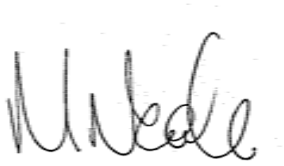
Auckland
Regional Council
TE RAUHĪTANGA TAIAO

Marine Water Quality Data Report 2008

July TR 2009/100

Auckland Regional Council
Technical Report No.100 July 2009
ISSN 1179-0504 (Print)
ISSN 1179-0512 (Online)
ISBN 978-1-877540-13-4

Reviewed by:



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Recommended Citation:

Walker, J. (2009). Marine Water Quality Data Report 2008. Auckland Regional Council Technical Report: TR 2009/100. 49p.

Marine Water Quality Data Report 2008

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Contents

1 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 Regional Councils' Resource Management Act (1991) section 35 obligations with respect to state of the environment reporting.
- Contribute to community outcome 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 promoting awareness of water quality issues.

This programme fits under the "Natural Environment and Heritage" component of the ARC's Long Term Community Consultation Plan 2006-16. 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 the community'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 ARC's management strategies are effective in sustaining ecosystem functions and uses. By achieving this outcome we are working towards achieving the ARC mission of:

- "Working in partnership with our regional community to achieve social, economic, cultural and environmental wellbeing".

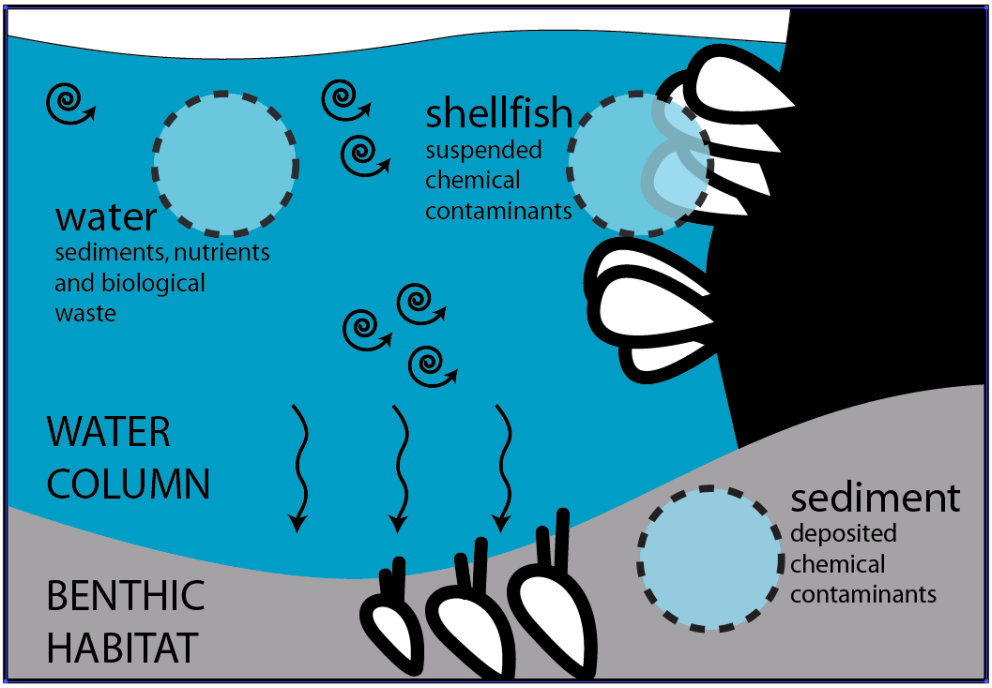
The marine water quality programme monitors water quality across the Auckland Region. Information obtained is also used in conjunction with ecological and contaminant data to provide an integrated overview of the physical, chemical, and biological condition of the Region's marine environment (Figure.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

- 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 sedentary, filter-feeding shellfish therefore provide an integrated measure of ambient chemical contaminant levels in the water column.
- The sediment contaminant monitoring programme monitors chemical contaminant levels in near-shore sediments. Many contaminants attach to particulate material which settles out of the water column and accumulates in depositional zones. These contaminants are toxic to the benthic organisms that live in 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 and Manukau Harbours. A second tier ecological programme tracks long-term (decadal) shifts in habitat availability and quality throughout the region.

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 monitors 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 some water quality parameters.

Figure 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 2008 calendar year collected from 27 monitoring sites across the Auckland Region, and includes summary statistics tabulated by parameter and grouped by spatial proximity.

2 Methods

2.1 Programme design

Sampling of surface waters for marine water quality monitoring is undertaken monthly by ARC 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, theses sites are: Shelly Beach in the Kaipara Harbour, where water samples are collected from a wharf; and the Upper Waitemata Harbour, and Tamaki Estuary which are sampled by boat. At each site, water samples are collected from the surface waters (the top 1 m) by lowering a 1 litre plastic bottle and 500ml glass bacteria bottle into the water. The 1 litre plastic and glass bacteria bottles are sent to Watercare and analysed for chemical compounds (see appendix 1)and bacteriological species (enterococci and faecal coliforms).

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

- 6 sites in Manukau Harbour;
- 7 sites in the inner Hauraki Gulf and outer Waitemata Harbour;
- 1 site in Kaipara Harbour;
- 3 sites in Mahurangi Harbour;
- 2 sites in Tamaki Estuary;
- 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 for the Manukau Harbour. This avoids introducing diurnal variation to the dataset and improves the power of long term trend detection

Table 1:

Marine water quality sites sorted from north to south and 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
Town Basin	East Coast	1748748	5970344	1993
Orewa	East Coast	1753273	5949612	1991
Browns Bay	East Coast	1757934	5935780	1991
Shelly Beach	Kaipara Harbour	1723513	5951893	1991
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
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

Figure 2
Location of the 27 marine quality monitoring sites

Monitoring sites were selected to provide information on:

- Water quality across a disturbance gradient from high to degraded;
- 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 20 parameters. Some parameters are determined in the field but most are analysed in the laboratory (see Table 20, appendix 1). 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. Follow 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-1). Pervious to this, these parameters were measured in the lab by Watercare.

2.4 Quality control, data storage and analysis

Quality control is undertaken in accordance with Auckland Regional 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 ARC 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 ARC's water quality archiving database (HYDSTRA) and complies with ISO 9001:2008 accreditation.

2.5 Reports

This is the 18th data report since the inception of the monitoring programme, although it is the third 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 Regional Council on (09) 366 2000, in electronic format where available from the ARC's website: www.arc.govt.nz.

A comprehensive trend analysis is conducted approximately every 5 years, with the last report published in 2008 (Scarsbrook 2008) with a pervious report published in 1999 (Vant and Lee, 1998). Auckland Regional Council's State of the Environment Report 2004 briefly summaries water quality issues, including an assessment of the ecological health of the Region's marine resources and land use pressures (ARC, 2004).

The marine water quality monitoring programme is also reviewed approximately every 5 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 Regional Council web site.

A specific review of the Mahurangi Harbour, Upper Waitemata Harbour and Tamaki Estuary was last undertaken in 2001 (*ARC, 2003)

3 Results

Data from the 2008 calendar year are presented as box plots to display the range over which water quality parameters were recorded. These plots also show the variations in the water quality parameters among sites and locations. These data are also summarised in tables in section 3.2. Data tables contain additional summary statistics (sample sizes, means and standard error) in addition to the data presented in the box plots. Sites are listed from north to south for each data table. For the box plots, sites are listed from north to south and then grouped by location (e.g. all sites with the Manukau Harbour are grouped).

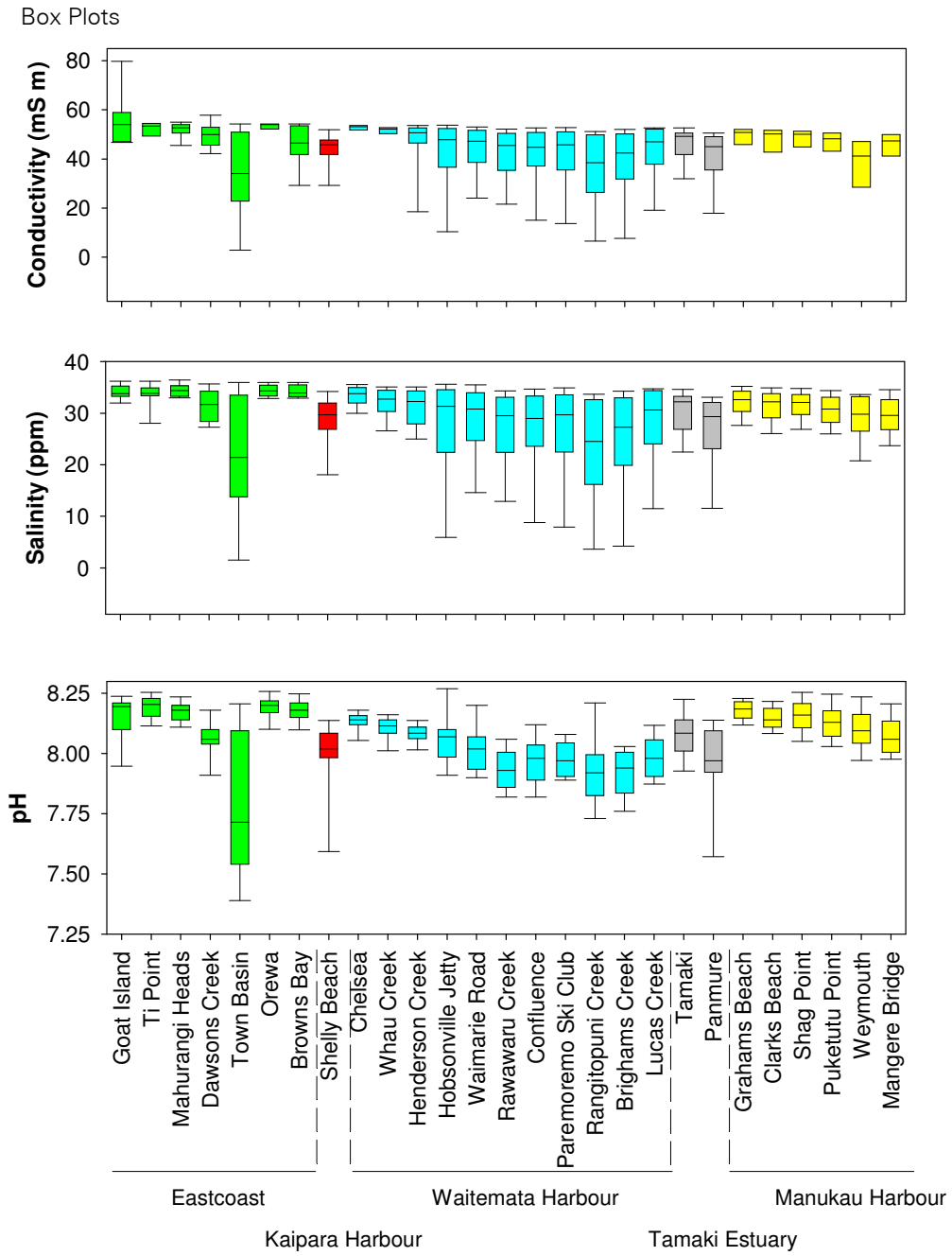


Figure 3

Spatial patterns in conductivity, salinity and pH. Boxes represent the median, 25th and 75th percentiles while whiskers are 5th and 95th percentiles for data collected from January 2008 to December 2008. Percentiles values calculated using the standard method in SigmaPlot (v8).

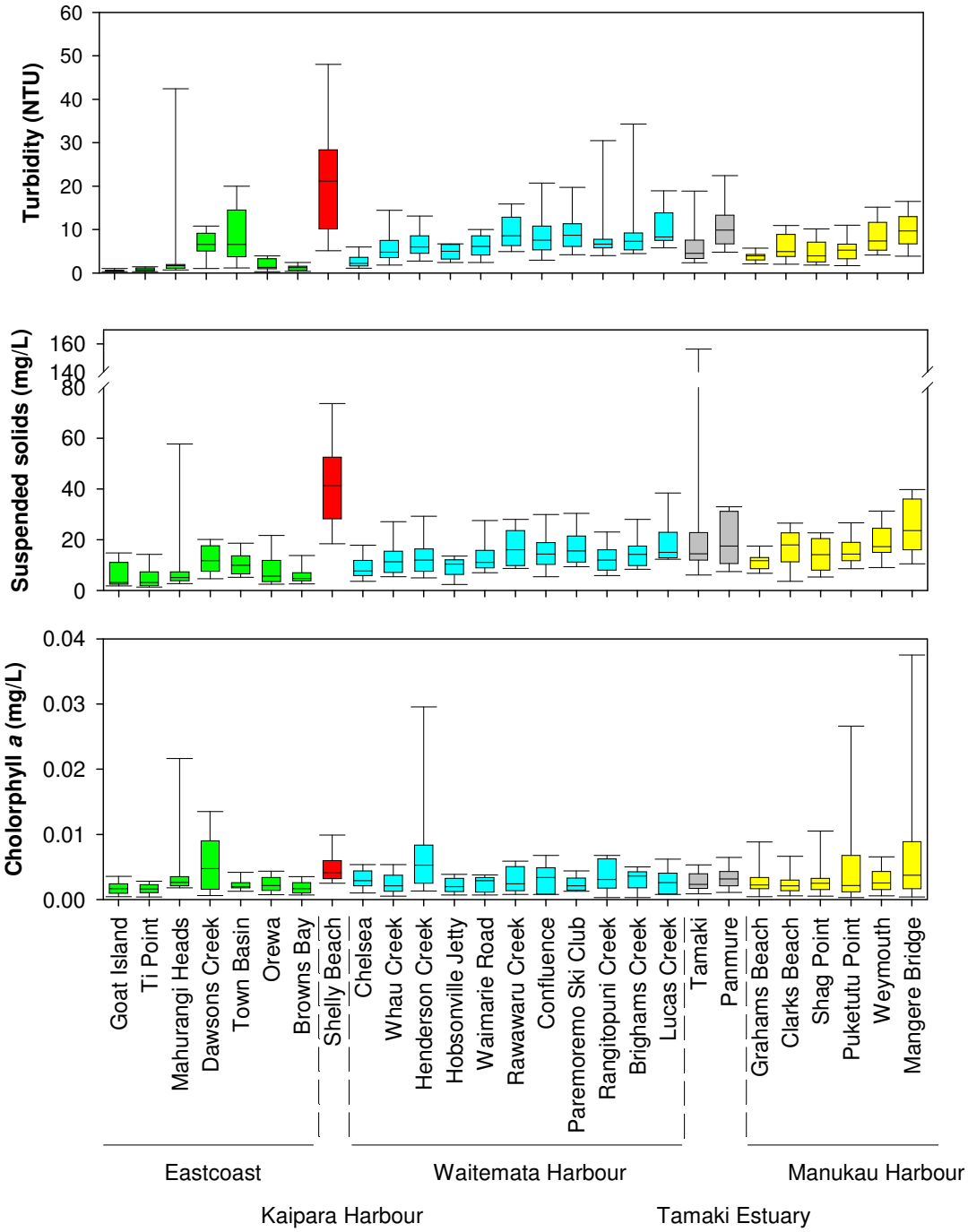


Figure 4

Spatial patterns in turbidity, suspended sediment, and chlorophyll *a*. Boxes represent the median, 25th and 75th percentiles while whiskers are 5th and 95th percentiles for data collected from January 2008 to December 2008. Percentiles values calculated using the standard method in SigmaPlot (v8). Note the scale break in the y –axis of the suspended sediment plot.

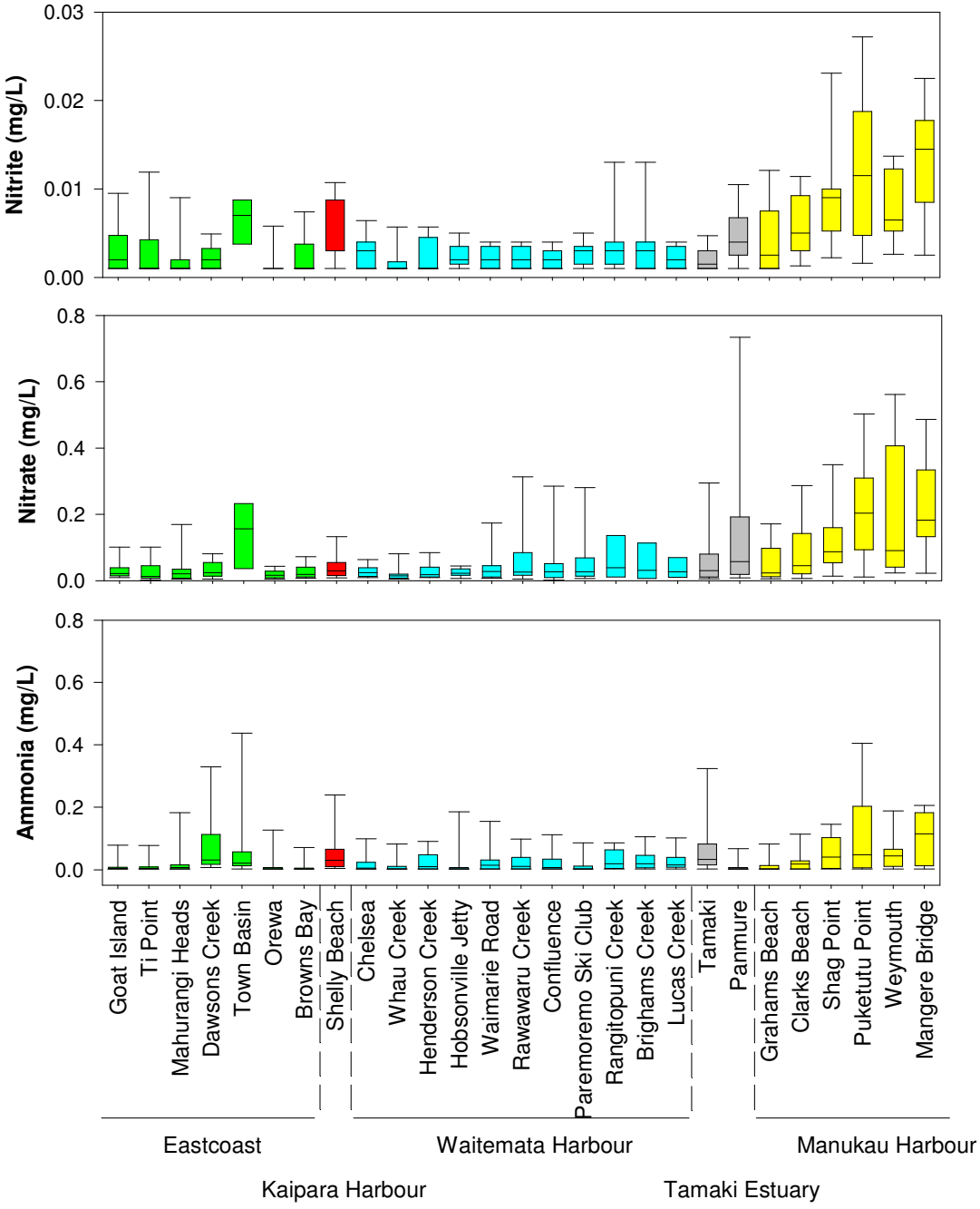


Figure 5

Spatial patterns in nitrite, nitrate and ammonia. Boxes represent the median, 25th and 75th percentiles while whiskers are 5th and 95th percentiles for data collected from January 2008 to December 2008. Percentiles values calculated using the standard method in SigmaPlot (v8).

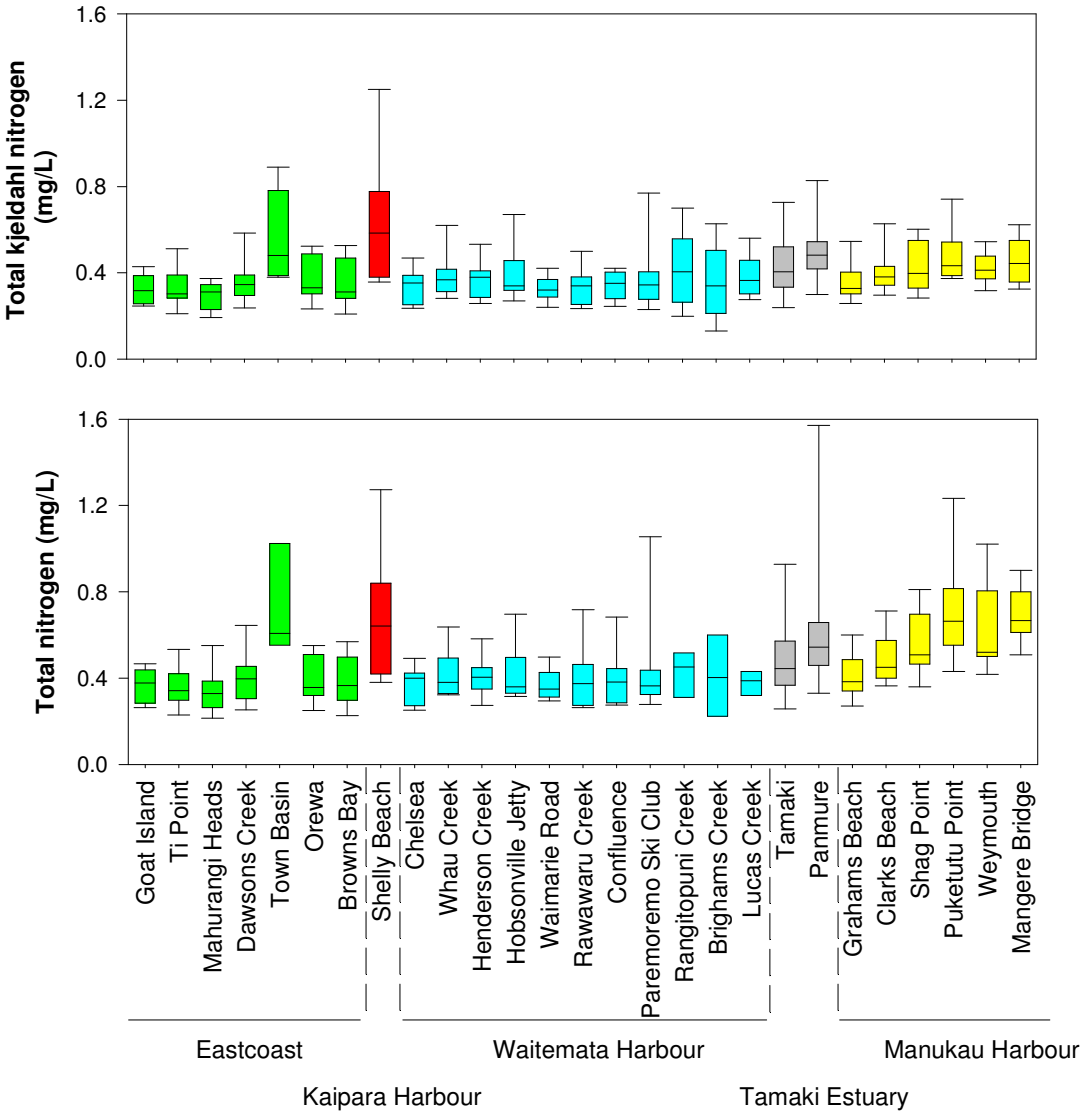


Figure 6

Spatial patterns in total kjedahl nitrogen and total nitrogen. Boxes represent the median, 25th and 75th percentiles while whiskers are 5th and 95th percentiles for data collected from January 2008 to December 2008. Percentiles values calculated using the standard method in SigmaPlot (v8)

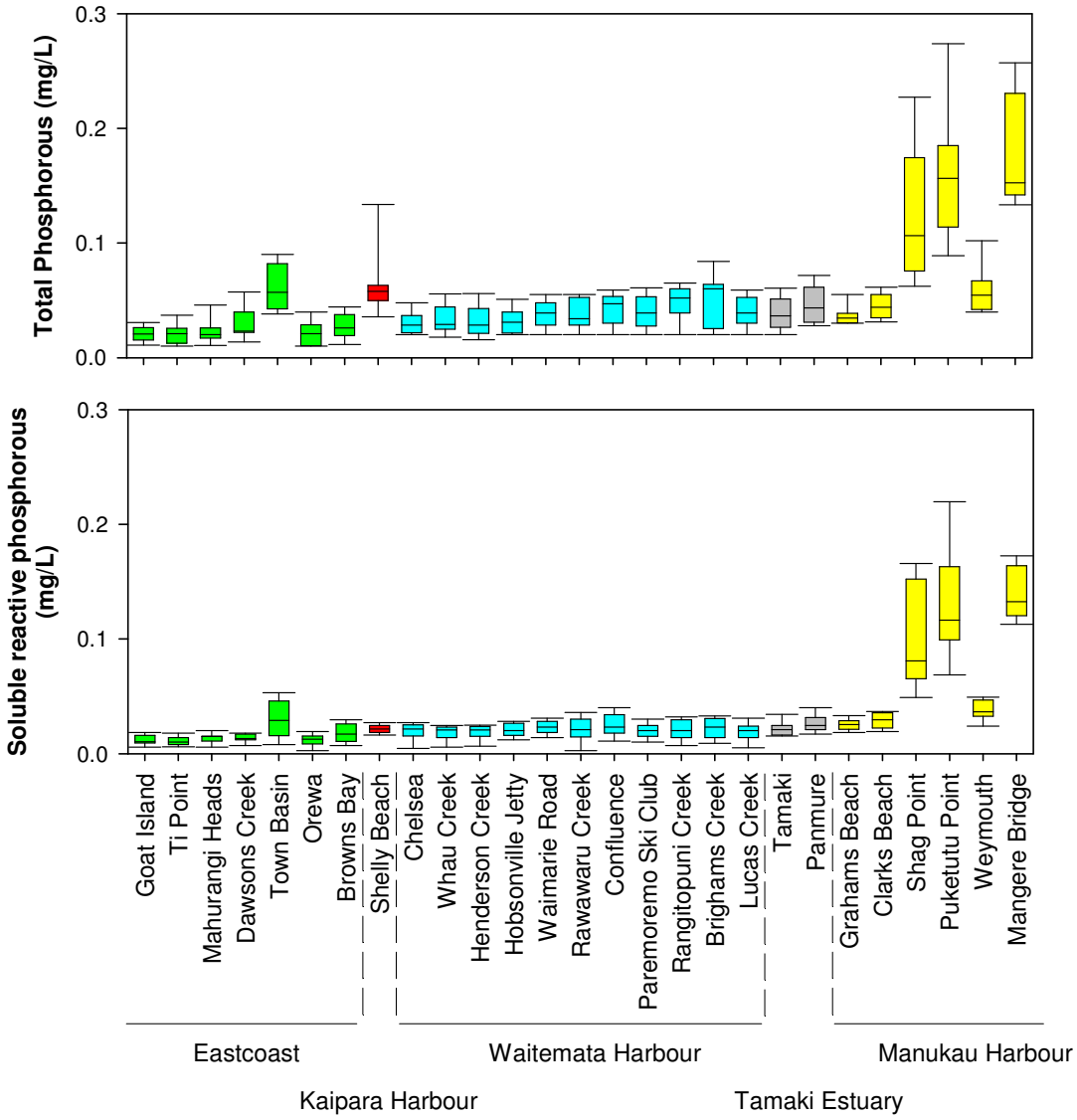


Figure 7

Spatial patterns in total phosphorous and soluble .reactive phosphorous. Boxes represent the median, 25th and 75th percentiles while whiskers are 5th and 95th percentiles for data collected from January 2008 to December 2008. Percentiles values calculated using the standard method in SigmaPlot (v8).

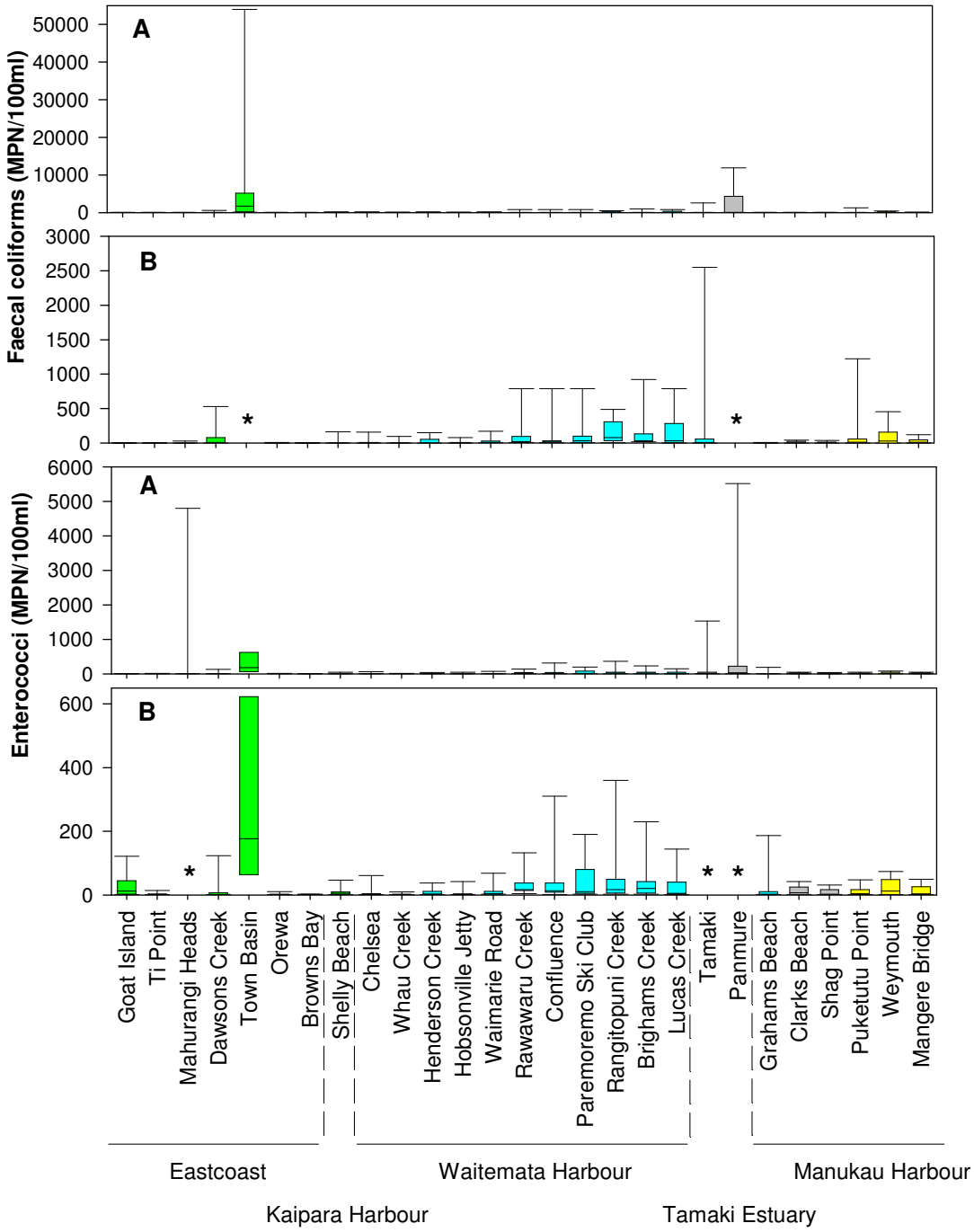


Figure 8

Spatial patterns in faecal coliforms and enterococci. Plot A for faecal coliforms and enterococci display all 27 sites and the full data range. Plot B for both faecal coliforms and enterococci display 25 and 24 sites respectively allowing for greater resolution of sites with substantially lower concentrations of bacteria. Asterisk (*) denote removed sites. Boxes represent the median, 25th and 75th percentiles while whiskers are 5th and 95th percentiles for data collected from January 2008 to December 2008. Percentiles values calculated using the standard method in SigmaPlot (v8).

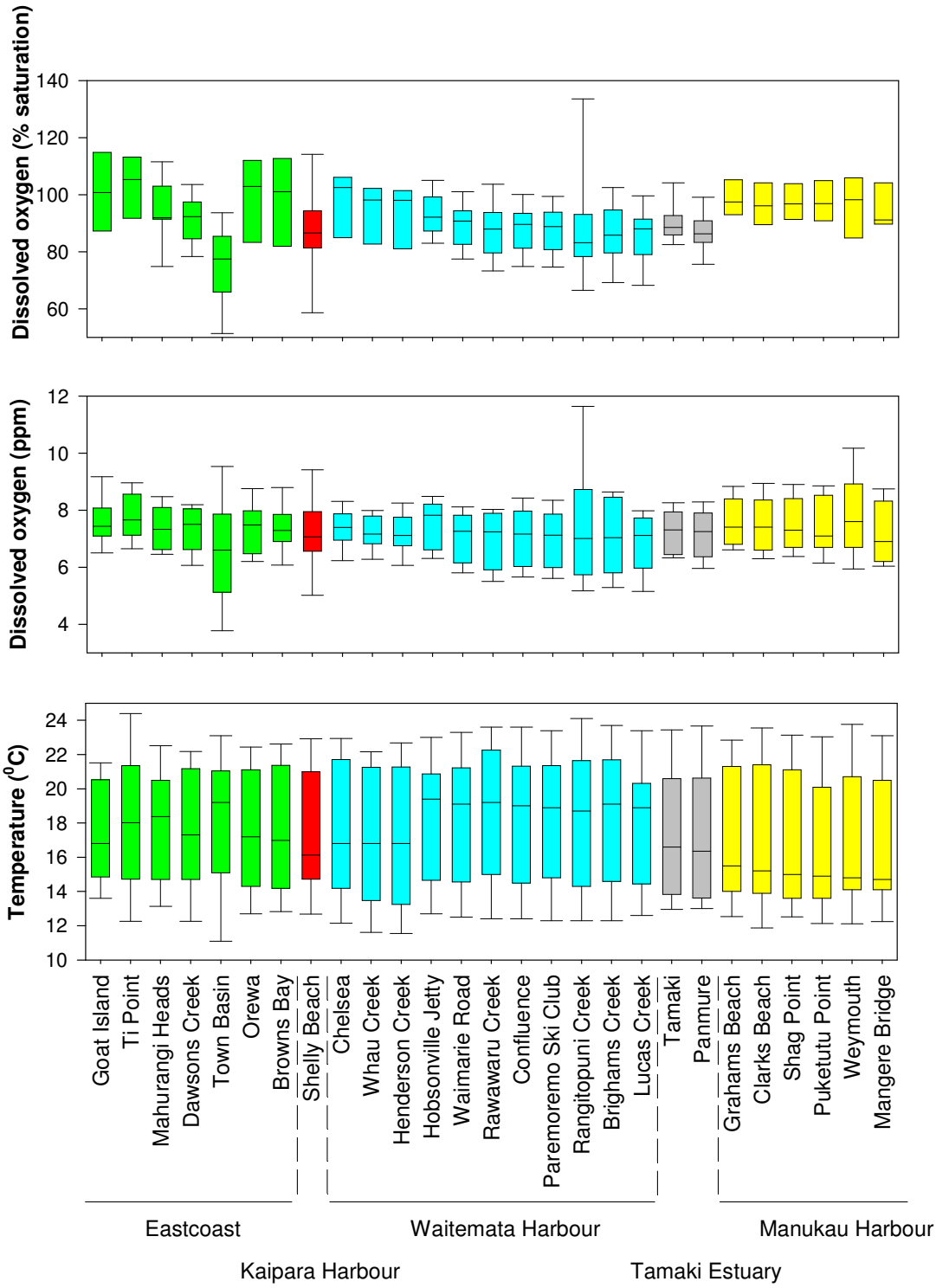


Figure 9

Spatial patterns in two indices of dissolved oxygen (ppm and % saturation) and sea surface temperature. Boxes represent the median, 25th and 75th percentiles while whiskers are 5th and 95th percentiles for data collected from January 2008 to December 2008. Percentiles values calculated using the standard method in SigmaPlot (v8).

3.1 Data tables

Table 2.

Electrical conductivity (mS cm)

Site	Count	Min	Max	Median	Mean	Standard error
Goat Island	5	50.7	54.7	54.0	53.1	0.8
Ti Point	5	51.4	54.6	54.2	53.5	0.6
Mahurangi Heads	9	45.5	55.0	52.6	51.9	1.0
Dawson's Creek	9	42.2	57.8	49.9	49.6	1.6
Town Basin	9	0.5	41.9	27.4	26.0	4.8
Orewa	5	51.8	54.3	54.0	53.4	0.5
Browns Bay	5	51.7	54.4	53.9	53.3	0.5
Shelly Beach	12	26.7	52.4	45.7	43.8	2.0
Chelsea	5	51.3	53.9	53.2	52.8	0.5
Whau Creek	5	49.7	53.2	52.1	51.7	0.6
Henderson Creek	5	48.8	53.3	52.0	51.3	0.8
Hobsonville Jetty	9	10.4	53.8	47.9	43.0	4.6
Waimarie Rd	9	19.6	53.1	44.2	42.4	3.4
Rarawaru Creek	9	21.5	52.1	45.5	41.9	3.4
Confluence	9	15.0	52.6	44.7	41.9	3.9
Paremoremo Ski Club	9	13.6	52.8	45.7	41.4	4.2
Rangitopuni Creek	9	6.5	51.2	38.4	36.2	5.0
Brighams Creek	9	7.6	52.0	42.5	38.5	4.8
Lucas Creek	9	12.1	52.8	45.3	41.3	4.2
Tamaki	12	30.6	52.7	49.1	46.0	2.0
Panmure Basin	11	17.7	50.7	44.9	39.9	3.5
Grahams Beach	6	42.2	52.1	50.8	49.2	1.6
Clarks Beach	6	40.0	52.5	50.2	48.0	2.0
Shag Point	6	41.6	51.8	50.1	48.4	1.6
Puketutu Point	6	40.7	50.9	48.3	47.1	1.7
Weymouth	6	19.6	50.9	41.2	38.4	4.6
Mangere Bridge	6	39.1	50.6	47.4	46.0	1.9

Table 3

Salinity (ppt)

Site	Count	Min	Max	Median	Mean	Standard error
Goat Island	12	31.6	36.3	33.8	34.0	0.4
Ti Point	12	25.9	36.3	33.9	33.7	0.8
Mahurangi Heads	11	32.9	36.5	34.4	34.5	0.4
Dawson's Creek	11	27.1	35.7	31.7	31.8	0.9
Town Basin	9	0.3	26.9	16.9	16.3	3.1
Orewa	12	32.7	36.0	34.4	34.3	0.3
Browns Bay	12	32.8	36.0	34.0	34.2	0.3
Shelly Beach	12	16.4	34.6	29.7	28.4	1.5
Chelsea	12	29.5	35.7	33.8	33.4	0.5
Whau Creek	12	26.1	35.2	32.8	32.0	0.8
Henderson Creek	12	24.8	35.2	32.3	31.2	1.1
Hobsonville Jetty	9	5.9	35.6	31.3	27.8	3.2
Waimarie Rd	9	14.6	35.5	30.8	29.5	1.8
Rarawaru Creek	9	12.9	34.3	29.5	27.0	2.4
Confluence	9	8.8	34.7	29.0	27.1	2.7
Paremoremo Ski Club	9	7.9	34.9	29.7	26.8	2.9
Rangitopuni Creek	9	3.6	33.7	24.5	23.1	3.4
Brighams Creek	9	4.2	34.3	27.3	24.8	3.2
Lucas Creek	9	6.9	34.8	29.3	26.7	2.9
Tamaki	12	22.0	34.6	32.2	30.3	1.2
Panmure Basin	12	11.0	33.3	29.4	26.4	2.2
Grahams Beach	11	27.1	35.4	32.6	32.2	0.8
Clarks Beach	11	25.5	35.0	32.2	31.5	0.9
Shag Point	11	26.7	35.0	32.1	31.5	0.8
Puketutu Point	11	26.0	34.6	30.8	30.5	0.9
Weymouth	11	19.6	33.6	29.8	29.3	1.3
Mangere Bridge	11	23.4	34.9	29.6	29.6	1.1

Table 4

pH (pH units)

Site	Count	Min	Max	Median	Mean	Standard error
Goat Island	12	7.89	8.25	8.20	8.15	0.03
Ti Point	12	8.10	8.26	8.21	8.20	0.01
Mahurangi Heads	11	8.11	8.24	8.18	8.18	0.01
Dawson's Creek	11	7.90	8.20	8.06	8.05	0.02
Town Basin	9	7.35	8.10	7.62	7.65	0.07
Orewa	12	8.08	8.27	8.20	8.19	0.01
Browns Bay	12	8.08	8.26	8.18	8.18	0.01
Shelly Beach	12	7.44	8.14	8.02	7.99	0.05
Chelsea	12	8.03	8.19	8.14	8.13	0.01
Whau Creek	12	7.99	8.17	8.12	8.11	0.01
Henderson Creek	12	8.00	8.14	8.09	8.08	0.01
Hobsonville Jetty	9	7.91	8.27	8.07	8.06	0.03
Waimarie Rd	9	7.90	8.26	8.06	8.07	0.03
Rarawaru Creek	9	7.82	8.06	7.93	7.93	0.03
Confluence	9	7.82	8.12	7.98	7.96	0.03
Paremoremo Ski Club	9	7.89	8.08	7.97	7.98	0.02
Rangitopuni Creek	9	7.73	8.21	7.92	7.92	0.05
Brighams Creek	9	7.76	8.03	7.94	7.91	0.03
Lucas Creek	9	7.87	8.13	7.98	7.97	0.03
Tamaki	12	7.90	8.25	8.09	8.08	0.03
Panmure Basin	12	7.44	8.15	7.97	7.96	0.05
Grahams Beach	12	8.11	8.23	8.19	8.18	0.01
Clarks Beach	12	8.08	8.22	8.14	8.15	0.01
Shag Point	12	8.03	8.26	8.16	8.16	0.02
Puketutu Point	12	8.02	8.25	8.13	8.13	0.02
Weymouth	12	7.96	8.26	8.10	8.10	0.02
Mangere Bridge	12	7.97	8.21	8.06	8.08	0.02

Table 5

Turbidity (NTU)

Site	Count	Min	Max	Median	Mean	Standard error
Goat Island	12	0.3	1.1	0.6	0.6	0.1
Ti Point	12	0.3	1.5	0.8	0.8	0.1
Mahurangi Heads	11	0.7	52.4	1.7	6.2	4.6
Dawson's Creek	11	1.0	10.9	6.6	6.5	1.0
Town Basin	9	1.2	20.0	6.6	8.7	2.1
Orewa	12	0.3	4.1	1.3	1.8	0.4
Browns Bay	12	0.3	2.7	1.2	1.2	0.2
Shelly Beach	12	3.7	51.5	21.2	21.7	4.0
Chelsea	12	1.0	6.1	2.3	2.9	0.5
Whau Creek	12	1.4	16.6	4.8	5.9	1.2
Henderson Creek	12	2.2	14.0	6.0	7.0	0.9
Hobsonville Jetty	9	2.4	6.7	5.0	4.9	0.6
Waimarie Rd	9	2.4	15.6	6.4	7.3	1.1
Rarawaru Creek	9	5.0	15.9	8.6	9.5	1.3
Confluence	9	3.0	20.7	7.6	8.7	1.8
Paremoremo Ski Club	9	4.2	19.7	8.7	9.4	1.5
Rangitopuni Creek	9	4.0	30.5	6.7	9.1	2.7
Brighams Creek	9	4.5	34.3	7.4	10.1	3.1
Lucas Creek	9	5.9	18.9	8.3	10.3	1.4
Tamaki	12	2.1	23.5	4.6	6.4	1.6
Panmure Basin	12	4.5	23.9	9.9	11.0	1.7
Grahams Beach	12	2.0	5.9	4.0	3.8	0.3
Clarks Beach	12	1.8	11.0	5.0	6.2	0.9
Shag Point	12	1.7	10.9	4.0	4.8	0.8
Puketutu Point	12	1.3	12.2	5.3	5.3	0.8
Weymouth	12	4.1	15.6	7.4	8.3	1.1
Mangere Bridge	12	3.9	17.2	9.7	10.1	1.2

Table 6

Suspended sediment (mg/L)

Site	Count	Min	Max	Median	Mean	Standard error
Goat Island	12	1.6	16.0	3.1	6.0	1.4
Ti Point	12	1.2	16.8	3.2	4.9	1.3
Mahurangi Heads	11	2.7	70.0	5.1	11.2	5.9
Dawson's Creek	11	4.3	20.6	11.7	12.2	1.7
Town Basin	9	5.2	18.6	10.0	10.6	1.4
Orewa	12	2.4	24.0	5.6	8.1	1.9
Browns Bay	12	2.4	15.0	4.8	6.1	1.0
Shelly Beach	12	18.2	76.0	41.3	42.1	5.1
Chelsea	12	2.8	19.2	7.7	9.0	1.3
Whau Creek	12	5.4	30.7	11.3	12.5	2.1
Henderson Creek	12	4.2	33.6	11.9	13.4	2.2
Hobsonville Jetty	9	2.3	13.6	10.4	9.3	1.2
Waimarie Rd	9	7.0	34.0	15.2	16.0	2.4
Rarawaru Creek	9	8.7	28.0	16.0	16.5	2.4
Confluence	9	5.4	30.0	14.4	15.1	2.4
Paremoremo Ski Club	9	9.4	30.4	15.6	17.0	2.3
Rangitopuni Creek	9	5.8	23.0	12.0	12.3	1.8
Brighams Creek	9	8.4	28.0	14.2	14.7	2.0
Lucas Creek	9	12.3	38.4	15.0	18.6	3.0
Tamaki	12	5.5	200.0	14.5	32.9	15.6
Panmure Basin	12	7.1	33.0	17.5	19.5	2.8
Grahams Beach	12	6.4	19.0	11.7	11.4	1.0
Clarks Beach	12	1.0	27.2	18.0	16.8	2.3
Shag Point	12	5.0	23.0	14.2	13.9	1.9
Puketutu Point	12	8.0	27.0	14.3	15.8	1.7
Weymouth	12	8.2	34.0	17.3	19.0	2.0
Mangere Bridge	12	9.0	41.0	23.6	25.4	3.0

Table 7

Chlorophyll a (mg/L)

Site	Count	Min	Max	Median	Mean	Standard error
Goat Island	12	0.0003	0.0039	0.0017	0.0018	0.0003
Ti Point	12	0.0003	0.0029	0.0017	0.0016	0.0002
Mahurangi Heads	11	0.0006	0.0236	0.0019	0.0040	0.0020
Dawson's Creek	10	0.0018	0.0091	0.0032	0.0036	0.0007
Town Basin	8	0.0006	0.0140	0.0037	0.0049	0.0016
Orewa	12	0.0007	0.0036	0.0017	0.0020	0.0003
Browns Bay	12	0.0007	0.0039	0.0025	0.0023	0.0003
Shelly Beach	12	0.0024	0.0115	0.0042	0.0048	0.0007
Chelsea	12	0.0013	0.0044	0.0024	0.0026	0.0003
Whau Creek	12	0.0011	0.0051	0.0035	0.0031	0.0004
Henderson Creek	12	0.0003	0.0098	0.0021	0.0030	0.0008
Hobsonville Jetty	9	0.0007	0.0038	0.0029	0.0024	0.0004
Waimarie Rd	9	0.0003	0.0068	0.0029	0.0031	0.0006
Rarawaru Creek	9	0.0008	0.0062	0.0026	0.0027	0.0006
Confluence	9	0.0008	0.0055	0.0029	0.0032	0.0005
Paremoremo Ski Club	9	0.0008	0.0059	0.0024	0.0031	0.0006
Rangitopuni Creek	9	0.0009	0.0380	0.0062	0.0085	0.0038
Brighams Creek	9	0.0003	0.0068	0.0031	0.0037	0.0008
Lucas Creek	9	0.0003	0.0050	0.0036	0.0031	0.0005
Tamaki	12	0.0013	0.0042	0.0023	0.0024	0.0002
Panmure Basin	12	0.0006	0.0073	0.0026	0.0033	0.0006
Grahams Beach	12	0.0003	0.0099	0.0023	0.0031	0.0008
Clarks Beach	12	0.0003	0.0081	0.0021	0.0025	0.0006
Shag Point	12	0.0003	0.0108	0.0025	0.0035	0.0010
Puketutu Point	12	0.0003	0.0337	0.0022	0.0056	0.0027
Weymouth	12	0.0003	0.0068	0.0026	0.0030	0.0006
Mangere Bridge	12	0.0003	0.0494	0.0038	0.0082	0.0039

Table 8

Nitrite (mg/L)

Site	Count	Min	Max	Median	Mean	Standard error
Goat Island	12	0.001	0.011	0.002	0.003	0.001
Ti Point	12	0.001	0.014	0.001	0.003	0.001
Mahurangi Heads	11	0.001	0.010	0.001	0.002	0.001
Dawson's Creek	10	0.001	0.005	0.002	0.002	0.000
Town Basin	8	0.001	0.016	0.007	0.007	0.002
Orewa	12	0.001	0.007	0.001	0.002	0.001
Browns Bay	12	0.001	0.008	0.001	0.002	0.001
Shelly Beach	12	0.001	0.011	0.003	0.005	0.001
Chelsea	12	0.001	0.007	0.003	0.003	0.001
Whau Creek	12	0.001	0.006	0.001	0.002	0.001
Henderson Creek	12	0.001	0.006	0.001	0.002	0.001
Hobsonville Jetty	9	0.001	0.005	0.002	0.003	0.000
Waimarie Rd	9	0.001	0.014	0.004	0.005	0.001
Rarawaru Creek	9	0.001	0.004	0.002	0.002	0.000
Confluence	9	0.001	0.004	0.002	0.002	0.000
Paremoremo Ski Club	9	0.001	0.005	0.003	0.003	0.000
Rangitopuni Creek	9	0.001	0.013	0.003	0.004	0.001
Brighams Creek	9	0.001	0.013	0.003	0.004	0.001
Lucas Creek	9	0.001	0.004	0.002	0.002	0.000
Tamaki	12	0.001	0.005	0.002	0.002	0.000
Panmure Basin	12	0.001	0.012	0.004	0.005	0.001
Grahams Beach	12	0.001	0.013	0.003	0.005	0.001
Clarks Beach	12	0.001	0.012	0.005	0.006	0.001
Shag Point	12	0.001	0.027	0.009	0.009	0.002
Puketutu Point	12	0.001	0.029	0.012	0.012	0.002
Weymouth	12	0.002	0.014	0.007	0.008	0.001
Mangere Bridge	12	0.001	0.024	0.015	0.014	0.002

Table 9

Nitrate (mg/L)

Site	Count	Min	Max	Median	Mean	Standard error
Goat Island	12	0.007	0.116	0.022	0.033	0.009
Ti Point	12	0.001	0.111	0.013	0.030	0.010
Mahurangi Heads	11	0.005	0.201	0.021	0.036	0.017
Dawson's Creek	9	0.005	0.081	0.024	0.034	0.009
Town Basin	8	0.002	0.377	0.157	0.152	0.044
Orewa	12	0.005	0.048	0.016	0.019	0.004
Browns Bay	12	0.007	0.078	0.020	0.028	0.006
Shelly Beach	12	0.007	0.147	0.030	0.043	0.012
Chelsea	12	0.009	0.067	0.025	0.028	0.005
Whau Creek	12	0.005	0.095	0.015	0.022	0.007
Henderson Creek	12	0.009	0.090	0.018	0.030	0.008
Hobsonville Jetty	9	0.007	0.044	0.022	0.024	0.004
Waimarie Rd	9	0.005	0.604	0.038	0.122	0.057
Rarawaru Creek	9	0.005	0.313	0.026	0.066	0.033
Confluence	9	0.002	0.285	0.027	0.056	0.029
Paremoremo Ski Club	9	0.007	0.281	0.027	0.060	0.029
Rangitopuni Creek	8	0.003	0.292	0.040	0.078	0.036
Brighams Creek	8	0.005	0.614	0.032	0.110	0.074
Lucas Creek	8	0.008	0.187	0.027	0.048	0.022
Tamaki	12	0.006	0.337	0.031	0.070	0.029
Panmure Basin	12	0.007	0.793	0.058	0.167	0.074
Grahams Beach	12	0.004	0.193	0.024	0.050	0.017
Clarks Beach	12	0.004	0.329	0.046	0.082	0.028
Shag Point	12	0.009	0.419	0.088	0.121	0.032
Puketutu Point	12	0.008	0.549	0.204	0.217	0.046
Weymouth	12	0.019	0.604	0.091	0.202	0.059
Mangere Bridge	12	0.002	0.536	0.183	0.219	0.043

Table 10

Ammonia (mg/L)

Site	Count	Min	Max	Median	Mean	Standard error
Goat Island	12	0.003	0.102	0.004	0.014	0.008
Ti Point	12	0.003	0.106	0.004	0.013	0.008
Mahurangi Heads	11	0.003	0.176	0.003	0.020	0.016
Dawson's Creek	11	0.003	0.210	0.008	0.033	0.019
Town Basin	9	0.012	0.377	0.096	0.104	0.038
Orewa	12	0.003	0.099	0.003	0.011	0.008
Browns Bay	12	0.003	0.186	0.003	0.019	0.015
Shelly Beach	12	0.003	0.310	0.031	0.055	0.024
Chelsea	12	0.003	0.086	0.003	0.012	0.007
Whau Creek	12	0.003	0.076	0.003	0.009	0.006
Henderson Creek	12	0.003	0.106	0.003	0.014	0.009
Hobsonville Jetty	9	0.003	0.155	0.014	0.029	0.016
Waimarie Rd	9	0.003	0.232	0.022	0.038	0.018
Rarawaru Creek	9	0.003	0.102	0.015	0.027	0.011
Confluence	9	0.003	0.110	0.013	0.028	0.013
Paremoremo Ski Club	9	0.003	0.098	0.011	0.025	0.011
Rangitopuni Creek	9	0.003	0.106	0.021	0.033	0.011
Brighams Creek	9	0.003	0.086	0.019	0.031	0.011
Lucas Creek	9	0.003	0.105	0.019	0.031	0.011
Tamaki	12	0.003	0.438	0.016	0.055	0.035
Panmure Basin	12	0.003	0.390	0.039	0.076	0.031
Grahams Beach	12	0.003	0.104	0.003	0.016	0.008
Clarks Beach	12	0.003	0.145	0.018	0.026	0.011
Shag Point	12	0.003	0.154	0.040	0.056	0.016
Puketutu Point	12	0.003	0.478	0.048	0.110	0.041
Weymouth	12	0.003	0.232	0.044	0.055	0.018
Mangere Bridge	12	0.003	0.209	0.115	0.102	0.023

Table 11

Total kjeldahl nitrogen (mg/L)

Site	Count	Min	Max	Median	Mean	Standard error
Goat Island	12	0.244	0.433	0.317	0.325	0.021
Ti Point	12	0.192	0.518	0.303	0.332	0.028
Mahurangi Heads	11	0.190	0.380	0.312	0.294	0.019
Dawson's Creek	11	0.229	0.630	0.345	0.359	0.032
Town Basin	9	0.380	0.890	0.480	0.559	0.067
Orewa	12	0.206	0.526	0.331	0.368	0.030
Browns Bay	12	0.183	0.532	0.311	0.355	0.032
Shelly Beach	12	0.356	1.400	0.585	0.631	0.086
Chelsea	12	0.236	0.490	0.354	0.333	0.024
Whau Creek	12	0.270	0.646	0.369	0.394	0.032
Henderson Creek	12	0.256	0.579	0.380	0.371	0.026
Hobsonville Jetty	9	0.270	0.670	0.340	0.391	0.041
Waimarie Rd	9	0.240	0.550	0.370	0.378	0.026
Rarawaru Creek	9	0.235	0.500	0.340	0.330	0.029
Confluence	9	0.245	0.420	0.352	0.339	0.022
Paremoremo Ski Club	9	0.230	0.770	0.344	0.376	0.054
Rangitopuni Creek	9	0.199	0.700	0.404	0.420	0.055
Brighams Creek	9	0.130	0.627	0.340	0.358	0.055
Lucas Creek	9	0.276	0.560	0.364	0.381	0.032
Tamaki	12	0.210	0.806	0.405	0.430	0.044
Panmure Basin	12	0.270	0.852	0.482	0.508	0.047
Grahams Beach	12	0.257	0.600	0.328	0.355	0.027
Clarks Beach	12	0.284	0.676	0.381	0.404	0.030
Shag Point	12	0.280	0.610	0.398	0.426	0.033
Puketutu Point	12	0.370	0.810	0.433	0.476	0.036
Weymouth	12	0.311	0.550	0.412	0.422	0.021
Mangere Bridge	12	0.320	0.650	0.443	0.457	0.030

Table 12

Total nitrogen (by calculation, mg/L)

Site	Count	Min	Max	Median	Mean	Standard error
Goat Island	12	0.260	0.471	0.379	0.362	0.023
Ti Point	12	0.214	0.535	0.342	0.365	0.029
Mahurangi Heads	11	0.214	0.591	0.329	0.333	0.031
Dawson's Creek	9	0.254	0.645	0.397	0.400	0.039
Town Basin	8	0.452	1.158	0.608	0.728	0.094
Orewa	12	0.227	0.558	0.357	0.389	0.030
Browns Bay	12	0.201	0.581	0.366	0.385	0.033
Shelly Beach	12	0.380	1.416	0.642	0.679	0.086
Chelsea	12	0.249	0.508	0.400	0.364	0.025
Whau Creek	12	0.323	0.664	0.381	0.418	0.032
Henderson Creek	12	0.273	0.625	0.405	0.403	0.028
Hobsonville Jetty	9	0.315	0.697	0.361	0.418	0.042
Waimarie Rd	9	0.294	1.024	0.453	0.506	0.069
Rarawaru Creek	9	0.264	0.718	0.375	0.398	0.049
Confluence	9	0.276	0.683	0.382	0.397	0.042
Paremoremo Ski Club	9	0.279	1.056	0.365	0.439	0.080
Rangitopuni Creek	8	0.227	0.899	0.452	0.468	0.072
Brighams Creek	8	0.176	1.186	0.403	0.469	0.116
Lucas Creek	8	0.307	0.694	0.388	0.409	0.044
Tamaki	12	0.218	1.006	0.445	0.501	0.060
Panmure Basin	12	0.278	1.657	0.544	0.680	0.118
Grahams Beach	12	0.268	0.627	0.384	0.410	0.031
Clarks Beach	12	0.359	0.725	0.451	0.492	0.034
Shag Point	12	0.322	0.826	0.508	0.556	0.043
Puketutu Point	12	0.393	1.388	0.664	0.706	0.074
Weymouth	12	0.415	1.024	0.520	0.632	0.063
Mangere Bridge	12	0.484	0.915	0.667	0.690	0.036

Table 13

Total phosphorus (mg/L)

Site	Count	Min	Max	Median	Mean	Standard error
Goat Island	12	0.005	0.031	0.021	0.020	0.002
Ti Point	12	0.005	0.040	0.021	0.020	0.003
Mahurangi Heads	11	0.005	0.050	0.020	0.022	0.003
Dawson's Creek	11	0.012	0.060	0.023	0.029	0.004
Town Basin	9	0.038	0.090	0.057	0.062	0.007
Orewa	12	0.005	0.040	0.021	0.021	0.003
Browns Bay	12	0.010	0.046	0.026	0.027	0.003
Shelly Beach	12	0.034	0.157	0.058	0.064	0.009
Chelsea	12	0.020	0.050	0.029	0.030	0.003
Whau Creek	12	0.017	0.058	0.029	0.033	0.004
Henderson Creek	12	0.015	0.060	0.029	0.033	0.004
Hobsonville Jetty	9	0.020	0.051	0.031	0.032	0.004
Waimarie Rd	9	0.020	0.111	0.046	0.050	0.006
Rarawaru Creek	9	0.020	0.055	0.034	0.039	0.004
Confluence	9	0.020	0.059	0.047	0.042	0.004
Paremoremo Ski Club	9	0.020	0.061	0.039	0.040	0.005
Rangitopuni Creek	9	0.020	0.065	0.052	0.049	0.005
Brighams Creek	9	0.020	0.084	0.060	0.050	0.007
Lucas Creek	9	0.020	0.059	0.039	0.040	0.004
Tamaki	12	0.020	0.063	0.037	0.037	0.004
Panmure Basin	12	0.027	0.072	0.044	0.046	0.005
Grahams Beach	12	0.030	0.062	0.035	0.036	0.003
Clarks Beach	12	0.030	0.062	0.044	0.045	0.003
Shag Point	12	0.060	0.241	0.107	0.128	0.017
Puketutu Point	12	0.084	0.277	0.157	0.163	0.017
Weymouth	12	0.040	0.111	0.055	0.059	0.006
Mangere Bridge	12	0.131	0.261	0.153	0.179	0.014

Table 14

Soluble reactive phosphorus (mg/L)

Site	Count	Min	Max	Median	Mean	Standard error
Goat Island	12	0.005	0.019	0.011	0.012	0.001
Ti Point	12	0.006	0.018	0.010	0.011	0.001
Mahurangi Heads	11	0.005	0.021	0.015	0.014	0.001
Dawson's Creek	11	0.007	0.018	0.013	0.014	0.001
Town Basin	9	0.008	0.053	0.029	0.030	0.005
Orewa	12	0.003	0.020	0.013	0.012	0.002
Browns Bay	12	0.006	0.030	0.017	0.017	0.002
Shelly Beach	12	0.016	0.028	0.022	0.022	0.001
Chelsea	12	0.003	0.027	0.022	0.019	0.002
Whau Creek	12	0.005	0.025	0.021	0.018	0.002
Henderson Creek	12	0.006	0.025	0.021	0.018	0.002
Hobsonville Jetty	9	0.012	0.028	0.020	0.021	0.002
Waimarie Rd	9	0.014	0.050	0.031	0.031	0.004
Rarawaru Creek	9	0.003	0.036	0.021	0.022	0.003
Confluence	9	0.011	0.040	0.023	0.025	0.003
Paremoremo Ski Club	9	0.010	0.030	0.020	0.020	0.002
Rangitopuni Creek	9	0.007	0.032	0.020	0.021	0.003
Brighams Creek	9	0.009	0.033	0.023	0.022	0.003
Lucas Creek	9	0.005	0.031	0.020	0.019	0.003
Tamaki	12	0.015	0.037	0.021	0.022	0.002
Panmure Basin	12	0.016	0.043	0.025	0.026	0.002
Grahams Beach	12	0.018	0.034	0.026	0.025	0.001
Clarks Beach	12	0.018	0.037	0.030	0.029	0.002
Shag Point	12	0.046	0.166	0.081	0.102	0.013
Puketutu Point	12	0.063	0.230	0.117	0.130	0.014
Weymouth	12	0.021	0.050	0.037	0.039	0.003
Mangere Bridge	12	0.113	0.173	0.133	0.139	0.007

Table 15

Faecal coliforms (MPN/100ml)

Site	Count	Min	Max	Median	Mean	Standard error
Goat Island	12	1.0	2.0	1.0	1.2	0.1
Ti Point	12	1.0	5.0	2.0	2.2	0.3
Mahurangi Heads	11	1.0	33.0	1.0	5.8	3.1
Dawson's Creek	11	1.0	630.0	11.0	84.9	55.9
Town Basin	9	130.0	54000.0	1700.0	7616.7	5844.9
Orewa	12	1.0	13.0	1.0	2.2	1.0
Browns Bay	12	1.0	5.0	1.0	1.7	0.4
Shelly Beach	12	0.9	230.0	2.0	22.1	18.9
Chelsea	12	1.0	220.0	3.0	23.4	18.0
Whau Creek	12	1.0	130.0	5.0	14.9	10.5
Henderson Creek	12	1.0	170.0	5.0	32.5	15.9
Hobsonville Jetty	9	1.0	79.0	2.0	11.7	8.5
Waimarie Rd	9	1.0	490.0	9.0	69.7	42.4
Rarawaru Creek	9	8.0	790.0	23.0	125.8	84.0
Confluence	9	5.0	790.0	17.0	103.2	86.0
Paremoremo Ski Club	9	2.0	790.0	33.0	123.2	84.4
Rangitopuni Creek	9	4.0	490.0	79.0	163.7	63.3
Brighams Creek	9	17.0	920.0	33.0	158.7	96.6
Lucas Creek	9	1.0	790.0	33.0	161.3	94.2
Tamaki	12	1.0	3500.0	9.5	330.5	289.4
Panmure Basin	12	12.0	13000.0	64.0	2481.5	1263.6
Grahams Beach	12	0.9	7.8	1.0	1.7	0.6
Clarks Beach	12	1.0	49.0	2.0	11.2	4.9
Shag Point	12	0.9	46.0	7.5	10.1	3.8
Puketutu Point	12	0.9	1700.0	12.5	162.5	140.1
Weymouth	12	1.0	490.0	30.0	110.5	46.9
Mangere Bridge	12	1.0	140.0	12.5	29.7	12.1

Table 16

Enterococci (CFU/100ml)

Site	Count	Min	Max	Median	Mean	Standard error
Goat Island	12	1.0	1.0	1.0	1.0	0.0
Ti Point	12	1.0	18.0	1.0	3.0	1.4
Mahurangi Heads	11	1.0	6000.0	1.0	547.5	545.3
Dawson's Creek	10	1.0	136.0	1.0	16.2	13.3
Town Basin	8	23.0	2600.0	176.0	532.1	305.9
Orewa	12	1.0	12.0	1.0	2.8	1.0
Browns Bay	12	1.0	2.0	1.0	1.3	0.1
Shelly Beach	12	1.0	54.0	5.0	10.4	4.5
Chelsea	12	1.0	78.0	1.0	9.8	6.4
Whau Creek	12	1.0	12.0	1.0	2.3	0.9
Henderson Creek	12	1.0	42.0	3.0	8.8	3.6
Hobsonville Jetty	9	1.0	42.0	2.0	6.2	4.5
Waimarie Rd	9	1.0	80.0	4.0	16.9	8.1
Rarawaru Creek	9	4.0	132.0	17.0	32.0	13.1
Confluence	9	1.0	310.0	13.0	49.1	33.0
Paremoremo Ski Club	9	2.0	190.0	10.0	43.8	23.1
Rangitopuni Creek	9	2.0	360.0	17.0	57.9	38.3
Brighams Creek	9	2.0	230.0	20.0	42.6	24.1
Lucas Creek	9	1.0	144.0	5.0	28.8	15.4
Tamaki	12	1.0	2060.0	8.5	205.0	170.2
Panmure Basin	12	3.0	7400.0	26.5	758.1	610.6
Grahams Beach	12	1.0	260.0	2.5	25.8	21.3
Clarks Beach	12	1.0	42.0	7.0	13.3	4.5
Shag Point	12	1.0	32.0	2.5	8.4	3.3
Puketutu Point	12	1.0	54.0	4.0	11.7	4.6
Weymouth	12	1.0	80.0	12.5	23.0	7.9
Mangere Bridge	12	1.0	56.0	3.0	13.1	5.0

Table 17

Dissolved oxygen (% saturation)

Site	Count	Min	Max	Median	Mean	Standard error
Goat Island	5	78.0	116.2	100.8	101.0	6.8
Ti Point	5	82.1	113.8	105.3	103.0	5.7
Mahurangi Heads	9	74.9	111.5	92.0	94.8	3.4
Dawson's Creek	10	77.8	104.1	92.4	91.6	2.5
Town Basin	9	51.4	93.7	77.5	75.6	4.5
Orewa	5	72.2	112.1	102.9	98.7	7.4
Browns Bay	5	69.7	114.4	101.1	98.1	7.9
Shelly Beach	11	53.0	116.4	86.6	87.7	4.8
Chelsea	5	70.3	107.4	102.5	96.9	6.8
Whau Creek	5	68.4	105.4	98.1	93.6	6.5
Henderson Creek	5	65.9	104.2	98.0	92.6	6.8
Hobsonville Jetty	9	83.0	105.0	92.1	93.1	2.4
Waimarie Rd	9	77.5	114.6	92.0	92.6	3.2
Rarawaru Creek	9	73.3	103.7	87.9	87.1	3.1
Confluence	9	74.9	100.1	89.6	87.8	2.6
Paremoremo Ski Club	9	74.6	99.4	88.8	87.3	2.6
Rangitopuni Creek	9	66.5	133.6	83.2	88.2	6.4
Brighams Creek	9	69.2	102.5	85.8	86.3	3.5
Lucas Creek	9	68.2	99.6	88.0	85.6	3.1
Tamaki	12	81.5	104.5	88.5	90.6	2.1
Panmure Basin	12	73.8	99.7	86.3	87.2	2.1
Grahams Beach	6	90.9	111.2	97.4	99.0	3.1
Clarks Beach	6	87.5	109.8	96.2	97.0	3.4
Shag Point	6	87.4	109.5	96.8	97.5	3.3
Puketutu Point	6	86.8	106.7	96.9	97.3	3.0
Weymouth	6	83.3	114.6	98.3	97.2	4.9
Mangere Bridge	6	87.3	109.9	91.2	95.4	3.6

Table 18

Dissolved oxygen (ppm)

Site	Count	Min	Max	Median	Mean	Standard error
Goat Island	12	6.3	9.2	7.4	7.7	0.2
Ti Point	12	6.5	9.0	7.7	7.8	0.2
Mahurangi Heads	10	6.5	8.5	7.3	7.4	0.2
Dawson's Creek	11	6.0	8.2	7.5	7.3	0.2
Town Basin	9	3.8	9.5	6.6	6.6	0.6
Orewa	12	6.1	8.9	7.5	7.3	0.3
Browns Bay	12	5.9	8.8	7.3	7.4	0.2
Shelly Beach	12	4.7	9.8	7.1	7.2	0.4
Chelsea	12	6.1	8.3	7.4	7.4	0.2
Whau Creek	12	6.2	8.0	7.2	7.2	0.2
Henderson Creek	12	6.1	8.4	7.1	7.2	0.2
Hobsonville Jetty	9	6.3	8.5	7.8	7.5	0.3
Waimarie Rd	9	5.8	10.5	7.2	7.4	0.4
Rarawaru Creek	9	5.5	8.0	7.2	7.0	0.3
Confluence	9	5.7	8.4	7.2	7.1	0.3
Paremoremo Ski Club	9	5.6	8.4	7.1	7.1	0.3
Rangitopuni Creek	9	5.2	11.6	7.0	7.5	0.7
Brighams Creek	9	5.3	8.6	7.0	7.1	0.4
Lucas Creek	9	5.2	8.0	7.1	6.9	0.3
Tamaki	12	6.3	8.3	7.3	7.3	0.2
Panmure Basin	12	5.9	8.3	7.3	7.1	0.3
Grahams Beach	11	6.6	8.8	7.4	7.6	0.2
Clarks Beach	11	6.3	9.0	7.4	7.5	0.3
Shag Point	11	6.4	9.0	7.3	7.5	0.3
Puketutu Point	11	6.1	8.9	7.1	7.4	0.3
Weymouth	11	5.9	10.5	7.6	7.7	0.4
Mangere Bridge	11	6.0	8.8	6.9	7.2	0.3

Table 19

Temperature (◦C)

Site	Count	Min	Max	Median	Mean	Standard error
Goat Island	12	13.3	21.6	16.8	17.3	0.8
Ti Point	12	11.9	21.6	17.1	17.2	0.9
Mahurangi Heads	11	13.1	22.8	18.4	17.7	1.0
Dawson's Creek	11	12.2	22.3	17.3	17.5	1.1
Town Basin	9	11.1	23.1	19.2	18.0	1.3
Orewa	12	12.6	22.5	17.2	17.4	1.0
Browns Bay	12	12.8	22.8	17.0	17.4	1.0
Shelly Beach	12	12.5	23.5	16.1	17.3	1.0
Chelsea	12	12.0	23.3	16.8	17.3	1.1
Whau Creek	12	11.4	22.4	16.8	17.0	1.1
Henderson Creek	12	11.4	22.7	16.8	17.1	1.2
Hobsonville Jetty	9	12.7	23.0	19.4	18.0	1.2
Waimarie Rd	9	11.8	24.3	17.0	17.7	1.3
Rarawaru Creek	9	12.4	23.6	19.2	18.7	1.3
Confluence	9	12.4	23.6	19.0	18.3	1.3
Paremoremo Ski Club	9	12.3	23.4	18.9	18.3	1.2
Rangitopuni Creek	9	12.3	24.1	18.7	18.3	1.4
Brighams Creek	9	12.3	23.7	19.1	18.5	1.3
Lucas Creek	9	12.6	23.4	18.9	18.0	1.2
Tamaki	12	12.9	23.8	16.6	17.5	1.1
Panmure Basin	12	13.0	23.9	16.4	17.5	1.1
Grahams Beach	11	12.4	23.2	15.5	16.7	1.1
Clarks Beach	11	11.6	24.1	15.2	16.7	1.2
Shag Point	11	12.3	23.6	15.0	16.6	1.1
Puketutu Point	11	11.9	23.5	14.9	16.4	1.1
Weymouth	11	11.8	24.3	14.8	16.6	1.2
Mangere Bridge	11	11.9	23.6	14.7	16.5	1.1

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5 Appendix 1

Table 20:

Summary of marine water quality parameters, detection limits, analytical methods and the 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	APHA (2005) 4500-H B	Lab
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_3)	mg/L	-	Calculation (NNN - NO2)	Lab
Nitrite nitrogen (NO_2)	mg/L	0.002	APHA (2005) 4500-NO2 B	Lab
Ammoniacal nitrogen (NH_4-N)	mg/L	0.001	APHA (2005) 4500-NH3 G Mod	Lab
Nitrate/Nitrite nitrogen NO_3 + NO_2 (aka NNN)	mg/L	0.005	APHA (2005) 4500-NO3 F	Lab
Total kjeldahl nitrogen (TKN)	mg/L	0.1	APHA (2005) 4500-org A, D Modified	Lab
Total nitrogen (TN)	mg/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
Faecal coliforms	MPN/100ml	2	APHA (2005) 9221 E	Lab
Presumptive coliforms	MPN/100ml	2	APHA (2005) 9221 B	Lab

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 waters 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 conduce. 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 passage 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 NO_3^-, nitrite NO_2^- and ammonia (NH_4^++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 (NH_3) and the ammonium ion (NH_4), at normal pH values ammonium (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.

The indicator organisms used for water quality monitoring are generally bacteria that are present as normal inhabitants in the gut of healthy warm-blooded animals, including humans, and are shed in large numbers in faecal matter (at a rate of 106 – 109 individuals per gram). They are not usually considered to present a risk to public health when present in natural waters (i.e., they are not generally disease causing or pathogenic when contacted through this route), but their presence is taken to indicate

faecal contamination and hence the possibility that pathogenic micro organisms that are found in the gut may also be present.

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.

Presumptive and faecal coliforms

The term coliform is used to describe a heterogeneous group of bacteria belonging to the family Enterobacteriaceae, which are characterised by their ability to ferment lactose with the production of acid and gas at 35°C. Included within this definition are members of the Escherichia, Klebsiella, Enterobacter, Serratia, and Citrobacter genera. While members of all of these genera are typically found in faecal material, only one, Escherichia coli, is truly faecal specific.

The results of coliform or presumptive coliform tests are often highly variable and do not necessarily indicate the degree of faecal contamination. This is because members of the coliform group are also found as natural inhabitants of soil and decaying vegetation, and therefore elevated levels in waters may be due to naturally occurring organisms. Nevertheless, the presumptive coliform test may provide useful information on the level and nature of contamination when used in association with other analyses such as the faecal coliform test.

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