Physical environment, nutrient budget, and ecology of Lake Moana-nui, Tokoroa

CBER Contract Report 42

Client report prepared for
the South Waikato District Council and Environment Waikato

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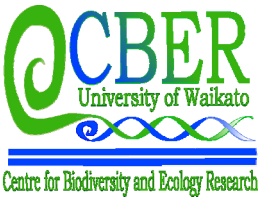

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1.0 Introduction

1.1 Shallow lakes and eutrophication

Shallow lakes are of high ecological, social, and economic importance because of their biodiversity, fisheries, cultural values and use for recreational activities. The value of such lakes has typically been compromised by eutrophication (Perrow *et al*. 1999), the process of increasing plant and/or algae growth in a water body due to an increase in nutrient loading. Eutrophication is particularly relevant to the many shallow lakes of the North Island where the predominant catchment land use activity is intensive pastoral agriculture, with its associated high diffuse nutrient load (nitrogen and phosphorus) to waterways.

Shallow lakes may exist in either of two alternative stable states: clear water or turbid (Scheffer 1999). Enhanced eutrophication often results in the clear water state, dominated by aquatic plants (macrophytes) and supporting diverse communities of fish, birds and invertebrates, being replaced by an algal dominated system, with turbid water and animal communities of low diversity (Perrow *et al*. 1999). The preferred condition is usually the clear-water state where the lake is dominated by macrophytes, although this may depend on the requirements of a particular lake.

1.2 Lake Moana-nui

Lake Moana-nui is a small shallow lake located on the southwestern outskirts of Tokoroa, in the Waikato region of the North Island, New Zealand (38^{o} 14.029'S, 175 51.161'E; Fig. 1.1). The lake is an artificial impoundment of the Matarawa Stream contained behind a dam of compacted ignimbrite fill and was first filled in 1975 for the purpose of servicing the recreational requirements of Tokoroa. The total area of the lake is approximately 8 ha with a maximum depth of approximately 3 m and an average depth of approximately 1.5 m. Its altitude is approximately 300 m a.s.l., maximum length is 700 m and maximum width is 120 m. On its western side a small arm, approximately 200 m long, runs towards the southeast and is spring fed. The lake supports a large community of birds, including the endemic New Zealand dabchick (*Poliocephalus rufopectus*), is stocked annually with 200 rainbow trout (*Oncorhynchus*

mykiss) fingerlings, and there are resident brown trout (*Salmo trutta*). The upper catchment of the Matarawa Stream (ca. 5000 ha) drains an extensive area of pastoral farmland to the south and southeast and also receives storm water from the streets along its eastern margin (South Waikato District Council 1998). The lake is dominated by extensive beds of exotic *Egeria densa* and native *Potamogeton ochreatus*, and maintains particularly clear water (median Secchi depth of 2.8 m). Lake Moana-nui is currently managed as a recreational reserve.

A draft plan for the lake was developed by OPUS International Consultants Limited in conjunction with the South Waikato District Council in 1998. The draft plan and community feedback identified the need for a general resource assessment of the lake with more detailed information required on:

- water and nutrient budgets for the lake,
- bathymetry,
- physico-chemical conditions,
- sediment loading rates/lake infilling rate, and the
- terrestrial and aquatic flora and fauna.

As part of a University of Waikato MSc (Tech) project, an investigation into the above issues was commissioned in conjunction with the South Waikato District Council and Environment Waikato in November 2000.

1.3 Scope of this report

This report is based on fortnightly monitoring data collected over a 14 month period from November 2000 to January 2002 and a survey of the lake bathymetry and vegetation distribution. The project also included a detailed investigation into the associations between macroinvertebrates and the native and exotic plants in the lake, and experiments evaluating the effects of the large populations of the water flea *Simocephalus vetulus* that the lake maintains on algal concentrations and therefore water clarity. The aim of this report is to present and discuss the results of the monitoring, surveys, and experiments in order to make recommendations for the future management and health of Lake Moana-nui.

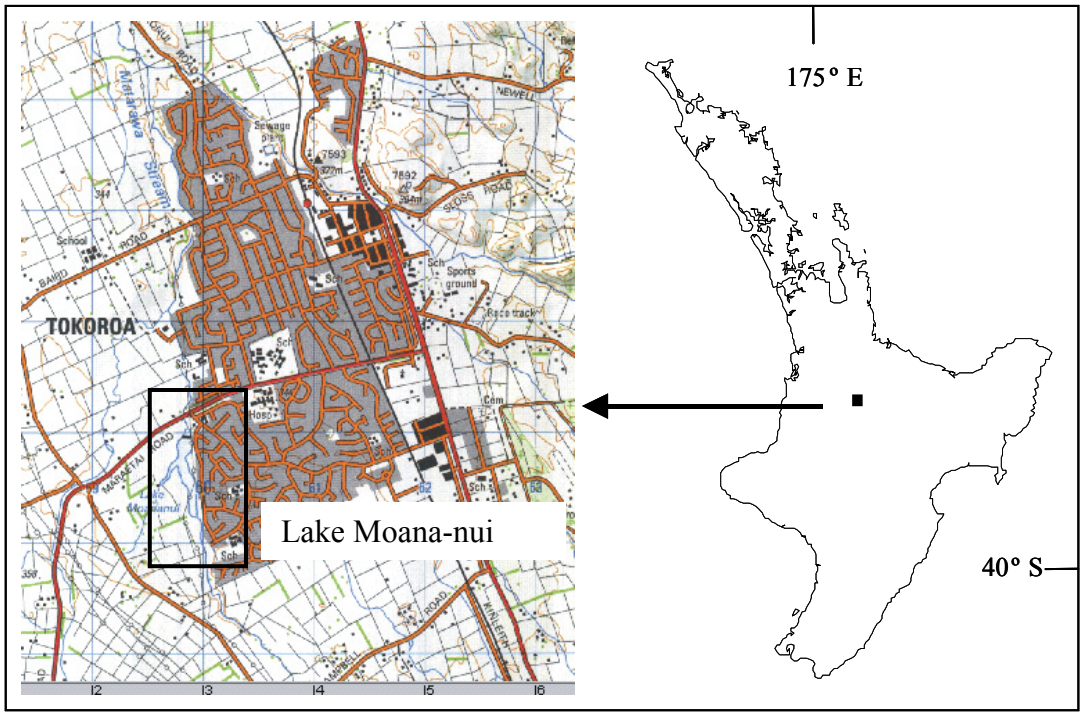

Figure 1.1. Lake Moana-nui location map.

2.0 Methods

2.1 Lake bathymetry

The bathymetry of Lake Moana-nui was investigated on 16th January 2002. GPS equipment and a weighted tape measure were used to measure the lake depth at 125 points within and around the lake perimeter.

2.2 Physical and chemical conditions

Physical and chemical data was collected from the water surface at three sites within the lake (Fig. 2.1) fortnightly from November 2000 to January 2002. Site 1 was located at the northern end of the lake adjacent to the western side if the spillway, Site 2 was located on the western edge of the lake approximately 20 m north of the lake arm and Site 3 was located on the eastern edge approximately 50 m south of the playground. Dissolved oxygen was measured using either a YSI Model 57 or 55 meter. Temperature and conductivity were measured using a YSI Model 30 meter and pH was measured using a Eutech Instruments Pte Ltd Model pH Scan WP 1 meter. Secchi depth was measured from a jetty at the northern end of the lake (Fig. 2.1) on each sampling occasion.

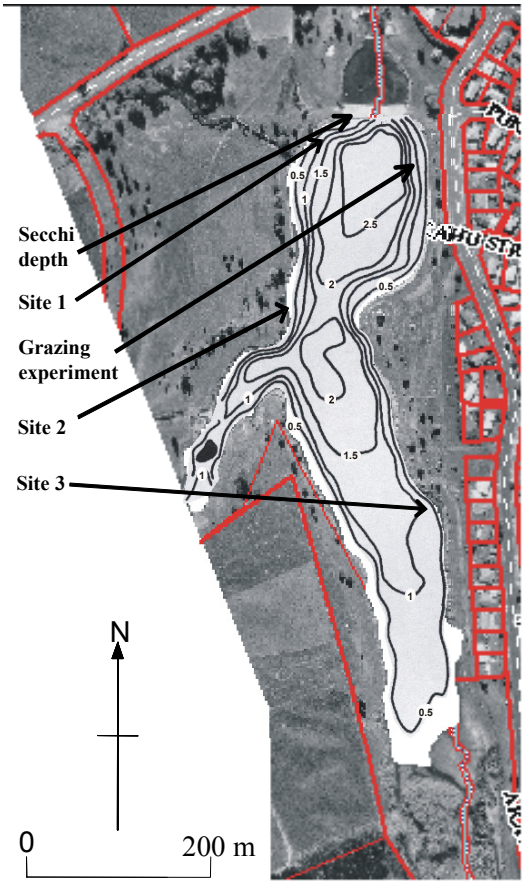

Fig. 2.1. Location of the sampling sites, grazing experiment site and the lake bathymetry.

Water samples for nutrient and sediment analysis were collected from the surface layer of the lake by submerging 250 mL and 1 L acid washed plastic bottles respectively. Water samples were analysed for the dissolved inorganic nutrients ammonia nitrogen, NO_x (total oxidised nitrogen), and dissolved reactive phosphorus (DRP) concentration using a Lachat QuickChem FIA 8000 series auto-analyser. Suspended solids (SS) and inorganic suspended solids (ISS) were determined using the method described in section 208 D of the Standard Methods for the Examination of Water and Wastewater (APHA 1976).

2.3 Water, nutrient, and sediment budgets

The flow of all four of the inlets and the outlet of Lake Moana-nui were gauged as part of routine fortnightly monitoring. The width of each stream or drain was measured and

this was divided into 5 or 10 sections depending on stream width. At each point across the stream the depth was recorded and the water velocity measured at 0.6 of the depth where mean water velocity occurs. The width and depth and water flow measurements allow the cross sectional area of the stream to estimated and the calculation of the volume of water flowing in the stream at the time of gauging. Because the main entrance to the arm inlet enters the arm through a culvert the water flow was measured at 12 points within the mouth of the culvert on the lake side and averaged. The cross sectional area of the culvert was determined and this allowed the volume of water flowing through the culvert at the time of measurement to be estimated. In addition to the stream gauging, an automatic water level recorder (Fig. 2.2) was installed in the Matarawa Stream near the entrance of the stream to the lake, courtesy of Environment Waikato. This device recorded the depth of the Matarawa Stream at half hour intervals from May 2001 to January 2002. The constant level data and the fortnightly gauging enabled the production of a rating curve that modelled the stream flow at all stream depths and the quantification of the total volume of water flowing into the lake during the nine month depth recording period. For the Matarawa Stream inlet before the installation of the water level recorder, the other inlets, and the outlet, the volume of water entering or leaving the lake in cubic meters per second was calculated for each gauging occasion and averaged. These volumes were then multiplied by the number of seconds in a year to provide a crude estimate of the total water volume flowing into the lake through each inlet and out through the outlet during a year of monitoring.

Nutrient and sediment samples were taken from the surface waters of the inlets and outlets as for the lake monitoring. Mean plant-available nutrient and sediment concentrations in mg/L were multiplied by the estimated annual input and output volumes to produce an estimated nutrient and sediment budget.

Fig. 2.2. Automatic level recorder on the Matarawa Stream inlet.

2.4 Aquatic plants

Plant distribution was recorded at the same time as the lake bathymetry. Macrophyte samples were taken from *E. densa*, attached *P. ochreatus*, *E. canadensis* and detached floating *P. ochreatus* on 20 November 2000, 2 February 2001, 7 May 2001, 3 October 2001 and 14 December 2001. The first sampling occasion was prior to a lowering of lake level for earthworks in December 2000, which resulted in the collapse of the macrophyte beds within the lake. At least three replicate macrophyte samples were taken of each species at three sites around the lakes littoral zone (Fig. 2.1) where the species occurred. All samples were collected using a 250 μm mesh bag, similar to that used by Humphries (1996).

2.5 Macroinvertebrates

Macroinvertebrates were separated from macrophytes within five days of collection and the resulting macroinvertebrate sample preserved in 70% iso-propyl alcohol (IPA). All of the collected macrophytes were then placed in pre-weighed aluminium trays and dried at 60 °C until a constant dry weight was achieved. Macroinvertebrates were identified to the lowest practical taxonomic level using Winterbourn, Gregson &

Dolphin (2000) and Winterbourn (1973), and quantified by abundance and biomass (Parsons & Matthews, 1995). Macroinvertebrate abundance and dry weight biomass (mg) per macrophyte dry weight biomass (g) was calculated for all species in all samples. The Shannon-Wiener index of species diversity was calculated for all macroinvertebrate samples using PRIMER (Clarke & Gorley 2001).

One-way ANOVA followed by Tukey post-hoc tests were used to identify differences in diversity, abundance and biomass between sampling dates and macrophyte species. For instances when the distribution of data was markedly non-normal a non-parametric Kruskal-Wallis test followed by Dunn's multiple comparison tests were used. Statistical packages used were SPSS (2000) and Instat (2000).

2.6 Zooplankton

Macrophyte associated zooplankton were sampled at sites 1, 2 and 3 on the same sampling occasions as the macroinvertebrates (Fig. 2.1). At least three replicate zooplankton samples were taken from within each macrophyte type present at each site. Samples were taken by lowering a 1 m long, 76 mm internal diameter P.V.C. tube into the water column and placing a bung in the top end. The tube was then raised to near the surface and a bung placed in the bottom end. Samples were emptied into a graduated jug and the volume recorded. Samples were then poured through a 200 μm mesh net and the zooplankton retained were washed into a plastic container and preserved in 10 % formalin.

For zooplankton identification and enumeration, the entire sample was filtered through a 40 μm mesh, washed into a beaker and made up to 20-30 mL. A series of 5 ml aliquots from the beaker were enumerated until the entire sample, or a total of 300 zooplankton had been counted. Aliquots were counted in a 10 mL perspex counting tray with a gridded base, and identified at 25 times magnification on the moving stage of a dissecting microscope. Crustacean zooplankton were identified using Chapman & Lewis (1976) and expressed as zooplankton numbers per litre. Data and statistical analyses were performed as for macroinvertebrate abundance.

2.7 *Simocephalus vetulus* and water clarity

Two in-situ grazing experiments were carried out, between the 5th and 7th September and the 18th and 20th December 2001 respectively at the northern end of Lake Moana-nui (Fig. 2.1). The protocol used was that of Carrick *et al*. (1991) in which *S. vetulus* clearance rates were evaluated from algal loss rates across a gradient of *S. vetulus* biomass in 3 L enclosures. *S. vetulus* were collected, concentrated and then added to 50, three litre enclosures (3 L apple juice bottles) containing filtered lake water in different densities. The aim was to generate in the enclosures, densities of *S. vetulus* that were 0.5, 1, 2 and 3 times the ambient *S. vetulus* concentration found in the lake prior to the experiment. The enclosures were then randomly secured to a rope strung between two plastic supports and placed in the lake 8 m from shore where the water depth was 1.25 m and macrophyte coverage 100% (Fig. 2.3). Half the bottles were incubated for 24 hours and the other half for 44 hours. Following incubation *S. vetulus* were filtered out and samples were taken to determine the concentrations of chlorophyll *a* and algal densities.

S. vetulus abundance and biomass was determined for each enclosure. To assess the chlorophyll *a* and species-specific clearance rates by *S. vetulus*, *S. vetulus* biomass was regressed against algal or chlorophyll *a* growth rate (rate of increase) (Carrick *et al*. 1991). The slope of the linear regression relationship between GR and *S. vetulus* dry weight biomass gives an estimate of the weight specific *S. vetulus* feeding rate on chlorophyll *a* and total phytoplankton. The relationship between abundance (number L^{-1}) and biomass (mg L^{-1}) of *S. vetulus* in the experimental enclosures, and the measured feeding rates were used to estimate the potential effect that *S. vetulus* could have on chlorophyll *a* and total algae at different times of the year.

3.0 Results

3.1 Lake bathymetry

The bathymetric map was stretched over an aerial photograph of the lake in Fig. 2.1. The total lake area is approximately 5 ha and the average depth of the lake is 1-1.5 m. The percentage of total lake area and the approximate area of the lake within each depth interval is presented in Table 3.1.

Table 3.1. Results of the bathymetric investigation of 16/1/02.

Depth interval (m)	% of lake area	Area (m^2)	Volume (m^3)
0-0.5	16.49	8,245	2,061
0.5-1	28.33	14,165	10,624
1-1.5	19.84	9,920	12,400
1.5-2	16.99	8,495	14,866
2-2.5	10.97	5,485	12,341
2.5-3	7.38	3,690	10,148
Total	100	50,000	62,440

Assuming that the middle of each depth interval is the mean depth for that portion of the lake bottom, i.e. 0.25 m for the 0-0.5 m interval, the estimated volume of the lake is 62,400 m^3.

3.2 Physical and chemical conditions

Table 3.2. summarises the physical and chemical data collected between November 2000 and November 2001. Raw physical and chemical data are presented in Appendices 1 and 2.

Table 3.2. Median, minimum and maximum values for physical and chemical data at each monitoring site

Site	Parameter	TSS (mg/L)	ISS (mg/L)	pH	Cond (µS /cm)	Temp °C	DO (mg/L)	DO (% sat)	NH_4 (mg/L)	DRP (mg/L)	NO_x (mg/L)
1	Median	2.1	0.44	8.4	149.2	16.2	13.5	128	0.02	0.012	1.248
	Max	119.0	86.8	10.1	180.9	22.2	15.5	178	0.35	0.039	5.452
	Min	1.1	0	6.2	124.4	8.2	9.0	80	0.00	0.003	0.159
2	Median	2.4	0.6	8.1	149.1	15.7	11.8	123	0.01	0.018	1.452
	Max	20.2	14.9	9.8	181.9	24.1	16.4	183	0.28	0.087	3.693
	Min	0.3	0	6.9	126.7	8.9	9.8	75	0.00	0.000	0.139
3	Median	2.3	0.6	8.8	115.5	16.8	12.5	117	0.03	0.023	0.772
	Max	11.5	4.7	10.3	168.3	25.1	16.7	192	0.09	0.057	2.051
	Min	0.4	0	7.6	95.2	4.2	9.6	98	0.00	0.000	0.112

3.2.1 Total suspended solids and inorganic suspended solids

Total suspended solids (TSS) and inorganic suspended solids (ISS) (Fig. 3.1a and b) were generally low at all sites throughout the year. Suspended solids ranged from 0.4 to 118 mg L^{-1} and inorganic suspended solids ranged from 0 to 86.8 mg L^{-1}. Peaks in both occurred on 26 April, 29 May and 19 July, and were likely associated with high rainfall and wind events prior to sampling.

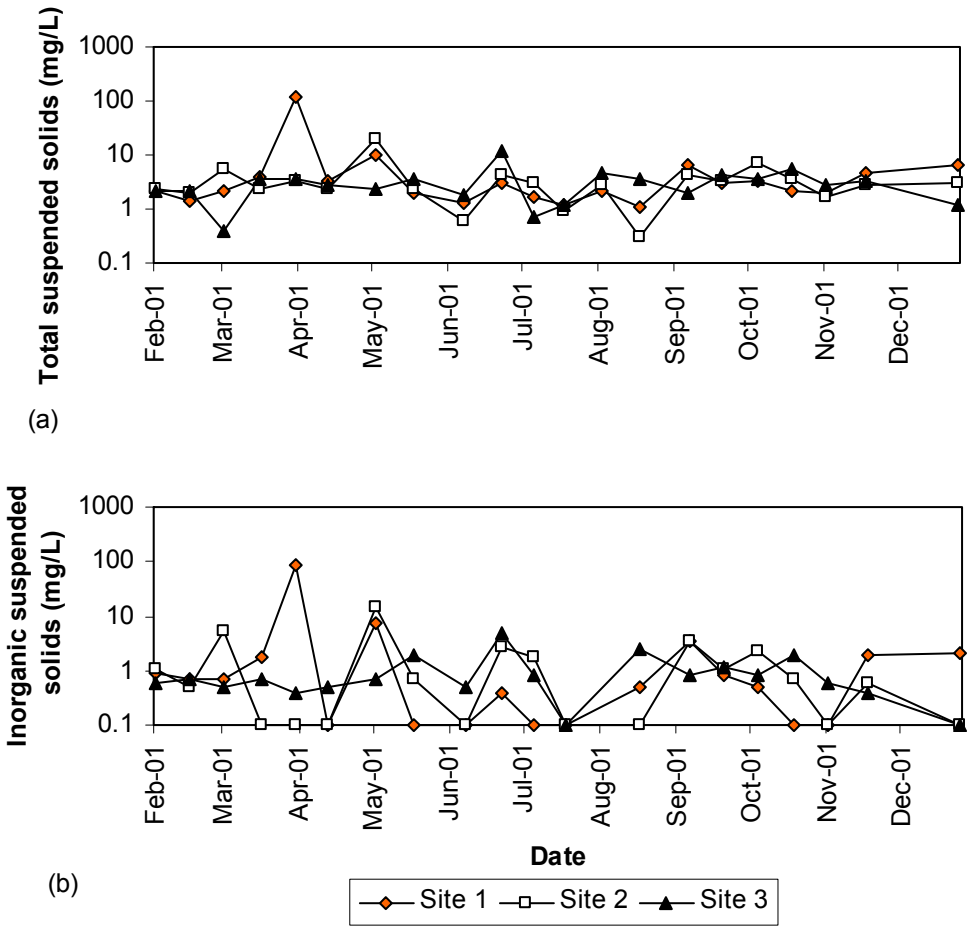

Figure 3.1 (a and b). Temporal changes in total suspended solids and inorganic suspended solids. 0.1 has been added to inorganic suspended solids to plot zero values on a log scale.

3.2.2 Secchi depth

Secchi depths (Fig. 3.2) ranged from 0.85 to 3.8 m (lake bottom) and reflect the very low ambient levels of suspended solids (organic and inorganic). The lowest water

clarity was associated with the collapse of macrophyte beds in December 2000, as a result of the lowering of lake levels.

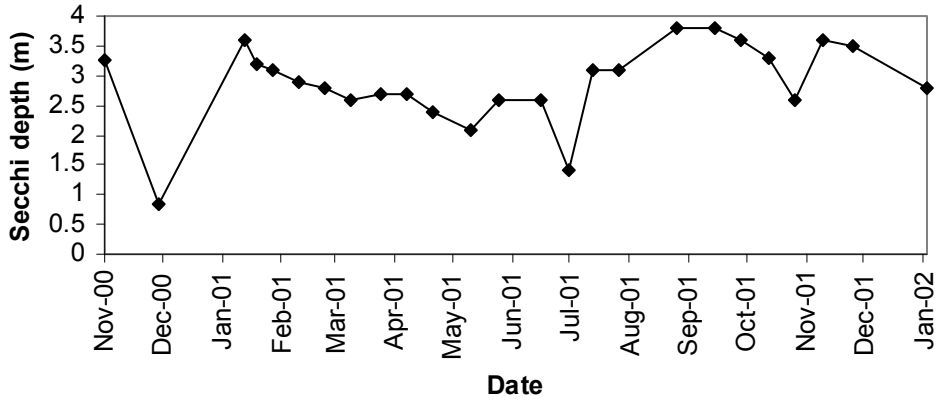

Figure 3.2. Temporal changes in Secchi depth.

3.2.3 pH

pH at the three sites (Fig. 3.3) fluctuated during the year ranging from 6.2 to 10.3 but was generally alkaline. pH at site 2 was generally lower than at the other sites.

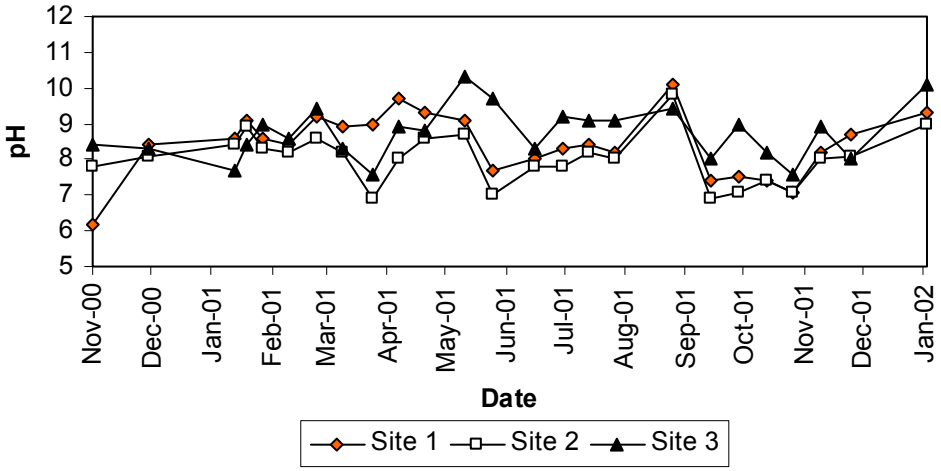

Figure 3.3. Temporal changes in pH.

3.2.4 Conductivity

Conductivity corrected to 25°C ranged from 95.2 to 180.9 µs cm^{-1} (Fig. 3.4), with site 3 showing lower values all year round.

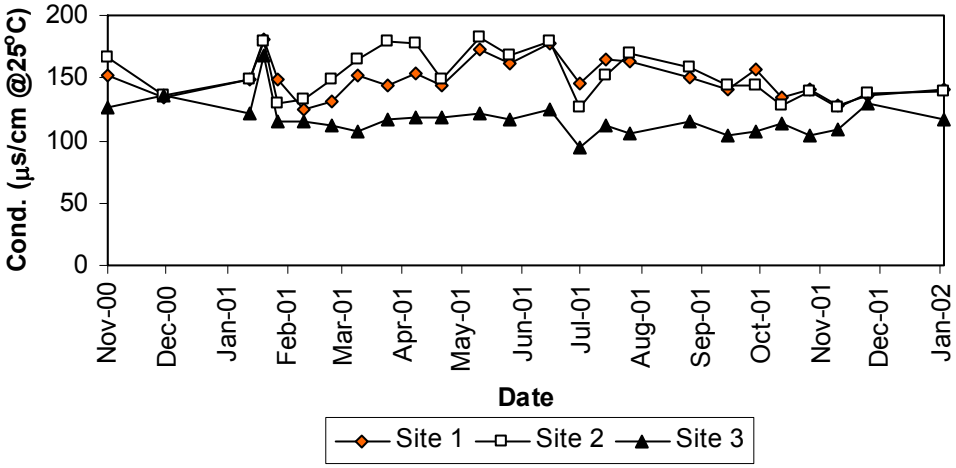

Figure 3.4. Temporal changes in conductivity.

3.2.5 Temperature

Temperature ranged between 4.2 and 25.1 °C (Fig. 3.5), and was highest during the summer months (December to February) and lowest during the winter months (May to July).

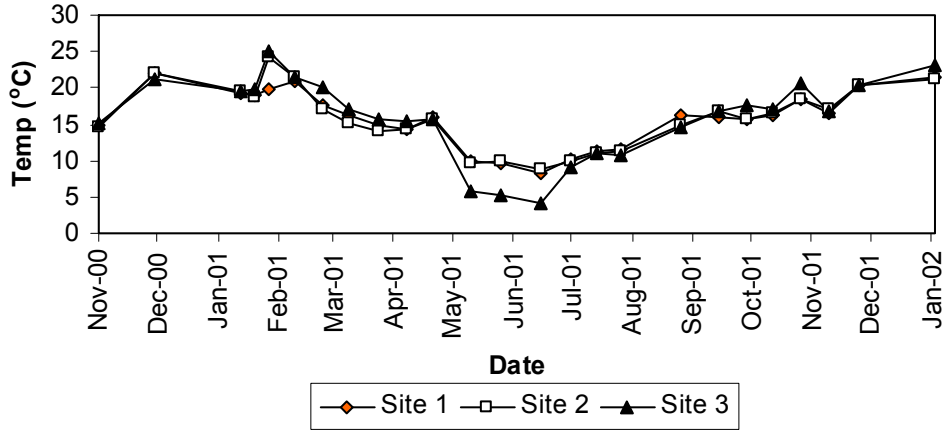

Figure 3.5. Temporal changes in temperature.

3.2.6 Dissolved oxygen

Dissolved oxygen was generally high throughout the year ranging from 7.5 to 16.9 mg L^{-1} (Fig. 3.6a). Dissolved oxygen was nearly always supersaturated (Fig. 3.6b) and ranged from 75 to 192 %.

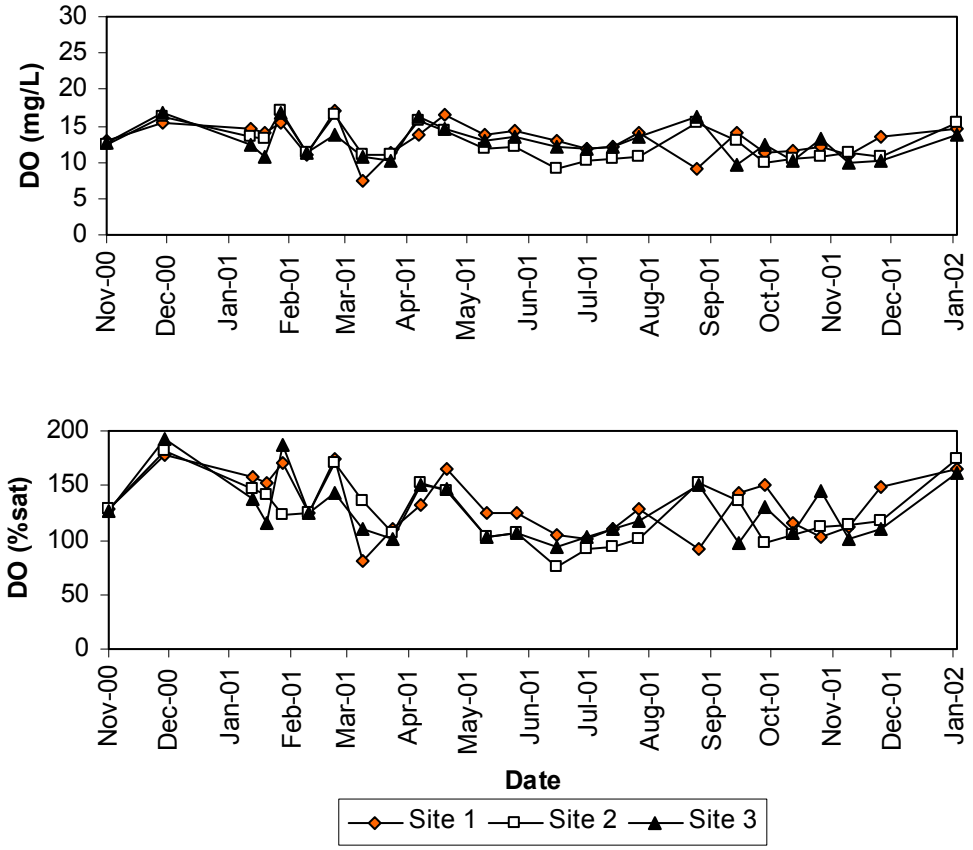

Figure 3.6 (a & b). Temporal change in dissolved oxygen concentration and % saturation.

3.2.7 Plant nutrients

NO_x (Fig. 3.7a) fluctuated throughout the year and ranged from 0.1 to 5.5 mg L^{-1}. Ammonia levels were generally low at all sites throughout the year (Fig. 3.7b), ranging from 0 to 0.35 mg L^{-1}. Dissolved reactive phosphate (DRP) (Fig. 3.7c) was generally low with concentrations ranging from 0 to 0.1 mg L^{-1}.

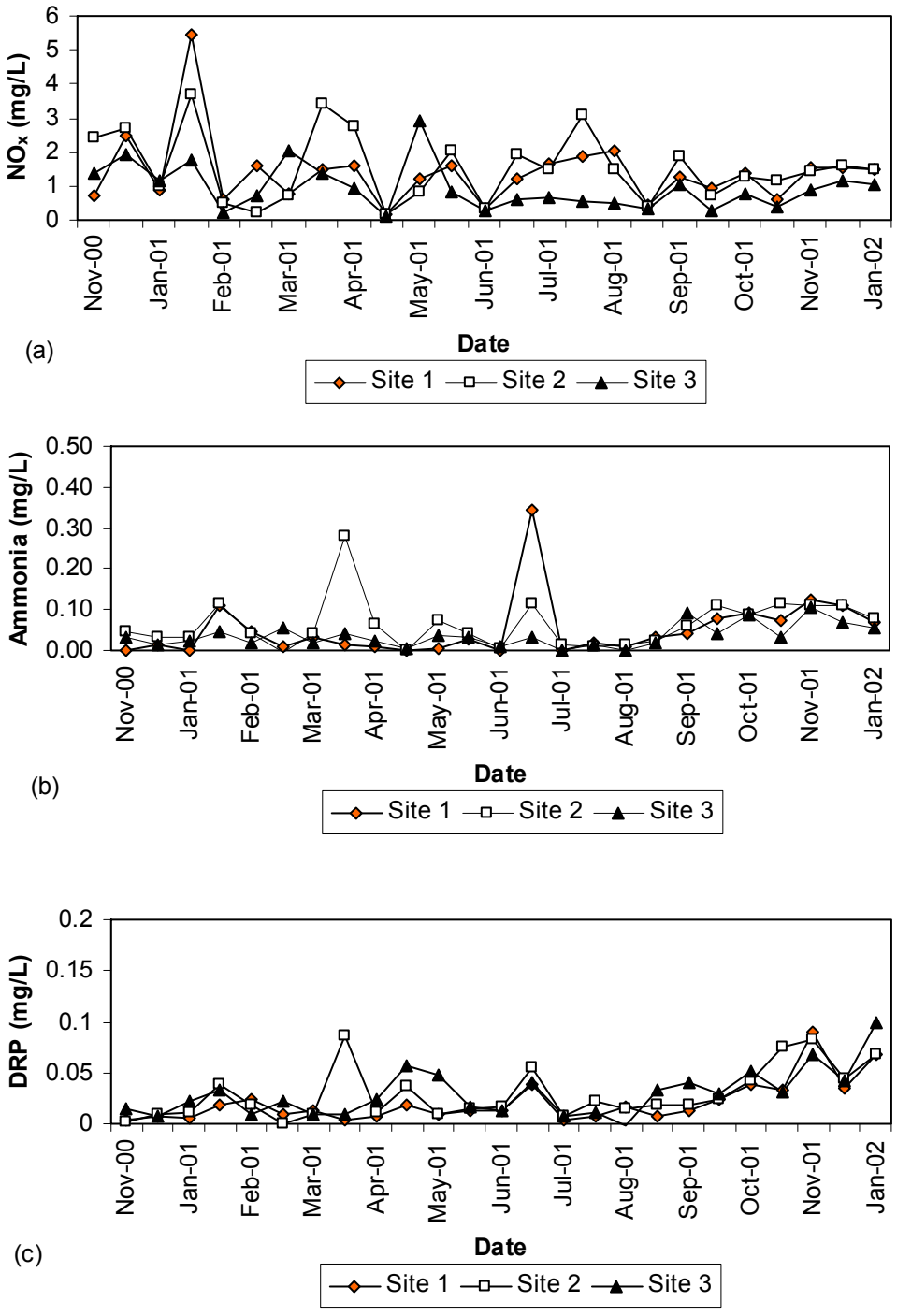

Figure 3.7 (a-c). Temporal changes in NO_x, ammonia and dissolved reactive phosphorus (DRP) in Lake Moana-nui.

3.3 Water, nutrient, and sediment budgets

3.3.1 Water budget

Table 3.3 summarises the estimated total volume of water flowing into, and out of Lake Moana-nui for the period from 14 March 2001 to 13 March 2002. The relative contribution of each inflow is presented graphically in Fig. 3.9. Raw data used in the calculation of the water budget are presented in Appendix 2. The most important inflows to Lake Moana-nui in terms of water volume are the Matarawa Stream and the arm inlet. The lake flushing rate is the ratio of the outflow rate to the lake volume (Vant 1987). Using the lake volume calculated from the bathymetric study, the estimated flushing rate was 138.7 times the lake volume per year. The inverse of flushing rate is residency time. The estimated residency time for Lake Moana-nui was therefore 2.63 days.

Table 3.3. Estimated annual discharge for the inlets and the outlet of Lake Moana-nui

Inlet or outlet	Total discharge (m^3/year)
Drain by Monitoring Site 1	43,800
Drain entering side arm	152,162
Side arm inlet	4,375,336
Matarawa Stream inlet	5,285,404
Total Q into lake Moana-nui	9,856,704
Matarawa Stream Outlet	8,665,428
Losses to evaporation, groundwater etc.	1,191,275

3.3.2 Nutrient budget

The nutrient concentrations in the inlets and outlet of Lake Moana-nui are summarised in Table 3.4. All of the collected nutrient data is presented in Appendix 2. Mean DRP concentrations in all of the inlets are above the default ANZECC (2000) guideline of 0.01 mg/L for the protection of aquatic ecosystems. Mean NO_x concentration in all inlets other than the Arm inlet are above the default ANZECC (2000) guideline of 0.444 mg/L. Mean NH_4 concentration in the drain by Site 1 and the Matarawa Stream are above the default ANZECC (2000) guideline of 0.021 mg/L.

Table 3.4. Summary of the nutrient concentrations of the inlets and outlet of Lake Moana-nui

Nutrient		Drain by Site 1	Drain entering lake arm	Arm inlet	Matarawa Stream inlet	Matarawa Stream outlet
DRP (mg/L)	Mean	0.027	0.022	0.021	0.052	0.028
	Min	0.000	0.004	0.003	0.012	0.001
	Max	0.197	0.099	0.060	0.165	0.084
NO_x (mg/L)	Mean	1.497	2.237	0.243	1.329	1.395
	Min	0.163	0.216	0.073	0.102	0.071
	Max	2.460	3.523	3.861	3.894	2.773
NH_4 (mg/L)	Mean	0.063	0.010	0.021	0.076	0.044
	Min	0.000	0.000	0.000	0.000	0.000
	Max	0.574	0.057	0.077	0.436	0.125

Table 3.5 presents the estimated total nutrient load to the lake. The Matarawa Stream contributes the highest amount of DRP and NO_x, while the Arm inlet contributes the highest amount of ammonia. Table 3.5 shows a net load of DRP, NO_x and ammonia into the lake.

Table 3.5. Estimated annual nutrient loads to Lake Moana-nui

Inlet/outlet	Nutrient load (kg/year)		
	DRP	NH_4	NO_x
Drain by Site 1	1.173	2.750	65.548
Drain entering lake arm	3.290	1.576	340.454
Arm inlet	90.884	90.365	9812.964
Matarawa Stream inlet	275.194	402.463	7024.536
Total load into the lake	370.541	497.155	17243.502
Matarawa Stream outlet	245.368	381.125	12090.446
Net nutrient load	**125.174**	**116.030**	**5153.056**

3.3.3 Sediment budget

The concentrations of total suspended solids (TSS) and inorganic suspended solids (ISS, the inorganic fraction of TSS) in the inlets and the outlet of Lake Moana-nui are summarised in Table 3.6. All of the collected TSS and ISS data is presented in Appendix 2. The Matarawa Stream inlet had the highest mean TSS and ISS concentrations and the outlet had the lowest concentrations over the monitoring period.

Table 3.6. Summary of the suspended solids concentrations of the inlets and outlet of Lake Moana-nui

Parameter		Drain by Site 1	Drain entering lake arm	Arm inlet	Matarawa Stream inlet	Matarawa Stream outlet
Total suspended solids (mg/L)	Mean	5.43	5.65	4.46	8.99	2.76
	Min	1.10	0.00	0.00	3.20	0.50
	Max	16.80	57.50	13.80	32.00	9.10
Inorganic suspended solids (mg/L)	Mean	2.73	3.75	2.03	5.08	0.90
	Min	0.00	0.00	0.00	0.80	0.00
	Max	11.00	46.50	9.00	20.25	6.20

Table 3.7 presents the estimated total TSS and ISS loads to the lake. The Matarawa Stream inlet is by far the largest source of TSS and ISS for the lake with the Arm inlet being a source also. Taking into account the estimated amount of TSS and ISS leaving the lake, the net load of TSS and ISS accumulating in the lake (infilling rate) is 44.2 and 28.5 tonnes/year respectively. SS also includes organic matter which may decompose in the lake therefore ISS load is likely to be a better estimate of the lake infilling rate.

Table 3.7. Estimated annual total suspended sediment loads to Lake Moana-nui

Inlet/outlet	Total suspended solids (tonnes/year)	Inorganic suspended solids (tonnes/year)
Drain by Site 1	0.24	0.12
Drain entering lake arm	0.86	0.57
Arm inlet	19.50	8.89
Matarawa Stream inlet	47.52	26.86
Total load into the lake	68.11	36.43
Matarawa Stream outlet	23.95	7.98
Net load	**44.16**	**28.46**

3.4 Aquatic plant distribution

The dominant aquatic plants present in Lake Moana-nui include *Egeria densa*, *Potamogeton ochreatus* (floating and detached*)* and *Elodea canadensis*. The distribution and abundance of *E. densa*, attached *P. ochreatus*, floating *P. ochreatus* and *E. canadensis* varied throughout the year (Fig. 3.8). *E. densa* was generally the dominant species at all sites and occurred in the littoral zone approximately 1-2 metres away from the lake edge. When present, floating *P. ochreatus* occurred adjacent to the lake edge, presumably blown by the wind, or scattered in clumps on the surface of *E.*

densa beds. Attached *P. ochreatus* occurred either emerging through dense beds of *E. densa* or in mono-specific beds beyond the *E. densa*, approximately 4 to 5 metres from the lake edge. *E. canadensis* was only present at site 2 on the December sampling occasion, and was growing between the *E. densa* bed and the lake edge. *E. densa* was generally the most abundant macrophyte in terms of dry weight in net samples (Fig. 3.8). This reflects the high-density nature of the beds of this species in the lake. The densities of attached and floating *P. ochreatus* were more variable and often lower than *E. densa*. The distribution of macrophytes surveyed in conjunction with the bathymetric survey is shown in Figure 3.9.

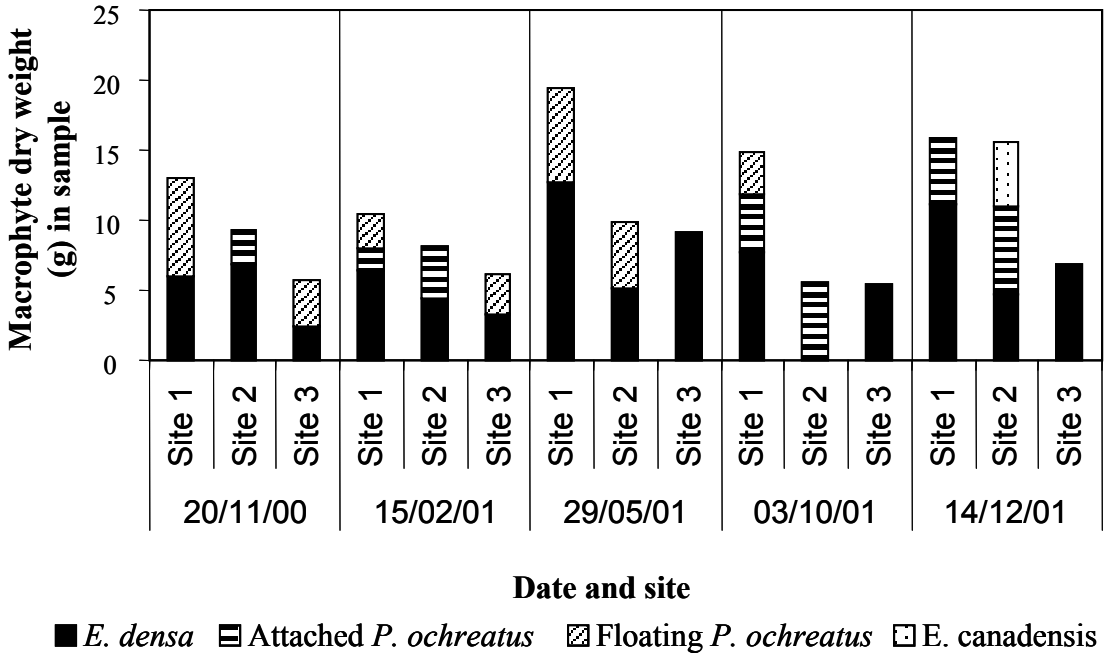

Figure 3.8. Dry weights of the different macrophyte species in bag samples at each site on each sampling date.

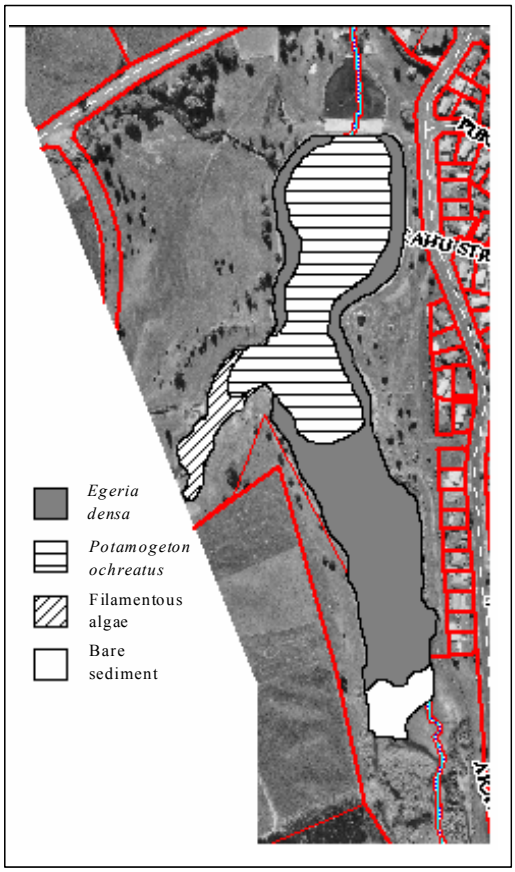

Figure 3.9. General distribution of aquatic plants.

3.5 Macroinvertebrates

3.5.1. Macroinvertebrate diversity

A total of 24 macroinvertebrate taxa were recorded throughout the study period: 22 associated with *E. densa*, 15 associated with attached *P. ochreatus*, twelve associated with floating *P. ochreatus*, and 14 associated with *E. canadensis*, with nine common to all species of macrophyte (Table 3.8).

Table 3.8. List of macroinvertebrate taxa found in macrophyte samples. (* = present)

Macroinvertebrates		*Egeria densa*	Attached *Potamogeton ochreatus*	Floating *P. ochreatus*	*Elodea canadensis*
Group	Taxa				
Mollusca (Snails)	*Gyraulus* sp.	*	*	*	*
	Physa sp.	*	*	*	*
	Lymnaea sp.	*	*	*	*
	Potamopyrgus antipodarum (Grey)	*	*		
	Sphaeriidae	*			*
Hemiptera (Waterboatman)	*Sigara* sp.	*	*	*	*
	Anisops wakefieldi White	*	*	*	*
Chironomid midges	*Paratrichocladius* sp.	*	*		
	Chironomus sp.			*	
	Paratanytarsini sp.	*			
	Corynocera sp.	*			
Shore flies	Ephydridae			*	
Dobsonflies	*Xanthocnemis zelandica* (McLachlan)	*	*	*	*
Moth larvae	*Hygraula nitens* (Butler)	*	*	*	*
Caddisflies	*Paraoxyethira hendersoni* (Mosely)	*	*	*	*
	Oxyethira albiceps (McLachlan)	*			
	Triplectides cephalotes (Walker)	*			
	Polyplectropus sp.	*			
Diving beetles	*Liodessus* sp.	*			
	Antiporus sp.	*	*		*
Mites	*A. carina*	*	*		*
Leeches	Hirudinea	*	*		*
Flatworms	Platyhelminthes	*	*	*	*
Worms	Oligochaeta	*	*	*	

Shannon-Wiener diversity was comparable between *E. densa,* attached *P. ochreatus*, and *E. canadensis* but generally lower on floating *P. ochreatus* (Fig. 3.10). Different species of macrophyte harboured highest invertebrate diversities at different times of the year, with the lowest overall diversity occurring in the winter (Fig. 3.10). A one-way ANOVA and post-hoc Tukey tests were used to test differences between overall mean diversity on each sampling date. Macroinvertebrate Shannon-Wiener diversity differed significantly with respect to sampling date ($P < 0.001$), with significantly higher diversity on 15 February 2001 (mean = 2.33) than 3 October 2001 (mean = 1.76), and diversity on the 29 May 2001 (mean = 0.99) was significantly lower than all other sampling dates. Due to seasonal differences in macrophyte distribution, differences in Shannon-Wiener diversity on different macrophytes were evaluated for each sampling date. Results of the one-way ANOVA and post-hoc Tukey tests are presented in Table

3.9. The main differences in macroinvertebrate diversity appear to lie between attached forms and floating *P. ochreatus*.

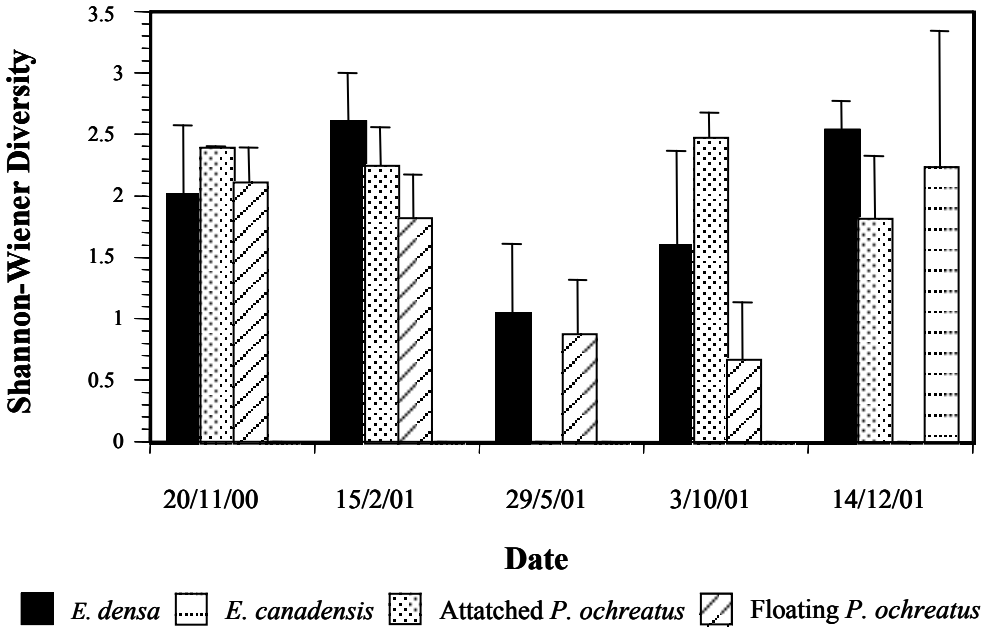

Figure 3.10. Macroinvertebrate community diversity (+ standard deviation) inhabiting different macrophyte species in Lake Moana-nui on each sampling occasion.

Table 3.9. Summary of the Results of the one-way ANOVA and Tukey test for macroinvertebrate diversity on different macrophyte species. (Ed = *E. densa*, APo = attached *P. ochreatus*, FPo = floating *P. ochreatus*, Ec = *E. canadensis*)

Date		Ed	APo	FPo	Ec	ANOVA	Tukey differences	
20/11/00	Mean	2.00	2.40	2.20	-	F = 0.619	-	
	Std. dev.	0.60	0.01	0.27	-	P = 0.551		
15/02/01	Mean	2.60	2.30	1.80	-	F = 11.76	Ed/FPo	P < 0.001
	Std. dev.	0.38	0.31	0.67	-	P = 0.000		
29/05/01	Mean	0.90	-	1.00	-	F = 0.002	-	
	Std. dev.	0.70	-	0.41	-	P = 0.966		
03/10/01	Mean	1.60	2.50	0.70	-	F = 8.608	Ed/FPo	P = 0.034
	Std. dev.	0.80	0.20	0.46	-	P = 0.003	AP/FPo	P = 0.002
14/12/01	Mean	2.60	1.82	-	2.13	F = 4.398	Ed/APo	P = 0.022
	Std. dev.	0.22	0.50	-	2.24	P = 0.028		

3.5.2. Macroinvertebrate abundance

Total macroinvertebrate abundance varied between 27 and 313 individuals g (dry

macrophyte weight)$^{-1}$ over the study period, with communities dominated by molluscs (*Gyraulus* sp., *Physa* sp. and *Lymnaea* sp.) and Diptera (Fig. 3.11). Dominance of Diptera was largely due to high numerical abundance of the chironomid *Paratrichocladius* sp. There was significant variation in total macroinvertebrate abundance on different sampling dates with significant differences between 20 November 2000 (mean = 113.5 individuals g^{-1}) and 15 February 2001 (mean = 52.7 individuals g^{-1}), and 20 November 2001and 14 December 2001 (mean = 34.5 individuals g^{-1}). Total macroinvertebrate abundance on different macrophytes was evaluated for each sampling date. Results of the one-way ANOVA and post-hoc Tukey tests are presented in Table 3.10. The main differences in macroinvertebrate abundance appear to lie between attached forms and floating *P. ochreatus*.

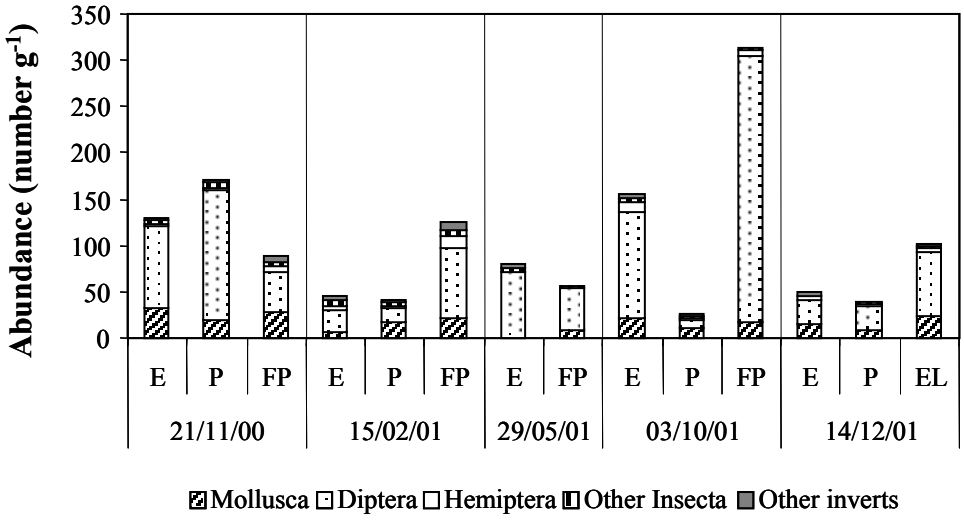

Figure 3.11. Abundance of the major taxonomic groups inhabiting the different species of macrophyte on each sampling occasion. Abundance is expressed as macroinvertebrate dry weight (mg) per macrophyte dry weight (g). E = *E. densa*, P = Attached *P. ochreatus*, FP = Floating *P. ochreatus* and EL = *E. canadensis.*

Table 3.10. Summary of the Results of the one-way ANOVA and Tukey tests for total macroinvertebrate abundance (no. /g) on different macrophyte species. (Ed = *E. densa*, APo = attached *P. ochreatus*, FPo = floating *P. ochreatus*, Ec = *E. canadensis*)

Date		Ed	APo	FPo	Ec	ANOVA	Tukey differences	
20/11/00	Mean (no. /g)	125.1	175.4	71.6	-	F = 5.232	Apo/FPo	P = 0.025
	Std. dev.	51.2	23.0	25.7	-	P = 0.018		
15/02/01	Mean (no. /g)	27.5	39.0	122.4	-	F = 13.238	Ed/Fp	P < 0.001
	Std. dev.	18.1	12.4	81.9	-	P = 0.000	Apo/FPo	P = 0.002
29/05/01	Mean (no. /g)	79.2	-	61.1	-	F = 0.887	-	
	Std. dev.	54.4	-	24.1	-	P = 0.361		
03/10/01	Mean (no. /g)	155.0	25.3	313.2	-	F = 9.852	Ed/Ec	P = 0.021
	Std. dev.	105.3	4.1	136.2	-	P = 0.002	APo/Fpo	P = 0.001
14/12/01	Mean (no. /g)	27.0	34.4	-	55.3	F = 7.952	Ed/Ec	P = 0.002
	Std. dev.	8.9	14.5	-	64.7	P = 0.003	APo/Ec	P = 0.018

3.5.3. Macroinvertebrate biomass

Total macroinvertebrate biomass varied from 25 to 313 mg (macroinvertebrate dry weight) g (macrophyte dry weight)$^{-1}$ with biomass dominated by molluscs (Fig. 3.12). There was significant variation in macroinvertebrate biomass on different sampling dates with significant differences between the winter sampling (29 May 2001) and all other dates (P = 0.001). Macroinvertebrate biomass on different macrophytes was evaluated for each sampling date. Results of the one-way ANOVA and post-hoc Tukey tests (Table 3.11) showed that generally there was no significant difference in macroinvertebrate abundance between macrophyte species other than between *E. densa* and attached *P. ochreatus* on the 14 December 2001.

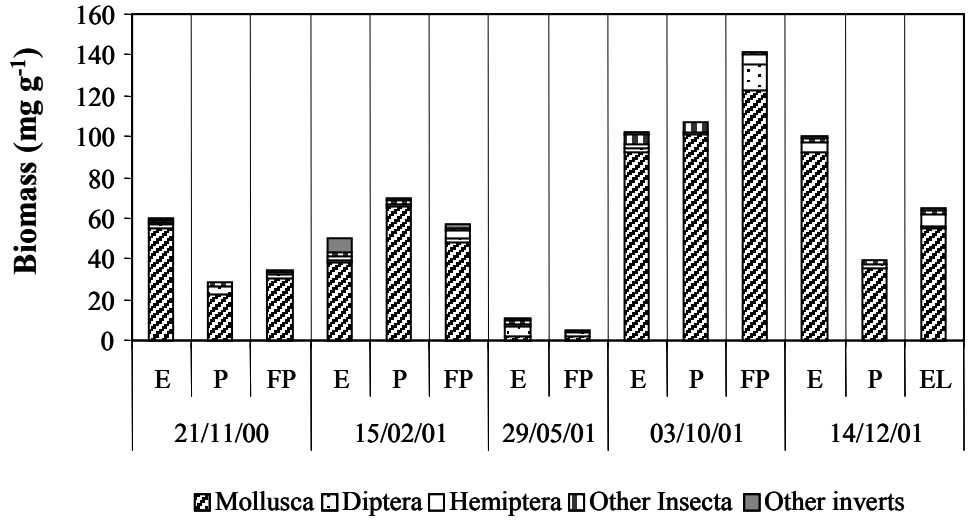

Figure 3.12. Biomass of the major taxonomic groups inhabiting the different species of macrophyte on each sampling occasion. Biomass is expressed as macroinvertebrate dry weight (mg) per macrophyte dry weight (g). E = *E. densa*, P = Attached *P. ochreatus*, FP = Floating *P. ochreatus* and EL = *E. canadensis.*

Table 3.11. Summary of the Results of the one-way ANOVA and Tukey tests for total macroinvertebrate biomass on different macrophyte species. (Ed = *E. densa*, APo = attached *P. ochreatus*, FPo = floating *P. ochreatus*, Ec = *E. canadensis*)

Date		Ed	APo	FPo	Ec	ANOVA	Tukey differences	
20/11/00	Mean (mg/g)	59.6	28.4	34.3	-	F = 1.306	-	
	Std. dev.	42.2	11.2	22.7	-	P = 0.298		
15/02/01	Mean (mg/g)	50.1	69.6	56.9	-	F = 0.349	-	
	Std. dev.	36.6	44.8	85.7	-	P = 0.708		
29/05/01	Mean (mg/g)	11.6	-	6.1	-	F = 3.935	-	
	Std. dev.	7.9	-	3.1	-	P = 0.066		
03/10/01	Mean (mg/g)	102.2	107.5	141.2	-	F = 0.252	-	
	Std. dev.	111.9	57.9	144.7	-	P = 0.781		
14/12/01	Mean (mg/g)	100.4	39.6	-	112	F = 4.694	Ed/APo	P = 0.018
	Std. dev.	56.2	14.4	-	65.3	P = 0.023		

3.6. Zooplankton

Crustacean zooplankton richness among macrophytes was low, with seven zooplankton taxa recorded throughout the study period (Table 3.12). The number of zooplankton taxa present in tube samples varied from two to six. Total zooplankton abundance ranged from 14.33 to 2400 individuals L^{-1} over the study period, with communities dominated by *S. vetulus* and cyclopoid copepods (Fig. 3.13).

Table 3.12. List of the zooplankton taxa identified in tube samples taken from amongst aquatic vegetation. (* = present)

Taxa	*Egeria densa*	Attached *P. ochreatus*	Floating *P. ochreatus*	*Elodea canadensis*
Simocephalus vatulus	*	*	*	*
Bosmina meridionalis	*	*	*	
Ceriodaphnia dubia	*	*	*	*
Daphnia sp.		*		
Chydorus sp.	*	*	*	*
Chydorid sp.	*	*	*	*
Cyclopoid sp.	*	*	*	*

There was significant variation in total zooplankton abundance among sampling dates ($P = 0.016$). Tukey tests indicated significantly lower abundances of zooplankton in October than December 2001 sampling occasions. Due to seasonal differences in the abundance and distribution of macrophytes, difference in total zooplankton abundance among macrophytes was investigated for each sampling occasion. Results of the one-way ANOVA and post-hoc Tukey tests are presented in Table 3.13. Generally total zooplankton abundance did not differ between macrophyte types, although total abundance was found to be higher on floating *P. ochreatus* than on attached plants in November 2000, and there was also higher abundance on *E. densa* compared to attached *P. ochreatus* in October 2001.

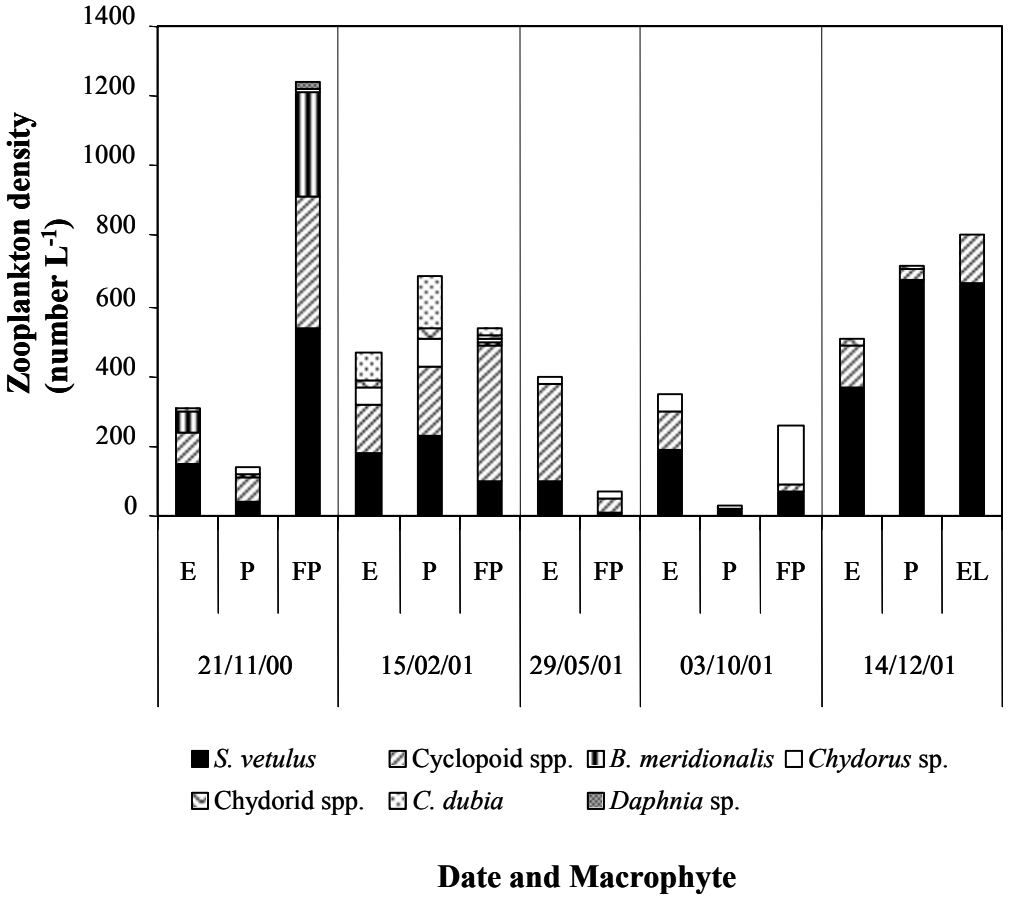

Figure 3.13. Abundance of zooplankton taxa inhabiting different species of macrophyte on each sampling occasion. E = *E. densa*, P = Attached *P. ochreatus*, FP = Floating *P. ochreatus* and EL = *E. canadensis.*

Table 3.13. Summary of the results of the one-way ANOVA and Tukey tests for total zooplankton abundance on different macrophyte species. (Ed = *Egeria densa*, APo = attached *P. ochreatus*, FPo = floating *P. ochreatus*, Ec = *Elodea canadensis*)

Date		Ed	APo	FPo	Ec	ANOVA	Tukey differences	
20/11/00	Mean (no./L)	307	137	1246	-	P < 0.001	Ed/FPo	P < 0.001
	Std. Dev.	182	125	281	-		APo/FPo	P < 0.001
15/02/01	Mean (no./L)	456	684	536	-	P = 0.282	-	
	Std. Dev.	192	515	0.6	-			
29/02/05	Mean (no./L)	399	-	70	-	P = 0.462	-	
	Std. Dev.	671	-	26	-			
03/10/01	Mean (no./L)	352	26.6	253	-	P = 0.022	Ed/APo	P = 0.018
	Std. Dev.	266	21	70	-			
14/12/01	Mean (no./L)	511	714	-	809	P = 0.316	-	
	Std. Dev.	362	474	-	119			

3.7 *Simocephalus vetulus* and water clarity

The results of the regression of algal growth rates in terms of total phytoplankton and chlorophyll *a*, on *S. vetulus* biomass are presented in Table 3.14. All regressions showed

negative responses, i.e. decreasing algal numbers and chlorophyll *a* concentrations with increasing *S. vetulus* biomass, and all but chlorophyll *a* in the 1 day incubation of Experiment 1 were statistically significant.

Table 3.14. Results of the regression of growth rates on *S. vetulus* biomass showing significance and feeding rates.

Experiment	Incubation time (days)	Species	Response	Feeding rate		Level of significance
				mL/mg/day	µL/indiv/day	
1	1	Total algae	-	113.8	967.0	***
		Chlorophyll a	-	14.5	123.2	NS
	1.833	Total algae	-	115.2	979.2	***
		Chlorophyll a	-	64.2	545.7	**
2	1	Total algae	-	110.9	1723.4	***
		Chlorophyll a	-	158.0	2455.3	***
	1.833	Total algae	-	95.5	1484.1	***
		Chlorophyll a	-	85.0	1320.9	***

NS = not significant, * = slightly significant (P<0.05), ** = moderately significant (P<0.01), *** = highly significant (P<0.001).

Using the concentrations of *S. vetulus* recorded in the lake as part of the zooplankton study, the total effect on water clarity on those days can be estimated. These results are presented in Table 3.15. The chlorophyll *a* results show that *S. vetulus* grazing can clear algae (chlorophyll *a*) from up to 77 % of lake water when densities are high in the summer.

Table 3.15. Seasonal *S. vetulus* feeding effects on chlorophyll *a* and total algal densities

Date	Mean density (indiv./L)	Est. biomass (mg/L)	Population clearance range (%)			
			Chlorophyll *a*		Total algae	
			min	max	min	max
20/11/00	235.2	3.02	4.39	47.79	28.89	34.85
15/02/01	195.8	2.56	3.71	40.39	24.41	29.45
29/05/01	103.5	1.46	2.11	23.04	13.92	16.80
03/10/01	101.6	1.43	2.08	22.67	13.70	16.53
14/12/01	392.3	4.90	7.10	77.34	46.75	56.39

3.8 Fish

A total of nine fyke nets (25-30 mm stretched mesh), two panel gill nets, and 18 Gee minnow traps with 2-mm mesh were set in Lake Moana-nui between 1054 h and 1435 h on 8 June 2000. The panel gill nets were 2 m deep and 40 m long, comprising the following panel lengths of monofilament nylon stretched-mesh sizes: 6 m of 25-mm stretched mesh, 8 m of 38-mm stretched mesh, 8 m of 56-mm stretched mesh, 8 m of

84-mm stretched mesh, and 10 m of 106-mm stretched mesh. The nets were retrieved between 1540 h and 1645 h in the same order that they were set, to give a fishing time of 5-6 h. The fyke nets were baited with canned dog food, and the minnow nets were baited with Vegemite.

The fyke nets caught nothing , and the panel gill nets caught one male brown trout (550 mm fork length, FL), one ripe female brown trout (605 mm FL), and one female rainbow trout (450 mm FL). About 250 waterboatmen (Corixidae) comprised most of the stomach contents of the female brown trout, which was dead when retrieved.

Electroshocking was carried out with generator-powered bank-mounted equipment at three sites between 1530 h and 1630 h in a total of 158 m of the lake margin (270 m^2 in area). Five bronze-coloured goldfish (*Carassius auratus*) were the only fish caught by electroshocking. Five goldfish (42-52 mm FL) were caught, four of which were in the western arm in an area 45 m by 1 m (mean depth 0.30 m) with good cover formed by tussocks of long grass overhanging the water's edge at the lake margin.

Most of the central lake bed was covered in dense beds of macrophytes that extended to within about 40 cm of the water surface. *Potamogeton ochreatus* appeared to dominate the macrophyte beds near the weir, but *Egeria densa* was dominant at the southern end. The water was very clear at the weir end, but quite murky and green at the southern end.

Few macrophytes were seen in the western arm; the water was very clear, with extensive mats of grey-green algae covering the bed. This alga was very fragile, and rose to the surface with the turbulence of the outboard motor.

4.0 Discussion

4.1 Lake physical and chemical conditions

Low values of total suspended solids (TSS) and inorganic suspended solids (ISS) in Lake Moana-nui are as expected in lakes that are dominated by abundant submerged macrophytes. Sediment entering lakes settles quickly from the water column and

resuspension of sediments due to wind and wave action is retarded or stopped completely with plant colonisation (Vant 1987). Peaks in TSS and ISS occurred during the period of wind-induced circulation in the autumn and winter. Low TSS levels and the high median Secchi depth in Lake Moana-niu probably reflect the high macrophyte production, and low phytoplankton production in the lake. Based on median Secchi depth (water clarity), Lake Moana-nui falls into the eutrophic category (total nitrogen, total phosphorus and chlorophyll *a* concentrations not monitored).

Median pH levels in Lake Moana-nui seemed to randomly fluctuate showing no seasonal pattern. pHs of greater than 9 were common. Low pH levels may have been associated with high concentrations of dissolved organic matter in the surface waters, a large portion of which occur as organic acids (Wetzel 2001). High pH values can result when biological activity (photosynthesis) reduces the concentrations of carbon dioxide and calcium carbonate (Wetzel 2001).

Median conductivity values for Lake Moana-nui were higher than those found in shallow, macrophyte-dominated (93-135 $\mu s\ cm^{-1}$) lakes by Boswell (1985) and probably reflect the geology of the catchment. The close proximity of sites 1 and 2 to the lake arm, which is spring fed (potentially high in dissolved ions), and the general flow of water in a northerly direction (unlikely to mix with waters at southern end) may be why these sites had higher mean conductivity than site three.

Seasonal surface temperature ranges (STR) for sites 1 (13.8 °C) and 2 (15.2 °C) in Lake Moana-nui are within expected ranges (13.0 ± 3.1 °C) for North Island lakes (Green *et al*. 1987). The high STR at site 3 (20.9°C) is probably due to the shallowness of the lake area around this site (0.5 m) (Fig. 2.1) hence a lesser volume of water to be heated per unit area of lake surface, than at the other sites (Green *et al*. 1987). Low temperatures are also likely to be due to the lakes central North Island location and high elevation.

High median nutrient concentrations in the lake reflect the agricultural land use activities within the lake catchment. Agriculture is the most prevalent cause of nutrient enrichment in New Zealand lakes and has characteristically high diffuse nutrient run-off

(Vant 1987). Peaks in nutrient concentrations are often associated with increased run-off during high rainfall events (Collier *et al*. 1995) and this could account for the peaks in NO_x and DRP in Lake Moana-nui. This could also explain the increasing trend in DRP over the 2001/2002 spring and summer seasons with inlet stream levels being consistently high over this period (*pers. obs*.). Peaks in ammonia concentrations could have arisen as the end product of decomposition of organic matter, and from the breakdown of other nitrogenous compounds such as urea and proteins (Wetzel 2001). Total nitrogen (N), total phosphorus (P) and chlorophyll *a* levels were not monitored in this study, therefore it is not possible to calculate a trophic level index for the lake. However, the high dissolved nutrient concentrations observed probably reflect high total N and P levels. The growth of algae in a lake is proportional to the quantity of nutrients in the lake assuming that algae take up and use nutrients at a ratio of 16N:1P. Using median values, the ratio of available N:P in Lake Moana-nui is in the order of 100:1 indicating that phosphorus is the potential limiting nutrient.

High median dissolved oxygen concentrations (7.5 – 16.9 mg L^{-1}) and high saturation (75 – 192 %) during the day at all three sites is probably due to the abundant submerged vegetation. Photosynthesis of the plants and associated epiphyton can generate large amounts of oxygen (Wetzel 2001). Dissolved oxygen is important for fish and other aquatic life to breathe and levels measured in Lake Moana-nui during the day generally exceed 80 percent saturation which is the level required for aquatic plants and animals to live.

4.2 Water, nutrient, and sediment budgets

The extent to which nutrients accumulate in a waterbody is highly dependant on the flushing rate. If the inflow volume of a lake is high compared to the basin volume, algae can be flushed out of the lake before they can grow to nuisance levels and this can occur even in lakes containing high nutrient concentrations such as Lake Moana-nui. A residency time greater than about three days is a prerequisite for excessive algal growths therefore the short residency time (2.6 days) in Lake Moana-nui is important in contributing to the characteristically high water clarity (Ryding & Rast 1989).

Calculation of the nutrient and sediment budgets for the lake identified that the

Matarawa Stream is a major source of inorganic nitrogen, and perhaps more importantly phosphorus to the lake (phosphorus is potentially the limiting nutrient for algal and plant growth). The Matarawa Stream is also the major source of suspended solids and sediment to the lake which explains the shallow depths at the southern end of the lake where water entering the lake loses energy and sediment settles out. Agricultural land management practices in the upper catchment are more than likely responsible for these high nutrient and sediment loads. An assessment of the health of the inlets was beyond the scope of this report, however high nutrient (above ANZECC (2000) default guideline values) and sediment loads suggest that riparian management of the inlet streams is required to reduce both nutrient and sediment loads.

4.3 Aquatic plants

During the past century many New Zealand lakes have undergone rapid invasions by exotic submerged macrophyte species such as *Elodea canadensis, Lagarosiphon major, Egeria densa* and *Ceratophyllum demersum*. These tall canopy forming exotics are able to exploit space that is not utilised by low growing native species (Howard-Williams *et al*. 1987), and invasions have resulted in the replacement of native communities with dense mono-specific beds of tall adventives (Wells *et al*. 1997). These tall growing macrophytes are now a dominant feature in the littoral zone of a wide variety of New Zealand lakes (Miller & Death 1997), including Lake Moana-nui. In more recent years, further to exotic plant invasion, eutrophication has resulted in the collapse of submerged plant communities with most Waikato lakes switching to turbid, phytoplankton dominated states. Lake Moana-nui is therefore unique to the Waikato region due to its clear water and abundance of exotic and native populations of macrophytes.

In shallow lakes like Lake Moana-nui, macrophyte production may dominate the entire lake bed. Macrophytes promote clear water in lakes by reducing the re-suspension of sediments (Scheffer 1999), through the reduction of phytoplankton growth by shading, extracting nutrients from the water and through the release of growth inhibiting substances. Aquatic plants are an important habitat for invertebrates. They provide invertebrates and zooplankton with protection from predators, are a direct and indirect source of food and increase the amount of available habitat (Humphries 1996). In turn the invertebrates inhabiting the macrophytes are important as detritus decomposers (van

den Berg *et al*. 1997), in influencing algal growth and concentrations (zooplankton), and because of their abundance in lakes, are an important link in energy transfer as a source of food for fish and waterfowl.

Further weed control through lake level manipulation in Lake Moana-nui combined with nutrient enrichment from the upper Matarawa Stream catchment may lead to a switch to algal domination. This in turn could lead to degradation of the recreational trout fishery, a reduction in macroinvertebrate diversity and abundance of birdlife due to the loss of macroinvertebrate food associated with submerged plants, a marked increase in water turbidity and a reduction in the aesthetic and recreational value of the lake. Macrophytes are an integral part of the Lake Moana-nui ecosystem. Macrophytes contribute to the high water clarity of the lake through the stabilisation of bottom sediments, the tying up of plant nutrients that would otherwise be utilised by algal growth, and by providing habitat for filter feeders, particularly *Simocephalus vetulus*, that can remove algae from the water.

4.4 Macroinvertebrates

The macroinvertebrate communities associated with the macrophytes in Lake Moana-nui were characterised by low species richness. A total of 24 macroinvertebrate taxa were recorded throughout the study period, which is consistent with the poor diversity found in studies of macrophyte associated macroinvertebrate communities in other New Zealand lakes (e.g. Winterbourn & Lewis 1975; Talbot & Ward 1987; Biggs & Malthus; Miller & Death 1997). Low macroinvertebrate diversity in Lake Moana-nui could be the result of the shallow depth ranges in the lake, and/or the low macrophyte diversity providing low habitat diversity.

Macroinvertebrate communities associated with all macrophyte types in Lake Moana-nui were dominated by the snails *Lymnaea* sp., *Physa* sp., and *Gyraulus* sp., and/or the chironomid midge *Paratrichocladius* sp. (Orthocladinae). The dominance of these snails is in contrast to other New Zealand lakes where *Potamopyrgus antipodarum* generally dominates (Biggs & Malthus 1982; Talbot & Ward 1987; Miller & Death 1997; James *et al*. 1998) along with oligochaete worms (Stark 1993; Miller & Death 1997). The co-dominance of Chironomidae is consistent with other New Zealand

studies (Mylechreest 1978; Stark 1981; Biggs & Malthus 1982; Talbot & Ward 1987; James *et al*. 1998), as is the co/sub-dominance of *Gyraulus* sp. (Talbot & Ward 1987).

Macroinvertebrates generally showed no preference for exotic *E. densa* or native attached *P. ochreatus* in terms of diversity, abundance or biomass. The main differences in community composition lay between attached forms (*E. densa* and *P. ochreatus*) and floating *P. ochreatus* in terms of diversity, abundance and biomass, and total abundance was found to be greater on floating *P. ochreatus*. The higher macroinvertebrate diversity on attached macrophytes compared to floating *P. ochreatus* is probably due to the increased habitat complexity associated with attached forms. For example, floating *P. ochreatus* would occupy a narrow range of temperatures and light intensities at the surface, compared to attached forms that occupy a greater depth range. Submerged plants have been found to be more important for invertebrate diversity in comparison to true floating macrophyte species (Dvorak & Best 1982; Cattaneo *et al*. 1998).

Seasonal environmental changes and/or disturbance (lowering of lake level) were assessed as being more important in determining macroinvertebrate community composition in Lake Moana-nui than macrophyte type. It has been suggested that changing water levels (lowering) can adversely affect macroinvertebrate communities in littoral zones (Hunt & Jones 1972; Mylechreest 1978; Humphries 1996). There was reduced total macroinvertebrate abundance in the February 2001 sampling date, following the lowering of lake level, but no difference in macroinvertebrate community in terms of Shannon-Wiener diversity or biomass. The macroinvertebrate community recovered quickly after the lake level lowering. Lows in macroinvertebrate diversity, and total abundance and biomass occurred in the winter (29 May 2001) samples, and this coincided with low taxonomic diversity in attached macrophyte beds at the three sampling sites (there was no attached *P. ochreatus* at any of the sampling sites at this time).

4.6 Zooplankton

A total of seven different zooplankton taxa were identified inhabiting the macrophytes of Lake Moana-nui throughout the study period. Low taxa richness is typical of New Zealand limnetic communities, with the limnetic zooplankton generally consisting of

one species of calanoid copepod and one to three species of cladocerans (usually *Bosmina meridionalis*, and/or *Ceriodaphnia dubia* and more rarely *Daphnia carinata*) (Chapman & Green 1987). These limnetic species, in addition to *Simocephalus vetulus*, some chydorid species, and cyclopoid copepods were found amongst the macrophytes in Lake Moana-nui. The presence and abundance of these taxa shows the importance of macrophytes for increasing zooplankton diversity in New Zealand lakes. *S. vetulus* was generally the most abundant zooplankton species amongst the macrophytes in Lake Moana-nui. High abundance of *Simocephalus* has been reported in studies elsewhere with the abundance of this species being directly proportional to the abundance of weedy habitat (Quade 1969; Lauridsen *et a*l. 1996; Perrow *et al*. 1999).

All of the zooplankton taxa recorded, except *Daphnia* sp. were found to be associated with all of the macrophyte types, irrespective of whether the macrophytes were native or exotic. *Daphnia* sp. was found only associated with attached *P. ochreatus*. This was probably due to lower density beds of *P. ochreatus* generally growing on the open water side of the *E. densa* beds, with *Daphnia* being primarily a pelagic zooplankter.

Total zooplankton abundance in relation to different plant types changed seasonally. There was significantly higher zooplankton abundance associated with *E. densa* than with attached *P. ochreatus* samples in October 2001 and there was also a preference shown for floating *P. ochreatus* over attached forms in November 2000 before the lowering of the lake level. The highly dissected leaf and stem structure of *E. densa* may provide larger surface area for attachment for macrophyte dependant species such as chydorids and *S. vetulus*, and increased protection from predation for non macrophyte dependant species, such as cyclopoids and *C. dubia*, compared to *P. ochreatus* (Stansfield *et al*. 1997). Higher total abundance in November floating *P. ochreatus* samples is probably attributable to high *B. meridionalis* numbers at this time.

4.6 *Simocephalus vetulus* and water clarity

The *Simocephalus vetulus* community in Lake Moana-nui was found to have substantial grazing effects on algal communities, potentially filtering up to 77 % of the total algal production per day. Because *S. vetulus* is primarily a macrophyte-associated cladoceran, its importance for maintaining lake water clarity is dependant on the amount of

submerged vegetation (habitat) present in the lake. Loss of submerged vegetation form Lake Moana-nui would therefore result in the loss of the *S. vetulus* population. More detailed information on the *S. vetulus* grazing investigation can be sourced in the thesis associated with this study.

4.8 Fish

The fish density was sparse, which may account for the abundance of invertebrates. Fish, especially in their pelagic larval phase, can prey on zooplankton and reduce their density, thereby decreasing water clarity.

5.0 Conclusions and recommendations

Lake Moana-nui is currently in a healthy ecological condition with abundant plant and animal life. Although generally falling within the eutrophic category, Lake Moana-nui maintains far greater water clarity than other Waikato lakes despite having nutrient concentrations typical of hypertrophic waterbodies. This report has identified that a combination of factors contribute to the ability of Lake Moana-nui to maintain a clear a water state, namely, a high flushing rate (flushing out of algae), high abundance of submerged aquatic vegetation (stabilisation of bottom sediments), and large numbers of plant associated *Simocephalus vetulus* (control of algae through grazing). All of these factors are dependant on one another forming a rather delicate balance. Further vegetation control through lake level manipulation may upset this balance resulting in the loss of water clarity to the detriment of the plant and animal communities. The following are possible aquatic vegetation control measures that may be employed in Lake Moana-nui and the advantages and disadvantages of each are outlined. It is highly recommended that only selected areas of the lake are controlled while still leaving the majority of the macrophyte beds.

1 Covering bottom sediments – Covering lake bottom sediments with plastic sheeting or particulate material (e.g. fly ash) could be used to prevent sediment-water nutrient exchange and to reduce macrophyte growth. Advantages of this method are that areas of the lake could be selectively covered while still

maintaining adequate macrophyte cover to help maintain water clarity and provide food for trout and birds. Disadvantages are the higher relative cost and that in Lake Moana-nui sediment may quickly build up on top of the sediment cover.

2 Spraying weeds – A herbicide could be used to kill undesirable weed growths. An advantage of using this method is that problem areas can be selectively targeted at optimum times of the year when recreational use of the lake is high. Disadvantages include a reduction in food resources for wildlife, sprays are perceived as being environmentally unfriendly, and a build up of dead plant material and the lake would require regular application.

3 Harvesting – This method involves cutting and removal of selected areas of vegetation. Advantages are that the results are immediate. Disadvantages are the regularity that harvesting may be required and the disposal of vegetation may be problematic.

4 Biocontrol – Grass carp could be introduced and contained in the lake. Grass carp have been used successfully to control weeds in New Zealand (Rowe & Champion 1994) and a small number of grass carp may be able to control macrophyte growth while still maintaining most of the macrophyte beds. An advantage of this method is the low cost after the initial outlay. Disadvantages are that grass carp are unselective plant eaters and may eat beneficial plants and it would be up to two years before results are seen, and would escape without the construction of extensive barriers. Also, partial control of macrophytes by grass carp has yet to be demonstrated (e.g., Wells et al. 2003).

5 No intervention – Weeds are part of a healthy lake ecosystem and no intervention is a cheap and low impact solution. An education programme may help to shift local perceptions. The disadvantage of this option is the persistence of the weed problem. Keeping invasive fish species such as koi carp (*Cyprinus carpio*) out of the lake is especially important. The absence of bullies and smelt may also contribute to the good water clarity, as they eat zooplankton at

appropriate life stages.

It is recommended that the South Waikato District Council focus its efforts on changing community perceptions about the value of the aquatic weeds in the lake through some form of education (e.g. signage around the lake reserve, a school education programme). Also, although an evaluation of the ecological health of the inlets was beyond the scope of this report, the loads of nutrients and sediment entering the lake suggest that riparian management of the Matarawa Stream upstream of the lake would go a long way to reducing the external loads of nutrients and sediment reaching the lake. Especially useful in developing and implementing a riparian management programme for the Matarawa Stream are Collier et al (1995), Ministry for the Environment (2001) and Auckland Regional Council (2001).

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Appendix 1: Physical and chemical monitoring data.

Physical and chemical monitoring data from Site 1

Date	Secchi (m)	pH	Conductivity (µs/cm @25C)	Temperature (°C)	Dissolved O_2 (mg/L)	TSS (mg/L)	ISS (mg/L)	Ammonia (mg/L)	NO_x (mg/L)	DRP (mg/L)
20-Nov-00	3.3	6.2	152.5	14.9	13.0			0.00	0.70	0.004
18-Dec-00	0.9	8.4	134.3	22.0	15.5			0.01	2.46	0.008
31-Jan-01	3.6	8.6	149.2	19.2	14.6			0.00	0.90	0.005
7-Feb-01	3.2	9.1	180.9	19.0	14.0			0.11	5.45	0.018
15-Feb-01	3.1	8.6	149.6	19.9	15.5			0.05	0.60	0.023
28-Feb-01	2.9	8.4	124.4	21.0	10.9	2.1	0.8	0.01	1.57	0.009
14-Mar-01	2.8	9.2	131.2	17.6	17.0	1.4	0.6	0.03	0.77	0.012
28-Mar-01	2.6	8.9	152.1	16.2	7.5	2.2	0.6	0.01	1.48	0.003
12-Apr-01	2.7	9.0	143.8	14.8	11.3	4.0	1.6	0.01	1.61	0.007
26-Apr-01	2.7	9.7	153.9	14.4	13.8	118.8	86.8	0.00	0.16	0.019
9-May-01	2.4	9.3	143.9	16.0	16.4	3.4	0.0	0.00	1.22	0.009
29-May-01	2.1	9.1	172.4	10.0	13.8	10.0	7.1	0.03	1.61	0.013
13-Jun-01	2.6	7.7	161.3	9.5	14.4	2.0	0.0	0.00	0.32	0.012
4-Jul-01	2.6	8.0	177.8	8.2	12.8	1.3	0.0	0.35	1.20	0.038
19-Jul-01	1.4	8.3	145.4	10.1	11.9	3.0	0.3	0.00	1.63	0.003
1-Aug-01	3.1	8.4	165.2	11.4	12.2	1.7	0.0	0.02	1.85	0.007
14-Aug-01	3.1	8.2	162.7	11.5	14.1	1.2	0.0	0.01	2.02	0.016
13-Sep-01	3.8	10.1	151.2	16.2	9.0	2.1	0.4	0.03	0.46	0.008
3-Oct-01	3.8	7.4	141.3	16.0	14.1	6.6	3.5	0.04	1.25	0.014
17-Oct-01	3.6	7.5	157.5	15.7	11.2	3.0	0.7	0.08	0.93	0.024
31-Oct-01	3.3	7.4	133.8	16.2	11.5	3.2	0.4	0.09	1.37	0.039
14-Nov-01	2.6	7.1	141.0	18.5	12.0	2.2	0.0	0.07	0.62	0.033
28-Nov-01	3.6	8.2	127.8	16.6	11.0	2.0	0.0	0.12	1.56	0.089
14-Dec-01	3.5	8.7	136.0	20.4	13.5	4.5	1.9	0.11	1.55	0.034
21-Jan-02	2.8	9.3	140.8	21.6	14.6	6.3	2.0	0.07	1.46	0.067

Physical and chemical monitoring data from Site 2									
Date	**pH**	**Conductivity** (µs/cm @°25C)	**Temperature** °C	**Dissolved O_2** (mg/L)	**TSS** (mg/L)	**ISS** (mg/L)	**Ammonia** (mg/L)	**NO_x** (mg/L)	**DRP** (mg/L)
20-Nov-00	7.8	165.9	14.5	12.5			0.05	2.42	0.003
18-Dec-00	8.1	135.4	22.1	16.3			0.03	2.70	0.009
31-Jan-01	8.4	149.1	19.5	13.5			0.03	1.01	0.010
7-Feb-01	8.9	179.4	18.8	13.2			0.12	3.69	0.038
15-Feb-01	8.3	129.7	24.1	17.2			0.04	0.50	0.018
28-Feb-01	8.2	132.3	21.5	11.2	2.4	1.0	0.00	0.21	0.000
14-Mar-01	8.6	149.5	17.1	16.4	2.0	0.4	0.04	0.72	0.010
28-Mar-01	8.2	165.2	15.1	10.9	5.4	5.4	0.28	3.42	0.087
12-Apr-01	6.9	178.6	14.1	11.0	2.3	0.0	0.07	2.76	0.010
26-Apr-01	8.0	177.7	14.2	15.6	3.4	0.0	0.00	0.14	0.037
9-May-01	8.6	148.8	15.7	14.2	2.4	0.0	0.07	0.82	0.009
29-May-01	8.7	181.9	9.6	11.8	20.2	14.9	0.04	2.06	0.014
13-Jun-01	7.0	168.2	10.0	12.0	2.3	0.6	0.00	0.36	0.016
4-Jul-01	7.8	179.2	8.9	9.0	0.6	0.0	0.12	1.94	0.054
19-Jul-01	7.8	126.7	9.9	10.3	4.4	2.5	0.01	1.48	0.007
1-Aug-01	8.2	152.4	10.9	10.5	3.0	1.7	0.01	3.08	0.022
14-Aug-01	8.0	169.9	11.2	10.8	0.9	0.0	0.02	1.46	0.014
13-Sep-01	9.8	158.3	15.0	15.4	0.3	0.0	0.02	0.41	0.018
3-Oct-01	6.9	143.6	16.8	13.0	4.1	3.4	0.06	1.84	0.018
17-Oct-01	7.1	143.3	15.6	9.8	3.3	1.0	0.11	0.69	0.024
31-Oct-01	7.4	127.8	16.6	10.3	7.0	2.1	0.09	1.24	0.042
14-Nov-01	7.1	139.2	18.5	10.6	3.5	0.6	0.11	1.13	0.075
28-Nov-01	8.0	127.0	17.0	11.3	1.6	0.0	0.11	1.45	0.082
14-Dec-01	8.1	136.9	20.3	10.7	2.7	0.5	0.11	1.58	0.043
21-Jan-02	9.0	139.5	21.2	15.4	2.9	0.0	0.08	1.51	0.067

Physical and chemical monitoring data from Site 3									
Date	**pH**	**Conductivity** (µs/cm @°25C)	**Temp** °C	**Dissolved O_2** (mg/L)	**TSS** (mg/L)	**ISS** (mg/L)	**Ammonia** (mg/L)	**NO_x** (mg/L)	**DRP** (mg/L)
20-Nov-00	8.4	126.5	15.2	12.7			0.03	1.39	0.014
18-Dec-00	8.3	136.5	21.1	16.9			0.01	1.92	0.007
31-Jan-01	7.7	122.0	19.6	12.5			0.02	1.14	0.023
7-Feb-01	8.4	168.3	19.7	10.6			0.05	1.77	0.032
15-Feb-01	9.0	115.3	25.1	16.7			0.02	0.22	0.008
28-Feb-01	8.6	115.5	21.6	11.2	2.2	0.5	0.06	0.74	0.023
14-Mar-01	9.4	112.0	20.2	13.7	2.1	0.6	0.02	2.05	0.009
28-Mar-01	8.3	106.7	17.0	10.8	0.4	0.4	0.04	1.36	0.009
12-Apr-01	7.6	117.5	15.6	10.2	3.6	0.6	0.02	0.94	0.024
26-Apr-01	8.9	117.9	15.4	16.2	3.5	0.3	0.01	0.11	0.057
9-May-01	8.8	119.0	15.8	14.6	2.9	0.4	0.04	2.90	0.048
29-May-01	10.3	121.8	5.8	13.0	2.4	0.6	0.03	0.82	0.017
13-Jun-01	9.7	116.9	5.1	13.4	3.6	1.8	0.01	0.26	0.013
4-Jul-01	8.3	125.1	4.2	12.0	1.8	0.4	0.03	0.60	0.041
19-Jul-01	9.2	95.2	9.0	11.8	11.5	4.7	0.00	0.67	0.008
1-Aug-01	9.1	112.7	11.1	12.0	0.7	0.7	0.01	0.57	0.011
14-Aug-01	9.1	105.8	10.6	13.5	1.2	0.0	0.00	0.51	-0.001
13-Sep-01	9.4	115.5	14.6	16.4	3.5	2.4	0.02	0.35	0.033
3-Oct-01	8.0	104.8	16.7	9.6	1.9	0.7	0.09	1.04	0.041
17-Oct-01	9.0	107.5	17.7	12.4	4.4	1.1	0.04	0.28	0.029
31-Oct-01	8.2	113.1	17.2	10.2	3.6	0.7	0.09	0.77	0.051
14-Nov-01	7.6	103.4	20.6	13.1	5.3	1.8	0.03	0.40	0.032
28-Nov-01	8.9	109.5	16.8	9.9	2.9	0.5	0.10	0.86	0.068
14-Dec-01	8.0	130.1	20.5	10.1	3.3	0.3	0.07	1.18	0.042
21-Jan-02	10.1	117.5	23.0	13.8	1.2	0.0	0.06	1.07	0.099

Appendix 2: Raw data for the water, nutrient and sediment budgets

Sample date	Total flow (m^3/s)	DRP (mg/L)	NO_2 (mg/L)	Ammonia (mg/L)	NO_x (mg/L)	TSS (mg/L)
14/03/01	0.002	0.000	0.002	0.000	0.507	8.9
28/03/01	0.000	0.126	0.048	0.574	0.641	14.9
12/04/01	0.000	0.019	0.031	0.064	2.137	16.8
26/04/01	0.000	0.012	0.034	0.028	1.523	14.2
9/05/01	0.000	0.008	0.002	0.000	0.163	3.9
29/05/01	0.002	0.008	0.001	0.000	1.709	1.2
13/06/01	0.001	0.006	0.002	0.022	1.849	2.4
4/07/01	0.001	0.006	0.001	0.000	0.212	2.6
19/07/01	0.005	0.016	0.005	0.235	0.907	1.1
1/08/01	0.001	0.003	0.009	0.000	2.162	1.6
14/08/01	0.001	0.005	0.003	0.013	2.070	1.4
29/08/01	0.002	0.004	0.009	0.000	2.298	5.1
13/09/01	0.002	0.007	0.001	0.009	0.420	5.8
3/10/01	0.000	0.011	0.005	0.020	2.459	10.5
17/10/01	0.001	0.007	0.002	0.013	0.886	2.9
31/10/01	0.000	0.022	0.005	0.024	2.248	1.2
14/11/01	0.004	0.197	0.011	0.053	1.716	4.2
28/11/01	0.002	0.029	0.010	0.132	1.887	3.4
14/12/01	0.002	0.016	0.008	0.025	1.894	2.3
21/01/02	0.001	0.035	0.006	0.043	2.243	4.1
Mean	0.001	0.027	0.010	0.063	1.497	5.4

Sample date	Total flow (m^3/s)	DRP (mg/L)	NO_2 (mg/L)	Ammonia (mg/L)	NO_x (mg/L)	TSS (mg/L)
14/03/01	0.007	0.004	0.003	0.000	2.398	1.1
28/03/01	0.005	0.037	0.011	0.001	3.158	1.8
12/04/01	0.003	0.022	0.017	0.057	3.255	9.8
26/04/01	0.001	0.019	0.004	0.001	3.282	13.1
9/05/01	0.005	0.011	0.002	0.000	0.216	4.1
29/05/01	0.005	0.005	0.003	0.004	3.162	2.9
13/06/01	0.003	0.004	0.001	0.011	0.775	5.4
4/07/01	0.008	0.013	0.002	0.000	0.323	0.3
19/07/01	0.008	0.033	0.005	0.125	0.383	1.0
1/08/01	0.003	0.009	0.010	0.000	3.200	1.0
14/08/01	0.003	0.008	0.002	0.015	2.187	2.3
29/08/01	0.003	0.009	0.009	0.000	3.523	1.9
13/09/01	0.004	0.013	0.001	0.009	0.489	1.0
3/10/01	0.005	0.013	0.002	0.010	3.078	0.0
17/10/01	0.004	0.031	0.002	0.012	1.075	0.9
31/10/01	0.005	0.027	0.003	0.014	2.955	0.0
14/11/01	0.008	0.099	0.006	0.028	2.326	4.5
28/11/01	0.006	0.025	0.005	0.003	2.733	1.4
14/12/01	0.004	0.014	0.005	0.019	3.014	57.5
21/01/02	0.009	0.036	0.004	0.012	3.216	2.9
Mean	0.005	0.022	0.005	0.010	2.237	5.6

Water, nutrient, and sediment budget data for the lake arm inlet							
Sample date	**Total flow (m^3/s)**	**DRP (mg/L)**	**NO_2 (mg/L)**	**Ammonia (mg/L)**	**NO_x (mg/L)**	**TSS (mg/L)**	**ISS (mg/L)**
14/03/01	0.078	0.005	0.002	0.000	1.923	5.6	3.6
28/03/01	0.085	0.060	0.016	0.177	3.361	2.9	1.2
12/04/01	0.094	0.014	0.025	0.048	3.861	4.4	2.5
26/04/01	0.087	0.026	0.005	0.000	3.503	13.8	9.0
9/05/01	0.095	0.016	0.078	0.010	2.232	3.3	0.8
29/05/01	0.121	0.005	0.001	0.000	1.907	1.5	0.0
13/06/01	0.114	0.010	0.001	0.008	0.773	0.9	0.0
4/07/01	0.113	0.020	0.002	0.000	0.285	0.0	0.0
19/07/01	0.144	0.052	0.003	0.070	0.826	1.5	0.0
1/08/01	0.165	0.014	0.000	0.000	3.218	1.0	0.0
14/08/01	0.163	0.003	0.000	0.009	0.073	2.2	0.0
29/08/01	0.177	0.018	0.011	0.000	3.507	2.3	1.0
13/09/01	0.172	0.013	0.002	0.003	0.553	0.7	0.0
3/10/01	0.177	0.014	0.003	0.007	3.175	1.1	0.1
17/10/01	0.152	0.013	0.004	0.011	1.029	10.0	0.6
31/10/01	0.124	0.024	0.005	0.007	3.188	9.1	5.5
14/11/01	0.139	0.026	0.006	0.048	1.882	13.5	8.1
28/11/01	0.200	0.031	0.005	0.000	2.976	5.2	3.0
14/12/01	0.198	0.017	0.004	0.008	3.149	7.7	4.3
21/01/02	0.178	0.035	0.004	0.006	3.435	2.4	0.9
Mean	0.139	0.021	0.009	0.021	2.243	4.5	2.0

Water, nutrient and sediment budget data for the Matarawa Stream Inlet							
Sample date	**Total Q (m^3)**	**Total flow (m^3/s)**	**DRP (mg/L)**	**NO_2 (mg/L)**	**Ammonia (mg/L)**	**NO_x (mg/L)**	**TSS (mg/L)**
14/03/01		0.083	0.027	0.005	0.000	1.294	6.9
28/03/01		0.098	0.038	0.011	0.012	1.349	15.8
12/04/01		0.089	0.012	0.006	0.014	3.894	3.9
26/04/01		0.093	0.057	0.005	0.007	2.006	3.8
9/05/01		0.123	0.049	0.004	0.000	0.101	4.9
29/05/01	258441		0.037	0.006	0.006	2.135	10.5
13/06/01	592856		0.024	0.003	0.018	1.410	3.2
4/07/01	185559		0.029	0.004	0.000	0.158	4.0
19/07/01	208970		0.066	0.007	0.045	0.461	25.2
1/08/01	140473		0.026	0.436	0.506	1.414	11.2
14/08/01	180843		0.016	0.003	0.018	1.048	6.7
29/08/01	226352		0.030	0.014	0.000	1.427	6.6
13/09/01	222155		0.038	0.009	0.019	0.286	3.7
3/10/01	203689		0.029	0.003	0.015	1.812	3.3
17/10/01	201717		0.045	0.015	0.065	0.485	6.6
31/10/01	165342		0.098	0.009	0.185	1.487	5.0
14/11/01	69694		0.165	0.021	0.485	0.880	32.0
28/11/01		0.308	0.086	0.008	0.029	1.553	10.4
14/12/01		0.127	0.054	0.009	0.044	1.660	7.3
21/01/02		0.127	0.115	0.017	0.055	1.721	8.8
Mean			0.052	0.030	0.076	1.329	9.0

Note: 29/5/01 to 14/11/01 was continuously monitored

Water, nutrient, and sediment budget data for Matarawa Stream outlet						
Sample date	**Total flow (m^3/s)**	**DRP (mg/L)**	**NO_2 (mg/L)**	**Ammonia (mg/L)**	**NO_x (mg/L)**	**TSS (mg/L)**
14/03/01	0.243	0.004	0.016	0.006	1.575	2.2
28/03/01	0.192	0.001	0.018	0.000	1.130	5.9
12/04/01	0.212	0.023	0.009	0.023	2.774	2.3
26/04/01	0.171	0.019	0.034	0.020	1.608	2.6
9/05/01	0.219	0.051	0.041	0.026	0.071	7.1
29/05/01	0.266	0.042	0.014	0.040	1.760	2.5
13/06/01	0.220	0.016	0.008	0.028	1.599	0.9
4/07/01	0.251	0.018	0.010	0.000	0.190	1.2
19/07/01	0.373	0.045	0.007	0.065	0.592	3.7
1/08/01	0.242	0.011	0.150	0.037	2.122	0.5
14/08/01	0.265	0.019	0.014	0.030	1.896	0.7
29/08/01	0.280	0.012	0.019	0.003	1.796	1.8
13/09/01	0.274	0.015	0.011	0.030	0.283	9.1
3/10/01	0.199	0.014	0.012	0.061	1.700	2.5
17/10/01	0.222	0.012	0.012	0.064	0.610	1.3
31/10/01	0.248	0.033	0.019	0.075	1.581	2.8
14/11/01	0.591	0.036	0.015	0.074	1.064	2.4
28/11/01	0.301	0.064	0.025	0.112	1.674	2.4
14/12/01	0.411	0.084	0.034	0.125	1.838	2.7
21/01/02	0.317	0.049	0.020	0.060	2.041	0.7
Mean	0.275	0.028	0.024	0.044	1.395	2.8