Waterways
Centre for Freshwater Management

Diurnal Variation in Wairewa Water Quality

Summer Scholarship Report

WCFM Report 2011 - 003

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TITLE: **Diurnal Variation in Wairewa Water Quality**

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Wairewa/Lake Forsyth on Banks Peninsula, Canterbury, New Zealand

Abstract

Lake Forsyth/Te Roto o Wairewa is a hypertrophic coastal lake in Canterbury, New Zealand. The diurnal and diel variation of significant water quality parameters were measured for three months over summer 2010/11 at three sites on the lake. These included dissolved oxygen (DO), pH, conductivity, temperature, nitrate, phosphate and turbidity.

DO, pH and temperature displayed distinct diurnal and diel trends with a large range in values recorded, while conductivity showed less clear patterns. Diurnal concentrations of nitrate, phosphate and turbidity at 09:30 and 14:30 showed that nitrate and turbidity tended to increase, while phosphate decreased overall. Sharp peaks in phosphate were observed, and remain unexplained

Diel nitrate and phosphate concentration showed indistinct patterns, while turbidity reflected wind activity. A depth profile was undertaken measuring all water quality parameters mentioned and demonstrated the Lake Forsyth is unstratified.

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Section 1 Introduction

1.1 Diurnal variation in water parameters

Lakes can experience significant diurnal and diel variation in water chemistry parameters (Chapman 1992; Jekatierynczuk-Rudczyk et al. 2002). This is primarily related to the photosynthetic activity of algae and macrophytes living in the lake. During the day, these organisms photosynthesise, causing an increase in oxygen concentration through the conversion of carbon dioxide to oxygen in the presence of sunlight. This has a similar effect upon pH levels, as during photosynthesis HCO_3^- molecules are used instead of CO_2, which then increase the concentration of OH^- molecules, thereby increasing the pH. At night, the opposite process occurs (respiration), causing the oxygen concentration and pH to decrease.

The range of diurnal and diel variation is also dependent upon the weather conditions. On bright sunny days, the level of photosynthesis (and therefore dissolved oxygen (hereafter referred to as DO) and pH) will be higher due to the intensification of UV irradiation (Jekatierynczuk-Rudczyk et al. 2002). Conversely, on overcast/rainy days photosynthesis will occur at a lower degree due to the decrease in light, resulting in lower levels of DO and pH.

1.2 Lake Forsyth/Wairewa

Lake Forsyth (Wairewa) is a small coastal lake in Canterbury, 5.6 m^2 at its maximum extent and has a 110 km^2 catchment (Livingston et al. 1986). Depth in the main water body ranges averages between 1-2 m, while near the outlet the maximum recorded depth is 4.1 m (Irwin 1978).

Over the past 150 years, the Wairewa catchment has undergone significant land-use changes. The catchment in the early 19th Century was predominately forested, however by 1895 all millable trees were cut down (due to an increase of sawmills in the region) resulting in a significant increase in soil erosion (Main et al. 2003). Consequently, the sedimentation rate of the 20th Century was 3.8 mm/year, compared to 0.1 mm/year of the preceding 5000 years (Reid 2004). According to Burns (2000) trophic guidelines, Lake Forsyth is in a highly eutrophic state (TP > 0.098mg/L, TN > 1.6mg/L and Chl a > 31 µg/L), with high levels of nutrient enrichment.

A significant issue that occurs at Wairewa (as a result of such a highly eutrophic state) is the annual blooms of toxic algae, such as *Anabaena spp.* and *Nodularia spumigens*. Peak blooms occur in late January, fluctuating until May (Main et al. 2003). Woodward & Schulmeister (2005) proposed that the annual *N. spumigens* blooms (which were first reported in a local newspaper in 1907 (Main et al. 2003)) are a legacy from the erosion/increased sedimentation due to deforestation, coupled with the conversion to dairy farming around this time. As these species fix nitrogen it has been proposed that the main factor limiting their growth is phosphorus.

There is a significant amount of phosphorus contained in the catchment's soil (Lynn 2005), and possibly in the faeces of fauna, for example, the black swan *Cygnus atratus* Latham (Woodward & Schulmeister 2005), however this may only become available during wind activity. In addition, species such *as N. spumigens* need a favourable salinity range, warm temperatures and calm conditions to bloom due the extremely fragile nature of their cell walls (*Julie Edwards, pers. comm 13/01/2011*).

Wairewa is one of the only two customary lakes in New Zealand and is extremely important to the Waiwera Rūnaka. A Mahinga Kai Cultural Park has been proposed for the lake, which involves a catchment wide approach to management with the aim of restoring the lake health and Mahinga Kai (traditional food) species and encouraging biodiversity, thereby preventing further toxic algal blooms (Jellyman & Cranwell 2007).

1.3 Research Aims

The aim of this study was to evaluate the diurnal and diel range of significant water quality parameters (pH, DO, conductivity, temperature, turbidity, nitrate and phosphate concentrations) to use a baseline for further studies in Lake Forsyth/Wairewa.

Section 2 Methods

The study was undertaken over a three month period during summer (8th Dec- 16th Feb) in 2010/2011.

2.1 Study sites

Water quality samples were taken once a week at one of three sites around Lake Forsyth (43°48'06"S 172°44'53"E; Table 1; Figure 1), during the summer. Sample days were randomly chosen in order to account for any variability as a result of different weather conditions (Table 2). Seven 12 hour samples (08:00 – 20:00) were taken at the three sites (4 ECan, 2 Catons Bay, 1 Outlet). Three 24 hour samples (08:00-08:00) were taken at Catons Bay.

Table 1: Study site grid references.

Study Sites	S	E
ECan	43°48'48"	172°44'11"
Catons bay	43°47'27"	173°45'31"
Lake Outlet	43°49'30"	172°42'33"
Depth Profile Sites		
1	43°47'48"	172°48'41"
2	43°47'55"	172°45'19"
3	43°48'10	172°44'47"

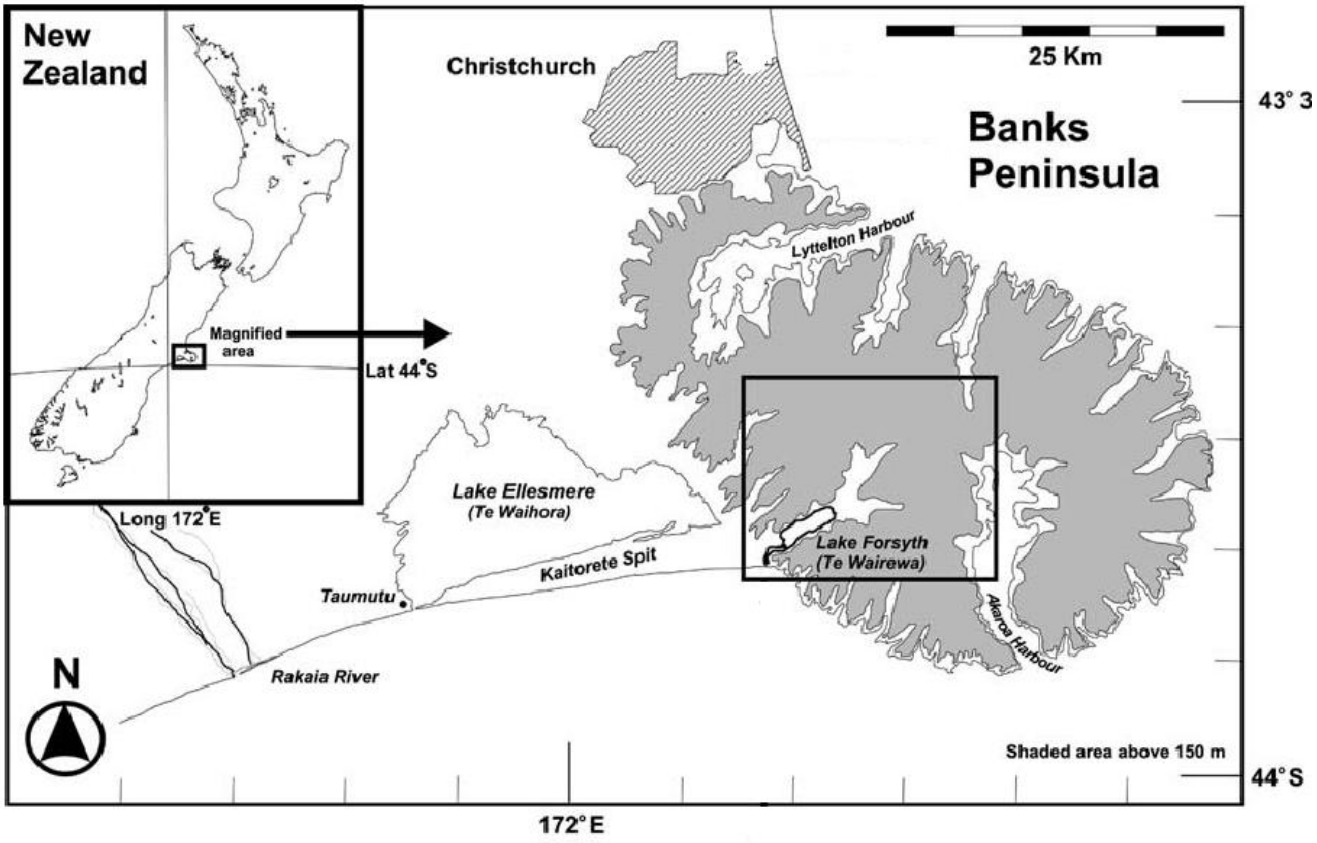

Figure 1: Lake Forsyth, from Woodward & Schulmeister (2005).

Table 2: Prevailing weather conditions at sample sites.

Site	Date	Sunny/Cloudy	Wind
ECan	8/12/2010	Sunny, few clouds	Mild
Catons Bay	13-14/12/2010	Sunny, few clouds	Very windy early morning and afternoon
ECan	21/12/2010	Overcast	Extremely windy
Lake Outlet	30/12/2010	Cloudy, but very bright	Mild/no wind
Catons Bay	4/01/2011	Overcast	Mild
ECan	18/01/2011	Cloudy (bright) turning overcast in afternoon and spitting	No wind in morning, very strong in afternoon
Catons Bay	20-21/01/2011	Overcast	Mild/no wind
ECan	24/01/2011	Sunny	Mild
Catons Bay	5/02/2011	Overcast	Mild
Catons Bay	15-16/02/2011	Sunny	Mild

2.2 Parameter measurement

DO, pH, conductivity and temperature were read every hour for all samples. During the 12 hour samples nitrate, phosphate and turbidity was measured twice (once at 09:30 and again at 14:30), while during the 24 hour sample these were measured every hour.

A HACH meter was used to measure the water quality parameters of DO, pH, and conductivity. The meter was calibrated at the beginning of the study, but was reading up to 0.3 pH units higher at the end of the study. DO and conductivity readings remained unchanged.

A HACH photospectrometer was used to measure the turbidity, nitrate-nitrogen (NO_3-N) and phosphate (PO_4) concentrations. Samples were taken at approximately 10cm depth in a well-mixed area (at Catons Bay this was approximately 5m from shore, while the ECan and Outlet sites had well mixed water at shore). Water samples were unfiltered, for nitrate and phosphate analysis, and the blank used was a lake water sample to which the reagents had not been added.

A depth profile was undertaken at 1pm on 08/02/2011 on a sunny, still day. DO, pH and conductivity were measured at the top (0m), middle (0.75m) and bottom (1.5m) on three random sites at the middle of the lake. Turbidity, NO_3-N and PO_4 concentrations were measured at the different depths at the first sample site.

Section 3 Results

3.1 Twelve Hour Samples

3.1.1 Key parameters

Lake Forsyth showed diurnal variation in DO, pH, Temperature, and to a lesser extent, conductivity. While DO and temperature appeared to vary dependent upon the weather, pH changed independent of the weather. Conductivity varied very little over the day, with most samples increasing during the day, irrespective of weather conditions.

DO increased steadily throughout the day in all 12 hour samples, tending to peak around 1-2pm, sometimes peaking as late at 8pm (Figure 2). At the ECan site DO was highest on still sunny days with few clouds, ranging from 7.31-13.31mg/L and lowest on overcast windy days, ranging from 6.05-11.12mg/L. The 12 hour Catons Bay/Outlet samples had still/mild wind and were overcast, resulting in very similar trends between the samples. The outlet sample had the highest DO, ranging between 10.3-14.3mg/L and may be related to the higher level of sunlight on that sample. Overall DO ranged from 7.14-14.3mg/L for those three samples.

The pH did not appear to follow a weather trend at the ECan site on the 12 hour samples (Figure 3), with high values occurring on both overcast and sunny days where it was either very windy or still. The pH for all samples ranged between 7.62-13.31.

Conductivity varied little throughout the day in all samples and appeared to change independent of weather/wind conditions. Conductivity was highest at the ECan and Lake Outlet sites (ranging between 1985-2128µS/cm), and lowest at the Catons Bay/Picnic area (1764-1845µS/cm) (Figure 4).

Temperature showed a clear diurnal trend, increasing throughout the day and decreasing at night (Figure 5), with a large range between samples. Temperature was both highest (24°C) and lowest (14°C) at the ECan site.

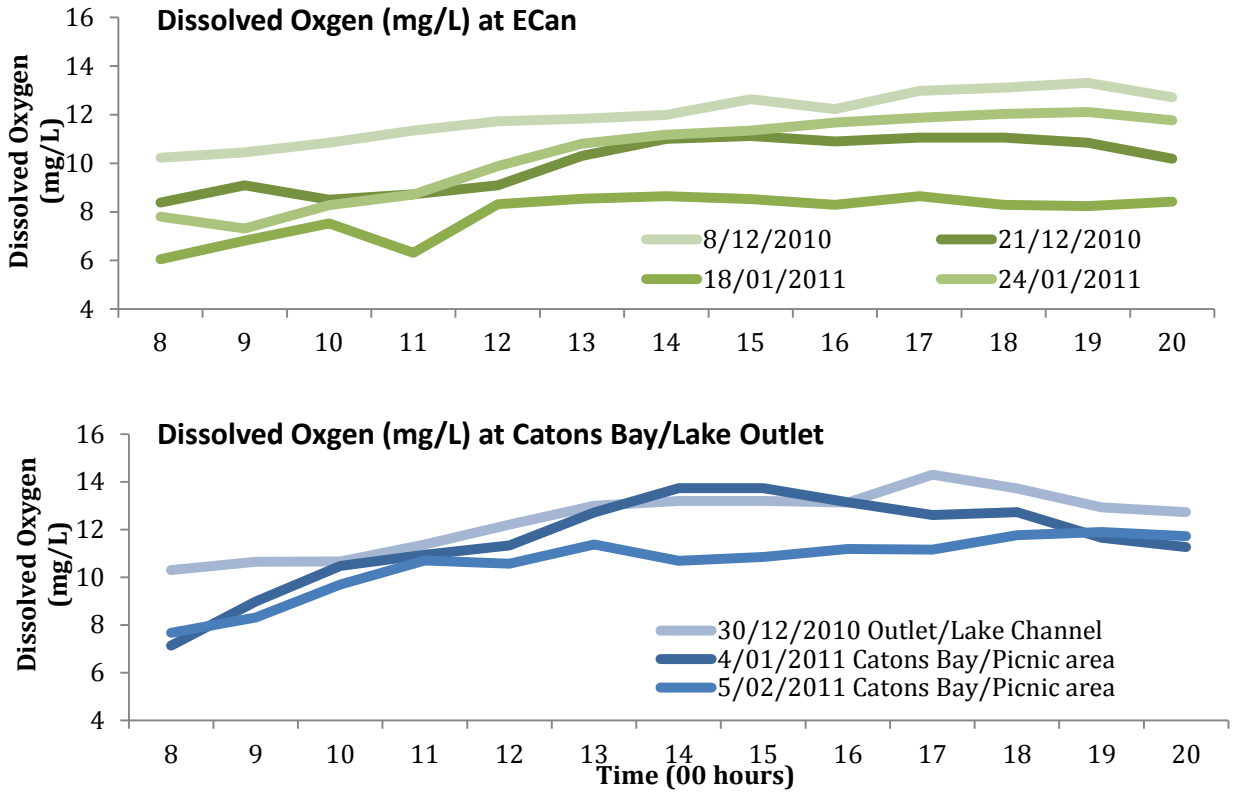

Figure 2 Dissolved Oxygen (mg/L) for the four ECan and three Catons Bay/Lake Outlet site 12 hour sampling events.

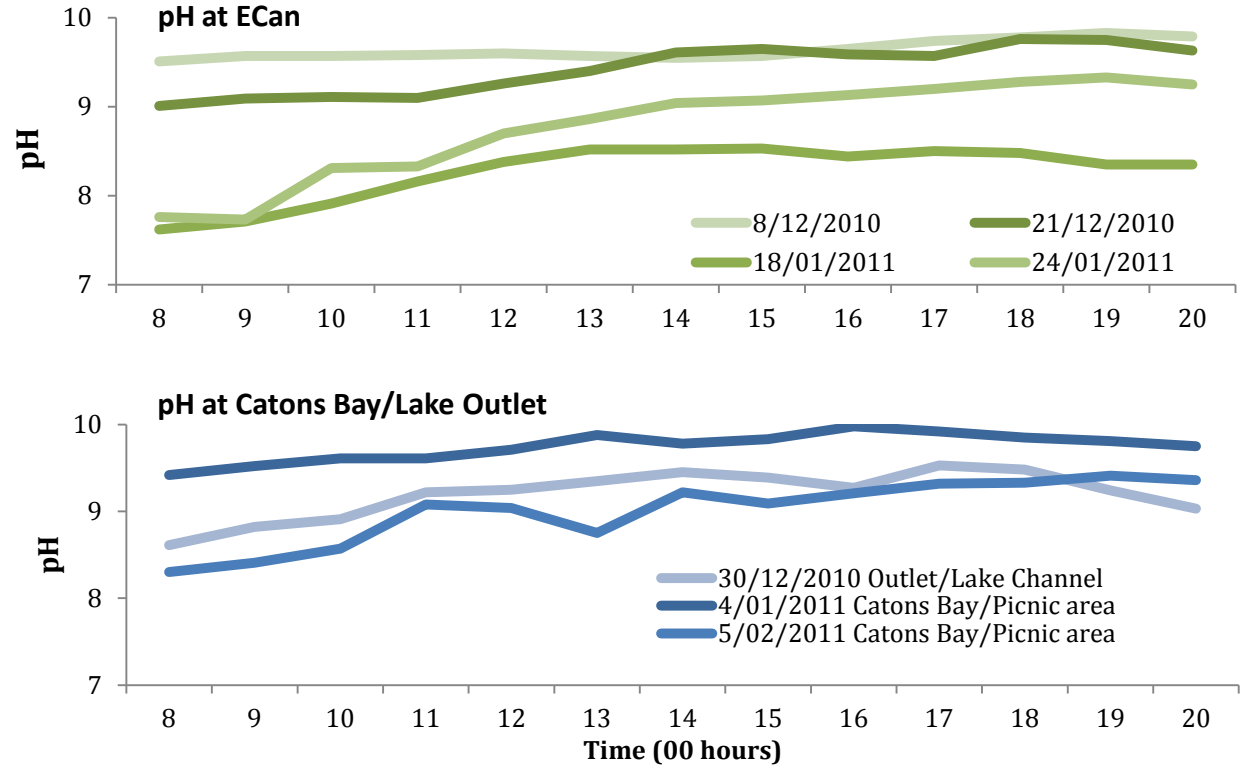

Figure 3 pH for the four ECan and three Catons Bay/Lake Outlet site 12 hour sampling events.

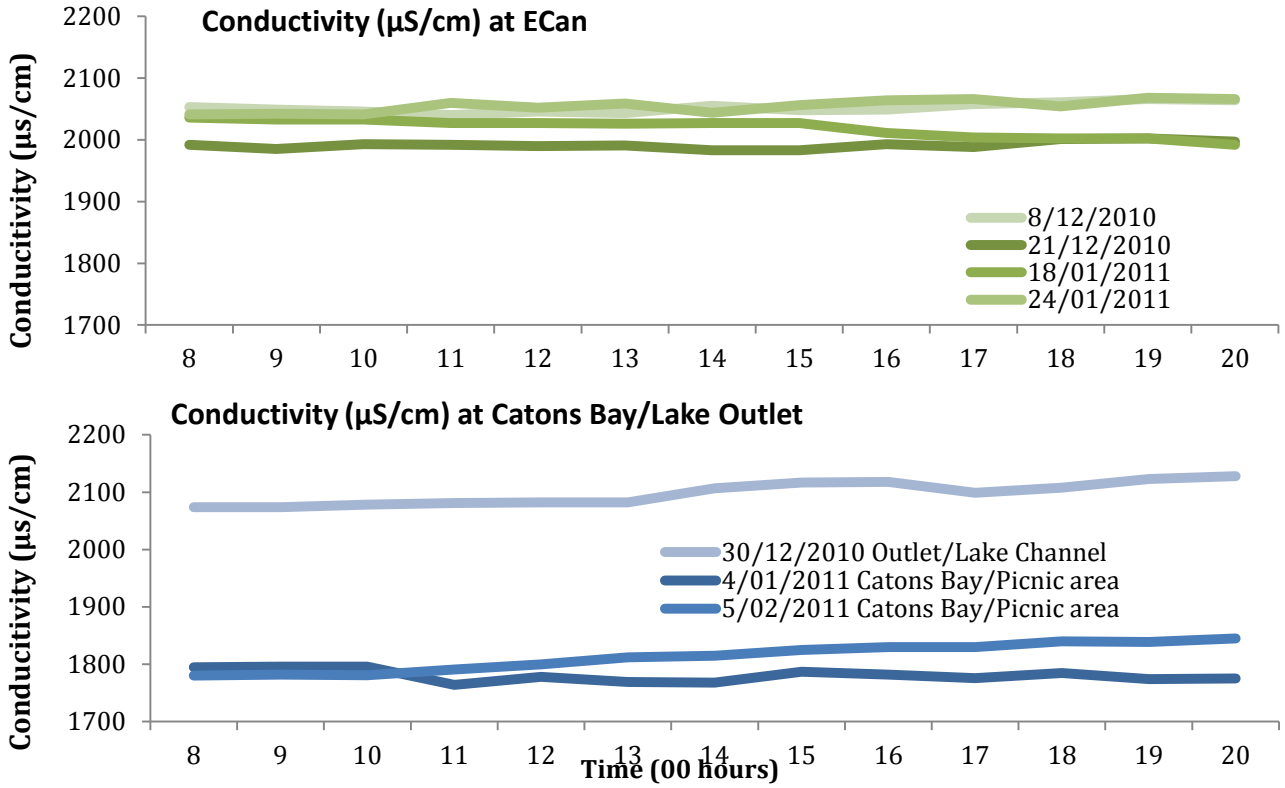

Figure 4 Conductivity (µS/cm) for the four ECan and three Catons Bay/Lake Outlet site 12 hour sampling events.

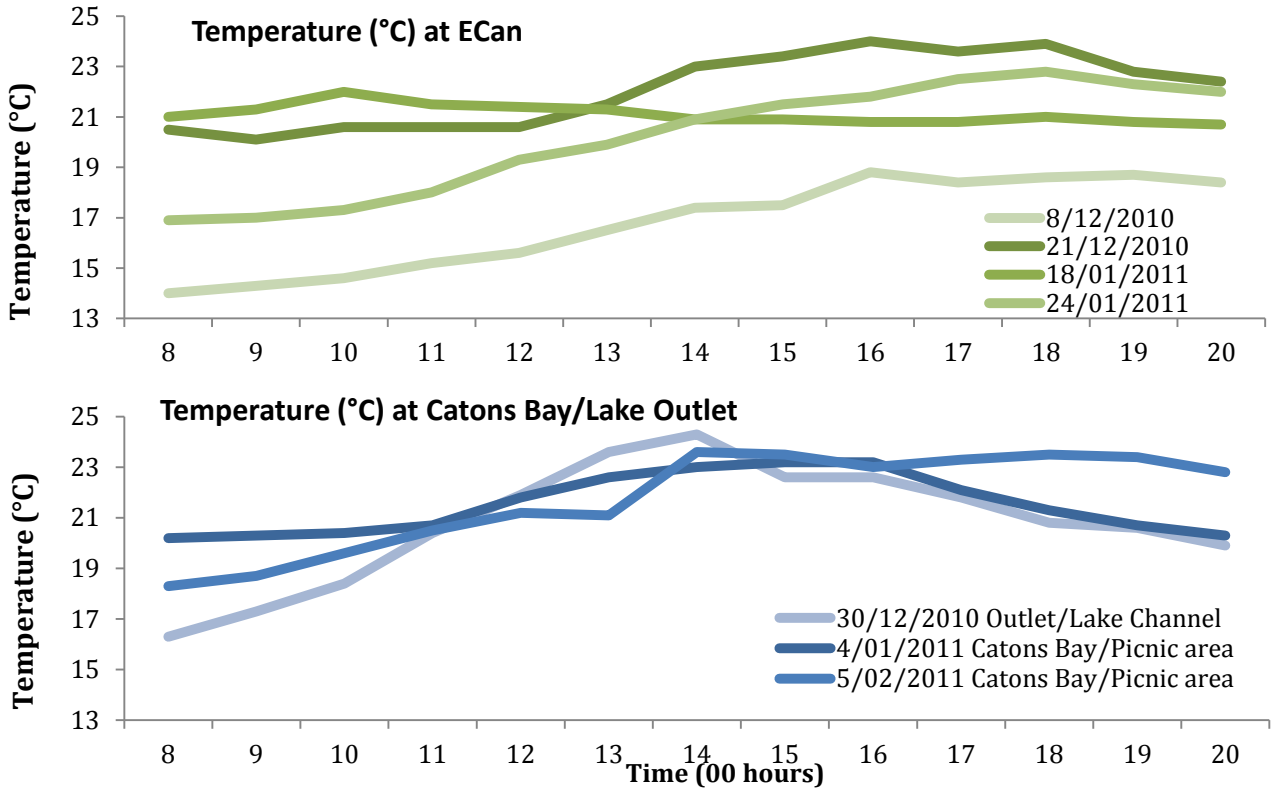

Figure 5 Temperature (°C) for the four ECan and three Catons Bay/Lake Outlet site 12 hour sampling events.

3.1.2. Nutrients and Turbidity

Nitrate, phosphate and turbidity commonly changed between 09:30-14:30 in the 12 hour samples (Figure 6), changing independent of weather conditions. NO_3-N and turbidity levels mainly either remained the same or increased while PO_4 showed commonly decreased from 9:30-14:30. The average NO_3-N concentration at 9:30 was 0.26mg/L, increasing to 0.34mg/L at 14:30. The average PO_4 concentration at 9:30 was 0.61mg/L, decreasing to 0.47mg/L at 14:30. The average turbidity at 9:30 was 26NTU, increasing to 43NTU at 14:30.

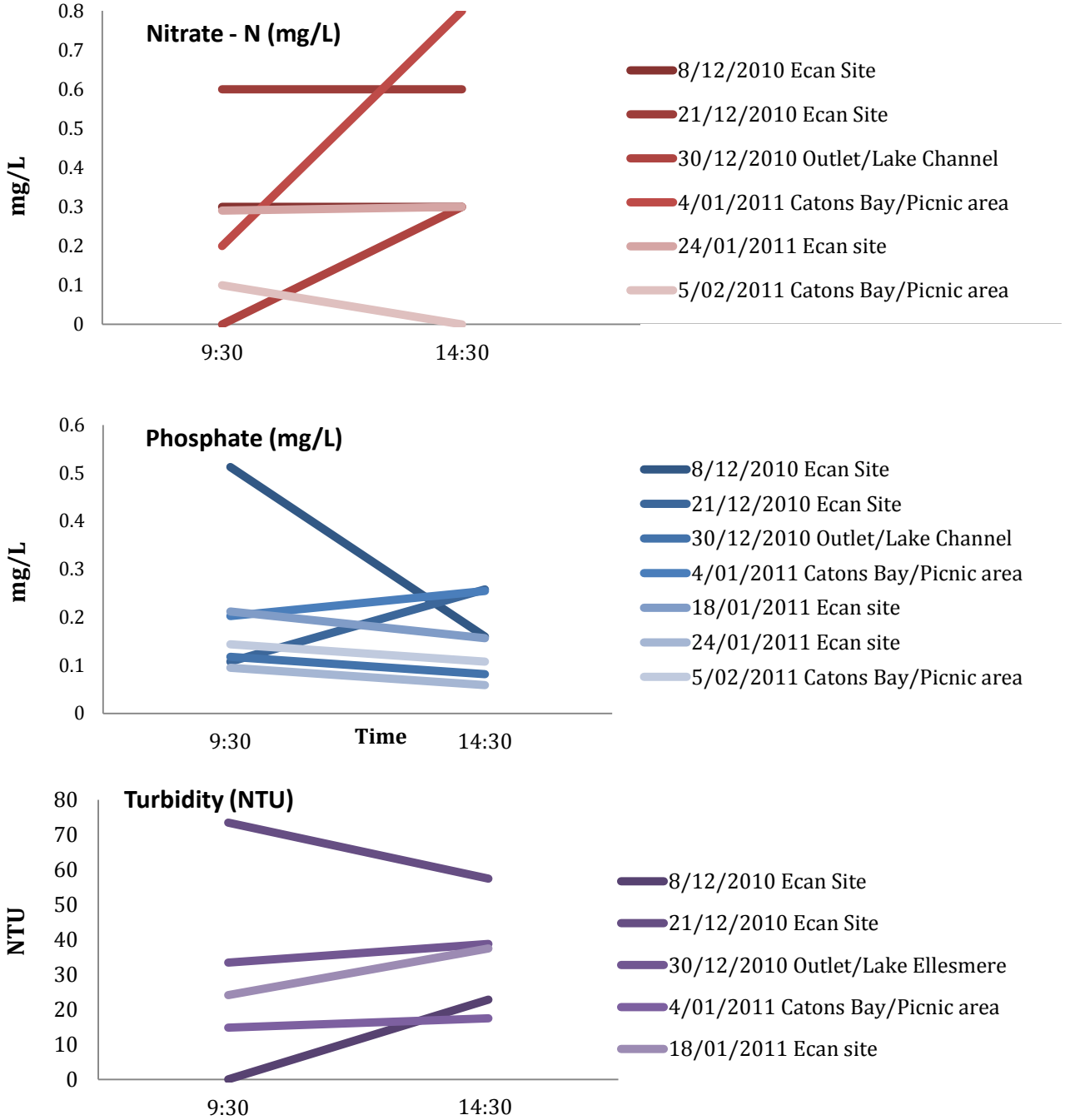

Figure 6 9:30 and 14:30 samples for nitrate (mg/L) phosphate (mg/L) and turbidity (NTU) at the ECan, Catons Bay and Outlet sites.

3.2. 24 Hour Samples

3.2.1 Key parameters

The 24 hour sample showed clear diel trends in DO, pH and temperature, with an unclear trend in conductivity (Figure 7). Temperature showed a clear diurnal trend, reaching a maximum around 3-4pm and a minimum between 5-7am. The temperature ranged between 15.5-24.2°C.

DO reached a maximum between 1-4pm (generally at 1pm) (Figure 7). DO tended to decline from 1pm, except in the December sample where the peak was reached at 4pm, remaining elevated until 9pm. The minimum DO occurred at 4am in all samples. DO ranged from 4.89-13.7mg/L.

The pH showed a similar trend, yet with a far later peak (5-7pm) (Figure 7). The minimum pH occurred between 3-4am. Interestingly the December sample had a higher pH and a less dramatic diel fluctuation. The pH ranged from 7.21-10.26.

Conductivity showed a continual increase in the February sample, an overall increase in the December sample and a continual decrease in the January sample, with no clear diel trend noticeable.

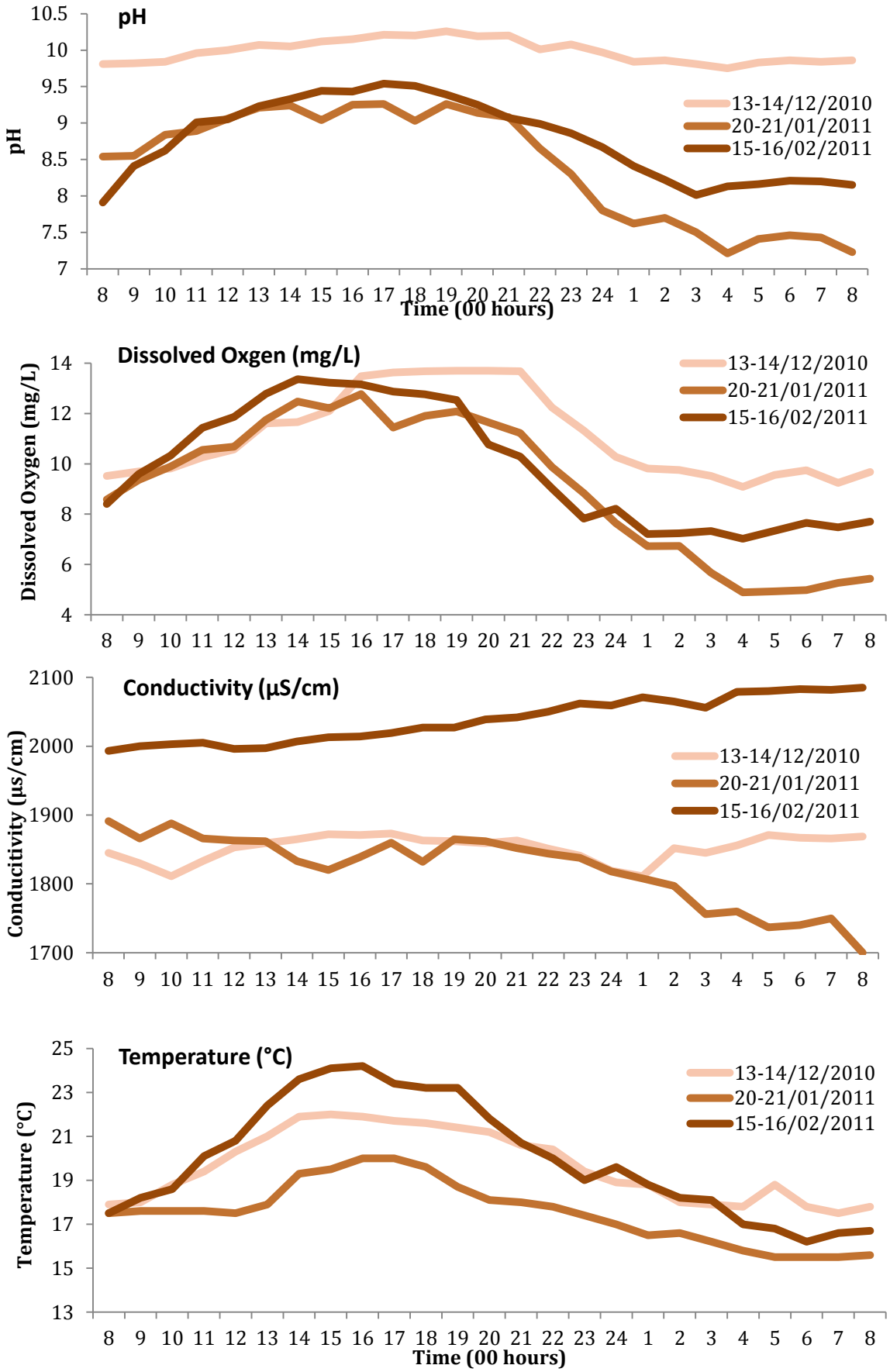

Figure 7 Dissolved Oxygen (DO), pH, conductivity (µS/cm) and temperature over the 24 hour Catons Bay samples.

3.2.2 Nutrients and turbidity

The nutrient and turbidity 24 hour samples show extreme diel variability (Figure 8). Nitrate, phosphate appeared to act independently of wind/weather conditions. However, turbidity increased with increased wind activity. The average concentration of nitrate is 0.27mg/L, while the minimum was 0mg/L and maximum was 1.3mg/L. Average phosphate concentration was 0.79mg/L, while the minimum was 0.1mg/L and maximum was 2.75mg/L, however it may have been higher as 2.75mg/L was the limit of the photospectrometer. Average turbidity was 21NTU, while minimum was 1.5NTU and maximum was 53.5NTU.

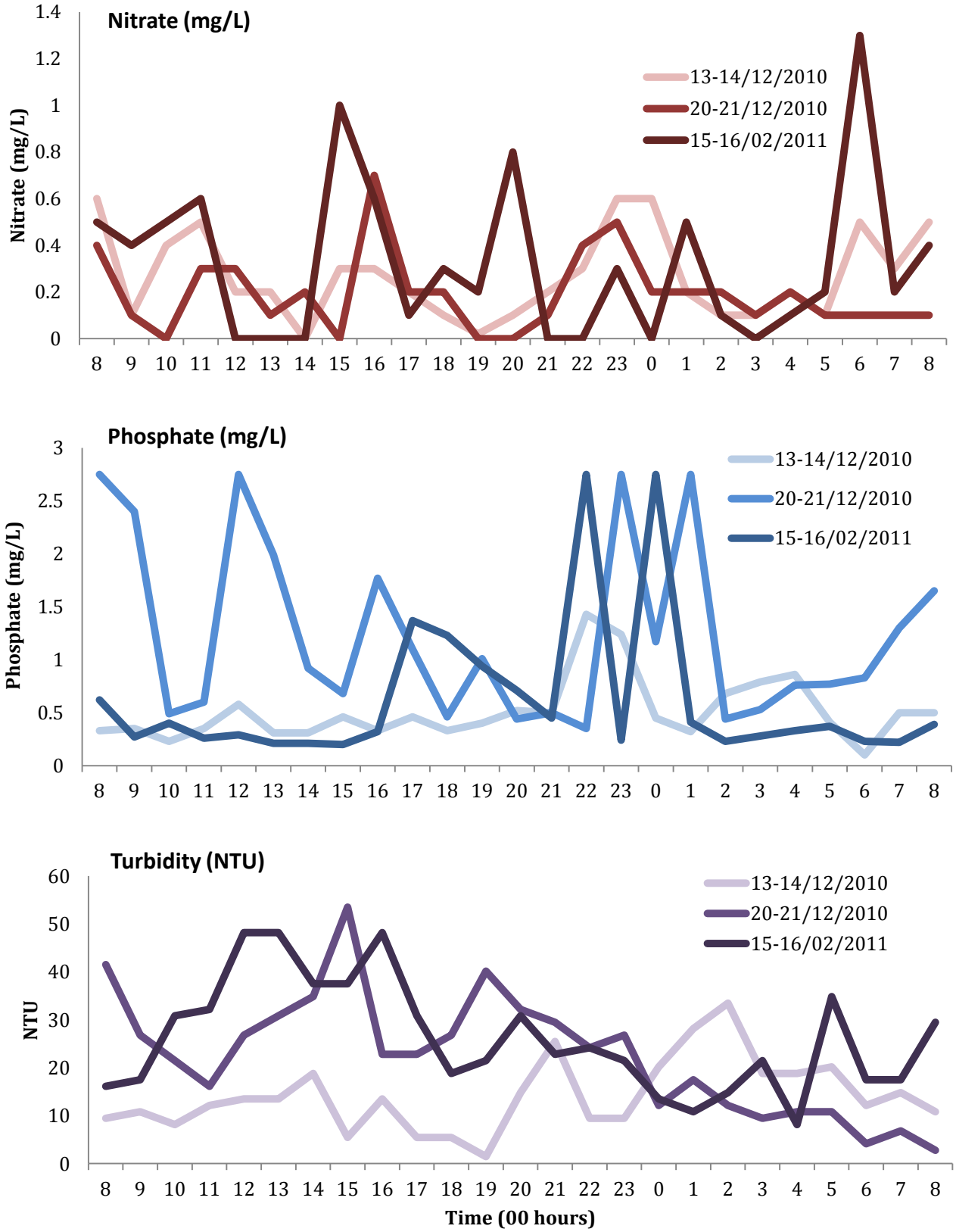

Figure 8 Nitrate (mg/L), phosphate (mg/L) and turbidity (NTU) over the 24 hour Catons Bay sample.

3.3 Depth Profile

The depth profile survey demonstrated Lake Forsyth has little if any vertical stratification, with only a very minor decrease in key water quality parameters with depth, though likely within the analytical error for these parameters. Dissolved oxygen and pH slightly decreased with depth at all sample sites (Table 3). Conductivity decreased with depth at Site 1 and 2, yet increased at Site 3 (Table 3). Temperature decreased with depth at Site 1 and 3, yet increased with depth at Site 2 (Table 3). The nutrient and turbidity sample taken at Site 1 display an interesting trend, with NO_3-N increasing with depth, yet PO_4 concentration decreasing with depth (Table 3). The turbidity did not show a clear trend (Table 3).

Table 3. Depth Profile survey of DO (mg/L), pH, conductivity (µS/cm), temperature (°C), nutrients (mg/L) and turbidity (NTU) at three random sites in the middle of Lake Forsyth on 08/02/2011.

Profile Site:	**1**	**2**	**3**
DO (% Sat)			
TOP (0m)	9.05 (103.6)	8.99 (101.3)	9.2 (105)
MIDDLE (0.75m)	9.04 (101.4)	8.96 (101.5)	9.5 (109.1)
BOTTOM (1.5m)	8.87 (101.5)	8.68 (98.8)	8.79 (101.6)
pH			
TOP (0m)	8.59	8.45	8.95
MIDDLE (0.75m)	8.66	8.29	8.81
BOTTOM (1.5m)	8.49	8.03	8.67
Conductivity			
TOP (0m)	1552	1956	1843
MIDDLE (0.75m)	1536	1926	1887
BOTTOM (1.5m)	1647	1889	1919
Temperature			
TOP (0m)	21	20.4	21.3
MIDDLE (0.75m)	20.8	21	20.9
BOTTOM (1.5m)	20.3	21.1	20.3
NO_3-N			
TOP (0m)	0.1		
MIDDLE (0.75m)	0.2		
BOTTOM (1.5m)	0.4		
PO_4			
TOP (0m)	0.34		
MIDDLE (0.75m)	0.36		
BOTTOM (1.5m)	0.21		
Turbidity			
TOP (0m)	14		
MIDDLE (0.75m)	13		
BOTTOM (1.5m)	16		

Section 4 Discussion

Significant diurnal and diel variation was recorded at Lake Forsyth over the 2010/11 summer. As expected, pH, DO, temperature (and frequently conductivity) increased during the day and often peaked mid-late afternoon. This is attributed to the photosynthetic activity on plants and algae within the lake. Weather conditions had an effect upon DO and pH, primarily where sunny days tended to have higher values than overcast days.

An *Anabaena* spp. bloom was recorded on 10/01/2011 (Stuff.co.nz, 10/01/2011). The next sampling showed (18/01/2011) had extremely low DO and pH levels. DO ranged between 6.05-8.64mg/L, while pH ranged between 7.62-8.53. These were very low values in comparison to the average DO (10.35mg/L) and pH (9.09).

There was no clear link between prevailing wind conditions and nutrient concentrations or turbidity. This was surprising as wind was expected to be the primary driving mechanism behind an increase in phosphate due to the resulting re-suspension of sediment from the lake bed. Although this study was unable to provide a conclusive link between weather and phosphorous activity, it may still occur. The release of phosphorous into the lake is significant due to the fact that it may potentially be a limiting factor to toxic algal blooms. Knowing about the behaviour of phosphate is therefore extremely important to future management of Lake Forsyth, particularly in regard to the desired goal of creating a Mahinga Kai Cultural Park.

Section 5 Conclusions

Lake Forsyth showed significant diel and diurnal variation in the pH, DO, temperature and (to a lesser degree) conductivity over the Summer 2010/11 study period. These parameters generally increased during the morning, reaching a peak early-late afternoon, decreasing to a minimum around 4am. The recorded variability in pH and DO is attributed to photosynthesis during the day and respiration at night.

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Appendix Raw Data

Time	DO (mg/L)	DO (% Sat)	Temp (oC)	pH	Cond (uS/cm)	NO_3-N (mg/L)	PO_4 (mg/L)	Turbidity (FAU)	Comments
ECan	**Site**	**8/12/10**							***Stage Height: 1.7m; exposed location***
8	10.22	98	14	9.51	2053				
9	10.45	101.7	14.3	9.57	2049	0.3	1.57	0	Fine, with few clouds, mild wind
10	10.85	106.4	14.6	9.57	2046				
11	11.34	112.6	15.2	9.58	2040				
12	11.72	117.5	15.6	9.6	2046				
13	11.83	120.8	16.5	9.57	2043				
14	11.99	124.9	17.4	9.55	2055	0.3	0.49	18	
15	12.64	125.8	17.5	9.57	2048				
16	12.23	130.9	18.8	9.65	2049				
17	12.98	138	18.4	9.74	2058				
18	13.11	140.1	18.6	9.78	2061				
19	13.31	142.8	18.7	9.83	2066				
20	12.72	135.6	18.4	9.79	2064				
Catons	**Bay**	**13/12/10**							***More sheltered site***
8	9.52	101.9	17.9	9.81	1845	0.6	0.33	8	Very windy early
9	9.7	101.7	18	9.82	1830	0.1	0.35	9	
10	9.81	105.8	18.8	9.84	1811	0.4	0.23	7	Mainly sunny with few clouds
11	10.26	112	19.4	9.96	1833	0.5	0.35	10	
12	10.57	117.6	20.3	10	1853	0.2	0.58	11	White foam appeared around 3am
13	11.61	131.6	21	10.07	1859	0.2	0.31	11	
14	11.66	134.5	21.9	10.05	1865	<dl	0.31	15	
15	12.1	148.3	22	10.12	1872	0.3	0.46	5	Very windy again
16	13.48	154.3	21.9	10.15	1871	0.3	0.33	11	
17	13.63	156.1	21.7	10.21	1873	0.2	0.46	5	
18	13.68	153.2	21.6	10.2	1863	0.1	0.33	5	
19	13.7	155.8	21.4	10.26	1862	0.02	0.4	2	
20	13.7	155	21.2	10.19	1859	0.1	0.52	12	

21	13.68	153.2	20.6	10.2	1863	0.2	0.5	20	
22	12.24	136.9	20.4	10.01	1851	0.3	1.43	8	Light gone at 10pm
23	11.32	130	19.4	10.08	1841	0.6	1.24	8	
0	10.28	118	18.9	9.97	1819	0.6	0.45	16	
1	9.81	105.9	18.8	9.84	1811	0.2	0.32	22	
2	9.75	102.3	18	9.86	1852	0.1	0.68	26	
3	9.52	101.8	17.9	9.81	1845	0.1	0.79	15	
4	9.08	97	17.8	9.75	1856	0.2	0.86	15	
5	9.56	102	18.8	9.83	1871	0.1	0.41	16	
6	9.74	102.5	17.8	9.86	1867	0.5	0.1	10	
7	9.24	97.2	17.5	9.84	1866	0.3	0.5	12	
8	9.68	102.5	17.8	9.86	1869	0.5	0.5	9	
Time	**DO (mg/L)**	**DO (% Sat)**	**Temp (oC)**	**pH**	**Cond (us/cm)**	**NO_3-N (mg/L)**	**PO_4 (mg/L)**	**Turbidity (FAU)**	**Comments**
ECan		**21/12/10**							
8	8.38	94.3	20.5	9.01	1992				Cloudy and extremely windy
9	9.09	97	20.1	9.09	1985	0.6	0.33	56	
10	8.5	95.9	20.6	9.11	1993				
11	8.73	99	20.6	9.1	1992				
12	9.09	104	20.6	9.26	1990				
13	10.3	118	21.5	9.4	1991				
14	11	130	23	9.61	1983	0.6	0.79	44	Sunny with mild wind
15	11.12	132.8	23.4	9.65	1983				
16	10.9	131.8	24	9.59	1993				
17	11.06	132.8	23.6	9.57	1988				
18	11.05	133.3	23.9	9.76	2001				
19	10.84	128	22.8	9.75	2002				Cloudy
20	10.19	119.4	22.4	9.63	1997				

Outlet		**30/12/10**							
8	10.3	105.3	16.3	8.61	2074				Cloudy, mild wind
9	10.65	111.6	17.3	8.82	2074	<dl	0.36	26	
10	10.66	113.5	18.4	8.91	2078				
11	11.37	126.4	20.4	9.22	2081				
12	12.21	137.7	21.9	9.25	2082				Cloudy, no wind
13	13	149.5	23.6	9.35	2082				Cloudy, mild wind
14	13.2	153.6	24.3	9.45	2107	0.3	0.25	30	
15	13.2	150.4	22.6	9.39	2117				
16	13.13	150.3	22.6	9.27	2118				Cloudy, no wind
17	14.3	162	21.8	9.53	2099				
18	13.72	154.3	20.8	9.48	2108				
19	12.93	144.3	20.6	9.24	2123				
20	12.73	141.3	19.9	9.03	2128				
Time	**DO (mg/L)**	**DO (% Sat)**	**Temp (oC)**	**pH**	**Cond (us/cm)**	**NO_3-N (mg/L)**	**PO_4 (mg/L)**	**Turbidity (FAU)**	
Catons	**Bay**	**4/01/11**							
8	7.14	79.4	20.2	9.42	1795				
9	8.98	99.2	20.3	9.52	1796	0.2	0.62	12	
10	10.48	115.8	20.4	9.61	1796				
11	10.94	121.8	20.7	9.61	1764				
12	11.33	129.1	21.8	9.71	1778				
13	12.72	146.6	22.6	9.88	1769				
14	13.73	159.5	23	9.78	1768	0.8	0.78	14	
15	13.74	160.8	23.2	9.83	1787				
16	13.14	152.2	23.2	9.98	1782				
17	12.61	145.1	22.1	9.92	1776				
18	12.73	144.8	21.3	9.85	1785				
19	11.65	130.5	20.7	9.81	1774				
20	11.26	120.8	20.3	9.75	1775				

ECan	**Site**	**18/01/11**							
8	6.05	69.3	21	7.62	2036				
9	6.82	78.4	21.3	7.71	2033	0.3	0.65	19	
10	7.53	88.2	22	7.91	2033				
11	6.31	73.2	21.5	8.16	2027				
12	8.32	97.6	21.4	8.38	2027				
13	8.54	98.6	21.3	8.52	2026				
14	8.64	99	20.9	8.52	2027	0.1	0.48	29	
15	8.53	98.1	20.9	8.53	2027				
16	8.29	95.2	20.8	8.44	2011				
17	8.64	99.4	20.8	8.5	2004				
18	8.29	95.4	21	8.48	2002				
19	8.24	94.8	20.8	8.35	2002				
20	8.42	96.9	20.7	8.35	1992				
Time	**DO (mg/L)**	**DO (% Sat)**	**Temp (oC)**	**pH**	**Cond (uS/cm)**	**NO_3-N (mg/L)**	**PO_4 (mg/L)**	**Turbidity (FAU)**	
Catons	**Bay**	**21/12/10**							
8	8.58	90.1	17.5	8.54	1891	0.4	2.75	32	Sunny
9	9.36	98	17.6	8.55	1866	0.1	2.4	21	
10	9.89	103.5	17.6	8.84	1888	<dl	0.49	17	
11	10.55	110	17.6	8.89	1866	0.3	0.6	13	
12	10.68	111	17.5	9.06	1863	0.3	2.75	21	
13	11.75	121.9	17.9	9.21	1862	0.1	1.99	24	
14	12.48	134.8	19.3	9.24	1833	0.2	0.92	27	
15	12.21	132.9	19.5	9.04	1820	0	0.68	41	
16	12.77	139.8	20	9.25	1839	0.7	1.77	18	
17	11.44	125.2	20	9.26	1860	0.2	1.1	18	
18	11.9	129.2	19.6	9.03	1832	0.2	0.46	21	
19	12.08	128.9	18.7	9.26	1865	<dl	1.01	31	

20	11.65	122.8	18.1	9.14	1862	<dl	0.44	25	
21	11.22	118.3	18	9.08	1852	0.1	0.5	23	
22	9.87	103.2	17.8	8.65	1844	0.4	0.35	19	
23	8.84	91.5	17.4	8.3	1838	0.5	2.75	21	
0	7.64	97.5	17	7.8	1818	0.2	1.17	10	
1	6.73	69.1	16.5	7.62	1808	0.2	2.75	14	
2	6.74	69.2	16.6	7.7	1797	0.2	0.44	10	
3	5.67	57.8	16.2	7.5	1756	0.1	0.53	8	
4	4.89	47.8	15.8	7.21	1760	0.2	0.76	9	
5	4.93	49.5	15.5	7.41	1737	0.1	0.77	9	
7:00	4.98	50.1	15.5	7.46	1740	0.1	0.83	4	
7:40	5.27	52.5	15.5	7.43	1750	0.1	1.3	6	
8:10	5.43	54.3	15.6	7.23	1590	0.1	1.65	3	
ECan	**Site**	**24/01/11**							
8	7.8	81.6	16.9	7.76	2041				
9	7.31	77.6	17	7.73	2042	0.29	0.29	1	Cloudy,still
10	8.28	87.3	17.3	8.31	2041				
11	8.71	94.1	18	8.33	2060				Sunny,slight wind
12	9.88	108.5	19.3	8.7	2052				
13	10.8	119.5	19.9	8.86	2059				
14	11.17	126.5	20.9	9.04	2044	0.3	0.18	27	
15	11.34	129.5	21.5	9.07	2056				
16	11.67	134.3	21.8	9.13	2064				Sunny, mild wind
17	11.87	138.3	22.5	9.2	2066				
18	12.03	140.9	22.8	9.28	2054				
19	12.11	141.3	22.3	9.33	2068	<dl	0.33	9	
20	11.77	145.2	22	9.25	2066				

Time	DO (mg/L)	DO (% Sat)	Temp (oC)	pH	Cond (uS/cm)	NO_3-N (mg/L)	PO_4 (mg/L)	Turbidity (FAU)	
Catons	**Bay**	**5/02/11**							
8	7.67	824	18.3	8.3	1780				
9	8.31	89.8	18.7	8.41	1782	0.1	0.44	29	Overcast, still
10	9.69	106.8	19.6	8.57	1781				
11	10.7	119.8	20.5	9.08	1791				Wind change
12	10.57	120	21.2	9.04	1800				Mild
13	11.37	130.8	21.1	8.75	1812				
14	10.69	126.7	23.6	9.22	1815	0	0.33	69	Mild
15	10.85	127.9	23.5	9.09	1825				
16	11.18	131.4	23	9.21	1830				
17	11.16	132.5	23.3	9.32	1830				
18	11.76	139.7	23.5	9.33	1840				
19	11.9	140.6	23.4	9.41	1839				
20	11.72	137.4	22.8	9.36	1845				
Time	DO (mg/L)	DO (% Sat)	Temp (oC)	pH	Cond (uS/cm)	NO_3-N (mg/L)	PO_4 (mg/L)	Turbidity (FAU)	
Catons	**Bay**	**15/2/11**							***Slightly sheltered location***
8	8.4	87.6	17.5	7.91	1993	0.5	0.62	13	Still
9	9.6	101.4	18.2	8.41	2000	0.4	0.27	14	
10	10.33	109.3	18.6	8.62	2003	0.5	0.4	24	
11	11.43	124.9	20.1	9.01	2005	0.6	0.26	25	
12	11.87	131.1	20.8	9.05	1996	<dl	0.29	37	
13	12.78	146.8	22.4	9.23	1997	<dl	0.21	37	
14	13.36	156.5	23.6	9.33	2007	<dl	0.21	29	
15	13.23	155	24.1	9.44	2013	1.0	0.2	29	
16	13.16	155.9	24.2	9.43	2014	0.6	0.32	37	
17	12.87	150	23.4	9.54	2019	0.1	1.37	24	
18	12.76	148.7	23.2	9.51	2027	0.3	1.23	15	

19	12.54	145.6	23.2	9.39	2027	0.2	0.94	17	
20	10.77	122.1	21.8	9.25	2039	0.8	0.71	24	
21	10.29	113.1	20.7	9.07	2042	<dl	0.45	18	
22	9.02	98.9	20	8.99	2050	<dl	2.75	19	
23	7.82	85.2	19	8.86	2062	0.3	0.24	17	
0	8.22	89	19.6	8.67	2059	<dl	2.75	11	
1	7.21	76.3	18.8	8.41	2071	0.5	0.41	9	
2	7.24	76.3	18.2	8.22	2065	0.1	0.23	12	
3	7.33	75.3	18.1	8.01	2056	<dl	0.28	17	
4	7.02	72.2	17	8.13	2079	0.1	0.33	7	
5	7.34	75.4	16.8	8.16	2080	0.2	0.37	27	
6	7.65	77.4	16.2	8.21	2083	1.3	0.23	14	
7	7.48	76.2	16.6	8.2	2082	0.2	0.22	14	
8	7.7	78.1	16.7	8.15	2085	0.4	0.39	23	

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