# *LakeScience Rotorua*

## *A newsletter about research on the Rotorua Lakes*

*Produced as an occasional publication by the LakesWater Quality Society, in association with the Royal Society of NZ (Rotorua Branch)*

ISSUE 7 March 2003

Welcome to the seventh issue of our email newsletter for those involved in or interested in scientific or management work on the Rotorua Lakes. It is up to **you** to make this informal newsletter a success by providing it with copy – our Society is merely providing the vehicle. We email it free of charge to all those who attended the Rotorua Lakes 2001 Symposium and are on email, and also to anyone else who requests it. If you don't wish to receive future copies, please email us. We will snail mail it on request. The newsletters will also be posted on the Royal Society (Rotorua Branch) website at www.rotorua.rsnz.org . If you are interested in, or working on lakes, but not the Rotorua Lakes, we are still very happy to receive material from you and to send you newsletters.

The more copy we receive, the more frequently we will be able to send this newsletter out. Electronic copy is preferred but not essential. Only minimal editing is carried out. We hope to send another issue out in June 2003 – given sufficient copy.
**Technical content of all contributions is essentially the responsibility of the authors**


All material and correspondence relating to *LakeScience Rotorua* to Nick Miller, millern@wave.co.nz, 91 Te Akau Road, R D 4, ROTORUA.

**CONTENTS**



NEWS

This has certainly been the summer of the cyanobacterial bloom. Lake Rotoiti was closed, in entirety, on 24 January 2003, following closure of the Western end of the lake on 8 January. Lake Rotoehu was closed on 12 February, and portions of Lake Rotorua were closed on 28 February. Rotorua and Rotoiti (except for Okawa Bay) were re-opened on 16 March, based on one set of samples. Reports of a cyanobacterial bloom on Lake Tarawera have been received and Lake Taupo has now been reported to also be undergoing a bloom (19 March). These problems have received extremely wide publicity, with a significant impact on tourism. Lake Rotoiti has been virtually empty of boats for the past two months. Anecdotal evidence has emerged concerning health problems caused by contact with the water of affected lakes, and a general state of confusion as to the causes and effects of the blooms has prevailed, particularly in the news media. There are current signs of a re-emergence of the bloom on Rotoiti.

**If you know of any colleagues, friends or students who would like to receive this newsletter, please ensure that we receive their email address and they will be added to the distribution list.**

# LakesWater Quality Society Inc.

formerly known as The Lakeweed Control Society


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## ROTORUA LAKES 2003

### A SYMPOSIUM ON PRACTICAL MANAGEMENT FOR ACHIEVING BETTER LAKE WATER QUALITY

**9 – 10 OCTOBER 2003**

**Centra Hotel, Rotorua**

The LakesWater Quality Society Inc, with a financial membership in excess of 200, has been active in encouraging effective control of nuisance aquatic macrophytes in the Rotorua Lakes since the early 1960's. In more recent years, under its new name, it has been active in pursuing research and management leading to improved water quality in the Rotorua and other lakes. In 2001 it initiated and hosted , in conjunction with The Royal Society of New Zealand (Rotorua Branch) the Rotorua Lakes 2001 Symposium, which examined the needs for future research on lakes in the Rotorua District and elsewhere in New Zealand.

This symposium was hailed as a timely event, which lead to a significant renaissance in lakes research in this country. One product of the symposium was the endowment, by Environment Bay of Plenty, of the Chair in Lake Management and Restoration at the University of Waikato. In 2002 we hosted a one-day workshop on sewerage of small lakeside settlements.

Our Society intends to host another symposium, this time devoted to practical lake management options, strategies and practices. The Symposium is being financially supported by funding from Environment BOP's Environmental Enhancement Fund.

This symposium will be held in Rotorua on Thursday 9th and Friday 10th October 2003. There will be a modest registration fee, with concessions for students. The format will be similar to that of the 2001 Symposium, with delivered papers, posters, a field trip and discussion forums. There will be keynote speakers.

We invite initial expressions of interest, either to attend or to present a paper. There will be a limited number of oral papers, but all papers received will be printed in the Proceedings, and available as abstracts in the Registrants' Handbook. Poster presentations will also be welcome. We are looking, particularly but **not** exclusively, for papers and proposals in the following interest areas:

- Nutrient control in lakeside settlements
- Farm and forest management to reduce nutrient outflows and other environmental effects
- Land use controls and guidelines
- Lake restoration and protection
- Public and interest-sector education to promote practices that help lake management

Updates on ongoing lake research conducted since the 2001 Symposium will be very welcome as poster presentations, as there is keen public interest in developments since that Symposium.. However, papers of major importance may be selected for oral presentation, even if outside the interest areas listed above.

As with the 2001 event, we are looking forward to seeing a wide range of interest groups present, as any initiatives in lake management will need to be accepted by the public and by land users in the catchments. If you are interested in receiving further information on this symposium, please communicate with our secretary at the above address, or by Email to millern@wave.co.nz

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## CALL FOR PAPERS

ROTORUA LAKES 2003 SYMPOSIUM: PRACTICAL MANAGEMENT FOR ACHIEVING BETTER LAKE WATER QUALITY (9-10 October 2003)

**PLEASE COMPLETE THIS FORM AND RETURN IT AS SOON AS POSSIBLE.**
You may complete this form EITHER by printing it off, filling it in and posting it to our Secretary at the above address, OR:
by completing it electronically and emailing it as a Word attachment to: millern@wave.co.nz
All returned forms will be acknowledged promptly.

**Title of paper:** ----------

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**Name of Presenter:** ----------

**Institution or organisation (where Relevant):** ----------

**Address:** ----------

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**Phone:** ---------- **Fax:** ----------

**Email:** ----------

Please tick your preferred methods of presentation:

(if completing this form electronically, here is a tick to copy and paste) ✓

an oral presentation ☐ a poster presentation ☐

Will you be presenting a Power Point Presentation? Yes ☐ No ☐

Further information for presenters on following page.

Please note that pressure on time may mean that some presentations may be required to be by poster.
**Oral presentations will be allocated 15 minutes, with an additional 5 minutes of question time.**
The venue has the usual audiovisual facilities, i.e. screens, overhead projector, slide projector, data projector etc. If you wish to use computer presentations (PowerPoint or similar) you are advised to bring your own laptop, however one will be supplied with backups (on PowerPoint 2000) of all PowerPoint presentations. The usual precautions regarding backup overhead transparencies, floppy disks etc apply.

**Abstracts** will be published in the Registrants' Handbook, supplied to all Registrants. Please see the following page for instructions on preparation of Abstracts. The **full text** of all papers will be published in the proceedings, together with text of all discussions. These Proceedings will be published following the Symposium in 2003.
**WE REQUIRE ABSTRACTS TO BE SUPPLIED TO US BY 30 AUGUST 2003.**

**PLEASE ENSURE THAT WE ARE SUPPLIED WITH A DIGITAL FULL TEXT PRESENTATION BY THE DATE OF THE SYMPOSIUM. This is to aid prompt publication of the Proceedings.**

We remind all those intending to present a paper that this Symposium is intended to examine practical management proposals for improved lake water quality. We also comment that a significant number of those at the Symposium will not have a scientific background, so clear presentation, with explanation of any jargon used, is desirable (this does not mean "dumbing down" your presentation!) The average lay person will appreciate and understand a clear presentation of scientific topics.

**University of Waikato - Biological Sciences**
***Professor David Hamilton***

David Hamilton and his two Ph.D. students, Eloise Ryan and David Burger, from have been extremely busy with monitoring the past summer's "events".

*Lake Rotoiti - David Hamilton*
David and Professor Warwick Silvester have carried out several measurements to determine nitrogen fixation rates associated with the bloom of *Anabaena planktonica* in Lake Rotoiti. Fixation rates are consistently higher in Okawa Bay than in the main body of the lake. Preliminary estimates indicate that about 60 kg of atmospheric nitrogen is being added to the lake each day as a result of the fixation by the *Anabaena*. This species has therefore freed itself of nitrogen growth limitation, and control of phosphorus supply is essential to control future growth.

One of the remarkable things about the bloom of *A. planktonica* on Lake Rotoiti this summer has been the length of time over which the bloom has persisted. Most blooms are typified by a boom-bust cycle and tend to be transient. The bloom persistence in Rotoiti suggests that phosphorus is recycled extremely efficiently by the cells. There are three main hypotheses that we plan to test to explain the persistence of the bloom:
(1) *A. planktonica* appears to be less buoyant than other blue-green algae and therefore may not be subject to the very high loss rates that other bloom species experience when they are blown into bays and washed up onto the shore;
(2) There is very little sedimentation of cells that would remove the phosphorus (contained in the cells) from the water column. Instead, there may be a very high phosphorus recycling efficiency by *A. planktonica* in the surface waters.
(3) Phosphate (bioavailable phosphorus) is somehow being supplied from the deep waters, where concentrations are very high, to the water surface, even though there is a summer temperature gradient that would normally prevent this transfer. One of the mechanisms for this transfer could be geothermal activity and/or bubbling of gases (e.g. carbon dioxide or methane), entraining deeper waters into the surface. Intense artificial bubbling ('destratification') is used to completely mix some reservoirs to prevent vertical gradients of oxygen and nutrients.

A new Ph.D. student, Amanda Baldwin, is about to start research on Lake Rotoiti, examining some of the factors responsible for its declining in water quality. Amanda has a B.Sc. (Hons) from Otago University and has been working in the Northland Regional Council (NRC) for the past three years. She was closely involved with the NRC's restoration of Lake Omapere.

*Lake Rotorua - David Burger*
Temperature and dissolved oxygen loggers have been deployed at a 20m deep site in Lake Rotorua to monitor the frequency and duration of thermal stratification in the lake over the summer period. The water column has also been sampled approximately twice-weekly since mid-January to observe water column nutrient trends relative to stratification and deoxygenation periods. Preliminary results indicate that the lake has been stratified on four occasions since October, with stratification remaining in place for up to 20 days. The lake became completely deoxygenated at 20 meters depth during one such event, with a corresponding 9-fold increase in ammonia and phosphorous concentrations in the bottom waters. The effect of this nutrient pulse on the lake as a whole is still being investigated.

Week-long benthic chamber experiments were conducted at 3 sites in November and February to experimentally determine nutrient release from the bottom sediments. During each experiment, the chambers were deployed by divers and then sampled by boat four times a day for five days. Eight sediment traps have also been deployed during the chamber experiments. Both the chambers and sediment traps will be deployed again in May and August in order to capture trends over a full year.

*Phytoplankton dynamics - Eloise Ryan*
Eloise is currently investigating the role mixing, light and nutrients play in controlling the vertical distribution of phytoplankton. Lakes Tarawera, Tikitapu and Okareka are presently exhibiting deep peaks of chlorophyll known as DCM (Deep Chlorophyll Maxima). The DCM in Lakes Tikitapu and Okareka are composed of dinoflagellates whereas in Lake Tarawera it is dominated by diatoms. These three lakes were chosen to allow us to look at the effect of lake size on production, DCM and taxonomy. The effect of embayments on the DCM is also been investigated in Lake Tarawera. The DCMs contribute substantially to the production of the lakes, and although the full results are not yet available, it appears that the phytoplankton are viable and growing at the DCM. The DCM is likely to be very important to the fisheries in the Rotorua lakes as there are large zooplankton grazing on the deep-living phytoplankton, which will potentially provide food for fish species and thus trout.

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**Cyanobacteria in the Rotorua Lakes – a human health risk?**
**Susie Wood – Massey/Victoria University**

Cyanobacterial blooms have seen health warnings issued on a number of New Zealand's recreational lakes, water supplies and along 400 km of the Waikato River during the 2002/2003 summer. High cell counts of cyanobacteria have been recorded in many of the Rotorua Lakes this summer including; Rotoiti, Rotoehu, Rotorua, Okaro, Ngapouri, Ngwhera and Tarawera. The potentially toxic species of *Microcystis, Anabaena* and *Aphanizomenon* are responsible for these blooms. Are these species producing cyanotoxins in the Rotorua Lakes and do they really pose a risk to human health?

*Cyanobacteria and Cyanotoxins*
Cyanobacteria are a group of photosynthetic bacteria also commonly known as blue-green algae. There are approximately 2000 species worldwide and more than 40 of these are known to have toxin - producing strains. Within potentially toxic species there are toxic and non-toxic strains, thus just because cyanobacteria are found in a water body it does not necessarily mean that cyanotoxins will also occur. What triggers a strain to produce toxins is not fully understood but is believed to be linked to the genetics of individual species.

Cyanotoxins are a diverse group of natural toxins. They can be divided into three broad groups by chemical structure: cyclic peptides, alkaloids and lipo polysaccharides (LPS).

- The hepatotoxic cyclic peptides (e.g. microcystins and nodularin) are the largest group and most commonly found. Work by Susie Wood at Massey/Victoria University, has identified microcystin toxins from more than 80 water bodies in New Zealand with levels of up to 9000 ng/ml in one sample.
- The alkaloids (e.g. anatoxin-a, saxitoxins, cylindrospermopsin) are a diverse group, which generally have strong neurotoxic effects. In 1999, Institute of Environmental Science and Research Limited (ESR) scientist David Stirling identified the toxin cylindrospermopsin, which has caused numerous stock deaths in tropical Australia, in Lake Waitawa. Until recently this toxin had not been found elsewhere in New Zealand and the species responsible for producing it remained unknown (see article below for an update on this). The lethal neurotoxin anatoxin-a is believed to be responsible for a number of dog deaths in the Waikanae and Mataura Rivers. Current work at ESR and Massey/Victoria University is investigating further suspected occurrences of anatoxin - a, in particular in planktonic species. Work is currently underway to investigate whether cyanobacteria in New Zealand produce saxitoxins.

- Lipo polysaccharides (LPS's) or endotoxins - these are believed to be responsible for allergenic (sensitisation, skin and eye irritations) effects.

*Monitoring Programmes for cyanobacteria*

Monitoring of cyanobacteria and cyanotoxins presents a special challenge because the requirements are different from other well recognised monitoring programs e.g.: when monitoring for toxic chemicals concentrations are likely to be highest closest to the outfall. Problems associated with monitoring for cyanobacteria include:

- Cyanobacteria often multiply in open water environments and scum-forming species can be concentrated by wind action
- Formation/dispersion of scum's can change within days/hours
- Cyanotoxins are mostly cell bound when the cells are alive. When cells die toxins can be released. It may be necessary to monitor both cell bound and extracellar toxin levels
- Cyanotoxin levels are not always homogenous throughout a bloom and can vary over the time span of a bloom event
- Species composition can change within a cyanobacterial bloom over time
- There may be a need to be flexible with sampling sites
- A good local knowledge of bloom history may help anticipate bloom formation.

*Detection of Cyanotoxins*

There are a variety of chemical and biological methods available for detection and quantification of cyanotoxins. However many of these are too complex and costly for large scale or routine screening of water bodies. Below are some of the more commonly used methods:

- The mouse bioassay (in which mice are intraperitoneally injected with toxins) is currently used worldwide and in New Zealand to determine bloom toxicity. With the continual discovery of new cyanotoxins some means of determining toxicity of a sample may always be required
- There are a number of instrumental methods: High Performance Liquid Chromatography (HPLC) and Liquid Chromatography Mass Spectrometry (LC/MS) - these can confirm and quantify cyanotoxins but cannot detect their toxicity
- PP2A – Protein Phosphatase Inhibition Assay – makes use of the biochemical activity of microcystins & nodularins
- ELISA – Enzyme-Linked Immuno Sorbent Assay - uses antibodies that have been raised to specific toxins
- Invertebrate Bioassays for example using aquatic invertebrates to determine bloom toxicity, however no one invertebrate is sensitive to the whole range of cyanotoxins
- PCR Probes – detect for toxin genes, currently only available for some species.

*Cyanobacteria in the Rotorua Lakes – Research and work in progress.*

Samples have been collected from a number of Rotorua Lakes or samples sent to Massey University – Wellington by Environment Bay of Plenty. Work is currently in progress identifying cyanobacteria species in these samples and testing for known cyanotoxins. Some preliminary results are given below. Further samples are still awaiting analysis.

| Location | Date | Cyanobacteria species | Microcystins[1] (ng/ml) | Saxitoxins[2] (ng/ml) | Anatoxin-a[3] (presence/absence) |
|---|---|---|---|---|---|
| Rotoiti – Okawa Bay | 12/3/03 | *A planktonica, M. aeruginosa, A. crassa** | - | 0 | 0 |
| Rotoehu – West end | 12/3/03 | *M. aeruginosa,* | 0** | 0 | 0 |
| Rotoehu – Otautu Bay | 12/3/03 | *M. aeruginosa,* | 0.7 | 0 | - |
| Rotoehu | 24/2/02 | *M. aeruginosa, Aphanizomenon gracile**, | - | - | 0 |
| Rotoehu | 24/2/02 | *M. aeruginosa, Aphanizomenon gracile**, | - | - | 0 |
| Rotorua | 12/3/03 | NO | 0 | 0 | - |
| Okaro | 12/3/03 | **M. aeruginosa** | 0 | 0 | 0 |
| Rerewhakaaitu | 12/3/03 | NO | 0 | 0 | - |
| Tarawera | 12/3/03 | *Anabaena lemmermannii, A. spiroides, Oscillatoria sp.** | 0 | 0 | 0 |
| Ngapouri | 12/3/03 | *A. planktonica* | 0 | 0 | - |
| Ngahera | 12/3/03 | *A. planktonica* | 0 | - | - |

[1] ELISA used to detect microcystins [2] ELISA used to detect for saxitoxins [3] HPLC-FL used to detect for anatoxin-a, some samples checked with HPLC-UV and LC/MS

* Species identification not completed. ** Retesting required – dilution factor may have been too great. NO – no cyanobacteria species observed in sample - Indicates sample not yet tested for this toxin.

*Lipo polysaccharides*

This summer a number of people working or involved in recreational activity on Lake Rotoiti and other lakes in the Rotorua area have complained of a "burning sensation" and "rashes" after skin contact with the lake water. It seems likely that Lipo polysaccharides may be responsible for these irritative and allergenic effects. Cyanobacterial samples from New Zealand have not been tested for the presence of LPS's.

Recent research in Europe has found there is no correlation between the toxin content and the allergenic effects of cyanobacteria. It had been suggested that allergenic effects are likely to be caused by lipo polysaccharides of the cyanobacteria cells walls. However experimental evidence has shown that there are no allergenic effects when axenic (bacteria free) cyanobacteria cultures have been tested for LPS's. This indicates that it may be the LPS of contaminant bacterial flora rather than those of the cyanobacteria cell walls that are responsible for allergenic effects.

*Conclusions:*

- Results from the samples tested to date show only low levels (0.7ug/L) of the cyanotoxin microcystin at one location. Recommended guidelines for microcystin levels in drinking water are currently 1ug/L. At these levels the toxin does not pose a risk for recreational activity.

- Samples from other dates are still awaiting analysis.

- It is important to remember that only known cyanotoxins have been tested for and some methods used for these analyses have limitations. The toxin analysis methods used do not determine toxicity of the cyanobacterial blooms.

- As a comparison samples from Waikato lakes were also collected at a similar time and are currently been analysed. In Lake Hakanoa, a small lake near Huntly, levels of microcystin were measured at 100ug/L. At these levels recreational activity on/in this lake is extremely hazardous. The species responsible for this bloom were *Anabaena planktonica* and *Microcystis aeruginosa.* Why toxin levels are much higher in this lake compared to the Rotorua lakes where similar species occur is not known.

- Research worldwide in continually finding new cyanotoxins. Thus as a good precautionary measure any cyanobacteria species from a genus known to produce cyanotoxins should be regarded as a potential toxin producer.

- Cyanobacteria have been found to produce toxins at different times during a bloom – thus a negative result from a one off sample does not necessarily mean the water will be safe for the remainder of the bloom. Toxin levels can also vary spatially within a bloom. Ideally toxin analysis on water sample should be carried out regularly however this can prove expensive and cell counts are a more practical measure of estimating risks in water bodies used for recreational activity. Levels of 15 000 – 20 000 cells/ml are currently used in New Zealand.

- Cyanobacterial blooms can appear/disappear very quickly, so continually monitoring of water bodies with known problems should occur. Apart from the potential production of cyanotoxins, cyanobacterial blooms can cause other water quality problems e.g.: low dissolved oxygen levels.

- During cyanobacteria blooms and scum's it is necessary to consider both the toxin content of the cyanobacteria cells and the water and possible allergenic effects.

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**A New Toxic Cyanobacteria Species in New Zealand**

*Susie Woods - Work with Dr David Stirling - Biotoxin Research Scientist, Environmental Science and Research Limited.*

*First reports of the cylindrospermopsin producing Cylindrospermopsis raciborskii in New Zealand.*

The planktonic cyanobacteria *Cylindrospermopsis raciborskii* was originally thought to be a tropical species however a recent review of it worldwide distribution has shown an increasing number of reports of this species from many temperate countries including America, Austria, France, Germany, Greece, Portugal, Hungary, Slovakia and Spain.

*Cylindrospermopsis raciborskii* is a potentially toxic cyanobacteria species – the primary toxin that *Cylindrospermopsis sp.* produces is cylindrospermopsin (CYN) (an alkaloid hepatotoxin), however it

has also been recorded as producing saxitoxins in Brazil and further unidentified hepatotoxins in Portugal.

In 1999 David Stirling detected the first reports of the toxin CYN in New Zealand in a bloom sample from Lake Waitawa. But a rigorous identification the causative organism was not carried out. At the time it was thought that the species responsible for causing the bloom and the CYN was *Cylindrospermum sp*. There are some morphological similarities between *Cylindrospermum sp.* and *Cylindrospermopsis sp*. and because *Cylindrospermopsis sp.* was not described in the New Zealand taxonomic literature it is possible that the species was wrongly identified.

On Thursday the 13th of March as part of my PhD Study a sample was collected from Lake Waahi, a shallow mesotrophic lake in the lower Waikato River basin. High cell counts of the cyanobacteria species *Cylindrospermopsis raciborskii* were observed. Cell counts of 160 000cells/ml have since been recorded at this lake. The discovery of this bloom of *Cylindrospermopsis raciborskii* in Lake Waahi is the first reported occurrence of this species in New Zealand. Using LC-MS/MS the cyanotoxin CYN and the analog deoxy-cylindrospermopsin was unambiguously detected. The toxicity of the sample was also confirmed by mouse bioassay.

Unlike many cyanobacteria species (e.g.: *Anabaena sp.* and *Microcystis sp.)* which form scum's on the surface of the water *Cylindrospermopsis raciborskii* often stays well distributed throughout the water column and has highest concentration below the water surface. Thus apart from the fact that the water is usually a deep blue-green colour is can be hard to tell that there is a bloom occurring. *Cylindrospermopsis raciborskii* is small and indistinct, the filaments are only 1.5-2µm wide. A variety of morphs of this species occur including straight and curled morphs. The morphs in Lake Waahi are all straight. Work is currently under way at Massey University using PCR techniques to investigate similarities between New Zealand and Australian strains.

*Cylindrospermopsis raciborskii* presents several problems when using conventional monitoring methods. Often cell counts are used as indicators of the potential risk to human health, however unlike other cyanobacteria species *Cylindrospermopsis raciborskii* appears to produce toxin continuously and research has shown that at various stages of a *Cylindrospermopsis raciborskii* bloom extracellular toxin levels varied between 19-98%. Studies on several reservoirs in Queensland have showed that CYN persisted in the water column for up to 6 weeks after cells of *Cylindrospermopsis raciborskii* were below detectable levels. The limnology of Lake Waahi is likely to be different from these tropical reservoirs thus just how long the water will remain dangerous after the bloom disappears remains unknown.

CYN is known to accumulate in the viscera of fish and the hepatopancreas tissue of crustaceans. Consumption of fish and other aquatic organism from affected lakes should be avoided.

Lake Waahi remains the only lake in New Zealand where *Cylindrospermopsis raciborskii* has been seen by the author. It has not been found in any of the Rotorua Lakes. Recent work in America has called this species an "invasive toxic alga" and has plotted its spread across North America, so it seems likely that this species will be found in other locations in New Zealand.

A full species description and photos will be available shortly from Susie Wood.

For further information contact Susie Wood, PhD Student, Massey University, Wellington. Ph. 04 801 2794, extn 6918, Email S.Wood@massey.ac.nz

*Acknowledgements*

Many thanks to the following people and organisations – with out their help this project would not be possible. The LakesWater Quality Society for their generous funding of this project, David Stirling (Environmental Science and Research Ltd) for his enthusiasm, advice and ingenious ideas, Neale Towers, Lyn Briggs & Jan Sprosen – (Agresearch – Ruakura) for their fantastic help with ELISA techniques and materials required for these assays, Anna Crowe (Cawthron Institute) for taxonomic advice and general encouragement, John Ruck (Massey University) and Bob Wear (Victoria University) for their support and supervision of this project, Peter Baker (Australian Water Quality Society) for valuable taxonomic advice, David Hamilton and Eloise Ryan (Waikato University) for PhD directional advice and encouragement and the many other people around the country who have supplied me with cyanobacteria samples!