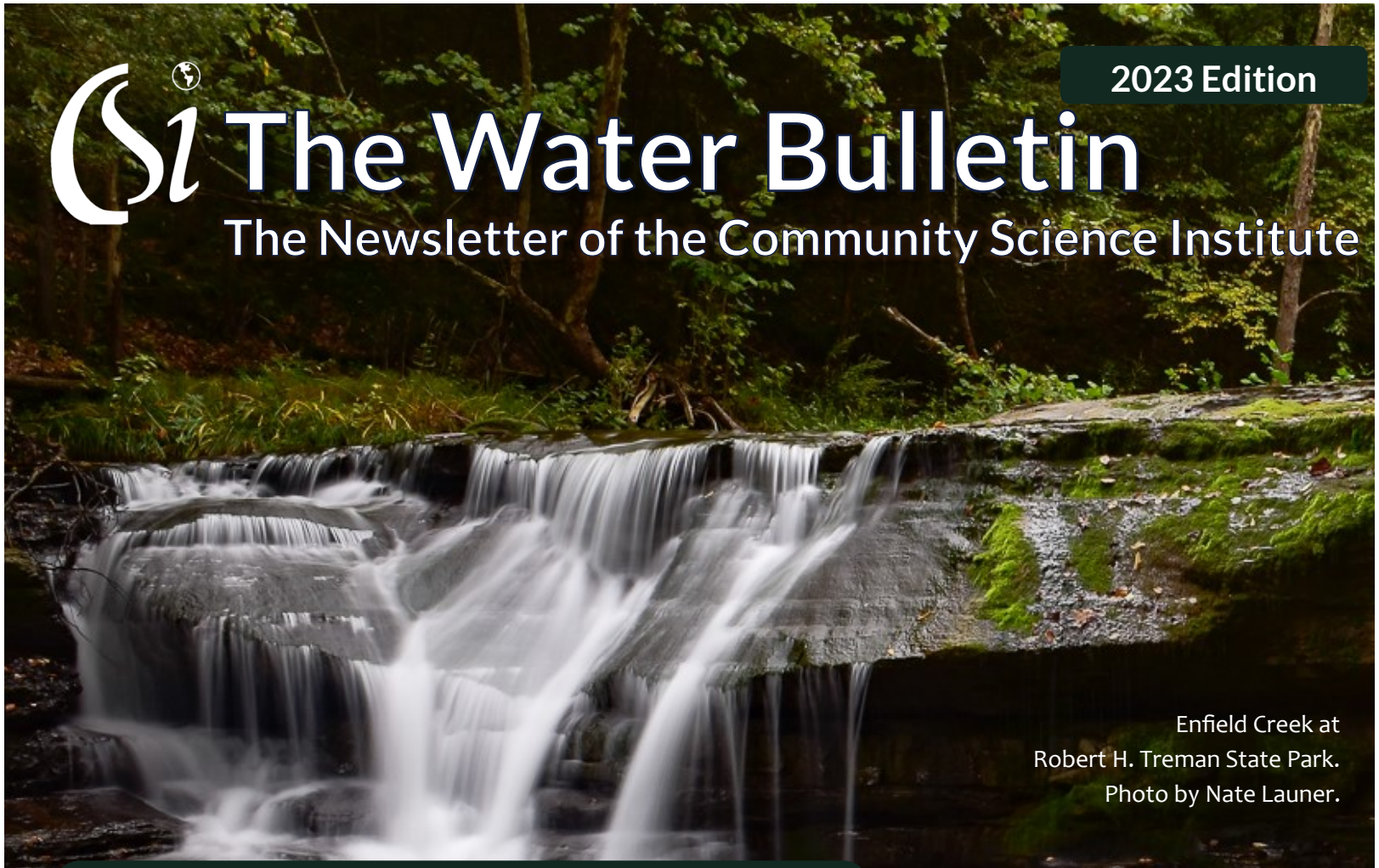
2023 Edition

The Water Bulletin

The Newsletter of the Community Science Institute



Enfield Creek at Robert H. Treman State Park. Photo by Nate Launer.

What Does it Mean to be a "Certified" Lab?

Community Science Institute (CSI) operates a "certified lab," but what does that really mean? And why bother with lab certification? In this article, we'll answer these two questions and give a brief history about the organization that certifies our lab. First, let's consider the importance of data — by the end of this article, I hope to convey more specifically the importance of "data of known and documented quality."[1]

Most environmental compliance and clean-up decisions are made based on data. The quality of the data determines the effectiveness of these decisions, so regulatory agencies need to have a way to be certain that the data they use are of high quality. Laboratories may opt into an accreditation program to assure the overall reliability of their data, such that data can be used for regulatory purposes. In New York State (NYS), the enforcement of certain laws and regulations require that environmental testing be done by an accredited lab.[2] Such state water quality regulations implement federal requirements, namely those from the Clean Water Act (CWA) and the Safe Drinking Water Act (SDWA). Back in the 1970s, the CWA and SDWA granted the Environmental Protection Agency (EPA) the authority to implement controls on the release of pollutants into public drinking water supplies and navigable waters.[3,4] This set the stage for compliance monitoring and the need for testing.

Inside this Edition

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The EPA and its regulatory partners carry out environmental compliance activities via 44 different programs across the country.[5] Given the extent of these activities, it's reasonable to set standards for the quality of the data that reaches enforcement agencies. Standardizing data quality should include how the data are produced. In the laboratory, what we test for is termed an analyte (e.g., chloride, nitrate, and *E. coli*) and how we test it is called a method. It's tempting to assume that two labs testing the same sample for the same analyte using the same method will produce comparable results, but how can regulators be sure? If both labs are certified by the same national accreditation program, that program evaluates whether each lab is meeting quality assurance and performance criteria to say that the results are comparable. So, how did such a program come about?

For the EPA to do its job, it had to approve testing procedures for water and encourage laboratories to use them. In 1978, the EPA started a certification program for drinking water laboratories with states acting as implementation partners.[6] Following EPA guidance, many states expanded this certification program to include other types of testing (e.g., soil and solid hazardous waste). By the 1980s, multiple state programs had created divergent accreditation requirements. The commercial laboratory community and other stakeholders advocated for greater consistency across the different accreditation programs. To acknowledge this problem, the EPA recommended to Congress that the government explore the feasibility of a national laboratory accreditation program.[6]

In light of the EPA's suggestion, the first framework for an environmental testing accreditation program was developed in the 1990s by a group of state and federal representatives.[6] Shortly after, an organization called the National Environmental Laboratory Accreditation Conference (NELAC) was established to set standard practices for a unified accreditation program referred to as the National Environmental Laboratory Accreditation Program (NELAP).[6] From the start, the national laboratory accreditation effort lacked strong support from Congress: it relied on voluntary participation of states to implement the program, and efforts did not have secure year-to-year federal funding. For over a decade, the EPA fostered NELAC with the hope that it would eventually be self-sufficient.[6]

In 2006, NELAC merged with a voluntary consensus standard organization, the Institute for National Environmental Laboratory Accreditation (INELA), to form The NELAC Institute (TNI).[6] Like CSI, TNI is a 501(c)3 nonprofit organization. Its mission is to "foster the generation of environmental data of known and documented quality through an open, inclusive, and transparent process that is responsive to the needs of the community."[1]

To recap, the structure for national accreditation is as follows: The NELAC Institute (TNI) guides the National Environmental Laboratory Accreditation Program (NELAP).[6] States may apply to NELAP to become an accreditation body and may select to operate an accreditation program which covers all of the EPA regulatory programs or just one — typically, chemistry and microbiology under the drinking water program. In New York State, the Environmental Laboratory Approval Program (ELAP) serves as the accreditation body for NELAP and administers certification to environmental laboratories such as CSI.

So, bottom line, what is CSI doing that is not required of an uncertified lab? Let's talk more explicitly about what is involved in producing "data of known and documented quality" according to ELAP.[1] The following four points help to convey what is expected of a certified lab:

1) Proficiency testing (PTs): ELAP certified labs demonstrate proficiency for all certified tests by achieving passing scores in PT studies. These studies happen year-round and consist of samples, corresponding to each certified test, prepared by accredited providers that must be incorporated into the lab's regular workflow. PT results are reported to ELAP; if a PT result falls outside acceptance limits, ELAP may remove testing for the failed analyte(s) from the lab's certification.

2) Quality system: Certified labs use a quality system that includes quality assurance (QA) and quality control (QC). QA is a program that specifies measures used to produce defensible data. It includes proactive measures incorporated into lab procedures and recordkeeping (e.g. establishing standard procedures for each step of the lab

testing process). Quality control (QC) is applied more narrowly. These are reactive measures that take place during lab activities to detect errors (e.g. calibration check to verify an instrument is working properly during a test). ELAP uses a ~55 page checklist to assess whether a lab's quality system meets their requirements.

3) Approval of test methods: Only certain test methods are approved by ELAP and can be used to conduct testing for a particular analyte. In water testing, test methods are referred to by a code that cites a specific reference, e.g., SM 4500-Cl- D is a method for testing chloride that's found in *Standard Methods for the Examination of Water and Wastewater*. CSI must not only acquire the equipment and supplies to test for an analyte following a certain method, but we must draft a standard operating procedure (SOP) and demonstrate initial capability in said test before getting approval from ELAP to include that test on our certification.

4) On-site audits: CSI lab receives an external, multi-day audit by ELAP assessors. The audit checks overall compliance with ELAP standards over the past two years. Hundreds of pages of procedures are sent to ELAP for review before the audit begins. During the audit, assessors dig through our records, including reagent preparation logs, reports sent to clients, test performance records, etc. Assessors will also observe and question staff as they perform the day's work during the audit. Once the audit is complete, the lab and ELAP carry on months of correspondence. The lab might relay hundreds of pages of evidence and documents to show improvement in areas flagged for minor or major issues during the audit.

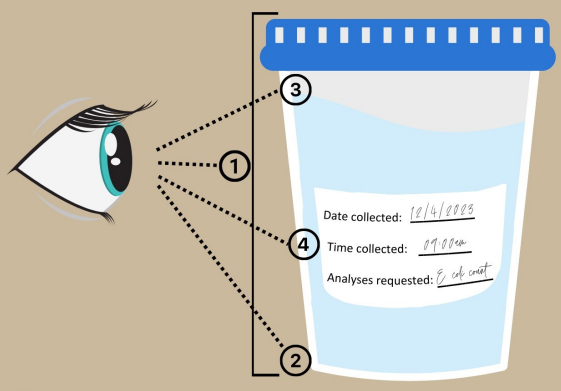
The above points are just some of the safeguards required by an ELAP-certified lab to protect the quality of the data. Getting ELAP certified means data can be used for regulatory purposes because it meets the requirements of TNI, whose mission is to produce data of known and documented quality through a national lab accreditation program. In the next section, we will talk about what happens to a sample when it enters the lab as a way of presenting the necessary 'habits' for a lab and its staff to maintain certification.

The Four Steps of a Sample's Journey

Step 1: Sample Intake

The journey of a sample's movements through the lab begins with sample intake. When a water sample arrives at our door, CSI staff inspect the sample and its associated chain of custody paperwork to ensure:

A. The sample was collected in the correct container: mason jars, pop bottles, and cupped hands are not acceptable vessels (1). Testing depends on getting a representative sample, so we need to start out with a clean container that meets the requirements of the requested test(s). CSI staff equip volunteers and clients with the appropriate bottles prior to sample collection. In addition to checking that the sample has been collected in the correct container, staff also inspect the container to make sure that it is not damaged (2) or defective and that it has been filled to the appropriate volume (3).



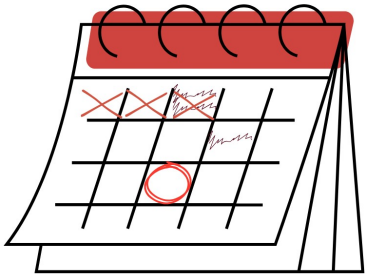
1. Correct sample container for the analysis requested
2. No cracks
3. Filled to the top
4. Collected within the hold time

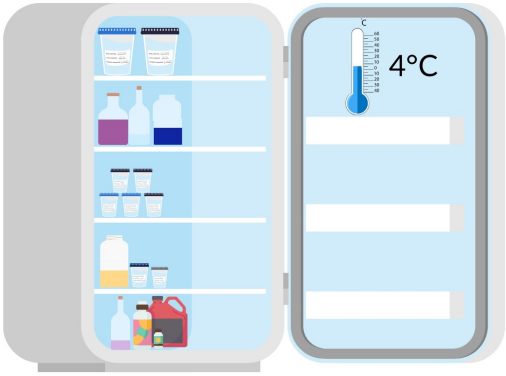
B. The sample was collected within the hold time (4) for the requested test (see Box 1): our lab's most popular drinking water test, the basic potability test for total coliform and *E. coli*, requires samples to be tested within 30 hours of collection.

C. The chain of custody is complete: the chain of custody document includes relevant information for the sample including the name of the sample collector, date and time of sampling, sampling location, etc. Importantly, it serves as a record of where the sample has been.

These features ultimately matter to the data user and the data's intended purpose. In the battle to produce high quality data, the front desk is our first line of defense.

Step 2: Sample Preservation and Storage





Once the sample has passed initial inspection (Sample Intake), we must incorporate the test (or tests) required for that sample into our analysis schedule. For our Synoptic Stream and Lake Monitoring Program, we usually analyze samples for 10-12 different analytes. Each analyte has different requirements for how they must be treated, including their maximum hold time and preservation requirements (See Box 1).

In some ways, these staggered deadlines translate to a fairly straightforward process of triage: we test analytes with earlier deadlines right away, while analytes with longer deadlines can be put off until we have the time or need more fridge space for incoming samples. The more samples CSI's lab receives, the more complicated triage becomes.

CSI's Synoptic Stream and Lake Monitoring Program includes over a dozen different monitoring groups. Monitoring "events" (the date on which each group collects samples) occur at distinct times, but most monitoring events occur between April and November. On top of this, CSI's laboratory processes samples on a rolling basis from the general public, who often need water tests for home sales or in response to drinking water concerns. General public water samples tend to occur more commonly during the summer alongside our monitoring season, when we might average one event per week for months on end.

In a 5-day period during CSI's peak monitoring season:

- 220 samples were accepted
- 81 Chain of Custody documents were completed
- 357 tests were performed on the samples
- 289 data points were generated for our public water quality database

At that time of year, the longer deadlines from older sets begin to fall around shorter deadlines from newer sets. Managing these deadlines requires a delicate balancing act. This balancing act might look chaotic from the outside, but it is actually quite organized. We manage this dance (mostly) without tripping, but it requires a lot of planning in the off season to be ready to stay on top of things.

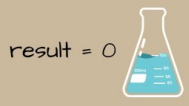
Box 1: Defining the Common Laboratory Terms "Hold Time" and "Preservation"

Hold Time: An analyte's "hold time" is how long a sample can be stored before analysis without risk of significant change in the analyte. Some analytes, including turbidity, soluble reactive phosphorus, and *E. coli*, can change quickly even in a refrigerator. These analytes need to be measured either within the first 24 or 48 hours of the samples being collected. Other analytes, such as chloride or specific conductance, are more stable. These analytes might have a hold time as long as four weeks. Many nutrients, such as total phosphorus or total nitrogen, have a hold time of four weeks, **as long as they are "preserved"** within 24 or 48 hours of collection.

Preservation: "Preserving" a sample prevents microbiological activity from changing the concentration of the analyte. The most common analytes we test for that require preservation are nutrients. Any microbes in the sample can consume nutrients and change their concentration. Preservation is a process that inhibits life (i.e. microbiological activity) without interfering with the analyte being tested. Adding concentrated sulfuric acid to the sample will inhibit life, or disinfect, by reducing the pH of the sample to below 2 (making it highly acidic). This kills any bacteria present in the sample. Sulfuric acid is effective because it is a strong acid that does not interfere with nutrient analysis. Preserving the sample in this way allows us to extend the hold time from 48 hours to 4 weeks. If the sample will also be tested for analytes that can be destroyed by acid, such as alkalinity, only a small portion of the sample is preserved with sulfuric acid. This portion is called a "subsample."

Step 3: Sample Testing

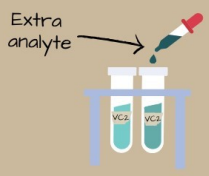
Once the scheduled time arrives, it's time to get down to the testing. This is where the quality control measures from the quality system come into play. Each analytical batch includes several quality control (QC) measures to ensure the results match our standards. These QC measures are designed to demonstrate that a certain standard of precision and accuracy is met in each analytical batch. They also serve to anticipate the most common "What about…?" or "How do you know…?" questions that others may ask when assessing our data. The QC measures used vary by analyte, but there are a few measures that apply to almost every assay, such as:



Blank (distilled water)
A blank sample is tested to show that there is no contamination from the equipment, the water used for rinsing, or the reagents, standards, and dilutions used in analysis.

Standard
A standard is a prepared stock of known concentration which is analyzed alongside samples to show that results are accurate and that the method results are not biased high or low.

Duplicate
A duplicate is a random sample that is analyzed twice to show that results are consistent and precise.



Spike
A spike involves analyzing a sample a second time but adding a known amount of the analyte. The measured result for the spiked sample should be a known amount higher than the unspiked sample. If the spike results are significantly high or low, it can indicate something else in the sample is interfering with and biasing the analysis.

Analysts are responsible for ensuring that each of these QC measures pass. If any QC measure fails, analysts investigate whether there is a problem with equipment, reagents (chemicals in tests), or our technique. Thanks to their experience, analysts develop precise expectations for how a test run should go and keep an eye out for any deviation from those expectations. Even small deviations can indicate mistakes or problems with equipment or reagents. For example, an analyst may notice they are using the wrong cuvette (a square test tube) or that a reagent has degraded and needs to be prepared anew. Other deviations, such as color remaining in a sample after it has been filtered, might tell the analyst that this sample should be treated with extra care to ensure accurate results.

All of these considerations or deviations require documentation. CSI analysts keep exhaustive, careful notes of not just their results but also any abnormal observations, what batch of chemicals and materials were used, and when and by whom the assay was performed.

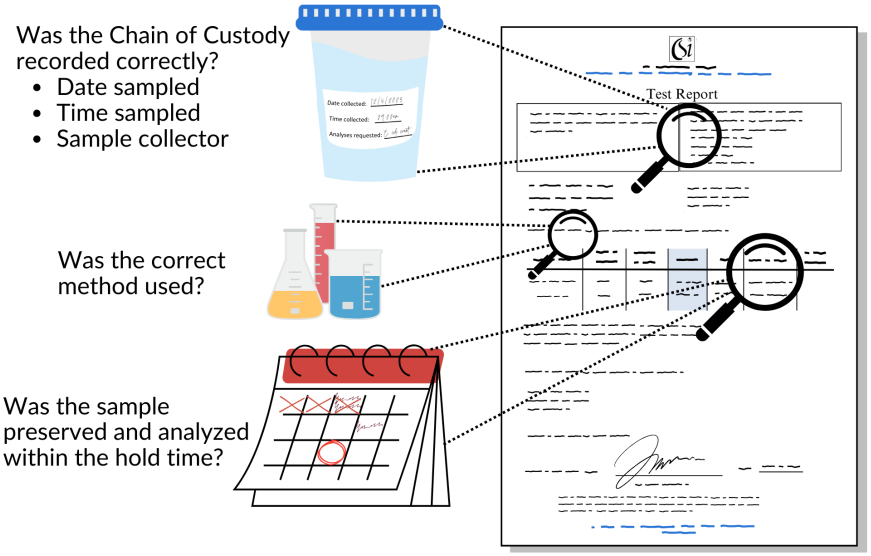
A tremendous amount of documentation occurs in CSI's lab. All of our i's must be dotted and our t's crossed! In a five day period:

- 447 items required initials
- 1,469 items were noted with the date
- 1,060 items were noted with the time

Step 4: Data Reporting

If at this point you think the water sample's journey is nearing the end, think again. Once analysis is complete, we can discard the water sample, but the data still has a ways to go before it makes it onto our public water quality database or into a report.

First, the data must be transcribed from the lab bench sheets (the sheets of paper where analysts take careful notes, make calculations, and record results). Given the thousands of initials, dates, and times analysts write each week, they must remind themselves to produce legible handwriting! Data from bench sheets are recorded in reports for CSI's fee-for-service clients or directly on our public water quality database for our volunteer monitoring programs. As reports are written and data is uploaded to the database, data are double checked to confirm that each step along the sample's journey (sample intake, sample preservation and storage, and sample testing) was completed



correctly.

The chain of custody must be recorded, demonstrating who, when, where, and how the sample was collected. The sample must have been preserved and analyzed within the hold time and using the correct method.

Documentation is also checked. Any time an essential step is performed, be it analysis, sample intake, reagent preparation, or even when something is crossed out on a bench sheet, the analyst must initial and write the date to show that the step was completed.

The number of steps required to accept and process a bacterial sample prior to issuing a certified report or uploading data to our database:

96

Remarks will also be added to reports and CSI's database documenting the condition of the sample when it was received and any unusual occurrences during storage and analysis.

After a report is written for a client or the monitoring data is compiled for the database, the data must be checked once more against the bench sheets and chain of custody sheets to ensure all information was correctly transcribed before the results can leave our office. Even then, however, our obligation does not end. We maintain paper and digital records of all reports we send out for many years. For some analytes like lead, we must maintain records for up to 12 years!

Maintaining laboratory certification involves a tremendous amount of work; there are many meticulous steps to take, quality controls (QC) and proficiency tests (PT) to pass, standard operating procedures (SOPs) to follow, and required documentations to make that all occur in an orderly fashion. However, all of these steps are worth it to maintain data of known and documented quality that we can post with confidence to our database or report to clients.

- Noah Mark, *Technical Director*; Seth Bingham, *Water Quality Scientist*
- Statistics compiled by Charlene Mottler, *Administrative and Laboratory Assistant*

HAB or HAB Not? *Oscillatoria* Clumps in the Cayuga Lake Watershed

HABs Harriers have grown accustomed to glancing out at the lovely Cayuga Lake shoreline, not just with an eye toward rippling sunlight on the water reflecting the myriad colors of the sky or a sudden blurp-like splash of one of its dozens of species of lake fish surfacing for just a moment. In recent years, Community Science Institute's (CSI's) seasoned team of volunteer Harmful Algal Bloom (HAB) monitors (AKA HABs Harriers) have developed a keen eye for recognizing seasonal population explosions of *Microcystis* and *Dolichospermum* along the shoreline of our beloved lake.

When a high density of one of these two genera of cyanobacteria appears on the water's surface, possibly having a streaky appearance or resembling spilled green paint, HABs Harriers know just what to do. They carefully document the site, collect a sample, and transport it to the CSI lab for microscopy and toxin analysis. While certain species of both *Microcystis* and *Dolichospermum* are known cyanotoxin producers, CSI's volunteer monitoring results since 2018 mainly show microcystin* toxins associated with blooms containing *Microcystis* and not with blooms containing just

*The cyanotoxin microcystin has been the main focus of New York State Department of Environmental Conservation (NYSDEC) toxin-testing, and it is currently the only cyanotoxin for which there is a NY State certified test.

Dolichospermum. But as many a disappointed beach-goer knows, the presence of any HAB warrants an immediate beach closure, no matter what genera of cyanobacteria caused the bloom, since cyanotoxins other than microcystin might always be present.

Microcystis and *Dolichospermum*, while dominating HABs in Cayuga Lake, are just two of many different types of cyanobacteria that have been forming cyanoHABs in the Finger Lakes region and throughout the world over the past decade.** Additionally, not all population booms of potentially toxin-producing cyanobacteria present themselves as the typical HABs that people are trained to spot.

In 2022 and 2023, high localized accumulations of another genus of cyanobacteria, *Oscillatoria*, were reported on the surface of Cayuga Lake by some of CSI's HABs Harriers who questioned the appearance of small clumps of floating material that drifted into their HABs monitoring zones. These clumps were described by some as looking a bit like goose poop and made some observers question whether there had been a nearby sewage leak (see Figure 1). Some have described them as brownish or very dark green and perhaps a bit "furry" when observed up close. If touched with a stick, they fall apart easily, but slimy strands of the cyanobacteria forming most of their bulk might hang off of the end of the stick.

Figure 1. *Oscillatoria* clumps off of the Ithaca Farmers' Market dock on June 25, 2023. Photo by Adrianna Hirtler.

Like *Dolichospermum*, *Oscillatoria* are filamentous cyanobacteria. That means that their cells connect to one another end to end to form string-like colonies. Unlike *Dolichospermum*, whose long filaments of interconnected cells may tangle together in bunches and/or fall apart easily to form shorter strands when disturbed, *Oscillatoria* cells seem to have more resilient connections and these filaments even have the ability to move independently! They glide along underwater surfaces and weave themselves together into mats. Most of the time, *Oscillatoria* are probably not seen by the average lake observer since these mats tend to be fully submerged, covering the rocks and muck on the bottom of stagnant or slow-flowing water bodies. But sometimes clumps of these mats break free and float to the surface, made buoyant by bubbles of oxygen created by the photosynthesizing *Oscillatoria* and trapped within the mat-like structure. Other species of phytoplankton and zooplankton seem to also find that these mats create a substrate on which they can eke out a living — other organisms besides just *Oscillatoria* are found mixed in with the *Oscillatoria* filaments if you look at one of these clumps under a microscope.

Some members of the *Oscillatoria* genus have been known to produce cyanotoxins, so some might wonder whether these clumps warrant concern or if they need not be treated in the same way as other HABs in Cayuga Lake. It has been challenging enough to share a clear message with the public on how to identify typical Cayuga Lake HABs, but it would require a whole new education campaign to get people looking out for high densities of *Oscillatoria*. It might also complicate things in a way that could confuse current identification of *Microsystis* and *Dolichospermum*-dominated HABs. When CSI reached out to the New York State Department of Environmental Conservation (NYSDEC) in 2022 and 2023 about their recommendations regarding *Oscillatoria* clumps, they stated that as of yet they do not have any. They also did not have any information to share regarding the potential toxicity of this phenomenon.

Since first noticing the occurrence of *Oscillatoria* clumps as part of CSI's lake plankton sampling project, CSI has tested a few *Oscillatoria*-dominated samples for microcystin. We have not yet found elevated concentrations of

**For example, though not yet recorded as a dominant genus in Cayuga Lake HABs, the cyanobacteria *Aphanizomenon* has been documented as causing HABs in a local pond. "CyanoHABs" are HABs that are dominated by cyanobacteria. There are other HABs, such as "Red Tides" that have occurred in Florida, that are caused by different types of organisms. Most freshwater HABs are cyanoHABs.

microcystin in the samples tested. Since the CSI testing lab does not currently have the resources to support testing for other cyanotoxins, we reached out to Dr. Greg Boyer in the SUNY College of Environmental Science and Forestry (ESF) Chemistry Department. Dr. Boyer has developed a lab with specialized equipment and expertise in the realm of cyanotoxin analysis and has agreed to accept samples from CSI. In the summer of 2023, CSI developed an informational handout on *Oscillatoria* blooms and started inviting volunteers to report sightings.

One sample, collected on June 26th off of the Ithaca Farmers Market dock, was sent to the Chemistry Department at SUNY ESF for cyanotoxin analysis (Microcystins, Anatoxin-a's, Cylindrospermopsins and Analytic Shellfish Toxins) and no cyanotoxins were detected. This is fortunate news, but as there are likely different species of *Oscillatoria* residing throughout the lake (potentially with different cyanotoxin producing capabilities), and since there seems to be little published research focusing on the toxicity of *Oscillatoria* clumps (and, in particular, *Oscillatoria* clumps in the Great Lakes watershed), CSI is encouraging volunteers to participate in documenting what they're seeing out on Cayuga Lake. CSI intends to send more samples to SUNY ESF for toxin analysis in the future as clumps are brought to our attention by volunteers.

Unlike the typical HABs spotted on Cayuga Lake, *Oscillatoria* clumps can be seen at different times of the year. They are not restricted to the typical HABs season corresponding to warmer lake temperatures. The first place that I personally noticed the phenomenon of *Oscillatoria* clumps was on the Cayuga Inlet in the very early spring. Then I started noticing them at times throughout the summer at East Shore Park. This year, for the first time since CSI started its lake plankton survey program in 2019, I observed them more regularly at certain sites near the south end of Cayuga Lake from early spring through early July. Many questions remain about the occurrence and potential hazards of *Oscillatoria* clumps, and we hope that CSI HABs Harriers (as well as some of our other volunteers!) will help us look for and document sightings of the clumps.

Whether or not *Oscillatoria* clumps prove to be a health hazard for humans, pets or wildlife, the documentation of their occurrence, like that of other HABs, does have other reasons for being important. If there is a connection between an increase in the appearance of these clumps and overall increases in the prevalence of high densities of *Oscillatoria* in the lake, do increases in *Oscillatoria* point to anything else related to overall lake health? Increases in *Oscillatoria* prevalence have been documented in lakes where eutrophication (an increase in, yet destabilization of, biological life resulting from increased nutrient loading) has occurred and their densities have correspondingly decreased as nutrient loading was addressed. This was apparently the case on Lake Washington in Washington State, which went through a process of eutrophication in the 1960s during which time it saw an increase in *Oscillatoria*. When phosphorus levels were reduced in the lake, *Oscillatoria* densities also decreased.[7]

Should we be treating the appearance of Oscillatoria clumps as HABs or not? The jury is definitely still out. By knowing what to look for, recording what we observe and analyzing samples for toxins, hopefully we can learn more about this phenomenon in our local freshwater ecosystems. And by paying attention, we might learn about new ways in which our daily observations help keep us informed about water quality in our cherished lakes and streams. This is one of the many benefits of community-based water quality science that CSI volunteers have proven the success of over the years.

- Adrianna Hirtler, *Biomonitoring Coordinator*

Chloride in Cayuga Lake

In recent months, residents and stakeholders in the Cayuga Lake watershed have raised relevant questions about salt in Cayuga Lake given talk of a possible sale of Cargill's Cayuga Rock Salt Mine. Salinization of freshwater is a growing ecological and public health concern not just in our watershed, but worldwide.[8] Road deicing salts, resource extraction, agriculture, wastewater discharge, industrial activities, irrigation, and climate change have all been linked to elevated chloride in freshwater.[8, 9] In many North American lakes, even a small percentage of impervious land

cover (>1%) surrounding a lake is associated with increasing chloride concentrations.[10]

Chloride is often used as an indicator of salinization because it is part of different kinds of salts that might be associated with degraded water quality. Sodium chloride (NaCl) is one of the most common of these salts, not just at your dinner table, but also in our environment. Chloride is a natural and healthy part of freshwater ecosystems when found at low levels. However, when elevated, it can decrease biodiversity, hinder growth and reproduction in aquatic organisms, impact the flow of nutrients and energy, mobilize heavy metals, and contaminate drinking water.[11, 12] For water bodies with a "best use" designation for drinking water, the NYSDEC water quality standard for chloride is set at less than 250 mg/L.[13] There is currently no statewide enforceable limit for chloride concentrations that aims to protect aquatic life.[13] The Environmental Protection Agency (EPA) suggests that chloride concentrations should not exceed 230 mg/L, which is the "highest concentration of chloride that is not expected to pose a significant risk to the majority of species in a given environment".[14]

History of Chloride in Cayuga Lake

Community Science Institute began monitoring water quality, including chloride, in Cayuga Lake in 2007. Other researchers and agencies have also been interested in the question of chloride in the lake. In the 1960s and 1970s, Cayuga Lake had much higher chloride levels than it does today.[15 - 17] In 1963, Berg reported that the chloride concentration of Cayuga Lake was 88 mg/L, whereas CSI data from 2022 show that the median chloride concentration in Cayuga Lake is 53.9 mg/L.

Cayuga Lake and its neighbor to the west, Seneca Lake, historically have had higher chloride levels than the other Finger Lakes. This has been attributed to the depth of these two lakes and their corresponding proximity to saline groundwater that lies underneath both lakes.[15, 17] However, in 1989, Effler and Johnson used modeling to demonstrate that the chloride concentration of Cayuga Lake could be attributed to loading from mining operations. Indeed, they found that chloride concentrations in Cayuga Lake dropped after 1970 (102 mg/L) when Cargill purchased the Cayuga Rock Salt Company and terminated the practice of directly discharging "unsaleable fines" (i.e. salt waste) into Cayuga Lake.[16] Eighteen years after the sale, the chloride concentration fell to 46 mg/L.[16] A report prepared by NYSDEC in 2001 also demonstrated that chloride concentrations in Cayuga Lake had decreased from the 1970s to the 1990s.[18] This was in contrast to other Finger Lakes (except Seneca Lake) which presented relative increases in chloride concentration during this time.[18]

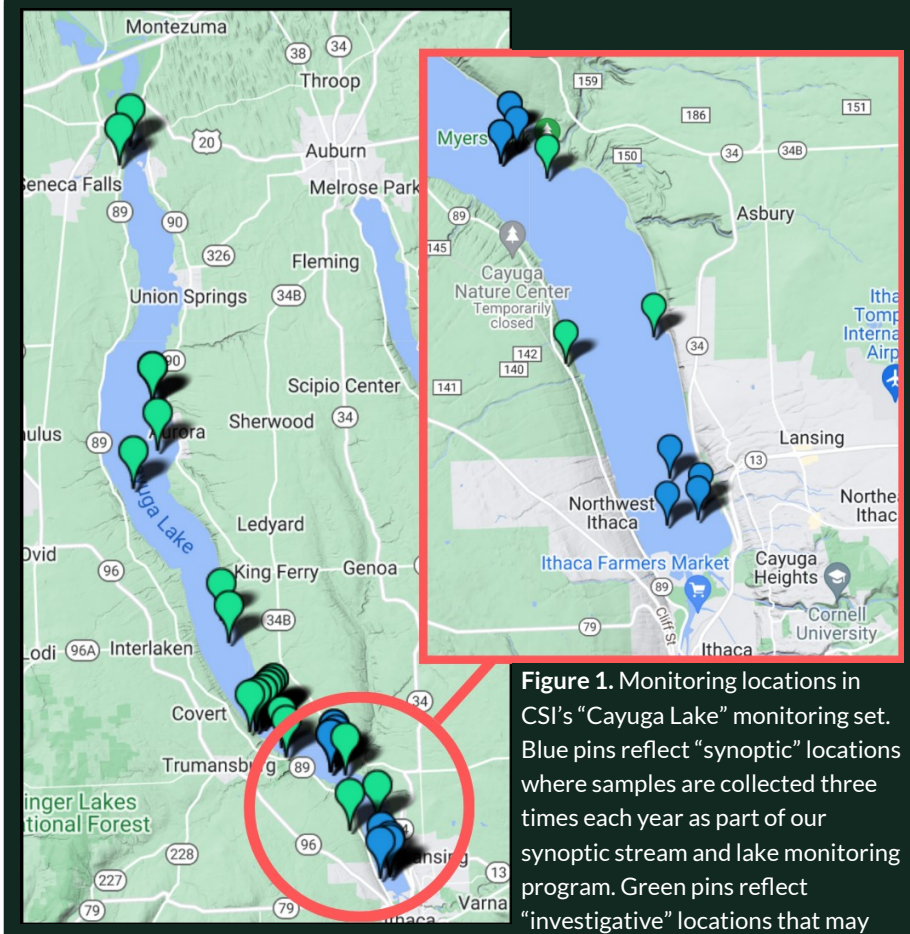


Figure 1. Monitoring locations in CSI's "Cayuga Lake" monitoring set. Blue pins reflect "synoptic" locations where samples are collected three times each year as part of our synoptic stream and lake monitoring program. Green pins reflect "investigative" locations that may have only been sampled once. These images are screenshots from CSI's public database (http://www.database.communityscience.org/monitoringsets/9).

What do CSI data say about chloride in Cayuga Lake?

There are two places on CSI's water quality database where you can find data on chloride in Cayuga Lake. The first is our "Cayuga Lake" monitoring set. The data within this monitoring set come from samples collected as part of our Journey of Water Program in collaboration with Discover Cayuga Lake. Samples are collected three times each year

from sites in the southern portion of the Lake, extending as far north as Myers Park (Figure 1). Occasionally, samples have also been collected from other locations farther north on the lake. These results are also included in this monitoring set.

The second monitoring set which contains data on Cayuga Lake chloride is our "Cayuga Lake East Shore" monitoring set. The data within this monitoring set are collected by CSI volunteers who monitor the east shore of Cayuga Lake on the same day that they monitor Salmon Creek. Samples are collected along the shoreline of the lake from the Salt Point Natural Area south to just past the mouth of Minnegar Brook (Figure 2).

Figure 2. Monitoring locations in CSI's "Cayuga Lake East Shore" monitoring set. Blue pins reflect "synoptic" locations where samples are collected three times each year as part of our Synoptic Stream and Lake Monitoring Program. Green pins reflect "investigative" locations that may have only been sampled once. These images are screenshots from CSI's public database (http://www.database.communityscience.org/monitoringsets/7).

Thanks to the long-term data sets collected and maintained through CSI, we can analyze trends in water quality over time. Since 2007, we have been monitoring chloride on Cayuga Lake through the two monitoring sets listed above. To determine if the median chloride concentration in our "Cayuga Lake" and our "Cayuga Lake East Shore" monitoring sets is changing over time, we performed statistical tests called simple linear regression. Simple linear regression is a useful tool for understanding how one variable (the predictor variable, in our case "year") explains or predicts another (the response variable, in our case "median chloride concentration"). From these analyses, we found that the median chloride concentration is increasing over time in both of our Cayuga Lake monitoring sets. In the "Cayuga Lake" monitoring set, median chloride concentration has been increasing at a rate of 0.72 mg/L per year since 2007 (Figure 3). In contrast, we found a slower rate of change in our "Cayuga Lake East Shore" monitoring set. In this monitoring set, median chloride concentration has been increasing at a rate of 0.56 mg/L per year since 2007 (Figure 4). For more detailed results and explanations about the simple linear regressions performed here, see Box 1.

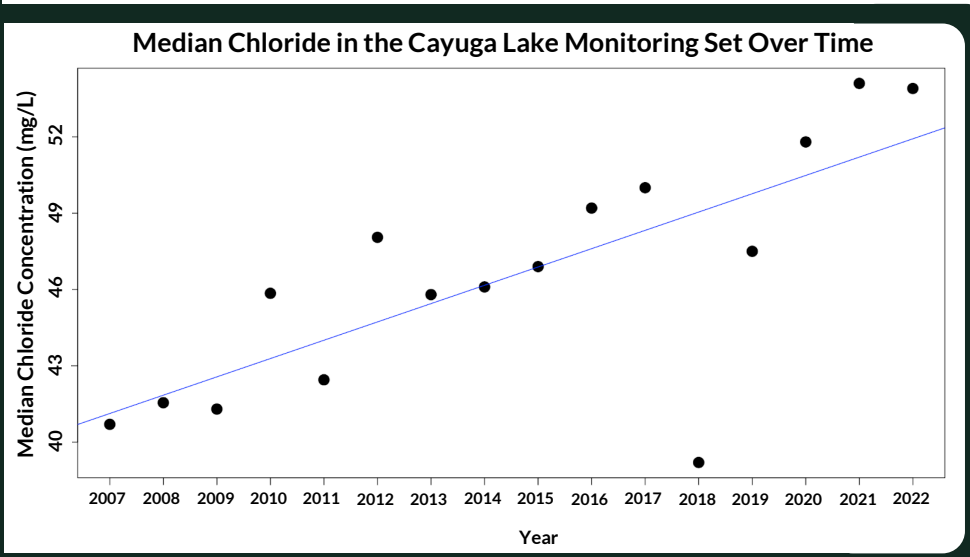


Figure 3. Median chloride concentration from the "Cayuga Lake" monitoring set from 2007-2022. Each dot represents the median chloride concentration across all monitoring sites for a given year. The line reflects the line of best fit. Note that median chloride was relatively low in 2018 compared to other years but is not considered a statistical outlier.

While our analyses revealed a statistically significant increase in median chloride concentration over time, there are two important points that should be noted about this conclusion. First, the relationships between median chloride concentration and year are somewhat weak for both monitoring sets. The stronger the relationship between two variables, the closer the R^2 value will be to 1. The R^2 values for the "Cayuga Lake" and the "Cayuga Lake East Shore" monitoring sets are 0.519 and 0.266 respectively. While the relationship between median chloride concentration and year in the "Cayuga Lake" monitoring set is stronger

than the same relationship in the "Cayuga Lake East Shore" monitoring set, an R^2 of 0.519 is not considered a particularly strong relationship.

The second important consideration is the rate of change in median chloride concentration. In both analyses, the rate of annual increase in median chloride is quite small. In the "Cayuga Lake" monitoring set, the median chloride concentration in 2022 was 53.9 mg/L. Given a rate of change of 0.7199 mg/L per year, we could expect median chloride concentrations to reach the chloride drinking water limit of 250 mg/L in the "Cayuga Lake" monitoring set in approximately 272 years. However, this assumes that median chloride concentration will continue to increase at its current rate, which may not be true given changes in land use and climate. Continued monitoring of these sites by CSI volunteers will allow us to detect how these trends may change over time.

In summary, CSI data demonstrate that median chloride concentration has been increasing in Cayuga Lake since 2007, albeit slowly. These findings generally agree with data collected by the NYSDEC as part of their Consolidated Statewide Lake Assessment Program (CSLAP). In their 2018 Finger Lakes Water Quality Report, they find that chloride has increased on Cayuga Lake by about 15% since 2001[13]. In 2022, the seasonal median chloride concentration ranged from 49.2-62.4 mg/L across four of the five CSLAP monitoring sites (a 2022 report was not available for one of the sites), which is similar to the CSI 2022 median chloride concentrations for both monitoring sets.

Beyond the Lake

While this article focuses on chloride in Cayuga Lake itself, it is relevant to note that CSI volunteers have also been monitoring chloride in Cayuga Lake tributaries since 2002. It is useful to monitor chloride concentrations under base flow conditions as streams are largely fed by groundwater during base flow conditions. Elevated chloride levels in

Box 1: Simple Linear Regression Detailed Statistical Results and Explanations

	"Cayuga Lake" Monitoring Set	"Cayuga Lake East Shore" Monitoring Set
F Statistic and *P* Value	$F(1,14) = 17.2$; $P < 0.001$	$F(1,14) = 6.43$; $P = 0.024$
R^2 Value	Adj. $R^2 = 0.519$	Adj. $R^2 = 0.266$
Equation	Y = 0.7199X - 1403.6187	Y = 0.5618X - 1080.5138

The equation models the linear relationship between the response variable (median chloride concentration) and the predictor variable (year). The number in front of the "X" is the slope of the line which reflects the rate of change. In the "Cayuga Lake" monitoring set, median chloride concentration is increasing at a rate of 0.7199 mg/L per year. In the "Cayuga Lake East Shore" monitoring set, the median chloride concentration is increasing at a rate of 0.5618 mg/L per year.

The R^2 value reflects how much of the variation in the response variable (median chloride concentration) can be explained bye the predictor variable (year). In the "Cayuga Lake" monitoring set, year explains about 52% of the variation in median chloride. In the "Cayuga Lake East Shore" monitoring set, year explains about 27% of the variation in median chloride.

The *P* value (and its corresponding *F* statistic) reflect the probability that there is no relationship between the response and predictor variable. Typically, a *P* value less than 0.05 is considered statistically significant. In both monitoring sets, the regressions were statistically significant ($P<0.05$), meaning that median chloride concentration can be predicted by year.

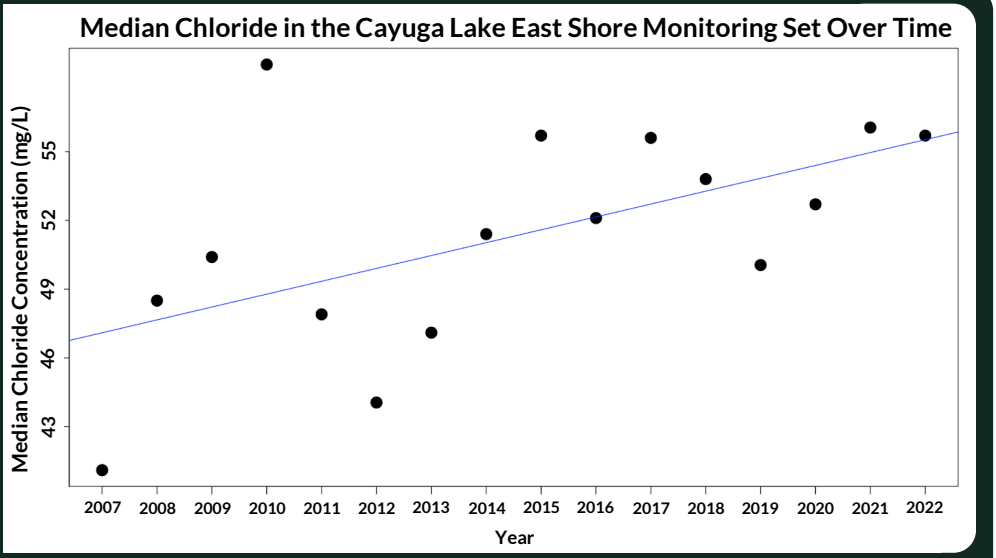


Figure 4. Median chloride concentration from the "Cayuga Lake East Shore" monitoring set from 2007-2022. Each dot represents the median chloride concentration across all monitoring sites for a given year. The line reflects the line of best fit.

streams during a base flow monitoring event may reflect groundwater contamination.[19] At CSI's recent Water Quality Data Jam on November 3, 2023 at the Tompkins County Public Library, Six Mile Creek volunteers discovered that chloride concentrations have been increasing over time across several of their monitoring locations. This and other trends can all be explored on CSI's public water quality database: database.communityscience.org. We highly encourage our readers to visit CSI's database to dive deeper into these data. There is a treasure trove of certified data, not just on chloride, but on other water quality indicators like nutrients as well. We also house data for more than just the Cayuga Lake watershed. You can explore data from other Finger Lakes' (Seneca, Keuka, Canandaigua) watersheds and the Upper Susquehanna River Watershed. With over twenty years of water quality data, there is plenty to discover!

The data used for the analyses in this article were downloaded from CSI's public database (database.communityscience.org/queries) on October 5, 2023 and include Cayuga Lake data from 2007-2022. RStudio Version 2023.01.1+494 was used to perform statistical analyses and make graphs.

Note: A correction was made to this article after a statistical error was detected in the equations for the linear relationships in both Cayuga Lake monitoring sets. This version, corrected on 1/25/2024, reflects accurate statistical models.

- Grascen Shidemantle PhD, *Executive Director*

HABs on Cayuga Lake: Takeaways from the 2023 Monitoring Season

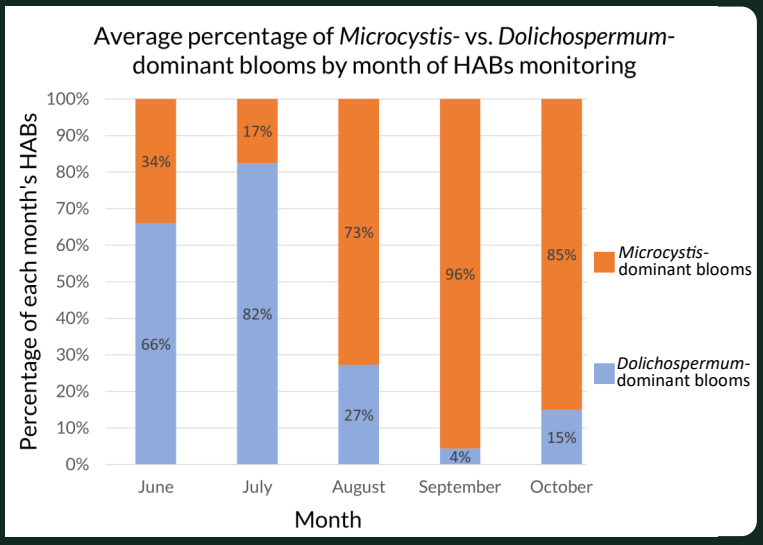


Figure 1. The monthly average percentage of blooms dominated by *Dolichospermum* (blue) vs. *Microcystis* (orange) from all 6 years of the Cayuga Lake HABs Monitoring Program. Note that participation in June and October is lower than other months, as the HABs monitoring season officially takes place from July - September.

The Cayuga Lake HAB Monitoring Program, led by Community Science Institute in partnership with Cayuga Lake Watershed Network and Discover Cayuga Lake, has reached the end of its sixth season. As they have since the start of the program in 2018, our HAB volunteers (who we call "HAB Harriers") surveyed assigned segments of Cayuga Lake's shoreline weekly from July-September in 2023, collecting samples when they observed a Harmful Algal Bloom. Some HAB Harriers started monitoring in June and monitored as late as October this year! At Community Science Institute's state-certified water quality testing laboratory, when we receive a HAB sample from our HAB Harriers, we first describe the taxonomic composition of the bloom through microscopy, noting which genus or genera of cyanobacteria are dominant and present. In samples containing cyanobacteria, we

test HABs for chlorophyll *a* and microcystin toxins. Chlorophyll *a*, a pigment found in all organisms that photosynthesize, including cyanobacteria, can be used to approximate the density of a bloom. Microcystin is a liver toxin that can be produced by some genera of cyanobacteria[20]. Data from the 2023 HAB monitoring season agree with previous seasons' findings as to taxonomic composition of blooms and how that composition correlates with toxin concentrations. Our 2023 HAB monitoring data leave open the question of whether or not HABs have increased in frequency over time. Other findings add nuance to the chlorophyll *a* threshold of a bloom.

CSI data show that early season blooms on Cayuga Lake tend to be dominated by cyanobacteria in the genus *Dolichospermum*, while blooms that occur later in the summer are usually dominated by cyanobacteria in the genus *Microcystis* (Figure 1). This pattern is reflected in data collected by CSI's HAB Monitoring Program since 2018[21]. These compositional shifts are important to note because blooms that contain *Microcystis* typically test at higher levels of microcystin than blooms that are dominated by *Dolichospermum*.

CSI data in 2023 show that in Cayuga Lake HABs containing *Microcystis*, concentrations of chlorophyll *a* and microcystin toxins are highly positively correlated . To date, each season of data on Cayuga Lake's HABs has shown this relationship (Figure 2). This essentially means that for blooms that contain *Microcystis*, as bloom density increases, so too does the toxicity of the bloom. Despite the strength of this relationship, there are certain exceptions that are worth exploring.

The New York State Department of Environmental Conservation (NYSDEC) uses specific criteria for defining a bloom. One of these is that blue-green algae chlorophyll levels must be at or above a concentration of 25 µg/L for a bloom to be considered a HAB[22]. Across all six years of the Cayuga Lake HAB Monitoring Program, the vast majority

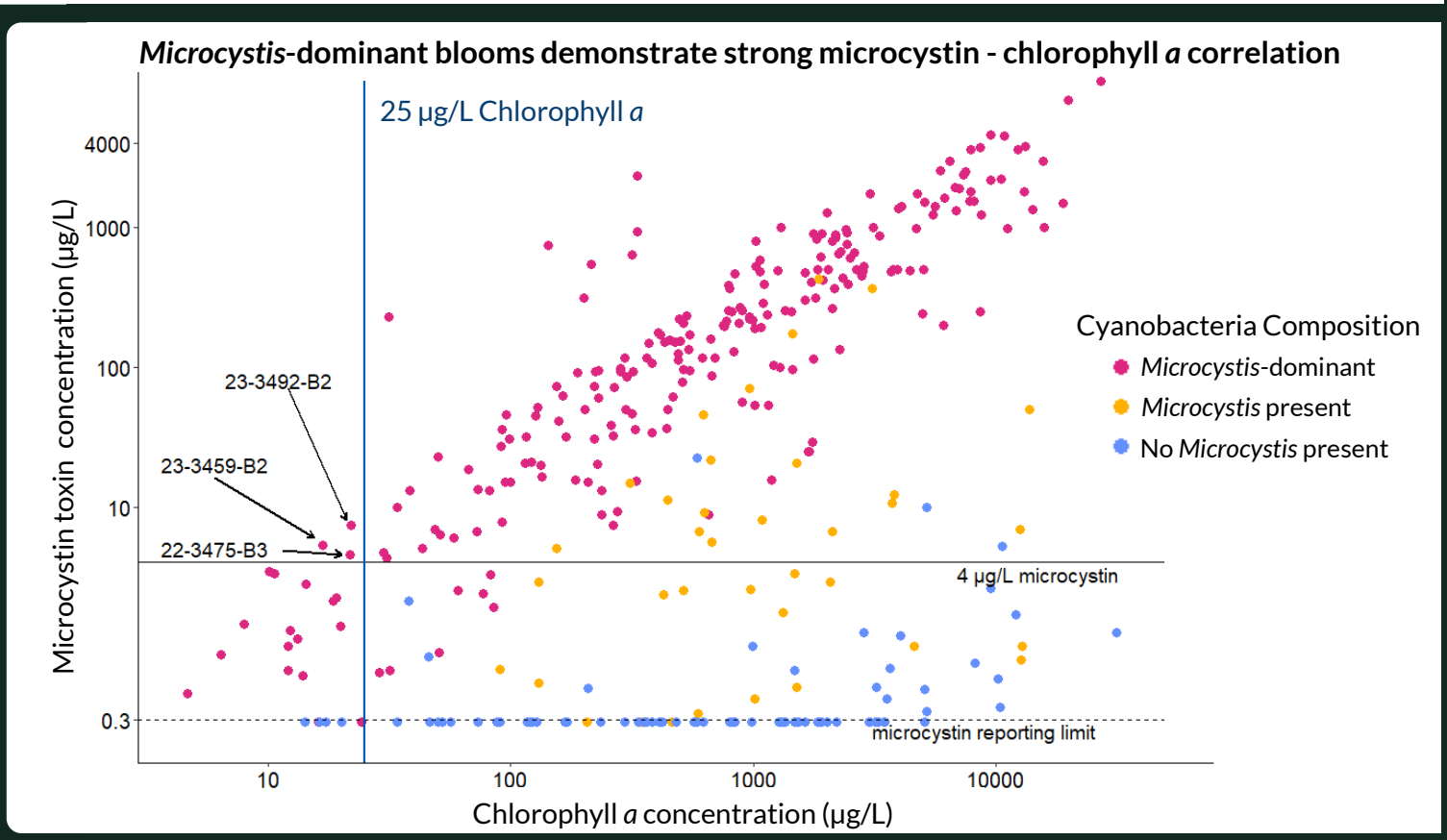


Figure 2. The relationship between chlorophyll *a* concentration and microcystin concentration in bloom samples collected from Cayuga Lake with data pooled from all of CSI's years of monitoring HABs (2018-2023). Bloom cyanobacteria composition is denoted by color: *Microcystis*-dominant blooms are shown in red, blooms with *Microcystis* sp. present but not dominant are in yellow, and blooms with no *Microcystis* sp. are in blue. Both axes use a logarithmic scale, with additional tick marks to demonstrate regulatory limits for different designated uses on the y-axis. The solid black horizontal line denotes 4 µg/L of microcystin, or the contact recreation limit set by NYSDOH. The dotted black line denotes 0.3 µg/L, the CSI laboratory reporting limit and the drinking water limit set by NYSDOH for microcystin. The solid vertical blue line denotes 25 µg/L of chlorophyll *a*, the threshold for defining a bloom set by NYSDEC.

of HABs that have contained microcystin toxins at concentrations above the New York State Department of Health's (NYSDOH) contact recreation limit of 4 µg/L have also exhibited chlorophyll *a* levels above 25 µg/L, as demonstrated by Figure 2. However, there have been three blooms over the years that have contained chlorophyll *a* levels below 25 µg/L with microcystin toxins at concentrations above 4 µg/L. One of these occurred in the 2022 monitoring season, and two occurred in the 2023 monitoring season. Each bloom is identified in Figure 2 with a bloom code, and a photo (Figure 3) illustrates how sparse bloom 23-3492-B2 appeared. These unusual occurrences demonstrate that a sparse bloom is not a guarantee of a low concentration of microcystin toxins. Regardless of how dense a bloom appears, they all have the potential to be toxic and should be avoided. A unique feature of CSI's Cayuga Lake HAB Monitoring Program is that it includes systematic toxin testing for observed blooms. This feature allows Community Science Institute to note anomalous blooms such as these three.

Figure 3. Bloom 23-3492-B2, observed on September 26, 2023. This bloom contained a chlorophyll *a* concentration of 22 µg/L and a microcystin toxin concentration of 7.41 µg/L. Photo by HABs Harrier Glenn Withiam.

Thanks to CSI's network of HAB Harriers who routinely monitor designated segments of the lake's shoreline during the main HAB season, we are also able to collect data on the frequency of HABs throughout the lake. Though our data showed a yearly increase in HABs through our first four years of data collection, data from the past two years have deviated from this trend (Figure 4). Looking at the six years of data our HAB Harriers have collected, we cannot yet draw conclusions about whether or not HABs on Cayuga Lake are overall increasing, decreasing, or staying the same in frequency. Additional years of monitoring may demonstrate that HABs are indeed increasing in frequency and that 2022 and 2023 are anomalies. Alternatively, HABs may be generally occurring at the same frequency (roughly 70-80 HABs/year) and 2021 was an anomaly. Long-term data, such as that explored in "Chloride in Cayuga Lake" can illuminate trends that are muddied by year-to-year variation in shorter-term data collection. We look forward to continuing to investigate long-term trends in HABs as our dedicated volunteers document future years of Cayuga Lake's HABs.

- Grace Haynes, *Outreach & Programs Coordinator, Cayuga Lake HABs Monitoring Program Coordinator*

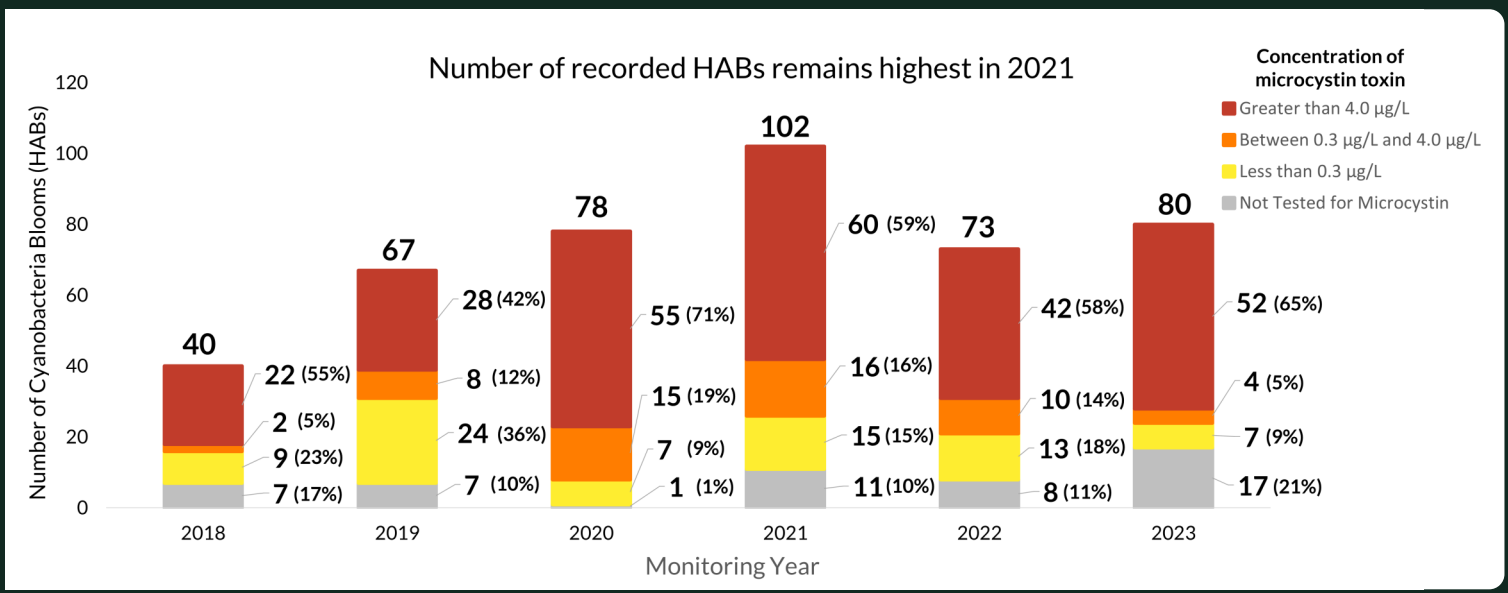


Figure 4. Number of harmful algal blooms on Cayuga Lake reported through our Cayuga Lake Harmful Algal Bloom Monitoring Program annually from 2018-2023. Note the different colors within each bar which correspond to different concentrations of microcystin toxin.

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Community Science Institute extends our deepest gratitude to our community-based volunteers, our members, and our funders, without whom none of our monitoring, and by extension this newsletter, would be possible.

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Water Bulletin - Fall 2023

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It is now more important than ever to work together to tackle the increasingly urgent and complex environmental issues of our time including climate change, harmful algal blooms (HABs), and changes in water quantity and quality. To do so, we must enrich our understanding of these issues through scientific monitoring and data collection, communicate data and their implication(s) effectively, and facilitate the collaborative development of equitable solutions.

This Fall 2023 issue of the Water Bulletin highlights the capability of Community Science Institute (CSI) to help tackle these issues by communicating the meaning and importance of operating a certified lab and supporting community-based efforts to understand water quality issues of local concern, such as *Oscillatoria* clumps, chloride levels in Cayuga Lake, and patterns of Harmful Algal Blooms on Cayuga Lake. It highlights CSI's unique capabilities as a certified water testing laboratory that supports the work of over two hundred and fifty volunteers to help connect community, science, and management so that we can protect our shared water resources.

You can support our efforts by becoming a member of CSI or renewing your membership today! In 2024, we have set a goal of raising $25,000 to support CSI's monitoring and education work. Help us reach this goal by joining a community that is taking action to protect water – now, and in the future.

With sincere thanks, The CSI Team

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