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Lake Champlain Community Scientist Volunteer Network Communicates Critical Cyanobacteria Information to Region-wide Stakeholders

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Abstract: Lake Champlain is a treasured resource for recreation, tourism, and drinking water situated in New York, Vermont (U.S.), and Québec (Canada). Because its shores span two states and two countries, management strategies for the lake require strong cross-boundary partnerships and cooperation. In recent decades, increased prevalence of harmful cyanobacteria blooms has impacted public health and recreation. A lake-wide cyanobacteria monitoring program was established in 2001 with an emphasis on water sample collection and analysis to inform management strategies. In 2012, this program transitioned from laboratory-based analyses at a limited number of locations to a visual assessment protocol validated by water samples. This transition opened the door to more effective and widespread monitoring, communication, and inclusion of a greater number of monitoring locations and stakeholders. Today, through a unique partnership of community scientist volunteers, public beach managers, nonprofit organizations, and state and federal agencies, a comprehensive network of trained cyanobacteria monitors generates timely data on water quality conditions to relay critical public health information. The majority of these reports are provided by trained community scientist volunteers, strengthening the geographic coverage of the program and the environmental literacy of lake users. This program now trains hundreds of community scientists, documents thousands of water quality condition reports annually, and communicates cyanobacteria conditions to the public via an online Cyanobacteria Tracker map. In this article, we describe the evolution of this successful program, discuss key findings from analysis of these volunteer-collected data, and suggest how similar programs could be effectively developed in other regions.

Keywords: *harmful cyanobacteria blooms, community science, education and outreach*

Cyanobacteria are microscopic, photosynthetic bacteria that can form large visible accumulations ("blooms") when chemical and physical conditions are favorable for growth (Paerl and Otten 2013). Cyanobacteria blooms are unsightly, are a nuisance to recreation, and can pose a risk to humans and pets when cyanotoxins are produced (Boyer 2007; Stone and Bress 2007). Land management activities have caused accelerated eutrophication in freshwater bodies around the world (Bennett et al. 2001) and led to increases in the prevalence of harmful cyanobacteria blooms. In addition, climate change has created more favorable conditions in which cyanobacteria are expected to dominate phytoplankton communities because of physiological (e.g., more rapid growth) and physical (e.g. increased stratification) factors (Paerl and Huisman 2008; O'Neil et al. 2012). Monitoring programs for cyanobacteria vary among U.S. states and there are multiple state agencies and local non-government groups with jurisdictional responsibilities that differ geographically for recreational and drinking water uses (Hardy et al.

Research Implications

- A novel visual assessment protocol was developed to indicate public health risk due to cyanobacteria on Lake Champlain.
- Community scientist volunteers collect critical public health information that is rapidly shared with stakeholders and lake users.
- Laboratory analyses show that the visual assessment protocol is a useful and effective indicator for public health risk.
- This article shares program findings and recommended practices so this approach can be successfully implemented in other regions.

2021). Cyanobacteria monitoring programs for relatively large lakes are each unique because they typically span multiple jurisdictions and are guided by local community needs and resource constraints.

Lake Champlain is a treasured natural resource located between the U.S. states of New York and Vermont, and the Canadian province of Québec (Figure 1). The lake is 19 km wide at its widest point, up to 122 m deep, and nearly 200 km long with a relatively large watershed (21,325 km^2) that has a population of approximately 571,000. Lake Champlain has more than 800 km of shoreline. The lake is used extensively for recreation, fishing, and as a drinking water source. The bordering U.S. states and Québec each have individual harmful cyanobacteria bloom response plans that differ in their history and scope. Their intersection, and the collaboration among several key groups, is a story of science and community coming together to address a challenge to water quality and public recreation.

Some areas of Lake Champlain have experienced cyanobacteria blooms since at least the late 1960s (Smeltzer 2003), but harmful cyanobacteria blooms were not widely reported in the lake until recent decades (Watzin et al. 2003). Two dog deaths in 1999 and 2000 were attributed to cyanotoxin poisoning and caused concerns about human and animal health risks. This led to increased documentation of bloom events and expanded monitoring. Because of the heterogeneous chemical and physiographic conditions in Lake Champlain, cyanobacteria blooms are not evenly distributed. Frequent and relatively intense annual cyanobacteria blooms tend to occur in the shallow, eutrophic regions and bays of the northeast section of the lake, including Missisquoi and St. Albans Bays (Smeltzer et al. 2012; Isles et al. 2015). Because cyanobacteria bloom formation and persistence are strongly influenced by local environmental conditions like wind and currents, water temperature, and nutrient availability, bloom conditions on Lake Champlain can change quickly.

In 2001, lake management partners developed a monitoring program aimed at detecting and identifying cyanobacteria blooms and associated toxins (microcystin and anatoxin-a) at sites that might impact drinking water and recreation at public beaches (Watzin et al. 2002; 2003; Boyer 2007). The program began with geographically-focused surveys and laboratory analyses of samples collected by professional staff. In the past two decades, it has grown to a network of hundreds of community scientist volunteers who primarily use a visual assessment protocol to identify and report on cyanobacteria growth conditions. Diverse stakeholders have worked together to form a unique partnership aimed at understanding and reporting on this resource management challenge. The partnership has been highly effective for data collection and for educating the community on the important issue of cyanobacteria blooms.

In this paper, we will 1) tell the story of collaborative efforts on Lake Champlain to address a challenging resource management issue, 2) explain how the Lake Champlain Cyanobacteria Monitoring Program works to serve as a useful model for other lakes, and 3) share program findings, best practices, and broader perspectives on community scientist volunteer-based cyanobacteria monitoring.

Cyanobacteria Monitoring on Lake Champlain

Development of the Lake Champlain Cyanobacteria Monitoring Program from Laboratory-based Analyses to Visual Assessment Protocol

Cyanobacteria monitoring on Lake Champlain began in 2001 with a laboratory-based approach

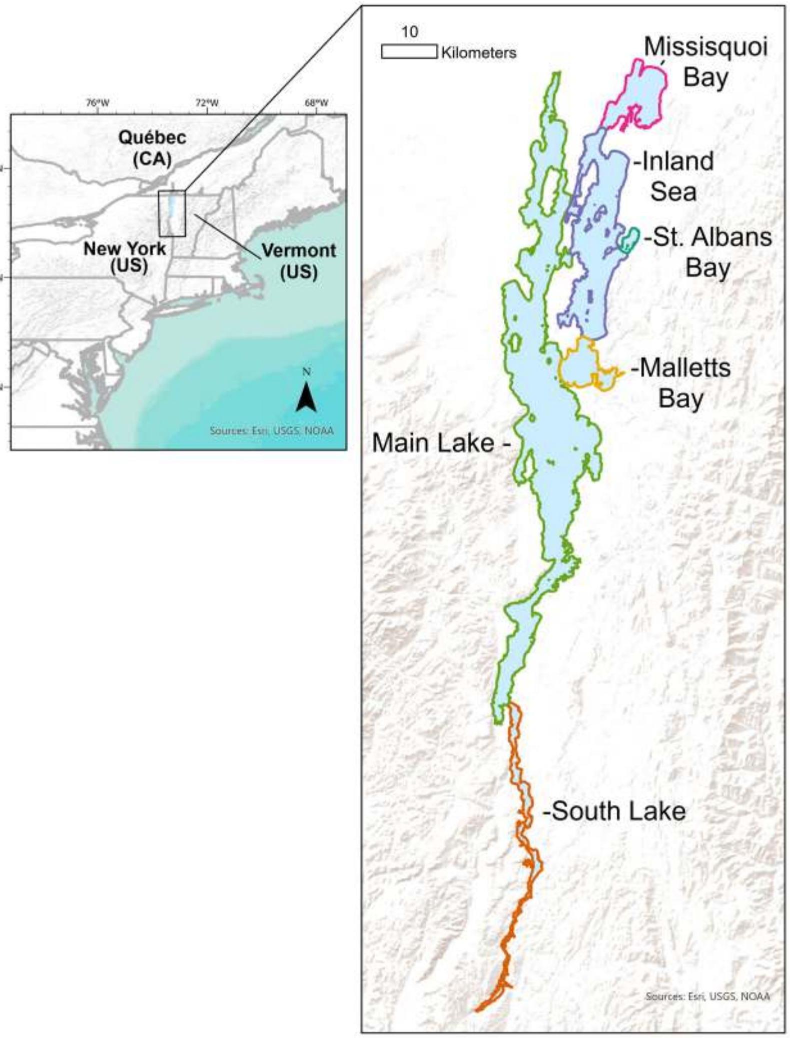

Figure 1. Map of Lake Champlain, with lake segments labeled and distinguished by color.

derived from the established World Health Organization (1999) alert framework (Watzin et al. 2006a). This initial monitoring was focused on off-shore locations that had a history of harmful cyanobacteria blooms (e.g., Missisquoi and St. Albans Bays), areas in the vicinity of public water intakes, and where recreational activities were concentrated (public beaches in Burlington, VT). Water samples were collected as grab samples or with a vertical plankton net tow and screened under a microscope for the presence of cyanobacteria. If present, the samples were evaluated for cyanobacteria cell density, and exceedance of a cyanobacteria cell density threshold triggered analysis for cyanotoxins. These analytical results were available within 24–48 hours of sample collection. Analysis for cell density and cyanotoxins would then continue at weekly intervals until cell density dropped below the threshold value (Watzin et al. 2002; 2003; 2004; 2005; 2006a; 2006b). Once this approach was established, the program collected samples from 30 - 50 routinely monitored stations each summer from 2004–2012 (Watzin et al. 2007; 2008; 2009; 2011a; 2011b).

As awareness of cyanobacteria-related public health and recreational impacts grew, there was an increase in inquiries about water quality conditions in unmonitored lake regions and near-shore recreational areas. Anecdotal accounts indicated that blooms in unmonitored locations may have impacted recreation, but data were not available to confirm these accounts for public health management. Funding availability limited the program's capacity to expand geographic coverage of laboratory-based sampling and analyses, and cyanobacteria conditions could change on shorter timescales than the 24–48-hour timescale required for laboratory analysis.

To fill this information gap, program partners developed a novel visual assessment protocol to provide rapid assessments of visible water quality characteristics. The protocol was intended to provide actionable information on public health risk due to cyanobacteria in Lake Champlain more quickly than the typical 24-hour laboratory turnaround; provide a simple basis for beach managers to close beaches based on observed conditions; and increase geographic monitoring coverage by recruiting and training community scientist volunteers. This visual assessment protocol was officially adopted by the program in 2012, and data quality was evaluated by comparing visual assessment reports with laboratory-based results for cyanobacteria and cyanotoxins. Both approaches were used simultaneously for several summers to ensure usefulness. As the value of the visual assessment protocol became evident, the collection of water samples at every station was replaced by quality assurance samples collected at a subset of locations.

Overview of the Lake Champlain Cyanobacteria Monitoring Program Today

The Lake Champlain Cyanobacteria Monitoring Program is now a unique partnership that leverages existing monitoring programs around the lake and works with stakeholders from across the watershed. This partnership includes the Lake Champlain Basin Program (LCBP), an organization that coordinates management of Lake Champlain; Departments of Environmental Conservation (DEC) and Departments of Health (DOH) in New York and Vermont; and the Lake Champlain Committee, a watershed-based nonprofit. In addition to these coordinating partners, several other stakeholders actively participate, including: state and municipal park staff throughout the watershed; State University of New York at Plattsburgh; University of Vermont; and hundreds of community scientists that volunteer their time to monitor cyanobacteria in Lake Champlain.

Financial support for the Lake Champlain Cyanobacteria Monitoring Program is through a successful public-private funding partnership. The program is largely supported with U.S. Environmental Protection Agency funding to the LCBP, which then provides annual grants to the Lake Champlain Committee to implement the community scientist volunteer program. Additional monitoring, technical, and outreach support is provided by Vermont and New York DEC, Vermont and New York DOH, the New York Office of Parks, Recreation, and Historic Preservation, and Vermont State Parks. The Cyanobacteria Tracker and cyanotoxin analyses are currently supported by the Vermont DOH through funding received from the U.S. Centers for Disease Control and Prevention grants.

LCBP support began with $25,000 to supplement a U.S. Center for Disease Control grant for the initial 2000 field season; two decades later, the funding level planned for the 2022 field season is over $100,000. This includes one full-time-equivalent and supports efforts to recruit, train, and assist volunteers, review reports, and conduct outreach. Currently, Vermont state personnel support for the program totals approximately one full-time-equivalent, in addition to two summer interns and laboratory staff that assist with laboratory analyses. In New York, multiple state personnel, totaling two full-time-equivalents, coordinate efforts to monitor and report cyanobacteria blooms state-wide, including coordination with the Lake Champlain Cyanobacteria Monitoring Program.

Annual funding support from the LCBP has been critical to develop and maintain this volunteer-based monitoring program, and the LCBP continues to support the program as a high priority in their annual budget. Hundreds of community scientist volunteers, municipal and state recreational staff, and drinking water facility operators are trained each year to use the visual assessment protocol to identify and report on the presence or absence of cyanobacteria blooms. Although state and provincial jurisdictions maintain their own cyanobacteria bloom response protocols and management plans beyond the Lake Champlain Cyanobacteria Monitoring Program, this lake-wide, trans-boundary program provides consistent data that is useful to inform state and provincial response protocols and management programs.

The visual assessment protocol classifies water quality conditions into three categories and communicates these to the public as "generally safe," "low alert," or "high alert (Table 1). Community scientist volunteers are trained on protocol methodology and then given a toolkit with gloves, water sampling jars, photo cards for documenting blooms, thermometers to measure water temperature, written monitoring protocols with detailed guidance on how to assess conditions, and links to online resources. If cyanobacteria are observed (category 1d, category 2, or category 3), three photographs are requested: a close-up view of the water, a broad view to evaluate the extent of the bloom, and a water sample in a clear jar in front of a photo card. Photos are taken after 20 minutes to allow for settling and for cyanobacteria to float toward the water surface (Figure 2).

To submit a visual assessment report, program staff and community scientist volunteers upload observations through an online form that includes date, time, location, water quality condition, water temperature, water surface conditions, and a free-form field for additional information. Each report is vetted by program staff and then displayed on the online Cyanobacteria Tracker map (Figure 3; VTDOH 2021). This online map immediately publishes all cyanobacteria monitoring data to lake users, who can check the recent reports before traveling to recreate on the lake, and compiles data for lake managers. Reports on the map are color-coded based on whether the most recent assessment (up to two weeks old) was "generally safe," "low alert," or "high alert," and a table provides all approved reports for the year. Figure 4 summarizes the flow of information from the field collection to public dissemination.

Community scientist volunteers are asked to make weekly observations in at least one location for the duration of the monitoring period (mid-June through early fall), regardless of cyanobacteria conditions. These "routine" observations are made on the same day each week between the times of 10:00 and 15:00, when cyanobacteria blooms, if present, are typically most visible. Routine reports are critical to assessing the prevalence of cyanobacteria over time because they are conducted at a regular interval at consistent locations, and document seasonal patterns of both the presence and absence of cyanobacteria blooms.

Community scientists also are asked to submit "supplemental" reports immediately if they observe a cyanobacteria bloom outside of their routine reporting day or time, and to report daily during an active bloom until it is no longer present. Supplemental reports are critical for immediate public health response, recreation management (e.g., beach closures), and for determining changes in the persistence of blooms over time.

Table 1. Cyanobacteria condition categories of the visual assessment protocol.

Category	Cyanobacteria observed	Water description	Photo requested	Status
1a	No	Clear	No	Generally safe
1b	No	Brown or turbid	No	Generally safe
1c	No	Other material present	No	Generally safe
1d	Yes	Few cyanobacteria present—recreation not impaired	Yes	Generally safe
2	Yes	Cyanobacteria present—less than bloom levels	Yes	Low alert
3	Yes	Cyanobacteria bloom in progress	Yes	High alert

Figure 2. Close-up (left), broad view (middle), and water sample (right) photographs of water quality conditions. These photos show "high alert" conditions in North Hero, Vermont. Photos by community scientist volunteer Jeff van den Noort.

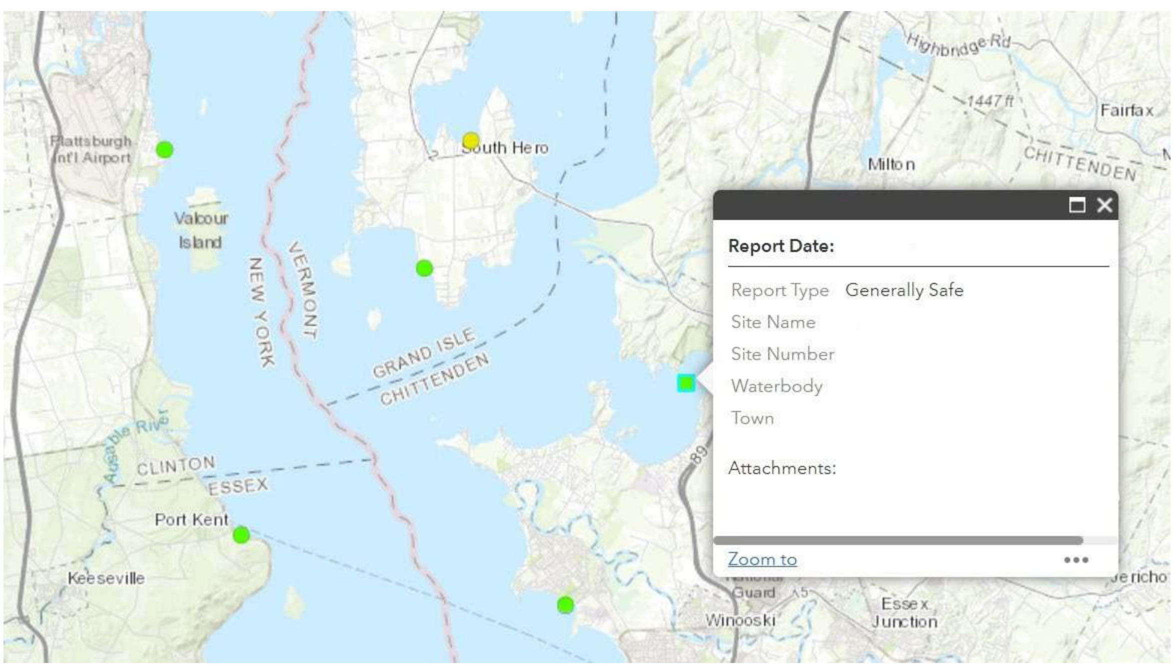

Figure 3. Screenshot of the Cyanobacteria Tracker map public interface. Sites with cyanobacteria monitoring reports are shown as colored circles on the map; green circles indicate "generally safe" conditions, yellow circles indicate "low alert" conditions, and red circles (not pictured) indicate "high alert" conditions. Selecting a site displays additional data, including photos taken to accompany the report. Visit the site here: https://www.healthvermont.gov/tracking/cyanobacteria-tracker.

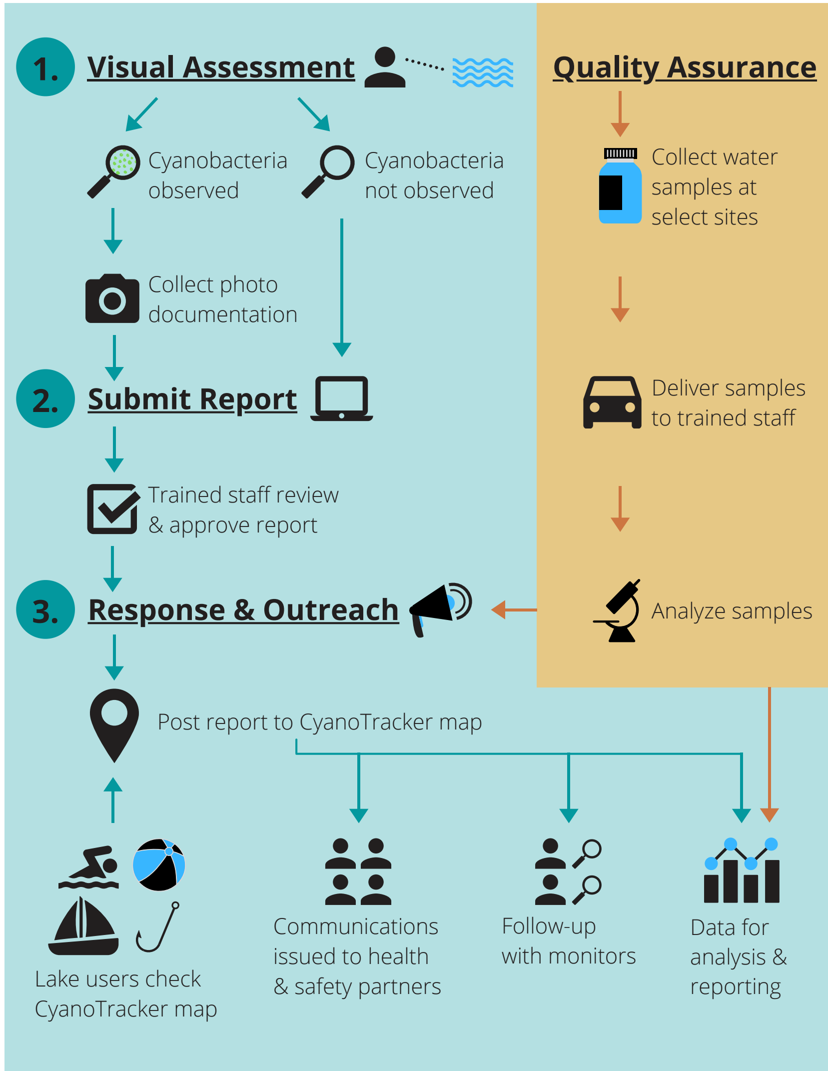

Figure 4. Summary of the flow of information in the Lake Champlain Cyanobacteria Monitoring Program.

Program Efficacy and Key Findings

The visual assessment protocol has greatly enhanced cyanobacteria monitoring on Lake Champlain by leveraging available funds to increase geographic coverage, and by focusing on the most important information for public health and recreation management. Before 2012, the annual average number of cyanobacteria monitoring reports ranged from 180 to 460; following the adoption of the visual protocol in the 2012–2020 time period, an annual average of 1,404 reports were received (Figure 5a). Lake-wide geographic coverage also grew from an annual average of 47 locations prior to 2012, to an annual average of 138 locations in 2012–2020 (Figure 5b). Interest in the program continues to grow; in 2019 and 2020, approximately 2,000 reports were received each year from over 170 unique locations on Lake Champlain.

Results from nine years of using the visual assessment protocol are consistent with historical monitoring trends (Smeltzer et al. 2012). Over 95% of the 9,555 routine visual assessments submitted since 2013 (when routine and supplemental reports began to be distinguished) reported "generally safe" conditions, indicating no visual accumulations of cyanobacteria (Figure 6). In contrast, 41% of supplemental reports, which are often collected in response to active cyanobacteria bloom conditions, were of low or high alert level during this time period. This contrast highlights the importance of collecting both routine and supplemental reports;

while supplemental reports are critical for short-term public health response and information on bloom persistence, routine reports document the presence or absence of cyanobacteria blooms with regular frequency in order to capture both types of information and assess longer-term trends.

Grouping report data by lake region shows that cyanobacteria growth greatly varies geographically, and that some areas of the lake are more susceptible to cyanobacteria blooms during the monitoring season than others (Figure 7). For example, 98% of reports from Main Lake locations since 2013 indicated "generally safe" conditions, while that figure is 77% and 79% for St. Albans and Missisquoi Bays, respectively. These differences are due to distinct physiographic and biogeochemical characteristics and heterogeneous nutrient availability (Isles et al. 2015) and have important implications for lake management.

To ensure that the visual assessment protocol effectively indicates public health risk, a subset of visual assessment reports is compared to laboratory-based analyses of cyanobacteria taxonomy, cyanobacteria cell density, and cyanotoxin concentrations for concurrent and co-located water samples at Vermont monitoring locations (Shambaugh et al. 2018; 2019; 2020). Favorable comparisons should show that reports in different visual assessment protocol categories generally differentiate between low and high cyanobacteria cell densities, and that conditions described as category 1 are indeed "generally safe," with no cyanotoxin concentrations measured above a public safety threshold value for recreation.

Results of 371 quality assurance comparisons during the 2017–2019 time period show that the visual assessment protocol is a useful and effective indicator of public health risk (Figure 8). Median cyanobacteria cell densities for samples associated with visual assessment report categories 1a–c, 1d, 2, and 3 each differed by at least one order of magnitude and were each significantly different from the others by the non-parametric Kruskal-Wallis test ($p < 0.0001$). During this time period, no laboratory analyses for microcystin or anatoxin exceeded the lowest public safety threshold concentration values for recreation within Lake

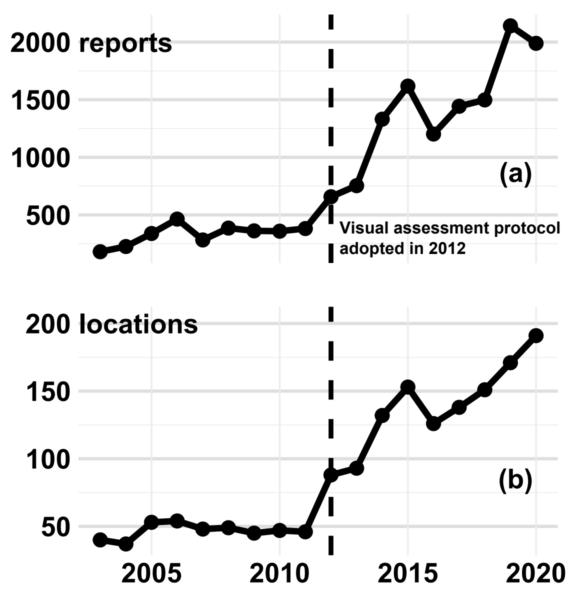

Figure 5. The number of (a) cyanobacteria monitoring reports received and (b) the number of locations monitored on Lake Champlain from 2003–2020. The dashed vertical line indicated the adoption of the visual assessment protocol in 2012, which facilitated an increase in the number of sites monitored and reports received. These plots include routine and supplemental reports.

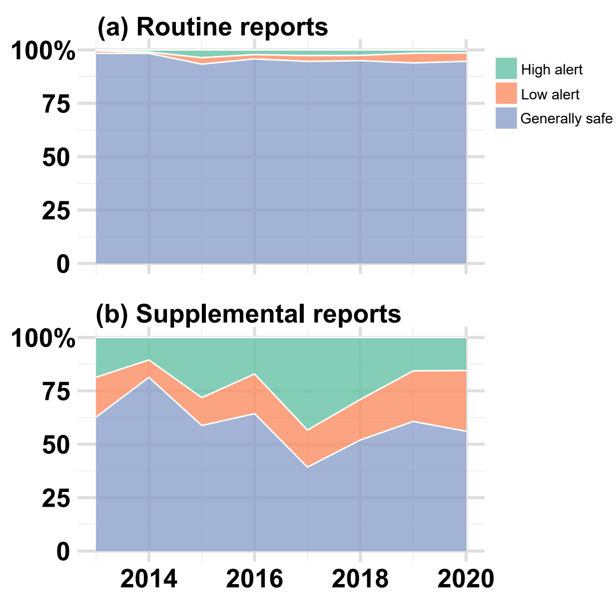

Figure 6. Percentages of (a) routine and (b) supplemental cyanobacteria monitoring reports received and vetted from 2013–2020, colored by status ("generally safe," "low alert," or "high alert"). Supplemental reports are biased toward alert statuses because they often are submitted specifically in response to an active cyanobacteria bloom.

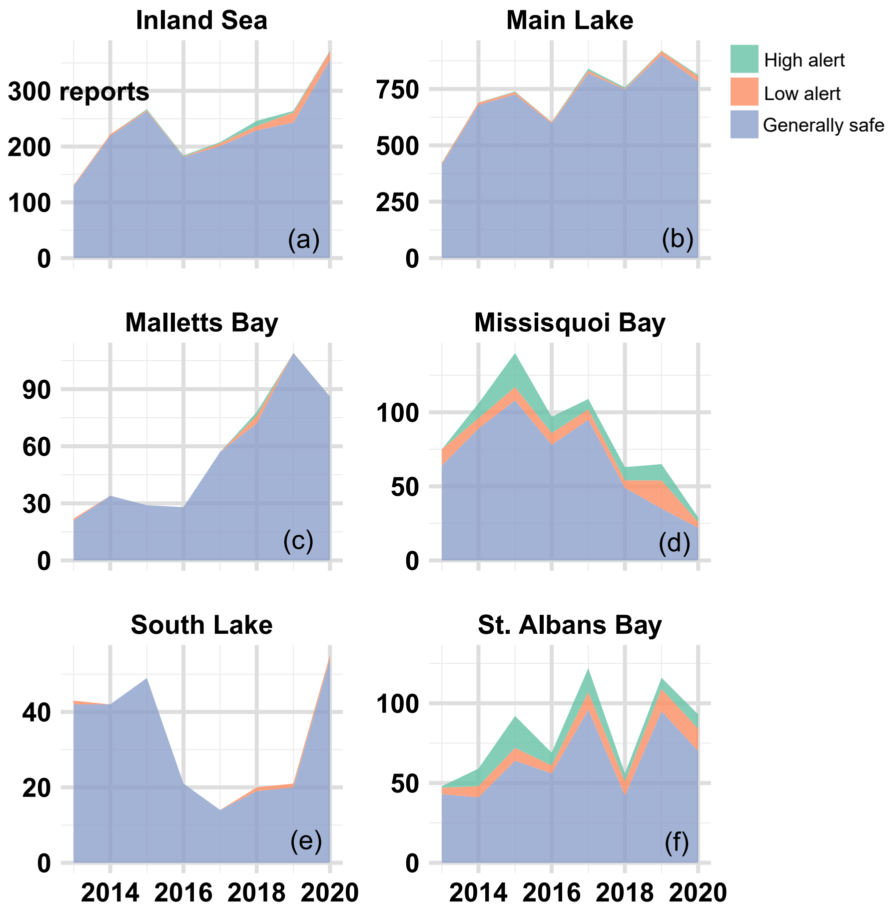

Figure 7. Number of routine cyanobacteria monitoring reports received by lake segment from 2013–2020, colored by status ("generally safe," "low alert," or "high alert"). Figure 1 shows a map of region locations.

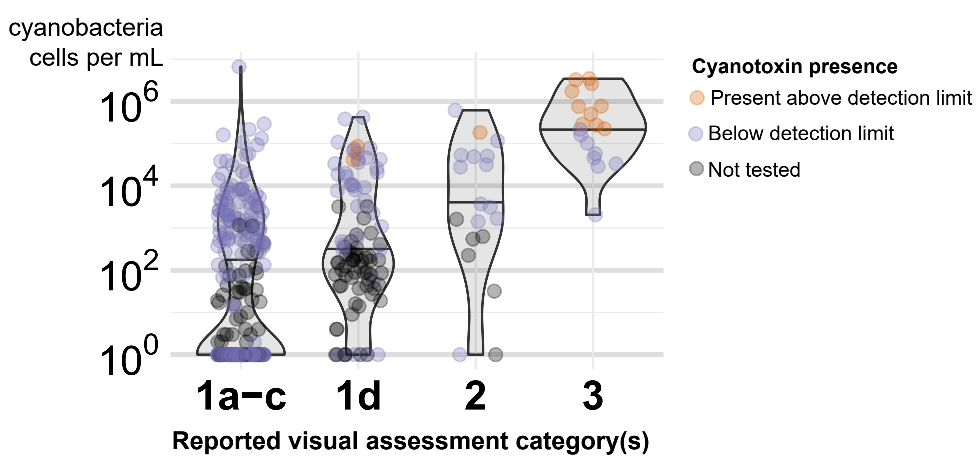

Figure 8. Laboratory-based quality assurance checks of cyanobacteria cell densities and cyanotoxin concentrations compared to categories reported using the visual assessment protocol during from 2017-2019. Violin plots are shaped by cyanobacteria cell density distribution, and medians are indicated with horizontal lines. Points are colored by analytical results for microcystin and anatoxin cyanotoxins: at least one cyanotoxin present above the detection limit (orange), neither cyanotoxin present above detection limits (purple), or not tested for cyanotoxins (black). Analytical detection limits are 0.16 µg L^{-1} and 0.5 µg L^{-1} for microcystin and anatoxin, respectively. Of these 371 quality checks, 103 had zero cyanobacteria cells per mL and were category 1a, b, or c. To plot on a log scale, cyanobacteria cell densities were transformed by adding 1 to each value.

Champlain management jurisdictions (6 μg L^{-1} and 10 μg L^{-1}, respectively). Importantly, all cyanotoxin detections for samples associated with visual assessment categories 1a-d ("generally safe") were well below these threshold values. Further, different visual conditions generally indicated a different likelihood of cyanotoxin detection. For example, samples associated with 99.1% of visual assessment reports described as category 1 ("generally safe") had no detectable cyanotoxins present. Although sample sizes differ, 47.4% of samples associated with category 3 reports ("high alert") had no detectable cyanotoxins present (n = 19).

Best Practices and Broader Perspectives

Practice Recommendations for Developing a Community Scientist-based Program

Our long experience running a community scientist-based monitoring program has allowed us to identify and share these essential best practices for others who may consider developing a similar program:

1) Communicate regularly to provide ongoing training and support. Weekly communications during the monitoring season and at several times throughout the year help keep trained community scientists engaged and informed, and contribute toward maintaining the target frequency and quality of reports. Weekly emails include reminders on protocols, links to report instructions, a compilation of weekly reporting results, photographs and descriptions of cyanobacteria, and contact information (view an example of a weekly email at https://mailchi.mp/lakechamplaincommittee.org/week-20-cyanobacteria-monitoring-report-community?e=abafd0bc76). These emails also profile exemplary community scientists, feature different lake phenomena each week, and reinforce participants' valuable contributions to the program.

2) Budget time and resources for frequent volunteer support. It is helpful for program staff to frequently follow up with monitors, whether it is to answer questions about water conditions they observe, clarify an element of their online report form submittal, or troubleshoot technical issues. Community scientists have a wide range of experience with technology and some need additional assistance to submit reports. We recommend giving community scientists step-by-step guidance on how to fill out online report forms, label photos on a smartphone, and fulfill other program reporting requirements. We also suggest creating a range of education and outreach materials that target different learning styles, including visual, auditory, and verbal.

3) Strike a balance between public and private monitoring sites. Although data from high-traffic public areas (e.g., beaches, boat launches, and parks) are most useful for the general public, backyard monitoring also provides valuable information and the opportunity for more volunteers to engage in water quality issues.

4) Provide training to improve the quality of photographic documentation. Submitted photos are valuable and effective at confirming reported water conditions and complementing education and outreach efforts (Figure 2). In addition, posting report photos on an online map (e.g., as with the Lake Champlain Cyanobacteria Tracker) provides a learning opportunity for anyone who checks on water quality conditions. Photos of water quality conditions can be challenging to capture, especially when cyanobacteria are visible at low densities (e.g., category 1d). Factors that influence the quality of photos include sun glare, low light, camera focus, and image resolution. Specific training at the onset of the program on how to take high quality photographs can prevent data quality issues later in the season. Community scientist volunteers should be encouraged to provide narrative descriptions of their photos, such as approximate bloom extent along the shore and into the water; this approach creates a more efficient report review process for trained staff.

5) Let community scientist volunteers know they are valued. Because the community scientist volunteers are key to the success of the monitoring program, we recommend thanking volunteers early and often in all communications. Constant feedback is incredibly valuable, and sharing volunteers' monitoring results weekly by personalized email communication affirms the value of their contributions. Our experience suggests that maintaining personal contact and emphasizing the importance of volunteers in trainings, direct communications, and social media throughout the year improves participation and increases volunteer retention.

6) Encourage communication on all water-related phenomena and unusual conditions. It is helpful to encourage monitors to share unusual observations with program staff and submit a water sample if they see something unfamiliar. This approach assists community scientists with cyanobacteria identification and fosters environmental literacy, especially when these findings are shared with all program participants. In recent years, community scientists have encountered cyanobacteria in Lake Champlain that are challenging to evaluate solely by visual observation. For example, the benthic cyanobacterium *Scytonema* sp. has been observed several times in parts of Lake Champlain, where it can form surface accumulations that may appear more similar to filamentous green algae than other cyanobacteria. In addition, the colonial cyanobacterium *Gloeotrichia* sp. appeared at several Lake Champlain locations in 2017 as small surface scums that appear more similar to pollen than other cyanobacteria.

7) Encourage reporting beyond the peak recreation season. We recommend targeting personnel time and resources to maintain report frequency and quality after the close of the peak recreational season. This is a time when cyanobacteria blooms and associated public health risks may still occur even though many seasonal community scientist volunteers have left summer residences, volunteer interest and dedication can wane, and seasonal parks may be unstaffed but still accessible to the public.

The season when cyanobacteria are active on Lake Champlain is starting earlier and ending later than in the past. Based on projected impacts of climate change in the Lake Champlain watershed, including increased temperatures (up to 0.49°C decade^{-1}) and days over 32.2°C (90°F) (Guilbert et al. 2014), cyanobacteria blooms may increase in intensity and persistence in the future. Climate change has already altered ecological conditions in the northeastern U.S. and southern Canada, and different aspects of climate change favor cyanobacteria growth (Paerl and Huisman 2008; Harke et al. 2016) and make mitigation and control efforts more challenging to implement (Paerl et al. 2020). Cyanobacteria monitoring programs in regions with a similar outlook will need to dedicate adequate resources throughout a longer growing season in order to protect public health and inform effective lake management.

Conclusion

The success of this program demonstrates that visual assessments conducted by trained community scientist volunteers are a viable way to document and disseminate critical public health information. Our initial laboratory-based approach was a valuable first step in understanding cyanobacteria blooms in Lake Champlain, and the development of the visual assessment protocol has allowed the program to greatly expand geographic coverage and rapidly deliver the most important information to stakeholders. This simple method creates opportunities to share water quality conditions in a way that resonates with the public and generates actionable information to immediately protect public health. The combination of our visual tool with quality assurance sampling for cyanobacteria densities and cyanotoxin concentrations has allowed our collaborative team to monitor a very large geographic area with credibility and public engagement.

We are currently developing methods to compare cyanobacteria seasons to historic data and incorporate satellite-based measurements and model outputs (Schaeffer et al. 2018). However, because monitoring locations and times are dependent on volunteer locations and schedules, they can vary from year to year, which confounds statistical analyses on a lake-wide or even site-by-site basis. This is one limitation of the community-scientist based program, compared to a traditional research program that may have limited geographic coverage but a more consistent sampling regime.

Lake Champlain cyanobacteria monitoring partners continue to seek out opportunities that will enhance and improve the monitoring program. For example, the visual assessment protocol guidance for the Lake Champlain program is heavily focused on the planktonic (floating) cyanobacteria. We are working to improve guidance materials to better incorporate information on benthic (bottom dwelling) cyanobacteria as well. In addition, collaborations are underway to evaluate the combination of visual assessments with dipstick cyanotoxin testing as a way to quickly reopen a beach with confidence that cyanotoxin concentrations are below the public safety threshold values for recreation.

The visual assessment protocol is now used to evaluate smaller lakes throughout Vermont. Since 2012, New York DEC has evaluated cyanobacteria bloom reports from lakes in other parts of the state using a combination of visual evaluation and analytical results to determine a bloom status designation. In 2019, New York DEC initiated the New York Harmful Algal Bloom System (NYHABS), which is similar to the Cyanobacteria Tracker map. Most states around the U.S. accept photos as documentation of potential cyanobacteria blooms and, with training for community scientist volunteers and a reasonable level of sustained funding, could build similar cyanobacteria data collection and outreach tools.

The Lake Champlain Cyanobacteria Monitoring Program has built a common understanding of cyanobacteria blooms around Lake Champlain that can be understood by all lake users and used by all jurisdictions following their respective response plans. As pressures on water quality continue and climate change exacerbates potential cyanobacteria bloom conditions, we expect that the future of cyanobacteria monitoring will be driven by lake users' enthusiasm to adapt and steward their resource.

Our community scientist-based monitoring program has had a positive impact well beyond expanding the number of people who are collecting water quality data. Each person who attends a training becomes familiar with cyanobacteria, associated potential health risks, the water quality conditions that increase the likelihood of blooms, and individual actions they can take to improve water quality. Community scientist volunteer training gives each participant a way to be actively involved with their watershed or lake. By assessing water conditions at a local site on a routine basis week after week, community scientist volunteers deepen their connection to nature, and actively participate in stewardship of their natural resources.

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