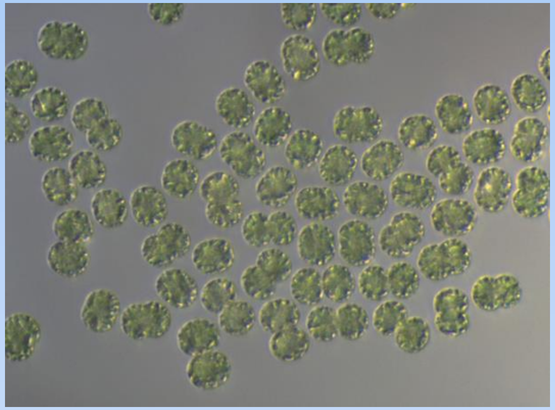
Nuisance & Harmful Algae Blooms



June 14th, 2019
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Aquatic Ecosystems Consulting
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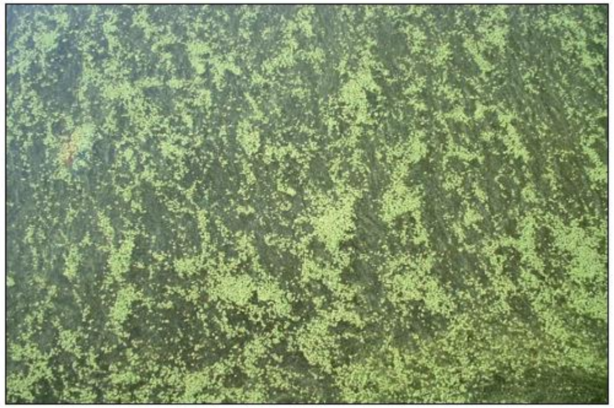
June 14, 2019
Lower Hudson Lake Conference

What is an algae bloom??

What do Harmful Algal Blooms (HABs) look like?

HABs may look like parallel streaks, usually green, on the water surface.



HABs may look like green dots, clumps or globs on the water surface.

HABs may look like blue, green, or white spilled paint on the water surface.

HABs may make the water look bright green or like pea soup.

Not all blooms that look like this are harmful! NYSDEC

What do non-toxic green algal blooms look like?

Green algae can look like floating rafts on the water, but do not produce harmful toxins.

Green algae can look like bubbling scum on the water and may be entangled with other plant material, but do not produce harmful toxins.

Green algae can look silky, hairy or like wet fabric on the rocks, plants or water surface, but do not produce harmful toxins.

Green algae can look stringy or hairy or like a tumbleweed in the water or on the lake bottom, but do not produce harmful toxins.

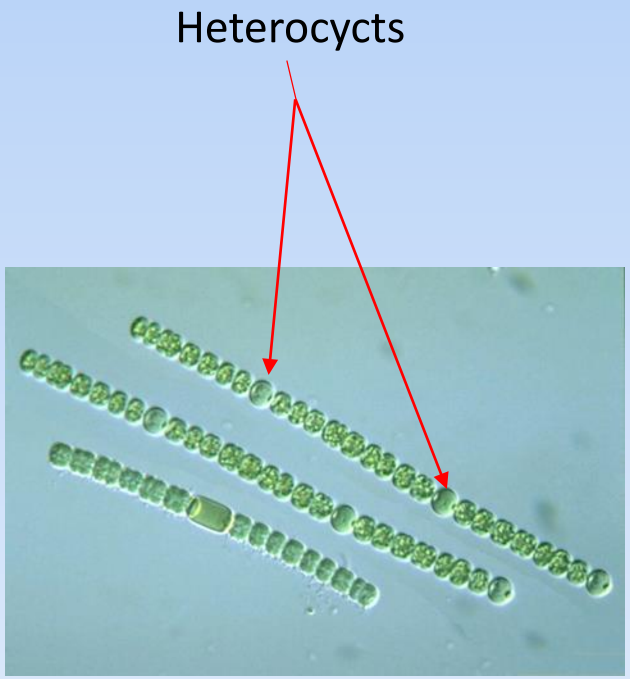
Harmful Algae Bloom (HABs) – Nuisance & Public Health Issue

- Harmful algal blooms or HABs are algal blooms composed of phytoplankton called cyanobacteria known to naturally produce biotoxins
- HABs occur when certain types of microscopic algae grow quickly in water, forming visible patches that may harm the health of the environment, plants, or animals

<u>What are cyanobacteria??</u>

- Cyanobacteria: phylum of bacteria that obtain their energy through photosynthesis
- Only photosynthetic prokaryotes able to produce oxygen
- “Cyanobacteria" comes from the color of the bacteria also called "blue-green algae"

- Cyanobacteria have the ability to fix atmospheric CO2 and N2 through a structure called a heterocyst
- Bloom- forming cyanobacteria have a gas vesicle for buoyancy and depth regulation which is key in their ability to form blooms



When do Nuisance or Harmful Algae blooms occur??

Harmful algae blooms can occur anytime but most often occur in late summer/early fall

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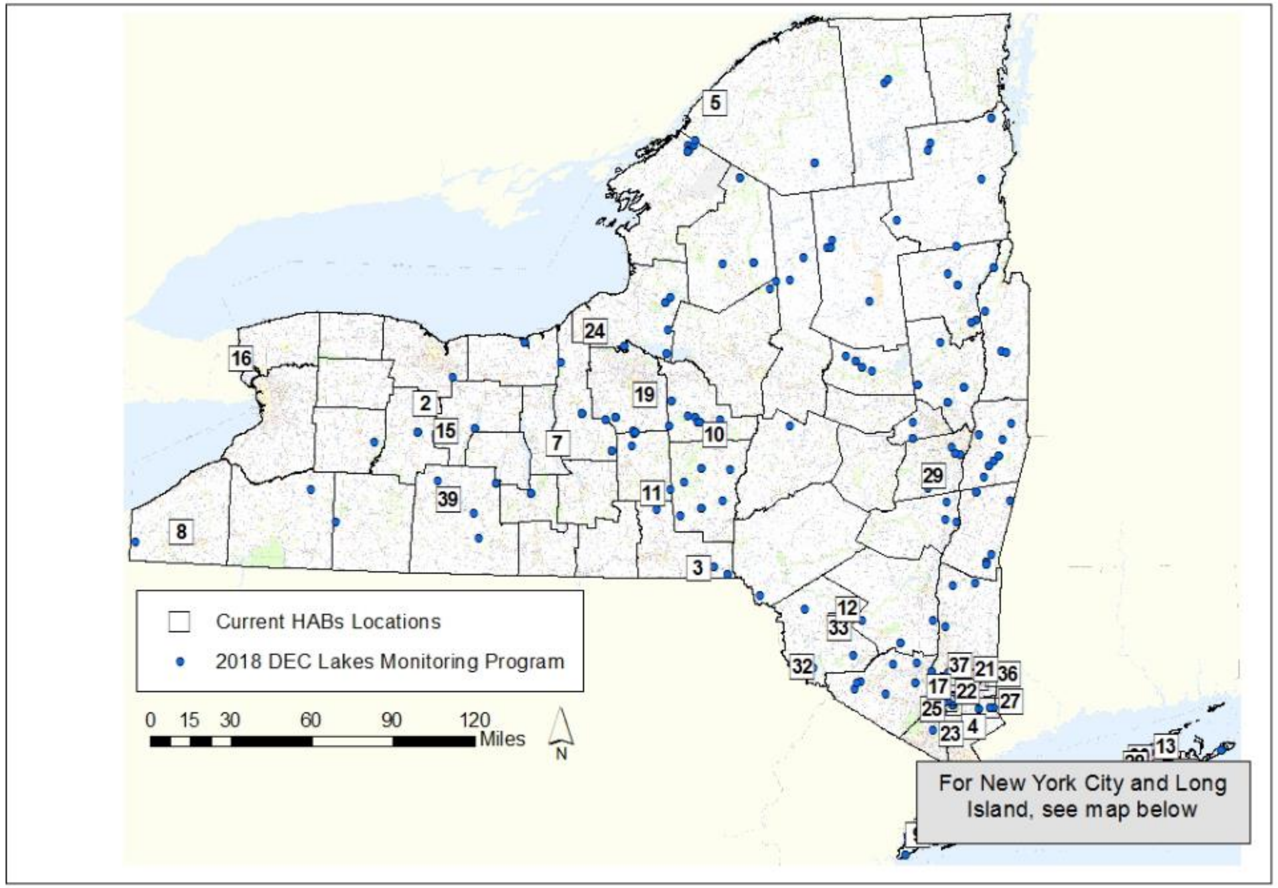
Harmful Algal Blooms (HABs) Notifications Page

2018 HABs Notifications



Waterbodies with HABs Notifications

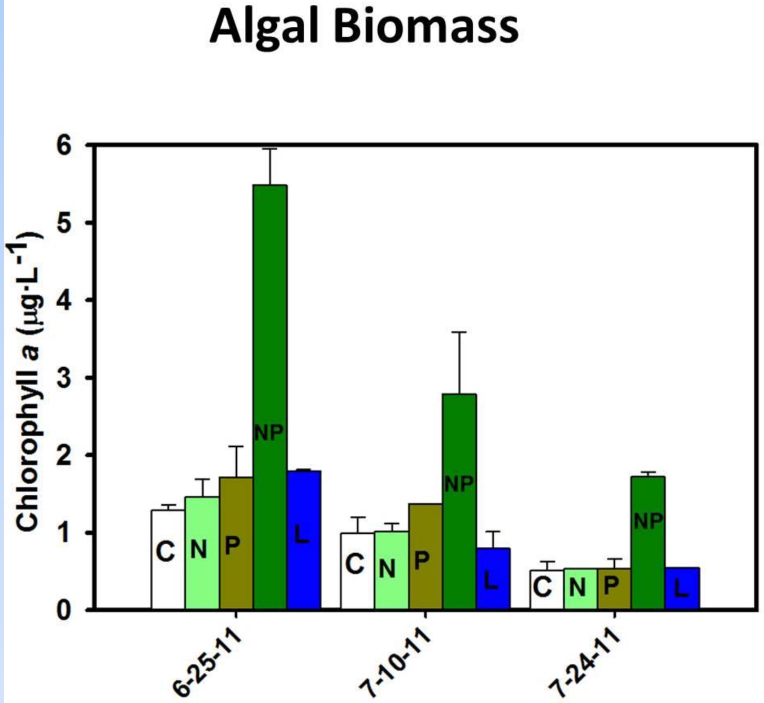
Map Number	Waterbody Name	County	Bloom Status	Extent of Bloom	Status Date	Type of Report	Change in Status
1	Agawam Lake	Suffolk	Confirmed	Widespread/Lakewide	7/10/18	Lab sample	Updated Listing
2	Avon Marsh Dam Pond	Livingston	Suspicious	Small Localized	7/12/18	Visual Report	Updated Listing
3	Beaver Lake	Broome	Confirmed	Not Reported	7/8/18	Lab sample	New
4	Bedford Lake	Westchester	Confirmed	Open Water	7/8/18	Lab sample	New
5	Black Lake	St Lawrence	Confirmed	Open Water	7/7/18	Lab sample	New
6	Bowne Pond	Queens	Confirmed with High Toxins	Not Reported	7/9/18	Lab sample	Updated Listing
7	Cayuga Lake*	Multiple	Confirmed	Small Localized	7/7/18	Lab sample	Updated Listing
8	Chautauqua Lake*	Chautauqua	Confirmed	Large Localized	7/9/18	Lab sample	Updated Listing
9	Clove Lake	Richmond	Confirmed with High Toxins	Not Reported	7/10/18	Lab sample	New
10	Craine Lake	Madison	Suspicious	Small Localized	6/24/18	Visual Report	No Change
11	Dean Pond	Cortland	Confirmed	Widespread/Lakewide	7/10/18	Lab sample	New
12	Evens Lake	Sullivan	Confirmed	Widespread/Lakewide	6/27/18	Lab sample	No Change
13	Fresh Pond	Suffolk	Confirmed	Small Localized	7/8/18	Lab sample	New
14	Harlem Meer	New York	Confirmed	Small Localized	7/9/18	Lab sample	Updated Listing
15	Honeoye Lake*	Ontario	Suspicious	Small Localized	7/12/18	Visual Report	New
16	Hyde Park Lake	Niagara	Confirmed	Large Localized	7/10/18	Lab sample	New
17	Indian Lake	Putnam	Confirmed	Small Localized	6/23/18	Lab sample	No Change
18	Indian Pond	Bronx	Confirmed	Widespread/Lakewide	7/3/18	Lab sample	Updated Listing
19	Jamesville Reservoir	Onondaga	Confirmed	Not Reported	6/22/18	Lab sample	No Change
20	Kissena Lake	Queens	Confirmed	Small Localized	7/9/18	Lab sample	Updated Listing
21	Lake Carmel	Putnam	Suspicious	Widespread/Lakewide	6/29/18	Visual Report	No Change
22	Lake Mahopac	Putnam	Suspicious	Widespread/Lakewide	6/29/18	Visual Report	No Change
23	Lake Mohegan	Westchester	Confirmed	Not Reported	7/4/18	Lab sample	Updated Listing
24	Lake Neatahwanta	Oswego	Confirmed	Not Reported	7/10/18	Lab sample	Updated Listing
25	Lake Peekskill	Putnam	Suspicious	Not Reported	7/2/18	Visual Report	Updated Listing
26	Lake Ronkonkoma	Suffolk	Confirmed with High Toxins	Large Localized	6/26/18	Lab sample	New
27	Lake Waccabuc	Westchester	Confirmed	Open Water	7/8/18	Lab sample	Updated Listing
28	Laurel Lake	Suffolk	Confirmed	Not Reported	6/27/18	Lab sample	No Change
29	Lawson Lake	Albany	Confirmed	Small Localized	7/2/18	Lab sample	No Change

Why do harmful/nuisance algae blooms occur??

What fuels algae growth – nutrients (nitrogen, phosphorus)?

Harmful algal blooms also need:

- Sunlight
- Low water turbulence



Experiment: spiking 4X ambient N & P

C = Control

N = +Nitrogen

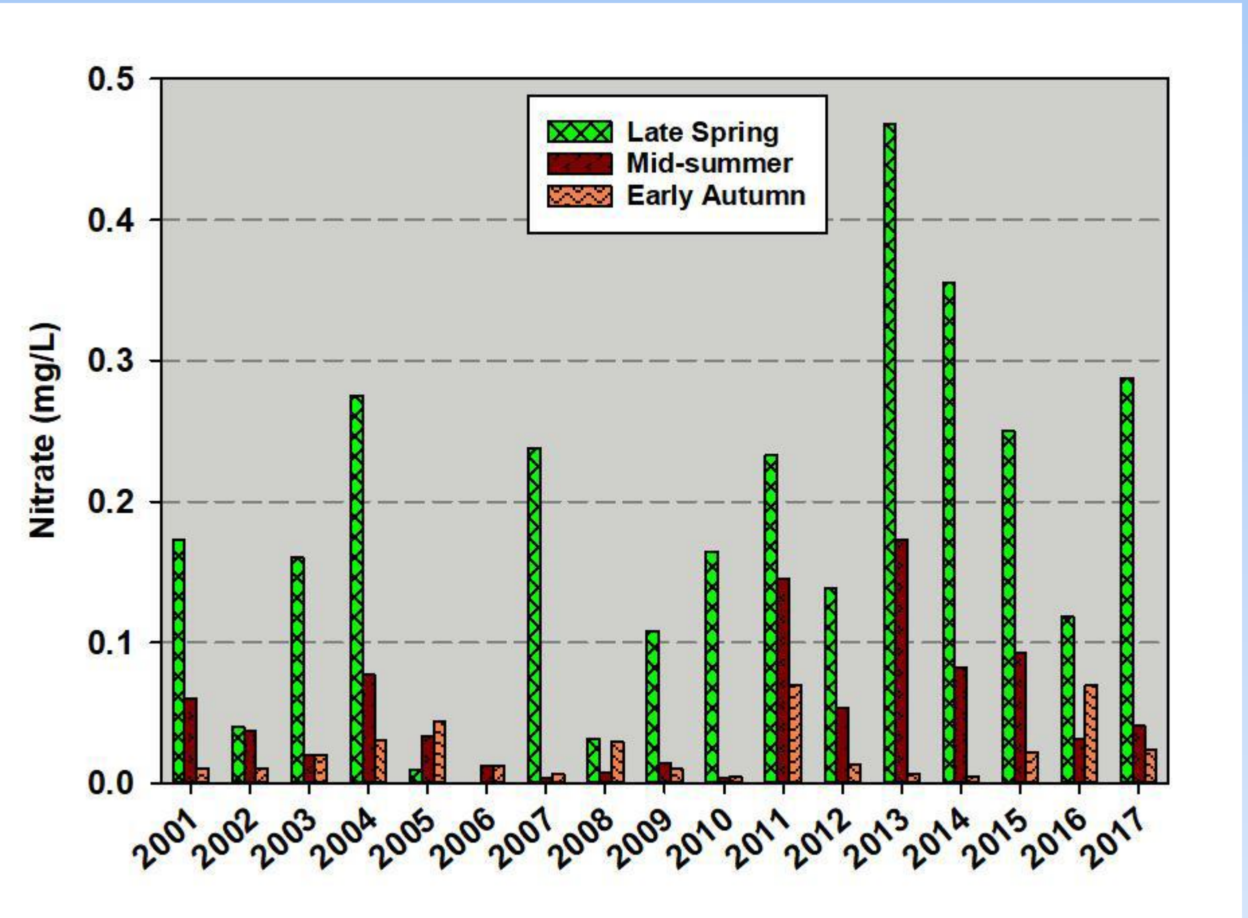
P = +Phosphorus

NP = +Nitrogen +Phosphorus

What fuels algae growth?

Lake ecosystems are generally P-limited

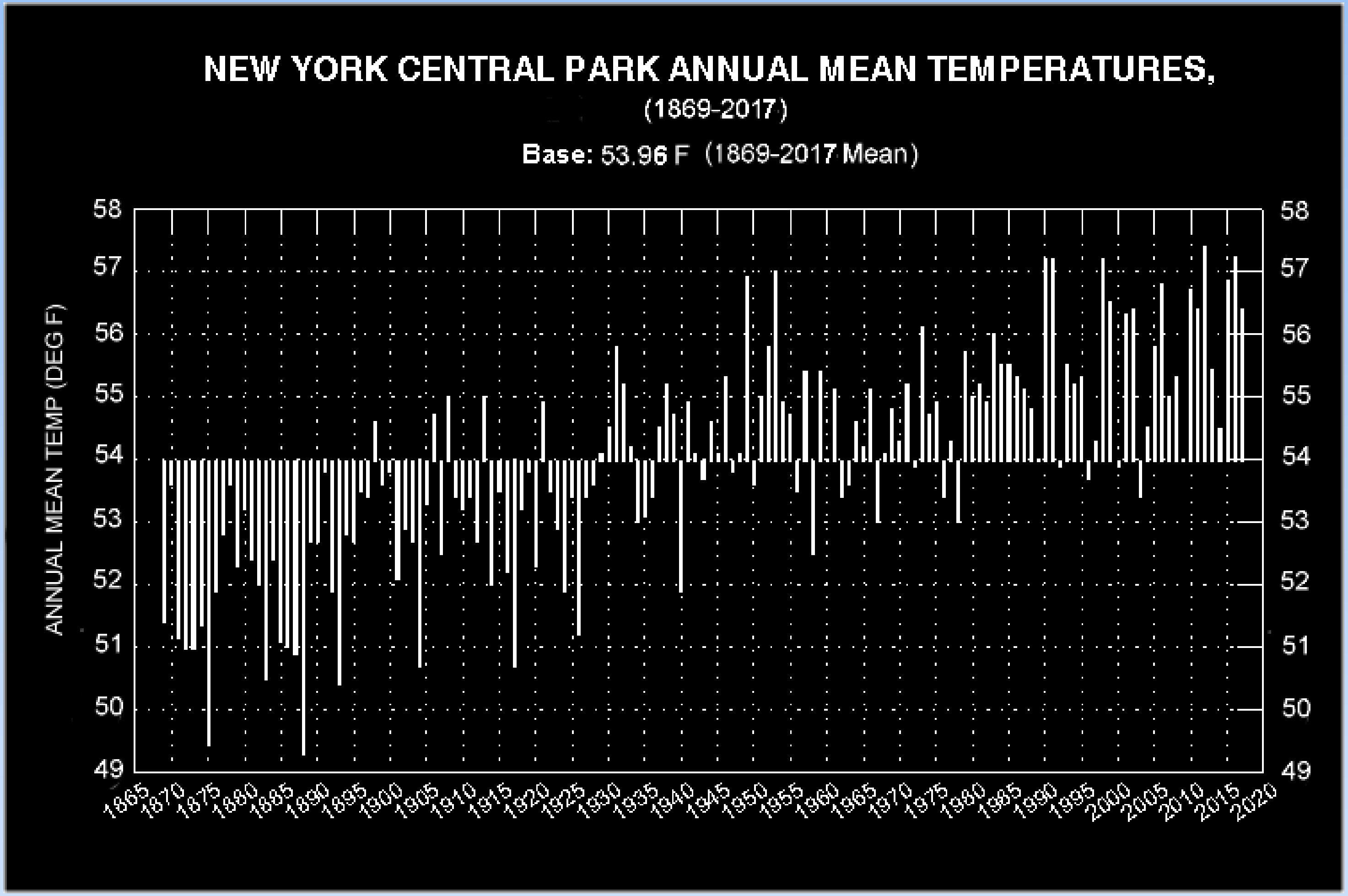
- addition of P to lakes can shift the balance to N-limitation
- With ↑ availability of P and Nitrate limitation: balance can shift towards cyanobacteria dominance since they can float to the surface and fix atmospheric nitrogen
- With other factors: low turbulence, sunlight conditions are favorable for a nuisance/harmful algae bloom



Why have harmful/nuisance algae blooms become more common??





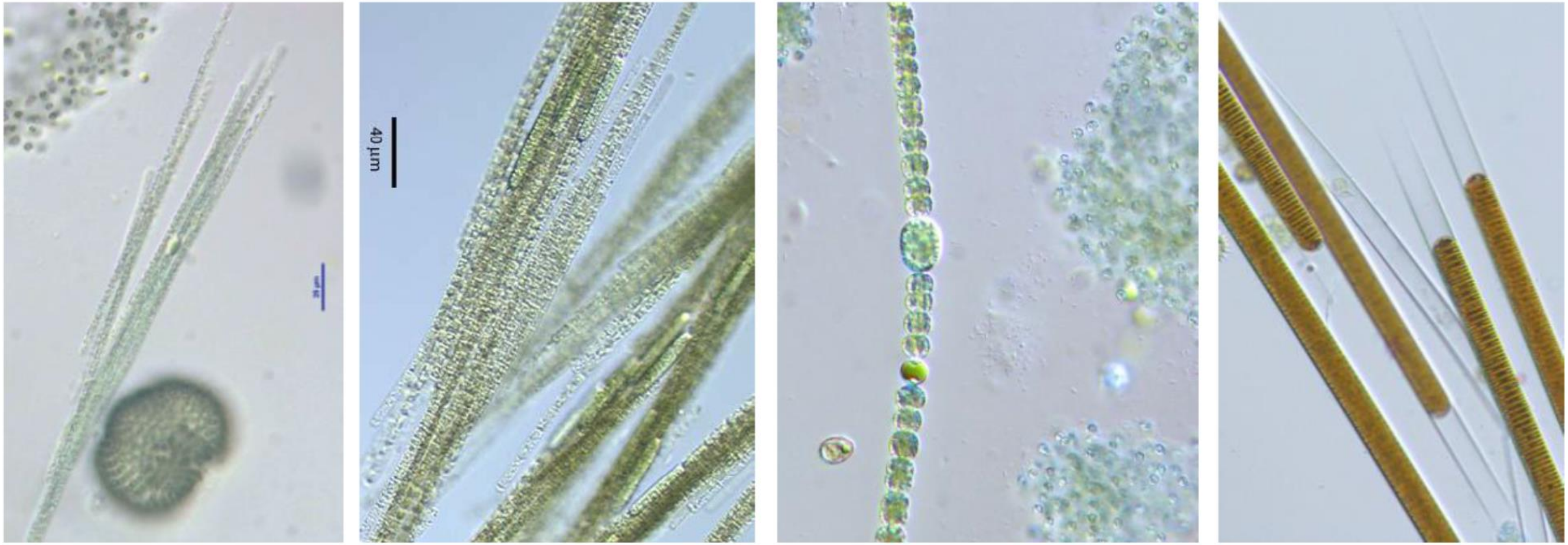



- Faulty septic systems
- Sewage overflows
- Farming
- Increasing impervious surfaces

- Higher mean atmospheric temperature lengthening growing season
- Use of fertilizers, road salt, abrasives which contain phosphorus

<u>What organisms are responsible for harmful algae blooms??</u>

Common Bloom-forming Cyanobacteria



Aphanizomenon flos-aquae +*Woronichinia naegeliana*

Aphanizomenon: detail of filaments + akinetes

L: *Dolichospermum planctonicum*
R: *Microcystis aeruginosa*

Limnoraphis birgei

What are the range of effects of harmful algal blooms?

- Harmful algal blooms can:
- Produce toxins that can sicken or kill people and animals
- Raise treatment costs for drinking water
- Hurt industries that depend on clean water
- Lower property value

What effects do harmful algae blooms have on public health??

Table 1. Cyanotoxins on the Contaminant Candidate List (CCL)

Cyanotoxin	Number of known variants or analogues	Primary organ affected	Health Effects[1]	Most common Cyanobacteria producing toxin[2]
Microcystin-LR	80~90	Liver	Abdominal pain Vomiting and diarrhea Liver inflammation and hemorrhage Acute pneumonia Acute dermatitis Kidney damage Potential tumor growth promotion	*Microcystis* *Anabaena* *Planktothrix* *Anabaenopsis* *Aphanizomenon*
Cylindrospermopsin	3	Liver		*Cylindrospermopsis* *Aphanizomenon* *Anabaena* *Lyngbya* *Rhaphidiopsis* *Umezakia*
Anatoxin-a group[3]	2-6	Nervous System	Tingling, burning, numbness, drowsiness, incoherent speech, salivation, respiratory paralysis leading to death	*Anabaena* *Planktothrix* *Aphanizomenon* *Cylindrospermopsis* *Oscillatoria*

[1]Source: *Harmful Algal Research and Response National Environmental Science Strategy (HARRNESS)*

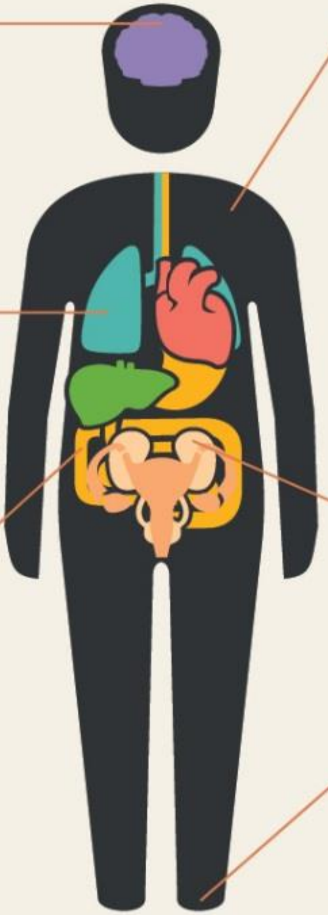
- Safe Drinking Water Act (SDWA): protects public health by regulating the nation's public drinking water supply and its sources: rivers, lakes, reservoirs, springs, and ground water wells
- SDWA requires EPA to publish a list (Contaminant Candidate List - CCL) of unregulated contaminants that are known or expected to occur in public water systems in the U.S. that may pose a risk in drinking water
- The cyanotoxins (most widespread are peptide toxins in the class called microcystins) included in the most recent CCL are produced by several species of cyanobacteria

Health Impacts of Cyanotoxins

CLEAN WATER ACTION
CLEAN WATER FUND

***Note:** Not all cyanotoxins lead to all of these health impacts. These listed impacts are caused by microcystins or cylindrospermopsin, the two cyanotoxins that EPA has issued Health Advisories for.*

IN HUMANS



Brain

Source: Ingestion

Symptoms:

- Headache
- Incoherent speech
- Drowsiness
- Loss of coordination

Respiratory System

Source: Inhalation

Symptoms:

- Dry cough
- Pneumonia
- Sore throat
- Shortness of breath
- Loss of coordination

Digestive System

Source: Ingestion, drinking contaminated water, or eating contaminated fish

Symptoms:

- Abdominal pain
- Nausea
- Vomiting
- Diarrhea
- Stomach cramps

Body

Source: Contact, e.g. swimming

Symptoms:

- Irritation in eyes, nose, and throat
- Blistering around the mouth
- Skin rash, including tingling, burning and numbness
- Fever
- Muscle aches (from ingestion)
- Weakness (from ingestion)

Organs

Source: Ingestion

Symptoms:

- Kidney damage
- Abnormal kidney function
- Liver inflammation

Nervous System

Source: Ingestion

Symptoms:

- Tingling
- Burning
- Numbness

IN PETS

Symptoms:

Vomiting

Fatigue

Shortness of breath

Difficulty breathing

Coughing

Convulsions

Liver failure

Respiratory paralysis leading to death

Not all Cyanobacteria species produce toxins

How do we identify harmful algae blooms??

How do we identify harmful Cyanobacteria blooms?

Currently: visual evaluation and/or strip tests → public notice

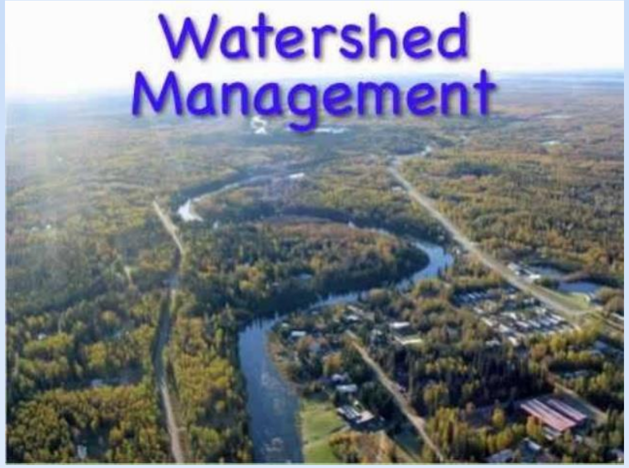
Many cyanobacteria blooms are non-toxic

A more appropriate response algorithm if resources allowed it?

- samples collected to identify characterize phytoplankton species assemblage/identify dominant species
- are the dominant species known toxin producer (not all are!)
- if yes, a sample would be collected and characterized for toxicity
- if above regulatory limit, public should be advised not to swim

How can we limit the occurrence of harmful algae blooms??

- Watershed management
- Prevent entry of nutrients
- Remove nutrients
- Lock up nutrients
- Algaecide
- Buffer vegetation



Acknowledgements

- Dr. John Wehr
- Hill and Dale Association
- North Lake Association
- Louis Calder Biological Station
- Calder Undergraduate Research Program
- National Science Foundation

Cyanobacteria Bloom and Nutrient Imbalance Linked to Stocked Sterile Carp in a Eutrophic Lake

Watershed Science & Technical Conference

September 15th, 2011

Authors: Steve Di Lonardo, Shampa Panda, Alissa Perrone, Kam Truhn & Dr. John Wehr

Louis Calder Biological Station - Fordham University

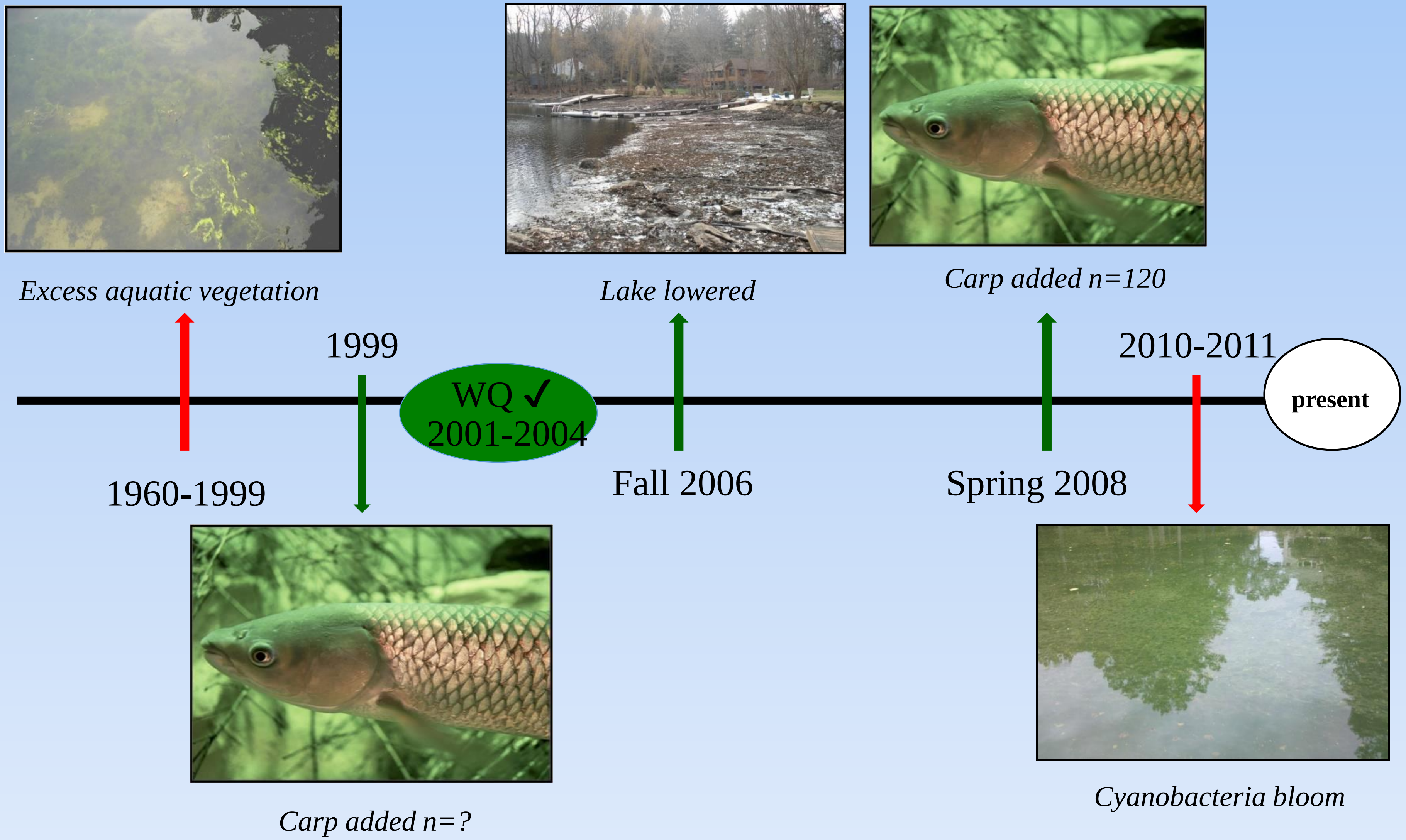
North Lake

- Uses: non-motorized boating, swimming, and recreation
- Area: ~7.8 hec (19.6 a)
- Mean/Max depth: 3 m/10m
- Issues: eutrophication
- Symptoms: excess aquatic vegetation
- Management strategies: biomanipulation (carp), hypolimnetic drawdown

North Lake (Armonk, NY)

Map from Google Earth 6

Management Over Time



2001-2004: Vegetation controlled by carp

Phytoplankton community:

- “species rich”
- “community composition exhibited a typical seasonal progression of species from late spring to late summer”
- “different species progressively dominated during each month, but most were observed throughout the sampling period”

2001-2004: Vegetation controlled by carp

Late May →	July →	September
Flagellates	Colonial species	Filamentous species
Chrysophytes	Colonial bluegreens	Filamentous diatoms (minor)
Cryptomonads	Colonial greens	Filamentous bluegreens
Unicells and Diatoms	Flagellates	Colonial species
Small diatoms	Chrysophytes	Colonial diatoms (major)
Green algae	Dinoflagellates	Colonial bluegreens

2005-2006: Resurgence of vegetation

Phytoplankton community:

- "mid- to late-summer phytoplankton communities indicate relatively high amounts of phosphorus and nitrogen"
- "a possible trend toward lower biological diversity (first suggested in 2005 sampling) seems apparent"
- "Community composition exhibited a seasonal progression from late spring to late summer of species that are typical for a eutrophic lake"

2005-2006: Resurgence of vegetation

Late Spring →	Mid-summer →	Late summer
Dominant *Diatoms + Flagellates*	**Dominant** *Colonial + Filamentous species*	**Dominant** *Filamentous species*
Diatoms Chrysophytes	Filamentous bluegreens Colonial bluegreens	Filamentous bluegreens Filamentous diatoms
	Colonial greens	
Sub-Dominant	**Sub-Dominant**	**Sub-Dominant**
Filamentous bluegreens	Flagellates	Colonial species
Colonial diatoms	Chrysophytes	Colonial bluegreens
Green algae	Dinoflagellates	

2008-2011: Vegetation suppressed: Cyanobacteria bloom (2010-2011)

Phytoplankton community:

- "surface-blooming, filamentous bluegreens (cyanobacteria) were more abundant than in past years, and remained abundant for several months"
- "under-ice sample obtained in January 2011 verified a continuation of this bloom into winter: a five-month span"
- "North Lake is clearly eutrophic, and appears to be experiencing greater algal biomass and surface blooms than in prior years"

2008-2011: Vegetation suppressed: Cyanobacteria bloom (2010-2011)

Late Spring →	Mid-Summer →	Late summer →	Early Autumn
Moderate density	Heavy density	Bloom conditions	Bloom conditions
Major Algal Groups			
•Colonial green algae •Colonial chrysophytes •Chain-forming diatoms	•Chain-forming diatoms •Filamentous bluegreens •Colonial bluegreens	•Filamentous bluegreens •Colonial bluegreens	•Filamentous bluegreens •Colonial bluegreens
Sub-Dominant Groups			
•Unicellular bluegreens •Euglenoids	•Colonial green algae •Colonial chrysophytes •Dinoflagellates	•Colonial green algae •Colonial diatoms	•Colonial chrysophytes •Diatoms •Dinoflagellates

2010-11 Cyano Bloom

Cyanobacteria	June	Aug	Sep	Oct	Jan
Anabaena cf. *variabilis*	2	4	4	3	0
*Anabaena flos-aquae**	1	1	2	0	0
Aphanizomenon flos-aquae	1	2	4	5	5
Aphanocapsa cf. *incerta*	0	1	1	0	0
Aphanocapsa parasitica	0	1	0	0	0
Aphanothece cf. *nidulans*	0	1	1	0	0
Coelosphaerium naegelianum	0	1	2	3	2
Chroococcus cf. *minutus*	0	0	3	0	0
Dactylococcopsis acicularis	3	2	0	0	0
Dactylococcopsis smithii	2	1	1	0	0
Gomphosphaeria aponica	0	3	4	4	3
Lyngbya sp. (12-15 mm)	0	2	4	2	0
Microcystis aeruginosa	0	2	2	0	0
Oscillatoria sp. B	0	0	1	0	0
Pseudanabaena catanata	1	0	1	0	0
Rhabdoderma spp.	0	0	0	0	0
Unknown unicells (2mm)	0	0	0	0	0

Cyanobacteria Species Abundance Key

1= Rare

2 = Occasional

3 = Common

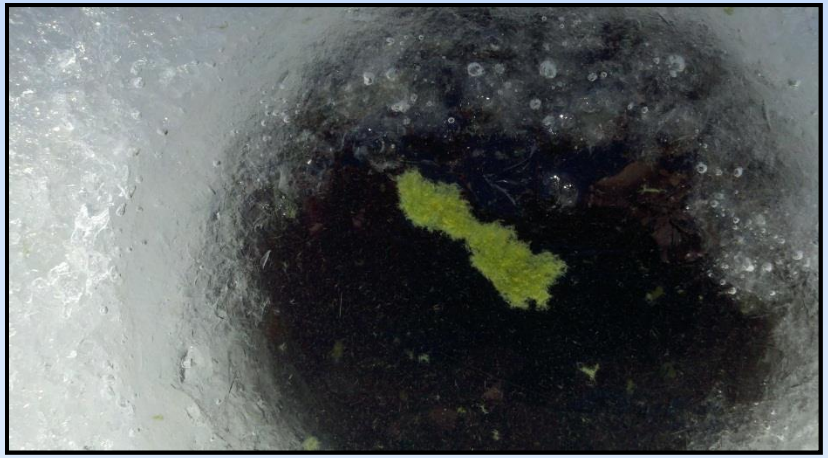
4 = Abundant or dominant

5 = Massive or macroscopic blooms

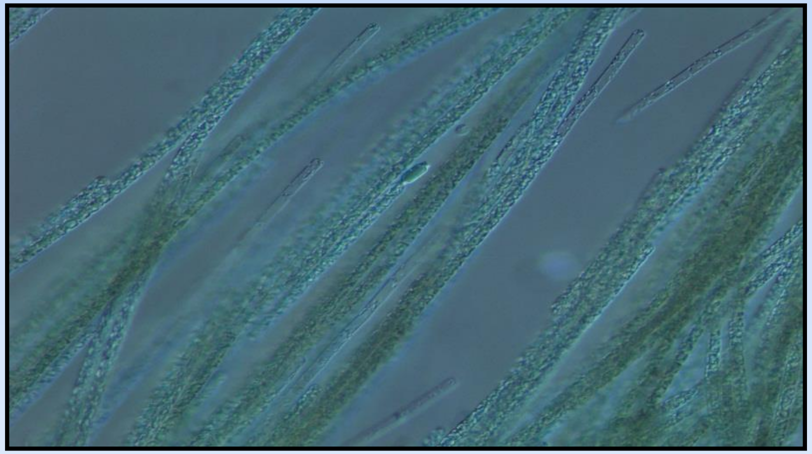
Aug 2010- Jan 2011: Cyano Bloom
Below WHO drinking water guidelines (<1 $\mu g \cdot L^{-1}$)

August 2010 bloom

Dom: Anabaena
cf. variabalis / fluos-aquae

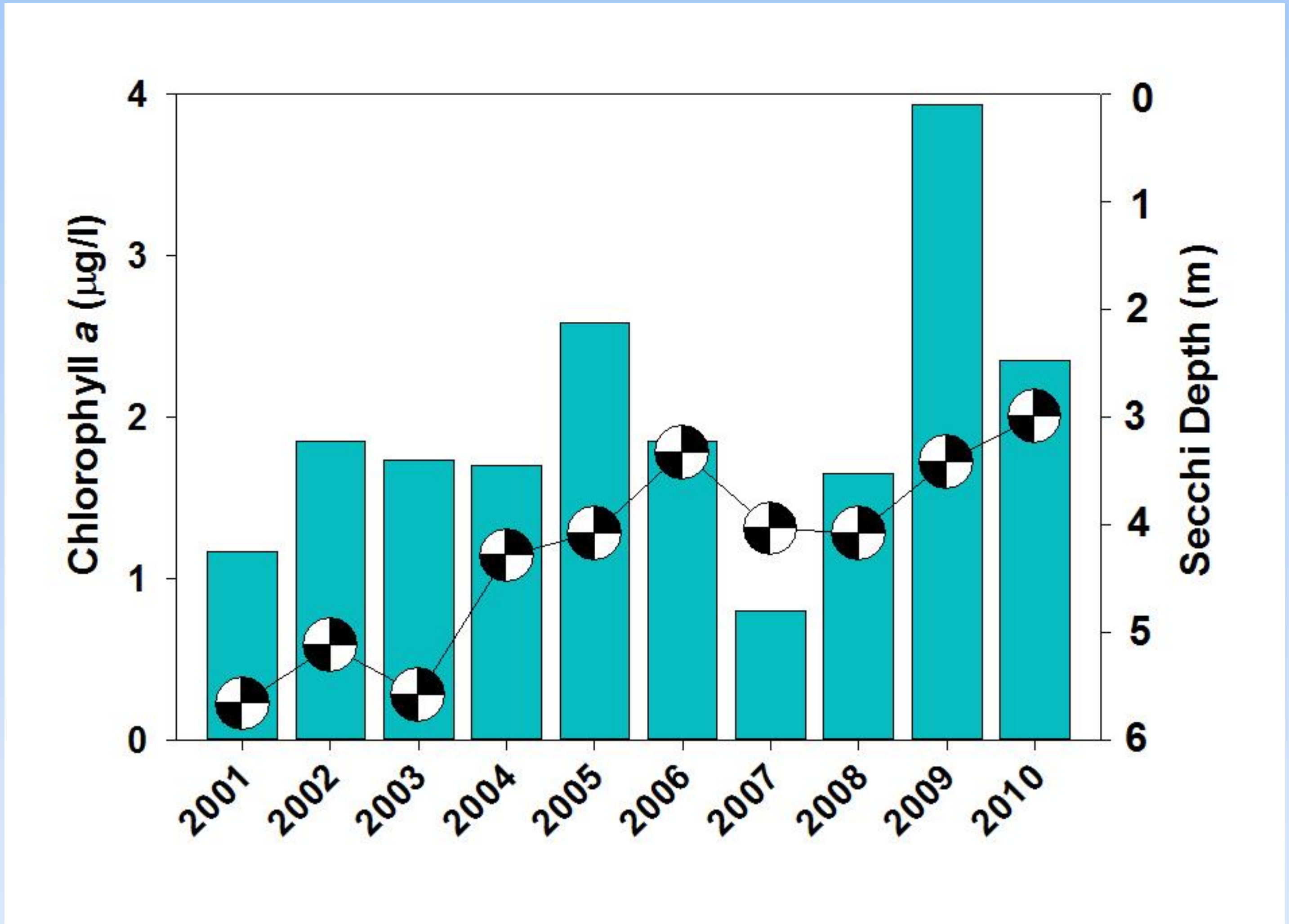


January 2011 bloom

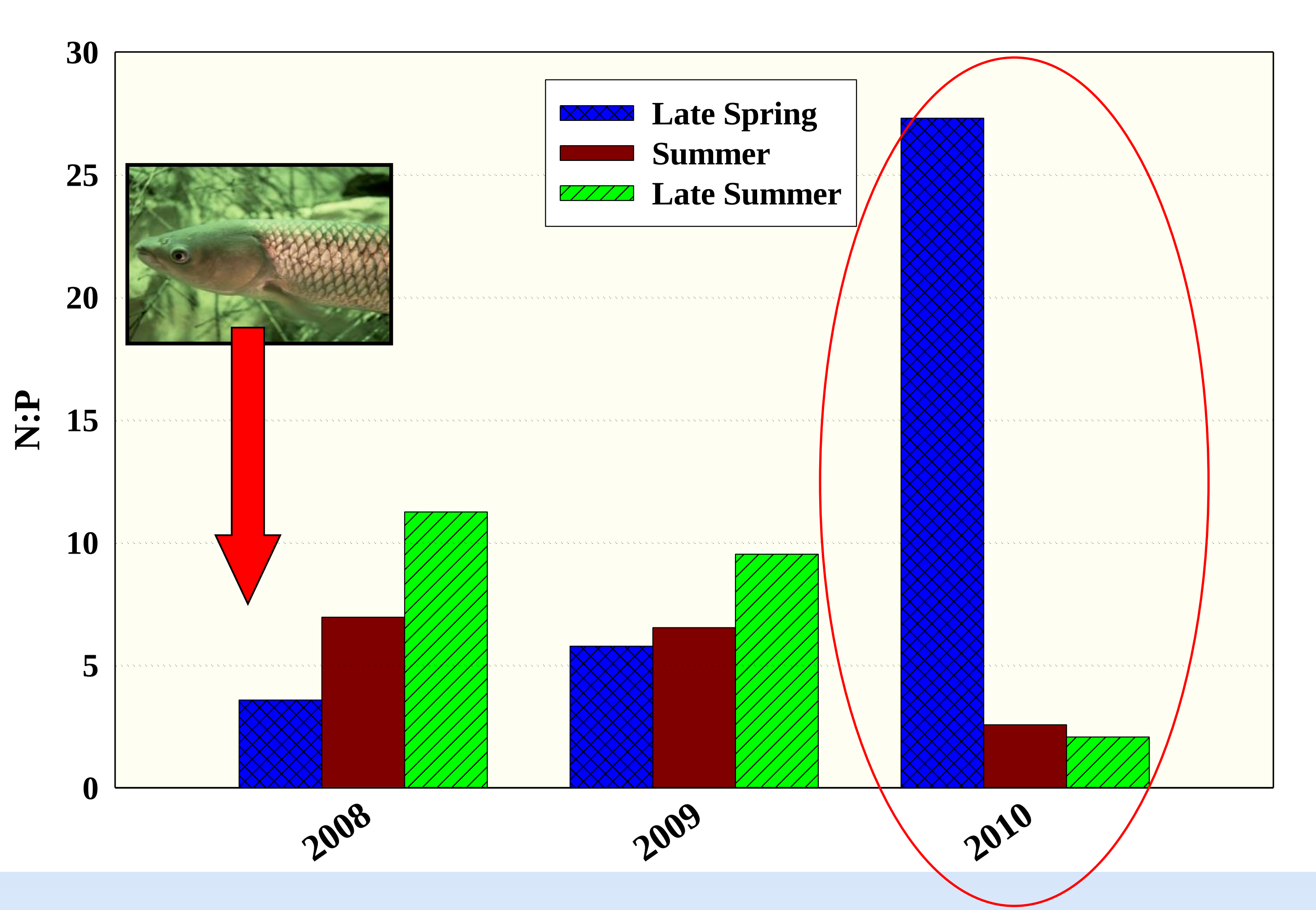


Dom: Aphanizomenon fluos-aquae

Long-Term Trends: Spring-Summer

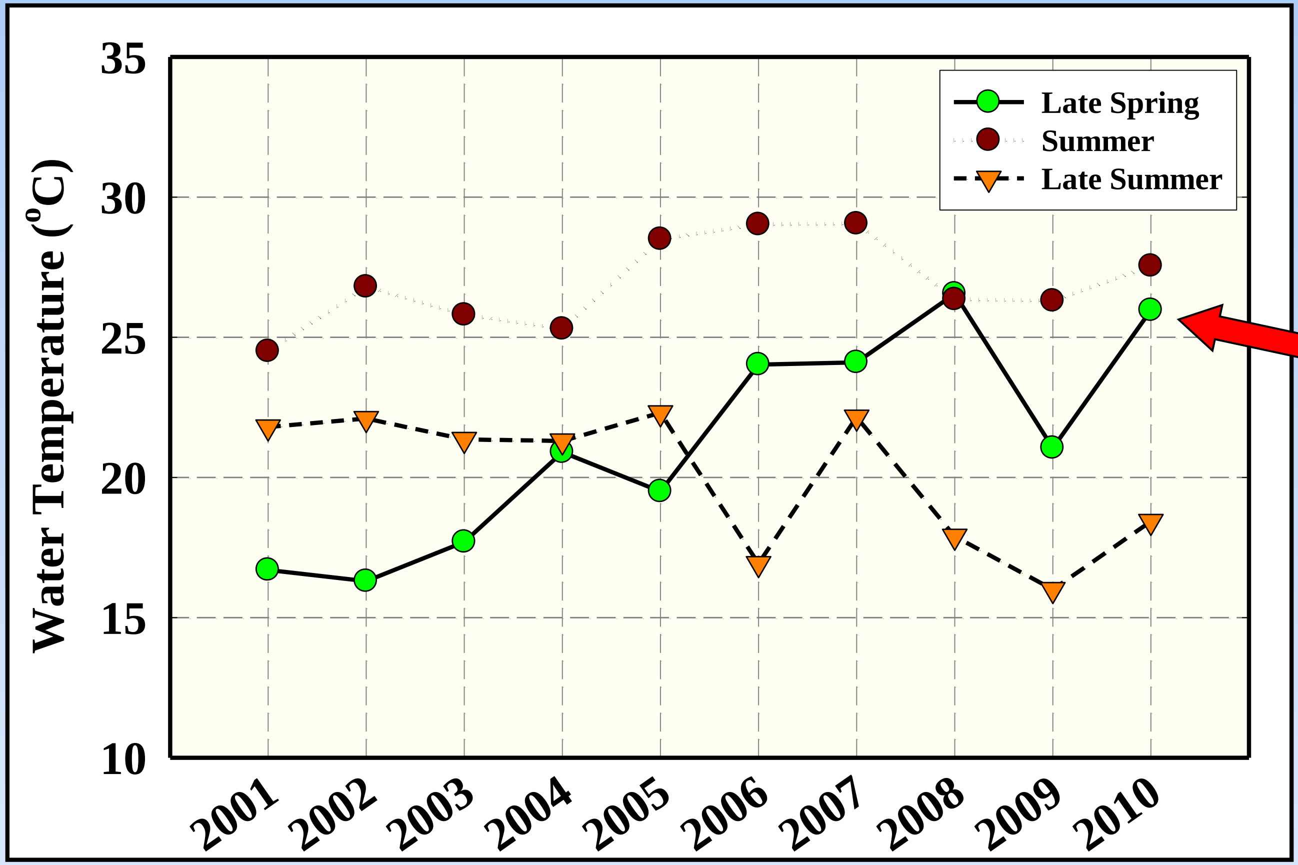


Nitrogen:Phosphorus Ratio



- **Cause of the cyanobacteria bloom in 2010?**
  - **Management using grass carp addresses the symptom (excess vegetation) and not the source (elevated nutrients - N, P)**
  - **Primary cause: Carp (too many) suppressed vegetation making N, P available to algae**
  - **Secondary cause: Weather was warmer and drier than average, favoring cyanobacteria bloom**

Water Temperature

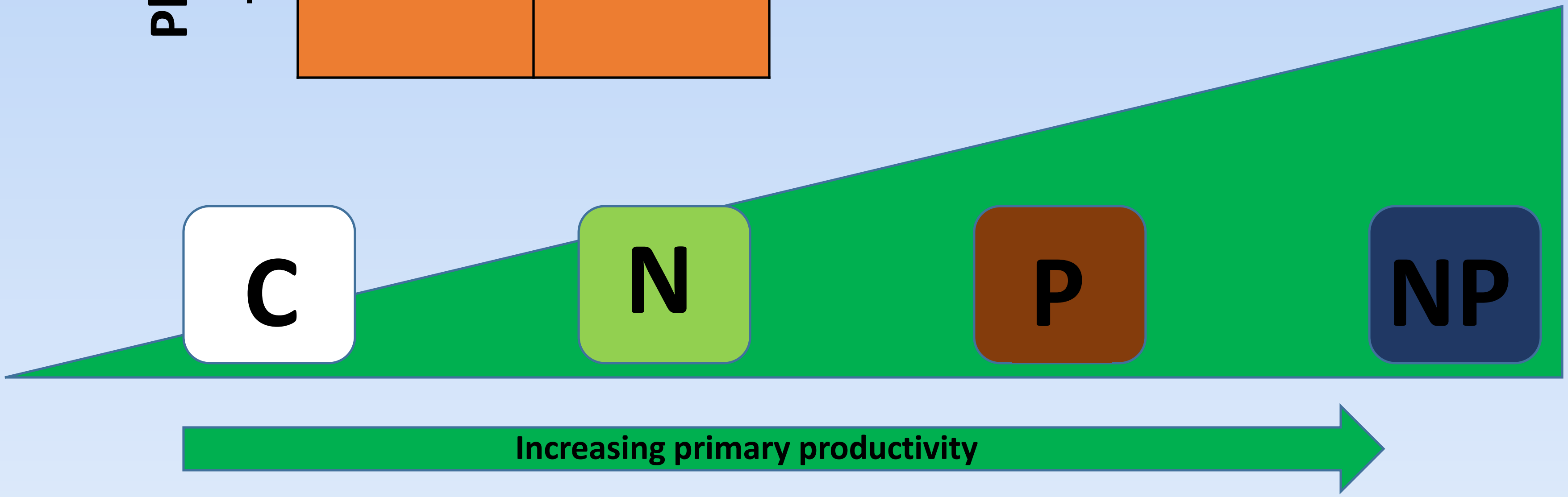


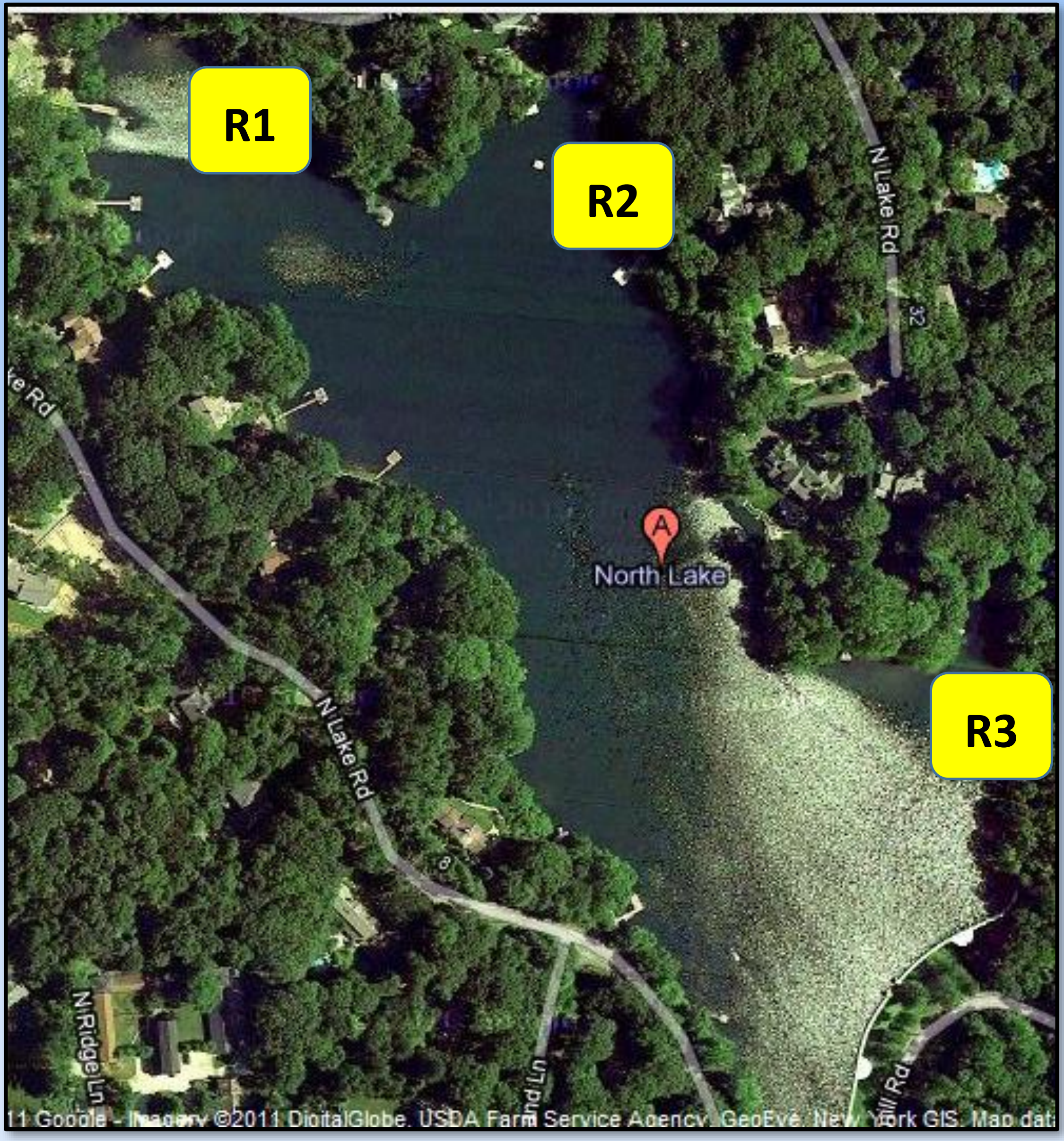
⬆Spring water temp a factor in algal bloom??

Hypothesis – Experimental design

	Nitrogen +	Nitrogen –
Phosphorus +	++	+-
Phosphorus –	+-	--

Treatments: 4X ambient levels

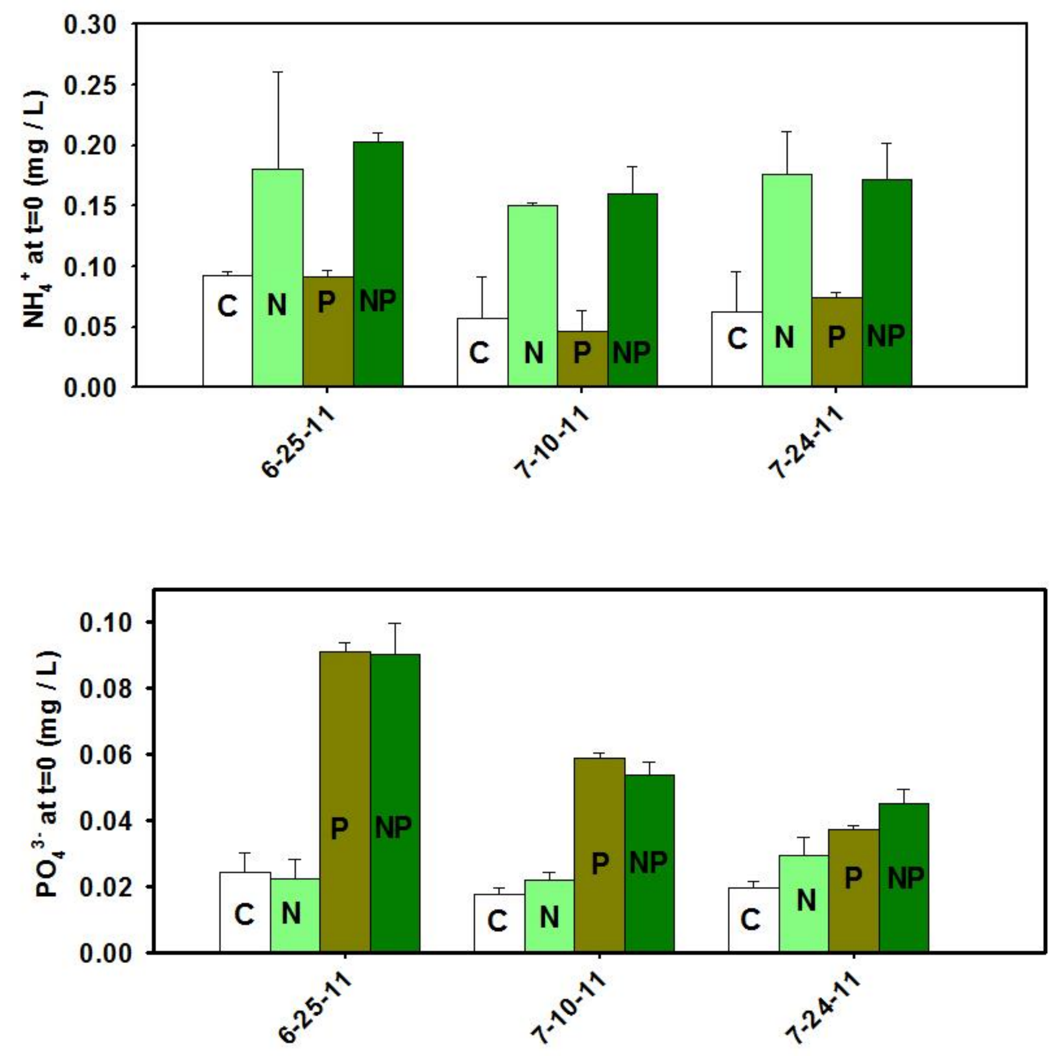




Map from Google Earth 6

- Control
- Nitrogen
- Phosphorus
- Nitrogen + Phosphorus

Experimental Treatments – Nutrient Effects

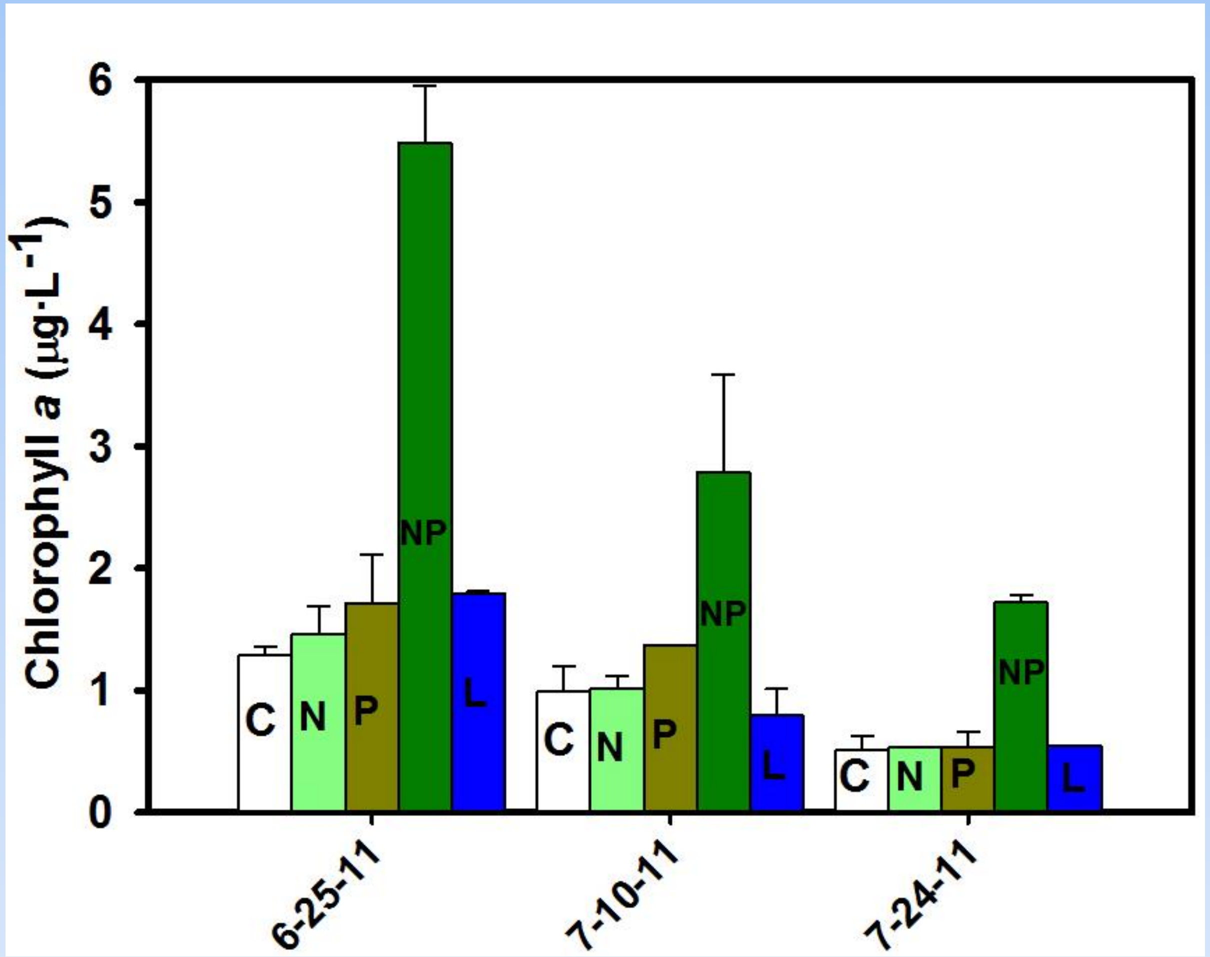


Initial NH_4^+ and PO_4^{3-} Values

- **Max initial NH_4^+:**
  +N treatment
  +NP treatment

- **Max initial PO_4^{3-}:**
  +P treatment
  +NP treatment

Algal Biomass



C

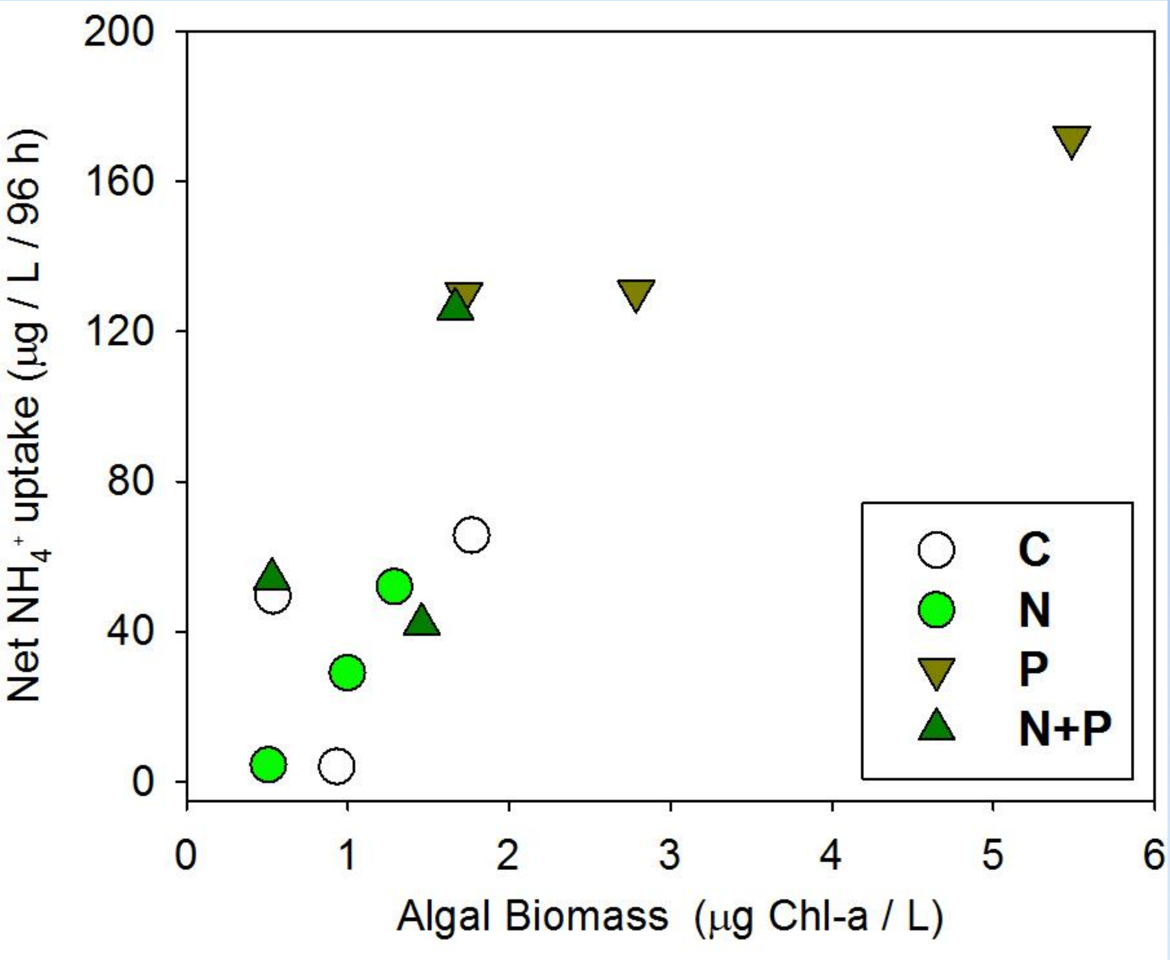
N

P

NP

Nitrogen Uptake

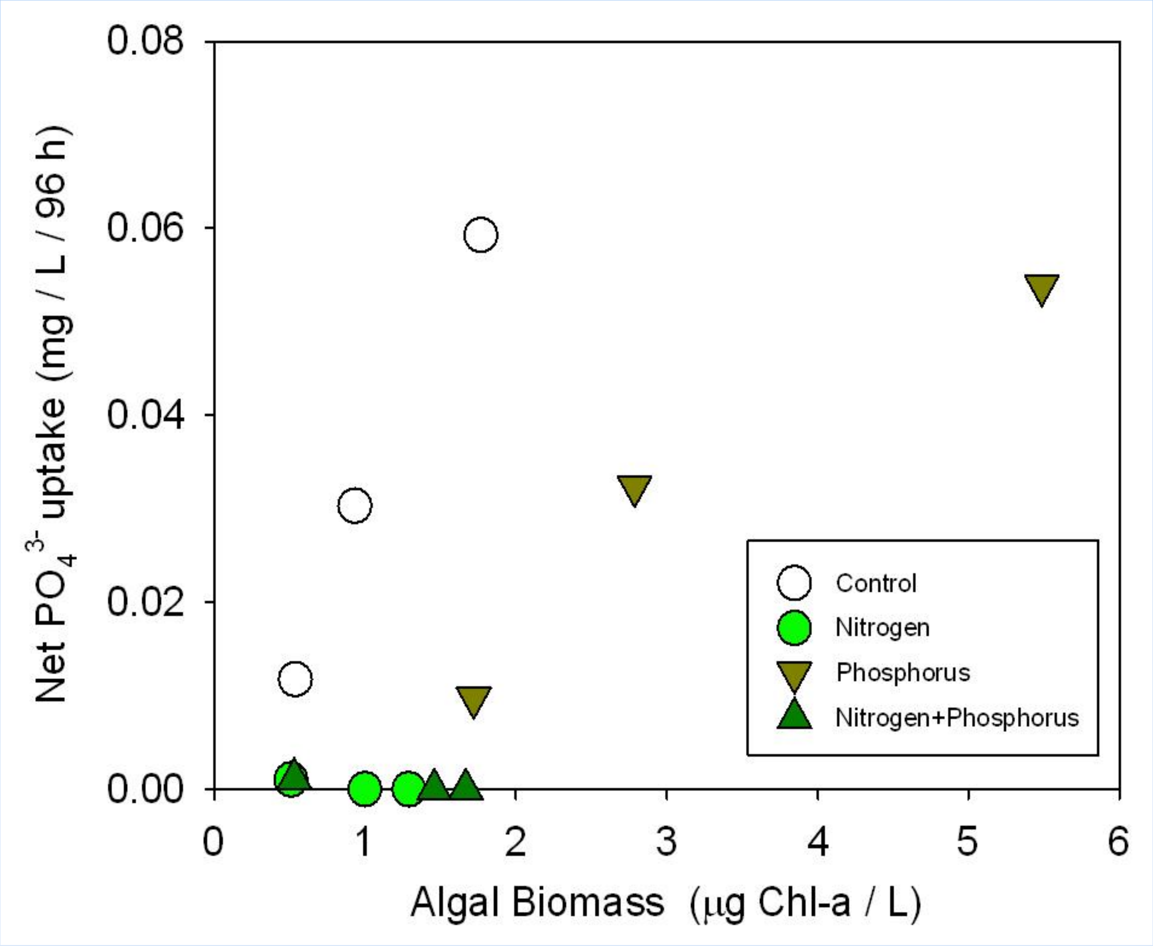
+ Correlation: F = 66.54, P = 0.0012, r^2 = 0.6887



- Max N uptake:
  +P treatment
- Uptake dependent on biomass
- <u>Similar trend for all N forms</u>
  - NH_4^+ (p= 0.0012, F=66.54, r^2= 0.6887)
  - NO_3^- (p= 0.001, F=21.31, r^2= 0.703)
  - TDN (p= 0.329 ,F= 21.31, r^2= 0.703)

Phosphorus Uptake

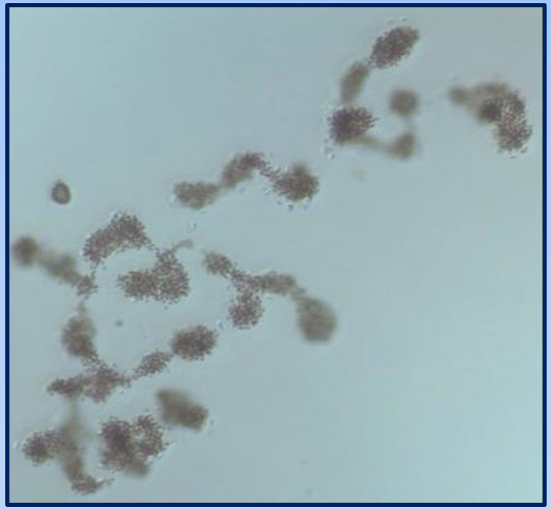
+ trend: $F = 3.63$, $P = 0.086$, $r^2 = 0.193$



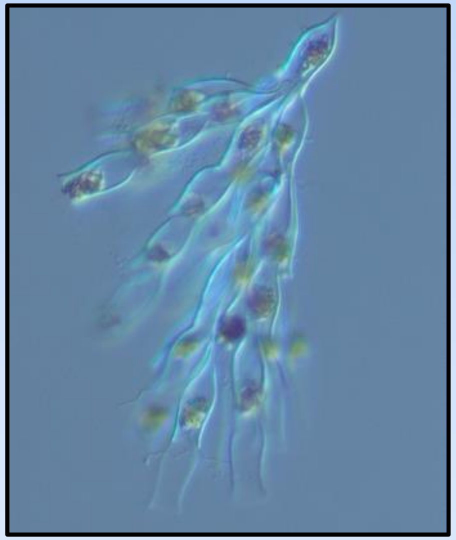
- **Max P uptake:**
  +P treatment
- **Uptake dependent on biomass**
- **<u>Similar trend for all P forms</u>**
  - **PO_4^{3-} (p= 0.086, F=3.63, r^2= 0.193)**
  - **TDP (p= 0.009,F= 10.57, r^2= 0.514)**

Phytoplankton Community Composition (Summer 2011)

- **Many planktonic cyanobacteria species**
- **Most were not N-fixing taxa**
- **Other species also common**

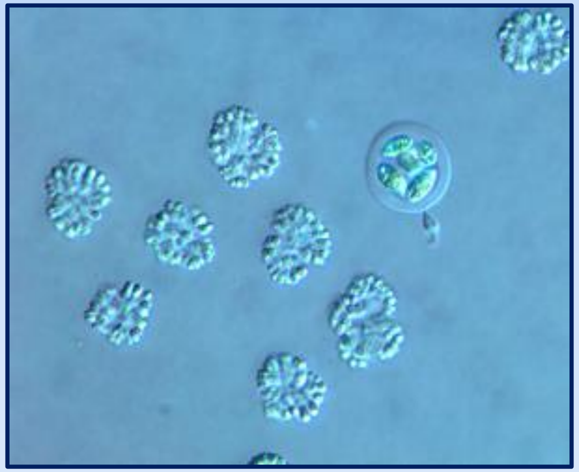


Microcystis aeruginosa



Dinobryon divergens

Woronichinia naegeliana

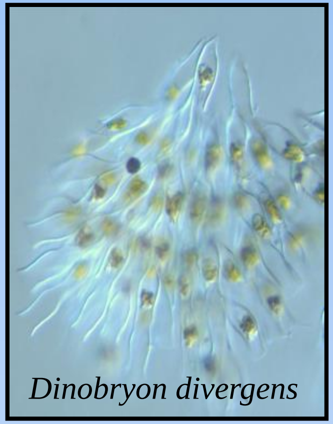


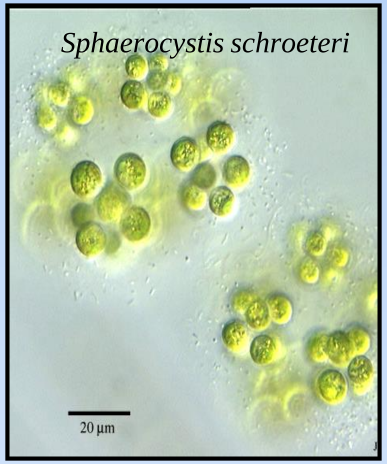
Snowella littoralis

Phytoplankton Community Composition (August 2010)

- **Major algal groups:**
- **Filamentous bluegreens**
- **Colonial bluegreens**
- **Sub-dominant groups:**
- **Colonial green algae**
- **Colonial diatoms**
- **Cyanobacteria (N-fixers) dominant = Bloom**


Oocystis lacustris

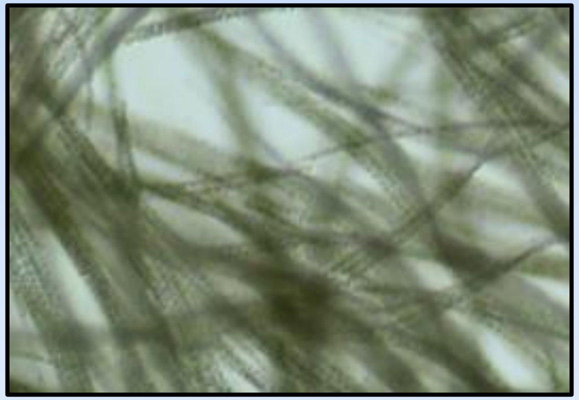

Dinobryon divergens



Sphaerocystis schroeteri


Anabaena variabilis


Ceratium hirundinella


Aphanizomenon flos-aquae

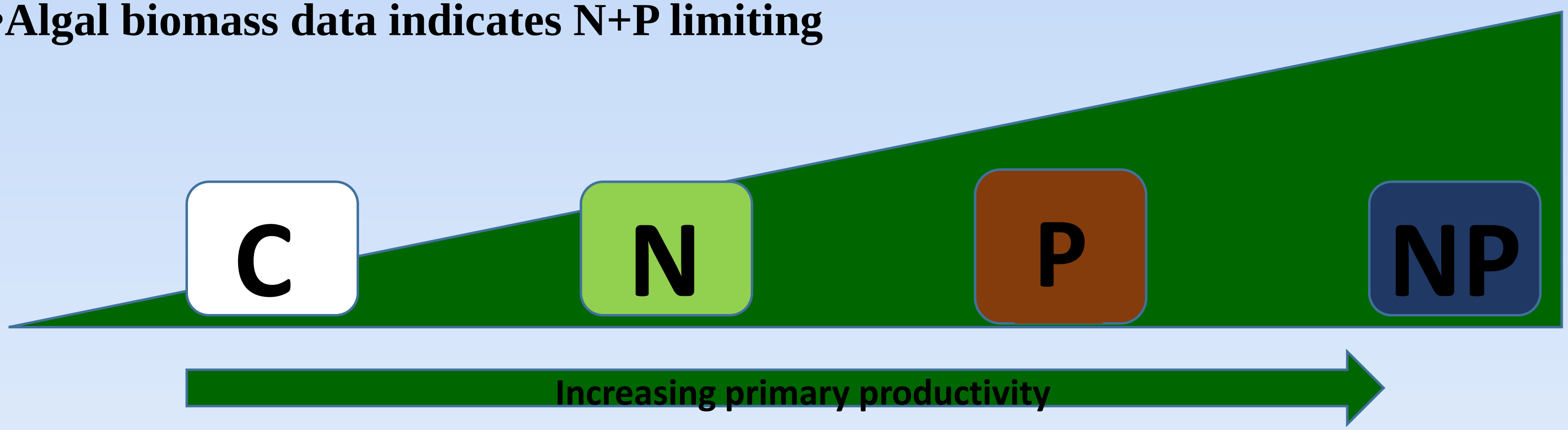
Discussion

Nitrogen

Phosphorus		
+	++	+-
-	+-	--

Nutrient data indicates P limiting

•Algal biomass data indicates N+P limiting



Implications of Findings

- Addition of carp suppressed aquatic vegetation growth- favoring algal blooms

- Lake receives N and P from fertilizers via runoff (+ wildlife)
- (↑ runoff due to ↑ impervious surfaces & ↓ vegetation)




Management Strategies

- To address high nutrient levels:
  - Reduce nutrient input (fertilizer, road salt, wildlife)
  - Catchment ponds, wetlands, vegetation buffers
  - Increase nutrient removal by lake drawdown