The Water Bulletin

The Newsletter of the Community Science Institute

Fall 2019

Photo by Cayuga Lake HABs Harrier David Johnson

Two Years of Monitoring Blooms on Cayuga Lake

Intense phytoplankton blooms, including cyanobacteria blooms that are often referred to as harmful algal blooms (HABs), have increased in freshwater lakes, ponds, and reservoirs across the world since the early 1980s [1]. Here on Cayuga Lake, a lack of historical data and a continually expanding monitoring program make it difficult to tell whether bloom occurrences are actually increasing. However, observations over the past several years indicate that cyanobacteria blooms have become a regular part of Cayuga Lake dynamics during the summer months.

Inside this Edition

Two Years of Monitoring Blooms on Cayuga Lake

In 2019, the Community Science Institute (CSI) confirmed 67 cyanobacteria blooms on Cayuga Lake in partnership with the dedicated HABs Harrier volunteers of the Cayuga Lake Harmful Algal Bloom (HABs) Monitoring Program. Blooms occurred on 26 days from July to October (Figure 1). This is an increase of six bloom days and 27 blooms over 2018. This increase may be due in whole or in part to increased monitoring. In 2018, roughly 30% of the Cayuga Lake shoreline was monitored while this year, coverage increased to just over 47%, with 24 new volunteers and 17 new shoreline monitoring zones including Camp Comstock, Camp Barton, and all four State Parks on Cayuga Lake. Blooms reported in new monitoring zones accounted for 24 of the 67 confirmed blooms reported in 2019, or most of the increase of 27 blooms over 2018.

Throughout the summer, HABs Harrier volunteers identified cyanobacteria blooms along the Cayuga Lake shoreline and were among the first to alert lifeguards at public beaches, local health departments, and municipal authorities. Harriers once again helped patrol the route of the Women Swimmin' Fundraiser, protecting the swimmers from possible exposure to blooms. As shoreline monitoring coverage increases, so too does our understanding of the patterns of cyanobacteria blooms and our ability to help manage exposure effectively. Helping to manage exposure to these harmful blooms as a community, acquiring the knowledge to do so, and fostering environmental stewardship are perhaps the most important purposes of the program. This would not be possible without the care, dedication, and support of the volunteers around Cayuga Lake.

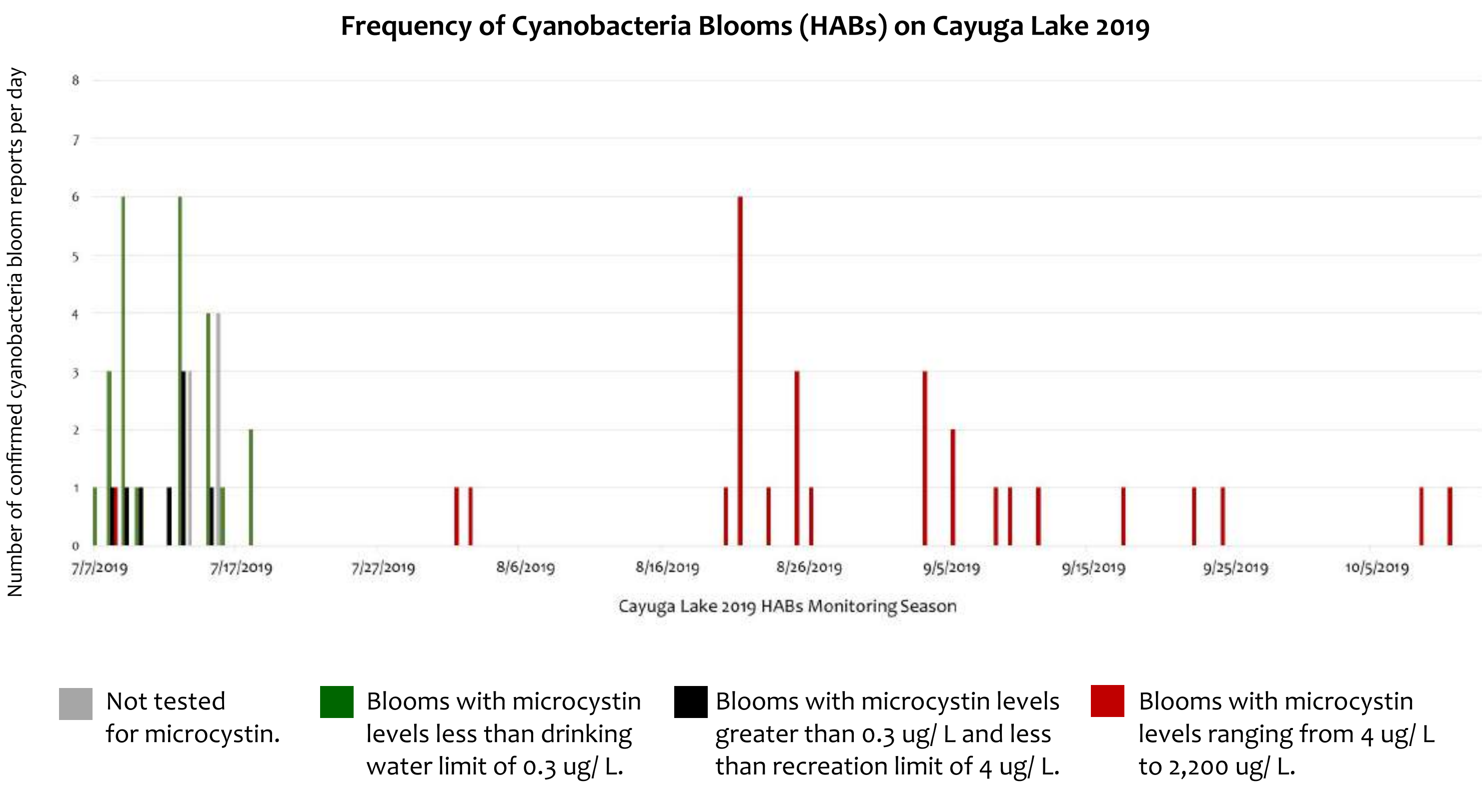
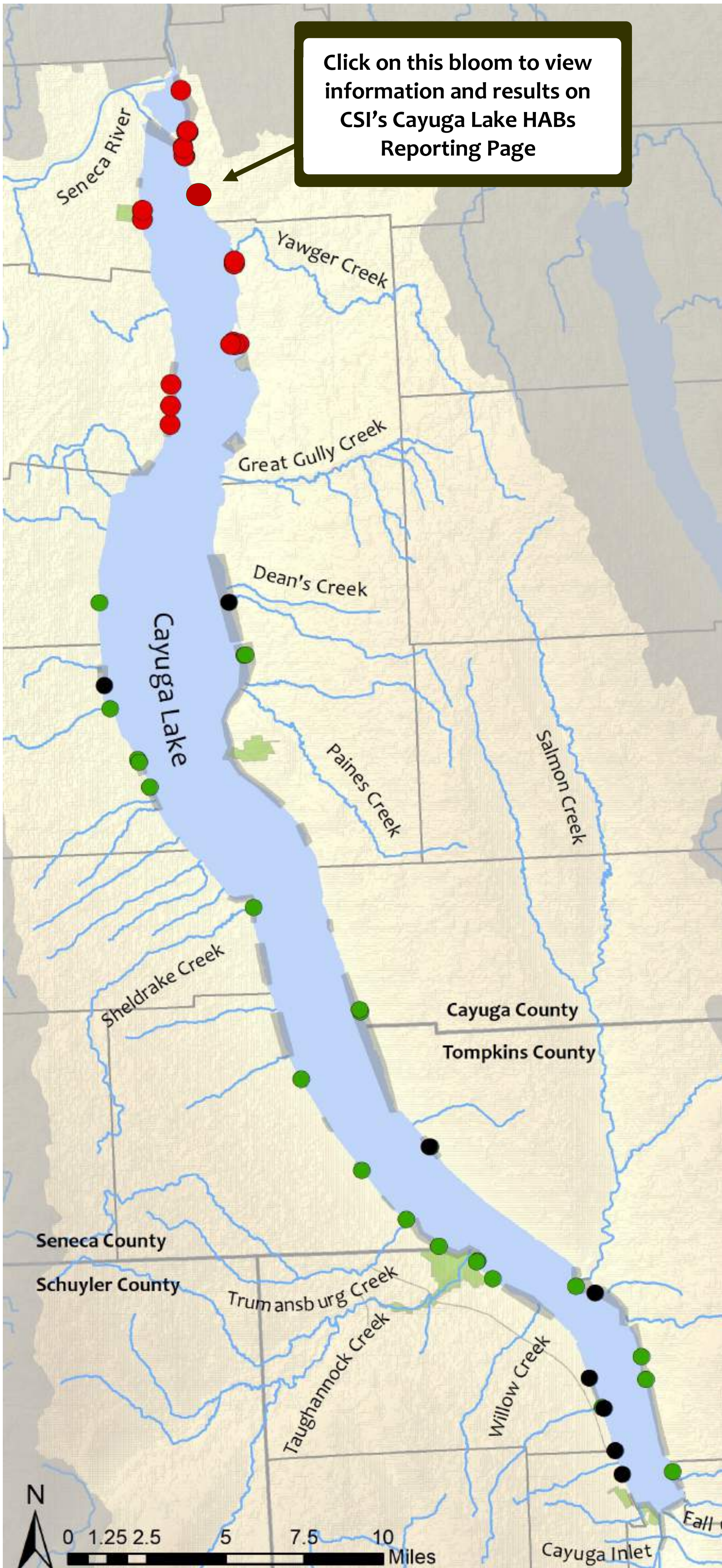


Figure 1. There were 67 confirmed cyanobacteria blooms (HABs) that occurred during the 2019 Cayuga Lake HABs monitoring season. They occurred in a similar pattern as 2018, with numerous blooms occurring in July, a lull during August, and numerous blooms then occurring in late August and September. Two blooms were sampled as late as October 8th and 10th. Source of data: Cayuga Lake 2019 HABs Reporting Page on CSI's website at www.communityscience.org



Whether or not the number of bloom occurrences is on the rise may not be as important as the patterns of bloom occurrence that monitoring data reveal. Two interesting patterns observed in 2018 have repeated in 2019. The first is the combination of geographic distribution and seasonal succession of blooms with high concentrations of the cyanotoxin microcystin. In 2018, results from CSI analyses of Cayuga Lake bloom samples, confirmed by NYSDEC, showed that most of the blooms with microcystin toxin concentrations exceeding the guidance value of 4 ug/L for contact recreation occurred during the late summer months in the northern half of the lake (see CSI Water Bulletin, Fall 2018). In 2019 this pattern of seasonal succession and geographic distribution was even more distinct. Thus, 27 of the 28 blooms with microcystin toxin concentrations above the recreation limit occurred from late August through early October (Figure 1). All 28 occurred within eight miles of the northern end of the lake (Figure 2, Map).

Figure 2. Map of microcystin toxin levels in confirmed cyanobacteria blooms on Cayuga Lake during the 2019 monitoring season. For bloom location details, view the interactive HABs reporting map online at: www.communityscience.org

Map Legend

- Blooms with microcystin levels ranging from 4 ug/ L to 2,200 ug/ L.
- Blooms with microcystin levels greater than 0.3 ug/ L and less than the recreation limit of 4 ug/ L.
- Blooms with microcystin levels less than the drinking water limit of 0.3 ug/ L.
- Shoreline zones monitored weekly from July through September by HABs Harriers
- New York State Parks

The second repeating pattern concerns the cyanobacteria taxa associated with the microcystin toxin. The concentration of microcystin in a bloom on Cayuga Lake appears to be correlated with the genus (type) of cyanobacteria that forms the bloom. In 2018, CSI found that blooms dominated by the genus *Dolichospermum* had very low concentrations of microcystin toxin while blooms in which the genus *Microcystis* was either present or dominant had high concentrations of microcystin (see CSI Water Bulletin, Fall 2018). These correlations were observed again in 2019 (Figure 3).

Microcystin Toxin Increased with Cyanobacteria Biomass when *Microcystis* Taxa were Present or Dominant: Monitoring Seasons 2018 and 2019

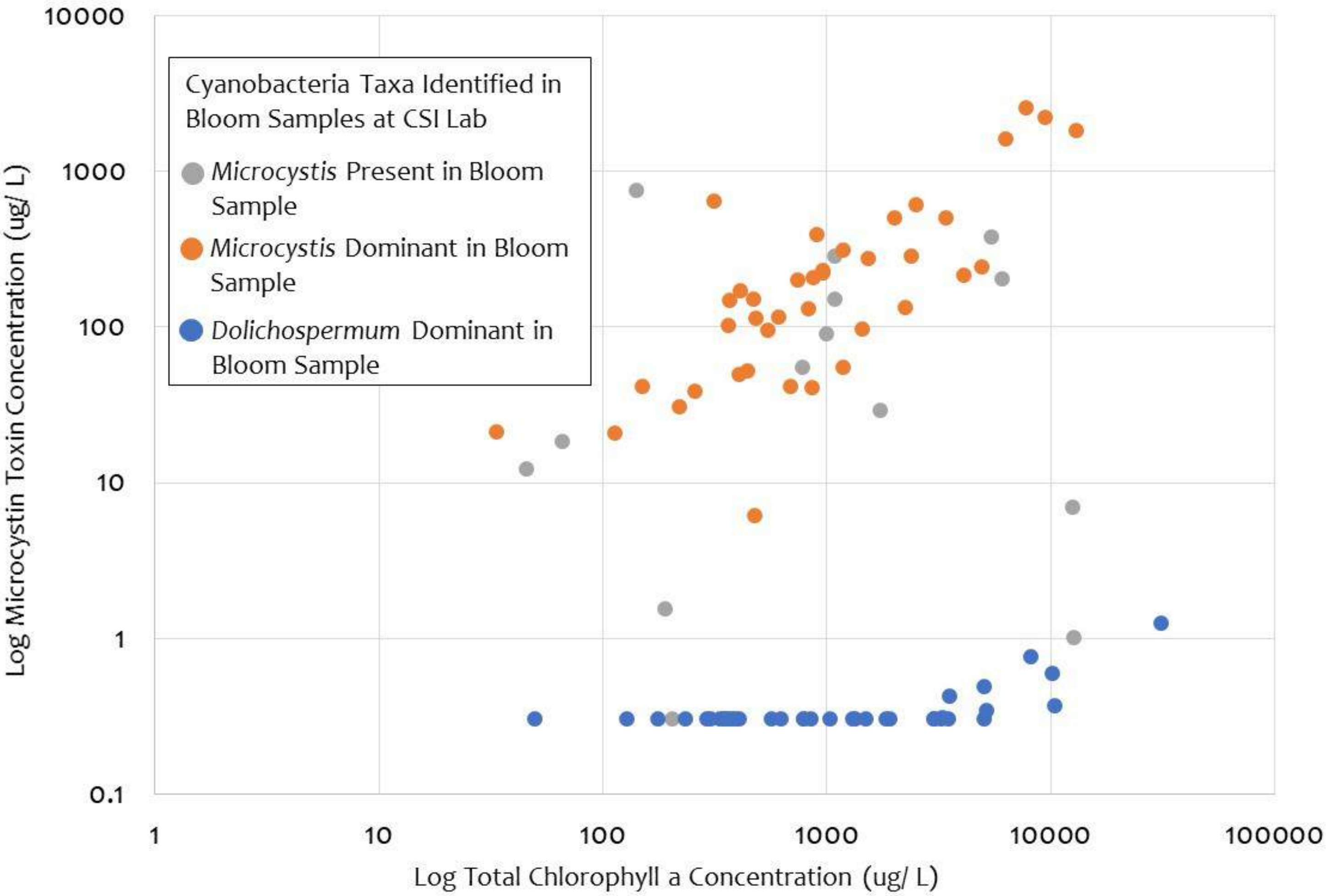


Figure 3. Microcystin toxin increased with cyanobacteria biomass when *Microcystis* taxa were present or dominant in the bloom sample during the monitoring seasons of 2018 and 2019. Microcystin toxin was low or not detectable in blooms dominated by *Dolichospermum* taxa, regardless of the density of the bloom.

Interestingly, the observations of the Cayuga Lake Plankton Survey Project (see page 5 in this issue) suggest that *Microcystis* populations are distributed unevenly around the lake, with relatively denser populations at the north end, even during non-bloom conditions. This uneven distribution of *Microcystis* under non-bloom conditions (see map on page 6) is consistent with the dominance of *Microcystis* blooms at the north end of Cayuga Lake (see map on page 3). The implication appears to be that relatively large populations of microcystin-producing *Microcystis* congregate in roughly the northern fifth of Cayuga Lake and that these populations can multiply and grow rapidly into a bloom when local conditions are right. Monitoring in 2020 and beyond will provide opportunities to test this idea and to investigate whether other toxins are produced by Cayuga Lake cyanobacteria in addition to microcystin.

Nathaniel Launer and Stephen Penningroth

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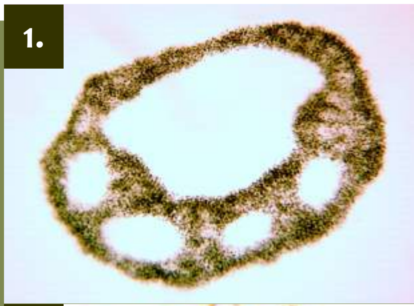

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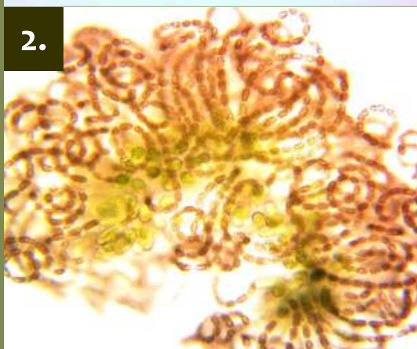

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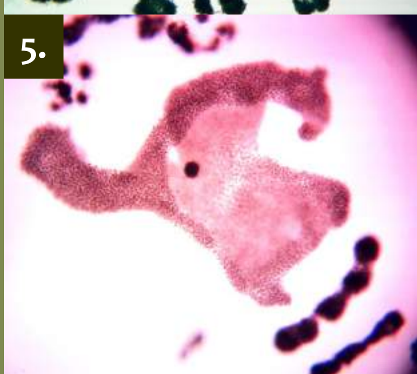

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The Habitat of HABs - Beyond the Blooms

CSI's volunteer-powered HABs monitoring program has tracked the presence, location and microcystin toxin content of over a hundred harmful algal blooms of cyanobacteria in Cayuga Lake since 2018. With now two years' worth of data, a few patterns are beginning to emerge. For example, there appear to be more blooms with high microcystin concentrations at the north end of the lake compared with the south end (see map, Figure 2). The data in which these patterns are emerging come from HABs samples collected by volunteers at various locations around the lake during the 2018 and 2019 bloom seasons from July through September. Yet cyanobacteria are present every day of the year, though usually invisible or inconspicuous to the naked eye. From the beginning of the HABs monitoring program, we became curious about what was happening with cyanobacteria and other phytoplankton in non-bloom conditions, which is really the majority of the year and even the majority of the bloom season.

The Cayuga Lake Plankton Project

In a humble attempt to better understand some of the general dynamics of cyanobacteria in Cayuga Lake throughout the bloom season, we began collecting weekly non-bloom plankton net samples at East Shore Park in the summer of 2018 and identifying cyanobacteria taxa (types) under the microscope. While lake water abounds with microscopic organisms, they are usually spread out and hard to find in a random drop. Plankton nets allow background levels of cyanobacteria and other plankton to be concentrated (in our methodology, roughly 2,000-fold) to levels where looking at a single drop under the microscope gives an approximate sense of the microscopic life forms that are out there. These weekly plankton net samples that were collected at East Shore Park in 2018 helped CSI staff become familiar with the different forms of cyanobacteria found in Cayuga Lake and with the myriad of other phytoplankton and zooplankton taxa that live in the lake along with them. The Cayuga Lake plankton project, initiated in 2019, expanded the scope of the East Shore Park plankton project to include similar "snapshots" of planktonic life every two weeks at seven additional locations around the lake. Some of these samples (both plankton net and direct grab samples from the same locations) were tested for microcystin.

Views from Under the Microscope

1. *Microcystis* identified in a bloom that occurred on September 21, 2019

2. *Dolichospermum* identified in a bloom that occurred on July 3, 2018

3. *Merismopedia* in a Cayuga Lake Plankton Project sample on August 27, 2019

4. *Microcystis* identified in a bloom that occurred on September 5, 2019

5. *Microcystis* identified in a bloom that occurred on September 13, 2018

6. *Dolichospermum* identified in a bloom that occurred on September 9, 2019

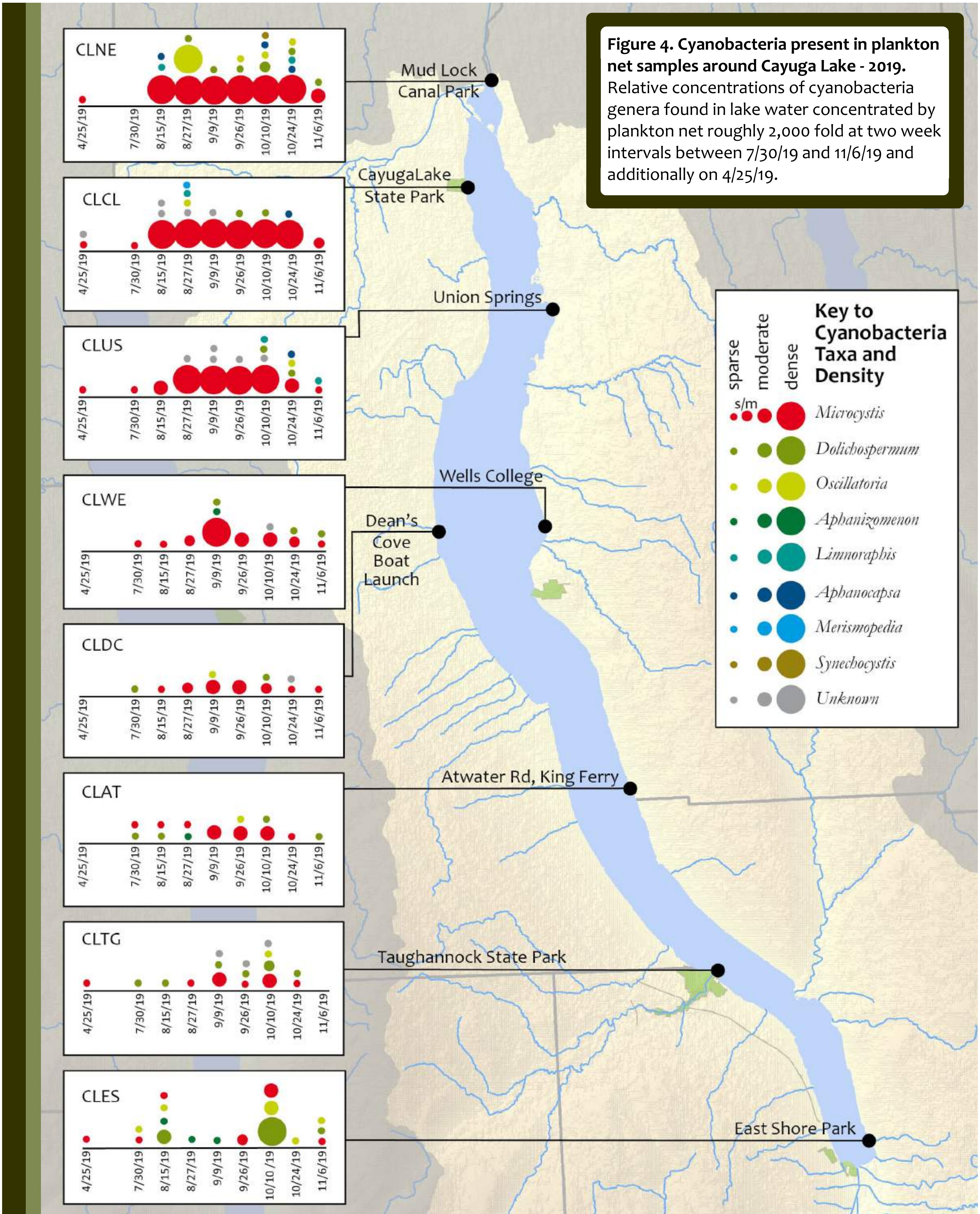


Figure 4. Cyanobacteria present in plankton net samples around Cayuga Lake - 2019. Relative concentrations of cyanobacteria genera found in lake water concentrated by plankton net roughly 2,000 fold at two week intervals between 7/30/19 and 11/6/19 and additionally on 4/25/19.

The first time we collected plankton net samples around the lake was April 25th of 2019, well before the beginning of the typical bloom season in July. *Microcystis*, the main microcystin toxin-producing genus that we find in cyanobacteria blooms on Cayuga Lake, was present in low concentrations in five of the eight plankton net samples (see Figure 4). All of the April 25th plankton net (concentrated) samples were tested for microcystin. Concentrated samples from three locations at the north end of the lake (CLUS, CLNE, CLCL) showed microcystin levels above the drinking water limit of 0.3 micrograms per liter. The plankton net sample collected at Cayuga Lake State Park (CLCL) had 12.96 micrograms of microcystin per liter even though *Microcystis* was only sparsely present (at about five colonies in a random drop compared to hundreds of colonies in a typical bloom sample pulled directly from the lake). Testing of additional plankton net samples over the summer supported a general correlation between microcystin toxin concentrations and relative abundance of *Microcystis* in concentrated samples under non-bloom conditions.

We sampled at the same eight locations around the lake again on July 30th and every 2 weeks thereafter until early November. Sometimes it was sunny, sometimes raining, sometimes windy and other times calm. Under all of these conditions, *Microcystis* was consistently present in most samples. As the season progressed, a pattern began to emerge in which cyanobacteria populations (and especially *Microcystis*) were consistently denser in plankton net samples collected at the north end of the lake (Figure 4).

We continued the plankton net study as lake temperatures cooled. On October 24, two of the sites at the north end of the lake still had dense concentrations of cyanobacteria in plankton net samples. As cyanobacteria concentrations subsided, we ended the bi-weekly sampling. We will, however, collect another sample a few months out to check in with what's going on in the lake.

Two especially interesting insights have come from our Cayuga Lake plankton project. One is that in concentrating cyanobacteria with the plankton net, we have observed that cyanobacteria are still sometimes producing microcystin toxin at significant levels, even under non-bloom conditions. Another insight from the project is aligned with volunteer HABs monitoring observations: populations of cyanobacteria appear to be denser at the northern end of Cayuga Lake than at the southern end even under non-bloom conditions (Figure 4).

In addition to the plankton project described here, in 2019 a number of volunteers have stepped forward to join the effort to observe phytoplankton around Cayuga Lake under non-bloom conditions. We currently have five volunteers with microscopes looking independently at drops of lake water that have been concentrated using a sieve or plankton net. We've started an online *iNaturalist* project for recording these observations, called "Cayuga Lake Phytoplankton." This online project pools phytoplankton observations from all three Cayuga Lake counties and allows volunteer microscopists to help each other as well as seek outside help in identifying new phytoplankton taxa they might find. The *iNaturalist* project is just getting started. It will serve as yet another way that volunteers can contribute to efforts to understand the multi-faceted and interdisciplinary problem of harmful algal blooms. Developing an increased awareness and record of the biological backdrop in which these HABs are occurring can bring new insights to the approaches that we take to address them.

Adrianna Hirtler

Monitoring Nutrients in the Cayuga Lake Watershed

The global problem of eutrophication has placed an emphasis on the role of nutrients in promoting cyanobacterial harmful algal blooms (HABs) [e.g. 2, 3]. One of these nutrients, phosphorus, is a factor the New York State Department of Environmental Conservation (NYSDEC) has correlated with HABs occurrence on Cayuga Lake [4]. Modeling in support of a phosphorus total maximum daily load (TMDL) for Cayuga Lake shows that 97% of the annual total phosphorus load entering the lake comes from tributary streams [5]. Monitoring nutrient inflows is vital to our understanding of nutrient-driven HABs given that tributary, non-point sources are the overwhelming contributor of phosphorus, and possibly nitrogen, that feed the foundation of the lake's food web [6, 7].

Tributaries that feed a lake correspond to catchment zones or drainage areas. Like a jigsaw puzzle, the Cayuga Lake watershed is comprised of drainage areas that vary in size, gradient and land cover. In 2013, an intensive 9-month monitoring effort by the Upstate Freshwater Institute (UFI) as part of the Cayuga Lake Modeling Project (CLMP) included five major tributaries that represent 61.0% of the Cayuga Lake watershed: Cayuga Inlet (107 mi^2), Fall Creek (127 mi^2), Six Mile Creek (47.7 mi^2), Taughannock Creek (69.0 mi^2) and Salmon Creek (88.8 mi^2) (Chart 1). The CLMP excluded 292.7 mi^2 or 39.0% of the Cayuga Lake watershed drainage from direct measurement of phosphorus, deeming this area "unmonitored tributaries" [7]. Collectively, the scores of streams that make up this remaining 39.0% of the watershed area are significant to our understanding of whole-lake nutrients.

Click on a monitoring location to view the monitoring set and all available data in CSI's online public database!

Monitored Sub-Watersheds of Cayuga Lake

	Nutrient Monitoring Location	Sub-Watershed Area (mi^2)
1	Yawger Creek Mouth	15.8
2	Williamson Creek Mouth	1.4
3	Great Gully Creek Mouth	15.8
4	Dean's Creek Mouth	2.7
5	Paines Creek Mouth	15.1
6	Mill Creek Mouth	2.9
7	Town Line Creek Mouth	1.3
8	Trumansburg Creek Mouth (Camp Barton)	13.7
9	Taughannock Creek Mouth (Taughannock Falls)	69.0
10	Salmon Creek Mouth	88.8
11	Fall Creek Mouth (Cayuga Street Bridge)	127
12	Cayuga Inlet Mouth (Cass Park)	107
13	Six Mile Creek Mouth (Plain Street)	47.7

Land Cover (%)

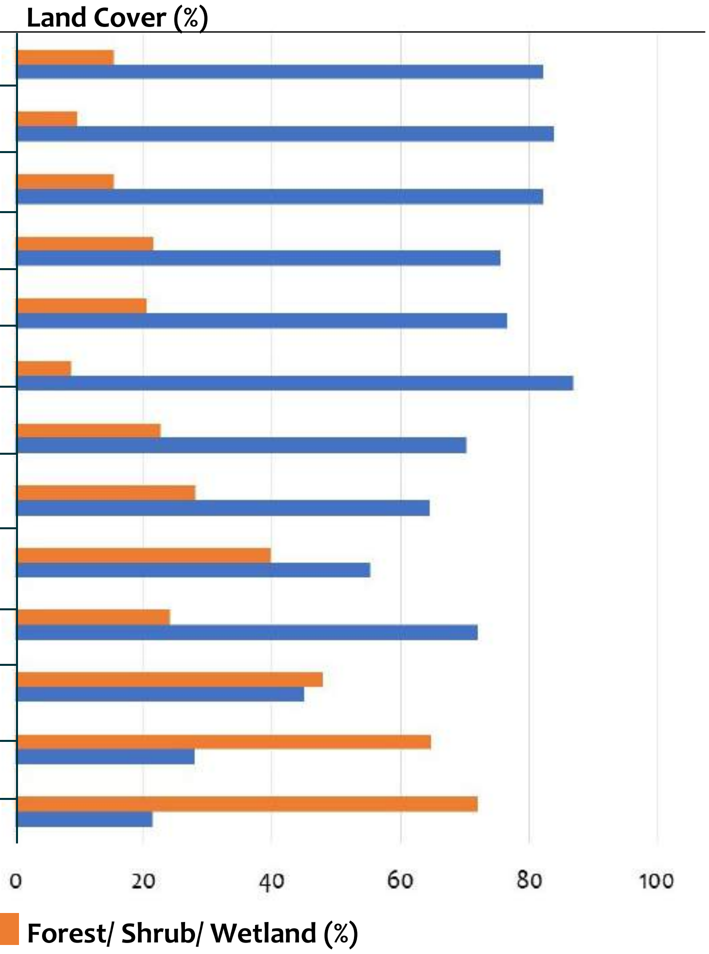


Chart 1. Nutrients are monitored near the mouths of 13 Cayuga Lake tributaries; actual monitoring location name found in CSI online database shown in parentheses. Land cover is broken into two categories: agricultural % (NLCD 2011 81, 82) & forest/ shrub/wetland % (NLCD 2011 41, 42, 43, 52, 71, 90, 95) [8]. *Model My Watershed* was used to delineate sub-watersheds and corresponding land cover [9].

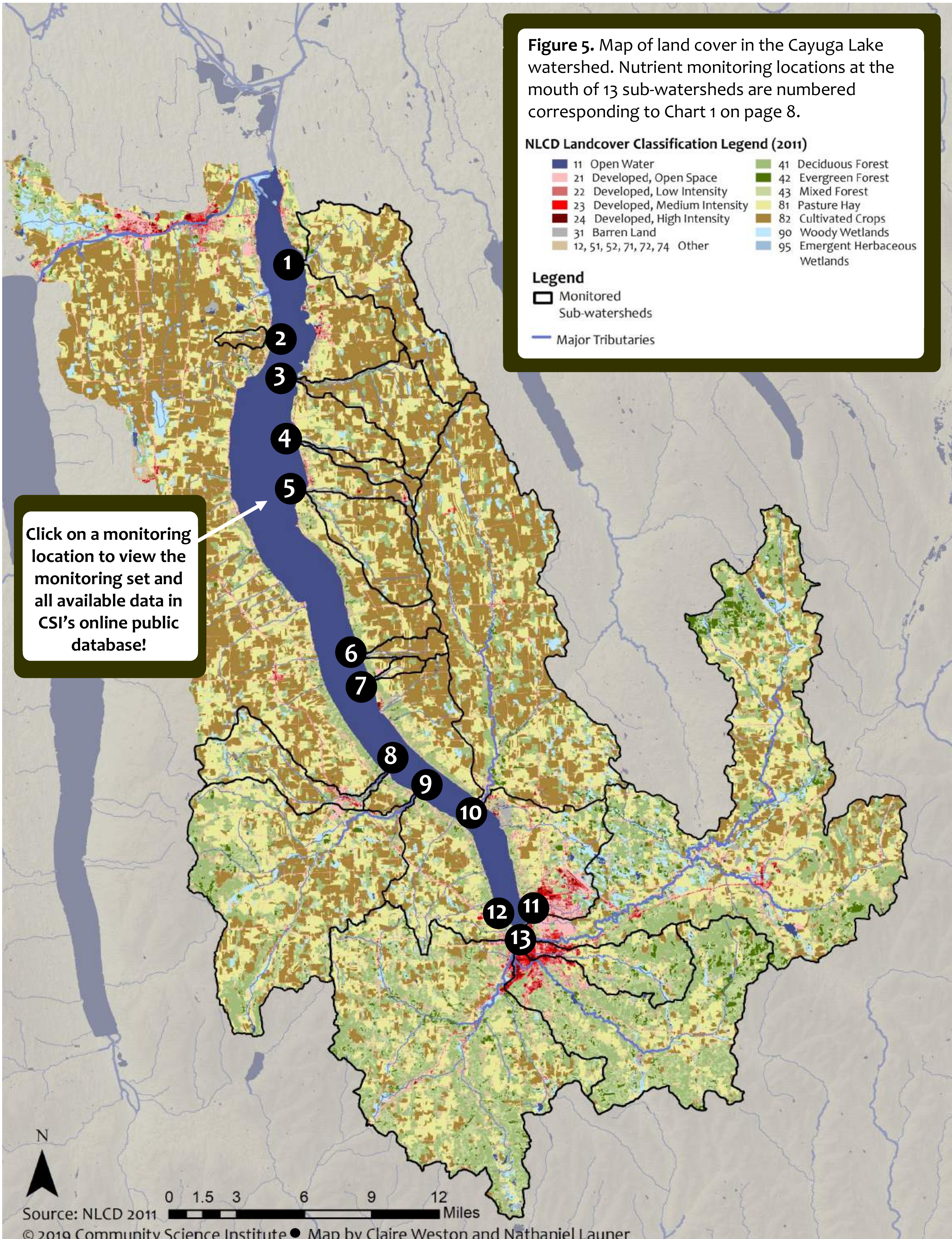


Figure 5. Map of land cover in the Cayuga Lake watershed. Nutrient monitoring locations at the mouth of 13 sub-watersheds are numbered corresponding to Chart 1 on page 8.

This article looks at nutrient data from locations near the mouths of 13 streams that have been monitored by CSI and our volunteer partner groups from three to 17 years, depending on the stream (http://database.communityscience.org/monitoringregions/1). Of these thirteen mouth locations, five represent the drainage areas covered in CLMP's 2013 study and eight represent 68.8 mi^2 or 23.5% of the "unmonitored tributaries" referenced in the CLMP. As shown in Chart 1, the watersheds of northern streams range from 55% to 84% agricultural land use. Six Mile Creek, Fall Creek, and Cayuga Inlet—the three big drainage basins in the south—exhibit significantly greater forest/shrub/wetland coverage than the northern tributaries.

CSI has been tracking tributary nutrients for almost two decades. "Nutrients" is a catchall term for different forms of phosphorus and nitrogen. The focus on phosphorus by state monitoring efforts is based on the assumption that phosphorus is the limiting nutrient for freshwater autotrophs such as algae and cyanobacteria (HABs). CSI tracks two major forms of phosphorus: total phosphorus (TP) and soluble reactive phosphorus (SRP). Soluble reactive phosphorus is considered to be almost 100% bioavailable [10]. Total phosphorus is a measure of all forms of dissolved, particulate, organic and inorganic phosphorus.

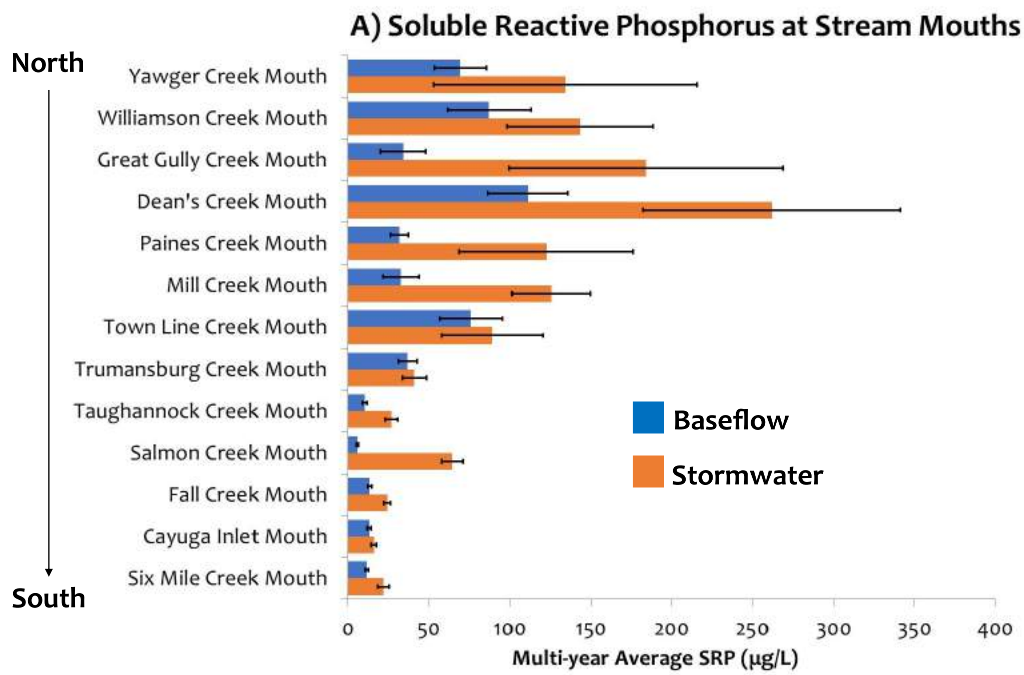
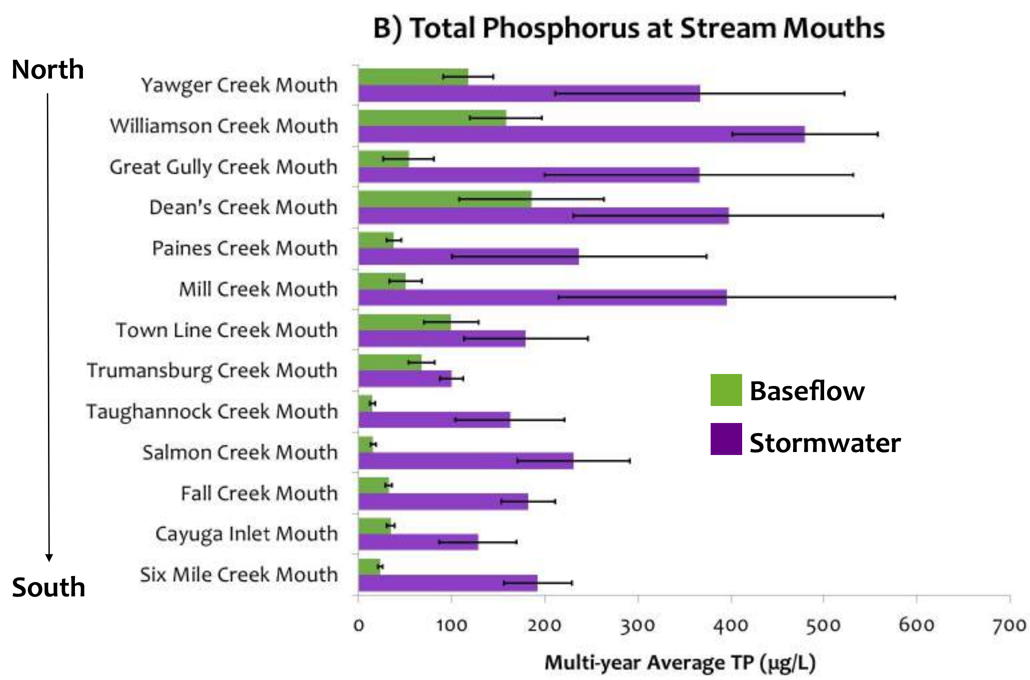


Figure 6. Phosphorus at stream mouths. Side-by-side bars in the plot represent flow regime (base flow and stormwater). The error bars represent one standard error of the mean. Number of stream mouth samples ranged from 3 to 45.

A) Multi-year averages of soluble reactive phosphorus (SRP) concentrations at thirteen stream mouths.



B) Multi-year averages of total phosphorus (TP) concentrations at thirteen stream mouths. Note that total phosphorus is influenced by phosphorus-containing sediment particles, which are elevated under stormwater conditions.

Another common metric for surface water nutrient monitoring is total nitrogen (TN). TN is the sum of inorganic nitrogen (nitrate + nitrite, often referred to as NOx compounds) and total Kjeldahl nitrogen (TKN), which refers to the analytical method for deriving ammonia and organic nitrogen. Research suggests that various cyanobacteria taxa can assimilate nitrogen based on available source, even inorganic forms like ammonium and nitrate, following different pathways [11-13].

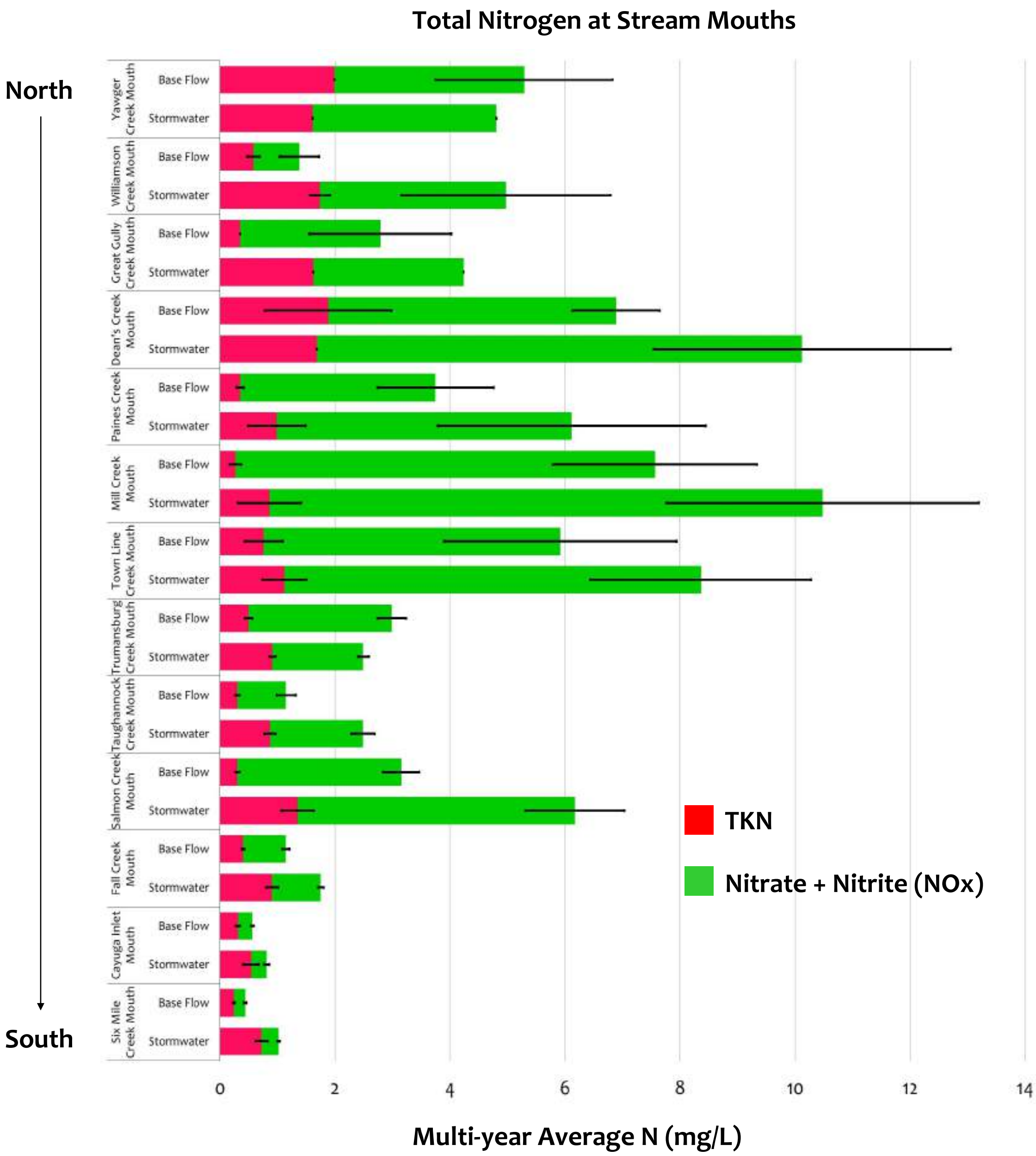


Figure 7. Multi-year average concentration of total nitrogen (TN) at the mouths of 13 streams, calculated as the sum of NOx and TKN. Side-by-side stacked bars represent base and storm-water flow regimes for each location. The error bars represent one standard error of the mean where n>1 . Number of stream mouth samples ranged from 1 to 44.

As shown in Figures 6 and 7, CSI categorizes stream nutrient data under two flow regimes: "base flow" and "stormwater." Base flow conditions assume that groundwater is the largest contributor to stream flow. A monitoring event is qualified as stormwater if daily mean discharge, as indicated by a USGS gaging station, is at least twice the historic daily median. Most streams are not gaged, and volunteer field observations of turbulence and turbidity are used to assess whether the stream was sampled under stormwater conditions.

Figures 6 and 7 show that nutrient concentrations tend to be greater at the mouths of northern streams, which drain more heavily agricultural areas, than at the mouths of southern streams, which drain less farmland and more forest/shrub/wetland areas. There also appear to be relationships between flows and nutrient levels, with higher flows producing greater concentrations of some forms of nutrients.

An early lesson in basic hydrology is that all land uses influence water quality. CSI's monitoring programs represent an ongoing inquiry into this intuitive connection between the terrestrial and the aquatic, and we can employ statistics to help tell the story of how nutrients relate to land cover.

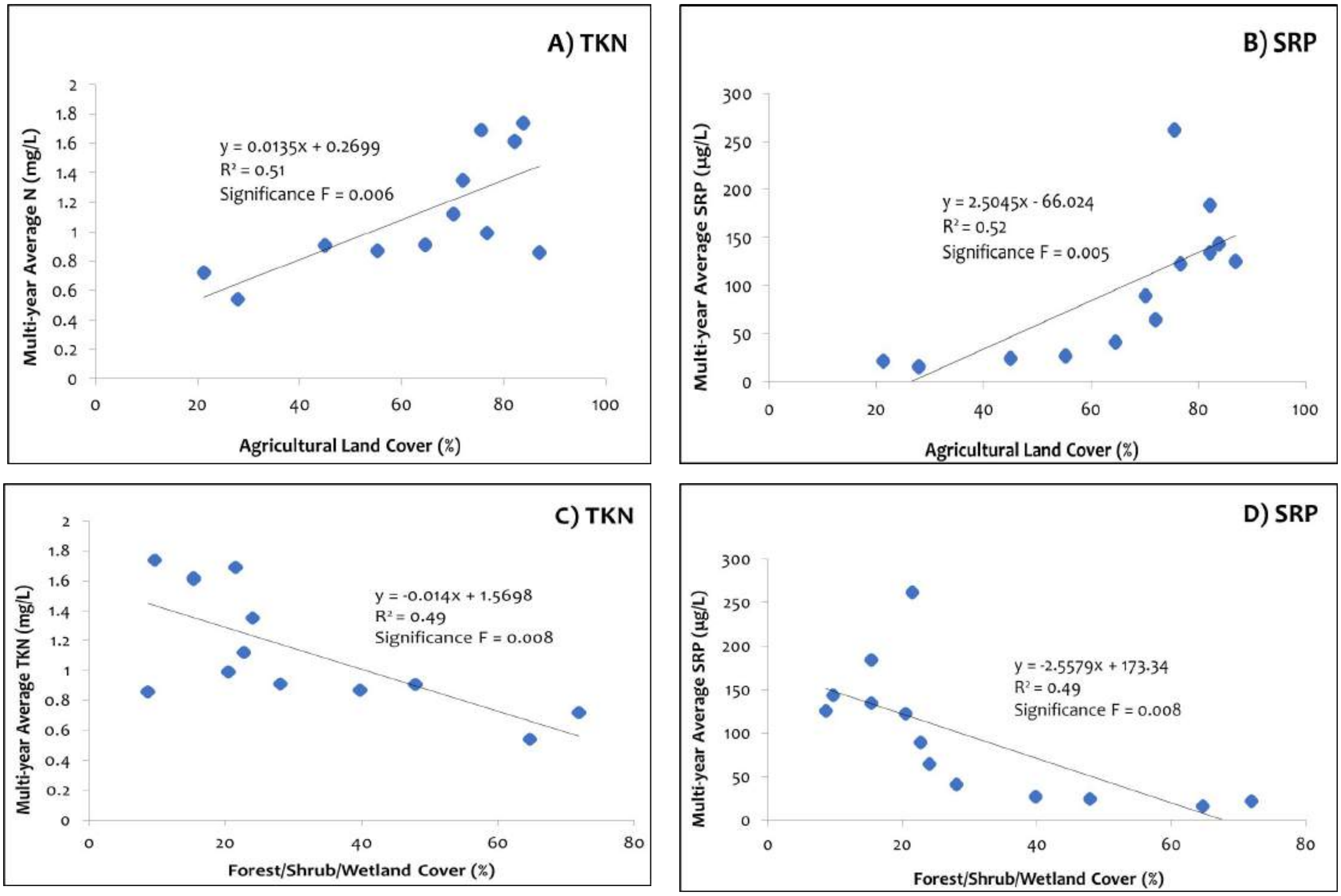


Figure 8. Simple linear regressions of multi-year average stormwater concentrations at stream mouths of two nutrient forms, TKN and SRP, against land cover. **A)** TKN (mg/L) versus agricultural cover (%); **B)** SRP (µg/L) versus agricultural cover (%); **C)** TKN (mg/L) versus forest/shrub/wetland cover (%); **D)** SRP (µg/L) versus forest/shrub/wetland cover (%).

The statistical analyses presented in Figures 8 A and B confirm that there is a positive correlation between agricultural land cover and stormwater nutrient levels. Conversely, Figures 8 C and D show that there is a negative correlation between forest/shrub/wetland cover and stormwater nutrient concentrations. While TKN and SRP showed the strongest stormwater correlations with land cover, similar, albeit weaker, correlations were also observed for NOx and TP.

The data presented above suggest that land and water are inextricably tied: topography determines where water flows; as water is pulled across the landscape by gravity, it picks up whatever is in its path, finding its way to drains, ditches, streams, and lakes. The data and trends presented here reflect the dynamic interactions within watersheds. Year to year, CSI's volunteer monitoring networks continue to provide data that grows our understanding of both nutrients and, potentially, of HABs, as well. Through these efforts, we and our volunteer partners hope to provide the community with a record of local water quality, encapsulating and elucidating the complicated relationships between land and water.

Noah Mark

Phosphorus in Peer Review

An article describing soluble reactive phosphorus (SRP) in Cayuga Lake tributary streams was recently published in the peer-reviewed journal *Water*. Entitled "Long-Term Study of Soluble Reactive Phosphorus Concentration in Fall Creek and Comparison to Northeastern Tributaries of Cayuga Lake, NY: Implications for Watershed Monitoring and Management," it is based on two long-term data sets. One set of data was collected by Cornell Professor Emeritus David Bouldin and his students in the 1970s and 2000s. The other data set was collected by CSI and our Direct Streams and Fall Creek volunteer partner groups from, respectively, 2009 to 2018 and 2002 to 2018. The article draws two significant conclusions. First, the level of SRP, which is bioavailable to fuel weed and algae growth including HABs, has remained constant in Fall Creek over the past four decades despite changes in land use, regulations, and waste management. A second conclusion is that Fall Creek and other sub-watersheds that drain into the southern end of Cayuga Lake are not representative of phosphorus levels in the Cayuga Lake watershed as a whole. Rather, effective watershed-wide nutrient management needs to take into account significantly higher levels of phosphorus and nitrogen identified by CSI-volunteer monitoring partnerships in tributary streams draining predominantly agricultural areas that comprise the northern ~40% of the Cayuga Lake drainage, as described by Noah Mark in this issue. The article is available to read and download at the journal's website:

www.mdpi.com/2073-4441/11/10/2075

or

under *Publications* on CSI's website:

www.communityscience.org

Stephen Penningroth

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Photo of a bloom near Aurora on July 13, 2019 sampled by HABs Harrier and Quadrant Leader Christy VanArnum

Help Monitor HABs on Cayuga Lake

You can support the effort to understand these harmful blooms and protect Cayuga Lake. To learn more about blooms and how to recognize them visit www.dec.ny.gov or www.communityscience.org.

If you see a suspicious algal bloom,
AVOID IT and report it.
Keep kids and pets away!

Quickly report it on CSI's website at www.communityscience.org
or by email at habshotline@gmail.com

Join the Cayuga Lake HABs Monitoring Program as a HABs Harrier volunteer and help monitor blooms on Cayuga Lake. Anyone is welcome to volunteer! HABs Harriers do the following:

- Attend a two hour HABs identification and sampling workshop in June.
- Survey assigned lengths of shoreline once a week, mid-July through September.
- Collect HABs samples and transport them to CSI lab for further analysis.
- Be available to respond to HABs sightings reported by members of the public.

If you can't volunteer, but you still want to help, you can!

- Learn about HABs and how to recognize blooms on CSI's website
- Donate to CSI to support the Cayuga Lake HABs Monitoring Program

For more information about volunteering contact:

Community Science Institute
info@communityscience.org
(607) 257-6606
www.communityscience.org

Cayuga Lake Watershed Network
programs@cayugalake.org
(607) 319-0475
www.cayugalake.org

Community Science Institute

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NYSDOH-ELAP #11790

EPA Lab Code NY01518

Partnering with Communities to Protect Water Since 2002

This Fall 2019 issue of the Water Bulletin highlights the ability of the Community Science Institute to respond to emerging threats by collecting regulatory quality data capable of informing long-term management strategies. In the Cayuga Lake watershed, this would not be possible without each of the more than 150 dedicated volunteers who partner with CSI to monitor Cayuga Lake and its tributary streams.

The threat harmful algal blooms (HABs) pose to Cayuga Lake shows no sign of abating. CSI is leading the effort to gain a better understanding, through the collection of long-term data sets, of when and where blooms occur and the types of toxicity they manifest. Water is an invaluable natural resource that fundamentally shapes the landscape, heritage, economy and community of this region. CSI is uniquely positioned to help protect the diverse aquatic ecosystems on which our human communities ultimately depend.

You can support our efforts by volunteering, by renewing your Community Science Institute membership or by becoming a new member today. Together, we can take action to understand and protect our water—now and in the future.

With sincere thanks,

The CSI Team

Membership Levels

- ☐ $25 (Creek)
- ☐ $50 (Stream)
- ☐ $100 (River)
- ☐ $250 (Lake)
- ☐ $500 (Estuary)
- ☐ $1000 (Watershed)
- ☐ > $1000 (Ocean)
- ☐ Other $________

HELP PROTECT CLEAN WATER! DONATE TODAY

Send contributions to Community Science Institute, 283 Langmuir lab, 95 Brown Rd/ Box 1044, Ithaca, NY 14850

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