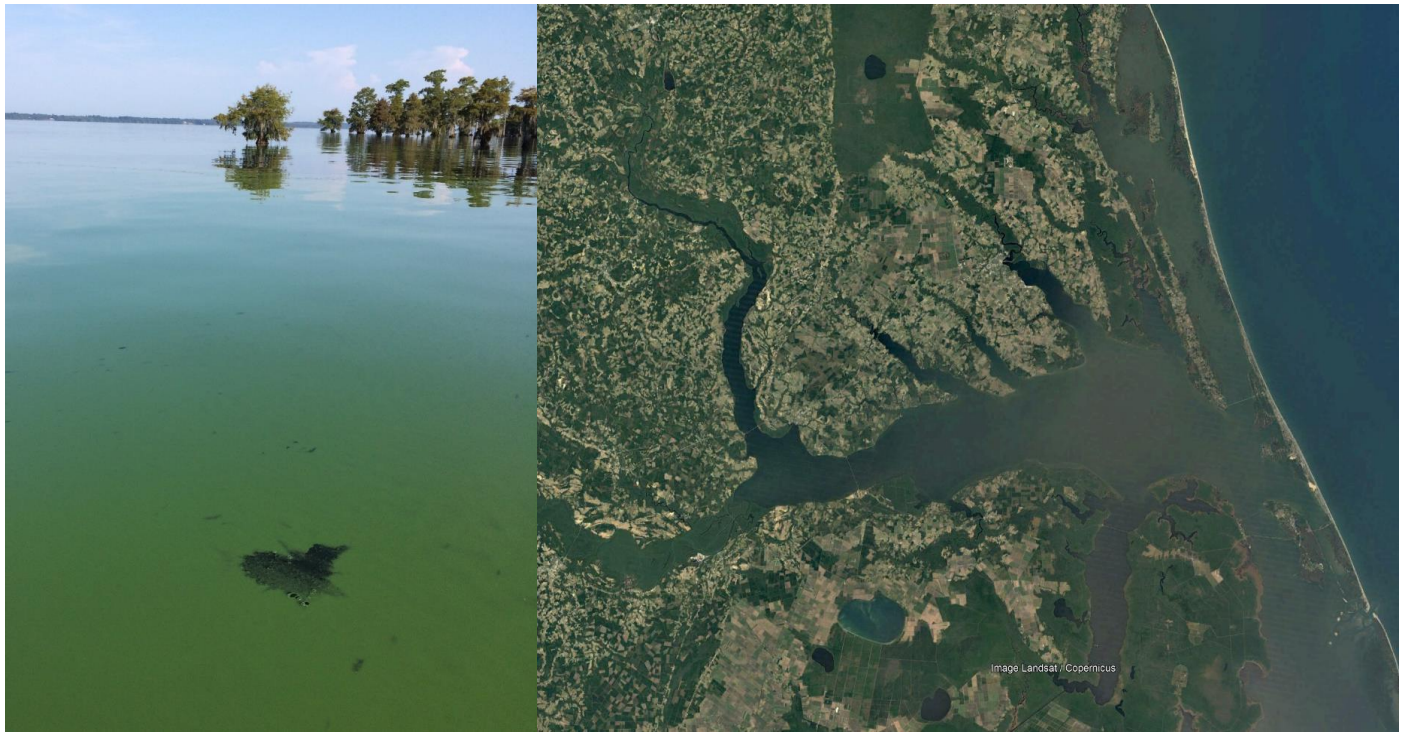
Experimental and observational evidence for a dual (N and P) nutrient management strategy for the Albemarle Sound system



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3 November 2023

Understanding which nutrient limits algal growth is critical for management

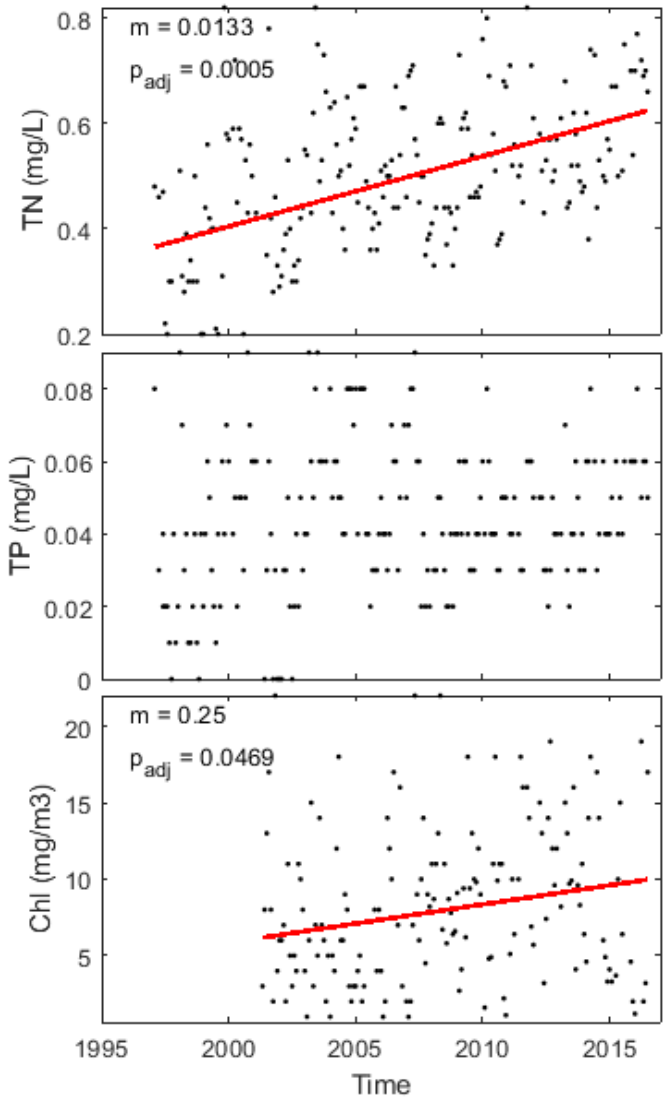
2021 NPDES Permit Application for International Paper- Franklin Mill

EFFLUENT CHARACTERISTICS	DISCHARGE LIMITATIONS			MONITORING REQUIREMENTS [a]		
	Monthly Average	Weekly Average	Minimum	Maximum	Frequency	Sample Type
Flow (MGD) [b]	NL	NA	NA	NL	1/Day	Measured
Flow, Seasonal (MG) [b]	NA	NA	NA	14,000	1/Month	Measured
pH (S.U.)[d]	NA	NA	6.0	9.0	1/Week	Grab
Total Suspended Solids (mg/l)[c][d]	374	NA	NA	748	1/Week	Grab
Total Suspended Solids (x 10^6) (lb/sea)	NA	NA	NA	2.88	1/Month	Grab
BOD_5 (mg/l)[c][d]	183	NA	NA	366	1/Week	Grab
BOD_5 (x 10^6) (lb/sea)	NA	NA	NA	4.4	1/Month	Grab
COD (mg/l)	NL	NA	NA	NL	1/Month	Grab
Color, PCU	NL	NA	NA	NL	1/Week	Grab
Total Nitrogen (mg/l)	NL	NA	NA	NL	1/Month	Grab
Total Phosphorus (mg/l)	2	NA	NA	NL	1/Week	Grab
Total Phosphorus (x 10^6) (lb/sea)	NA	NA	NA	0.2	1/Month	Grab
Ammonia-Nitrogen (NH_3-N) (mg/l) [c]	2.15	NA	NA	3.19	1/Week	Grab
Ammonia-Nitrogen (NH_3-N) (x 10^6) (lb/sea) [c]	0.22	NA	NA	0.32	1/Month	Grab

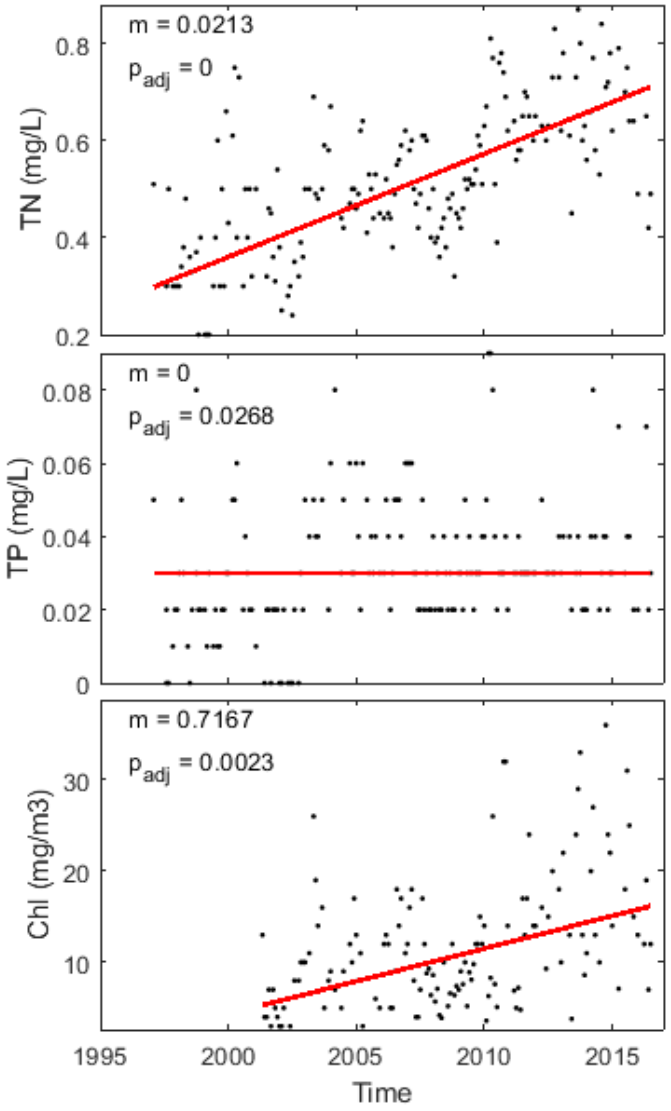
Limits on P discharge but no limit on N discharge to Chowan River

Trends in Albemarle Sound Water Quality

D9995C West Able. Sound



M39C East Able. Sound



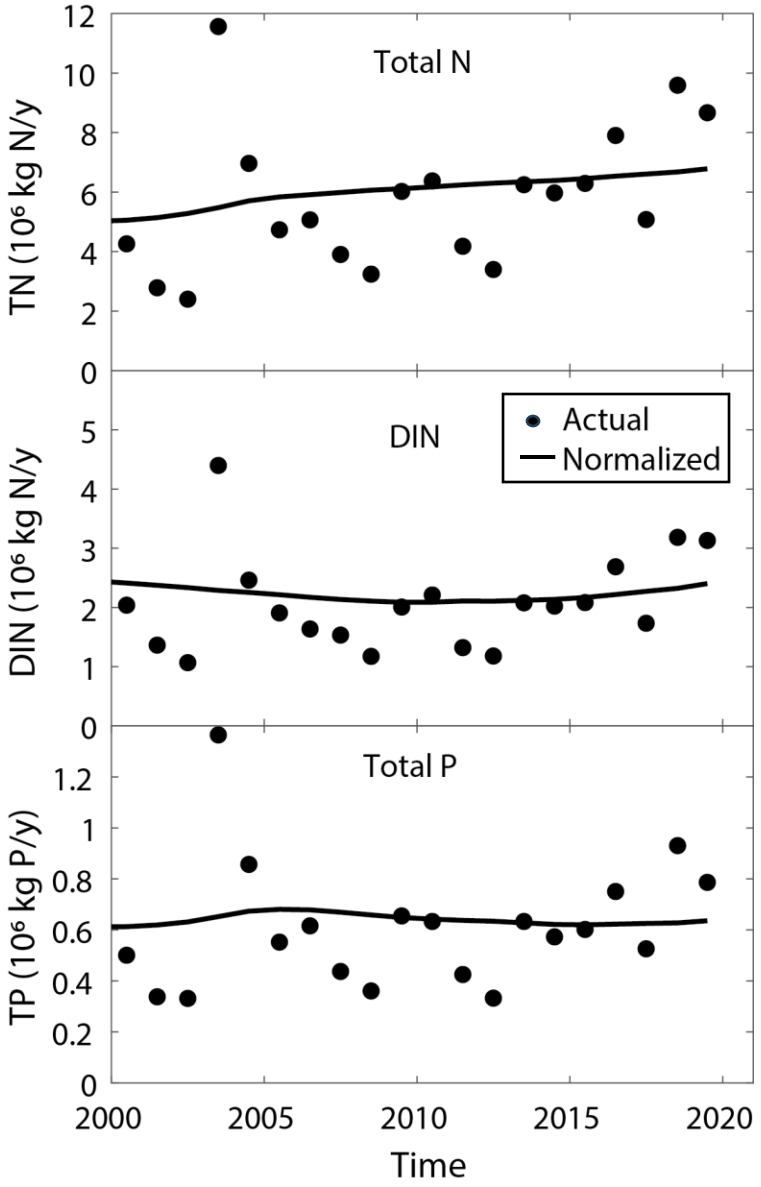
Chlorophyll *a* ↑

Total N ↑

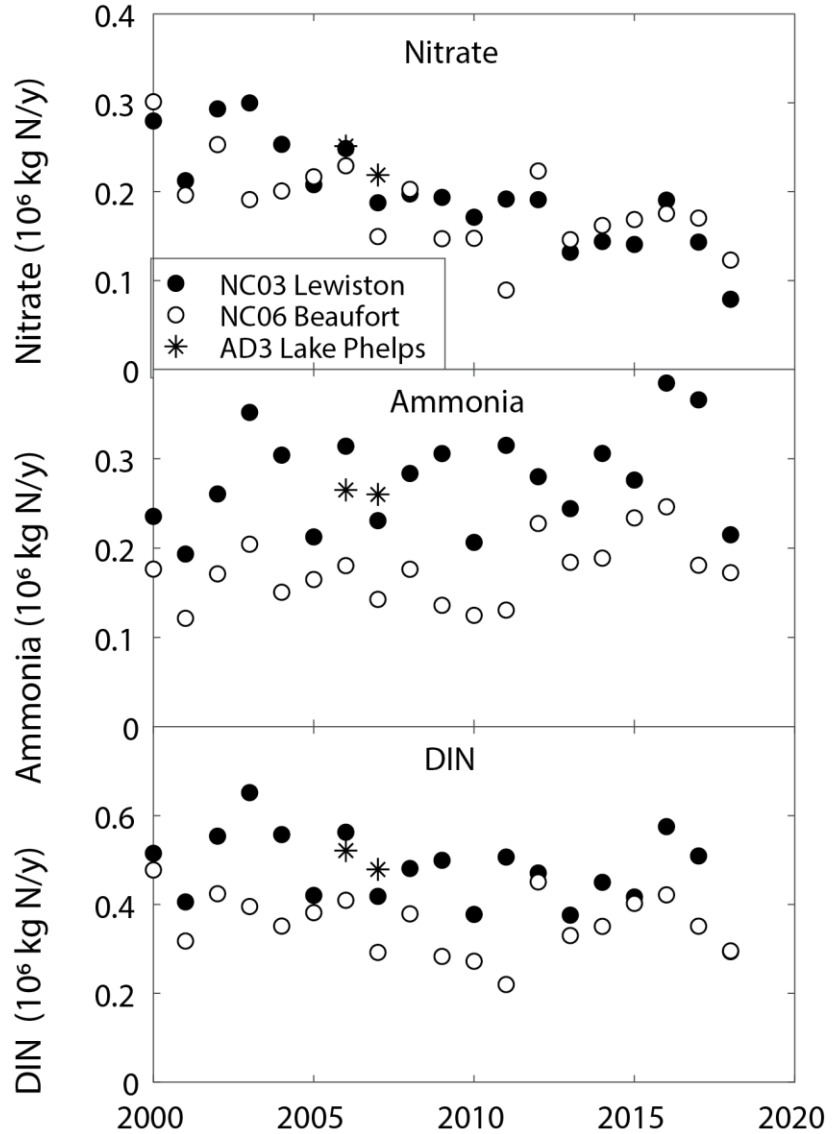
Total P →

Trends in Riverine and Atmospheric Nutrient Loads

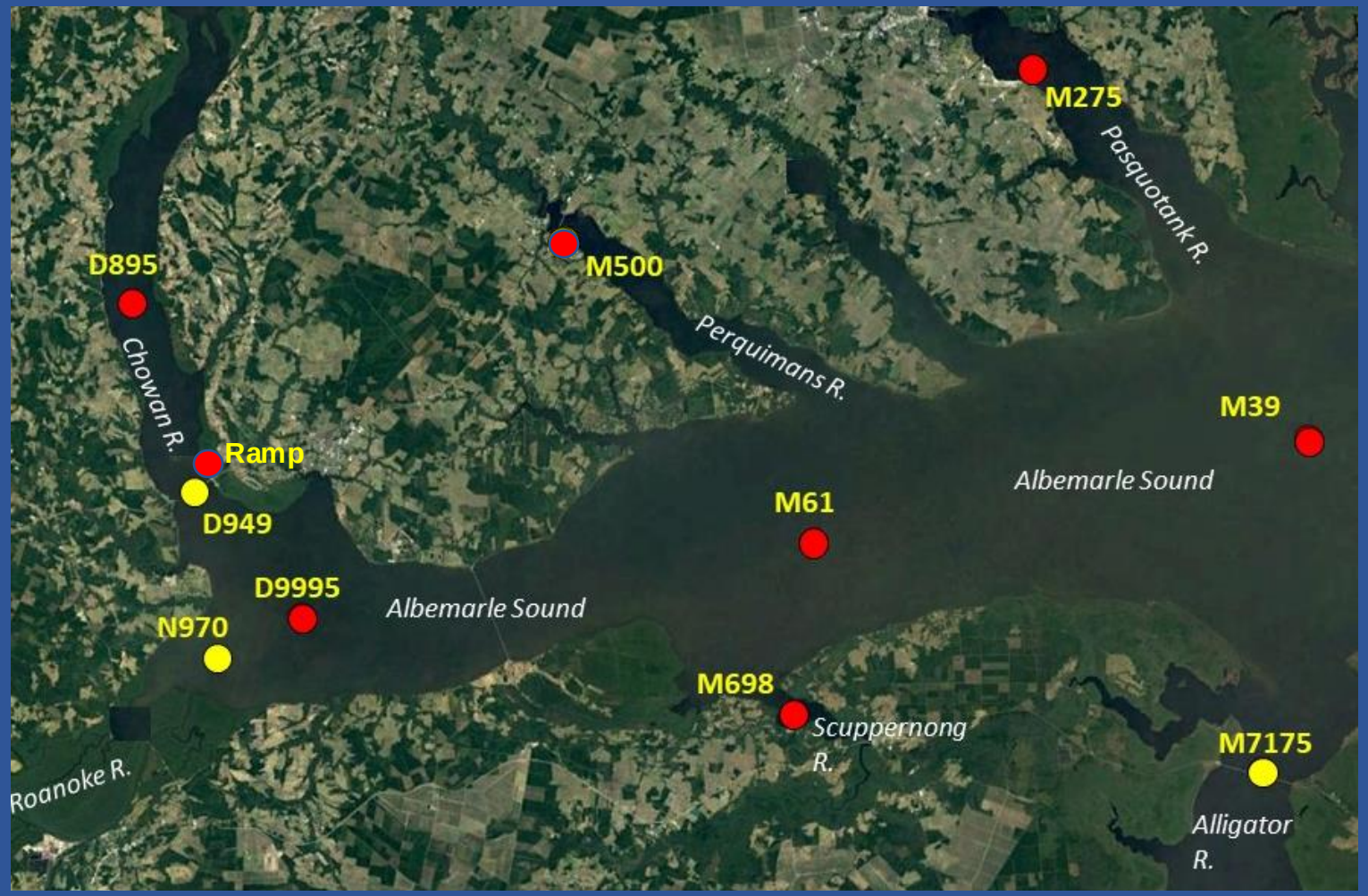
Roanoke + Chowan River Load



Atmospheric Deposition



Locations of Stations Assessed for Nutrient Limitation Status (red)

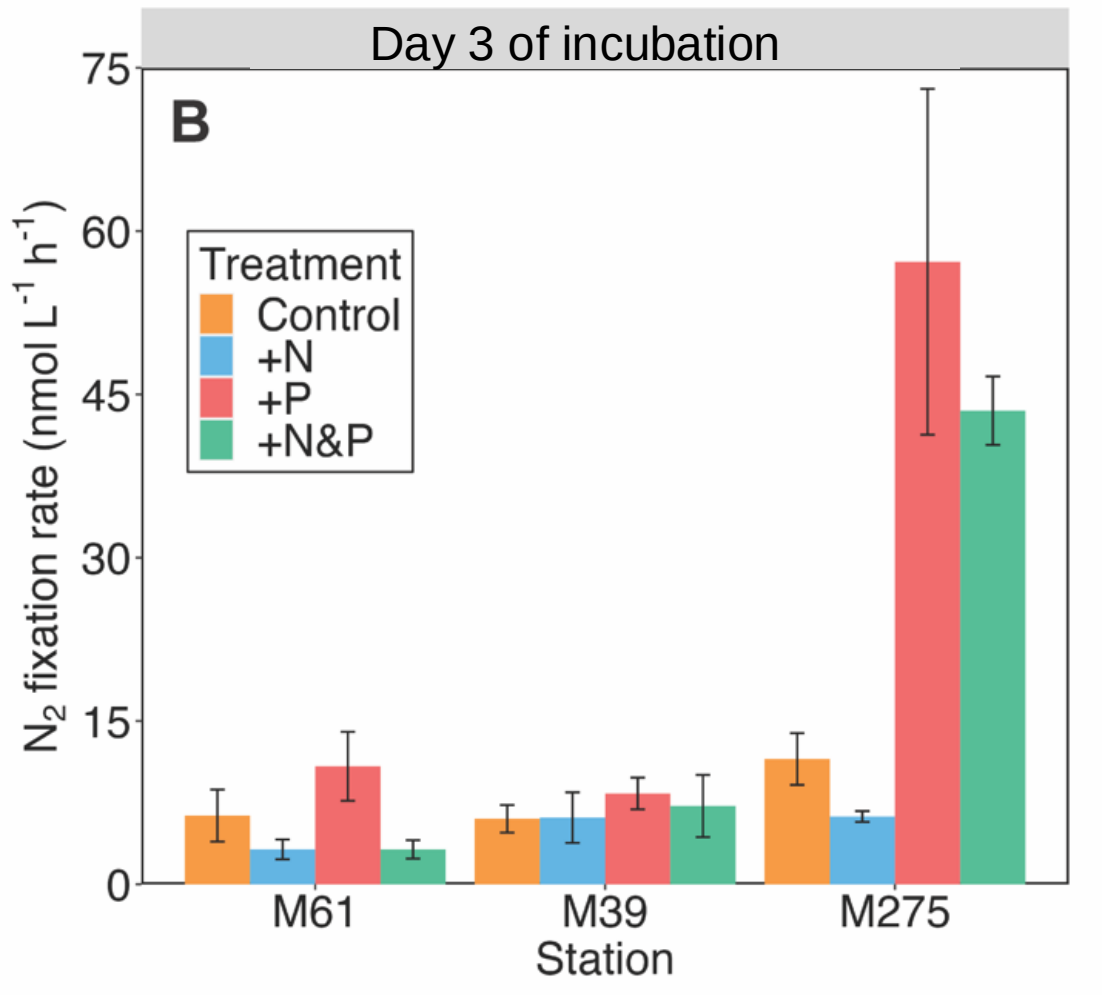


Summary of nutrient limitation responses from experiments conducted in Albemarle Sound and its tributary estuaries

	Oct 2018	May 2019	Aug 2019	Oct 2019	May 2021	Jul 2021	Oct 2021	Apr 2022	Jul 2022	Oct 2022
West Albemarle					N	N	N	---	N	N
Central Albemarle					N	---	N	N	Co	N
East Albemarle					N	---	N	N	N	---
Chowan R.	N				---	N	---	---	N	N
Edenton Bay		N	P	N						
Scuppernong R.					---	---	N	P		
Pasquotank R.					---	---	---	---	Co	---
Perquimans R.									---	N

21	N	= N limitation
2	P	= P limitation
2	Co	= N & P Co-limitation
15	---	= No nutrient limitation

Stimulation of N_2 fixation by P addition was common



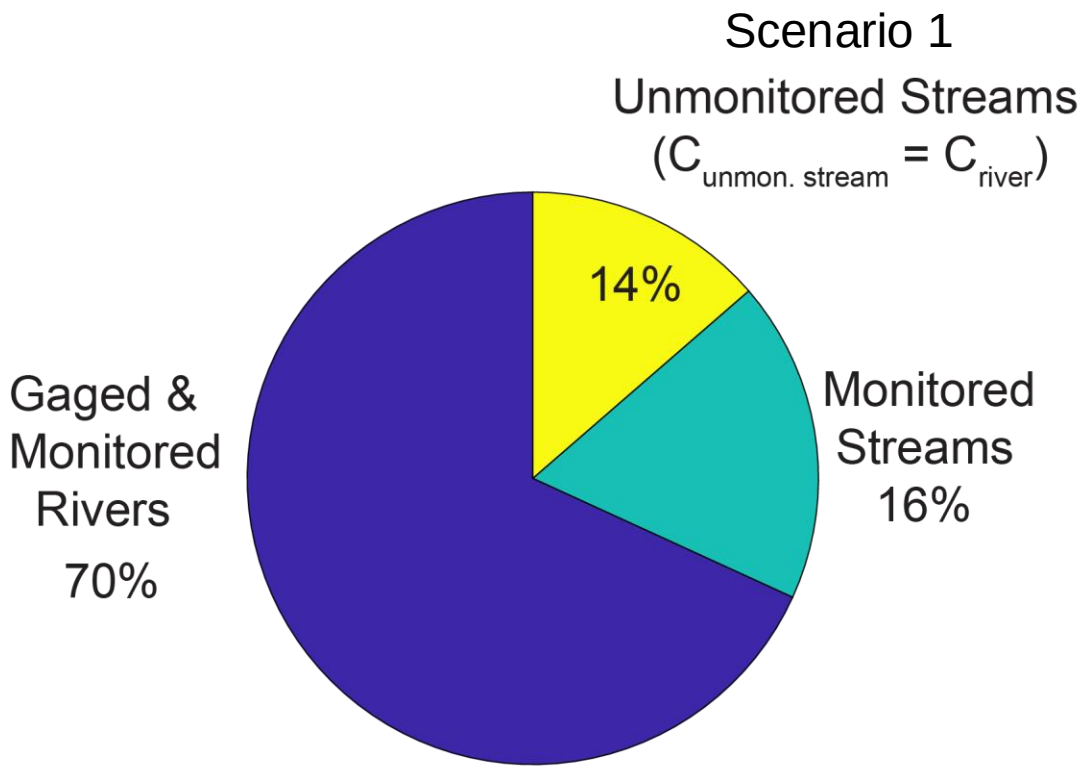
<u>Average increase over control</u>

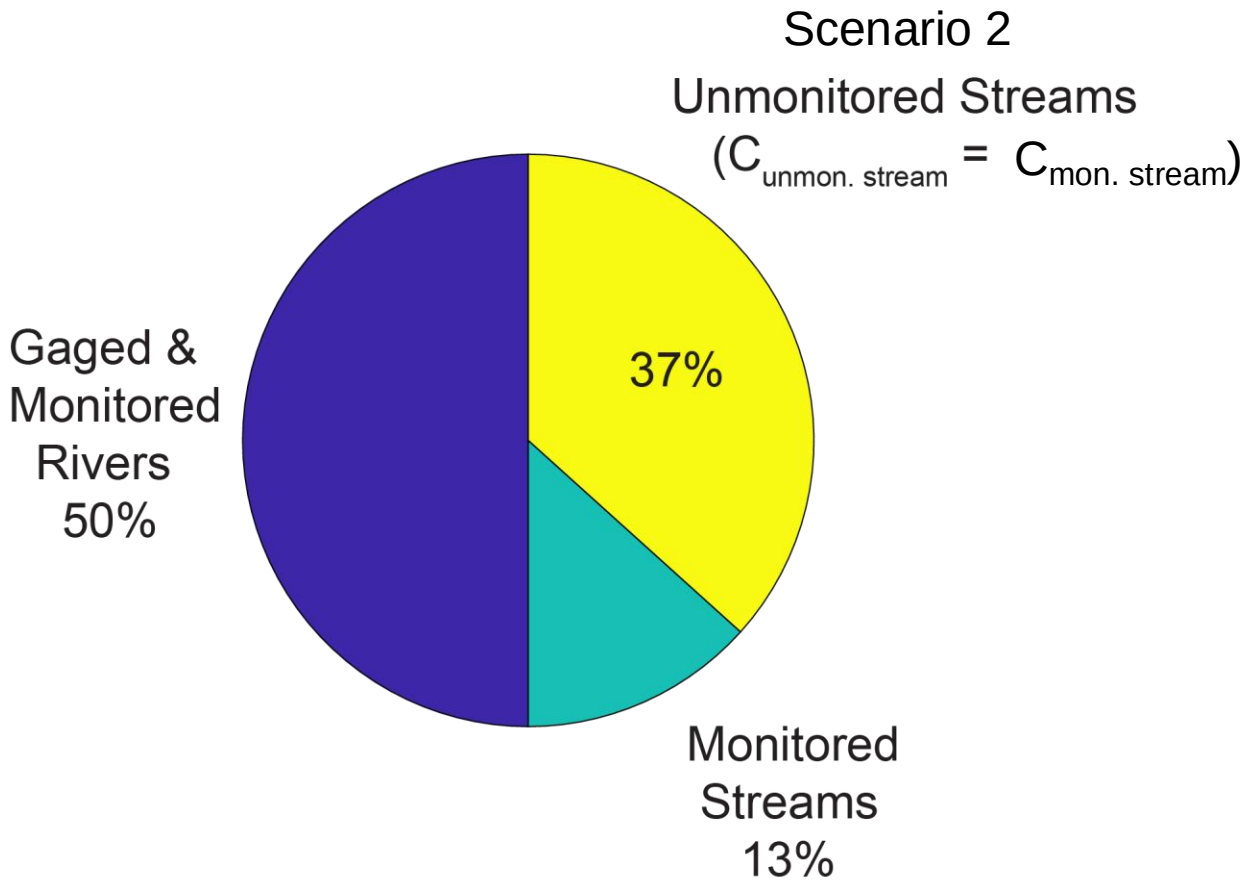
~2X at Day 3

~20X at Day 7

Local vs Distant, Upstream N Sources

Distant Upstream Sources are Known,
Big Question is Contribution from Small Unmonitored Streams



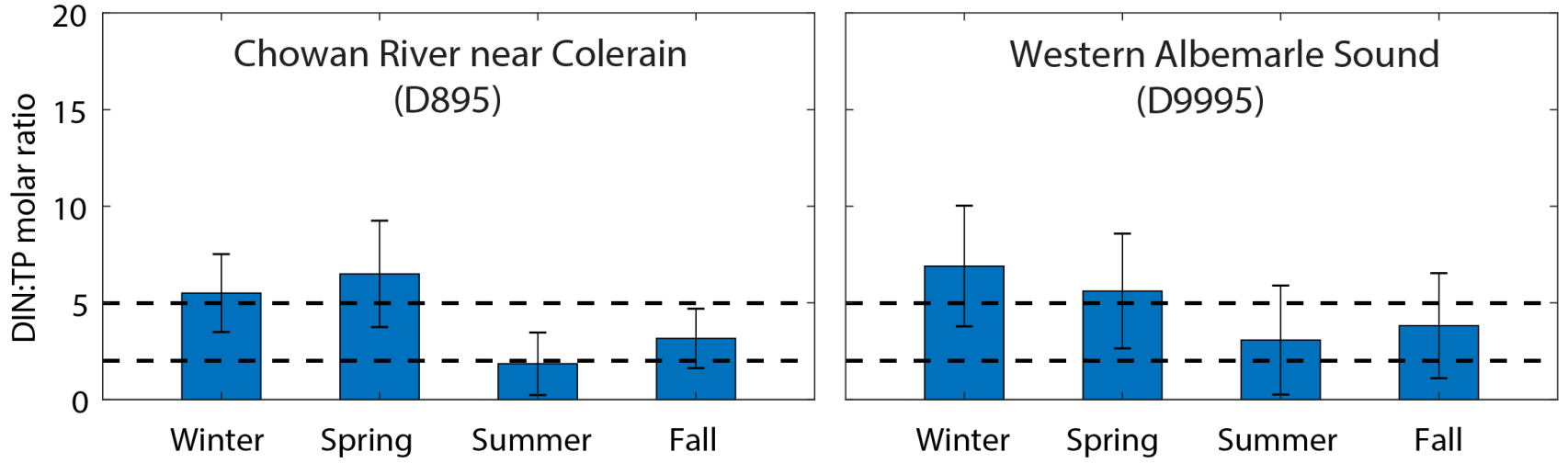


Conclusions

1) Strong evidence for N limitation in Albemarle Sound
2) Some tributary estuaries are likely not nutrient limited due to excessive nutrient inputs and strong light attenuation
3) P limitation can occur during N_2 fixing cyanobacteria blooms
4) N_2 fixation is likely constrained by P availability
5) Both N and P inputs should be managed to control algal blooms across the greater Albemarle Sound region
    a) Best management practices that target N and P
    b) Point source permits that require limits on both N and P

(Photo: Rose Jacot)

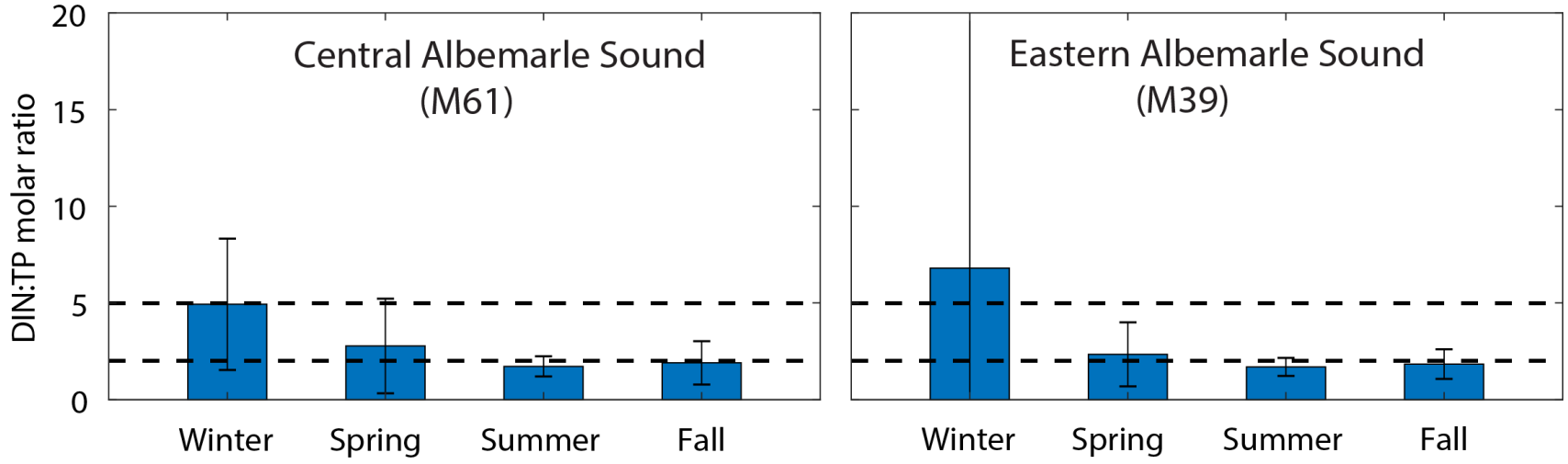
Nutrient (N:P) ratios also indicate N limitation during warm months



P limitation

Co-limitation

N limitation



P limitation

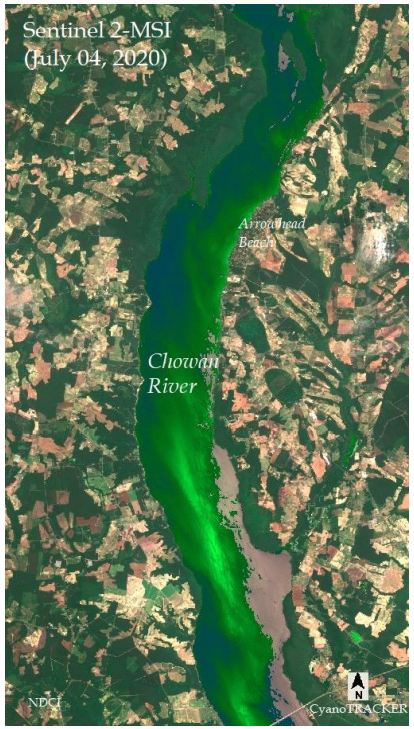
Co-limitation

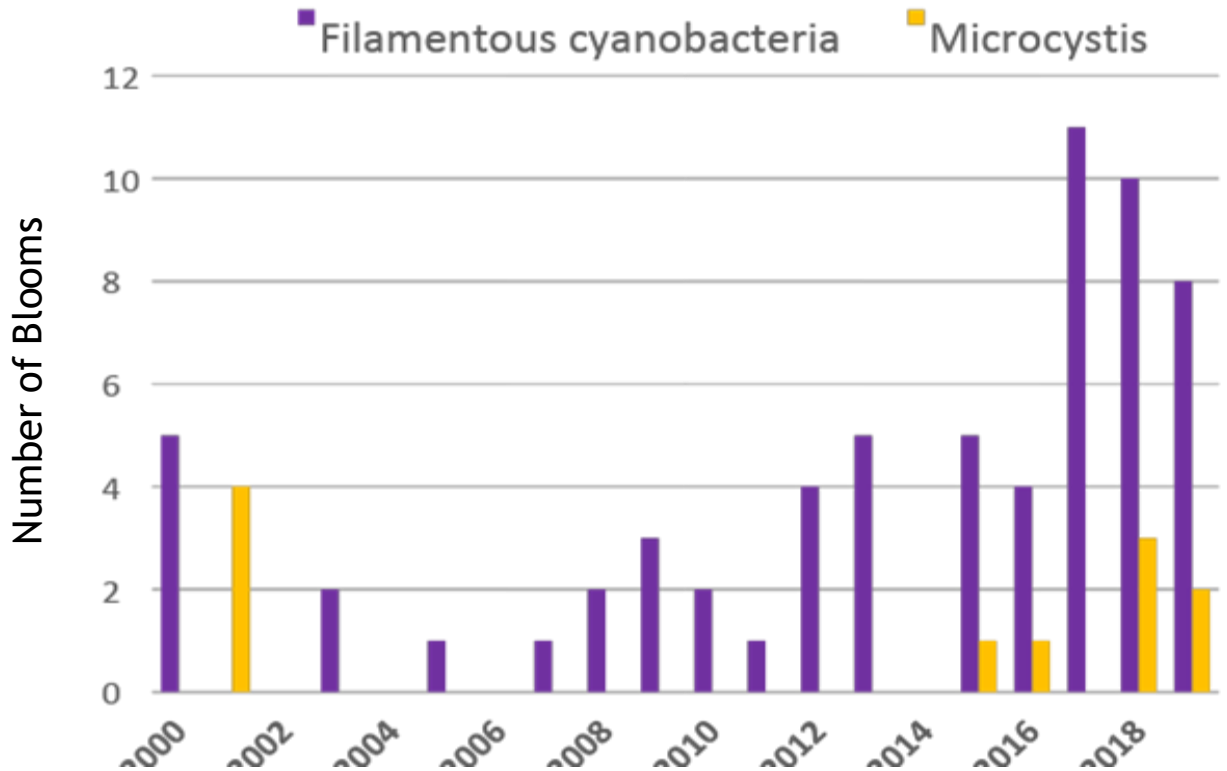
N limitation

Frequent intense blooms during the 1970's

Chowan River declared NC's first Nutrient Sensitive Water

Recurrent cyanobacteria blooms during recent summers



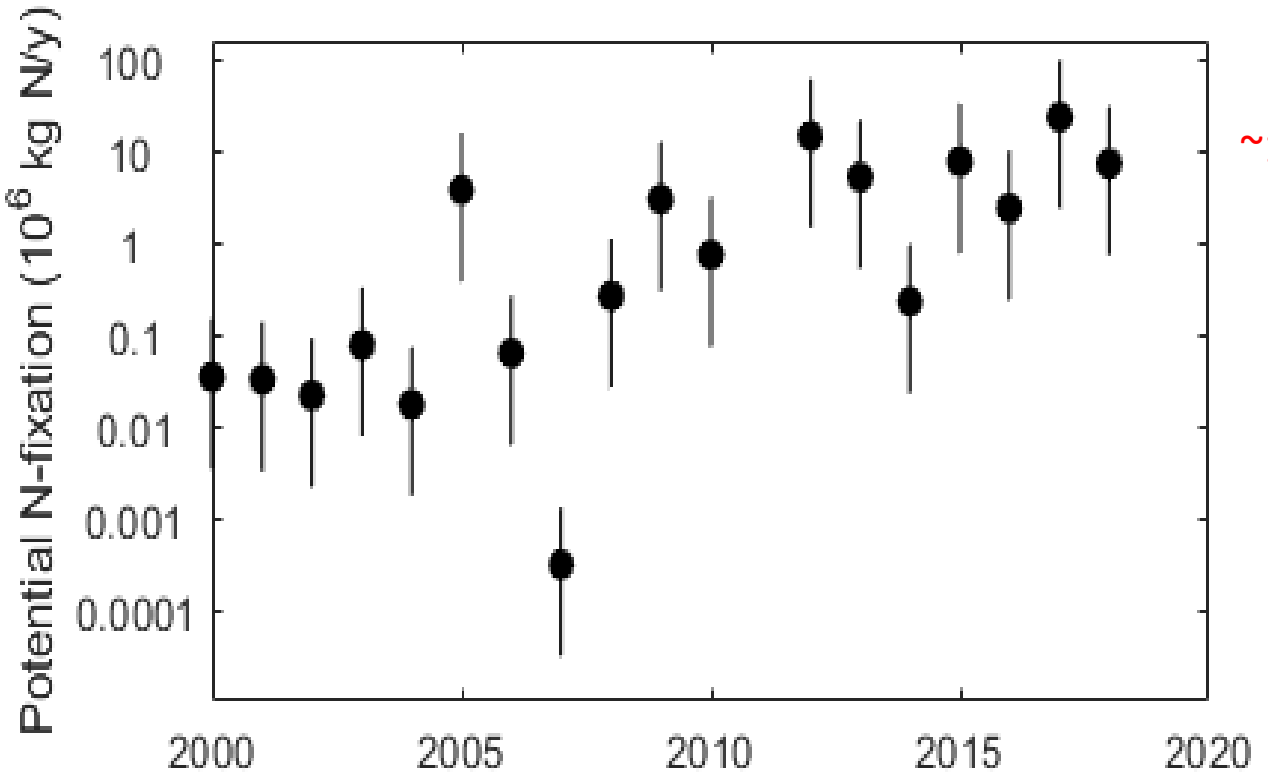


Elizabeth Fensin (NC DEQ-DWR)

Summary Map of Trend Slopes for Phytoplankton Biomass as Chlorophyll *a*

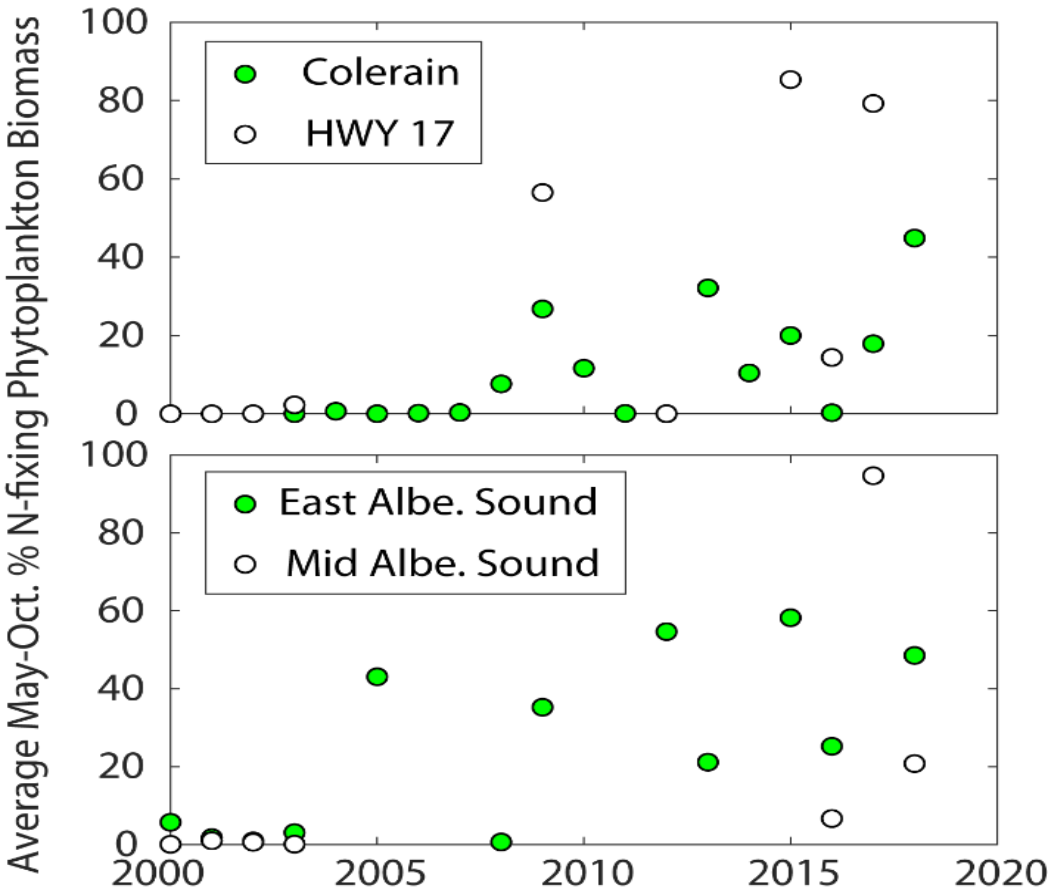
Potential N_2 fixation estimated from concentration of heterocystous cyanobacteria scaled to volume of Albemarle Sound

Biomass (NCDEQ) X Biomass-specific rate (Klowann et al 2016) = Estimated rate



~100% trib. TN load

Increasing trend in biomass of N_2 fixing cyanobacteria



<u>Observed Genera</u>

Anabaenopsis

Aphanizomenon

**Cylindrospermopsis (most common)*

**Dolichospermum (bloom dominant)*

Raphidiopsis

Experimental Design

Treatments

P addition \ N addition		
	0,0 Control	1,0 +N
	0,1 +P	1,1 N+P

Incubation

- 3-4 days under natural light & temp.

Response Variables

- Total phytoplankton (Chlorophyll *a*)
- Phytoplankton composition
- Nutrient concentrations
- N_2 fixation

Liebig's Law of the Minimum

Biomass is limited by a substance that is least available relative to organisms requirement for biomass synthesis.

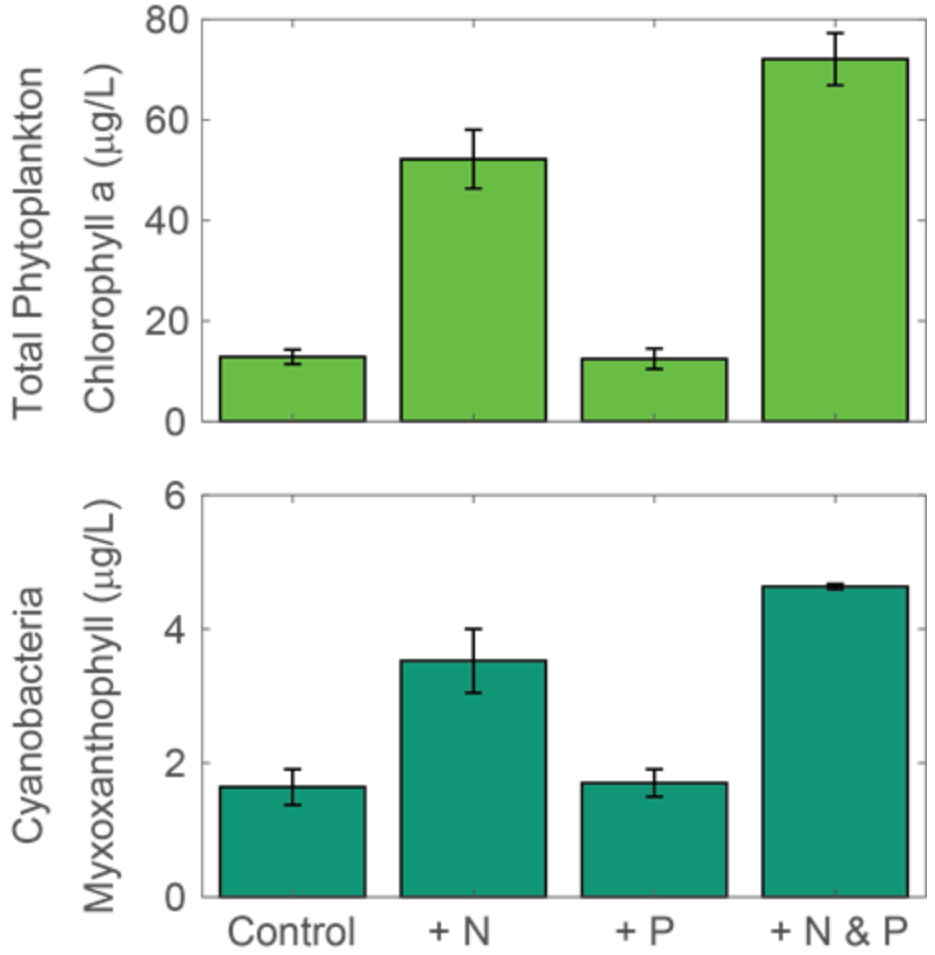
Macronutrients

?
- N (NO_3^-, NH_4^+)
- P (PO_4^{3-})

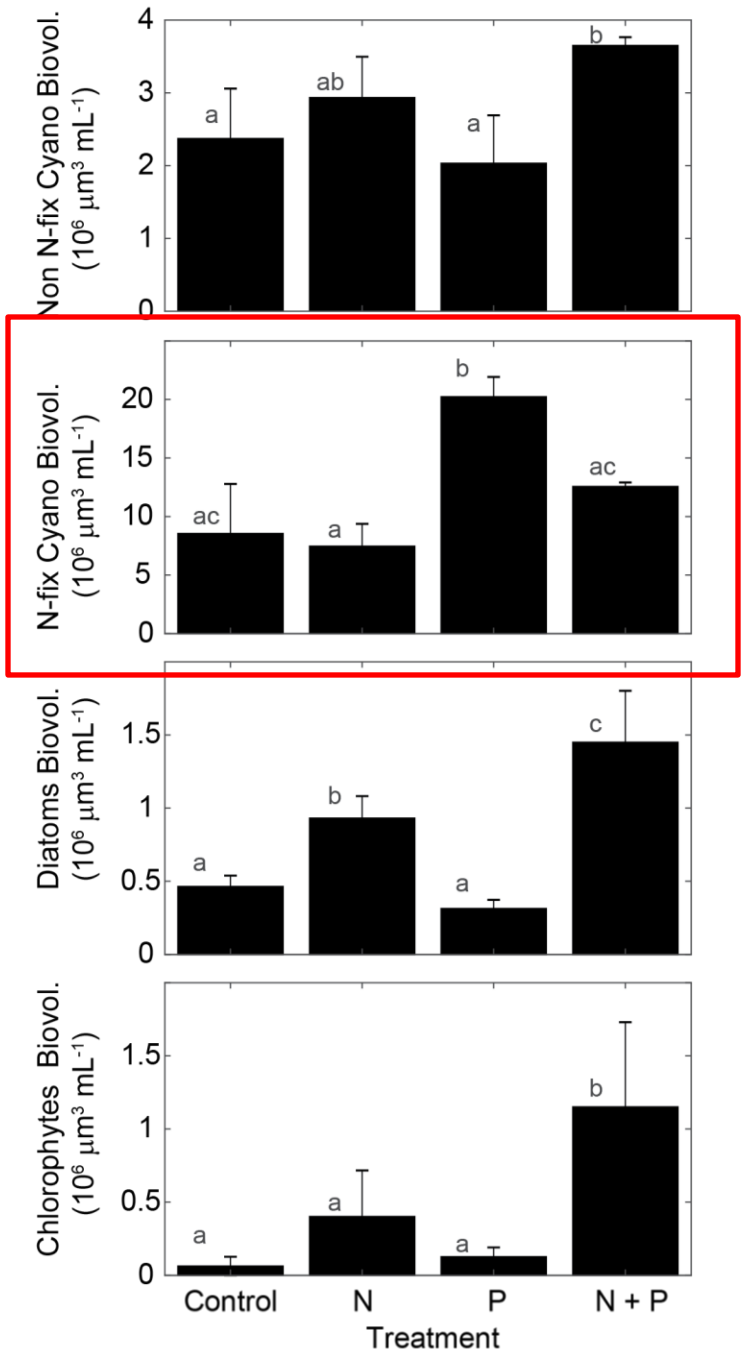
2019 experiments conducted in collaboration with Chowan Edenton Environmental Group

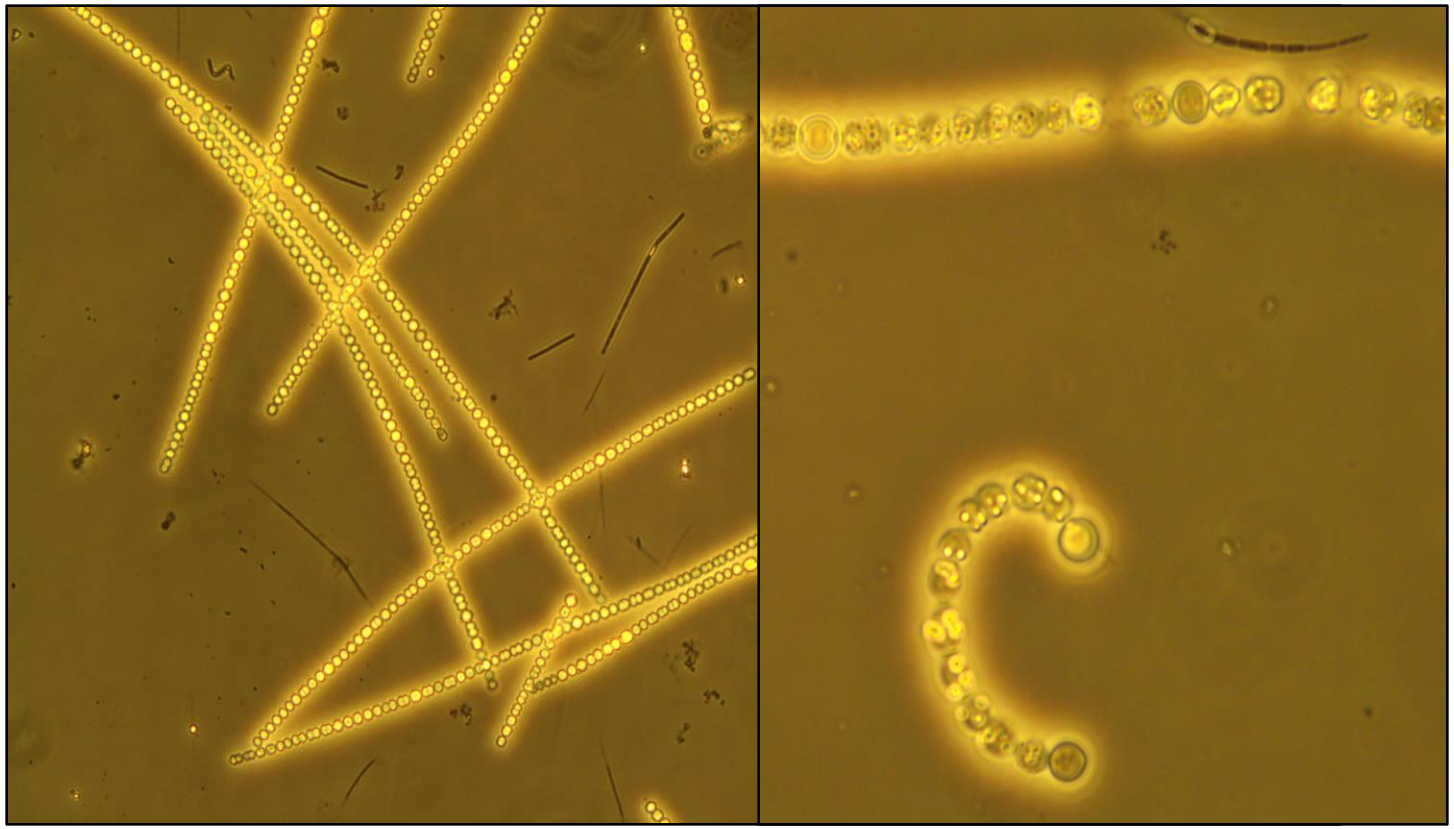
May 2019 Experiment- Edenton Bay

Clear N limitation of total phytoplankton and cyanobacteria



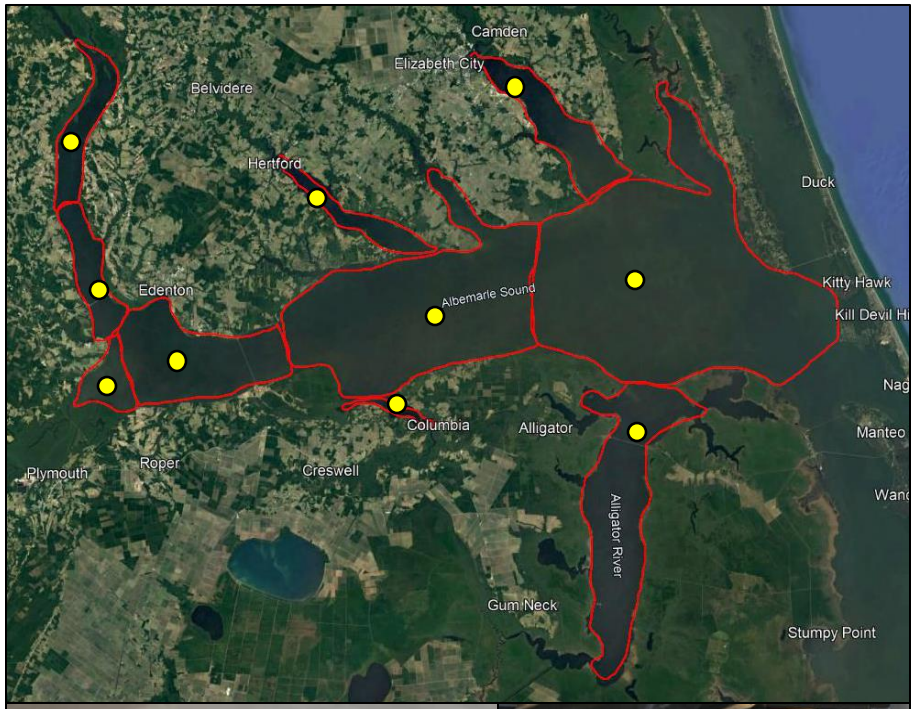
A closer look at impacts of P addition on algae from Edenton Bay during August 2019 experiment

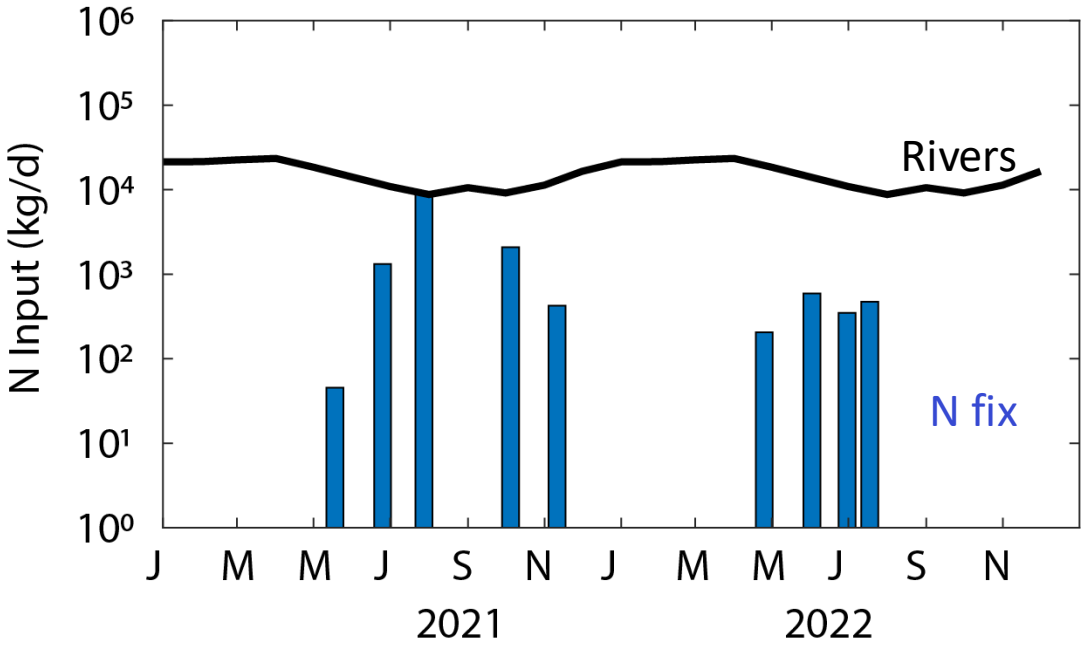




P additions stimulated N_2-fixing Dolichospermum bloom

Actual N_2 fixation measurements by acetylene reduction





- Collected early morning
- Mid-day acetylene reduction assay
- *In situ* temp, 20% PAR in portable incubator
- 3/1 acetylene to N_2 reduction ratio
- Scaled to 12 h photoperiod and polygon volume