



# Marine Water Quality Annual Report: 2011

July 2013

Technical Report 2013/031

Auckland Council  
Technical Report 2013/031  
ISSN 2230-4525 (Print)  
ISSN 2230-4533 (Online)

ISBN 978-1-927266-16-8 (Print)  
ISBN 978-1-927266-17-5 (PDF)

This report has been peer reviewed by the Peer Review Panel using the Panel's terms of reference

Submitted for review on 17 April 2013

Review completed on 22 July 2013

Reviewed by one reviewer

Approved for Auckland Council publication by:



Name: Grant Barnes

Position: Manager, Research, Investigations and Monitoring Unit

Date: 22 July 2013

Recommended citation:

Walker, J and Vaughan, M (2013). Marine water quality annual report: 2011.  
Auckland Council technical report, TR2013/031

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# Marine Water Quality Annual Report: 2011

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## 1.0 Introduction

The marine environment in the Auckland region encompasses two oceans, four major harbours, and numerous estuaries. This wide variety of marine habitats supports a diverse range of plants and animals, including seaweeds, invertebrates (e.g. sponges and kina), mangroves, seagrass, shellfish, marine mammals, fish and sea birds.

The aesthetics, use, and health of near coastal waters are influenced by the quality of freshwater that runs from the land through streams, rivers and the stormwater system. The microbiological contamination of beaches after heavy rainfall and the sedimentation of harbours and estuaries illustrate the connections between inland and coastal waters, and the sensitivity of these ecosystems.

The marine water quality programme is designed to meet the following objectives:

- Satisfy the Auckland Council's Resource Management Act 1991 section 35 obligations with respect to state of the environment reporting.
- Contribute to the need to maintain and enhance the quality of the environment monitoring (Local Government Act 2002).
- Help inform the efficacy and efficiency of policy initiatives and strategies.
- Assist with the identification of large scale and/or cumulative impacts of contaminants associated with varying land uses and disturbance regimes and link these to particular activities.
- Provide baseline, regionally representative data to support the resource consent process and compliance monitoring.
- Answering queries from the public, and promote awareness of water quality issues.

This programme fits under the "Natural Environment and Heritage" component of the Auckland Council's Long-term Community Plan 2009-19. A key issue for the region is to manage the effects of growth and development on our natural environment. This includes balancing the needs for environmental protection with Auckland's social, economic and cultural well-being and aspirations for our coastal resources and marine animal and plant life.

Specific objectives include managing and minimising the effects of present and future urban and rural development, growth, and intensification across the region. The water quality parameters provide information on the condition of the region's marine environment, and feedback on management actions. This is necessary to confirm that Auckland Council's management strategies are effective in sustaining ecosystem functions and uses. By achieving this outcome we are working towards achieving Auckland Council's mission of:

- "The world's most liveable city"

Information from the marine water quality programme is also used to measure the success of several strategic directives in the Auckland Plan including: Directive 7.10 "Manage land to support the values of waterbodies by protecting them where they are high and reviving them where they are degraded" and Directive 7.12 "Protect coastal areas, particularly those with high values – including special natural character, significant marine habitats and recreational importance – from the impacts of use and development, and enhance degraded areas".

The marine water quality programme monitors water quality across the Auckland region. Information obtained is also used in conjunction with ecological and contaminant data to provide an integrated overview of the physical, chemical, and biological condition of the region's marine environment (Figure 1-1)

- The marine water quality programme monitors natural occurring parameters, some of which can become elevated in association with natural variations in ocean hydrodynamics, land erosion and biological wastes (organic material and faecal contaminants) in the water column.
- The shellfish contaminant monitoring programme indirectly monitors chemical contaminants in the water column. Direct measurement of chemical contaminants in water is unreliable because concentrations are commonly below analytical detection limits, and they vary widely due to water movement and the patchy nature of inputs. However, some plants and animals accumulate contaminants over time, even when ambient levels in the water column are relatively low. The tissues of oysters and mussels therefore provide an integrated measure of ambient chemical contaminant levels in the water column.
- The sediment contaminant monitoring programme monitors chemical contaminant levels in estuarine and harbour sediments. Many contaminants attach to particulate material which settles out of the water column and accumulates in depositional zones. These contaminants can be toxic to the benthic organisms that live in these sediments. Reduced sediment quality may impact on the ecological "health" of an area by reducing sensitive species and favouring tolerant species.
- The benthic ecology programme monitors temporal changes in specific sediment dwelling, ecological communities in the Mahurangi, Waitemata, Kaipara and Manukau Harbours and East Coast estuaries.

Collectively, these programmes provide consistent, long-term information on the quality of Auckland's coastal environment. These programmes are strengthened further by the streams and rivers monitoring programme which monitor similar parameters to those in the marine water quality programme. This alignment enables trends in the marine environment and the freshwater environment to be compared allowing the determination (to a certain degree) of the source of some water quality parameters.

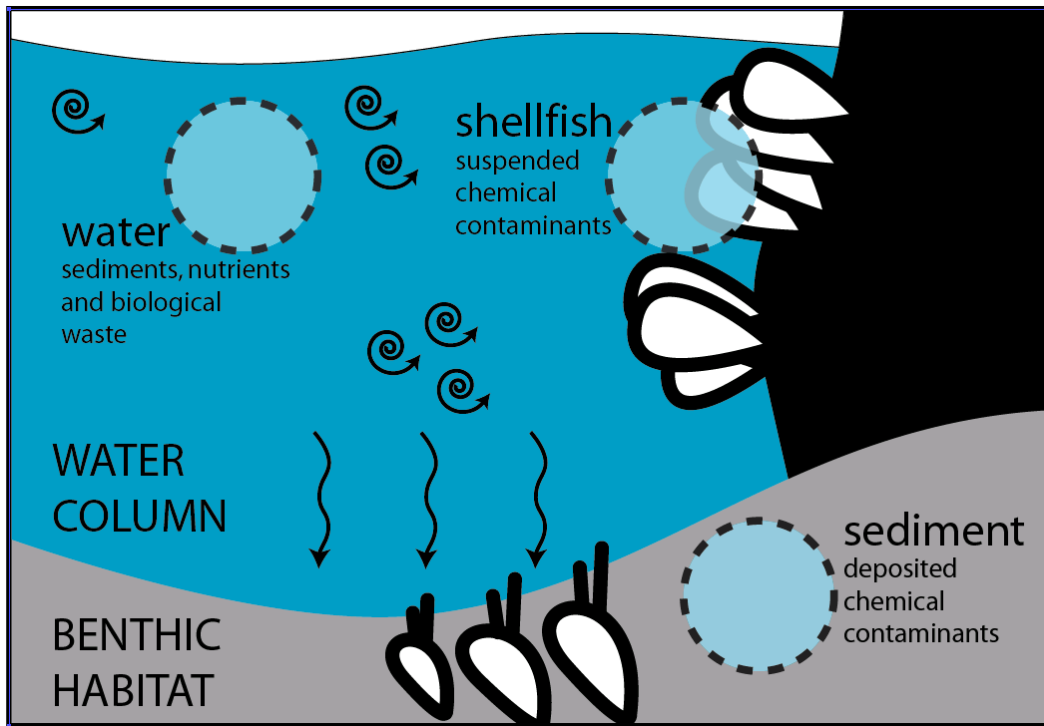


Figure 1-1 The relationship between sediment contaminants, coastal water quality and shellfish contaminant monitoring programmes

## 1.1 Report content

This report provides 12-months of summary data from the 2011 calendar year collected from 35 monitoring sites across the Auckland region, and includes summary statistics tabulated by parameter and grouped by spatial proximity.



## 2.0 Methods

### 2.1 Programme design

Sampling of surface waters for marine water quality monitoring is undertaken monthly by Auckland Council technical officers, predominantly by helicopter. This enables sites spread over a broad area to be collected within a narrow time frame due to tidal constraints (these constraints are described below). There are a few sites where water samples are not collected using a helicopter, these sites are: the Upper Waitemata Harbour which are sampled by boat, and the Tamaki Estuary sampled from land. At each site, water samples are collected from the surface waters (the top 1 m) by lowering a 2 litre plastic bottle and 500ml glass bacteria bottle into the water. The 2 litre plastic and glass bacteria bottles are sent to Watercare and analysed for chemical compounds (see 6.0) and enterococci.

Sampling is divided into 6 geographically distinct runs, summarised below. Routine water quality monitoring locations are summarised in Table 2-1 and illustrated in Figure 2-1.

- 7 sites in Manukau Harbour;
- 7 sites in the inner Hauraki Gulf and outer Waitemata Harbour;
- 7 sites in Kaipara Harbour;
- 3 sites in Mahurangi Harbour;
- 2 sites in Tamaki Estuary;
- 2 sites in the Tamaki Strait (1 site in Turanga Estuary and 1 site at the mouth of the Wairoa River).
- 8 sites in the Upper Waitemata Harbour.

Temporal variation is avoided as much as possible by maintaining a consistent sampling time relative to tidal cycle. Samples are collected approximately 30mins–3hrs hours after high tide for the Kaipara Harbour, Waitemata Harbour and Hauraki Gulf sites and 2.5–4 hours after high tide for the Manukau Harbour. This avoids introducing diurnal variation to the dataset and improves the power of long term trend detection

Table 2-1 Marine water quality sites sorted from north to south, grouped by location.

Spatial reference is NZTM coordinates and the year which sampling at each site started are also listed.

Site	Location	Easting	Northing	Start
Goat Island	East Coast	1761835	5984910	1993
Ti Point	East Coast	1760222	5978524	1991
Mahurangi Heads	East Coast	1754382	5959892	1993
Dawsons Creek	East Coast	1753554	5966410	1993
Orewa	East Coast	1753273	5949612	1991
Browns Bay	East Coast	1757934	5935780	1991
Shelly Beach	Kaipara Harbour	1723526	5951872	1991
Kaipara River	Kaipara Harbour	1726372	5946975	2009
Makarau estuary	Kaipara Harbour	1728450	5953472	2009
Omokoiti beacon	Kaipara Harbour	1718659	5961178	2009
Kaipara Heads	Kaipara Harbour	1709351	5970137	2009
Tauhoa Channel	Kaipara Harbour	1717979	5969681	2009
Hoteo River	Kaipara Harbour	1726690	5967497	2009
Chelsea	Waitemata Harbour	1753944	5922872	1991
Whau Creek	Waitemata Harbour	1748289	5920291	1991
Henderson Creek	Waitemata Harbour	1746712	5923648	1991
Hobsonville Jetty	Waitemata Harbour	1749321	5927317	1993
Waimarie Road	Waitemata Harbour	1746213	5929089	1993
Rarawaru Creek	Waitemata Harbour	1744434	5928653	1993
Confluence	Waitemata Harbour	1743962	5929039	1993
Paremoremo Ski Club	Waitemata Harbour	1745746	5930178	1993
Rangitopuni Creek	Waitemata Harbour	1742836	5929868	1993
Brighams Creek	Waitemata Harbour	1742758	5928019	1993
Lucas Creek	Waitemata Harbour	1750045	5932471	1993
Tamaki	Tamaki Estuary	1769372	5917448	1992
Panmure	Tamaki Estuary	1765295	5913934	1992
Turanga Estuary	Tamaki Strait	1774464	5914091	2009
Wairoa River	Tamaki Strait	1786443	5909850	2009
Grahams Beach	Manukau Harbour	1749651	5888082	1987
Clarks Beach	Manukau Harbour	1748630	5897349	1987
Shag Point	Manukau Harbour	1748379	5908452	1987
Puketutu Point	Manukau Harbour	1753877	5908724	1987
Weymouth	Manukau Harbour	1764925	5897672	1987
Mangere Bridge	Manukau Harbour	1758588	5910714	1987
Manukau Heads	Manukau Harbour	1708915	5970600	2009



## Saline Water Quality Monitoring Sites

Map Produced by  
Research, Investigations  
& Monitoring Unit,  
Auckland Council



Figure 2-1 Location of the 35 marine quality monitoring sites

Monitoring sites were selected to provide information on:

- Water quality across a disturbance gradient from high to low;
- A range of exposure levels including open coast, sheltered coast, harbours, large estuaries and tidal creeks;
- The main harbours and large estuaries;
- Areas with a variety of adjacent land uses ranging from urban/industrial to rural;

## **2.2 Water quality parameters**

The water quality of the region's coastal environment is determined by measuring 19 parameters. Some parameters are measured in the field but most are analysed in the laboratory (see Table 6-1, 6.0). The number and type of parameters has varied since the programme's inception as new technology became more affordable, instrument sensitivity improved and the programme objectives were modified.

## **2.3 Programme changes**

The monitoring programme was last reviewed in June 2005. Following this review biological oxygen demand (BOD) was dropped in July 2005 from the list of analytical laboratory tests. The measurement of water clarity using Secchi disk also ceased in July 2005 due to the difficulty of accurately estimating Secchi disk readings from the helicopter. Turbidity (measured in NTU) was deemed to be a useful approximate surrogate.

In November 2008 a hand held multi-parameter water probe was introduced to the programme. The hand held probe (YSI 556 MPS) is able to take in situ measures of salinity, conductivity, temperature, and two dissolved oxygen readings (% saturation and concentration recorded in mg. L<sup>-1</sup>). Previous to this, these parameters were measured in the lab by Watercare.

In January 2009 six new sites in the Kaipara Harbour were added to this programme. In addition, one site at the Manukau heads, one site at Turanga estuary and one site at the mouth of the Waioira River were also added. This allows for greater coverage of the coastal waters of the Auckland region.

Faecal coliforms were deleted from the list of laboratory tests as Enterococci is a more appropriate bacteria indicator in marine waters. Also total nitrogen (TN) was added to the list of chemical variables as TN can be calculated from the current nitrogen species analysed at the Watercare's lab.

## **2.4 Quality control, data storage and analysis**

Quality control is undertaken in accordance with Auckland Council's internal standards, including procedures for the collection, transport and storage of samples, and methods for data verification and quality assurance to ensure consistency across the monitoring programme. Samples are analysed under contract to the Auckland Council by Watercare Laboratory Services Ltd, an IANZ

accredited laboratory. Analytical methods follow the “Standard Methods for the Examination of Water and Wastewater” 18th Edition (APHA 1992). All field and laboratory data are stored in the Auckland Council’s water quality archiving database (HYDSTRA) and complies with ISO 9001:2008 accreditation.

## 2.5 Reports

This is the 21<sup>st</sup> data report since the inception of the monitoring programme, and it is the fifth time since 2000 that the data has been reported separately from the rivers, streams and lakes water quality monitoring programmes. Previous reports described in the list of references can be obtained by contacting the Auckland Council on (09) 301 0101, or in electronic format from Auckland Council's website under ‘Technical publications and research’:

<http://www.aucklandcouncil.govt.nz/en/planspoliciesprojects/reports/technicalpublications>

A comprehensive trend analysis is conducted approximately every five years, with the last report published in 2008 (Scarsbrook 2008, TP2008/005) and a previous report published in 1999 (Vant and Lee, 1998). Auckland Regional Council's *State of the Auckland region report 2009* briefly summarises water quality issues, including an assessment of the ecological health of the region’s marine resources and land use pressures (Auckland Regional Council, 2010).

The marine water quality monitoring programme is also reviewed approximately every five years. Recent reviews were conducted concurrently with the last trend analysis in 2008 (Scarsbrook 2008, TP2008/005). A number of recommendations were made in this report along with detailed analysis of long term changes in water quality for the Auckland region. This report is available on the Auckland Council web site.

A specific review of the Mahurangi Harbour, Upper Waitemata Harbour and Tamaki Estuary was last undertaken in 2001 (Wilcock and Kemp, 2001).

## 3.0 Results

Data from the 2011 calendar year are presented as box plots to display the ranges over which water quality parameter results were recorded. These plots also show the variations in the water quality parameters among sites and locations and the data are summarised in tables in section 3.3. Data tables contain summary statistics (sample sizes, maximum/minimum, means and standard error). For box plots and data tables, sites are grouped by location (e.g. all sites within the Manukau Harbour are grouped) and then listed from north to south.

### 3.1 Box plots

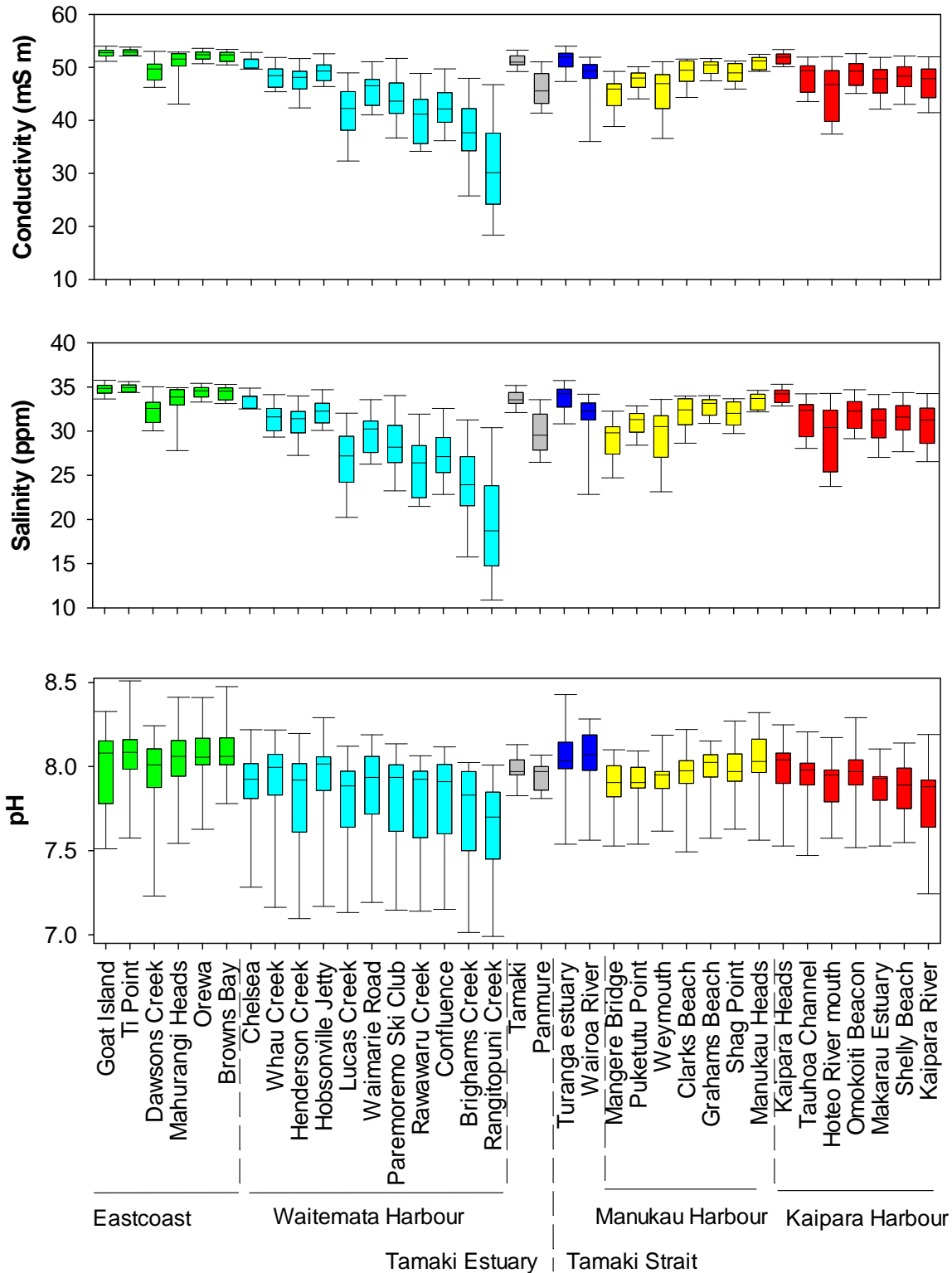


Figure 3-1 Spatial patterns in conductivity, salinity and pH.

Boxes represent the median, 25<sup>th</sup> and 75<sup>th</sup> percentiles while whiskers are 5<sup>th</sup> and 95<sup>th</sup> percentiles for data collected from January 2011 to December 2011. Percentiles values calculated using the standard method in SigmaPlot (v12).

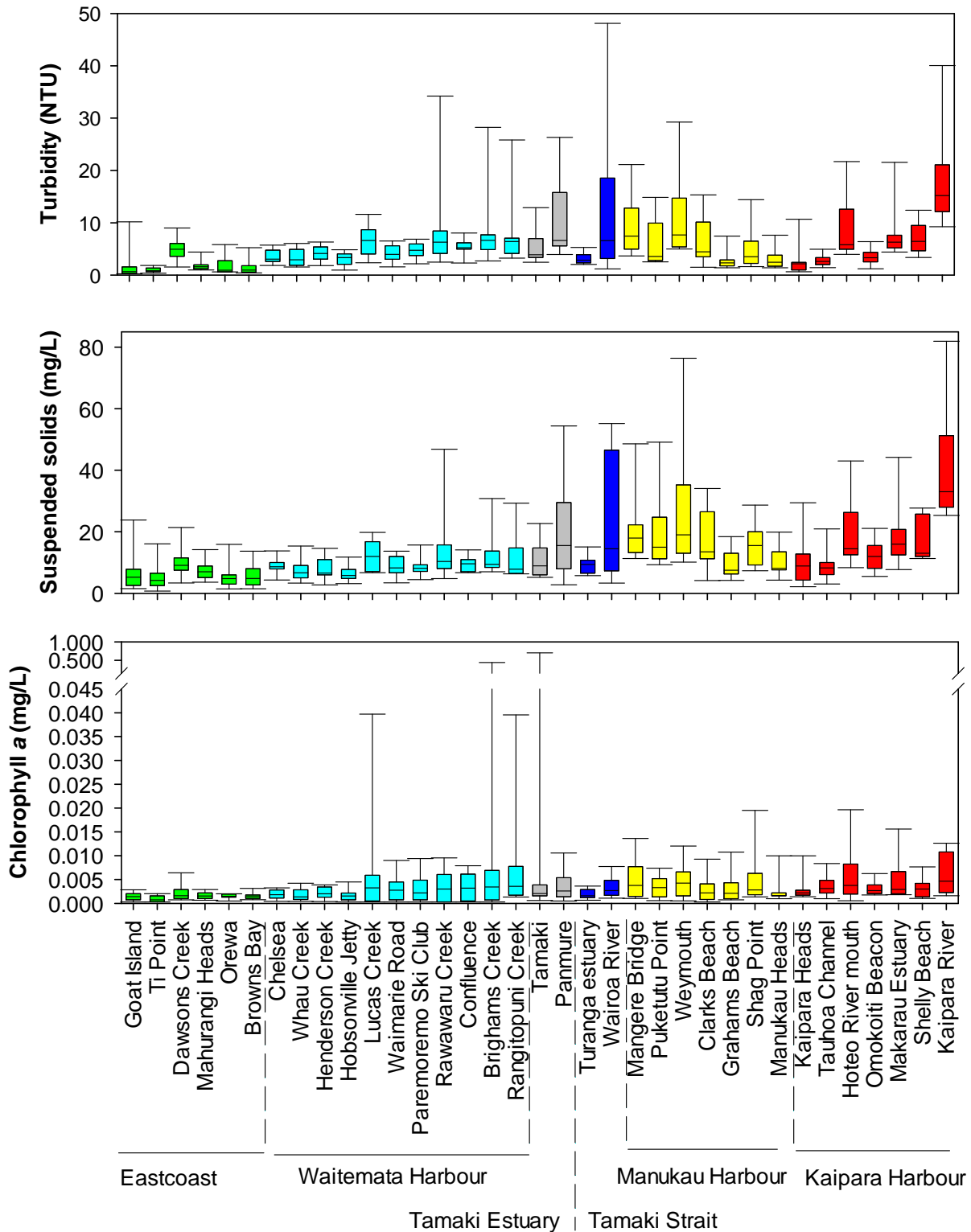


Figure 3-2 Spatial patterns in turbidity, suspended sediment, and chlorophyll a.

Boxes represent the median, 25<sup>th</sup> and 75<sup>th</sup> percentiles while whiskers are 5<sup>th</sup> and 95<sup>th</sup> percentiles for data collected from January 2011 to December 2011. Percentiles values calculated using the standard method in SigmaPlot (v12). Note the scale break in the y-axis of the chlorophyll a.



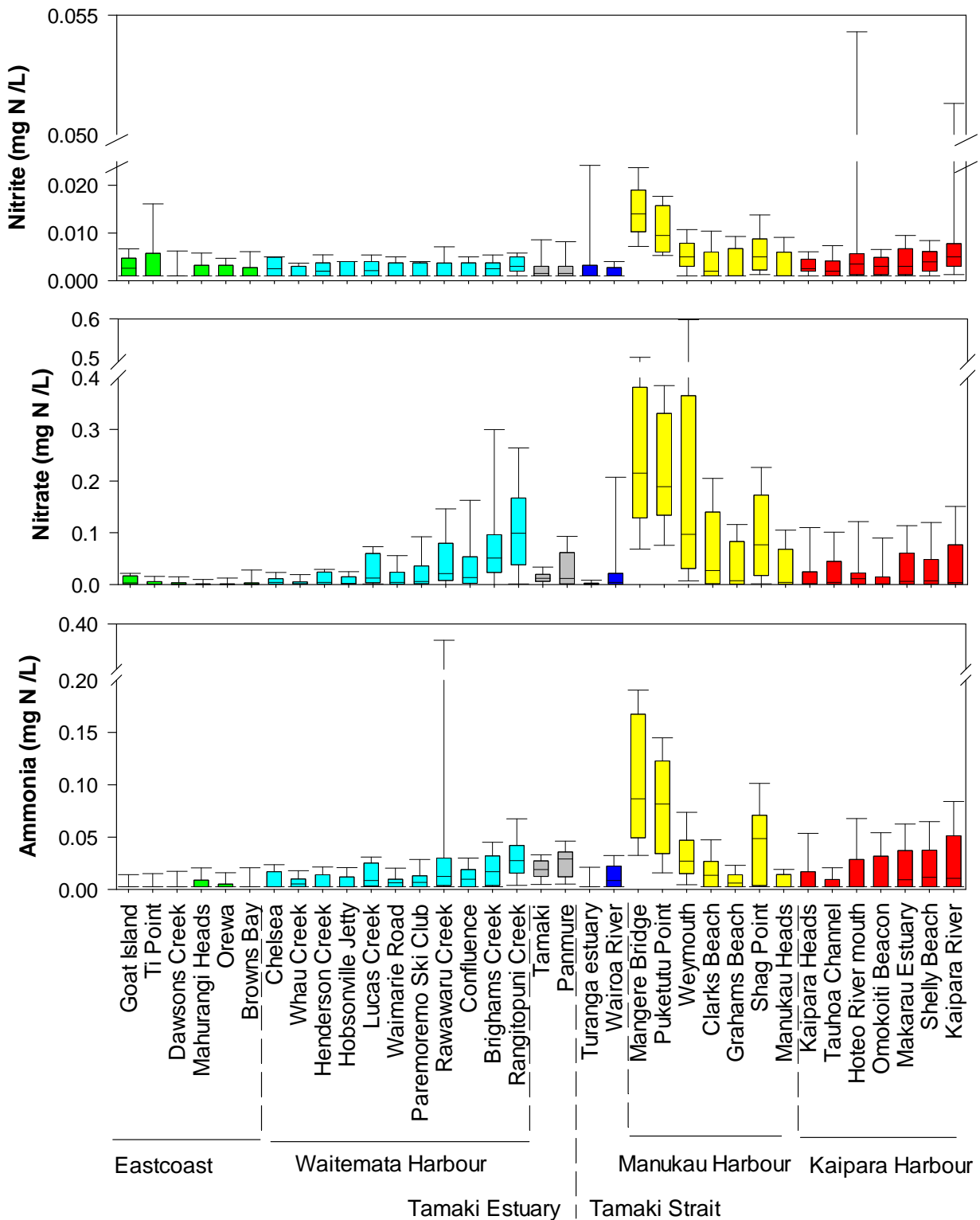


Figure 3-3 Spatial patterns in nitrite, nitrate and ammonia.

Boxes represent the median, 25<sup>th</sup> and 75<sup>th</sup> percentiles while whiskers are 5<sup>th</sup> and 95<sup>th</sup> percentiles for data collected from January 2011 to December 2011. Percentiles values calculated using the standard method in SigmaPlot (v12). Note the scale break in the y-axis of all three plots.

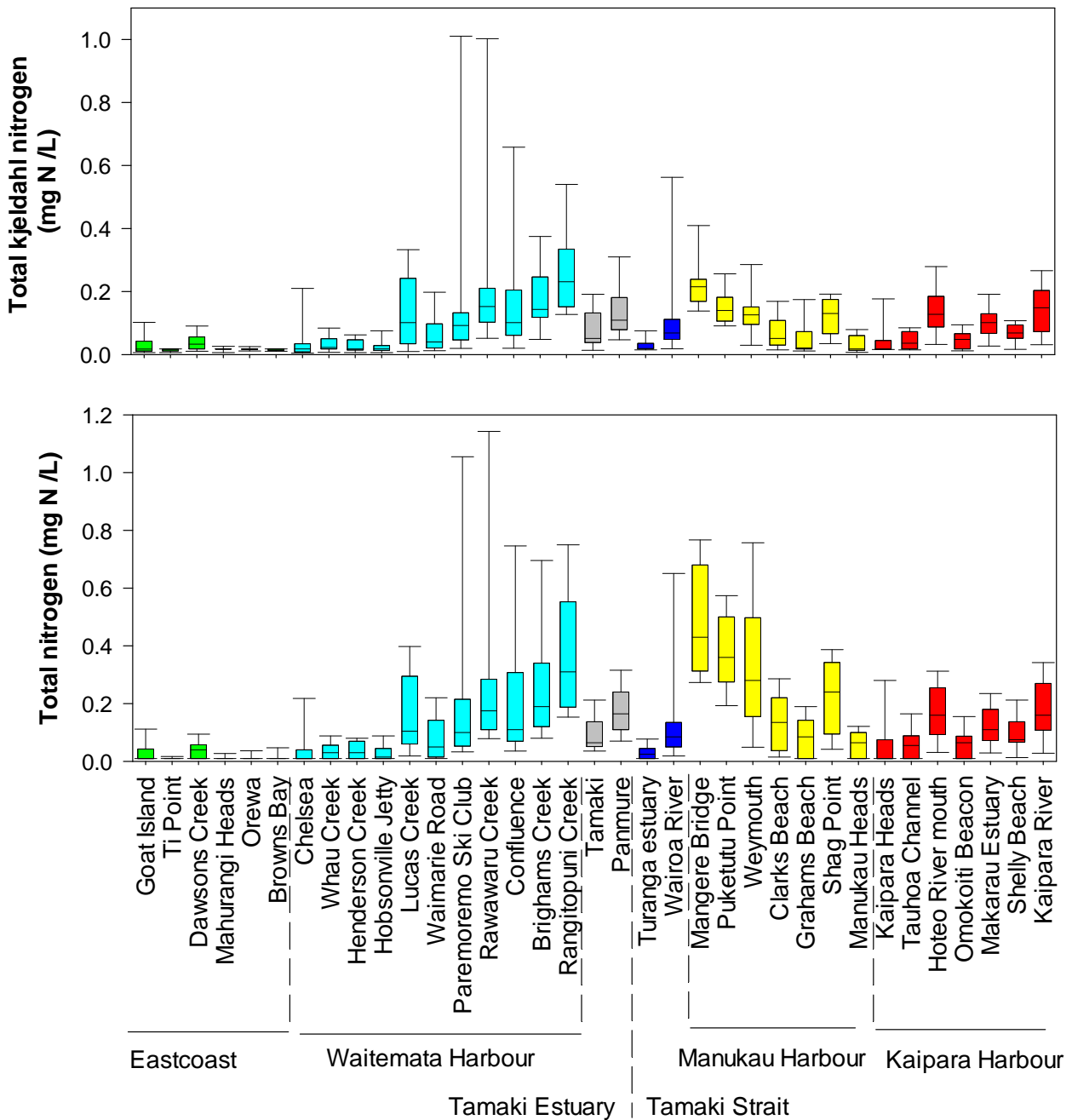


Figure 3-4 Spatial patterns in total kjeldahl nitrogen and total nitrogen.

Boxes represent the median, 25<sup>th</sup> and 75<sup>th</sup> percentiles while whiskers are 5<sup>th</sup> and 95<sup>th</sup> percentiles for data collected from January 2011 to December 2011. Percentiles values calculated using the standard method in SigmaPlot (v12).

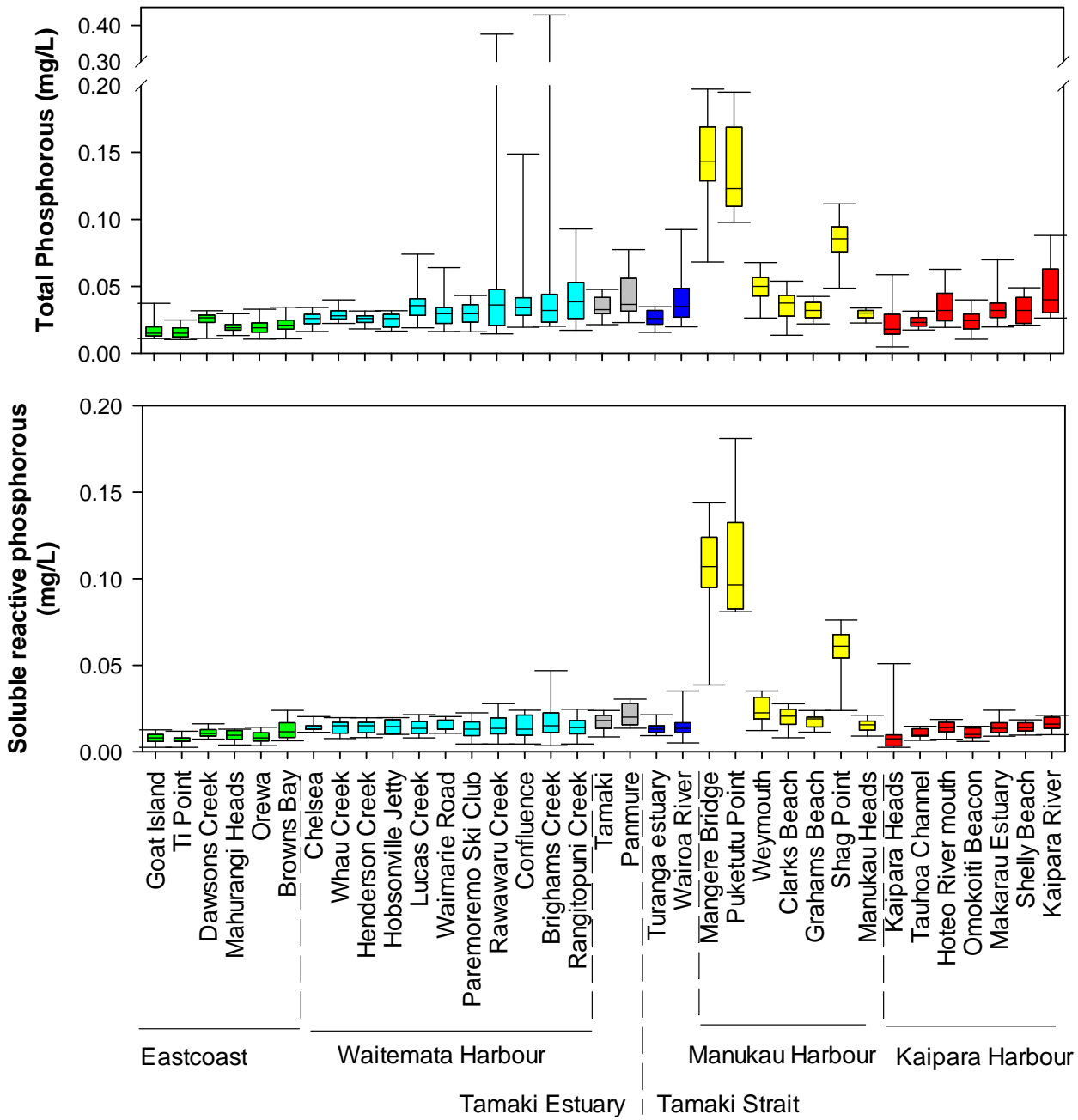


Figure 3-5 Spatial patterns in total phosphorous and soluble reactive phosphorous.

Boxes represent the median, 25<sup>th</sup> and 75<sup>th</sup> percentiles while whiskers are 5<sup>th</sup> and 95<sup>th</sup> percentiles for data collected from January 2011 to December 2011. Percentiles values calculated using the standard method in SigmaPlot (v12). Note the scale break in the y-axis of the Total phosphorus plot.

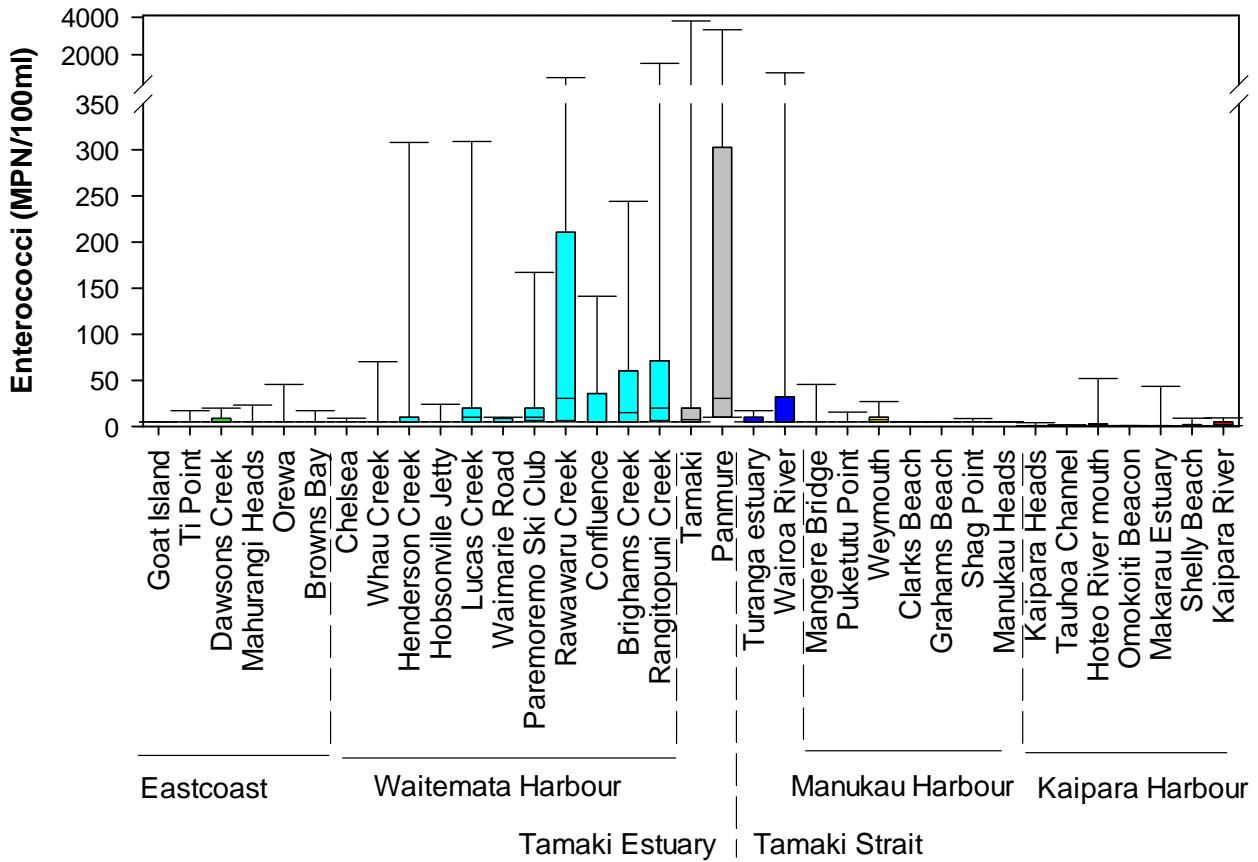


Figure 3-6 Spatial patterns in enterococci.

Boxes represent the median, 25<sup>th</sup> and 75<sup>th</sup> percentiles while whiskers are 5<sup>th</sup> and 95<sup>th</sup> percentiles for data collected from January 2011 to December 2011. Percentiles values calculated using the standard method in SigmaPlot (v12). Note the scale break in the y-axis of the plot.

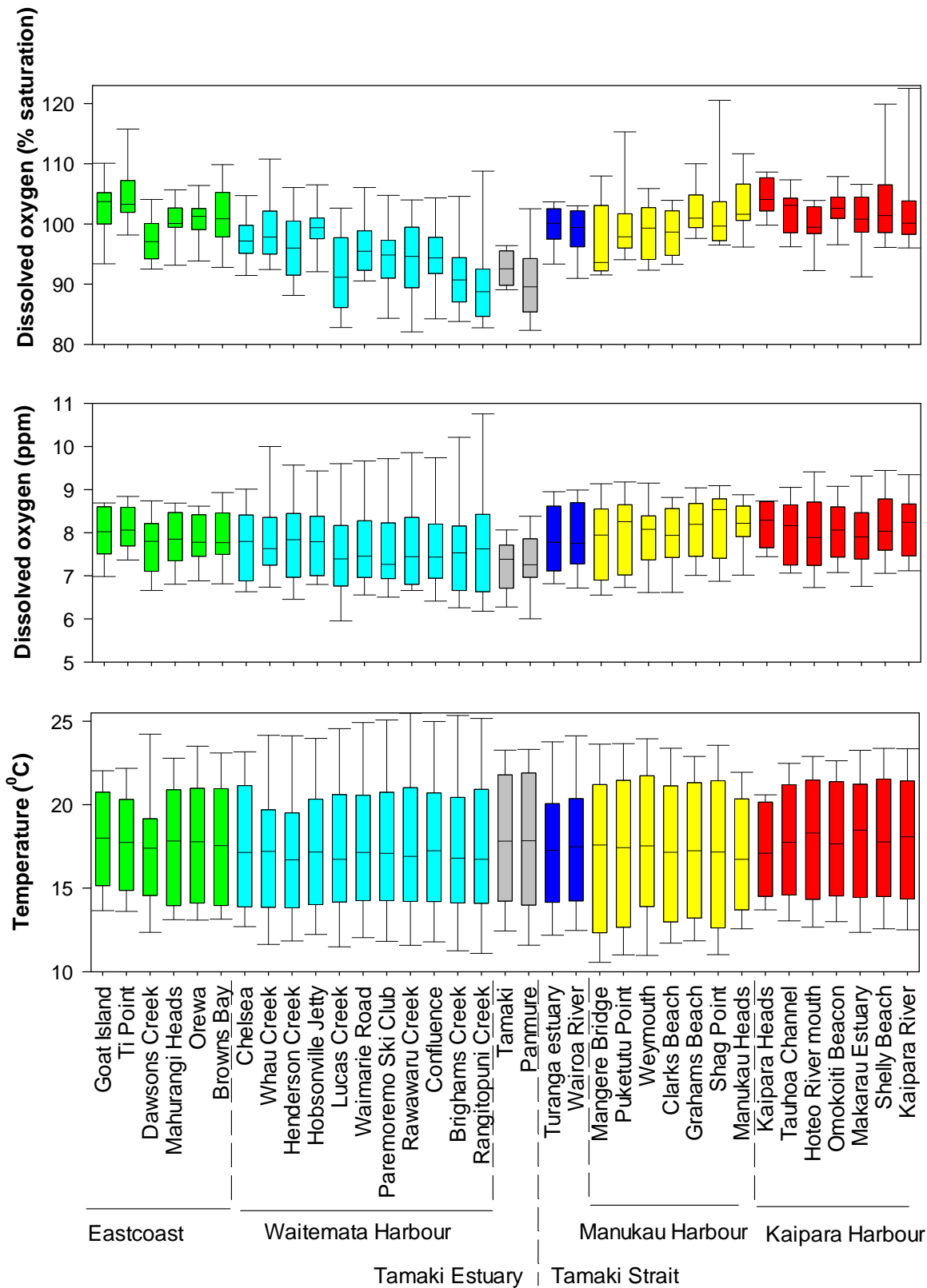


Figure 3-7 Spatial patterns in two indices of dissolved oxygen (ppm and % saturation) and sea surface temperature.

Boxes represent the median, 25<sup>th</sup> and 75<sup>th</sup> percentiles while whiskers are 5<sup>th</sup> and 95<sup>th</sup> percentiles for data collected from January 2011 to December 2011. Percentile values calculated using the standard method in SigmaPlot (v12).

## 3.2 Marine Water Quality Index

Using the methodology described in Appendix 1 and first applied in the 2009 annual water quality report, water quality indices and classes were generated for each of the 35 sites (Table 3-1).

Mahurangi Heads maintained its position having the best water quality in 2011 and was classed as excellent. Six other sites were also classed as excellent, including four sites that were previously good or fair in 2010 (Ti Point, Orewa, Browns Bay, Whau Creek, Turanga Estuary Mouth and Hobsonville Jetty). Mangere Bridge had the worst water quality of all the monitoring sites in 2011 retaining its status from 2010, with exceedances of the target levels occurring commonly and often of high magnitude.

There were 17 sites that changed quality class from their 2010 classification, which reflects the variable nature of water quality data. The majority of changes were increases in water quality class. Of the 17 sites 3 changed by two classes. For example a increase in water quality (from Fair to Excellent) was observed at Hobsonville Jetty-(Waitemata Harbour) which reverted back to the 2009 class; and decrease in class (Good to Poor) at Chelsea (Central Waitemata) and Tamaki (Tamaki Estuary).

Of interest is the numbers of sites classified as having Poor water quality (35 %). In 2009 only four sites were allocated this class, 2010 had 14 sites and in 2011 there were 12 sites classed as having Poor water quality. The decline in water quality class can be attributed to failures to comply with quality thresholds (see Table 5-1, Appendix A) for concentrations of suspended sediments, turbidity and typically one of the nutrient tests (e.g. ammoniacal nitrogen, total phosphorus or nitrate + nitrite nitrogen).

Table 3-1 Water quality index

and the resultant water quality class for the sites monitored. The 2010 water quality class is also presented for inter-annual comparisons.

Site	scope	frequency	magnitude	Index	2011 class	2010 class
Whau Creek	11.1	0.9	0.1	93.6	Excellent	Good
Mahurangi Heads	11.1	1.9	0.0	93.5	Excellent	Excellent
Orewa	11.1	1.9	0.0	93.5	Excellent	Excellent
Browns Bay	11.1	1.9	0.0	93.5	Excellent	Good
Turanga Est Mouth	11.1	1.9	0.0	93.5	Excellent	Good
Hobsonville Jetty	11.1	1.9	0.1	93.5	Excellent	Fair
Ti Point	11.1	2.8	0.1	93.4	Excellent	Excellent
Dawsons Creek	22.2	2.8	0.3	87.1	Good	Good
Omokoiti Beacon	22.2	2.8	0.1	87.1	Good	Fair
Tauhoa Channel	33.3	2.8	0.5	80.7	Good	Fair
Waimarie Road	33.3	3.7	0.7	80.6	Good	Fair
Goat Island	33.3	3.8	0.8	80.6	Good	Excellent
Paremoremo Ski Club	33.3	3.7	1.2	80.6	Good	Fair
Manukau Heads	44.4	4.6	1.1	74.2	Fair	Fair
Grahams Beach	55.6	5.6	3.1	67.7	Fair	Poor
Shelly Beach	55.6	10.4	2.2	67.3	Fair	Fair
Lucas Creek	55.6	8.3	8.7	67.2	Fair	Poor
Clarks Beach	55.6	12.1	5.2	67.0	Fair	Poor
Henderson Creek	55.6	5.6	19.3	65.9	Fair	Poor
Kaipara Heads	66.7	6.5	2.1	61.3	Fair	Fair
Confluence	66.7	7.4	3.2	61.2	Fair	Poor
Makarau Estuary	66.7	9.4	6.5	60.9	Fair	Fair
Hoteo River mouth	66.7	12.3	7.9	60.6	Fair	Fair
Tamaki	33.3	4.7	63.6	58.5	Poor	Good
Weymouth	66.7	20.8	19.5	58.1	Poor	Poor
Panmure	66.7	14.0	34.4	55.9	Poor	Poor
Puketutu Point	66.7	34.3	25.5	54.3	Poor	Poor
Chelsea	77.8	7.4	13.2	54.3	Poor	Good
Wairoa River Mouth	77.8	17.6	21.0	52.4	Poor	Fair
Shag Point	77.8	25.0	11.5	52.4	Poor	Poor
Kaipara River	77.8	34.0	21.3	49.5	Poor	Poor
Mangere Bridge	77.8	35.2	31.3	47.5	Poor	Poor
Brighams Creek	77.8	13.0	50.3	46.0	Poor	Poor
Rangitopuni Creek	88.9	18.5	23.2	45.9	Poor	Poor
Rarawaru Creek	100.0	16.7	23.8	39.9	Poor	Poor

### 3.3 Data tables

Table 3-2 Electrical conductivity (mS.cm<sup>-1</sup>)

Site	Count	Min	Max	Median	Mean	Standard error
Goat Island	12	50.87	54.08	52.79	52.71	0.26
Ti Point	12	52.10	54.00	52.87	52.86	0.17
Dawsons Creek	12	46.01	53.37	49.71	49.48	0.62
Mahurangi Heads	12	40.30	52.98	51.59	50.71	1.00
Orewa	12	50.55	53.79	52.39	52.19	0.27
Browns Bay	12	50.39	53.62	52.35	52.00	0.30
Chelsea	11	49.66	53.02	51.50	50.99	0.34
Whau Creek	12	45.13	52.65	48.42	48.30	0.61
Henderson Creek	11	41.97	52.17	48.10	47.38	0.86
Hobsonville Jetty	12	45.97	52.62	49.31	49.23	0.60
Lucas Creek	12	30.98	49.96	42.27	41.83	1.51
Waimarie Road	12	40.53	51.61	46.52	45.72	0.95
Paremoremo Ski Club	12	36.33	51.98	43.63	43.91	1.37
Rawawaru Creek	12	34.07	50.58	41.18	40.67	1.43
Confluence	12	35.90	51.08	42.16	42.40	1.23
Brighams Creek	12	25.07	50.11	37.66	37.46	1.97
Rangitopuni Creek	12	16.88	49.36	30.13	31.57	2.60
Tamaki	12	49.15	53.46	51.00	51.19	0.37
Panmure	12	40.94	51.28	45.55	45.96	0.94
Turanga Estuary	12	47.08	54.34	51.93	51.22	0.61
Wairoa River	12	32.11	52.06	49.37	47.99	1.53
Mangere Bridge	12	38.16	49.25	45.93	45.11	0.97
Puketutu Point	12	43.96	50.33	48.00	47.58	0.57
Weymouth	11	36.11	51.41	46.94	45.47	1.42
Clarks Beach	12	44.31	51.63	49.48	49.00	0.74
Grahams Beach	12	47.35	51.74	50.46	50.03	0.41
Shag Point	12	45.72	51.22	48.97	48.84	0.53
Manukau Heads	12	49.23	52.65	51.22	50.91	0.33
Kaipara Heads	12	50.04	53.62	51.92	51.71	0.32
Tauhoa Channel	12	43.37	52.50	49.41	48.33	0.84
Hoteo River mouth	12	36.61	52.82	46.75	45.02	1.48
Omokoiti Beacon	12	44.86	52.97	49.29	48.98	0.72
Makarau Estuary	12	41.89	52.68	47.89	47.47	0.91
Shelly Beach	12	42.75	52.77	48.35	48.09	0.83
Kaipara River	12	41.33	52.73	47.90	47.27	1.00



Table 3-3 Salinity (ppt)

Site	Count	Min	Max	Median	Mean	Standard error
Goat Island	12	33.45	35.82	34.85	34.78	0.19
Ti Point	12	34.36	35.75	34.92	34.89	0.13
Dawsons Creek	12	29.86	35.25	32.57	32.40	0.46
Mahurangi Heads	12	25.78	34.97	33.87	33.31	0.72
Orewa	12	33.21	35.56	34.57	34.38	0.20
Browns Bay	12	33.09	35.44	34.53	34.24	0.23
Chelsea	11	32.50	35.00	33.91	33.49	0.26
Whau Creek	12	29.13	34.72	31.61	31.52	0.46
Henderson Creek	11	26.99	34.35	31.42	30.86	0.63
Hobsonville Jetty	12	29.75	34.74	32.26	32.21	0.45
Lucas Creek	12	19.30	32.72	27.20	26.89	1.07
Waimarie Road	12	25.87	33.93	30.24	29.67	0.69
Paremoremo Ski Club	12	23.01	34.27	28.18	28.38	0.99
Rawawaru Creek	12	21.43	33.14	26.42	26.06	1.01
Confluence	12	22.63	33.53	27.13	27.29	0.88
Brighams Creek	12	15.32	32.81	23.94	23.83	1.38
Rangitopuni Creek	12	9.94	32.27	18.72	19.79	1.79
Tamaki	12	32.05	35.32	33.55	33.64	0.28
Panmure	12	26.18	33.75	29.55	29.84	0.69
Turanga Estuary	12	30.63	35.97	34.22	33.67	0.45
Wairoa River	12	20.07	34.27	32.26	31.33	1.09
Mangere Bridge	12	24.19	32.26	29.82	29.22	0.71
Puketutu Point	12	28.31	33.03	31.31	30.99	0.42
Weymouth	11	22.79	33.85	30.51	29.50	1.03
Clarks Beach	12	28.59	34.01	32.41	32.04	0.54
Grahams Beach	12	30.78	34.07	33.13	32.78	0.31
Shag Point	12	29.58	33.69	32.01	31.90	0.40
Manukau Heads	12	32.17	34.76	33.70	33.44	0.25
Kaipara Heads	12	32.77	35.48	34.22	34.04	0.24
Tauhoa Channel	12	27.93	34.63	32.36	31.57	0.61
Hoteo River mouth	12	23.18	34.85	30.41	29.19	1.07
Omokoiti Beacon	12	28.98	34.97	32.25	32.04	0.53
Makarau Estuary	12	26.85	34.74	31.23	30.93	0.66
Shelly Beach	12	27.47	34.80	31.59	31.39	0.61
Kaipara River	12	26.46	34.78	31.24	30.80	0.73

Table 3-4 pH (pH units)

Site	Count	Min	Max	Median	Mean	Standard error
Goat Island	12	7.46	8.37	8.08	8.00	0.08
Ti Point	12	7.41	8.59	8.09	8.08	0.08
Dawsons Creek	12	6.96	8.29	8.01	7.94	0.10
Mahurangi Heads	12	7.45	8.49	8.06	8.03	0.07
Orewa	12	7.51	8.47	8.06	8.06	0.07
Browns Bay	12	7.72	8.55	8.06	8.10	0.06
Chelsea	12	7.07	8.29	7.93	7.88	0.08
Whau Creek	12	6.98	8.25	8.00	7.90	0.10
Henderson Creek	12	6.91	8.26	7.92	7.82	0.10
Hobsonville Jetty	12	6.98	8.32	8.02	7.91	0.10
Lucas Creek	12	6.95	8.16	7.89	7.79	0.09
Waimarie Road	12	7.00	8.21	7.94	7.86	0.09
Paremoremo Ski Club	12	6.99	8.18	7.94	7.81	0.09
Rawawaru Creek	12	6.99	8.10	7.93	7.78	0.09
Confluence	12	7.01	8.15	7.91	7.80	0.09
Brighams Creek	12	6.87	8.03	7.83	7.72	0.10
Rangitopuni Creek	12	6.84	8.03	7.70	7.65	0.09
Tamaki	11	7.80	8.15	7.97	7.98	0.03
Panmure	11	7.80	8.07	7.97	7.95	0.03
Turanga Estuary	12	7.37	8.53	8.04	8.04	0.08
Wairoa River	12	7.43	8.30	8.07	8.04	0.07
Mangere Bridge	12	7.42	8.13	7.91	7.88	0.05
Puketutu Point	12	7.52	8.12	7.91	7.89	0.05
Weymouth	11	7.56	8.22	7.95	7.93	0.05
Clarks Beach	12	7.40	8.28	7.98	7.94	0.06
Grahams Beach	12	7.46	8.17	8.03	7.97	0.05
Shag Point	12	7.52	8.31	7.97	7.98	0.05
Manukau Heads	12	7.40	8.36	8.03	8.02	0.07
Kaipara Heads	11	7.44	8.27	8.04	7.99	0.06
Tauhoa Channel	11	7.40	8.21	7.98	7.95	0.07
Hoteo River mouth	11	7.53	8.18	7.95	7.91	0.05
Omokoiti Beacon	11	7.44	8.31	7.97	7.96	0.07
Makarau Estuary	11	7.48	8.11	7.93	7.88	0.05
Shelly Beach	11	7.50	8.14	7.89	7.88	0.06
Kaipara River	11	7.18	8.21	7.88	7.80	0.09

Table 3-5 Turbidity (NTU)

Site	Count	Min	Max	Median	Mean	Standard error
Goat Island	12	0.24	13.30	0.65	1.90	1.06
Ti Point	12	0.27	1.94	0.82	0.96	0.14
Dawsons Creek	12	0.87	10.10	4.95	4.98	0.64
Mahurangi Heads	12	0.90	4.79	1.58	1.90	0.33
Orewa	12	0.58	6.65	0.92	1.84	0.54
Browns Bay	12	0.39	6.03	0.96	1.56	0.47
Chelsea	11	1.69	5.88	3.04	3.58	0.39
Whau Creek	12	1.48	6.10	2.94	3.42	0.48
Henderson Creek	11	1.72	6.46	4.13	3.99	0.44
Hobsonville Jetty	12	0.71	5.00	3.35	3.11	0.37
Lucas Creek	12	1.81	11.80	6.63	6.63	0.87
Waimarie Road	12	1.24	6.74	3.94	4.17	0.47
Paremoremo Ski Club	12	1.82	7.01	4.73	4.71	0.43
Rawawaru Creek	12	2.22	43.80	6.28	9.31	3.22
Confluence	12	1.42	8.75	5.26	5.36	0.48
Brighams Creek	12	1.92	34.90	6.64	8.78	2.49
Rangitopuni Creek	12	3.11	29.90	6.42	8.35	2.20
Tamaki	12	2.24	13.10	3.87	5.58	1.05
Panmure	12	3.76	28.50	6.62	10.64	2.25
Turanga Estuary	12	1.98	5.81	2.86	3.14	0.31
Wairoa River	12	1.08	53.90	6.59	13.34	4.64
Mangere Bridge	12	3.61	22.70	7.45	9.11	1.72
Puketutu Point	12	2.50	16.10	3.56	5.94	1.32
Weymouth	12	4.98	33.00	7.68	11.09	2.43
Clarks Beach	12	0.69	16.50	4.46	6.33	1.35
Grahams Beach	11	1.32	7.84	2.32	3.01	0.61
Shag Point	12	1.37	15.20	3.52	5.28	1.27
Manukau Heads	12	1.38	9.05	2.44	3.08	0.61
Kaipara Heads	12	0.61	13.00	2.16	2.88	0.99
Tauhoa Channel	12	1.41	5.19	2.61	2.76	0.33
Hoteo River mouth	12	3.69	23.40	5.82	8.74	1.80
Omokoiti Beacon	12	0.82	6.54	3.32	3.54	0.46
Makarau Estuary	12	4.29	22.50	6.28	8.43	1.72
Shelly Beach	12	3.15	12.40	6.45	7.07	0.89
Kaipara River	12	8.20	45.70	15.20	18.30	2.89

Table 3-6 Suspended sediment (mg/L)

Site	Count	Min	Max	Median	Mean	Standard error
Goat Island	12	1.50	28.00	5.25	7.18	2.14
Ti Point	12	0.40	19.00	4.20	5.44	1.42
Dawsons Creek	12	2.20	25.00	9.10	10.00	1.58
Mahurangi Heads	12	3.20	16.00	7.00	7.45	0.96
Orewa	12	1.10	18.00	4.75	5.81	1.32
Browns Bay	12	1.40	14.00	4.80	6.08	1.17
Chelsea	11	4.20	14.00	8.60	8.92	0.88
Whau Creek	12	3.30	18.00	6.65	7.51	1.13
Henderson Creek	11	2.50	15.00	6.60	8.22	1.15
Hobsonville Jetty	12	3.00	13.00	5.80	6.32	0.78
Lucas Creek	12	6.70	21.00	12.00	12.23	1.43
Waimarie Road	12	2.50	14.00	8.25	8.87	0.99
Paremoremo Ski Club	12	3.50	16.00	8.15	8.86	0.99
Rawawaru Creek	12	4.00	60.00	10.35	14.89	4.26
Confluence	12	6.70	15.00	9.60	9.58	0.72
Brighams Creek	12	6.80	35.00	9.45	12.93	2.30
Rangitopuni Creek	12	6.30	32.00	7.85	12.06	2.33
Tamaki	12	5.20	23.00	8.90	11.39	1.80
Panmure	12	1.20	61.00	15.50	19.99	4.87
Turanga Estuary	12	5.60	16.00	9.40	9.29	0.89
Wairoa River	12	1.80	57.00	14.50	23.76	5.81
Mangere Bridge	12	11.00	54.00	18.00	21.08	3.57
Puketutu Point	12	9.00	56.00	15.00	20.08	3.86
Weymouth	12	9.30	86.00	19.00	28.03	6.46
Clarks Beach	12	2.30	35.00	13.50	16.98	2.88
Grahams Beach	11	4.00	19.00	7.50	9.41	1.42
Shag Point	12	7.00	32.00	15.50	15.65	2.05
Manukau Heads	12	4.20	22.00	8.15	9.97	1.45
Kaipara Heads	12	2.10	33.00	8.85	10.65	2.53
Tauhoa Channel	12	2.10	23.00	8.25	9.33	1.58
Hoteo River mouth	12	7.20	49.00	14.50	19.38	3.30
Omokoiti Beacon	12	5.10	22.00	12.00	12.17	1.45
Makarau Estuary	12	6.30	46.00	16.00	19.36	3.39
Shelly Beach	12	11.00	28.00	13.00	17.25	1.95
Kaipara River	12	25.00	93.00	33.00	41.25	5.62

Table 3-7 Chlorophyll a (mg/L)

Site	Count	Min	Max	Median	Mean	Standard error
Goat Island	12	0.0003	0.0031	0.0014	0.0014	0.0002
Ti Point	12	0.0003	0.0021	0.0008	0.0010	0.0002
Dawsons Creek	12	0.0007	0.0067	0.0016	0.0024	0.0006
Mahurangi Heads	12	0.0006	0.0031	0.0016	0.0016	0.0002
Orewa	12	0.0003	0.0020	0.0015	0.0014	0.0001
Browns Bay	12	0.0007	0.0033	0.0014	0.0016	0.0002
Chelsea	11	0.0003	0.0033	0.0018	0.0020	0.0003
Whau Creek	12	0.0003	0.0047	0.0014	0.0018	0.0004
Henderson Creek	12	0.0003	0.0039	0.0020	0.0021	0.0003
Hobsonville Jetty	12	0.0003	0.0048	0.0016	0.0017	0.0004
Lucas Creek	12	0.0003	0.0536	0.0033	0.0073	0.0043
Waimarie Road	12	0.0003	0.0098	0.0028	0.0032	0.0008
Paremoremo Ski Club	12	0.0003	0.0104	0.0022	0.0031	0.0009
Rawawaru Creek	12	0.0003	0.0101	0.0030	0.0037	0.0010
Confluence	12	0.0003	0.0080	0.0032	0.0035	0.0008
Brighams Creek	12	0.0003	0.6307	0.0035	0.0557	0.0523
Rangitopuni Creek	12	0.0012	0.0526	0.0036	0.0083	0.0041
Tamaki	12	0.0003	1.0000	0.0021	0.0856	0.0831
Panmure	12	0.0003	0.0122	0.0026	0.0036	0.0010
Turanga Estuary	12	0.0006	0.0039	0.0016	0.0019	0.0003
Wairoa River	12	0.0008	0.0078	0.0027	0.0033	0.0007
Mangere Bridge	12	0.0010	0.0140	0.0038	0.0052	0.0013
Puketutu Point	12	0.0003	0.0077	0.0033	0.0034	0.0007
Weymouth	12	0.0003	0.0127	0.0043	0.0048	0.0011
Clarks Beach	12	0.0003	0.0104	0.0022	0.0030	0.0008
Grahams Beach	12	0.0007	0.0120	0.0021	0.0034	0.0010
Shag Point	12	0.0012	0.0240	0.0028	0.0054	0.0018
Manukau Heads	12	0.0008	0.0130	0.0016	0.0027	0.0009
Kaipara Heads	12	0.0013	0.0130	0.0022	0.0030	0.0009
Tauhoa Channel	12	0.0008	0.0093	0.0031	0.0036	0.0007
Hoteo River mouth	12	0.0003	0.0236	0.0038	0.0058	0.0018
Omokoiti Beacon	12	0.0017	0.0067	0.0027	0.0032	0.0004
Makarau Estuary	12	0.0018	0.0180	0.0029	0.0050	0.0014
Shelly Beach	12	0.0010	0.0081	0.0030	0.0033	0.0006
Kaipara River	12	0.0015	0.0132	0.0047	0.0061	0.0012

Table 3-8 Nitrite (mg N/L)

Site	Count	Min	Max	Median	Mean	Standard error
Goat Island	12	0.00000	0.02200	0.00289	0.00740	0.00244
Ti Point	12	0.00000	0.01900	0.00050	0.00329	0.00161
Dawsons Creek	12	0.00000	0.01900	0.00000	0.00250	0.00158
Mahurangi Heads	12	0.00000	0.01200	0.00000	0.00150	0.00101
Orewa	12	0.00000	0.01700	0.00000	0.00175	0.00140
Browns Bay	12	0.00000	0.03100	0.00000	0.00483	0.00289
Chelsea	11	0.00000	0.02500	0.00400	0.00646	0.00245
Whau Creek	12	0.00000	0.02000	0.00150	0.00425	0.00194
Henderson Creek	11	0.00000	0.03000	0.00400	0.01046	0.00352
Hobsonville Jetty	12	0.00000	0.02700	0.00200	0.00692	0.00264
Lucas Creek	12	0.00100	0.07400	0.01250	0.02725	0.00828
Waimarie Road	12	0.00000	0.06000	0.00400	0.01392	0.00582
Paremoremo Ski Club	12	0.00000	0.10600	0.00550	0.02225	0.00936
Rawawaru Creek	12	0.00000	0.15400	0.02100	0.04492	0.01509
Confluence	12	0.00000	0.18300	0.01350	0.03783	0.01635
Brighams Creek	12	0.00000	0.35000	0.05100	0.08033	0.02855
Rangitopuni Creek	12	0.00000	0.28200	0.09900	0.10442	0.02529
Tamaki	12	0.00000	0.03900	0.01200	0.01351	0.00310
Panmure	12	0.00000	0.10500	0.01150	0.02975	0.01024
Turanga Estuary	12	0.00000	0.01000	0.00000	0.00158	0.00086
Wairoa River	12	0.00000	0.28400	0.00400	0.03025	0.02324
Mangere Bridge	12	0.06200	0.52300	0.21550	0.24742	0.04248
Puketutu Point	12	0.05400	0.38900	0.18900	0.22008	0.03167
Weymouth	12	0.00610	0.68300	0.09700	0.18951	0.06060
Clarks Beach	12	0.00000	0.21900	0.02700	0.06467	0.02295
Grahams Beach	12	0.00000	0.12200	0.00710	0.03477	0.01336
Shag Point	12	0.00000	0.23200	0.07650	0.09405	0.02383
Manukau Heads	12	0.00000	0.10900	0.00400	0.03109	0.01185
Kaipara Heads	12	0.00000	0.13000	0.00150	0.02092	0.01126
Tauhoa Channel	12	0.00000	0.11900	0.00400	0.02433	0.01055
Hoteo River mouth	12	0.00000	0.13100	0.01100	0.02567	0.01241
Omokoiti Beacon	12	0.00000	0.11100	0.00100	0.01533	0.00936
Makarau Estuary	12	0.00000	0.13100	0.00600	0.02800	0.01218
Shelly Beach	12	0.00000	0.12300	0.00700	0.03008	0.01284
Kaipara River	12	0.00000	0.15600	0.00350	0.03625	0.01682

Table 3-9 Nitrate (mg N/L)

Site	Count	Min	Max	Median	Mean	Standard error
Goat Island	12	0.0010	0.0070	0.0026	0.0031	0.0006
Ti Point	12	0.0010	0.0200	0.0010	0.0038	0.0016
Dawsons Creek	12	0.0010	0.0072	0.0010	0.0018	0.0006
Mahurangi Heads	12	0.0010	0.0066	0.0010	0.0020	0.0005
Orewa	12	0.0010	0.0050	0.0010	0.0018	0.0004
Browns Bay	12	0.0010	0.0070	0.0010	0.0020	0.0005
Chelsea	12	0.0010	0.0050	0.0025	0.0028	0.0006
Whau Creek	12	0.0010	0.0040	0.0010	0.0018	0.0003
Henderson Creek	12	0.0010	0.0056	0.0020	0.0025	0.0005
Hobsonville Jetty	12	0.0010	0.0040	0.0010	0.0022	0.0004
Lucas Creek	12	0.0010	0.0060	0.0021	0.0025	0.0005
Waimarie Road	12	0.0010	0.0050	0.0010	0.0021	0.0005
Paremoremo Ski Club	12	0.0010	0.0040	0.0010	0.0019	0.0004
Rawawaru Creek	12	0.0010	0.0080	0.0010	0.0024	0.0006
Confluence	12	0.0010	0.0050	0.0010	0.0022	0.0005
Brighams Creek	12	0.0010	0.0060	0.0025	0.0025	0.0005
Rangitopuni Creek	12	0.0010	0.0060	0.0030	0.0033	0.0005
Tamaki	12	0.0010	0.0100	0.0015	0.0027	0.0008
Panmure	12	0.0010	0.0100	0.0015	0.0025	0.0007
Turanga Estuary	12	0.0010	0.0320	0.0010	0.0043	0.0026
Wairoa River	12	0.0010	0.0040	0.0010	0.0018	0.0004
Mangere Bridge	12	0.0060	0.0240	0.0140	0.0146	0.0016
Puketutu Point	12	0.0050	0.0180	0.0095	0.0108	0.0014
Weymouth	12	0.0010	0.0110	0.0050	0.0054	0.0009
Clarks Beach	12	0.0010	0.0110	0.0020	0.0037	0.0010
Grahams Beach	12	0.0010	0.0100	0.0010	0.0035	0.0010
Shag Point	12	0.0010	0.0150	0.0050	0.0059	0.0012
Manukau Heads	12	0.0010	0.0100	0.0010	0.0034	0.0009
Kaipara Heads	12	0.0010	0.0063	0.0025	0.0030	0.0005
Tauhoa Channel	12	0.0010	0.0080	0.0020	0.0029	0.0006
Hoteo River mouth	12	0.0010	0.0720	0.0035	0.0097	0.0057
Omokoiti Beacon	12	0.0010	0.0070	0.0030	0.0033	0.0006
Makarau Estuary	12	0.0010	0.0100	0.0030	0.0040	0.0009
Shelly Beach	12	0.0010	0.0090	0.0040	0.0040	0.0007
Kaipara River	12	0.0010	0.0690	0.0050	0.0103	0.0054

Table 3-10 Ammonia (mg N/L)

Site	Count	Min	Max	Median	Mean	Standard error
Goat Island	12	0.00250	0.01900	0.00250	0.00388	0.00138
Ti Point	12	0.00250	0.01500	0.00250	0.00458	0.00141
Dawsons Creek	12	0.00250	0.02200	0.00250	0.00442	0.00163
Mahurangi Heads	12	0.00250	0.02200	0.00250	0.00604	0.00197
Orewa	12	0.00250	0.01800	0.00250	0.00479	0.00141
Browns Bay	12	0.00250	0.02100	0.00250	0.00550	0.00202
Chelsea	11	0.00250	0.02400	0.00250	0.00805	0.00260
Whau Creek	12	0.00250	0.02000	0.00525	0.00698	0.00162
Henderson Creek	11	0.00250	0.02300	0.00250	0.00732	0.00219
Hobsonville Jetty	12	0.00250	0.02200	0.00250	0.00646	0.00211
Lucas Creek	12	0.00250	0.03200	0.00850	0.01338	0.00314
Waimarie Road	12	0.00250	0.02300	0.00625	0.00750	0.00179
Paremoremo Ski Club	12	0.00250	0.03000	0.00665	0.00973	0.00268
Rawawaru Creek	12	0.00250	0.45400	0.01250	0.06646	0.03909
Confluence	12	0.00250	0.03200	0.00970	0.01158	0.00292
Brighams Creek	12	0.00250	0.04900	0.01700	0.01938	0.00440
Rangitopuni Creek	12	0.00250	0.07500	0.02750	0.02946	0.00577
Tamaki	12	0.00250	0.03400	0.01900	0.01929	0.00264
Panmure	12	0.00250	0.05000	0.02900	0.02604	0.00402
Turanga Estuary	12	0.00250	0.02300	0.00250	0.00542	0.00200
Wairoa River	12	0.00250	0.03600	0.00850	0.01233	0.00317
Mangere Bridge	12	0.02600	0.19100	0.08650	0.09942	0.01734
Puketutu Point	12	0.01400	0.15000	0.08150	0.08042	0.01313
Weymouth	12	0.00250	0.07400	0.02700	0.03396	0.00670
Clarks Beach	12	0.00250	0.04800	0.01350	0.01833	0.00475
Grahams Beach	12	0.00250	0.02600	0.00600	0.00896	0.00219
Shag Point	12	0.00250	0.10300	0.04850	0.04629	0.01051
Manukau Heads	12	0.00250	0.02100	0.00250	0.00729	0.00193
Kaipara Heads	12	0.00250	0.05600	0.00250	0.01267	0.00553
Tauhoa Channel	12	0.00250	0.02400	0.00250	0.00671	0.00190
Hoteo River mouth	12	0.00250	0.07400	0.00250	0.01696	0.00692
Omokoiti Beacon	12	0.00250	0.06200	0.00250	0.01504	0.00567
Makarau Estuary	12	0.00250	0.06400	0.00925	0.02058	0.00668
Shelly Beach	12	0.00250	0.07100	0.01150	0.02138	0.00663
Kaipara River	12	0.00250	0.08900	0.01050	0.02629	0.00891



Table 3-11 Total kjedahl nitrogen (mg N/L)

Site	Count	Min	Max	Median	Mean	Standard error
Goat Island	12	0.005	0.123	0.018	0.029	0.010
Ti Point	12	0.005	0.018	0.017	0.015	0.001
Dawsons Creek	12	0.010	0.098	0.033	0.039	0.008
Mahurangi Heads	12	0.004	0.028	0.018	0.017	0.002
Orewa	12	0.010	0.028	0.018	0.018	0.001
Browns Bay	12	0.010	0.018	0.018	0.016	0.001
Chelsea	11	0.004	0.247	0.018	0.041	0.021
Whau Creek	12	0.002	0.095	0.023	0.033	0.007
Henderson Creek	11	0.005	0.065	0.018	0.028	0.006
Hobsonville Jetty	12	0.005	0.095	0.018	0.025	0.007
Lucas Creek	12	0.002	0.350	0.102	0.133	0.033
Waimarie Road	12	0.010	0.233	0.040	0.064	0.018
Paremoremo Ski Club	12	0.011	1.367	0.092	0.192	0.108
Rawawaru Creek	12	0.037	1.338	0.153	0.241	0.101
Confluence	12	0.009	0.785	0.102	0.176	0.062
Brighams Creek	11	0.043	0.375	0.143	0.182	0.033
Rangitopuni Creek	12	0.120	0.620	0.231	0.268	0.040
Tamaki	12	0.007	0.203	0.051	0.076	0.018
Panmure	12	0.042	0.338	0.109	0.134	0.025
Turanga Estuary	12	0.013	0.078	0.019	0.030	0.006
Wairoa River	12	0.010	0.687	0.068	0.133	0.054
Mangere Bridge	12	0.134	0.462	0.215	0.225	0.025
Puketutu Point	12	0.087	0.270	0.140	0.151	0.016
Weymouth	12	0.010	0.310	0.126	0.135	0.022
Clarks Beach	12	0.010	0.178	0.051	0.071	0.015
Grahams Beach	12	0.011	0.180	0.021	0.052	0.017
Shag Point	12	0.028	0.197	0.130	0.120	0.016
Manukau Heads	12	0.005	0.080	0.018	0.032	0.008
Kaipara Heads	12	0.016	0.200	0.018	0.045	0.017
Tauhoa Channel	12	0.014	0.087	0.036	0.044	0.008
Hoteo River mouth	12	0.018	0.313	0.128	0.139	0.022
Omokoiti Beacon	12	0.010	0.101	0.048	0.047	0.008
Makarau Estuary	12	0.018	0.200	0.102	0.102	0.015
Shelly Beach	12	0.016	0.110	0.068	0.067	0.009
Kaipara River	12	0.018	0.280	0.149	0.142	0.022

Table 3-12 Total nitrogen (by calculation, mg N/L)

Site	Count	Min	Max	Median	Mean	Standard error
Goat Island	12	0.010	0.130	0.010	0.029	0.011
Ti Point	12	0.010	0.020	0.010	0.011	0.001
Dawsons Creek	12	0.010	0.100	0.040	0.041	0.008
Mahurangi Heads	12	0.010	0.030	0.010	0.013	0.002
Orewa	12	0.010	0.040	0.010	0.014	0.003
Browns Bay	12	0.010	0.050	0.010	0.016	0.004
Chelsea	11	0.010	0.250	0.010	0.045	0.022
Whau Creek	12	0.010	0.100	0.030	0.036	0.008
Henderson Creek	11	0.010	0.080	0.030	0.036	0.009
Hobsonville Jetty	12	0.010	0.100	0.015	0.029	0.008
Lucas Creek	12	0.010	0.410	0.105	0.162	0.040
Waimarie Road	12	0.010	0.250	0.050	0.078	0.021
Paremoremo Ski Club	12	0.030	1.400	0.100	0.217	0.110
Rawawaru Creek	12	0.070	1.500	0.175	0.288	0.112
Confluence	12	0.030	0.830	0.110	0.216	0.070
Brighams Creek	11	0.070	0.730	0.190	0.264	0.062
Rangitopuni Creek	12	0.150	0.810	0.310	0.376	0.060
Tamaki	12	0.030	0.230	0.065	0.093	0.017
Panmure	12	0.058	0.340	0.165	0.175	0.023
Turanga Estuary	12	0.010	0.080	0.025	0.030	0.007
Wairoa River	12	0.010	0.690	0.085	0.166	0.063
Mangere Bridge	12	0.270	0.770	0.430	0.486	0.054
Puketutu Point	12	0.160	0.580	0.360	0.382	0.037
Weymouth	12	0.010	0.850	0.280	0.329	0.067
Clarks Beach	12	0.010	0.310	0.135	0.139	0.028
Grahams Beach	12	0.010	0.190	0.085	0.087	0.020
Shag Point	12	0.030	0.390	0.240	0.220	0.037
Manukau Heads	12	0.010	0.130	0.065	0.059	0.013
Kaipara Heads	12	0.010	0.340	0.010	0.058	0.028
Tauhoa Channel	12	0.010	0.180	0.055	0.062	0.016
Hoteo River mouth	12	0.010	0.330	0.160	0.167	0.027
Omokoiti Beacon	12	0.010	0.170	0.065	0.062	0.014
Makarau Estuary	12	0.020	0.250	0.110	0.127	0.020
Shelly Beach	12	0.010	0.230	0.075	0.097	0.018
Kaipara River	12	0.010	0.360	0.160	0.183	0.029

Table 3-13 Total phosphorus (mg/L)

Site	Count	Min	Max	Median	Mean	Standard error
Goat Island	12	0.011	0.042	0.015	0.018	0.002
Ti Point	12	0.010	0.027	0.015	0.016	0.001
Dawsons Creek	12	0.009	0.033	0.027	0.025	0.002
Mahurangi Heads	12	0.013	0.031	0.019	0.020	0.001
Orewa	12	0.010	0.035	0.019	0.020	0.002
Browns Bay	12	0.009	0.035	0.021	0.022	0.002
Chelsea	11	0.015	0.035	0.026	0.026	0.002
Whau Creek	12	0.022	0.042	0.028	0.029	0.002
Henderson Creek	11	0.017	0.032	0.026	0.025	0.001
Hobsonville Jetty	12	0.016	0.033	0.026	0.025	0.002
Lucas Creek	12	0.019	0.086	0.036	0.037	0.005
Waimarie Road	12	0.016	0.076	0.030	0.031	0.005
Paremoremo Ski Club	12	0.013	0.045	0.030	0.030	0.002
Rawawaru Creek	12	0.013	0.429	0.036	0.082	0.037
Confluence	12	0.017	0.194	0.034	0.046	0.014
Brighams Creek	12	0.019	0.591	0.032	0.079	0.047
Rangitopuni Creek	12	0.015	0.100	0.039	0.044	0.007
Tamaki	12	0.019	0.050	0.033	0.035	0.002
Panmure	12	0.022	0.084	0.037	0.043	0.005
Turanga Estuary	12	0.015	0.035	0.026	0.026	0.002
Wairoa River	12	0.018	0.099	0.035	0.042	0.007
Mangere Bridge	12	0.043	0.202	0.144	0.144	0.011
Puketutu Point	12	0.096	0.201	0.123	0.137	0.010
Weymouth	12	0.020	0.072	0.050	0.049	0.004
Clarks Beach	12	0.009	0.055	0.038	0.036	0.004
Grahams Beach	12	0.021	0.043	0.032	0.032	0.002
Shag Point	12	0.039	0.118	0.086	0.084	0.005
Manukau Heads	12	0.022	0.034	0.030	0.029	0.001
Kaipara Heads	12	0.003	0.068	0.018	0.022	0.005
Tauhoa Channel	12	0.017	0.033	0.023	0.024	0.001
Hoteo River mouth	12	0.019	0.067	0.032	0.035	0.004
Omokoiti Beacon	12	0.008	0.042	0.025	0.025	0.003
Makarau Estuary	12	0.019	0.075	0.032	0.036	0.005
Shelly Beach	12	0.021	0.051	0.032	0.032	0.003
Kaipara River	12	0.026	0.094	0.040	0.049	0.006

Table 3-14 Soluble reactive phosphorus (mg/L)

Site	Count	Min	Max	Median	Mean	Standard error
Goat Island	12	0.003	0.013	0.008	0.008	0.001
Ti Point	12	0.003	0.013	0.007	0.007	0.001
Dawsons Creek	12	0.007	0.017	0.011	0.011	0.001
Mahurangi Heads	12	0.003	0.013	0.010	0.009	0.001
Orewa	12	0.003	0.015	0.008	0.009	0.001
Browns Bay	12	0.006	0.026	0.012	0.013	0.002
Chelsea	11	0.011	0.021	0.013	0.014	0.001
Whau Creek	12	0.007	0.020	0.015	0.014	0.001
Henderson Creek	11	0.008	0.020	0.015	0.014	0.001
Hobsonville Jetty	12	0.010	0.020	0.015	0.014	0.001
Lucas Creek	12	0.008	0.023	0.014	0.014	0.001
Waimarie Road	12	0.010	0.021	0.013	0.015	0.001
Paremoremo Ski Club	12	0.003	0.024	0.013	0.013	0.002
Rawawaru Creek	12	0.003	0.029	0.014	0.015	0.002
Confluence	12	0.003	0.024	0.013	0.014	0.002
Brighams Creek	12	0.003	0.055	0.015	0.018	0.004
Rangitopuni Creek	12	0.003	0.026	0.014	0.014	0.002
Tamaki	12	0.008	0.025	0.018	0.017	0.001
Panmure	12	0.013	0.031	0.020	0.021	0.002
Turanga Estuary	12	0.009	0.022	0.013	0.014	0.001
Wairoa River	12	0.003	0.042	0.014	0.015	0.003
Mangere Bridge	12	0.017	0.146	0.107	0.105	0.009
Puketutu Point	12	0.081	0.194	0.097	0.109	0.010
Weymouth	12	0.011	0.036	0.023	0.024	0.002
Clarks Beach	12	0.006	0.028	0.021	0.020	0.002
Grahams Beach	12	0.011	0.025	0.019	0.018	0.001
Shag Point	12	0.013	0.077	0.061	0.059	0.005
Manukau Heads	12	0.009	0.022	0.016	0.015	0.001
Kaipara Heads	12	0.003	0.068	0.008	0.012	0.005
Tauhoa Channel	12	0.006	0.015	0.010	0.010	0.001
Hoteo River mouth	12	0.006	0.019	0.014	0.014	0.001
Omokoiti Beacon	12	0.006	0.015	0.010	0.010	0.001
Makarau Estuary	12	0.008	0.027	0.014	0.015	0.001
Shelly Beach	12	0.009	0.019	0.014	0.014	0.001
Kaipara River	12	0.009	0.021	0.016	0.016	0.001

Table 3-15 Enterococci (CFU/100ml)

Site	Count	Min	Max	Median	Mean	Standard error
Goat Island	11	5.00	5.00	5.00	5.00	
Ti Point	12	5.00	20.00	5.00	6.67	1.28
Dawsons Creek	12	5.00	20.00	5.00	7.92	1.68
Mahurangi Heads	12	5.00	31.00	5.00	7.17	2.17
Orewa	12	5.00	63.00	5.00	9.83	4.83
Browns Bay	12	5.00	20.00	5.00	6.67	1.28
Chelsea	11	5.00	10.00	5.00	5.45	0.45
Whau Creek	12	5.00	96.00	5.00	13.00	7.56
Henderson Creek	11	5.00	380.00	5.00	40.91	33.94
Hobsonville Jetty	12	5.00	30.00	5.00	7.50	2.09
Lucas Creek	12	5.00	390.00	10.00	50.42	32.24
Waimarie Road	12	5.00	10.00	5.00	6.25	0.65
Paremoremo Ski Club	12	5.00	230.00	10.00	29.58	18.29
Rawawaru Creek	12	5.00	960.00	30.50	145.25	80.43
Confluence	12	5.00	170.00	5.00	29.17	14.18
Brighams Creek	12	5.00	250.00	15.00	57.17	25.30
Rangitopuni Creek	12	5.00	1900.00	20.00	233.58	160.55
Tamaki	12	5.00	5172.00	7.50	491.33	428.56
Panmure	12	10.00	3441.00	30.50	602.58	359.96
Turanga Estuary	12	5.00	20.00	5.00	7.50	1.31
Wairoa River	12	5.00	1300.00	5.00	148.25	109.50
Mangere Bridge	12	5.00	63.00	5.00	9.83	4.83
Puketutu Point	12	5.00	20.00	5.00	6.25	1.25
Weymouth	12	5.00	30.00	7.50	10.00	2.22
Clarks Beach	11	5.00	5.00	5.00	5.00	
Grahams Beach	12	5.00	5.00	5.00	5.00	
Shag Point	12	5.00	10.00	5.00	5.42	0.42
Manukau Heads	12	5.00	5.00	5.00	5.00	
Kaipara Heads	12	0.85	5.00	1.00	1.40	0.34
Tauhoa Channel	11	0.85	2.00	1.00	1.08	0.09
Hoteo River mouth	11	0.85	58.00	1.00	8.90	5.47
Omokoiti Beacon	11	0.85	1.00	1.00	0.99	0.01
Makarau Estuary	11	0.85	54.00	1.00	5.80	4.82
Shelly Beach	11	0.85	10.00	1.00	2.35	0.85
Kaipara River	11	0.85	10.00	2.00	3.17	0.89

Table 3-16 Dissolve oxygen (% saturation)

Site	Count	Min	Max	Median	Mean	Standard error
Goat Island	11	91.80	111.10	103.70	102.88	1.44
Ti Point	12	97.50	117.40	103.25	104.94	1.58
Dawsons Creek	12	92.30	105.40	97.05	97.19	1.11
Mahurangi Heads	12	91.90	106.80	100.05	100.15	1.07
Orewa	12	93.00	106.70	101.25	100.78	1.09
Browns Bay	12	90.90	111.50	100.85	101.08	1.51
Chelsea	12	91.10	106.30	97.15	97.54	1.18
Whau Creek	12	91.70	114.00	97.80	99.01	1.68
Henderson Creek	12	87.40	108.00	96.00	96.23	1.64
Hobsonville Jetty	12	91.90	108.50	99.35	99.09	1.25
Lucas Creek	12	82.40	103.40	91.15	91.82	1.97
Waimarie Road	12	90.10	107.70	95.45	96.39	1.43
Paremoremo Ski Club	12	82.70	106.50	94.85	94.50	1.74
Rawawaru Creek	12	79.30	105.60	94.60	94.14	2.01
Confluence	12	82.60	105.70	94.35	94.28	1.71
Brighams Creek	12	83.60	106.00	90.70	91.74	1.90
Rangitopuni Creek	12	82.20	110.30	88.75	91.18	2.45
Tamaki	12	88.90	96.60	92.55	92.77	0.80
Panmure	12	81.70	103.40	89.55	90.68	1.89
Turanga Estuary	12	92.10	104.00	100.10	99.69	0.98
Wairoa River	12	89.10	103.10	99.40	98.73	1.15
Mangere Bridge	12	91.50	109.20	93.60	96.74	1.77
Puketutu Point	12	93.70	120.80	97.85	99.87	2.06
Weymouth	11	92.20	106.60	99.30	98.64	1.44
Clarks Beach	12	92.90	104.40	98.65	98.78	1.11
Grahams Beach	12	97.50	111.40	100.95	102.18	1.18
Shag Point	12	96.40	120.60	99.65	102.78	2.49
Manukau Heads	12	95.30	113.60	101.60	102.92	1.39
Kaipara Heads	12	99.70	108.80	104.05	104.45	0.89
Tauhoa Channel	12	95.80	108.30	103.10	102.14	1.05
Hoteo River mouth	12	90.60	104.20	99.45	99.53	1.07
Omokoiti Beacon	12	95.70	109.20	102.60	102.49	0.97
Makarau Estuary	12	88.30	106.90	100.80	100.75	1.42
Shelly Beach	12	95.40	122.50	101.40	103.52	2.23
Kaipara River	12	95.50	123.50	100.10	103.43	2.58

Table 3-17 Dissolved oxygen (ppm)

Site	Count	Min	Max	Median	Mean	Standard error
Goat Island	11	6.86	8.70	8.02	8.00	0.17
Ti Point	12	7.30	8.90	8.06	8.13	0.15
Dawsons Creek	12	6.54	8.87	7.80	7.69	0.20
Mahurangi Heads	12	6.63	8.71	7.85	7.85	0.18
Orewa	12	6.68	8.65	7.78	7.83	0.16
Browns Bay	12	6.56	9.00	7.77	7.88	0.19
Chelsea	12	6.60	9.18	7.80	7.74	0.23
Whau Creek	12	6.55	10.32	7.63	7.95	0.30
Henderson Creek	12	6.36	9.79	7.84	7.84	0.29
Hobsonville Jetty	12	6.78	9.66	7.79	7.87	0.25
Lucas Creek	12	5.90	9.77	7.40	7.55	0.34
Waimarie Road	12	6.55	9.88	7.46	7.75	0.29
Paremoremo Ski Club	12	6.44	9.95	7.27	7.67	0.30
Rawawaru Creek	12	6.63	10.01	7.45	7.72	0.32
Confluence	12	6.33	9.96	7.44	7.69	0.31
Brighams Creek	12	6.13	10.50	7.54	7.69	0.37
Rangitopuni Creek	12	6.10	10.78	7.63	7.86	0.44
Tamaki	12	6.25	8.17	7.39	7.25	0.17
Panmure	12	5.96	8.55	7.26	7.30	0.22
Turanga Estuary	12	6.79	8.95	7.78	7.85	0.22
Wairoa River	12	6.64	9.03	7.76	7.86	0.22
Mangere Bridge	12	6.49	9.29	7.95	7.87	0.26
Puketutu Point	12	6.65	9.24	8.26	8.00	0.26
Weymouth	11	6.58	9.29	8.08	7.92	0.24
Clarks Beach	12	6.57	8.87	7.94	7.89	0.21
Grahams Beach	12	6.99	9.06	8.20	8.10	0.20
Shag Point	12	6.81	9.14	8.54	8.18	0.23
Manukau Heads	12	6.94	8.90	8.22	8.14	0.17
Kaipara Heads	12	7.40	8.74	8.29	8.19	0.15
Tauhoa Channel	12	7.01	9.07	8.17	8.07	0.21
Hoteo River mouth	12	6.64	9.47	7.89	7.98	0.26
Omokoiti Beacon	12	6.97	9.09	8.06	8.08	0.19
Makarau Estuary	12	6.50	9.40	7.90	7.97	0.23
Shelly Beach	12	6.95	9.60	8.04	8.16	0.22
Kaipara River	12	7.00	9.45	8.24	8.17	0.21

Table 3-18 Temperature (°C)

Site	Count	Min	Max	Median	Mean	Standard error
Goat Island	12	13.62	22.35	18.01	17.85	0.87
Ti Point	12	13.49	22.40	17.74	17.67	0.86
Dawsons Creek	12	12.20	24.34	17.40	17.52	1.11
Mahurangi Heads	12	13.00	23.24	17.82	17.62	1.00
Orewa	12	12.90	23.76	17.79	17.74	1.05
Browns Bay	12	13.07	23.28	17.55	17.65	1.03
Chelsea	12	12.63	23.29	17.14	17.61	1.08
Whau Creek	12	11.60	24.43	17.21	17.23	1.20
Henderson Creek	12	11.75	24.15	16.70	17.22	1.19
Hobsonville Jetty	12	12.18	23.99	17.17	17.49	1.16
Lucas Creek	12	11.27	24.56	16.73	17.56	1.28
Waimarie Road	12	11.92	24.99	17.14	17.72	1.26
Paremoremo Ski Club	12	11.69	25.22	17.09	17.69	1.28
Rawawaru Creek	12	11.55	25.68	16.91	17.84	1.37
Confluence	12	11.64	25.02	17.24	17.74	1.29
Brighams Creek	12	11.04	25.35	16.80	17.63	1.37
Rangitopuni Creek	12	10.91	25.22	16.73	17.57	1.38
Tamaki	12	12.19	23.38	17.81	17.75	1.12
Panmure	12	11.19	23.38	17.84	17.45	1.21
Turanga Estuary	12	12.14	24.34	17.26	17.38	1.10
Wairoa River	12	12.36	24.31	17.48	17.61	1.14
Mangere Bridge	12	10.22	23.88	17.59	17.20	1.36
Puketutu Point	12	10.54	24.02	17.43	17.40	1.33
Weymouth	11	10.69	24.22	17.53	17.71	1.33
Clarks Beach	12	11.49	23.78	17.15	17.19	1.21
Grahams Beach	12	11.60	23.29	17.24	17.32	1.18
Shag Point	12	10.51	23.81	17.17	17.34	1.33
Manukau Heads	12	12.47	22.31	16.73	17.14	1.00
Kaipara Heads	12	13.54	20.75	17.10	17.30	0.77
Tauhoa Channel	12	12.93	22.79	17.75	17.88	0.99
Hoteo River mouth	12	12.61	23.02	18.30	17.97	1.10
Omokoiti Beacon	12	12.93	22.90	17.66	17.76	1.00
Makarau Estuary	12	12.29	23.53	18.48	18.01	1.13
Shelly Beach	12	12.54	23.70	17.77	17.95	1.11
Kaipara River	12	12.43	23.67	18.08	17.98	1.13



## 4.0 References

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## 5.0 Appendix A

The communication of water quality data is often hampered by the volume of results and the complexity of the information. In this report, a water quality index developed by the Canadian Council of Ministers for the Environment (CCME) (2001) was applied to the marine water quality data collected by Auckland Council to enable improved understanding and communication of the work.

The CCME approach uses water quality results to produce four water quality indices, and these indices can be used to assign a water quality class to each monitoring site. The four indices are;

- Scope – This represents the percentage of parameters that failed to meet the objective at least once during the time period under consideration (the lower this index, the better).
- Frequency – This represents the percentage of all individual tests that failed to meet the objective during the time period under consideration (the lower this index, the better).
- Magnitude – This represents the amount by which failed tests exceeded the objective (the lower this index, the better). This is based on the collective amount by which individual tests are out of compliance with the objectives and is scaled to be between 1 and 100. This is the most complex part of the index derivation and the reader is referred to CCME (2001) for full details.
- WQI – This represents an overall water quality index based on a combination of the three indices described above. It is calculated thus;

$$WQI = 100 - \left[ \frac{\sqrt{(\text{Scope}^2 + \text{Frequency}^2 + \text{Magnitude}^2)}}{1.732} \right]$$

The divisor 1.732 normalises the resultant values to a range between 0 and 100, where 0 represents the “worst” water quality and 100 represents the “best” water quality.

The WQI index is used by Auckland Council to assign a water quality class to each site using the following ranges;

- Greater than 90 = excellent water quality
- Between 75 and 90 = good water quality
- Between 60 and 75 = fair water quality
- Lower than 60 – poor water quality

The above indices are calculated for each site based on nine water quality parameters (Table 29). The objectives against which the water quality data are tested (Table 29) are derived from the ranges observed at six reference sites (Goat Island, Ti point, Mahurangi Heads, Orewa, Browns bay and Hobsonville) over the five year preceding this report (2005 to 2009). This represents a change from the 2007 and 2008 reports. It was considered thresholds based on a fixed period, whilst providing consistency would not capture longer term trends in water quality, nor account for

improvements in the measurement of parameters (for example, improved meter performance or improvements in detection limits).

The ranges at these reference sites were used, as this represents the best achievable water quality in the Auckland region. Therefore, the index represents the deviation from “natural” conditions in the Auckland region, rather than indicating whether the water quality is suitable for a particular purpose.

Table 5-1 The seven water quality parameters

and their objectives, used to produce the water quality indices.

Dissolved oxygen (% saturation)	greater than 78%
pH	Between 7.6 and 8.3
Turbidity	Less than 7.7 NTU
Ammoniacal nitrogen	Less than 0.089 mg N l <sup>-1</sup>
Total suspended sediment	Less than 25 mg l <sup>-1</sup>
Total phosphorus	Less than 0.062 mg P l <sup>-1</sup>
Nitrate + nitrite nitrogen	Less than 0.105 mg N l <sup>-1</sup>
Chlorophyll a	Less than 0.0059 mg l <sup>-1</sup>
Enterococci	Less than 140 CFU 100ml <sup>-1</sup>

## 6.0 Appendix B

Table 6-1 Summary of marine water quality parameters...

detection limits, analytical methods and two sources of data collection.

Parameter	Unit	Detection Limit	Method	Source
Dissolved oxygen	ppm	0.1	Handheld meter (YSI-556)	Field
Dissolved oxygen saturation	% sat	0.01	Handheld meter (YSI-556)	Field
Temperature	°C	0.1	Handheld meter (YSI-556)	Field
Conductivity	(mS cm)	0.1	Handheld meter (YSI-556)	Field
Salinity	ppt	0.01	Handheld meter (YSI-556)	Field
pH	pH units	0.01	Handheld meter (YSI-556)	Field
Suspended sediment	mg/L	0.2	APHA (2005) 2540 D	Lab
Turbidity	NTU	0.1	APHA (2005) 2130 B	Lab
Chlorophyll a	mg/L	0.0006	APHA (2005) 10200 H	Lab
Nitrate nitrogen (NO <sub>3</sub> )	mg N /L	-	Calculation (NNN - NO <sub>2</sub> )	Lab
Nitrite nitrogen (NO <sub>2</sub> )	mg N /L	0.002	APHA (2005) 4500-NO <sub>2</sub> B	Lab
Ammoniacal nitrogen (NH <sub>4</sub> -N)	mg N /L	0.001	APHA (2005) 4500-NH <sub>3</sub> G Mod	Lab
Nitrate/Nitrite nitrogen NO <sub>3</sub> + NO <sub>2</sub> (aka NNN)	mg N /L	0.005	APHA (2005) 4500-NO <sub>3</sub> F	Lab
Total kjeldahl nitrogen (TKN)	mg N /L	0.1	APHA (2005) 4500-org A, D Modified	Lab
Total nitrogen (TN)	mg N /L	0.02	APHA (2005) 4500-org N, C Modified	Lab
Soluble reactive phosphorus	mg/L	0.01	APHA (2005) 4500-P F Mod	Lab
Total phosphorus	mg/L	0.01	APHA (2005) 4500-P B,F	Lab
Enterococci	CFU/100ml	2	APHA (2005) 9230 C	Lab

## 7.0 Physico-chemical measures

### Dissolved oxygen

Dissolved oxygen saturation gives a direct measure of the quantity of oxygen diffused into the water column and consequently is an important indicator of a water's ability to support life.

Dissolved oxygen fluctuates both diurnally (throughout the day) and seasonally. Diurnal changes are caused predominantly by the respiratory activities of aquatic biota, particularly plants at night, and photosynthetic activity during the day. Seasonal variations mainly follow changes in temperature, which is inversely related to oxygen solubility.

Supersaturation of water is not unusual where macroalgae or phytoplankton is abundant. During the hours of daylight the release of oxygen during photosynthesis augments the transfer of oxygen through the surface of the water by diffusion. The negative side to the presence of these plants is the consumption of oxygen at night (i.e., by respiration), which can lead to serious oxygen depletion and subsequent effects on other biota. Depression in dissolved oxygen levels caused by this phenomenon is usually greatest in the early hours of the morning.

### Conductivity

Conductivity is a substance's ability to "carry" an electrical current. The more ions and molecules that are dissolved in water the more electrical current that water is able to conduct. Conductivity is measured in microSiemens (S), and is directly proportional to the amount of osmotic pressure exerted on fish cellular membranes. Conductivity is related to salinity and temperature and should be interpreted in association with these two parameters.

### Temperature

Sea surface temperatures (SST) show seasonal patterns and typically display a lag period with air temperature. Heat transfer between the atmosphere and water surface primarily influences SST and elevated water temperature can influence aquatic biota in the following ways:

An increase in water temperature results in a reduction in the dissolved oxygen carrying capacity of the water. This may be critical for sensitive organisms particularly where dissolved oxygen is already reduced.

High water temperatures can also stress organisms leaving the organisms vulnerable to infection by parasites and harmful bacteria.

### Chloride (salinity)

The chlorine ion makes up 55% of the salt in seawater. Calculations of seawater salinity are made of the parts per 1000 of the chlorine ion present in one kilogram of seawater. Typically, seawater has a salinity of 35 parts per thousand.

### pH

The pH is a measure of the hydrogen ion concentration and therefore indicates the acid or alkaline nature of the water. The pH range is from 0-14 and each unit represents a ten-fold change in hydrogen ion concentration. Marine waters have a pH of around 8.2 although 7.8 to 8.8 are considered to be the normal range. In the absence of contaminant discharges the major influence

on pH levels is likely to be the photosynthetic activity of algae. This occurs when carbon dioxide is absorbed changing the carbon dioxide-bicarbonate equilibrium of the waters and elevating pH.

Most aquatic organisms and some bacterial processes require that pH be in a specified range. For example, the activity of nitrifying bacteria is optimal over a narrow pH range from 7 to 8.5. If pH changes above or below the preferred range of an organism (including microbes), physiological processes may be adversely affected. This is especially true for most organisms if the ambient pH drops to below ~7 or rises to above 9. Physical damage to the gills, skin and eyes can also occur when pH is sub-optimal for fish, and skin damage increases susceptibility to fungal infections. pH is driven more frequently to greater extremes under eutrophic conditions, allowing algal species with tolerance to extreme pH levels to grow and dominate communities, and to potentially form algal blooms. pH is important in calcium carbonate solubility (calcite or aragonite), which is important for shell-forming organisms. Shell growth (i.e. calcification) is inhibited if water becomes too acidic.

### **Water clarity and turbidity**

Public perception of water quality is often based on their observation of water clarity, in that poor water clarity is aesthetically unpleasing, regardless of other water quality parameters. Marine water clarity is expressed by measuring turbidity and secchi disk transparency and is directly related to the concentration of suspended sediments in the water column (see below).

Turbidity is a measure of the degree to which light is scattered in water by suspended particles and colloidal materials. Samples are analysed in the laboratory using a meter and the results are given as nephelometric turbidity units (NTU). When turbidity levels are high light penetration is reduced, thereby limiting the ability of algae to photosynthesise (i.e., a reduction in the so-called euphotic depth). Organisms that are visually oriented may have difficulty locating and catching prey in turbid water and the fine suspended material that is characteristic of turbid water may detrimentally affect gill structures of marine organisms.

### **Suspended sediment**

Suspended sediment (SS) is a measurement that includes suspended material in the water column such as plankton, non-living organic material, silica, clay and silt. High SS levels reduce light penetration and provide media for pollutants to attach to, resulting in a reduction in water quality for a variety of uses, such as recreational and ecological functions. Suspended sediment can reduce light penetration through the water column and extended periods can inhibit the growth of macroalgae. In calm environments the suspended material will settle out as sediment and may potentially smother benthic species, clog gills and filtering apparatus interfering with feeding capability.

### **Nutrients (nitrogen and phosphorus)**

Nutrients are chemical compounds that are necessary for normal plant growth. Routine water quality monitoring records two groups of essential nutrients; nitrogen and phosphorus.

The nutrients nitrogen (N) and phosphorus (P) are essential building blocks for plant and animal growth. Nitrogen is an integral component of organic compounds such as amino acids and proteins. Phosphorus is also found in nucleic acids and certain fats (phospholipids). The availability

of readily assimilated forms of nitrogen and phosphorus are commonly accepted as factors limiting algal growth. Anthropogenic activities increase the nutrient loading through the discharge of waste products, fertilisers and stormwater runoff. Nutrient enrichment can result in a proliferation of algae and phytoplankton which potentially has a number of detrimental effects including:

- Blooms of problem algae washing up on beaches
- Toxic algal blooms (e.g. red tides and paralytic shellfish poisoning)
- Excessive fluctuations in dissolved oxygen, pH and reduced light levels transmission.

### **Nitrite, nitrate and ammonia**

Nitrogen exists in water both as inorganic and organic species, and in dissolved and particulate forms. Inorganic nitrogen is found both as nitrate  $\text{NO}_3^-$ , nitrite  $\text{NO}_2^-$  and ammonia ( $\text{NH}_4^+ + \text{NH}_3$ ).

Nitrite is the intermediate step in the conversion of ammonia to nitrate. It is usually short lived in the aquatic environment in the presence of oxygen and is typically an indication of a source of nitrogenous waste in the immediate vicinity of the sampling site.

Ammonia occurs in a number of waste products. Ammonia is reported as a combination of un-ionised ammonia ( $\text{NH}_3$ ) and the ammonium ion ( $\text{NH}_4$ ), at normal pH values ammonium ( $\text{NH}_4$ ) dominates. Un-ionised ammonia is the more toxic form to aquatic life and is highly dependent on water temperature, salinity and pH. Ammonium is the form of nitrogen taken up most readily by phytoplankton and assimilated into amino acids.

The particulate nitrogen pool consists of plants and animals, and their remains, as well as ammonia adsorbed onto mineral particles. Particulate nitrogen can be found in suspension or in the sediment. Some portion of the particulate nitrogen pool is subject to rapid mineralisation and is dissolved into the water column and becomes more biologically available. Total nitrogen (abbreviated TN) is a measure of all forms of dissolved and particulate nitrogen present in a water sample.

### **Total and soluble reactive phosphorus**

Phosphorus is found in water as dissolved and particulate forms. Dissolved phosphorus is readily available for plants, and consists of inorganic orthophosphate and organic phosphorus-containing compounds. The particulate phosphorus pool consists of plants and animals, and their remains, phosphorus in minerals and phosphate adsorbed onto mineral surfaces. Particulate phosphorus can be found in suspension or in the sediment. The adsorption and desorption of phosphate from mineral surfaces forms a buffering mechanism that regulates dissolved phosphate concentrations in rivers and estuaries. Total phosphorous (abbreviated TP) is a measure of all the various forms of phosphorus (dissolved and particulate) found in water. Dissolved reactive phosphorus (DRP) is considered to be the bioavailable fraction of phosphorus and is an important indicator of water quality. It is frequently cited as the nutrient limiting the proliferation of algae in New Zealand's marine environment.

### **Chlorophyll a (phytoplankton)**

Chlorophyll-a is probably a better 'instantaneous' indicator of trophic status than nutrient concentrations. This is because nutrient concentrations are affected by biological uptake, which in

turn are influenced by uptake capabilities, interaction with grazers, temperature, turbulence and turbidity levels. Concentrations of nitrogen (or phosphorous) taken from water column samples can also underestimate nutrient availability in a system because large pools of nutrients can be found in sediment.

### **Microbiological**

Microbial indicator organisms are typically used in water quality monitoring to provide a measure of faecal contamination and hence the sanitary quality of marine water.

It is necessary to use indicator organisms for routine monitoring purposes because there is such a wide variety of pathogens that may be present in faecal matter, that it is impossible to test for all of them at once. Detection of some pathogens, particularly viruses, is also expensive and time consuming. Also, the infective doses for many pathogens, particularly of viruses, are so low as to make routine measurement impracticable.

In New Zealand three bacterial indicator groups have been routinely used for water quality monitoring. These are the presumptive coliform, faecal coliform, and enterococci groups. For marine water quality it has been recommended to use enterococci as the preferred indicator bacteria.

### **Enterococci**

For marine waters, only faecal streptococci (or enterococci) show a dose-response relationship for both gastrointestinal illnesses. Enterococci are therefore recommended as the faecal indicator for monitoring marine water quality. Different pathogen-indicator organism relationships may exist between marine and fresh waters, so the same level of faecal indicator bacteria in freshwater and marine environments does not mean the health risk is the same