A comparison of historic water quality data and HAB events at Barren River and Dale Hollow Lakes

ERDC
Engineer Research and Development Center

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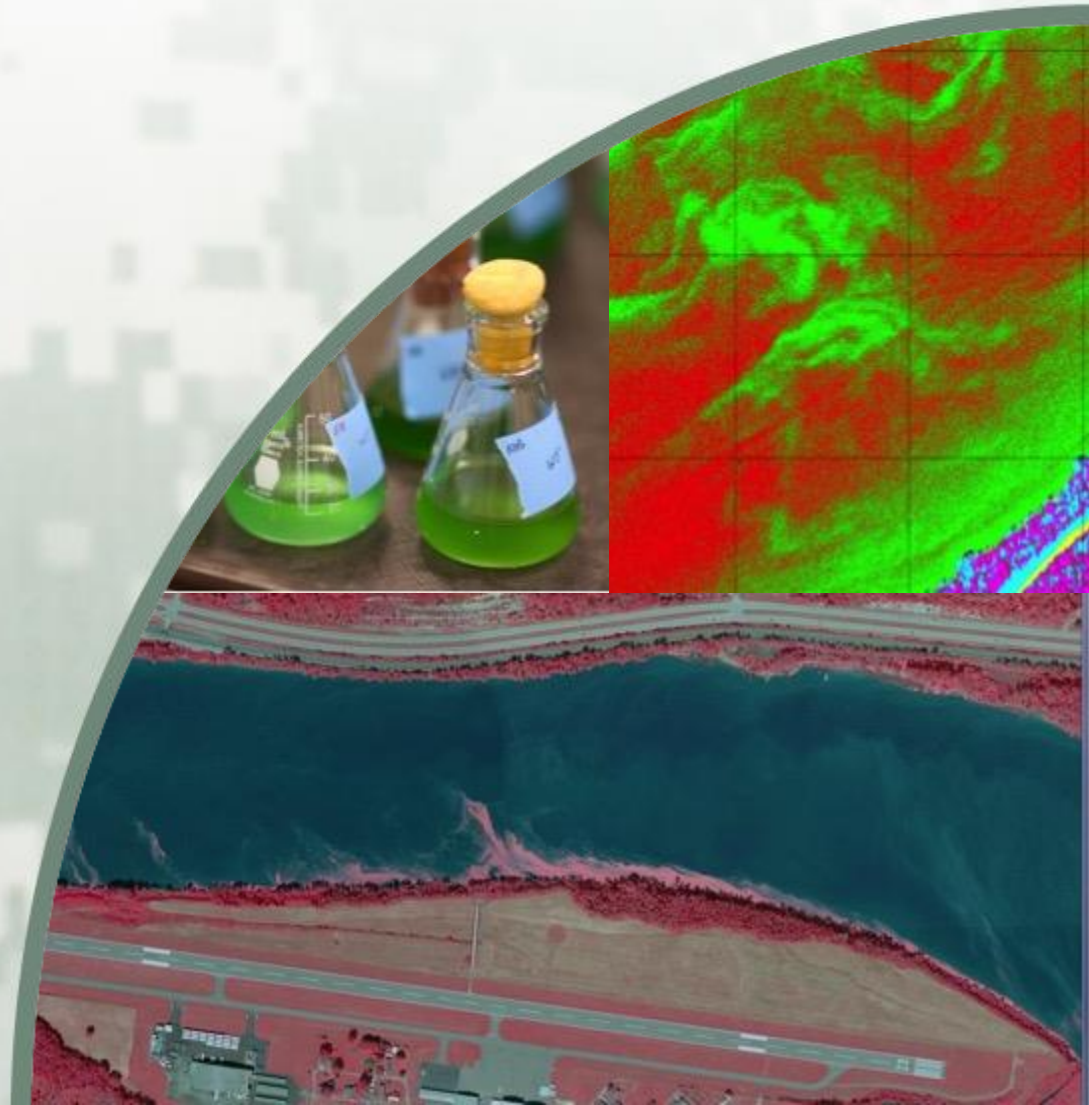


US Army Corps of Engineers®

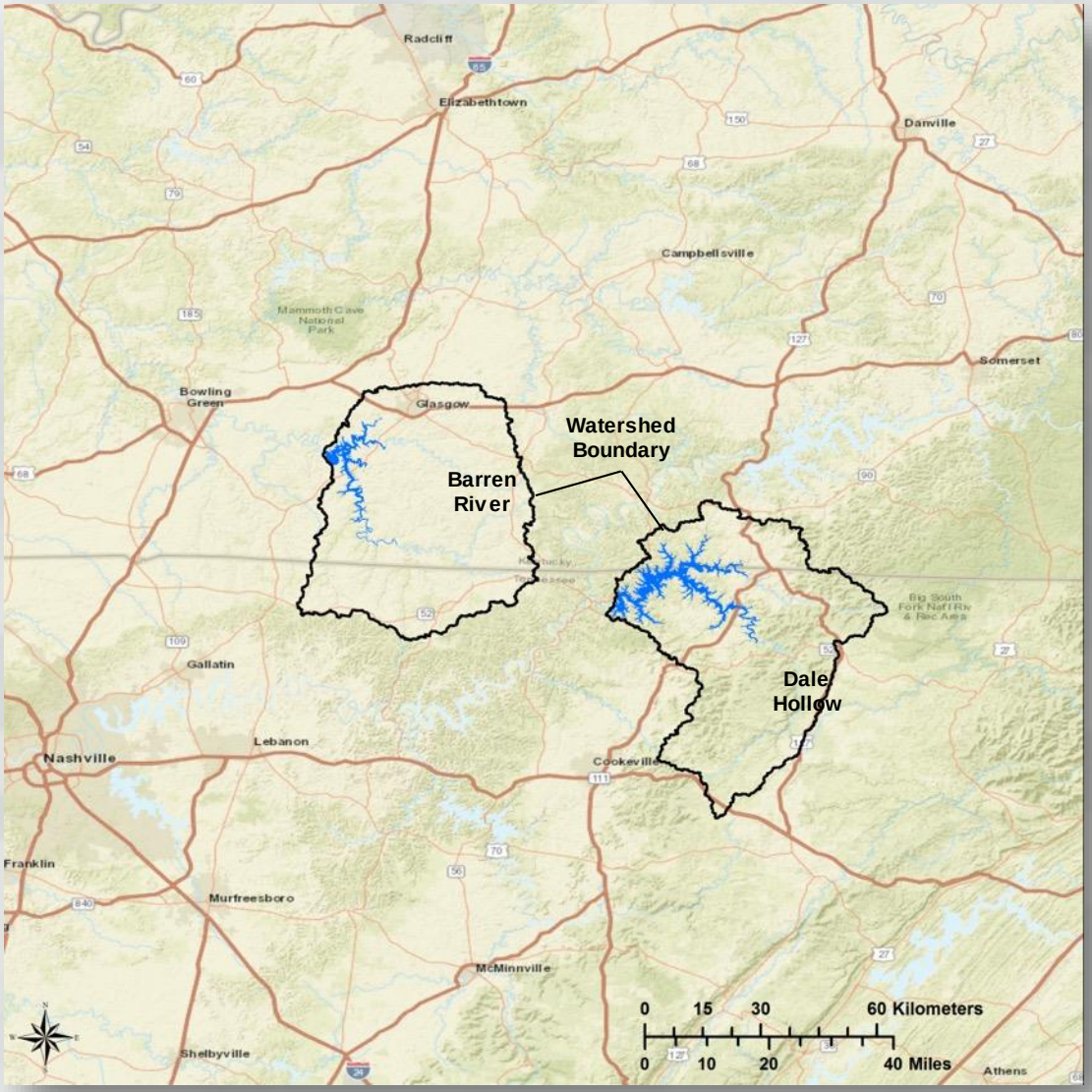
Background

- HAB events are increasing in frequency throughout the USA
- HAB events reported in Barren River Lake since 2013
- No reported HAB events in Dale Hollow Lake
- Lakes are in adjacent watersheds with similar environmental factors
- Why are HABs occurring in one and not the other?

Hypothesis

- Water quality differences are driving the differences in bloom occurrence with increased nutrient loading leading to HAB events in Barren River Lake

Comparison of lakes

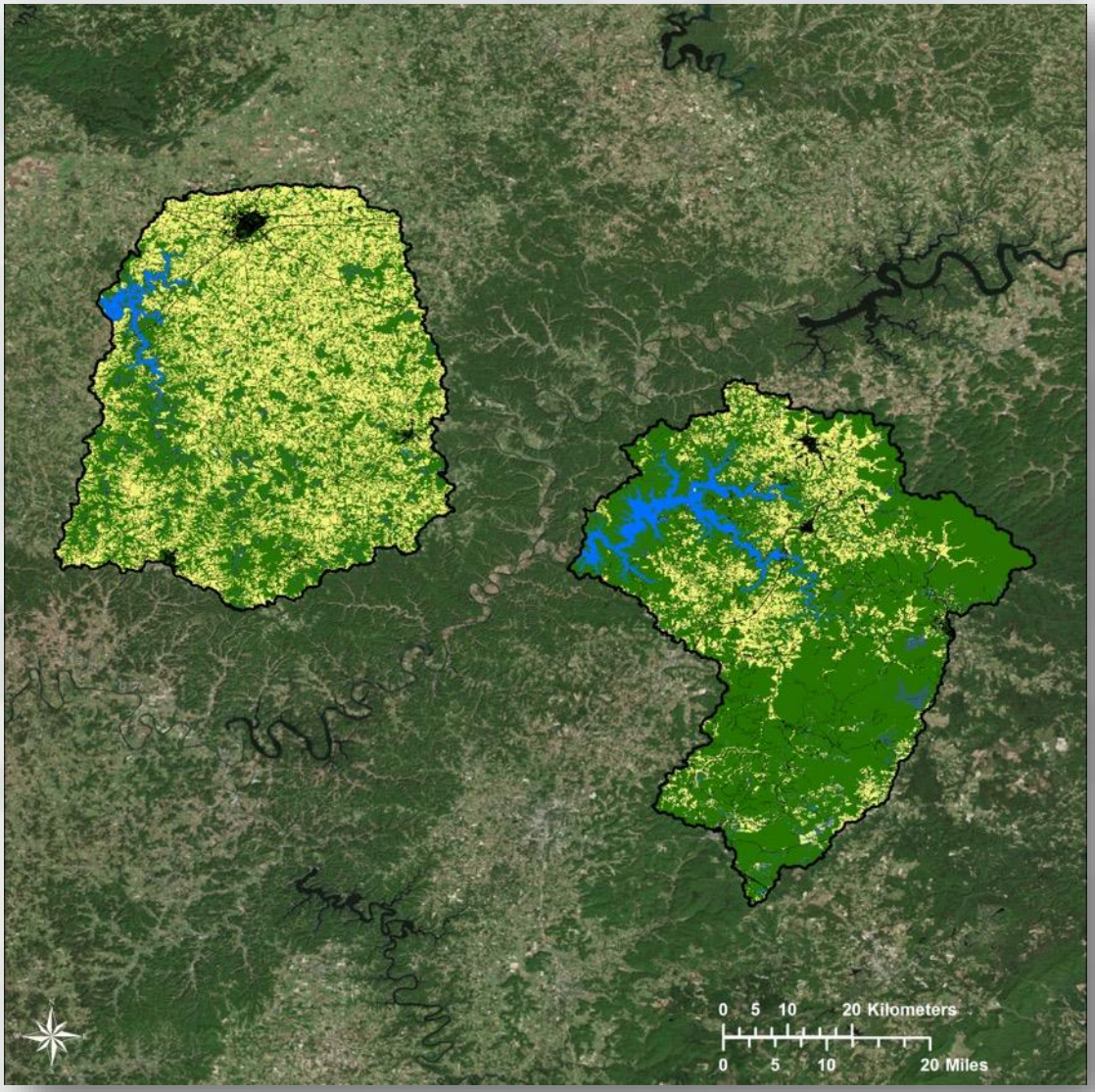


Barren River Reservoir

- Surface Area - 3,890 ha
- Watershed Area - 243,773 ha
- Annual rainfall – 51.2 inches

Dale Hollow Reservoir

- Surface Area – 10,322 ha
- Watershed Area - 242,508 ha
- Annual rainfall – 53.1 inches



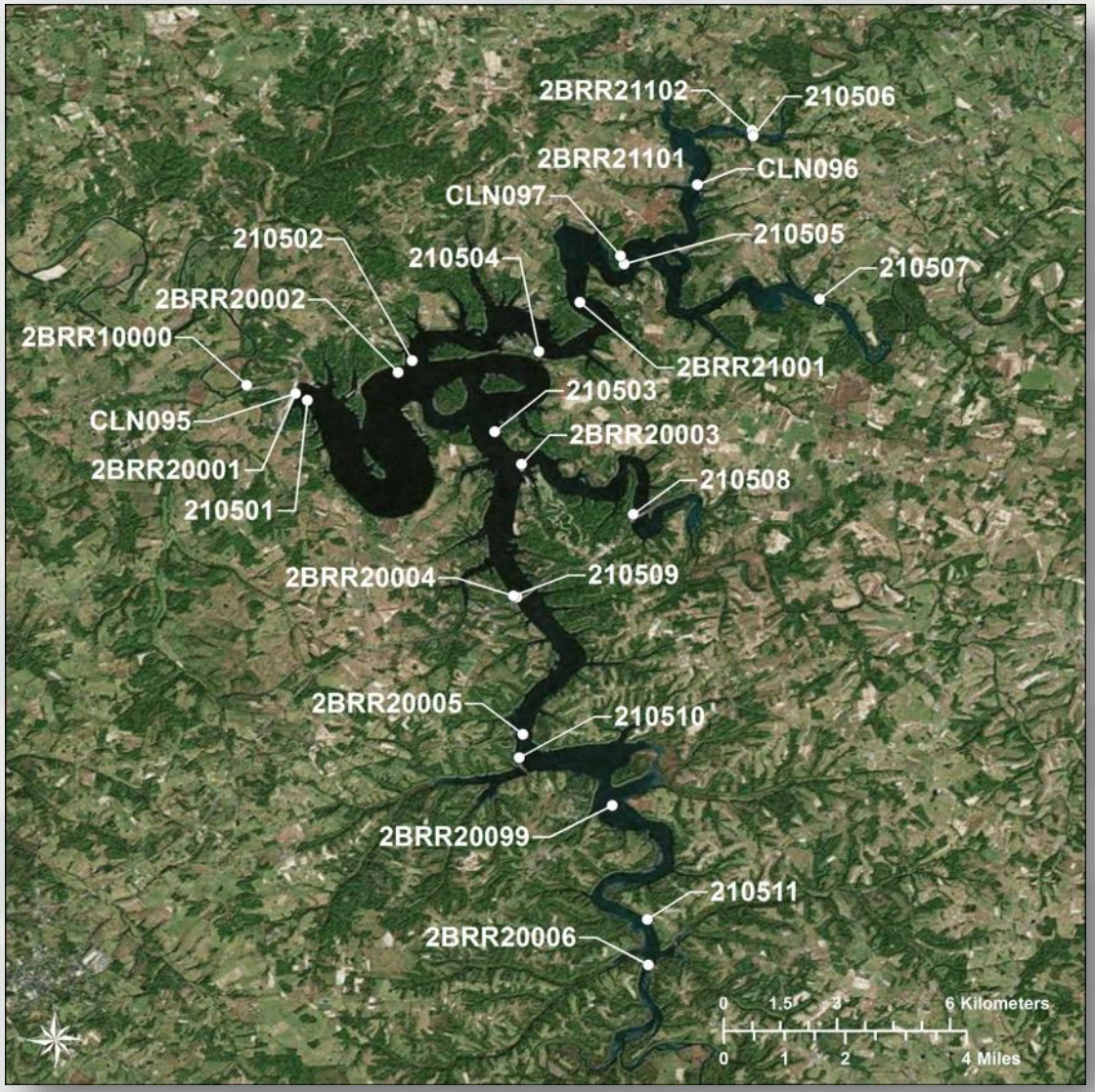
Barren River Reservoir

- Landcover (National Gap Analysis)
  - Agricultural – 114,121 ha
  - Developed – 15,553 ha
  - Forested – 103,187 ha
  - Sparse – 452 ha
  - Open Water – 3,890 ha
  - Disturbed – 6,768 ha

Dale Hollow Reservoir

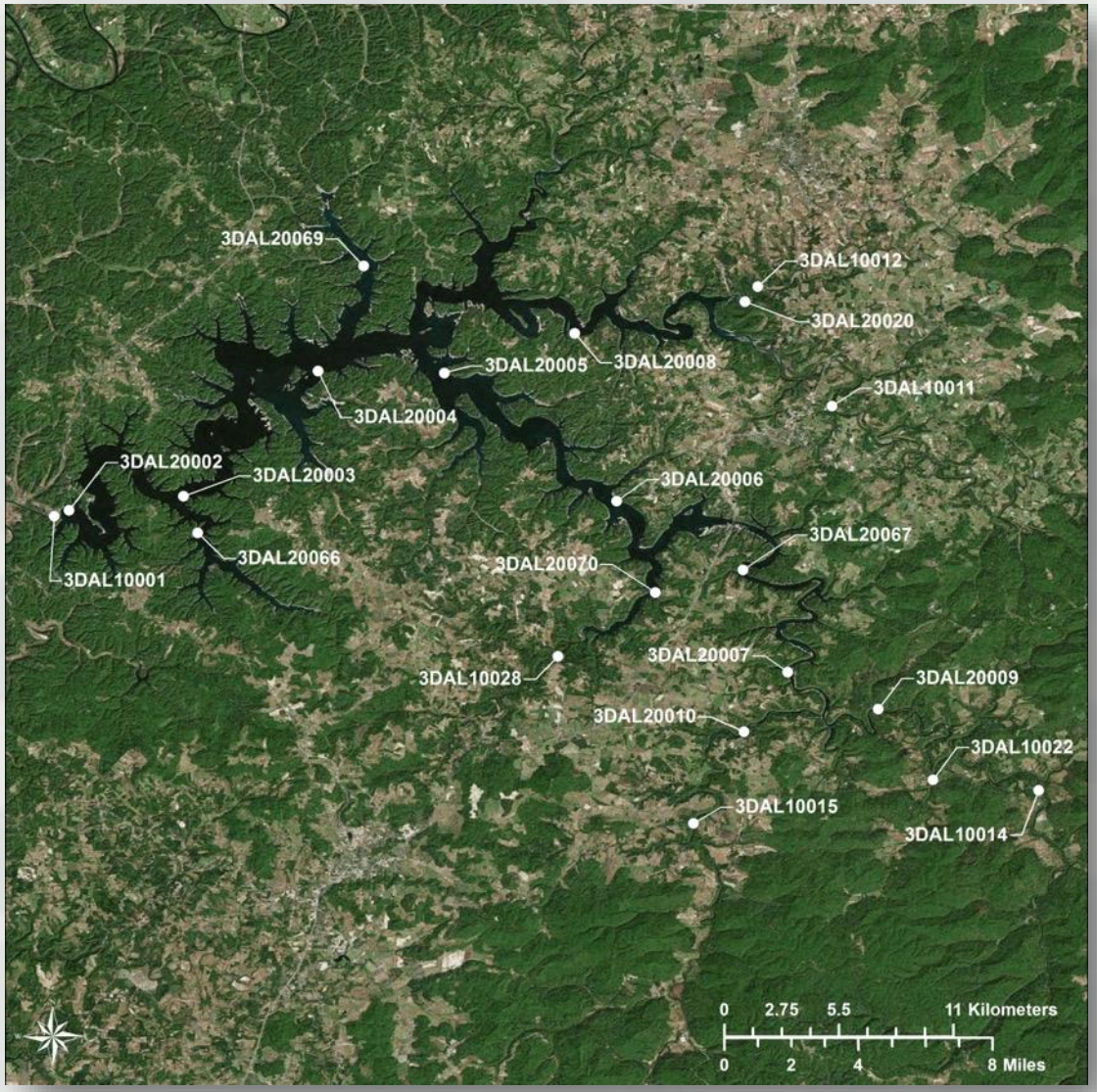
- Landcover (National Gap Analysis)
  - Agricultural – 45,489 ha
  - Developed – 13,884 ha
  - Forested – 162,237 ha
  - Sparse – 144 ha
  - Open Water – 10,322 ha
  - Disturbed – 8,865 ha

Barren River Project



Water Quality Sampling Locations
US Army Corps of Engineers
Louisville District

Dale Hollow Project



Water Quality Sampling Locations
US Army Corps of Engineers
Nashville District

Caveats to remember when looking at the data

- Limited to May-August time frame
- Surface (0 depth) samples only

- Is it reliable?
  - Many inconsistencies in frequency of sampling
- Differences between labs (Barren River data)
  - Split samples sent to RTI Laboratories were removed – data were orders of magnitude higher in some cases
- Some stations removed due to proximity to boat ramps (elevated nutrients due to sediment perturbations)

Station Selection: Barren River

Station Number	Ammonia	Iron	Nitrite	TOC	Phosphorus	Temperature	Phytoplankton	HAB
2BRR10000	9	10	13	14	15	34	0	29
2BRR10007	8	9	12	14	15	32	0	0
2BRR10009	2	2	2	2	2	2	0	0
2BRR10011	3	2	3	3	3	3	0	0
2BRR11002	9	9	14	15	16	34	0	0
2BRR11103	5	2	4	5	5	7	0	0
2BRR11111	9	10	14	15	16	34	0	0
2BRR12001	2	0	2	2	2	3	0	0
2BRR13001	2	0	2	2	1	2	0	0
2BRR20001	1	3	5	6	7	384	45	30
2BRR20002	1	0	1	1	1	32	43	30
2BRR20004	1	0	1	1	1	7	6	30
2BRR20005	1	0	1	1	1	31	43	0
2BRR21001	1	0	1	1	1	31	39	30
2BRR21003	1	0	1	1	1	7	5	30
2BRR22001	1	0	1	1	1	6	5	0

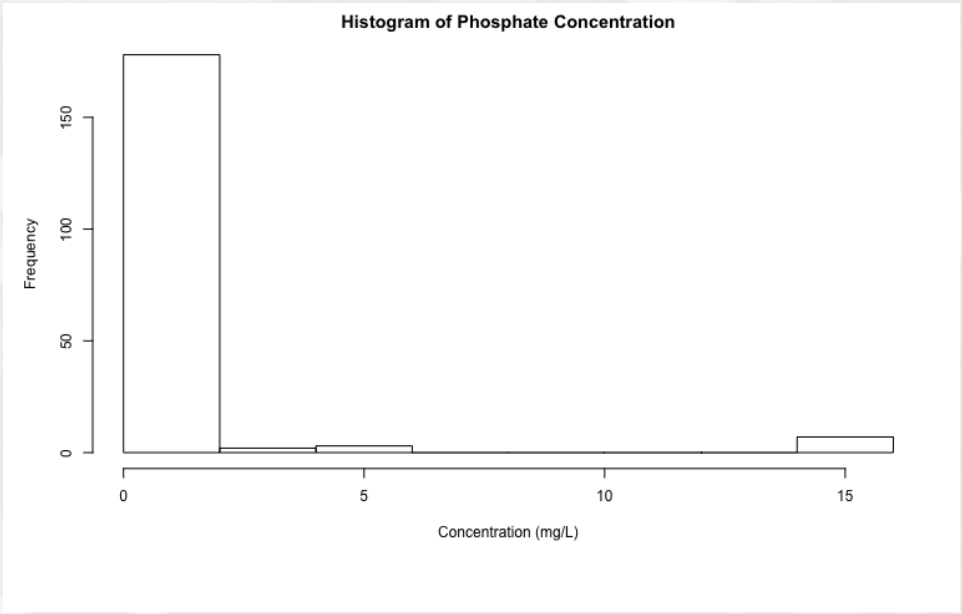
57 stations in data set, 16 used in analysis

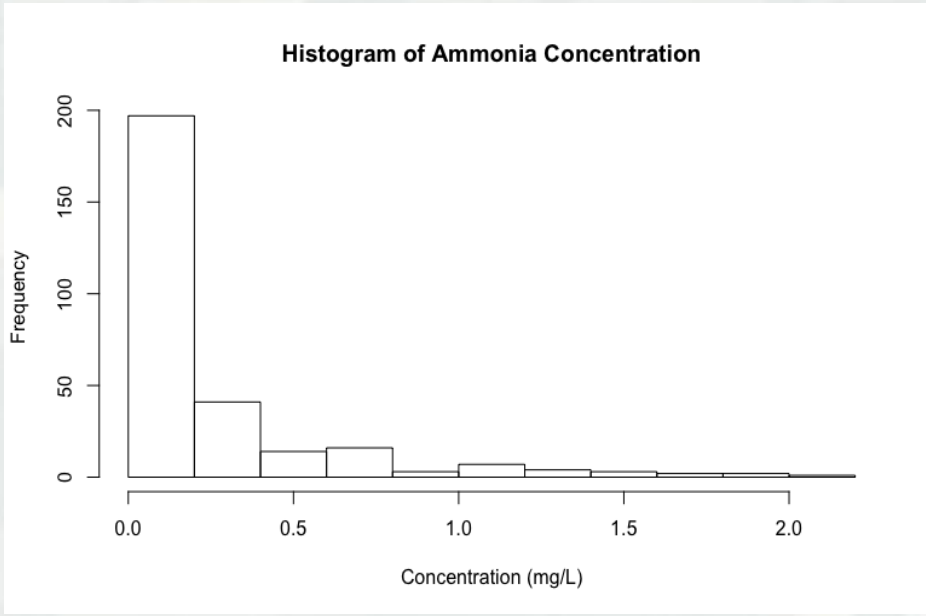
Station Selection: Dale Hollow

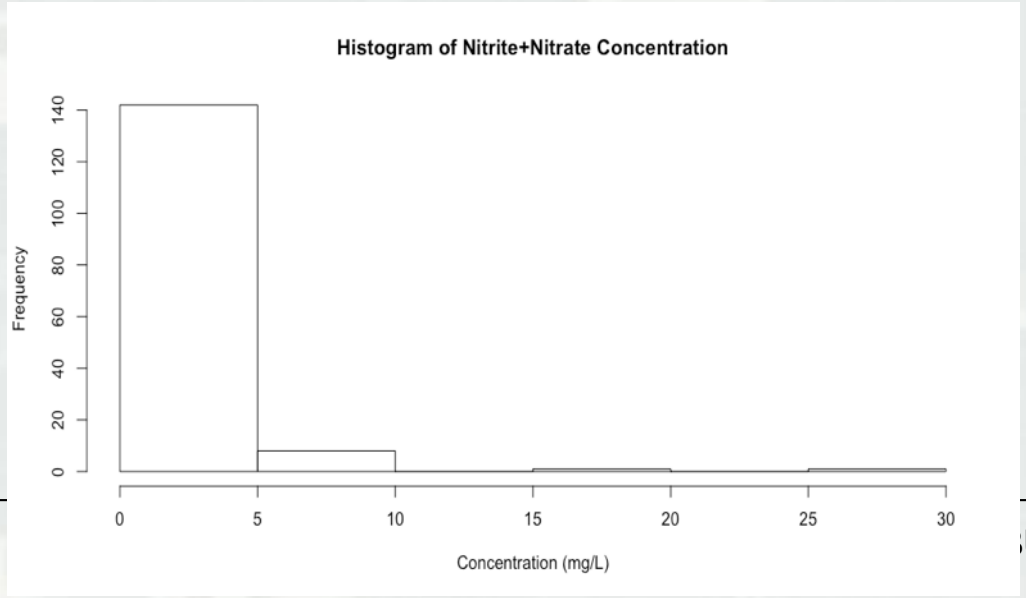
Station Number	Ammonia	Iron	Nitrite	TOC	pH	Phosphorus	Temperature	Phytoplankton
3DAL20002	33	34	34	28	83	32	84	0
3DAL20003	0	0	0	0	69	0	69	0
3DAL20004	33	34	34	28	54	32	54	1
3DAL20005	0	0	0	0	42	0	42	0
3DAL20006	33	34	34	28	48	32	48	0
3DAL20007	26	27	27	22	47	26	47	4
3DAL20008	33	34	34	28	43	32	43	0
3DAL20009	16	16	16	11	44	15	44	6
3DAL20010	17	17	17	12	44	16	44	8
3DAL20020	8	8	8	8	22	8	22	5
3DAL20050	0	0	0	0	0	0	0	0
3DAL20052	0	0	0	0	0	0	0	0
3DAL20053	0	0	0	0	0	0	0	0
3DAL20054	0	0	0	0	0	0	0	0
3DAL20055	0	0	0	0	0	0	0	0
3DAL20056	0	0	0	0	0	0	0	0
3DAL20057	0	0	0	0	0	0	0	0
3DAL20058	0	0	0	0	0	0	0	0
3DAL20059	0	0	0	0	0	0	0	0
3DAL20060	0	0	0	0	0	0	0	0
3DAL20061	0	0	0	0	0	0	0	0
3DAL20062	0	0	0	0	0	0	0	0
3DAL20063	0	0	0	0	0	0	0	0
3DAL20064	0	0	0	0	0	0	0	0
3DAL20065	0	0	0	0	0	0	0	0
3DAL20066	0	0	0	0	3	0	3	0
3DAL20067	0	0	0	0	17	0	17	0
3DAL20068	0	0	0	0	0	0	0	0
3DAL20069	0	0	0	0	3	0	3	0
3DAL20070	0	0	0	0	4	0	4	0

All 30 stations used in data analysis

Outlier Removal: Barren River

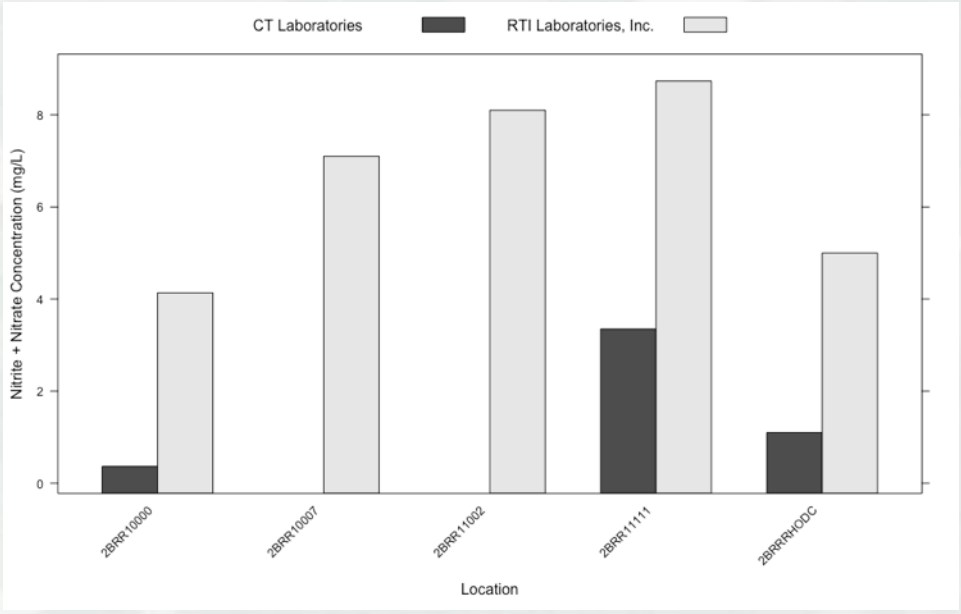




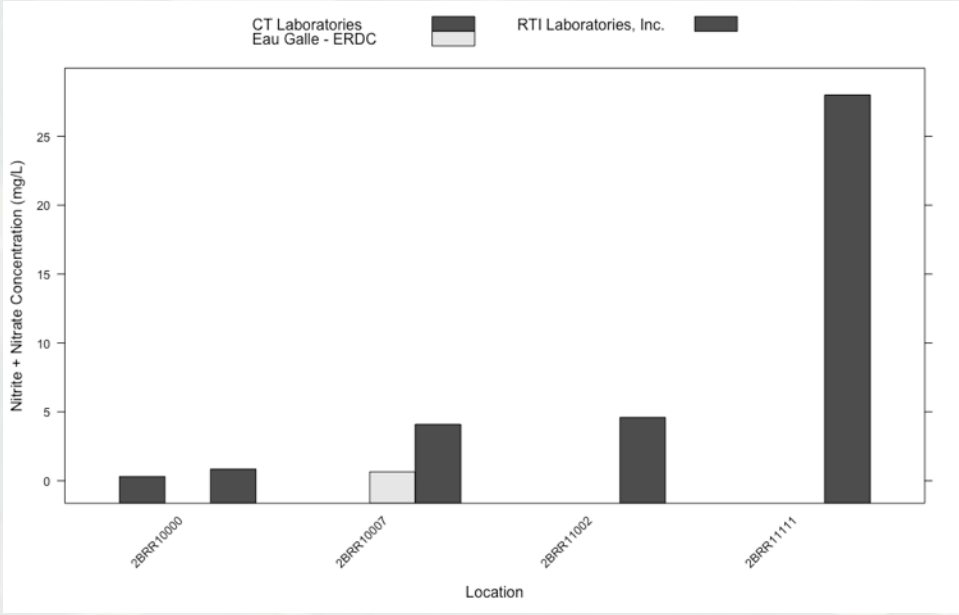


Outlier Removal: Lab Variation

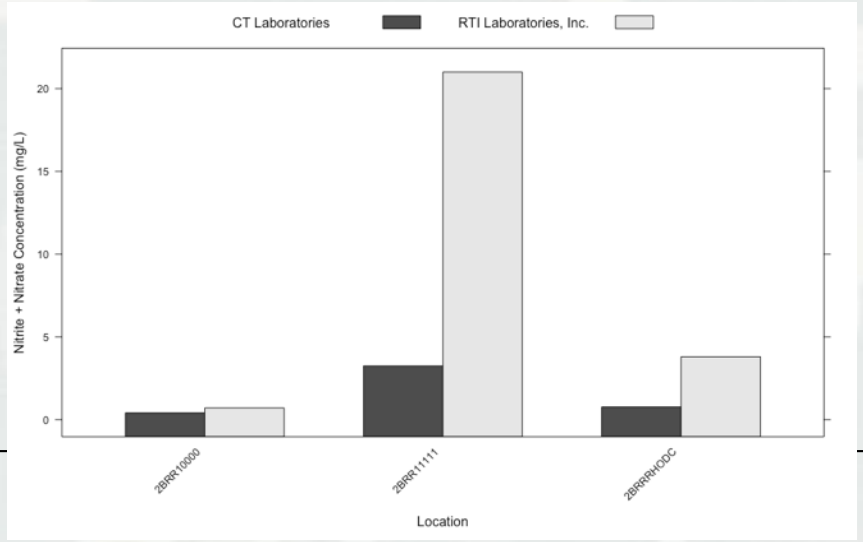
June

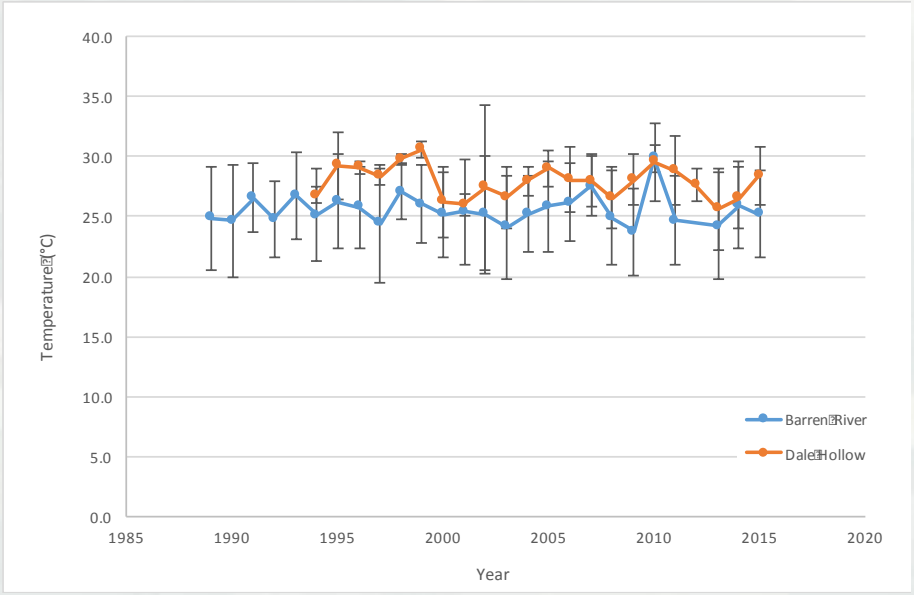


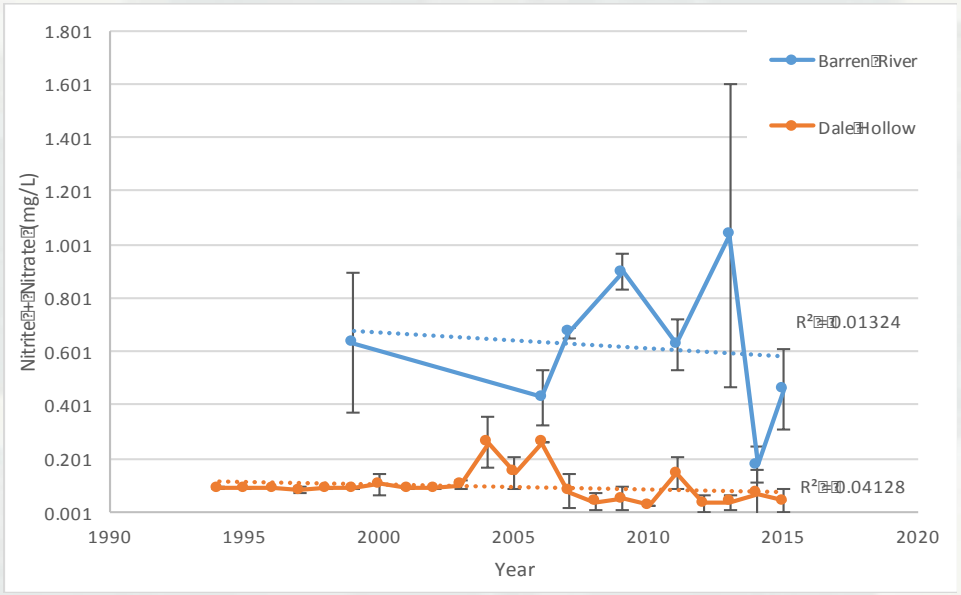
July

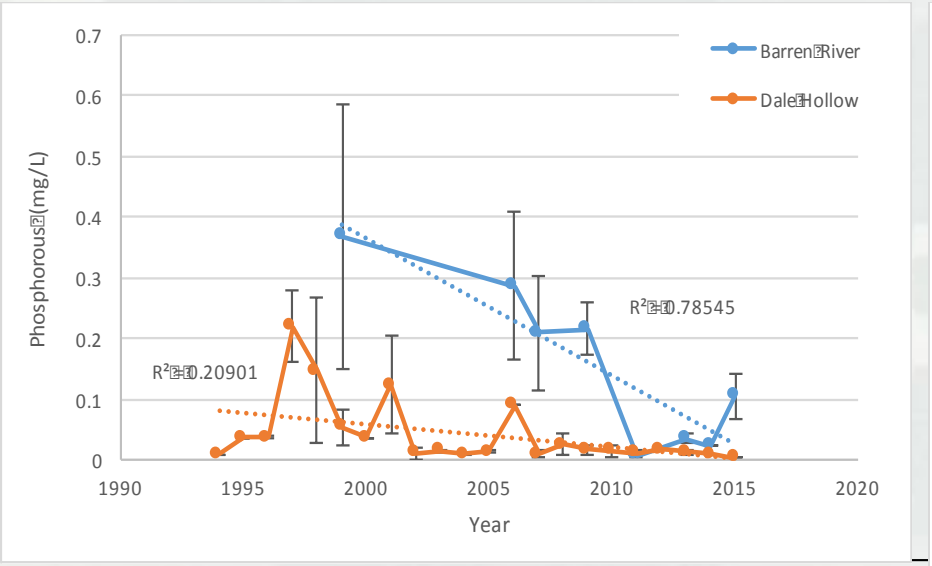


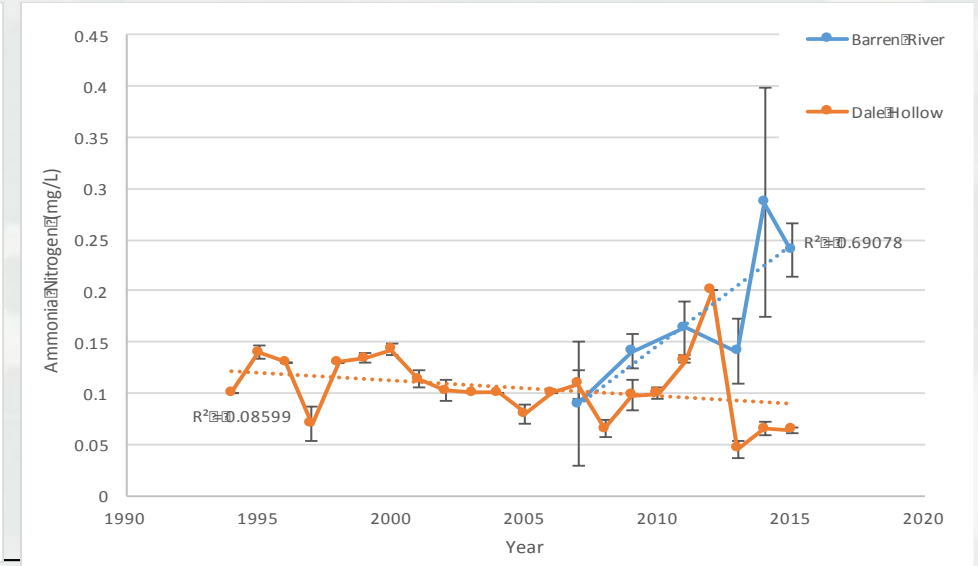
August



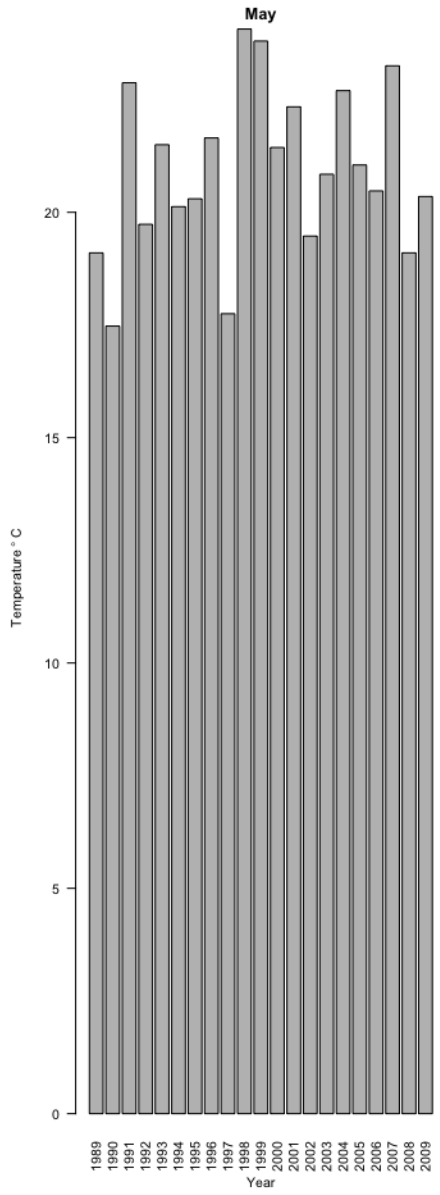

Temperature (°C)
Year
Barren River
Dale Hollow

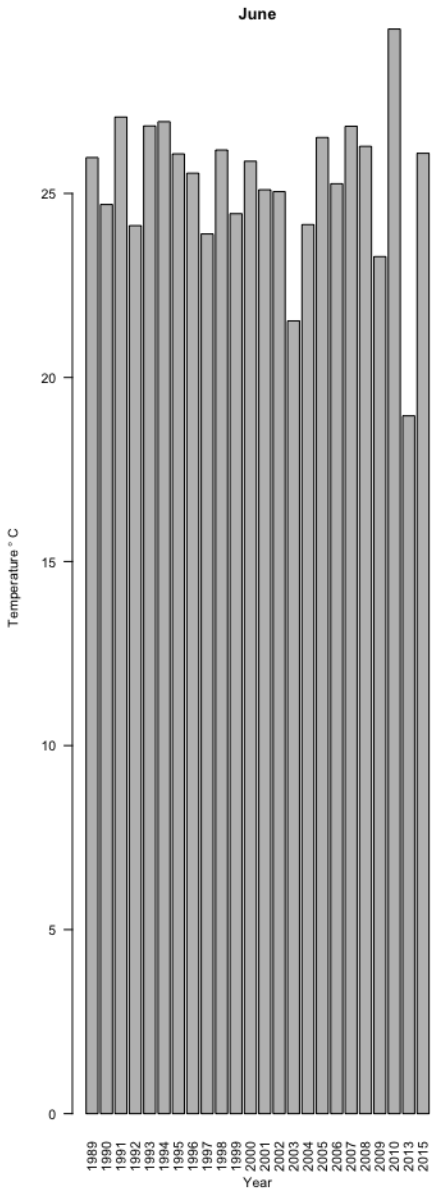

Nitrite + Nitrate (mg/L)
Year
Barren River
Dale Hollow
R² = 0.01324
R² = 0.04128

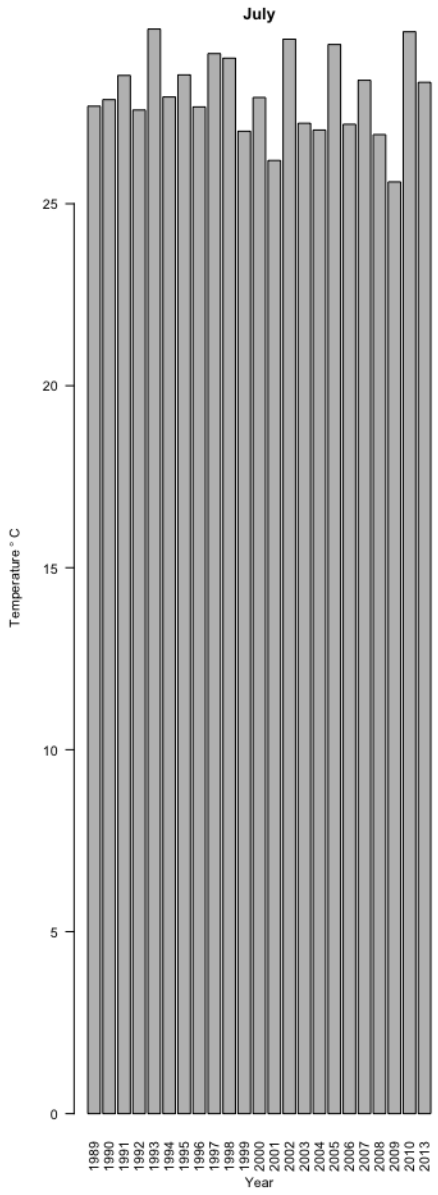

Phosphorous (mg/L)
Year
Barren River
Dale Hollow
R² = 0.78545
R² = 0.20901

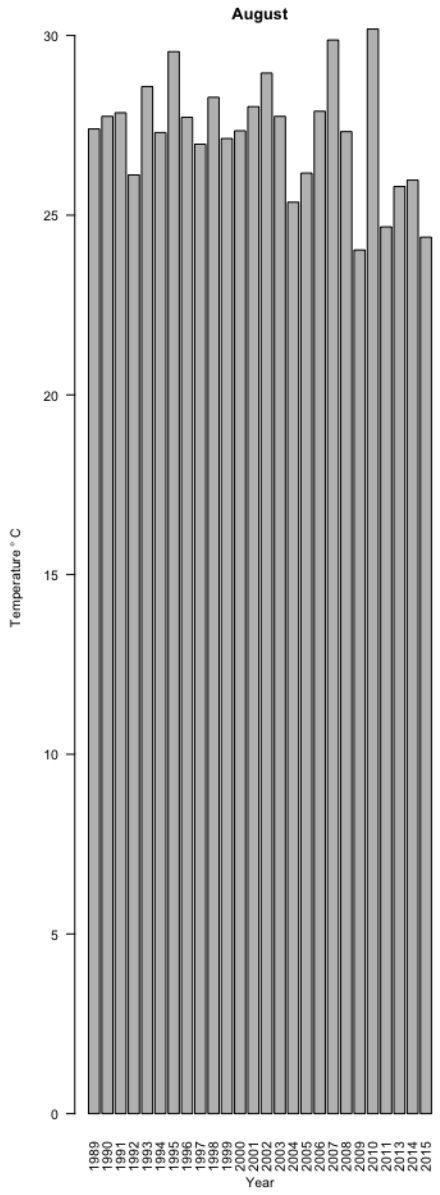

Ammonia Nitrogen (mg/L)
Year
Barren River
Dale Hollow
R² = 0.69078
R² = 0.08599

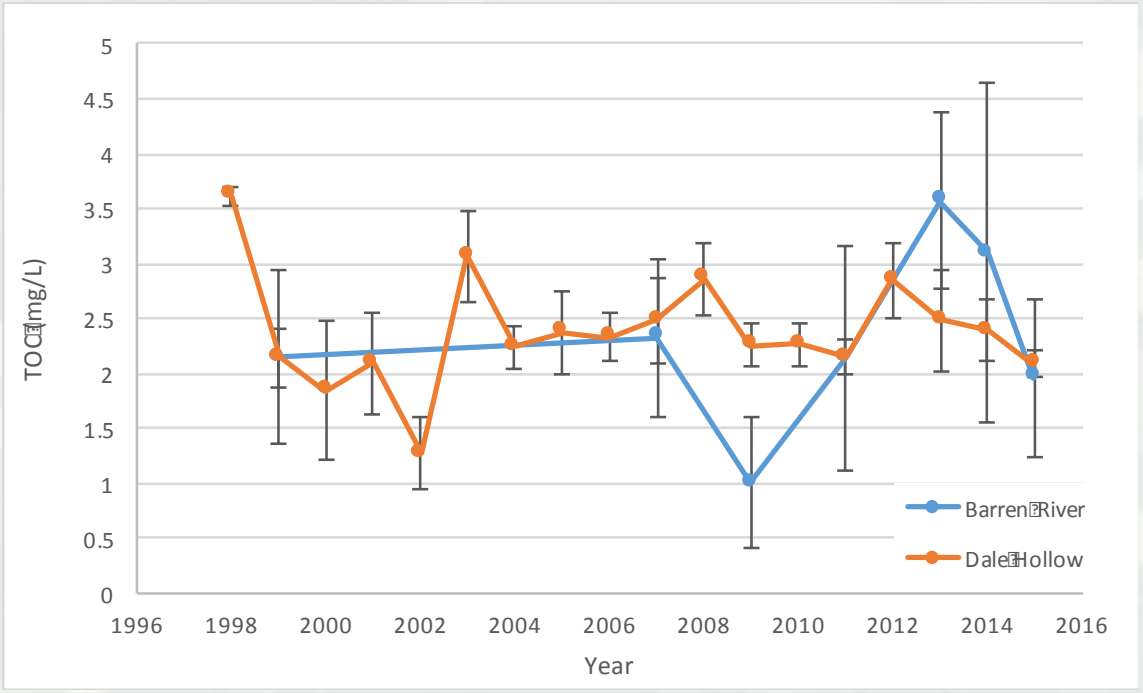
Monthly Water Temperature



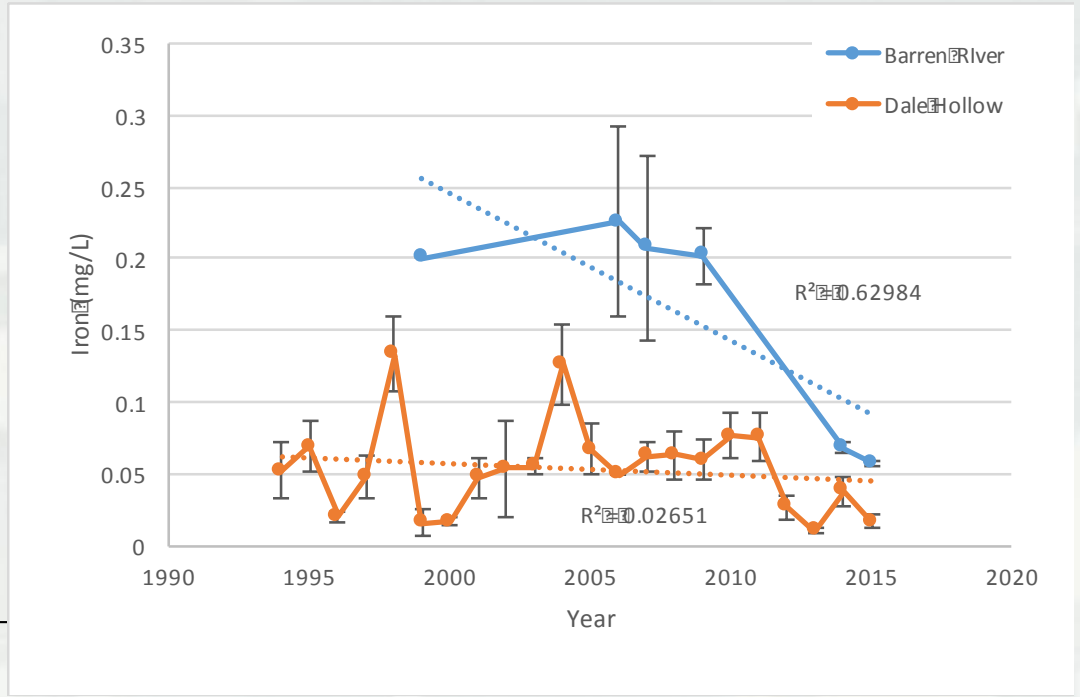




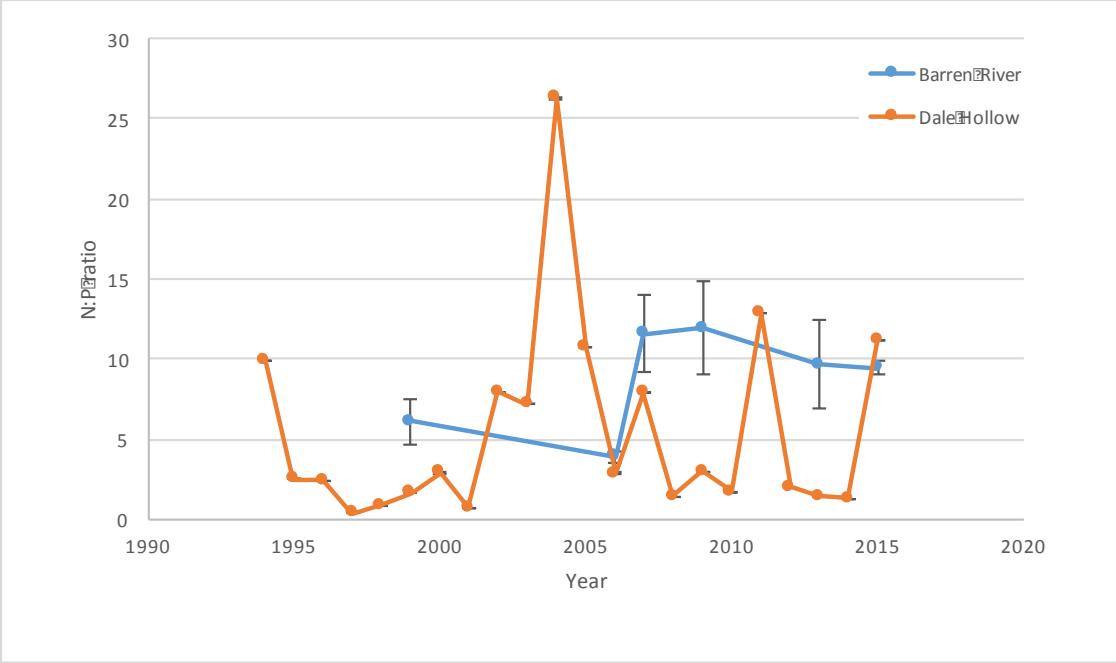




Do rain events contribute to this variability?



N:P ratio



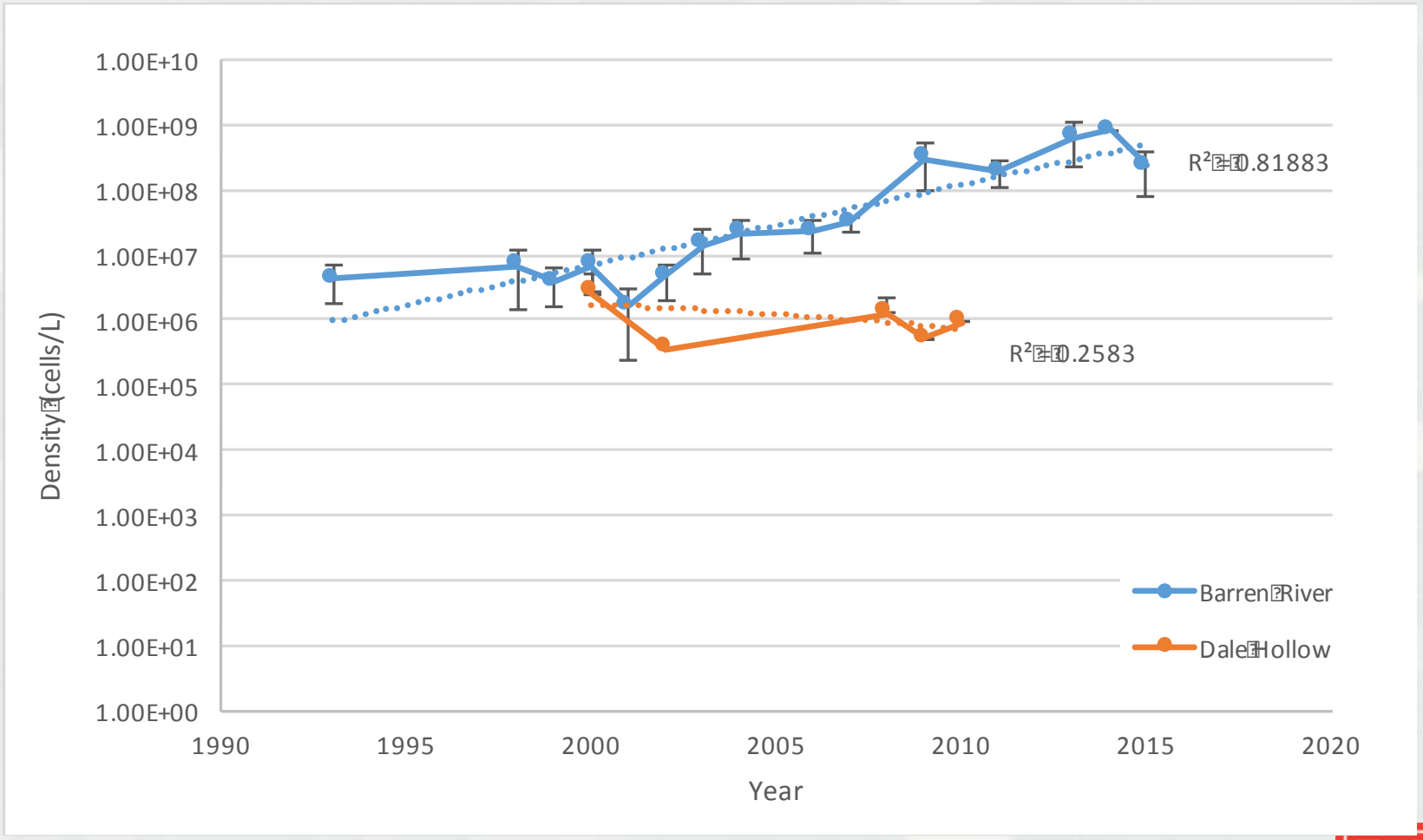
N:P ratio between 5-10 can lead to communities dominated by cyanobacteria

Bulgakov, N. G.; Levich, A. P. Archiv für Hydrobiologie - Hauptbände Volume 146 Number 1 (1999), p. 3 - 22

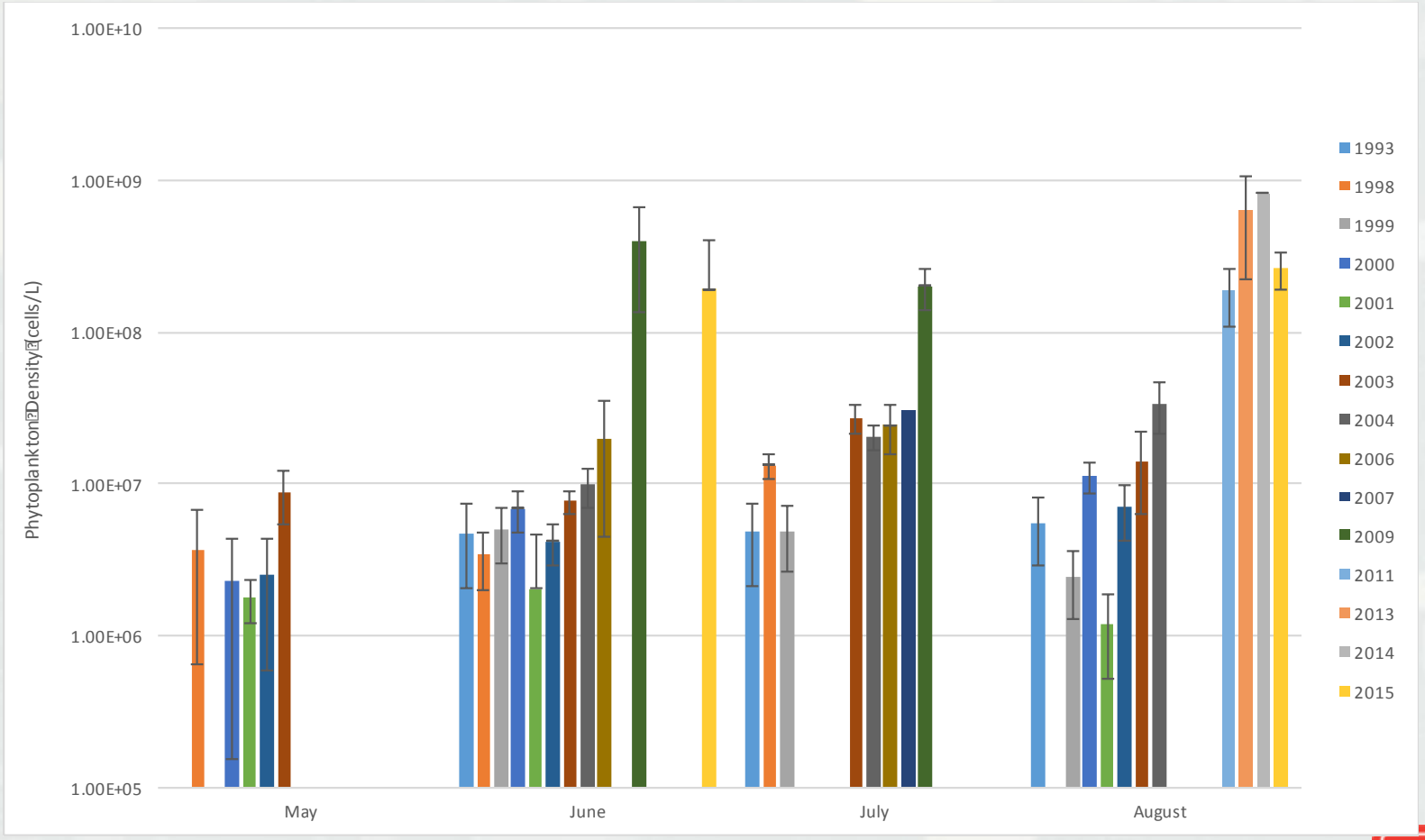
N:P ratio > 8.5 may be optimal depending on species

Christopher A. Klausmeier, Elena Litchman2,3, Tanguy Daufresne & Simon A. Levin Nature 429, 171-174 (13 May 2004)

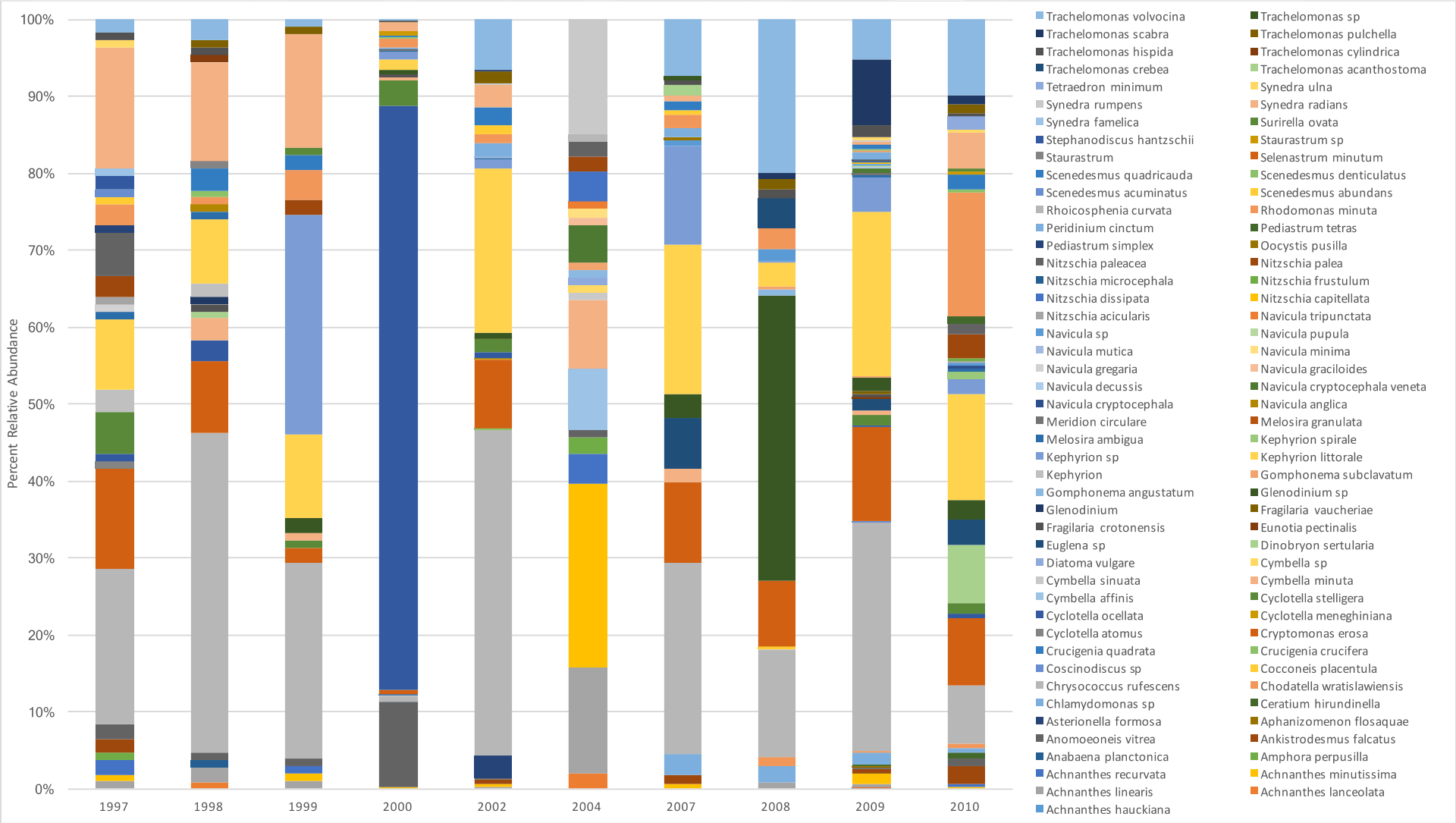
Annual average phytoplankton density



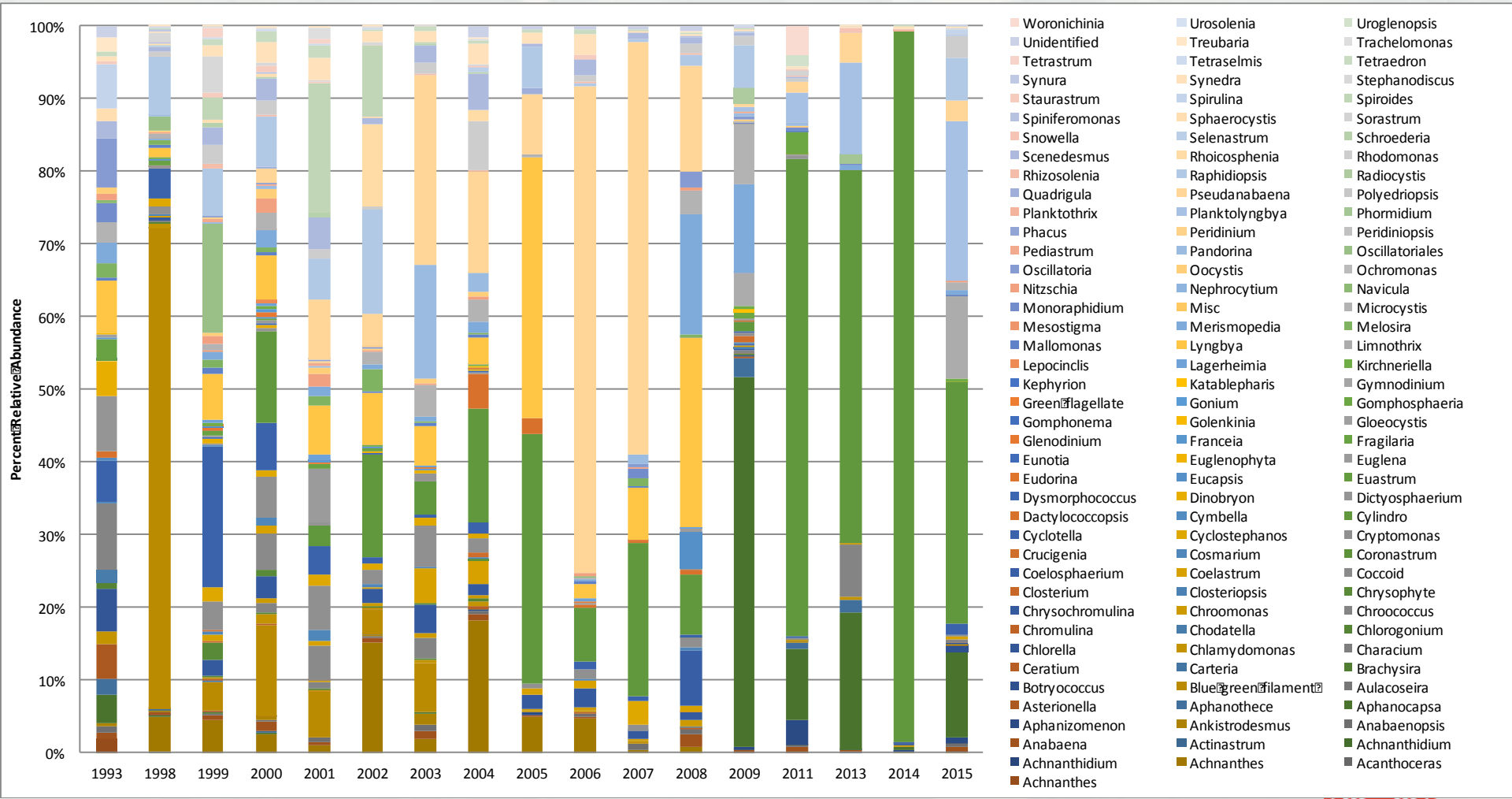
Total phytoplankton by month (BR)



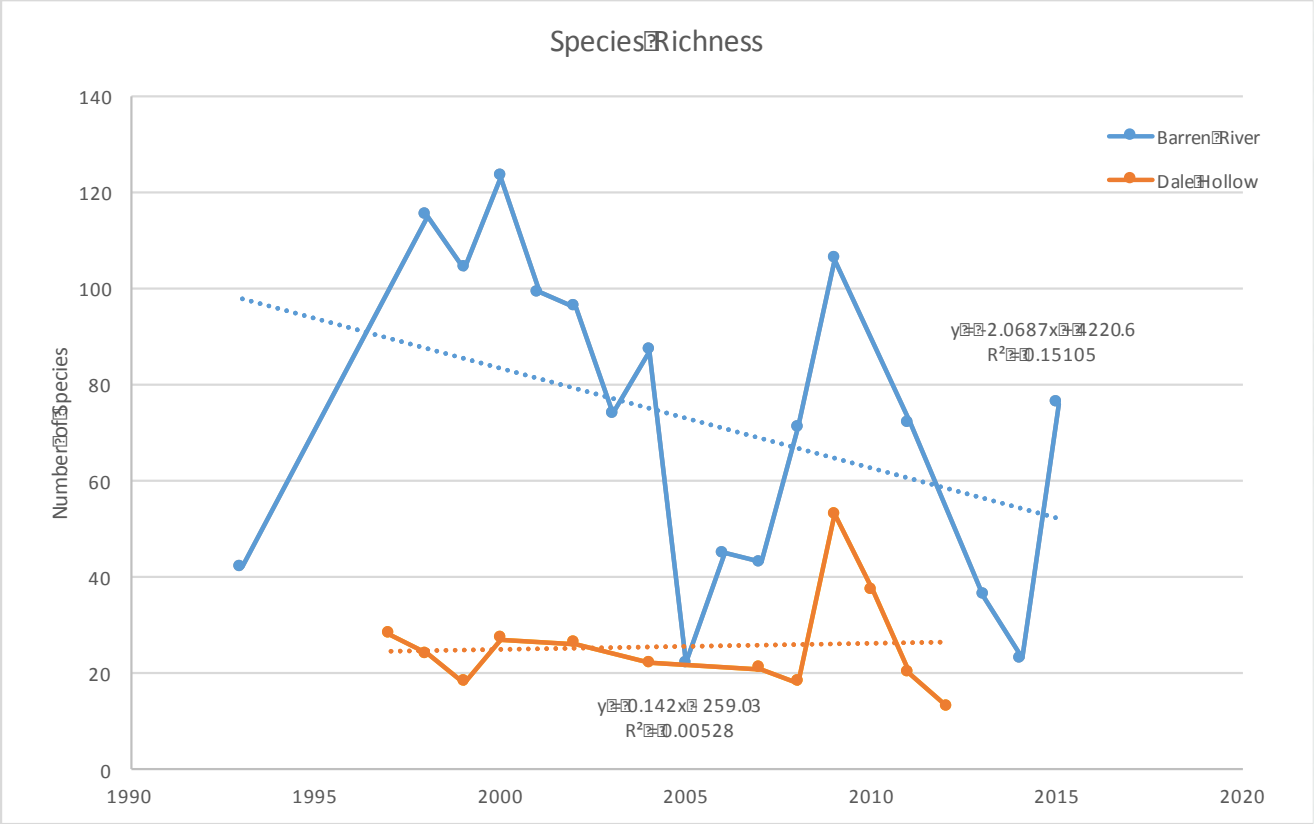
Dale Hollow Total Phyto Diversity



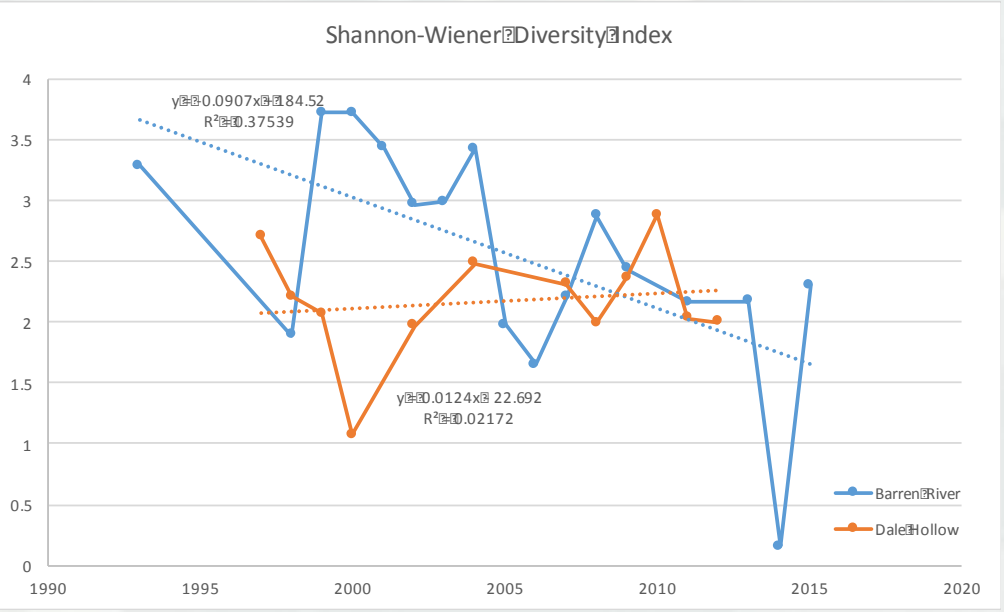
Barren River Total Phyto



Barren River Lake HABs



Shannon Diversity Index

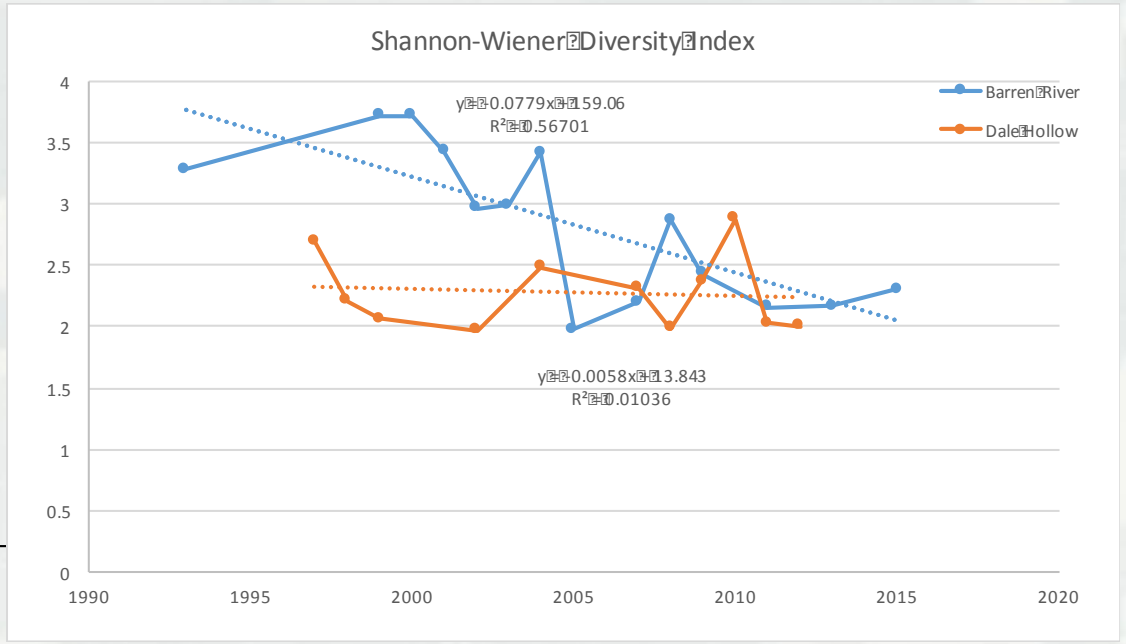


$$H' = -\sum_{i=0}^{R} \rho_i ln(\rho_i)$$

Difference in diversity is statistically significant ($p<0.05$, Welch's unequal variance T-Test)

With outliers

Outliers removed



Summary

- More agriculture in BR could be the source of historically higher N and P levels
- Increasing phytoplankton densities in BR, constant in DH
- Decreasing phytoplankton and HAB species diversity at BR

- Possible drivers
  - Increasing ammonia
  - Could decreasing phosphorus be optimizing N:P for bloom formation at BR?

- Frequent changes in the N:P ratio at DH may inhibit HAB occurrence.
  - Due to rain fall events, number of inlets?

Conclusions and Recommendations

- N:P ratio likely a contributing factor
- Loss of phytoplankton diversity may also play a role
- Periodic flush of reservoir needed to induce variation in nutrient and phytoplankton concentrations
- SOPs needed to standardize HAB sampling and analysis
  - ► e.g. avoid sampling near boat ramps

Research Team

- Jed Eberly – Environmental Microbiologist

  Lead PI, responsible for project oversight, cyanobacteria culturing, molecular techniques, and experimental design

- Christina Saltus – GISP

  Data processing and analysis

- Scott Bourne – Research Physical Scientist

  Laboratory and meso-scale hyperspectral imaging, image processing

- Cari Jung - Environmental Microbiologist

  Data analysis, district consulting and support, HAB monitoring

Questions?