

# The Influence of Atmospheric Deposition of Nitrogen on a Shallow Seepage Lake in the North Carolina Coastal Plain

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# UNDERSTANDING LAKE CHANGES

**Data**

versus

**Assumptions**

Water and nutrient  
budgets--

assess internal + external  
nutrient sources

Influence of  
atmospheric

deposition--greatest in  
shallow seepage lakes

Our lake will be clear

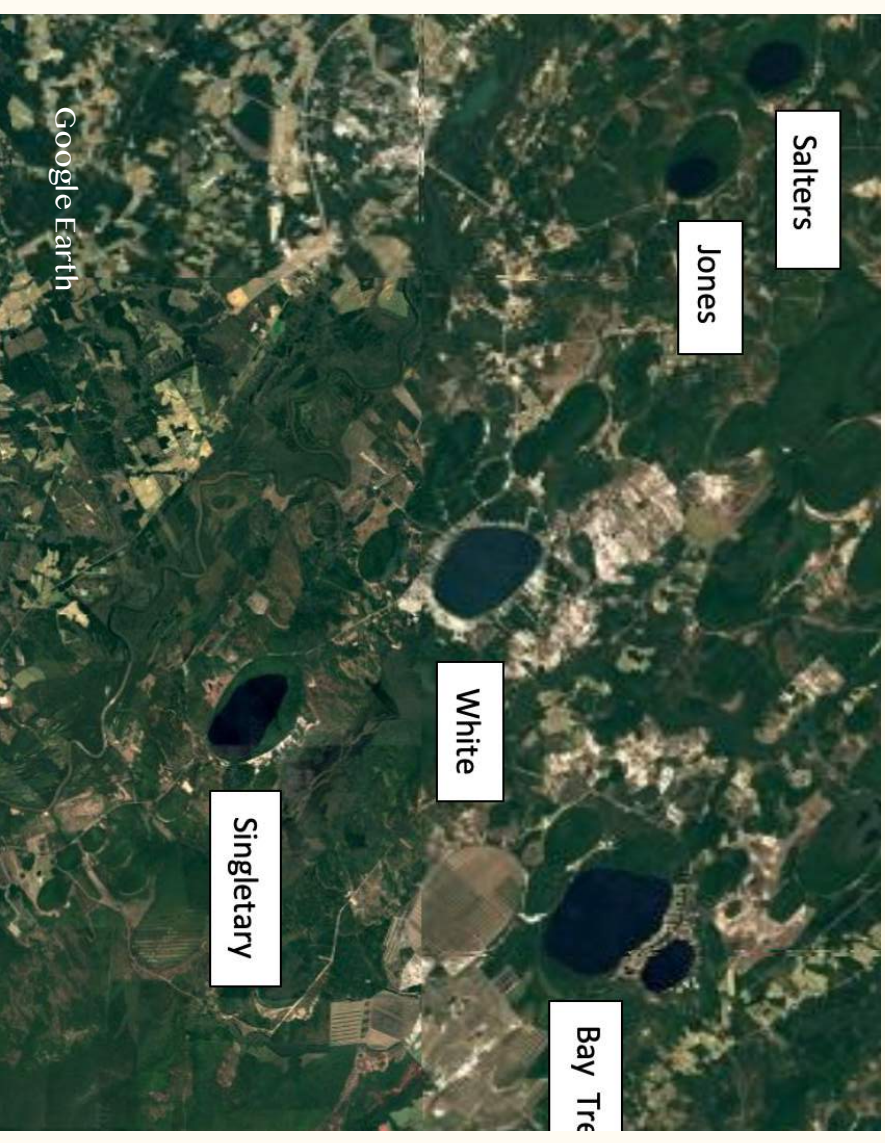
Lake level will be  
static

# NC Bay Lakes

Thousands of Carolina Bays in Atlantic Coastal plain, with similar morphology-- most are wetlands

Bladen Bay Lakes are oriented SE-NW

Sand rim at SE shore, situated in wetland basins



# WHITE LAKE

**Shallow**

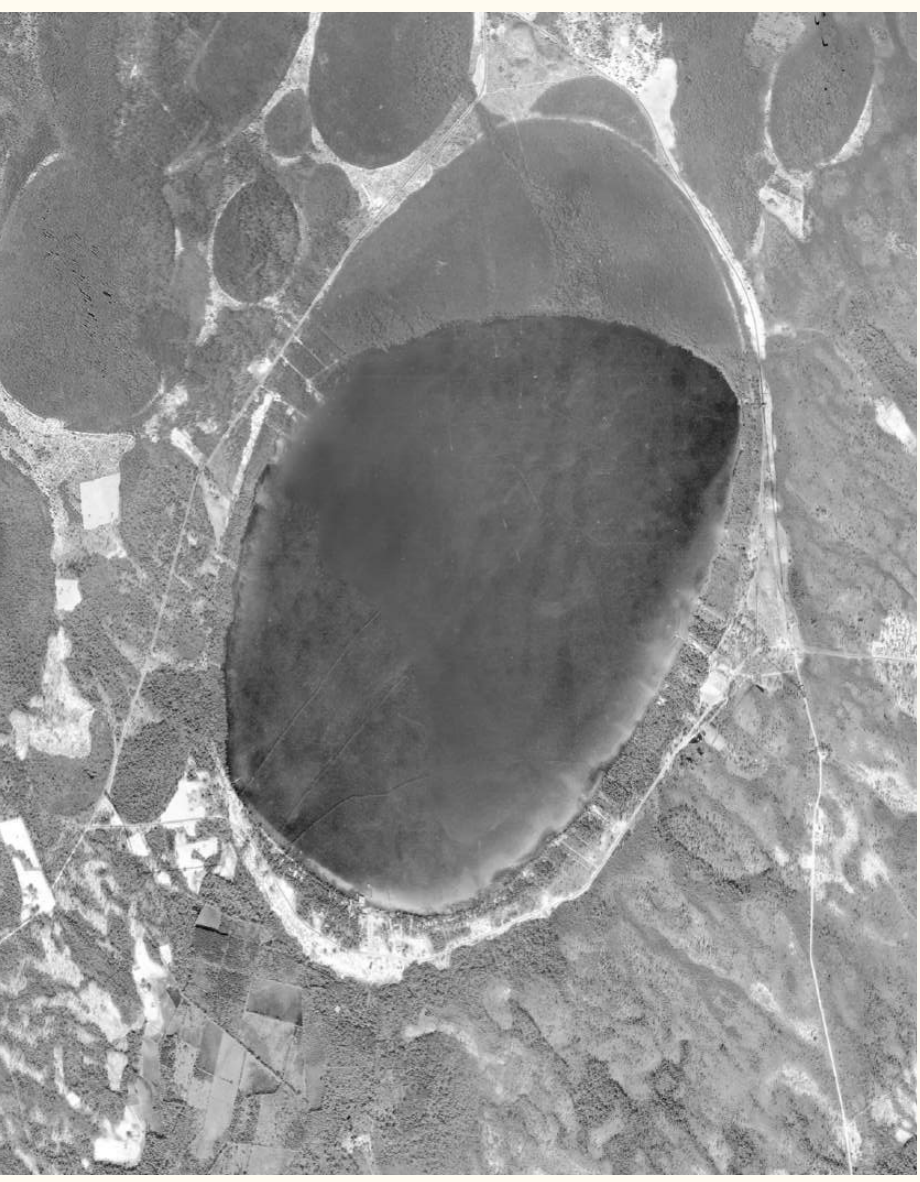
Mean Depth 1.9 m, Max 2.9 m

**Small**

1,067 acres

**Seepage Lake**

No inlet, source water =  
rainfall + GW

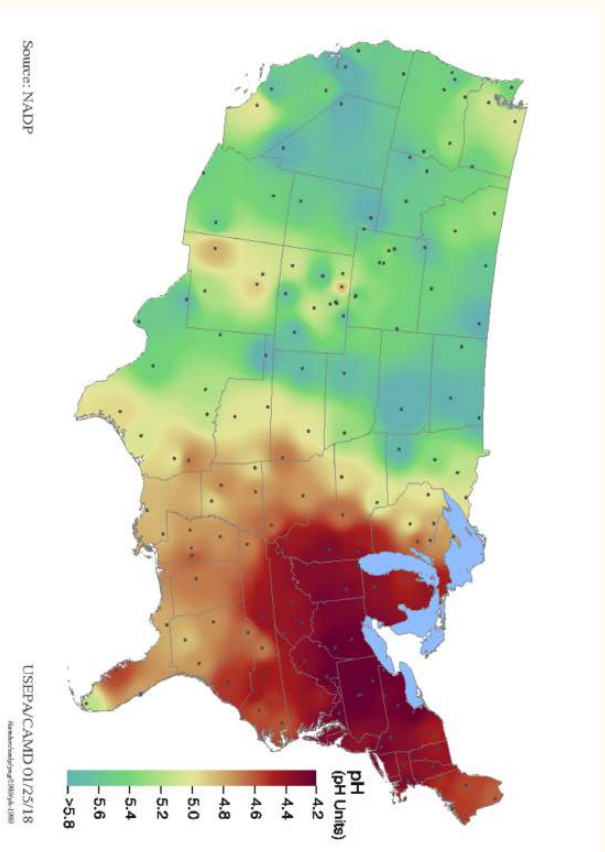


Digital Compilation of 1938 USDA Aerial Photos, Provided by NC Mountains to Sea Trail

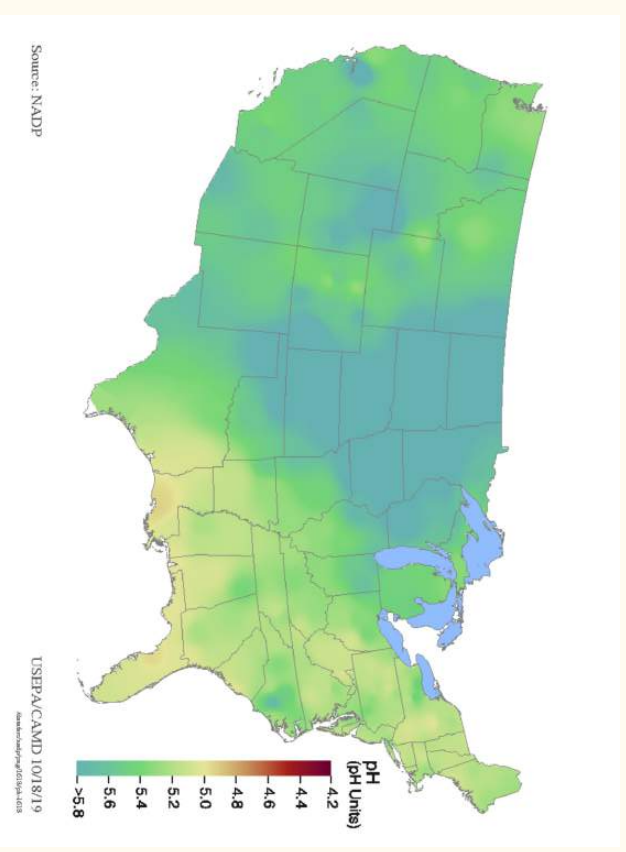


# Atmospheric Change: Less Acidic Rainfall

pH, 1989

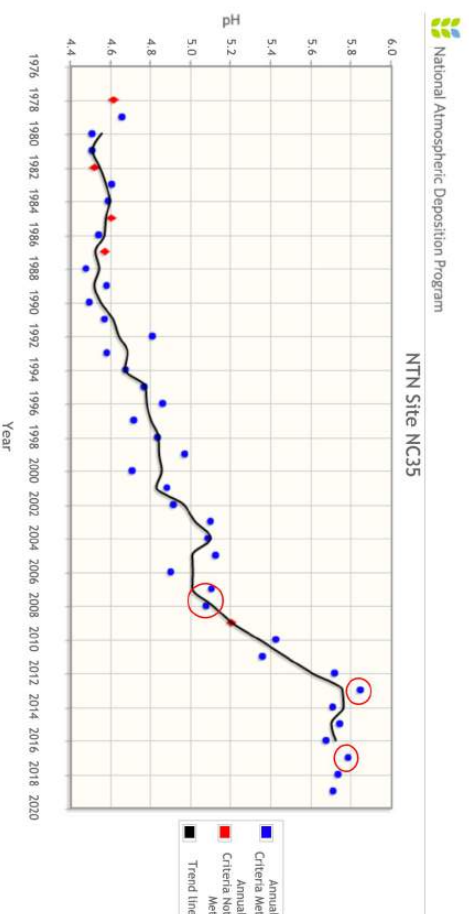
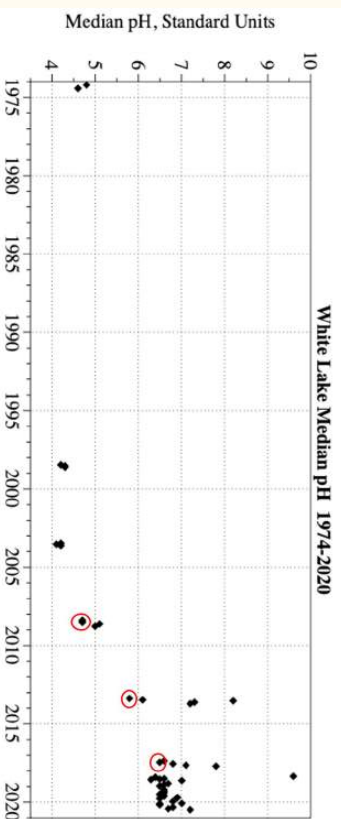


pH, 2016-2018



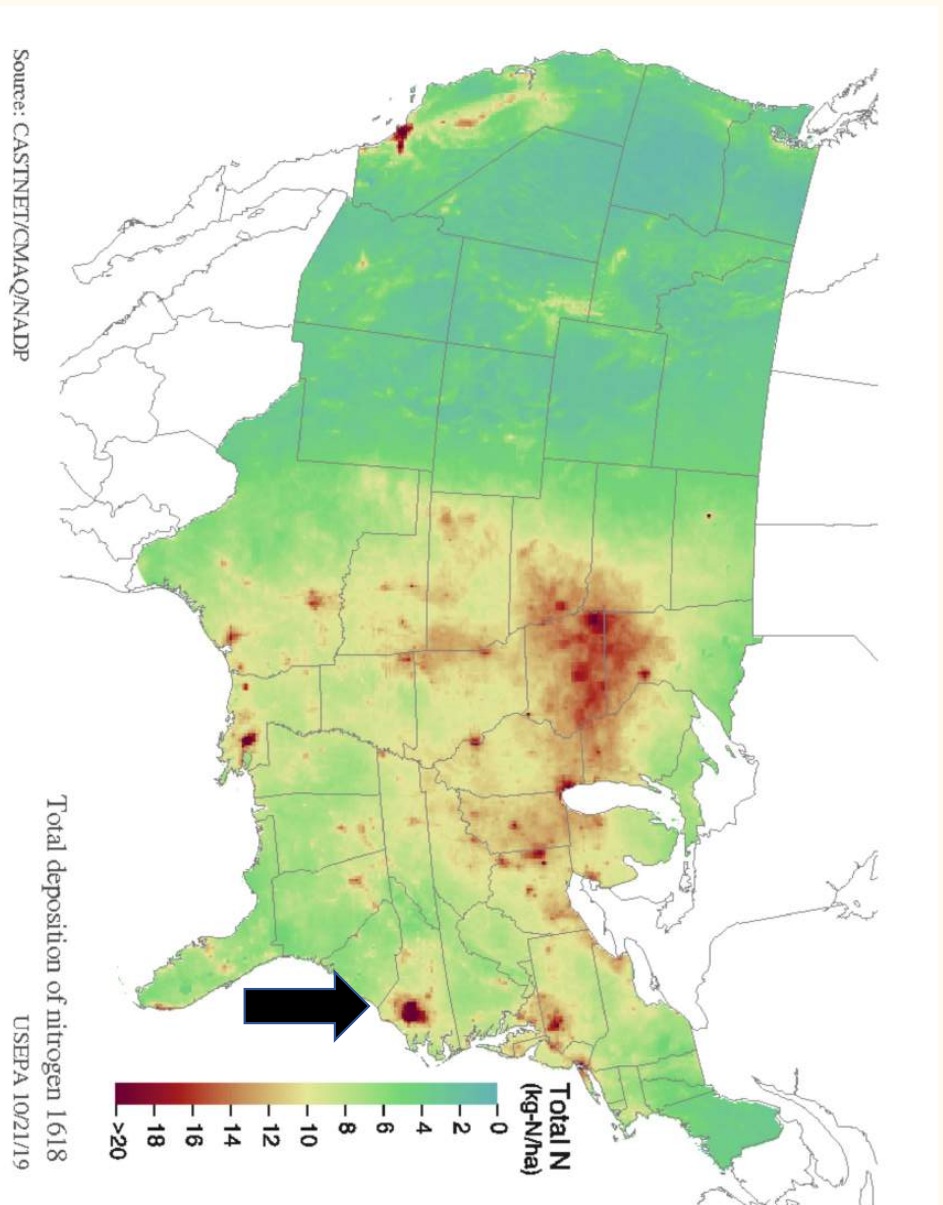
Data from National Atmospheric Deposition Program, US EPA Clean Air Status and Trends Network (CASTNET)

# pH Changed in Lake as pH Changed in Rain



Increase in  
White Lake's pH  
levels  
over same  
period as  
rainfall pH  
increased  
at nearby NADP  
station  
(NC 35, at  
Clinton)

# Atmospheric Change: A Nitrogen Hot Spot in NC



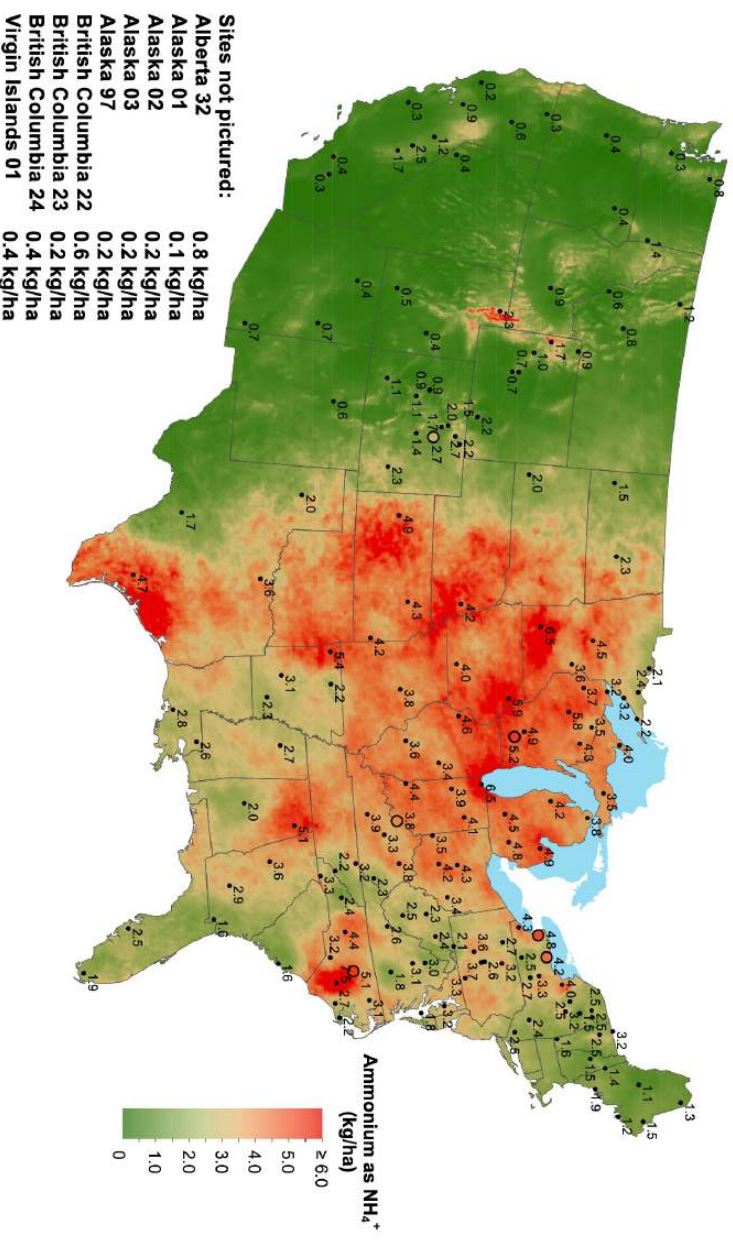
Reduction in  $\text{NO}_x$  (acid)  
4X Increase in  $\text{NH}_3$  (base)  
Dry Deposition High  
TN Deposition = Wet +  
Dry  
in kg-N/ha/year  
(2018 Data)

Data from National Atmospheric Deposition Program, US EPA Clean Air Status and Trends Network (CASTNET)

# High Ammonium Deposition

2020 annual deposition level was 7.5 kg/ha at Clinton monitoring station

Ammonium ion wet deposition, 2020



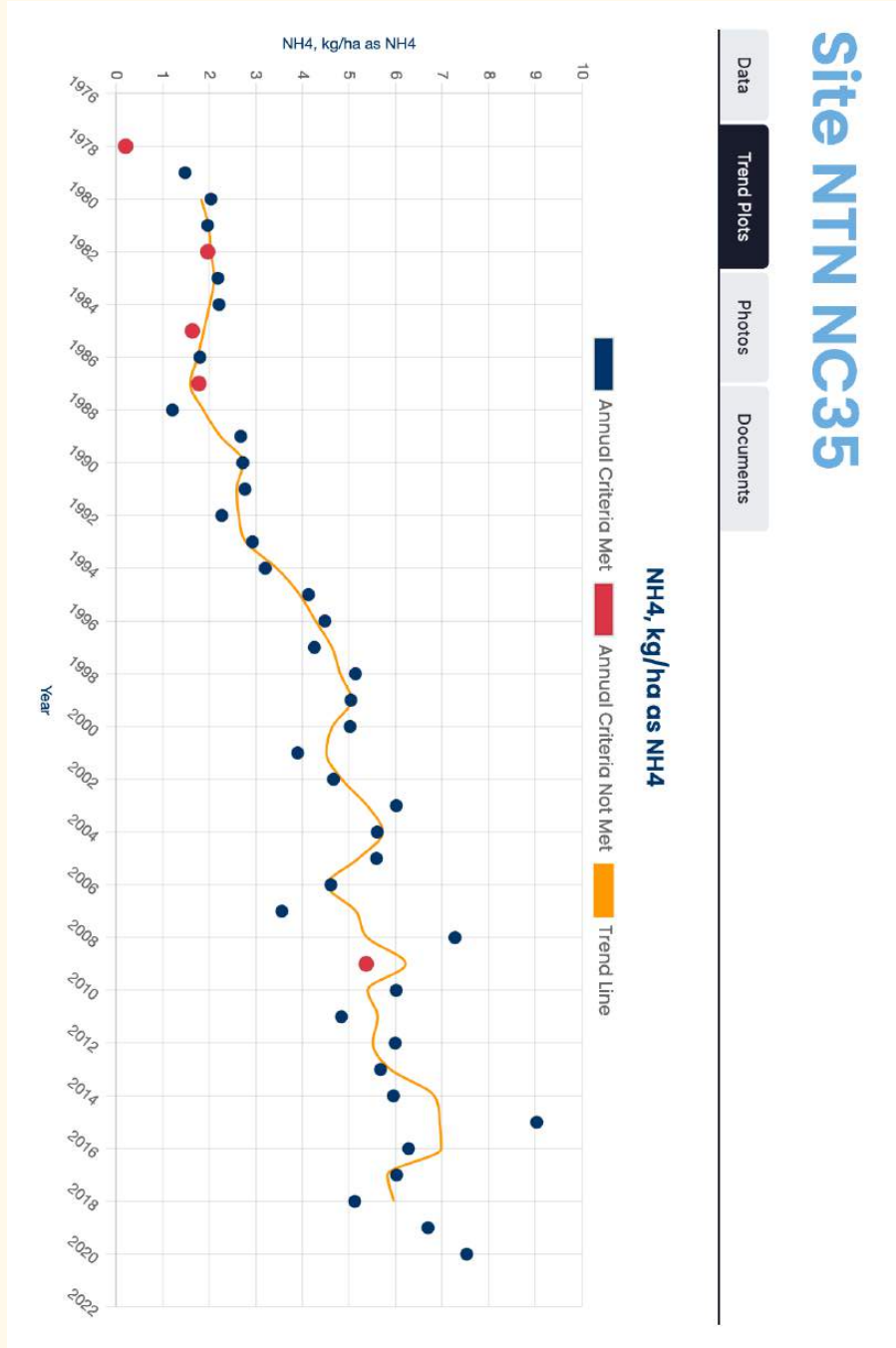
Data from National Atmospheric Deposition Program, US EPA Clean Air Status and Trends Network (CASTNET)



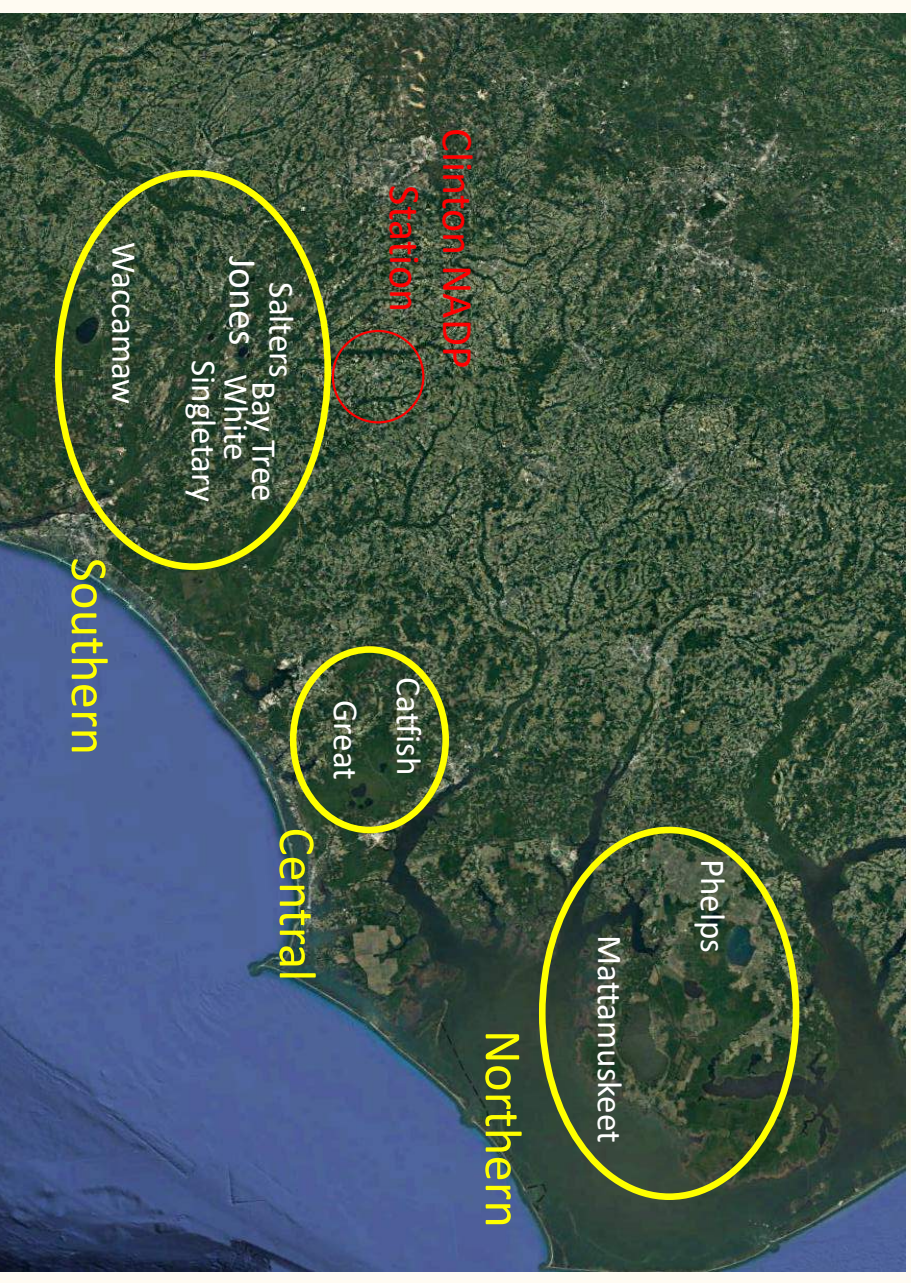
# Ammonium Deposition Trend Plot

Site NTN NCC35 is  
Clinton NADP  
monitoring station—  
close to Bay Lakes

Increase over time,  
with more annual  
variability



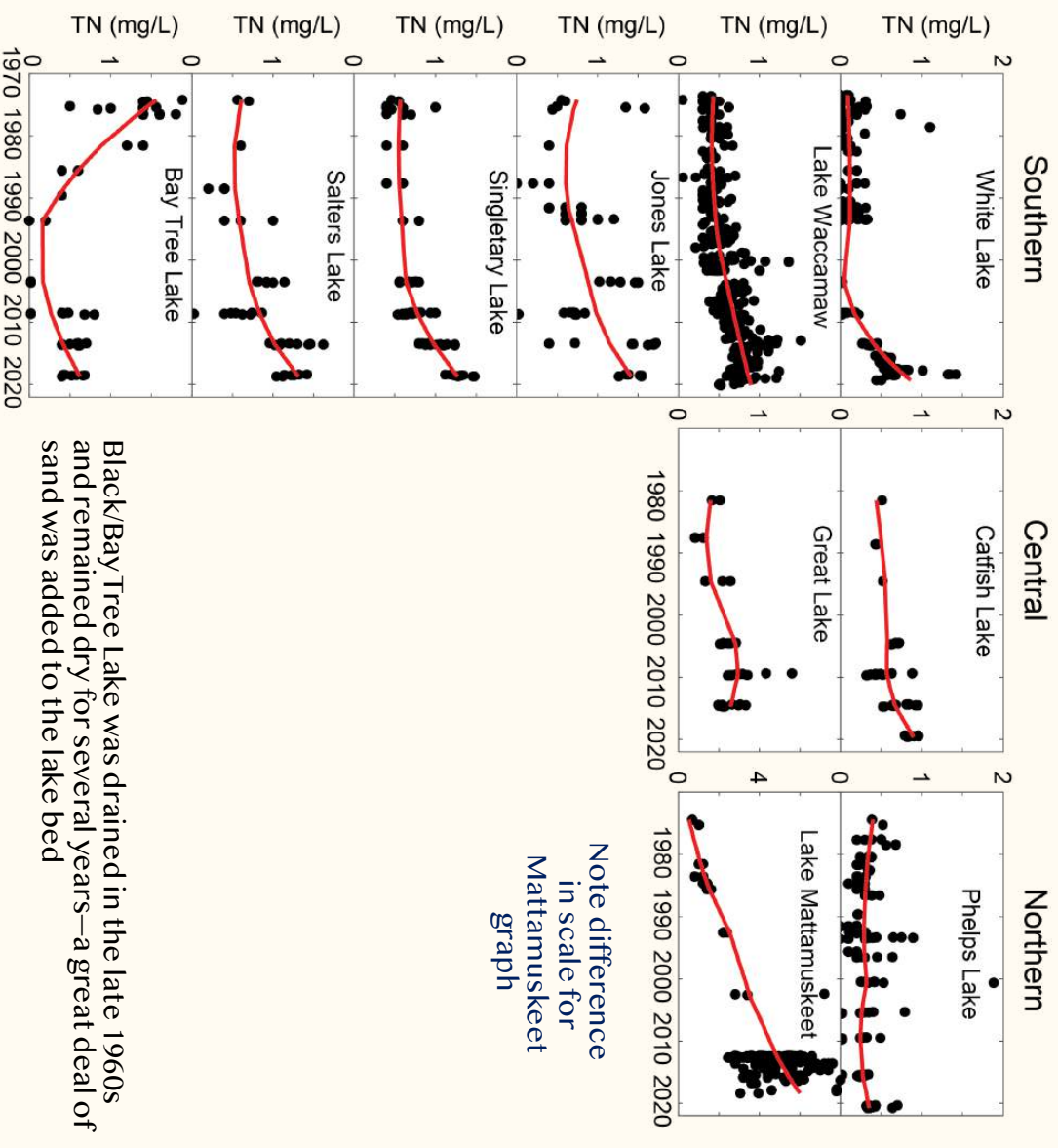
# Comparing Bay Lakes Nitrogen Trends Over Time



# Bay Lakes Total Nitrogen

Historical Data from:  
Weiss and Kuenzler  
(1976), US EPA (1975),  
NC Division of Water  
Resources Ambient  
Monitoring Program  
(1980-2018)

No similar trend for P



Black/Bay Tree Lake was drained in the late 1960s and remained dry for several years—a great deal of sand was added to the lake bed



# Nutrients in Rainfall and in White Lake

White Lake Rainfall Nutrients 2020-2021

DATE	RAIN (inches)	TP (mg/L)	TN (mg/L)	NH3-NH4 (mg/L)	NO3-NO2 (mg/L)	DIN % TN	RAIN TN/TP (mass)	LAKE NH3-NH4 (mg/L)	LAKE TN/TP (mass)
2/13/20	0.25	0.017	0.586	0.159	0.082	41%	34.5	0.044	27.9
3/5/20	1.25	0.012	0.302	0.123	0.049	57%	25.2	0.050	22.6
4/23/20	0.25	0.008	0.190	0.107	0.068	92%	23.8	0.033	26.3
5/29/20	3.3	0.045	1.35	0.410	0.328	55%	30	0.037	40.3
9/17/20	2.5	0.007	0.385	0.176			55		40.4
11/12/20	2.75	<0.002	0.202	0.018	0.011	14%			
8/18/21	0.75	<0.002	0.190	0.029	0.059	46%		<0.010	30.5

# Rain is a Source of Bioavailable P and N

Total Phosphorus Range = <0.002 to 0.045 mg/L

Total Nitrogen Range = 0.19 to 1.35 mg/L

Ammonium Range = 0.018 to 0.410 mg/L

DIN as % of TN = 14 to 92%

Rain TN/TP (mass) Range = 24 to 55

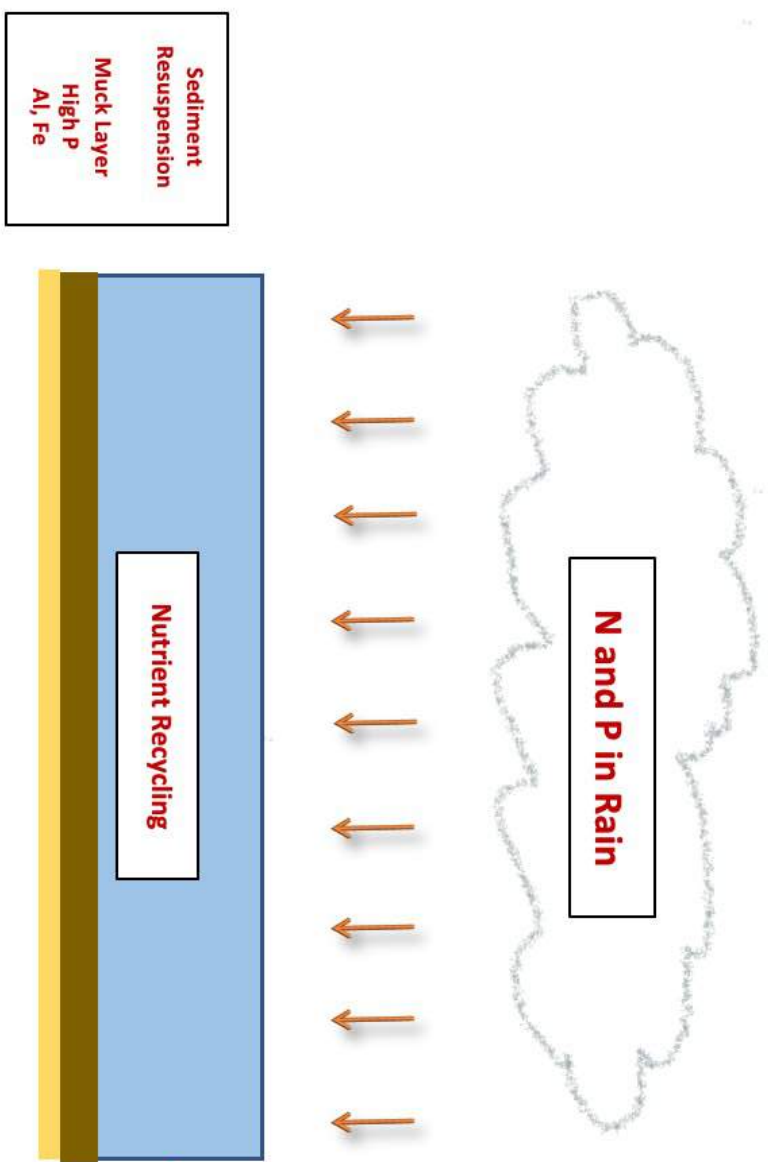
White Lake TN/TP (mass) Range (Feb-Apr 2020) = 22 to 40

*Historical TN/TP (mass) for White Lake = 12*

Big Rains (3"+) More Common

**Rainfall is a  
Diffuse Nutrient  
Source**

**Has a Larger,  
More Rapid  
Influence**



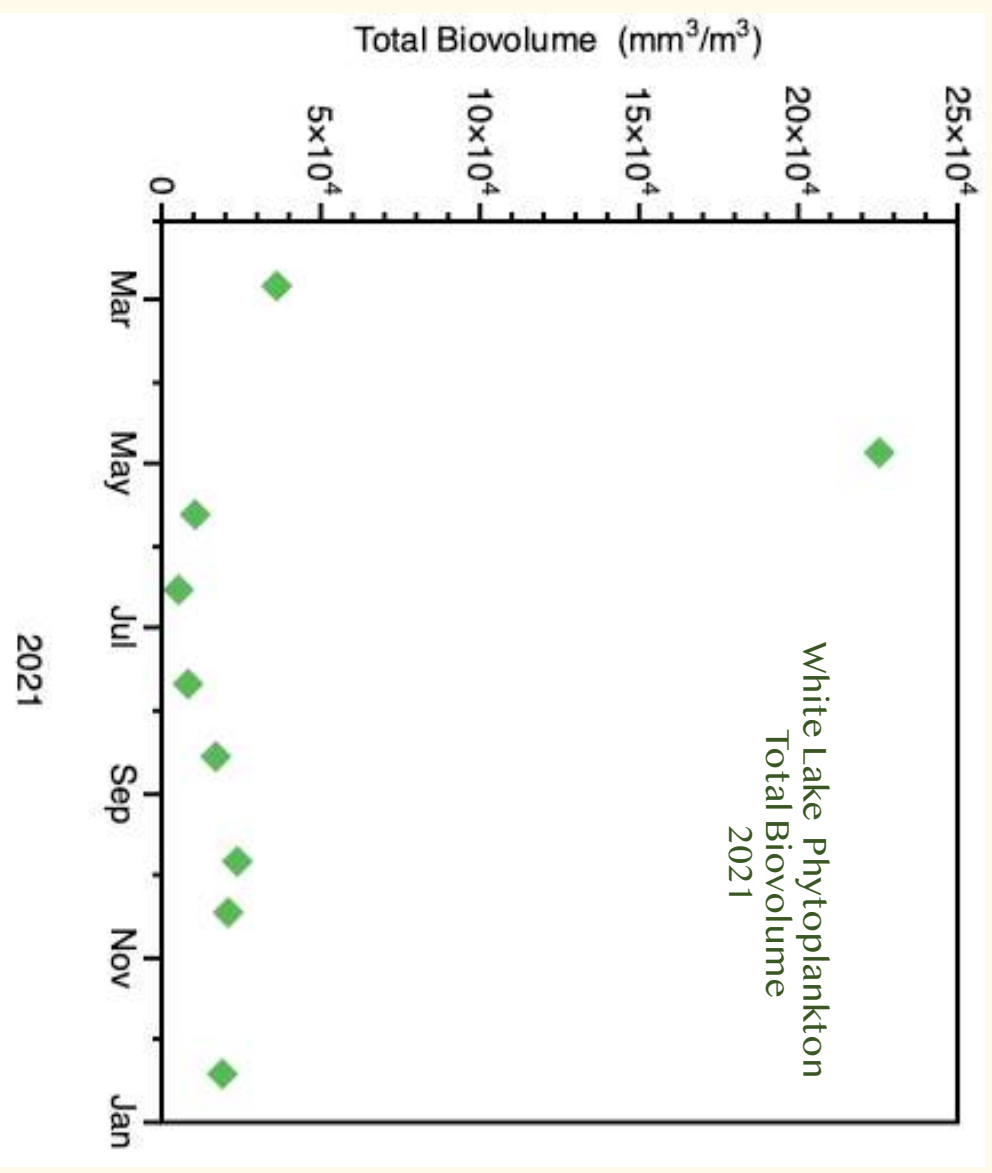
# Phytoplankton Response to N in Big Rains

Two >3" rains in February 2021

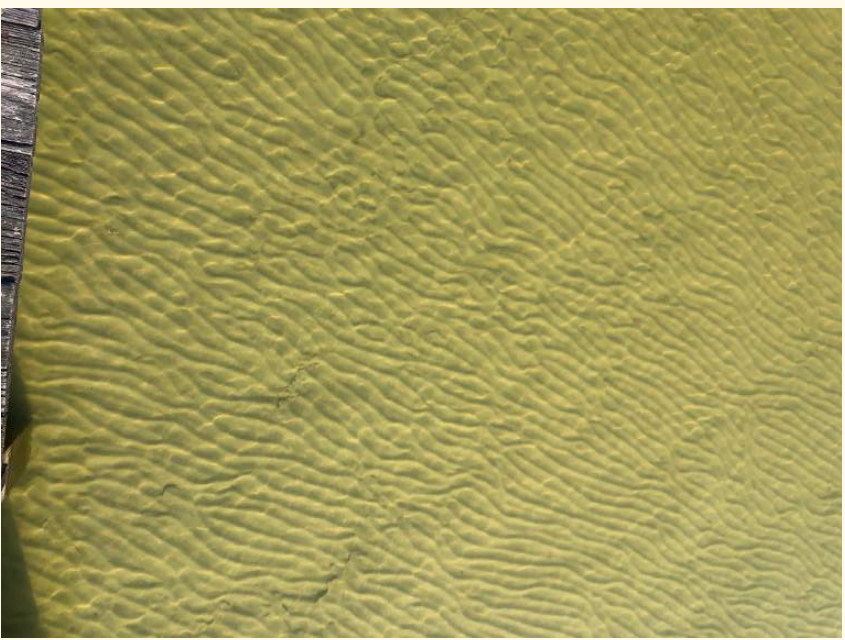
Bloom of a small desmid,

*Cosmarium tinctum*

>90% of Total BV in April

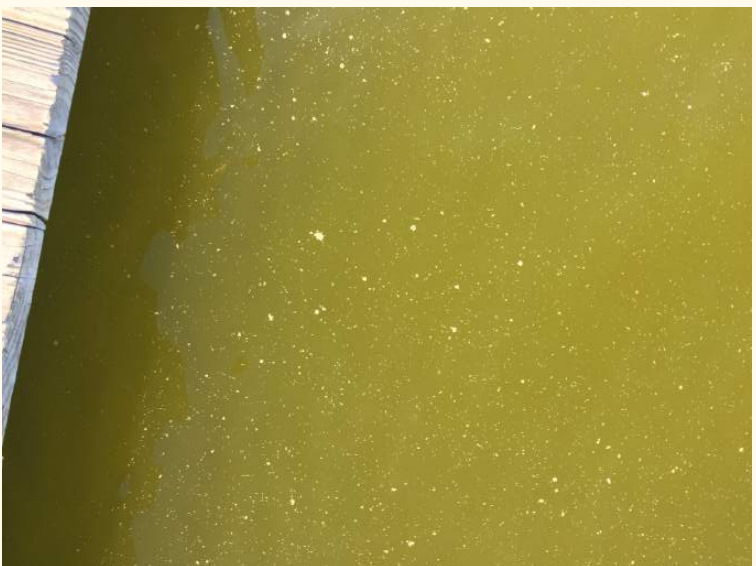


# April 2021 Desmid Bloom, and April 2022 Clear Water Conditions (No Big Winter Rains, DIN)





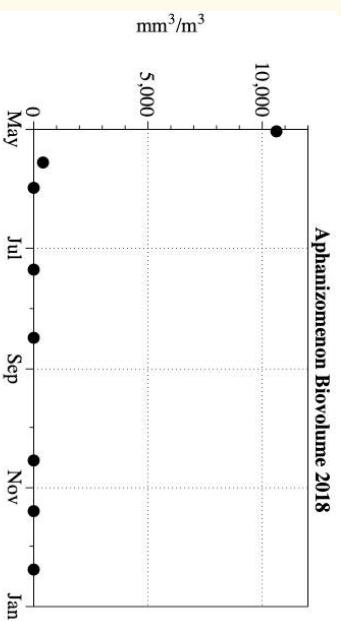
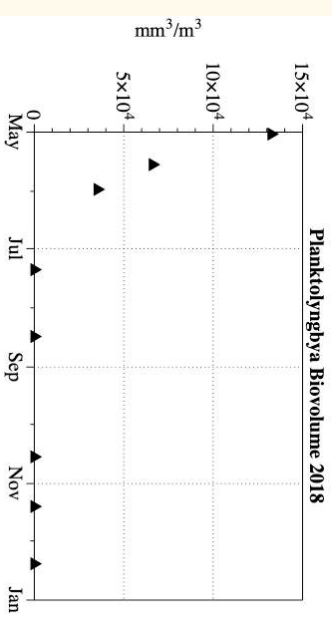
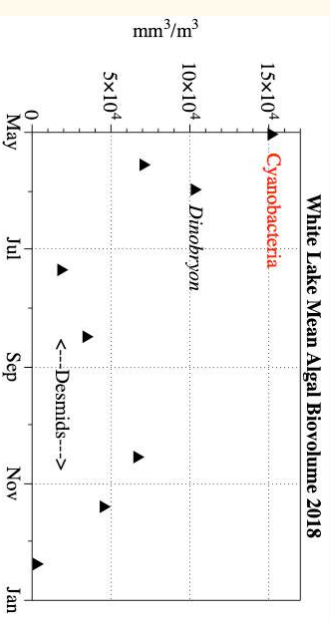
# Same Place, March 2018 Filamentous Cyanobacterial Bloom Persisted Through the Winter

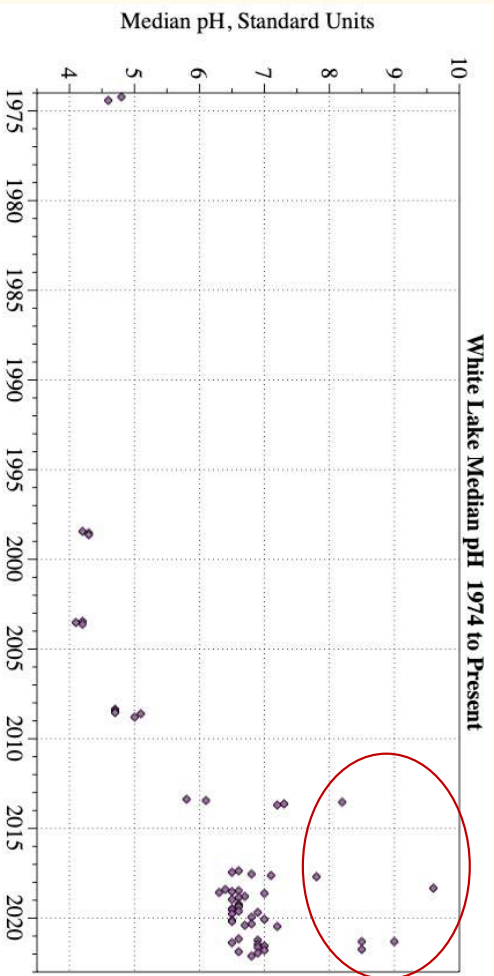


Low-dose  
Water Column  
P-stripping  
Alum Treatment  
Applied to  
White Lake  
May 3-16, 2018

Filamentous  
Cyanobacteria  
Eliminated  
After Treatment

Desmids,  
Greens,  
Chrysophytes  
Generally  
Dominate  
Phytoplankton  
Biovolume  
Phytoplankton  
Diversity Is  
Increasing





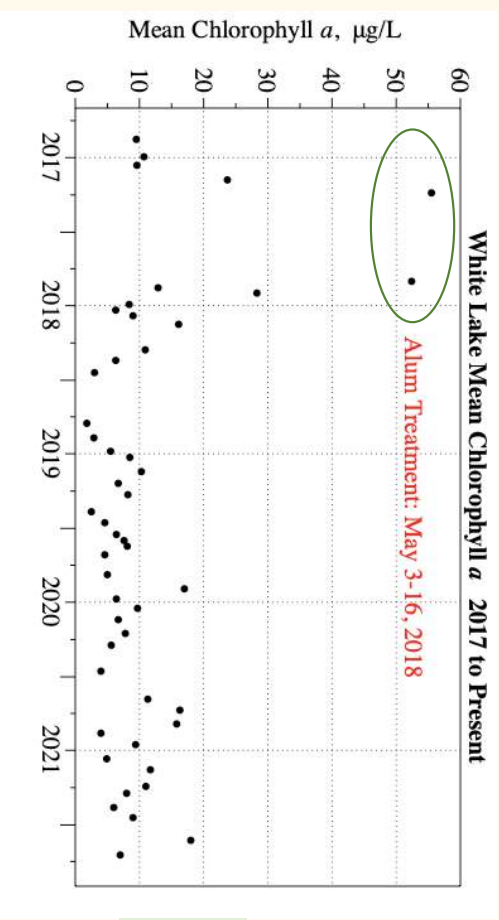
**Alkalinity Very Low,  
pH Can Spike  
During Blooms**

Fish Kill Started as 2018 Alum Treatment Started  
(pH +2 units in 2 Weeks)

Shallow, Well-Mixed Lake, No pH Refuge

pH Spike in April 2021 (+0.5 in afternoon, to 9)

**Highest Chlorophyll *a* Values  
Associated with Filamentous  
Cyanobacterial Bloom—  
Sept 2017 to May 2018**



Feb 2022  
*Gonatozygon*  
(desmid)

# A Healthy, Less Acidic, More Productive White Lake

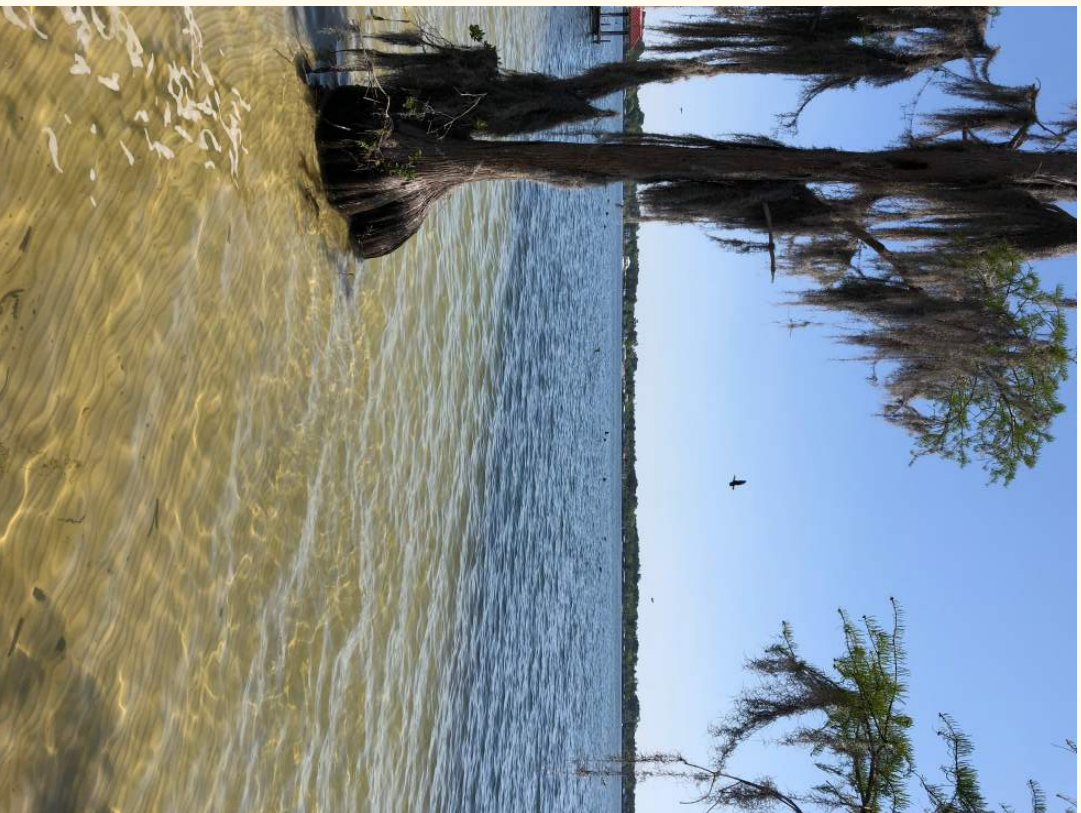
Unusual aquatic  
communities:  
Desmids,  
Aquatic Vegetation

Periods of clarity are a gift,  
not a given

A challenging message!



Thanks to the Town of White Lake, NC State Parks, and the many scientists who have worked at White Lake  
*In memory of a grand limnologist, David Frey*



White Lake Watch [www.whitelakewatch.com](http://www.whitelakewatch.com)