8.5 Lake Spectacle

Annual mean and median chemical and bacteriological quality of Lake Spectacle

Date	Depth (m)	BOD (mg/L)	Chl a (mg/L)	Chloride (mg/L)	EC (mS/m)	FaeC (MPN/100mL)	PresC (MPN/100mL)	NH_4-N (mg/L)	NNN[1] (mg/L)	DRP (mg/L)	TP (mg/L)	pH	SS (mg/L)	TKN (mg/L)	Turb (NTU)	Secchi[2] (m)
25-Feb-04	0	<2.0	0.0777	41.6	26.1	8	1100	0.02	0.020	<0.01	0.2	7.8	40.7	2.2	71.2	0.1
18-May-04	0	<2.0	0.0030	43.3	27.4	280	800	0.01	0.003	0.01	0.14	7.3	44.6	1.4	45.9	0.2
20-Aug-04	0	<2.0	0.0397	40.8	26.9	17	800	0.01	0.002	<0.01	0.1	8.2	32.0	1.9	29.5	0.3
23-Nov-04	0	2.6	0.0095	43.8	28.5	2	30	0.02	0.004	0.01	0.08	8.6	19.0	1.9	28.5	0.3
Mean			0.0325	42.4	27.2	77	683	0.02	0.007	0.01	0.13	8.0	34.1	1.9	43.8	0.2
Median			0.0246	42.5	27.2	13	800	0.02	0.004	0.01	0.12	8.0	36.4	1.9	37.7	0.2
25-Feb-04	5	3.3	0.0816	43.0	26.8	23	80	0.03	0.047	<0.01	0.18	7.6	72.6	2.3	74.0	
18-May-04	5	<2.0	0.0031	43.4	27.7	170	500	0.01	0.004	0.01	0.15	7.3	52.4	1.6	49.8	
20-Aug-04	5	2.5		41.1	27.3			0.01	0.003	<0.01	0.11	8.5	34.0	1.3	29.4	
23-Nov-04	5	3.7		44.2	28.4			0.03	0.003	0.01	0.1	8.0	26.0	1.8	30.7	
Mean		3.2	0.0424	42.9	27.6	97	290	0.02	0.014	0.01	0.135	7.9	46.3	1.8	46.0	
Median		3.3	0.0424	43.2	27.5	97	290	0.02	0.004	0.01	0.13	7.8	43.2	1.7	40.3	

NNN represents nitrate + nitrite nitrogen. FaeC = Faecal coliforms; PresC = Presumptive coliforms.

8.6 Lake Tomarata

Annual mean and median chemical and bacteriological quality of Lake Tomarata

Date	Depth	BOD	Chl a	Chloride	EC	FaeC	PresC	NH_4-N	NNN[1]	DRP	TP	pH	SS	TKN	Turb	Secchi[2]
	(m)	(mg/L)	(mg/L)	(mg/L)	(mS/m)	(MPN/100mL)	(MPN/100mL)	(mg/L)	(mg/L)	(mg/L)	(mg/L)		(mg/L)	(mg/L)	(NTU)	(m)
25-Feb-04	0	<2.0	0.0078	40.6	18.6	13	170	<0.01	0.012	<0.01	0.03	7.6	3.3	0.5	3.4	1.3
18-May-04	0	<2.0	0.0041	38.8	18.1	2300	5000	<0.01	0.006	0.01	0.02	7.4	2.3	0.5	3.0	1.2
20-Aug-04	0	<2.0	0.0058	38.6	18.2	<2	8	<0.01	0.004	<0.01	0.03	6.9	1.0	0.7	1.7	2.3
23-Nov-04	0	<2.0	0.0045	39.7	18.7	4	110	0.01	0.002	<0.01	0.02	7.9	1.9	1.3	1.1	2.7
Mean			0.0056	39.4	18.4	772	1322	0.01	0.006	0.01	0.03	7.5	2.1	0.8	2.3	1.9
Median			0.0052	39.3	18.4	13	140	0.01	0.005	0.01	0.03	7.5	2.1	0.6	2.3	1.8
25-Feb-04	5	<2.0	0.0039	40.4	18.5	11	500	0.01	0.017	<0.01	0.03	7.6	3.2	0.2	2.8	
18-May-04	5	<2.0	0.0049	39.4	18.2	50	5000	<0.01	0.004	0.01	0.02	7.4	3.8	0.3	3.2	
20-Aug-04	5	<2.0		38.3	18.2				0.003	<0.01	0.03	7.1	2.0	1.4	2.0	
23-Nov-04	5	<2.0		39.1	18.6			0.01	0.004	<0.01	0.02	7.8	1.3	0.7	1.1	
Mean			0.0044	39.3	18.4	31	2750	0.01	0.007	0.01	0.03	7.5	2.6	0.7	2.3	
Median			0.0044	39.3	18.4	31	2750	0.01	0.004	0.01	0.03	7.5	2.6	0.5	2.4	

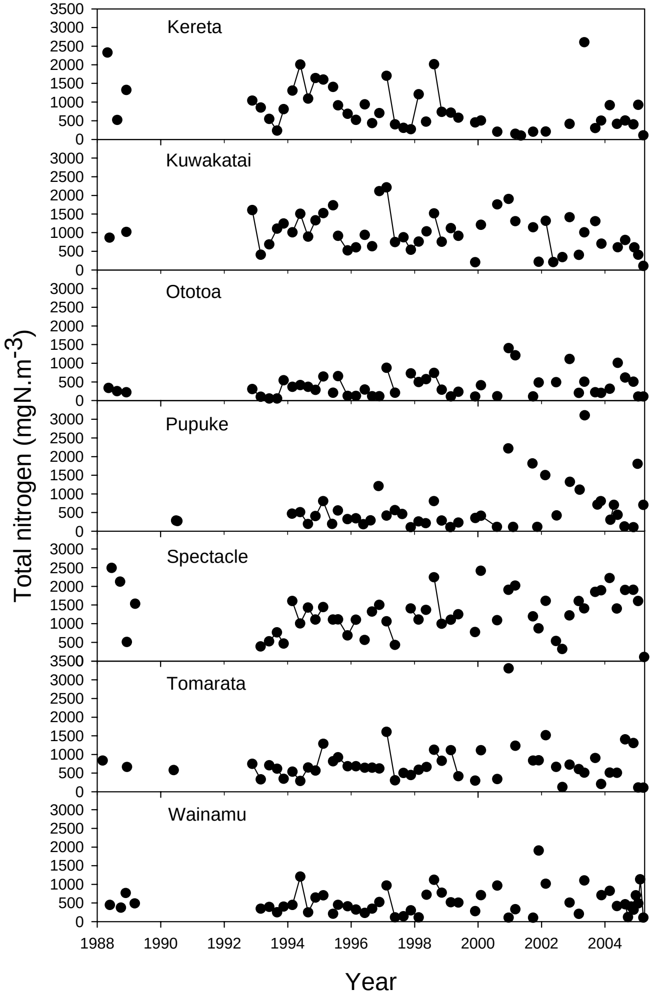
NNN represents nitrate + nitrite nitrogen. FaeC = Faecal coliforms; PresC = Presumptive coliforms.

8.7 Lake Wainamu

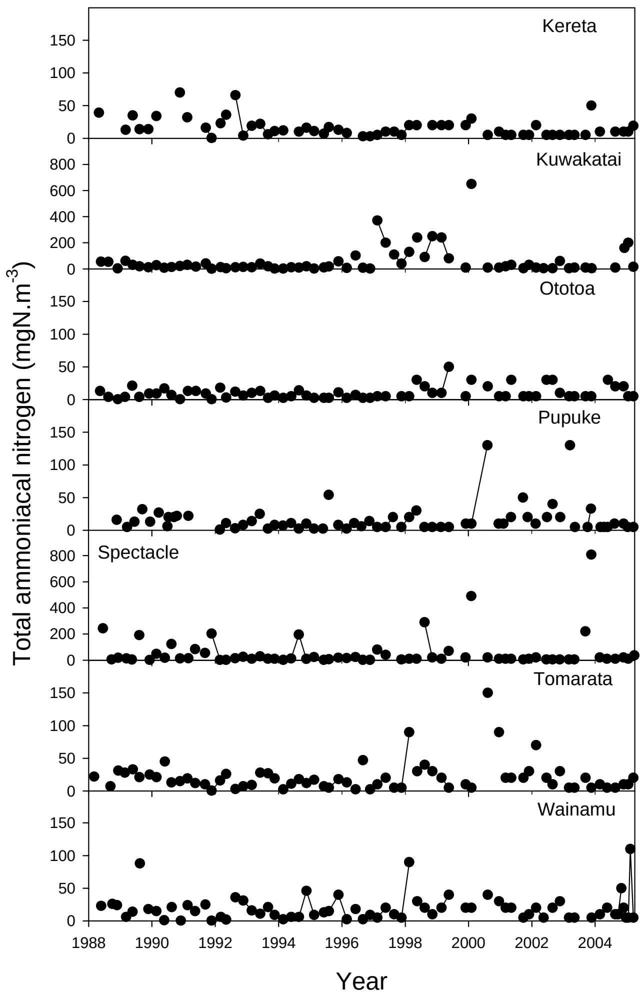
Annual mean and median chemical and bacteriological quality of Lake Wainamu

Date	Depth (m)	BOD (mg/L)	Chl a (mg/L)	Chloride (mg/L)	EC (mS/m)	FaeC (MPN/100mL)	PresC (MPN/100mL)	NH_4-N (mg/L)	NNN[1] (mg/L)	DRP (mg/L)	TP (mg/L)	pH	SS (mg/L)	TKN (mg/L)	Turb (NTU)	Secchi[2] (m)
25-Feb-04	0	<2.0	0.0042	41.7	20.9	4	300	0.01	0.015	<0.01	0.03	7.7	3.6	0.7	8.5	0.3
18-May-04	0	<2.0	0.0036	38.6	18.4	23	50	0.02	0.016	0.01	0.03	7.4	1.9	0.4	11.3	0.6
20-Aug-04	0	<2	0.0133	40.3	20.6	2	9	0.01	0.056	<0.01	0.03	7.8	2.8	0.3	10.8	0.9
22-Sep-04	0		0.0029					0.01	0.014	0.02	0.03		3.8	<0.2	9.5	1.1
29-Oct-04	0		0.0068					0.02	0.004	0.02	0.03		2.0	0.4	10.5	1.2
25-Nov-04	0	<2	0.0068	43.1	22.2	<2		0.02	0.016	0.02	0.03	7.6	1.8	0.3	7.7	0.9
21-Dec-04	0		0.0026					<0.01	0.003	0.01	0.05		4.7	<0.2	8.9	1.4
Mean			0.0057	40.9	20.5	10	120	0.02	0.018	0.02	0.03	7.6	2.9	0.4	9.6	0.9
Median			0.0042	41.0	20.8	4	50	0.02	0.015	0.02	0.03	7.7	2.8	0.4	9.5	0.9
25-Feb-04	10	<2.0	0.0086	41.2	20.3	<2	300	<0.01	0.023	0.01	0.03	7.9	6.2	0.8	8.8	
18-May-04	10	<2.0	0.0037	42.0	24.6	170	500	<0.01	0.012	<0.01	0.02	7.4	<0.9	0.4	2.3	
20-Aug-04	10	<2		40.7	20.6			0.01	0.065	0.01	0.03	7.6	1.5	0.4	11.1	
22-Sep-04	10		0.0016					0.01	0.021	0.02	0.04		4.6	<0.2	10.8	
29-Oct-04	10		0.0389					0.05	0.019	0.02	0.03		2.8	<0.2	14.7	
25-Nov-04	10	<2		41.6	21.6			0.02	0.064	0.02	0.03	7.5	2.9	0.2	12.4	
21-Dec-04	10		0.0025					<0.01	0.003	0.01	0.03		6.9	0.7	10.1	
Mean			0.0111	41.4	21.8	170	400	0.02	0.030	0.02	0.03	7.6	4.2	0.5	10.0	
Median			0.0037	41.4	21.1	170	400	0.02	0.021	0.02	0.03	7.6	3.8	0.4	10.8	

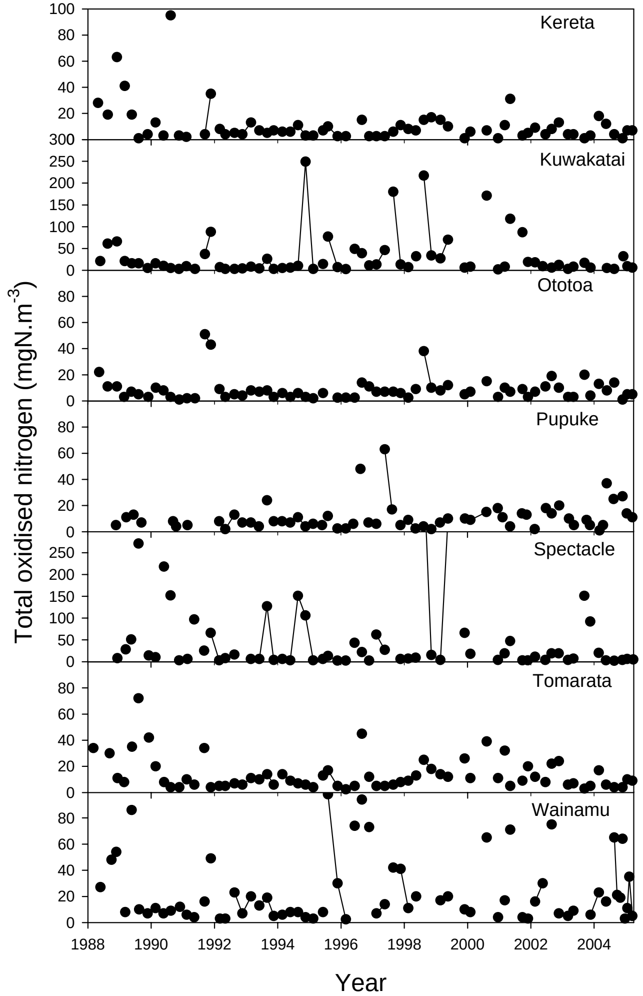
NNN represents nitrate + nitrite nitrogen. FaeC = Faecal coliforms; PresC = Presumptive coliforms.



Total nitrogen (mgN.m-3)
Kereta
Kuwakatai
Ototoa
Pupuke
Spectacle
Tomarata
Wainamu
Year

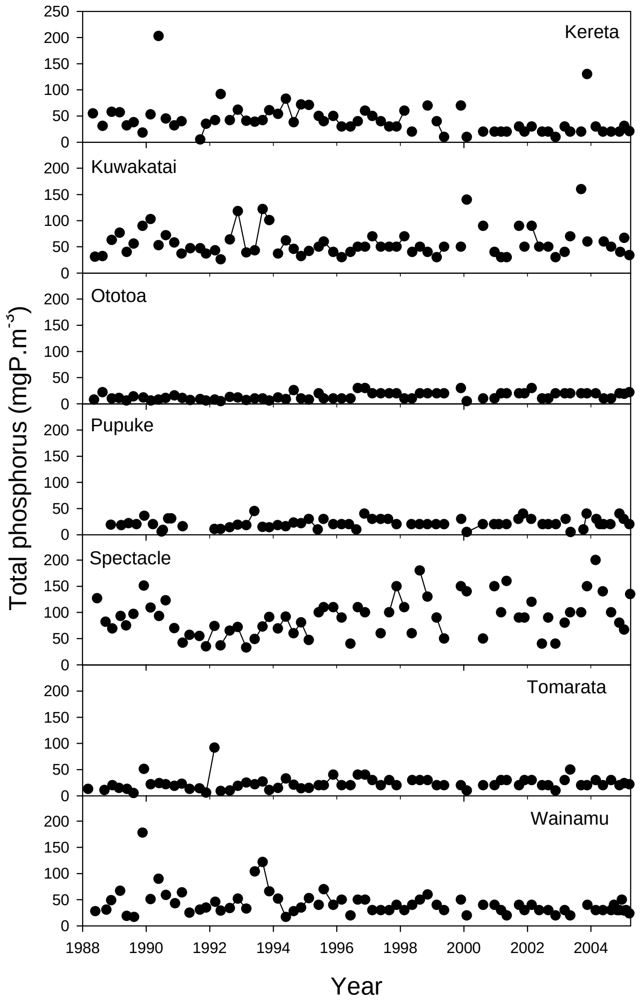


Total ammoniacal nitrogen (mgN.m-3)
Kereta
Kuwakatai
Ototoa
Pupuke
Spectacle
Tomarata
Wainamu
Year



Total oxidised nitrogen (mgN.m-3)
Kereta
Kuwakatai
Ototoa
Pupuke
Spectacle
Tomarata
Wainamu
Year

Table 8.8a Lakes time series data back to 1988.



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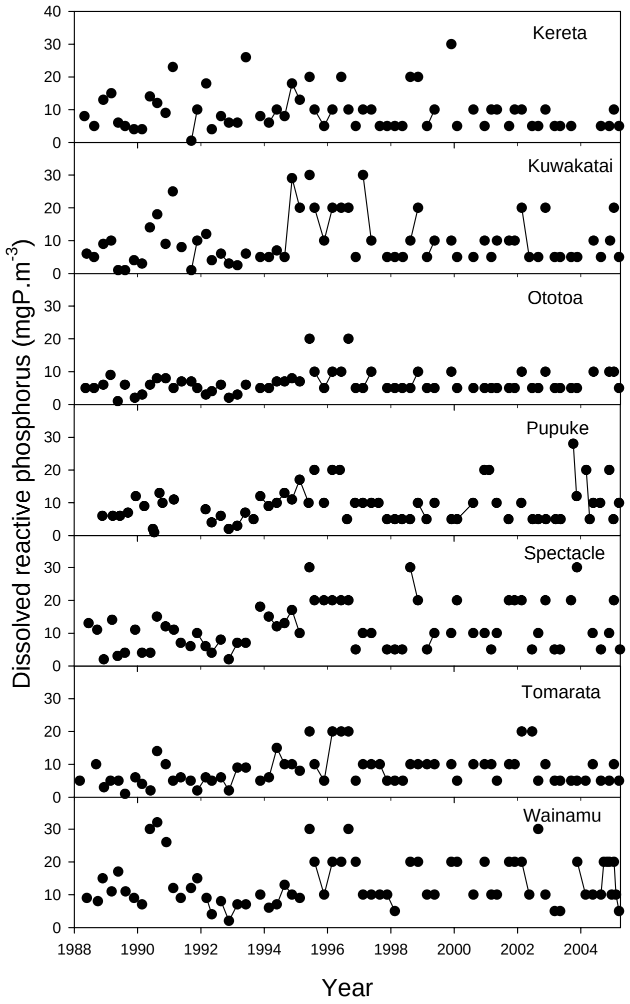

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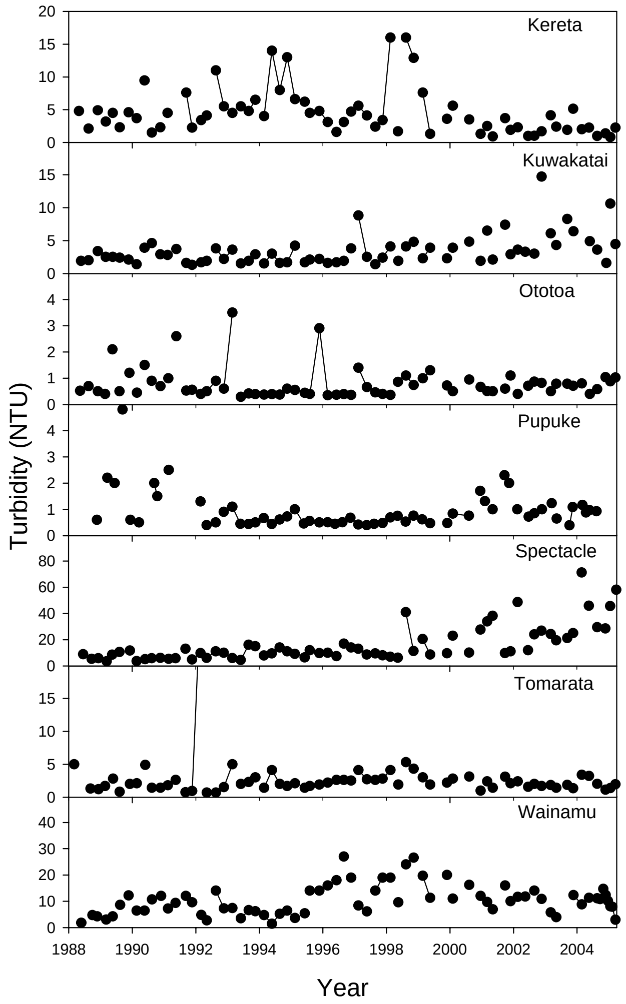
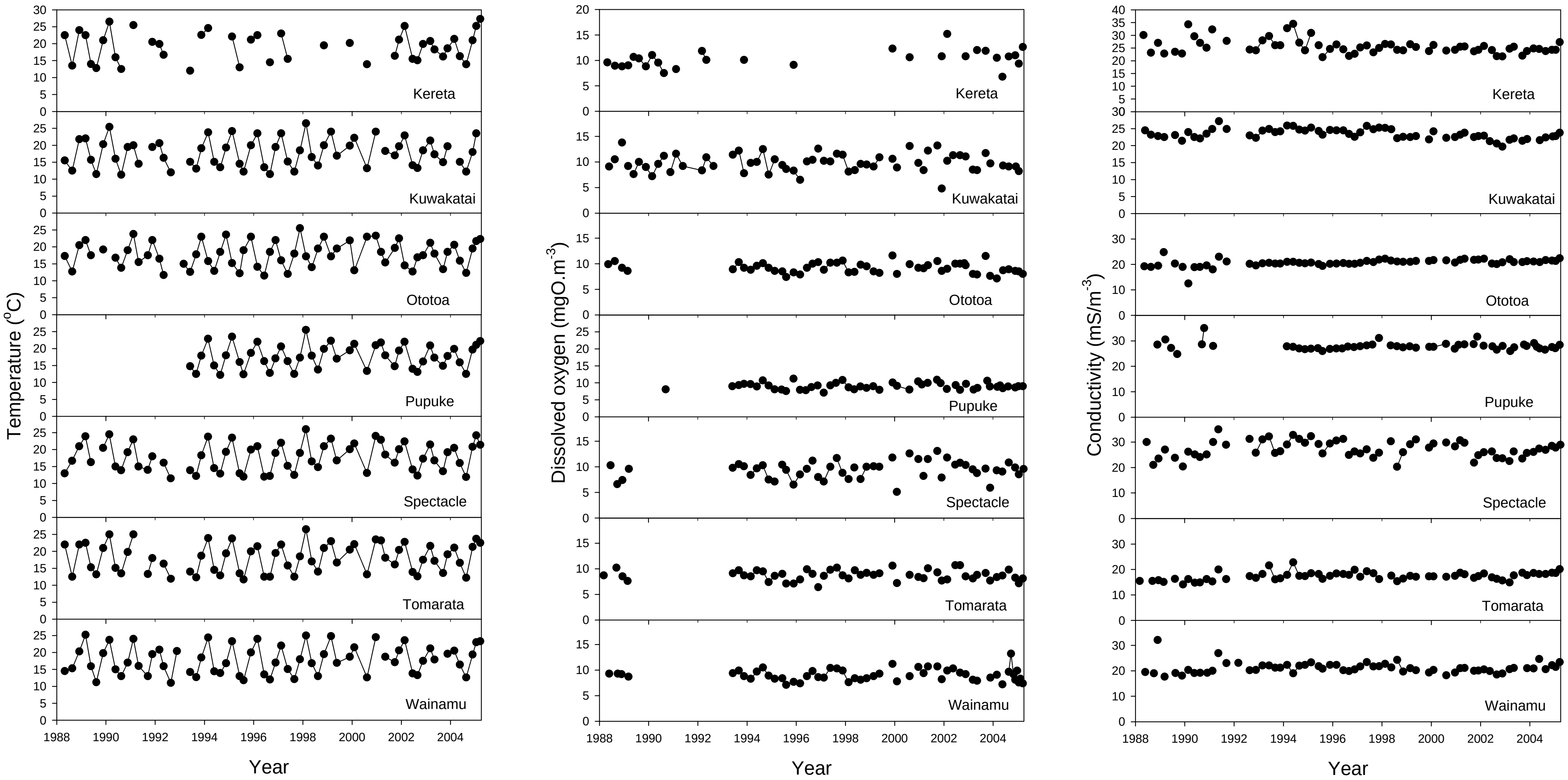
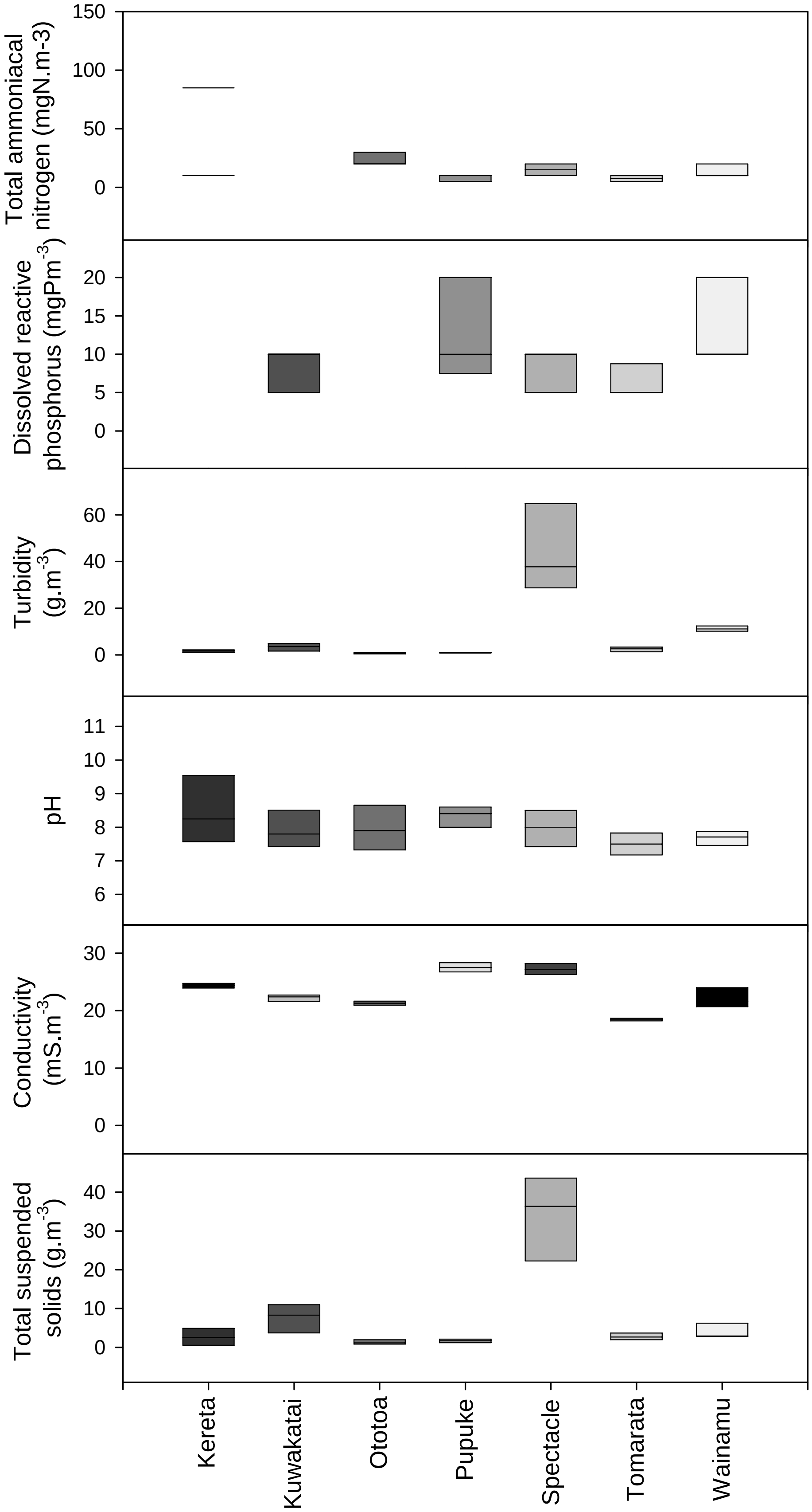
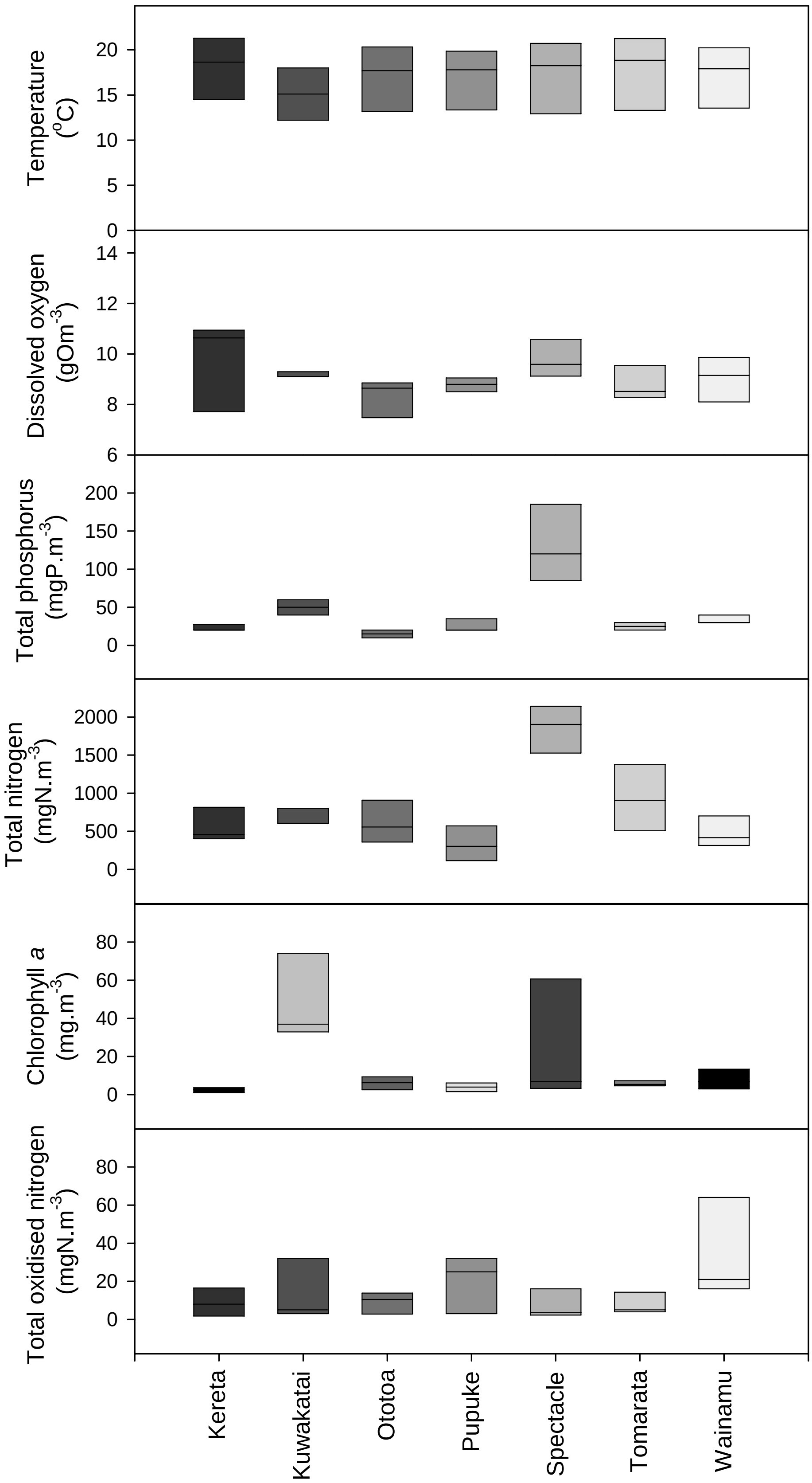
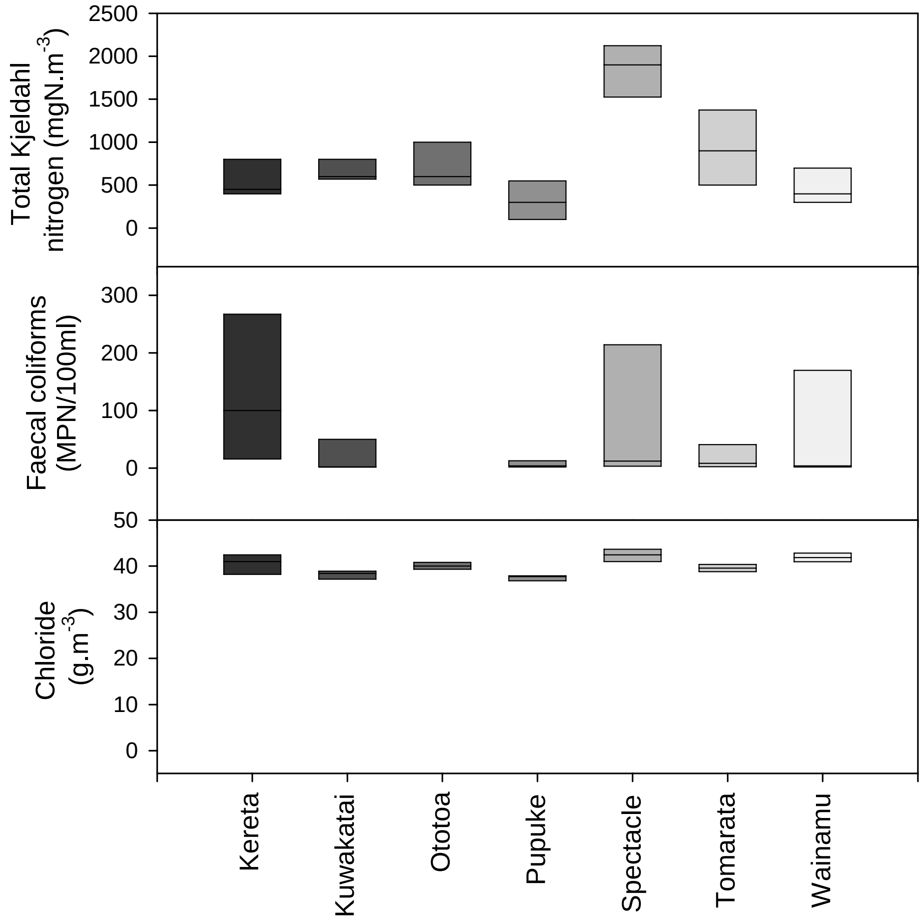


Table 8.8b Lakes time series data back to 1988.




Total ammoniacal nitrogen (mgN.m-3)
150
100
50
0
Dissolved reactive phosphorus (mgPm-3)
20
15
10
5
0
Turbidity (g.m-3)
60
40
20
0
pH
11
10
9
8
7
6
Conductivity (mS.m-3)
30
20
10
0
Total suspended solids (g.m-3)
40
30
20
10
0
Kereta
Kuwakatai
Ototoa
Pupuke
Spectacle
Tomarata
Wainamu


Temperature (°C)
Dissolved oxygen (gOm-3)
Total phosphorus (mgP.m-3)
Total nitrogen (mgN.m-3)
Chlorophyll a (mg.m-3)
Total oxidised nitrogen (mgN.m-3)
Kereta
Kuwakatai
Ototoa
Pupuke
Spectacle
Tomarata
Wainamu



Total Kjeldahl nitrogen (mgN.m-3)
2500
2000
1500
1000
500
0
Faecal coliforms (MPN/100ml)
300
200
100
0
Chloride (g.m-3)
50
40
30
20
10
0
Kereta
Kuwakatai
Ototoa
Pupuke
Spectacle
Tomarata
Wainamu

Lake Wainamu Surface	Count	Mean	Median	Minimum	Maximum	IQR Range	Skewness	Lake Wainamu Bottom	Count	Mean	Median	Minimum	Maximum	IQR Range	Skewness
Chlorophyll a ($mg.m^{-3}$)	61	12.0	7.3	0.2	50.0	11.1	1.81		51	8.0	5.2	0.2	50.0	7.4	2.91
Dissolved oxygen mg/l)	54	9.0	8.8	7.1	13.2	6.1	0.87								
Dissolved reactive phosphorus ($mgP.m^{-3}$)	68	13.7	10.0	2.0	32.0	11.0	0.84		66	12.7	10.0	2.0	30.0	12.0	0.83
Conductivity (mS/m^{-3})	63	21.1	20.9	17.7	32.1	2.2	2.24		62	20.7	20.6	17.2	26.9	2.4	0.69
Total ammoniacal nitrogen ($mgN.m^{-3}$)	70	19.3	15.0	0.5	110.0	17.0	2.62		67	17.8	12.0	0.5	110.0	15.0	2.81
Total oxidised nitrogen ($mgN.m^{-3}$)	70	26.9	13.5	2.5	144.0	28.0	1.80		69	23.2	10.0	2.5	144.0	21.0	2.06
pH	65	7.6	7.6	6.5	8.3	0.5	-0.68		64	7.4	7.4	6.5	8.1	0.4	-0.38
Water clarity (m)	62	1.1	1.0	0.3	2.6	0.4	1.14								
Temperature (°C)	64	17.8	17.3	11.0	25.2	14.2	0.18								
Total nitrogen ($mgN.m^{-3}$)	52	526.5	446.0	103.0	1903.0	416.5	1.45		51	464.4	410.0	14.0	1903.0	491.0	1.67
Total phosphorus ($mgP.m^{-3}$)	70	42.3	35.0	17.0	178.0	161.0	3.10		68	37.8	30.0	16.0	122.0	14.0	2.28
Total suspended solids ($g.m^{-3}$)	51	4.8	4.5	1.9	10.3	2.0	1.06		49	4.0	3.2	1.1	9.2	1.8	1.24

Lake Kuwakatai Surface	Count	Mean	Median	Minimum	Maximum	IQR Range	Skewness	Lake Kuwakatai Bottom	Count	Mean	Median	Minimum	Maximum	IQR Range	Skewness
Chlorophyll a (mg.m^{-3})	58	77.5	57.0	3.8	240.5	88.9	1.08		52	55.7	33.0	3.1	234.0	53.0	1.56
Dissolved oxygen mg/l)	61	9.8	9.7	4.8	13.8	9.0	-0.04								
Dissolved reactive phosphorus (mgP.m^{-3})	64	10.0	7.5	1.0	30.0	6.0	1.22		62	9.7	6.5	1.0	30.0	5.0	1.33
Conductivity (mS/m^{-3})	62	23.4	23.2	19.7	27.2	2.0	0.09		61	23.1	23.1	12.4	25.9	2.2	-2.71
Total ammoniacal nitrogen (mgN.m^{-3})	65	58.2	17.0	1.0	650.0	46.0	3.60		64	55.2	12.0	1.0	650.0	37.5	3.58
Total oxidised nitrogen (mgN.m^{-3})	66	31.8	10.5	2.0	249.0	26.0	2.77		65	26.6	9.0	1.0	249.0	19.5	3.08
pH	64	8.1	8.1	6.5	9.5	1.0	-0.07		62	7.6	7.7	6.2	8.9	0.5	-0.21
Water clarity (m)	61	1.4	1.3	0.5	2.4	0.7	0.45								
Temperature (°C)	61	17.8	18.0	11.3	26.5	15.2	0.19								
Total nitrogen (mgN.m^{-3})	49	980.5	914.0	106.0	2211.0	2105.0	0.44		48	753.8	658.0	58.0	1733.0	559.5	0.58
Total phosphorus (mgP.m^{-3})	66	57.0	50.0	26.0	160.0	134.0	1.79		65	47.9	40.0	20.0	140.0	25.0	1.71
Total suspended solids (g.m^{-3})	48	8.5	6.5	2.7	26.0	6.8	1.71		47	5.8	4.0	0.8	26.0	3.4	2.32

Lake Ototoa Surface	Count	Mean	Median	Minimum	Maximum	IQR Range	Skewness	Lake Ototoa Bottom	Count	Mean	Median	Minimum	Maximum	IQR Range	Skewness
Chlorophyll a ($mg.m^{-3}$)	53	5.5	3.9	0.2	47.0	5.6	4.90		37	6.2	4.0	0.7	47.0	3.5	3.88
Dissolved oxygen mg/l)	52	9.2	9.2	7.1	11.6	4.5	0.24								
Dissolved reactive phosphorus ($mgP.m^{-3}$)	63	6.5	5.0	1.0	20.0	3.0	2.13		47	7.0	5.0	2.0	20.0	5.0	2.00
Conductivity (mS/m^{-3})	63	20.7	20.9	12.5	24.8	1.3	-2.32		51	21.2	21.2	12.5	24.1	1.4	-2.81
Total ammoniacal nitrogen ($mgN.m^{-3}$)	65	10.4	6.0	0.5	50.0	8.0	1.79		50	51.0	15.0	2.5	460.0	55.0	2.95
Total oxidised nitrogen ($mgN.m^{-3}$)	66	8.7	7.0	1.0	51.0	7.0	3.02		52	11.5	9.0	1.0	72.0	9.5	3.68
pH	63	7.7	7.7	6.2	8.8	0.5	-0.48		49	7.5	7.6	6.5	8.1	0.6	-0.63
Water clarity (m)	64	4.6	4.5	1.6	8.4	2.0	0.50								
Temperature (°C)	63	17.9	17.8	11.5	25.5	14.0	0.03								
Total nitrogen ($mgN.m^{-3}$)	48	395.8	298.3	52.0	1403.0	400.0	1.39		47	655.8	363.0	105.0	3319.0	592.0	2.45
Total phosphorus ($mgP.m^{-3}$)	67	14.6	12.0	5.0	30.0	25.0	0.58		51	16.4	20.0	3.0	30.0	10.0	0.09
Total suspended solids ($g.m^{-3}$)	49	1.1	1.0	0.2	3.9	0.5	1.93		48	5.0	1.8	0.5	58.9	5.5	5.17

Lake Pupuke Surface	Count	Mean	Median	Minimum	Maximum	IQR Range	Skewness	Lake Pupuke Bottom	Count	Mean	Median	Minimum	Maximum	IQR Range	Skewness
Chlorophyll a (mg.m^{-3})	49	7.9	6.3	1.0	43.9	6.0	3.04		51	8.0	6.3	1.0	43.9	6.1	3.04
Dissolved oxygen mg/l)	49	9.0	9.0	7.1	11.2	4.1	0.40								
Dissolved reactive phosphorus (mgP.m^{-3})	63	9.4	10.0	1.0	28.0	6.0	1.20		64	16.7	10.0	1.0	110.0	13.0	3.24
Conductivity (mS/m^{-3})	51	27.9	27.7	24.8	35.0	1.4	2.27		51	28.6	28.2	25.0	37.3	1.2	2.38
Total ammoniacal nitrogen (mgN.m^{-3})	64	16.8	10.0	1.0	130.0	15.0	3.83		64	191.3	52.5	5.0	1300.0	255.0	2.12
Total oxidised nitrogen (mgN.m^{-3})	60	11.1	8.0	1.0	63.0	8.0	2.87		60	35.6	17.0	2.0	127.0	47.5	1.17
pH	60	8.5	8.4	6.7	9.5	1.0	-0.29		60	8.5	8.4	7.0	9.5	1.0	-0.05
Water clarity (m)	167	4.0	3.9	1.0	8.6	2.0	0.51								
Temperature (°C)	47	17.7	17.8	12.2	25.5	13.3	0.10								
Total nitrogen (mgN.m^{-3})	45	616.4	409.0	103.9	3105.0	535.3	2.17		46	851.8	631.0	111.0	3217.0	856.0	1.78
Total phosphorus (mgP.m^{-3})	63	22.0	20.0	5.0	45.0	40.0	0.46		63	46.6	31.0	6.0	180.0	40.0	1.99
Total suspended solids (g.m^{-3})	59	4.8	2.2	0.0	31.0	2.0	2.56		59	11.2	3.9	0.9	112.0	4.8	3.46

Lake Spectacle Surface	Count	Mean	Median	Minimum	Maximum	IQR Range	Skewness	Lake Spectacle Botom	Count	Mean	Median	Minimum	Maximum	IQR Range	Skewness
Chlorophyll a ($mg.m^{-3}$)	58	75.7	65.0	3.0	298.2	67.5	1.56		53	72.4	59.0	1.4	264.1	73.9	1.19
Dissolved oxygen mg/l)	51	9.4	9.6	5.1	13.1	8.0	-0.30								
Dissolved reactive phosphorus ($mgP.m^{-3}$)	64	11.7	10.0	2.0	30.0	14.0	0.80		63	12.9	10.0	0.5	60.0	15.0	2.14
Conductivity (mS/m^{-3})	62	27.2	26.9	20.3	35.0	4.6	-0.06		60	27.4	27.1	20.7	34.0	4.6	-0.06
Total ammoniacal nitrogen ($mgN.m^{-3}$)	66	56.5	13.0	1.0	807.0	22.0	4.18		66	61.4	20.0	0.5	914.0	31.0	4.64
Total oxidised nitrogen ($mgN.m^{-3}$)	65	72.3	13.0	2.0	703.0	60.0	2.96		65	58.2	11.0	2.0	623.0	54.5	3.40
pH	65	7.6	7.5	6.4	9.7	0.6	1.14		63	7.5	7.4	6.4	9.4	0.5	1.43
Water clarity (m)	59	0.4	0.4	0.1	0.8	0.2	0.50								
Temperature (°C)	63	17.9	18.0	11.5	26.0	14.5	0.10								
Total nitrogen ($mgN.m^{-3}$)	50	1271.9	1234.5	105.0	2494.0	733.0	0.11		50	1367.2	1365.8	107.0	2713.0	566.0	0.27
Total phosphorus ($mgP.m^{-3}$)	66	92.2	90.0	33.0	200.0	167.0	0.58		65	103.7	100.0	34.0	220.0	52.0	0.65
Total suspended solids ($g.m^{-3}$)	49	20.7	18.4	6.0	72.0	9.3	2.07		46	24.6	21.5	9.3	55.0	15.0	1.08

Lake Tomarata Surface	Count	Mean	Median	Minimum	Maximum	IQR Range	Skewness	Lake Tomarata Bottom	Count	Mean	Median	Minimum	Maximum	IQR Range	Skewness
Chlorophyll a ($mg.m^{-3}$)	58	10.2	9.1	1.3	36.0	6.7	1.46		52	9.1	7.7	1.0	36.0	8.0	1.63
Dissolved oxygen mg/l)	51	8.7	8.7	6.4	10.7	4.3	0.00								
Dissolved reactive phosphorus ($mgP.m^{-3}$)	66	8.2	6.0	1.0	20.0	5.0	1.23		65	7.5	5.0	0.5	20.0	5.0	1.32
Conductivity (mS/m^{-3})	62	17.4	17.4	14.1	22.8	2.0	0.69		61	17.2	17.3	14.0	22.8	2.0	0.45
Total ammoniacal nitrogen ($mgN.m^{-3}$)	67	21.2	17.0	0.5	150.0	19.0	3.31		66	18.3	10.0	0.5	150.0	15.0	3.50
Total oxidised nitrogen ($mgN.m^{-3}$)	67	13.9	9.0	2.5	72.0	11.0	2.21		66	12.3	7.0	2.0	72.0	10.0	2.39
PH	65	7.4	7.3	6.5	8.2	0.6	0.14		64	7.3	7.3	6.5	8.1	0.4	0.09
Water clarity (m)	57	1.8	1.5	0.8	3.3	1.1	0.68								
Temperature (°C)	63	18.0	18.1	11.7	26.5	14.8	0.06								
Total nitrogen ($mgN.m^{-3}$)	51	742.8	647.0	109.0	3306.0	337.5	2.75		50	669.2	643.8	106.0	2311.0	489.0	1.52
Total phosphorus ($mgP.m^{-3}$)	66	23.3	20.0	5.0	92.0	87.0	2.78		65	21.5	20.0	3.0	92.0	11.0	3.08
Total suspended solids ($g.m^{-3}$)	49	3.2	3.1	1.2	7.8	1.5	1.32		44	3.2	3.1	1.1	7.8	1.8	1.20

Lake Kereta Surface	Count	Mean	Median	Minimum	Maximum	IQR Range	Skewness
Chlorophyll a (mg.m^{-3})	57	12.6	7.0	0.7	94.0	13.9	3.04
Dissolved oxygen mg/l)	28	10.3	10.4	6.8	15.2	8.4	0.51
Dissolved reactive phosphorus (mgP.m^{-3})	63	10.5	8.0	0.5	70.0	5.0	4.13
Conductivity (mS/m^{-3})	62	25.6	24.9	21.4	34.5	2.5	1.36
Total ammoniacal nitrogen (mgN.m^{-3})	62	138.9	12.5	0.5	3530.0	15.0	5.08
Total oxidised nitrogen (mgN.m^{-3})	65	10.9	7.0	1.0	95.0	9.5	3.77
pH	64	8.5	8.5	6.6	10.2	1.7	-0.07
Water clarity (m)	ns	ns	ns	ns	ns	ns	ns
Temperature (°C)	43	19.2	19.9	12.0	27.3	15.3	0.00
Total nitrogen (mgN.m^{-3})	47	813.4	580.0	101.0	2604.0	2503.0	1.22
Total phosphorus (mgP.m^{-3})	65	41.9	38.0	5.0	203.0	198.0	2.95
Total suspended solids (g.m^{-3})	48	7.3	4.7	0.5	31.0	5.7	1.96

9 Appendix 3: coastal water quality parameters - 2004 time series plots.

Figure 9.1a: Sea temperature (C) at coastal water quality monitoring sites during 2004.

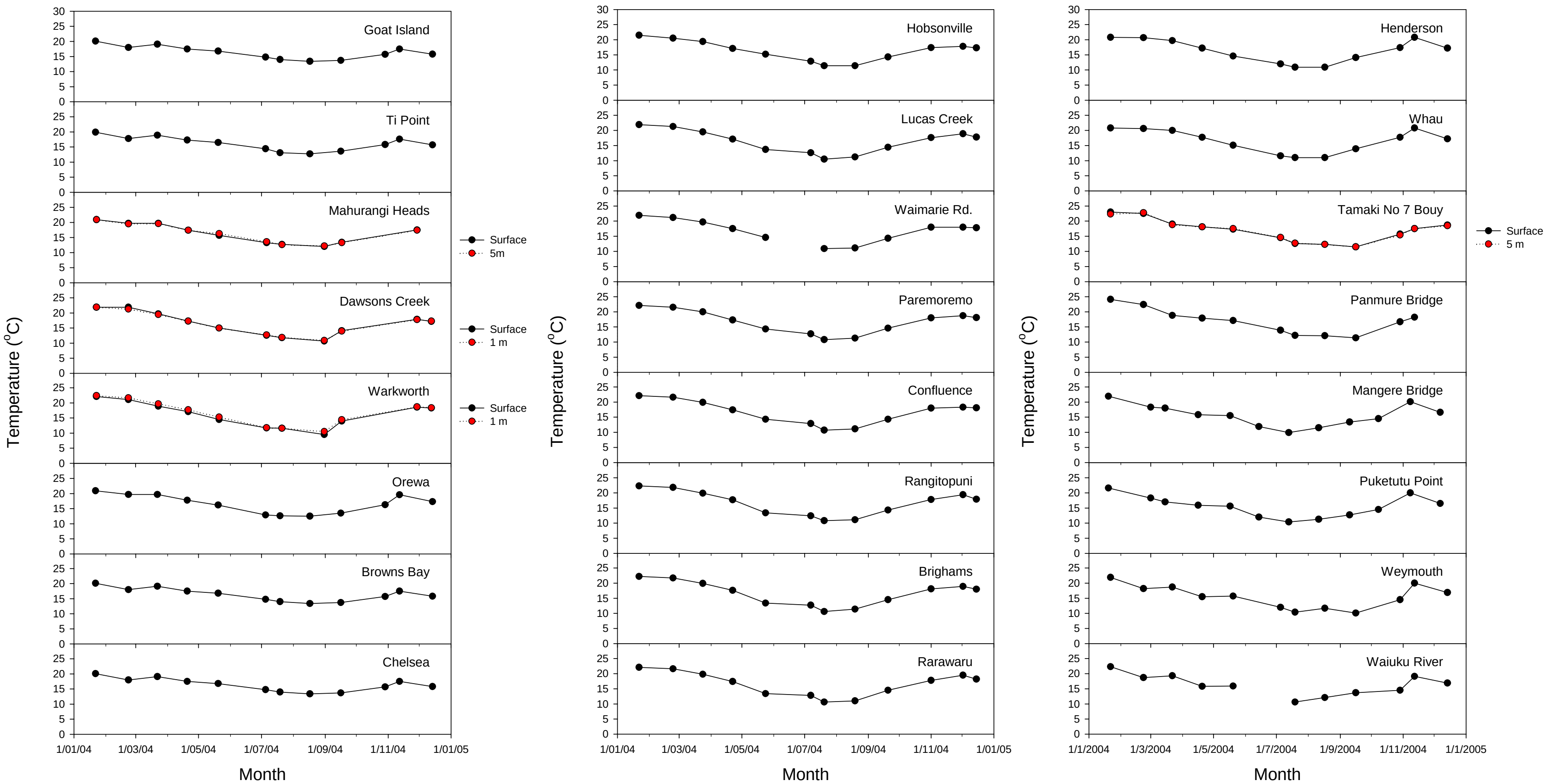


Figure 9.1b: Sea temperature (°C) at coastal water quality monitoring sites during 2004.

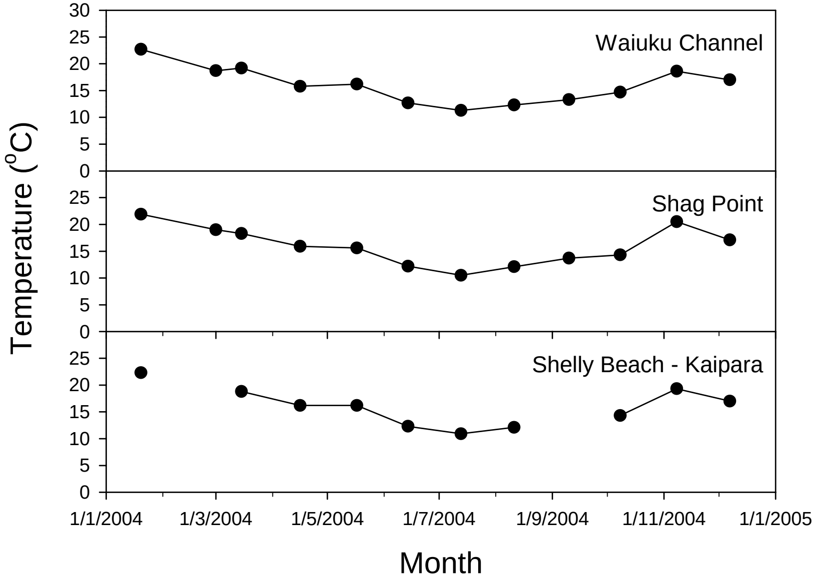


Figure 9.2a: Salinity (parts per thousand (ppt)) at coastal water quality monitoring sites during 2004.

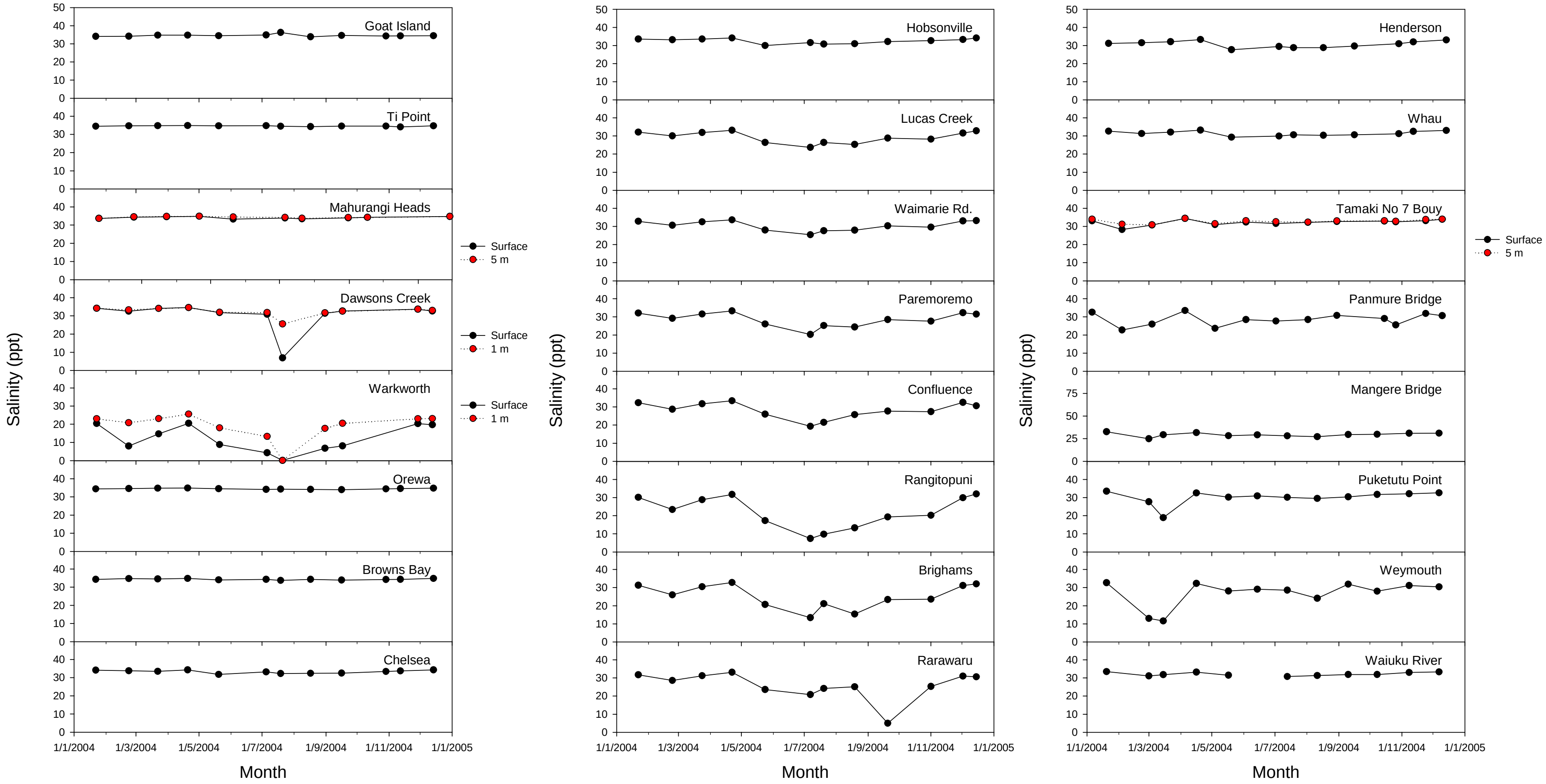


Figure 9.2b: Salinity (parts per thousand (ppt)) at coastal water quality monitoring sites during 2004.

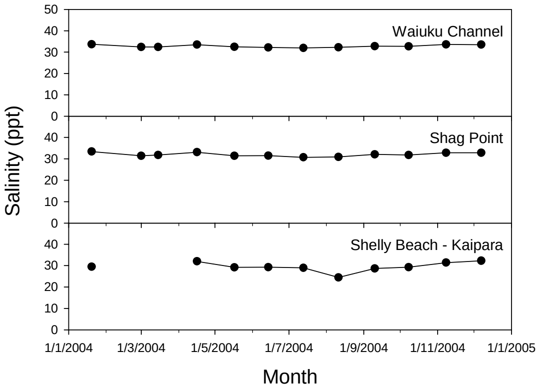


Figure 9.3a: pH at coastal water quality monitoring sites during 2004.

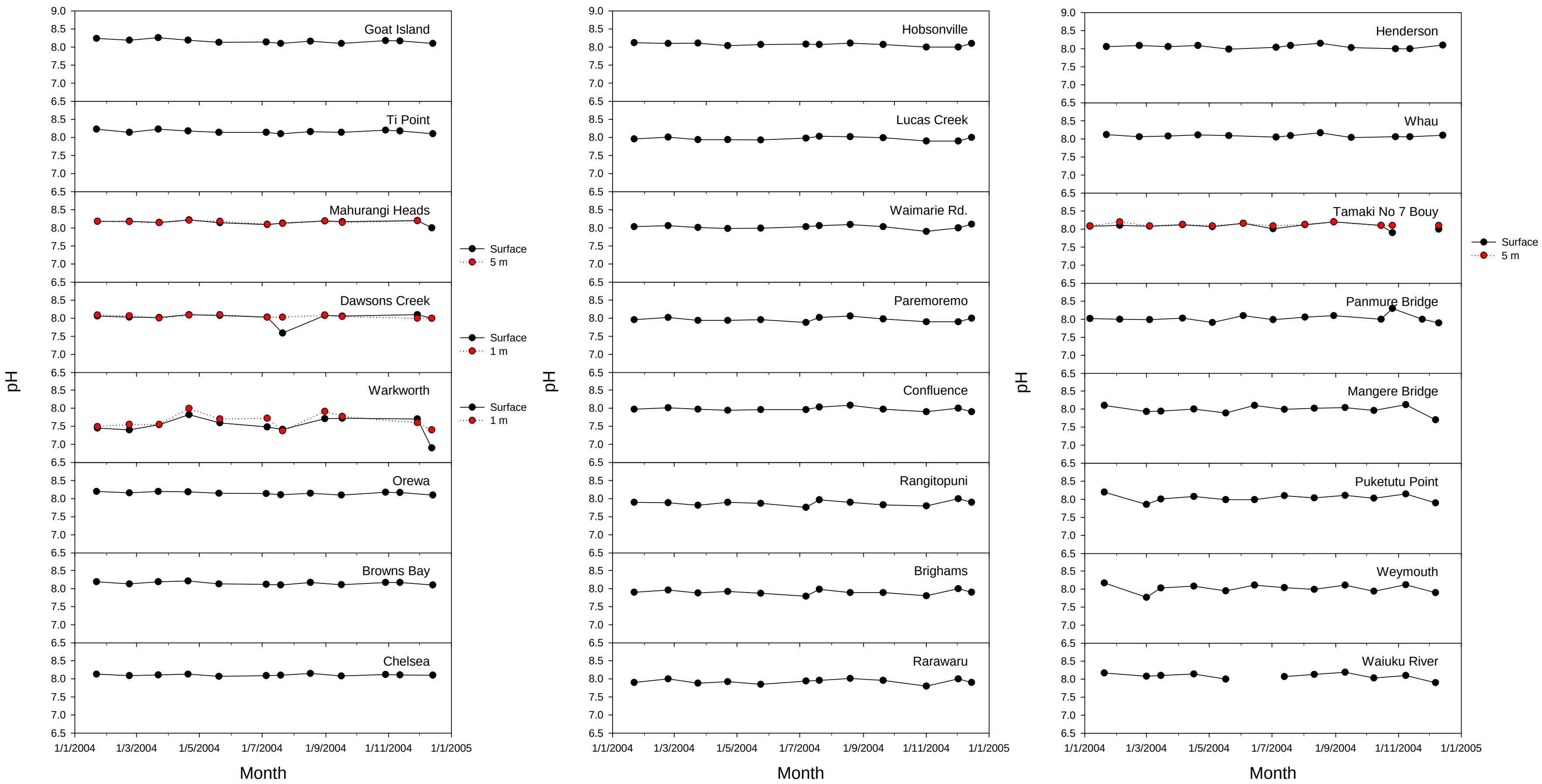


Figure 9.3b: pH at coastal water quality monitoring sites during 2004.

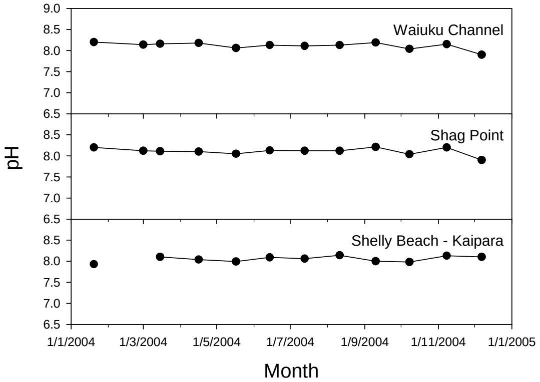


Figure 9.4a: Suspended solids (mg/l) at coastal water quality monitoring sites during 2004.

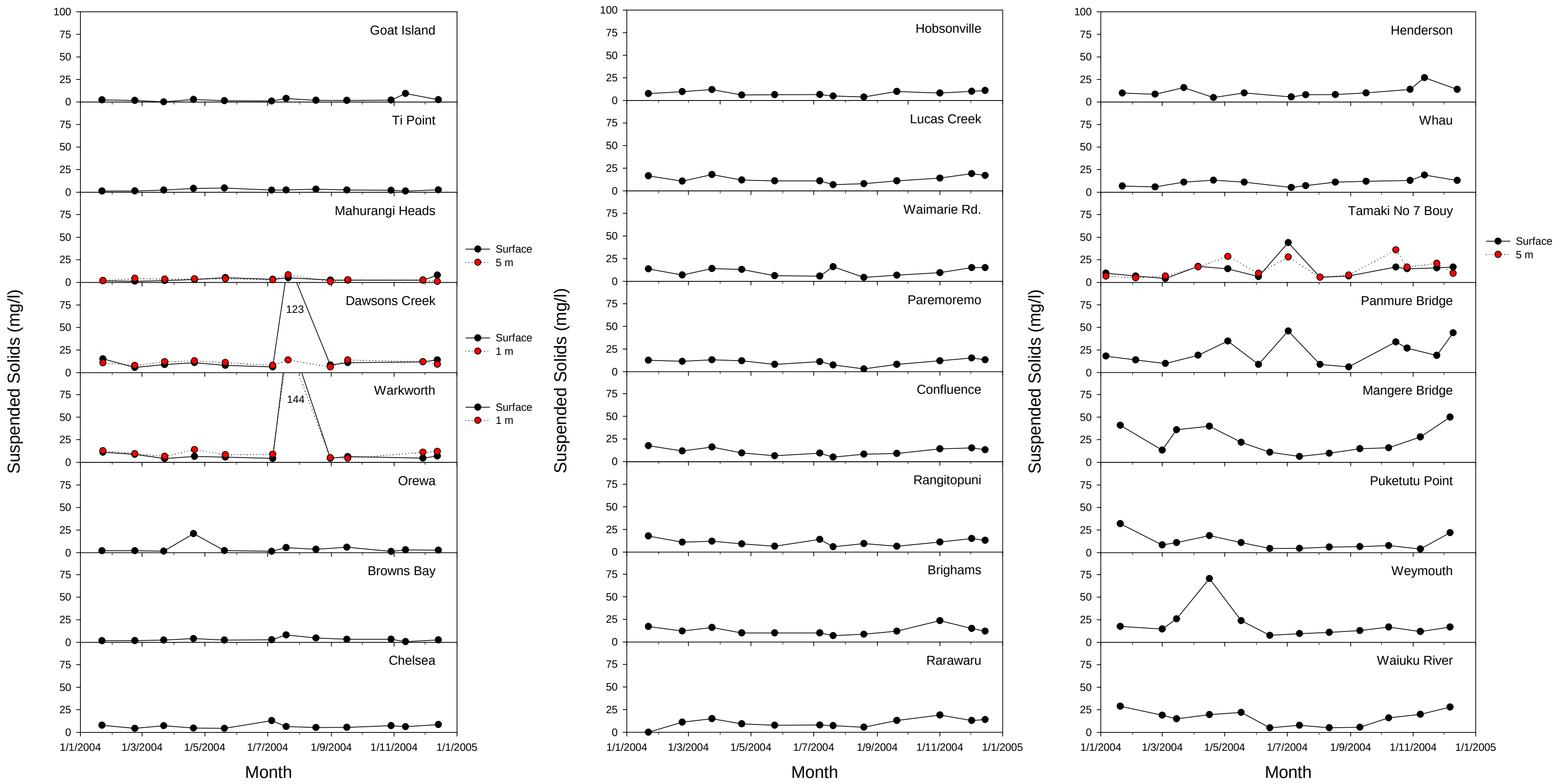


Figure 9.4b: Suspended solids (mg/l) at coastal water quality monitoring sites during 2004.

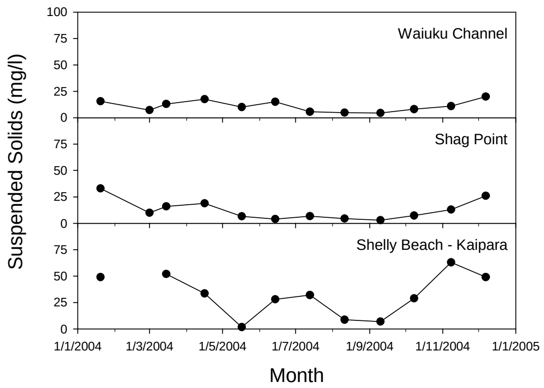


Figure 9.5a: Turbidity (NTU) at coastal water quality monitoring sites during 2004.

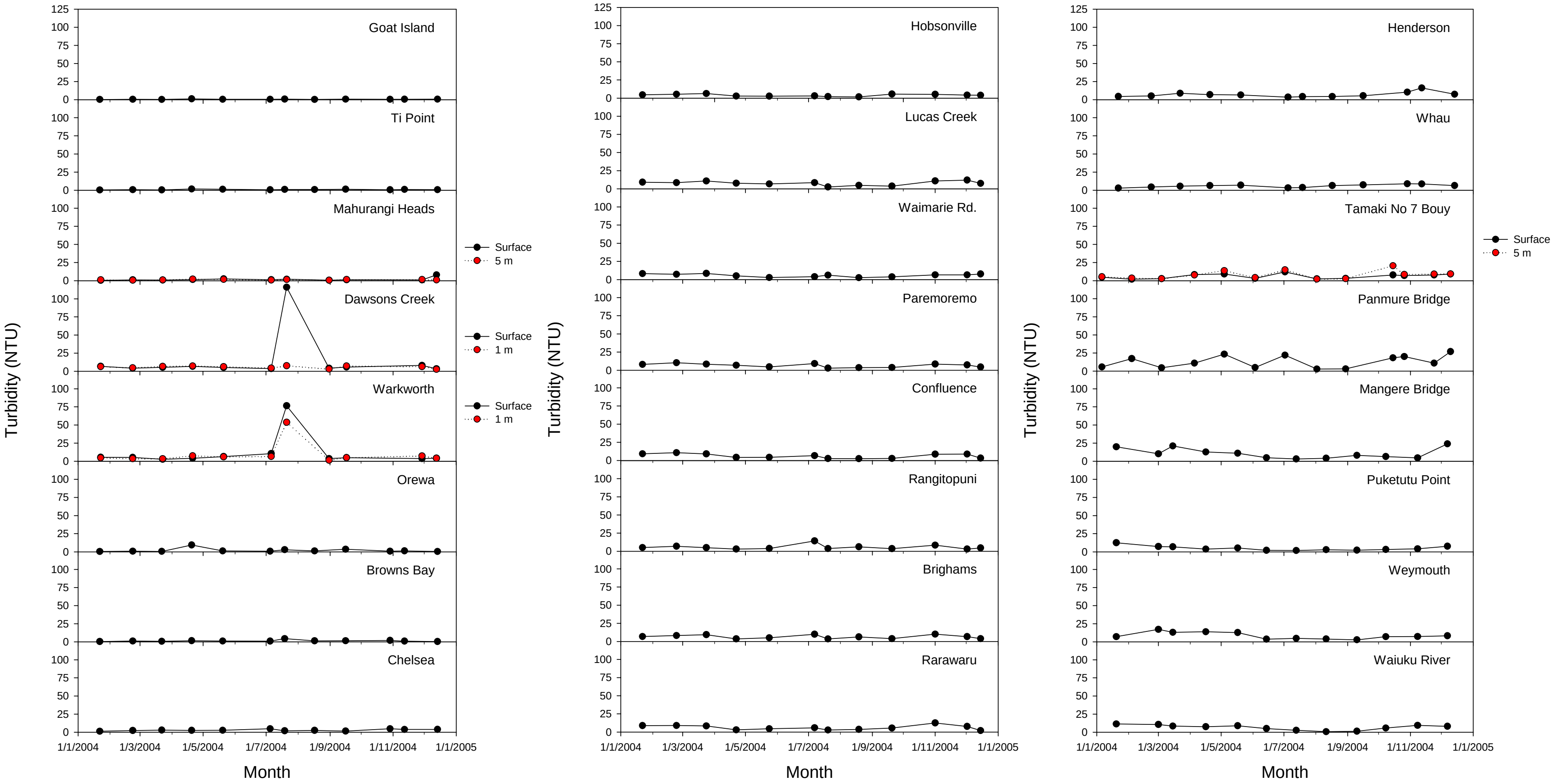


Figure 9.5b: Turbidity (NTU) at coastal water quality monitoring sites during 2004.

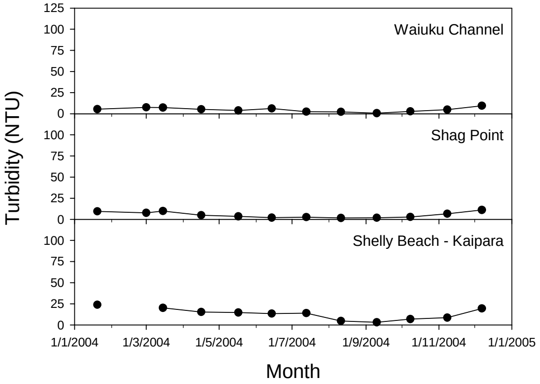


Figure 9.6a: Secchi depth (m) at coastal water quality monitoring sites during 2004.

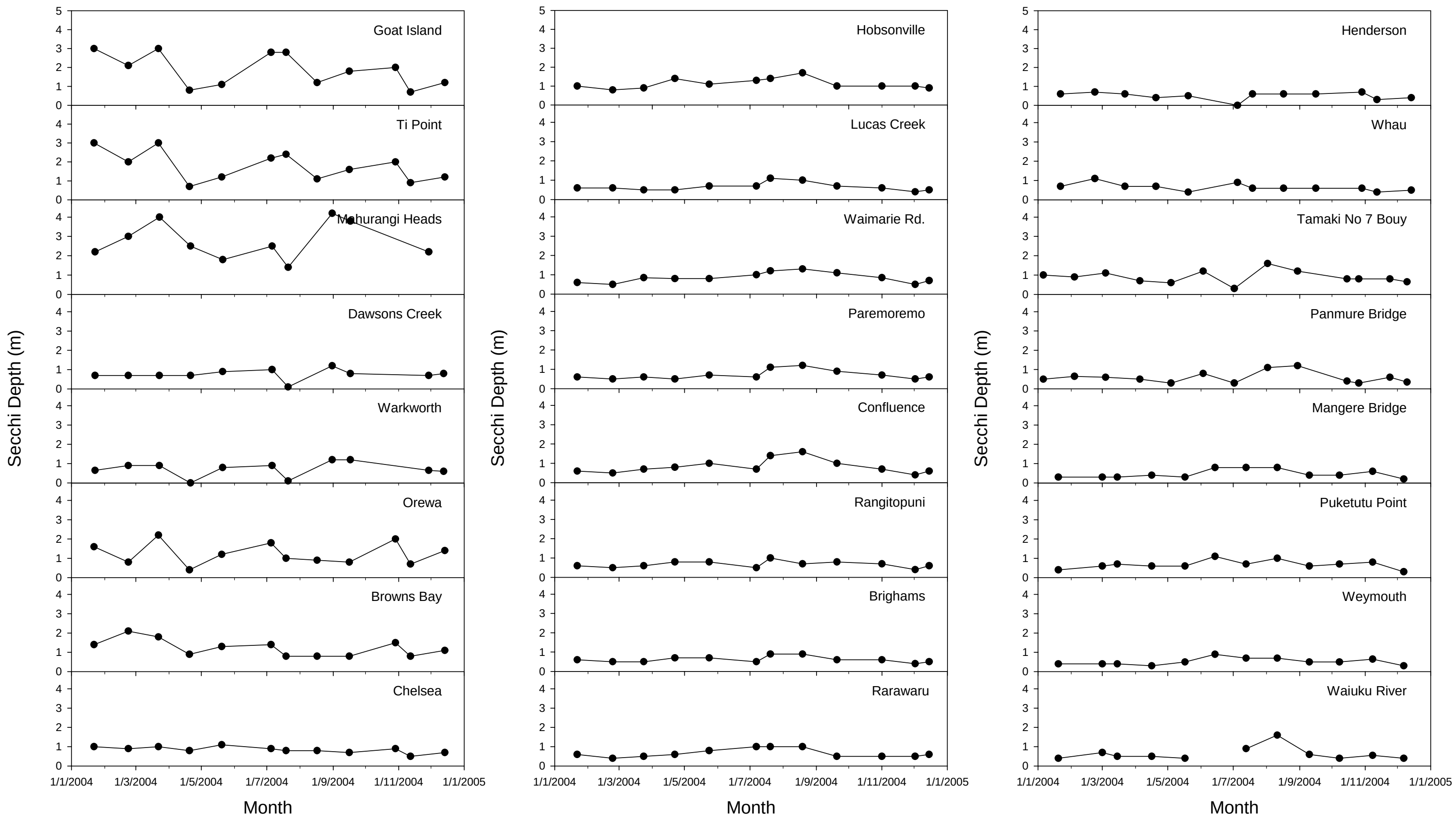


Figure 9.6b: Secchi depth (m) at coastal water quality monitoring sites during 2004.

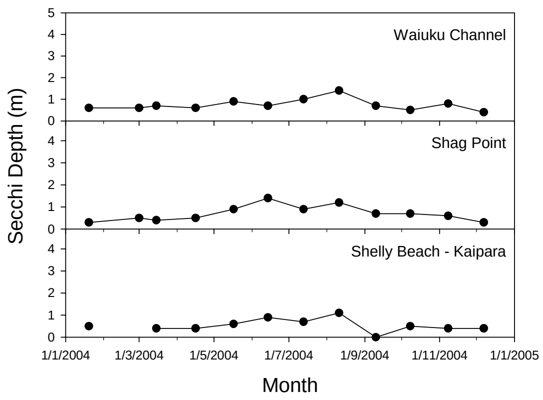


Figure 9.7a: Dissolved oxygen concentration (mg/l) at coastal water quality monitoring sites during 2004.

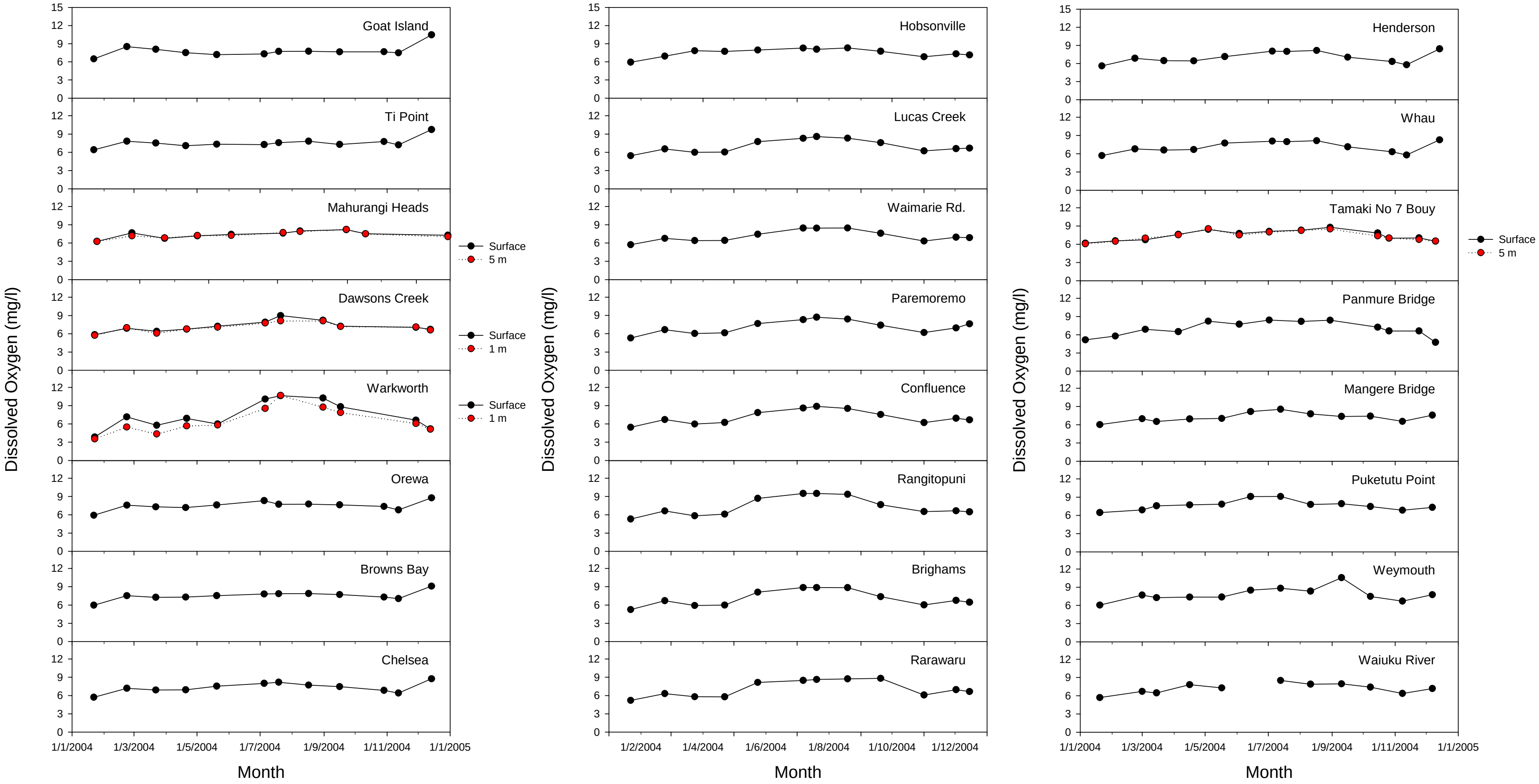


Figure 9.7b: Dissolved oxygen concentration (mg/l) at coastal water quality monitoring sites during 2004.

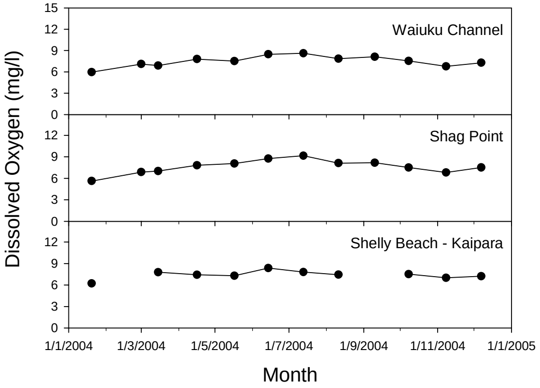


Figure 9.8a: Dissolved oxygen saturation (%) at coastal water quality monitoring sites during 2004.

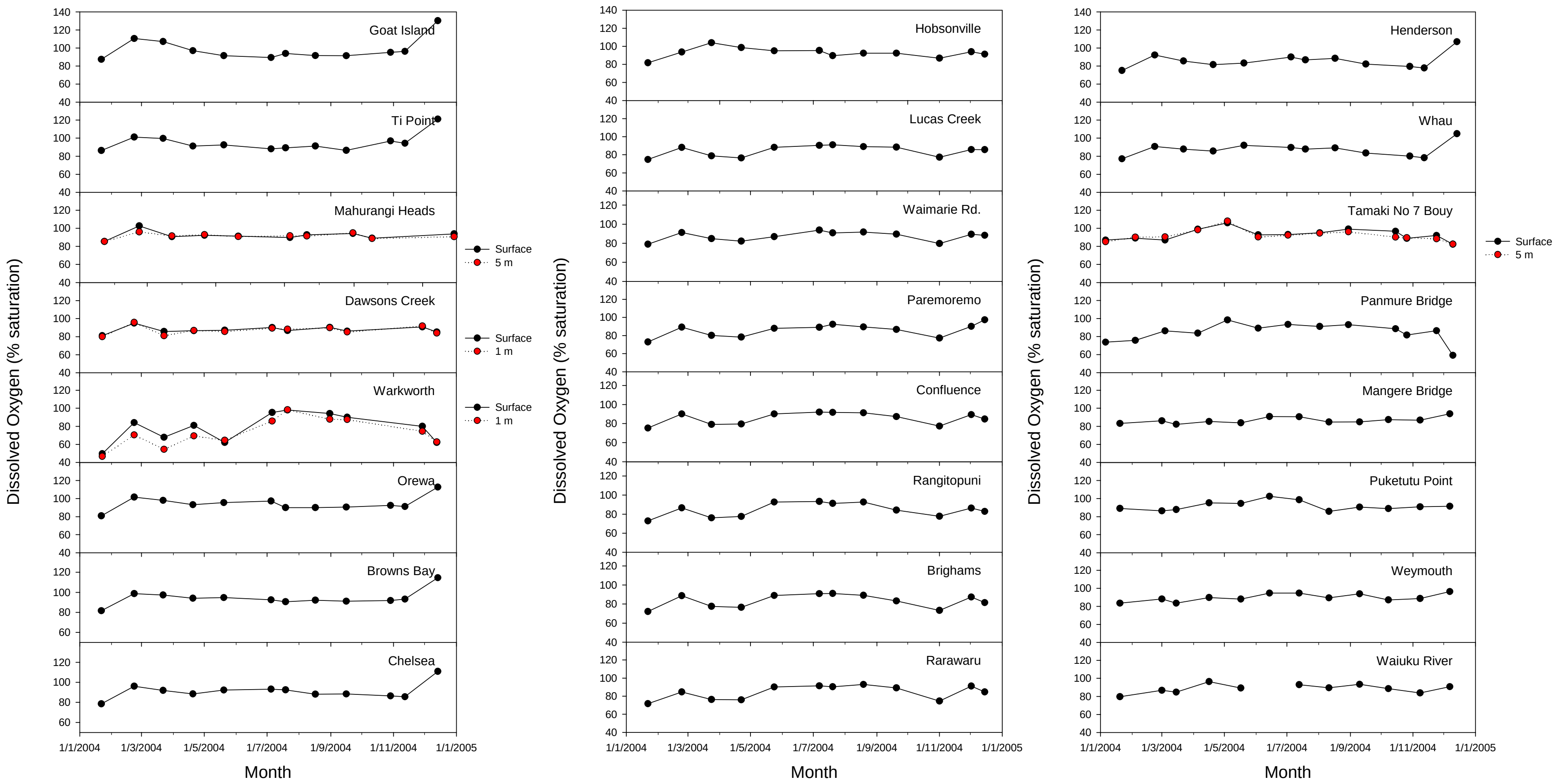


Figure 9.8b: Dissolved oxygen saturation (%) at coastal water quality monitoring sites during 2004.

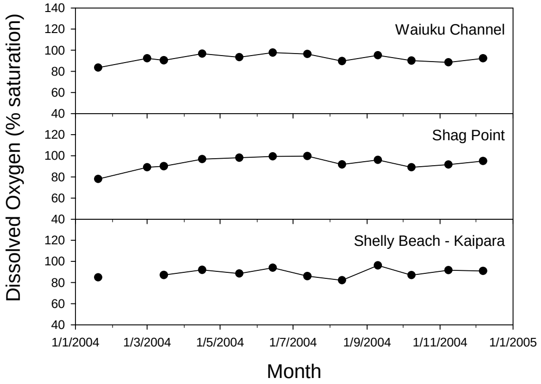


Figure 9.9a: Ammonia concentration (mg/l) at coastal water quality monitoring sites during 2004.

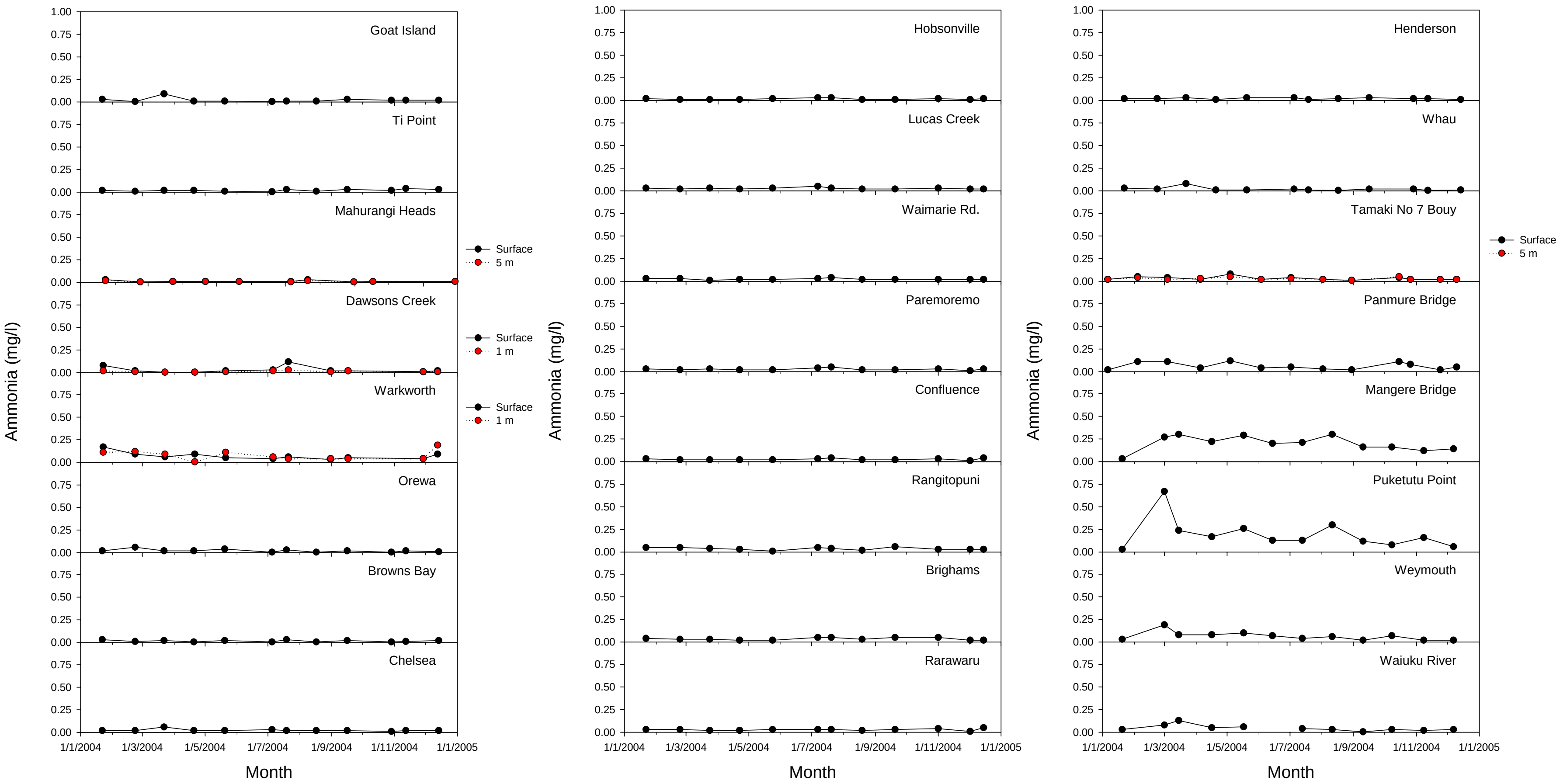


Figure 9.9b: Ammonia concentration (mg/l) at coastal water quality monitoring sites during 2004.

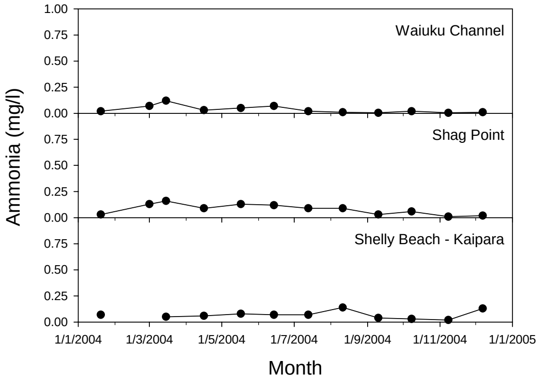


Figure 9.10a: Nitrate (NO_3) concentration (mg/l) at coastal water quality monitoring sites during 2004.

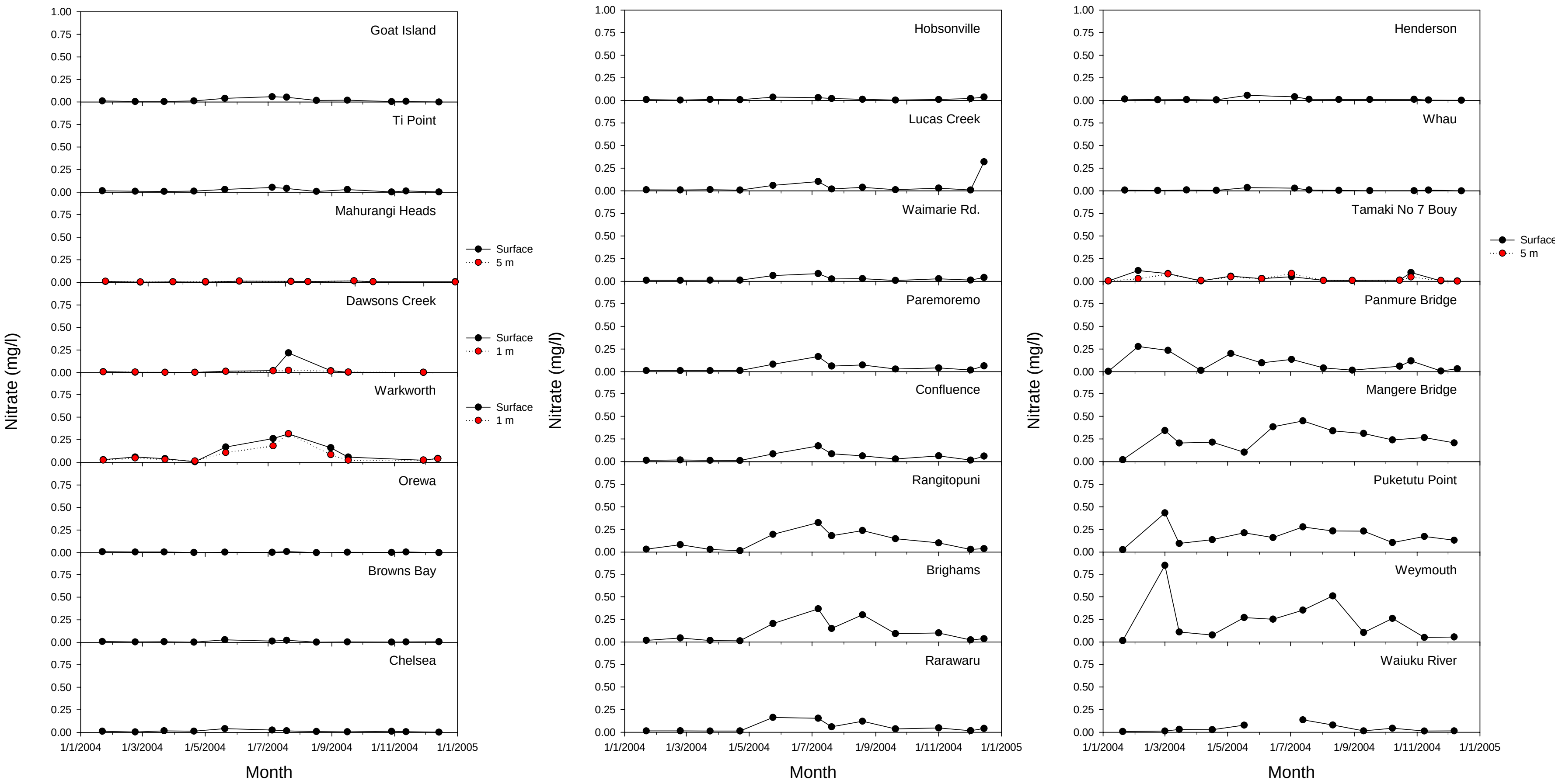


Figure 9.10b: Nitrate (NO_3) concentration (mg/l) at coastal water quality monitoring sites during 2004.

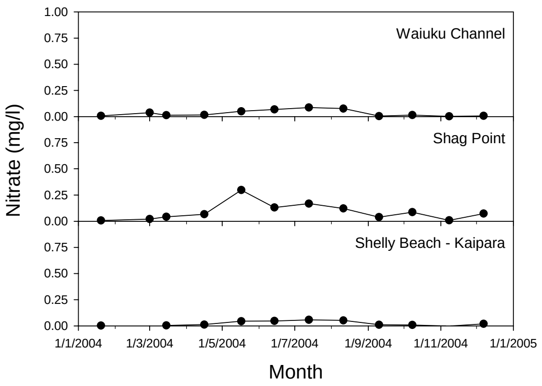


Figure 9.11a: Nitrite (NO_2) concentration (mg/l) at coastal water quality monitoring sites during 2004.

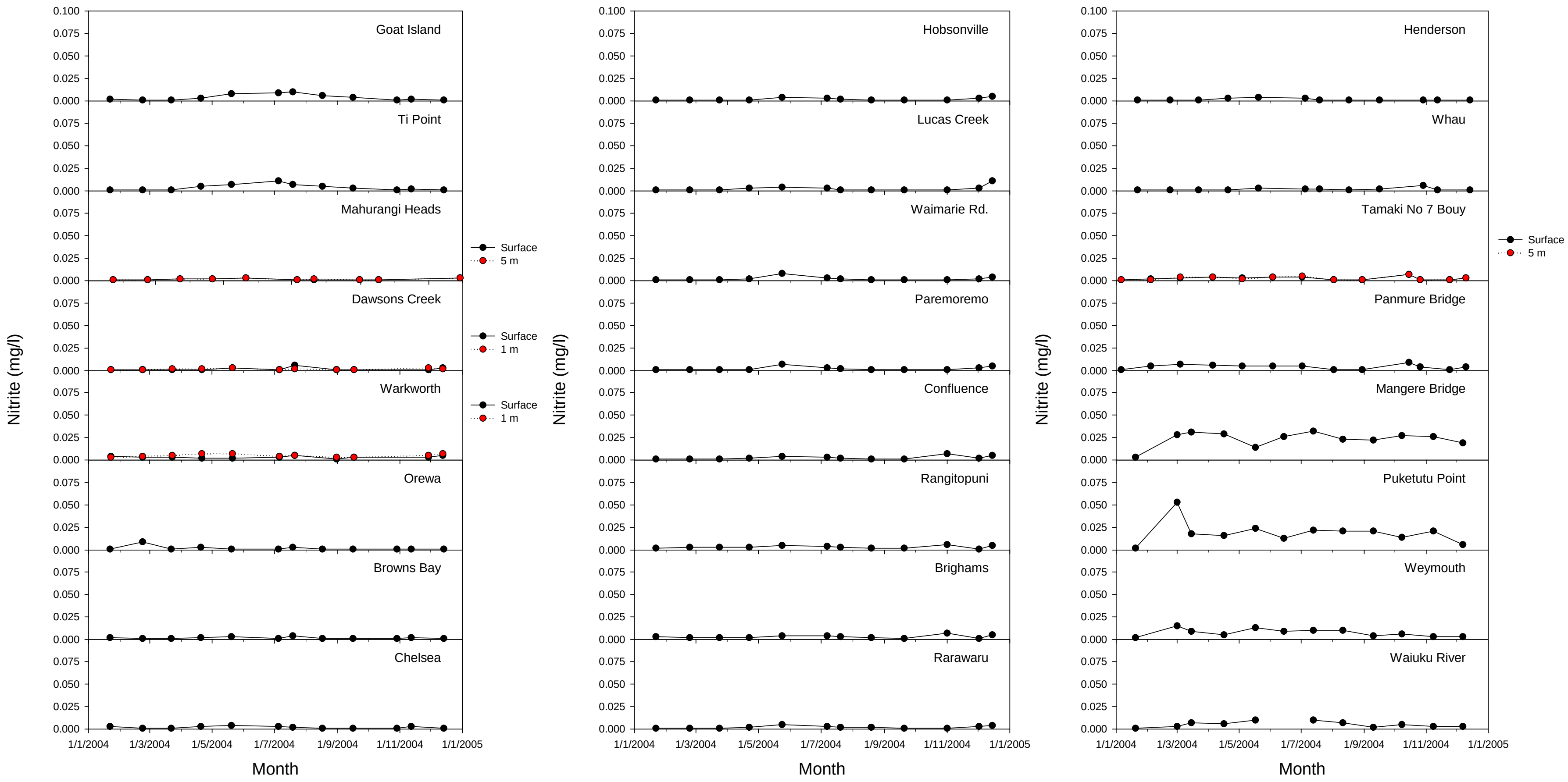


Figure 9.11b: Nitrite (NO_2) concentration (mg/l) at coastal water quality monitoring sites during 2004.

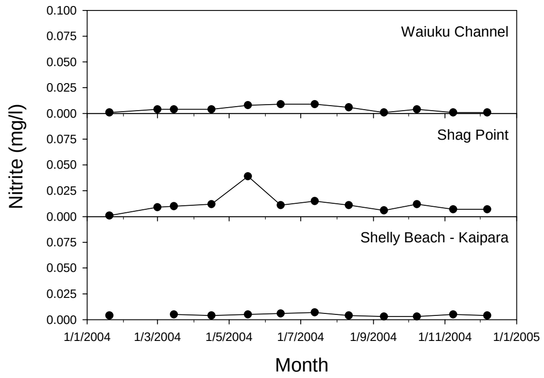


Figure 9.12a: Phosphorus concentration (mg/l) at coastal water quality monitoring sites during 2004.

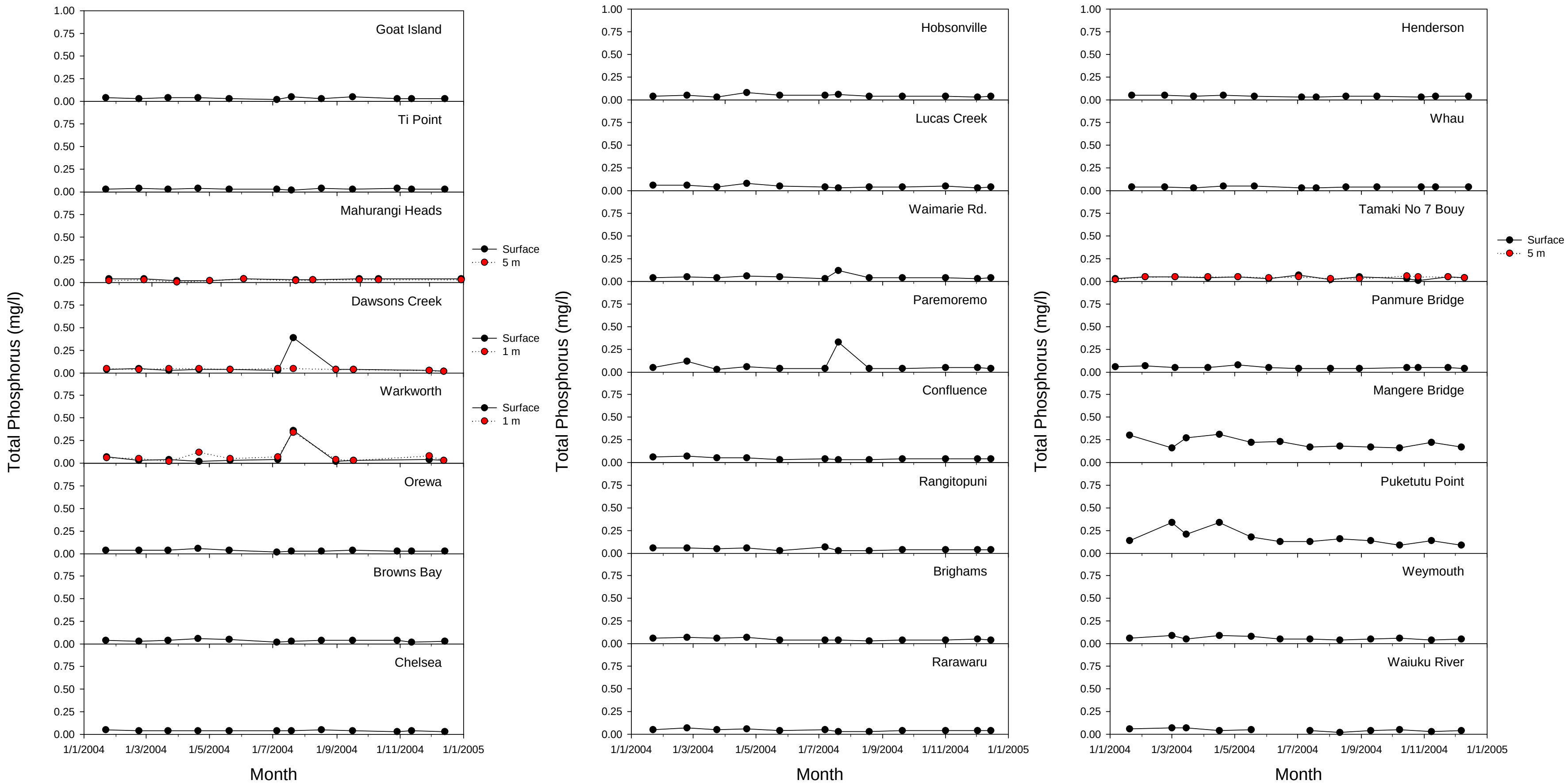


Figure 9.12b: Phosphorus concentration (mg/l) at coastal water quality monitoring sites during 2004.

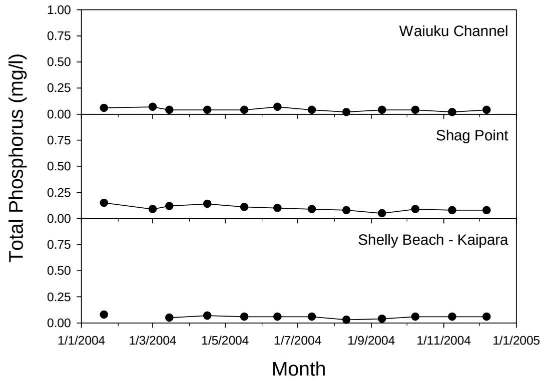


Figure 9.13a: Dissolved reactive phosphorus (DRP) concentration (mg/l) at coastal water quality monitoring sites during 2004.

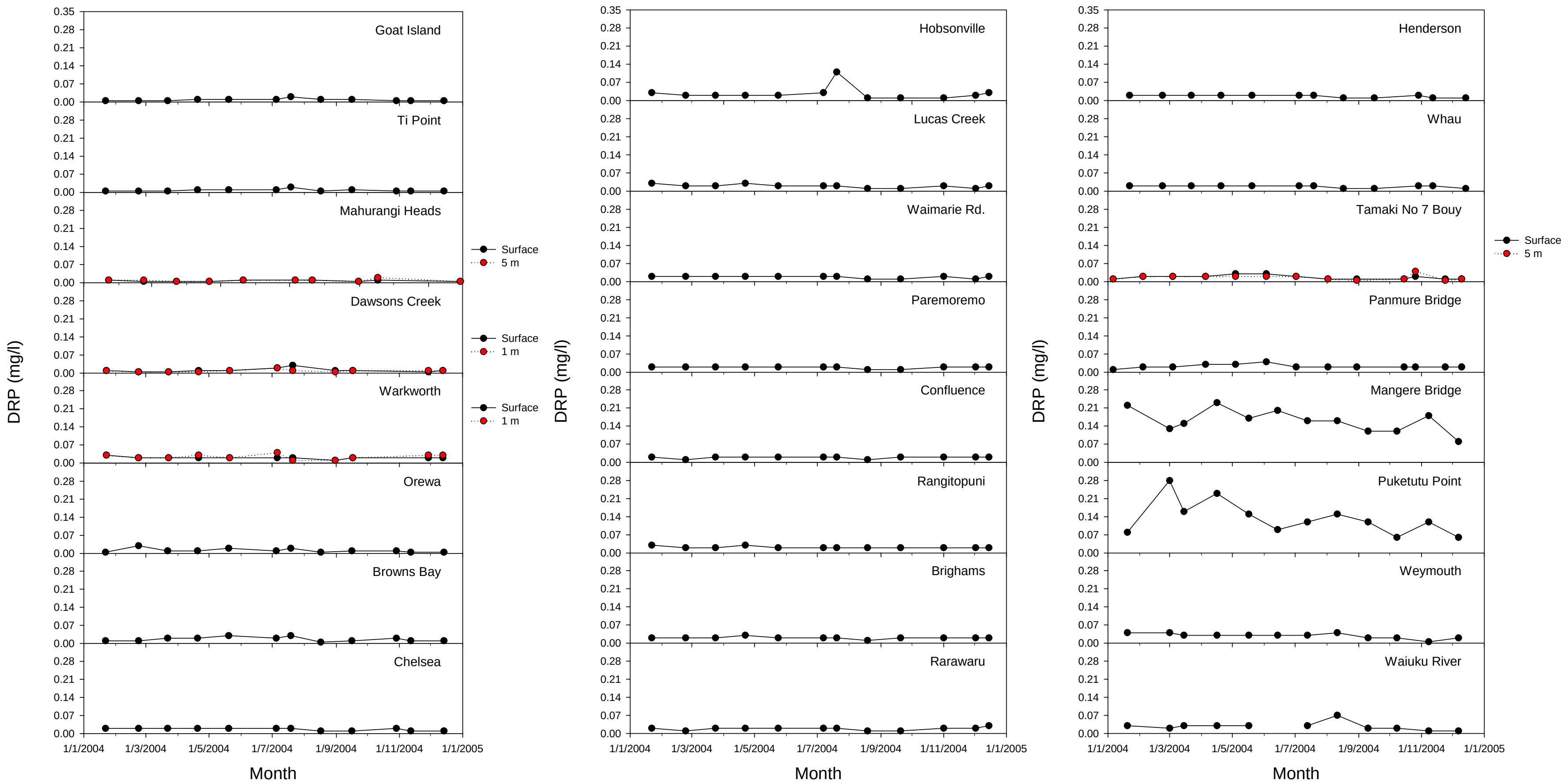


Figure 9.13b: Dissolved reactive phosphorus (DRP) concentration (mg/l) at coastal water quality monitoring sites during 2004.

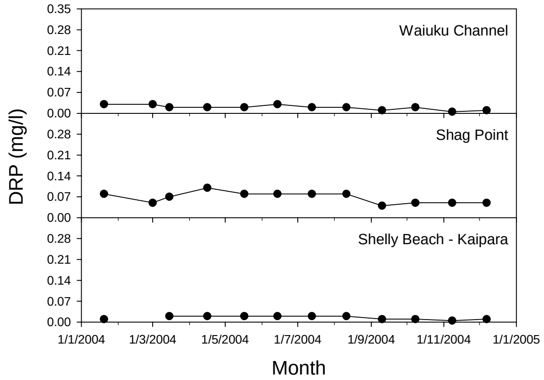


Figure 9.14a: Chlorophyll a concentration (g/l) at coastal water quality monitoring sites during 2004.

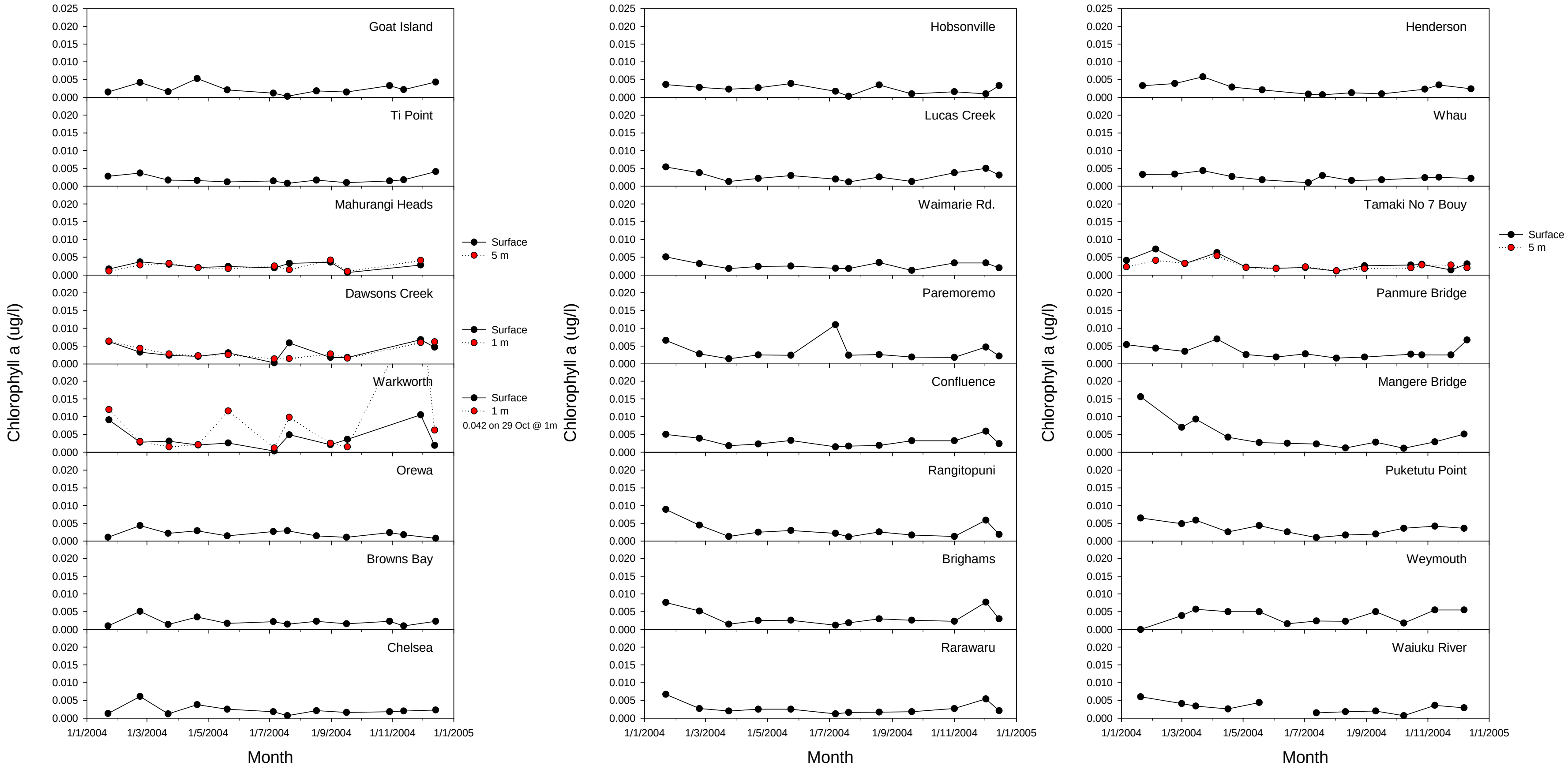


Figure 9.14b: Chlorophyll a concentration (g/l) at coastal water quality monitoring sites during 2004.

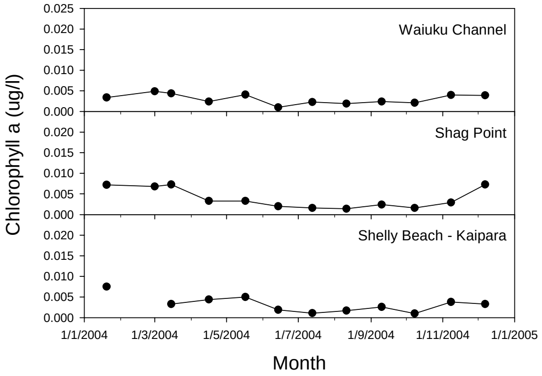


Figure 9.15a: Faecal coliform concentration (MPN/100 ml) at coastal water quality monitoring sites during 2004.

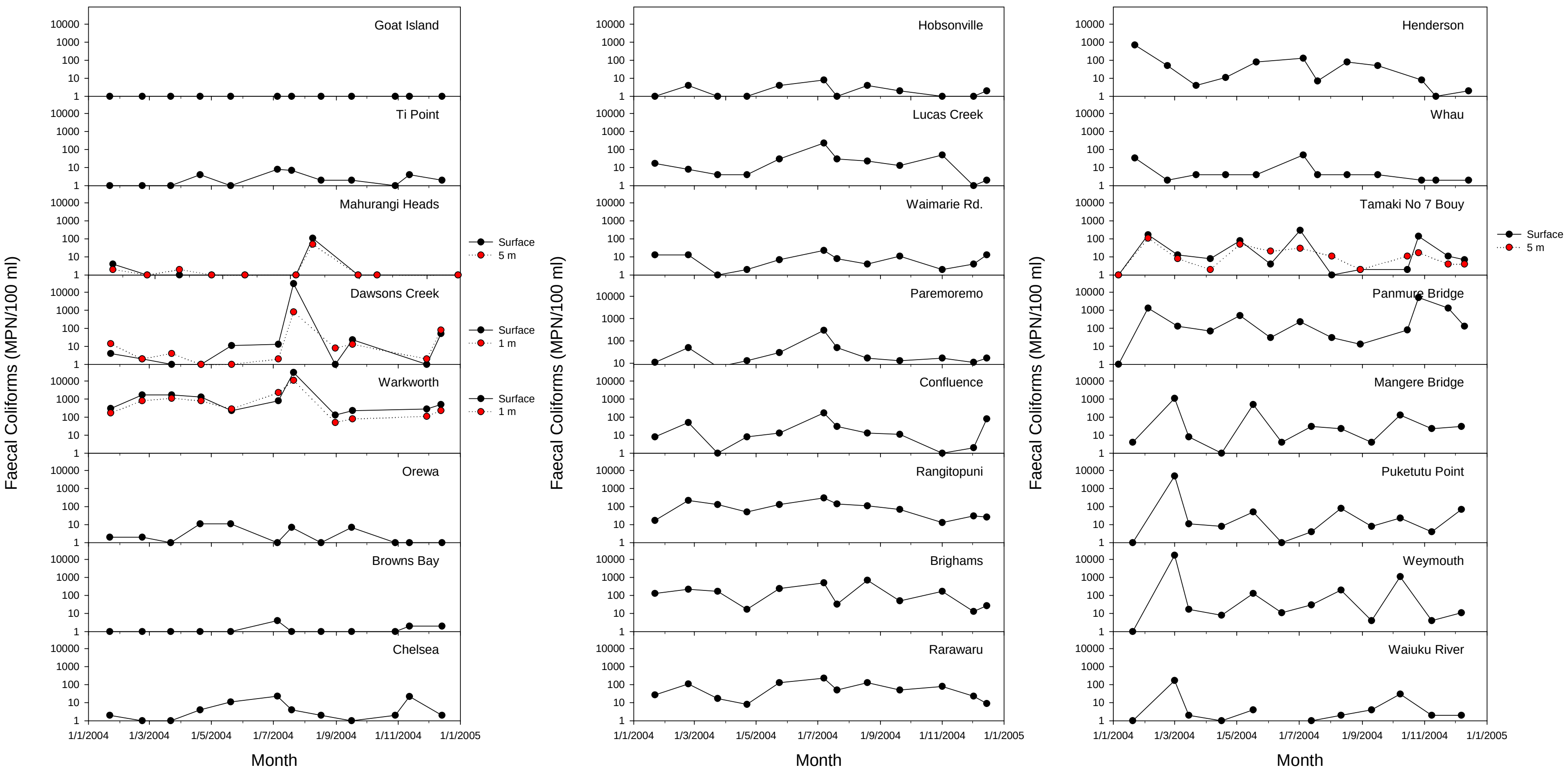


Figure 9.15b: Faecal coliform concentration (MPN/100 ml) at coastal water quality monitoring sites during 2004.

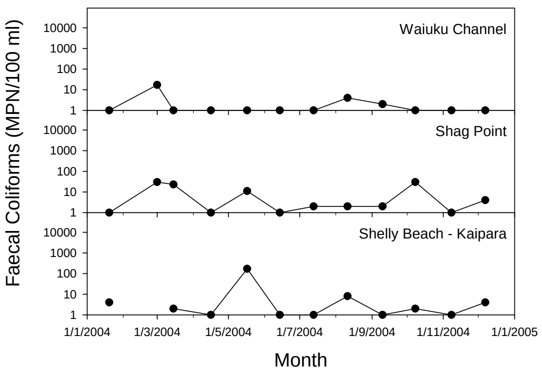


Figure 9.16a: Enterococci concentration (cfu/100 ml) at coastal water quality monitoring sites during 2004.

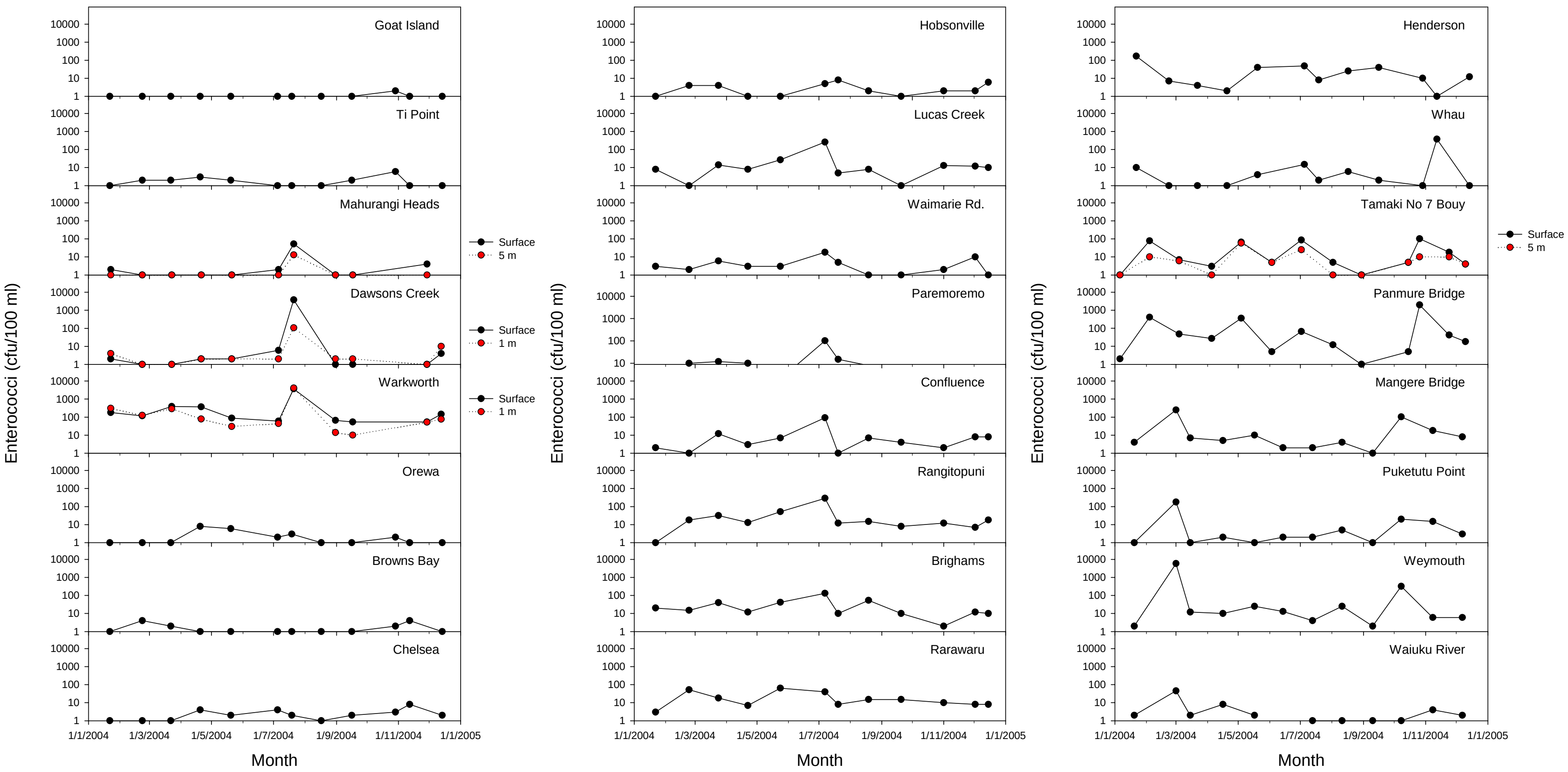
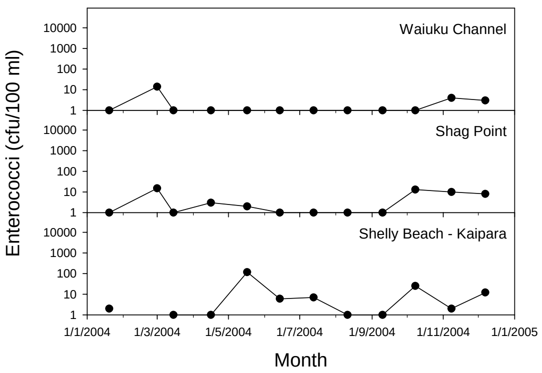


Figure 9.16b Enterococci concentration (cfu/100 ml) at coastal water quality monitoring sites during 2004.



10 Appendix 4: Description of Water Quality Variables

10.1 Physio-chemical Measures

10.1.1 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 riparian vegetation shading of the waterway. In catchments developed for urban uses or intensive agriculture, riparian vegetation has generally been removed to ameliorate flooding problems or maximise land use and as a result stream temperatures tend to be elevated.

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

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

(ii) 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 saturation levels are already reduced (see next section).

10.1.2 Dissolved Oxygen

Dissolved oxygen saturation (DO (sat)) gives a direct measure for the assessment of a waterway's ability to support aquatic life and is therefore one of the more important water quality parameters in our surveys. However where low saturation levels occur there is often a multiplicity of possible causes. DO (sat) levels show natural fluctuations both diurnally (throughout the day) and seasonally. Diurnal changes are caused predominantly by the respiratory activities of aquatic biota, particularly plants. Seasonal variations are 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 DO (sat) levels caused by this phenomenon is usually greatest in the early hours of the morning.

10.1.3 Biochemical Oxygen Demand

Biochemical oxygen demand (BOD) is a measure of the amount of oxygen required to break down the organic matter in a set volume of water in a five-day period at 20 degrees Celsius. High BOD levels in water bodies indicate the presence of organic matter, which may exert an oxygen demand resulting in a reduced dissolved oxygen concentration and therefore a reduction of water quality.

10.1.4 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.

10.1.5 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.

10.1.6 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 many 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.

10.1.7 Suspended Solids (also called non-filterable residue)

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.

10.1.8 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. For lakes and coastal surveys, turbidity and secchi disk readings are used to quantify water clarity. For secchi disk readings, the observer lowers the disk and notes the depth at which the disk disappears from view. A second reading is taken when the disk is raised through the water column until it reappears. Stream water clarity is expressed by measuring turbidity and black disk transparency.

10.1.9 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.

10.1.10 Black Disk Transparency

Black disk transparency is a measure of horizontal water clarity. 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). It is a good estimate of the distance that sighted animals can see horizontally under water. This method, in conjunction with turbidity, is used to quantify stream water clarity.

10.2 Microbial Measures

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 humans, and are shed in large numbers in faecal matter (at a rate of 10^6 – 10^9 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 microorganisms that are found in the gut may also be present.

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

In New Zealand three bacterial indicator groups have been routinely used for water quality monitoring. These are the presumptive coliform, faecal coliform, and enterococci groups.

10.2.1 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.

10.2.2 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, studies undertaken on behalf of the United States Environmental Protection Agency (USEPA) comparing indicator levels with health effects have indicated that enterococci (see later) provide a much better index of health risk than faecal coliforms. The USEPA have subsequently developed enterococci guidelines for health risk monitoring of recreational water quality in the USA. These guidelines have been used to form the basis of New Zealand's provisional guidelines for recreational water quality monitoring. 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. The only major impediment to this use is the inability to discriminate between contamination of human and non-human origin. Such assessments must be made on the basis of subjective evaluation of likely sources and routes of contamination within the catchment.

10.3 Nutrient Measures (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:

(i) Choking waterways leading to reduced drainage capacity,

(ii) Loss of amenity values,

(iii) Physical habitat reduction,

(iv) Excessive fluctuations in dissolved oxygen and pH,

(v) Reduced suitability for stock watering or horticultural irrigation.

10.3.1 Ammonia

Ammoniacal nitrogen is a macro-nutrient but is considered in general water quality evaluations in terms of its toxicity to many 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 (NH_3) and the ammonium ion (NH_4^+), 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 coastal waters ammonia toxicity is influenced by salinity in addition to pH and temperature. The chronic exposure limit for sensitive coastal organisms under ambient conditions is 2.3 mg/L.

10.3.2 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. 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.

10.3.3 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.

10.4 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 stormwater. Total and soluble metal concentrations are measured at urban sites because levels rarely exceed effect levels in non-urban areas.