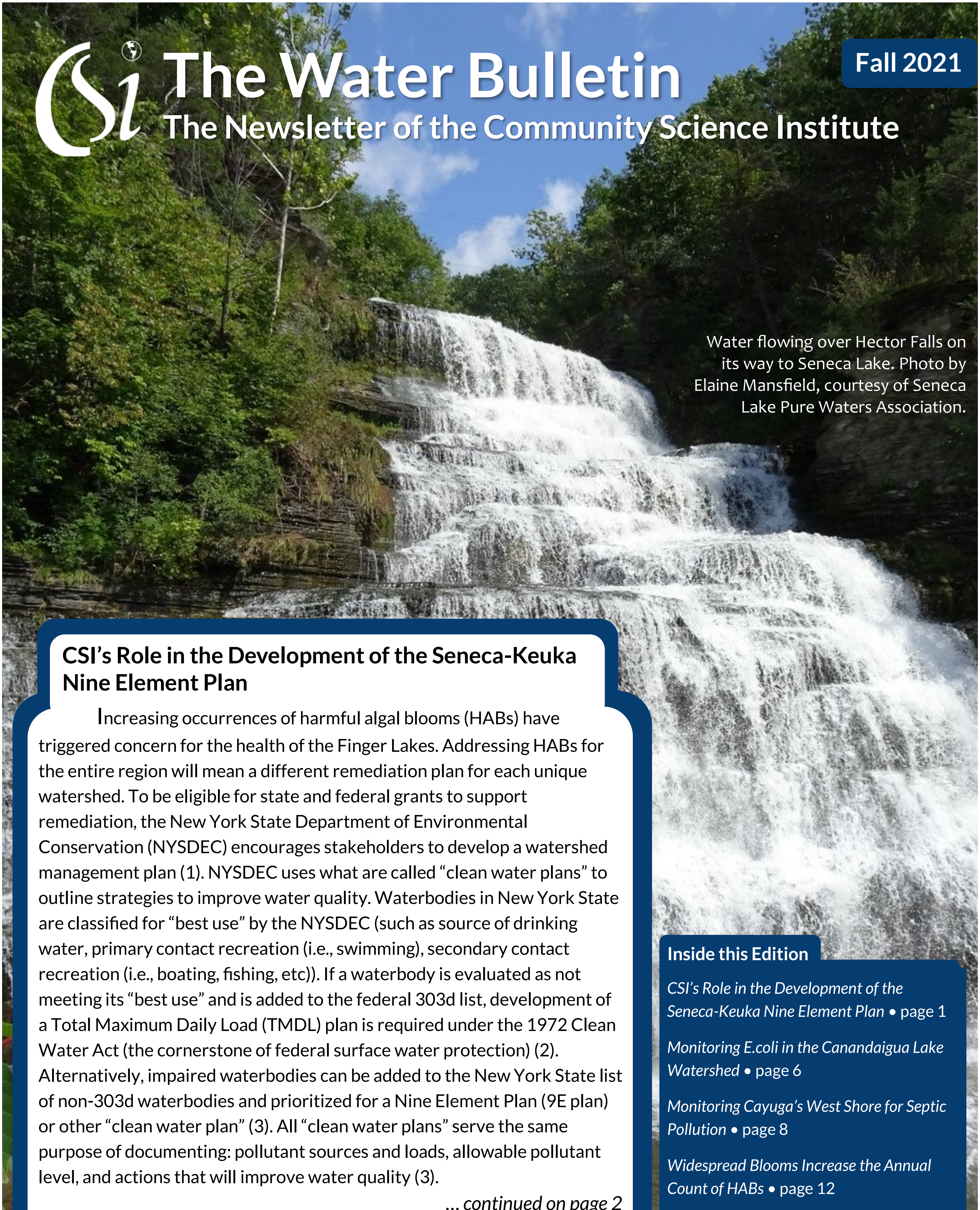
The Water Bulletin
The Newsletter of the Community Science Institute
Fall 2021



Water flowing over Hector Falls on its way to Seneca Lake. Photo by Elaine Mansfield, courtesy of Seneca Lake Pure Waters Association.

CSI's Role in the Development of the Seneca-Keuka Nine Element Plan

Increasing occurrences of harmful algal blooms (HABs) have triggered concern for the health of the Finger Lakes. Addressing HABs for the entire region will mean a different remediation plan for each unique watershed. To be eligible for state and federal grants to support remediation, the New York State Department of Environmental Conservation (NYSDEC) encourages stakeholders to develop a watershed management plan (1). NYSDEC uses what are called "clean water plans" to outline strategies to improve water quality. Waterbodies in New York State are classified for "best use" by the NYSDEC (such as source of drinking water, primary contact recreation (i.e., swimming), secondary contact recreation (i.e., boating, fishing, etc)). If a waterbody is evaluated as not meeting its "best use" and is added to the federal 303d list, development of a Total Maximum Daily Load (TMDL) plan is required under the 1972 Clean Water Act (the cornerstone of federal surface water protection) (2). Alternatively, impaired waterbodies can be added to the New York State list of non-303d waterbodies and prioritized for a Nine Element Plan (9E plan) or other "clean water plan" (3). All "clean water plans" serve the same purpose of documenting: pollutant sources and loads, allowable pollutant level, and actions that will improve water quality (3).

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In the case of Seneca and Keuka Lakes, the only waterway on the 303d list is Reeder Creek, a northeastern tributary of Seneca Lake whose catchment area includes the Seneca Army Depot (4). However, Seneca Lake stakeholders realized that water quality conditions were suboptimal and that a "clean water plan" would be required to achieve preferred status by the EPA and NYSDEC for funding watershed remediation directed at HABs. While research has identified multiple environmental factors that promote HABs, reductions in nutrient loading are often underscored as the best management tool to limit HABs proliferation. Seneca Lake shares a watershed with Keuka Lake, and together they comprise roughly 50% of the water in the Finger Lakes. Stream monitoring partnerships between the Seneca Lake Pure Waters Association (SLPWA) and the Community Science Institute (CSI), ongoing since 2013, had provided ample evidence that the Seneca-Keuka watershed is challenged by various water quality impacts including phosphorus and nitrogen nutrients (database.communityscience.org/monitoringregions/4). Missing, however, was a comprehensive plan to identify the sources and quantities of nutrient pollution, determine goals for nutrient reductions, and define best management practices (BMPs) needed to attain better health for the lakes.

In 2018, several regional stakeholders including, among others, SLPWA, the Keuka Lake Association (KLA), the Keuka Water Improvement Cooperative (KWIC), and the Seneca Watershed Intermunicipal Organization (SWIO) formed a consortium for the purpose of reducing nutrient loading to Seneca and Keuka Lakes and chose development of a 9E plan as the means to do so. 9E plans, which are based on the principle of adaptive management, emphasize stakeholder participation during development and include a comprehensive implementation plan that identifies funding sources, schedules major steps in the plan, and evaluates how well the plan performs (1). Further, 9E plans can be used effectively for watershed protection or restoration. Three-quarters of the Seneca-Keuka 9E plan's cost of ~$360,000 was covered by a Department of State (DOS) Consolidated Funding Application (CFA) grant, jointly submitted by four stakeholder organizations: SLPWA, SWIO, KWIC and KLA. Additional $90,000 was contributed by Corning Enterprises, SLPWA and KLA, and the two intermunicipal organizations, KWIC and SWIO (5). Finally, Yates, Ontario, Schuyler and Steuben counties each contributed $5,000 (5). With the achievement of full funding, development of the Seneca-Keuka 9E plan is on track to be completed in 2022. Specific projects to implement the plan are anticipated to be submitted to NYSDEC in 2023.

The Role of Water Quality Monitoring in the 9E Plan

The first element of a 9E plan is to identify and quantify sources of pollution in the watershed. Stream monitoring provides essential water quality data for constructing a model of nutrient transport as part of the 9E process. In 2013, SLPWA and CSI had begun sampling Seneca Lake tributaries several times a year out of SLPWA's concern for water quality degradation in Seneca Lake and the lack of current data for tributary streams. Over the years, SLPWA's Stream Team volunteers, with technical and logistical support from CSI, collected water samples at multiple locations on Catharine Creek, Big Stream, Kashong Creek, Keuka Outlet, Reeder Creek, and Glen Eldridge Creek (Figure 1) for analysis in CSI's certified lab (NYSDOH-ELAP# 11790). Results show the adverse effects of intense storms, including increased pathogenic bacteria and nutrient levels from upstream runoff, and suggest that high levels of phosphorus are widespread in the Seneca Lake watershed (database.communityscience.org/monitoringregions/4).

Water quality characterization of the Keuka Lake watershed began in 2018 when Maria Hudson of the Keuka Lake Association (KLA) launched a stream monitoring program for Keuka Lake tributaries and chose CSI's certified lab to analyze their stream samples under the program's Quality Assurance Project Plan (QAPP). The program began as part of PEERS (Professional External Evaluation of Rivers and Streams), a pilot program created by the NYSDEC to target non-point source pollution. Streams comprising 42% of the Keuka Lake drainage and different land use types were selected, including Sugar Creek, Cold Brook, Wagner Glen, and Eggleston Glen (Figure 1). The program targets nutrient inputs such as organic and inorganic nitrogen and phosphorus, chloride

Legend

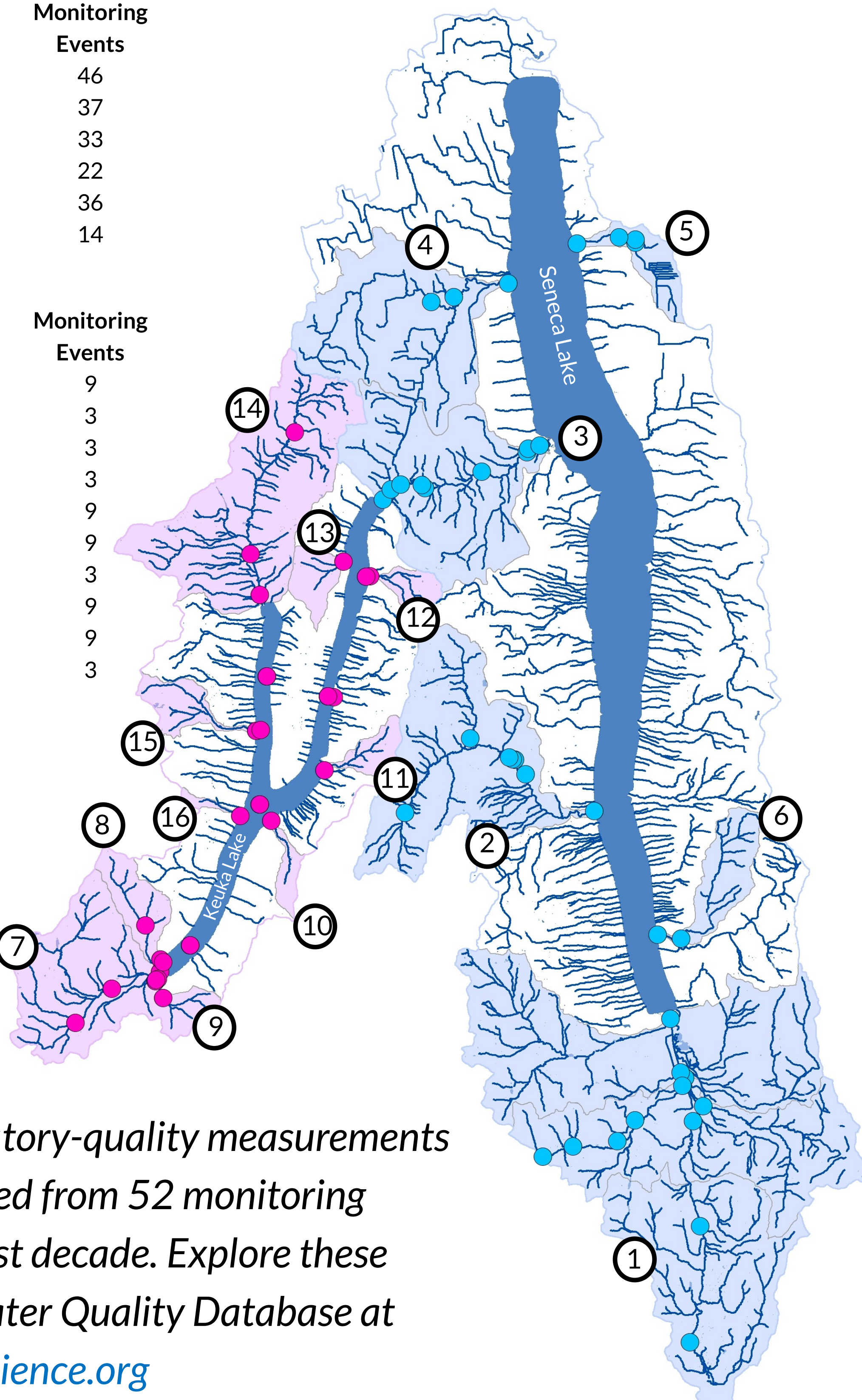
Seneca Lake Watershed

Monitored Subwatershed	Monitoring Locations	Monitoring Events
1. Catharine Creek	9	46
2. Big Stream	7	37
3. Keuka Outlet	11	33
4. Kashong Creek	3	22
5. Reeder Creek	5	36
6. Glen Eldridge Creek	1	14

Keuka Lake Watershed

Monitored Subwatershed	Monitoring Locations	Monitoring Events
7. Cold Brook	3	9
8. Glen Brook	2	3
9. Mt. Washington Brook	2	3
10. Day Rd. Brook	1	3
11. Eggleston Glen	1	9
12. Willow Grove	1	9
13. Brandy Bay	1	3
14. Sugar Creek	3	9
15. Wagner Glen	1	9
16. Pulteney Brook	1	3

Streams



Over 7,400 regulatory-quality measurements of water quality collected from 52 monitoring locations during the past decade. Explore these data on CSI's public Water Quality Database at database.communityscience.org

Figure 1. Map of monitored subwatersheds in the Seneca-Keuka watershed. For nearly a decade, Seneca Lake Pure Waters Association and the Keuka Lake Association have partnered with CSI to collect over 7,400 regulatory quality measurements of water quality from 52 monitoring locations throughout the Seneca-Keuka watershed during baseflow and stormwater conditions. Together, we have built long-term datasets that are now being used to guide the development of the Seneca-Keuka Nine Element Watershed Management Plan.

(a potential indicator of road salt), as well as total dissolved solids (minerals) and total suspended solids (silt/sediment). CSI has analyzed samples from Keuka Lake collected by KLA since 2017. Results reported in the CSI database (database.communityscience.org/monitoringsets/51) suggest that Keuka Lake remains oligotrophic, with low productivity and high water clarity; yet, as is the case with other lakes in the region, current trophic status is threatened by population pressures, certain agricultural practices, and climate change, which brings higher temperatures and more intense and frequent storms. As with Seneca Lake tributaries, collecting nutrient data on Keuka Lake tributary streams (database.communityscience.org/monitoringsets/54) has helped clarify where inputs are coming from and how much they are contributing to non-point source pollution of Keuka Lake.

SLPWA stream monitoring volunteers collecting samples from locations on the Keuka Outlet during a chilly morning in March 2021. Photo courtesy of Keuka Outlet Stream Team Leader Larry Martin

In 2019, Ecologic LLC and its subcontractor, Anchor QEA, were hired by the Seneca-Keuka 9E consortium to lead the effort to model nutrient loading, with guidance and support from the NYSDEC Finger Lakes HUB. Water quality data that had been collected by SLPWA and KLA through their stream monitoring partnerships with CSI served to jumpstart the next step in the 9E process: development of a computer model, which is a mathematical representation of the fate and transport of excess nutrients leading to the degradation of water quality within the watershed. A model helps identify pollution "hot spots" caused by certain activities such as stream bank erosion and fertilizer/manure runoff. Because monitoring of Seneca and Keuka Lake tributary streams had been ongoing for several years through partnerships with CSI, Ecologic LLC, Anchor QEA, and NYSDEC were able to analyze existing datasets available in CSI's online database (database.communityscience.org) and determine where more targeted sampling was needed for modeling purposes. In 2020, Ecologic LLC and Anchor QEA met with the KLA and SLPWA monitoring teams, the NYSDEC, and CSI to plan for additional data collection to finalize the model.

CSI's water quality monitoring partnerships with volunteers in the Seneca and Keuka Lake watersheds illustrate the value of long-term datasets. In addition to identifying sources and estimating quantities of nutrient loading, as they have done in the Seneca and Keuka Lake drainage, long-term datasets make it possible to evaluate whether best management practices (BMPs) succeed in improving water quality. Most importantly, by making long-term datasets publicly available in our free online database, CSI keeps stakeholders informed about the state of pollutants in their lakes and streams. With years of experience in certified water testing and managing volunteer-led monitoring programs, CSI is uniquely positioned to facilitate the collection of regulatory quality data in other Finger Lakes watersheds that can characterize pollution and support remediation efforts such as 9E plans.

What's Made the 9E Plan Development Successful?

Seneca-Keuka stakeholders have whittled the process of developing a "clean water plan," which typically takes several years, down to just a few years. Within that short time frame, they've formed a consortium across two lakes, raised the necessary funds, and are poised to finalize their 9E plan next year. Just as exciting is the fact that development of the plan has been voluntary, spurred on by a collective concern for the watershed.

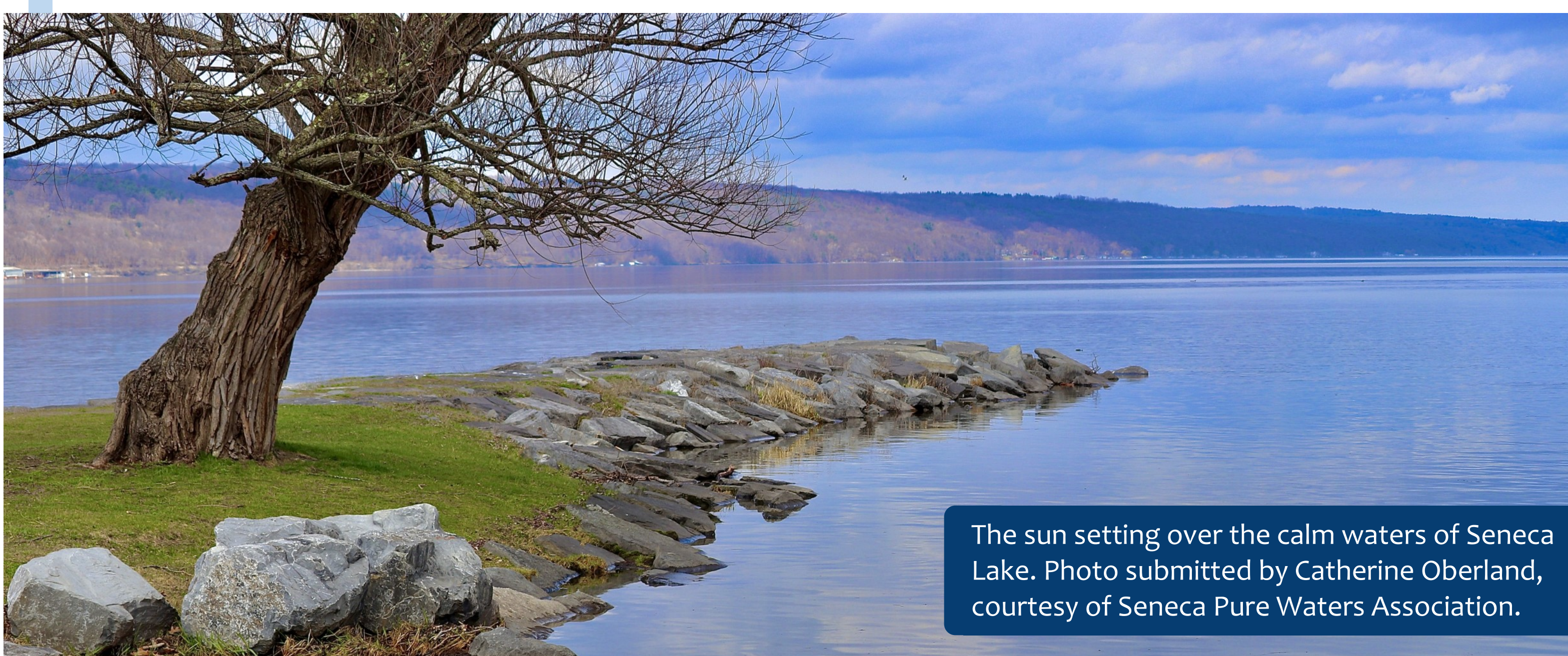
What accounts for the successful unfolding of the Seneca-Keuka 9E plan so far? Ian Smith, Seneca Lake Watershed Steward, points out that "we leverage volunteers extremely effectively to collect water quality data and address data gaps, [which has] allowed us to achieve approval from NYSDEC on model performance without significant losses in time." The efficiency of data collection is due in part to CSI's skill in working with teams of volunteers to collect regulatory-quality data, honed over two decades of implementing volunteer stream monitoring partnerships in our home watershed of Cayuga Lake. Our partnerships with SLPWA and KLA and their volunteers have resulted in the collection of over 7,400 certified data items approved for inclusion in the Seneca-Keuka 9E plan. In the Cayuga Lake watershed, CSI and our volunteer teams, with generous support from local and county governments, have worked since 2002 to build an archive of over 66,000 regulatory-quality data items for use in addressing a range of water quality concerns including phosphorus and nitrogen nutrients, salt, pathogenic bacteria and sediment (database.communityscience.org/monitoringregions/1).

Smith emphasized that "working closely with the Department of State and DEC through subcommittees really allowed us to progress quickly through the approval and model development process…." Smith also noted that public input and engagement have been key to bolstering solid relationships among stakeholders as the 9E plan is developed. Inclusion of "virtual outreach" such as recordings of presentations and "meetings, distributed material and online components" helped increase the number of participants above what is usually expected for these types of plans, according to Smith.

Conclusion

The 9E plan has been a process of envisioning a future of the Seneca-Keuka watershed that balances concerns for economy and environment. The Finger Lakes region has seen a great deal of change over the past two decades, including growth in new energy projects, tourism, services, and specialized agriculture (6). Capturing as much information as possible in the 9E process has been essential to developing a long-term plan that will identify the appropriate tools, timeline, and financial support required to meet the plan's targets. Current water quality data has been critical to forming a scientific overview of the sources and severity of nutrient pollution. Under the 9E plan, most of the practices designed to resolve water quality problems will be voluntary, so stakeholder feedback will be critical for ensuring that what is laid out in the plan is realistic and achievable. The Seneca-Keuka 9E consortium has responded agilely to concerns raised by the increasing frequency of HABs, securing the funds and building the relationships needed to develop a plan that, once implemented, will shape land use in the watershed for decades.

- Noah Mark, *Technical Director*



The sun setting over the calm waters of Seneca Lake. Photo submitted by Catherine Oberland, courtesy of Seneca Pure Waters Association.

Monitoring *E.coli* in the Canandaigua Lake Watershed

Located southeast of Rochester, Canandaigua Lake is a popular destination in the warmer months for swimmers and boaters. The lake has about 36 miles of shoreline, supplies drinking water to over 70,000 residents, and is the fourth largest of the eleven Finger Lakes (7). The Canandaigua Lake Watershed Association (CLWA) strives to protect the lake and surrounding watershed through science, education, and community engagement. This year, CLWA invited CSI to partner with them to monitor *Escherichia coli* (*E. coli*) bacteria at 16 sites on tributary streams and two public swimming beaches, Deep Run Park and Vine Valley (Figure 1). The goal was to investigate whether *E. coli* levels greater than 235 colonies/100 ml in the two swimming areas, the upper limit allowed by the New York State Department of Health (NYSDOH), were correlated with elevated *E. coli* in nearby streams. Though it is not required by law, many public beaches in NY are monitored during the swimming season for levels of *E. coli*, especially after rainstorms. Deep Run Beach and Vine Valley Beach are, however, not monitored regularly.

Previous studies have established that *E. coli* levels in streams and lakes are expected to increase due to stormwater runoff following heavy rain (8). The presence of elevated levels of *E. coli* is commonly used as an indicator that pathogenic bacteria may be present in water, although not all *E. coli* strains are considered pathogenic. This is why *E. coli* monitoring is so important for public swimming areas: without it, people could be swimming in water that exceeds the NYSDOH limit and possibly exposing themselves to bacteria-related illnesses.

Volunteers completed four partial monitoring events in 2021, three under base flow conditions and one under stormwater conditions. Base flow samples were collected on March 23rd, April 1st, and October 21st, while stormwater samples were collected on July 19th. Sampling locations were modeled on CSI's Synoptic Stream Monitoring Program in the Cayuga Lake watershed, with various sampling locations upstream in Canandaigua Lake tributaries and downstream at stream mouths in order to investigate which catchment areas *E. coli* may be coming from. Volunteers transported samples to the CSI lab where they were tested using certified EPA method 1604 for *E. coli* enumeration.

Across the three base flow sampling dates, 23 samples were collected from 16 sites (Figure 1). Of those 23 samples, only two were found to have *E. coli* levels above the NYS limit of 235 colonies/100 ml. Meanwhile, 13 sites were sampled during stormwater conditions, and 12 were found to exceed the *E. coli* limit, consistent with impacts from stormwater runoff. Concentrations ranged from 250 colonies/100 ml to 5,000 colonies/100 ml. All sampling results for Canandaigua Lake tributary streams can be found on the CSI database (**database.communityscience.org/monitoringsets/62**). Stormwater *E. coli* concentrations were 1,250 colonies/100 ml and 200 colonies/100 ml, respectively, at the Deep Run Park and Vine Valley swimming areas. Results for Canandaigua Lake may also be viewed on the CSI database (**database.communityscience.org/monitoringsets/61**).

The low *E. coli* concentration in the Vine Valley swimming area is surprising given that *E. coli* samples collected upstream on Vine Valley Stream were as high as 5,000 colonies/100 ml, and a sample collected from the mouth of the stream just north of the swimming area had 2,800 colonies/100 ml. One possible reason is that the stream enters the lake at Willow Grove Point, which juts out into the lake. The Vine Valley beach is located south of the point and could be somewhat shielded from stormwater runoff that enters the lake, leading to lower *E. coli* concentrations at the swimming area. Meanwhile, the Deep Run Park swimming area is located just south of where the stream enters the lake and does not appear to be shielded by any land formations (Figure 1 inset). This could explain why the swimming beach at Deep Run Park had *E. coli* far exceeding 235 colonies/100 ml under stormwater conditions. However, additional stormwater sampling is needed to confirm these results. Hopefully, future sampling of the tributaries and swimming areas will help provide clarity on possible trends for *E. coli* levels and support public health guidance at public swimming beaches.

We look forward to future opportunities to partner with the CLWA to continue monitoring Canandaigua Lake and its tributaries for *E. coli*, and possibly for other water quality indicators, as well.

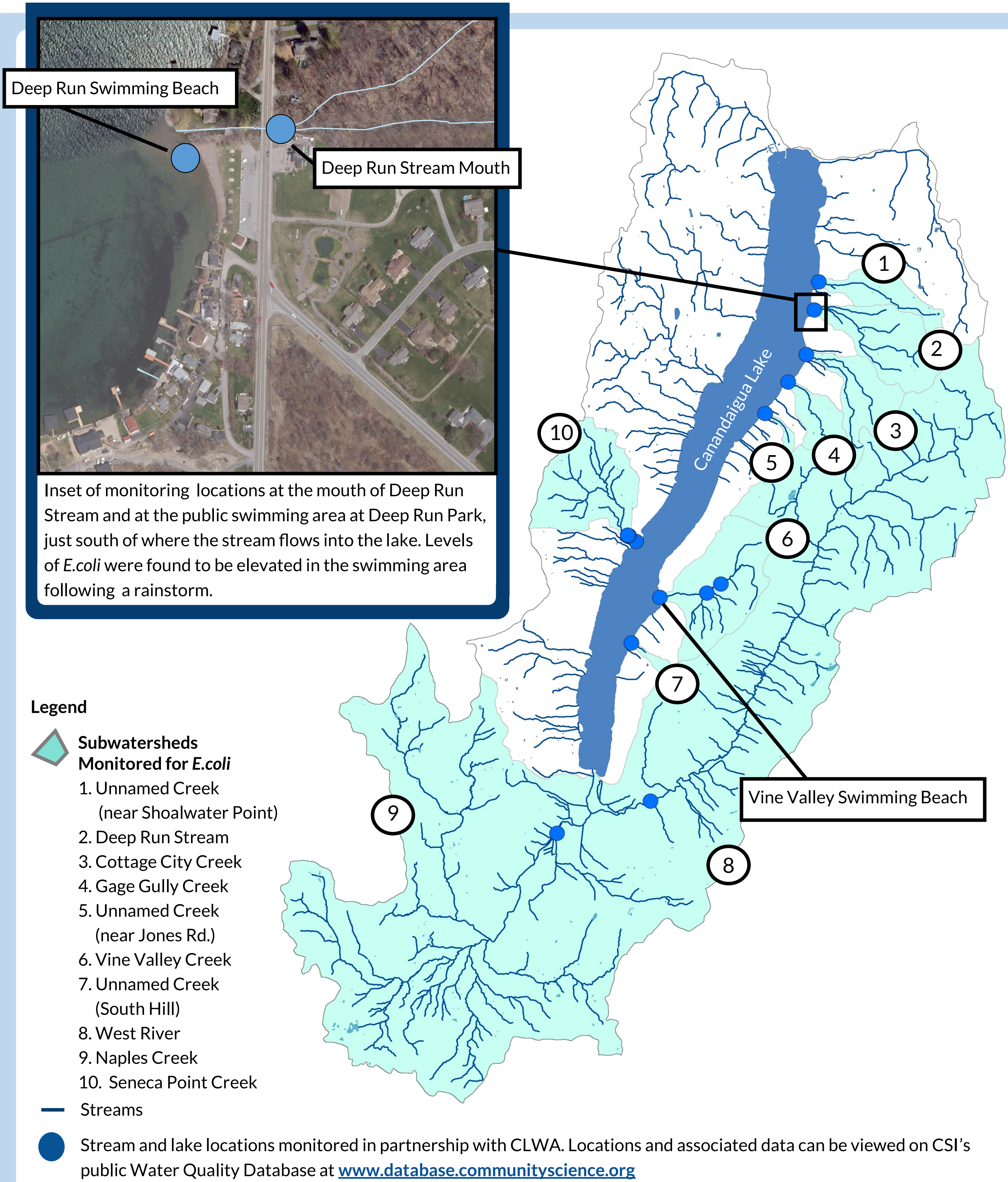


Figure 1. Map of monitoring locations within the Canandaigua Lake watershed and inset of the Deep Run Stream mouth and nearby shoreline.

- Kathryn Graham, *Lab Analyst*

Monitoring Cayuga's West Shore for Septic Pollution

Many lakeshore houses line Cayuga Lake's southwest shore. While some are summer vacation homes, others are occupied year-round. Water quality concerns have been raised around contact recreation, in addition to some households drawing drinking water directly from the lake. One widespread idea is that contamination from broken or aging septic systems of shoreline homes may be degrading water quality and pose a health risk for those recreating on the lake. But is there evidence to support this concern?

The Community Science Institute (CSI), in partnership with the West Shore Neighborhood Association (WSNA), has been collecting *Escherichia coli* (*E. coli*) data since 2014 to document lakeshore conditions and investigate possible contamination from near-shore septic systems. As the chief concern was monitoring recreational safety, CSI and WSNA chose to focus on bacteria contamination with this long-term dataset.

Four synoptic sampling events are conducted each summer, and weather conditions are noted. The 22 sampling locations are spread along the west shore of southern Cayuga Lake, covering approximately 14 miles of shoreline from Cass Park in Ithaca to the Town of Covert in Seneca County (Figure 1). A few locations (T501, W102, W106) are near the mouths of small tributary streams, and locations T695, T679, and T683 are close to Taughannock Creek, just south of Taughannock Falls State Park.

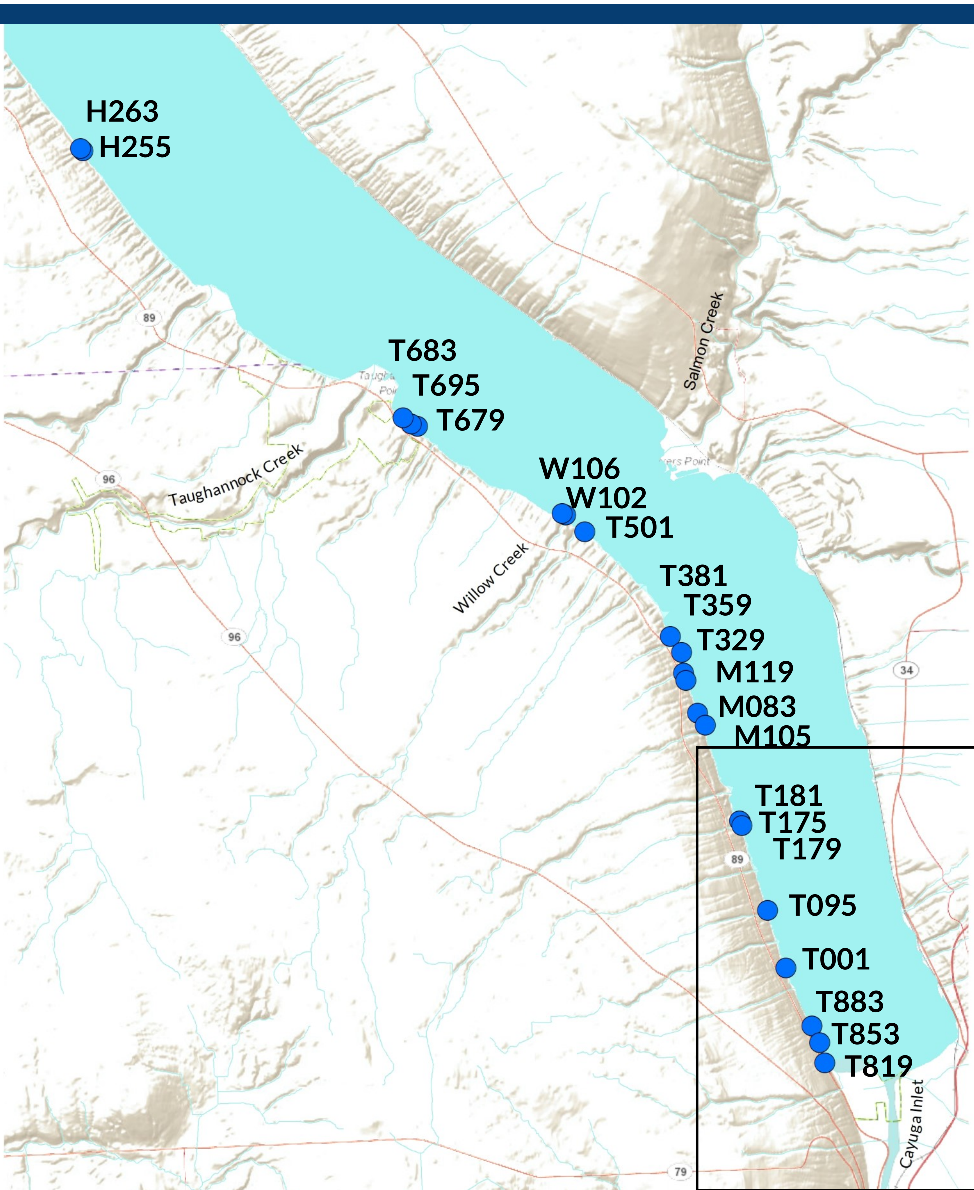


Figure 1. Map of Cayuga Lake shoreline locations monitored by the West Shore Neighborhood Association (WSNA).
All data available at:
database.communityscience.org/monitoringsets/39.

Legend
Streams
Monitored locations

Extent of Figure 3 satellite image on page 10.

Shoreline samples collected by WSNA volunteers are transported to the CSI lab and analyzed using certified EPA Method 1604, which is approved by the New York State Department of Health (NYSDOH) for *E.coli* enumeration. On southwest Cayuga Lake, in the ~14 mile stretch surveyed by WSNA, estimates show approximately 9-14 septic systems per square mile or less (9). Septic systems are common in areas outside of the reach of municipal sewage systems. In these areas, homeowners are solely responsible for maintaining their septic systems within local regulations. A typical septic system consists of a drain that feeds household sewage and wastewater into a septic tank, where waste separates by density, with the densest material settling to the bottom to be decomposed by bacteria. Liquid wastewater flows from the tank into pipes located in a drainfield, where it leaches into the soil to be further decomposed and filtered before eventually entering groundwater (10). If septic systems are not monitored and maintained, sewage can back up into the pipes or leak into nearby waterbodies without going through the process of settling and leachfield filtration. Flooding also presents issues, causing leachfields to become saturated and unable to process wastewater effectively.

An example of what septic contamination can look like: In a study done during 2015-2016 in Michigan to investigate septic contamination, researchers found *E. coli* values between 707 – 15,550 colonies/100 ml in the streams of the Upper Maple Watershed, as well as other indicators of human waste (11). Most states have regulatory limits for *E. coli*. The New York State Department of Health sets the upper limit for *E. coli* at 235 colonies/100 ml for swimming, far below levels indicating septic pollution. Finger Lakes State Parks uses this value to regulate their swimming beaches (12). If *E. coli* exceeds that value at a State Park beach, the beach is closed and cannot re-open until testing shows levels have fallen back below the threshold.

E. coli serves as a marker for the presence of other waterborne pathogens (13); most (but not all) strains of *E. coli* are harmless. Surface waters normally contain many kinds of bacteria which are beneficial parts of their ecosystems, with wildlife, domestic animals, and humans generally contributing some small amounts of bacteria to nearby waterbodies without ill effects. Further testing for indicators such as *Bacteroides thetaiotaomicron*, or alternatively, DNA analysis, may be used to confirm that *E.coli* is coming from human waste rather than other sources (14).

Fortunately, during the past eight years of collecting *E.coli* data, 441 samples out of 456 samples (97%) collected from the southwest shore of Cayuga Lake tested below the recreational limit of 235 colonies/100 ml. Of these, 232 (51%) were below the detection limit of 10 colonies/100 ml, and 209 (46%) ranged between 10 colonies/100 ml and 220 colonies/100 ml. Only 3% of the samples collected were found to have *E.coli* levels that exceeded the NYSDOH limit (range of values: 240 – 950 colonies/100 mL) (Figure 2). Average *E.coli* levels for each of the 22 monitoring locations ranged from <10 colonies/100 ml to 105 colonies/100 ml (Figure 3).

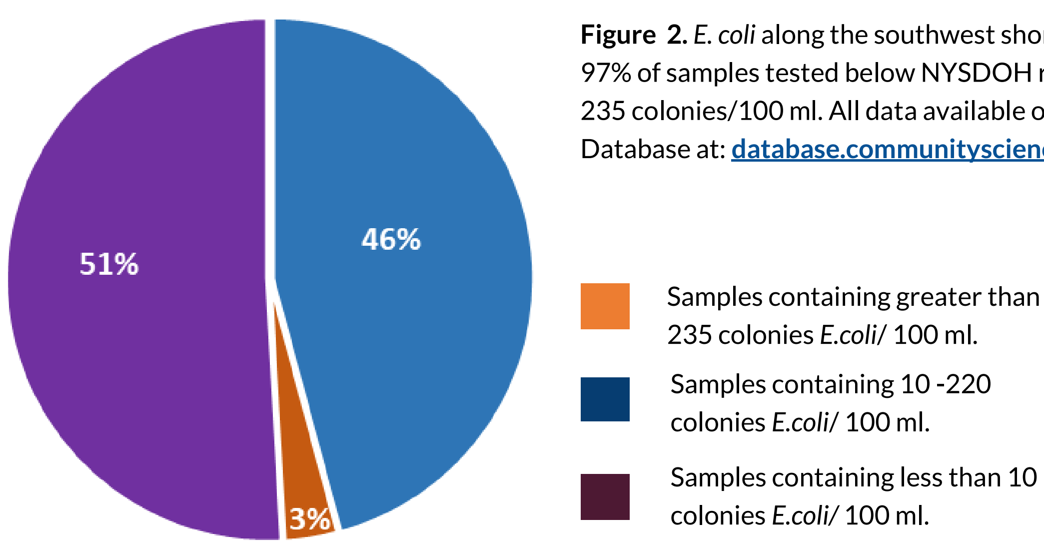


Figure 2. *E. coli* along the southwest shore of Cayuga Lake, 2014-2021. 97% of samples tested below NYSDOH recreation limit of 235 colonies/100 ml. All data available on CSI's public Water Quality Database at: database.communityscience.org/monitoringsets/39

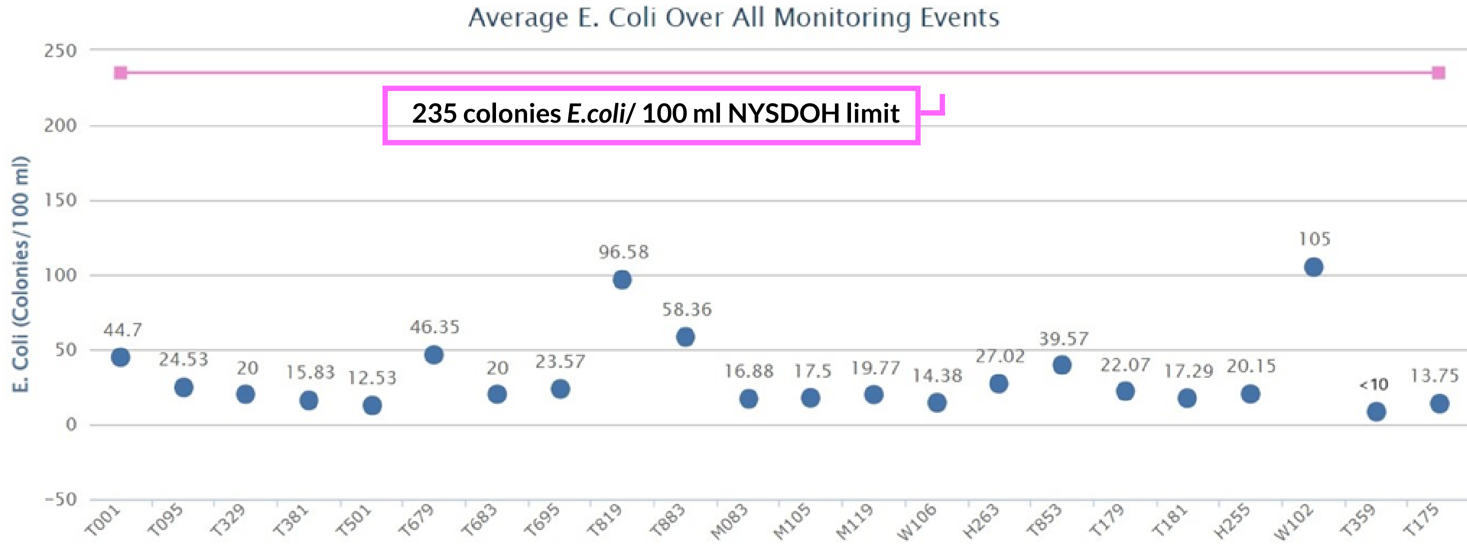


Figure 3. Screenshot from CSI's public Water Quality Database showing average *E. coli* concentrations at each monitoring location along the southwest shore of Cayuga Lake, 2014-2021. All data available at:database.communityscience.org/monitoringsets/39

Low *E. coli* levels along the southwest shore are comparable to other *E. coli* data from southern Cayuga Lake during the summer, tracked by CSI's monitoring partnership with Discover Cayuga Lake (Floating Classroom) since 2006. Average *E. coli* concentrations at seven open water monitoring locations at Secchi depth range from 17 colonies/100 ml to 88 colonies/100 ml (database.communityscience.org/monitoringsets/9). We observe that west shoreline *E. coli* levels, at baseflow conditions, are similar to *E. coli* levels found in open water.

The few west shore *E. coli* samples that have exceeded 235 colonies/100 ml are most likely due to runoff from tributaries. For instance, on May 14th, 2019, four sampling locations exceeded the guidance value (T883, T819, T001, T853). Weather data shows that the total daily precipitation for May 14th was about 0.75 inches (15), which the US Geological Survey (USGS) classifies as "moderate rainfall" (16). Anyone who spends time around Cayuga Lake will recognize the plumes of sediment that emerge from stream mouths after rain. The volunteer who collected the samples even noted that the water appeared "murky" on the tracking sheet. Satellite imagery from May 16th, two days after the samples were collected, shows an expansive plume emanating from Cayuga Inlet and reaching the locations where the samples were collected (Figure 4). Cayuga Inlet and nearby Fall Creek are both known to have elevated *E. coli* concentrations and turbidity following rainstorms (database.communityscience.org/monitoringregions/1).

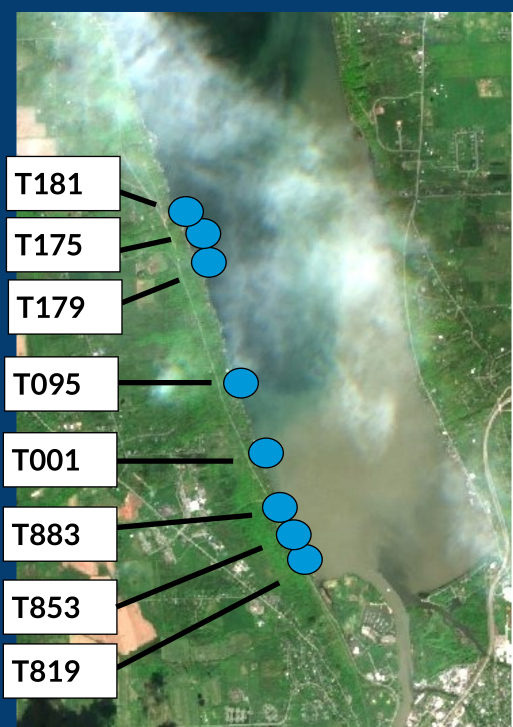


Figure 4. Satellite image of the southern shelf of Cayuga Lake on May 16th. A sediment plume caused by stormwater conditions in the Cayuga Inlet and Fall Creek can be seen extending well into the lake, impacting the four shoreline locations where levels of *E.coli* were found to exceed the limit for recreation. Imagery was not available during the rainstorm on May 14th due to heavy cloud cover (17).

Another sampling point with a higher average, W102, is located near the mouth of Willow Creek, a small tributary that may also load *E. coli* following rain (Figure 1). A timeline of results for W102 indicates the high average is due to a single sample taken on July 28th, 2021 (database.communityscience.org/

monitoringlocations/501. July 2021 had nearly double the total precipitation (7.03 inches), than July 2020 (3.65 inches) and July 2019 (3.85 inches) (14), suggesting runoff caused the unusually high result. Taken together, these data points indicate that certain locations in the WSNA monitoring set are more prone to contamination than others due to their proximity to tributary streams, a known source of high *E. coli* during stormwater conditions.

In conclusion, the results of long-term monitoring of *E. coli* along the southwest shore of Cayuga Lake indicate that under baseflow conditions for tributary streams, levels of pathogenic bacteria are low, within the limit for safe recreation. The rare instances of elevated *E. coli* levels can be explained by rain events causing major runoff from the tributaries. Septic systems may still be prone to failure under flood conditions, but in general stream runoff is likely the major contributor to elevated stormwater *E. coli* along the shore. This is consistent with the NYSDEC Cayuga Lake HABs action plan, which estimates that only 1% of annual total phosphorus loading in the entire Cayuga Lake watershed is attributable to septic systems (18). The majority of total phosphorus loading is attributed to non-point sources.

Many thanks to the West Shore Neighborhood Association for collecting all the samples, and for supporting our mission all these years. We look forward to continuing our partnership for years to come.

- Diana Beckenhaupt, *Lab Analyst*

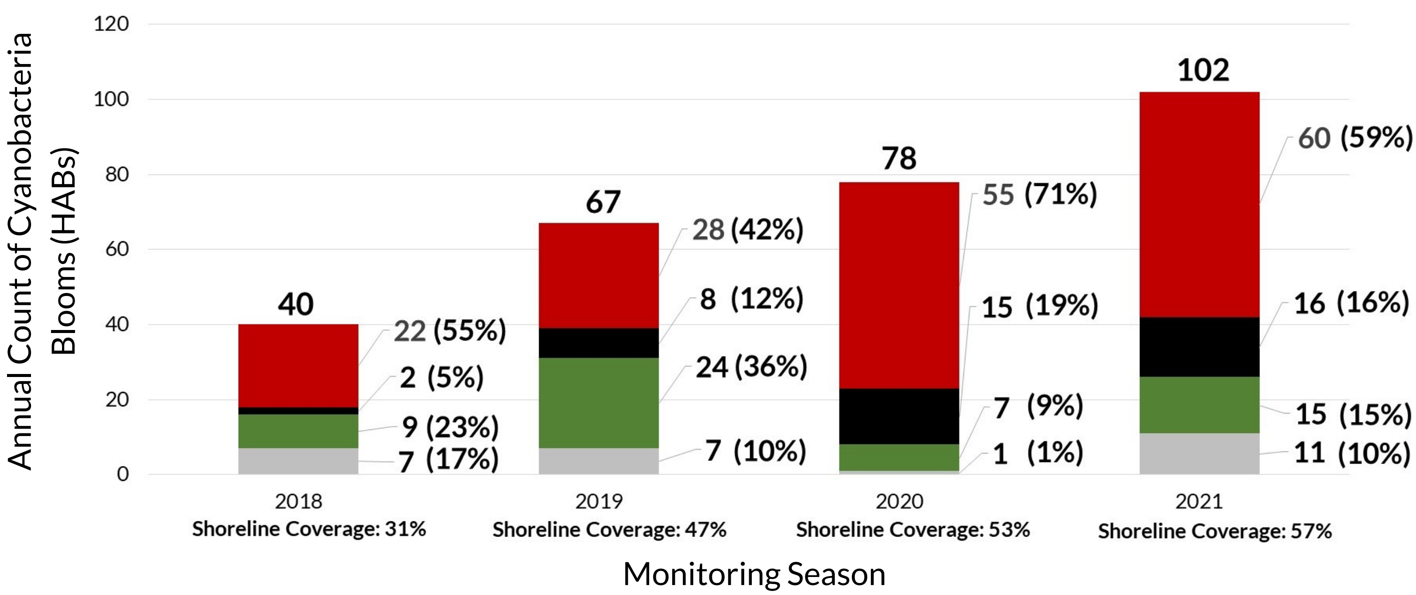
For more information about the West Shore Neighborhood Association (WSNA), visit their website at www.wsna-cayuga.org

Sunrise over Cayuga Lake as seen from Cayuga's southwest shore. Photo taken by WSNA President Chuck Tauck.

Widespread Blooms Increase the Annual Count of HABs

In 2021, two widespread bloom events occurred on July 19th - 20th and October 6th. These lake-wide events accentuated the worst HABs season to date for Cayuga Lake, both in the total number of blooms that occurred and the mean concentration of microcystin toxin detected in these blooms. Between June 29th and October 14th, the Community Science Institute (CSI), in partnership with our HABs Harrier volunteers, confirmed 102 cyanobacteria blooms, a substantial increase over the 78 blooms that were confirmed during the 2020 monitoring season (Figure 1). The mean concentration of microcystin toxin in the 2021 blooms was 23 μg/L , higher than the mean concentration of 18.5 μg/L in blooms that were documented during 2020 despite the higher proportion of low toxin blooms in 2021.

Annual Count of Cyanobacteria Blooms (HABs) in Three Microcystin Toxin Categories



Microcystin Categories

- Not tested for microcystin.
- Blooms with microcystin levels less than the method detection limit of 0.3 μg/L .*
- Blooms with microcystin levels greater than 0.3 μg/L and less than recreation limit of 4 μg/L .
- Blooms with microcystin levels ranging from 4 μg/L to 2,533 μg/L .

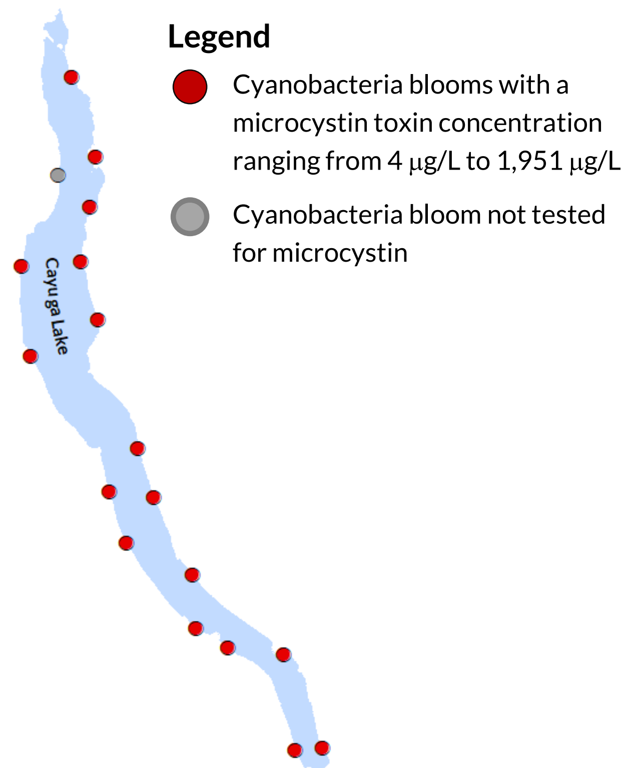
* 0.3 μg/L is also the New York State Department of Health (NYSDOH) limit for microcystin in finished drinking water

Figure 1. The annual count of cyanobacteria blooms (HABs) that occurred on Cayuga Lake in three microcystin toxin categories. The annual count of HABs on Cayuga Lake has increased each year and with the exception of 2019, the majority of blooms each year have microcystin toxin concentrations above the recreation limit of 4 μg/L .

This year, HABs Harriers patrolled 87 lakeshore zones, including the shoreline of municipal lakefront parks and all four New York State Parks on Cayuga Lake. Together, volunteers monitored roughly 57% of the lakeshore weekly. Because shoreline coverage did not increase substantially in 2021, and since there were only two more 'bloom days' than last year, much of the 2021 increase in the number of blooms is attributable to the two widespread HABs events in July and October. On October 6th, for example, CSI received reports of HABs from around the lake. Our volunteers were quick to report these blooms and collect samples for analysis at the CSI lab. By the end of the day, we had determined that within roughly five hours, blooms had occurred at 18 different locations along the Cayuga Lake shoreline (Figure 2).

Widespread bloom events also occurred on October 6th on neighboring Finger Lakes, including Seneca Lake and Canandaigua Lake. The occurrence of widespread blooms on multiple lakes on the same day strongly suggests that regional conditions were a factor, although which conditions may have facilitated bloom formation on that particular day is not clear. Nutrients are thought to be an important driver of HABs (19). Heavy rain was persistent in the days prior to October 6th, resulting in runoff that is known from years of monitoring to increase the transport by tributary streams of bioavailable phosphorus and nitrogen to Cayuga Lake and Seneca Lake (all nutrient data available in the 'Streams and Lakes' section of CSI's public Water Quality Database at database.communityscience.org). In addition, sediment runoff during these rainstorms could have contributed to the growth of cyanobacteria populations in the lake by increasing the turbidity of the water. Cyanobacteria contain unique types of chlorophyll capable of using diverse spectra of light for photosynthesis. This gives them a competitive advantage over other phytoplankton in low-light conditions, allowing cyanobacteria populations to grow rapidly in turbid water (20). Surface blooms are also associated with calm conditions. On the day of the lake wide bloom event of October 6th, volunteers reported there was no wind and that the surface of the lake was uncommonly calm. It is tempting to speculate that the lack of waves might have facilitated large populations of cyanobacteria rising to the surface of the lake *en masse*, accumulating to form the many widespread blooms that were observed. However, we do not know whether this is how the blooms formed that day.

Figure 2. Map of 18 HABs that occurred during October 6th, 2021, on Cayuga Lake



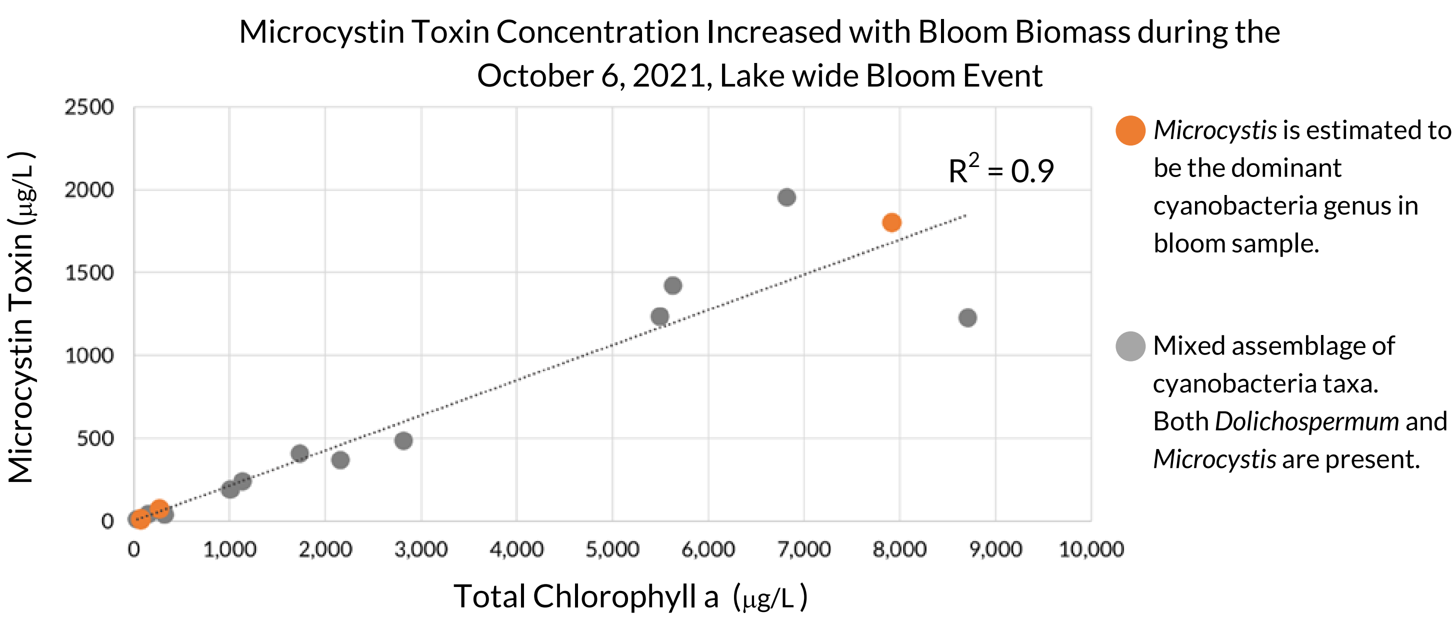


Figure 3. Cyanobacteria blooms that occurred on October 6th were dominated by the genus *Microcystis.* The density of these blooms and the microcystin toxin concentration were found to be highly correlated (correlation coefficient $R^2 = 0.9$). This confirms our earlier observation (21) that the concentration of microcystin toxin increases with bloom density when *Microcystis* represents approximately half or more of the cyanobacteria present in a bloom on Cayuga Lake.

The cyanobacteria blooms that occurred on Cayuga Lake on October 6th and were sampled by our HABs Harrier volunteers were found to have been formed predominantly, although not exclusively, by the genus *Microcystis*, with microcystin toxin concentrations ranging from 6.62 μg/L to 1,951 μg/L . Because blooms occurred at roughly the same time and samples were collected on the same day, October 6th represents, in effect, a lake-wide synoptic monitoring event for HABs, providing a unique opportunity to compare the composition, density and toxin concentration of blooms along the entire shoreline while environmental conditions remained roughly constant. Interestingly, microcystin toxin concentration correlated strongly with total chlorophyll a concentration (a measure of bloom density) (Figure 3), confirming our earlier observation that the microcystin concentration increases with bloom density when *Microcystis* is the most abundant genus in a bloom on Cayuga Lake (21).

The link between the microcystin toxin and the genus *Microcystis* helps us better understand the health risk posed by blooms on Cayuga Lake. Unfortunately, this correlation, though strong, is not an adequate basis for managing all the risks posed by HABs. *Microcystis* is just one of many bloom-forming genera of cyanobacteria, and each genus can produce several toxins. For example, *Dolichospermum* – the second most abundant bloom forming cyanobacteria genus that we observe in Cayuga Lake – is capable of producing other toxins in addition to microcystin, including the nerve toxin anatoxin-a and the hepatotoxin cylindrospermopsin (22). During the 2021 bloom monitoring season, our HABs Harrier volunteers collected additional samples from a subset of blooms, and these were analyzed for anatoxin-a at the CSI lab. Concentrations ranged from non-detect to 1.13 μg/L , similar to the low results obtained last year (23). It is important to note that the test for anatoxin-a has not been approved for regulatory use. Microcystin is among the few cyanotoxins with adverse health effects that have been thoroughly studied, making it possible for agencies such as the World Health Organization (WHO) and the U.S. Environmental Protection Agency (USEPA) to establish regulatory limits for drinking water and contact recreation. Moreover, microcystin is one of the few toxins for which a test method has been approved for regulatory use by USEPA. While microcystin is the most common cyanotoxin detected in New York State (24), other toxins such as anatoxin-a may be present in HABs for which no limits have been established and no test method has been approved for regulatory use. Because it is not possible to detect and report the presence of toxins other than microcystin with confidence, it is essential to avoid and report all blooms that may contain any type of cyanobacteria.

Another interesting observation in 2021 is that many more cyanobacteria blooms occurred during the month of October than in previous years. From 2018-2020, no more than two cyanobacteria blooms were recorded in October while this year there were 26 HABs in October. Climate change may be at least partly responsible. Cyanobacteria thrive in the warm layer of surface water that results from stratification, the natural process of lake water warming with seasonal temperatures and separating into a layer of warm water on the surface and a deep layer of cold water below. A recent study on the impact of warming temperatures on lake stratification predicts that stratification "will begin 22.0 ± 7.0 days earlier and end 11.3 ± 4.7 days later by the end of this century…" and notes that "a prolonging of lake stratification has been shown to increase the occurrence and intensity of toxic algal blooms" (25).

By continuing to monitor and analyze harmful algal blooms together with our volunteer partners, CSI can build and share long-term datasets that may help reveal patterns of bloom occurrences and increase our understanding of the ecology and toxicology of HABs. In this way we hope to provide reliable scientific information so that all who use and enjoy the waters of Cayuga Lake may continue to do so while making safe and informed decisions about HABs.

- Nathaniel Launer, *Director of Outreach, Cayuga Lake HABs Monitoring Program Coordinator*

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This Fall 2021 issue of the Water Bulletin highlights the capability of the Community Science Institute (CSI) to help tackle these issues by supporting community-based efforts to understand water quality issues of local concern including *E.coli* contamination of public swimming areas, communicating fast and accurate HABs data necessary for people to make safe decisions, and helping develop regional water quality protection plans such as the Seneca-Keuka Nine Element Plan through the collection of regulatory-quality data. 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.

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