Auckland Regional Council
TE RAUHĪTANGA TAIAO

State of the Environment Monitoring

Marine Water Quality Data Report 2005

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State of the Environment Monitoring: Marine Water Quality Data Report 2005

Environmental Research
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Contents

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1 Background

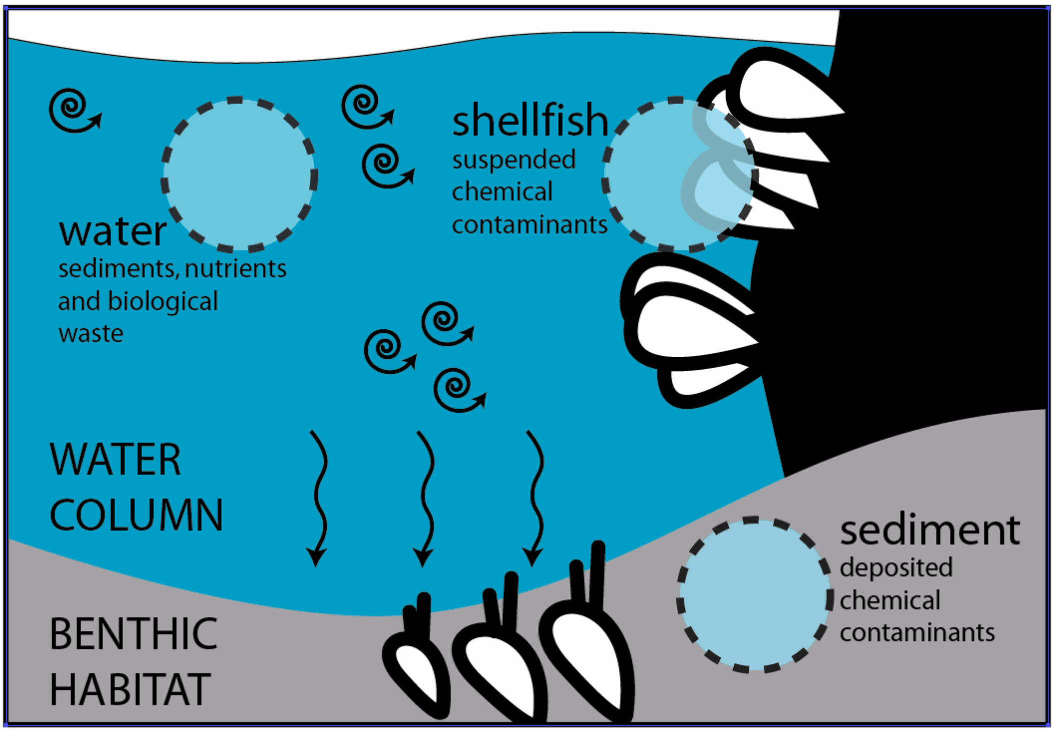
The marne environment in the Auckland Region encompasses two oceans, four major harbours, and numerous estuaries. This wide variety of marine habitats supports a diverse range of aquatic plants and animals, including seaweeds, mangroves and seagrass, shellfish, marine mammals, fish and sea birds.

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

This programme monitors marine 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 contaminants associated with erosion, nutrients 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 contaminants levels in the water column.
- The Sediment Contaminant 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.

Figure 1: The division between sediment contaminants, coastal water quality and shellfish contaminant monitoring programmes



Together, these programmes provide consistent, long-term information on the quality of Auckland's coastal environment.

2 Programme objectives

The 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 water quality programme fits under the "Natural Environment and Heritage" component of the ARCs 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".

2.1 Report content

This report provides 12-months of summary data from the 2005 calendar year collected from 27 monitoring sites across the Auckland Region, and includes:

- Summary statistics tabulated by parameter and grouped by spatial proximity.

- Site specific time series graphs by parameter across the entire data record.

2.2 Programme Design

Coastal water quality monitoring is undertaken monthly by ARC technical officers predominantly by helicopter, which enables sites spread over a broad area to be collected within a narrow time frame. The exceptions are: Shelly Beach in the Kaipara Harbour, where samples are collected from a wharf; and the Upper Waitemata Harbour, Mahurangi Harbour, and Tamaki Estuary which are sampled by boat.

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

- 6 sites in Manukau Harbour;
- 7 sites in the inner Hauraki Gulf and outer Waitemata Harbour;
- 1 sites 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 1–2.5 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.

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;

In addition, more spatially intense sampling is carried out in three areas identified as being particularly vulnerable to water quality degradation (Mahurangi Harbour, Upper Waitemata Harbour and Tamaki Estuary).

2.3 Water Quality Parameters

The water quality of the Region's coastal environment is determined by measuring up to 21 parameters, 15 routinely. Some parameters are determined in the field but most are analysed in the laboratory. The number and type of parameters has varied since the programmes inception as new technology became more affordable, instrument sensitivity improved and the programme objectives were modified. Details of the laboratory analytes and field measurements are given in appendix I.

Table 1. WQ-saline sites by geographic region, general water quality rating, sampling commencement and spatial reference.

Site	Location	Water quality	Easting	Northing	Start
Browns Bay	East Coast Bays	High	2668401	6497478	1991
Goat Island	East Coast Bays	High	2672411	6546605	1993
Orewa	East Coast Bays	High	2663769	6511321	1991
Ti Point	East Coast Bays	High	2670783	6540222	1991
Shelly Beach	Kaipara Harbour	Variable	2634008	6513666	1991
Dawsons Creek	Mahurangi Harbour	High	2664087	6528121	1993
Mahurangi Heads	Mahurangi Harbour	High	2664900	6521600	1993
Town Basin	Mahurangi Harbour	Poor	2659289	6532066	1993
Mangere Bridge	Manukau Harbour	Poor	2669004	6472408	1987
Puketutu Point	Manukau Harbour	Poor	2664289	6470427	1987
Shag Point	Manukau Harbour	Poor	2658790	6470166	1987
Grahams Beach	Manukau Harbour	Generally good	2660023	6449792	1987
Clarks Beach	Manukau Harbour	Generally good	2659019	6459062	1987
Weymouth	Manukau Harbour	Variable	2675316	6459353	1987
Panmure	Tamaki Estuary	Poor	2675718	6475615	1992
Tamaki	Tamaki Estuary	Poor	2679802	6479121	1992
Brighams Creek	Upper Waitemata Harbour	Variable	2653207	6489747	1993
Confluence	Upper Waitemata Harbour	Variable	2654413	6490765	1993
Hobsonville Jetty	Upper Waitemata Harbour	Variable	2659770	6489031	1993
Lucas Creek	Upper Waitemata Harbour	Variable	2660504	6494185	1993
Paremoremo Ski Club	Upper Waitemata Harbour	Variable	2656200	6491900	1993
Rangitopuni Creek	Upper Waitemata Harbour	Variable	2653289	6491596	1993
Rarawaru Creek	Upper Waitemata Harbour	Variable	2654885	6490378	1993
Waimarie Road	Upper Waitemata Harbour	Variable	2656665	6490810	1993
Chelsea	Waitemata Harbour	Variable	2664384	6484577	1991
Henderson Creek	Waitemata Harbour	Variable	2657153	6485367	1991
Whau Creek	Waitemata Harbour	Variable	2658723	6482007	1991

Figure 2: Monitoring locations

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 ARCs water quality archiving database (HYDSTRA).

Data analysis is performed in HYDSTRA using specially designed scripts that interpret, collate and output pre-determined summary statistics. For the purposes of data analysis, non-detect results (results below instrument sensitivity and reported with 'less than' values) were assumed at face value.

2.5 Programme changes

The analytical programme was reviewed in June 2005.

Our analysis determined that biological oxygen demand (BOD) was consistently recorded at the laboratory detection limit (<2 ppm) at all sites monitored. Following analytical convention and halving the detection limit resulted in most sites recording median BOD values of 1.6 to 1.7 ppm. Watercare Laboratory Services Ltd were requested to revise the analytical method to achieve a detection limit based on the industry standard 0.4 ppm. An improvement in the detection limit was not immediately forthcoming and as a consequence in July 2005 BOD was dropped for the remainder of the calender year.

The measurement of clarity using Secchi disk also ceased in July 2005 due to the practical difficulty of determining an accurate measure from the helicopter. Turbidity was deemed to be a useful approximate surrogate.

2.6 Reports

This is the 15th data report since the inception of the monitoring programme, although it is first 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 (09)

366 2000, in electronic format where available from the ARC's website: www.arc.govt.nz/publications or email: info@arc.govt.nz.

A comprehensive trend analysis is conducted approximately every 5 years, with the last 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 1999. A specific review of the Mahurangi Harbour, Upper Waitemata Harbour and Tamaki Estuary was undertaken in 2001.

Results

Table 2: Statistical summary of routine water quality variables obtained from each of the 27 monitoring sites for the 2005 calendar year plus the 01-05 median.

	Dissolved oxygen (g.m^{-3})								Dissolved oxygen (% saturation)							
Site	Count	Mean	Median	Min	Max	IQR	Skew	01 -05	Count	Mean	Median	Min	Max	IQR	Ske	01 -05
Mahurangi Harbour																
Town Basin	12	6.6	6.7	4.6	9.1	2.2	0.23	6.9	12	76.0	74.8	60.1	87.7	18.6	-0.30	77.5
Dawsons Creek	12	7.0	6.9	6.0	8.6	1.1	0.61	6.8	12	88.2	89.1	78.1	94.5	2.8	-1.22	86.0
Mahurangi Heads	12	7.1	7.0	5.8	8.0	0.8	-0.71	7.3	12	91.4	92.4	71.3	97.8	6.1	-2.23	91.3
Tamaki Estuary																
Panmure Basin	12	6.9	6.9	5.5	8.1	1.6	-0.03	7.0	12	86.3	85.4	77.5	100.3	5.3	0.89	85.4
No. 7 Buoy	12	7.1	7.1	6.1	8.2	0.8	0.09	7.4	12	90.7	89.6	85.4	100.3	5.9	0.89	90.1
Upper Waitemata Harbour																
Hobsonville Jetty	12	7.2	7.2	6.3	8.3	0.9	0.06	7.1	12	91.9	91.9	85.6	98.9	7.3	0.20	91.3
Waimarie Rd	12	7.1	7.0	5.8	8.6	1.6	0.24	6.9	12	88.8	86.9	81.6	99.1	6.6	0.59	84.6
Confluence	12	7.0	6.9	5.5	8.7	1.7	0.20	6.8	12	87.1	85.0	77.5	97.0	9.3	0.41	83.9
Paremoremo Ski Club	12	7.0	6.9	5.5	8.6	1.7	0.22	6.7	12	86.8	85.6	76.8	97.8	9.6	0.32	82.3
Rarawaru Creek	12	7.0	6.9	5.4	8.8	1.9	0.11	6.8	12	86.7	85.9	74.3	98.9	12.1	0.02	
Lucas Creek	12	6.8	6.9	4.8	8.8	1.5	-0.09	6.7	12	85.1	86.5	70.0	100.8	11.7	-0.24	81.0
Brighams Creek	12	6.8	6.7	5.3	8.7	1.6	0.34	6.7	12	84.7	83.4	75.3	95.5	10.4	0.23	82.7
Rangitopuni Creek	11	7.0	7.4	5.1	9.0	2.3	-0.21	6.7	11	83.8	83.0	71.5	95.1	11.3	0.03	82.5
Kaipara Harbour																
Shelly Beach	12	7.3	7.4	5.5	8.1	1.2	-0.78	7.4	11	88.8	88.9	69.0	100.8	7.6	-1.14	89.6
East Coast																
Goat Island	11	7.7	7.8	6.9	8.7	1.0	0.25	7.8	11	88.5	95.8	10.3	104.7	4.3	-3.15	96.2
Ti Point	11	7.6	7.6	6.6	8.3	0.5	-0.58	7.6	11	96.6	95.5	90.4	102.7	3.7	0.43	96.1
Orewa	11	7.6	7.7	6.1	8.5	0.8	-0.94	7.6	11	96.8	96.6	85.6	105.5	3.1	-0.66	96.5
Browns Bay	11	7.4	7.5	5.6	8.2	0.7	-1.32	7.5	11	94.0	94.8	77.5	103.5	7.7	-0.84	94.6
Chelsea	11	7.3	7.4	5.5	9.2	1.2	-0.09	7.4	11	92.1	91.8	78.4	103.4	11.3	-0.02	92.2
Henderson Creek	11	7.0	7.0	5.7	8.0	1.2	-0.32	7.0	11	87.1	86.0	75.0	98.4	7.3	-0.03	86.0
Whau Creek	11	7.2	7.2	5.3	9.1	1.4	-0.04	7.2	11	89.9	88.2	76.4	108.1	9.0	0.70	88.5
Manukau Harbour																
Clarks Beach	12	7.3	7.5	5.8	8.6	1.3	-0.44	7.5	12	92.7	91.8	84.2	104.7	7.6	0.74	92.5
Grahams Beach	12	7.5	7.8	6.2	8.3	1.1	-0.73	7.7	12	94.4	94.9	82.7	107.6	2.8	0.29	94.9
Weymouth	12	7.7	7.9	5.9	8.9	1.1	-0.70	7.6	12	94.4	93.7	84.2	110.2	6.6	1.10	93.6
Mangere Bridge	12	7.5	7.6	6.6	8.3	1.0	-0.40	7.5	12	92.9	89.7	82.5	113.4	12.0	1.16	89.9
Puketutu Point	12	7.5	7.7	5.9	8.2	0.7	-1.52	7.6	12	93.3	92.8	84.0	105.7	5.8	0.71	93.1
Shag Point	12	7.8	7.9	6.2	8.5	0.8	-1.05	7.8	12	96.2	95.7	89.7	107.2	5.1	0.97	96.0

	Temperature (°C)								Conductivity at 25°C (µS.cm^{-2})							
Site	Count	Mean	Median	Min	Max	IQR	Skew	01 -05	Count	Mean	Median	Min	Max	IQR	Skew	01 -05
Mahurangi Harbour																
Town Basin	12	17.2	17.2	11.5	23.1	6.5	-0.11	16.6	12	26.6	26.9	10.7	43.2	21.1	-0.03	26.2
Dawsons Creek	12	17.5	17.0	12.0	24.3	5.7	0.28	17.3	12	50.1	49.8	47.4	53.2	2.5	0.51	49.9
Mahurangi Heads	12	17.7	17.8	13.6	23.7	4.3	0.45	17.1	12	51.8	51.6	50.6	53.2	1.8	0.40	51.6
Tamaki Estuary																
Panmure Basin	12	18.0	18.0	12.9	24.1	9.0	0.13	17.1	11	44.4	45.0	35.3	51.9	12.7	-0.31	44.9
No. 7 Buoy	12	18.0	18.1	13.2	24.1	8.5	0.20	17.3	11	49.5	50.0	45.4	52.8	3.3	-0.37	49.8
Upper Waitemata Harbour																
Hobsonville Jetty	12	17.9	17.0	13.2	24.2	5.6	0.27	17.2	12	49.4	49.1	46.4	52.9	3.1	0.30	49.6
Waimarie Rd	12	18.0	17.5	13.1	24.7	6.3	0.21	18.0	12	44.6	46.3	21.2	52.6	5.9	-2.36	46.5
Confluence	12	18.2	18.1	13.0	25.0	6.6	0.13	17.9	12	45.5	45.8	39.0	52.4	7.6	0.04	44.7
Paremoremo Ski Club	12	18.2	18.0	13.2	24.7	6.6	0.15	18.0	12	45.4	45.6	35.6	52.0	6.4	-0.39	44.9
Rarawaru Creek	12	18.2	18.1	13.1	24.9	6.9	0.16	17.7	12	44.7	45.2	35.9	52.4	6.5	-0.27	44.2
Lucas Creek	12	18.2	17.9	13.0	24.9	6.7	0.19	17.7	12	45.8	46.2	36.8	52.4	6.8	-0.36	45.7
Brighams Creek	12	18.2	18.2	13.2	25.2	6.6	0.18	17.8	12	42.2	44.1	30.1	51.8	14.8	-0.31	41.5
Rangitopuni Creek	11	18.1	16.2	12.8	25.1	7.9	0.22	17.8	11	37.6	37.0	22.4	52.0	12.9	0.10	37.0
Kaipara Harbour																
Shelly Beach	12	17.2	16.8	13.0	23.5	6.1	0.41	16.4	11	44.7	46.7	31.5	50.3	3.9	-1.52	45.5
East Coast																
Goat Island	11	17.5	17.9	14.2	21.1	4.4	0.19	16.7								
Ti Point	11	17.5	17.8	13.9	21.5	4.6	0.17	16.5								
Orewa	11	17.7	17.1	13.4	22.7	5.1	0.21	17.0								
Browns Bay	11	17.7	17.3	13.5	23.9	5.6	0.45	16.7								
Chelsea	11	17.6	16.5	13.2	23.7	5.9	0.35	16.8								
Henderson Creek	11	17.4	15.8	12.6	23.8	6.6	0.21	17.2								
Whau Creek	11	17.5	16.0	12.5	23.9	7.3	0.17	17.2								
Manukau Harbour																
Clarks Beach	12	17.4	16.7	12.8	24.6	7.1	0.47	16.3								
Grahams Beach	12	17.2	16.7	13.0	23.6	7.0	0.42	16.3								
Weymouth	12	17.5	16.7	12.7	24.4	7.5	0.39	16.3								
Mangere Bridge	12	17.5	16.7	12.3	24.8	6.9	0.40	15.9								
Puketutu Point	12	17.4	16.2	12.6	24.4	6.6	0.48	15.9								
Shag Point	12	17.3	15.8	12.6	24.5	6.2	0.56	16.1								

Site	Salinity (ppt) Count	Mean	Median	Min	Max	IQR	Skew	01 -05	pH Count	Mean	Median	Min	Max	IQR	Skew	01 -05
Mahurangi Harbour																
Town Basin	12	16.50	16.7	6.1	27.9	13.75	0.02	8.7	12	7.6	7.6	7.5	7.8	0.2	0.26	7.6
Dawsons Creek	12	32.65	32.9	30.8	35.3	2.1	0.52	32.1	12	8.1	8.1	8.0	8.2	0.1	1.13	8.1
Mahurangi Heads	12	34.00	34.1	33.2	35.2	1.45	0.26	34.0	12	8.2	8.2	8.0	8.3	0.1	-0.12	8.2
Tamaki Estuary																
Panmure Basin	12	29.31	30.6	22.2	34.5	9.45	-0.44	29.1	12	7.9	8.0	7.3	8.1	0.0	-3.02	8.0
No. 7 Buoy	12	32.50	32.9	29.4	34.8	2.5	-0.45	31.9	12	8.0	8.1	7.3	8.2	0.0	-3.31	8.1
Upper Waitemata Harbour																
Hobsonville Jetty	12	32.60	32.7	30.1	34.9	2.775	-0.05	33.0	12	8.2	8.1	8.0	8.8	0.1	3.03	8.1
Waimarie Rd	12	30.98	31.1	26.9	34.7	5.1	-0.13	30.8	12	8.0	8.0	8.0	8.1	0.1	0.15	8.0
Confluence	12	29.83	29.7	24.8	34.6	6.825	-0.04	28.0	12	8.0	8.0	7.9	8.2	0.1	0.74	8.0
Paremoremo Ski Club	12	29.81	29.8	22.5	34.3	6.05	-0.47	29.0	12	8.0	8.0	7.9	8.1	0.1	0.31	8.0
Rarawaru Creek	12	29.25	29.3	22.7	34.5	6.275	-0.33	27.7	12	8.0	8.0	7.9	8.2	0.1	1.25	7.9
Lucas Creek	12	30.05	30.3	23.4	34.6	6.25	-0.36	29.7	12	8.0	8.0	7.9	8.1	0.1	0.02	8.0
Brighams Creek	12	27.52	28.5	18.7	34.1	11.5	-0.33	26.0	12	7.9	7.9	7.8	8.1	0.1	0.60	7.9
Rangitopuni Creek	11	24.03	24.0	13.5	34.3	9.15	0.15	21.1	11	7.9	7.9	7.8	8.1	0.2	0.55	7.9
Kaipara Harbour																
Shelly Beach	12	30.65	30.8	25.9	34.1	3.9	-0.35	29.5	12	8.1	8.1	7.9	8.2	0.1	-1.26	8.1
East Coast																
Goat Island	11	34.10	34.1	33.4	34.9	1	0.09	34.0	12	8.2	8.2	8.1	8.3	0.1	0.27	8.2
Ti Point	11	34.00	34.3	33.6	35.1	1.05	0.19	34.1	12	8.2	8.2	8.1	8.3	0.1	0.88	8.2
Orewa	11	33.70	33.5	26.0	35.1	1.25	-2.93	33.9	12	8.2	8.2	8.1	8.3	0.1	1.03	8.2
Browns Bay	11	33.80	34.0	32.9	35.1	1.5	-0.03	33.7	12	8.2	8.2	8.1	8.3	0.1	0.89	8.2
Chelsea	11	33.00	33.2	31.4	34.7	2.1	-0.04	32.8	12	8.1	8.1	8.1	8.2	0.0	1.59	8.1
Henderson Creek	11	30.60	29.6	19.5	34.1	5	-1.33	29.4	12	8.1	8.1	8.0	8.2	0.1	0.88	8.1
Whau Creek	11	32.10	31.5	27.5	34.3	2.75	-0.50	30.8	12	8.1	8.1	8.1	8.2	0.0	1.93	8.1
Manukau Harbour																
Clarks Beach	12	32.05	32.3	28.9	34.6	2.65	-0.40	31.8	12	8.1	8.1	8.0	8.2	0.1	-0.22	8.1
Grahams Beach	12	32.85	33.0	30.5	34.7	2	-0.26	32.6	12	8.2	8.2	8.1	8.2	0.1	-0.18	8.1
Weymouth	12	29.90	29.5	18.7	34.2	4.3	-1.46	30.0	12	8.1	8.1	7.9	8.2	0.0	-1.66	8.1
Mangere Bridge	12	30.30	30.2	25.1	33.7	4.4	-0.46	30.0	12	8.1	8.1	7.9	8.3	0.2	0.40	8.0
Puketutu Point	12	31.35	31.0	27.4	34.4	4.05	-0.20	31.0	12	8.1	8.1	8.0	8.2	0.1	0.23	8.1
Shag Point	12	32.00	32.2	29.4	34.6	2.65	-0.17	31.8	12	8.2	8.2	8.1	8.3	0.1	0.32	8.1

	Suspended solid (g. m^{-3})								Turbity (NTU)							
Site	Count	Mean	Median	Min	Max	IQR	Skew	01 -05	Count	Mean	Median	Min	Max	IQR	Skew	01 -05
Mahurangi Harbour																
Town Basin	12	8.3	7.3	0.8	19.6	4.7	1.07	7.6	12	5.10	5.18	2.20	8.10	3.05	0.07	5.55
Dawsons Creek	12	12.1	8.4	1.8	38.0	7.7	2.03	12.0	12	4.89	4.65	2.20	9.20	1.17	1.49	5.40
Mahurangi Heads	11	3.2	3.1	0.4	5.0	1.6	-0.78	3.3	12	1.31	1.25	0.53	1.90	0.33	-0.17	1.30
Tamaki Estuary																
Panmure Basin	12	19.8	14.5	5.8	57.0	11.5	2.01	15.0	12	12.16	9.55	4.40	34.00	7.51	1.97	8.40
No. 7 Buoy	12	14.7	7.2	3.0	60.0	9.5	2.51	8.5	12	7.24	4.20	2.43	30.40	4.18	2.70	4.00
Upper Waitemata Harbour																
Hobsonville Jetty	12	11.9	9.9	4.5	25.0	7.0	0.98	8.1	12	4.73	4.45	2.50	8.50	2.18	0.75	3.90
Waimarie Rd	12	11.6	9.6	3.0	25.0	8.9	0.87	10.1	12	6.09	5.51	2.76	10.30	2.50	0.40	6.35
Confluence	12	12.1	12.0	2.6	22.0	6.9	0.25	11.9	12	7.17	6.74	2.96	12.50	4.44	0.37	6.85
Paremoremo Ski Club	12	10.7	10.4	3.7	18.1	4.1	0.23	11.2	12	6.98	6.50	3.21	12.00	3.66	0.41	6.8
Rarawaru Creek	12	13.6	12.3	4.2	24.0	5.7	0.33	12.0	12	8.10	8.10	3.75	13.20	4.51	0.27	7.80
Lucas Creek	12	14.8	13.5	2.8	27.0	7.7	0.31	13.6	12	8.14	8.41	4.10	14.10	5.45	0.27	7.96
Brighams Creek	12	12.7	14.4	5.0	18.0	7.4	-0.72	13.0	12	7.51	7.04	4.82	12.00	3.71	0.72	7.65
Rangitopuni Creek	11	12.6	10.6	3.9	22.0	11.3	0.35	11.0	11	7.57	6.79	3.87	12.00	5.06	0.46	6.80
Kaipara Harbour																
Shelly Beach	12	31.7	22.9	11.0	75.7	24.0	1.23	45.0	12	11.89	9.05	2.00	30.20	8.63	1.13	15.30
East Coast																
Goat Island	12	4.2	2.8	1.4	13.6	2.9	2.15	2.1	12	0.41	0.40	0.20	0.60	0.28	0.00	0.50
Ti Point	12	5.2	2.3	1.2	33.0	2.1	3.37	2.5	12	0.65	0.55	0.36	1.10	0.50	0.67	0.70
Orewa	12	5.8	4.7	0.8	12.2	6.6	0.42	3.3	12	1.25	1.12	0.31	3.40	0.96	1.43	0.90
Browns Bay	12	5.8	4.2	0.8	14.0	5.2	0.94	3.3	12	1.30	1.16	0.27	4.00	0.72	2.02	1.00
Chelsea	12	8.3	6.5	0.8	16.1	5.5	0.54	6.1	12	2.74	2.70	1.80	4.30	0.90	0.78	2.66
Henderson Creek	12	14.8	13.0	1.2	28.1	13.3	0.10	11.9	12	6.00	5.65	2.90	9.00	2.20	0.36	7.00
Whau Creek	12	12.7	11.0	0.8	25.8	10.4	0.26	11.0	12	4.19	4.20	1.20	6.60	2.00	-0.14	5.90
Manukau Harbour																
Clarks Beach	12	20.1	19.5	6.6	41.3	15.7	0.56	20.0	12	7.82	8.15	1.80	23.00	6.41	1.49	7.25
Grahams Beach	12	12.3	11.4	4.6	28.0	11.1	0.94	10.8	12	4.65	4.07	0.88	13.00	2.60	1.61	4.40
Weymouth	12	17.1	15.8	9.8	34.0	9.3	1.22	17.8	12	9.04	7.95	2.50	18.00	5.41	0.88	7.95
Mangere Bridge	12	27.1	21.0	12.0	73.3	14.8	1.97	28.0	12	10.32	9.90	2.70	26.00	4.18	1.44	10.50
Puketutu Point	12	19.4	14.3	4.3	54.0	16.8	1.41	15.0	12	7.74	5.92	1.00	24.00	5.84	1.61	5.87
Shag Point	12	17.4	8.8	3.9	56.3	16.8	1.48	14.0	12	5.92	3.95	1.10	22.00	3.11	1.99	5.30

	Ammoniacal Nitrogen (g.N. m^{-3})								Nitrate/Nitrite (g.N. m^{-3})							
Site	Count	Mean	Median	Min	Max	IQR	Skew	01 -05	Count	Mean	Median	Min	Max	IQR	Skew	01 -05
Mahurangi Harbour																
Town Basin	12	0.089	0.080	0.024	0.163	0.056	0.415	0.060	12	0.106	0.106	0.053	0.222	0.059	1.170	0.163
Dawsons Creek	12	0.015	0.016	0.005	0.024	0.008	-0.459	0.020	12	0.014	0.012	0.003	0.055	0.011	2.622	0.012
Mahurangi Heads	12	0.015	0.017	0.002	0.031	0.011	0.156	0.010	12	0.011	0.010	0.002	0.034	0.004	2.363	0.010
Tamaki Estuary																
Panmure Basin	12	0.055	0.046	0.019	0.183	0.040	2.218	0.030	12	0.087	0.023	0.006	0.351	0.139	1.526	0.041
No. 7 Buoy	12	0.035	0.032	0.010	0.074	0.022	0.640	0.020	12	0.027	0.012	0.002	0.094	0.034	1.430	0.013
Upper Waitemata Harbour																
Hobsonville Jetty	12	0.026	0.019	0.004	0.130	0.012	3.209	0.010	12	0.017	0.018	0.006	0.036	0.015	0.567	0.015
Waimarie Rd	12	0.019	0.020	0.008	0.031	0.009	-0.121	0.020	12	0.026	0.018	0.004	0.080	0.023	1.385	0.023
Confluence	12	0.021	0.021	0.005	0.036	0.009	-0.296	0.020	12	0.042	0.020	0.007	0.152	0.050	1.523	0.039
Paremoremo Ski Club	12	0.021	0.020	0.008	0.043	0.014	0.803	0.020	12	0.034	0.022	0.004	0.114	0.040	1.510	0.032
Rarawaru Creek	12	0.022	0.021	0.010	0.046	0.005	1.410	0.022	12	0.036	0.018	0.004	0.136	0.042	1.753	0.046
Lucas Creek	12	0.022	0.023	0.006	0.045	0.018	0.408	0.028	12	0.024	0.017	0.004	0.064	0.022	1.082	0.030
Brighams Creek	12	0.029	0.029	0.007	0.052	0.008	0.322	0.030	12	0.072	0.032	0.002	0.232	0.093	1.169	0.074
Rangitopuni Creek	11	0.029	0.029	0.006	0.058	0.011	0.586	0.030	11	0.085	0.058	0.002	0.263	0.112	1.090	0.087
Kaipara Harbour																
Shelly Beach	12	0.063	0.048	0.024	0.121	0.059	0.704	0.046	12	0.034	0.022	0.004	0.123	0.028	2.060	0.021
East Coast																
Goat Island	12	0.025	0.014	0.002	0.131	0.013	3.040	0.010	12	0.025	0.019	0.008	0.063	0.021	1.280	0.018
Ti Point	12	0.019	0.020	0.009	0.035	0.014	0.432	0.010	12	0.019	0.016	0.007	0.040	0.018	0.810	0.016
Orewa	12	0.017	0.016	0.005	0.030	0.016	0.244	0.010	12	0.012	0.013	0.003	0.025	0.008	0.590	0.007
Browns Bay	12	0.017	0.015	0.002	0.048	0.011	1.240	0.010	12	0.018	0.018	0.007	0.027	0.008	0.040	0.012
Chelsea	12	0.018	0.020	0.003	0.028	0.011	-0.472	0.020	12	0.024	0.025	0.009	0.042	0.013	0.150	0.017
Henderson Creek	12	0.036	0.020	0.005	0.210	0.019	3.232	0.010	12	0.028	0.022	0.008	0.091	0.014	2.190	0.016
Whau Creek	12	0.017	0.017	0.000	0.045	0.012	1.160	0.010	12	0.018	0.017	0.007	0.042	0.008	1.680	0.010
Manukau Harbour																
Clarks Beach	12	0.030	0.029	0.011	0.052	0.023	0.298	0.029	12	0.054	0.030	0.002	0.164	0.055	1.370	0.036
Grahams Beach	12	0.018	0.016	0.005	0.038	0.016	0.707	0.010	12	0.026	0.014	0.003	0.115	0.028	2.270	0.022
Weymouth	12	0.042	0.037	0.019	0.130	0.021	2.505	0.033	12	0.153	0.064	0.008	0.765	0.171	2.420	0.112
Mangere Bridge	12	0.099	0.073	0.013	0.262	0.109	0.869	0.160	12	0.298	0.316	0.002	0.557	0.235	-0.240	0.290
Puketutu Point	12	0.110	0.110	0.016	0.238	0.098	0.441	0.130	12	0.423	0.294	0.090	1.450	0.326	1.880	0.203
Shag Point	12	0.046	0.027	0.012	0.122	0.040	1.213	0.049	12	0.094	0.084	0.005	0.211	0.076	0.411	0.090

	Dissolved Reactive Phosphorus (g.P.m^{-3})								Total Phosphorus (g.m^{-3})							
Site	Count	Mean	Median	Min	Max	IQR	Skew	01 -05	Count	Mean	Median	Min	Max	IQR	Skew	01 -05
Mahurangi Harbour																
Town Basin	12	0.020	0.020	0.010	0.031	0.010	0.220	0.020	12	0.037	0.041	0.017	0.091	0.020	1.570	0.040
Dawsons Creek	12	0.012	0.012	0.005	0.020	0.003	0.420	0.014	12	0.038	0.038	0.022	0.053	0.014	-0.023	0.040
Mahurangi Heads	12	0.011	0.011	0.005	0.020	0.002	0.988	0.020	12	0.031	0.030	0.020	0.052	0.010	0.949	0.030
Tamaki Estuary																
Panmure Basin	12	0.018	0.018	0.009	0.026	0.006	0.197	0.020	12	0.048	0.050	0.023	0.094	0.016	1.055	0.050
No. 7 Buoy	12	0.015	0.014	0.010	0.022	0.007	0.504	0.020	12	0.043	0.043	0.030	0.065	0.009	0.879	0.040
Upper Waitemata Harbour																
Hobsonville Jetty	12	0.014	0.014	0.008	0.020	0.007	-0.033	0.020	12	0.033	0.031	0.020	0.050	0.007	0.767	0.032
Waimarie Rd	12	0.019	0.019	0.011	0.042	0.006	2.330	0.020	12	0.037	0.039	0.024	0.060	0.015	0.537	0.040
Confluence	12	0.018	0.020	0.011	0.026	0.006	-0.012	0.020	12	0.039	0.038	0.020	0.060	0.009	0.292	0.040
Paremoremo Ski Club	12	0.016	0.016	0.010	0.020	0.007	-0.159	0.020	12	0.039	0.038	0.022	0.060	0.005	0.946	0.040
Rarawaru Creek	12	0.016	0.015	0.011	0.022	0.007	0.162	0.020	12	0.043	0.045	0.026	0.060	0.017	-0.117	0.050
Lucas Creek	12	0.016	0.017	0.010	0.020	0.007	-0.326	0.020	12	0.038	0.037	0.018	0.060	0.012	0.353	0.040
Brighams Creek	12	0.018	0.019	0.009	0.030	0.006	0.315	0.020	12	0.045	0.042	0.022	0.070	0.026	0.214	0.050
Rangitopuni Creek	11	0.017	0.016	0.008	0.030	0.007	0.409	0.020	11	0.047	0.044	0.023	0.070	0.022	0.175	0.050
Kaipara Harbour																
Shelly Beach	12	0.019	0.020	0.008	0.030	0.006	-0.406	0.020	12	0.059	0.052	0.028	0.127	0.026	1.396	0.070
East Coast																
Goat Island	12	0.013	0.012	0.006	0.020	0.008	0.420	0.020	12	0.025	0.022	0.014	0.055	0.010	1.950	0.030
Ti Point	12	0.013	0.010	0.005	0.037	0.006	2.100	0.020	12	0.027	0.030	0.015	0.037	0.014	-0.350	0.030
Orewa	12	0.011	0.011	0.005	0.020	0.006	0.730	0.020	12	0.027	0.027	0.016	0.043	0.013	0.500	0.030
Browns Bay	12	0.015	0.016	0.007	0.026	0.007	0.620	0.020	12	0.029	0.030	0.018	0.044	0.008	0.390	0.031
Chelsea	12	0.016	0.016	0.010	0.021	0.007	-0.250	0.020	12	0.030	0.030	0.016	0.046	0.016	0.300	0.030
Henderson Creek	12	0.016	0.017	0.009	0.020	0.008	-0.510	0.020	12	0.034	0.035	0.019	0.051	0.021	0.050	0.040
Whau Creek	12	0.015	0.015	0.009	0.021	0.010	-0.030	0.020	12	0.037	0.039	0.020	0.050	0.022	-0.190	0.040
Manukau Harbour																
Clarks Beach	12	0.017	0.019	0.005	0.026	0.008	-0.650	0.020	12	0.043	0.040	0.032	0.061	0.012	1.120	0.050
Grahams Beach	12	0.014	0.015	0.005	0.021	0.011	-0.300	0.020	12	0.039	0.037	0.025	0.059	0.017	0.640	0.040
Weymouth	12	0.020	0.021	0.005	0.040	0.013	0.450	0.030	12	0.049	0.043	0.035	0.104	0.010	2.910	0.060
Mangere Bridge	12	0.141	0.143	0.091	0.200	0.071	0.090	0.180	12	0.178	0.168	0.095	0.300	0.050	0.730	0.220
Puketutu Point	12	0.195	0.119	0.035	0.672	0.182	1.880	0.180	12	0.233	0.133	0.046	0.841	0.203	2.070	0.210
Shag Point	12	0.060	0.061	0.029	0.080	0.025	-0.432	0.080	12	0.085	0.082	0.044	0.134	0.021	0.418	0.110

	Enterococci (cfu/100mL)								Chlorophyll a (mg/L)							
Site	Count	Mean	Median	Min	Max	IQR	Skew	01 -05	Count	Mean	Median	Min	Max	IQR	Skew	01 -05
Mahurangi Harbour																
Town Basin	11	80	142	18	360	174	0.67	106	12	0.0030	0.0041	0.0008	0.0160	0.0023	2.730	0.0028
Dawsons Creek	11	2	2	2	5	0	2.81	2	12	0.0036	0.0033	0.0006	0.0083	0.0015	1.210	0.0033
Mahurangi Heads	11	2	2	2	2	0	0.00	2	11	0.0028	0.0013	0.0006	0.0148	0.0012	3.094	0.0017
Tamaki Estuary																
Panmure Basin	12	59	14	2	360	56	2.89	16	12	0.0036	0.0040	0.0015	0.0056	0.0022	-0.222	0.0028
No. 7 Buoy	12	20	2	2	116	22	2.39	3	12	0.0023	0.0024	0.0008	0.0035	0.0015	-0.197	0.0026
Upper Waitemata Harbour																
Hobsonville Jetty	12	3	2	2	17	0	3.46	2	12	0.0029	0.0029	0.0006	0.0076	0.0018	1.438	0.0027
Waimarie Rd	12	13	2	2	64	7	1.91	3	12	0.0030	0.0025	0.0006	0.0060	0.0025	0.428	0.0026
Confluence	12	8	3	2	58	3	3.28	5	12	0.0040	0.0042	0.0012	0.0083	0.0033	0.452	0.0043
Paremoremo Ski Club	12	12	5	2	56	15	2.18	8	12	0.0033	0.0025	0.0008	0.0066	0.0046	0.591	0.0028
Rarawaru Creek	12	15	7	2	84	13	2.78	15	12	0.0046	0.0038	0.0017	0.0100	0.0052	0.462	0.0032
Lucas Creek	12	15	6	2	108	8	3.31	10	12	0.0029	0.0026	0.0006	0.0055	0.0035	0.181	0.0031
Brighams Creek	12	22	8	2	162	8	3.30	17	12	0.0050	0.0065	0.0006	0.0097	0.0062	-0.210	0.0052
Rangitopuni Creek	11	54	12	2	480	10	3.31	18	11	0.0067	0.0062	0.0012	0.0156	0.0030	0.917	0.0060
Kaipara Harbour																
Shelly Beach	12	8	2	2	33	4	1.64	2	12	0.0041	0.0032	0.0018	0.0081	0.0021	1.072	0.0060
East Coast																
Goat Island	12	2	2	2	2	0	0.00	2	12	0.0018	0.0015	0.0006	0.0048	0.0012	1.630	0.0016
Ti Point	12	5	2	2	33	1	3.41	2	12	0.0016	0.0016	0.0006	0.0034	0.0011	0.840	0.0015
Orewa	12	4	2	2	12	2	2.22	2	12	0.0023	0.0020	0.0006	0.0060	0.0020	1.380	0.0020
Browns Bay	12	4	2	2	23	1	3.03	2	12	0.0019	0.0015	0.0006	0.0054	0.0010	1.800	0.0019
Chelsea	12	14	2	2	128	4	3.43	2	12	0.0027	0.0020	0.0006	0.0074	0.0018	1.400	0.0022
Henderson Creek	12	45	4	2	480	8	3.46	9	12	0.0017	0.0015	0.0006	0.0040	0.0013	1.160	0.0021
Whau Creek	12	12	2	2	118	2	3.46	2	12	0.0021	0.0016	0.0006	0.0051	0.0019	1.020	0.0025
Manukau Harbour																
Clarks Beach	12	5	2	2	24	1	2.35	2	12	0.0031	0.0024	0.0006	0.0074	0.0037	0.810	0.0029
Grahams Beach	12	2	2	2	3	0	3.46	2	12	0.0035	0.0025	0.0006	0.0085	0.0043	0.710	0.0027
Weymouth	12	89	7	2	950	16	3.45	4	12	0.0040	0.0036	0.0006	0.0082	0.0052	0.500	0.0047
Mangere Bridge	12	18	4	2	116	9	2.66	5	12	0.0074	0.0032	0.0006	0.0196	0.0142	0.810	0.0049
Puketutu Point	12	6	2	2	28	3	2.29	2	12	0.0047	0.0028	0.0006	0.0124	0.0077	0.590	0.0039
Shag Point	12	3	2	2	7	0	2.24	2	12	0.0050	0.0037	0.0006	0.0117	0.0062	0.702	0.0046

2.7 Historic Variation

The following series of gaphs show the variation over time of individual water quality variables at each site monitored. Data is included from the point that monitoring began.

Figure 3: Mahurangi harbour – salinity (ppt)

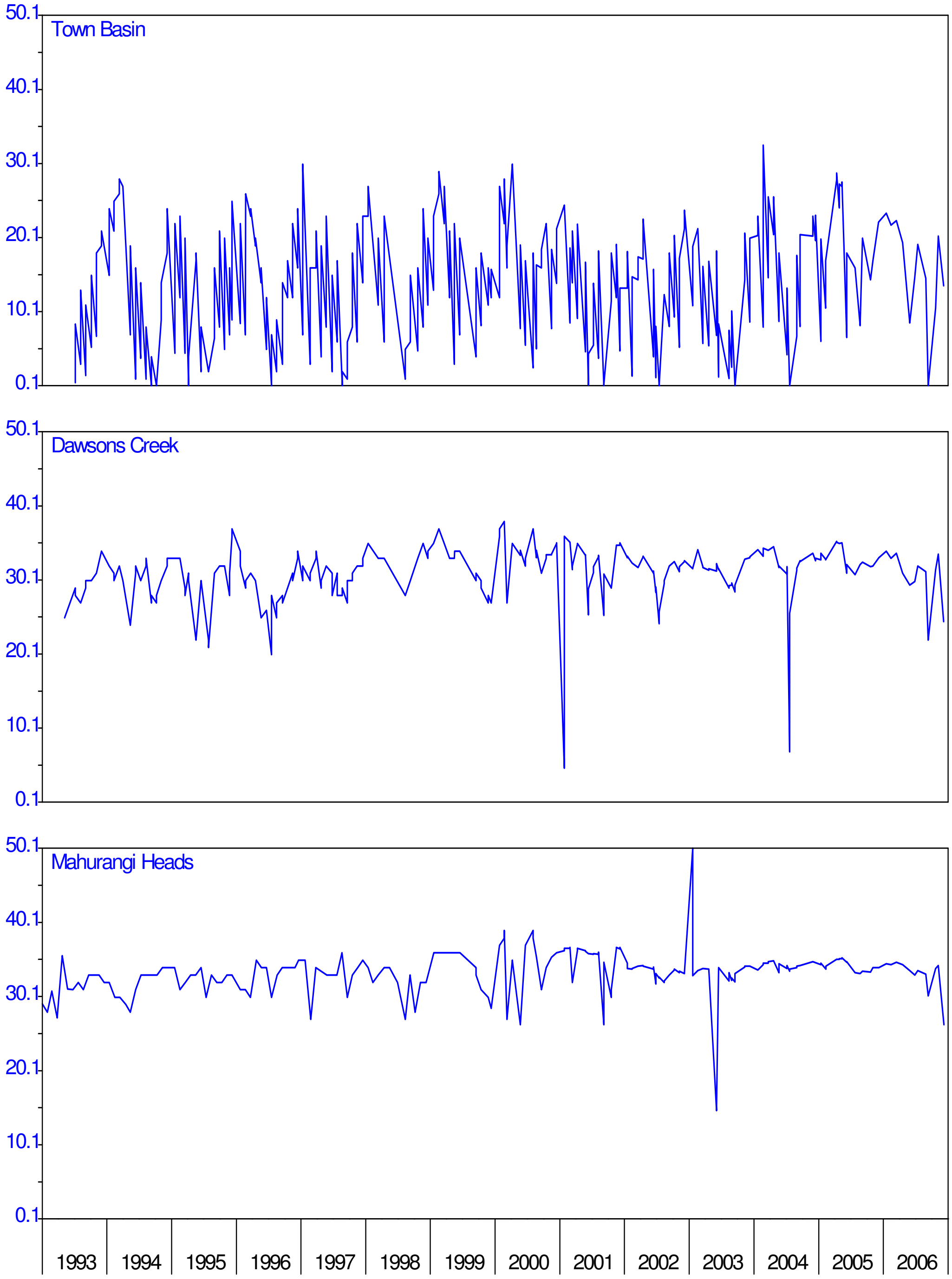


Figure 4: Mahurangi harbour – turbidity (NTU)

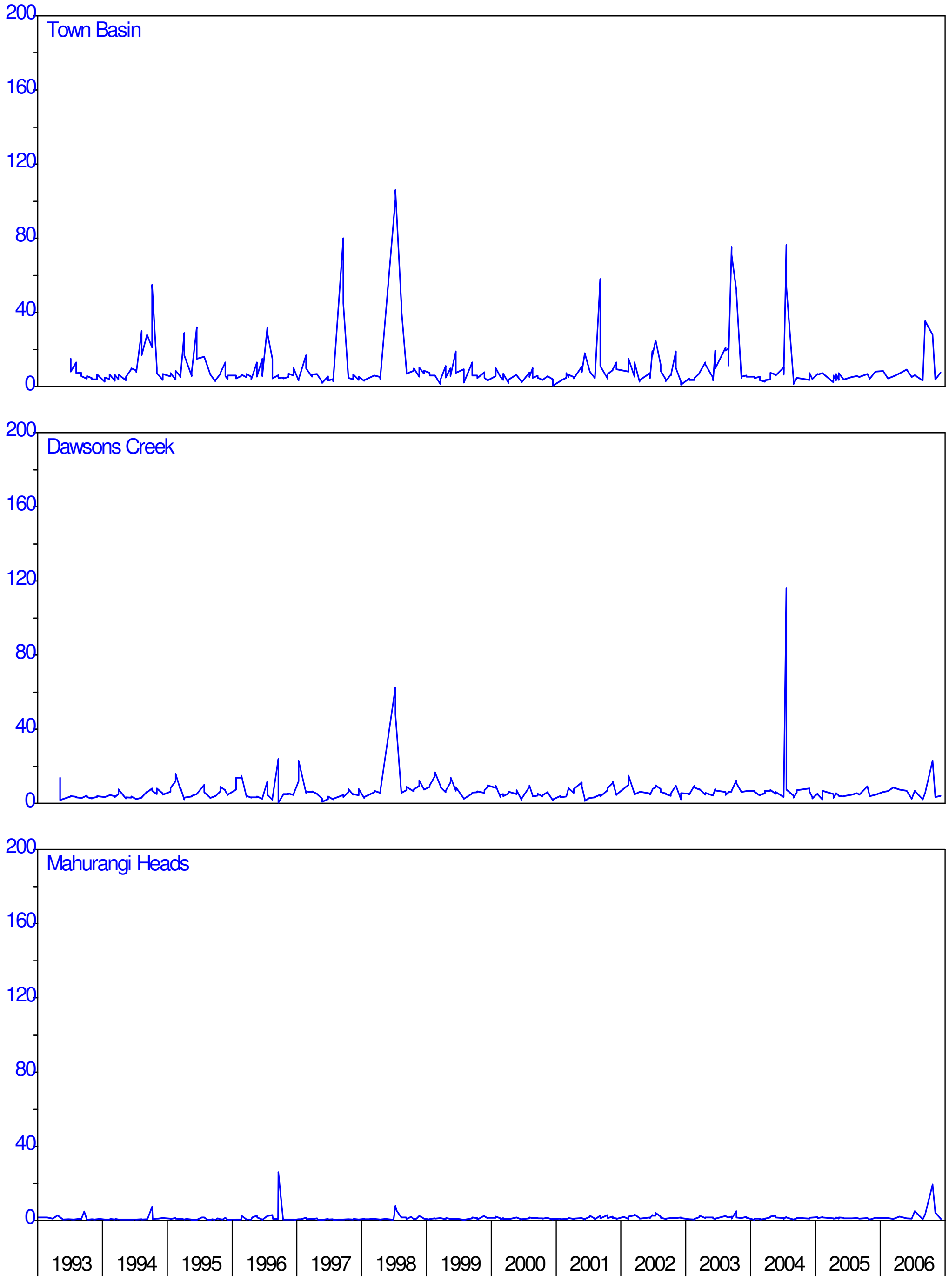


Figure 5: Mahurangi harbour – transparency (Secchi depth (m))

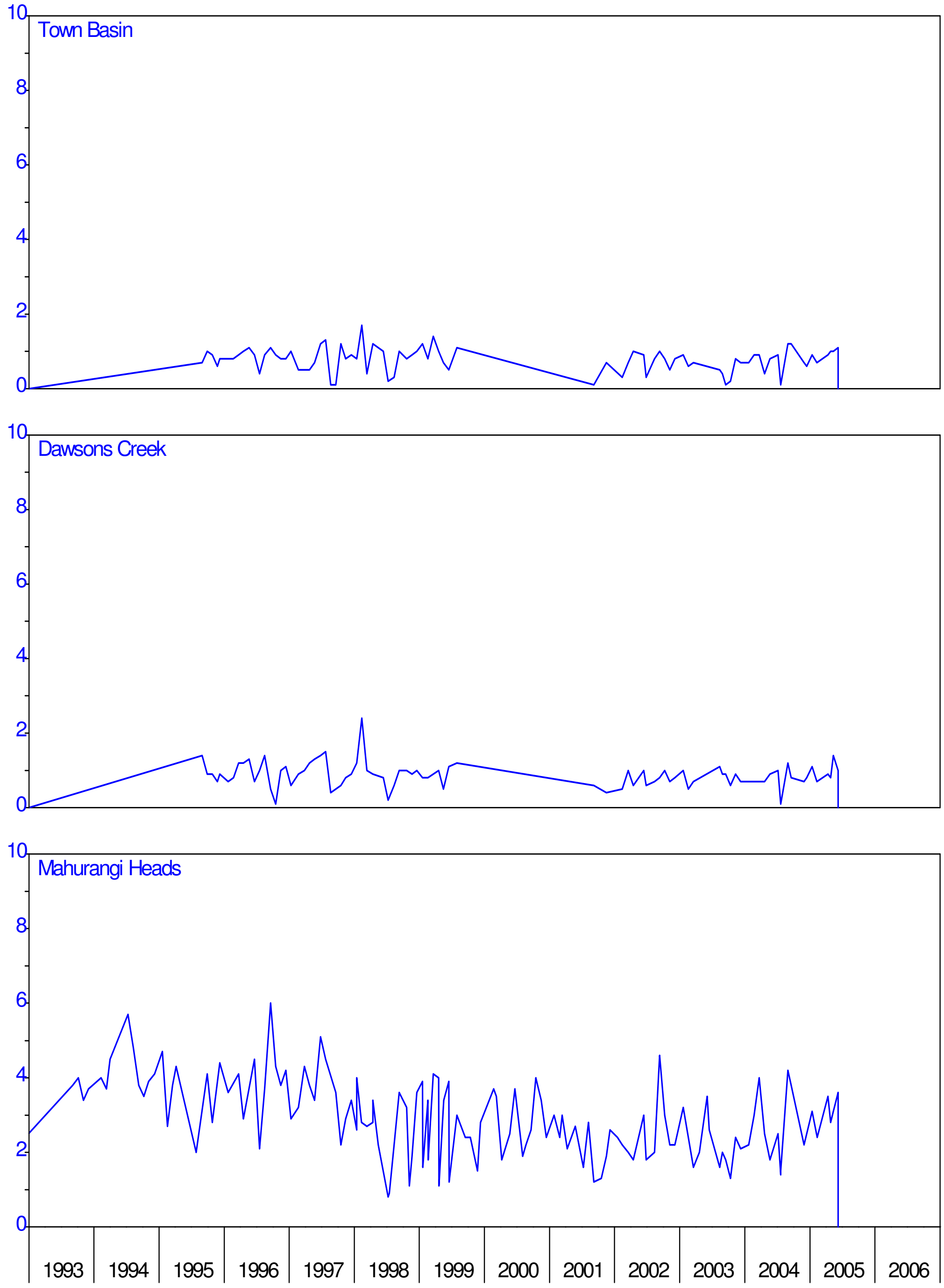


Figure 6: Mahurangi harbour – temperature (°C)

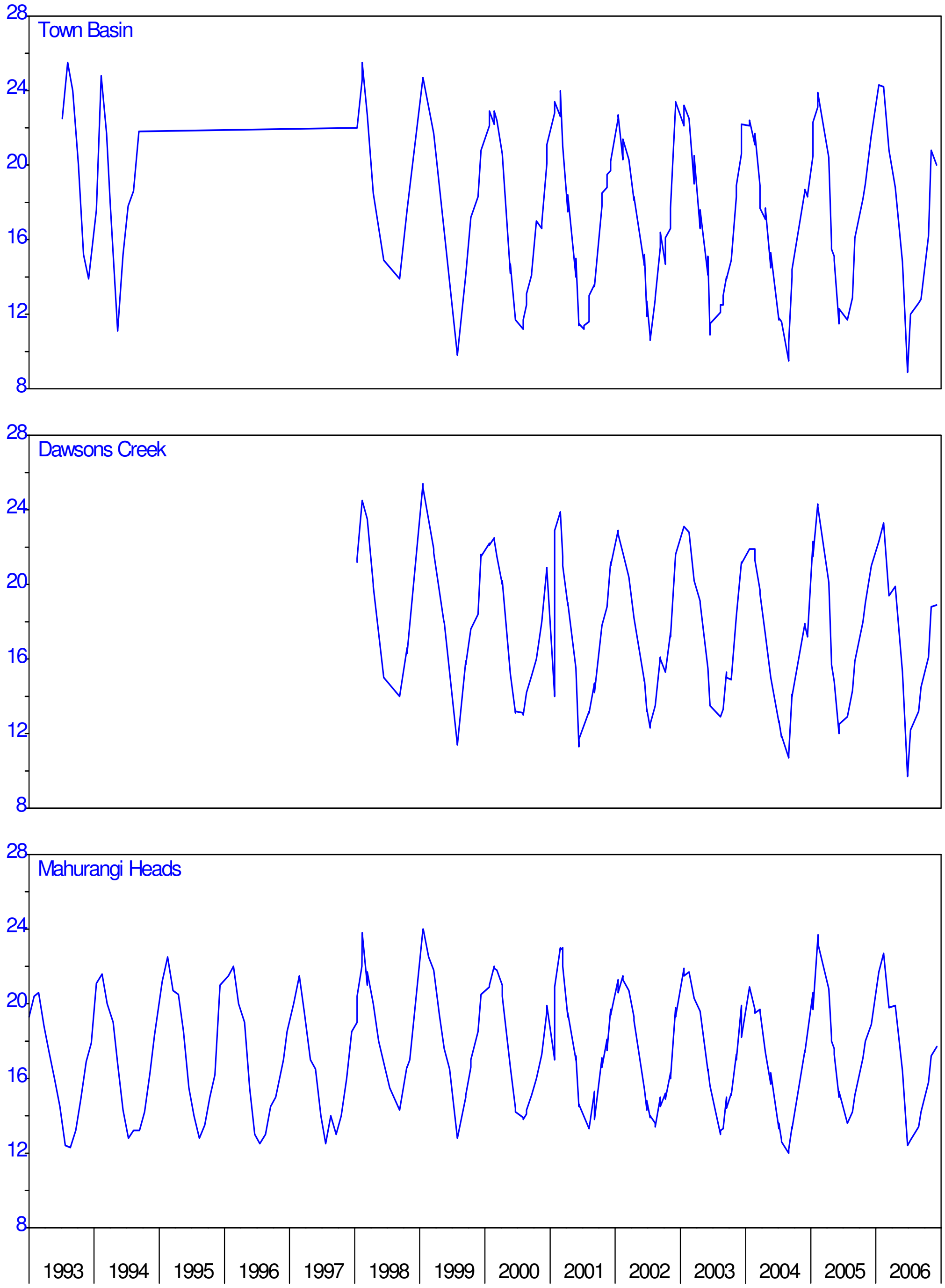


Figure 7: Mahurangi harbour - pH

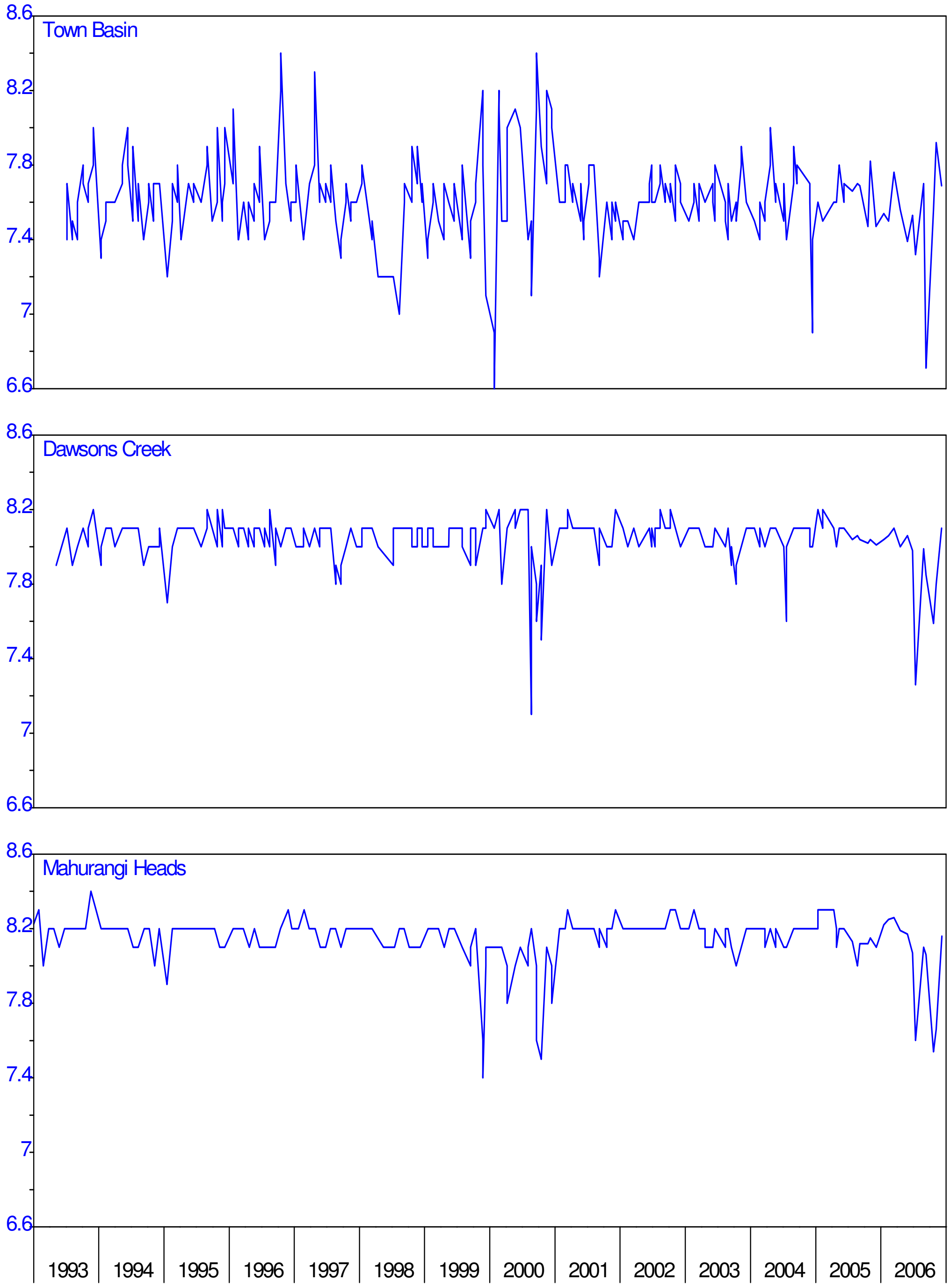


Figure 8: Mahurangi harbour – suspended solids (ppm)

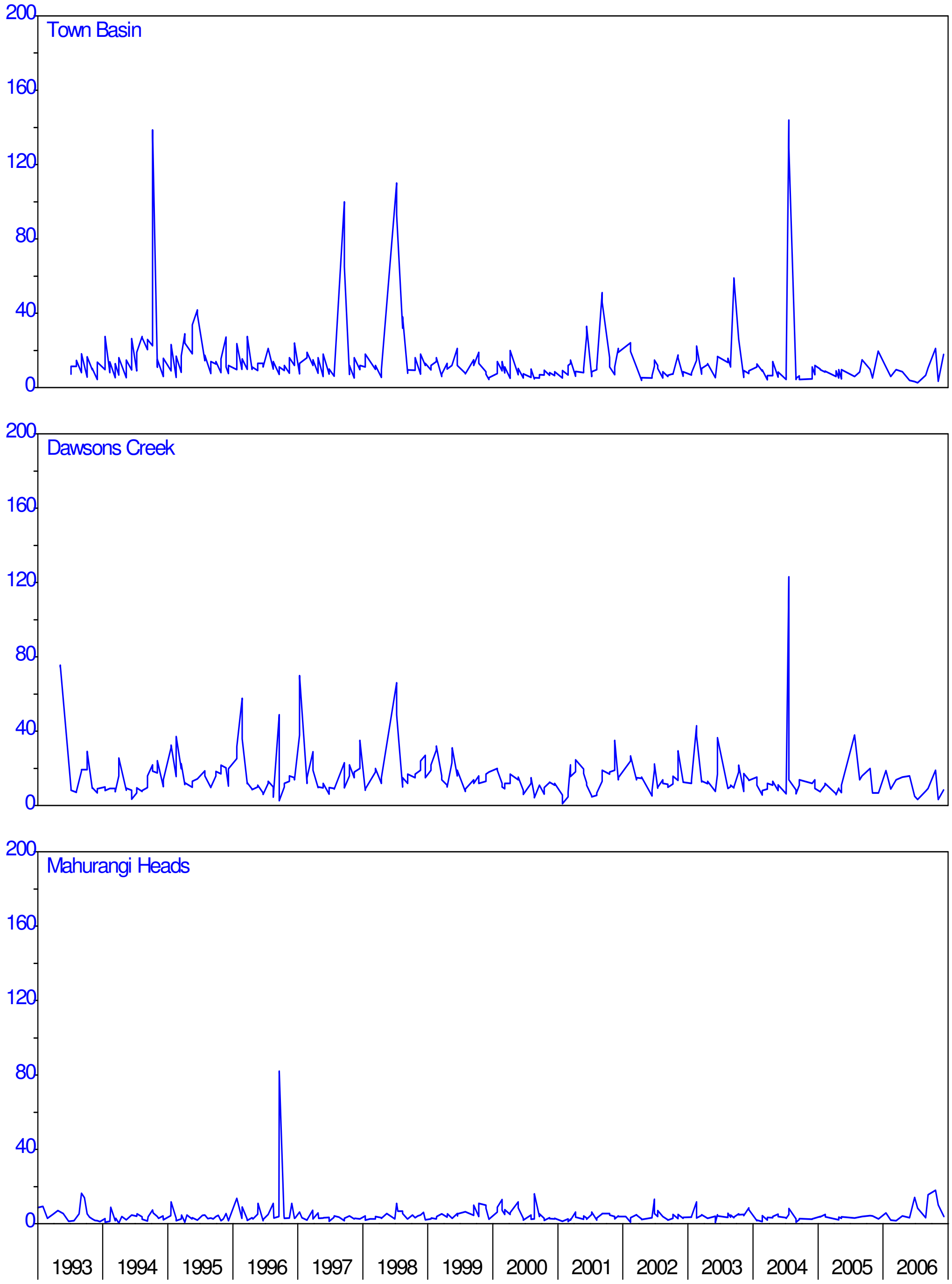


Figure 9: Mahurangi harbour – Nitrate+Nitrite ($gN.m^{-3}$)

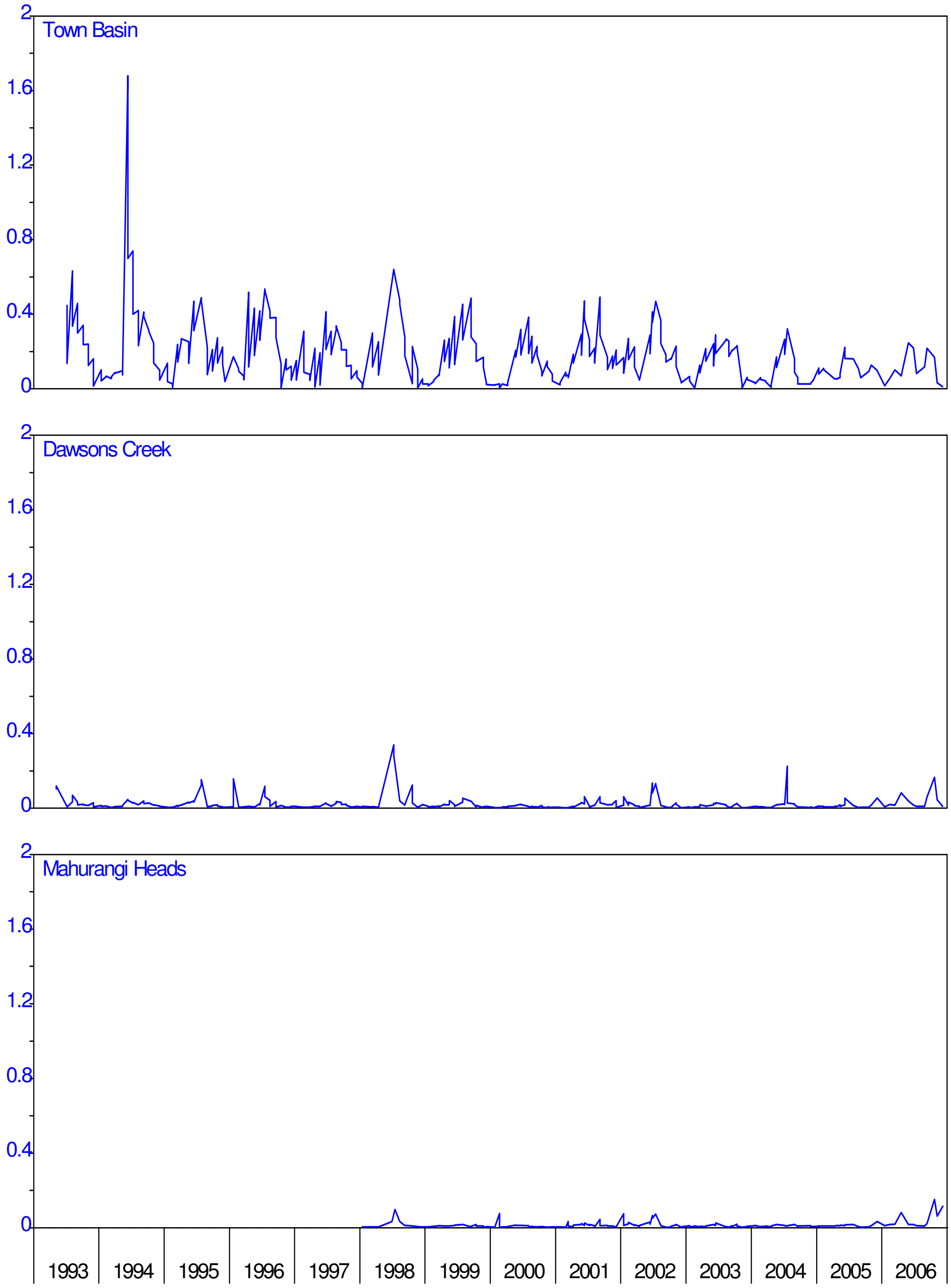


Figure 10: Mahurangi harbour – Ammoniacal nitrogen (gN.m^{-3})

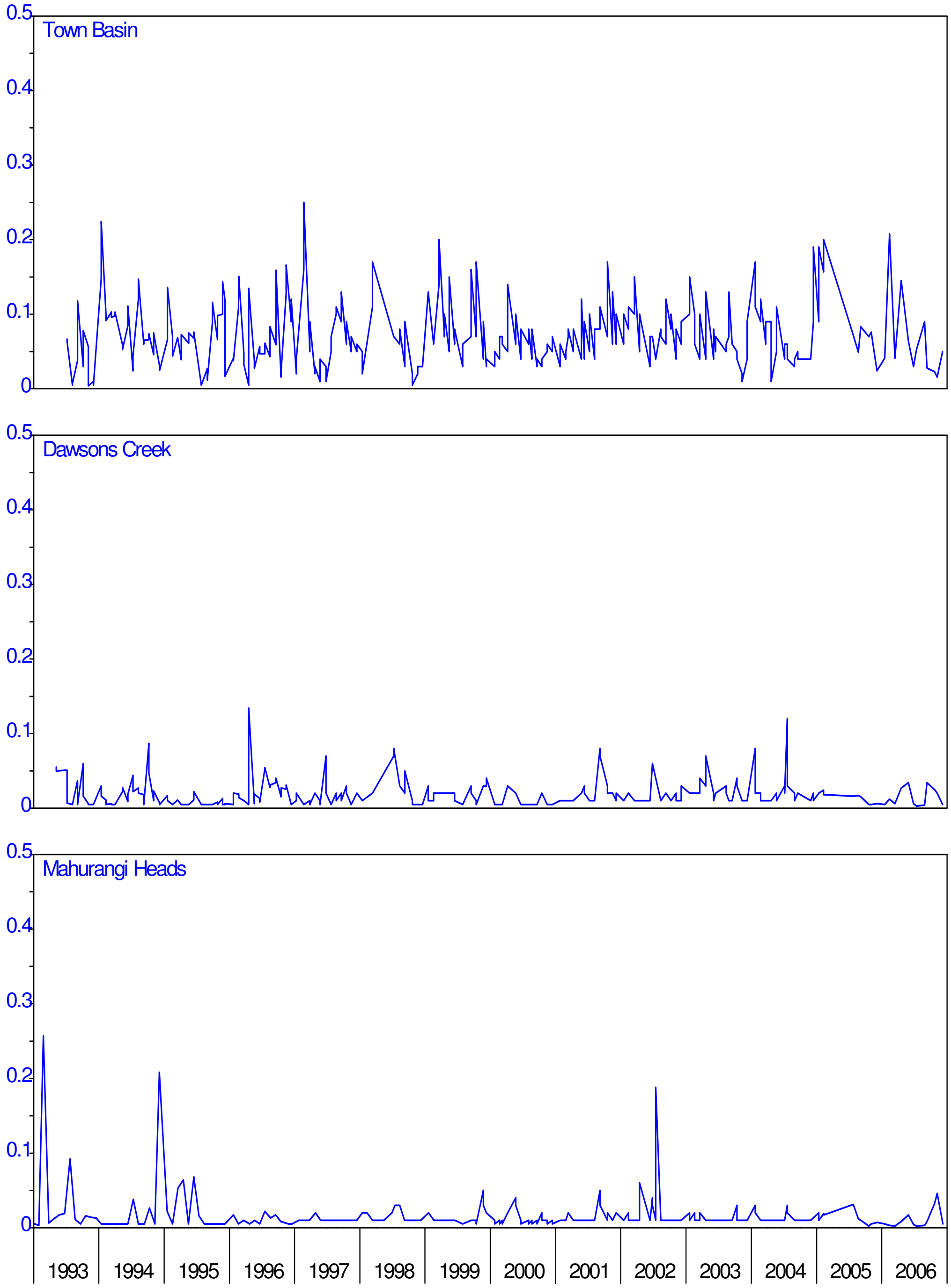


Figure 11: Mahurangi harbour – dissolved oxygen (%saturated)

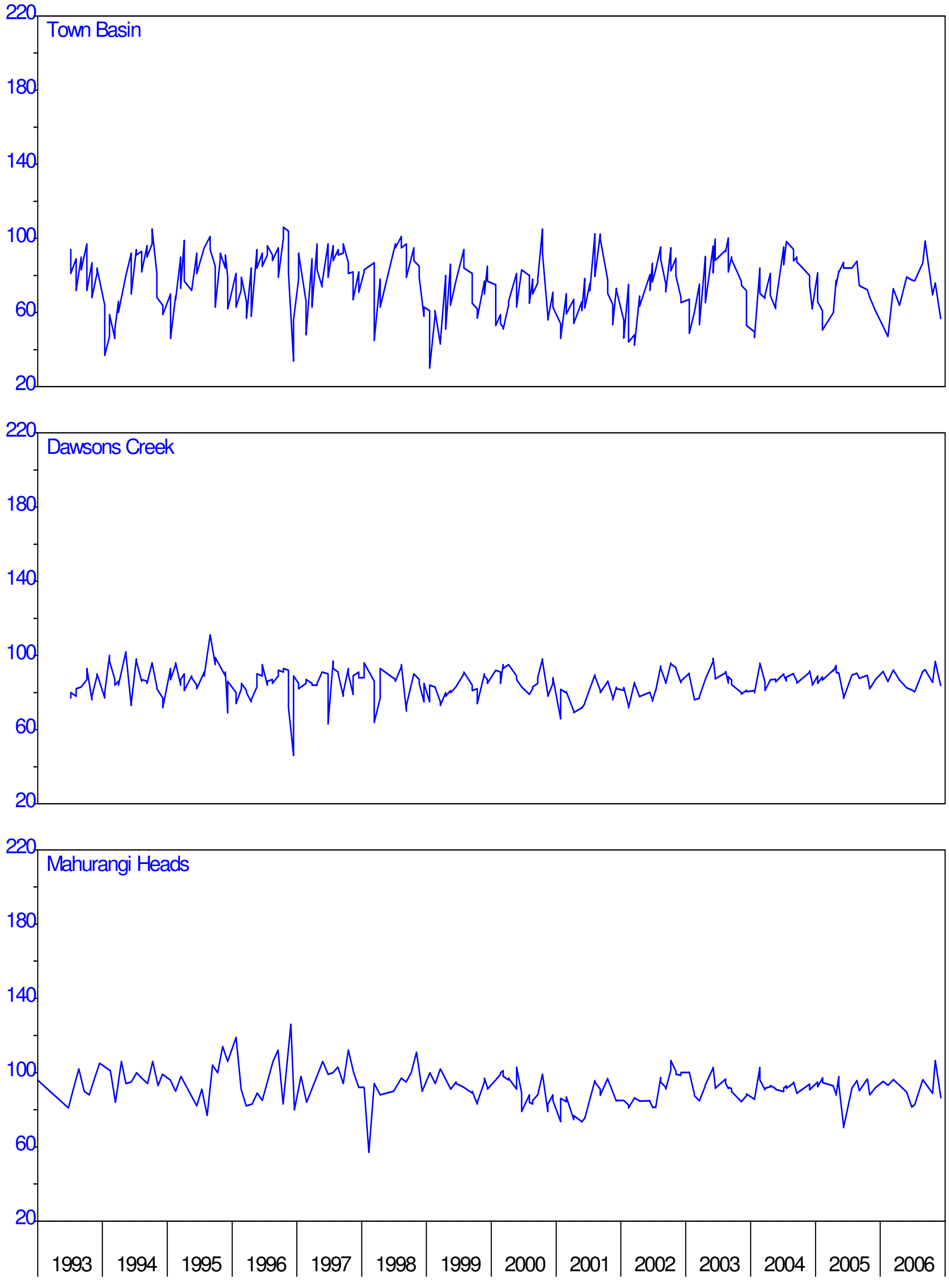


Figure 12: Mahurangi harbour – dissolved oxygen (ppm)

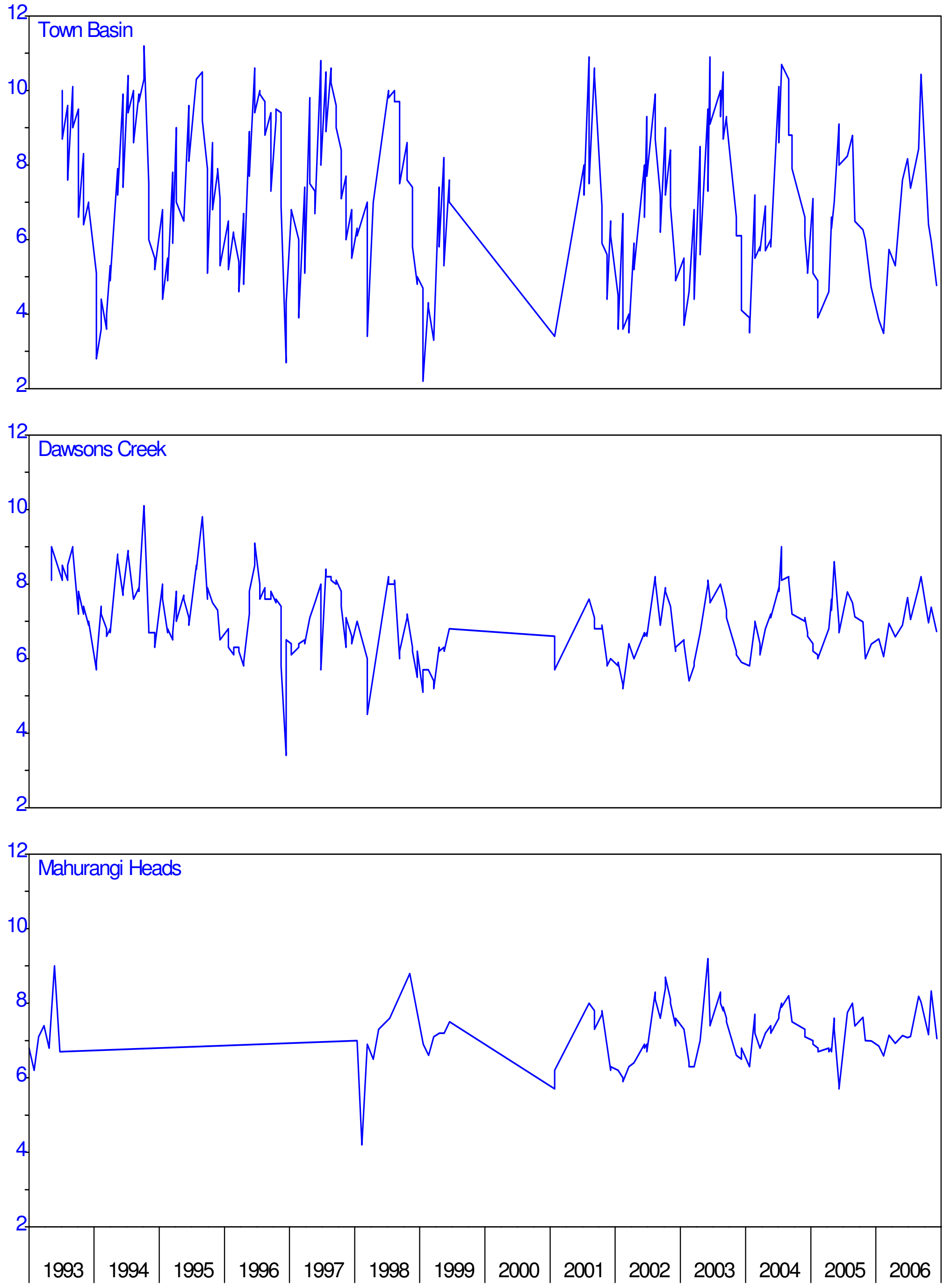


Figure 13: Mahurangi harbour – Total phosphorus (g.m^{-3})

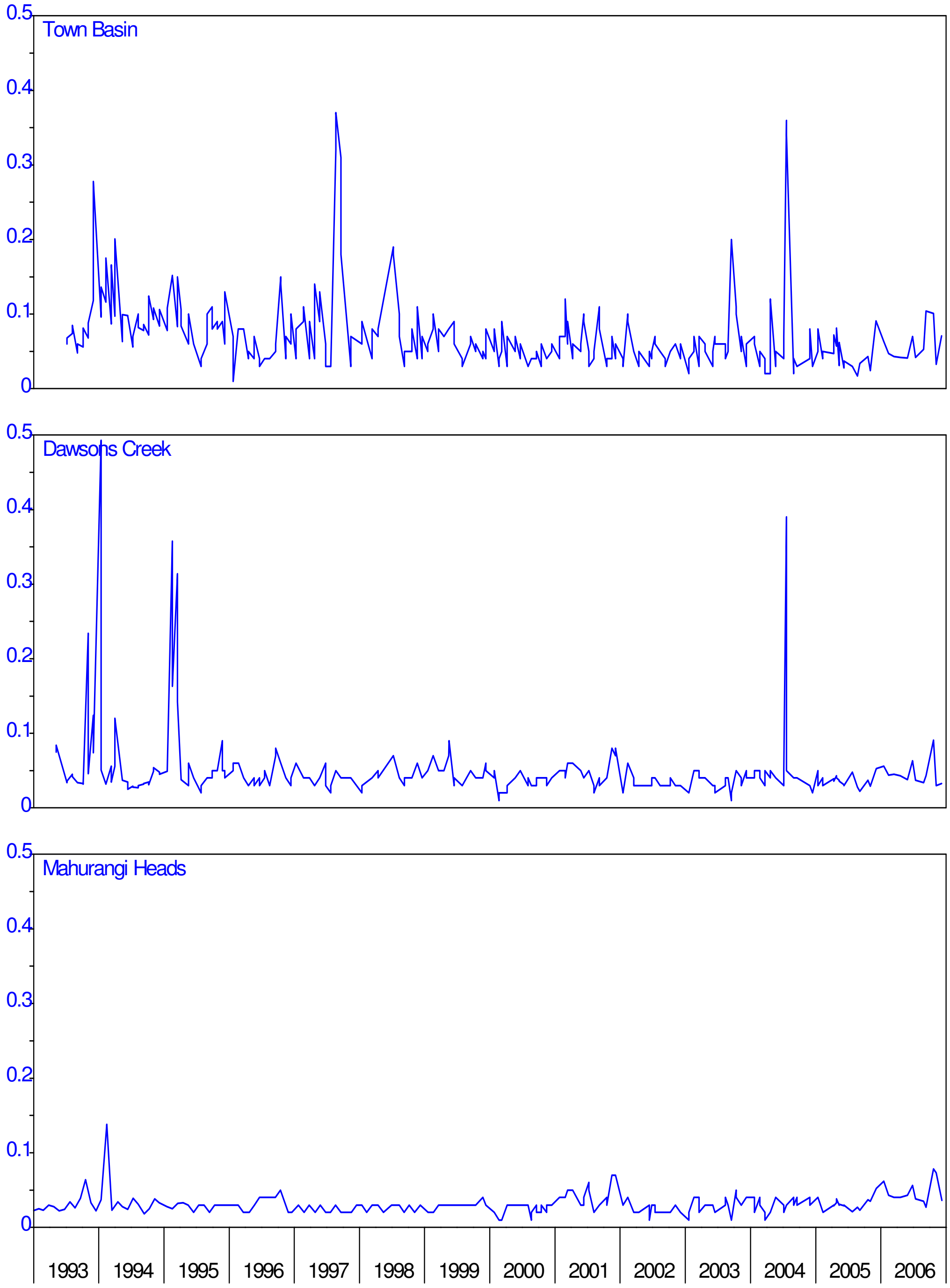


Figure 14: Mahurangi harbour – dissolved reactive phosphorus (gP.m^{-3})

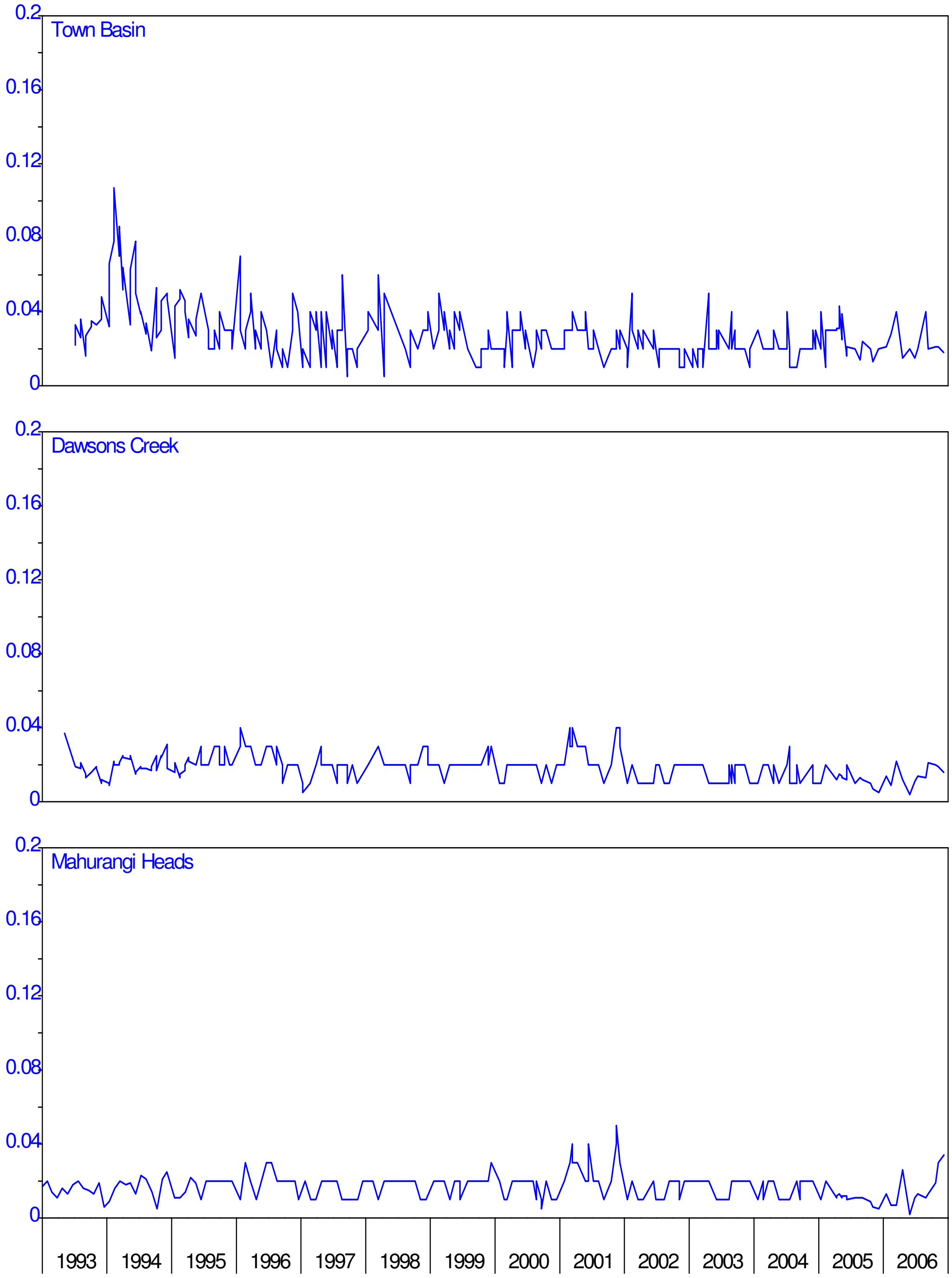


Figure 15: Mahurangi harbour – enterococci (cfu/100ml)

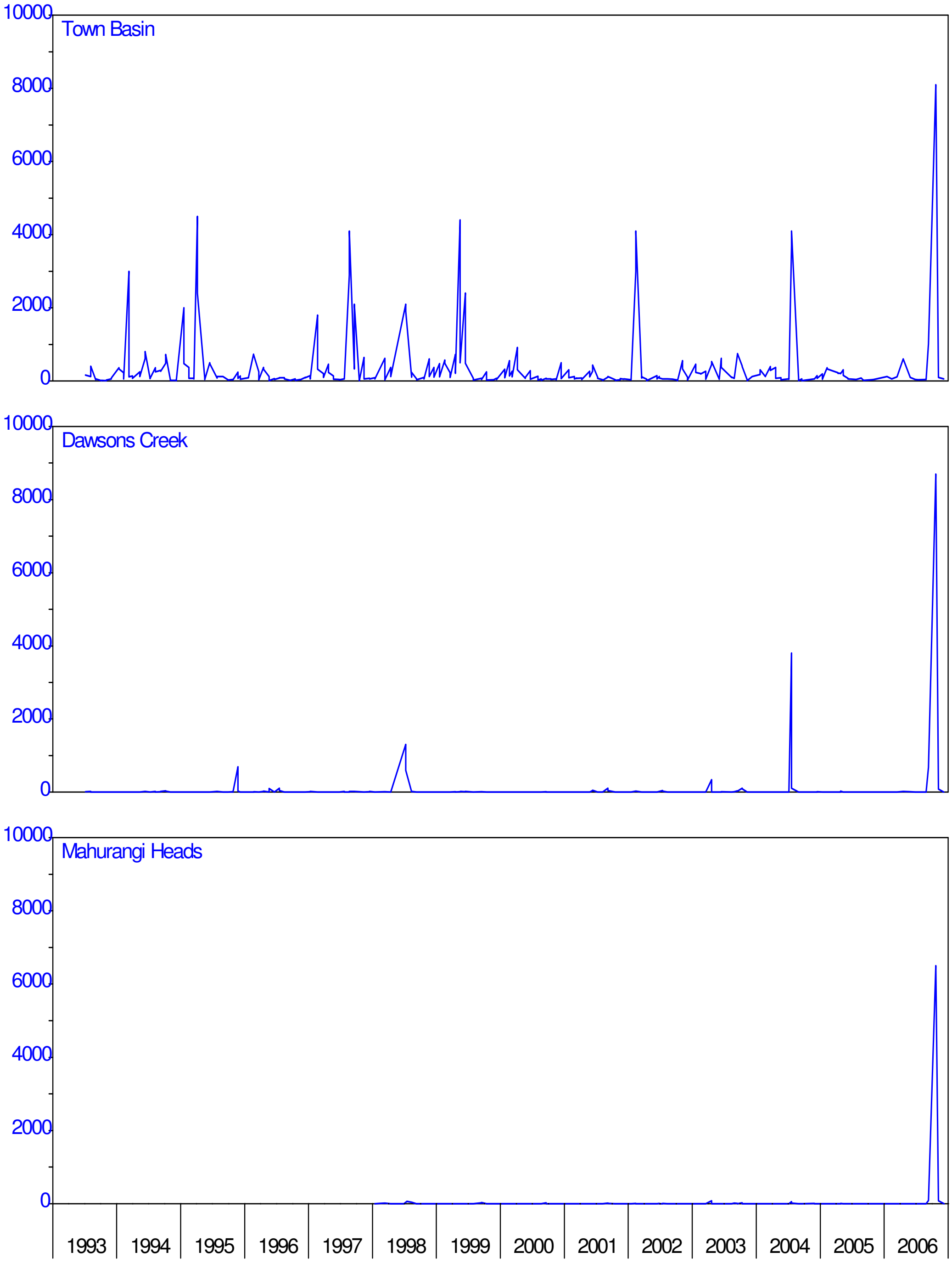


Figure 16: Mahurangi harbour – Chlorophyll a (ppm)

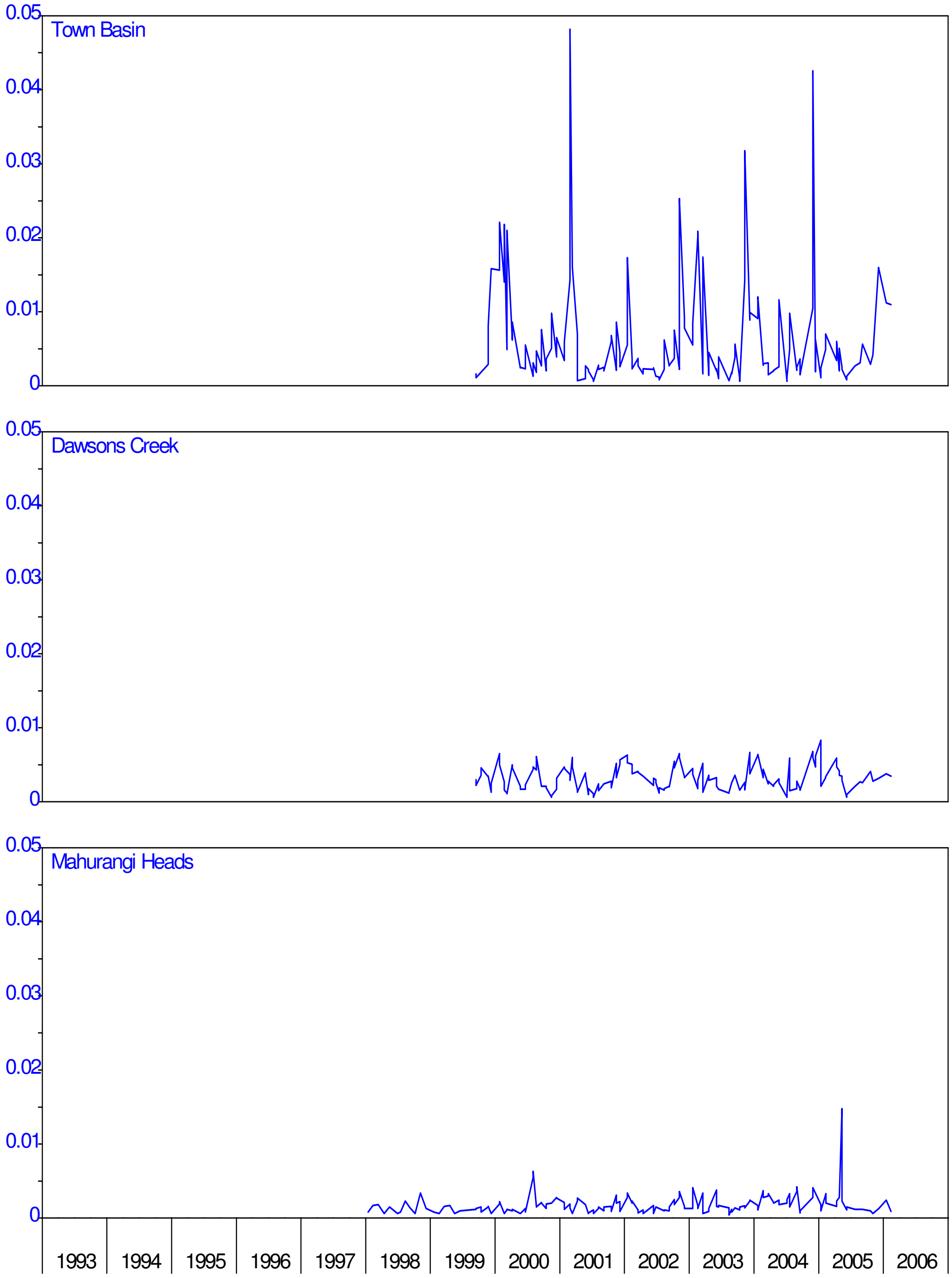


Figure 17 Upper Waitemata harbour – Salinity (ppt)

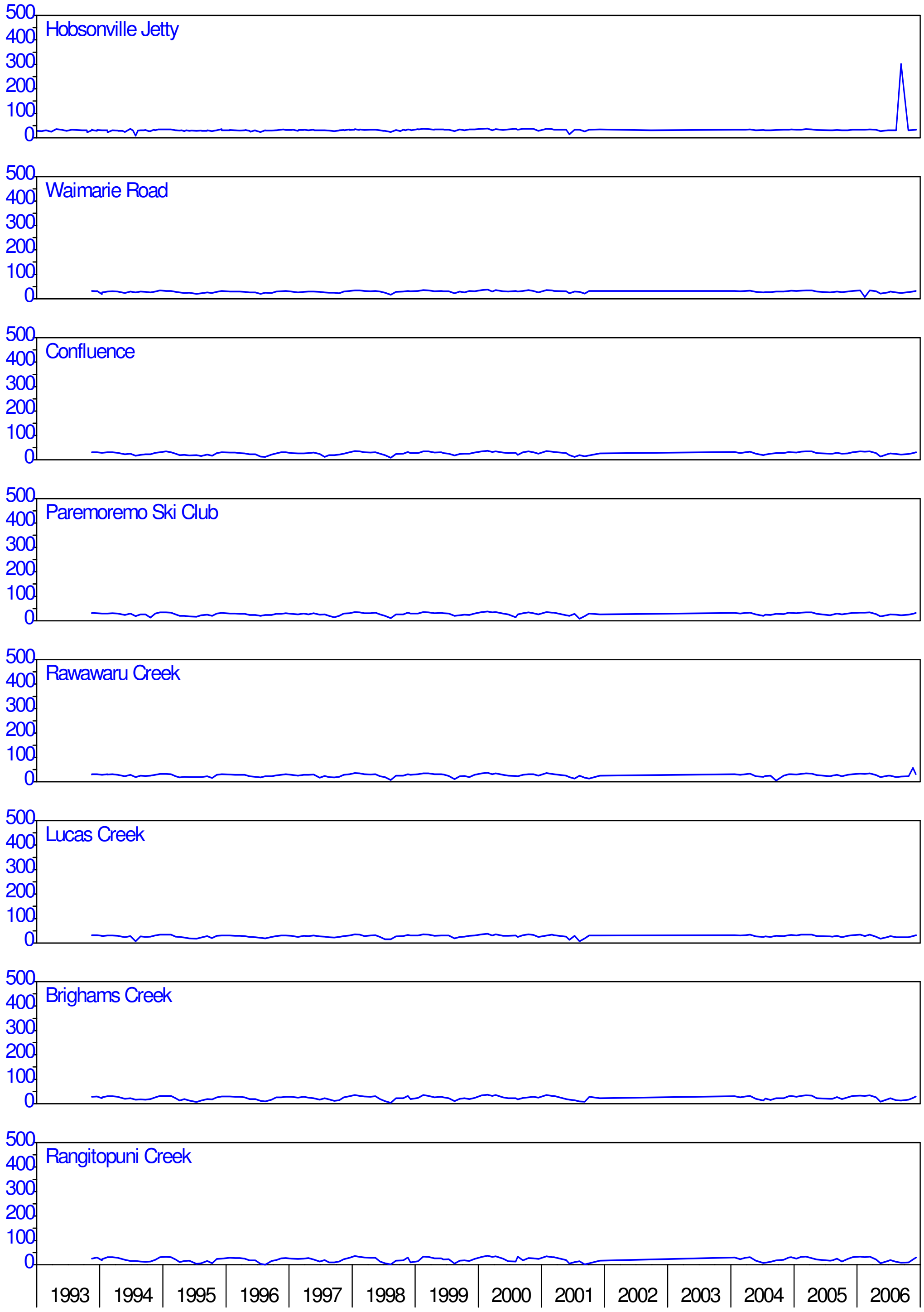


Figure 18: Upper Waitemata harbour – turbidity (NTU)

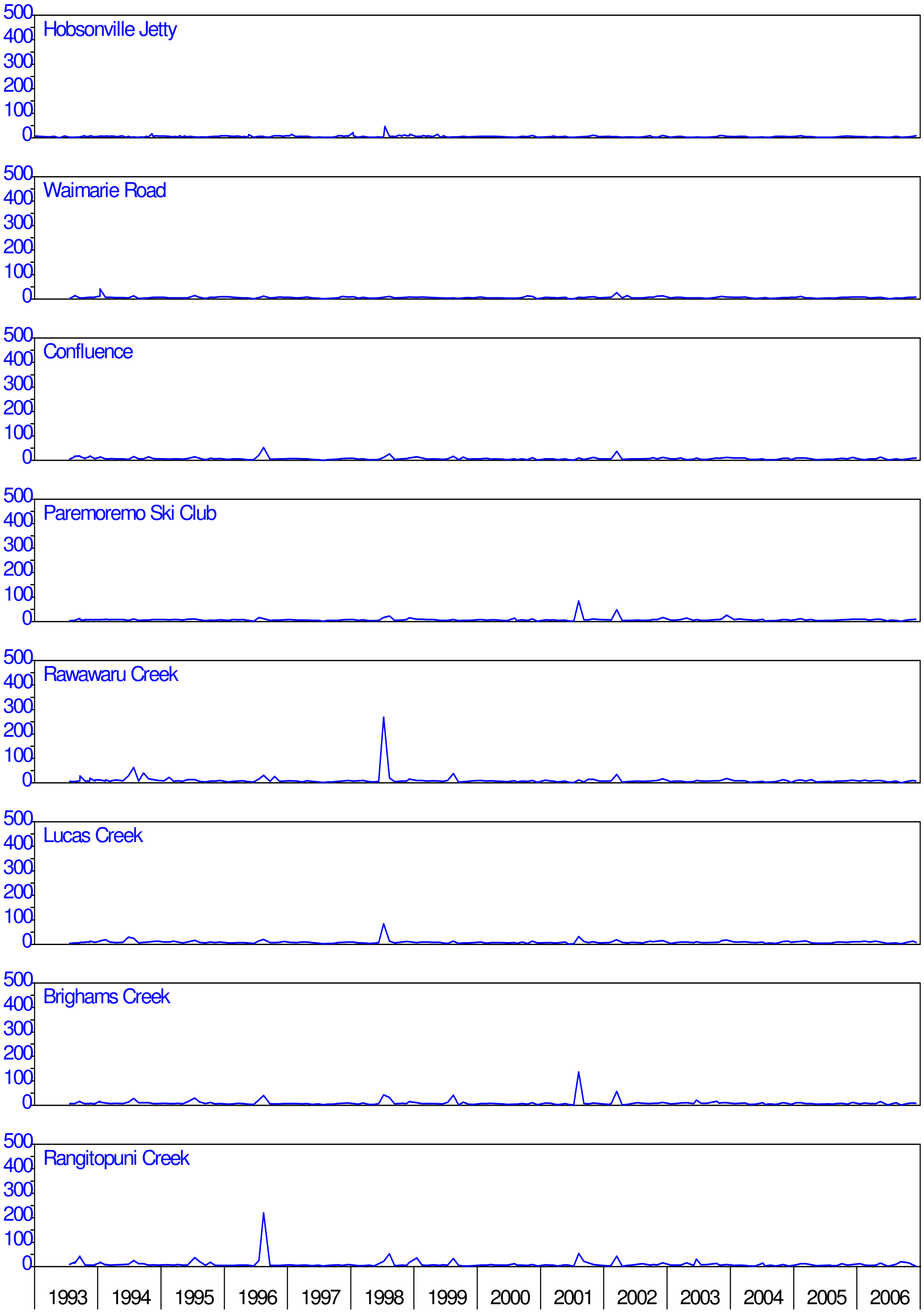


Figure 19: Upper Waitemata harbour – transparency (Secchi (m))

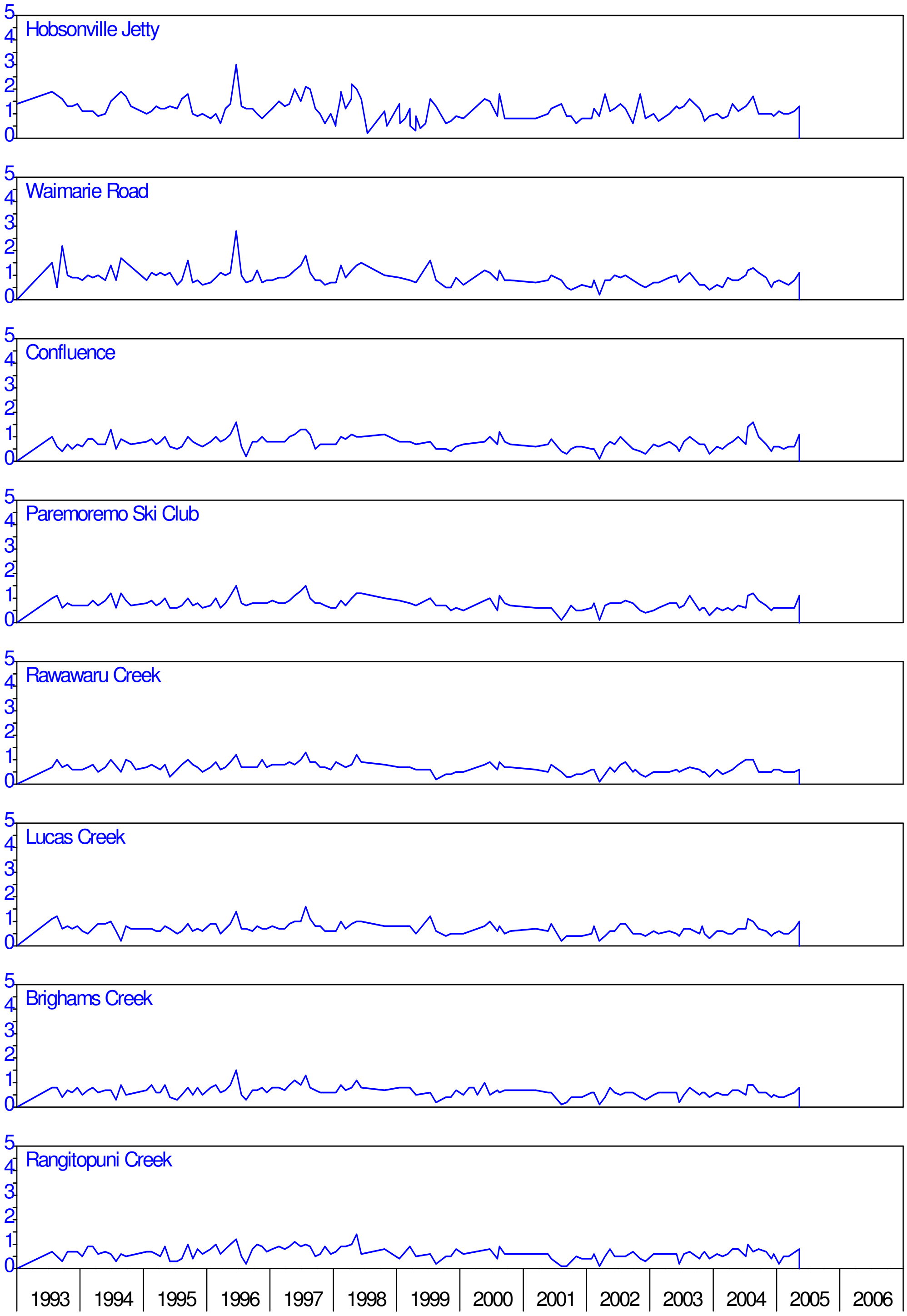


Figure 20: Upper Waitemata harbour – temperature (°C)

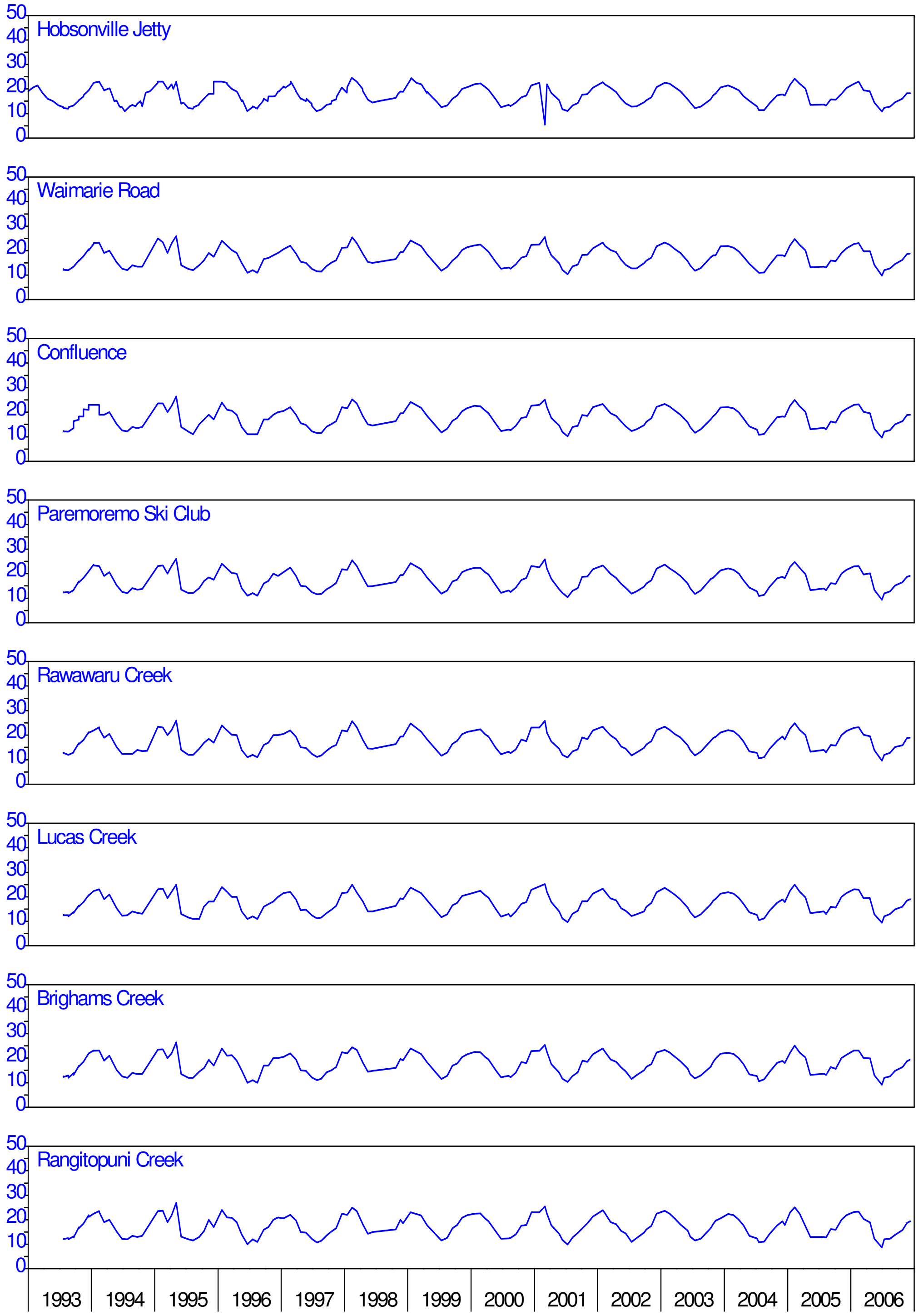


Figure 21: Upper Waitemata harbour - pH

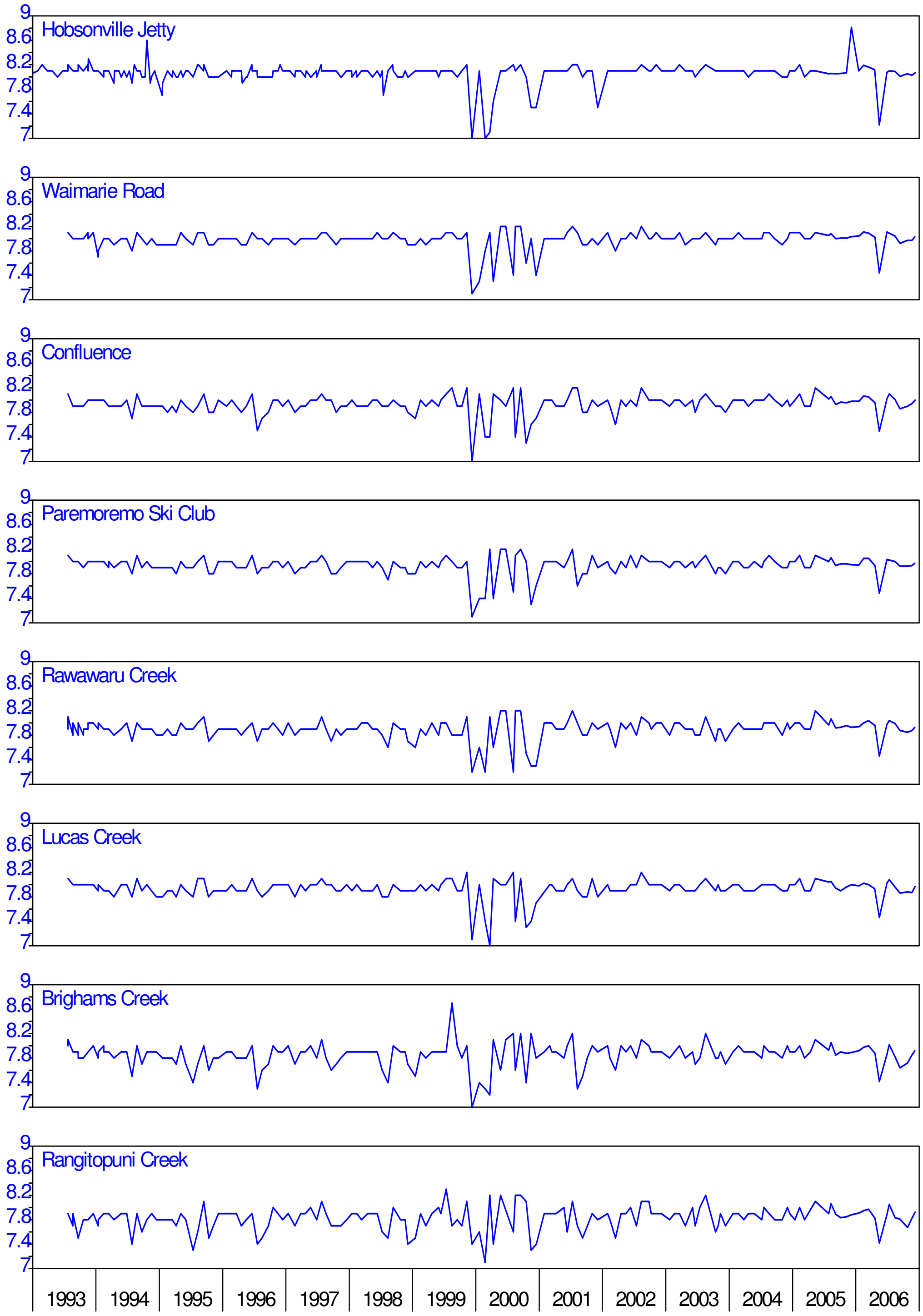


Figure 22: Upper Waitemata harbour – suspended solids (ppm)

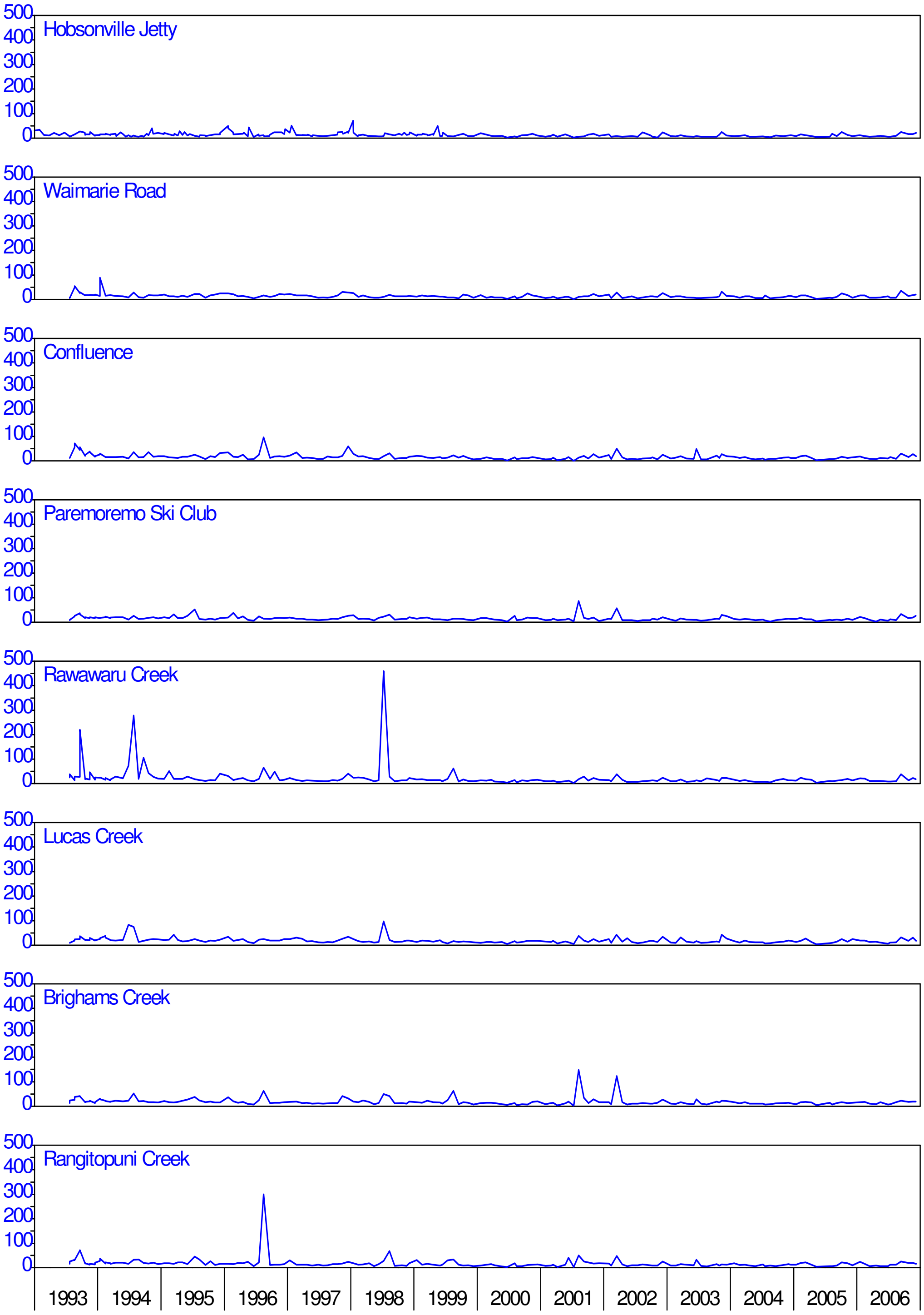


Figure 23: Upper Waitemata harbour – nitrate+nitrite (gN.m^{-3})

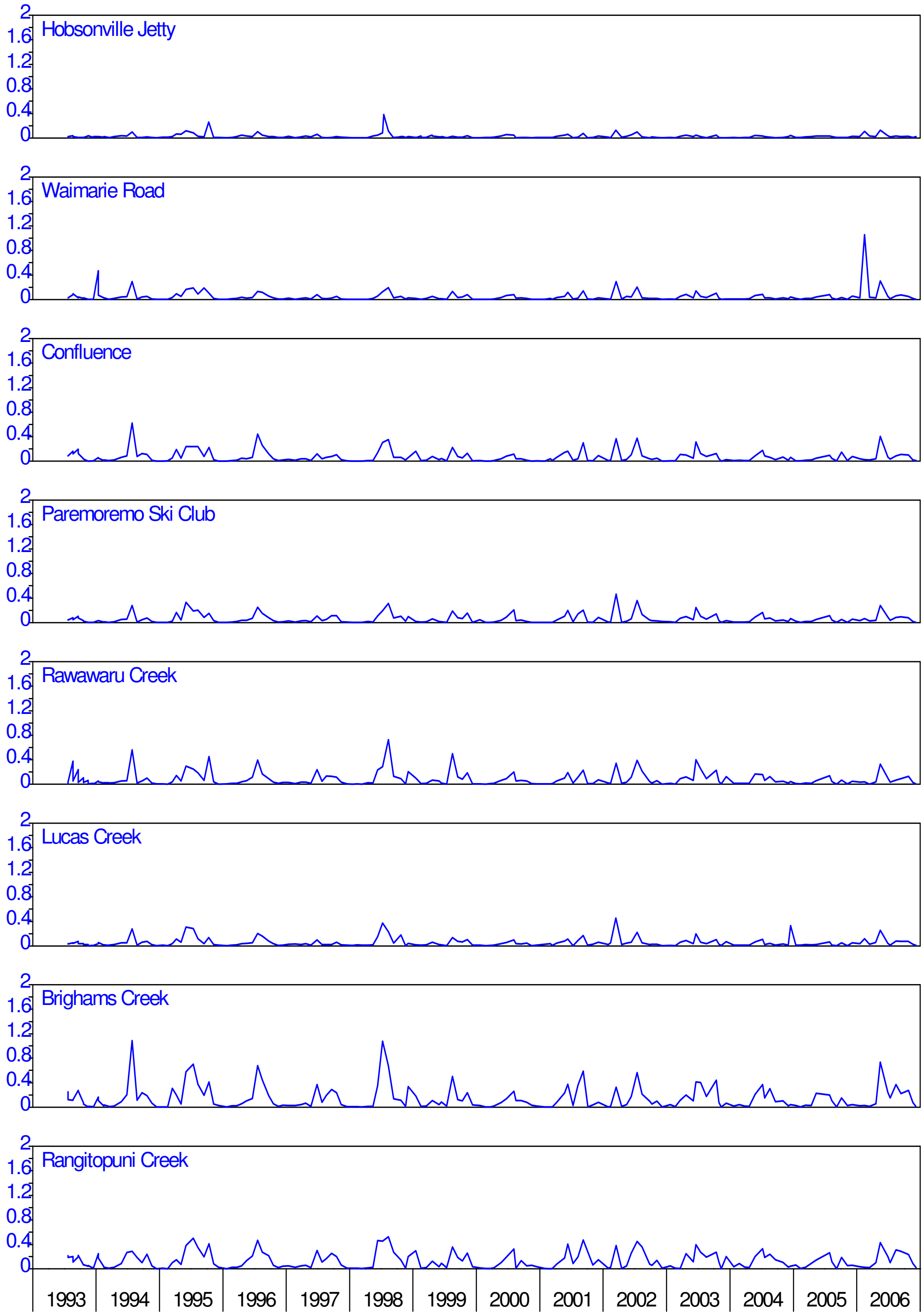


Figure 24: Upper Waitemata harbour – ammoniacal nitrogen ($gN.m^{-3}$)

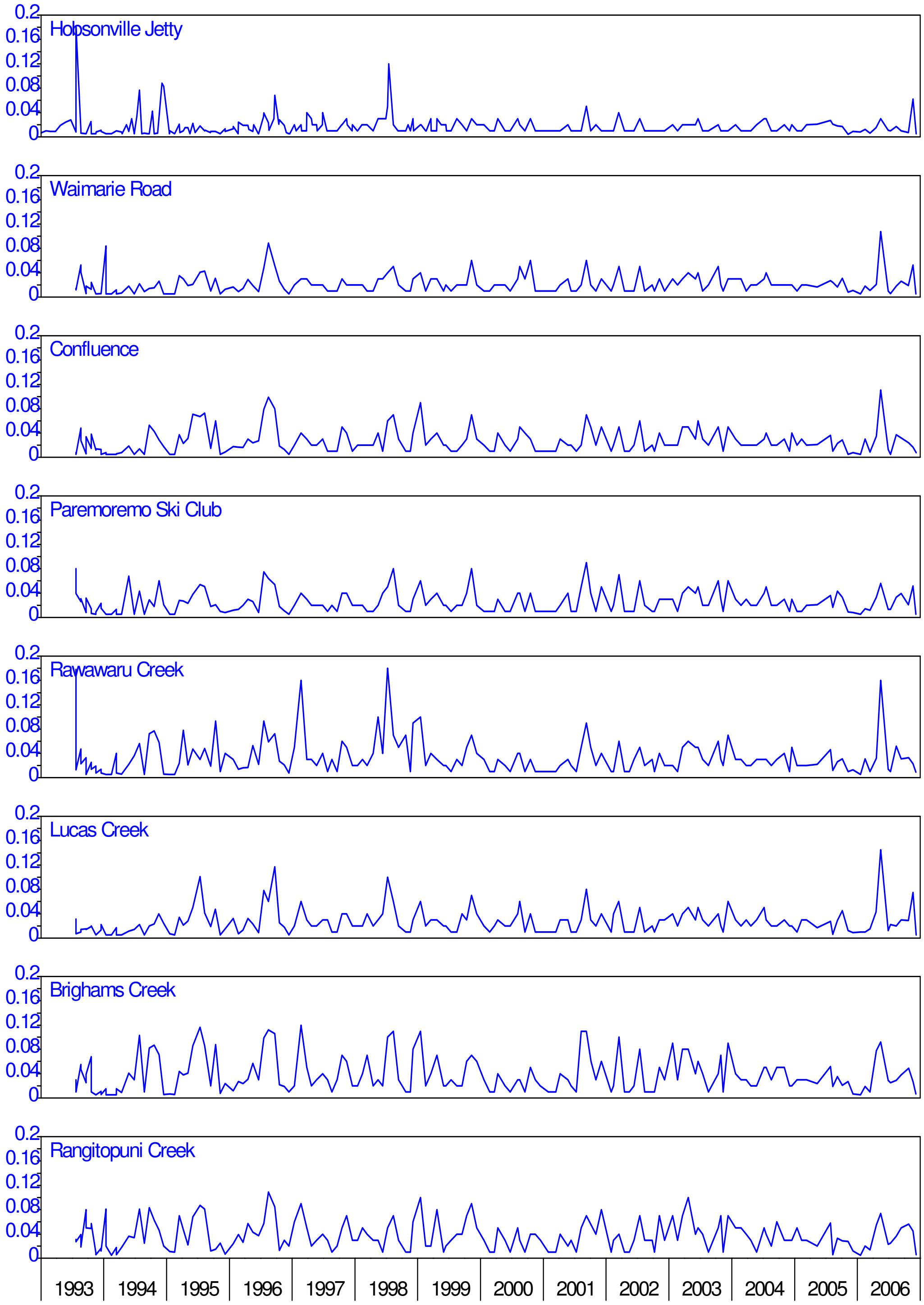


Figure 25: Upper Waitemata harbour – dissolved oxygen (% saturated)

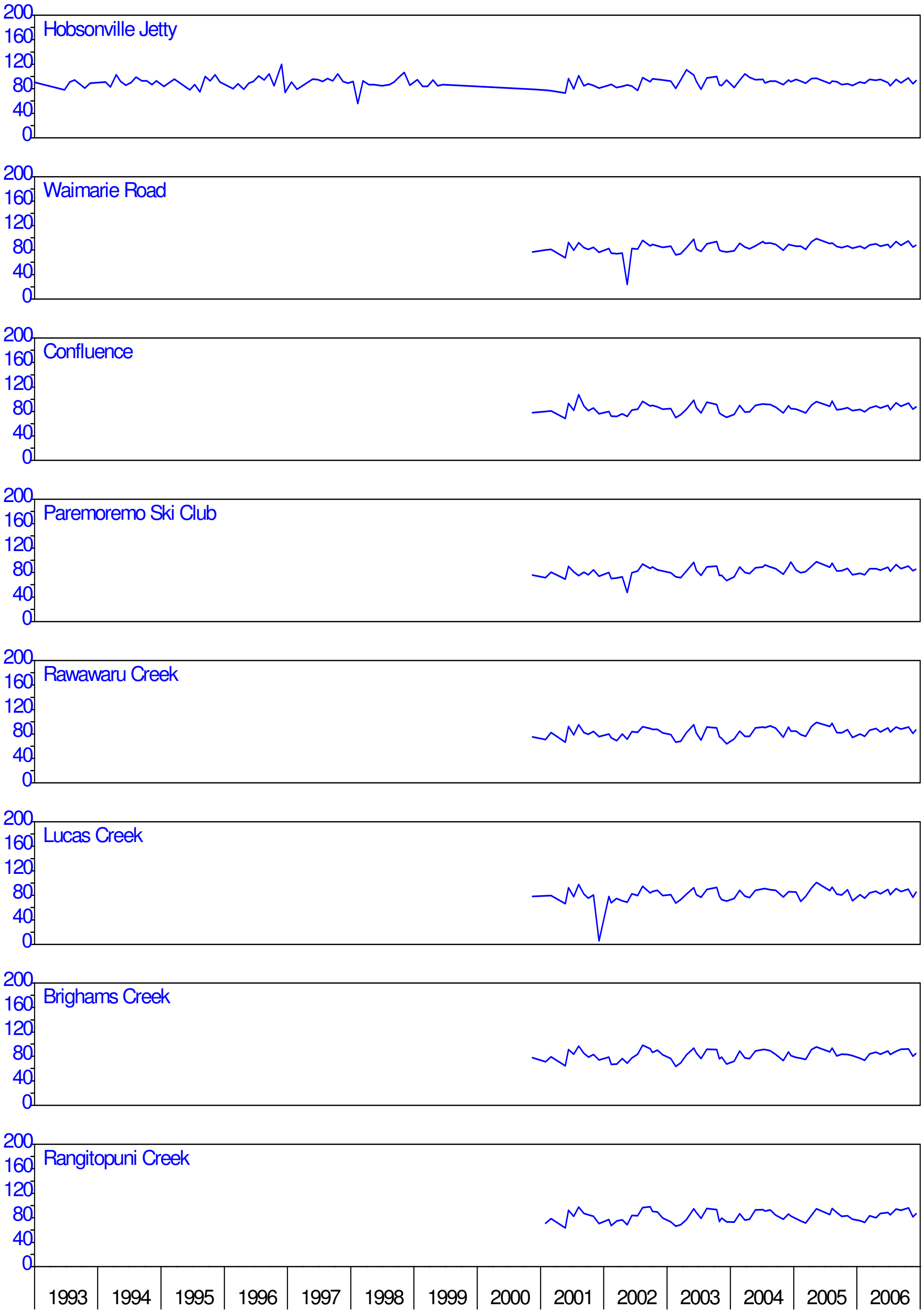


Figure 26: Upper Waitemata harbour – dissolved oxygen (ppm)

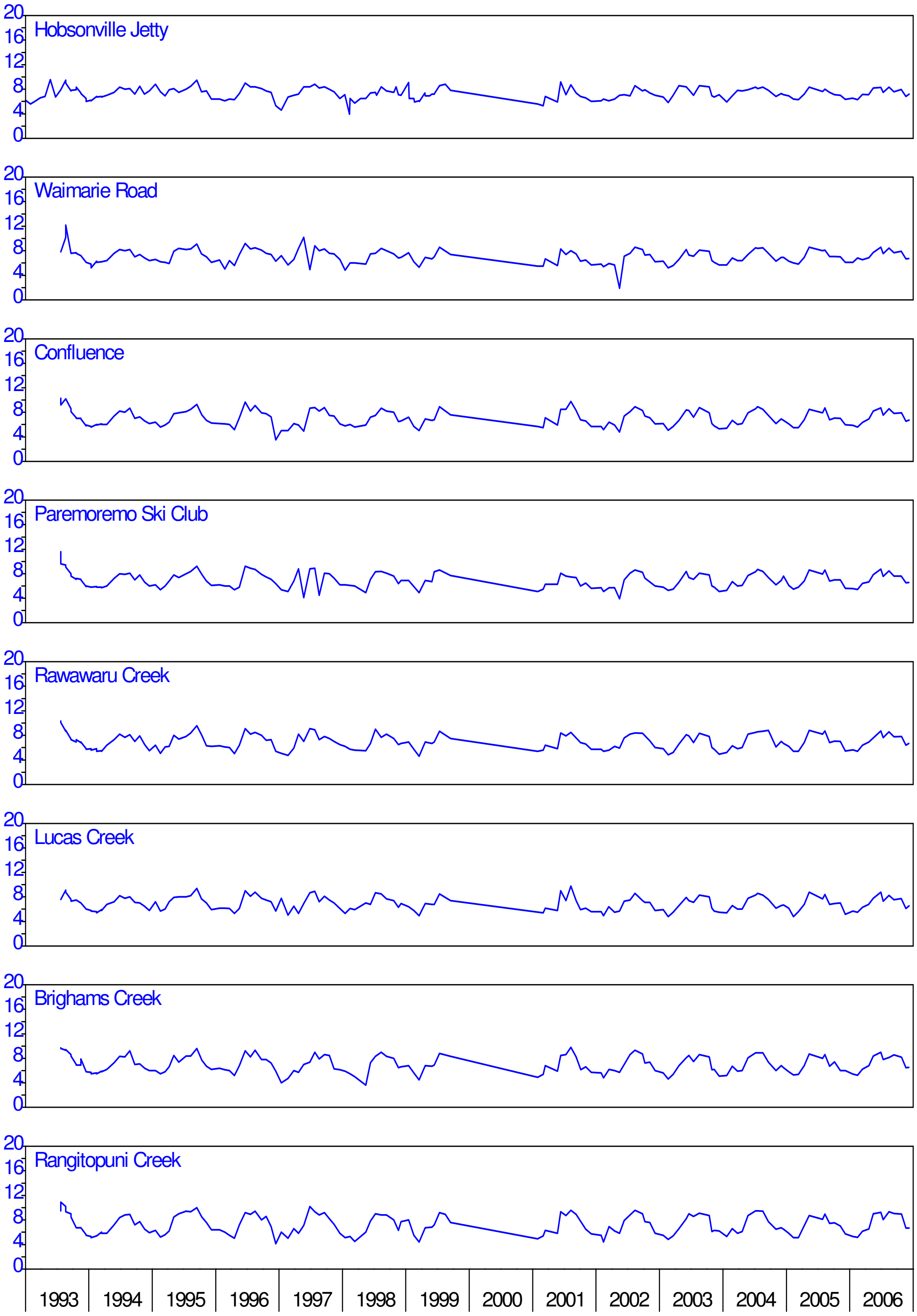


Figure 27: Upper Waitemata harbour – Total Phosphorus (g.m-3)

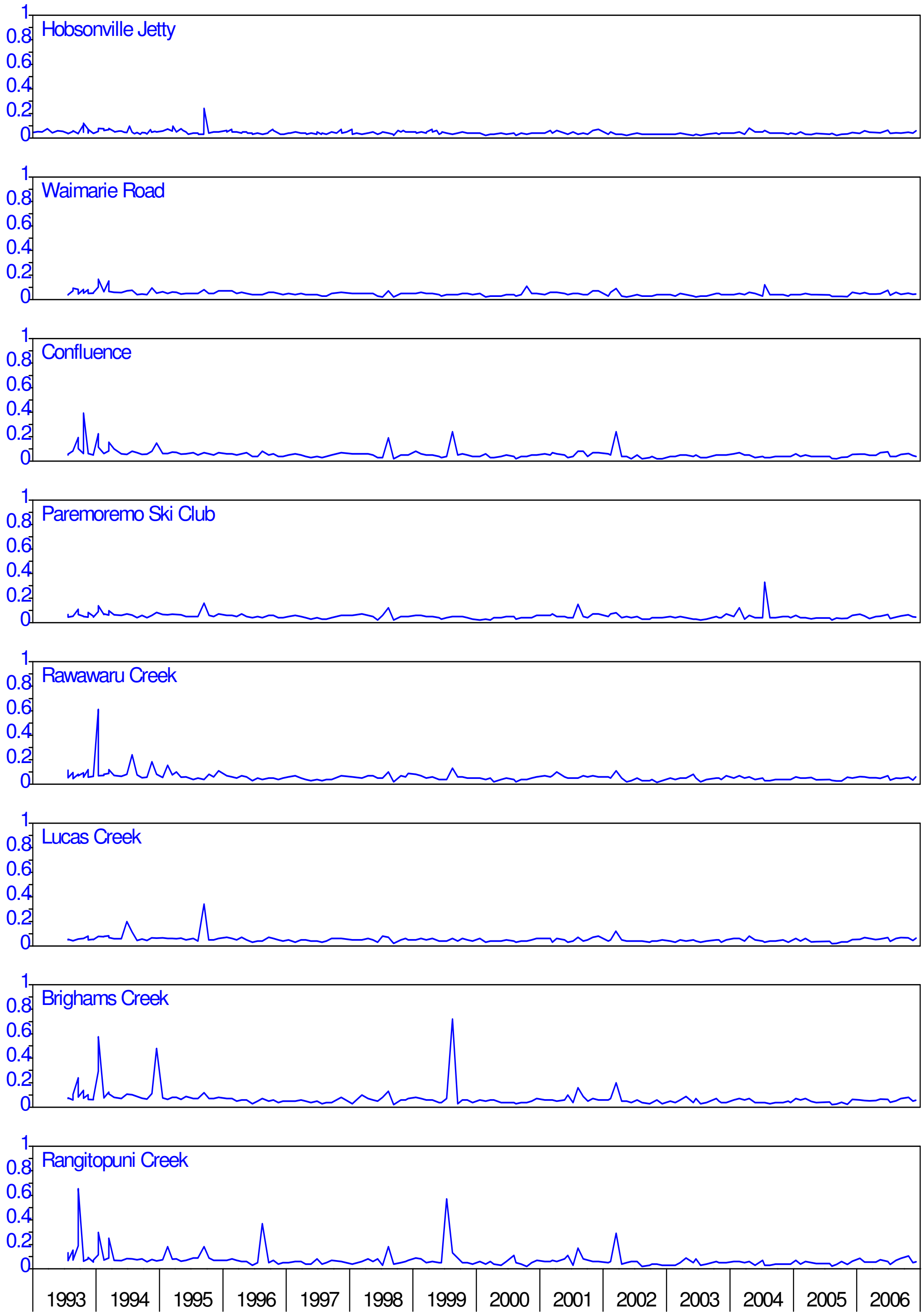


Figure 28: Upper Waitemata harbour – dissolved reactive phosphorus ($gP.m^{-3}$)

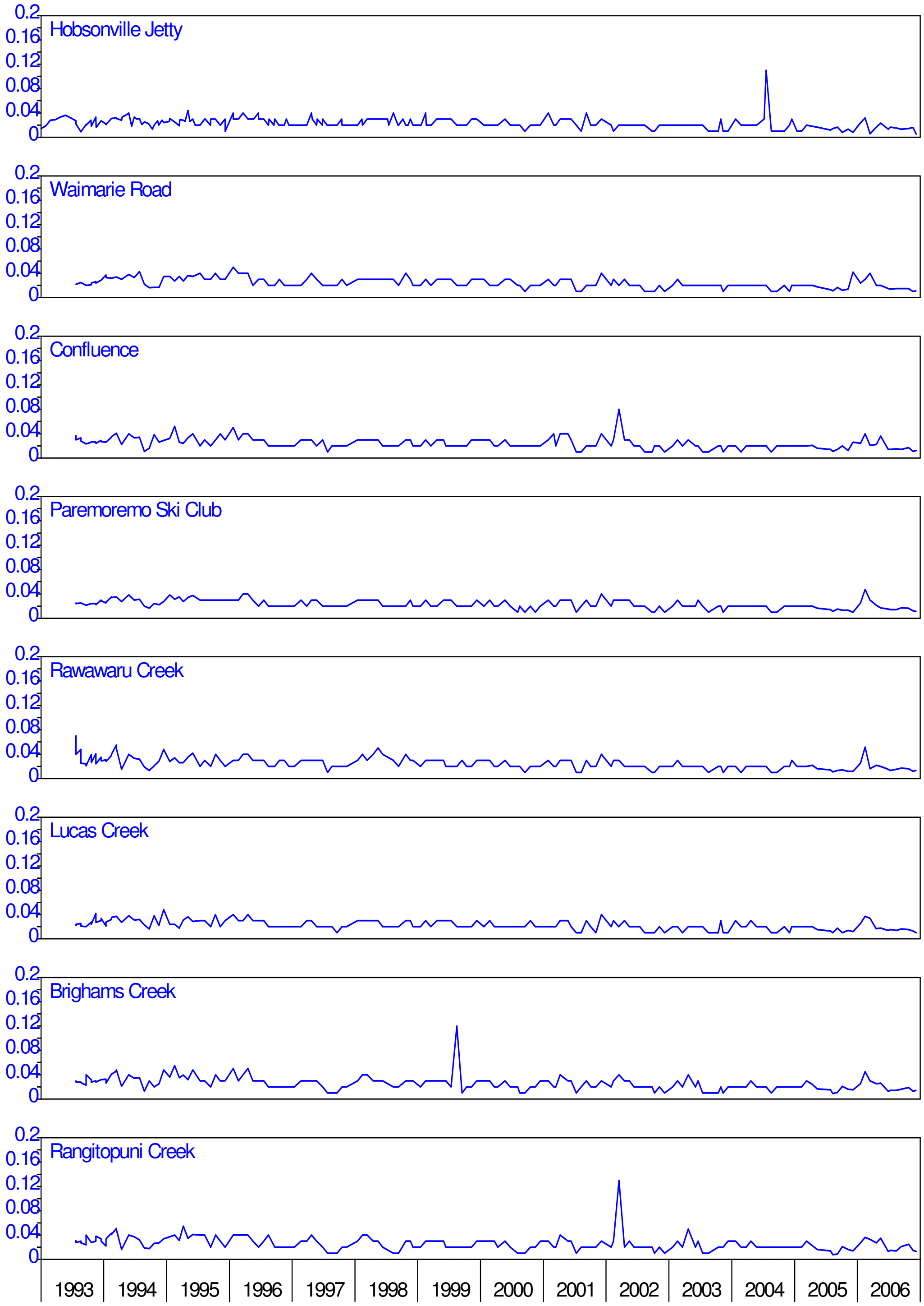


Figure 29: Upper Waitemata harbour – enterococci (cfu/100m)

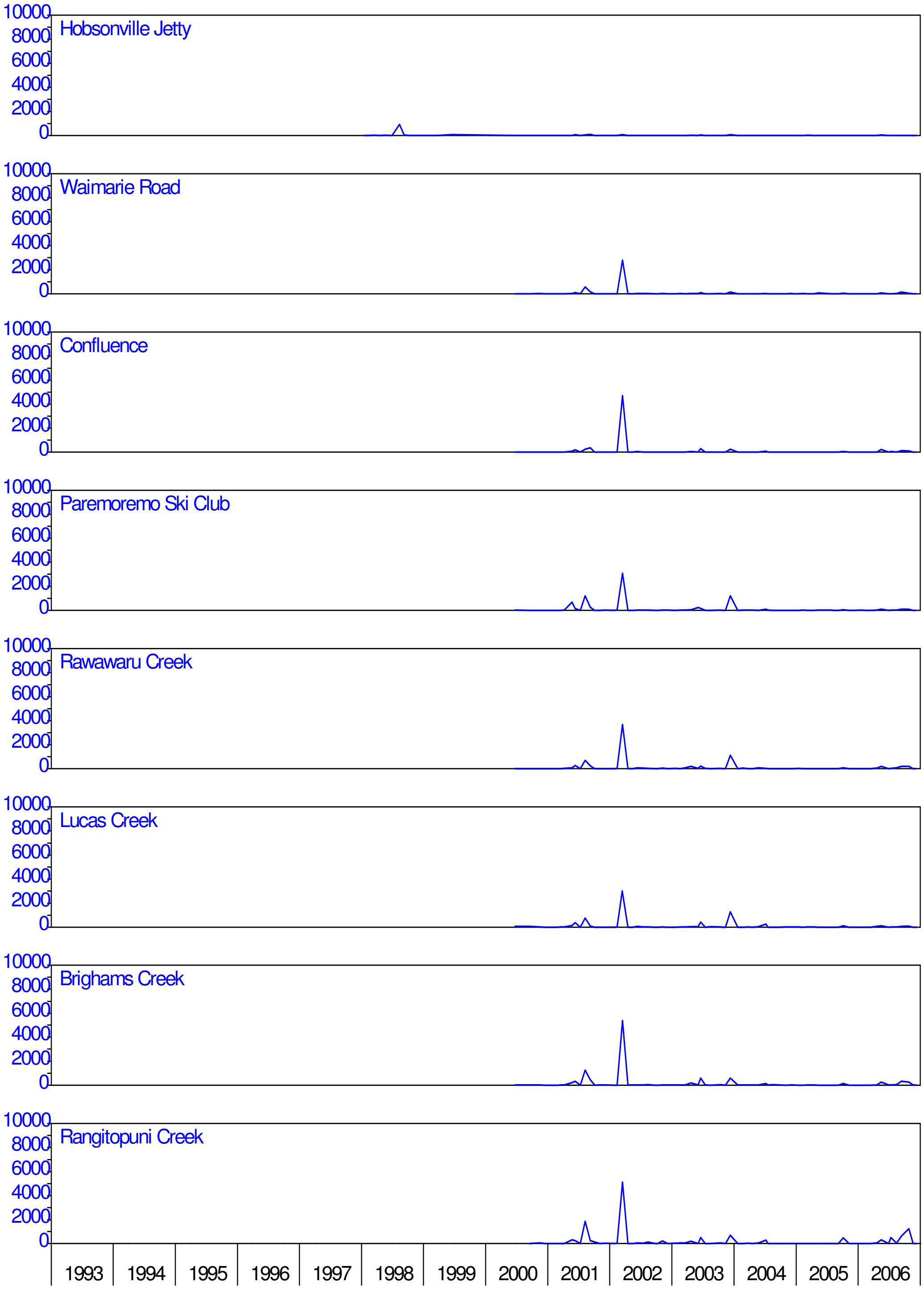


Figure 30: Upper Waitemata harbour – chlorophyll a (ppm)

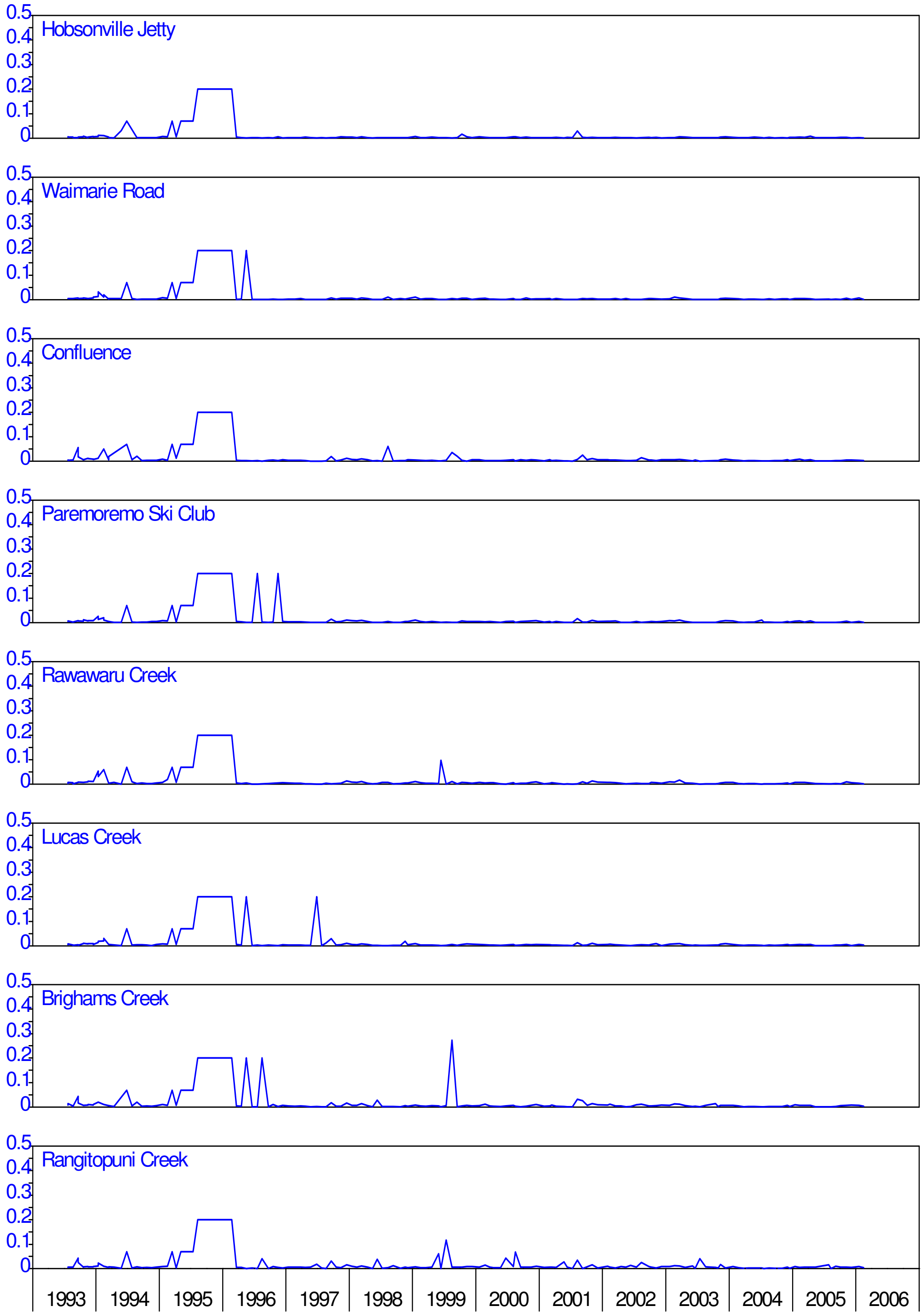


Figure 31: East Coast – salinity (ppt)

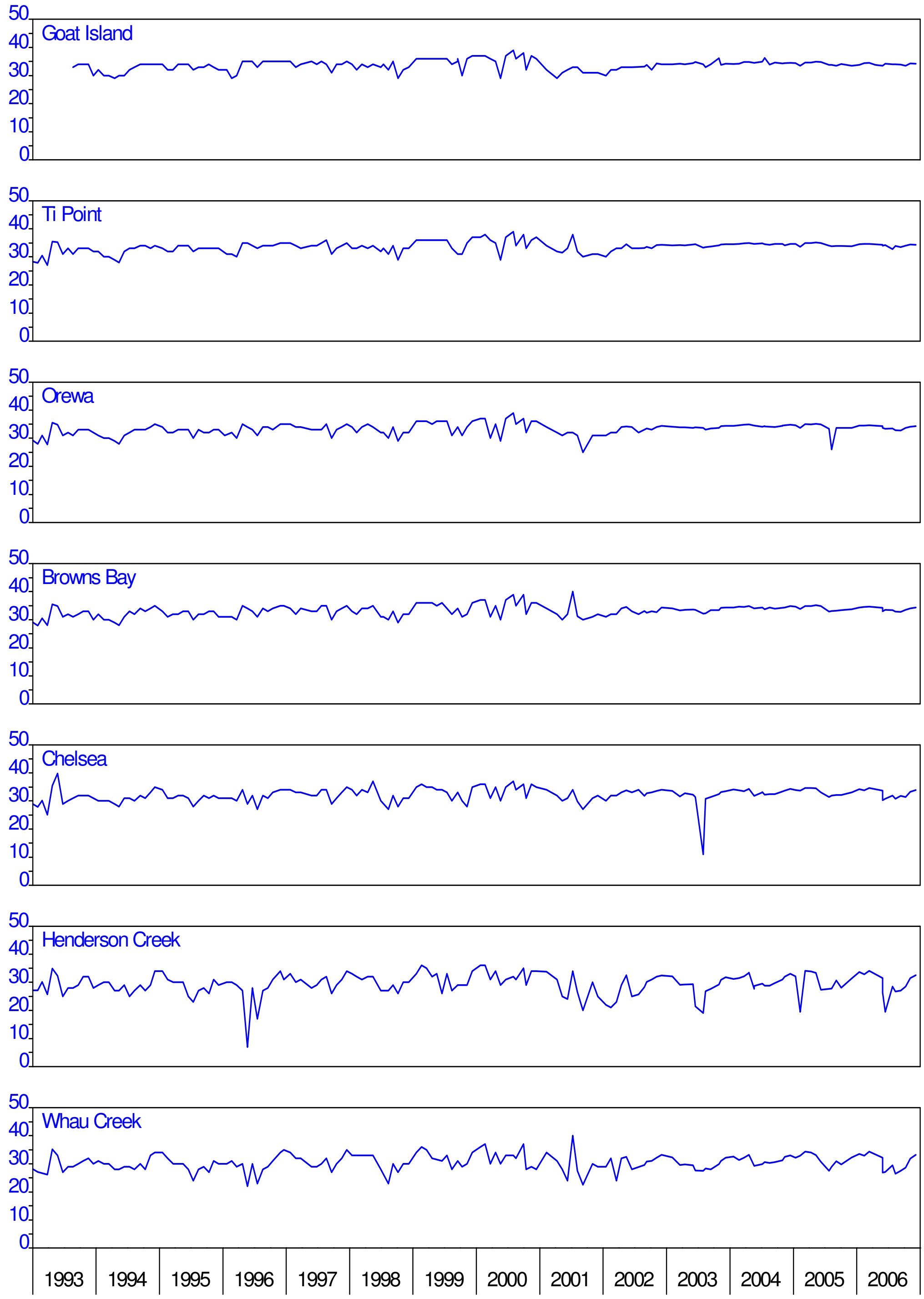


Figure 32: East Caost – turbidity (NTU)

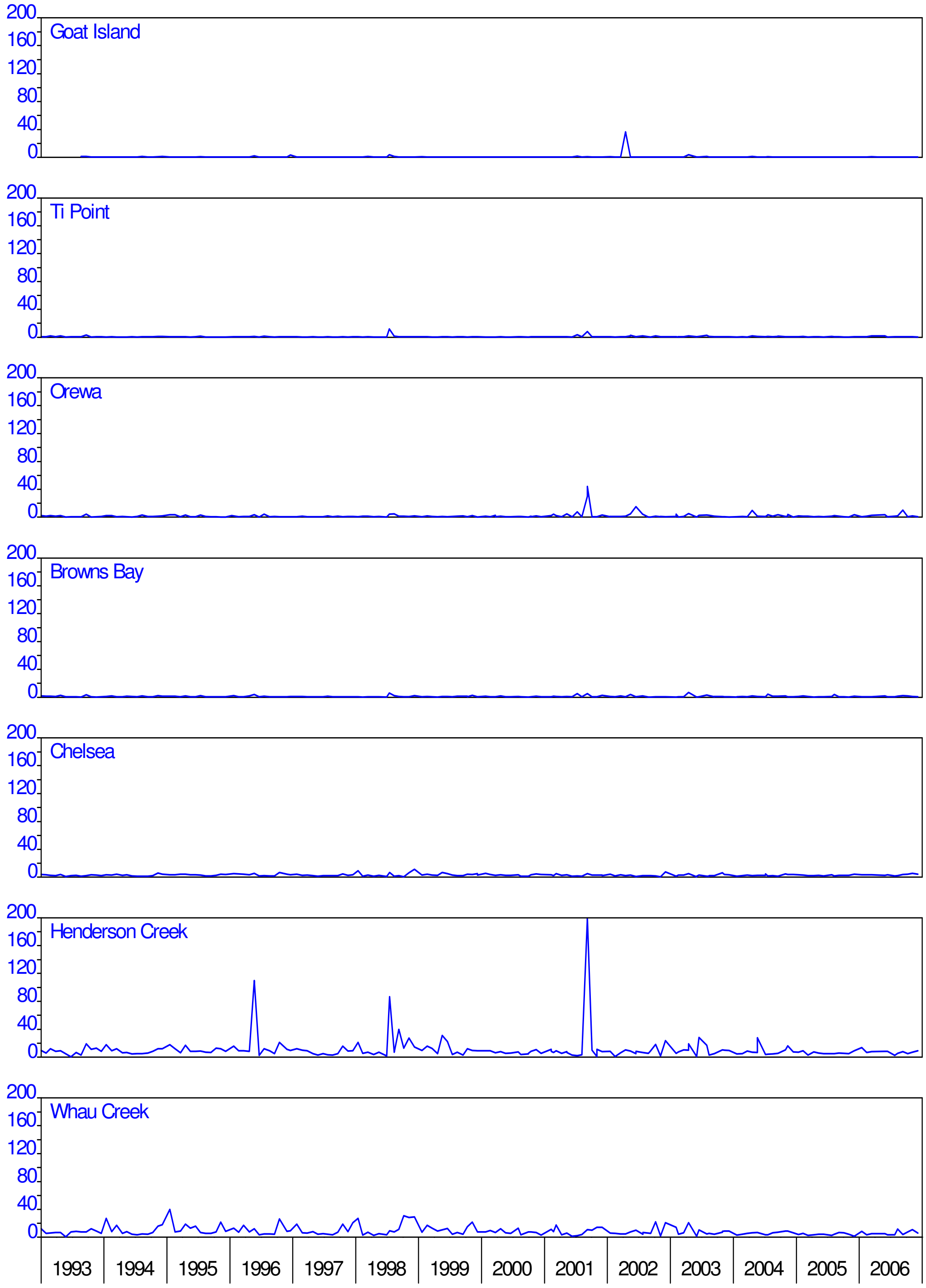


Figure 33: East Coast – transparency (Secchi (m))

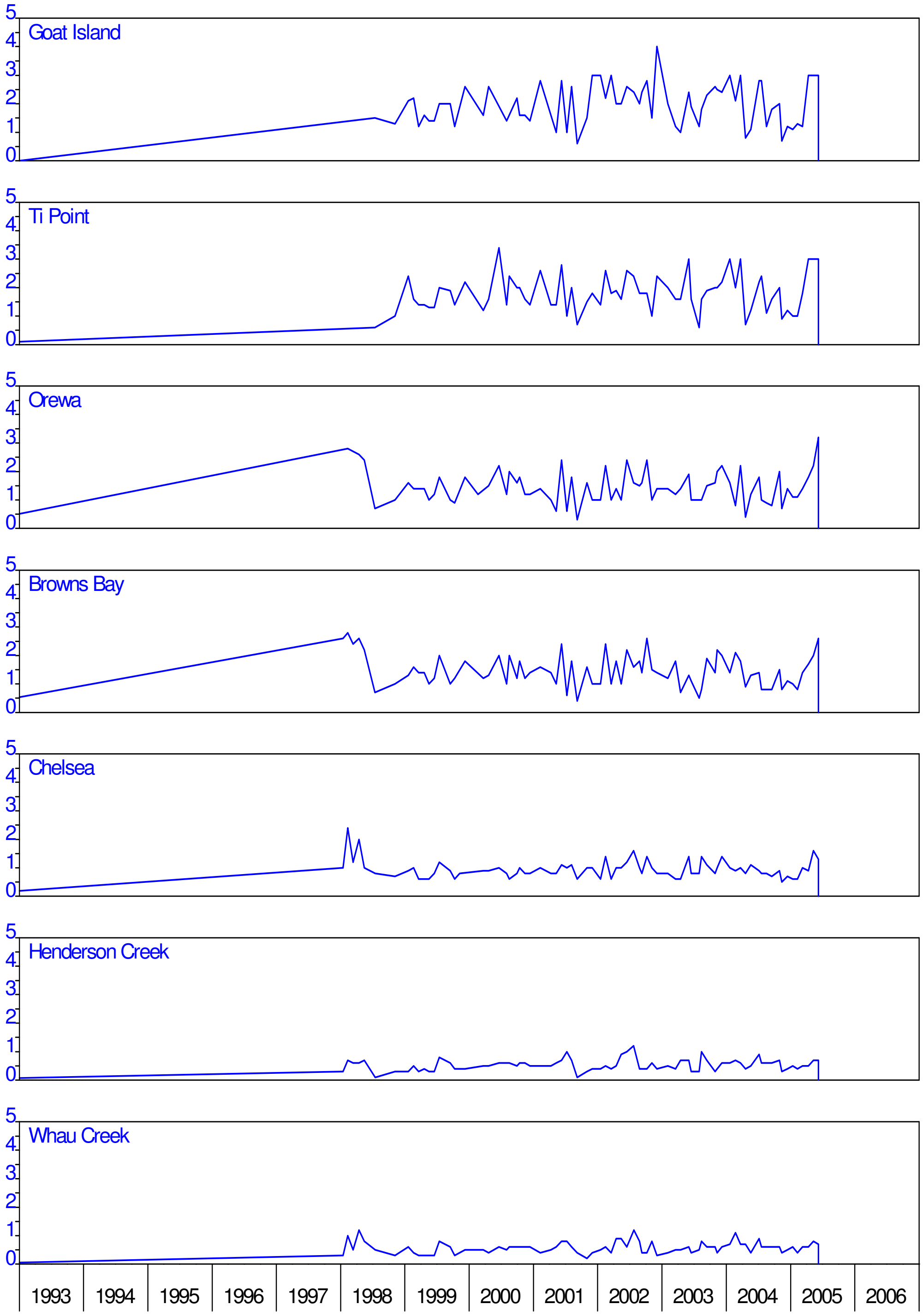


Figure 34: East Coast – temperature (°C)

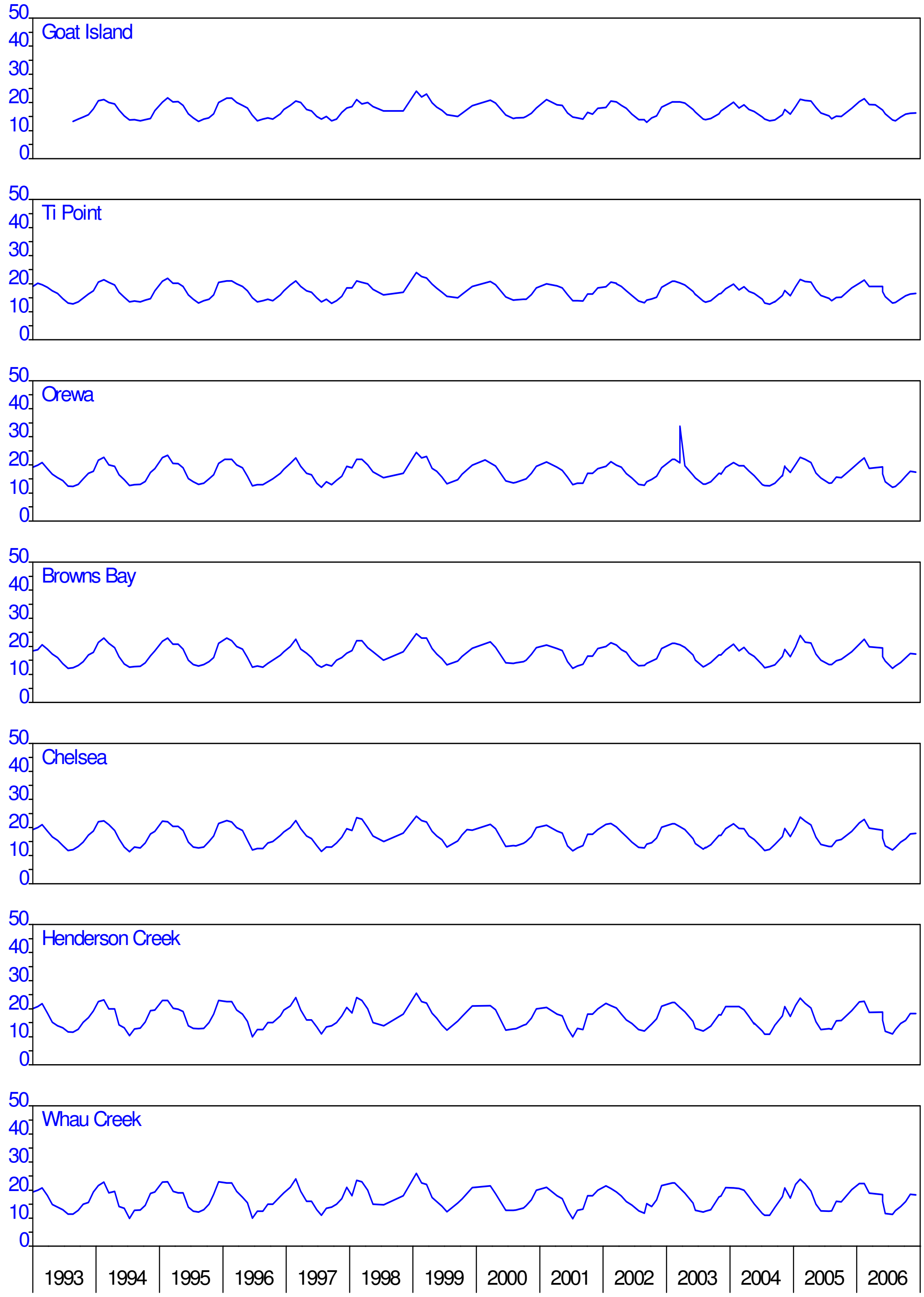


Figure 35: East Coast - pH

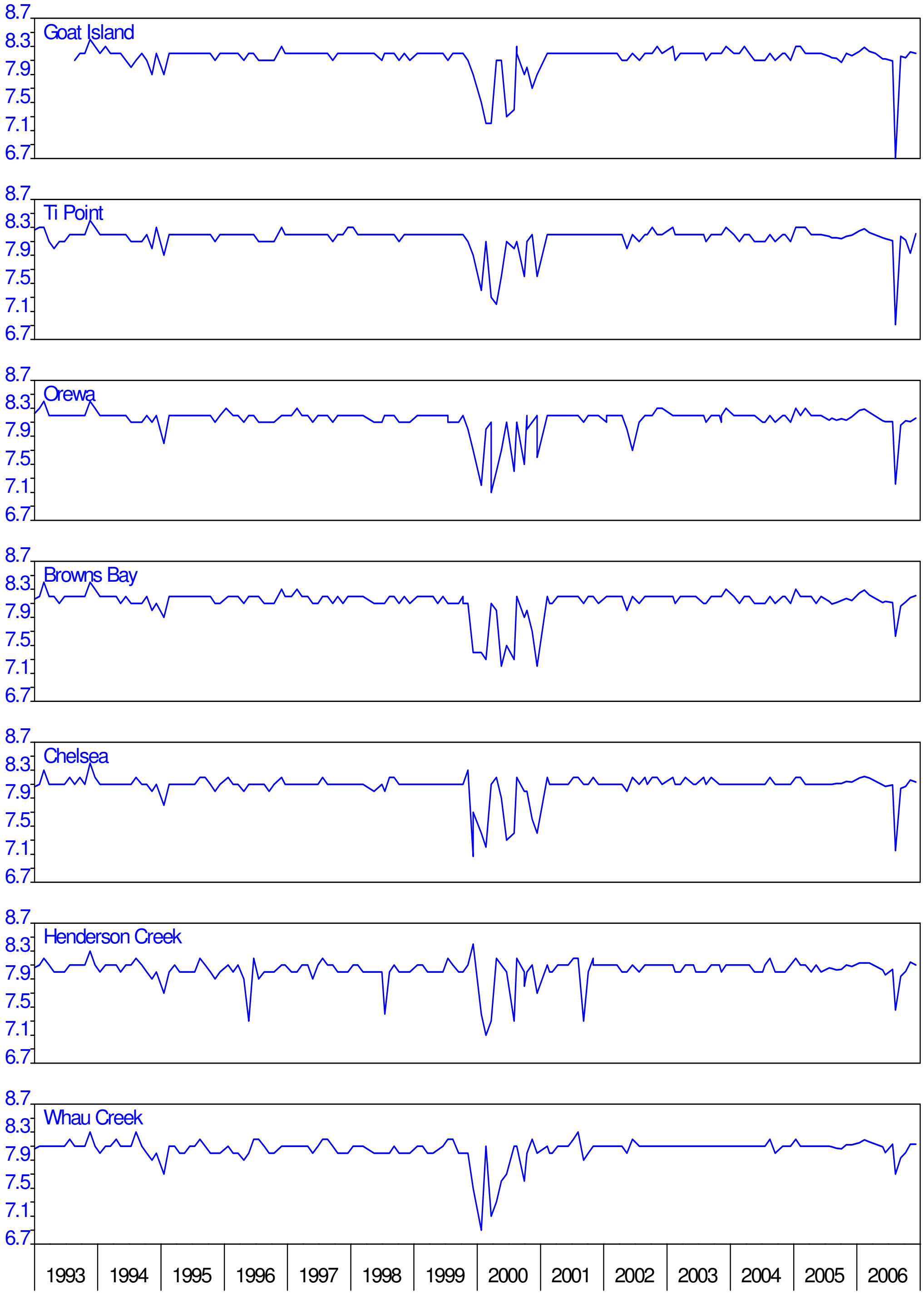


Figure 36: East Coast – suspended solids (ppm)

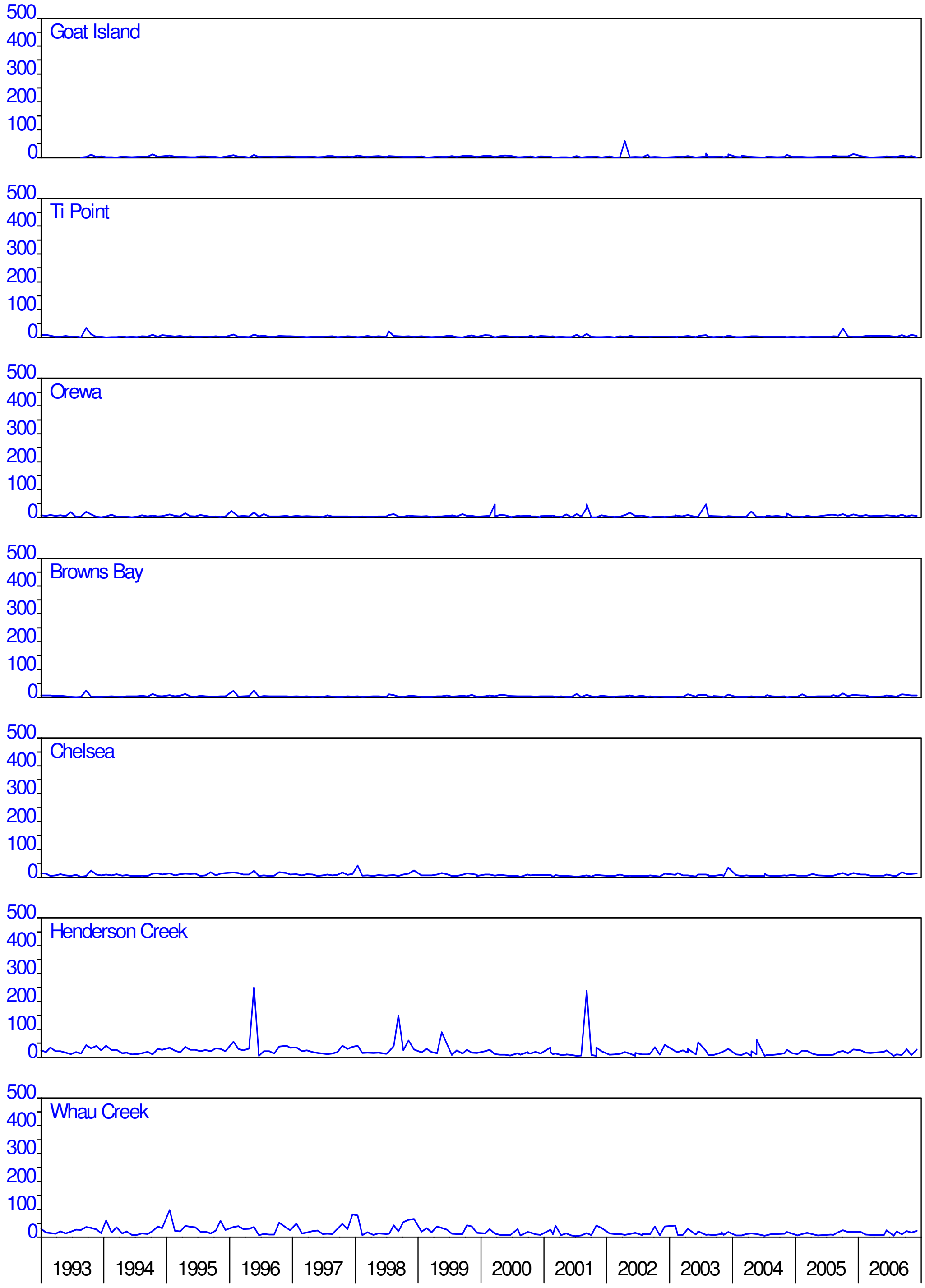


Figure 37: East Coast – nitrate+nitrite (gN.m^{-3})

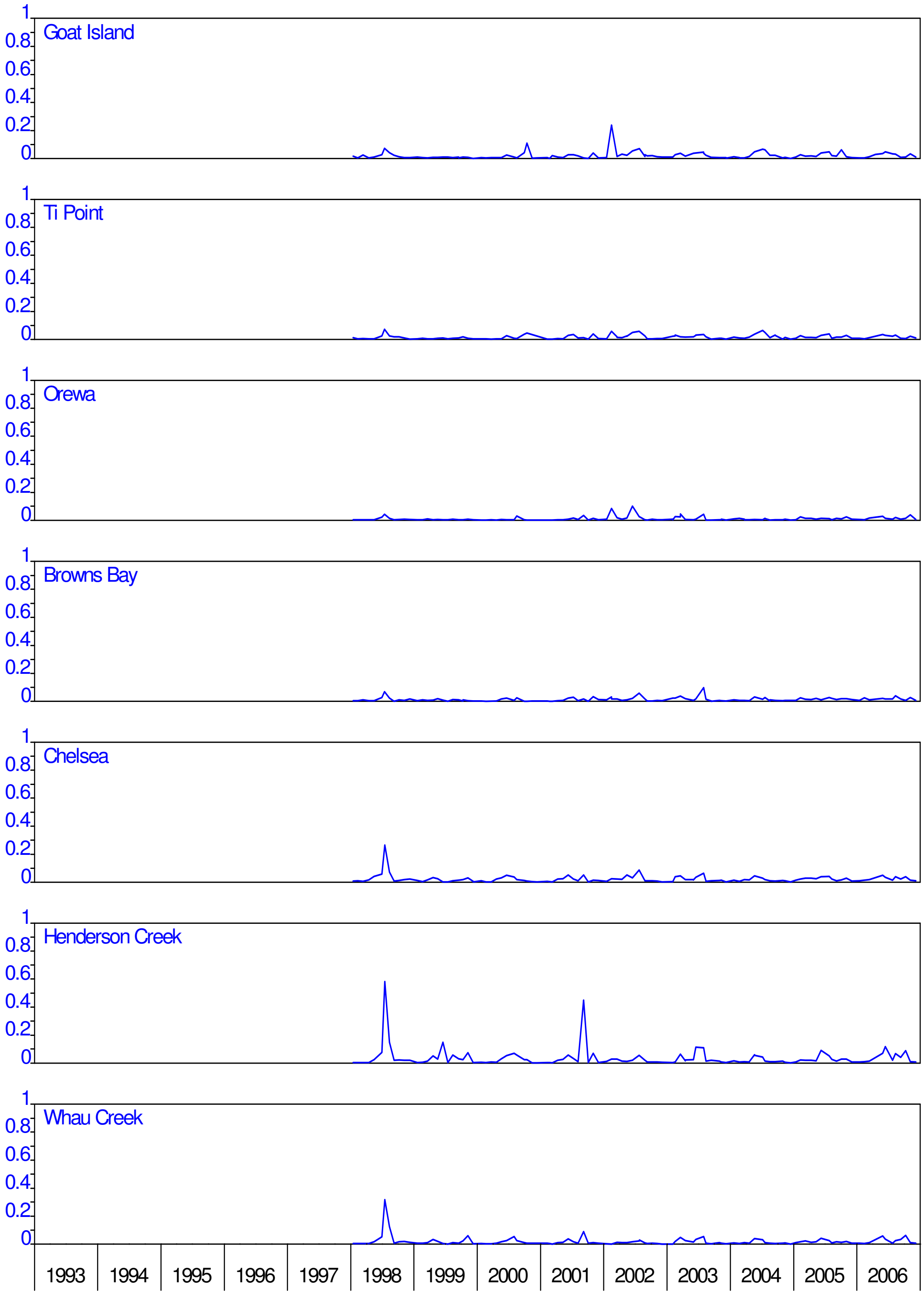


Figure 38: East Coast – ammoniacal nitrogen (gN.m^{-3})

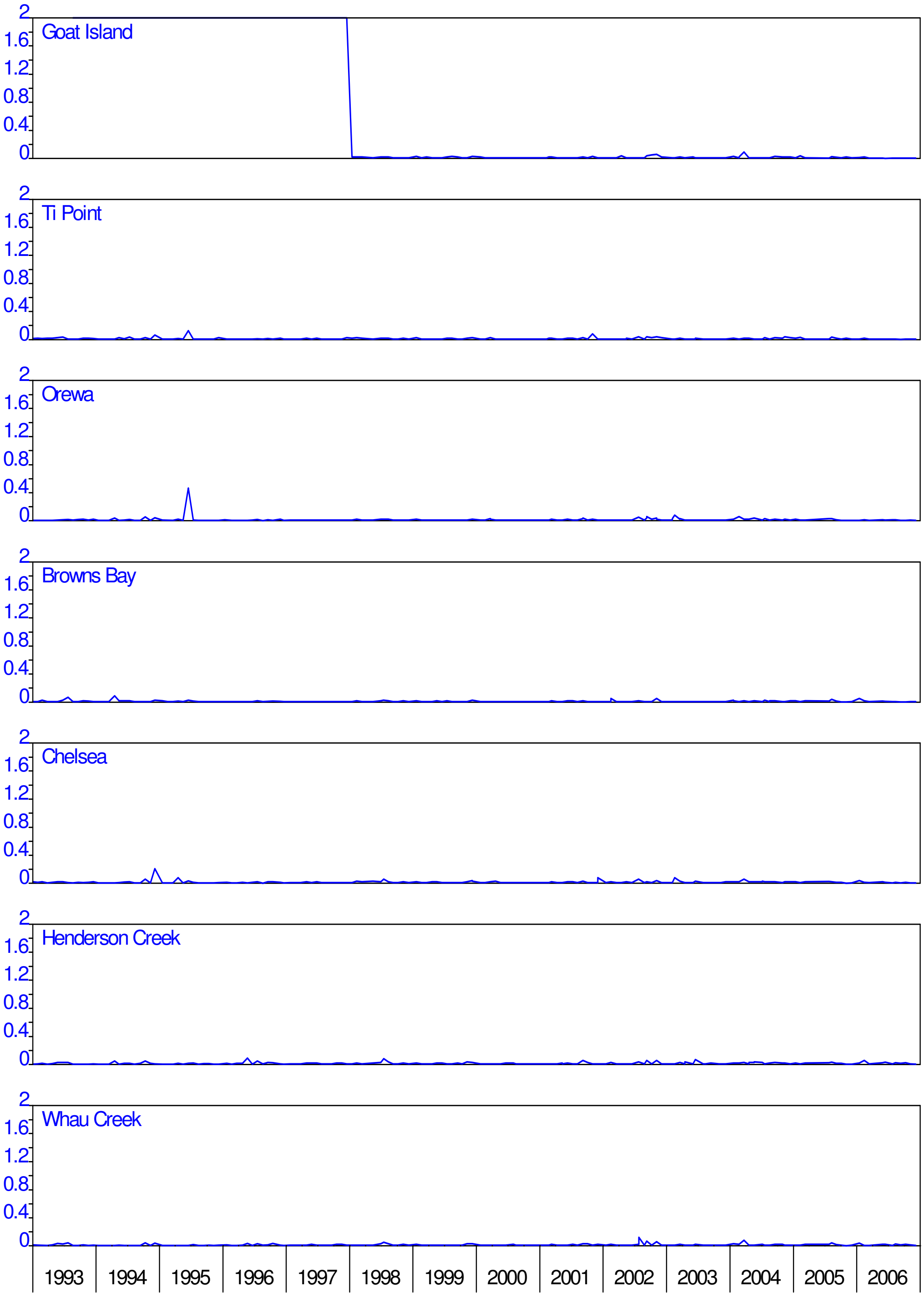


Figure 39: East Coast – dissolved oxygen (% saturated)

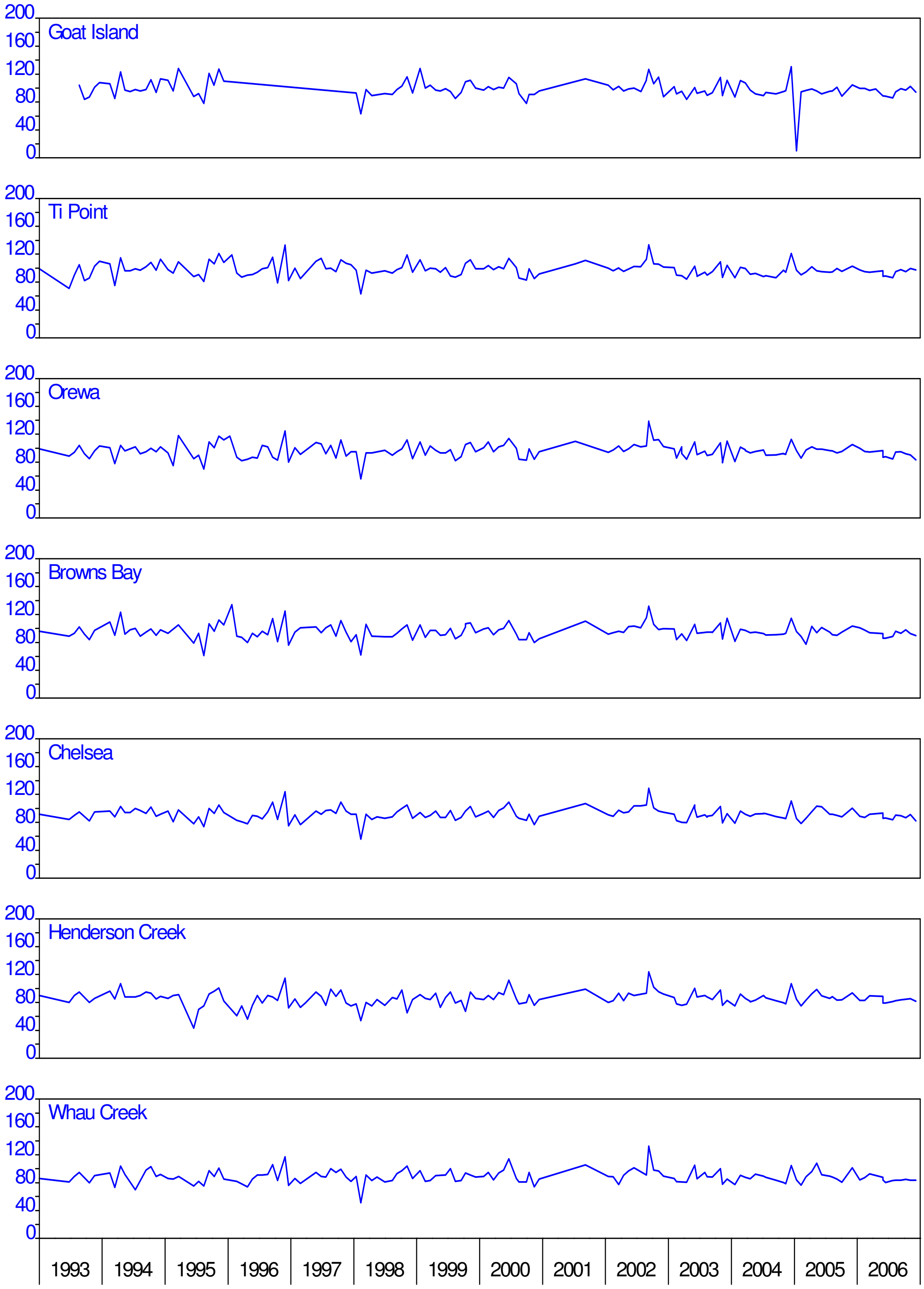


Figure 40: East Coast – dissolved oxygen (ppm)

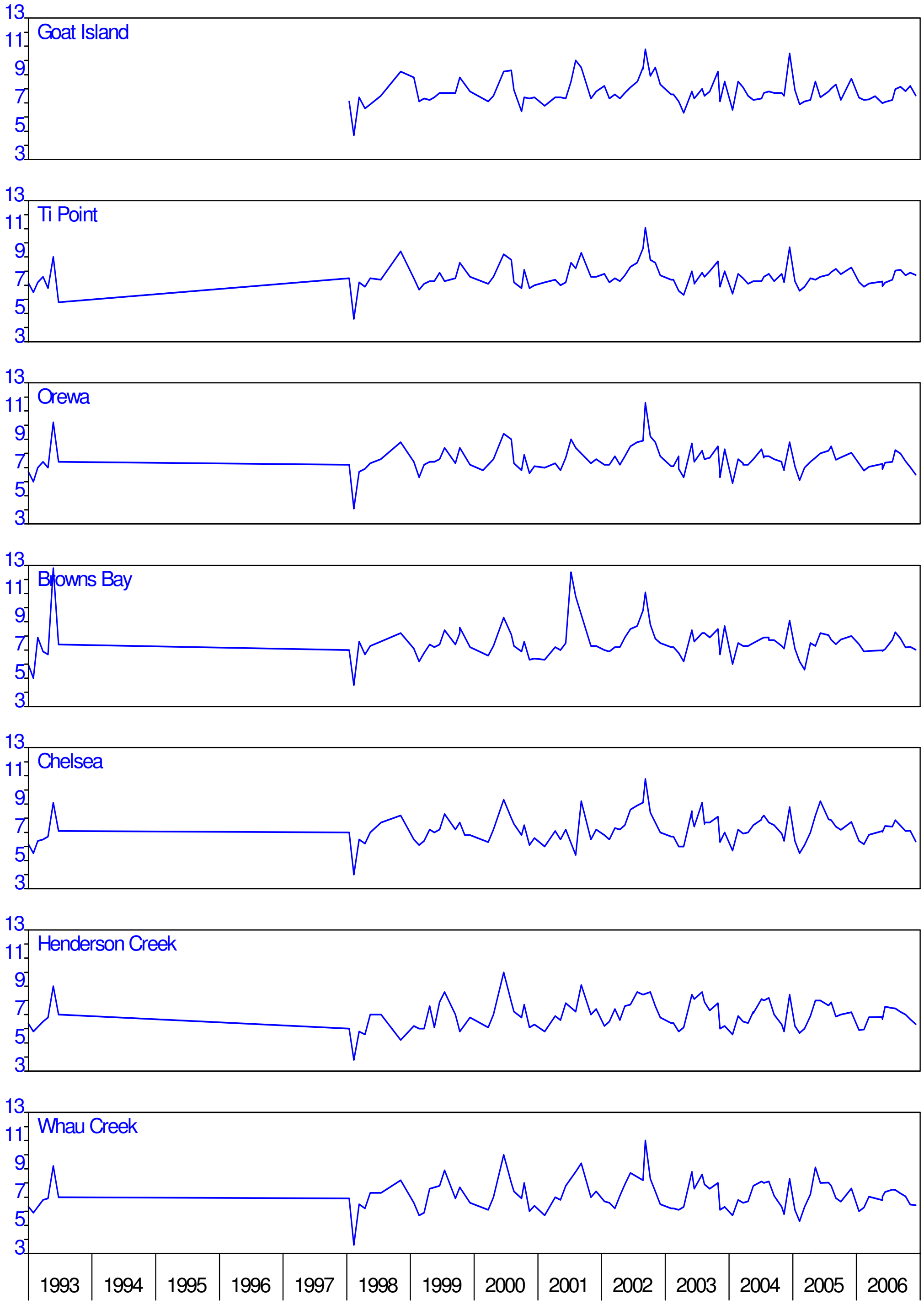


Figure 41: East Coast – total phosphorus (g.m-3)

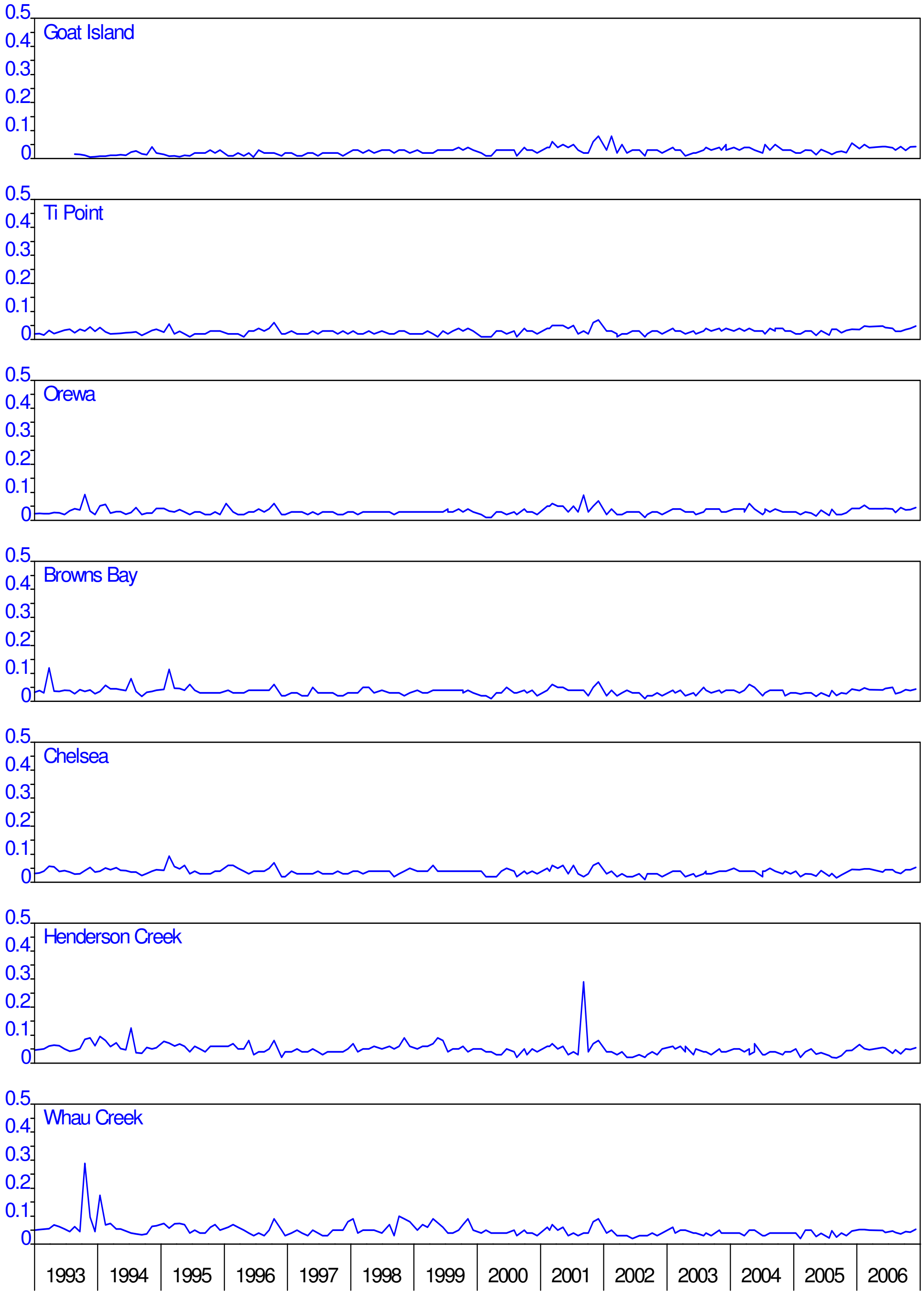


Figure 42: East Coast – dissolved reactive phosphorus (gP.m^{-3})

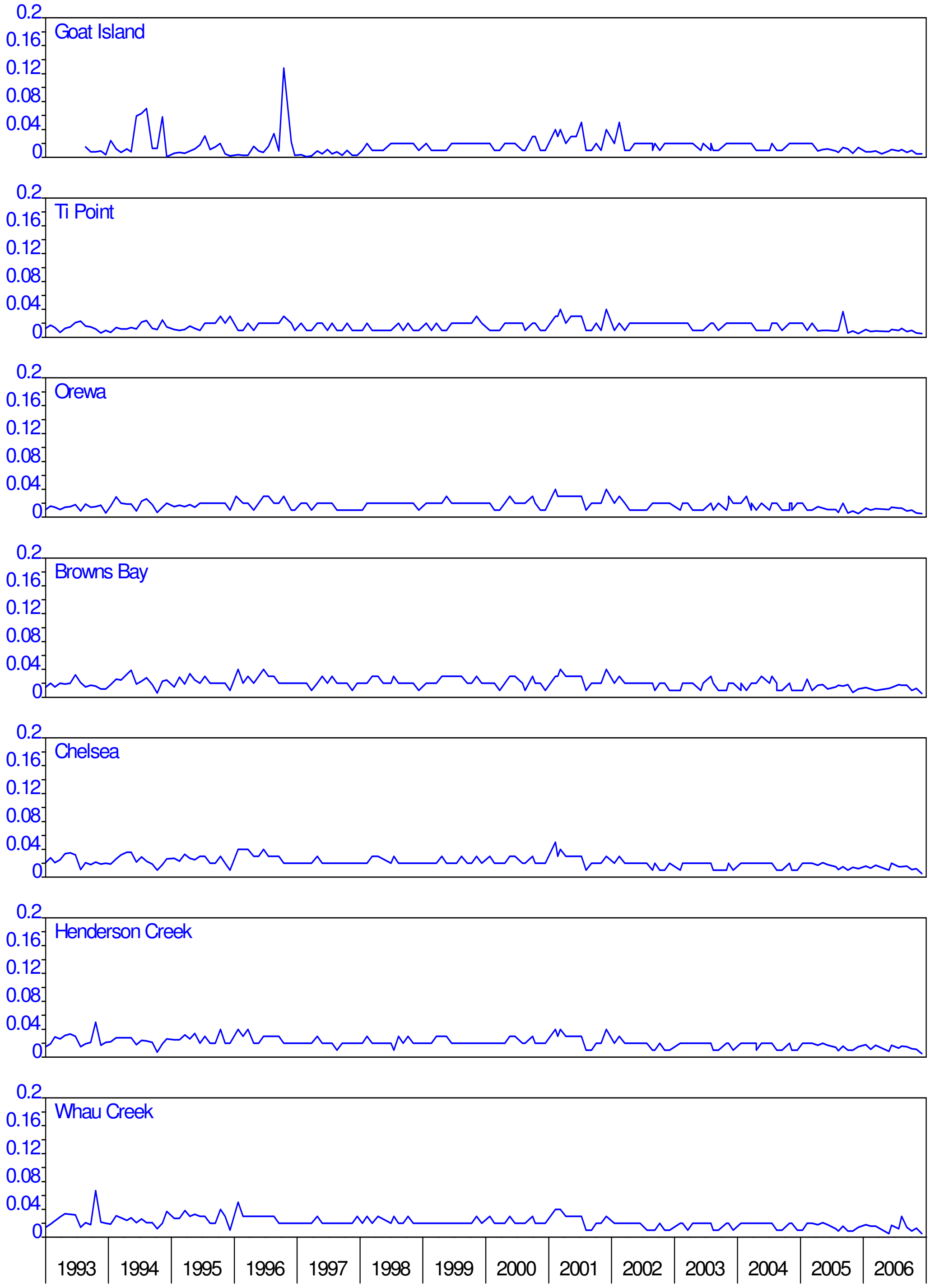


Figure 43: East Coast – enterococci (cfu/100ml)

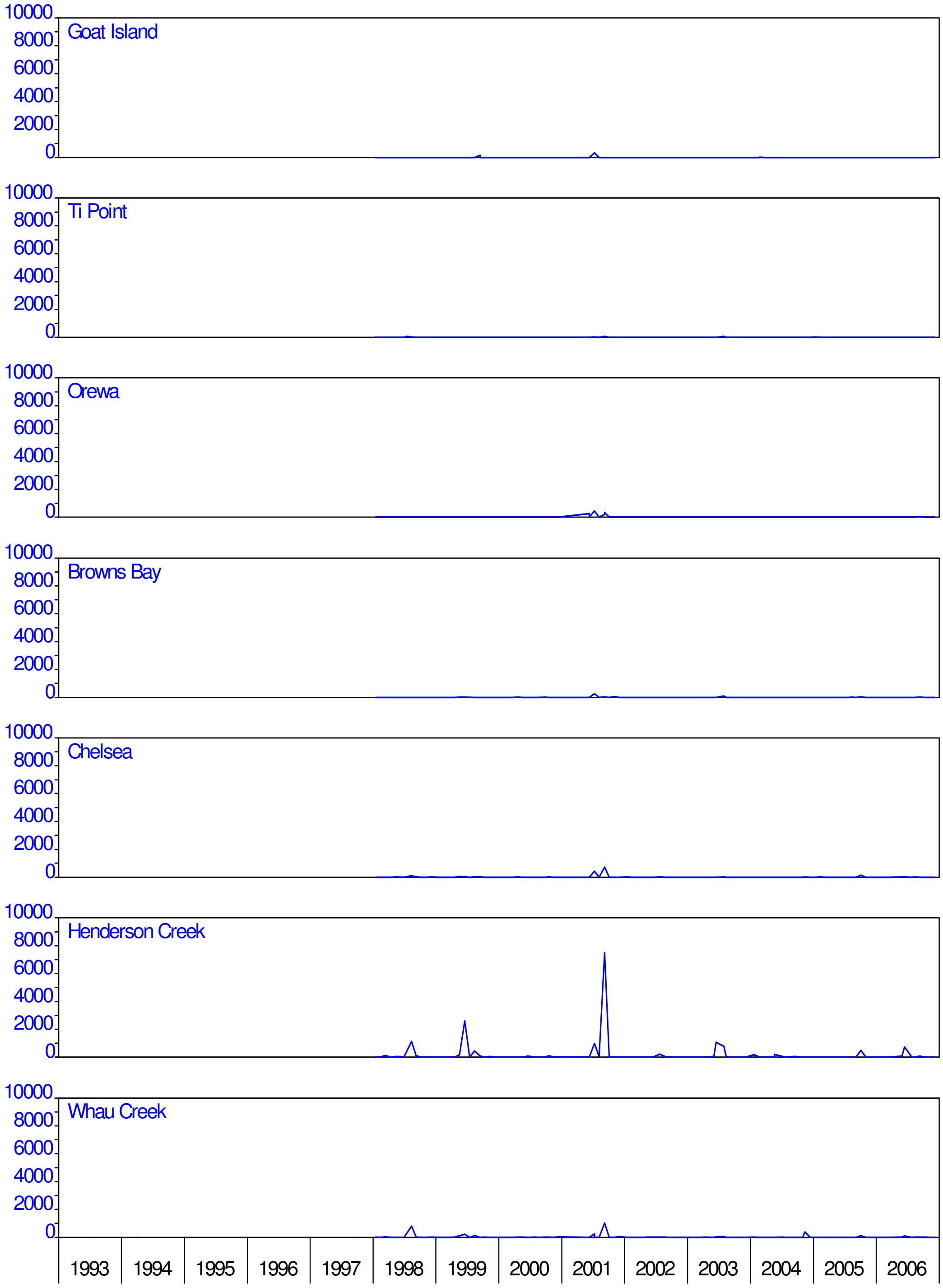


Figure 44: Manukau harbour – salinity (ppt)

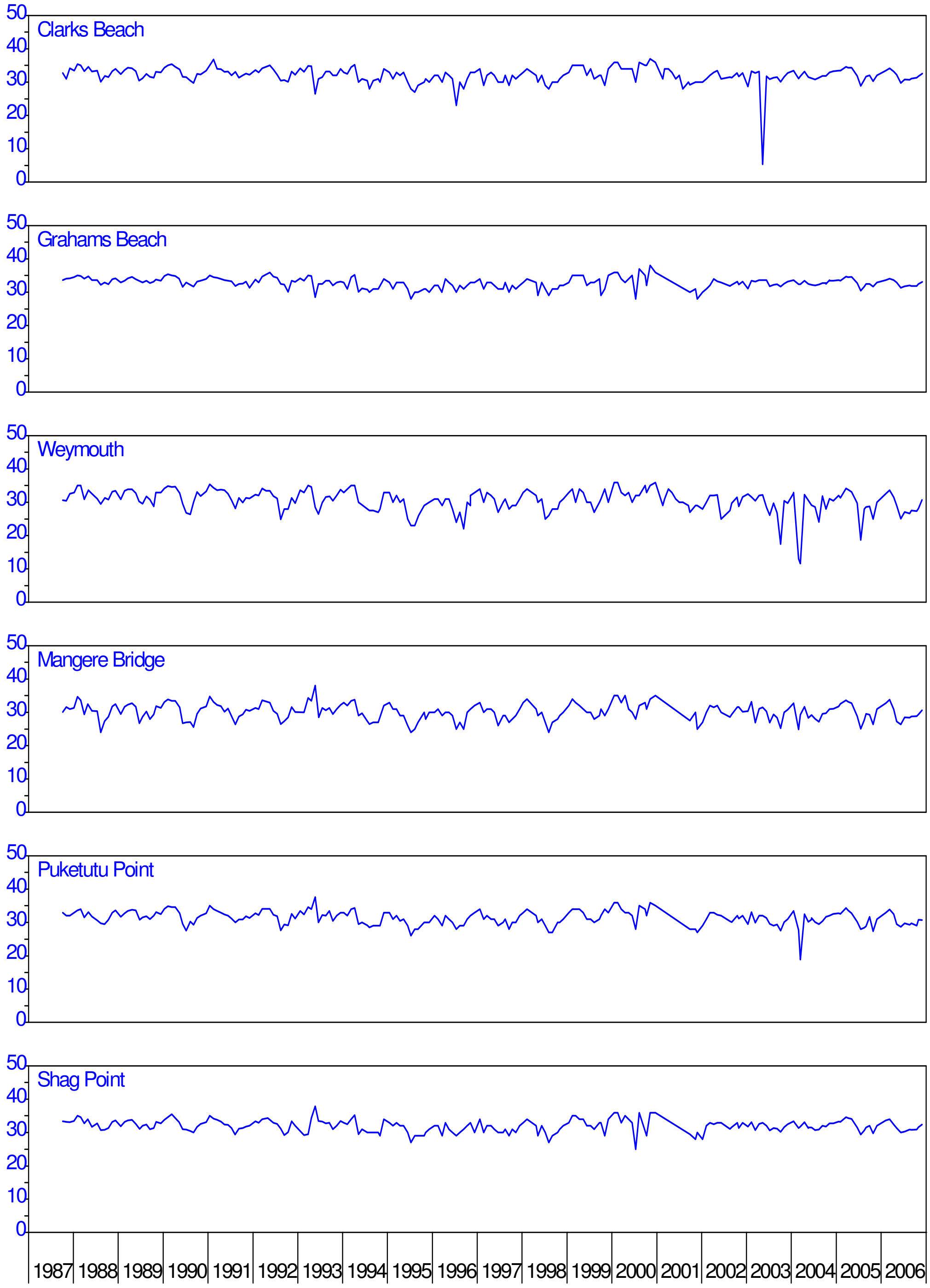


Figure 45: Manukau harbour – turbidity (NTU)

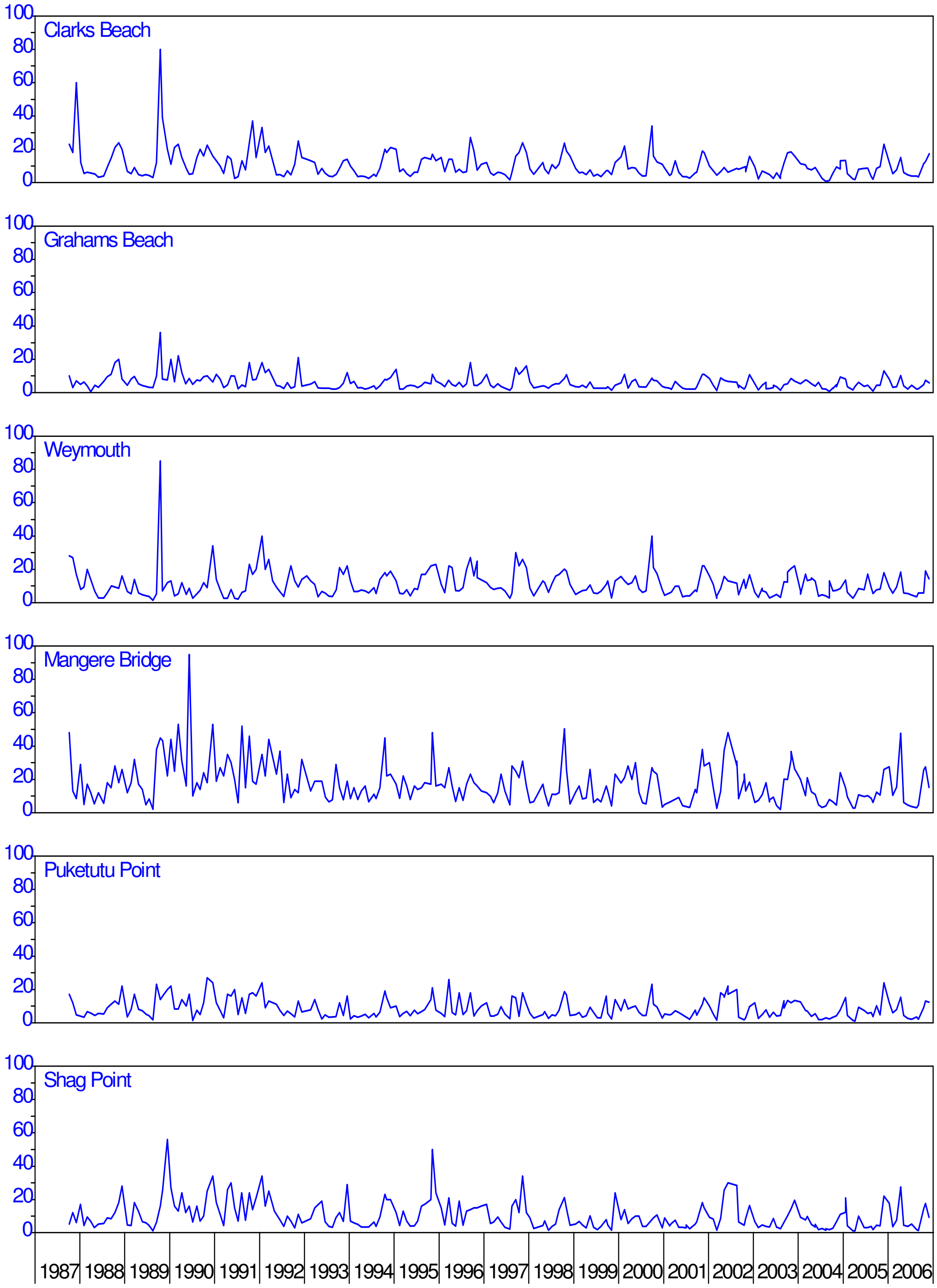


Figure 46: Manukau harbour – transparency (Secchi (m))

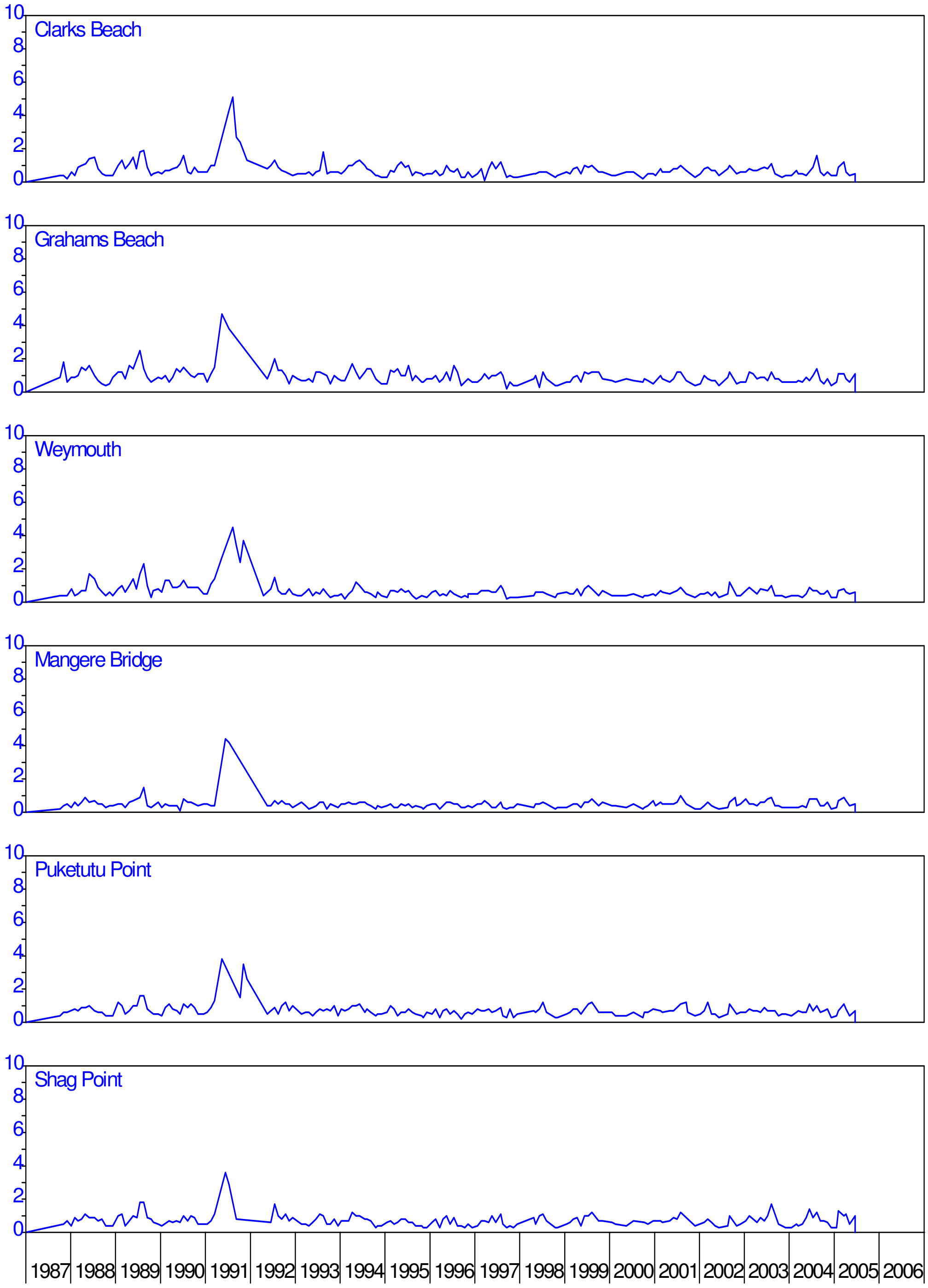


Figure 47: Manukau harbour – temperature (°C)

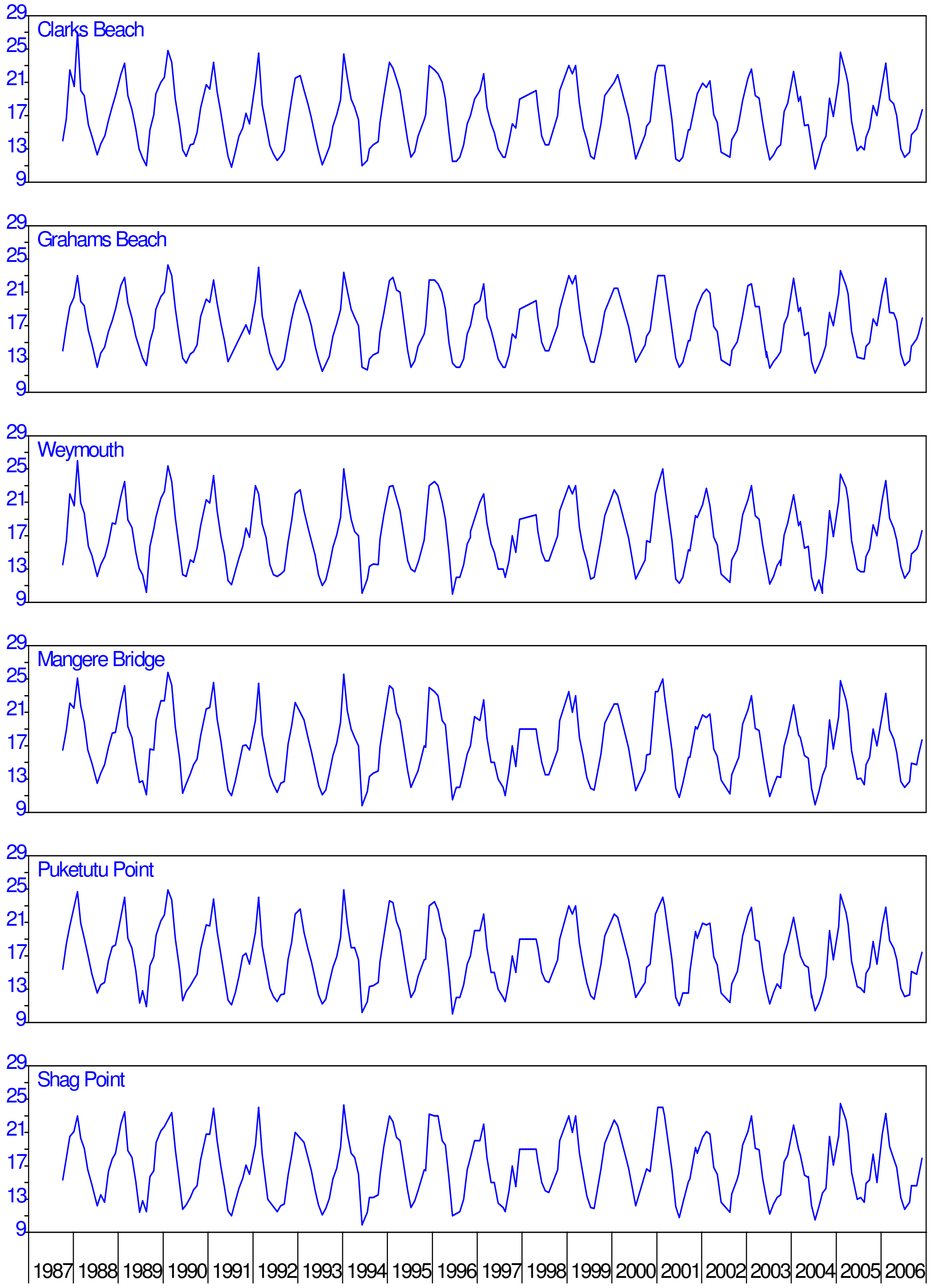


Figure 48: Manukau harbour - pH

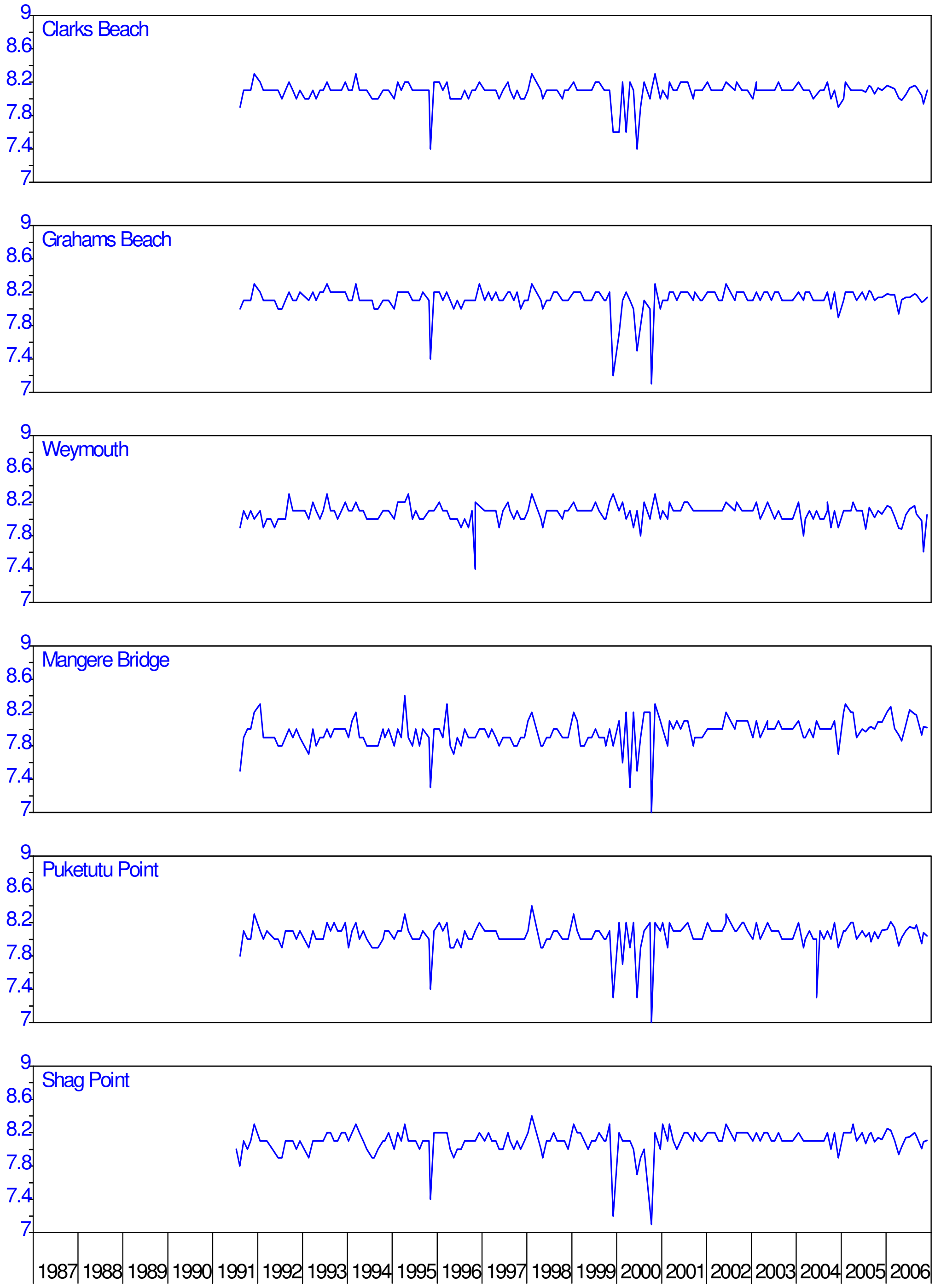


Figure 48: Manukau harbour – suspended solids (ppm)

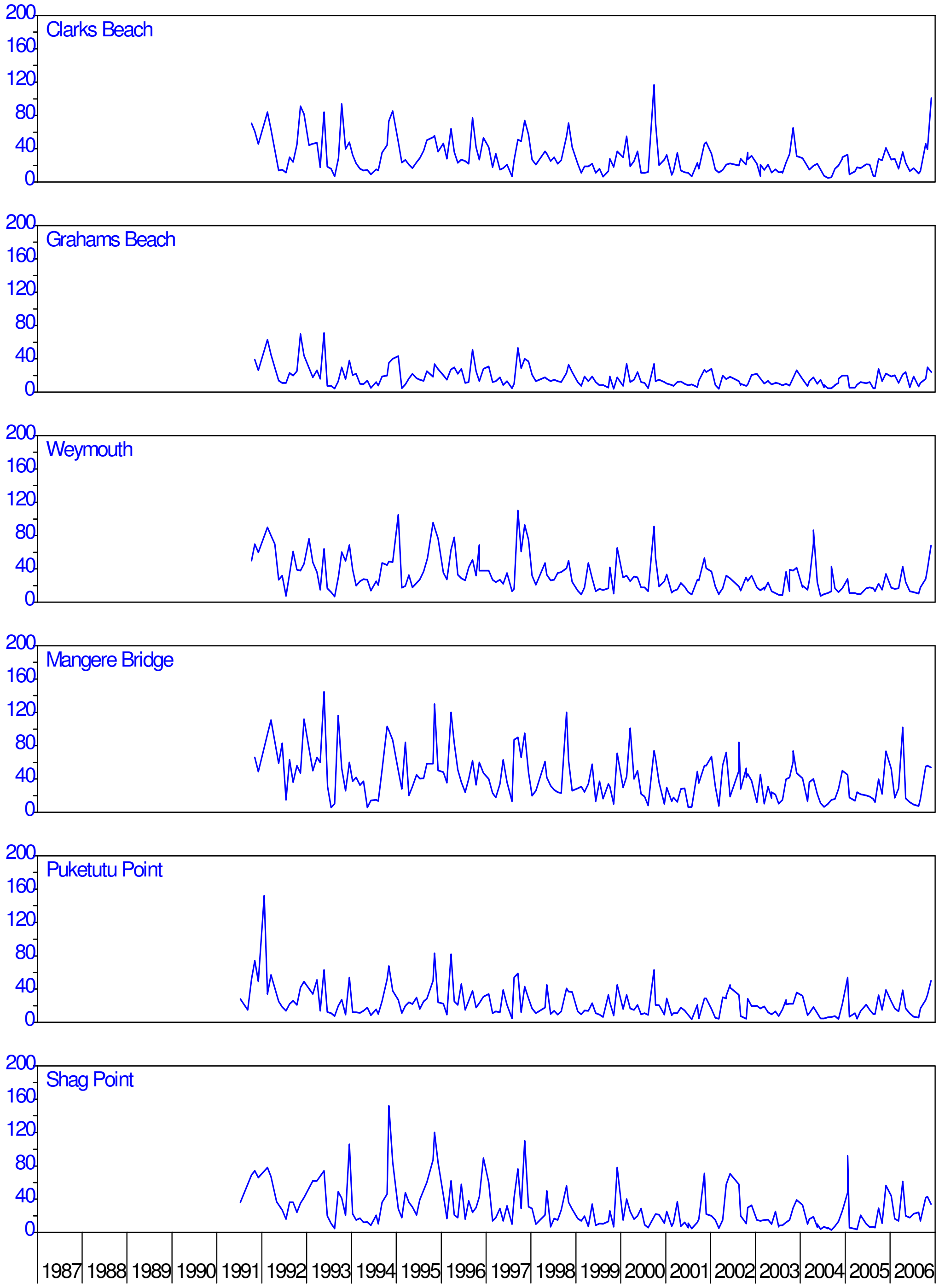


Figure 50: Manukau harbour – nitrate + nitrite (gN.m^{-3})

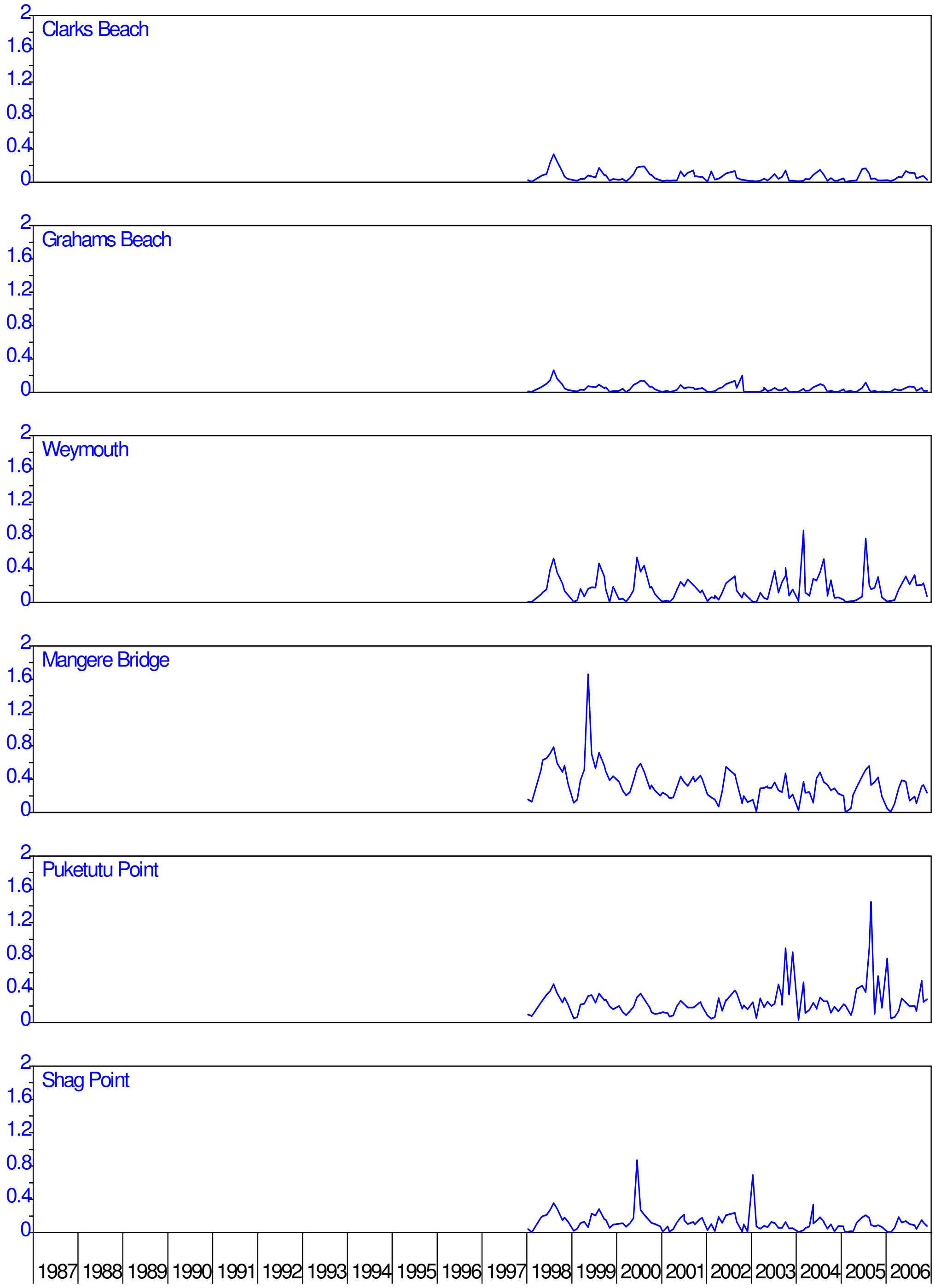


Figure 51: Manukau harbour – ammoniacal nitrogen (gN.m^{-3})

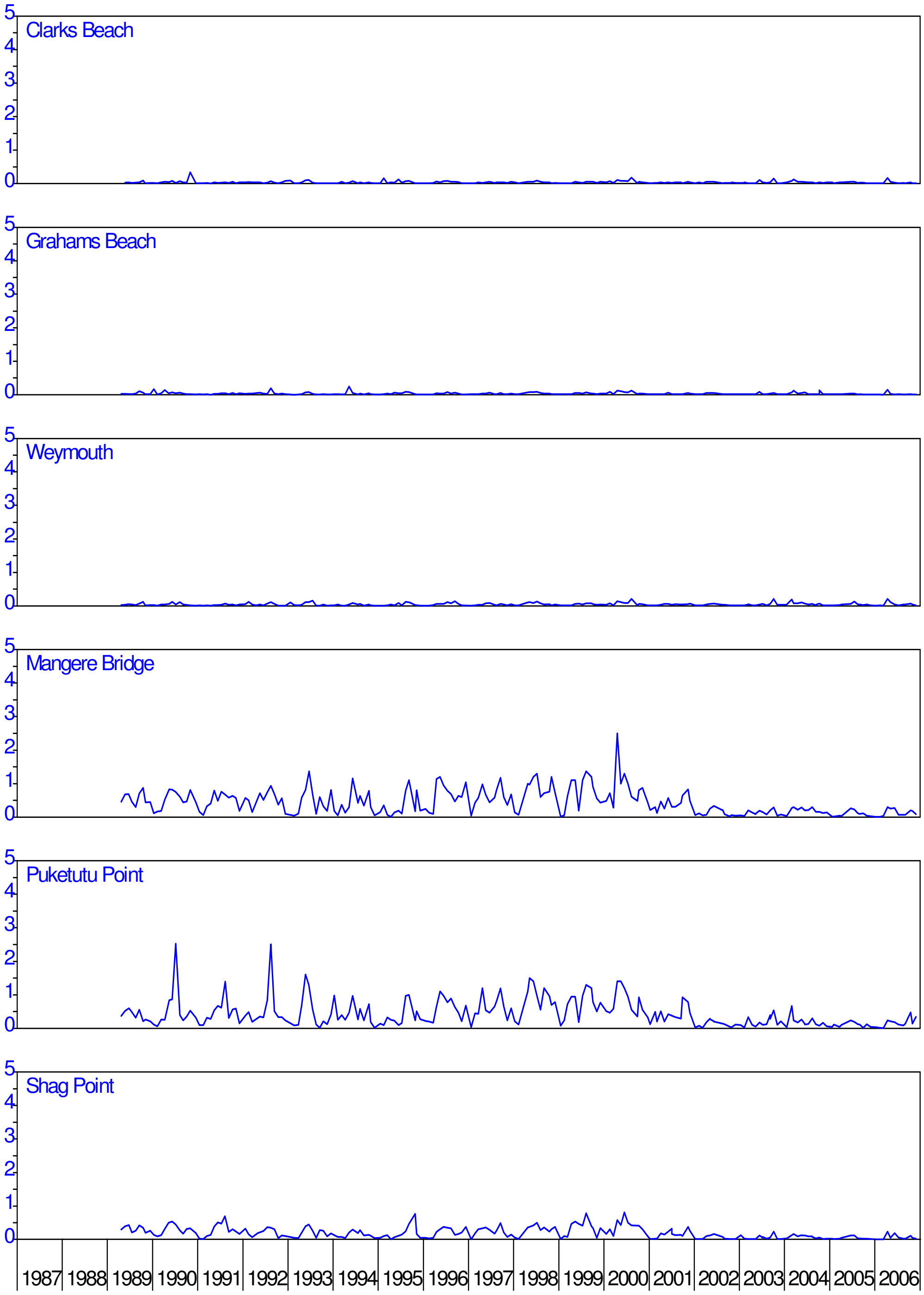


Figure 52: Manukau harbour – dissolved oxygen (% saturated)

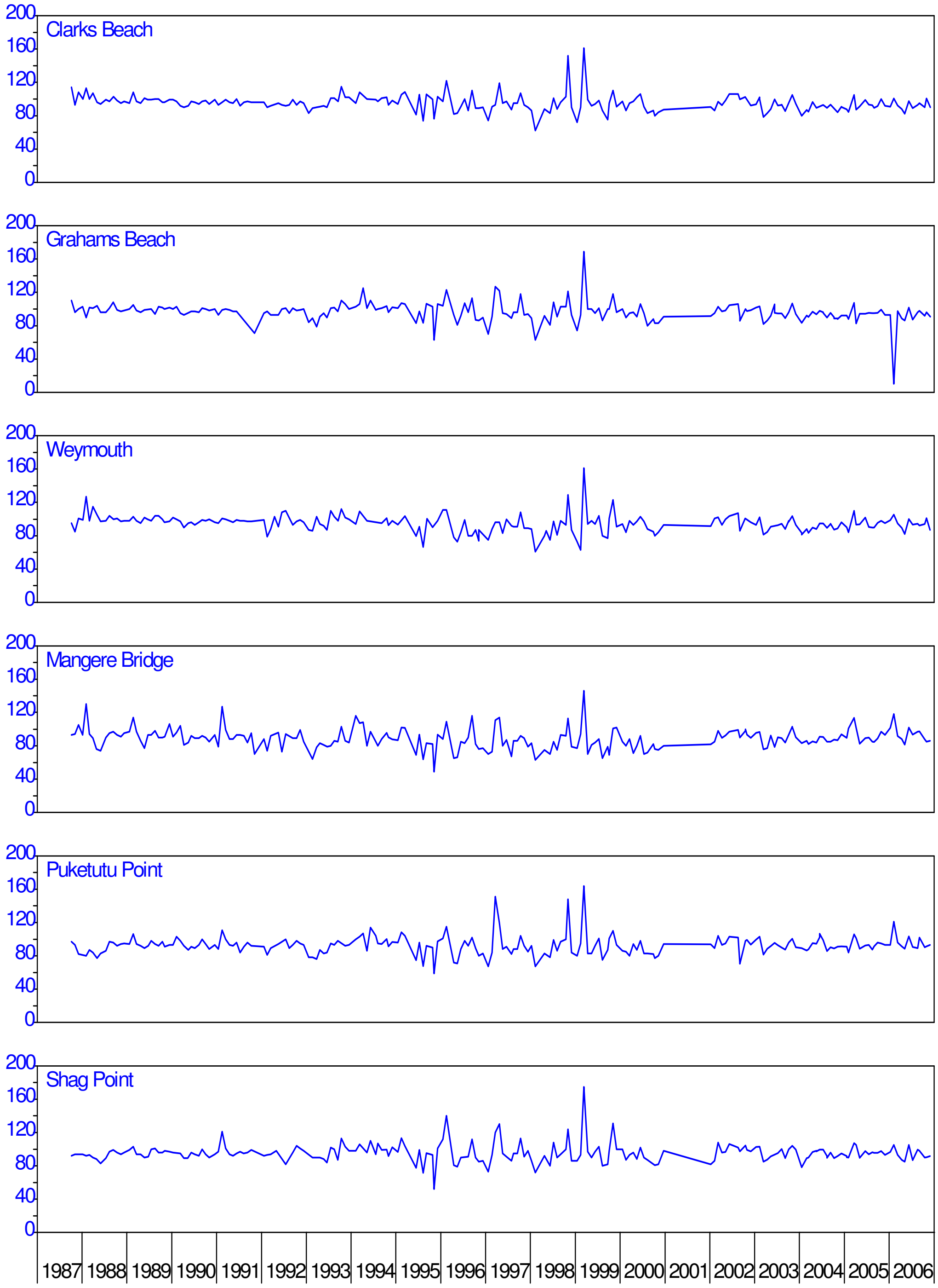


Figure 53: Manukau harbour – dissolved oxygen (ppm)

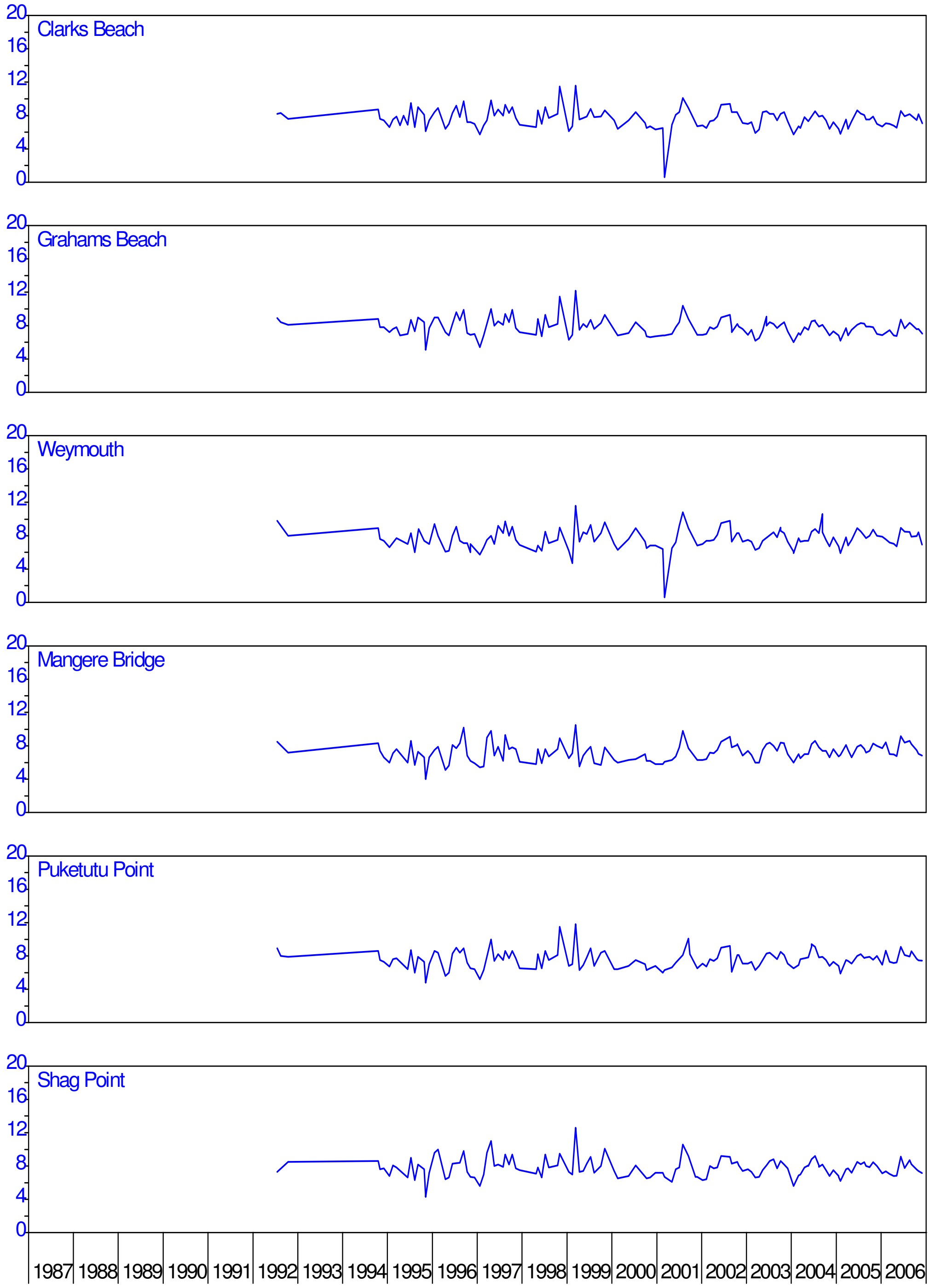


Figure 54: Manukau harbour – total phosphorus (g.m-3)

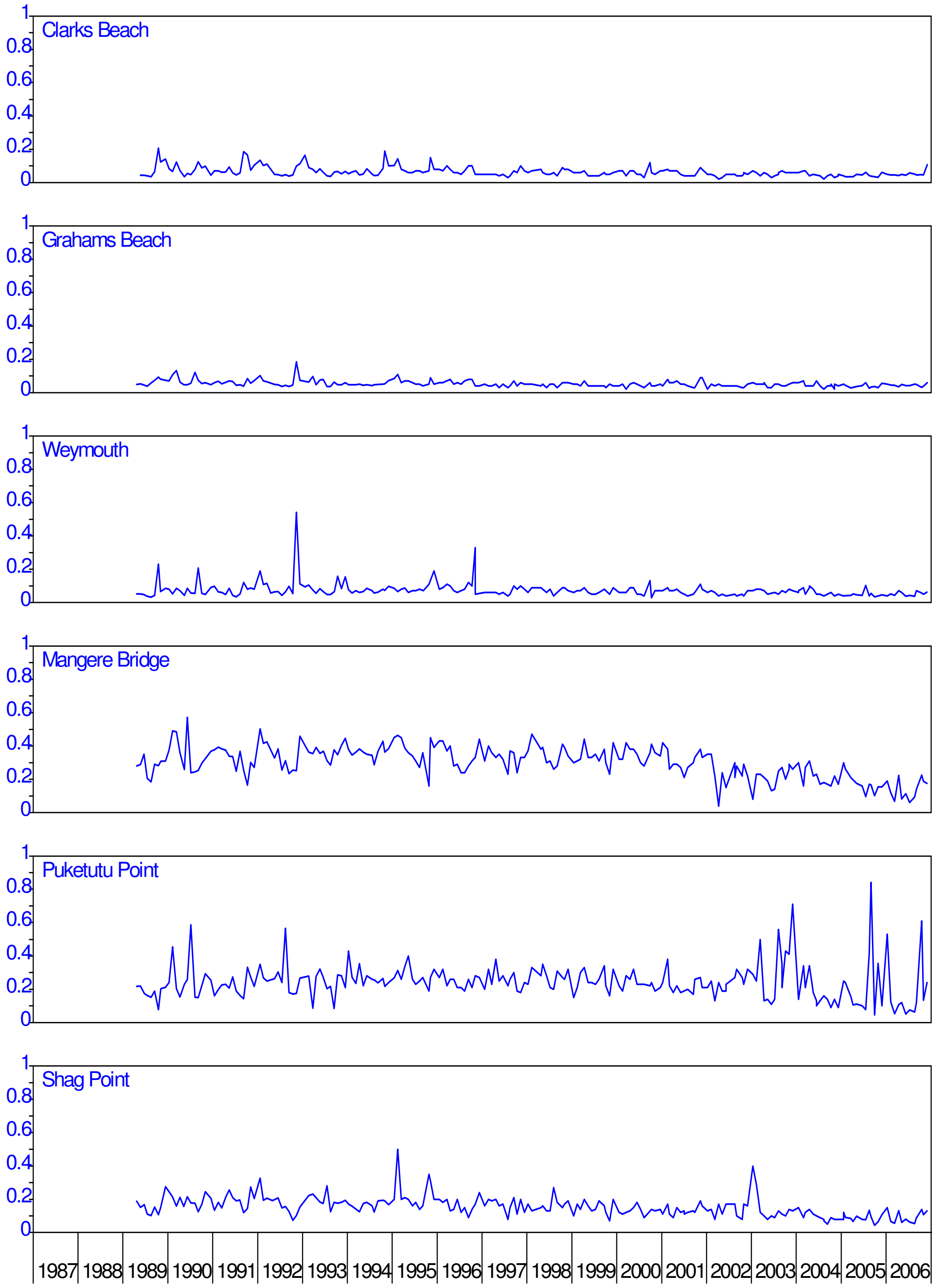


Figure 55: Manukau harbour – dissolved reactive phosphorus (gP.m^{-3})

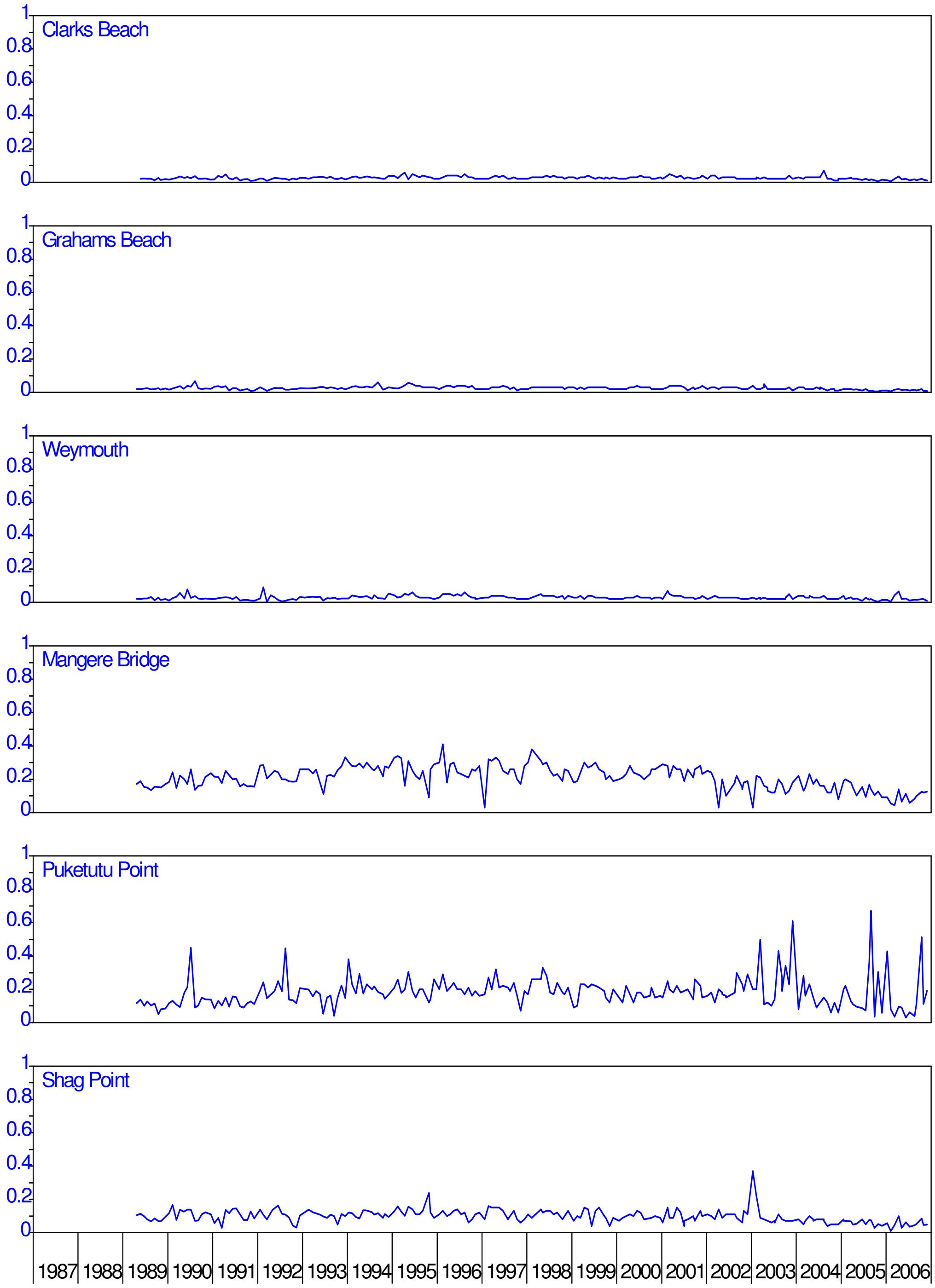


Figure 56: Manukau harbour – enterococci (cfu/100ml)

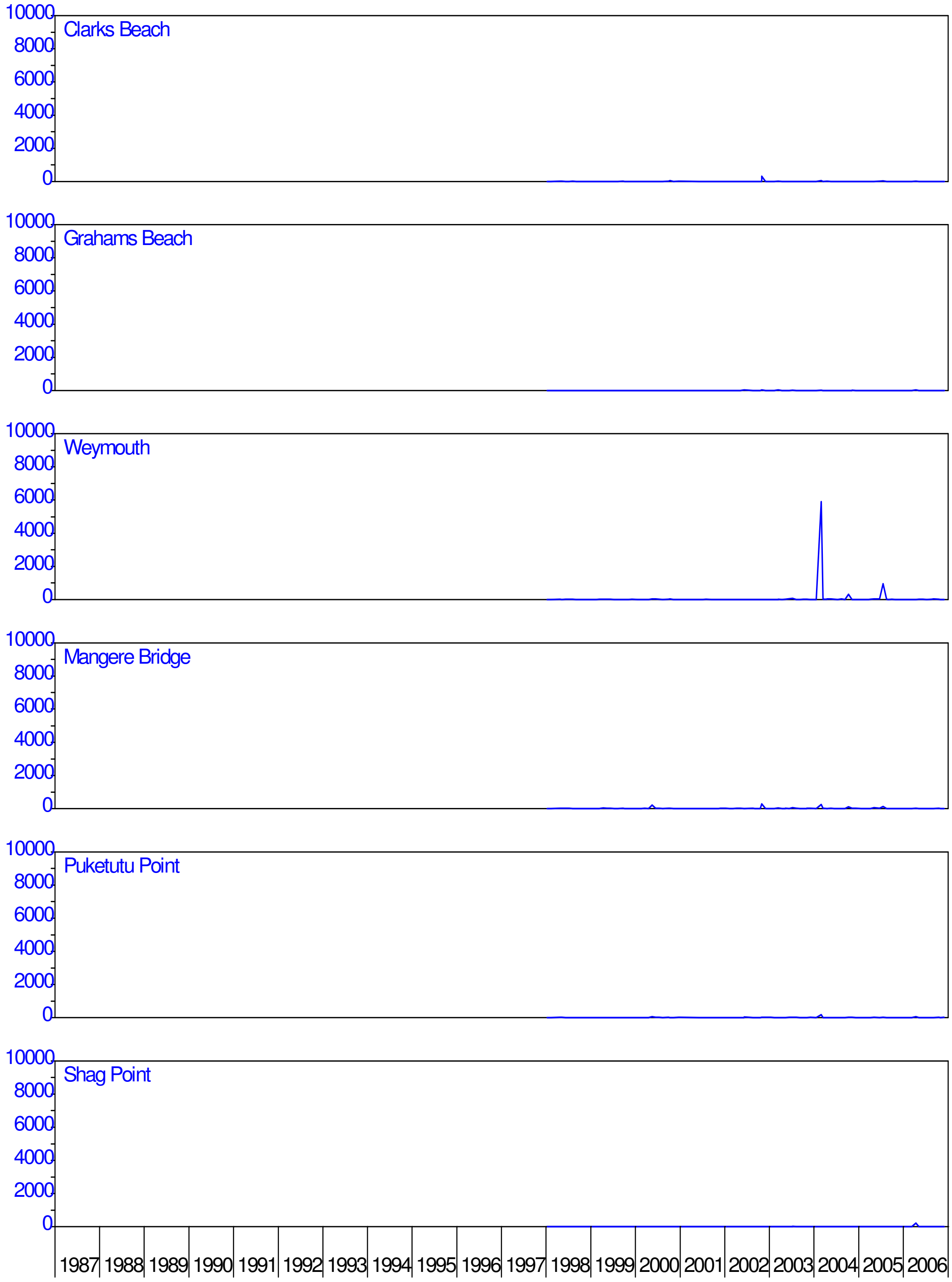


Figure 57: Manukau harbour – chlorophyll a (ppm)

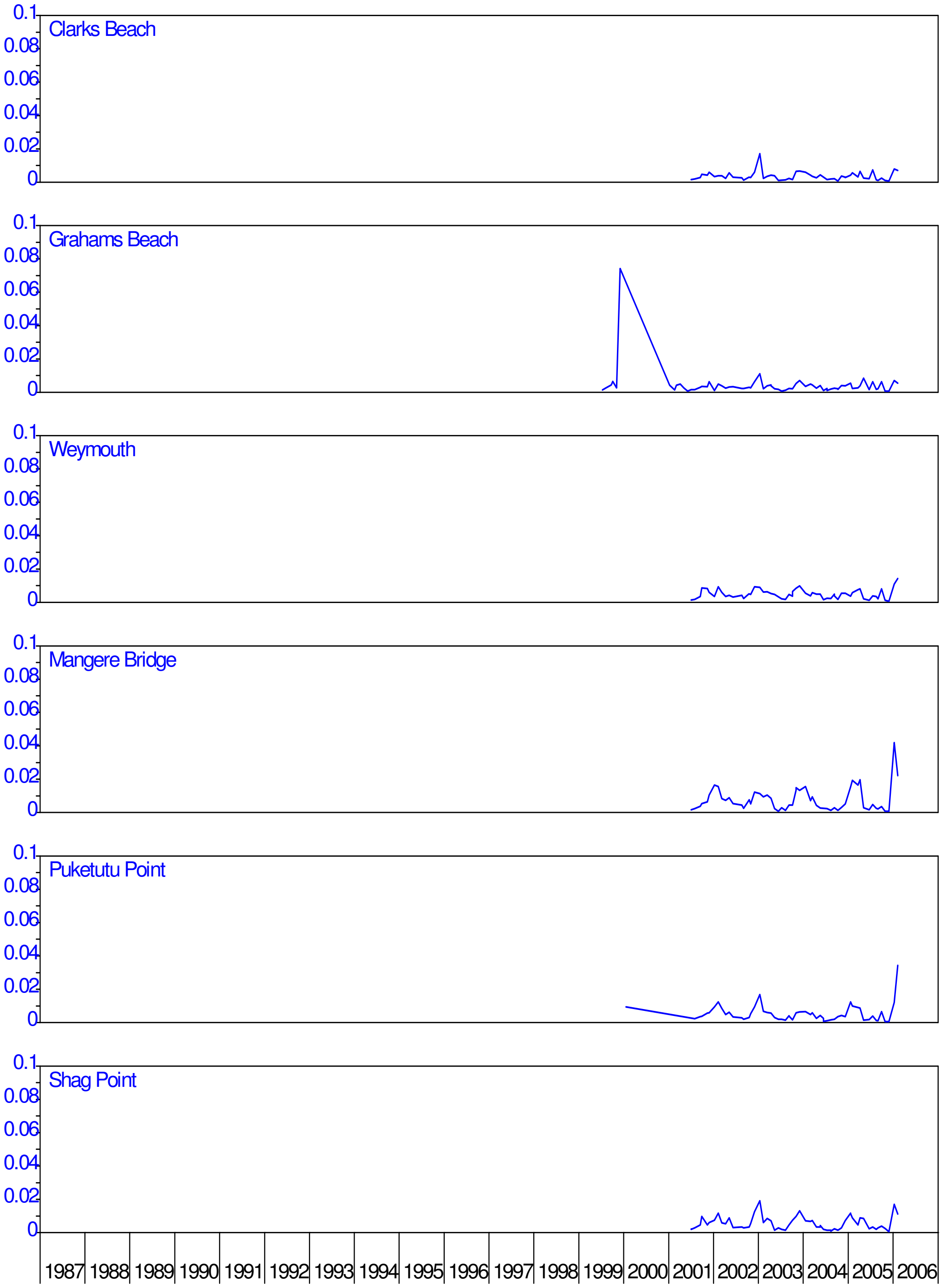


Figure 58: Kaipara harbour (Shelly beach) and Tamaki estuary – salinity (ppt)

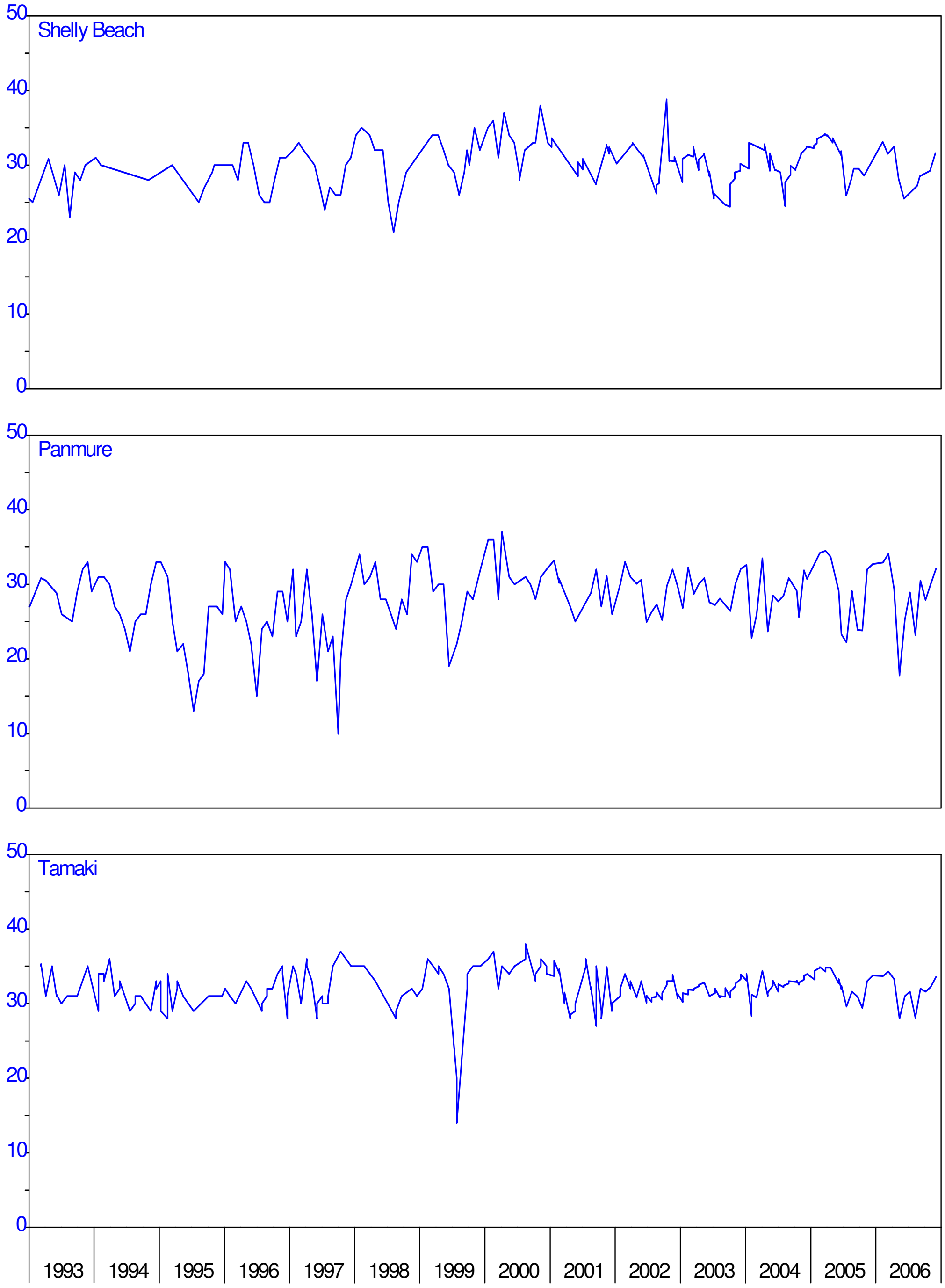


Figure 59: Kaipara harbour (Shelley beach) and Tamaki estuary – turbidity (NTU)

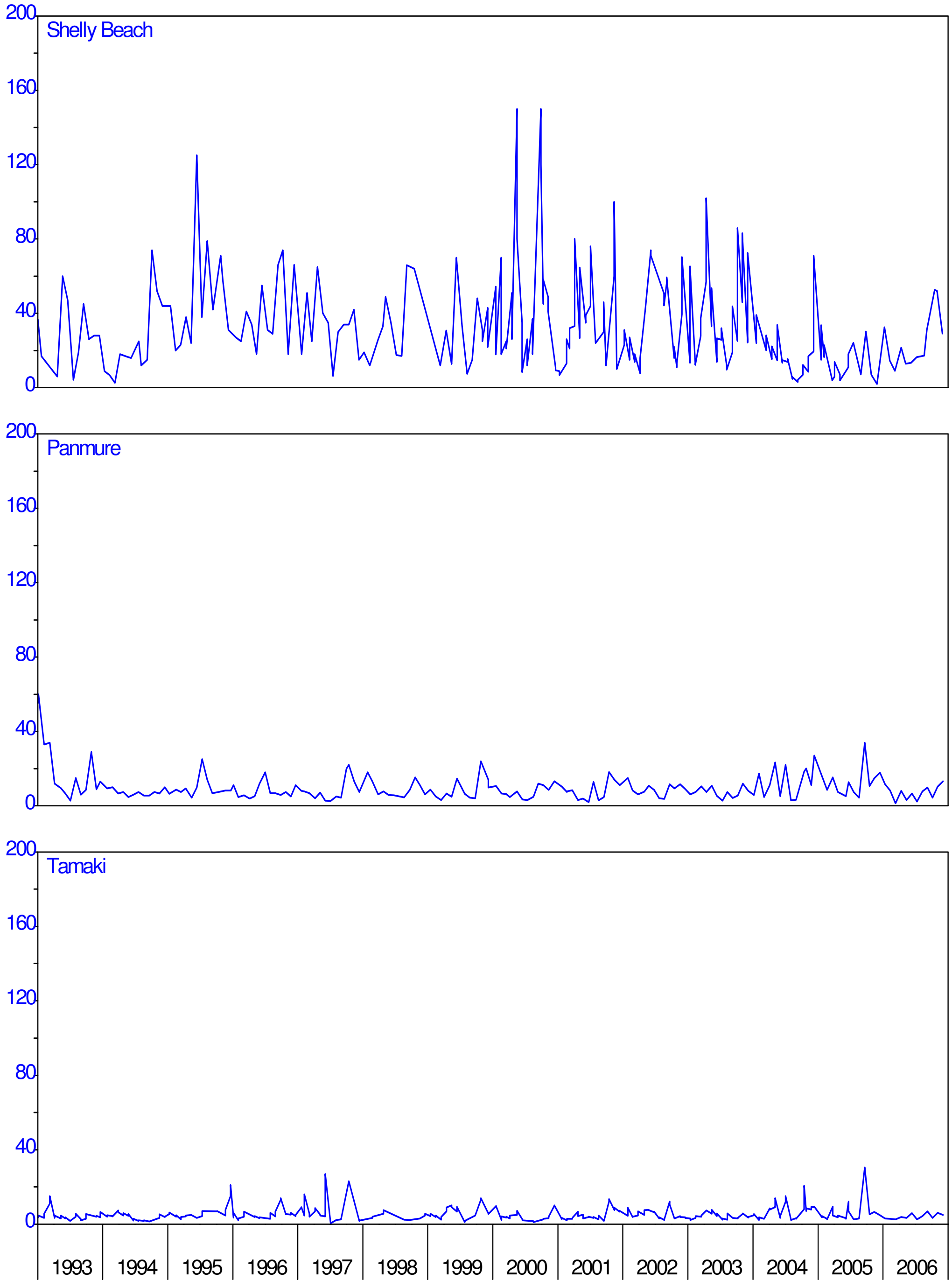


Figure 60: Kaipara harbour (Shelley beach) and Tamaki estuary – transparency (Secchi (m))

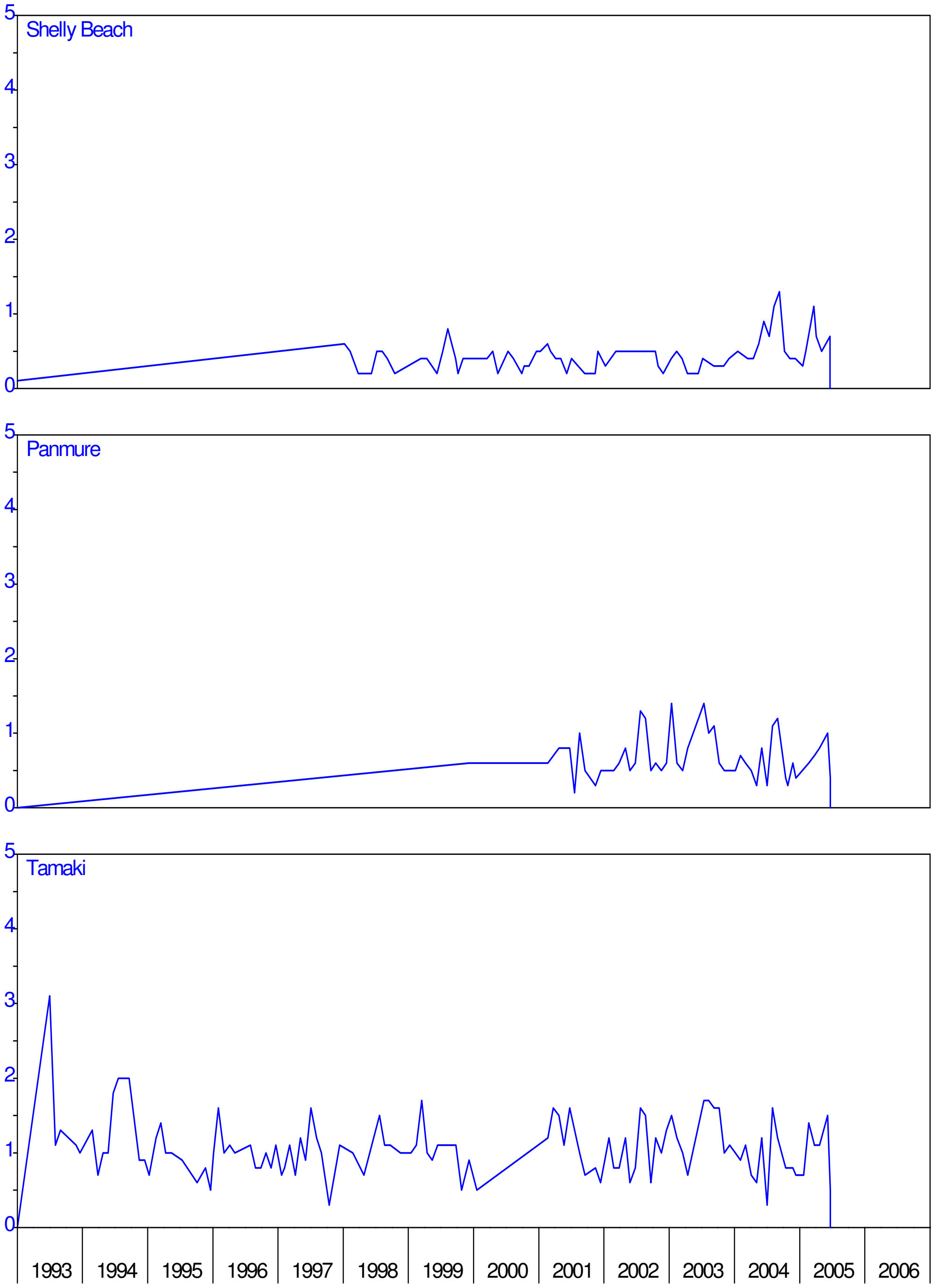


Figure 61: Kaipara harbour (Shelley beach) and Tamaki estuary – temperature (°C)

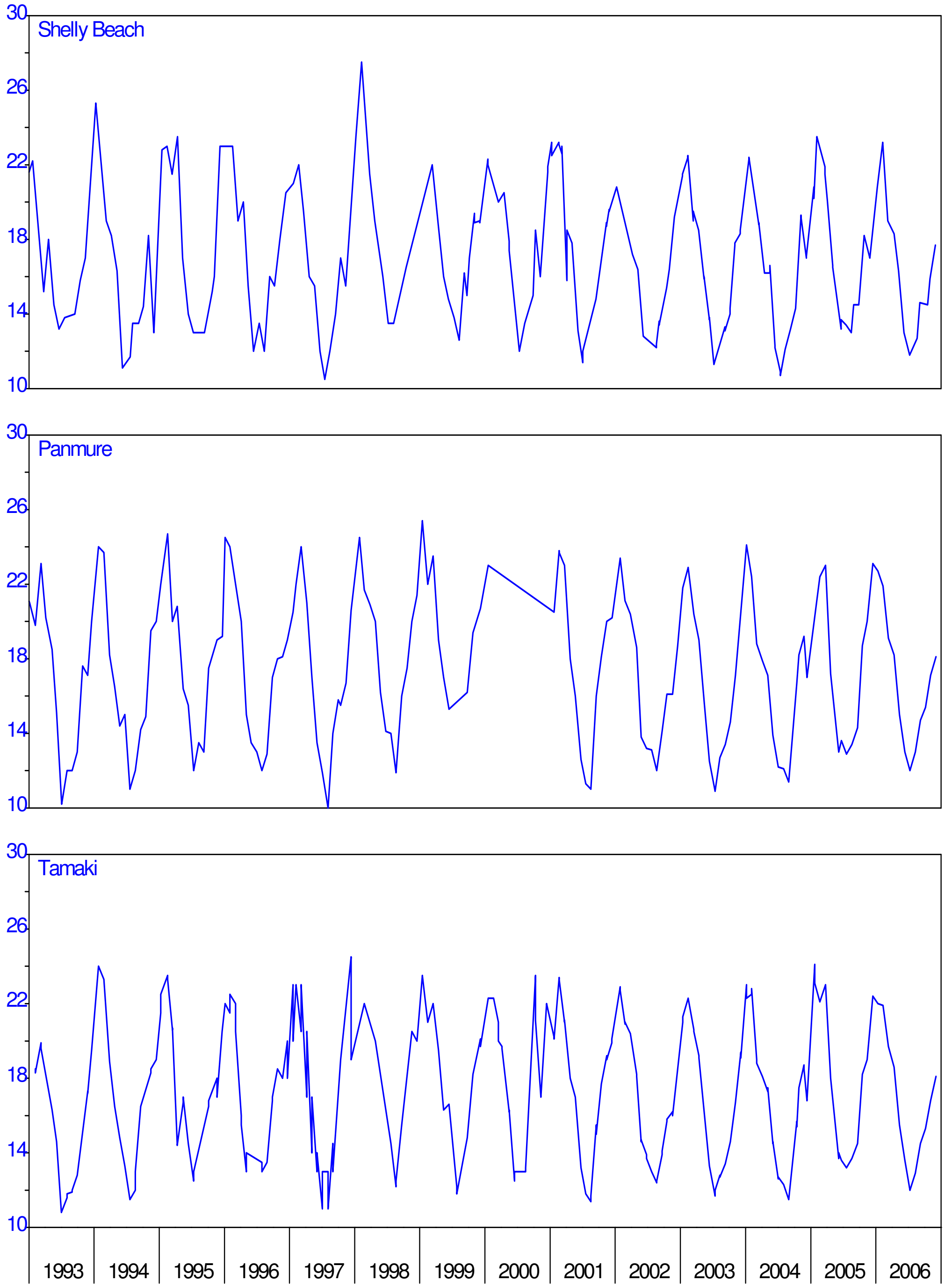


Figure 62: Kaipara harbour (Shelley beach) and Tamaki estuary – pH

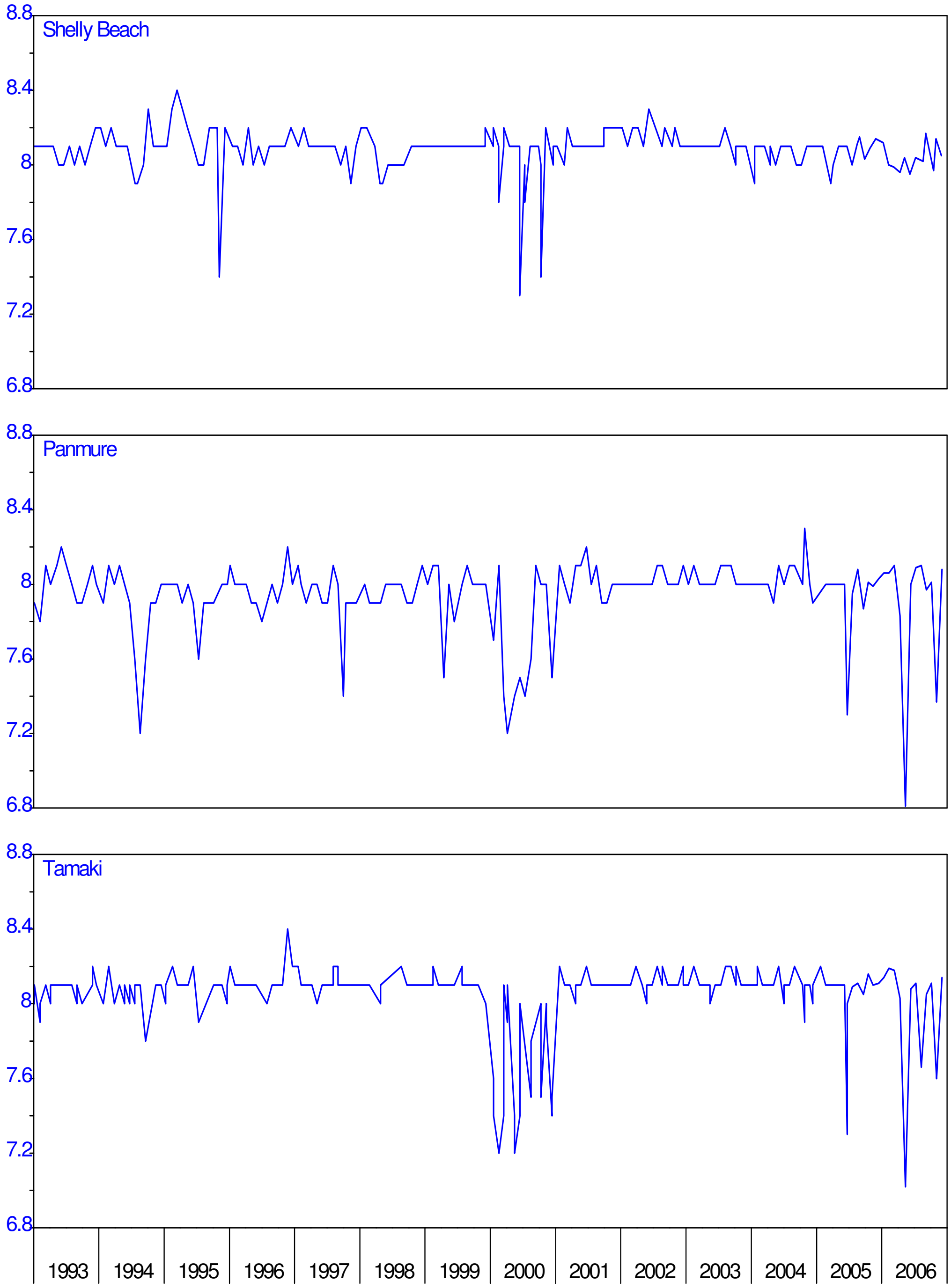


Figure 63: Kaipara harbour (Shelley beach) and Tamaki estuary – suspended solids (ppm)

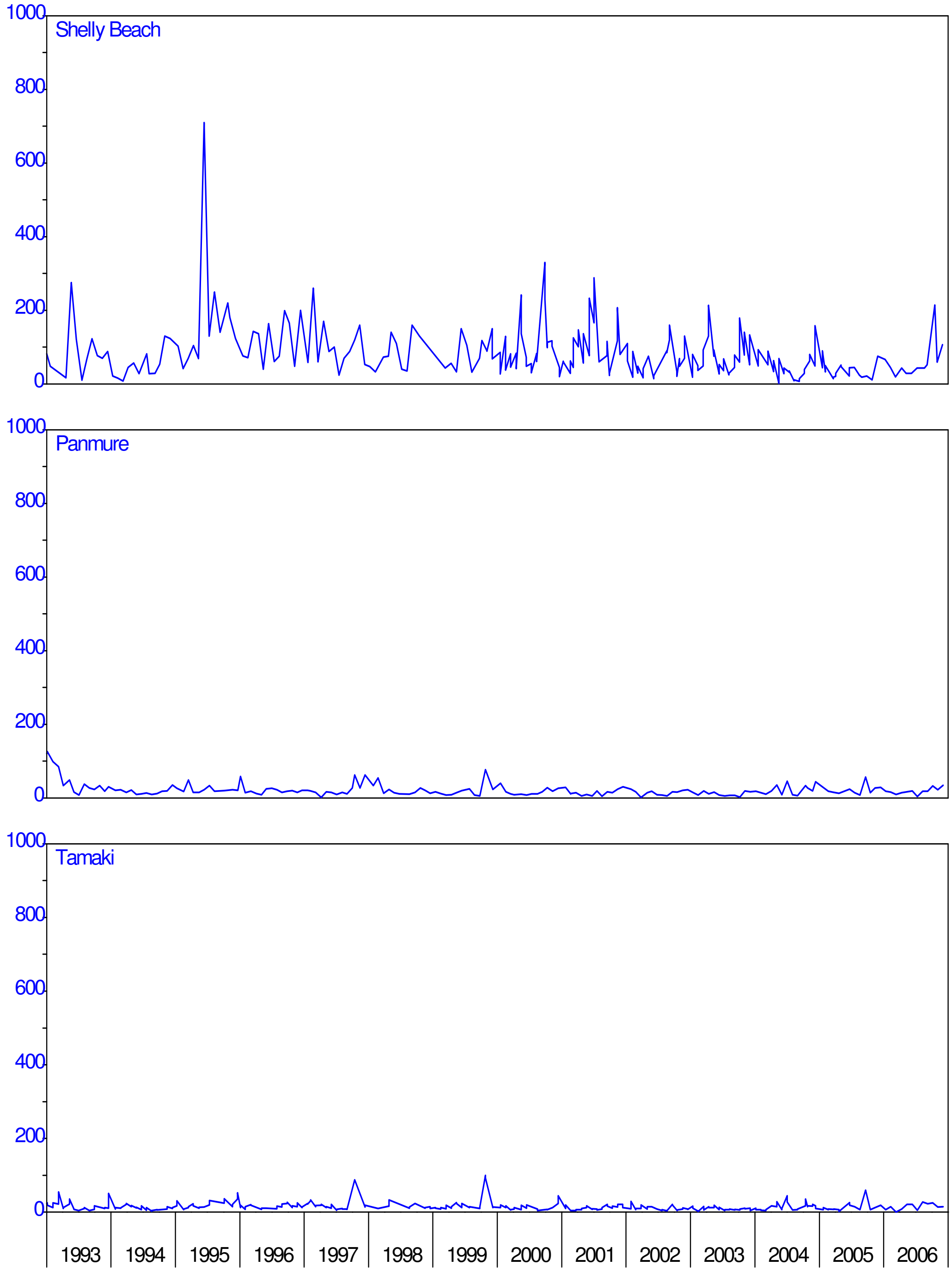


Figure 64: Kaipara harbour (Shelley beach) and Tamaki estuary – nitrate+nitrite (gN.m^{-3})

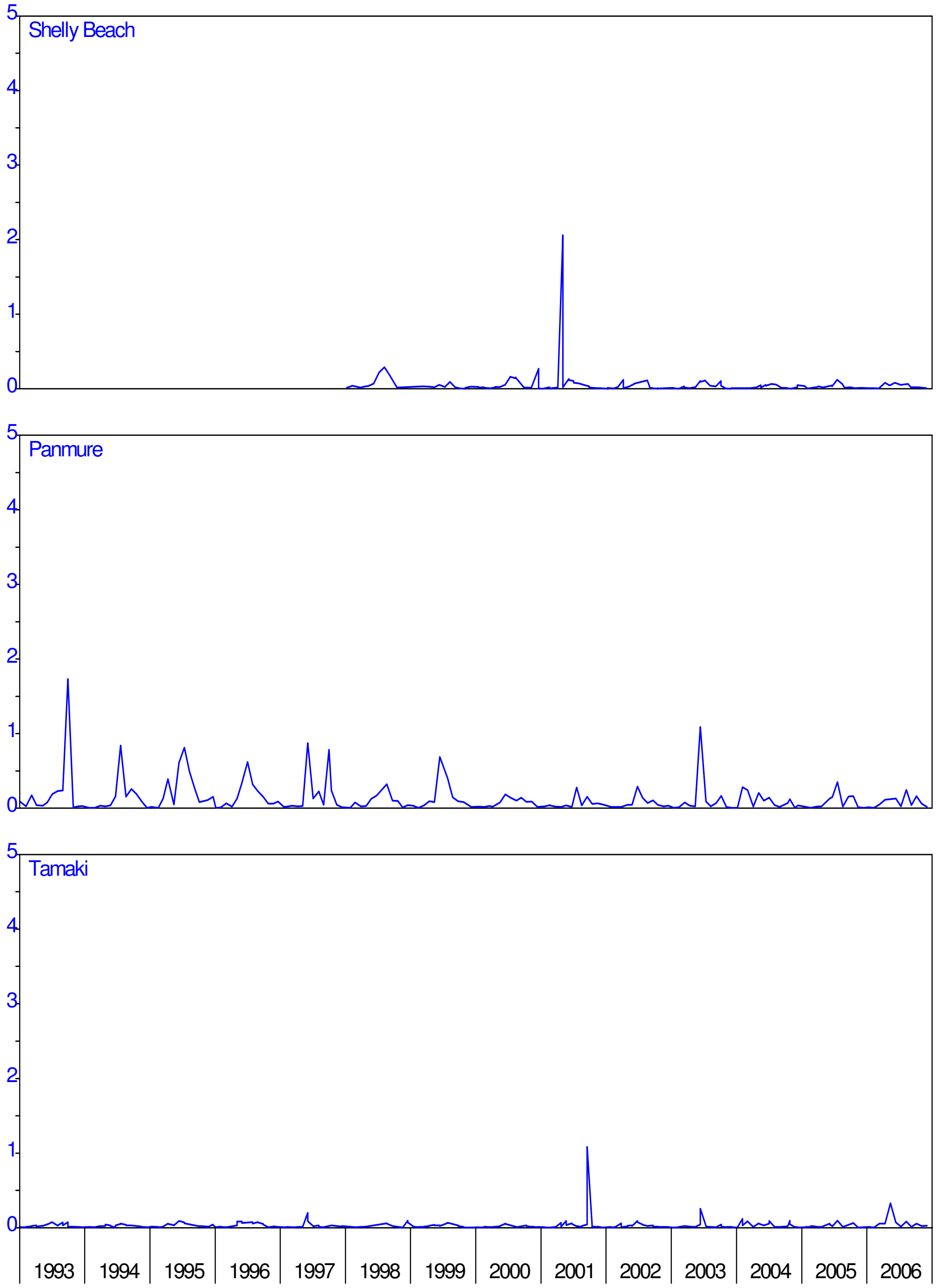


Figure 65: Kaipara harbour (Shelley beach) and Tamaki estuary – ammoniacal nitrogen (gN.m^{-3})

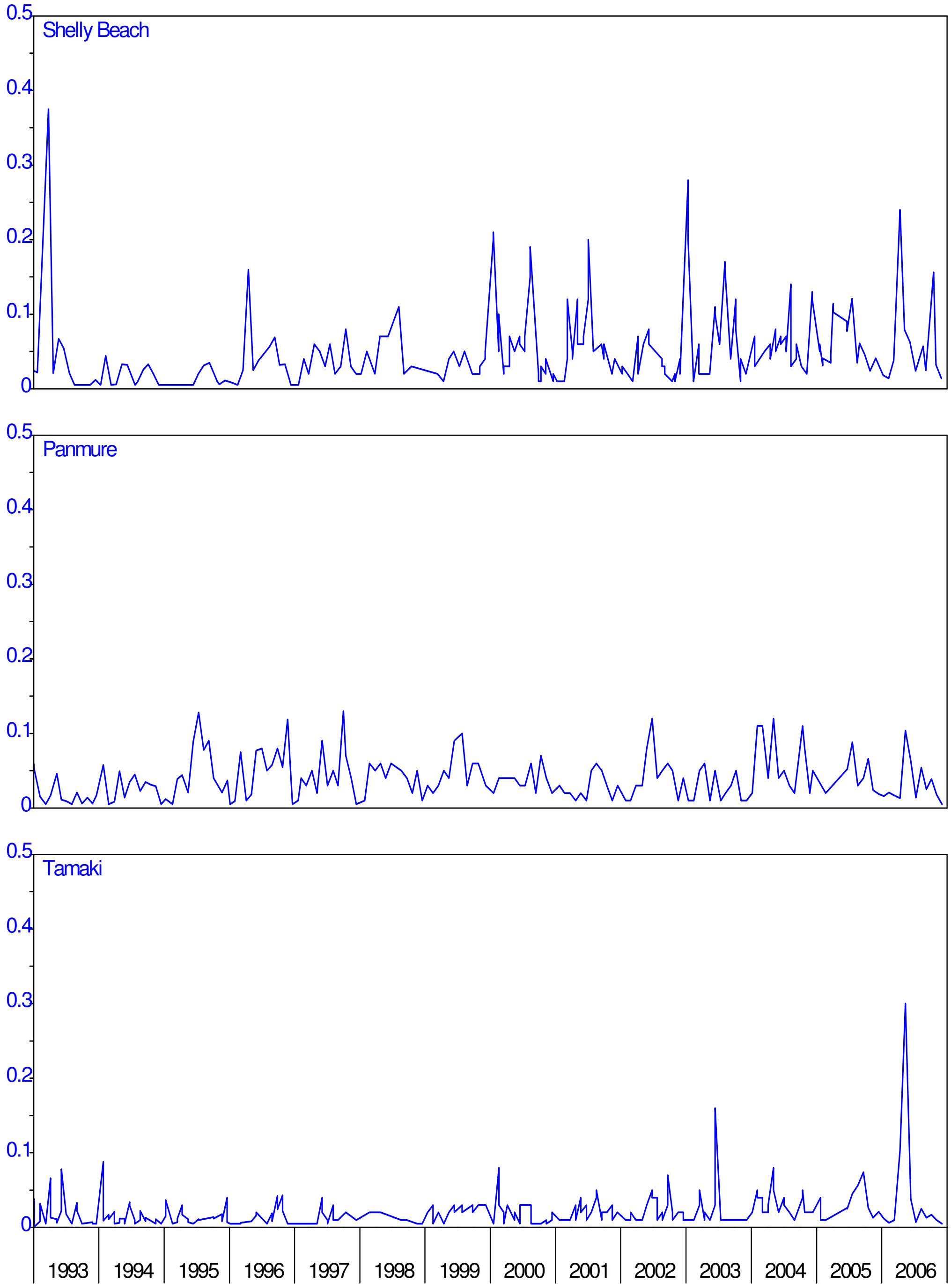


Figure 66: Kaipara harbour (Shelley beach) and Tamaki estuary – dissolved oxygen (% saturated)

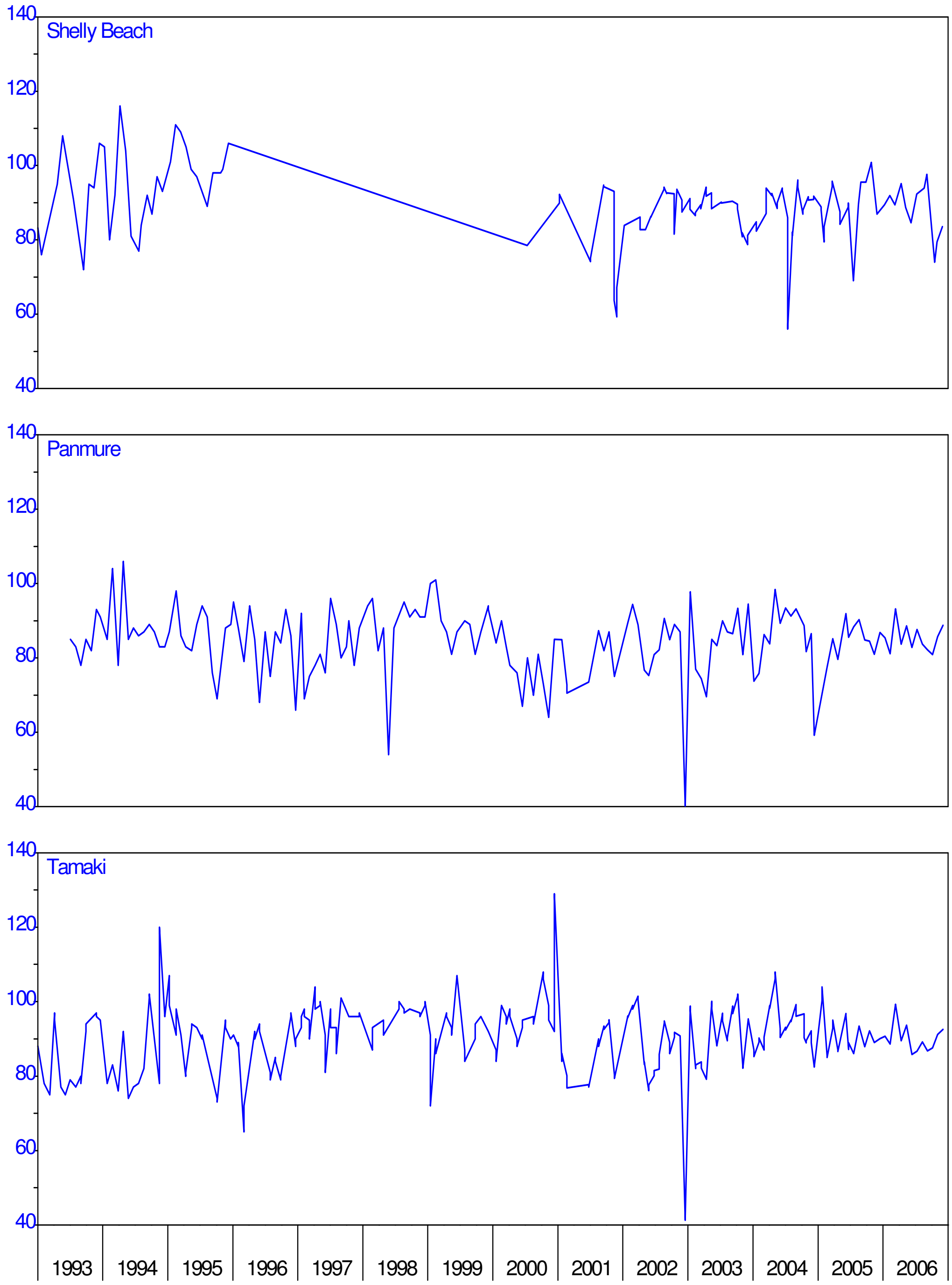


Figure 67: Kaipara harbour (Shelley beach) and Tamaki estuary – dissolved oxygen (ppm)

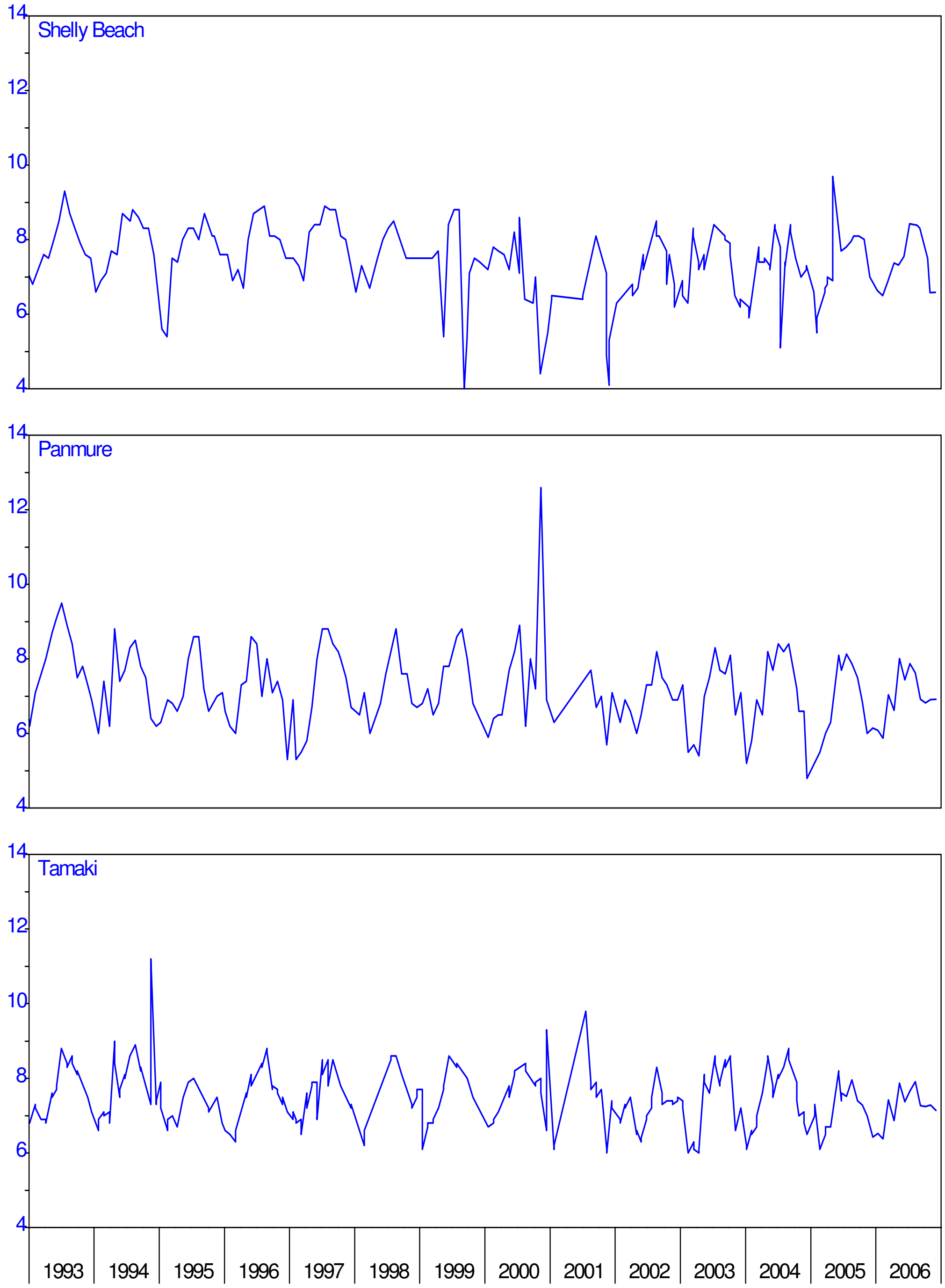


Figure 68: Kaipara harbour (Shelley beach) and Tamaki estuary – total phosphorus (g.m-3)

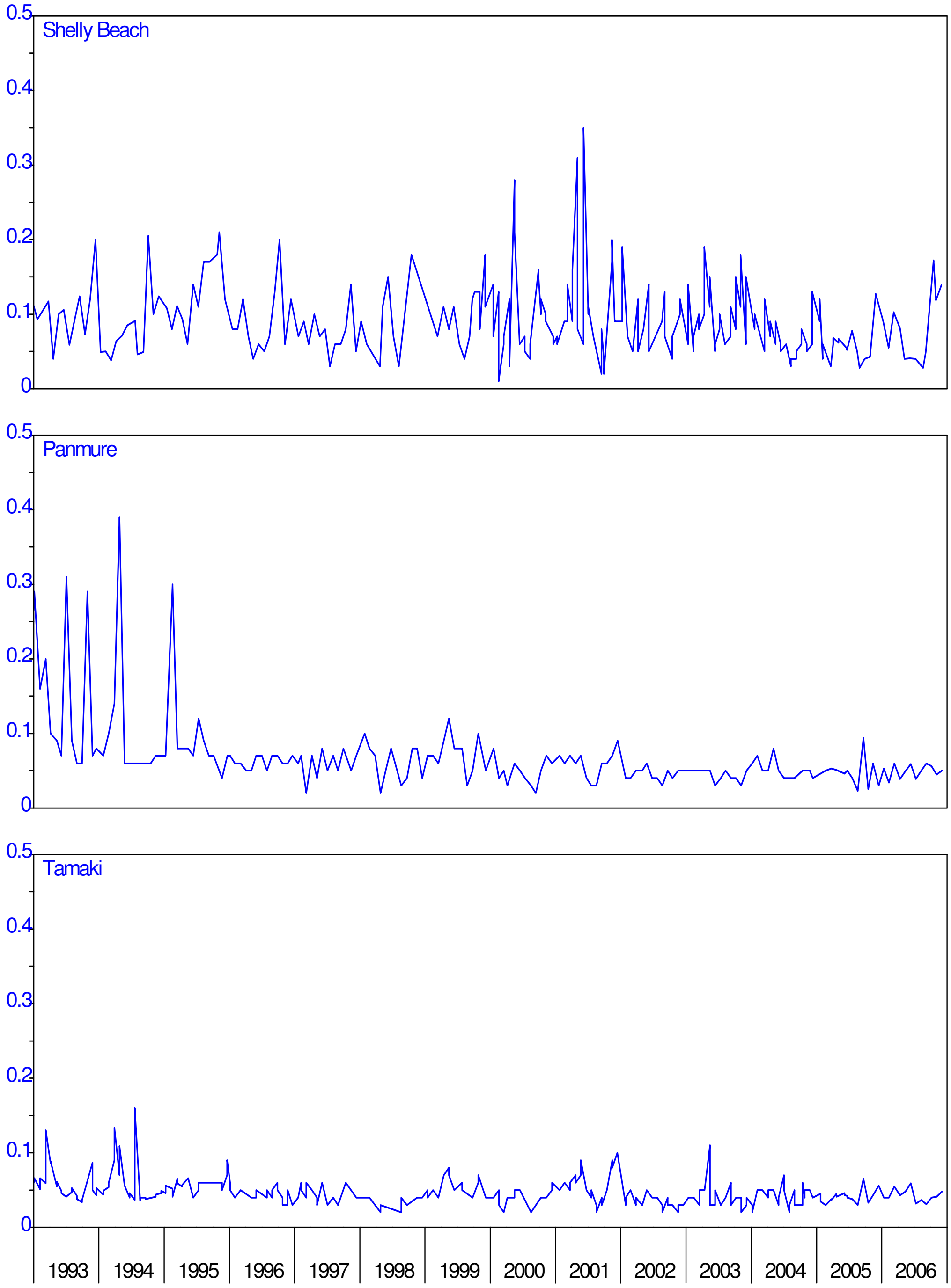


Figure 69: Kaipara harbour (Shelley beach) and Tamaki estuary – dissolved reactive phosphorus (gP.m^{-3})

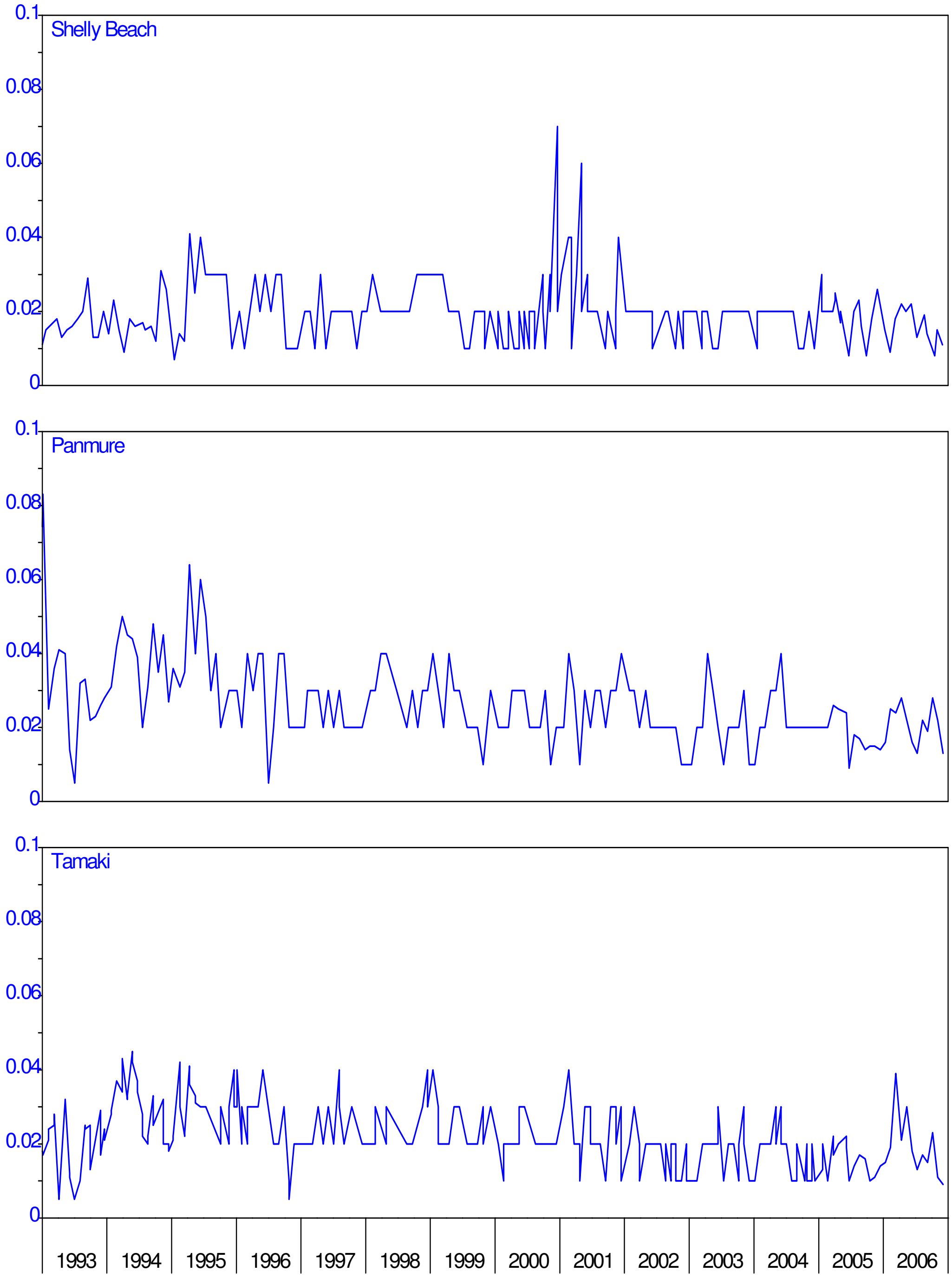


Figure 70: Kaipara harbour (Shelley beach) and Tamaki estuary – enterococci (cfu/100ml)

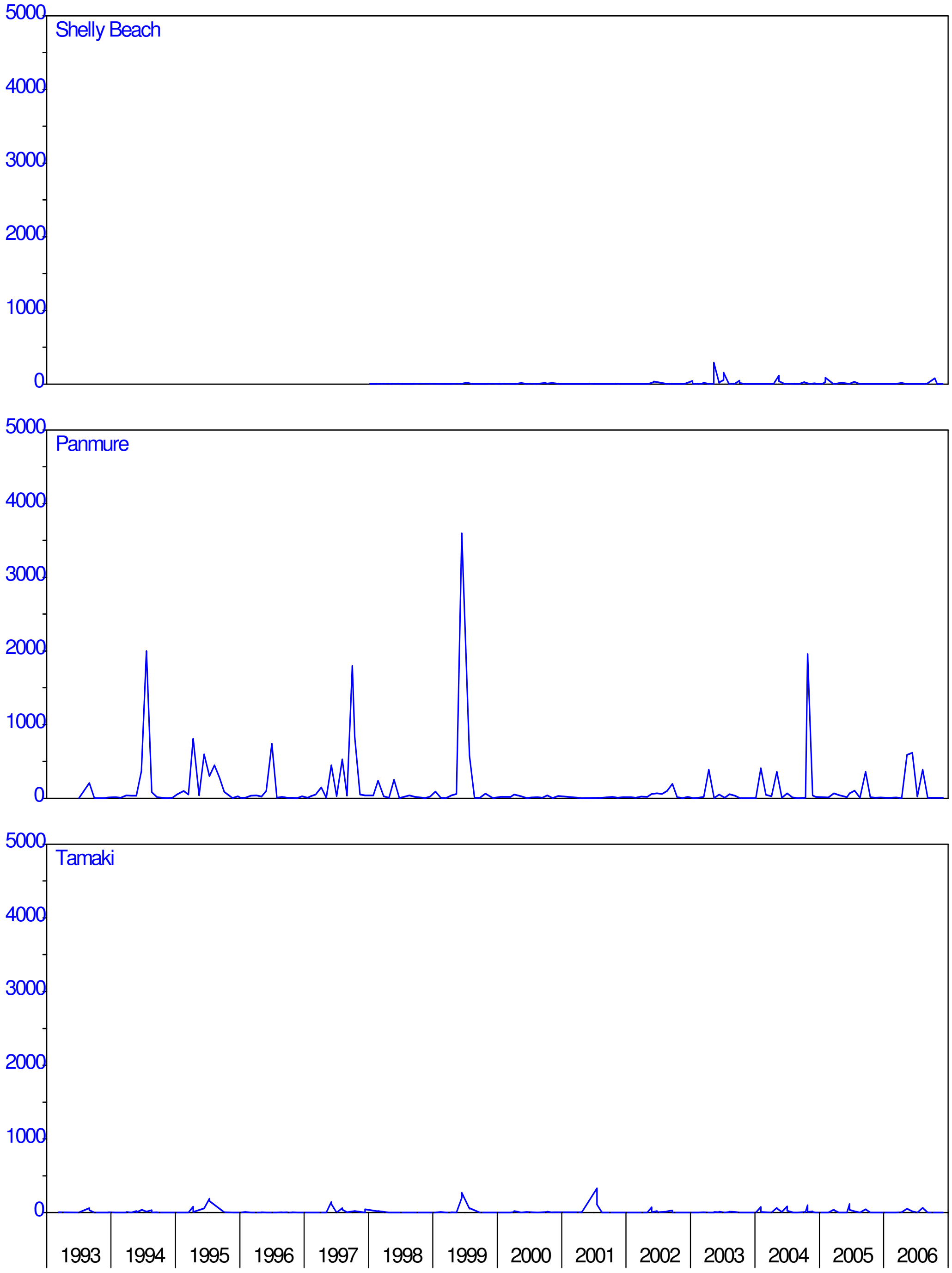
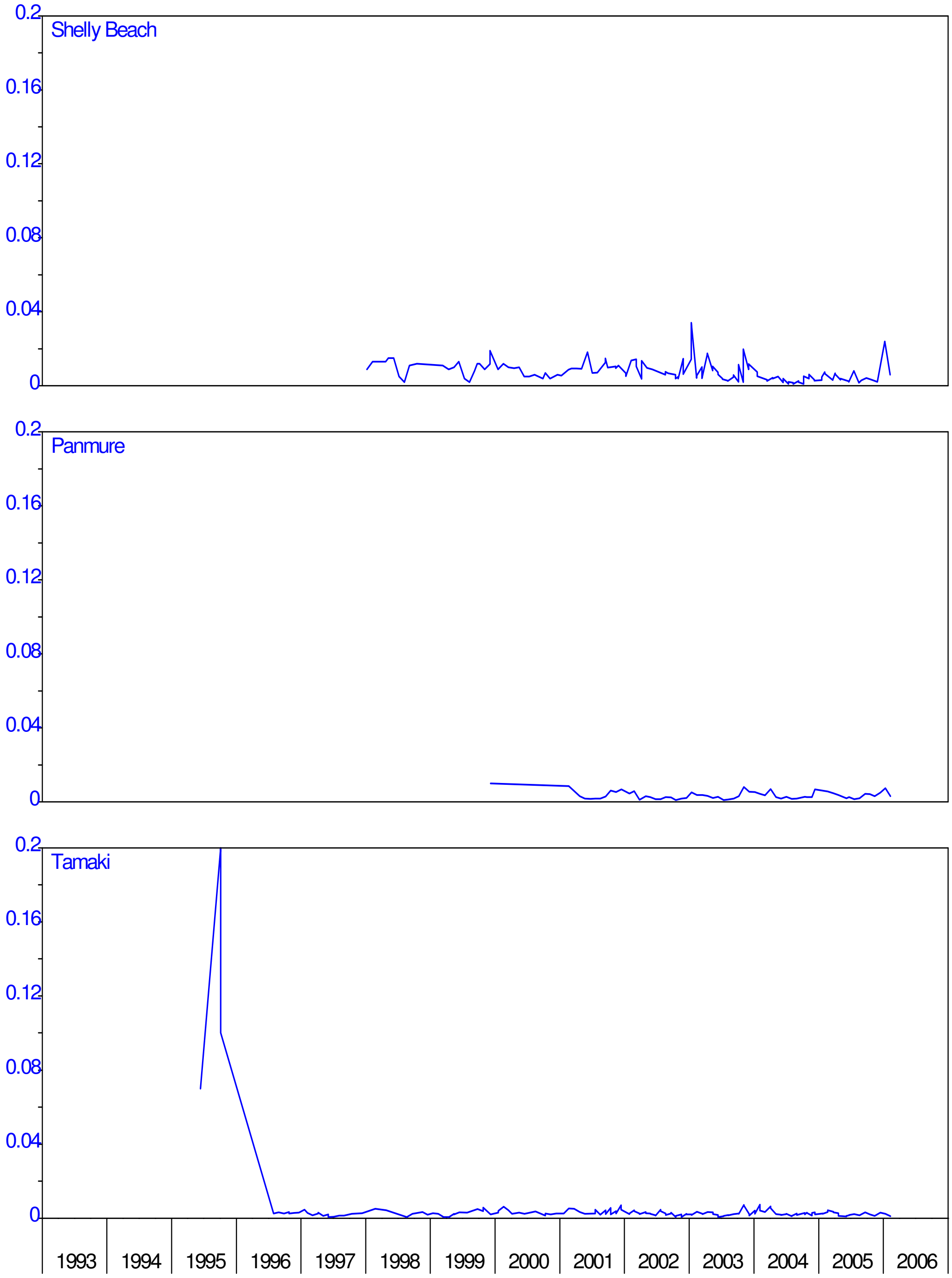


Figure 71: Kaipara harbour (Shelley beach) and Tamaki estuary – chlorophyll a (ppm)



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Appendix I: Water Quality Monitoring Parameters

Table 3: Summary of Water Quality Monitoring Parameters

Water quality parameter	Relevance to programme	Parameter monitored	Comments
Dissolved oxygen - concentration - saturation	- indicator of ability to sustain aquatic life - indicator of organic pollution - indicator of primary productivity	DO (conc) DO (%sat)	Routine (field)
Temperature	-indicator of ability to sustain aquatic life - indicator of primary productivity - mixing processes	Temp	Routine (field)
Conductivity	- indicator of total salts dissolved in water	Cond @ 25°C	Routine (lab)
Chloride	- major salt - indicator groundwater or saline influence	Cl	Routine (lab)
pH	- aquatic life protection - indicator of pollution	pH	Routine (lab)
Suspended solids	- catchment land use activity (erosive forces) - moderator of primary productivity - abrasive to aquatic life	SS	Routine (lab
Nutrients (N and P)	- important for plant growth (nutrient limitation) - enrichment, excessive productivity - indicator of point and non-point pollution	NH4-N, NO3-N+NO2-N, TN, DRP, TP	Routine (lab)
Metals - copper - lead - zinc - cadium	- potentially toxic to aquatic life. - indicator of urban pollution	Cu, Zn, Pb, Cd(all ppb). Total and soluble reported.	Routine (lab) at high disturbance urban sites
Faecal indicators - faecal coliforms - E. coli	- measure of faecal contamination - indicator of sanitary condition & disease risk	Faecal coliforms (MPN/100ml) E. coli (cfu/100ml)	Routine (lab) E. coli routine at Tamaki and Mahurangi sites.

Physio-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 waterbody's ability to support aquatic 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 aquatic plants in the form of macrophytes, periphyton or free-floating algae are abundant. During the hours of daylight the release of oxygen during photosynthesis augments the transfer of oxygen through the surface of the waterbody 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.

Temperature

Water bodies generally show seasonal patterns in temperature that are correlated with air temperature. Heat transfer between the atmosphere and water surface primarily influences stream temperature. Stream temperatures, in the absence of industrial discharges of heated water, are primarily regulated by the extent of shading of the waterway. In catchments developed for urban uses or intensive agriculture, natural sources of shading have been removed and as a result stream temperatures tend to be elevated.

Elevated water temperature can influence aquatic biota in the following ways:

- Community structure in compromised waterways dominated by thermotolerant species that can survive fluctuations in temperature, particularly those experienced in summer.
- 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 (see next section).

Conductivity

Conductivity is used to estimate the total dissolved solids (soluble salts) content of the water. The soluble salts concentration is an important consideration in relation to abstraction of water for horticultural use and in extreme situations the suitability of water for stock use.

Chloride

The major natural source of chloride is from groundwater, which in the Auckland Region ranges from 17-40 mg/L depending on the geology concerned. High chloride levels are present in wind blown spray in coastal environments and in rural and urban wastewater. Thus, high chloride levels are often used to indicate the presence of other contaminants in freshwater aquatic systems.

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. Natural freshwaters have a pH of around 7 although 6-9 is considered within the normal range. In the absence of contaminant discharges the major influence on pH levels is likely to be the photosynthetic activity of aquatic plants. This occurs when carbon dioxide is absorbed upsetting the carbon dioxide-bicarbonate equilibrium of the stream waters and elevating pH. This problem is most likely to occur in waterways with high nutrient levels and little overhanging vegetation to limit light levels and thereby in-stream plant growth.

pH does not have a directly toxic effect on aquatic biota although Manukau Harboury species are not tolerant to wide fluctuations in pH. The principal influence of pH is on the toxicity or mobility of other contaminants present in the water column or sediments. In urbanised situations receiving water sediments may contain large amounts of heavy metals such as zinc, copper and lead from stormwater runoff. Decreases in pH would tend to mobilise some of these bound contaminants. The toxicity of other contaminants such as ammonia, which is elevated in some rural waste discharges, generally increases with higher pH and temperature.

Suspended Solids

Suspended solids (SS) is a measurement of the suspended material in the water column, including 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 horticulture, irrigation, stock water supply, and recreational and ecological functions. Under the appropriate conditions the suspended material can settle out as sediment thereby causing further problems, such as smothering of biota.

Water Clarity

Public perception of water quality is often based on their observation of water quality or clarity, in that poor water clarity is aesthetically unpleasing, regardless of other water quality parameters. Stream water clarity is expressed by measuring turbidity and black disk transparency. The black disk reflects very little light and black disk transparency is the distance at which it becomes visible to an observer (using an underwater viewer).

Turbidity

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 aquatic plants (algae and macrophytes) 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 aquatic organisms.

Nutrients (nitrogen and phosphorus)

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

The availability of readily assimilated forms of the nutrients nitrogen and phosphorus are commonly accepted as factors limiting aquatic plant growth. Anthropogenic activities increase the nutrient loading through the discharge of waste products, fertilisers and general storm-water runoff. Nutrient enrichment can result in a proliferation of algae and macrophytes in waterways, which potentially has a number of detrimental effects including:

- Choking waterways leading to reduced drainage capacity,
- Loss of amenity values,
- Physical habitat reduction,
- Excessive fluctuations in dissolved oxygen and pH,
- Reduced suitability for stock watering or horticultural irrigation.

Ammonia

Ammoniacal nitrogen is a macro-nutrient but is considered in general water quality evaluations in terms of its toxicity to Manukau Harboury aquatic animals.

Ammonia occurs in a number of waste products, which if discharged to the environment can result in elevated ammonia levels. Ammonia is reported as a combination of un-ionised ammonia (NH3) and the ammonium ion (NH4), at normal pH values the latter form predominates. Un-ionised ammonia is the more toxic form to aquatic life. The toxicity of ammonia is very dependent on water temperature, salinity and pH (USEPA, 1985). Regulatory agencies, such as the ARC Environment, have tended to rely on overseas criteria such as those promulgated by the USEPA. The ARC has commissioned studies on Auckland freshwater biota, which corroborate that USEPA criteria are appropriate – ARC Environment and Planning Division TP23 (1992).

Ammonia toxicity for given pH and temperature combination can be calculated using a mathematical equation. As a generalisation a chronic or long term exposure limit of 0.77 mg/L is appropriate for sensitive freshwater organisms under ambient conditions. In saline waters ammonia toxicity is influenced by salinity in addition to pH and temperature. The chronic exposure limit for sensitive saline organisms under ambient conditions is 2.3 mg/L.

Nitrite plus Nitrate Nitrogen

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 therefore indicative of a source of nitrogenous waste in the immediate vicinity of the sampling site.

Nitrate is the end product of the breakdown (oxidation) of ammonia through the intermediate step of nitrite by microbial decomposition. It is not particularly toxic to aquatic life (USEPA, 1986). Water for use as potable supply is limited to 10 mg/L on public health grounds. In terms of crop irrigation water requirements higher nitrate levels could be seen as an advantage saving on fertiliser costs and to a limit. For stock drinking water requirements the recommended limit is 100 mg/L.

Sources of nitrate in aquatic systems are similar to those discussed for ammonia. Nitrate is poorly bound to the soil and is therefore highly mobile. It is readily leached into local groundwater systems, particularly under high rainfall events. In winter when ground conditions become saturated the capacity of the soil to assimilate waste is reduced, resulting in elevated nitrate levels in runoff.

Nitrate is an important plant nutrient (which is generally non-limiting), which in conjunction with sufficient available phosphorus can lead to proliferation of aquatic plants (algae and macrophytes). Respiration of aquatic plants at night can lead to reductions in dissolved oxygen to the point that other aquatic organisms may become stressed or killed. Photosynthetic activity of aquatic plants also leads to elevated stream pH, which has an effect on the toxicity of other contaminants in the water such as ammonia.

Total and Dissolved Reactive Phosphorus

Total phosphorus is a measure of all the phosphorus present in the sample and includes the soluble (bioavailable) fraction that is adsorbed onto sediment particles and present in the form of algae and other organic matter.

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 and other aquatic plants in New Zealand waterways.

Metals (copper, lead, zinc)

Copper, lead, and zinc are associated with urban areas with the source of these contaminants linked to air pollution, automobiles, and industrial land uses. Total and soluble metal concentrations are measured at urban sites because levels rarely exceed effect levels in non-urban areas.

Microbiological

Microbial indicator organisms are typically used in water quality monitoring to provide a measure of faecal contamination and hence the sanitary quality of water resources. A number of different indicator organisms and monitoring strategies can be used depending on whether the purpose of sampling is simply to detect and quantify the level of contamination, or whether some measure or index of public health risk is required.

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 huManukau Harbours, and are shed in large numbers in faecal matter (at a rate of 106 – 109 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 Manukau Harboury 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 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 present in a waterway. 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.

Faecal Coliforms

Faecal coliforms represent a subset of the coliform group that are differentiated by their ability to ferment lactose with the production of acid and gas at the elevated temperature of 44.5°C. This group are more specific indicators of faecal contamination than the coliform group, although the functional definition still includes some organisms that are natural inhabitants of soil and decaying vegetation. The use of the term faecal" in the group description is therefore somewhat misleading, and has lead to the use of the term "thermotolerant coliforms" as an alternative group name.

Faecal coliforms have historically been the indicator of choice for assessment of the sanitary quality of natural waters and have formed the basis of the previous microbiological guidelines for recreation and shellfish growing waters. However, the fact that non-faecal derived organisms are also included in the group lead to recommendations that the bacterium Escherichia coli provides a better index of health risk than just faecal coliforms. For further information on this topic refer to the "Recreational Water Quality Guidelines" published by Ministry for the Environment and Ministry of Health, Wellington, November 1999.

However, despite this the faecal coliform group is still considered appropriate for qualitative monitoring of faecal contamination in natural waters, and for assessment of long terms trends in water quality over time. It is in this context that the indicators are used in the baseline water quality studies. *Escherichia coli* has been monitored at selected sites since 1986 and widened to all sample locations in July 2006.

Regardless of indicator bacteria or group of bacteria used, impediments to their overall usefulness is the inability to discriminate between contamination of huManukau Harbour and non-huManukau Harbour origin. Such assessments must be made empirically using other more complex and expense analytical techniques including sterol and stanol ratios, and florescent whitening agents.

Table 4: Analytical methods of analysis

Identifier (+ unit)	Parameter	Method
DO (ppm)	Dissolved oxygen	Handheld meter (YSI-85)
DO (% sat)	Dissolved oxygen saturation	Handheld meter (YSI-85)
Temp (°C)	Temperature	Handheld meter (YSI-85)
Cond @ 25 °C(μS.cm^{-2})	Conductivity	Handheld meter (YSI-85)
Sal (ppt)	Salinity	Handheld meter (YSI-85) or calculation
Cl (g.m^{-3})	Chloride	APHA (1998) 4500-Cl
pH	pH	APHA (1998) 4500-H B
SS (g.m^{-3})	Suspended solids	APHA (1998) 2540 D
Turb (NTU)	Turbidity	APHA (1998) 2130 B
Secchi Disk (m)	Secchi Disk	Secchi Disk
Chl a (g.m^{-3})	Chlorophyll a	APHA (1998) PART 10200 H
BOD (g.m^{-3})	Biochemical Oxygen Demand	APHA (1998) 5210 5-2
NO3 (gN.m^{-3})	Nitrate nitrogen	Calculation NNN (gN.m^{-3}) - NO2 (gN.m^{-3})
NO2 (gN.m^{-3})	Nitrite nitrogen	APHA (1998) 4500-NO2 B
NH4-N (gN.m^{-3})	Ammoniacal nitrogen	APHA (1998) 4500-NH3 G
NO3-N+NO2-N (aka NNN) (gN.m^{-3})	Nitrate/Nitrite nitrogen	APHA (1998) 4500-NO3 F
DRP (g.m^{-3})	Dissolved reactive phosphorus	APHA (1998) 4500-P F
TP (g.m^{-3})	Total phosphorus	APHA (1998) 4500-P B,F
Entero (cfu/100ml)	enterococci	APHA (1998) 9230 C
FaeC (MPN/100ml)	Faecal colifoms	APHA (1998) 9221 E
Pres (MPN/100ml)	Presumptive coliforms	APHA (1998) 9221 B