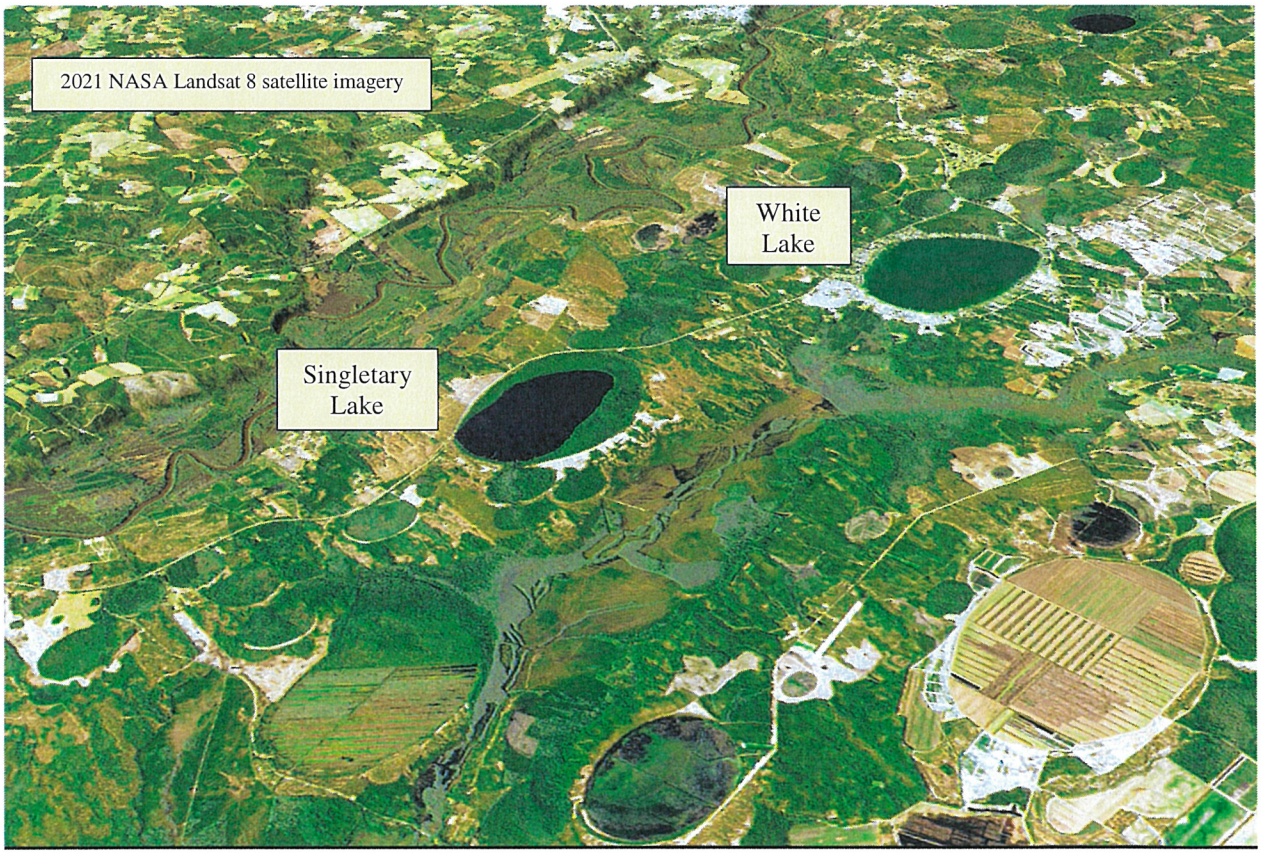
WQ Attachment 6.

Nutrient Comparisons Over Time, 1974-2022

Comparisons of lake data over time, and comparisons between White Lake and other Bay lakes provides a means to identify drivers of lake changes. A NC Water Resources Research Institute 1976 report on the Trophic Status of North Carolina Lakes by Dr. C. Weiss and Dr. E. Kuenzler includes data collected in 1974 (this is the first nutrient data reported for the Bay lakes), while NC DEQ conducts lake monitoring every five years for the summer period (May-September). LIMNOSCIENCES has been collecting monthly monitoring data at White Lake since May 2018 and sampled nearby Singletary Lake three times a year (February, June, September) in 2021 and 2022 as an acidic reference lake with an undeveloped lakeshore.



Singletary Lake is a blackwater lake that has no inlet, and the outlet was dredged, and a spillway dam created "160 yards from the original shoreline in the region of the sand rim", by the Resettlement Administration. At 569 acres, Singletary Lake occupies 56% of its bay (the remaining portion is wetlands), while White Lake, at 1,067 acres, occupies 71% of its bay (Frey 1949).

Attachment 6 continued.

White Lake: The following table includes 1974 data from Weiss and Kuenzler (1976), with the asterisk noting that a different methodology was used for chlorophyll a (the data is reported as "Turner units"), so results are not directly comparable with the other chlorophyll data in the table. 1998-2017 data from NC DEQ, and 2018-2022 data from LIMNOSCIENCES.

White Lake Monitoring Data Collected in June, From 1974 to 2022

	1974	2003	2013	2017	2018	2019	2020	2021	2022
Mean Temperature (C)	26.1	27.6	27.5	28.6	30.2	29.0	27.5	28	29.6
Mean Secchi Depth (m)	>3.0	2.6	2.8	1.2	1.75	>3.0	1.25	1.25	1.25
Mean Chlorophyll a (µg/L)	13*	5	2.5	10.7	8	5.5	6.4	9.4 (7.5)	3.4 (6.2)
pH Range (std. units)	4.6	4.2	6.0-6.8	6.5-7.4	6.6-7.3	6.2-6.7	7.1-7.3	6.8-7.0	6.7-6.9
Mean Dissolved Oxygen (mg/L)	8.6	8.0	7.0	7.3	7.6	7.9	8.6	7.8	8.1
Mean Total Nitrogen (mg/L)	0.211	0.11	0.39	0.68	0.50	0.481	0.757	0.870	0.745
Mean NO3-NO2 (mg/L)							0.013	<0.010	<0.010
Mean NH3-NH4 (mg/L)							0.006	0.014	0.010
Mean Total Phosphorus (mg/L)	0.017	<0.02	<0.02	0.02	0.02	0.014	0.025	0.031	0.029
TN/TP (mass)	12.4			34	25	34.4	30.3	28.1	26.0
# of Samples		3	3	7	7	6	6	6	6

White Lake experienced a filamentous cyanobacteria (*Planktolyngbya limnetica*) bloom from September 2017 to May 2018 (green line), and a low dosage alum treatment was applied 5/3 to 5/16/18. The June 2018 data is 6 weeks post-treatment.

Attachment 6 continued.

Singletary Lake: The following table includes 1974 data for Singletary Lake from Weiss and Kuenzler (1976) (chlorophyll a data with an asterisk was reported as "Turner units"); 2003-2018 data from NC DEQ; 2021-2022 data from LIMNOSCIENCES, and chlorophyll data in the table includes both lab measurements and field measurement with a handheld fluorometer (field data in parenthesis).

Singletary Lake Monitoring Data for June, 1974 to 2022

	1974	2003	2013	2018	2021	2022
Mean Temperature (C)	25.6	30.3	27.8	30.7	29.1	29.2
Mean Secchi Depth (m)	0.9	1.0	0.7	0.4	0.25	0.5
Mean Chlorophyll a (µg/L)	34*	12	6.2	12.2	11 (14)	11 (10)
pH Range (std. units)	4.2	3.6-3.7	5.4-5.6	4.1-4.2	4.3	4.26
Mean Dissolved Oxygen (mg/L)	8.5	7.6	8.7	6.6	7.3	6.36
Mean Total Nitrogen (mg/L)	0.306	0.340	0.43	0.730	0.881	0.625
NO3-NO2 (mg/L)	0.031	<0.02	<0.02	0.12	0.101	<0.010
NH3-NH4 (mg/L)	0.02	<0.02	0.02	0.02	0.036	0.059
Mean Total Phosphorus (mg/L)	0.022	0.023	0.023	0.04	0.038	0.030
TN/TP (mass)	13.9	14.8	18.7	18.25	23.2	20.8

Attachment 6 continued.

Nutrients were sampled in the Bay Lakes for the first time in 1974-5 as part of a comprehensive survey of NC lakes and reservoirs (Weiss and Kuenzler 1976). NC DEQ generally samples the lakes every 5 years, and Lake Waccamaw is on a different rotation, as monitoring schedules are based on river basins (it is in the Lumber River basin, and the Bladen County lakes are in the Cape Fear Basin). There is an ambient monitoring station at the southern end of Waccamaw that is monitored monthly, and there has been a clear trend of increasing TKN in that data. As TN includes phytoplankton N, chlorophyll data is included for 2013 (Bladen Co. lakes) and 2016 (Waccamaw).

Total Nitrogen, Ammonium, Nitrate-Nitrite (mg/L) and Chlorophyll a (ug/L) Ranges for Bay Lakes

	1974			1998			2013-16			
	TN	NH4	NO3-NO2	TN	NH4	NO3-NO2	TN	NH4	NO3-NO2	Chl a
Bay Tree (Black)	1.248-1.568	0.045-0.085	0.0523-0.628	0.21-0.44	<0.01-0.06	<0.01-0.11	0.24-0.77	<0.02-0.03	0.02-0.42	2.5-16.0
Jones	0.318-0.357	0.018-0.048	0.043-0.057	0.42-0.52	0.03-0.10	0.12	0.21-0.91	<0.02-0.38	<0.02-0.07	1.9-28.0
Salters	0.029-0.374	0.015-0.037	0.013-0.024	0.39-0.52	0.04-0.12	0.09-0.12	0.53-0.86	0.02-0.24	0.05-0.18	6.0-32.0
Singletary	0.260-0.306	0.020-0.050	0.030-0.031	0.22-0.34	<0.01-0.12	<0.01-0.04	0.41-0.69	<0.02-0.05	<0.02-0.07	3.8-16.0
White	0.123-0.211	0.030-0.038	0.011-0.013	0.06-0.21	<0.01-0.08	<0.01	0.27-0.63	<0.02	<0.02	3.4-30.0
Waccamaw	0.358-0.448	0.013-0.043	0.008-0.013				0.75-0.93	<0.02-0.04	<0.02-0.08	3.2-33.0

(Waccamaw Data from 2016)

Additional sampling of some of the Bay Lakes was conducted in September 2020:

Table 1. Total Nitrogen (mg N/L), Dissolved Nitrogen (mg N/L), Total Phosphorus (mg P/L) and pH (standard units) for the Bay Lakes in Bladen and Columbus Counties, NC. Data for 1974-5 taken from: Weiss, C.M., and E.J. Kuenzler. 1976. The Trophic State of North Carolina Lakes. Water Resources Research Institute of the University of North Carolina Report No. 119. Data for 2020 collected September 14-17, by LIMNOSCIENCES, with nutrient analysis by IEH Analytical Laboratories.

	1974			2020			
	pH	TN	TP	pH	TN	Dissolved N	TP
Bay Tree	7.0-7.1	0.48-1.568	0.13-0.238	4.4	0.460-0.472	0.198-0.225	0.022-0.023
Jones	3.1-4.8	0.32-0.36	0.013-0.023	3.9			
Salters	4.1-4.8	0.29-0.37	0.015-0.016				
Singletary	3.2-4.6	0.26-0.31	0.018-0.022	4.1	0.909-0.926	0.575-0.762	0.032-0.040
White	4.6-4.8	0.12-0.21	0.010-0.017	6.8	0.666-0.863	0.355-0.384	0.017-0.020
Waccamaw	6.8-7.5	0.36-0.45	0.017-0.025	6.4-6.9	0.803-0.822	0.661-0.838	0.021-0.024
Big Creek				5.92	1.71	1.39	0.091

Attachment 6 continued.

The following is taken from the 2021 White Lake Monitoring Report, which is available on the White Lake Watch web site:

There was generally little variability in Total Phosphorus monthly means in 2021, with a notable exception being April, when a desmid bloom was peaking. Total P values ranged from 0.037 to 0.040 mg/L (mean 0.039, Table 3); this month also had the highest Soluble Reactive P (SRP) levels, ranging 0.002 [at both northern lake depths] to 0.026 [at the mid-lake 2.0 m depth] (mean 0.011, Table 3).

Another notable situation occurred during September sampling, when a brown trail (due to a wave-board boat churning up bottom sediments) was seen at the mid-lake station location (Fig. 6). A grab sample taken in this plume at 0.5 m had a TP level of 0.054 mg/L (compared to 0.025-0.026 mg P/L at the other stations). Total Nitrogen was also higher at 1.01 mg/L (compared to 0.696-0.899 mg N/L at the other stations).

Figure 6. Top photos: the sediment plume, with a grab sample taken at sampling station WL-B1 (0.5 m depth); bottom photo: view of western lakeshore in early afternoon, showing a zone of sediments along the water's edge. Photos taken on September 28, 2021. The lake level was 64.4 feet NAVD 88.

Attachment 6 continued.

Summary Observations from Nutrient Monitoring in White Lake and Other Bay Lakes:

- White Lake Nitrogen levels were historically very low, and it ranked lowest among the Bay Lakes in Total Nitrogen levels in 1974
- Nitrogen levels have increased in all the Bay Lakes (Bay Tree is an outlier, however, as it was drained in the late 1960s)
- Phosphorus levels have remained consistent over time in all the Bay Lakes (Bay Tree excepted)
- Total Nitrogen/Total Phosphorus ratios have increased in White Lake and other Bay Lakes
- Rainfall is a significant source of nitrogen, and big rains can fuel algae blooms in White Lake
- White Lake was, and remains, a nitrogen-limited system
- Boating activity can introduce phosphorus-rich sediments into the water column
- Phosphorus levels can increase during algae blooms