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# Monitoring and Evaluation of Cyanobacteria in Lake Champlain

## Summer 2006

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# MONITORING AND EVALUATION OF CYANOBACTERIA IN LAKE CHAMPLAIN

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**Report to**

**Lake Champlain Basin Program**

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## EXECUTIVE SUMMARY

In 2006, monitoring for potential toxin-producing cyanobacteria continued on Lake Champlain with the following specific objectives:

- Continue monitoring of blue-green algae (BGA) at the Long-term Water Quality and Biological Monitoring Project sites, selected stations in the greater Burlington area, St. Albans Bay and Missisquoi Bay by UVM and the Vermont DEC.
- Continue to work with volunteer Citizen monitors in Missisquoi Bay and in other locations in the north lake and on the New York side of the lake.
- Continue screening for the presence of toxins when potential toxin-producing BGA are observed.
- Continue to use and refine a tiered BGA alert system framework, incorporating data and knowledge gained from 2003 through 2005.
- Maintain the existing communication network among state and provincial agencies in Vermont, New York and Quebec to facilitate regular exchange of information about current BGA conditions and the potential for human exposure to toxins. Continue to work toward a lake-wide standard for reporting this information.

Collections of net and whole water plankton began in June in most locations, and continued into mid-November. Sample sites encompassed all of Lake Champlain, but a special effort was made in Missisquoi Bay, St. Albans Bay, and the north lake, areas known to have problems with toxic blooms in the past. Citizen monitors living around the lake at 15 specific sites were recruited to collect samples from shoreline locations where algae accumulated.

In 2006, potential toxin-producing cyanobacteria species remained a common part of Lake Champlain's plankton. As in past years, highest abundances were found in Missisquoi Bay and St. Albans Bay, where total phosphorus and total nitrogen concentrations were also high. Also similar to past years, there was a high degree of spatial variability in toxin concentrations, and most high toxin concentrations were found in dense surface accumulations of algae or in scums. The seasonal median concentration of microcystin in Missisquoi Bay was 0.64 μg/L (range 0.03 – 21.3 μg/L); in St. Albans Bay, it was 0.06 μg/L (range 0.01 – 0.43 μg/L). A seasonal high concentration of about 42 μg/L was measured in a sample collected from a shoreline accumulation at Dunham's Bay in late August. Analysis for anatoxin-a by SUNY-ESF is still in progress.

The most striking difference between 2006 and previous years was a change in the taxonomic composition of the cyanobacteria, with an increase in the relative abundance of *Aphanizomenon* and a decrease in the relative abundance of *Microcystis*. The causes of this change are not known.

The e-mail notification system worked well to keep public health officials informed about algal and toxin conditions. In 2006, we continued to collaborate with Vermont Department of Health to post information about blue-green algae and the weekly results of our testing on their web site to improve communication with the users of Lake Champlain. Information from all locations where samples were tested was included on the website.

## INTRODUCTION

Lake Champlain is one of the largest lakes in the United States and is often called the "Sixth Great Lake." Although primarily a recreational lake, it also serves as a source of drinking water and a site for the disposal of municipal wastes in communities throughout the basin.

In response to a dog-poisoning attributed to cyanobacteria toxins in 1999, the LCBP initiated a study to investigate the occurrence of potential toxin-producing cyanobacteria and their toxins in Lake Champlain in 2000. Over the next seven years, this monitoring program has evolved to document the presence and extent of toxic cyanobacteria blooms in Lake Champlain, and the levels of cyanotoxins that have occurred.

In addition, a project supported through NOAA's MERHAB program began in 2002 and continues on Lake Champlain, through a partnership between UVM, SUNY-ESF and SUNY-Plattsburgh. The project has multiple objectives, including documenting the distribution of cyanotoxins in the lake, developing a rapid screening method for anatoxin, and developing methods for monitoring throughout the lower Great Lakes (Lakes Erie, Ontario and Champlain). Data collected from this project are not available rapidly enough to drive the weekly public alert system, but data are regularly shared among the project investigators.

Beginning in 2003, regular monitoring has been conducted by UVM in partnership with the LCBP long-term monitoring program and with citizen monitors recruited with the assistance of the Lake Champlain Committee. In 2006 we continued this effort with the following specific objectives:

### Objectives:

- Continue monitoring of BGA at the Long-term Water Quality and Biological Monitoring Project (LTMP) sites, selected stations in the greater Burlington area, St. Albans Bay and Missisquoi Bay by UVM and the Vermont DEC.
- Continue to work with volunteer Citizen Monitors in Missisquoi Bay and in other locations in the north lake and on the New York side of the lake.
- Continue screening for the presence of toxins when potential toxin-producing
- Continue to use a tiered BGA alert system framework, incorporating data and knowledge gained from 2003 through 2005.
- Maintain the existing communication network among state and provincial agencies in Vermont, New York and Quebec to facilitate regular exchange of information about current BGA conditions and the potential for human exposure to toxins. Continue to work toward a lake-wide standard for reporting this information.

## METHODS

### Field Collection

To survey plankton populations lakewide, we established partnerships with the VT DEC and NY DEC staff conducting the LCBP long-term monitoring program. VT DEC staff collected plankton samples from the 15 LTMP sites during their routine collections (Figure 1). Working with the Lake Champlain Committee, we also recruited volunteers to sample shoreline locations in Missisquoi Bay, Maquam Bay, and other areas of the lake (Figure 1). We also sampled sites in Missisquoi Bay, St. Albans Bay, and Burlington Bay, where the highest population density of basin residents live and two large water supply systems draw their water.

Frequency. Monitoring for the presence of BGA began in June at the LTMP sites and at the UVM sites and in early July at the citizen monitoring sites. The LTMP sites were sampled approximately biweekly regardless of bloom conditions, as dictated by the state's regular program activities. Frequency of sample collection in Burlington Bay, Missisquoi Bay, and St. Albans Bay was bi-weekly or weekly, as determined following the tiered alert system framework (Table 1). This framework, based on recommendations in Chorus and Bartram (1999) calls for less frequent sampling initially, then weekly sampling once bloom conditions appear. Citizen monitors sampled weekly from July through August. In Burlington Bay, cyanobacteria levels remained low throughout the season, and we remained at a bi-weekly sampling interval for the entire period. In Missisquoi and St. Albans Bay, algal densities were much higher, and weekly sampling was initiated in early July and continued into early November, when cell densities indicated the decline of the bloom.

Analytical Parameters. The following types of samples were collected in Burlington Bay, St. Albans Bay and Missisquoi Bay during 2006:

- whole water and net plankton
- whole water for total nitrogen
- whole water for total phosphorus
- whole water for chlorophyll *a*
- whole water for toxins (the analysis of this parameter began when microscopic analysis indicated potential toxin-producing taxa have reached densities of concern)

At the LTMP sites, only net plankton samples were collected for this project; however, total nitrogen, total phosphorus, and chlorophyll samples were collected as part of the Long-Term Biomonitoring Project.

In Burlington Bay, temperature, conductivity and oxygen were measured using a Seabird profiler from 0.5 m below the surface to 0.5 m above the bottom on some dates. Secchi depths were measured at all locations in Burlington Bay, Missisquoi Bay, St. Albans Bay, and at the Long-Term Biomonitoring Project sites.

**Figure 1. Location of the blue-green algae monitoring locations.**

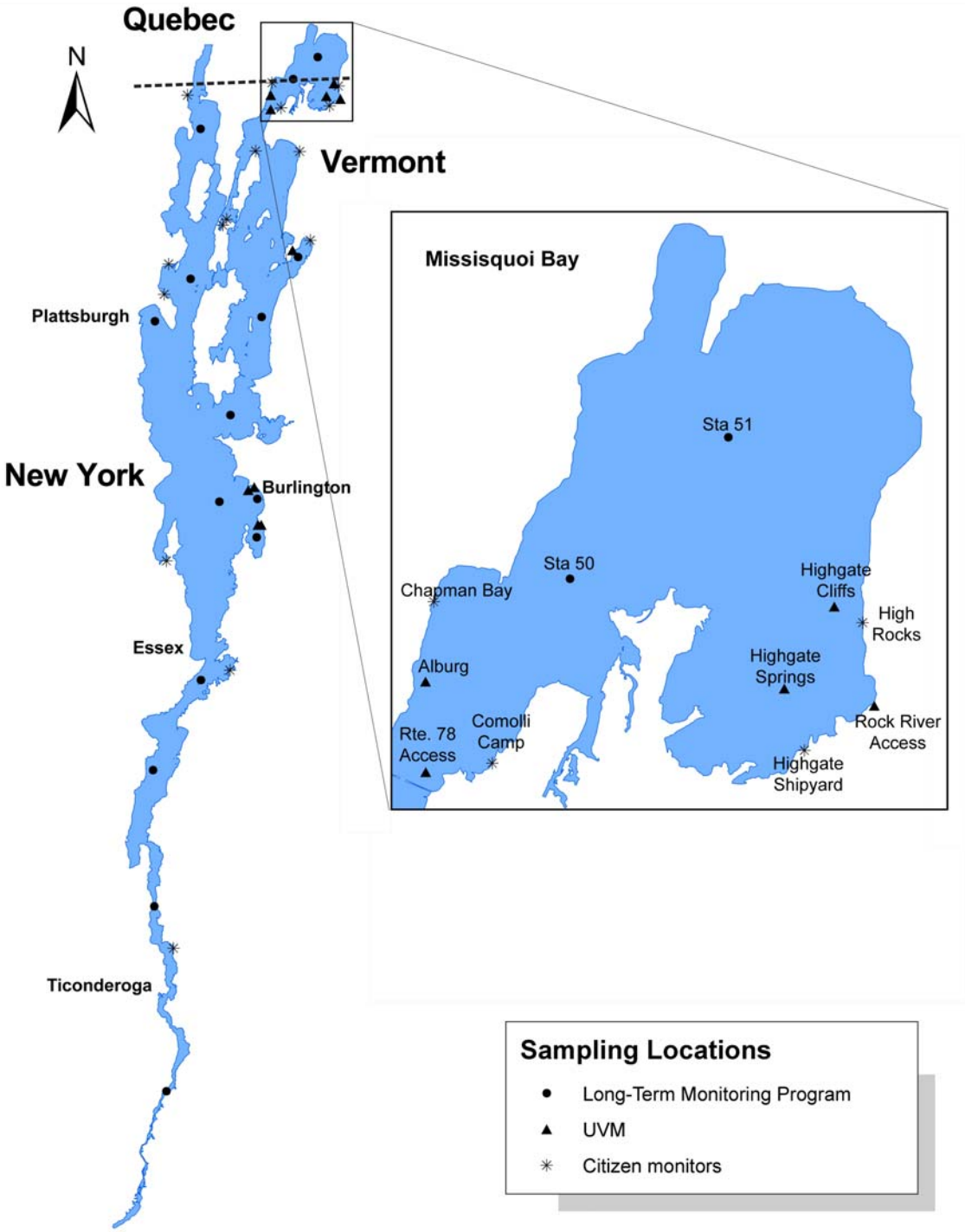


**Table 1. Outline of our prototype tiered sampling and alert framework.**

| | |
|---|---|
| **Qualitative Sampling** | |
| Frequency: | 2/month |
| Collect: | Vertical plankton tows (63-µm net, upper 3 m)<br>Screened within 48 hours |
| Conclusions: | If potential toxin-producing taxa observed,<br>proceed to *Quantitative sampling* |
| **Quantitative Sampling** | |
| Frequency: | 2/month |
| Collect: | Vertical plankton tow (63-µm net, upper 3m)<br>Full enumeration within 48 hours |
| Conclusions: | If BGA reaches densities reach 2000 cells/mL,<br>proceed to V*igilance level* |
| **Vigilance Level** | |
| Frequency: | 1/wk at midday |
| Collect: | Vertical plankton tow (63-µm net, upper 3m)<br>Full enumeration within 48 hours |
| Conclusions: | If BGA exceed 4,000 cells/mL,proceed to *Alert Level 1*<br>Return to *Quantitative sampling* if densities fall below 2,000 BGA cells/mL<br>Notify public health officials that BGA are abundant and blooms could form |
| **Alert Level 1** | |
| Frequency: | 1/wk at midday (or more frequently as needed) |
| Collect: | Whole water phytoplankton samples<br>Whole water chlorophyll *a*<br>Whole water toxin samples |
| Conclusions: | If microcystin concentration exceeds 6 µg/L (VDH recreational standard),<br>proceed to *Alert Level 2*<br>Notify public health officials of potential risks to humans and animals |
| **Alert Level 2** | |
| Frequency: | 1/wk at mid-day (or more frequently as weather conditions dictate) |
| Collect: | As for Alert Level 1 |
| Conclusions: | Return to *Alert Level 1* if microcystin concentration drops below 6 µg/L<br>Notify public health officials that significant risk to humans and animals exists.<br>Public Health Advisories should be issued by appropriate agencies. |

Sample Collection. Net plankton samples were obtained using a 63-µm Wisconsin net. A single 3 m tow was collected, placed in a cooler, and transported back to the laboratory where the total volume was recorded and a subsample was preserved for analysis.

Total nitrogen, total phosphorus, chlorophyll *a*, and whole water plankton samples were collected by surface grab sampling. Two replicates were collected for each parameter.

Preservation and storage. Nalgene high-density polyethylene bottles were used for all samples, excluding total nitrogen samples which were collected in 50 mL polypropylene centrifuge tubes. Total phosphorus containers were cleaned with 20% hydrochloric acid solution prior to use. Nitrogen samples were preserved with sulfuric acid to a pH less than 2 and stored at 4°C until analysis. Total phosphorus samples were frozen until analysis. Plankton samples were preserved with 1% Lugols iodine solution and stored in the dark until analysis. Chlorophyll samples were filtered within 24 hours and frozen prior to analysis. Lake water samples for toxin analysis were preserved in one of three ways: filtered and frozen upon return to the lab, filtered and shipped for analysis at SUNY-ESF.

**Sample Analysis**

Chlorophyll. All samples were thoroughly mixed and then filtered onto glass fiber filters (Whatman 934-AH; retention size ~1.5 µm) under low vacuum. After sufficient material was filtered to leave a visible green layer, filters were placed in clean 15 mL plastic centrifuge tubes and frozen. For chlorophyll extraction, 8 mL of 95% ethanol was added to each tube, all tubes were placed in an 80°C water bath for 8 minutes. Then samples were covered in foil and placed in a refrigerator overnight. After the extraction, samples were brought to room temperature, shaken to homogenize the extract, and centrifuged at 3000 rpm for 10 minutes. Non-acidified and acidified extract absorbance was measured at 665 and 750 nm.

Net plankton. Net plankton were analyzed either as qualitative or quantitative samples. Initially samples were evaluated qualitatively: all taxa present were noted and recorded. Once potentially toxic cyanobacteria were identified in the samples, evaluation became quantitative; individual algal units in the samples were identified and enumerated, and densities were calculated for each taxon.

An aliquot of well-mixed sample was placed in a Sedgwick Rafter cell and allowed to settle for 10 minutes. Slides were examined at 100X with phase contrast using an inverted Olympus IX70 microscope. For qualitative screening, the entire chamber was scanned and algal taxa present were recorded. For quantitative screening, algal units were identified and enumerated. Counting continued until 100 cells of the most abundant genus had been observed or at least 10 fields had been examined. Algal units were categorized by size (single cells, fragments of colonies or filaments, small, medium, or large colonies or filaments). The enumerated natural units were multiplied by a cell factor to estimate cell densities (Table 2). Cell densities were extrapolated to reflect plankton populations in the original lake water.

**Table 2. Cell factors used to estimate field densities of colonial algae.**

| Taxon | Unit Category | Estimated Cells/Unit | Cell Factor |
|---|---|---|---|
| *Anabaena spp., Aulacoseira, Fragilaria* | fragment | 1 – 20 | 10 |
| | small | 20 – 100 | 60 |
| | medium | 100 – 1000 | 500 |
| | large | >1000 | 1000 |
| *Microcystis, Coelosphaerium* | small | <100 | 50 |
| | medium | 100 - 1000 | 500 |
| | large | >1000 | 1000 |
| *Gloeotrichia spp.* | fragment | single trichome | 20 |
| | small | quarter of a colony | 2500 |
| | medium | half of a colony | 5000 |
| | large | entire colony | 10,000 |
| *Aphanizomenon spp.* | fragment | single trichome | measured |
| | small | small flake | 200 |
| | medium | medium flake | 500 |
| | large | large flake | 1000 |

Whole water plankton. Whole water plankton were examined using Utermöhl settling chambers. Aliquots of well-mixed samples were allowed to settle for 1-4 days, depending on the chamber volume, then counted using an Olympus IX70 or an Olympus IX71 inverted microscope with phase contrast at 400X. Both natural units and individual cells comprising the natural units were enumerated. Counting continued until 100 units of the most abundant taxa had been observed or 100 fields had been evaluated.

Total Phosphorus. Total phosphorus samples were thawed and mixed thoroughly. An aliquot (generally 50 mL) was digested using ammonium persulfate (1998) and analyzed following Quikchem™ Method 10-115-01-1-F using a Lachat Quikchem™ 8000 Series Flow Injection Analyzer.

Soluble Reactive Phosphorus. Immediately upon return from the field, samples were mixed thoroughly and filtered using Nalgene PES syringe filters (pore size 0.45 µm) to remove organic materials and suspended sediments. Filtered samples were analyzed within 24 hours following the ascorbic acid method (APHA 1998).

Total Nitrogen. Total nitrogen samples were analyzed using persulfate digestion (APHA 1998) and cadmium reduction following Quikchem™ Method 10-107-06-2-H using a Lachat Quikchem™ 8000 Series Flow Injection Analyzer.

Toxin Sample Preparation. Filters for analysis of toxins by high performance liquid chromatography (HPLC) and protein phosphatase inhibition assay (PPIA) at SUNY were placed on dry ice and shipped by overnight carrier. Filters for ELISA assay by UVM were placed in 15 mL glass centrifuge tubes with Teflon-lined caps in 8 mL of 50% methanol, shaken well and stored at –80°C until analysis.

Whole water samples for analysis by HPLC and PPIA at SUNY were kept cold and sent by overnight carrier within 24 hours.

Microcystin(s) by ELISA. Toxin samples in 50% methanol were thawed, shaken and re-frozen two times before beginning analysis. Extracted samples were diluted with deionized water until methanol represented less than 5% of the total volume, following recommendations to improve the accuracy of the method (Metcalf et al. 2000). Microcystin plate kits were purchased from Envirologix Inc. (Portland, ME).

Samples were run in duplicate following manufacturer's instructions on a KC Jr. plate reader (Biotek Instruments), utilizing standards provided in the kit. Mean values were used to determine the toxin concentration of each pair of samples. Samples exceeding the range recommended by the kit were diluted and re-analyzed. Samples below the range were also re-analyzed using manufacturer recommended dilution procedures for the standards.

Microcystin (s) by PPIA. PPIA analysis followed a modification of Carmichael and An (1999). Microcystin-LR standards (0.06 – 1000 μg/L) were prepared fresh from a 40 μg/L stock in 50% acidified methanol. The protein phosphatase 1, catalytic subunit Roche, was used at a working concentration of 0.1 mU/200 μL. All assays were done in 96 well plates in a 37°C incubator. Readings at 405 nm were taken every 5 minutes for 60 minutes using an E-max plate reader.

Anatoxin-a by HPLC. At SUNY, algal material was freeze-dried and then extracted with acidified methanol. Solid phase extraction cartridges were eluted with 100% methanol. Samples were analyzed in a Zorbax ACE C18 column with C-18 Phenomenex guard disk following James et al. (1997). Several duplicate samples were analyzed at Wright State University by Dr. Wayne Carmichael, using the same procedures, as a QA/QC check.

## RESULTS

### Cyanobacteria and Toxins at the Monitoring Sites

While many of the samples collected at the Long Term Monitoring Sites were analyzed qualitatively until mid to late summer, almost all of the samples collected by UVM and the citizen monitors were analyzed quantitatively. The total number of samples collected for each type of analysis (quantitative plankton, toxin and chlorophyll) was about 500 in 2006 (Table 3).

The alert status reached and the maximum density of potentially toxic cyanobacteria cells at each site monitored are listed in Table 4. *Aphanizomenon* spp., *Microcystis* spp. and *Anabaena flos-aquae* were all widely distributed at sites across Lake Champlain. In 2006, however, *Aphanizomenon* dominated in most samples in the north lake in late summer and fall, not *Microcystis* observed in previous years.

**Table 3. Number of quantitative samples collected and analyzed in the Cyanobacteria Monitoring Program in 2006.**

| Sample Type | Phytoplankton | | Microcystin whole water plankton | Anatoxin whole water plankton | Chlorophyll *a* whole water plankton |
|---|---|---|---|---|---|
| | net | water* | | | |
| **Number Collected** | 378 | 277 | 452 | 84 | 511 |
| **Number Analyzed** | 378 | 264 | 188 | 1 of 51** | 508 |

* ww counted as net

** shipped 51 samples, still awaiting data for all but one sample

At the Long-term Biomonitoring sites, cyanobacteria densities only reached the Alert Level at Station 40, St. Albans Bay, and Stations 50 and 51 in Missisquoi Bay, in August or September. The regular UVM Sites in Missisquoi Bay and St. Albans Bay also reached Alert Level, but earlier in the year than at the Long-term Biomonitoring sites. Several additional samples collected in Malletts Bay in June also reached Alert Level. At the citizen monitoring sites, all of which were located along the shoreline, Alert Level was reached in mid-July or early August in Missisquoi Bay, Carry Bay, Pelots Bay, North Hero State Park and at St. Albans Bay Park. Additional samples collected when algae were noticed in Beggs Park, Dunham Bay, Keeler Bay, and Knight Point also reached Alert Level. None of the regular Burlington Bay sites reached Alert Level in 2006, and none of the other main lake or south lake sites reached Alert Level in 2006.

The highest concentrations of microcystins in 2006 were found in a special sample collected from Dunham Bay (Table 5). Most sites in Missisquoi Bay and both sites in St. Albans Bay also showed measurable concentrations of microcystin in the late summer and fall. On a few dates, concentrations above 6 μg/L, the State of Vermont's threshold for recreational waters, were achieved in Missisquoi Bay or other areas of the north lake. Differing from previous years, the highest microcystin concentrations in Missisquoi Bay in 2006 were found in the western part of the Bay, at Comolli Camp, not in the east in the Highgate area. As in previous years, the citizen monitoring stations along the shoreline captured a significant number of the locations that attained alert level status. The citizen monitoring stations in the northeastern lake and Missisquoi Bay had much higher densities of potential toxin-producing taxa and more measurable microcystin concentrations than the citizen monitoring stations in other sections of the lake.

As examples of the seasonal variation at sites, Figures 2-5 show the season pattern of cell density and alert level status in Alburg, at the Rte 78 boatlaunch site, at Highgate Cliffs and Highgate Springs, all in Missisquoi Bay.

**Table 4. Summary of plankton sample status at cyanobacteria monitoring stations in 2006. All microcystin concentrations are based on ELISA tests conducted at UVM.**

**LCBP Long-Term Monitoring Program Sites**

| Region | Station/Location | Monitoring Status | Date Achieved | Cyanobacteria Present | Maximum Density of Potentially Toxic Cells/mL |
|---|---|---|---|---|---|
| South | 2. Benson Landing | Quantitative | 06/08/06 | *Anabaena*, *Aphanizomenon*, *Microcystis*, *Oscillatoria* | 37 (08/31/06) |
| | 4. Crown Point | Quantitative | 07/24/06 | *Anabaena*, *Aphanizomenon*, *Microcystis* | 36 (08/31/06) |
| | 7. Cole Bay | Quantitative | 07/20/06 | *Anabaena*, *Aphanizomenon*, *Microcystis* | 107 (08/23/06) |
| | 9. Diamond Island | Quantitative | 06/06/06 | *Anabaena*, *Aphanizomenon*, *Microcystis* | 357 (09/06/06) |
| Main | 16. Shelburne Bay | Quantitative | 06/05/06 | *Anabaena*, *Aphanizomenon*, *Microcystis* | 112 (09/01/06) |
| | 19. Main Lake | Quantitative | 06/16/06 | *Anabaena*, *Aphanizomenon*, *Microcystis* | 180 (06/16/06) |
| | 21. Burlington Harbor | Quantitative | 07/07/06 | *Anabaena*, *Aphanizomenon*, *Microcystis* | 685 (09/15/06) |
| | 25. Malletts Bay | Quantitative | 06/09/06 | *Anabaena*, *Aphanizomenon*, *Microcystis* | 223 (08/30/06) |
| Northwest | 33. Cumberland Bay | Quantitative | 07/10/06 | *Anabaena*, *Aphanizomenon*, *Microcystis* | 63 (08/10/06) |
| | 36. Point au Roche | Quantitative | 07/06/06 | *Anabaena*, *Aphanizomenon*, *Microcystis* | 403 (09/11/06) |
| | 46. Alburg Center | Quantitative | 06/23/06 | *Anabaena*, *Aphanizomenon*, *Microcystis* | 1,144 (08/08/06) |
| Northeast | 34. Inland Sea | Quantitative | 06/15/06 | *Anabaena*, *Aphanizomenon*, *Microcystis* | 635 (08/25/06 |
| | 40. St. Albans Bay | Alert 1 | 10/05/06 | *Anabaena*, *Aphanizomenon*, *Microcystis* | 10, 492 (10/05/06) |
| Missisquoi Bay | 50. Missisquoi Bay | Alert 1 | 09/22/06 | *Anabaena*, *Aphanizomenon*, *Microcystis* | 8931 (09/22/06) |
| | 51. Missisquoi Bay | Alert 1 | 08/24/06 | *Anabaena*, *Aphanizomenon*, *Microcystis* | 901,731 (10/06/06) |

**UVM Monitoring Stations**

| Region | Location | Monitoring Status | Date Achieved | Highest Microcystin (µg/L) Observed (wwp) | Cyanobacteria Present | Maximum Density of Potentially Toxic Cells/mL (net or wwp*) |
|---|---|---|---|---|---|---|
| Main | Burlington Water Bay | Quantitative | 06/07/06 | Not measured | *Anabaena, Aphanizomenon, Microcystis* | 503 (08/02/06) |
| | Champlain Water Bay | Quantitative | 06/21/06 | Not measured | *Anabaena, Aphanizomenon, Microcystis* | 723 (09/13/06) |
| | Mallets Bay | Alert 1 | 06/12/06 | 0.04 (06/12/06) | *Anabaena, Microcystis* | 81,726 (06/14/06) |
| | North Beach | Quantitative | 06/07/06 | Not measured | *Anabaena, Aphanizomenon, Microcystis* | 575 (08/02/06) |
| | Red Rocks Beach | Quantitative | 06/21/06 | Not measured | *Anabaena, Aphanizomenon, Microcystis* | 385 (09/27/06) |
| Northeast | St. Albans Boatlaunch | Alert 1 | 07/11/06 | 0.22 (10/03/06) | *Anabaena, Aphanizomenon, Microcystis, Nodularia* | 256,316 (10/31/06) |
| Missisquoi Bay | Southeast of Rte 78 bridge | Alert 1 | 10/17/06 | 2.71 (10/24/06) | *Aphanizomenon* | 514,600,000* (10/24/06) |
| | Rte. 78 Access | Alert 1 | 08/08/06 | 2.31 (08/29/06) | *Anabaena, Aphanizomenon, Microcystis* | 58,091 (09/12/06) |
| | Alburg | Alert 1 | 08/08/06 | 0.53 (09/19/06) | *Anabaena, Aphanizomenon, Microcystis* | 538,133 (10/17/06) |
| | Highgate Cliffs | Alert 2 | 08/29/06 | 15.11 (08/29/06) | *Anabaena, Aphanizomenon, Microcystis* | 95,385 (10/03/06) |
| | Missisquoi Border- VT | Alert 1 | 07/18/06 | 3.78 (07/18/06) | *Anabaena, Aphanizomenon, Microcystis* | 6,030 (07/18/06) |
| | Missisquoi Bay between Highgate Cliffs and Alburg | Alert 1 | 07/26/06 | 1.17 (07/26/06) | *Anabaena, Aphanizomenon, Microcystis* | 1,085,866* (07/26/06) |
| | Highgate Springs | Alert 2 | 08/29/06 | 9.49 (8/29/06) | *Anabaena, Aphanizomenon, Microcystis* | 104,302 (09/19/06) |
| | Rock River Access | Alert 1 | 07/18/06 | 4.08 (09/05/06) | *Anabaena, Aphanizomenon, Microcystis* | 376,286* (08/01/06) |

***** whole water grab, analyzed by rapid count protocol

## Citizen Monitoring Sites

| Region | Location | Monitoring Status | Date Achieved | Highest Microcystin (µg/L) Observed | Cyanobacteria Present | Maximum Density of Potentially Toxic Cells/mL |
|---|---|---|---|---|---|---|
| South | Littlefield Shore | Quantitative | 07/16/06 | Not measured | *Anabaena*, *Aphanizomenon*, | 1,421 (07/23/06) |
| Main | Long Point | Quantitative | 07/03/06 | Not measured | *Anabaena*, *Aphanizomenon*, *Microcystis* | 1,999 (07/09/06) |
| | Beggs Park | Alert 1 | 09/05/06 | 3.47 (09/05/06) | *Anabaena*, *Aphanizomenon*, *Coelosphaerium*, *Microcystis* | 78,441 (09/05/06) |
| | Pelots Bay | Alert 1 | 08/14/06 | 0.84 (08/28/06) | *Anabaena*, *Aphanizomenon*, *Microcystis* | 28,902 (08/14/06) |
| | Willsboro Bay | Quantitative | 07/24/06 | Not measured | *Anabaena*, *Aphanizomenon*, *Microcystis* | 1,929 (08/21/06) |
| Northwest | Cumberland Bay State Park | Vigilance | 08/14/06 | Not measured | *Anabaena*, *Aphanizomenon* | 2,466 (08/14/06) |
| | Point Au Roche | Quantitative | 07/17/06 | Not measured | *Anabaena*, *Aphanizomenon*, *Microcystis* | 697 (09/04/06) |
| | Rouses Point | Quantitative | 08/21/06 | Not measured | *Aphanizomenon*, *Microcystis* | 658 (09/05/06) |
| Northeast | Carry Bay | Alert 1 | 08/27/06 | 0.19 (09/11/06) | *Anabaena*, *Aphanizomenon*, *Microcystis* | 11,531 (09/11/06) |
| | Dunham Bay | Alert 2 | 08/14/06 | 42.14 (08/21/06) | *Anabaena*, *Aphanizomenon*, *Microcystis* | 74,710 (08/21/06) |
| | Keeler Bay | Alert 1 | 08/28/06 | 0.04 (08/14/06) | *Anabaena*, *Aphanizomenon*, *Microcystis* | 27,955 (08/28/06) |
| | Knight Point | Alert 1 | 08/28/06 | 1.97 (08/28/06) | *Aphanizomenon*, *Microcystis* | 59,400 (08/28/06) |
| | Maquam Bay | Quantitative | 07/10/06 | Not measured | *Anabaena*, *Aphanizomenon*, *Microcystis* | 3,815 (07/25/06) |
| | North Hero State Park | Alert 1 | 07/31/06 | 0.73 (08/14/06) | *Anabaena*, *Aphanizomenon*, *Microcystis* | 16,976 (08/14/06) |
| | St. Albans Bay Park | Alert 1 | 07/03/06 | 0.43 (07/17/06) | *Anabaena*, *Aphanizomenon*, *Microcystis* | 326,133 (07/17/06) |

| | | | | | | |
|---|---|---|---|---|---|---|
| Missisquoi Bay | Chapman Bay | Alert 1 | 08/07/06 | 1.98 (08/28/06) | *Anabaena*, *Aphanizomenon*, *Microcystis* | 83,392 (08/28/06) |
| | Comolli Campsite | Alert 2 | 08/13/06 | 21.29 (08/13/06) | *Anabaena*, *Aphanizomenon*, *Microcystis* | 10,112,000 (08/13/06) |
| | High Rocks | Alert 2 | 07/17/06 | 7.17 (07/17/06) | *Anabaena*, *Aphanizomenon*, *Microcystis* | 50,061 (08/14/06) |
| | Highgate Springs Shipyard | Alert 2 | 08/28/06 | 14.98 (08/28/06) | *Anabaena*, *Aphanizomenon*, *Microcystis* | 782,666 (07/25/06) |

**Lake Champlain supplemental samples collected by VT DEC: whole water or net samples, collected when bloom conditions were apparent, June – October**

| Region | Location | Monitoring Status | Date Achieved | Cyanobacteria Present | Maximum Density of Potentially Toxic Cells/mL |
|---|---|---|---|---|---|
| South | Button Bay | Vigilance | 09/06/06 | *Anabaena*, *Aphanizomenon*, *Microcystis* | 2,172 (net) 09/06/06 |
| Main | Mallets Bay Boatlaunch | Alert 1 | 06/09/06 | *Anabaena* | 188,355 (ww) 06/09/06 |
| Northeast | Carry Bay | Alert 1 | 09/07/06 | *Anabaena*, *Aphanizomenon*, *Microcystis* | 8,345 (net) 09/22/06 |
| | St. Albans Boatlaunch | Alert 1 | 09/05/06 | *Anabaena*, *Aphanizomenon*, *Microcystis* | 1,408,000 (ww) 09/05/06 |
| Missisquoi Bay | Rte 78 Access | Alert 1 | 08/17/06 | *Anabaena*, *Aphanizomenon*, *Microcystis* | 7,710,000 (ww) 08/17/06 |

**Table 5. Number of samples tested and maximum microcystin concentration measured, 2006.**

| Region | Collected by | Location | No. Samples Tested | Maximum Microcystin Conc. (µg/L) |
|---|---|---|---|---|
| South | Citizen Monitor | Littlefield Shore | 0 | |
| Main | Citizen Monitor | Long Point | 0 | |
| | | Beggs Park | 1 | 3.47 |
| | | Willsboro Bay | 0 | |
| | UVM | Red Rocks Beach | 0 | |
| | | Champlain Water Bay | 0 | |
| | | Burlington Water Bay | 0 | |
| | | North Beach | 0 | |
| | | Mallets Bay | 3 | 0.04 |
| | | Mallets Bay Marina | 1 | 0.04 |
| | VT DEC | Mallets Bay | 1 | 0.08 |
| Northwest | Citizen Monitor | Cumberland Bay State Park | 0 | |
| | | Point Au Roche | 0 | |
| | | Rouses Point | 0 | |
| Northeast | Citizen Monitor | Carry Bay | 2 | 0.19 |
| | | Dunham Bay | 2 | 42.14 |
| | | Keeler Bay | 1 | 0.04 |
| | | North Hero State Park | 4 | 0.73 |
| | | Pelots Bay | 4 | 0.84 |
| | | Knight Point | 1 | 1.97 |
| | | Maquam Bay | 0 | |
| St. Albans Bay | Citizen Monitor | St. Albans Bay Park | 9 | 0.43 |
| | UVM | St. Albans Bay Park | 1 | 0.05 |
| | | St. Albans Boatlaunch | 24 | 0.22 |
| Missisquoi Bay | Citizen Monitor | Chapman Bay | 4 | 1.98 |
| | | Comolli Campsite | 10 | 21.29 |
| | | High Rocks | 6 | 7.17 |
| | | Highgate Springs Shipyard | 11 | 14.98 |
| | UVM | Rte. 78 Access | 13 | 2.31 |
| | | Rte. 78 Access-shore | 5 | 0.82 |
| | | Southeast of Rte 78 Bridge | 2 | 2.71 |
| | | Alburg | 16 | 0.53 |
| | | Alburg-shoreline | 6 | 0.19 |
| | | Highgate Cliffs | 18 | 15.11 |
| | | Missiquoi Border-VT | 2 | 3.78 |
| | | Missisquoi Bay between sites | 1 | 1.17 |
| | | Highgate Springs | 20 | 9.49 |
| | | Highgate Springs-Shipyard | 2 | 0.35 |
| | | Rock River Access | 18 | 4.08 |
| **Total Number of Samples Tested** | | | **188** | |

**Figure 2. Alert status at Alburg over the summer 2006.**

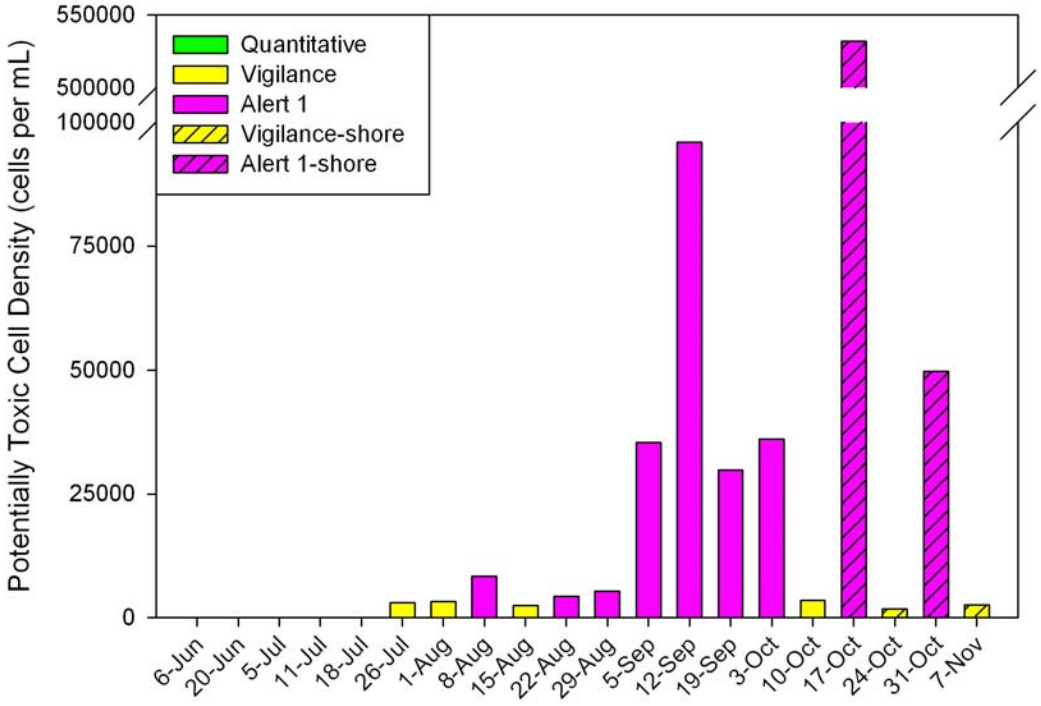



**Figure 3. Alert status at the Rte. 78 Access over the summer 2006.**

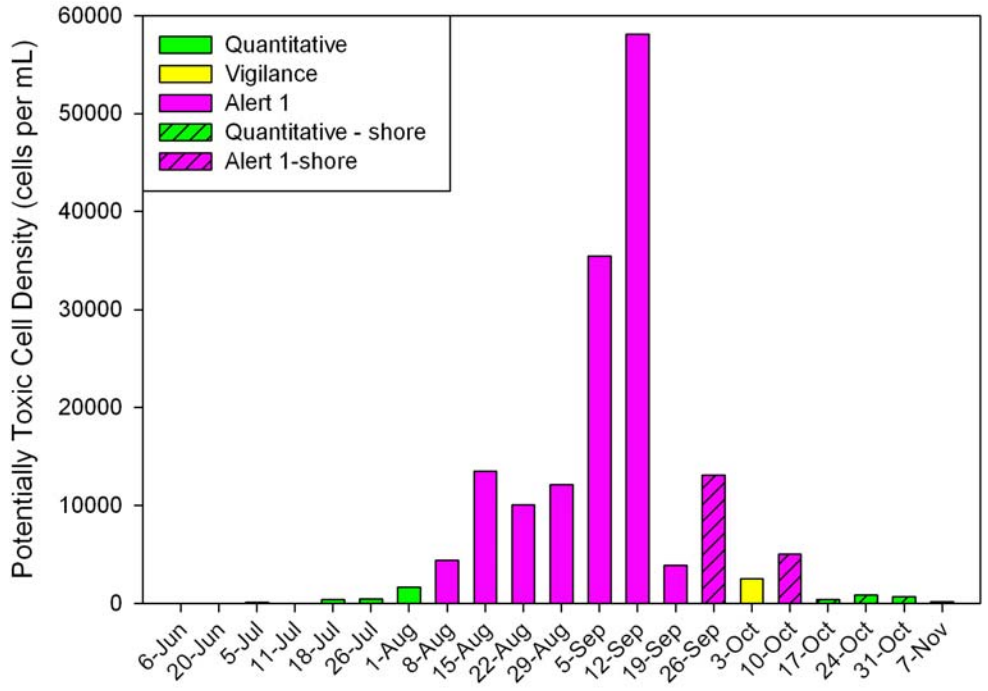


**Figure 4. Alert status at Highgate Cliffs over the summer 2006.**

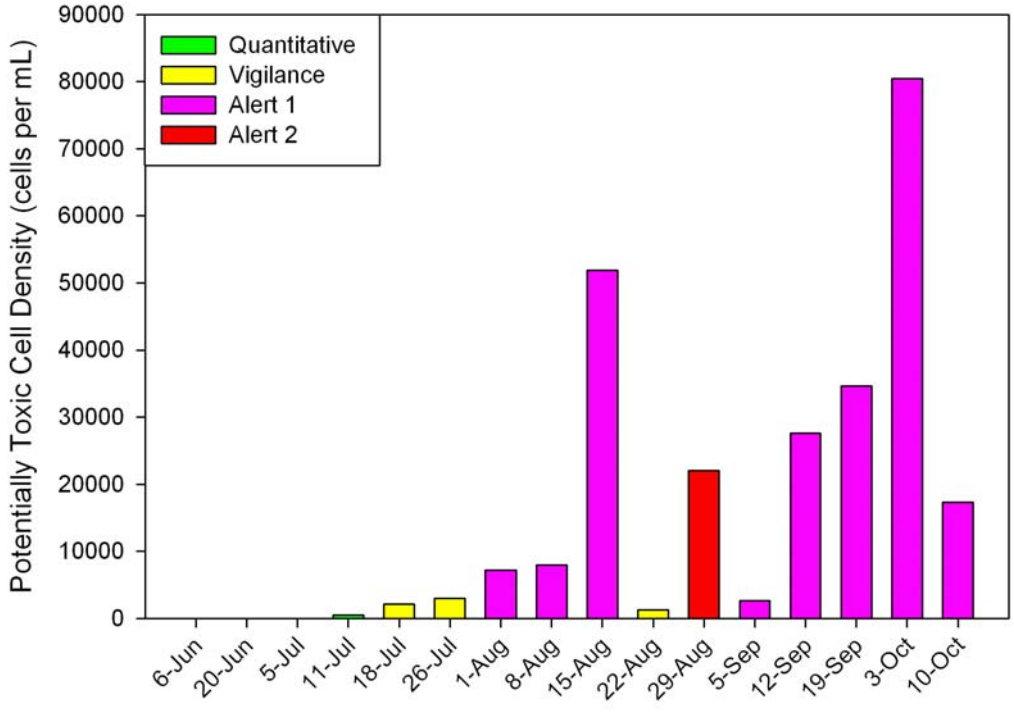
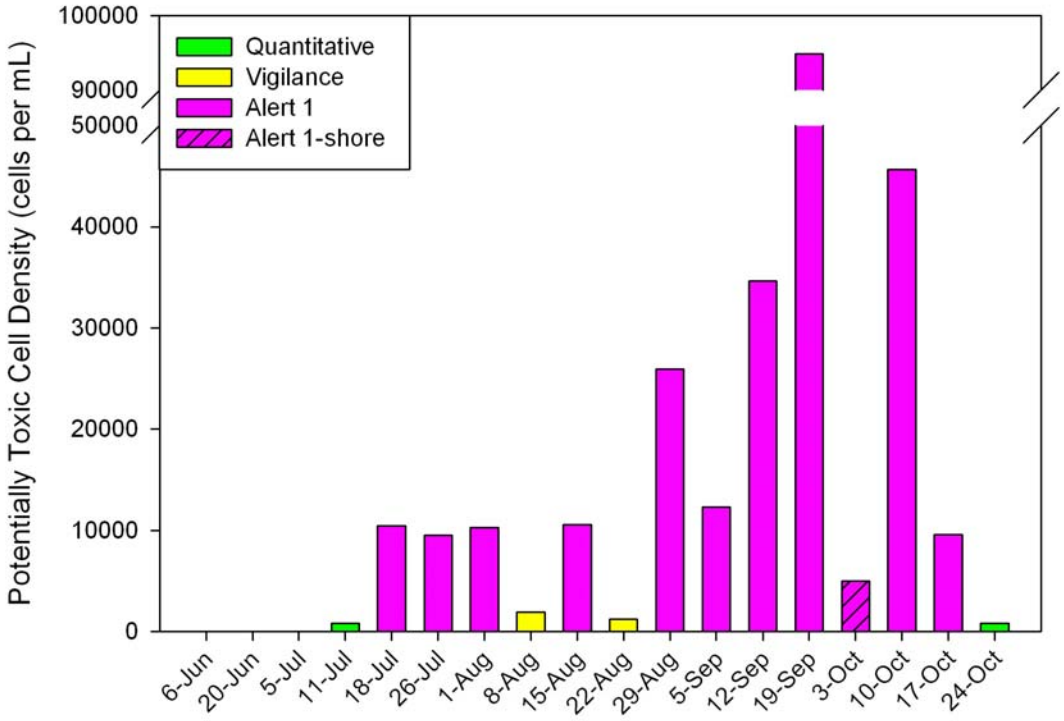
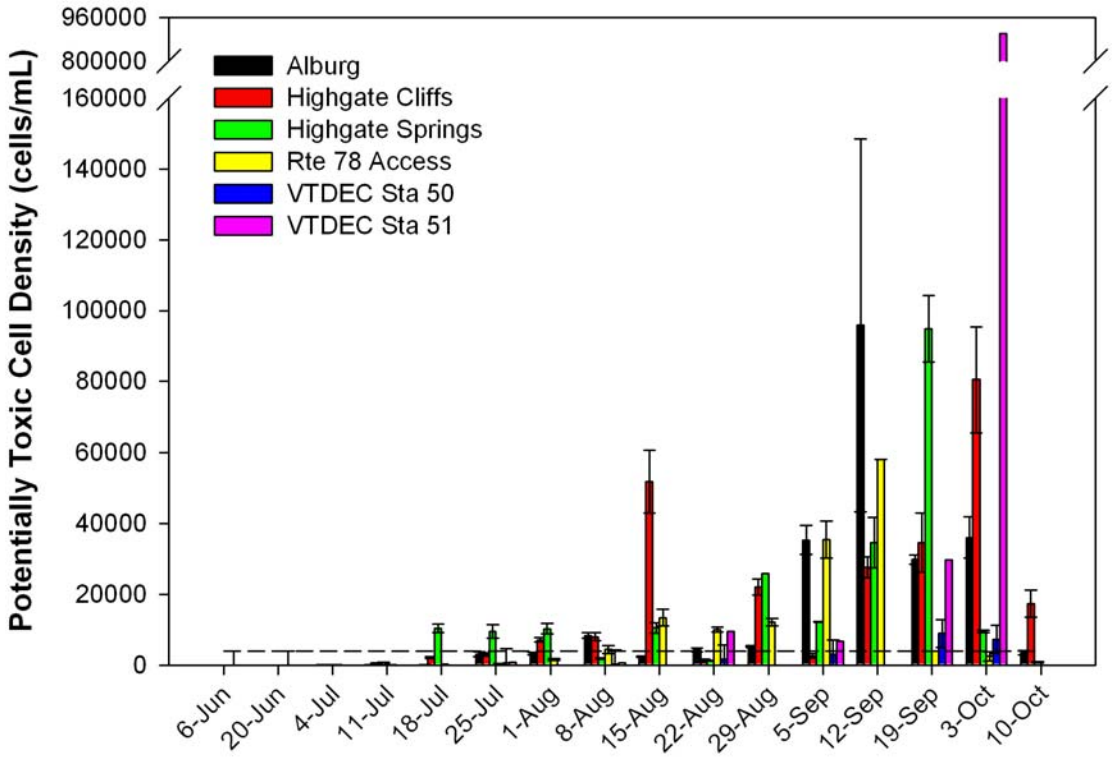



**Figure 5. Alert status at Highgate Springs over the summer 2006.**



The samples collected at LTMP Stations 50 and 51 in Missisquoi Bay generally showed similar patterns to the UVM stations, except for early October, when the highest densities of the season were found at Station 51 (Figure 6).

**Figure 6. Weekly mean of potentially toxic cyanobacteria cell densities in Missisquoi Bay offshore net samples.**




## Nutrients at the Cyanobacteria Monitoring Sites

Concentrations of total phosphorus (TP) and total nitrogen (TN) were averaged by date for monitoring sites in Burlington Bay, St. Albans Bay, and Missisquoi Bay. Mean concentrations of both nutrients were almost always highest in Missisquoi Bay, intermediate in St. Albans Bay, and lowest at Burlington Bay (Figure 7).

We also calculated the ratio of TN:TP in Burlington Bay, St. Albans Bay, and Missisquoi Bay (Figure 8). Although there was a bit more variability in 2006 than previous years, we found similar patterns to previous years, with generally lower ratios at Missisquoi Bay and St. Albans Bay compared to Burlington Bay, especially from mid-summer through the fall.

**Figure 7. Total phosphorus concentrations (mg/L) in Missisquoi Bay, St. Albans Bay, and Burlington Bay over the 2006 growing season.**

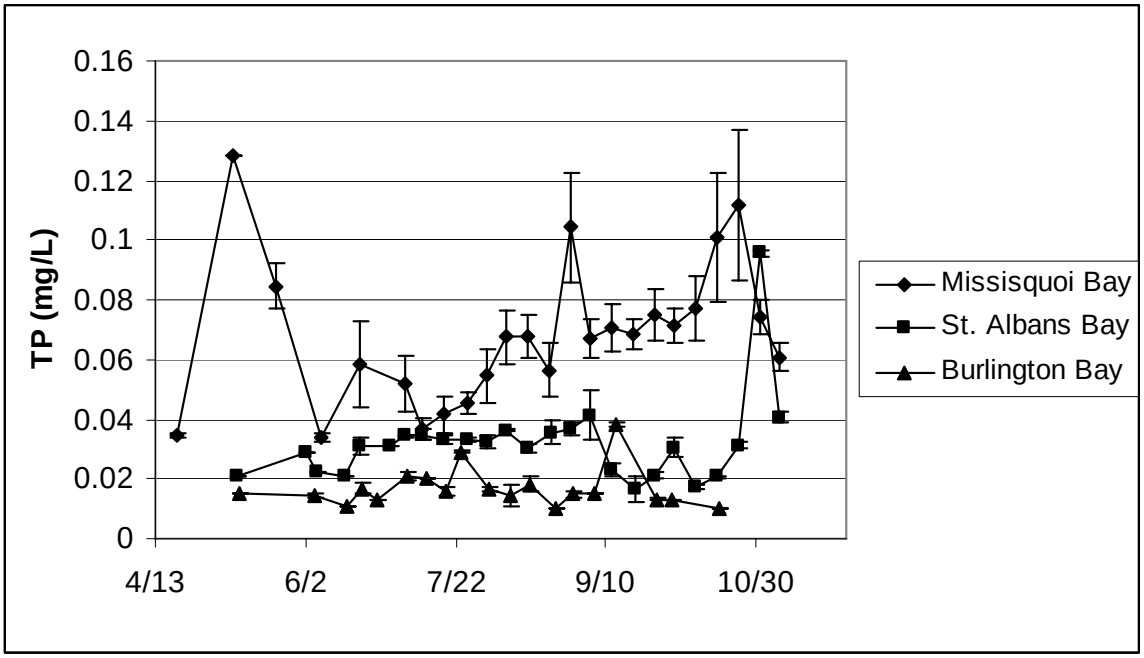
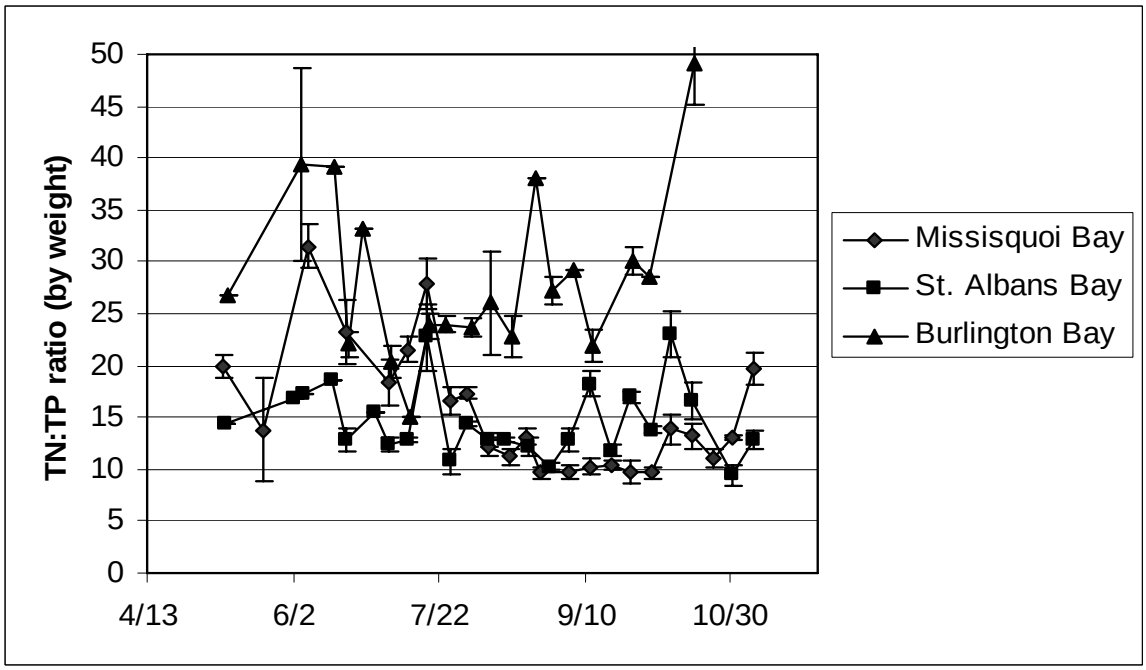



**Figure 8. TN:TP ratios across all stations sampled in Burlington Bay, St. Albans Bay and Missisquoi Bay in 2006.**



## Coordination

Coordination meetings were held with Vermont Department of Health officials in May 2006, and an e-mail distribution list that included 40 partner organizations and individuals was again established for regular information sharing over the summer season. Beginning in June, weekly or bi-weekly e-mail updates on monitoring results were distributed to these officials and to other professionals with an interest in bloom conditions and public health. Working with the Vermont Department of Health, we also posted background information about cyanobacteria and cyanotoxins, and provided information for a map depicting bloom conditions across the lake on their website (http://healthvermont.gov/enviro/bg_algae/weekly_status.aspx). Information on bloom conditions was updated on a weekly basis from early July through September.

# DISCUSSION AND CONCLUSIONS

## Comparison of Patterns of Cyanobacteria and Toxins 2003-2006

The most striking difference in the phytoplankton community between 2006 and previous years is the increase in relative abundance of *Aphanizomenon* and concomitant decrease in *Microcystis*, especially in Missisquoi Bay and St. Albans Bay (Figures 9-11).

**Figure 9. Seasonal mean percent generic composition of phytoplankton in Missisquoi Bay, 2003-2006.**

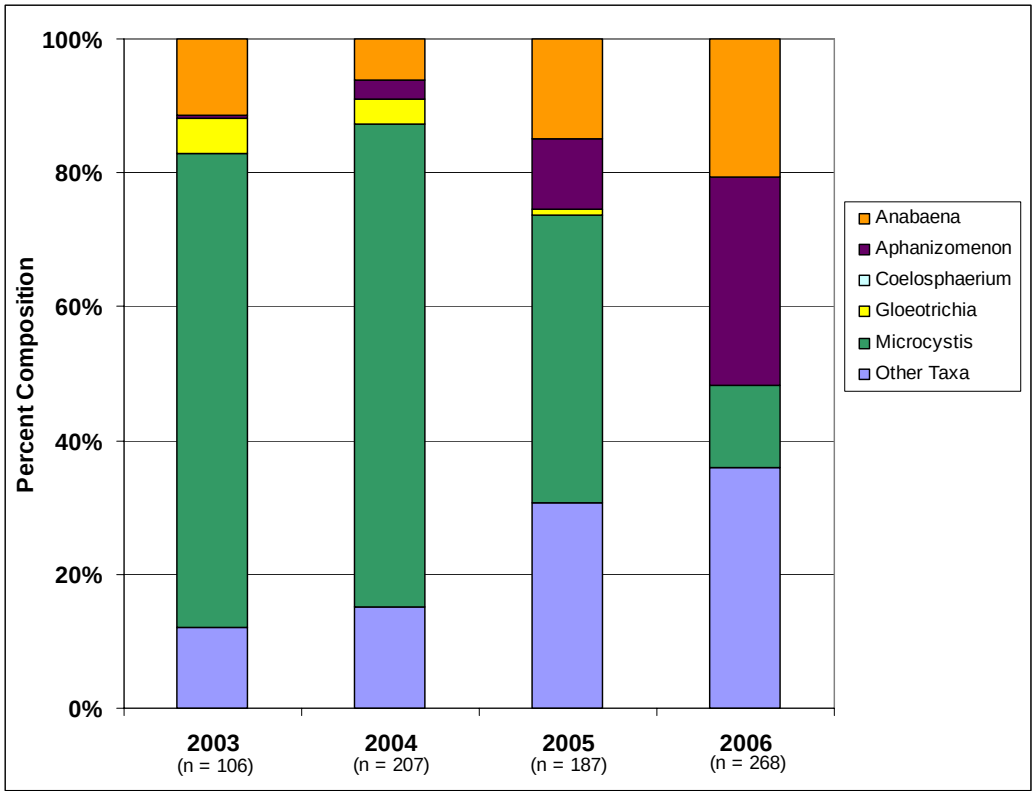


**Figure 10. Seasonal mean percent generic composition of phytoplankton in St. Albans Bay, 2003-2006.**

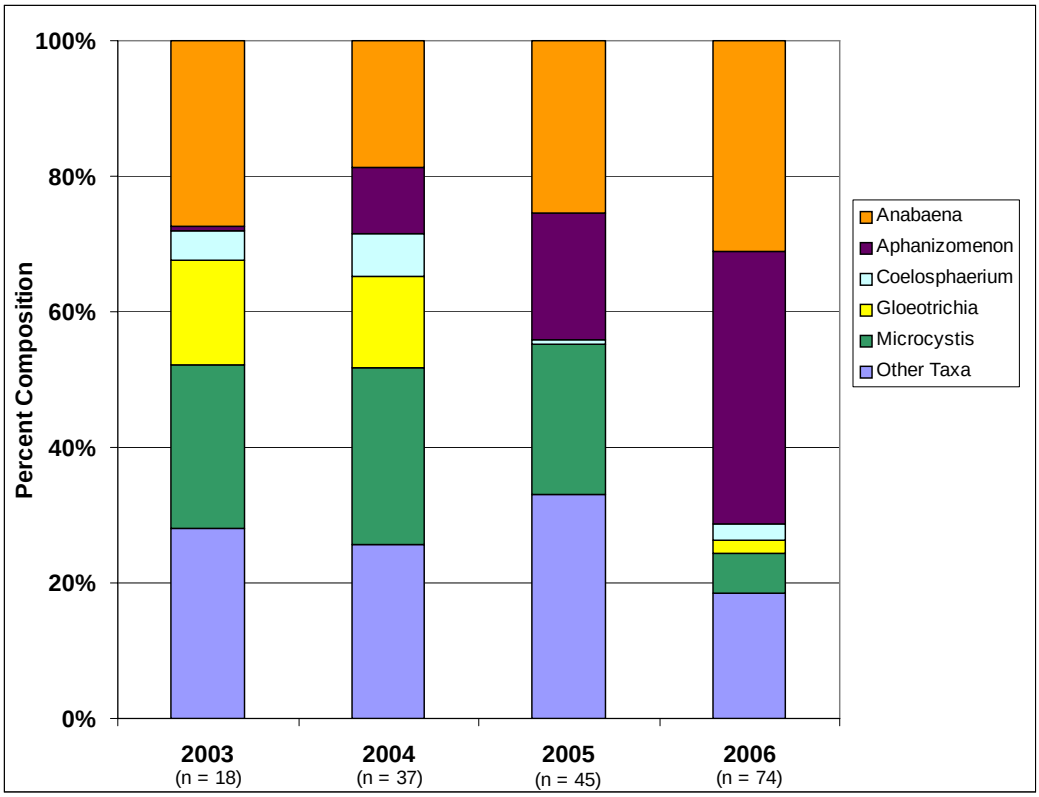
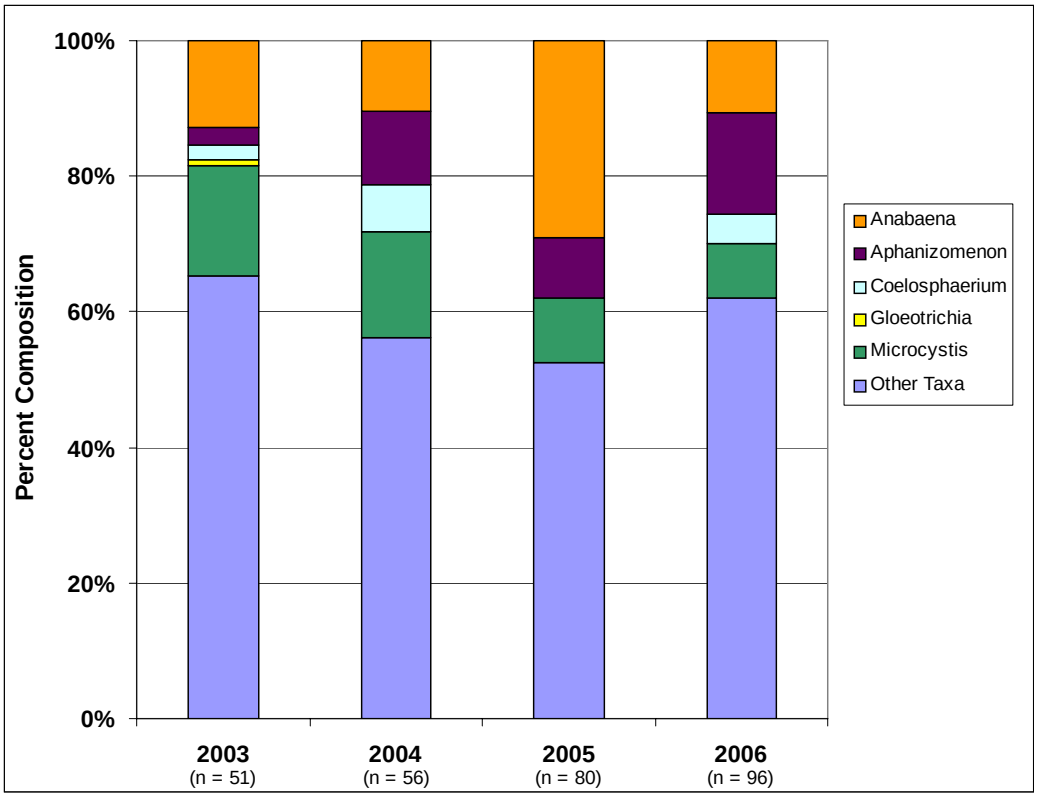



**Figure 11. Seasonal mean percent generic composition of phytoplankton in Burlington Bay, 2003-2006.**



Probably as a result of this change in composition, the median microcystin concentration measured in 2006 was slightly lower than 2004 and 2005 in both Missisquoi Bay and St. Albans Bay (Table 6). Changes in other areas of the lake are harder to evaluate because of the smaller sample sizes. Because the number of samples analyzed reflects the number of days when cell counts were at the Alert level, it is worth noting that despite the lower median concentration of microcystin in St. Albans Bay in 2006, the number of samples exceeding the density threshold actually doubled.

**Table 6. Microcystin concentrations (µg/L) in various lake segments, 2003 – 2006.**

| Lake Region | | 2003 | 2004 | 2005 | 2006 |
|---|---|---|---|---|---|
| Burlington Bay, Main Lake | Median | 0.02 | | 7.42 | 0.04 |
| | Range | ND - 0.12 | | 6.04 - 8.80 | 0.04 - 3.47 |
| | # of Samples | 9 | | 2 | 6 |
| Missisquoi Bay | Median | 0.20 | 0.88 | 0.74 | 0.64 |
| | Range | ND - 23.90 | ND – 6490 | ND - 22.10 | 0.03 - 21.29 |
| | # of Samples | 160 | 142 | 125 | 134 |
| Northeast Bays | Median | 0.05 | 0.51 | 0.08 | 0.27 |
| | Range | ND - 0.18 | ND - 17.50 | ND - 0.20 | 0.04 - 42.14 |
| | # of Samples | 6 | 8 | 7 | 14 |
| South Lake | Median | 0.53 | | 0.05 | |
| | Range | ND - 1.40 | | ND - 0.07 | |
| | # of Samples | 3 | | 3 | |
| St. Albans Bay | Median | 0.05 | 0.04 | 0.44 | 0.06 |
| | Range | ND - 0.46 | ND - 22.50 | 0.06 - 0.94 | 0.01 - 0.43 |
| | # of Samples | 16 | 22 | 15 | 34 |

The length of time that the bloom extended into the fall was also longer in 2006 than in previous years. There were cell counts at the Alert level in Missisquoi Bay and portions of the north lake well into November in 2006 – in most previous years, cell counts dropped below the Alert level before the end of October. This may, in part, reflect the warm weather that occurred in the fall of 2006.

In previous annual reports, we have discussed some of the environmental factors that can contribute to cyanobacteria dominance in the phytoplankton and favor one taxonomic group of cyanobacteria over another. The literature does suggest that high phosphorus concentrations and low N:P ratios are important contributors to cyanobacterial dominance (e.g, Smith 1983, Hyenstrand et al. 1998, Huszar and Caraco 1998, Downing et al. 2001, Scheffer 2005). Because both the *Anabaena* and *Microcystis* species are widely distributed and strongly associated with cyanotoxin challenges in lakes, there is comparatively more literature on these two taxa than *Aphanizominon.* A preliminary review of the literature focused specifically on *Aphanizomenon* provides conflicting evidence about which environmental factors are important in controlling its distribution. Light, temperature, available phosphorus, pH, and grazing have all been found to affect bloom formation and persistence (Healey and Hendzel 1976, Zevenboom et al. 1981,

Jacobsen 1994, De Nobel et al. 1998, Takano and Hino 2000, Tsujimura et al. 2001, Yamamoto and Nakahara 2005), but not always in the same way. Clearly there is a need for additional research into what factors are contributing to the shifts in relative abundance among the cyanobacteria taxa in Lake Champlain.

We have collected consistent data on both environmental characteristics and cyanobacteria abundance for the last four years (2003-2006). This large data set is now amenable to multivariate statistical analyses that might begin to provide some clues into what factors might be driving bloom dynamics in Lake Champlain. We will be exploring these associations in the coming year.

**Coordination**

The e-mail notification system again worked well in 2006 for rapid communication among the professional community. Our partnership with the Vermont Department of Health to post weekly information about bloom conditions on their website also continued to work well. In 2006, we updated the background information on blue-green algae, and provided additional detail in the distribution map.

Our volunteer citizen monitoring effort also continues to be highly successful. In 2006, our volunteer effort included 15 volunteers across all sections of the lake providing a good perspective on shoreline conditions lake-wide. In addition, through our partnership with the Lake Champlain Committee, we were able to catch several transitory bloom events along shorelines in New York and in the Islands.

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