Innovative Methods for the Determination of Water Quality in the Lakes Muskoka, Joseph and Rosseau

Prepared For:

Muskoka Lakes Association

Prepared By:
Gartner Lee Limited

GLL 21-193

December, 2001

Distribution

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December 5, 2001 GLL 21-193

Mr. Ian Beverley
Muskoka Lakes Association
121 Medora Street
Port Carling, Ontario
P0B 1J0

Dear Mr. Beverley:

Re: Final Report – Innovative Methods for the Determination of Water Quality

I am pleased to submit this final report to you on behalf of Gartner Lee Limited. It describes the program of water quality measurement and the results obtained from our pilot program in the summer of 2001. It also incorporates comments on the draft report provided by yourself and Rob Bosomworth. The report documents the findings of interest without a great deal of technical or scientific detail – I have attempted to relate the results to the concerns of the MLA and highlight findings of interest to your membership.

In the end, this was an ambitious program. This report represents a landmark in the level of investigation carried out by an association and is, in several aspects, cutting edge. Although results are not clearly unequivocal they do support our initial concerns that management programs of the agencies may not be revealing the true health of the lakes. The program confirmed that water quality in Lakes Muskoka, Joseph and Rosseau is generally excellent but does point to problem areas which require further investigation.

I have prepared an executive summary as part of the main body of the report. I will also prepare it as a stand-alone document for distribution to the MLA Board on December 6. I would also recommend that the MLA provide a copy of the report to Ms. Judi Brouse at the District of Muskoka.

In closing, I thank you for the opportunity to assist the MLA with this timely initiative and look forward to the next stages of your project.

Yours very truly,
GARTNER LEE LIMITED

Neil J. Hutchinson, Ph.D.
Senior Surface Water Specialist

NJH:le
Attach.

Executive Summary

Innovative Methods for the Determination of Water Quality in the Lakes Muskoka, Joseph and Rosseau.
Gartner Lee Ltd. December, 2001.

An ambitious program was undertaken in the summer of 2001 in order to gather preliminary information on innovative means of water quality determination in the Muskoka lakes. The 2001 program was one component of a larger initiative by the MLA. The objectives of the long term initiative were:

a) to review and summarize existing information on water quality in Lakes Muskoka, Joseph and Rosseau;

b) provide an opinion on the water quality stresses of most significance to the Muskoka Lakes and the MLA;

c) develop a research and monitoring program based on the results of task b;

d) liaison with management initiatives being undertaken elsewhere; and

e) advice on stewardship initiatives and other follow-up activities.

Our initial review (Tasks a and b) concluded that most of the potential stresses to the Muskoka lakes were either being addressed by management activities beyond the immediate influence of the MLA (i.e., acid rain, shoreline development policies) or that management activities were required but were beyond the direct influence of the MLA (contaminants, climate change). Our review did, however, indicate that past management programs were focussed on the open waters of the lake and that they may not be capturing the responses of most interest to lake users.

In spite of the overall excellent water quality in the main portions of the lakes, the attention of lake residents and scientists has been increasingly focussed on the nearshore, shallow areas of the lakes in recent years. The nearshore areas are important biologically, as the waters are well lit and provide habitat for much of the aquatic life in the lake. They are important to lake users, as the nearshore is where they most often view water quality – while swimming, standing on a dock or boating. Any problems in these areas will be immediately visible to the lake user.

The nearshore areas are also those portions of the lake that are most likely to suffer from the stresses that users may exert on the shoreline. If septic systems are old or poorly maintained, swimming in the nearshore area and water supply will be impaired by bacterial contamination. If the shoreline is cleared of its natural vegetation, the nearshore waters may become more muddy (turbid) as soils and attached nutrients wash into the lake with a rainstorm. If the natural vegetation is replaced with a manicured lawn then algal growth may proliferate as fertilizer residues are washed into the lake. In spite of these

concerns, no management efforts have been directed to the nearshore areas of Lakes Muskoka, Joseph and Rosseau. Our review therefore concluded that a research and monitoring program which was focussed on the nearshore area could be taken on by the MLA, was amenable to implementation by the Marine Patrol, would potentially reveal relationships between land use and nearshore water quality and could potentially generate results which could guide future management and stewardship activities in the lakes.

The MLA's 2001 program was therefore focussed on the nearshore areas of the lakes. A set of three tests were developed and applied at up to ten sites in each of Lakes Muskoka, Joseph and Rosseau over the course of the summer.

The 2001 studies investigated:

a) bacterial levels in nearshore areas;
b) levels of the plant nutrient phosphorus in nearshore waters; and
c) algal growth in nearshore areas of higher human activity.

The program was to implemented by the MLA's Marine Patrol under the supervision of Gartner Lee Limited for survey design, quality control and reporting.

The results confirmed that, although water quality in the lakes is generally excellent, specific patterns of nutrient enrichment, algal growth and bacterial growth suggest that water quality in the nearshore areas is not as good as in offshore areas. This further suggests that sampling programs which focus only on offshore, mid-lake water quality may not be sensitive enough to detect the more subtle effects of shoreline usage and development by humans.

Although there were no consistent and significant patterns relating shoreline use to degraded water quality, there were indications of impacts to nearshore nutrients, bacteria and algal density for specific land uses. These impacts were neither large nor dramatic, but do warrant further study to confirm if patterns exist. A combination of urbanization, agriculture and high density trailer park development appeared to have a consistent influence on the Indian River and more detailed studies in this location are warranted. Golf course runoff appears to result in increased phosphorus levels and algal growth in other nearshore areas.

Analysis of the algal data did not reveal clear indicators of cause and effect and many factors beyond land use may alter algal growth. We therefore recommend that subsequent programs focus on phosphorus and bacterial indicators until such time as scientific research by other investigators can be brought to bear on the questions at hand. Analysis of turbidity (water cloudiness) along with phosphorus may help identify sites for future algal work.

We conclude that the 2001 sampling program was successful, in that it demonstrated the feasibility of looking at nearshore indicators of water quality and the utility of the results. The MLA should consider means to improve the program by :

a) providing a greater focus on water quality through hiring environmental scientists and biologists as part of the Marine Patrol and increasing their training. These students may also benefit themselves and the MLA by incorporating their summer work into an independent study project for their course requirements;

b) maintaining and increasing the involvement of the MLA staff in the day to day running of the water quality program to develop and maintain internal expertise within the MLA. Identification of an internal "champion" of water quality issues will allow greater continuity of programs and increased cost savings in program implementation;

c) allowing an earlier start to the program, to allow the collection of more than 4 samples over the summer;

d) adding new sites, but only if there are sufficient resources to do so without straining the energy or good will of staff;

e) reduced reliance of Gartner Lee Limited for data analysis and report preparation, and increased reliance on Gartner Lee staff to train and assist MLA staff in carrying out the water quality program. Again, this method allows greater continuity, develops internal expertise and maximizes cost efficiencies for the MLA; and

f) supporting graduate student research into factors influencing the growth of nearshore algae. I have contacted Professor Frances Pick at the University of Ottawa. She is an expert in periphyton in streams and lakes, is currently supervising graduate student investigations and expressed great interest in the MLA program. I have made an extra copy of this report for Dr. Pick and will provide it to her, with the permission of the MLA.

These recommendations made above will allow the MLA to move from an ambitious and successful Year 1 program to a consistent and "self perpetuating" program in the years to come.

In the end, this was an ambitious program. This report represents a landmark in the level of investigation carried out by an association and is, in several aspects, cutting edge. Although results are not clearly unequivocal they do support our initial concerns that management programs of the agencies may not be revealing the true health of the lakes. The program confirmed that water quality in Lakes Muskoka, Joseph and Rosseau is generally excellent but does point to problem areas which require further investigation.

Gartner Lee Limited welcomed the opportunity to help the MLA launch this program. We look forward to continued involvement in program design and interpretation and encourage the MLA to maintain their internal resources for the sampling and implementation of the program. We also thank the MLA Marine Patrol for their dedication to and enthusiasm for the work, Cheryl Watt and Cheryl Hollis of the MLA office for dedication to the program and "Coli Plate" expertise and to the MLA Board for their support for this initiative.

Table of Contents

List of Figures

List of Tables

Appendices

1. Introduction

In March of 2001 Gartner Lee Limited were retained by the Muskoka Lakes Association to provide expert services in the development of environmental programs to protect the water quality in Lakes Muskoka, Joseph and Rosseau. The program was intended to follow-up on and complement the ongoing monitoring of Lakes Muskoka, Joseph and Rosseau which is carried out by the District Municipality of Muskoka and on monitoring studies carried out by the Ontario Ministry of the Environment's Dorset Environmental Science Centre in the mid 1990s.

The long-term vision for the program was captured in five tasks:

a) **review of existing information** on water quality in Lakes Muskoka, Joseph and Rosseau;

b) **an opinion on the water quality stresses of most significance** to the Muskoka Lakes and the MLA and rationale for that opinion, with particular emphasis on acid rain, nutrient enrichment and bacterial contamination;

c) **development of a research and monitoring program** to document conditions of nutrient runoff, bacterial contamination and algal growth in the nearshore waters as they are influenced by bottom substrate, development density and shoreline vegetation. The program was to be implemented by the MLA's Marine Patrol under the supervision of Gartner Lee Limited for survey design, quality control and reporting;

d) **liaison with other management initiatives** (District of Muskoka, MOE, Lake of Bays Association); and

e) **advice on stewardship initiatives** recommended for the MLA.

This report represents the results of the 2001 program, with particular emphasis on the research and monitoring program carried out by the Marine Patrol. A brief summary of other water quality stressors is presented, as well as preliminary advice on stewardship and follow-up.

2. Background

In the past, the water quality programs of the District Municipality of Muskoka and the MOE were focussed on protection of the entire water mass of each lake. Surveys of acid rain and nutrient enrichment

were intended to determine the average water quality for lake basins or large bays and relate these to stressors such as atmospheric deposition or the amount of development of cottages, resorts and towns on their shores and in the upstream watershed. A summary of past studies is presented below.

2.1 Acid Rain

The Muskoka Lakes were the focus of surveys by the MOE in 1985 and in 1993-1995. These surveys established that these lakes were naturally slightly acidic (pH 6.3 – 6.8) and slightly acid-sensitive but, by virtue of their large size and location in the watershed, contained sufficient mineral alkalinity to buffer acid rain inputs. Current levels of acid deposition did not threaten them. Legislated reductions of acid rain-forming compounds were negotiated and implemented by Ontario, Canada and the USA in the early 1990s and Ontario's reductions continue to this day. Although these reductions may not be sufficient to protect small, headwater lakes in Muskoka and many years of acid loading are stored in wetlands in the watershed, the large lakes are not currently threatened and are unlikely to suffer in the future. Continued political support is necessary, however, to ensure that the progress which has been made is not lost.

Recommendation: The MLA should continue to encourage reductions in acid rain-forming emissions through political support, in order to protect the Muskoka watershed.

2.2 Contaminants

There are no surveys of contaminant levels in the waters of Lakes Muskoka, Joseph and Rosseau. The only ongoing source of contaminants is the atmosphere, which deposits mercury, PCB and other contaminants from industrialized areas. These contaminants, in particular mercury, accumulate in the flesh of sport fish so that consumption advisories exist for all sport fish in the Muskoka lakes. The MOE/MNR "Guide to Eating Ontario Sport Fish" (2001-2002) recommends limited consumption of large smallmouth bass, lake trout and northern pike from the three lakes. For the most part, this reflects elevated concentrations of toxic methyl mercury in the fish. Mercury although present from natural sources, is also added to the atmosphere, and hence the lakes, through coal-fired electricity generation, waste incineration, industrial and consumer sources. Elevated mercury levels in fish and fish-eating wildlife are common throughout North America on the Precambrian Shield and reflect an industrial/consumer society and natural processes which cause the mercury to accumulate in fish and other biota. Although the problem has been well documented, the human sources of mercury have not been controlled and emissions continue.

Historically, large amounts of the pesticide DDT were used in attempts to control biting insects in the Muskoka watershed. Scientific evidence of widespread harm to the ecosystem from DDT prompted public concerns over its use and the pesticide was banned in the late 1960s. Residues of DDT and its

breakdown products (DDD and DDE) still persist in the fatty tissue of old fish such as lake trout, but are not present at concentrations high enough to warrant additional concern. Other organic contaminants, such as PCB, can occasionally be detected in biota, but not at concentrations which warrant concern. Mercury remains the most important contaminant of concern.

Recommendation: The MLA should encourage control of mercury emissions through political pressure, in order to protect the aquatic ecosystem and human consumers in the Muskoka watershed.

2.3 Climate Change

The most significant recent threat to the Muskoka lakes and watershed is climate change. Climate change (or "global warming") is brought about through the accelerated emissions of greenhouse gases such as carbon dioxide and methane from human industrial activities, mostly the production and consumption of fossil fuels. These greenhouse gases trap long-wave radiation emitted from the Earth's surface in the atmosphere, causing increased warming of the Earth's surface. Although there continues to be some debate as to the exact contributions of humans to recent warming, our understanding of the process, and the undeniable increase in atmospheric carbon dioxide levels over the past century, plus record-breaking extremes in temperature and precipitation over the past decades should serve as a strong signal on the need for decisive management action.

At the same time, the "Muskoka lifestyle" provides a clear vision of how climate change and greenhouse gas emissions are linked. The strong economy of Ontario that allows residents to purchase valuable lakefront properties for recreational purposes is driven by fossil fuel combustion, particularly that associated with the automotive industry. Access to our vacation properties is provided by large personal vehicles that contribute disproportionate amounts of greenhouse gases. (In the past, mass transit by railway and steamship provided access to Muskoka). Air quality advisories for southern Ontario now routinely include Muskoka, as urbanization and large numbers of vehicles move further north. Even recreational activities in the Muskoka lakes are driven by fossil fuel combustion from large and increasingly more powerful boats. In the winter, boats give way to snowmobiles.

The effects of climate change are difficult to discern and substantiate at this time. Hotter and drier summers will accelerate the loss of wetlands and reduce summer flows in Muskoka's lakes, with implications to water quality and fish habitat. Alterations to wetlands will change water clarity in the lakes. Warmer winters may increase snowfall but decrease the period of snow and ice cover. A warmer climate may introduce new insect-borne diseases such as Nile virus or encephalitis to add to the routine concerns over biting insects.

Recommendation: There is a close association between lifestyle choices, climate change (global warming) and the valued aspects of the Muskoka environment. The MLA should recognize the links between recreational activities and the recreational environment, and encourage politicians and individuals to make strong and convincing progress towards reducing carbon emissions and promoting a more sustainable recreational economy.

2.4 Outboard Engine Emissions and Boating

There is now an emerging body of research documenting emissions of contaminants into water from the use of outboard motors. The emissions are highest from two stroke engines with carburetors and are reduced by the use of newer technologies such as fuel injection and four stroke motors. Up to 25% of the fuel used in a conventional two-stroke engine may be lost to the water in the exhaust – wasted without being burnt. With the exhaust comes a host of pollutants - toluene, ethylene, benzene, xylene, polynuclear aromatic hydrocarbons (PAHs) and gasoline additives. Studies done in the USA show that these substances accumulate in high-use areas such as marinas during high use periods (i.e., weekends) and that they may reach concentrations that are harmful to aquatic biota. Some, such as PAH, react with ultraviolet radiation to become more toxic. Although the research is still in its earliest stages, concerns were such that the use of carburetted two-stroke outboards was recently banned in Lake Tahoe, Nevada, a very popular recreational boating area. Other outboard management initiatives included regulated limits to noise emissions from boats and a "no wake" zone within 600' of the shoreline to control erosion and protect sensitive wildlife. All of these initiatives were enforced by "marine patrols" who had the authority to issue summonses and tickets to offenders.

Recommendation: The MLA should investigate the impacts of outboard engines on the aquatic environment and take further steps to educate and enforce intelligent and sensitive recreational boating.

2.5 Nutrient Enrichment

Surveys conducted by the District Municipality of Muskoka and the MOE show that the nutrient status of the three large Muskoka lakes is excellent. Although the algal nutrient phosphorus has increased slightly from natural levels in response to human use, it remains very low, indicative of excellent water quality. Lake Joseph, by virtue of its small watershed with very thin soils, has spring phosphorus concentrations of 4 μg/L (parts per billion) or less (Figure 1). The immediate watershed of Little Lake Joseph contains wetlands that contribute natural phosphorus loads and so is slightly more enriched (4 – 8 μg/L, Fig. 1). Although Cox Bay in Lake Joseph is highly developed, phosphorus concentrations remain low. Lake Rosseau and Lake Muskoka are also of low nutrient status (4 – 7 μg/L) in the open water portions. Enrichment is apparent near the mouth of the Muskoka River (7 – 10 μg/L) as a result of inputs of human and natural sources from upstream in the watershed which accumulate and settle out in that basin.

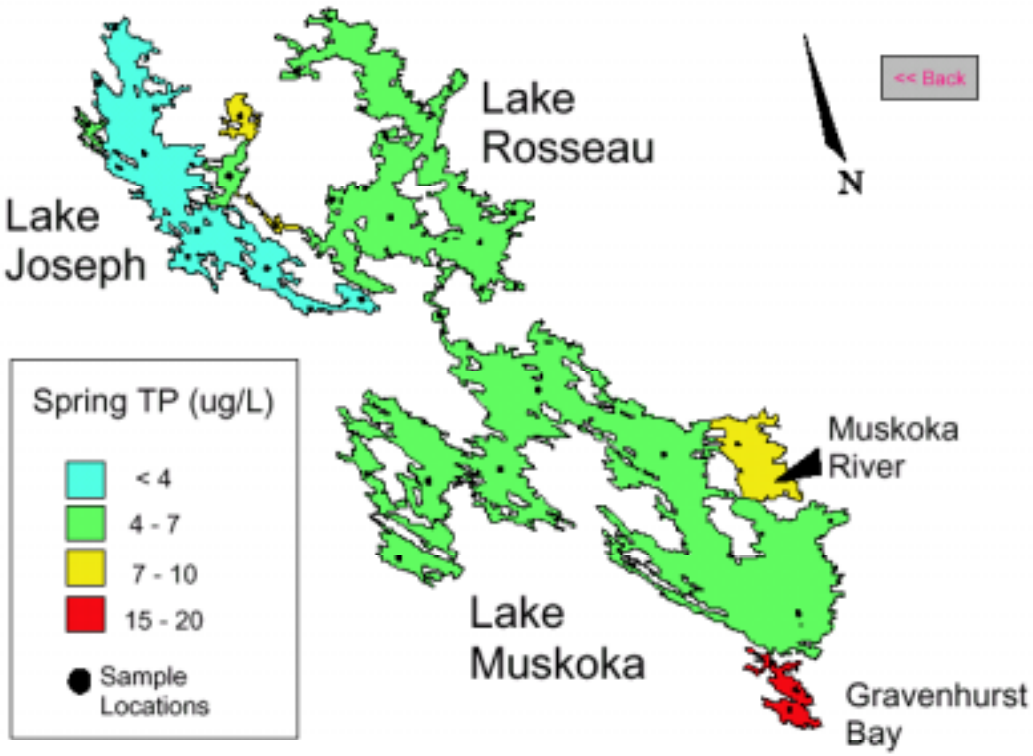


Figure 1. **Summary of Average Spring Concentrations of Total Phosphorus in Lakes Muskoka, Joseph and Rosseau from Surveys Conducted by MOE (Dorset Environmental Science Centre) in 1994, 1995 and 1996). Acknowledgements: Mr. Bev Clark, Environmental Monitoring and Reporting Branch, MOE Dorset.**

Muskoka and Gravenhurst Bays, on the other hand, are still recovering from past inputs of treated sewage from the Town of Gravenhurst. Nutrient enrichment problems such as blooms of nuisance algae and loss of oxygen from bottom waters were prevalent in the 1960s and 1970s. Conditions improved when phosphorus removal was added to the sewage treatment process in the 1970s and improved in the 1980s. In 1993, a new sewage treatment plant for the Town of Gravenhurst was commissioned, and it discharges a very high quality (low phosphorus) effluent to the main body of the lake. Recovery of Gravenhurst Bay continues although some enrichment will always be present by virtue of the bay's isolation from the main body of the lake, natural sources and urban runoff from the Town of Gravenhurst.

Overall, the management of nutrient status in Lakes Muskoka, Joseph and Rosseau is well served by the water quality policies of the District Municipality of Muskoka. Water quality remains excellent in nearly all areas of the lakes after more than a century of shoreline development. District policies recognize the linkage between shoreline development such as cottages, resorts and urban centres, phosphorus concentrations and water clarity in the lakes. The District calculate and enforce limits to shoreline development (and hence phosphorus loading) through their Official Plan policies and conduct their own monitoring programs such that development will not impair recreational water quality. These policies are focussed on the average water quality of the main water masses in the lakes.

2.6 Nearshore Water Quality

In spite of the overall excellent water quality in the main portions of the lakes, the attention of lake residents and scientists has been increasingly focussed on the nearshore, shallow areas of the lakes in recent years. The nearshore areas are important biologically, as the waters are well lit and provide habitat for much of the aquatic life in the lake. They are important to lake users, as the nearshore is where they most often view water quality – while swimming, standing on a dock or boating. Any problems in these areas will be immediately visible to the lake user.

The nearshore areas are also those portions of the lake that are most likely to suffer from the stresses that users may exert on the shoreline. If septic systems are old or poorly maintained, swimming in the nearshore area and water supply will be impaired by bacterial contamination. If the shoreline is cleared of its natural vegetation, the nearshore waters may become more muddy (turbid) as soils and attached nutrients wash into the lake with a rainstorm. If the natural vegetation is replaced with a manicured lawn then algal growth may proliferate as fertilizer residues are washed into the lake. In spite of these concerns, no management efforts have been directed to the nearshore areas of Lakes Muskoka, Joseph and Rosseau. Our review therefore concluded that a research and monitoring program which was focussed on the nearshore area could be taken on by the MLA, was amenable to implementation by the Marine Patrol, would potentially reveal relationships between land use and nearshore water quality and could potentially generate results which could guide future management and stewardship activities in the lakes.

2.7 Summary

Our review concluded that most of the potential stresses to the Muskoka lakes were either being addressed by management activities beyond the immediate influence of the MLA (i.e., acid rain, shoreline development policies) or that management activities were required but were beyond the direct influence of the MLA (contaminants, climate change). Information on human stresses to the nearshore areas was lacking and could potentially be addressed through focussed research, local management activities and stewardship initiatives. The MLA's 2001 program was therefore focussed on the nearshore areas of the lakes. A set of three tests were developed and applied at up to ten sites in each of Lakes Muskoka, Joseph and Rosseau over the course of the summer.

The 2001 studies investigated:

a) bacterial levels in nearshore areas;
b) levels of the plant nutrient phosphorus in nearshore waters; and
c) algal growth in nearshore areas of higher human activity.

3. Methods

The study design incorporated three separate measurement techniques which were applied across a variety of sites in each of the three lakes. The techniques were chosen so that they could be carried out by staff of the Marine Patrol and the MLA office with minimal supervision after the initial training period. Sampling effort was split equally between Lakes Muskoka, Joseph and Rosseau.

3.1 Site Selection

The intent of all studies was to establish:

a) whether or not the responses of algae, phosphorus or bacteria differed between off shore and nearshore sites; and

b) whether they differed between sites where the nature or intensity of nearshore development differed (i.e., comparisons between areas of low to no shoreline development and areas with a variety of development types).

The study sites were therefore selected to cover a range of activities – including enclosed bays where problems could be amplified because of restricted water mixing, areas of high cottage density or old cottages where septics may be more likely to have failed, areas near golf courses or resorts where intense land use changes have occurred, areas near agricultural activities, open areas where problems were not expected and reference areas where there was no or little development.

In all cases the program intended to focus on the overall level of the development type and not on the activities of individual cottagers or commercial interests. Comparisons of natural environments such as river mouths or wetland drainage areas with developed areas were incorporated into the study design. Finally, the study design attempted to compare the natural environment as a factor altering the response of the nearshore area to development : development along exposed shorelines was compared with development in sheltered bays or in the lee areas between islands.

Staff of Gartner Lee Limited met with the Marine Patrol and MLA staff to identify candidate sampling areas based on direct knowledge of the lakes. The categories of study site presented in Table 1 were used to guide selection of specific study sites.

Table 1. Categories of Study Site Investigated

Reference sites with little development
• open water (open water or exposed shoreline)
• adjacent to unaltered wetlands
• little or no shoreline development
"Developed" Sites
• adjacent to large resorts
• enclosed bays with cottages
• sheltered islands with old cottage development
• sites receiving golf course drainage
• exposed shorelines with high density of cottages
• adjacent to trailer parks
• adjacent to agricultural activities

The goal of the overall study design was to ensure that each site category was represented in each lake but, in the end, this was not possible as suitable sites in each category could not always be located.

The number of sampling sites was established by:

a) logistics - how much could be carried out by each Marine Patrol crew on a day;
b) logistics – how many samples could be reliably analyzed by MLA staff in a day;
c) cost; and
d) the availability of incubator space for the Coli Plates.

Six sites on each lake were chosen for phosphorus and algal measurements and ten for bacterial counts. The incubators for bacterial measurements could accommodate 12 bacterial samples but two of these were required for quality control samples (field duplicates and field blanks). An additional four sample sites for bacteria were therefore included on each lake.

The final study design and site selection is given in Table 2. The individual study sites were located on navigation charts of the three lakes and are kept on file at Gartner Lee Limited, along with detailed field notes on site characteristics.

3.2 Algal Measurements

The algal study was developed in response to anecdotal observations of increased algal abundance in the nearshore area by some lake residents. Most algal measurements reported for the Muskoka lakes in the past are for the "phytoplankton", the community of algae which live suspended in the water column throughout the lake. Reports of nearshore algae generally represent "periphyton" the algae which are attached to rock, sand, wood and other substrates in the shallow, sunlit areas of the lake. Periphyton are the form of algae which are observed as slippery rocks or a green film in nearshore waters. Few measurements of these forms have been made by past monitoring programs, Therefore, the purposes of the present study were to:

a) determine if periphyton abundance could be measured reliably;
b) to establish if measurements were related to adjacent land use activities; and
c) to determine if algal abundances were related to phosphorus concentrations in the nearshore areas.

Six sites were selected in each of Lakes Muskoka, Joseph and Rosseau and algal growth was measured over the summer months. Clean clay tiles ("artificial substrates") were placed at each site on July 3 and 4 and left in place until August 23 and 24. Tiles were placed in 30 cm of water on south-facing shores. They were checked every two weeks to ensure that water depth was still 30 cm. In August, the rocks were removed and scraped. The contents were sent to an algal taxonomist at the University of Toronto for analysis of algal species and abundance and to a commercial laboratory for analysis of chlorophyll (a photosynthetic pigment which is also an index of algal abundance).

Table 2. Study Site Selection, MLA Nearshore Studies, 2001

Gartner Lee Limited

Study Design - MLA Nearshore Studies - Summer 2001

Category	Lake Rosseau Sample No.	Lake Rosseau Location	Lake Joseph Sample No.	Lake Joseph Location	Lake Muskoka Sample No.	Lake Muskoka Location	Phosphorus	Periphyton	Bacteria
Resorts	R1	Clevelands House	J1	Pinelands	M1	Arundel			
Enclosed Bays	R2	Brackenrig Bay	J2	Stills Bay	M2	Walkers Bay			
Reference - little development	R3	Shadow River	J3	Burnegie Bay Inlet	M3	East Bay - not developed			
Islands, Sheltered, Old	R4	Tobin/May	J4	Cameron/Chiefs	M4	Eileen Gowan/Browning			
Golf Course Drainage		No Site Selected	J5	Hamer Bay	M5	Beaumaris			
Exposed Shore, High Density		No Site Selected	J6	Cox Bay	M6	Walkers Point			
Trailer Park	R5	Indian River							
Agriculture	R6	Indian River							
Open Water Reference	R7	Caledonia Island	J7	Black Forest Is.	M7	Christmas Is.			
	R8	Mazangah Island	J8	Cox Bay	M8	Walkers Bay Mouth			
Wetland Reference	R9	Macassa Bay	J9	Orgills Bay	M9	Upper East Bay			
Other Development	R10	Arthurlie Bay	J10	Sherwood Inn	M10	Tondern/Squirrel Is.			
Field Blank	R11	Distilled Water	J11	Distilled Water	M11	Distilled Water			
Field Duplicate	R12	Choose a site	J12	Choose a site	M12	Choose a site			
Lab Duplicate	R13	Choose a Site	J13	Choose a site	M13	Choose a site			

3.3 Phosphorus Measurements

The intent of the phosphorus program was to see whether phosphorus concentrations from nearshore samples differed from samples taken offshore at the same time. This would indicate whether or not septic systems, land clearing and fertilization add phosphorus which may not be detected in the middle of the lake because of mixing and dilution. Conventional water quality programs measure phosphorus from offshore samples only and it is important to understand if these provide accurate records of lake responses to human activities.

Water samples were collected for the analysis of total phosphorus at each of the six algal sites on four occasions in July and August and in two additional offshore sites in each lake at the same time. Samples were collected directly into the analytical digest tubes, as recommended by the Ontario Ministry of the Environment (Clark and Hutchinson, 1993) and analyzed at the Trent University Laboratory located at the Dorset Environmental Science Centre. A duplicate sample was collected on each lake on each of the four sampling runs to assess variation between samples. Sample "blanks" of distilled water were also submitted from each lake on each run to assess any sample contamination from the sampling program itself.

Phosphorus measurements were compared between nearshore sites and offshore sites and between nearshore sites with different land use activities. The average summer values were also correlated with the algal growth measured at the same six sites over the summer, as phosphorus is critical to algal growth.

3.4 Bacterial Measurements

The final environmental measurement used was a program of bacterial measurements based on the program run by the Lake of Bays Association last year and repeated this year. It relied on the "ColiPlate" a commercially available and validated assay for *E. coli* and total coliforms in water samples which can be carried out without the assistance of a commercial laboratory.

Samples of lake water were collected from ten sites on each lake on each of four occasions in July and August. Samples were collected from the surface in water depths of 1.5m or less into bottles which had been sterilized by boiling, and were stored on ice, in the dark until incubated.

At each sampling site, for each lake, a sample bottle was filled with distilled water as a sample "blank" to assess contamination during the sampling process. Distilled water is free of bacteria and these blanks were necessary to ensure that the sampling process itself did not introduce contamination into the bottles. An additional sample was split between two separate Coliplates and incubated to assess analytical and sampling variation. Finally, a third sample was split into two portions – one of which was analyzed by the Coliplate and one by a commercial laboratory as a check on the performance of the Coliplate. Water samples were carefully transferred to ColiPlates, which were then incubated at a steady temperature of 37°C for 24 hrs. At the end of this time, the number of bacteria were determined by a count of the number of cells in the Coliplate which changed colour or which fluoresced under an ultraviolet light source.

4. Results

The overall program was successful in that useful results were obtained from a pilot program which had not been attempted previously. The need for several modifications and improvements was noted in order to improve the field program in subsequent years.

The Marine Patrol did a very good job of collecting and co-ordinating samples but did express some concerns over understanding of the program and with the logistics of sampling many locations over a wide spread area in the three lakes. More intensive training would be warranted in future years. We would also recommend that the Marine Patrol include several students of biology or environmental science who could take a lead on running the program from within the patrol and would bring familiarity with issues to the program.

Although the initial program called for collection of six samples of phosphorus and bacteria over the summer, logistical concerns reduced the sampling effort to four dates for each lake. The reduced sampling intensity, although not ideal, was considered adequate to :

a) evaluate the program;

b) provide results and recommendations to guide future years; and

c) provide an initial assessment of nearshore water quality in Lakes Muskoka, Joseph and Rosseau.

Review of the results shows some trends which may have become more clear with additional sampling effort. Delay of the program start up until July also inhibited the ability to collect more samples and we recommend an earlier start up in future years.

Several of the clay tiles used for the algae work disappeared over the summer. This is inevitable in a field program and only partially hindered interpretation. This could be addressed if field crews collected natural stones from each site and sampled them in future years. This would reduce the liability of substrate losses but would require greater attention to detail at the sampling stage.

We therefore recommend the following program modifications for subsequent years :

a) increased number of samples of bacteria and phosphorus from each site;
b) earlier program start up;
c) Marine Patrol staff with training in biology;
d) more intensive training; and
e) review of periphyton sampling details.

4.1 Total Phosphorus

The results show that there are distinct differences between sites within each of the three lakes and between nearshore and offshore measurements of phosphorus. Figure 2 shows the mean and standard deviation of phosphorus concentrations in four samples taken at each site in July and August. The black bars denote sites at which the differences in concentrations were statistically significant from the sites with white bars. Grey bars are intermediate concentrations. These sites had higher concentrations but differences were not statistically significant for the number of samples taken.

In all cases, the "field blanks" of clean distilled water showed little evidence of sample contamination (Table 3). This indicates that field and laboratory procedures were adequate, and that results represented phosphorus concentrations in the lake samples themselves. Analysis of duplicate samples from the same site on a given day showed an acceptable degree of variation between individual samples (Table 4) . A paired T-test showed no significant differences between duplicate samples, again indicating acceptable sampling precision.

In all cases, phosphorus concentrations measured in the open water samples were among the lowest for each lake and all lakes showed differences between sites and between inshore and open water samples (Figure 2). Mean open water concentrations were very close to values reported by the MOE for each of the three lakes (see Figure 1), showing that the 2001 sampling year was typical and that the results were comparable to those of the MOE and the District Municipality of Muskoka.

Table 3. Phosphorus Concentrations (µg/L) Measured in Field Blanks of Distilled Water

Date	TP (ug/l)
16-Jul	0.4
16-Jul	0.2
16-Jul	0.1
26-Jul	0.8
26-Jul	0.9
26-Jul	0.8
3-Aug	1.1
3-Aug	2.2
3-Aug	1.4
24-Aug	1
24-Aug	1.7
24-Aug	1.4

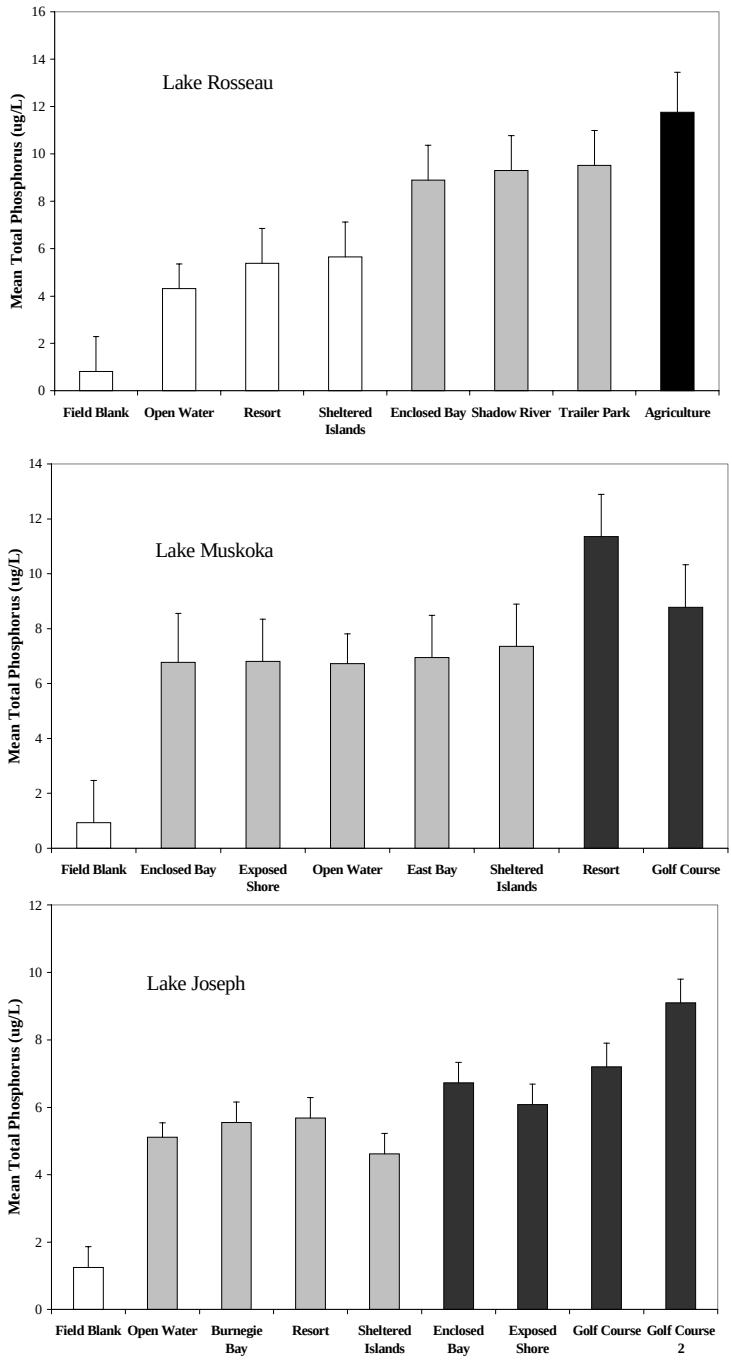


Figure 2. **Mean Total Phosphorus Concentration by Site Category for Lakes Rosseau (top), Muskoka (middle) and Joseph (bottom), Standard Error Bars are Presented, White bars Indicate Phosphorus Concentrations that Differ Significantly from Black Bars, Gray bars Represent Sites that are Similar to White and Black Bars**

Table 4. Results of Duplicate Analyses of Total Phosphorus Samples. Results Within 10% are Considered Acceptable

Date	Location	Result	Duplicate	% difference
1	R2	11.3	10.5	7.34
1	J1	5.5	5.8	-5.31
1	J1	5.5	4.5	20.00
1	M5	8.2	9.7	-16.76
1	M5	8.2	7.8	5.00
3	R2	6.8	6.4	6.06
3	J4	4.9	6.5	-28.07
3	M6	5.6	8.8	-44.44
4	R1	5.7	4.5	23.53
4	J1	6.3	6.1	3.23
4	M3	5.4	7.4	-31.25

Average open water concentrations in Lake Rosseau (Fig. 2 – top) appeared to be lower than those measured at the mouth of the Shadow River. Open water concentrations appeared to be lower than those in an enclosed bay with old development (Brackenrig Bay), among an island group with old development, and adjacent to a trailer park and agricultural land uses on the Indian River. Only the increased agricultural runoff values, however, were statistically significant. The trailer park and agricultural sites were located in the Indian River and so may also reflect urban runoff from Port Carling. More detailed sampling is recommended for this area in future years. High concentrations near the Shadow River most likely relate to natural sources of phosphorus from wetlands in the watershed. Riverine phosphorus levels are routinely higher than those in lakes. Further investigations are warranted in future years.

In Lake Muskoka, the open water reference, exposed shore, enclosed bay and island sites all had similar phosphorus concentrations, but phosphorus was elevated adjacent to a resort and a golf course (Figure 2 – middle). The open water phosphorus concentrations in Lake Muskoka are higher than those in the other lakes and this may have partially obscured between site differences which were more apparent in the other lakes. Statistical testing showed only that the resort and golf course sites were significantly higher than the distilled water samples. Nevertheless, the trends confirm the initial hypothesis that nearshore sites had elevated phosphorus concentrations. Further investigation are warranted in future years.

In Lake Joseph, average phosphorus concentrations were also higher in an enclosed bay with cottage development (Stills Bay), adjacent to a resort and adjacent to golf courses. The elevated levels on the exposed shore of Cox Bay may reflect the higher development intensity in that area while overland runoff from landscape alterations and fertilization runoff may have resulted in the high levels adjacent to the two golf courses. Although the golf courses and Cox Bay sites had higher concentrations than the other sites, the increases were only statistically significant in comparison with filed blanks of distilled water. Nevertheless, further investigation are warranted in future years.

Overall, the results from the nearshore phosphorus testing support an interpretation that the open water sampling program may not be representative. The Muskoka Lakes continue to maintain very good to excellent water quality offshore but open water samples underestimate phosphorus concentrations in nearshore areas which may be directly influenced by human activities and land uses. Further sampling is recommended to confirm these trends and to expand the database.

4.2 Algal Community

The algal measurements did not show a consistent relationship with phosphorus measurements or with sampling location. We note, however, that offshore measurements could not be made, as the methods were focussed on the nearshore attached algae. In addition, statistical comparisons could not be made because only one sample was taken for each site within each lake. Figures 3, 4 and 5 compare various measures of algal biomass across lakes.

For all lakes, the number of algal species identified ranged from 20 to 44 between sites (Figs. 3-5). Lake Joseph (Figure 5) showed the lowest overall number of species and the lowest algal biomass, whether measured as biomass of algal cells or as chlorophyll. This likely reflects the overall tendency for lower phosphorus concentrations in Lake Joseph, although algae did not show a strong relationship with phosphorus concentrations between lakes or between sites within a lake (Figure 6). The low numbers of samples prevent making firm conclusions but some trends towards increased algal abundance at high phosphorus concentrations were apparent.

Algal biomass varied in much the same way between sites as did chlorophyll (Figs. 3 – 5) and so future studies could conserve costs by omitting chlorophyll measurements in favour of direct counts of biomass and species richness which provide more detailed observations.

Neither species richness, chlorophyll concentration nor biomass showed consistent patterns between sites. Many factors will influence algal growth, such as the light environment (i.e., turbidity), activities of grazers such as crayfish or snails and exposure to wind. The only pattern of note was some tendency towards increased abundance of nutrient-tolerant blue-green algae adjacent to two of the three golf course sites. The hypothesized relationships of algal growth with land use and shoreline exposure did not emerge in the limited number of samples taken in 2001. Although further analysis and more samples may detect patterns the algal assays are relatively costly to analyze (but are inexpensive to maintain). The field of periphyton ecology in lakes is only now emerging for serious study in Canada. Any observations are useful but a more detailed study, which may be beyond the scope or the interest of the MLA, may be required to clearly identify the relationships between nearshore activities and periphyton growth.

Recommendation : Future studies by the MLA should focus on phosphorus measurements until those relationships are understood. Addition of turbidity measurements to better understand the light environment may allow refinement of the algal studies in future years. In the near future, algal studies by the MLA do not appear to be warranted.

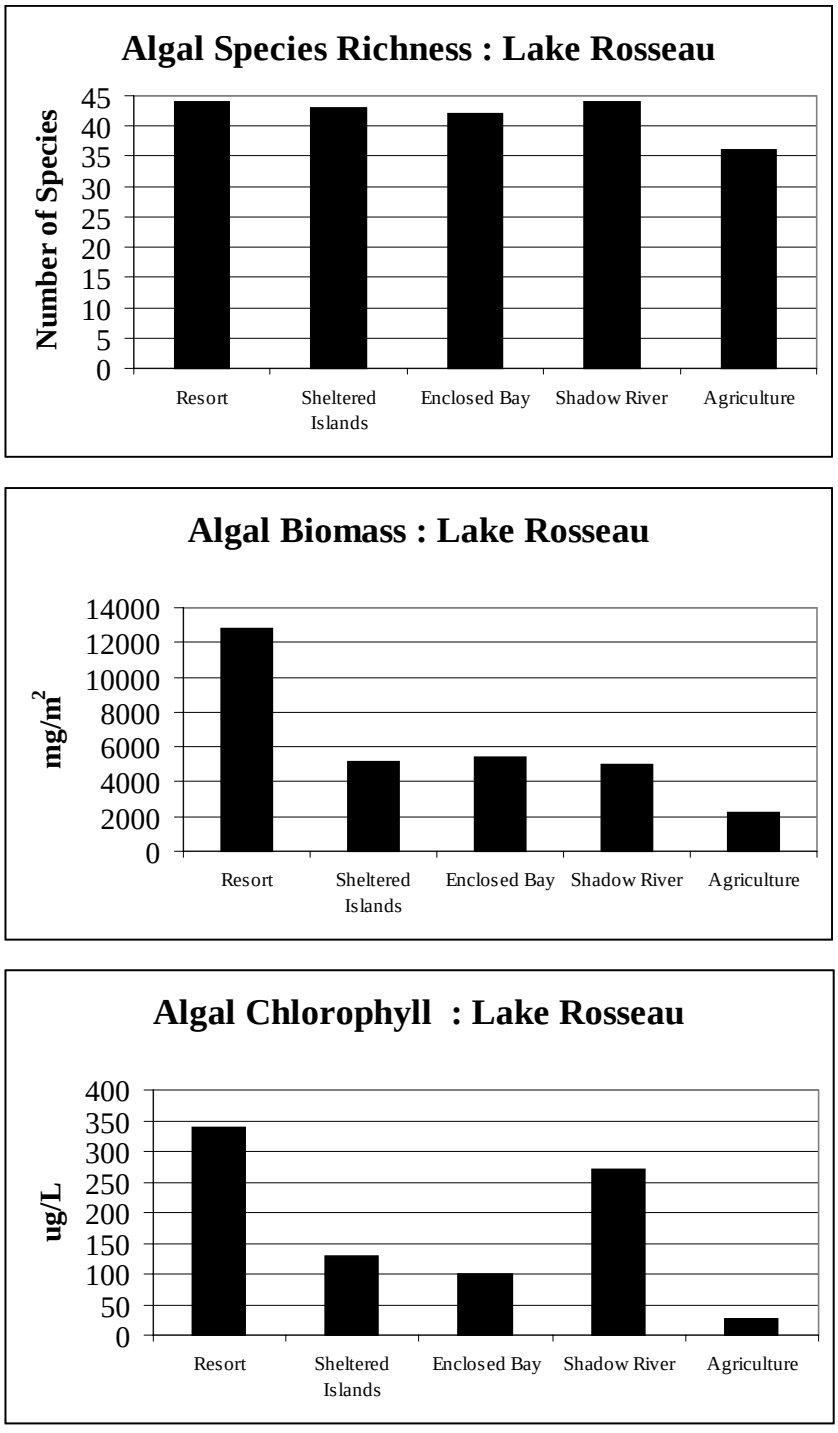


Figure 3. **Growth of Periphyton on Artificial Substrates in Lake Rosseau as Indicated by Species Richness (top), Total Algal Biomass (middle) and Chlorophyll Biomass (bottom)**

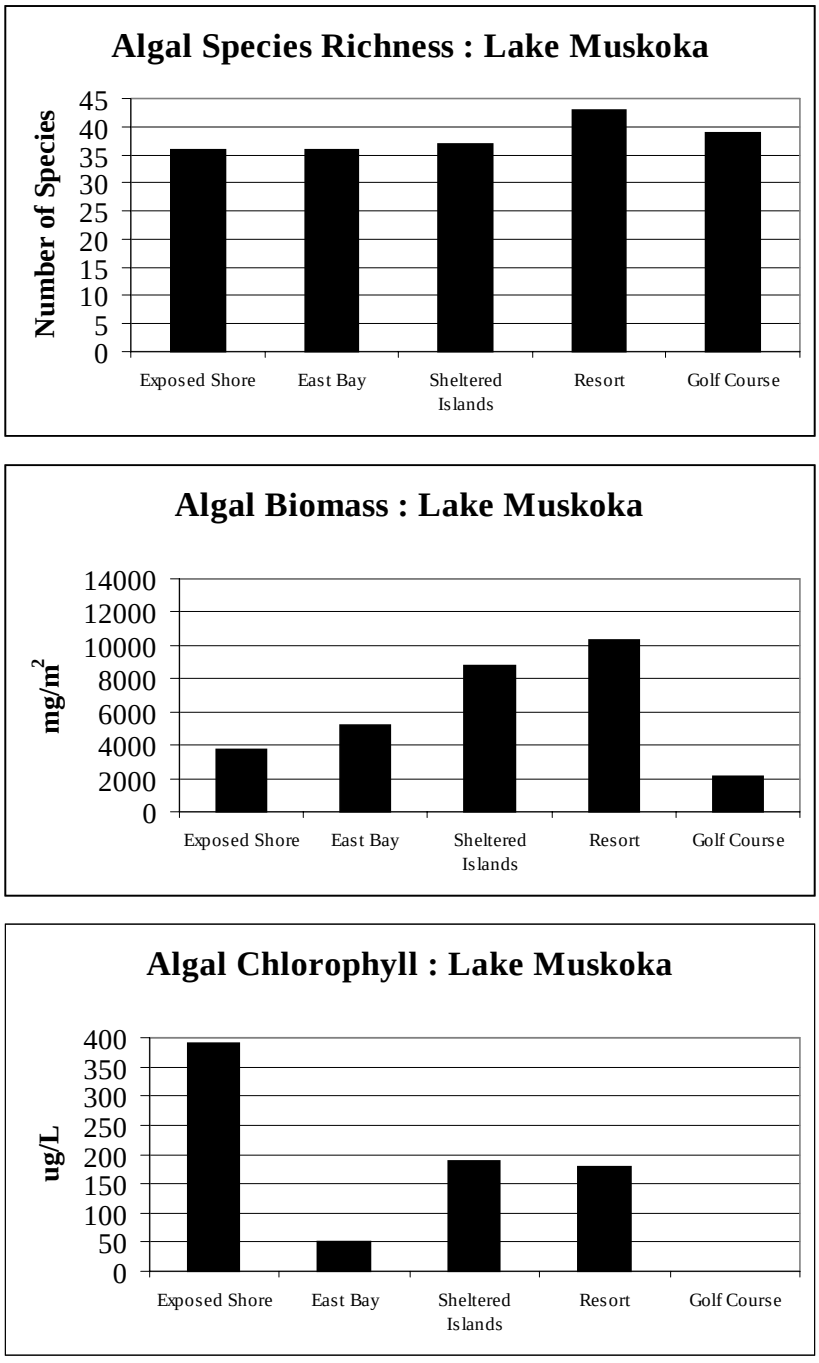


Figure 4. **Growth of Periphyton on Artificial Substrates in Lake Muskoka as Indicated by Species Richness (top), Total Algal Biomass (middle) and Chlorophyll Biomass (bottom)**

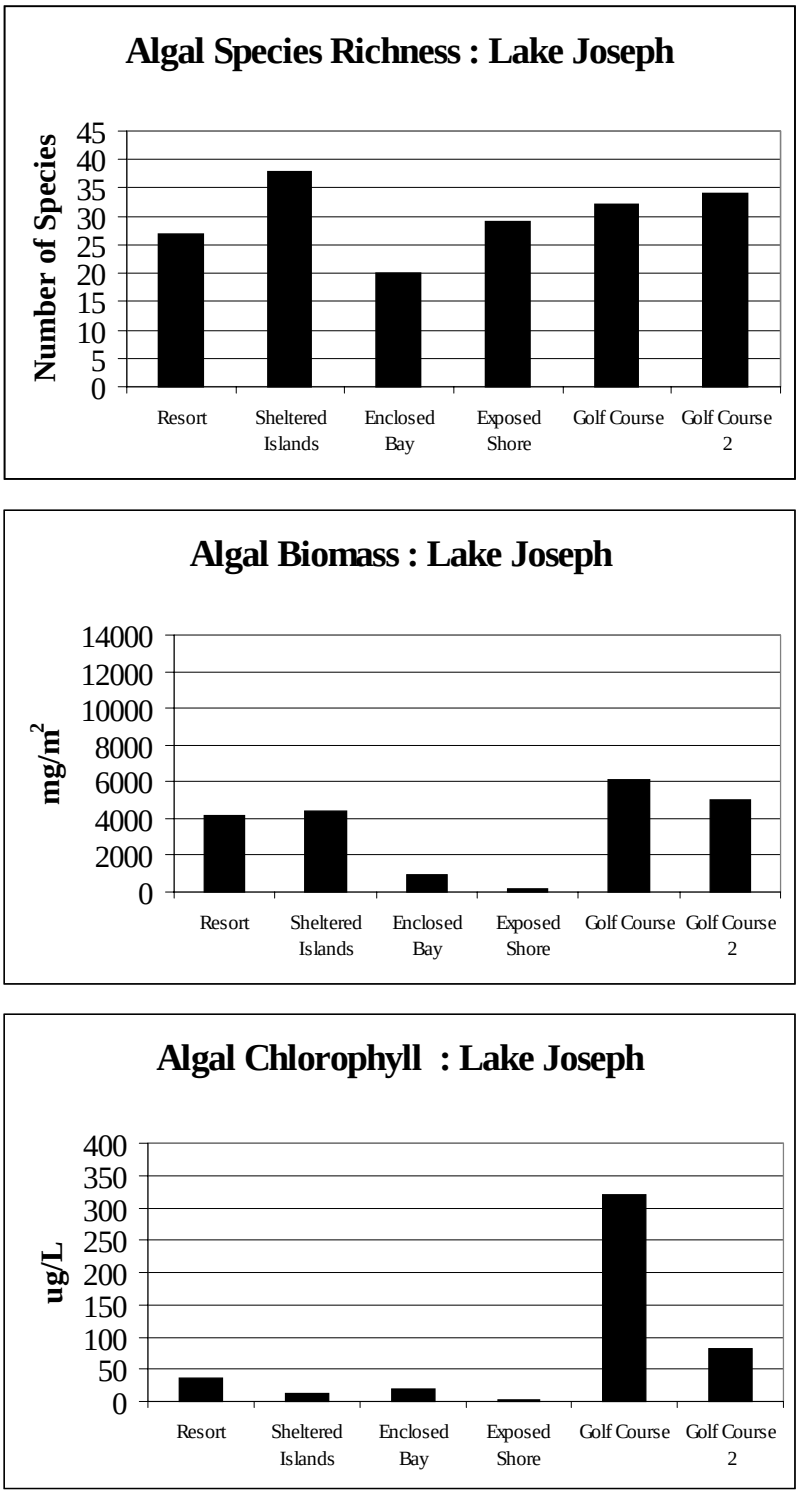
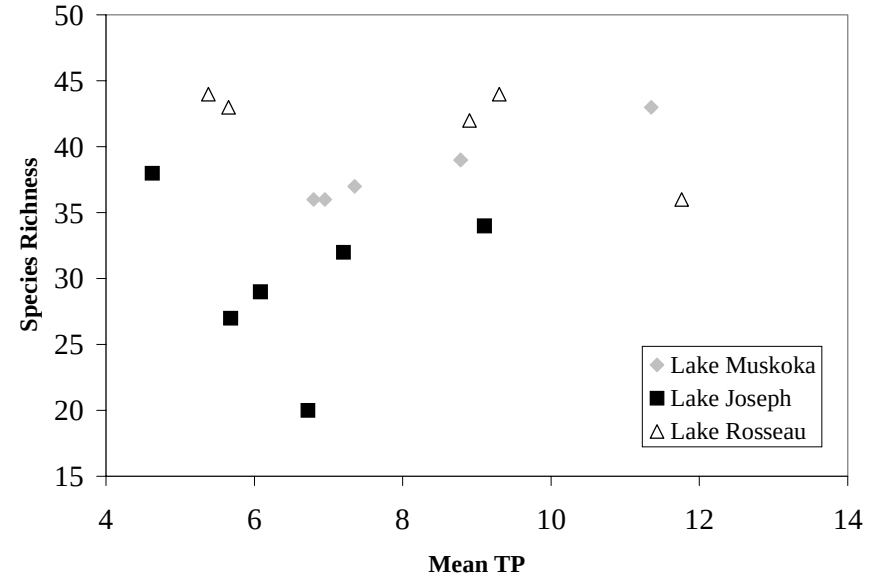


Figure 5. **Growth of Periphyton on Artificial Substrates in Lake Joseph. as Indicated by Species Richness (top), Total Algal Biomass (middle) and Chlorophyll Biomass (bottom)**



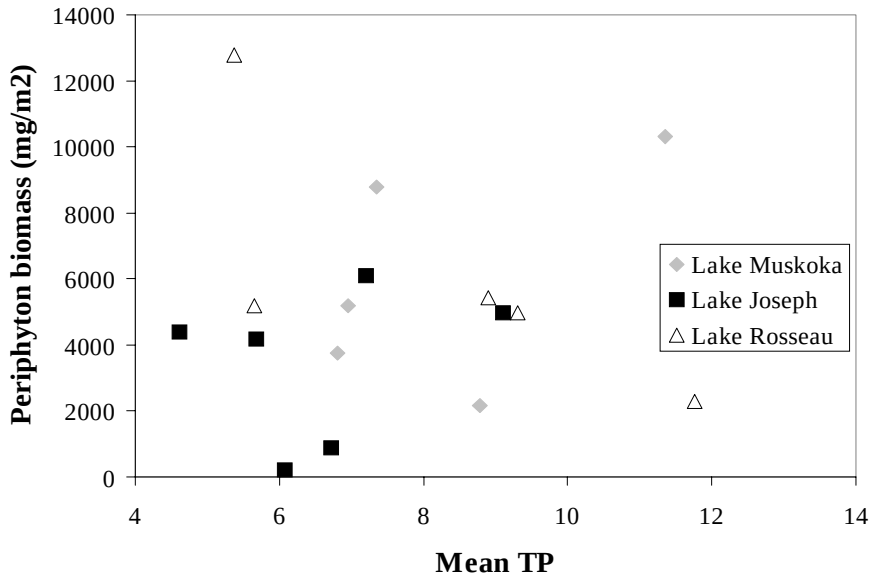


Figure 6. Relationship of Two Measures of Periphyton to Nearshore Phosphorus Concentration

4.3 Bacterial Studies

Quality control procedures for the bacterial samples showed that the sampling program was acceptable and representative. The bacterial samples showed no significant difference between duplicate samples overall but did indicate substantial variation between samples in some cases. This degree of variation is somewhat expected, however, in that bacteria are present in a non-random and non-uniform distribution in nature. Duplicate water samples illustrate variance due to measurement error as well as variance due to actual differences in bacterial distributions within a water sample. Unfortunately, logistical problems prevented comparison of Coli plate results with those from a commercial laboratory. Greater attention to training and scheduling in subsequent years is encouraged to provide better co-ordination.

The Ontario MOE's Provincial Water Quality Objective for the protection of swimming waters is that the geometric mean of 5 consecutive samples should not exceed 100 *E. coli* per 100 ml of water. On that basis, the water quality in the three Muskoka Lakes is excellent, as only three counts exceeded 100 over the entire sampling program. These samples, however, were all taken from areas of high development. (the Indian River near a trailer park, and two sites in Hamer Bay which receives runoff from cottages, a marina and a golf course which includes disposal of treated sewage). For the remainder of the lakes and sites, there was some evidence that bacterial counts increased near developed areas. *Mean E. coli* counts in open water areas were 3 – 4 counts per 100 mls, confirming that, although water quality in open areas is very good to excellent, that water should be treated before drinking. We note, however, that field blanks of distilled water contained, on average 3 *E. coli* per 100 ml. This corresponds to a positive count in one cell of the Coliplate and suggests that some component of the analysis results in very low level contamination.

Some caution should also be applied when comparing bacterial results to Ontario's water quality objective. The objective was developed for application in swimming beaches in rural and urban areas where sources may be more widespread than in the Muskoka Lakes and where there is a social imperative to maintain swimming beaches. Coliform bacteria, in general, are intended to be used as indicators of other potentially pathogenic bacteria, and not as water quality objectives in themselves. The presence of any bacteria is potential cause for concern and interpretation may have to be guided by more stringent objectives than 100 counts per 100 ml for body contact recreation. The results of the 2001 sampling (Figure 7) show that average counts for most sites were less than 20/100 ml for total coliform and less than 10/100 ml for *E. coli*. Further sampling is warranted but these counts of 20 and 10 may represent a reasonable natural background for consideration as a bacterial objective for the lakes. Observations of sampling programs carried out by other groups (Lake of Bays Association, Georgian Bay Association and the Severn Sound Remedial Action Plan) also suggest that interpretation of Muskoka water quality may best be carried out against these criteria. Examination of Figure 7 also suggests that wetland influence elevates bacterial counts and that proximity to wetlands should also influence interpretation. East Bay of Lake Muskoka was sampled at one site adjacent to a wetland and at another site as an area with little development as a reference. Both sites showed higher than average bacterial counts suggesting that the entire bay is influenced by wetland runoff.

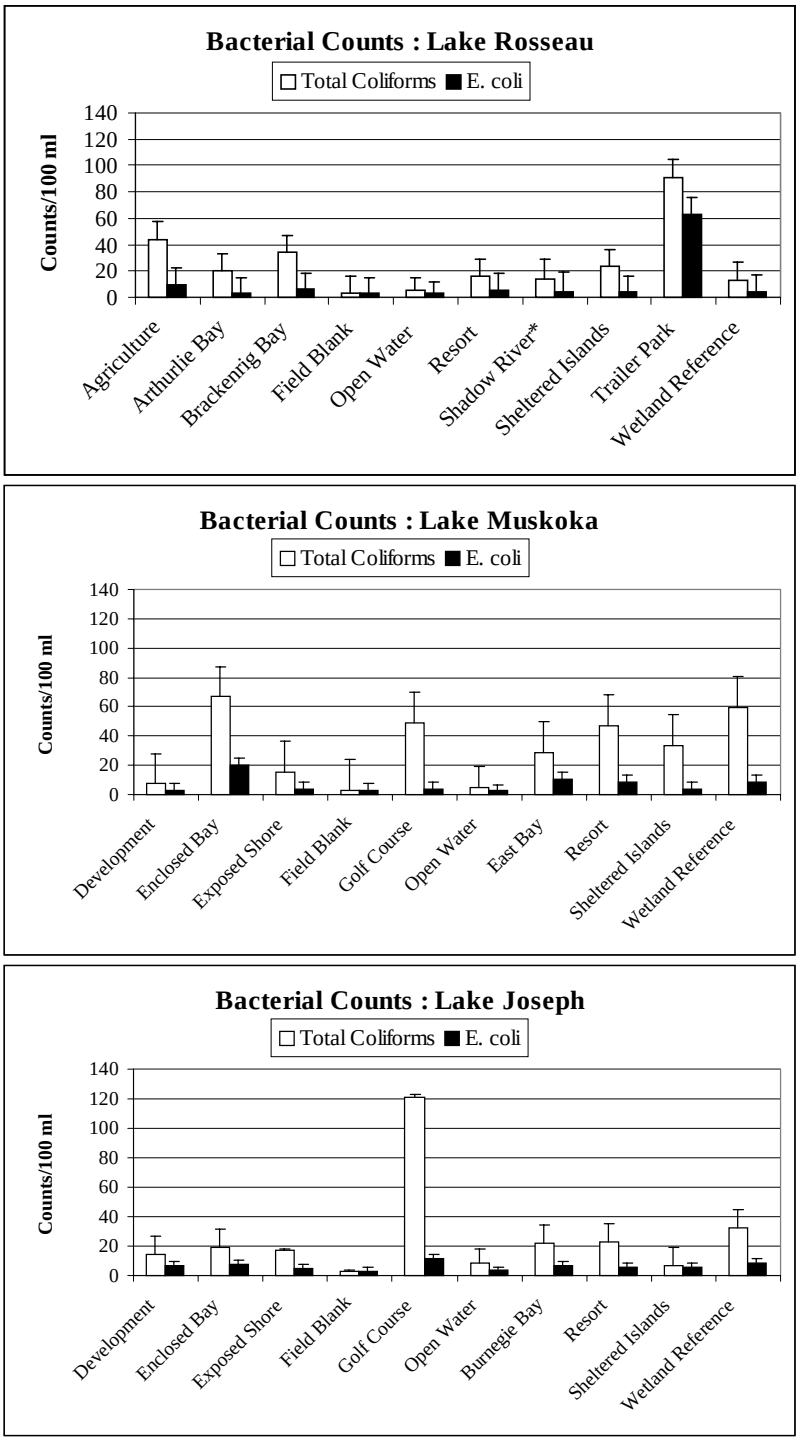


Figure 7. Comparisons of Mean Total Coliform and *E. coli* Measurements Between Sites and Lakes from the 2001 Sampling Program. Error Bars indicate One Standard Deviation from the Mean

In Lake Rosseau (Fig. 7, top), small increases were observed in all areas compared to the open water sites and the highest bacterial counts were recorded in nearshore and developed areas. The only substantial increase was in the Indian River, near a trailer park (but in an area also influenced by urban runoff and/or agriculture). Further analysis of this area is warranted.

In Lake Muskoka, (Fig. 7 , middle) counts were higher than in the other lakes. There was more variance between sites but the open water sites were consistently lower than nearshore sites.

In Lake Joseph, (Fig 7. bottom) there was little difference between sites, and counts were generally low. As in the other lakes, bacterial counts were higher in the nearshore areas than in offshore areas.

The bacterial program overall benefited from the dedication of MLA staff to the labour intensive process of inoculating, incubating and counting the Coli plates. Although the results suggest that the program be expanded this should only be done with a clear understanding of the workload requirements and the human resources necessary for proper training and implementation of the program.

5. Summary

An ambitious field program was undertaken in the summer of 2001 in order to gather preliminary information on innovative means of water quality determination in the Muskoka lakes. The results confirmed that, although water quality in the lakes is generally excellent, that specific patterns of nutrient enrichment, algal growth and bacterial growth suggest that water quality in the nearshore areas is not as good as in offshore areas. This further suggests that sampling programs which focus only on offshore, mid-lake water quality may not be sensitive enough to detect the more subtle effects of shoreline usage and development by humans.

Although there were no consistent and significant patterns relating shoreline use to degraded water quality, there were strong indications of impacts to nearshore nutrients, bacteria and algal density for specific land uses. These impacts were neither large nor dramatic, but do warrant further study to confirm if patterns exist. A combination of urbanization, agriculture and high density trailer park development appeared to have a consistent influence on the Indian River and more detailed studies in this location are warranted. Golf course runoff appears to result in increased phosphorus levels and algal growth in the nearshore area.

Analysis of the algal data did not reveal clear indicators of cause and effect and many factors beyond land use may alter algal growth. We therefore recommend that subsequent programs focus on phosphorus and bacterial indicators until such time as scientific research by other investigators can be brought to bear on the questions at hand. Analysis of turbidity (water cloudiness) along with phosphorus may help identify sites for future algal work.

We conclude that the 2001 sampling program was successful, in that it demonstrated the feasibility of looking at nearshore indicators of water quality and the utility of the results. The MLA should consider means to improve the program by :

a) providing a greater focus on water quality through hiring environmental scientists and biologists as part of the Marine Patrol and increasing their training. These students may also benefit themselves and the MLA by incorporating their summer work into an independent study project for their course requirements;

b) maintaining and increasing the involvement of the MLA staff in the day to day running of the water quality program to develop and maintain internal expertise within the MLA. Identification of an internal "champion" of water quality issues will allow greater continuity of programs and increased cost savings in program implementation;

c) allowing an earlier start to the program, to allow the collection of more than 4 samples over the summer;

d) adding new sites, but only if there are sufficient resources to do so without straining the energy or good will of staff;

e) reduced reliance of Gartner Lee Limited for data analysis and report preparation, and increased reliance on Gartner Lee staff to train and assist MLA staff in carrying out the water quality program. Again, this method allows greater continuity, develops internal expertise and maximizes cost efficiencies for the MLA; and

f) supporting graduate student research into factors influencing the growth of nearshore algae. I have contacted Professor Frances Pick at the University of Ottawa. She is an expert in periphyton in streams and lakes, is currently supervising graduate student investigations and expressed great interest in the MLA program. I have made an extra copy of this report for Dr. Pick and will provide it to her, with the permission of the MLA.

These recommendations made above will allow the MLA to move from an ambitious and successful Year 1 program to a consistent and "self perpetuating" program in the years to come.

In the end, this was an ambitious program. This report represents a landmark in the level of investigation carried out by an association and is, in several aspects, cutting edge. Although results are not clearly unequivocal they do support our initial concerns that management programs of the agencies may not be revealing the true health of the lakes. The program confirmed that water quality in Lakes Muskoka, Joseph and Rosseau is generally excellent but does point to problem areas which require further investigation.

Gartner Lee Limited welcomed the opportunity to help the MLA launch this program. We look forward to continued involvement in program design and interpretation and encourage the MLA to maintain their internal resources for the sampling and implementation of the program.

6. Acknowledgements

We thank the MLA Marine Patrol for their dedication to and enthusiasm for the work, Cheryl Watt and Cheryl Hollis of the MLA office for dedication to the program and "Coli Plate" expertise and to the MLA Board, particularly John Mollard, Ian Beverley and Rob Bosomworth for their support for this initiative.

Appendix 1

Bacterial Results

Gartner Lee

Appendix 2

Phosphorus Results

Gartner Lee