

Far North Harbours Water and Sediment Quality Investigation



Picture: Whangaroa Harbour sunset, NRC

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Executive Summary

The catchments of the Far North harbours are relatively undeveloped and little is known about their water nutrient characteristics. Following studies conducted in 1998-1999 and 2004, monitoring of seven Far North harbours was undertaken in 2013 to assess water and sediment quality. Each harbour had unique factors which affected freshwater inputs, sedimentation and natural baseline values. As the Far North harbours are undeveloped the factors determining harbour health are more from natural processes rather than anthropogenic activity. In each harbour several sites were selected based on those sites selected in the 2004 study. Over a period of three months seven harbours were monitored with samples being collected largely by boat with a range of water and sediment samples being taken. Samples were sent to Whangarei District Council laboratory, Water Care and Waikato University services for analysis. The main issues we examined in the 2013 study were sediment and nutrient enrichment and microbial contamination (which were the same issues looked at in the 2004 study).

Physical water clarity was good with only Hokianga Harbour having multiple readings exceeding the trigger value for turbidity. Water clarity is an important indicator of an environments ability to support aquatic life. Nutrient levels were within trigger values for most harbours with the exception of dissolved reactive phosphorus which exceeded the trigger value at most sites in all harbours. Generally in saline conditions nitrogen is the main limiting nutrient for primary production and phosphorus limitations are important at certain times of the year for primary producers. From that information it has been noted that nitrogen and phosphorus levels in estuaries should be monitored (Rees 2009). Micro bacteria readings were very low across all harbours with a large number of sites returning values below the minimum detection level. High levels of micro bacteria can indicate contamination in an environment of sewerage, rotting vegetation and animal waste; these can all adversely affect the marine environment causing unsafe swimming conditions and contamination of shellfish. During our sampling period rainfall was generally low with little to no rainfall on sampling days. This is likely to have affected the freshwater inputs and therefore sediment loading, nutrient enrichment and microbial contamination.

Generally nutrients from the 2013 study had lower median levels than those values from 2004. Hokianga Harbour had the most readings outside of the trigger values in 2013 and 2004 but the harbour also had the highest rainfall and highest percentage of mud in the 2013 study. As this study was only completed once we have a narrow data range in terms of repeated sampling. These results could be due to the low rainfall levels we saw during our time of sampling which contrasts to the higher rainfall levels seen in the 2004 study.

Parengarenga Harbour

This harbour was spilt into two sections for sampling (Northern and Southern arms). A total of twelve sites were sampled in the Northern arm and ten sites in the Southern arm. Rainfall was limited prior to sampling and salinity was high at time of sampling. Values for dissolved oxygen, turbidity, micro bacteria, chlorophyll a and total phosphorus were within the trigger values in both sections of the harbour. Values for ammonium and total nitrogen had all values within the trigger value for Parengarenga North and Parengarenga South had 90% of sites within the trigger values. Nitrite-nitrate nitrogen had 91% of sites within trigger values in Parengarenga North and all sites within the trigger value for Parengarenga South. Dissolved reactive phosphorus was the only nutrient with multiple sites exceeding the trigger value. The majority of sediment sites were classed as 'very good' (using the classification by Roberston and Stevens 2007) for total phosphorus and total nitrogen with only one site in the Northern arm reaching a value of enriched for total organic carbon.

Houhora Harbour

A total of seven sites were sampled. Rainfall was limited and salinity was high at time of sampling. Water values for dissolved oxygen, turbidity, micro bacteria, chlorophyll a and total nitrogen were within the trigger values for all sites. One site in the upper harbour was outside of the trigger value for ammonium and three sites were outside the trigger value for nitrite-nitrate nitrogen. Two sites were outside of the trigger value for total phosphorus. Sediment nutrients were largely classed as 'low to moderately enriched' with no values exceeding this rating.

Rangaunu Harbour

A total of ten sites were sampled. Rainfall was limited and salinity was high at time of sampling. Water nutrient samples in Rangaunu Harbour were not reported as they were not sent to an ISO accredited laboratory. Physical parameters returned results with all sites within trigger values for dissolved oxygen and only one site exceeding the trigger value for turbidity. For sediment values the majority of sites were classed as 'very good' and a few classed as 'low to moderately enriched' for total phosphorus and total nitrogen. One site was rated as 'enriched' for total organic carbon in the upper harbour.

Taipa River/ Mangonui Harbour

Two sites were sampled from Taipa River and four sites from Mangonui Harbour. Rainfall was limited at the time of sampling and salinity was high. For all sites values for dissolved oxygen, turbidity, micro bacteria, chlorophyll a nitrite-nitrate nitrogen, total phosphorus and total nitrogen had values within the trigger values. Dissolved reactive phosphorus however exceeded the trigger value for all sites. Ammonium had two sites in the upper Mangonui Harbour exceeding the trigger value. For sediment nutrients, half of the sites sampled were 'low to moderately enriched' for total phosphorus and total organic carbon while the other half were rated as 'enriched'. The majority of samples of total nitrogen were rated as 'very good' with one site rated as 'low to moderately enriched'.

Whangaroa Harbour

A total of eight sites were sampled. Rainfall was limited at the time of sampling and salinity was high. For all sites values for dissolved oxygen, turbidity, micro bacteria, chlorophyll a nitrite-nitrate nitrogen, total phosphorus and total nitrogen had all values within the trigger values. Dissolved reactive phosphorus however had all sites except one, at the harbour entrance, exceeding the trigger value. Ammonium had three sites exceeding the trigger value. For sediment nutrients, total nitrogen had four sites rated as 'low to moderately enriched' and three sites rated as 'very good'. Total phosphorus had three sites rated as 'enriched' and four sites rated as 'low to moderately enriched'. Total organic carbon had five sites rated as 'enriched', one site rated as 'very enriched' and one site rated as 'low to moderately enriched'.

Hokianga Harbour

A total of eleven sites were sampled. Hokianga had the highest rainfall in the 30 days preceding sampling and on the day of sampling. For all sites values for dissolved oxygen, micro bacteria, ammonium, nitrite-nitrate nitrogen and total phosphorus had values within the trigger values. Turbidity had all sites exceeding the trigger value except those near to the harbour entrance. Chlorophyll a also had nine sites exceeding the trigger value. Total nitrogen had one site exceeding the trigger value. Dissolved reactive phosphorus had all sites exceeding the trigger value. For sediment nutrients Hokianga Harbour had the highest readings overall of total phosphorus, total nitrogen and total phosphorus with the majority of sites being rated as 'enriched' for total phosphorus and total nitrogen. In terms of grain size profiles Hokianga

showed a definite spatial pattern with grains closer to the harbour entrance having a lower percentage of mud in the profile. This may also explain some of the nutrient results as nutrients bind to smaller particles such as mud more readily.

Whangape Harbour

Two sites were sampled in Whangape Harbour. Whangape had high rainfall in the 30 days preceding sampling. Values for dissolved oxygen, micro-bacteria, chlorophyll a, total nitrogen and total phosphorus were all within the trigger values. Values for ammonium and nitrite-nitrate nitrogen had one site exceeding the trigger value and one site within the trigger value. Turbidity and dissolved reactive phosphorus levels both exceeded the trigger values.

1 Introduction

1.1 Background

The Northland region contains 12 harbours, three of which are routinely monitored. Following previous studies, conducted in 1998-1999 and 2004, monitoring of seven Far North harbours was undertaken to assess water and sediment quality in these relatively undeveloped harbours. The environmental stressor's affecting each harbour will differ depending on surrounding land use type and tributaries. These stressors may arise from more natural processes rather than human activity as in the more developed harbour of Whangarei. This report aims to assess the current water and sediment quality in the Parengarenga, Houhora, Rangaunu, Taipa/Mangonui, Whangaroa, Hokianga and Whangape harbours. It also aims to draw comparison of the previous investigations and compare 'contaminant' levels between harbours studied.

Table 1. Examples of contaminants, sources and adverse environmental effects.

	Examples of sources			Adverse Effects		
Sediments	Natural weathering	Earthworks	Forest harvesting	Reduced water clarity	Habitat changes	Smothering
Nutrients	Animal waste discharge	Fertilisers	Waste water discharges	Algal blooms	Habitat changes	Excessive plant growth (i.e. mangroves)
Microbial	Animal waste discharge	Failing sewerage treatment devices	Sewerage discharge from boats	Aquaculture	Recreational health use	Shellfish gathering

1.2 Location Descriptions

Parengarenga Harbour

Parengarenga Harbour covers 6,500 ha, is a drowned river valley and is the most northern harbour of New Zealand. The harbour entrance is characterised by the large expanse of silica sand dunes which have been dredged and used in a variety of industries (Pritchard 1995 in Morrison 2005). The harbour is 90% intertidal and is surrounded by farmland, scrubland and forest. Ten per cent (10%) of the harbour is covered in mangroves which occupy the upper tidal arms (Morrison 2005). The water clarity of the harbour suggests that it is relatively unpolluted or affected by sedimentation as are other harbours (Morrison 2005). The harbour supports a wide range of invertebrates, sub tropical fish and migratory birds. It contains large expanses of sea grass which provides a valuable habitat for fish and invertebrates (Morrison 2005). GIS catchment analysis using the land use classification from the New Zealand Land Cover Database (LCDB2) indicated that in 2001, 33% (7647 ha) of the catchment was covered by high producing exotic grassland for cattle and dairy farming, 32% (7285 ha) was Manuka and Kanuka scrubland, 18% (4141 ha) was pine forest, 7% (1513 ha) harvested forests and 5% (1054 ha) coastal sand and gravel.

Houhora Harbour

Houhora Harbour is 1430 ha and is 8.5km long with a narrow channel extending up the harbour (Morrison 2005). At the harbour entrance is Mt Carmel which shelters a large part of the harbour.

It is noted that sea grass beds are extensive at the top end of the harbour. Erosion of the surrounding cliffs above residential areas is present and may contribute to sedimentation (Morrison 2005) decreasing water quality. The harbour provides habitat to many invertebrates with large banks of pipi and cockles as well as being home to many migratory birds (Morrison 2005). GIS catchment analysis using the land use classification from the New Zealand Land Cover Database (LCDB2) indicated that in 2001, 42% (3650 ha) of the catchment was covered by high producing exotic grassland for cattle and dairy farming, 24% (2064 ha) was indigenous forest, 19% (1625 ha) was pine forest, 5% (437 ha) was Manuka and Kanuka scrub forest and 3% (244 ha) harvested forest. A further 3% (243 ha) was low producing grassland and 2% (133 ha) broadleaved indigenous hardwoods.

Rangaunu Harbour

Rangaunu Harbour covers 11488 ha and is the fifth largest estuary in New Zealand (Morrison 2005). Fifty-three (53%) of the harbour is intertidal flats; the harbour has relatively low sediment and fresh water inputs and is known for its clear waters. The harbour is mainly sand and gravel through the main channels (Rangaunu Sediment Map 1986 in Morrison 2005). Salt marshes cover 300 ha and large areas of swamp have been reclaimed. Mangroves in the upper harbour are considered to be the largest mangrove forest in New Zealand and cover 30% of the intertidal area (Morrison 2005). Large extensive sea grass beds cover 27% of the intertidal area and extend into shallow subtidal areas. Mangroves increased 33% from 1944-1981 which has been attributed by infilling of the harbour by land run off (Shaw & Maingay 1990 in Morrison 2005). GIS catchment analysis using the land use classification from the New Zealand Land Cover Database (LCDB2) indicated that in 2001 64% (36071 ha) of the catchment was high producing exotic grassland used for cattle and dairy farming, 17% (9504 ha) was indigenous forests, 8% (4640 ha) is Manuka and Kanuka scrub forest and 4% (2122 ha) is pine forest. The harbour possesses a large array of habitat types which supports a number of organisms. The harbour is noted for its shark populations and eagle rays as well as juvenile and adult snapper surrounding reefs and sea grass beds. The harbour hosts around 10,000 internationally migratory birds as well as 1000 nationally migrating birds (Morrison 2005).

Mangonui/Taipa Harbour

Mangonui Harbour was an important whaling port in the 1840's and is composed of rocky headlands and intertidal reefs with sandy, shelly and gravel beaches. GIS catchment analysis using the land use classification from the New Zealand Land Cover Database (LCDB2) indicated that in 2001, Mangonui Harbour had 45% (11643 ha) covered by high producing exotic grassland, 22% (5670 ha) indigenous forest 15% (3926 ha) Manuka and Kanuka scrub forest and 8% (2031 ha) pine forest. Taipa River had 38% (4965 ha) of its catchment surrounded by high producing exotic grassland and 27% (3454 ha) being indigenous forest, 14% (1779 ha) Manuka and Kanuka scrub forest and 9% (1174 ha) pine forest.

Whangaroa Harbour

Whangaroa Harbour covers 2635 ha with 26% of the harbour being intertidal mudflats (Shaw & Maingay 1990 in Morrison 2005). Mangroves cover 16% of the harbour (400 ha), but have been reduced by 38% as reclamation of land has occurred on harbour edges (Morrison 2005). The harbour entrance is surrounded by rocky headlands and high tidal action. The harbour contains an array of sediments with parts possessing fine sandy-mud and other with coarse grains and then finer muds in the inner harbour (Dougan 1984 in Morrison 2005). The Whangaroa Harbour study carried out in 1985 estimated that the harbour has been infilling at a rate of 2.6 mm y⁻¹. When compared to the bathymetric study of 1849 this equates to 33cm of infilling and a substantial decreasing in the volume of water held in the harbour. The harbour is not a stopover for migratory birds (Shaw & Maingay 1990 in Morrison 2005).

Hokianga Harbour

The Hokianga Harbour covers 15,414 ha and is situated on the west coast of Northland. The harbour (which is a drowned river valley) is 64% subtidal and is the fourth largest harbour in New Zealand (Morrison 2005). The harbour entrance has been classified as having high salinity, oceanic water, strong currents, high water clarity and short water residence times (Morrison 2005). The middle harbour is described as having soft substrates surrounded by mangrove and salt marsh with moderate to strong currents. The upper harbour contains low salinity, silts and clays, large river arms and high tidal flats with areas of mangrove and salt marsh (Davidson & Kerr 2003 in Morrison 2005).

Historically the natural forest cover was removed in the early 1820's as Kauri logging became popular, the land was then converted to pasture. Small areas of lowland swamp forest still remain but mangrove habitat has been reduced from 6300 ha to 2700 ha (Morrison 2005). GIS catchment analysis using the land use classification from the New Zealand Land Cover Database (LCDB2) indicated that in 2001, 41 % (3784 ha) of the catchment was indigenous forest, 37% (3413 ha) is high producing exotic grassland for cattle and dairy farming, 11% (1016 ha) is Manuka and Kanuka scrub forest and 6% (556 ha) is pine forest.

From the report by Morrison (2005) two major water quality issues exist in the harbour; excessive siltation and water discolouration from accelerated erosion and bacterial pollution from sewage disposal and pastoral run-off (Hokianga County Council 1995 in Morrison 2005).

Whangape Harbour

Whangape Harbour covers 850 ha and is north of Hokianga Harbour on the west coast of Northland. The harbour is 53% mudflat, 28% subtidal and 19% mangroves (Morrison 2005). The harbour is the result of two river arms meeting; the Awatoa River (the larger northern arm) and the Rotokakahi River (the smaller southern arm). Both estuaries have subtidal channels lined with mangroves. It is noted that the Rotokakahi arm has eroding alluvial banks in the upper reaches leading to sedimentation (Morrison 2005). The harbour entrance is a narrow stretch of water 150m wide and 4km long. The harbour entrance is recorded to have medium to coarse sand carried in from the open coast and then a large expanse of shell gravel from living and dead pipi (Haywood *et al.* 1994 in Morrison 2005). Historically (7000-700 year BP) the land surrounding the harbour has been mixed conifer and hardwood forest with regular fires (both natural and anthropogenic). More recently as in the Hokianga, the Kauri forests have been logged out, increasing erosion and causing on-going sedimentation problems. The sediment loading has been offset by the narrow harbour entrance which helps to discharge sediment in large plumes.

2 Methodology

2.1 Sampling Methodology

Sites for sampling were based on those sampled in 2004 to maintain consistency. These sites were sampled in the field using GPS coordinates. Sites were visited by boat with one skipper and two technicians on board to collect samples and record field observations.

At each site a total of five water sample bottles and two sediment samples were collected. Sediment samples were collected using a metal grab which was lowered to the sea floor to 'grab' a sample of the sediment. The surface samples were taken from the top 2cm and placed into a sterile plastic collection bag. The sediment samples were then frozen and sent to Waikato University services and Water Care services for analysis. Water samples were collected using a sample pole which was held under the surface at approximately 0.5 metres depth. Sample bottles were kept on ice and sent to Water Care services within 24 hours. A YSI meter was used to measure dissolved oxygen (mg/l and percentage saturation), temperature and salinity. The meter was calibrated before each sampling event. A secchi disk was used to measure secchi depth (used to determine water clarity) and to ensure consistency one technician recorded secchi disk readings.

At some sites not all samples could be collected, especially sediment samples as the water was too deep or sediment type made collection difficult, (e.g. fine sand, gravel etc.). For Whangaroa and Houhora Harbour entrances sediment samples were not taken for these reasons. Water samples for Rangaunu Harbour have been excluded as samples were not sent to an ISO accredited laboratory therefore sampling methods and analyses were not consistent for this harbour. Raw data is included in a secure excel file which is available upon request.

Rainfall Information

Rainfall information was collected using Northland Regional Council (NRC) rain gauges and NIWA rain gauges from their website Cliflo.

2.2 Data Analysis

The tests carried out for each site are shown in tables 2-4. From the raw data the median and range was calculated for each variable and the percentage of sites that were within relevant trigger/guideline values. The data was compiled and results compared against Ministry of Environment (MfE), for microbial factors, ANZECC trigger values for water and physical parameters or guidelines set out by Robertson and Stevens (2007) (Table 5) for sediment values. Using these guidelines we have been able to graph our results in a meaningful way to then compare sites within each harbour and between the harbours studied.

Parameters for the water testing have been split into three categories; physical, microbial and nutrient parameters. Total organic carbon was calculated from ash free dry-weight (AFDW) using the formula $=0.4 \times (\text{AFDW}) + 0.0025 \times (\text{AFDW})^2$. Values for nitrite (NO^2) were all below the minimum detection rate for all harbours. Nitrite (NO^2) is usually undetectable in seawater and nitrate (NO^3) is therefore the same as nitrate-nitrite nitrogen (NNN) hence results for NO^2 and NO^3 have not been shown in the results section. Total Kjeldahl Nitrogen was also measured but has not been included in the results section as it does not have an ANZECC trigger value. Total Kjeldahl Nitrogen; is the sum of organic nitrogen and free ammonia, ammonium. Median values of TKN for 2013 were less than the median values recorded in the 2004 study.

Trigger values are used to assess risk of adverse effects to the environment due to nutrients and organic matter in various ecosystem types. The trigger values set out by ANZECC are the point at which environmental conditions become unfavourable. The microbial MfE guidelines are an indication of when it is safe to swim and collect shellfish. ANZECC guidelines do not include trigger values for nutrients and total organic carbon in sediments and there are currently no nationally accepted trigger values for nutrients in marine sediment. However Robertson and Stevens (2007) developed a classification (Table 5) for sediment nutrients and total organic carbon concentrations. This has been used by Southland Regional Council and Tasman District Council in similar monitoring programmes. Guidelines from Robertson and Stevens 2007 gauge whether or not sediments are enriched with a nutrient. Comparisons were then drawn against median and range values from the data collected in 2004 as well as median values for whole harbours from the 2013 dataset.

2.3 Sampling Parameters

Table 2 Suite of parameters analysed for all harbours.

Parameter Type	Water Quality Parameters	MfE/ANZECC Guideline Value	Reason for Monitoring
Physical	Temperature	N/A	<ul style="list-style-type: none"> Indicator of ability to sustain aquatic life and support biological diversity Indicator of excessive primary productivity Influences dissolved oxygen
	Salinity	N/A	<ul style="list-style-type: none"> Indicator of fresh and seawater mixing Affects biological diversity
	Dissolved oxygen	>80%-110%<	<ul style="list-style-type: none"> Indicator of ability to support marine flora and fauna Indicator of organic material Indicator of excessive primary productivity
Water Clarity	Secchi depth	N/A	<ul style="list-style-type: none"> Indicator of the quantity of suspended material in water column, e.g. sediment Indicator of ability to support aquatic life Affects primary production. Affects predator-prey relationships
	Turbidity	<10 NTU	
	Suspended solids	N/A	
Micro Bacteria	Enterococci Bacteria	<140/100mL	<ul style="list-style-type: none"> Indicator of faecal contamination Indicator of public health risk
	Feacal Coliforms	<150/100mL	
Aquatic Plants	Chlorophyll a (Chla)	0.004 g/m ³	<ul style="list-style-type: none"> Photosynthetic particle Indicator of aquatic plants/nutrient enrichment

Table 3. Suite of water parameters analysed for all harbours.

Parameter Type	Water Quality Parameters	ANZECC Guideline Value	Reason for Monitoring
Water Nutrients	Ammonium (NH ₄)	<0.015 g/m ³	<ul style="list-style-type: none"> Preferred form of nitrogen for plant uptake Indicator of nutrient enrichment/waste products Indicator of point and non-point source inputs
	Nitrate-nitrite nitrogen (NNN)	<0.015 g/m ³	<ul style="list-style-type: none"> Oxides of nitrogen (sum of NO², NO³ and NH³) Indicator of nutrient enrichment Indicator of point and non-point source inputs Affects primary productivity
	Total Nitrogen (TN)	0.3 g/m ³	<ul style="list-style-type: none"> The sum of organic and inorganic nitrogen compounds Indicator of nutrient enrichment Indicator of point and non-point source inputs Affects primary productivity
	Total Phosphorus (TP)	<0.03 g/m ³	<ul style="list-style-type: none"> Total of all filterable and particulate forms of phosphorus Indicator of nutrient enrichment Indicator of point and non-point source inputs Affects primary productivity
	Dissolved Reactive Phosphorus DRP	<0.005 g/m ³	<ul style="list-style-type: none"> A fraction of phosphorus that consists of inorganic orthophosphate that can be readily used by aquatic organisms Indicator of nutrient enrichment Indicator of point and non-point source inputs Affects primary productivity

Table 4. Suite of sediment parameters analysed for all harbours.

Parameter Type	Sediment Quality Parameters	Robertson & Stevens(enriched)/ ANZECC Guideline Value	Reason for monitoring
Sediment Nutrients	Ammoniacal nitrogen (NH ₄)	N/A	• Indicator of nutrient enrichment
	Nitrite/Nitrate nitrogen (NNN)	N/A	• Indicator of nutrient enrichment
	Total nitrogen (TN)	>2000 mg/kg	• Indicator of nutrient enrichment • Nitrogen exchange between water column and sediments can determine trophic status and algae growth
	Total phosphorus (TP)	>500 mg/kg	• Indicator of nutrient enrichment • Phosphorus exchange between water column and sediments can determine trophic status and algae growth
	Total organic carbon (TOC)	>2 %	• Indicator of organic enrichment • Measured as ash free dry weight and converted to TOC • High organic content can lead to release of excessive nutrients
Grain Size	< 63 um (Mud)		• Textural characteristics • Nutrients bind easier to smaller particles leading to a direct relationship between grain size and organic content/nutrients.
	63- 250 um (Fine Sand)		
	250- 500 um (Medium Sand)		
	500- 2000 um (Coarse Sand)		

Table 5. Robertson and Stevens 2007 guidelines for marine sediments.

Rating	Total Nitrogen (mg/kg)	Total Phosphorus (mg/kg)	Total organic carbon (%)
Very good	<500	<200	<1
Low-mod enrichment	500-2000	200-500	1-2
Enriched	2000-4000	500-1000	2-5
Very enriched	>4000	>1000	>5

2.3 Site Maps

Below are site maps for the seven harbours monitored. The number of sample sites varied between harbour depending on the size of the harbour and geographical points.

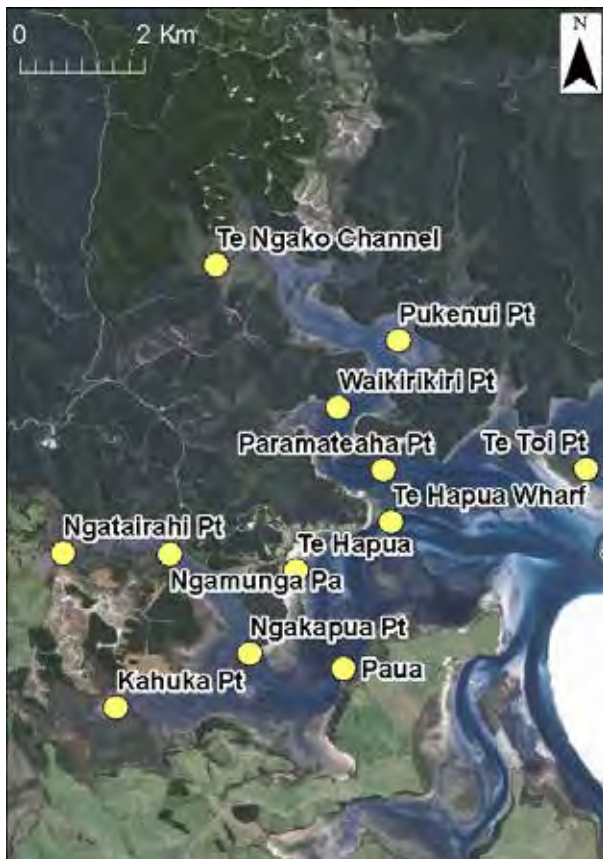


Figure 1 Parengarenga North monitoring sites.



Figure 2 Parengarenga South monitoring sites.



Figure 3 Houhora Harbour monitoring sites.



Figure 4 Rangaunu Harbour monitoring sites.



Figure 5 Taipa/Mangonui Harbour monitoring sites.



Figure 6 Whangaroa Harbour monitoring sites.



Figure 7 Hokianga Harbour monitoring sites.



Figure 8 Whangape Harbour monitoring sites

3 Results

3.1 Parengarenga North

3.1.1 Water Quality

Physical Parameters

Table 6. Range and median values for salinity, dissolved oxygen (DO), turbidity and suspended solids (SS) in the Parengarenga Harbour (North).

	Salinity	DO (g/m ³)	DO (%)	Turbidity (NTU)	SS (g/m ³)
Trigger value	No value	<5	80-110	10	No value
Median	34.15	7.425	102	1.8	5.9
Range	33.5-35.5	6.73-8.08	93.1-112.3	0.85-5.3	2.4-8.8
% of sites within trigger values	NA	100	100	100	NA

Parengarenga sampling was split into northern and southern arms of the harbour and was completed over two days. Parengarenga North was sampled on 30 January 2013. Rain data was collected from the Cape Reinga rain gauge which is monitored by NIWA. A total of 10.2mm fell during the 30 days prior to sampling. On the day of sampling 0.4mm was recorded and before sampling the largest downpour was 7.8mm on 4 January 2013. Salinity was fairly high with a narrow range of 33.5-35.5, indicating little freshwater input at the time of sampling. The highest salinity reading was at Te Hapua wharf and the lowest reading at Te Toi Point.

In Table 6 we can see that the percentage of sites within the trigger value for dissolved oxygen (g/m³ and % saturation) and turbidity was 100%. Figure 9 shows that at all sites values for turbidity were within the ANZECC guideline of 10 NTU. The lowest reading of turbidity was 0.85 (NTU) at Te Toi Point and the highest reading was 5.3 NTU at Ngatairahi Point (which is still within the guideline value). Similarly suspended solids lowest value was at Te Toi Point and highest value at Ngatairahi Point.

Microbial Parameters

Table 7. Range and median concentrations of enterococci (ENT) and faecal coliforms (FC) in the Parengarenga Harbour (North).

	ENT (MPN/100ml)	FC (CFU/100ml)
MfE guideline	140	150
Median	0.8	0.8
Range	0.8	0.8
% of sites within trigger values	100	100

Micro bacteria factors tested returned results within MfE values at all sites (Table 7). At all sites across Parengarenga North the values for enterococci and faecal coliforms were within the laboratory detection limit (<1.6/100ml). No spatial patterns were detected because of low recorded levels at all sites. This can be seen in Figure 10 for enterococci values.

Water Nutrient Parameters

Table 8. Range and median in water nutrient concentrations in the Parengarenga Harbour (North).

	Chl a (g/m ³)	NH ₄ (g/m ³)	NNN (g/m ³)	TN (g/m ³)	DRP (g/m ³)	TP (g/m ³)
ANZECC trigger value	0.004	0.015	0.015	0.3	0.005	0.03
Median	0.00098	0.0025	0.011	0.0675	0.0065	0.014
Range	0.0007-0.002	0.0025-0.0051	0.0035-0.046	0.01-0.2	0.0025-0.011	0.009-0.022
% of sites below trigger values	100	100	91	100	16.6	100

Values for chlorophyll a (Chla), ammonium (NH₄), total phosphorus (TP) and total nitrogen (TN) had all sites at 100% meaning no readings were above the trigger values for these parameters (Table 8). Nitrate-nitrite nitrogen (NNN) had >90% of sites within trigger values. Dissolved reactive phosphorus (DRP) had less than 20% of sites within trigger values.

Chlorophyll a had a range of 0.0007 to 0.002 g/m³ and all sites were within the trigger value of 0.004 g/m³. Total nitrogen had a range of 0.01-0.2 g/m³ and total phosphorus a range of 0.009-0.022 g/m³.

Figure 12 shows that ammonium levels for all sites in the Parengarenga North section of the harbour were within the ANZECC trigger value of 0.015 g/m³. Ammonium in the harbour ranged from 0.0025 to 0.0051 g/m³. All sites were below the minimum detection rate with a reading of 0.0025 g/m³ except for Te Hapua Rock which had a reading of 0.0051 g/m³.

Nitrate-nitrite nitrogen had a range of 0.0035 to 0.046 g/m³ with only one value of 0.046 g/m³ at Te Hapua wharf being outside the guideline. This meant NNN had 91% of sites within the trigger values.

Dissolved reactive phosphorus had a median value of 0.0065 (g/m³) which is higher than the Anzecc trigger value of 0.005 g/m³. In figure 11 two sites were within guideline limits; Ngatairahi Point and Ngamunga Pa (which are adjacent sites) with values of 0.0025 g/m³. The highest value recorded was 0.011 g/m³ at Te Hapua Rock.

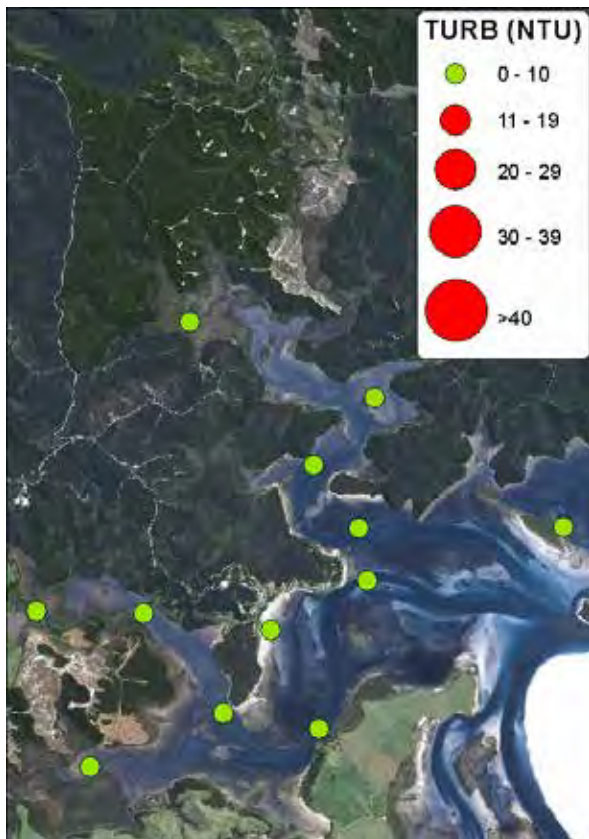


Figure 9 Turbidity levels (NTU) in Parengarenga Harbour (North).



Figure 10 Enterococci levels (MPN/100ml) in Parengarenga Harbour (North).

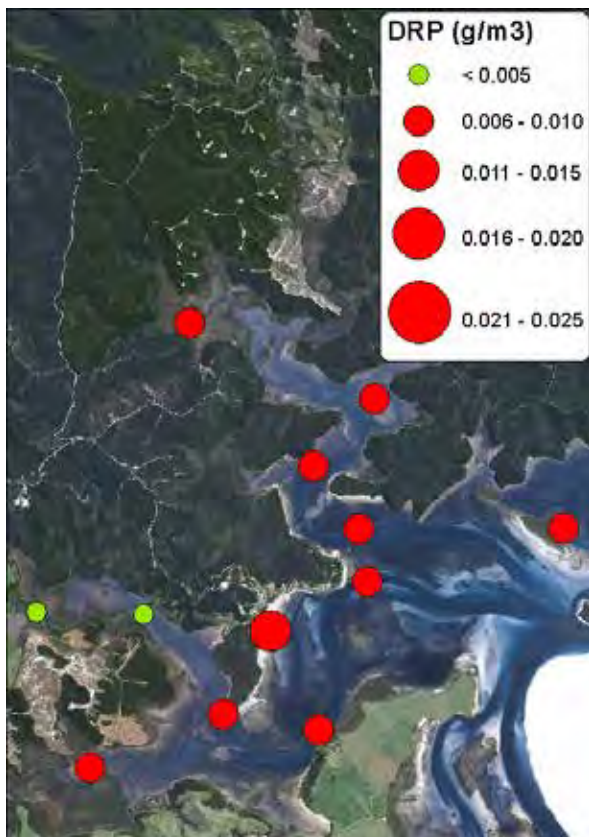


Figure 11 Dissolved reactive phosphorus (g/m^3) in Parengarenga Harbour (North).

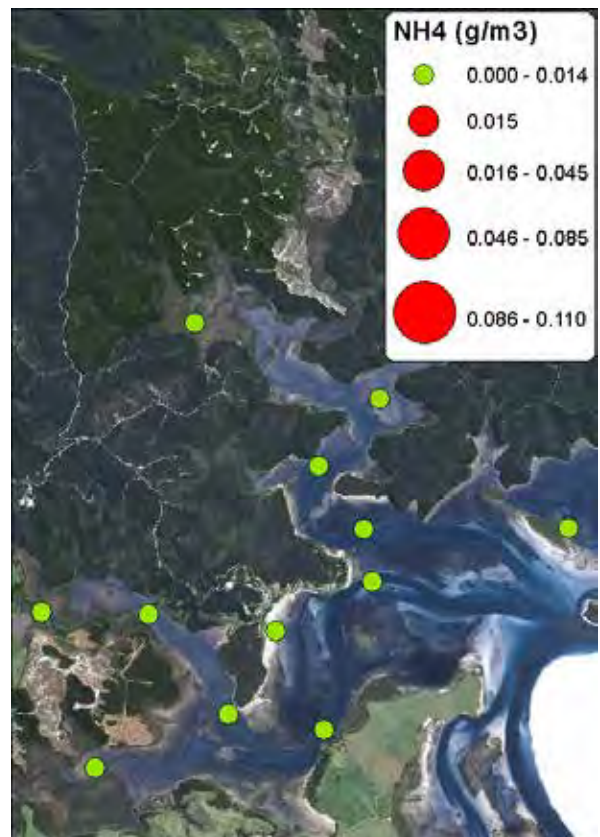


Figure 12 Ammonium (NH_4) levels (g/m^3) in Parengarenga Harbour (North).

3.1.2 Sediment Quality

Grain Size Analysis

The classification of grain size as shown in Figure 13 follows the change in grain size from the harbour entrance to the upper harbour. The first point is Te Toi Point which had the largest percentage of grains sized 250-2000 μm . Moving into the harbour the percentage of grains sized 63-250 μm increases until point 9 (Ngamunga Pa). Point 12 (Ngatairahi Point) had a large percentage of grains sized 250-500 μm .

Sediment Nutrients

Using the guidelines by Robertson and Stevens (2007) total nitrogen, total phosphorus and total organic carbon have been classified (Figures 14-16). In Table 9 the range and mean of sediment nutrients tested has been tabulated.

Table 9. Range and mean sediment nutrients concentrations in Parengarenga Harbour (North).

	NH ₄ (mg/kg)	NNN (mg/kg)	TN (mg/kg)	TP (mg/kg)	TOC (%)
Mean	9.1	0.61	263	102	0.92
Range	5.5-16	0.34-1.4	62-1300	28-180	0.32-2.53

From Figures 14-16 we can identify areas where sediment nutrients are classified as 'very good' and other areas where they are classified as 'enriched'.

Te Ngako channel had the highest readings for TN, TP and TOC. The highest value for NNN and NH₄ was at Paramateaha channel. The lowest value for NNN was Te Hapua wharf. The lowest value for NH₄ was at Ngatairahi Point. Te Ngako channel had the highest percentage of 'Mud' (Figure 13). The lowest values for TN, TP and TOC were at Ngakapua Point (Figure 13) which had no 'Mud' in the grain profile.

Total nitrogen (TN) (Figure 14) had a range of 63 to 1300 mg/kg with the lowest value being at Ngakapua Point. The highest reading was at Te Ngako channel. All sites fell under the 'very good' rating except for one site (Te Ngako channel) which had a reading of 1300 mg/kg therefore being classed as 'low to moderately enriched'.

Total phosphorus (TP) (Figure 15) had a range of 28 to 180 mg/kg with the lowest value being at Ngakapua Point. The highest value was again at Te Ngako channel. All sites were rated as 'very good' except for Te Ngako channel which has a 'low to moderately' enriched rating.

Total organic carbon (TOC) (Figure 16) had a range of 0.32 to 1.38%. The lowest reading was at Te Hapua wharf. This site and six others were rated 'very good'. Four sites came under the 'low to moderately enriched' rating and one site (Te Ngako channel) came under the rating of 'enriched' with a value of 2.53%.



Figure 13 Grain size for sediment samples in Parengarenga Harbour (North).

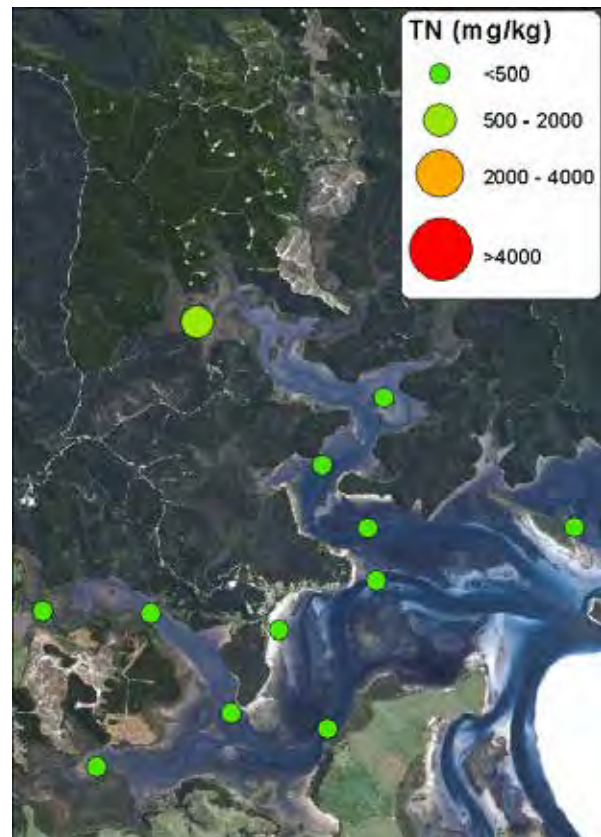


Figure 14 Total nitrogen concentrations in sediment (mg/kg) in Parengarenga Harbour (North).

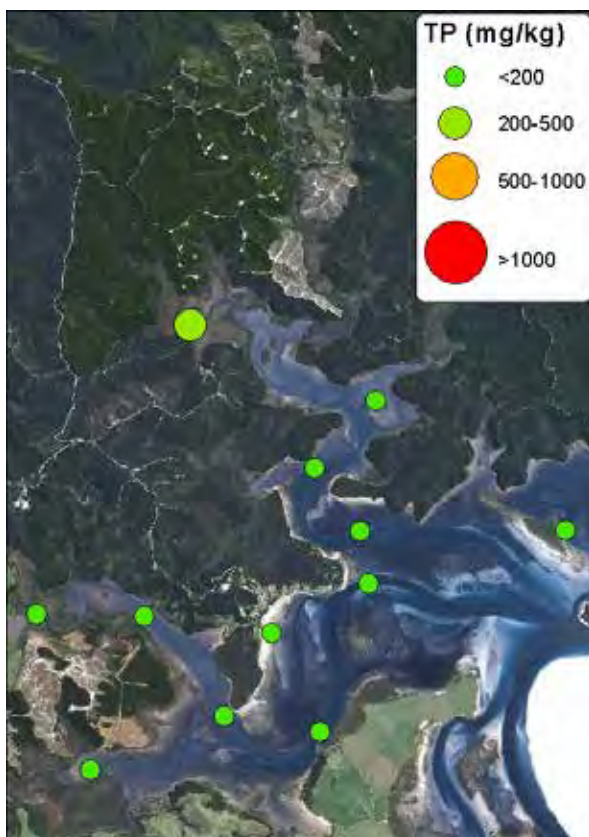


Figure 15 Total phosphorus concentrations in sediment (mg/kg) in Parengarenga Harbour (North).

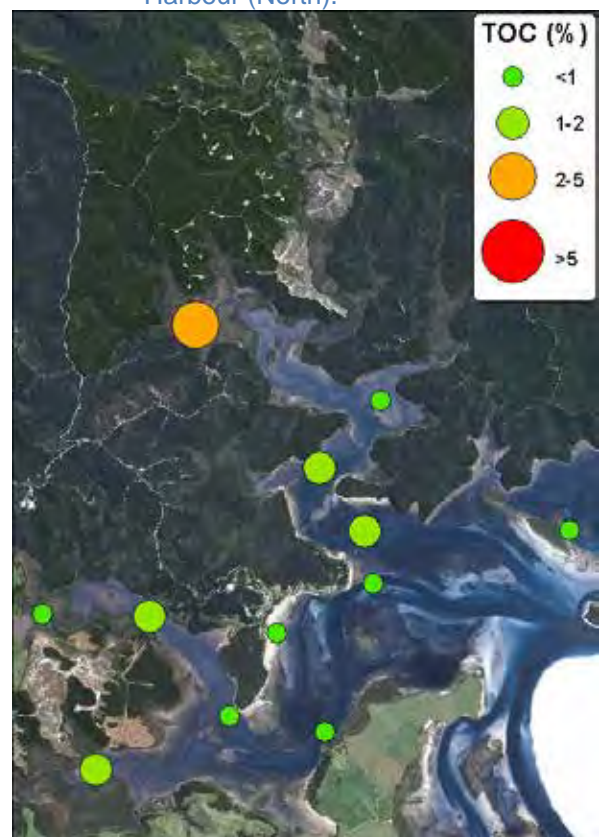


Figure 16 Total organic carbon levels in sediment (%) in Parengarenga Harbour (North).

3.2 Parengarenga South

3.2.1 Water Quality

Physical Parameters

Table 10. Range and median values for salinity, dissolved oxygen (DO), turbidity and suspended solids (SS) in the Parengarenga Harbour (South).

	Salinity	DO (g/m ³)	DO (%)	Turbidity (NTU)	SS (g/m ³)
ANZECC trigger value	No limit	<5	80-110	10	No limit
Median	34.4	6.995	95.95	1	9
Range	32.8-36.1	6.46-7.53	89.8-102.2	0.5-1.9	2.8-16
% of sites within trigger values	NA	100	100	100	NA

For Parengarenga South 0.2 mm of rain fell during sampling (31 January 2013) and previous rain fall was 1.4mm on 26 January. For the 30 days prior the total rain fall was 10.2mm with the largest event being 7.8mm on 4 January 2013. Salinity was fairly high with a narrow range of 32.8 to 36.1, indicating little freshwater input at time of sampling. The highest salinity reading was at Whawhakaou channel and the lowest reading was at Waihuahua channel.

In Table 10 the percentage of sites within the trigger value for dissolved oxygen (g/m³ and % saturation) and turbidity was 100%. Figure 17 shows that at all sites values for turbidity were within the ANZECC guideline of 10 NTU. The lowest reading of turbidity was 0.5 NTU at Akatarere Point and the highest reading was 1.9 NTU at Taiwhakangari Point. The lowest reading for suspended solids was at the harbour entrance and the highest value at Ngutukorari channel.

Microbial Parameters

Table 11. Range and median concentrations of enterococci (ENT) and faecal coliforms (FC) in the Parengarenga Harbour (South).

	ENT (MPN/100ml)	FC (CFU/100ml)
MfE guideline	140	150
Median	0.85	0.85
Range	0.85	0.85
% of sites within trigger values	100	100

Micro bacteria factors tested returned results within MfE guidelines (Table 11). At all sites across Parengarenga South the values for enterococci and faecal coliforms were below detection limit. No spatial patterns were detected because of low recorded levels at all sites. This can be seen in Figure 19 for enterococci values.

Water Nutrient Parameters

Table 12. Range and median in water nutrient concentrations in the Parengarenga Harbour (South).

	Chl a (g/m ³)	NH ₄ (g/m ³)	NNN (g/m ³)	TN (g/m ³)	DRP (g/m ³)	TP (g/m ³)
ANZECC trigger value	0.004	0.015	0.015	0.3	0.005	0.03
Median	0.00093	0.0025	0.0033	0.0245	0.005	0.0095
Range	0.0003-0.002	0.0025-0.027	0.0022-0.0044	0.01-0.86	0.0025-0.008	0.007-0.012
% sites within trigger value	100	90	100	90	30	100

Values for chlorophyll a (Chla), nitrate-nitrite nitrogen (NNN), total phosphorus (TP) had 100% of sites within trigger values (Table 12). Ammonium (NH₄) and total nitrogen (TN) had 90% of sites within trigger values while dissolved reactive phosphorus (DRP) had 30% of sites within trigger values.

Chlorophyll a (Chla) had a range of 0.003 to 0.002 g/m³ with all sites being within the trigger value of 0.004 g/m³. Nitrate-nitrite nitrogen (NNN) had a range of 0.0022 to 0.0044 g/m³ with all values being within the trigger value. Total phosphorus also had 100% of sites within the trigger value with no values outside of the 0.03 g/m³.

Figure 20 shows that ammonium levels for nine out of ten sites (90%) in the Parengarenga south section of the harbour were within the ANZECC trigger value of (0.015 g/m³). Several sites were below the minimum detection level (<0.005 g/m³). One site at Ngutukorari channel (upper harbour channel arm) was outside of the trigger value with a reading of 0.027 g/m³. Total nitrogen also had 90% of sites within the trigger value with one site at Ngutukorari channel with a reading (0.86 g/m³) outside of the trigger value of 0.3 g/m³. Ammonium and total nitrogen showed a similar spatial pattern where the two highest values were both recorded at Weraroa Point and Ngutukorari channel.

Dissolved reactive phosphorus had a median value of 0.005 g/m³ which is the same as the trigger value. DRP had a range of 0.0025-0.008 g/m³ and had 30% of sites. In figure 18 three sites were within guideline limits; Ngutukorari channel, Whawhakou channel and Waihuahua channel (which are all inner harbour channel arms) with values of 0.0025 g/m³. The remaining seven sites had values outside of the trigger value with the highest value being 0.008 g/m³ at the harbour entrance. There appears to be no relationship to salinity here as Whawhakou channel and Waihuahua channel include the lowest and highest salinity readings.

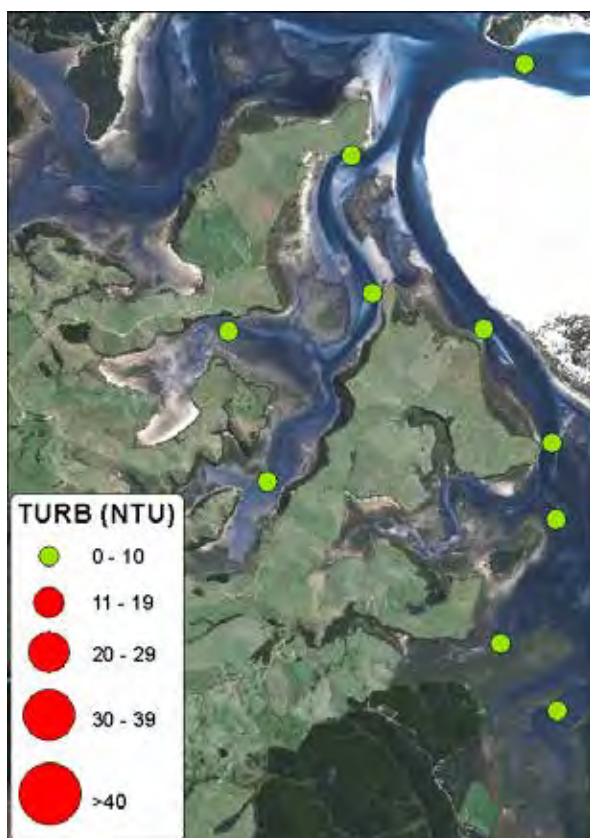


Figure 17 Turbidity levels (NTU) in Parengarenga Harbour (South).

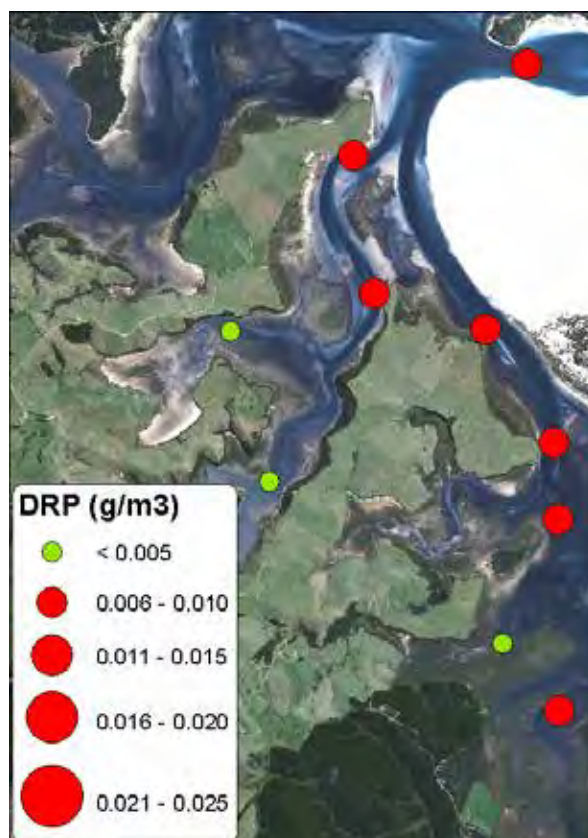


Figure 18 Dissolved reactive phosphorus (g/m^3) in Parengarenga Harbour (South).

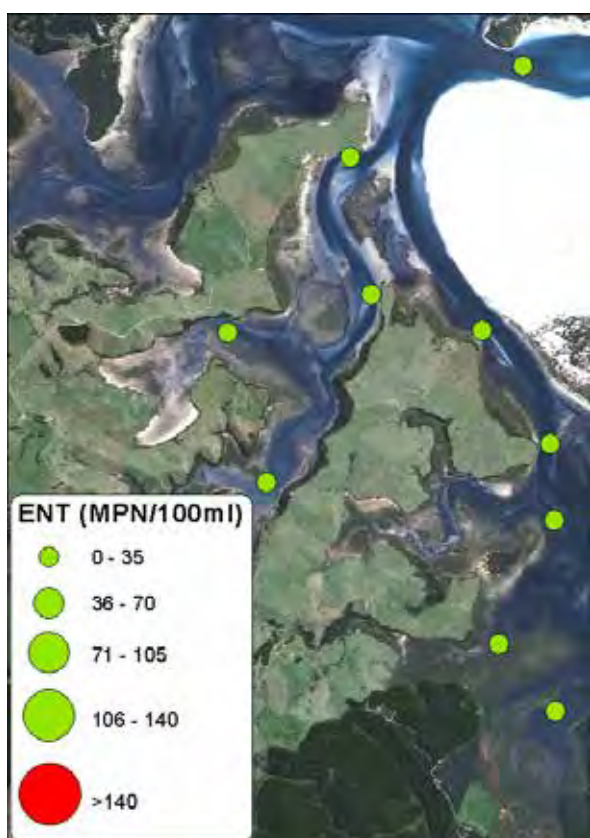


Figure 19 Enterococci levels (MPN/100ml) in Parengarenga Harbour (South).

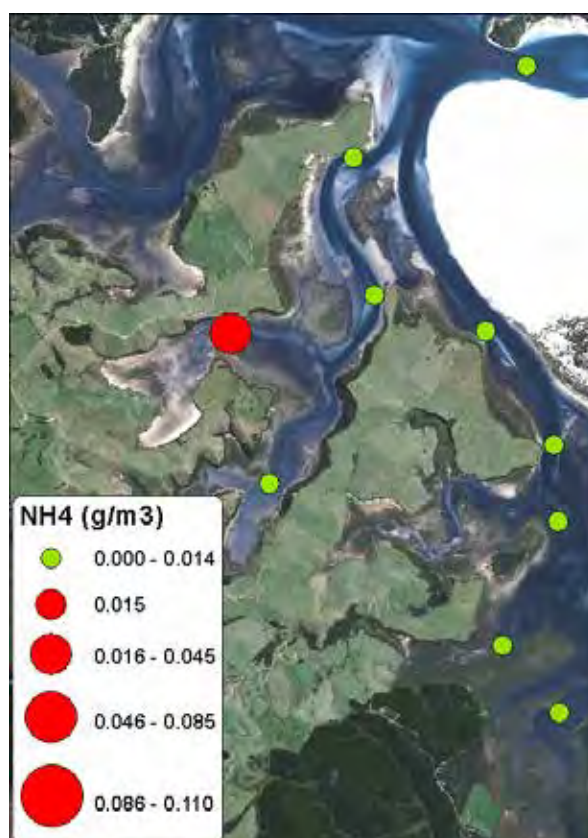


Figure 20 Ammonium (NH_4) levels (g/m^3) in Parengarenga Harbour (South).

3.2.2 Sediment Quality

Grain Size Analysis

The classification of grain size as shown in Figure 21 follows the change in grain size from the harbour entrance to the upper harbour. As we move further into the harbour the percentage of grains with 'fine sand' (63-250µm) increases until Taiwhakangari Point which has a profile of larger grains and the highest percentage of 'sand' (500-2000µm). The majority of points had 'fine sand' as the largest component of the grain sample. The southern end of the harbour generally had little 'mud' in the sediment sample.

Sediment Nutrients

Using the guidelines by Robertson and Stevens (2007) total nitrogen, total phosphorus and total organic carbon have been classified (Figures 22-24). In Table 13 the range and mean of sediment nutrients tested has been tabulated.

Table 13. Range and mean sediment nutrient concentrations in Parengarenga Harbour (South).

	NH ₄ (mg/kg)	NNN (mg/kg)	TN (mg/kg)	TP (mg/kg)	TOC (%)
Mean	9.68	0.243	218	60.3	0.4318
Range	4.3-16	0.12-0.037	25-500	18-200	0.120-0.974

From Figures 22-24 we can identify areas where sediment nutrients are classified as 'very good' and other areas where they are classified as 'enriched'.

Ammonium in the sediment had the lowest value at the harbour entrance, the highest value was at Whawhakaou channel. For NNN in the sediment the lowest value was at Ngutukorari channel and the highest value at Taiwhakangari.

Total nitrogen (TN) (Figure 22) had a range of 25 to 500 mg/kg with the lowest value being at the harbour entrance. The highest value was 500 mg/kg which was recorded at Horoiwi Point and Ngutukorari channel (upper harbour channel arms). These two sites were rated as 'low to moderately enriched' and all other sites were rated as 'very good'.

Total phosphorus (TP) (Figure 23) had a range of 18 to 200 mg/kg with the lowest value being at the harbour entrance. All sites were rated as 'very good' except for Horoiwi Point which was rated as 'low to moderately enriched' with the highest reading of 200 mg/kg.

Total organic carbon (TOC) (Figure 24) had a range of 0.120 to 0.974%. The lowest reading was 0.12% at the harbour entrance. All sites were rated as 'very good' for total organic carbon with the highest value of 0.974% at Horoiwi Point, still falling under the <1% classification.

Horoiwi Point recorded the highest levels for TN, TP and TOC. Horoiwi Point (Figure 24, point 10) had the largest values of 'Mud' and a large percentage of 'Fine sand'.



Figure 21 Grain size for sediment samples taken from Parengarenga Harbour (South).



Figure 22 Total nitrogen concentration in sediment (mg/kg) in Parengarenga Harbour (South).

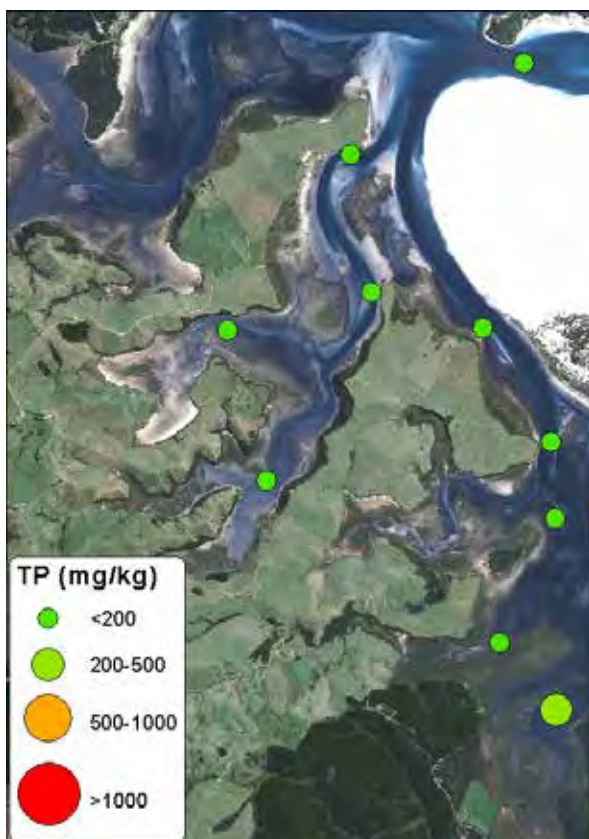


Figure 23 Total phosphorus concentration in sediment (mg/kg) in Parengarenga Harbour (South).

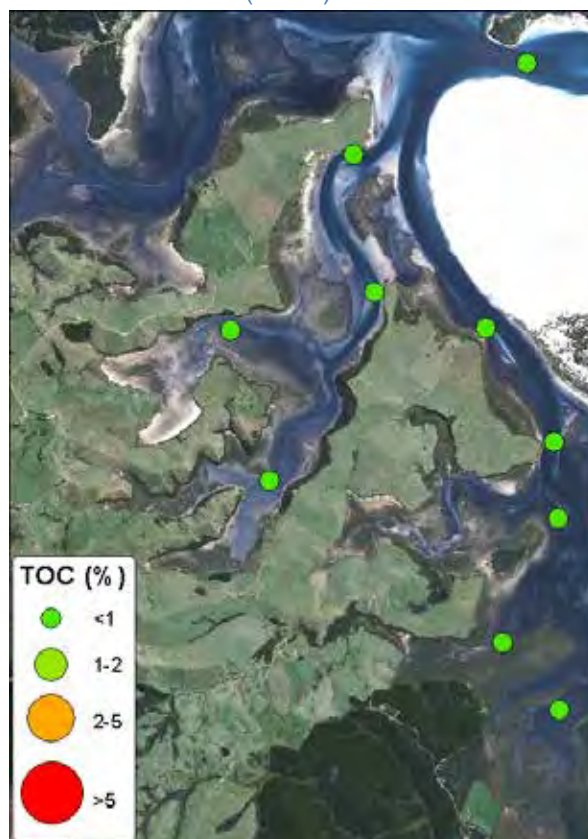


Figure 24 Total Organic Carbon levels in sediment (%) in Parengarenga Harbour (South).

3.3 Houhora Harbour

3.3.1 Water Quality

Physical Parameters

Table 14. Range and median values for salinity, dissolved oxygen (DO), turbidity and suspended solids (SS) in Houhora Harbour.

	Salinity	DO (g/m ³)	DO (%)	Turbidity (NTU)	SS (g/m ³)
ANZECC trigger value	No value	<5	80-110	10	No value
Median	34.4	7	95.7	2.3	6.7
Range	23.5-35	6.31-7.21	85.5-98.3	1.4-5.5	4.6-16
% of sites within trigger values	NA	100	100	100	NA

The nearest rain gauge at Waiharara is 18.6km away by road to Pukenui at Houhora Harbour. Houhora was sampled on 1 February 2013 with 0mm falling on the day of sampling. Nine millimetres fell within the previous 30 days with the largest event being 4mm on 17 January 2013. Salinity had a larger range when compared to other harbours (23.5-35) with the lowest reading being recorded at the corner of the oyster leases. The highest reading was recorded at Waimakumaku Street.

In Table 14 we can see that the percentage of sites within the trigger value for dissolved oxygen (g/m³ and % saturation) and turbidity was 100%. At all sites readings taken were within guideline values for these parameters. Figure 25 shows that at all sites readings for turbidity were within the ANZECC value of 10 NTU. The lowest reading of turbidity was 1.4 NTU at the harbour entrance and the highest reading was 5.5 NTU at the corner of the oyster leases (which coincides with the lowest salinity reading). For suspended solids the lowest value was at the harbour entrance and the highest value at Waimakumkau Street.

Microbial Parameters

Table 15. Range and median concentrations of enterococci (ENT) and faecal coliforms (FC) in Houhora Harbour.

	ENT (MPN/100ml)	FC (CFU/100ml)
MfE guideline	140	150
Median	0.85	0.85
Range	0.85-8.3	0.85-17
% of sites within trigger values	100	100

Micro bacteria factors tested returned results within MfE guidelines (Table 15). At all sites across Houhora Harbour the values for enterococci and faecal coliforms were within the guideline values and ranged from 0.85 to 8.3 (MPN/100ml) for enterococci and 0.85 to 17 (CFU/100ml) for faecal coliforms. Because values were typically low no spatial pattern was identified. This can be seen in Figure 26 for enterococci values.

Water Nutrient Parameters

Table 16. Range and median in water nutrient concentrations in the Houhora Harbour.

	Chl a (g/m ³)	NH ₄ (g/m ³)	NNN (g/m ³)	TN (g/m ³)	DRP (g/m ³)	TP (g/m ³)
ANZECC trigger value	0.004	0.015	0.015	0.3	0.005	0.03
Median	0.002	0.0025	0.014	0.069	0.01	0.02
Range	0.0008-0.003	0.0025-0.11	0.0086-0.018	0.01-0.19	0.009-0.021	0.011-0.048
% of sites within trigger values	100	85	57.1	100	0	71

Values for chlorophyll a (Chla) and total nitrogen (TN) were all within the guideline levels with 100% of sites within the trigger value for Houhora Harbour. Ammonium (NH₄), nitrate-nitrite nitrogen (NNN) and total phosphorus (TP) had >50% of sites with values within trigger values. Dissolved reactive phosphorus (DRP) had <50% of sites within trigger values (Table 16).

Chlorophyll a had a range of 0.0008 to 0.003 g/m³ with all sites being within the guideline value of 0.004 g/m³. Total nitrogen had a range of 0.01-0.19 g/m³ with no sites reaching the 0.3 g/m³ guideline value.

Figure 28 shows that ammonium levels for all sites except Waihopo Creek are within trigger values. Waihopo Creek had the highest reading of 0.11 g/m³. The next highest reading was 0.012 g/m³ at Waimakumaku Street. All other sites recorded ammonium levels that were below the detection limit.

Nitrate-nitrite nitrogen had a range of 0.0086 to 0.018 g/m³ with three values being outside of the guideline value. Total phosphorus had a compliance percentage of 71% with two sites being outside of the guideline value (Waihopo Creek and the corner of the oyster leases).

Dissolved reactive phosphorus had a median value of 0.01g/m³ which is outside of the guideline value of 0.005 g/m³. The range of 0.009 to 0.021 g/m³ means that no sites were within the guideline values for DRP in Houhora. In Figure 27 all sites are red as they are outside the guideline. The largest value is that of 0.021 g/m³ at Waihopo Creek. The lowest value was 0.009 g/m³ and was recorded at three sites; the harbour entrance, Ariawa Stream and the centre of the oyster leases.

Waihopo Creek is the most inland sampling point and the closest point to freshwater inputs. Waihopo Creek had the highest readings for NH₄ NNN and DRP and the second lowest reading of salinity from the sample sites.

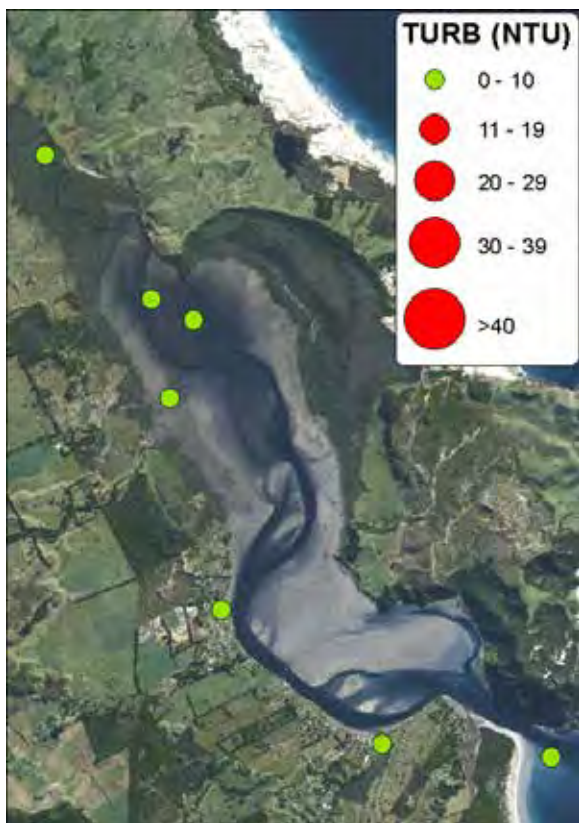


Figure 25 Turbidity levels (NTU) in Houhora Harbour.

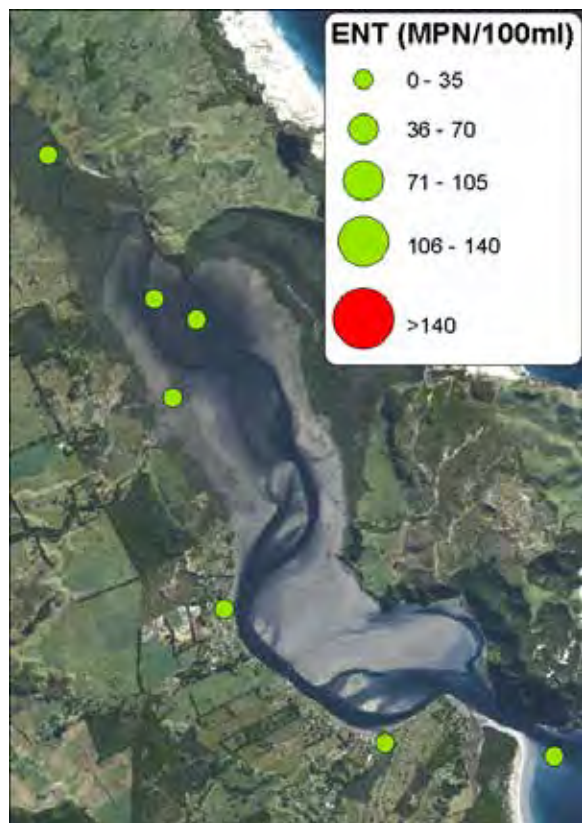


Figure 26 Enterococci levels (MPN/100ml) in Houhora Harbour.

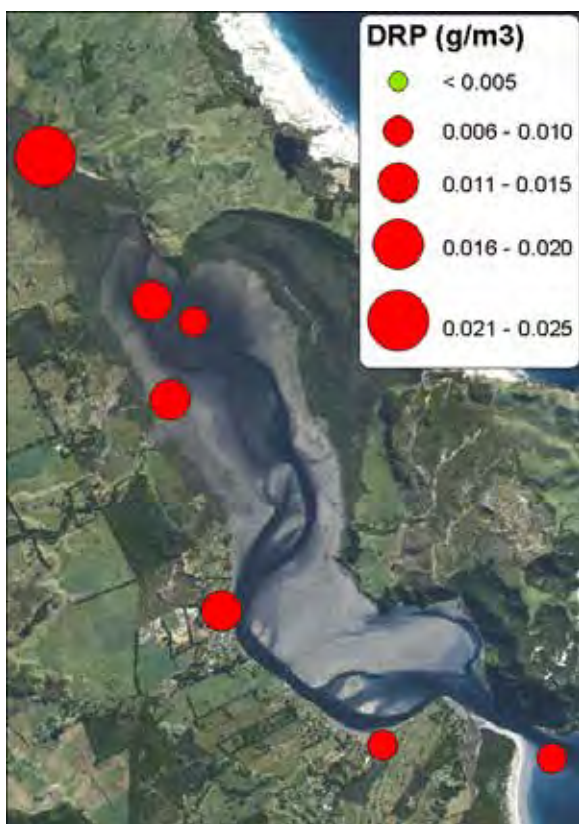


Figure 27 Dissolved reactive phosphorus (g/m^3) in Houhora Harbour.

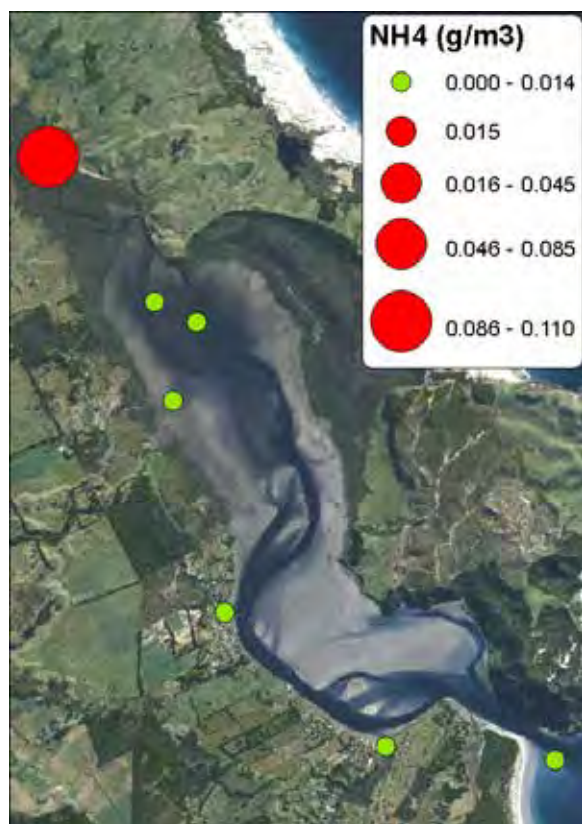


Figure 28 Ammonium (NH_4) levels (g/m^3) in Houhora Harbour.

3.3.2 Sediment Quality

Grain Size Analysis

The classification of grain size as shown in Figure 29 follows the change in grain size from the harbour entrance to the upper harbour. The harbour entrance sample was unable to be collected as the water was too deep for the grab to pull up sufficient sediment. As we move further into the harbour the percentage of grains with 'fine sand' (63-250µm) stays relatively steady with small increases in the percentage of 'mud' (grain size <63µm).

Sediment Nutrients

Using the guidelines by Robertson and Stevens (2007) total nitrogen, total phosphorus and total organic carbon have been classified (Figures 30-32). In table 17 the range and mean of each sediment nutrient tested has been tabulated.

Table 17. Range and mean sediment nutrients concentrations in Houhora Harbour.

	NH ₄ (mg/kg)	NNN (mg/kg)	TN (mg/kg)	TP (mg/kg)	TOC (%)
Mean	13.9	0.144	668	129	1.26
Range	7.4-19	0.0325-0.35	270-1100	52-220	0.56-1.89

From Figures 30-32 we can identify areas where sediment nutrients are classified as 'very good' and other areas where they are classified as 'enriched'.

Ammonium (NH₄) had the lowest value at Ariawa Stream and the highest value at the centre of the oyster leases. For nitrate-nitrite nitrogen (NNN) the lowest value was the corner of the oyster lease and the highest value was at Ariawa Stream.

Total nitrogen (TN) (Figure 30) had a range of 270 to 1100 mg/kg with the lowest value being at Ariawa Stream. The highest value was 1100 mg/kg which was recorded at the centre of the oyster leases. Four sites were classed as 'low to moderately enriched'; the centre and corner of the oyster leases, Waihopo Creek and Waimakumaku Street. The remaining two sites (Ariawa Stream and the Houhora Hotel) were rated as 'very good'.

Total phosphorus (TP) (Figure 31) had a range of 52 to 220 mg/kg. The lowest reading was at the Houhora Hotel and was rated as 'very good'. The highest reading was at the centre of the oyster leases which was rated as 'low to moderately enriched'. All other sites were rated as 'very good' (<200 mg/kg).

Total organic carbon (TOC) (Figure 32) had a range of 0.56 to 1.89%. The lowest reading was 0.56% at the Houhora Hotel. The highest value was 1.89% at Waimakumkau Street. Two sites were rated as 'very good'; Ariawa Stream and the Houhora Hotel whilst four sites were classed as 'low to moderately enriched'; Waihopo Creek, the corner and centre of the oyster leases and Waimakumkau Street.

Ariawa Stream and Houhora Hotel which were the two lowest reading sites for NH₄, TN, TP and TOC both had the same grain profile (Figure 29) with 75% of the sample being 'Fine sand' and the remainder being "Medium sand".



Figure 29 Grain size for sediment samples taken from Houhora Harbour.

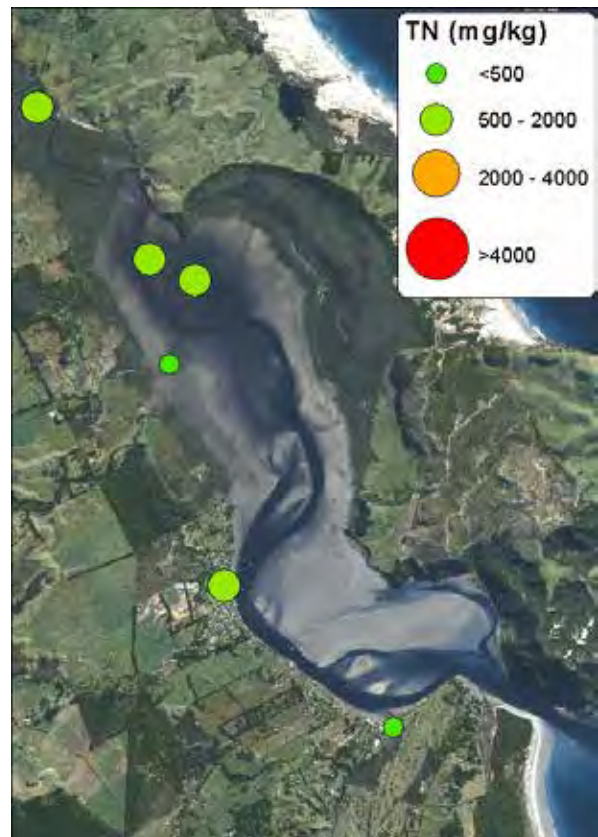


Figure 30 Total nitrogen concentration in sediment (mg/ kg) in Houhora Harbour.

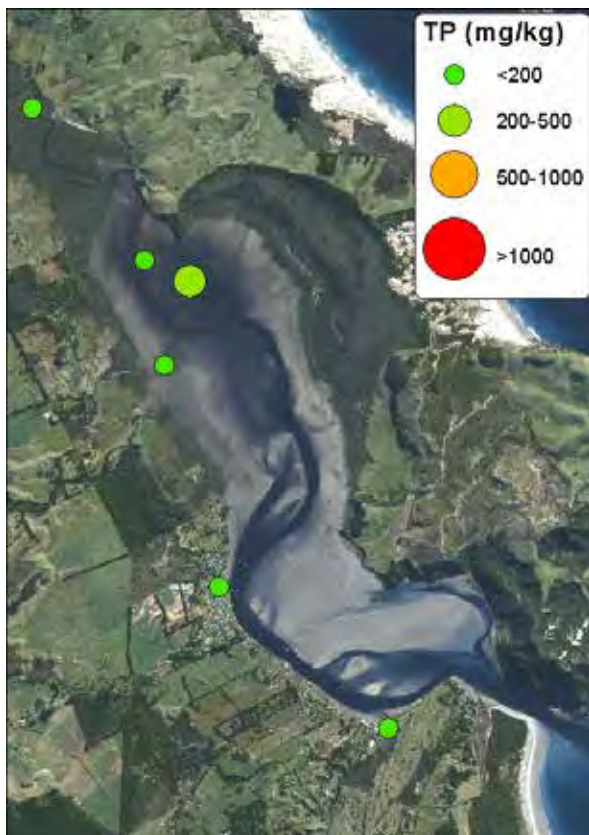


Figure 31 Total phosphorus concentration in sediment (mg/kg) in Houhora Harbour.

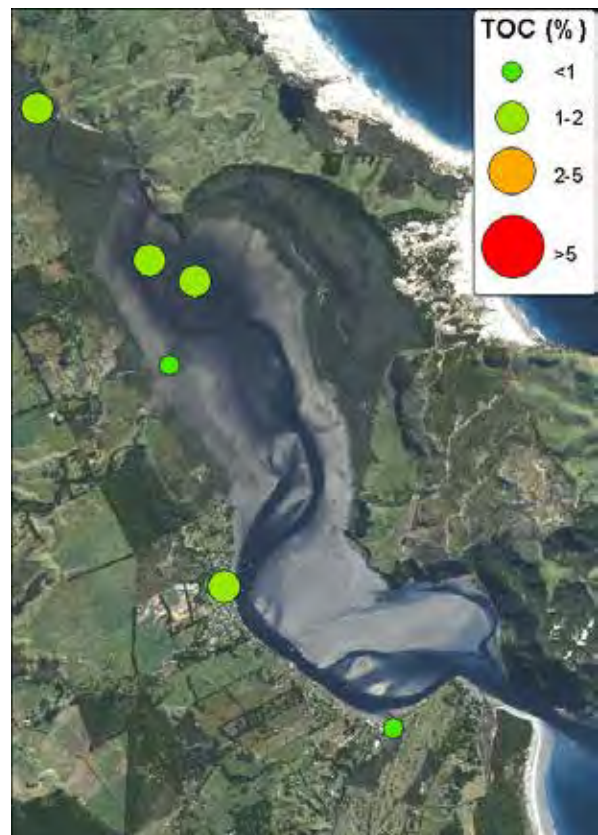


Figure 32 Total Organic Carbon levels in sediment (%) in Houhora Harbour.

3.4 Rangaunu Harbour

3.4.1 Water Quality

Physical Parameters

Table 18. Range and median values for salinity, dissolved oxygen (DO), turbidity and suspended solids (SS) in Rangaunu Harbour.

	Salinity	DO (g/m ³)	DO (%)	Turbidity (NTU)	SS (g/m ³)
ANZECC trigger value	No limit	<5	80-110	10	No limit
Median	33.25	7.185	99	3	8.9
Range	26.5-34.6	6.15-8.06	82.6-110	0.65-12	0.8-28
% of sites within trigger values	NA	100	100	90	NA

The rain gauge at Kaitia airport is 18 km away by road to Unahi at Rangaunu Harbour. Rangaunu was sampled on 29 January 2013 with 0mm falling on the day of sampling. Total rainfall for the 30 days prior to sampling was 39.2mm with the largest event being 35mm on 30 December 2012. Salinity had a median of 33.25 and a range of 26.5-34.6 indicating that freshwater input was limited at time of sampling. The highest salinity reading was at the upper Mangatete River whilst the lowest reading was at Awanui River. These sites are both inland and near to freshwater inputs.

In Table 18 the percentage of sites within the trigger value for dissolved oxygen (g/m³ and % saturation) was 100%. At all sites readings taken were within guideline values for these parameters. Turbidity had 90% of sites with readings within the trigger value. Figure 33 shows that at all sites (except for Waimanoni Creek) values for turbidity were within the ANZECC guideline of 10 NTU. The lowest reading of turbidity was 0.65 NTU at Waiparera Creek and the highest reading was 12 NTU at Waimanoni Creek. Suspended solids had the highest reading at Waimanoni Creek and the lowest reading at Wairakia Point. Waimanoni Creek was therefore highest for turbidity and suspended solids.

Microbial Parameters

Microbial factors were not reported for Rangaunu Harbour as samples were not sent to an ISO accredited laboratory.

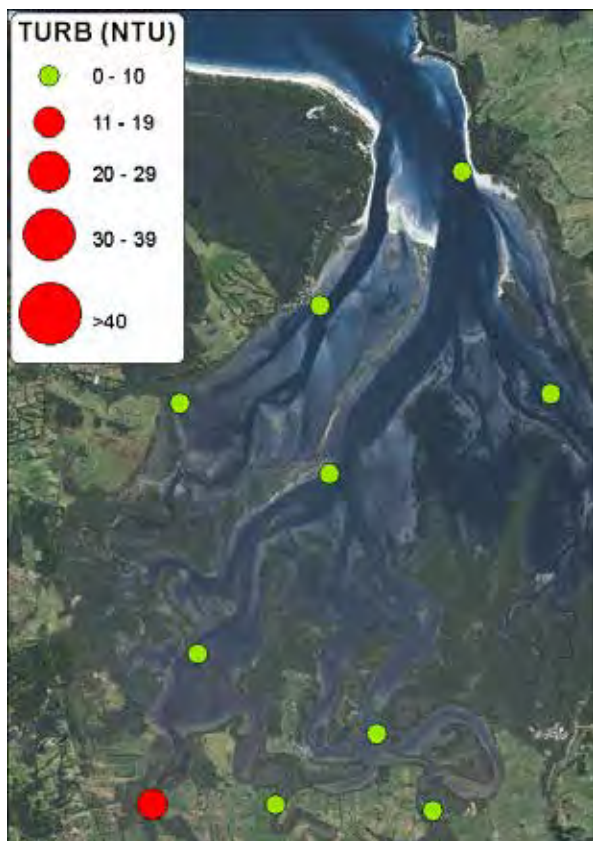


Figure 33 Turbidity levels (NTU)

Water Nutrient Parameters

Water nutrient parameters were not reported for Rangaunu Harbour as samples were not sent to an ISO accredited laboratory.

3.4.2 Sediment Quality

Grain Size Analysis

The classification of grain size as shown in Figure 34 follows the change in grain size from the harbour entrance to the upper harbour. As we move further into the harbour the percentage of grains 63-250µm stays relatively steady with small increases in the percentage of fine mud (grain size <63µm). The upper Mangatete River displays the largest percentage of grains sized 250-500µm.

Sediment Nutrients

Using the guidelines by Robertson and Stevens (2007) total nitrogen, total phosphorus and total organic carbon have been classified (Figures 35-37). In Table 19 the range and mean of each sediment nutrient tested has been tabulated.

Table 19. Range and mean sediment nutrients concentrations in Rangaunu Harbour.

	NH ₄ (mg/kg)	NNN (mg/kg)	TN (mg/kg)	TP (mg/kg)	TOC (%)
Mean	20.1	0.275	318	122	0.762
Range	5.8-57	0.04-0.41	64-920	24-360	0.2-2.2

From Figures 35-37 we can identify areas where sediment nutrients are 'very good' and other areas where they are 'enriched'.

Ammonium (NH₄) had the highest value at the Mangatete beacon and the lowest value at the upper Mangatete River. NNN had the highest value at Wairakia Point and the lowest value at the lower Mangatete River.

Total nitrogen (TN) (Figure 35) had a range of 64 to 920 mg/kg with the lowest value being at the upper Mangatete River. The highest value was 920 mg/kg which was recorded at Waimanoni Creek. Three sites were classed as 'low to moderately enriched'; Waimanoni Creek, the lower Mangatete River and Wairakia Point. The remaining six sites were rated as 'very good'.

Total phosphorus (TP) (Figure 36) had a range of 24 to 360 mg/kg with the lowest value being at Wairakia Point. The highest value was at Waimanoni Creek which was rated as 'low to moderately enriched' along with Awanui River and the lower Mangatete River. All other sites were rated as 'very good' (<200 mg/kg).

Total organic carbon (TOC) (figure 37) had a range of 0.2 to 2.2%. The lowest reading was 0.2% at Wairakia Point. The highest value was 2.2% at Waimanoni Creek which came under the rating of 'enriched'. Two sites were rated as 'low to moderately enriched'; lower Mangatete River and the Awanui River. Seven sites were classed as 'very good'; with TOC values under 1%.

Waimanoni Creek had the highest readings for TN, TP and TOC and one of the higher readings for percentage of 'Mud' (Figure 37)

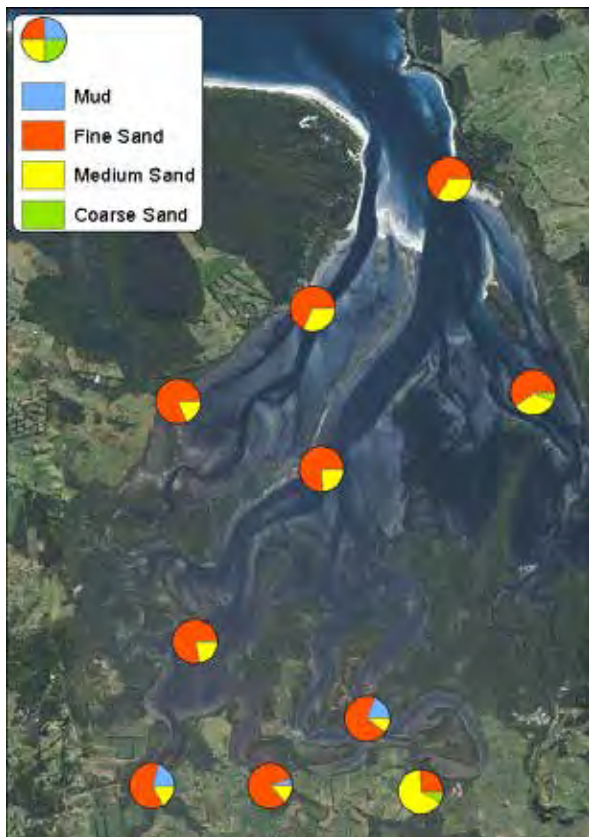


Figure 34 Grain size for sediment samples taken from Rangaunu Harbour.

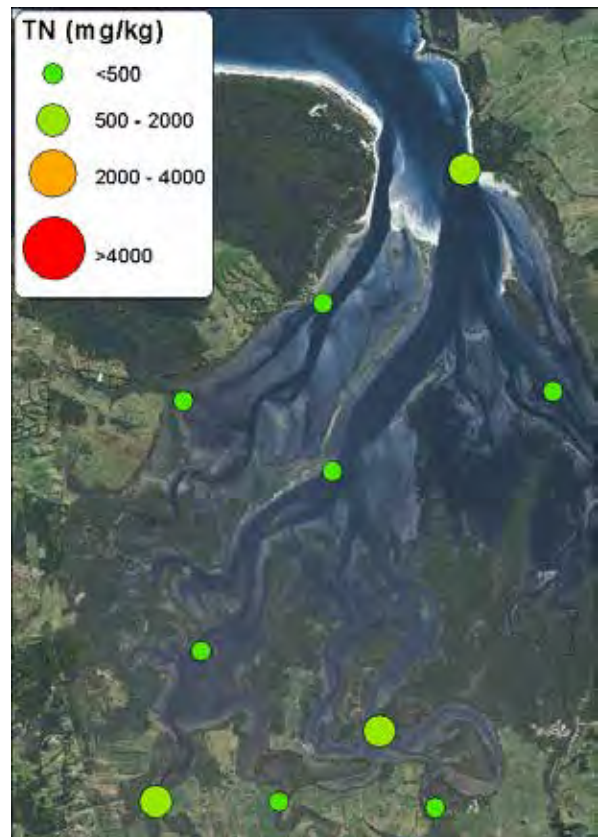


Figure 35 Total nitrogen concentration in sediment (mg/kg) in Rangaunu Harbour.

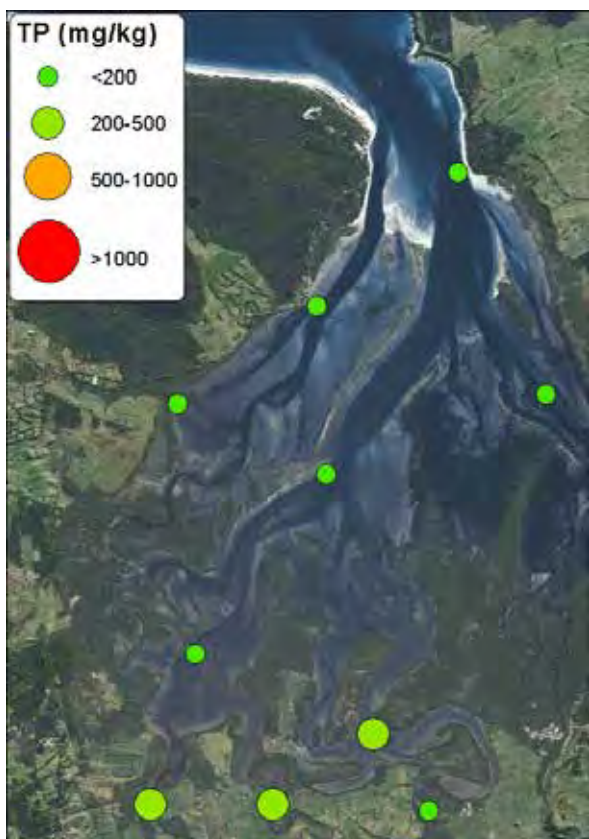


Figure 36 Total phosphorus concentration in sediment (mg/kg) in Rangaunu Harbour.

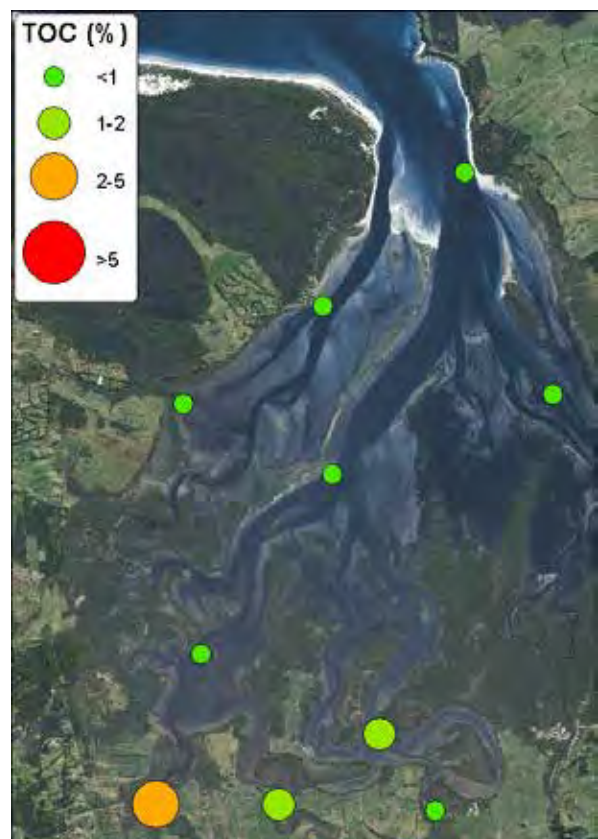


Figure 37 Total Organic Carbon levels in sediment (%) in Rangaunu Harbour.

3.5 Taipa/Mangonui Harbour

3.5.1 Water Quality

Physical Parameters

Table 20. Range and median values for salinity, dissolved oxygen (DO), turbidity and suspended solids (SS) in the Taipa River/Mangonui Harbour.

	Salinity	DO (g/m ³)	DO (%)	Turbidity (NTU)	SS (g/m ³)
ANZECC trigger value	No limit	5	80-110	10	No limit
Median	32.3	6.98	96.1	0.675	3.4
Range	28-34.5	6.65-7.09	91.5-97.6	0.4-1	2.1-12
% of sites within trigger values	NA	100	100	100	NA

The rain gauge for Taipa/Mangonui is located at the upper end of Oruru/Taipa River. Taipa River/Mangonui Harbour was sampled on 14 February 2013 with 0mm falling that day. For the previous 30 days 17mm had been recorded with the largest rainfall event being 9.5mm on 4 February 2013. Salinity was fairly high with a range of 28-34.5, indicating little freshwater input at time of sampling. The lowest salinity reading was at Oparihi and the highest reading was the lower Taipa River.

In Table 20 the percentage of sites within the trigger value for dissolved oxygen (g/m³ and % saturation) and turbidity was 100%. At all sites readings taken were within guideline values for these parameters. Figure 38 shows that at all sites values for turbidity were within the ANZECC guideline of 10 NTU. The lowest reading of turbidity was 0.4 NTU at the lower Taipa River and the highest reading was 1 NTU at Oparihi which has a direct inverse relationship to salinity. The lowest reading for suspended solids was at the harbour entrance and the highest reading was at Oruaiti River.

Microbial Parameters

Table 21. Range and median concentrations of enterococci (ENT) and faecal coliforms (FC) in Taipa River/Mangonui Harbour.

	ENT (MPN/100ml)	FC (CFU/100ml)
MfE trigger value	140	150
Median	0.85	0.85
Range	0.85-3.3	0.85-6.7
% of sites within trigger values	100	100

Micro bacterial factors tested returned results within MfE guidelines (Table 21). At all sites across Mangonui Harbour and Taipa River the values for enterococci and faecal coliforms were within the guideline values and ranged from 0.85 to 3.3 (MPN/100ml) for enterococci and 0.85 to 6.7 (CFU/100ml) for faecal coliforms. Because values were typically low no spatial pattern was identified. This can be seen in Figure 40 for enterococci values.

Water Nutrient Parameters

Table 22. Range and median in water nutrient concentrations in the Taipa River/Mangonui Harbour.

	Chl a (g/m ³)	NH ₄ (g/m ³)	NNN (g/m ³)	TN (g/m ³)	DRP (g/m ³)	TP (g/m ³)
ANZECC trigger value	0.004	0.015	0.015	0.3	0.005	0.03
Median	0.00099	0.0105	0.0035	0.01	0.007	0.0095
Range	0.0003-0.002	0.0025-0.024	0.002-0.0058	0.01-0.36	0.005-0.009	0.008-0.016
% of sites within trigger values	100	66	100	100	0	100

Nutrient levels for chlorophyll a (Chl a), nitrite-nitrate nitrogen (NNN), total phosphorus (TP) and total nitrogen (TN) all had 100% of sites within the trigger value in Taipa River and Mangonui Harbour. Ammonium (NH₄) had 66% of sites within the trigger value (Table 22). Dissolved reactive phosphorus had 0% of sites within the trigger value meaning all sites were outside of the 0.005 g/m³ value.

Chlorophyll a had a range of 0.0003 to 0.002 g/m³ with all sites being within the trigger value of 0.004 g/m³. Nitrite-nitrate nitrogen (NNN) had a range of 0.006-0.014 g/m³ with no sites reaching the trigger value. Total phosphorus had a range of 0.008 to 0.0016 g/m³, no values were outside of the trigger value. Total nitrogen had a range of 0.01 to 0.36 g/m³ with no sites reaching the 0.3 g/m³ guideline value.

Figure 41 shows that ammonium levels for all sites are within guideline values except for Oparihi and Oruaiti River. Oruaiti River had the highest reading of 0.024 g/m³. The next highest reading was 0.018 g/m³ at Oparihi. Both these sites are the most inner sites taken from Mangonui Harbour. All other sites were within the trigger value.

Dissolved reactive phosphorus had a median value of 0.007 g/m³ which is outside of the guideline value of 0.005 g/m³. The range of 0.005 to 0.009 g/m³ means that no sites were within the guideline values for DRP in Taipa River and Mangonui Harbour. In Figure 39 all sites are red as they are outside of the guideline and the largest value is that of 0.009 (g/m³) at the mid harbour point in Mangonui Harbour.

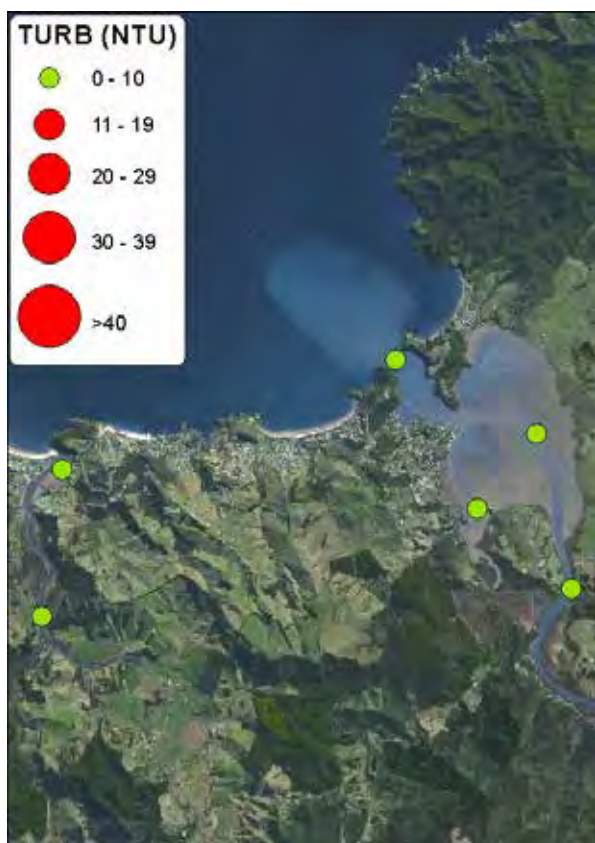


Figure 38 Turbidity levels (NTU) in Taipa River/Mangonui Harbour.

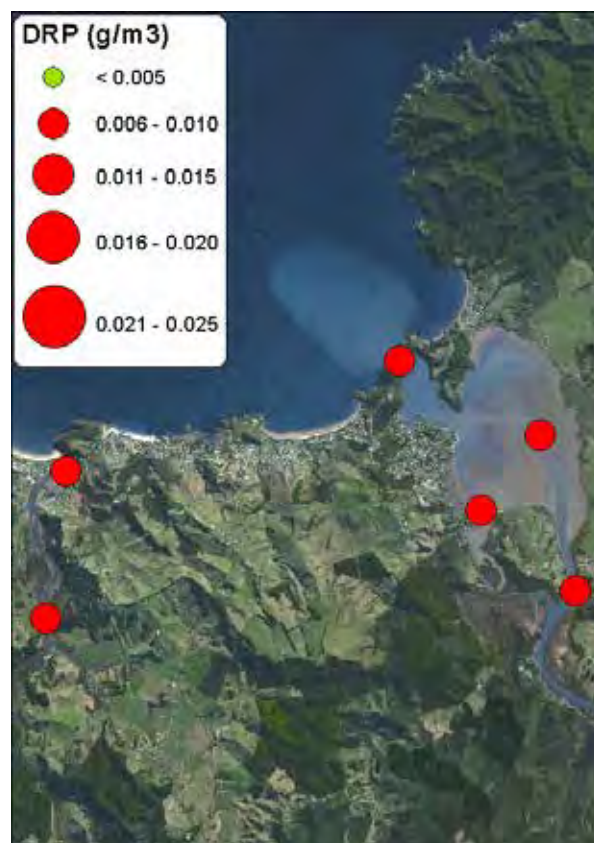


Figure 39 Dissolved reactive phosphorus (g/m³) in Taipa River/Mangonui Harbour.

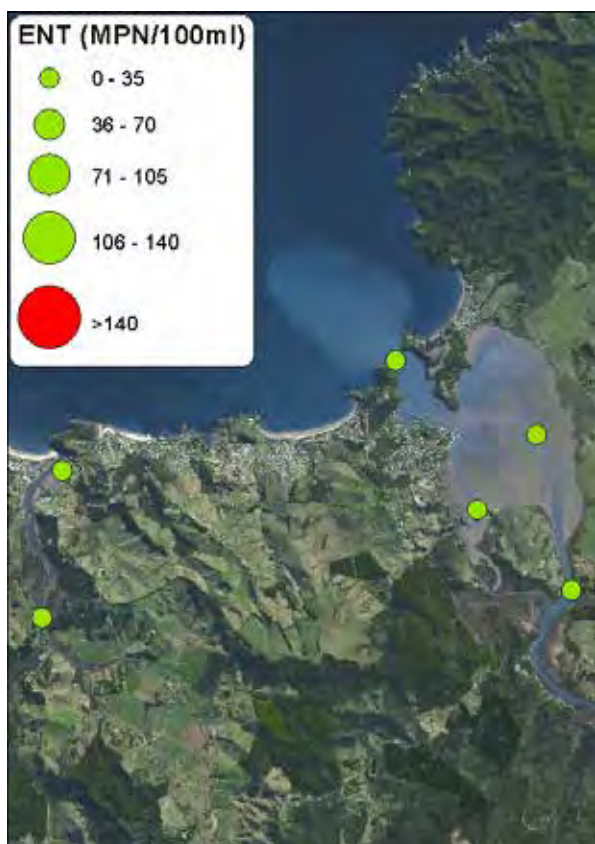


Figure 40 Enterococci levels (MPN/100ml) in Taipa River/Mangonui Harbour.

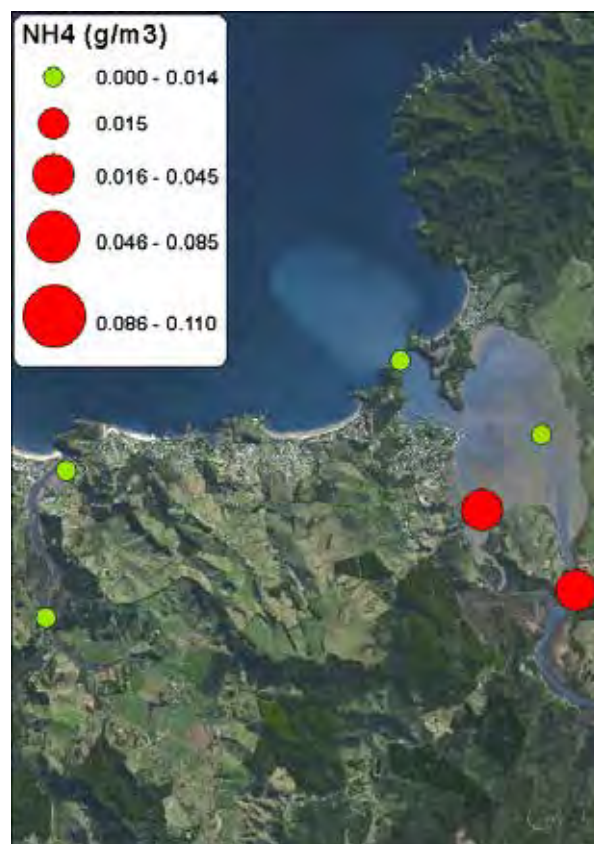


Figure 41 Ammonium (NH₄) levels (g/m³) in Taipa River/Mangonui Harbour.

3.5.2 Sediment Quality

Grain Size Analysis

The classification of grain size as shown in Figure 42 follows the change in grain size from the harbour entrance to the upper harbour. The harbour entrance had almost 100% mud and the largest profile of coarse sand is found in the upper harbour at Oruaiti River. At the lower Taipa River the sample contained a larger percentage of grains sized 63-250µm (fine sand). The lower Taipa River sample was taken on the fringe of the pipi beds that occupy a large expanse of the river mouth.

Sediment Nutrients

Using the guidelines by Robertson and Stevens (2007) total nitrogen, total phosphorus and total organic carbon have been classified (Figures 43-45). In Table 23 the range and mean of each sediment nutrient tested has been tabulated.

Table 23. Range and mean sediment nutrients concentrations in Taipa River/Mangonui Harbour.

	NH ₄ (mg/kg)	NNN (mg/kg)	TN (mg/kg)	TP (mg/kg)	TOC (%)
Mean	4.766	1.218	354	490	1.931
Range	2.9-8.5	0.32-3.8	59-900	280-710	1.18-2.5)

Ammonium (NH₄) had the highest value at the mid harbour point and the lowest value at the lower Taipa River. NNN had the highest value at the harbour entrance and the lowest point also at the lower Taipa River.

From figures 43-45 we can identify areas where sediment nutrients are 'very good' and other areas where they are 'enriched'.

Total nitrogen (TN) (Figure 43) had a range of 59 to 900 mg/kg. The highest value of 900 mg/kg was at the lower Taipa River and the lowest value of 59 mg/kg at the Oruaiti River. Five sites were rated as 'very good' whilst the highest value from the lower Taipa River was rated as 'low to moderately enriched'.

Total phosphorus (TP) (Figure 44) had a range of 280 to 710 mg/kg. The lowest value was at Oruaiti River. The highest value was at Oparihi which was rated as 'enriched' along with the harbour entrance and the lower Taipa River. All other sites were rated as 'low to moderately enriched', and were all in the inner Mangonui Harbour or upper Taipa River.

Total organic carbon (TOC) (Figure 45) had a range of 1.18 to 2.53%. The lowest reading was 1.18% at Oruaiti River (inner harbour point). The highest value was 2.58% at Oparihi which came under the rating of 'enriched' along with the mid harbour point and the lower Taipa River. The remaining three sites were rated as 'low to moderately enriched'.

Oruaiti River had the lowest values for TN, TP and TOC. Oruaiti River also had the highest percentage of 'Coarse sand' with almost no 'Fine sand'.

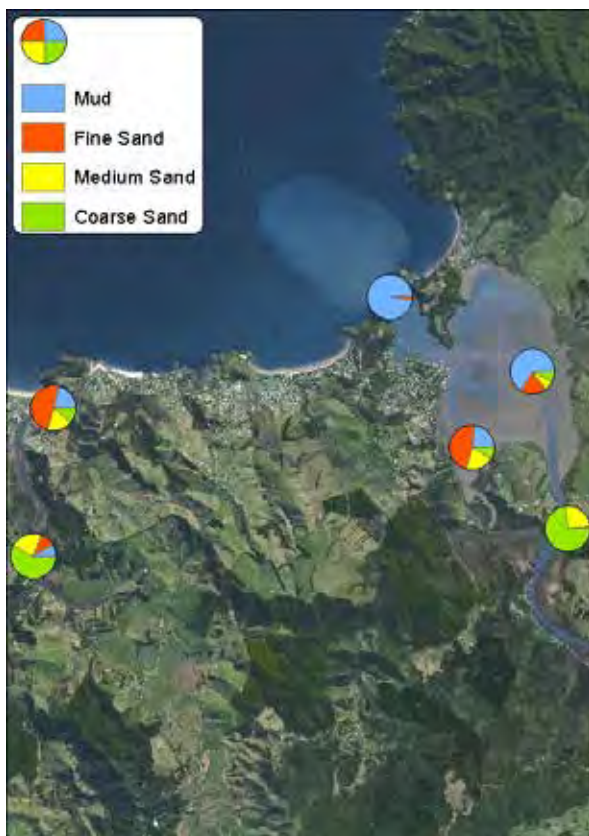


Figure 42 Grain size for sediment samples taken from Taipa River/Mangonui Harbour.

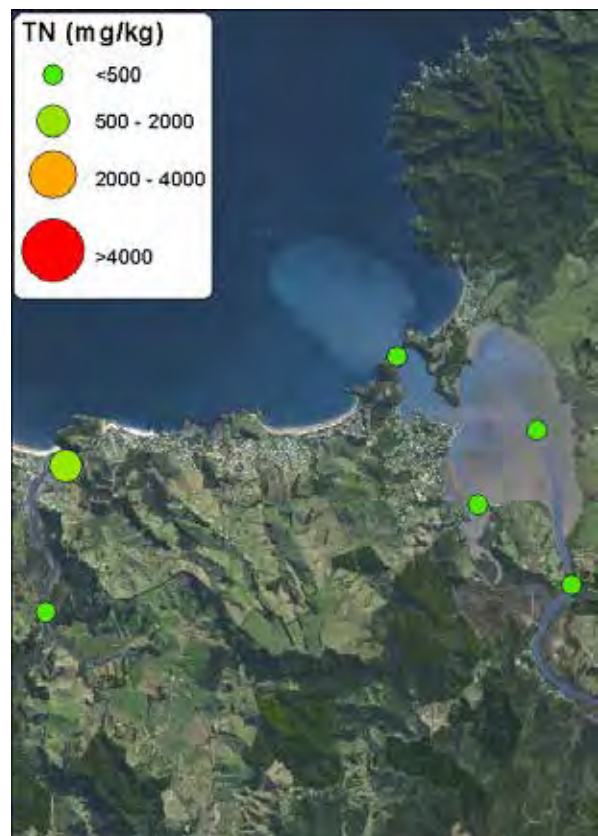


Figure 43 Total nitrogen concentration in sediment (mg/kg) in Taipa River/Mangonui Harbour.

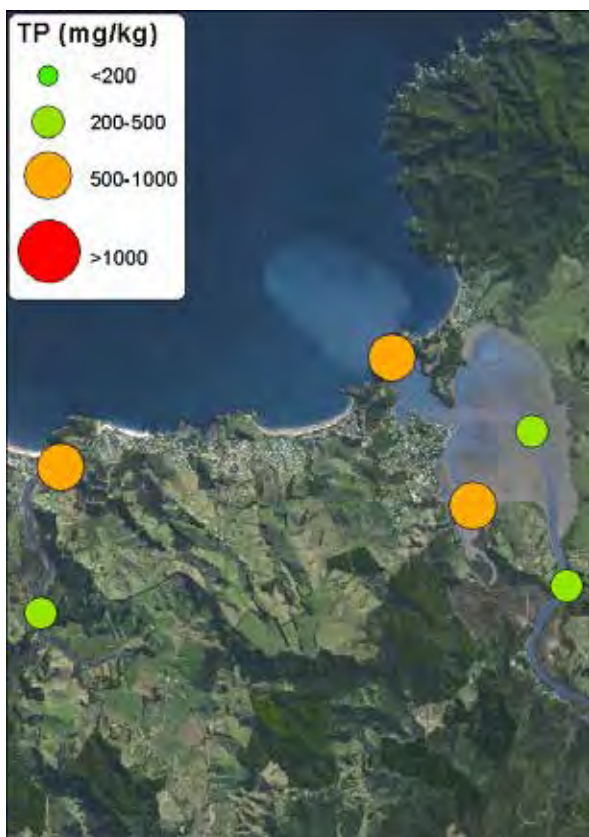


Figure 44 Total phosphorus concentration in sediment (mg/kg) in Taipa River /Mangonui Harbour.

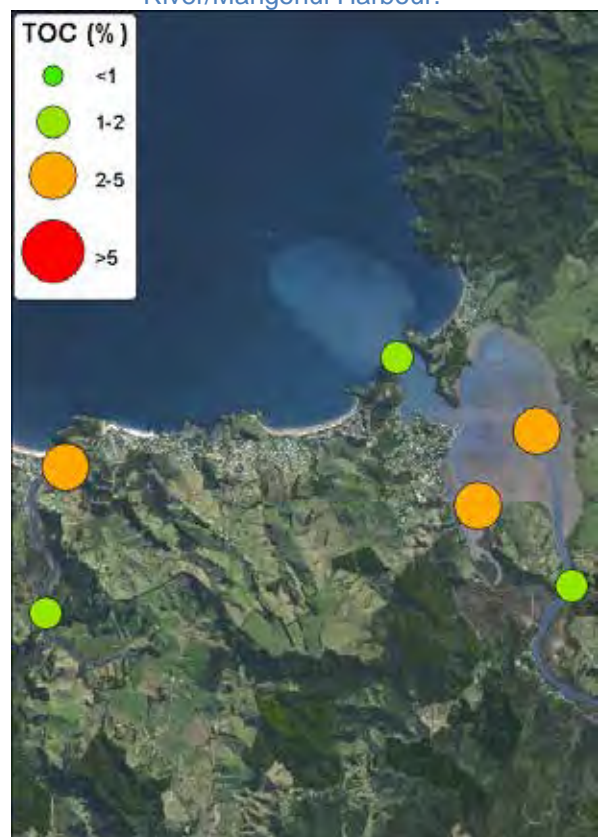


Figure 45 Total Organic Carbon levels in sediment (%) in Taipa River/Mangonui Harbour.

3.6 Whangaroa Harbour

3.6.1 Water Quality

Physical Parameters

Table 24. Range and median values for salinity, dissolved oxygen (DO), turbidity and suspended solids (SS) in Whangaroa Harbour.

	Salinity	DO (g/m ³)	DO (%)	Turbidity (NTU)	SS (g/m ³)
ANZECC trigger value	No limit	<5	80-110	10	No limit
Median	34.35	6.92	95.4	1.5	8.9
Range	33-34.5	6.3-7.47	87.9-102.1	0.3-3.6	1.5-19
% of sites within trigger values	NA	100	100	100	NA

On the day of sampling (14 February 2013) no rainfall was recorded at the Kaeo rain gauge. Prior to sampling the last rainfall event was on 4 February 2013 when 20.5mm fell. During the 30 days prior to sampling 41mm of rain fell at Kaeo. Salinity was fairly high with a narrow range of 33 to 34.6 (ppt), indicating little freshwater input at time of sampling. Because of the narrow range no spatial pattern was apparent for salinity.

In Table 24 the percentage of sites within the trigger value for dissolved oxygen (g/m³ and % saturation) and turbidity was 100%. Figure 46 shows that at all sites values for turbidity were within the ANZECC guideline of 10 NTU. The lowest reading of turbidity was 0.3 NTU at the harbour entrance and the highest reading was 3.6 NTU at Iwiatua Stream. Suspended solids had a range of 1.5 to 19 g/m³ and a median of 8.9 g/m³, the lowest reading was at the harbour entrance and the highest reading was at Waitapu Bay and Iwiatua Stream. The spatial pattern for turbidity and suspended solids was therefore the same.

Microbial Parameters

Table 25. Range and median concentrations of enterococci (ENT) and faecal coliforms, (FC) in Whangaroa Harbour.

	ENT (MPN/100ml)	FC (CFU/100ml)
MfE guideline	140	150
Median	0.85	0.85
Range	(0.85-1.7)	(0.85-1.7)
% of sites within trigger values	100	100

Micro bacteria factors tested returned results within MfE guidelines (Table 25). At all sites across Whangaroa Harbour the values for enterococci and faecal coliforms were within the guideline values and ranged from 0.85 to 1.7 (MPN/100ml) for enterococci and 0.85 to 1.7 (CFU/100ml) for faecal coliforms. Because values were typically low no spatial pattern was identified. This can be seen in Figure 47 for enterococci values.

Water Nutrient Parameters

Table 26. Range and median in water nutrient concentrations in Whangaroa Harbour.

	Chl a (g/m ³)	NH ₄ (g/m ³)	NNN (g/m ³)	TN (g/m ³)	DRP (g/m ³)	TP (g/m ³)
ANZECC trigger value	0.004	0.015	0.015	0.3	0.005	0.03
Median	0.0018	0.00985	0.0038	0.01	0.006	0.011
Range	0.0007-0.003	0.0025-0.018	0.001-0.01	0.01-0.032	0.0025-0.009	0.0025-0.019
% of sites within trigger values	100	62.5	100	100	12.5	100

For all sites within Whangaroa Harbour values for chlorophyll a (Chla), nitrite-nitrate nitrogen (NNN) total phosphorus (TP) and total nitrogen (TN) all had 100% within the trigger value. Dissolved reactive phosphorus had a compliance of 12.5% meaning seven out of eight sites were outside of the 0.005 g/m³ guideline. Ammonium (NH₄) had 71% of sites within trigger values (Table 26).

Chlorophyll a (Chla) had a range of 0.0007 to 0.003 g/m³ with all sites being within the guideline value of 0.004 g/m³. Nitrite-nitrate nitrogen (NNN) had a range of 0.001 to 0.01 g/m³ with no sites outside of the guideline values. Total nitrogen had a range of 0.01 to 0.32 g/m³ with no sites outside of the 0.3 g/m³ guideline value.

Figure 49 shows that ammonium levels for all sites are within guideline values except for three sites; Lane Cove, Touwai Bay and Kaeo River mouth. The largest reading was 0.018 g/m³ at Touwai Bay. The remaining four sites were all within the guideline value with three sites reading within the minimum detection level (Waitapu Bay, the harbour entrance and St Peters mid channel).

Dissolved reactive phosphorus had a median value of 0.006 g/m³ which is outside of the guideline value of 0.005 g/m³. Out of the eight sites sampled only the harbour entrance was within the guideline limit with the lowest value of 0.0025 g/m³. In Figure 48 only the harbour entrance point is depicted in green whilst all other sites are in red. The largest value was 0.009 g/m³ at Waitapu Bay.

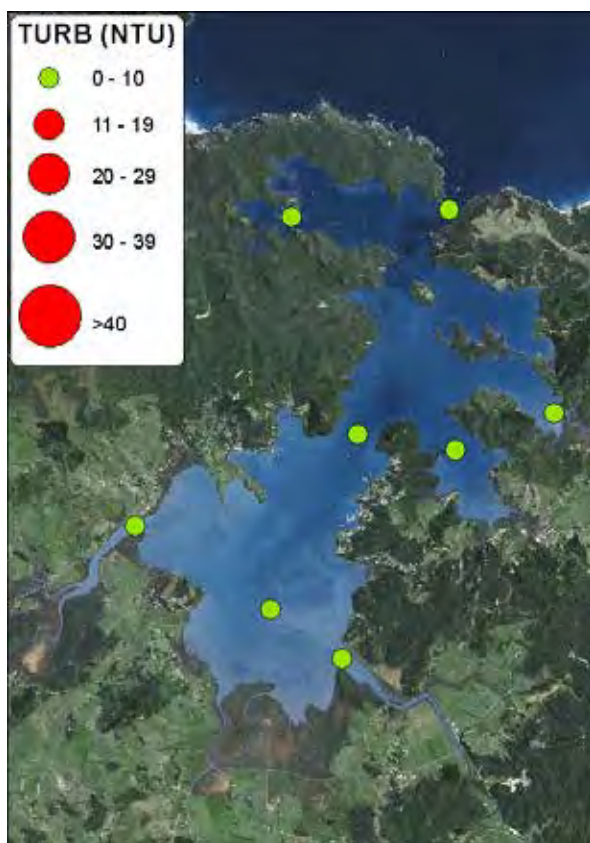


Figure 46 Turbidity levels (NTU) in Whangaroa Harbour.

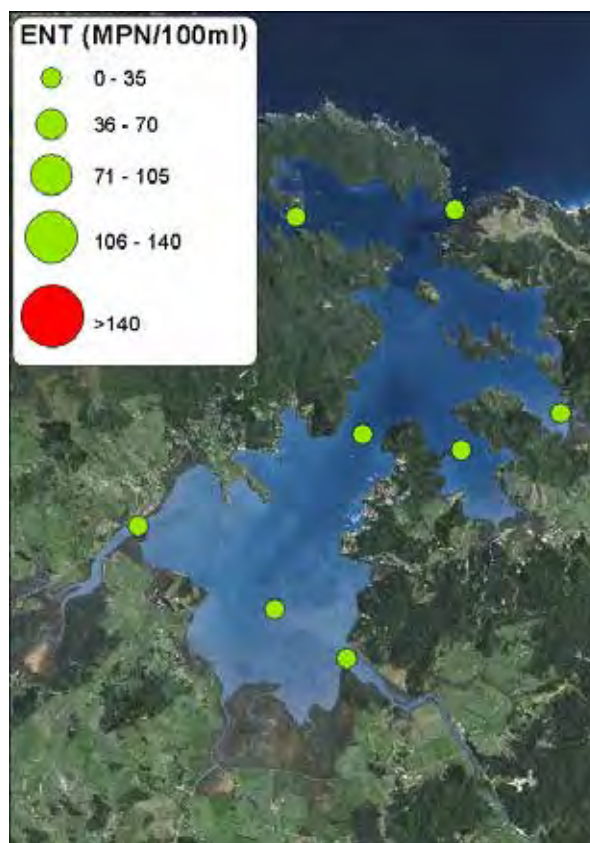


Figure 47 Enterococci levels (MPN/100ml) in Whangaroa Harbour.

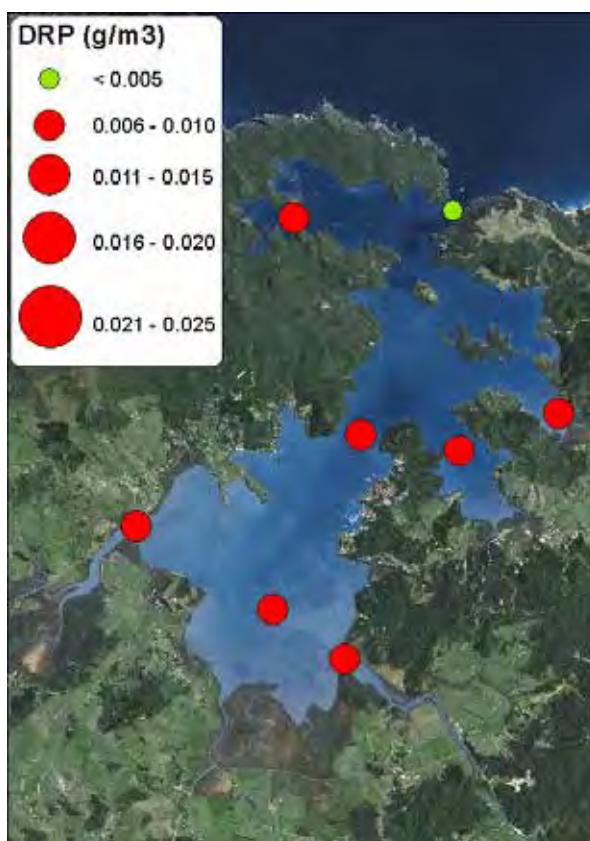


Figure 48 Dissolved reactive phosphorus (g/m^3) in Whangaroa Harbour.

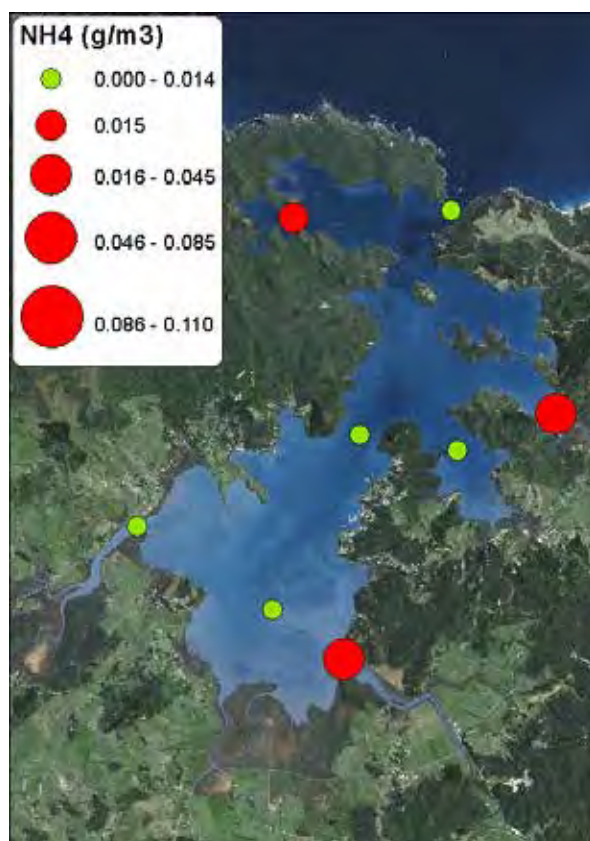


Figure 49 Ammonium (NH_4) levels (g/m^3) in Whangaroa Harbour.

3.6.2 Sediment Quality

Grain Size Analysis

The classification of grain size as shown in Figure 50 follows the change in grain size from the harbour entrance to the upper harbour. A small amount of sediment was collected from the harbour entrance which was used for grain size analysis. The sample was mostly shell hash which is reflected in the grain profile with 30% of the sample being grains sized 500-2000µm. For points Lane Cove, Waitapu Bay, Touwai Bay and St Peters mid channel grains sized <63µm (Mud) were >80% of the profile. The high percentage of large grains at the Kaeo River mouth may be due to gravel fractions from the nearby road.

Sediment Nutrients

Using the guidelines by Robertson and Stevens (2007) total nitrogen, total phosphorus and total organic carbon have been classified (Figures 51-53). In Table 27 the range and mean of each sediment nutrient tested has been tabulated.

Table 27. Range and mean sediment nutrients concentrations in Whangaroa Harbour.

	NH ₄ (mg/kg)	NNN (mg/kg)	TN (mg/kg)	TP (mg/kg)	TOC (%)
Mean	2.544	0.988	800	518	3.3
Range	(0.51-4.45)	(0.31-1.7)	(130-1600)	(390-710)	(1.26-6.04)

Sediment samples for nutrients from the harbour entrance could not be collected at the time of sampling. Ammonium (NH₄) had the highest value at Waitapu Bay and the lowest value at Touwai Bay. For NNN the highest value was at St Peters mid channel point and the lowest value at Kaeo River mouth.

From Figures 51-53 we can identify areas where sediment nutrients are classified as 'very good' and other areas where they are classified as 'enriched'.

Total nitrogen (TN) (Figure 51) had a range of 130 to 1600 mg/kg. The highest value of 1600 mg/kg was at Lane Cove and the lowest value of 130 mg/kg was at the southern end point. Three sites were rated as 'very good' and the remaining four sites were rated as 'low to moderately enriched'.

Total phosphorus (TP) (Figure 52) had a range of 390 to 710 mg/kg with the lowest value being at Kaeo River mouth. The highest value was at St Peters mid channel which was rated as enriched along with Lane Cove and Touwai Bay. The other four sites were rated as 'low to moderately enriched'.

Total organic carbon (TOC) (Figure 53) had a range of 1.26 to 6.04%. The lowest reading was 1.26% at the Kaeo River mouth which was rated as 'low to moderately enriched'. The highest value was 6.04% at Lane Cove which came under the rating of 'enriched'. The remaining five sites were rated as 'enriched'.

Spatial patterns appear to be inconsistent and as salinity had a narrow range we cannot use this to explain our results. Grain profiles for Lane Cove, Waitapu Bay, Touwai Bay and St Peters mid channel had the largest percentage of 'mud' in Whangaroa Harbour.

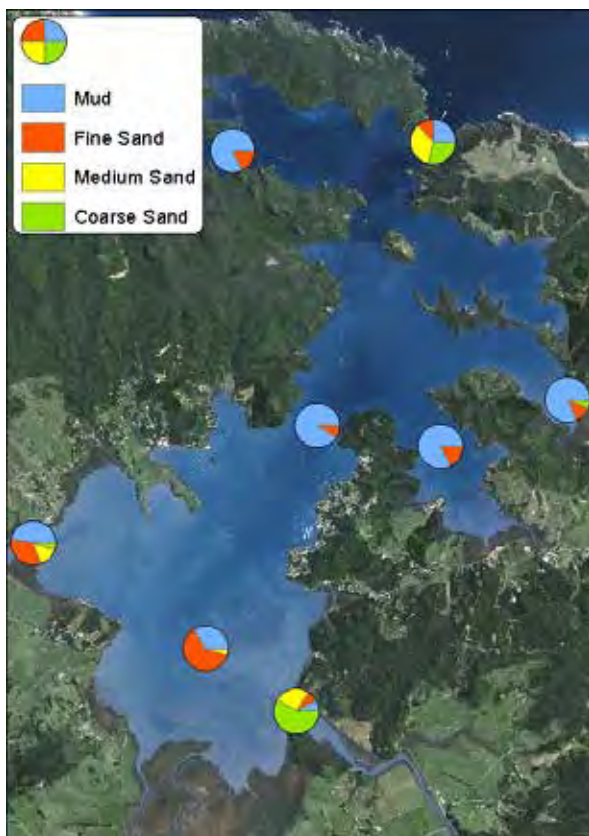


Figure 50 Grain size for sediment samples taken from Whangaroa Harbour

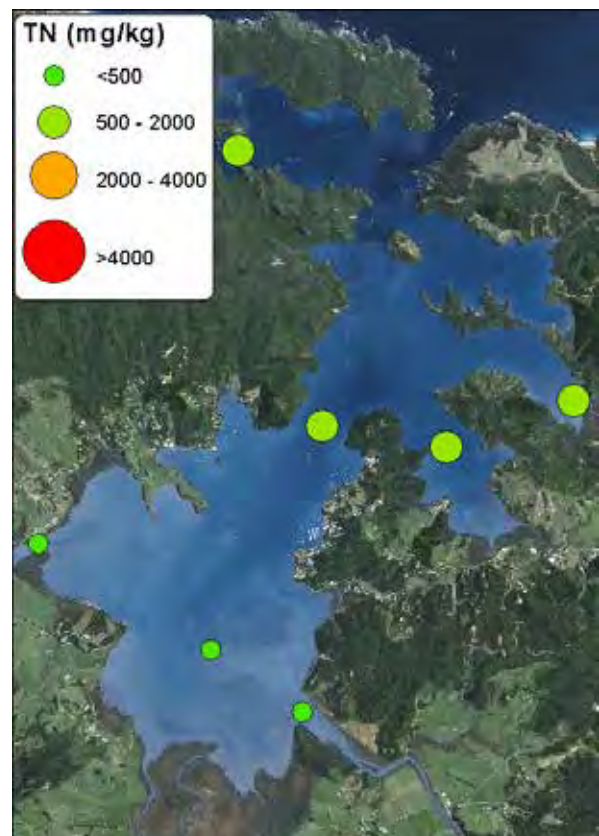


Figure 51 Total nitrogen concentration in sediment (mg/kg) in Whangaroa Harbour.

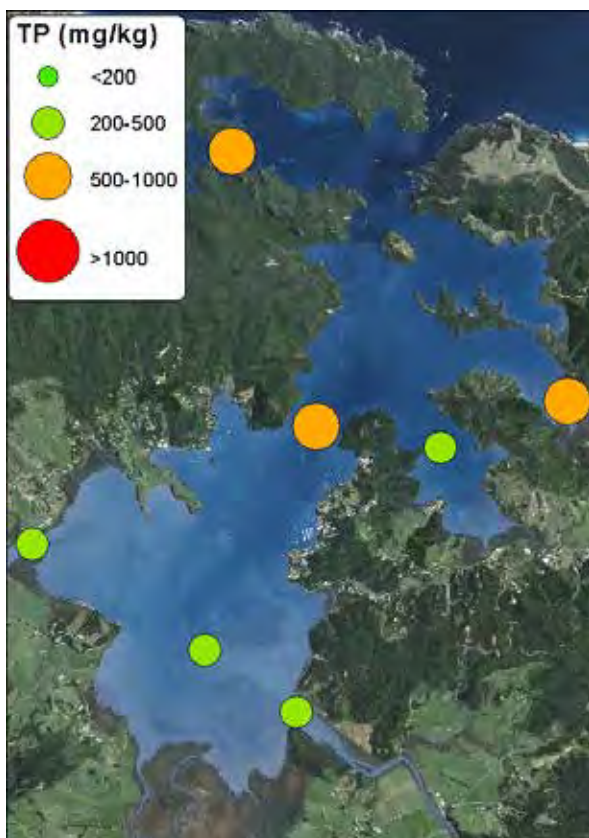


Figure 52 Total phosphorus concentration in sediment (mg/kg) in Whangaroa Harbour.

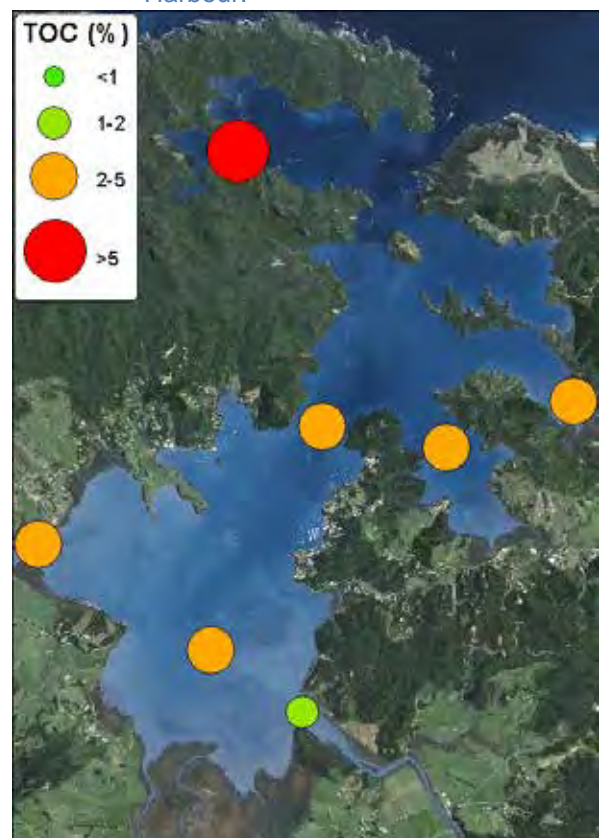


Figure 53 Total Organic Carbon levels in sediment (%) in Whangaroa Harbour.

3.7 Hokianga Harbour

3.7.1 Water Quality

Physical Parameters

Table 28. Range and median values for salinity, dissolved oxygen (DO), turbidity (TURB) and suspended solids (SS) in the Hokianga Harbour.

	Salinity	DO (g/m ³)	DO (%)	TURB (NTU)	SS (g/m ³)
ANZECC trigger value	No limit	<5	80-110	10	No limit
Median	28.35	6.87	94.45	17.35	29.5
Range	13.6-33.8	5.93-8.02	80-106.8	1.95-40.4	15-69
% of sites within trigger values	NA	100	100	18	NA

Hokianga rainfall data was collected from the Opononi rainfall gauge. On the day of sampling (15 January 2013) 1mm fell. Prior to sampling the last rainfall event was 11.5mm on 3 January 2013. For the 30 day period prior to sampling a total of 105mm had fallen. Salinity had a large range of 13.6 to 33.8 (ppt) with the lowest reading being at the upper Mangamuka River and the highest reading at the harbour entrance.

In Table 28 the percentage of sites within the trigger value for dissolved oxygen (g/m³ and % saturation) was 100%. Figure 54 shows that turbidity readings were inside trigger values at 18% of sites. Values at all sites except the two sites nearest to the harbour entrance had values outside of the trigger value of 10 NTU. The median for turbidity was also above the guideline at 17.35 NTU. The highest reading was 40.4 NTU at Orira River and the lowest reading was that of 1.95 NTU at the harbour entrance. The highest reading for suspended solids was also at Orira River and the lowest reading at Kawehitiki Point (which is close to the harbour entrance). Suspended solids showed a similar spatial pattern to turbidity.

Microbial Parameters

Table 29. Range and median concentrations of enterococci (ENT) and faecal coliforms (FC) in the Hokianga Harbour.

	ENT (MPN/100ml)	FC (CFU/100ml)
MfE trigger value	140	150
Median	5	2
Range	(5-41)	(1-42)
% of sites within trigger values	100	100

Micro bacteria factors tested returned results within MfE guidelines (Table 29). The total range was from 5 to 41 MPN/100ml for enterococci and 1 to 41 CFU/100ml for faecal coliforms. From Figure 55 eight of eleven sites enterococci levels were below detection limits (<5 MPN/100ml) and the remaining sites were within guideline values. The highest reading was 40 MPN/100ml at the upper Mangamuka at Tutekuha.

Water Nutrient Parameters

Table 30. Range and median nutrient concentrations in the Hokianga Harbour.

	Chl a (g/m ³)	NH ₄ (g/m ³)	NNN (g/m ³)	TN (g/m ³)	DRP (g/m ³)	TP (g/m ³)
ANZECC trigger value	0.004	0.015	0.015	0.3	0.005	0.03
Median	0.00645	0.0025	0.0094	0.375	0.0105	0.0185
Range	0.0003-0.02	0.0025-0.0095	0.006-0.014	0.01-0.33	0.005-0.013	0.005-0.026
% of sites within trigger values	27.3	100	100	91	0	100

Values for ammonium (NH₄), nitrate-nitrite nitrogen (NNN) and total phosphorus (TP) were all within the guideline levels with 100% of sites within the trigger values (Table 30). Chlorophyll a (Chla) and dissolved reactive phosphorus (DRP) had <30% of sites within trigger values, while total nitrogen (TN) had <95% of sites within trigger values.

Figure 56 shows that ammonium levels for all sites in the Hokianga Harbour were within the ANZECC guideline of (0.015 g/m³). Ammonium in the harbour ranged from 0.0025 to 0.0095 g/m³. The highest readings were 0.0095 g/m³ at Utakura River and 0.0055 g/m³ at Orira River (both sites in the upper harbour where salinity was low). Nine of the eleven readings were below the minimum detection rate (<0.005g/m³).

Nitrate-nitrite nitrogen (NNN) had a range of 0.006 to 0.014 g/m³ which is within the guideline value of 0.015 g/m³. This was also the case for total phosphorus which had a range of 0.005 to 0.026 g/m³ and a guideline level of 0.03 g/m³. Therefore all sites levels of TP and NNN were within the guideline levels.

Chlorophyll a had 27% of sites within the trigger value with eight sites outside the ANZECC guidelines. Chla ranged from 0.0003 to 0.022 g/m³ the lowest reading was at the harbour entrance and the highest reading was at the upper Mangamuka River. Total nitrogen had one site at Matawhera Point which was outside of guideline values with a reading of 0.33 g/m³.

Dissolved reactive phosphorus readings were outside of trigger values for all sites. In Figure 57 we can observe that dissolved reactive phosphorus levels were lowest at the three sites closest to the harbour entrance. The lowest reading was at the harbour entrance with a value of 0.005 g/m³. The highest readings were at Utakura River, Mangamuka River and Orira River which all had readings of 0.013 g/m³ (which are all sites in the upper harbour with lower salinity).

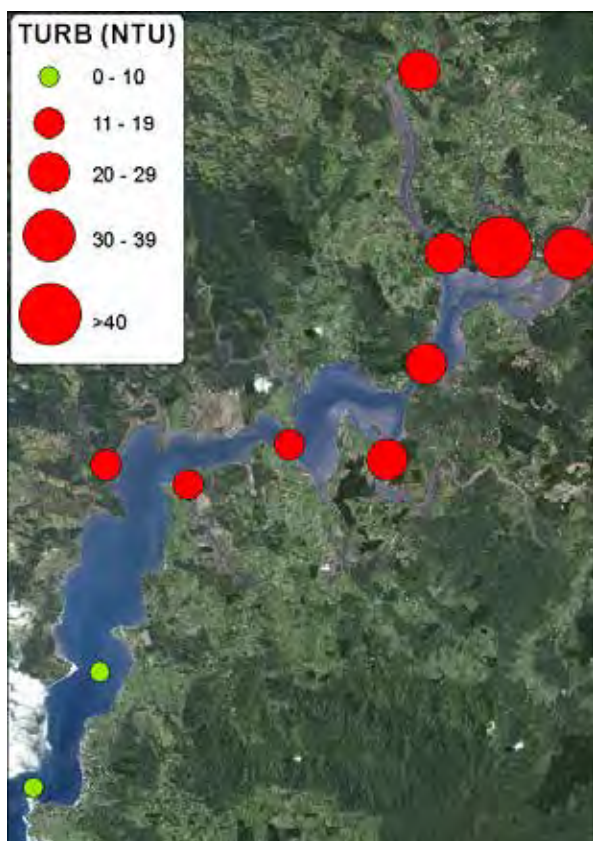


Figure 54 Turbidity levels (NTU) in Hokianga Harbour.

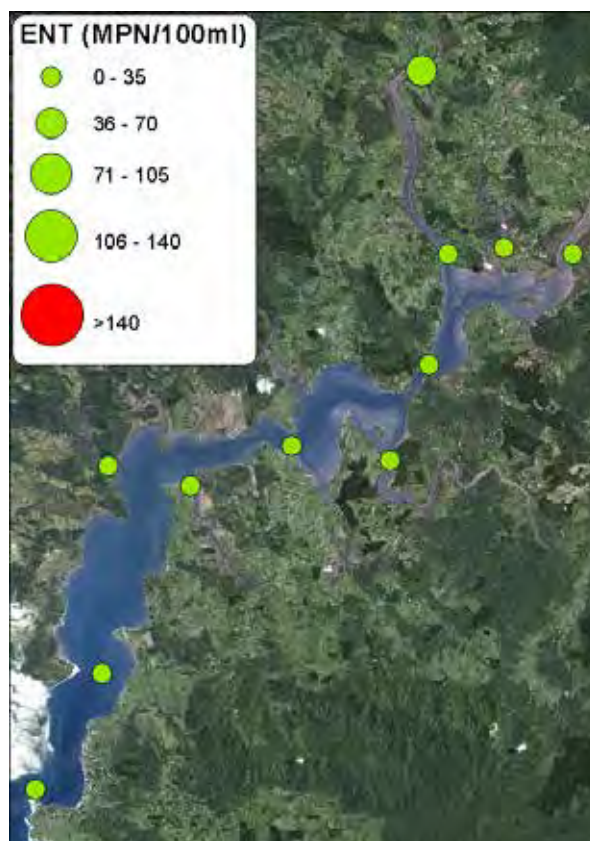


Figure 55 Enterococci levels (MPN/100ml) in Hokianga Harbour.

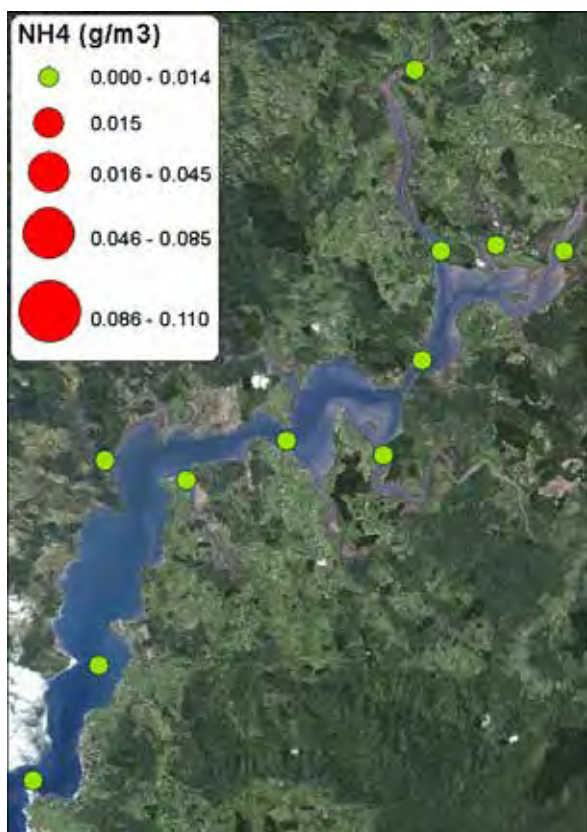


Figure 56 Ammonium (NH_4) levels (g/m^3) in Hokianga Harbour.

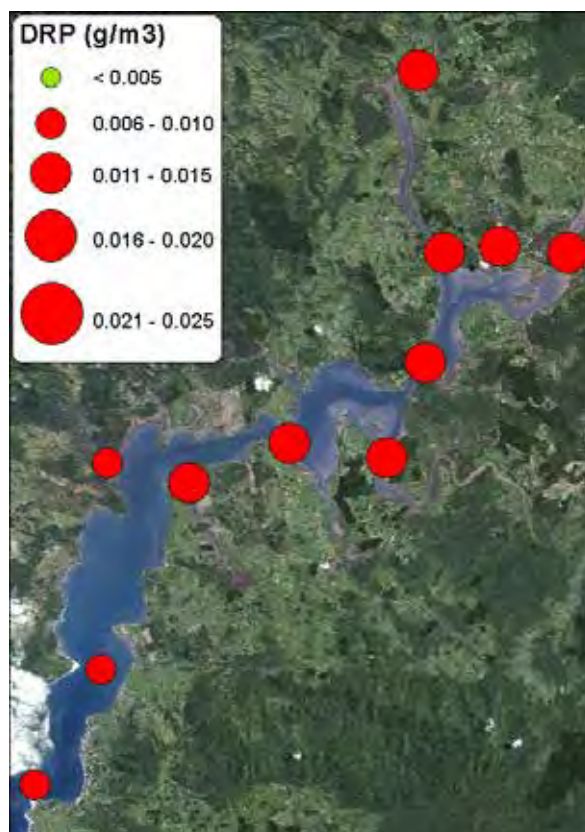


Figure 57 Dissolved reactive phosphorus (g/m^3) in Hokianga Harbour.

3.7.2 Sediment Quality

Grain Size Analysis

The classification of grain size as shown in Figure 58 follows the change in grain size from the harbour entrance to the upper Mangamuka River. At the harbour entrance and Kawehitiki Point the sediment contained no 'mud' (particles less than 63 microns). Moving up the harbour 'mud' became the majority of the sample except for the sample taken from Utakura River.

Sediment Nutrients

Using the guidelines by Robertson and Stevens (2007) total nitrogen, total phosphorus and total organic carbon have been classified (Figures 59-61). In Table 31 the range and mean of each sediment nutrient tested has been tabulated.

Table 31. Range and mean sediment nutrients concentrations in the Hokianga Harbour.

	NH ₄ (mg/kg)	NNN (mg/kg)	TN (mg/kg)	TOC (%)	TP (mg/kg)
Mean	22.7	0.604	1102	3.26	512
Range	4.8-64	0.31-1	43-2700	0.2-5.16	54-800

Ammonium (NH₄) had the lowest value at the harbour entrance and the highest value at Matawhera Point. NNN had the highest reading at Matawhera Point and the lowest reading at Kawehitiki Point.

From Figures 59-61 we can identify areas where sediment nutrients are classified as 'very good' and other areas where they are classified as 'enriched'.

Total Nitrogen (TN) had the lowest value of 43 mg/kg at the harbour entrance followed by 130 mg/kg at Whirinaki River and 180 mg/kg at Kawehitiki Point (Figure 59). Using the guidelines developed by Robertson and Stevens these values all fell under the 'very good' classification. There were seven sites that fell under the 'low to moderately enriched' class and only one site that was 'enriched' (Orira River) with a value of 2700 mg/kg.

The lowest values for total phosphorus as depicted in Figure 60 was also the two sites closest to the harbour entrance which fell into the 'very good' classification for total phosphorus in the sediment with a value of 54 mg/kg at the harbour entrance and 150 mg/kg at Kawehitiki Point. Three sites fell into the 'low to moderately enriched' category (Whakarapa, Takataka rock and Utakura River). The remaining six sites were classed as 'enriched' with the highest value being 800 mg/kg at the Upper Mangamuka River.

For total organic carbon the harbour entrance again had the lowest value of 0.2% followed by 0.4% in Kawehitiki Point (Figure 61). These values all fell under the 'very good' classification. Whirinaki River had a value of 1.8% making it 'low to moderately enriched'. There were six sites that fell under the 'low to moderately enriched' class and two sites that were 'enriched' (Takataka Point and Orira River) with values of 5.16% and 5.4% respectively.

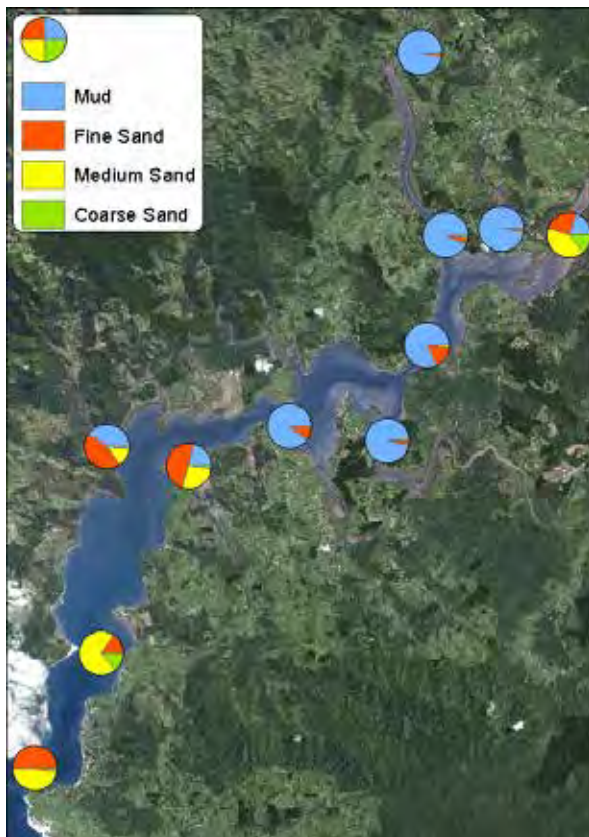


Figure 58 Grain size for sediment samples taken from Hokianga Harbour

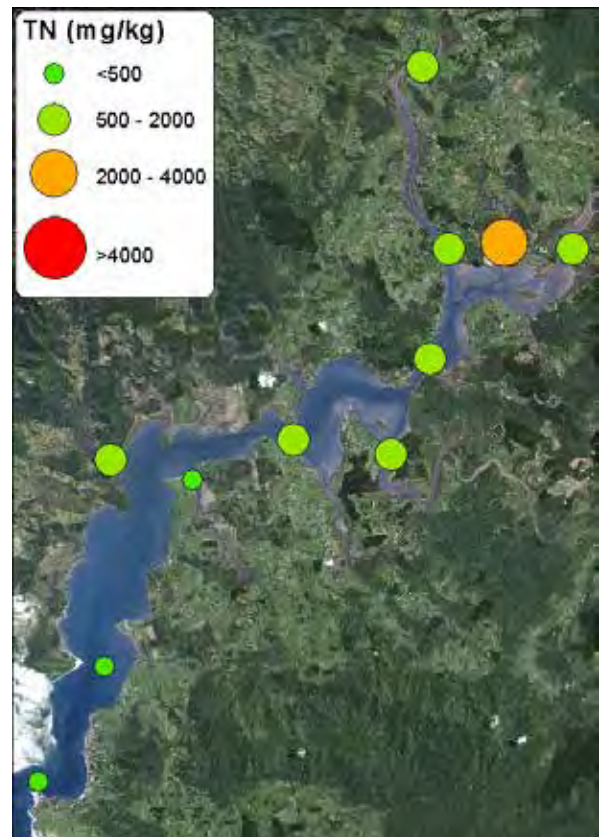


Figure 59 Total nitrogen concentration in sediment (mg/kg) in Hokianga Harbour.

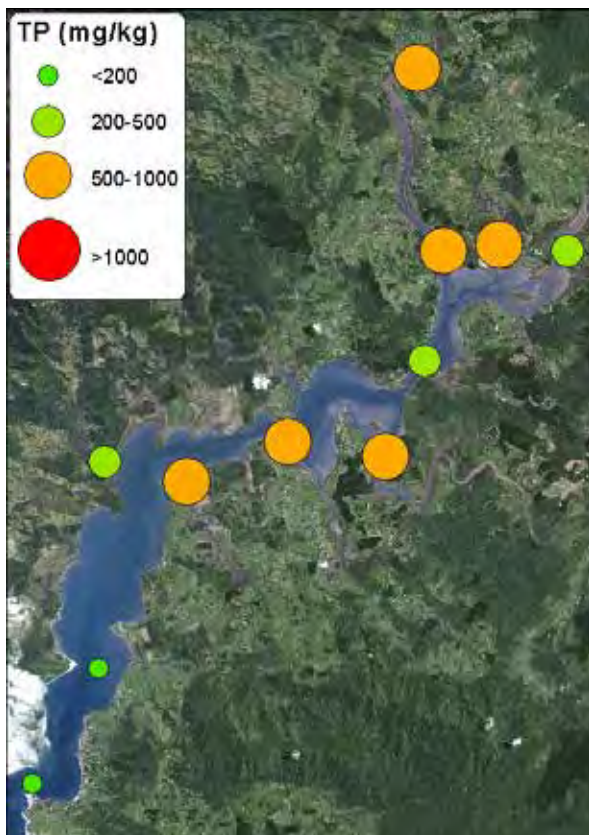


Figure 60 Total phosphorus concentration in sediment (mg/kg) in Hokianga Harbour.

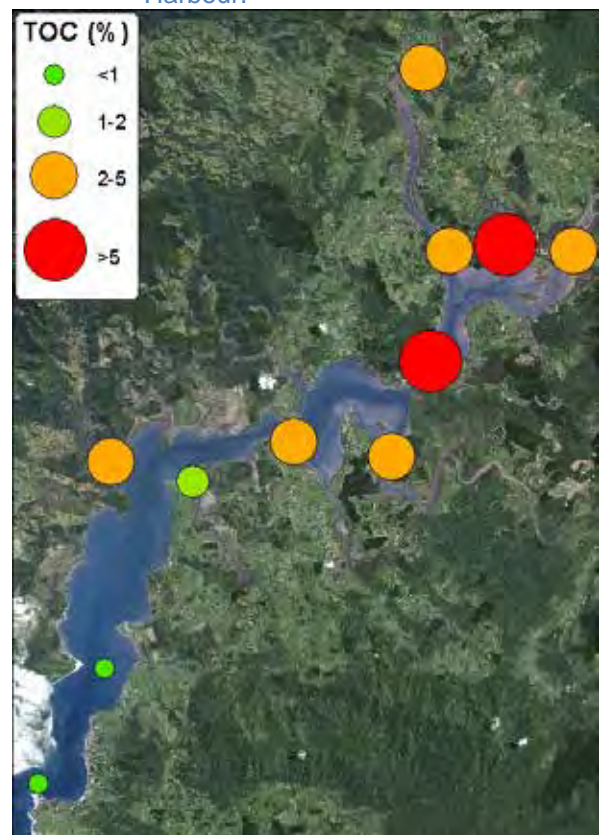


Figure 61 Total Organic Carbon levels in sediment (%) in Hokianga Harbour.

3.8 Whangape Harbour

3.8.1 Water Quality

Physical Parameters

Note: results are based on the recordings from only two sites in Whangape.

Table 32. Range and median values for salinity, dissolved oxygen (DO), turbidity and suspended solids (SS) in Whangape Harbour.

	Salinity	DO (g/m ³)	DO (%)	Turbidity (NTU)	SS (g/m ³)
ANZECC trigger value	No limit	<5	80-110	10	No limit
Median	32.1	6.925	88.6	20	44.5
Range	30.8-33.4	6.56-7.29	82.6-94.6	13-27	42-47
% of sites within trigger values	NA	100	100	0	NA

Whangape rainfall data was collected from Rotokakahi at Kohe Road. On the day of sampling (15 April 2013) 16.5mm fell and prior to sampling the last rainfall event was 18mm on 10 and 11 April. For the 30 day period a total of 71.5mm had fallen. Salinity for both sites was fairly high indicating little fresh water input at the time of sampling.

In Table 32 the percentage of sites within the trigger value for dissolved oxygen (g/m³ and % saturation) was 100%. At all sites readings taken were within guideline values for these parameters. Figure 62 shows that turbidity readings were outside of the guideline values for both sites sampled. The site 'north of Ahuriri pa' had the lowest reading of 13 NTU while the Whangape marae site had the highest reading of 27 NTU. Suspended solids also had 'high' readings with the lowest reading again at Ahuriri pa and the highest reading at Whangape marae.

Microbial Parameters

Table 33. Range and median concentrations of enterococci (ENT) and faecal coliforms (FC) in Whangape Harbour.

	ENT (MPN/100ml)	FC (CFU/100ml)
MfE guideline	140	150
Median	5.7	14.1
Range	1.6-9.8	8.2-20
% of sites within trigger values	100	100

Micro bacteria factors tested returned results within MfE trigger values (Table 33). The total range was from 1.6 to 9.8 MPN/100ml for enterococci and 8.2 to 20 (CFU/100ml) for faecal coliforms. Figure 63 shows that both sites sampled had very low reading for micro bacteria factors. Ahuriri pa had the lowest reading for both enterococci and faecal coliforms meaning Whangape marae had the two highest readings for micro bacteria.

Water Nutrient Parameters

Table 34. Range and median nutrient concentrations in Whangape Harbour.

	Chl a (g/m ³)	TN (g/m ³)	NH ₄ (g/m ³)	NNN (g/m ³)	TP (g/m ³)	DRP (g/m ³)
ANZECC trigger value	0.004	0.3	0.015	0.015	0.03	0.005
Median	0.00245	0.01	0.035	0.015	0.011	0.009
Range	0.002-0.003	0.01-0.032	0.0091-0.062	0.014-0.016	0.0025-0.019	0.007-0.011
% of sites within trigger values	100	100	50	50	100	0

Values for chlorophyll a (Chla), total phosphorus (TP) and total nitrogen (TN) were all within the guideline levels for both sites (compliance of 100%) (Table 34). Ammonium (NH₄) and nitrate, nitrite and nitrogen (NNN) had 50% of sites within the trigger value. Dissolved reactive phosphorus levels were outside the trigger value for both sites in the Whangape harbour.

Figure 65 shows that ammonium was within the guideline value for the site 'north of Ahuriri pa' and readings were outside of the guideline value for Whangape marae. North of Ahuriri pa had a reading of 0.0091 g/m³ and Whangape marae had a reading of 0.062 g/m³. For Nitrate, nitrite nitrogen the readings differed by 0.002 g/m³, with one reading at Whangape marae being just within the guideline and the reading north of Ahuriri pa being just outside of the guideline.

Readings for dissolved reactive phosphorus were outside of the guideline for both sites in Whangape Harbour with the highest reading coming from Whangape marae. In Figure 64 DRP is shown for the two sites sampled in Whangape.

3.8.2 Sediment Quality

No sediment samples were collected from Whangape Harbour.

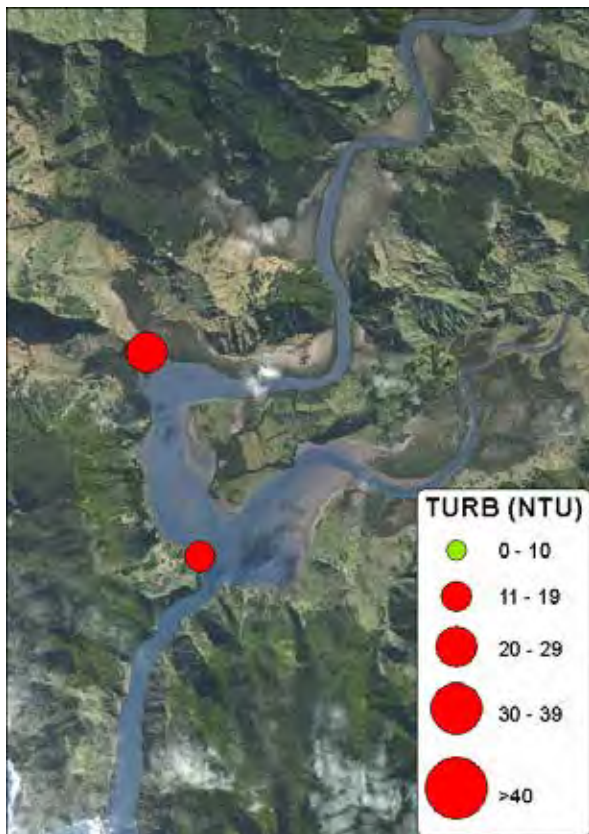


Figure 62 Turbidity levels (NTU) in Whangape Harbour.

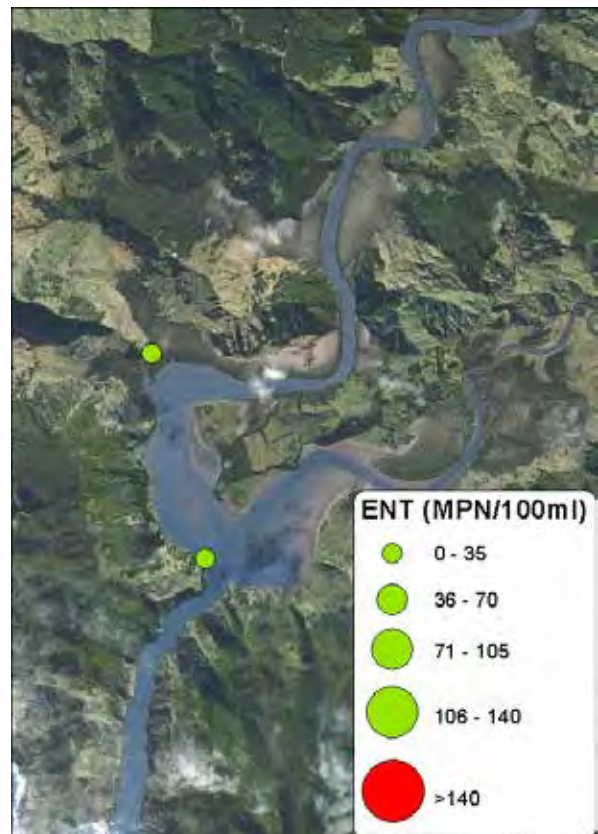


Figure 63 Enterococci levels (MPN/100ml) in Whangape Harbour.

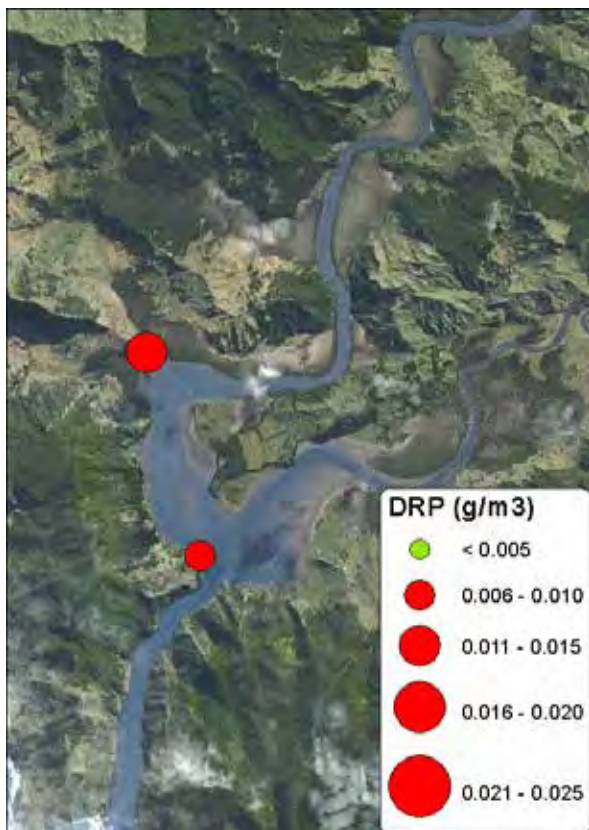


Figure 64 Dissolved reactive phosphorus (g/m³) in Whangape Harbour.

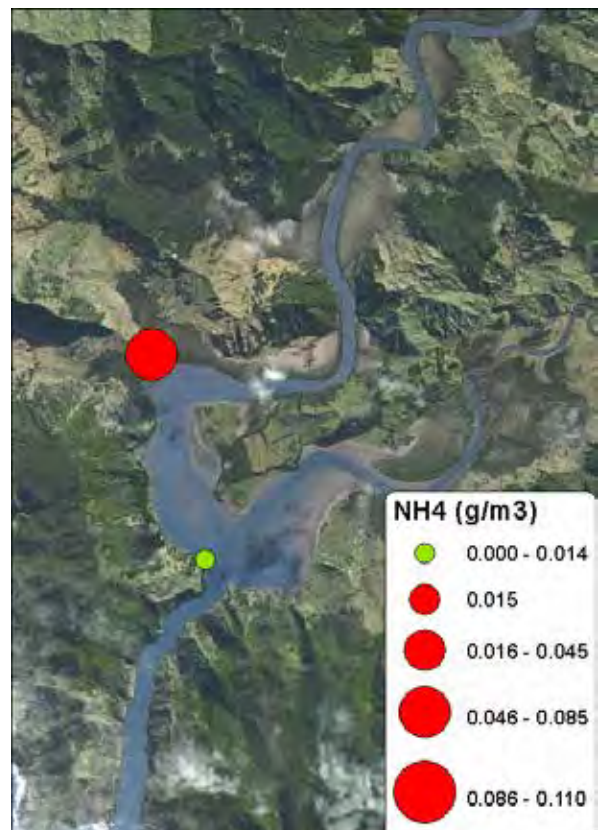


Figure 65 Ammonium (NH₄) levels (g/m³) in Whangape Harbour.

3.9 Comparison Between Harbours

Table 35. Median values of parameters for 2013 results.

2013 Results	ENT (MPN)	DRP (g.m ⁻³)	NH4 (g.m ⁻³)	NNN (g.m ⁻³)	SS (g.m ⁻³)	Turbidity (NTU)	Rainfall mm (30 days)
ANZECC Trigger Values	>140	0.005	0.015	0.015	-	>10	-
Hokianga	5	0.011	0.0025	0.0094	29.5	20.5	105
Whangaroa	0.85	0.006	0.0098	0.0044	10.2	1.5	41
Parengarenga - North	0.8	0.0065	0.0025	0.011	5.9	1.8	10.2
Parengarenga - South	0.85	0.005	0.0025	0.0033	9.0	1.0	10.2
Houhora	0.85	0.01	0.0025	0.014	8.9	2.3	8.1
Rangaunu		-	-	-	8.9	3.0	39.2
Mangonui/Taipa	0.85	0.007	0.0105	0.0035	3.4	0.675	17
Whangape	5.7	0.009	0.035	0.015	44.5	20	71.5

Note: Values in red are those that exceeded guideline values.

Physical Parameters

Salinity across the seven harbours ranged from 13.6-36.1 with the lowest reading recorded at the upper Mangamuka River in the Hokianga indicating relatively low levels of fresh water inputs during the period of sampling. For all harbour physical parameters for dissolved oxygen (g/m³ and % saturation) had 100% of sites within guideline values. Turbidity was within guideline values at all sites in Parengarenga (North and South), Houhora, Taipa and Mangonui, Whangaroa and 90% in Rangaunu. Hokianga had only 18% of sites within the guideline value. Whangape had 0% of sites within the guideline value for turbidity but only two sites were sampled. Suspended solids seemed to follow a similar pattern for turbidity and often the highest value for turbidity was at the same location for suspended solids highest value.

Microbial Parameters

Micro bacteria readings for enterococci and faecal bacteria were very low for all harbours with a large portion of sites having readings below the minimum detection level. All harbours had 100% of sites within the guidelines for enterococci and faecal coliforms (except for Rangaunu where sample data was unavailable). The highest value for enterococci was 41 (MPN/100ml) at the upper Mangamuka River which is still within the guideline value of 140 MPN/100ml. This site also coincided with the lowest salinity reading meaning that there was freshwater input.

Water Nutrient Parameters

Water nutrient concentrations were within ANZECC trigger values for most harbours and most parameters. Chlorophyll a had 100% of sites within trigger values for all harbours except in Hokianga where eight out of eleven sites were outside of the guideline value.

Dissolved reactive phosphorus consistently had readings outside of trigger values across all harbours. Sites within Houhora, Taipa, Mangonui, Hokianga and Whangape all had 0% of sites within the trigger values. Whangaroa had 12% of sites within the trigger values while Parengarenga North had 16% and Parengarenga South had 30% of sites within the trigger values. Spatial patterns were not consistent; values in Houhora and Hokianga harbour increased in the upper estuaries but for Parengarenga the lowest values were found in the upper channel

arms of the harbour. Generally where dissolved reactive phosphorus levels were low, salinity was high. Hokianga had the highest median value for DRP (excluding Whangape) (Table 25).

Ammonium had 100% of sites within guideline values at Hokianga Harbour and Parengarenga North, with concentrations at most sites below the minimum detection limits. At Parengarenga South 90% of sites were within guideline values and at Houhora 85 % of sites. Taipa/Mangonui had 66% of sites within guideline values and at Whangaroa 62% of sites. In Houhora, Mangonui and Parengarenga South values were highest in the upper estuary areas. In Whangaroa sites through the main channel and upper estuaries had the lowest values. The highest median value of ammonium was at Taipa and Mangonui (excluding Whangape) (Figure 25).

For nitrite-nitrate nitrogen, all sites at Parengarenga South, Taipa/Mangonui, Whangaroa and Hokianga were within ANZECC trigger values. Ninety-one per cent of sites in Parengarenga North were within the trigger values for nitrite-nitrate nitrogen and 71% of sites at Houhora. Of the two sites sampled at Whangape one site was within the guideline value. The highest median value for NNN was at Houhora Harbour (excluding Whangape) (Figure 25).

For all harbours values for total phosphorus were within trigger values except for Houhora Harbour where 71% of sites were within guidelines. For total nitrogen all sites in each harbour were within trigger values except for Hokianga Harbour and Parengarenga South which had 90% of sites within guidelines.

Sediment Quality

Grain size results were mapped for each harbour. Parengarenga, Houhora, Rangaunu and Taipa River were mainly comprised of sandy sediments (63-500um) with only low proportions of the grains sized less than 63 microns (mud). Mangonui, Whangaroa and Hokianga harbours were largely comprised of grains sized less than 63 microns (mud). At Hokianga and Whangaroa the harbour entrance sites contained a higher percentage of larger grains than those sites further up the harbour (with the exception of sites that may have contained gravel from road runoff). Mangonui Harbour entrance had almost 100% of the sample being comprised of grains less than 63 microns and further up the harbour the proportion of grains less than 63 microns decreased.

A sediment nutrient classification developed by Robertson and Stevens (2007) for total nitrogen, total phosphorus and total organic carbon were used to assess the concentrations of sediment nutrients found in the different harbours.

The majority of sites sampled were classified as 'very good' for total nitrogen. Out of 62 sites sampled 39 were rated as 'very good', 22 sites were rated as 'low to moderately enriched' and one site in the Hokianga Harbour was rated as 'enriched'. None of the sites were classified as 'very enriched'.

Total organic carbon concentrations varied across the harbours studied. Of the 62 sites sampled, 28 of the sites were rated as 'very good' with all sites within Parengarenga South coming under this rating, 15 sites were rated as 'low to moderately enriched' and 16 sites were rated as 'enriched'. Three sites were rated as 'very enriched'. Two of the sites classified as 'very enriched' were in the Hokianga Harbour and one site was in the Whangaroa Harbour.

Total phosphorus had 34 out of 62 sites rated as 'very good'. This included 11 out of 12 sites at Parengarenga North, nine out of 10 sites at Parengarenga South and five out of six sites at Houhora. Sixteen sites were rated as 'low to moderately enriched' and 12 sites were rated as 'enriched'. Six of the sites classified as 'enriched' were in the Hokianga Harbour.

Spatial patterns of distribution of sediment quality were hard to identify. Sites in the larger harbours seemed to have the lowest sediment levels near the harbour entrances (Hokianga, Parengarenga, and Rangaunu). This trend however was not true for Whangaroa Harbour where the reverse appeared to be the case.

3.10 Comparison Between Previous Studies

An investigation of water and sediment quality in the Far North Harbours has been completed twice before, once in 1998-1999 and again in 2004. The sites used in 1998-1999 were inconsistent with those used in 2004 and it is therefore difficult to make comparisons with this study. However the sites and parameters sampled in 2004 are generally consistent with this study. Below data from 2004 has been tabulated to compare to the 2013 data (Table 36). In 2004 the sampling was carried out during winter months so rainfall was considerably higher than in 2013. Differences that may be seen between the two studies could therefore be a result of seasonal variation rather than actual changes in water quality.

Table 36. Median values of water parameters for 2004 results.

2004 Results	ENT (MPN)	DRP (g.m ⁻³)	NH4 (g.m ⁻³)	NNN (g.m ⁻³)	SS (g.m ⁻³)	Turbidity (NTU)	Rainfall mm (30 days)
ANZECC Trigger Values	>140	0.005	0.015	0.015	-	>10	-
Hokianga	5	0.014	0.05	0.087	14.0	10.3	153.3*
Whangaroa	5	0.01	0.02	0.035	13.2	2.4	133.5
Parengarenga - North	5	0.0075	0.04	0.017	5.0	1.0	81.6
Parengarenga - South	5	0.0085	0.095	0.029	5.0	0.9	94.2
Houhora	5	0.012	0.05	0.04	4.0	1.2	109.5
Rangaunu	5	0.0105	0.035	0.042	4.5	1.3	84
Mangonui/Taipa	10	0.012	0.02	0.039	6.5	4.25	84.5*
Whangape	7.5	0.02	0.045	0.0425	31.5	9.95	151.5*

* Rainfall information collected from 2004 report, rain gauge sites differ to those used in 2013. Note: values in red are those that exceeded guideline values.

Physical Parameters

As was found in 2013, Hokianga also had the highest median value for turbidity and suspended solids in 2004. Median values for turbidity and suspended solids in 2013 were generally half of the readings recorded in 2004 for Rangaunu Harbour and Taipa/Mangonui and values have also decreased in Whangaroa Harbour. These apparent decreases could be due to the variation in rainfall from the two sample events.

The lowest levels of suspended solids and turbidity were associated with Parengarenga, Houhora, Rangaunu, Taipa, Mangonui and Whangaroa, with the majority of sample sites having, levels below or very close to the detection limits for turbidity in 2004. The highest levels of suspended solids and turbidity were recorded for mid to upper Hokianga 2013 and 2004.

Microbial Parameters

In 2004 the concentrations of faecal coliform and enterococci bacteria were generally low and at or near the minimum detection limits. Bacterial results tended to be highest in the upper estuarine areas, indicative of the lower mixing/dilution potential in these areas and/or increased inputs of faecal contaminants. This is the same as the 2013 micro bacterial data with

concentrations very low or below the minimum detection levels for a number of harbours. The median values for all harbour were higher for enterococci in 2004.

Water Nutrient Parameters

In 2004, the highest concentrations of dissolved reactive phosphorus were found in the Houhora, Rangaunu, Taipa and Hokianga harbours. Intra harbour spatial trends for dissolved reactive phosphorous concentrations showed higher concentrations were typically recorded in upper estuarine areas. All harbours had values outside of the ANZECC trigger value is 0.005 g/m³ in 2004. In this study Houhora, Taipa/Mangonui, Hokianga and Whangape Harbour had the highest concentrations of DRP.

Concentrations of ammonium exceeded trigger values for the majority of sites sampled and intra-estuary medians exceeded trigger values for all estuaries in 2004. The highest concentrations were generally found in the Parengarenga South, the upper Houhora and the upper Hokianga in 2004. In 2013, all sites within Hokianga and Parengarenga North were below or at minimum detection rate. Whangaroa, upper Houhora and Mangonui had the highest readings for ammonium in 2013.

Nitrate-nitrite nitrogen concentrations were above trigger levels for most sites in 2004, except for sites in the northwest of Parengarenga Harbour. Estuary medians exceeded trigger values for all estuaries. The highest concentrations were recorded in Hokianga, where results were highly elevated throughout the length of the estuary. In 2013 Parengarenga North and Houhora had the highest concentrations of nitrate-nitrite nitrogen with readings in all other harbours within the trigger value.

In 2004 total phosphorus exceeded trigger values for a number of sites in the Parengarenga South, upper Houhora, upper Rangaunu, Hokianga and most sites in Whangape. The median total phosphorus concentrations for these estuaries also exceeded the trigger value. There were no apparent spatial trends for total phosphorus. In 2013 all sites within all harbours (except for the upper Houhora) had values within the trigger value for total phosphorus.

Sediment Quality

In 2004 the study found a relationship between high levels of TOC and larger grain sizes. In 2004 Parengarenga, Houhora, Ranguanu, Taipa and Herekino estuaries were predominantly comprised of sandy sediments with only low proportions of sediments smaller than 63 microns, (silt and clay). Whangape, Hokianga, Whangaroa and Mangonui generally had high proportions of grains <63 microns with only the entrance sites having higher proportions of larger grains in 2013.

Total phosphorus concentrations in 2004 were highest in the upper reaches of the Hokianga, Whangaroa, upper Mangonui, Taipa, the upper Rangaunu and Whangape. Similarly in 2013 concentrations were highest in Hokianga, Whangaroa and Taipa/Mangonui and upper Rangaunu.

Total nitrogen concentrations in 2004 were highest in Parengarenga (north), Houhora and upper Hokianga. In 2013 concentrations were highest in Hokianga, Whangaroa and Houhora.

In 2004 and in 2013 ammonium concentrations were generally less than the specified minimum detection limits of the analytical method.

4 Syntheses

4.1 Summary of Key Findings

Knowledge of water and sediment quality is important in gauging environmental health and assessing ways to mitigate adverse impacts on our natural environment. Results from this study were across the board very pleasing with only one parameter consistently above trigger values (DRP). Below the results for all harbours have been summarised and reasoning for result values has been inferred.

Physical Parameters

Salinity/Temperature and Rainfall

Over the sampling period rainfall was relatively low with Hokianga having the most rainfall in the 30 days prior to sampling (105mm). In the 2004 study, sampling was carried out in winter months and consequently rainfall was significantly higher. This may have led to discrepancies in comparing the two studies due to seasonal variation. In 2013 salinity readings were high across all harbours and indicated that little freshwater inputs were present at time of sampling. In general most parameters are negatively correlated with salinity, as more freshwater enters estuaries more contaminants will be present as a result of land run-off (animal waste and fertilizer). This may explain the higher levels in 2004 of dissolved reactive phosphorus, nitrate-nitrite nitrogen and ammonium and may also explain spatial trends of higher nutrients and reduced water clarity in upper estuaries as they are the first to encounter increased rainfall/run off.

Dissolved Oxygen

In 2013 dissolved oxygen values at all sites were within trigger values for adverse environmental impacts. This means there is sufficient oxygen in the water column to support aquatic life and levels of nutrients are not causing blooms in aquatic plants or micro bacteria (which can lead to oxygen depletion). There was no issue or concern with oxygen levels in the Far North harbours.

Water Clarity

Turbidity values were within the trigger values for almost all harbours. Suspended solids and secchi disk readings generally followed the pattern of turbidity for highest and lowest readings. Hokianga was the only harbour with multiple readings outside of the trigger value (excluding Whangape) and the readings forming a gradient with the highest values of turbidity, suspended solids and lowest readings of secchi disk being in the upper estuary. Turbidity, suspended solids and secchi disk all measure water clarity in slightly different forms. The consistency between readings from each of these methods confirms the readings and conclusions made from these. Water clarity was very good in almost all harbours and there was little material in the water column. Material in the water column can have adverse effects of smothering and habitat change. Where readings of turbidity are increased it is expected that primary production will be lower as light cannot penetrate through the water column as easily. Turbidity was generally lower at all harbours in 2013 when compared to 2004. This may be directly due to the higher rainfall readings in 2004 which would have led to increased material and disturbance in the water column, from land runoff. For the Hokianga Harbour which had elevated Chlorophyll readings this could have also increased readings of turbidity.

Micro Bacteria Quality

Readings for enterococci and faecal coliforms were extremely low for all harbours in 2013. All sites within all harbours had readings of micro bacteria within the trigger value and some harbours had multiple sites with readings within the minimum detection level. This means that in

all harbours the water at time of sampling was safe for swimming and collecting seafood. The low levels of micro bacteria indicates that there was little pollution from animal or human waste or rotting vegetation that could lead to elevated micro bacteria levels. In 2004 the readings for micro-bacteria were also very low. As the samples from 2004 were taken in winter and samples from 2013 were taken in summer we can see that there was little seasonal variation during these two sampling events.

Chlorophyll a

Readings for the pigment chlorophyll a were all within trigger values for all harbours except for Hokianga Harbour where a number of sites were above the trigger value in 2013. Chlorophyll a can be an indicator of nuisance aquatic plant growth and algal levels. Algal blooms occur when there are high levels of both nitrogen and phosphorus and sufficient light levels for photosynthesis. The increased readings of turbidity in the Hokianga may be a result of the Chlorophyll a readings. Chlorophyll was not sampled in 2004.

Water Nutrient Quality

Nitrogen

In summer nitrogen is considered the main limiting factor in marine photosynthetic organisms, different forms of nitrogen have been measured in the water column to gauge what form of nitrogen is in highest concentration and what this may mean for the marine environment.

Total Nitrogen

Total nitrogen levels were within trigger values for all harbours except for a few sites within Hokianga and Parengarenga south in 2013. In 2004 values for total nitrogen were much higher and were outside of the trigger value for the majority of sites.

Nitrate-nitrite nitrogen

The trigger value for nitrate-nitrite nitrogen was within the guidelines for almost all sites with only a few sites having values outside of the trigger value in 2013. This indicates that levels of nitrate-nitrite nitrogen were not at a level in which they could trigger adverse environmental effects such as eutrophication (algal blooms).

Ammonium

The majority of readings for ammonium were within the trigger values and only a few sites at Taipa/Mangonui and Whangaroa and Houhora had readings outside the guideline values in 2013. Ammonium is produced as waste from animals and is then up taken by micro bacteria. In 2004 values for ammonium were outside trigger values at the majority of sites which again could be attributed to higher rainfall readings which could aid transport of nutrients into the marine environment and disturbance of marine sediments.

Phosphorus

Two forms of phosphorus were measured; total phosphorus (which measures all phosphorus in the system) and dissolved reactive phosphorus (which is the phosphorus available for use by marine organisms).

Total Phosphorus

Total phosphorus readings were within the trigger value with only a few sites at Houhora having readings outside the guideline value in 2013. In 2004 readings for TP were outside the trigger value for most harbours.

Dissolved Reactive Phosphorus

Values for dissolved reactive phosphorus were consistently above the ANZECC guideline for all harbours in 2013. As the majority of values were outside the trigger values for all harbours and

no spatial trends were evident it is difficult to determine the source of the nutrient. Readings for 2004 were also outside of the trigger value across all harbours.

Sediment Nutrient Quality

Total Phosphorus

Total phosphorus readings in the sediment were rated 'very good' for just over half of the sites sampled using the classification system developed by Robertson and Stevens (2007). Hokianga had the highest readings of total phosphorus with half of the sites having a rating of 'enriched'.

Total Organic Carbon

Total organic carbon readings had just under half of the total sites rated as 'very good' using the classification system developed by Robertson and Stevens (2007). When compared to 2004 data the mean value of total organic carbon was very similar to 2013.

Total Nitrogen

Total nitrogen in the sediment had ratings of 'very good' at the majority of sites sampled, using the classification system developed by Robertson and Stevens (2007). Only one site in the Hokianga came under the 'enriched rating' in 2013. When compared to 2013 the mean values for total nitrogen were much higher across all harbours in 2004.

Grain Size

The change between sediment size changes slightly within each harbour typically with smaller grains being present in the upper estuary areas. The prominent grain size differed between harbours however as Hokianga, Whangape, Whangaroa and Mangonui generally had high proportions of grains <63 microns and Parengarenga, Houhora, Rangaunu, Taipa and Herekino estuaries were predominantly comprised of sandy sediments with only low proportions of sediments smaller than 63 microns. Nutrients bind easier to finer sediments so this may explain why higher levels of sediment nutrients were found in the Hokianga and Whangaroa and the two sites at Whangape.

Ammonium

Readings for ammonium in sediment do not have a trigger value.

Summary

As was the case in 2004 the main contaminant issues continue to be sediment loading, nutrient enrichment and microbial contamination. From the data we have collected we have a good basis for the range of values that can be sampled and a general insight into the Far North harbours marine environments. During our study we had low rainfall and high salinity which contrasts the results of the 2004 study. This information can aid our understandings of how rainfall influences water nutrient levels. Generally turbidity levels were good indicating good water clarity for supporting aquatic life. Low levels of enterococci and faecal coliforms indicated that across all harbours micro bacteria was not a contaminant at the time of sampling. Generally chlorophyll a and nitrogen readings were good with only a small number of sites exceeding trigger values. Dissolved reactive phosphorus was the only nutrient that consistently exceeded ANZECC trigger values but nitrogen is normally the biggest indicator of environmental health in marine systems. Hokianga Harbour generally had the worst water quality but it also had the highest rainfall input which could explain this. As this study was only completed once we have a narrow data range in terms of repeated sampling. This makes it difficult to draw decisive conclusions about harbour health as low or high readings that we have encountered have only been seen once in our data set. To better understand the fluctuations in water nutrients a wider data set with multiple repeats of sampling is needed.

5 References/Index

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