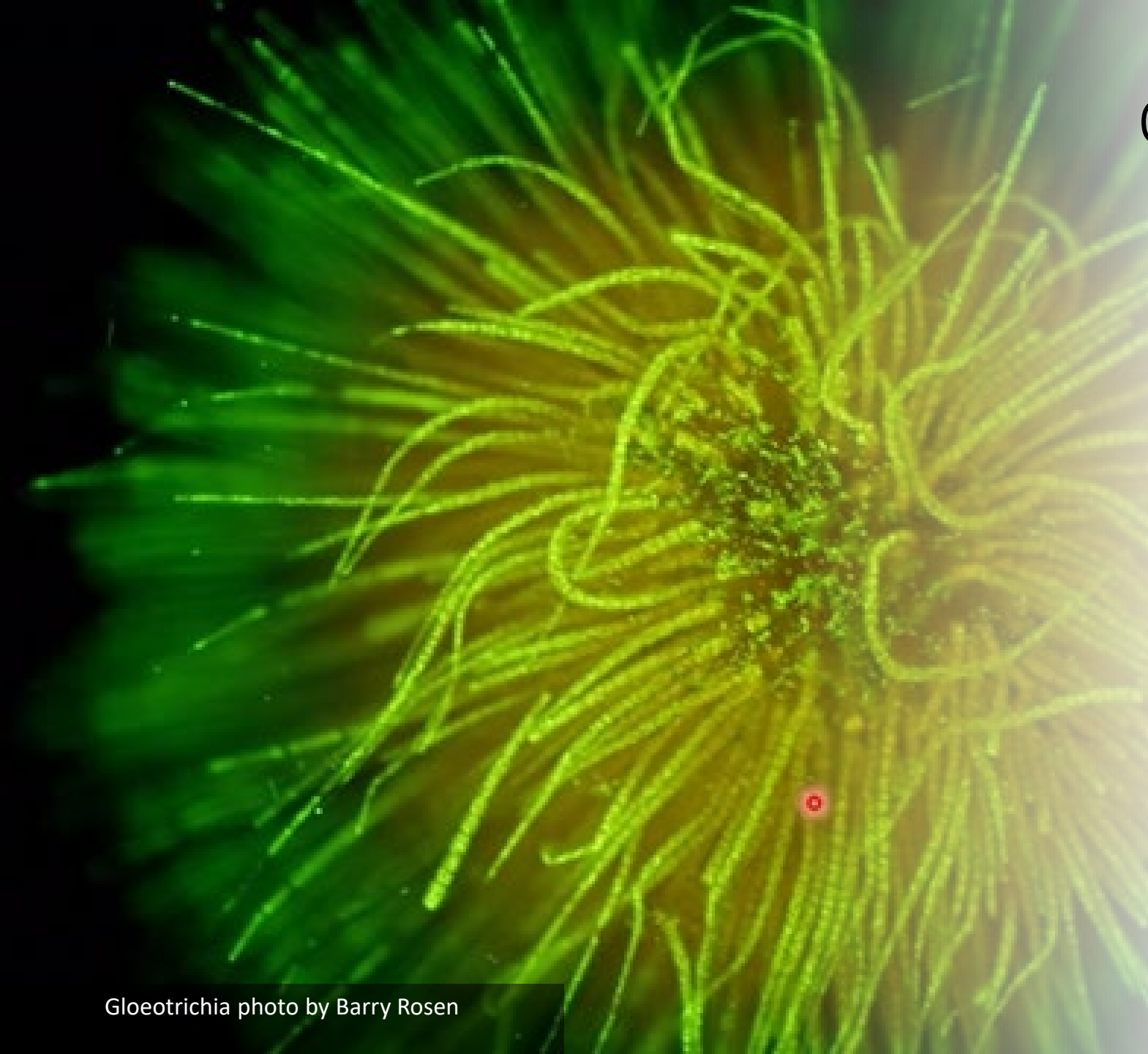


Gloeotrichia photo by Barry Rosen

Outline - Cyanobacteria

Context for Cyanobacteria on Cape Cod

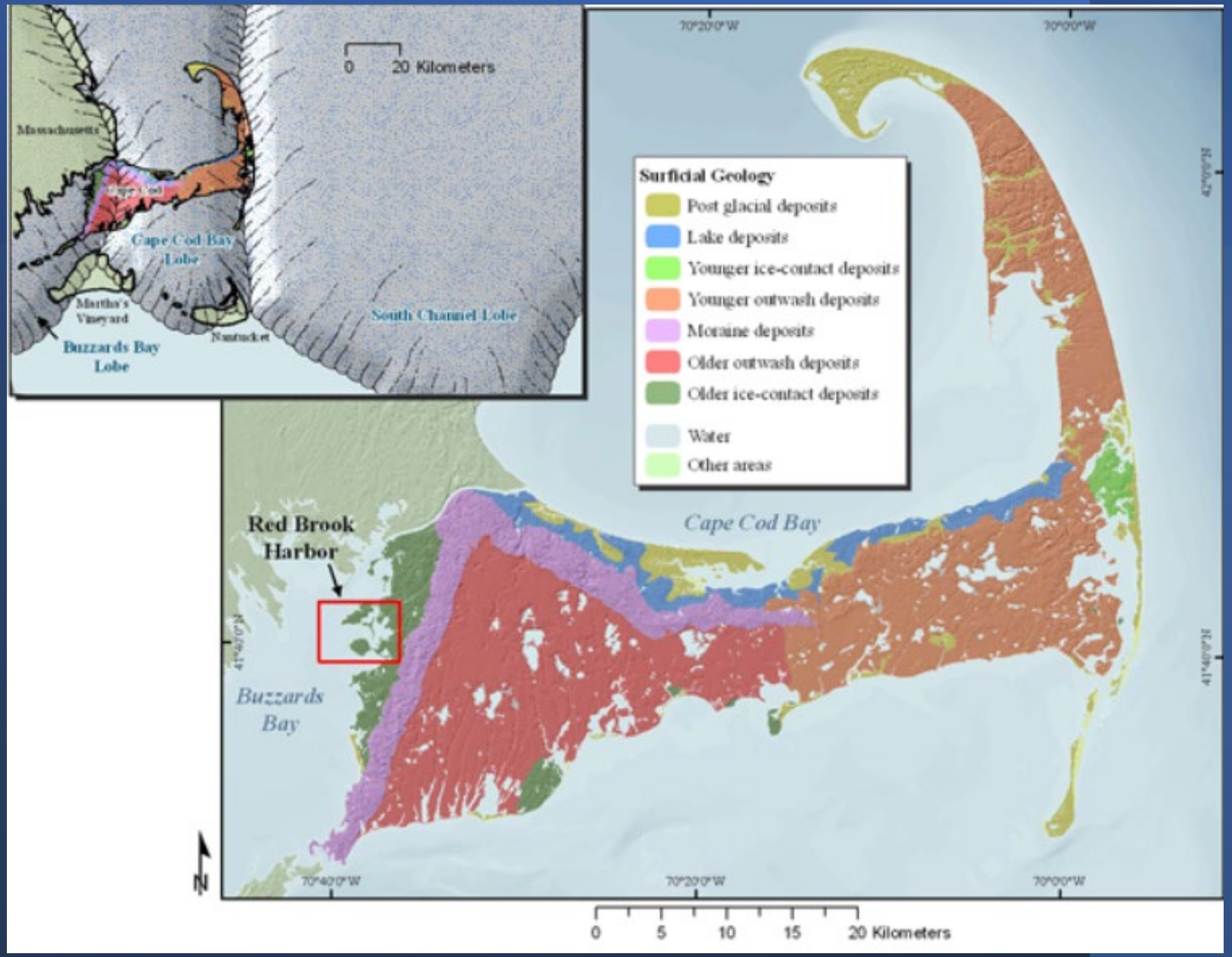
- Geologic perspective Kettle hole ponds
- Cyanobacteria –early oxygen producers

Cyanobacteria ecological strategies for success

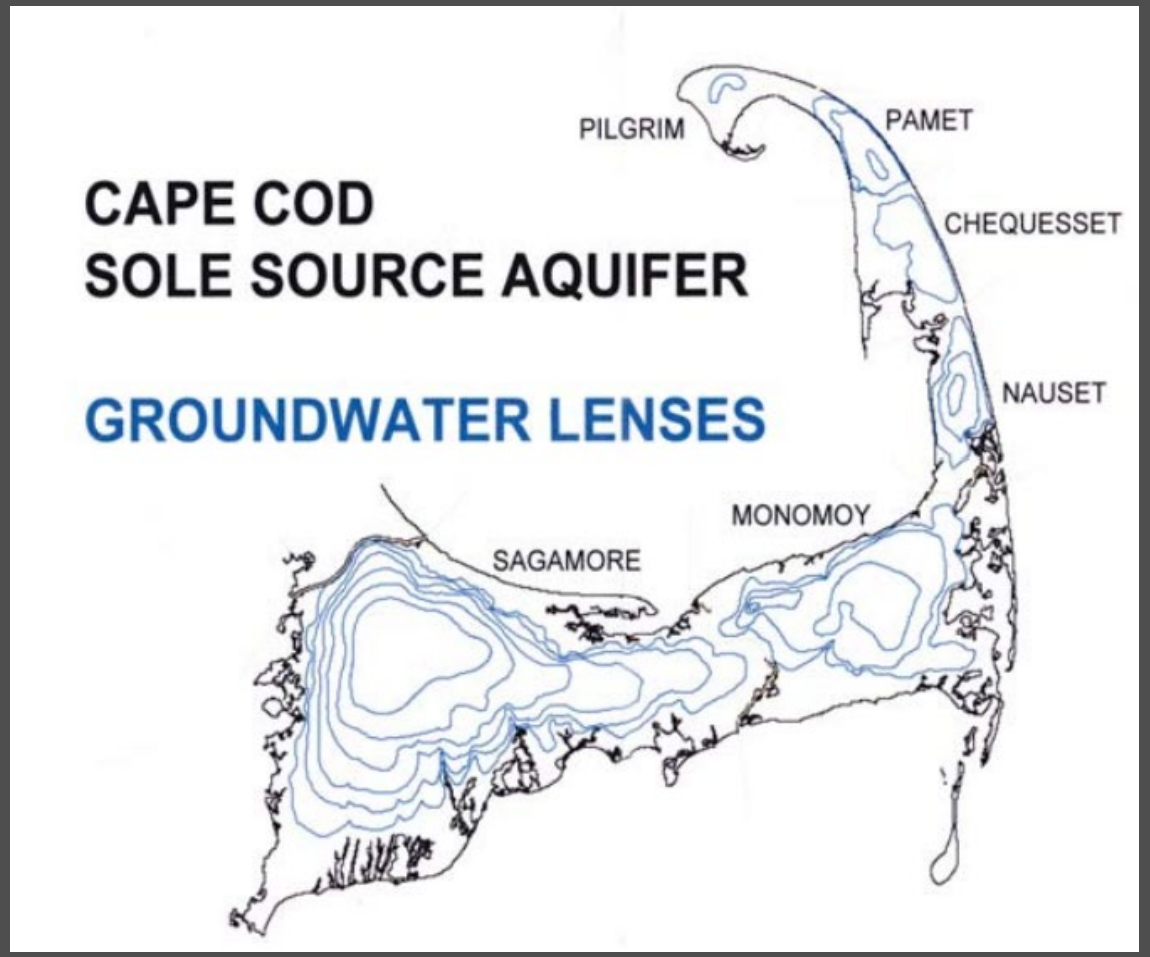
- Buoyancy
- Specialized cells
- Pigments
- Prokaryote advantage –rapid growth
- Toxins

Concerns, education, Safety

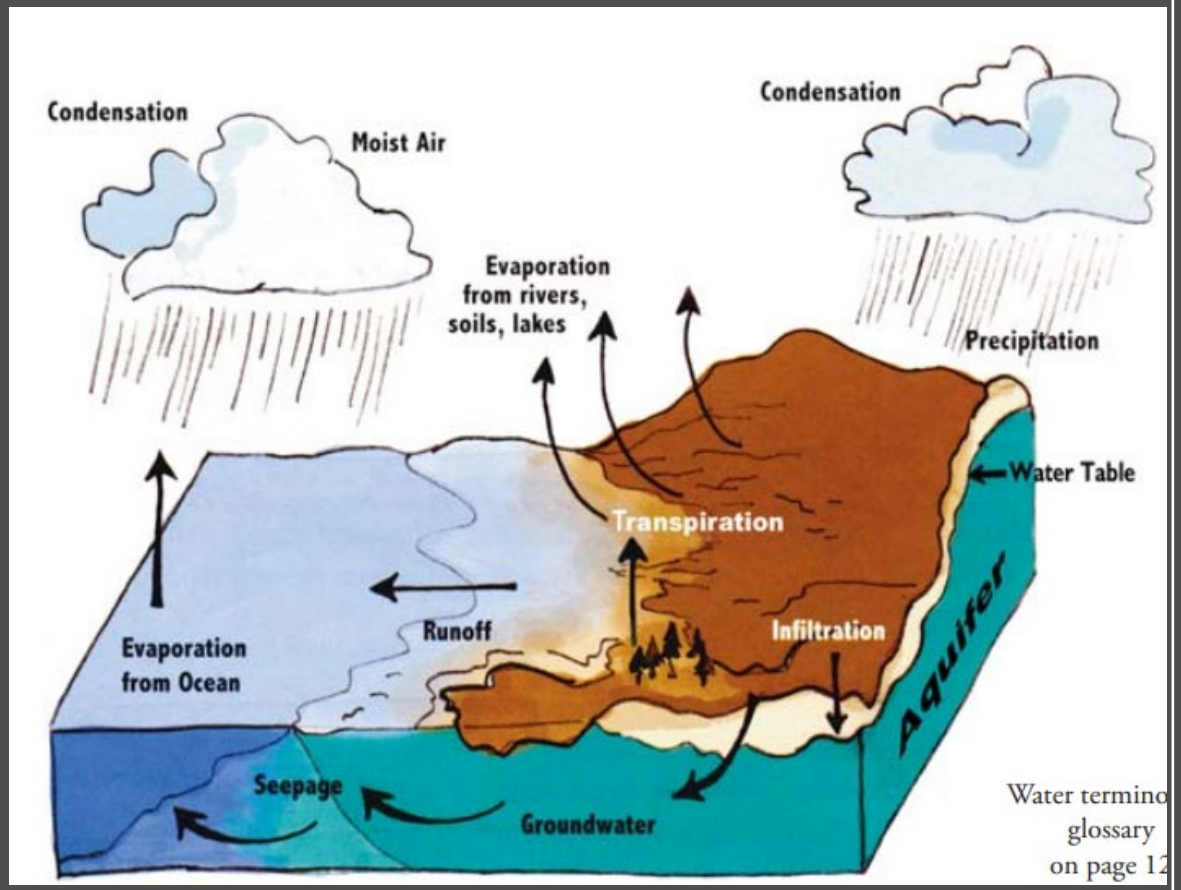
- APCC monitoring programs
- Cyanobacteria Risk Tiers
- Cyanobacteria Monitoring Program: Results 2021-2023



ESS1.C and LS4.A Rock Strata



ESS2.C & ESS3.C Human Impacts on Earth systems.



ESS2.D Weather and Climate.

Great Oxygenation Event-lead by the Cyanobacteria!

(wipe out as many competitors as possible!)

Toxin production evolved

O_2

4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0

Billion Years
Before Present

Precambrian Time: The Time of Prokaryotes

Phanerozoic Time Eukaryotic Time

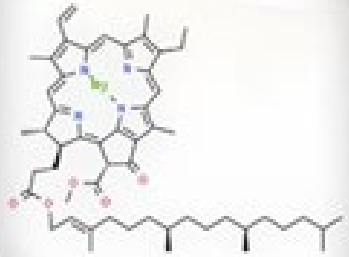
Archaean Era: Era of Archaea

Proterozoic Era: Era of Cyanobacteria

First Life

First Cyanobacteria

First Eukaryotes



chlorophyll *a*

Why toxins? Scavenger for iron, nitrogen storage, grazing? (pre-date metazoans), oxidative stress, quorum sensing, allelopathy. **Human perspective is inadequate.**

Shark Bay Western Australia

Stromatolites

ESS1.C and LS4.A Rock Strata

- Oldest known macrofossils dating back over 3 billion years (Earth is ~4.5 billion years old).
- Stromatolites are the reason why we're alive today!
- Before cyanobacteria the air was only 1% oxygen.

	Prokaryotes	Eukaryotes
Development	**400 million years ago**	**150 million years ago**
Cell structure	No nucleus, chloroplasts or mitochondria (Bacteria)	Nucleus, chloroplast, range of developed cell structures
Cell wall	Proteins and carbohydrates	Cellulose, silica
Movement	Gliding, mucilage and pores in cell wall (few are motile)	flagella
Specialized cells	Heterocytes Akinetes	Varies by class and genera
Algae type	Cyanobacteria	All other classifications

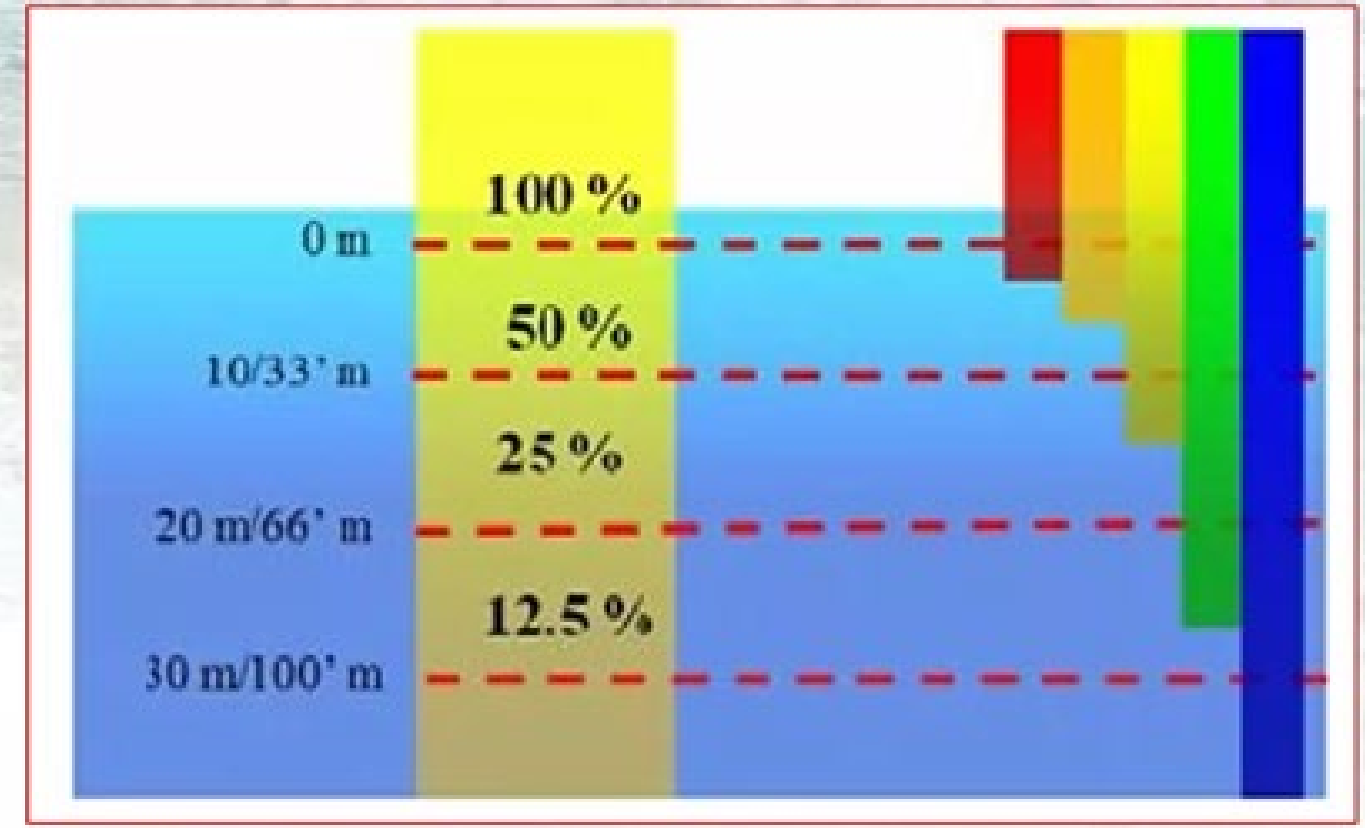
LS1.A Structure and function -Cyanobacteria prokaryote vs eukaryotic cells.

Algae: The World's Most Important Plants

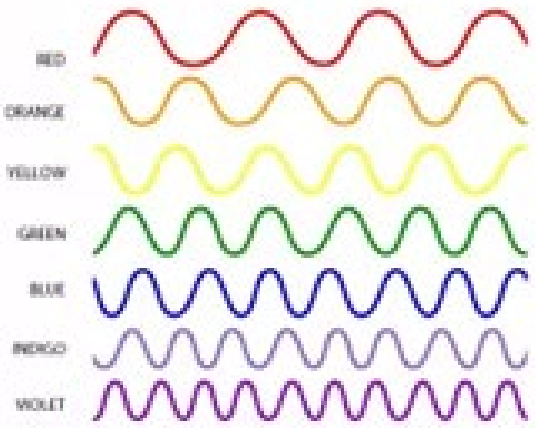
Images: Sarah Rushforth, Mindy Morales, and Kalina Monoylov

Buoyancy to optimize light capture

Penetration of light of various wavelengths through water; blue light is the strongest and red light is the weakest



Various pigments



LS1.B and LS4.C Adaptation, Growth and development of organisms

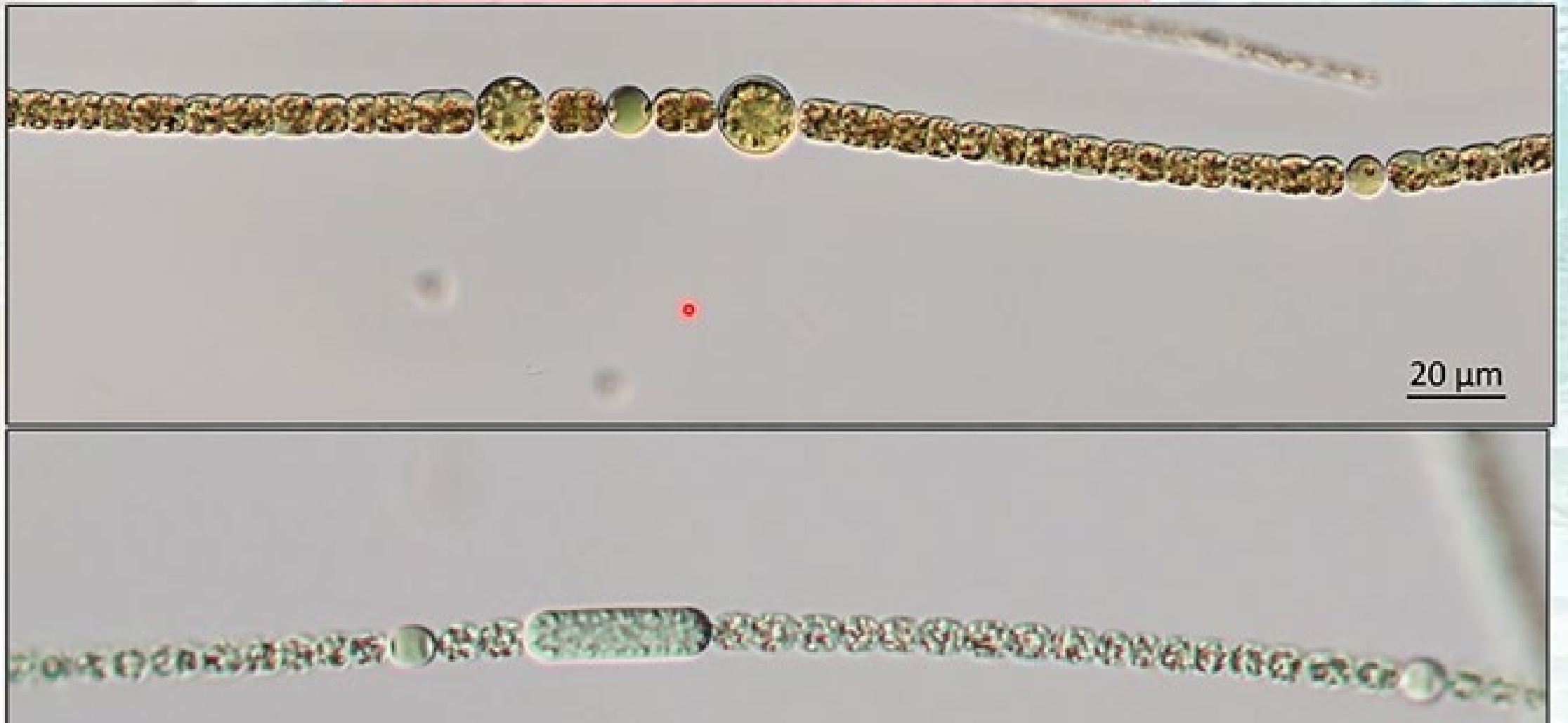
https://www.sciencedirect.com/science/article/pii/S1674205214606432

Planktonic

(gas vesicles/aka aerotopes)

Dolichospermum

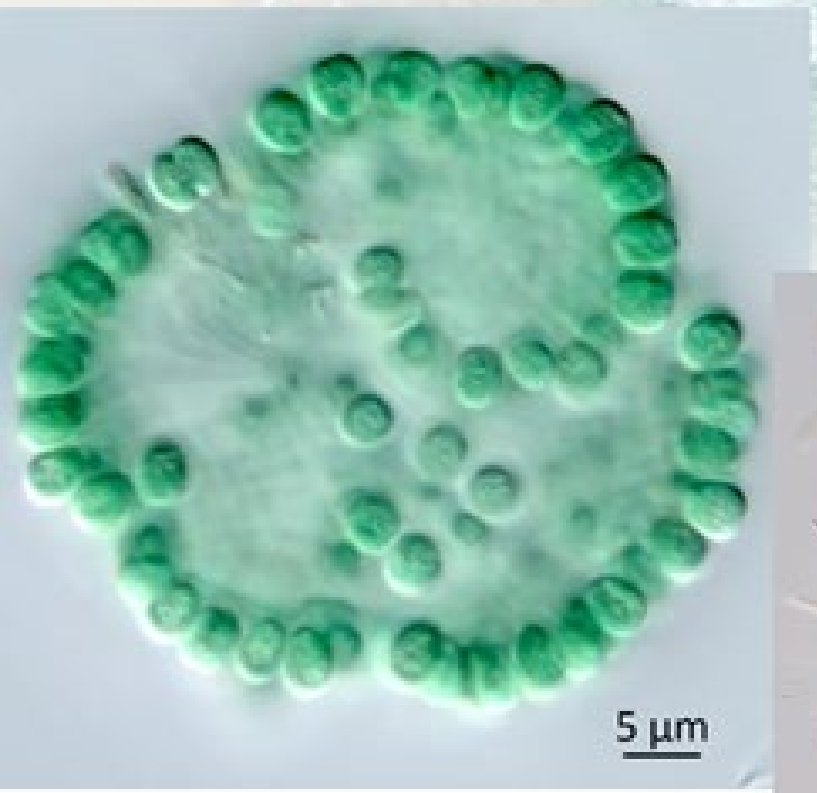
(in 2009 renamed-prior name was *Anabaena*)

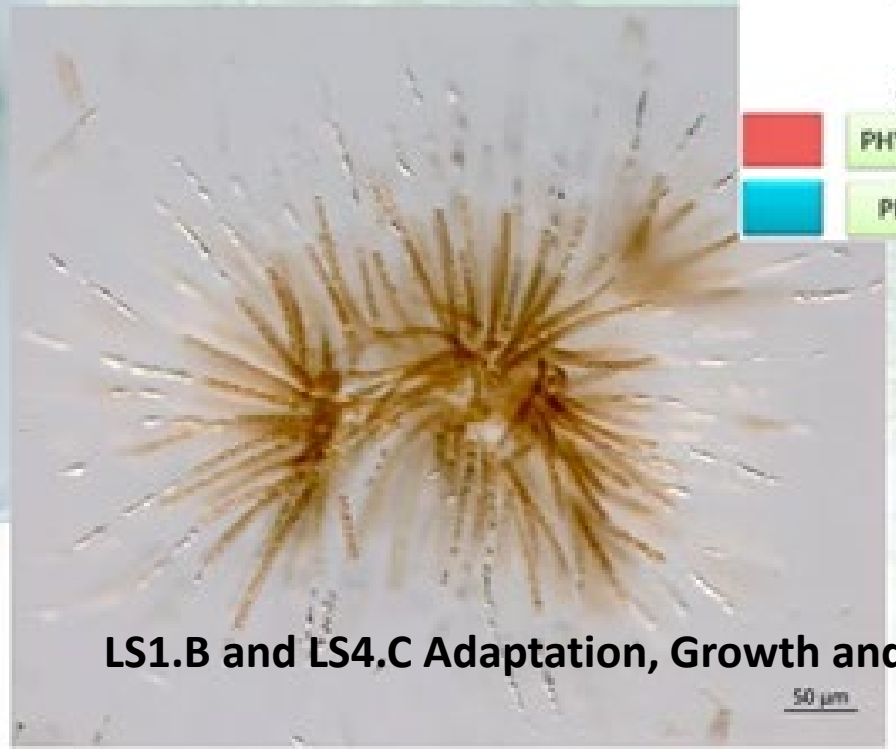


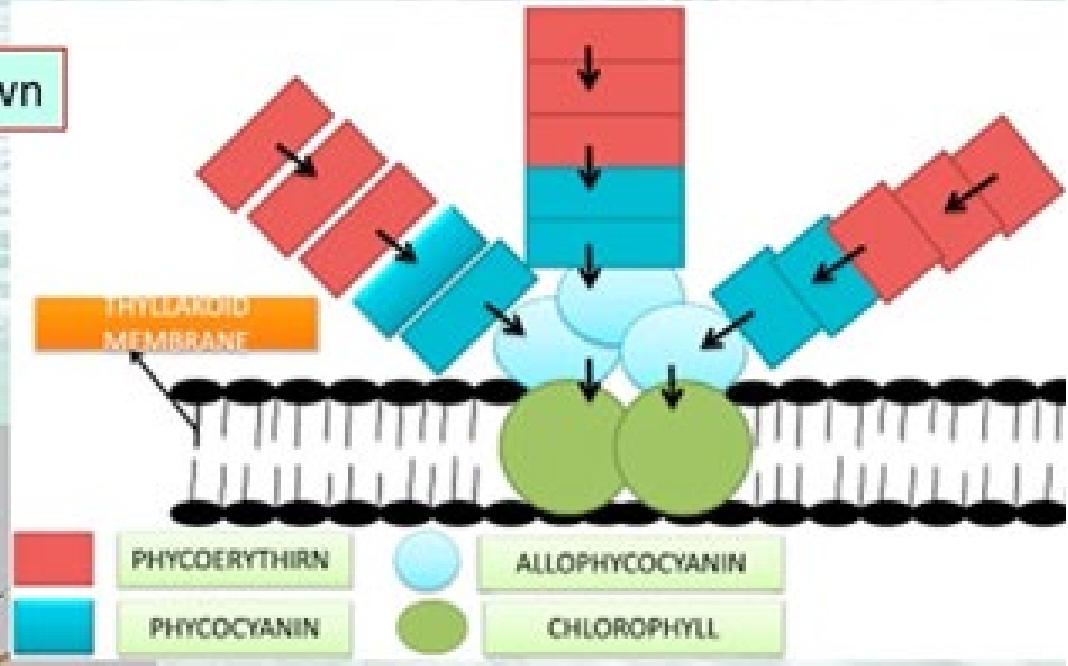
Light Capture and pigments

Chlorophyll *a*, phycocyanin, phycoerythrin, β-carotene and zeaxanthin, etc,

Pigments causes a variety of colors: green, black, pink, brown



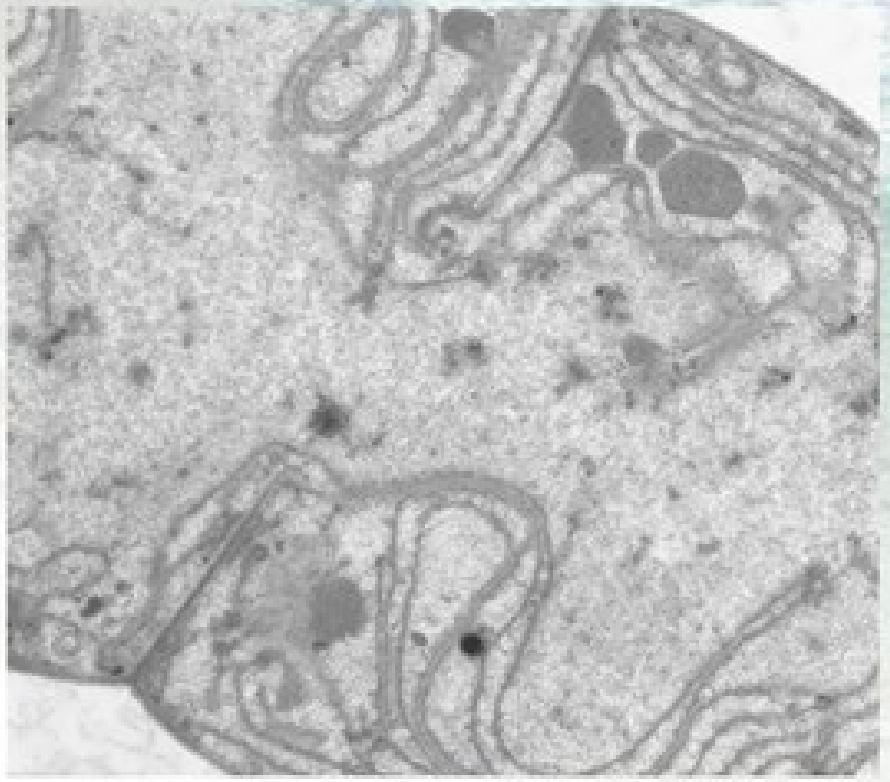




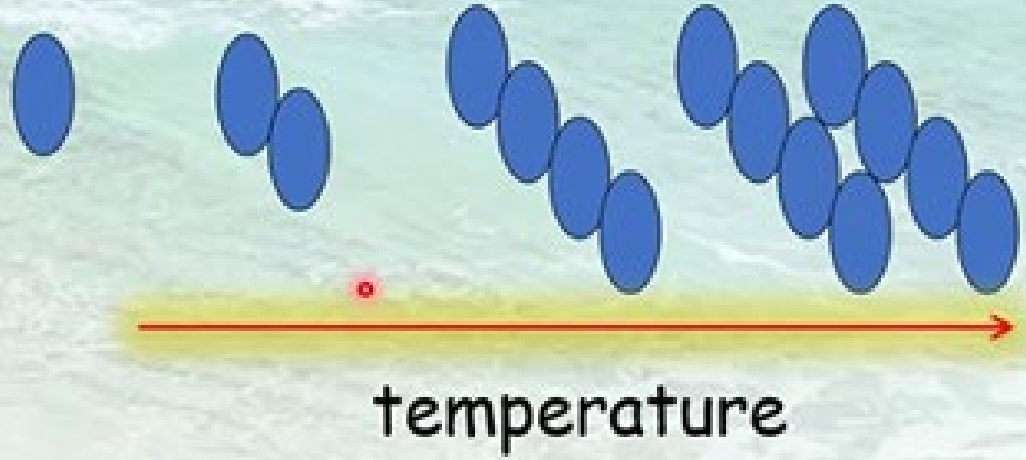
https://doi.org/10.1016/j.fct.2018.08.002

LS1.B and LS4.C Adaptation, Growth and development of organisms

Ecological Strategies: bacteria in a eukaryotic world-thermophiles grow faster



Rapid Growth



3 “doublings” or divisions per day!

Caveats: light, temperature, nutrients must not be limiting

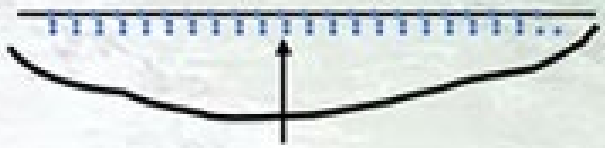
Drinking water & recreational impact

Beware of this phenomenon when sampling

initial distribution

100,000 cells/L;
20 µg/L toxin

buoyancy



10,000,000 cells/L;
2000 µg/L toxin

wind

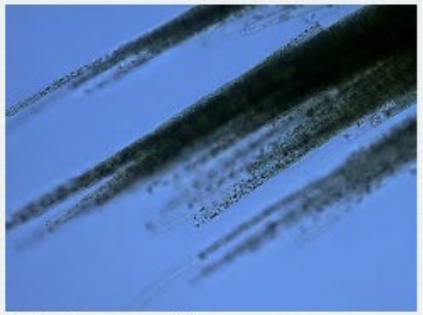
100,000,000 cells/L;
20,000 µg/L toxin

Notify your local health department and send a photo to **cyano@apcc.org** noting the location, day and time.

Identifying Harmful Algal Blooms (HABs)

Utah Lake, October 8, 2014

Dolichospermum spiroides

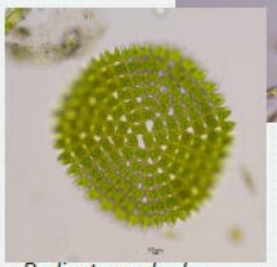


Aphanizomenon flos-aquae

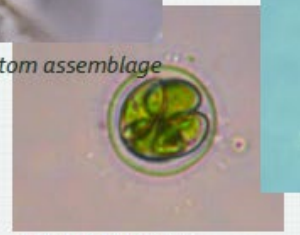
Cyanobacteria (Blue-Green) Bloom

HAB

Diatom assemblage



Pediastrum duplex



Oocystis species

Chlorophyta (Green Algae)

Very little cyanobacteria present

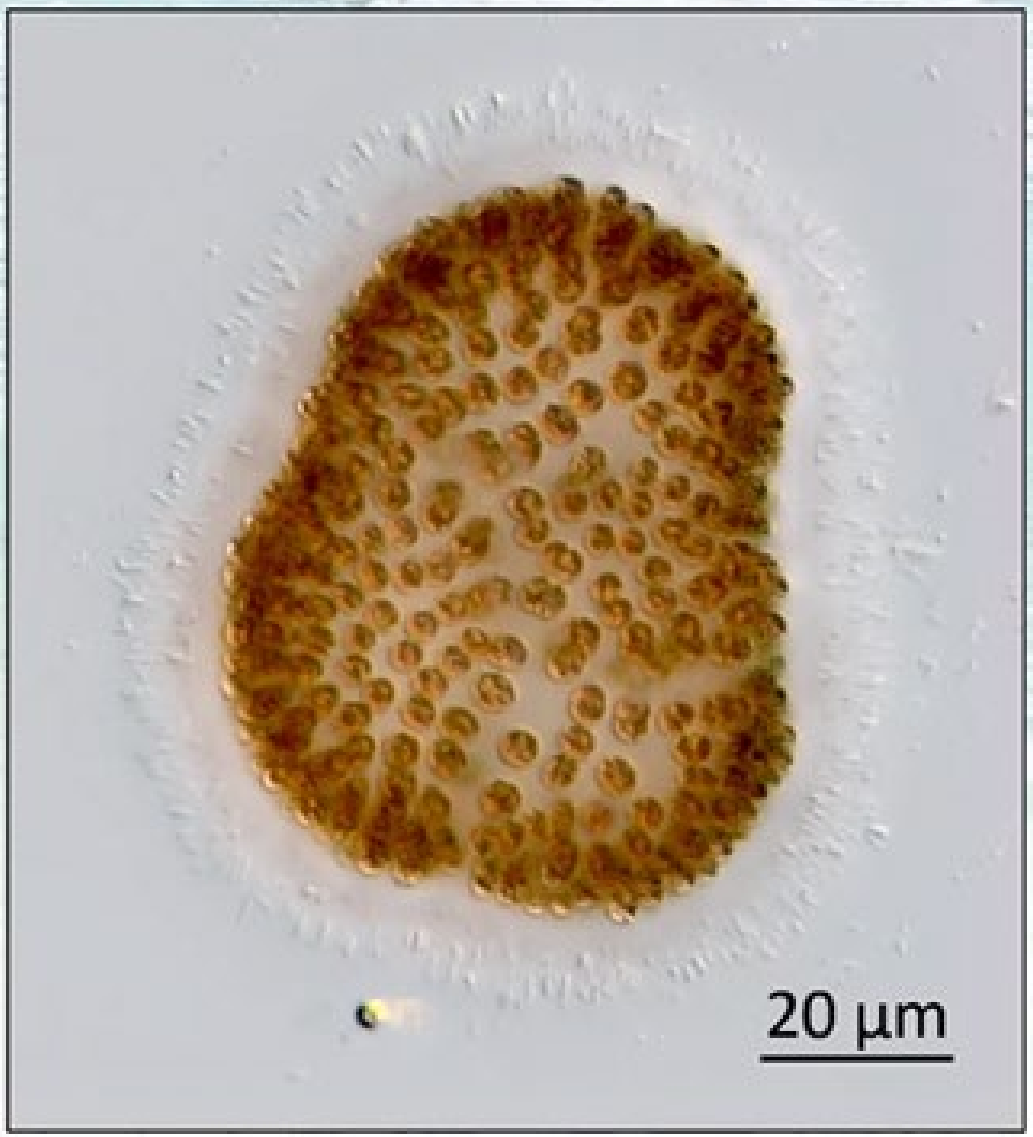
Not HAB

Euglena sp

Utah Lake, August 25, 2015

Unicellular forms

Microcystis wesenbergii



Woronichinia naegeliana

Cyanobacteria: Key cyanotoxin-producing organisms: a phylogenetical diverse group

Unicellular forms

Microcystis, Woronichinia

Order Chroococcales

Filamentous (non-N fixers)

Lyngbya, Phormidium, Microcoleus, Oscillatoria Planktothrix, Microseira

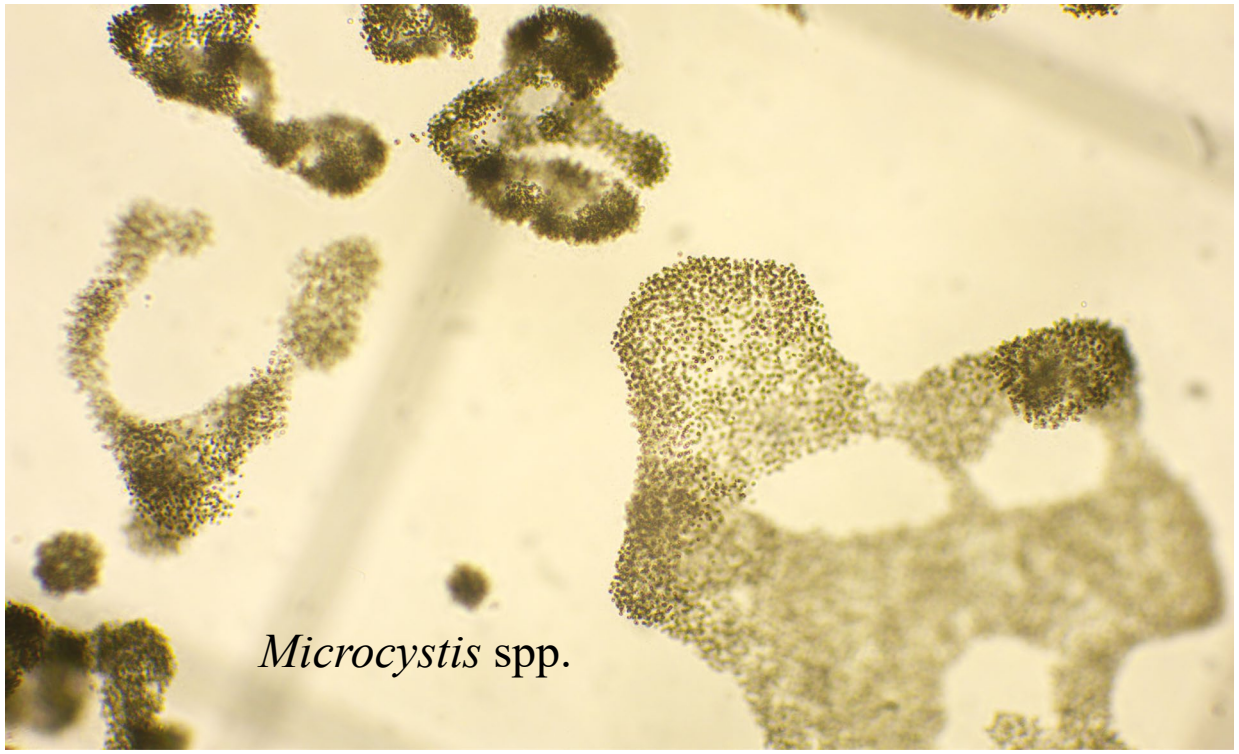
Order Oscillatoriales

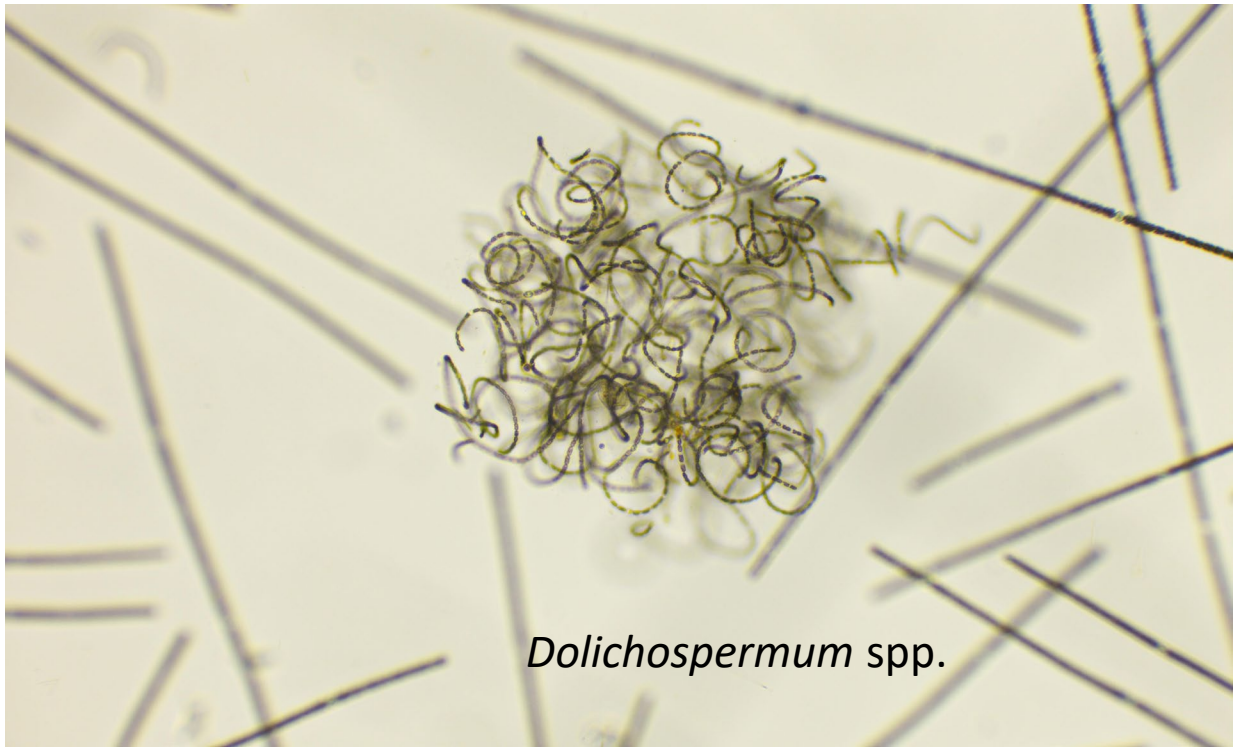
Filamentous (heterocystous)

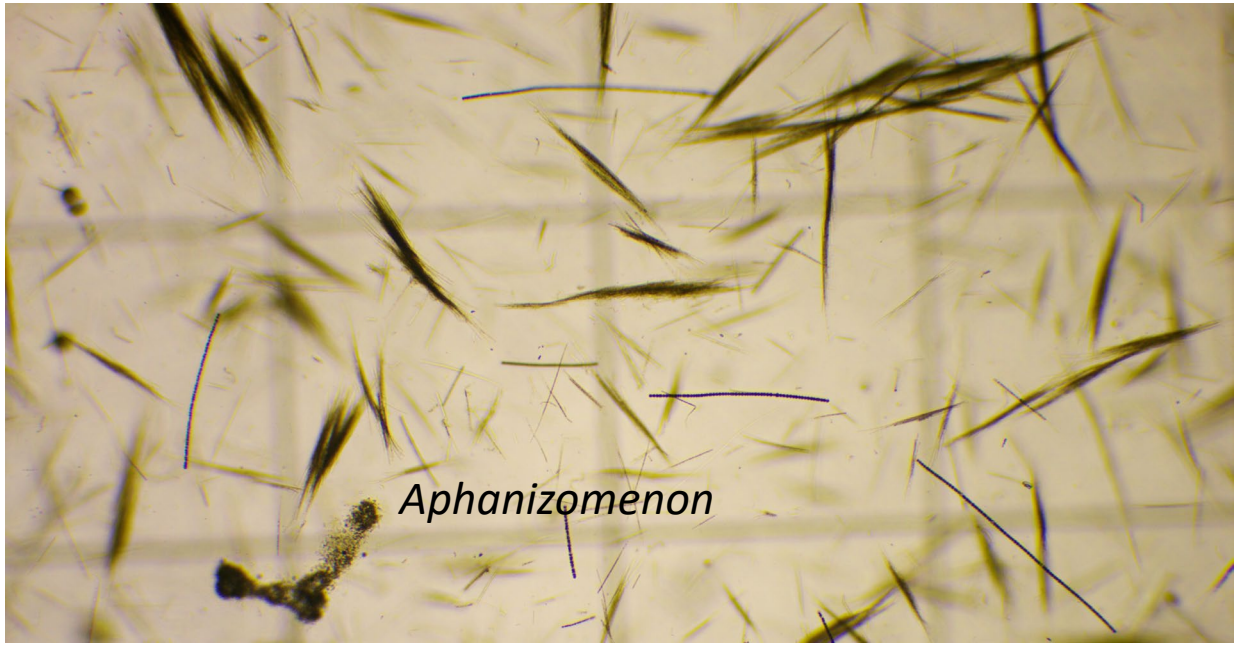
Dolichospermum
Aphanizomenon
Raphidiopsis
Nodularia
Anabaenopsis
Cylindrospermum
Cuspidothrix, Chrysosporum

Order Nostocales

Some genera are known to make more than one kind of toxin


Microcystis spp.


Dolichospermum spp.


Aphanizomenon


Woronichinia

Ecological Strategy: cyanotoxins

- **Hepatotoxins**
  - Disrupt proteins that keep the liver functioning, may act slowly (days to weeks)

microcystins (300+ variants)
nodularin
cylindrospermopsin

- **Neurotoxins**
  - Cause rapid paralysis of skeletal and respiratory muscles (minutes)

anatoxin -a
guanitoxin [anatoxin -a (s)]
saxitoxin
neosaxitoxin

- **Dermatotoxins**
  - Produce rashes and other skin reactions, usually within a day (hours)

lyngbyatoxin

- **b-*N*-methylamino-L-alanine**
  - Neurological: potentially linked to ALS

BMAA

Cyanobacteria Monitoring Program: 2017 - ongoing

Website: https://apcc.org/our-work/science/community-science/cyanobacteria/

Need:

- 890 ponds, ~ herring spawning;
- Pond associations and public concerns;
- EPA-approved method enables rapid assessment of cyanobacteria blooms and pond water quality.

Goals:

- Collect data to educate public on risks of harmful cyanobacteria blooms (HCBs),
- Motivate action to improve water quality.

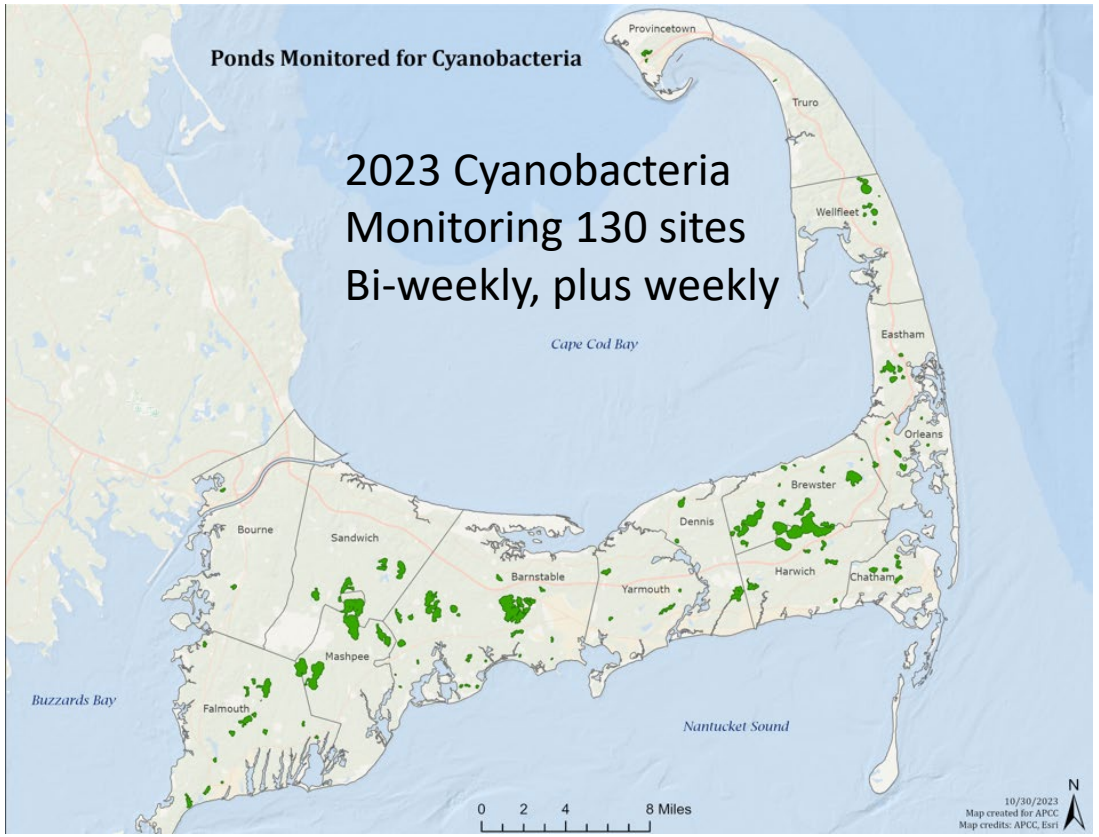
Elements:

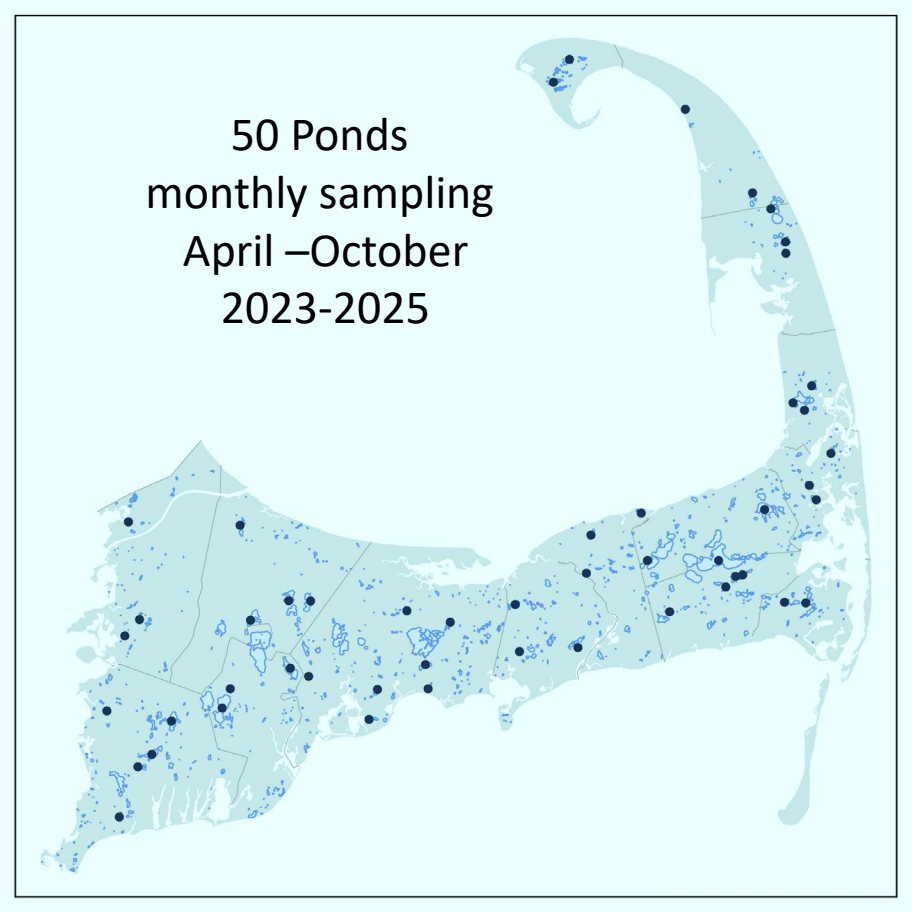
- **Biweekly sampling** from May - October;
- **Data interpreted within a framework of health regulations and guidance, risk levels and recommended actions;**
- **Website and interactive map viewer with results;**
- **Results to health agents and public within 24 hours**.

Methods: EPA-approved QAPP for Cyanobacteria Monitoring Collaborative, and Cyanocasting (Nancy Leland). Toxin tests added in 2022.

APCC Two Pond Monitoring Projects

Cyanobacteria and Cape Cod Regional Pond Monitoring Project





Pond Water Quality Monitoring Program – Selected Ponds

Ponds by Town

Barnstable
Garretts Pond
Hathaway Pond
Long Pond
Lovells Pond
Lake Elizabeth
Micah Pond
Parker Pond

Bourne
Flax Pond
Queen Sewell Pond
Red Brook Pond

Brewster
Cliff Pond
Long Pond
Slough Pond

Chatham
Goose Pond
Barclay Pond

Dennis
Coles Pond
Flax Pond
Scargo Lake

Eastham
Bridge Pond
Herring Pond
Ministers Pond

Falmouth
Coonamesset Pond
Jenkins Pond
Mares Pond
Shivericks Pond
Wing Pond

Harwich
Cornelius Pond
Hawksnest Pond
Sand Lake
Walkers Pond

Mashpee
Johns Pond
Moody Pond
Santuit Pond

Orleans
Crystal Lake
Pilgrim Lake
Reubens Pond

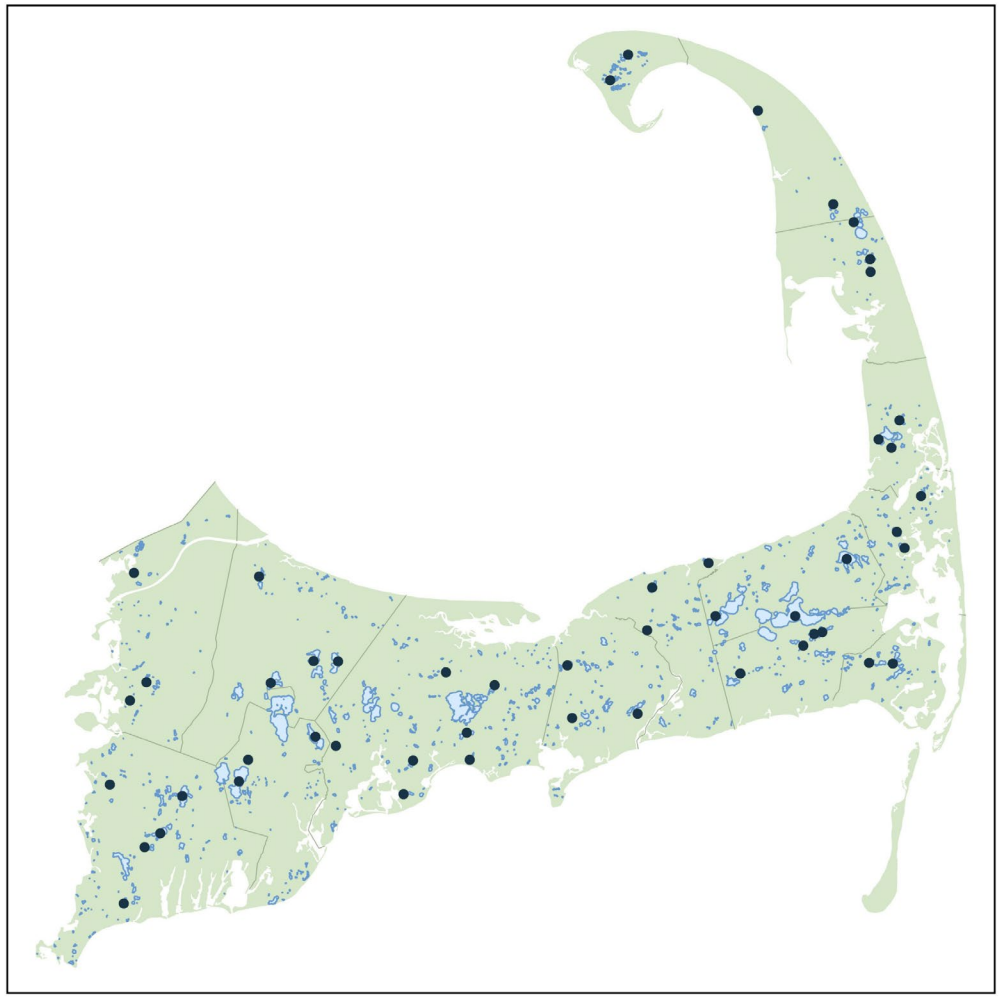
Provincetown
Blackwater Pond
Clapps Pond

Sandwich
Lawrence Pond
Peters Pond
Shawme Lake
Spectacle Pond

Truro
Village Pond
Great Pond

Wellfleet
Duck Pond
Great Pond
Herring Pond

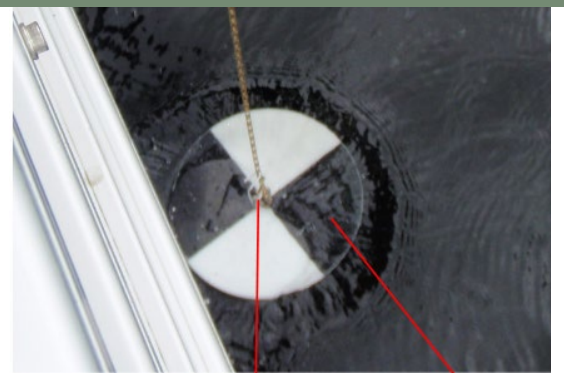
Yarmouth
Dennis Pond
James Pond
West Sandy Pond



Pond Water Quality Monitoring Program – How it works

Pond Sampling

- Monthly March – November
- 2-4 samples per pond – collected from deepest point
- Field Parameters
  - DO, Temp, pH, Conductivity, Secchi
- Lab Parameters – in 3 bottles
  - TN, TP, Chl-a, alkalinity, and dissolved nutrients



TN, TP

Alkalinity

Chlorophyll-a, Phaeophytin, Nitrate/nitrite, Ammonium, and Orthophosphate

APCC Monitoring Team

Sophia Feuerhake

Volunteers ☺

John-Tyler Percy (JT)

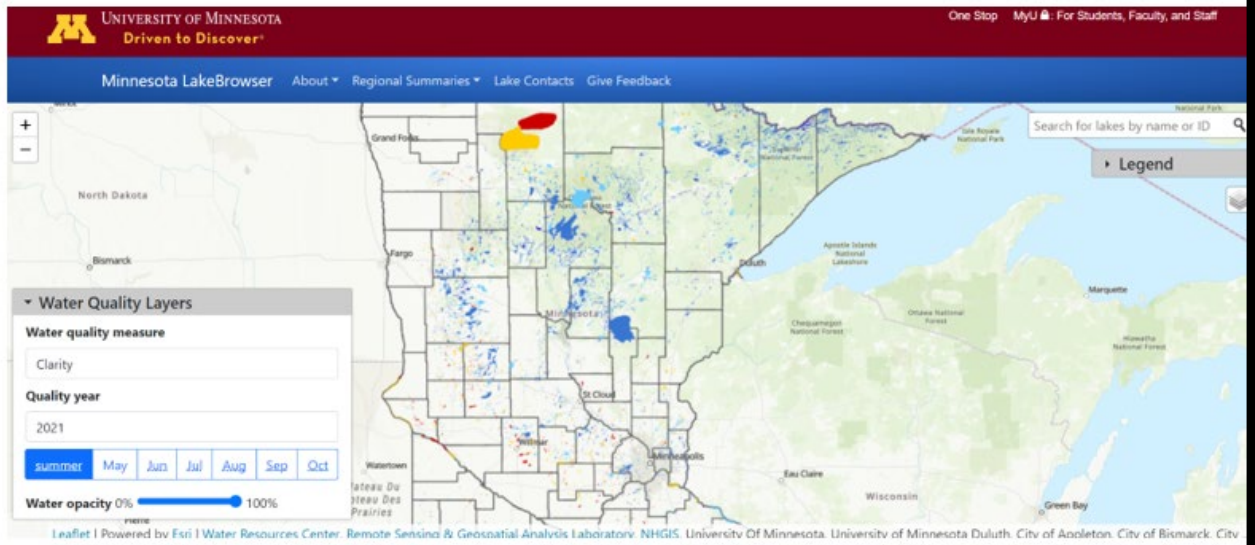
We will bring:

- Life vests
- All monitoring gear
- A canoe and paddles

You will need:

- Muck boots
- A hat/sunscreen
- Weather appropriate clothing
- Transportation between ponds
- Water/snacks

https://lakes.rs.umn.edu/



About the Minnesota LakeBrowser

The LakeBrowser has provided satellite-derived data on lake clarity, an indicator of water quality, for more than 10,000 Minnesota lakes since 2002. An online interactive tool with [illegible] of lake clarity, chlorophyll [illegible]

transparency

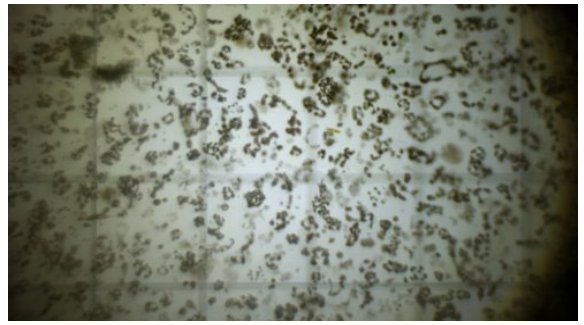
Leif Olmanson (olman002@umn.edu)

PS4.A Wave properties

APCC's Cyanobacteria Monitoring Program

APCC Staff with Summer and Fall Interns 2022-2023

APCC
Association to
Preserve Cape Cod

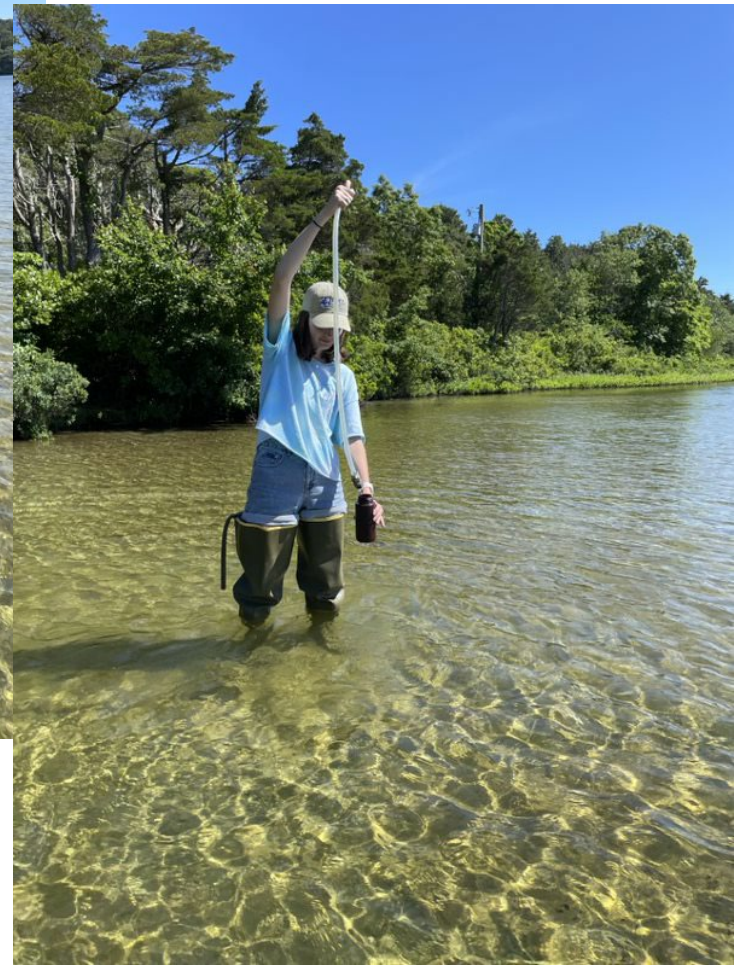


Whole Lake Water Sample
WLW

- Samples are taken using a 1-meter tube (IT tube)
- Samples contains the concentrations of cyanobacteria in 1-meter of the water column (surface to just above the bottom)
- Sample processed by APPC staff to obtain data about cyanobacteria different size fractions
- Sample is not used to forecast future bloom accumulations

Integrated **t**ube (IT)

Chiara Nava 2022



Leah Stucker 2022

Meri Ratal 2022

Leah Stucker 2022

Plankton Tow Net Sample

- We use a 53*um (mesh size)* student plankton tow net
- Net is towed across a 3-meter distance
- The net is “cast” near the surface
- Net sample collects larger cyanobacteria colonies, which tend to form visible blooms and scums

Net sample can tell you:

- If there is toxic planktonic cyanobacteria in the pond
- If cyanobacteria is dominant over other algae
- Gives you information about the size of the cyanobacteria populations

Shore line net sample relevance to public health:

- Sample is analogous to a natural cyanobacteria accumulation that may occur on a pond if the wind condensed cyanobacteria over 3 meters
- Nearshore accumulations of cyanobacteria are considered to pose a higher risk because the shoreline and shallow waters are where children and pets typically interact with the pond

Bloom **F**orming **C**olonies (BFC)

ZAPPR-Separator

- Separates zooplankton and cyanobacteria
- Concentrates buoyant cyanobacteria genus
- Increases of cyanobacteria concentrations and their growth rates measured from BFC samples can help forecast cyanobacteria blooms

cyanoCasting

LIM-TEX®

Cyanobacteria Populations and Biomass

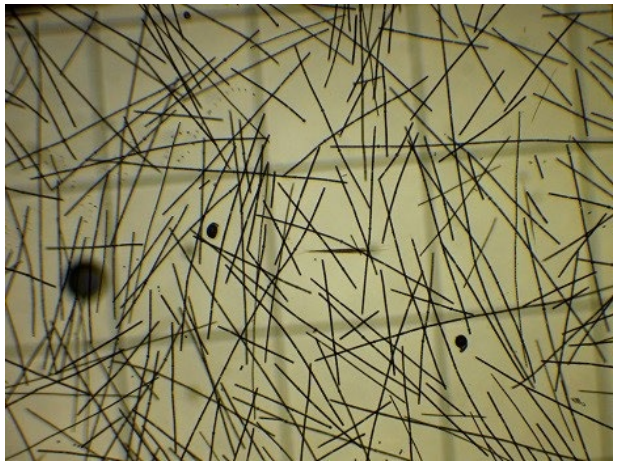
- The amount of cyanobacterial biomass in waterbodies, is measured with a fluorometer
- We measure the pigment phycocyanin (PC) which is a unique pigment found in cyanobacteria used for photosynthesis
- Concentrations of PC provide information on the composition of the cyanobacterial populations. For example, phycocyanin concentrations in the genus Dolichospermum, Aphanizomenon and Woronichina are similar and tend to be much higher than phycocyanin concentrations in Microcystis.

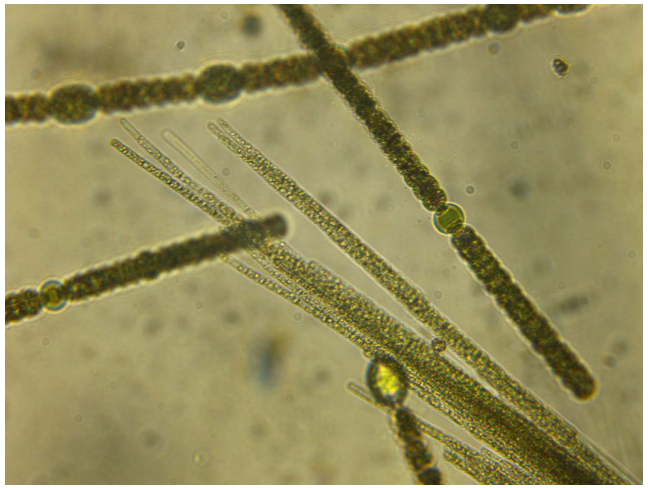
- Cyanobacterial biomass (PC) has been shown to be correlated with cyanotoxin concentrations, including microcystin (MC) in Microcystis dominated systems and anatoxin-a (ATX) in Dolichospermum dominated systems.

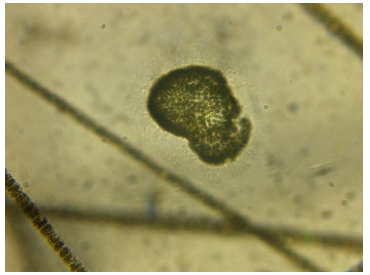
Procedure for Processing

Santuit Pond July 26, 2022

Phyco Tech	***Dolichospermum*** **67%**	*Aphanizomenon* *5%*	*Woronochinia* *5%*	*Microcystis* *23%*
UNH-CFB	***Dolichospermum*** **90%**	*Aphanizomenon* *4%*	*Woronochinia* 1%	*Microcystis* *5%*
APCC*	***Dolichospermum*** **96%**	*Aphanizomenon* *2%*	*Woronochinia* *2%*	
Northeast Labs	***Anabaena***	*Cuspidothrix*	*Snowella*	







Dolichospermum: 96%
Woronichinia: 2%
Aphanizomenon: 2%

*APCC images

APCC 2022 Cyanobacteria Risk Categories Revised 7/26/2022

Criteria		APCC Acceptable	APCC Potential for Concern	APCC Use Restriction Warranted
Microcystin	Potential microcystin calculated by APCC based on measurement of phycocyanin in Bloom Forming Colony samples.	Potential microcystin calculated at low levels that do not warrant additional toxin testing[2,4].	Potential microcystin is elevated to a point where an exceedance is deemed possible and confirmatory toxin testing warranted[2,4].	
	Measured microcystin by Barnstable County Water Quality Lab.	Less than 4 ppb microcystin measured in GRAB sample.	Between 4 and 8 ppb microcystin measured in GRAB sample.	Greater than 8 ppb microcystin measured in GRAB sample[3].
Cyanobacteria Blooms and Scums	Cyanobacteria bloom material reported and confirmed by APCC.	None present at the time and place of sample collection.	A cyanobacteria scum or bloom is present but is deemed to be insignificant by the Massachusetts Department of Public Health and the town's health agent.	A cyanobacteria scum or bloom is present and is deemed to be significant by the Massachusetts Department of Public Health or the town's health agent[3].
Notes	To interpret cyanobacteria data using this table, the most hazardous result determines the category the pond is placed in from right to left. A pond that meets even a single criterion in the "Use Restriction Warranted" column will be placed in that category. Likewise, a pond that meets even a single criterion in the "APCC Potential for Concern" category but does not meet any criteria in the "APCC Use Restriction Warranted" category, will be placed in the "APCC Potential for Concern" category. If a pond meets no criteria in the "APCC Use Restriction Warranted" or the "APCC Potential for Concern" category, that pond is placed in the "APCC Acceptable" category. [2] Developed with recommendations from Nancy Leland of Lim-Tex Inc. and affiliated with the University of New Hampshire Center for Freshwater Biology. [3] Criteria attributed to MDPH.			

Deep Pond 2020-2022 Cyanobacteria Risk Comparison

	July		August		September		October	
h-30th	1st-15th	16th-31st	1st-15th	16th-31st	1st-15th	16th-30th	1st-15th	16th-3

Jenkins Pond 2020-2022 Cyanobacteria Risk Comparison

	July		August		September		October	
h-30th	1st-15th	16th-31st	1st-15th	16th-31st	1st-15th	16th-30th	1st-15th	16th-3

Mares Pond 2020-2022 Cyanobacteria Risk Comparison

	July		August		September		October	
h-30th	1st-15th	16th-31st	1st-15th	16th-31st	1st-15th	16th-30th	1st-15th	16th-3

For general questions about cyanobacteria, contact the Massachusetts Department of Public Health

617-624-5757

www.mass.gov/dph/algae

NIH https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2785771/

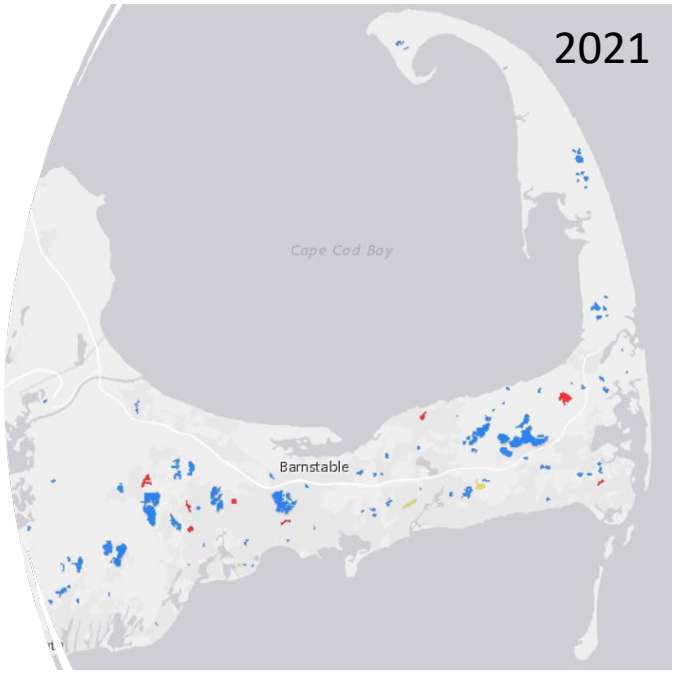
CDChttps://blogs.cdc.gov/yourhealthyourenvironment/2021/08/09/staying-safe-from-cyanobacteria-blue-green-algae-in-fresh-water/ **Wear Gloves & Boots & a Mask**

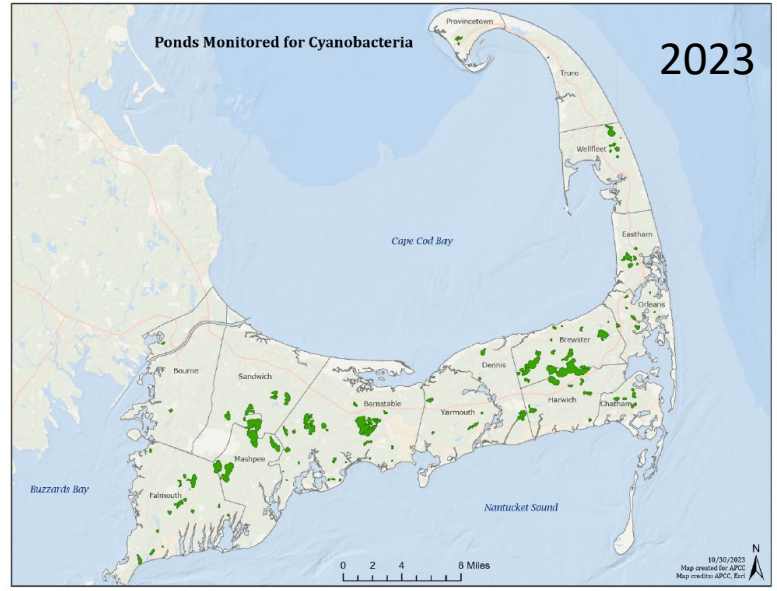
Cyanobacteria Monitoring Program: Results 2021-2023

- In 2021, 144 ponds in all 15 towns monitored;
  - HCBs in ponds of 12 of 15 towns;
  - 36 ponds had recommendations for “Use Restriction” advisory (i.e., “high” levels warranting advisories to avoid contact with water);

- In 2022, 140 ponds in all 15 towns
  - HCBs in ponds of 11 of 15 towns
  - 24 ponds had recommendations for “Use Restriction” advisory (i.e., “high” levels warranting advisories to avoid contact with water);

- In 2023, 116 ponds in all 15 towns , 130 locations monitored
  - HCBs in ponds of 7 of 15 towns
  - 13 ponds had recommendations for “Use Restriction” advisory (i.e., “high” levels warranting advisories to avoid contact with water);
  - 31 ponds in 2023 had scums that warranted Potential for Concern.



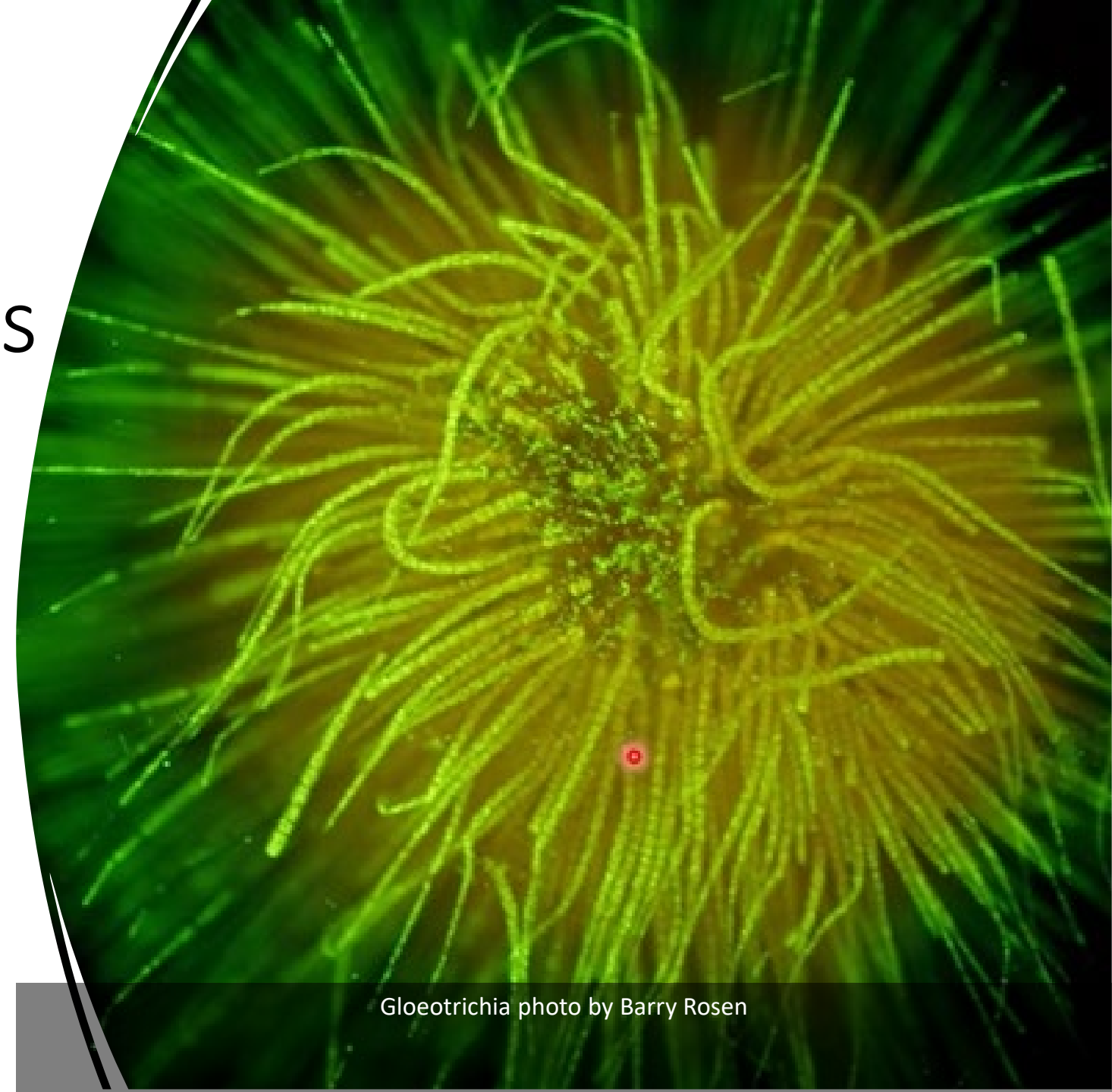


Cyanobacteria

Harmful Cyano Blooms HCBs

in Cape Cod Ponds

- HCBs have occurred in 13 of the 15 Cape Cod Towns since 2021
- HCBs are variable in their occurrence within ponds
- HCBs vary between years
- HCBs serve like the canary in coal mines to raise awareness of pond ecosystem health



Gloeotrichia photo by Barry Rosen

Strategies for Preventing and Managing Harmful Cyanobacterial Blooms (HCB-1)

Visit HCB-2 Website

Home

Interactive Tools

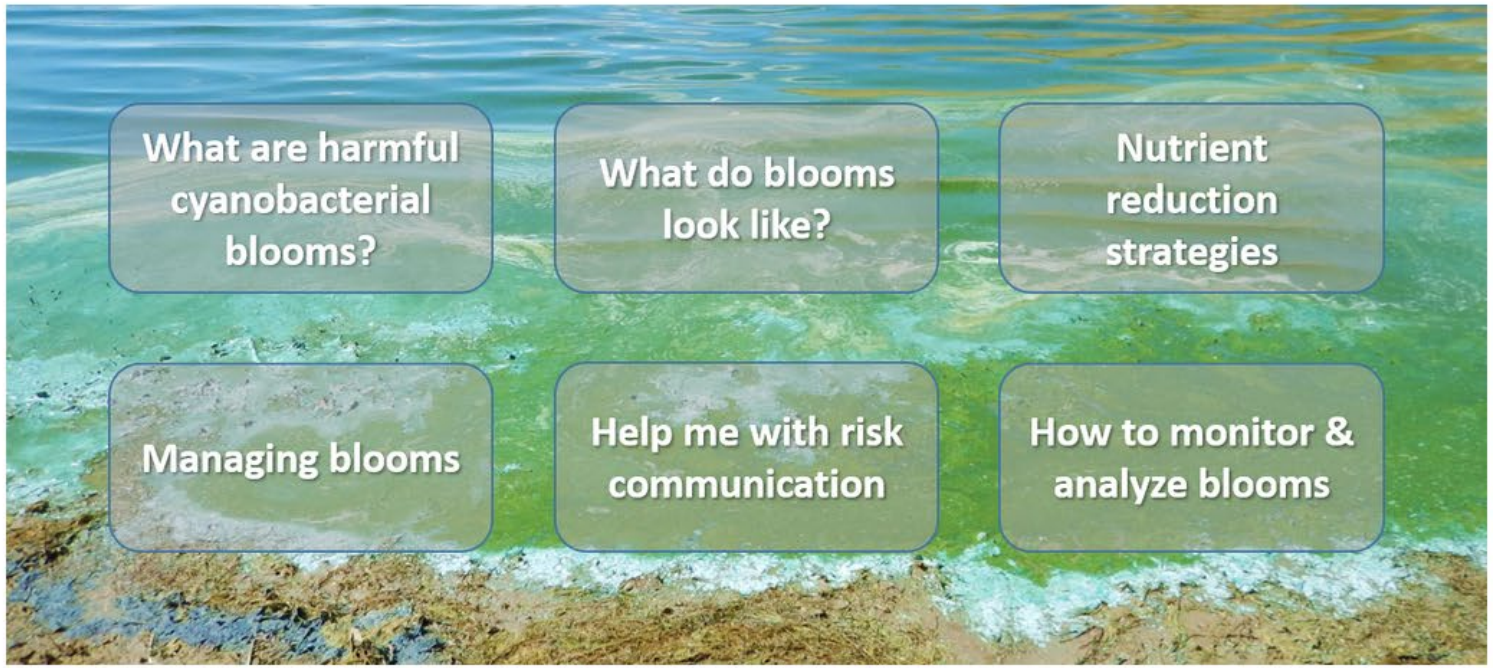
1. Overview

2. Using this Guidance for Cyanobacterial Bloom Response

3. Introduction to the Cyanobacteria

4. Monitoring

5. Strategies for



Source: Wyoming DEQ

Cyanobacteria are microscopic, photosynthetic organisms that can be found naturally in all aquatic systems. Under certain conditions, cyanobacteria can multiply and become very abundant, discoloring the water throughout a water body or accumulating at the surface. These occurrences are known as blooms. Cyanobacteria may produce potent toxins (cyanotoxins) that pose a threat to human health. Cyanobacteria can also harm wildlife and domestic animals, aquatic ecosystems, and local economies by disrupting drinking water systems and source waters, recreational uses, commercial and recreational fishing, and property values.

Thank YOU for your interest!!

Keep a look out for the
Bio Indicators of Healthy Life
on our Cape Cod Ponds
Thank you!

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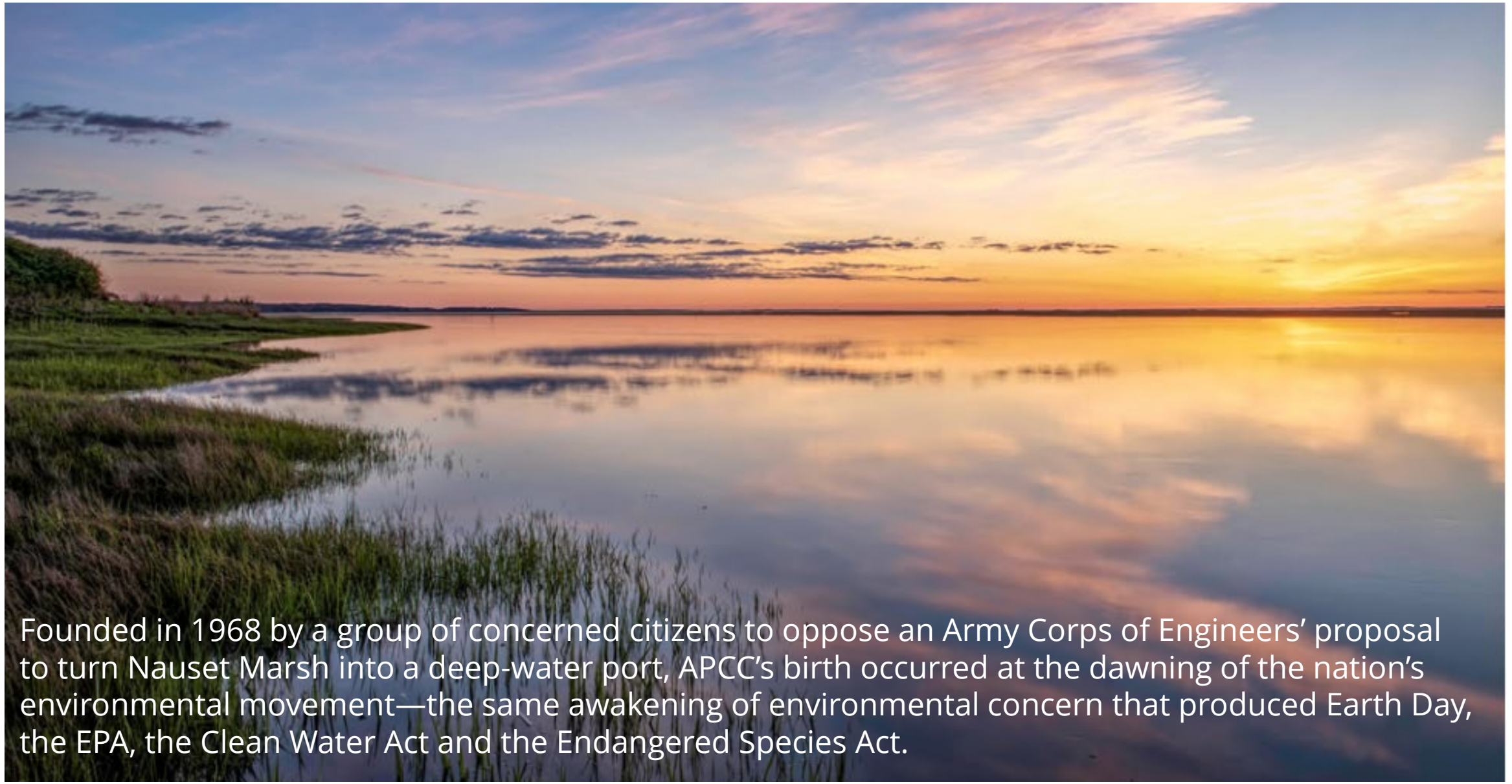

Founded in 1968 by a group of concerned citizens to oppose an Army Corps of Engineers' proposal to turn Nauset Marsh into a deep-water port, APCC's birth occurred at the dawning of the nation's environmental movement—the same awakening of environmental concern that produced Earth Day, the EPA, the Clean Water Act and the Endangered Species Act.

Cyanobacteria Risks at two Herring Run Ponds