Coastal Sediment Monitoring Programme

Whāngārei Harbour and Bay of Islands 2014 Results

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Executive Summary

Northland Regional Council (council) monitored sediment metal and nutrient concentrations in surficial sediments at 32 sites in the Whāngārei Harbour and Bay of Islands in 2014. The same sites have previously been sampled by council in 2012 and 2010. The main aims of this programme are to assess the contaminant and enrichment status of the sediment, identify environmental issues and track changes in the quality of the sediment over time. This information can then be used to assess the effectiveness of Regional Plans, to inform decision makers and to help develop policy initiatives and strategies.

Sediment Metals

Concentrations of copper and zinc exceeded ANZECC ISQG-Low effect trigger values at the Upper Hātea River and the Waiharohia Canal sites and the concentration of lead exceeded the threshold effects level developed by MacDonald *et al*. (1996) at both these sites. In addition, the concentrations of copper at the Kissing Point and Lower Hātea River sites exceeded the threshold effects level. Metal concentrations at four sites in Whāngārei Harbour, are therefore at levels which have the potential to cause adverse effects on marine ecosystems. Beyond the Hātea River concentrations of metal contaminants were below ANZECC ISQG-Low effect trigger values and threshold effects levels, with concentrations of metals generally decreasing towards the entrance of the harbour. In the Bay of Islands all metal concentrations were below the ANZECC ISQG-Low effect trigger values and the threshold effects levels.

Comparisons with surveys conducted by council in 2010 and 2012 indicate that metal concentrations have remained relatively stable at most sites. The main exceptions to this were large decreases in the concentrations of copper, lead and zinc at Otaika Creek and decreases in the concentrations of chromium and zinc at Tamaterau.

Sediment Nutrients

The nutrient concentrations recorded in this study indicate that a number of sites in the Bay of Islands and the Hātea River were ‘enriched’ using criteria developed by Robertson and Stevens (2007). In the Whāngārei Harbour, the Upper Hātea River, and the Waiharohia Canal sites were both classified as ‘very enriched’ for phosphorus and ‘enriched’ for both nitrogen and total organic carbon (TOC); the Lower Hātea River, was classified as ‘enriched’ for TOC, nitrogen and phosphorus; and Limeburners Creek and Kissing Point were ‘enriched’ for TOC and phosphorus. Beyond the Hātea River most sites were classified as ‘low to moderately enriched’ or ‘very good’ with nutrient concentrations generally decreasing towards the entrance of the harbour.

In the Bay of Islands, elevated nutrient concentrations were more widespread, although higher concentrations were generally found in more sheltered estuarine environments compared to exposed sites in the outer bay. One site was classified as ‘enriched’ for nitrogen, thirteen sites for phosphorus and eight sites for TOC.

Concentrations of TOC and nutrients were more variable over the two years (2012 & 2014) compared to concentrations of metal contaminants. Interestingly large decreases in nitrogen and phosphorus were observed at Limeburners Creek, which is the receiving environment for discharges from the Whāngārei wastewater treatment plant. Field observations indicated that the sediment collected in Limeburners Creek in 2014 contained a lot of calcareous worm tube cases which made it difficult to collect a sample with the grab. It is possible that fine sediment escaped from the grab sample which may have affected the nutrient concentrations.

1 Introduction

Metal contaminants can have lethal and sub lethal effects on marine organisms and in a contaminated environment the species diversity and species richness may decrease as the community becomes dominated by a smaller number of more tolerant species, which are able to survive and reproduce in these conditions (Clarke & Warwick 2001). Metal contaminants are generally not subject to bacterial attack or other breakdown so are permanent additions to the marine environment. Although plants and animals can usually regulate metal contaminants within a certain range, metals that cannot be excreted remain within the organisms and accumulate over time. As metals accumulate in an organism they can interfere with biological processes. The contaminants can also move progressively up the food chain as organisms are consumed by other animals including humans and this may ultimately pose a risk to human health.

While nutrients are essential for all forms of life, nutrients that enter the environment from human sources, such as fertilizer, stormwater and treated wastewater may exceed the needs of an ecosystem. Initially surplus nutrients may stimulate algal growth and subsequently benthic communities and fish populations because there is an increase in food via additional plant material and organic detritus. However, large increases in algae can disturb the ecosystem, as algal growth can decrease light levels, and as the algae dies they are decomposed by bacteria which consume oxygen and can cause the water to become anoxic (hypoxia). Nutrient enrichment can also cause algal blooms including toxic algal blooms.

Since 2010 council has monitored sediment metal concentrations in surficial sediments at 32 sites in the Whāngārei Harbour and Bay of Islands. Surveys have been conducted every two years in 2010, 2012 and 2014. In 2012 and 2014 sediment nutrient concentrations and total organic carbon (TOC) were also monitored.

The main objectives of this programme are to:

- assess contaminant and nutrient status in sediments;
- compare sediment metal levels with sediment quality guidelines; and
- examine spatial and temporal trends in metal and nutrient concentrations.

The results from this programme will also enable council to assess the performance and effectiveness of Regional Plans, inform decision makers and help with the development of policy initiatives and strategies. The results also provide a background data set with which to compare contaminant levels from point source discharges (e.g. industrial stormwater discharges).

The programme addresses council's responsibilities under the Resource Management Act (1991) in relation to sustainable management principals set out in Part II (Section 5) and directives to monitor the state of the environment as set out in Part IV (Section 35; 1 & 2a Section 30; 1a). The programme also satisfies the Regional Community Outcomes of the Long Term Council Community Plan 2009-2019 (LTCCP).

This report presents the results of the 2014 sediment survey. A comparison of this data with surveys conducted in 2010 and 1012 is also presented.

2 Methods

2.1 Sampling Sites

2.1.1 Whāngārei Harbour

Sediment samples were collected from 16 subtidal sites distributed throughout the Whāngārei Harbour. Sites were located in order to capture the inputs from the harbour's main tributaries and to ensure a good geographical spread through the harbour (Figure 1). Five sites were located in the Hātea River arm of the harbour, as a significant proportion of the harbour's catchment drains into this arm, with sites also located in the Otaika Creek, Mangapai River, Takahiwai Creek and Blacksmith Creek.

2.1.2 Bay of Islands

Sixteen subtidal sites were located throughout the Bay of Islands. Sites were located in order to capture the main freshwater inputs to the bay and to ensure a good geographical spread throughout the outer bay (Figure 2). All site co-ordinates can be found in Appendix 1.

2.2 Sample Collection and Analysis

Sediment was collected with a grab sampler, from which the surface sediment (top 2cm) was collected, with a sterilised plastic scoop. Separate samples were collected for grain size analysis and geochemical analysis. In the field samples were stored on ice in zip-lock bags. The samples were transported to council's office, frozen and sent to external laboratories for chemical analysis. Sediment samples were analysed externally by Water Care Laboratory Services to determine ash free dry weight (AFDW), total nitrogen, total phosphorus, total cadmium, total chromium, total copper, total zinc, total nickel and total lead. Total organic carbon (TOC) was calculated from ash free dry-weight (AFDW) using the formula TOC = 0.4 x (AFDW) + 0.0025 x $(AFDW)^2$ (Robertson *et. al.* 2002). Sediment grain size was analysed by Waikato University with a laser diffraction particle analyser. In 2010, only cadmium, chromium, copper, lead and zinc, and sediment grain size were monitored. Nickel, nitrogen, phosphorus and ash free dry weight were added to the programme in 2012.

2.3 Data Analysis and Guideline Values

The sediment metal concentrations were assessed against ANZECC ISQG-Low Trigger values (Australian New Zealand Environment Conservation Council 2000) and threshold effect levels (TEL) developed by MacDonald *et al*. (1996) (Table 1).

Table 1. Sediment quality guidelines (all units are mg/kg).

	MacDonald *et al.* (1996)	ANZECC (2000)	
	TEL	ISQG-Low	ISQG-High
Copper	18.7	65	270
Lead	30.2	50	220
Zinc	124	200	410
Chromium	52.3	80	370
Nickel	15.9	21	52
Cadmium	0.68	1.5	10

ANZECC guidelines do not include trigger values for nutrients or TOC in sediments and there are currently no nationally accepted guideline values. Instead sediment nutrient concentrations and TOC were assessed against a classification developed by Robertson and Stevens (2007) (Table 2).

Table 2. Sediment nutrient guidelines (nitrogen and phosphorus units are mg/kg).

	Good	Low to moderately enriched	Enriched	Very enriched
Nitrogen	<500	500-2000	2000-4000	>4000
Phosphorus	<200	200-500	500-1000	>1000
TOC	<1%	1-2%	2-5%	5%

Figure 1. Location of sampling sites in Whāngārei Harbour.

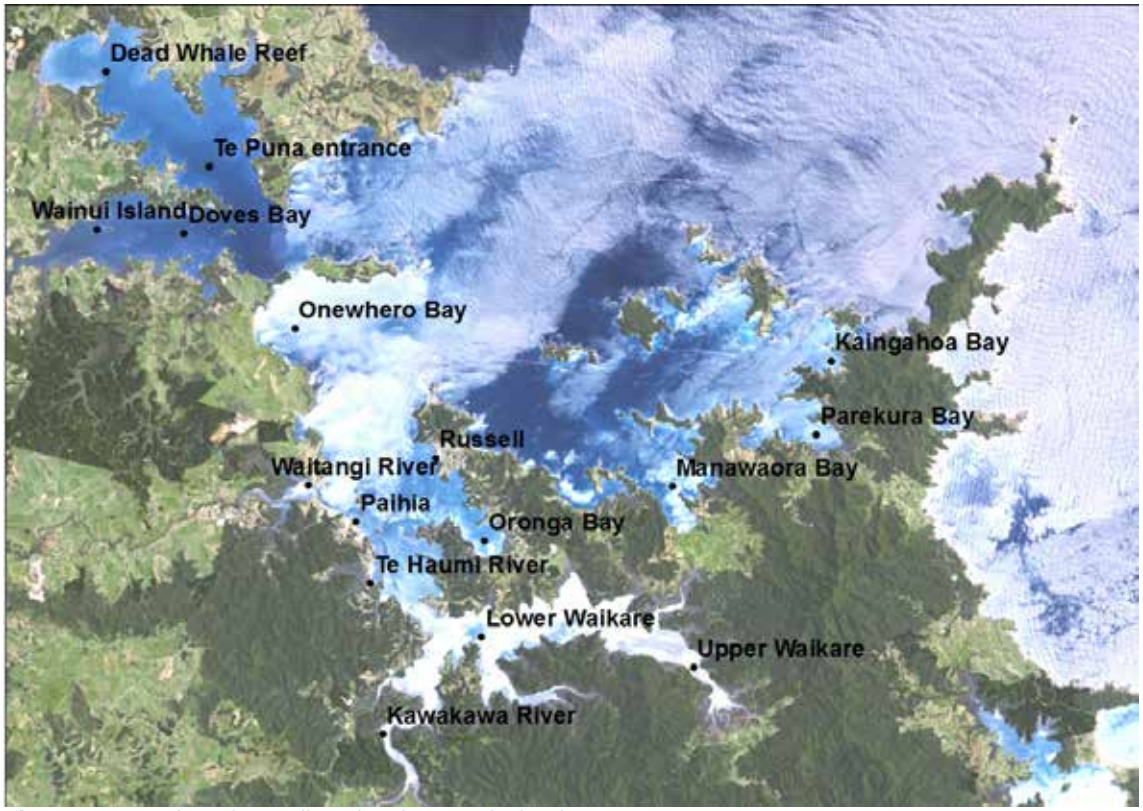

Figure 2. Location of sampling sites in Bay of Islands.

3 Results

3.1 Copper

Whāngārei Harbour

The highest total copper concentrations were recorded at the Upper Hātea River and the Waiharohia Canal, and the concentrations at these two sites exceeded the ANZECC ISQG-Low effect trigger value of 65 mg/kg (Figure 3). These two sites also had the highest concentrations of copper in 2012 and 2010 (Table 3). All of the other copper concentrations measured were below the ANZECC ISQG-Low effect trigger value but concentrations at Kissing Point and the Lower Hātea River sites exceeded the threshold effect level of 18.7 mg/kg developed by MacDonald *et al*. (1996) (Figure 3 and Table 3). Concentrations of copper tended to decrease from the Hātea River to the entrance of the harbour. At Home Point and Marsden Point near the harbour entrance the concentrations of copper were below the detection limits (<0.45 mg/kg).

Similar spatial patterns were observed in 2010 and 2012, with the highest concentrations recorded at sites in the Hātea River and lowest concentrations towards the harbour entrance (Table 3). In 2010 four sites exceeded the threshold effect level levels but no sites exceed ANZECC. Interestingly, in 2010 the copper concentration at Otaika Creek (29 mg/kg) exceeded the threshold effect level but in subsequent years (2012 and 2014) the concentrations were well below the threshold effect level (6.8 mg/kg and 8.5 mg/kg). In 2012, three sites exceeded the threshold effect level and one site, Waiharohia Canal exceeded the ANZECC ISQG-Low effect trigger value.

Bay of Islands

In the Bay of Islands all the copper concentrations measured were below the ANZECC ISQG-Low effect trigger value of 65 mg/kg and the threshold effect level of 18.7 mg/kg developed by MacDonald *et al*. (1996) (Figure 4). The highest values were recorded at the Kawakawa River (15 mg/kg) and Wainui Island (14 mg/kg), the same two sites as in 2010 and 2012. The lowest value was recorded at Onewhero Bay (4 mg/kg) (Figure 4).

In 2010 and 2012 all of the copper concentrations measured were also below the ANZECC ISQG-Low effect trigger value and the threshold effect level (Table 5). In 2010 the highest value was recorded at Wainui Island and in 2012 the highest value were recorded at Kawakawa River. The lowest value was recorded at Onewhero bay in all three years.

3.2 Zinc

Whāngārei Harbour

The highest total zinc concentrations were recorded at the Upper Hātea River (220 mg/kg) and the Waiharohia Canal (290 mg/kg), the same two sites as in 2012 and 2010 (Figure 5 and Table 3). The concentration of zinc at these two sites exceeded the ANZECC ISQG-Low effect trigger value of 200mg/kg. All of the other zinc concentrations were below the ANZECC ISQG-Low effect trigger value and the threshold effect level of 124 mg/kg developed by MacDonald *et al*. (1996). The highest concentrations were recorded at sites in the Hātea River with concentrations decreasing towards the entrance of the harbour (Figure 5). At Home Point, Marsden Point, Marsden Bay and Takahiwai Creek the zinc concentrations were below the detection limits (<6.7 mg/kg).

Similar spatial patterns were found in 2010 and 2012 with the highest concentrations recorded at sites in the Hātea River and lowest concentrations towards the harbour entrance (Table 3). In 2010 the

Upper Hātea River and Otaika Creek exceeded the threshold effect level and Waiharohia Canal exceeded ANZECC, with the highest concentrations recorded at sites in the Hātea River. In 2012 the Upper Hātea River and Waiharohia Canal both exceeded the threshold effect level but no site exceeded the ANZECC ISQG-Low effect trigger value.

Bay of Islands

In the Bay of Islands all of the zinc concentrations measured were below the ANZECC ISQG-Low effect trigger value of 200 mg/kg and the threshold effect level of 124 mg/kg developed by MacDonald *et al*. (1996) (Figure 6 and Table 5). The highest values were recorded at the Kawakawa River (86 mg/kg) and the two sites in the Waikare Inlet (Upper Waikare Inlet and Lower Waikare Inlet). The lowest concentration was recorded at Onewhero Bay (14 mg/kg) (Figure 6).

In 2010 and 2012 all of the zinc concentrations measured were also below the ANZECC ISQG-Low effect trigger value and the threshold effect level (Table 5). In 2010, the highest value was recorded at the Kawakawa River and in 2012 at Upper Waikare Inlet. The lowest value was recorded at Onewhero Bay in all three years.

3.3 Lead

Whāngārei Harbour

All of the lead concentrations measured were below the ANZECC ISQG-Low effect trigger value of 50 mg/kg but the concentrations at the Upper Hātea River (31 mg/kg) and the Waiharohia Canal (39 mg/kg) did exceed the threshold effect level of 30.2 mg/kg developed by MacDonald *et al*. (1996) (Figure 7 and Table 3). The highest total lead concentrations were recorded at sites in the Hātea River, with concentrations decreasing towards the harbour entrance. The lowest concentrations were found at Marsden Bay (0.66 mg/kg), Home Pont (0.7 mg/kg) and Marsden Point (0.66 mg/kg).

Again similar patterns were found in 2010 and 2012, with the highest concentrations recorded at the Upper Hātea River and Waiharohia Canal sites in all three years (Table 3). In 2010 the Waiharohia Canal exceeded the threshold effect level level and in 2012 both the Waiharohia Canal and the Upper Hātea River exceeded the threshold effect level level. No site has exceeded the ANZECC ISQG-Low effect trigger value in the three years of sampling.

Bay of Islands

All lead concentrations were below the ANZECC ISQG-Low effect trigger value of 50 mg/kg and the threshold effect level of 30.2 mg/kg, developed by MacDonald *et al*. (1996) (Figure 8 and Table 5). The highest values were recorded at the Kawakawa River (13 mg/kg) and the two sites in the Waikare Inlet (Upper Waikare Inlet (12 mg/kg) and Lower Waikare Inlet (12 mg/kg)). The lowest concentration was recorded at Parekura Bay (3.2 mg/kg).

In 2010 and 2012 all of the lead concentrations measured were also below the ANZECC ISQG-Low effect trigger value and the threshold effect level (Table 5). In 2010, the highest value was recorded at the Lower Waikare Inlet and in 2012 at Russell. The lowest value was recorded at Kaingahoa Bay in all three years.

3.4 Chromium

Whāngārei Harbour

All of the chromium concentrations measured were below the ANZECC ISQG-Low effect trigger value of 80 mg/kg and the threshold effect level of 52.3 mg/kg developed by MacDonald *et al*. (1996) (Figure

9 and Table 3). The highest concentrations were recorded at the Upper Hātea River, Waiharohia Canal, Kissing Point and Waimahanga Creek. Lower concentrations were found towards the harbour entrance with the lowest values found at Marsden Bay, Takahiwai Creek and Marsden Point (Figure 9).

In 2010 and 2012 all chromium concentrations were also below the ANZECC ISQG-Low effect trigger value and the threshold effect level (Table 3). The highest concentrations were found at the Upper Hātea River and Waiharohia Canal in all three years with the lowest levels near the entrance of the harbour.

Bay of Islands

All chromium concentrations were below the ANZECC ISQG-Low effect trigger value of 80 mg/kg and the threshold effect level of 52.3 mg/kg developed by MacDonald *et al*. (1996) (Figure 10 and Table 5). The highest values were recorded at Wainui Island (39 mg/kg) and Doves Bay (35 mg/kg) in the Kerikeri Inlet. The lowest concentration was found at Te Haumi River (5 mg/kg).

In 2010 and 2012 all of the chromium concentrations measured were also below the ANZECC ISQG-Low effect trigger value and the threshold effect level (Table 5). In 2010 and 2012 the highest values were also recorded at Wainui Island and Doves Bay in the Kerikeri Inlet. The lowest value was recorded at Te Haumi River in all three years.

3.5 Nickel

Whāngārei Harbour

All nickel concentrations were below the ANZECC ISQG-Low effect trigger value of 21 mg/kg and the threshold effect level of 15.9 mg/kg developed by MacDonald *et al*. (1996) (Figure 11 and Table 3). The highest concentrations were recorded at the Upper Hātea River (14 mg/kg) and Waiharohia Canal (14 mg/kg) sites, with levels close to the threshold effect level (Figure 11). Lower concentrations were found towards the harbour entrance with the lowest values found at Marsden Bay and Marsden Point (both 1 mg/kg). In 2012 the highest concentrations were also recorded at the Upper Hātea River and Waiharohia Canal and the concentration at Waiharohia Canal exceeded the threshold effect level (Table 3). The lowest value was again recorded at Marsden Bay (0.83 mg/kg). Nickel was not measured in 2010.

Bay of Islands

In the Bay of Islands all of the nickel concentrations were below the ANZECC ISQG-Low effect trigger value of 21 mg/kg and the threshold effect level of 15.9 mg/kg developed by MacDonald *et al*. (1996) although levels at Doves Bay (15 mg/kg) and Wainui Island (14 mg/kg) were close to the threshold effect level (Figure 12 & Table 5). The lowest concentrations were recorded at Kaingahoa Bay (2.8 mg/kg) and Te Hamui River (3.2 mg/kg). Nickel was not measured in the Bay of Islands in 2010 or 2012.

3.6 Cadmium

Whāngārei Harbour

All of the cadmium concentrations were below the ANZECC ISQG-Low effect trigger value of 1.5 mg/kg and the threshold effect level of 0.68 mg/kg developed by MacDonald *et al*. (1996) (Figure 13 and Table 3). Thirteen of the sites had concentrations below the detection limit (<0.09 mg/kg). The only sites with concentrations above the detection limit were the Upper Hātea River (0.17 mg/kg), Waiharohia Canal (0.16 mg/kg) and Limeburners Creek (0.16 mg/kg).

In 2010 and 2012 all cadmium concentrations were also below the ANZECC ISQG low effect trigger value and the threshold effect level (Table 3). The highest concentrations were recorded at the Upper Hātea River, Otaika Creek and Waiharohia Canal in 2010 and at the Upper Hātea River and Waiharohia Canal in 2012. In 2010 and 2012, concentrations at most other sites were below or close to detection limits.

Bay of Islands

The concentration of cadmium was below the detection limit at 15 of the 16 sites (Figure 14. The only site with a concentration above the detection limit was Wainui Island (0.098 mg/kg) which was below both the ANZECC ISQG-Low trigger value and the threshold effect level (MacDonald *et al*. 1996).

3.7 Total Organic Carbon (TOC)

Whāngārei Harbour

The highest levels of TOC were found at the Upper Hātea River (4.93 %w/w) and Waiharohia Canal (4.03 %w/w) sites (Figure 15 and Table 4). The lowest values were recorded near the harbour entrance at Marsden Point (0.24 %w/w), Home Point and Marsden Bay (both 0.32 %w/w). ANZECC guidelines do not include trigger values for TOC in marine sediments but Robertson and Stevens (2007) have developed their own enrichment classification for TOC. In their classification levels below 1% are classified as 'very good', levels between 1-2% are classified as 'low to moderately enriched', levels between 2-5% are classified as 'enriched' and levels above 5% as 'very enriched'. Using these criteria, nine sites were classified as 'very good', two sites were 'low to moderately enriched' and five sites as 'enriched' (Figure 15). The level for TOC at the Upper Hātea River site (4.9 %w/w) was very close to the threshold for 'very enriched'. In 2012, five sites were classified as 'very good', nine sites were 'low to moderately enriched' and two sites were 'enriched' (Table 4).

Bay of Islands

The highest levels of TOC were found at Doves Bay (4.75 %w/w) and the entrance to Te Puna Inlet (4.61 %w/w) (Figure 16 and Table 6). The lowest values were at Paihia and Kaingahoa Bay (both 1.22 %w/w). Under the classification developed by Robertson and Stevens (2007) eight sites were classified as 'low to moderately enriched' and eight sites as 'enriched' (Figure 16 & Table 6). The levels of TOC at both Doves Bay and the entrance to Te Puna were close to the threshold for 'very enriched'. In 2012, eight sites were classified as 'low to moderately enriched' and eight sites as 'enriched' (Table 6).

3.8 Nitrogen

Whāngārei Harbour

The highest concentration of nitrogen was recorded at the Waiharohia Canal (3400 mg/kg), with the lowest value recorded at Home Point (20 mg/kg) (Figure 17 and Table 4). ANZECC guidelines do not include trigger values for nitrogen in marine sediments but Robertson and Stevens (2007) have developed their own classification for sediment nitrogen concentrations. In their classification concentrations below 500 mg/kg are classified as 'very good', concentrations between 500-2000 mg/kg are classified as 'low to moderately enriched', concentrations between 2000-4000 mg/kg are classified as 'enriched' and concentrations above 4000 mg/kg as 'very enriched'. Using this classification system the concentrations of nitrogen at seven sites were classified as 'very good', six sites as 'low to moderately enriched' and three sites 'enriched' (Figure 17 & Table 4). In 2012 one site (Limeburners Creek) was classified as 'very enriched' six sites were 'low to moderately enriched' and nine sites were 'very good' (Table 4).

Bay of Islands

The highest concentration of nitrogen was recorded at the entrance to Te Puna Inlet (2100 mg/kg) and the lowest value was at Parekura Bay (320 mg/kg) (Figure 18 and Table 6). Under the classification developed by Robertson and Stevens (2007) four sites were classified as 'very good', eleven sites as 'low to moderately enriched' and one site as 'enriched'. In 2012, four site were 'very good' and twelve sites were 'low to moderately enriched' (Table 6).

3.9 Phosphorus

Whāngārei Harbour

The highest concentrations of phosphorus were recorded at the Upper Hātea River (1200 mg/kg) and the Waiharohia Canal (1300 mg/kg) with the lowest concentrations found at Marsden Point (62 mg/kg) (Figure 19 and Table 4). ANZECC guidelines do not include trigger values for phosphorus in sediments but Robertson and Stevens (2007) have also developed a classification for sediment phosphorus concentrations. In their classification concentrations below 200 mg/kg are classified as 'very good', concentrations between 200-500 mg/kg are classified as 'low to moderately enriched', concentrations between 500-1000 mg/kg are classified as 'enriched' and concentrations above 1000 as 'very enriched'. Under this classification seven sites were classified as 'very good', four sites as 'low to moderately enriched' three sites as 'enriched' and two as 'very enriched' (Figure 19 and Table 4). The concentration of phosphorus at Limeburners Creek was also very close to the threshold for 'very enriched'. In 2012, eight sites were 'very good', three sites were 'low to moderately enriched', four sites were 'enriched and one site (Limeburners Creek) was 'very enriched' (Table 4).

Bay of Islands

The highest phosphorus concentration was at Wainui Island (850 mg/kg) and the lowest value was at Kaingahoa Bay (320 mg/kg) (Figure 20 and Table 6). Under the classification developed by Robertson and Stevens (2007) three sites were classified as 'low to moderately enriched' and thirteen sites as 'enriched' (Figure 20). In 2012, thirteen sites were 'enriched' and one site was 'very enriched' and two were low to moderately enriched (Table 6).

3.10 Grain Size

Whāngārei Harbour

Sites in in the tidal creek environments of the Upper harbour (Hātea River, Otaika Creek and Mangapai River) tended to have high proportions of mud and fine sand (Figure 21). However the sediment composition in Limeburners Creek was quite different. At Limeburners Creek the sediment comprised approximately equal proportions of mud, fine sand, and medium sand. Sites in the outer harbour tended to comprise mainly medium sand and fine sand with little or no mud.

Bay of Islands

Sites in sheltered estuarine environments such as Waikare Inlet, Kerikeri Inlet, Te Puna Inlet, and in sheltered bays such as Oronga Bay and Manawaora Bay, had high proportions of mud. However the sediment composition at two estuarine sites, Waitangi Estuary and Kawakawa River was quite different (Figure 22). The sediment at both these sites comprised approximately 35% of both mud and coarse sand and 10-20% of both fine sand and medium sand. At more exposed sites such as Paihia, Russell, Kaingahoa, Parekura and Onewhero Bay the sediment had low proportions of mud and higher proportions of fine sand, medium sand and coarse sand.

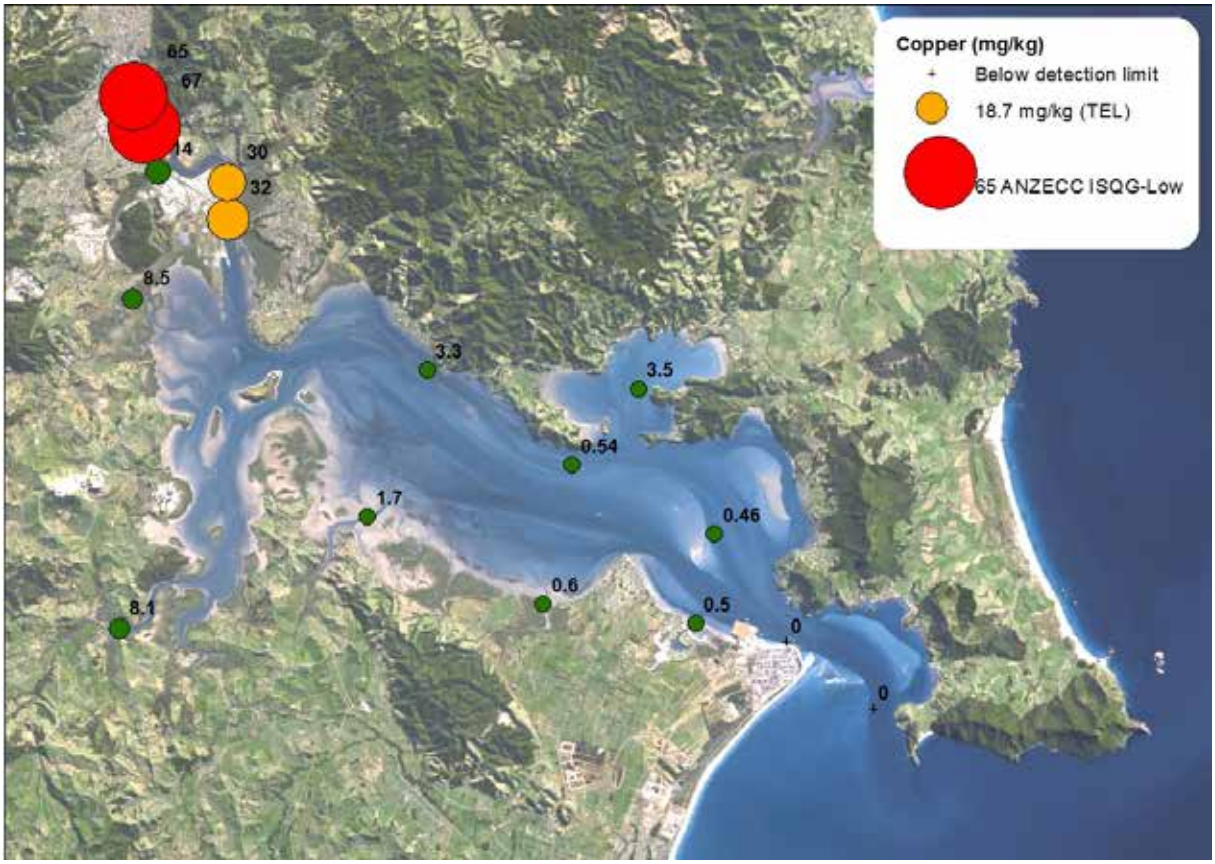

Figure 3. Sediment copper concentrations in the Whāngārei Harbour in 2014.

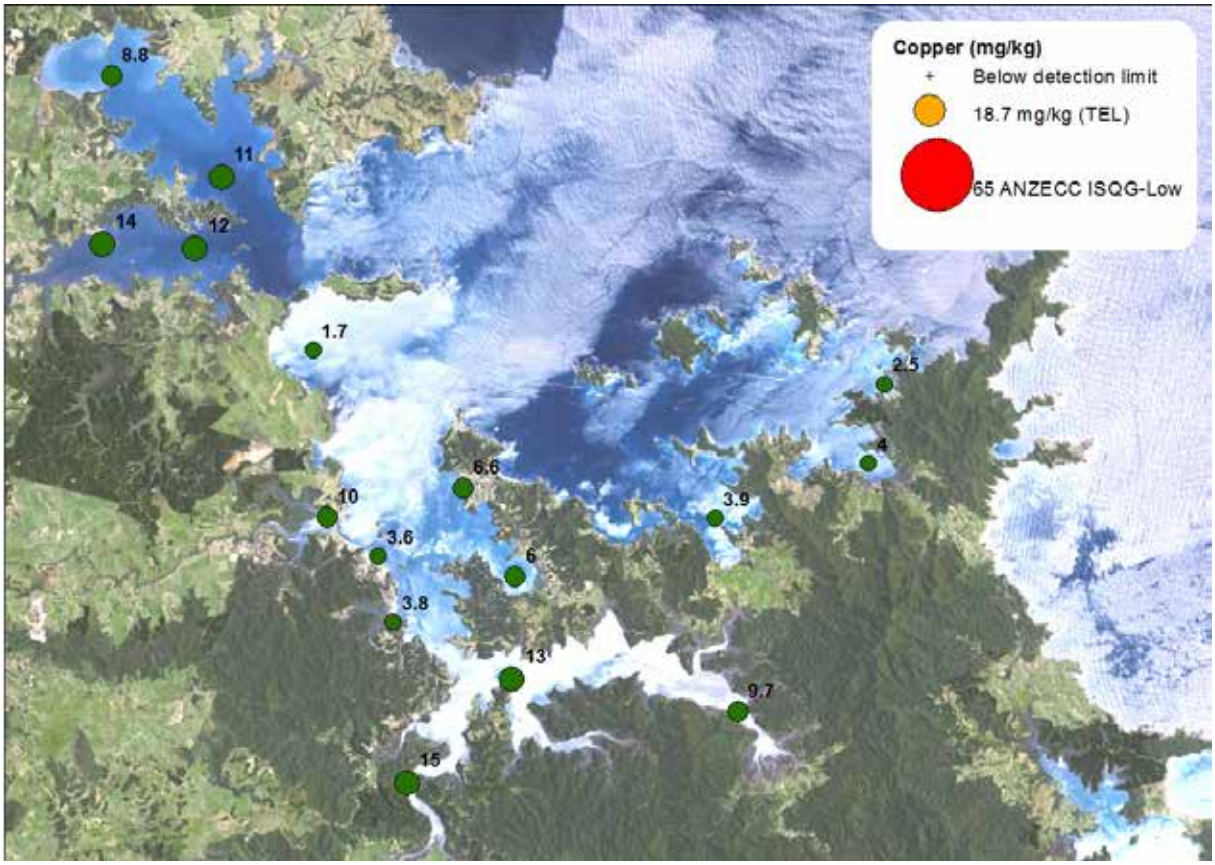

Figure 4. Sediment copper concentrations in the Bay of Islands in 2014.

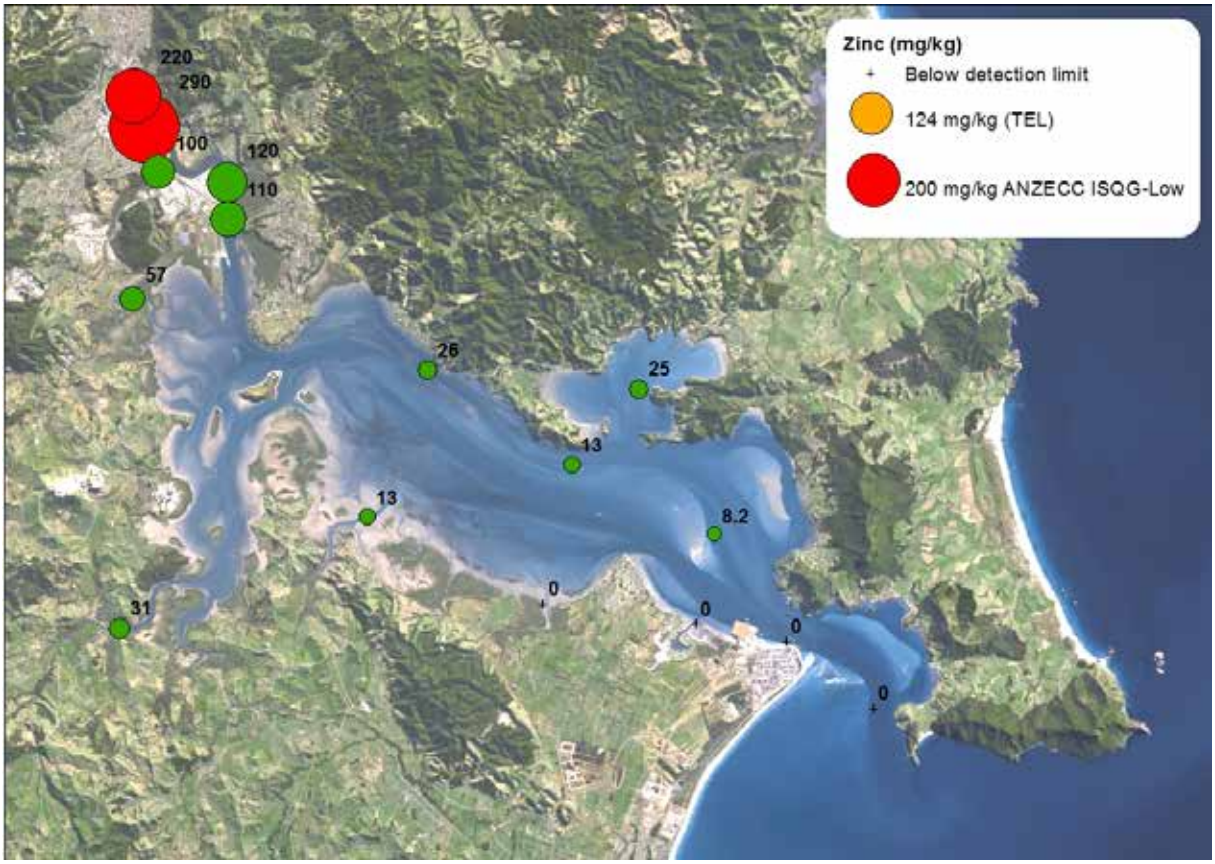

Figure 5. Sediment zinc concentrations in the Whāngārei Harbour in 2014.

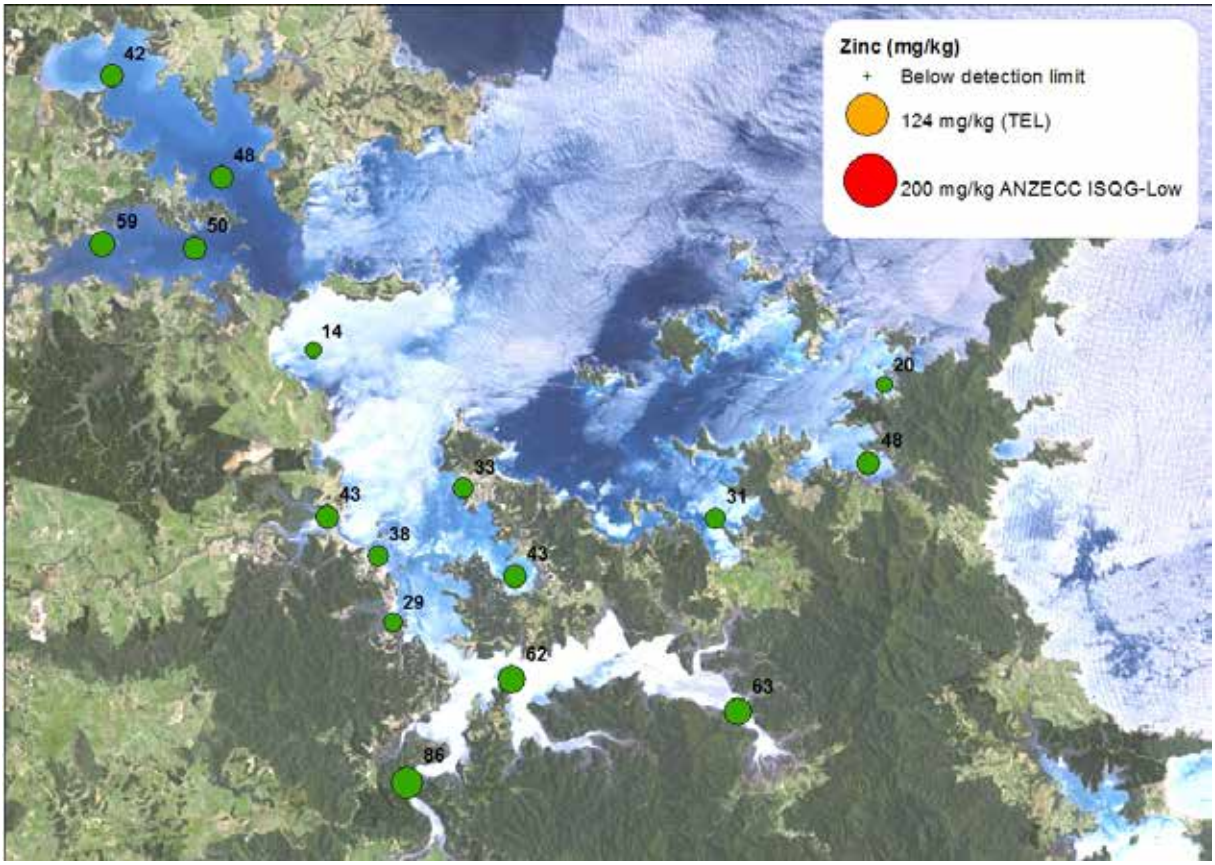

Figure 6. Sediment zinc concentrations in the Bay of Islands in 2014.

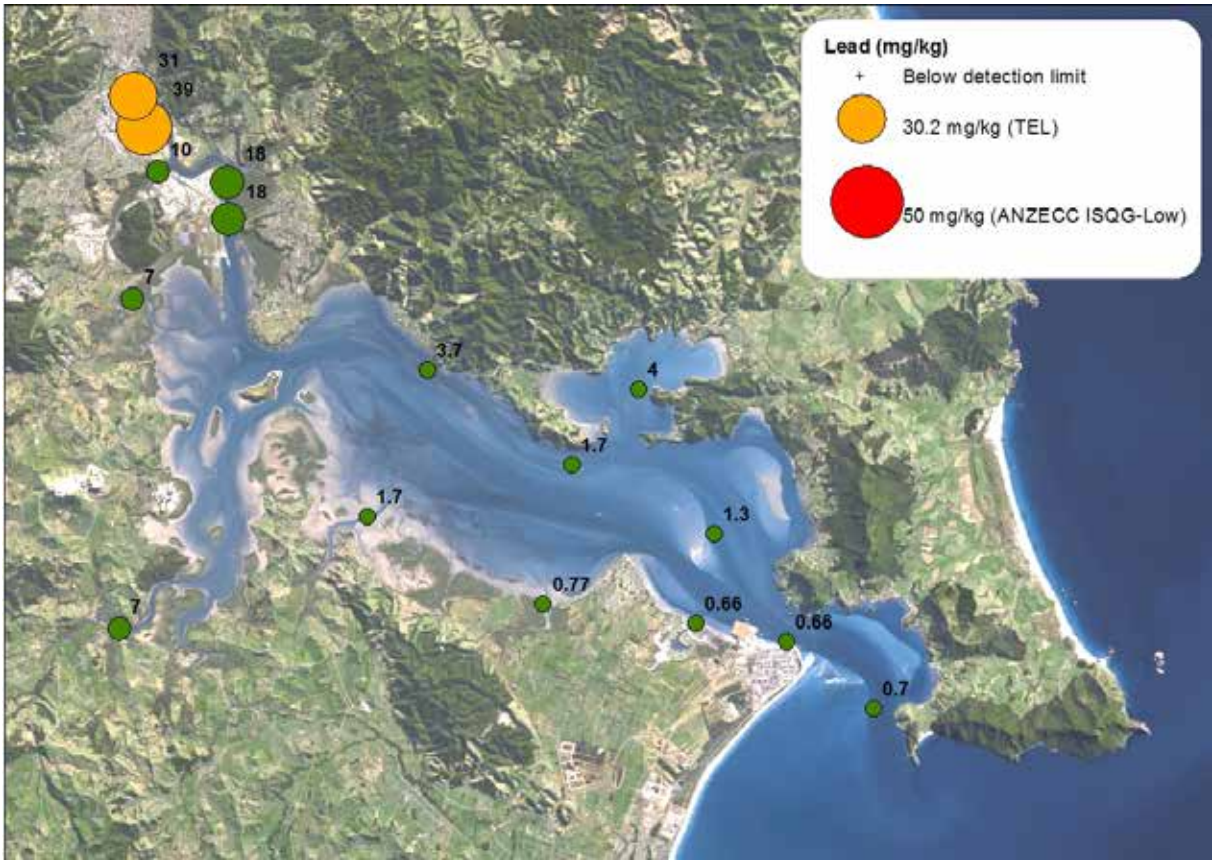

Figure 7. Sediment lead concentrations in the Whāngārei Harbour in 2014.

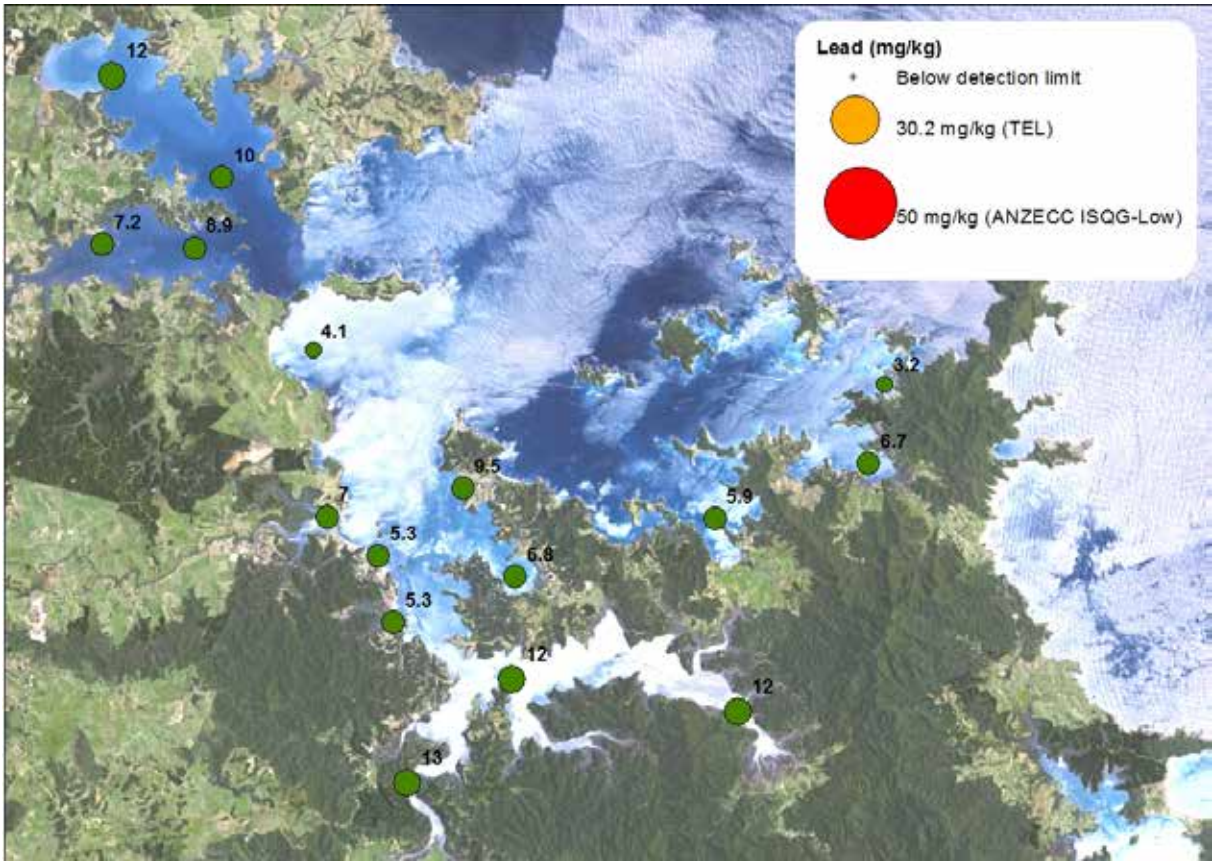

Figure 8. Sediment lead concentrations in the Bay of Islands in 2014.

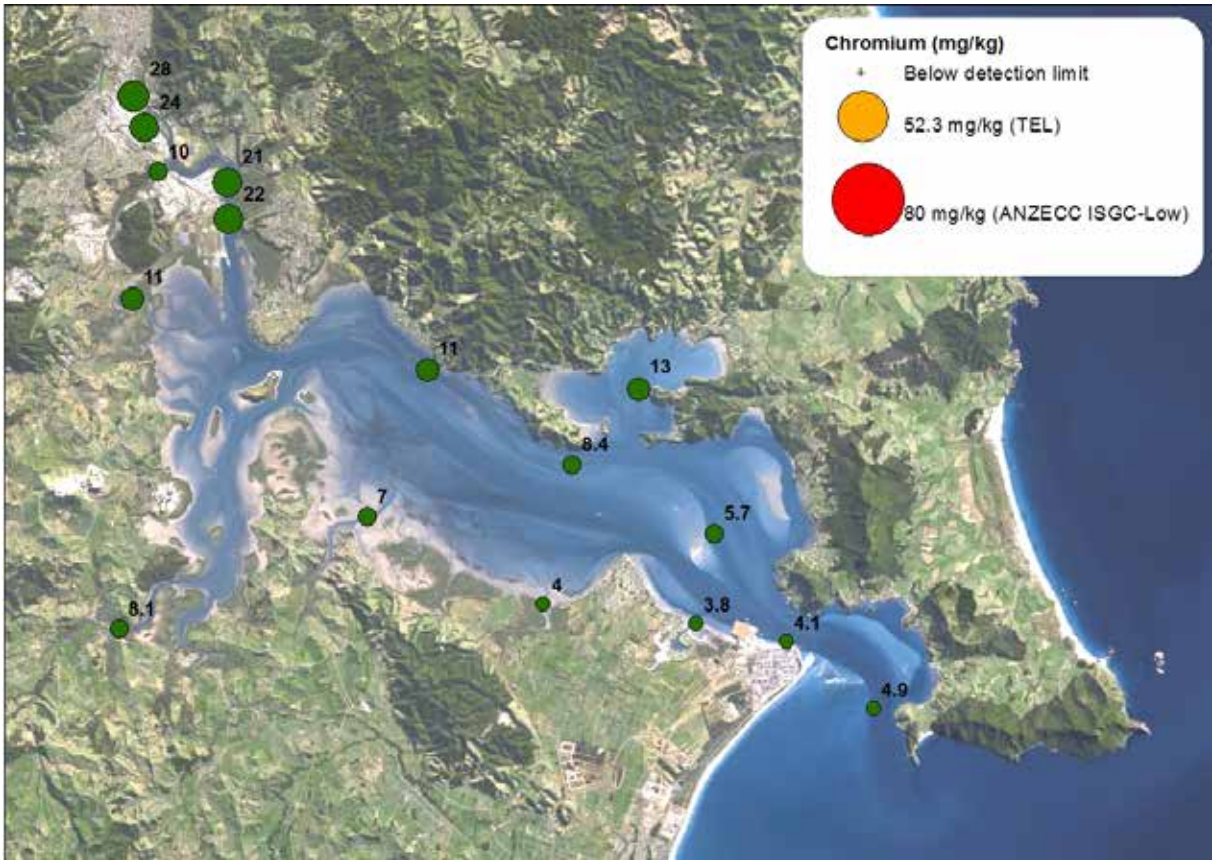

Figure 9. Sediment chromium concentrations in the Whāngārei Harbour in 2014.

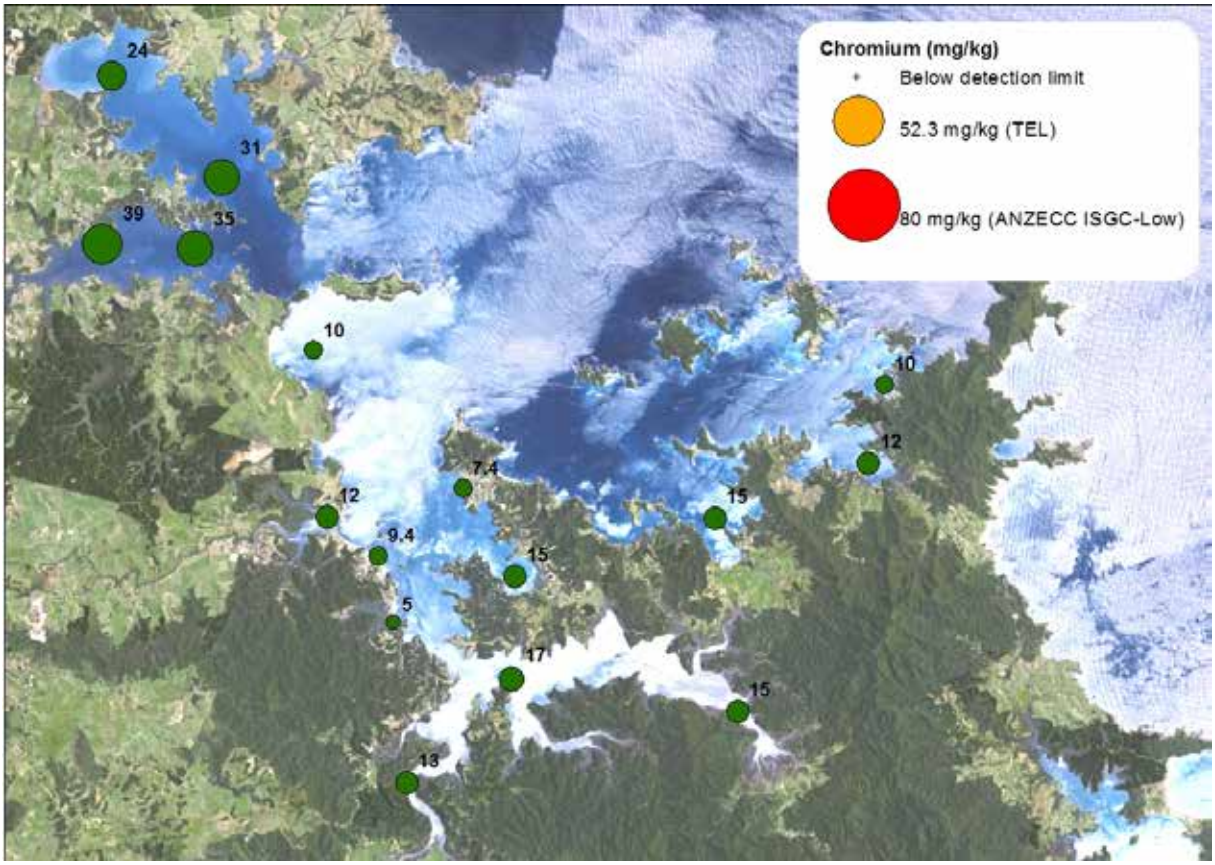

Figure 10. Sediment chromium concentrations in the Bay of Islands in 2014.

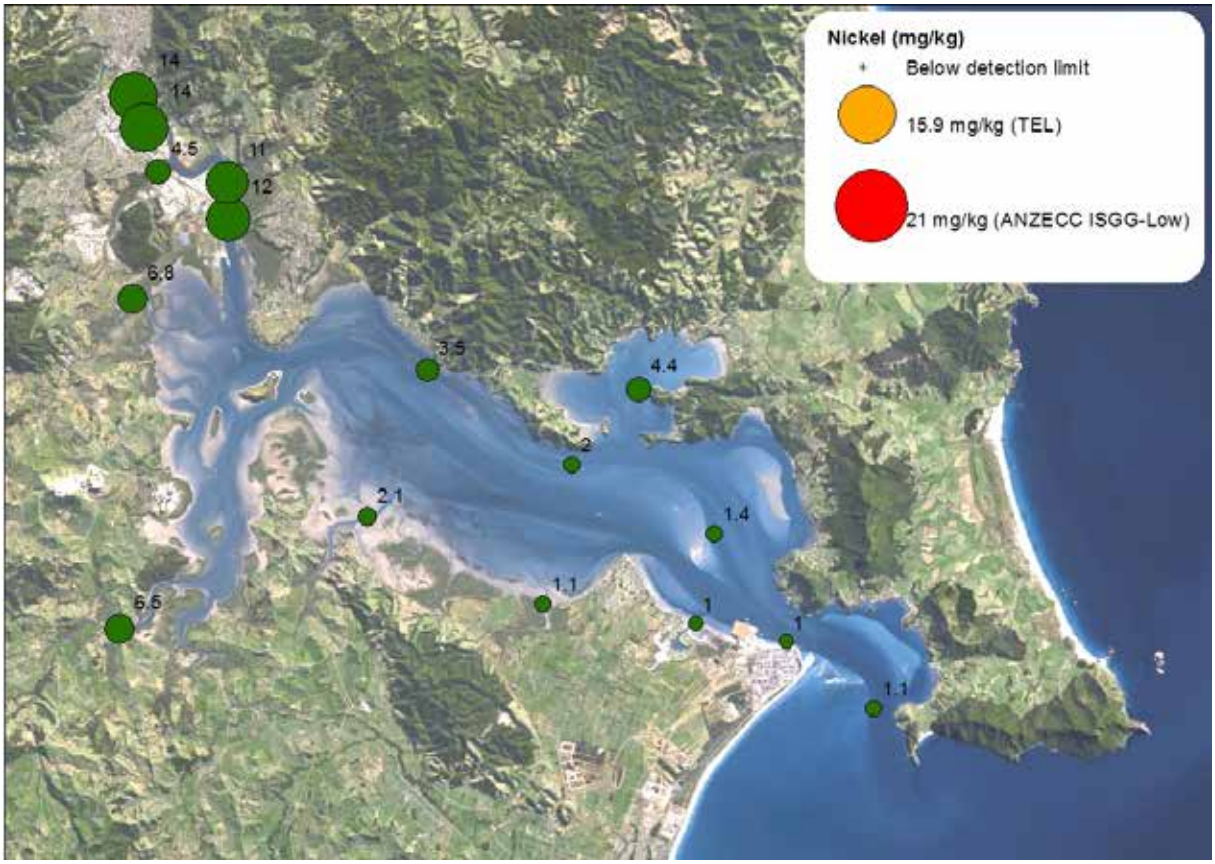

Figure 11. Sediment nickel concentrations in the Whāngārei Harbour in 2014.

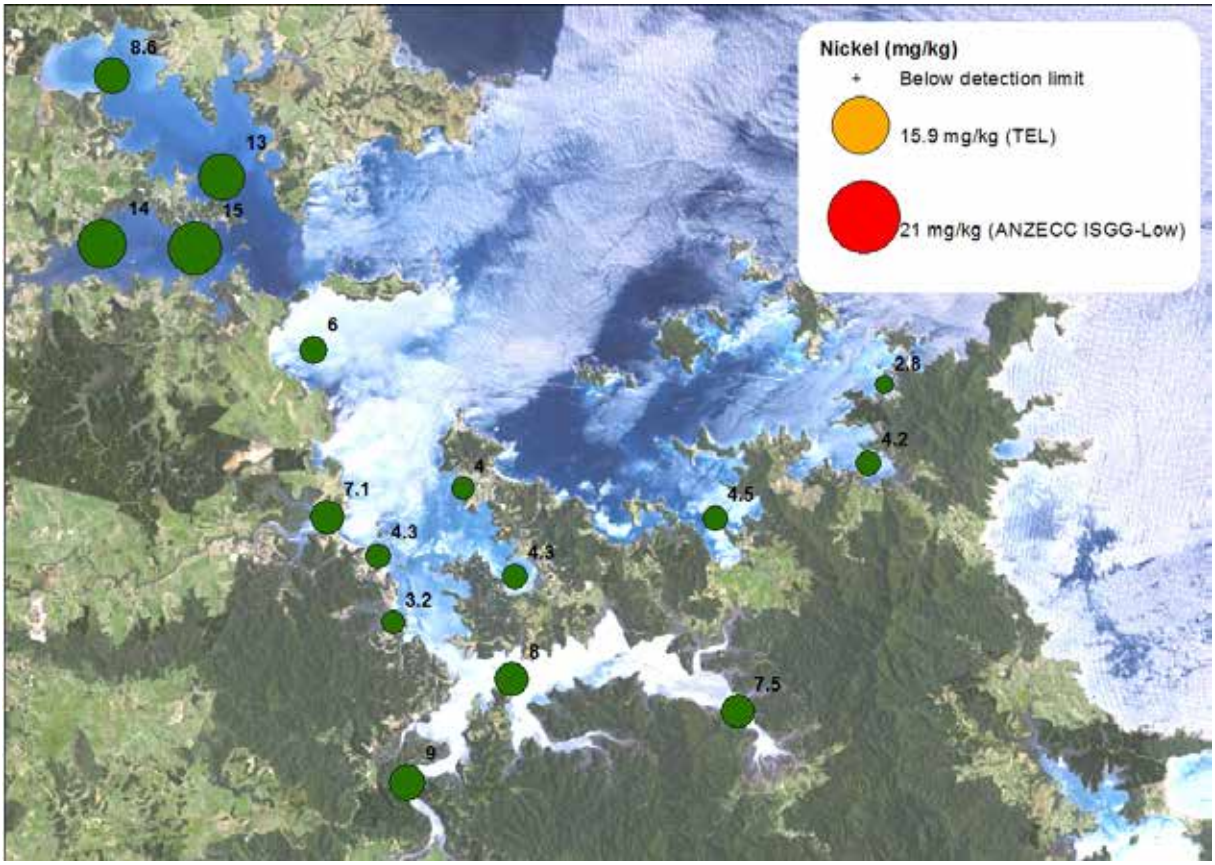

Figure 12. Sediment nickel concentrations in the Bay of Islands in 2014.

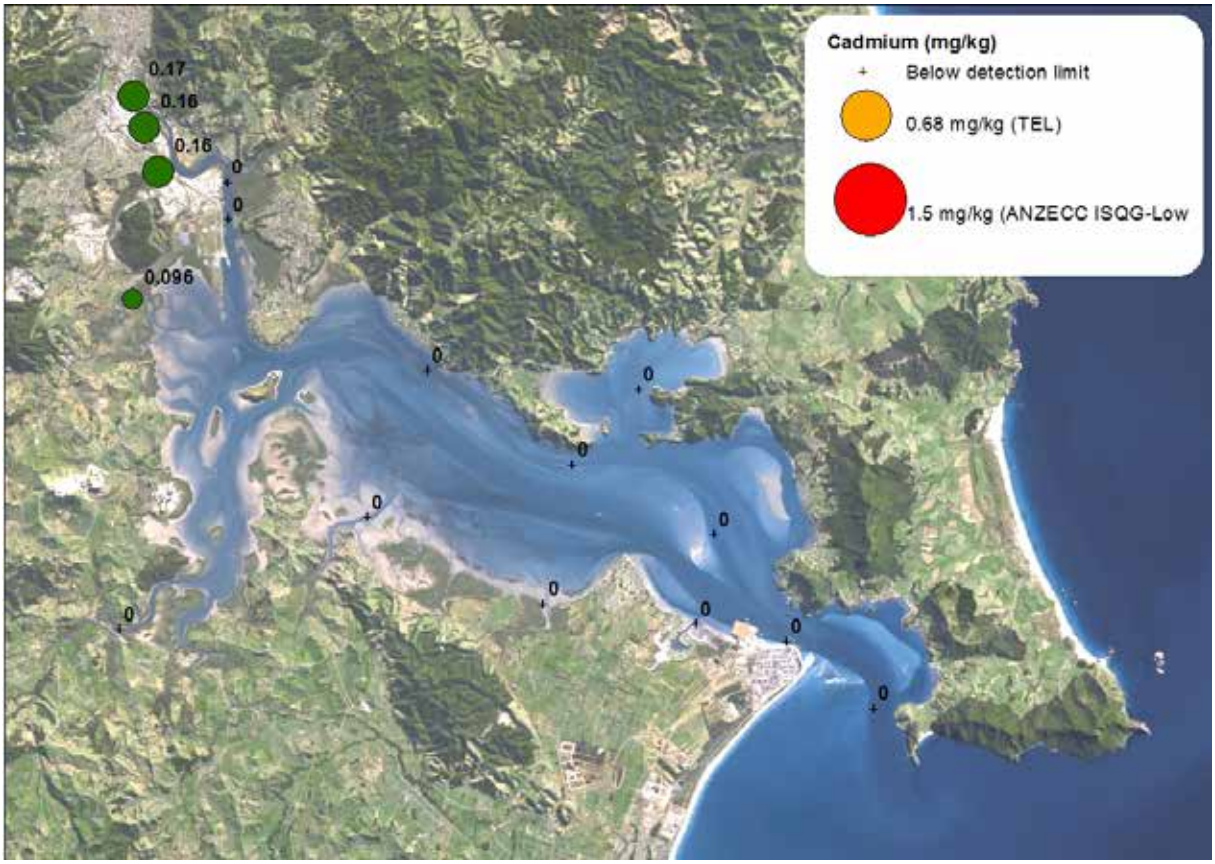

Figure 13. Sediment cadmium concentrations in the Whāngārei Harbour in 2014.

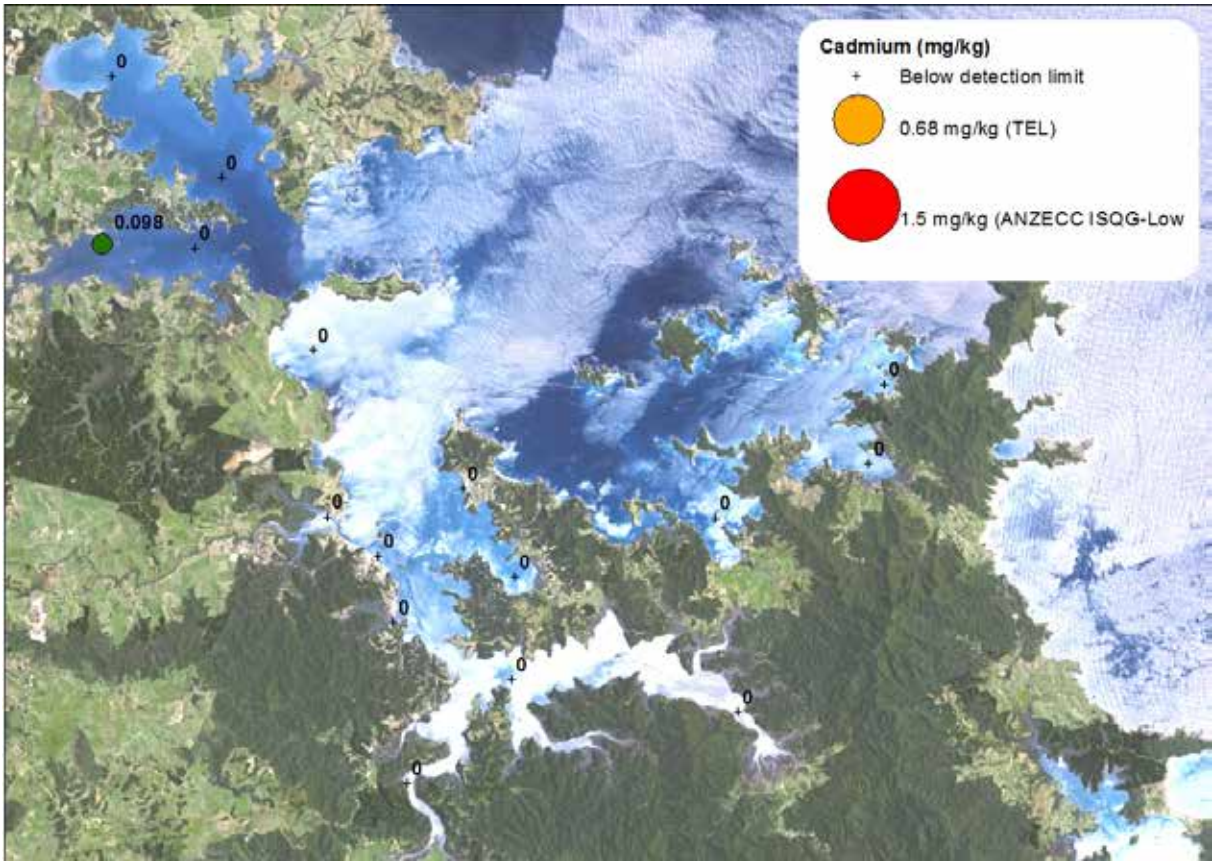

Figure 14. Sediment cadmium concentrations in the Bay of Islands in 2014.

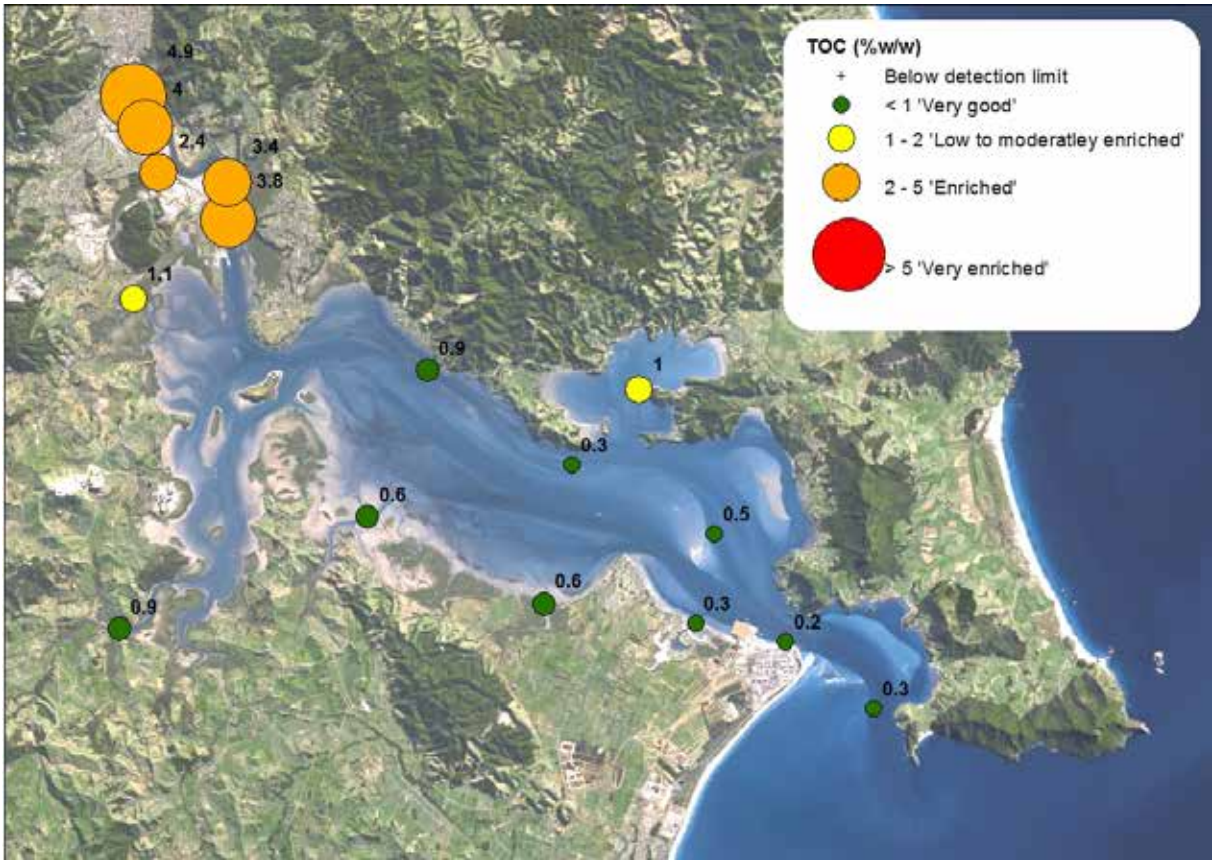

Figure 15. Sediment TOC concentrations in the Whāngārei Harbour in 2014.

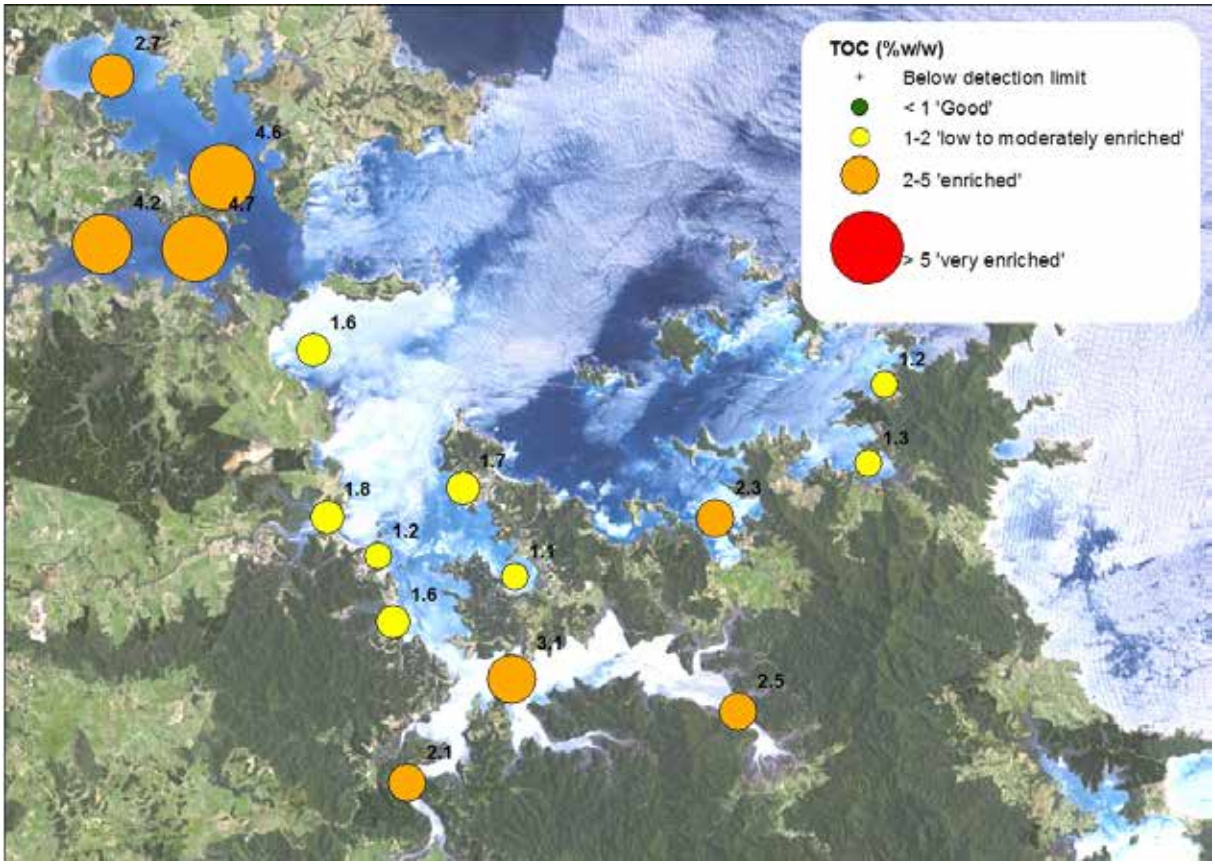

Figure 16. Sediment TOC concentrations in the Bay of Islands in 2014.

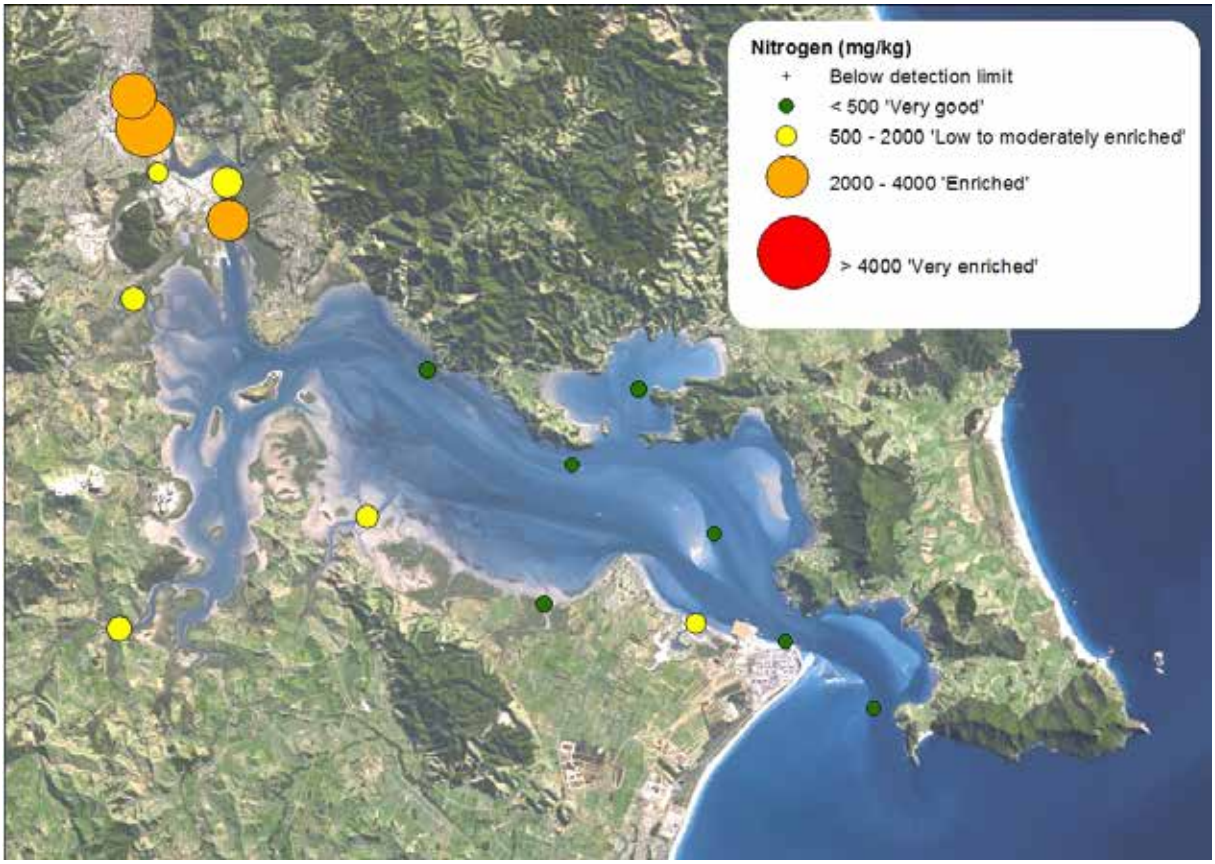

Figure 17. Sediment nitrogen concentrations in the Whāngārei Harbour in 2014.

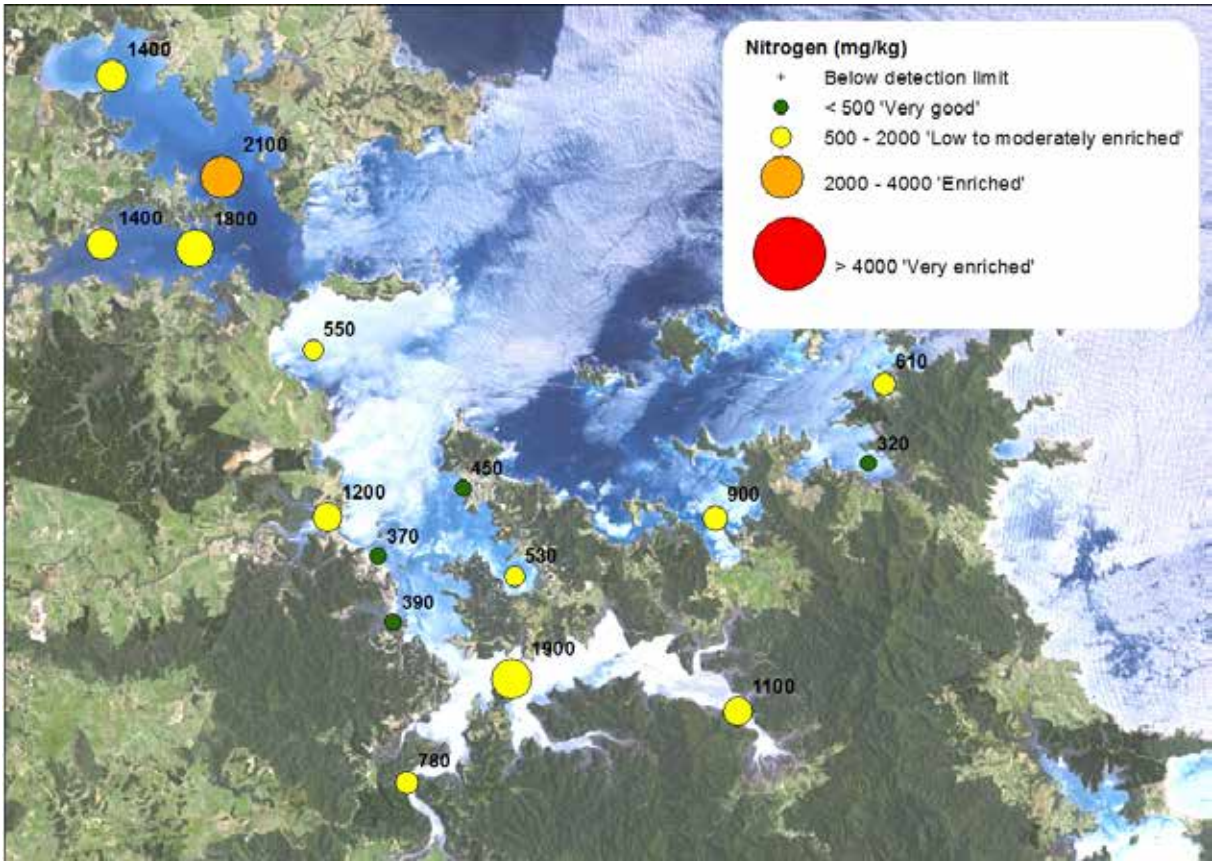

Figure 18. Sediment nitrogen concentrations in the Bay of Islands in 2014.

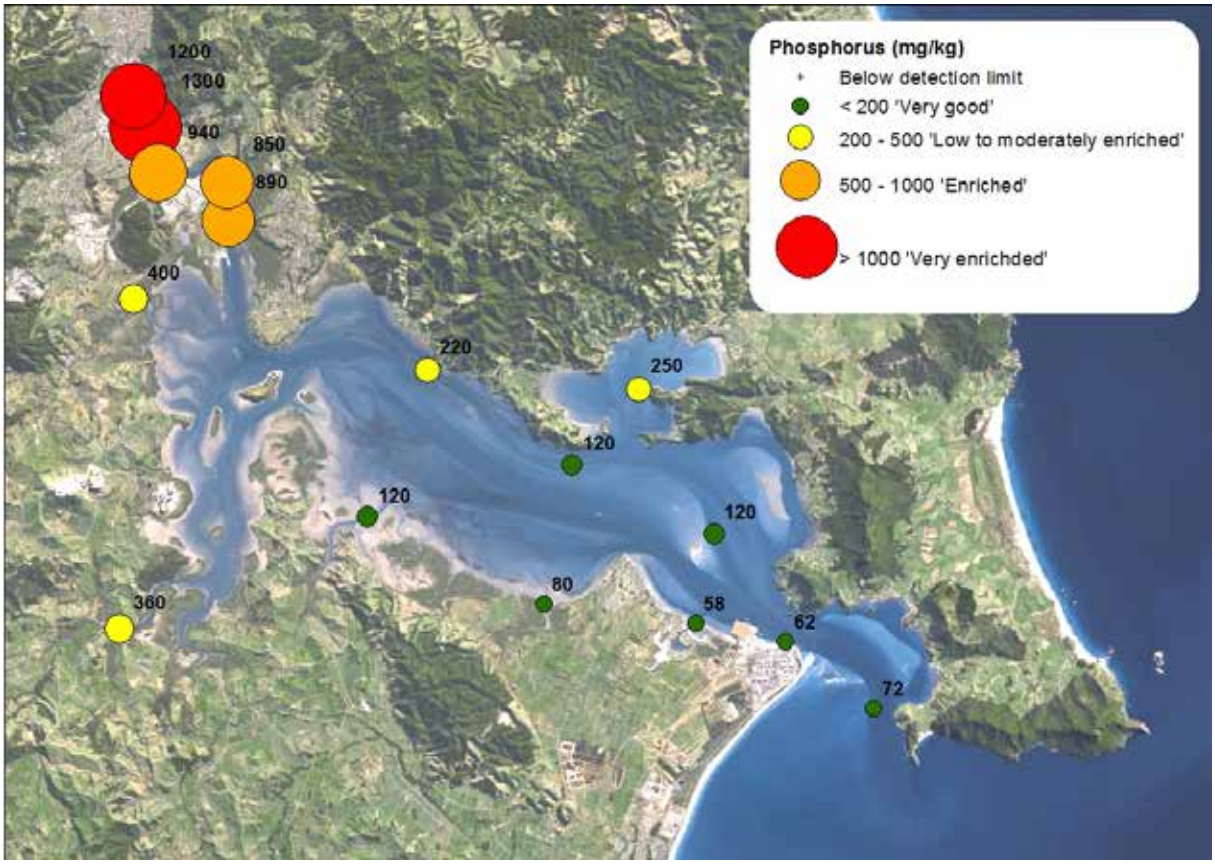

Figure 19. Sediment phosphorus concentrations in the Whāngārei Harbour in 2014.

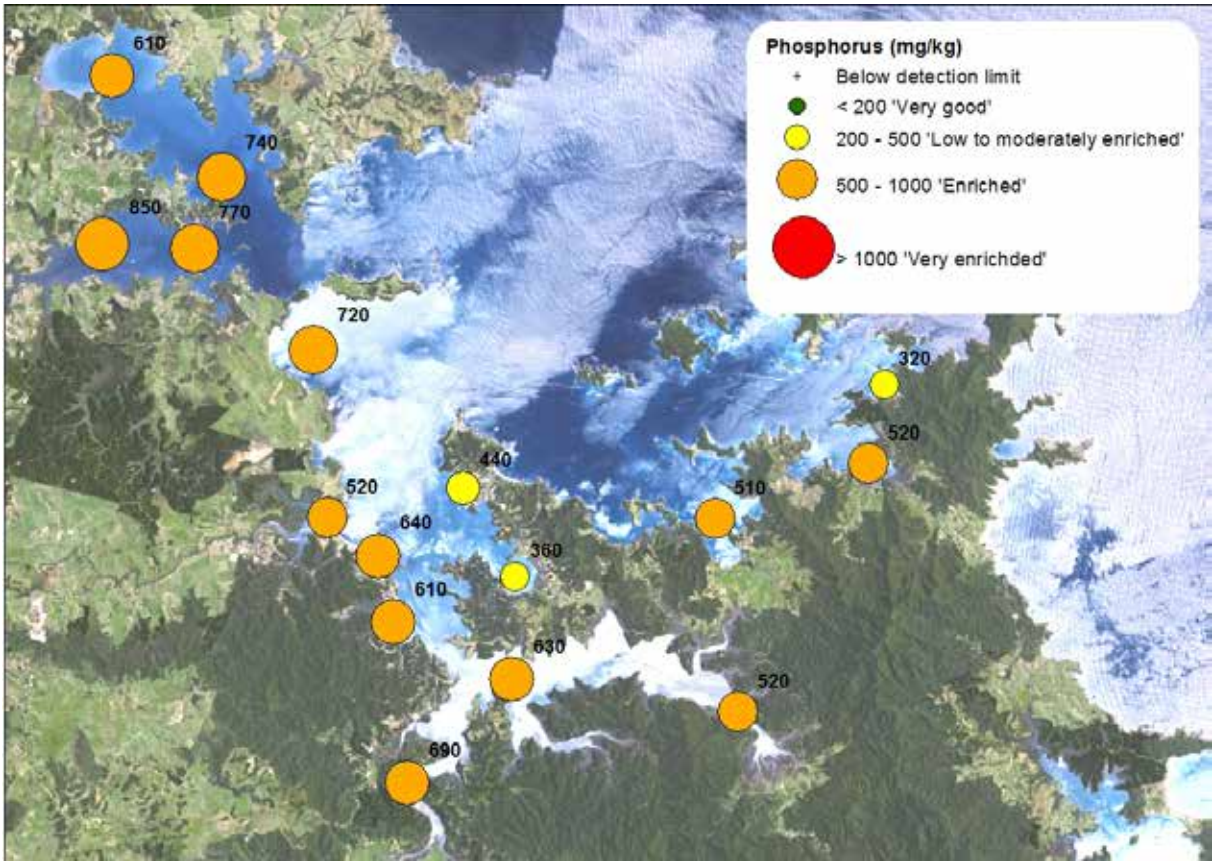

Figure 20. Sediment phosphorus concentrations in the Bay of Islands in 2014.

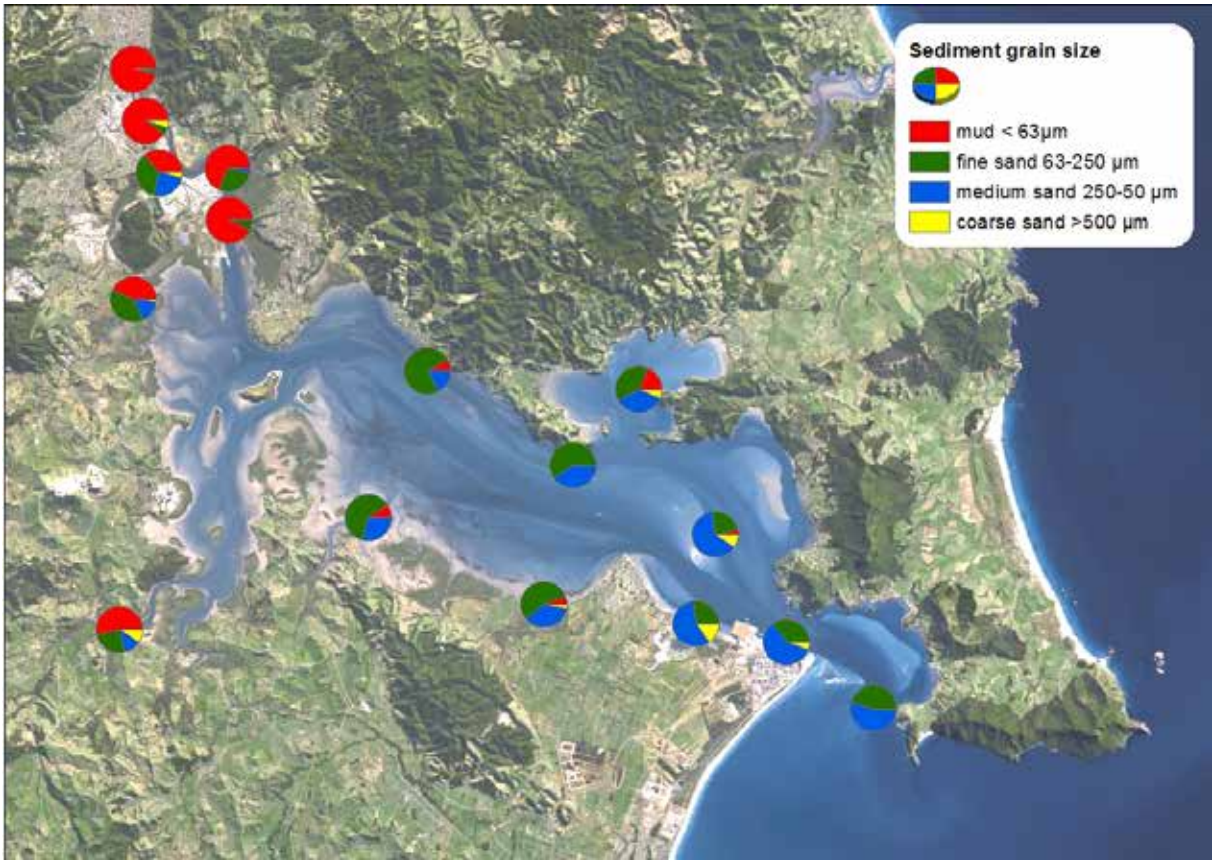

Figure 21. Sediment grain size characteristics in the Whāngārei Harbour in 2014.

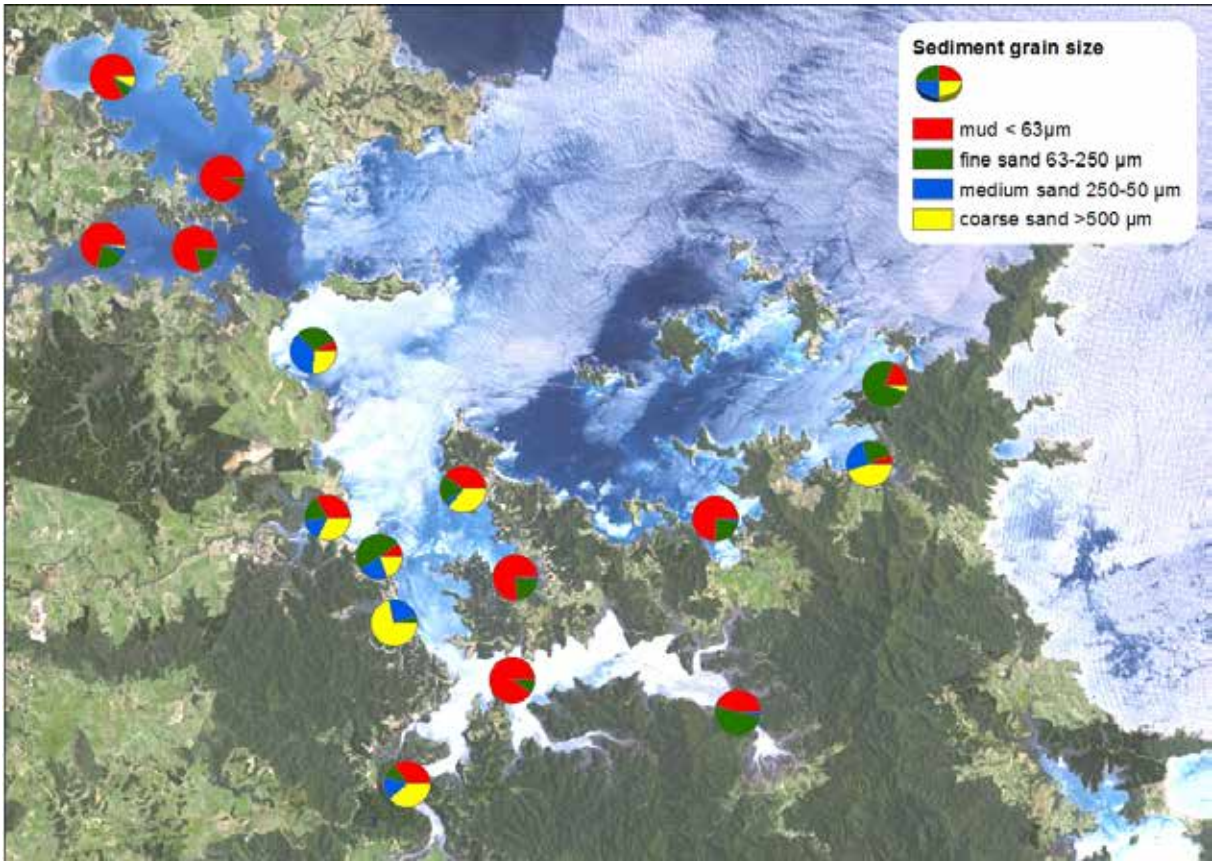

Figure 22. Sediment grain size characteristics in the Bay of Islands in 2014.

3.11 Trends over time for Metal Concentrations

A key aim of council's sediment monitoring programme is to identify changes in contaminant concentration over time. However the time series is relatively short (4 years) and there are only three data points, so no formal statistical trend analysis was conducted. It is likely that at least another couple of sampling events will be required before meaningful statistical analysis can be conducted. As nickel, nitrogen phosphorus and TOC were only sampled in 2012 and 2014 more time may be required to identify meaningful trends for these parameters.

Whāngārei Harbour

Concentrations of metals were relatively stable at most sites in Whāngārei Harbour (Table 3). The main exceptions to this were large decreases in concentrations of copper, lead and zinc at Otaika Creek and decreases in concentrations of chromium and zinc at Tamaterau.

Overall the contaminant status has deteriorated slightly since 2010 with four samples exceeding ANZECC ISQG-Low trigger values compared to one in 2010 and two in 2012 (Table 3). The contaminant status for copper and zinc in the Upper Hātea River had deteriorated, and the contaminant status of the Waiharohia Canal has deteriorated for copper, with all of these concentrations exceeding ANZECC ISQG-Low in 2014. Meanwhile the contaminant status for both copper and zinc in the Otaika Creek improved. In 2010, the concentrations of both copper and zinc exceeded the threshold effect level but in 2012 and 2014 concentrations were below the threshold effect level.

Concentrations of TOC and nutrients were more variable over the two years of sampling (2012 & 2014) than concentrations of metals (Table 4). One noticeable observation was a decrease in the concentrations of nitrogen and phosphorus at Limeburners Creek which is the receiving environment for wastewater treatment. Field observations show that it was difficult to collect a grab sample at this site because of the large quantities of calcareous cases from tube worms, which caused problems with the grab closing fully.

Levels of TOC tended to increase between 2012 and 2014 at sites in the Hātea River but decreased at sites towards the harbour entrance (Marsden Bay, Marsden Point, Snake Bank, Takahiwai Creek). The nutrient enrichment status of five sites deteriorated, five sites improved and six sites were unchanged, but significantly in 2014 five sites were classified as enriched compared to just one site in 2012 (Table 4).

Large increases of nitrogen were observed at four sites (Upper Hātea River, Waiharohia Canal, Waimahanga Creek, and Mangawhati Point) and a large decrease in the concentration of nitrogen was found in Limeburners Creek (Table 4). The nutrient enrichment status of five sites deteriorated, two sites improved and nine sites remained the same. Significantly in 2014 no sites were classified as 'very enriched' due to an improvement in the status of Limeburners Creek, which was classified as 'low to moderately enriched in 2014. Meanwhile there was a deterioration in the status at Upper Hātea River, Waiharohia Canal and Lower Hātea River from 'low to moderately enriched' in 2012 to 'enriched' in 2014.

Large increases in phosphorus were found at the Upper Hātea River, Waiharohia Canal, Lower Hātea River and Tamaterau while a decrease was observed at Limeburner's Creek. The enrichment status of three sites deteriorated, one improved and twelve were unchanged (Table 4).

There was also quite a lot of variability in the proportion of mud at sites in the Hātea River and at Mangapai River. At the Lower Hātea River and Mangapai River sites there was an increase in the proportion of mud between 2010 and 2014 but at the Upper Hātea River, Waiharohia Canal and

Kissing Point there was a decrease in 2012 followed by a rebound in 2014. Meanwhile at Limeburners Creek there was an increase in 2012 followed by a decrease in 2014.

Bay of Islands

Concentrations of metals were relatively stable throughout the Bay of Islands and the contaminant status of sediment in the Bay of Islands has remained the same with all metal concentrations below ANZECC ISQG-Low at all sites in 2014, 2012 and 2010 (Table 5).

Concentrations of TOC and nutrients were more variable over the two years of sampling (2012 & 2014) than concentrations of metals (Table 6). Large increases in the concentrations of nitrogen were found at Lower Waikare Inlet, Te Puna Inlet and Waitangi while large decreases were found at the Kawakawa River. The enrichment status of two sites deteriorated, one site improved and thirteen sites were unchanged.

Phosphorus concentrations decreased at 13 of the 16 sites with large decreases observed at Wainui Island, Upper Waikare, Russell, Kaingahoa Bay and Onewhero Bay (Table 6). Despite the decreases observed at most sites the nutrient status only improved at two sites, with fourteen sites unchanged.

A large decrease (> 1%) was observed in the level of TOC between 2012 and 2014 at Kawakawa River. In both 2012 and 2014 the same eight sites were classified as 'enriched' and the same eight sites 'low to moderately enriched (Table 6).

There was less variability in the proportion of mud at sites in the Bay of Islands compared to Whāngārei. The main exceptions to this were at Wainui Island and Oronga Bay where there was a decrease in 2012 followed by a rebound in 2014.

Table 3. Metal concentrations (mg/kg) of sediment in the Whāngārei Harbour.

2014

	Cadmium	Chromium	Copper	Lead	Nickel	Zinc
Upper Hātea River	0.17	28	65	31	14	220
Waiharohia Canal	0.16	24	67	39	14	290
Limeburners Creek	0.16	10	14	10	4.5	100
Kissing Point	<0.09	21	30	18	11	120
Lower Hātea River	<0.09	22	32	18	12	110
Otaika Creek	0.096	11	8.5	7	6.8	57
Mangapai River	<0.088	8.1	8.1	7	6.5	31
Mangawhati Point	<0.09	7	1.7	1.7	2.1	13
Tamaterau	<0.089	11	3.3	3.7	3.5	26
Manganese Point	<0.089	8.4	0.54	1.7	2	13
Takahiwai Creek	<0.090	4	0.6	0.77	1.1	<6.8
Parua Bay	<0.091	13	3.5	4	4.4	25
Snake Bank	<0.089	5.7	0.46	1.3	1.4	8.2
Marsden Bay	<0.09	3.8	0.5	0.66	1	<6.7
Home Point	<0.089	4.9	<0.45	0.7	1.1	<6.7
Marsden Point	<0.089	4.1	<0.45	0.66	1	<6.7

2012

	Cadmium	Chromium	Copper	Lead	Nickel	Zinc
Upper Hātea River	0.16	27	38	39	14	160
Waiharohia Canal	0.16	31	79	51	16	150
Limeburners Creek	<0.1	15	26	17	8.6	110
Kissing Point	<0.1	17	19	18	9.5	110
Lower Hātea River	0.11	16	16	20	7.3	73
Otaika Creek	<0.1	9.4	6.8	6.4	4.7	52
Mangapai River	<0.1	7.6	8.5	8.4	5	38
Mangawhati Point	<0.1	3.8	<0.5	0.66	0.93	<7.5
Tamaterau	<0.1	8.6	2.3	2.5	2.7	18
Manganese Point	<0.1	7.3	0.71	1.9	2	14
Takahiwai Creek	<0.1	2.4	<0.5	0.62	0.88	<7.5
Parua Bay	<0.1	11	3.2	3.9	3.9	22
Snake Bank	<0.1	4.4	<0.5	1.1	1.1	<7.5
Marsden Bay	<0.1	2.7	<0.5	0.53	0.83	<7.5
Home Point	<0.1	4.5	<0.5	0.67	1	<7.5
Marsden Point	<0.1	5.8	<0.5	1	1.2	<7.5

2010

	Cadmium	Chromium	Copper	Lead	Nickel	Zinc
Upper Hātea River	0.15	30	42	27	Not measured	168
Waiharohia Canal	0.57	27	54	38	Not measured	210
Limeburners Creek	0.09	11.7	7.7	7.1	Not measured	49
Kissing Point	0.11	22	27	26	Not measured	109
Lower Hātea River	0.2	17	16.4	15.5	Not measured	86
Otaika Creek	0.16	16.4	29	19.5	Not measured	139
Mangapai River	0.05	8.1	8.2	7.3	Not measured	35
Mangawhati Point	0.01	6.9	1	1.5	Not measured	10.6
Tamaterau	0.02	21	6.4	6	Not measured	45
Manganese Point	<0.01	8.9	1.6	2.7	Not measured	15.8
Takahiwai Creek	0.01	4.7	0.5	0.87	Not measured	7.5
Parua Bay	0.02	17.7	3.7	5.4	Not measured	39
Snake Bank	<0.01	7.1	0.6	1.58	Not measured	9.2
Marsden Bay	0.02	7.2	0.9	1.34	Not measured	10.3
Home Point	<0.01	3.4	<0.2	0.53	Not measured	4.4
Marsden Point	<0.01	6.1	0.3	0.9	Not measured	7.3

Green = below TEL, Orange = exceeded TEL, Red = exceeded ANZECC ISQG-Low effect trigger values.

Table 4. Nutrient concentrations of sediment in the Whāngārei Harbour

2014

	TOC (%w/w)	Nitrogen(mg/kg)	Phosphorus (mg/kg)
Upper Hātea River	4.93	2400	1200
Waiharohia Canal	4.03	3400	1300
Limeburners Creek	2.36	600	940
Kissing Point	3.36	1400	850
Lower Hātea River	3.80	2000	890
Otaika Creek	1.06	910	400
Mangapai River	0.97	1000	360
Mangawhati Point	0.65	760	120
Tamaterau	0.93	410	220
Manganese Point	0.32	30	120
Takahiwai Creek	0.56	470	80
Parua Bay	1.02	470	250
Snake Bank	0.52	160	120
Marsden Bay	0.32	560	58
Home Point	0.32	20	72
Marsden Point	0.24	33	62

2012

	TOC (%w/w)	Nitrogen(mg/kg)	Phosphorus (mg/kg)
Upper Hātea River	1.22	500	950
Waiharohia Canal	1.81	450	780
Limeburners Creek	1.22	4900	1200
Kissing Point	1.35	1200	580
Lower Hātea River	4.79	1400	920
Otaika Creek	0.73	860	380
Mangapai River	1.60	1300	430
Mangawhati Point	0.97	100	50
Tamaterau	0.52	540	120
Manganese Point	0.32	87	140
Takahiwai Creek	2.02	320	83
Parua Bay	1.31	460	230
Snake Bank	1.68	190	83
Marsden Bay	1.47	140	54
Home Point	0.52	14	59
Marsden Point	1.31	110	75

Green = ‘very good’, Yellow = ‘low to moderate enrichment’, Orange = ‘enriched’, Red = ‘very enriched’

Table 5. Metal concentrations (mg/kg) of sediment in the Bay of Islands.

2014

	Cadmium	Chromium	Copper	Lead	Nickel	Zinc
Wainui Island	0.098	39	14	7.2	14	59
Doves Bay	<0.087	35	12	8.9	15	50
Te Puna Entrance	<0.091	31	11	10	13	48
Dead Whale Reef	<0.09	24	8.8	12	8.6	42
Kawakawa River	<0.091	13	15	13	9	86
Lower Waikare	<0.089	17	13	12	8	62
Upper Waikare	<0.09	15	9.7	12	7.5	63
Te Haumi River	<0.09	5	3.8	5.3	3.2	29
Paihia	<0.091	9.4	3.6	5.3	4.3	38
Waitangi River	<0.088	12	10	7	7.1	43
Oronga Bay	<0.09	15	6	6.8	4.3	43
Russell	<0.09	7.4	6.6	9.5	4	33
Manawaora Bay	<0.091	15	3.9	5.9	4.5	31
Parekura Bay	<0.089	12	4	6.7	4.2	48
Kaingahoa Bay	<0.09	10	2.5	3.2	2.8	20
Onewhero Bay	<0.09	10	1.7	4.1	6	14

2012

	Cadmium	Chromium	Copper	Lead	Nickel	Zinc
Wainui Island	<0.09	42	15	8.3	Not measured	64
Doves Bay	<0.09	38	13	11	Not measured	51
Te Puna Entrance	<0.09	31	10	12	Not measured	50
Dead Whale Reef	<0.089	24	8	13	Not measured	42
Kawakawa River	<0.09	16	17	13	Not measured	69
Lower Waikare	<0.09	17	13	13	Not measured	60
Upper Waikare	<0.09	16	9.6	16	Not measured	71
Te Haumi River	<0.089	8.4	7.3	10	Not measured	47
Paihia	<0.089	11	6.9	7.2	Not measured	42
Waitangi River	0.099	12	13	7.8	Not measured	50
Oronga Bay	<0.089	16	6.2	8.2	Not measured	46
Russell	<0.091	15	10	17	Not measured	56
Manawaora Bay	<0.09	17	3.9	6.7	Not measured	33
Parekura Bay	<0.091	15	3.8	7.7	Not measured	58
Kaingahoa Bay	<0.089	12	2.7	3.9	Not measured	23
Onewhero Bay	0.09	16	1.6	5.7	Not measured	17

2010

	Cadmium	Chromium	Copper	Lead	Nickel	Zinc
Wainui Island	0.05	47	15.1	10.3	Not measured	59
Doves Bay	0.05	40	12.9	10.6	Not measured	47
Te Puna Entrance	0.04	32	10.1	11.2	Not measured	45
Dead Whale Reef	0.03	27	8.6	13.4	Not measured	43
Kawakawa River	0.06	14.6	13.8	13	Not measured	82
Lower Waikare	0.03	19.6	13.3	13.8	Not measured	61
Upper Waikare	0.03	15.8	10.3	11.6	Not measured	55
Te Haumi River	0.02	8.9	5.1	7.7	Not measured	42
Paihia	0.03	9.6	2.7	5.7	Not measured	32
Waitangi River	0.13	9.5	6.3	6.1	Not measured	46
Oronga Bay	0.02	14.2	5	7.1	Not measured	42
Russell	0.03	12.5	7.9	13.7	Not measured	40
Manawaora Bay	0.03	14.9	3.2	6.2	Not measured	28
Parekura Bay	0.02	13.3	5.6	6.9	Not measured	41
Kaingahoa Bay	0.04	11.3	2.4	3.7	Not measured	19.8
Onewhero Bay	0.06	14.2	1.2	5.1	Not measured	12.7

Green = below TEL, Orange = exceeded TEL, Red = exceeded ANZECC ISQG-Low effect trigger values

Table 6. Nutrient concentrations of sediment in the Bay of Islands

2014

	TOC (%w/w)	Nitrogen(mg/kg)	Phosphorus (mg/kg)
Wainui Island	4.16	1400	850
Doves Bay	4.75	1800	770
Te Puna Entrance	4.61	2100	740
Dead Whale Reef	2.75	1400	610
Kawakawa River	2.15	780	690
Lower Waikare	3.10	1900	630
Upper Waikare	2.49	1100	520
Te Haumi River	1.56	390	610
Paihia	1.22	370	640
Waitangi River	1.77	1200	520
Oronga Bay	1.06	530	360
Russell	1.64	450	440
Manawaora Bay	2.32	900	510
Parekura Bay	1.26	320	520
Kaingahoa Bay	1.22	610	320
Onewhero Bay	1.64	550	720

2012

	TOC (%w/w)	Nitrogen(mg/kg)	Phosphorus (mg/kg)
Wainui Island	4.43	1300	950
Doves Bay	4.84	1600	800
Te Puna Entrance	4.34	1600	730
Dead Whale Reef	2.92	1200	570
Kawakawa River	3.36	1300	730
Lower Waikare	3.10	1300	630
Upper Waikare	2.79	1000	650
Te Haumi River	1.02	260	660
Paihia	1.94	480	650
Waitangi River	1.47	530	530
Oronga Bay	1.64	930	370
Russell	1.02	890	730
Manawaora Bay	2.06	770	520
Parekura Bay	1.35	360	530
Kaingahoa Bay	1.47	710	420
Onewhero Bay	1.31	400	1000

Green = ‘very good’, Yellow = ‘low to moderate enrichment’, Orange = ‘enriched’, Red = ‘very enriched’

4 Discussion

4.1 Sediment Metal Concentrations

Metal concentrations at four sites in the Hātea River, in the Whāngārei Harbour, are at levels which have the potential to cause adverse effects on marine ecosystems. Concentrations of copper and zinc exceeded ANZECC ISQG-Low effect trigger values at the Upper Hātea River and the Waiharohia Canal and concentrations of lead exceeded the threshold effects level developed by MacDonald *et al*. (1996). In addition concentrations of copper at Kissing Point and at the Lower Hātea River exceeded the threshold effects level. Council's surveys in 2010 and 2012 (Northland Regional Council 2011, Griffiths 2012) also found high levels of metal contaminants in the Hātea River and previous studies have reported elevated concentrations of metals in the sediment at the Upper Hātea River and the Waiharohia Canal (Venus 1984, Northland Regional Council 1990, Webster *et al.* 2000, Northland Regional Council 2003 and Griffiths 2011a).

The Hātea River, flows through the city of Whāngārei, the main urban centre in Northland, where the majority of the urban and industrial development in the catchment is centred. Road runoff, stormwater discharges, industrial discharges and leachates from landfills are all possible sources of metal contamination. The high concentrations of metals in the Hātea River are also consistent with these sites being located in depositional tidal creek environments, where there is a high proportion of mud. Sediment grain size is an important factor which influences the concentrations of heavy metals in estuarine sediments (Abrahim *et al.* 2007). Heavy metal absorption tends to increase as sediment grain size decreases, which reflects the tendency for heavy metals to be preferentially absorbed on the large surface area of fine grained sediments rich in clay minerals (Abrahim *et al.* 2007).

Interestingly, relatively low concentrations of metal contaminants were found at Limeburners Creek, which is encouraging given that the Whāngārei wastewater treatment plant discharges into this catchment. Beyond the Hātea River, concentrations of metals were below ANZECC ISQG-Low effect trigger values and the threshold effect levels in 2014. Concentrations of metals tended to decrease towards the entrance of the harbour.

In the Bay of Islands all of the metal concentrations measured were below the ANZECC ISQG-Low effect trigger values (Australian New Zealand Environment Conservation Council 2000) and the threshold effect levels developed by MacDonald *et al*. (1996) in all three years (2010, 2012 and 2014). The highest concentrations of copper, lead and zinc tended to be found at the Kawakawa River and the Upper Waikare Inlet and the highest concentrations of chromium and nickel were found at the two sites in the Kerikeri Inlet (Wainui Island and Doves Bay). Sediment monitoring conducted as part of the council's Estuary Monitoring Programme has also found elevated concentrations of chromium and nickel at sites located in the Kerikeri Inlet (Griffiths 2011b). The lowest concentrations of zinc, copper and lead were generally found at Kaingahoa Bay and Onewhero Bay in all three years, with the lowest levels of chromium found at Te Haumi River.

Comparisons with surveys conducted by council in 2010 and 2012 indicate that metal concentrations have remained relatively stable at most sites. The main exceptions to this were large decreases observed in concentrations of copper, lead and zinc at Otaika Creek and decreases in the concentrations of chromium and zinc at Tamaterau.

4.2 Sediment TOC and Nutrient Concentrations

The nutrient concentrations recorded in this study indicate that a number of sites in the Bay of Islands and the Hātea River, in Whāngārei Harbour, were 'enriched' using criteria developed by Robertson and Stevens (2007). In Whāngārei Harbour, the Upper Hātea River and the Waiharohia Canal were classified as 'very enriched' for phosphorus, and 'enriched' for both nitrogen and TOC. The Lower Hātea River was also classified as 'enriched' for nitrogen, phosphorus and TOC, while the Limeburners Creek and below Kissing Point were 'enriched' for phosphorus and TOC. The main sources of nutrients to the Hātea River are likely to be discharges from the waste treatment plant, seepage from the wastewater network, discharges from boats, industrial discharges and stormwater.

In the Bay of Islands, thirteen sites were classified as 'enriched' for phosphorus, eight sites for TOC and one site for nitrogen. The potential sources of nutrients to the Bay of Islands include discharges from wastewater treatment plants, seepage from the wastewater network, septic tanks, discharges from boats, industrial discharges, runoff from agricultural land and discharges from farm dairy effluent systems.

Nutrients have only been measured on two sampling occasions (in 2012 and 2014) but much higher variability was observed compared to concentrations of metal contaminants. In Whāngārei there were noticeable decreases in the nitrogen and phosphorus concentration at Limeburners Creek, which is the receiving environment for discharges from the Whāngārei wastewater treatment plant. Field observations indicated that the sediment collected in Limeburners Creek in 2014 contained a lot of calcareous worm tube cases which made it difficult to collect a sample with the grab. It is possible that fine sediment escaped from the grab sample which may have affected the nutrient concentrations.

5 Acknowledgements

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Appendix 1

Whāngārei Harbour site co-ordinates

Site ID	Site name	X	Y
110087	Upper Hātea River	1719787	6046046
110088	Waiharohia Canal	1720058	6045305
110089	Limeburners Creek	1720386	6044261
110090	Kissing Point	1722003	6044028
110091	Lower Hātea River	1722034	6043143
110092	Otaika Creek	1719777	6041276
110093	Mangapai River	1719456	6033503
110094	Mangawhati Point	1725310	6036143
110095	Tamaterau	1726715	6039595
110096	Manganese Point	1730134	6037371
110097	Takahiwai Creek	1729451	6034096
110098	Parua Bay	1731692	6039152
110099	Snake Bank	1733480	6035744
110100	Marsden Bay	1733033	6033638
110101	Home Point	1737224	6031642
110102	Marsden Refinery	1735163	6033209

Bay of Islands site co-ordinates

Site ID	Site name	X	Y
110071	Wainui Is	1691353	6104383
110072	Doves Bay	1694063	6104274
110073	Te Puna entrance	1694858	6106356
110074	Dead Whale Reef	1691625	6109335
110075	Kawakawa River	1700310	6088551
110076	Lower Waikare	1703397	6091598
110077	Upper Waikare	1710058	6090643
110078	Te Haumi River	1699922	6093272
110079	Paihia	1699476	6095228
110080	Waitangi River	1697958	6096369
110081	Oronga Bay	1703499	6094615
110082	Russell	1701959	6097208
110083	Manawaora Bay	1709386	6096336
110084	Parekura Bay	1713920	6097953
110085	Kaingahoa Bay	1714378	6100278
110086	Onewhero Bay	1697547	6101273

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