Harmful Algal Blooms: Awareness, Response, and Emerging Research

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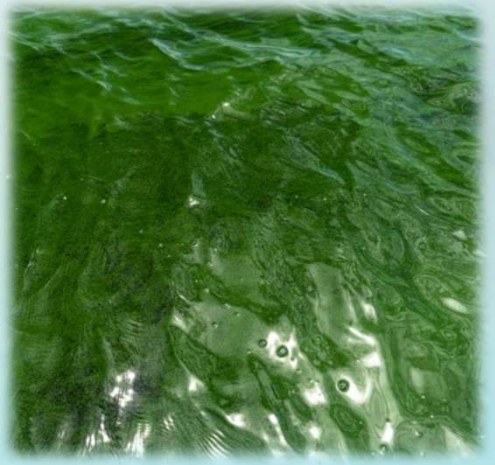
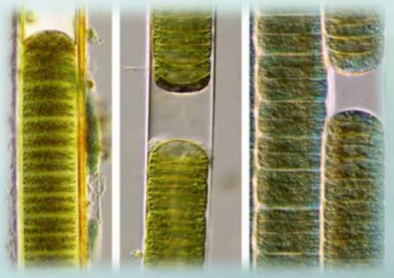
What are HABs?

- HABs – Harmful Algal Blooms (aka cHABS)
- Blue-green algae = cyanobacteria
- Naturally present in systems - overabundance becomes problematic.
- A variety of species (marine vs. freshwater)



What are HABs?



- Distribution: waterbody-wide, or localized near the shoreline, shallows
- Surface accumulations: wave, wind actions
- Forms: Unicellular or benthic
- May migrate vertically to different locations in the photic zone
- Exposures to cyanobacteria and cyanotoxins during recreational activities
- Adverse health effects

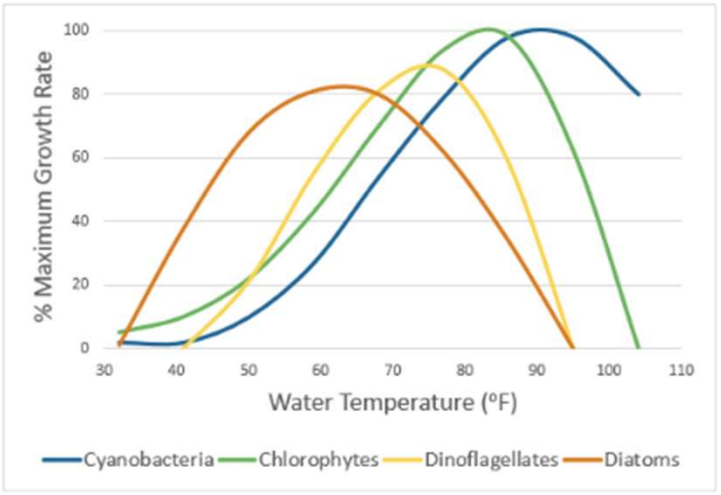
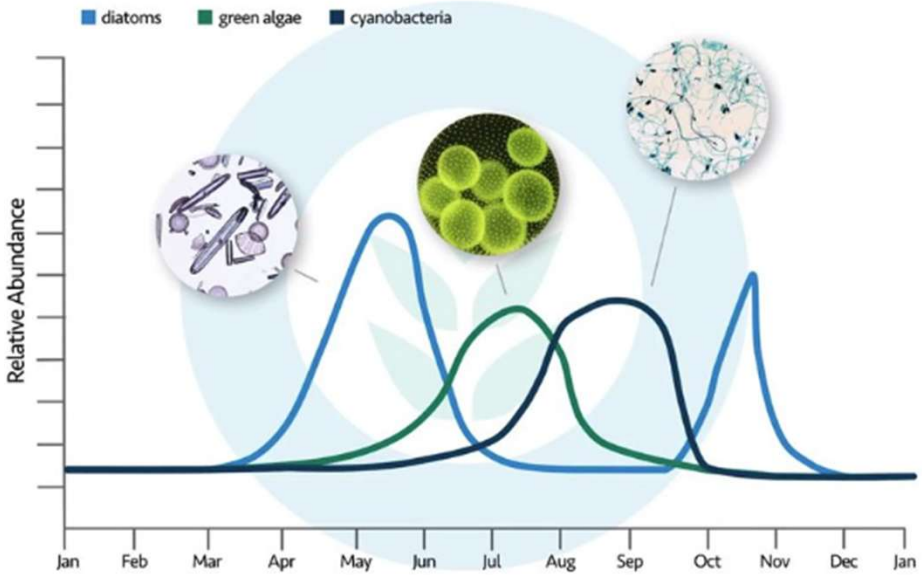
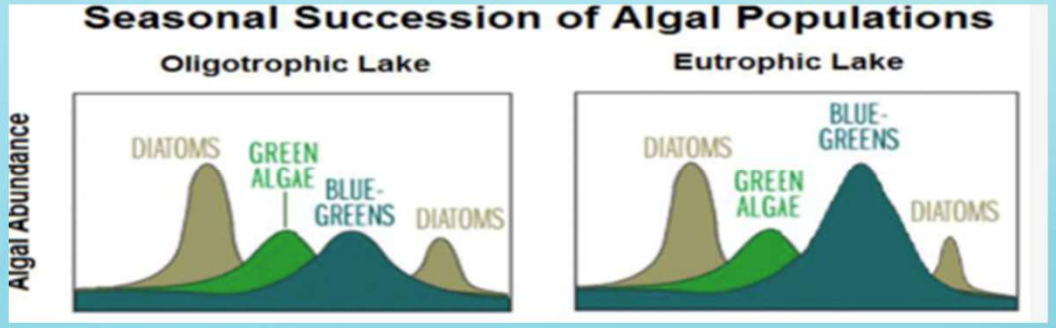


Figure 3-1. High temperature selection of cyanobacteria relative to other common phytoplankton groups.

Source: Modified from Paerl (2014) [197]. Used with permission.

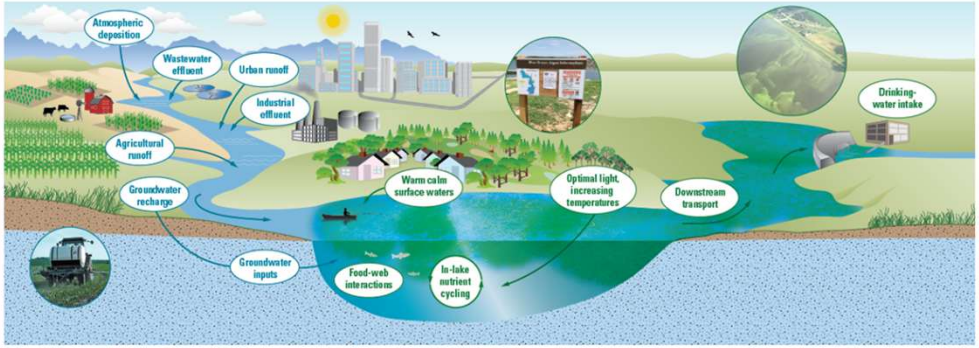


Graph by SePro. *NJDEP does not endorse any specific companies or products*



Sugar, Spice and Everything… Not So Nice…

- Caused by chemical and physical factors:
- Weather/Climate Change
- Water temperature
- Sunlight
- Light availability
- Nutrients (TPHOS/Nitrogen)
- Stagnant water / water flow*
- Type of system



Key factors related to CyanoHAB occurrence and toxicity. (USGS, 2017)
Source: Graham, J.L., Dubrovsky, N.M., and Eberts, S.M., 2017, Cyanobacterial harmful algal blooms and U.S. Geological Survey science capabilities (ver 1.1, December 2017): U.S. Geological Survey Open-File Report 2016–1174, 12 p.
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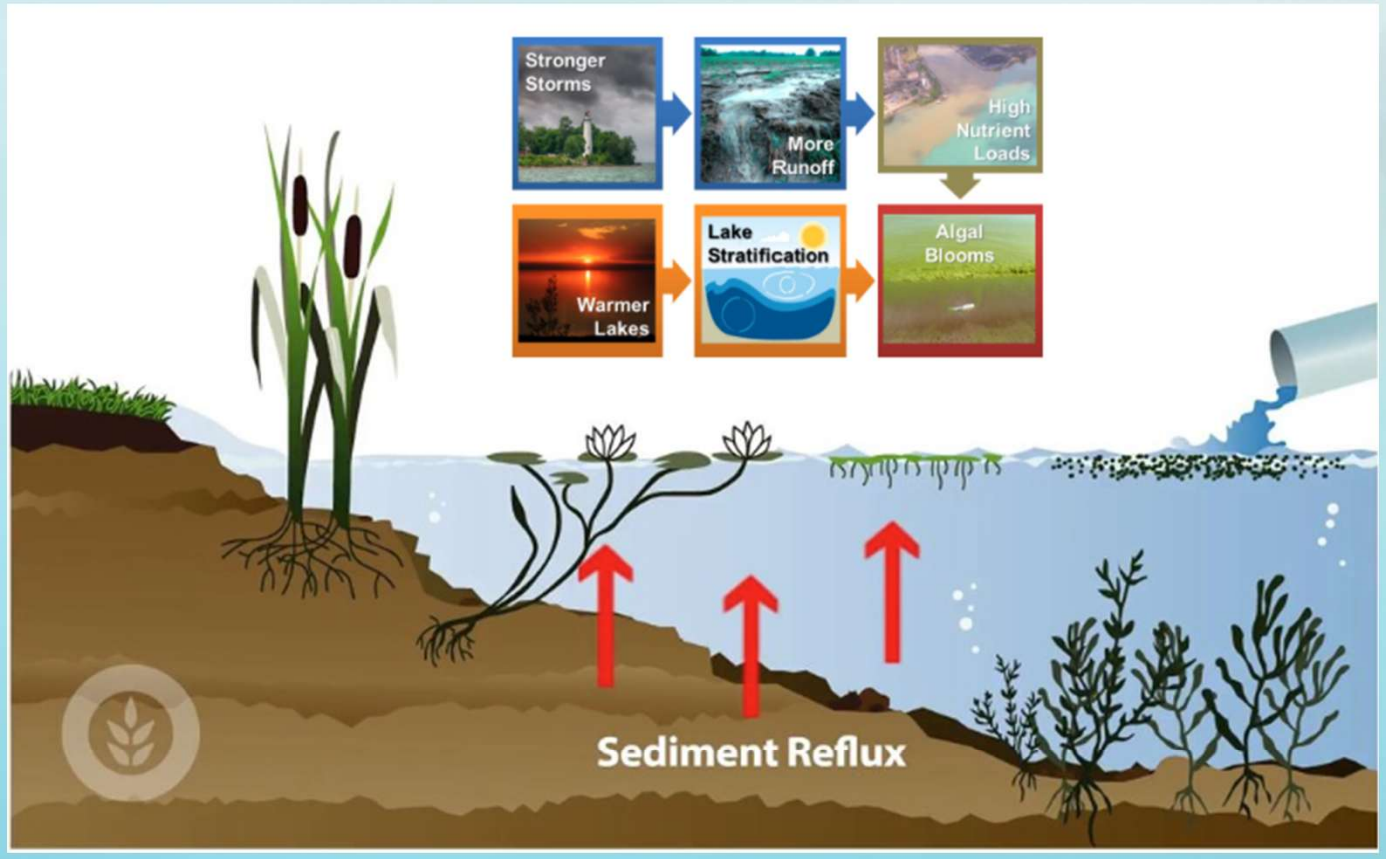

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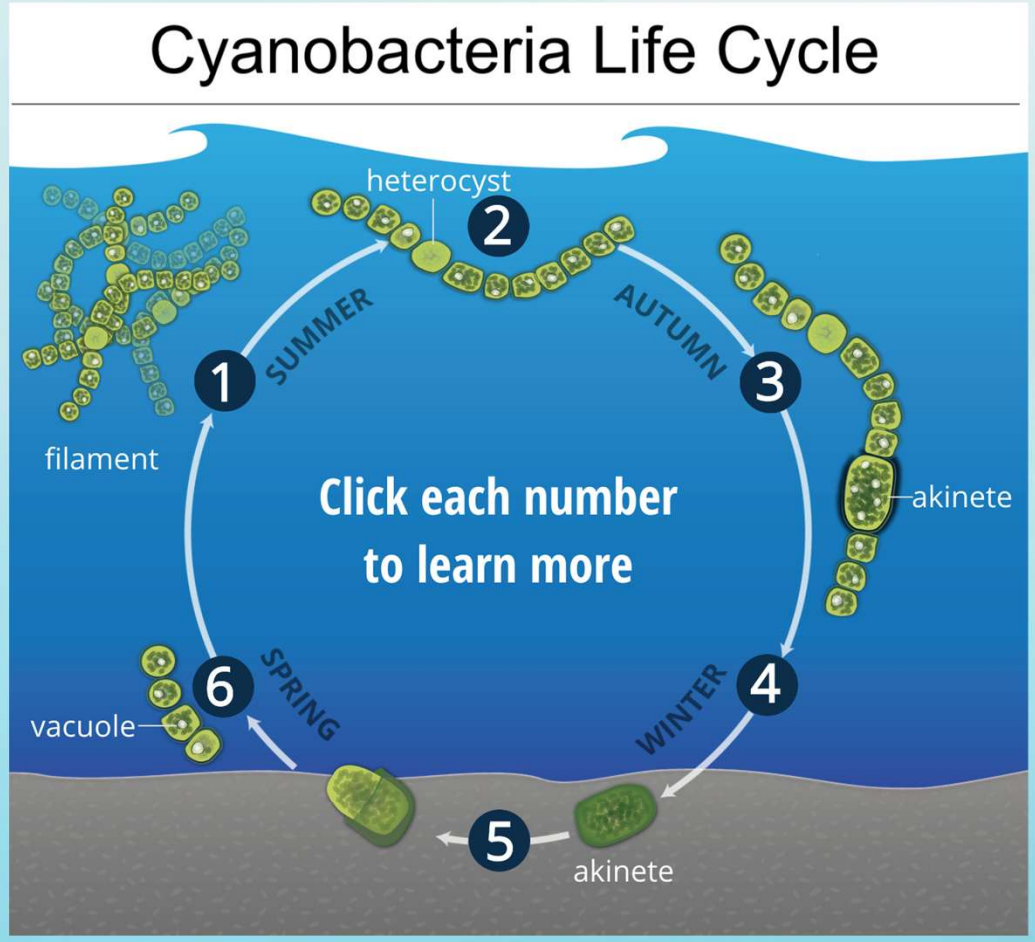


Graphic adapted from Hense and Beckmann (2006) and Kaplan-Levy et al. (2010).
(https://hab.whoi.edu/species/species-life-cycle/cyanobacteria/)

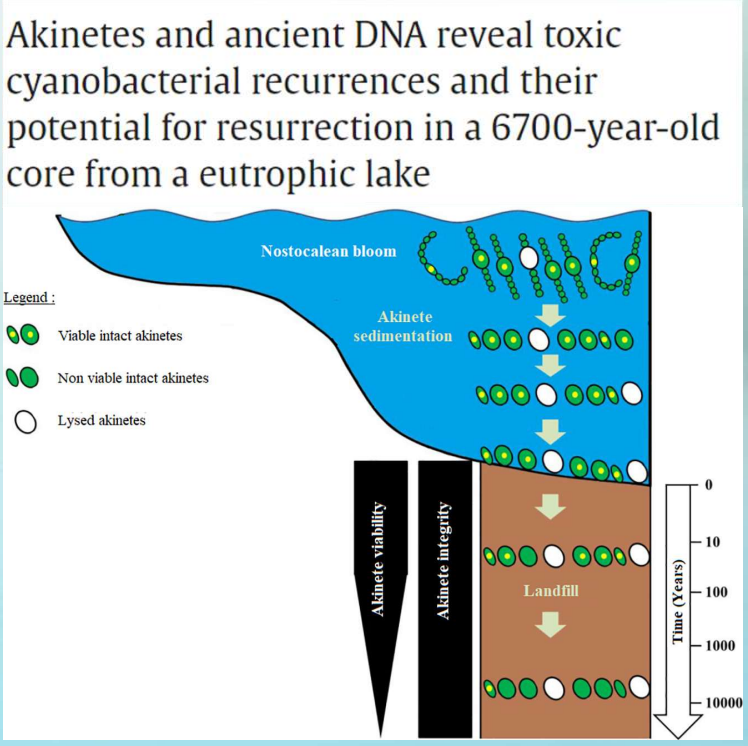
NJDEP does not endorse any specific companies or products

History of HABs

- Ancient Recognition:
  - Noted for centuries, records date back to ancient Greece and China, where discolored water and fish kills were described
  - 3.5 million years ago through fossils
- Scientific Discovery:
  - In the early 20th century, scientists began linking specific algal species to marine toxins
- Modern Awareness:
  - Since the 1970's increased nutrient pollution and climate change have led to more frequent and severe HABS worldwide
- Global Concern:
  - Impacts to fisheries, public health, economies globally prompting coordinated monitoring and research efforts

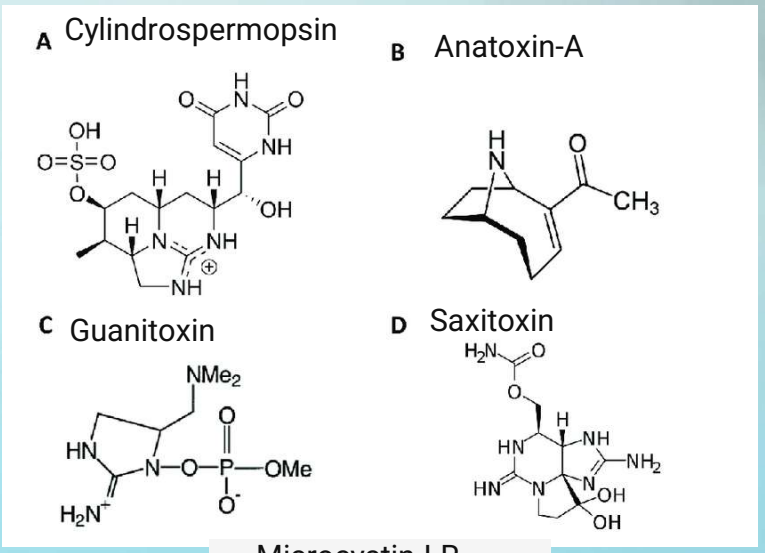
Akinetes Dormancy

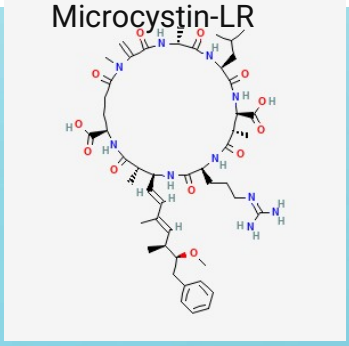
- Evaluate the recurrence of toxic blooms
- Sediment core spanning 6700 years Lake Aydat
- Akinete count revealed that Nostocales have been present for over a six-thousand-year period
- Linked to the natural damming of the river
- Increase in akinete density around 1800 cal.yr BP
- Intensification of human activities (woodland clearance, crop planting, grazing, etc.) in the catchment area of the lake, and beginning eutrophication
- Source: https://doi.org/10.1016/j.scitotenv.2019.07.100



How are HABS Toxic?

- 4 more common toxins: Anatoxin-a, Saxitoxin, Microcystin, Cylindrospermopsin ++
- Most detected toxin – microcystin
- Sub-toxin: Guanitoxin = responsible for pet mortality
- 80+ known cyanotoxins produced by HABs





Recreational Toxin Thresholds

- Microcystins (as total including microcystin –LR and other detectable congeners): 2 µg/L
- Cylindrospermopsin: 5 µg/L
- Anatoxin-a: 15 µg/L
- Saxitoxin: 0.6 µg/L

- https://www.epa.gov/habs/protecting-human-health-cyanotoxin-exposure-during-recreation

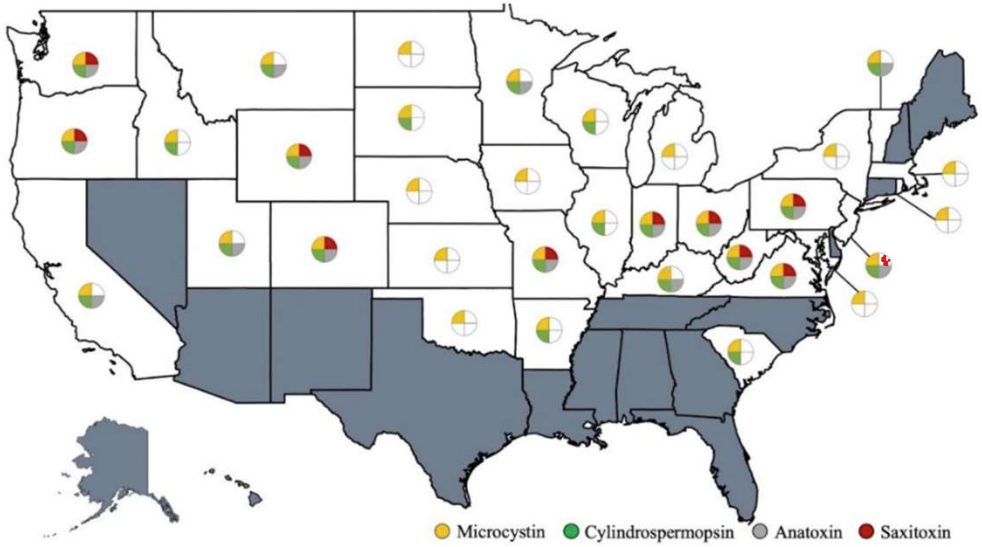


Figure 2-3. U.S. states that have recreational threshold values for the four most common cyanotoxins as of June 2021.

Source: Adapted from Mehinto et al. (2021) [5151].

Key Elements of a HAB Strategy & Response Plan

A. Prevention and Risk Reduction:

- Identify common sources of nutrient pollution (agriculture, storm water septic, runoff, etc)
- Promote land use practices that reduce nutrient runoff (green infrastructure, buffer zones, etc) – guidance documents
- Emphasize stakeholder engagement (municipalities, utilities, farmers, etc)

B. Monitoring and Surveillance:

- Scalable monitoring framework:
- Routine WQ monitoring (CHLA, toxins, etc)
- Remote sensing, citizen science, predictive modeling / review from data collections (sharing data too!)

HAB Strategy Response: Example NJDEP

- 2017 HAB response program – unified statewide approach
- Primary focus of the Response Strategy- protection of human health
- Designed to identify:

HAB Program Timeline:

2019

- Governor Murphy Announces More than $13 Million in Funding and New Initiatives to Address Harmful Algal Bloom
- Aerial surveillance flights

2020

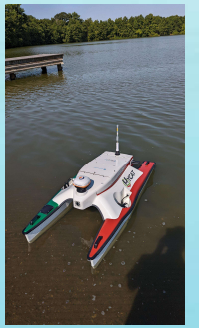
- Formation of HAB Team
- 10 additional continuous monitoring buoys (12)

2021

- Fluorometer Loaner Program initiated

2022

- Autonomous Surface Vehicle



2024

- HAB Lake Management Guidance Document by the HAB Expert Team

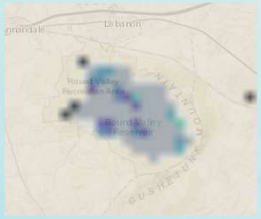
2025

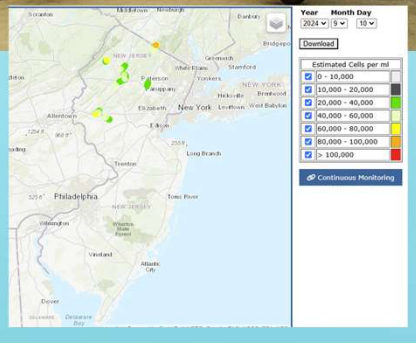
- Re-assessment of data
- Two more buoys (13 Buoys)

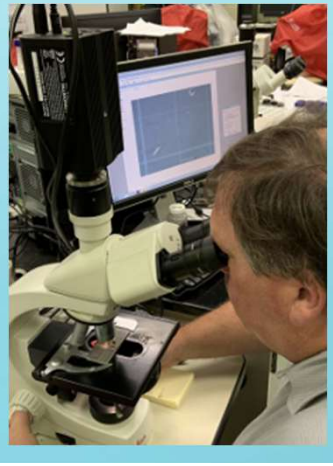
Annual HAB Summit, annual reports, online reporting development and analytical capabilities for additional toxins and equipment upgrades.

What is in the toolbox?

CYAN



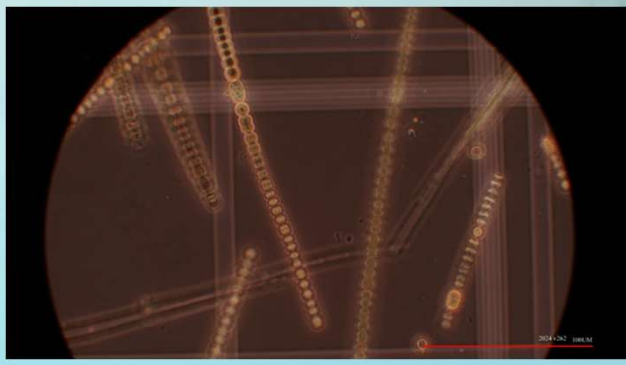




Key Elements of a HAB Strategy & Response Plan

C. <u>Response Planning:</u>

- Outline tiered response triggers (cell counts, toxin levels, etc)
- Response actions may vary:
  - Public health advisories/closures
  - Signage and public communication strategies
  - Technical mitigation guide or reference (situational based)



D. <u>Communication and Public Outreach:</u>

- Importance of transparency and trust-building
- Clear messaging templates, infographics, alert systems, etc. (dashboards/web portals)
- Coordination with local health departments, recreation agencies, and the public

HAB Strategy Response: Response Planning: Example NJDEP

HAB Alert Level	Criteria	Recommendations
HAB Not Present	**HAB reported and investigated. No HAB present.**	**None**
WATCH *Suspected or confirmed HAB with potential for allergenic or irritative health effects*	Suspected HAB based on field survey **OR** Confirmed cell counts ≥20K - <80K cells/mL **AND** No known toxins above public health thresholds	**Public Bathing Beaches Open** Waterbody Accessible: Use caution during **primary contact (e.g. swimming) and secondary (e.g. non-contact boating)** activities Do not ingest water (people/pets/livestock) Do not consume fish
ADVISORY *Confirmed HAB with moderate risk of adverse health effects and increased potential for toxins above public health thresholds*	Lab testing for toxins Microcystins: ≥2 µg/L Cylindrospermopsin: ≥5 µg/L Anatoxin-a: ≥15 µg/L Saxitoxin: ≥0.6 µg/L **OR** Confirmed cell counts ≥80K cells/mL	**Public Bathing Beaches Closed** Waterbody Remains Accessible: Avoid primary contact recreation Use caution for secondary contact recreation Do not ingest water (people/pets/livestock) Do not consume fish
WARNING *Confirmed HAB with high risk of adverse health effects due to high toxin levels*	Toxin (microcystins) ≥20 - <2000 µg/L	**Public Bathing Beaches Closed** Cautions as above May recommend against secondary contact recreation.
DANGER *Confirmed HAB with very high risk of adverse health effects due to very high toxin levels*	Toxin (microcystins) ≥2000 µg/L	**Public Bathing Beaches Closed** Cautions as above. Possible closure of all or portions of waterbody and possible restrictions access to shoreline.

WATERBODY:

www.state.nj.us/dep/hab/

WATCH

HEALTH EFFECTS RISK

HARMFUL ALGAL BLOOM (HAB)

FLORACIONES DE ALGAS NOCIVAS

Always keep children and pets away from areas with blooms or scums.

*Public Bathing Beaches will be closed under the authority of NJDOH regulation, New Jersey State Sanitary Code Chapter IX Public Recreational Bathing N.J.A.C. 8:26.

POSTED BY:

WATERBODY:

www.state.nj.us/dep/hab/

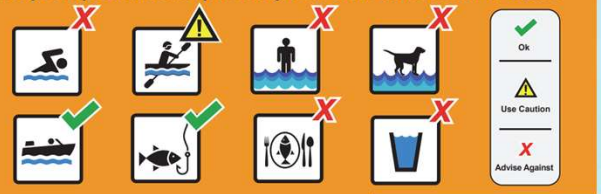
ADVISORY

MODERATE HEALTH RISK

HARMFUL ALGAL BLOOM (HAB)

FLORACIONES DE ALGAS NOCIVAS

Always keep children and pets away from areas with blooms or scums.



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POSTED BY:

WATERBODY:

www.state.nj.us/dep/hab/

WARNING

HIGH HEALTH RISK

HARMFUL ALGAL BLOOM (HAB)

FLORACIONES DE ALGAS NOCIVAS

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POSTED BY:

WATERBODY:

www.state.nj.us/dep/hab/

DANGER

VERY HIGH HEALTH RISK

HARMFUL ALGAL BLOOM (HAB)

FLORACIONES DE ALGAS NOCIVAS

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POSTED BY:

BEACH CLOSED

PLAYA CERRADA

HARMFUL ALGAL BLOOM (HAB)

No Swimming • No Wading

FLORACIONES DE ALGAS NOCIVAS No nadar • No vadear

Contact can make people and animals sick.

El contacto puede enfermar a personas y animales.

www.state.nj.us/dep/hab/

*Public Bathing Beaches are closed under the authority of NJDOH regulation, New Jersey State Sanitary Code Chapter IX Public Recreational Bathing N.J.A.C.8:26.

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WATERBODY:

www.state.nj.us/dep/hab/

WINTER WATCH

A HAB was previously confirmed at this waterbody and may persist or reoccur.

HEALTH EFFECTS RISK

HARMFUL ALGAL BLOOM (HAB)

FLORACIONES DE ALGAS NOCIVAS

Always keep children and pets away from areas with blooms or scums.

Avoid it & Report it

*Public Bathing Beaches will be closed under the authority of NJDOH regulation, New Jersey State Sanitary Code Chapter IX Public Recreational Bathing N.J.A.C. 8:26.

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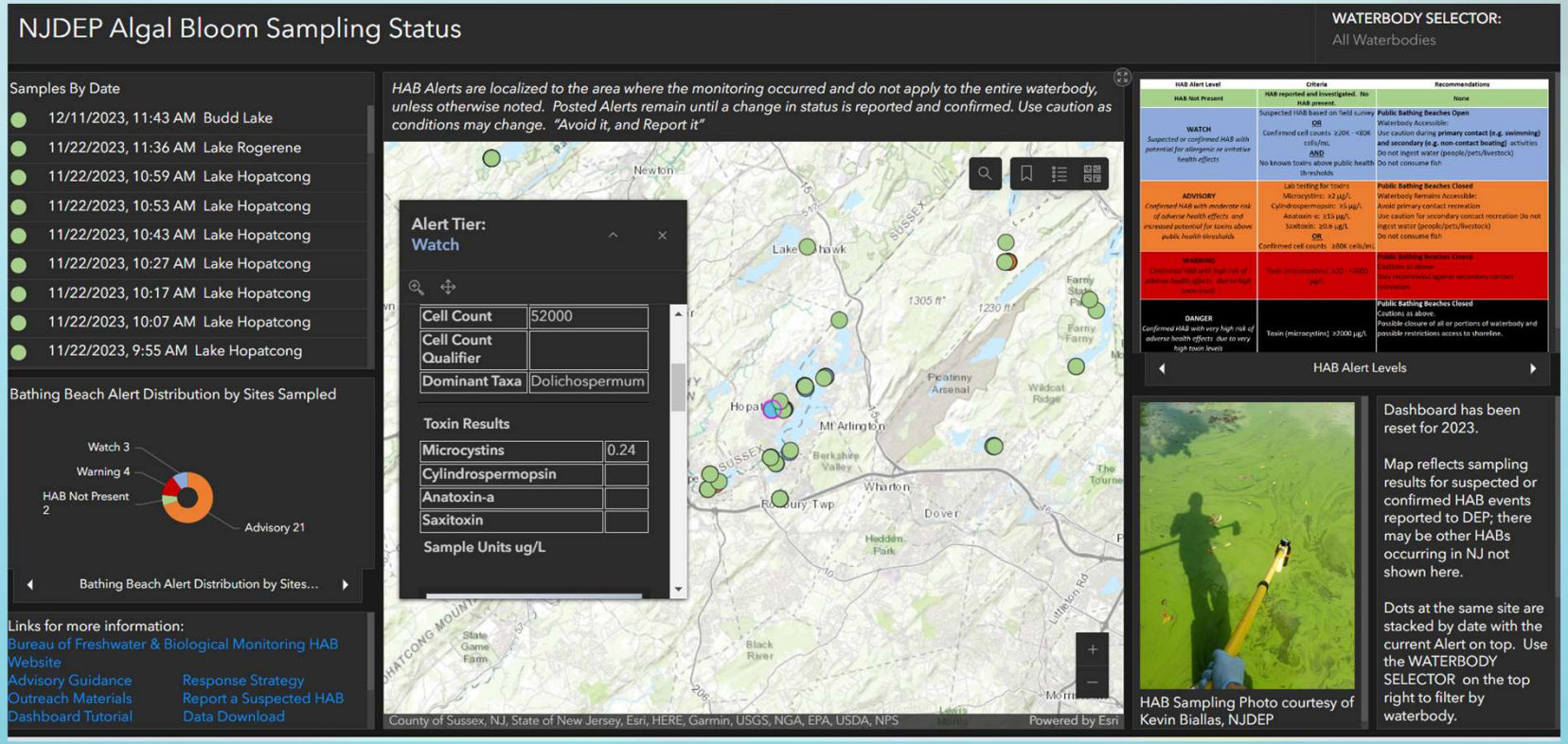
HAB Dashboard



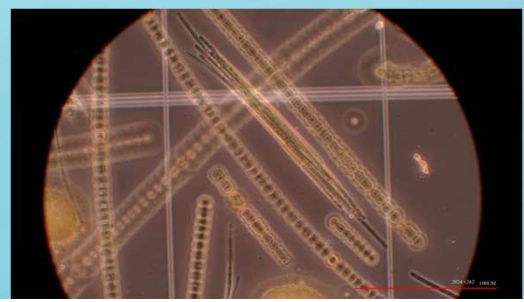
Key Elements of a HAB Strategy & Response Plan

E. Interagency Coordination:

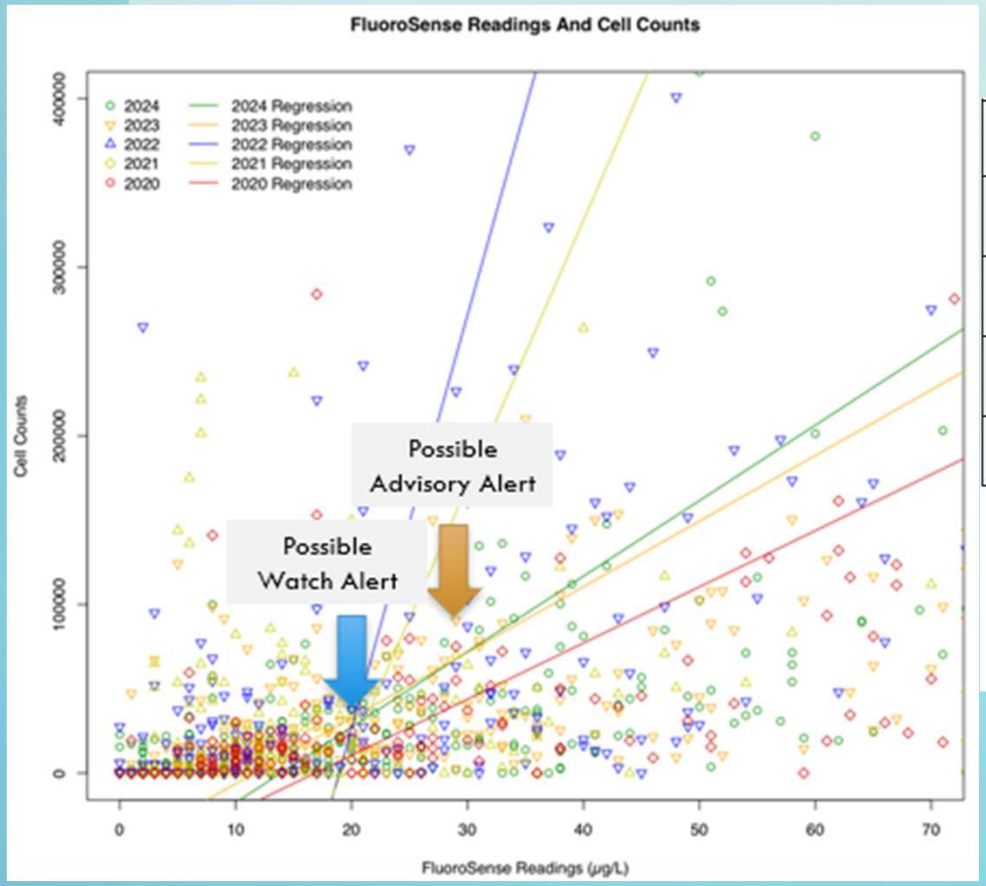
- Environmental agencies, public health (DOH), recreation depts, emergency management, academia /research institutions, etc.

F. Evaluation and Adaption:

- Annual review and updates as needed
- Using lessons learned from past blooms to refine strategy
- Keep up with latest research and innovation (novel detection methods, forecasting models, etc)



FluoroSense Guidance



Cell Count Ranges (Cells/ml)	Median FluoroSense Reading (µg/L)	Possible HAB Alerts*
20,000 to 39,999	20	Watch
40,000 to 79,999	29	Potential Watch – Nearing Advisory
80,000 to 99,999	43	Advisory
>100,000	72	>Advisory (Greater than Advisory)

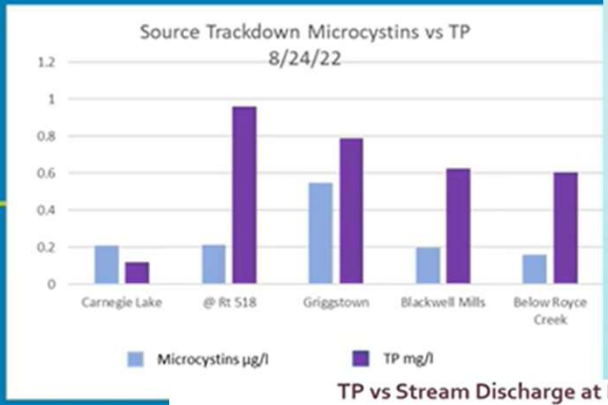
__Note__: HAB alerts are determined by cell counts and toxin analysis only. This is to display how the FluoroSense meter is a preliminary screening tool to respond to the potential onset of a HAB. Note these measurements are for screening and not intended to replace lab analysis used to determine alerts. In addition, these correlations are based on statewide data, differences may occur at specific waterbodies.

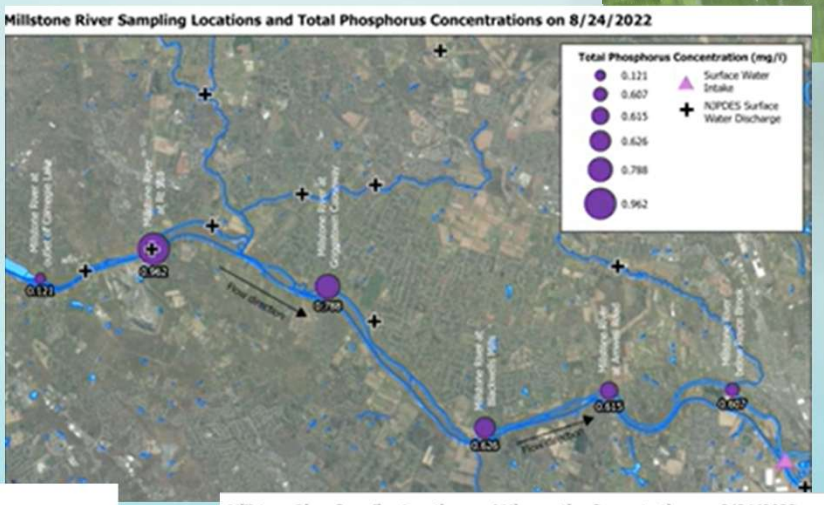
Millstone River (2022)

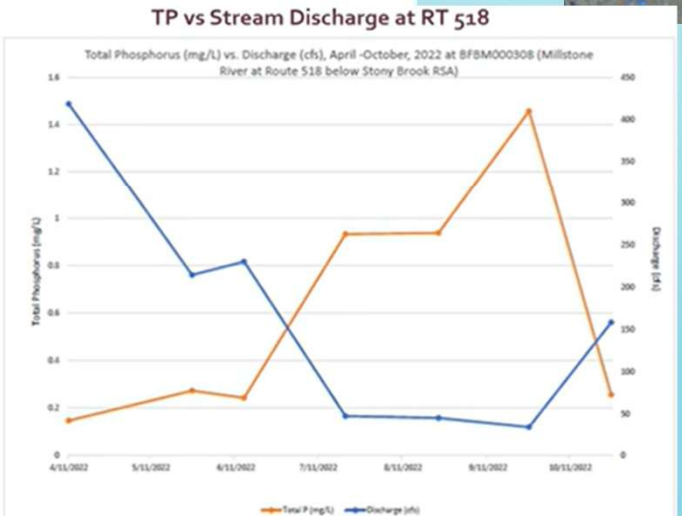
Source Trackdown Study: Results

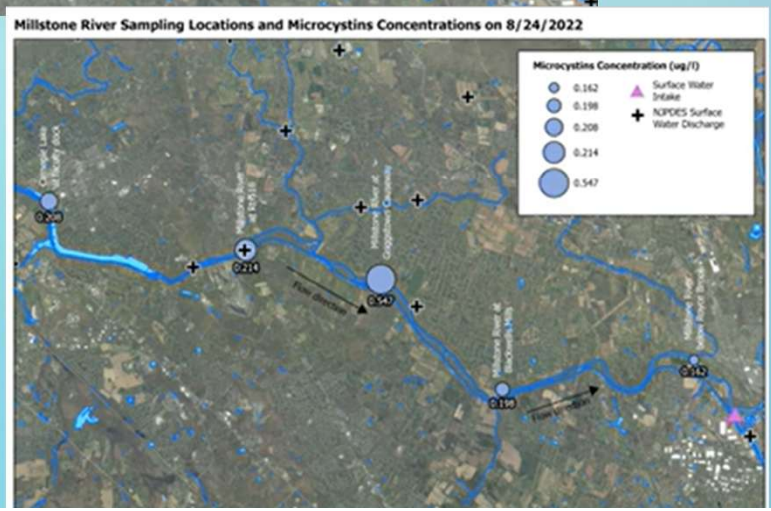
Site	Microcystins (µg/l)	TP (mg/l)	Ortho-P (mg/l)
Carnegie Lake	0.208	0.121	0.00556
@ Rt 518	0.214	0.962	0.831
Griggstown	0.547	0.788	0.683
Blackwell Mills	0.198	0.626	0.531
Below Royce Creek	0.162	0.607	0.506

Stream SWQS for TP = 0.1 mg/l









Photos by: NJWSA
with their drones

Cozy Lake (2023)

7/3/23
Suspected HAB.

7/5/23
Response, confirmed HAB.

7/8/23
Warning alert tier - beach closure

7/19/23
BFBM alerted that shallow wells and/or point wells, septic systems/cess pools. Drinking water advisory.

7/20/23
Public notice on Jefferson's twp website, and social media.

8/3/23
Re-sampled, remained an Advisory.

- Lake association, voluntary (120 homes part of it) – limited funds for lake maintenance.
- Well types –permits, historical info, etc.
- Increased surveillance and efforts, discussion on a potential study for ground water and surface water connections.

- Assembled an internal cross-program.
- Tested 21 homes. Pre and post treatment.

- Detectable concentrations in 12/21 homes.
- Provided bottled water to those who requested.

Water Quality Concerns for Lakefront Communities

Sources of Contamination

Microorganisms may exist naturally or be introduced to surface waterbodies by stormwater runoff or septic systems. These sources of contamination can also feed microorganisms and result in an overgrowth (i.e. harmful algal blooms). Some examples of waterborne microorganisms are:

- ***E. coli***
- ***Cryptosporidium* and *Giardia* Parasites**
- **Viruses (Adenovirus)**
- **Cyanobacteria/Harmful Algal Blooms (HAB)**
  HABs can overgrow in nutrient rich environments. Signs of overgrowth may include a blue-green or green discoloration to the water or a "spilled paint" or "pea soup" like consistency on the surface.

Harmful Algal Bloom

NEVER USE UNTREATED SURFACE WATER FROM THESE SOURCES

- **Identify** your water source.
- **Test** for possible contamination.
- **Seek an alternate water source**, if needed.

HABs: If you suspect a HAB, call 1-877-WARNDEP.
Boiling untreated HAB waters will not remove the toxin and may worsen the contamination.

Surface Water

Untreated surface water should never be used for any potable use, showering, handwashing, dishwashing, drinking, or preparing food, especially for infants or children. Even with various types of home treatment some risks remain. While water may often appear to be "clean," one drop of water can contain thousands of microorganisms, some of which could be potentially dangerous or make you ill.

Poorly Constructed Wells

An older shallow or poorly constructed well located near a water body may be at higher risk because it is connected to surface water through the groundwater. Wells with inadequate casing length, or casing and grout deterioration are also at higher risk to contamination from septic tank leaching or other contaminants. **Make sure your well has been properly installed, maintained, and is undergoing routine testing.** You may be at risk if your well:

- Was constructed prior to 1936 (prior to current protective construction standards)
- Is a hand-dug well composed from brick, stone, or concrete rings.
- Has significantly lower water levels or dries up when nearby surface water levels decline.

Hand-dug Well

Information on Harmful Algal Blooms can be found at the website: www.nj.gov/dep/hab. For more information on well construction, permitting or interpreting well record documents, contact the NJDEP Bureau of Water Allocation & Well Permitting at 609-984-6831 or wellpermitting@dep.nj.gov. If you are unsure about the construction of your well, complete an individual well search to obtain records from the NJDEP or contact a licensed well driller to evaluate your well.

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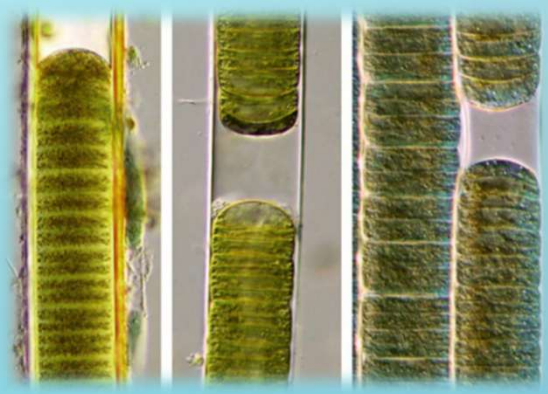
Parvin Lake: Benthic HABS (2024)

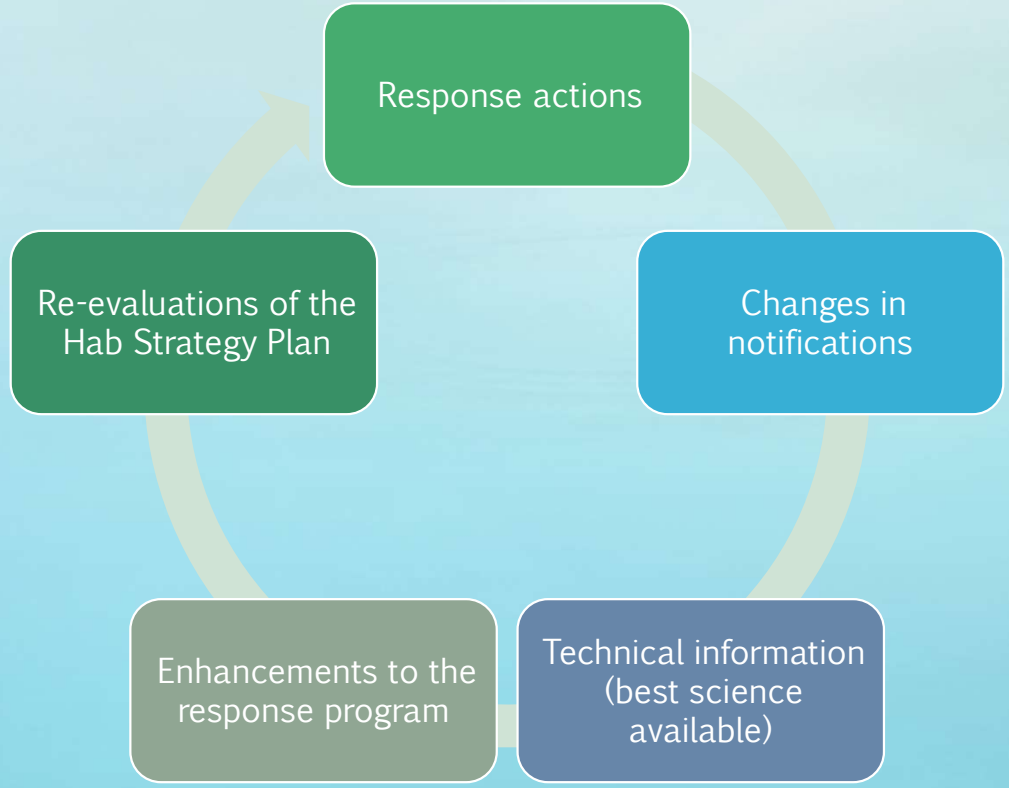
- *Lyngbya* species – causing benthic mats
- Causes odor issues, dermatoxins, saxitoxins, etc
- Wave, wind, natural processes to uproot
- Highest saxitoxin for 2024: - 8/21/24 - 14.40 ug/L
- Challenging to sample, not your typical unicellular bloom
- Partnered with state parks on coordination



Hopewell Quarry (2024)

- Enclosed quarry
- Used recreationally for swimming
- Group uses a lake management consulting firm, and is part of the HAB lab with MSU
- Re-tested for MCT and method 544
- Needed to determine where that toxin was coming from
  - Benthic hab?
  - Coming from somewhere else in quarry?
  - Residual from recent algicide applications?
- Likely residual from recent application

HAB Program continues to evolve..



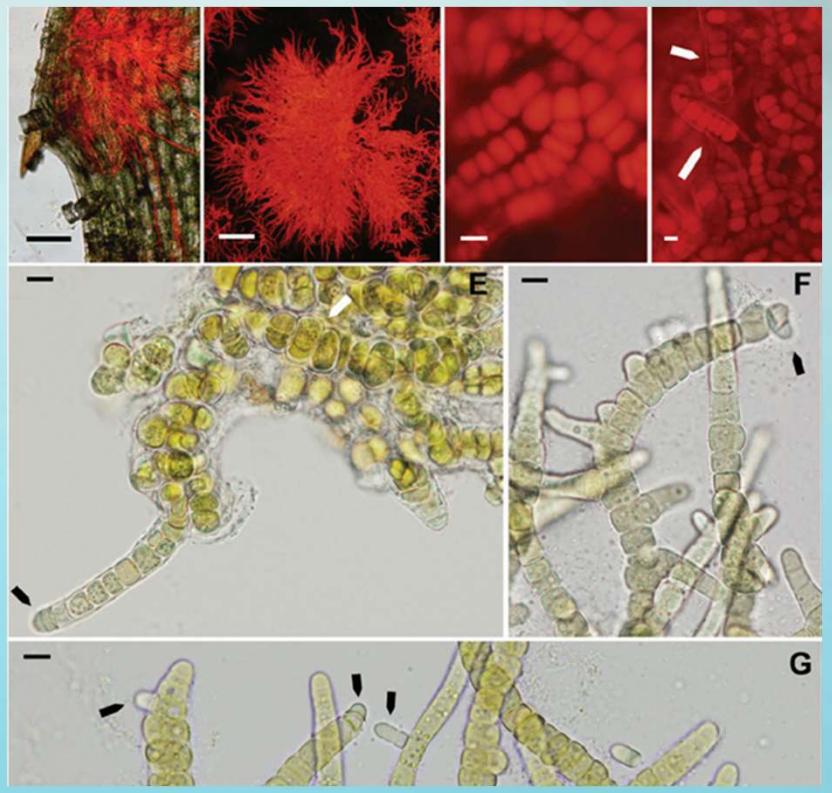
Emerging Research

- Research related to HABs
- Research projects are funded through the EPA special monitoring initiative fund
  - Awarded end of 2024 season
  - Two Projects
  - Microplastics Monitoring Surveillance of Cyanos/AVM
- Projects within the northeast focused on HAB research

Surveillance of Cyanos/AVM

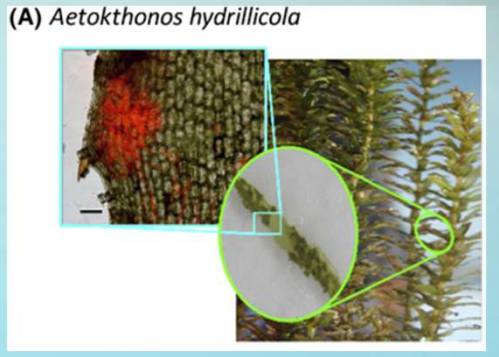
- Cyanobacteria and toxin production.
  - Cyanobacteria: *Aetokthonos hydrillicola*
  - Novel toxins - *aetokthonotoxin* (AETX) and *aetokthonostatin*.
  - Capable of producing two toxins with distinct chemical compositions which is highly unusual.

- Recent Findings:
  - *Aetokthonos hydrillicola* detected in NY in 2023
  - Produces neurotoxin linked to Avian Vacuolar Myelinopathy (AVM)



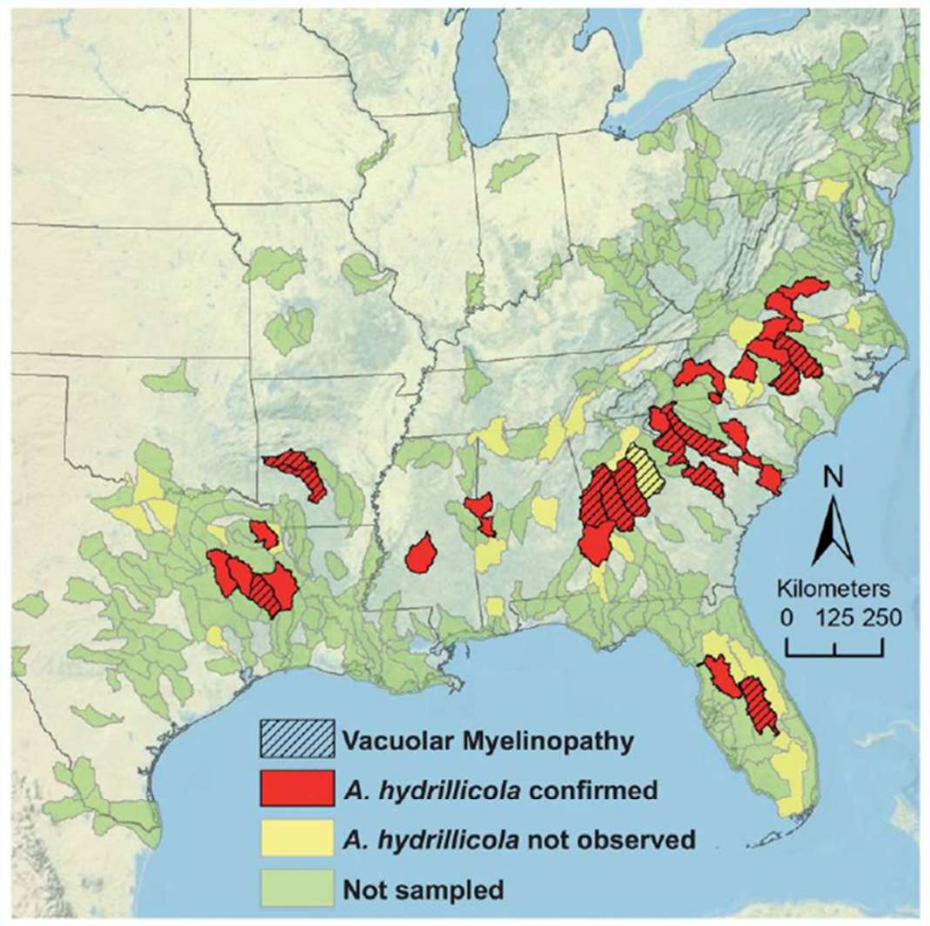
Avian Vascular Myelinopathy (AVM)

- Disease produced by toxin that comes from cyanobacteria (*Aetokthonos hydrillicola*), that attacks the nervous system of predatory birds
- Neurotoxin: aetokthonotoxin (ATX)
- Herbicide treatment - Avoid use of bromide, (i.e. diquat dibromide) that are used to combat Hydrilla = stimulates toxin



- Environmental factors: seasonal water temperature declines and lake turnover, enriching bromide availability and triggering toxin production
- Grows easily on the leaf and stem surface of aquatic plants
- 95% of the leaf and stem surfaces of aquatic plants (primarily hydrilla)


Vacuolar Myelinopathy
400 µm
Eagles develop VM from preying on neurologically impaired coots who have ingested the toxin
Coots and other animals consume vegetation contaminated with the neurotoxin and develop Vacuolar Myelinopathy (VM)
A. hydrillicola
200 µm
The cyanobacterium Aetokthonos hydrillicola grows on aquatic vegetation and produces a neurotoxin



Risk to Public and Pets:

- Skin rashes, eye irritation, tingling in fingers/toes, and other uncomfortable effects
- Pets and livestock: clinical signs – vomiting, diarrhea, seizures, death, etc.

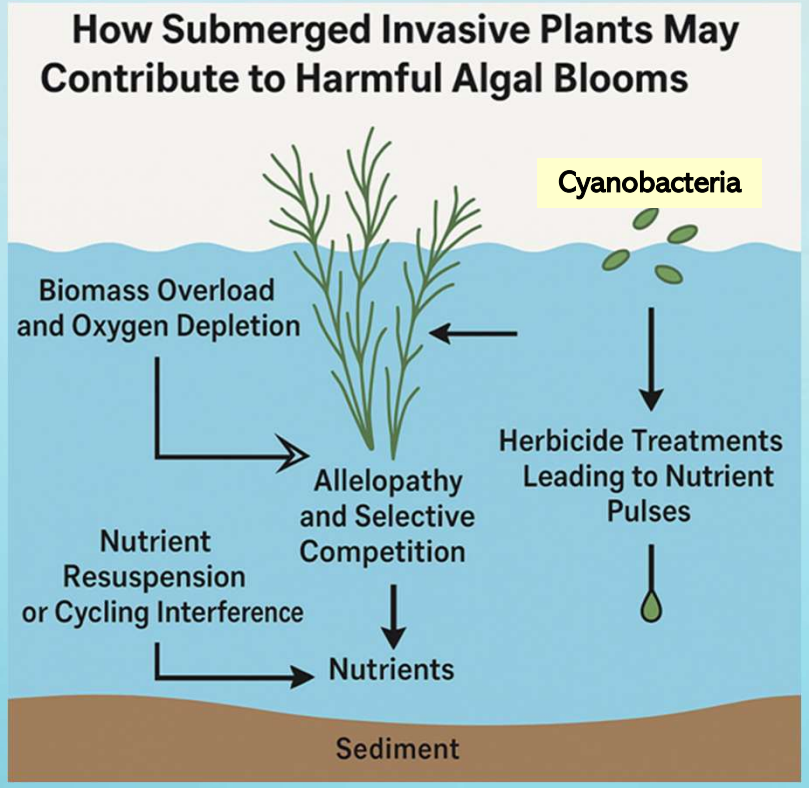
Gap Addressed:

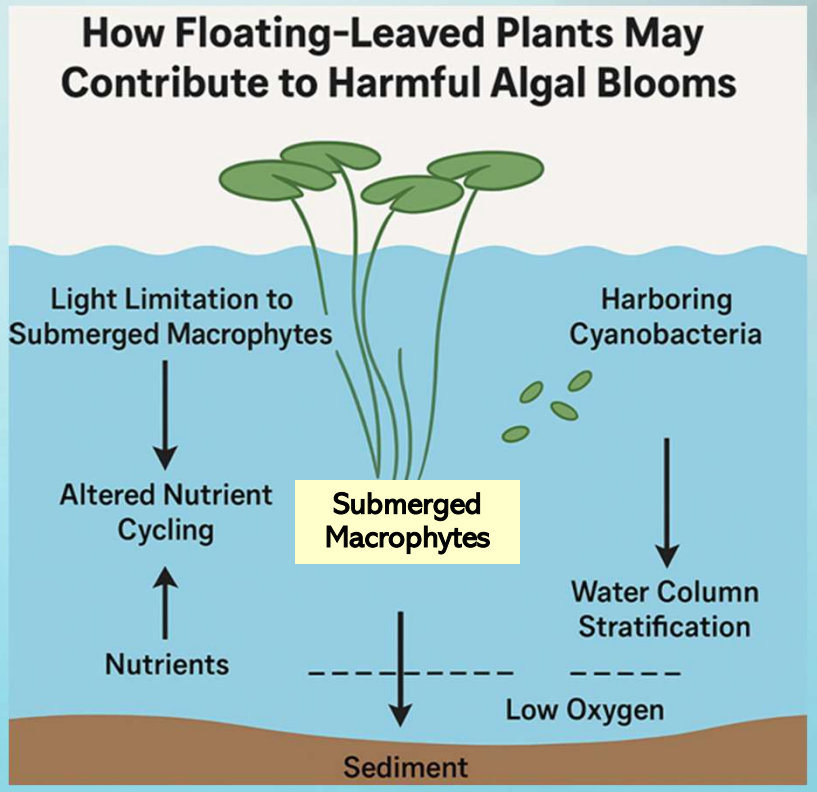
- Documenting and monitoring for presence of epiphytic cyanobacteria and toxins serving as a threat to human and wildlife health in waterbodies throughout NJ.

Aquatic Vegetation Survey Pilot Program

- Conducting surveys on lakes through the Lake Monitoring Program
- Supports the Natural Lands Management (Natural Heritage Program) and NJ AIS Coordinator (as part of the NJ Aquatic Invasive Species Management Plan)
- Plant biomass contributes to the nutrient cycle = some more than others?
- Abundance of certain species can contribute to HABs
  - *Myriophyllum spicatum*
  - *Egeria densa*
  - *Hydrilla verticillata*

A balancing act – plant + HABs





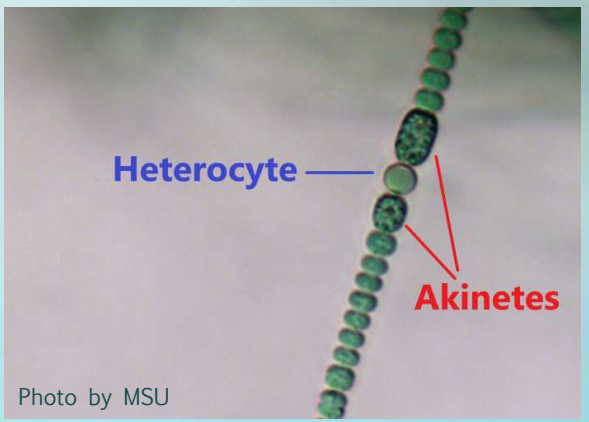
Infographics developed with the assistance of AI

Benthic HABs: Maryland

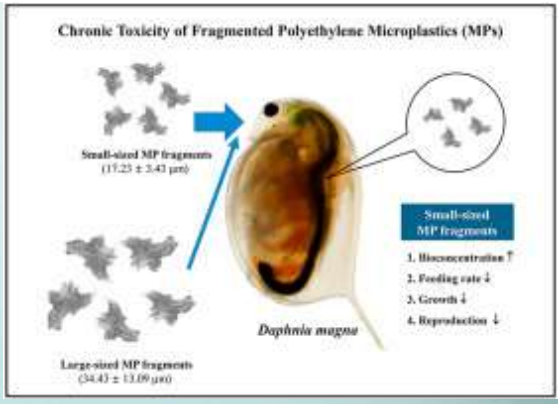
- Toxins being produced from benthic mats (BFA)?
- Utilizing whirlpaks → LCMS/ELISA Method(s)
- Saxitoxin detection in benthic cyanobacteria mats dominated by *Microseira wollei* (formerly *Lyngbya*)
- Saxitoxins detected in lakes using ELISA method (0.48 - 906 µg/g Saxitoxin)
- Anatoxin found in mat samples dominated by *Microcoleus* (formerly *Phormidium sp.*) in two lakes and the Potomac River
- Unclear if there is a "peak season" for BFA mats, more research needed

USACE Studies on Akinete Dormancy

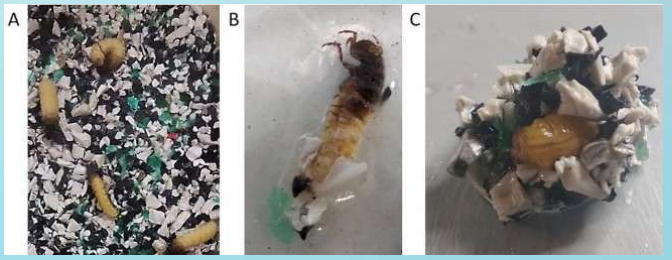
- Preventative management - by targeting overwintering cells.
- Methods for identifying overwintering cells and density separation of cells from sediment.
- Incubation studies can simulate environmental conditions
- Environmental conditions for akinete germination and growth of quiescent vegetative *Microcystis sp.* cells include light (≥0.5 µmol) and temperature (20–30˚C).
- Link: https://doi.org/10.1002/2688-8319.12326



Monitoring Microplastics



- Affecting growth rates of certain cyanobacteria species
    - *".. Microplastics with different colors not only inhibit the growth of microalgae but also affect the feeding behavior of zooplankton [30]."*
    - *"..alter algal photosynthesis, growth, gene expression, and colony size and morphology, possibly via adhesion and/or transfer of adsorbed pollutants from microplastics;"*



- **Implement Zooplankton Monitoring**
    - Pilot study underway for 2024 - 2028.
- **Microplastics monitoring in the future?**
  Alice Belskis – Micros in Macros (2025 - 2029)
- Interstate Technology & Regulatory Council's Microplastic Report: **https://mp-1.itrcweb.org/**

Key Takeaways

- A strong HAB strategy balances prevention, detection, response, and communication.
- Plans should be iterative, scalable, and interdisciplinary
- Flexibility is crucial – no one-size-fits-all, but the principles are transferable
- Research on HABs continues to evolve over time
- Important to be informed on the latest research to further support HAB response planning and management strategies

Useful links related to HAB management:

- Keep your pet safe: https://www.uvm.edu/seagrant/sites/default/files/uploads/publication/HABs_brochure_2018_05_05.pdf
- Lake Management Guidance Document: https://dep.nj.gov/hab/hab-guidance/
- Lake Management Planning: https://www.nalms.org/home/lake-management-planning/
- Strategies for Preventing and Managing Harmful Algal Blooms: https://hcb-1.itrcweb.org/introduction/
- Water Quality Concerns for Lakefront Communities: https://dep.nj.gov/wp-content/uploads/hab/hab_lakes_factsheet-2.pdf

Thank you!

Questions?

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- Aetokthonos hydrillicola gen. et sp. nov.: Epiphytic cyanobacteria on invasive aquatic plants implicated in Avian Vacuolar Myelinopathy. Phytotaxa (2014) Doi: 10.11646/phytotaxa.181.5.1

- Hunting the eagle killer: A cyanobacterial neurotoxin causes vacuolar myelinopathy. Breinlinger, Steffen, Tabitha J. Phillips, Brigette N. Haram, Jan Mareš, José A. Martínez Yerena, Pavel Hrouzek, Roman Sobotka et al. Science (2021) Doi: 10.1126/science.aax9050

- James et. Al (2005) – Impact of herbicide-treated hydrilla on algal growth
  ~ Demonstrated that chemical control of hydrilla led to nutrient release and increased phytoplakton biomass favoring cyanobacteria.

- Netherland et al (2016). Aquatic Plant Management an HAB risk.
  ~Review cases where AIS plant removal led to HABs due to released nutrients and reduced competition.

- Vila & Burks (2006) – Invasive Aquatic vegetation Impacts on Ecosystem Function.
  ~Showed how AIS alter nutrient dyanmics, benthic composition, and microbial processes that can destabilize the system.

- https://dnr.maryland.gov/waters/bay/pages/algal_blooms/ecosystem-disruptive-habs.aspx
  (poster has not been posted on website yet – presentation at NALMS)