosporidium*, and G*iardia* (MfE and MoH 2003). It is not feasible to analyse water samples directly for these pathogenic organisms. However, these pathogens are usually associated with faecal indicator bacteria (e.g. faecal coliforms). Measurement of the concentration of these indicator bacteria gives an indication of the health risk arising from pathogenic organisms associated with contact recreation.

Faecal coliform concentrations were generally below detection limits at all sites. Concentrations were elevated at times at the Awatoto site (Figure 2-12). It is possible that these elevated concentrations are associated with the river plume from the Waitangi Estuary and/or the proximity to the municipal waste water outfalls of Napier and Hastings.

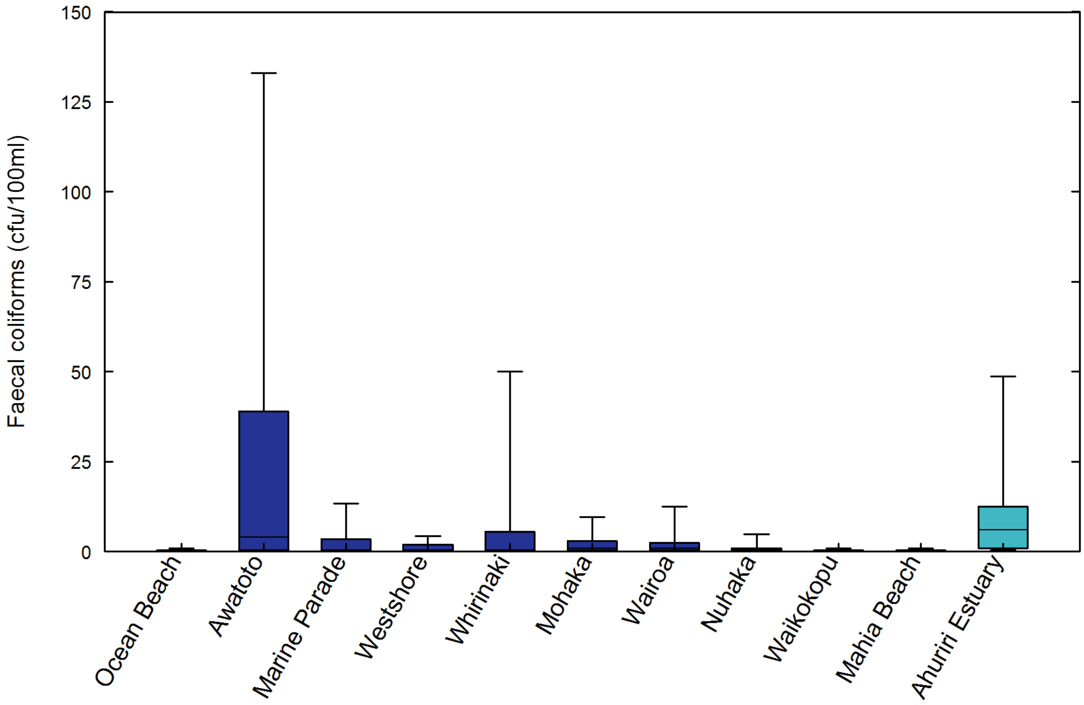

Figure 2-12: Boxplot depicting Faecal Coliform concentrations at nearshore water quality monitoring sites (2009-2013).

There were no significant trends in the data from the long term monitoring sites (Table 2-6).

Table 2-6: Trend analysis of faecal coliform concentrations at nearshore water quality monitoring sites (2006-2013). Statistically significant trends are indicated in bold. BLUE highlight for PAC indicates an improving trend, RED indicates a deterioration.

Site	Faecal coliforms (fcu/100ml)		
	Median	Trend p value	Percent Annual Change
Ocean Beach	0.05	0.251	0.00
Awatoto	9.50	0.886	-1.05
Marine Parade	1.00	0.633	0.00
Westshore	0.75	0.291	0.00
Whirinaki	1.25	0.244	-13.33
Mohaka	1.75	1.000	0.00
Ahuriri Estuary	3.75	0.943	2.22

2.1.10 Dissolved oxygen

Dissolved oxygen is a vital component of the life supporting capacity of estuarine and coastal ecosystems. Fish, invertebrates and other organisms are stressed when insufficient oxygen is dissolved in the water. The ideal dissolved oxygen saturation for ecosystem health is between 90% and 110% (Davies-Colley 2013).

Various elements of aquatic systems either consume and/or produce oxygen. Plants and algae growing in the water produce oxygen as a by-product of photosynthesis during daylight hours, and consume it during night-time hours. This supplements oxygen passively diffusing into the water from the atmosphere or being infused by turbulence or aeration of the surface waters through wind and wave processes. However, plants and algae also use oxygen when they respire, as do animals and bacteria living in the water. The breakdown of organic matter by aerobic micro-organisms in the water and the sediment also consumes oxygen.

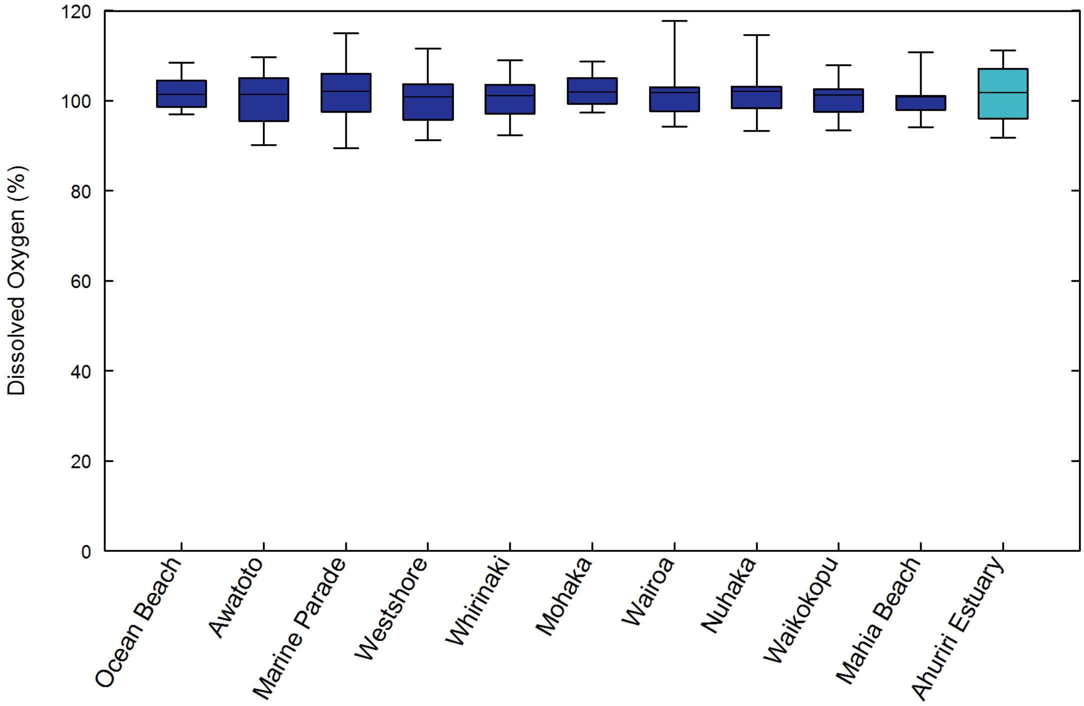

Figure 2-13: Dissolved oxygen saturation at nearshore water quality monitoring sites (2009-2013).

Dissolved oxygen saturation of the surface waters of Hawke's Bay is generally around 100% (Figure 2-13), indicating that waters are generally neither over-producing, nor over-consuming oxygen. Trend analyses indicate an increasing trend in dissolved oxygen saturation at the Mohaka site (**Table 2-7**).

Table 2-7: Trend analysis of dissolved oxygen saturation at nearshore water quality monitoring sites (2006-2013). Statistically significant trends are indicated in bold. BLUE highlight for PAC indicates an improving trend, RED indicates a deterioration.

Site	Dissolved oxygen saturation (%)		
	Median	Trend p value	Percent Annual Change
Ocean Beach	98.81	0.056	1.79
Awatoto	98.11	0.941	0.01
Marine Parade	99.19	0.219	1.22
Westshore	97.73	0.088	1.20
Whirinaki	97.57	0.118	1.36
Mohaka	100.53	0.018	1.23
Ahuriri Estuary	98.40	0.352	1.22

Water with dissolved oxygen concentrations consistently below 5.0 mg/l is generally considered unable to support sensitive species and the ecological integrity of these systems is considered to be compromised. Dissolved oxygen concentrations that are greater than 8.0 mg/l are typically capable of supporting the full range of aquatic organisms (MfE 2013).

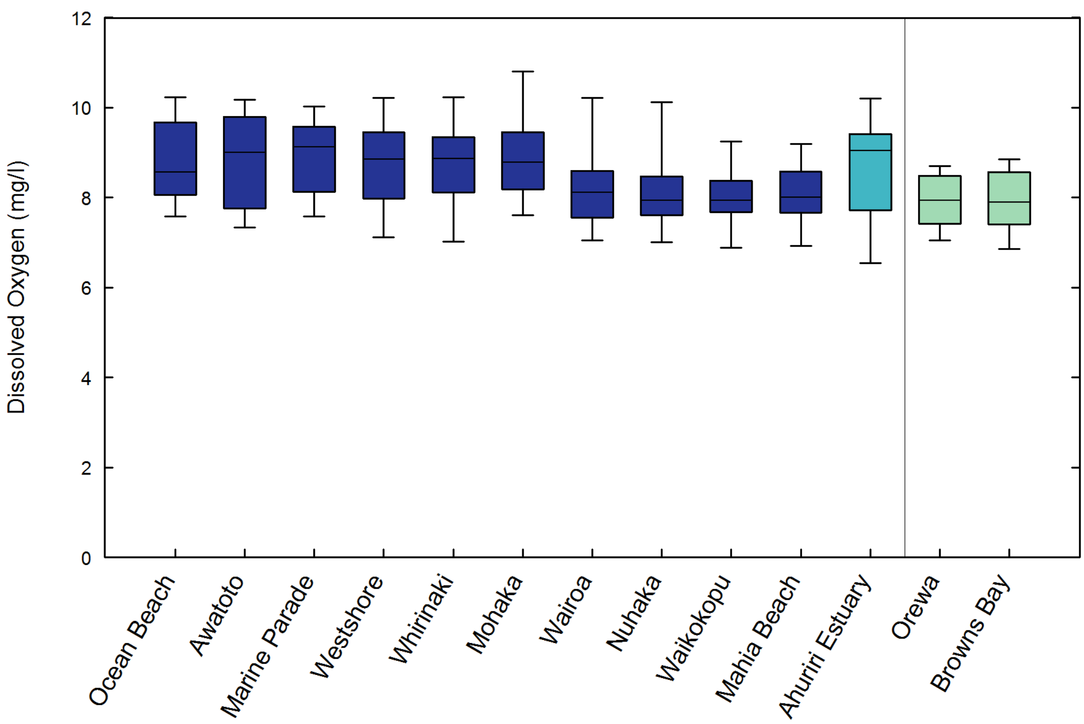

Figure 2-14: Dissolved oxygen concentrations at nearshore water quality monitoring sites (2009-2013).

Median dissolved oxygen concentrations at monitoring sites were all above 8 mg/l (Table 2-8).

While surface water dissolved oxygen concentrations appear healthy for Hawke's Bay, oxygen depletion usually occurs in deeper waters, where aeration by waves and wind is minimal, and benthic (seafloor) oxygen consumption is high. Water column dissolved oxygen profiles are an area of ongoing research for HBRC.

Table 2-8: Trend analysis of Dissolved oxygen concentrations at nearshore water quality monitoring sites (2006-2013). Statistically significant trends are indicated in bold. BLUE highlight for PAC indicates an improving trend, RED indicates a deterioration.

Site	Dissolved oxygen concentration (mg/l)		
	Median	Trend p value	Percent Annual Change
Ocean Beach	8.43	0.887	0.30
Awatoto	8.63	0.887	0.36
Marine Parade	8.55	0.603	0.44
Westshore	8.46	0.943	-0.24
Whirinaki	8.36	0.570	1.32
Mohaka	8.40	0.394	1.03
Ahuriri Estuary	8.52	0.882	-0.17

2.2 HAWQi – Hawke's Bay Water Quality Information

In December 2012, HBRC, with the assistance of the Cawthron Institute, deployed the *HAWQi (**HA**wke's Bay* **W**ater **Q**uality **i**nformation) water quality buoy approximately 5 km off Tangoio Bluff, Hawke Bay. HAWQi collects continuous temperature, conductivity, turbidity, dissolved oxygen and chlorophyll *a* data.

Figure 2-15: Hawke's Bay Water Quality information buoy - HAWQi.

HAWQi runs a series of Seabird© temperature and conductivity sensors (surface, 5 m and 14 m depth), with an optical chlorophyll *a*, turbidity and dissolved oxygen sensor at 5 m. The deep water instruments (5 m and 14 m) communicate as an inductive array, which minimises a requirement for easily-damaged cables. An

Airmar© PB150 ultrasonic weather station with accelerometer and GPS sensor are deployed 1 m above sea level. An independent GPS with geofencing ensures that the position of is communicated independently to the base telemetry station – this ensures that should the buoy become detached from the mooring, it can be tracked and recovered.

The software used to control the hardware and electronic settings remotely was developed by the Monterey Bay Aquarium Research Institute (MBARI), California, and provided to HBRC. Data are telemetered to HBRC by radio, and are integrated with HBRC time-series data management systems HydroTel and Hilltop.

HAWQi provides HBRC with continuous, real-time data which provide context for 'point-in-time' grab samples. These data also allow transient events such as algae blooms to be identified and monitored.

A report written by the Cawthron Institute (Knight 2014) used continuous data from HAWQi to develop an algorithm to correct satellite imagery of chlorophyll *a* concentrations in Hawke's Bay for the elevated turbidity found in these waters. This algorithm enables the use of historical satellite imagery to analyse changes in chlorophyll *a* concentrations in Hawke's Bay over the last decade.

These data show clear seasonal signals, with inter-annual variations. Trend analysis reveals a small but significant increase in chlorophyll *a* concentrations of 0.02 mg/ m^3 per year (Knight 2014).

2.3 Conclusions

- For those parameters where comparison is possible, water quality in Hawke's Bay is comparable to, or better than, at other sites around the country.
- Sites have high variability in turbidity and suspended sediment concentrations, indicating periodic episodes of high sediment input from river sources or swell-induced resuspension.
- There are few trends in water quality over the reporting period.
- Dissolved nutrients are higher at Ocean Beach than at sites within Hawke Bay itself. When viewed with the opposite pattern with chlorophyll *a* concentrations highlights the potential role of oceanic upwelling as a driver of productivity.
- Current SoE monitoring of nearshore waters and the freshwater network is ineffective at capturing large events which are the periods when most of sediments and contaminants are introduced to the marine environment.
- Current SoE monitoring currently only samples surface waters. Depth profiles should be added to the monitoring profiles to capture variations in dissolved oxygen concentrations and other variables with depth.

3 Recreational Water Quality

Hawke's Bay's coastal waters, freshwater lakes and rivers are frequently used for a range of recreational activities. However, these areas can become unsuitable for contact recreation through contamination from human and animal faecal matter, which may carry harmful, illness-causing pathogens.

"Contact recreation" includes any activity that brings people into contact with water where a reasonable risk of inhaling or ingesting water exists. At times, human or animal faecal material may enter the water from land run-off, discharges or from natural populations of animals or birds. During these events, water may contain pathogens from this faecal matter. The risk of contracting illnesses such as gastro-enteritis, respiratory illnesses, hepatitis A, giardiasis, cryptosporidiosis, campylobacterosis, and salmonellosis increases as exposure to pathogenic organism increases (MfE and MoH 2003).

To monitor the risk associated with contact recreation, Hawke's Bay Regional Council (HBRC) undertake annual Recreational Water Quality monitoring in collaboration with Territorial Local Authorities (TLAs) and the Public Health Unit of the Hawke's Bay District Health Board (PHU). Although not confined to the coastal areas of Hawke's Bay, HBRC operates the Recreational Water Quality monitoring programme from the coastal project and therefore the full programme is reported in this chapter.

The aims of the programme are to:

- Determine the suitability of the coastal, estuarine and freshwater sites for recreational use;
- Assist in safeguarding public health and the environment;
- Compare current water quality with that of previous seasons;
- Provide a baseline for future research;
- Identify problems and target investigations to those areas requiring mitigation, remediation or further research and development.

3.1 Long-term monitoring

Thirty seven sites within Hawke's Bay were sampled during the 2009-2014 summer seasons, however many of the sites have records of more 10 years. These sites are commonly used for recreation, including swimming, water skiing, rowing, diving, fishing, surfing and shellfish gathering.

The sites were sampled weekly, with the exception of the Clive River and Puhokio Stream sites, which were sampled fortnightly. Sampling was conducted between November and March inclusive, and samples were collected and stored prior to laboratory analysis, in accordance with the sampling procedures outlined in sections D2 and E2 of the MfE and MoH guidelines (2003). Additional environmental information was collected for each site at the time of sampling, including water temperature, turbidity, electrical conductivity and the number of people present. Further information on this programme is available in (Gilmer 2014).

3.1.1 Faecal indicator bacteria

The most common illnesses associated with swimming include gastroenteritis, respiratory illnesses, and skin and ear infections. These illnesses can be caused by a wide range of pathogenic organisms including viruses, bacteria and protozoan species – these include *Salmonella, Campylobacter, Cryptosporidium*, and G*iardia* (MfE and MoH 2003). It is not feasible to analyse water samples for these pathogenic organisms, however these pathogens are associated with enterococci and *Escherichia coli (E. coli)* bacteria that are specific to the gut of warm-blooded animals. The concentration of these indicator bacteria gives an indication of the health risk associated with the pathogenic organisms contacted during recreation.

Samples were analysed for the indicator bacteria enterococci at marine sites. Enterococci survives better in saline waters than *E. coli,* providing a better indication of risk. Samples collected at freshwater sites were analysed for the indicator bacteria *E. coli*.

At estuarine or freshwater sites subject to tidal influences, dual testing of indicator bacteria was undertaken. This ensured that the indicator organism appropriately indicated the risk of adverse health effects. Where electrical conductivity readings indicated a freshwater environment (<10,000 µS/cm), the laboratory analysis was conducted for *E. coli* only, otherwise both *E. coli* and enterococci levels were measured. The indicator bacteria reported on for these sites is the one most commonly sampled for at these sites and is specified in the trend tables.

3.1.2 Water quality guidelines

All sampling and evaluation of results was undertaken in accordance with the 'Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas 2003' (MfE and MoH 2003) (**Table-3-1**).

Table-3-1: Water quality guideline values and indicator organisms used to assess marine and freshwater recreational areas (MfE and MoH, 2003).

Response Level	Marine Water Enterococci CFU/100 ml Single Sample	Freshwater *E. coli* CFU/100 ml Single sample	Shellfish gathering waters Faecal coliforms CFU/100 ml (over season)
Green Mode	<140	<260	
Amber Mode	140 - 280	260 - 550	
Red Mode	>280*	>550	
Seasons results			Median concentration < 14/100 ml and 90% of samples < 43/100 ml

CFU = Colony forming units on an agar plate.

- Note: 2 consecutive samples taken within 24 hrs exceeding 280 enterococci/100 ml are required before action mode is initiated.

When water quality is within the 'Green' mode, the risk of contracting an illness from bathing is considered acceptable (MfE and MoH 2003). If the water quality is in the 'Amber' mode there is an increased risk of illness, but this risk is also considered acceptable. This result signals agencies should conduct follow up sampling of the site to determine whether contamination levels have increased to the 'Red' mode.

If levels of bacteria exceed the levels set out in the 'Red' mode, then contact recreation in the water is deemed to pose an unacceptable health risk. At this stage the PHU informs the public of the elevated risk of illness through sign-posting, media releases and/or phone or website.

While freshwater exceedances are assessed for compliance on the result of a single sample, in marine waters the guidelines require two samples taken within 24 hours to exceed the action level of 280 enterococci CFU/100ml. For the purposes of this report we have reported on only one circumstance:

- Single sample exceedances.

It is important to note that health-based risk communication generally adopts a precautionary approach that aims to protect the most vulnerable members of the public.

The recreational shellfish-gathering microbiological guideline values are also obtained from the MfE and MoH Guidelines (2003, section: F). The guidelines state that faecal coliform is the indicator used, and:

- the season median faecal coliform concentration should not exceed 14 CFU/100 ml, and that
- no more than 10% of samples per season should exceed 43 CFU/100 ml.

3.1.3 Data summaries and visualisation

Maps have been used to spatially represent the number of days water quality samples have exceeded MfE/MoH guideline values over the last 5 years for indicator bacteria (from November 2009 to March 2014). The region has been split into 3 areas for easy interpretation.

Box plots have been used to summarise water quality data for the same time period. Box plots graph data as a box representing statistical values. The lower boundary of each box indicates the 25th percentile, a line within the box marks the median, and the higher boundary of each box indicates the 75th percentile. The line at the end of the whiskers (error bars) above and below the box indicate the 90th and 10th percentiles respectively.

The sites are grouped as marine (dark blue), estuarine (turquoise) and freshwater (light blue) sites. The enterococci concentrations for marine sites are compared to enterococci trigger values on the left and the *E. coli* concentrations for freshwater sites are compared to *E. coli* trigger values on the right. Estuarine sites are compared against either enterococci or *E. coli* depending on which indicator best represents risk at that site.

3.1.4 Trend analysis

Trend analyses in this section was conducted using Mann-Kendall trend tests rather than seasonal Kendall tests, since no seasonality was expected. A 'significant' trend existed where there was a less than 5% probability that the observed data was obtained by chance.

To estimate the strength of trends over time, a Theil-Sen slope estimator was used. The non-parametric Theil-Sen slope estimator estimates the median slope amongst lines through all pairs of points in the dataset. This approach is effective at estimating the true slope in water quality data series because it is less sensitive to outliers.

The values derived from the Theil-Sen slope estimator are referred to as 'Percent Annual Change' (PAC). A trend in PAC was considered meaningful if the PAC was greater than 1% per year. An increase in observed values represents a deterioration (i.e. there is more contaminant in the water) in water quality.

In all tables that present trend results, the changes are represented in bold when they are significant (i.e. p value is less than 0.05). Given a significant trend for a particular variable, the PAC is highlighted in blue if there was a significant improvement in the water quality variable, and highlighted in red if there was a significant deterioration in the water quality variable.

It is inappropriate to compare trends when datasets cover a different time period. For this reporting, we decided to adopt an 8 out of 10 year stipulation, whereby any dataset that had samples from at least 8 years of time period between November 2004 and March 2014 could be considered. Results of trend analyses for sites that contain less than 8 years of data are presented in the result tables alongside the respective site and the different time period noted.

3.2 Suitability for Recreation Grade

The general water quality at a site is described using the Suitability for Recreation Grade (SFRG) by combining the Microbial Assessment Category (MAC), with a Sanitary Inspection Category (SIC). The MAC is derived from the 95^{th} percentile value for the past 5 years of data which determines which category (A-D) is assigned to the site. The SIC is a catchment risk assessment tool that uses land use cover to assess all potential catchment risks. The SFRG grade descriptions can be used to indicate how suitable a site is for contact recreation, as follows (see also MfE & MoH, [2003]):

Very Good – the site has generally excellent microbial water quality and very few potential sources of faecal pollution exist. Water is considered suitable for contact recreation almost all of the time.

Good – the site has water quality considered suitable for contact recreation most of the time. Swimming should be avoided during or following heavy rain.

Fair – the site has water quality generally suitable for contact recreation, but because significant sources of faecal contamination exist, extra care should be taken to avoid swimming during or following rainfall or if signs of pollution, such as discoloured water, odour, or debris in the water exist.

Poor – the site is susceptible to faecal pollution and microbial water quality is not always suitable for contact recreation. During dry weather conditions, ensure that the swimming location is free of signs of pollution, such as discoloured water, odour or debris in the water, and avoid swimming at all times during and for up to three days following rainfall.

Very Poor – the site is very susceptible to faecal pollution and the microbial water quality may often be unsuitable for contact recreation. Swimming at these sites is not recommended.

Follow-Up – a contradiction exists between the bacterial levels observed in the MAC, and the *risk* outlined in the SIC which requires further work e.g. the catchment risk based on the SIC appears low, however the 95% percentile of the observed bacteria levels is high, or the catchment risk is assessed as high but the 95^{th}% percentile of the observed bacterial levels is low.

3.3 Faecal source tracking

If large concentrations of indicator bacteria are recorded at priority sites such as estuaries, lagoons, or sites that have ongoing contamination issues, the samples are sent to ESR laboratory in Christchurch for faecal sterol and Polymerase Chain Reaction (PCR) analysis. This analysis allows for identification of the sources of the bacterial contamination.

During the reporting period, Waipuka Stream at Ocean Beach and Opoutama were further investigated because they had high readings of faecal indicator bacteria. Additional samples were collected from these sites and sent to ESR for faecal sterol and PCR analyses. Follow up investigations based on high readings of faecal indicator bacteria will continue to be conducted throughout the region to identify faecal origin at priority swimming sites.

3.4 Results

3.4.1 Northern Hawkes Bay

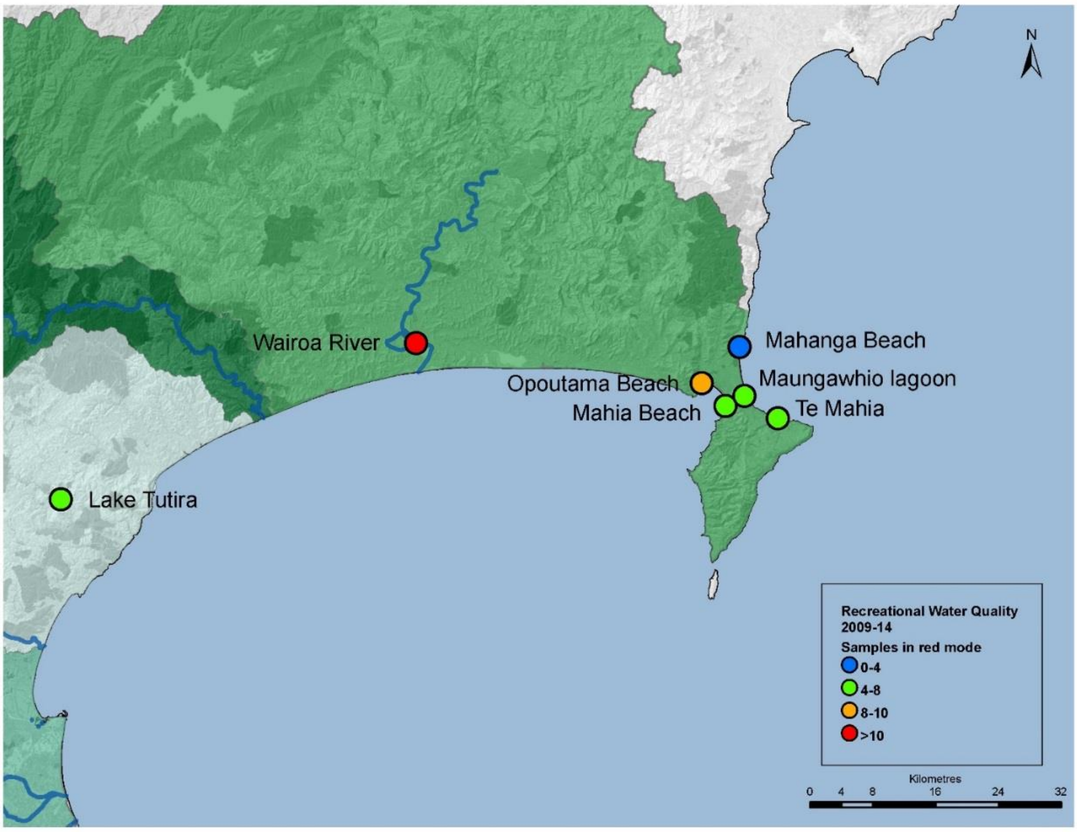

Figure 3-1: Northern sub-region sites 2009-14 samples in red mode. Northern Hawkes Bay beach sites have generally poorer water quality than southern beaches. All sites had 4 to 8 samples in the red mode (Figure 3-1) indicating that there was intermittent bacterial contamination occurring at these sites. Despite Opoutama Beach having a small, but significant improvement in water quality (**Error! Reference source not ound.**) over the time period, Opoutama Beach had the lowest compliance of all Hawkes' Bay coastal sites and faecal source tracking was undertaken at this site (Section 3.4.2).

Estuarine sites in Mahia were at a higher standard when compared to similar systems in the rest of the region. Te Mahia, the estuarine receiving area of the Whangawehi Stream, was sampled for 3 years of the 5 year period. The Maungawhio Lagoon site had 4 to 8 samples in the red mode.

Table 3-2: Northern sub-region site risk and performance summary (2004-2014): Statistically significant trends are indicated in bold. BLUE highlight for PAC indicates an improving trend, RED indicates a deterioration.

Site	Site type (indicator)	SFRG	Median value (cfu/100ml)	Trend p value	Percent Annual Change	SIC category: Primary Impact	MAC category (95th percentile)
Mahanga Beach	Marine (Enterococci)	Good	1	0.46	0.0	Low: Stream focal point of drainage.	B: (66.65)
Mahia Beach	Marine (Enterococci)	Fair	6.5	0.70	0.0	Moderate: Urban stormwater.	C: (400)
Opoutama Beach	Marine (Enterococci)	Poor	**3**	**0.04**	**-4.18**	Moderate: River –agricultural, birds, feral animals.	D: (847.5)
Te Mahia	Marine (Enterococci)	Poor interim	6	No trend*	N/A	Moderate: River – agriculture activities.	D: (1025)
Maungawhio Lagoon	Estuarine (*E. coli*)	Poor	7	0.241	0	High: Intensive agriculture.	C: (550)
Wairoa River	Estuarine (*E. coli*)	Very poor	**56**	**0.00**	**7.21**	High: Intensive agriculture.	D: (2665)
Lake Tutira	Lake	Very poor	34	0.40	1.68	High: Manual change to accommodate all biological processes.	C: (497)

The Wairoa River site has the highest number of samples in red mode (Figure 3-1) reflecting its large catchment and multiple impacts on water quality (Figure 3-2). This site also had the highest median bacteria concentration (Figure 3-2). There was an increasing trend in the contaminant concentrations (Table 3-2), indicating a decline in water quality.

Lake Tutira is the only lake site in the recreational water monitoring programme, the lake had between 4 and 8 samples in the red mode (Figure 3-1). Lake Tutira is also affected by other water quality issues which may affect the health of recreational users, such as duck itch and algae blooms. To account for this, the SFRG was manually changed to 'Very Poor' to reflect these other issues.

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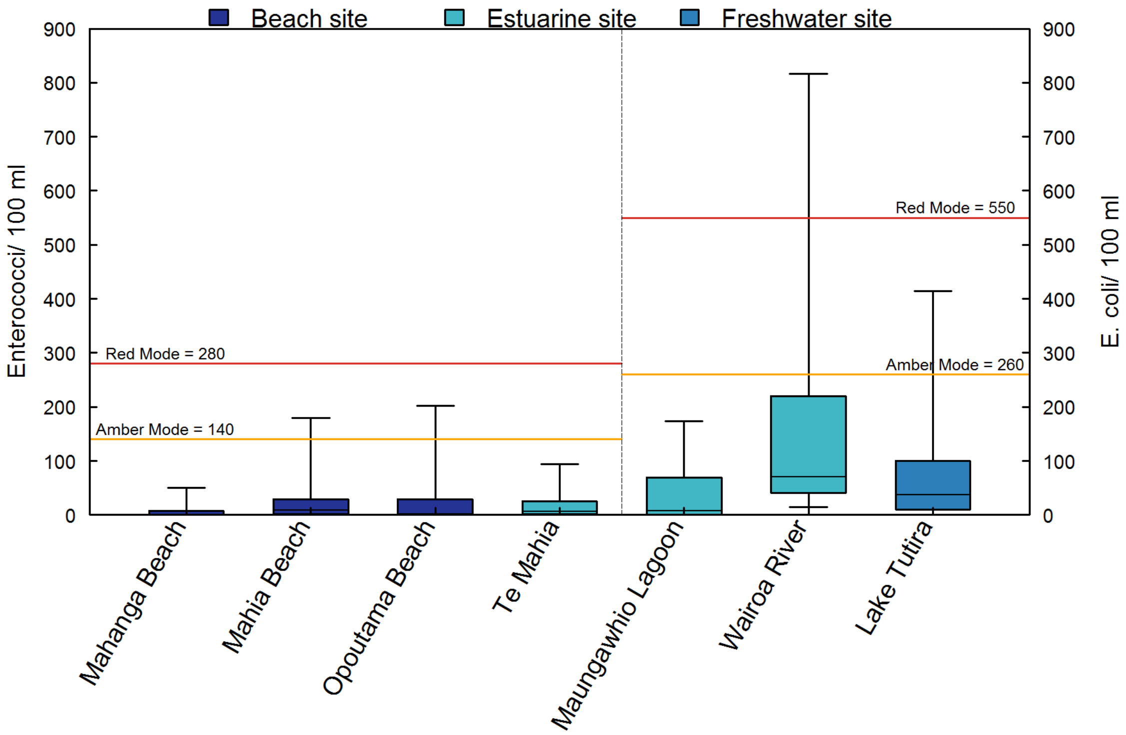


Figure 3-2: Northern sites, 5 year data with exceedance guideline thresholds (2009-2014) Red and amber lines indicate the MfE and MOH (2003) trigger values for Red and Amber modes respectively. The concentrations of indicator bacteria (cfu/ 100 ml) associated with these modes are written above the line.

3.4.2 Opoutama Beach – Faecal Source Tracking

Opoutama Beach lies on the western side of the Mahia Isthmus. The catchment is characterised by a mix of grazing, native and exotic vegetation and a small coastal settlement. Opoutama's Suitability for Recreation Grade (SFRG) has fluctuated from 'Poor' (2007) to 'Good' (2009 and 2010) and back to 'Poor' in 2013. The primary reason for the grade changes has been changes in the 95th percentile of indicator bacteria counts for the previous 5 years, from 520 CFU/100ml in 2007 (Grade D) to 165 CFU/100ml in 2010 (Grade B). This highlights the influence that a few high counts can have on the microbiological assessment category, and therefore the SFRG for a site.

This 'Poor' SFRG grading is unusual for Hawke's Bay's exposed open coastal beaches so Opoutama beach was selected for further investigation into the source of contaminants using faecal source tracking.

During the 2013/14 season, 2 samples were collected for faecal source tracking using faecal sterol and PCR marker analyses. Samples were collected on the 11th February, 2014 following a rainfall related enterococci count of 1050 CFU/100ml (action level guideline = 280CFU/100ml), when 82.5mm rain was recorded at Kopuawhara. This exceedance follows an earlier rainfall related exceedance of 1400 CFU/100ml enterococci on 27th January, 2014. Samples were sent to ESR for analysis.

Both samples were dominated by enterococci from ruminant sources. Further analytical lab testing indicated that the samples were from cows.

Further sampling is being completed outside the normal monitoring season to validate the results of the initial sample. Potential management solutions in this catchment are being identified by the Land Management section of HBRC.

Figure 3-3: Opoutama Beach 2005.

3.4.3 Central Hawkes Bay

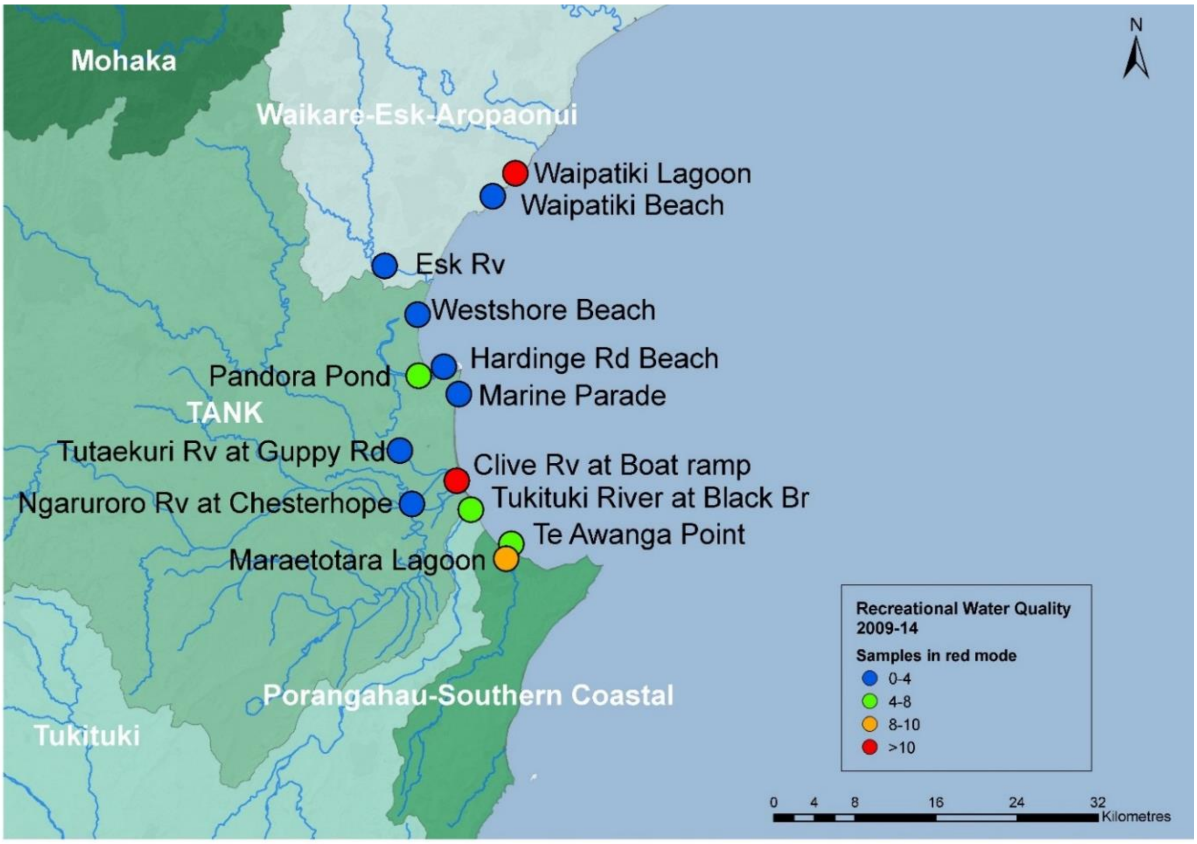


Figure 3-4: Central sub-region sites 2009-14 days in the red mode.

Open beach sites within the central sub-region performed to a high standard (Figure 3-4), with most having between 0 and 4 samples in red mode and MAC's of A and B (Table 3-3). The higher concentrations of faecal bacteria observed the Te Awanga Point (Figure 3-5) suggest the Maraetotara River may be contributing faecal loads to this beach.

Concentrations of faecal indicator bacteria were generally higher at estuarine sites (Table 3-3). The Clive Rv at Boat Ramp site had the highest median concentration of bacteria and the most samples in the red mode (Figure 3-4) indicating ongoing problems with water quality at this site.

Three sites within the Ahuriri Catchment reported significant improvements in recreational water quality. Hardinge Road beach, Westshore Beach and Pandora Pond all saw significant reductions in the faecal indicator bacteria concentrations (Table 3-3).

Table 3-3: Central sub-region site risk and performance summary 2004-2014. Statistically significant trends are indicated in bold. BLUE highlight for PAC indicates an improving trend, RED indicates a deterioration.

Site	Site type (indicator)	SFRG	Median value (cfu/100ml)	Trend p value	Percent Annual Change	SIC category: Primary Impact	MAC category (95th percentile)
Hardinge Rd Beach	Marine (Enterococci)	Good	**3**	**0.00**	**-4.57**	Moderate: Urban stormwater.	A: (25.75)
Marine Parade	Marine (Enterococci)	Interim/ Good	1	No trend*	-66.90	Moderate: Urban stormwater.	A: (29)
Te Awanga Point	Marine (Enterococci)	Fair	6	0.88	0.0	Fair: River – agricultural.	C: (228.6)
Waipatiki Beach	Marine (Enterococci)	Good	**1**	**0.00**	**0.00**	Very Low: focal point for drainage.	B: (120)
Westshore Beach	Marine (Enterococci)	Good	**4**	**0.00**	**-5.31**	Moderate: Urban stormwater.	A: (38.6)
Pandora Pond	Estuarine (Enterococci)	Fair	**9**	**0.04**	**-7.35**	Moderate: Urban stormwater.	B: (192.5)
Clive Rv at Boat Ramp	Estuarine (*E. coli*)	Very Poor	110	0.81	0.49	High: Bird life and agriculture	D: (586.3)
Maraetotara Lagoon	Estuarine (*E. coli*)	Poor	74	0.37	2.36	Moderate: Low intensity agriculture.	C: (500)
Waipatiki Lagoon	Estuarine (*E. coli*)	Very Poor	81	0.44	-1.75	High: Incidence of birdlife.	D: (1060)
Esk Rv	River (*E. coli*)	Fair	44	0.17	2.94	Moderate: Low intensity agriculture.	C: (518)
Ngaruroro Rv at Chesterhope	River (*E. coli*)	Fair	53	0.45	1.87	Moderate: Low intensity agriculture.	C: (365.5)
Tukituki Rv at Black Bridge	River (*E. coli*)	Poor	30	0.46	1.74	High: Unrestricted stock access.	C: (550)
Tutaekuri Rv at Guppy Rd	River (*E. coli*)	Fair	36	0.43	1.57	Moderate: Low intensity agriculture.	C: (317.5)

*Less than 8 year's data

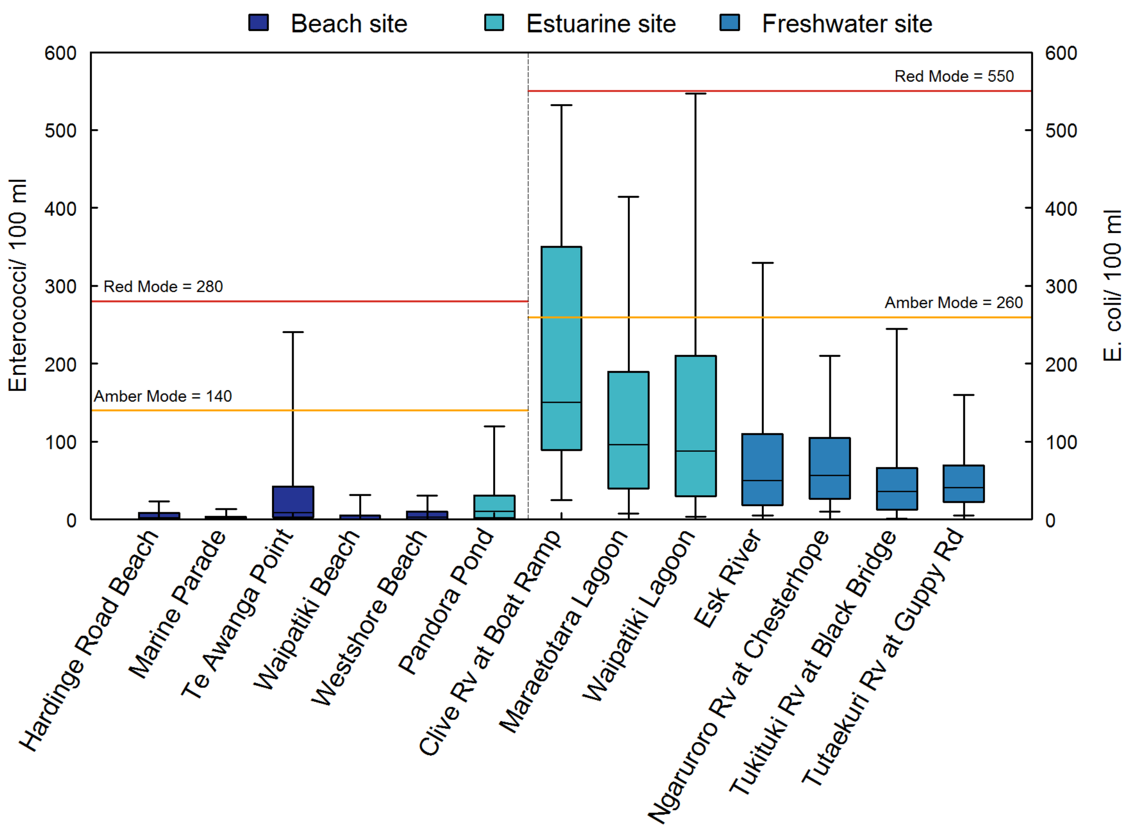


Figure 3-5: Central sites, 5 year data with exceedance guideline thresholds (2009-2014). Red and amber lines indicate the MfE and MOH (2003) trigger values for Red and Amber modes respectively. The concentrations of indicator bacteria (cfu/ 100 ml) associated with these modes are written above the line.

3.4.4 Southern Hawkes Bay

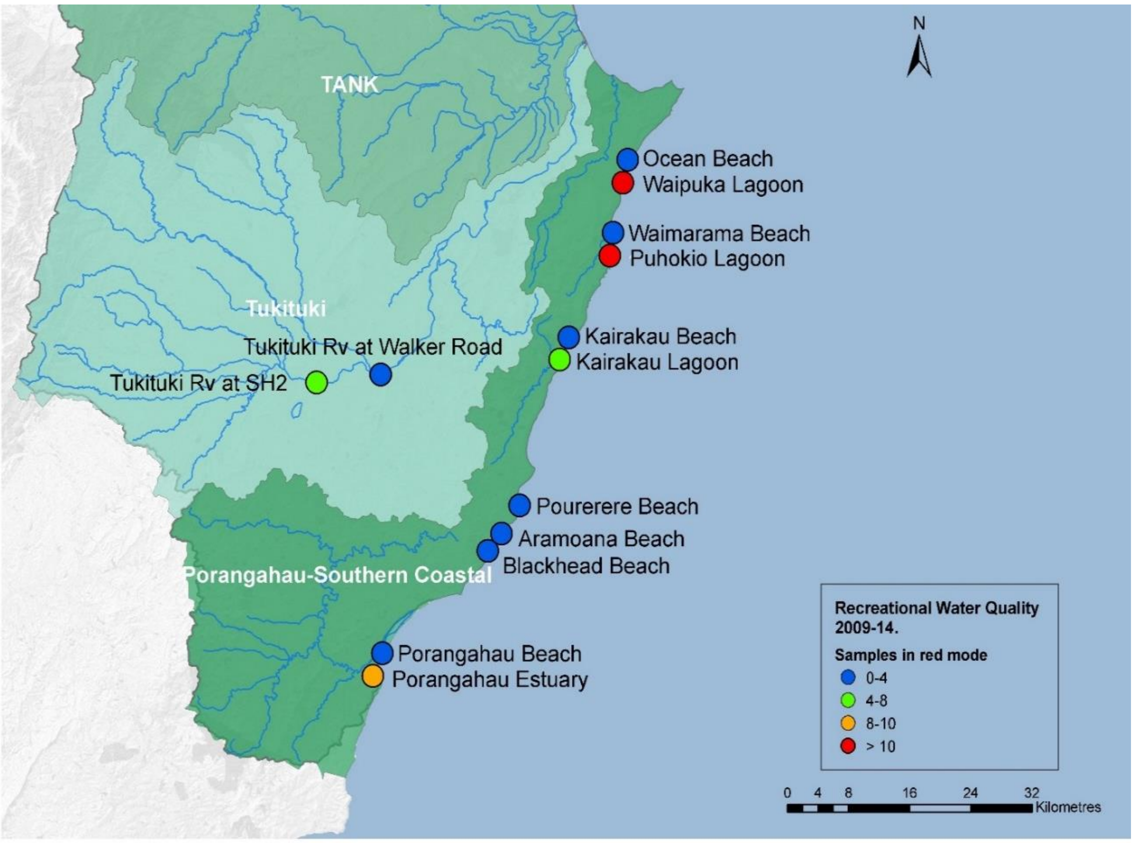


Figure 3-6: Southern sub-region sites 2009-14 samples in the red mode.

The southern sub region has high recreational water quality at beach sites, with most sites remaining within guideline levels throughout the season. These sites are generally not influenced by freshwater inputs or urban centres, and have no other significant sources of contamination.

The estuarine sites tend to have higher bacterial concentrations (Figure 3-7) and are affected by short lived spikes in bacterial numbers (Figure 3-7). Both the Waipuka Stream and the Porangahau Estuary sites had significant declines in water quality. In particular, the Waipuka Stream had more than 10 samples exceeding recreational guideline, because of the large number of exceedances of recreational guidelines in recent years, faecal source tracking analysis has been undertaken at this site (Section 3.4.5). The Porangahau Estuary also had a high number of samples (8-10) exceed guidelines, and a decline in water quality of 15.7 % each year.

Table 3-4: Southern sub-region site risk and performance summary 2004-2014. Statistically significant trends are indicated in bold. BLUE highlight for PAC indicates an improving trend, RED indicates a deterioration.

Site	Site type (indicator)	SFRG	Median value (cfu/100ml)	Trend p value	Percent Annual Change	SIC category/Primary Impact	MAC category: (95th percentile)
Aramoana Beach	Marine (Enterococci)	Very Good	1	0.61	0.00	Very low: No significant source.	A: (33.55)
Blackhead Beach	Marine (Enterococci)	Very Good	**1**	**0.01**	**0.00**	Very low: No significant source.	B: (47)
Kairakau Beach	Marine (Enterococci)	Very Good	1	0.60	0.00	Very low: No significant source.	A: (32.8)
Ocean Beach	Marine (Enterococci)	Very Good	1	0.19	0.00	Very low: No significant source.	B: (41.5)
Porangahau Beach	Marine (Enterococci)	Very Good	**1**	**0.00**	**0.00**	Very low: No significant source.	A: (23.1)
Pourerere Beach	Marine (Enterococci)	Very Good	**1**	**0.00**	**0.00**	Very low: No significant source.	A: (17.5)
Waimarama Beach	Marine (Enterococci)	Good	**1**	**0.00**	**0.00**	Low: River focal point of drainage.	A: (26.2)
Kairakau Lagoon	Estuarine (*E. coli*)	Very Poor	11	0.79	0.00	High: Unrestricted stock access.	D: (1210)
Porangahau Estuary	Estuarine (*E. coli*)	Very Poor	**14**	**0.00**	**15.72**	High: Unrestricted stock access to waterways.	D: (1018)
Puhokio Lagoon	Estuarine (*E. coli*)	Very Poor	180	0.50	-1.50	High: Unrestricted stock access to waterways.	D: (2215)
Waipuka Lagoon	Estuarine (*E. coli*)	Very Poor	**54**	**0.00**	**9.61**	High: Incidence of birdlife.	D: (1118)
Tukituki Rv at SH2	River (*E. coli*)	Very Poor	**26**	**0.00**	**7.06**	High: Run-off from low intensity agriculture.	C: (492)
Tukituki Rv at Walker Rd	River (*E. coli*)	Interim	12	No trends*	-4.18	Moderate: Runoff from low intensity agriculture.	B: (245)

*Less than 8 year's data

There are 2 freshwater river sites in the southern area, both on the Tukituki River. The Tukituki at SH2 at Waipukurau had several samples exceed recreational water quality criteria, and showed a deteriorating trend in water quality. The Tukituki River on Walker Road site did not have enough years to complete trend analyses, however sample results for this site appear to be moderate, with a Hazen percentile of 245 (B class).

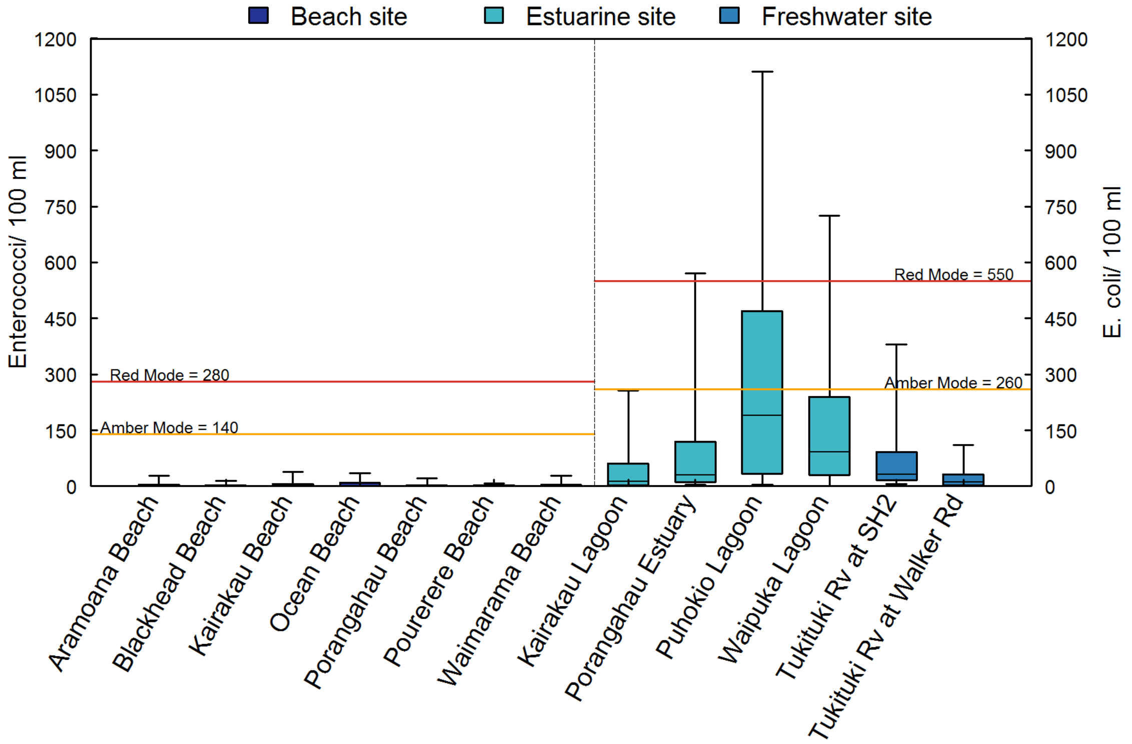


Figure 3-7: Southern sites, 5 year data with exceedance guideline thresholds (2009-2014). Red and amber lines indicate the MfE and MOH (2003) trigger values for Red and Amber modes respectively. The concentrations of indicator bacteria (cfu/ 100 ml) associated with these modes are written above the line.

3.4.5 Waipuka Stream – Faecal Source tracking

The catchment for Waipuka Stream and Ocean Beach is predominantly high producing grassland (pastoral farming), with small sections of exotic forest and some of the most extensive sand dune complexes within Hawke's Bay.

Waipuka Stream has consistently been graded 'Poor' in terms of its Suitability for Recreation Grade since the grades were first introduced, primarily because of high faecal indicator bacteria counts. During the 2013/2014 season 6 exceedances (30% of samples taken during the year) of national guidelines occurred at Waipuka Stream, indicating that during these times the risk of recreation within the stream was high. Following these exceedances, and the history of poor water quality for the site, faecal source tracking was undertaken during the 2013/2014 season.

Faecal source tracking was undertaken twice using faecal sterol and PCR marker analyses from two discrete samples following periods of high rainfall.

Results from the PCR marker analyses of the first sample suggested up to 50% of the contamination came from ruminant (cattle, deer, goat and sheep) and bird faeces. The faecal sterol analysis indicated a higher proportion of the contamination was from wildfowl, with some evidence of ruminant contamination. In general ruminant and wildfowl faeces were considered to be the major source of contamination. An inspection after the results were received identified a large number of geese upstream of the monitoring site.

The second set of results indicated older rather than fresh faecal material. The sources could not be identified because there was too little material in the sample. The faecal sterol analysis also failed to detect any animal faecal source, and decaying plant material or kitchen sources were suggested.

Work has commenced with the Land Management team at HBRC and with the local community to reduce geese numbers using appropriate plantings

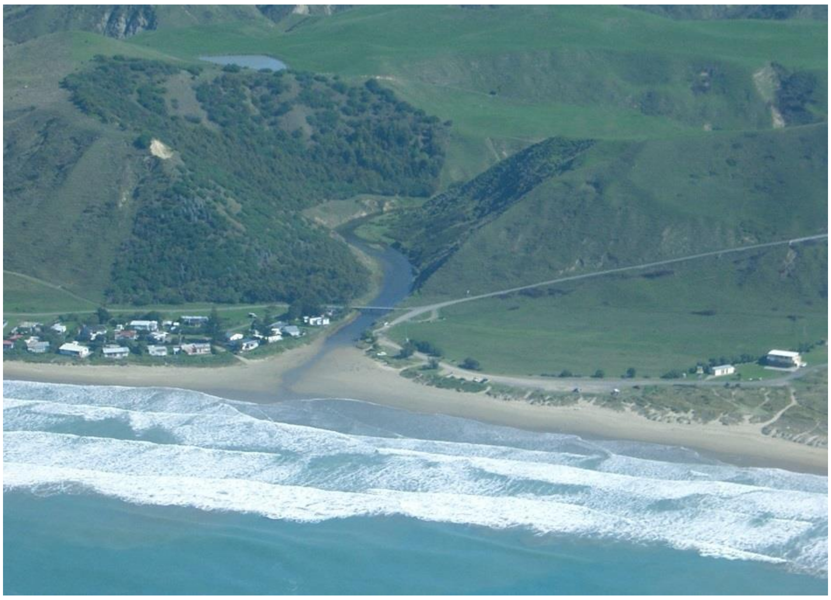


Figure 3-8: Waipuka Stream at Ocean Beach 2005.

3.5 Shellfish gathering sites

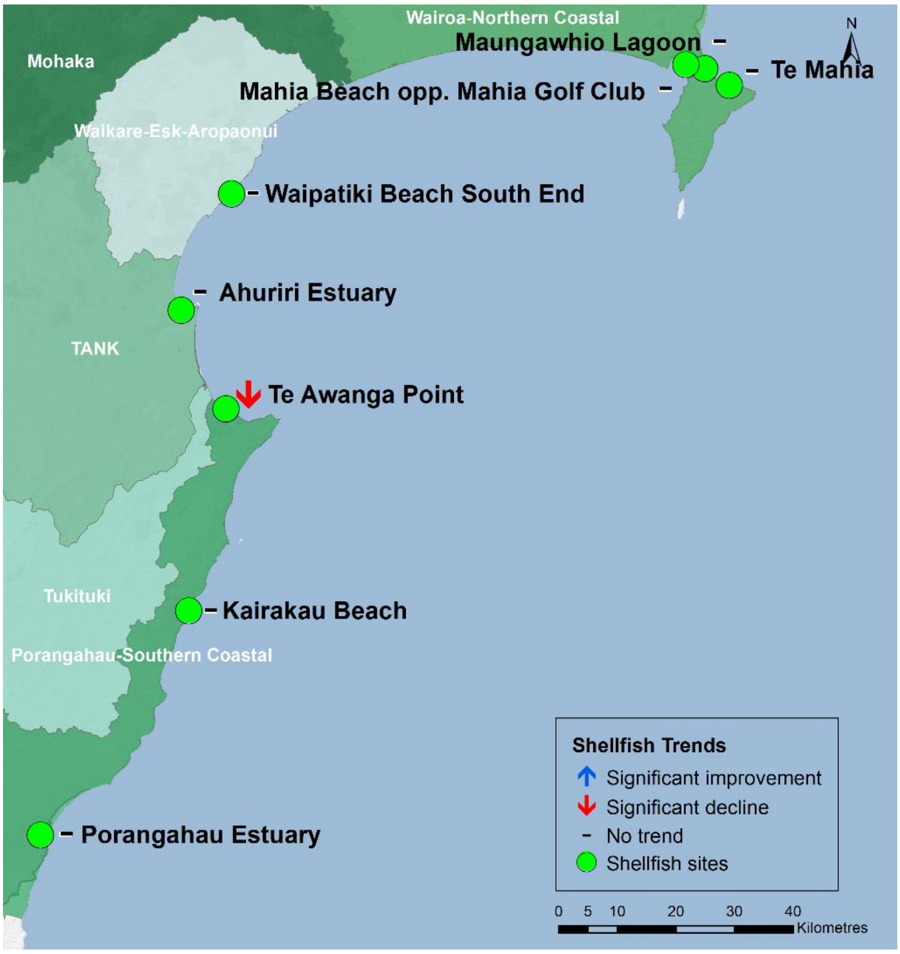


Figure 3-9: Trends in water quality at Hawkes' Bay shellfish gathering sites. HBRC undertakes water quality monitoring at locations favoured for shellfish gathering (

Figure **3-9**) as part of the Recreational Water Quality programme. Water at popular shellfish gathering sites is monitored for faecal contamination (using faecal coliform indicators) to determine the relative risk to the public from consuming any shellfish gathered. Sites with more than 4 years' data were considered for trend analysis.

Catchment risks were considered under the guidelines (2003) using the same parameters and environmental conditions as the standard recreational water quality sites. Shellfish may be affected by exposure to both agriculture and urban stormwater. It is important to note that monitoring for shellfish gathering is based on the water quality of the surrounding waters, not on the shellfish themselves. Additionally, the Ministry for Primary Industries does not recommend collecting shellfish from areas where sewage or stormwater is discharged and after heavy rain (www.foodsmart.govt.nz). This advice applies to the Ahuriri Estuary.

Te Awanga Point was the only site with a deterioration in faecal coliform water quality. Interestingly, this contradicts the enterococci data used to assess compliance for recreational water quality for the same site, which indicates no trend (see Table **3-3**).

Kairakau Beach had the lowest faecal coliform counts (95^{th} ile = 32.8 faecal coliforms MPN (Table 3-5)), while Poranghau Estuary had the highest levels (95^{th} ile = 1018 faecal coliforms MPN).

Table 3-5: Catchment Site Categories and trend analysis for shellfish gathering areas (2009-2014): Statistically significant trends are indicated in bold. BLUE highlight for PAC indicates an improving trend, RED indicates a deterioration.

Site	Trend p value	Percent Annual Change	SIC category and primary Impact	95th Percentile for Faecal Coliforms
Ahuriri Estuary	0.24	-2.56	Moderate, Urban stormwater (Pandora Pond) probably agriculture if site specific.	325 MPN/100ml
Kairakau Beach	0.5	0.0	Very Low, no primary impact, secondary is private sewage disposal.	32.8 MPN/100ml
Mahia Beach	0.62	0.0	Moderate, stormwater.	400 MPN/100ml
Maungawhio Lagoon	0.68	0.58	High, intensive agriculture.	975 MPN/100ml
Porangahau Estuary	No trend < 5 years data.	28.9	High, intensive agricultural.	1018 MPN/100ml
Te Awanga Point	**0.00**	**10.6**	Moderate, agriculture.	228.6 MPN/100ml
Te Mahia	No trend < 5 years data.	0.0	Moderate, river and agriculture.	924 MPN/100ml
Waipatiki Beach South End	0.13	0.0	Very low, no primary, secondary river focal points of drainage.	120 MPN/100ml

MPN/100ml = Most Probable Number per 100ml of sample

Water quality at shellfish monitoring sites in Hawkes's Bay can fluctuate seasonally due to changes in environmental conditions associated with the specific site. In general open coast sites have less pressure from land use activities and adjoining freshwater inputs, and score better due to the lower risk within the guideline structure. The estuarine sites have a naturally higher risk due to the slower residence time, warmer waters, the presence of wading birds and because they are the receiving environment of entire or multiple land use sub-catchments.

Mahia beach at the golf club was compliant for 4 out of the 5 years and was the highest performing site for the 5 year time frame (Table 3-6). The guideline values (MfE, 2003) are strongly influenced by high spikes in concentrations of faecal bacteria, hence the 95th percentile values are high for this site. Kairakau and Waipatiki Beach both were compliant in 3 out of the 5 years. Te Mahia at boat ramp was non-compliant for all 4 years it was monitored for shellfish gathering. The site is the receiving environment for the Whangawehi Stream. The pressures identified within the catchment include stock access to waterways, feral goats and water fowl present in high number.

Te Awanga Point had the lowest level of compliance with shellfish gathering guidelines.

Table 3-6: Long-Term Compliance with Shellfish Gathering Guidelines (2009-2014).

Shellfish compliance	2009/10	2010/11	2011/12	2012/13	2013/14	Compliance
Mahia Beach at Golf club	Yes	No	Yes	Yes	Yes	4/5
Maungawhio lagoon	N/A	N/A	No	No	No	0/3
Te Mahia at Boat ramp	N/A	No	No	No	No	0/4
Waipatiki at Sth end	Yes	No	No	Yes	Yes	3/5
Ahuriri estuary	No	No	No	Yes	Yes	2/5
Te Awanga Beach	No	No	No	No	No	0/5
Kairakau Beach	No	Yes	Yes	Yes	No	3/5
Porangahau Estuary	N/A	N/A	N/A	No	No	0/2

3.6 Conclusions

- Water quality at beach sites has a high standard of compliance, being suitable for recreation most – if not all – of the time. All beaches generally perform above the 2 consecutive exceedance guideline value. HBRC uses compliance with a single exceedance as a precautionary approach to hazards from coastal water quality.

- The freshwater river sites are generally of a high standard under summer low flow conditions. Bacterial concentration can exceed guidelines during periods of prolonged rainfall. In general, water quality at freshwater sites are more influenced by direct land-use and discharges of surface run off than marine waters.

- Estuarine and lagoon areas generally have the poorest water quality, since they are the receiving environment for entire freshwater catchments. Estuaries have generally slow moving, warm waters which promote bacterial survival and reproduction. They are also favoured environments for wading and migrating birds which also contribute to faecal accumulation.

- Shellfish sites tend to fluctuate between compliance and non-compliance year-on-year.

- As an urban site subject to stormwater exposure, Ahuriri Estuary would not be recommended for shellfish gathering, irrespective of its level of compliance with the criteria used here.

4 Sediment Quality

Coastal sediments are composed of a variety of geological materials. The size of coastal sediment particles is also affected by their geological composition as well as the processes that transport and deposit sediments. Sediment type and size affects biodiversity because sediments provide substrate for various habitats, which may affect the species found, and can provide sites for contaminant retention.

Contaminants derived from land based activities may be deposited in coastal sediments of the coastal environment. Contaminants can accumulate here as they bind to organic material and fine sediments. They can be consumed by filter feeders and other organisms that consume sediment particles while feeding (e.g. flounder), and bio-accumulate up the food chain. At high concentrations various contaminants can be toxic to several species. Contaminants can also accumulate in popular kaimoana species making them unfit for consumption.

Under the current RCEP (HBRC 2014), HBRC identifies that some parts of the CMA are being 'affected by the dumping and discharging of contaminants directly or indirectly into coastal waters.' The RCEP also includes the anticipated environmental results that there will be 'no deposition of substances which contain hazardous substances onto the foreshore or seabed in quantities which will adversely affect the life supporting capacity of the coastal marine area' (17.5) and specifically, the 'avoidance of residue from boat maintenance operations entering the coastal marine area' (16.4). Sediment quality monitoring is the data source required for monitoring these outcomes.

Sediment grab samples monitored at randomly selected sites throughout the Hawke's Bay's CMA (Section 4.1) to assess physical characteristics and trace metal concentrations characteristic of the Hawke's Bay region. Specific monitoring occurs in the Napier Inner Harbour adjacent to boat maintenance, repair and mooring facilities (Figure 4-1).

4.1 Long-term SoE monitoring

The Sediment Quality monitoring programme was established in 2005, since then the sediments of the Inner Harbour have been sampled 3 times, and the wider Hawke's Bay has been sampled once in 2007.

All samples were composite samples[1] collected from the surface (i.e. the top 2 cm) of the sediment. These were either surficial scrapes using a Teflon spatula on exposed sediments (Napier Inner Harbour) or collected using a 0.024m^2 Eckman grab sampler on submerged sediments.

Samples are collected at 5 permanent sites within the Napier Inner Harbour. Sediment samples from these sites were analysed for the following groups of contaminants.

- trace metals - 2005, 2007, 2011
- antifouling co-biocides - 2005, 2007, 2011
- organic biocides (DDT isomers and polycyclic aromatic hydrocarbons- (PAHs)) – 2007, 2011
- organonitro and organophosphorus pesticides - 2005, 2007, 2011
- organotin compounds - 2005, 2007, 2011

[1] Composite samples are formed when multiple samples were taken at any 1 site, combined, and then a sub-sample taken. This manner of collecting samples provides greater representation of the study site and reduces the likelihood that highly variable results are collected.

Most of these are classed as category one toxic contaminants in New Zealand (MfE 1998). Additional information was collected at each sampling site, including date and time of sampling, GPS co-ordinates, sediment texture, tidal state, 'gross contaminants', such as paint flakes in sediment and the proximity of the site to hull washing/maintenance facilities. A summary of these details is provided in Table 4-2.

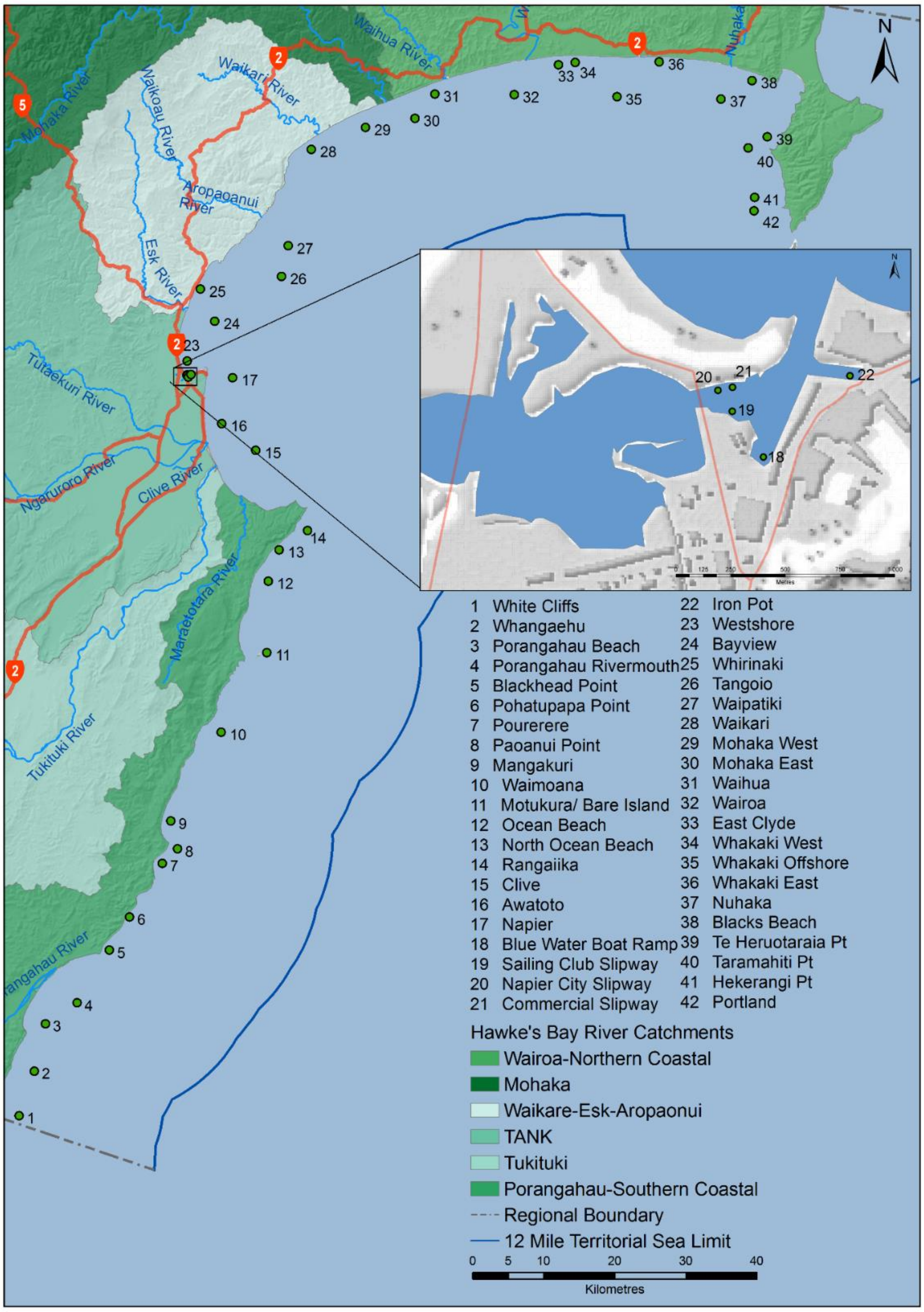


Figure 4-1: Map of randomly selected nearshore coastal sediment monitoring sites and Napier Inner Harbour permanent monitoring sites.

For the coastal sediments, the sampling stations were selected using a USEPA derived probabilistic sampling design that allowed for an unbiased assessment of sediment quality (USEPA 2000). A hexagonal grid was placed randomly over a chart of the area and stations were randomly selected from within each grid cell. This sampling design is often used to infer regional and national sediment patterns with respect to contamination and biological effects. Sampling was limited to areas within a 5 km radius of the coastline, with stations ranging in depth from 6 m to 34 m. For these sites the samples were analysed for heavy metals only. If a sample was unable to be taken at a site due to hard substrate the site was moved 1 kilometre and tried again.

All samples were also analysed to determine ash-free dry weight (AFDW) and sediment particle size distribution. The sediment particle size distribution of a sample also indicates the likely bioavailability of the contaminants present in the sediment. Sediments with a high proportion of small grains, such as silt and clay, have a high surface-to-volume ratio – this enhances adsorption and reduces the bioavailability of contaminants (Landrum and Robbins, 1990).

AFDW can be related to total organic carbon (TOC) content by the equation (Robertson 2002):

$$TOC = 0.40\,(AFDW) + 0.0025\,(AFDW)^2$$

Organic carbon in sediment binds with organic contaminants to reduce their bioavailability. Therefore a higher TOC content reduces the bioavailability of organic pollutants.

4.1.1 Sediment quality guidelines

Where applicable, contaminant concentrations were compared against ANZECC (2000) guidelines. This provides 2 sediment quality guidance values for some contaminants.

- the Interim Sediment Quality Guideline-low (ISQG-low)
- the Interim Sediment Quality Guideline-high (ISQG-high)

If the contaminant concentration is less than the ISQG-low value, then adverse biological effects are unlikely. If the concentration of a contaminant is greater than the ISQG-low value, but is less than the ISQG-high value, biological effects are expected occasionally. Finally, if the concentration is greater than the ISQG-high value, then adverse effects are expected frequently.

These ISQG values should be used as trigger values, not pass/fail values. They form part of a decision tree process that is used when applying the sediment guidelines (ANZECC 2000). Should the ISQG-low value be exceeded then the decision tree defines what type of action is required. This is usually remedial action, or the initiation of further site-specific studies to determine the actual risk to the ecosystem in question. While the ANZECC guidelines are benchmark values for monitoring sediment quality in New Zealand, their use is limited to the contaminants included in the guidelines.

Table 4-1: ANZECC sediment quality guideline values indicating possible biological effects.

	ANZECC Sediment quality guideline value		
	<ISGQ Low	>ISGQ-low & <ISGQ-high	> ISGQ-high
Biological effect	**Unlikely**	**Occasional negative**	**Frequently negative**
4,4'-DDE[1]	2.2	2.2 - 27	27
2,4' + 4,4'-DDD[1]	2	2 - 20	20
Total DDT[1,4]	1.6	1.6 - 46	46
Low molecular weight PAHs[1,2]	552	552 - 3160	3160
High molecular weight PAHs[1,3]	1700	1700 - 9600	9600
Total PAHs[1]	4000	4000 - 45000	45000
Arsenic	20	20 - 70	70
Cadmium	1.5	1.5 - 10	10
Chromium	80	80 - 370	370
Copper	65	65 - 270	270
Lead	50	50 - 220	220
Nickel	21	21 - 52	52
Zinc	200	200 - 410	410
Tributyltin	5	5 - 70	70

[1] Normalised to 1% total organic carbon.
[2] Low Molecular Weight PAHs are the sum of the concentrations of naphthalene, 2-methyl-naphthalene, acenaphthalene, acenaphthene, fluorene, phenanthrene and anthracene.
[3] High Molecular Weight PAHs are the sum of the concentrations of fluoranthene, pyrene, benzo[a]anthracene, chrysene, benzo[a]pyrene and dibenzo[a,h]anthracene.
[4] Total DDT is the sum of the concentrations of 2,4’-DDE, 2,4’-DDD, 2,4’-DDT, 4,4’-DDE, 4,4’-DDD and 4,4’-DDT.

4.1.2 Data summaries and visualisation

The current dataset is not long enough to assess trends in sediment quality. Therefore only state data is presented here. Bar charts are used to depict contaminant metal concentrations and stacked bar charts are used to describe sediment particle size proportions.

Organic contaminants were normalised to 1% organic carbon by dividing the measured concentrations (mg/kg or µg/kg) by the TOC concentration (%). This allows for comparison between sediments of different organic content and comparison with the ANZECC (2000) guidelines.

4.2 Napier Inner Harbour

The Napier Inner Harbour is located at the mouth of the Ahuriri Estuary (Figure 4-1). It is exposed to a variety of contaminant sources including contaminants from the wider catchment through the Ahuriri estuary as well as direct input of stormwater and contaminants from boat maintenance activities (Wade 2012).

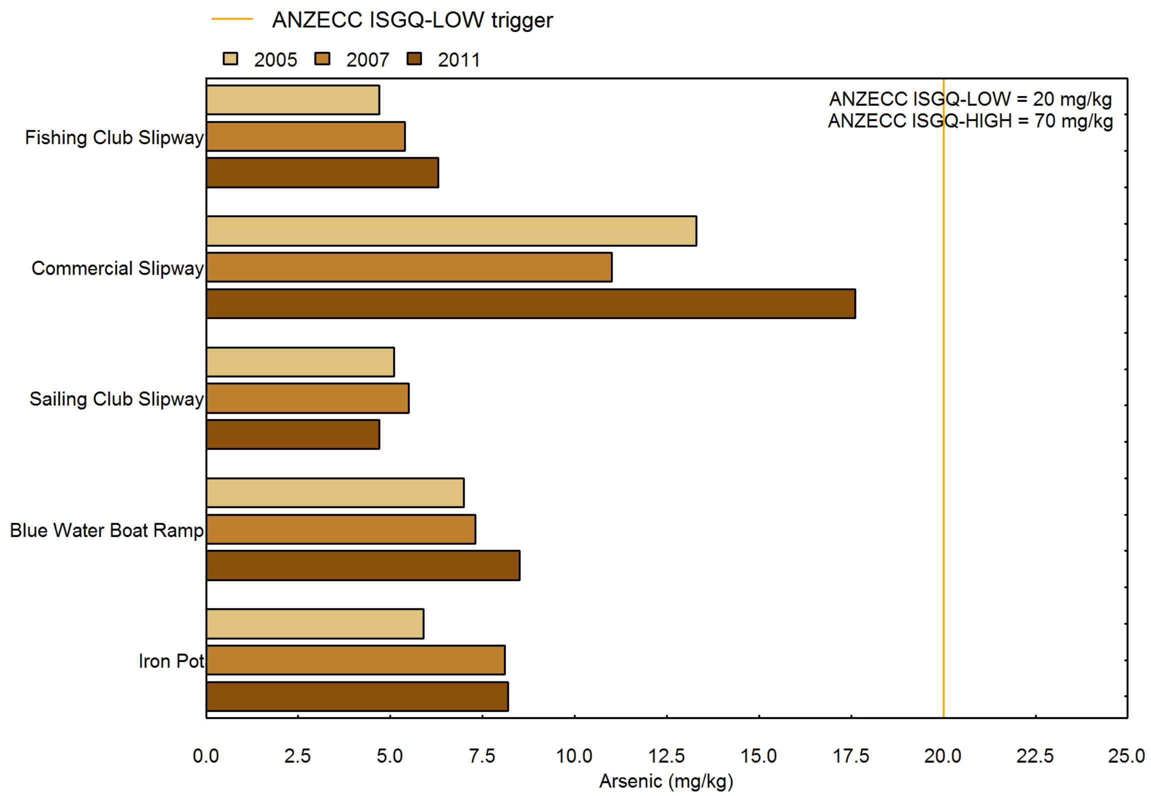
Sampling sites in the Inner Harbour were selected to account for varied levels of exposure to boat maintenance activities and stormwater (Figure 4-1). The main source of contamination associated with boat maintenance activities comes from marine paints. The presence of visible paint particles is frequently recorded at the commercial slipway and to a lesser extent the fishing club slipway site. Antifouling paint biocides are more persistent in the marine environment when associated with paint particles (Thomas K.V. 2003). These discrete particles are likely to explain a large proportion of the contaminants seen in samples from these sites.

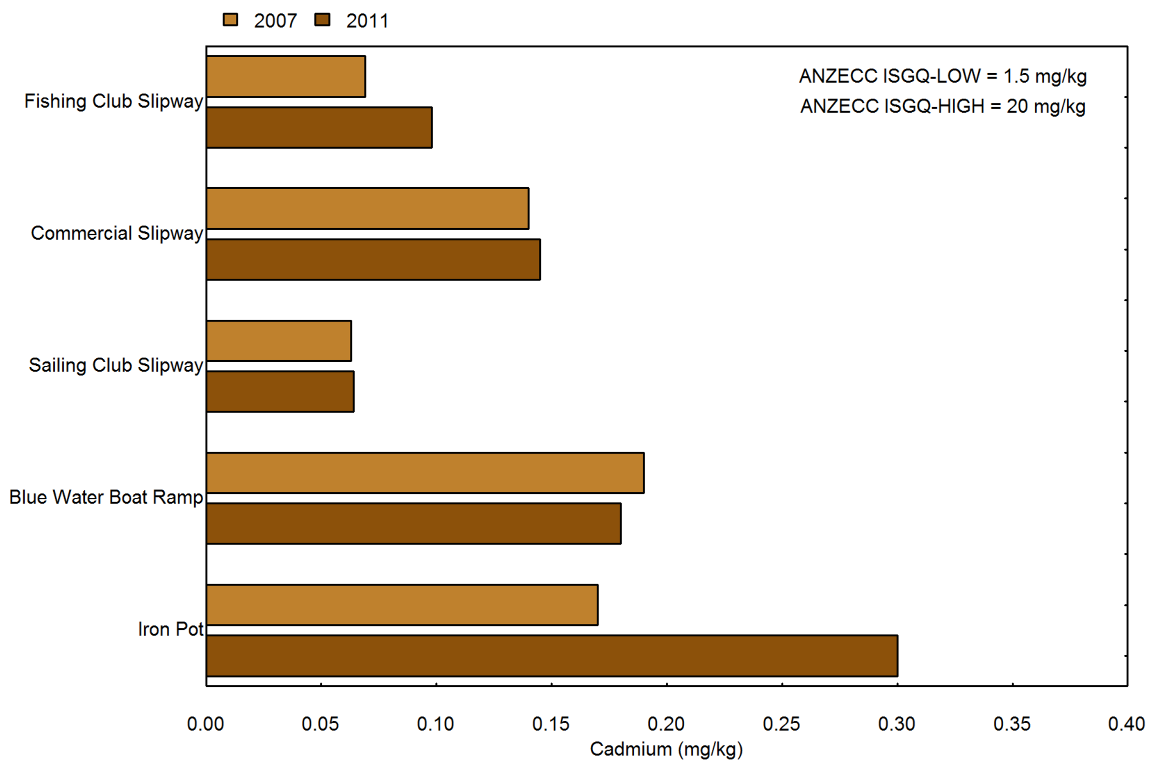
Site	Location (NZTM)	Sediment description	Distance from hull washing facility
Site 1: Fishing Club Slipway	1934586 E 5622468 N	Mix of sand/gravel and silt. Some paint flecks.	5 m
Site 2: Commercial Slipway	1934646 E 5622473 N	Mix of sand/gravel and silt. Large amount of paint flecks	5 m
Site 3: Sailing Club Slipway	1934716 E 5622318 N	Mix of sand/gravel and silt	50 m
Site 4: Blue Water Boat Ramp	1934796 E 5622519 N	Fine mud/silt with anoxic black coloration	300 m
Site 5: Iron Pot	1935192 E 5622519 N	Fine mud/silt with anoxic black colouration	~600 m

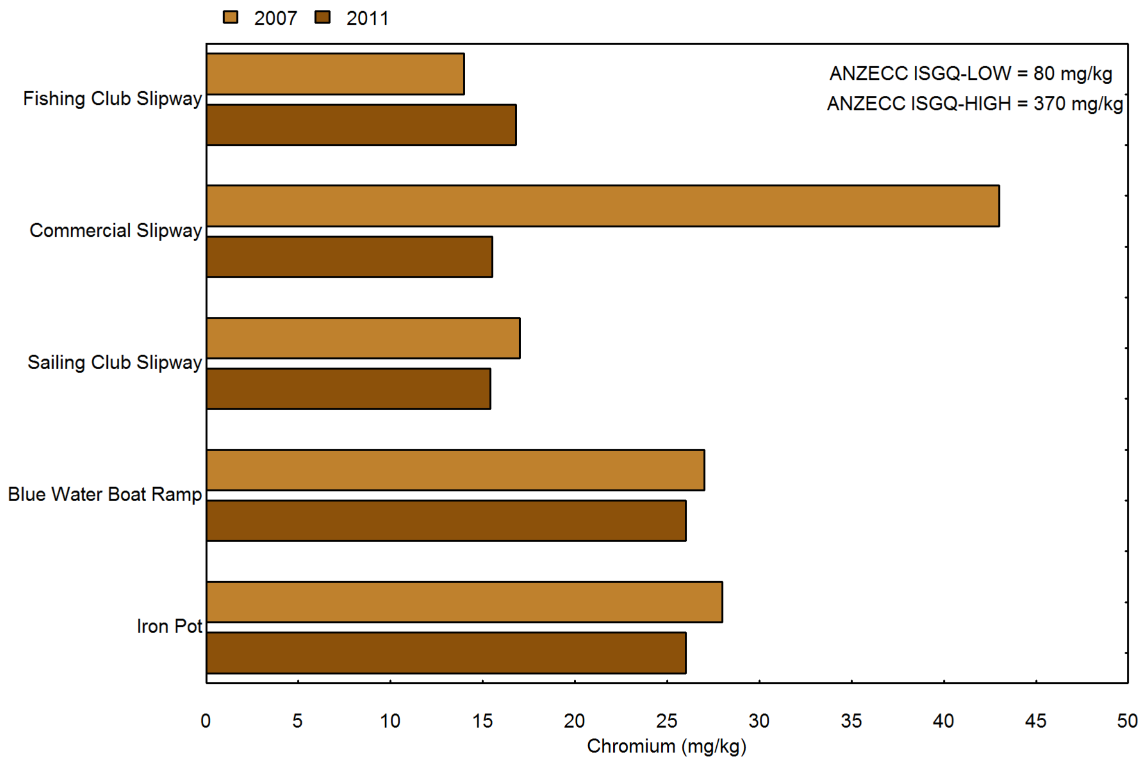
Table 4-2: Site names, locations and general sediment description.

4.2.1 Trace metals

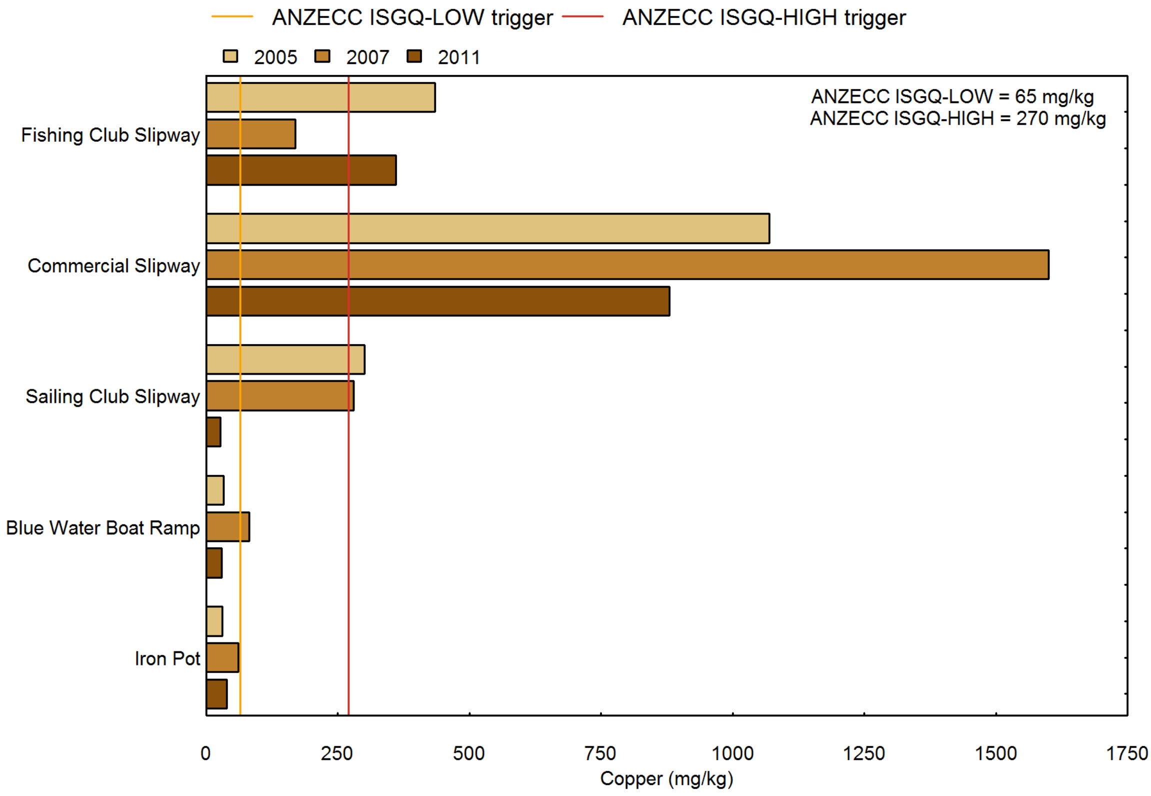
Concentrations of trace metals in the sediments of the Inner Harbour frequently exceed ANZECC guideline values (ANZECC, 2000). Concentrations were highest in those areas adjacent to boat maintenance and repair facilities, especially at the commercial slipway site. Copper is now the most common biocide in antifouling paints. Concentrations of copper, lead and zinc have been monitored since 2005 and regularly exceed the ANZECC ISGQ high guideline value at the commercial slipway site, suggesting ecological impacts on the sediments at this site. These metals are commonly associated with the antifouling paint used on marine vessels. Arsenic has also been monitored since 2005. Arsenic, along with cadmium, chromium and nickel which have been monitored since 2007, are all below the ANZECC guideline trigger values.


ANZECC ISGQ-LOW trigger
2005
2007
2011
ANZECC ISGQ-LOW = 20 mg/kg
ANZECC ISGQ-HIGH = 70 mg/kg
Fishing Club Slipway
Commercial Slipway
Sailing Club Slipway
Blue Water Boat Ramp
Iron Pot
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
22.5
25.0
Arsenic (mg/kg)

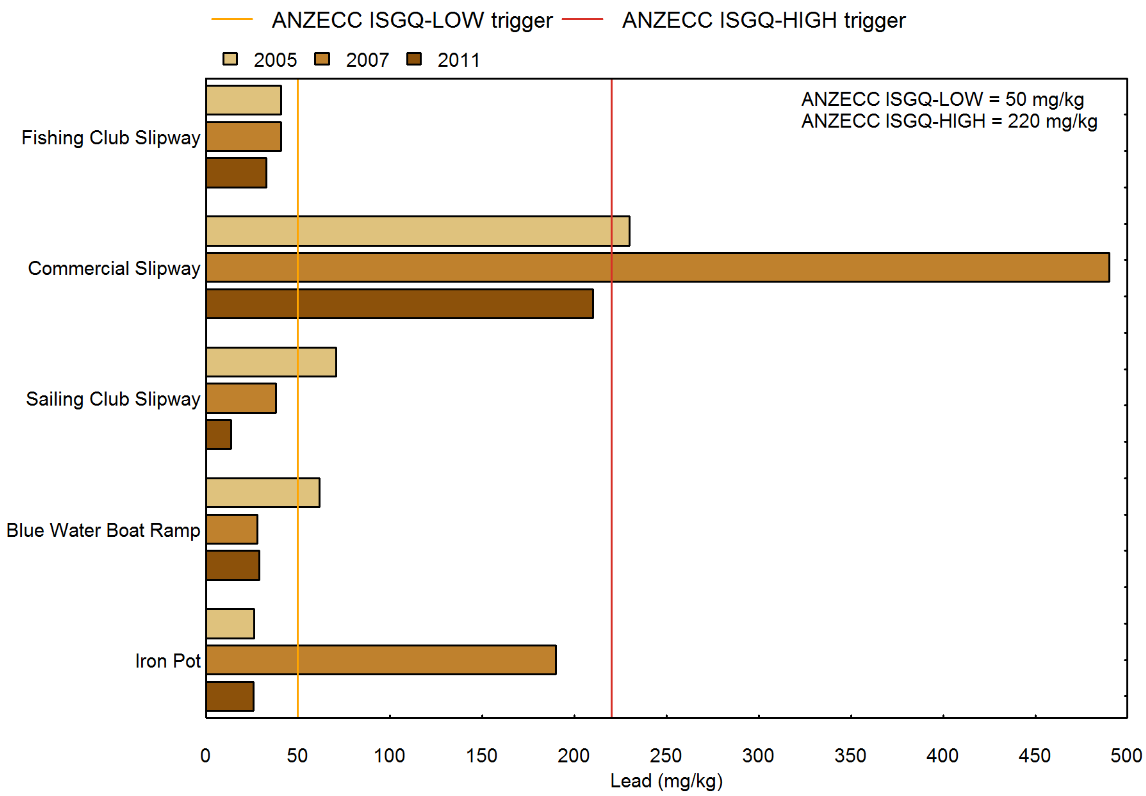

2007
2011
ANZECC ISGQ-LOW = 1.5 mg/kg
ANZECC ISGQ-HIGH = 20 mg/kg
Fishing Club Slipway
Commercial Slipway
Sailing Club Slipway
Blue Water Boat Ramp
Iron Pot
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
Cadmium (mg/kg)

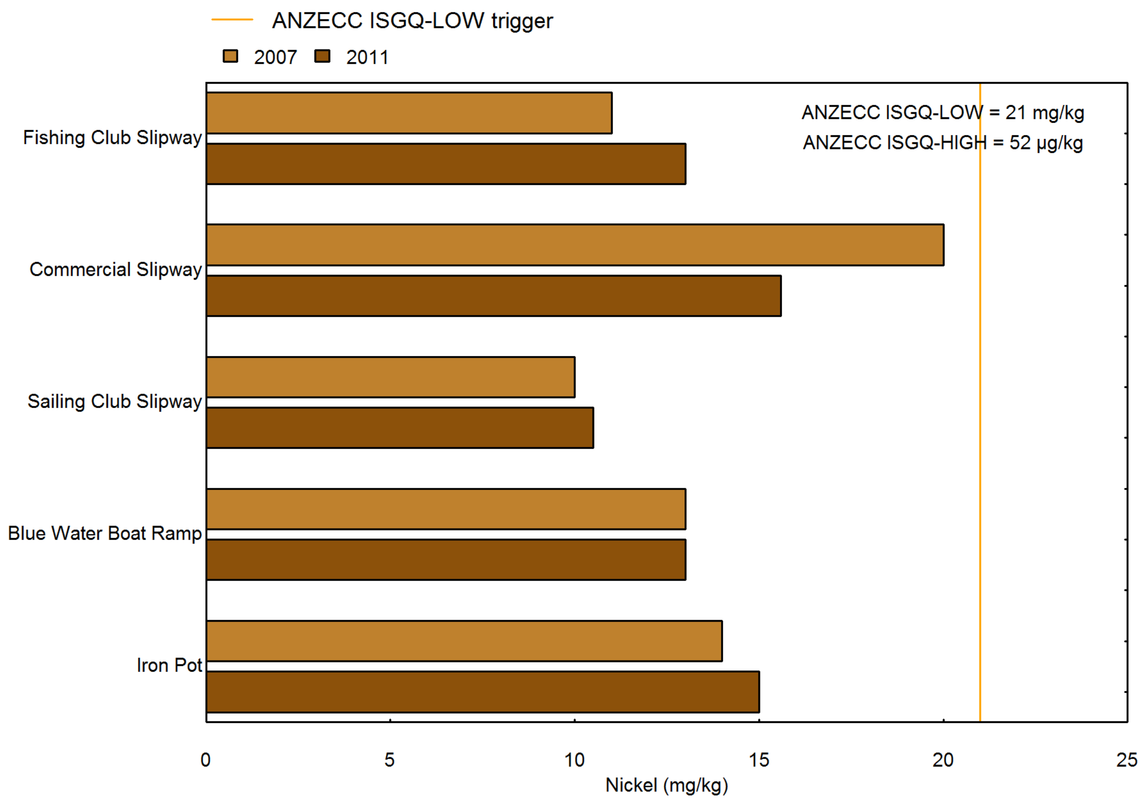


2007
2011
ANZECC ISGQ-LOW = 80 mg/kg
ANZECC ISGQ-HIGH = 370 mg/kg
Fishing Club Slipway
Commercial Slipway
Sailing Club Slipway
Blue Water Boat Ramp
Iron Pot
0
5
10
15
20
25
30
35
40
45
50
Chromium (mg/kg)



ANZECC ISGQ-LOW trigger
ANZECC ISGQ-HIGH trigger
2005
2007
2011
ANZECC ISGQ-LOW = 65 mg/kg
ANZECC ISGQ-HIGH = 270 mg/kg
Fishing Club Slipway
Commercial Slipway
Sailing Club Slipway
Blue Water Boat Ramp
Iron Pot
0
250
500
750
1000
1250
1500
1750
Copper (mg/kg)


ANZECC ISGQ-LOW trigger
ANZECC ISGQ-HIGH trigger
2005
2007
2011
ANZECC ISGQ-LOW = 50 mg/kg
ANZECC ISGQ-HIGH = 220 mg/kg
Fishing Club Slipway
Commercial Slipway
Sailing Club Slipway
Blue Water Boat Ramp
Iron Pot
0
50
100
150
200
250
300
350
400
450
500
Lead (mg/kg)


ANZECC ISGQ-LOW trigger
2007
2011
ANZECC ISGQ-LOW = 21 mg/kg
ANZECC ISGQ-HIGH = 52 µg/kg
Fishing Club Slipway
Commercial Slipway
Sailing Club Slipway
Blue Water Boat Ramp
Iron Pot
0
5
10
15
20
25
Nickel (mg/kg)

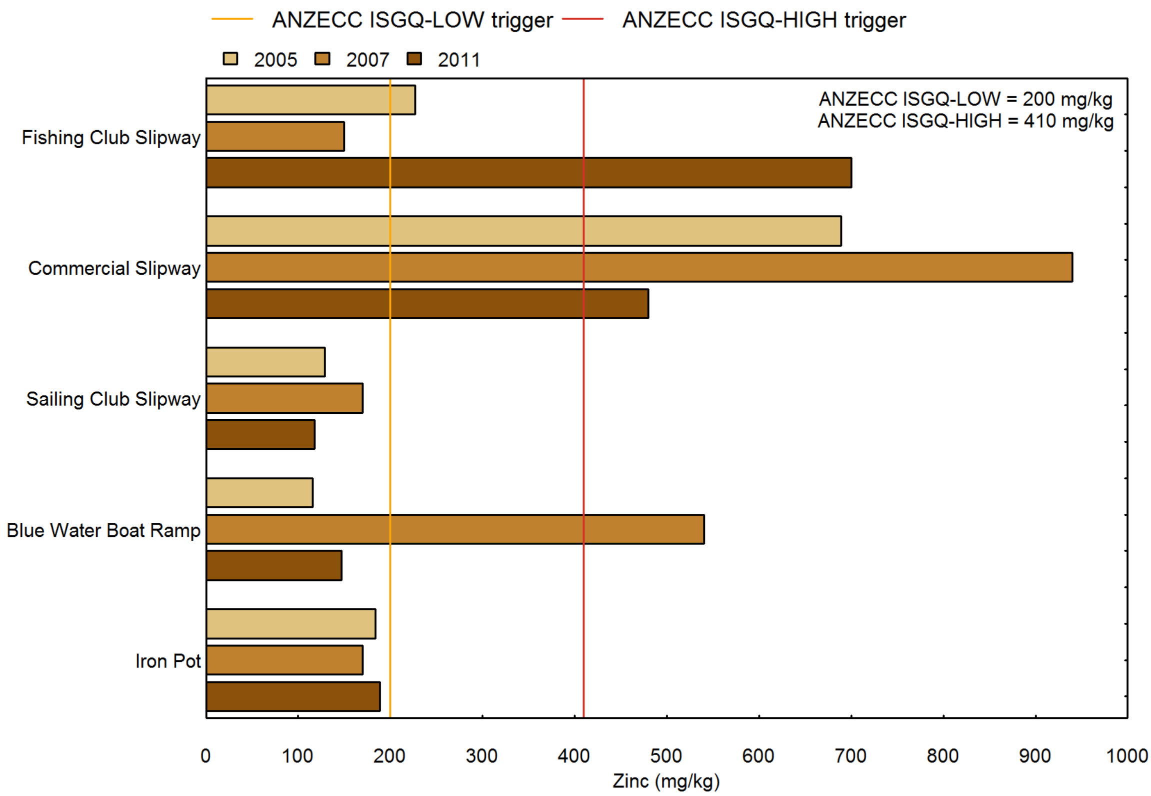
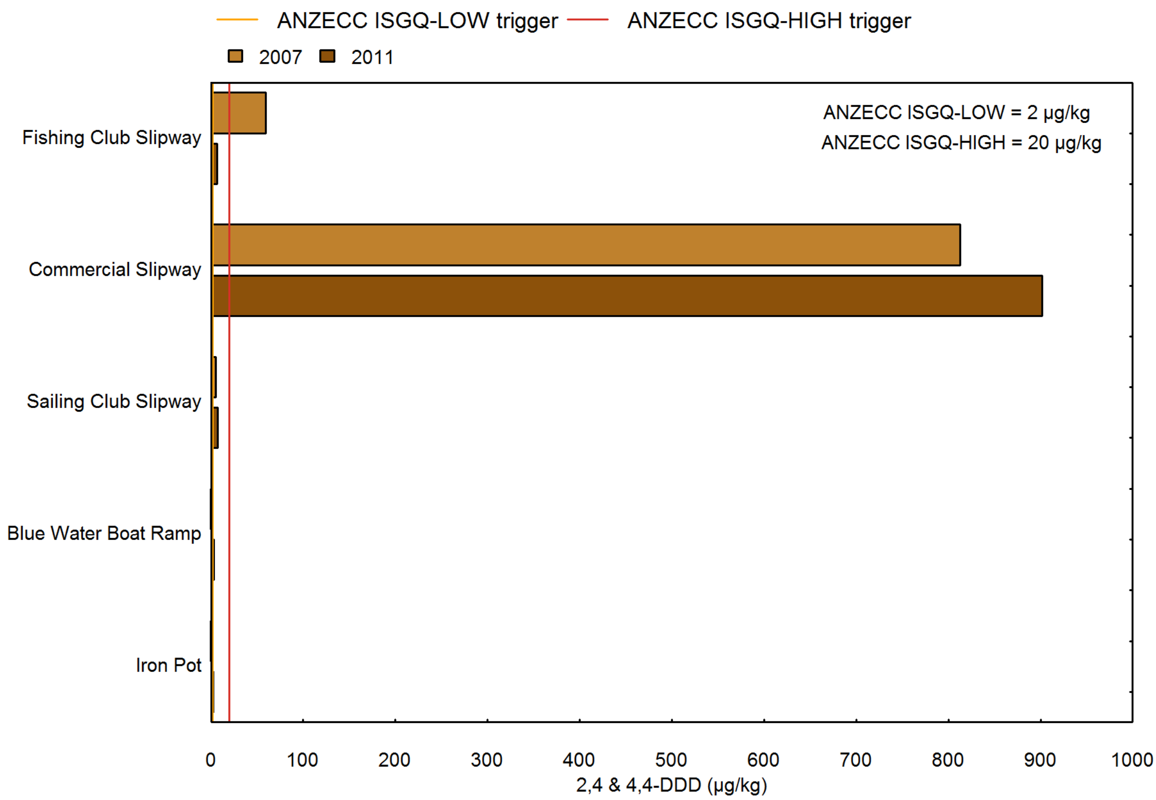


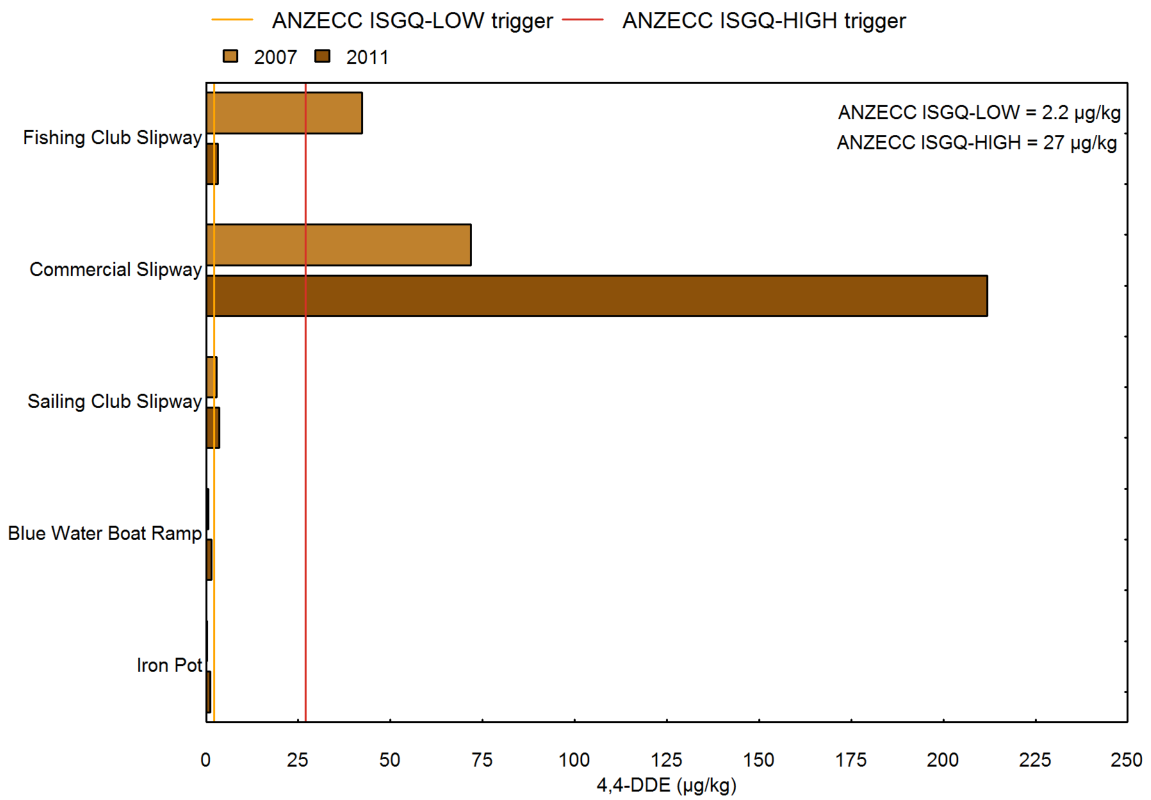
Figure 4-2: Trace metal concentrations in the Napier Inner Harbour. Amber line denotes the ANZECC ISGQ-Low guideline value, the red line denotes the ANZECC ISGQ-High guideline value.

4.2.2 Organic biocides

Organic biocides include DDT (1,1,1-trichloro-2,2-di(4-chlorophenyl)ethane and PAHs (polycyclic aromatic hydrocarbons).

The concentrations of DDT compounds have been monitored since 2007. DDT is the sum of two DDT isomers and a proportion of DDD and DDE which are the major metabolites of DDT itself. DDT was a common pesticide in the twentieth century and was also used as an active ingredient in antifouling paints. The use of DDT was banned in New Zealand in 1989. However, DDT and its metabolites persist at the commercial slipway site in concentrations far higher than ANZECC guideline values. The high concentrations of DDT and its metabolites suggest that there has been recent contamination of DDT at this site (Nick Kim, pers. comm.).


ANZECC ISGQ-LOW trigger
ANZECC ISGQ-HIGH trigger
2007
2011
ANZECC ISGQ-LOW = 2 µg/kg
ANZECC ISGQ-HIGH = 20 µg/kg
Fishing Club Slipway
Commercial Slipway
Sailing Club Slipway
Blue Water Boat Ramp
Iron Pot
0
100
200
300
400
500
600
700
800
900
1000
2,4 & 4,4-DDD (µg/kg)


ANZECC ISGQ-LOW trigger
ANZECC ISGQ-HIGH trigger
2007
2011
ANZECC ISGQ-LOW = 2.2 µg/kg
ANZECC ISGQ-HIGH = 27 µg/kg
Fishing Club Slipway
Commercial Slipway
Sailing Club Slipway
Blue Water Boat Ramp
Iron Pot
0
25
50
75
100
125
150
175
200
225
250
4,4-DDE (µg/kg)

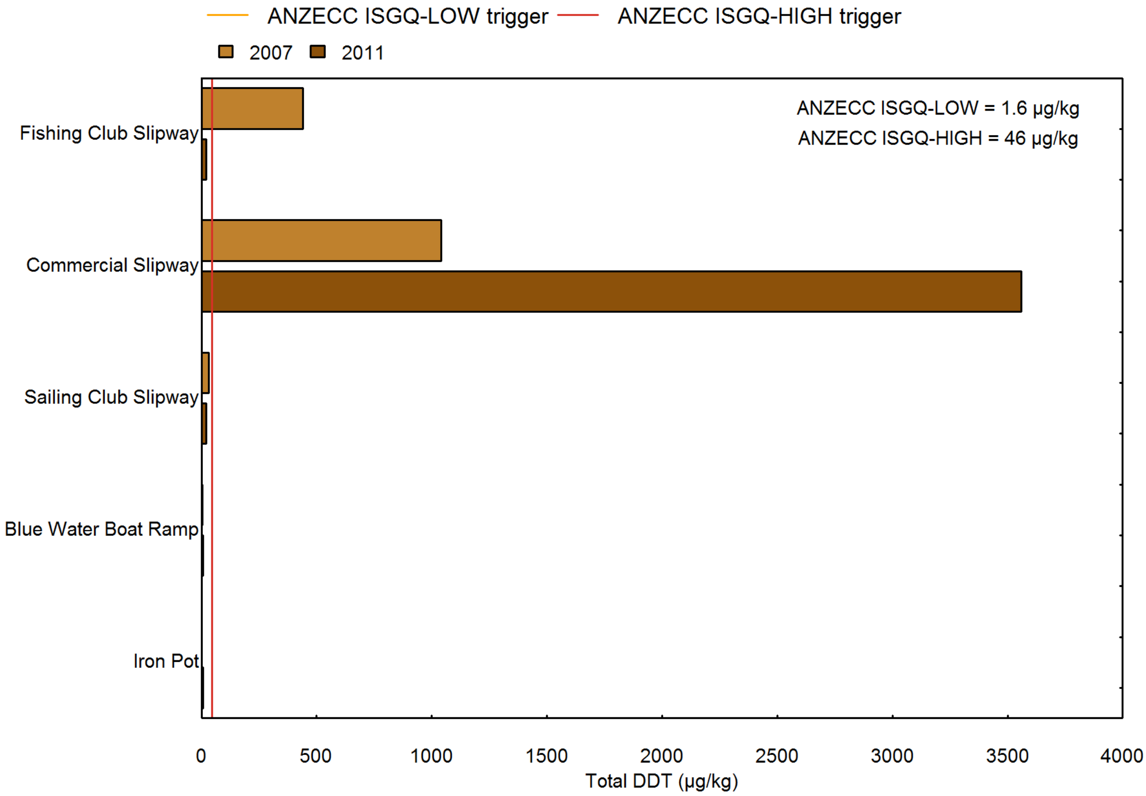
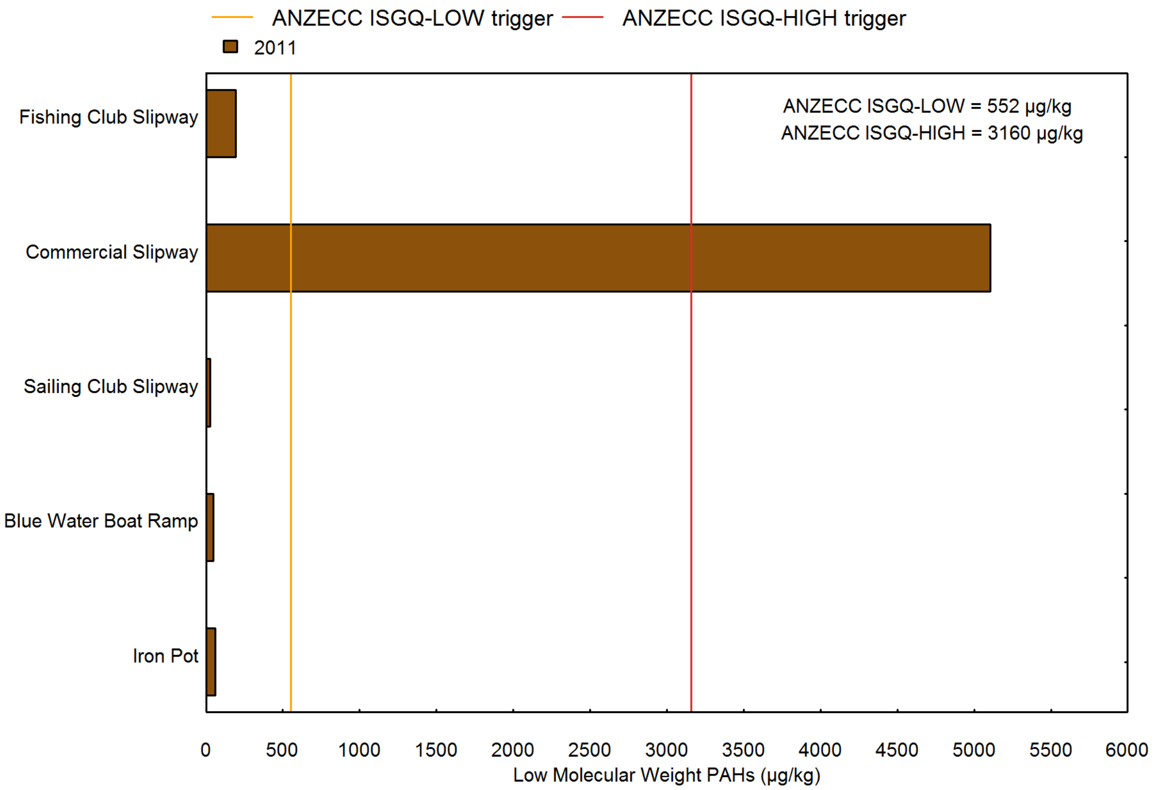
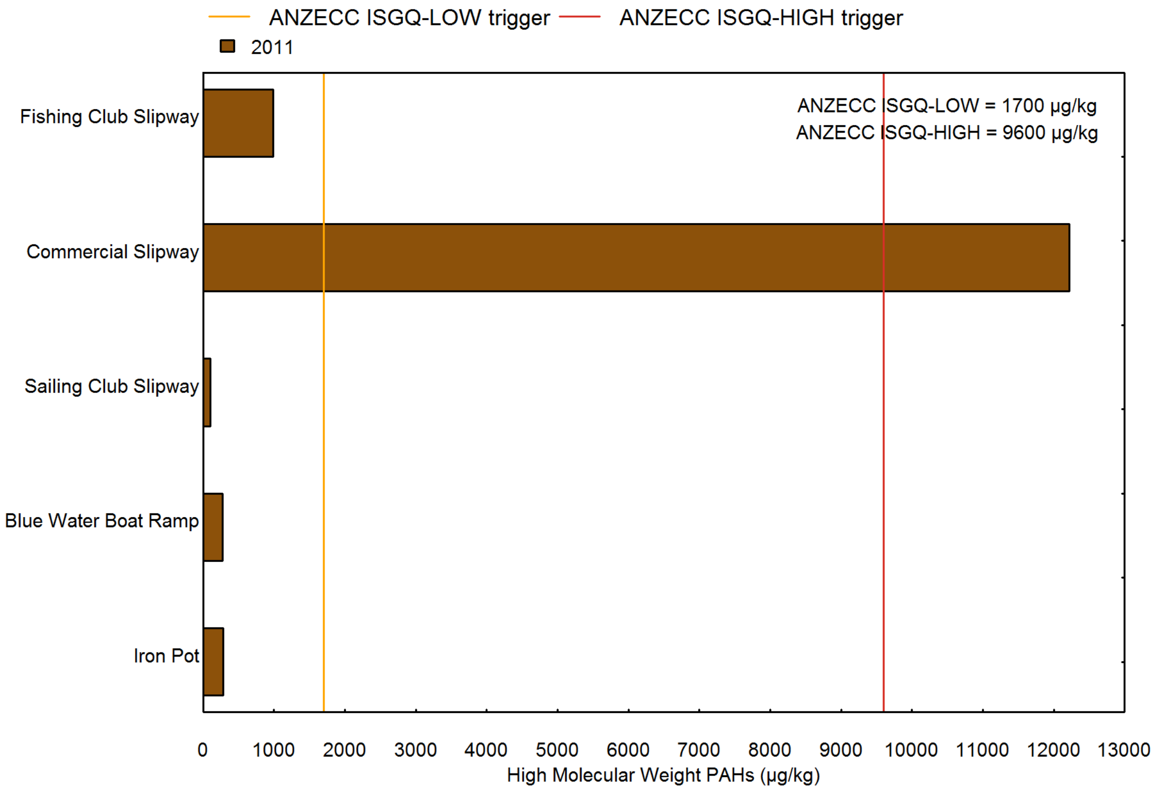


Figure 4-3: DDT concentrations in the Napier Inner Harbour. Amber line denotes the ANZECC ISGQ-Low guideline value, the red line denotes the ANZECC ISGQ-High guideline value. Contaminants were normalised to 1% organic carbon by dividing the measured concentrations (µg/kg) by the TOC concentration (%).

The concentrations of PAHS were first monitored in 2011. PAHs are a diverse group of persistent organic chemicals that are toxic to many species. Elevated PAH concentrations around boat maintenance areas are associated with antifouling paints and the leakage of hydrocarbon products from marine vessels (Johnsen 1999). ANZECC splits PAHs into different molecular weight compounds for the purpose of assessing environmental effects. Concentrations of PAHS are relatively low at all sites except the commercial slipway site at which there are likely ecological impacts). At this site, concentrations of low and high molecular weight PAHs exceed the ANZECC ISGQ-High trigger values and concentrations of total PAHs exceed the ANZECC ISGQ-Low trigger value.


ANZECC ISGQ-LOW trigger
ANZECC ISGQ-HIGH trigger
2011
ANZECC ISGQ-LOW = 552 µg/kg
ANZECC ISGQ-HIGH = 3160 µg/kg
Fishing Club Slipway
Commercial Slipway
Sailing Club Slipway
Blue Water Boat Ramp
Iron Pot
0 500 1000 1500 2000 2500 3000 3500 4000 4500 5000 5500 6000
Low Molecular Weight PAHs (µg/kg)


ANZECC ISGQ-LOW trigger
ANZECC ISGQ-HIGH trigger
2011
ANZECC ISGQ-LOW = 1700 µg/kg
ANZECC ISGQ-HIGH = 9600 µg/kg
Fishing Club Slipway
Commercial Slipway
Sailing Club Slipway
Blue Water Boat Ramp
Iron Pot
0 1000 2000 3000 4000 5000 6000 7000 8000 9000 10000 11000 12000 13000
High Molecular Weight PAHs (µg/kg)

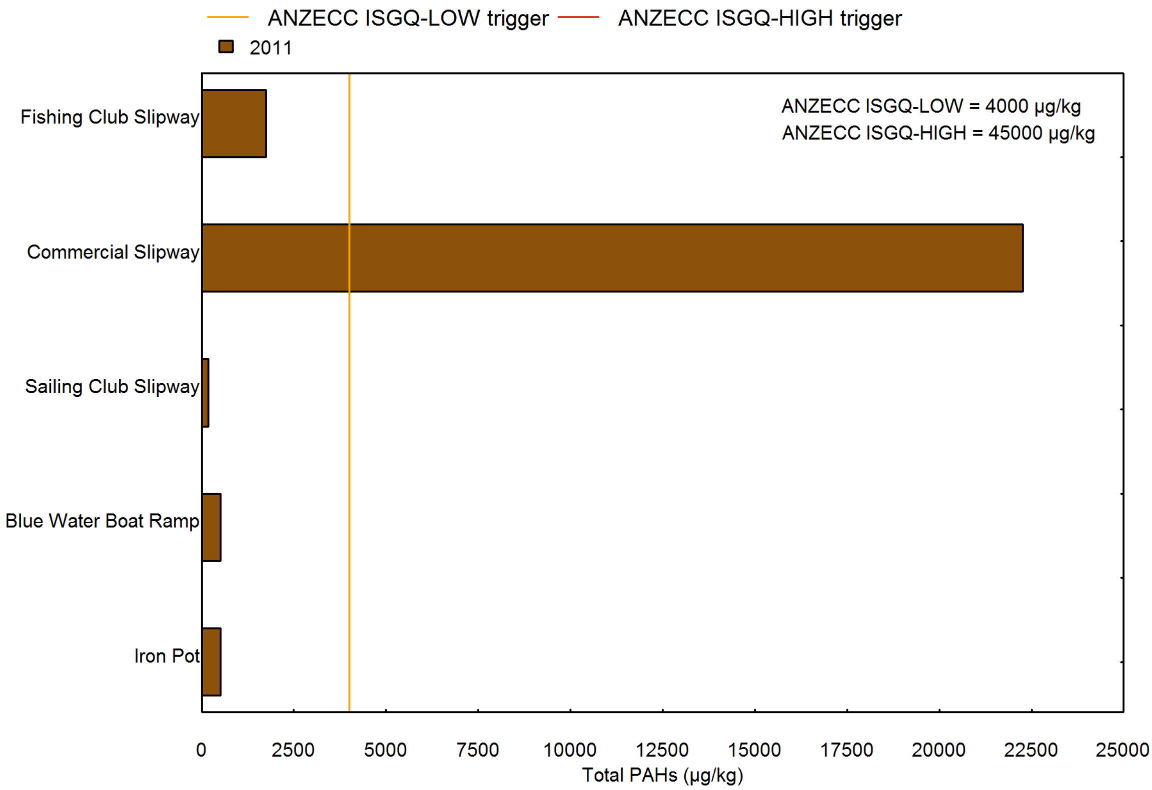


Figure 4-4: PAH concentrations in the Napier Inner Harbour. Amber line denotes the ANZECC ISGQ-Low guideline value, the red line denotes the ANZECC ISGQ-High guideline value. Contaminants were normalised to 1% organic carbon by dividing the measured concentrations (µg/kg) by the TOC concentration (%).

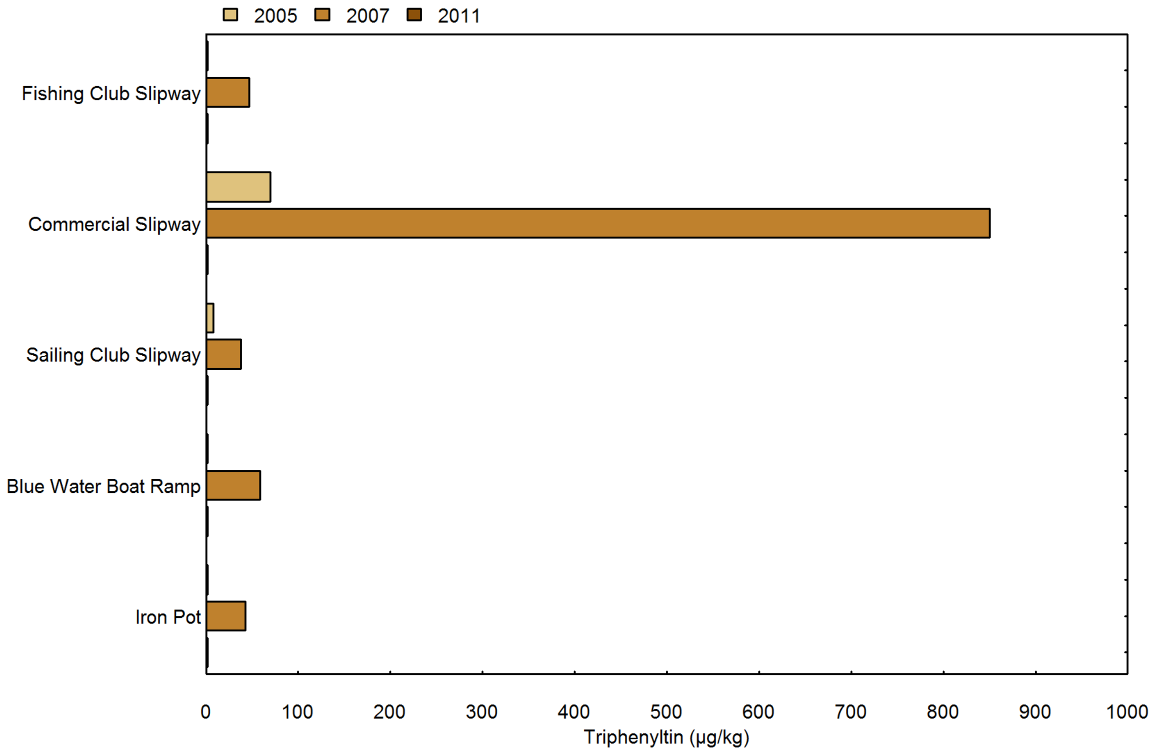
4.2.3 Organotin compounds

The organotin compounds include Tributytin (TBT) and Triphenyltin (TPT) and the degradation compounds of TBT: Dibutytin (DBT) and Monobutyltin (MBT).

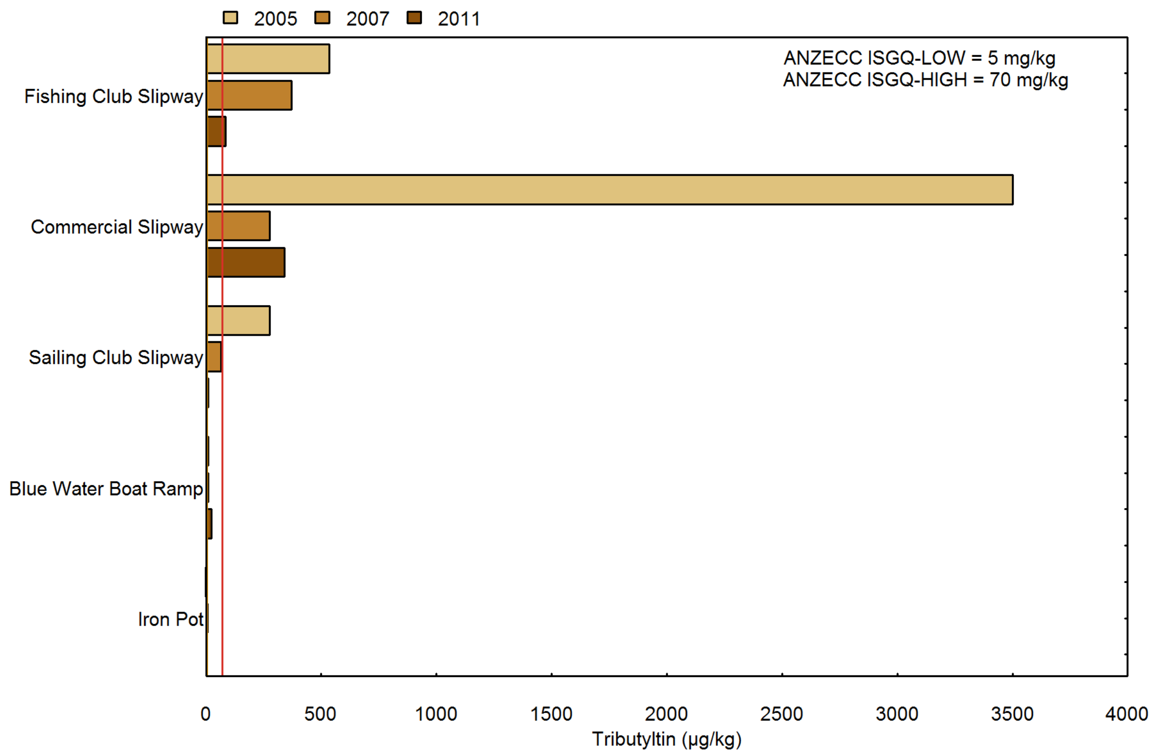
The use of organotin compounds as a marine antifoulant is banned under the International Convention on the Control of Harmful Anti-foul Systems on Ships, due to the high toxicity of triorganotin compounds, especially TBT (Cole 2015). TBT was banned from use in New Zealand in 1988. TBT persists for a long time in aquatic sediments, especially under anoxic conditions (Dowson 1996).The 2 triorganotin compounds have the highest toxicity, while DBT and MBT are successively less toxic.

The highest concentrations of these biocides are around the commercial slipway site although DBT and MBT concentrations are also elevated around the fishing club slipway and in the earlier samples at the sailing club slipway.

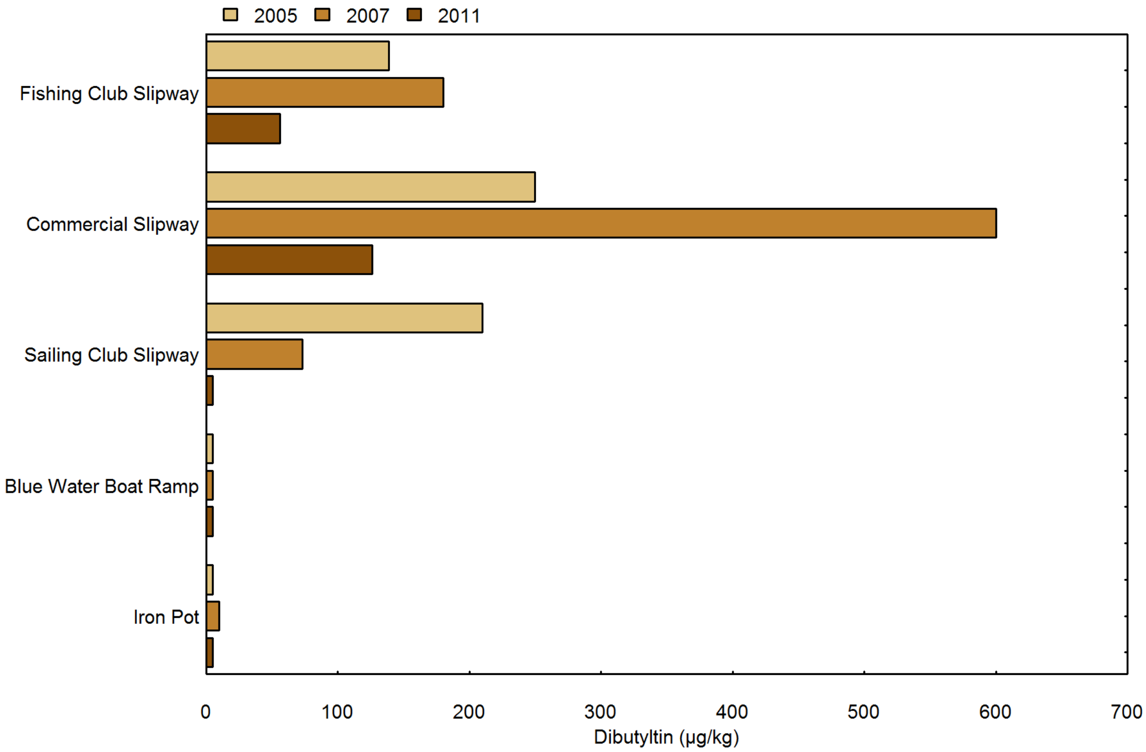
The elevated concentrations of DBT and MBT in the more recent samples suggests degradation of historic contamination, although concentrations of TBT at the commercial slipway site are still above the ANZECC ISGR-High trigger value.



2005
2007
2011
Fishing Club Slipway
Commercial Slipway
Sailing Club Slipway
Blue Water Boat Ramp
Iron Pot
0
100
200
300
400
500
600
700
800
900
1000
Triphenyltin (µg/kg)



2005
2007
2011
ANZECC ISGQ-LOW = 5 mg/kg
ANZECC ISGQ-HIGH = 70 mg/kg
Fishing Club Slipway
Commercial Slipway
Sailing Club Slipway
Blue Water Boat Ramp
Iron Pot
0
500
1000
1500
2000
2500
3000
3500
4000
Tributyltin (µg/kg)



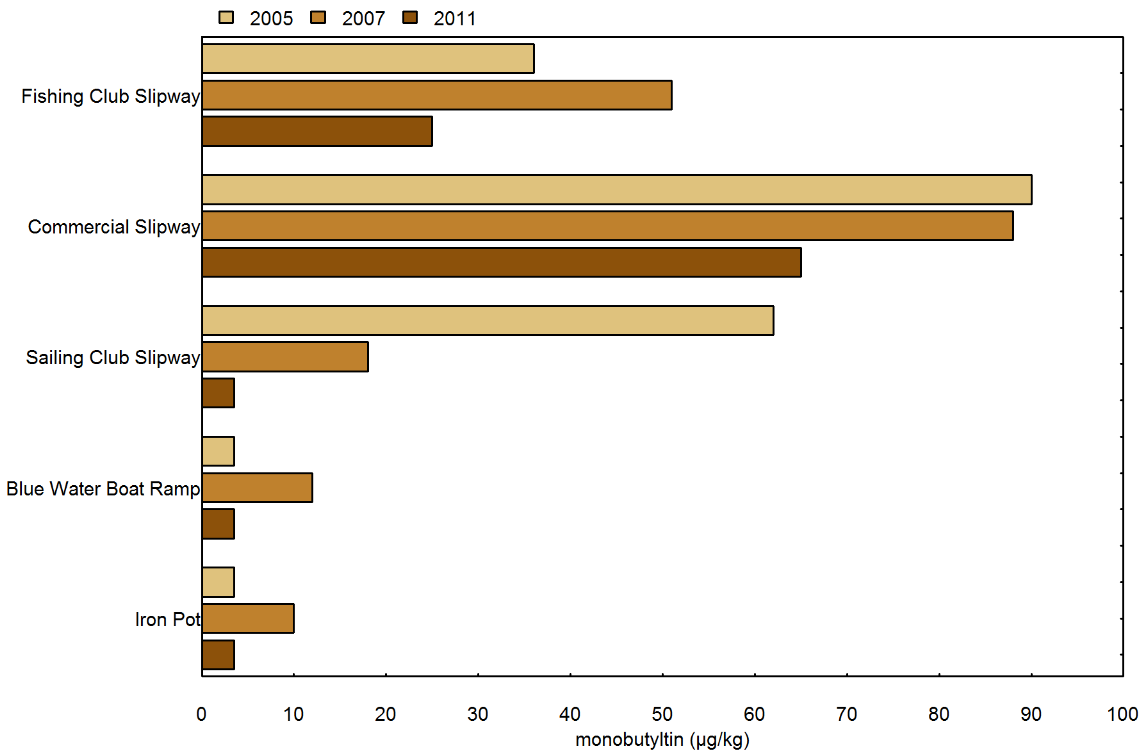
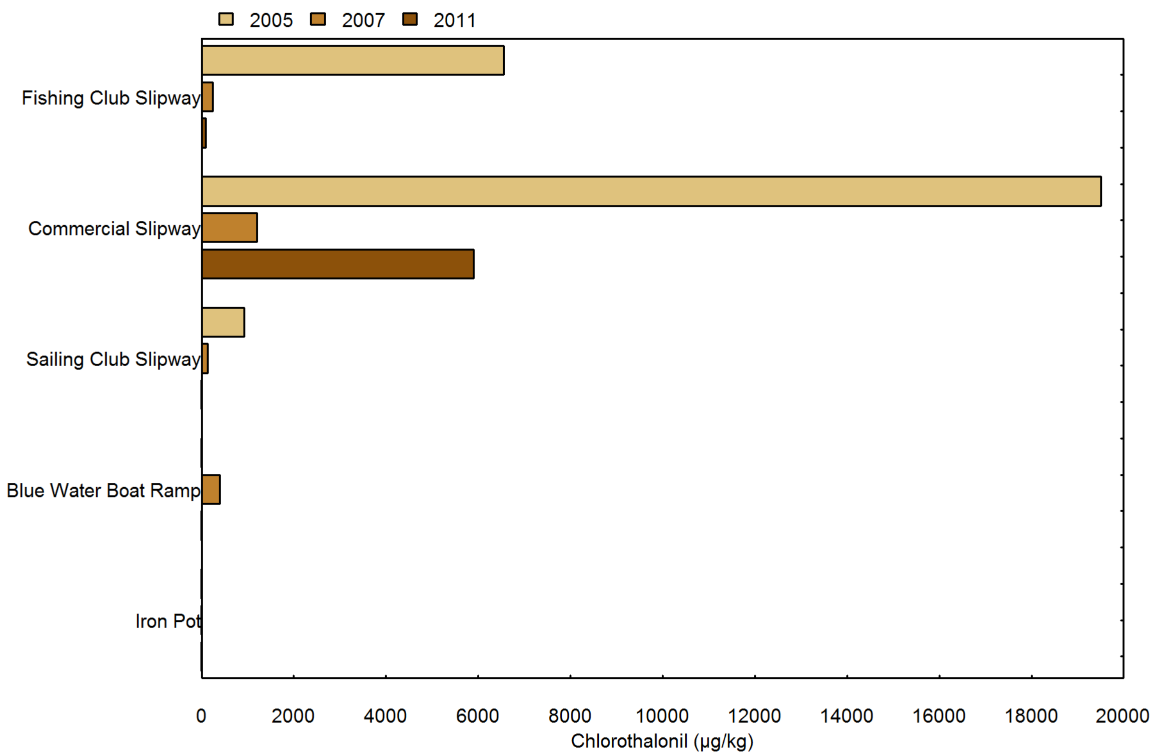
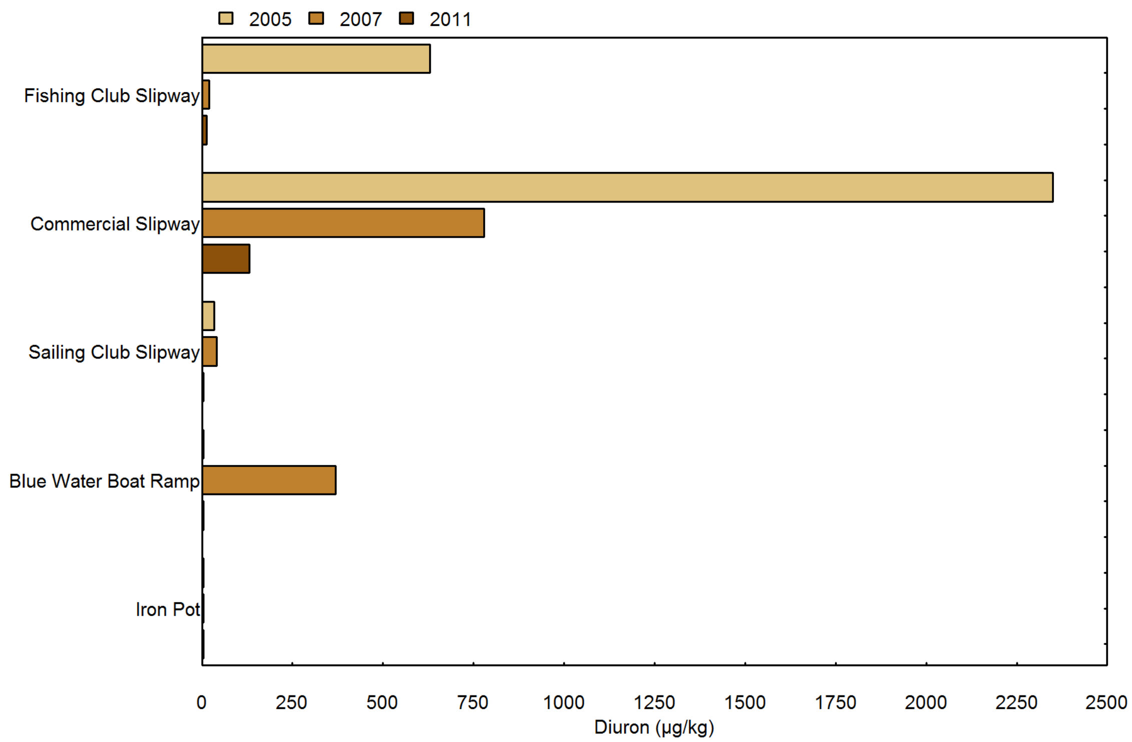


Figure 4-5: Organotin compound concentrations in the Napier Inner Harbour. Amber line denotes the ANZECC ISGQ-Low guideline value, the red line denotes the ANZECC ISGQ-High guideline value.

4.2.4 Modern biocides

During a recent review of antifouling paints, the NZ EPA highlighted a distinct group of biocides (Chlorothalonil, Diuron and Irgarol) which pose high risks compared to other biocides used in New Zealand (EPA 2013). Since these are relatively new biocides there are no current guideline values as to the toxicity of these biocides in the marine environment. Concentrations of these biocides have been found to be elevated at times around the commercial slipway site.





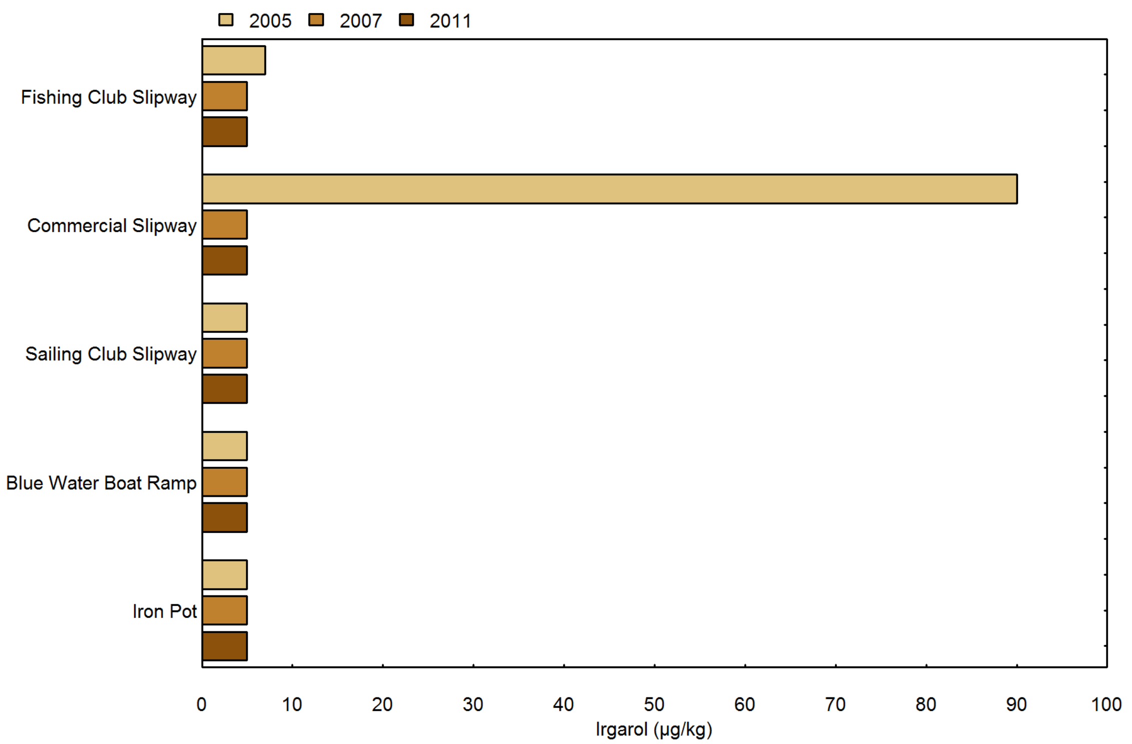


Figure 4-6: Biocide concentrations in the Napier Inner Harbour.

4.3 Nearshore Coastal Sediments

The results presented below are ordered by site from North to South from top to bottom of Figure 4-7.

4.3.1 Sediment composition

Hawke's Bay coastal sediments are primarily composed of sand with small proportions of silt/clay. The exceptions to this pattern are 2 sites (Nuhaka and Clive) which are mostly silt/clay.

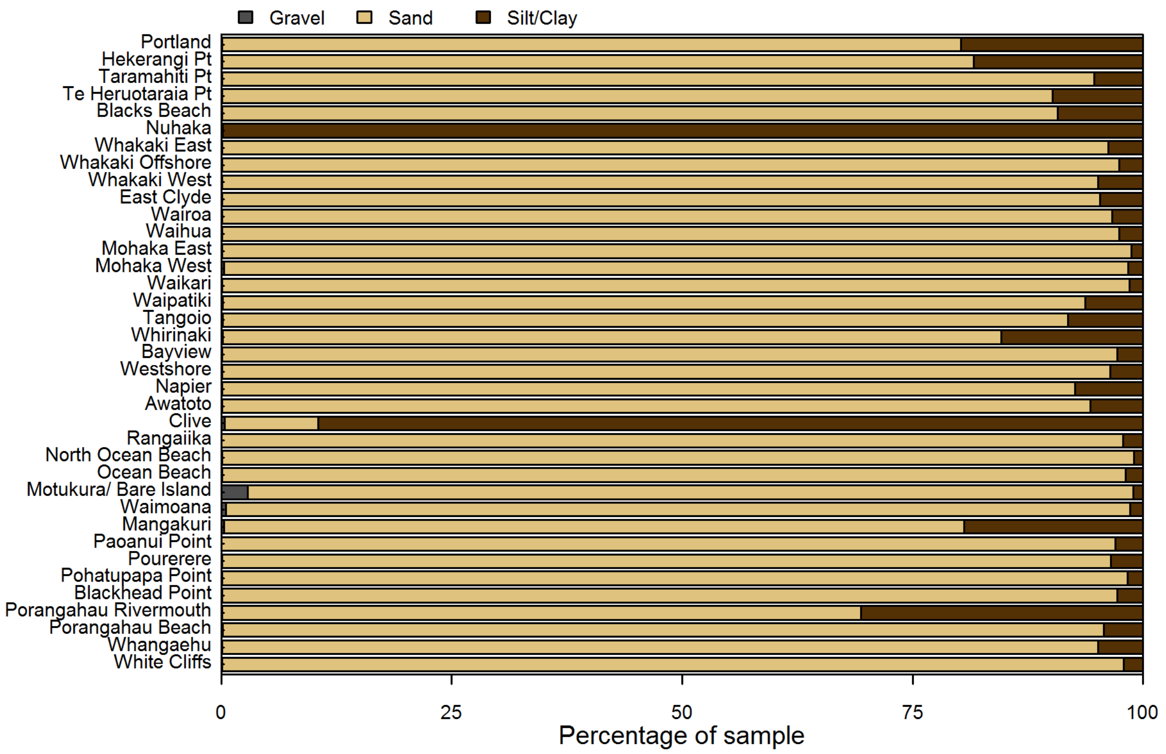
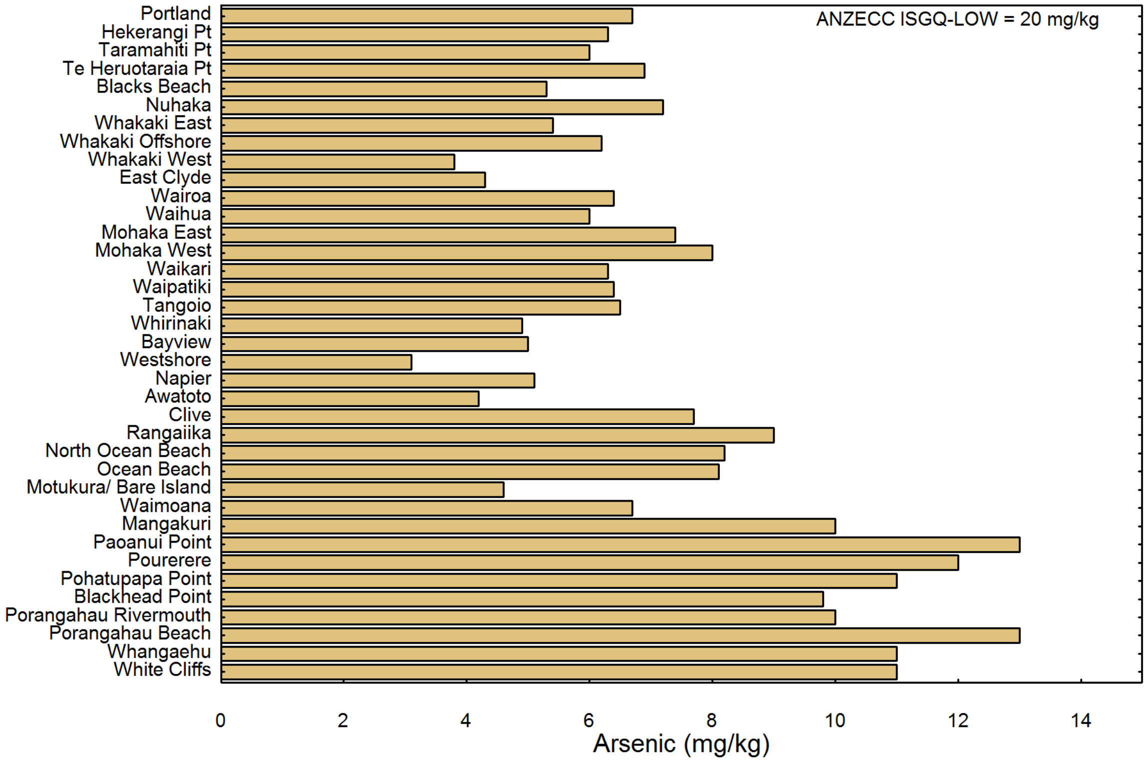


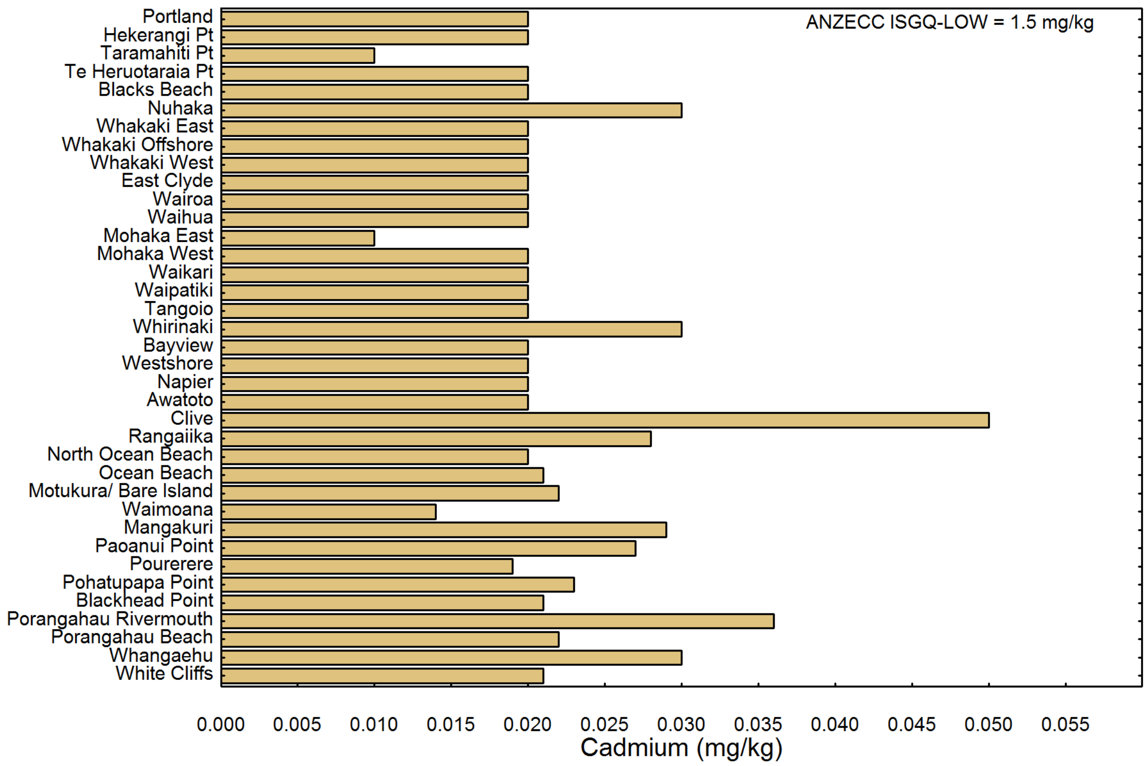
Figure 4-7: Grainsize analysis at nearshore sediment sites.

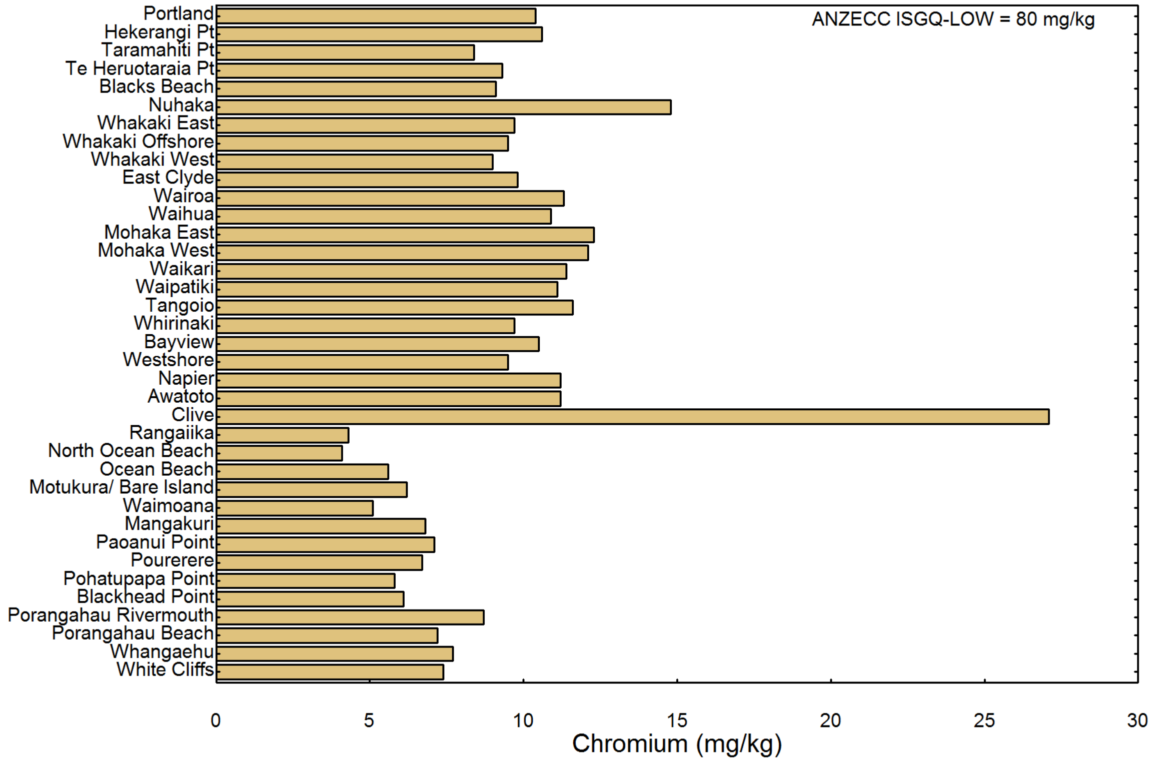
4.3.2 Trace metals

Trace metal concentrations were generally lower at the coastal sites than at the Inner Harbour sites. With the exception of arsenic, metal concentrations were higher at those sites in Hawke Bay itself than those along the southern coast. This is most likely due to the proximity of the Hawke Bay sites to a larger number of anthropogenic inputs. Trace metal concentrations also tended to be higher at those sites with a high silt/ clay content, e.g. Nuhaka and Clive.

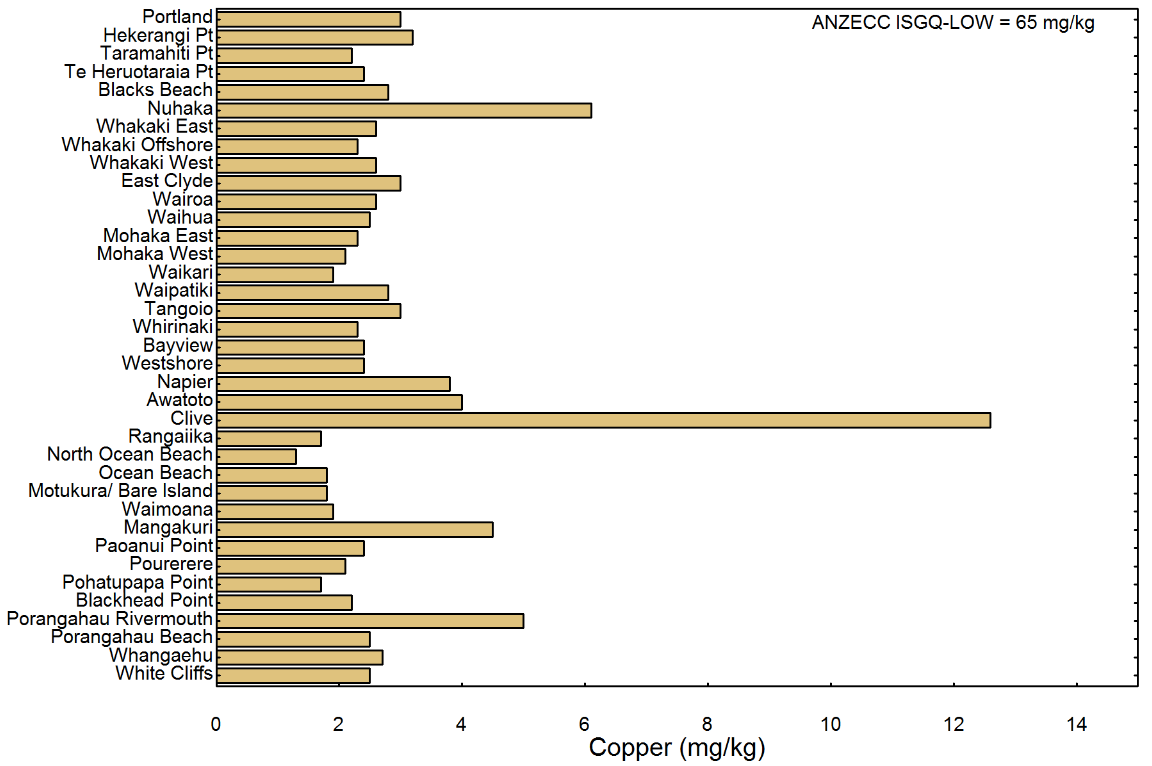
Trace metals were present at concentrations higher than the detection limits at most sites. The only exception to this was mercury concentrations at Blackhead Point, Pohatupapa Point, Pourere and Motukura/Bare Island. Only mercury at Wairoa exceeded the ANZECC ISGQ low guideline. At this site mercury concentrations would be expected to occasionally cause adverse biological effects.


Portland
Hekerangi Pt
Taramahiti Pt
Te Heruotaraia Pt
Blacks Beach
Nuhaka
Whakaki East
Whakaki Offshore
Whakaki West
East Clyde
Wairoa
Waihua
Mohaka East
Mohaka West
Waikari
Waipatiki
Tangoio
Whirinaki
Bayview
Westshore
Napier
Awatoto
Clive
Rangaiika
North Ocean Beach
Ocean Beach
Motukura/ Bare Island
Waimoana
Mangakuri
Paoanui Point
Pourerere
Pohatupapa Point
Blackhead Point
Porangahau Rivermouth
Porangahau Beach
Whangaehu
White Cliffs
ANZECC ISGQ-LOW = 20 mg/kg
0
2
4
6
8
10
12
14
Arsenic (mg/kg)

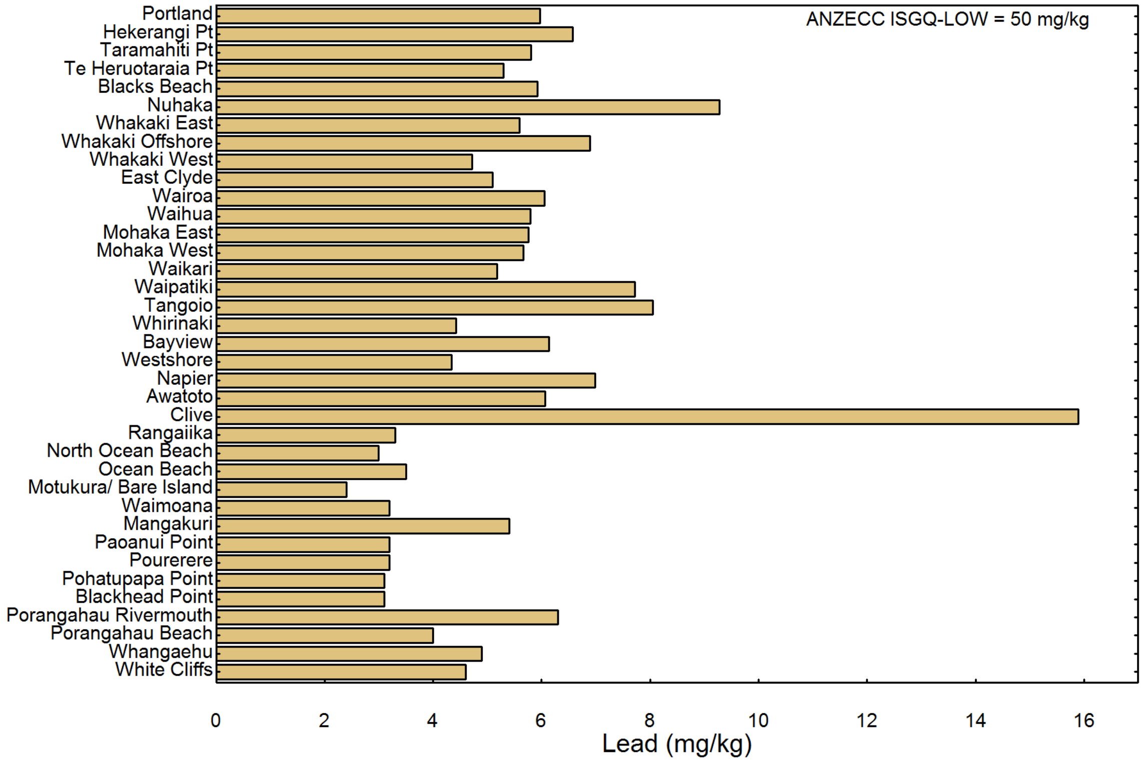

Portland
Hekerangi Pt
Taramahiti Pt
Te Heruotaraia Pt
Blacks Beach
Nuhaka
Whakaki East
Whakaki Offshore
Whakaki West
East Clyde
Wairoa
Waihua
Mohaka East
Mohaka West
Waikari
Waipatiki
Tangoio
Whirinaki
Bayview
Westshore
Napier
Awatoto
Clive
Rangaiika
North Ocean Beach
Ocean Beach
Motukura/ Bare Island
Waimoana
Mangakuri
Paoanui Point
Pourerere
Pohatupapa Point
Blackhead Point
Porangahau Rivermouth
Porangahau Beach
Whangaehu
White Cliffs
ANZECC ISGQ-LOW = 1.5 mg/kg
0.000
0.005
0.010
0.015
0.020
0.025
0.030
0.035
0.040
0.045
0.050
0.055
Cadmium (mg/kg)



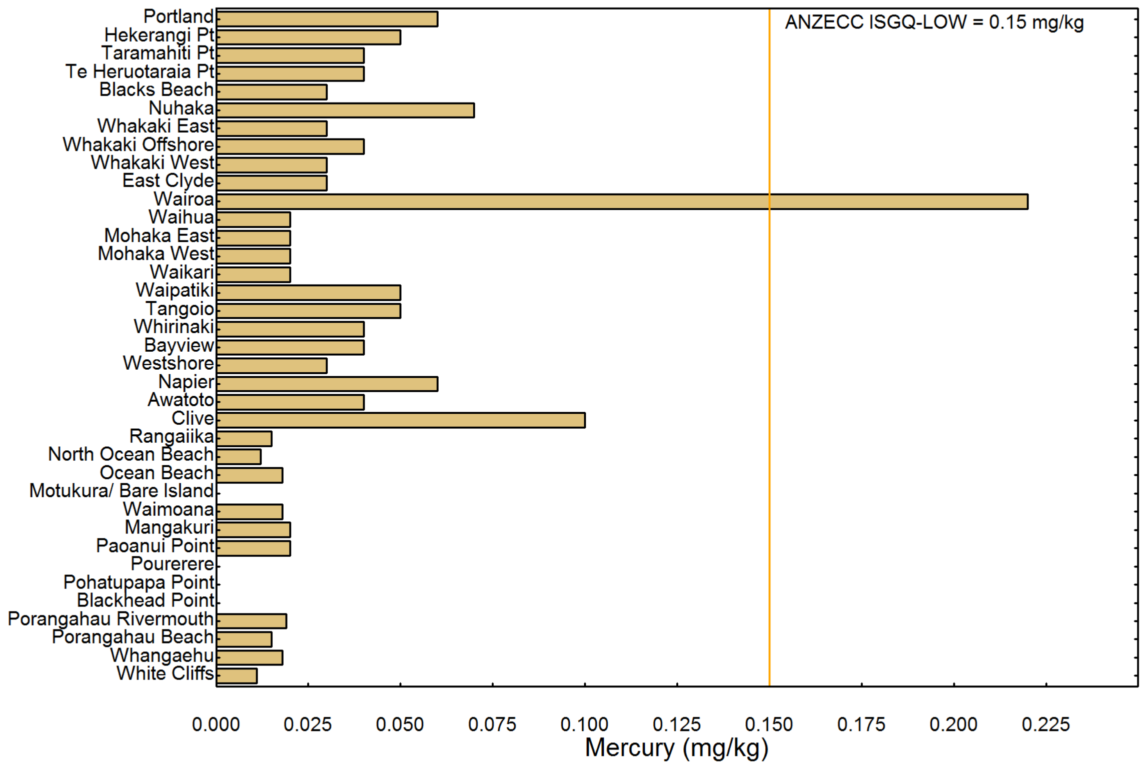
ANZECC ISGQ-LOW = 80 mg/kg
Portland
Hekerangi Pt
Taramahiti Pt
Te Heruotaraia Pt
Blacks Beach
Nuhaka
Whakaki East
Whakaki Offshore
Whakaki West
East Clyde
Wairoa
Waihua
Mohaka East
Mohaka West
Waikari
Waipatiki
Tangoio
Whirinaki
Bayview
Westshore
Napier
Awatoto
Clive
Rangaiika
North Ocean Beach
Ocean Beach
Motukura/ Bare Island
Waimoana
Mangakuri
Paoanui Point
Pourerere
Pohatupapa Point
Blackhead Point
Porangahau Rivermouth
Porangahau Beach
Whangaehu
White Cliffs
0
5
10
15
20
25
30
Chromium (mg/kg)



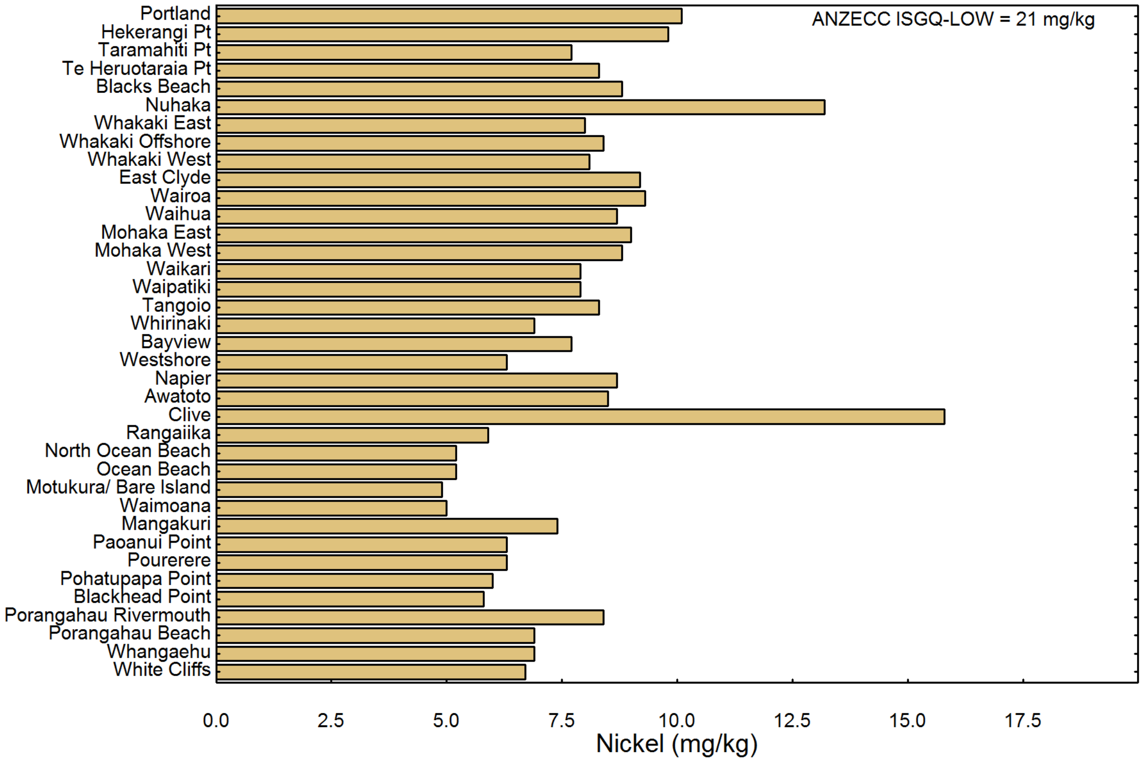
ANZECC ISGQ-LOW = 65 mg/kg
Portland
Hekerangi Pt
Taramahiti Pt
Te Heruotaraia Pt
Blacks Beach
Nuhaka
Whakaki East
Whakaki Offshore
Whakaki West
East Clyde
Wairoa
Waihua
Mohaka East
Mohaka West
Waikari
Waipatiki
Tangoio
Whirinaki
Bayview
Westshore
Napier
Awatoto
Clive
Rangaiika
North Ocean Beach
Ocean Beach
Motukura/ Bare Island
Waimoana
Mangakuri
Paoanui Point
Pourerere
Pohatupapa Point
Blackhead Point
Porangahau Rivermouth
Porangahau Beach
Whangaehu
White Cliffs
0
2
4
6
8
10
12
14
Copper (mg/kg)



ANZECC ISGQ-LOW = 50 mg/kg
Portland
Hekerangi Pt
Taramahiti Pt
Te Heruotaraia Pt
Blacks Beach
Nuhaka
Whakaki East
Whakaki Offshore
Whakaki West
East Clyde
Wairoa
Waihua
Mohaka East
Mohaka West
Waikari
Waipatiki
Tangoio
Whirinaki
Bayview
Westshore
Napier
Awatoto
Clive
Rangaiika
North Ocean Beach
Ocean Beach
Motukura/ Bare Island
Waimoana
Mangakuri
Paoanui Point
Pourerere
Pohatupapa Point
Blackhead Point
Porangahau Rivermouth
Porangahau Beach
Whangaehu
White Cliffs
0
2
4
6
8
10
12
14
16
Lead (mg/kg)



ANZECC ISGQ-LOW = 0.15 mg/kg
Portland
Hekerangi Pt
Taramahiti Pt
Te Heruotaraia Pt
Blacks Beach
Nuhaka
Whakaki East
Whakaki Offshore
Whakaki West
East Clyde
Wairoa
Waihua
Mohaka East
Mohaka West
Waikari
Waipatiki
Tangoio
Whirinaki
Bayview
Westshore
Napier
Awatoto
Clive
Rangaiika
North Ocean Beach
Ocean Beach
Motukura/ Bare Island
Waimoana
Mangakuri
Paoanui Point
Pourerere
Pohatupapa Point
Blackhead Point
Porangahau Rivermouth
Porangahau Beach
Whangaehu
White Cliffs
0.000
0.025
0.050
0.075
0.100
0.125
0.150
0.175
0.200
0.225
Mercury (mg/kg)



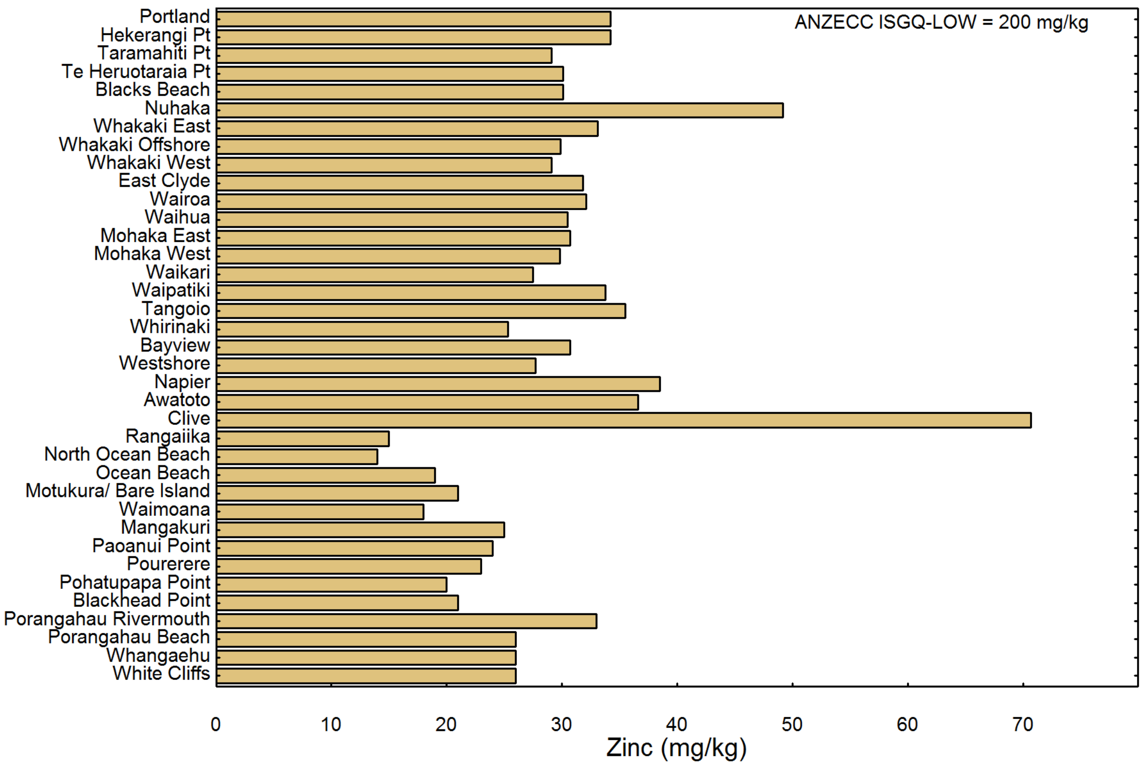


Figure 4-8: Trace concentrations of metal contaminants at nearshore coastal sediment monitoring sites.

4.4 Conclusions

- Contaminant concentrations at sites in the Inner Harbour indicate ongoing point source contamination at some sites. These contaminants are commonly associated with boat maintenance activities and stormwater.
- Concentrations of many contaminants often exceed ANZECC sediment quality guidelines at the commercial slipway site and infrequently at others.
- Elevated concentrations of trace metals in near-shore sediments are associated with a higher proportion of fine sediments.
- Only mercury levels in Wairoa near-shore sediments exceed ANZECC guidelines. The source of this mercury is unknown and it will be investigated in future monitoring.

5 Estuaries

The interface between land and sea - including intertidal, estuarine and fringing coastal habitats - is a distinctive and dynamic environment. Estuarine animals and plants must contend with harsh conditions such as prolonged periods of emersion and immersion, and associated changes in salinity, temperature and oxygen availability.

Despite this, estuaries provide valuable habitat for bird roosting, feeding and breeding, and are important spawning and nursery grounds for fish. Estuaries also provide the ecological services that help to sustain environmental quality and integrity. Estuaries not only buffer the effects of land-use on the open ocean, but also buffer the effects of the ocean on the land. They are productive habitats and have an important role in flow regulation and water quality enhancement, and can help mitigate of erosion caused by scouring and wave action.

Estuaries represent the downstream receiving environment of the freshwater drainage network, so it is understandable that they are sensitive to the same effects of land-use activities as streams and rivers throughout the catchment. In New Zealand, estuaries are being recognised as the most at risk coastal environments, as they are the end-point for the cumulative contaminants (e.g. nutrients, sediments, trace metals, pesticides etc.) from the surrounding catchment.

Given the importance of estuary ecosystems and the services they provide, and the risk from contaminants, monitoring of the long-term health and state is required to ensure that these vital ecosystems are being sustained in a way that will retain these key functions.

5.1 Long-term SoE monitoring

The Estuarine Ecology Monitoring Programme (EEMP) annually monitors Ahuriri, Porangahau, Waitangi and Wairoa Estuaries. This programme focuses on monitoring sediment characteristics, and animals living within the sediment (infauna) as indicators of wider ecosystem pressure, state and health. Monitoring is conducted annually between January and March, and is undertaken in line with the Estuarine Environmental Assessment and Monitoring National Protocol (Robertson 2002).

The indicators measured include:

- Sediment grain-size, organic material, nutrients and trace metals;
- Sediment-dwelling animals (infauna).

Methods for the collection of samples for the estuarine ecology monitoring programme are outlined in detail in (Madarasz-Smith 2007).

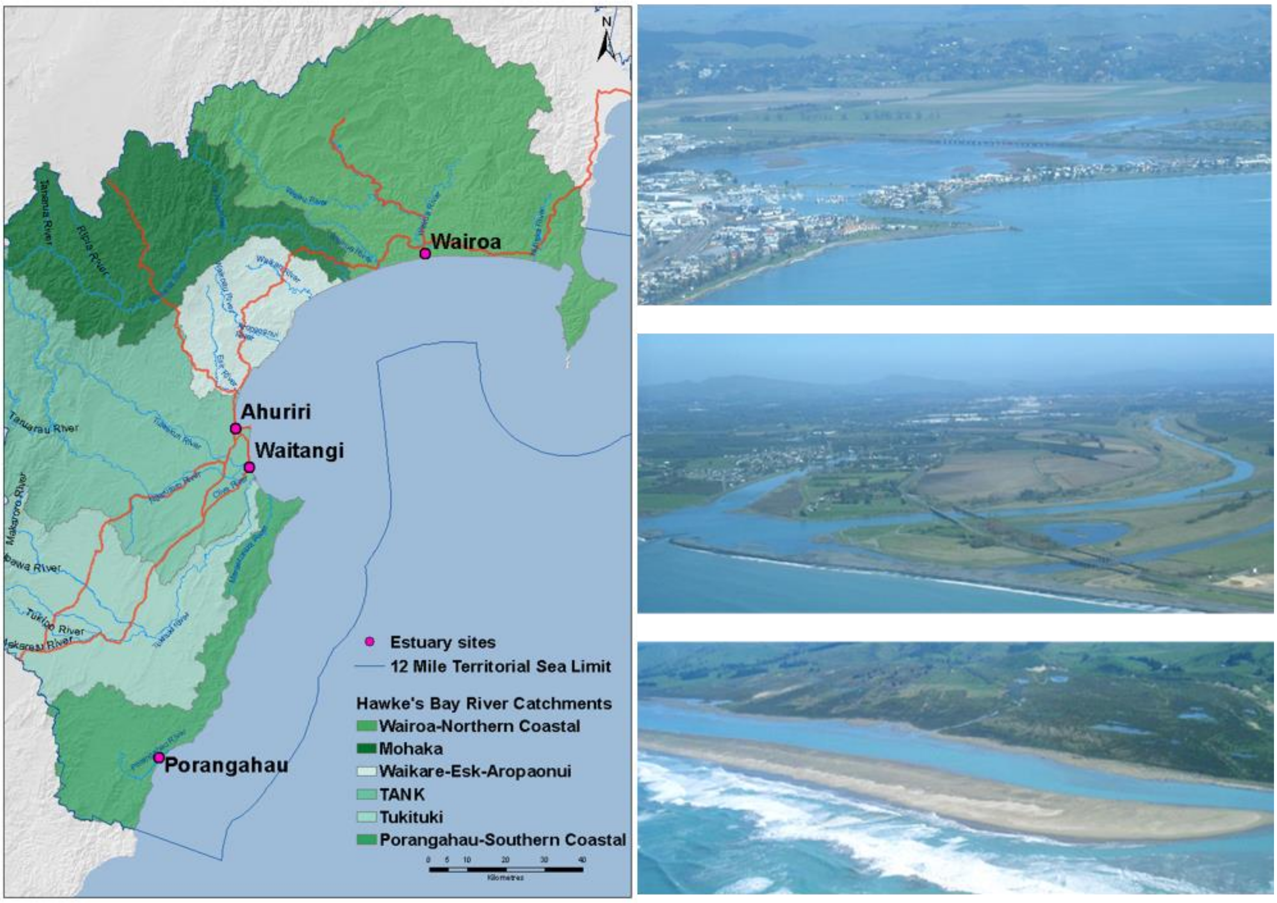


Figure 5-1: Map of sites included in the Estuarine Ecology Monitoring Programme as at 2013. Photos of Ahuriri Estuary (top), Waitangi Estuary (middle), Porangahau (bottom).

Table 5-1: Data on regional estuaries included in the Estuarine Ecology Monitoring Programme (EEMP).

Estuary	Sampling Period	Estuary Type	Estuary Volume (m³)	Catchment Size (Ha)	Catchment Land-use (>80%)
Ahuriri Estuary	AHUA 2006-2013 AHUB 2006-2013 AHUD 2007-2013 AHUE 2009-2013	Tidal Lagoon	6,347,333	14,583	Sheep and Beef (53%) Built-up Area (15%) Short-rotation crops (10%)
Porangahau Estuary	2008-2013	Tidal Lagoon	1,667,332	80,085	Sheep and Beef (79%) Exotic Forest (6.5%)
Wairoa Estuary	2011-2013	Rivermouth Estuary	9,734,902	264,547[2]	Indigenous Forest (36%) Sheep and Beef (34.5%)
Waitangi Estuary	2012	Tidal Lagoon	-	337,058	Sheep and Beef (42%) Manuka/Kanuka (16%) Indigenous Forest (13%)

[2] This value only refers to Wairoa catchment land within the Hawke's Bay Regional boundary. Part of the catchment is outside this boundary in the Gisborne District, but land-use information was not available for this part of the catchment at the time of writing.

5.1.1 Data summaries and visualisation

Box plots have been used throughout Section 2 to summarise sediment quality data and diversity indices for the 5 year period between 2009 and 2013 unless otherwise specified. Box plots graph data as a box representing statistical values. The lower boundary of each box indicates the 25th percentile, a line within the box marks the median, and the higher boundary of each box indicates the 75th percentile. The line at the end of the whiskers (error bars) above and below the box indicate the 90th and 10th percentiles respectively.

5.1.2 Trend and multivariate analyses

Trend analyses

Trend analysis of environmental monitoring data can help identify when issues are changing in significance. For example, if nitrate concentrations are increasing or decreasing at a particular site, the cause and significance of these changes may need to be identified.

Trend analyses in this section uses non-parametric statistical approaches similar to those used in recent nationwide water quality analyses undertaken for the LAWA project (Ballantine 2012). For these data a Mann-Kendall trend test was applied as sites had been sampled annually. January was used as the 'start' month.

Further information on trend testing can be found in section 2.1.3.

Diversity analyses

The nature of estuarine infaunal assemblages are diverse and variable. Therefore several tests are used in conjunction to describe the make-up of estuarine and marine assemblages. Collectively these 'diversity indices' describe how a sample community's individuals and species are mixed and spread.

Diversity indices were calculated using the PRIMER 'Diverse' routine. Macrofaunal data were transformed using a ln (x+1) function to meet the assumptions of ANOVA. A Ln (x+1) transformation was used to retain information concerning relative abundance, and to ensure that commonly occurring species did not dominate the analysis (Clarke 1994, Zar 1996).

Multivariate analyses

A PERMANOVA (permutational multivariate analysis of variance) was used to examine differences in the community structure based on a model using the permutation of raw data for the fixed factor of 'year' on individual sites (PERMANOVA +). PERMANOVA is a standard technique used to determine whether the infaunal community structure (all the organisms living within the sediment of the estuary) vary either within space or time. It can help ecologists to determine whether a particular site is dynamically stable, or changing. Spatial variations in species composition were also assessed using multi-dimensional scaling (MDS, PRIMER 6 – Appendix B). This technique presents a graphical display of how similar (close) or different (separated) sites or times are from one another.

5.2 Sediment Quantity, Composition and Quality

Estuarine sediments form complex habitats that can support diverse benthic communities. They generally reflect the surrounding geology of the catchment, but may be influenced by larger-scale catchment land-use and point-source discharges. Sediment inputs into estuaries can result in a 'muddying' of estuary sediments (a move from sands to muds). Nutrient enrichment of estuary sediments can fuel nuisance algal growth, while increasing trace metal and contaminant levels can affect the growth, reproduction and survival of animals and plants within the system.

At each site within the Estuary Ecology Monitoring programme, sediments were assessed to determine their current state and trends.

At each site sediment quality was assessed using surficial sediments from 0 cm to 2 cm in depth. The whole sediment fraction was analysed for the common trace metals arsenic, cadmium, copper, chromium, lead, nickel and zinc.

5.2.1 Sediment composition

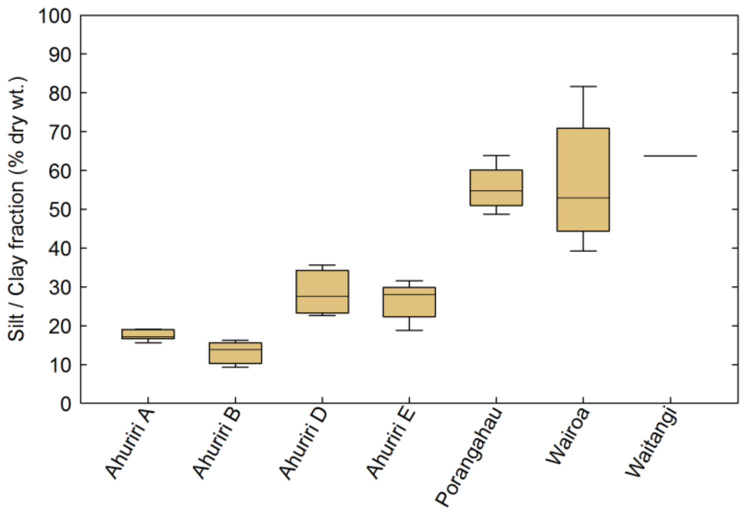


Figure 5-2: 5 year median levels of silt/clay (mud) in sediments (2009-2013).

Sediments in the Lower Ahuriri Estuary are generally dominated by medium sands, with lower levels of muds (silt/clay) compared to other regional estuaries (Figure 5-2). This is typical of transitory systems where channels and currents transport finer grained sediments offshore, and shallow intertidal areas where muds can be re-suspended by waves and wind. By contrast, the Porangahau, Wairoa and Waitangi are more characteristic of depositional environments, with higher levels of muds within the sediment complex.

Trend analysis of the data indicates significant increases in the silt/clay fraction of the sediments at 3 of the 6 sampling sites, suggesting a 'muddying' of the sediments at these sites (Table 5-2). Of particular importance, the 'less disturbed' sites with lower concentrations of silt/clay appear to be experiencing increasing trends in silt/clay content. The lack of significant trends at the Wairoa site is likely to be confounded by the relatively short data record (3 years). Interestingly Ahuriri E recorded a significant decrease in the amount of silt/clay present. This site is adjacent to the main channel, and these observations may represent a period of erosion.

Table 5-2: Trend analysis of silt/clay (mud) fraction in estuary sediments over the monitoring period. Statistically significant trends are indicated in bold. BLUE highlight for PAC indicates an improving trend, RED indicates a deterioration.

Site	Silt/Clay fraction (<63um) %		
	Median	Trend p value	Percent Annual Change
Ahuriri A	**14.50**	**0.000**	**11.38**
Ahuriri B	**10.90**	**0.001**	**7.53**
Ahuriri D	**26.45**	**0.001**	**7.19**
Ahuriri E	**24.50**	**0.002**	**-10.35**
Porangahau	**52.54**	**0.000**	**8.04**
Wairoa	53.59	0.124	17.31

Sediment composition is a key driver in the macroinvertebrate community present at estuary sites. Estuary systems with silt/clay fractions <25% generally have communities with higher diversity and abundance than those with >25% silt/clay (Robertson 2015), although much lower concentrations have been shown to affect the health of macroinvertebrate communities. This would indicate that mid-Ahuriri estuary sites appear only moderately impacted by sediments, while the lower Ahuriri (AHUD, AHUE), Porangahau, Wairoa and Waitangi estuaries are likely to be sediment 'stressed'. Wairoa Estuary tends towards highly variable mud content (between from 88% to 35%) and therefore a wider sediment study or additional ecological monitoring site may be warranted.

A comparison with data published on 25 estuaries throughout New Zealand (Robertson, 2015) indicates that these Hawke's Bay estuaries have some of the highest sediment mud contents (silt/clay %) recorded. Median levels of silt/clay recorded in the Porangahau, Waitangi and Wairoa Estuaries were recorded at 54.7%, 52.8% and 63.7% respectively. These sites approach or exceed published literature on sediment stress in estuary infauna.

These high results, combined with increasing trends in muddying between 2006 and 2013 is a significant finding and would suggest catchment management is necessary to reduce sediment loads from entering and depositing within regional estuaries.

5.2.2 Sediment nutrients

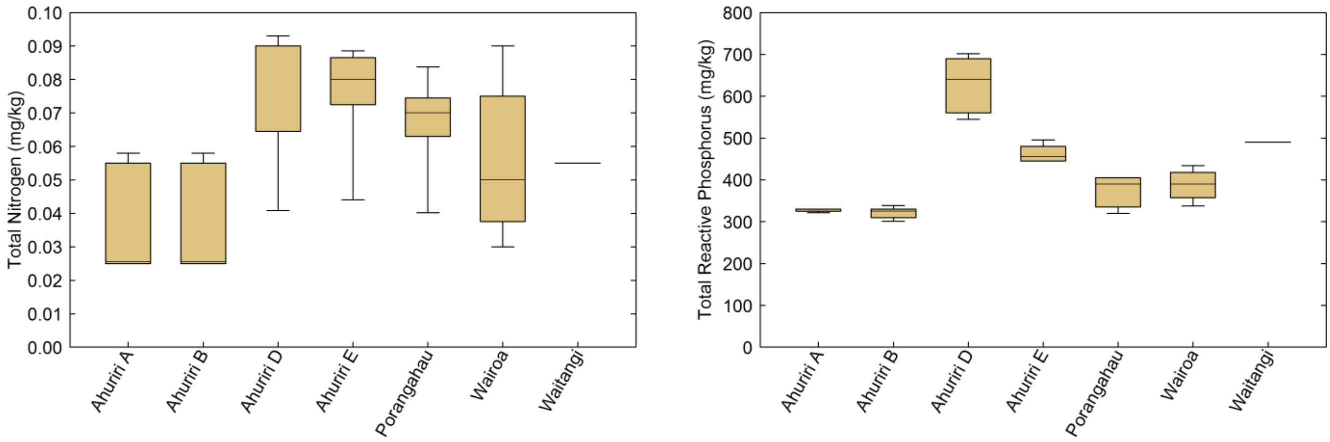


Figure 5-3: Sediment total nitrogen and total recoverable phosphorus. 5 year medians (2009-2013).

Sediment nutrient concentrations were lowest at Ahuriri A and B sites, and highest at Ahuriri D and E sites with Ahuriri D site having the highest sediment total recoverable phosphorus (TRP) levels of all the monitored estuarine sites.

While some of the inter-site variability may be due to differences in the silt/clay fraction (see footnote on normalisation) of the sites, the relationship is not consistent, which suggests this is not the dominant cause of differences between sites. With the exception of Ahuriri D, TRP concentrations within sediments of the lower Ahuriri, Porangahau, Wairoa and Waitangi estuaries do not appear to suggest significant eutrophication of the estuary sediments by phosphorus. The concentrations of TRP at site Ahuriri D suggest enrichment, and would suggest a localised source of phosphorus to the system.

Ahuriri A and B appear to reflect background concentrations of total nitrogen, with many samples returning results less than 0.05g/100g (= <500mg/kg). Sites Ahuriri D, E, and the Porangahau, Wairoa and Waitangi Estuaries vary with median concentrations of sediment total nitrogen between 0.09 and 0.05g/100g. These results do not suggest significant eutrophication of the estuary sediments by nitrogen (Robertson 2016).

To account for differences in sediment composition over time, which can affect contaminant retention capacity, results for sediment metal and nutrient analyses were normalised to 100% mud content before trend testing was undertaken.[3]

Three of the 6 monitored sites recorded decreasing trends in the normalised sediment total nitrogen concentrations. These were Ahuriri B and D, and Porangahau. Ahuriri E was the only site to exhibit significant increases in normalised sediment total nitrogen. Porangahau Estuary also recorded significantly decreasing trends in the concentrations of normalised total recoverable phosphorus.

[3] For further information on the normalisation process, refer to Robertson et al, (2002).

Table 5-3: Trend analysis of normalised total nitrogen in estuary sediments over the monitoring period. Statistically significant trends are indicated in bold. BLUE highlight for PAC indicates an improving trend, RED indicates a deterioration.

Site	Normalised Total Nitrogen (g/100gms)		
	Median	Trend p value	Percent Annual Change
Ahuriri A	**0.33**	**0.824**	**-0.55**
Ahuriri B	**0.29**	**0.016**	**-5.80**
Ahuriri D	**0.29**	**0.002**	**-10.62**
Ahuriri E	**0.31**	**0.001**	**8.57**
Porangahau	**0.14**	**0.000**	**-5.83**
Wairoa	0.11	0.165	9.61

Table 5-4: Trend analysis of normalised total recoverable phosphorus in estuary sediments over the monitoring period. Statistically significant trends are indicated in bold. BLUE highlight for PAC indicates an improving trend, RED indicates a deterioration.

Site	Normalised Total Recoverable Phosphorus (mg/kg)		
	Median	Trend p value	Percent Annual Change
Ahuriri A	2222.33	0.000	-13.48
Ahuriri B	2858.06	0.000	-7.75
Ahuriri D	2417.99	0.032	-6.64
Ahuriri E	1963.16	0.010	8.63
Porangahau	**758.38**	**0.000**	**-10.24**
Wairoa	735.16	0.246	-10.69

5.2.3 Sediment chlorophyll *a*

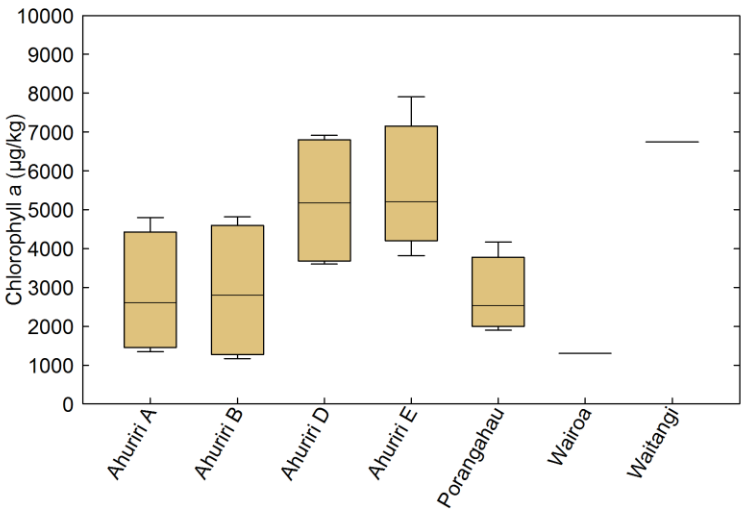


Figure 5-4: 5 year median levels of sediment chlorophyll *a* (2009-2013).

Sediment chlorophyll *a* measures the levels of photosynthetic activity occurring in the sediments and is used to measure the trophic state of the sediment. Results presented exclude 2012, as a change in methodology meant that sample results could not be compared. For that reason both Waitangi and Wairoa Estuaries are a single result only.

The highest median concentration of sediment chlorophyll *a* was observed at Waitangi Estuary, however given this represents only a single sampling event, further sampling would be required to determine the accuracy of this result. Similarly Wairoa Estuary reported the lowest concentrations of chlorophyll *a,* however these also come from a single sampling event and so should be treated with caution.

Extraction methods differ between analytical providers, so meaningful comparison between regions is impossible. However it appears that chlorophyll-*a* sediment concentrations at Ahuriri D and E, and possibly Waitangi estuary may indicate slightly enriched sediments.

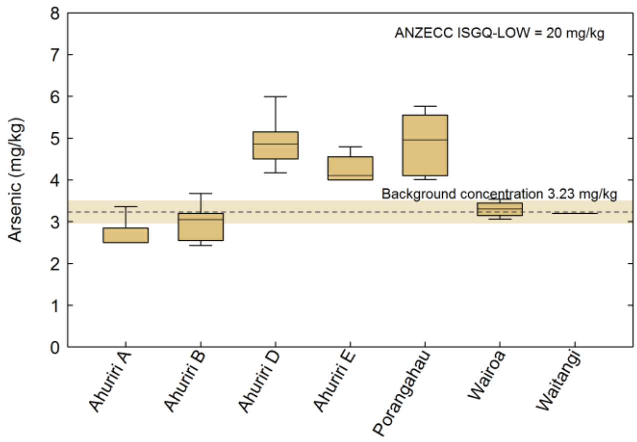
Table 5-5: Trend analysis of chlorophyll a in estuary sediments over the monitoring period. Statistically significant trends are indicated in bold. BLUE highlight for PAC indicates an improving trend, RED indicates a deterioration.

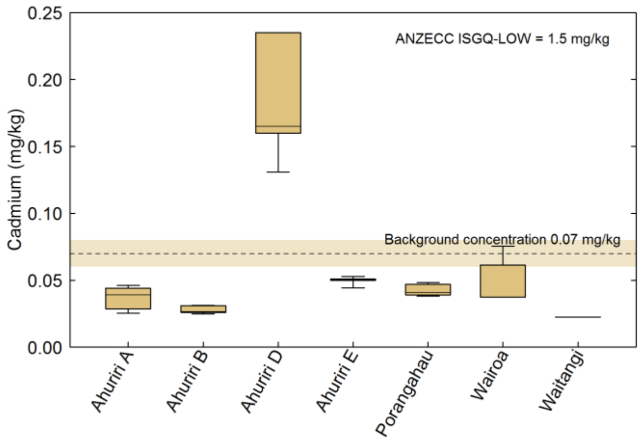
Site	Chlorophyll *a* (µg/kg)		
	Median	Trend p value	Percent Annual Change
Ahuriri A	2450	0.082	6.12
Ahuriri B	2500	0.104	6.00
Ahuriri D	5000	0.871	0.65
Ahuriri E	5150	0.256	6.31
Porangahau	2800	0.717	1.19
Wairoa	Not analysed		

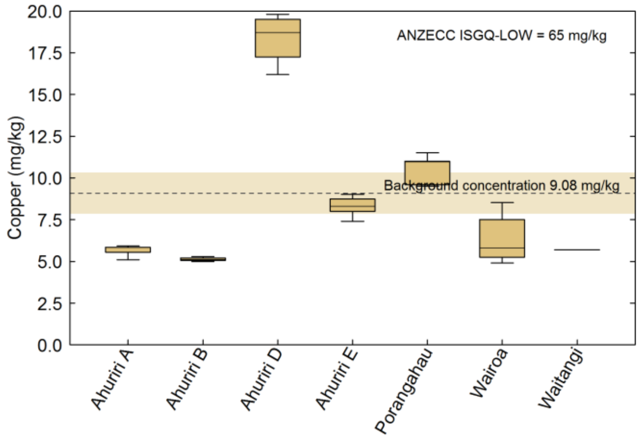
There was no statistically-significant trend in sediment chlorophyll *a* concentrations between the beginning of sampling and 2013.

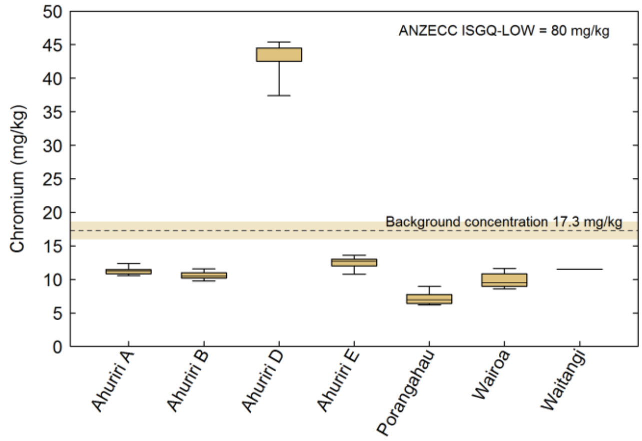
It is important to note that while the results of sediment nutrient and chlorophyll *a* concentrations do not appear indicative of eutrophic systems, the sampling approach taken in the national monitoring protocol has a focus on downstream environments. New guideline approaches *(Robertson 2016)* suggests focusing on upper reaches and other sensitive environments, along with additional indicators for determining trophic status. These guidelines have been implemented to complement the current programme and will be reported on in the future.

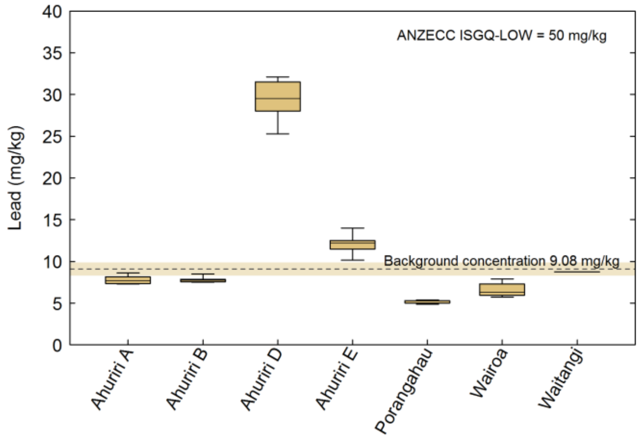
5.2.4 Sediment toxicants

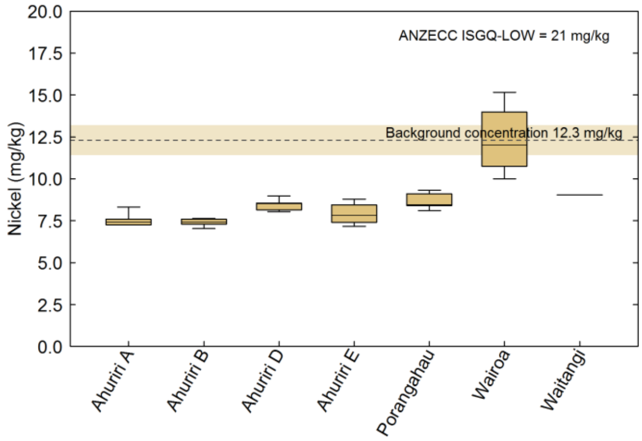












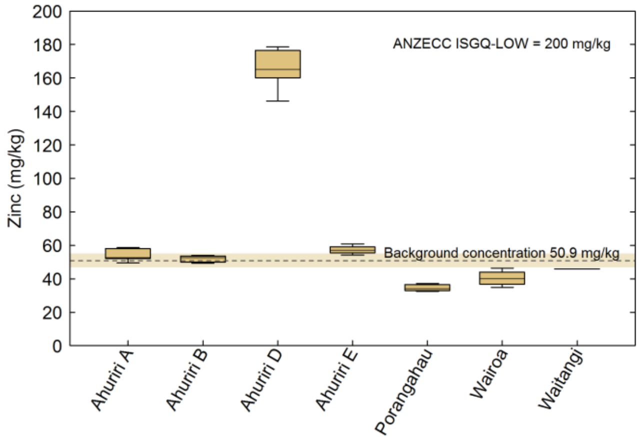


Figure 5-5: 5 year median levels (2009-2013) of trace metal contaminants in estuary sediments (Ahuriri A-D, Porangahau); 2011-13 (Wairoa) and 2013 (Waitangi). Amber dashed line indicates background levels as described by Strong,ISQG = Interim sediment quality guidelines, Low and High (ANZECC, 2000).

Concentrations of toxicant contaminants in the estuary sediments generally fell well within ANZECC guidelines for likely ecological effects. Where results fall below ANZECC ISQG – Low, adverse ecological effects can be expected to occur rarely (ANZECC, 2000). The exception to this was at site Ahuriri D, which is located adjacent to the stormwater discharge in to the Ahuriri Estuary from the Thames/Tyne (Pandora) Industrial Estate. This site showed concentrations of toxicants that were significantly higher than all other sites, and – for the trace metals chromium, lead and zinc - at levels which are approaching the ANZECC ISQG – Low. Given that these results represent the median concentrations of these toxicants, individual samples did exceed these guidelines in some sample events. When exceeded, adverse ecological events could be expected to occur occasionally.

Specifically the toxicants chromium, lead and zinc are associated with many of the industrial practices occurring in the adjacent catchment, and point source control would be expected to reduce the amounts making their way in to the estuary.

As with nutrients, sediment metal results were normalised to 100% mud content before spatial and temporal comparisons were made.

Table 5-6: Trend analysis of normalised arsenic in estuary sediments over the monitoring period. Statistically significant trends are indicated in bold. BLUE highlight for PAC indicates an improving trend, RED indicates a deterioration.

Site	Normalised Arsenic (mg/kg)		
	Median	Trend p value	Percent Annual Change
Ahuriri A	**17.12**	**0.000**	**-10.33**
Ahuriri B	22.81	0.368	1.75
Ahuriri D	**17.07**	**0.006**	**-10.17**
Ahuriri E	17.81	0.209	5.37
Porangahau	**9.52**	**0.000**	**-17.55**
Wairoa	6.25	0.106	-19.76

Normalised arsenic concentrations showed significant declines at sites Ahuriri A, D and Porangahau.

Table 5-7: Trend analysis of normalised cadmium in estuary sediments over the monitoring period. Statistically significant trends are indicated in bold. BLUE highlight for PAC indicates an improving trend, RED indicates a deterioration.

Site	Normalised Cadmium (mg/kg)		
	Median	Trend p value	Percent Annual Change
Ahuriri A	**0.30**	**0.000**	**-16.93**
Ahuriri B	**0.26**	**0.001**	**-8.96**
Ahuriri D	**0.70**	**0.000**	**-19.2**
Ahuriri E	**0.20**	**0.008**	**7.230**
Porangahau	**0.08**	**0.000**	**-5.33**
Wairoa	**0.09**	**0.000**	**-25.59**

Likewise, all sites showed a decrease in normalised sediment cadmium concentrations, excepting Ahuriri E which reported a significant increase in cadmium over the sampling period.

Table 5-8: Trend analysis of normalised chromium in estuary sediments over the monitoring period. Statistically significant trends are indicated in bold. BLUE highlight for PAC indicates an improving trend, RED indicates a deterioration.

Site	Normalised Chromium (mg/kg)		
	Median	Trend p value	Percent Annual Change
Ahuriri A	**75.25**	**0.000**	**-12.34**
Ahuriri B	**93.24**	**0.000**	**-9.10**
Ahuriri D	**146.79**	**0.000**	**-13.91**
Ahuriri E	50.06	0.277	2.37
Porangahau	**13.84**	**0.000**	**-10.01**
Wairoa	17.08	0.115	-16.60

Normalised chromium concentrations at sites Ahuriri A, B, and D, and Porangahau had significant decreases. No significant increases were observed.

Table 5-9: Trend analysis of normalised copper in estuary sediments over the monitoring period. Statistically significant trends are indicated in bold. BLUE highlight for PAC indicates an improving trend, RED indicates a deterioration.

Site	Normalised Copper (mg/kg)		
	Median	Trend p value	Percent Annual Change
Ahuriri A	**38.89**	**0.000**	**-12.15**
Ahuriri B	**48.20**	**0.000**	**-7.43**
Ahuriri D	**64.46**	**0.001**	**-8.47**
Ahuriri E	**33.21**	**0.017**	**6.42**
Porangahau	19.38	0.063	-1.91
Wairoa	**11.01**	**0.003**	**-12.09**

Normalised copper concentrations at sites Ahuriri A, B, and D, and Wairoa had significant decreases. A significant increase in normalised sediment copper at Ahuriri E was observed.

Table 5-10: Trend analysis of normalised nickel in estuary sediments over the monitoring period. Statistically significant trends are indicated in bold. BLUE highlight for PAC indicates an improving trend, RED indicates a deterioration.

Site	Normalised Nickel (mg/kg)		
	Median	Trend p value	Percent Annual Change
Ahuriri A	**50.17**	**0.000**	**-11.12**
Ahuriri B	**64.35**	**0.003**	**-7.40**
Ahuriri D	28.78	0.348	-3.17
Ahuriri E	**31.66**	**0.001**	**8.77**
Porangahau	15.43	0.508	-1.01
Wairoa	11.60	0.203	-9.56

Normalised nickel concentrations at sites Ahuriri A and B indicated significant decreases over the sampling period. A significant increase in normalised sediment nickel at Ahuriri E was observed.

Table 5-11: Trend analysis of normalised lead in estuary sediments over the monitoring period. Statistically significant trends are indicated in bold. BLUE highlight for PAC indicates an improving trend, RED indicates a deterioration.

Site	Normalised Lead (mg/kg)		
	Median	Trend p value	Percent Annual Change
Ahuriri A	**53.20**	**0.000**	**-14.62**
Ahuriri B	**69.98**	**0.001**	**-8.48**
Ahuriri D	**99.15**	**0.000**	**-12.25**
Ahuriri E	50.17	0.521	1.96
Porangahau	**9.86**	**0.000**	**-9.79**
Wairoa	22.35	0.203	-9.56

Normalised lead concentrations indicated a significant decrease at sites Ahuriri A, B, and D, and Porangahau. No significant increases in normalised lead were observed.

Table 5-12: Trend analysis of normalised zinc in estuary sediments over the monitoring period. Statistically significant trends are indicated in bold. BLUE highlight for PAC indicates an improving trend, RED indicates a deterioration.

Site	Normalised Zinc (mg/kg)		
	Median	Trend p value	Percent Annual Change
Ahuriri A	**382.73**	**0.000**	**-14.67**
Ahuriri B	**462.35**	**0.001**	**-7.89**
Ahuriri D	**576.35**	**0.001**	**-10.77**
Ahuriri E	**225.80**	**0.001**	**9.63**
Porangahau	**66.16**	**0.000**	**-6.97**
Wairoa	74.16	0.133	-13.44

Normalised zinc concentrations showed a significant decrease at sites Ahuriri A, B, and D, and Porangahau. A significant increase was observed at site Ahuriri E.

Overall sediment trace metal concentrations appear well within ANZECC interim sediment quality guidelines for all sites except Ahuriri D. At these sites adverse ecological effects would be expected rarely.

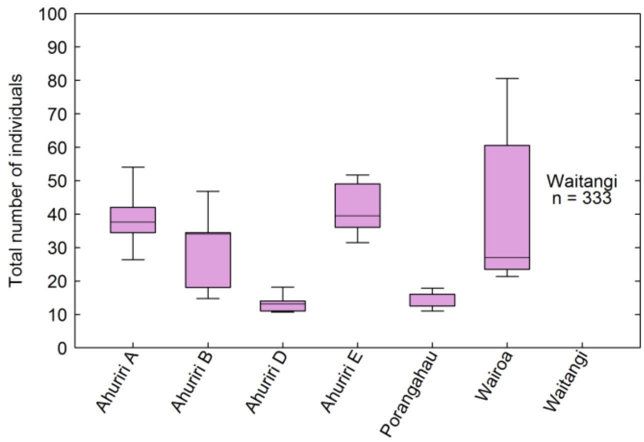
Site Ahuriri D has significantly higher concentrations of zinc, lead, cadmium, chromium and copper. While median levels (represented in the graphs) appear to fall within guideline values, individual samples exceed concentrations where adverse ecological effects could be expected occasionally.

5.3 Community composition and diversity indices

5.3.1 Abundance and richness

The communities of organisms that inhabit estuaries are diverse and variable. In order to describe these communities in a way that helps us to interpret their state and health, various community metrics and indices are used. These are described below:

- **Total number of individuals (n):** This refers to the sum of all individuals found within a core.
- **Total number of species (s):** This refers to the sum of the different species found within a core (may also be referred to as taxa richness).
- **Margalef's richness (d):** Margalef's richness is a measure of biodiversity based on the number of species, adjusted for the number of individuals sampled. Values for this index increase with the number of species, and decreases with relative increases in the number of individuals.
- **Peilou's evenness:** Peilou's evenness is a measure of how evenly the abundance is represented over the species total. As an example if a community is dominated by a single species of high abundance with only single representatives from others species present, then this community would be described as 'uneven' and would score close to 0. If a community was represented by even numbers of individuals across a range of species, then it would be described as 'even' and would score close to 1.
- **Shannon diversity (H'):** Shannon diversity is a measure of the biodiversity of a sample and is based on the probability that an individual in a sample will be the same species as the next individual of a sample. Values close to 0 describe low diversity (higher probability of the same species), while values close to 1 describe high diversity (higher probability of a different species).
- **Simpson diversity (λ):** Simpson's diversity is similar to Shannon diversity however they use **a** slightly different arithmetic processes to derive their scores. As with the Shannon index, values close to 0 describe low diversity (higher probability of the same species), while values close to 1 describe high diversity (higher probability of a different species).



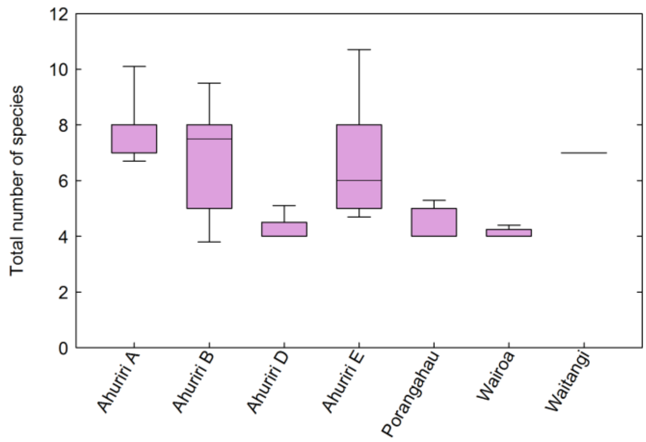


Figure 5-6: Total number of individuals and species by estuarine site. 5 year medians (2009-2013), samples per core (0.013m^2).

Sites Ahuriri D and Porangahau had the lowest number of individuals in each core (abundance per 0.013m^2), with median numbers of 13 and 16 respectively. Waitangi Estuary reported the highest number (n = 333) of individuals per core. This core was dominated by the amphipod *Paracorophium excavatum* (average of 227 individuals in each core) and the estuarine snail *Potamopyrgus estuarinus* (average of 97 individuals in each core).

Porangahau Estuary recorded a significant increase in the total number of individuals over the sampling period, while Wairoa Estuary recorded a significant decrease. This does not necessarily denote either a positive or negative trend (grey highlight), as increased numbers of single opportunistic species may in fact represent an environmental decline, whereas a reduction may represent improvement. Instead, these data need to be considered alongside data on diversity (Shannon, Simpson), evenness (Peilou's evenness) and richness (number of species) before a conclusion can be reached.

Table 5-13: Trend analysis of total number of individuals in estuary infaunal samples per core (0.013m^2). Statistically significant trends are indicated in bold. BLUE highlight for PAC indicates an improving trend, RED indicates a deterioration, GREY indicates no specific ecological significance with direction.

Site	Total number of individuals (N)		
	Long-term median	Trend p value	Percent Annual Change
Ahuriri A	33.5	0.911	0.00
Ahuriri B	22.0	0.596	1.52
Ahuriri D	13.5	0.677	0.00
Ahuriri E	41.0	0.218	-4.88
Porangahau	**13.0**	**0.007**	**7.69**
Wairoa	**32.0**	**0.000**	**-111.57**

Sites Ahuriri A, B and E reported the highest species richness per core (0.013m^2), with median species counts of 7.5, 7.5 and 6 respectively. Waitangi recorded a species richness of 7 from a single sampling event, and all other sites recorded a median of 4 species per core.

Ahuriri E reported decreasing species richness over the sampling period. However, as with the abundance measure, whether this is ecologically significant depends on the species that remain. A reduction of opportunistic species (those well adapted to moderate-high organic enrichment) may represent environmental improvements, or a reduction of sensitive species may represent decline. These data should be viewed in conjunction with information on community composition and particularly those species that characterise a site (Appendix C).

Table 5-14: Trend analysis of total number of species in estuary infaunal samples per core (0.013m^2). Statistically significant trends are indicated in bold. BLUE highlight for PAC indicates an improving trend, RED indicates a deterioration, GREY indicates no specific ecological significance with direction.

Site	Total number of species (S)		
	Long-term median	Trend p value	Percent Annual Change
Ahuriri A	7.00	0.663	0.00
Ahuriri B	5.00	0.847	0.00
Ahuriri D	4.00	0.190	0.00
Ahuriri E	**6.50**	**0.003**	**-15.37**
Porangahau	4.00	0.305	0.00
Wairoa	4.00	0.698	0.00

5.3.2 Margalef's richness and Peilou's evenness

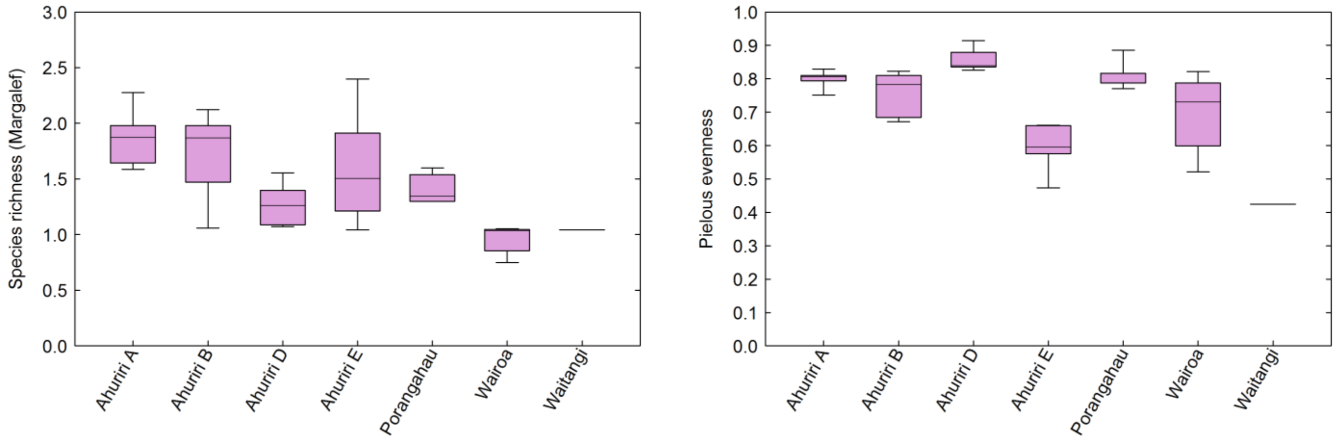


Figure 5-7: Margalef species richness (d) and Peilou's evenness (J) by estuarine site. 5 year medians (2009-2013), samples per core (0.013m²).

Unlike species richness measure described in figure 8-6, Margalef's richness also accounts for abundance of individuals within each species.

Patterns observed for Margalef's richness closely approximate those observed above with richness highest at sites Ahuriri A and B, which were 1.81 and 1.87 respectively, and lowest at Wairoa and Waitangi, which were 1.03 and 1.04, respectively. Richness appears to be significantly decreasing at site Ahuriri E, but increasing at Wairoa.

Table 5-15: Trend analysis of Margalef richness (d) in estuary infaunal samples per core (0.013m²). Statistically significant trends are indicated in bold. BLUE highlight for PAC indicates an improving trend, RED indicates a deterioration, GREY indicates no specific ecological significance with direction.

Site	Species richness (Margalef (d))		
	Long-term median	Trend p value	Percent Annual Change
Ahuriri A	1.76	0.310	1.63
Ahuriri B	1.49	0.498	-1.28
Ahuriri D	1.41	0.076	-5.20
Ahuriri E	**1.61**	**0.007**	**-11.67**
Porangahau	1.44	0.641	-0.73
Wairoa	**0.90**	**0.003**	**23.82**

As observed in Figure 5.6, Peilou's evenness was highest at Ahuriri D and Porangahau (0.84 and 0.82 respectively) and lowest at Ahuriri E and Waitangi (0.59 and 0.42 respectively).

Table 5-16: Trend analysis of Peilou's evenness in estuary infaunal samples per core (0.013m²). Statistically significant trends are indicated in bold. BLUE highlight for PAC indicates an improving trend, RED indicates a deterioration, GREY indicates no specific ecological significance with direction.

Site	Peilou's evenness (J)		
	Long-term median	Trend p value	Percent Annual Change
Ahuriri A	**0.80**	**0.005**	**1.75**
Ahuriri B	**0.78**	**0.011**	**-1.94**
Ahuriri D	0.88	0.851	0.16
Ahuriri E	0.59	0.099	-5.81
Porangahau	0.83	0.573	-0.38
Wairoa	**0.67**	**0.000**	**28.10**

5.3.3 Shannon and Simpson diversity

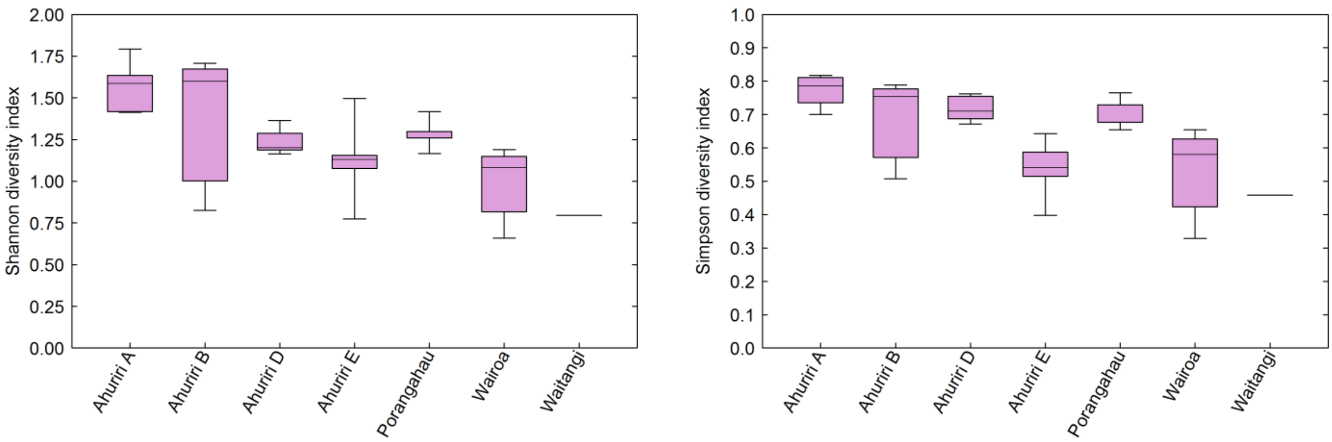


Figure 5-8: Shannon diversity and Simpson diversity index. 5 year medians (2009-2013).

As shown in Figure 8-8, Shannon diversity is highest at Ahuriri A and Ahuriri B at 1.53 and 1.60 respectively. Site Ahuriri E appears to have low, but variable diversity, with the lowest infaunal diversity observed in Waitangi and Wairoa estuaries, with scores of 0.80 and 1.08 respectively.

Ahuriri E reported a decreasing trend in Shannon diversity over the monitoring period, while diversity at Wairoa appears to be increasing. The decreasing abundance noted at Wairoa, when coupled with the increasing diversity and increasing Peilou's evenness (Table 8-13), indicates a shift towards a more diverse and resilient community.

Table 5-17: Trend analysis of Shannon diversity index for estuary infaunal samples per core (0.013m²). Statistically significant trends are indicated in bold. BLUE highlight for PAC indicates an improving trend, RED indicates a deterioration, GREY indicates no specific ecological significance with direction.

Site	Shannon diversity (H')		
	Long-term median	Trend p value	Percent Annual Change
Ahuriri A	1.53	0.164	1.53
Ahuriri B	1.33	0.187	-2.47
Ahuriri D	1.28	0.314	-2.04
Ahuriri E	**1.12**	**0.006**	**-11.09**
Porangahau	1.28	0.841	0.09
Wairoa	**0.90**	**0.000**	**32.94**

The similarities in the Shannon and Simpson indices are reflected in the similarity of the relative patterns (Figure 8-8). Simpson diversity appeared highest at sites Ahuriri A, Ahuriri B and Porangahau with scores of 0.76, 0.75 and 0.73 respectively, and lowest at Ahuriri E, Wairoa and Waitangi with 0.54, 0.58 and 0.46 respectively.

Simpson diversity and Shannon diversity both significantly declined at Ahuriri E, and significantly increased at Wairoa. A significant increase was also detected in the diversity observed at site Ahuriri A, which was not detected in the Shannon diversity trend analysis.

Table 5-18: Trend analysis of Simpson diversity index for estuary infaunal samples per core (0.013m^2). Statistically significant trends are indicated in bold. BLUE highlight for PAC indicates an improving trend, RED indicates a deterioration, GREY indicates no specific ecological significance with direction.

Site	Simpson diversity (λ)		
	Long-term median	Trend p value	Percent Annual Change
Ahuriri A	**0.77**	**0.005**	**1.70**
Ahuriri B	0.71	0.083	-1.96
Ahuriri D	0.73	0.192	-1.57
Ahuriri E	**0.53**	**0.021**	**-9.05**
Porangahau	0.7	0.394	-0.99
Wairoa	**0.491**	**0.000**	**37.58**

5.4 Multivariate Infaunal Analyses

The high variability of estuarine community assemblages through time was assessed using multi-dimensional scaling (MDS). Although this approach did not show division of the years (excepting Wairoa – as indicated by the relatively high 'stress[4]' results, possibly due to short sampling period), a PERMANOVA detected significant differences in the community structure between years for individual sites (Table 8-19). *A posterior* pairwise comparison determined which years were significantly different.

Table 5-19: PERMANOVA results examining the effect of year on individual sites. All data ln(x+1) transformed and based on Bray-Curtis similarity.

Site	PERMANOVA (Site by Year)		
	SS	p(perm) value	Pairwise
Ahuriri A	74408	0.001	All (25/28) except 2009:2012,13, 2012:2013
Ahuriri B	55606	0.001	All (24/28) except 2007:2008,13, 2009:2011, 2012:2013
Ahuriri D	23905	0.001	All (10/15) except 2009:2011,12,13, 2011:2012, 2012:2013
Ahuriri E	20302	0.001	All (9/10) except 2009:2011
Porangahau	77374	0.001	All (27/28) except 2012:2013
Wairoa	19299	0.001	All years

A two-way PERMANOVA on the combined dataset revealed significant differences between all years and all sites, with a significant interaction factor indicating that each site was affected differently by year (table8-20).

Table 5-20: PERMANOVA results examining the effect of year and site. All data ln(x+1) transformed and based on Bray-Curtis similarity.

Factor	PERMANOVA (All Sites/All Years)		
	SS	p(perm) value	Pairwise
Year	109330	0.001	All years significantly different
Site	458660	0.001	All sites significantly different
Year*Site	180310	0.001	'Year' affects sites differently

A SIMPER analysis was undertaken using the complete dataset (all sites, all years) based on the factor site. SIMPER analysis identifies the importance of specific taxa in accounting for the variability between individual sites. The species that 'characterise' a particular site contribute to at least 90% of the cumulative similarity of each of the replicates within that site.

The species that characterise sites where mud content is relatively low (sites Ahuriri A and Ahuriri B) tend to be intolerant of, or sensitive to, muds. *Macomona liliana* (wedge shell) prefers mud concentrations around 16.7%, while the cockle *Austrovenus stutchburyi*, an optimal concentration of 11.5% (Anderson 2007). Interestingly, at those sites where mud concentrations were moderate-high (~20-30% - Ahuriri D and E), *Austrovenus stutchburyi* were still fairly abundant. However, at these sites, species that more commonly reach optimal abundance with higher mud concentrations such as *Helice crassa* (41.2% (Anderson 2007)),

[4] 'Stress' levels in MDS represent a 'goodness of fit' of the data to the model.

Arthritica bifurca (55-60%) *Scolecolepides sp.*(25-30%) and *Paracorphium excavatum (95-100%)* (Norkko 2002)) were also species that explained over 90% of the variability within the site (Appendix C).

5.5 Species Distributions across Mud Gradients

As shown by the SIMPER anlaysis (Appendix C), Ahuriri E contains species both sensitive to high mud content (e.g. *Austrovenus stutchburyi* and *Notoacmea helmsii*), as well as those typical of more sediment disturbed areas (e.g. *Helice crassa* and *Scolecolepides sp.*). This sites has the highest abundance of cockles of all the sites sampled and also contains significant portions of shell hash (broken shell ~17.2%) which may act to moderate some of the effects of the muds.

This is supported by site Ahuriri E being the only site with moderately high mud content to contain significant numbers of cockle (*Austrovenus stutchburyi* Figure 5-9).

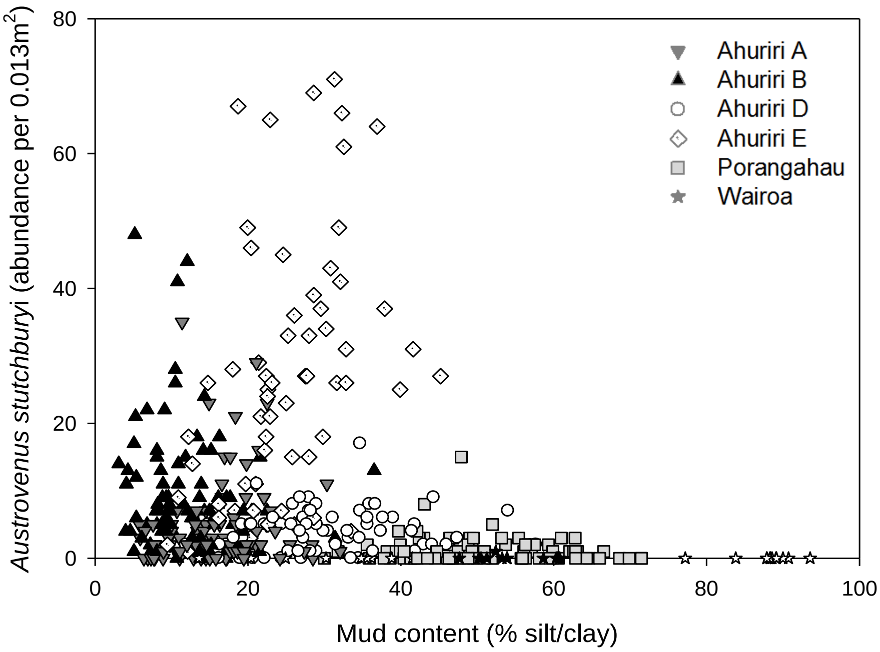


Figure 5-9: Abundance of cockle (*Austrovenus stutchburyi*) per core in relation to mud content (% silt/clay). .

In general all species/site relationships corresponded well to those expected for varying silt/clay (mud) concentrations. For example, mud-sensitive species such as *Aonides trifida* and *Macomona liliana* mostly appear in high abundance at sites where mud content are less than 25% (Figure 5-10, Figure 5-11). This indicates species may be lost in Hawke's Bay estuaries when mud concentrations exceed 25%. These species are valued as an important food source for fish and birds, and play an influential role in the community and ecosystem dynamics including nutrient cycling (Thrush 2006) and bioturbation (Volkenborn 2012), therefore loss of these species can have concomitant effects of site health and integrity.

Mud tolerant species such as the spionid polychaete *Scolecolepides* spp. again follow expected patterns with the highest concentrations found at Porangahau Estuary, and at other sites with mud content around 35%-70% (Figure 5-12). This is slightly higher than the published optimal range for this species at 25%-30% mud (Norkko 2002). The Porangahau results are an outlier, with the remainder of the abundances well within the published optimal range.

Deposition of land-sourced sediment also affects macrofaunal assemblages. Sediment deposition events leaving as little as 3 mm of sediment <63µm in size, can have observable effects on the community structure (Lohrer 2004).

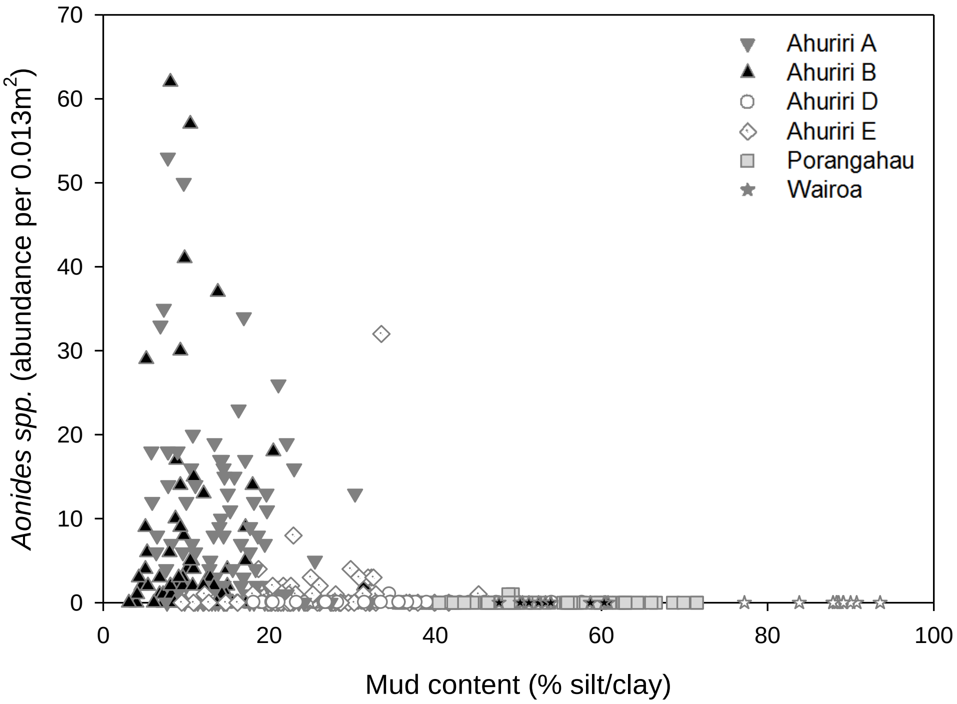


Figure 5-10: Abundance of *Aoinides* sp. per core in relation to mud content (% silt/clay).

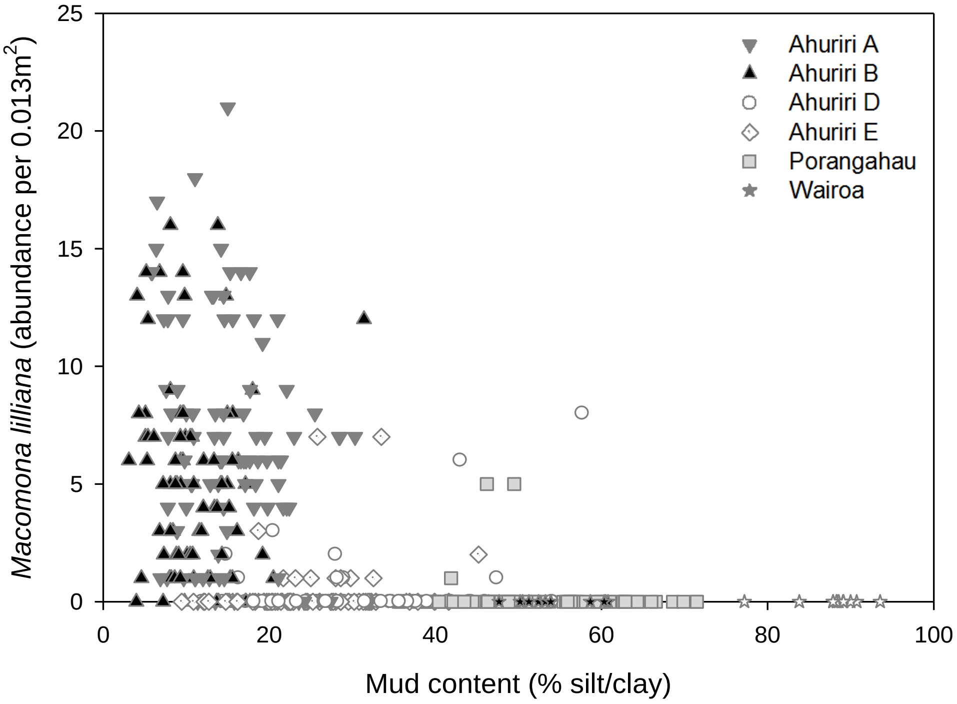


Figure 5-11: Abundance of the bivalve *Macomona liliana* per core in relation to mud content (% silt/clay).

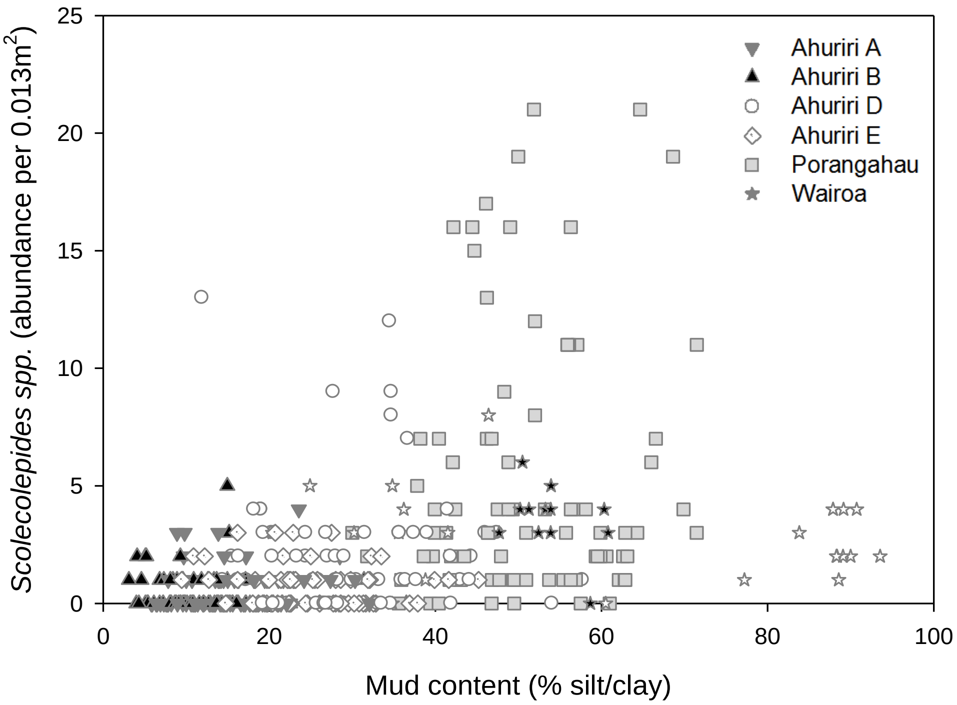


Figure 5-12: Abundance of the spionid polychaete *Scolecolepides* sp. per core in relation to mud content (% silt/clay).

5.6 Traits Based Index (TBI)

The functional Traits Based Index (TBI) uses richness of macrofaunal taxa in several different functional trait groups. The TBI can be used as a measure of health for an estuary as it is an approach to quantifying resilience within a community. Taxa are categorised based on functional trait categories including: size, position in the sediment, shape, mobility, feeding mode, sediment reworking and type of topographic feature created (e.g. pits, tubes etc). The score for a taxon depends on the number of functional groups it contributes to, and is standardised to a score between 0 and 1, where scores close to 1 indicate high functional redundancy (resilience) and scores close to 0 indicating low functional resilience, and therefore high risk of loss of function from loss of particular species.

The TBI has not yet been tested in Hawke's Bay however an initial analysis has shown a close relationship between TBI score and mud concentrations (Figure 5-13). This initial application still requires verification and improved understanding of how a 'reference' condition in Hawke's Bay may score, however the results appear to represent ecosystem health as a function of mud concentrations well. Compared to other analysed estuaries (*see* Rodil 2013), the overall scores for Hawke's Bay appear low (<0.3), however further work needs to be undertaken to determine whether reference with other regions is appropriate.

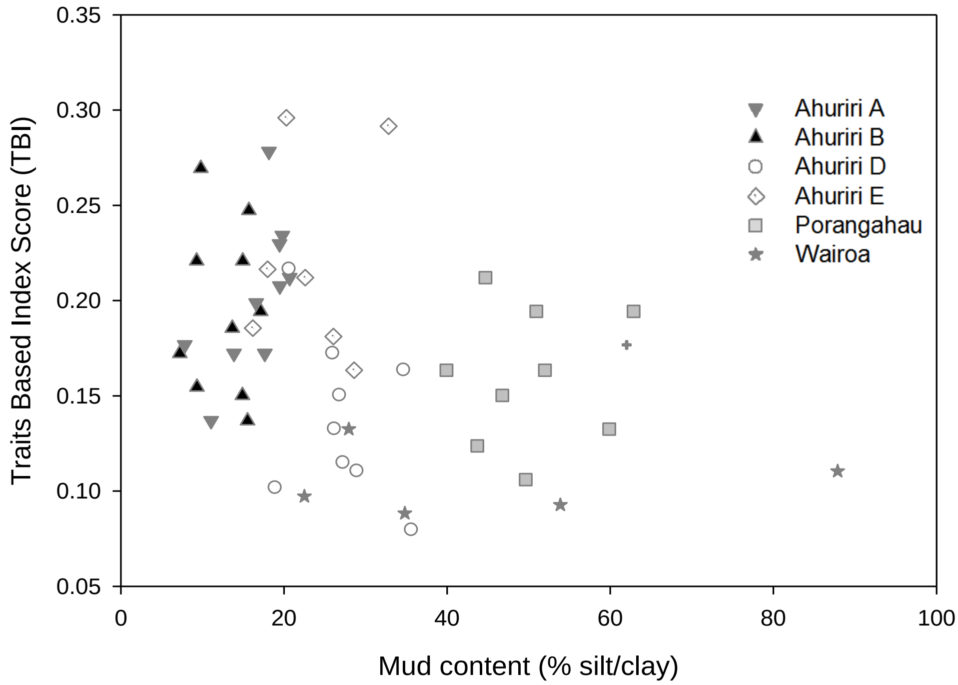


Figure 5-13: Function Traits Based Index (TBI) of Hawke's Bay estuaries and mud content (% silt/clay).

5.7 Conclusions

- There was evidence of moderate sediment stress at sites in the middle Ahuriri Estuary (Ahuriri A and B), with higher levels of sediment stress likely at sites in the lower Ahuriri (Ahuriri D and E), Porangahau, Wairoa and Waitangi Estuaries.
- There were increasing silt/clay fractions (‘muddiness’) at all sites excluding Ahuriri E and Wairoa. No trend is available for Waitangi as the record is too short.
- Sediment nutrient levels do not appear excessive, however a localised source for phosphorus is evident at site Ahuriri D and places this site in a FAIR category (Stevens, 2013).
- Sediment trace metal levels appear well within ANZECC interim sediment quality guidelines for all sites excluding Ahuriri D. At these sites adverse ecological effects would be expected rarely.
- Site Ahuriri D shows significantly higher levels of zinc, lead, cadmium, chromium, and copper. While median levels appear to fall within guideline values, individual samples exceed concentrations, and adverse ecological effects could be expected occasionally.
- The infauna associated with individual estuary sites appears to be responding to mud concentrations. Species reported as intolerant of higher mud fractions are largely absent from sites where mud concentrations exceeds 25% (e.g. *Aonides trifida, Macomona liliana).*
- A Traits Based Index (TBI) applied to the sites corresponds closely to concentrations of mud (silt/clay) indicting a reduction in the resilience of sites as mud concentration increases.
- Overall ‘Poor’ scores in the TBI compared to other regions are unable to be explained at this time.

6 Sandy beaches

Sandy beaches are the most common coastal habitat in Hawke's Bay, making up 48% of the coastline (Stevens and Robertson 2005). The biota within this environment face pressures due to tidal inundation and subsequent changes in oxygen, temperature and salinity, and varying wave force and swash environments. Additional pressures associated with coastal development, increased stormwater and wastewater flows, people and vehicle traffic can compromise the integrity of these communities, and reduce the ecosystem services provided by – and the resilience of – these habitats.

Recognition of the role sandy beach ecosystems play has generally lagged behind the understanding of other coastal environments (Defeo 2005). In addition to protecting the terrestrial edges from the sea, sandy beaches support a range of fauna and coastal fisheries. They cycle nutrients, filter large volumes of seawater and provide crucial nesting and foraging habitat (Schlacher 2007).

Natural environmental pressures associated with sandy beach ecosystems can sometimes be augmented or even eclipsed by the effects of both on-beach and adjacent land-based activities.

6.1 Long-term SoE monitoring

Monitored beaches were selected (Table 6-1) to represent soft-sediment ecosystems within the Hawke's Bay region. Selection was guided by the results of an inventory of beach and reef systems within Hawke's Bay (Madarasz-Smith 2007).

Sites were selected according to the following criteria:

- Beach type being suitable for monitoring over time;
- Contributing to regional knowledge of soft-sediment communities;
- Likelihood of development in the short to medium term; and/or
- Beaches subject to other pressures that, when monitored, would help understand how effective the Regional Resource Management Plan was.

Table 6-1: Sandy beach sites included in the Sandy Beach Monitoring Programme.

Beach	Sampling years	Mean Wave Height[5]	Sediment type	Development status
Mahanga	2007;2008;2013	Moderate	Medium	Existing baches and new development approved
Opoutama	2009-2013	Moderate	Medium/Coarse	
Ocean Beach	2007;2008;2013	Moderate/ High	Medium	Existing baches to the south, no current development plans to the north.
Waimarama	2008;2009	Moderate	Medium	Existing development, more pending, semi-urban.
Pourerere	2009;2010;2011;2012	Moderate/ High	Medium	Existing baches
Blackhead	2007; 2008; 2013	Moderate/ High	Medium	Small settlement of existing baches. Blackhead beach forms the southern end of the Te Angiangi Marine Reserve.

[5] Derived from the Sandy Beach and Rock Platform Inventory found in the Hawke's Bay Coastal Inventory Report (2007)

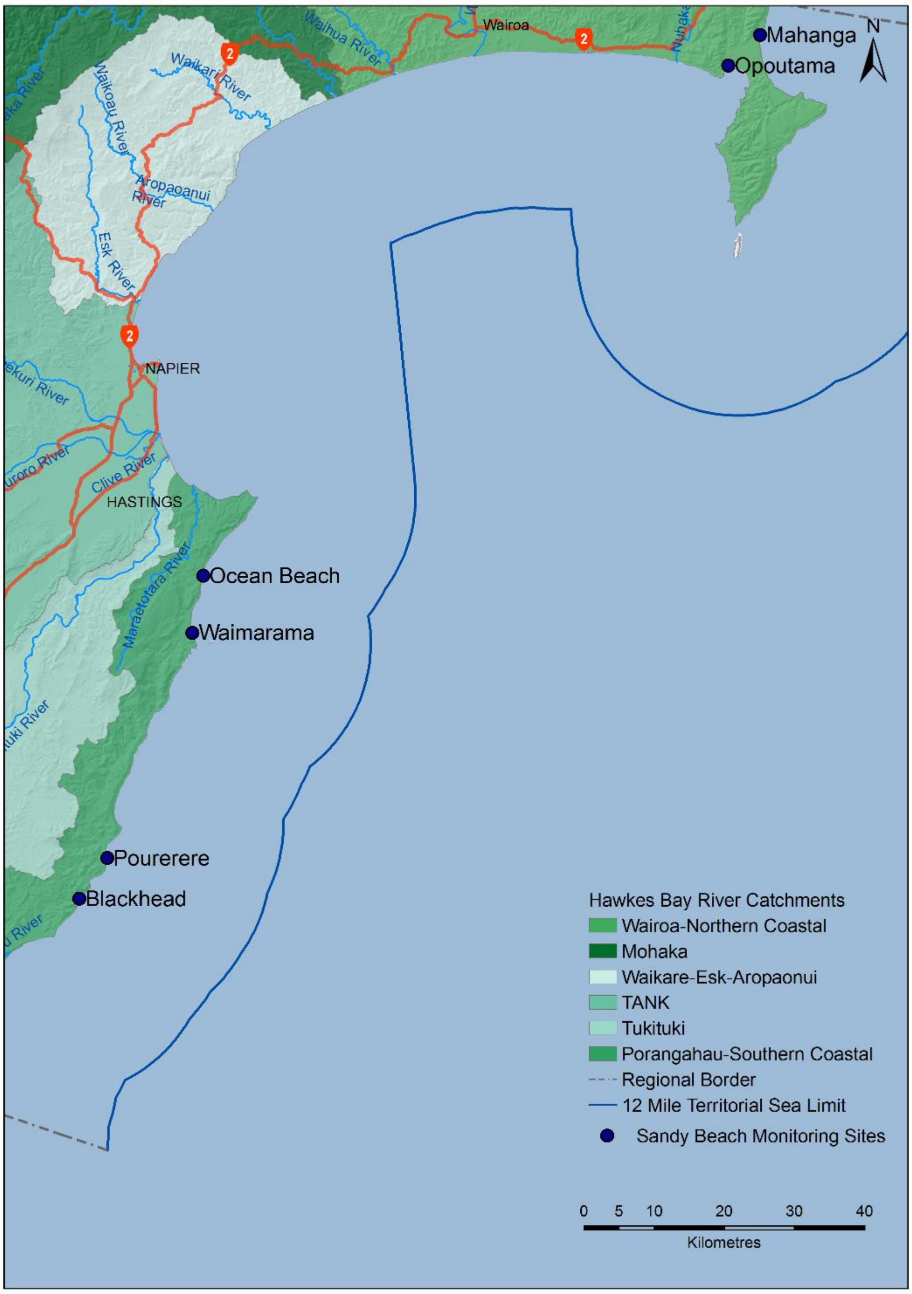


Figure 6-1: Map of sites included in the Sandy Beach Monitoring Programme as at 2013.

Sampling at the selected beaches (Figure 6-1) was designed to provide comparable information around the infaunal communities at different tide heights, years and where applicable, different levels of anthropogenic development.

The initial aim of the sandy beach ecological monitoring programme was to provide information for trend detection in future years (see Madarasz-Smith 2007). However, results of inaugural sampling indicated low-abundance, highly variable communities, which would not be suitable for detecting trends over time in a statistically robust fashion. As a consequence the objectives of the study were changed in 2008 to provide a robust baseline inventory (see Madarasz-Smith 2008).

Sample collection methods for the sandy beach ecological monitoring programme are outlined in detail in (Madarasz-Smith 2007, Madarasz-Smith 2007).

One of the biggest threats to sandy beach ecosystems is vehicle traffic, and the passage of vehicles can have negative impacts on populations of infaunal species (see Taylor, Marsden and Hart 2012) and sand dune systems (Stephensen 1999). The impact of vehicle traffic on the beaches of Hawke's Bay is currently unquantified. All the beaches included in this monitoring programme are regularly exposed to vehicular traffic and there are very few beaches within the region that are not accessible by vehicle which could be used as a control site.

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6.2 Data summaries and visualisation

Boxplots (see Section 2.1.2) were used to visualise basic diversity indices.

A SIMPER analysis was undertaken using the complete dataset (all sites, all years) based on the factor site. SIMPER analysis identifies how important specific taxa may be in accounting for the variability between individual sites. The species that 'characterise' a particular site contribute to $\leq$90% of the similarity (Appendix E).

A stacked bar chart is also used as a simple way to visualise the difference between the infaunal communities at each beach. This bar chart groups the species together into animal groupings (Figure 6-3). These are marine worms; crustaceans; bivalves; marine snails and other. The relative contribution of these groups to the whole community is displayed.

6.3 Community composition

The concentration of infauna at the sampled sites was generally low in species richness and there were few individuals present (Figure 6-2). Cores enumerated in the low intertidal zone generally had higher diversity than those collected in the mid intertidal zone.

The SIMPER analysis (Appendix E) suggests that at most sites *Waitangi chelatus* was the most prevalent species. *Waitangi chelatus* are crustaceans and the prevelance of this species, combined with the presence of many other crustaceans, means that at most of sites crustaceans are the dominant animal group (Figure 6-3).

The most common bivalve species was the tuatua (*Paphies subtriangulata*), present at all beaches except Blackhead, and was the dominant species at Mahanga Beach (Av. Abundance = 0.6/core). Bivalves were also common at Waimarama where *Paphies subtriangulata* was accompanied by the cockle *Austrovenus stutchburyi*. Waimarama had the highest relative abundance of bivalves compared to other beaches (Figure 6-3).

The community composition at Opoutama Beach appears to be quite different from the other beaches, with the SIMPER showing the cores were dominated by the polychaete worm *Glycera ovigera*, green mussel *Perna canaliculus* spat, and nematode worms. The community composition at Opoutama is likely to be driven by its natural depositional nature. The movement of the currents within Hawke's Bay bring large amounts of organic material to Opoutama beach in the form of marine algae, wood chips and other material. This depositional environment is the probable cause of Opoutama being the only beach where *Perna canaliculus* spat were found. The prevalence of *Glycera ovigera* is also related to the depositional environment. This species is a carnivorous polychaete worm which feeds on other smaller worms such as *Nematoda sp*.

Nematoda are present in large numbers. They are detrital feeders that play important roles in breaking down organic material that comes ashore at Opoutama beach.

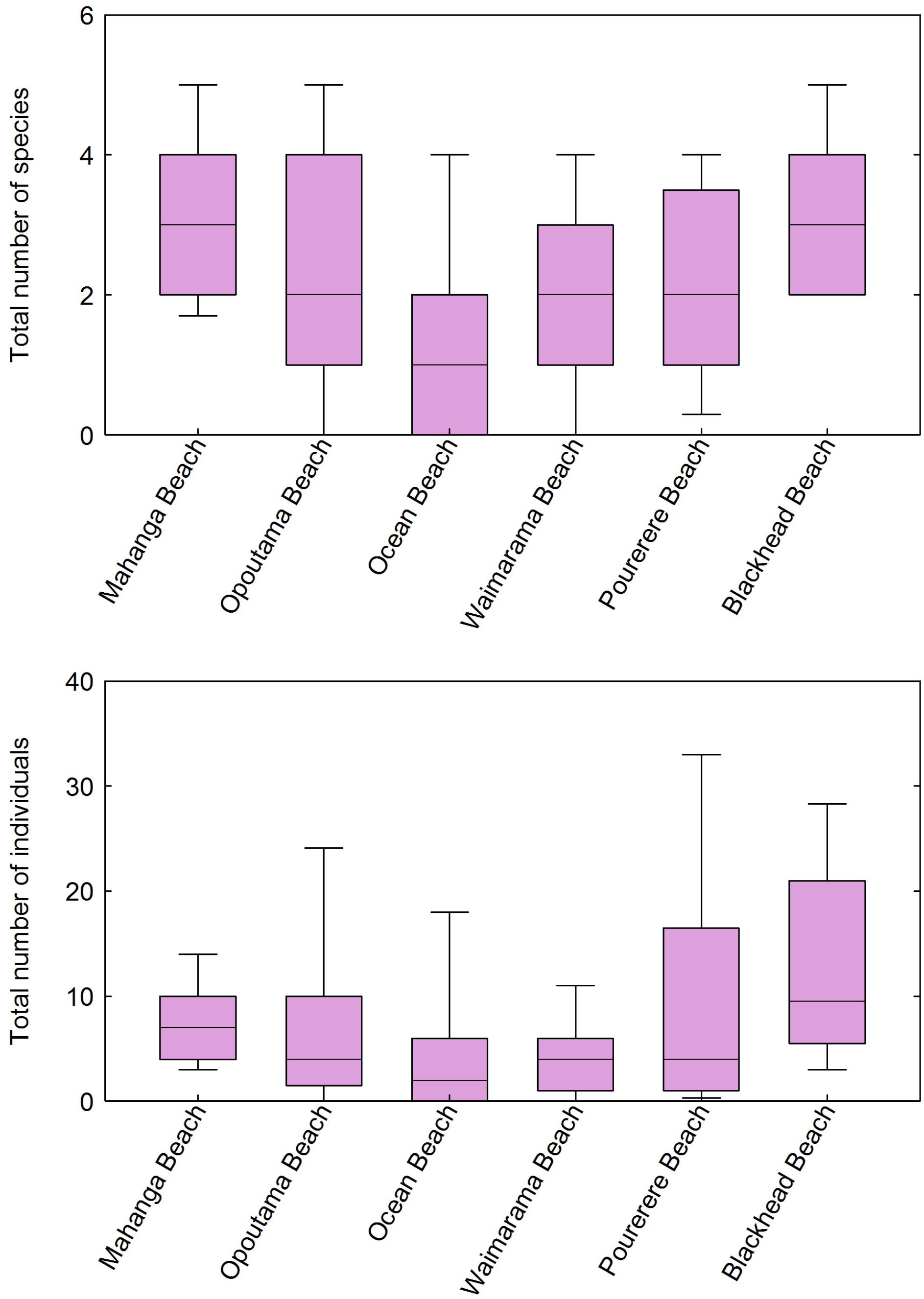

Figure 6-2: Total number of individuals and species by beach

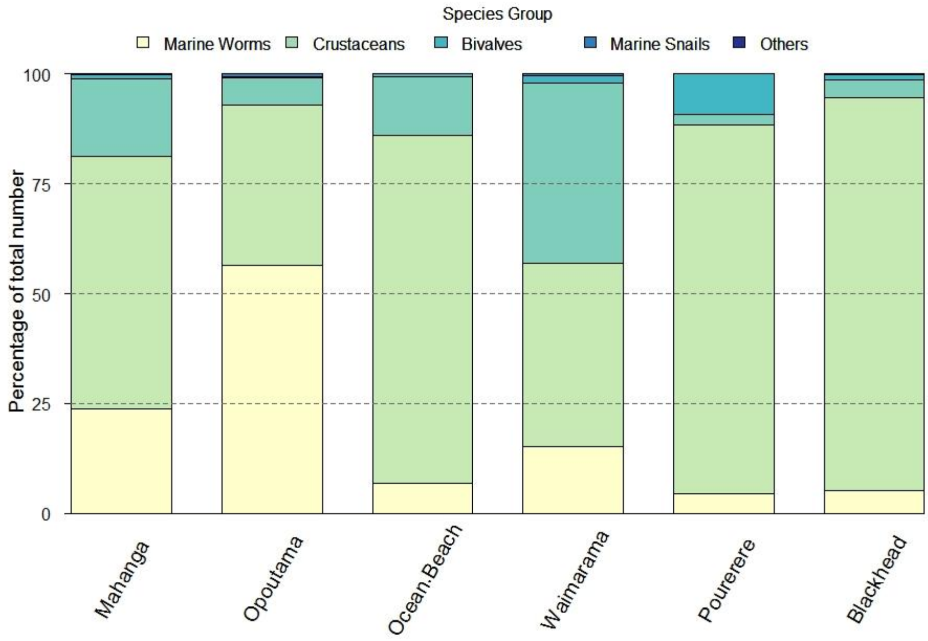

Figure 6-3: Relative contribution (percentage) of different animal groups to the infaunal community at each site.

No differences were detected between control and developed sites. This suggests that interannual variability driven by environmental variables has more of an influence on sandy beach infaunal community composition than anthropogenic influences.

6.4 Conclusions

- Infaunal community composition is highly variable. Natural variability has a more significant influence than year or development status.
- At most beaches the infaunal community is dominated by amphipod crustaceans.
- The depositional nature of Opoutama beach has had a large influence on the infaunal community composition.
- Waimarama beach has a much higher abundance of bivalves than other beaches.
- More emphasis is required on monitoring the abundance and distribution of bivalve species given their environmental and cultural importance as kaimoana species.

7 Intertidal reefs

The Hawke's Bay coastline contains a variety of reef systems, from extensive flat papa (blue mudstone or fine sandstone) platforms to high relief boulder structures. The major reef platforms are generally located south of Cape Kidnappers and at Mahia Peninsula, with reef also found in the centre of Hawke Bay between Tangoio and Waikare. 42 % of Hawke's Bay's coastline is classified as rocky reef ('rockfield' and 'boulder field') (Stevens and Robertson 2005).

Reefs are diverse and important habitats that provide for a large variety of macro-algae, invertebrates, fish and birds (Cresswell and Warren 1990). They underpin much of the coastal fishery providing spawning habitat, settling habitat for larvae, nursery and feeding habitats for a variety of species. The diversity of these habitats is driven by the harsh and dynamic climatic conditions that they are exposed to. Organisms that inhabit these areas must acclimatise to regular periods of exposure to air and sunlight and cope with the constant pressure of energetic wave forces.

Intertidal reefs are exposed to a variety of biological and human induced pressures. Hawke's Bay's intertidal reefs, particularly the southern reefs, are popular areas for shellfish gathering, specifically for paua (*Haliotis iris)*, crayfish (*Jasus edwardsii*) and kina (*Evichinus chloroticus*). This gathering pressure can lead to a reduction in biomass of these key reef species. There is also potential disturbance to the intertidal reef ecosystem through trampling, overturning of rocks (Hardinge Road) and vehicles being driven on reefs.

Another anthropogenic influence on intertidal reefs is their susceptibility to invasion by exotic species. Of the three reefs surveyed, Hardinge Road is at the biggest risk from exotic species due to its proximity to Napier Port, which is a potential pathway for pest introduction from ocean-going vessels. Invasive wakame (*Undaria pinnatifida*) and the brown algae (*Colpomenia sinuosa)* are already well established on this reef. Other invasive species that have not been detected but are a potential threat are the Mediterranean fanworm (*Sabella spallanzanii*) and the sea squirt (*Styela clava*). The main potential threat posed by these species is the displacement of native species.

One of the greatest threats to intertidal reefs is sedimentation. Hawke's Bay, with its highly erodible geology and limited tree cover is particularly susceptible to this problem. However, energy from swells and tides can mitigate these effects by quickly moving sediments offshore into deeper areas. Increased turbidity can reduce photosynthesis, and reduce overall productivity, and deposited sediment can decrease the amount of space available for new recruits in a system where space for settlement is premium.

Many reef species can be susceptible to changes in water quality. Reductions in water quality can occur through increased levels of suspended sediment, increased freshwater inputs and elevated levels of contaminants through stormwater inputs. The susceptibility of species to these pressures is varied however decreased water quality can change the community structure of reef systems (Bellgrove 2010).

7.1 Long-term SoE monitoring

Sampling sites were selected to represent the different intertidal reef structures typical of Hawke Bay. Sites were geographically spread across the region and are exposed to varying levels of anthropogenic impacts. A description of the differing coastal environments of Hawke's Bay can be found in Stevens and Robertson (2005).

Sampling was conducted on intertidal reef areas at Kairakau, Hardinge Road and Te Mahia (Figure 7-1) to collect information on the number and percentage cover of all macroscopic (>4mm) fauna and flora present on the reefs.

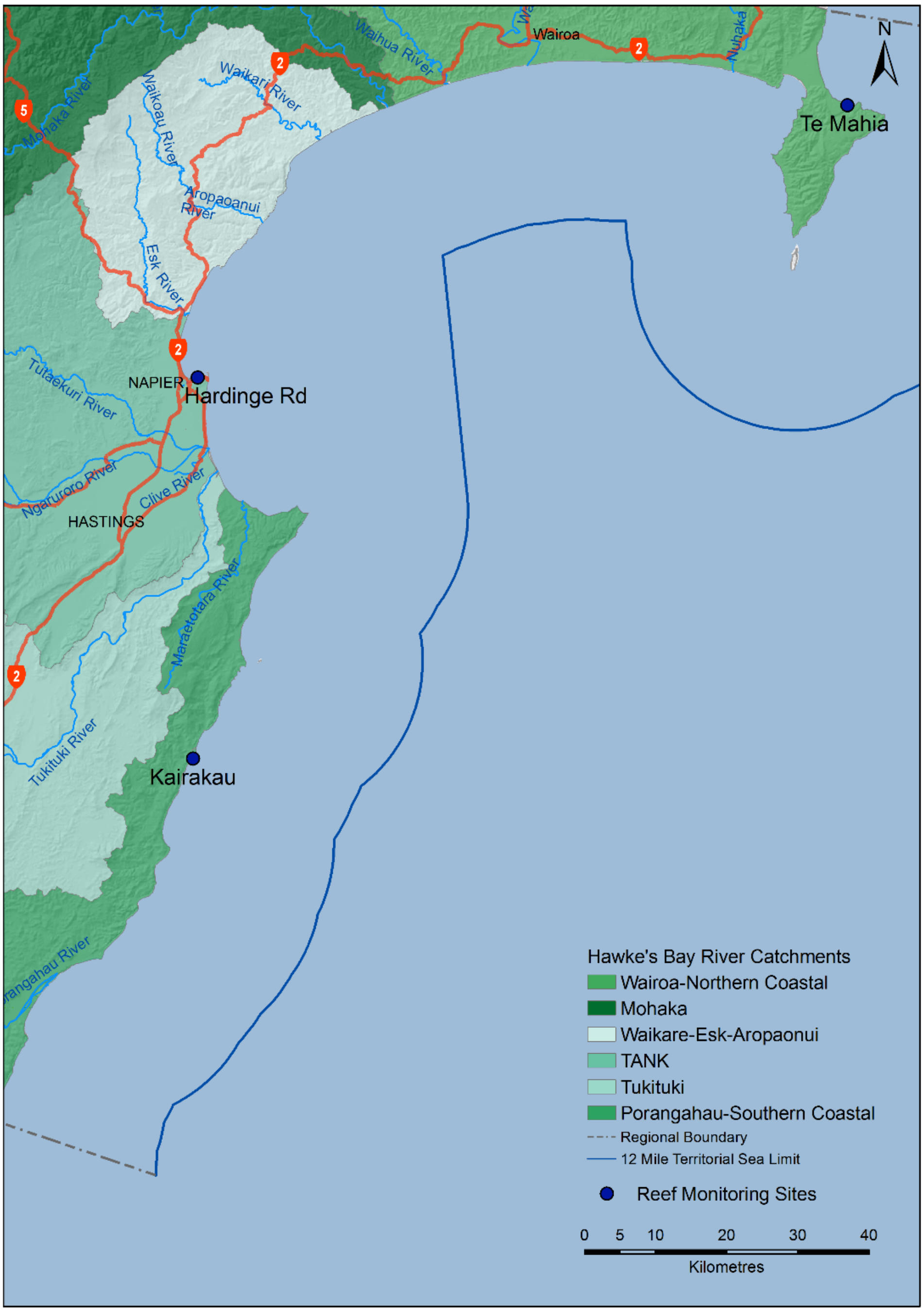

Figure 7-1: **Reef monitoring locations.**

Sampling dates were chosen to target particularly large low tides (height ≤ 0.1 m above Mean Sea Level) at an appropriate time to allow the maximum amount of time for sampling.

Each reef is visited seasonally (quarterly) to account for seasonal changes in community composition (see Table 7-1 for sampling dates). The community composition was initially only described in the low and mid intertidal zones however the upper intertidal zone was added at each site through the year.

Table 7-1: Details of reef sampling locations and dates.

Reef	Date	Season	Tidal Zone Monitored
Te Mahia	11th January 2013	Summer	Low
	26th April 2013	Autumn	Low
	23rd July 2013	Winter	Low, Mid
	8th October 2013	Spring	Low, Mid, Upper
Hardinge Road	14th January 2013	Summer	Low, Mid
	30th April 2013	Autumn	Low, Mid, Upper
	22nd July 2013	Winter	Low, Mid, Upper
	9th October 2013	Spring	Low, Mid, Upper
Kairakau	10th January 2013	Summer	Low, Mid
	29th April 2013	Autumn	Low, Mid, Upper
	24th July 2013	Winter	Low, Mid, Upper
	7th October 2013	Spring	Low, Mid, Upper

The intertidal extent of the reef at each site was assessed at low tide by marking the landward and seaward edges of the reef. These coordinates were recorded using a handheld Global Positioning System (GPS) unit (Garmin GPS 60 with ± 4 m accuracy). By placing a tape measure across the intertidal extent of the reef in a straight line, a cross shore transect was formed. A visual assessment of the cross-shore reef topography and species zonation was then conducted. Topographical features and the location of dominant algal flora, sessile and mobile invertebrates were recorded.

Community assemblages on all reefs were surveyed using a stratified sampling design. The reef was divided into 3 strata, representing the low, mid and upper intertidal zone. The survey took place along three longshore (parallel with shore) transects, representing the low, mid, and upper intertidal sections of the reef. The starting locations for each transect at all sites were selected using a 2 stage process. Firstly, with the use of a tape measure, the intertidal extent of the reef was measured and divided into 3 zones of equal size (representing upper, mid and low intertidal). Secondly a point along the tape measure within each intertidal areas that was representative of algal species in those zones was selected. At each point another tape measure was laid out for 20 m parallel to the shore. These formed the upper, mid and low intertidal longshore transect. The start and the end point of the 3 transects was then recorded using the GPS unit and a photograph was taken of each transect.

The intertidal transects extended for 20 m from the starting location on the down shore transect. The first 1 m^2 quadrat of the alongshore transect was placed with the mid-point of the quadrat edge on the start point. The 1 m^2 quadrat was placed at 2 m intervals along each transect to make up 10 quadrats in total. Macroscopic flora and fauna were identified and classified to the lowest practical taxonomic grouping for each quadrat.

Proportional cover of macroalgal species and density of mobile invertebrates were assessed in a 2 dimensional space by only including those species directly visible without disturbing the algae cover or turning rocks. A digital photograph was taken of each quadrat to allow for verification of recorded cover and counts.

7.2 Site characterisation

Trend analysis cannot be conducted on the data because the time series are not long enough. The current report instead focuses on describing intertidal reef community composition.

7.2.1 Te Mahia

The Te Mahia rock platform is on the northern side of Mahia Peninsula. While the northerly orientation of this coastline protects it from the large southerly swells that impact the Hawke's Bay coastline, it is still exposed to regular periods of north and easterly swells. This reef is an important resource for local people, as both a food gathering area and a place of recreation.

The reef at Te Mahia is a broad, flat, siltstone platform that extends up to 500 m out to sea at its widest point (Figure 7-2). Most of the reef is covered in *coralline* turfs that trap sandy sediment and provide an environment for epiphytic algae.

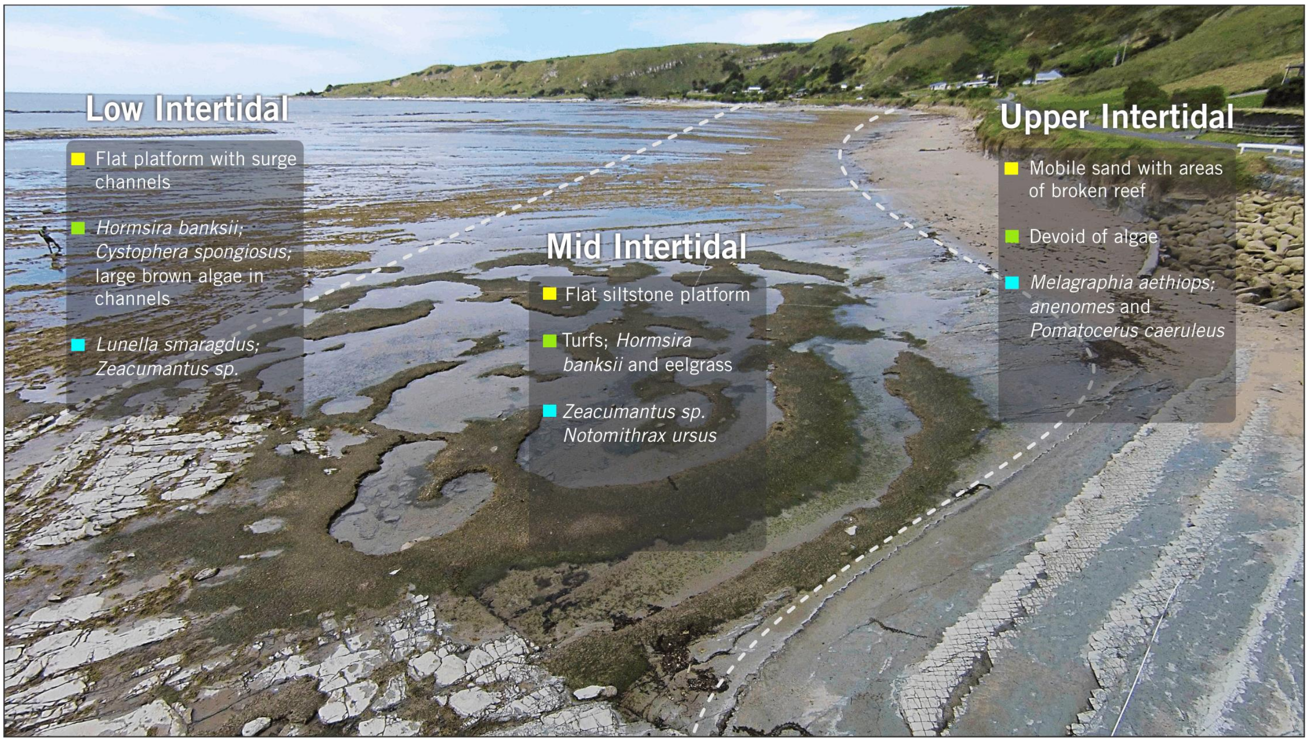

Figure 7-2: Tidal zonation of species at Te Mahia reef monitoring site.

This flat topography of the reef means that the platform drains almost entirely at low tide. There are occasional boulders or outcrops to provide shelter for large numbers of invertebrates. Most invertebrates on the reef are either highly mobile (Pagurus *sp.*) or well camouflaged (*Notomithrax ursus*). The exception to this was large concentrations of Zeacumantus *sp.* recorded during the spring sampling round.

The algal community almost entirely covers the reef, with very little bare substrate in the mid and low intertidal zones. The community is dominated by *Coralline turf*, *Hormosira banksii* and *Cladostephus spongiosus* with seasonal epiphytic Lyngbya *sp.* These are the only incidences of *Cladostephus spongiosus* and Lyngbya *sp.* recorded in this monitoring programme.

Large brown algae are in those parts of the reef that stay permanently wet, with *Cystophera torulosa* and *Carpophyllum plumosum* occupying the surge channels. There is also a moderate sized patch of Zostera *sp.* in the mid intertidal zone which is the largest patch of Zostera *sp.* on the Mahia coastline.

The prevelance of Lyngbya *sp.* throughout the low intertidal zone is of interest. This genus has not been found anywhere else in Hawke's Bay and it appears to be most common at Te Mahia in autumn and winter. This potential seasonal variation will be examined with further sampling. Lyngbya *sp.* is a naturally occurring form of marine cyanobacteria which has been known to cause human health issues when found in large amounts, and which can also cause ecological issues. While the Lyngbya *sp.* bloom in Te Mahia is of a low volume, it is persistent, and its relevance as a description of system health should be identified.

The mid intertidal transect was located to include the Zostera *sp*. At present the extent of some of this area is monitored but the condition of the overall patch is unclear. It is necessary to develop an effective method for monitoring patch size and condition of this important habitat.

The upper intertidal transect is located on a raised area of rocky reef. This area is devoid of life except for in pools and overhangs where some relief from the sun is offered.

7.2.2 Hardinge Road

Hardinge Road is located in the Ahuriri district of Napier (Figure 7-3). This reef is unusual in Hawke's Bay because it is mostly man-made. The reef is the site of the old landing wharf that was decommissioned when the new breakwater harbour for the Port of Napier was built. This wharf has degenerated, and the coarse limestone boulders that were once fill for the wharf have spread across the foreshore, creating the reef. These boulders are interspersed with areas of cobble and gravel. Due to its northerly aspect, the reef is protected from most of the large swells that enter Hawke Bay. The limestone boulders are quite small (< 50 cm), and potentially mobile, creating a very dynamic reef structure. The high relief structure of this reef supports a wide range of algae and invertebrate species in large numbers.

Figure 7-3: Tidal zonation of species at Hardinge Road monitoring site.

The Hardinge Road reef adjoins the well-populated residential suburb of Ahuriri and is a popular recreational area. Situated between the mouth of the Ahuriri estuary and the port of Napier, this area is commonly used for swimming, the recreational collection of shellfish and surfing. The impact of negative anthropogenic effects such as trampling, fishing pressure, decreased water quality, and the probability of introduction of exotic species at this site, is high.

The reef at Hardinge Road is relatively narrow (less than 50 m at low tide) and steep (1:20 gradient) compared to Te Mahia and Kairakau. The reef is composed of limestone boulders with patches of sand and gravel. This environment offers habitat for a large variety of invertebrates and small algal species.

Similar to Te Mahia, large numbers of *Zeacumantus* sp*.* were observed in the mid intertidal zone. The high relief structure of the reef also holds large numbers of *Lunella smaragdus*, *Melagraphia aethiops, Patiriella regularis*, chitons and *Onchidella negricans. Onchidella negricans* is a small sea slug that is a generalist herbivore (Alfaro 2009). Although sometimes found in high concentrations here - especially in the upper intertidal zone - it was not recorded at either of the other reefs.

Hardinge Road reef had the highest mean proportion of bare rock per quadrat (28.4%) and also a far higher mean proportion of pebble/gravel per quadrat (39.1%) than the other reefs. This relatively high proportion of bare substrate could be a combination of the relatively mobile substrate here preventing settlement and the large numbers of invertebrates resulting in increased grazing pressure.

The mobile nature of the reef has also resulted in an algal community characterised by turfing and encrusting species rather than large algaes. The community is dominated by coralline turfs*, Gigartina* sp*., Apophoea sinclairii* and *Ralfsia* sp*.* There is a conspicuous absence of *Hormosira banksii* (Neptune's necklace) which is usually associated with corraline turf. The zone that is typically occupied by *Hormosira banksii* appears to be occupied by *Gigartina* turf. Given the prevalence of *Hormosira banksii* elsewhere in Hawke's Bay, it is conceivable that some disturbance or a reduction in water quality has removed the *Hormosira banksii* in this area. In Australia, Bellgrove et al. (2010) have recorded the deleterious effect of wastewater on *Hormosira banksii* communities and their inability to recolonise due to competition from coralline turfs*.*

Hardinge Road reef is bordered by Napier Port to the east and Ahuriri inner harbour to the west. It is therefore highly exposed to potential incursion of exotic species from vessels. This is evident from the prevalence of *Undaria pinnatifida* in the low intertidal and sub tidal zones and the prevalence of *Colpomenia sinuosa* during autumn and winter.

The most obvious difference between Hardinge Road reef and the rest of Hawke's Bay is the absence of *Hormosira banksii.* While the absence of a species is not at first glance important, it may be symptomatic of stressors on an ecological system. Unfortunately it is unknown if *H. banksii* was present historically on this reef system. *Hormosira banksii* plays an important role in the mid intertidal zone of the other two reefs reported on here. It is generally the only large brown algae present in this zone and provides important refugia for invertebrates and shading for sub canopy species.

7.2.3 Kairakau

The Kairakau intertidal reef system is typical of the reef platforms of central and southern Hawke's Bay (Figure 7-4). The broad mud and siltstone (papa) platform features large pools and broken surge channels that support biologically diverse intertidal communities. Kairakau reefs are recognised as having very high wildlife values (RCEP, 2006).

The area is identified as a Significant Conservation Area in the HBRC's Regional Coastal Environment Plan (2002). Objectives for the area include:

- Maintenance of the habitat of the intertidal communities found on the platform;
- Prevention of any irreversible reduction in the aerial extent of the *Zostera* beds due to human activity; and

▪ Minimization of disturbance to wildlife.

This sampling site is fairly remote being 2 km from Kairakau settlement and 1 km from Mangakuri settlement.

Figure 7-4: Tidal zonation of species at Kairakau reef monitoring site.

The broad papa platform at Kairakau is scattered with outcrops, boulders, channels and pools, providing a range of habitats for invertebrates and algal species.

The invertebrate community here is characterised by large numbers of *Lunella smaragdus* and *Melagraphia aethiops.* There were also high concentrations of *Pagurus sp.* and chitons.

The Kairakau reef is generally wetter than the other reefs at low tide due to the large number of pools and channels. This is reflected in the low tide algal community having high proportional cover of the large brown algaes *Cystophera torulosa* and *Carpophyllum plumosum* alongside the ubiquitous coralline turf and *Hormosira banksii*.

The mid intertidal zone is dominated by patchy cover of *Zostera sp.* interspersed with *Hormosira banksii* and coralline turf. The *Zostera* sp. cover on the southern Hawke's Bay reefs is the most wide scale occurrence of this species seen in Hawke's Bay.

The upper intertidal zone here is almost devoid of algae and regularly inundated with sand which moves up and down the shore.

The southern Hawke's Bay intertidal reef platforms have the most extensive *Zostera* sp. beds found in Hawke's Bay. The *Zostera* sp. at Kairakau, although included through the low and mid intertidal transects, is not being effectively monitored. Traditional techniques of measuring patch size and condition are not effective and are time consuming because patches are numerous and variable in size. An aerial imagery approach is required and cost effective methodologies for this are being considered.

7.3 Conclusions

- The time period of the dataset for the reef sites is too short to allow for any trend analysis of community change over time.
- Reef location has a significant influence on species found there.
- There is an unexpected absence of the normally ubiquitous *Hormsira banksia* algae at Hardinge Road.
- The reason for the presence of blooms of *Lyngbya* sp. at the Te Mahia reef is unknown. This algae is commonly associated with elevated nutrients in the surrounding waters and high iron content in the surrounding reefs.
- More work is needed to understand the link between geology, water quality and the species present at a site.
- The current reef monitoring programme is ineffective in monitoring the aerial extent of eelgrass (*Zostera* sp.) beds around the region. Options for using aerial imagery are being evaluated.

8 Summary

Hawke's Bay's coastal environments are subject to the combined pressures of activities occurring both on land and in the ocean. This report describes how Hawke's Bay's coastal environments are responding to these pressures, and details the state, and trends, within our current data for:

- Nearshore water quality (section 2)
- Recreational water quality (section 3)
- Soft sediments (section 4)
- Estuaries (section 5)
- Sandy beaches (section 6)
- Intertidal reefs (section 7)

The coastal environment is the downstream receiving environment for streams and rivers, so is affected by poor environmental conditions in those environments.

Elevated turbidity, suspended sediment and nutrient concentrations occur in some Hawke's Bay catchments, with generally poorer quality following heavy rain. High levels of sediment deposition from rivers are the greatest threat to marine environments. However, existing SOE monitoring does not show whether nearshore water quality is at natural background levels, or is affected by sediment resuspension and inputs from rivers.

Most contaminants are delivered to the coastal environment during storm events, which are generally not well represented in the SOE water quality monitoring programmes. Estuarine sediments in Hawke's Bay have some of the highest mud content in New Zealand, and this is getting worse at many sites (Figure 5-2). Increasing muddiness affects the type and abundance of species found within estuarine environments, with many mud-sensitive species largely absent from muddy estuaries.

Estuarine contaminant levels are generally low, but point source contributions do have an effect on estuarine sediment quality. A reduction of sediments and point source contaminants making their way into estuarine and coastal environments is important to ensure that estuarine functions and services are retained.

The nearshore coastal environment is also muddy (Section 0). In general the sediments of the Bay appear to be well sorted marine sands, with some mud/silt and gravels. However nearshore sediment monitoring sites - at Nuhaka and Clive have relatively high silt/clay (mud) content from rivers.

However, sediment transport and hydrodynamics within Hawke's Bay is poorly understood, so the likely transport and fate of fluvial sediments is unclear. Various methods may be used in future to examine variable nutrient concentrations, and sediment deposition in the nearshore environment (Section 2.1.7)

Contaminants such as trace metals and pesticides can bind to fine sediments. Elevated concentrations of fine sediments can therefore often be associated with elevated concentrations of contaminants. This is the case in nearshore coastal sediments (Section 0) with trace metal concentrations generally highest (Figure 4-8) at Nuhaka and Clive.

Recreational water quality within Hawke's Bay is generally very good (Section 3). Most of Hawke's Bay's coastal marine beaches are good to very good in terms of their suitability for recreation. Recreational water quality of river sites can be more variable, particularly when affected by heavy rain. Coastal lagoons tend to have poorer water quality, and this can often be caused by large populations of birdlife.

Fine sediments and contaminants from upstream catchments can also have negative impacts on sandy beach and on intertidal rocky reef communities. However, given these environments in Hawke's Bay are typically high in wave energy, species are generally robust and sediment usually resides for a short time. These conditions mean that with the exception of large-scale events (e.g.: southern Hawke's Bay in the 2011 storm), sediments and contaminants rarely have long-lasting impacts.

Stress in the coastal environment can also be caused by direct human influences. This may be from point source discharges, which may be having an influence on the Napier Inner Harbour (Section 4.2) but also more widespread effects. These effects can be diverse. The influence of vehicle traffic on the ecology of the region's beaches and reefs is currently unquantified. Similarly, the impact of the recreational and customary collection of shellfish from the region's reefs is unknown. Introduced species also pose a threat to the regions marine ecosystems and invasive species can displace native species and change the ecosystem characteristics of reefs and estuaries.

Environment:	Summary conclusions:
Nearshore water quality	• Generally within expected values; • Increase in turbidity at Marine Parade; • Increase in temperature at Whirinaki; • Increase in dissolved oxygen at Mohaka.
Recreational water quality	• Many areas considered 'Very Good' for recreational activities; • Some areas experience high bacterial loads from ruminant and avian sources.
Coastal sediment quality	• Point source contamination of the Napier Inner Harbour associated with boat maintenance and stormwater; • River inputs of sediments.
Estuaries	• Increasing muddiness; • Changes in infauna due to increasing mud; • Localised source contaminants in some areas.
Sandy beaches	• Large natural variability in ecology.
Intertidal reefs	• Expansion of invasive species; • Impacts of shellfish harvesting and associated vehicular traffic unknown.

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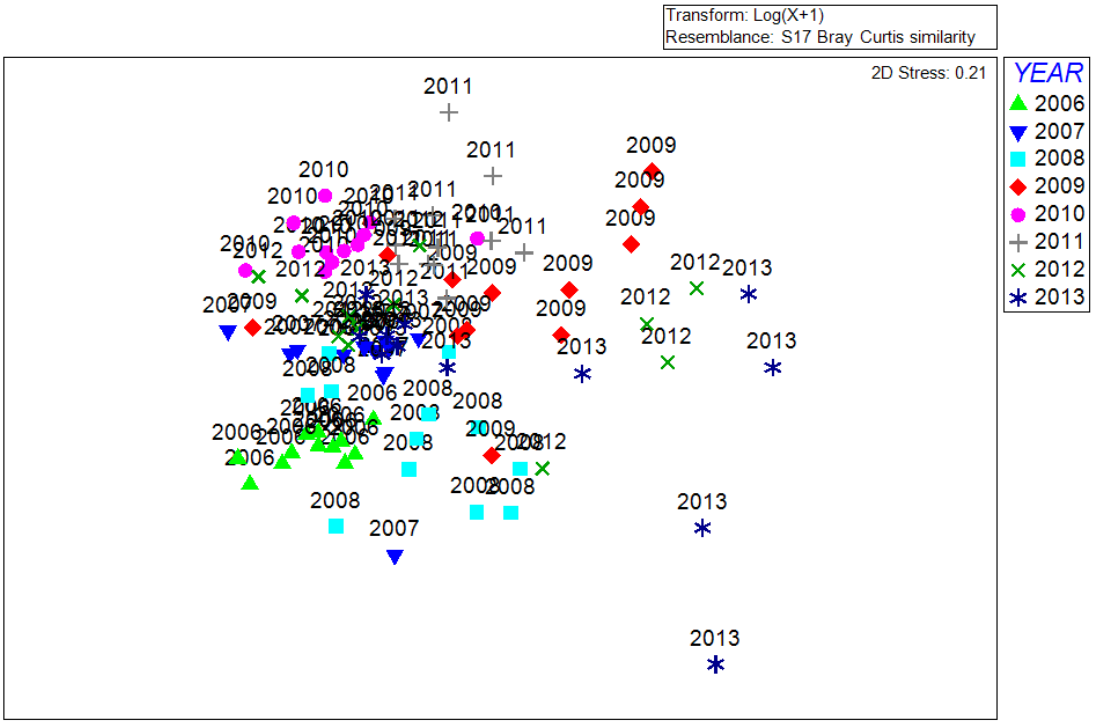
Appendix A Sediment monitoring site co-ordinates

Survey	Site Name	NZTME	NZTMN
2007-Hawke Bay	East Clyde	1986902	5666144
2007-Hawke Bay	Portland	2014432	5645585
2007-Hawke Bay	Wairoa	1980659	5661916
2007-Hawke Bay	Waihua	1969497	5662025
2007-Hawke Bay	Mohaka East	1966688	5658588
2007-Hawke Bay	Mohaka West	1959723	5657324
2007-Hawke Bay	Waikari	1952090	5654221
2007-Hawke Bay	Waipatiki	1948849	5640649
2007-Hawke Bay	Tangoio	1947894	5636347
2007-Hawke Bay	Whirinaki	1936512	5634574
2007-Hawke Bay	Bayview	1938513	5630024
2007-Hawke Bay	Hekerangi Pt	2014497	5647475
2007-Hawke Bay	Westshore	1934647	5624420
2007-Hawke Bay	Napier	1941041	5622078
2007-Hawke Bay	Awatoto	1939507	5615608
2007-Hawke Bay	Clive	1944283	5611843
2007-Hawke Bay	Taramahiti Pt	2013592	5654412
2007-Hawke Bay	Te Heruotaraia Pt	2016283	5655977
2007-Hawke Bay	Blacks Beach	2014144	5663917
2007-Hawke Bay	Nuhaka	2009767	5661328
2007-Hawke Bay	Whakaki East	2001083	5666557
2007-Hawke Bay	Whakaki Offshore	1995118	5661621
2007-Hawke Bay	Whakaki West	1989233	5666477
2007-Southern	Blackhead Point	1923693	5541511
2007-Southern	Rangaiika	1951588	5600568
2007-Southern	Porangahau Rivermouth	1919133	5534089
2007-Southern	Porangahau Beach	1914674	5531128
2007-Southern	Whangaehu	1913122	5524479
2007-Southern	White Cliffs	1910992	5518197
2007-Southern	Motukura/ Bare Island	1945829	5583382
2007-Southern	North Ocean Beach	1947561	5597867
2007-Southern	Ocean Beach	1946045	5593436
2007-Southern	Waimoana	1939402	5572180
2007-Southern	Mangakuri	1932341	5559677
2007-Southern	Paoanui Point	1933279	5555766
2007-Southern	Pourerere	1931154	5553709
2007-Southern	Pohatupapa Point	1926524	5546169

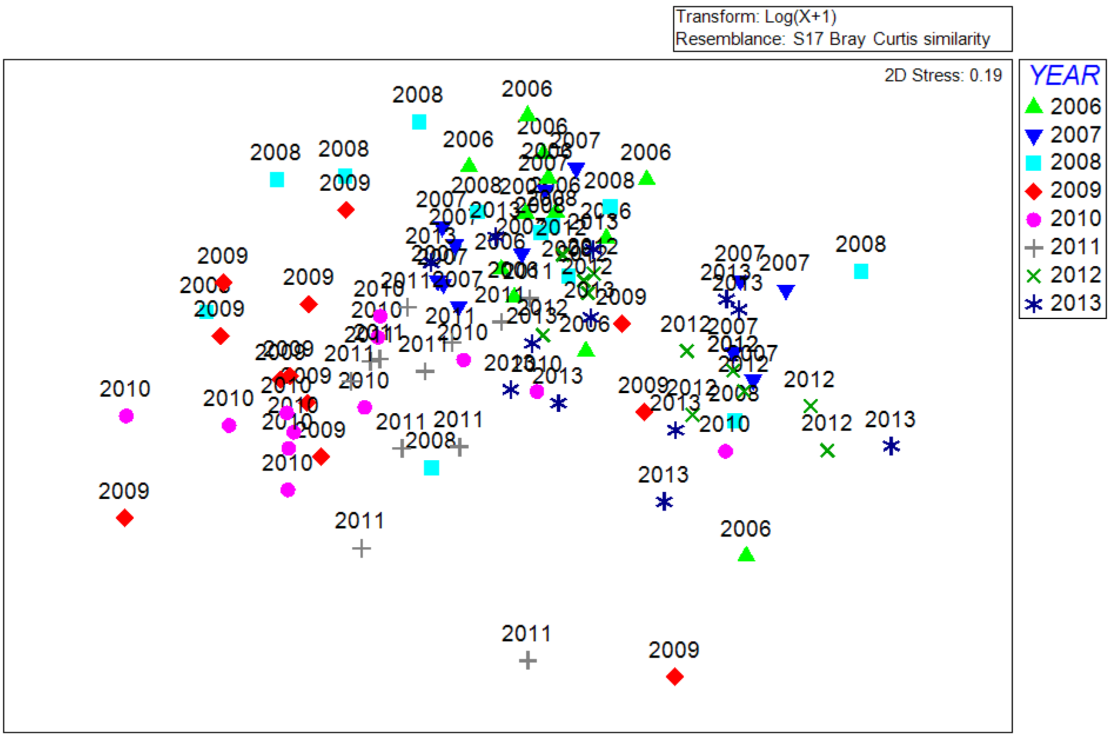
Appendix B MDS Plots – Estuarine Infauna

MDS ordination produces a plot or “map” in which the distance between samples represents their rank ordered similarities, with closer proximity in the plot representing higher similarity.

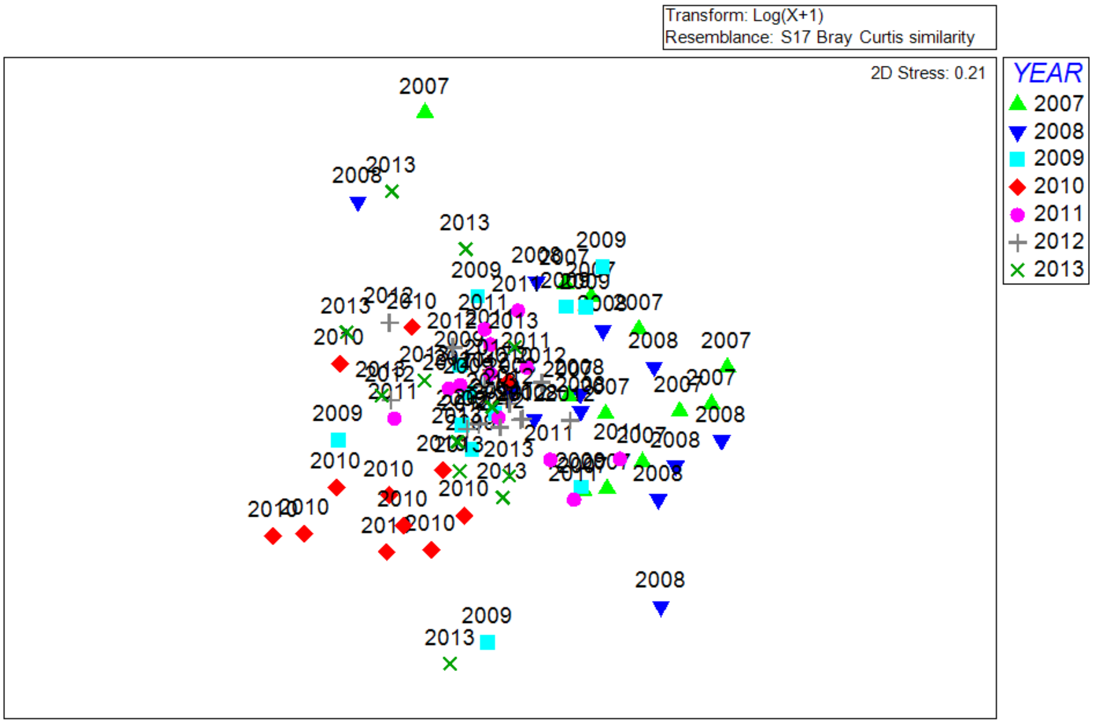
Ahuriri Site A



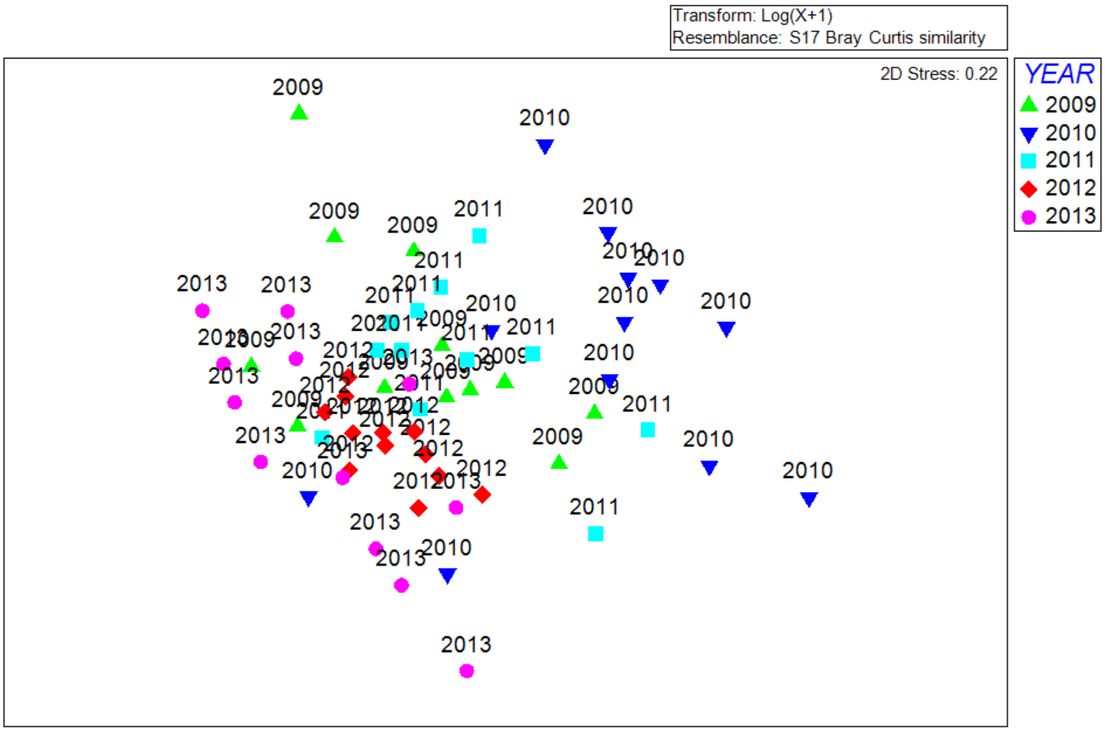
Ahuriri Site B



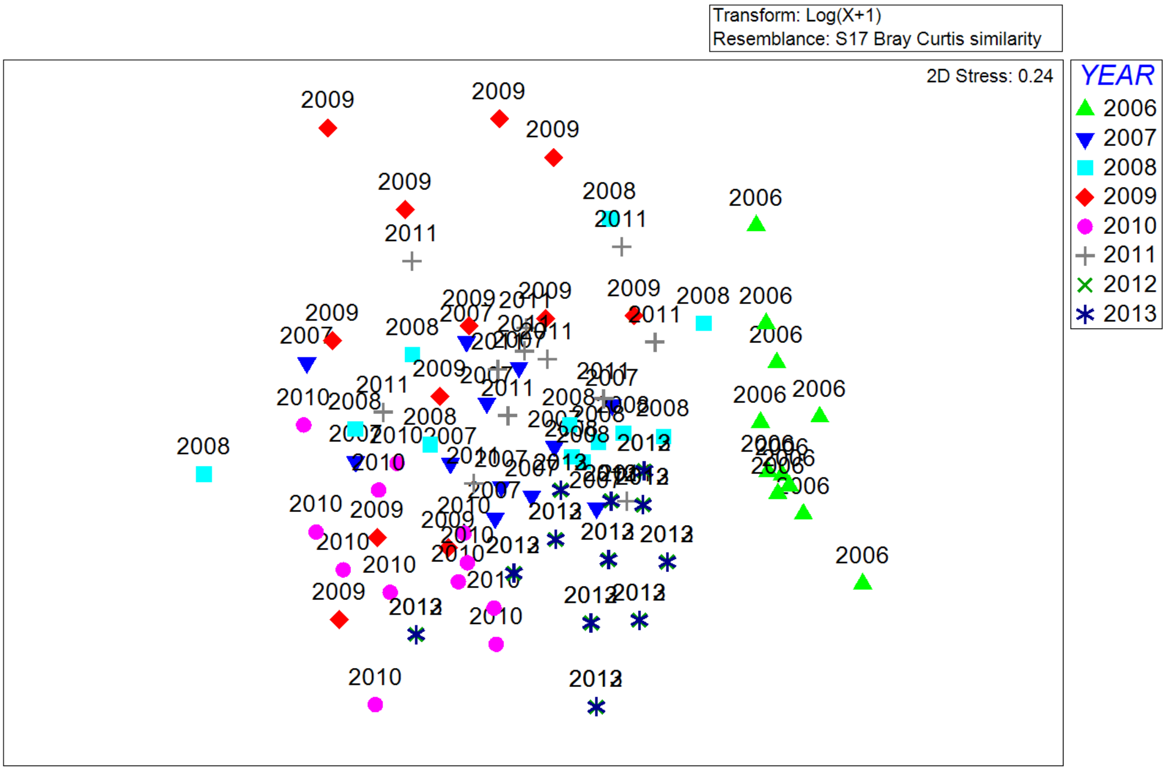
Ahuriri Site D



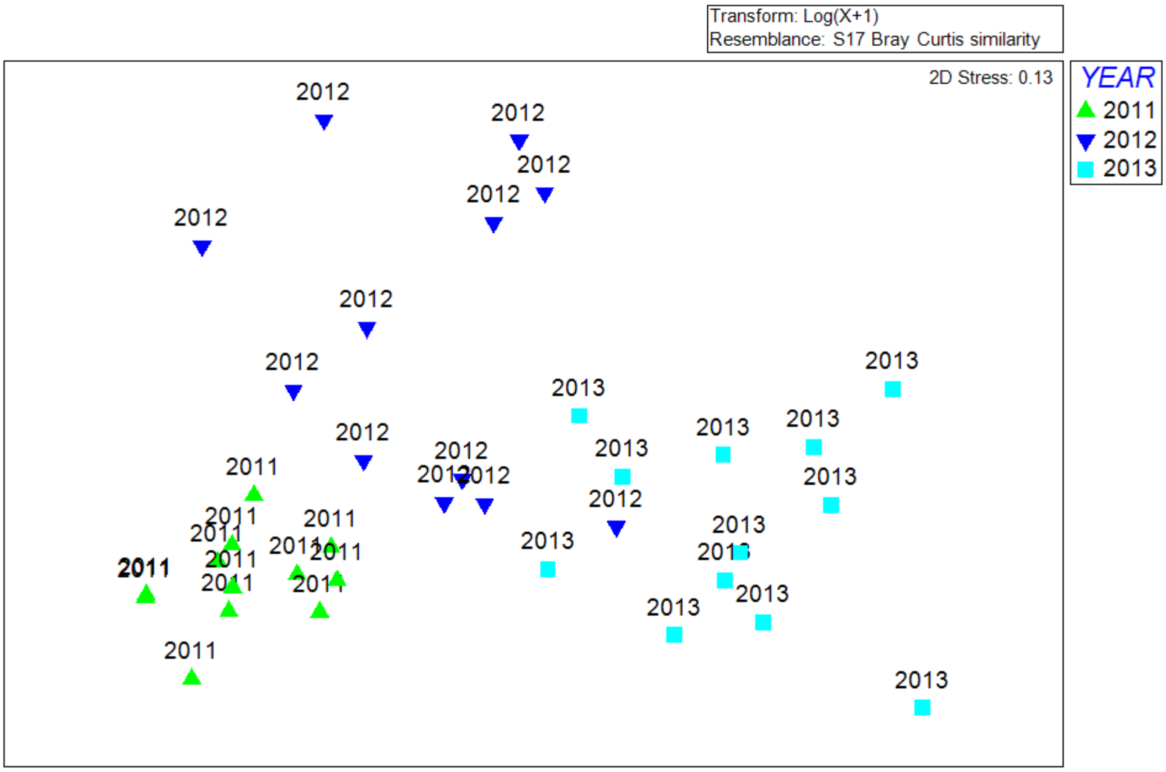
Ahuriri Site E



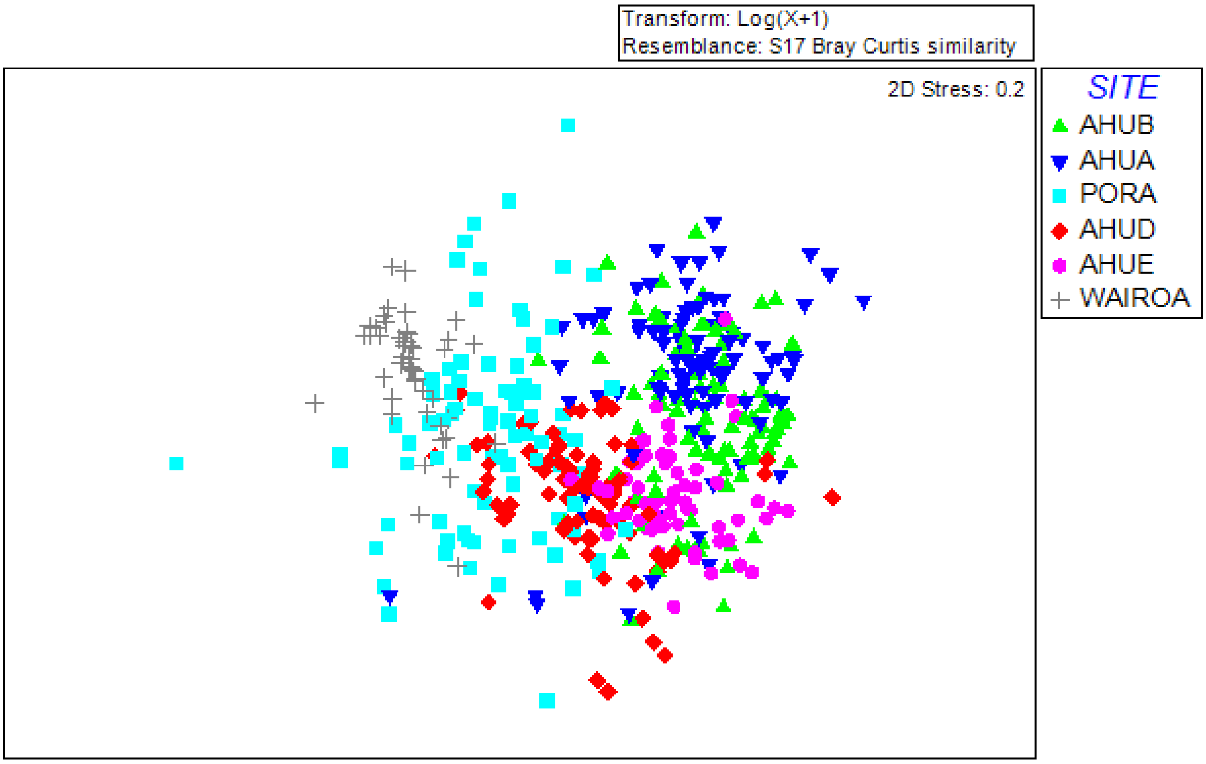
Porangahau



Wairoa



All years by site



Appendix C SIMPER analysis results

The SIMPER results quantitatively defines the contribution that each species makes to the similarity of replicates within each site.

Species	Ahuriri A (Av. Sim. 40%)				
	Av. Abund	Av. Sim	Sim/SD	Contrib %	Cum. %
Macomoa liliana	1.88	13.98	1.52	34.89	34.89
Austrovenus stutchburyi	1.41	8.61	1.16	21.49	56.39
Aonides trifida	1.24	4.87	0.63	12.16	68.55
Nicon aestuariensis	0.70	3.43	0.70	8.56	77.11
Heteromastus filiformis	0.76	2.32	0.53	5.79	82.90
Prionospio *sp.*	0.51	1.66	0.51	4.14	87.04
Notoacmea helmsi	0.75	1.52	0.32	3.80	90.84
Species	Ahuriri B (Av. Sim. 41%)				
	Av. Abund	Av. Sim	Sim/SD	Contrib %	Cum. %
Austrovenus stutchburyi	2.04	21.49	1.64	52.42	52.42
Macomoa liliana	1.46	10.6	1.02	25.85	78.28
Aonides trifida	0.87	2.39	0.49	5.84	84.11
Helice crassa	0.31	1.37	0.30	3.34	87.45
Nicon aetuariensis	0.43	1.30	0.40	3.17	90.62
Species	Ahuriri D (Av. Sim. 48%)				
	Av. Abund	Av. Sim	Sim/SD	Contrib %	Cum. %
Austrovenus stutchburyi	1.30	15.50	1.19	32.49	32.49
Helice crassa	1.08	13.79	1.21	28.92	61.41
Scolecolepides *sp.*	0.85	8.67	0.88	18.17	79.58
Nicon aestuariensis	0.75	8.23	0.87	17.27	96.84
Species	Ahuriri E (Av. Sim. 54%)				
	Av. Abund	Av. Sim	Sim/SD	Contrib %	Cum. %
Austrovenus stutchburyi	3.22	29.09	2.92	54.12	54.12
Helice crassa	1.52	13.0	1.81	24.19	78.32
Notoacmea helmsi	0.73	2.57	0.56	4.79	83.11
Nicon aestuariensis	0.47	2.20	0.58	4.09	87.20
Scolecolepides *sp.*	0.44	2.01	0.54	3.74	90.93
Species	Porangahau (Av. Sim. 34%)				
	Av. Abund	Av. Sim	Sim/SD	Contrib %	Cum. %
Scolecolepides *sp.*	1.35	14.25	1.14	42.09	42.09
Nicon aestuariensis	0.88	8.79	0.84	25.96	68.04
Arthritica bifurca	0.72	4.35	0.48	12.83	80.88
Austrovenus stutchburyi	0.51	3.19	0.48	9.41	90.29
Species	Wairoa (Av. Sim. 57%)				
	Av. Abund	Av. Sim	Sim/SD	Contrib %	Cum. %
Paracorphium excavatum	3.27	21.61	1.47	37.71	37.71
Nicon aestuariensis	1.58	12.80	1.53	22.33	60.04
Scolecolepides *sp.*	1.37	11.63	1.71	20.29	80.33
Potamopyrgus estuarinus	2.02	10.18	0.95	17.7	98.09

Av. Abundance – Average abundance per 0.013m^2 core.
Av. Sim – Average similarity within replicates.
Sim/SD – Similarity divides by the standard deviation.
Contrib% - How much this species contributes to the overall similarity at a site.
Cum% - Cumulative tally of the species contributions towards site similarity.

Appendix D Average dissimilarity of infauna between estuarine sites

	Ahuriri A	Ahuriri B	Ahuriri D	Ahuriri E	Porangahau	Wairoa
Ahuriri A		62.81	74.50	69.60	83.89	89.58
Ahuriri B	62.81		70.29	64.29	84.33	92.62
Ahuriri D	74.50	70.29		61.05	68.61	78.19
Ahuriri E	69.60	64.29	61.05		80.67	88.25
Porangahau	83.89	84.33	68.61	80.67		74.61
Wairoa	89.58	92.62	78.19	88.25	74.61	

Appendix E SIMPER analysis at sandy beach sites

The results of SIMPER analysis of infaunal cores at sandy beach sites.

Species	Blackhead Beach (Av. Similarity 35.63%)			
	Av. Abundundance	Av. Similarity	Contribution %	Cumulative %
Waitangi chelatus	1.38	19	53.31	53.31
Waitangi brevirostris	0.74	8.32	23.36	76.67
Cumacea	0.82	5.17	14.51	91.18
Species	Mahanga Beach (Av. Similarity 18.58%)			
	Av. Abundance	Av. Similarity	Contribution %	Cumulative %
Paphies subtriangulata	0.6	6.71	36.29	36.29
Cumacea	0.48	2.62	14.17	50.46
Orbinia papillosa	0.27	1.98	10.69	61.16
Waitangi brevirostris	0.25	1.66	9	70.16
Haustorius sp.	0.3	1.52	8.25	78.41
Aglaophamus macroura	0.25	1.02	5.53	83.94
Harpacticoid copepod	0.23	0.99	5.33	89.28
Zoea larvae	0.23	0.62	3.37	92.65
Species	Ocean Beach (Av. Similarity 6.08%)			
	Av. Abundance	Av. Similarity	Contribution %	Cumulative %
Waitangi chelatus	0.46	2.02	33.17	33.17
Haustorius sp.	0.15	0.87	14.34	47.51
Flabellifera	0.13	0.65	10.64	58.15
Glycera ovigera	0.08	0.49	8.01	66.15
Cumacea	0.19	0.49	8	74.15
Paphies subtriangulata	0.17	0.35	5.72	79.87
Patuki breviuropodus	0.14	0.27	4.49	84.36
Microphoxus sp	0.08	0.26	4.27	88.63
Austrovenus stutchburyi	0.08	0.16	2.56	91.19
Species	Opoutama Beach (Av. Similarity 8.64%)			
	Av. Abundance	Av. Similarity	Contribution %	Cumulative %
Glycera ovigera	0.27	2.98	34.47	34.47
Perna canaliculus (spat)	0.2	1.03	11.98	46.45
Nematoda	0.27	1.03	11.92	58.38
Waitangi brevirostris	0.18	0.54	6.3	64.67
Paphies subtriangulata	0.12	0.51	5.88	70.55
Nemertea	0.2	0.45	5.25	75.8
Cumacea	0.16	0.44	5.09	80.89
Patuki breviuropodus	0.22	0.4	4.6	85.5
Oligochaeta	0.27	0.33	3.78	89.27
Waitangi chelatus	0.19	0.32	3.69	92.96
Species	Pourerere Beach (Av. Similarity 13.7%)			
	Av. Abundance	Av. Similarity	Contribution %	Cumulative %
Waitangi chelatus	1.04	7.54	55.06	55.06
Orbinia papillosa	0.22	2.09	15.28	70.34
Paphies subtriangulata	0.17	0.93	6.81	77.15
Waitangi brevirostris	0.27	0.78	5.72	82.87
Aglaophamus macroura	0.11	0.58	4.23	87.1
Pisinna Sp.	0.27	0.54	3.98	91.07
Species	Waimarama (Av. Similarity 14.67%)			
	Av. Abundance	Av. Similarity	Contribution %	Cumulative %
Waitangi chelatus	0.57	6.53	44.54	44.54
Paphies subtriangulata	0.53	5.29	36.08	80.62
Austrovenus stutchburyi	0.22	1.17	7.97	88.58
Glycera ovigera	0.07	0.29	2	90.59