HAWKE'S BAY
REGIONAL COUNCIL

The estuaries of the TANK Catchments:
Ahuriri and Waitangi estuaries, Values, State and Trends.

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Environmental Science - Water Quality and Ecology

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Executive summary

As the interface between land and sea, estuarine environments are uniquely distinctive and dynamic environments. They occur at the bottom of the freshwater system, linking fresh and marine waters. As such, estuaries are vulnerable to the impacts of land use and surface water activities.

Although management of estuaries largely comes under the New Zealand Coastal Policy Statement (NZCPS), there is an increasing awareness that stressors that arise from activities on land, need to be managed under the National Policy Statement for Freshwater Management (NPSFM). By managing upstream, to provide for the values associated with the downstream estuarine environment.

The following report outlines the current state of attributes associated with estuarine values derived from the TANK interim agreements, and provides recommendations that may be used in the upstream limit setting process to provide for these values.

Estuarine Water Quality (section 2)

Several variables are used to assess the overall health of the estuarine waters in both the Ahuriri and Waitangi estuaries. These include measures of sediments (clarity, turbidity and suspended sediments), nutrients (nitrogen and phosphorus species), oxygen (dissolved oxygen), and productivity (chlorophyll *a).* Assessment of these variables indicates large concentrations of sediments and nutrients being directed to the estuaries. This is resulting in high levels of productivity (algal blooms) and low dissolved oxygen concentrations, particularly within the Ahuriri Estuary.

This indicates that sediment and nutrient inputs into these systems are compromising the aquatic ecosystems values of these estuaries.

Contact Recreation and Food Gathering (section 3)

The Pandora Pond at the Ahuriri Estuary is currently classified as being in 'Good' condition for contact recreation. Rivers feeding into the Waitangi Estuary are classified as 'Good' – Tutaekuri River at Guppy Road, 'Fair' – Ngaruroro River at Chesterhope, and 'Poor' – Clive River at Guppy Road, based on microbiological water quality.

All other water quality attribute states suggested that they are not adversely affecting contact recreation values, although turbidity and chlorophyll levels at Clive River are likely to impinge on values at this site.

Shellfish collection at Ahuriri Estuary is not recommended due to faecal levels. Other edible species (e.g. fish) do not appear to be impacted.

This indicates that at some sites of the TANK estuarine catchments, the values of contact recreation and food gathering are adversely affected, particularly by faecal inputs.

Estuarine Sediment Quality (section 4)

Sediments of the Ahuriri and Waitangi Estuary are demonstrating moderate (mid-Ahuriri) to high (Upper Ahuriri and Waitangi) levels of sediment stress. This stress relates mostly to silt/clay (mud) concentration within the sediment matrix, but also to nutrient levels in the sediments. Increasing trends in mud content were observed at some of the sites with moderate sediment stress, highlighting a need for remedial action to avoid these becoming highly sediment stressed.

Both Waitangi and Ahuriri estuaries have areas where contaminants from surrounding land use (industry/residential) are elevated. In the Ahuriri Estuary this is proximate to the Thames/Tyne stormwater discharge, in the Waitangi Estuary this is in the subtidal sediments of the Clive River.

These data indicate that sediment and nutrient inputs into these systems are compromising the aquatic ecosystems values of these estuaries.

<u>Estuarine Ecology</u> (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%.

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

<u>Estuarine Habitats and Ecosystems</u> (section 6)

Both estuaries are significantly altered from their original form by both natural and man-made events. This reduces resilience to other stressors which for these estuaries include; grazing, sedimentation, invasive species, human disturbance and stormwater discharges.

<u>Fish</u> (section 5)

Both the Waitangi and the Ahuriri Estuary play a critically important role in the life-cycles of many fish species. These include many that are commercially important to the Hawke's Bay coastal fishery, as well as important to cultural and recreational fishers.

Habitat alteration and loss are likely to have reduced the functional capacity of the estuaries for these life-stages, and water quality (particularly dissolved oxygen and nitrate concentrations) is likely to be limiting/toxic for some fish species.

Improvement in both understanding of fish distribution and abundance, crucial habitat needs, and reductions in sediment and nutrient loads would promote fish habitat and quality.

In general the report highlights several areas where scope exists to improve the values associated with the Ahuriri and Waitangi estuaries, through upstream freshwater management.

1 Introduction

As they form the interface between land and sea, estuarine habitats are unique, distinctive and dynamic environments. They experience rapid chemical and physical changes over tidal cycles, yet provide some of the most important and diverse habitats supporting bird roosting, feeding and breeding, fish spawning and nursery grounds, and ecological services that help to sustain environmental quality and integrity. They are productive habitats, and play an important role in water regulation and nutrient cycling.

Although management of estuaries largely comes under the New Zealand Coastal Policy Statement (NZCPS), there is an increasing awareness that stressors that arise from activities on land, need to be managed under the National Policy Statement for Freshwater Management (NPSFM). By managing upstream, to provide for the values associated with the downstream estuarine environment.

Two estuaries within the Hawke's Bay region fall within the catchments included in the combined TANK (Tutaekuri, Ahuriri, Ngaruroro and Karamu) plan change being managed by Hawke's Bay Regional Council (HBRC). These are the Ahuriri and Waitangi estuaries.

The following report outlines the current state of attributes associated with estuarine values derived from the TANK interim agreements, and provides recommendations that may be used in the upstream limit setting process to provide for these values.

1.1 The catchments

1.1.1 The Ahuriri Estuary

The Ahuriri Estuary has a relatively small catchment area (14,583 ha) which is mostly characterised by sheep and beef agriculture (High producing grassland - Table 1-1). Urban land use contributes a relatively large proportion (15%) of the catchment, as the catchment includes the city of Napier (Figure 2-1).

Table 1-1: Catchment characteristics of the Ahuriri Estuary. Information has been taken from the Land Cover Data Base (New Zealand) version 4 (LCDB4). Note: the LDCB4 categories have been summarised to seven principal land cover categories.

Estuary Type*	Estuary Volume (m^3)	Catchment Size (Ha)	Land cover (LCDB4)
Tidal Lagoon	6,347,333	14,564	High producing grassland (53%) Urban areas (18%) Cropping (10%) Plantation forestry (7%) Orchards/ Vineyards (6%) Native cover (4%) Low producing grassland (1%)

Due to the small catchment size (Table 1-1) there are no large rivers entering the Ahuriri Estuary, freshwater inputs are instead in the form of a handful of small streams originating from the surrounding lowland country.

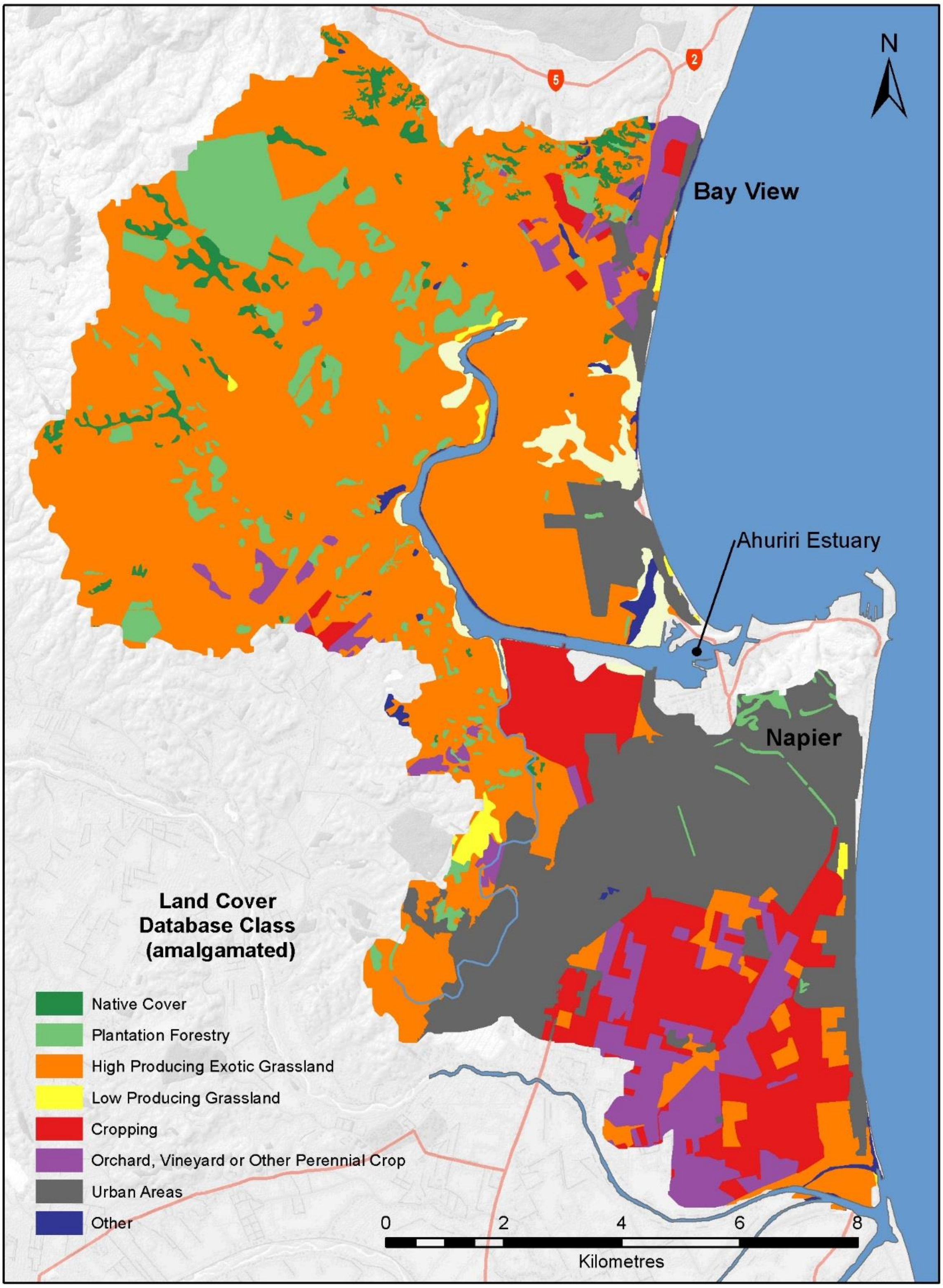


Figure 1-1: Land use within the Ahuriri Catchment. Information has been taken from the Land Cover Data Base (New Zealand) version 4 (LCDB4). Note: the LDCB4 categories have been summarised to seven principal land cover categories..

1.1.2 The Waitangi Estuary

The catchment of the Waitangi Estuary comprises of three large sub-catchments; the Karamu/Clive, the Ngaruroro and the Tutaekuri rivers. The combined size of these three catchments is 335,721 ha (Table 1-2), over twenty times the size of the Ahuriri Estuary catchment. The table below (Table 1-2) outlines the size and land cover characteristics of each sub-catchment. The map below (Figure 1-2) shows the catchment to be split into three broad land uses: native cover in the headwaters, high producing grassland through the middle reaches, and more mixed land use in the lower reaches towards the estuary.

The Ngaruroro catchment is the largest of the three with an area of 202,200 hectares. It originates in the Ruahine ranges and has the largest proportion of native cover (Table 1-2).

Table 1-2: Catchment characteristics of the Waitangi Estuary. Information has been taken from the Land Cover Data Base (New Zealand) version 4 (LCDB4). Note: the LDCB4 categories have been summarised to seven principal land cover categories.

Estuary Type*	Estuary Volume (m^3)	Catchment Size (Ha)	Sub-catchment: size (Ha)	Land cover (LCDB4)
Tidal River	-	335,721	Karamu/Clive: 51,462	High producing grassland (56%) Orchards/ Vineyard (15%) Cropping (11%) Urban areas (6%) Plantation forestry (2%) Native cover (0%) Low producing grassland (0%)
			Ngaruroro: 202,200	Native cover (53%) High producing grassland (35%) Plantation forestry (6%) Orchards/ Vineyard (2%) Cropping (1.2%) Low producing grassland (1%) Urban areas (0.1%)
			Tutaekuri: 82,059	High producing grassland (53%) Native cover (23%) Plantation forestry (20%) Low producing grassland (1%) Orchards/ Vineyard (1%) Cropping (0.5%) Urban areas (0.2%)

The Tutaekuri also has its headwaters in the Ruahine range and therefore a large proportion of the catchment (23%) in native cover.

The Karamu catchment is more comparable to the Ahuriri, the headwaters are in lowland hill country and the catchment is mostly high producing grassland.

The city of Hastings and the town of Havelock North sit mostly in the Karamu/Clive catchment (6% of the catchment) although the Ngarururo and Tutaekuri also have a small proportion of urban areas.

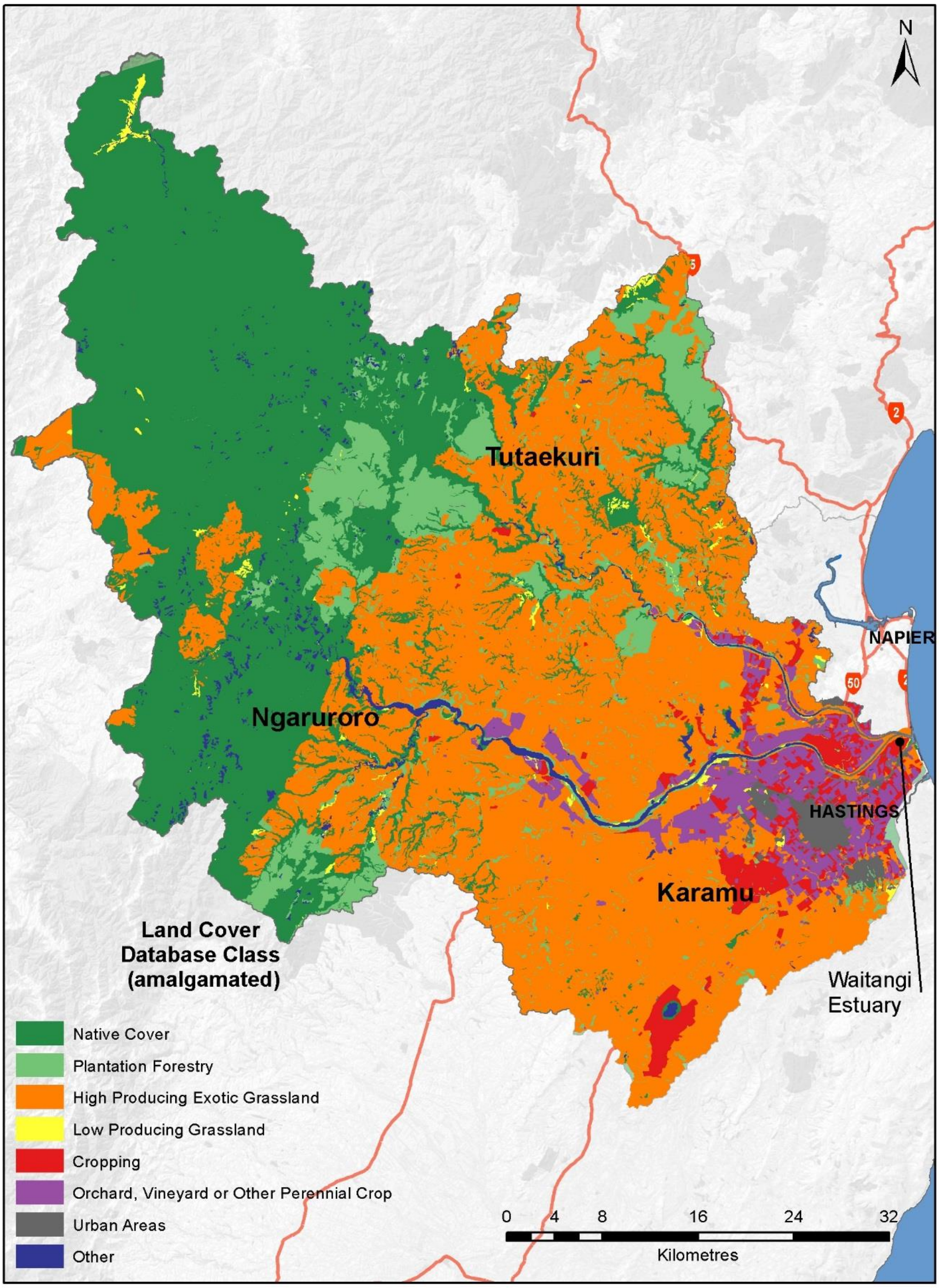
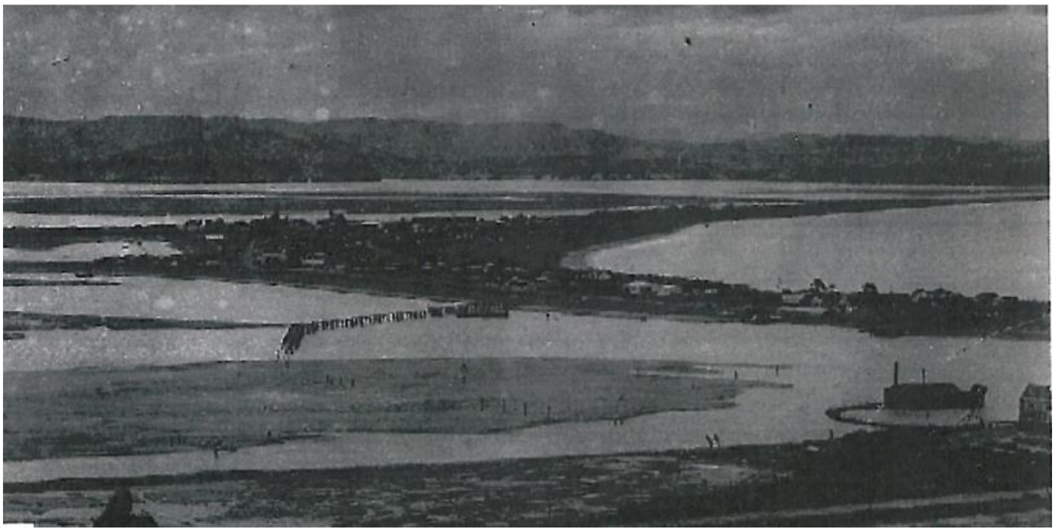


Figure 1-2: Land use within the Waitangi Estuary catchment. Information has been taken from the Land Cover Data Base (New Zealand) version 4 (LCDB4). Note: the LDCB4 categories have been summarised to seven principal land cover categories.

1.2 The receiving environment

1.2.1 The Ahuriri Estuary

In a region dominated by alluvial flood plain river mouths, the Ahuriri Estuary (Te Whanganui-a-Orotu) represents one of the few tidal lagoon estuaries in Hawke's Bay. Formed in the wake of the 1931 earthquake, the Ahuriri Estuary is the remnants of the former Ahuriri Lagoon. The earthquake resulted in an uplift of between 1 m and 2 m, exposing approximately 1300 ha (Chague-Goff, Nichol et al. 2000). Drainage and reclamation following the earthquake has reduced the area to its current size of approximately 470 ha of true estuary, and around 175 ha of associated wetlands (Comerty 1996).



Despite extensive modification, reclamation, drainage and discharges, the estuary is recognised as an area of regional and national significance, with high wildlife and fisheries values. The estuary provides important feeding area for 20 species of trans-equatorial migrants (waders and terns), six Australian species (herons, ibises and duck), and several native species including white heron and royal spoonbill (Knox 1979). Additionally, the estuary makes a significant contribution to Hawke's Bay marine fisheries, supporting approximately 29 species of fish during some stage of their life cycle. Some species (e.g. kahawai, grey mullet, yellow-bellied flounder, stargazer and parore) use the area for feeding, and around 11 species use the area as a nursery or spawning ground. These include commercially important species such as yellow-bellied flounder, grey mullet, sand flounder, common sole, and yellow-eyed mullet (Kilner and Akroyd 1978).

Ahuriri Estuary is listed as a Significant Conservation Area under the Regional Coastal Environment Plan (HBRC 2014), a Wetland of Ecological and Representative Importance (WERI), and a Site of Special Wildlife Interest (SSWI) (Henriques 1990). A Wildlife Refuge status protects the areas between the Southern Marsh, Westshore Lagoon and the estuary, from the low level bridge to Pandora Pond.

1.2.2 The Waitangi Estuary

The Waitangi Estuary is a Tidal River estuary. The estuary has a shifting gravel bar mouth and three large freshwater inputs. The mouth of the estuary is very dynamic and its location and shape depend upon the influence of flow and ocean swells. The estuary is channelized and - in the case of the Ngaruroro arm – quite deep (approximately 4 m). The majority of the estuary is well stratified, with the tidal prism pushing upstream as a salt wedge under the freshwater. Due to the large freshwater inputs, the estuary is generally well flushed, with short residence times. This means that any waterborne contaminants pass through the estuary to the ocean relatively quickly.

The Waitangi Estuary has a long history of modification. In a natural state the estuary mouth would have moved up and down the coast as the path of the rivers changed with each flood event. Both the rivers and the estuary are now bound by stop-banks, to prevent this movement and flooding of the surrounding areas. This restriction has caused channelization and deepening of the estuary, and a large reduction in the area of associated wetlands. There have also been large-scale changes in the paths of the rivers entering the estuary. Prior to the 1931 earthquake the Tutaekuri River flowed into the Ahuriri Estuary and was diverted into the Waitangi Estuary to prevent flooding of Napier. Up until the 1950s the lower reaches of the Ngaruroro River followed the meandering bed of what is now the Clive/ Karamu. To prevent flooding of the Clive township, the Ngarururo River was moved to follow a straight, stop-banked path from upstream of the Chesterhope Bridge to the sea.

Despite this extensive modification the Waitangi Estuary supports important estuarine habitats and species. There remains significant wetland habitat at Muddy Creek providing important feeding and roosting habitat for several bird species. The gravel bar at the mouth of the estuary provides important roosting and breeding habitat for several sea bird species (Stephenson 2010). The Clive Arm of the estuary has the largest expanse of *Ruppia* sp. beds in the region and there is a vibrant whitebait fishery at the Waitangi Estuary, supported by at least two large spawning sites (Section 7.5)

1.3 TANK Interim Agreements

The following interim agreements were made with specific reference to the Ahuriri Estuary.

Recognition of the Ahuriri Estuary as a site of ecological, cultural and recreational significance.

- Recommends all reasonable measure be undertaken to support these uses and values.

Concern about sediment, nutrient, bacteria and contaminant inputs into the estuary.

- Recommends that HBRC investigate and report back to group on sources and possible reduction.

Concern about poor water quality in urban streams.

- Recommends that HBRC investigate and report back to group on causes and possible improvements.

While no specific interim agreements were made in relation to the Waitangi Estuary, several agreements reached in relation to estuarine and wetland management are considered relevant. These include:

Estuaries managed for contact recreation and food gathering.

- Recognition that this may mean improvements are required to achieve community aspirations.

Recognition of the importance of wetlands

- Preservation of remaining wetlands
- Protection for those deemed ecologically significant.

2 Water Quality

Estuaries are transitional zones between land and coastal environments. They receive particulate and dissolved matter transported from their upstream catchments by rivers. In estuaries this material is exposed to a complex suite of physical, biological and chemical processes. The material is either deposited in estuary sediments, used in plant and animal growth, transmitted to the atmosphere through gaseous exchange or flows directly to the oceanic environment.

Water quality has been monitored monthly in the TANK estuaries since March 2013. The analysis detailed in this chapter describes data from the monitoring period March 2013 to May 2016. Monthly monitoring continues and, while the data collected so far is sufficient to give a description of state, it is too short to examine any inter-annual trends in estuarine water quality.

Water quality has been sampled at eight sites within the Ahuriri estuary (Figure 2-1) since March 2013. Examination of data from the initial year of sampling highlighted elevated concentrations of some contaminants in the waters of the estuary. Consequentially, seven water quality sites were added to the programme (May 2015) at third order streams (n=5) and pump stations (n=2) within the Ahuriri estuary catchment. The aim of monitoring these sites is to increase understanding around sediment and nutrient concentrations and loads feeding into the estuary itself. This data (May 2015 – May 2016) is presented alongside data for the longer time period (March 2013 – May 2016) from the upstream freshwater State of the Environment (SOE) site in the Taipo Stream and the near-shore water quality SOE site at Westshore to allow for comparison between the freshwater, estuarine and marine environments.

The priority in determining the number and location of sampling sites within the Ahuriri and Waitangi estuaries was to achieve a reasonable longtitudinal spread throughout the estuary, because estuarine processes may differ depending on the position within the estuary system. The exact location of each site was then decided by the availability of access points.

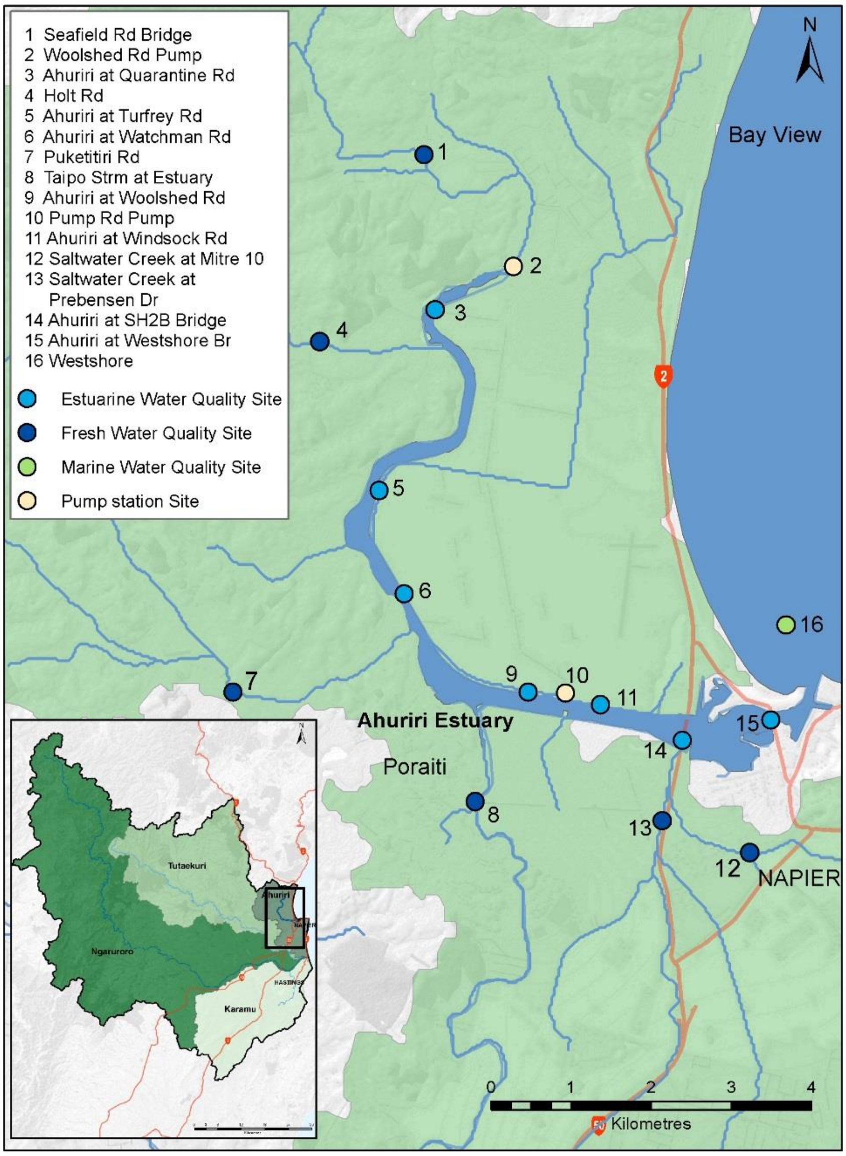


Figure 2-1: Map showing the water quality sites in the Ahuriri Estuary and catchment alongside the closest upstream freshwater SOE monitoring sties and the downstream coastal long-term SOE site.

Water quality was initially monitored at seven sites in the Waitangi Estuary from March 2013. In September 2014 the number of monitoring sites was rationalised to four sites: 'Ngaruroro Estuary D/S'; Clive River at SH2 Bridge'; 'Waitangi at SH2 Bridge' and 'Waitangi at mouth'. This data is presented with long-term data from the most downstream freshwater SOE site on each of the rivers: 'Clive Rv'; 'Ngarururo Rv at Fernhill; and 'Tutaekuri Rv at Brookfields Br' and the long-term data from the near-shore water quality SOE site at Awatoto (Figure 2-2). The sampling sites are distributed across the three arms of the Waitangi estuary because each arm is very different in terms of the fresh water entering it, the extent of saline influence and the benthic habitat within. There is often little mixing between the waters of the three arms until they reach the area of high turbulence at the mouth of the estuary (Figure 2-3).

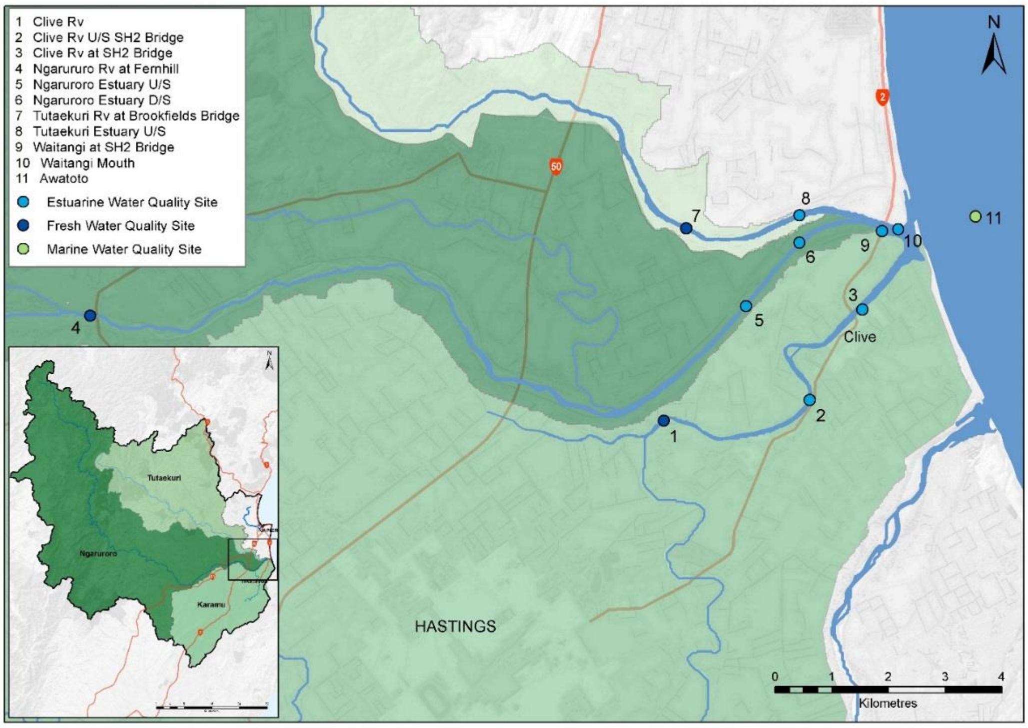


Figure 2-2: Map showing the 7 water quality sites in the Waitangi Estuary with the closest upstream freshwater and downstream coastal long-term SOE sites.

Water quality measurements can be compared to management guidelines or trigger values, which in New Zealand are usually the ANZECC guidelines (ANZECC, 2000). However, ANZECC does not include any water quality guideline values for New Zealand estuaries. Instead the ANZECC guidelines recommend applying guideline values for estuaries in South-East Australia. However, this approach is not appropriate in the Ahuriri and Waitangi estuaries, because they have very different hydrological and morphological characteristics to the estuaries found in South East Australia. Instead the water quality of the streams and rivers feeding into the two estuaries is compared against the ANZECC trigger values for lowland rivers (ANZECC, 2000)

Water quality of the two estuaries is affected by their differing physical characteristics and the quality of their freshwater riverine inputs. These physical characteristics such as bathymetry and flow have a direct impact on the extent of saline influence which in turn relates to the flushing and residence time of the estuary. Estuaries such as the Waitangi Estuary, which are well flushed and have short residence times, are less likely to have water quality issues than estuaries like the Ahuriri , which are poorly flushed, with long residence times.

Figure 2-3: The confluence of the waters of the Ngarururo and Tutaekuri arms in the Waitangi Estuary (April 2015). Following a rainfall event the Ngaruroro is often more turbid than the Tutaekuri highlighting the lack of mixing.

2.1 Data visualisation

Box plots have been used throughout Section 2 to summarise water quality data for full dataset between March 2013 and May 2016. 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 ordered from left to right in order from the furthest upstream site to the furthest downstream site, both within the estuary and tributaries. Freshwater inputs are coloured dark blue, estuarine waters turquoise, pumped inputs are coloured yellow and coastal SOE sites are green.

2.2 Water quality guidelines

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. These guidelines are not intended to provide limits for the quality of water bodies. 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). For the purposes of this report nutrient concentrations, turbidity, pH and dissolved oxygen saturation in freshwater inputs are compared against ANZECC lowland river trigger values (Table 2-1).

Table 2-1: Default trigger values for lowland rivers in New Zealand. (ANZECC, 2000).

Total Phosphorus (mg/ l)	Dissolved Reactive Phosphorus (mg/ l)	Total Nitrogen (mg/ l)	Dissolved Inorganic Nitrogen (mg/ l)	Turbidity (ntu)	DO (% saturation)		pH	
					Lower limit	Upper limit	Lower limit	Upper limit
0.033	0.010	0.614	0.444	5.6	98	105	7.2	7.8

However, ANZECC does not include any water quality guideline values for marine or estuarine 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, let alone one country to another. Applying the south-east Australian ANZECC guidelines is not considered appropriate in this context since they are based on very different waters to those found in Hawke's Bay. Using inappropriate guidelines can give a false impression of conditions being relatively better or worse than they actually are.

2.3 Conductivity

Conductivity is a measure of the ability of water to pass an electric current. Conductivity in estuarine water is primarily affected by the presence of inorganic dissolved solids such as sodium and chloride associated with saltwater. Conductivity can be used to classify the water as either fresh, brackish or saltwater, using the Venice System for the Classification of Marine Waters According to Salinity (Table 2-2). In coastal areas and estuaries species distributions vary with salinity, suggesting this is a major limiting factor in their distribution. Water salinity also influences chemical and physical processes occurring in different areas of the estuary.

Table 2-2: The Venice System for Classification of Marine Waters According to Salinity.

Salinity (ppt)	Conductivity (mS/cm)	Classification
< 0.5	1.2	Fresh water
0.5 – 30	1.2 – 46	Brackish water
>30	>46	Salt water

The following boxplots suggest that the Ahuriri Estuary is marine dominated and is brackish or salt water throughout (Figure 2-4). The waters of the Waitangi Estuary are more river dominated and are mostly fresh or slightly brackish (Figure 2-5). However, measurements of the maximum extent of saltwater influence (Section 7.5) suggest that saltwater regularly extends upstream of many sites in the Waitangi Estuary, at depth. This is because the Waitangi is highly stratified, so denser salt water pushes upstream along the relatively deep channels underneath the freshwater, which flows downstream over the top, with limited mixing. This situation means that shallow water samples collected from the bank may fail to capture the saltwater influence. By contrast the Ahuriri Estuary appears to be well mixed throughout. Most of the estuary is very shallow with limited freshwater inflow, and the action of the wind is enough to cause a high degree of mixing.

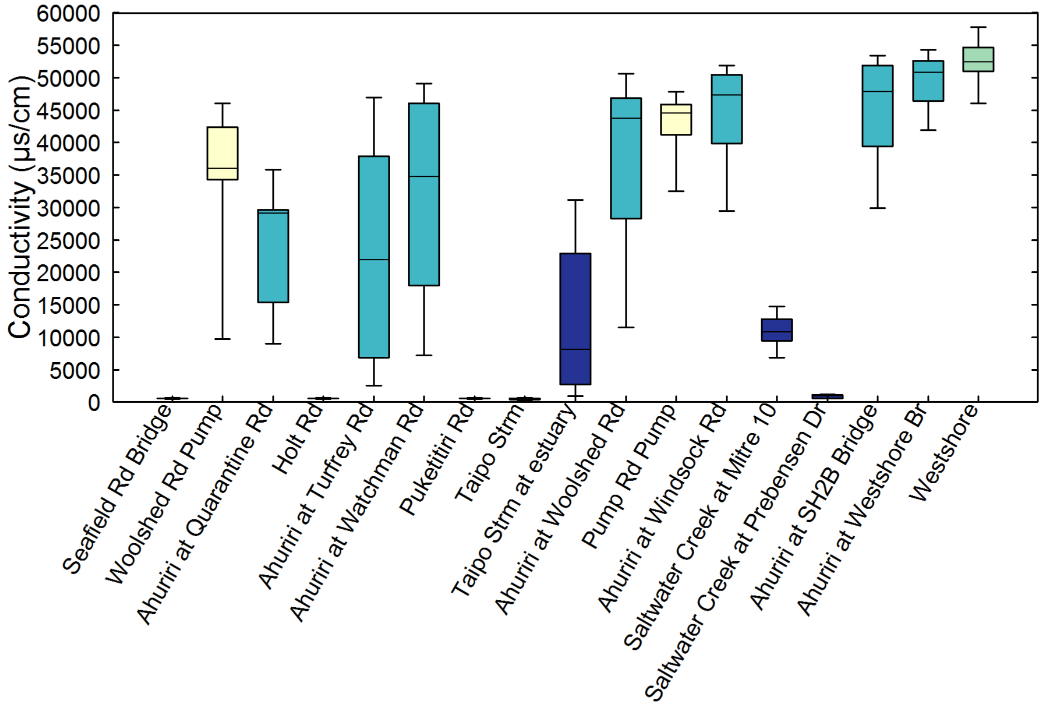


Figure 2-4: Conductivity measurements in the Ahuriri estuary (see Figure 2.1 for location of sites).

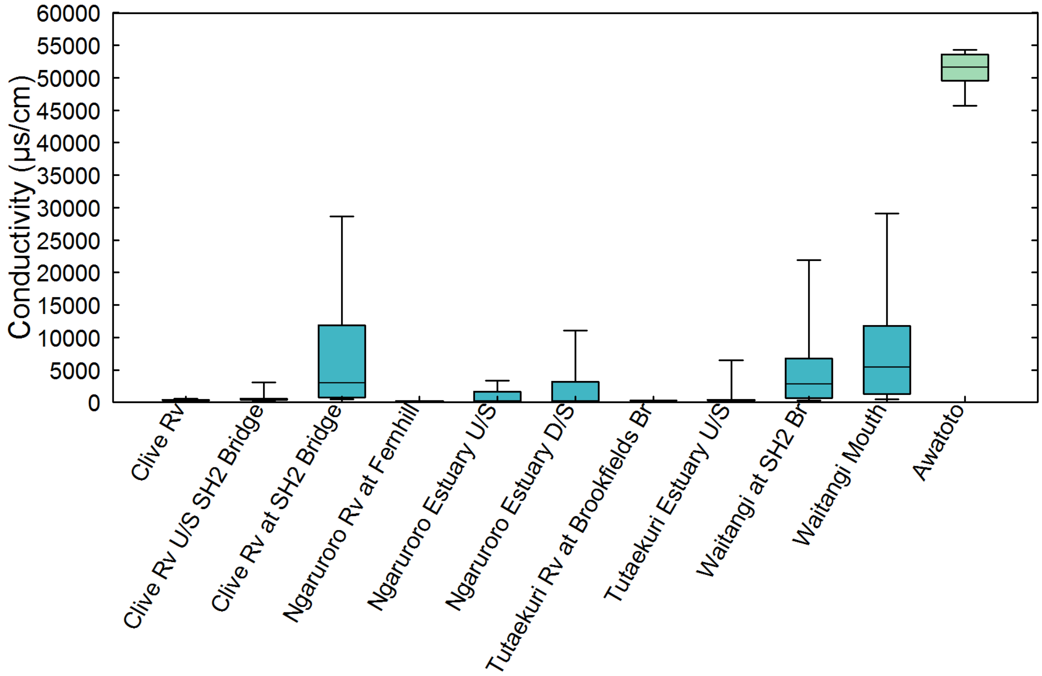


Figure 2-5: Conductivity measurements in the Waitangi estuary (see Figure 2.2 for location of sites).

2.4 Water Clarity (Turbidity and Suspended Sediment)

Turbidity is a measure of the degree of light scattering in water caused by suspended sediment and organic particles in the water column. The higher the concentration of suspended particles, the higher the turbidity.

Estuarine waters are generally more turbid than marine or riverine waters due to flocculation, phytoplankton production and the resuspension of sediments. However, elevated turbidity can adversely affect estuarine ecology, by reducing the light available for photosynthesis. Phytoplankton and free-floating macroalgae tend to out-compete benthic plants for light, when this becomes a limiting factor. This could explain the predominance of phytoplankton in the upper Ahuriri Estuary and the dominance of benthic macroalgae in the Clive/Karamu arm.

Suspended sediment can smother benthic organisms and habitats when it settles, can cause damage to the gills of fish and crustaceans and can reduce the efficiency of filter feeding causing a loss of condition in filter feeding animals. Suspended sediment also transports contaminants (particulate nutrients, metals and other potential toxicants) where they attach to sediment particles. Suspended sediment also is related to the growth of pathogens and waterborne diseases. Suspended organic particles can lead to depletion of dissolved oxygen in the water column. Suspended sediment concentrations can also be used to calculate sediment loads coming from rivers. The suspended sediment load for the Ngaruroro and Tutaekuri Rivers was calculated by Hicks et al. (2011) to be 0.21 and 1.3 million tonnes respectively.

In many estuaries there is a location where suspended-solid concentrations are highest, called the estuarine turbidity maximum (ETM) (Schoellhamer 2001). The location of the ETM is determined by the joint action of tide- and density-driven currents (Schuttelars 2002). These areas of elevated turbidity in estuaries are typically found where saltwater and freshwater meet. They can be highly productive, because they stimulate plankton growth, and create larval fish nursery areas and creates feeding areas for larger fish.

The waters of both the Ahuriri (Figure 2-6) and Waitangi (Figure 2-9) are more turbid than either the riverine waters entering them or the marine waters receiving them.

Turbidity measurements (Figure 2-6) and suspended sediment concentrations (Figure 2-7) suggest that the ETM is located around the Quarantine Road area of the Ahuriri Estuary. Chlorophyll *a* concentrations (Figure 2-16) suggest this is a very productive part of the estuary, and large numbers of mullet have been observed feeding in this area.

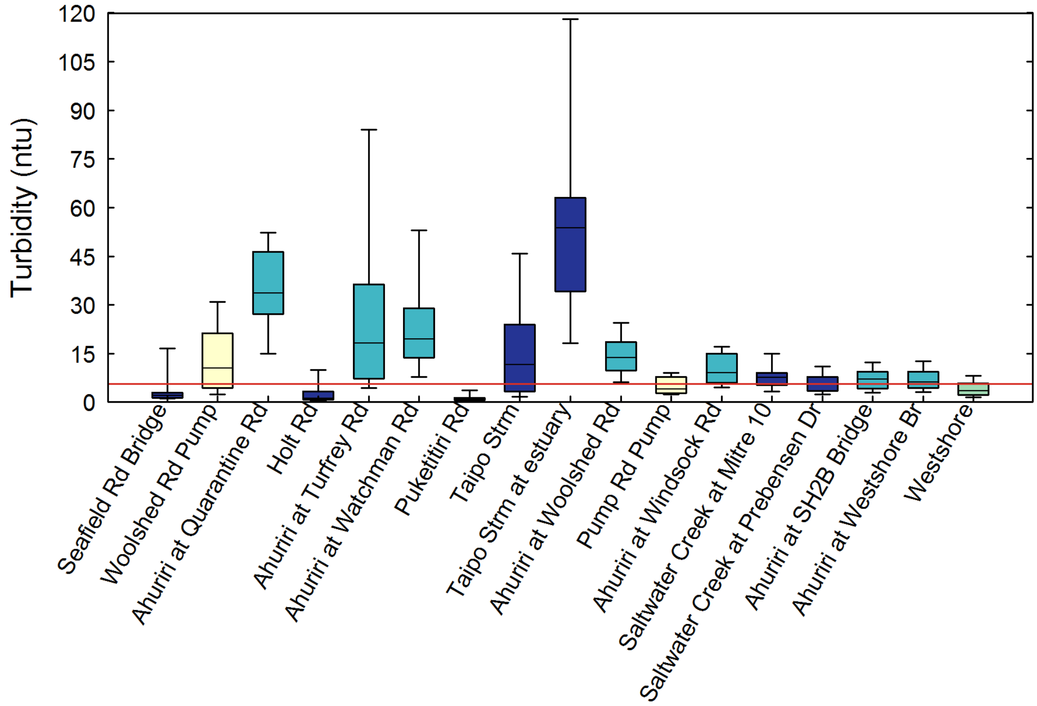


Figure 2-6: Turbidity measurements in the Ahuriri Estuary.

Turbidity within some of the tributaries regularly exceeds trigger values with median turbidity measurements at sites in the Taipo stream and Saltwater Creek exceeding ANZECC lowland river trigger values (Figure 2-6). These turbidity measurements are mirrored by suspended sediment concentrations in the Taipo Stream.

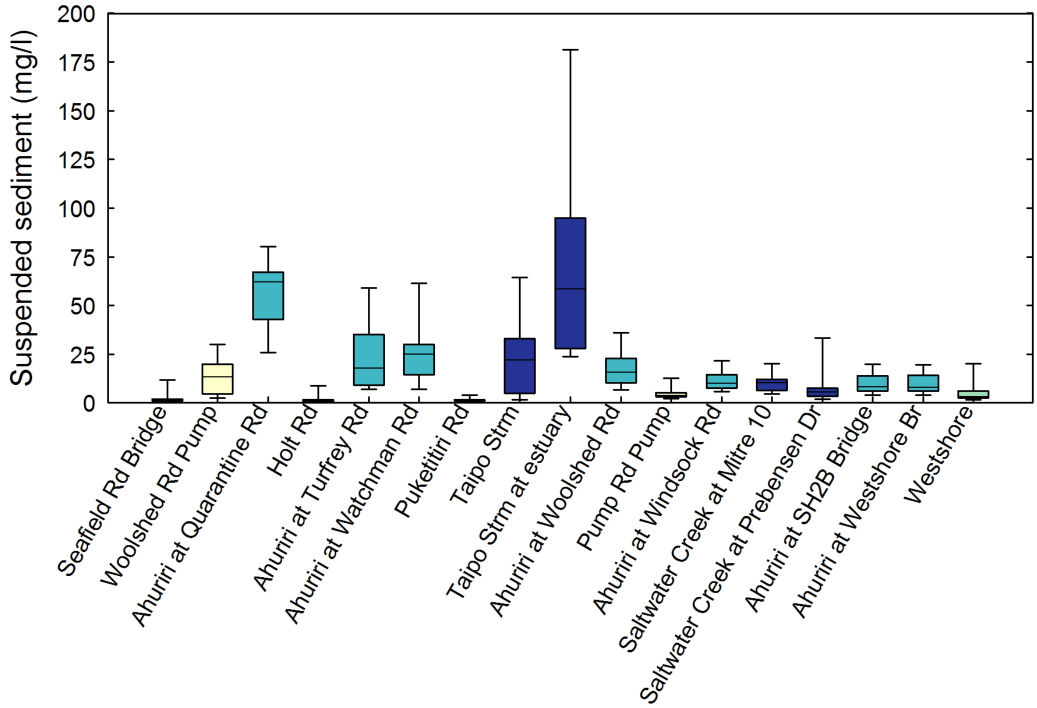


Figure 2-7: Suspended sediment concentrations in the Ahuriri Estuary.

The situation in the Waitangi Estuary is more complex because there are three river systems with much larger flows and loads than those entering the Ahuriri. Turbidity (Figure 2-9) and suspended sediment concentrations (Figure 2-10) are higher at sites within the estuary than the river inputs, especially in the Ngarururo arm. It is likely that processes like flocculation within the estuary are augmented by active erosion of the vertical, un-vegetated banks of the Ngaruruo and Tutaekuri arms (Figure 2-8).

Figure 2-8: Active erosion on the banks of the Waitangi Estuary.

Turbidity readings and suspended sediment concentrations are lowest at the Clive sites. The slow moving nature of this stretch of estuary means that any suspended sediment rapidly settles out and there is little opportunity for resuspension or erosion.

It is possible that the maps of the maximum extent of saline influence (Section 7.5) could be used to predict the general location of the ETM in the Clive/Karamu and Tutaekuri arms of the estuary

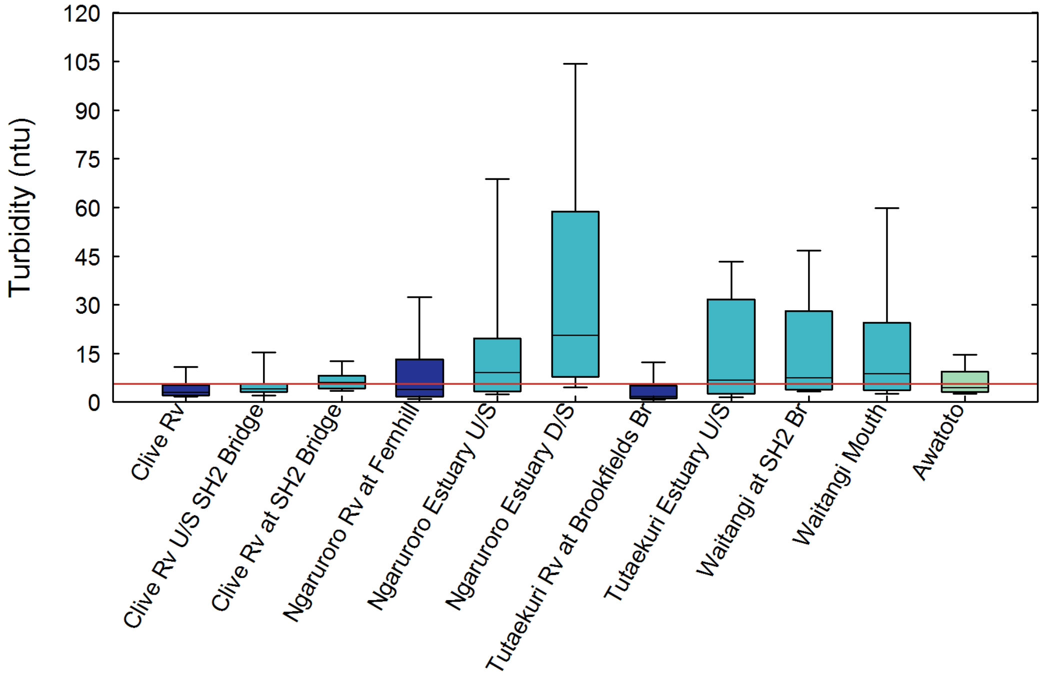


Figure 2-9: Turbidity measurements in the Waitangi Estuary.

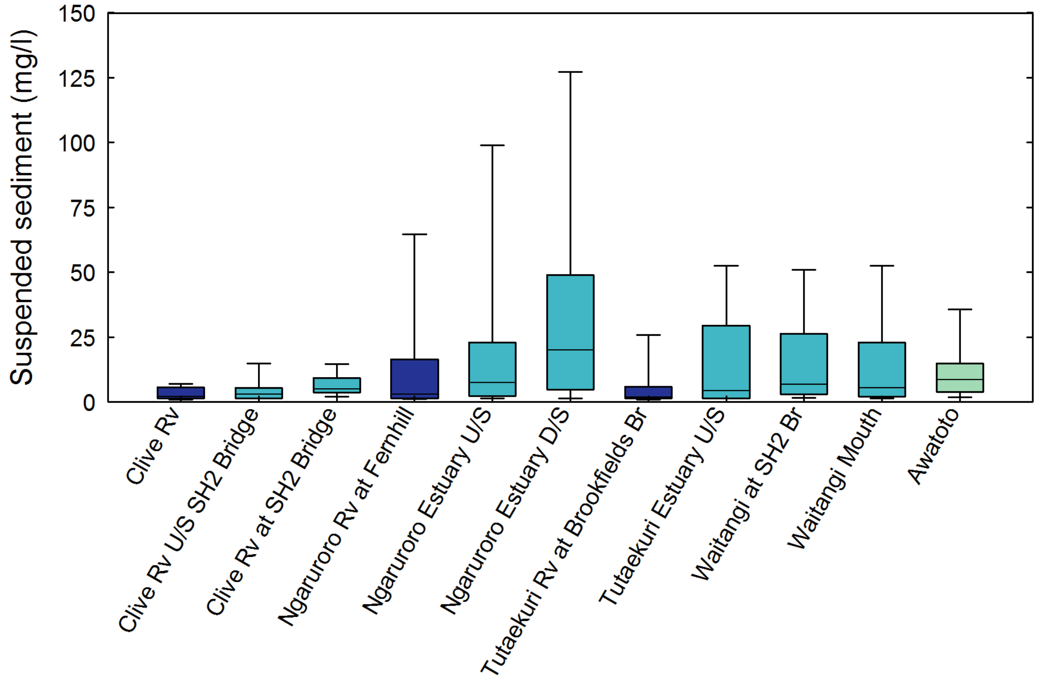


Figure 2-10: Suspended sediment concentrations in the Waitangi Estuary.

2.5 Nutrients

Estuaries are important sites of nutrient cycling in the coastal environment. Estuaries receive constant nutrient inputs both from upstream freshwater inputs and oceanic inputs on the incoming tide. These inputs can be augmented by anthropogenic activity through sewage plant, stormwater and industrial discharges, and agricultural runoff. These nutrients can then be influenced by a complex suite of processes. Through the processes of adsorption and flocculation nutrients can bind to sediments and large particles. Estuaries can process nitrogen and release it to the atmosphere through denitrification. Nutrients can also be made available to primary producers through remineralisation and re-suspension.

Some of the most obvious indicators of elevated nutrients in estuaries are elevated concentrations of phytoplankton and growth of macro-algae. However, elevated nutrient concentrations, especially nitrate, ammoniacal nitrogen and phosphorus can also be toxic to many invertebrates, fish and seagrass and have the capacity to alter the estuarine ecosystem.

2.5.1 Phosphorus

Phosphorus concentrations in the Ahuriri are elevated compared to the nearby marine waters (Figure 2-12), with a large proportion of this phosphorus present as dissolved reactive phosphorus (DRP). The highest concentrations are recorded in the upper estuary, with declining concentrations towards the mouth.

It is concern around these concentrations that initiated the sampling of third order streams within the Ahuriri catchment in May 2015. Concentrations of DRP and total phosphorous (TP) in these streams exceed ANZECC guidelines for lowland streams at all sites. The highest concentrations are in those streams lower down the catchment, the Taipo Stream and Saltwater Creek.

In order to evaluate the contribution of the streams to the estuary on an ongoing basis, streams gaugings to estimate flow and calculate loads are required. Stream gaugings have been initiated recently, but it is not yet possible to calculate loads. However, the streams are small and generally of low flow, so these streams are not expected to be the sole contributing origin of ongoing elevated phosphorus in the Ahuriri Estuary. The estuary may be experiencing legacy effects from long-term inputs of nutrients from these streams that have bound to sediments.

These legacy nutrients can continue to affect water quality. Phosphorous typically binds to iron in the water column and is precipitated out onto the sediment. If the sediment becomes anoxic, which is the case in much of the Ahuriri Estuary, this phosphorous can become re-mineralised back into the water column (as DRP) and become available to primary producers.

These primary producers are phytoplankton and macroalgae (U*lva* and *Gracilaria* species). The waters of the upper estuary are rich in organic material in the form of phytoplankton, as demonstrated by the high chlorophyll-*a* concentrations at the Quarantine Road site. There are also inputs of organic material from bird and fish faeces, macroalgae, and the surrounding farmland during rain events. The low flow and shallow nature of the upper estuary means this organic material precipitates on the sediment surface, rather than being flushed from the receiving reach, as it would be in a more river-dominated estuary. The phosphorus in this organic material is readily remineralised through decomposition processes (Corbett 2010).

There are also a large number of birds resident in the Ahuriri. Bolton-Ritchie (2005) observed the contribution that bird faeces can make to elevated nutrient concentrations (both nitrogen and phosphorus) in the Avon-Heathcote estuary in Canterbury. The large numbers of wildfowl present in the Ahuriri estuary indicate a similar situation may exist in the Ahuriri Estuary.

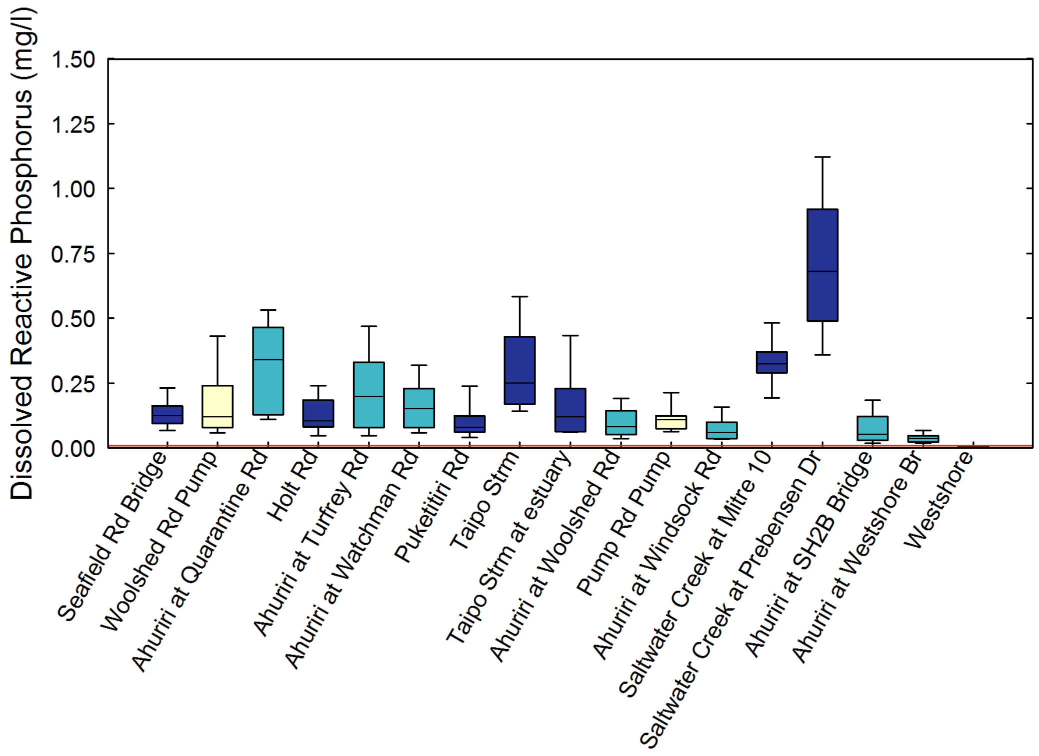


Figure 2-11: Dissolved reactive phosphorus concentrations in the Ahuriri Estuary.

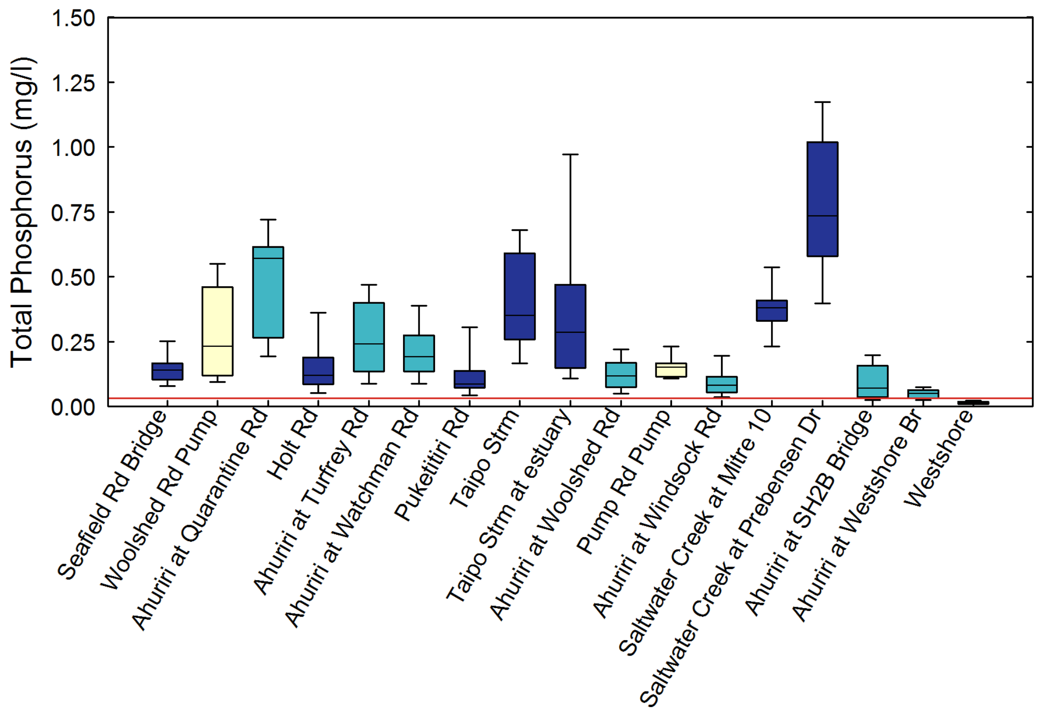


Figure 2-12: Total phosphorus concentrations in the Ahuriri Estuary.

Decreases in estuaries in phosphorus concentration towards the ocean are probably caused by a combination of dilution by seawater, as well as removal of phosphorus from the water column through biological uptake by phytoplankton and macroalgae, and binding of phosphorus to the iron in sediment particles.

Phosphorus concentrations in the Waitangi Estuary are generally much lower than in the Ahuriri Estuary. Of the riverine inputs into the estuary, the Clive River has the highest concentration of P, though both the Clive River and Tutaekuri River SOE sites median DRP concentrations exceed ANZECC guidelines for lowland rivers. Elevated concentrations continue downstream, particularly in the Clive River arm of the estuary.

There is likely a similar situation in the Clive arm of the Waitangi Estuary as observed in the Ahuriri Estuary with elevated phosphorus concentrations driven by a combination of upstream inputs and legacy effects of anoxic sediment processes releasing deposited sediment bound phosphorus.

There is a slight reduction in DRP and TP concentrations between the upstream and downstream sites in the Clive River that is not seen in the Tutaekuri. It is possible this is due to uptake by benthic macroalgae (*Ruppia* species) as well as some precipitation of particulate phosphorus in the slow moving waters.

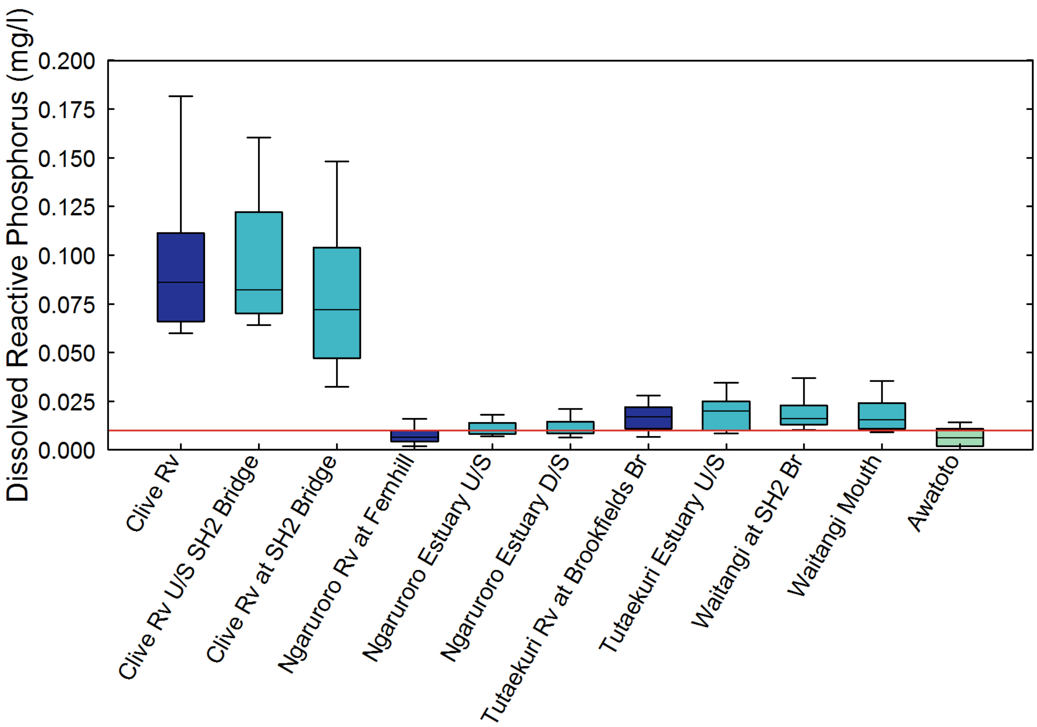


Figure 2-13: Dissolved reactive phosphorus concentrations in the Waitangi Estuary.

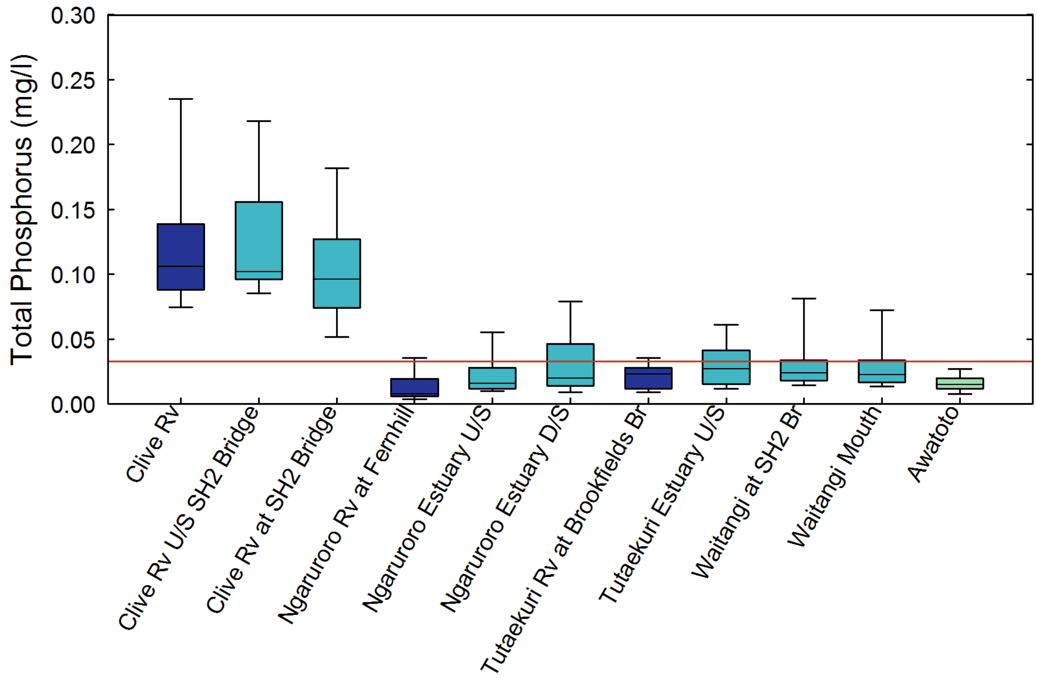


Figure 2-14: Total phosphorus concentrations in the Waitangi Estuary.

2.5.2 Nitrogen

Nitrogen concentrations in the Ahuriri estuary are highest at sites furthest from the sea. Most of this nitrogen is in particulate forms. Dissolved forms of inorganic nitrogen (ammonia-NH_4^+, nitrate-NO_3^-, and nitrite-NO_2^-) known as DIN, are comparably low.

DIN concentrations in the estuary (Figure 2-16) are notably lower than those in the streams at Seafield Road, the Taipo stream and Saltwater Creek. It is likely that any DIN available in the water column is rapidly used by phytoplankton growth, which is prolific in the Ahuriri Estuary (Figure 2-15), particularly in the upper reaches (Section 2.6).

Figure 2-15: Orange discolourations caused by a Cylindrotheca sp. bloom in the upper Ahuriri Estuary (April 2016).

The low DIN concentrations suggest most of the total nitrogen (TN) present is made up of particulate matter. This particulate nitrogen consists of plants, animals and their by-products, as well as nitrogen compounds adsorbed onto sediment particles. TN concentrations are highest in the upper estuary, where both particulate matter (section 2.4) and phytoplankton concentrations (section 2.6) are also highest.

DIN and TN concentrations in many of the streams entering the Ahuriri estuary exceed ANZECC guideline concentrations. Median concentrations in Saltwater Creek exceed guideline values for DIN and concentrations in the Taipo stream and at Seafield Road exceed guideline concentrations some of the time.

Median concentrations of TN exceed ANZECC guidelines at the Taipo Steam, Saltwater Creek and both pump station sites. Median concentrations at the other stream sites are approaching guideline values.

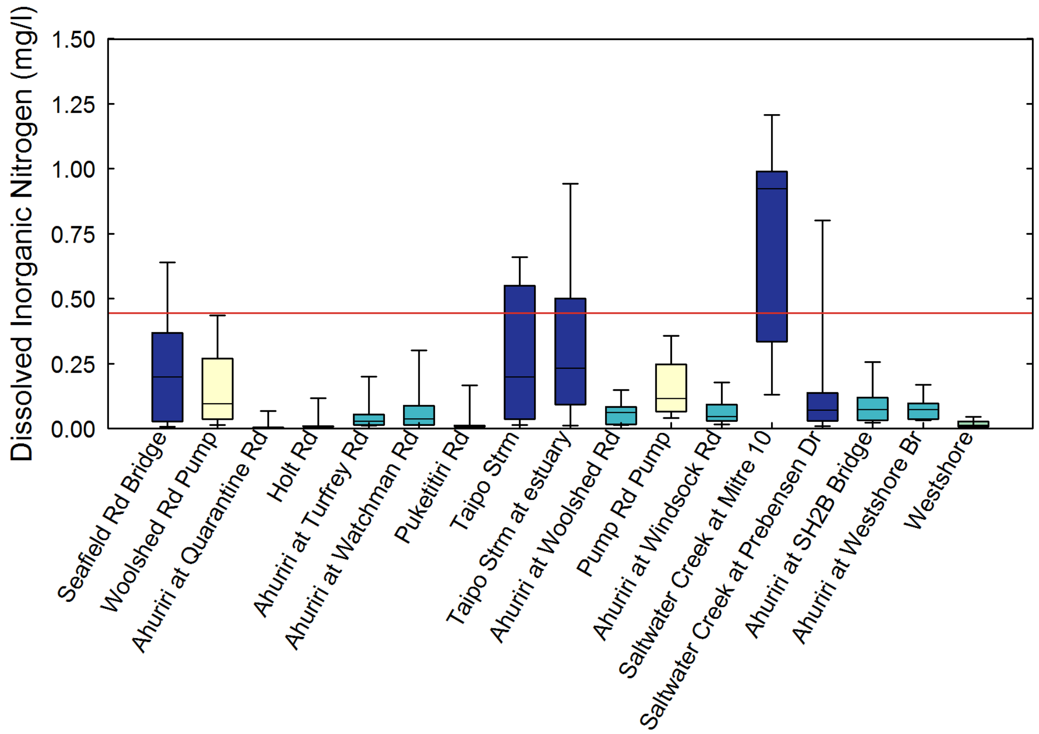


Figure 2-16: Dissolved inorganic nitrogen concentrations in the Ahuriri Estuary.

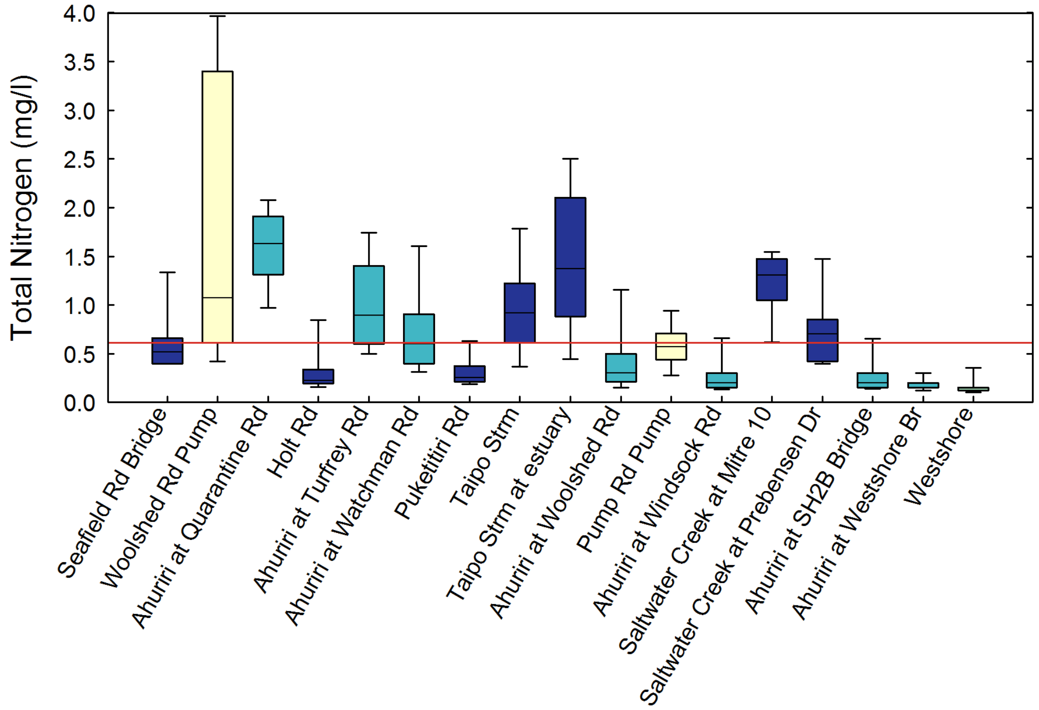


Figure 2-17: Total nitrogen concentrations in the Ahuriri Estuary.

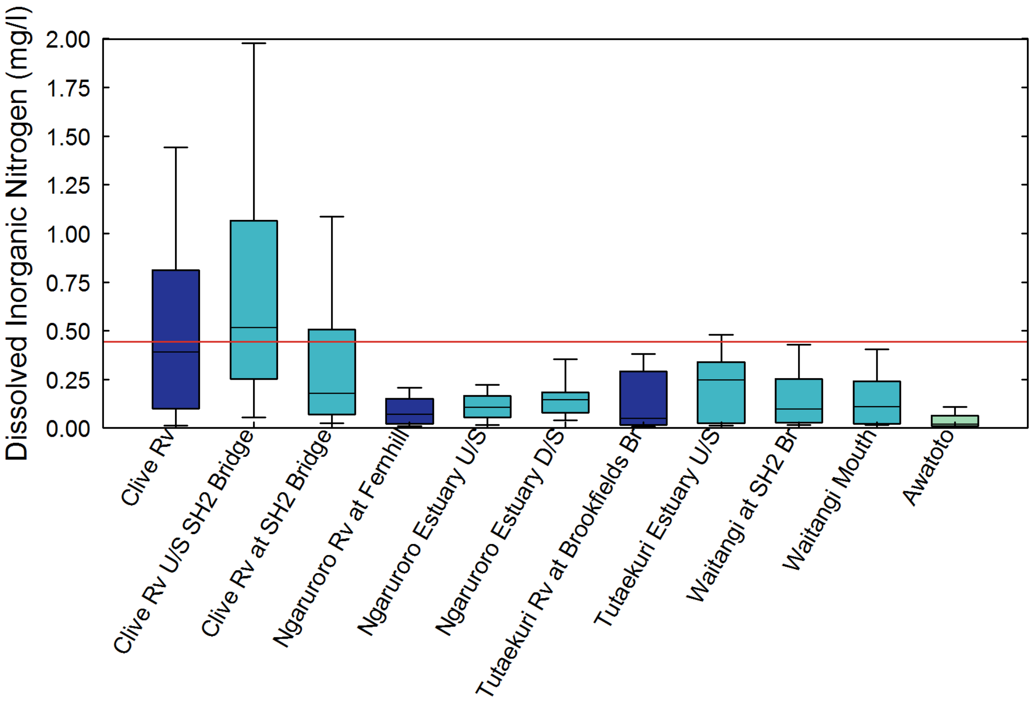


Figure 2-18: Dissolved inorganic nitrogen concentrations in the Waitangi Estuary.

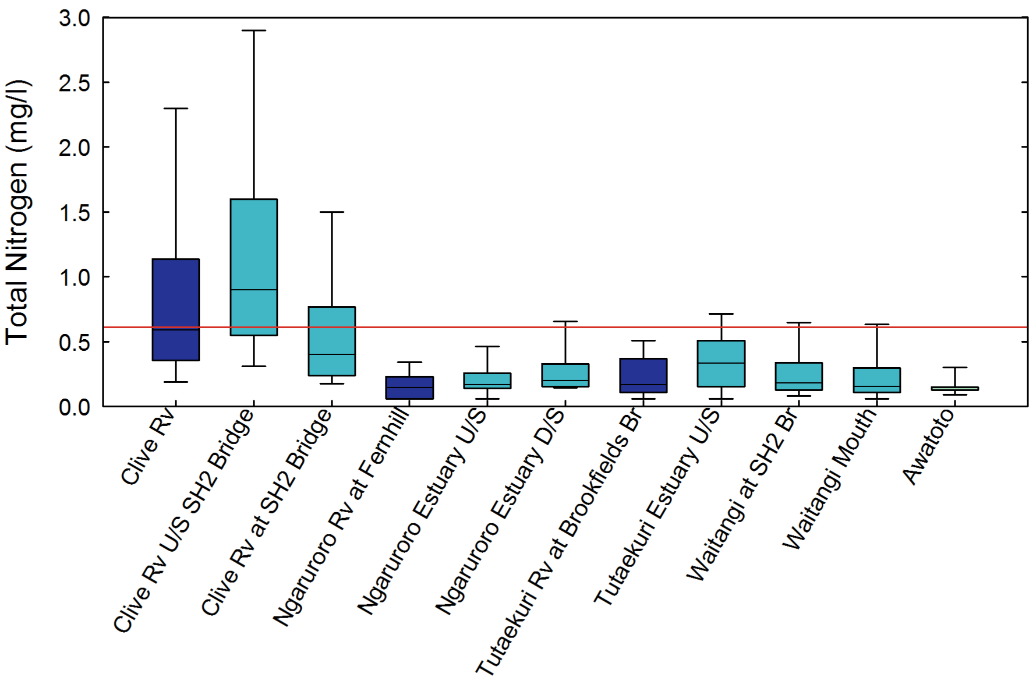


Figure 2-19: Total nitrogen concentrations in the Waitangi Estuary.

Total nitrogen (Figure 2-19) and DIN (Figure 2-18) concentrations in the Waitangi Estuary display a similar pattern to the concentrations of phosphorus. Concentrations of nitrogen in in the Ngaruroro and Tutaekuri rivers are comparatively low compared to the elevated concentrations in the Clive River. DIN and TN concentrations in the Clive River frequently exceed ANZECC guidelines.

This pattern of nutrient concentrations is similar in the waters of the estuary, where nitrogen concentrations at Ngarururo and Tutaekuri sites are low compared to elevated concentrations at the Clive sites. DIN makes up a much larger proportion of the TN in the Waitangi Estuary than the Ahuriri Estuary. These concentrations can promote phytoplankton blooms (Figure 2-23) and macroalgae mats (Figure 2-20) in the Waitangi Estuary.

2.6 Chlorophyll-*a*

In the freshwater environment, elevated nutrient levels typically cause increased growth of macrophytes and macroalgae. In the marine environment, this increased nutrient levels usually causes increased concentrations of phytoplankton, although at times can be expressed in terms of macroalgae blooms. Chlorophyll-*a* (chla) concentrations are used as a proxy for phytoplankton concentrations in the water column. It is not possible to compare these water column concentrations with chla results from the freshwater State of the Environment (SOE) monitoring programme, because different methods are used. For this reason, only estuarine sites are displayed in the boxplots below.

Elevated nutrient levels in estuaries can also lead to increase in benthic macroalgae such as *Ulva* and *Gracilaria* species (Figure 2-20) however methodologies are not yet in place to measure this.

Figure 2-20: *Ulva* sp. bloom in the Waitangi Estuary (March 2016).

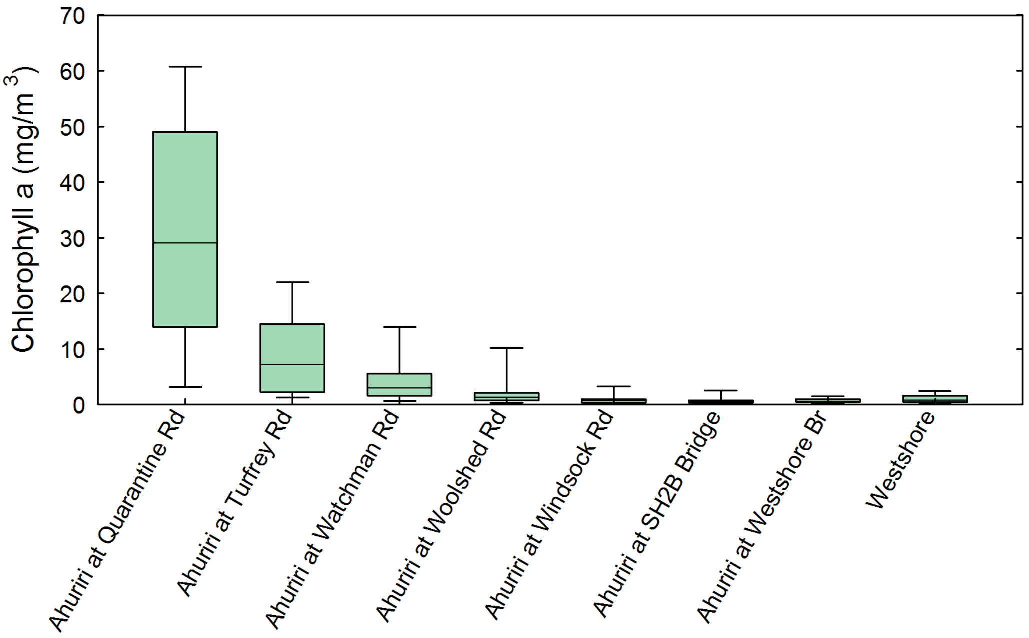


Figure 2-21: Chlorophyll-*a* concentrations in the Ahuriri Estuary.

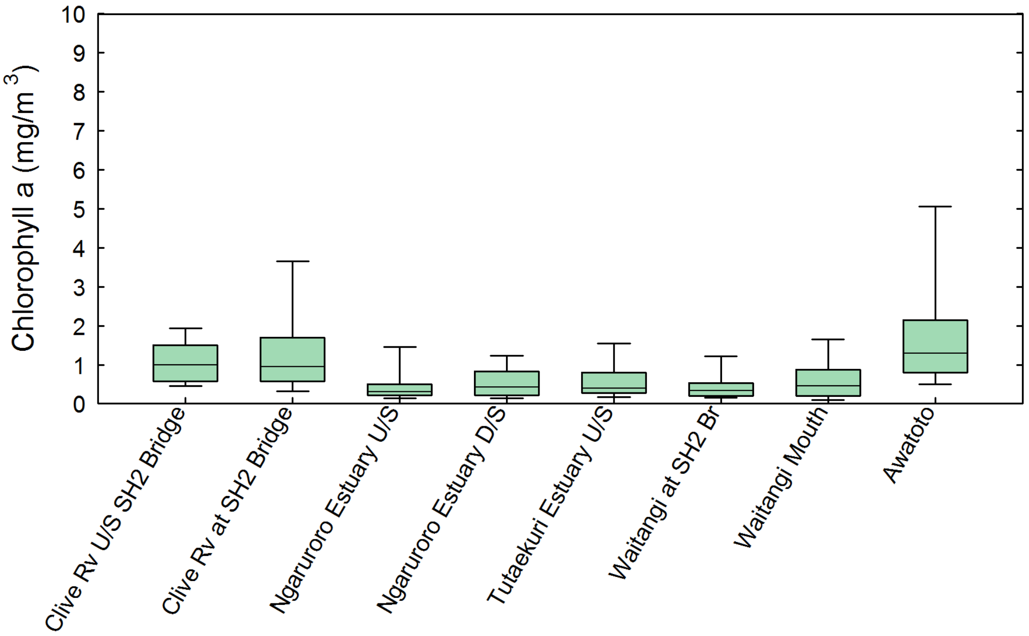


Figure 2-22: Chlorophyll-*a* concentrations in the Waitangi Estuary.

Figure 2-23: Orange discolouration caused by a *Cryptomonas* sp. bloom in the Waitangi Estuary (March 2015).

The upper reaches of the Ahuriri Estuary (Quarantine Road to Woolshed Road) appear to be highly productive in terms of chla (Figure 2-21) concentrations, most likely driven by the relatively high nutrient concentrations in this area. The slow moving, shallow, warm waters are ideal for phytoplankton reproduction (Figure 2-15). The high turbidity (Figure 2-6) favours phytoplankton over benthic macroalgae since the high turbidity inhibits the penetration of light, which is necessary for macroalgal growth.

Chlorophyll-*a* concentrations in the Waitangi estuary are generally lower than background levels found at the Awatoto coastal SOE monitoring site (Figure 2-22). Any phytoplankton blooms which occur are likely to be short-lived due to the relatively high flow in this estuary. Spot measurements are unlikely to capture these events. For example, phytoplankton blooms have been observed in the Clive (Figure 2-23) and Ngaruroro arms of the estuary.

2.7 Dissolved oxygen

Aquatic species require dissolved oxygen for respiration. In healthy waters dissolved oxygen saturations of 80% to 110 % are typical. Plants and algae growing in water produce oxygen as a by-product of photosynthesis. Oxygen is also passively diffused into water from the atmosphere or is mixed by turbulence or aeration induced by waves and tide. Dissolved oxygen levels can fluctuate on a daily basis. In systems with slow water movement, open to sunlight and large volumes of phytoplankton or macroalgae, these fluctuations can be extreme. These fluctuations have been observed in the Karamu catchment (Wilding 2015). During daylight hours dissolved oxygen levels can increase to very high levels as large amounts of oxygen is produced by photosynthesis of the algae, this same algae then uses up all the oxygen overnight through respiration leading to very low dissolved oxygen levels in the morning. Decomposition of organic material in sediments can also reduce dissolved oxygen in the water column.

Dissolved oxygen saturations in the Ahuriri estuary and its tributaries fluctuate between 1% and 250%. This suggests that both tributaries and the main stream of the estuary are experiencing extreme fluctuations in dissolved oxygen saturation. Low saturations can cause mortality in some species, however the effect of low dissolved oxygen saturation is related to duration of exposure. The recorded concentrations are from discrete samples and continuous measurements are required to understand the impact of these concentrations.

Figure 2-24 shows continuous dissolved oxygen saturation data from an oxygen sensor deployed near the Quarantine Road site in the Ahuriri Estuary between May and July 2015. There is a clear daily fluctuation between periods of reduced dissolved oxygen saturation (as low as 20%) at night and during the early morning, and periods of elevated dissolved oxygen saturation in the afternoons and evening (177%).

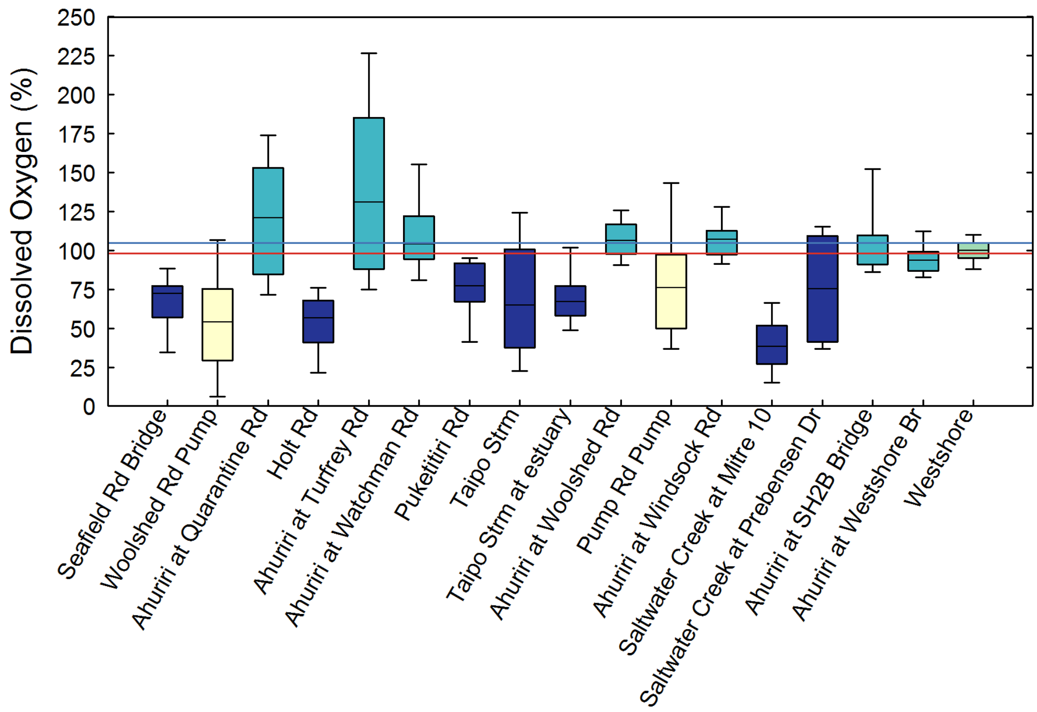


Figure 2-24: Dissolved oxygen concentrations in the Ahuriri Estuary.

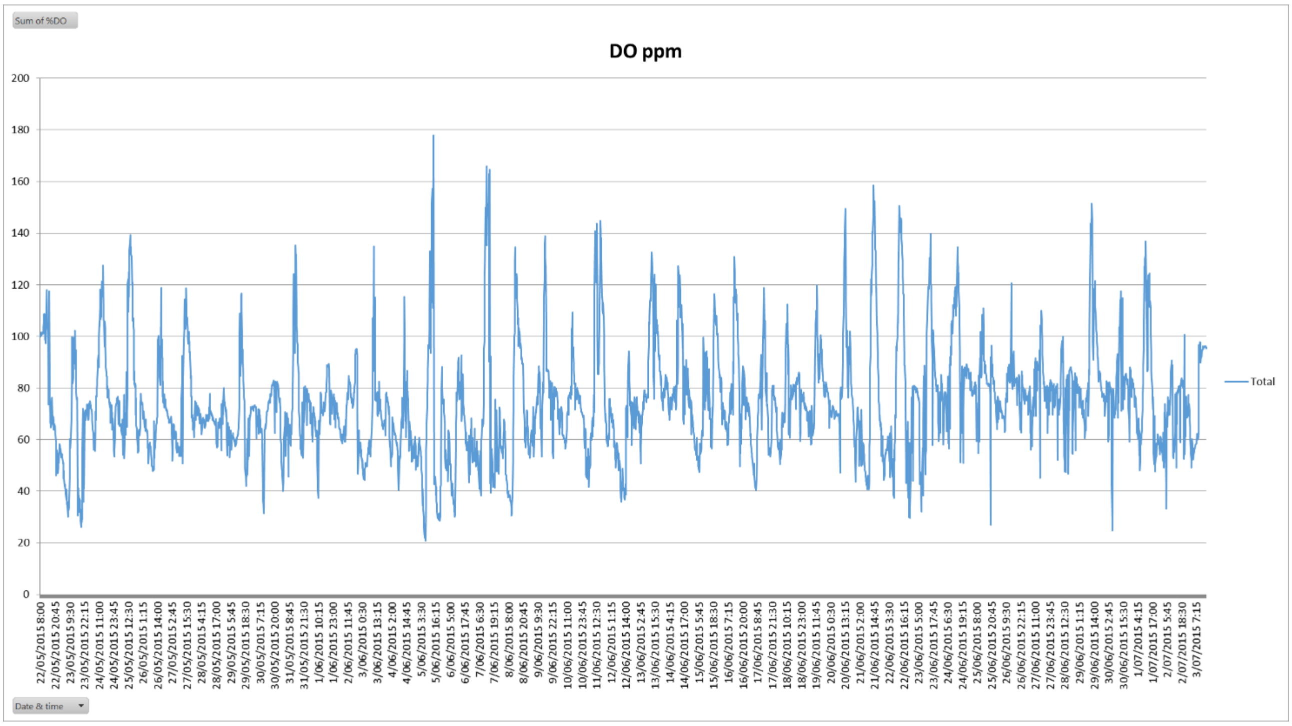


Figure 2-25: Continuous dissolved oxygen data for Ahuriri Estuary (22 May 2015 – 3/07/2015).

The periods of reduced oxygen saturation over the dataset are much longer than when the dissolved oxygen saturation is elevated. The median of the data over the entire dataset is only 72.5%. This suggests that whilst phytoplankton productivity can cause periods of elevated dissolved oxygen saturation, the main driver of dissolved oxygen saturations in the Ahuriri Estuary is organic decomposition processes which generally depress dissolved oxygen saturations.

Dissolved oxygen concentrations are at acceptable levels within the Ngaruruo and Tutaekuri arms of the Waitangi estuary. Dissolved oxygen concentrations in the Clive River indicate hypoxic conditions. All but one of these samples was collected prior to midday.

The very low dissolved oxygen concentrations in the Clive River (Figure 2-26) are typical of slow moving water with no shading and large amounts of macro algal growth. The oxygen demand for macro algal respiration during the hours of darkness have exceeded the water's ability to provide oxygen. Chla concentrations at the Clive sites are low, (Figure 2-22) suggesting that the dissolved oxygen conditions in the Clive are generally due to macro algae rather than phytoplankton.

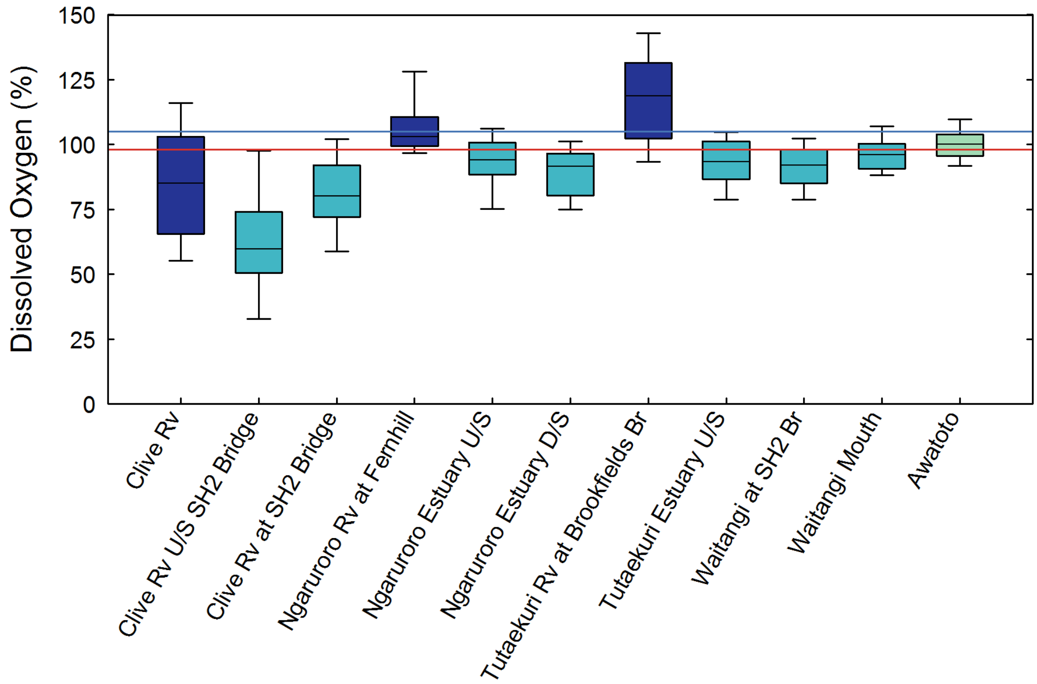


Figure 2-26: Dissolved oxygen concentrations in the Waitangi Estuary.

2.8 Conclusions

2.8.1 Ahuriri Estuary

- Concentrations of nutrients in all the tributaries entering the Ahuriri Estuary are elevated and frequently exceed ANZECC guideline values.
- Nutrient concentrations within the Ahuriri Estuary are likely a combination of recycling of legacy inputs and ongoing high concentration inputs.
- Suspended sediment concentrations are elevated in some tributaries, particularly the Taipo Stream and Saltwater Creek. Continuous inputs of fine sediments are leading to increasing muddiness (Section 4) in the estuarine sediments.
- Elevated nutrient concentrations lead to frequent phytoplankton (and to a lesser extent macroalgal) blooms. In turn the respiration, photsynthesis and breakdown of these phytoplankton blooms lead to periods of extreme elevated and reduced dissolved oxygen saturation.
- The upper Ahuriri Estuary is in a highly eutrophic state.

2.8.2 Waitangi Estuary

- Water quality in the three arms of the estuary reflects the quality of water in their respective rivers.

- During rainfall events suspended sediment and turbidity is elevated in the Tutaekuri and Ngaruroro arms of the estuary as sediment is received from the upstream catchments and the un-vegetated banks of the estuary are actively eroded.
- Suspended sediment concentrations and turbidity are low in the Clive arm of the estuary.
- Nutrient concentrations are elevated, although chlorophyll *a* concentrations are generally not. The elevated nutrient concentrations generally promote macro-algal growth, which in turn affects dissolved oxygen concentrations.

2.9 Recommendations

- Identify sources of sediment and nutrients in upstream catchments.
- Manage nutrient and sediment concentrations entering the estuaries.
- Manage streambank erosion in the Waitangi Estuary.

3 Contact Recreation and Food Gathering

Like many Hawke's Bay rivers and lagoons, the Pandora Pond (or Humber Street Pond) within the Ahuriri Estuary, and the Waitangi Estuary provide recreational opportunities, including swimming, kayaking, sailing, and waka ama. On an exposed coastline such as Hawke's Bay, these areas provide important opportunities for aquatic recreation.

A study of the current state of the Ahuriri Estuary for contact recreation and food gathering is described in Madarasz-Smith (2013). A summary of these data, with updated contact recreation information is provided below. A similar assessment has not been undertaken for the Waitangi Estuary, however a brief description of the current state of the contact recreation sites located upstream of the Waitangi Estuary on the Tutaekuri, Ngaruroro and Clive Rivers has been included.

3.1 Attributes and guidelines

Contact recreation attribute and guidelines are described in Table 3-1. Current guidelines for the attributes associated with shellfish/fish gathering are detailed in Table 3-2

Table 3-1: Current water quality guidelines associated with contact recreation. cfu = colony forming units, NTU = Nephelometric turbidity units, BD = black disk.

Attribute	Guideline value[1]		Source	Value
	Satisfactory	Unsatisfactory/ Unacceptable		
Enterococci (cfu/100 mL)	<280 cfu/100 mL	>280 cfu/100 mL	(MfE and MoH 2003)	Human health
Turbidity (NTU)	0.5-10 NTU	>10 NTU	(ANZECC 2000)	Aquatic ecosystems
Visual clarity (BD)	>1.6 m	<1.6 m	(MfE 1994)	Aesthetic and safety
Chlorophyll *a* (g/m^3)	<4 µg/L	>4 µg/L	(ANZECC 2000)1	Aquatic ecosystems
Toxic algal species (cells/mL)	Absent	Present	-	Human health and aquatic ecosystems

[1]These guidelines refer to ANZECC 2000 for South-Eastern Australia which is used in the absence of New Zealand specific estuarine guidance.

Table 3-2: Current guideline values associated with water and shellfish quality. MPN = Most Probable Number.

Attribute	Guideline		Source	Relevance
	Satisfactory	Unsatisfactory/ Unacceptable		
Faecal coliforms in overlying waters	Seasonal median ≤ 14 MPN/100mL ≤ 10% of samples ≤ 43MPN/100mL	Seasonal median > 14 MPN/100mL > 10% of samples > 43MPN/100mL	(MfE and MoH 2003)	Human Health
Toxic algal species in overlying waters	Not present	Present	Nil	Human Health and Aquatic Ecosystems
E. coli in shellfish flesh	Median ≤ 230 MPN/100g and ≤ 10% of samples ≤ 700 MPN/100g	Median > 230 MPN/100g and > 10% of samples > 700 MPN/100g	(NZFSA 1995)	Human Health

Trace metals	Below FSA guidelines	Above FSA guidelines	Human Health

3.2 Ahuriri Estuary and Waitangi Estuary

3.2.1 Contact Recreation

A suitability for recreation grade (SFRG) for Pandora Pond, Tutaekuri River at Guppy Road, Ngaruroro River at Chesterhope Bridge and Clive River at the Boat ramp was generated at the completion of the 2015/16 season:

Site	Catchment Risk	Microbiological Risk Assessment (MAC)	% Suitable for swimming over a season	Suitability for Recreation Grade (SFRG)
Pandora Pond, Ahuriri	Moderate	B	97%	Good
Tutaekuri Rv, Waitangi	Moderate	B	98%	Good
Ngaruroro Rv, Waitangi	Moderate	C	98%	Fair
Clive Rv, Waitangi	High	C	96%	Poor

This grading indicates that Pandora Pond and the Tutaekuri River are satisfactory for swimming most of the time, however exceptions may be following heavy rainfall. (MFE and MOH, 2003).

The Ngaruroro River at Chesterhope Bridge can be considered generally satisfactory for swimming although caution is advised after rain, or if the water appears discoloured.

Clive River, with a poor grading, would generally not be considered suitable for contact recreation.

The conflict between the advice provided with the gradings and the data on the percent of the time the waterbodies were suitable for recreation, highlights the precautionary approach taken by the guidelines.

Other attributes can impact in a person's choice to partake in, and enjoy, a contact recreation experience (see Table 3-1). These are described in Madarasz-Smith, 2013.

3.2.2 Food gathering

The Ahuriri Estuary has traditionally been an important food source for local hapu and whanau. Maori occupation dates back as far as the 12th century, and the estuary was used not only to provide food to the local area, but also as a resource that aided in the development of trade and social relationships with neighbouring hapu (Black and Ataria, 2008).

Although very little information exists to confirm the food gathering values of the Waitangi Estuary, this area is actively used for fishing of several species, including flounder, mullet and inanga.

There is relatively little information regarding the state of food resources within the Ahuriri Estuary. While Hawke's Bay Regional Council undertakes monitoring of waters overlying popular shellfish gathering areas, comparing measured concentrations with national guideline values, there is some concern regarding the relevance and applicability of these guidelines for assessing the risks to human health.

Table 3-3: Levels of compliance with MfE and MoH guidelines for shellfish gathering waters, in Ahuriri Estuary (2006-2016).

Year	Median concentration (MPN /100mL)	Proportion of samples >43 MPN/100 mL (%)	Compliant with guideline values?
2006/07	9	**20**	**No**
2007/08	14	10	Yes
2008/09	10	5	Yes
2009/10	**14**	**20**	**No**
2010/11	**39**	**40**	**No**
2011/12	5	**20**	**No**
2012/13	3	0	Yes
2013/14	2	10	Yes
2014/15	2	**12**	**No**
2015/16	4	**20**	**No**

The compliance of waters in the Ahuriri Estuary with seasonal guidelines for water quality at shellfish gathering sites is variable (Table 3-3). This variability exemplifies one of the underlying concerns with the current guidelines. This is that they produce highly variable results for the same shellfish gathering waters, hindering the ability to provide consistent, reliable communication regarding the level of risk with the public.

However, the historic levels of non-compliance and the recommendation that shellfish should not be gathered from areas influenced by urban runoff indicate that water quality in the Ahuriri Estuary should not be considered generally appropriate for shellfish gathering purposes.

The most comprehensive study undertaken to date examined the effects of stormwater contaminants on edible shellfish resources. This study concluded that at the time of the study, the risk to human health associated with consumption of cockles and yellowbelly flounder could be considered negligible. For example, it would be necessary to consume 6 kg of cockles or 11 kg of flounder each day to exceed the tolerable limit for zinc, and 11 kg of cockles or 123 kg of flounder to exceed the tolerable daily intake limit for copper (Ataria, Tremblay et al. 2008).

Although shellfish and fish gathering is not compromised by levels of contamination that constitute immediate health risks, the presence of stormwater contaminants is likely to impose a barrier to food gathering by tangata whenua.

3.3 Conclusions

- In general the water bodies monitored for contact recreation within the Ahuriri and Waitangi estuaries demonstrate a high level of compliance with NZ Guidelines for microbiological water quality.
- Clive River achieved a high level of compliance, but a history of poor water quality in this area means contact recreation is still not advised.
- Periods of stormwater inflow associated with high rain events can carry high levels of faecal indication bacteria into the estuary and rivers, and therefore care should be taken following heavy rain.

- Access by stock can contribute direct faecal input, and stock exclusion is recommended.
- Madarasz-Smith (2013) describes other attributes associated with contact recreation in the Ahuriri Estuary, and concludes that other water quality metrics, such as visual clarity and algal growth do not generally impair recreational values.
- The Ahuriri Estuary is not considered suitable for shellfish collection based on faecal indicator monitoring.
- Trace metal levels in sampled fish do not appear to exceed food safety guidelines, but the presence of stormwater contaminants is likely to impose a barrier to food gathering by tangata whenua.

3.4 Recommendations

- Continue faecal source tracking at Clive River to confirm dominant faecal sources and guide management options.
- Manage direct faecal inputs by removing stock access.
- Manage stormwater inputs into the Ahuriri Estuary to support food gathering and contact recreation values.

4 Estuarine Sediment Quality

Estuarine and marine sediments form the complex habitats that support the diverse communities found within the benthic environment. Sustaining sediment quality is as fundamental to ensuring a healthy and functioning ecosystem as sustaining the quality of the surrounding waters.

As naturally depositional environments, estuaries and other coastal areas can become contaminant ‘sinks’, accumulating toxic compounds within the sediment matrix. Trace metals, hydrocarbons, organotins and organopesticides typically enter the coastal marine area via stormwater and diffuse discharges. During periods of wet weather, contaminants can be washed off road surfaces, industrial sites, roofs, and other surfaces into the stormwater network, or into rivers and streams. These contaminants are present either in solution, or bound to the sediment or suspended particulate matter that is also washed off during the rainfall events.

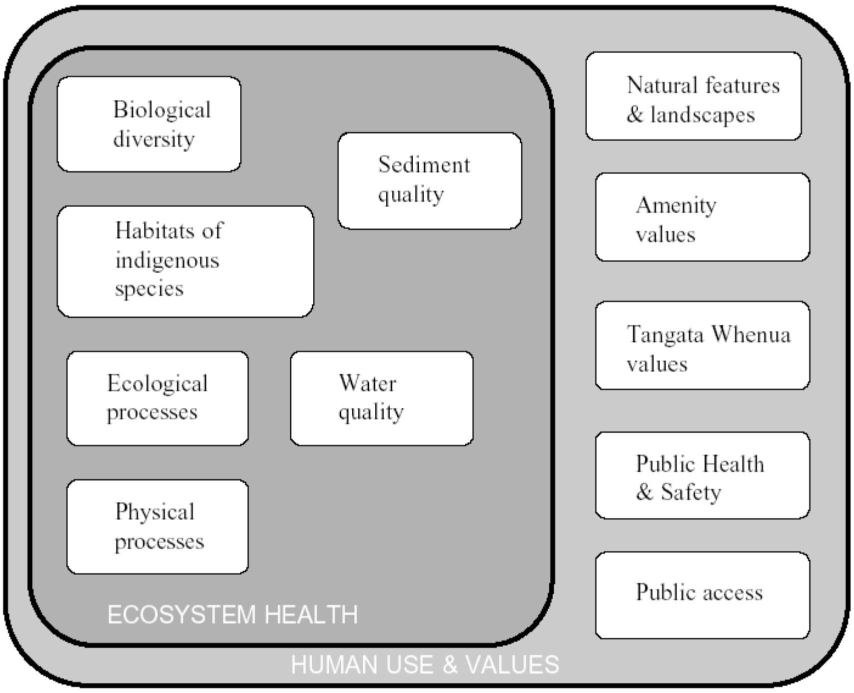


Figure 4-1: Diagrammatic of how sediment quality contributes to the policy goals for the coastal marine area. (from MfE, 1998).

Sediments begin to settle out as soon as the water loses enough energy to no longer be able to keep them in suspension, meaning that larger, coarser sediments will begin to settle earlier on than smaller, lighter, fine-grained particles. It is the smaller particles (<63µm = 0.063mm) that tend to accumulate in the settling or depositional low energy environments such as estuaries and shallow embayments. These finer sediments have reactive surface properties that bind trace metals so that metals are primarily retained to fine grained particles, making these depositional areas vulnerable to the contaminant accumulation.

Contaminants bound to sediments may continue to breakdown and leach into the interstitial1 waters, continuing to pollute for some time, or may be ingested by bottom feeders (e.g. flounder) and may bioaccumulate, causing sublethal or lethal effects in the surrounding flora and fauna.

Many of the heavy metals, hydrocarbons, organotins and organopesticides can have significant adverse effects on aquatic life when they accumulate in sediments. The reproductive system can be affected causing genetic abnormalities, and affecting growth and reproductive success (e.g. Tributyltin (TBT), zinc, mercury, lead, DDT), they can cause muscular and neurological degeneration (e.g. lead), affect plant growth and photosynthesis (e.g. copper, lead, DDT), interfere with respiration and affect the microstructure of the gills (e.g. copper), and may accumulate in marine biota causing illness in human consumers (e.g. methyl mercury poisoning).

Therefore monitoring the quality of sediments gives a measure of environmental health as marine and estuarine animals and plants are as strongly influenced by the quality of the sediments surrounding them as they are by the waters above them.

4.1 Estuarine sediment quality monitoring (SOE)

The Estuarine Ecology Monitoring Programme (EEMP) annually monitors Ahuriri and Waitangi 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).

Table 4-1: Data on the TANK estuaries.

Estuary	Sampling Period	Estuary Type	Estuary Volume (m^3)	Catchment Size (Ha)	Catchment Land-use (>80%)
Ahuriri Estuary	AHUA 2006-2013 AHUB 2006-2013 AHUD 2007-2013 AHUE 2009-2013 AHEF 2016	Tidal Lagoon	6,347,333	14,583	Sheep and Beef (53%) Built-up Area (15%) Short-rotation crops (10%)
Waitangi Estuary	2013, 2016	Tidal Lagoon	-	337,058	Sheep and Beef (42%) Manuka/Kanuka (16%) Indigenous Forest (13%)

4.1.1 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 2011 and 2016 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

[1] Occurring in the spaces between sediment grains. Also known as porewater.

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.

4.1.2 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.

4.2 Estuarine Sediment Quantity, Composition and Quality

Sediments in estuaries and oceans 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.

4.2.1 Sediment composition

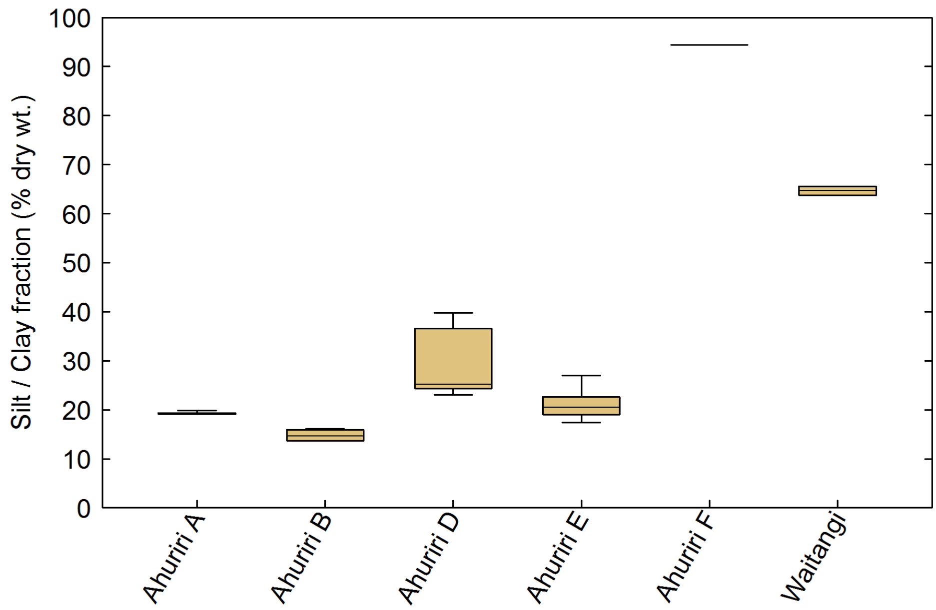


Figure 4-2: 5 year median levels of silt/clay (mud) in sediments (2012-2016).

Sediments in the Lower Ahuriri Estuary are generally dominated by medium sands, with lower levels of muds (silt/clay). 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 Ahuriri D, F and Waitangi are more characteristic of depositional environments, with higher levels of muds within the sediment complex. Noticeably Ahuriri F with a median silt/clay fraction of 94.4% demonstrates an almost compete in filling by muds.

Trend analysis of the data indicates significant increases in the silt/clay fraction of the sediments at 2 of the 4 sites that were able to be analysed, suggesting a 'muddying' of the sediments at these sites Table 4-2. Of particular importance, the 'less disturbed' sites with lower concentrations of silt/clay appear to be experiencing increasing trends in silt/clay content. 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 4-2: 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.

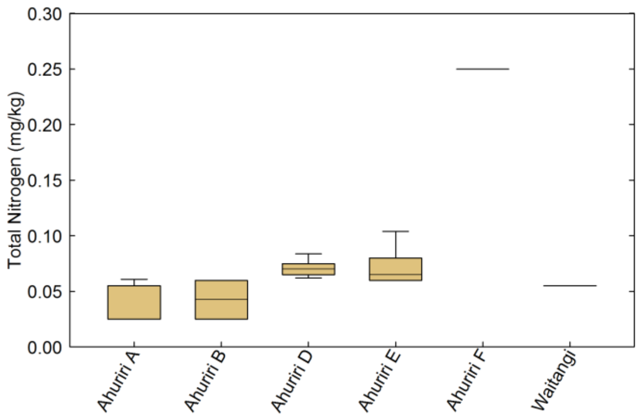
Site	Silt/Clay (Mud) (mg/kg)		
	Median	Trend p value	Percent Annual Change
Ahuriri A	16.65	0.000	6.64
Ahuriri B	12.40	0.000	5.80
Ahuriri D	27.60	0.154	2.34
Ahuriri E	22.40	0.000	-5.80

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) and Waitangi estuaries are likely to be sediment 'stressed'.

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 Waitangi Estuary (64%) exceeds published literature on sediment stress in estuary infauna.

These high results, combined with increasing trends in muddying between 2006 and 2016 is a significant finding and would suggest catchment management is necessary to reduce sediment loads from entering and depositing within regional estuaries.

4.2.2 Sediment nutrients



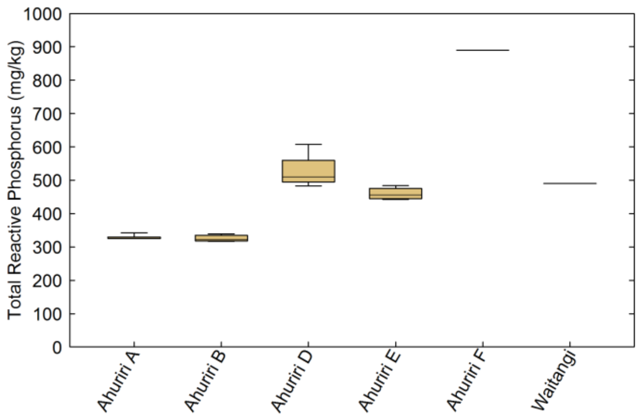


Figure 4-3: Sediment total nitrogen and total recoverable phosphorus. 5 year medians (2012-2016).

Sediment nutrient concentrations were lowest at Ahuriri A and B sites, and moderate at Ahuriri D, E and Waitangi. In response to concerns about habitat change and eutrophication in the upper Ahuriri Estuary, sediment samples were collected in 2016 at site Ahuriri F. These indicate significantly higher levels of nutrients in the sediments of the upper estuary.

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 Waitangi Estuary vary with median concentrations of sediment total nitrogen between 0.06 and 0.08g/100g. These results do not suggest significant eutrophication of the lower estuary sediments by nitrogen (Robertson 2016). By contrast the upper estuary appears to be approaching levels which would indicate significant enrichment of sediments by nitrogen, at a level which is likely to impact ecological health.

With the exception of Ahuriri F, TRP concentrations within sediments of the lower Ahuriri 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 some enrichment, probably a localised source of phosphorus. Results from Ahuriri F indicate significant sources into the system in the upper reaches, but little is known about the behaviour and cycling of phosphorus at this site, which may act to mitigate or enhance expressions of eutrophication.

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.[2]

Three of the 4 monitoring sites recorded decreasing trends in the normalised sediment total nitrogen and total recoverable phosphorus concentrations. These were Ahuriri A, B and D. Ahuriri E was the only site to exhibit significant increases in normalised sediment total nitrogen. Trend analysis could not be conducted for Waitangi as only 2 sampling occasions have been undertaken.

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

Table 4-3: 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/100g)		
	Median	Trend p value	Percent Annual Change
Ahuriri A	0.246	0	-9.156
Ahuriri B	0.27	0	-6.827
Ahuriri D	0.274	0	-8.237
Ahuriri E	0.324	0.005	4.519

Table 4-4: 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	1982.429	0	-11.034
Ahuriri B	2673.559	0	-6.565
Ahuriri D	2407.407	0	-6.233
Ahuriri E	2087.012	0	5.648

Sediment chlorophyll *a*

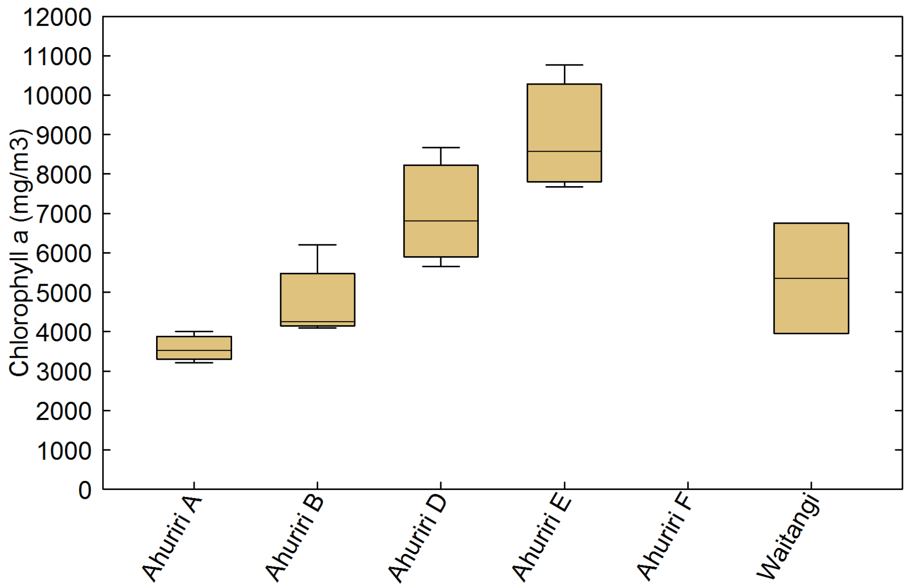


Figure 4-4: 5 year median levels of sediment chlorophyll *a* (2012-2016).

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 Ahuriri E, significantly higher than Ahuriri A which may be considered to reflect background levels. Given that this area is high in shell hash, this result is somewhat surprising and warrants further investigation. The stable nature of this sediment may however provide substrate for microphytobenthos which may contribute to these increased chlorophyll concentrations.

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 may indicate slightly enriched sediments.

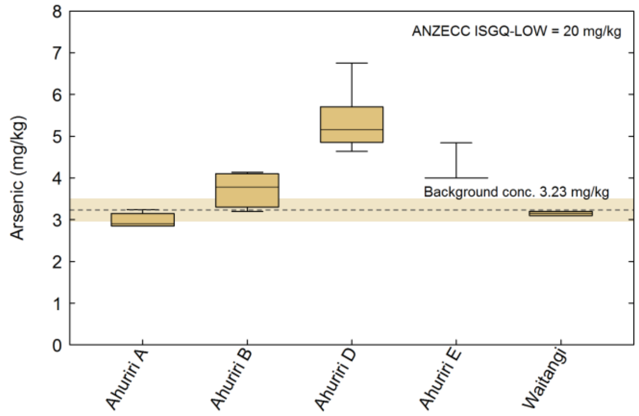
Table 4-5: Trend analysis of chlorophyll a in estuary sediments over the monitoring period. Statistically significant trends are indicated in bold. BLUE highlight for PAC indicates an improving trend, RED indicates a deterioration.

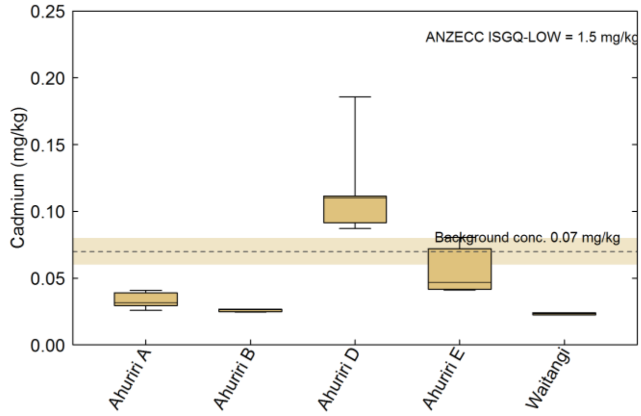
Site	Chlorophyll *a*		
	Median	Trend p value	Percent Annual Change
Ahuriri A	3050	0.000	5.74
Ahuriri B	3250	0.000	11.56
Ahuriri D	5100	0.013	4.90
Ahuriri E	6550	0.000	10.58

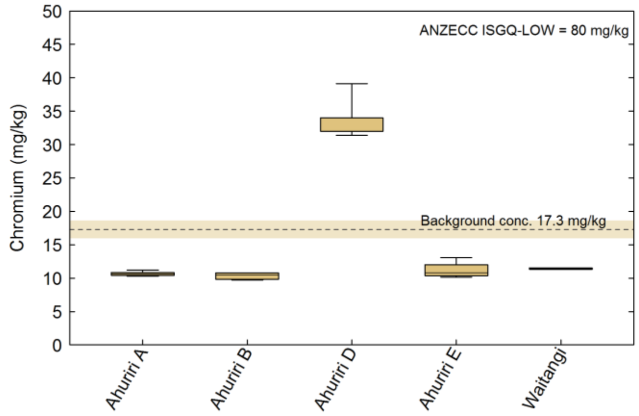
All sites indicated statistically-significant increases in sediment chlorophyll a concentrations between the beginning of sampling and 2016. This is contrast to earlier analyses (Wade et al, 2016) which indicated no significant trends in sediment chlorophyll *a* in the period up to 2013. This may indicate the influence of three very dry years in Hawke's Bay on sediment productivity.

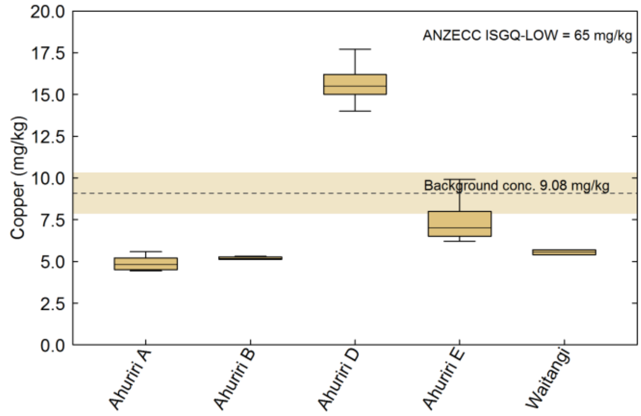
It is important to note that while the results of sediment nutrient and chlorophyll *a* concentrations do not appear indicative of excessively eutrophic systems, the sampling approach taken in the national monitoring protocol has a focus on downstream environments. New guideline approaches *(Robertson 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.

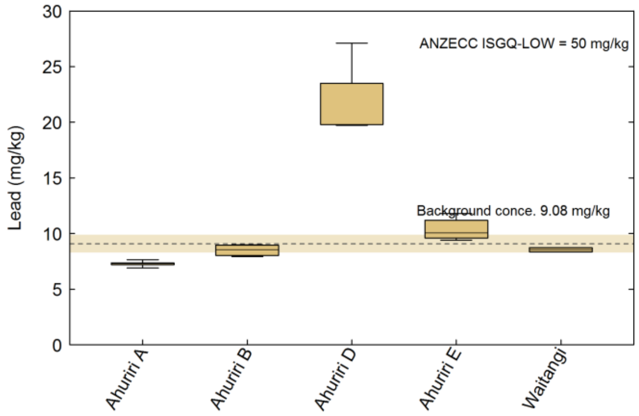
4.2.3 Sediment toxicants

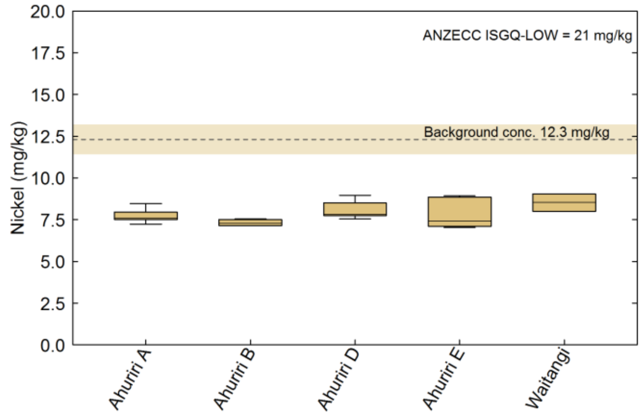












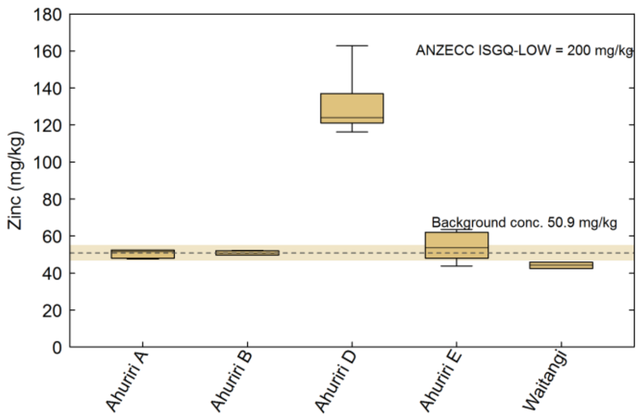


Figure 4-5: 5 year median levels (2012-2016) of trace metal contaminants in estuary sediments (Ahuriri A-E) and 2013, 16 (Waitangi). Amber dashed line indicates background levels as described by Strong, ISQG = Interim sediment quality guidelines, Low and High (ANZECC, 2000).

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 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 4-6: 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	16.41	**0.003**	**-3.71**
Ahuriri B	22.379	**0.000**	**12.19**
Ahuriri D	18.798	0.631	-0.886
Ahuriri E	19.854	**0.007**	**5.01**

Normalised arsenic concentrations showed a significant decline at Ahuriri A, but significant increases at Ahuriri B and E.

Table 4-7: 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	0.26	**0.000**	**-12.71**
Ahuriri B	0.25	**0.000**	**-10.68**
Ahuriri D	0.60	**0.000**	**-19.14**
Ahuriri E	0.23	**0.000**	**9.45**

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 4-8: 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	68.10	**0.000**	**-8.47**
Ahuriri B	87.28	**0.000**	**-6.31**
Ahuriri D	146.40	**0.000**	**-11.69**
Ahuriri E	51.70	**0.049**	**2.38**

Normalised chromium concentrations at sites Ahuriri A, B, and D significant decreases, while Ahuriri E reported a significant increase in normalised chromium.

Table 4-9: 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	33.14	**0.000**	**-10.45**
Ahuriri B	44.01	**0.000**	**-5.87**
Ahuriri D	67.05	**0.000**	**-8.23**
Ahuriri E	34.22	0.132	2.31

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

Table 4-10: 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	47.29	**0.000**	**-10.10**

Ahuriri B	67.14	**0.000**	**-4.91**
Ahuriri D	97.41	**0.000**	**-11.44**
Ahuriri E	50.51	0.386	1.09

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

Table 4-11: 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	46.10	**0.000**	**-7.71**
Ahuriri B	57.39	**0.000**	**-6.17**
Ahuriri D	31.18	**0.001**	**-4.66**
Ahuriri E	34.32	**0.001**	**4.38**

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

Table 4-12: 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	328.17	**0.000**	**-10.93**
Ahuriri B	440.70	**0.000**	**-7.13**
Ahuriri D	569.98	**0.000**	**-10.84**
Ahuriri E	230.45	0.096	2.09

Normalised zinc concentrations showed a significant decrease at sites Ahuriri A, B, and D. No significant increases were observed.

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 arsenic, cadmium, chromium, copper, lead and zinc. 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.

4.3 Waitangi Estuary Sediment Study

The Waitangi Estuary is the common mouth of the 3 major river systems – the Tutaekuri, Ngaruroro and the Clive Rivers. The land-use in these catchments is described in Table 4-1. While the Ahuriri Estuary receives most of the stormwater from the Napier area, the role of the Waitangi Estuary in receiving stormwater is less well established, yet equally important. The Waitangi receives stormwater from the centres of Havelock North and Hastings via the Karamu Stream, from Clive via the Clive River and from the Awatoto area of Napier via the Tutaekuri Blind Arm.

Additionally, the high level of cropping, horticulture and viticulture undertaken in areas proximate to the estuary increase the potential for contaminants associated with stormwater, fertiliser and pesticides to be retained in the sediments of the Waitangi Estuary.

To describe the background concentration of contaminants of concern in the Waitangi Estuary sediments, a sediment survey was undertaken in June 2016.

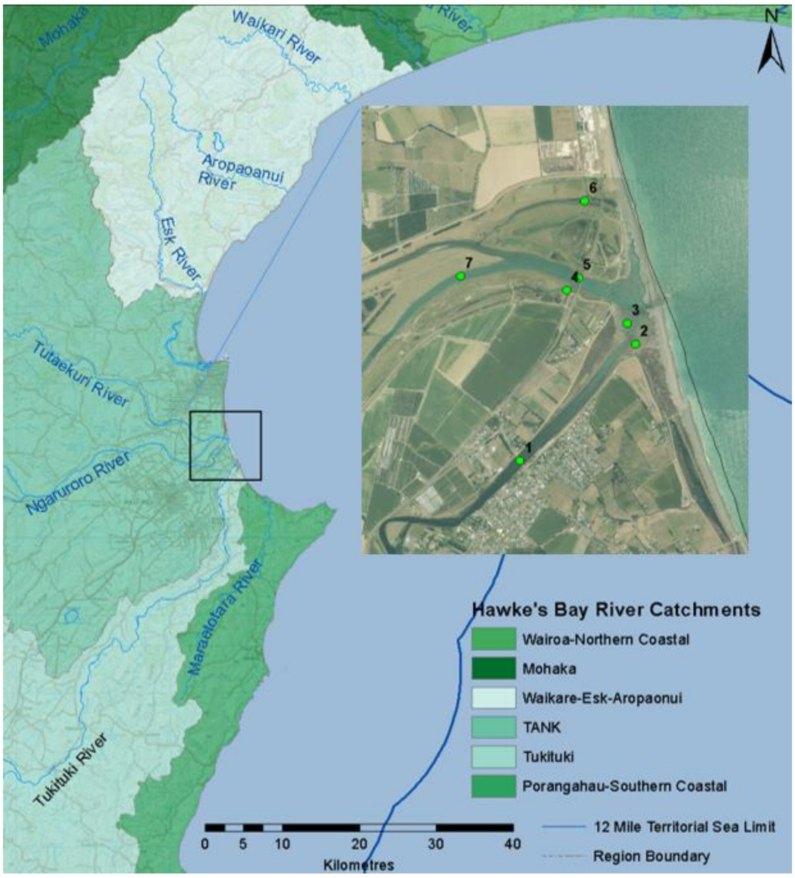


Figure 4-6: Waitangi Estuary sediment survey sites June 2016. Site 1 – Clive River, 2 – Muddy Creek, 3 – Waitangi Estuary, 4 – Waitangi at Railway, 5 – Ngaruroro at Rail Bridge, 6 – Tutaekuri Blind Arm, 7 - Ngaruroro River

4.3.1 Trace metals

Sediment samples were tested for USEPA priority trace metal pollutants – antimony, arsenic, beryllium, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, thallium and zinc.

All samples fell well below ANZECC interim sediment quality guidelines – low (ISQG-Low). At these levels adverse effects would rarely be expected to occur. Subtidal sediments in the Clive River had noticeably higher levels of trace metal contaminants compared to other sites, and at times these approached ANZECC ISQG – Low guidelines (e.g. zinc).

4.3.2 Nutrients and Organic Carbon

Sediment total recoverable phosphorus levels ranged between 390 mg/kg at Muddy Creek and 820 mg/kg at the subtidal Clive River site. These ranges would indicate minor to moderate enrichment of phosphorus in the estuary sediments, with the Clive River and Tutaekuri Blind Arm indicating significant sources into the system.

Muddy Creek sediment nitrogen levels appear to reflect background concentrations of total nitrogen, with samples returning a result less than 0.05g/100g (= <500mg/kg). Sites within the Waitangi Estuary and Tutaekuri Blind Arm vary with concentrations of sediment total nitrogen between 0.05 and 0.06g/100g. These results do not suggest significant eutrophication of the lower estuary sediments by nitrogen (Robertson 2016). By contrast the Clive River site appears to be approaching levels which would indicate significant enrichment of sediments by nitrogen, at a level which is likely to impact ecological health.

Similarly total organic carbon (TOC) levels were within levels which would not be expected to cause stress for all sites excepting the Clive River site. At this site, levels of sediment TOC (2.4%) would be expected to cause significant and persistent stress (Robertson 2016). However as this is only a single sample result, care does need to be taken on its wider application and further testing is recommended.

4.3.3 Pesticides and tributyltin (TBT)

No pesticides or tributyltin were detected at any of the sites tested.

4.3.4 Polycyclic Aromatic Hydrocarbons (PAHs)

Polycyclic aromatic hydrocarbons are the combustion products of hydrocarbons. These can be the source of vehicle and industry emissions, and analysis of the components can offer some indication of the likely source.

In general, PAHs were observed in all samples, albeit at fairly low concentrations. The PAHs present were typically of pyrogenic sources, resulting from incomplete combustion and indicating vehicle emissions and/or burning of organic material as the primary sources.

4.4 Conclusions

- Evidence of moderate sediment stress at sites in the mid-Ahuriri.
- Evidence of high sediment stress at sites in the upper Ahuriri and Waitangi estuaries.
- Ahuriri sites A and B are demonstrating increasing trends in mud content. Ahuriri F and Waitangi do not have long enough records to determine trends.
- Upper Ahuriri Estuary is showing significant eutrophication of sediments, with concomitant anoxic sediment state.
- Sediments of the Waitangi Estuary typically contain low levels of trace metals, below environmental effect guidelines.
- Subtidal sediments of the Clive River were generally higher in trace metals and levels of sediment nitrogen would indicate significant enrichment. Levels of sediment phosphorus at this site, and within the Tutaekuri Blind Arm, indicate moderate enrichment of phosphorus.
- Total organic carbon levels support the nutrient data, indicating stress on aquatic organisms at the Clive River site.
- Polycyclic Aromatic Hydrocarbons were present at low levels and indicate vehicle emissions and/or burning of organic material as the primary sources.

4.5 Recommendations

- Reduction of sediment loads for both TANK estuaries is considered a high priority.
- Reduction of nutrient loads, particularly in the Ahuriri Estuary is also considered a high priority.

5 Estuarine Ecology

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.

Monitoring of the estuarine environment is essential to ensure that the health of the estuary is suitable to underpin the valuable ecological functions it provides.

5.1.1 Data summaries and visualisation

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

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 Community composition and diversity indices

5.2.1 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).

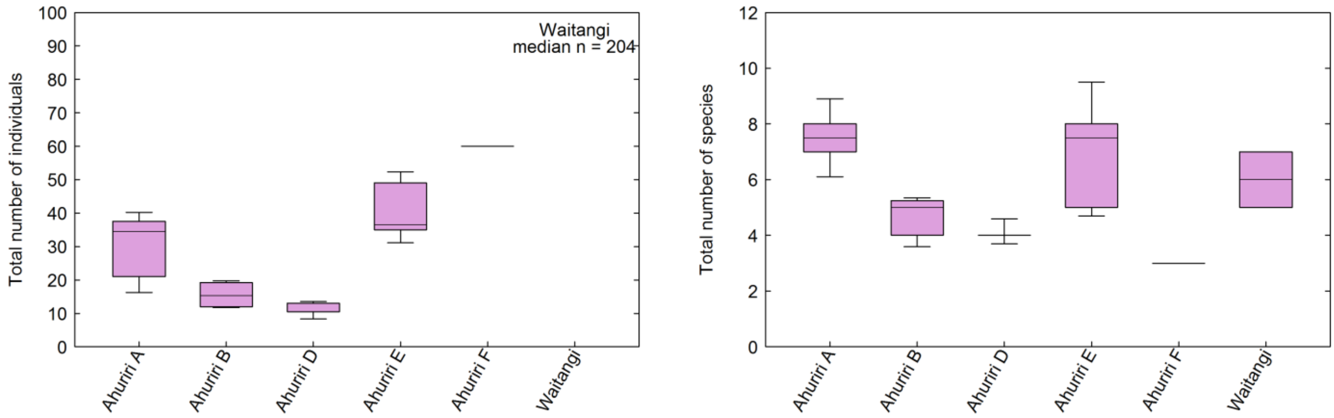


Figure 5-1: Total number of individuals and species by estuarine site. 5 year medians (2012-2016), samples per core (0.013m²).

Sites Ahuriri B and D had the lowest number of individuals in each core (abundance per $0.013m^2$), with median numbers of 19 and 11 respectively. Waitangi Estuary reported the highest number of individuals per core with a median from the two samples of 204 individuals. 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). Ahuriri F also reported a high count for N , with a median of 60 individuals per core. This site was dominated almost exclusively by the nereid polychaete *Nicon aestuariensis.*

No statistically significant trends were observed in the number of individuals present at each of the TANK estuary sites over the 7-10 year sampling period (Table 5-1). Therefore, the number of individuals per core has remained relatively stable over this time.

Table 5-1: 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)		
	Median	Trend p value	Percent Annual Change
Ahuriri A	33.00	0.638	-0.76
Ahuriri B	19.00	0.127	-2.63
Ahuriri D	11.00	0.510	0.00
Ahuriri E	41.00	0.250	-2.44
Waitangi	NT	NT	NT

Sites Ahuriri A, and E reported the highest species richness per core ($0.013m^2$), with median species counts of 7. The lowest median species richness was recorded at site Ahuriri D (4) (Table 5-2).

No statistically significant trends were observed in the number of species present at each of the TANK estuary sites over the 7-10 year sampling period. Therefore, the number of species per core has remained relatively stable over this time.

Table 5-2: Trend analysis of total number of species 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	Total number of species (S)		
	Median	Trend p value	Percent Annual Change
Ahuriri A	7.00	0.144	0.00
Ahuriri B	5.00	0.607	0.00
Ahuriri D	4.00	0.920	0.00
Ahuriri E	7.00	0.969	0.00
Waitangi	NT	NT	NT

5.2.2 Margalef's richness and Peilou's evenness

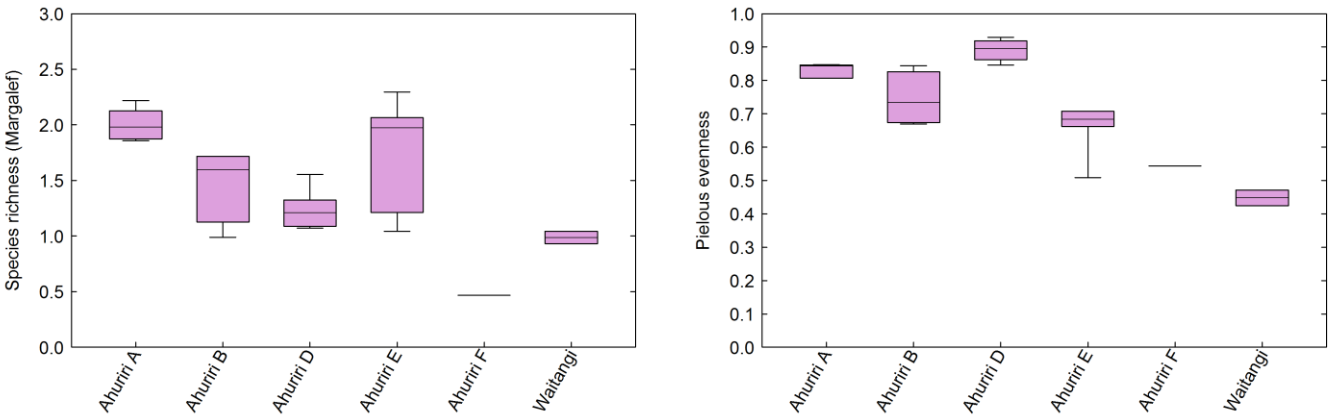


Figure 5-2: Margalef species richness (d) and Peilou's evenness (J) by estuarine site. 5 year medians (2012-2016), samples per core (0.013m^2).

Unlike species richness measure described in Figure 5-1, Margalef's richness also accounts for abundance of individuals within each species.

Margalef's richness was highest at sites Ahuriri A and E, which were 1.84 and 1.72 respectively, and lowest at Ahuriri F and Waitangi. A statistically significant increase in richness was observed at Ahuriri A (Table 5-3).

Table 5-3: 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))		
	Median	Trend p value	Percent Annual Change
Ahuriri A	1.84	**0.004**	**2.66**
Ahuriri B	1.51	0.973	0.00
Ahuriri D	1.44	0.316	-0.25
Ahuriri E	1.72	0.826	0.53
Waitangi	NT	NT	NT

As observed in Figure 5-2, Peilou's evenness was highest at Ahuriri D and A (0.89 and 0.82 respectively) and lowest at Ahuriri F and Waitangi. A statistically significant increase in richness was observed at Ahuriri A (Table 5-4).

Table 5-4: 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)		
	Median	Trend p value	Percent Annual Change
Ahuriri A	0.82	**0.000**	**1.35**
Ahuriri B	0.79	0.461	-0.31
Ahuriri D	0.89	0.316	-0.25
Ahuriri E	0.66	0.327	1.10
Waitangi	NT	NT	NT

5.2.3 Shannon and Simpson diversity

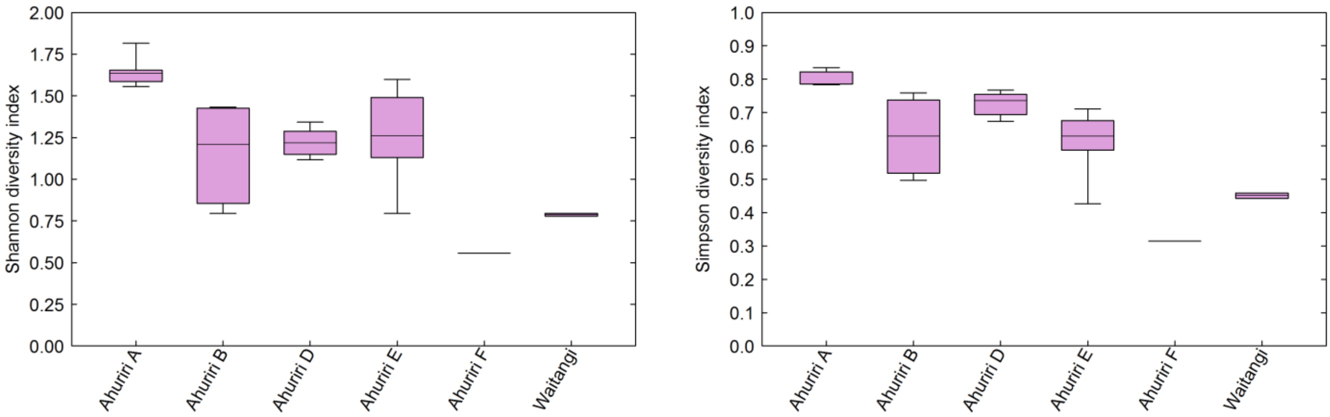


Figure 5-3: Shannon diversity and Simpson diversity index. 5 year medians (2012-2016).

As shown in Figure 5-3, Shannon diversity is highest at Ahuriri A and B at 1.56 and 1.36 respectively. The lowest infaunal diversity observed at Ahuriri F and Waitangi. A similar pattern is observed for Simpson diversity, although site Ahuriri D elevates its position compared to Shannon diversity.

A statistically significant increase in Shannon and Simpson diversity was observed at Ahuriri A

Table 5-5: 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')		
	Median	Trend p value	Percent Annual Change
Ahuriri A	1.56	**0.032**	**2.05**
Ahuriri B	1.36	0.392	-1.01
Ahuriri D	1.26	0.807	-0.17
Ahuriri E	1.23	0.461	1.55
Waitangi	NT	NT	NT

Table 5-6: Trend analysis of Simpson 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	Simpson diversity (λ		
	Median	Trend p value	Percent Annual Change
Ahuriri A	0.78	**0.00**	**1.49**
Ahuriri B	0.72	0.572	-0.387
Ahuriri D	0.74	0.147	-0.809
Ahuriri E	0.62	0.327	1.204
Waitangi	NT	NT	NT

5.3 Multivariate Infaunal Analyses

The high variability of estuarine community assemblages through time was visually assessed using multi-dimensional scaling (MDS). The MDS plots presented in Appendix B show little visually identifiable separation by year for sites AHUA, AHUB and AHUE. This is supported by the relatively high 'stress[3]' reported for these plots (0.21-0.24). Visual grouping is most obvious at site AHUE despite a high stress, and site Waitangi due to a data record of only two years at this site.

A PERMANOVA detected significant differences in the community structure between years for individual sites (Table 5-7). *A posterior* pairwise comparison determined which years were significantly different.

Table 5-7: 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[4]	113870	0.001	All (49/55) except 2012:2013,14,15, 2013:2014,15, 2014:2015
Ahuriri B	77811	0.001	All (38/45) except 2007:2008,13,14, 2009:2011, 2012:2013,14, 2013:2014
Ahuriri D	45135	0.001	All (25/45) except 2007:2008, 2008:2014, 2009:2011,12,13,14,16, 2011:2012,14,16, 2012:2013,14,15, 2013:2014,15,16, 2014:2015,16, 2015:2016
Ahuriri E	54759	0.001	All (26/27) except 2009:2011
Waitangi	5968	0.001	All (2 years only)

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 (Table 5-8).

Table 5-8: 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	166310	0.001	All years significantly different except 2007:2008 and 2012:2013
Site	339160	0.001	All sites significantly different
Year*Site	131650	0.001	'Year' affects sites differently (except AHUA and AHUB in 2013)

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.

[3] 'Stress' levels in MDS represent a 'goodness of fit' of the data to the model.
[4] Replicate AHUA15_7 has been removed from all analyses as an extreme outlier.

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 such as as *Helice crassa* (41.2% (Anderson 2007)),and *Scolecolepides sp.*(25-30% (Norkko 2002)) were common features of the intertidal macrofauna.

Sites where sediment mud concentrations were high (sites Ahuriri F and Waitangi) were dominated almost exclusively by *Nicon aestuariensis*, *Halopyrgus estuarinus*, *Paracorophium excavatum*. These are species whose optimum range of mud content is between 95-100%

5.4 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 5-4). Other than site Ahuriri E, cockle abundances generally reduce at mud concentrations >25%.

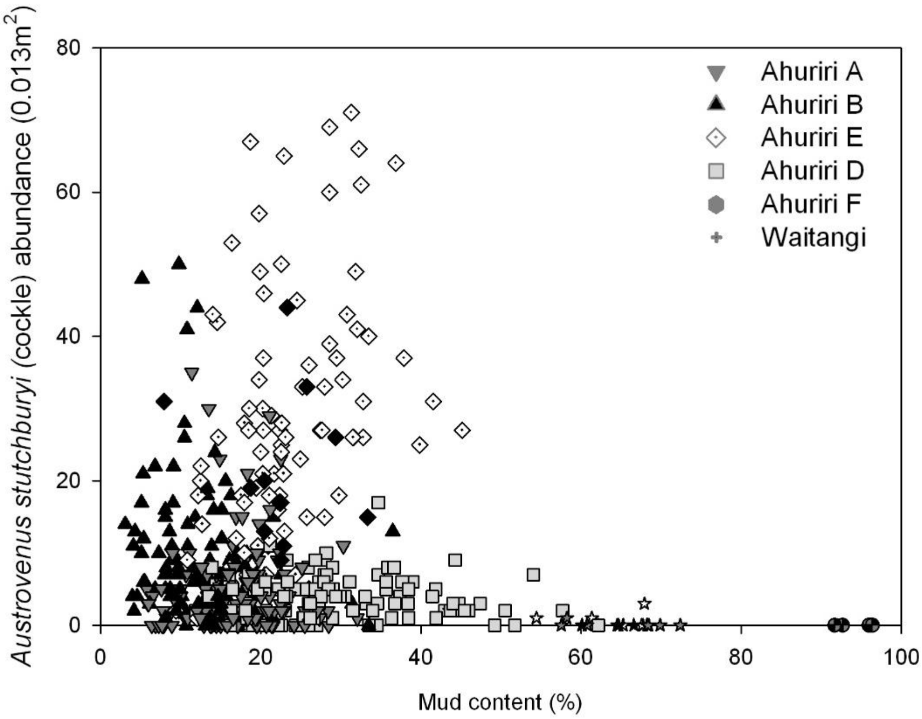


Figure 5-4: Abundance of cockle (*Austrovenus stutchburyi*) per core in relation to mud content (% silt/clay). .

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 5-5, Figure 5-6). 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 Ahuriri D and Waitangi, and at other sites with mud content around 35%-70% (Figure 5-7). This is slightly higher than the published optimal range for this species at 25%-30% mud (Norkko 2002), and this species is absent when mud content >90% (e.g. Ahuriri F).

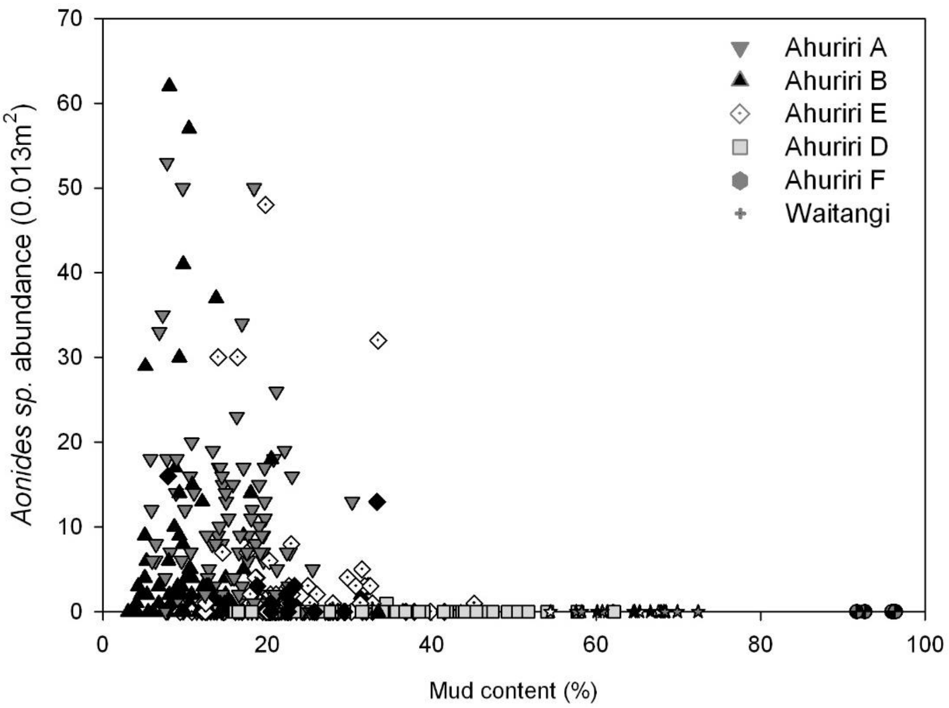


Figure 5-5: Abundance of *Aonides* sp. per core in relation to mud content (% silt/clay).

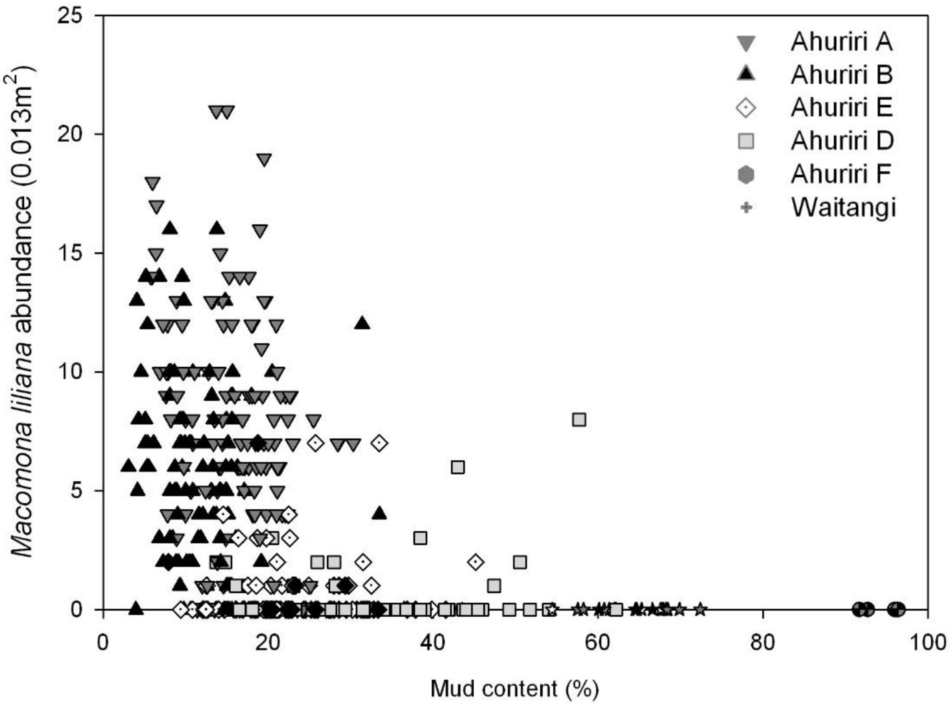


Figure 5-6: Abundance of the bivalve *Macomona liliana* per core in relation to mud content (% silt/clay).

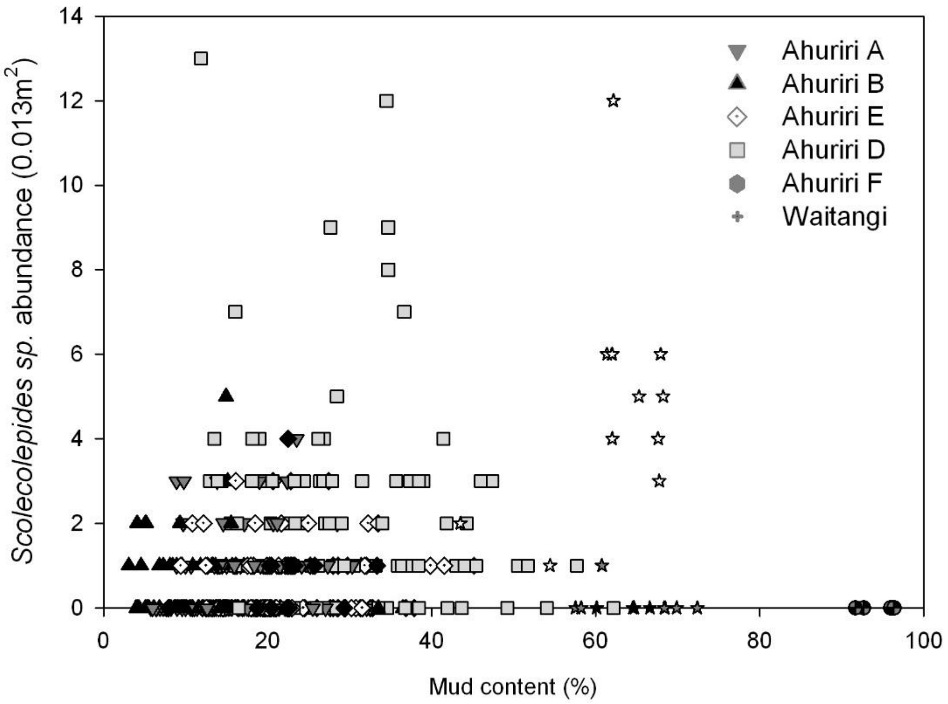


Figure 5-7: Abundance of the spionid polychaete *Scolecolepides* sp. per core in relation to mud content (% silt/clay).

5.5 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 previously been used in Hawke's Bay, but has been applied for the first time to estuaries of the TANK catchments. This first use of the technique still requires verification and improved understanding of how a 'reference' condition in Hawke's Bay may score. Compared to other analysed estuaries (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.

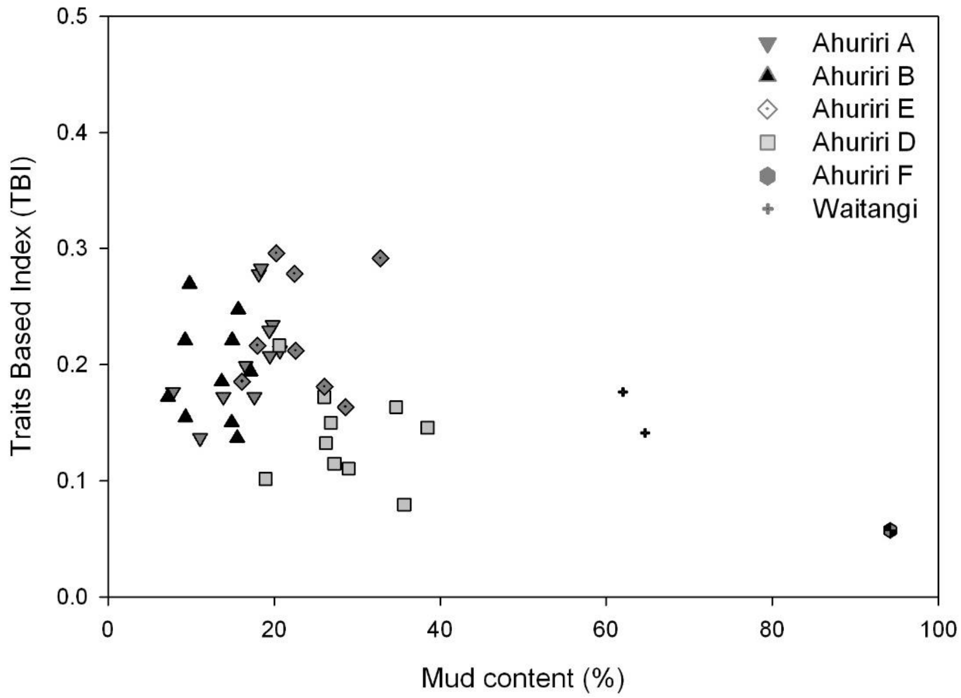


Figure 5-8: Function Traits Based Index (TBI) of TANK estuaries and mud content (% silt/clay).

5.6 Conclusions

- 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) was applied and indicates 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.

5.7 Recommedation

- Benthic health in TANK estuaries appears to be adversely affected by sediment inputs. Sediment control is recommended.

6 Estuarine habitats and Ecosystems

Estuaries provide habitat for a plethora of species including fish (Section 7), birds (Section 6.1) and invertebrates (Section 5). All species are dependent on the habitat provided by a diverse array of estuarine plants, macroalgae and sediments. The functionality of these habitats relies on their integrity in terms of species diversity and their protection from exposure to stressors such as sedimentation, poor water quality, grazing, contaminants, human disturbance and introduced species.

6.1 Birds

The Ahuriri and Waitangi estuaries both provide important habitat for many bird species, both resident and migratory. The most impressive migration is of the bar-tailed godwit (kuaka) which arrive by their hundreds in our estuaries in early spring from Alaska before departing to China in March or April. These birds rely on the good health of the estuary in terms of it being able to provide the food resources the godwits require following their long migration. The bar-tailed godwit is just one of many migratory wading birds that the Ahuriri and Waitangi estuaries play host to, including the golden plover, knot, eastern curlew, ruddy turnstone, American and Asian whimbrel, Siberian tattler and the red-knecked stint (Rook 1985). Rare and endangered resident birds, such as the Australasian bittern, the dabchick and dotterels, can also be found in the Waitangi and Ahuriri estuaries. The Waitangi estuary in particular, also provides roosting and nesting opportunities for several seabirds (terns and gulls) on the gravel bar. Appendix A includes lists of species found in the two estuaries, amongst others, during the 2011 Ornithological Society of New Zealand census (OSNZ 2011)

In an inventory of wetland sites of special wildlife interest (Rook 1985), the authors consider the Ahuriri Estuary as a 'high' value estuarine wetland and the Waitangi Estuary a 'moderate-high' value estuarine wetland. Stephenson (Stephenson 2010) argues that the Waitangi Estuary should also be elevated to 'high' for the following reasons (reproduced ad verbatim):

- Dabchick (Nationally Vulnerable) currently utilise wetland areas adjacent to the river mouth (as shown above).

- Great egret (Nationally Critical) still regularly use the estuary and brackish wetlands in this area during winter.
- Australasian bittern (Nationally Endangered) inhabit freshwater and brackish wetlands in this area. As above this is a key species to protect.
- Many of the banded dotterel (Nationally Vulnerable) that breed on the river probably overwinter on or near the coast around the river mouth.
- Some years a mixed colony of black-billed gulls (Nationally Endangered) and white-fronted terns nests at the river mouth, with around 200-300 pairs nesting. Again this may represent about 3-5% of the National population.
- The river mouth is an overwintering site for 30-75 black-fronted terns (Nationally endangered) each winter. This is one of the key sites in the North Island for this highly endangered tern.

6.2 Habitat mapping

Habitat mapping of the Ahuriri and the Waitangi Estuary was carried out in 2013 and 2014. Habitat mapping is an important element of estuarine health monitoring and feeds into monitoring tools such as the estuarine trophic index (ETI). This mapping will be conducted every five years to allow for monitoring of changes in habitat extent and species diversity over time.

Mapping was conducted using standard approaches defined in the National Estuary Monitoring Protocol (Robertson et al., 2002). For the aerial photography, Kiwi-image (NZ Defence Force) at a resolution of 0.6m was used. Structural wetland classes were identified at a scale of 1:20,000 using broad scale habitat mapping and field visits. The findings were then digitised in ArcMap (ESRI, Eagle Technologies).

6.2.1 Ahuriri Estuary

The Ahuriri Estuary was modified by tectonic uplift during the 1931 earthquake. Ongoing drainage works following the earthquake have reduced the size of the estuary to just 12% (Ataria et al. 2008) of its original size. Despite this extensive modification, the Ahuriri estuary continues to support some important areas of estuarine vegetation.

580 hectares of the estuary were mapped in 2013/14 (Figure 6-1). The most dominant vegetation type (20% total cover) is grassland (Table 6-1). The grassland is typified by rank grasses and annual weeds representative of the mostly agricultural catchment of the Ahuriri Estuary where grazing pasture often extends to the water’s edge.

The main areas of wetland vegetation are along the western edge of the estuary (Figure 6-1) and are generally herbfield at the water’s edge typified by glasswort (*Sarcocornia quinqueflora*) – the most common estuarine vegetation (14%). The other common estuarine vegetation type is rushland occupying 11% of the estuary, the main species found in these areas is *Juncus kraussii*.

Table 6-1: Habitat characteristics of the Ahuriri Estuary.

Structural Wetland Classes	Area ha	Area m^2	% cover
Open water	260.4	2603909	45%
Grassland	114.4	1143997	20%
Herbfield	83.7	836657	14%
Rushland	61.5	614770	11%
Treeland	7.0	70411	1%
Scrub	6.0	6008	1%
Sedgeland	2.9	29326	1%
Reedland	0.3	2728	0%
Flaxland	0.1	396	0%
Soft mud/sand	16.5	164583	3%
Firm mud/sand	10.9	108726	2%
Gravel field	5.9	58832	1%
Very soft mud/sand	4.6	46255	1%
Firm sand	3.8	38446	1%
Boulder field	1.9	18687	0%
Recreation area	0.6	6333	0%
Soft sand	0.2	1992	0%

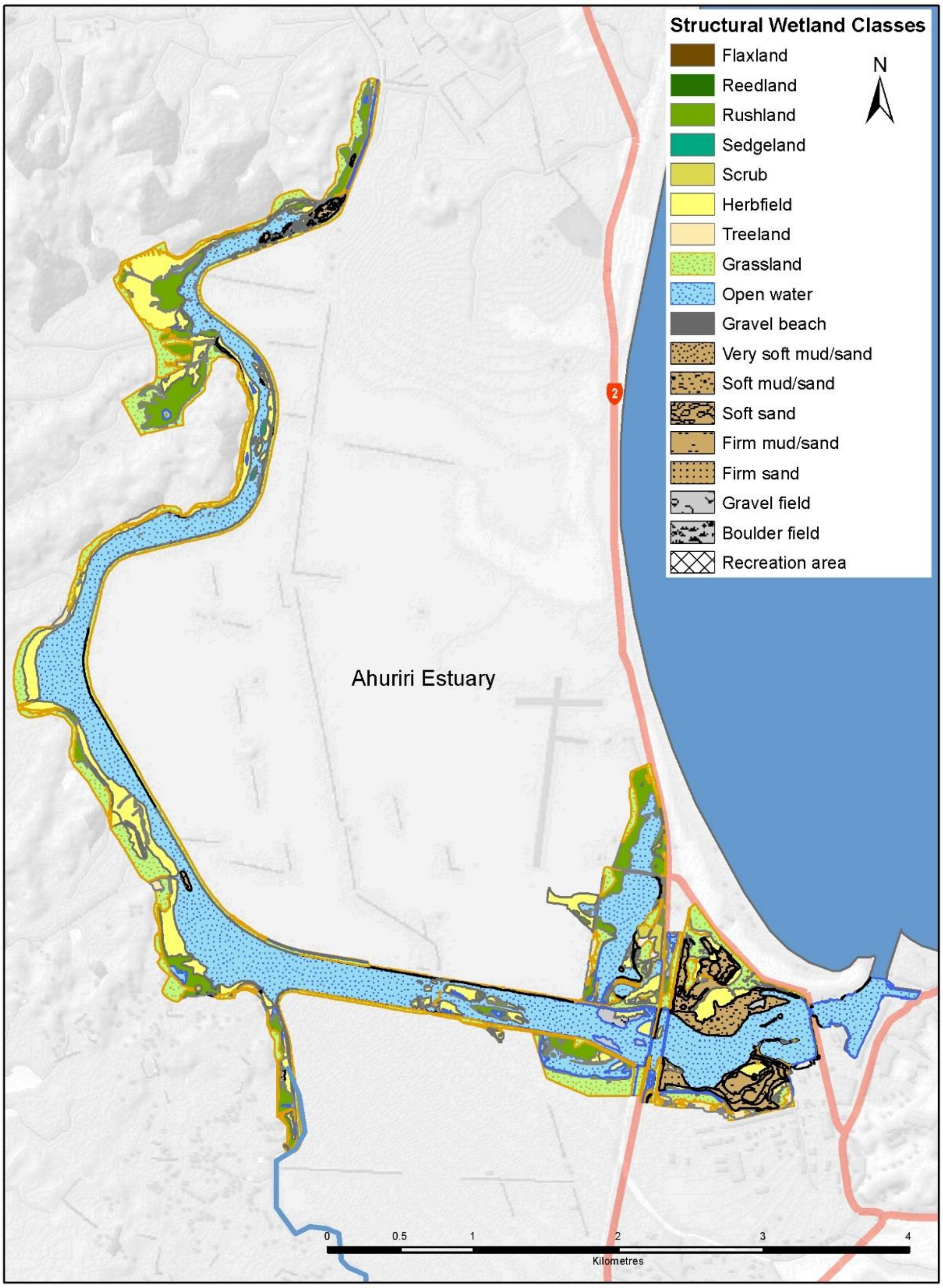


Figure 6-1: Habitat map of the Ahuriri Estuary.

6.2.2 Waitangi estuary

240 hectares of the Waitangi estuary were mapped in 2013. The Waitangi estuary is a highly modified estuary mainly due to flood protection works. Both the path of the Tutaekuri and Ngaruroro Rivers have been channelised and stop banked. As a consequence of this modification there is minimal estuarine vegetation along these arms of the estuary. The majority being steep banks with rank grass right to the water's edge and grassland (typified by rank grass) is the dominant vegetation type (37%) (Table 6-2).

The largest area of estuarine vegetation is along the southern side of the estuary (Figure 6-2) with a narrow margin of sedgeland and rushland along the Clive, there is an area of scrub and rushland to the north and east of the Clive arm whilst Muddy Creek to the south and east of the Clive arm is dominated by sedgeland.

Table 6-2: Habitat characteristics of the Waitangi Estuary.

Structural Wetland Classes	Area ha	Area m2	% cover
Grassland	90.38	903790.25	37%
Open water	57.71	577054.92	24%
Rushland	11.00	110020.33	5%
Scrub	10.52	105194.72	4%
Sedgeland	8.35	83513.74	3%
Treeland	6.50	65008.32	3%
Reedland	1.22	12186.65	1%
Herbfield	0.93	9297.39	0%
Flaxland	0.37	3690.90	0%
Gravel beach	26.94	269369.52	11%
Recreation area	8.85	88505.44	4%
Very soft mud/sand	7.93	79324.63	3%
Firm sand	3.41	34098.50	1%
Soft mud/sand	3.26	32579.18	1%
Firm clay	2.16	21583.49	1%
Gravel field	1.64	16400.69	1%
Mobile sand	0.36	3642.63	0%

The rushland to the north east of the Clive is typified by *Juncus kraussii* and *Juncus procerus.* The dominant species of sedge in the Muddy Creek area is *Bolboschoenus fluvialis*. This is the largest area of sedgeland in the Napier area. The Muddy Creek area is of particular importance in terms of the Waitangi Estuary since it is the only intertidal part of the estuary where estuarine vegetation still dominates.

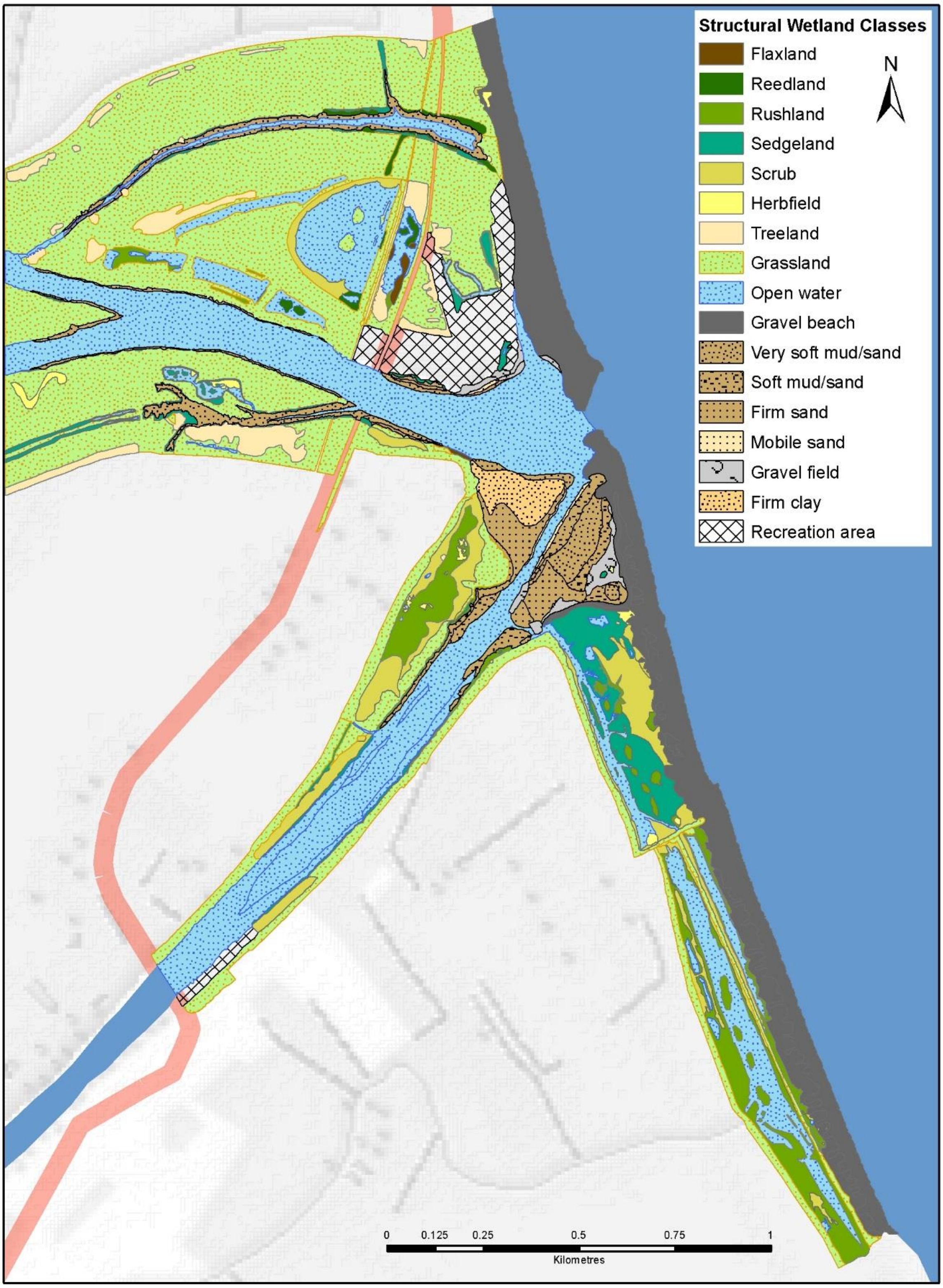


Figure 6-2: Habitat map of the Waitangi Estuary.

6.3 Stressors

Both estuaries and their habitats are exposed to a variety of stressors and several habitat changes have been observed. Studies conducted in the Ahuriri have been more comprehensive than the Waitangi, therefore there is more information around changes in habitat condition and extent.

6.3.1 Grazing

Cattle and sheep at times have access to both the Waitangi and Ahuriri estuaries. Stock access can be damaging to the estuarine ecosystem as the estuarine vegetation diversity can be reduced by grazing and trampling (Figure 6-3). Trampling and grazing can also damage bird nesting and roosting areas. Trampling can in turn lead to pugging of the estuarine sediments killing infaunal invertebrates and reduced oxygen in the sediments.

Figure 6-3: Grazing impacts on the Ahuriri Estuary. This figure shows grazing effects on Sarcocornia beds. Grazed bed to the right of the figure, ungrazed vegetation to the left.

Unrestricted stock access can also lead to the degradation of estuary banks (Figure 6-4) which can increase erosion and impact on water quality. Stock can also have a direct impact on water quality by the introduction of urine and faeces to the water.

Figure 6-4: Impacts on estuary banks. Unrestricted cattle access to the water on the Ngaruroro arm of the Waitangi Estuary.

6.3.2 Sedimentation

Section 4.2.1 outlines the increasing trends in 'muddiness' at sites in the Ahuriri and a high proportion of muds in the sediments of the Waitangi.

As part of the Akroyd and Kilner (1978) ecological study the sediments of the lower Ahuriri estuary were mapped (Figure 6-5). These sediments were mapped again as part of the HBRC habitat mapping exercise in 2013-14. A comparison of the two maps is shown below in figure#. Whilst the later survey only covers the intertidal part of the estuary, the surveyed sediments are dominated by soft mud/ sand whilst the sediments in the 1978 survey are mostly sand.

Increasing levels of sedimentation and the associated anoxia and turbidity can be harmful to estuarine plants, especially sub and intertidal eelgrass (*Zostera sp.*) and seagrass (*Ruppia sp.*) which are susceptible to either being smothered by sediment or inhibited by reduced light availability due to increased turbidity. Akroyd and Kilner (1978) recorded *Zostera* and "[a]bundant beds of *Ruppia*" in the upper Ahuriri Estuary. These beds are no longer present and have been replaced by soft sediment and a water column dominated by phytoplankton and high turbidity.

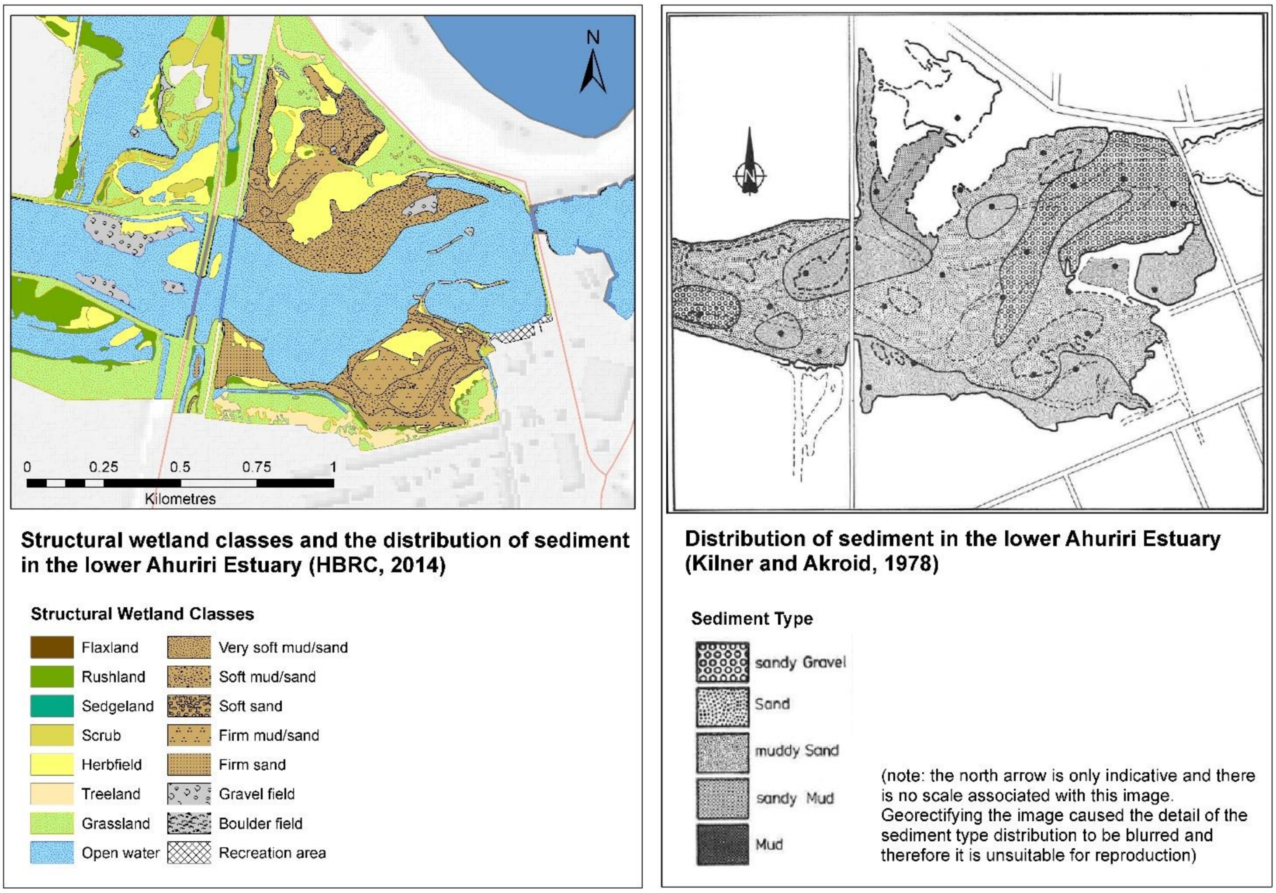


Figure 6-5: Ahuriri Estuary sediments 1978 - 2014. A comparison of the sediment composition mapping from 1978 with the more recent HBRC mapping from 2014. .

6.3.3 Invasive species

Both estuaries are susceptible to invasion by exotic species. Exotic species can modify habitats, displace and kill native species, impact on hydrology and water quality. The main vector for exotic species in the marine environment is transport by marine vessel traffic through either hull fouling or ballast water. Of the two, the

Ahuriri Estuary is the most exposed to this risk. There is an active port in the Inner Harbour at the mouth of the Ahuriri Estuary which accommodates both commercial fishing and recreational vessels. Those vessels that arrive from other ports are a potential pathway for exotic species carried as fouling on the vessels hulls. The risk to the Waitangi estuary is much smaller since there is no port although small recreational vessel are launched on the boat ramp at Clive.

In recent years there has been a marked expansion in the extent of the serpulid polychaete *Ficopomatus enigmaticus* in the Ahuriri Estuary. *Ficopomatus enigmaticus* was first recorded in the Ahuriri Estuary in 1993 (Probert 1993). *Ficopomatus enigmaticus* is a colony forming calcareous tubeworm and the distribution, size and number of these colonies has been rapidly expanding. The Department of Conservation (DOC) has recently established photo points and permanent quadrats to monitor the expansion of the tubeworm (Figure 6-6).

Figure 6-6: Ficopomatus enigmaticus in the Ahuriri Estuary. DOC staff measuring the extent of ficopomatus enigmaticus colonies in the Ahuriri Estuary 2016.

The cause of the rapid expansion of the *Ficopomatus enigmaticus* is currently unknown. HBRC are working with DOC and others to try and understand the cause of its expansion and are investigating remediation works. *Ficopomatus enigmaticus* has also recently been discovered in the Clive arm of the Waitangi Estuary, although its current extent is unknown.

6.3.4 Human disturbance

Some species, particularly birds, are secretive and can be vulnerable to human disturbance, even abandoning areas that are disturbed too often by humans. It is reported that bittern have abandoned the Muddy Creek area of the Waitangi estuary since the construction of a bike and walking path along the edge of it has greatly increased the number of visitors (Rook, pers.comm.).

The human disturbance on the estuarine environment is also evident in the quantity of domestic and building waste that gets dumped around the vehicle access on the northern side of the Waitangi estuary (Figure #).

This waste is not only unsightly but can also be toxic to animals and persists for a long time in the marine environment.

Figure 6-7: Rubbish dumped at the mouth of the Waitangi Estuary.

Human disturbance has also taken the form of widespread physical modification in terms of stop-bank construction, drainage networks and land reclamations. This modification has no doubt reduced the size of wetland areas associated with the estuaries and has channelized the main parts of the estuaries.

6.3.5 Stormwater

The ability of the Karamu Stream (into Waitangi Estuary) and the Ahuriri Estuary to buffer stormwater discharges from the wider catchment and prevent flooding and associated social and economic costs, is one of the values associated with these important TANK catchments, however stormwater can carry a large quantity of contaminants into the ultimate receiving environment.

Common sources of stormwater derived contaminants are described below (

Table 6-3).

Table 6-3: Sources of stormwater derived contaminants that may affect values associated with the Karamu and Ahuriri receiving environments.

Contaminant	Value affected	Source
Trace Metals	Ecological integrity, food gathering	Roofing, plumbing, industry, garden sprays, vehicles, atmospheric deposition.
Bacteria	Contact recreation, food gathering	Wastewater infiltration, animal wastes.
Polycyclic Aromatic Hydrocarbons	Ecological integrity, recreation, amenity	Organic compounds produced by incomplete combustion or pressure (e.g. industrial, vehicles, fuels etc.).
Nutrients	Ecological integrity, recreation, amenity	E.g. Nitrogen, phosphorus from fertilisers, detergents, plant debris.
Suspended Sediments	Ecological integrity, recreation, amenity	Erosion
Gross pollutants (litter)	Ecological integrity, recreation, amenity	Litter

A recent review of consented stormwater in these catchments (Haidekker 2016) has highlighted the quality issues around stormwater inputs, that may compromise values associated with these estuaries. The key findings are repeated below.

Trace metals

Sediment trace metal concentrations throughout the waterways that convey stormwater into the Ahuriri Estuary exceed background concentrations of cadmium, zinc, lead, copper, mercury, arsenic, chromium, nickel indicating metal enrichment of these sediments from land-based activities. Of these:

- Chromium, copper, mercury, arsenic and nickel exceed interim sediment quality guidelines (ISQG) – low (ANZECC, 2000) indicating adverse biological effects may occur occasionally as a result.
- Zinc, lead and chromium exceed interim sediment quality guidelines – high, suggesting that at these sites adverse biological effects may occur frequently (Strong 2004, Smith 2014, Strong 2014).
- Additional studies have observed lead and zinc in the estuary proper proximate to stormwater discharges at levels that exceed environmental guidelines (Madarasz-Smith 2007, Ataria, Tremblay et al. 2008, Smith 2010, Aussiel 2011, HBRC 2014, Strong 2014).

Within the streams contributing to the Waitangi Estuary, the following were observed:

- Sediment levels of lead and zinc within the Havelock North streams at levels where adverse effects could be expected occasionally.
- Levels of copper and lead in the low gradient tributaries (e.g. Riverslea, Windsor, Tomoana, and Irongate) are at levels where adverse effects could be expected occasionally, while zinc levels could be expected to cause frequent adverse effects.

- The Ruahapia Streams appear the most contaminated, with copper, lead and zinc levels exceeding ISQG-High.
- In the Karamu Stream, only zinc exceeds environmental guidelines (Forbes 2015).

Polycyclic Aromatic Hydrocarbons (PAHs)

PAHs have been observed in the sediment of the Ahuriri Estuary at sites adjacent to stormwater discharges (e.g. the Tyne Street outlet (Ataria, Tremblay et al. 2008) and South East Wetland (Aussiel 2011)) at levels exceeding ISQG – Low and exceeding ISQG – High. This would suggest that adverse biological effects are likely to be occurring occasionally - frequently within the estuary due to these stormwater contaminants. Analysis of the compounds suggests the source is likely to be of petrogenic rather than pyrogenic sources indicating that they are likely to have come from unburnt fuel sources (e.g. fuel leakage, spills etc) rather than combusted petroleum compounds (e.g. motor vehicle emissions) (Ataria, Tremblay et al. 2008).

Recent monitoring of the effects of the Hastings District Council stormwater discharges on the receiving environment indicate PAHs in sediments within the Havelock North streams at levels where adverse effects could be expected occasionally. In the low gradient tributaries (e.g. Riverslea, Windsor, Tomoana, and Irongate) PAHs are at levels where adverse effects could also be expected occasionally, while zinc levels could be expected to cause frequent adverse effects (Forbes 2015).

Nutrients

- Maximum levels of monitored nutrients from stormwater sampled under conditions of the Napier City Council/Hawke's Bay Regional Council stormwater discharge consent at the Westshore tide gates into the Ahuriri Estuary show that large masses of nutrients and sediments can enter the estuary during peak flows.
- Similarly, a composite sample taken from the Ruahapia in August 2014 indicates levels of nutrients that exceed trigger values (ANZECC, 2000).
- Pumped drainage indicates that at times a single pump station can contribute between 103 and 342kg of total nitrogen per day into the Ahuriri Estuary at times when they are running.
- Pumped drainage indicates that at times a single pump station can contribute between 19 and 40kg of total phosphorus per day into the Ahuriri Estuary at times when they are running.

Ecological Effects

Ecotoxicological data for the stormwater discharged from the Pandora Industrial area into the Ahuriri Estuary at the Thames/Tyne interface indicates a high likelihood of adverse biological effects on organisms within the immediate receiving environment. Additionally, concentrations of nutrients and many trace metal species in the stormwater entering the estuary at the Thames/Tyne confluence are reported to be an order of magnitude higher than available national data (Strong, 2014).

Stormwater conclusions

Several sites that receive stormwater within the Ahuriri and Karamu systems are flagged as at risk of effects on the ecology due to stormwater contamination.

Two approaches may be considered based on these data. Either these risks are considered inappropriate, and stormwater management is put in place to reduce the contaminant loads into these receiving environments Alternatively, the risks are considered triggers for further work to identify any *actual* as opposed to *potential* effects on the biota of the receiving environment.

In order to reduce contaminant loads, on-site stormwater management should be implemented as best practise, so as to avoid adverse effects on the values associated with receiving environments.

Initially, industries that contribute disproportionate volumes of contaminants should be the primary focus for reduction, while over time changes to landscape development can provide opportunities for reducing stormwater contaminants into waterways.

6.4 Habitat loss and change

Exposure of estuarine ecosystems to stressors such as sedimentation, degraded water quality and grazing, can result in changes in the species representation within habitats in the estuary and also loss of these habitats altogether.

6.4.1 *Zostera* and *Ruppia* beds.

Kilner and Akroyd (1978) describe that "Parore exploit the abundant beds of *Ruppia sp.* in the upper Ahuriri estuary" and that there are beds of *Zostera sp.* (seagrass) at the mouth of the Taipo Stream. These are both important habitats for juvenile fish. Morrison (Morrison 2014) describes how juvenile habitat areas can serve as bottle necks in the lifecycles of many fish.

Both the abundant *Ruppia sp.* and *Zostera sp.* beds no longer exist in the Ahuriri Estuary, the cause of the loss of these important habitats, or when they were lost, is unknown. Seagrass beds are known as biodiversity and productivity hotspots (Morrison 2014) and it is possible that the loss of these and other habitats within Hawke's Bays estuaries has impacted on the populations of many fish species.

There are still some beds of *Ruppia sp.* in the Clive arm of the Waitangi estuary (Figure 6-8), upstream of the SH2 road bridge. However, these beds are under threat from poor water quality and flood maintenance activities.

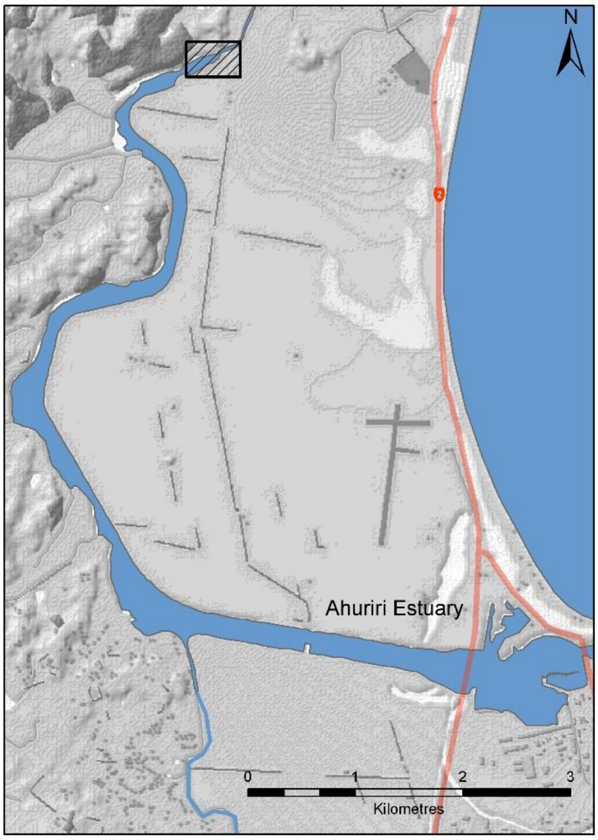
Figure 6-8: ***Ruppia* bed in the Waitangi Estuary.**

6.4.2 Reedland and sedgeland

Over the past five years there has been a concerning decline in the extent of reedland (Raupo – *Typha orientalis*) and sedgeland (*Bolboschoenus fluviatilis*) at the top of the upper Ahuriri Estuary. This decline has meant the loss of the largest area of reedland and sedgeland in the Ahuriri estuary. These kinds of habitats are very important as roosting, nesting and feeding areas for many bird species.

The decline was first observed in 2012 prior to the habitat mapping described in section 6.2.1 taking place. Examination of historical satellite imagery using google earth shows the loss of approximately 4.5 hectares (45,000m^2) between 2010 and 2015. The only remaining vegetation visible in the image on the right is glasswort. The rushland and sedgeland have been replaced by anoxic muds denuded of vegetation.

The reason for this loss of vegetation is currently not understood however HBRC are working with other agencies to try to discover the reason for this loss.



Upper Ahuriri Estuary 2010

Upper Ahuriri Estuary 2015

6.5 Restoration and other monitoring

Despite the ecological degredation described above, there are many positive monitoring and restoration projects underway in the two estuaries.

The Department of Conservation has been working for many years at the top of the Ahuriri Estuary in restoring areas of ephemeral wetland for Bittern conservation. This project has had great success in increasing the numbers of Bittern in the upper estuary (Rook, pers comm.).

Ngā Hapū o Te Whanganui-a-Orotū published a report (Ormsby 2016) lead by Nga Hapu o Tutaekuri providing a baseline of information around the mauri (ecological health) of key taonga mahinga kai species and stormwater impacts in the Ahuriri estuary (Te Whanganui-a-Orotū). This cultural research focussed on:

(1) Fish survey of the lower Ahuriri Estuary;

(2) Heavy metal residue analysis in Pātiki tissue within the lower Ahuriri Estuary;

(3) Cockle sampling and analysis for heavy metal & faecal bacterial contaminant burdens in flesh samples within the lower Ahuriri Estuary;

(4) Cockle abundance and shell length survey within the lower Ahuriri Estuary

Ngā Hapū o Te Whanganui-a-Orotū found that “not only is the mauri of the Ahuriri Estuary highly degraded but also the mauri of mana whenua is affected as we no longer conduct cultural practises of traditional and seasonal food gathering, and are forced to rely on non-traditional food sources which further degrades the mauri of our whānau." (Ormsby 2016).

On the Clive arm of the Waitangi Estuary, members of Kohupatiki marae (Figure 6-9) have been active in restoring their river for many years. This work has involved native plantings along the banks of the Clive River and monitoring of taonga mahinga kai species (patiki and tuna). The monitoring of these species has used set nets overnight on good fishing days as defined by the maori fishing calendar. All fish caught were measured, weighed, tagged and released.

Figure 6-9: Tom Mcguire of Kohupatiki marae. Deploying a setnet for monitoring black flounder numbers in the Clive arm of the Waitangi estuary.

HBRC also has an enhancement plan for the northern side of the Waitangi Estuary (Figure 6-10). It is hoped that this enhancement will halt much of the current degradation that is occurring (Section 6.3.4) and will meet community needs around this part of the estuary.

These needs will be addressed by:

(1) Enhancing ecological function through the addition of wetland habitats and planting of indigenous coastal plants.

(2) A series of developments that will utilise the sites high profile and proximity to Hawke's Bay's largest cities to its advantage, improving its attractiveness as a site for environmental, cultural and historical education.

(3) The construction of a celestial star compass that will reconnect Maori with the site, promoting mana as well as providing for cultural education opportunities. It is anticipated the compass will attract a wider range of community to the site who will subsequently experience a rehabilitating estuarine environment and benefit from the educational material that will be present.

(4) Providing infrastructure that will better manage vehicle and public use of the estuary.

Figure 6-10: HBRC concept plan for the Waitangi Estuary.

6.6 Conclusions

- Both estuarine ecosystems are highly modified from their original form.
- The extent and type of vegetation around each estuary has been mapped by HBRC.
- Stock access continues to degrade both estuarine ecosystems.
- Periodic sedimentation events are affecting the ecosystem health of the estuary.
- Invasive species are present in both estuaries and rapidly expanding in the Ahuriri Estuary.
- Stormwater has the potential to deliver high concentrations of trace metals, nutrients, hydrocarbons and faecal contaminants to the estuaries.
- Estimates of between 103-341kg of TN and 19-40kg of TP per pump, per day being delivered to the Ahuriri Estuary waters.

6.7 Recommendations

- Permanently fence all stock access to the waterways.
- Enhance bankside vegetation of the estuaries.
- Explore reasons for loss of habitat in the Ahuriri Estuary
- Explore control of invasive species, specifically *Ficopomatus enigmaticus*, in both estuaries.
- A move towards source control and treatment for stormwater.
- An assessment of total loads of nutrients being delivered to the Ahuriri and Waitangi estuaries via stormwater and pumped drainage needs to be undertaken.

7 Fish in estuaries

Estuaries play a significant role in the life-cycles of many fish species. Estuaries provide nursery areas for juveniles (flounder species), spawning habitat (Section 7.5) for galaxiid species like Inanga (*Galaxias maculatus*), feeding opportunities for many species and are an important migratory route between freshwater and marine environments. There is only one fish species which calls the estuary its home for all of its lifecycle, this is the estuarine triplefin (*Grahamina nigripenne*).

Water quality and habitat integrity is essential to maintain the role of the estuary within the lifecycle of fish. Lowe (Lowe 2013) found that large-scale environmental changes within estuaries affected the functioning of snapper nursery areas within the Kaipara Harbour both directly (reducing the fitness of individual fish) and indirectly (by reducing the area of biogenic habitats). There have undoubtedly been large habitat changes in both the Ahuriri and Waitangi estuaries (Section 6) and what the impact of these changes has been on fish populations is unknown.

Kilner and Akroyd (1978) consider the Ahuriri Estuary to be a rich and productive estuary, and that furthermore in the context of Hawke Bay it is the most important estuary to fisheries production. This is the most comprehensive study of the fish population of any of the estuaries within Hawke's Bay. Ataria et al. (2008) conducted a one off survey of fish species in the lower estuary using gill, seine and fyke nets. Given the potential importance of the Ahuriri estuary to fish, quarterly fish monitoring was commenced in January 2015.

Estuaries are important areas for both customary and recreational fishing which rely on the health of spawning, nursery and feeding habitats. The importance of these areas is exemplified by there being several monitoring and restoration programmes in these areas.

7.1 Sampling

The fish population is currently monitored at three locations within the Ahuriri estuary (see map). These samples were chosen to give a broad representation of different areas of the estuary that could be practically fished and also had an overlap with estuarine sediment monitoring sites (Ahuriri A & E). Sampling is conducted quarterly and conducted around the low tide in line with advice given as part of Envirolink grant on fish monitoring in Hawke's Bay estuaries (Morrison, 2010).

At each site, samples are collected using a fine mesh beach seine net (Figure 7-1). This net is 10 m long with a 3 m drop and 6 mm mesh. The net is fished three times at each site in a semi-circular motion with one end of the net anchored on the shore whilst the other end is walked around with the net fully extended.

At each site, all fish are identified, measured (to fork length) and weighed.

Figure 7-1: HBRC staff fishing with a beach seine net in the Ahuriri Estuary.

7.2 Data summaries and visualisation

Current monitoring data for the Ahuriri Estuary is compared with that from the study by Kilner and Akroyd(1978) and Ataria et al. (2008) and relative abundances of species at each site are compared using pie charts.

The inclusion of weight as a measured parameter means that over time it will be possible to generate condition indices for the species caught using Fulton's Condition Index in order to assess changes in fish condition over time and with season.

$$K = \frac{w}{l^3}$$ Fulton's Condition Index

However, due to the short temporal nature of the data and small number of samples at this early stage this is not possible.

7.3 Ahuriri Estuary

Akroyd and Kilner (1978) conducted a biological investigation of the Ahuriri estuary downstream of the confluence with the Taipo Stream. This investigation studied both the fish and invertebrate macrofauna population of this area. While the Akroyd and Kilner study was more extensive than the current monitoring programme it is still worthy of comparison in terms of the species encountered.

The current study has so far recorded 16 species of fish in the estuary, similar to Ataria et al. (2008), but less than the 20 species encountered by Akroyd and Kilner (1978). Most of this difference can be explained by the different fishing methods used. Akroyd and Kilner (1978) fished with a beach seine as used in this current study but also used fyke nets, set nets, dip nets and whitebait nets. The species not encountered were generally those larger, faster moving species that could easily swim away from the beach seine net.

	Akroyd and Kilner 1978	Ataria et al, 2008	Wade 2015
Observed species	Long-finned eel		
	Short-finned eel	Short-finned eel	Short-finned eel
	Sand flounder	Sand flounder	Sand flounder
	Yellow bellied flounder	Yellow bellied flounder	Yellow bellied flounder
	Yellow eyed mullet	Yellow eyed mullet	Yellow eyed mullet
	Spotted stargazer		Spotted stargazer
	Common sole		Common sole
	Common smelt	Common smelt	Common smelt
	Spotty	Spotty	Spotty
	Black flounder		Species not caught
	Parore	Parore	
	Kahawai	Kahawai	
	Grey mullet	Grey mullet	
	Cockabully	Cockabully	
	Common bully	Common bully	
	Inanga	Inanga	
	Trevally	Trevally	
	Red cod		
	Gurnard		
	Garfish		
	Species not caught	Herring	
		Wrasse	
			Leather Jacket
			Rainbow trout
			Anchovy
		Clingfish	Clingfish
			Gambusia
			Estuarine triplefin
			Sand stargazer
Number of species	**20**	**16**	**15**
Reported but not observed	Snapper		
	Moki		
	Spiny dogfish		
	School shark		
	Skate		
	Brown trout		
	Barracouta		
	Blue mackerel		
	Kingfish		

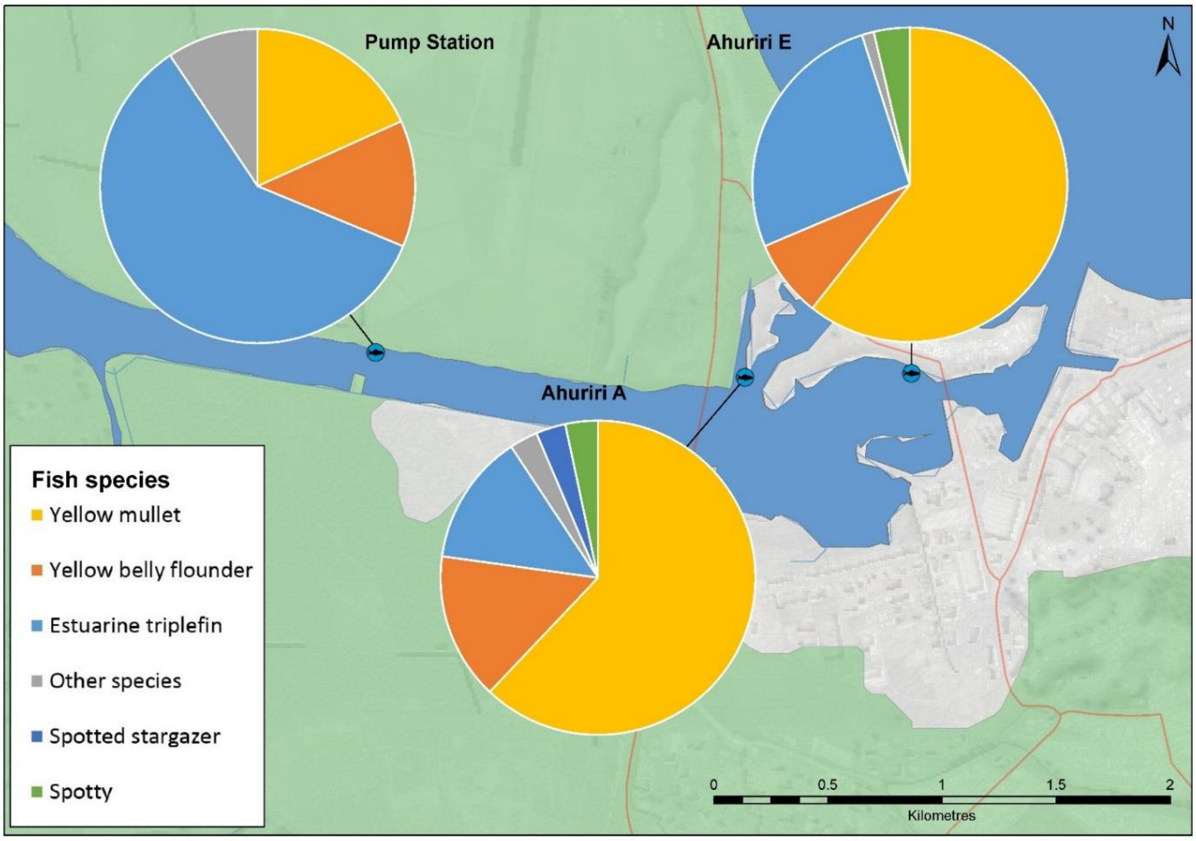
The most common species at all sites were yellow eyed mullet (*Aldrichetta forsteri*), yellow belly flounder (*Rhombosolea leporina*) and estuarine triplefin (*Grahamina nigripenne*). Many of the individuals caught were small or juvenile fish with some species difficult to differentiate from each other.

The majority of the juvenile flounder caught were recorded as yellow belly flounder although it is likely that many of these were sand flounder (*Rhombosolea plebia*) Fish identified in this study as estuarine triplefin (*Grahamina nigripenne*) are likely to have previously been identified as common bully (*Gobiomorphus cotdianus*) and cockabully (*Tripterygion nigripenne*).

Of some concern is the capture of mosquito fish (*Gambusia affinis*) at two sites. Mosquito fish were captured at the Pump Station and Ahuriri A sites in January 2015. The water at these sites had a conductivity of >45000 µs/cm and it is unusual to catch mosquito fish in areas with such high salinities although Morrison (pers comm) has encountered mosquito fish in the Manaia estuary in Waikato. Mosquito fish have not been recorded in the Ahuriri catchment before and predictive modelling of the distribution of mosquitofish (Crow et al. 2014) does not include the Ahuriri as an area where they would be caught. It

The capture of juveniles of leather jacket, anchovy and sand stargazer (species not previously encountered) along with juveniles of many other species confirms the role of the estuary as a nursery area for a variety of species.

Akroyd and Kilner (1978) associated different parts of the estuary with different species. This characterisation is similar to the distributions found in the present monitoring which captured triplefins, and mainly juvenile flounder and mullet at the Pump Station site and juvenile flounder and mullet at the Ahuriri A site. However the current study found large numbers of juvenile yellow eyed mullet at the Ahuriri E site which was characterised by larger transient fish species such as Kahawai, Trevally and Snapper in the previous study.



7.4 Waitangi Estuary

There has been no organised fish monitoring within the Waitangi estuary although there have been some preliminary observations made by council staff over the past 2 years and a fine mesh beach seine has been fished twice. Catches were generally dominated by yellow eyed mullet and estuarine triplefin. The proportion of the catch that was juvenile flounders was much smaller than in the Ahuriri and on both occasions juvenile (post-settlement) kahawai were captured.

The Waitangi Estuary supports an important customary fishery for black flounder (*Rhombosolea retiaria*). The degradation of this fishery has led to the establishment of a monitoring programme for black flounder led by Tom McGuire of Kohupatiki marae on the banks of the Clive. This programme monitor’s flounder numbers using gill nets set overnight at three locations on the Clive arm of the estuary. Captured fish are tagged, weighed and released. To date no tagged fish have been recaptured.

Recently, the black flounder from this estuary were included as part of a national project by Waikato University aimed at improving knowledge around the lifecycle of these fish. This project led by Dr. Nicholas Ling has used otolith chemistry to look at the movement of fish between freshwater and marine environments. Initial findings suggest that fish in the Clive move between the freshwater and estuarine environment whilst fish in the Ngaruroro spend their whole lifecycle in the freshwater environment.

Being a riverine dominated estuary the Waitangi Estuary supports a large recreational and customary whitebait fishery. The importance of areas of the Waitangi Estuary and to a lesser extent the Ahuriri Estuary is included in the following section.

7.5 Inanga (*Galaxias maculatus*)

Seasonal whitebait fishing is probably the most popular customary and recreational fishing taking place in the regions estuaries. Whitebaiting is particularly popular at the mouth of the Waitangi Estuary. Nowadays, however, it can be difficult to catch whitebait in Hawkes Bay’s rivers. Earlier fishers around New Zealand described being able to scoop whitebait out of the rivers with buckets, with excess whitebait being used as fertiliser. How well these anecdotes reflect reality is difficult to determine, but although it is difficult to quantify, there has undoubtedly been a decline in the whitebait run compared with days gone by (McDowell 1996).

In New Zealand, the term whitebait usually refers to the juvenile stages of five native migratory species of *Galaxias*. The New Zealand Smelt, *Retropinna retropinna*, are also caught by whitebaiters and are sometimes included in the collective term ‘whitebait’. This section focuses on *G. maculatus* (inanga), which is the most commonly caught whitebait species.

Inanga are the most well studied whitebait species, and their life history is relatively well understood. In late summer or early autumn, ripe fish congregate in the upper estuaries to spawn. They utilise an egg stranding strategy), whereby eggs are laid amidst flooded bank vegetation on the high spring tides. The spring tides refer to the approximately fortnightly cycle when the gravitational forces of the sun and moon are combined to produce the greatest tidal amplitude, which means the high tide submerges areas of stream/estuary banks that usually remain dry. The deposited eggs adhere to the fine root mats, stem bases or other vegetative and detrital material at the high tide mark, and are left stranded when the tides recede (Figure 7-2). Eggs typically take 2 to 4 weeks to develop before hatching on the returning spring high tides inundate the spawning sites, eggs hatch and the larvae are swept out to sea. The larvae take approximately 3-6 months to develop in the ocean, after which time they return to rivers as the transparent juveniles that comprise the whitebait fishery.

Figure 7-2: Inanga eggs.

The quality of spawning habitat exerts a large influence over egg survival, and protecting inanga spawning habitat has been considered a key mechanism for increasing whitebait numbers for decades (Taylor 2002). A high density of grass stems or thick and fibrous root mats seem to provide optimal habitat (Hickford 2011). Stock grazing and trampling in estuarine spawning areas results in both poor quality habitat quality as well as direct egg mortality (Hickford 2014). As such, excluding stock from potential spawning areas immediately before and during the late summer/autumn spawning period is a necessary measure to ensure successful reproduction of inanga. In Hawkes Bay, inanga eggs may still be present on river banks into winter.

Intense efforts to locate eggs were undertaken by the Department of Conservation in the early 1990s, which uncovered two spawning sites in the Waitangi estuary (Rook 1994). The Clive spawning site (see Figure 7.4) extended over 80 m of bank when first discovered in 1991, and in the winter of 1992 a fence was erected to extend the area of protected bank and associated spawning habitat. In 1993, the extent of area where eggs were found had doubled to 160 m (Rook 1994). This demonstrates that increasing the reproductive success of inanga can be as simple as fencing off potential spawning habitat. A second spawning site was also found in a small tributary of the Tutaekuri backwater channel (see Figure 7.4). Although two spawning sites were found in this system, there were no spawning sites found anywhere near the main stems of the Tutaekuri or Ngaruroro Rivers. Collectively, the freshwater tidal areas of the Waitangi estuary need to provide suitable spawning habitat for all of the inanga living in the extensive river networks of the Karamu, Tutaekuri and Ngaruroro. At present, there is only a very small area of confirmed spawning habitat in the Waitangi estuary, which appears disproportionately small for the size of the river network and associated inanga population that it should support. As such, identifying and protecting more potential spawning habitat in the Waitangi estuary should be a high priority if increasing whitebait numbers is desired. No spawning sites have yet been identified in the Ahuriri system, although the lower reaches of the Taipo Stream seemed likely (Rook 1994).

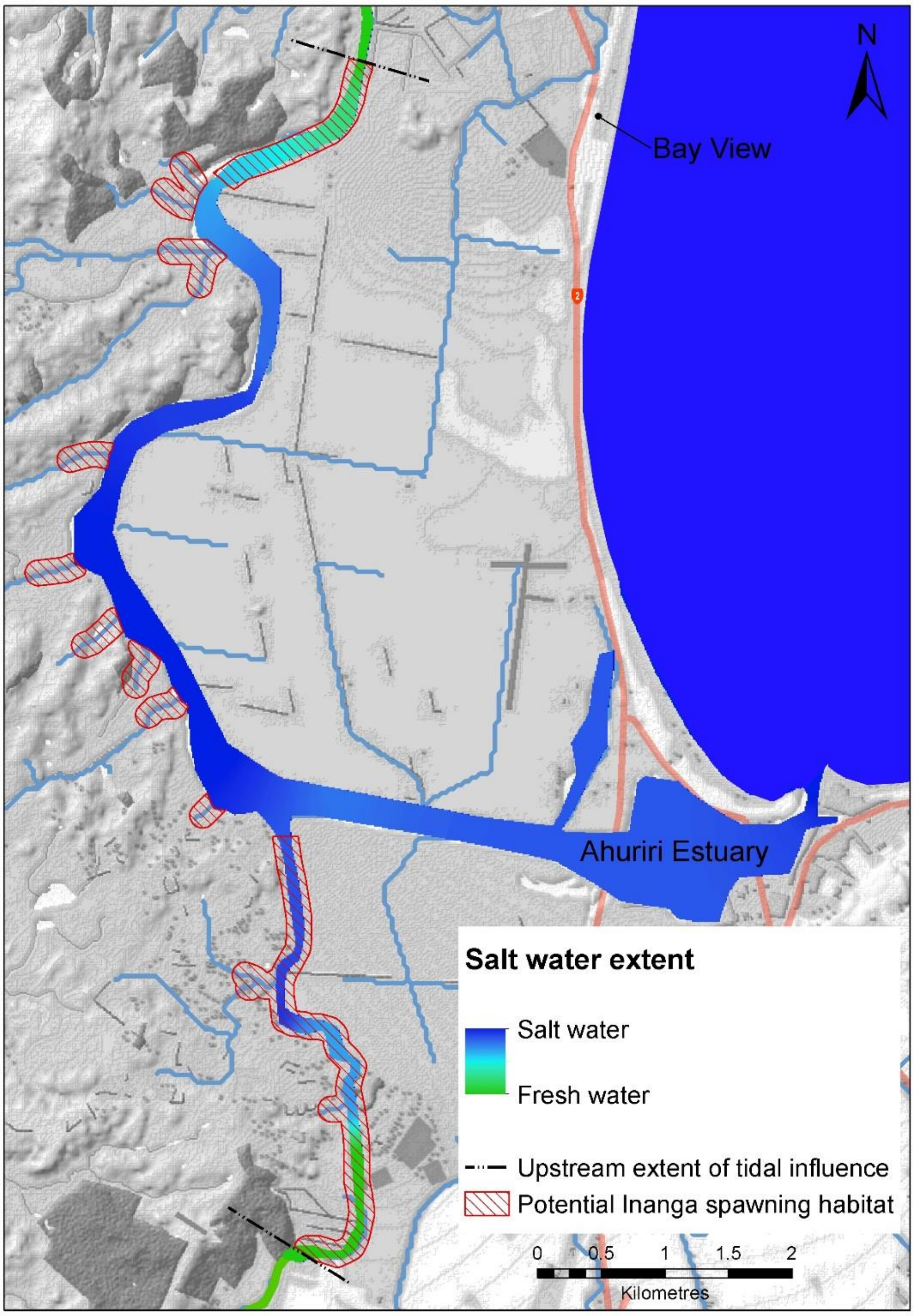


Figure 7-3: Map of saltwater influence in the Ahuriri Estuary. The dashed line marks the extent of tidal influence (where the water moves up and down with the tidal cycle) and the shaded areas mark potential inanga spawning areas.

Salinity patterns can help identify potential inanga spawning habitat (Richardson 2002). Spawning sites of inanga are typically located near the upstream penetration of the saltwater. The freshwater flowing downstream sits on top of the saltwater pushing upstream, and so salinity in the surface water can remain low. Low salinity is necessary for high fertilisation success (Hicks 2010), and so the upstream penetration of saltwater often relates to an area of the estuary where water level is tidally influenced and provides an egg stranding mechanism, but the surface water where spawning takes place remains fresh enough to achieve high rates of fertilisation. In highly stratified estuaries, such as the Waitangi, the freshwater of the rivers can ‘slide’ over the top of the more salty bottom water. The lack of vertical mixing keeps the surface water fresh, and results in a large area of tidally influenced freshwater habitat that may be suitable for spawning (Hicks 2010).

Salinity surveys have been undertaken in the Waitangi estuary (Rook 1994), and the two identified spawning sites generally fit with the pattern of being close to the upstream penetration of the saltwater. For the Karamu arm, the spawning site was approximately 4km downstream of the upstream limit of saltwater. In the Tutaekuri Blind Arm, the spawning site was located at the confluence of a small tributary which provided a source of freshwater into a strongly tidal section the estuary. These salinity surveys also established that the estuary is highly stratified, with the surface water remaining relatively fresh close to the point at which the river passes through the gravel spit and enters the open ocean. The strong stratification means there is a large extent of tidal habitat with low salinity surface water, and hence a large extent of potential spawning habitat (Hicks 2010).

The salinity surveys provide guidance on how to identify areas to set aside for inanga spawning. If riparian habitat is in poor condition, inanga may not use such areas for spawning, or eggs deposited there may suffer very high mortality. As such, limiting protective works to currently used areas may mean the potential spawning habitat is never fully realised. Additionally, continually changing river mouth morphologies and sea level variation will affect salinity dynamics in estuaries. If only a subset of currently used habitat is protected, this would limit the ability of populations to adapt and spawn successfully should conditions change. A more inclusive and bet-hedging approach would be to identify a larger area of estuary that currently provide freshwater tidal habitat, and protect as much of it as possible (Hicks et. al. 2010). This more inclusive approach to protecting spawning habitat is becoming more common, for example with both Environment Southland (Hicks 2013) and Environment Canterbury (Greer 2015) pursuing similar habitat based protection, rather than existing egg site based protection.

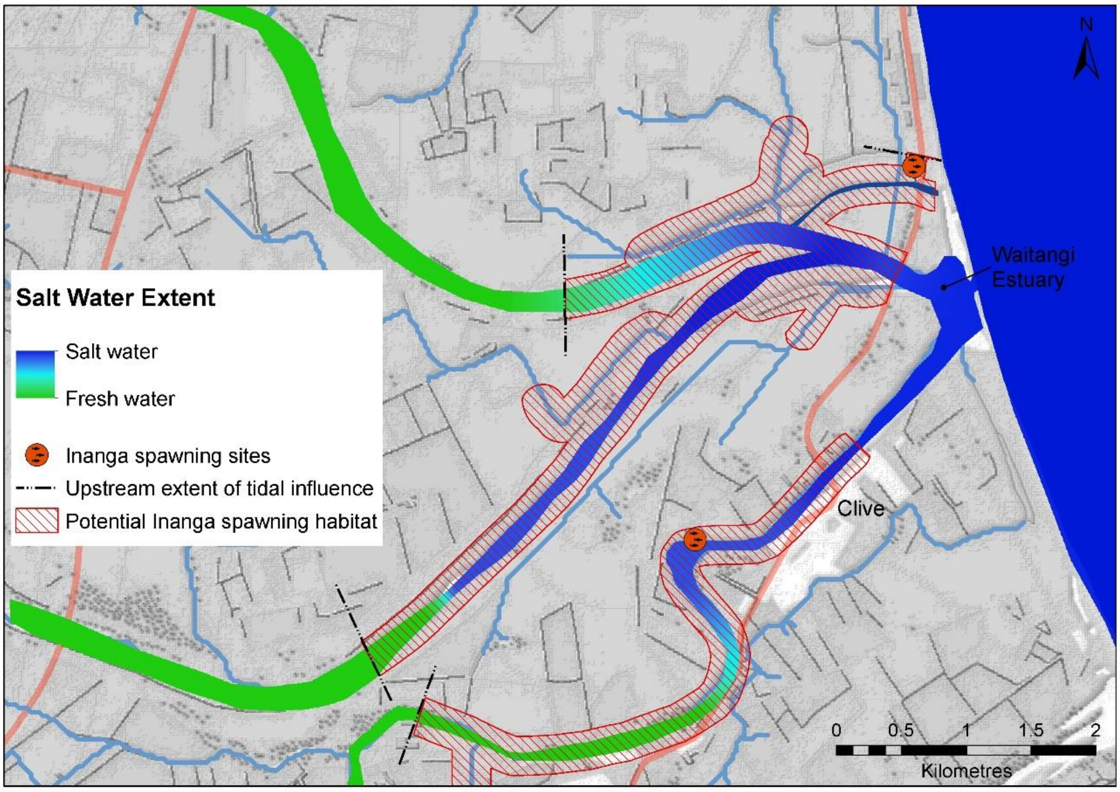


Figure 7-4: Map of the extent of saltwater intrusion into the Waitangi Estuary. The dashed line marks the extent of tidal influence (where the water moves up and down with the tidal cycle) and the shaded areas mark potential inanga spawning areas.

Potential and identified spawning areas in both the Ahuriri and Waitangi estuaries are marked in Figure 7-3 and Figure 7-4. In the Waitangi Estuary, the ideal approach for maximising protection of spawning habitat would be to protect and enhance the channel margins between the upstream limit of the saltwater indicated in Figure 7-4 , all the way to the main estuary basin. In the Ahuriri estuary, the upper limits of the estuary as well as the numerous small, freshwater tributaries would be a high priority (Figure 7-3). Having better quality riparian habitat throughout the estuary would mean inanga can spawn wherever they prefer, both under current conditions and into the future. Protecting and enhancing these estuarine margins would also provide for a range of other ecological values.

7.6 Conclusions

- The Ahuriri Estuary provides habitat for many fish species, some of them commercially important.
- The number of fish species that inhabit the Waitangi Estuary is unknown.
- Black flounder numbers in the Waitangi are declining.
- The Waitangi Estuary has several identified and unidentified whitebait spawning areas.
- Whitebait spawning areas have yet to be identified in the Ahuriri Estuary.

7.7 Recommendations

- Identify and protect whitebait spawning habitat in the Ahuriri Estuary
- Identify and protect further whitebait spawning habitat in the Waitangi Estuary

- Identify habitats of significance for fish species in the two estuaries.
- Manage and restore habitats of significance.

8 Values and Current State Assessment – AHURIRI ESTUARY

VALUE	ISSUE	CURRENT STATE	RECOMMENDATIONS
Food Gathering	Water quality – lower abundance of edible species.	• Areas adjacent to localised discharges where ecotoxicity is observed.	• Stormwater management. • Land management to address diffuse sources.
	Habitat loss – sedimentation, physical alteration	• Estuary confined and physically altered. • Hard edging reduces potential for habitat creep due to climate change. • Some loss of habitat for edible species likely.	• Stop further habitat loss from physical alteration. • Scope potential restoration of habitat. • Reduce sediment loading through fencing and planting. • Manage sediment concentration by setting upstream sediment limits. • Enhance understanding of distribution of fish and shellfish within the estuary
	Bacterial and pathogen contamination of water	• Shellfish gathering not advised due to urban location.	

VALUE	ISSUE	CURRENT STATE	RECOMMENDATIONS
Contact Recreation	Bacterial and pathogen contamination of water	• Pandora Pond 'Good' for contact recreation.	• Continue to monitor and retain current state
	Localised discharge points	• High faecal loads at times	• Stormwater management
	Turbidity	• High turbidity maxima	• Reduce sediment loading through fencing and planting. • Manage sediment concentration by setting upstream sediment limits.
	Harmful Algal Blooms	• Low frequency	

VALUE	ISSUE	CURRENT STATE	RECOMMENDATIONS
Aquatic Ecosystems	Water Quality • Dissolved nutrients • Dissolved oxygen • Turbidity/deposition	• High dissolved nutrients • Low dissolved oxygen at times in urban waterways. • High levels of turbidity and sediment deposition	• Stormwater management. • Nutrient management. • Reduce sediment loading through fencing and planting. • Manage sediment concentration by setting upstream sediment limits
	Habitat	• Reduced habitat through physical alteration • Loss of important habitats e.g. seagrass due to turbidity/deposition	• Reduce sediment loading through fencing and planting. • Manage sediment concentration by setting upstream sediment limits.
	Grazing	• Many estuarine areas remain actively grazed	• Stock exclusion
	Invasive Species	• Expansion of the invasive marine worm *Ficopomatus enigmaticus.*	• Work with DoC/biosecurity/MPI

VALUE	ISSUE	CURRENT STATE	RECOMMENDATIONS
Bird Habitat	Habitat • Grazing • Sedimentation • Food source • Disturbance	• Reduced habitat through physical alteration • Loss of important habitats e.g. seagrass • Reduction in quality food source due to sedimentation. • Disturbance of birds by humans and dogs.	• Stock exclusion • Reduce sediment loading through fencing and planting. • Manage sediment concentration by setting upstream sediment limits. • Restoration of wetland margins. • Explore ways to reconcile bird habitat protection and recreational values.

9 Values and Current State Assessment – WAITANGI ESTUARY

VALUE	ISSUE	CURRENT STATE	RECOMMENDATIONS
Food Gathering	Reduced ability to gather food (kaimoana) in the estuary	• Unknown – anecdotal evidence points to a large decline in abundance	• Increase understanding of importance of the Waitangi Estuary in terms of food gathering • Enhance understanding of distribution of fish and shellfish within the estuary.
	Water quality – lower abundance of edible species	• Elevated sediment concentrations in the estuary • Elevated dissolved nitrogen concentrations in the Clive arm of the estuary	• Reduce sediment and nutrient concentrations and loads into the estuary.
	Habitat loss – sedimentation, physical alteration	• High 'muddiness' (silt/clays) in the estuary sediments.	• Stop further habitat loss from physical alteration • Scope potential restoration of habitat
	Bacterial and pathogen contamination of water	• Frequent exceedances of MfE/MoH guidelines at the Clive River site.	• Reduce faecal sources. • Stock exclusion.

VALUE	ISSUE	CURRENT STATE	RECOMMENDATIONS
Contact Recreation	Bacterial and pathogen contamination of water	• Clive boat ramp site frequently exceeds bathing guidelines	• Manage sources of contamination.
	Localised discharge points	• Faecal source analysis has identified potential ruminant and avian sources of contamination.	• Stock exclusion.
	Turbidity	• Waters of the estuary are frequently highly turbid	• Reduce sediment loading through fencing and planting. • Manage sediment concentration by setting upstream sediment limits.

VALUE	ISSUE	CURRENT STATE	RECOMMENDATIONS
Aquatic Ecosystems	Water Quality • Nutrients	• Nutrient concentrations in the waters of the Clive arm of the Waitangi Estuary have high nutrient concentrations • Seasonal macro-algal mats and some phytoplankton blooms.	• Identify sources of nutrients and manage
	Sediment Quality • Mud content	• 'Muddiness' (silt/clays) in the Waitangi Estuary very high.	• Manage catchments upstream to reduce sediment inputs into the Ngaruroro and Tutaekuri rivers. Mitigate active erosion of estuary banks.
	Benthic Habitat	• Reduced habitat through physical alteration • Changes in benthic species	• Reduce sediment loading through fencing and planting. • Manage sediment concentration by setting upstream sediment limits.
	Fish Habitat	• Prolific macroalgal and macrophyte growth in the Clive Arm of the estuary leading to loss of gravel habitat	• Manage nutrient inputs upstream • Restore vegetation to banks to provide shade.
	Inanga spawning habitat	• Continued stock access to estuary banks damaging potential spawning habitat	• Restrict stock access to estuary banks
	Stormwater	• Ongoing stormwater inputs are having an unquantified/unknown effect on the Waitangi Estuary.	• Understand the extent of the impact of stormwater discharges on the estuary • Manage and mitigate stormwater inputs into the estuary, particularly the Clive Arm

VALUE	ISSUE	CURRENT STATE	RECOMMENDATIONS
Bird Habitat	Habitat	Reduced habitat through physical alteration • Loss of important habitats e.g. ephemeral wetlands	• Restore wetland margins
	Human disturbance	• Disturbance of roosting seabirds on the gravel bar and sensitive species in Muddy Creek	• Explore ways to reconcile bird habitat protection and recreational values

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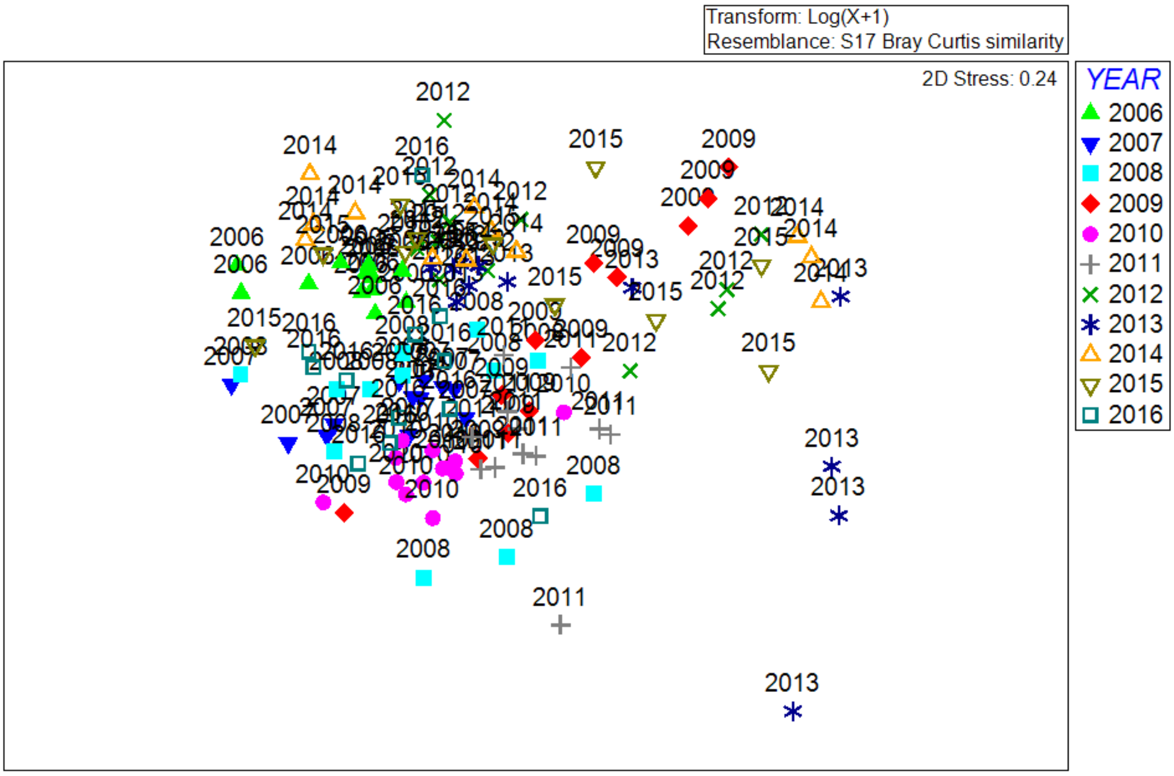
Appendix A Waitangi Sediment Survey Results

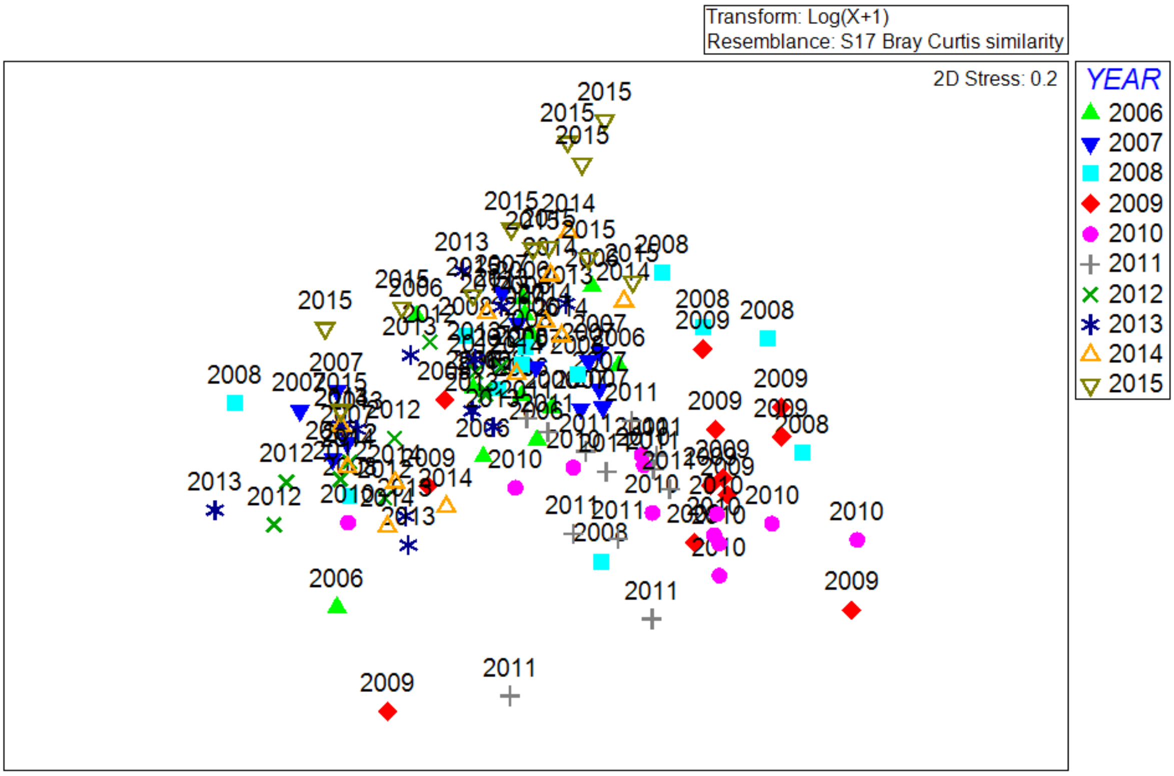
Analyte	Clive Rv at Bridge_1	Muddy Creek_2	Clive River_3	Waitangi Railway Bge_4	Ngaruroro Rail Bge_5	Tutaekuri Blind Arm_6	Ngaruroro Waitangi_7
	Subtidal	Intertidal	Intertidal	Intertidal	Subtidal	Intertidal	Subtidal
Dry Matter g/100g as rcvd	39	74	72	64	54	67	65
Total Nitrogen g/100g dry wt	0.27	< 0.05	0.05	0.06	0.1	< 0.12	0.07
Total Organic Carbon g/100g dry wt	2.4	0.25	0.51	0.64	0.89	0.53	0.91
Total Recoverable Antimony mg/kg dry wt	0.1	< 0.04	0.05	0.04	0.05	< 0.04	0.06
Total Recoverable Arsenic mg/kg dry wt	6	3.1	3.5	2.8	3.9	2.4	3.3
Total Recoverable Beryllium mg/kg dry wt	0.76	0.47	0.5	0.62	0.62	0.47	0.59
Total Recoverable Cadmium mg/kg dry wt	0.16	0.021	0.038	0.034	0.049	0.095	0.047
Total Recoverable Chromium mg/kg dry wt	21	10.2	11.8	13.1	16.2	12.9	12.9
Total Recoverable Copper mg/kg dry wt	20	4.7	6.9	7.4	8.8	5.2	8.3
Total Recoverable Lead mg/kg dry wt	24	7.4	9.5	10.3	11	7.2	10.8
Total Recoverable Mercury mg/kg dry wt	0.099	0.043	0.062	0.067	0.08	0.049	0.058
Total Recoverable Nickel mg/kg dry wt	13.8	8	9.3	10.2	12	10.3	10.3
Total Recoverable Phosphorus mg/kg dry wt	820	390	430	460	510	680	420
Total Recoverable Selenium mg/kg dry wt	< 2	< 2	< 2	< 2	< 2	< 2	< 2
Total Recoverable Silver mg/kg dry wt	< 0.2	< 0.02	0.03	0.03	0.04	0.02	0.04
Total Recoverable Thallium mg/kg dry wt	0.12	0.05	0.06	0.08	0.09	0.08	0.1
Total Recoverable Zinc mg/kg dry wt	178	38	43	47	50	47	51

Appendix B Multi-dimensional Scaling of Estuarine Data

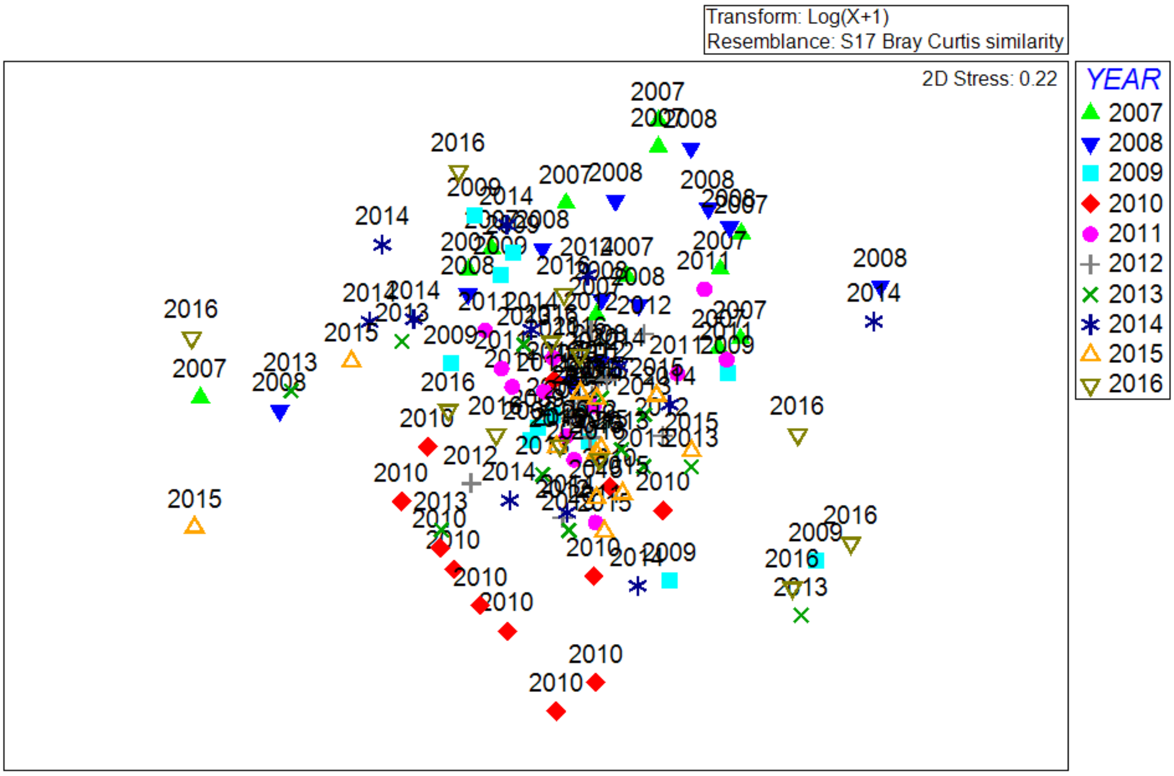
Ahuriri A



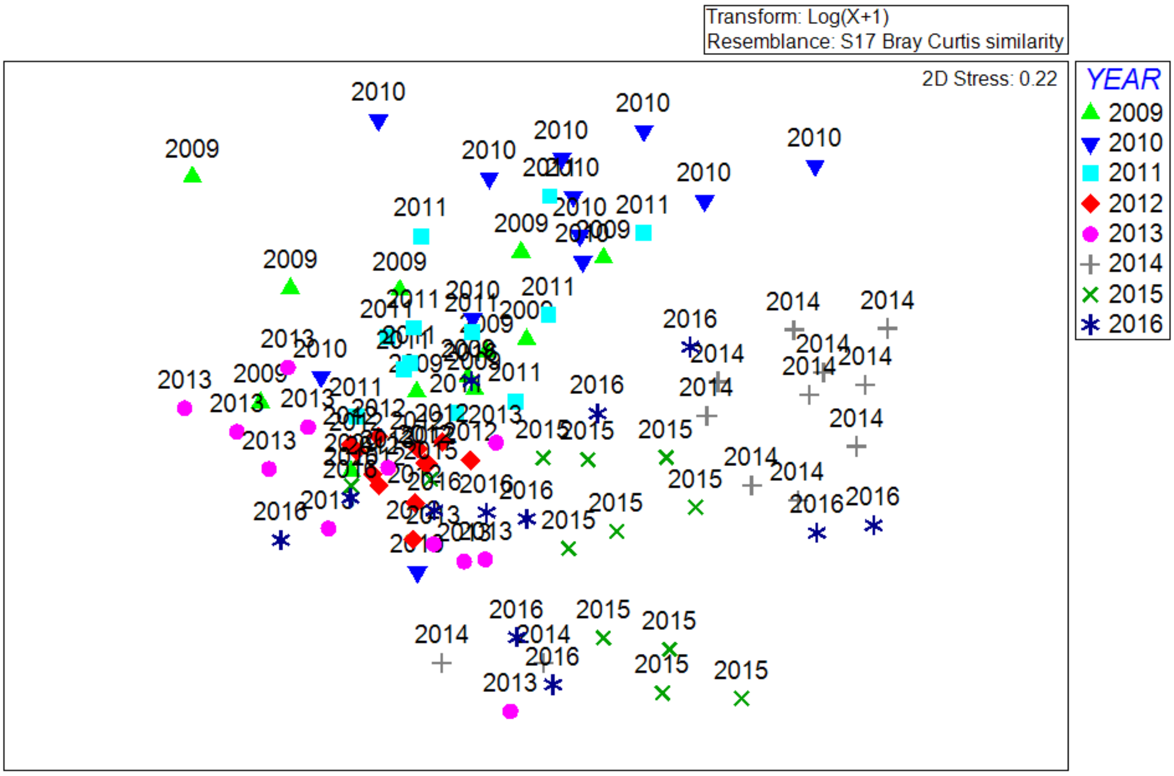
Ahuriri B



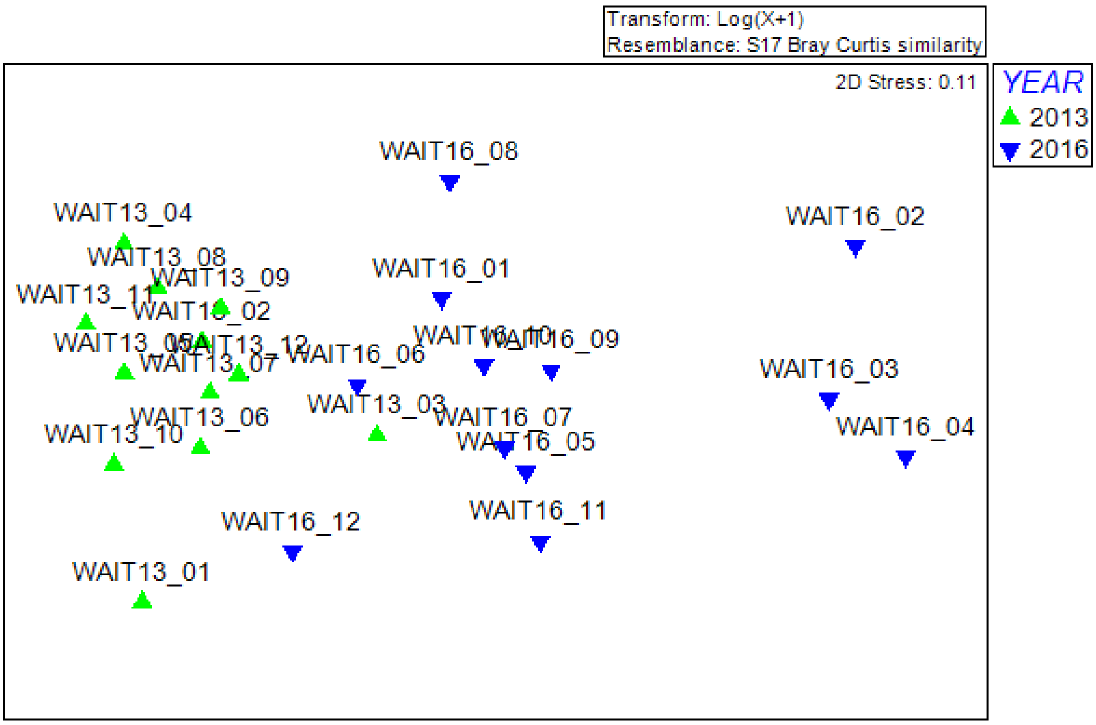
Ahuriri D



Ahuriri E


Transform: Log(X+1)
Resemblance: S17 Bray Curtis similarity
2D Stress: 0.22
YEAR
2009
2010
2011
2012
2013
2014
2015
2016

Waitangi


Transform: Log(X+1)
Resemblance: S17 Bray Curtis similarity
2D Stress: 0.11
YEAR
2013
2016
WAIT16_08
WAIT13_04
WAIT16_02
WAIT13_08
WAIT13_09
WAIT16_01
WAIT13_11
WAIT16_06
WAIT16_09
WAIT16_03
WAIT13_06
WAIT13_03
WAIT16_07
WAIT13_10
WAIT16_05
WAIT16_04
WAIT16_12
WAIT16_11
WAIT13_01

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. 35%)				
	Av. Abund	Av. Sim	Sim/SD	Contrib %	Cum. %
Macomoa liliana	1.84	12.99	1.43	36.34	36.34
Austrovenus stutchburyi	1.39	8.71	1.14	24.37	60.72
Nicon aestuariensis	0.65	2.90	0.65	8.11	68.83
Aonides trifida	0.83	2.21	0.39	6.17	75.00
Heteromastus filiformis	0.69	1.92	0.50	5.38	80.38
Prionospio *sp.*	0.43	1.21	0.44	3.38	83.77
Helice crassa	0.35	1.18	0.32	3.30	87.06
Scolecolepides *sp.*	0.28	0.90	0.30	2.52	89.58
Notoacmea helmsi	0.57	0.88	0.25	2.46	92.04
Species	**Ahuriri B (Av. Sim. 39%)**				
	Av. Abund	Av. Sim	Sim/SD	Contrib %	Cum. %
Austrovenus stutchburyi	1.96	21.00	1.55	52.70	52.70
Macomoa liliana	1.44	10.98	1.02	27.55	80.25
Helice crassa	0.33	1.60	0.32	4.02	84.28
Aonides trifida	0.65	1.20	0.32	3.02	87.29
Nicon aestuariensis	0.37	1.06	0.35	2.65	89.94
Nemertea	0.26	0.82	0.29	2.06	92.00
Species	**Ahuriri D (Av. Sim. 47%)**				
	Av. Abund	Av. Sim	Sim/SD	Contrib %	Cum. %
Austrovenus stutchburyi	1.31	16.64	1.29	35.55	35.55
Helice crassa	1.08	14.13	1.13	30.17	65.72
Scolecolepides *sp.*	0.82	8.27	0.87	17.66	83.38
Nicon aestuariensis	0.65	6.31	0.72	13.48	96.87
Species	**Ahuriri E (Av. Sim. 48%)**				
	Av. Abund	Av. Sim	Sim/SD	Contrib %	Cum. %
Austrovenus stutchburyi	3.19	27.71	3.06	58.10	58.10
Helice crassa	1.20	8.32	1.09	17.46	75.56
Notoacmea helmsi	0.61	1.82	0.50	3.81	79.37
Nicon aestuariensis	0.43	1.74	0.53	3.66	83.03
Eliminus modestus	0.56	1.67	0.50	3.50	86.53
Scolecolepides *sp.*	0.37	1.37	0.45	2.87	89.40
Prionospia sp.	0.41	0.82	0.38	1.72	91.13
Species	**Ahuriri F (Av. Sim. 75%)**				
	Av. Abund	Av. Sim	Sim/SD	Contrib %	Cum. %
Nicon aestuariensis	4.01	59.34	6.16	81.40	81.40
Halopyrgus (Potamopyrgus) estuarinus	1.70	13.56	0.90	18.60	100.00
Species	**Waitangi (Av. Sim. 63%)**				
	Av. Abund	Av. Sim	Sim/SD	Contrib %	Cum. %
Halopyrgus (Potamopyrgus) estuarinus	4.24	33.09	4.12	50.20	50.20
Paracorphium excavatum	3.95	21.23	1.66	32.21	82.41
Nicon aestuariensis	0.85	4.97	1.53	7.53	89.94
Scolecolepides *sp.*	0.93	2.75	0.66	4.17	94.11

Av. Abundance – Average abundance per 0.013m^2 core.
Av. Sim – Average similarity within replicates.
Sim/SD – Similarity divided 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.