Water Treatment Trial, Sullivan Lake 2005

Prepared by Paul Scholes, Environmental Scientist

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P O Box 364
Whakatane
NEW ZEALAND

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Executive Summary

Sullivan Lake, Whakatane, a hypertrophic stormwater lake provided the site for the trialling of several water treatment products. Water treatment products included bacterial-enzyme concentrates, treated chalk, and Iron Making Slag. Water treatment products were applied to small enclosures or mesocosms to test their effectiveness in a natural environment.

The mesocosms were monitored for changes in water quality including: water clarity; nutrients (phosphorus and nitrogen); chlorophyll *a*; dissolved oxygen, biochemical oxygen demand; pH and conductivity. Sediment samples were also taken to ascertain any change in nutrient availability and decrease in organic material.

Improvements in water quality were most readily seen in water clarity monitoring and in changes of turbidity. Bacterial based treatments achieved greater than 170 percent increase in water clarity compared to a control mesocosm within 16 days, and in some cases turbidity was halved.

Dissolved oxygen, biochemical oxygen demand, pH and conductivity were less revealing. Oxygen levels were maintained at a higher concentration in most mesocosms in comparison to the control mesocosm. Biochemical oxygen demand decreased with algae die-off in all mesocosms including the control.

The change in chlorophyll *a* concentrations correlated with the decreasing total phosphorus concentrations in the mesocosms. However, the greatest reduction in chlorophyll *a* concentrations, when compared to the control mesocosm, was in the mesocosms treated with bacterial treatment products.

The control mesocosm had a much higher total phosphorus concentration possibly due to the high phosphorus contained in its sediments. The bacterial treatment products displayed the greatest reduction in total phosphorus over the shortest time period. Ammonium nitrogen decreased in all mesocosms as the water quality improved with the on-set of winter. This change in season masked assessing the full effects of the treatments and it is recommended that the trial be repeated for some or all treatments over a summer period when water quality becomes increasing worse.

Bacterial-enzyme concentrates showed proof of water quality enhancement although the other treatments did show some water quality gains. To more comprehensively trial one or several of these products a whole water body treatment is recommended. Sullivan Lake is a potential site for such a trial.

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Chapter 1: Introduction

Increased urbanisation, farming and even birds can decrease the quality of our lakes and streams by increasing the level of nutrients, particularly nitrogen and phosphorus, in the water. This can cause poor water clarity; scum and foams; unpleasant odours; and algae. Such water quality deterioration is often termed *eutrophication*, and is particularly brought about by an increase in nutrients, particularly nitrogen and phosphorus.

Better land management is one way to help improve or to stop our water bodies becoming *eutrophic,* but changes may take years to improve water quality. To help improve water quality in the short term, mechanical, chemical and biological methods have been used. The technology behind these methods continues to improve and expand and some methods have the benefit that they have little or no risk to the surrounding environment.

In the course of finding solutions to the remediation of lake water quality in the Bay of Plenty region, several treatment methods using environmentally friendly products chalk (BioAktiv), bacteria and enzymes, and Iron Making Slag have been made known to Environment Bay of Plenty. It was proposed to trial the effectiveness of some of these treatments in mesocosms situated in Sullivan Lake, Whakatane.

Treatment of Sullivan Lake, with bacterial solutions and other treatment products will be monitored to ascertain the effectiveness of the products to suppress blue-green algae growth and improve water quality. If found to be successful this treatment may have possibilities to treat other water bodies with similar water quality problems.

1.1 Treatments

1.1.1 Non-Pathogenic Microbial Enzyme Treatment

There are a range of microbes and enzymes discovered in the natural environment that perform essential activities in the aquatic environment to maintain a balanced system. In the natural environment, both bacteria and the enzymes they produce play a significant part in biodegradation. Bacteria produce the enzymes essential for metabolising the food source (organic material) into energy necessary for further growth of the living organism. The enzymes facilitate the phase of metabolism in which complex compounds are broken down into simpler ones (catabolism). This in turn speeds the process of converting the food source into available energy supply for the bacteria. By utilising this process the cellulose material of the blue-green algae would be broken down, with the additional benefits of a steady reduction of solids, biofilm and nitrates.

Biodegradation technology has been employed for many years in the waste water sector. Utilising synergized blends of scientifically selected and adapted bacteria, enzymes, and nutrients, wastes associated with domestic, municipal, commercial, and industrial waste systems are readily transformed to waters of an acceptable standard to be put back into the natural environment. Treatment of Sullivan Lake with non-pathogenic bacteria and enzymes will help to augment and accelerate natures own biodegradation process, resulting in the reduction of blue-green algae and improved water quality.

Three different products on available in New Zealand have been trialled. One treatment uses Expel's GT-900 Waste Degrader, consisting of nine bacillus strains of approximately 5 billon colony forming units per gram. These non-pathogenic bacteria come in their own nutrient solution to initially feed the enzymes with provide the initial food for the bacteria.

Microzyme Pond Treat from Biocare is another blend of naturally occurring, scientifically selected microbes and enzymes formulated to aid decomposition and digestion of the biomass that builds up on a pond or lake bottom (sludge). Six facultative and aerobic microbial cultures make up Microzyme Pond Treat which are selected to be effective over a range of substrates to produce the enzymes amylase, protease, cellulose, liginase, xylanase, pectinase, lipase and kerainase. These enzymes work to break down leaves, fertiliser and other runoff, fish and bird wastes, and other organic and inorganic material contained in sludge. The standard microbial count of Microzyme Pond Treat is around 2.0 billion cfu/g.

The third product is known as EM or Effective Micro-organisms.

How they Work

A period of time after introducing the specially selected bacteria into the lake waters, the spores will vegetate (go from dormant to active) producing specific enzymes, and degrade or digest the available organic material and seston. The introduced micro-organisms are capable of exponential growth, doubling their numbers every twenty to thirty minutes. Micro-organisms play a vital role in the normal biological cycle by converting soluble organic compounds into new bacterial cells and inorganic elements. This natural biological process provides conversion of waste organics (animal and plant life) to carbon dioxide and water.

These bacteria are naturally occurring strains found in soil and water. They have been selected because they are safe and stable; non-pathogenic; non-toxic; and facultative (capable of growth with or without oxygen) and are not genetically modified.

These products include basic spore forming, waste degrading strains of bacillus to reduce organic loadings in the water column, preventing a build up of sludge on the pond bottom. When used, the nutrients dropping to the pond bottom are so reduced that the anaerobic sludge dwelling bacteria is unable to form toxic hydrogen sulphide gas and sludge accumulations are reduced.

1.2 Mineral Treatments

1.2.1 BioAktiv

BioAkitiv supplied by Unitrade International is a chalk based product that has been modified by using bioresonnance. Adding BioAktiv to a water body introduces oxygen and causes aerobic bacteria to multiply. Carbon is consumed and carbon dioxide is released changing the pH of the water body reducing ammonia development. Continued oxygen enrichment slows anaerobic rotting (denitrification) while encouraging aerobic putrification.

BioAktiv being predominantly $CaCO_3$ is likely to bind with phosphorus (P) in the bottom sediments, and this may be permanent reducing internal phosphorus cycling.

It is assumed BioAktiv would introduce calcite crystals to the lake. Calcite crystals present a relatively large surface area for adsorption. Associated with phosphate adsorption onto calcite is the molecular exchange of $CO_{3\text{-}2}$ and $PO_{4\text{-}3}$ on the surface of growing calcite crystals as follows:

$3CO_3 - 2(S) + 2PO_4 - 3(L) <--> 3CO_3 - 2(L)+ 2PO_4 - 3(S)$

where S and L denote calcite and aqueous phases, respectively.

1.2.2 Iron Making Slag – New Zealand Steel Co-product

Slag is a non-metallic by-product or the iron making process. Iron Making Slag is made up of a range of oxides such as silicon, titanium and sulphur. An important slag parameter is the so-called basicity index. This is the ratio of the basic slag components such as CaO, MgO and FeO to the acidic slag components such as SiO_2, TiO_2, and Al_2O_3. The relative amounts of these oxides determine, to a large extent, the physical properties of the molten slag such as melting temperature, viscosity and fluidity which in turn determine its ability to remove impurities from the iron in the production of steel.

The chemical elements of the Iron Making Slag are sealed into the material through the iron making process and is material similar to synthetic manufactured zeolites. As such, the slag has properties similar to zeolites with a rigid three dimensional structure (honeycomb). It is this structure that allows water to move freely through a series of interconnected tunnels allowing the Iron Making Slag to act as a microsieve, allowing some positively charged ions to pass freely while trapping others. The material will have an affinity for ions such as ammonium and potassium.

Iron Making Slag is also likely to act as a natural flocculent reducing the amount of suspended particles in the water column. This will increase water clarity and allow sunlight to penetrate further allowing phytoplankton other than blue-green algae to benefit. As denitrification takes place nuisance algae will be eliminated in favour of less toxic algal species.

Iron Making Slag has been tested as roading, drainage and water treatment material since the early 1990’s. Filter beds containing the Iron Making Slag have been successful in phosphorus removal in several New Zealand trials. Other studies have found that pH may affect phosphorus adsorption and that release may occur at high and low pH values. Testing has also shown that some iron and manganese can leach from the slag in low pH conditions (Miller, 2005).

1.3 Sullivan Lake – Trial Location

Sullivan Lake situated in the Whakatane township (Figure 1) has generally poor water quality and is subject to algal blooms. Algal blooms can pose a serious health risk to recreational users of water bodies with algal blooms. This is primarily due to blooms of cyano-bacteria (a blue-green algae) that have the ability to release cyano-toxins which can cause dermatitis, hay fever like symptoms, gastroenteritis, nerve cell damage, and liver damage.

These forms of blue-green algae are found in Sullivan Lake due to its sheltered waters, shallow bathemetery, high nutrient loads, low flushing rates, and relatively high temperatures. Without any immediate change in a few of these factors influencing the habitat these algae thrive in, it is likely that blooms will continue to be persistent and that the Lake can pose a health risk to anyone using these waters. Decaying algae form putrid odours and luminous colours all of which negatively impact on community and cultural values.

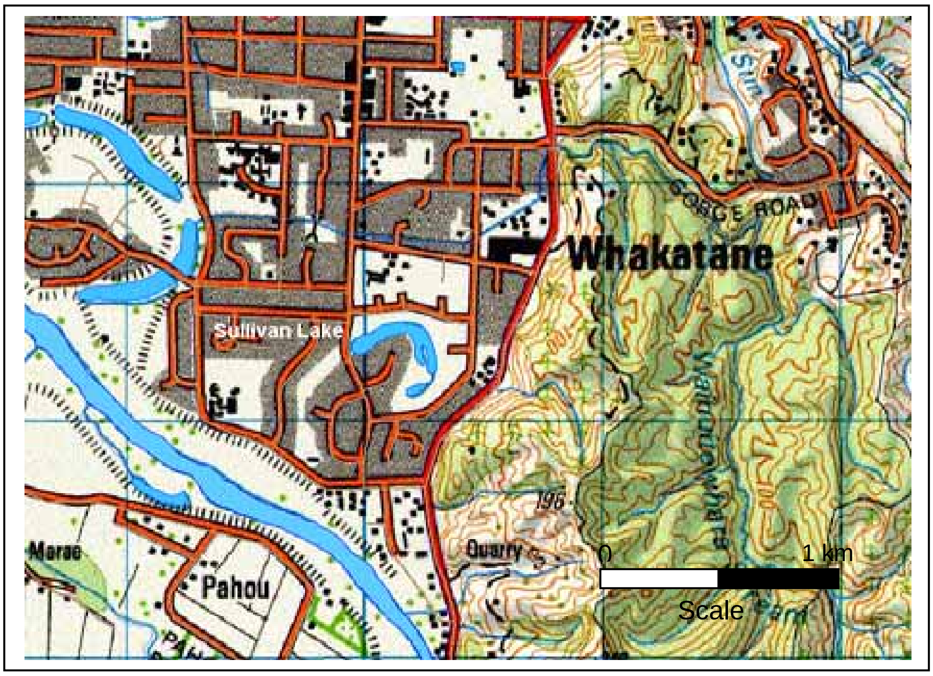


Figure 1 Location map of Sullivan Lake, Whakatane.

This project has been to trial water treatment products to improve the water quality of the lake thereby providing a mechanism to relieve the algal problem. These treatments if proved useful, may be able to be applied to other problem lakes in the Bay of Plenty region or wider New Zealand.

The Lake is recognised as a bird refuge, bird life being dominated by waterfowl. Mosquito fish, goldfish (Carassius) and eels are contained in the waters. Most of the lake substrate is devoid of macrophytes although floating sweetgrass (Glyceria fluitans) and Egeria densa exist around the lake margins.

1.3.1 Water Quality

Current water clarity has been measured at the lake outlet as turbidity. With a median turbidity of 22 NTU and a similar mode, a reduction of turbidity to 10–15 NTU or under for a period of several weeks not including increase due to stormwater runoff, would signal an improvement in turbidity, water clarity and a reduction in the algal population. Turbidity information would be supplemented by water transparency data taken before and after the treatment. A 50% change in transparency would also be a measure of a successful water quality improvement.

A change in the nutrient balance in a water body is necessary to achieve a sustained change in the phytoplankton regime of a water body. Total phosphorus (TP) concentrations have a statistically significant correlation with chlorophyll *a* concentrations ($p<0.001$, $r=0.766$, $n=63$) and therefore a reduction in TP is likely to impact on chlorophyll *a* levels.

The internal P cycling within the lake has not been measured so the interchange of P in the sediments and water column is unknown. However a successful outcome would be to reduce the P as seen in the water column to levels representative of a healthier water body. Average total phosphorus concentrations of 0.03 – 0.05 g/m3 over the summer period would constitute such an improvement as a result of treatment. However, dependant upon the P load in the sediments and the depth of organic build up such an improvement may not be possible with the proposed dosing regime. A summer average of under 0.10 may be a more realistic goal for this trial.

Algal change Sampling of algal species in December 2003 (Table 1) found a variety of cyano-bacteria species with total cell counts over 400,000/ml. One goal would be to bring cyano-bacteria into safe recreational water quality limits: i.e. below 15,000 cells/ml.

Table 1: Algal species and cell counts, Lake Sullivan

Lake	Date	Species	Individual Counts (cells/ml)
Sullivans Lake	17-Dec-03	A. planktonica	175
Sullivans Lake	17-Dec-03	A. spiroides	15174
Sullivans Lake	17-Dec-03	M. aeruginiosa	349669
Sullivans Lake	17-Dec-03	A. circinalis	21504
Sullivans Lake	17-Dec-03	M. flos-aquae	16542
		Total	**403064**

Ideally chlorophyll *a* concentrations would remain below the current median of 64.2 mg/m^3 (Table 2). The highest Rotorua lake chlorophyll *a* concentration was 57.7 mg/m^3 at the height of the algal bloom. Concentrations in Sullivan Lake are much higher. Keeping chlorophyll *a* levels below 50 mg/m^3 would be a great improvement, although this is unlikely to achieve the safe algal cell count.

Table 2 Lake statistics from September 2001 to June 2003

	Turbidity NTU	pH	Chla mg/m^3	NH_4N g/m^3	NOxN g/m^3	DRP g/m^3	TP g/m^3
Mean	28.8	8.31	98.86	0.0406	0.0222	0.0147	0.162
Median	22	8.39	64.20	0.013	0.01	0.012	0.148
Mode	22	7.5	130	0.005	0.0005	0.008	0.141
Standard Deviation	34.4	0.76	130.09	0.0581	0.049	0.0110	0.074
Minimum	7.3	6.87	6.90	0.001	0.0005	0.004	0.013
Maximum	265	10.10	992	0.288	0.325	0.07	0.475
Count	59	70	70	70	55	69	64

Chapter 2: Methods

To test the effectiveness of each of the treatments rather than trialling treatments under laboratory conditions it was decided that the treatments needed to be proven in the field. Sullivan Lake was determined to be a good testing ground as the water body is hypertrophic, had existing water quality data, has frequent blue-green algal blooms, is shallow and easily accessible.

Mesocosms are used to provide a cost effective low risk method of determining the effectiveness of the treatment products.

Seven mesocosms were situated within Sullivan Lake to trial the range of water treatment products made available to Environment Bay of Plenty (Figure 2). Mesocosms were constructed with 2 µm thick clear agricultural quality polythene attached to 1 mm thick x 100 mm wide rigid plastic which would be inserted into the lake bed sediments. The resulting polythene tube would rise above the lake level and is attached to stakes to maintain position to provide a column of lake water partitioned off from the main body of the lake. On average the mesocosms had a circumference of 5.3 m with and a depth from 1.10 m to 1.22 m.

The mesocosms were dosed with selected products according to the manufacturers/suppliers specifications to prevent and inhibit the growth of cyano-toxic blue-green algae and to improve water quality. Dosing and product details are in Table 3.

Figure 2 Mesocosms before installation (right) and mesocoms installed in Sullivan Lake.

Table 3 Treatment dose rates and application methods.

Treatment	Recommended Dose	Application
Microzyme pond treat	Week 1: 100 g Week 3: 80 g Week 5: 60 g Week 7+: 50 g	Sprinkle over water surface
GT-900	Initial shock dose of 115 mls 60 mls every three days there after	Add to 5-10 litres of water leave for half an hour then add to water body
BioAktiv	Initial dose 90 g then as required (1 kg of BioAktiv for 200-300 m^2 of water body)	Add to water to form well mixed slurry then add to water body
Iron Making slag	Initial dose 100 g then as required	Sprinkle over water surface
EM	2 mud balls/ solution added later	Drop mud balls in water body

Two mesocosms were used as controls and the other five provided receptacles for treatment. Only five mesocosms were initially installed with the final two mesocosms installed several weeks later, one being treated and the other becoming a control.

Monitoring of the mesocosms was initially undertaken every two or three days for the first two weeks and then weekly to two weekly thereafter. Monitoring was usually undertaken between 10 00 a.m. and 12 00 a.m. One metre integrated tube samples were taken from the surface and instrument readings were taken at an approximate depth of 0.5 metres.

Field measurements included: water clarity by secchi disk; pH and conductivity by YSI meter; dissolved oxygen and temperature by YSI meter.

Samples were taken less frequently than field measurements and were analysed for: alkalinity; pH; BOD5; conductivity; suspended solids; turbidity; fluorescence; dissolved reactive phosphorus (DRP); total phosphorus (TP); total kjeldahl nitrogen (TKN); ammonium nitrogen (NH_4N); oxides of nitrogen (NOxN); and chlorophyll *a*.

The following methods were used to derive the results from the field sampling. All samples for chemical analysis were stored and returned with the time period stipulated according to the method requirements.

After completion of mesocosm monitoring and upon removal of mesocosms core samples of mesocosms were taken and the top 10 cm were analysed for nutrients and carbon content.

Table 4 Methods used for chemical / biological analysis.

Parameter	**Method**	**Detection Limit**
Suspended Solids	APHA method 2540D	0.1 g/m^3
Total Organic Carbon	Catalytic oxidation, IR detection. APHA 5310B 20th ed. 1998	0.5 g/m^3
Total nitrogen	Persulphate digestion, auto cadmium reduction, flow injection analyzer	1 mg/m^3
Ammonium nitrogen	NWASCO Misc Pub. No. 38, 1982. phenol hypochlorite colorimetry	1 mg/m^3
Oxidised nitrogen	Flow injection analyser, APHA 4500 NO3-1	1 mg/m^3
Total Phosphorus	Acid persulphate digestion, molybdate colorimetry. Flow injection analyser. APHA 4500-PH	4 mg/m^3
Dissolved Reactive Phosphorus	NWASCO Misc Pub. No. 38, 1982. Antimony – phosphate – molybdate	4 mg/m^3
Secchi disc	Measured in metres	(to 0.1 m increments) without a viewing tube
pH	APHA Method 4500 H+	pH measurement @ 25oC
Chlorophyll-a total filterable	Total phytoplankton filterable on 0.7µm and above, GFC filtration, acetone pigment extraction, spectrofluorometric measurement	0.1 mg/m^3
Conductivity	YSI Conductivity meter 33 @ 25 deg C	
Total Recoverable Phosphorus	Nitic/hydrochloric digestion ICP-MUS USEPA 2002	40 mg/kg-DW

Chapter 3: Results and Analysis

Installation of the mesocosms occurred at the end of severe blue-green algal blooms occurring in the lake. With the onset of autumn the lake went through a period of lower temperatures and consequently lower phytoplankton productivity and thus an improvement in water quality. In mid May an intense rainfall introduced high sediment levels to the lake.

The seams of mesocosms after a month in the water were beginning to fail. It is difficult to estimate how much interchange was occurring between the mesocosms and the lake at this time.

Mesocosm 5 was, in the writer's opinion, overdosed with EM solution turning the mesocosm a distinct brown colour. The mesocosm remained this brown colour for at least 16 days, after which time leakage occurred and colour was lost. It would seem the EM solution attracted an eel into the mesocosm. The eel was found dead, probably due to low oxygen levels in the system and the eel not being able to find its way out of the mesocosm. Little appreciable change was observed in mesocosm 5 probably due to the high dosage of EM solution and for that reason results will not be discussed in detail. The reader can examine the data in Appendix II.

A record of dosing and observations is tabled in Appendix I. Results are discussed on a parameter by parameter basis initially.

3.1 Water Clarity

Water clarity is measured by secchi disk and turbidity. Secchi depth was measured more frequently than turbidity, turbidity only being measured when mesocosms were sampled. Figure 1 displays the seechi depths and turbidity recorded over the length of the trial.

It took about nine to ten days for the treatments to have some effect on water clarity. Comparison with the control mesocosm, once changes occurred, indicates the improvement in water clarity for some treatments were dramatic. However, there was not much actual change from the lake water clarity, although initially chlorophyll *a* levels were higher in the mesocosms as is demonstrated below (section 3.5). Treatments appeared to continue to improve water clarity in their respective mesocosms until the beginning of May. At this time it appears that due to leakage, lake water was integrating with the mesocosm water. This can be seen by all mesocoms following a similar trend from that point forward (Figures 3 & 4). Only the Iron Making Slag and GT-900 treated mesocosms survived after the storm event in mid May with minimal leakage, and while the lake showed no real improvement in secchi depth, the two surviving mesocosms do show some improvement.

Turbidity (Figure 3) shows a similar pattern to secchi depth, accept that the control mesocosm retains a longer constant turbidity compared to secchi depth. Turbidity increases when treatment products are added to the mesocosms, particularly the BioAktiv, due to the flour like composition of this agent. Microzyme's turbidity, like secchi depth, shows the most rapid decrease. All treatments showed an improvement in turbidity until the mesocosms started leaking at which time turbidity decreased.

Figure 4 displays the percentage difference in secchi depth between treated mesocosms and the control. Two comparisons are made, one between the control mesocosm and the treated mesocosms and the other between the initial water quality at the start of the trial and detailing progress as the trial proceeds. Comparison with the control indicates the Microzyme treatment to have responded most consistently and achieve the greatest water clarity, however comparison of the change in secchi depth from the start of the trial indicates GT-900 to have preformed the best overall.

As the mesocosms start leaking around day 29, the steady improvement in the control mesocosm's water clarity appears to accelerate indicating that the phytoplankton rich water in the mesocosm is exchanging with the clearer lake waters. Phytoplankton numbers are also dwindling due to the lower temperatures with the onset of winter.

Both graphs in Figure 4 also show that after day 29 the control mesocosm starts to have water clarity similar to the other mesocosms. This again demonstrates the impact of the interchange with lake water when the integrity of the mesocosms was disrupted. However, more importantly it demonstrates the ability of these treatments to make rapid gains in water clarity in a relatively short period.

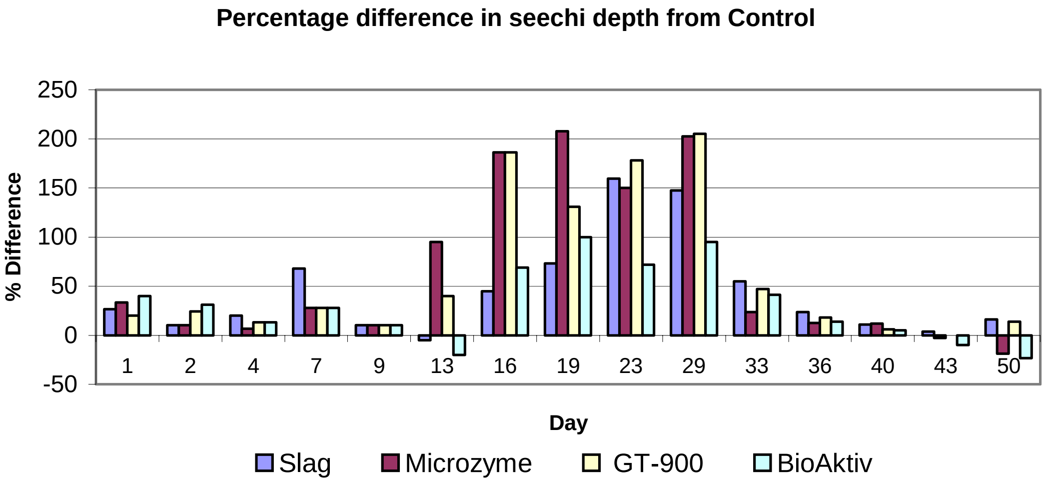


Figure 3 Seechi depth and turbidity in mesocosms and Lake Sullivan

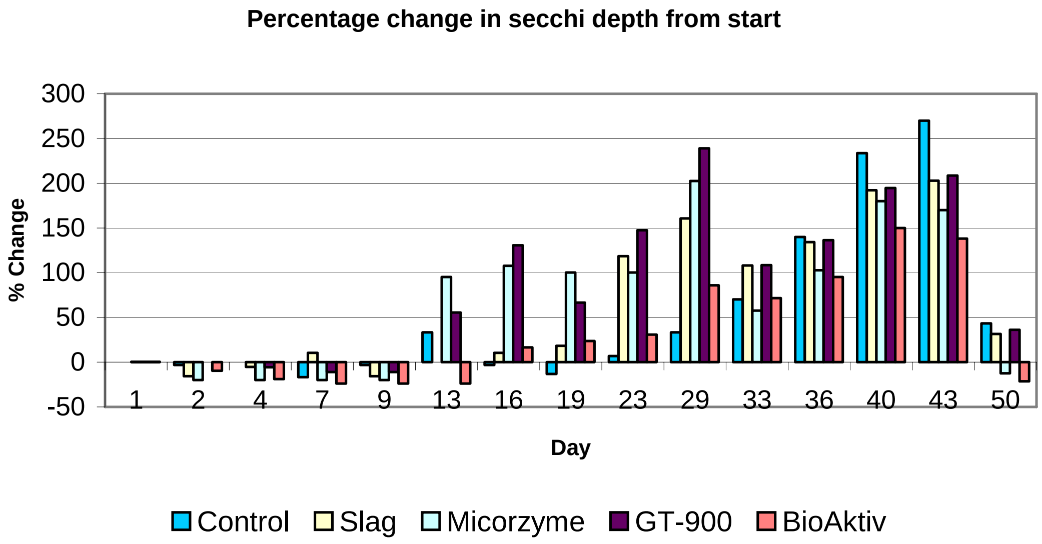


Figure 4 *Percentage change in secchi depth from the control mesocosm and from the beginning of the trial.*

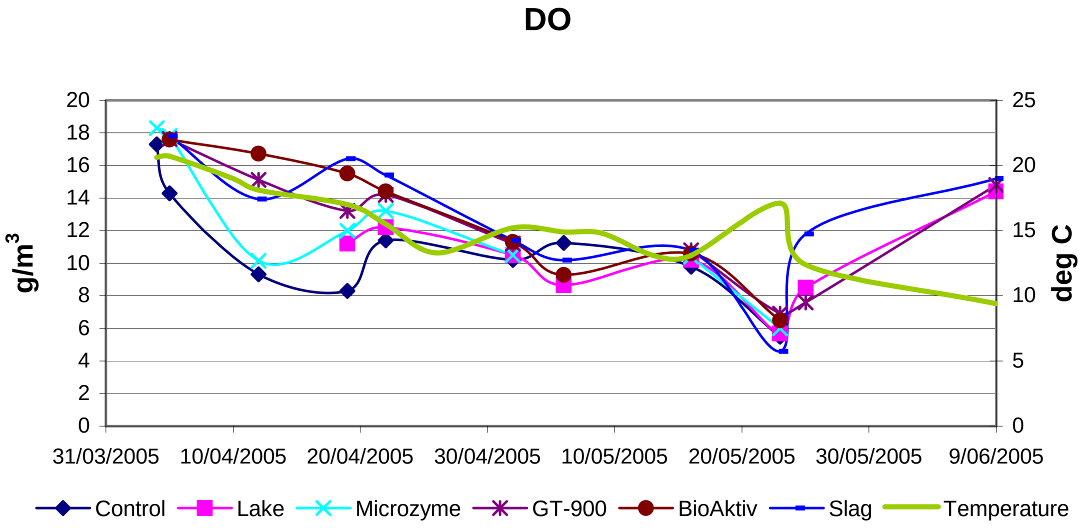
3.2 Oxygen

The mesocosms treated with BioAktiv consistently had the highest dissolved oxygen (DO) concentrations, with the Iron Making Slag treated system being slightly higher before leakage occurred (Figure 5). Once the mesocosms were infiltrated by lake water DO concentrations became very similar.

Biochemical oxygen demand (BOD_5) remained similar for most mesocosms. Interestingly enough the BioAktiv treated system had the highest BOD_5 along with the highest DO concentrations. This mesocosm also had high algal biomass as shown below in the chlorophyll *a* concentrations (Figure 7) which may have impacted on the DO and BOD_5 results.

DO shows a general decline in most mesocosms even with a consistent decrease in temperature. Slag and Microzyme treated mesocosms do show some initial increase in DO concentrations before the systems started leaking.

Mesocosms were monitored for stratification. Only the control mesocosm displayed some signs of stratification with the bottom three centimetres dropping from 10.8 g/m^3 to 4.6 g/m^3 and below.



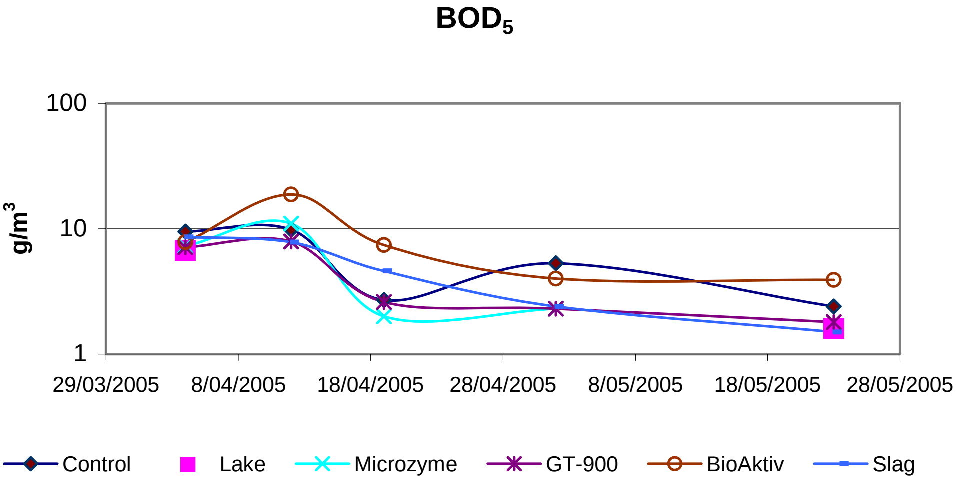


Figure 5 *Dissolved oxygen concentrations and BOD$_5$ in mesocosms and Sullivan Lake.*

3.3 Conductivity and pH

The largest change in pH and conductivity was experienced in the mesocosm dosed with BioAktiv. As BioAktiv is primarily calcium carbonate this is not an unexpected result. The pH did improve with treatments, although lake water also generally moved from alkaline towards neutral. A neutral pH is observed with the influx of stormwater to the lake and subsequent mixing with the leaking mesocosms on the 23 July.

While conductivity slowly increased in the mesocosms, the mesocosm treated with Slag had the lowest conductivity. This is not unexpected as the Slag will have high cation exchange capacity and acts as microsieves trapping positively charged ions.

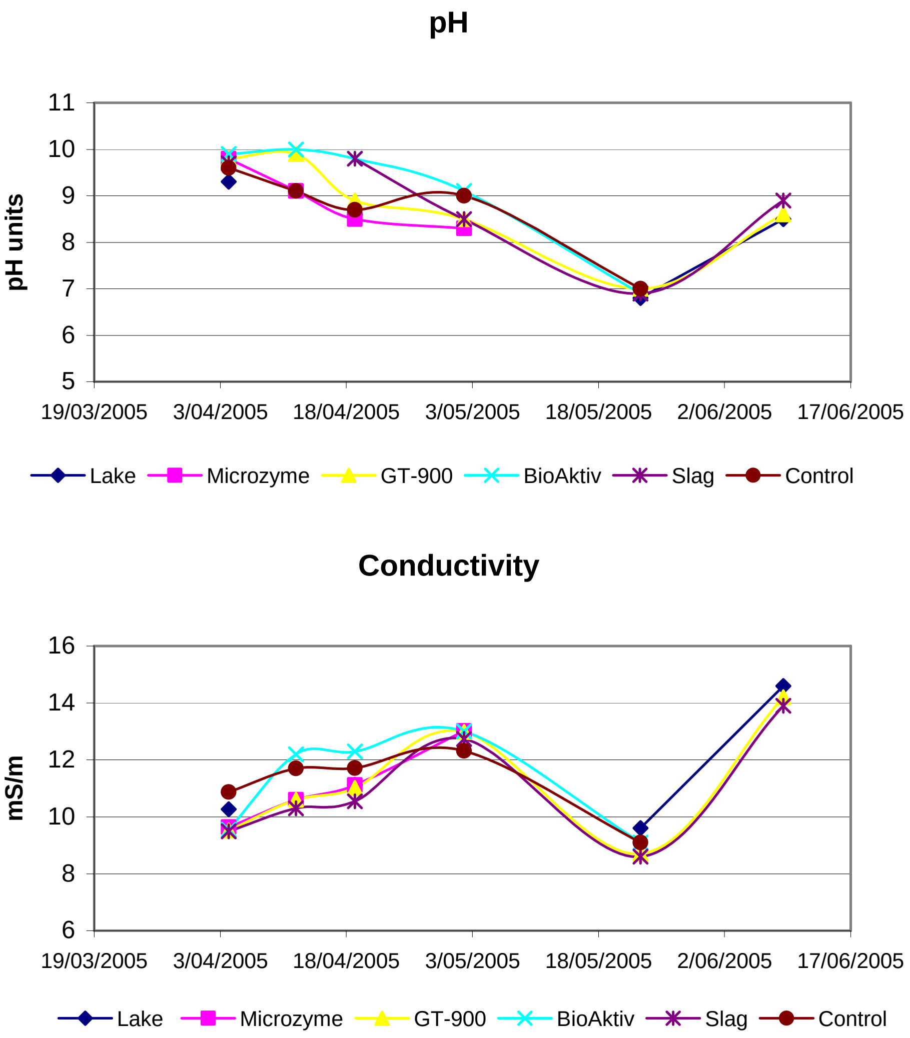


Figure 6 Conductivity and pH in mesocosms and Sullivan Lake.

3.4 Nutrients

Figure 7 displays changes in nutrient status of the mesocosms before they began exchanging with lake water.

Concentrations of total phosphorus (TP), dissolved reactive phosphorus (DRP), and oxides of nitrogen (NOxN) in treated mesocosms are similar before treatment. The control mesocosm has much higher phosphorus levels than the other mesocosms before treatment began. This is likely to be due to the earlier installation date of the control mesocosm and possible nutrient release from anoxic sediments.

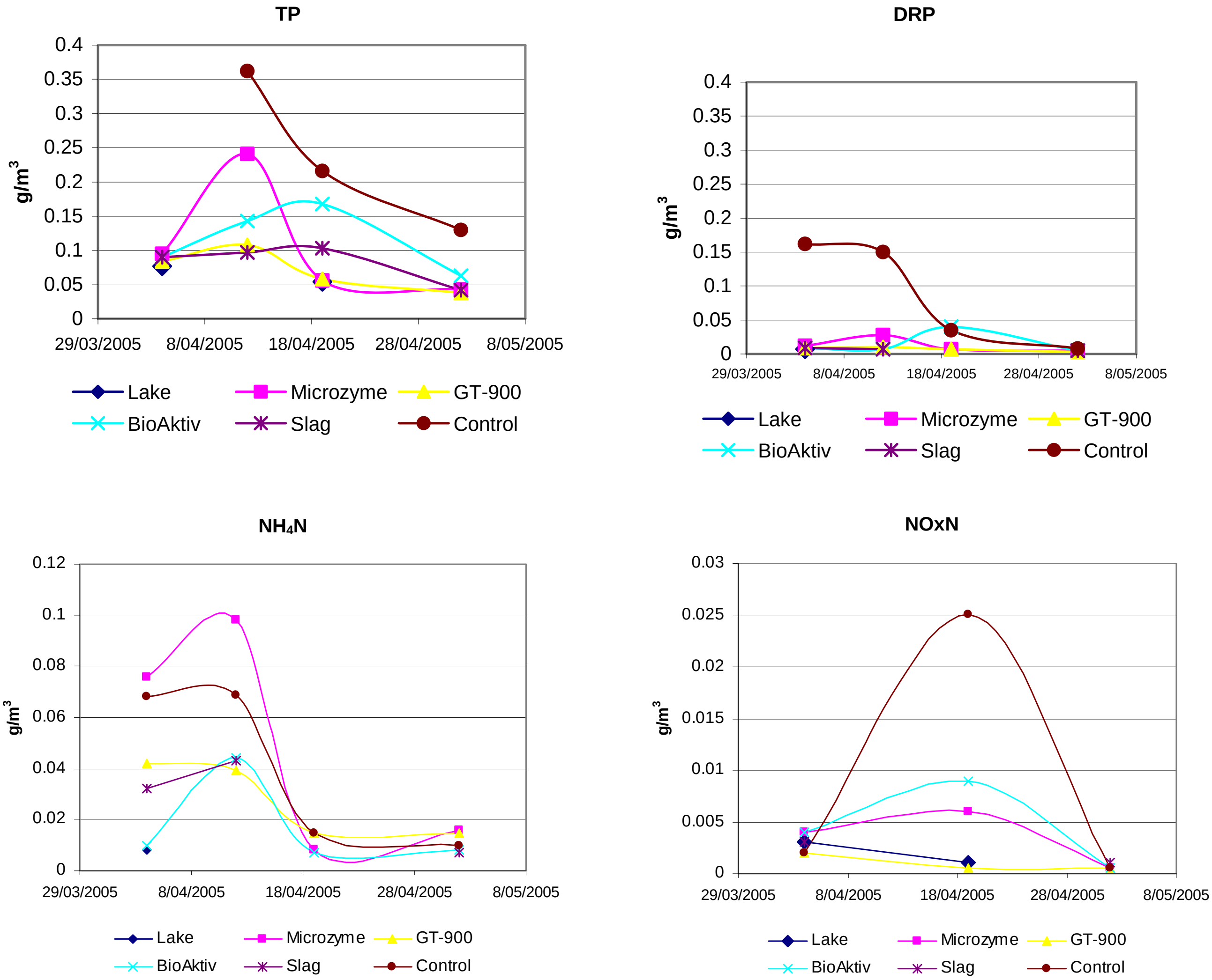


Figure 7 Nutrient concentrations in mesocosms and Lake Sullivan.

Phosphorus levels started to decease in the control mesocosm as algal die-off occurred with the onset of winter. The treated mesocosms continued to have unchanged or increased phosphorus levels soon after treatments were added and this seems to be directly related to algal concentrations. Correlation between TP and chlorophyll *a* of the four treated mesocosms shows a good relationship (Pearson r=0.763, p<0.001, n=18), although such a relationship does not exist between DRP and chlorophyll *a*. Concentrations of DRP in the treated mesocosms are low throughout the sampling period unlike the control mesocosm. The control mesocosm had an initially high DRP concentration, which decreases as chlorophyll *a* concentrations decrease. Why there is such a variation in DRP between mesocosms may be a due to the control mesocosm being installed slightly earlier than the treated mesocosms and consequently an increase in DRP generated from the sediments has occurred. The sediments in the control mesocosm had a higher total recoverable phosphorus than the other mesocosms (Figure 9).

Comparison of the changing nutrient status of the mesocosms for ammonium nitrogen is difficult to make due to the variation between mesocosms (Figure 7). Variation may be due to differences in disturbance of the sediments on installation of the mesocosms and subsequent ammonium nitrogen release. However, there is a general reduction in ammonium-nitrogen in all mesocosms by day 16 of the treatment. The control showed a reduction in ammonium nitrogen, with only the mesocosm treated with Microzyme showing a greater reduction before leakage compromised the mesocosms. Unfortunately a crucial result for the slag has not been analysed.

As ammonium nitrogen decreased in the control mesocosm at day 16 of the trial, nitrate nitrogen increased, probably as a result of nitrification. The microzyme treated mesocosm, which had a higher ammonium nitrogen concentration than the control mesocosm before day 16, had a much reduced nitrate nitrogen concentration at day 16. As the chlorophyll *a* concentration in the Microzyme treated mesocosm was the lowest of all the mesocosms at day 16 (as well as total nitrogen concentration) it is likely that nitrification-denitrification occurred releasing nitrogen to the atmosphere. This may have also occurred to some extent in the other mesocosms, but as ammonium nitrogen levels were initially much lower and total nitrogen is higher any gains from treatment are difficult to ascertain.

3.5 Chlorophyll *a*

Algal concentrations, as indicated by chlorophyll *a* concentrations, were much higher in the control mesocosm than other mesocosms before treatment began (Figure 8). This is likely to be due to elevated nutrient concentrations in the mesocosm and the earlier installation time allowing algae to proliferate. After treatment, water temperature started to drop and this decrease also occurs with chlorophyll *a* concentrations in the control mesocosm.

Two treated mesocosms have a decrease in chlorophyll *a* greater than that seen in the control mesocosm, the Microzyme and GT-900 treated mesocosms (Figure 8). Both the Microzyme and BioAktiv treated mesocosms initially had an increase in chlorophyll *a* concentrations, where as the Slag treated system increased in chlorophyll *a* 16 days after treatment, while all other mesocosms decreased in chlorophyll *a* concentration.

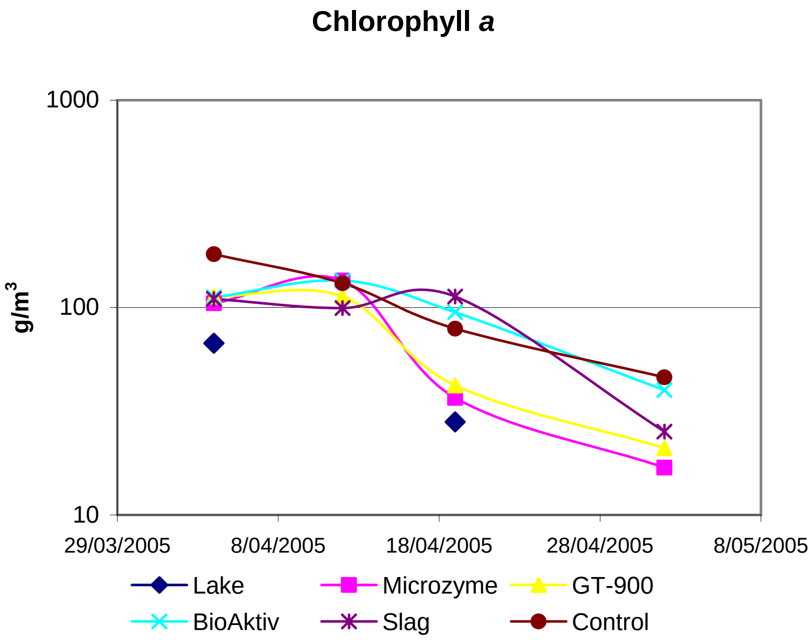


Figure 8 Chlorophyll a concentrations in mesocosms, Lake Sullivan.

3.6 Sediments

All of the treated mesocosms have less nutrients (N & P) and total organic carbon (TOC) than the control mesocosm at the end of the trial (Figure 9). The control did however have lowest percentage dry matter (DM) of all the mesocosms, with a high concentration of total recoverable phosphorus (TRP) compared to the other mesocosms.

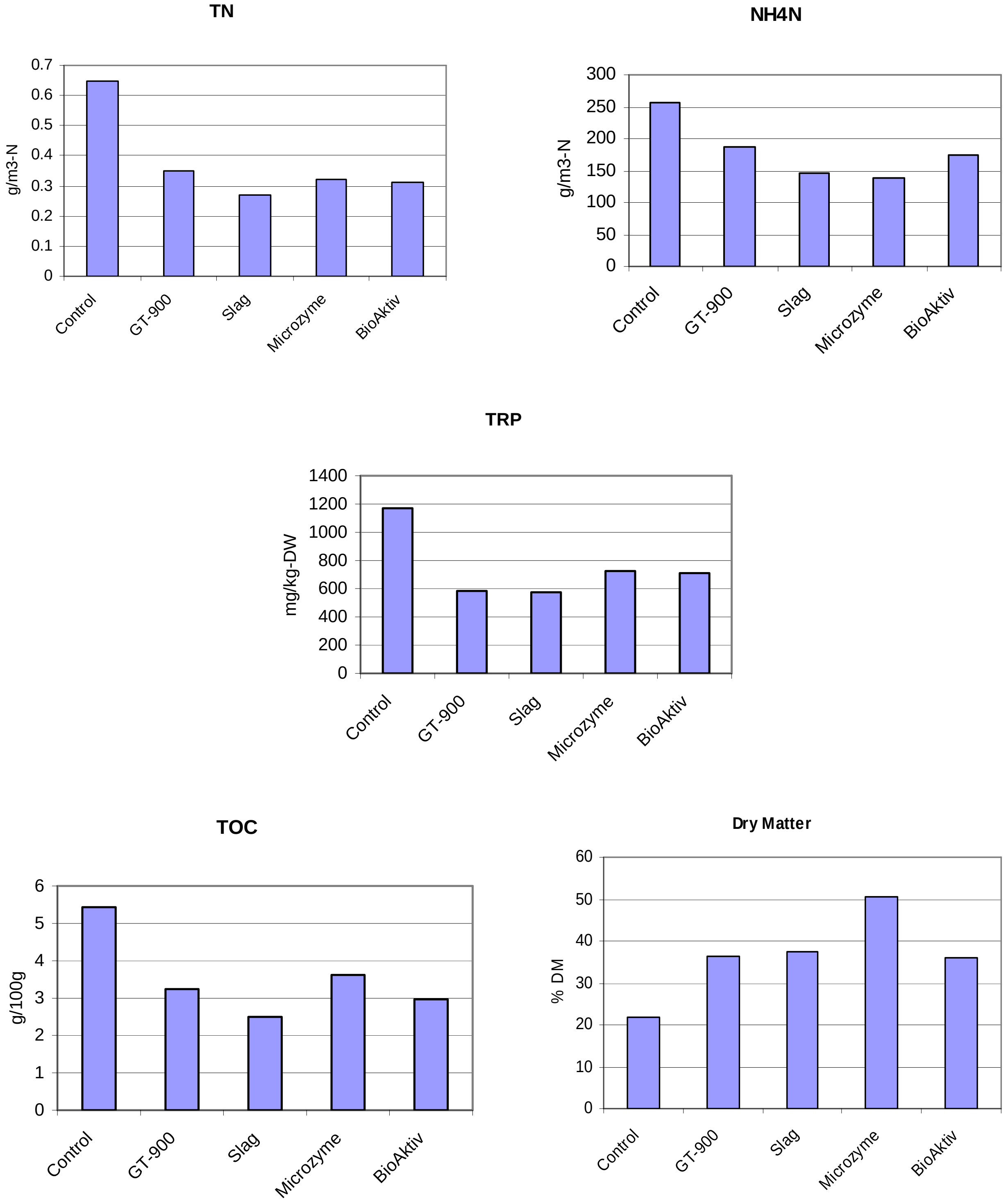


Figure 9 Total nitrogen (TN), ammonium nitrogen (NH_4N), total recoverable phosphorus (TRP), total organic carbon (TOC) and dry matter results for sediments in mesocosms, Sullivan Lake.

TOC concentrations correlate well with TN, NH_4N and TRP. The Microzyme treated mesocosm does show a lower relative NH_4N concentration to TOC and the GT-900 treated mesocosm has the same relationship for TRP. As there were no replicate mesocosms it is difficult to say whether these differences are due to treatments or are a result of variations in the sediment. The control mesocosm does display the greatest organic load as expressed by the TN and TOC, which does tie in with the greater phytoplankton mass observed in the control mesocosm (Figure 8). This does suggest the treatments had some impact on the water quality by reducing biomass and NH_4N concentrations. However, the sediment sample in the control mesocosm had a larger wet mass along with a higher TOC, therefore NH_4N generation may be higher than the other mesocosms.

Chapter 4: Cost Analysis

An estimation of cost for treatment of Lake Sullivan is given in the table below.

Treatment	Annual Treatment Cost	Annual Treatment Quantity
Microzyme	$14,500	15 pails (25x 450g Pouches)
GT-900	$15,000	2200 litres (summer dosing)
BioAktiv	$16,500	235 kg BioAktiv
Iron Making Slag	$76	1.9 tonne (1 dose only)

Note: costs are estimates only

These costs don’t take into account labour and applications costs associated with delivering the dosage to the water body. Applications costs will vary markedly, as a treatment such as iron making slag needs to be even applied over the entire surface of the water body for maximum effect compared to a product such as the Microzyme pouches, which can be easily tossed into the water body in a few locations.

It is difficult to estimate what the cost of treating larger water bodies, such as one of the degraded Rotorua Lakes, is with one of these treatment solutions due to the changing economies of scale. That is that with using a large quantity of a commercial product the price could dramatically decrease. Iron Making Slag and other zeolite products do have a consistent tonnage price with transportation costs then becoming a factor.

To give an estimation of the scale of cost on larger water bodies, a cost estimate for a three to five year programme of treating Lake Rotoehu with a bacterial liquid concentrate, batch brewed on site (product not tested in this trail), was estimated at $700,000 including labour.

Chapter 5: Conclusion

To constitute a successful outcome in the testing of several ‘environmentally friendly’ water treatment products, a recognisable gain in water quality parameters is called for. A gain in water clarity and dissolved oxygen, reductions in nutrients and chlorophyll *a* concentrations, and a shift in pH are all possible measures of water quality improvement.

In the trial of four different water treatment products in mesocosms situated in Sullivan Lake, all products displayed an improvement in water clarity in comparison to a control mesocosm. Microzyme and GT-900 achieved a 200% greater water clarity than measured in the control mesocosm. Turbidity, another measure of water clarity, also decreased from greater than 20NTU to 10NTU and under in some cases.

Dissolved oxygen levels in the mesocosms generally decreased as the trial progressed. Mesocosms were initially supersaturated with oxygen due to the higher algal content and warmer temperatures. As temperatures dropped with the change in season, algae levels decreased as did dissolved oxygen concentrations. Due to the effect of algae on oxygen concentrations and the fact that dissolved oxygen was measured at height of algal photosynthetic exposure, dissolved oxygen was not a useful indicator of performance of the treatment products in this trial. However, the mesocosm treated with Microzyme initially developed an oxygen sag, which is likely to be the result of microbial functioning.

Changes in biochemical oxygen demand (BOD_5) were fairly similar for most treated mesocosms, with only the mesocosm treated with BioAktiv showing a higher BOD_5 than both the control and other treated mesocosms. This could be due do the greater phytoplankton content of this mesocosm. The other treated mesocosms had a significantly lower BOD_5 than the control mesocosm by day 16 of the trial, indicating some level of treatment had occurred.

The effect of the change in seasons was evident in the mesocosms, indicated by the correlation of changing chlorophyll *a* concentrations with temperature. TP also had a good correlation with chlorophyll *a* in the treated mesocosms. The mesocosms treated with Microzyme and GT-900 had the greatest reduction in chlorophyll *a* and also achieved the lowest TP concentrations in the shortest time. Total phosphorus was much higher in the control mesocosm than the treated mesocosms and this may have been in part due to the higher total recoverable phosphorus concentrations found in its sediments.

Other nutrient data has not been as revealing as the TP concentrations. Ammonium nitrogen concentrations reduced in all mesocosms to a similar concentration, while nitrate nitrogen increased in all mesocosms except for the GT-900 treated mesocosm. Dissolved inorganic nitrogen concentrations only reduced to low levels when phytoplankton levels decreased. The mesocosm treated with Microzyme looks as though it may have had a net nitrogen loss within the water column as the initially high ammonium nitrogen concentrations reduced without a large increase in nitrate nitrogen, when compared to the control mesocosm. This is likely to be due to the bacterial treatment, as nitrifiers introduced to the system function to recycle nitrogen contained in the water column. All treated mesocosms had lower nutrient levels in their sediments than the control mesocosm suggesting some level of treatment occurred in sediment water interface and that naturally occurring bacteria are being aided by treatments other than bacterial augmentation.

The mesocosms treated with bacterial mixes (Microzyme and GT-900) performed best when it came to the greatest reduction of phytoplankton, as measured my chlorophyll *a*. This analysis concludes that the bacterial mixes of GT-900 and Microzyme were the most effective water quality restoration at the respective dosage quantities used in this trial.

The other treatments of Iron Making Slag and BioAktiv did not appear to be as effective in terms of water quality restoration as the bacterial mixes, although some water quality gains were made. The trial was only successfully implemented for around one month, so any further dosing or improvements in water quality that may have come with a longer (successful) trial period are not seen. Also the added complication of the transition of summer to autumn impacting water quality has made conclusions on the success of treatments all the more difficult. Ideally any future trial run in Sullivan Lake with similar mesocosms would start in spring and run over the summer period when the lake is under more ecological stress.

Chapter 6: Recommendations

A repeat of the trial that was performed in Sullivan Lake in 2005 would be recommended to further test the performance of water treatment products. Improvements on mesocosm design and running a trial over the spring to autumn period, as well as changes to the sampling regime would provide better data on the treatment products.

An option would be to trial only the better performing treatments found in this research (bacterial treatments) with replicates.

As bacterial treatment methods are non-toxic, non-pathogenic, natural water treatments that augment existing bacteria and help with nutrient and carbon cycling, thus limiting available food for blue-green algae as well as breaking down the algae themselves, further trialling or investigation is warranted.

The extent and role of bacterial communities within water bodies is not well known. However, it is likely that naturally occurring bacterial communities are also being impacted by nutrient loading and changes in algal communities. Hence, using bacteria to eliminate algal blooms and utilise excess nutrients can help restore other aquatic communities including the natural bacterial ones.

Two types of bacterial treatments were trialled in this research and as the trial was of a limited period and a relatively small water quantity was treated it is recommended that a larger trial be carried out on a larger water body for a year long period. Sullivan Lake is such a potential water body given its size, body of historic water quality data and a community desire improved water quality. The downside of Sullivan Lake as further testing ground is the impact of stormwater flows during heavy rainfall periods. These have the potential to significantly impact the system.

From a cost perspective either of the bacterial treatments used in the research would be of a similar cost for lake-wide treatment of Sullivan Lake, however the GT-900 used a more intensive dosing regime than the Microzyme and therefore is likely to be more costly.

The Iron Making Slag is being trialled in other stream and lake trials. As it is a low cost treatment and dependant on the outcome of current research being undertaken (Lake Okaro mesocosm trial), treatment of an entire water body may be an option to further trial the usefulness of this product.

Chapter 7: References

Miller, N., 2005: Locally Available Adsorbing Material, Sediment Sealing and Flocculants for Chemical Remediation of Lake and Stream Water. Report prepared for Environment Bay of Plenty by Analytical & Environmental Consultants.

Appendix

Appendix I	Mesocosm Timetable and Observations
Appendix II	Monitoring Data

Appendix I – Mesocosm Timetable and Observations

Date	Activity	Observations
10/03/05	Control mesocosm installed	Algal blooms prevalent in lake
18/03/05	Sludge sample for EM obtained	
31/03/05	4 mesocosms installed	Control mesocosm has already obtained a stronger algal growth than experienced in lake. Control bailed out to remove algal growth.
04/04/05	Monitoring/sampling of mesocosm and mesocosms receive first doses	All mesocosms have high turbidity with a grass green colour with algae visible before dosing. After dosing Mesocom 4 (BioAktiv) turns a milky green and becomes more turbid, the finer powders sprinkled on mesocosms 2 & 6 float on the surface.
05/04/05	Monitoring	Little change in mesocosms from the previous day, still grass green with visible algae. Mesocosm 4 is slightly more turbid and the powder on mesocosms 2 & 6 has disappeared.
07/04/05	Monitoring, GT-900 dose	Mesosoms turbid, grass green with visible algae – no real change.
10/04/05	Monitoring, GT-900 dose	Mesosoms turbid, grass green with visible algae – no real change.
11/04/05	Monitoring	All mesocosms a pea green colour with strong visible algae.
13/04/05	Monitoring, GT-900 dose, Zeolite 100g	All mesocosms a pea green colour with strong visible algae. More accumulated leaf litter in lake.
16/04/05	Monitoring, GT-900 dose	Control mesocosm has a thick layer of algae on surface. Mesocosm 2 is green with visible algae and improved water clarity. Mesocosm 3 & 4 are green and very turbid with visible algae. Mesocosm 6 is brown-green, visible algae and turbid.
19/04/05	Monitoring, GT-900 dose Install mesocosms 1 & 5	Control mesocosm has a thick layer of algae on surface. No change in mesocosm 2. Algae appears more intense in 4 & 6.
22/04/05	Monitoring, GT-900 dose, 4 EM mud balls added to mesocosm 5	No change.
26/04/05	Monitoring, GT-900 dose, 75g Microzyme	Seem splitting on mesocosm 6 – some leakage. White swans found dead, take sample for algae toxicity testing. Contol sahows no change with thick surface algae. Other mesocosms show some improvement as dose the lake apart from mesocosm 4 which still has thick algae near surface.
29/04/05	Monitoring, GT-900 dose	Mesocosms 3,4 & leaking able to repair 3 & 6. mesocosms 1 & 5 green, turbid with visible algae.
02/05/05	Monitoring, GT-900 dose	
06/05/05	Monitoring, GT-900 dose	Mesocosm 2 leaking. Mesocosms 1 & 5 green with strong algal growth. Other mesocosm have a similar brown-green colour to the lake.
09/05/05	Monitoring, GT-900 dose, EM solution 3.8L	Algae obvious in all mesocosms and in lake. Control has thick algae at surface.
13/05/05	Monitoring, GT-900 dose	Control also leaking. Water clarity improved in control, 2, 3,4 & 6 with seechi disk to bottom on 2,3,6 & lake. Mesocosm 1 is green with visible algae. Mesocosm 5 is brown due to dose solution.
16/05/05	Monitoring, GT-900 dose	Seechi disk to bottom on 2, 3 & 6. Mesocosm 1 is green with thick visible algae. Mesocosm 5 is brown due to dose solution.
18/05/05	Observation after heavy rain	Control mesocosm over topped due to lake level rise. High suspended sediment levels in lake, brown in colour.
20/05/05	Observation after heavy rain	High suspended sediment levels in lake, brown in colour. Mesocosms generally look ok.
23/05/05	Monitoring, GT-900 dose	Mesocosm 1 leaking. Mesocosm 5 still a dark brown colour from dosing. High suspended sediment levels in lake, brown in colour.

Date	**Activity**	**Observations**
25/05/05	Monitoring, GT-900 dose. Remove mesocosms control, 2 & 4. Sediment samples taken.	Mesocosm 3 and 6 has green brown colour. Strong growths of filamentous algae on walls. Mesocosm 5 strong brown colour and a dead eel found inside. Lake is brown green and highly turbid.
09/06/05	Monitoring - Final	Lake turbid green brown. Strong filamentous algae growth on all mesocosms. Mesocosm 5 is less dark brown and more brown green similar to lake.
20/06/05	Mesocosms removed, sediment sampled	

Appendix II – Monitoring Data

Site No	Treatment	Date	Alkalinity	Conductivity	SS	Turbidity	BOD5	pH	DRP	NH4N	TOxN	TKN	TN	TP	Chlorophyll a
			g/m3-CaCO3	mS/m @25C	g/m3	NTU	g/m3		g/m3	g/m3	g/m3	g/m3	g/m3	g/m3	mg/m3
BOP130054	Lake	04/04/05	24.7	10.3	17	15.0	6.7	9.3	0.007	0.008	0.003			0.077	67.3
BOP130054	Lake	19/04/05	38.2	11.1	12	10.0		8.6			0.001	0.53	0.531	0.054	28.1
BOP130054	Lake	23/05/05		9.6	34	39.0	1.6	6.8	0.061	0.166	0.441	1.14	1.581		
BOP130054	Lake	09/06/05	46.3	14.6	16	9.4	4.4	8.5	0.008	0.006	0.0005	0.944	0.9445	0.081	41.7
BOP130065	Control	04/04/05	40.8	10.9	19	23.0	9.5	9.6	0.162	0.068	0.002				181.0
BOP130065	Control	12/04/05	42.6	11.7	19	27.0	9.8	9.1	0.15	0.069				0.362	131.0
BOP130065	Control	19/04/05	42.2	11.7	14	26.0	2.7	8.7	0.035	0.015	0.025	1.780	1.805	0.216	79.1
BOP130065	Control	02/05/05	40.8	12.3	22	31.0	5.3	9.0	0.008	0.01	0.0005	1.690	1.691	0.13	46.1
BOP130065	Control	23/05/05		9.1	16	21.0	2.4	7.0			0.437	1.160	1.597	0.132	
BOP130066	Microzyme	04/04/05	32.9	9.6	19	23.0	7.3	9.8	0.012	0.076	0.004			0.095	105.0
BOP130066	Microzyme	12/04/05	40.6	10.6	23	30.0	11.0	9.1	0.028	0.098		3.940		0.241	135.0
BOP130066	Microzyme	19/04/05	38.6	11.1	10	1.0	2.0	8.5	0.007	0.008	0.006	0.658	0.664	0.056	36.7
BOP130066	Microzyme	02/05/05	39.6	13.0	8	5.8	2.3	8.3	0.005	0.016	0.0005	0.582	0.5825	0.043	16.9
BOP130067	GT-900	04/04/05	30.9	9.5	20	23.0	7.1	9.8	0.009	0.042	0.002			0.084	113.0
BOP130067	GT-900	12/04/05	33.8	10.6	20	24.0	7.9	9.9	0.01	0.039				0.108	113.0
BOP130067	GT-900	19/04/05	38.8	11.0	13	12.0	2.6	8.9	0.007	0.015	0.0005	0.822	0.8225	0.058	42.1
BOP130067	GT-900	02/05/05	39.4	13.0	10	6.4	2.3	8.5	0.003	0.015	0.0005	0.932	0.9325	0.038	21.0
BOP130067	GT-900	23/05/05		8.7	19	23.0	1.8	7.0			0.403	0.936	1.339	0.094	
BOP130067	GT-900	09/06/05	41.9	14.2	16	5.6	3.0	8.6	0.008	0.012	0.002	0.726	0.728	0.053	30.3
BOP130068	BioAktiv	04/04/05	32.3	9.6	20	26.0	7.8	9.9	0.009	0.01	0.004			0.09	112.0
BOP130068	BioAktiv	12/04/05	42.9	12.2	18	24.0	11.0	10.0	0.007	0.044				0.143	135.0
BOP130068	BioAktiv	19/04/05	46.2	12.3	18	16.0	7.4	9.8	0.04	0.007	0.009	1.71	1.719	0.168	95.0
BOP130068	BioAktiv	02/05/05	44.8	13.0	7	7.8	4.0	9.1	0.005	0.008	0.0005	0.792	0.7925	0.063	40.0
BOP130068	BioAktiv	23/05/05		9.1	21	24.0	3.9	6.9	0.056	0.192	0.426	0.642	1.068	0.114	
BOP130069	Slag	04/04/05	31.4	9.5	21	22.0	8.6	9.7	0.009	0.032	0.003			0.09	110.0
BOP130069	Slag	12/04/05	37.2	10.3	17	24.0	7.8	9.7	0.007	0.043				0.097	99.4
BOP130069	Slag	19/04/05	34.7	10.6	26	27.0	4.6	9.8				1.83		0.103	113.0
BOP130069	Slag	02/05/05	39.5	12.7	14	6.3	2.4	8.5	0.005	0.007	0.001	0.956	0.957	0.042	25.2
BOP130069	Slag	23/05/05		8.6	18	24.0	1.5	6.9	0.05	0.205	0.368	1.01	1.378	0.109	
BOP130069	Slag	09/06/05	41.4	13.9	18	8.1	3.0	8.9	0.01	0.014	0.004	0.812	0.816	0.068	32.6

Mesocosm Field Monitoring, Sullivan Lake

Mesocosm	**Date**	**Temperature** degC	**Seechi** m	**Conductivity** uS/cm	**DO** mg/l	**pH**	**Fluoro** ug/l	**Turb** NTU
Control	04/04/05	20.7	0.30	101.3	17.3		15.8	6.0
meso2	04/04/05	20.6	0.40	94.2	18.3		13.2	6.1
meso3	04/04/05	20.6	0.36	92.7			9.8	6.9
meso4	04/04/05	20.6	0.42	91.4			12.1	5.6
meso6	04/04/05	20.6	0.38	92.8			12.4	6.3
Lake	04/04/05	20.6	0.34	102.6				
Control	05/04/05	20.7	0.29	101.5	14.3			
meso2	05/04/05	20.5	0.32	91.2	17.8			
meso3	05/04/05	20.6	0.36	92.0	17.6			
meso4	05/04/05	20.6	0.38	90.1	17.6			
meso6	05/04/05	20.7	0.32	87.9	17.8			
Control	07/04/05		0.30					
meso2	07/04/05		0.32					
meso3	07/04/05		0.34					
meso4	07/04/05		0.34					
meso6	07/04/05		0.36					
Control	10/04/05	19.2	0.25	114.0		8.3		
meso2	10/04/05	19.1	0.32	96.3		8.2		
meso3	10/04/05	19.1	0.32	109.2		9.1		
meso4	10/04/05	19.1	0.32	107.9		10.1		
meso6	10/04/05	19.0	0.42	92.6		9.3		
Lake	10/04/05	19.1	0.40	98.2		8.8		
Control	12/04/05	18.3	0.29	94.5	9.3	8.9	13.7	6.6
meso2	12/04/05	18.0	0.32	92.3	10.2	9.2	8.4	8.2
meso3	12/04/05	18.1	0.32	92.3	15.1	8.9	8	5.9
meso4	12/04/05	17.9	0.32	105.1	16.7	9.0	11.8	5.7
meso6	12/04/05	18.1	0.32	90.6	13.9	9.3	7.7	5.6
Control	16/04/05		0.40					
meso2	16/04/05		0.78					
meso3	16/04/05		0.56					
meso4	16/04/05		0.32					
meso6	16/04/05		0.38					
Control	19/04/05	16.9	0.29		8.3			
meso2	19/04/05	17	0.83		12			
meso3	19/04/05	17	0.83		13.2			
meso4	19/04/05	17	0.49		15.5			
meso6	19/04/05	17	0.42		16.4			
Lake	19/04/05	17	0.73		11.2			
Control	22/04/05	15.6	0.26	96.4	11.4	8.46		
meso2	22/04/05	15.5	0.80	92.1	13.2	8.64		
meso3	22/04/05	15.5	0.60	92	14.2	7.88		
meso4	22/04/05	15.5	0.52	100.5	14.4	8.75		
meso6	22/04/05	15.5	0.45	87.1	15.4	8.49		
meso1	22/04/05	15.5	0.60	93	15.7	8.89		
meso5	22/04/05	15.5	0.60	92.3	15.3	8.58		
Lake	22/04/05	15.6	0.62	89.1	12.2	8.73		
Control	26/04/05	13.4	0.32	91.6		8.62		
meso2	26/04/05	13.3	0.80	89.3		8.54		
meso3	26/04/05	13.3	0.89	89.3		8.42		
meso4	26/04/05	13.3	0.55	94.5		8.93		
meso6	26/04/05	13.3	0.83	87.5		9.28		
meso1	26/04/05	13.3	0.63	89.4		9.13		

meso5	26/04/05	13.3	0.52	89.4		9.23		
Lake	26/04/05	13.4	0.78	97.9		9.16		
Control	02/05/05	15.3	0.40		10.2		9.4	7.1
meso2	02/05/05	15.2	1.21		10.5		8.8	1.9
meso3	02/05/05	15.2	1.22		11.2		6.8	2.1
meso4	02/05/05	15.2	0.78		11.3		9.7	2.4
meso6	02/05/05	15.2	0.99		11.4		8.5	2.2
meso1	02/05/05	15.2	0.60		8.6		4	3.8
meso5	02/05/05	15.2	0.68		11.2		4.3	3.3
Lake	02/05/05	15.3	1.20		9.8		8.6	2.3
Control	06/05/05	15.2	0.51	87.6	11.24	8.28	9.2	6.7
meso2	06/05/05	14.8	0.63	70.5		8.48	5.7	5.7
meso3	06/05/05	14.9	0.75	78.8		8.26	7.9	3.6
meso4	06/05/05	15	0.72	80.7	9.28	7.76	6.7	3.3
meso6	06/05/05	14.9	0.79	78.3	10.18	7.94	7.6	3.1
meso1	06/05/05	15.1	0.63	88.3	15.8	8.9	4.7	3.4
meso5	06/05/05	15	0.73	88.8	16.2	8.54	4.7	3.4
Lake	06/05/05	14.8	0.54	72.4	8.65	8.98	5.8	4.2
Control	09/05/05	14.8	0.72	85.7		8.82		
meso2	09/05/05	14.9	0.81	79.3		8.66		
meso3	09/05/05	15	0.85	78		8.51		
meso4	09/05/05	14.8	0.82	80.3		8.55		
meso6	09/05/05	14.8	0.89	77.4		8.36		
meso1	09/05/05	15	0.72	98.1		8.41		
meso5	09/05/05	14.8	0.61	108.9		8.78		
Lake	09/05/05	15.3	0.70	77		8.95		
Control	13/05/05	13.1	1.00	84.4		7.95		
meso2	13/05/05	13.3	1.12	85.3		8.45		
meso3	13/05/05	13.2	1.06	81.6		8.46		
meso4	13/05/05	13.2	1.05	83.1		8.63		
meso6	13/05/05	13.1	1.11	80.3		8.6		
meso1	13/05/05	13.2	0.67	84.1		8.77		
meso5	13/05/05	13.2	0.56	106.6		8.56		
Lake	13/05/05	13.2	1.13	85.1		8.48		
Control	16/05/05	13.1	1.11	80.5	9.8	7.99		
meso2	16/05/05	13.1	1.08	80.2	10.4	7.34		
meso3	16/05/05	13.1	1.11	81	10.8	7		
meso4	16/05/05	13.1	1.00	82	10.6	7.7		
meso6	16/05/05	13.1	1.15	80.4	10.8	7.35		
meso1	16/05/05	13.1	0.62	81.4	10.6	7.93		
meso5	16/05/05	13.1	0.62	105.4	5.2	7.43		
Lake	16/05/05	13.1	0.88	80.3	10.2	7.89		
Control	23/05/05	17.1	0.43	74	5.5	8.24	5.14	7.69
meso2	23/05/05	17.1	0.35	76.7	6	8.32		
meso3	23/05/05	17.1	0.49	71.4	6.9	8.24	4.91	7.44
meso4	23/05/05	17.1	0.33	75.2	6.5	7.88	4.9	8.4
meso6	23/05/05	17.1	0.50	71.5	4.6	7.97	4.3	7.2
meso1	23/05/05	17.1	0.39	76.9	6.6	7.25	11.4	5.7
meso5	23/05/05	17.1	0.61	100.9	2.3	7.8	11.5	3.6
Lake	23/05/05	17.1	0.29	78.8	5.7	6.5	5.6	12.5
meso3	25/05/05	12.4	0.64	98.1	7.6	8.45	16.5	7.6
meso6	25/05/05	12.4	0.58	99.9	11.8	7.11	15.9	4.4
meso1	25/05/05	12.3	0.55	104.3	7.8	6.97	21.8	4.2
meso5	25/05/05	12.3	0.51	99	6	7.29	20.6	2.7
Lake	25/05/05	12.3	0.51	106.2	8.5	7.66	20.2	4.9
meso3	09/06/05	9.4	0.78	99	14.8	9	12.3	2.6

meso6	09/06/05	9.4	0.84	96.6	15.2	9	15.6	2.8
meso1	09/06/05	9.4	0.62	99.8	13.8	9.01	23.7	2.9
meso5	09/06/05	9.4	0.65	99.8	14	9.35	25.7	2.6
Lake	09/06/05	9.3	0.54	102.6	14.4	9.04	25.9	3.9