

Management of Lakes & Beaches Plagued with Cyanotoxins

Fred S. Lubnow, Ph.D.
Director of Aquatic Programs
Princeton Hydro, LLC

The New York State Federation
Of Lake Associations
May 2017



Princeton Hydro

pH

What are Algae?

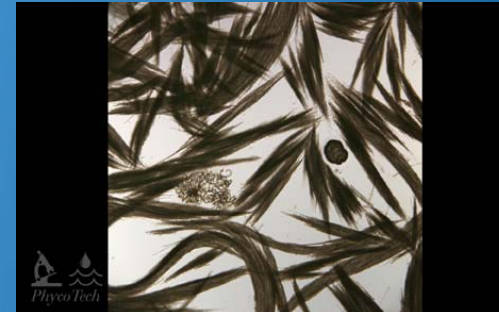
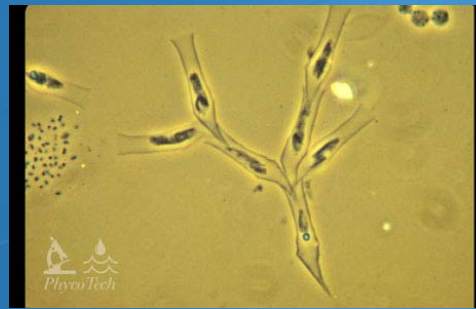
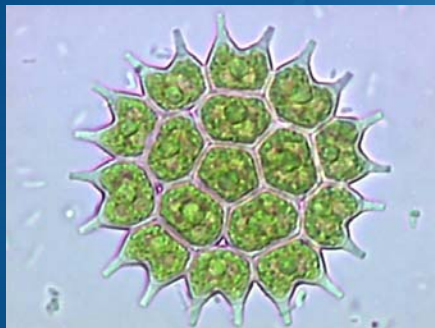
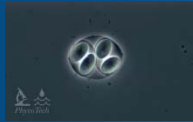
- Most are microscopic, photosynthetic organisms
- More of an ecological term than taxonomic
- Base of the aquatic food web; many algae are necessary and good
- However, some algae, particularly the blue-green algae (cyanobacteria) are a nuisance (surface scums, taste and odor)



Princeton Hydro

pH

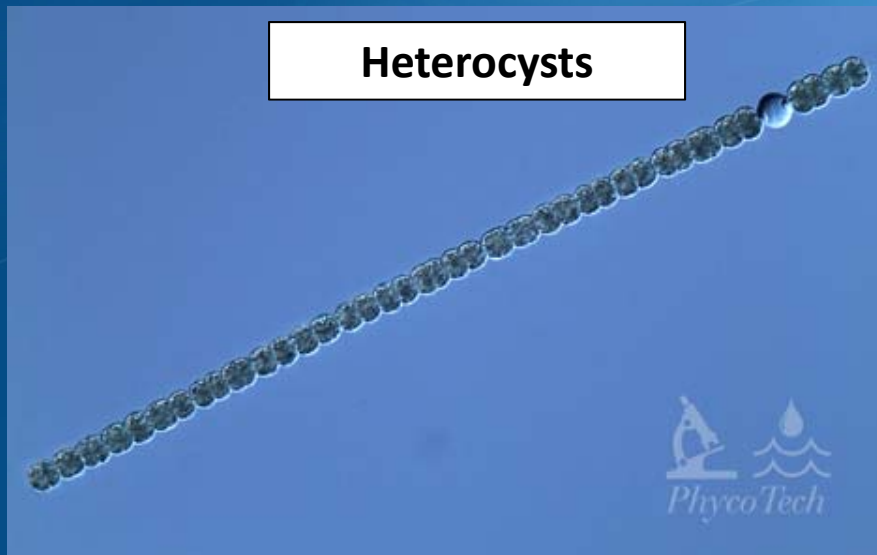
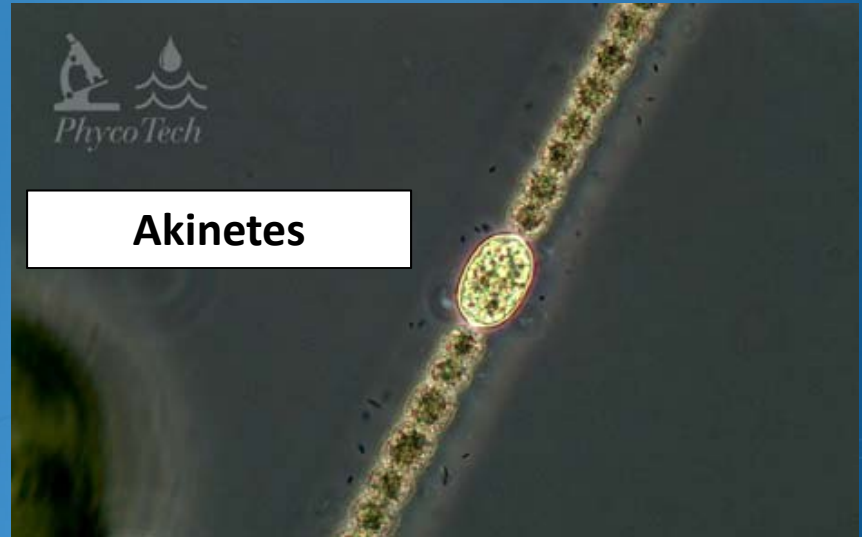
Diversity of Freshwater Algae



Cyanobacteria (blue-green algae)

- Photosynthetic bacteria
- Very old organisms so they are very well adapted to their environments
- The dominant nuisance group of algae in freshwater ecosystems
- Many can “fix” their own nitrogen
- Responsible for nuisance scums, impact on recreational usage, potable water supplies and ecological value
- Can produce taste and odor compounds (geosmin / MIB) and **cyanotoxins**.
- Many are not grazed by zooplankton

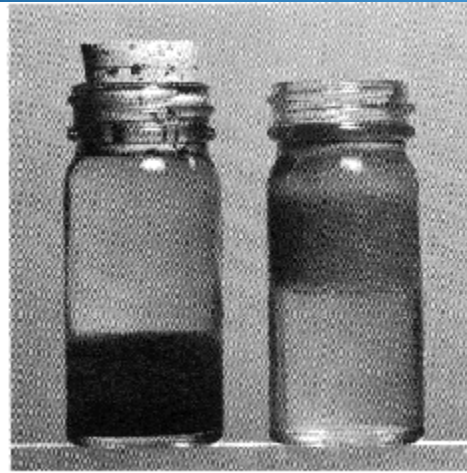
Blue-Green Algae



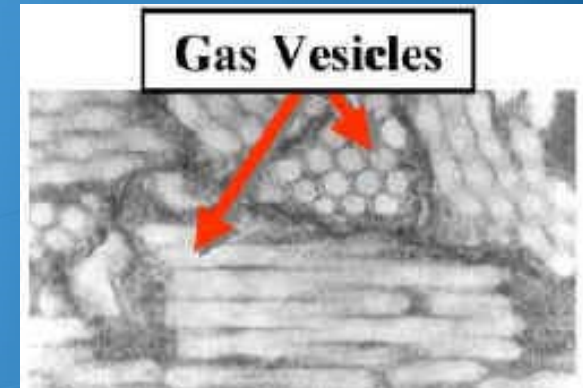
Gas Vacuoles and Gas Vesicles



a



b



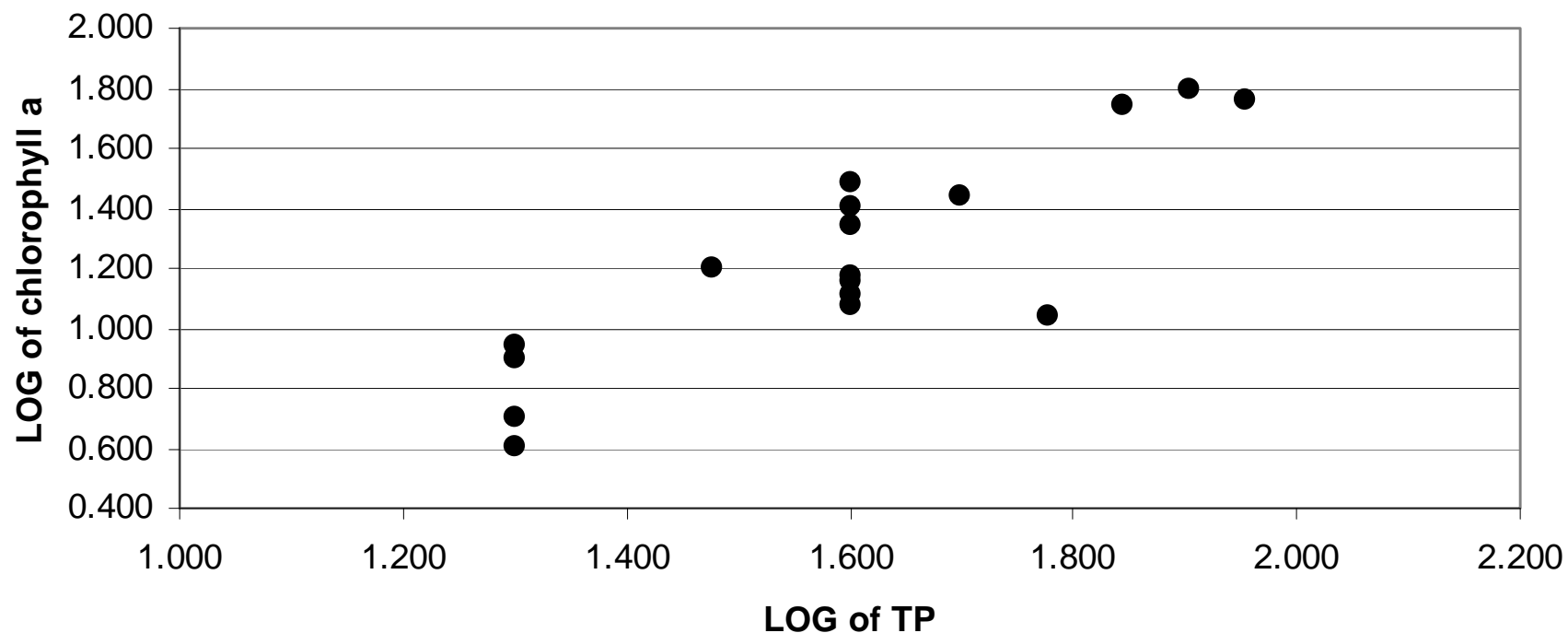


Conditions that Result in an Blue-Green Algal Bloom

- High seasonal temperatures
- Still water conditions / thermal stratification
- Total Phosphorus concentrations as low as 0.03 mg/L (30 ppb) can generate nuisance blooms / scums



Greenwood Lake, Passaic County, NJ and Orange County, NY



Harmful Algal Blooms (HABs)

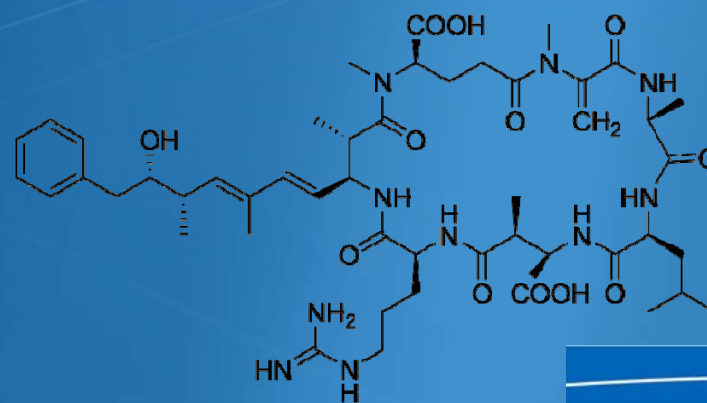


Princeton Hydro

pH

Cyanotoxins (toxins generated by blue-green algae)

- **Hepatotoxins** – microcystins, nodularins, cylindrospermopsins
- **Neurotoxins** – anatoxins, saxitoxins, BMAA
- **Dermatotoxins** – lyngbyatoxins and aplysiatoxins



Cyanotoxins are NOT Taste and Odor Compounds

- Cyanotoxins are colorless, tasteless and odorless compounds
- Taste and odor compounds such as Geosmin and MIB can be produced by cyanobacteria (blue-green algae) and some actinobacteria
- Blue-green algae can produce T&O compounds and not produce cyanotoxins and they can produce cyanotoxins but no T&O compounds

Recommended Limitations of Cyanotoxins

- Currently, US EPA does not have any regulatory requirements or restrictions for blue-green algae or cyanotoxins
- World Health Organization (WHO) has a drinking water guideline of 1 ug/L for microcystin-LR
- US EPA developed Health Advisories for two cyanotoxins in May 2015 in drinking water supplies

US EPA Health Advisories

10-DAY EXPOSURE LEVELS VIA ORAL EXPOSURE ONLY

Microcystins	Cylindrospermopsin
0.3 µg/L for bottle-fed infants	0.7 µg/L for bottle-fed infants
1.6 µg/L for adults	3 µg/L for adults

September / October 2016 (NJ)



Princeton Hydro

pH

September / October 2016 (PA)



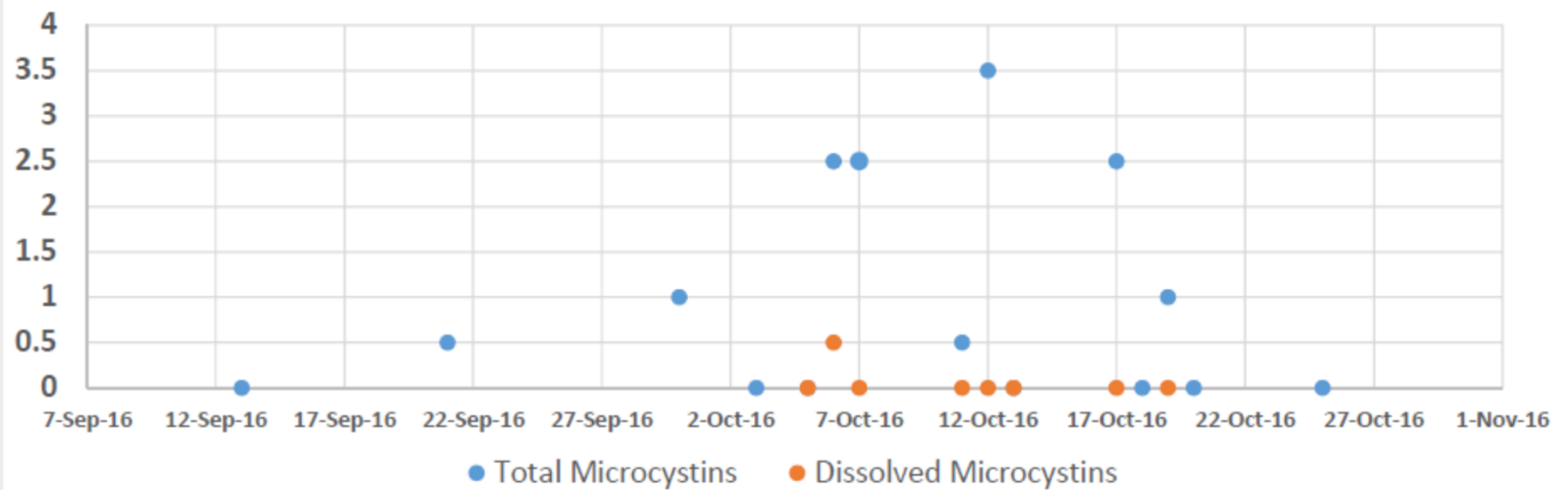
September / October 2016 (NY)



Princeton Hydro

pH

Microcystins Concentrations (ug/L) in a NJ Drinking Water Supply



Recreational Waterbodies

- Even if the water is not used as a potable source of water, cyanotoxins can impact users of recreational waterbodies
- Most impacts are associated with primary contact recreation (swimming, wading, water skiing, jet skiing, etc.)
- Livestock and pets susceptible to the cyanotoxin poisoning
- From the late 1920's to 2012 one study identified 368 cases of cyanotoxin poisoning in the U.S.

Cyanotoxins in Recreational Waterbodies

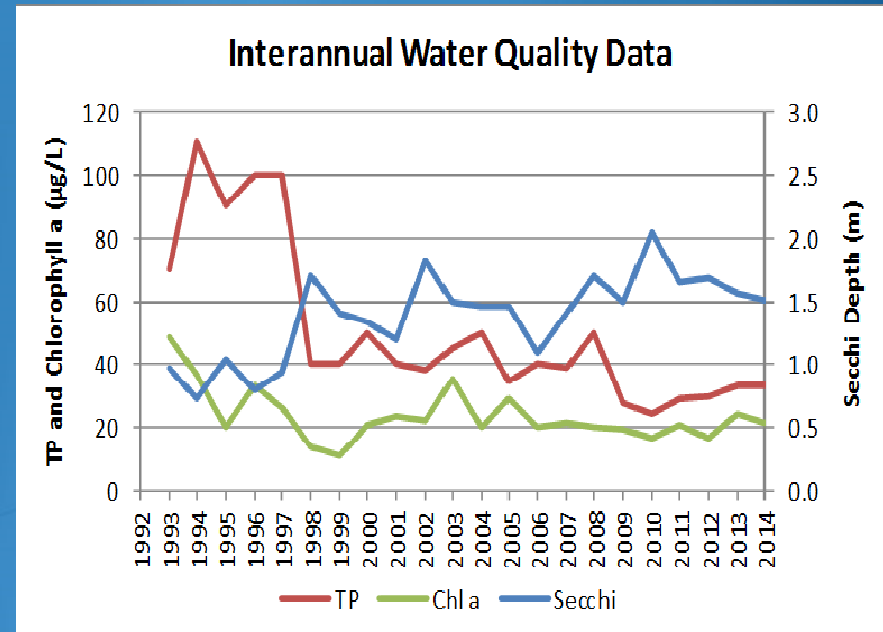
- Draft Human Health Recreational Ambient Water Quality criteria and/or Swimming Advisories for freshwater recreational waterbodies were released in November 2016 by US EPA
- Draft criteria for microcystins is 4 ug/L
- Draft criteria for cylindrospermopsin is 8 ug/L

Princeton Hydro's PARE™ Program – A Strategy For Dealing with HABs

- **Predict** – Use long-term database, keystone parameter data relationships, and/or remote sensing techniques to forecast a bloom
- **Analyze** – Measure/ quantify bloom's severity:
 - Chlorophyll *a*, nutrients
 - Cyanobacteria ID and cell counts
 - Monitor for Microcystin or other cyanotoxins
- **React** – Implement measures to prevent, control or terminate bloom
- **Educate** – Share information with public

Predict

- Develop algorithms from long-term data sets
 - **Weather**
 - Phosphorus : nitrogen ratio
 - Chlorophyll *a*
 - DO/Temperature profiles
 - **Secchi disk values**
 - **Color / appearance**
- Utilize remote sensing technology to track blooms
- Conduct *in-situ* mesocosm experiments
- CSLAP



Analyze

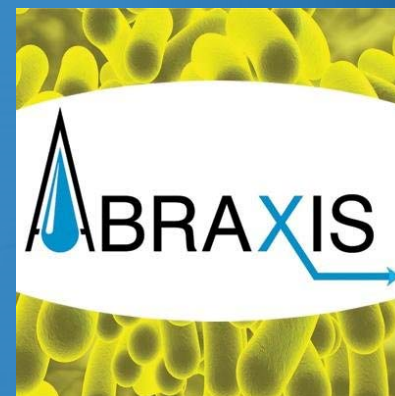
- Phytoplankton ID, enumeration and quantification
- Measure precursors of impending bloom
 - Declining Secchi disc clarity : < 1 meter
 - Chlorophyll *a* : >20 µg/L
 - Cyanobacteria cell counts : 5,000 cells/mL (single genus), 15,000 cells/mL (more than one)
- Measure Microcystin
 - Field kits
 - Analytical lab testing

Algal Identification and Enumeration

- Focus the counts (cells / mLs) on the blue-green algae
- While most blue-green algae appear to have the ability to generate cyanotoxins, not all can
- Multiple cyanotoxins

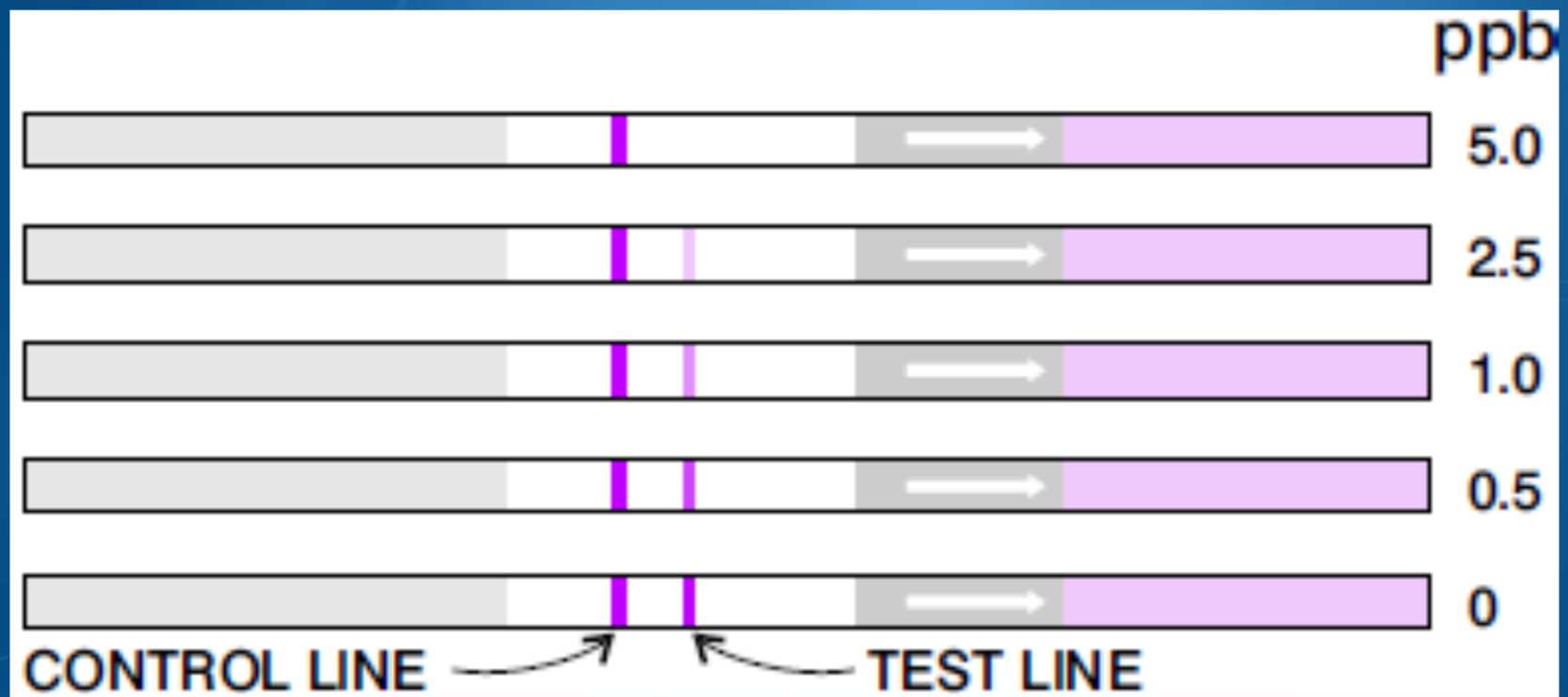
WHO CYANOBACTERIA CELL COUNT ACTION LEVEL	
SPECIES	ACTION LEVEL
<i>Microcystis spp.</i>	2,000 cells/mL
Combination of all <u>potentially toxic</u> cyanobacteria species present	15,000 cells/mL

Abraxis – measuring cyanotoxins



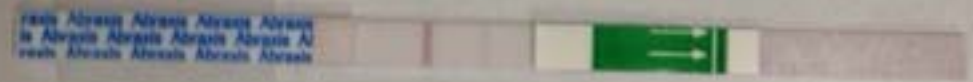
Princeton Hydro

pH

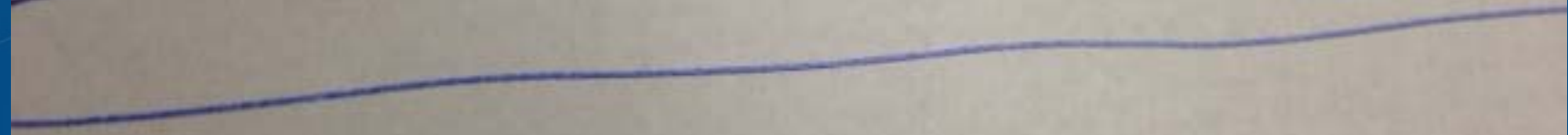


total 100

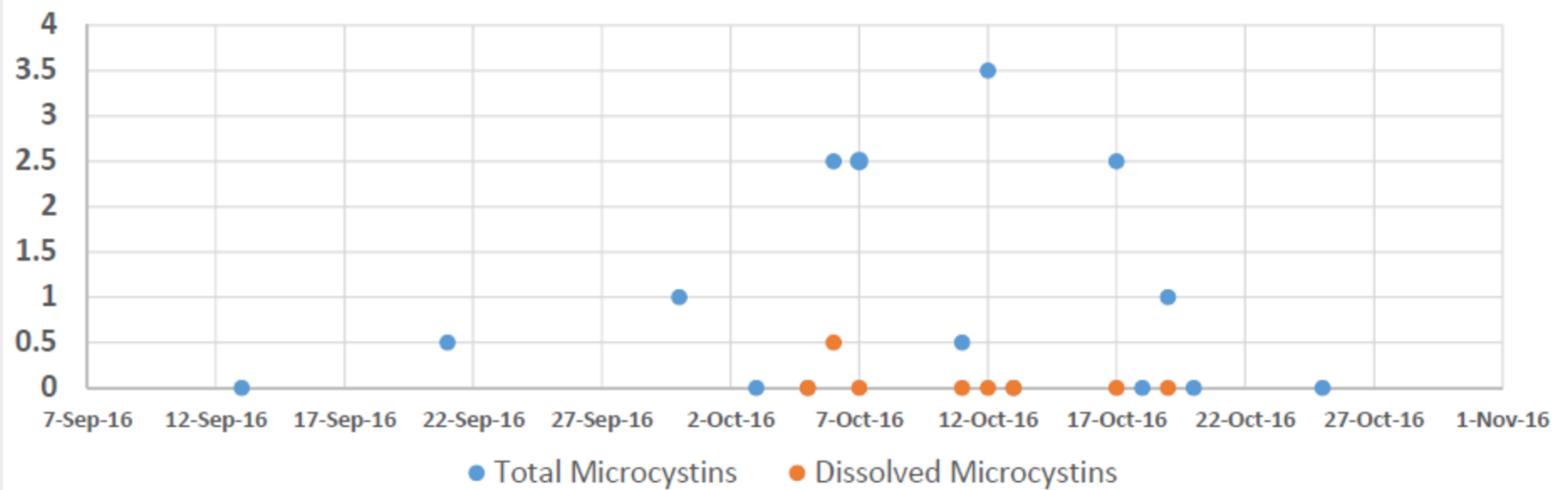
S



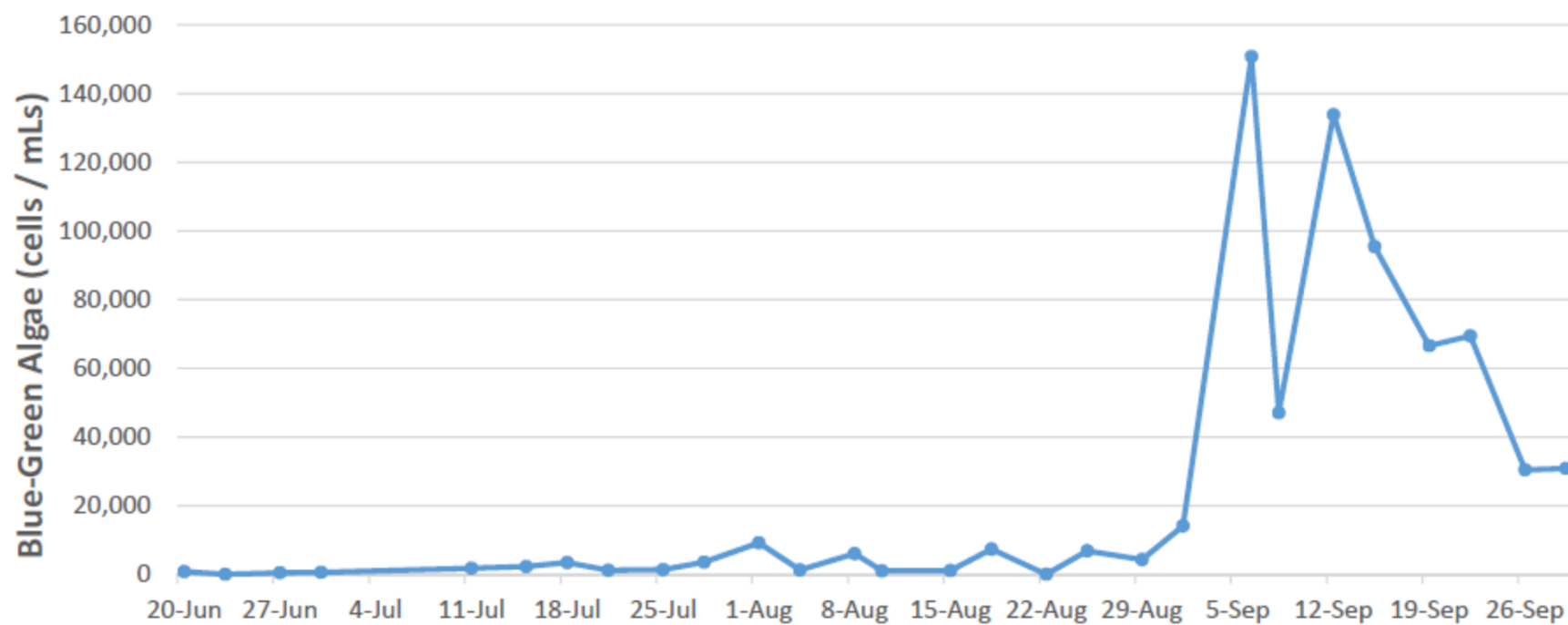
I



Microcystins Concentrations (ug/L) in a NJ Drinking Water Supply



RAW water - Summer 2016



Princeton Hydro

pH

EPA/WHO Guidance

Relative Probability of Acute Health Effects	Cyanobacteria (cells/mL)	Microcystin-LR (µg/L)	Chlorophyll-a (µg/L)
Low	< 20,000	<10	<10
Moderate	20,000-100,000	10-20	10-50
High	100,000-10,000,000	20-2,000	50-5,000
Very High	> 10,000,000	>2,000	>5,000

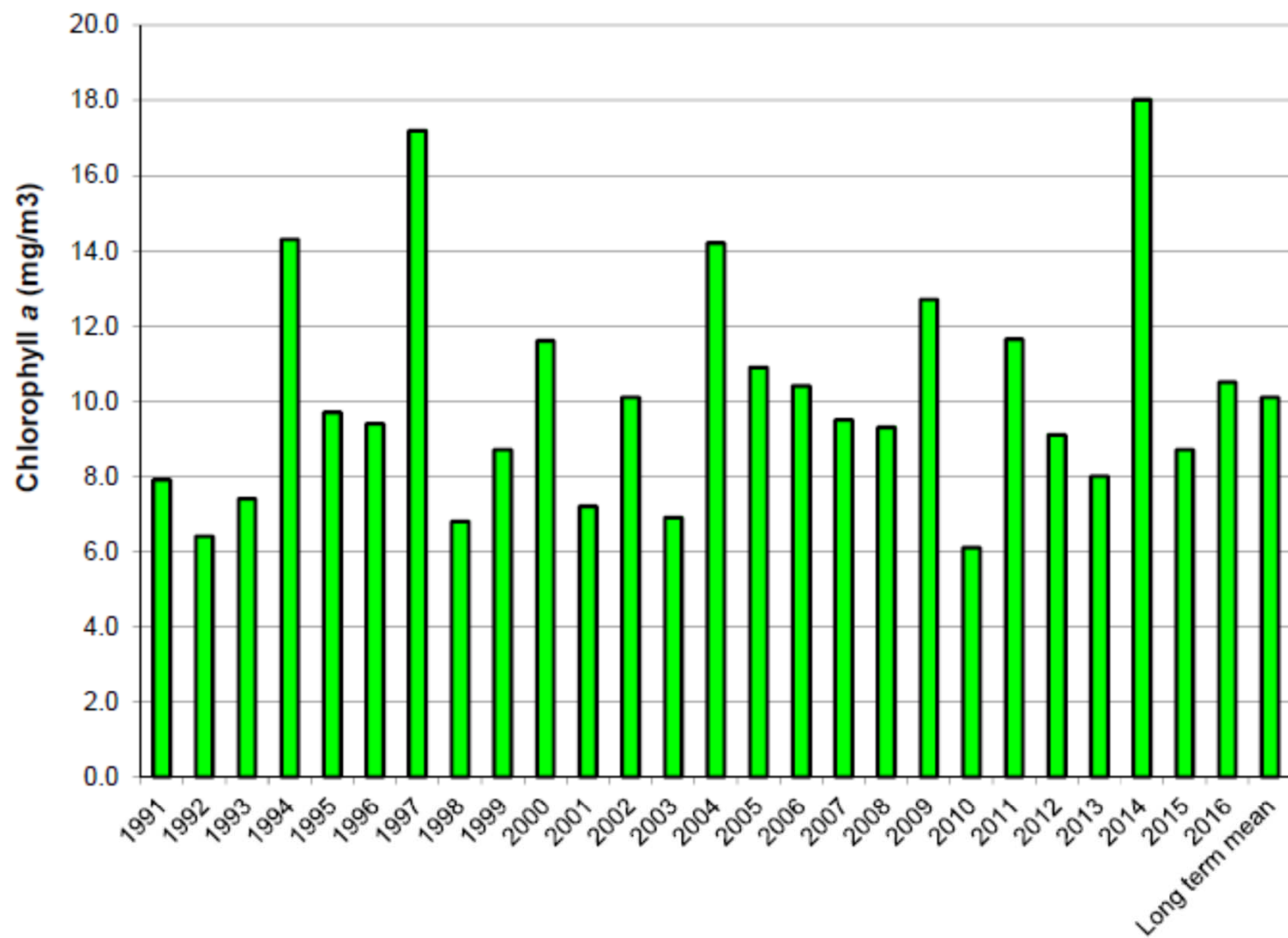
<https://www.epa.gov/nutrient-policy-data/guidelines-and-recommendations#what3>

React - What We Need to Understand

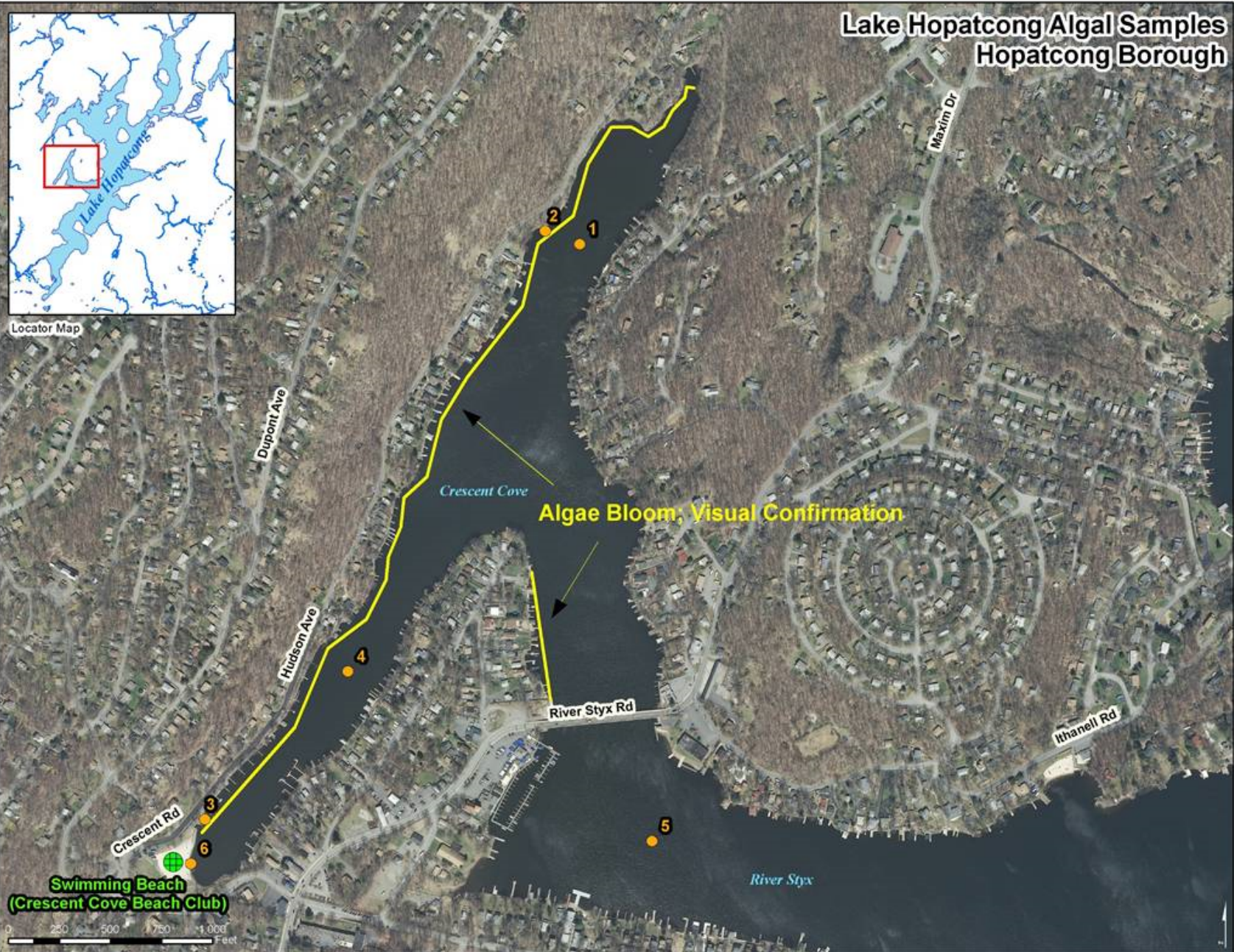
- Biological links and interactions
 - Nitrogen fixers versus Non-Nitrogen fixers
 - Role of Iron and Silica
 - Do early bloom species set stage for more problematic later blooming species?
 - Zooplanktivory / Fishery relationships.
- Nitrogen/Phosphorus – type, availability, sources
- Applicability of pre-emptive controls -
 - Physical (mixing), Chemical (alum and alum surrogates), Biological (biomanipulation)

Near-Shore Management

- Cyanotoxin management for recreational waterbodies will focus on the beaches and near-shore areas where there is direct contact with water
- A lake's overall, long-term Management Plan should include a component that focuses on the beach / near-shore area; many of the preventative measures will contribute toward the control of cyanotoxins
- However, a “mini-plan” (PARE) should be in place for the beaches



Lake Hopatcong Algal Samples Hopatcong Borough



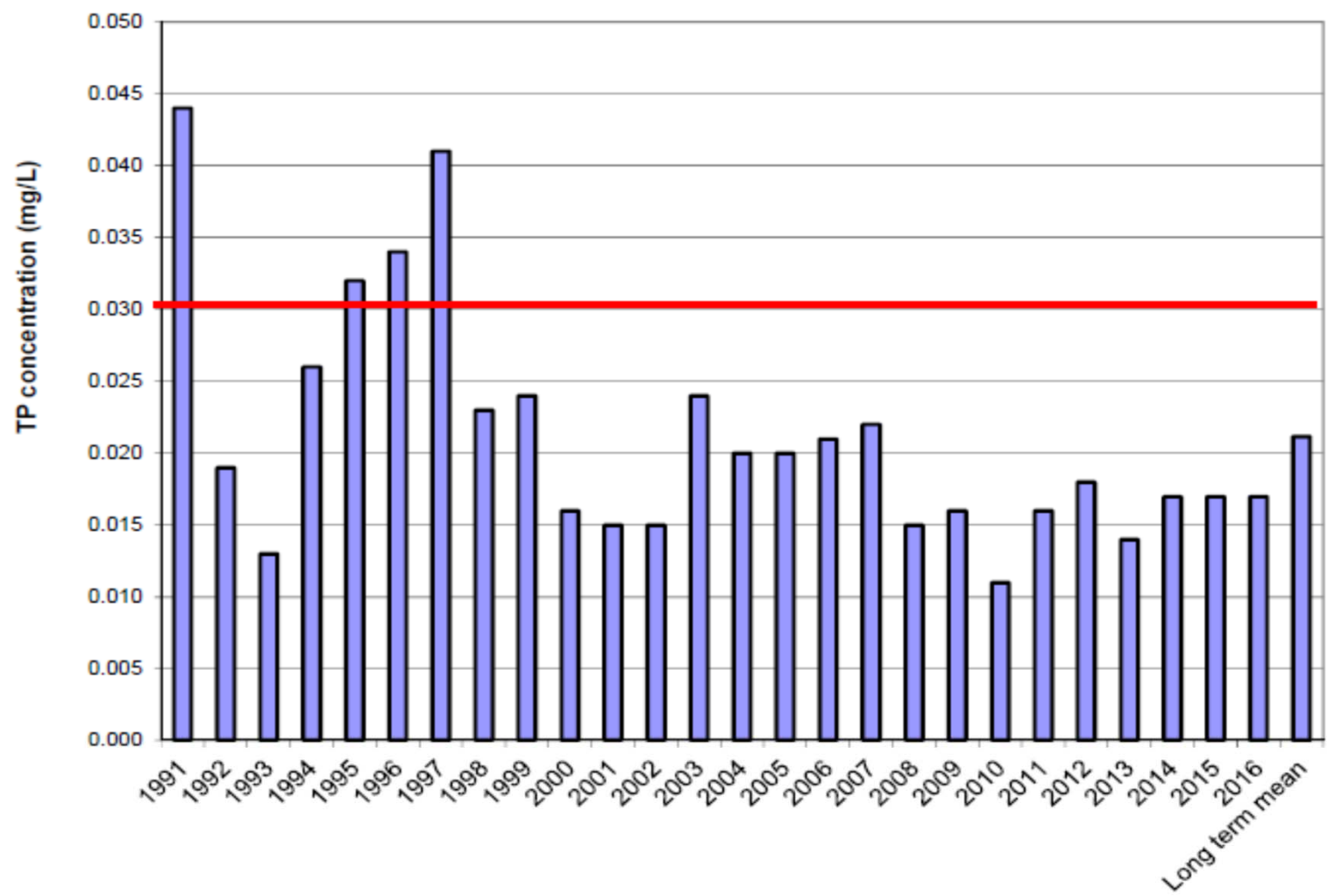
Lake Hopatcong Algal Sampling 8/5/2014

Site	Site Coordinates	Microcystin µg/l	Dominant Blue Green Algal Species	Cell Count cells/ml	Chl "a" µg/l	Sample Depth meters
1	-74.6533460721 40.9489719098	3.315	<i>Anabaena sp</i>	<600	61.9	1
2	-74.6539569399 40.9489719098	84.5	<i>Anabaena sp</i>	> 10,000	275.9	0.05 (surface)
3	-74.6599679341 40.9412379747	23.3	<i>Anabaena sp</i>	> 10,000	181.5	0.05 (surface)
4	-74.657437886 40.9432294947	3.1	<i>Anabaena sp</i>	<600	73.1	1.02
5	-74.6520488191 40.940953995	0.907	<i>Anabaena sp</i>	<600	27.2	0.05 (surface)
		0.931	<i>Anabaena sp</i>	<600	28.9	0.97
6	-74.660213156 40.9406403482	2.84	<i>Anabaena sp</i>	<600	64.7	0.05 (surface)

Lake Hopatcong Microcystins Testing for 2015

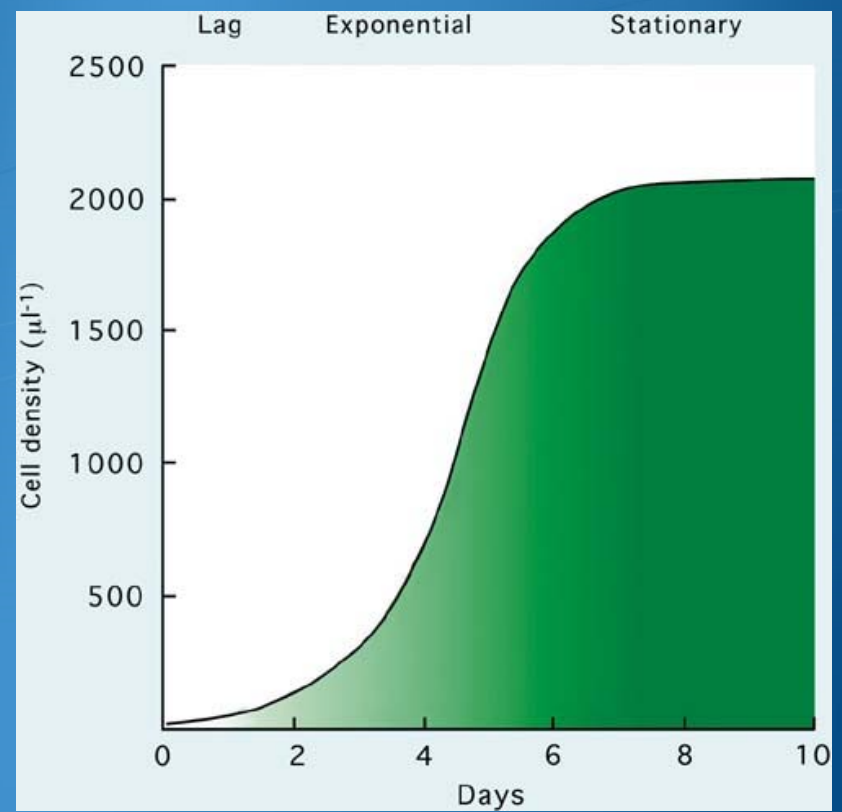
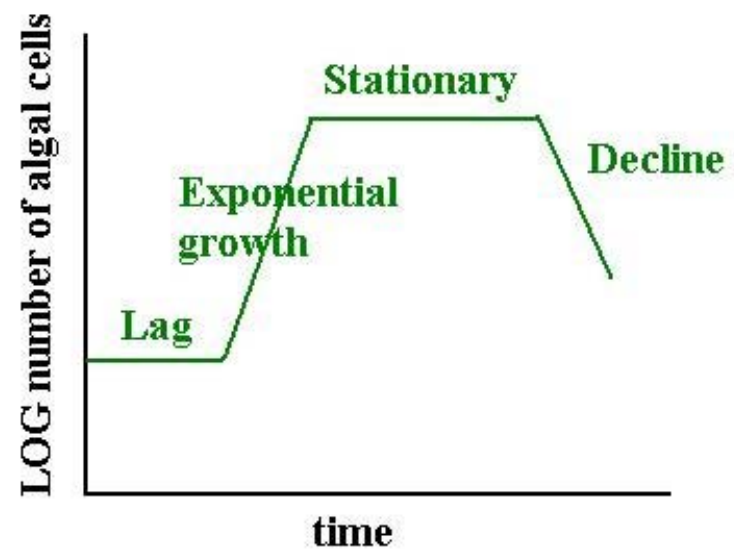
Near-Shore Sampling Station	6/16/2015*	21-Jul-15	22-Sep-15
Beach in Northern Jefferson (B-1)	0 ppb / 0 ppb	0 ppb	0 ppb
CAPP Beach (B-2)	0 ppb / 0 ppb	0.5 ppb	0 ppb
Western shoreline of Crescent Cove (B-3)	0 ppb / 0 ppb	0 ppb	0 ppb
Borough of Hopatcong Beach (B-4)	0 ppb / 0 ppb	0 ppb	0 ppb
Barnes Bros Beach (B-5)	0 ppb / 0 ppb	0 ppb	0 ppb
Hopatcong State Park Beach (B-6)	0 ppb / 0 ppb	0 ppb	0 ppb

* two microcystin samples were run per collected water sample
ppb = ug/L



React

- Watershed management programs targeting nutrient load reductions to reduce bloom frequency/intensity
- Make use of nutrient sequesters
 - Alum
 - PhosLock
 - Iron
 - Nitrogen supplementation
- Aeration / Destratification / Mixing
- Biomanipulation
- Ozone / Oxidizers
- **Very limited use of algicides**



Implementing the PARE Program

- Use a variety of factors to determine when to respond to a bloom (Secchi depth, chlorophyll *a*, color of water / visual confirmation).
- For drinking water systems, when microcystin samples should be collected is largely based on cyanobacterial algal counts (cells / mLs)
- For recreational lakes, it tends to be the general appearance of water.
- Once the total blue-green algae counts exceed 15,000 cells / mLs run the Abraxis test strip analysis to measure microcystins
- Analogous to conducting fecal coliform / *E. coli* beach testing

Education and Outreach

- Inform/educate public about cyanobacteria and related health problems.
- Inform/educate public about measures to help prevent blooms.
 - Septic management
 - Fertilizer use
 - Shoreline buffer creation/maintenance
 - Waterfowl control
- Monitoring is part of solution, need to address bloom before it peaks.
- Know when not to go in the water; prevent pets from drinking the water
- Copper sulfate alone is not the answer .

Summarizing Management Options

- Many in-lake management techniques can contribute toward reducing algal blooms (nutrient inactivation, Floating Wetland Islands, biomanipulation, etc.)
- Watershed programs to reduce the **external pollutant loads** (e.g. TMDLs; BMPs)
- Aeration / Destratification / Circulation
- Nutrient Inactivation
- Ozone
- Oxidizers (e.g. GreenClean)
- **CAREFUL** use of copper products (Earth-Tec)

Installation of a Destratification System



Conclusions

- Blue-green algal blooms are triggered by dry and hot conditions with elevated amounts of phosphorus
- Many blue-green algae generate cyanotoxins, which are not taste and odor compounds
- Develop a Plan to specifically address near-shore areas where this is primary contact with the water
- Educate the community on what to look for relative to summer / fall algal blooms