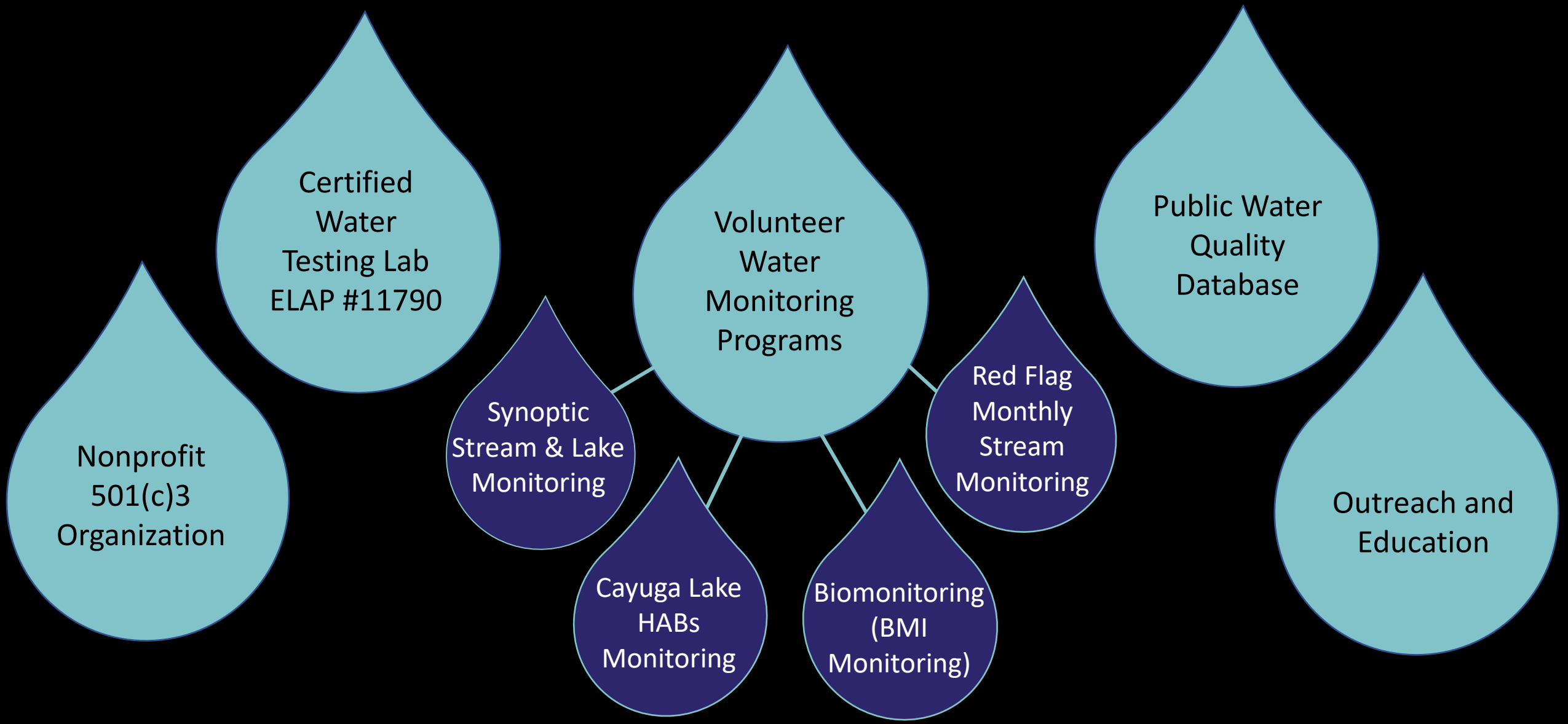
Cyanobacterial growth on Cayuga Lake:

what we do and don't know about "HABs"

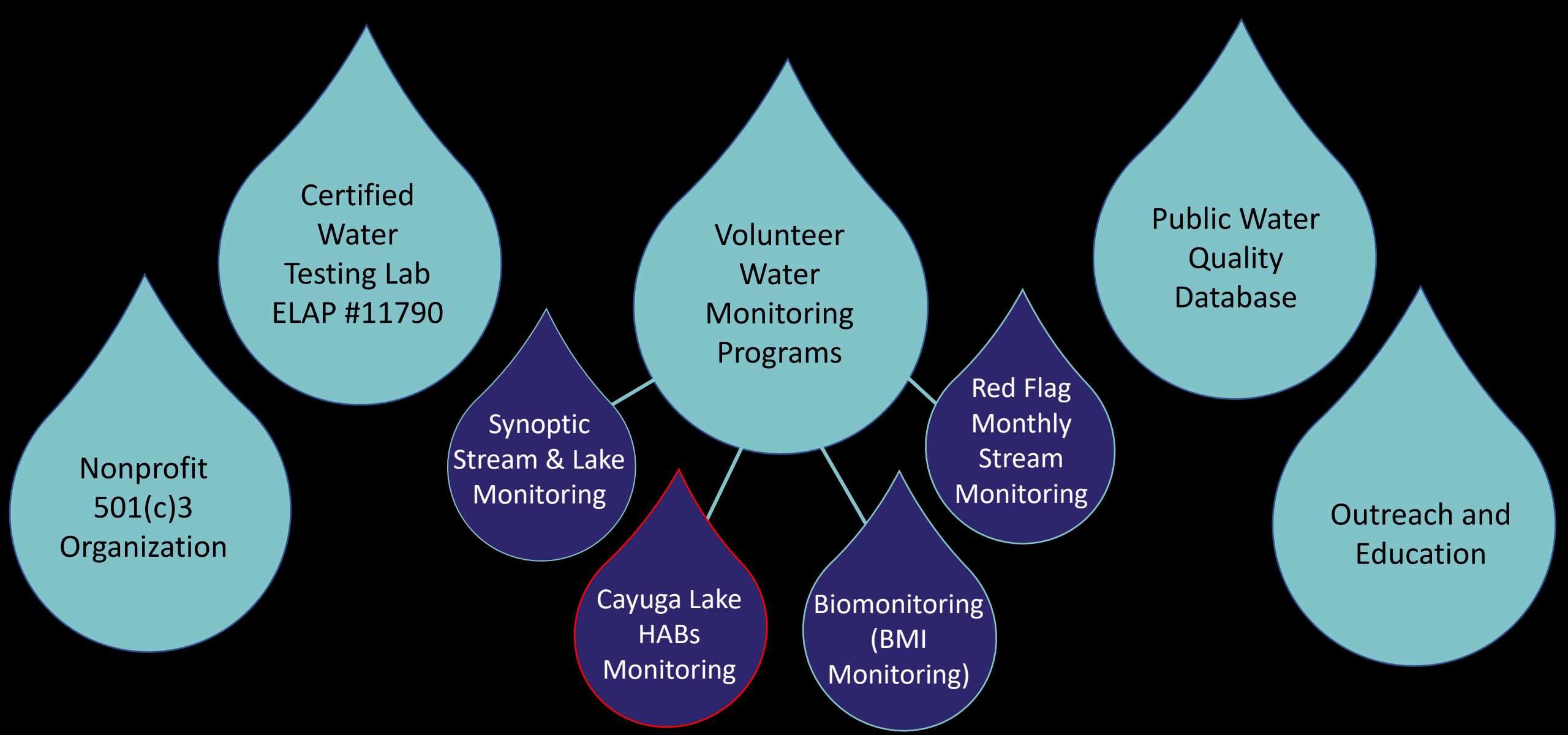
Grace Haynes
Outreach and Programs Coordinator
Cayuga Lake HABs Monitoring Program Coordinator
Community Science Institute (CSI)

Photo by Holly Davidson, CSI HABs volunteer



Community Science Institute's Mission

To partner with community-based volunteer groups to better understand and protect local streams and lakes by collecting and disseminating scientifically credible, regulatory-quality data that inform long-term, sustainable management strategies.



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Outline

What is a “harmful algal bloom”?

- Types of HABs
- Cyanobacteria

Impacts of freshwater HABs

- Impacts on humans
- Impacts on aquatic life

HABs on Cayuga Lake

- CSI’s Cayuga Lake HABs Monitoring Program
- Cayuga Lake HABs patterns

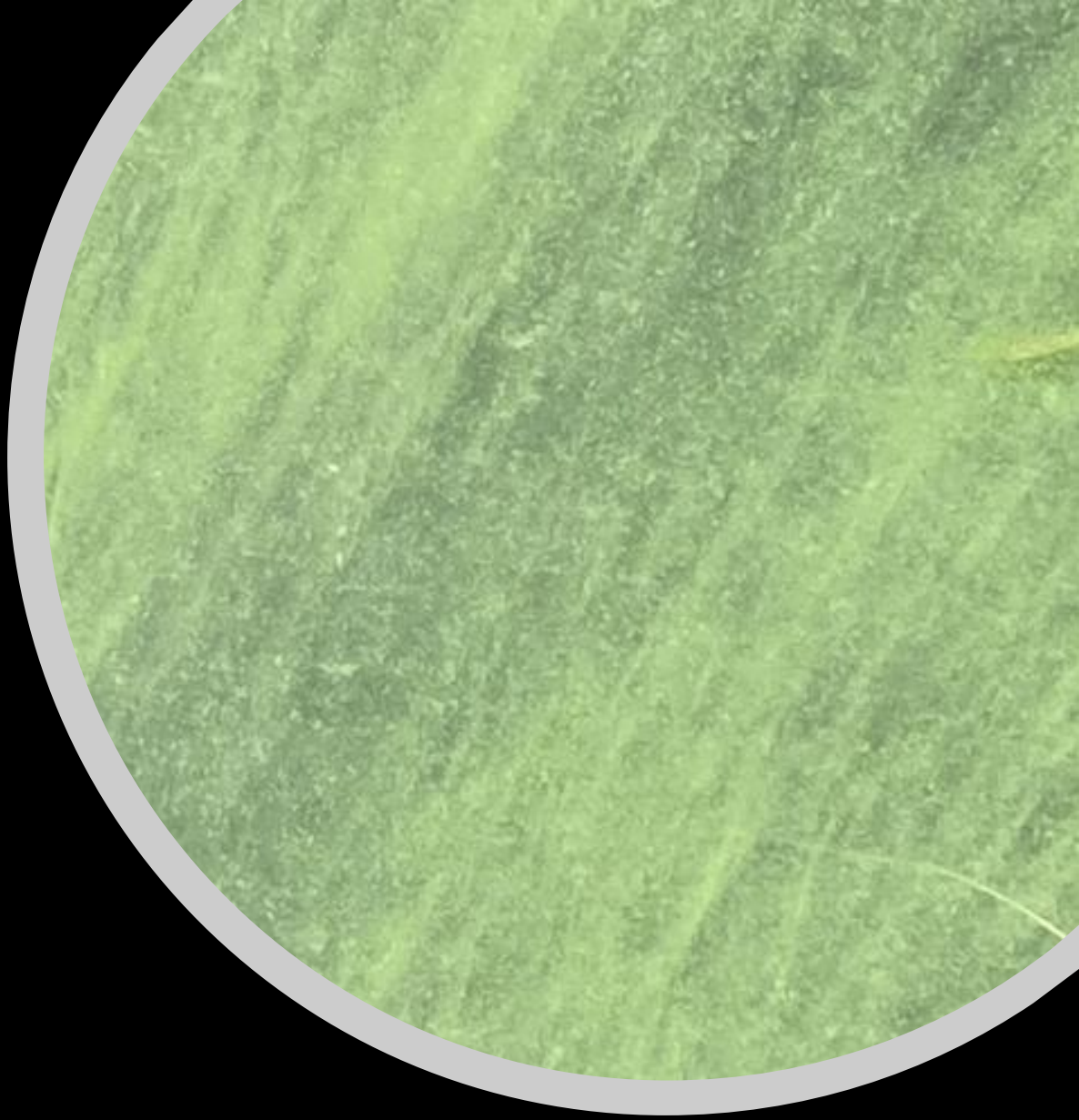
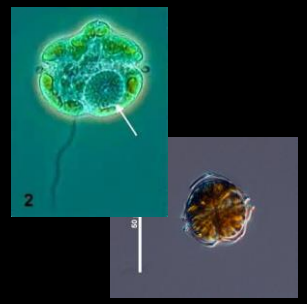


Photo by Jeanne Sullivan, CSI HABs volunteer

What is a “Harmful Algal Bloom”?

“Harmful algal bloom” is largely a misnomer!

Dinoflagellates

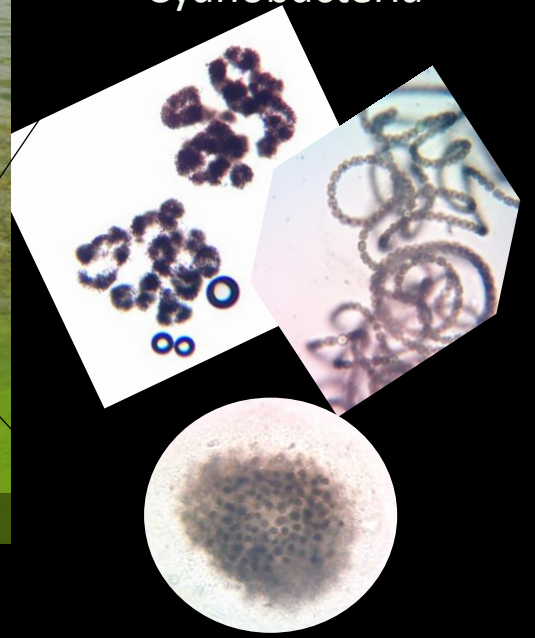


Diatoms

Marine “harmful algal blooms”
Aka “red tides”

Freshwater “harmful algal blooms”

Cyanobacteria



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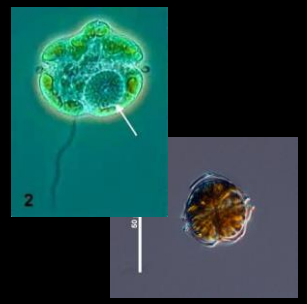


Diatoms

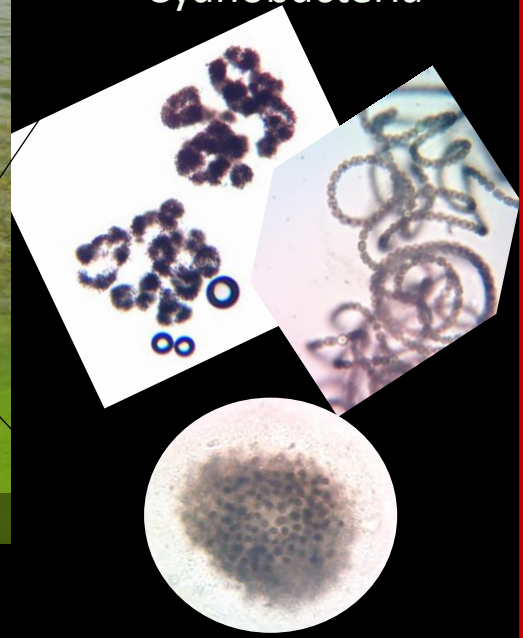
Marine “harmful algal blooms”

Photo by Flickr User AJC1

Freshwater “harmful algal blooms”

Photo by Joni Dropkin, CSI HABs volunteer

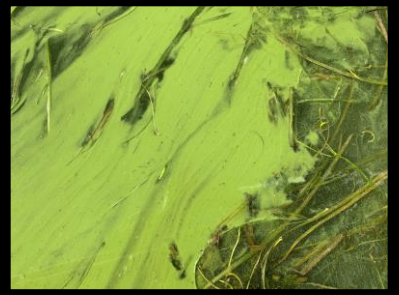
Cyanobacteria



What is a freshwater “Harmful Algal Bloom”?

Photo by Ken Riemer, CSI HABs volunteer

Cyanobacteria



Photos by Holly Davidson and Joni Dropkin, CSI HABs volunteers

What are cyanobacteria?

A LITTLE HISTORY LESSON

How cyanobacteria changed the world

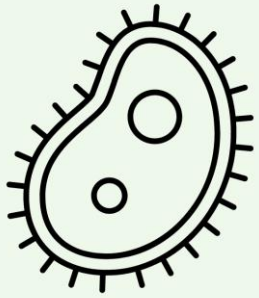
~4.5B YEARS AGO

A LITTLE HISTORY LESSON

How cyanobacteria changed the world

~4.5B

~3.8B YEARS AGO



A LITTLE HISTORY LESSON

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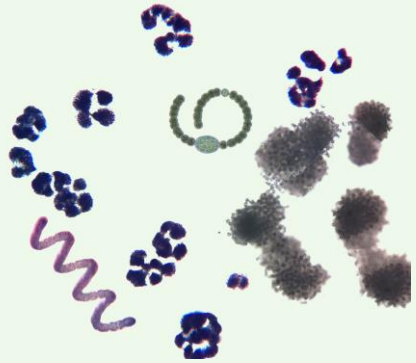
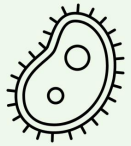


~2.7B YEARS AGO

~4.5B

~3.8B



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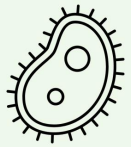
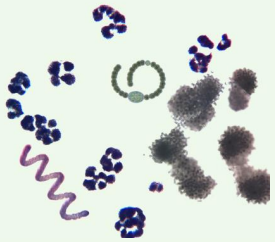
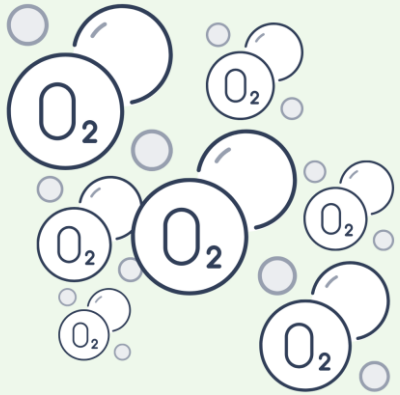


~3.8B



~2.7B

~2.4 - 2.1B YEARS AGO



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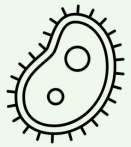
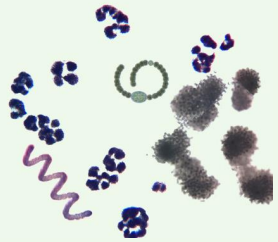
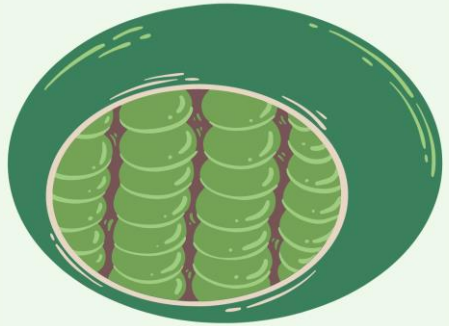




~2.7B

~2.4 - 2.1B



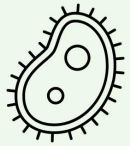
>1B YEARS AGO

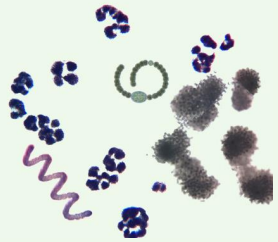
A LITTLE HISTORY LESSON

How cyanobacteria changed the world

~4.5B

~3.8B

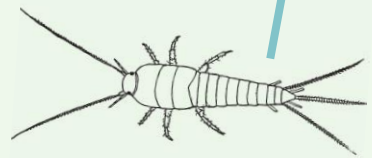




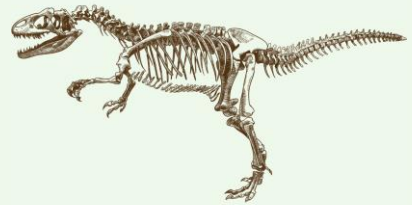
~2.7B

~2.4 - 2.1B

>1B



~480M YEARS AGO

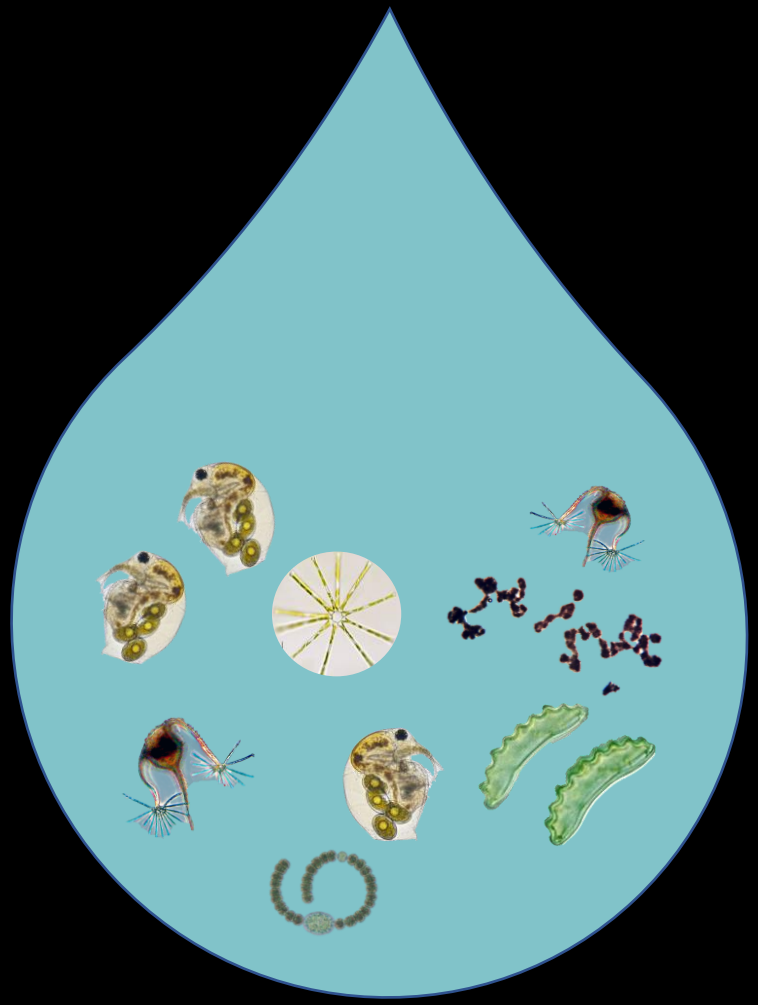


~200M YEARS AGO

~250,000 YEARS AGO

Cyanobacteria

Part of a healthy, balanced , normal freshwater ecosystem



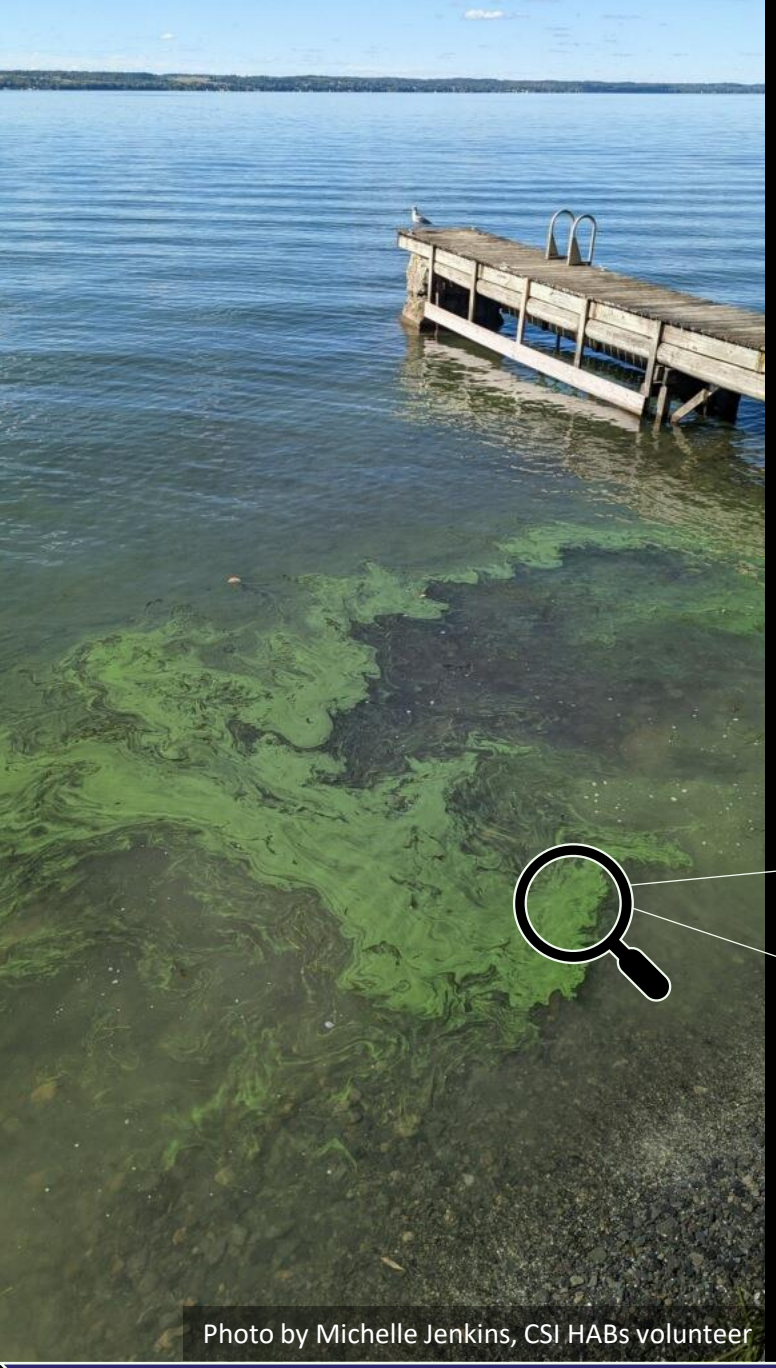
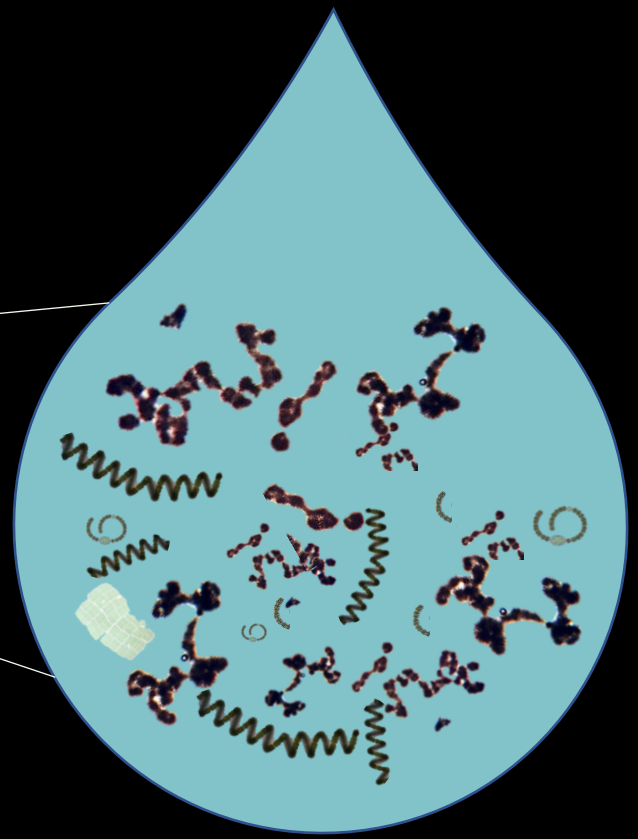


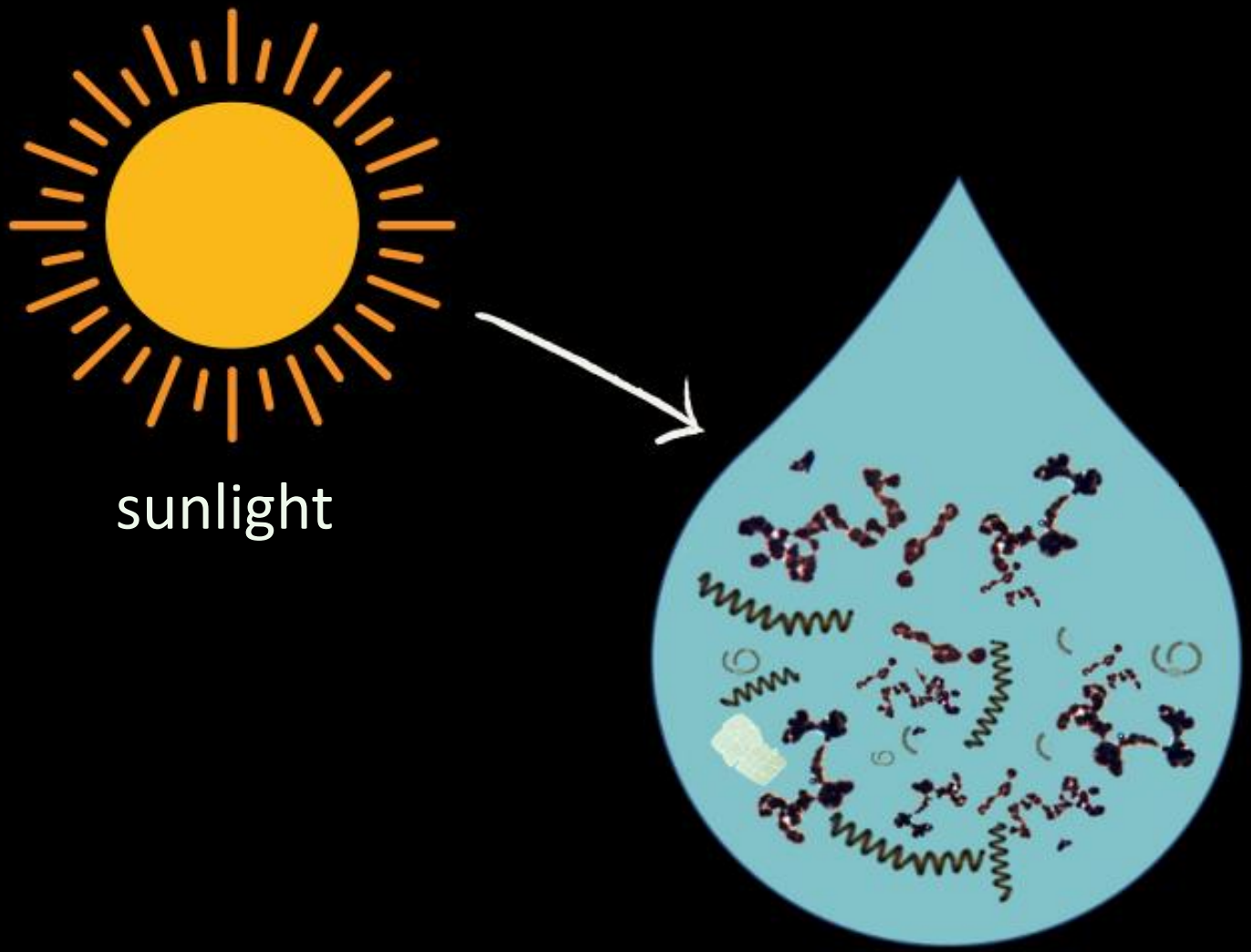
Photo by Michelle Jenkins, CSI HABs volunteer

When do they become “harmful”?

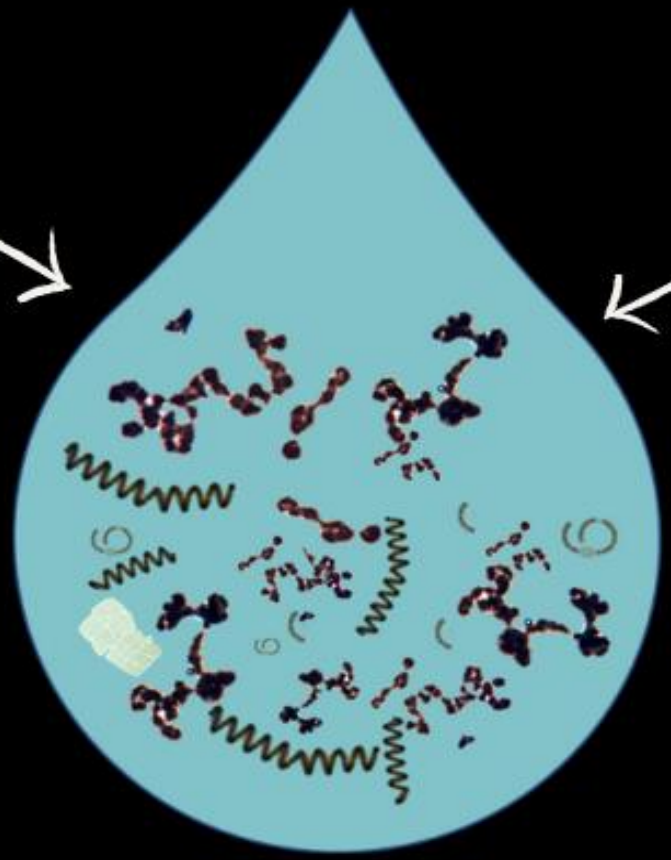
A “HAB” is an explosive population growth of these cyanobacteria, which may produce toxins



What causes blooms?


sunlight

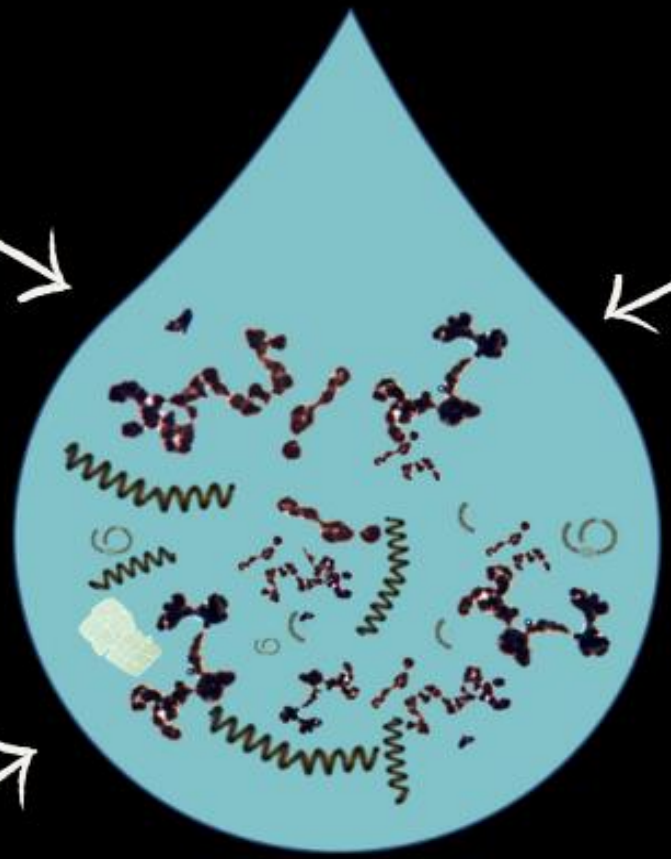
sunlight

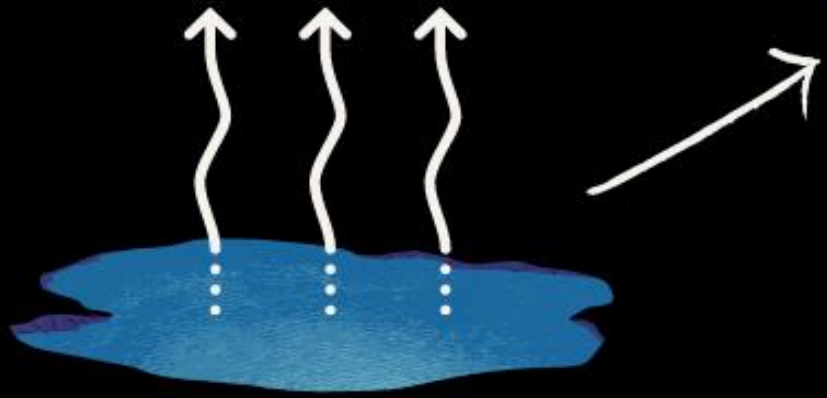


still conditions

sunlight

still conditions

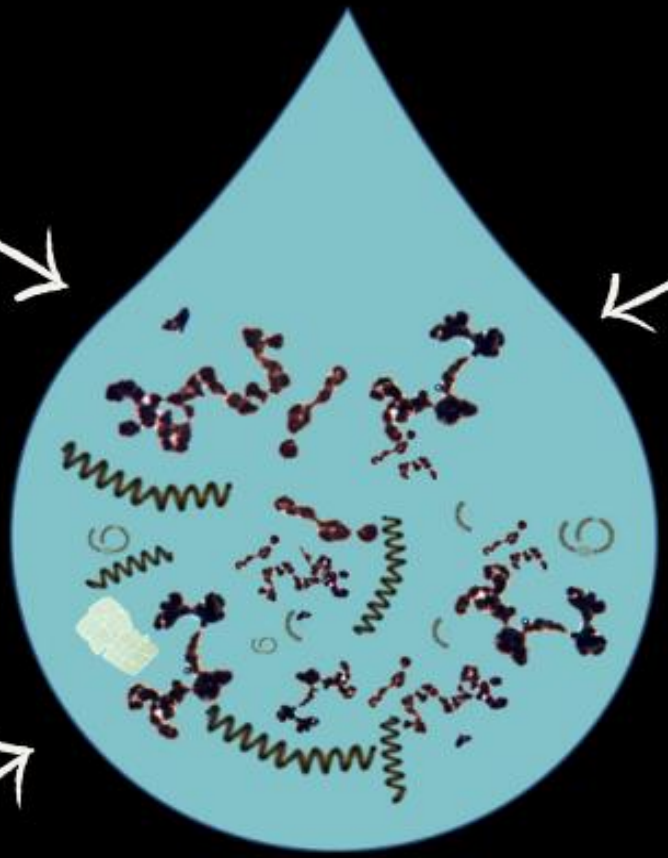


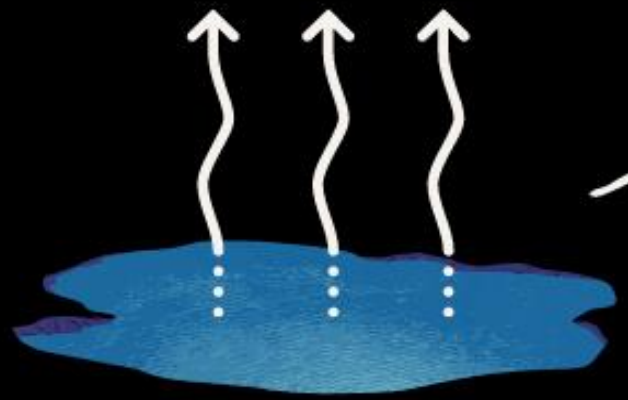


increased temperature

sunlight

still conditions





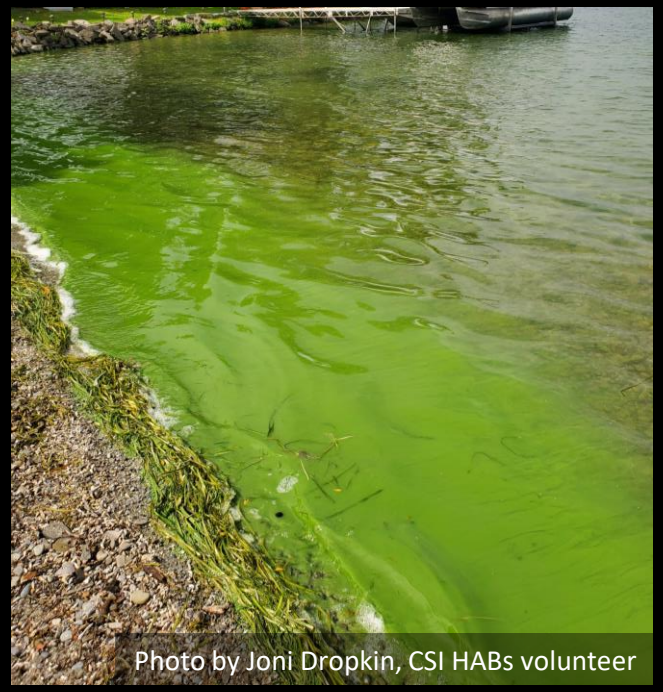
increased temperature

15
P
Phosphorus
30.974

7
N
Nitrogen
14.006

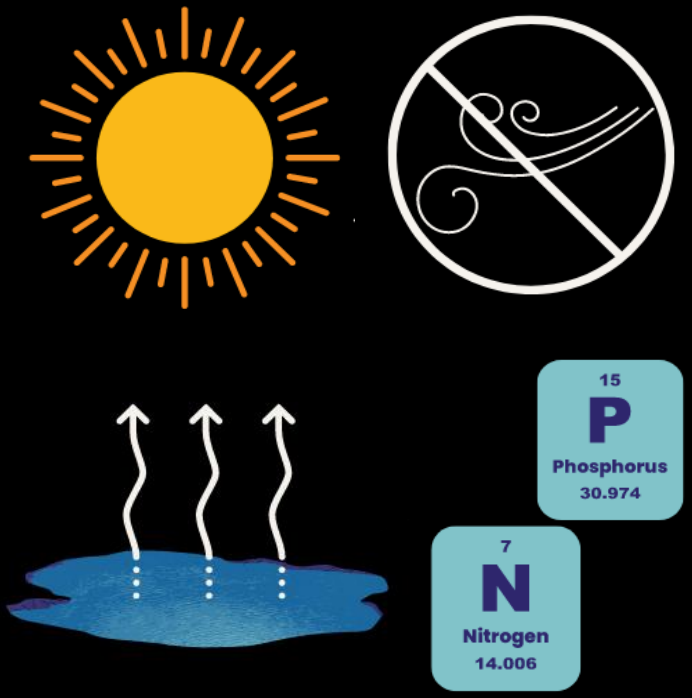
nutrients

What is a Harmful Algal Bloom?



Cyanobacteria

First photosynthesizers



Grow in certain conditions

Who cares if their populations are exploding?

Cyanobacteria produce chemical compounds

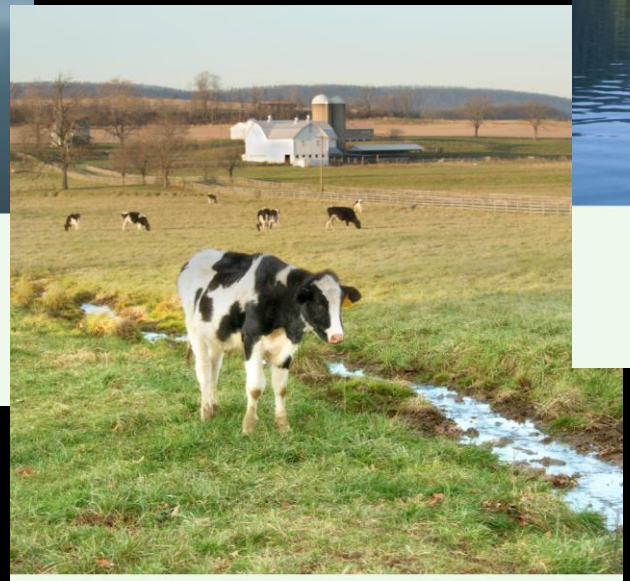
Beneficial compounds	Harmful compounds ("cyanotoxins")
• Anti-cancer drugs • Anti-viral drugs (can help treat HIV) • Antibacterial drugs	• Liver toxins • Neurotoxins

Namikoshi and Rinehart 1996, Singh et al. 2011

Impacts on humans

DRINKING WATER

CONTACT RECREATION
(swimming, fishing, kayaking)

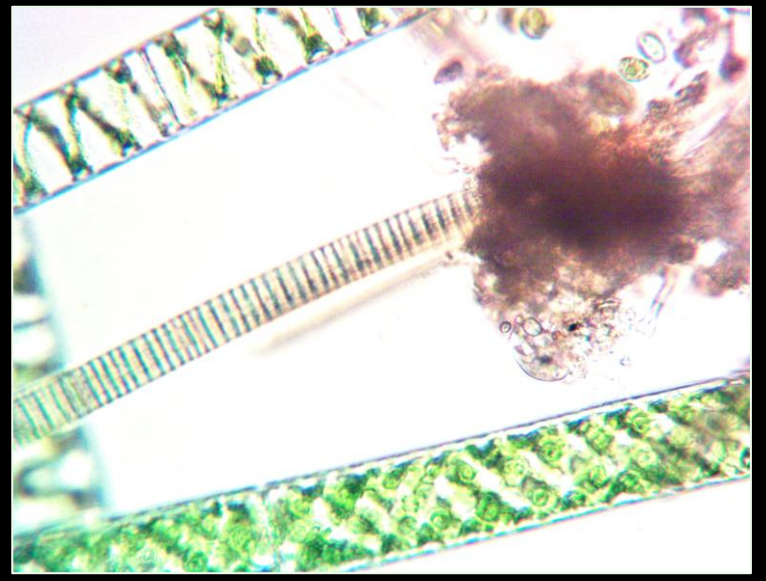


LIVESTOCK

ECONOMICS

Broad impacts on the ecosystem

Anoxic conditions



Out-competing other primary producers

Carmichael and Boyer 2016, Bownik 2016, Babica et al. 2006

Cyanobacteria produce chemical compounds

Beneficial compounds	Harmful compounds ("cyanotoxins")
• Anti-cancer drugs • Anti-viral drugs (can help treat HIV) • Antibacterial drugs	• Liver toxins • Neurotoxins

microcystin toxin

Namikoshi and Rinehart 1996, Singh et al. 2011

Cyanotoxin / Zooplankton interactions

copepods

water fleas

Microcystin's possible impacts:

- Mortality
- Decreased digestion
- Decreased motility

Bownik 2016

Cyanotoxin / crustacean interactions

red swamp crawfish

Mollusks and crustaceans seem to be more tolerant of microcystin concentrations, but this is variable

Bownik 2016

Cyanotoxin / Amphibian interactions

the green frog

Microcystin's possible impacts:

- Altered enzyme activity
- Delayed hatching
- Susceptibility to parasites

Buss et al. 2019, Mehinto et al. 2021

Cyanotoxin / Fish interactions

Rainbow trout

Brown trout

Microcystin's possible impacts:

- Skeletal malformations
- Oxidative stress
- Increased heart rate

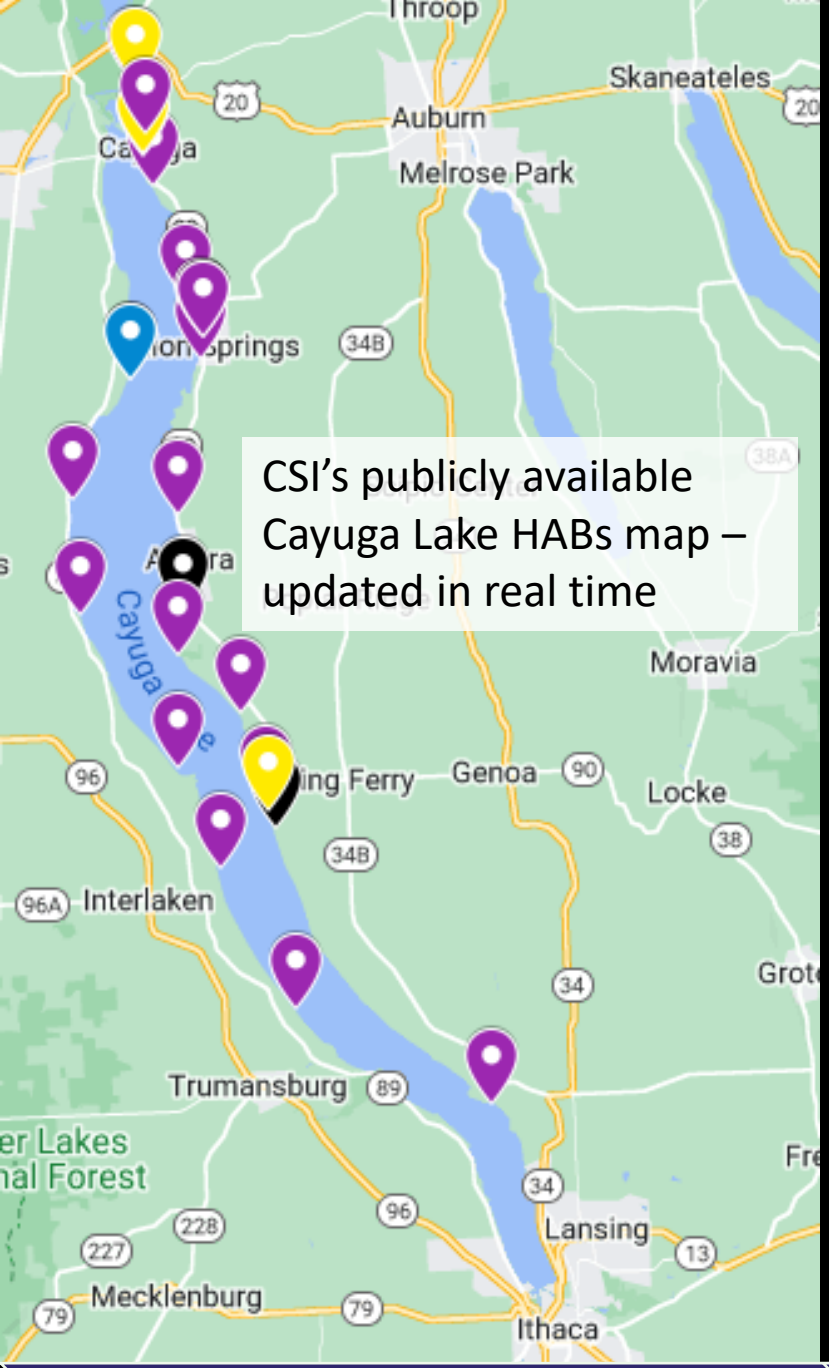
Mehinto et al. 2021, Best et al. 2001, Gélinas et al., 2012

Impacts of Freshwater HABs

Cyanotoxins

Threats to humans

Threats to wildlife



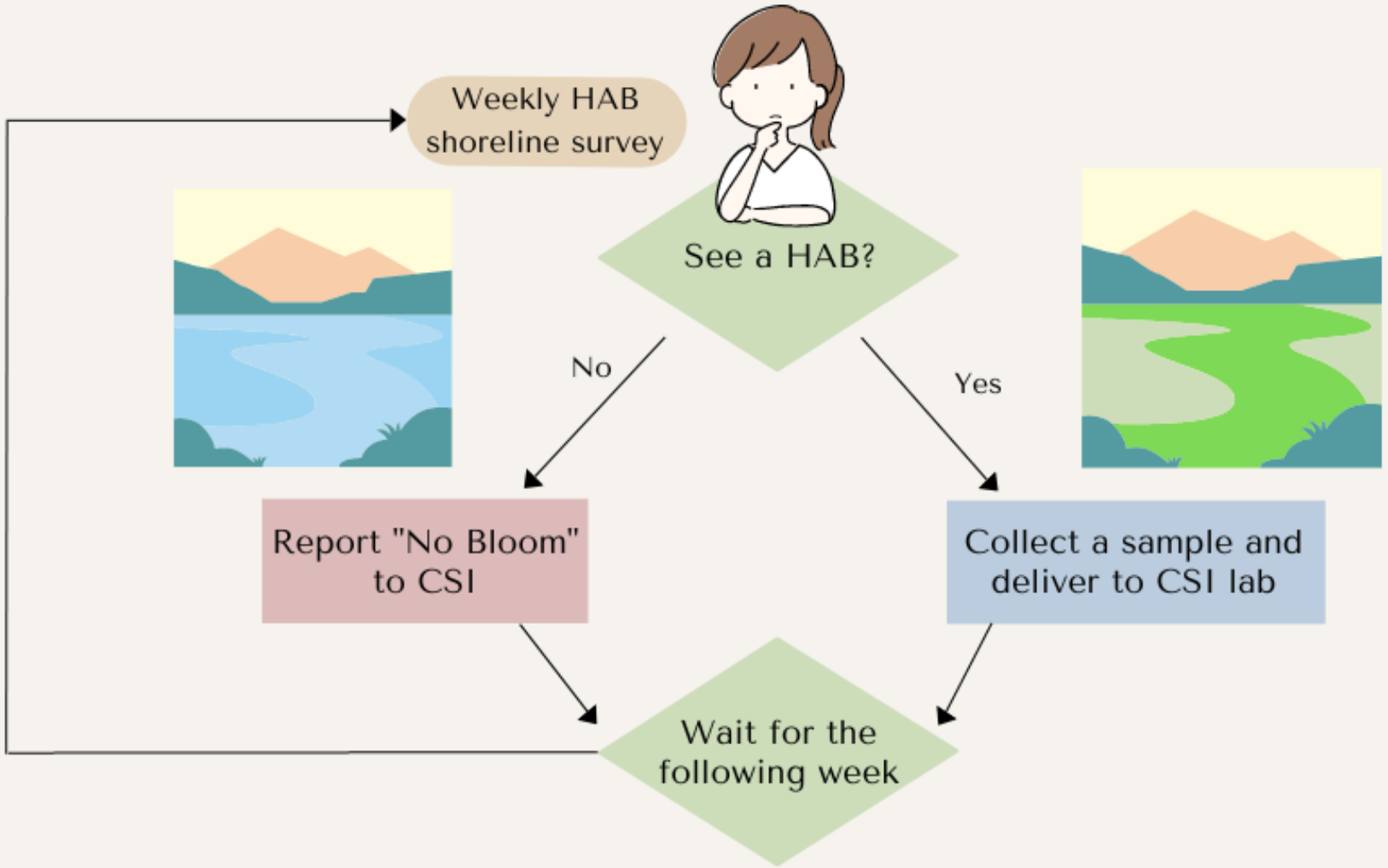
CSI's publicly available Cayuga Lake HABs map – updated in real time

HABs on Cayuga Lake

CSI's Harmful Algal Bloom Monitoring Program

- 5 years and counting
- 146 volunteers
- Most thorough HABs monitoring in New York State

HAB "HARRIER" DUTIES



Note: “harrier” comes from the verb harry, to harass or attack repeatedly. As in “a harrier hawk attacks small game.” This term was applied to our HABs volunteers to describe their vigilance.

CSI LAB DUTIES

Receive potential HAB sample

Does cyanobacteria dominate the sample?

No

Remove pin from public HABs map

Yes

Report "cyanobacteria bloom" on public HABs map

Run lab analyses:

- Chlorophyll *a* ≈ bloom density*
- Microcystin ≈ bloom toxicity**

Report all results on public HABs map

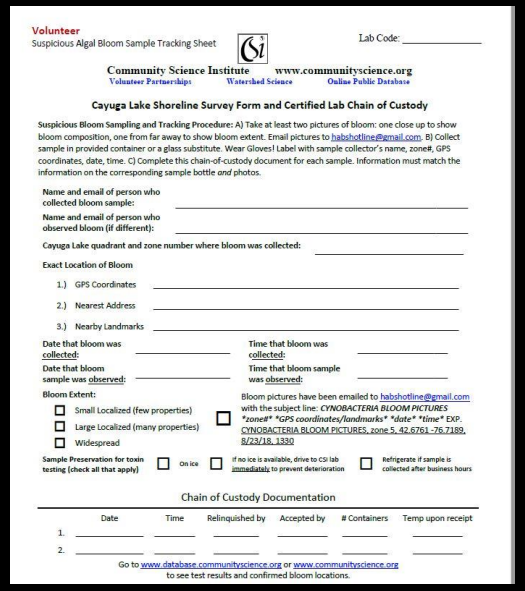
*Chlorophyll *a* can stem from organisms besides cyanobacteria, making this a *rough* estimate of bloom density

**Microcystin is only one of the possible cyanotoxins generated by cyanobacteria. It is a measure of toxicity *from microcystin toxin*, not of toxicity overall

HABs on Cayuga Lake: data collected

Data from volunteers:

- Location
- Time and date
- Photos
- Descriptions



Volunteer
Suspicious Algal Bloom Sample Tracking Sheet

Lab Code: _____

Community Science Institute www.communityscience.org
Volunteer Partnerships Watershed Science Online Public Database

Cayuga Lake Shoreline Survey Form and Certified Lab Chain of Custody

Suspicious Bloom Sampling and Tracking Procedure: A) Take at least two pictures of bloom: one close up to show bloom composition, one from far away to show bloom extent. Email pictures to habshotline@gmail.com. B) Collect sample in provided container or a glass substitute. Wear Gloves! Label with sample collector's name, zone#, GPS coordinates, date, time. C) Complete this chain-of-custody document for each sample. Information must match the information on the corresponding sample bottle *and* photos.

Name and email of person who collected bloom sample: _____

Name and email of person who observed bloom (if different): _____

Cayuga Lake quadrant and zone number where bloom was collected: _____

Exact Location of Bloom

1.) GPS Coordinates _____

2.) Nearest Address _____

3.) Nearby Landmarks _____

Date that bloom was collected: _____ Time that bloom was collected: _____

Date that bloom sample was observed: _____ Time that bloom sample was observed: _____

Bloom Extent:

☐ Small Localized (few properties)
☐ Large Localized (many properties)
☐ Widespread

Bloom pictures have been emailed to habshotline@gmail.com with the subject line: *CYNOBACTERIA BLOOM PICTURES *zone#* *GPS coordinates/landmarks* *date* *time* EXP. CYNOBACTERIA BLOOM PICTURES, zone 5, 42.6761 -76.7189, 8/23/18, 1330

Sample Preservation for toxin testing (check all that apply) ☐ On ice ☐ If no ice is available, drive to CSI lab immediately to prevent deterioration ☐ Refrigerate if sample is collected after business hours

Chain of Custody Documentation

	Date	Time	Relinquished by	Accepted by	# Containers	Temp upon receipt
1.						
2.						

Go to www.database.communityscience.org or www.communityscience.org to see test results and confirmed bloom locations.

Data from CSI lab:

- Cyanobacteria composition
- Chlorophyll *a* concentration
- Microcystin toxin concentration

	Microscopy		Total Chlorophyll a		Microcystin	
Bloom Sample Code	Description	Analysis Date	Result in ug/L	Analysis Date	Result in ug/L	Analysis Date
22-3456-B1	sparse/moderate Dolichospermum	7/22/2022	117	7/26/2022	< 0.30	7/25/2022
22-3400-B1	sparse Microcystis	8/1/2022	10.12	8/3/2022	3.47	8/5/2022
22-3475-B3	sparse Microcystis, sparse Oscillotoria, sparse Merismopedia, Pseudoanabaena present	8/8/2022	21.8	8/8/2022	4.58	8/19/2022
22-3402-B3	dense Microcystis, sparse/moderate Dolichospermum, Pseudoanabaena present	8/7/2022	2448	8/8/2022	916.00	8/12/2022
22-3458-B4	dense Microcystis, sparse/moderate Dolichospermum, sparse Limnoraphis, Pseudoanabaena	8/11/2022	2805	8/12/2022	451.00	8/12/2022

A note about chlorophyll *a* and microcystin toxin

Bloom Sample Code	Microscopy		Total Chlorophyll a		Microcystin		
	Description	Analysis Date	Result in ug/L	Analysis Date		Result in ug/L	Analysis Date
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22-3475-B3	sparse Microcystis, sparse Oscillotoria, sparse Merismopedia, Pseudoanabaena present	8/8/2022	21.8	8/8/2022		4.58	8/19/2022
22-3402-B3	dense Microcystis, sparse/moderate Dolichospermum, Pseudoanabaena present	8/7/2022	2448	8/8/2022		916.00	8/12/2022
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22-3475-B3	sparse Microcystis, sparse Oscillotoria, sparse Merismopedia, Pseudoanabaena present	8/8/2022	21.8	8/8/2022		4.58	8/19/2022
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22-3458-B4	dense Microcystis, sparse/moderate Dolichospermum, sparse Limnoraphis, Pseudoanabaena	8/11/2022	2805	8/12/2022		451.00	8/12/2022

Non-bloom chlorophyll *a* levels: ≤25 µg/L

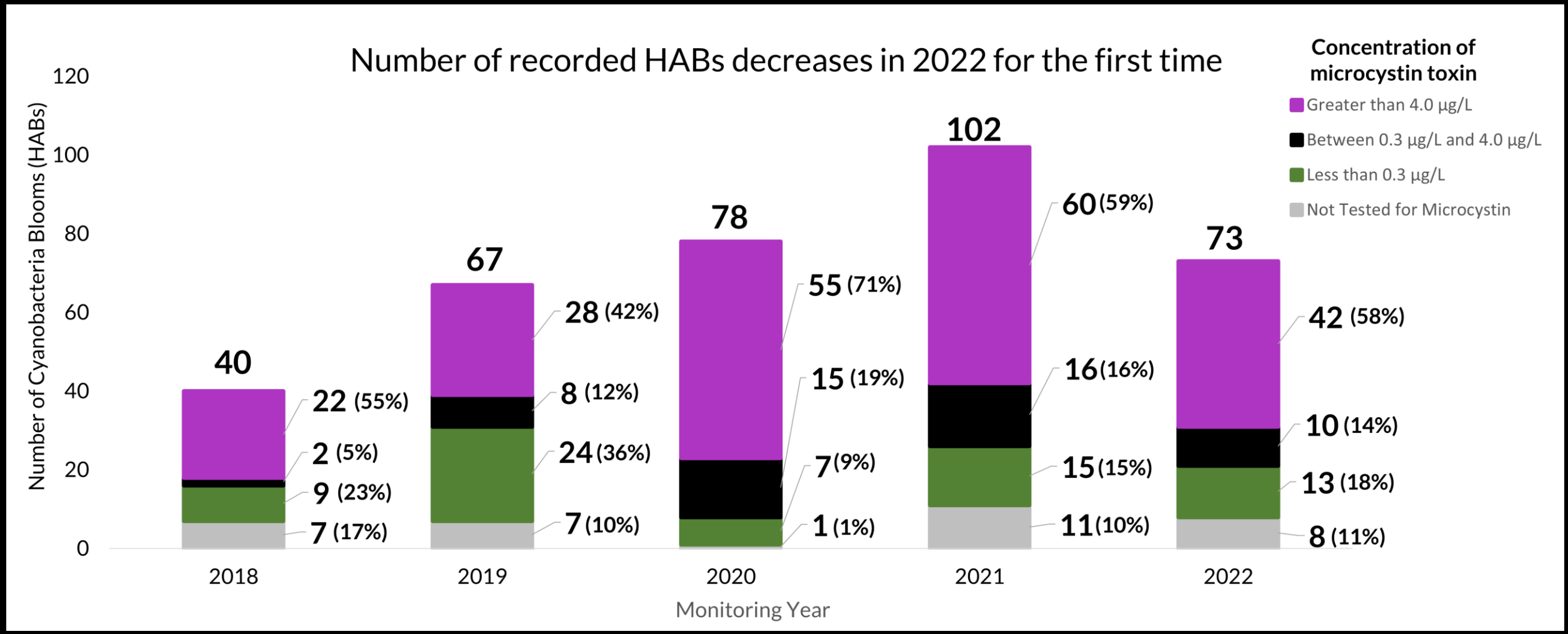
A note about chlorophyll *a* and microcystin toxin

Bloom Sample Code	Microscopy		Total Chlorophyll a		Microcystin		
	Description	Analysis Date	Result in ug/L	Analysis Date		Result in ug/L	Analysis Date
22-3456-B1	sparse/moderate Dolichospermum	7/22/2022	117	7/26/2022	<	0.30	7/25/2022
22-3400-B1	sparse Microcystis	8/1/2022	10.12	8/3/2022		3.47	8/5/2022
22-3475-B3	sparse Microcystis, sparse Oscillotoria, sparse Merismopedia, Pseudoanabaena present	8/8/2022	21.8	8/8/2022		4.58	8/19/2022
22-3402-B3	dense Microcystis, sparse/moderate Dolichospermum, Pseudoanabaena present	8/7/2022	2448	8/8/2022		916.00	8/12/2022
22-3458-B4	dense Microcystis, sparse/moderate Dolichospermum, sparse Limnoraphis, Pseudoanabaena	8/11/2022	2805	8/12/2022		451.00	8/12/2022

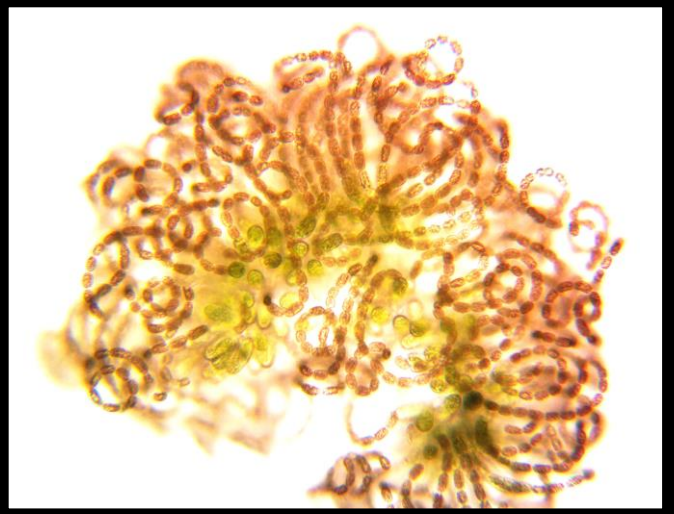
Microcystin limits
(set by NY State Dept. of Health):

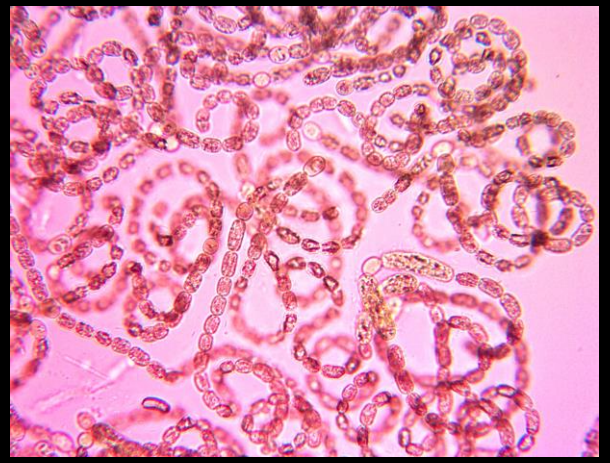
- Drinking water limit: ≤0.3 µg/L
- Contact recreation limit: ≤4 µg/L

It is NEVER safe to swim in a bloom! Always keep pets and children away from blooms!

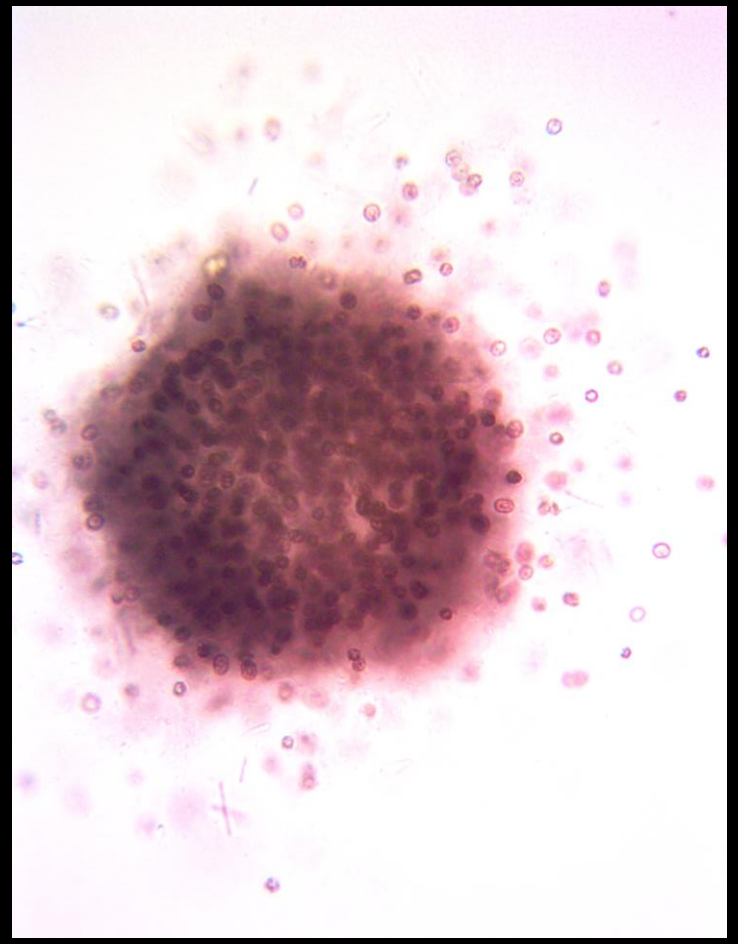

Number of recorded HABs decreases in 2022 for the first time
Concentration of microcystin toxin
Greater than 4.0 µg/L
Between 0.3 µg/L and 4.0 µg/L
Less than 0.3 µg/L
Not Tested for Microcystin
Number of Cyanobacteria Blooms (HABs)
120
100
80
60
40
20
0
40
22 (55%)
2 (5%)
9 (23%)
7 (17%)
67
28 (42%)
8 (12%)
24 (36%)
7 (10%)
78
55 (71%)
15 (19%)
7 (9%)
1 (1%)
102
60 (59%)
16 (16%)
15 (15%)
11 (10%)
73
42 (58%)
10 (14%)
13 (18%)
8 (11%)
2018
2019
2020
2021
2022
Monitoring Year

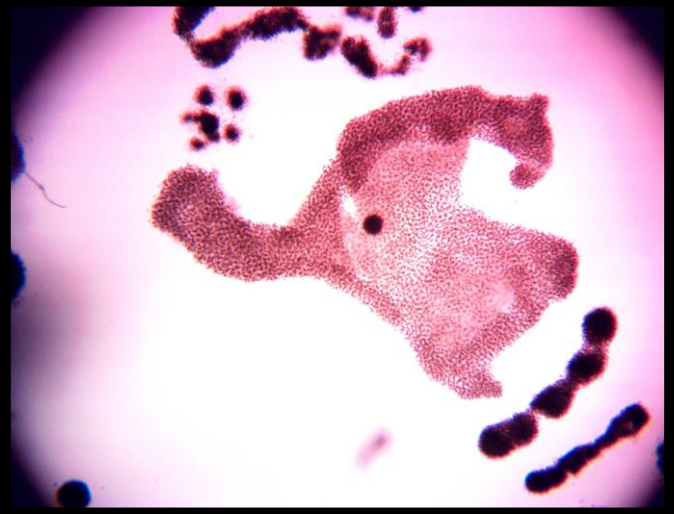
Dolichospermum sp.

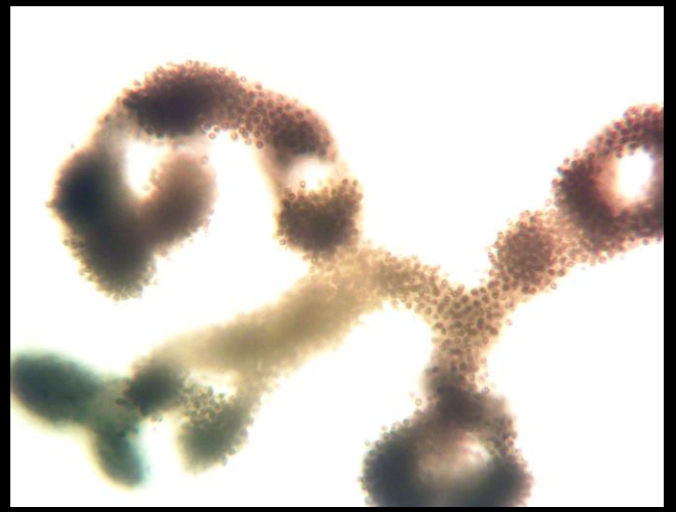




Microcystis sp.



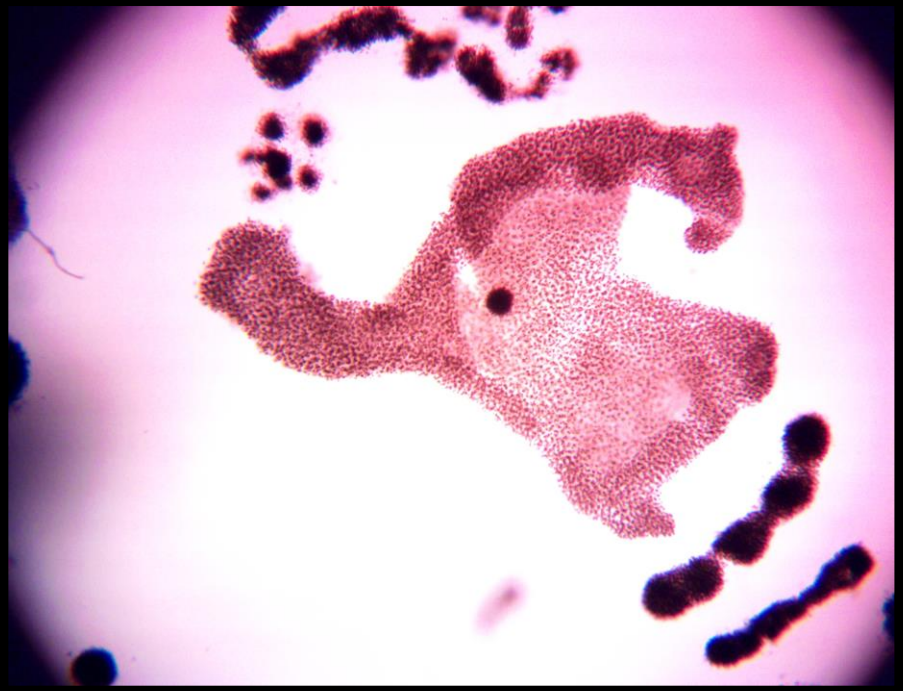




Cayuga Lake Cyanobacteria

Dolichospermum sp.

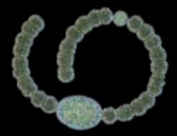
Microcystis sp.



Dolichospermum sp. and *Microcystis* sp. are Cayuga Lake's most common bloom-forming cyanobacteria

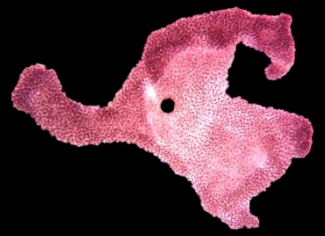
Cayuga Lake HABs – cyanobacteria

July



= *Dolichospermum* sp.

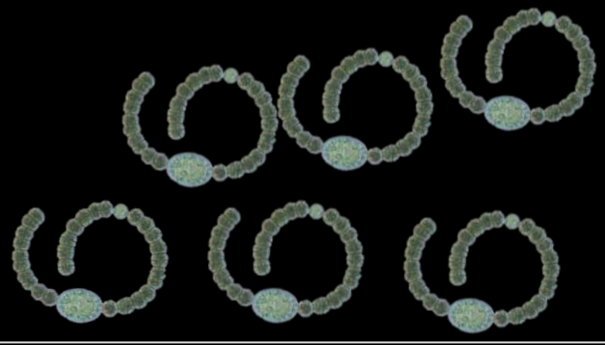
August



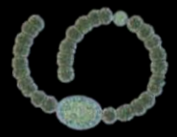
= *Microcystis* sp.

September

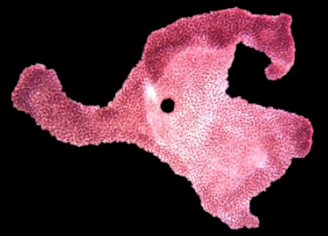
Cayuga Lake HABs – cyanobacteria



July | August | September

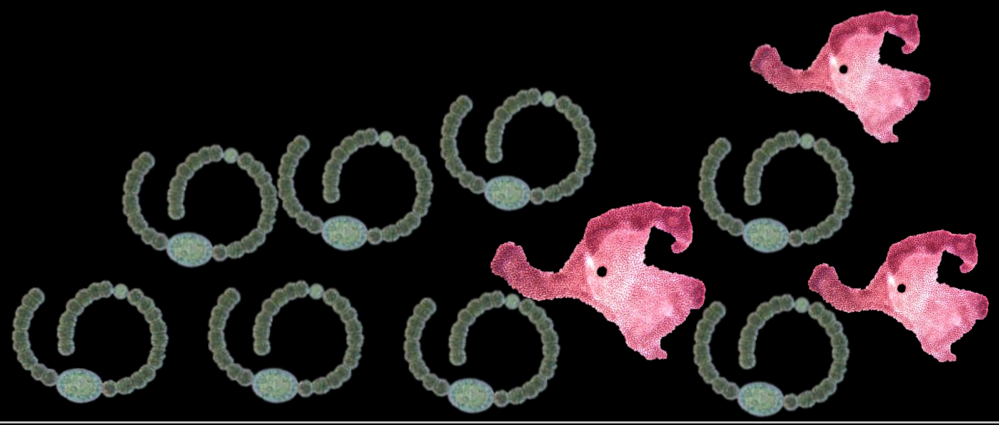


= *Dolichospermum* sp.



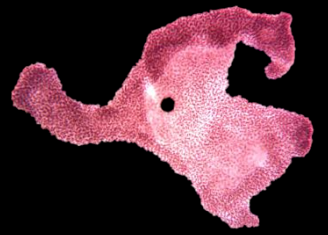
= *Microcystis* sp.

Cayuga Lake HABs – cyanobacteria



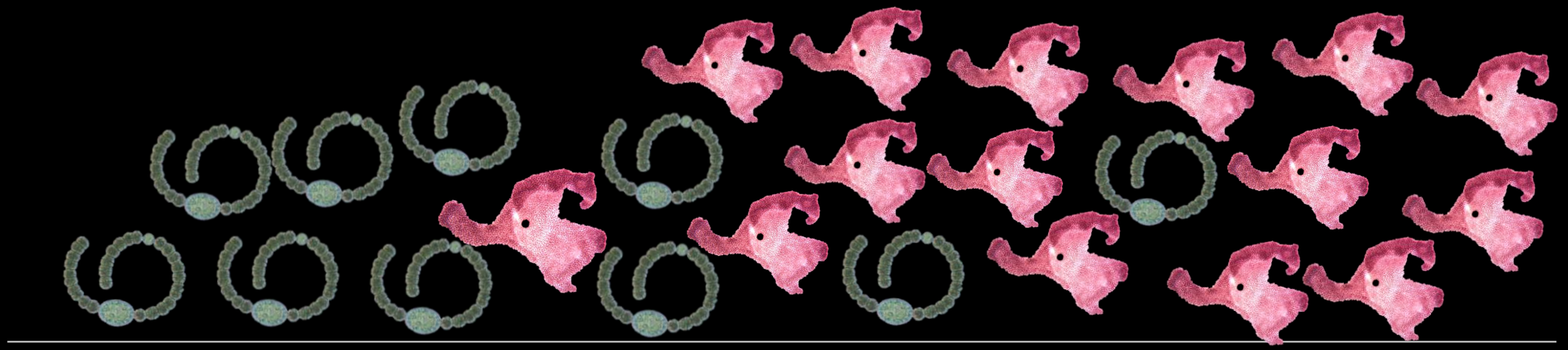
July August September

= *Dolichospermum* sp.



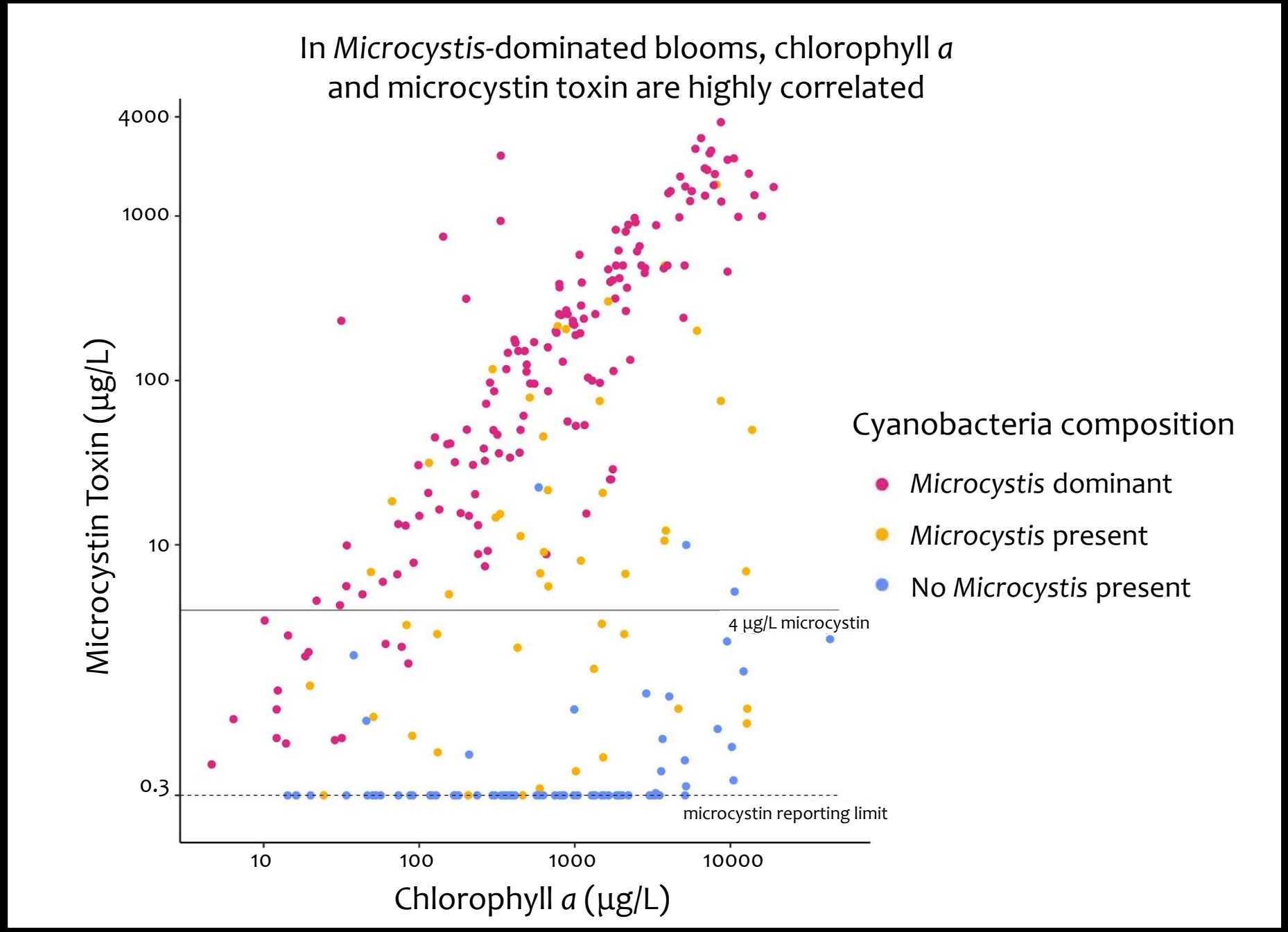
= *Microcystis* sp.

Cayuga Lake HABs – cyanobacteria



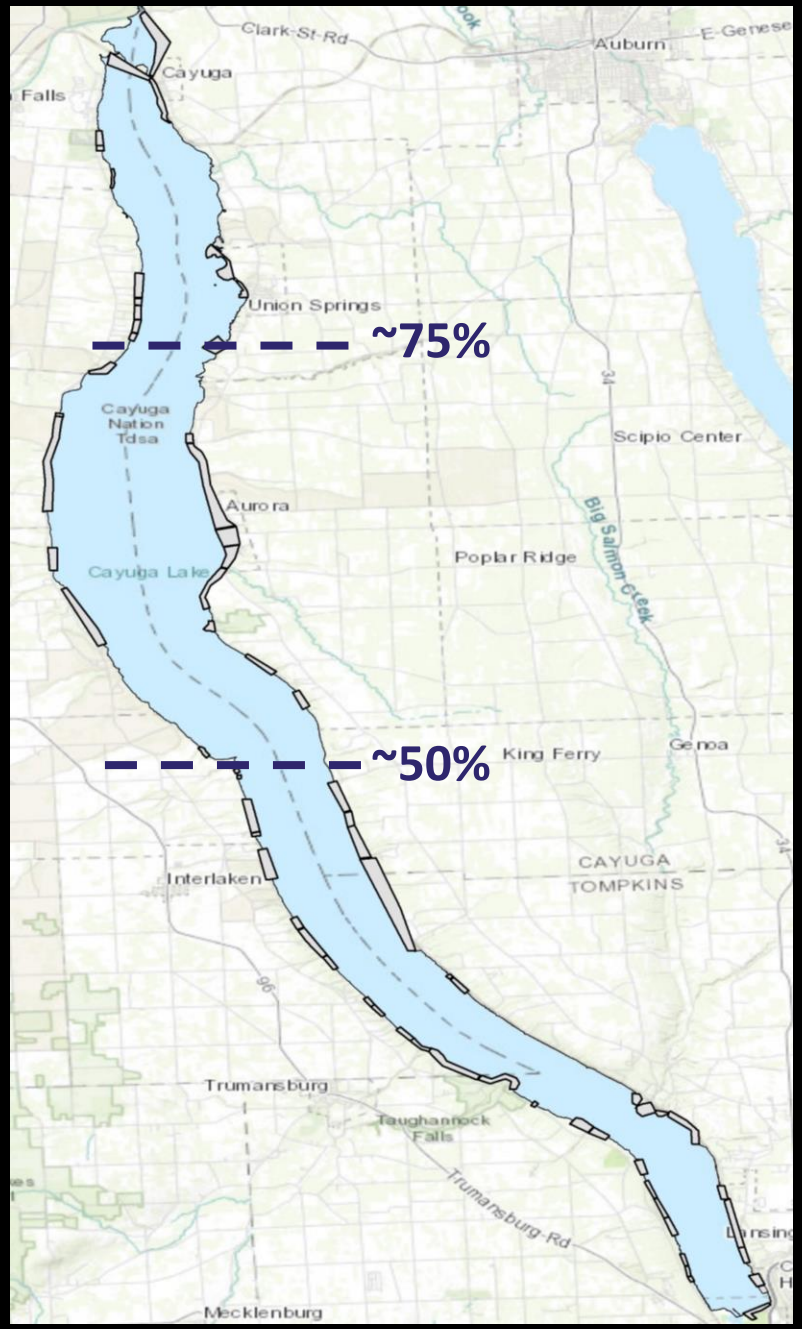
= *Dolichospermum* sp.

= *Microcystis* sp.


In *Microcystis*-dominated blooms, chlorophyll *a* and microcystin toxin are highly correlated
Microcystin Toxin (µg/L)
4000
1000
100
10
0.3
4 µg/L microcystin
microcystin reporting limit
10
100
1000
10000
Chlorophyll *a* (µg/L)
Cyanobacteria composition
Microcystis dominant
Microcystis present
No *Microcystis* present

Spatial Patterns

microcystin toxin recreation limit: **≤4 µg/L**



Spatial Patterns

>4µg/L = high in microcystin toxin

62% of **all HABs** observed occur north of Sheldrake Point

80% of HABs high in microcystin toxin occurred north of Sheldrake Point

>4µg/L = high in microcystin toxin

44% of **all HABs** observed occur in the northern ¼ of Cayuga Lake

64% of HABs high in microcystin toxin occurred in the northern ¼ of Cayuga Lake

>4µg/L = high in microcystin toxin

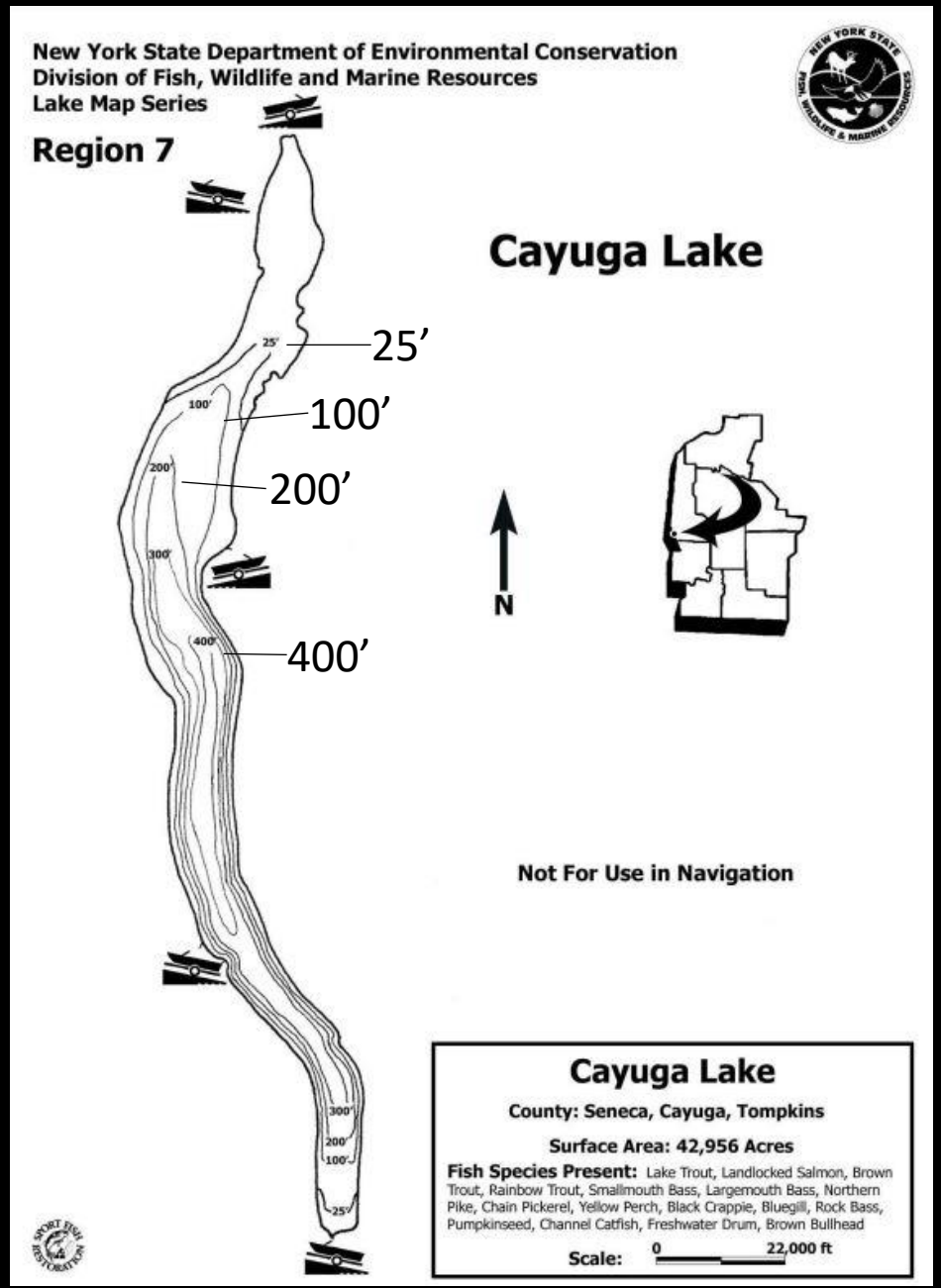
Why are Cayuga Lake HABs different on the northern vs. southern end?

Why are Cayuga Lake HABs different on the northern vs. southern end?

Potential explanations:

- Nutrients
- Shallow water
  - Warmer water
  - Higher density of *Microcystis*

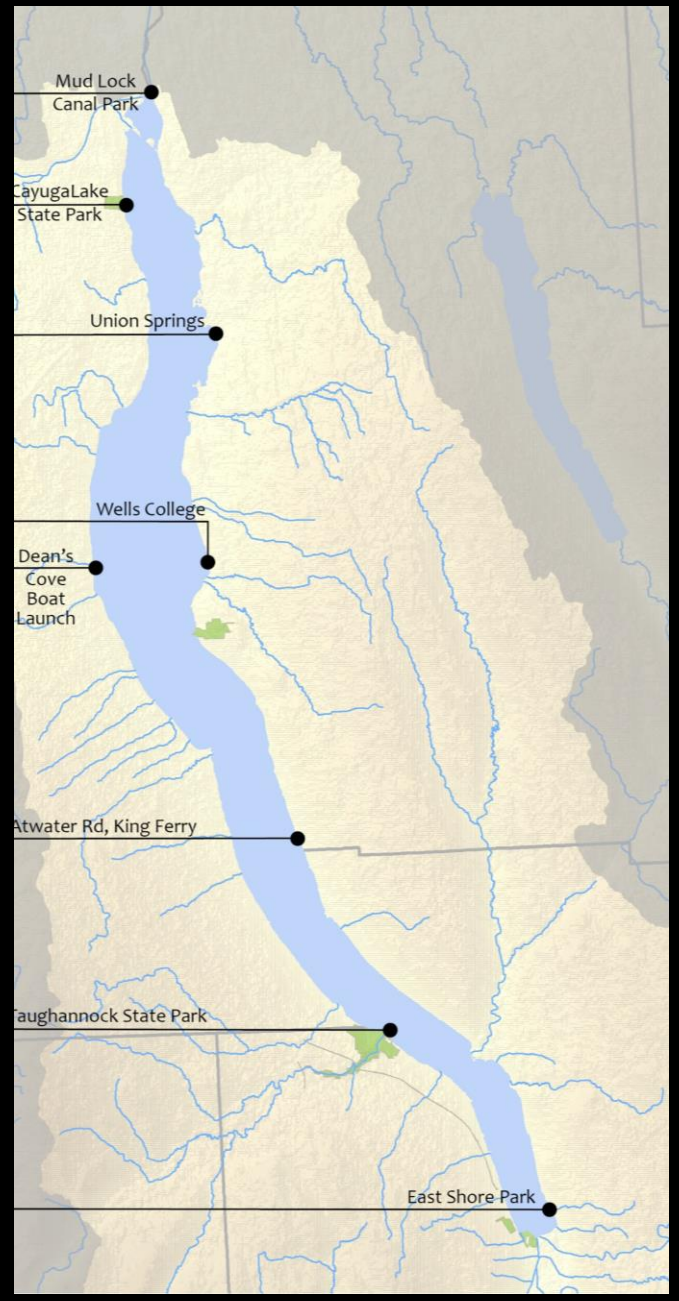
O'Leary et al. 2019



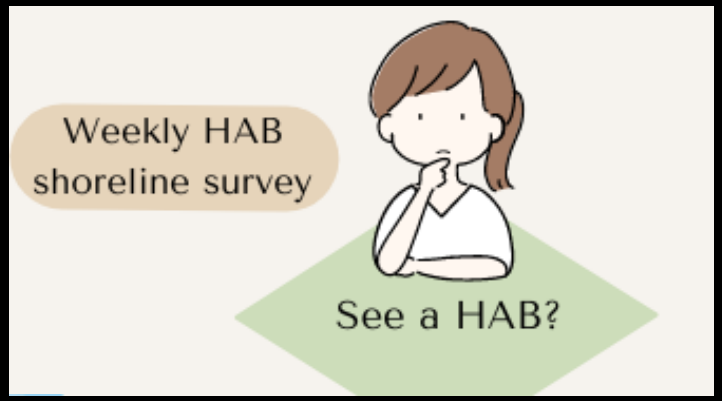
Plankton Net Surveys

8 locations are regularly surveyed during non-bloom conditions.

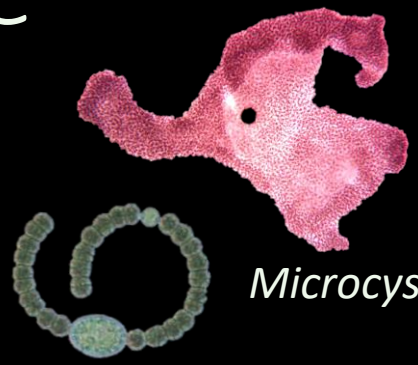
Surveys demonstrate denser populations of *Microcystis* sp. at the north end of the lake



HABs on Cayuga Lake



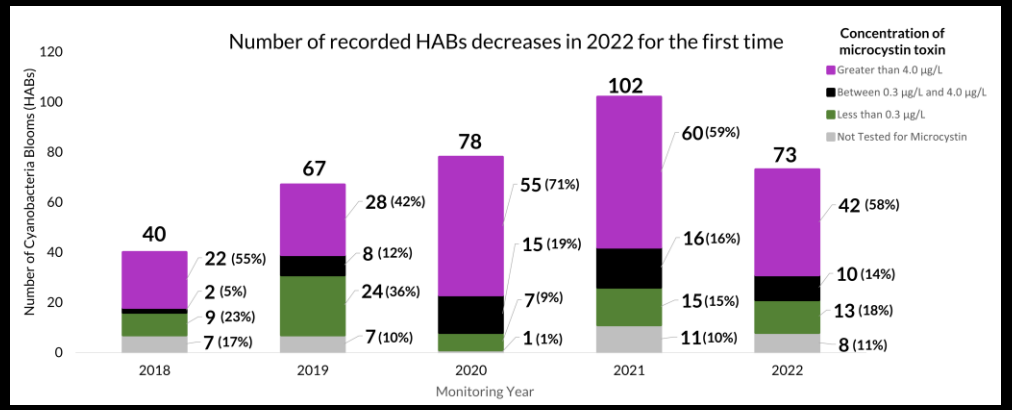
CSI volunteers!



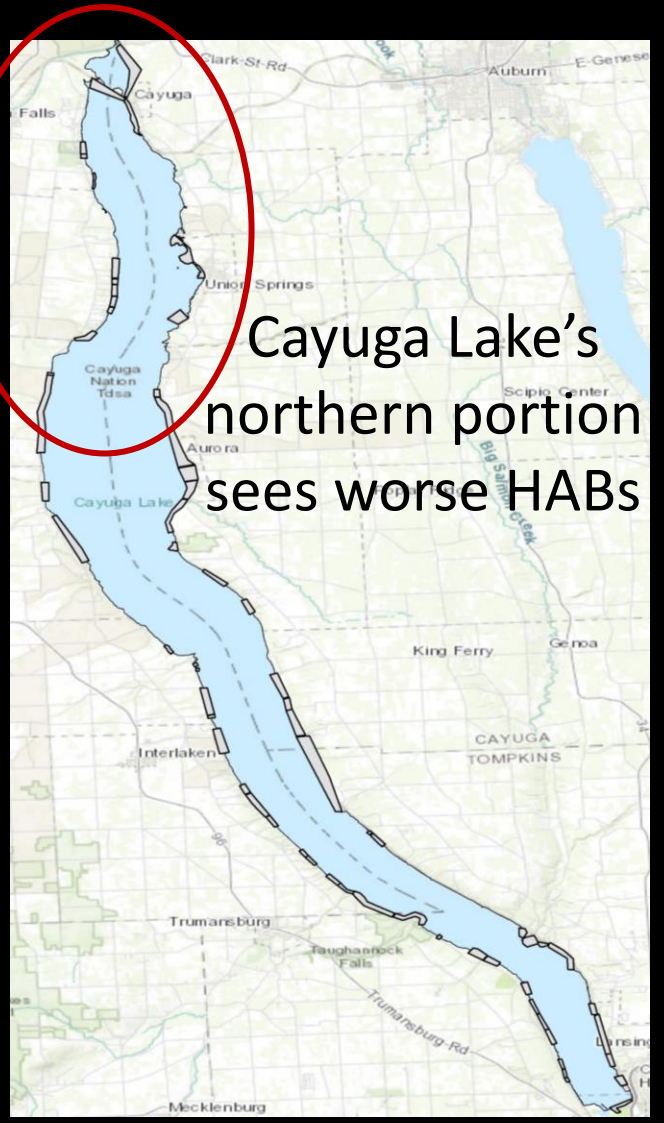
Microcystis sp.

Dolichospermum sp.

Main cyanobacteria

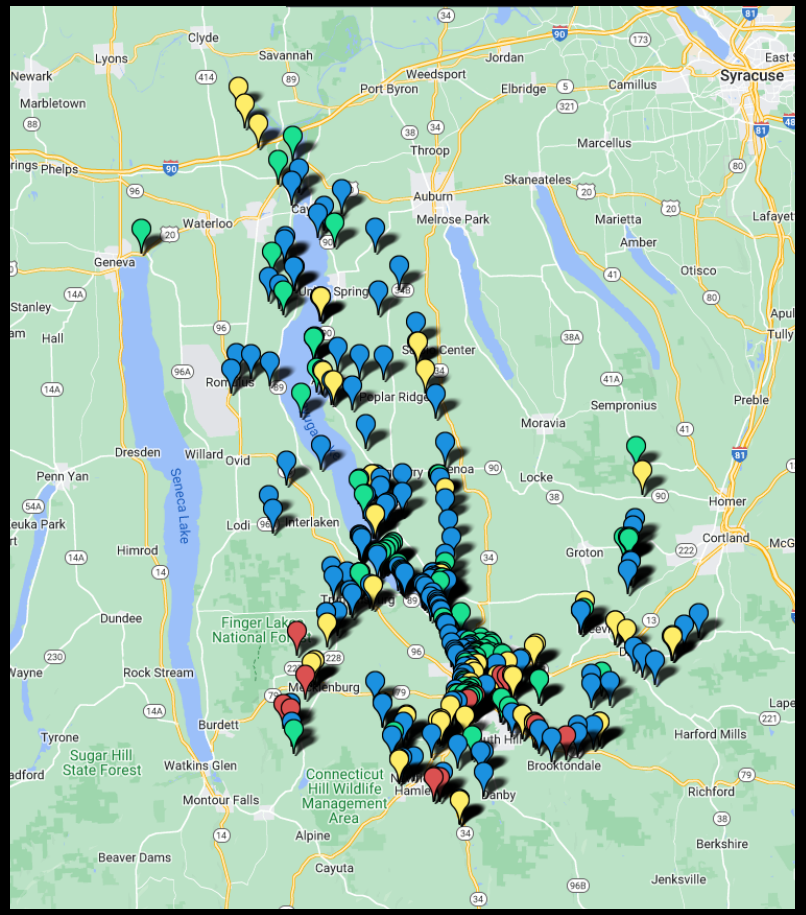


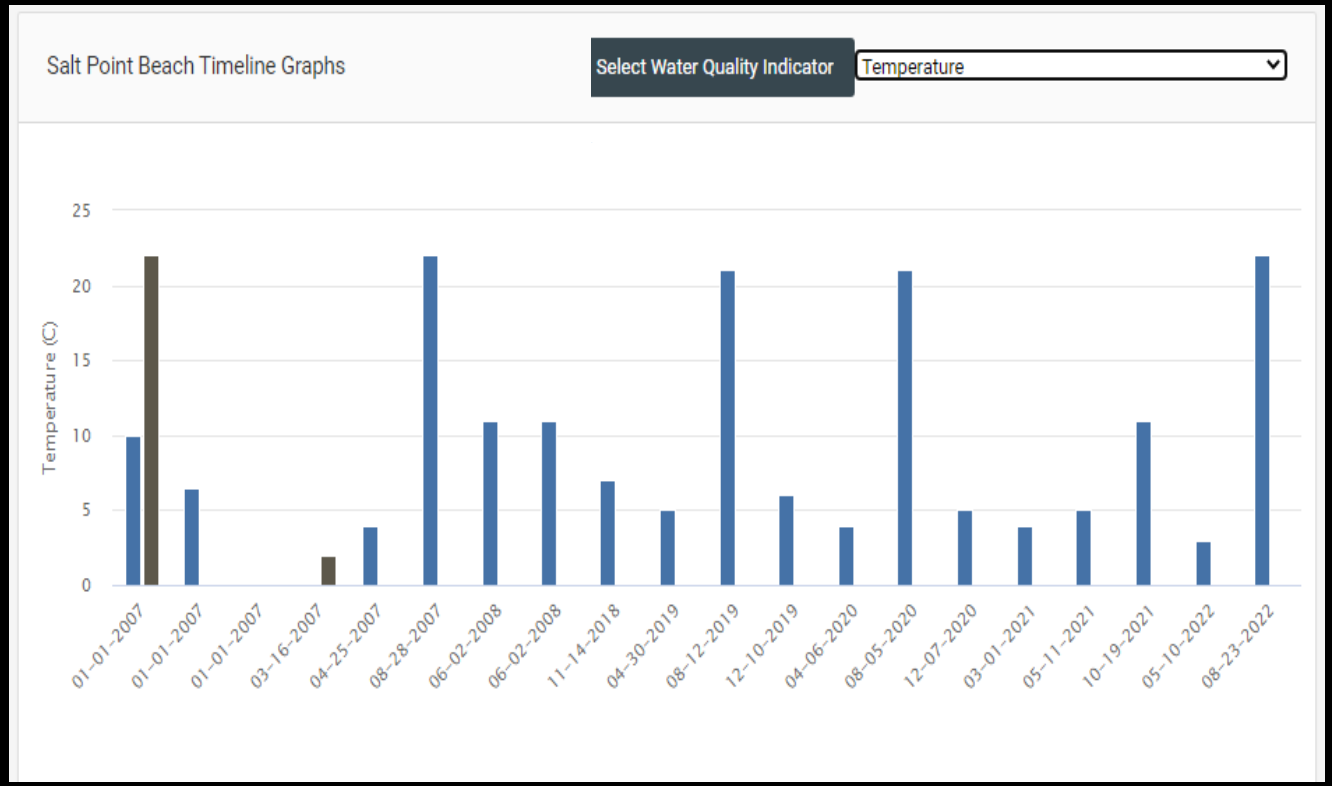
HABs are (mostly) increasing



Cayuga Lake's northern portion sees worse HABs

HABs Database





Coming soon…March 2023

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