Benthic Cyanobacteria: Drinking Water Reservoirs

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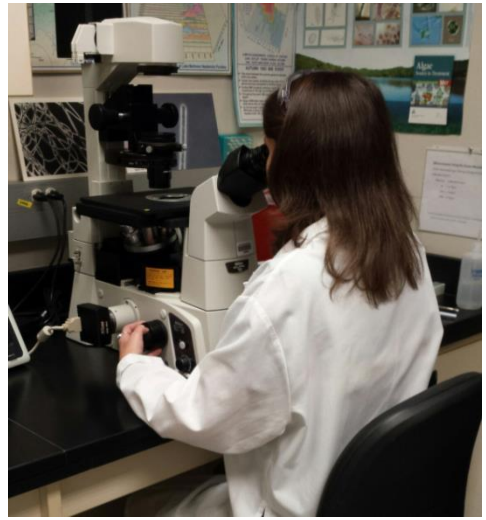
Metropolitan Water District of Southern California

- Who We Are
  - Regional Water Wholesaler
  - Provides water to 19 million people in S. California
- Source Waters
  - Colorado River
  - State Water Project
    - Sacramento-San Joaquin Delta
    - Sierra Snowpack
- Water System
  - CR Aqueduct
  - 9 Reservoirs
  - 5 Water Treatment Plants

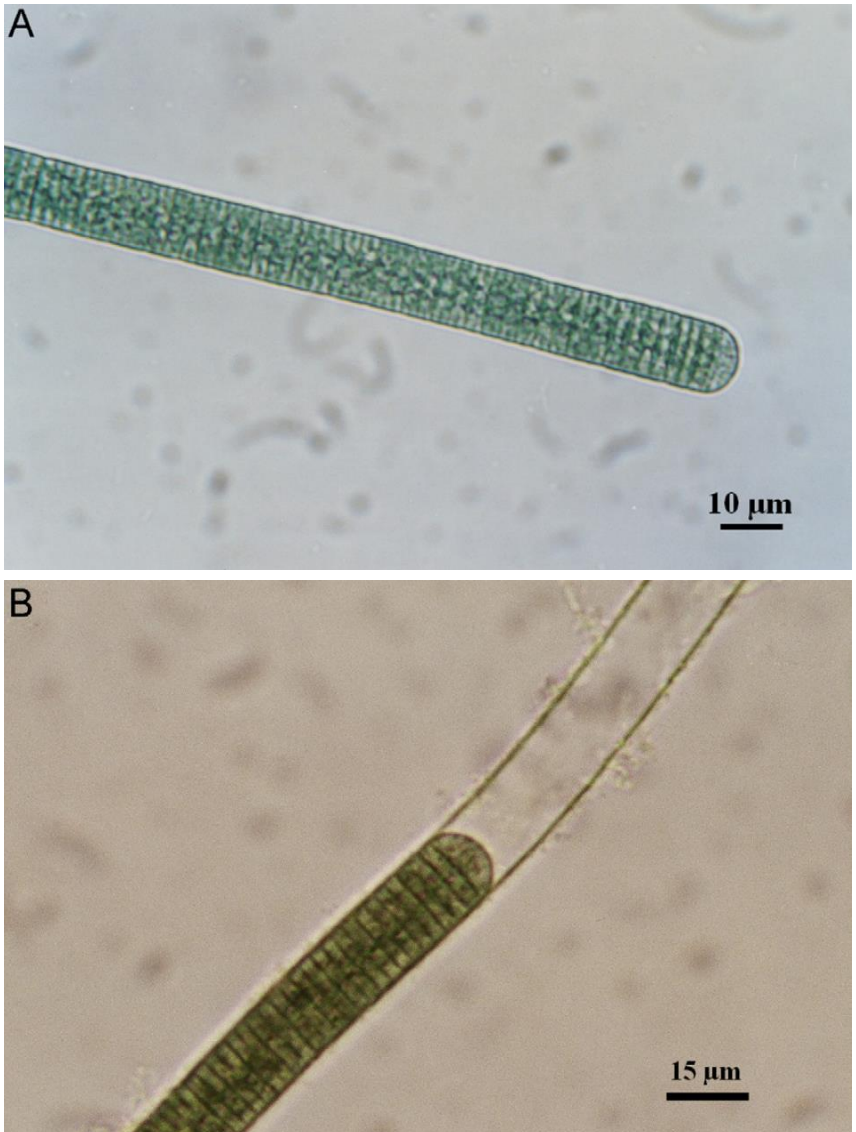
Monitoring Tools for Benthic Cyanobacteria

- Sample Collection:
  - SCUBA Diving (grab samples and surveys)
  - Scrub Sampler (when dive entry unsafe)



- Laboratory Analysis:
  - Microscopic Analysis
  - Toxin Analysis - ELISA and LC/MS/MS
  - T&O Analysis - SPME

Cyanotoxins in Reservoirs



Izaguirre et al., 2007

Table 2 – Concentrations of microcystin detected in benthic algal samples from three reservoirs in southern California, using the PPIA method

Reservoir of origin	Date	Location	Concentration ($\mu g\, g^{-1}$ dry wt)
Lake Mathews	6/17/2003	Site 4	32.4 ± 7.2
Lake Mathews	3/3/2004	Site 7	1.23 ± 0.83
Lake Mathews	4/5/2004	Site 7	1.34 ± 0.02
Lake Mathews	3/3/2004	Site 9	2.32 ± 1.35
Lake Mathews	3/2/2004	Site 19	1.26 ± 0.45
Diamond Valley Lake	1/21/2004	East Dam	288.0 ± 20.63
Lake Perris	8/6/2004	Site 9	15.6 ± 5.02

The samples were obtained by divers at various sites at 6 m depth where benthic algae are collected periodically for taste-and-odor monitoring, and contained varying amounts of sediment in addition to algae and other organisms. For a map and description of some of the sites in Lake Mathews, see McGuire et al. (1984). For similar information on DVL, see Izaguirre and Taylor (in press).

Cyanobacteria Isolates

Izaguirre et al., 2007

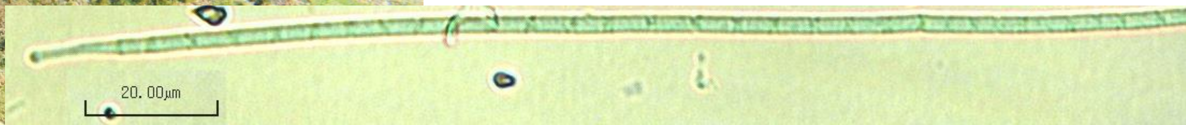
Table 1 – Concentrations of microcystin detected by PPIA in 14 cyanobacterial isolates from Lake Mathews, Lake Skinner, Diamond Valley Lake, and Lake Perris

Strain	Intracellular ($\mu g L^{-1}$)	Intracellular ($\mu g mg^{-1}$ carbon)	Extracellular ($\mu g L^{-1}$)
LM603a	148.1 ± 15.6	1.33 ± 0.12	9.1 ± 0.11
LM603b	90.6 ± 11.7	1.15 ± 0.08	3.6 ± 0.56
LM603c	136.0 ± 30.3	nt	3.7 ± 0.53
LM603d	337.8 ± 19.45	nt	
LS703a	370.6 ± 43.9	nt	
LS703b	316.8 ± 103.9	2.01 ± 0.26	
LS703c	292.1 ± 44.9	2.12 ± 0.42	
LS703d	323.3 ± 20.7	nt	
DVL1003c	432.0 ± 17.0	4.15 ± 0.08	
DVL1103a	1.69	nt	
DVL1103c	243.0 ± 12.0	nt	
LP904b	<2.1	nt	
LP904c	441.3 ± 109.8	2.1	
LP904d	<2.1	nt	

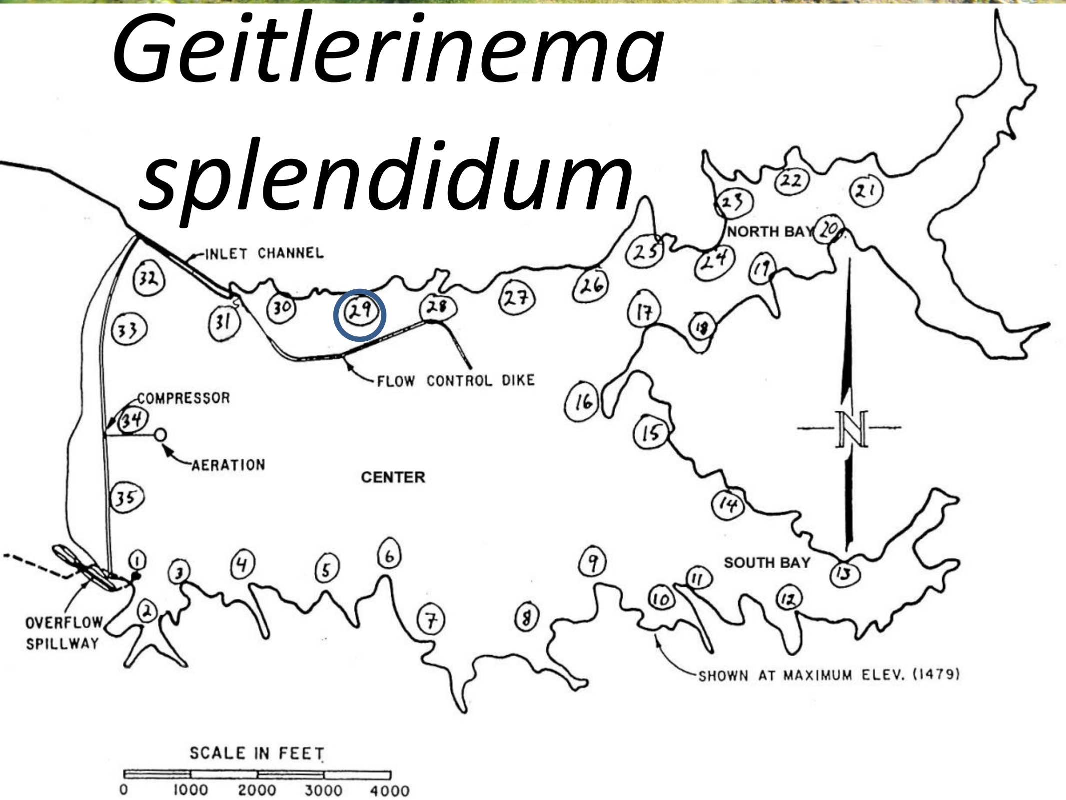
All values are the mean of duplicate analyses. The mean dry weight of seven representative cultures was 308.9 ± 109.9 $mg L^{-1}$. "nt" = not tested.

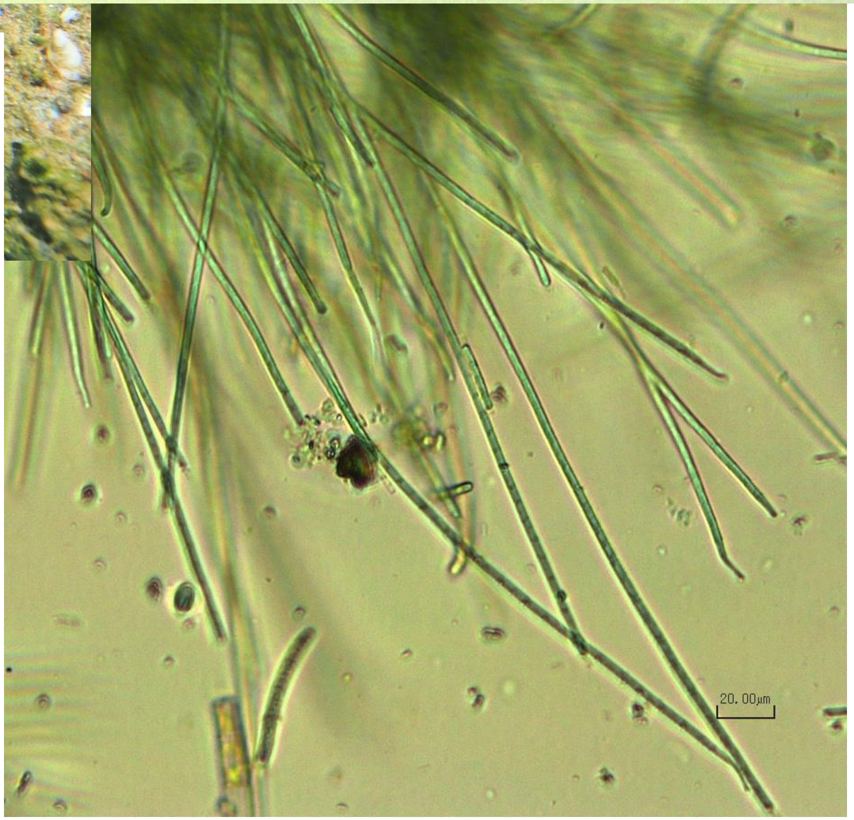
- Strain specificity
- Loss of toxin production in culture
- Benthic bound microcystin
- Difficulty in taxonomic identification

Skinner 9/16/2015
Site 29
Habit: Mud and macrophytes, stagnant muds with H_2S. Forms both unialgal mats and mixed with other cyanobacteria.



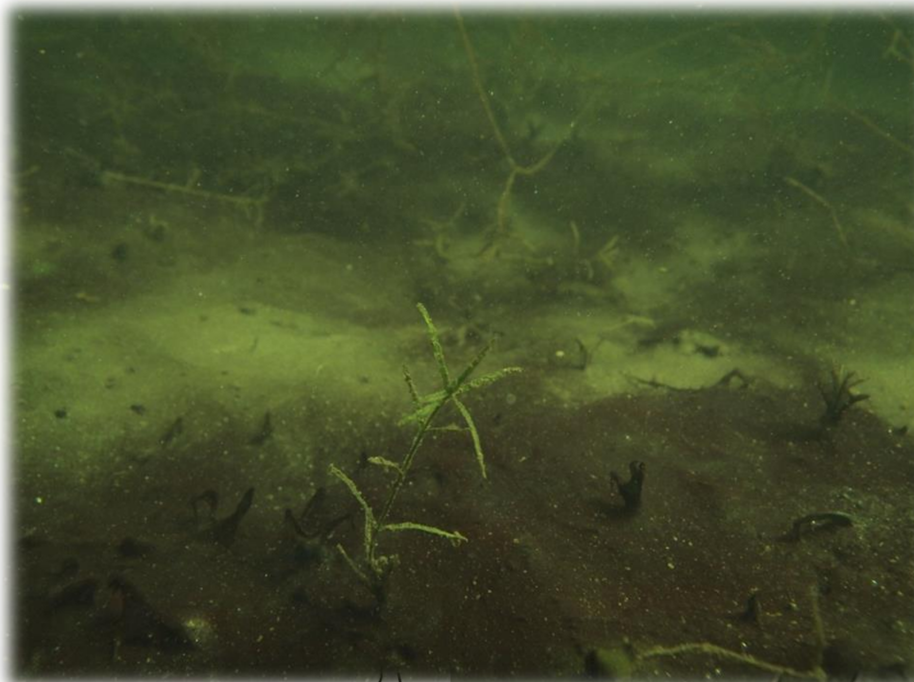
Geitlerinema splendidum

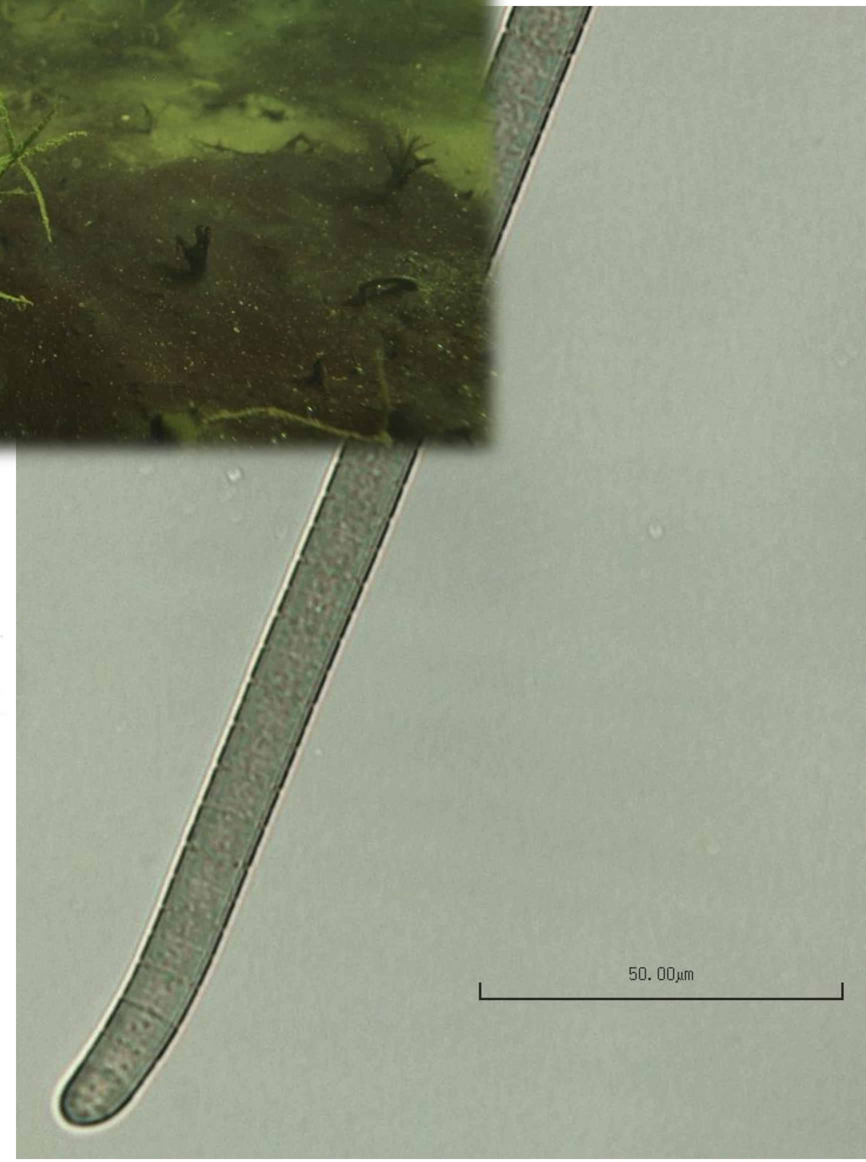


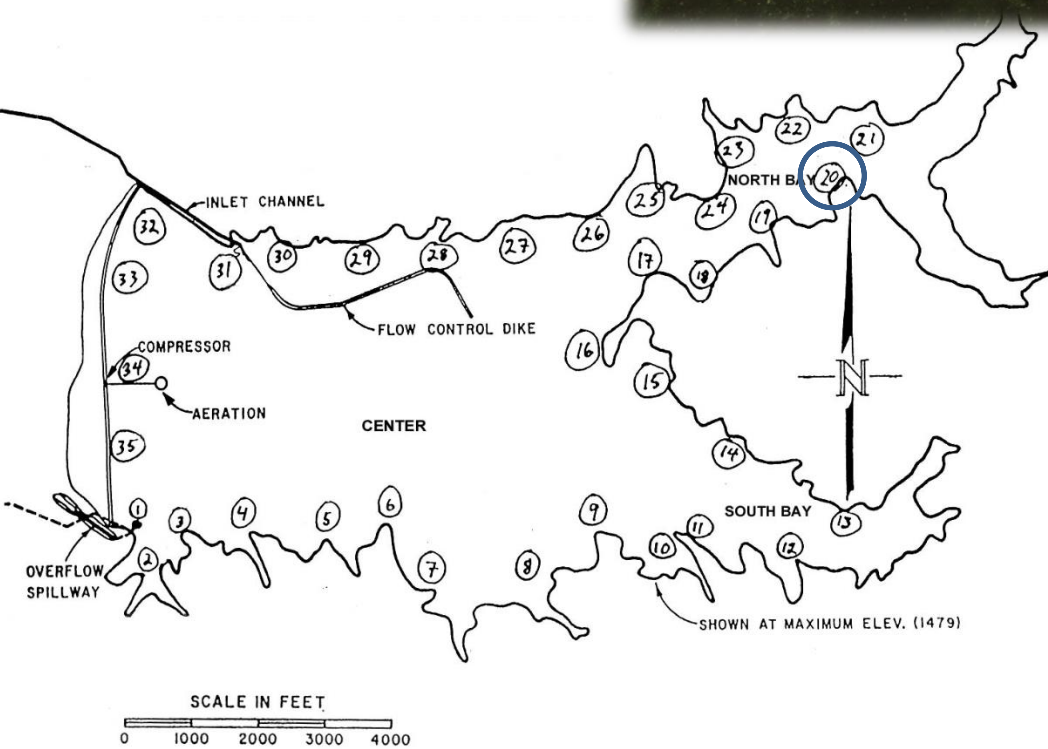


Phormidium chalybeum

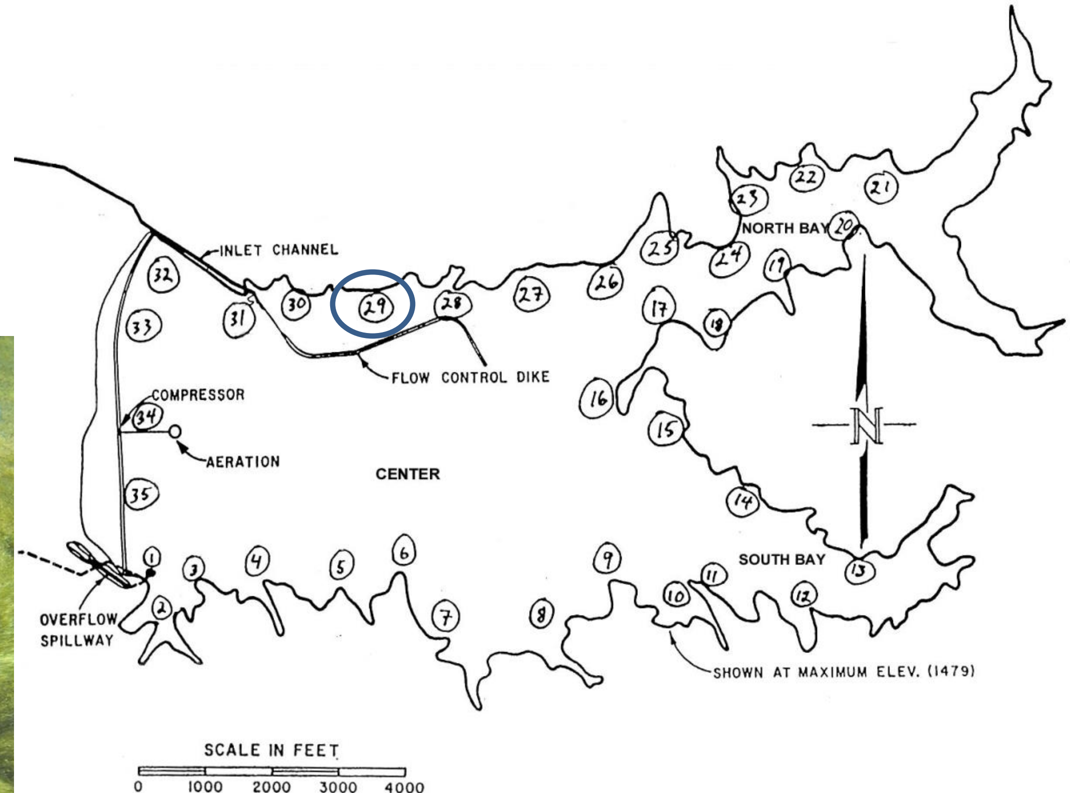
Lake Skinner
Site 20 - MIB
Collected 9/18/2014
Habit: Mud, stagnant water.
Fragile mats. Unialgal mats.

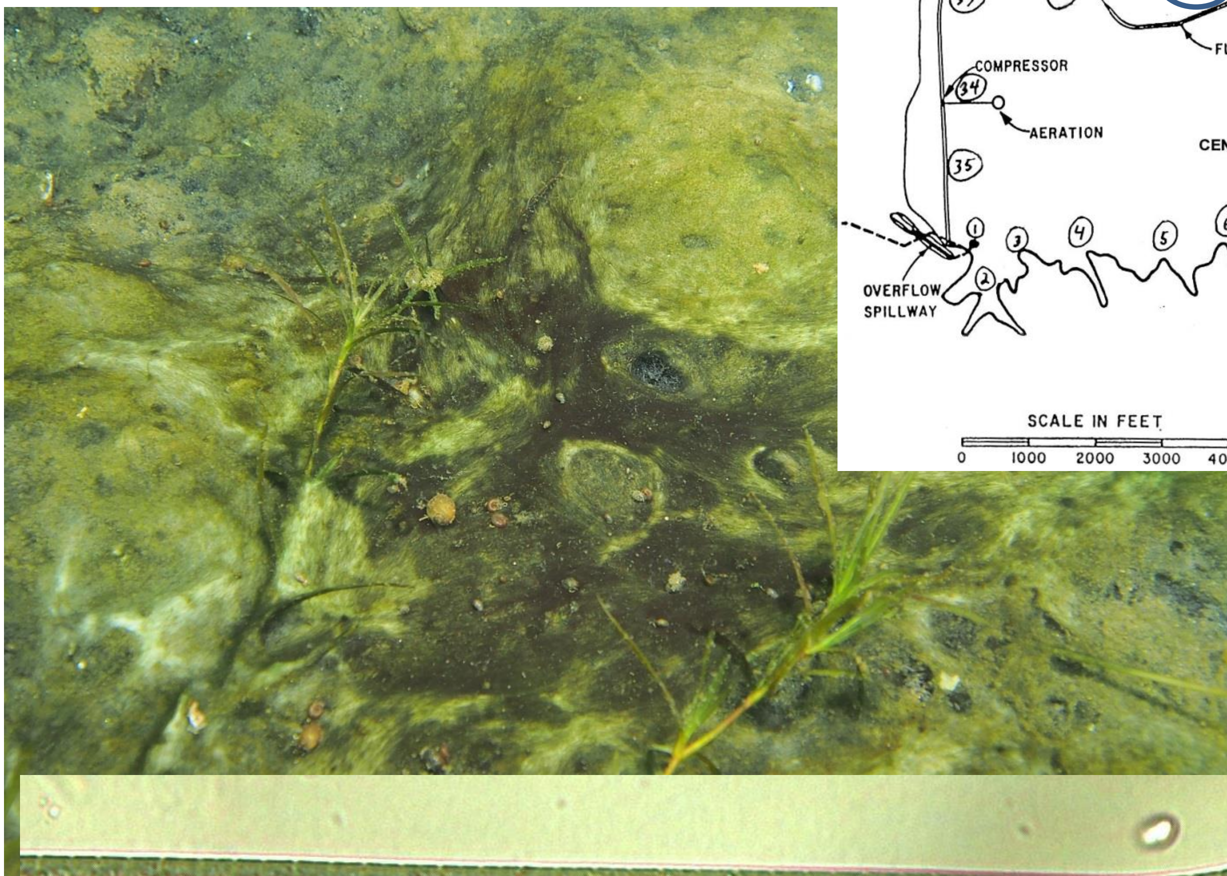


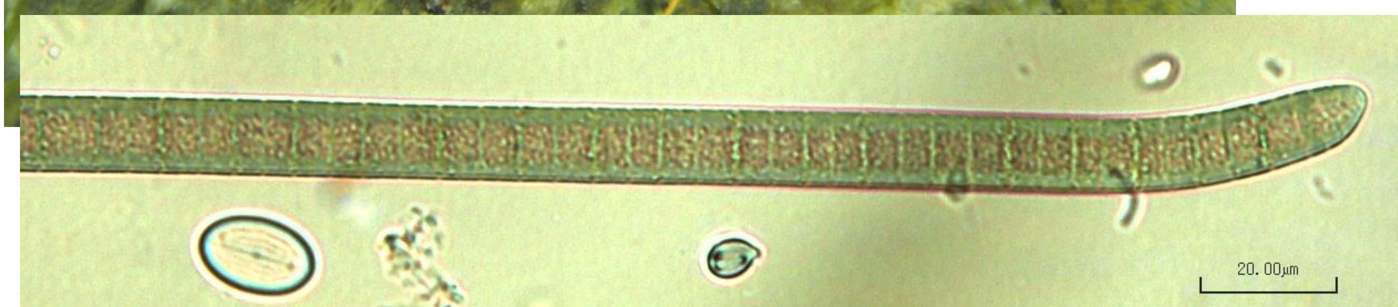




Phormidium chalybeum

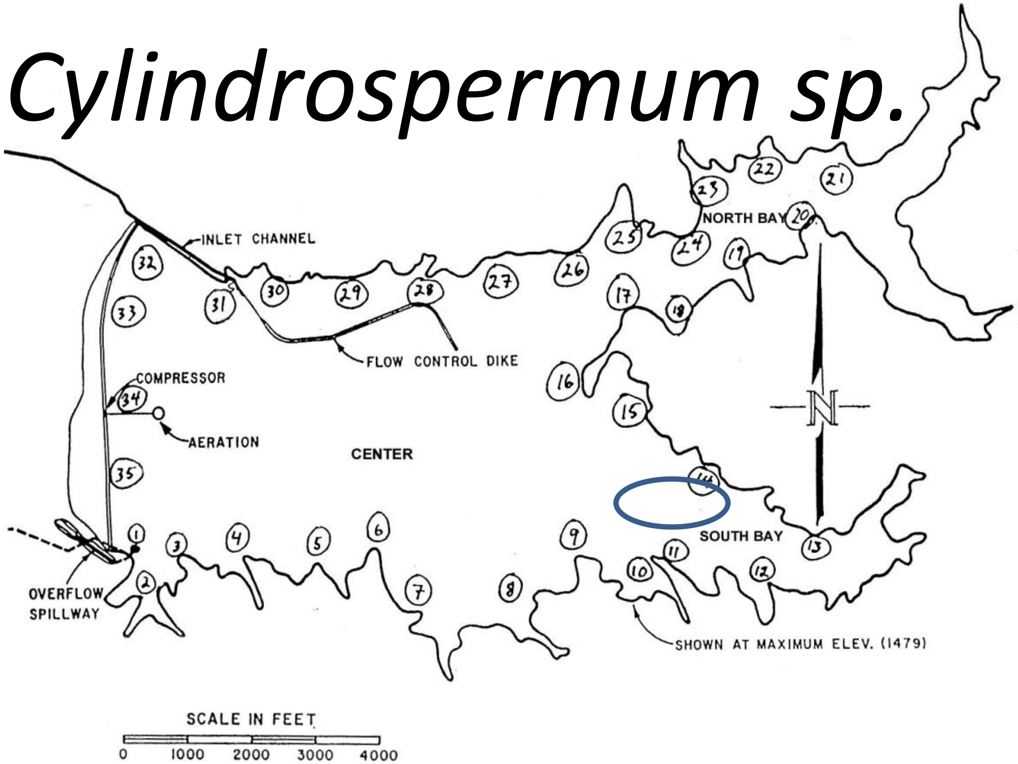


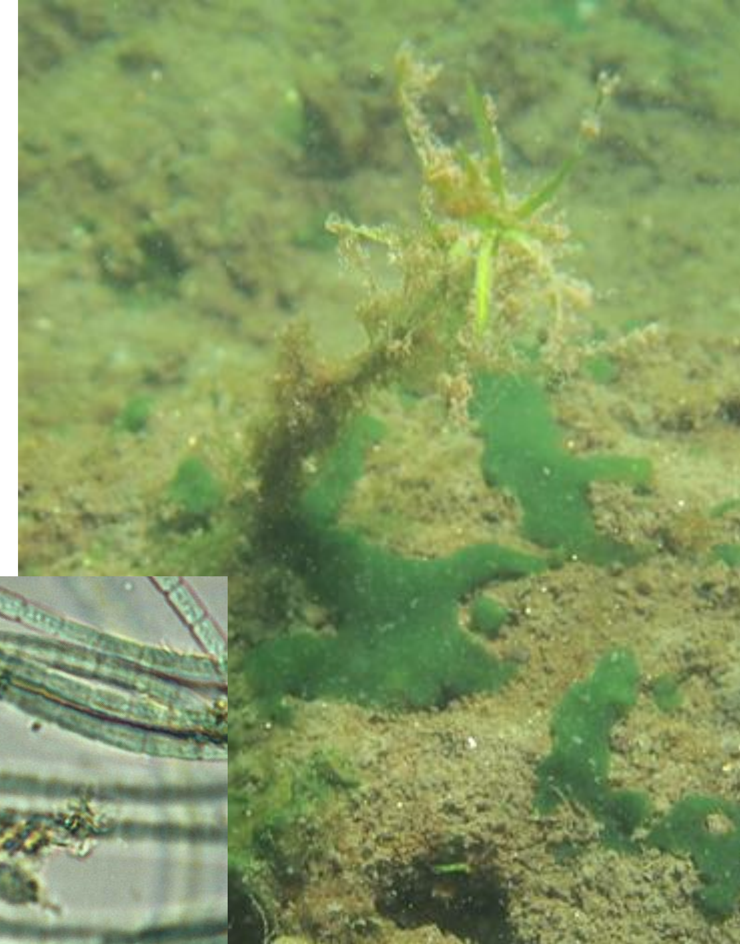


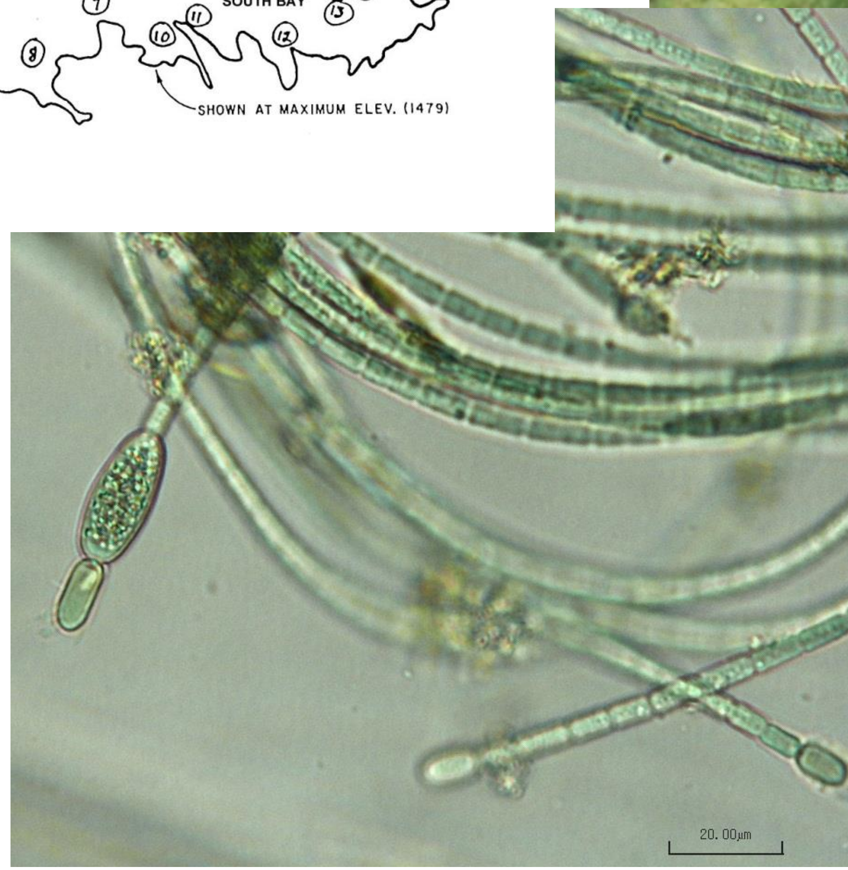


Skinner 9/16/2015
Site 29 - MIB
Habit: Mud. Stagnant waters with H_2S. Fragile mats. Mixed mats with other cyanobacteria and other bacteria (*Beggiatoa sp.*)

Cylindrospermum sp.



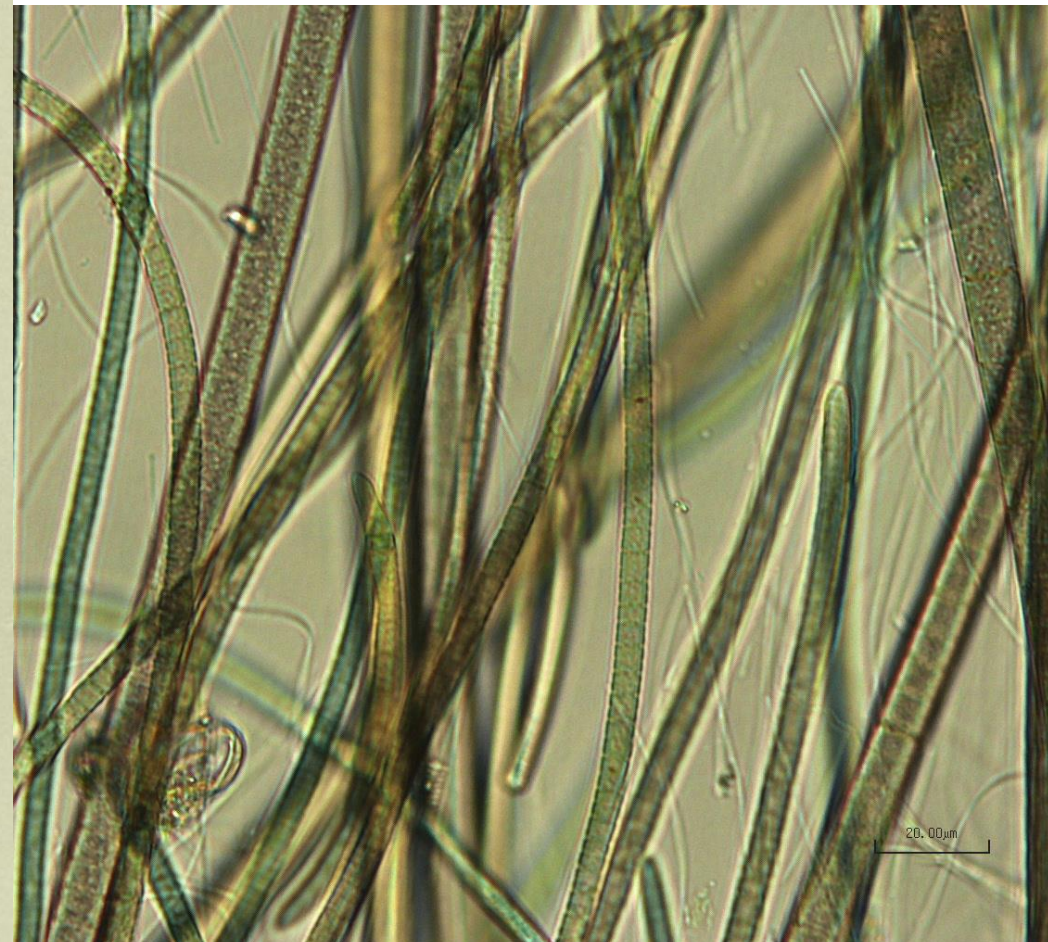




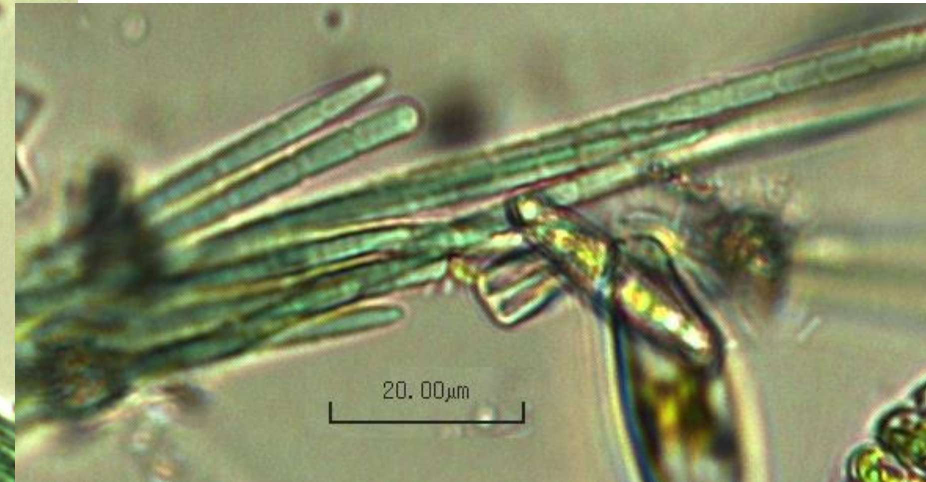
Lake Skinner 11/5/2014
S. Arm
Habit: Mud bottom. Periphytic. Around macrophytes. Mucilagenous/globulous mats. Nearly unialgal mats.

Phormidium formosum

Habit: Periphytic. Stagnant water. Mud. Never in unialgal assemblages.



Taxonomic Help: *Tricholeus sp. or Microcoleus sp.*



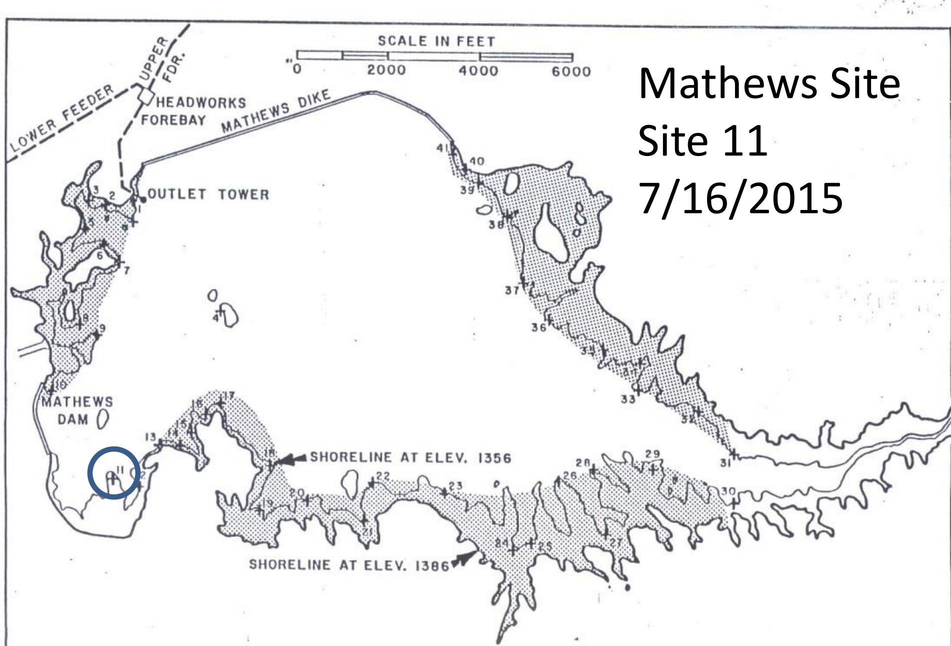
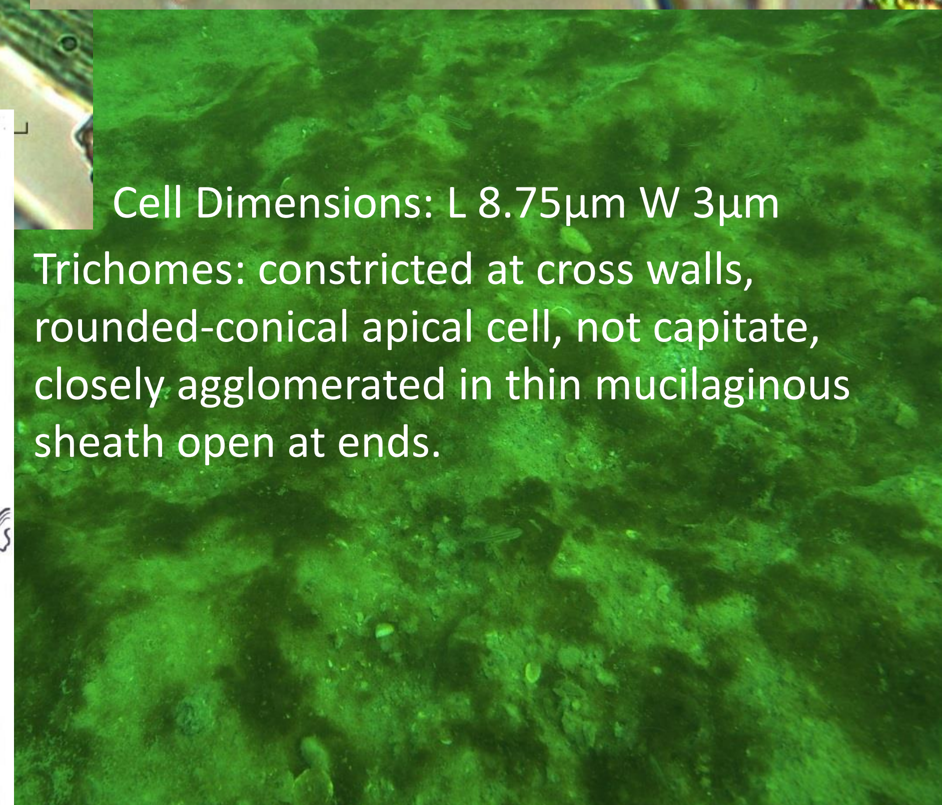


FIGURE 3. LAKE MATHEWS TREATMENT AREAS

Mathews Site
Site 11
7/16/2015

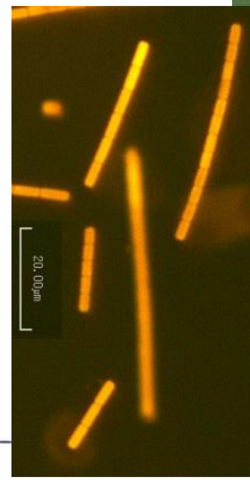


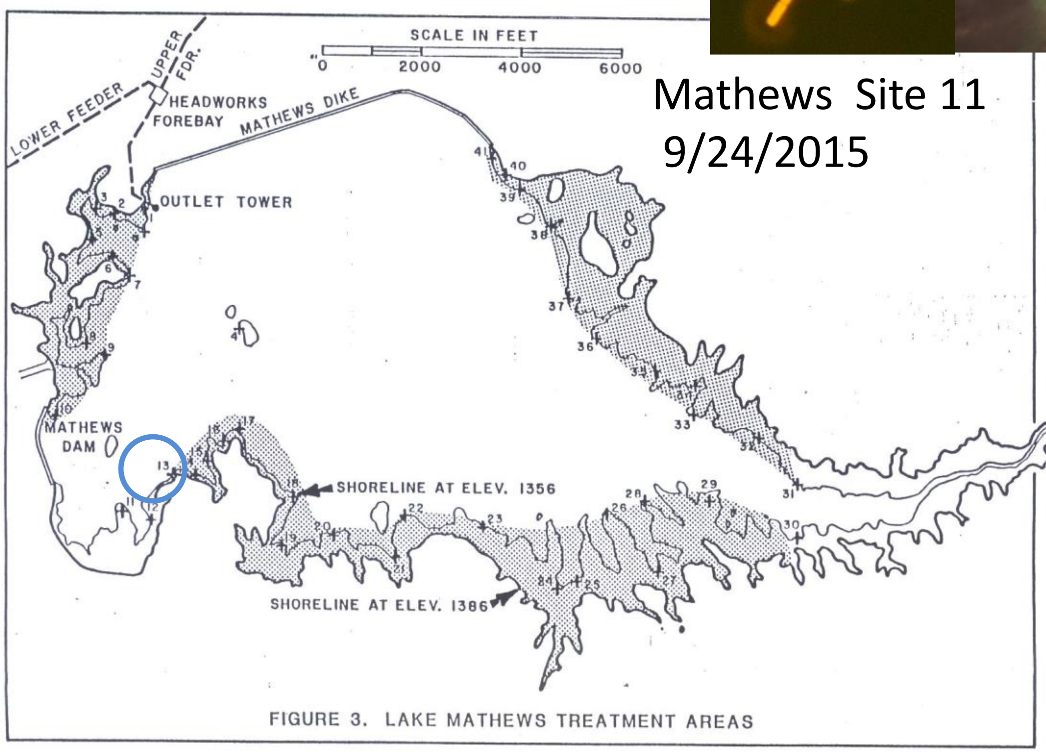
Cell Dimensions: L 8.75µm W 3µm

Trichomes: constricted at cross walls, rounded-conical apical cell, not capitate, closely agglomerated in thin mucilaginous sheath open at ends.

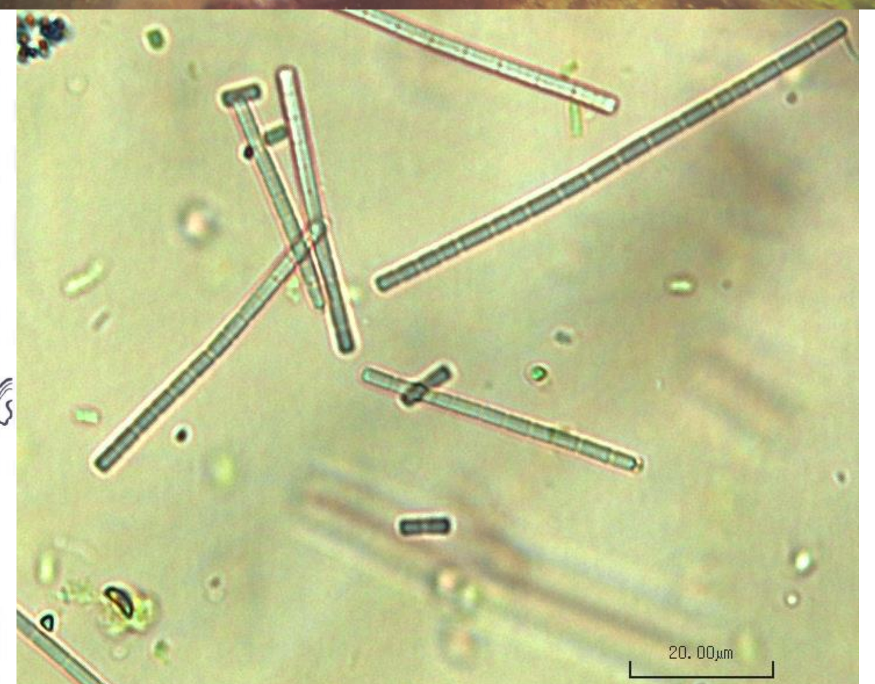
Taxonomic Help: *Pseudanabaena sp.*

Cell Dimensions: L 5µm W 2.5µm
Cells purple/red color
Trichomes: 5-20 cells long, constricted cross walls, no attenuation, rounded apical cells.





Mathews Site 11
9/24/2015



Taxonomic Help:

Treatment Plant Filter 11/21/2017
Cell Dimensions: L 5µm W 2.5µm
Trichomes: Coiled. Cross wall constrictions.
Apical cells rounded.

Cyanotoxin Monitoring

Past (Pre-2017)

- Monthly microscopic analysis.
- Perform ELISA when potential planktonic cyanotoxin producers are observed.
- Perform LC/MS/MS when there is a positive ELISA hit.
- Increased monitoring if potential problems exist.

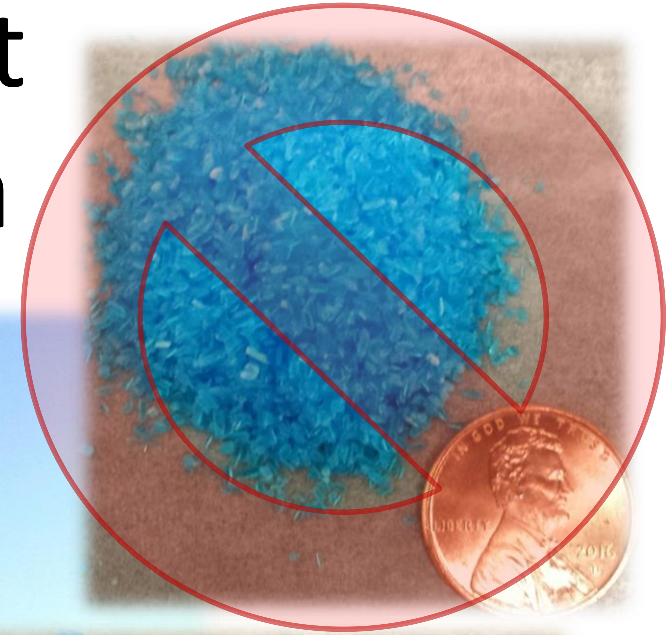
2017 to Future

- Monthly microscopic analysis.
- Monthly ELISA monitoring at surface sites at all reservoirs.
- ELISA on benthic samples.
- Perform LC/MS/MS when there is a positive ELISA hit.
- Increased monitoring if potential problems exist.
  - Best places to assess impact of toxins produced by benthic species within reservoir system?

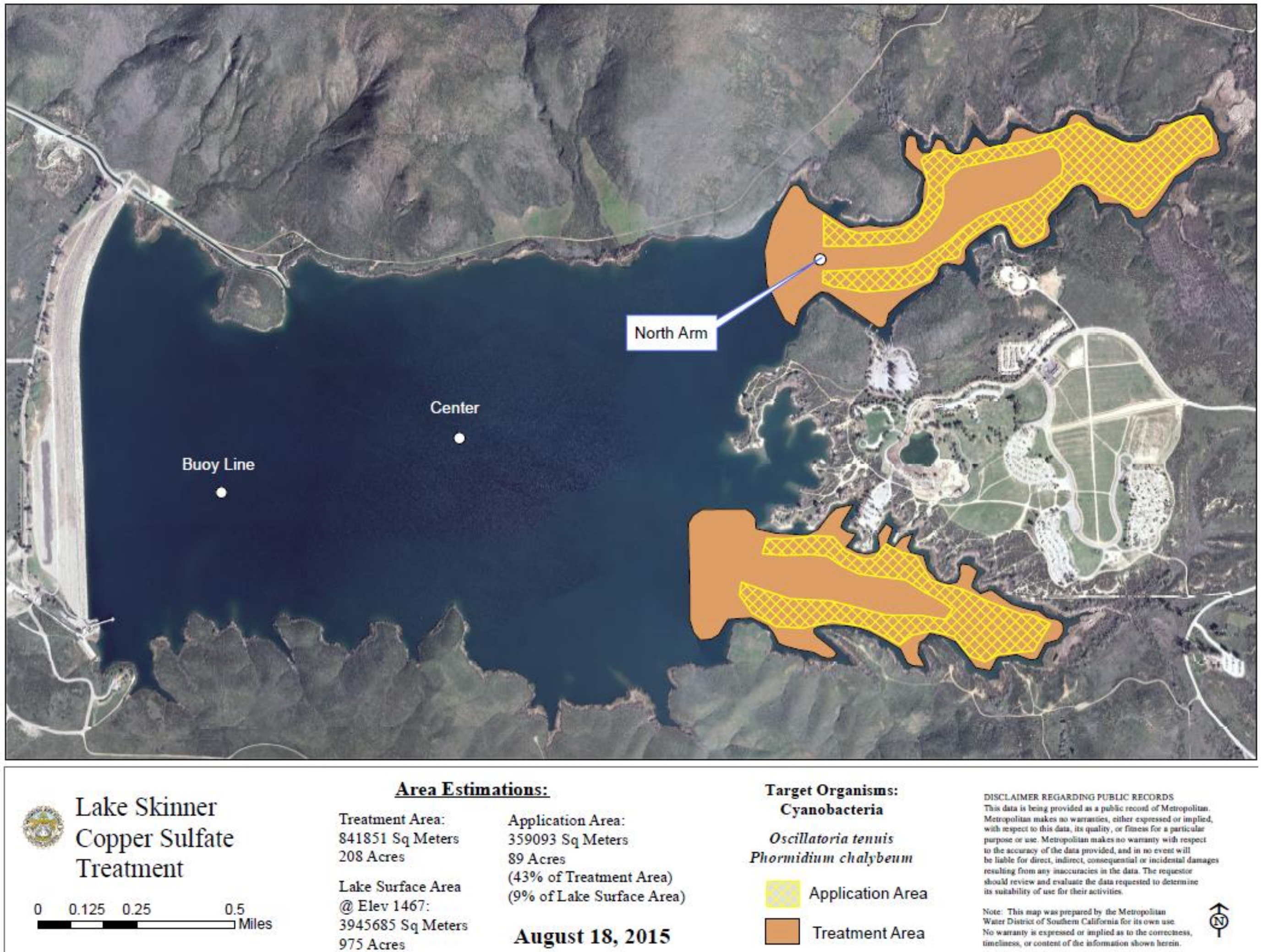
Benthic Cyanobacteria Management

- While benthic cyanotoxin producing organisms have been found, we have not found widespread impacts to reservoirs (though regular ELISA monitoring has only been performed for the last year).
- What will happen if we do find benthic cyanotoxin producers impacting water quality? How will they be managed?

Copper Sulfate Treatment of Benthic Cyanobacteria

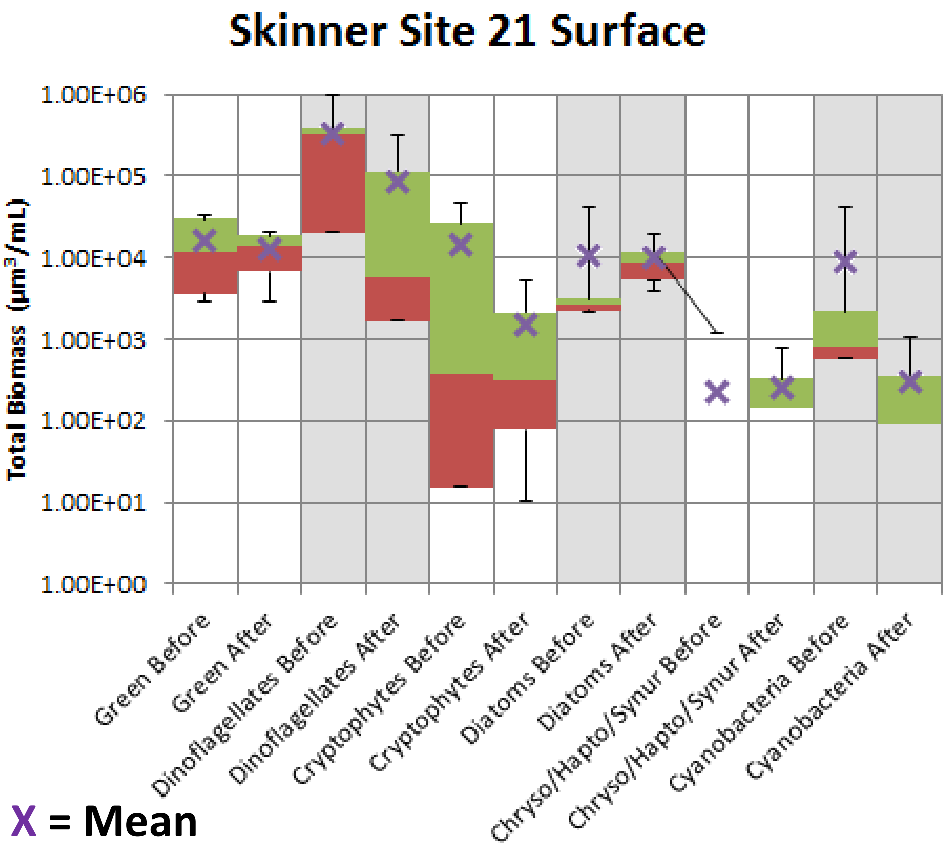


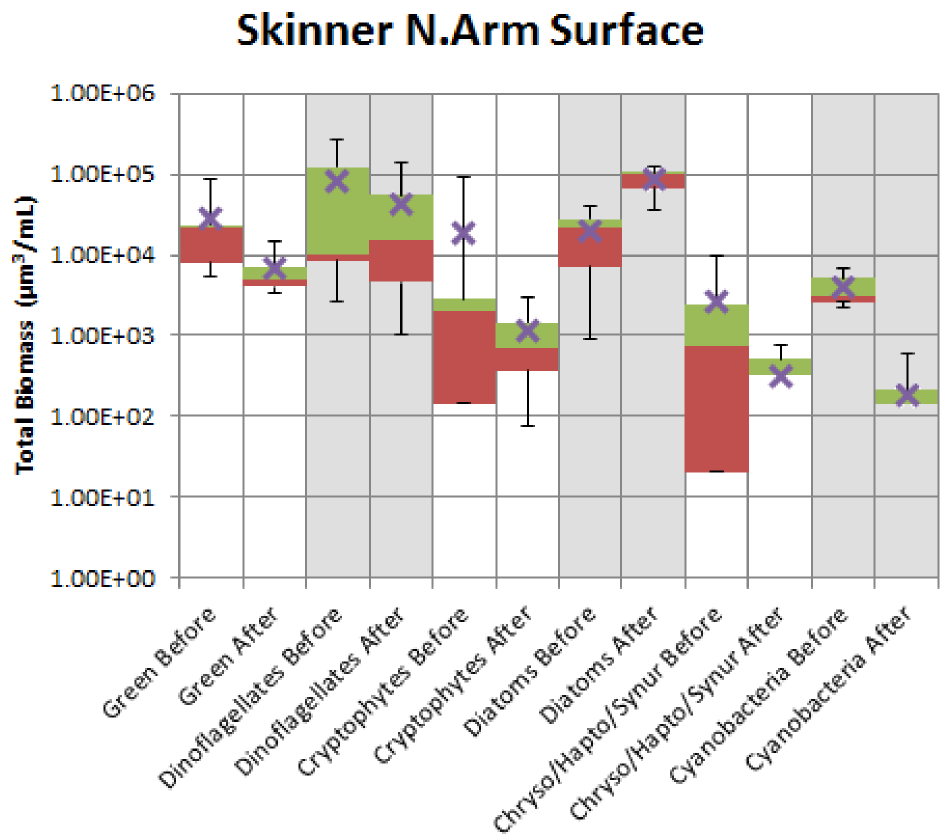
Phormidium chalybeum and *Oscillatoria tenuis*, MIB and Geosmin Producer Copper Sulfate Treatment 8/18/2015



Phytoplankton Populations Before and After Benthic Copper Treatment 8/15/2015

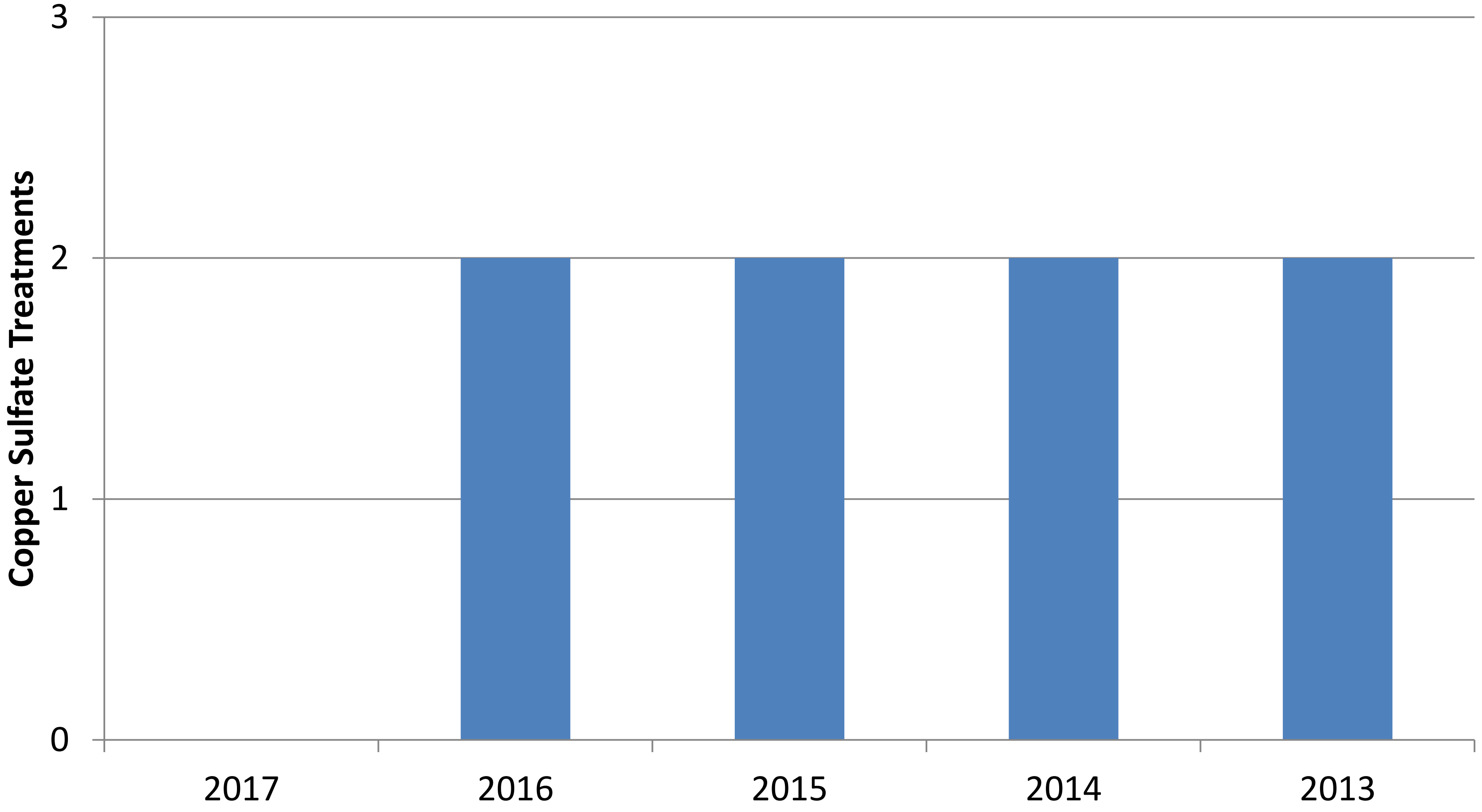
- Mann Whitney test – There were no significant differences in any phytoplankton group before and after treatment with the exception of cyanobacteria N.Arm, which were significantly lower after treatment.





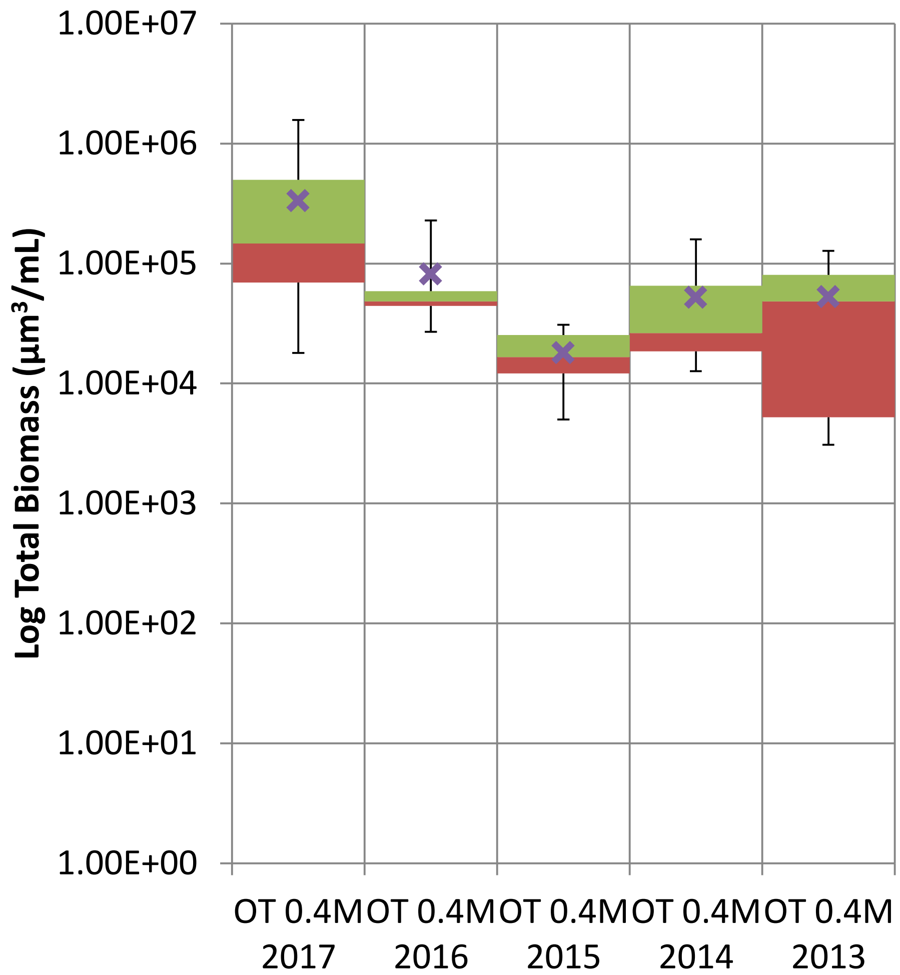
X = Mean

Benthic Copper Treatments Skinner



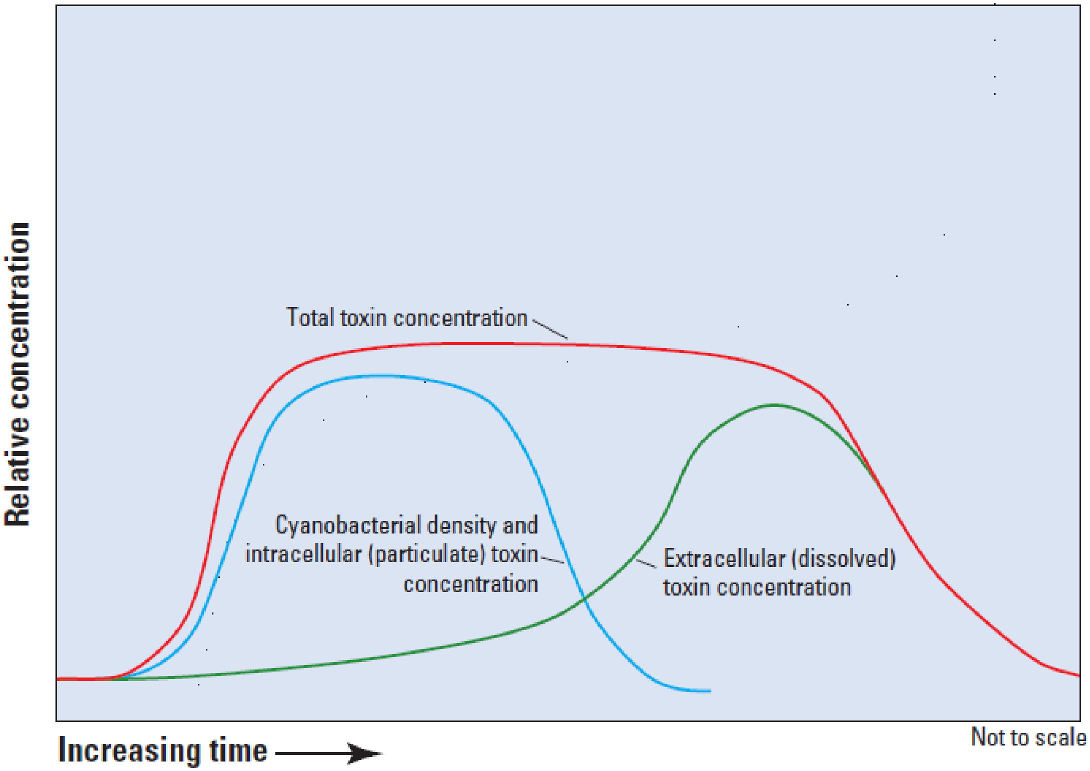
Skinner Source Water Change Impact on Benthic Cyanobacteria

- Source water change
  - 2013-2016 Colorado River Aqueduct (low nutrients)
  - 2017 State Project Water (higher nutrients)
- Source water change impact on reservoir
  - Fewer macrophytes
  - Greater phytoplankton
  - = less light penetration



Future Plans and Questions

- Many benthic T&O producers are intermixed with potential toxin producing benthic cyanobacteria
- When we treat with copper sulfate for a benthic T&O producer do we see a corresponding release of toxin due to cell lysis?



Graham et al., 2008 Cyanobacteria in Lakes and Reservoirs, USGS

Future Plans and Questions

- What % coverage of a potential toxin producing species constitutes a problem?
  - Reservoirs
  - Aqueduct (River)
- Continued ELISA monitoring.
- More dive surveys of benthic cyanobacteria populations.

Thank You

Photo Credits: Microscopic images taken by Margaret Spoo-Chupka; Underwater Images taken by Reservoir Management Divers (Kelly Lorenz, Matt Williams, Stephen Reynolds, Dennis Otsuka, and Randy Whitney).