Auckland Regional Council
TE RAUHITANGA TAIAO

Saline Water Quality State and Trends in the Auckland Region

August TR 2008/005

Auckland Regional Council
Technical Report No.005 August 2008
ISSN 1179-0504 (Print)
ISSN 1179-0512 (Online)
ISBN 978-1-877483-44-8

Reviewed by:

Name: Jarrod Walker

Position: Project Leader Marine Science

Organisation: Auckland Regional Council

Date: 29 October 2008

Approved for ARC Publication by:

Name: Grant Barnes

Position: Group Manager Monitoring and Research

Organisation: Auckland Regional Council

Date: 29 October 2008

Recommended Citation:

Scarsbrook, M. 2008. Saline water quality state and trends in the Auckland region. Prepared by National Institute of Water and Atmospheric Research Limited for Auckland Regional Council. Regional Council Technical Report 2008/005. 54 pages.

Saline Water Quality State and Trends in Auckland Region

Mike Scarsbrook

Prepared for
Auckland Regional Council

NIWA Client Report: HAM2008-096
June 2008

NIWA Project: ARC08217

National Institute of Water & Atmospheric Research Ltd
Gate 10, Silverdale Road, Hamilton
P O Box 11115, Hamilton, New Zealand
Phone +64-7-856 7026, Fax +64-7-856 0151
www.niwa.co.nz

Contents

Reviewed by:

David Roper

Approved for release by:

Bob Wilcock

Formatting checked:

A. Bartley

1 Executive Summary

Auckland Regional Council (ARC) operates a long-term water quality monitoring network at 27 sites located among the Region's harbours, estuaries and wider coastal zone. This monitoring network has produced New Zealand's most comprehensive long-term water quality dataset for coastal waters. Objectives of this network include State of the Environment reporting, identification of major environmental issues, and assessment of the efficacy and efficiency of Council policy initiatives and strategies.

This report provides a state of the environment summary for saline waters, which together with a recently completed freshwater SoE report, provides the information required to develop a more integrated network for future environmental monitoring in the region.

The project brief for NIWA's analyses of the ARC saline dataset required an assessment of quality state and trends, and potential drivers (e.g., climate variability and anthropogenic impacts) at 27 long-term saline monitoring sites. These analyses focused on Manukau Harbour, where intensive monitoring over 20 years has provided an opportunity to track significant changes in resource management and water quality. Another key aim of this report was to identify relationships between estuarine/harbour state and trends and river/stream water quality, specifically Tamaki, Mahurangi and Upper Waitemata Harbour catchments. Information on stream-estuarine water quality linkages will be used to inform the integration of future SoE monitoring.

Three sites in Manukau Harbour (Puketutu Point, Mangere Bridge and Shag Point) stood out from all other sites with respect to nitrogen and phosphorus concentrations. These three sites have been heavily affected by historic discharges from the Mangere Wastewater Treatment Plant. The highest levels of faecal indicator bacteria were observed in the upper Waitemata and Mahurangi harbours. These elevated levels should be of concern for resource managers, as values such as shellfish gathering and recreation are impacted by these high levels of faecal indicator bacteria.

Inner harbour sites tended to have poor water quality, whereas water quality in coastal or outer harbour sites was relatively good. Relationships between salinity and both average water quality rank and the number of shellfish gathering guideline exceedences at a site supported the hypothesis that sites close to the influence of streams (i.e., upper harbour) tended to have lower water quality.

Water quality in Manukau Harbour has shown dramatic improvements since decommissioning of the Mangere Oxidation Ponds, completed in 2002. In particular, levels of ammoniacal nitrogen, total phosphorus and suspended sediments show marked decreases in the last five years. Across the region as a whole there were significant improving trends in levels of faecal indicator bacteria, total suspended sediments, total phosphorus, soluble reactive phosphorus and nitrate. Most of these improvements are consistent with decreased anthropogenic pressures. Trends that should be of concern to resource managers include increasing levels of sediments and/or nutrients at a few sites (e.g., Mahurangi @ Mahurangi Heads and Manukau Harbour @ Weymouth).

Analyses showed a strong overlap in temporal trends observed in streams and estuaries in the region, indicating that stream water quality is a major driver of water quality at inner harbour sites. Climate variability, as measured by the Southern Oscillation Index (SOI) was also found to be strongly associated with temporal patterns of water quality, especially relating to temperature and nitrogen concentrations.

Auckland Regional Council's Saline Water Quality Programme provides a very valuable, long-term dataset for investigating changes in state and changes over time in a selection of the Regions harbours and estuaries. There appears to be some redundancy in the suite of variables measured, specifically those variables used to measure suspended sediment levels, and there is a significant spatial bias in site locations. It is recommended that ARC investigate a redesign of the network, with a reduction in sites sampled in the Upper Waitemata Harbour possibly allowing for new sites to be added in the Kaipara, West Coast and Hauraki Gulf.

The value of the dataset could be improved by integration with freshwater monitoring data and more detailed information on pressures (e.g., number and type of point source discharges). A more detailed study of climate variability effects on harbour and estuary environments would also be of value. Development of region-specific water quality guidelines would also greatly enhance future reporting on state and trends, especially given the paucity of pristine reference sites in the Region.

2 Introduction

Auckland Regional Council (ARC) operates a long-term water quality monitoring network at 27 sites located among the Region's harbours, estuaries and wider coastal zone. This monitoring network has produced New Zealand's most comprehensive long-term water quality dataset for coastal waters. The network, initiated in 1987 to monitor the state of the Manukau Harbour, provides information that underpins state of the environment reporting as per obligations under s35 of the Resource Management Act (1991), helps inform the efficacy and efficiency of Council policy initiatives and strategies, and assists with the identification of large scale and/or cumulative impacts of contaminants associated with anthropogenic pressures. Another key feature of the network is its ability to track improvements in harbour water quality after implementation of improved waste water treatment (e.g., upgrades to the Mangere Wastewater Treatment Plant).

ARC is also seeking to provide an integrated approach to environmental monitoring of freshwater and saline environments across the region. This report provides a state of the environment summary for saline waters, which together with a stream SoE report already completed (Scarsbrook 2007), provides the information required to develop a more integrated network for future environmental monitoring in the region.

The project brief for the research summarised in this report set out the following aims:

1. To assess water quality state and trends at 27 long-term saline monitoring sites, with a focus on Manukau Harbour.
2. To compare and contrast differences in state and trends within the Manukau Harbour and the wider Auckland Region, attributing causality to anthropogenic influences or natural variation.
3. Develop relationships between estuarine/harbour state and trends and river/stream water quality, specifically Tamaki, Mahurangi and Upper Waitemata Harbour catchments.

It should be noted that attributing causality (point 2 above) is not possible given the nature of the dataset, but inferences about the association between anthropogenic pressures and water quality patterns can be made.

3 Methods

Monthly water quality data from 27 saline sites in Auckland Region were supplied to NIWA by ARC. Screening of the data identified a small number of presumed errors in the dataset. These errors were checked with ARC staff and either corrected, or the datapoint in question was deleted.

3.1 Study sites

The Saline Water Quality Programme contains 27 sites (Figure 1) located in the Manukau, Kaipara, Waitemata, Mahurangi and Tamaki Harbours and Eastern Coastal zone. The sites have been sampled over varying lengths of time (Table 1), with the six Manukau Harbour sites having the longest period of record (1987-2007).

Table 1:

Site information and data ranges.

Site	Easting	Northing	Begin Date	End Date
Manukau				
Clarks Beach	2660023	6449792	5/10/1987	13/07/2007
Grahams Beach	2659019	6459062	7/10/1987	13/07/2007
Mangere Bridge	2669004	6472408	7/10/1987	13/07/2007
Puketutu Point	2664289	6470427	7/10/1987	13/07/2007
Shag Point	2658790	6470166	7/10/1987	13/07/2007
Weymouth	2665300	6461900	5/10/1987	13/07/2007
Tamaki				
Panmure	2675718	6475615	9/11/1992	16/07/2007
No. 7 Buoy (Tamaki)	2679802	6479121	9/11/1992	16/07/2007
Upper Waitemata				
Brighams Creek	2653207	6489747	22/07/1993	19/07/2007
Confluence	2654107	6490782	22/07/1993	19/07/2007
Hobsonville Jetty	2659770	6489031	19/03/1991	19/07/2007
Lucas Creek	2660504	6494185	22/07/1993	19/07/2007
Paremoremo Ski Club	2656200	6491900	22/07/1993	19/07/2007
Rangitopuni Creek	2653233	6492595	22/07/1993	19/07/2007
Rarawaru Creek	2654885	6490378	22/07/1993	19/07/2007
Waimarie Rd	2656665	6490810	22/07/1993	19/07/2007
Orewa	2663769	6511321	19/03/1991	17/07/2007
Ti Point	2670783	6540222	19/03/1991	17/07/2007
Goat Island	2672411	6546605	20/08/1993	17/07/2007
Browns Bay	2668401	6497478	19/03/1991	17/07/2007
Waitemata				
Chelsea Wharf	2664384	6484577	19/03/1991	17/07/2007
Henderson Ck	2657153	6485367	19/03/1991	17/07/2007
Whau Creek	2658723	6482007	19/03/1991	17/07/2007
Kaipara @ Shelly Beach	2634008	6513666	6/11/1991	13/07/2007
Mahurangi				
Dawson's Creek	2664087	6528121	6/05/1993	18/07/2007
Mahurangi Heads	2664900	6521600	19/03/1991	18/07/2007
Town Basin	2659700	6532400	7/07/1993	18/07/2007

3.2 Water quality parameters

The ARC directly measures, or collects water samples for the analysis of up to 23 water quality parameters at saline sites. However, a number of these are measured infrequently or sporadically, and only 15 had sufficient data for analyses of trend and/or state (Table 2). Conductivity, chloride and BOD_5 data were excluded due to large gaps in the dataset for these variables. Note that measurements of water temperature, dissolved oxygen and water clarity are taken in the field, with all other variables being measured using standard laboratory protocols. Only data from surface sampling are included.

Table 2:

Analytical methods for water quality parameters summarised in this report.
Modified from Appendix 1, Table 4 of ARC (2007). The 15 water quality parameters analysed in this report are in bold text.

Identifier (+ unit)	Parameter	Method
DO (% saturation)	**Dissolved oxygen**	**Handheld meter (YSI-85)**
TEMP (℃)	**Temperature**	**Handheld meter (YSI-85)**
COND @ 25 ℃(mS m^{-1})	Conductivity	Handheld meter (YSI-85)
SAL	**Salinity**	**Handheld meter (YSI-85)**
CLAR (m)	**Clarity**	**Secchi disk**
pH	**pH**	**APHA (2005) 4500-H B**
TSS (mg L^{-1})	**Total suspended solids**	**APHA (2005) 2540 D**
TURB (NTU)	**Turbidity**	**APHA (2005) 2130 B**
NH_4-N (mg (N) L^{-1})	**Ammoniacal nitrogen**	**APHA (2005) 4500-NH3 G**
NO_3-N (mg (N) L^{-1})	**Nitrate nitrogen**	**APHA (2005) 4500-NO3 F**
NO_2-N (mg (N) L^{-1})	**Nitrite nitrogen**	**APHA (2005) 4500-NO2 B**
SRP (mg L^{-1})	**Soluble reactive phosphorus**	**APHA (205) 4500-P F**
TP (mg L^{-1})	**Total phosphorus**	**APHA (2005) 4500-P B, F**
CL (mg L^{-1})	Chloride	APHA (1998) 4500-Cl
BOD5	Biochemical Oxygen Demand	APHA (2005) 5210 5-2
CHLA	**Phytoplankton**	**APHA (2005) PART 10200 H**
ENT (MPN/100 ml)	**Enterococci**	**APHA (2005) 9230 C**
FAEC (MPN/100 ml)	**Faecal colifoms**	**APHA (2005) 9221 E**

Figure 1:

Saline and freshwater water quality monitoring locations within Auckland Region. See Table 1 for additional saline site information.

3.3 Water quality state

In the present report, water quality state was summarised both as long-term average allowing direct comparisons between sites, and by changes in state over time. For the long-term summary all data available at each site were used to produce box and whiskers plots to summarise the distribution of data at each site (Statistica 7). For the summaries of moving state, annual median values (based on the financial year July-June) were calculated using monthly data for all water quality parameters at each site from 1993 to 2007 – the period when sampling at all 27 sites overlapped. These annual site medians were then used to calculate the annual 5th, 50th and 95th percentile values across the 27 ARC monitoring sites. The 50th percentile (median) gives us a picture of what is happening in the regional "average" site in terms of annual median water quality data. The 5th and 95th percentiles tells us about changes in state over time in the region's "best" and "worst" saline sites. Trends in these annual summary values (1993-2007) were assessed using Spearman rank correlation.

For a subset of water quality parameters (TSS, NO_3-N, NH_4-N, SRP and Faecal Coliforms) a global median value for each site was also calculated. This value was used to produce a site ranking from low to high water quality for each selected parameter. An overall site average rank was also calculated, providing a high level summary of water quality at each site.

Finally, water quality state was also summarised in relation to shellfish gathering. The MFE (2003) guidelines were used to determine whether faecal coliform levels were considered safe with respect to shellfish gathering. These guidelines state "The median faecal coliform content of samples taken over a shellfish-gathering season shall not exceed a Most Probable Number (MPN) of 14/100 mL, and not more than 10% of samples should exceed an MPN of 43/100 mL (using a five-tube decimal dilution test)."

3.4 Water quality trends

All trend analyses on monthly data presented in this report were done using a new trend analysis software package (Time Trends 1.10) developed by NIWA using Envirolink funding.

Monthly water quality data from 27 sites were analysed for trends in individual parameters using Seasonal Kendall tests on raw data. The Sen Slope Estimator (SSE) was used to represent the magnitude and direction of trends in data. Values of the SSE were relativised by dividing through by the raw data median (RSSE), allowing for direct comparison between sites. Trends are reported for the full record of data at each site.

Following the convention of Scarsbrook et al. (2003) and Scarsbrook (2006), the statistical significance of trends at the regional scale (i.e., aggregating trend data for individual sites) was determined using a binomial test. The null hypothesis of this test postulates that the true proportion of upward (or downward) slopes is ½. If this hypothesis was rejected ($P < 0.05$), a regional trend for the period was inferred. This analysis used RSSE values from all sites, rather than just sites that returned a statistically significant Seasonal Kendall test.

Note that I have assumed that the laboratory methods have not changed significantly during the period of record, so assume that observed trends are 'real' rather than possible artifacts of changes in method and/or detection limit (Stansfield 2001).

4 Results

4.1 Water quality state

4.1.1 Suspended sediments

The variables turbidity, visual clarity and total suspended solids all provide a similar picture of suspended sediment levels across the 27 sites (Fig. 2). Water clarity was highest at the more open coastal sites (e.g., Mahurangi Harbour @ Heads, Goat island and Ti Point). Kaipara Harbour @ Shelly Beach had the lowest clarity, and highest turbidity and TSS). Sites in Manukau Harbour (especially Mangere & Puketutu) tended to have lower clarity than other harbour sites. Note that these measures reflect the presence of both organic and inorganic particles in the water. Organic particles will include both living (e.g., phytoplankton) and detrital material.

4.1.2 Nitrogen

Three Manukau Harbour sites (Mangere Bridge, Puketutu Point and Shag Point) were heavily enriched in N compared with other sites (Fig. 3). This was particularly strong for NO_2-N (nitrite) and NH_4-N (ammoniacal nitrogen), both of which are indicators of the presence of wastewater discharges. Nitrite levels (NO_2-N) were also elevated at the three other Manukau sites. Of the other monitoring sites, Mahurangi @ Town Basin also shows elevated concentrations of all three nirogen species.

4.1.3 Phosphorus

Both SRP and TP showed marked elevations at Mangere Bridge, Puketutu Point and Shag Point (Fig. 4), whereas phosphorus concentrations tended to be lowest at open coastal sites (e.g., Goat Island, Ti Point, Orewa). Apart from the Manukau Harbour sites closest to Mangere Wastewater Treatment Plant, TP was highest at the Kaipara @ Shelly Beach site, probably reflecting the elevated suspended sediments levels at this site (Fig. 2).

4.1.4 Faecal indicator bacteria

Levels of Enterococci and faecal coliforms gave similar patterns across the monitoring network (Fig. 5). Highest median concentrations were observed at Mahurangi @ Town Basin. Levels at some sites in the Upper Waitemata Harbour (e.g., Brighams, Rawawaru and Rangitopuni Creeks) were also elevated. Open coastal sites had the lowest levels of faecal indicator bacteria. It is interesting to note that the Manukau Harbour sites were not in the top 5 with respect to faecal indicator bacteria levels.

4.1.5 Chlorophyll *a*, temperature and dissolved oxygen

Chlorophyll *a* concentrations tended to be lowest at open coastal zones (e.g., Ti Point) and highest in inner harbour sites (e.g., Kaipara @ Shelly Beach). Temperature showed the greatest range in the sites of the Upper Waitemata Harbour, but overall temperature did not vary greatly between sampling sites. Mahurangi @ Town Basin had the greatest range in dissolved oxygen. Manukau Harbour sites had the highest maximum DO levels, with extremes of almost 180% saturation.

4.1.6 Salinity and pH

Salinity was very stable at open coastal sites, but tended to be lower and highly variable at sites at the heads of Waitemata (e.g., Rangitopuni Creek) and Mahurangi harbours (Mahurangi @ Town Basin). Patterns in pH mirrored those of salinity. These patterns reflect mixing with freshwaters at the head of these harbours. Therefore, values of salinity and/or pH may provide useful indicators of the position of monitoring sites relative to anthropogenic contaminants delivered by the region's streams and rivers.

Figure 2:

Box and whiskers plots for all suspended sediment related variables across 27 saline monitoring sites. See Table 1 for data range.

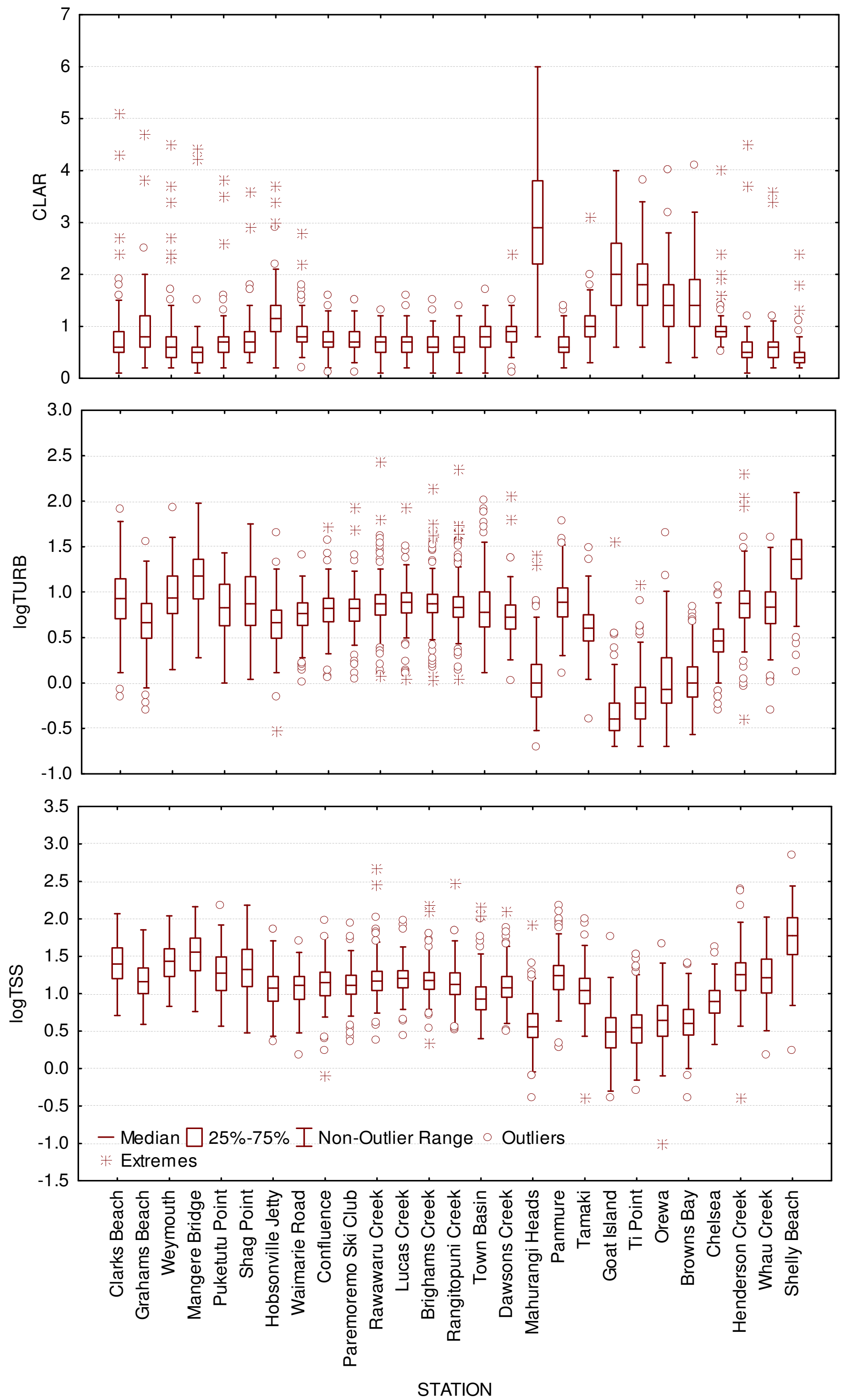


Figure 3:

Box and whiskers plots for nitrogen species across 27 saline monitoring sites. See Table 1 for data range.

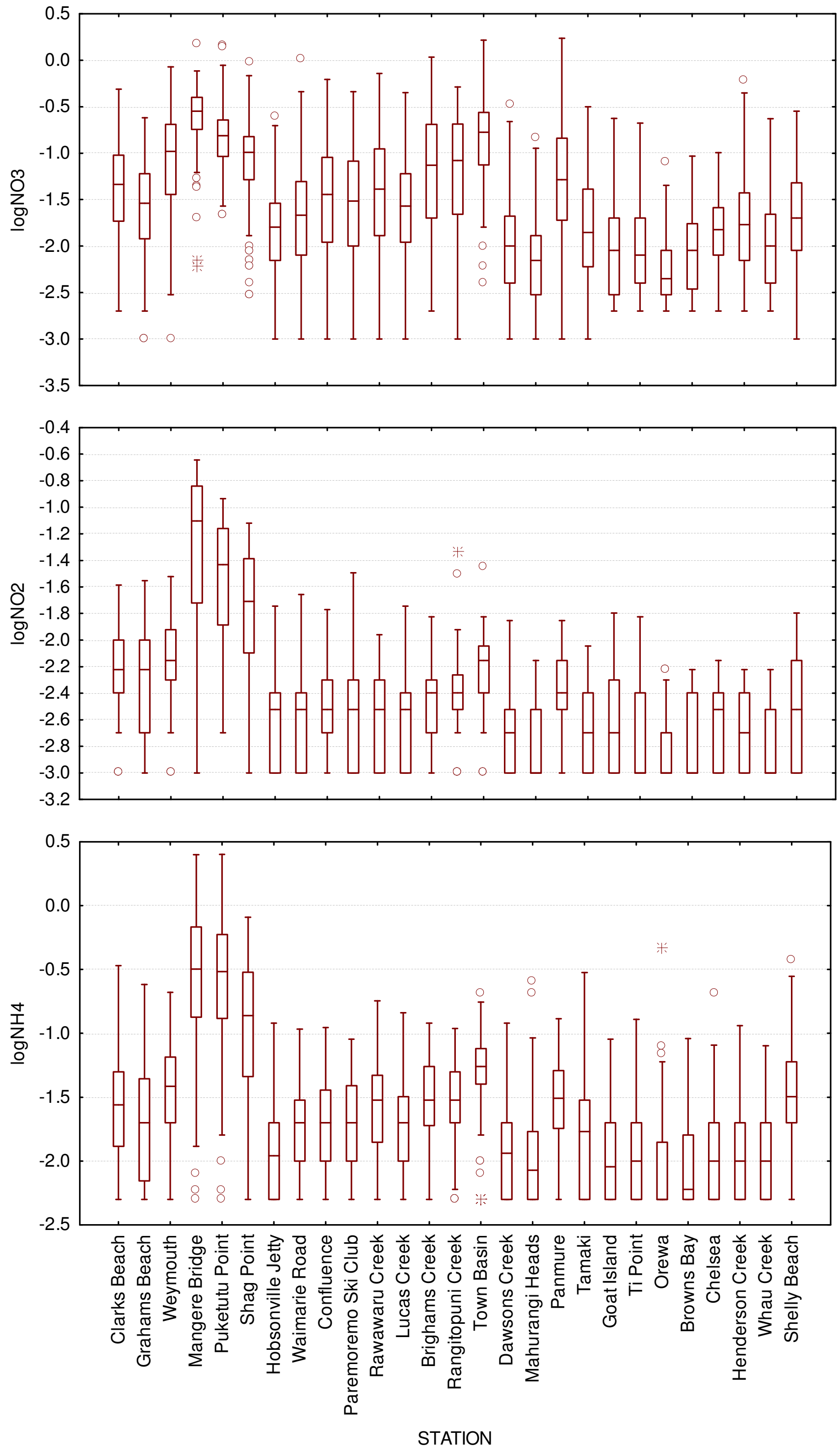


Figure 4:

Box and whiskers plots for phosphorus species across 27 saline monitoring sites. See Table 1 for data range.

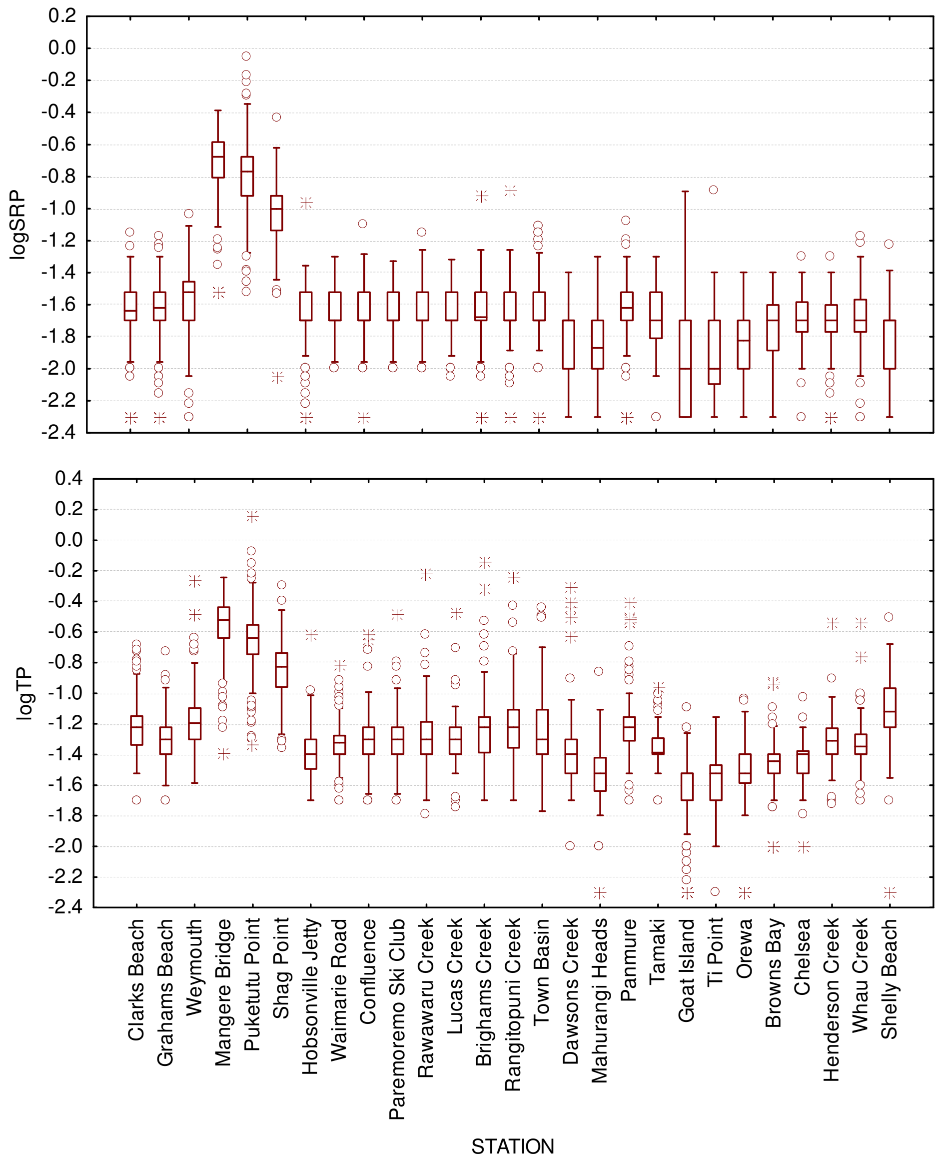


Figure 5:

Box and whiskers plots for faecal indicator bacteria (ENT = Enterococci; FC = Faecal coliforms) across 27 saline monitoring sites. See Table 1 for data range.

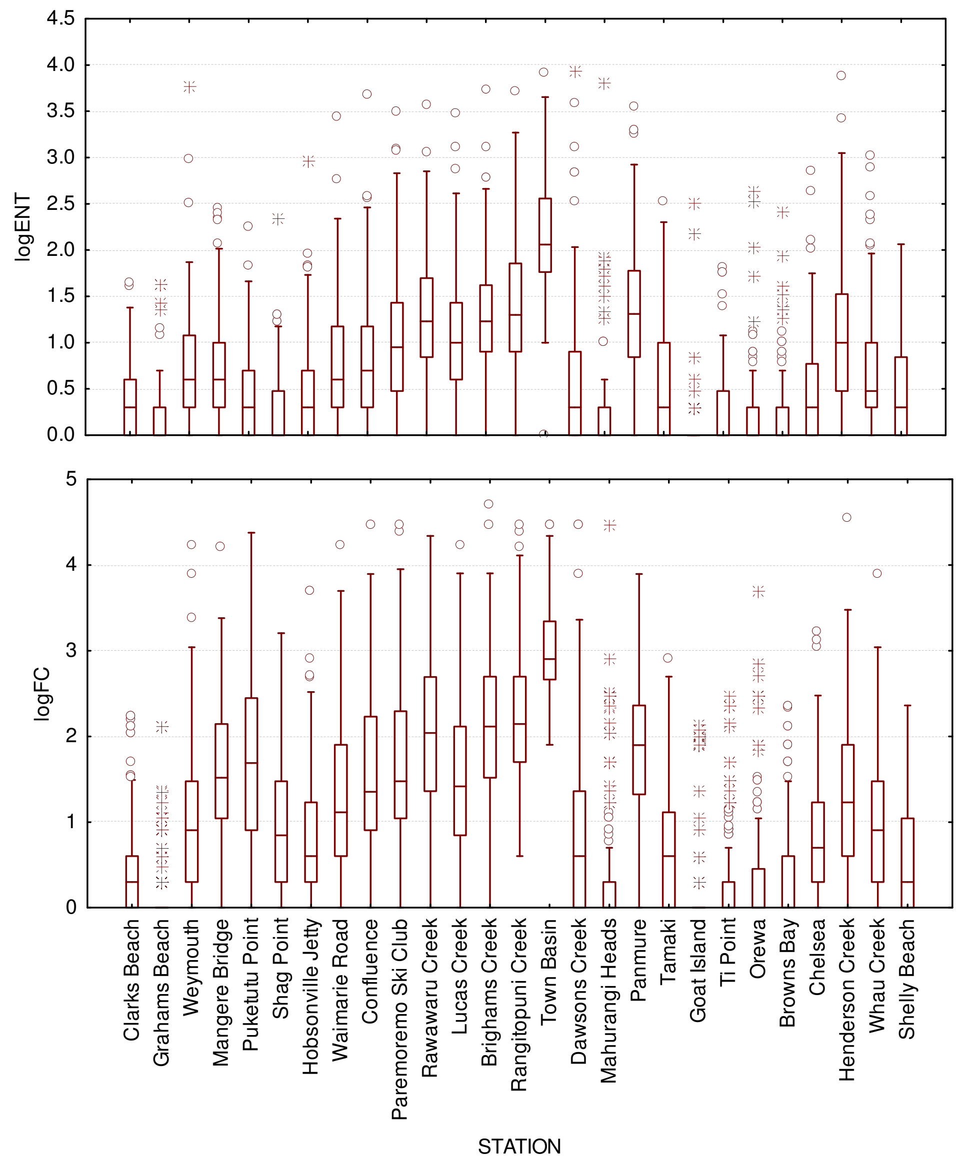


Figure 6:

Box and whiskers plots for chlorophyll *a*, temperature and dissolved oxygen (DO%) across 27 saline monitoring sites. See Table 1 for data range.

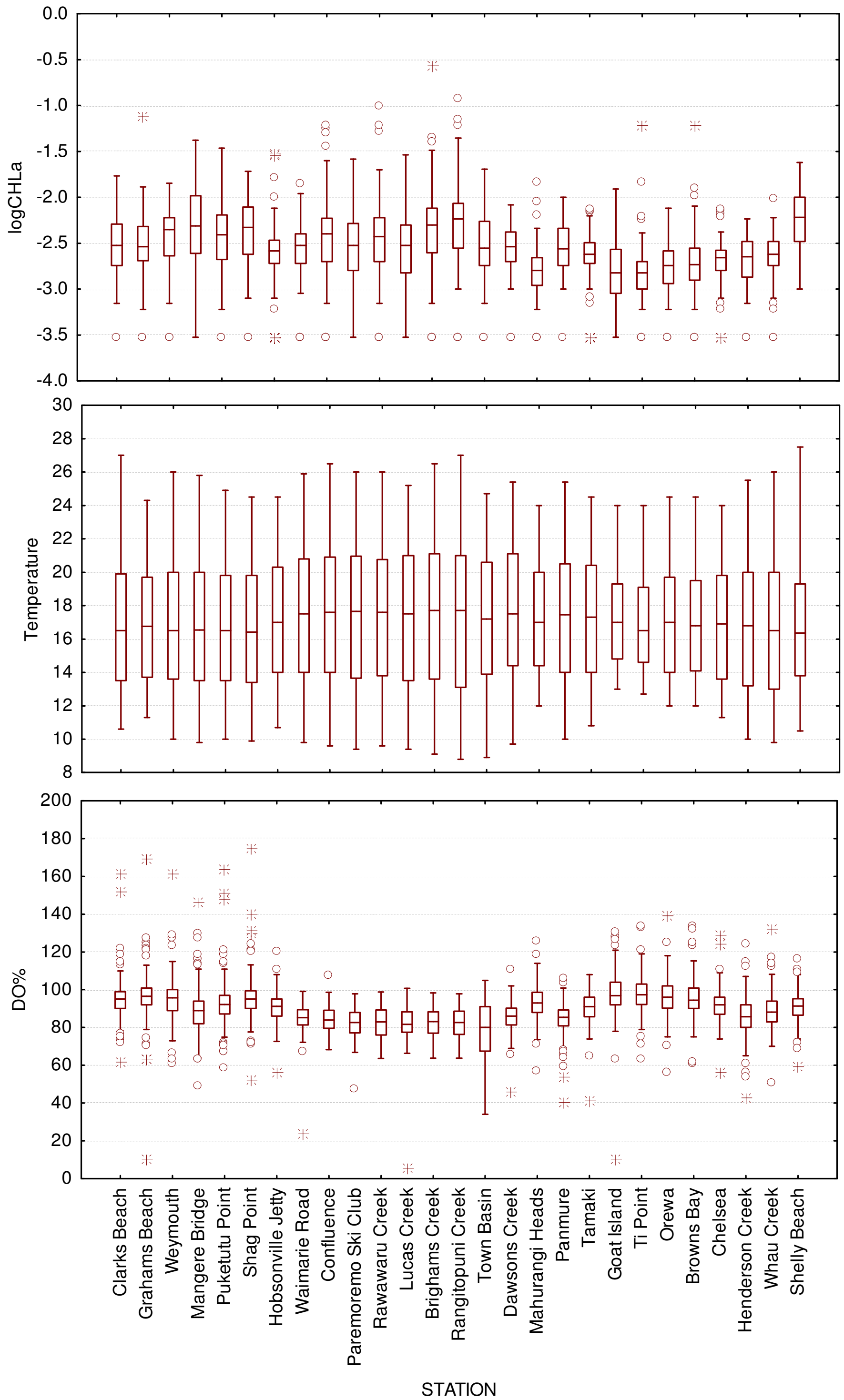
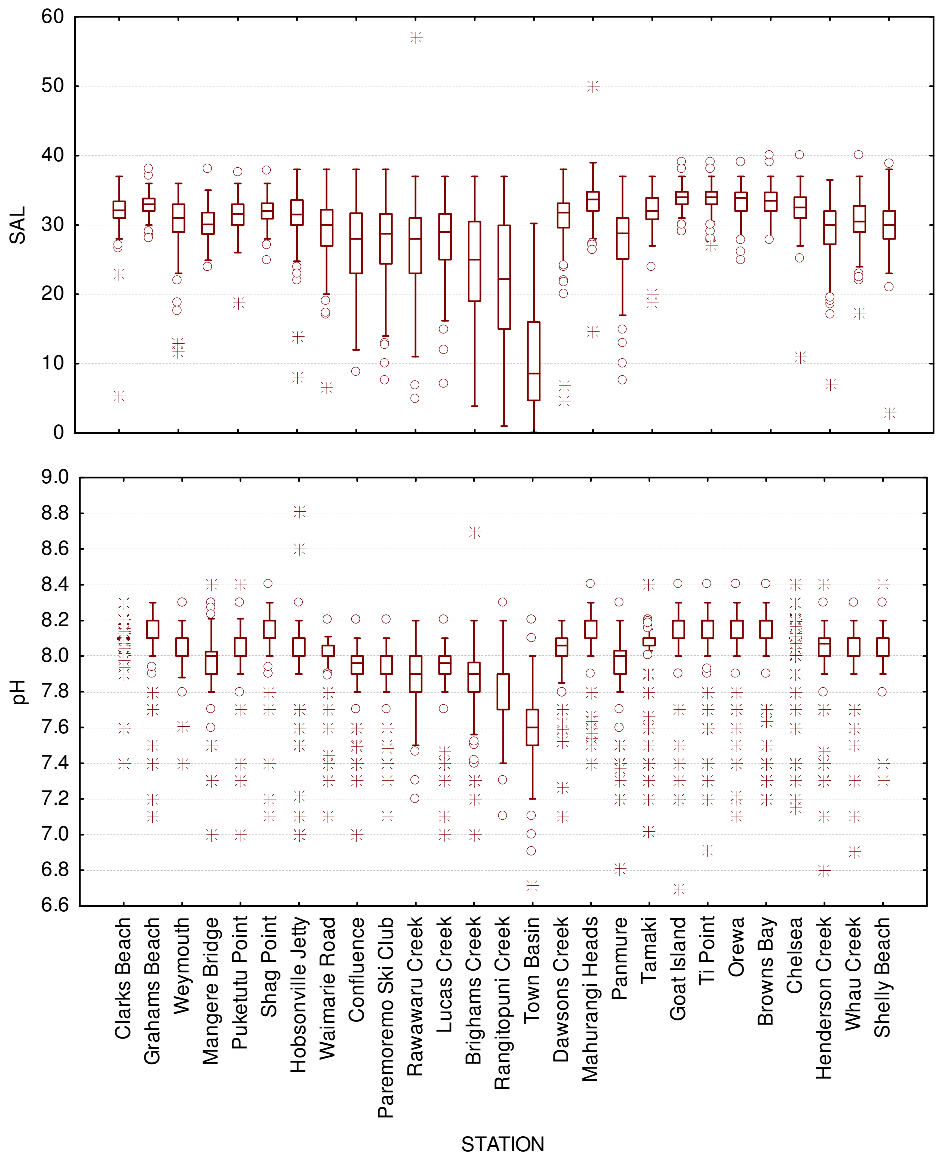


Figure 7:

Box and whiskers plots for salinity and pH across 27 saline monitoring sites. See Table 1 for data range.



4.1.7 Correlations between variables

There was a high degree of inter-correlation among the 15 water quality variables included in ARC's saline water quality moniroring programme (Table 3). Conductivity, chloride and BOD_5 data were excluded due to large gaps in the dataset for these variables.

Median values for turbidity, clarity, total suspended solids and total P were all very strongly correlated ($r_S > 0.80$). Total P was also very strongly correlated (positively) with values for nitrate and nitrite-N, ammoniacal-N, soluble reactive P and Chlorophyll *a*. There were also strong (negative) correlations between values for salinity, pH and %DO and values for faecal indicator bacteria. Given that values of salinity and pH appear to reflect the influence of freshwater and position in the cathment (Fig. 7), this latter correlation suggests that levels of faecal indicator bacteria tend to decrease with distance from freshwater sources.

The high level of inter-correlation suggests a certain level of redundancy in the suite of variables sampled in the saline monitoring programme, especially those directly related to suspended sediment.

Table 3:

Spearman rank correlation matrix for median values of 15 water quality variables measured at 27 sites. The strongest correlations (i.e., $r_s > 0.8$) are highlighted in bold italics.

	SAL	TURB	CLAR	TEMP	pH	TSS	NO3	NO2	NH4	DO%	TP	SRP	FAEC	ENT	CHLa
TURB	-0.59	1.00													
CLAR	0.63	-0.93	1.00												
TEMP	-0.54	-0.15	0.12	1.00											
pH	0.93	-0.51	0.53	-0.64	1.00										
TSS	-0.42	0.94	-0.90	-0.34	-0.34	1.00									
NO3	-0.64	0.69	-0.65	0.04	-0.65	0.67	1.00								
NO2	-0.41	0.60	-0.53	-0.11	-0.47	0.64	0.94	1.00							
NH4	-0.57	0.73	-0.65	-0.08	-0.57	0.73	0.94	0.90	1.00						
DO%	0.90	-0.37	0.39	-0.71	0.90	-0.15	-0.39	-0.16	-0.31	1.00					
TP	-0.55	0.85	-0.82	-0.16	-0.50	0.88	0.90	0.87	0.93	-0.26	1.00				
SRP	-0.27	0.67	-0.62	-0.26	-0.31	0.78	0.80	0.84	0.77	-0.05	0.84	1.00			
FAEC	-0.89	0.55	-0.58	0.47	-0.89	0.41	0.76	0.56	0.66	-0.81	0.61	0.42	1.00		
ENT	-0.94	0.57	-0.61	0.56	-0.91	0.36	0.60	0.37	0.49	-0.88	0.46	0.25	0.91	1.00	
CHLa	-0.64	0.75	-0.72	0.09	-0.61	0.74	0.78	0.72	0.83	-0.40	0.88	0.65	0.59	0.47	1.00

4.2 Water quality ranking by site

Six water quality variables were chosen to form the basis of a simple water quality index calculated from a ranking of long-term (i.e, full data range of monthly values) medians at each site (Table 4). These six variables were chosen because they had the fewest gaps in the data record and they are known to reflect anthropogenic pressures. Goat Island was not included due to large gaps in the data set. Median values for each variable at each site were calculated based on all available monthly data. Sites were ranked for each variable and given an overall average rank across all six variables.

Open coastal sites (Ti Point, Mahurangi @ Heads, Orewa and Brown's Bay) had the highest average rank, reflecting a high degree of flushing and distance from freshwater inputs of contaminants (Fig. 8). In contrast, sites in the Upper Waitemata Harbour, inner Manukau and upper Tamaki were worst.

Figure 9 shows the relationship between median salinity and the average water quality ranking. There is a strong positive association between the two, supporting the hypothesis that the greater the contribution of freshwaters at a site (i.e., reduced salinity) the lower the overall water quality. The six Manukau Harbour sites greatly increase the scatter in the data, and when removed the relationship is very much stronger (R^2 = 0.93). This suggests that the impact of a large point source discharge (Mangere Wastewater Treatment Plant) overwhelms the underlying relationship between water quality and interactions with freshwater catchments.

Table 4:

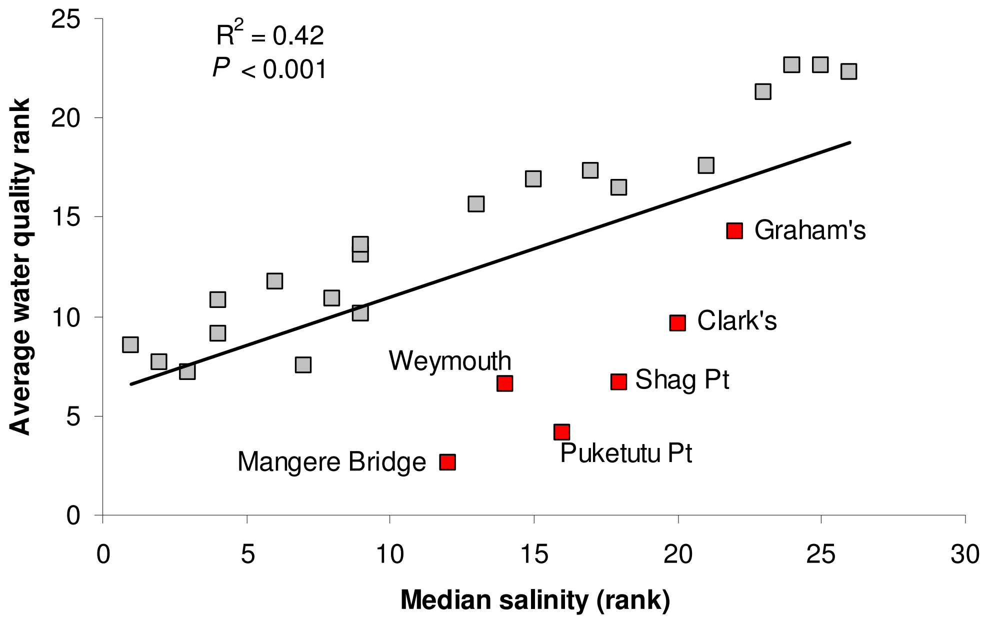
Median values (monthly data for full data range) for a selection of water quality variables. Sites are ordered by average rank across these variables with high values indicating relatively good water quality and low values reflecting poorer water quality. Goat Island was excluded in the analysis. The categorical WQ ranking relates to Fig. 8, and reflects arbitrary cut-off values between categories.

Site	TSS	NO3-N	NH4-N	TP	SRP	FC	Average rank	WQ ranking
Mahurangi Heads	3.6	0.007	0.0085	0.03	0.0135	1	22.6	Very good
Orewa	4.4	0.0045	0.005	0.03	0.015	1	22.6	Very good
Ti Point	3.5	0.008	0.01	0.03	0.01	1	22.3	Very good
Browns Bay	4	0.009	0.006	0.036	0.02	1	21.3	Very good
Chelsea	7.9	0.015	0.01	0.04	0.02	5	17.6	Good
Dawsons Creek	12	0.01	0.0115	0.04	0.02	4	17.3	Good
Hobsonville Jetty	11.9	0.016	0.011	0.04	0.02	4	16.9	Good
Tamaki	11	0.014	0.017	0.041	0.02	4	16.5	Good
Whau Creek	16.4	0.01	0.01	0.045	0.02	8	15.6	Good
Grahams Beach	14.5	0.029	0.02	0.05	0.024	1	14.3	Good
Waimarie Road	13	0.0215	0.02	0.0475	0.02	13	13.6	Good
Henderson Creek	18	0.017	0.01	0.049	0.02	17	13.1	Good
Paremoremo Ski Club	13	0.0305	0.02	0.05	0.02	30	11.8	Fair
Lucas Creek	16	0.027	0.02	0.05	0.02	26	10.9	Fair
Confluence	14.1	0.036	0.02	0.05	0.02	22.5	10.8	Fair
Shelly Beach	59.7	0.02	0.032	0.076	0.02	2	10.1	Fair
Clarks Beach	25	0.046	0.0275	0.06	0.023	2	9.6	Fair
Rawawaru Creek	14.7	0.041	0.03	0.05	0.02	110	9.1	Fair
Town Basin	8.45	0.1675	0.055	0.05	0.02	800	8.6	Fair
Rangitopuni Creek	13.3	0.083	0.03	0.06	0.02	140	7.7	Poor
Panmure	17.5	0.052	0.031	0.06	0.024	79	7.5	Poor
Brighams Creek	15	0.074	0.03	0.06	0.021	130	7.1	Poor
Shag Point	21.05	0.102	0.1375	0.1495	0.0995	7	6.6	Poor
Weymouth	27	0.104	0.0385	0.064	0.03	8	6.6	Poor
Puketutu Point	18.8	0.154	0.305	0.23	0.17	49	4.2	Poor
Mangere Bridge	36	0.282	0.318	0.3005	0.21	33	2.7	Poor

Figure 8:
Water quality rank for 26 saline monitoring sites (Goat Island site excluded due to significant gaps in data record). Refer to Table 4 for details of site rankings.

Figure 9:

Relationship between median salinity (rank transformed) and average water quality rank at 26 ARC saline monitoring sites. Manukau Harbour sites are labelled.



4.3 Water quality and shellfish gathering guidelines

Important note: The analyses summarised below provide information on levels of faecal coliform bacteria in relation to shellfish gathering guidelines. These levels are reported solely as a comparative measure of water quality between sites, and changes over time. The information reported herein is NOT sufficient to determine whether a particular site is deemed "safe" for shellfish gathering.

The MfE (2003) microbiological guidelines for recreational shellfish gathering use the numbers of faecal coliform bacteria as an indicator to denote the potential presence of pathogenic bacteria, viruses and protozoa. Shellfish gathering is deemed safe with respect to pathogenic bacteria, viruses and protozoa (but not biotoxins or heavy metals) when "the median faecal coliform content of samples taken over a shellfish-gathering season shall not exceed a Most Probable Number (MPN) of 14/100 mL, and not more than 10% of samples should exceed an MPN of 43/100 mL".

For the purposes of this report all monthly faecal coliform bacteria data for 26 ARC monitoring sites (Goat Island excluded) were used. The number of years between 1994 and 2006 where faecal coliform levels exceeded guideline values were calculated for each site (Fig. 10).

Most Upper Waitemata Harbour sites, along with Mahurangi at Town Basin, Tamaki @ Panmure, Manukau @ Mangere Bridge and Manukau @ Puketutu Point all exceeded the shellfish gathering guidelines in most years between 1994 and 2006. In contrast, coastal and outer harbour sites (e.g., Manukau Harbour at Clark's and Graham's beaches) had few or no exceedences.

There was a strong relationship between median salinity and the number of exceedences at a site (Fig. 11), reflecting the proximity to sources of contaminants. Note that Manukau Harbour sites were not outliers in this relationship, suggesting that the Mangere Wastewater Treatment Plant does not act as an over-whelming source of faecal coliform bacteria. This may be due to major upgrades in wastewater treatment at the Mangere Plant.

Figure 12 shows that there have been dramatic reductions in levels of faecal coliform bacteria at the three Manukau Harbour sites closest to the Mangere Wastewater Treatment Plant over the period 1987-2007. Puketutu Point and Mangere Bridge now meet shellfish gathering guidelines in some years, while Shag Point now meets shellfish gathering guidelines in most years.

Note that these results are for the purposes of highlighting differences between sites and changes over time and should not be used as a definitive guide to the designation of sites as safe, or otherwise.

Figure 10:

Number of exceedences of shellfish gathering guidelines (based on median and 90th %ile values; MfE 2003) over a 13-year period (1994-2006).

Figure 11:
Relationship between number of exceedences between 1994-2006 and median salinity (rank-transformed).

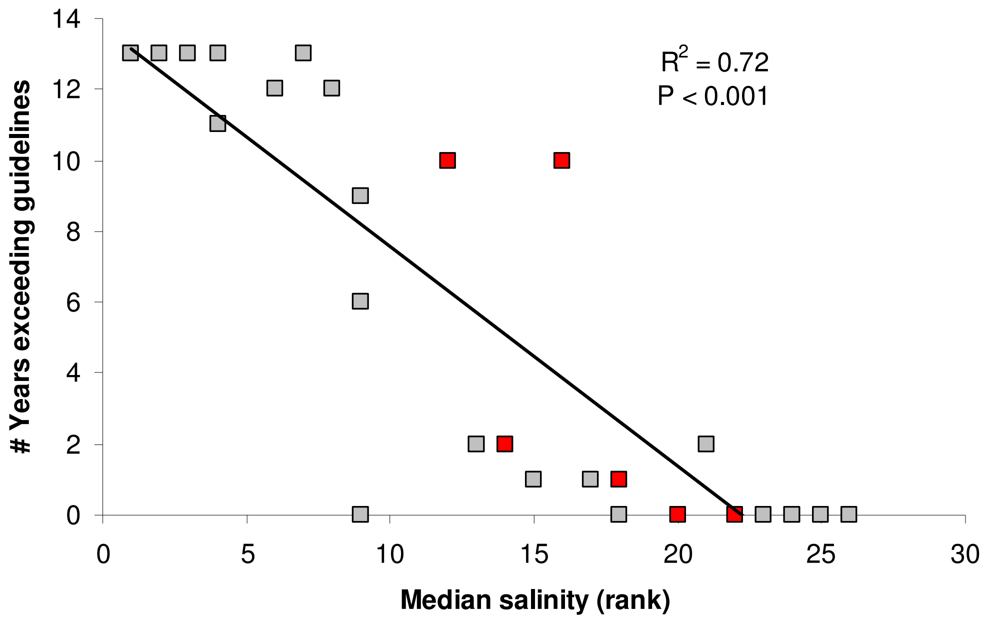
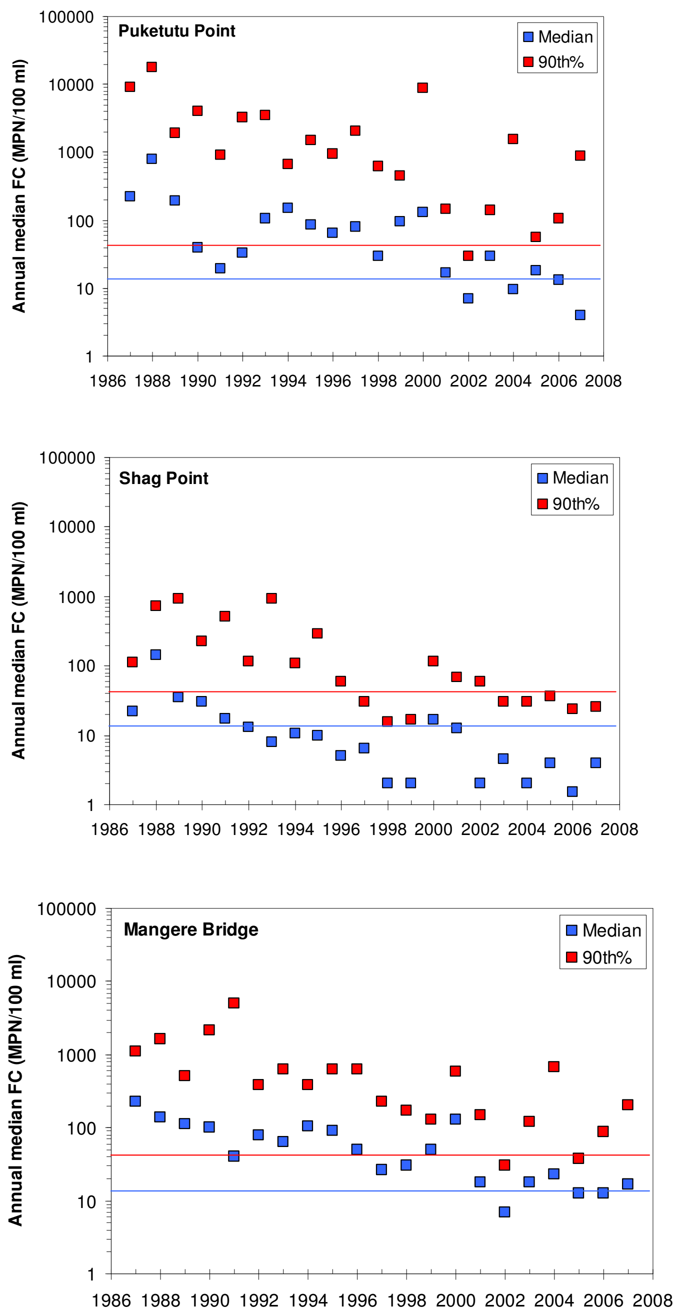


Figure 12:

Changes in faecal coliform numbers over time at Puketutu Point, Shag Point and Mangere bridge sites in Manukau Harbour. Red line is the guideline value (MfE 2003) relating to the 90th %ile (i.e., no more than 10% of samples in any one year/season shall exceed 43 MPN/100 ml). Blue line is the guideline value (MfE 2003) relating to the median (i.e., median of samples in any one year/season shall be less than 14 MPN/100 ml).



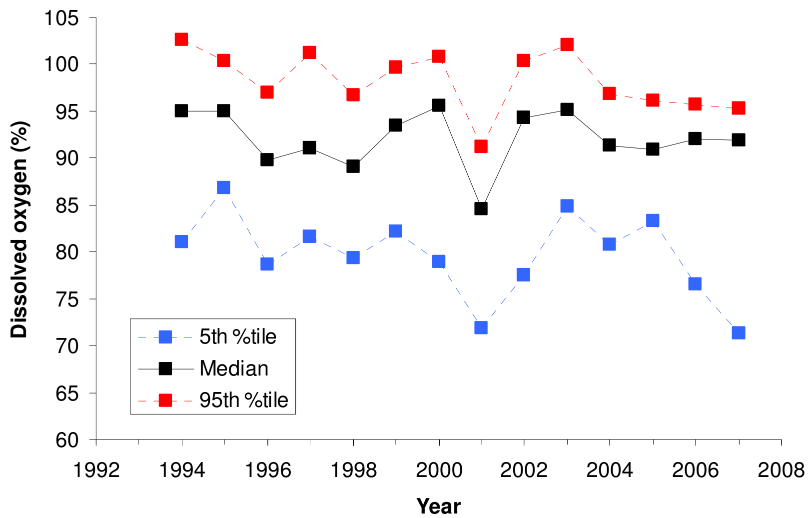
4.4 Regional-scale water quality state over time (1993-2007)

Figure 13 (a-k) provides a regional-scale summary of annual median water quality state over the 14-year period from July 1993 – June 2007. Note that each annual period starts in July and ends in June (i.e., financial year) and is designated as "the year ending".

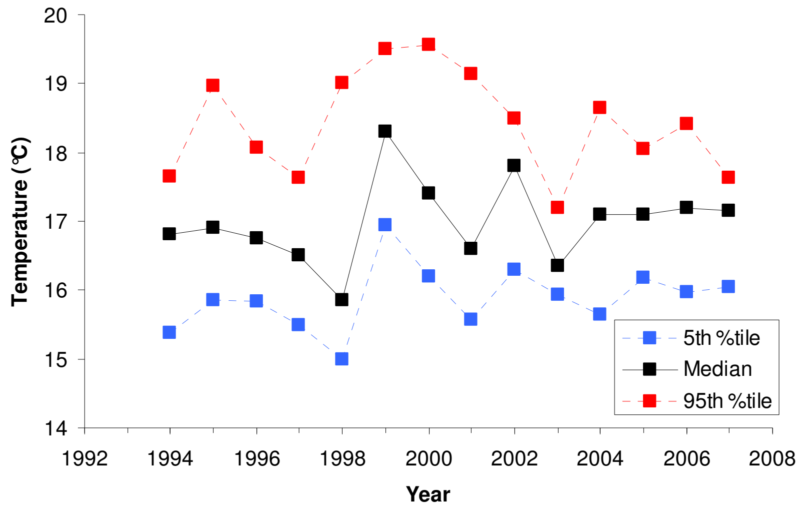
Figure 13:

Regional-scale summary for water quality variables over the period 1993-2007. Each figure summarises annual median data from all 27 sites by showing the 5th, median and 95th percentile values over time.

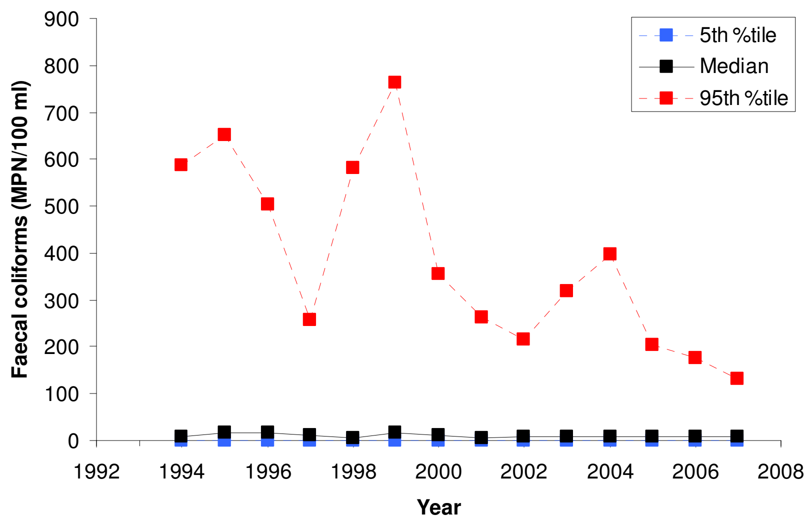
a) Dissolved oxygen (%)



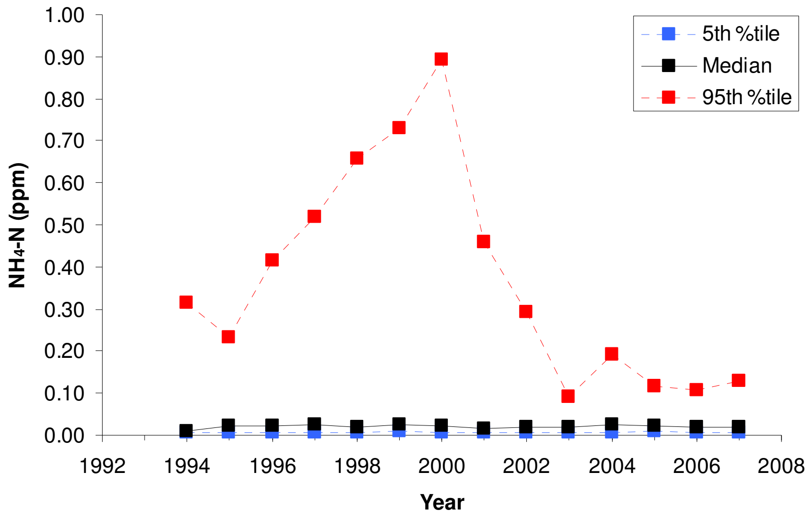
b) Temperature (°C)



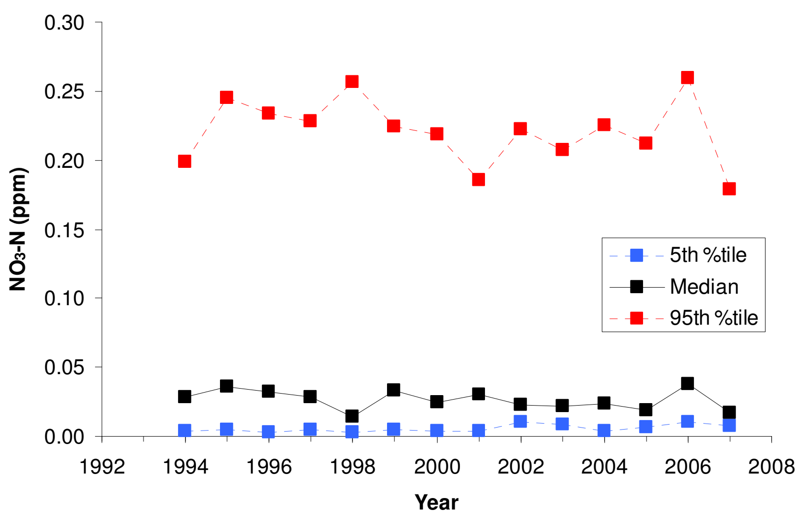
c) Faecal coliforms (MPN/100 ml)



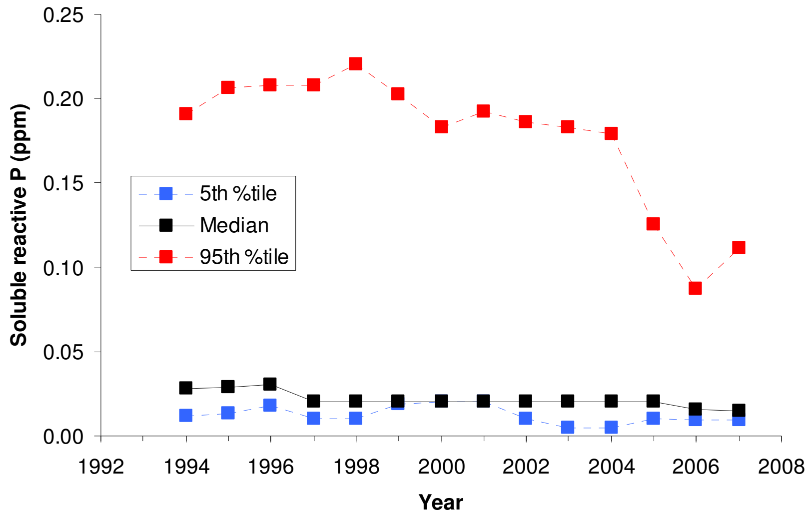
d) Ammoniacal nitrogen (mg L⁻¹)



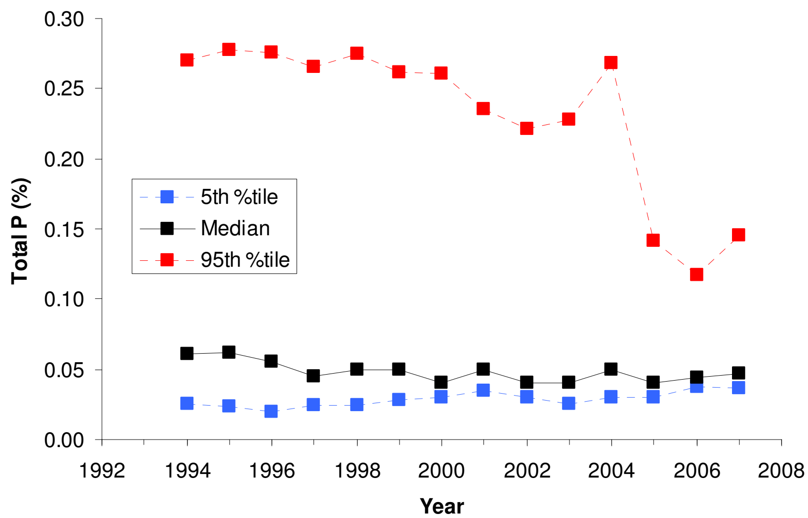
e) Nitrate nitrogen (mg L⁻¹)



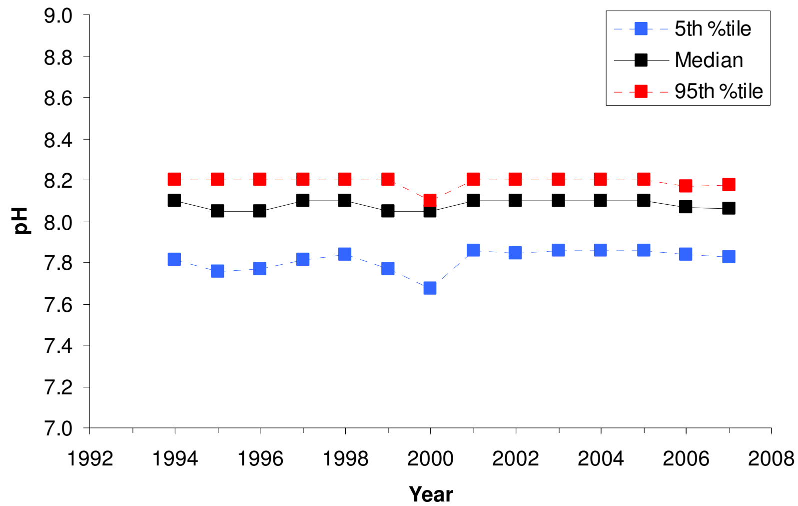
f) Soluble reactive phosphorus (mg L^{-1})



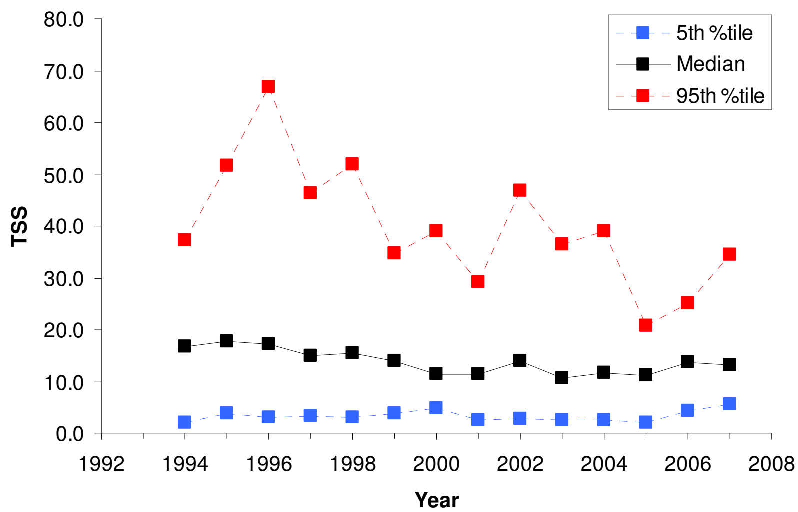
g) Total phosphorus (mg L^{-1})



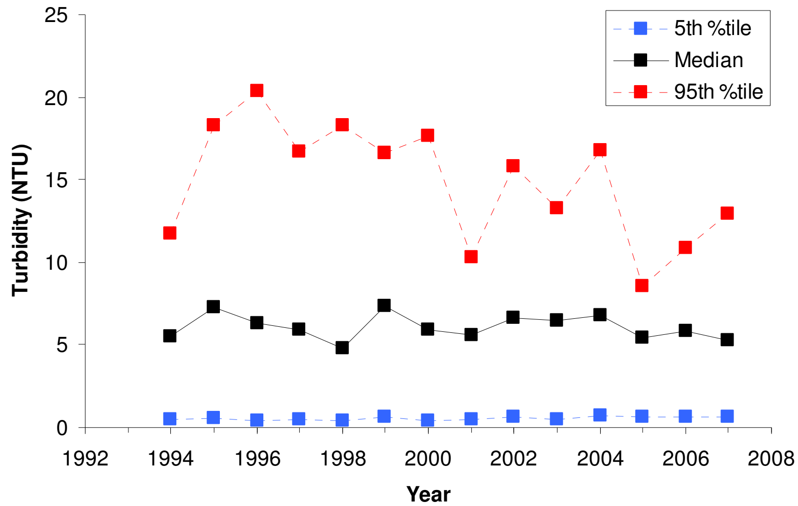
h) pH



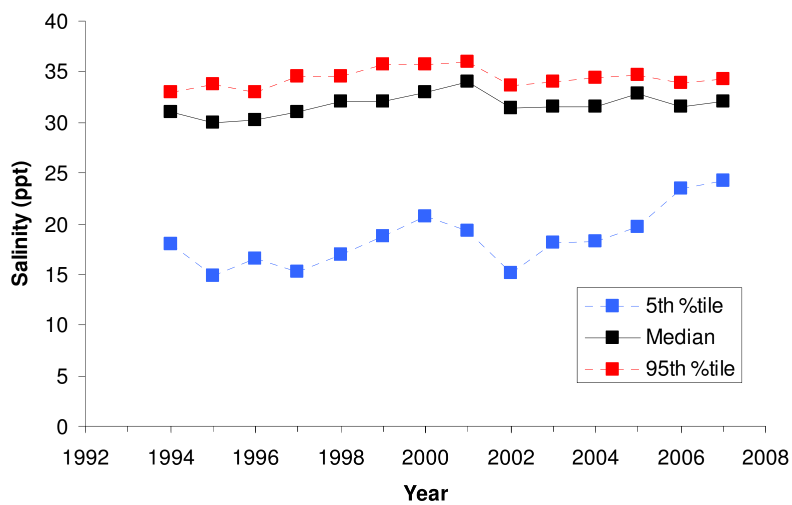
i) Total suspended sediments (mg L-1)



j) Turbidity (NTU)



k) Salinity (ppt)



Changes over time in regional-scale summary statistics (Fig. 13 a-k) were analysed using Spearman rank correlation (Table 5).

Increases over time in the 5th %ile for NO_3-N, total P and turbidity (Table 5) should be of concern to resource managers, as these changes indicate that some of the "best sites" in the region may be experiencing deteriorating water quality. Trends in salinity, pH and temperature also showed increases over time, but these changes may reflect climatic variability. Significant changes for the regional-scale median included decreases in phospohorus and suspended sediments, both consistent with improving water quality. The 95th %ile showed significant changes that are consistent with decreased anthropogenic pressures and improving water quality. For example, reductions in faecal coliforms, NH_4-N, SRP, TP, TSS and turbidity are all consistent with greater sediment controls and point source discharge management.

Table 5:

Trends (Spearman rank correlation coefficients) in regional summary data over the period 1993-2007 (based on financial year). '*' = $P < 0.05$; '**' = $P < 0.01$; '***' = $P < 0.001$.

	5th %ile	Median	95th %ile
NH_4-N	0.358	-0.194	-0.591**
Dissolved oxygen	-0.376	-0.079	-0.56*
Faecal coliforms	NA	-0.331	-0.771***
NO_3-N	0.653***	-0.358	-0.257
pH	0.588***	0.175	-0.45*
Salinity	0.705***	0.53*	0.253
Soluble reactive P	-0.581**	-0.838***	-0.845***
Temperature	0.459*	0.352	-0.183
Total P	0.799***	-0.645***	-0.851***
Total suspended solids	0.143	-0.752***	-0.666***
Turbidity	0.537**	-0.209	-0.541**

4.5 Long-term water quality trends in Manukau Harbour (1987-2007)

Water quality parameters that reflect suspended sediment concentrations (i.e., TSS, Turbidity and TP) all showed significant decreasing trends in Manukau Harbour over the entire period of record. Sites closest to the Mangere Wastewater Treatment Plant (i.e., Puketutu Point, Mangere Bridge and Shag Point) also showed significant decreases in faecal coliforms and NH_4-N concentrations.

NO_3-N concentrations showed increasing trends at Puketutu Point & Weymouth, but decreased at Graham's Beach and Shag Point. Soluble reactive P showed decreasing trends at Clark's, Graham's, Mangere Bridge and Shag Point.

Table 6:

Relative Sen Slope Estimates (RSSE; % of raw data median per annum) for nine water quality paramteres at six Manukau Harbour sites (1987-2007). Values given in bold italics are statistically significant ($P < 0.05$).

Site	TSS	TURB	CHL*a*	NO_3-N	NH_4-N	SRP	TP	TEMP	FC
Clarks Beach	-0.032	-0.017	0.000	-0.013	0.000	-0.004	-0.023	0.000	0.000
Grahams Beach	-0.035	-0.025	0.000	-0.025	-0.025	-0.021	-0.022	0.001	0.000
Mangere Bridge	-0.039	-0.027	-0.065	-0.007	-0.058	-0.023	-0.036	-0.002	-0.108
Puketutu Point	-0.027	-0.020	-0.051	0.040	-0.041	0.001	-0.014	0.000	-0.123
Shag Point	-0.059	-0.032	-0.064	-0.016	-0.072	-0.025	-0.041	0.002	-0.083
Weymouth	-0.048	0.000	-0.043	0.013	0.013	0.000	-0.020	0.000	0.000

Figure 13:

Long-term trends in TSS at six Manukau Harbour sites. Line-of-best-fit is a LOWESS smoother with 30% span. Arrows indicate a significant decreasing trend (Seasonal Kendall test).

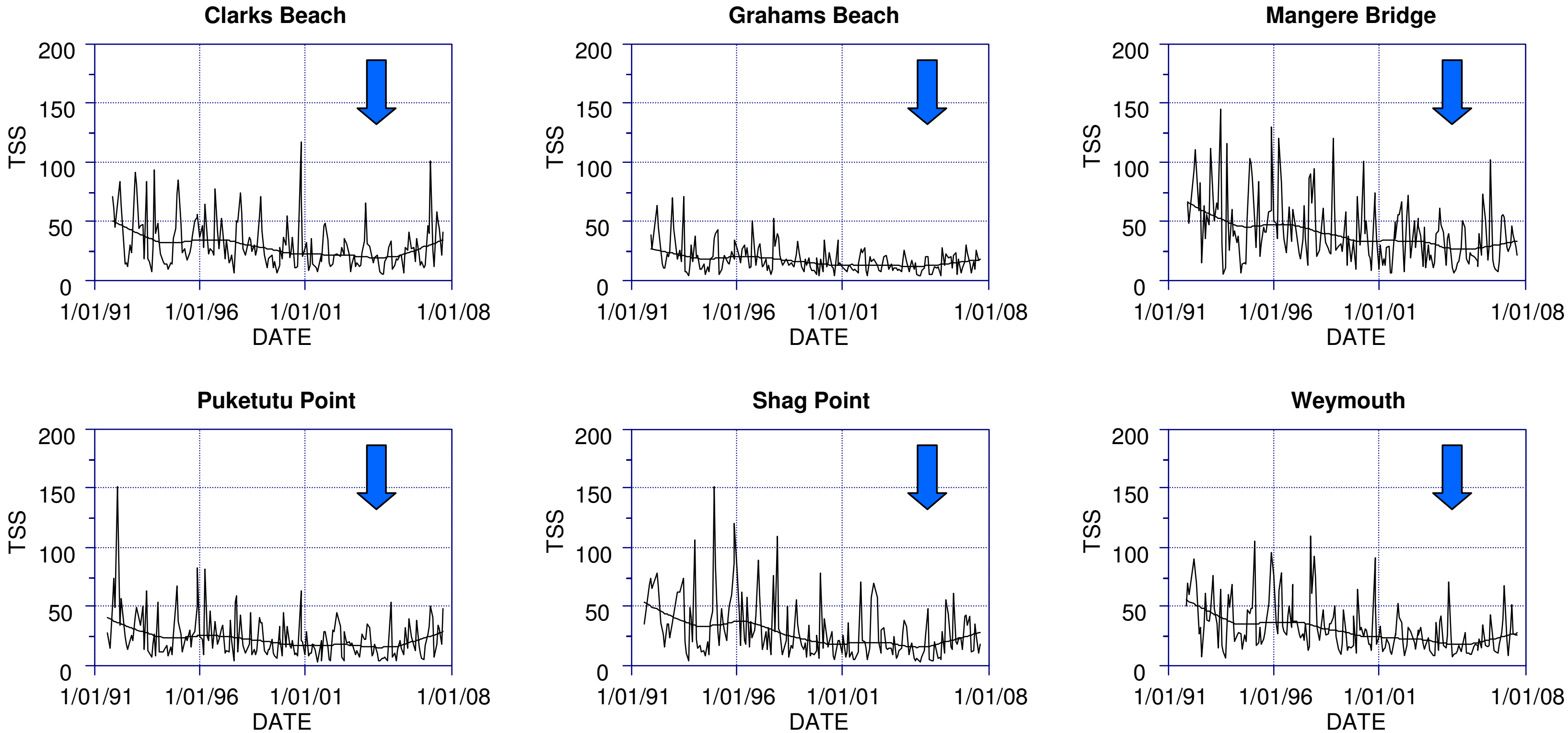


Figure 14:

Long-term trends in NO_3-N at six Manukau Harbour sites. Line-of-best-fit is a LOWESS smoother with 30% span. Arrows indicate a significant decreasing or increasing trend (Seasonal Kendall test).

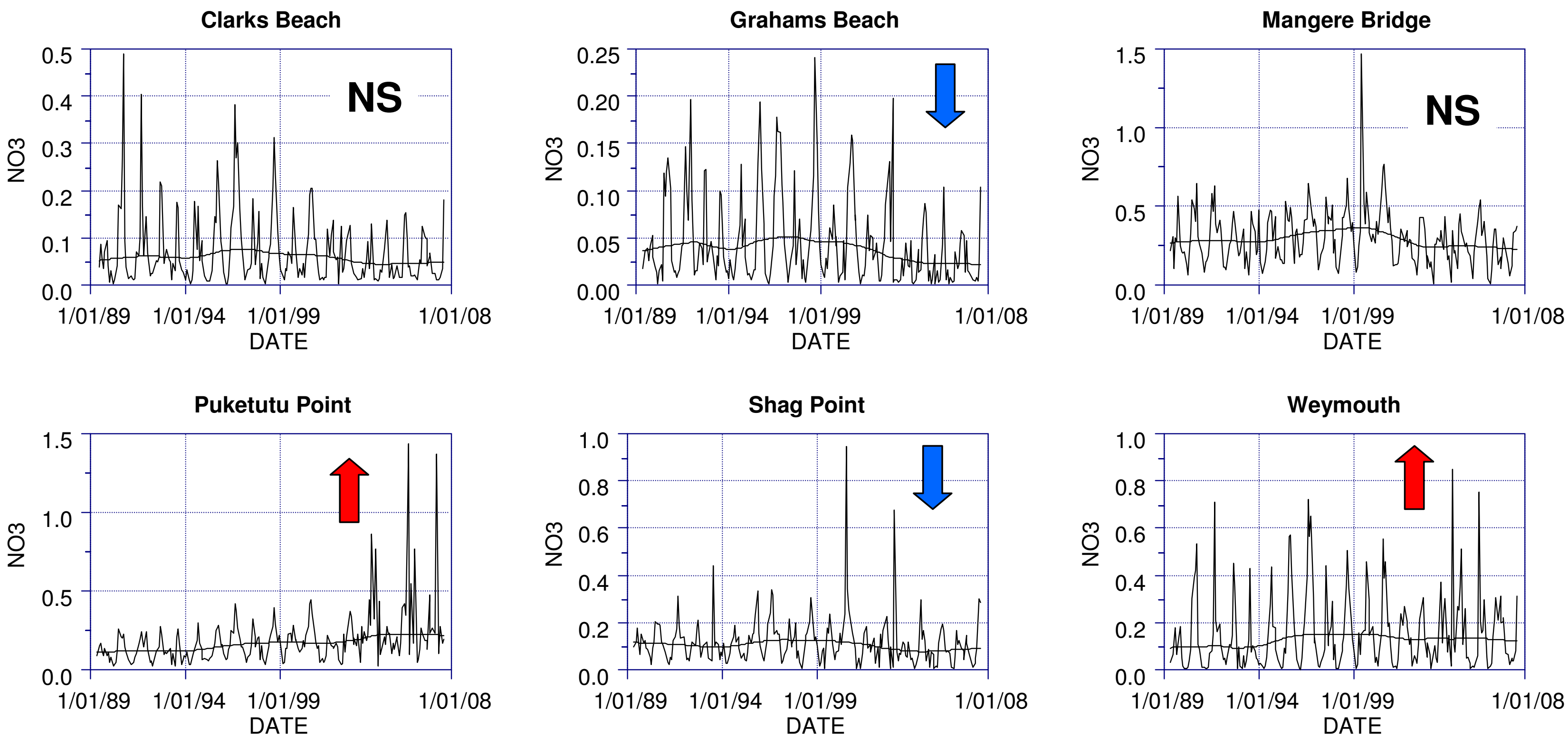


Figure 15:

Long-term trends in NH_4-N at six Manukau Harbour sites. Line-of-best-fit is a LOWESS smoother with 30% span. Arrows indicate a significant decreasing or increasing trend (Seasonal Kendall test).

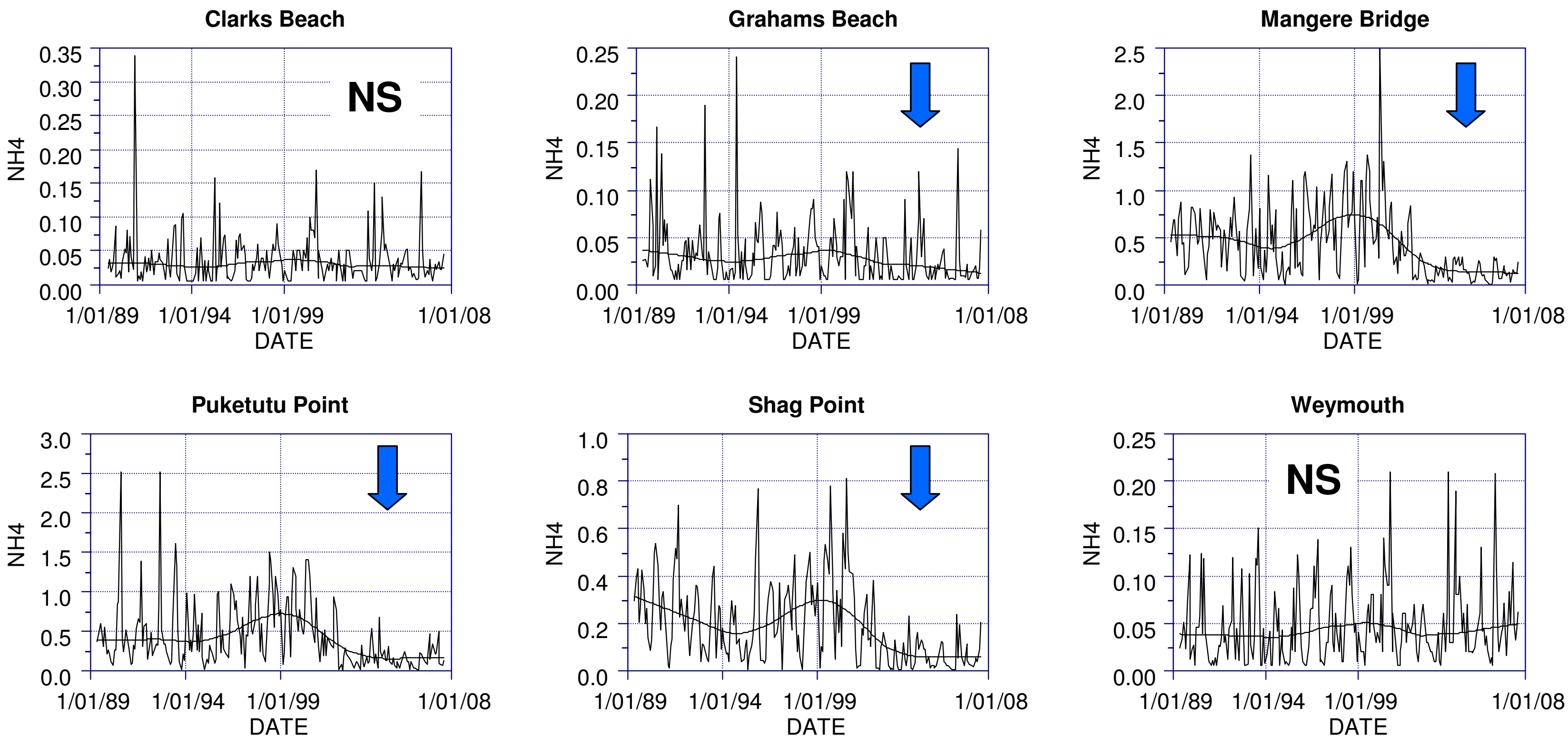
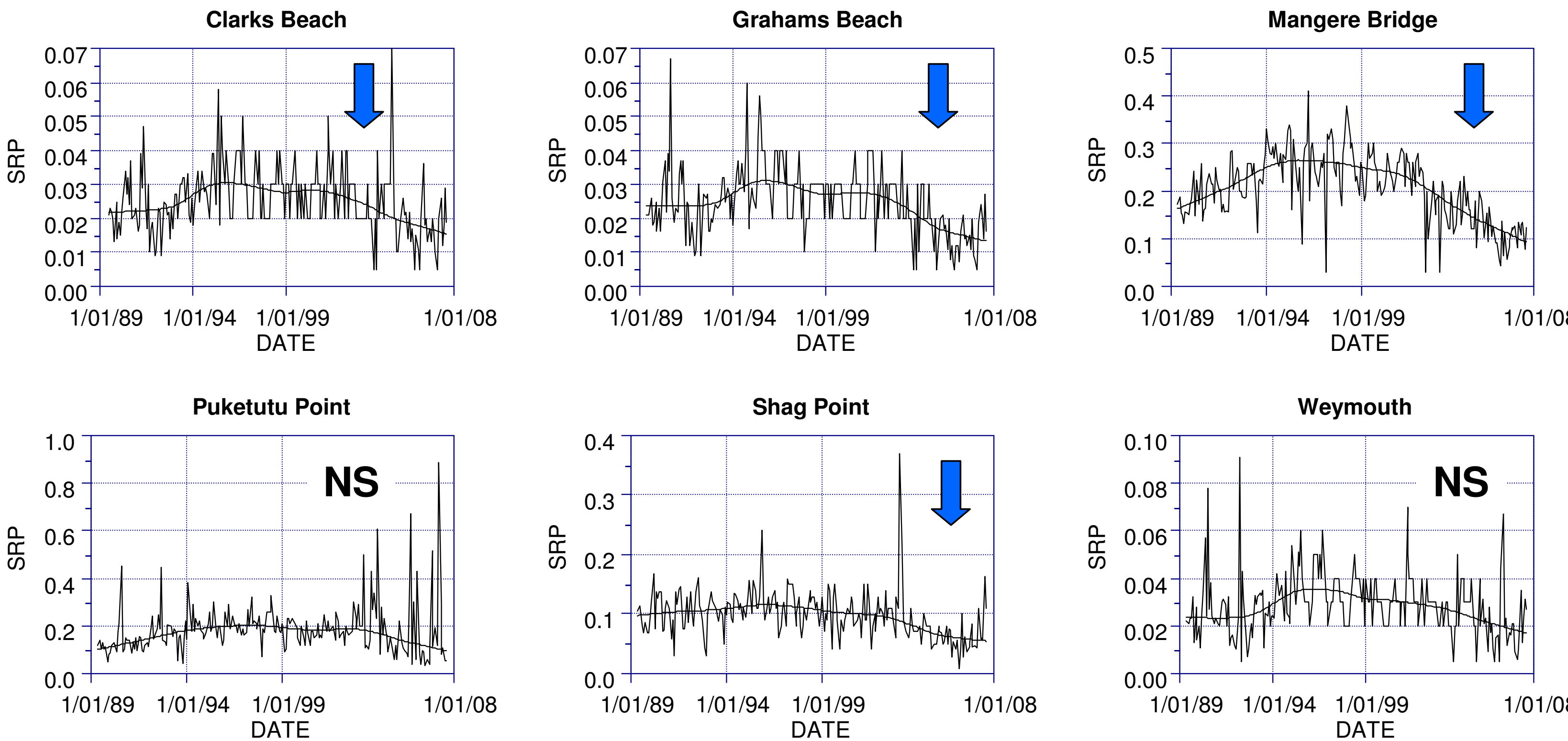


Figure 16:

Long-term trends in SRP at six Manukau Harbour sites. Line-of-best-fit is a LOWESS smoother with 30% span. Arrows indicate a significant decreasing or increasing trend (Seasonal Kendall test).



4.6 Water quality trends at 21 other saline sites

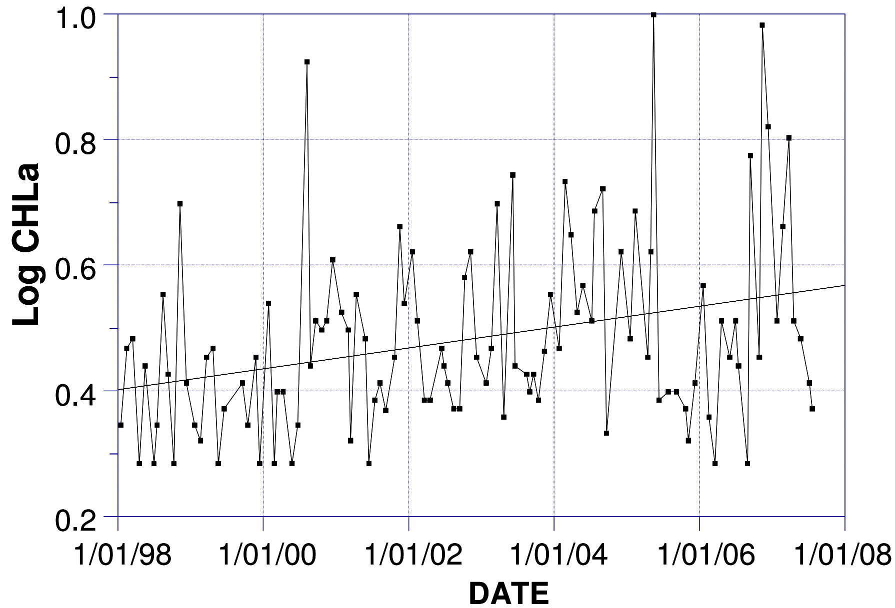
Most of the statistically significant trends observed at the 21 saline monitoring sites outside Manukau Harbour (Table 7) are indicative of improvements in water quality over the entire period of record (see Table 1 for data ranges). TSS showed significant decreasing trends at 13 sites. Concentrations of SRP and TP also decreased significantly at 19 and 14 sites, respectively. Improvements in water quality were especially apparent in the eleven Waitemata Harbour sites (Lucas Creek to Whau Creek in Table 7). Trends indicative of deteriorating water quality over the period of record were observed in Mahurangi Harbour @ Mahurangi Heads, where turbidity, chlorophyll *a* and total P increased significantly (Fig. 17); Ti Point showed increases in chlorophyll *a* and total P; and Goat Island showed increases in NO_3-N and TP.

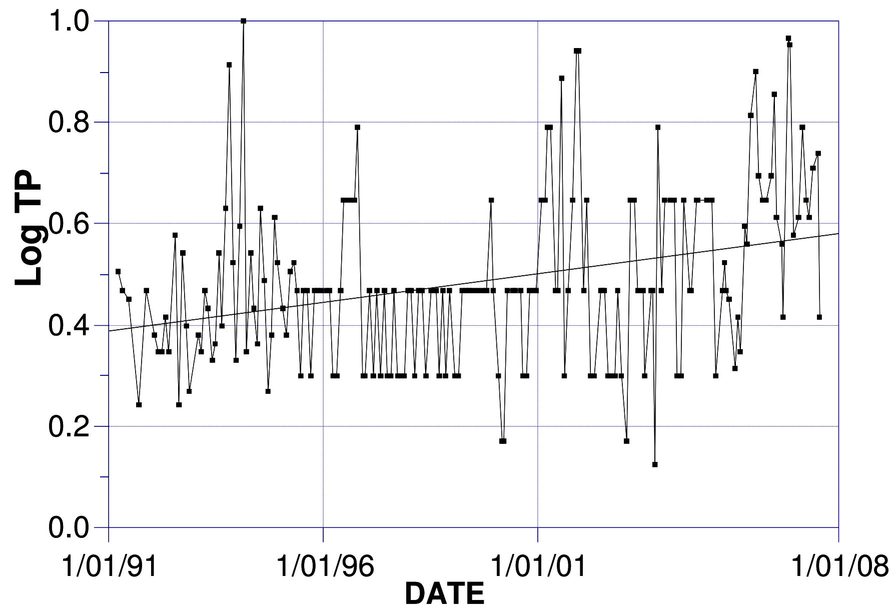
Table 7:

Relative Sen Slope Estimates (RSSE; % of raw data median per annum) for nine water quality paramteres at 21 Auckland saline Harbour sites (1987-2007). Values given in bold italics are statistically significant ($P < 0.05$).

Site	TSS	TURB	CHLa	NO3	NH4	SRP	TP	TEMP	FC
Tamaki									
Panmure	***-0.023***	-0.006	0.000	***-0.038***	0.000	***-0.040***	***-0.042***	***-0.003***	***-0.033***
No. 7 Buoy (Tamaki)	-0.016	***0.017***	0.000	0.000	0.000	***-0.035***	***-0.010***	0.000	0.000
Mahurangi									
Dawsons Creek	***-0.020***	0.014	0.000	-0.020	0.000	***-0.030***	0.000	***-0.007***	0.000
Mahurangi Heads	-0.004	***0.030***	***0.063***	0.000	0.000	***0.000***	***0.017***	***0.004***	0.000
Town Basin	-0.017	0.003	0.000	***-0.066***	0.002	***-0.015***	***-0.040***	0.000	***-0.063***
Kaipara									
Kaipara@Shelly Beach	***-0.058***	***-0.035***	***-0.150***	0.000	***0.078***	0.000	***-0.017***	0.000	0.000
East coast									
Ti Point	-0.008	0.000	***0.067***	0.000	0.000	***-0.030***	***0.013***	***0.003***	0.000
Goat Island	0.000	0.000	0.000	***0.078***	0.000	***-0.010***	***0.057***	0.000	0.000
Orewa	0.000	0.000	0.000	0.000	0.000	***-0.013***	***0.010***	***0.003***	***0.000***
Browns Bay	-0.005	0.000	0.000	0.000	0.000	***-0.015***	0.000	***0.004***	0.000
Upper Waitemata Harbour									
Lucas Creek	***-0.028***	0.004	0.000	-0.004	0.000	***-0.040***	***-0.016***	0.002	0.000
Brighams Creek	***-0.034***	-0.005	0.020	-0.003	-0.007	***-0.042***	***-0.035***	0.000	-0.037
Confluence	***-0.035***	-0.007	0.000	-0.006	0.000	***-0.035***	***-0.034***	0.001	-0.022
Rangitopuni Creek	***-0.036***	-0.009	0.000	0.006	-0.023	***-0.038***	***-0.035***	0.000	-0.034
Rawawaru Creek	***-0.040***	-0.011	0.000	-0.021	-0.011	***-0.060***	***-0.034***	0.002	***-0.054***
Paremoremo Ski Club	***-0.031***	0.006	0.000	0.000	0.000	***-0.040***	***-0.024***	0.001	0.000
Waimarie Road	***-0.030***	0.000	0.000	0.005	0.000	***-0.055***	***-0.027***	0.000	-0.009
Hobsonville Jetty	***-0.036***	***-0.017***	0.000	***-0.029***	0.000	***-0.025***	***-0.013***	***0.004***	***-0.025***
Waitemata Harbour									
Chelsea	-0.013	0.000	-0.045	0.000	0.000	***-0.025***	0.000	***0.003***	***-0.050***
Henderson Creek	***-0.039***	***-0.016***	0.000	-0.018	0.000	***-0.020***	***-0.018***	0.002	0.000
Whau Creek	***-0.058***	***-0.032***	-0.042	-0.020	0.000	***-0.025***	***-0.020***	***0.004***	-0.018

Figure 17:
Long-term trends in Chlorophyll *a* and total P in Mahurangi Harbour @ Mahurangi Heads.





4.7 Regional scale trends in water quality

Figure 18 summarises trends at all 27 monitoring sites for nine water quality variables. With the exception of temperature, all variables show a distribution of trends with the centre of the distribution (i.e., median) below zero. This implies regional-scale reducing trends. Table 8 provides the results of a binomial test, which assesses whether the proportion of sites having positive or negative RSSE is significantly greater than 50%. Faecal coliforms, NO_3-N, SRP, TP and TSS all show significant negative regional-scale trends, indicating improving water quality. In contrast, temperature shows a significant increasing trend.

Figure 18:

Box and whiskers plot of relative Sen slope estimate (RSSE; % of raw data median p.a.) for nine water quality variables at 27 saline monitoring sites in Auckland Region.

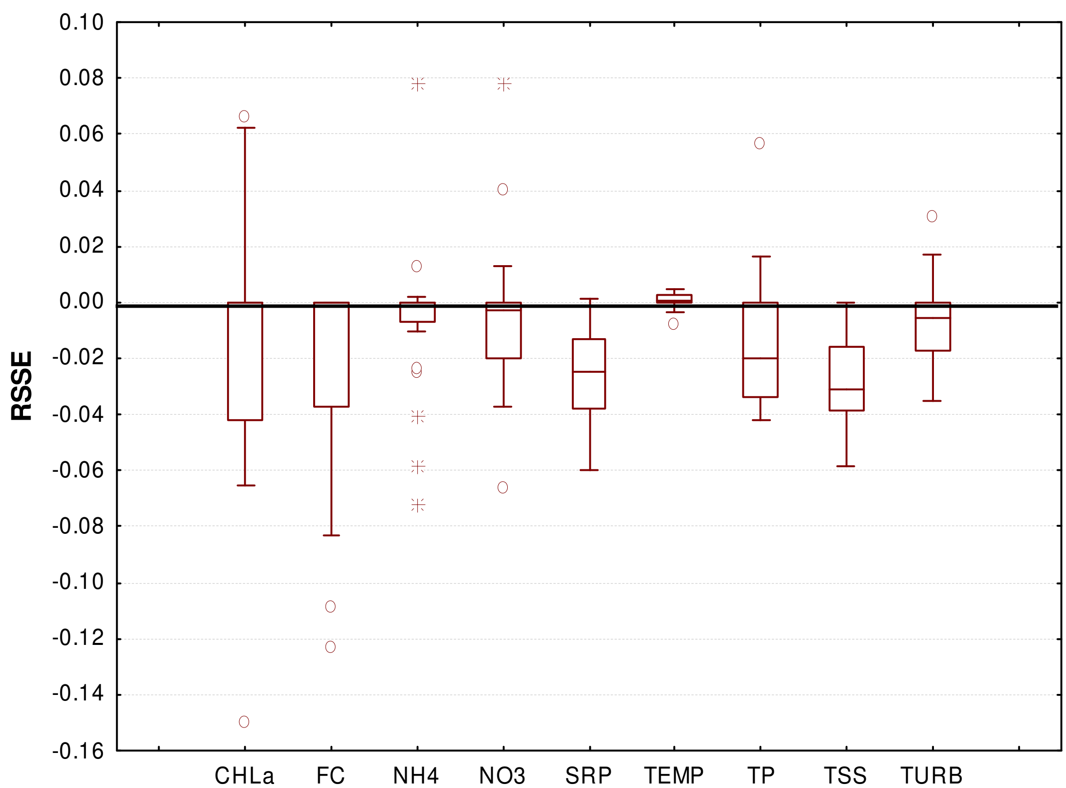


Table 8:

Numbers of positive and negative RSSE across 27 saline sites and *P*-values of resulting binomial tests for eight water quality variables. Values of RSSE = 0 are excluded.

	Positive	Negative	P-value
CHLa	3	7	0.172
FC	0	13	<0.001
NH_4-N	3	7	0.172
NO_3-N	5	14	0.032
SRP	1	23	<0.001
TEMP	15	3	0.004
TP	4	20	<0.001
TSS	0	25	<0.001
TURB	6	14	0.058

4.8 Do regional trends in streams & estuaries match?

Scarsbrook (2007) carried out an SoE analysis of stream water quality in Auckland Region. Results of a regional-scale assessment of freshwater trends (Table 9) closely mirror those observed for the saline monitoring sites (Table 8). Across the region as a whole, during the period from the early 1990s until the mid 2000s, there were significant decreasing trends in sediment related variables (TSS, Turbidity and TP) in both streams and their receiving estuaries and harbours. Concentrations of NO3-N, SRP and faecal coliforms also trended down significantly in both environments. This was a period of a regional-scale increasing trend in water temperature.

Table 9:

Numbers of positive and negative RSSE across 23 freshwater sites and *P*-values of resulting binomial tests for nine water quality variables. Values of RSSE = 0 are excluded. Data obtained from Table 5 in Scarsbrook (2007).

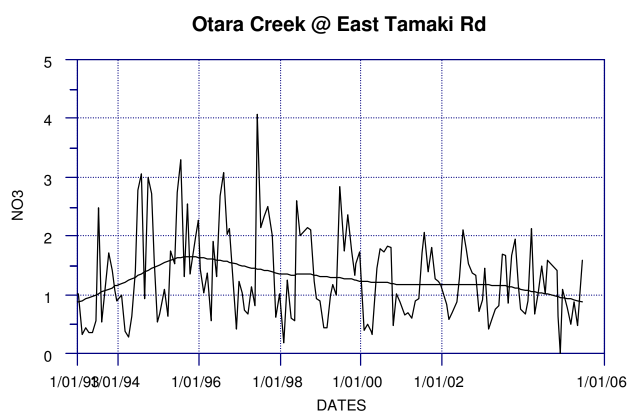
	Positive	Negative	P-value
FC	5	12	0.047
NH4	8	9	0.185
NO3	6	17	0.012
SRP	1	9	0.009
TEMP	11	2	0.010
TP	0	20	<0.001
TSS	2	21	<0.001
TURB	4	19	0.001

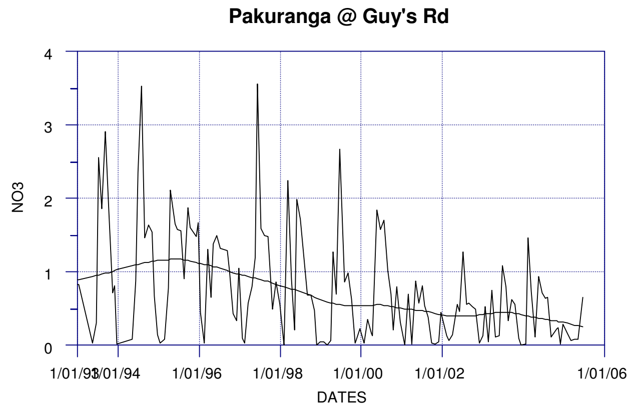
The link between temporal patterns in water quality of streams and estuaries is compared for Tamaki Estuary, Mahurangi Harbour and Upper Waitemata Harbour in the following examples using NO_3-N as an indicator of land use intensification. Nitrate has long been known as a major contaminant of waterways that originates from intensive agriculture, horticulture and urban point and diffuse sources. Furthermore, it is soluble and moderately persistent, as compared with NH_4-N, which is a reduced form of N that is less mobile (from terrestrial sources) and is readily oxidised to nitrate, or is taken up by aquatic plants. Other water quality variables might not be expected to covary between connected freshwater and saline waters to the same extent, either because of rapid changes in concentration when leaving freshwaters and entering the saline environment (e.g. *E.coli*, conductivity) or because of other confounding sources that might mask land use effects (e.g. DRP and TP have naturally elevated levels in coastal waters).

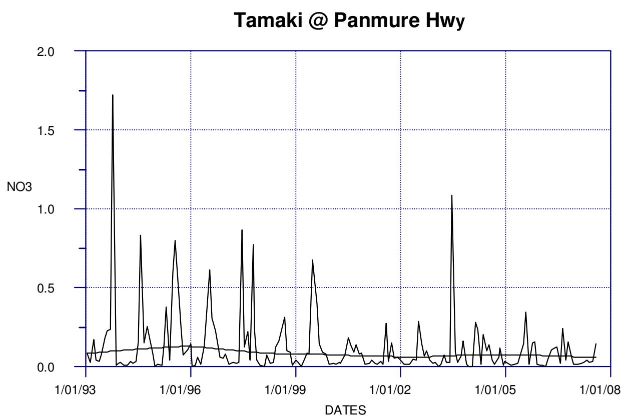
Tamaki Estuary – Data for NO_3-N concentrations in Otara Creek, Pakuranga Creek and Tamaki Estuary are shown below in Figure 19. There were very strong correlations between observed patterns in Otara Creek and Tamaki Estuary (Spearman rank correlation on LOWESS smoothed data (see lines of best fit in Fig. 16); r_S = 0.70) and between smoothed values in Pakuranga Creek and Tamaki Estuary (r_S = 0.93).

Figure 19:

Concentrations of NO_3-N concentrations in Otara Creek, Pakuranga Creek and Tamaki Estuary.



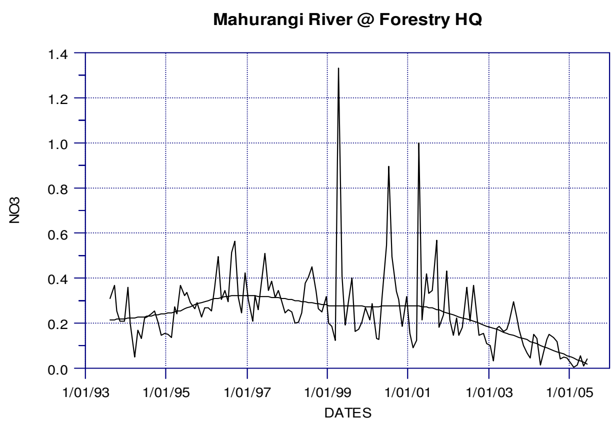


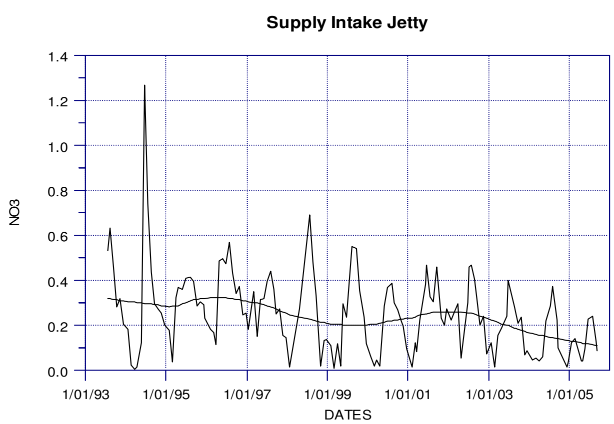


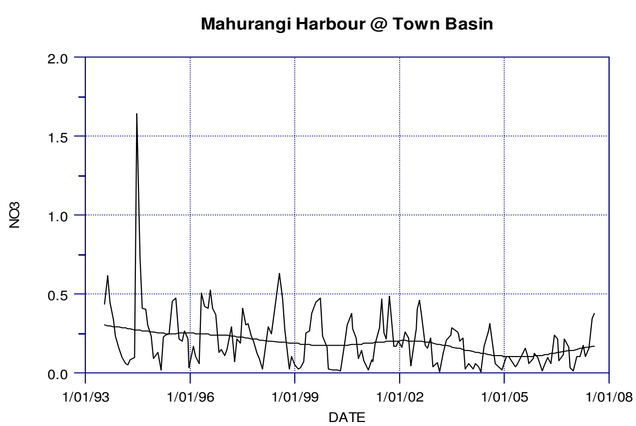
Mahurangi Harbour – Data for NO_3-N concentrations in the Supply Intake Jetty and Mahurangi River freshwater stream sites, and Mahurangi Harbour @ Town basin, are shown below in Figure 20. There was a very strong correlations between observed patterns in Supply Intake Jetty and Mahurangi Harbour @ Town Basin (Spearman rank correlation on LOWESS smoothed data, r_S = 0.90) but a relatively weak correlation between smoothed values for Mahurangi River @ Forestry HQ and Mahurangi Harbour (r_S = 0.19), probably reflecting the difference in distance between the respective freshwater sites and the harbour site, and the different degrees of connectivity.

Figure 20:

Concentrations of NO_3-N concentrations at the Supply Intake Jetty and Mahurangi River freshwater stream sites, and Mahurangi Harbour.



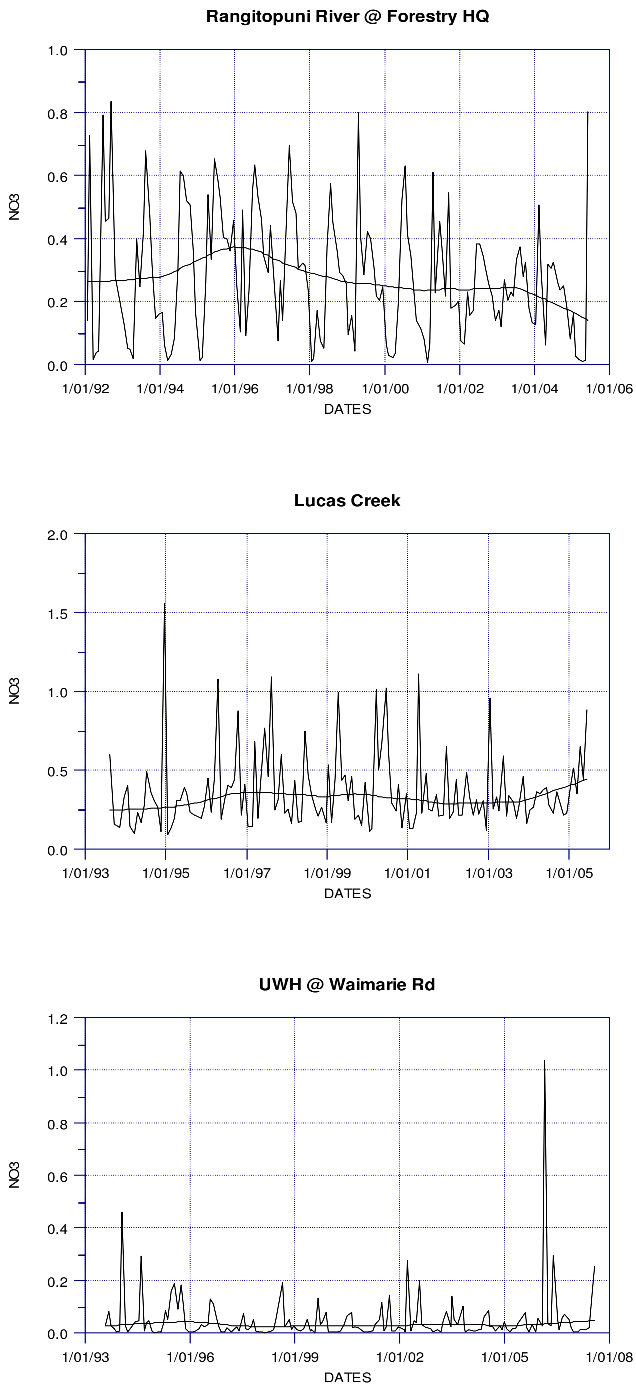




Upper Waitemata Harbour – Data for NO_3-N concentrations in Rangitopuni River and , Lucas Creek (freshwater stream sites) and the Waimarie Road site in the Upper Waitemata Harbour are shown below in Figure 21. Rangitopuni Creek was weakly correlated with the UWH site (r_s = 0.30, Spearman rank correlation on LOWESS smoothed data) whereas Lucas Creek NO_3-N concentrations were practically uncorrelated with the saline site (r_s = 0.03). Rangitopuni River enters UWH upstream of the Waimarie Road site and would have some influence on harbour waters at that site, whereas Lucas Creek enters UWH downstream of the Waimarie Road site and would thus be less influential. In addition, the smoothed LOWESS data for Rangitopuni and Waimarie both indicate downward trends in NO_3-N concentration whereas the Lucas creek data differs by having an upward trend, showing that this site differs in that respect from the other two.

Figure 21:

Concentrations of NO_3-N concentrations at the Rangitopuni River and Lucas Creek (freshwater stream sites) and Upper Waitemata Harbour @ Waimarie Rd.



4.9 Links between climate variability and water quality

Scarsbrook et al. (2003) showed strong associations between some water quality variables (e.g., temperature, SRP and NO_3-N) and climate variability across NIWA's National River Water Quality Network (NRWQN). The approach used by Scarsbrook et al. (2003) was repeated using the 20-year Manukau dataset to identify the strength of associations between the Southern Oscillation Index (SOI; used to define El Nino/La Nina climate conditions) and temporal patterns in water quality variables. Note that a 13-month moving average was used in analyses to remove seasonal influences.

On average, temperature, NO_3-N and NH_4-N showed the strongest associations with SOI across Manukau Harbour (Fig. 20). The relationship was positive for these three variables, indicating that values tended to be higher during positive (La Nina) phases of the SOI and lower during the negative (El Nino) phases (Fig. 21). Warmer seas around New Zealand during La Nina phases are a well known phenomenon and have been linked to coastal algal blooms (Rhodes et al. 1993).

Figure 20:

Percent variance explained by SOI (13-month moving average) for nine water quality variables across six sites in Manukau Harbour. Letters above bars indicate whether bars are significantly different (letters differ) or not based on 1-way ANOVA.

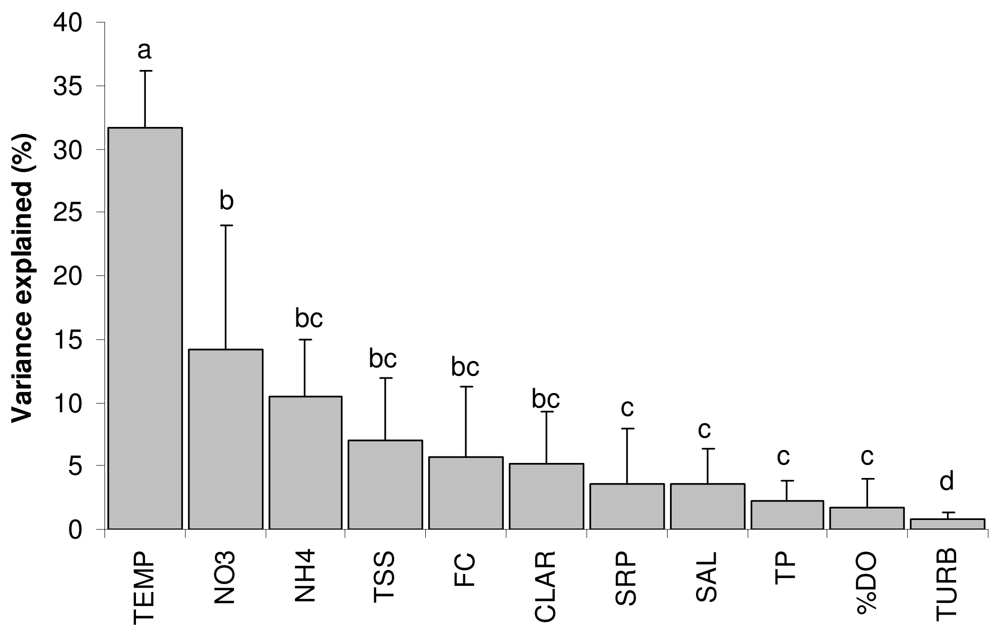
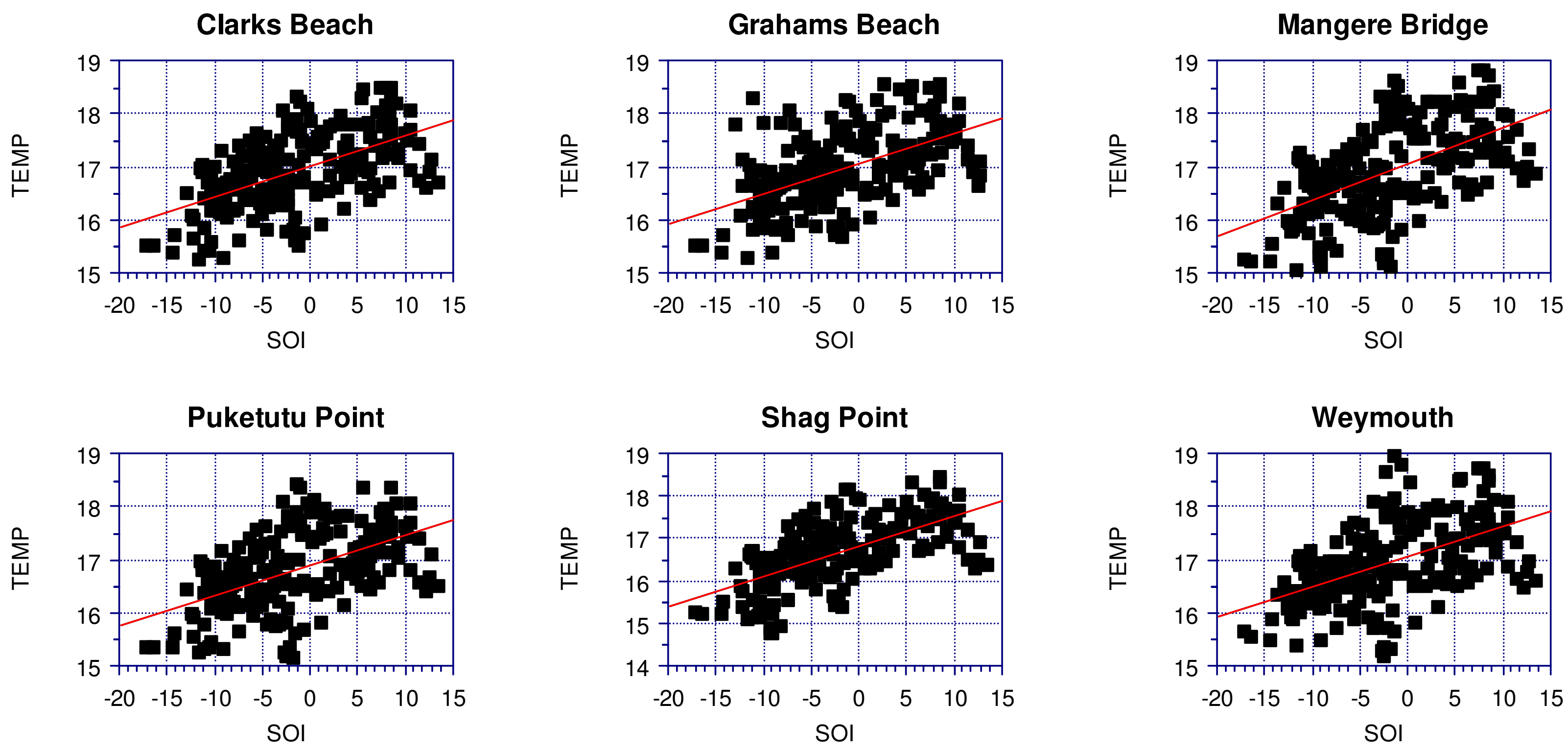


Figure 21:

Relationship between Southern Oscillation Index (SOI) and temperature at six Manukau Harbour sites.



5 Conclusions and recommendations

5.1 State

Three sites in Manukau Harbour (Puketutu Point, Mangere Bridge and Shag Point) stood out from all other sites with respect to nitrogen and phosphorus concentrations. These three sites have been heavily affected by historic discharges from the Mangere Wastewater Treatment Plant. However, despite these discharges, levels of faecal indicator bacteria were not particularly high at these sites. The highest levels of faecal indicator bacteria were observed in the upper Waitemata and Mahurangi harbours. These elevated levels should be of concern for resource managers, as values such as shellfish gathering and recreation are impacted by these high levels of faecal indicator bacteria.

In general, inner harbour sites tended to have poor water quality, whereas water quality in coastal or outer harbour sites was relatively good. Relationships between salinity and both average water quality rank and the number of shellfish gathering guideline exceedences at a site supported the hypothesis that sites close to the influence of streams (i.e., upper harbour) tended to have lower water quality. However, the absence of any upper harbour reference sites (i.e., sites unimpacted by humans) means that differences in water quality cannot be linked to direct human impact, as the observed pattern may also stem from natural physicochemical differences between enclosed, estuarine sites and open coastal sites.

A moving snapshot of state at the regional scale highlighted significant improvements in water quality throughout the region. Most of the improvements are consistent with decreased anthropogenic pressures. For example, reductions in faecal coliforms, NH_4-N, SRP, TP, TSS and turbidity are all consistent with greater sediment controls and point source discharge management. While there is a clear picture of improvements in wastewater treatment at Mangere, which can be linked to water quality patterrns, this is not the case for other sites around the region. However, strict sediment controls on the land have been a major focus of the ARC's management activities since the early 2000s, so reductions in sediment-related variables are to be expected.

5.2 Trends

Water quality in Manukau Harbour has shown dramatic improvements since decommissioning of the Mangere Oxidation Ponds completed in 2002. In particular, levels of ammoniacal nitrogen, total phosphorus and suspended sediments show highly significant decreasing trends over the period 1987-2007, with marked decreases in the last five years. The only cause for concern is the increases in dissolved nutrients (NO_3-N and SRP) observed at Puketutu Point since 2001, and increasing NO_3-N trends at the Weymouth site. In a trend analysis carried out on ARC's stream monitoring network, Scarsbrook (2007) identified only one site with a significant increasing trend in NO_3-N and this was Ngakoroa @ Mills Rd. Ngakoroa Stream is a major freshwater tributary of Manukau Harbour and the Mills Rd site drains a catchment comprised of 74% pasture and 21% horticulture – the most developed catchment of those monitored by ARC.

Trends at the 21 other saline monitoring sites were, in general, indicative of improvements in water quality. The only site causing concern was Mahurangi @ Mahurangi Heads, where TP, chlorophyll *a* and turbidity have trended up. However, there is insufficient information to allow these trends to be linked to changes in land management.

Across the region as a whole there were significant improving trends in levels of faecal indicator bacteria, total suspended sediments, total phosphorus, soluble reactive phosphorus and nitrate. There was also a significant increasing trend for temperature.

5.3 Drivers of water quality patterns

Estuaries and harbours constitute the ultimate receiving environment for contaminants generated on the land and transported by streams and rivers. Therefore, changes in land management practises should be reflected in changes in river water quality and eventually water quality in estuaries. Thus, one of the key aims of this report was to comment on the relationships between stream water quality patterns and saline water quality patterns.

The regional-scale trends observed in the present study mirror those observed by Scarsbrook (2007). Furthermore, temporal patterns of nitrate concentrations in Tamaki estuary were strongly correlated with nitrate concentrations in two major tributaries (Otara Creek and Pakuranga Creek). These results, along with the observed relationship between salinity and water quality, indicates that stream water quality is a major driver of water quality at inner harbour sites.

This report also provides preliminary evidence that climate variability is an important driver of patterns in some water quality parameters. Water temperature was strongly associated with SOI, and changes in the thermal regime of estuaries will have significant influences on biogeochemical processes. Futher research is needed to identify climate variability effects on estuarine ecosystems.

5.4 Recommendations on current and future monitoring networks

- ARC's Saline Water Quality Programme provides a very valuable, long-term dataset for investigating changes in state and changes over time in a selection of the region's harbours and estuaries. It is the most comprehensive coastal water quality dataset in the country. The suite of water quality parameters is appropriate, and no major parameters are missing. However, there is some redundancy in the suite of parameters and the value of collecting data for TSS and turbidity should be investigated.

- There is only one site in Kaipara Harbour, but seven sites in the upper Waitemata Harbour, and eleven in the Waitemata in total. However, the distribution of sites in the Waitemata reflects on-going investigations into the effects of urbanisation on the Harbour. There are four coastal monitoring sites along the East Coast (Goat Island, Ti Point, Orewa and Brown's Bay), but none associated with the outlet of major western harbours (i.e., Maukau or Kaipara). Also, there are no sites associated with the Wairoa River estuary further south. Given the likelihood of future urban and lifestyle developments in these areas an investigation into the possibility of locating long-term monitoring sites in these areas is warranted. These additional sites might be funded through relocation of existing SoE sites, or through savings gained by reduction of analytes, or reduction in sampling frequency (e.g. from monthly to bimonthly) at some sites. These changes will require further investigation to ensure the SoE network continues to meet ARC objectives.
- Future state of the environment reporting would benefit from more detailed information on pressures (e.g., number and type of point source discharges), so that observed trends in water quality can be directly linked to resource management activities.
- Development of region-specific water quality guidelines would greatly enhance future reporting on state and trends in the region's harbours and estuaries, particularly given the paucity of suitable reference sites that might otherwise provide a benchmark.

6 References

Auckland Regional Council (2007). State of the Environment Monitoring: River & Stream Water Quality Data Report 2005. ARC Technical Publication 327. Auckland.

MfE (2003). Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas. Published in June 2002 by Ministry for the Environment, Wellington. Updated in June 2003. 159 p.

Rhodes, L.L.; Haywood, A.J.; Ballantine, W.J. & MacKenzie, A.L. (1993). Algal blooms and climate anomalies in north-east New Zealand, August-December 1992. *New Zealand Journal of Marine & Freshwater Research 27*: 419-430.

Scarsbrook, M.R.; McBride, C.G.; McBride, G.B. & Bryers, G.G. (2003). Effects of climate variability on rivers: consequences for long-term water quality analysis. *Journal of the American Water Resources Association 39*: 1435-1447.

Scarsbrook, M. (2006). State and trends in the National River Water Quality Network (1989-2005). Prepared for Ministry for the Environment. NIWA Client report HAM2006-131. 45 p.

Scarsbrook, M. (2007). Saline water quality state and trends in Auckland Region. ARC Technical Publication No. 336. 41 p.

Stansfield, B. (2001). Effects of sampling frequency and laboratory detection limits on the determination of time series water quality trends. *New Zealand Journal of Marine & Freshwater Research 35*: 1071-1075.