CEES

Algae and their Metabolites

Taste & Odor Compounds and Microcystin Occurrences in Patoka Lake

2011 Monitoring Report

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Patoka Lake, IN

- Five sampling stations:
  - 3 samples in Lick Fork (PRAT-1; -2; -3);
  - 1 offshore of the ACOE recreation area near the dam (PRAT-4);
  - 1 in the main basin near Jackson State Recreation Area (PRAT-5);

- Stations were chosen to focus on inputs to the drinking water intake (near PRAT-3)

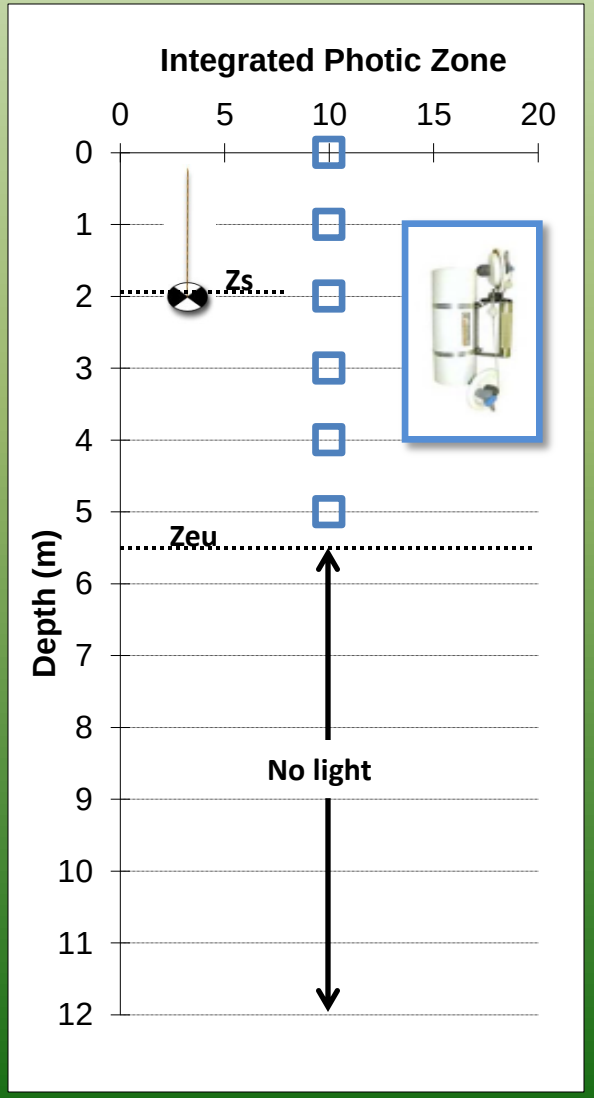
Site name	Max depth (m)	Site code
Upper Lick Fork	8.4	PRAT-1
Central Lick Fork	13.6	PRAT-2
Lower Lick Fork (near intake)	13.8	PRAT-3
ACOE (near dam)	16.6	PRAT-4
Main Basin (Jackson SRA)	15.3	PRAT-5

Water Samples

- Sampled monthly at 5 stations
  - May through September
- Physical and Chemical Water Quality at each station
- Sampled for:
  - Algal populations (number and type) - CEES
  - Algal toxin – microcystin - CEES
  - Taste and odor compounds – Paragon Lab
  - Nutrients – Paragon Lab

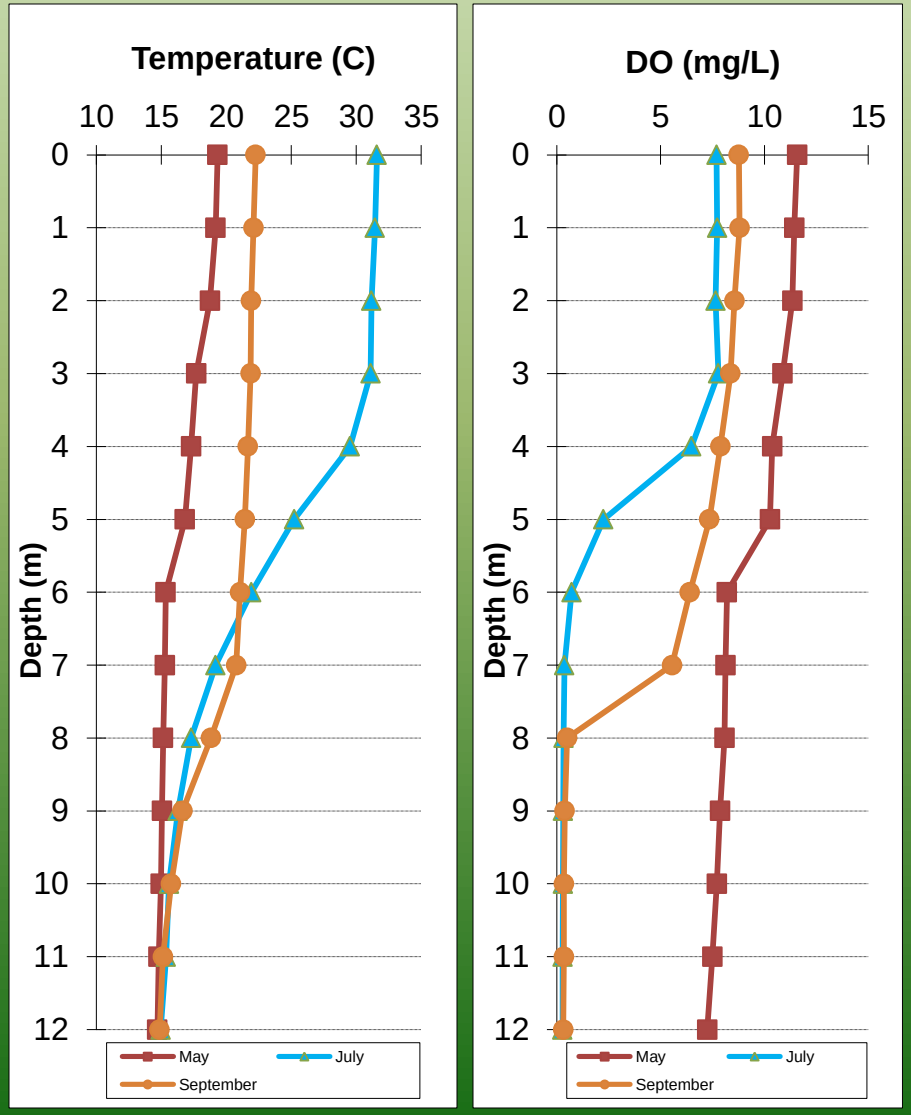
Sampling Methodology

- Example PRAT-3 (near intake) in July 2011
  - Photic depth (Zeu) measured with a Secchi disk (Zs), using the relationship:
    - Zeu = 2.7 x Zs
- Water samples were integrated within the photic zone of the water column, using a Van Dorn bottle

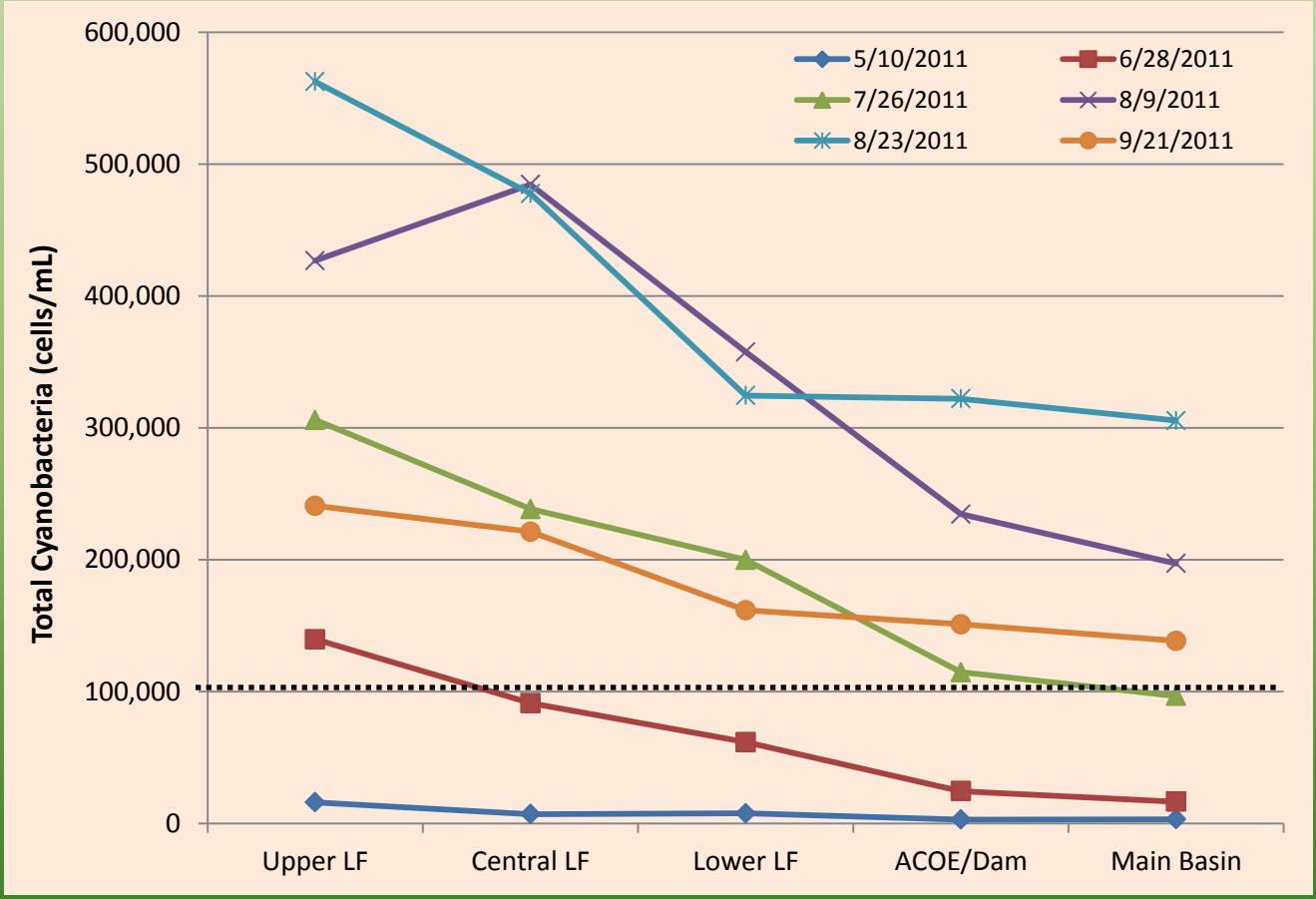


Field Measurements

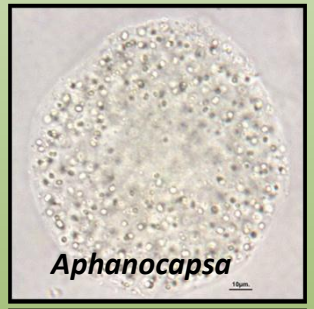
- Water Temperature and Dissolved Oxygen (DO) profiles at all sites
- Optimal temp for cyanobacterial growth is 26°C
- DO reflects metabolic activity of algae (=photosynthesis)



Total Cyanobacteria: Patoka Lake 2011

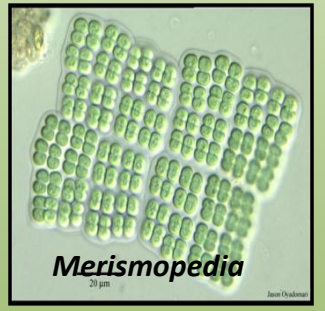


Blue-green Algae in Patoka Lake



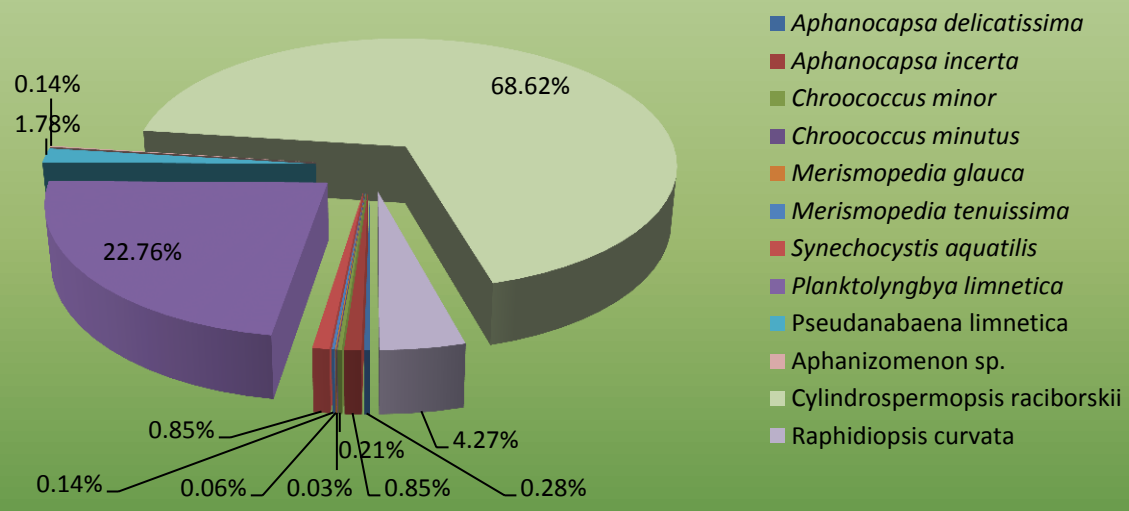
	Upper LF	Central LF	Lower LF	ACOE	Main basin
Chroococcales					
Aphanocapsa delicatissima	1	1			
Aphanocapsa incerta	1	1	1	1	1
Chroococcus minor	1	1	1	1	1
Chroococcus minutus	1	1	1	1	1
Coelosphaerium kuetzingianum	1	1	1	1	1
Merismopedia glauca	1	1	1		
Merismopedia tenuissima	1	1	1	1	
Snowella lacustris			1	1	1
Synechocystis aquatilis	1	1	1	1	1
Oscillatoriales					
Planktolyngbya limnetica	1	1	1	1	1
Pseudanabaena limnetica	1	1	1	1	1
Nostocales					
Anabaena planctonica		1			
Aphanizomenon spp.	1	1	1	1	1
Cylindrospermopsis raciborskii	1	1	1	1	1
Raphidiopsis curvata	1	1	1	1	1

Total of Chroococcales	**8**	**8**	**8**	**7**	**6**
Total of Oscillatoriales	**2**	**2**	**2**	**2**	**2**
Total of Nostocales	**3**	**4**	**3**	**3**	**3**



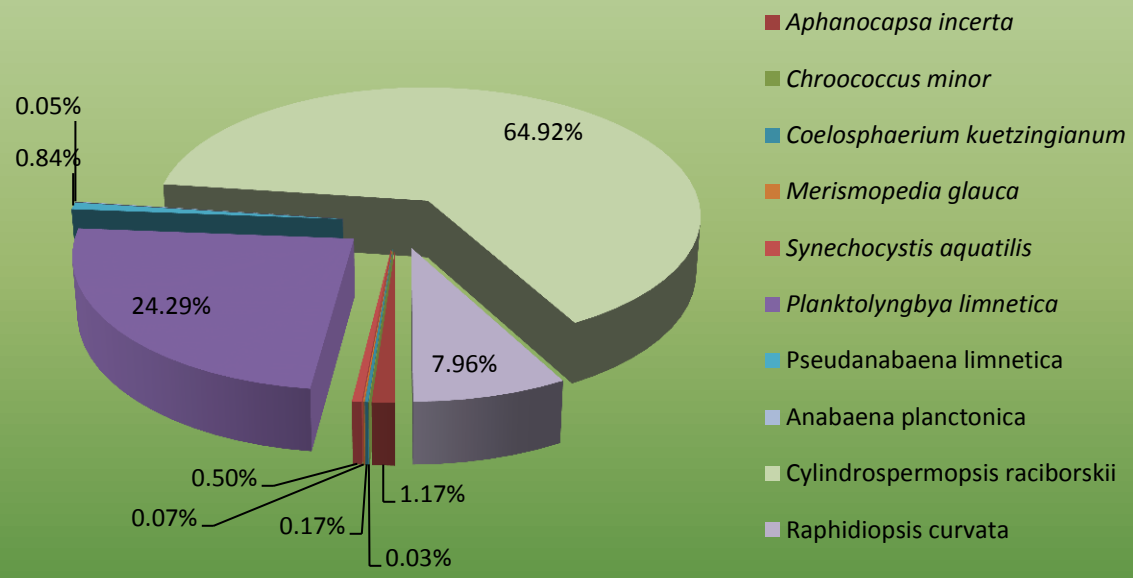
A total of 15 cyanobacteria species were found in Patoka Lake

Blue-green Algae Community: Upper Lick Fork (August, 23rd 2011)



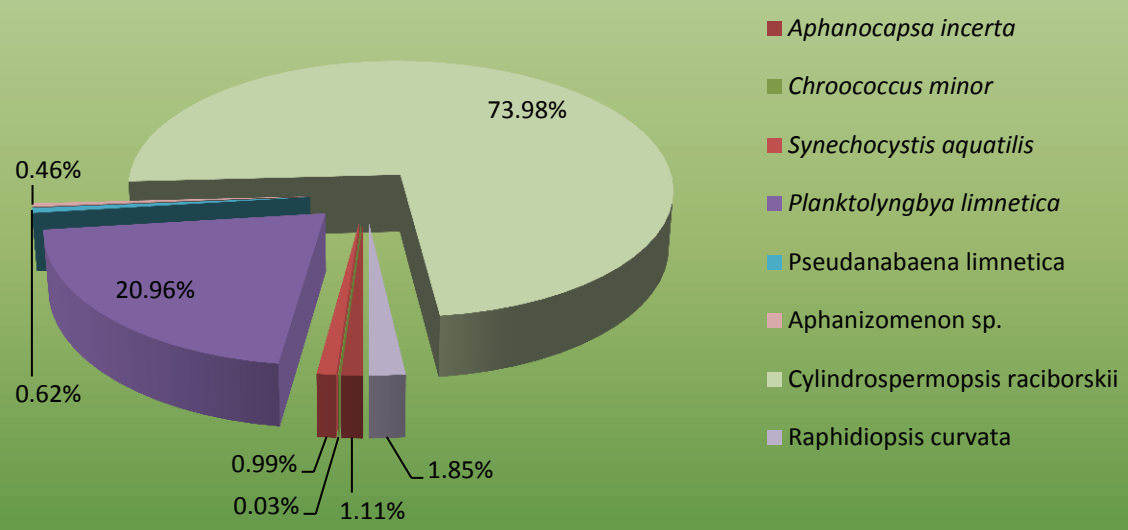
- Dominant species: *Cylindrospermopsis raciborskii*
- Sub-dominant species: *Planktolyngbya limnetica*
- Total = 12

Blue-green Algae Community: Central Lick Fork (August, 23rd 2011)



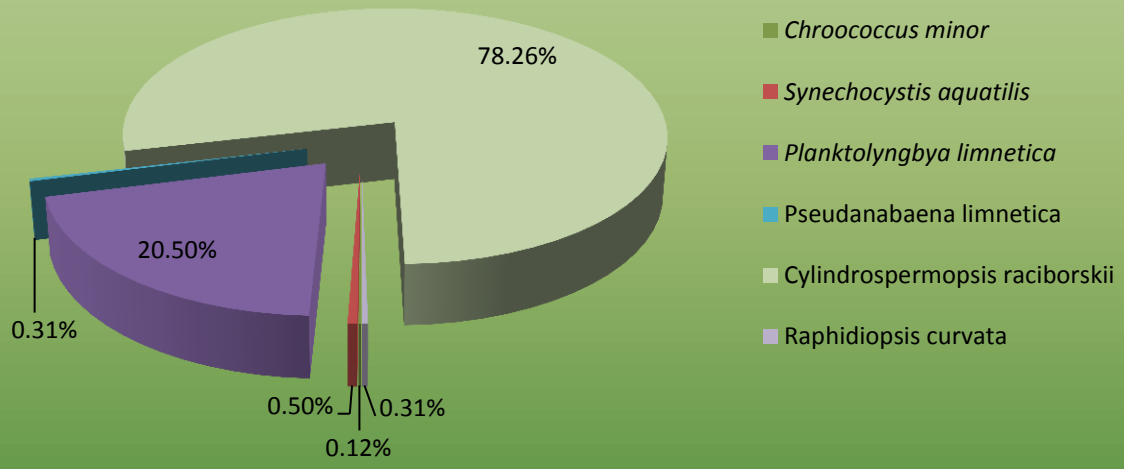
- Dominant species: *Cylindrospermopsis raciborskii*
- Sub-dominant species: *Planktolyngbya limnetica*
- Total = 10

Blue-green Algae Community: Lower Lick Fork (August, 23rd 2011)



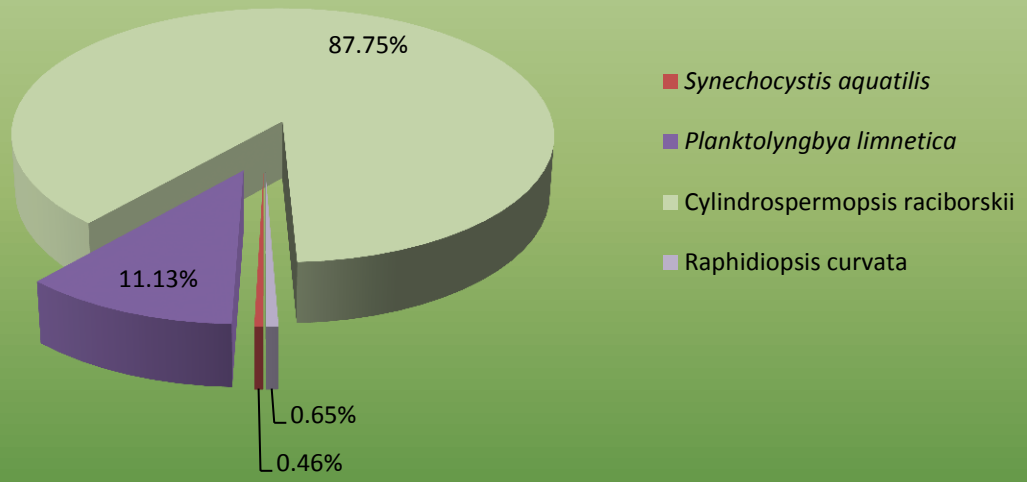
- Dominant species: *Cylindrospermopsis raciborskii*
- Sub-dominant species: *Planktolyngbya limnetica*
- Total = 8

Blue-green Algae Community: ACOE near Dam (August, 23rd 2011)



- Dominant species: *Cylindrospermopsis raciborskii*
- Sub-dominant species: *Planktolyngbya limnetica*
- Total = 6

Blue-green Algae Community: Main Basin (August, 23rd 2011)



- Dominant species: *Cylindrospermopsis raciborskii*
- Sub-dominant species: *Planktolyngbya limnetica*
- Total = 4

Potential Controls on Species Distribution in Patoka Lake

- 2 species dominate blue-green algae community in Patoka Lake
  - Gradient in abundance from Lick Fork to Main Basin
  - Shift to higher abundance of Nostocales toward Main Basin

- Dominant taxa are:
  - 1 species of Nostocales
    - *Cylindrospermopsis raciborskii* (tropical species)
  - 1 species of Oscillatoriales
    - *Planktolyngbya limnetica*
    - *(+1 Pseudanabaena limnetica* sub-dominant in Lick Fork only)

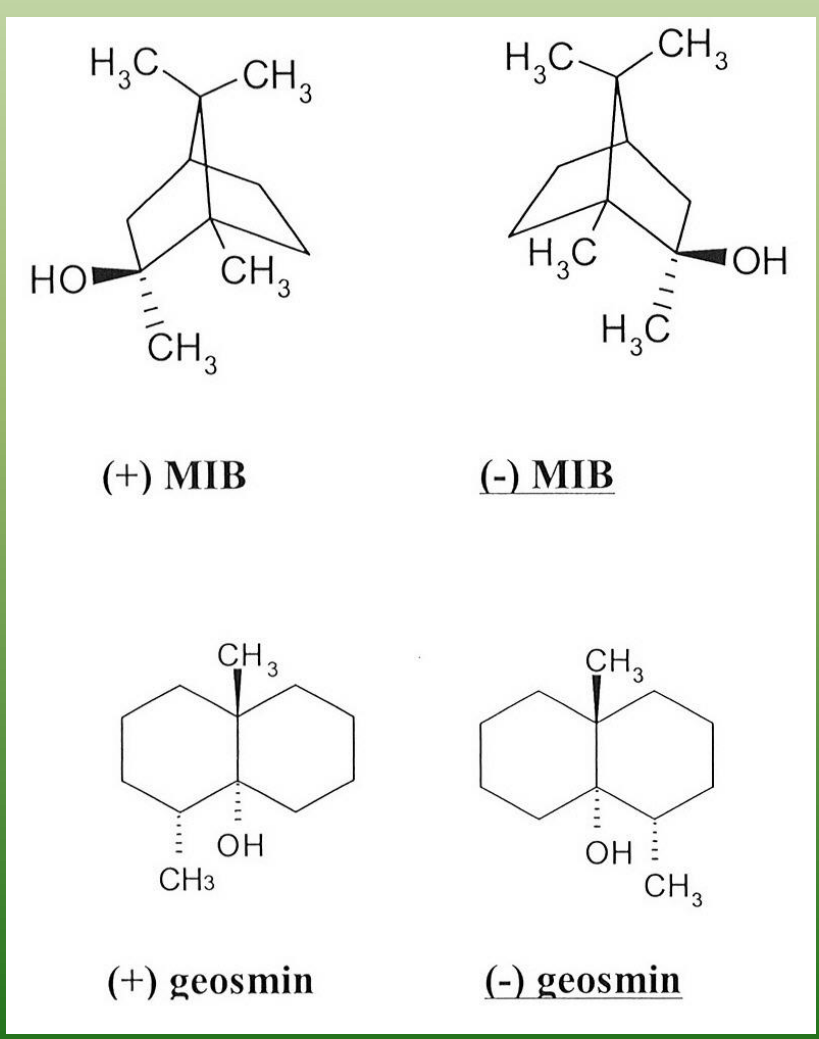
- Nostocales fix atmospheric nitrogen, also turbulence tolerant, prefer low light, do well with nitrogen depletion (later in season)
- Oscillatoriales store phosphorus, prefer low light and tolerate turbulence, dominate in higher nutrient conditions

Algal Volatile Organic Compounds (AVOCs)

- Algal metabolites are central to many source-water issues;
- Prokaryotic and eukaryotic algae are well known as sources of biologically active compounds;
- Algal metabolites that affect aesthetics such as taste-and-odor (T/O) have no known effects on human health;
- Nevertheless, aesthetics are the primary criteria that determine consumer confidence in the safety of a water supply;
- Furthermore, AVOCs account for the majority of reported T/O, with substantial costs to water production and aqua-culture industries each year .

Terpenoids (Isoprenoids)

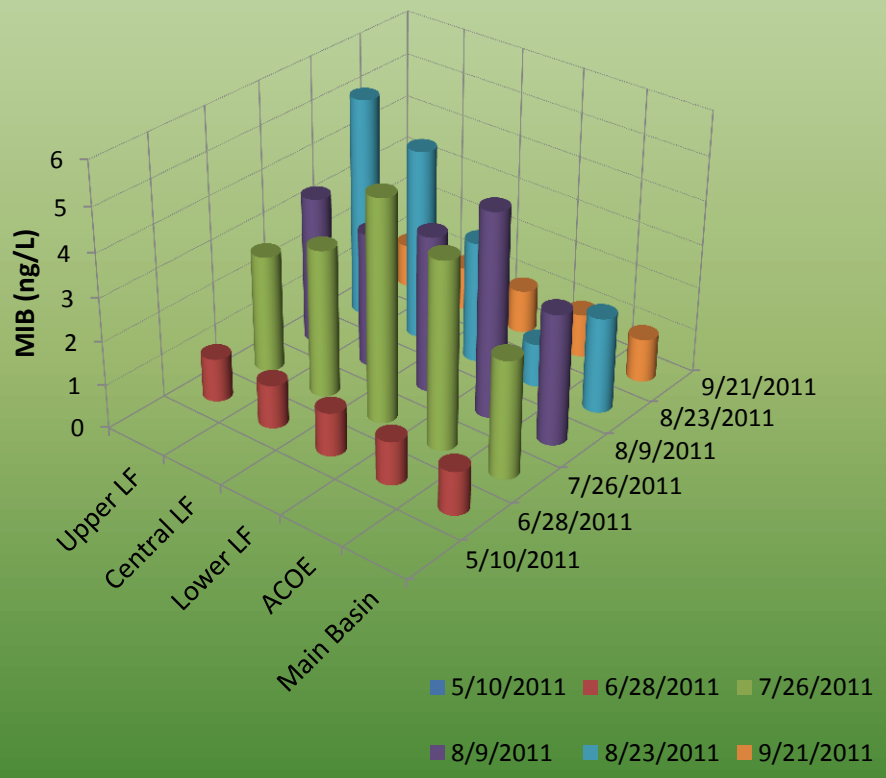
- Geosmin (1,2,7,7-tetramethyl-2-norborneol) and MIB (*2-methyl-isoborneol*) account for most reported source-water odors
- High potent earthy, musty, muddy aromas
  - OTC ~ 10 ng/L (ppt) or less
- Production occurs throughout active growth
- Release may occur during the stationary phase or at the onset of senescence
- Geosmin production is intensified in heterocyst (Nostocales)



MIB Occurrences in Patoka Lake

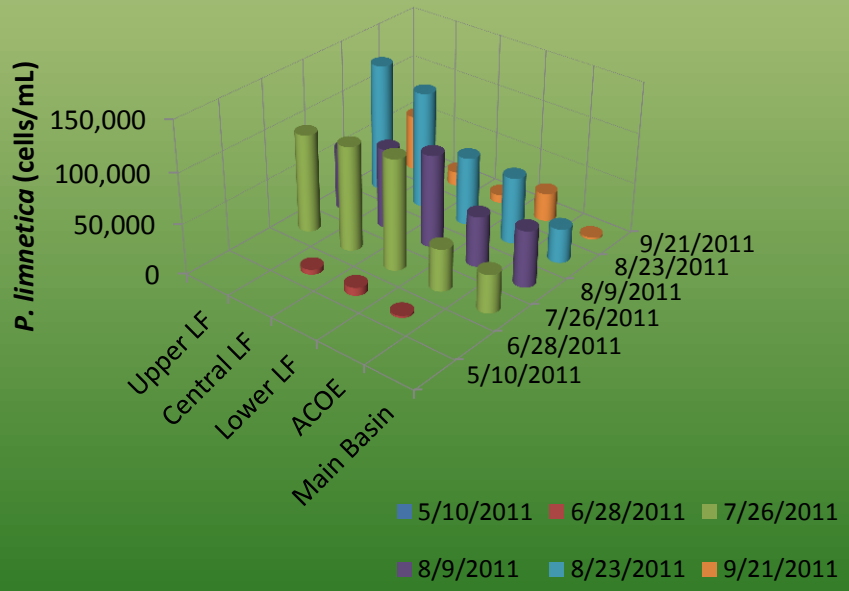
- No MIB in May (lab issue)
- BDL <2 ng/L in June
- Seasonal pattern: major detections July and August

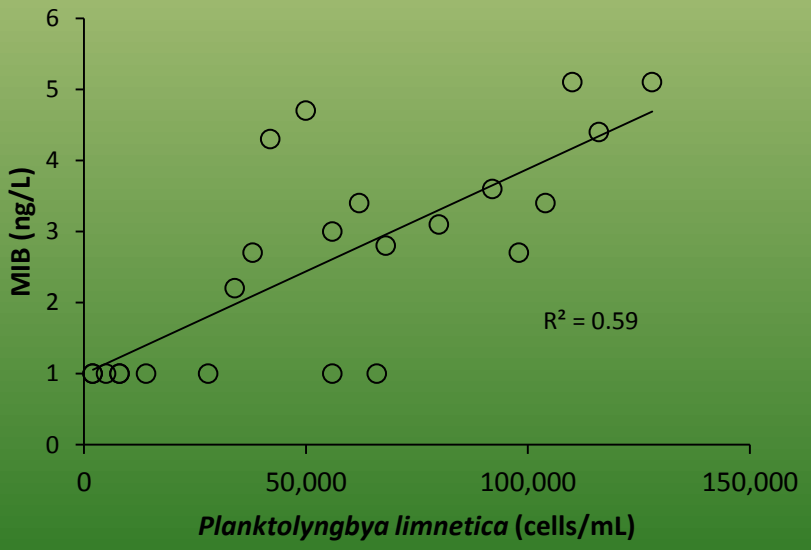
- Average concentration
  - MIB = 3.64 ng/L for the entire reservoir
- Maximum concentration
  - MIB = 5.1 ng/L at Upper Lick Fork (August 23rd)



MIB Occurrences in Patoka Lake

- The first occurrence of MIB in July in Lick Fork associated with the growth of *Planktolyngbya limnetica*

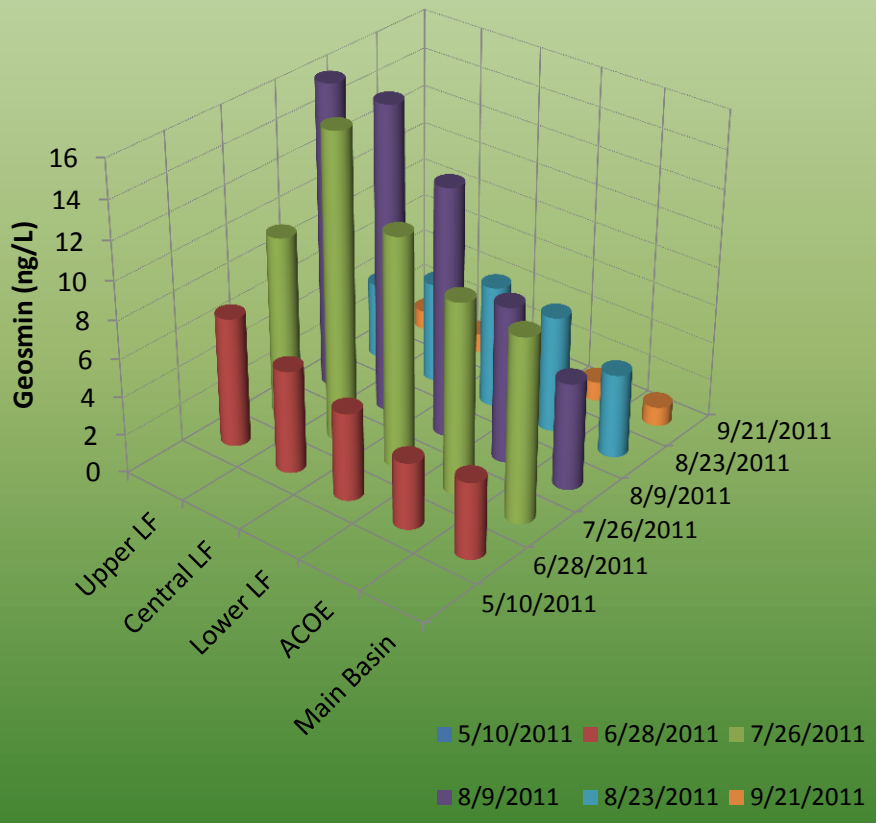




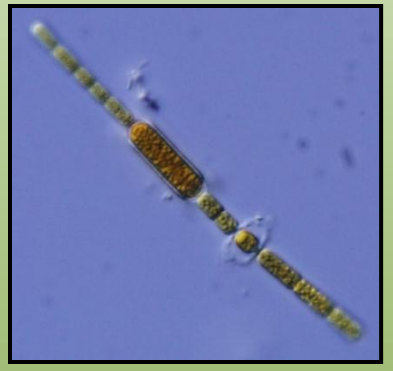
Geosmin Occurrences in Patoka Lake

- No Geosmin data in May
- Geosmin occurred throughout the entire summer 2011
- Longer duration and more commonly at higher levels than MIB (above OTC)
- BDL <2 ng/L in September

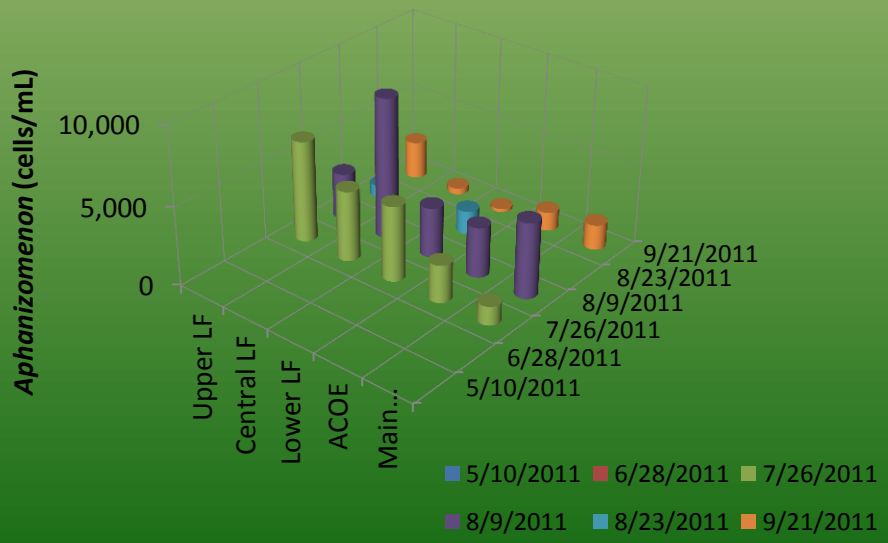
- Average concentration
  - Geosmin = 8.32 ng/L for the entire reservoir
- Maximum concentration
  - Geosmin = 16 ng/L (August 9th) at Upper and Central Lick Fork

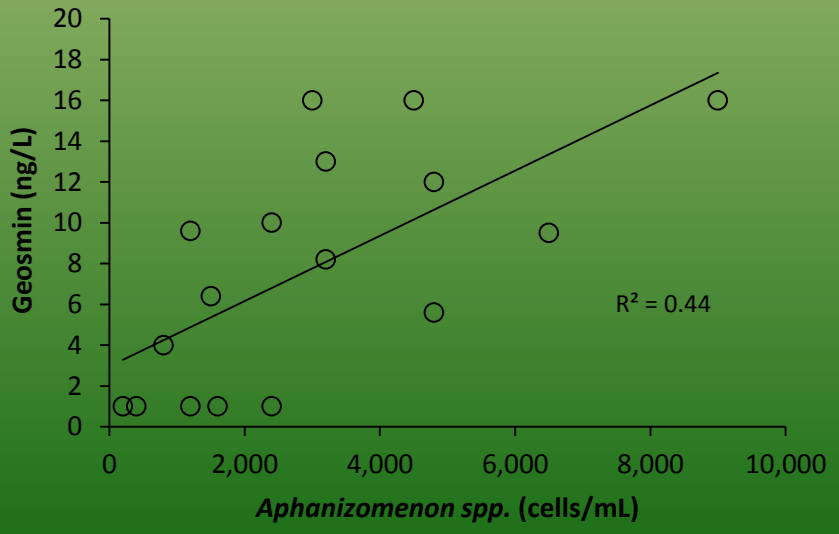


Geosmin Occurrences in Patoka Lake



- Dominance of Nostocales in Lick Fork :
  - *Cylindrospermopsis raciborskii;*
  - *Raphidiopsis curvata;*
  - *Aphanizomenon spp.,* strong known producer;
- Geosmin correlates with the presence of *Aphanizomenon spp*. in the water





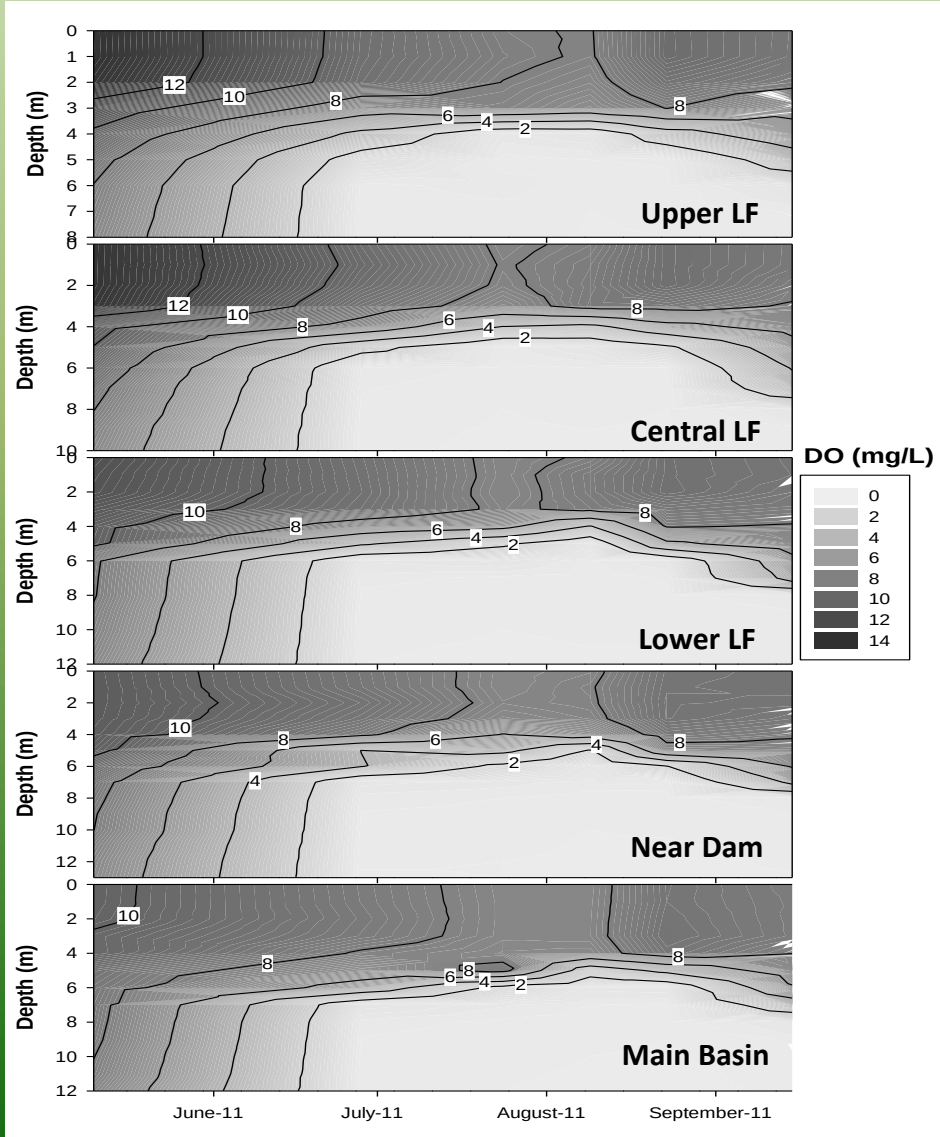
Other Algal Metabolite - Microcystin

	Dermatotoxins, Irritant Toxins	Hepatotoxins	Neurotoxins	Taste & Odor compounds
Chroococcales				
Aphanocapsa spp.	LPS	MYC		
Chroococcus spp.	LPS			
Coelosphaerium spp.	LPS	MYC		
Merismopedia spp.	LPS	MYC		
Snowella spp.	LPS	MYC		
Synechocystis spp.	LPS	MYC	BMAA	
Oscillatoriales				
Planktolyngbya spp.	LPS, Lyngbyatoxins		STX	MIB, Geosmin
Pseudanabaena spp.	LPS	MYC	ATX	MIB, Geosmin
Nostocales				
Anabaena spp.	LPS	MYC, Nodularin, CYN	ATX, BMMA, Neosaxitoxins, STX	MIB, Geosmin
Aphanizomenon spp.	LPS	MYC, CYN	ATX, BMMA, Neosaxitoxin, STX	Geosmin
Cylindrospermopsis spp.	LPS	CYN	STX, BMAA	
Raphidiopsis spp.	LPS	CYN	ATX	

- Cyanobacterial blooms are often associated with the production of algal toxins
- *C. raciborskii* was dominant in 2011 = no production
- No microcystin was reported in Patoka Lake

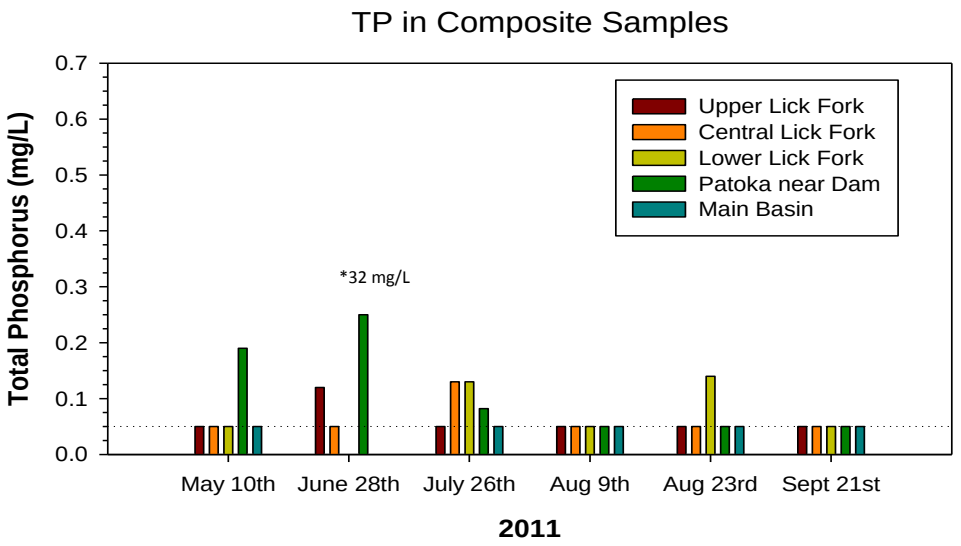
Dissolved Oxygen

- Strong Oxygen gradient in LF during May and June
- Bottom becomes anoxic from mid-June
- Oxycline is around 6m throughout the entire summer

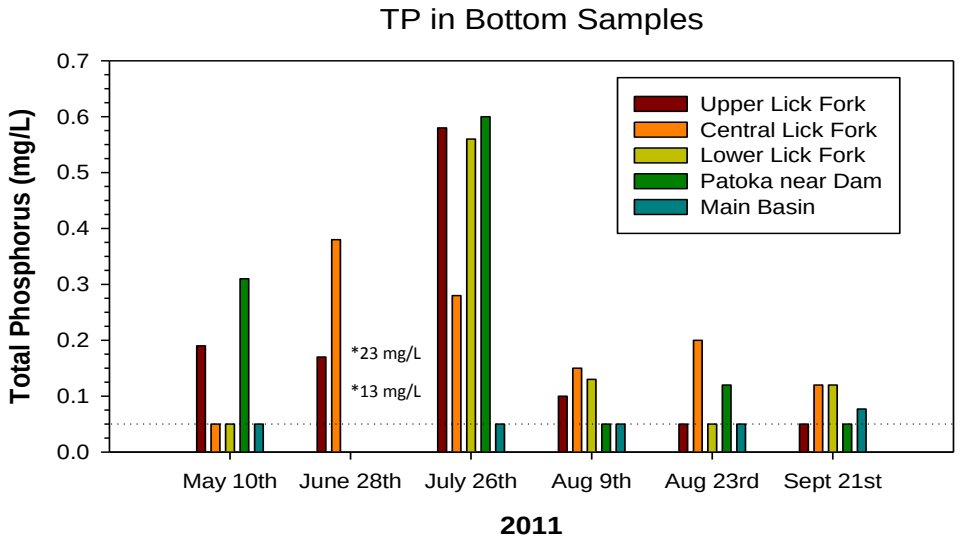


Nutrients - Phosphorus

- Only Total Phosphorus data are 'available'
  - In discussion with Paragon Lab about ortho-P
  - 40 of 60 samples have ortho-P higher than TP
  - Four extraordinary TP values > 3.6 mg/L
  - Max = 32 mg/L !
- TP is most of the time depleted in composite samples
- Bottom release of Phosphorus in July



* Deleted value



Conclusions

- Lick Fork has the highest algae concentrations with strong gradients from Upper to Lower Lick Fork
- Algae is concentrated deeper in the water column
- Very warm water temps were favorable for the development and the growth of 'sub'-tropical species, such as *C. raciborskii*
- MIB and Geosmin are highest in Upper Lick Fork,
- Microcystin not detected in 2011 in the reservoir
- Patoka Lake is stratified throughout the season with anoxic bottom waters at most stations for long periods of time
- Both internal and external nutrient loading are problematic in Patoka Lake especially in Lick Fork
- High algal densities in Lick Fork may be supported by internal nutrient loads

Questions?

Nutrients - Phosphorus

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- In discussion with Paragon Lab about ortho-P
- 40 of 60 samples have ortho-P higher than TP
- Four extraordinary TP values > 3.6 mg/L
- Max = 32 mg/L !