

Three Mile Lake

2008 Monitoring Results from the Ontario Lakes for the Future Program



ontario lakes
for the future

A Program of



citizens'environmentwatch

Prepared for
Three Mile Lake Association
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1 Introduction

The Ontario Lakes for the Future (OLF) program is a scientifically-based water quality monitoring program designed to help local community groups take care of their lakes. The program is designed to

1. Educate community members about how their lake works;
2. Facilitate the collection of data that describes the lake (via training and supply of equipment); and
3. Empower community members to protect and enhance their lake.

OLF is a program of Citizens' Environment Watch (CEW), an Ontario-wide environmental charity. OLF is based on the Muskoka Lakes Association's Water Quality Initiative. Muskoka Lakes Association volunteers have been learning about their lakes, monitoring their health and taking action to protect them through this program since 2001. CEW is grateful to the Muskoka Lakes Association for sharing their expertise with other lake associations in Ontario.

The following report summarizes the monitoring efforts that were undertaken by volunteers on Three Mile Lake in the summer of 2008. Where available, other monitoring data (e.g. From the Ministry of Environment's Lake Partner Program) is also included for comparison.

Monitoring data and results are also available for wide distribution on CEW's website at <http://www.citizensenvironmentwatch.org>. Useful definitions are available on the website as well as in the Glossary at the end of this report.

2 Background

The Three Mile Lake Association monitored total phosphorus concentration and secchi depth in the centre of their lake through the Ministry of Environment's (MOE) Lake Partner Program (LPP) between 1999 and 2006. They are interested in finding out what the water quality is like in the nearshore zone, and therefore decided to participate in the OLF program in 2008.

Both spring turnover ($[TP]_{so}$) and seasonal average ($[TP]_{epi}$) total phosphorus concentration were measured each year from 2002 to 2006, as shown in Figure 1. Each year, both measurements were very similar. Over that period, the average $[TP]_{so}$ was $7.66\mu\text{g/L}$ while the average $[TP]_{epi}$ was $8.3\mu\text{g/L}$. These figures suggest that the lake's nutrient level is healthy for an oligotrophic lake; only in 2006 did the concentration exceed the $10\mu\text{g/L}$ mesotrophic threshold. A slight upward trend (increase in concentration) is noticeable to 2006.

Likewise, volunteers had measured water clarity (secchi depth) at the same location near the middle of the lake in 1999, and each year between 2001 and 2006 (Figure 2). The average secchi depth over that time frame was 4.58m, with each measurement consistently being near the range of 4 to 5m. While there is no "objective" associated with secchi depth, these

Three Mile Lake Historic Total Phosphorus

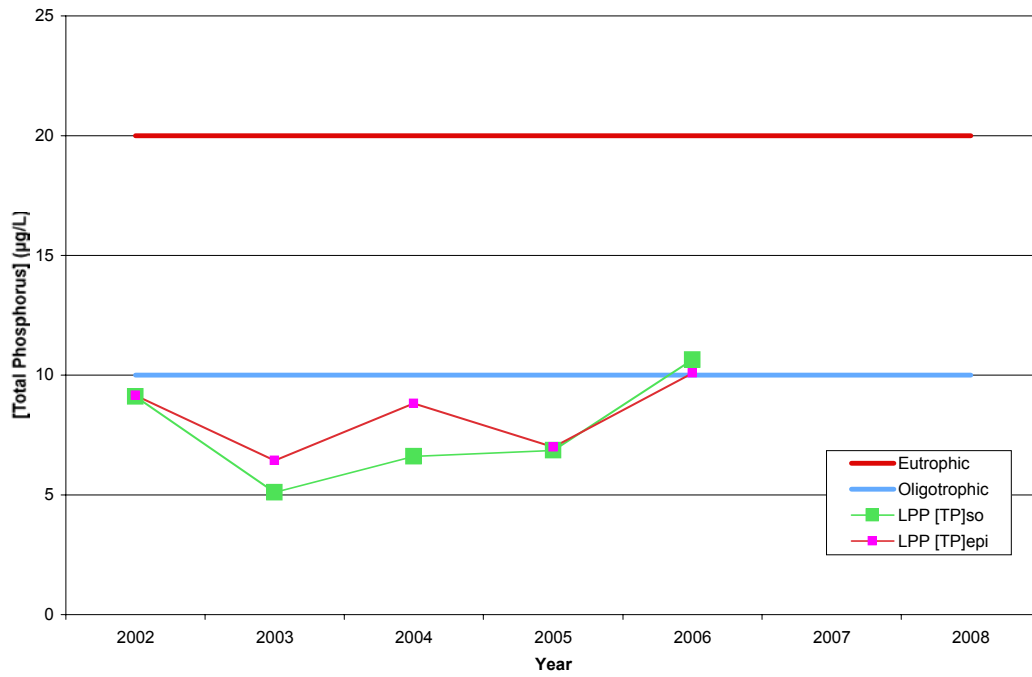


Figure 1 - Three Mile Lake Total Phosphorus Concentration at Site TML-0

Three Mile Lake Secchi Depth

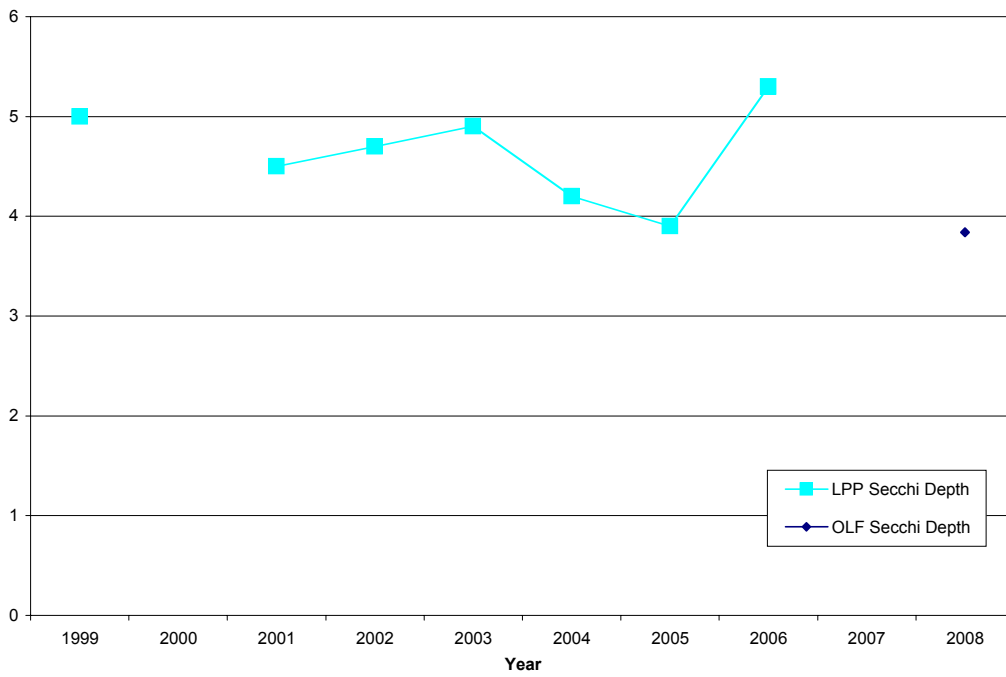


Figure 2 - Three Mile Lake Secchi Depth at Site TML-0

results also suggest a healthy lake; compared with other lakes in the area, 4m is a very good reading. As with total phosphorus concentration, there is a slight but noticeable trend suggesting that clarity is decreasing.

There are no historic bacteria measurements available for comparison.

3 Monitoring Locations

Four nearshore sites were selected for monitoring total phosphorus concentration and bacteria levels. Secchi depth was monitored at a site (TML-0) near the centre of the lake. These five sites are shown in Figure 3. An interactive version of this map is also available online at <http://tiny.cc/3mile>.



Figure 3 - Three Mile Lake sites

Site TML-0 was monitored for clarity (secchi depth). Sites TML-1, -2, -3 and -4 were each monitored for total phosphorus concentration, total coliform and *E.Coli*.

4 Results

Samples were collected and analyzed in 2008 according to protocols outlined in Appendix A – Scientific Methods. Secchi depth and $[TP]_{so}$ are directly comparable to LPP results discussed in Section 2. Nearshore $[TP]_{epi}$ and bacteria measurements form a baseline measurement for future monitoring activities.

4.1 Total Phosphorus

$[TP]_{so}$ was not monitored. Unfortunately, this means that no direct comparisons with historic data can be made.

Figure 4 shows average seasonal $[TP]$ measured at the four nearshore sites. Concentration observed at sites TML-1 and -3 were below $10\mu\text{g/L}$, while concentration at sites TML-2 and -4 were above $10\mu\text{g/L}$. This suggests that concentrations are higher in the south end of the lake than the north end, however all readings are in the same range as the historic $[TP]_{epi}$ observed in the centre of the lake, so further data should be collected before any conclusions are drawn.

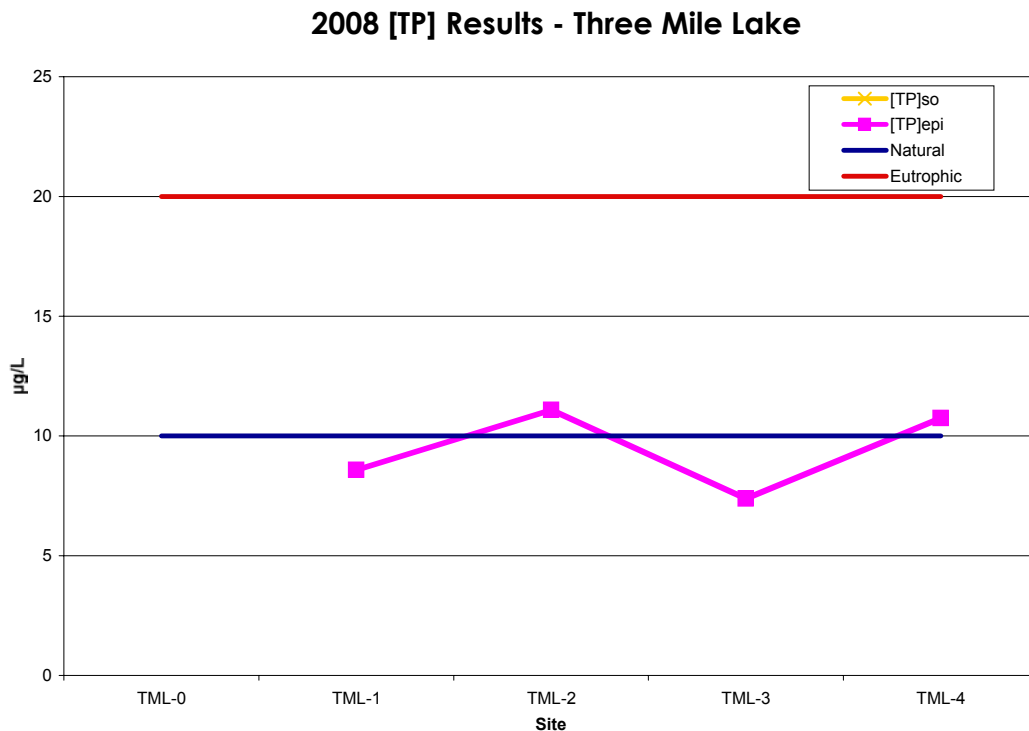


Figure 4 - 2008 Nearshore Average TP Concentration

4.2 Bacteria

Figure 5 shows the average seasonal bacteria counts measured at the four nearshore sites. (Averages shown are geometric means to account for the tendency of bacteria to agglomerate.) Total coliform are shown in pink, and *E.Coli* are shown in yellow.

Total coliform counts observed at sites TML-2, -3 and -4 fall within the expected range (identified in pink on Figure 5), while counts at site TML-1 are higher than expected. The standard deviation of the measurements at site TML-1 is also higher than expected. This may indicate that a discreet source of bacteria may be contributing to the bacteria in the lake at that location. All *E.Coli* measurements are within the expected range, and much lower than the Ontario Provincial Water Quality Objective of 100 counts/100mL (the level deemed “safe” for swimming). This suggests that if there is a discreet source of bacteria, it is contributing total coliform but not *E.Coli*, and is therefore likely not related to human or animal waste. Further investigation is not warranted unless this observation continues to be evident in future years.

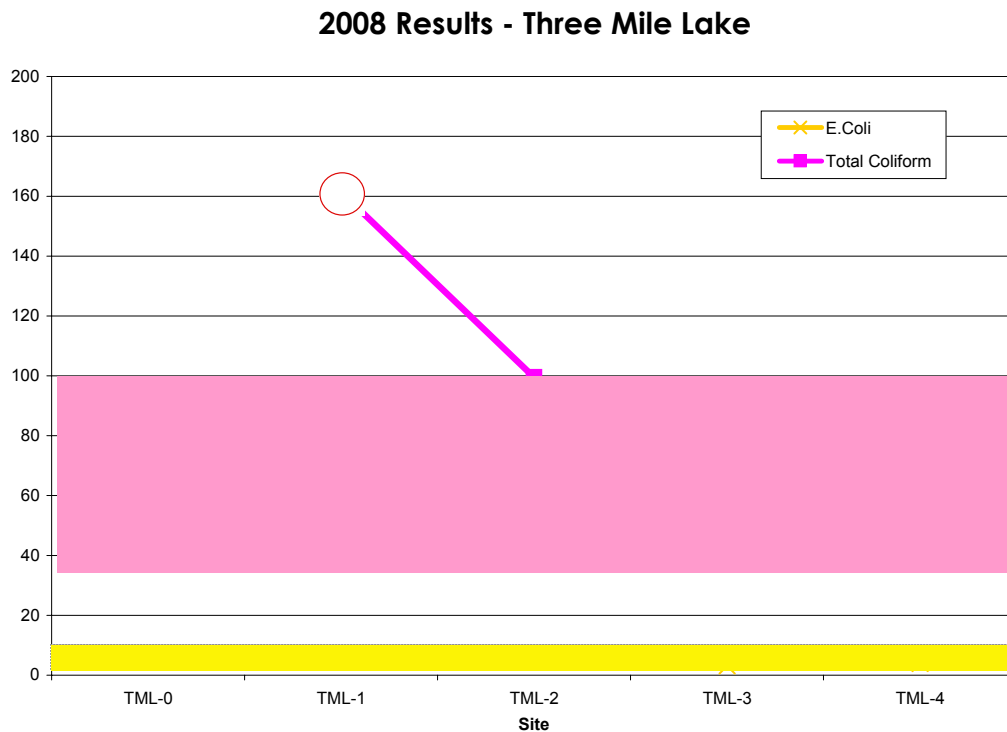


Figure 5 - 2008 Nearshore Average Bacteria Counts

4.3 Secchi Depth

The secchi depth observed in 2008 is shown in Figure 2. It is slightly below the range of historic secchi depth measurements, reinforcing the suggestion that there may be a slight decrease in water clarity over time.

5 Recommendations

It is very difficult to draw conclusions after only one year of data collection, and the only direct comparison between data collected in 2008 and historic data is in secchi depth. However, it is possible to make some recommendations that will lead to more definitive conclusions and, by extension, actions, in future years.

1. Ensure that data collection is comparable to and builds on other data already available for the lake. Specifically, spring turnover total phosphorus ($[TP]_{so}$) should be collected in future years (either through the OLF program or the LPP) to evaluate whether or not nutrient concentration in the lake is increasing towards an unhealthy level. Nearshore measurements taken in the future will also be directly comparable to those collected in 2008.
2. $[TP]_{epi}$ should be collected at site TML-0 to provide a baseline to compare nearshore measurements to for the given sampling year. Since TP loading originates on land, the concentration at the centre of the lake approximates a homogenous average concentration, while nearshore sites represent a more acute measurement of the affects of that loading. By identifying the area(s) that loading is having the greatest impact in the nearshore zone (when compared to the centre of the lake), action can be taken to remediate any sources of this loading.
3. Likewise, it may also be useful to measure bacteria in the centre of the lake to provide a baseline for comparison with nearshore measurements.
4. Overall, monitoring should be continued in order to evaluate if and when the lake is at risk of algae blooms and other symptoms of damage caused by humans around the lake. If this damage is observed early, it will be possible to carry out remedial measures proactively, avoiding unpleasant affects of eutrophication and high bacteria levels.

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For Citizens' Environment Watch

Appendix A

Scientific Methods

A1 Review of Protocols

The monitoring protocols used in the Ontario Lakes for the Future program were originally developed in 2001 by Dr. Neil Hutchinson of Gartner Lee Ltd for the Muskoka Lakes Association, which represents residents of Lakes Muskoka, Rosseau and Joseph (<http://www.mla.on.ca>). These protocols govern the collection, analysis and reporting of water samples.

It is part of best practices to periodically review protocols to ensure that they are relevant and effective. CEW assembled a Review Team in February 2008 to advise on how to increase the effectiveness of OLF monitoring protocols. Effective protocols must ensure scientific integrity while balancing the appropriateness for community-based monitoring. The member of the Review Team consisted of:

- Dr. Harvey Shear - Professor, Department of Geography, University of Toronto
- Dr. Karl Schiefer, Bluewater Biosciences

Details on the Review Team qualifications and Terms of Reference are available upon request from CEW.

Each member provided guidance regarding the general appropriateness of bacteria and phosphorus concentration as indicators of ecosystem health. In addition, they considered both the bacteria and phosphorus concentration protocols provided suggestions for increasing their effectiveness considering:

- Materials and equipment used;
- Data collection techniques;
- Data analysis techniques (not methodologies or technology);
- Quality control/quality assurance measures (including collection and analysis);
- Reporting techniques; and
- On-going evaluation.

CEW staff compiled a set of final recommendations which were approved by the Review Team. These recommendations were integrated into the 2008 Field Manuals, and are included below.

The coordinator of the Ontario Ministry of the Environment's Lake Partner Program at the time, Bev Clark, also contributed to the Review Team. Given his specific expertise in phosphorus sampling however, Bev was not comfortable advising on bacteria monitoring and therefore did not feel qualified to approve the final set of recommendations.

A2 Schedule

Sampling occurred on a biweekly schedule roughly between Victoria Day and Labour Day. Eight sampling dates were established over the course of this time.

A3 Sites

Sites for each sampling area were predetermined through consultation with the local community group. Volunteers were given a Google Map with satellite imagery with their sites marked, as well as digital photographs of each site. There are two types of sites: nearshore and offshore. Nearshore sites were located where the water depth is between 50cm and 150cm. Offshore sites are located in deep water near the centre of the sampling area (e.g. lake or bay).

Generally, bacteria monitoring was carried out in the nearshore zone, with total phosphorus monitoring in the deep water. Nearshore phosphorus monitoring was also undertaken in areas local community members had concerns about algae growth or other symptoms of elevated nutrient levels, or where previous monitoring suggested nutrient levels may be elevated.

A4 Monitoring Parameters

The following parameters were used as indicators of water quality:

- Total Phosphorus: $[TP]_{so}$ and $[TP]_{epi}$ ¹
- Bacteria: Total coliform and *E.coli*
- Secchi depth
- Temperature

The parameters measured at each sampling date were also predetermined based on the consultation with community members. Volunteers followed the Field Manual in measuring these parameters. In addition, supplementary information was also recorded on the datasheet, e.g. rainfall, air temperature and sample time. A copy of the data sheet is included in Appendix B.

A4.1 Phosphorus

Digest tubes were supplied by and returned to the Trent University Laboratory at the Ministry of Environment's Dorset Environmental Science Centre. Tubes were distributed to Team Leaders who applied appropriate labels and distributed them to Team Members.

The tubes were filled directly from surface water to avoid potential problems relating to the 'container effect' in which phosphorus may adhere to the sides of sampling vessels and not be transferred to the digest tube used for analysis (Clark and Hutchinson, 1992). Volunteers used the 'plunge and sweep' method to fill digest tubes; they turned the tubes upside-down, plunged them into the lake to approximately forearm depth, turned the tube 90° and 'swept' upwards towards the surface, filling the tube. Digest tubes were kept on ice and delivered to the Team where they stayed chilled until they were sent to the lab in Dorset.

A4.2 Total Coliform

Volunteers collected samples for total coliform analysis using 300mL juice bottles. The

¹ See definition of Total Epilimnetic Phosphorus in the Glossary

bottles were purchased new from the Consolidated Bottle Company. The bottles and caps were sterilized in boiling water, sealed and labelled either by CEW staff or Team Leaders.

The bottles were opened at the sampling location. Volunteers were instructed not to come in contact with either the inside of the bottle or the underside of the cap during sampling. The bottles were rinsed (completely filled and then emptied) with lake water three times. The bottle was then filled using the ‘plunge and sweep’ method described in Section A4.1. Samples were placed on ice in the field and returned to the Team Leader for analysis. If the bottle was contaminated, volunteers were instructed to empty any water in the bottle and rinse it with lake water three times before refilling.

Within the same day, analysis was completed as soon as possible after receiving all of the samples. The elapsed time was routinely within 3 hours of sample collection. The samples were kept on ice, in the dark to preserve the bacteria at the naturally occurring level. Water from each sample was poured into a commercially available bacteria testing kit, as shown in Figure A1. The kit is known by the trade name ColiPlate, and is manufactured by Bluewater Biosciences Inc. (<http://www.bluewaterbiosciences.com>).

Each ColiPlate has 96 wells containing an agar that reacts with coliform bacteria and turns blue. Actual bacterial counts are determined by comparing the number of blue cells to a table of Most Probable Numbers (MPN). The MPN table can be seen by visiting http://www.bluewaterbiosciences.com/products_coliplate_MPNchart.html.



Figure A1 - ColiPlate with 11 blue wells.

Any well that could be identified as any shade of blue or green was counted as a positive blue well, as per instructions from Bluewater Biosciences. Note that the ColiPlates have a detection limit of three counts/100mL (a count of zero blue wells corresponds to a count of “less than three” coliform/100mL). This barrier was handled by assigning all readings of “less than three” counts of coliform/100mL sample as an absolute value of 1 count/100mL.

This is a conservative estimate that reminds the reader that no untreated surface water is free from bacterial contamination.

A4.3 *Escherichia coli*

After testing for total coliform, each ColiPlate was used to analyze for *Escherichia coli* (*E. coli*). This was done by exposing the plate to a 366nm ultraviolet light. The wells that tested positive for *E. coli* fluoresced under the UV light. The number of fluorescent wells was counted and the MPN of organisms/100 mL was determined by comparison with the MPN tables. After the readings were finished, the ColiPlates were emptied into a septic system and the plastic plates were returned to Bluewater Bioscience office to be cleaned and reused.

As with total coliform measurements, all readings of “less than three” counts of *E. coli*/100mL sample as an absolute value of 1 count/100mL. This is a conservative estimate that reminds the reader that no untreated surface water is free from bacterial contamination.

A4.4 Secchi Depth

A secchi disk (Figure A2) was used to measure secchi depth in metres. Each disk was attached to with 15 metres of rope (length labelled at 50cm intervals). To record the secchi depth, the volunteer lowered the secchi disk on the rope into the water on the shady side of the boat until they could no longer see it. At this point, the volunteer recorded the depth on the sample date’s data sheet, lowered the disk a little further, raised the disk towards the boat until it reappeared and recorded the second depth on the same data sheet. Secchi depth was calculated as the arithmetic mean of the two recorded measurements.



Figure A2 - Secchi disk

(http://www.uwosh.edu/news_bureau/releases/feb06/lake%20monitoring.htm)

A4.5 Temperature

Temperature readings were recorded for all sites in degrees Celsius. Volunteers hung a pool thermometer from a rope into the surface water when first arriving at each site. After all of the other protocols were completed, the sampler then read the thermometer and recorded the reading.

A5 Quality Assurance/Quality Control

Replicability of experiments and results is paramount to the effective use of the scientific method. Collecting environmental data in the field is unfortunately subject to countless uncontrollable variables, which makes replicability difficult. For this reason, quality control and quality assurance protocols that aim to identify misinformation and procedural error are of utmost importance in the OLF program. Rigorous training, documentation and random duplicate measures were used throughout the 2008 season.

Quality assurance (QA) is a set of systematic procedures (i.e. preconditions and postconditions) designed to increase the probability of achieving reliable results, even though they cannot guarantee quality results. Quality Control (QC) is objective reports back on the reliability of results. In other words, QC is the measure of reliability.

A5.1 Quality Assurance

The QA procedures followed as part of the 2008 OLF program were:

- Volunteers filled out and submitted data sheets providing meta-data for every sample (a sample data sheet is found in Appendix B).
- A trained Team Member was required to participate in each sample collection (untrained “helpers” could always assist).
- Training sessions were provided by CEW in May prior to the first sampling date. If a volunteer was not able to attend the training session, they had the option of being trained by the CEW field staff at a mutually convenient time.
- Results of samples were recorded on paper, in MS Excel spreadsheets, and in an MS Access database. Data is additionally stored on Web servers that host the CEW website.

A5.2 Phosphorus Quality Control

More than ten percent of all phosphorus samples were duplicated. Most duplicates took place during the spring turnover period at deep water sites (sites which stratify). The samples were collected at the same time as the regular phosphorus samples using identical TP tubes and protocols. The duplicate measurements show the range of phosphorus results that can be expected as a result of sampling and laboratory variation.

A5.3 Bacteria Quality Control

Previous use of these protocols between 2002 and 2007 involved duplicating ten percent of all bacteria samples and comparing a further five percent of all bacteria samples with “blank” samples of commercially available bottled water. After these six years of study, CEW felt that the general reliability of the ColiPlate technology had been well demonstrated. We also felt that the literature available on the ColiPlate technology sufficiently confirmed its efficacy (http://www.bluewaterbiosciences.com/products_coliplate_verification.html; Lifshitz and Joshi, 1998). Moreover, volunteers often previously confused the various types of bacteria duplicate tests, which caused anxiety and cast doubt on the QC results that were reported.

For these reasons, lab duplicates and “blank” samples were not used in the OLF program in 2008.

Five percent of all bacteria (total coliform and *E.coli*) samples were duplicated and analyzed using the ColiPlate technology. These duplicate samples were spread evenly over all sampling areas, but were concentrated on sample dates 1 and 8. (Concentrating the duplicate samples made it easier to ensure volunteer teams collected the duplicate samples).

The samples were collected at the same time as the regular bacteria samples using identical collection vessels and protocols. The duplicate measurements show the range of coliform and *E.coli* results that can be expected.

A6 Analysis

The raw data was entered, analyzed and graphed using Microsoft Excel. Statistical calculations, e.g. T-tests, were also calculated using Microsoft Excel. The most recent spring turnover phosphorus data from the Ministry of Environment’s Lake Partner Program were compiled for data comparisons. These were compared to $[TP]_{so}$ that were collected by OLF volunteers in May. $[TP]_{epi}$ were calculated only if the sample size was at least six.

Appendix B

Sample Data Sheet

General Information

Date	<i>July 1</i>	Sample Time	<i>9:00 am</i>
Trained Sampler	<i>John Doe</i>	Other Volunteers	<i>Jane Doe Tom Doe</i>
Rainfall (heavy, moderate, light, none)	<i>light</i>	Air Temp.	<i>16° C</i>

Secchi Depth

Avg. = 1.80 m

LAK-0	"Down" Depth	<i>1.85 m</i>	"Up" Depth	<i>1.75 m</i>
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For Lab use

Preparation Time		Analysis Time	
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Site Specific Information

For lab use

Site Code	Water Temp.	Waves	Water Depth	Distance from Shore	Blue	TC Count	Flor.	EC Count
LAK-0	<i>21° C</i>	<input type="checkbox"/> Calm <input checked="" type="checkbox"/> Rough			<i>13</i>	<i>36</i>	<i>9</i>	<i>25</i>
LAK-1	<i>20° C</i>	<input checked="" type="checkbox"/> Calm <input type="checkbox"/> Rough	<i>80 cm</i>	<i>3 m</i>	<i>20</i>	<i>59</i>	<i>5</i>	<i>13</i>
LAK-2	<i>21° C</i>	<input checked="" type="checkbox"/> Calm <input type="checkbox"/> Rough	<i>60 cm</i>	<i>1.5 m</i>	<i>37</i>	<i>123</i>	<i>10</i>	<i>28</i>
LAK-3		<input checked="" type="checkbox"/> Calm <input type="checkbox"/> Rough	<i>110cm</i>	<i>5 m</i>	<i>9</i>	<i>25</i>	<i>0</i>	<i>>3</i>
LAK-4	<i>20° C</i>	<input type="checkbox"/> Calm <input checked="" type="checkbox"/> Rough	<i>140cm</i>	<i>2.5 m</i>	<i>68</i>	<i>328</i>	<i>1</i>	<i>3</i>

Glossary

Definitions

Arithmetic mean: This type of average is calculated by adding together a group of numbers and dividing the sum by the number of numbers.

Clarity: Water clarity is influenced both by dissolved and suspended matter. Clarity often indicates a lake's overall water quality, especially the amount of algae present. Algae are natural and essential, but too much of the wrong kind can cause problems (<http://www.dnr.state.wi.us/org/water/fhp/lakes/under/wclarity.htm>).
[http://www.dnr.state.wi.us/org/water/fhp/lakes/under/wclarity.htm - table2](http://www.dnr.state.wi.us/org/water/fhp/lakes/under/wclarity.htm-table2)

E.Coli: Fully known as *Escherichia Coli*, it is a subset of total coliforms, and is exclusively associated with faecal waste (Schiefer, 2001) making it a good indicator of faecal contamination. There are several different strains of *E.Coli*; most waterborne strains are themselves not harmful, but some (such as *E.Coli* O157:H7) can cause serious illness (OMH, 2001). For more information, please see http://www.citizensenvironmentwatch.org/wqi/muskoka_lakes/waterquality.php#bact.

Geometric Mean: This type of average is calculated by multiplying together a group of n numbers and then taking the n^{th} root of the resulting product. Geometric mean is used to indicate the central tendency or typical value of a set of numbers (http://en.wikipedia.org/wiki/Geometric_mean). It is typically used to calculate average bacteria counts because as a living organism, bacteria counts are highly sporadic and inconsistent.

Phosphorus: Phosphorus is a component of DNA and RNA and an essential element for all living cells (<http://en.wikipedia.org/wiki/Phosphorus>). It is found in fertilizers, soaps, and in human waste. Typically phosphorus is not removed from waste streams by conventional private treatment systems (septic systems) or by some municipal treatment systems.

Lakes on the Canadian Shield are typically oligotrophic, meaning poor in nutrients. Phosphorus is usually the limiting nutrient, that is, phosphorus is in short supply so every bit of phosphorus added to the lake system is directly used to create biological matter such as algae. This makes phosphorus the most important indicator of human-based environmental impacts on our lakes. For more information, please see http://www.citizensenvironmentwatch.org/wqi/muskoka_lakes/waterquality.php#eutro.

Sampling Area: A geographic location encompassing a group of OLF program monitoring sites.

Secchi Depth: An expression of water clarity, measured using a secchi disk - a small disk attached to a rope. Alternating quarters of the top side of the disk are coloured white and

black. The secchi depth is the depth of water whereby the sampler can no longer distinguish the white and black quarters of the disk.

Site: The discrete and unique location where samples are to be collected on each sample date.

Spring Turnover Phosphorus ([TP]_{so}): A single phosphorus concentration measurement taken in a stratified lake during the spring turnover period. This measurement has been shown to adequately represent the overall phosphorus concentration in a lake (Clark, 1992). Typically the spring turnover lasts for a few days when the temperature of the entire water column is consistent (usually 4°C) allowing the water column to mix. In practice, measurements taken anytime in May are considered to be adequate by Ontario's Ministry of the Environment (http://www.ene.gov.on.ca/envision/water/lake_partner/index.htm).

Standard Deviation: The most common measure of statistical dispersion, measuring how widely spread the values in a data set are (http://en.wikipedia.org/wiki/Standard_deviation). The smaller the standard deviation, the more consistent and predictable are the numbers making up a data set. In the OLF program, a large standard deviation within a year suggests that water quality is much different at different times throughout the sampling period, which could mean that specific conditions or influences are affecting water quality at a given site over the course of the season.

Total Epilimnetic Phosphorus ([TP]_{epi}): The arithmetic mean of phosphorus concentration measurements taken above a stratified water column's thermocline over the ice-free period. *Note:* average phosphorus concentration as reported by OLF is very similar to, but not exactly [TP]_{epi} as samples are not collected over the entire ice-free period.

Total Coliform: Coliform include a variety of bacteria. In practice, detectable coliform are usually enteric, found in the intestinal tracts of humans and other warm-blooded species. For more information, please see http://www.citizensenvironmentwatch.org/wqi/muskoka_lakes/waterquality.php#bact.