Mark Vander Borgh: 25+ years of Science

Environmental Biologist/Monitoring Coalition Program Coordinator: Division of Water Resources

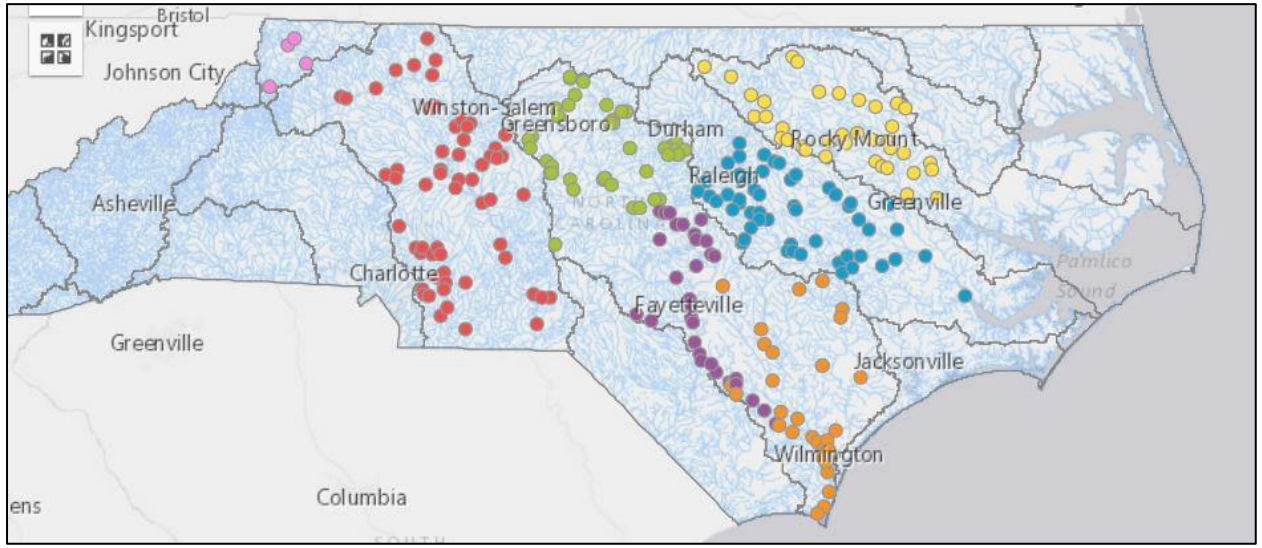
Cape Fear River Partnership meeting

Feb 15, 2024

North Carolina Department of Environmental Quality

NC DWR Monitoring Coalition Program

- Monitoring Coalitions are groups of stakeholders that combine resources and expertise to fund and perform in-stream water quality monitoring.
- Monitoring compliments, and is performed in coordination, with the Division's Ambient Monitoring Program
- Monitoring Coalition Program Coordinator
- Six Coalitions in 4 major water basins
  - Upper, Middle and Lower Cape River
  - Tar-Pamlico, Yadkin Pee Dee, and Lower Neuse
- Total annual budgets = $1,000,000
- Water quality monitoring = $704,000



- Monitoring stations = 254 sampled monthly, 2X summer
- Data generated = 36,000 records annually with a compiled dataset of 1,031,183 records
- Data used in planning, modeling, NPDES permits, USEPA triennial report (AKA 303d impairment list), research, special studies…….

NC DWR Algal Assessment Program

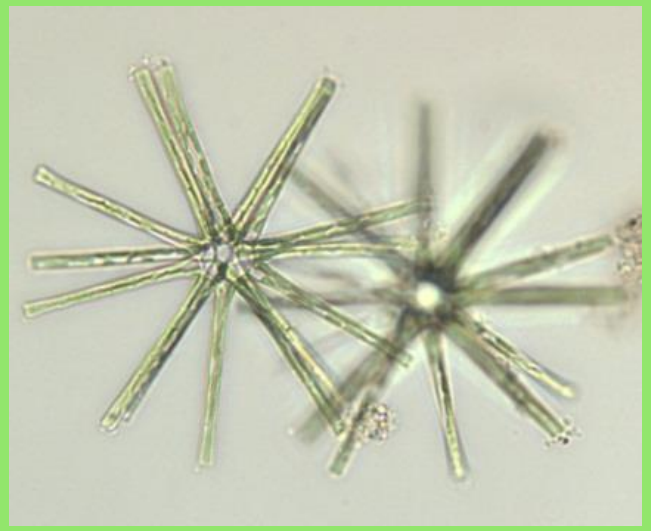
- NC DWR Program started circa 1980 with USEPA Clean Lakes Program and *Pfiesteria*
- Hired as a Biologist (Phycologist) for Division of Water Quality in 1999
- Cleaned house (Laboratory), built a database and began to sample, analyze and promote algae
- Wrote the Algal and Aquatic Plant Sampling and Analysis SOP 2003
- Redefined program focus and laboratory capabilities
  - Routine: Ambient Lakes Monitoring Program (monitoring on a 5-year rotation)
    - Selected specific sites evaluate over time with focus on water supplies and recreational waters
    - 30-40 sites/month ≈ 200-220 samples/year
  - Episodic: Bloom response and assessments
    - Algae and associated microbial growths (i.e., bacteria, fungus and protozoa)

- Developed a strong working relationship with Division of Health and Human Services (DHHS)
  - Cyanobacteria and cyanotoxins.
- Developed potential harmful algal bloom (HAB) response strategy, created a presentation, hit the road
- "Potentially Harmful Algal Blooms: Roles and Responsibilities." 2014
- Outlined what state agencies, municipalities/lake managers, academic institutions and other NC water quality related agencies would have to do to provide a coordinated response to a HAB

Roles and Responsibilities

1st: Exposure risk determination

- Division of Water Resources (DWR)
  - Experts in algal bloom evaluation
  - Network of regional offices and local contacts
- Division of Public Health (DPH)
  - Experts in human and animal health
    - State lab can analyze for Microcystin
  - Network of county health departments, doctors and veterinarians



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Roles and Responsibilities

2nd: Exposure risk control

- Controlling access
  - Municipalities
  - Parks and recreation
  - Public utilities
  - Home owner associations
  - Clubs and campgrounds
  - Private citizens
  - ?????

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Roles and Responsibilities

3rd: The science

- Academic institutions & private Labs
  - Research the risks
  - Verify and validate response actions
  - Provide wide range of toxin testing
  - Develop new tests
  - Engage in studies to determine when, why and where PHABs exist

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Cape Fear River Microcystis Blooms 2009-2012

- Microcystis blooms began in 2009
- First documentation of cyanotoxins in and near water supplies
- Fostered interagency roles, responsibilities and capabilities
  - Monitoring, sampling and COMMUNICATION
  - Water Sciences Section (ambient and coalition), Regional Offices, Public Water Supplies, DHHS, Academics and PIOS
  - Press releases and public notification
- Synoptic study in 2010
  - 16 stations sampled on the same day
  - 5 sampling events in one season
  - No blooms, but GREAT DATA
    - Ambient phytoplankton, nutrients and chl-a
- Blooms returned 2011
  - Earlier coordination pays off
  - Documentation of “visible algal growths”
  - Lasted 7 weeks and stretched 70 miles at peak
  - Cyanotoxin data collected
    - Ambient and Finished Drinking water

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HABs in the Cape Fear: 2012

Event:

- June 20: sparse growths begin in various location
- July 2: WTPs reports substantial “shore to shore” bloom at LD1
- July 3: Microcystin testing of ambient, raw and finished drinking water
- July 9: Microcystin results released
  - Ambient water = 4.35 µg/L above LD1 and 8.51 µg/L below LD1)
  - Raw = 3.86 µg/L @ Sweeny, 0.29 µg/L @ Brunswick, 1.1 µg/L @ International Paper
  - Finished = 0.18 µg/L @ Sweeny, 0.12 µg/L @ Brunswick
- July 24: Last report of *Microcystis* flecks at LD2, Elwell Ferry & LD1

Take Home:

Microcystins are being produced, bloom lasted about a month

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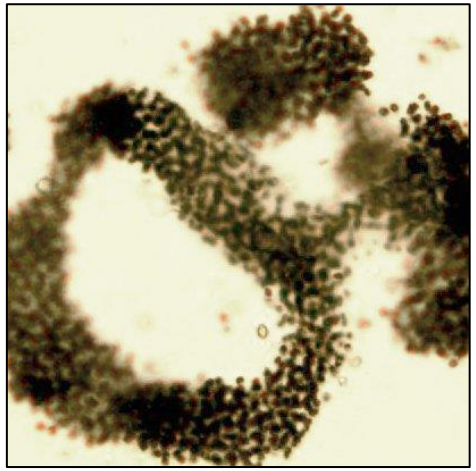
Waterville Lake: and so it begins….

2012 Basinwide Assessment

- Intensive Survey Branch
- 4 stations monthly June-Sept
- Blooms documented in August
  - *Microcystis* and *Dolichospermum*
  - First use of Abraxis test strips
    - Microcystin (MCY) >10 µg/L
    - Confirmed Auburn University
- Began discussions with Duke
  - Employee safety

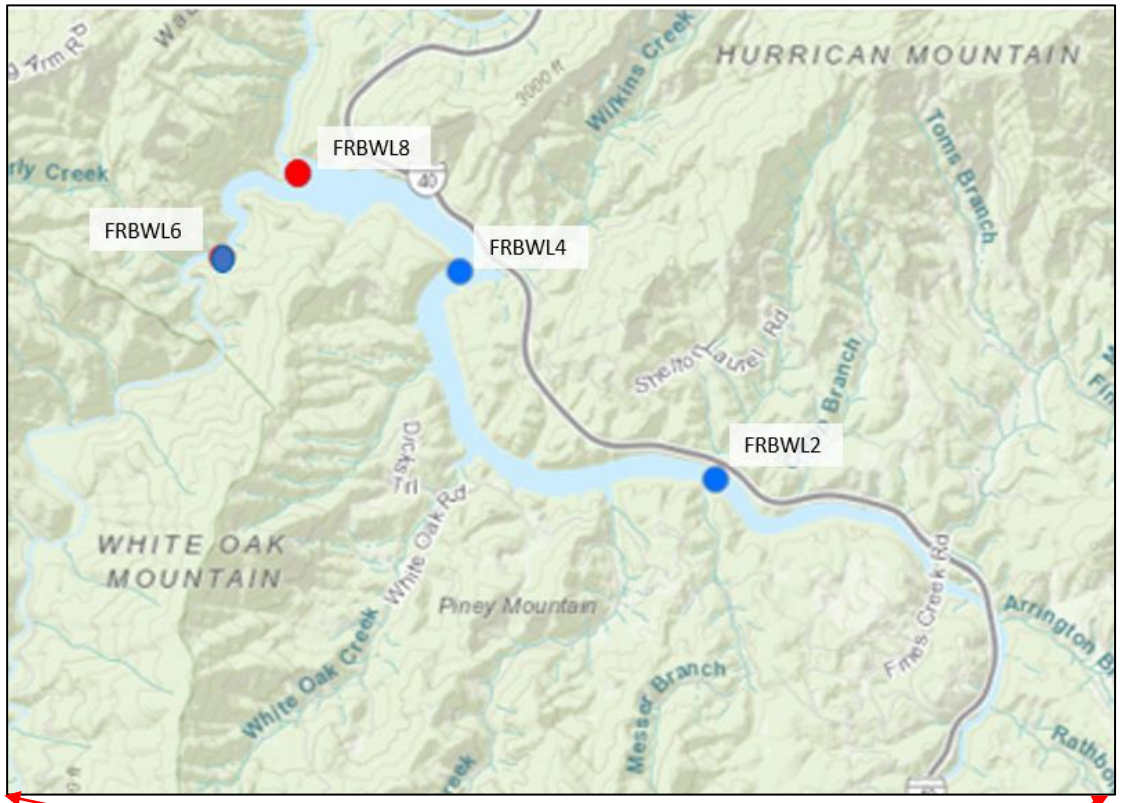


Waterville lake 2012 (note shoreline stains)

Waterville Lake: pushing the limits

- Waterville Lake: A Case Study
- Investigation>Studies>Response Strategy
  - 5 consecutive years and counting……
- Instigated HAB Response Procedures
- Fostered Cyanotoxin Testing
- Required Interagency Coordination
- Forced Inter-state Communication

- Ultimate HAB Implications
  - Downstream Recreational Use
    - Tennessee Dept Environment and Conservation
  - Watershed Assessment and Planning

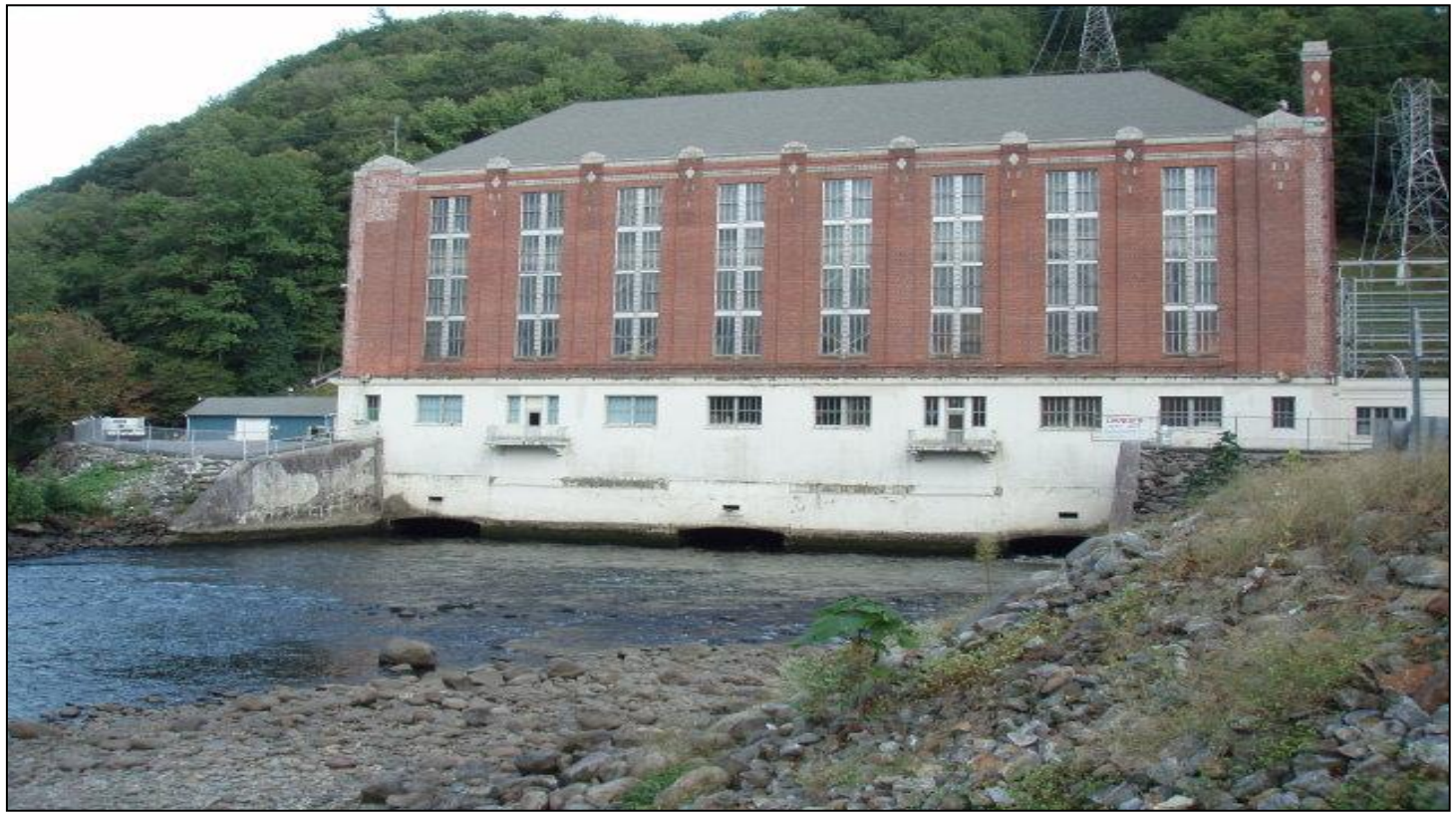


Waterville Lake: Background

Waterville Lake (AKA: Walters Lake)

- 340 acre reservoir on the Pigeon River
- 4.5 miles long, 0.25 - 0.10 miles wide
- Isolated with limited public access
- Dam safety and security issues

- Constructed in 1920s
  - Reservoir and hydroelectric facility
  - Water piped down 6 miles to facility
- Owned and Operated by Duke Energy
- Catchment: Haywood Co.
  - Nutrients, nutrients and nutrients
- Susceptible to algal blooms
  - Reported over past 20 years
  - Returning annually
- Outflow (tailrace) beginning of White Water Rafting recreational area (TN)



Waterville: A learning experience .

Bloom investigations

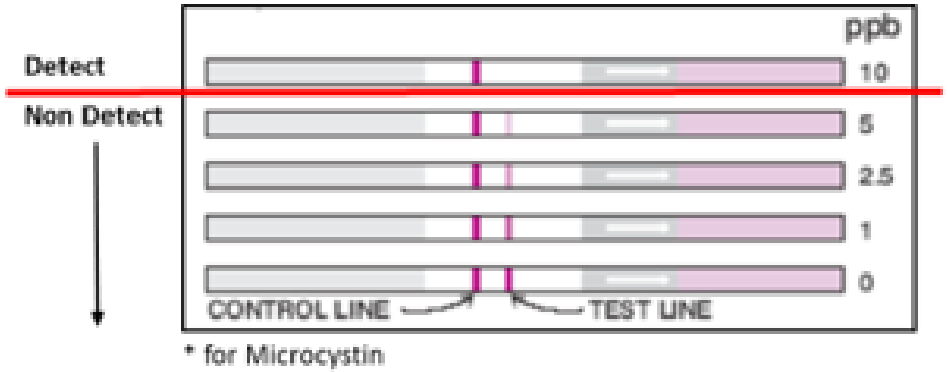
- Asheville Regional Office
  - Concerned citizen call 2015
    - Visual from bridge
    - Limited eastern (upper) portion
    - 1 station
    - Access and monitoring issues identified
    - Microcystin >10 ug/l Division Public Health (DPH)
  - Duke notification 2016
    - Concentration around dam
    - 1 station
    - Response deficiencies identified
      - Logistics
        - Failed holding times
          - Chl-a 24 hrs
        - Toxin results slow
      - Sampling protocols
    - Regional staff use test strips
      - Microcystin > 40 µg/L
      - Confirmed DPH
        - Much lower

Waterville Lake at dam 2016

Waterville Lake from bridge 2015

Abraxis Cyanotoxin Test Strips

- Qualitative tests
  - Detect MCY > 10 µg/L
  - Non-Detect < 10 µg/L
  - Can be diluted to 20, 40..
- Field, Lab or Office
- Rapid turnaround ≈ 40-50 min
- Commercially available
- ≈ $20/strip
- Other toxin test strips available too!



* for Microcystin

In-House Cyanotoxin Testing 2017

- Water Sciences Section: Chemistry Lab
- Enzyme-linked immunosorbent assay (ELISA)
- Cyanotoxin automated analysis system (CAAS)
- Can test for multiple toxins
  - Cylindrospermopsin, anatoxin, domoic acid (marine)
- Currently only testing microcystin
- 96 well plate = $464.00 ≈ $55/test

Abraxis CAAS benchtop instrument

- New Analyte
  - Requires an SOP based on approved EPA methods
  - Develop new parameter codes and tracking (Labworks)
  - Adding box to sample submittal sheets
  - Shipping and handling requirement (i.e. holding times)
  - Rigid QA procedures
  - Same process will be needed for the other cyanotoxins

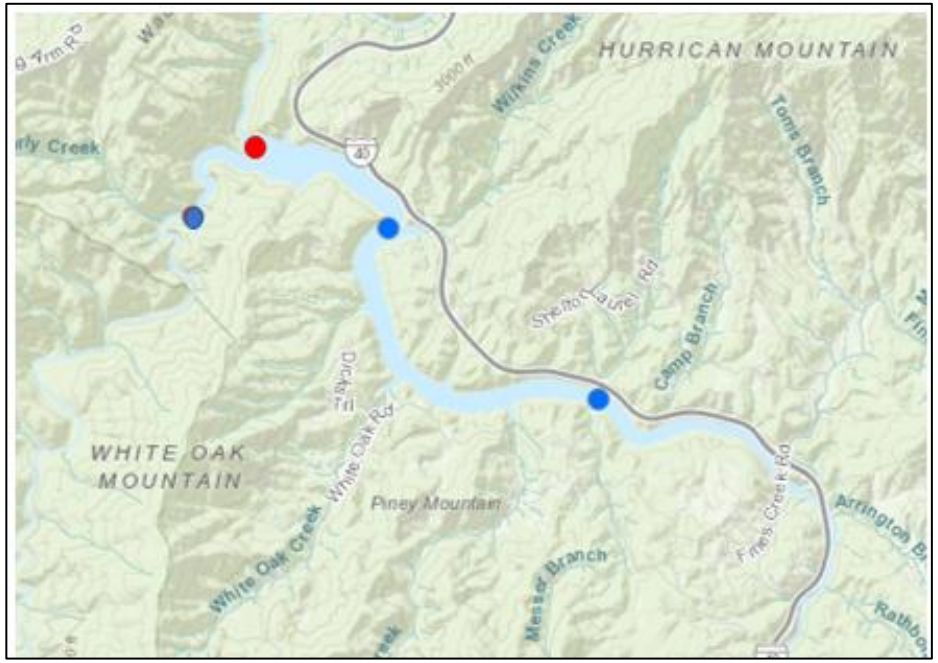
PTEG Bottle

By 2023, over 1,000 data points

Waterville: A learning experience cont..

2017 Basinwide Assessment/Special Study

- Intensive Survey Branch, Schnetzer Lab (NCSU) & Duke
- 4 stations monthly June – Sept.
  - Upper and lower end
- Goal:
  - Document blooms (phyto, chl-a)
  - Determine toxin production
  - Establish duration
  - Test new Cyanotoxin testing techniques
    - PTEG bottles for cyanotoxin samples
    - SPATTS (Solid Phase Adsorption Toxin Tracking (MacKenzie 2004)) deployed at Dam (red dot)
      - Dissolved (extracellular)
    - Discrete samples for ELISA
      - Dissolved



Waterville Lake study 2017

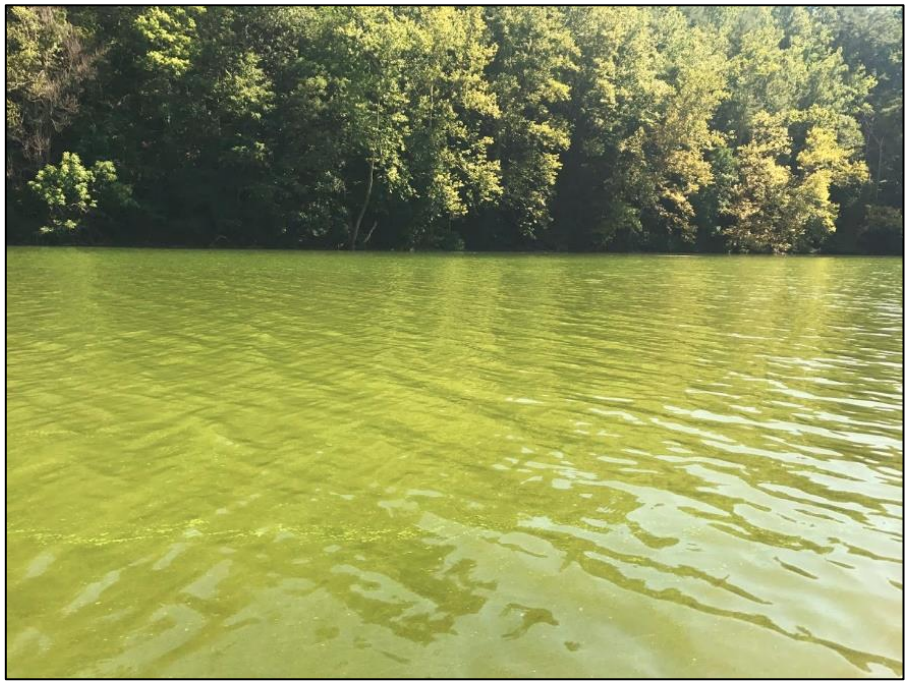
SPATTS at High Rock Lake 2016

Waterville 2017: A learning experience cont…

- Results:
  - Blooms started upper end in June
  - Blooms move to lower end August through Sept
  - Microcystin present throughout study

- New questions:
  - Do the toxins make it past the dam?
  - Through the hydro facility ?

SPATTs near FRBWL8			
Date Deployed	**Date Collected**	**Days on site**	**Microcystin (ng/[g resin*day])**
6/28/2017	7/12/2017	14	14.83
7/12/2017	8/29/2017	48	15.21
8/29/2017	9/19/2017	21	10.29
9/19/2017	9/25/2017	6	19.11



Waterville Lake upper end 2017

SPATTS Fresh vs. Deployed

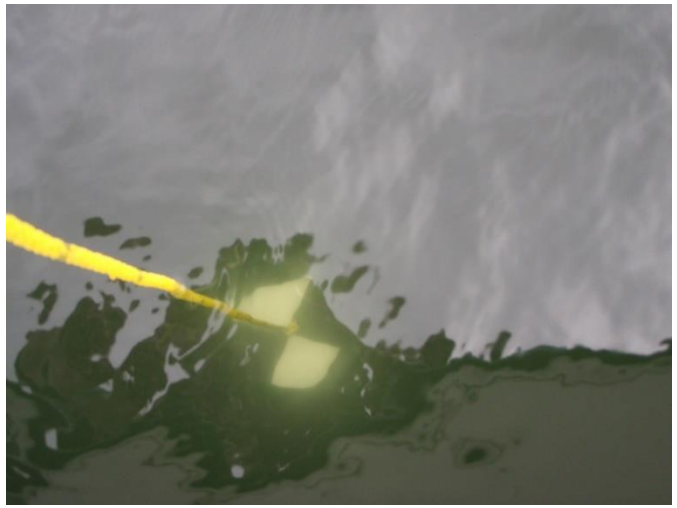
Waterville 2018: A learning experience cont…..

- Results:
  - Unprecedented 9 sampling events
    - 25 data points
    - 25 phytoplankton samples processed
    - 13 toxin ELISA tests ran
  - Bluegreens growths begin June
  - Blooms begin and peaked in August
  - Hurricane washes out in Sept
  - Continue sporadically into October
- Microcystin production during peak
  - Upper end = 2.7 ug/L to 580 ug/L
  - Lower end = 0.48 to 260 ug/L
  - Below dam
    - dry reach = below detection
    - hydro facility = inconclusive
- Hydropower emergency operations
- Tennessee contacts made

Waterville Lake near dam 2018

White Lake, Bladen Co.

- Ambient Lake Monitoring Program 2013: Eutrophication occurring, pH increasing
- Special study 2015: Results “What the pH happened”
- Water Color Study



August 2013 Mid-lake

June 2015 North End

July 2015 South End

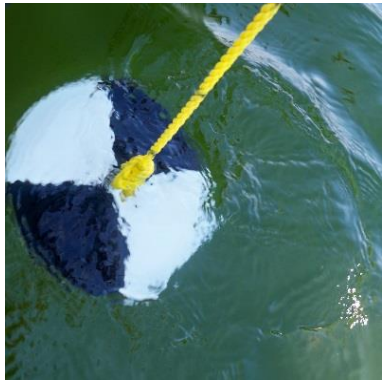
White Lake, Bladen Co.

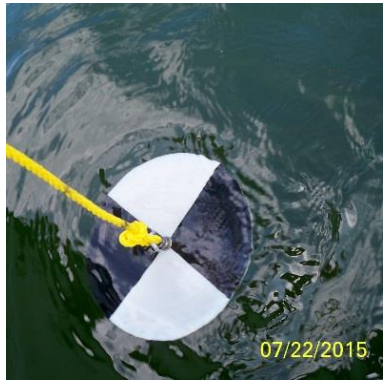
- Goal: Document Watercolor
- Determine: Apparent or True?
- Method:
  - Photograph secchi disk
    - surface, mid-depth (1m) and bottom (2m)
  - Collect water
    - surface, mid-depth (1m) and bottom (2m)
  - Document color of collected water
    - Visual assessment
    - Photograph

White Lake, Bladen Co.

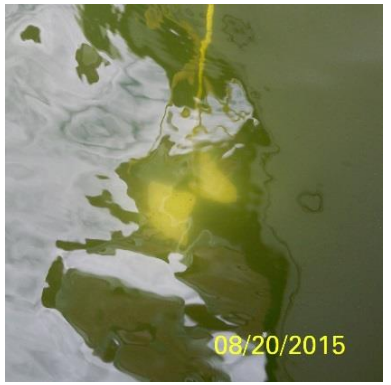
- Secchi Disk
  - determines transparency and light attenuation
- Visible Green Tint
- Secchi Disk Visible to Bottom (hard to photo)

Surface

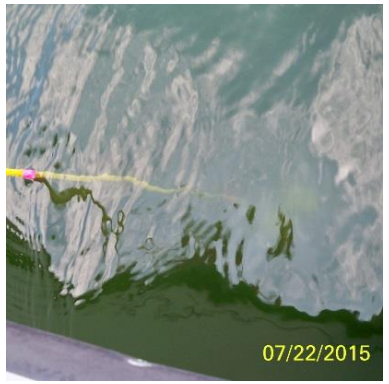


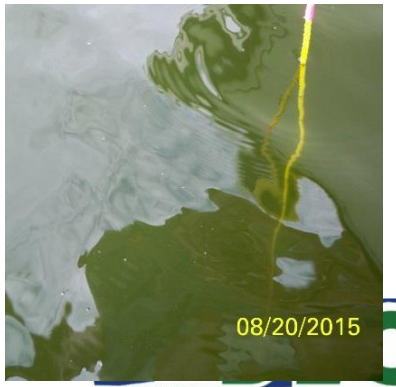


Mid-depth



Bottom





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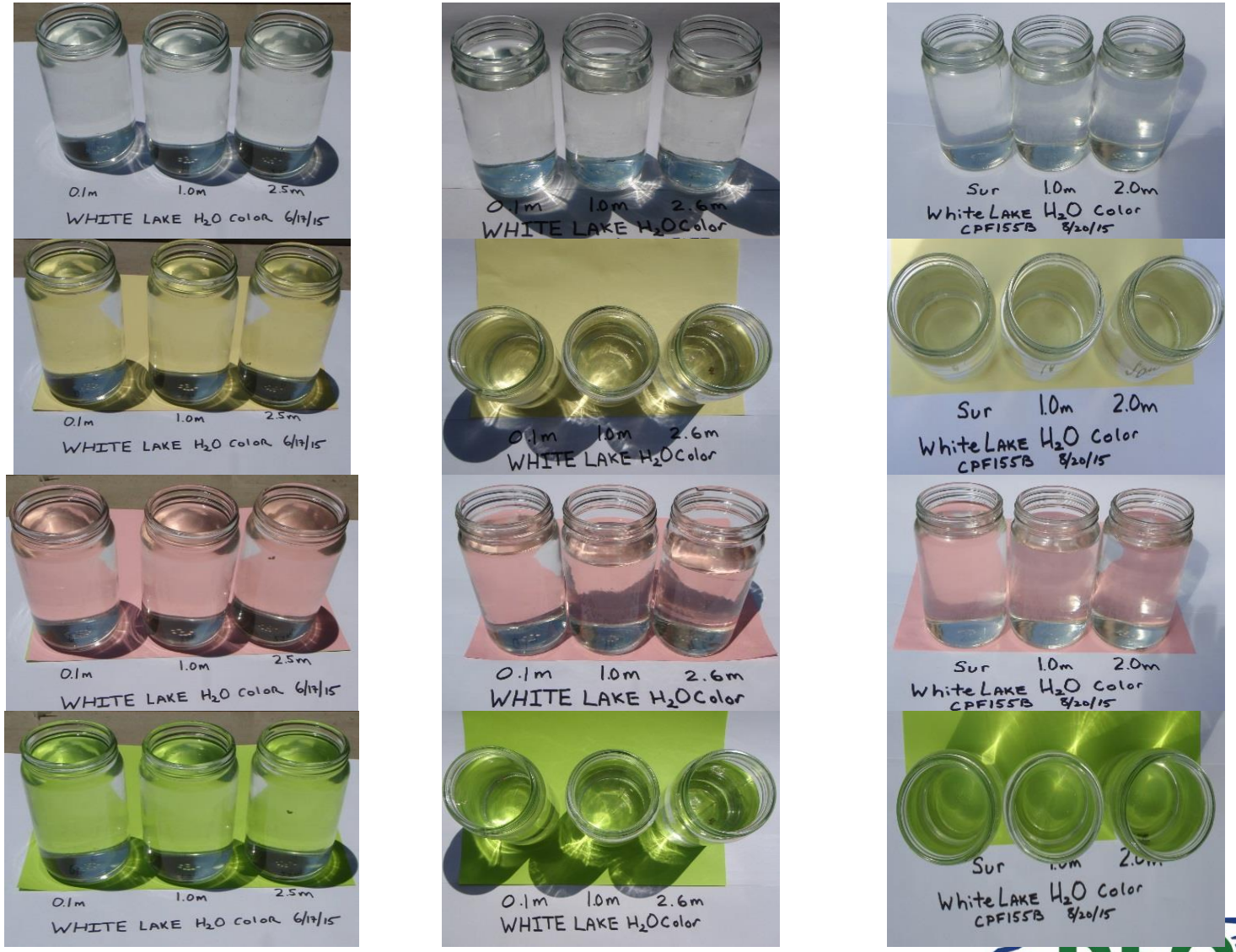
White Lake Watercolor: In the Glass Jars

- Water Collected at 3 Depths
  - Poured into Glass Jars
  - Shipped on ice
- Visual Analyses
  - Crystal Clear
- Jars with Background Color
- Water Reflects Color
  - i.e. is the sky really blue?

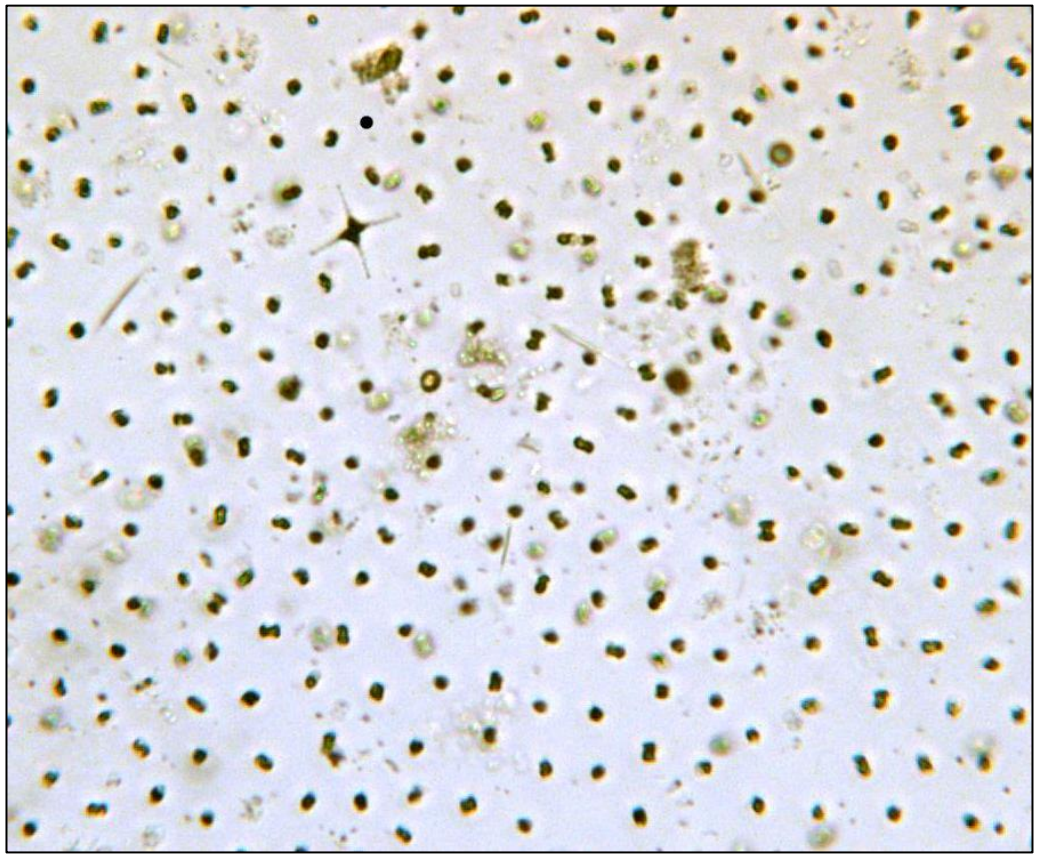
Results:

Apparent and true

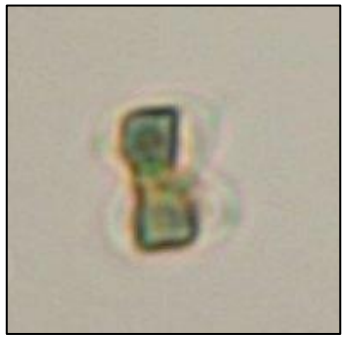
Watercolor Reflection of Benthic Plants



White Lake, Bladen Co.



Unidentified cells in photic zone samples



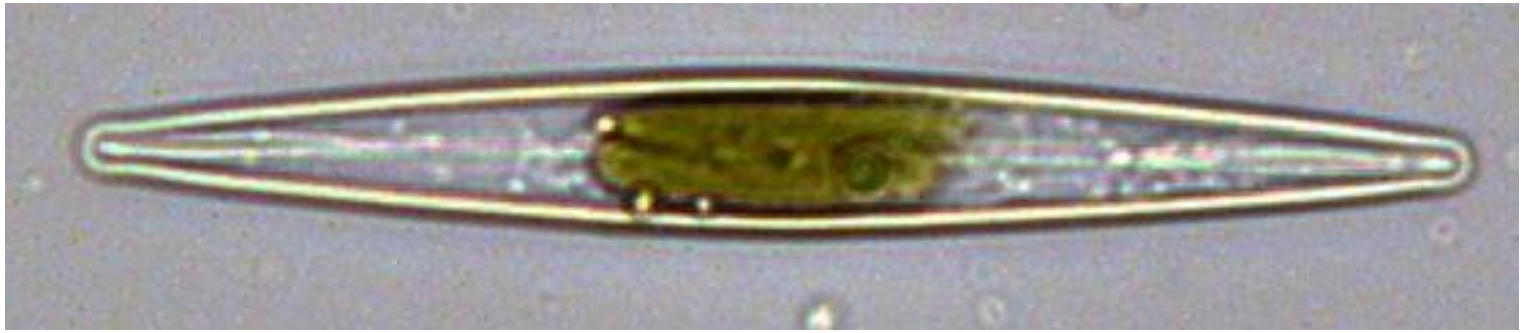
Individual *Sphaerozosma* cell

- Unidentified alga
- Goose poop?
- Benthic Green filamentous alga
- *Sphaerozosma*

***Sphaerozosma* filament**
(found during benthic flora survey)

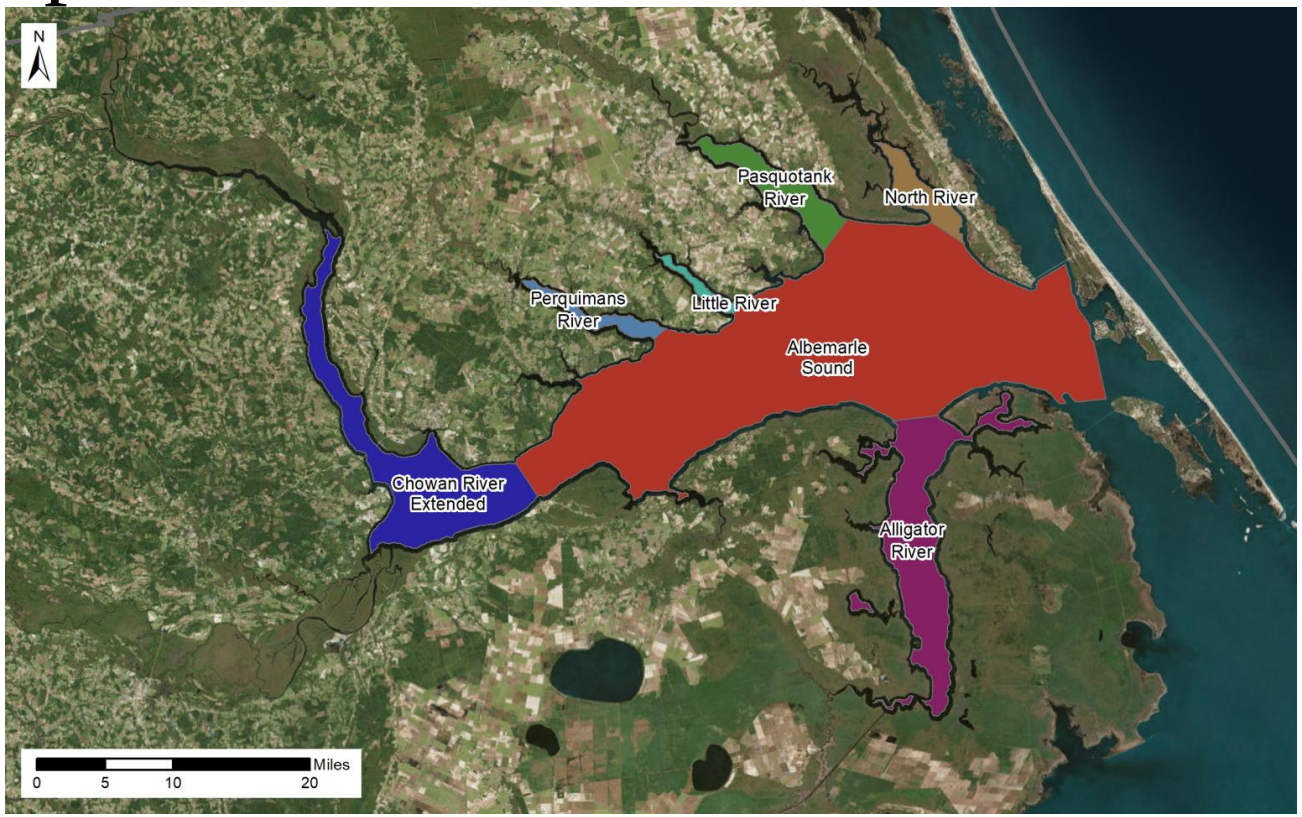
Nutrient Criteria Development Plan (NCDP)

- Periphyton assemblage assessments in flowing waters added to the NC DWR NCDP 2003
- USEPA R4 “Southeastern Plains Nutrient Biological Response Study (SPINBR)” 2005
- NC DWR “Evaluation of Periphyton Based Water Quality Monitoring Methods for North Carolina Wadeable Streams” 2007
  - Periphyton samples analyzed by the Philadelphia Academy of Sciences
- Duke University Masters Project: “Evaluating the use of periphyton as an indicator of nutrient over-enrichment in North Carolina Wadeable Stream” 2018
- Coordinating with DWR Ambient Monitoring Program to collect phytoplankton and cyanotoxins in the Chowan/Albemarle System
- EPA N-STEPS NC CyAN Albemarle Analysis Project 2023
  - Utilizing satellite imaging to assess past and present trends of algal blooms in the Chowan /Albemarle System



NC CyAN Report Overview

- N-STEP project (USEPA and Tetra Tech)
- Satellite Imaging Data
  - Cyanobacteria Assessment Network (CyAN)
    - Initiated in March of 2020
    - Final report February 2023
- Evaluates phycocyanin
  - Blue green algae pigment
  - Can be linked to cyanotoxins
- Explored 7 polygons (shape files)
  - Pixels 300m x 300m
  - Pixel + Pixel + Pixel = Raster
  - Raster + Raster + Raster / Averaged
- Data expressed as cells/ml
- Evaluated by year and growing season



Name	Area (sq km)
Albemarle Sound	1,024
Chowan River Extended	208
Alligator River	178
Pasquotank River	59
North River	36
Perquimans River	23
Little River	12

Full report: NSTEPS NC CyAN Analysis_v3.0_02922023

NC CyAN SMK Trend Analysis

↔ = no change
↑ = increase

Estuary	Frequency Total Bloom Trend
Albemarle Sound	↔
Alligator River	↑
Chowan River Extended	↑
Little River	↑
North River	↔
Pasquotank River	↔
Perquimans River	↑

NC CyAN SMK Trend Analysis

↔ = no change
↑ = increase

Estuary	Magnitude Normalized Trend
Albemarle Sound	↔
Alligator River	↑
Chowan River Extended	↔
Little River	↔
North River	↔
Pasquotank River	↔
Perquimans River	↑

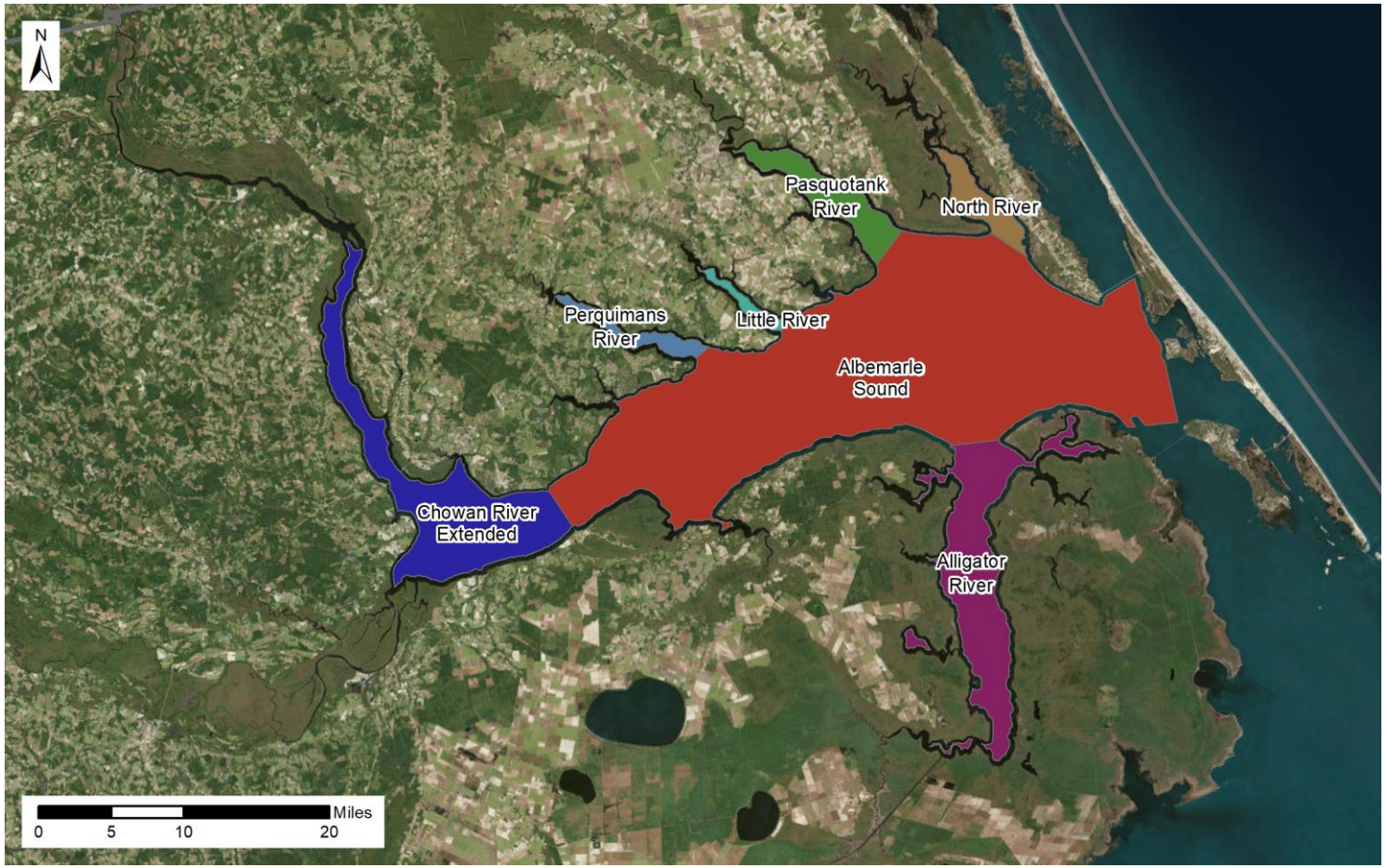
NC CyAN SMK Trend Analysis

↔ = no change
↑ = increase

Estuary	Extent Total Bloom Trend
Albemarle Sound	↔
Alligator River	↑
Chowan River Extended	↑
Little River	↑
North River	↔
Pasquotank River	↔
Perquimans River	↑

NC CyAN Report: Take Home

- From 2008 to present
- Increasing CyAN trends observed
  - Frequency, Magnitude, and Extent
    - Alligator and Perquimans
  - Frequency and Extent only
    - Chowan and Little
- Non-significant trends
  - Albemarle Sound
  - North River and Pasquotank
    - But among highest values



White Algae?

Diatom & Filamentous Greens: Dead, Dried, and Sun-bleached
Habitat: Rocks, plants, and debris previously submerged in water.
Description: Diatoms = sparkly powder. Filamentous Greens = paper-like.

Dried diatoms on rocks
Rocky RIver, Chatham County, NC

Dried filamentous greens along shoreline
Roanoke River, Martin County, NC (photo: Kevin Dockendorf)

Diatoms dried on log

Filamentous greens dried on vegetation

Sulfur Bacteria

Gammaproteobacterium: Thiothrix

Habitat: Sulfur rich waters with adequate oxygen content.
Description: Small (< 16um), colorless filaments with numerous sulfur granules.

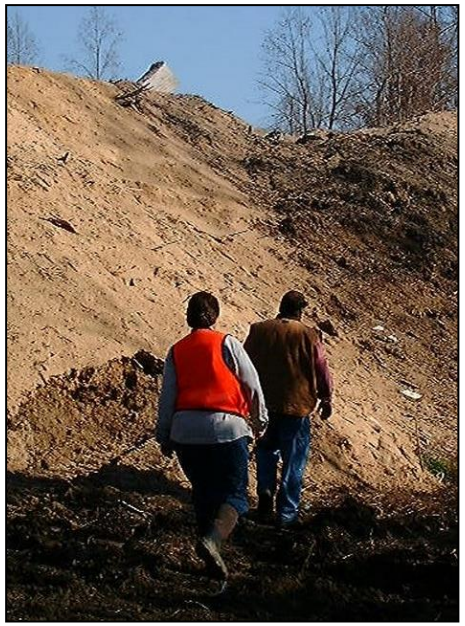
UT to Honeycutt Creek
Durham County, NC (photo: Judy Garrett)

Tufts of *Thiothrix*

Green and white growths on rock

Algae or, Surprise!

- *Saprocheate saccharophilia*
- Fungal hyphae look like colorless algae
- X-ray diffraction to identify cell walls as chiton
- Indicator of sawmills, wood production facilities and clear-cutting stormwater



Large saw dust pile
Yadkin County, NC

Filamentous green alga
Stigeoclonum

***Saprochaete* filaments**

White filaments in stream next to saw dust pile

Spirogyra

Green Algae (Chlorophyta)

Habitat: Freshwater lakes, streams and ponds

Description: Non-branching filaments with spiral chloroplasts. Silky to touch

***Spirogyra* degrading**
White Lake, Bladen County, NC

***Spirogyra* filaments degrading**
White Lake, Bladen County, NC

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Sewage fungus

Phycomycetes: *Leptomitus lacteus*

Habitat: Waters rich in organic matter.

Description: White cottony masses attached to substrate.
Colorless filaments, branching with sporangium.

Stream running through Small Acres Farm
Henderson County, NC (photo: Ed Williams)

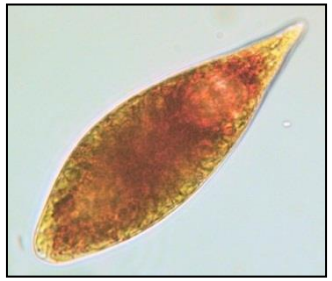
Cottony mass in petri dish

***Leptomitus* filaments**

Red Water

***Euglena* bloom in University Lake**
Orange County, NC (photo: Ed Holland)

***Azolla* growth in Wet Ash Swamp**
Brunswick County, NC (photo: Stephanie Garrett)



Euglenoid Algae
(Euglenophyta): *Euglena sanguinea*

Aquatic Fern
(Azollaceae): *Azolla*

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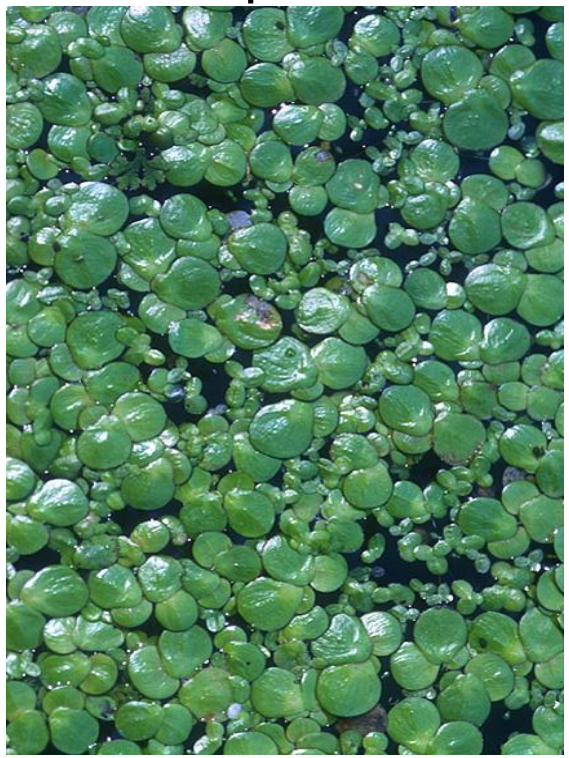
Spirodela polyrhiza

Giant Duckweed (Lemnaceae)

Habitat: Freshwater lakes and ponds

Description: Small (< 5mm) floating vascular plant with roots



***Spirodela* during summer**
(photo: Wikimedia commons)

Green on top with a small red dot
Red underneath
Growths turn red after frost (die off)

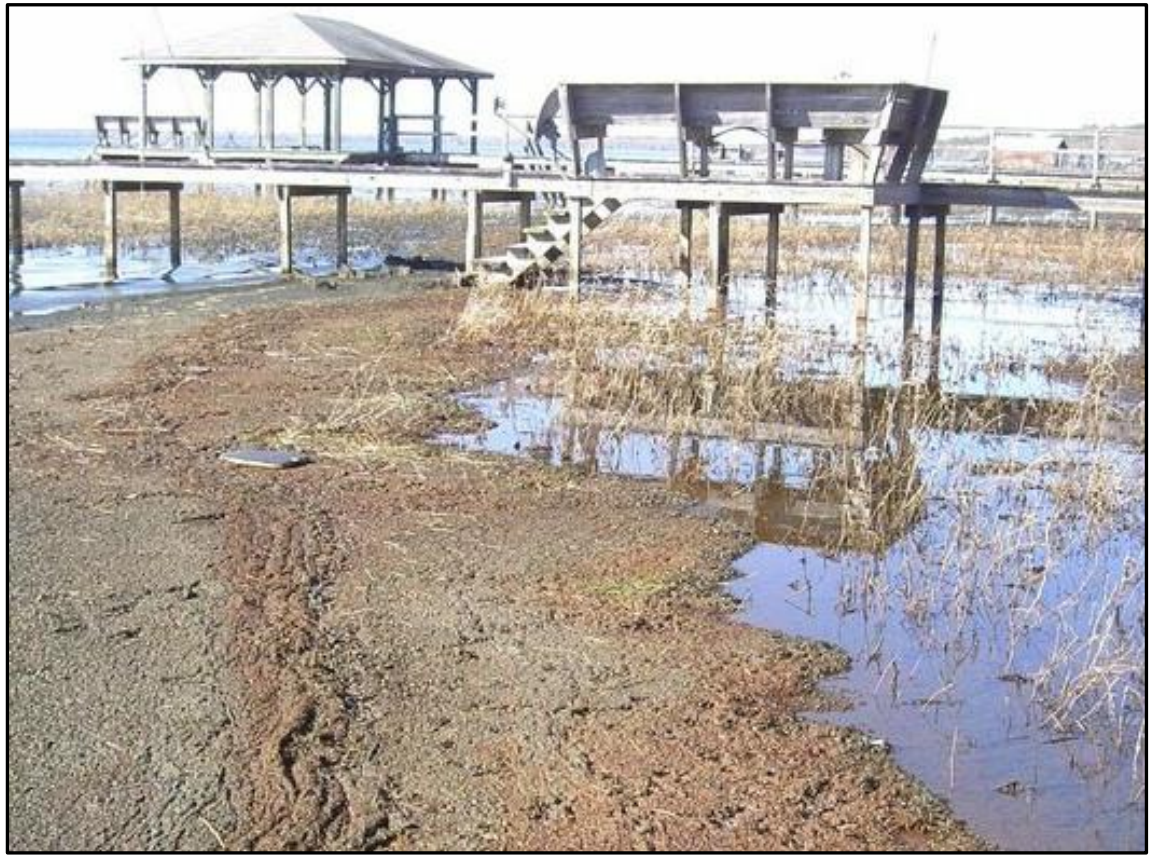
***Spirodela* with red dot and red underneath**

Tolypothrix

Blue Green Algae (Cyanophyta)

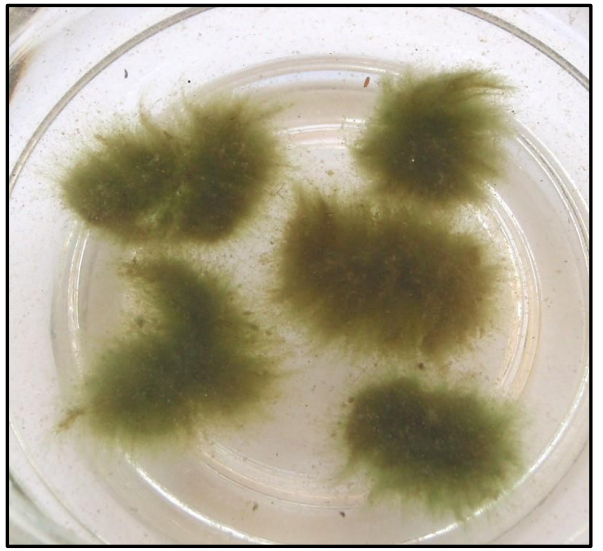
Habitat: Fresh water lakes.

Description: Filaments pseudo-branching with oval rod-like heterocytes

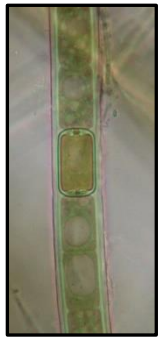


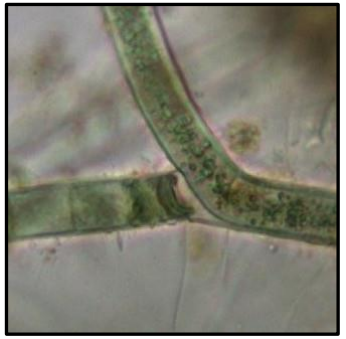
Thick odorous mats along Lake Waccamaw shoreline

Columbus County, NC (photo: Stephanie Petter Garrett



Free floating cottony tufts (10-30 cm)



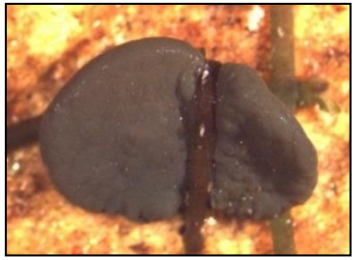


Oval heterocyte and pseudo-branching filaments

Nostoc parmelioides

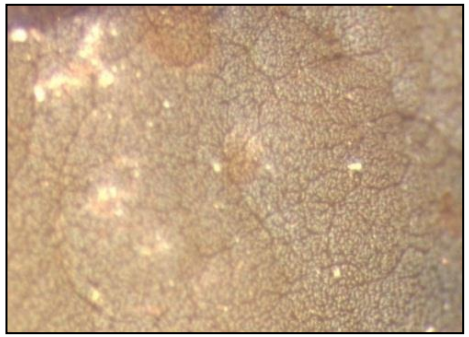
Blue Green Algae (Cyanophyte)
Habitat: Cold, fast moving, high quality streams.
Description: Long curly filaments within dense rubbery matrix.

Algae and *Podostemon* covering rock
John's River, Burke County, NC



Ear-like colony

Midge inhabiting colony



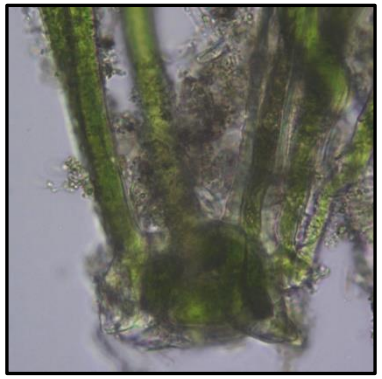
Rubbery skin on colony

***Nostoc* filaments**

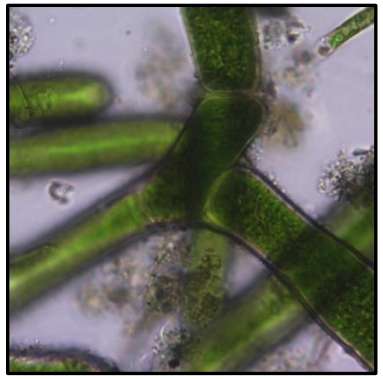
Basicladia

Green Algae (Chlorophyta)
Habitat: Turtle shells in freshwater lakes and ponds.
Description: Dark green branched filaments with hold fast

Common Snapping Turtle (Chelydra serpentine)
Stasavich Science and Nature Center River Park North
Greenville, Pitt County, NC



***Basicladia* hold fast**



Branching filaments

Densely packed reticulated chloroplasts

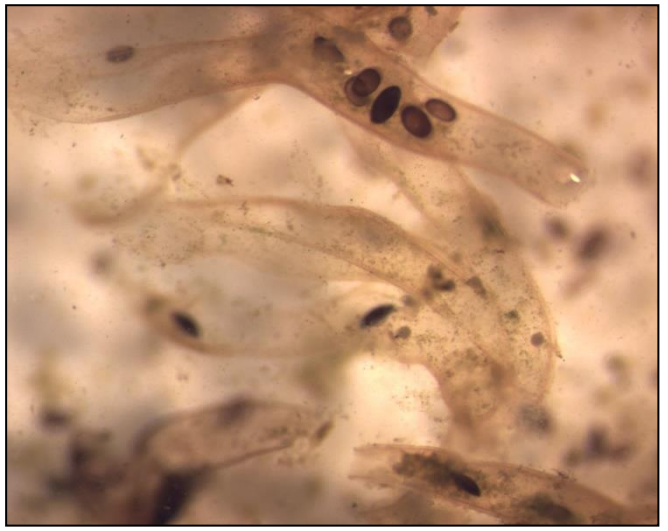
Plumatella?

Moss-animals (Bryozoa)

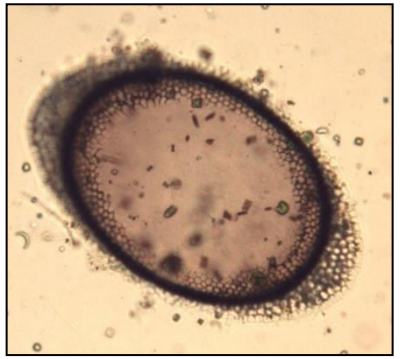
Habitat: Attached to hard substrates in fresh water

Description: Mossy, brownish, mats with firm tubular branches

***Plumatella* growing in Creswell WWTP effluent pipe**
Washington County, NC



Translucent branches with stratoblasts



***Plumatella* stratoblast**

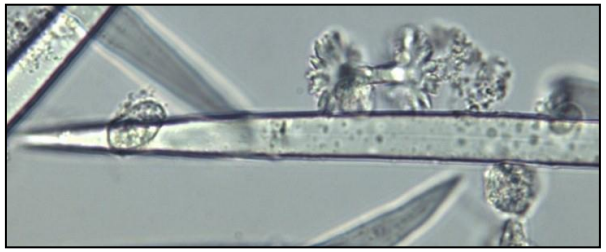
Freshwater Sponges

Sponges (Porifera): *Spongilla lacustris*

Habitat: Widely distributed in well oxygenated ponds and streams.

Description: Multi-cellular animals of various shapes and sizes with cells embedded in a gelatinous matrix.

Sponges in WWTP pond
Durham County, NC



Sponge spicules and gemmules

Sponge from WWTP pond

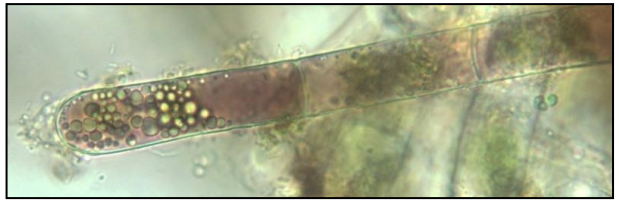
Sponge from unknown creek

NORTH CAROLINA
Department of Environmental Quality

Mougeotiopsis

Green Algae (Chlorophyta)
Habitat: Acidic freshwater lakes and ponds.
Description: Long, unbranched filaments, discoid chloroplasts with some cells containing a purple sap.

Characteristic chloroplasts

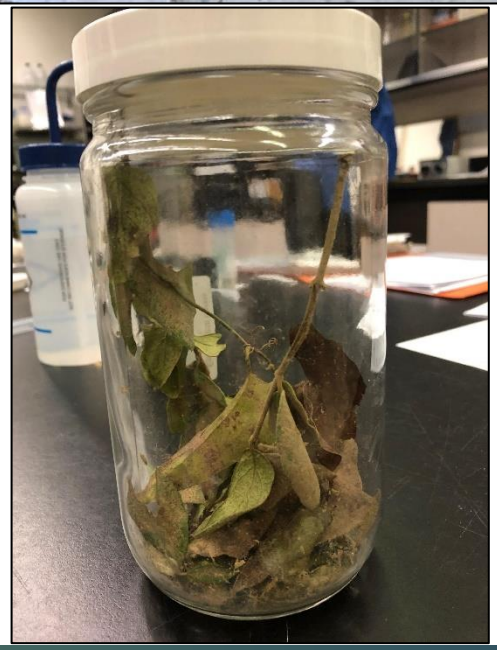


Purple sap within cells

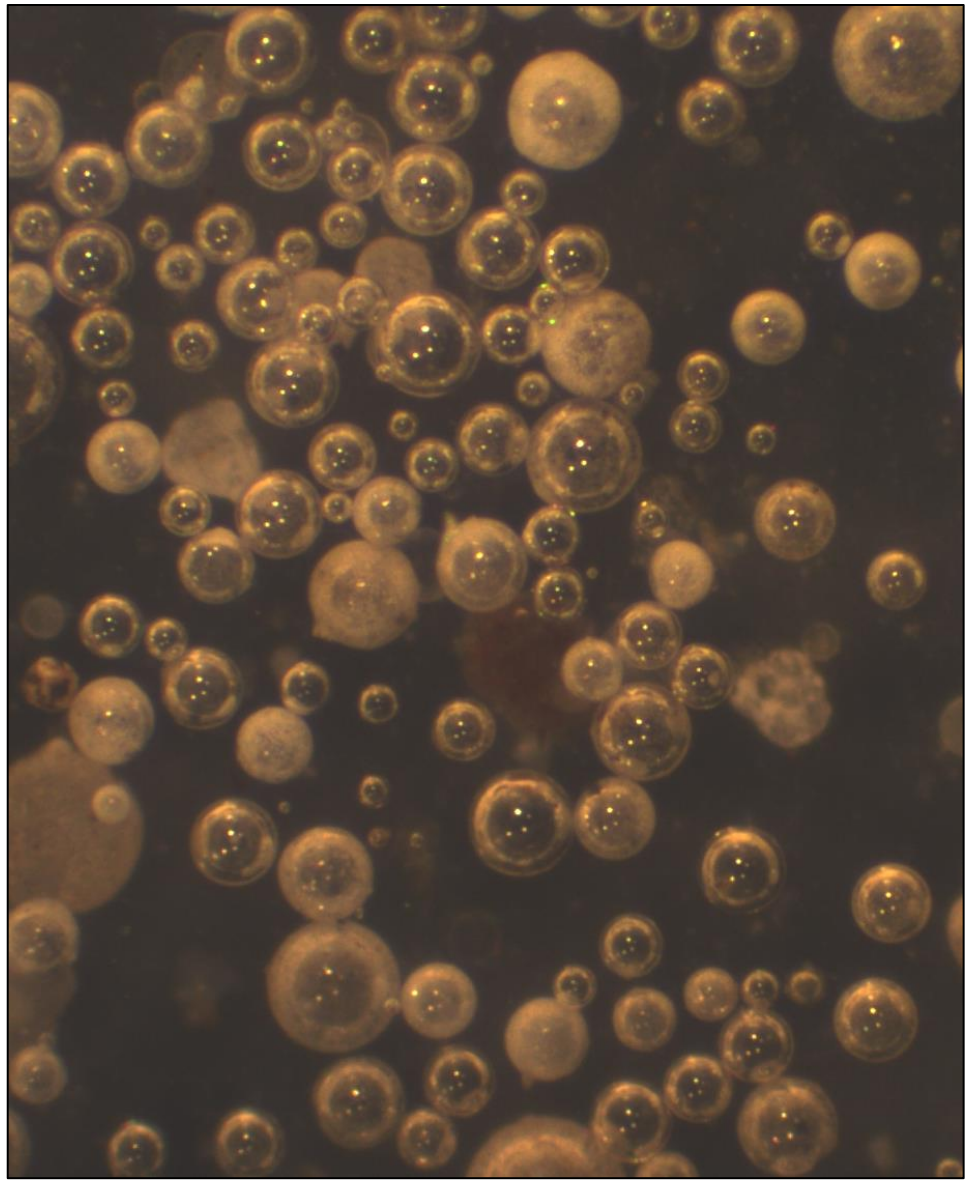
Floating cloud-like filamentous masses of *Mougeotiopsis*
Cliff of Neuse State Park, Wayne County, NC.

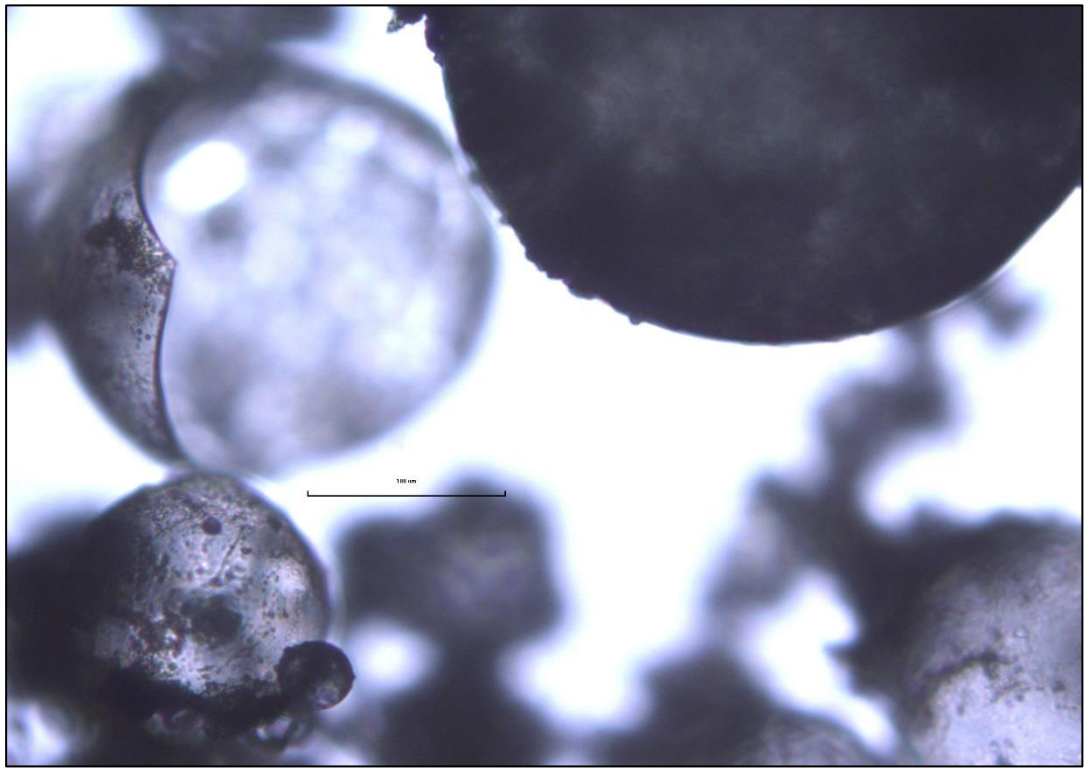
Not Algae: Cenospheres

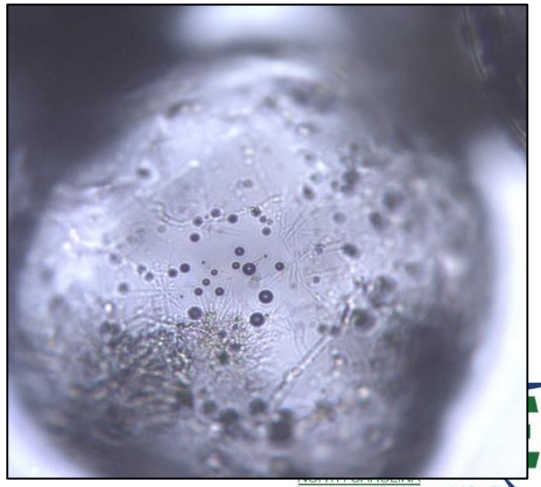
- Hollow, “glass” spheres (10-1000 µm) formed as by-product of coal combustion
- Lightweight, inert, largely made of silica and alumina.
- Are buoyant and are easily transported on surface of flowing waters.
- Indicator of coal ash deposits/contamination (coal ash contains between 0.01-1% cenospheres)
- Can appear as white/tan/brown surface film or as sand deposited on debris and vegetation during high water
- May have an iron oxide coating that can contain heavy metals



Not Algae: Cenospheres



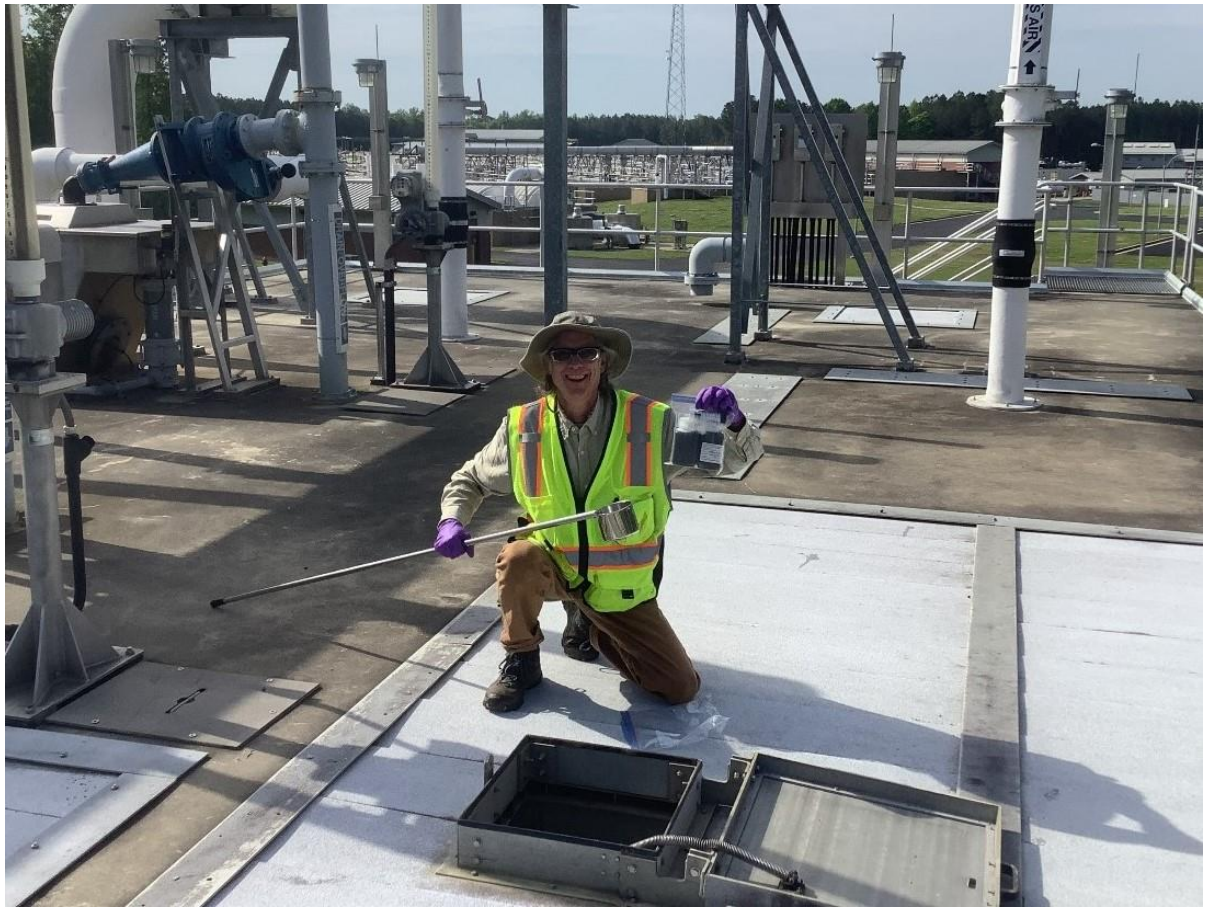




Department of Environmental Quality

What next? PFAS in Surface Water Foam and Biosolids

- Emerging Compounds: Per and polyfluoroalkyl compounds
- Sampling method development
- To be continued…



Who I Am

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