Sediment Phosphorus Comparisons Between White Lake and Lake Waccamaw

Diane Lauritsen, LIMNOSCIENCES
John Holz and Tadd Barrow, HAB Aquatic Sciences
Shannon Brattebo, Tetra Tech
William James, Univ. of Wisconsin-Stout

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Two Bay Lake Systems:

White Lake	**Lake Waccamaw**
1,067 acres, no surface inlet, clear water	9,067 acres, Big Creek inlet, blackwater
Lake water pH historically <5, now above 6	Lake water pH neutral
Lake comprises 70% of bay, wetlands on W side	Lake comprises 90% of bay, wetlands on N side
4.8 miles of lakeshore, commercial and residential development, no protected land	14.2 miles of lakeshore, residential development, state park-owned lands
Sewer in all areas; $5 M in loans for rehabilitation projects	Sewer in most areas, 1 trailer park on septic
No stormwater ordinances	Stormwater ordinances, $4.5 M in grants for stormwater projects
Primary production mostly in benthic zone: filamentous algae, low-growing SAV	Primary production mostly in benthic zone: emergent and submerged vegetation, filamentous algae

Sediments Important in Shallow Lakes

Lower water volume : sediment surface area

Serve as phosphorus storehouse

Frequent sediment resuspension

Mean depths: White Lake 1.9 m,
Lake Waccamaw 2.3 m

White Lake Sediment Sampling
Feb. 11, 2019

3 Sites Sampled

All three in the mucky sediments described as “pulpy peat” in Frey 1949

This sediment type comprises half of the lake bottom

Lake Waccamaw Sediment Sampling Feb. 12, 2019

4 Sites Sampled

Three in the mucky sediments described as “pulpy peat” in Frey (1949)

This sediment type comprises a third of the lake bottom

Two of the three sites were in the *Hydrilla* treatment zone in the NW region of the lake

One sandy sediment site near the mouth of Big Creek

P-Fractionation of Sectioned Cores and Anoxic Incubation of Intact Cores

One sediment core sectioned into 2 cm segments up to 10 cm, and 5 cm segments thereafter

Samples placed on ice and express-shipped to IEH Analytical Labs in Seattle

P fractions determined from successive extractions with NH_4Cl, Bicarbonate/Dithionate, NaOH, and HCl (after Rydin and Welch 1998)

Total Aluminum, Total Iron, Total Calcium and % Solids also measured

One intact sediment core was collected from each muck site and sealed in its coring tube after the overlying water was carefully removed

Cores placed on ice and express-shipped to UW-Stout

14-day incubations under anoxic conditions, measuring Soluble Reactive Phosphorus release

Higher P at Waccamaw, Total Al Values Similar

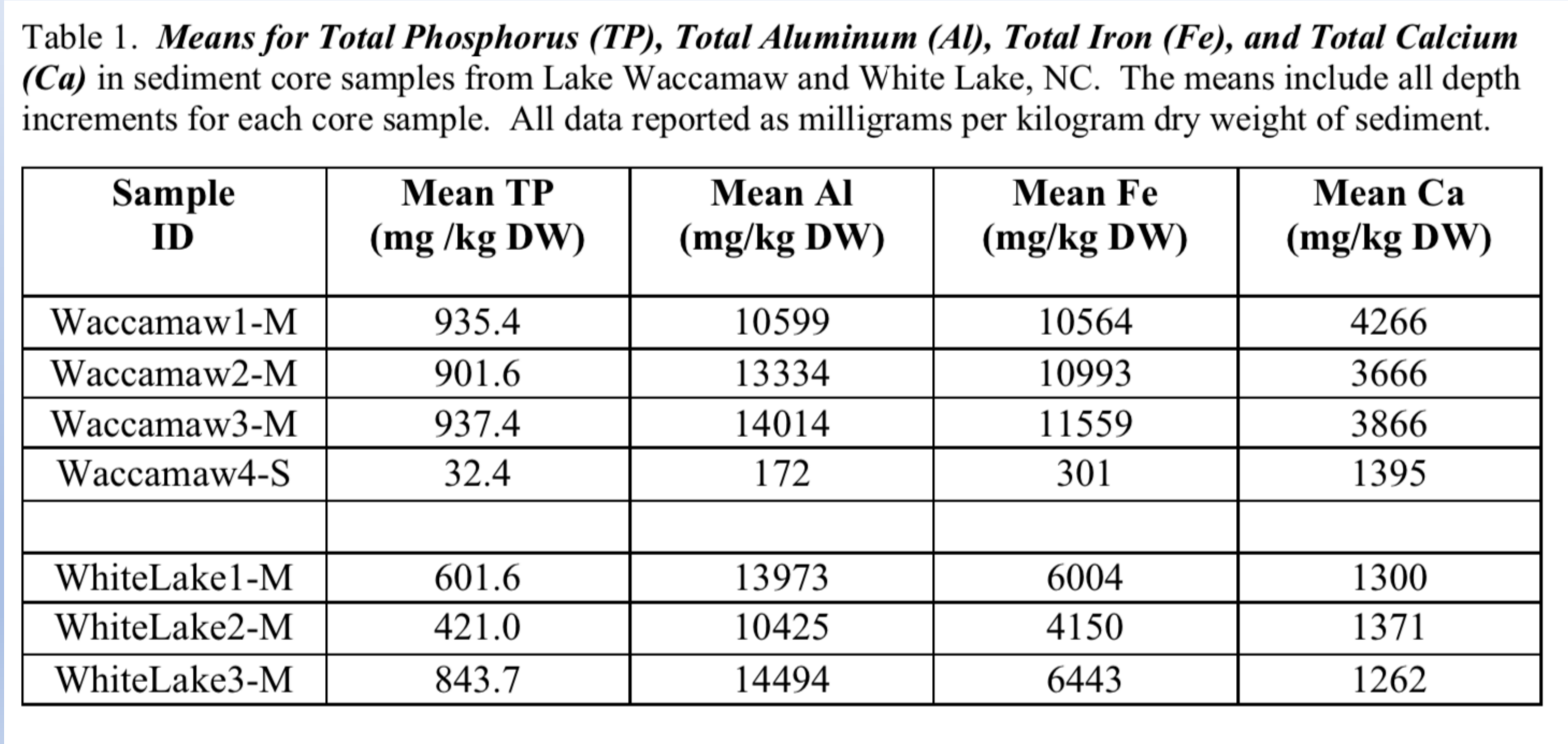


Table 1. ***Means for Total Phosphorus (TP), Total Aluminum (Al), Total Iron (Fe), and Total Calcium (Ca)*** in sediment core samples from Lake Waccamaw and White Lake, NC. The means include all depth increments for each core sample. All data reported as milligrams per kilogram dry weight of sediment.

Sample ID	**Mean TP (mg /kg DW)**	**Mean Al (mg/kg DW)**	**Mean Fe (mg/kg DW)**	**Mean Ca (mg/kg DW)**
Waccamaw1-M	935.4	10599	10564	4266
Waccamaw2-M	901.6	13334	10993	3666
Waccamaw3-M	937.4	14014	11559	3866
Waccamaw4-S	32.4	172	301	1395
WhiteLake1-M	601.6	13973	6004	1300
WhiteLake2-M	421.0	10425	4150	1371
WhiteLake3-M	843.7	14494	6443	1262

Al-Bound Phosphorus Dominant in Muck Sediments of Both Lakes

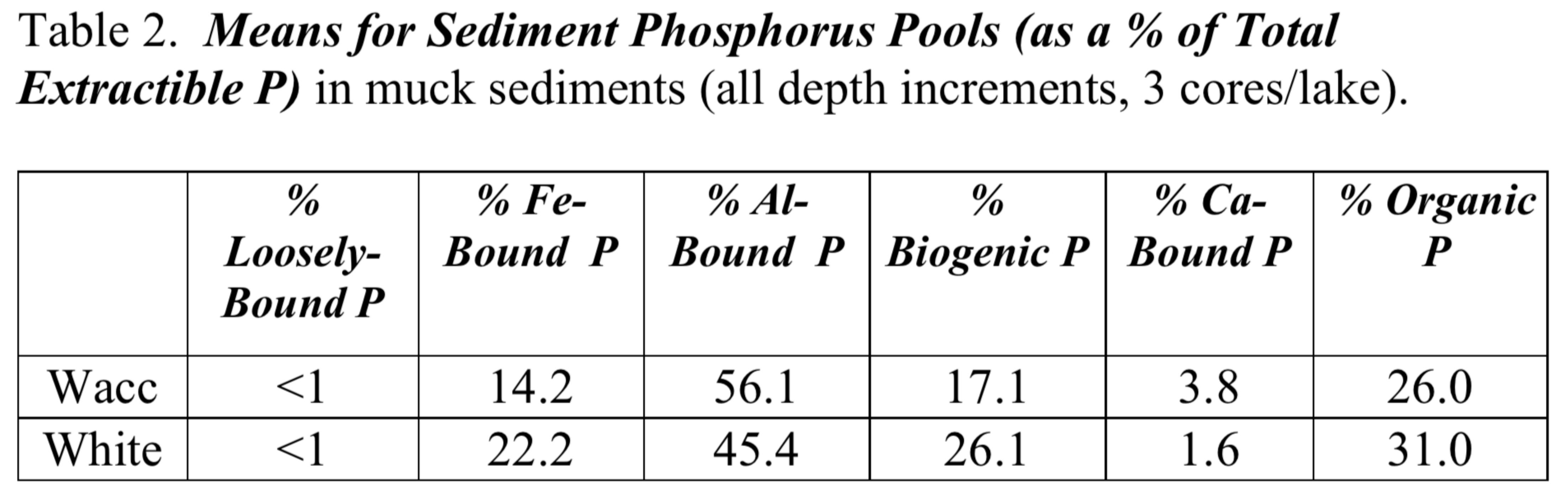


Table 2. ***Means for Sediment Phosphorus Pools (as a % of Total Extractible P)*** in muck sediments (all depth increments, 3 cores/lake).

	% Loosely-Bound P	***% Fe-Bound P***	***% Al-Bound P***	***% Biogenic P***	***% Ca-Bound P***	***% Organic P***
Wacc	<1	14.2	56.1	17.1	3.8	26.0
White	<1	22.2	45.4	26.1	1.6	31.0

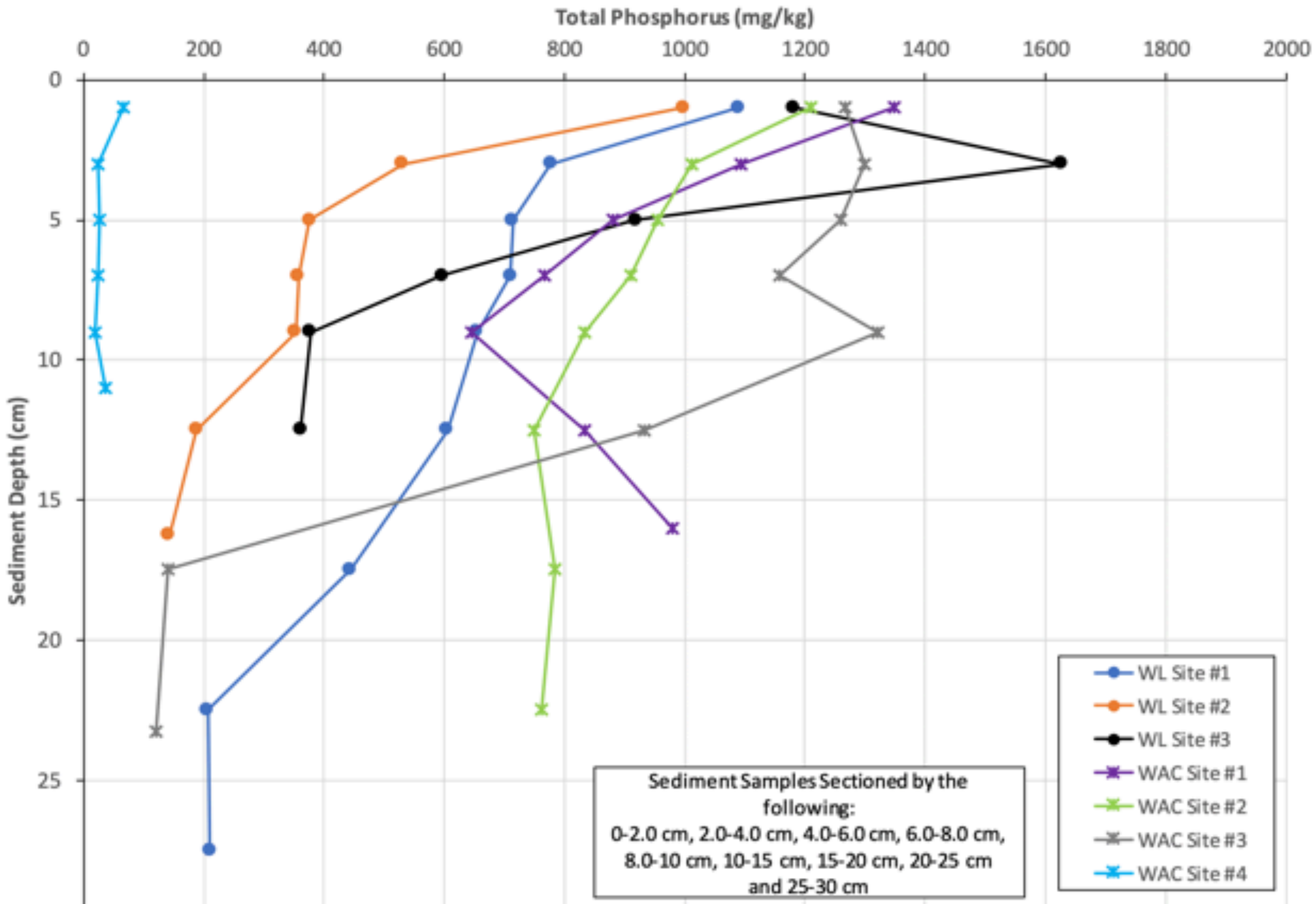
Total P

Sandy site at Lake Waccamaw had much less P

Muck sediments at Waccamaw had higher P than White Lake sediments

Trend of decreasing P with sediment depth

One outlier at White Lake—high Fe-Bound P



Sediment Samples Sectioned by the following:
0-2.0 cm, 2.0-4.0 cm, 4.0-6.0 cm, 6.0-8.0 cm, 8.0-10 cm, 10-15 cm, 15-20 cm, 20-25 cm and 25-30 cm

Figure 1. ***Total extractible P*** (mg/kg DW) from Lake Waccamaw (sites 1-3 muck, #4 sand) and White Lake (sites 1-3 muck) sediment cores.

Al-Bound P

Very little Al-P at Waccamaw sand site

Tight range of values in 0-2 cm depth increment for both lakes

Greater decline with depth in White Lake sediments

Highest value at Waccamaw in 8-10 cm depth increment

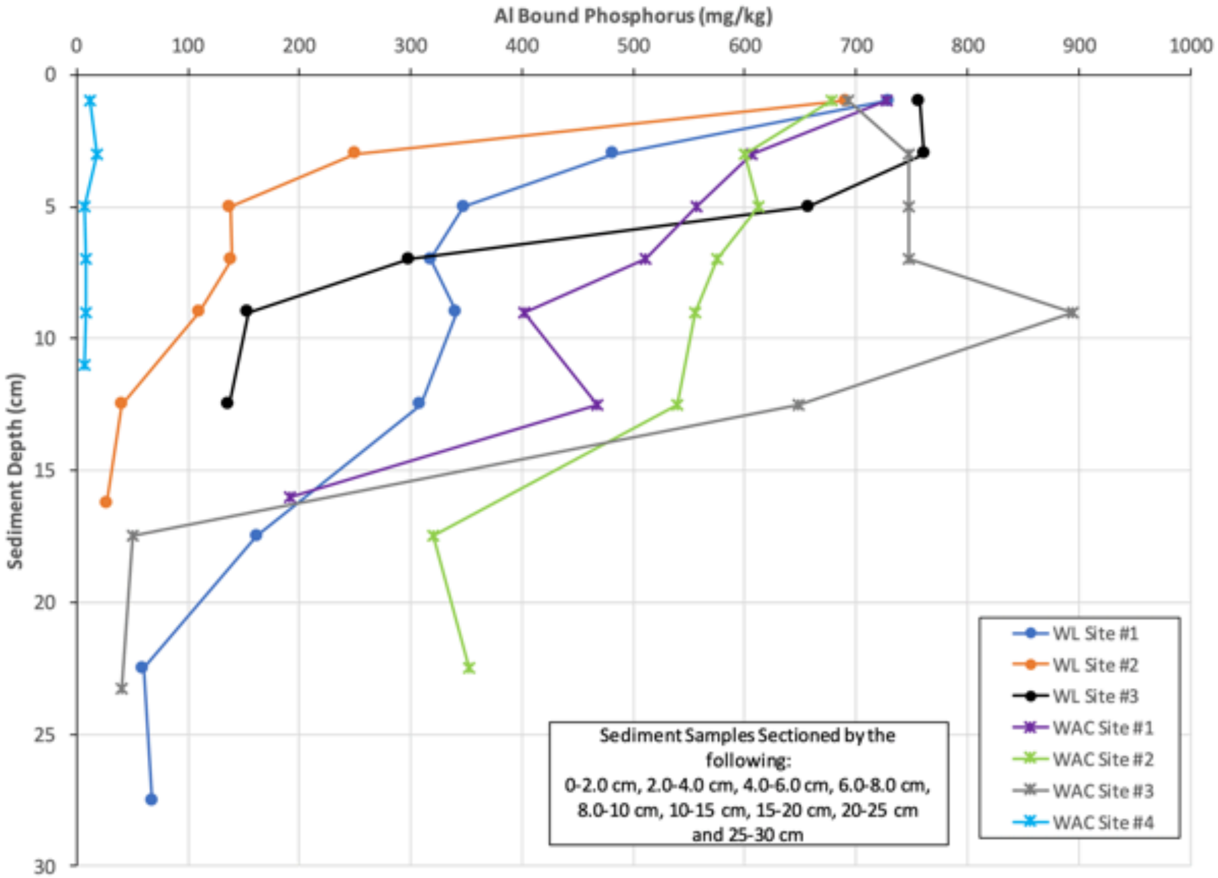


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Figure 2. ***Al-Bound P*** (mg/kg DW) for and White Lake (sites 1-3 muck) sediment core samples from Lake Waccamaw (sites 1-3 muck, #4 sand)

Mobile P (Fe-P)

Very little Fe-P at Waccamaw sandy site

Similar values between lakes

Little decline in Fe-P with sediment depth; two Waccamaw cores had highest values in deeper sediment increments

White Lake outlier—very different value of Fe-P in one depth increment

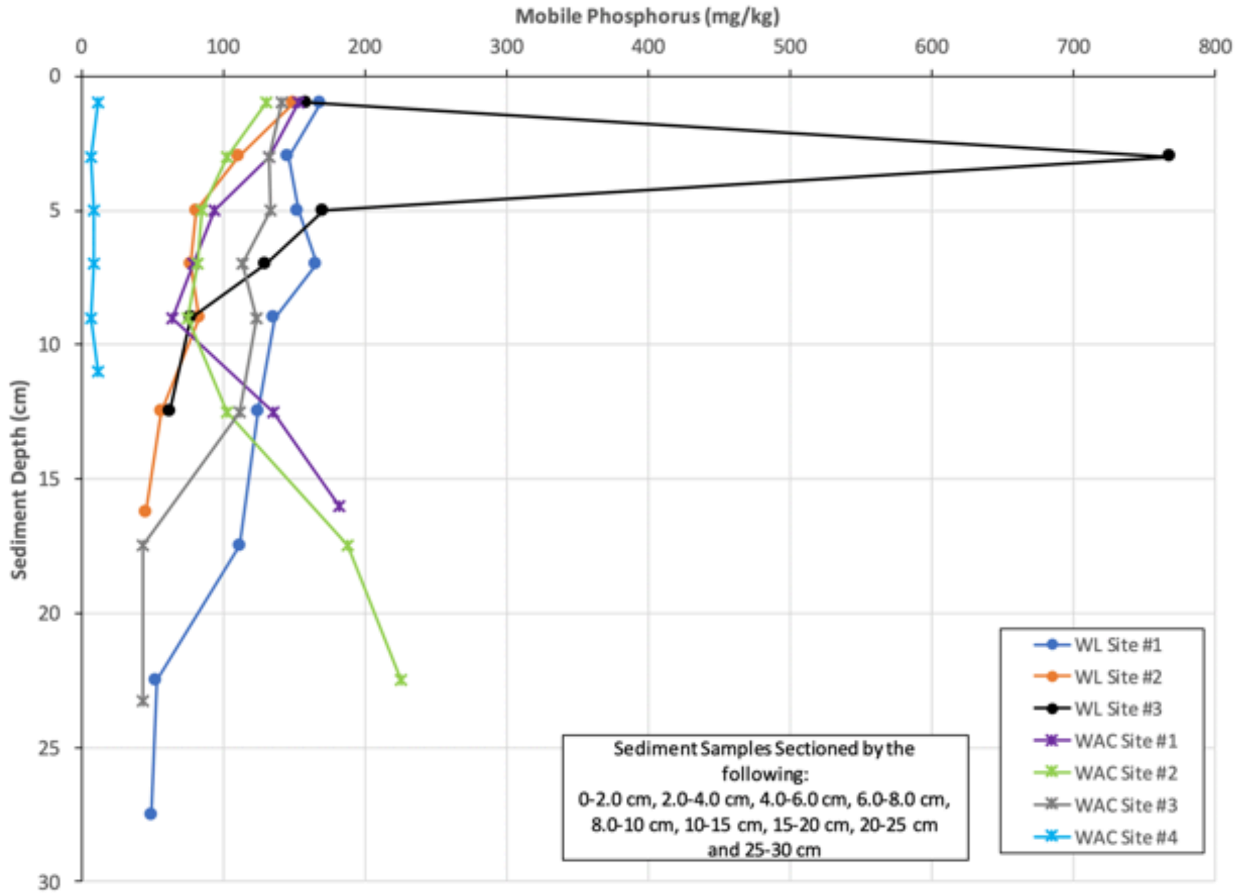
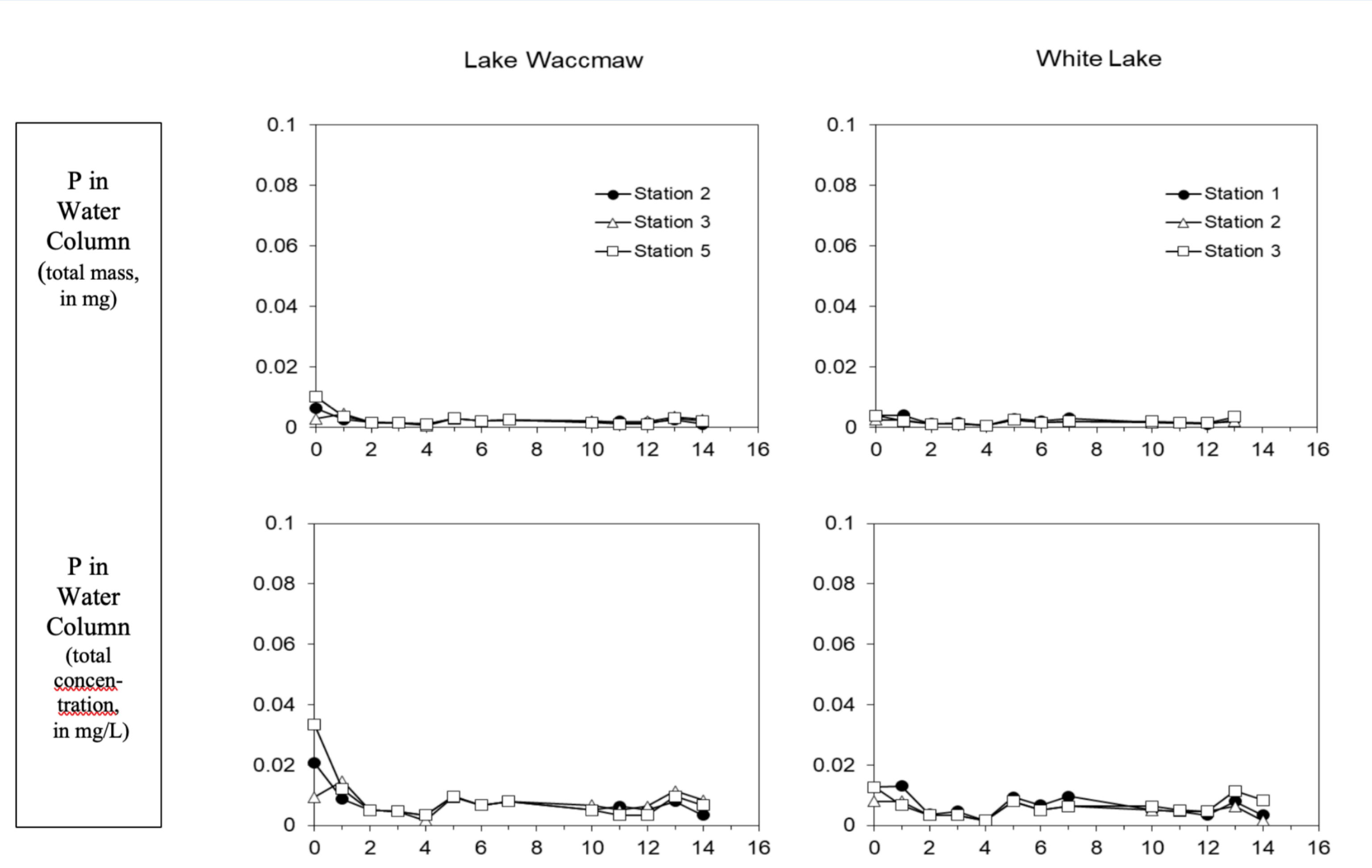


Figure 3. ***Mobile P*** (mg/kg DW) for and White Lake (sites 1-3 muck) sediment core samples from Lake Waccamaw (sites 1-3 muck, #4 sand)

Lab Incubations Under Anoxic Conditions: Mobile, or Fe-Bound P Becomes Bioavailable (Measured as SRP)



Why No Significant P Release Under Anoxia?

The naturally-occurring and abundant metal Aluminum in the sediments of both lakes is available to adsorb soluble reactive (dissolved) Phosphorus that can be released during hypoxia/anoxia

Wetland soils have natural capacity to retain P--high Al and Fe

(Richardson, 1985. Mechanisms controlling phosphorus retention capacity in wetlands. Science 228: 1424-1427)

Phosphorus inactivation of sediments with a binding agent (alum, Phoslock) is typically done when Mobile P (Fe-P) is the dominant form of sediment P and anoxic conditions are extended (lake stratification)

Processes That Regulate P Cycling in Lakes

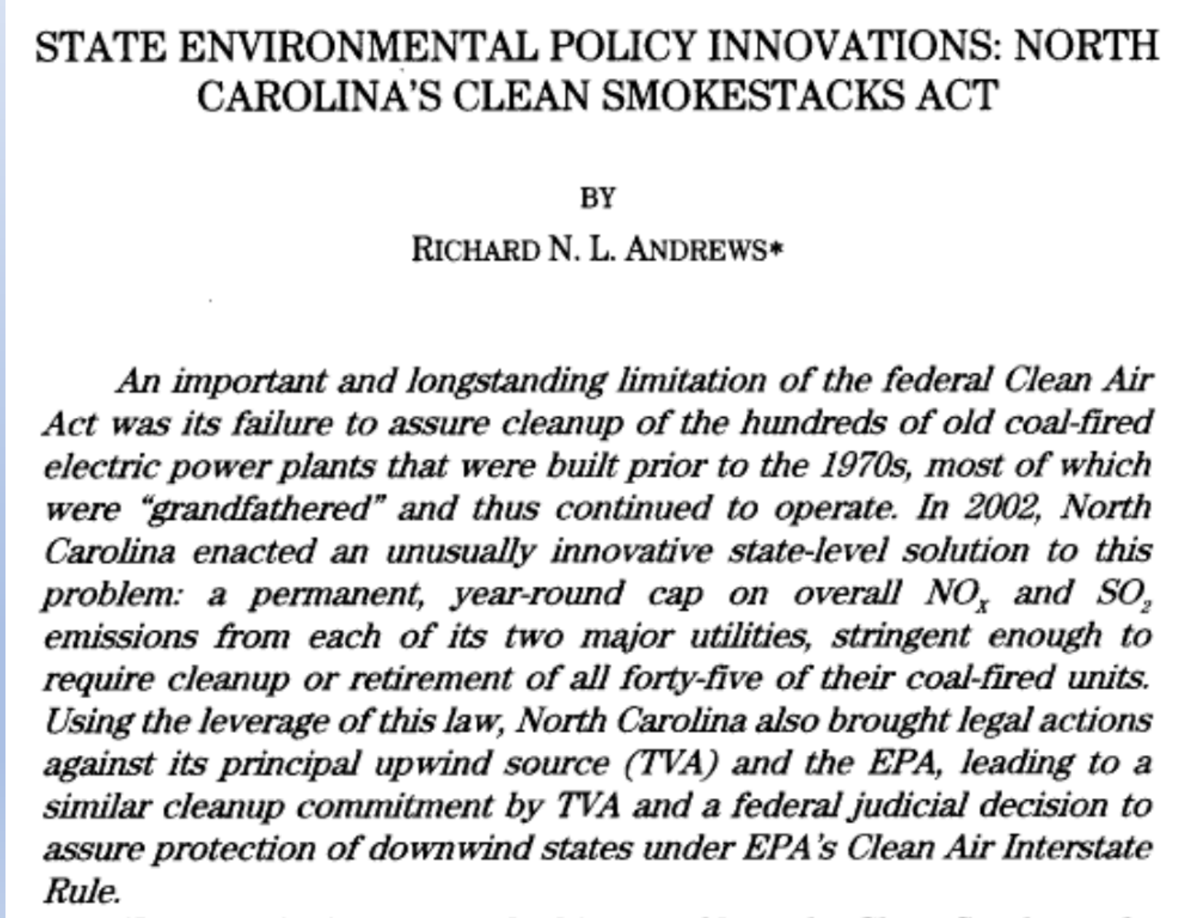
***Dissolved oxygen concentration**—anoxic conditions at Waccamaw after 2012 SAV die-off significant enough to affect benthic invertebrates*

***Temperature**—seasonal variability, climate change*

***Microbial activity = Biogeochemistry**--dependent on pH, temp, DO*

➡***pH**—changed at White Lake*

White Lake Was an Acid Rain Lake
Rainfall pH Has Increased From 4.5 to 5.8

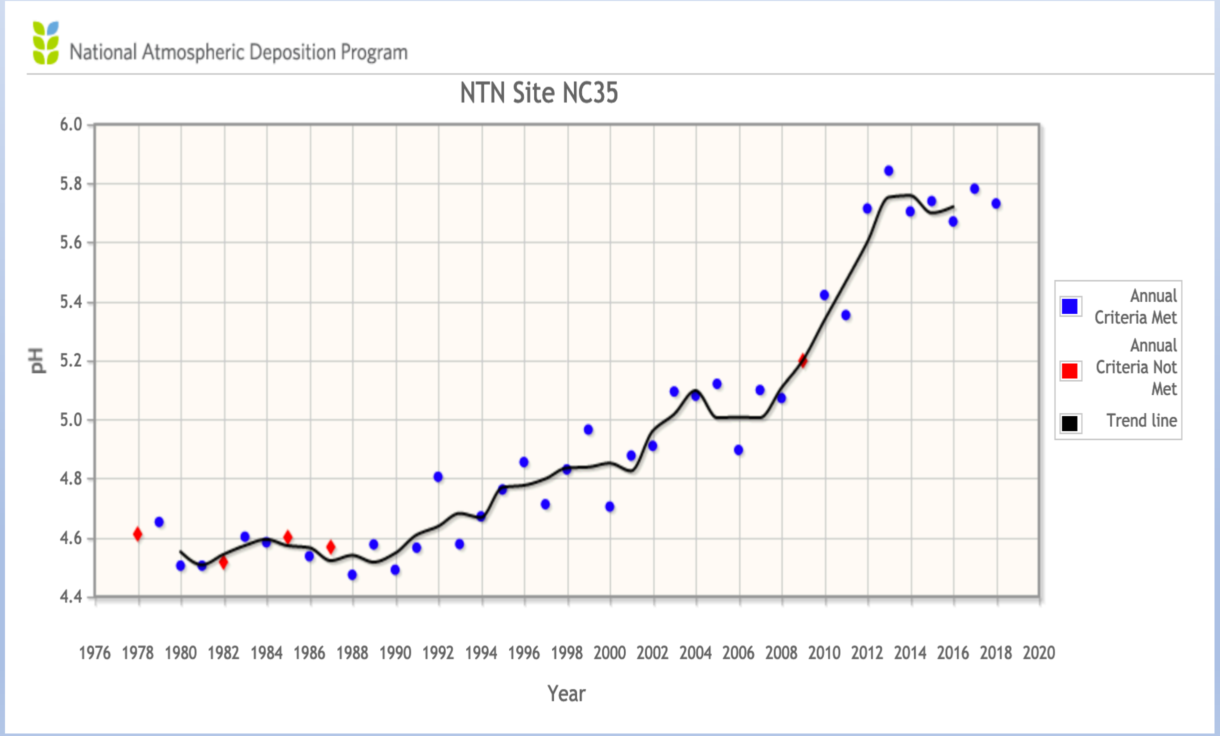


STATE ENVIRONMENTAL POLICY INNOVATIONS: NORTH CAROLINA'S CLEAN SMOKESTACKS ACT

BY

RICHARD N. L. ANDREWS*

An important and longstanding limitation of the federal Clean Air Act was its failure to assure cleanup of the hundreds of old coal-fired electric power plants that were built prior to the 1970s, most of which were "grandfathered" and thus continued to operate. In 2002, North Carolina enacted an unusually innovative state-level solution to this problem: a permanent, year-round cap on overall NO_x *and* SO_2 *emissions from each of its two major utilities, stringent enough to require cleanup or retirement of all forty-five of their coal-fired units. Using the leverage of this law, North Carolina also brought legal actions against its principal upwind source (TVA) and the EPA, leading to a similar cleanup commitment by TVA and a federal judicial decision to assure protection of downwind states under EPA's Clean Air Interstate Rule.*



Biogeochemical Changes with Changing pH

Bioavailability of P—Sorption with Aluminum

P and Al in Sediments, in groundwater, in surface water runoff

Low Alkalinity of lake water

2018 Low-Dose Alum Treatment to mitigate persistent cyanobacterial bloom—pH levels had shot up rapidly in early May

pH range in White Lake for 2019: 6.2-6.9

Management Focus for White Lake

Atmospheric Deposition and Sediments/Biogenic are largest P sources

Sediment resuspension—P becomes available--can we moderate boating activity to reduce its impact?

Aesthetics vs. Lake Health—

Change the narrative (Bad Algae vs. Algae Bad)

Manage elevated water column P if it occurs (trigger point 0.04 mg/L ?)

Mean water column P in 2019 was 0.018 mg/L

Thank You:

Town of White Lake for providing funding for White Lake sediment sampling

Lake Waccamaw State Park for providing a boat and staff for sediment sampling at Lake Waccamaw

Contact: ddlauritsen@gmail.com

www.whitelakewatch.com