

# **Lake Champlain Long-Term Water Quality and Biological Monitoring Program**

## **2006 Annual Report**

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# Program Background and Purpose

The Lake Champlain Long-Term Water Quality and Biological Monitoring Program began in 1992 and has continued each year since then. The project is conducted by the Vermont Department of Environmental Conservation (DEC) and the New York State DEC, with funding provided by the Lake Champlain Basin Program and the two states.

The current monitoring program grew from the Lake Champlain Diagnostic-Feasibility Study conducted by Vermont DEC and New York State DEC (1997). The Diagnostic-Feasibility Study focused primarily on the measurement of phosphorus and chloride concentrations in the lake and its tributaries to support a phosphorus loading budget and mass balance model for Lake Champlain. The Diagnostic-Feasibility Study also provided vertical water column profile data on several other water quality measurements at deep-water stations. The present long-term monitoring project continued sampling a subset of the lake and tributary station network that was established for the previous Lake Champlain Diagnostic-Feasibility Study, and extended the program to include a broader range of chemical and biological measurements.

The purposes, scope, and methods for the current monitoring project are described in annual work and quality assurance project plans, approved by the U.S. Environmental Protection Agency. One of the original purposes of the program was to provide a current limnological survey of Lake Champlain, including a data set that would support the development of hydrodynamic, eutrophication, and food web models for the lake (e.g., Applied Science Associates, Inc. 1996, Levine *et al.* 1997, HydroQual, Inc. 1995). The primary purpose of the project was redefined in 1995 to be the detection of long-term environmental change in the lake, and the sampling program was modified to more efficiently serve this purpose. The list of sampling variables was narrowed to include those lake and tributary constituents judged by the Lake Champlain Basin Program Technical Advisory Committee to be the most meaningful for assessing the long-term effects of management actions and other changes in the environment. Optimum sampling frequencies were determined from a statistical power analysis. The power analysis was conducted to ensure that sample sizes would be adequate, but not excessive, for the purpose of statistically documenting the anticipated magnitude of water quality changes in the lake and its tributaries over time.

The Technical Advisory Committee of the Lake Champlain Basin Program reviewed the program again in 2006-2007 and began to incorporate the concept of “ecological indicators” into the work plan. Criteria for these indicators require that they be ecologically and socially relevant, measurable, statistically sound, and interpretable (Watzin *et al.* 2005). Changes to the monitoring program were implemented to more closely align sampling parameters and methodology with ecological indicators to provide quantifiable measures of overall ecosystem health. This is an on-going process and the sampling program will continue to incorporate elements of the ecological indicators program over the next several years.

The project data are stored in a computerized database and are freely available on request and on the Internet to researchers, management agencies, consultants, students, and the general public. The purpose of this report is to describe the project methods, document the database for users of the data, and report on program activities during 2006.



## Sampling and Analytical Methods

Detailed descriptions of the field sampling and analytical methods and quality assurance procedures can be found in the annual Work and Quality Assurance Project Plan (New York State DEC and Vermont DEC 2007). A brief summary of methods is provided here.

The sampling station network includes the core set of 15 lake stations and 18 tributary stations (19 beginning in 2007 with the addition of the Rock River) shown in Figure 1 and listed in Table 1. The tributary stations are located as near to the river mouths as possible on rivers which have continuous flow gages operated by the U.S. Geological Survey (USGS) or the Quebec Ministry of Sustainable Development, Environment, and Parks (MDDEP). These lake and tributary stations have been sampled consistently during the entire monitoring period since 1992, with the exception of stations 9 and 16 which were added in 2001, and station 51 which was added in 2006. Other lake stations listed in Vermont DEC and New York State DEC (1997) have been sampled during short-term surveys for a limited number of water quality measurements.

The 15 core lake stations are sampled for most chemical tests using Kemmerer or Van Dorn water bottle devices, with discrete depth samples combined to form vertical water column composites. The lake stations are sampled approximately biweekly from May to early November each year. When thermal stratification exists, composite samples (composed of 2-3 discrete-depth samples) are obtained from both the epilimnion and hypolimnion layers. Temperature and dissolved oxygen concentrations are measured in vertical profile at discrete depths at the deeper stations. Chlorophyll-a is sampled as a vertically integrated composite of the photic zone, defined as twice the Secchi disk depth.

Quantitative biological sampling in the lake for phytoplankton, zooplankton, and mysids is conducted concurrently with the water quality sampling. Beginning in 2006, phytoplankton and zooplankton were sampled biweekly. Mysids are sampled monthly, six months per year. Zooplankton and mysid samples are analyzed at the Lake Champlain Research Institute (SUNY-Plattsburgh) under contract with the New York State DEC. Beginning in 2006, phytoplankton samples are analyzed by the Vermont DEC.

Close-interval, *in situ* vertical profiles for temperature, dissolved oxygen, pH, specific conductance, total dissolved solids, turbidity, and reduction-oxidation potential are obtained at some sites in the lake using a multi-probe sonde unit. In 2006, close-interval profiles were collected for temperature, dissolved oxygen, pH, and specific conductance during every site visit using a multi-probe sonde unit. (Hydrolab, Inc. 1991, 2006.)

Tributary samples are obtained from bridges using depth and velocity-integrating sampling devices. An effort is made to obtain up to 20 samples per year at each tributary site, including as high a proportion of samples as possible during high flow conditions in order to improve the precision of tributary annual mass loading estimates (Vermont DEC and New York State DEC 1997). Beginning in 2006, a minimum of four additional collections were to be made during base flow conditions.

A list of the tests sampled in the lake and the tributaries and the current chemical analytical methods is given in Table 2. During the period of this program, chemical analyses have been conducted by the Vermont DEC Laboratory, the New York State Department of Health



Laboratory, and other private contracted laboratories in New York. In some cases, samples were split in the field and analyzed concurrently at laboratories in both states. Currently, all samples are analyzed at the Vermont DEC Laboratory only. Care should be taken by data users when combining results of samples analyzed at different laboratories. A previous analysis of paired samples (Vermont DEC and New York State DEC 1998) revealed small but statistically significant differences between the results obtained by the different laboratories for many of the tests. The laboratory where each sample was analyzed (VT or NY) is recorded in the project database.

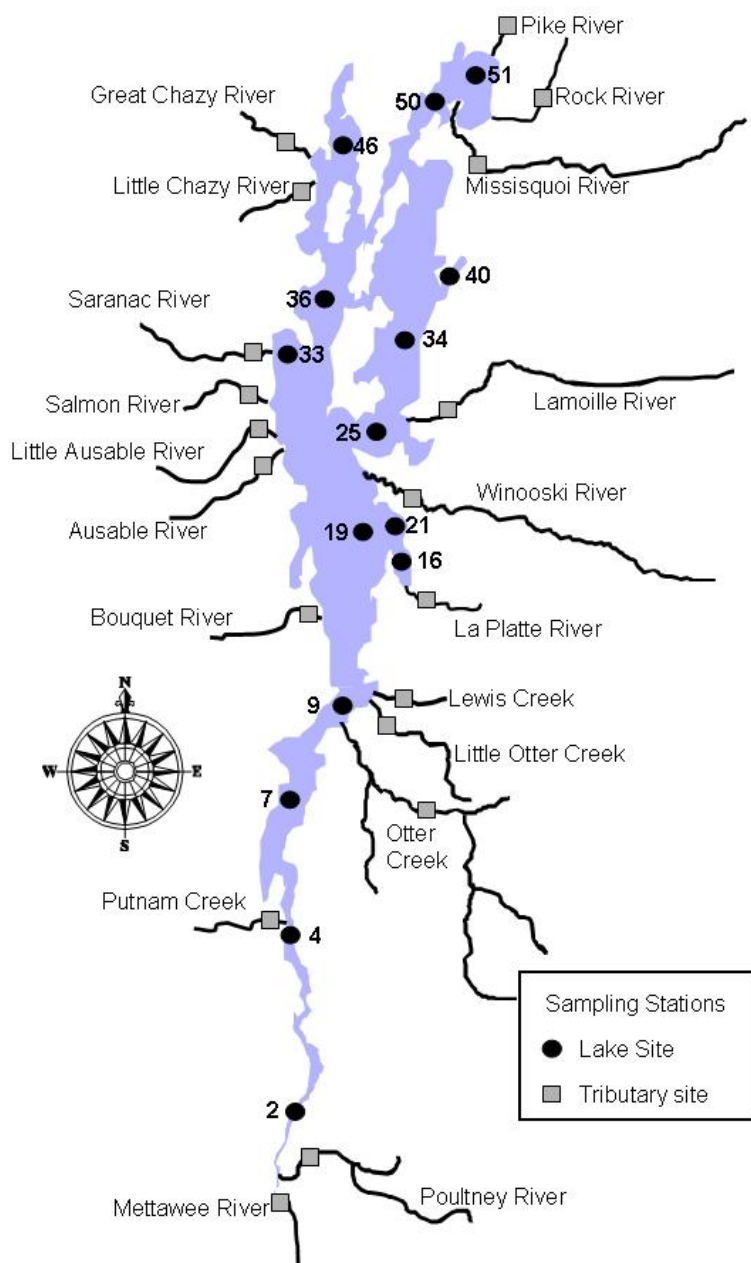


Figure 1. Lake and tributary stations.



Table 1. List of lake and tributary sampling stations and their locations. The station codes used in the database for the tributary stations are given in parentheses.

Lake Station	Latitude N	Longitude W	Tributary Station	Latitude N	Longitude W
2	43° 42.89'	73° 22.98'	Winooski (WINO01)	44° 31.52'	73° 15.41'
4	43° 57.10'	73° 24.47'	Otter (OTTE01)	44° 09.94'	73° 15.40'
7	44° 07.56'	73° 24.77'	Missisquoi (MISS01)	44° 55.23'	73° 07.63'
9	44° 14.53'	73° 19.75'	Lamoille (LAMO01)	44° 37.96'	73° 10.39'
16	44° 25.55'	73° 13.92'	Poultney (POUL01)	43° 34.24'	73° 23.53'
19	44° 28.26'	73° 17.95'	Pike (PIKE01)	45° 07.38'	73° 04.18'
21	44° 28.49'	73° 13.90'	Lewis (LEWI01)	44° 14.80'	73° 14.77'
25	44° 34.92'	73° 16.87'	Little Otter (LOTT01)	44° 12.24'	73° 15.11'
33	44° 42.07'	73° 25.09'	LaPlatte (LAPL01)	44° 22.21'	73° 13.01'
34	44° 42.49'	73° 13.61'	Saranac (SARA01)	44° 41.52'	73° 27.19'
36	44° 45.37'	73° 21.30'	Ausable (AUSA01)	44° 33.63'	73° 26.95'
40	44° 47.12'	73° 09.73'	Mettawee (METT01)	43° 33.33'	73° 24.10'
46	44° 56.90'	73° 20.40'	Great Chazy (GCHA01)	44° 58.81'	73° 25.96'
50	45° 00.80'	73° 10.43'	Bouquet (BOUQ01)	44° 21.84'	73° 23.41'
51	45° 02.50'	73° 07.78'	Little Ausable (LAUS01)	44° 35.65'	73° 29.79'
			Salmon (SALM01)	44° 38.40'	73° 29.70'
			Putnam (PUTN01)	43° 57.35'	73° 25.99'
			Little Chazy (LCHA01)	44° 54.12'	73° 24.88'
			Rock River (ROCK02) <sup>1</sup>	44° 59.49'	73° 04.22'

<sup>1</sup>Added in 2007.



Table 2. List of current analytical methods for tests included in the project database.

Measurement	Test Code	Reporting Units	Method Reference <sup>3</sup>	Method Number
Total Phosphorus	TP	mg/L	APHA (1998)	4500-P H
Dissolved Phosphorus	DP	mg/L	APHA (1998)	4500-P H
Ortho-Phosphorus <sup>1</sup>	OP	mg/L	USEPA (1983)	365.1
Chloride	TCI	mg/L	APHA (1998)	4500-Cl G
Dissolved Silica <sup>2,4</sup>	DSi	mg/L	APHA (1998)	4500-SiO <sub>2</sub> F
Alkalinity	Alk	mg/L	APHA (1998)	2320-B
Total Nitrogen	TN	mg/L	APHA (1998)	4500-N C
Total Kjeldahl Nitrogen <sup>1</sup>	TKN	mg/L	USEPA (1983)	351.2
Total Nitrate/Nitrite Nitrogen <sup>1</sup>	TNOX	mg/L	USEPA (1983)	353.2
Total Ammonia Nitrogen <sup>1</sup>	TNH3	mg/L	USEPA (1983)	350.1
Total Suspended Solids <sup>5</sup>	TSS	mg/L	APHA (1998)	2540-D
Total Organic Carbon <sup>1</sup>	TOC	mg/L	USEPA (1983)	415.2
Dissolved Organic Carbon <sup>1</sup>	DOC	mg/L	USEPA (1983)	415.2
Dissolved Inorganic Carbon <sup>1,2</sup>	DIC	mg/L	APHA (1995)	4500-CO <sub>2</sub>
Calcium, Magnesium, Sodium, Potassium, Iron <sup>4</sup>	Ca, Mg, Na, K, Fe	mg/L (µg/L for Fe)	USEPA (1992) USEPA (1994)	3010-A 6020-A
Lead <sup>1</sup>	Pb	µg/L	USEPA (1983)	239.2
Dissolved Oxygen <sup>2</sup>	DO	mg/L	APHA (1998) Hydrolab (1991, 2006)	4500-OC
Chlorophyll-a <sup>2</sup>	Chl-a	mg/L	USEPA (1997)	445.0
Temperature	Temp	°C	VT DEC (2006) YSI (1998) Hydrolab (1991)	1.1.2
Conductivity	Cond	µS/cm	VT DEC (2006) YSI (1998) Hydrolab (1991)	1.6.2
pH	pH		VT DEC (2006) YSI (1998) Hydrolab (1991)	1.5.5
Secchi Disk Depth <sup>2</sup>	Secchi	m	VT DEC (2006)	1.2.1

<sup>1</sup> No longer included in the sampling program.

<sup>2</sup> Not currently sampled in the tributaries. Chlorophyll-a was sampled in tributaries from 1995-2005.

<sup>3</sup> APHA = American Public Health Association

USEPA = U.S. Environmental Protection Agency

VT DEC = Vermont Department of Environmental Conservation

YSI = Yellow Springs Instrument, Corp.

<sup>4</sup> Sampled on five year cycle after 2005; next sampling occurs in 2010.

<sup>5</sup> Not sampled in the lake after 2005.



# Project Database

The project database is maintained by the Vermont DEC on its computer network using the commercial database program Microsoft® Access 2003. Daily tape backup is provided, and copies of backup files are archived in separate locations. Database security features are employed to prevent editing or deletion of the original data by users other than the authorized database administrators. Copies of the current database are also available at the New York State DEC.

The database is updated annually within a few months of the end of the field season. The data are freely available on request in either electronic or paper copy form to other government agencies, researchers, consultants, students, and the general public, and on the Internet at [http://www.anr.state.vt.us/dec/waterq/lakes/htm/lp\\_longterm.htm](http://www.anr.state.vt.us/dec/waterq/lakes/htm/lp_longterm.htm)

Sample documentation includes database fields for the station name (Table 1) and the date and time of collection. For lake samples, other fields give the sampling depth in meters for discrete depth samples, and the depth layer for composite samples, using the following codes:

- COM = composite sample
- E = epilimnion layer
- H = hypolimnion layer
- U = unstratified conditions
- P = vertical profile sample

The database includes a field for quality assurance information using the codes given below. Only the results from the regular (A) samples are provided on the project website.

- A = regular sample
- D = field duplicate sample
- B = field blank sample

The laboratory at which each sample was analyzed is coded in the database as follows:

- VT = Vermont DEC Environmental Laboratory
- NY = New York State Department of Health Laboratory, or other private contract laboratories in New York

The analytical results for each sample are contained in database fields with names corresponding to the test codes indicated in Table 2. Each chemical test field in the database has an associated remark field (e.g. "TP\_R") in which "less than" or "greater than" signs are entered where necessary for results below or above analytical detection limits.

Database integrity is enforced in several ways. Primary keys are defined to uniquely identify each record in the database and prevent duplication. The primary keys are composed of multiple fields that uniquely identify each sample (e.g., station, date, time, stratum, depth). Validation rules are used to ensure that data entries conform to a consistent format. Table relationships are defined within the database in a manner that permits subsets of the data (e.g., results for specific stations or tests) to be extracted using simple queries.

The biological monitoring data for phytoplankton and zooplankton are not yet fully analyzed or available electronically, and are not included in the project database. These data will be



provided as part of the publicly available project database as soon as possible. All vertical profile *in situ* sampling results obtained using the multi-probe sonde have been reviewed for accuracy and organized into the database.

Flow rates in the monitored tributaries are continuously measured by the USGS or the Quebec MDDEP. A list of the downstream-most flow gages on these tributaries is given in Table 3. The flow data can be used with the water quality sampling results to estimate mass loading rates, and for other purposes. The historical daily flow data for many of the USGS gages are available at the following website: <http://water.usgs.gov/waterwatch>

Table 3. List of U.S. Geological Survey (USGS) and Quebec Ministry of Sustainable Development, Environment, and Parks (MDDEP) stream flow gages on monitored tributaries.

<b>Tributary</b>	<b>Gage Location</b>	<b>State</b>	<b>Reference No.</b>	<b>Agency</b>
Ausable	Au Sable Forks	NY	4275500	USGS
Bouquet	Willsboro	NY	4276500	USGS
Great Chazy	Perry Mills	NY	4271500	USGS
Little Ausable	Valcour	NY	4273800	USGS
Little Chazy	Chazy	NY	4271815	USGS
Mettawee	Middle Granville	NY	4280450	USGS
Putnam	Crown Point Center	NY	4276842	USGS
Salmon	S. Plattsburgh	NY	4273700	USGS
Saranac	Plattsburgh	NY	4273500	USGS
Pike	Bedford	QC	030420	MDDEP
Pike <sup>1</sup>	Notre-Dame-de-Stanbridge	QC	030424	MDDEP
Lamoille	E. Georgia	VT	4292500	USGS
LaPlatte	Shelburne Falls	VT	4282795	USGS
Lewis	N. Ferrisburg	VT	4282780	USGS
Little Otter	Ferrisburg	VT	4282650	USGS
Missisquoi	Swanton	VT	4294000	USGS
New Haven <sup>2</sup>	Brooksville	VT	4282525	USGS
Otter	Middlebury	VT	4282500	USGS
Poultney	Fair Haven	VT	4280000	USGS
Winooski	Essex Jct.	VT	4290500	USGS
Rock <sup>1</sup>	St. Armand	QC	030425	MDDEP

<sup>1</sup>New gages on the Pike and Rock were installed by Quebec MDDEP in 2002.

<sup>2</sup>The New Haven River is a tributary to the Otter Creek that is not directly sampled by the project, but is included in the gage network to supplement the hydrologic coverage for the Otter Creek watershed.



## Accessing the Results

The project website ([http://www.anr.state.vt.us/dec/waterq/lakes/htm/lp\\_longterm.htm](http://www.anr.state.vt.us/dec/waterq/lakes/htm/lp_longterm.htm)) provides the ability for data users to selectively view the original data for specific sampling stations, time periods, and analytical tests using simple, interactive query forms. The tabular data displayed on the website can be readily transferred to standard spreadsheet programs for further analysis. The current quality assurance project plan is available for viewing via a link on the webpage.

Descriptive statistical summaries of the lake and tributary results for the entire monitoring period are also available at the project website. These statistical summaries include the total number of samples (N), the arithmetic mean, and the minimum, 25th percentile, median, 75th percentile, and maximum values for each sampling station and test. When results are below analytical detection limits, the detection limit is used in the statistical summary (i.e., “less than” signs are ignored). The summary statistics combine data from all laboratories and all depths within the water column (for lake samples). Results of duplicate and blank analyses are not included.

Simple summary figures have been prepared for each parameter currently sampled. Data are presented as box plots of the median, 10<sup>th</sup>, 25<sup>th</sup>, 75<sup>th</sup> and 90<sup>th</sup> percentiles for each station for the entire sampling period. Lake data are presented as both annual and cumulative summaries of unstratified and epilimnetic samples. Tributary data are presented as cumulative summaries only. Figures are updated annually after the new data are reviewed and added to the database.

The tributary stations were sampled during 1990-1992 for total phosphorus, dissolved phosphorus, and chloride by the Lake Champlain Diagnostic-Feasibility Study (Vermont DEC and New York State DEC 1997) using the same sampling and analytical methods employed by the current long-term monitoring program. These earlier tributary data have been added to the project database and are included in the summary statistics as well.

## Summary of Sampling Activities During 2006

Tables 4 and 5 provide a summary of sampling activities accomplished during 2006. Table 4 lists the number of sampling visits to each lake and tributary station in relation to the target frequencies specified in the project work plan. Table 5 lists the number of samples collected and analyzed for each monitoring parameter.



Table 4. Number of sampling visits during 2006 at each lake and tributary station in comparison with work plan targets.

Lake Station	Sampling Visits	Work Plan Target	Tributary Station	Sampling Visits	Work Plan Target
2	19	12	AUSA01	18	24
4	19	12	BOUQ01	18	24
7	15	12	GCHA01	18	24
9	15	12	LAMO01	19	24
16	18	12	LAPL01	18	24
19	18	12	LAUS01	18	24
21	18	12	LCHA01	18	24
25	20	12	LEWI01	19	24
33	18	12	LOTT01	19	24
34	19	12	METT01	19	24
36	18	12	MISS01	20	24
40	20	12	OTTE01	19	24
46	19	12	PIKE01	18	24
50	21	12	POUL01	19	24
51	21	12	PUTN01	19	24
			SALM01	18	24
			SARA01	18	24
			WINO01	18	24

Table 5. Number of samples collected and analyzed for each monitoring parameter during 2006.

Parameter	Lake	Tributaries	Total
TP	409	405	814
DP	407	221	628
Cl	409	244	653
TN	408	222	630
Alk	64	15	79
DO (Winkler)	493	--	493
Chl-a	294	--	294
TSS	--	216	216
Temp	165	248	413
Cond	--	226	226
pH	--	216	216
Secchi depth	289	--	289
Multiprobe depth profiles	271	--	271
Zebra mussel veligers	125	--	125
Zebra mussel settled juveniles	6	--	6
Mysids	72 <sup>1</sup>	--	72 <sup>1</sup>
Zooplankton	117 <sup>2</sup>	--	117 <sup>2</sup>
Phytoplankton	159 <sup>2</sup>	--	159 <sup>2</sup>

<sup>1</sup>Samples currently being analyzed. <sup>2</sup>Samples analyzed but results not yet available.



## **Specific Analyses, Presentations, and Reports**

Certain analyses of the data were required by the 2006 project work plan. In addition, project personnel prepared special presentations and reports during 2006 from the monitoring program data. These items are listed below and presented in more detail in the Appendices.

### **Comparison of Dissolved Oxygen Methods**

The 2006 project work plan required that a comparison of dissolved oxygen sampling methods be made to evaluate the Winkler titration results vs. the results obtained using multiprobe devices. The results of this analysis are provided in Appendix A.

### **Comparison of Results from Missisquoi Bay Stations 50 and 51**

The 2006 project work plan required that a comparison of sampling results be made between stations 50 and 51 in Missisquoi Bay, and with results from other locations in the bay monitored by the University of Vermont's Lake Champlain Blue-Green Algae Monitoring Program. The results of this comparison are provided in Appendix B.

### **Wastewater Phosphorus Discharge Data**

The project work plan requires an annual compilation of wastewater phosphorus discharge data for all facilities in the Vermont and New York portions of the Lake Champlain Basin. These data are provided for Vermont in Appendix C and for New York in Appendix D.

### **The Growing Hypoxic Zone in the Northeast Arm of Lake Champlain**

A presentation on The Growing Hypoxic Zone in the Northeast Arm of Lake Champlain was made at the Lake Champlain Research Consortium's Research Symposium, held on September 29, 2006 at St. Michael's College, Colchester, VT. The abstract and selected figures from this presentation are provided in Appendix E.

### **Environmental Implications of Increasing Chloride Levels in Lake Champlain and Other Vermont Waters**

An analysis of long-term trends in chloride concentrations in Lake Champlain and its tributaries, and a discussion of the environmental implications of these trends based on a literature review, were presented in a report submitted to the Lake Champlain Basin Program for publication as part of the LCBP Technical Report Series. The Executive Summary of this report is provided in Appendix F.

### **Monitoring Cyanobacteria in Lake Champlain.**

The partnership between the Lake Champlain Long-Term Monitoring Program, the University of Vermont's Rubenstein Ecosystem Science Laboratory, and the Vermont DEC's Lay Monitoring Program regarding monitoring of cyanobacteria in Lake Champlain was highlighted in two publications during 2006. Abstracts and summaries are provided in Appendix G.



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# Appendices

## A. Comparison of Dissolved Oxygen Methods

Hypolimnetic dissolved oxygen (DO) concentrations and trends are important indicators of trophic state and eutrophication in lakes since DO levels reflect the balance of lake metabolic processes such as primary production and community respiration. Adequate dissolved oxygen concentrations in the hypolimnion are essential to cold-water fish and benthic organisms, and help minimize the release of phosphorus from lake sediments.

Vertical depth profiles of DO have been obtained at deep stations in Lake Champlain throughout the course of the long-term monitoring program. Measurements have been made using two methods: (a) the traditional Winkler iodometric method on water samples brought to the surface and analyzed by volumetric titration at the laboratory, and (b) *in situ* multiprobe methods using electronic devices equipped with either “Clark cell” membrane electrodes or, starting in 2006, a new luminescent optical probe.

It is important to measure DO in Lake Champlain in an accurate and reproducible manner so that small incremental changes can be detected over time if they exist, and spurious findings due to analytical differences can be avoided. The data obtained on Lake Champlain from the two DO methods were compared in order to determine whether these methods provide results that are equivalent.

DO measurements using multiprobe devices began in 1992 under the long-term monitoring program, and the use of Winkler titration began in 1995. Prior to 2006, New York field crews employed multiprobe devices for DO exclusively, while Vermont crews obtained samples only for Winkler titration. Beginning in 2006, Vermont crews employed a multiprobe device and also continued to obtain samples for Winkler titration. Field crews from both states occasionally visited the same lake station on the same date during the 1995-2006 monitoring period. This provided the opportunity to compare a large number of DO results obtained by the two different methods at the same station, date, and depth. When Vermont crews began using both methods concurrently in 2006, many more paired samples became available for comparison.

Figure 2 shows the results of a statistical comparison of the results from the two methods. There was a total of 874 DO sample pairs obtained during 1995-2006 at the same station, date, and depth. A statistical comparison (paired t-test) across all these sample pairs indicated that there was no significant difference between the overall mean DO value between the two methods. The deviations from the 1:1 lines in Figure 2 were assessed using the root mean squared error (RMSE) statistic, which was 0.53 mg/L for the entire set of paired samples.

When the 2006 Vermont data only were used for the comparison, there was a small but statistically significant difference between the means, with a RMSE of 0.20 mg/L. This difference between means (9.49 mg/l vs. 9.36 mg/l), while statistically significant because of the large sample size, is probably too small to be of much practical importance. The smaller RMSE value for the 2006 Vermont data could have been due to the fact that the paired measurements were obtained at essentially the same time during the day. Many of the previous measurements, while made at the same station, date, and depth, were obtained by different state field crews at times that could have differed by hours. Diurnal changes in DO and variations in thermocline depth due to internal seiche movement could have altered the DO concentrations during the



course of some sampling days. Another factor could have been the use of the new luminescent optical DO probe by Vermont in 2006, with its reportedly better precision and greater ease of calibration than the membrane electrodes employed by New York crews.

The differences (i.e., residuals) from the 1:1 lines in Figure 2 were examined for any systematic bias in the results related to time, depth, or temperature. A slight but statistically significant positive trend (assessed by linear regression) in these differences was evident over time (1995-2006) when all the data were pooled, suggesting that the multiprobe results tended to be lower than the Winkler results during the early years of the monitoring program. No such trend over time was seen for the Vermont only data within the 2006 sampling season.

The differences were also somewhat dependent on both depth and water temperature. Greater depths and lower temperature tended to produce negative differences (multiprobe < Winkler). The same observation was made during an earlier study on Lake Champlain (Vermont DEC and New York State DEC, 1997). Since colder temperatures occur at greater depths during the summer (i.e., depth and temperature co-vary) it is not clear which of these two variables may be causing this bias.

In summary, the two DO methods produced results that were reasonably comparable. The systematic biases that were detected were relatively small in magnitude. Probably of greatest concern is the bias seen as a function of depth and temperature. This could affect the comparability of hypolimnetic samples, which are of greatest importance for the use of DO as an environmental indicator. It is not clear from this analysis which method is most “correct,” but the existence of this small bias should be taken into consideration if results from the two methods are combined in an analysis of DO trends.

Both DO methods have advantages and disadvantages relative to each other. The multiprobe method has the advantage of being able to produce many measurements at close depth intervals (e.g., every meter) and can therefore resolve fine details in the vertical stratification patterns within the water column. In contrast, it is feasible to obtain samples for Winkler analysis only every 5-10 meters in Lake Champlain, depending on total station depth.

The multiprobe devices, especially the luminescent optical probe, appear to provide greater precision than the Winkler method when comparing the results of field duplicate measurements. The mean relative percent differences (RPD) between all field duplicate pairs obtained during the course of the long-term monitoring program are summarized in Table 6. Separate water samples obtained as field duplicates and analyzed by Winkler titration had a mean RPD of 3.9%. Measurements taken at the same depth but at different times during the sequence of obtaining a single DO profile of the water column had a mean RPD of only 0.8% when using the luminescent optical probe.



Table 6. Precision of DO field duplicates.

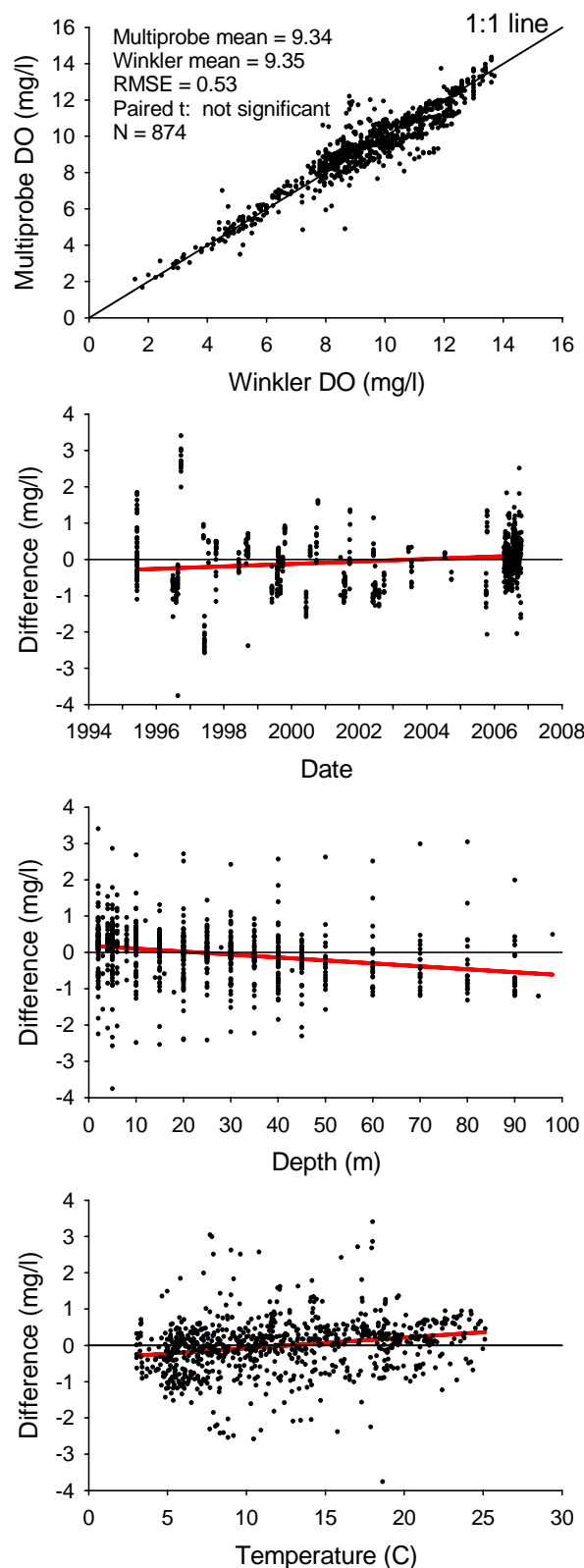
<b>Method</b>	<b>Number of duplicate pairs</b>	<b>Mean RPD</b>
Winkler titration	21	3.9%
Clark cell membrane electrode	869	2.6%
Luminescent optical probe	246	0.8%

In practice, however, the multiprobe devices have presented more difficulties than the Winkler method in obtaining accurate results. Problems have occurred with field calibration, electronic drift, and membrane maintenance such that unreliable DO measurements are sometimes produced. Different instruments have been used over the years. It has been necessary to carefully screen the entire database of multiprobe measurements to eliminate obviously erroneous values. The statistical analysis shown in Figure 2 used the data only after such screening had occurred, so the comparisons shown in Figure 2 are better than they would have been using the original data, prior to quality assurance review. It is possible that some non-obvious errors remain in the database. In contrast, the calibration of the Winkler method is relatively simple, requiring only the proper preparation of reagents in the laboratory. Obvious errors in the Winkler DO results have been far less frequent.

It is recommended that the long-term monitoring program continue to employ both DO methods, at least for the next few years. If further experience with the new luminescent optical probes and comparison of the data indicate that the results are consistently accurate and equivalent, then it may be possible to consider using only the multiprobe method in the future.



## 1995-2006 All data



## 2006 - Vermont multiprobe only

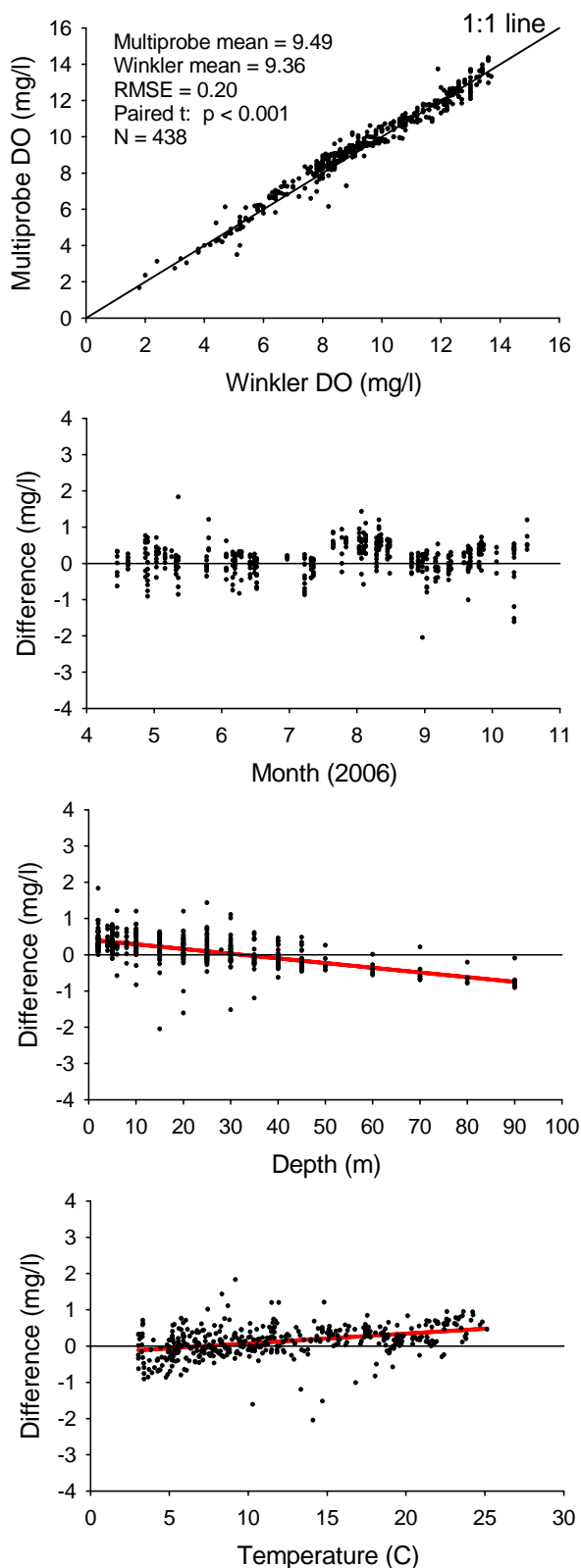


Figure 2. Comparison of Lake Champlain DO results obtained at the same station, date, and depth with multiprobe devices and the Winkler titration method. Differences were calculated as the multiprobe result minus the Winkler result. Slopes of all regression lines (shown in red) are significant at  $p < 0.001$ .



## **B. Comparison of Results from Missisquoi Bay Stations 50 and 51**

Since extensive cyanobacteria sampling began on Missisquoi Bay in 2001, there has been discussion that the historical sampling point in the bay (station 50) is not representative of conditions in much of the bay. Algal densities reported by the University of Vermont (UVM) Cyanobacteria Monitoring Program show that the eastern side of the bay often has significantly higher cell densities and chlorophyll concentrations than the Lake Champlain Long-Term Monitoring Program (LTMP) monitoring location, which lies on the western side. In 2006, a second LTMP location (station 51) was added to the northeast, in a centrally-located open-water area of the bay.

We used paired t-tests or ranking tests to identify differences between the stations that might be occurring on an individual sampling date. Collections were made by both the Vermont and New York crews using similar protocols. The New York crew typically collected from station 51 first, while the Vermont crew typically went to station 50 first. Although all water quality parameters were compared, only total phosphorus, total nitrogen and chlorophyll-a differed significantly as a result of station location (Figures 3-5), with higher concentrations occurring at station 51. Secchi depths measured by the LTMP at the two stations were not significantly different. A storm event occurred in the basin on May 20<sup>th</sup> and the effects are evident in the graphed data.

Phytoplankton were collected by the Vermont crew at the two stations during each visit. Tows were made to twice the Secchi depth at each station with a 63µm net. A second 3m tow was provided to UVM as part of the cyanobacteria monitoring program. Total phytoplankton abundance of the LTMP samples (cells/L, Figure 6) did not differ significantly between the stations ( $p = 0.437$ , t-test performed on log-transformed data). The statistical power of the test was low, however, and differences between the two stations may become detectable after additional data are collected.

Phytoplankton samples collected for the cyanobacteria monitoring program were evaluated for the presence of potentially toxic species. UVM routinely samples four offshore locations in the Vermont portion of Missisquoi Bay. Two are located on the western side, Alburg and the Rt. 78 Access, while Highgate Cliffs and Highgate Springs are located on the eastern side. Data from 2006 are presented in Figure 7 (M. Watzin, unpublished data), when densities of potentially toxic cyanobacteria ranged widely across the bay. In general, on the days when samples were available from both LTMP and UVM collections, LTMP's station 50 had the lowest cell densities while station 51 was more reflective of cell densities observed on the eastern side.



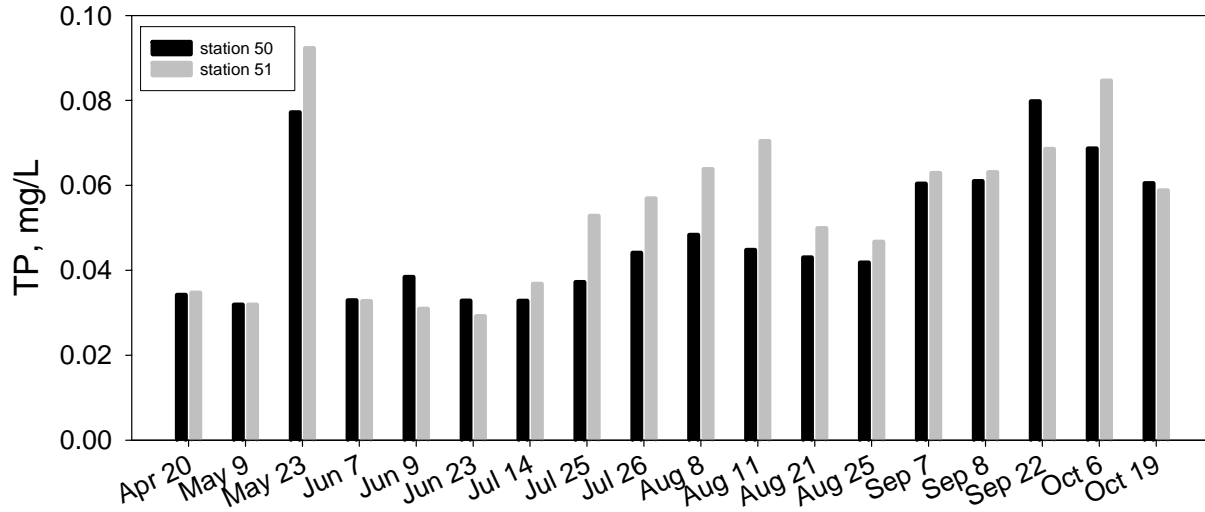


Figure 3. Total phosphorus at LTMP Missisquoi stations in 2006. Station 50 mean = 0.048 mg/L; Station 51 mean = 0.054 mg/L;  $p = 0.029$ ;  $\alpha = 0.05$ .

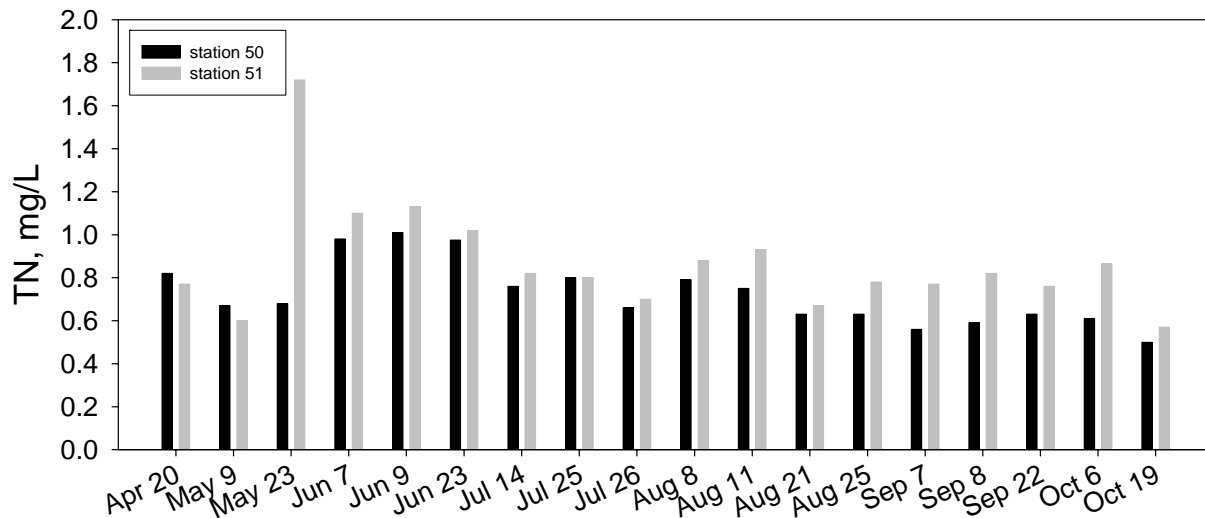


Figure 4. Total nitrogen at LTMP Missisquoi stations in 2006. Station 50 mean = 0.72 mg/L; Station 51 mean = 0.87 mg/L;  $p < 0.001$ ,  $\alpha = 0.05$ . Normality test failed, comparisons made with Wilcoxon Rank tests.



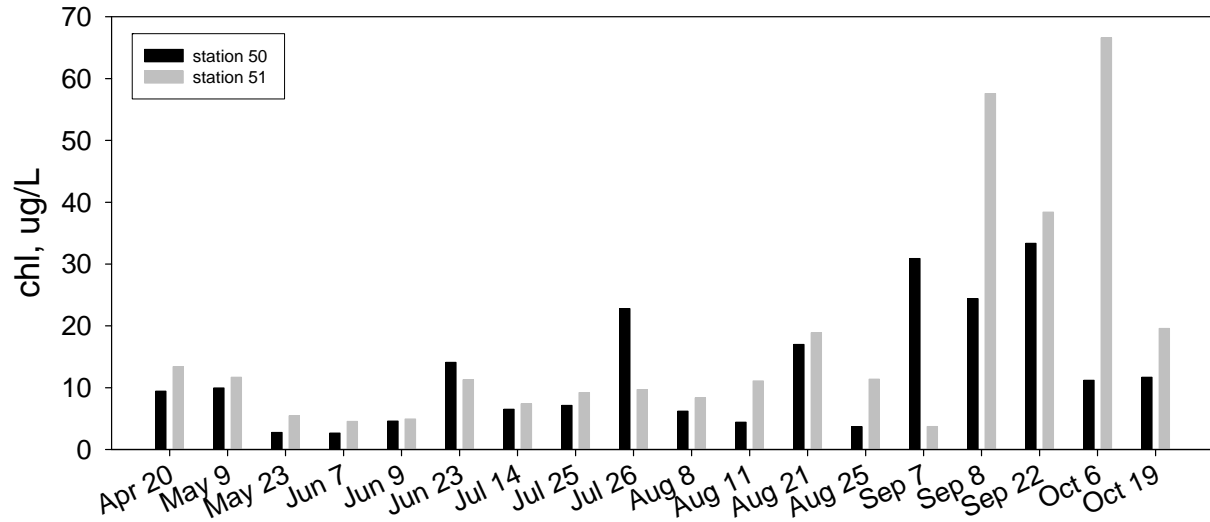


Figure 5. Chlorophyll at LTMP Missisquoi stations in 2006. Station 50 mean = 12.38  $\mu\text{g/L}$ ; Station 51 mean = 17.41  $\mu\text{g/L}$ ;  $p=0.048$ ;  $\alpha=0.05$ . Normality test failed, comparison made with Wilcoxon Rank tests.

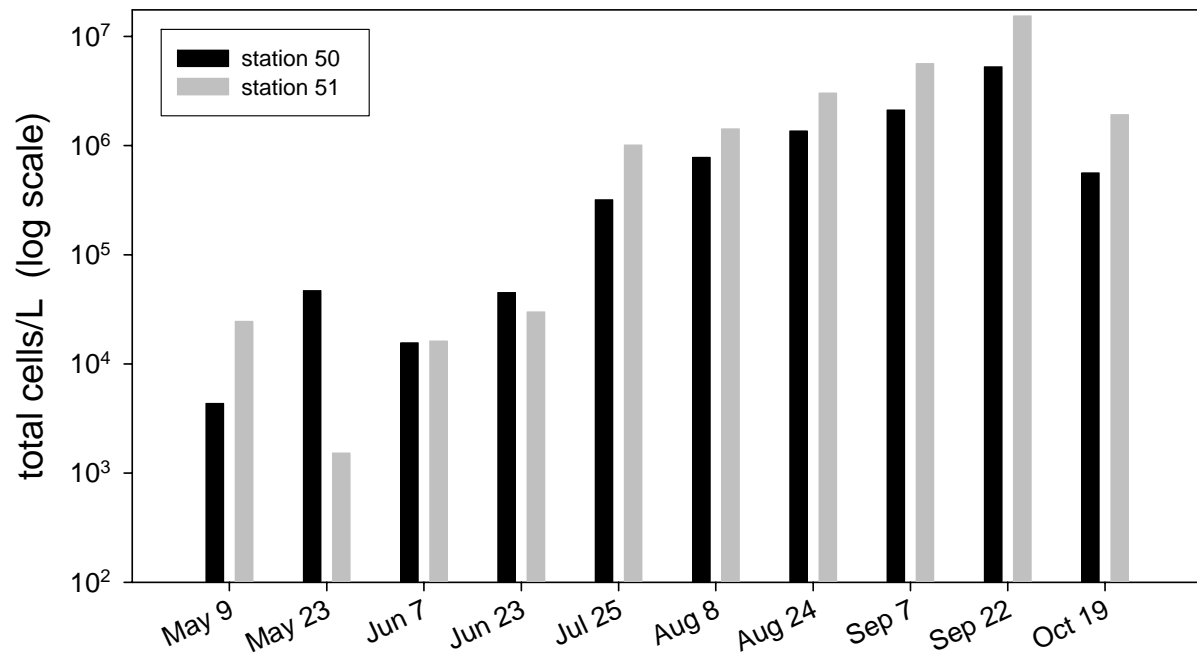


Figure 6. Total phytoplankton abundance (cells/L, log scale) at LTMP Missisquoi Bay stations in 2006. Station 50 geometric mean = 222,703 cells/L; Station 51 geometric mean = 324,771 cells/L ( $p=0.437$ ,  $\alpha=0.05$ , paired t-test).



## 2006 Weekly Mean of Potentially Toxic Cyanobacteria Density in Missisquoi Bay Offshore (Net) Samples

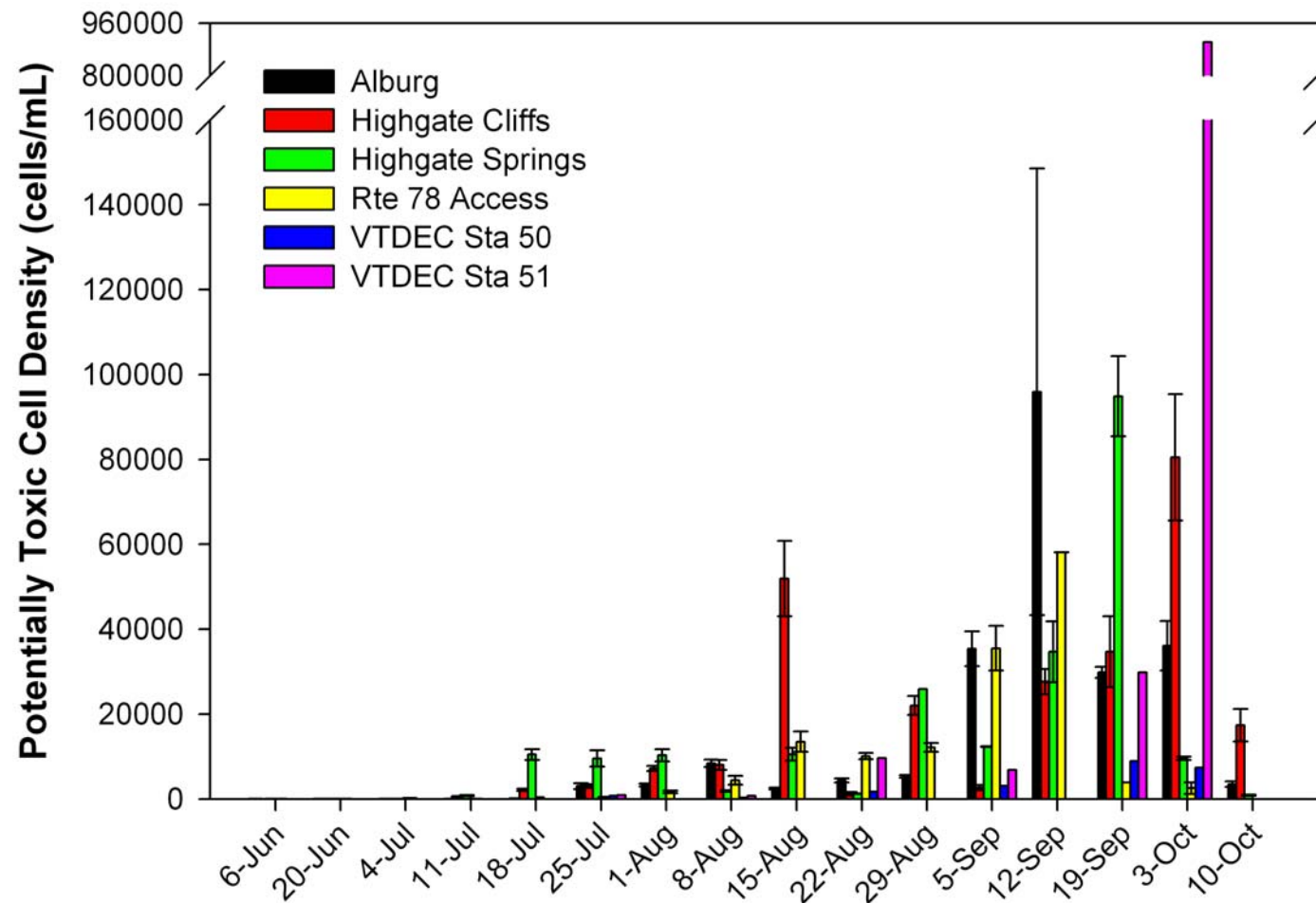


Figure 7. Weekly mean densities of potentially toxic cyanobacteria in offshore samples from Missisquoi Bay, provided by Mary Watzin from the 2006 Blue-green algae monitoring project data.



## Conclusions

Data from the 2006 field season demonstrated that station location is an important consideration when evaluating water quality parameters within Missisquoi Bay. Significantly higher total phosphorus, total nitrogen and chlorophyll were observed consistently at LTMP station 51 compared to LTMP station 50. Data from UVM's cyanobacteria monitoring program showed the wide degree of variability evident with respect to phytoplankton densities in offshore locations around the bay. While cell densities at LTMP station 51 are more representative of other offshore locations than are those observed at station 50, station 51 did not consistently represent phytoplankton conditions around the bay throughout the summer of 2006 nor were phytoplankton concentrations there significantly higher than those at station 50.

Pesticide samples collected concurrently with both lake and tributary water quality samples suggest that the Pike River may have an identifiable influence on water quality at LTMP Station 51. Pesticide concentrations at Station 51 were elevated compared to station 50 and the Missisquoi River, more reflective of the higher concentrations observed in the Pike (Vermont Agency of Agriculture, Food and Markets; Nat Shambaugh, unpublished data).

Tributary nutrient data may support the pesticide observation. TN concentrations in the Pike were also significantly higher than those in the Missisquoi during 2006 (Figure 8,  $p = 0.011$  using Mann Whitney Rank sums). TN concentrations were significantly higher at station 51 when compared to station 50 during the year, possibly as a result of the inflowing water from the Pike. Note that these data reflect differences in grab sample concentration, not in loading. Though this was not the case for TP during 2006 (Figure 9,  $p=0.589$  using Mann Whitney Rank sums), historical data from the tributaries indicates that concentrations of TN and TP in the Pike are typically higher than those of the Missisquoi (TN  $p<0.001$ , and TP  $p<0.001$ ).



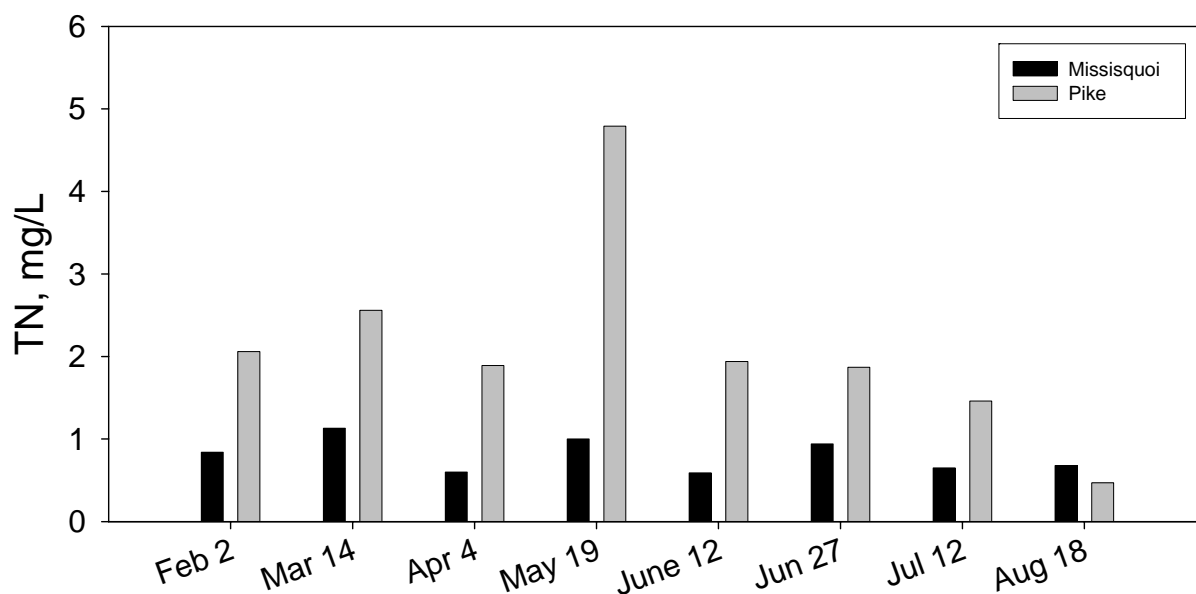


Figure 8. Total nitrogen (mg/L) in the Pike and Missisquoi Rivers during 2006. Missisquoi River mean = 0.8037 mg/L; Pike River mean = 2.13 mg/L. Normality test failed, comparisons made with Mann Whitney Rank sums.

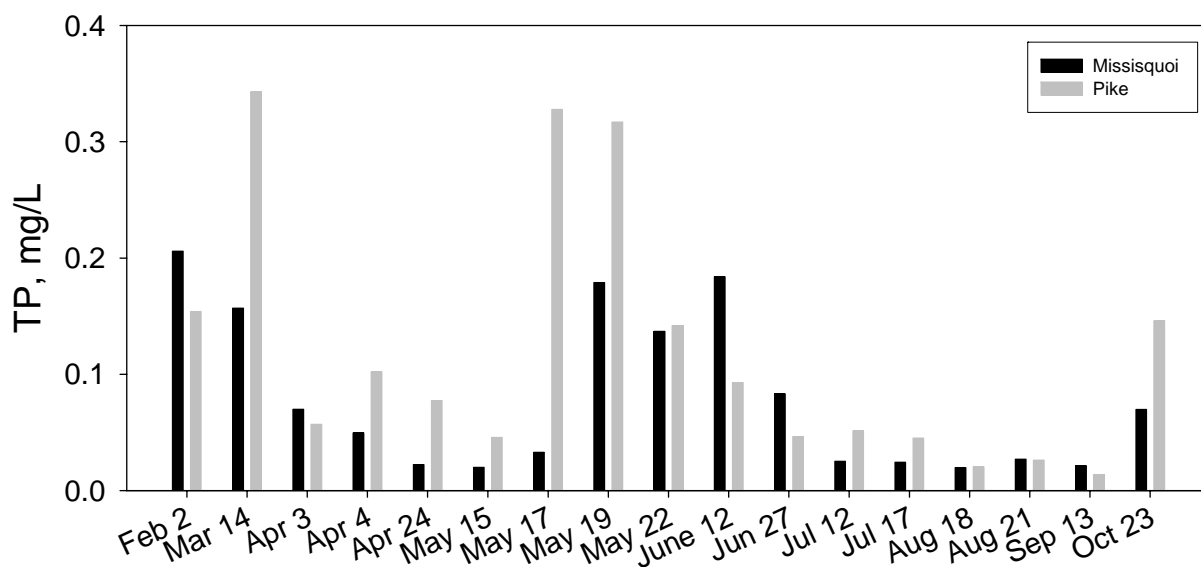


Figure 9. Total phosphorus (mg/L) in the Pike and Missisquoi Rivers during 2006. Missisquoi River mean = 0.0797 mg/L; Pike River mean = 0.1173 mg/L. Normality test failed, comparisons made with Mann Whitney Rank sums.



Based on the 2006 data, it appears that no single location can adequately characterize water quality throughout Missisquoi Bay. Station 50 should continue to be monitored because it is the only site in the bay for which a long-term record exists. Station 50 has been monitored consistently since 1990 by the LTMP and the preceding Lake Champlain Diagnostic-Feasibility Study, and is co-located with the station sampled since 1979 by the Vermont Lay Monitoring Program. Sampling should continue at station 51 as well, because this site appears to be more representative of water quality conditions in the bay. Furthermore, the central location of station 51 in the bay is more consistent with the way the in-lake phosphorus concentration criteria for Lake Champlain are to be measured.



## C. Vermont 2006 Wastewater Phosphorus Discharge Data

Vermont Facility	Receiving Lake Segment	2006 Mean Flow (mgd)	2006 Mean TP Conc. (mg/L)	2006 Mean TP Load (mt/yr)	TMDL Wasteload Allocation (mt/yr)
Benson	01 South Lake B	0.014	2.393	0.046	0.122
Castleton	01 South Lake B	0.343	0.198	0.094	0.397
Fair Haven	01 South Lake B	0.247	0.425	0.145	0.414
Poultney	01 South Lake B	0.259	0.189	0.068	0.414
West Pawlet	01 South Lake B	0.015	4.883	0.098	0.276
Orwell	02 South Lake A	0.026	2.575	0.093	0.228
Brandon	04 Otter Creek	0.455	0.243	0.152	0.580
Middlebury	04 Otter Creek	1.158	0.433	0.693	1.823
Otter Valley Union High School	04 Otter Creek	0.002	5.391	0.012	0.173
Pittsford	04 Otter Creek	0.072	2.142	0.213	0.483
Pittsford Fish Hatchery	04 Otter Creek	1.344	0.011	0.019	0.691
Proctor	04 Otter Creek	0.282	1.933	0.752	0.359
Rutland City	04 Otter Creek	4.806	0.283	1.880	5.634
Salisbury Fish Hatchery	04 Otter Creek	0.832	0.050	0.057	0.181
Shoreham	04 Otter Creek	0.012	4.800	0.078	0.242
Vergennes	04 Otter Creek	0.416	0.365	0.209	0.621
Wallingford	04 Otter Creek	0.070	2.800	0.271	0.829
West Rutland	04 Otter Creek	0.202	0.106	0.029	0.364
Barre City	05 Main Lake	3.446	0.108	0.516	3.314
Burlington East	05 Main Lake	0.652	0.417	0.375	0.994
Burlington Electric	05 Main Lake	0.104	0.014	0.002	0.017
Burlington North	05 Main Lake	1.302	0.368	0.662	1.657
Cabot	05 Main Lake	0.027	0.258	0.009	0.041
Essex Junction	05 Main Lake	2.057	0.593	1.686	2.569
IBM	05 Main Lake	3.359	0.433	2.010	5.531
Marshfield	05 Main Lake	0.021	3.325	0.097	0.311
Montpelier	05 Main Lake	1.998	0.525	1.448	3.290
Northfield	05 Main Lake	0.723	0.358	0.358	0.829
Plainfield	05 Main Lake	0.057	2.042	0.160	0.691
Richmond	05 Main Lake	0.097	0.193	0.026	0.184
South Burlington Airport Park.	05 Main Lake	1.685	0.425	0.989	1.906
Stowe	05 Main Lake	0.314	0.417	0.181	0.282
Waterbury	05 Main Lake	0.281	4.592	1.779	0.563
Weed Fish Culture Station	05 Main Lake	6.933	0.027	0.261	0.914
Williamstown	05 Main Lake	0.092	3.967	0.506	1.036
Winooski	05 Main Lake	0.921	0.498	0.634	1.160
Hinesburg	06 Shelburne Bay	0.208	0.242	0.069	0.276
Shelburne #1	06 Shelburne Bay	0.329	0.300	0.136	0.348
Shelburne #2	06 Shelburne Bay	0.353	0.483	0.236	0.497
South Burlington Bart. Bay	06 Shelburne Bay	0.646	0.239	0.213	0.878
Burlington Main	07 Burlington Bay	4.780	0.418	2.756	4.392
Brown Ledge Camp	09 Malletts Bay	0.002	1.962	0.004	0.005
Fairfax	09 Malletts Bay	0.050	4.527	0.314	0.539
Hardwick	09 Malletts Bay	0.220	2.783	0.845	0.410
Jeffersonville	09 Malletts Bay	0.036	6.733	0.335	0.532
Johnson	09 Malletts Bay	0.169	0.475	0.111	0.224
Milton	09 Malletts Bay	0.236	0.742	0.242	0.829
Morrisville	09 Malletts Bay	0.389	0.525	0.282	0.352
Wyeth Nutritional PBM Nutritionals	09 Malletts Bay	0.107	0.043	0.006	0.352
Northwest State Correctional	11 St. Albans Bay	0.030	0.103	0.004	0.028
St. Albans City	11 St. Albans Bay	2.912	0.267	1.072	2.762
Enosburg Falls	12 Missisquoi Bay	0.298	0.308	0.127	0.373
Newport Center	12 Missisquoi Bay	0.024	0.493	0.017	0.006



North Troy	12 Missisquoi Bay	0.087	0.489	0.059	0.760
Richford	12 Missisquoi Bay	0.300	1.233	0.510	0.420
Rock Tenn	12 Missisquoi Bay	0.201	0.525	0.146	1.260
Sheldon Springs	12 Missisquoi Bay	0.022	2.317	0.069	0.373
Swanton	12 Missisquoi Bay	0.498	0.417	0.286	0.746
Troy/Jay	12 Missisquoi Bay	0.060	2.545	0.212	0.221
Alburg	13 Isle LaMotte	0.075	0.042	0.004	0.108
<b>TOTAL</b>			<b>24.7</b>		<b>55.8</b>







## D. New York 2006 Wastewater Phosphorus Discharge Data

NY Facility	Lake Segment	2006 Mean Q (MGD)	2006 Mean TP conc. (mg/L)	2006 Mean TP Load (mt/yr)	WLA TMDL (mt/yr)
Fort Ann	South Lake B	0.063	2.500	0.217	0.220
Granville	South Lake B	0.710	0.450	0.440	0.712
Great Meadows Corr	South Lake B	0.357	0.350	0.173	0.276
Washington Corr	South Lake B	0.117	0.190	0.031	0.119
Whitehall	South Lake B	0.675	1.000	0.932	0.596
<b>South Lake B Total<sup>1</sup></b>				<b>1.793</b>	<b>1.924</b>
Crown Point	South Lake A	0.039	3.800	0.186	0.088
IP Ticonderoga	South Lake A			3.465	6.341
Ticonderoga	South Lake A	1.342	1.296	2.044	1.473
<b>South Lake A Total</b>				<b>5.695</b>	<b>7.902</b>
Port Henry	Port Henry	0.472	2.400	1.483	0.553
Westport	Port Henry	0.125	1.554	0.206	0.331
<b>Port Henry Total</b>				<b>1.689</b>	<b>0.884</b>
Ausable Forks	Main Lake	0.061	3.895	0.326	0.740
Keeseville	Main Lake	0.298	0.812	0.324	0.331
Lake Placid	Main Lake	1.244	1.106	1.906	2.152
Peru	Main Lake	0.199	2.169	0.522	0.613
Peru/Valcour	Main Lake	0.004	3.149	0.017	0.008
Wadhams	Main Lake	0.007	2.573	0.025	0.040
Willsboro	Main Lake	0.037	3.518	0.175	0.331
<b>Main Lake Total</b>				<b>3.294</b>	<b>4.215</b>
Adk Fish Hatchery	Cumberland Bay			0.022	0.075
Cadyville	Cumberland Bay	0.003	4.901	0.019	0.041
Champlain Park	Cumberland Bay	0.050	2.659	0.165	0.290
Dannemora	Cumberland Bay	0.845	2.343	2.734	3.361
Plattsburgh City	Cumberland Bay	5.483	1.161	8.638	10.844
Saranac Lake	Cumberland Bay	1.963	0.635	1.689	2.235
St Armand	Cumberland Bay	0.037	3.900	0.200	0.281
<b>Cumberland Bay Total</b>				<b>13.469</b>	<b>17.127</b>
Altona Correctional	Isle LaMotte	0.071	0.401	0.039	0.083
Champlain Village	Isle LaMotte	0.300	0.405	0.147	0.571
Chazy	Isle LaMotte	0.032	0.771	0.032	0.099
Rouses Point	Isle LaMotte	0.763	1.327	1.327	2.613
Wyeth-Ayerst Chazy	Isle LaMotte	0.041	2.520	0.145	0.066
<b>Isle LaMotte Total</b>				<b>1.692</b>	<b>3.432</b>
<b>Lake Total</b>				<b>27.632</b>	<b>35.485</b>

<sup>1</sup>Data incomplete for South Lake B. Some estimates involved in load calculations.



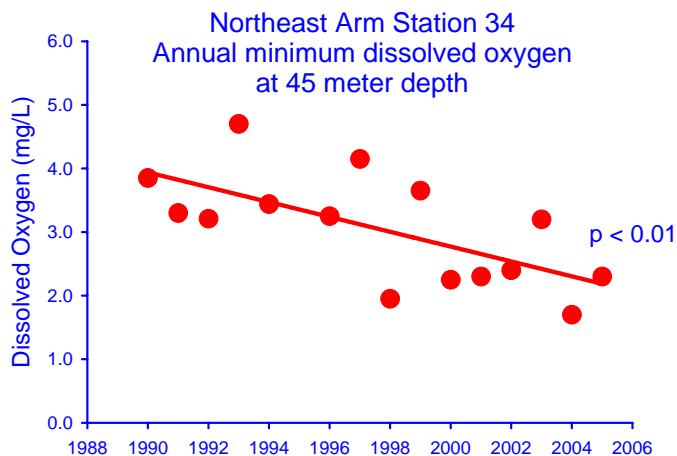
## E. The Growing Hypoxic Zone in the Northeast Arm of Lake Champlain

Paper presented at the  
Lake Champlain Research Consortium Water Quality Conference  
September 29, 2006  
St. Michael's College

Presented by  
Eric Smeltzer  
Vermont Department of Environmental Conservation

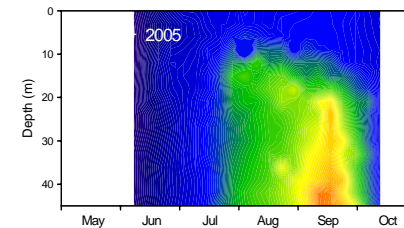
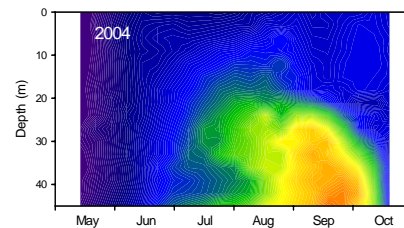
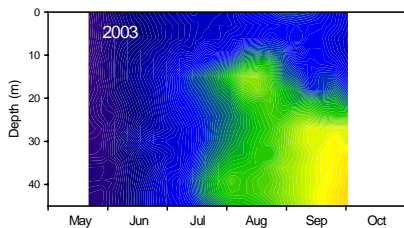
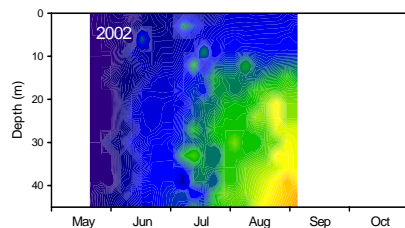
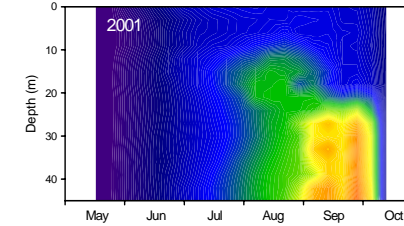
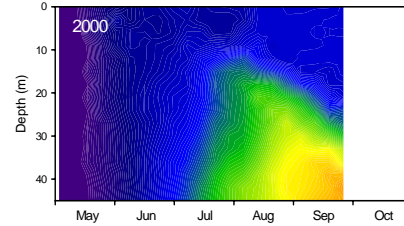
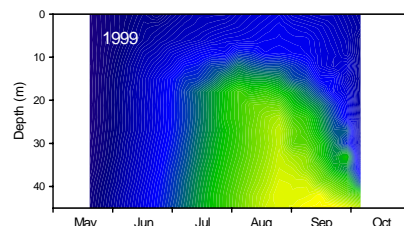
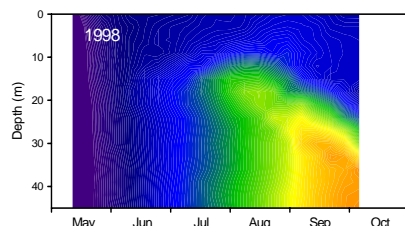
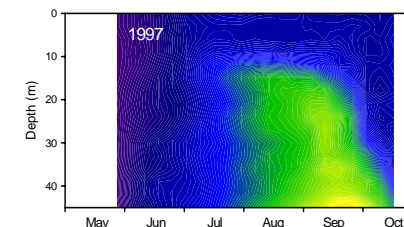
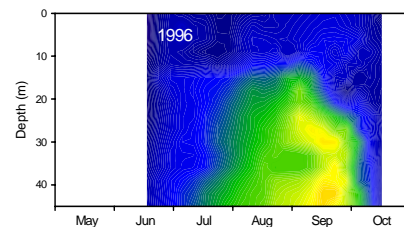
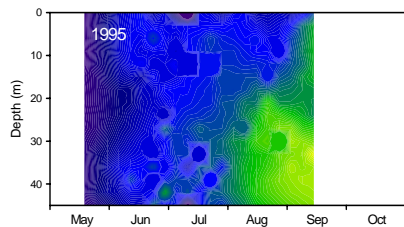
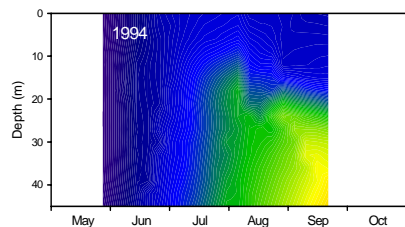
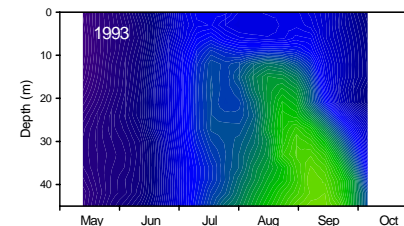
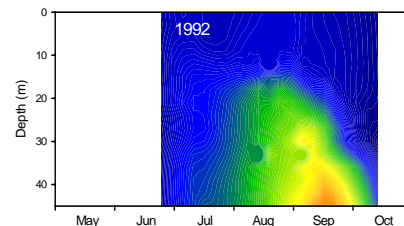
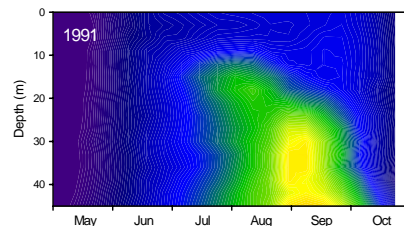
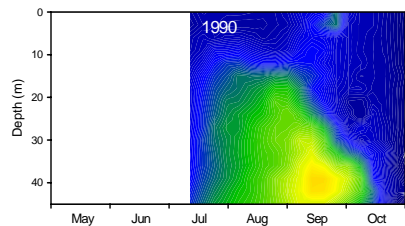
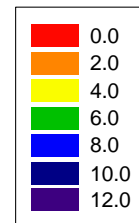
### ABSTRACT

Long-term monitoring of dissolved oxygen concentrations during the period of 1990-2005 has revealed an expansion of the extent and severity of the hypoxic zone in the hypolimnion of the Northeast Arm (Inland Sea) portion of Lake Champlain. Annual minimum bottom dissolved oxygen concentrations have declined significantly over this time period. Degradation of habitat for fish and benthic organisms and greater internal phosphorus loading are possible consequences of the increased hypoxia. The growing oxygen deficit and a concurrent trend of increasing total phosphorus concentrations indicate an alarming acceleration of eutrophication in this region of the lake. Since the Northeast Arm has a relatively small immediate drainage basin, the major sources of phosphorus must come from the watersheds of adjoining lake segments such as Missisquoi Bay and St. Albans Bay. Evaluating proposed solutions such as phosphorus reduction from adjacent watersheds and multiple causeway removals would benefit from a better understanding of the hydrodynamics of the entire northeast region of Lake Champlain.





# Northeast Arm Station 34 Dissolved oxygen (mg/L) 1990-2005





## **F. Environmental Implications of Increasing Chloride Levels in Lake Champlain and Other Vermont Waters**

**Prepared by  
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Vermont Department of Environmental Conservation**

### **Executive Summary**

Chloride is not usually considered a pollutant of concern in freshwater. However, data emerging in the northeastern United States and elsewhere indicate that chloride concentrations may be elevated far above typical background levels of less than 10 mg/L, especially in urban environments.

Environmental effects of severely elevated chloride can result in physical changes (e.g., increased water density that can change mixing and stratification cycles in lakes) or biological toxicity. Biological effects are highly variable. Many organisms are tolerant of chloride exceeding 5,000 mg/L while others are sensitive to concentrations below 500 mg/L. Little data exist to determine effects of chronic exposure on aquatic organisms. Sensitivity to salinity has been shown to be species-specific, and influenced by the extent and periodicity of exposure. Sources of chloride in temperate regions include industrial and municipal wastewaters, agricultural wastes, and deicing salt. In arid regions, rising salinity is linked to anthropogenic activities that have raised water table levels.

In Vermont, there is sufficient evidence that chloride and its effects on the aquatic environment warrant closer scrutiny:

- Chloride levels are steadily increasing in Lake Champlain, though concentrations in the open waters of the lake (less than 30 mg/L) currently are not of concern for aquatic biota or human health. The EPA ambient aquatic life water quality criteria for chloride are 860 mg/L (acute) and 230 mg/L (chronic). The Vermont Department of Health has a Secondary maximum contaminant level of 250 mg/L for chloride in drinking water.
- Major lake tributaries are now carrying higher loads of chloride to the lake than they have historically.
- Some streams have chloride concentrations exceeding chronic criteria. Streams flowing through areas of high density development and high density road systems are likely to be receiving the greatest inputs of chloride.
- The occurrence of high chloride levels during the summer and fall low flow periods in streams near high density development suggests that elevated concentrations in groundwater may exist at some locations.
- Deicing salt application can result in increased chloride concentrations in streams and ponds.

Because chloride has not been considered a pollutant, available data are limited. Monitoring of urban streams, Lake Champlain, and lake tributaries should be continued. Biological assessments are needed to understand the impacts of chronic exposure. Groundwater evaluations would be prudent in areas of high road density and development. While there are areas of elevated chloride in Vermont, it is likely that these concentrations can be stabilized, and



possibly reduced, if action is taken to minimize inputs. Deicing salts are increasingly identified as an important source of chloride to the environment. New technologies exist that minimize environmental impacts of winter road and sidewalk maintenance while enhancing safety. A public education campaign to raise awareness and promote better salt management practices by homeowners, private applicators and municipalities would benefit Vermont lakes and streams.

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**Additional activity utilizing data from this report**

1. “Increasing chloride in Vermont surface waters – the tip of the iceberg?” Paper presented at the annual meeting of the New England Association of Aquatic Biologists, March 29 – 31, 2006 by Angela Shambaugh (Vermont Department of Environmental Conservation).
2. “Chloride in Vermont Surface Waters” Poster presented at the Lake Champlain Research Consortium Water Quality Conference, September 29, 2006, St. Michael’s College by Doug Burnham<sup>1</sup>, Jim Kellogg<sup>1</sup>, Rich Langdon<sup>1</sup> and Angela Shambaugh<sup>1</sup> (<sup>1</sup> Vermont Department of Environmental Conservation).
3. “Increasing chloride levels in Lake Champlain and other Vermont waters” Presentation to the Vermont Water Quality Division, December 13, 2006 by Angela Shambaugh.



## **G. Monitoring Cyanobacteria in Lake Champlain**

### **A partnership approach to monitoring cyanobacteria in Lake Champlain**

Mary Watzin, Emily Brines Miller, Angela Shambaugh, and Meghan Kreider  
Great Lakes Research Review 7:8 – 13. 2006

Summary: The increasing incidences of toxic cyanobacteria blooms worldwide have created a need for practical and efficient monitoring to protect the public health. We developed a monitoring and alert framework based on the World Health Organization (WHO) recommendations and applied it on Lake Champlain during the summers of 2002 – 2004. The protocol began with the collection of phytoplankton samples to maximize the chance of finding potential toxin-producing cyanobacteria. Samples were collected lake-wide in partnership with ongoing monitoring efforts, but because open water sample sites did not capture conditions along the shoreline, we added nearshore and shoreline stations in problem areas using citizen monitors. Samples were examined qualitatively until potential toxin-producing taxa were found. Primary toxin analysis was for microcystins using ELISA (enzyme-linked immunosorbent assay) methods. Cell densities, locations of colonies and toxin concentrations were reported weekly to public health officials. We found that screening for potential toxin-producing cyanobacteria and then measuring toxin concentrations when cell densities reached critical levels worked well to identify problem locations. The majority of the 84 samples with microcystin levels greater than 1 µg/L, the WHO level of concern, were collected in shoreline locations. With pre-season training and regular communication and support, citizen monitoring can greatly enhance a monitoring effort and provide invaluable data a very reasonable cost.

### **Application of the WHO alert level framework to cyanobacterial monitoring in Lake Champlain, Vermont**

Mary Watzin, Emily Brines Miller, Angela Shambaugh, Meghan Kreider  
Environmental Toxicology 21(3):278 – 288. 2006

Abstract: The increasing incidence of toxic cyanobacteria blooms worldwide has created a need for practical and efficient monitoring in order to protect public health. We developed a monitoring and alert framework based on World Health Organization (WHO) recommendations and applied it on Lake Champlain during the summers of 2002-2004. The protocol began with collection of net samples of phytoplankton in order to maximize the chance of finding potential toxin-producing cyanobacteria. Samples were collected lake wide in partnership with ongoing monitoring efforts, but because open water sample sites did not capture conditions along the shoreline, we added near-shore and shoreline stations in problem areas. Samples were examined qualitatively until potential toxin-producing taxa were found. Then quantitative analyses began, using a rapid screening method to estimate cell density based on colony size. A final cell density of 4000 cells/mL triggered toxin analyses. Primary analysis was for microcystins using ELISA methods. Cell densities, locations of colonies, and toxin concentrations were reported weekly to public health officials. We found that screening for potential toxin-producing cyanobacteria and then measuring toxin concentrations when cell densities reached critical levels worked well to identify problem locations. Although the WHO recommends using chlorophyll *a* concentration, it was not a good indicator of problem densities of potential toxin-producing cyanobacteria. Our cell density screening method missed no developing blooms but produced less precise density estimates at high cell counts. Overall, our framework appears to provide an efficient and effective method for monitoring cyanotoxin risks.