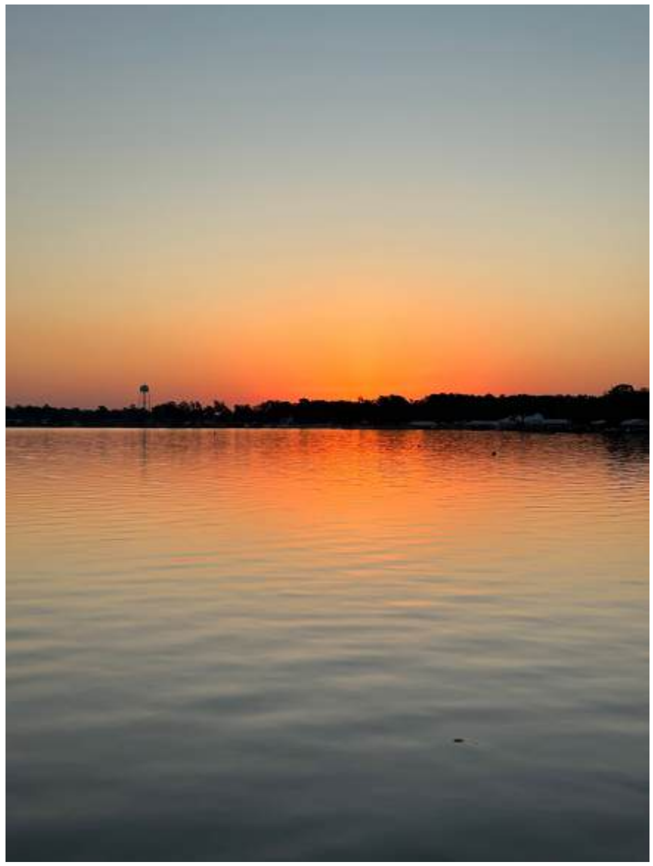
White Lake,
Bladen County, NC

Lake Monitoring Results 2024



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May 15, 2025

Introduction

White Lake is a unique and valuable resource that has undergone changes due to human activities. There are, however, several fundamental attributes of White Lake that have not changed over time:

- It is a small and very shallow Bay lake (a lake type described in Frey 1949). The maximum depth is less than 3 meters, with a mean depth of less than 2 meters.
- It is well-mixed, and water temperatures can change quickly. The growing season extends through most of the year.
- Roughly half of the lake bottom is muddy sediments (Frey 1949), with sandy sediments found in the shallow perimeter of the lake.
- It is a rain basin, or seepage lake, as there is no natural surface water inlet to the lake. Rainfall on the lake surface is the primary source of water with groundwater being a secondary source.
- The clarity of the lake water is due to the minimal influence of wetlands (whereas the other Bay Lakes are wetlands-influenced, blackwater systems) and to the natural water flow patterns east to west.

Understanding what has changed (and why) has been a focus of recent study of White Lake. Lake chemistry (pH in particular) and productivity have changed since 2008, with phytoplankton blooms (2013 and 2017-18) and the presence of the invasive aquatic weed hydrilla in most of the lake (in 2017). Special projects that have been conducted in recent years include:

- May 2018 Alum Treatment: The treatment was done to mitigate the 2017-2018 filamentous cyanobacterial bloom, which had caused pH levels to spike rapidly (to 9+, which denotes impaired waters) by the time the treatment was initiated ; the extreme conditions resulted in a fish kill, which subsided as the treatment lowered pH to pre-bloom levels.
- NCSU 2019-2020: Propagation of a rare aquatic plant found in the lake, and an assessment of herbicide effects on it, in the event that herbicide treatment of hydrilla would be needed.
- Lauritsen et al. 2019: Sediment phosphorus analysis, and comparisons with Lake Waccamaw. Aluminum-bound phosphorus is the dominant fraction with iron-bound phosphorus secondary in the muddy sediments of both lakes.
- Shank and Zamora 2019: Development of a groundwater model, delineation of the groundwatershed, confirmation that rainfall on the lake surface is the primary source water for the lake, and confirmation that the surficial aquifer is the source of the springs.
- Consolvo 2022: A geohydrological assessment of groundwater flow in the area, and confirmation that the semi-confined surficial aquifer is the source of the springs.
- Lumber River Council of Governments 205(j) Grant 2018-2020: Assessment of stormwater outfalls to the lake, rainfall nutrient monitoring, and winter waterfowl counts.
- Lumber River Council of Governments 2022: Lake Management Strategic Plan, Town of White Lake. Included land use strategies and a draft stormwater ordinance to facilitate lake stewardship.

The Town of White Lake has also invested $5 million in its wastewater collection system since 2019.

White Lake water quality monitoring has been conducted for the past seven consecutive years (2018-2024). The 2021 White Lake Monitoring report (LIMNOSCIENCES 2022, available at www.whitelakewatch.com, along with a quality assurance QAPP document and other annual reports) was developed as a comprehensive review document which includes data from most of the special projects as well as monitoring data from previous years and a literature review.

This 2024 monitoring report focuses primarily on the data collected for the year, including:

- Lake levels, rainfall, and physical-chemical parameters
- White Lake's nutrient levels, including comparisons with nearby Singletary Lake
- The productivity of the lake and its variability over time

The Town of White Lake has provided financial support for special studies and lake monitoring work, while personnel from the Singletary Lake office of NC State Parks have provided logistical assistance. Dr. Linda Ehrlich, with Spirogyra Diversified Environmental Services, has provided detailed taxonomic work on phytoplankton abundance and biovolumes. Aquatic vegetation sampling was conducted in October 2024 by NC State University personnel. Steve Bunn collected rainfall and lake level information.

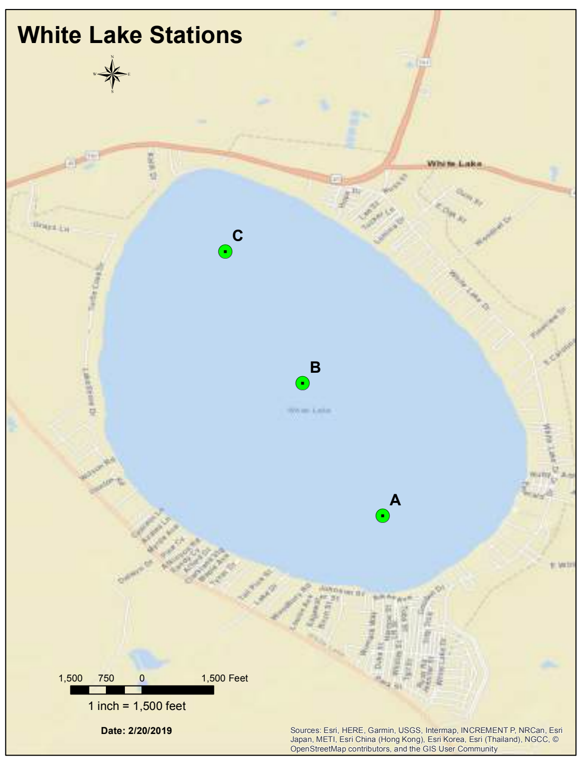


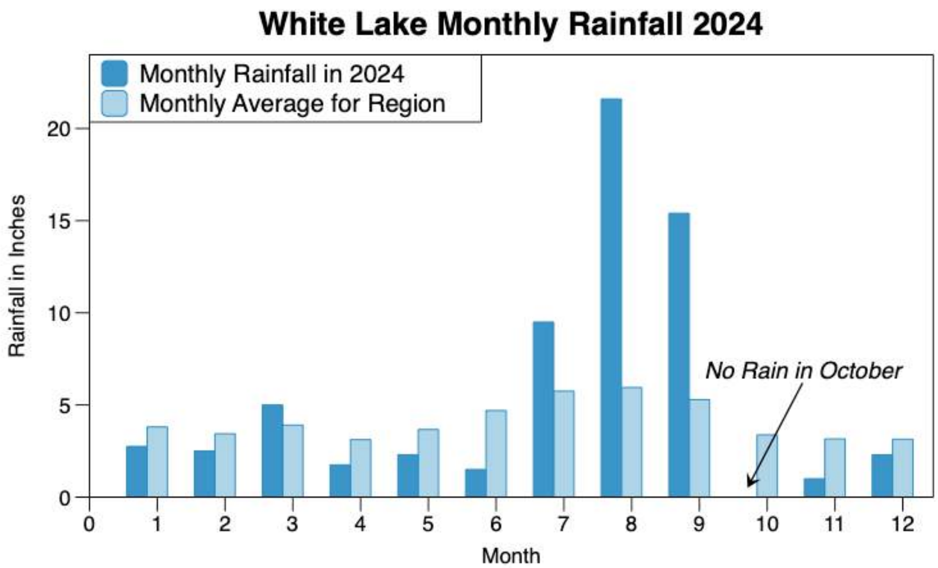
Figure 1. White Lake monitoring stations, which correspond to NCDEQ sample stations.

Results

1. 2024 Rainfall and Lake Level Variability

Total rainfall in 2024 was above average at 65.6 inches, a volume which equates to 86% of the total volume of the lake. More than 70% of the annual total fell in the 3-month period July-September, with highest rainfall seen in August (with Tropical Storm Debby on August 7-8 contributing 9.8", and a total of 19" of rain over a 10-day period; Fig. 2a). Two additional storms in September ("Potential Tropical Cyclone 8" and Hurricane Helene) contributed 15" of rain over 13 days. This rainfall pattern—multiple big storms--was similar to what was measured at White Lake in 2013, when the first greening of the lake occurred (Fig. 2b).

a.



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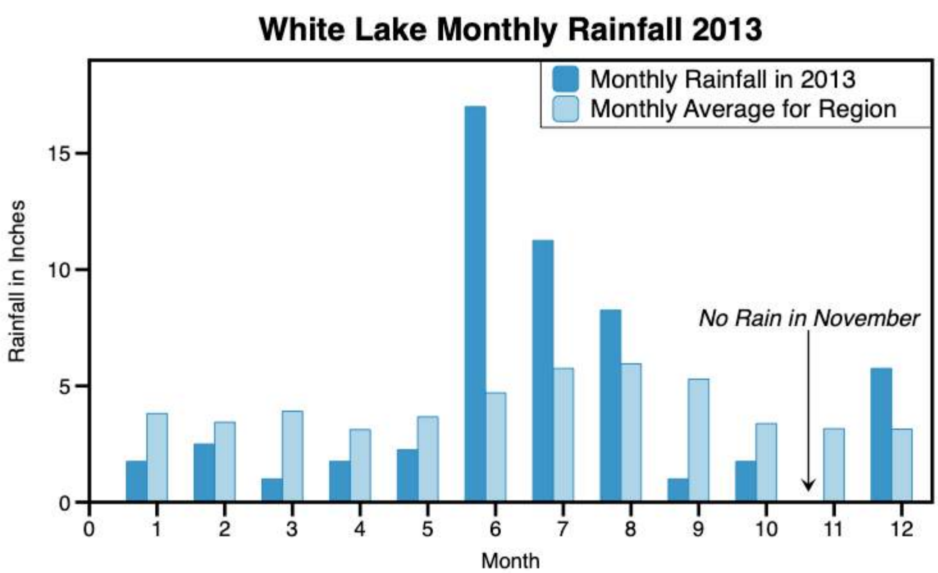


Figure 2. White Lake monthly rainfall, in inches, measured at the Town WWTP for 2024 and 2013, with long-term monthly averages for the region (measured at Elizabethtown, NC).

The variation in lake elevations was greater in 2024 (20.4 inches) than what has been observed over the past six years, as periods of drought alternated with periods of high rainfall. The lowest level, 63.7 ft NAVD 88 on July 5, was followed by a high of 65.4 ft NAVD 88 on August 12 and again on September 18 (Fig. 3). The six-year (2019-2024) mean high-water level was 64.9 feet NAVD 88. The total variation in lake levels (high to low) over the five-year period was 22.8 inches which is in line with what has been measured historically.

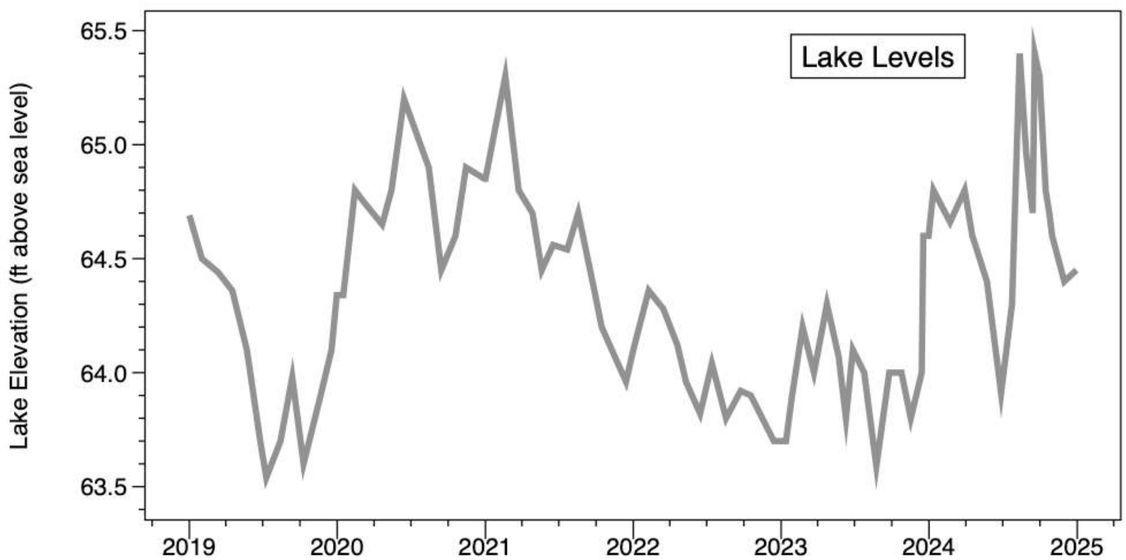


Figure 3. White Lake elevations for the period 2019-2024 (elevation reported in feet above sea level, NAVD 88 datum).

Stormwater pipes can direct large volumes of water to the lake during large rainfall events.

2. Rainfall pH in the Region Continues to Increase

Improvements in air quality have resulted in the elimination of acid rain across the continent in recent years, including at White Lake, so that the baseline pH of the rainfall and lake water has increased 1.5 units. Emissions from intensive animal agriculture have created a regional hot spot for nitrogen, and one form, ammonia, increases the pH of the rain (ammonia is a strong base, which is the opposite of an acid) The median annual pH level at a nearby National Atmospheric Deposition Program monitoring station has increased 0.3 units since 2019, to slightly above 6 in 2022 and 2023 (2024 data is not yet available; Fig. 4).

In addition to influencing the pH of the rainfall (and thereby the lake), ammonia is an inorganic, or readily available form of nitrogen which means that it can stimulate rapid phytoplankton growth.

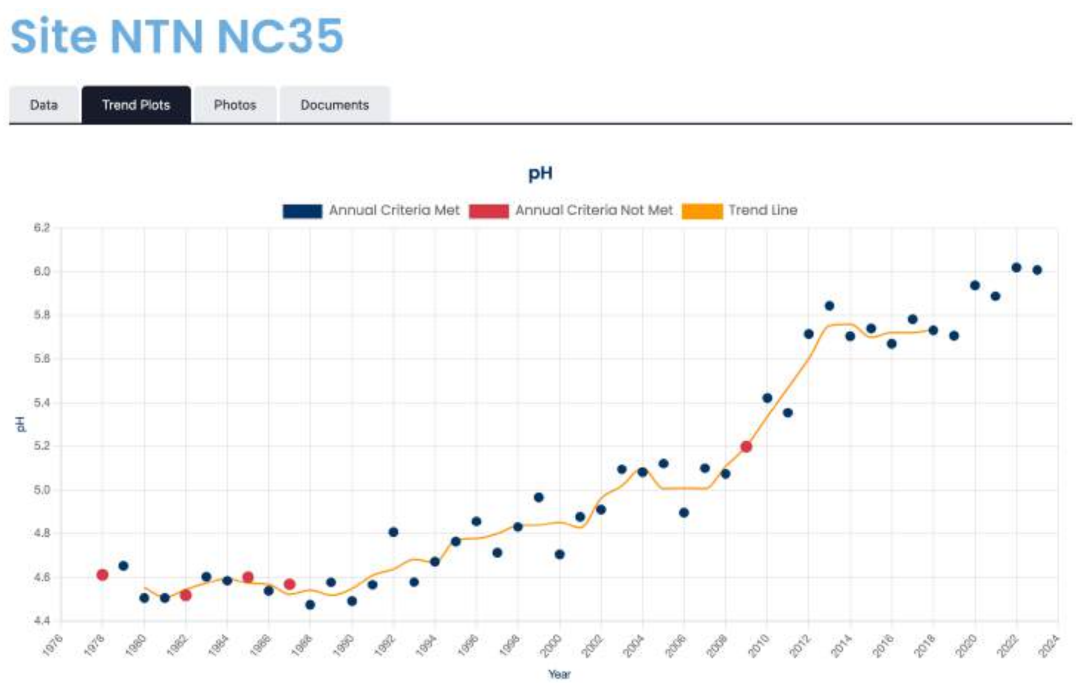


Figure 4. Median annual pH (SU) of rainfall at the Clinton Crops Research Station in Sampson County (NC35). NADP web site, https://nadp.slh.wisc.edu/sites/ntn-NC35/ accessed 5/11/25.

3. Lake Clarity and Turbidity

Lake clarity, as measured by Secchi depth, was lowest (1.1 m) in April and highest a month later (2.4 m, which is close to the lake bottom) (Fig. 5). Turbidity levels were greatest in Feburary and April (4.9 and 5.0 NTU respectively) and dropped considerably in May (to 1.6 NTU) (Fig. 6).

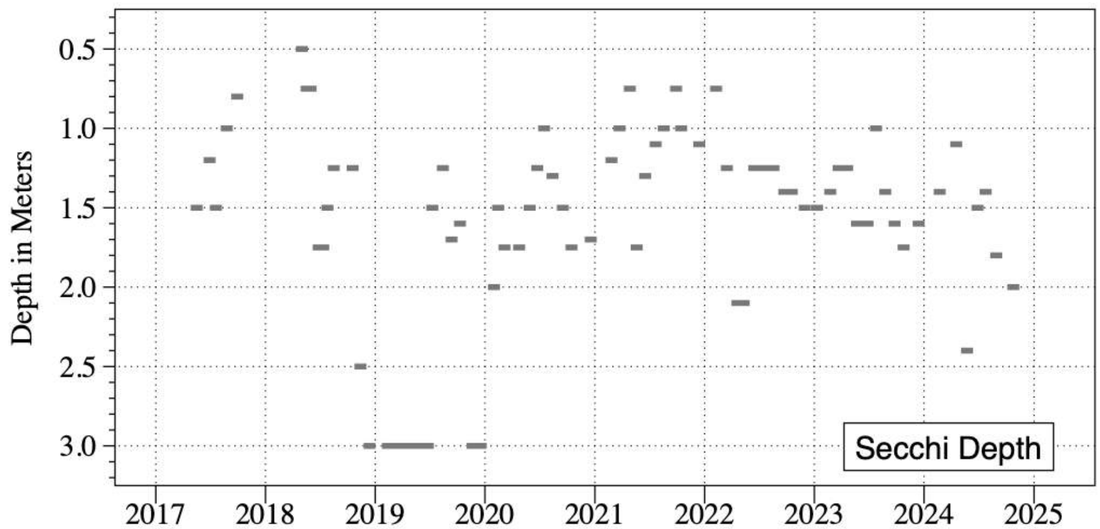


Figure 5. White Lake water clarity (in meters), as measured with a Secchi disk, from 2017 (NC DEQ data) through 2024 (LIMNOSCIENCES data for 2018-2024). Note that the y-axis is inverted, so that the top of the graph is equivalent to the lake surface. As the lake depth varies with lake level, during periods when the Secchi disk was visible on the bottom, it was reported as 3 meters, even though the actual depth was not 3 meters.

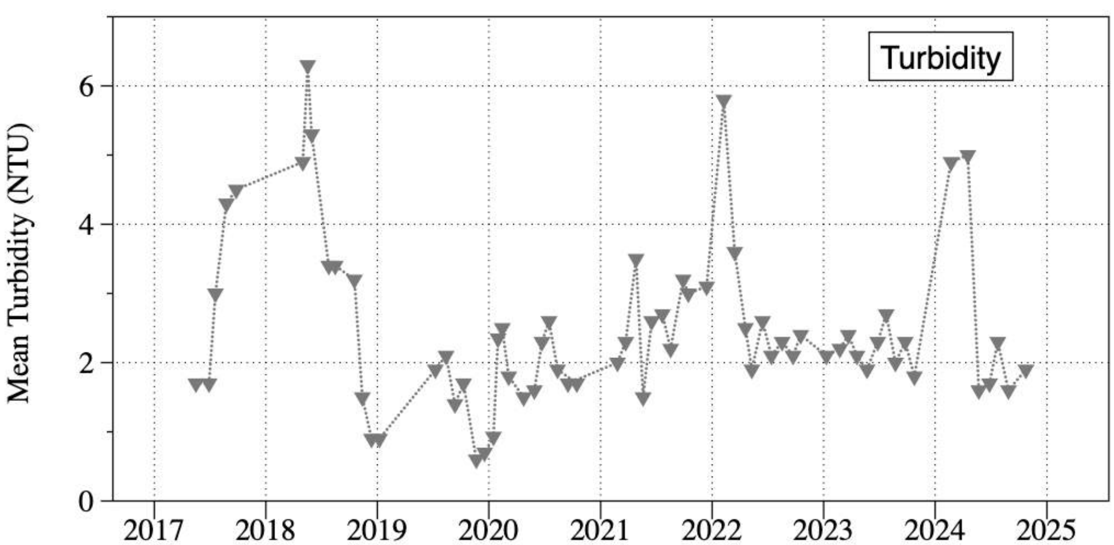


Figure 6. White Lake turbidity (in NTU), from 2017 (NC DEQ data) through 2024 (LIMNOSCIENCES data for 2018-2024).

Nearshore conditions may vary considerably from one portion of the lakeshore to another, as evidenced in May 2024 (Fig. 7).

a.

b.

Figure 7. The view from a) the eastern shoreline of White Lake at Goldston's Motel, and b) the southwestern shoreline at Lake Place condos, May 23, 2024, when water clarity was highest at the midlake sample stations.

4. <u>White Lake Nutrient Levels</u>

Total phosphorus (TP) levels were highest in April (22 µg/L) and lowest in May (12 µg/L; Fig. 8a). Soluble reactive phosphorus (SRP) levels were at or below detection limits (1 µg/L) from February through July, and only slightly higher (2 µg/L) in August and October (Appendix 1).

Total nitrogen (TN) was also highest in April (727 µg/L) and the lowest in May (465 µg/L; Fig. 8b). The highest mean NO_3-NO_2 (32 µg/L) was found in June (Appendix 1).

Ratios of TN/TP (mass) did not vary as much in 2024 as in previous years, ranging from 29 in October to 45 in August (Appendix 1).

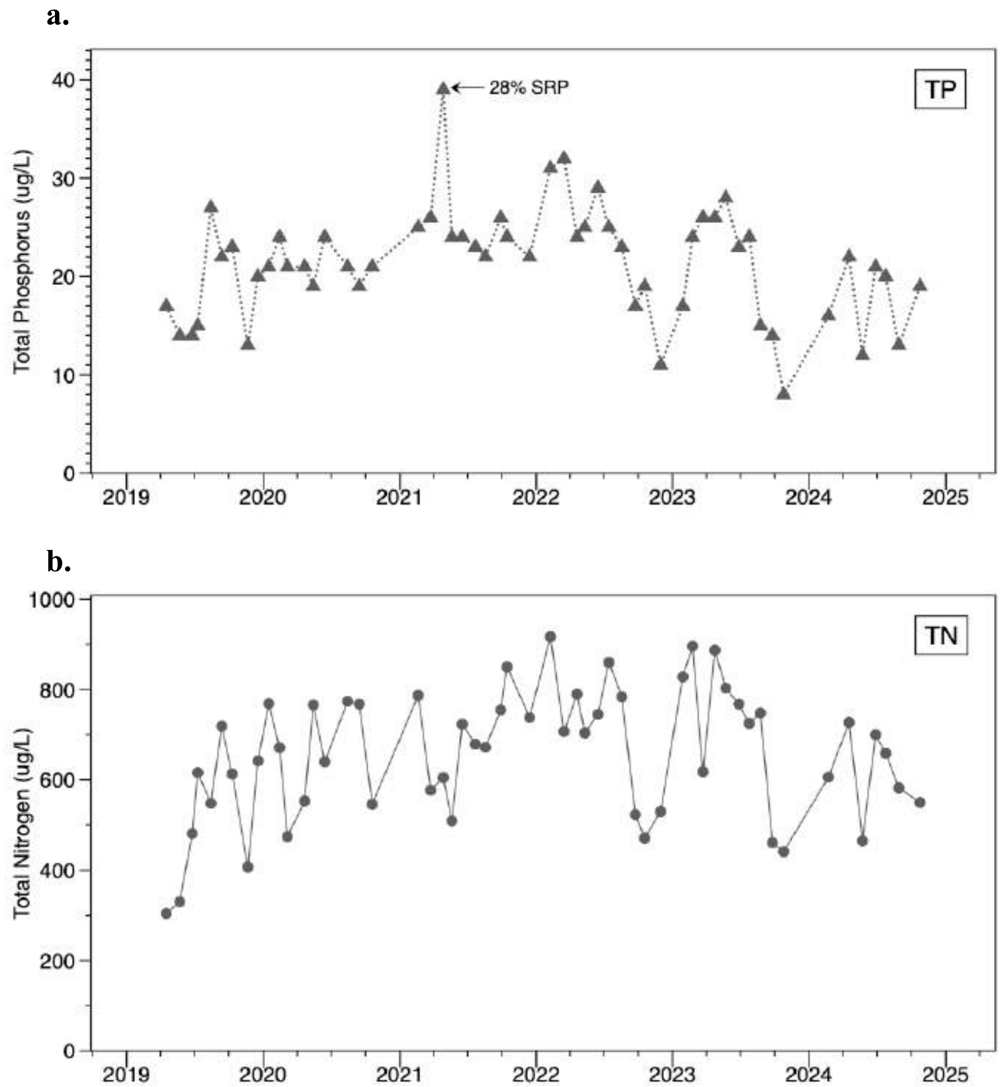


Figure 8. White Lake monthly means for: a) total phosphorus (TP, µg/L), and b) total nitrogen (TN, µg/L), from 2017 (NC DEQ data) through 2024 (LIMNOSCIENCES data for 2018-2024).

Dissolved Organic Carbon (DOC) levels can vary considerably from month to month in White Lake, and in 2024, the highest mean was measured in April (Fig. 9). Note that the graphs for TN and TP show units as µg/L, while the graph for DOC shows units as mg/L.

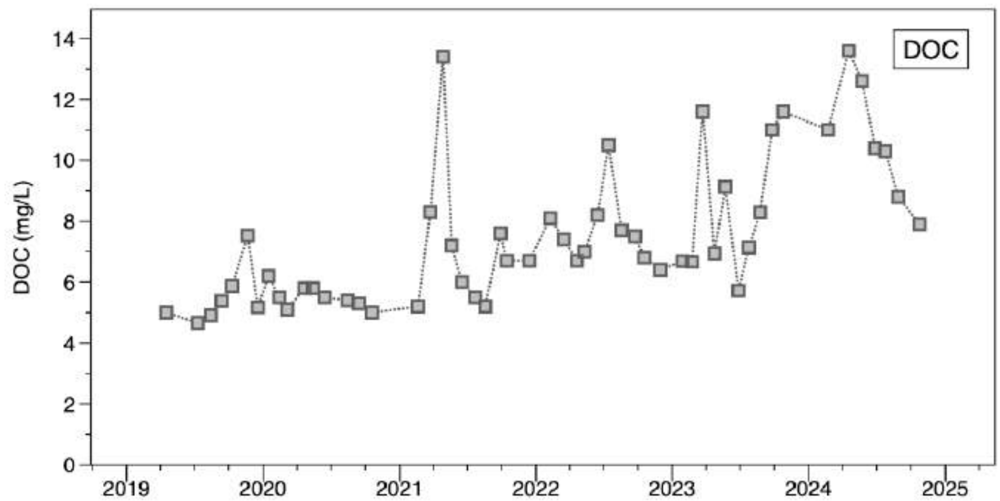


Figure 8. White Lake monthly means for dissolved organic carbon (DOC, mg/L) from 2017 (NC DEQ data) through 2024 (LIMNOSCIENCES data for 2018-2024). Note the difference in scale for DOC compared to TP and TN graphs.

5. <u>Chlorophyll *a* and pH</u>

In White Lake, the trends in phytoplankton biomass (as measured by chlorophyll *a* levels) have been similar since the 2017-2018 cyanobacterial bloom, with late winter-early spring peaks in some years (e.g., 2021) and mid-late summer peaks as well; in 2024, the highest mean chlorophyll a was found in August (Fig. 11a). A comparison of chlorophyll *a* data using two methods, 1) laboratory analysis of samples, and 2) field measurements with a handheld Turner fluorometer (see photos below from May 2024 sampling, when clarity was highest), found generally good agreement between the two, so field measurements can be a reliable method for assessing conditions quickly.

The pH levels measured in 2024 showed little variation over time, with a range of less than a full unit, indicating a moderate influence from photosynthesis (Fig. 11a, b).

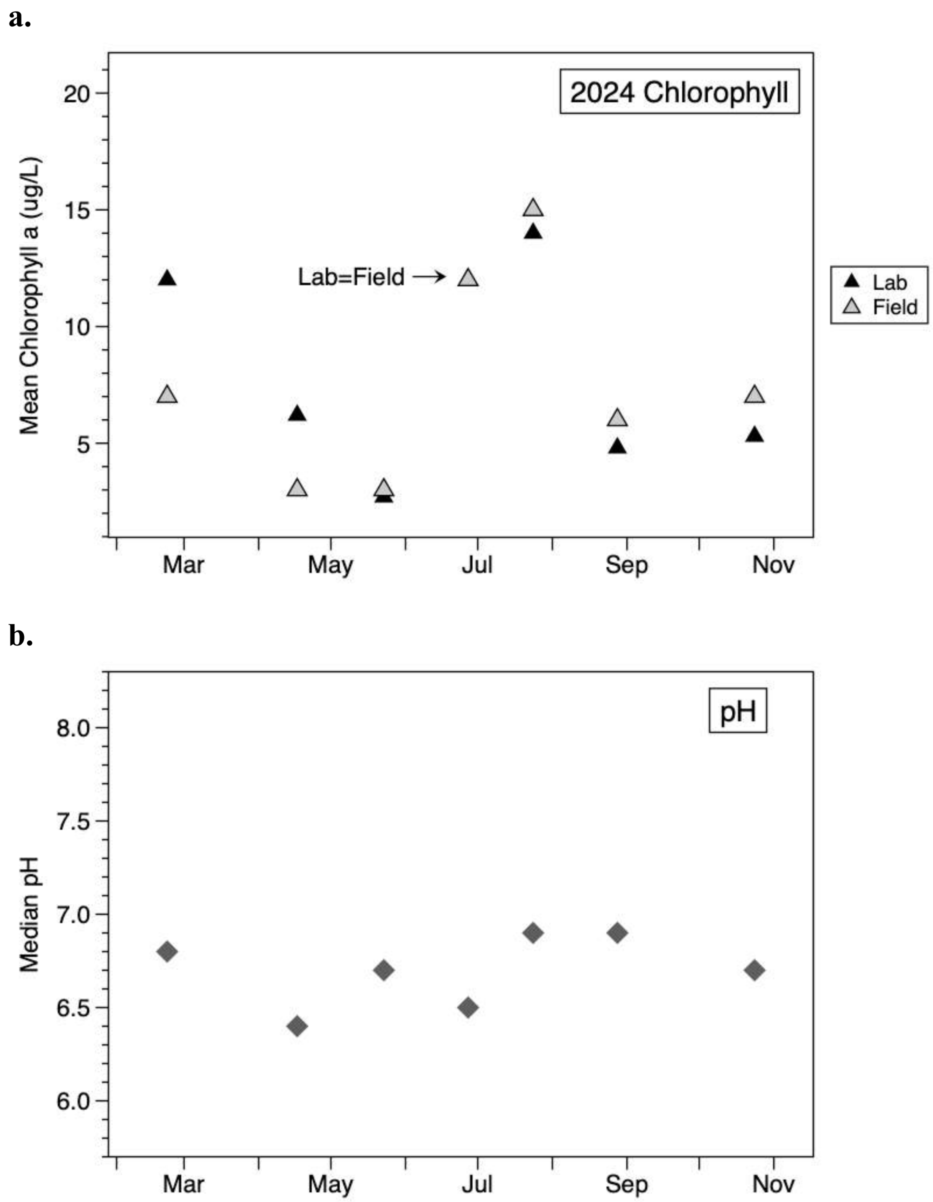


Figure 11. White Lake 2024 data for a) mean chlorophyll *a* (µg/L) (field measurements were taken with a handheld fluorometer); and b) median pH (SU).

Comparisons of the White Lake phytoplankton community in the month of July provide a snapshot of summer conditions over time; the data show that desmids (Charophyta) have dominated the biovolume at least since 2017 (Table 2). The first documented phytoplankton bloom in White Lake occurred in July 2013, after a large amount of rain in June-July (Table 1); this was the first time that pH levels above 8 were seen, but the elevated levels did not persist once the bloom (dominated by an "unidentified green alga") dissipated (Fig. 4, NCDEQ 2014). In July 2024, the pH levels were below 7, andthe desmid *Staurastrum tetracerum* dominated the biovolume (75%; Table 2).

Biovolumes were lower in August as this desmid had largely disappeared from the community (analysis in progress).

Table 2. White Lake nutrient, clarity, pH and phytoplankton data comparisons for the month of July, from 2013 to 2024 (2013-2017 data from NC DEQ; 2018 to 2024 data from LIMNOSCIENCES, with algal identifications by Dr. Linda Ehrlich, with Spirogyra Diversified Environmental Services).

	2013	2017	2018	2019	2020	2021	2022	2023	2024
Secchi Depth (m)	1.25	1.5	1.75	1.5	1.0	1.2	1.25	1.0	1.4
Turbidity (NTU)	4.3	3.0	1.9	1.9	2.6	2.7	2.1	2.7	2.3
Chl a (µg/L)	27.7	9.6	6	8.5	9.7	4.9 (11)	6.5 (9.8)	22 (24)	14 (15)
Phyto Cells/mL	114,533	241,873	150,643	38,033	169,176	221,699	34,488	105,308	96,332
Dominant Taxa (#cells/mL)	*Unidentified green* (99%)	*Planktolyngbya* (79%)	*Synechococcus* (52%)	*Synechococcus* (36%) *Staurastrum* (34%)	*Staurodesmus* (43.6%)	*Aphanocapsa* (37%) *Planktolyngbya* (32%)	*Synechococcus* (42%) *Planktolyngbya* (13%)	*Planktolyngbya* (71%) *Staurodesmus* (21%)	*Planktolynbgya* (70%) *Staurastrum* (15%)
Phyto Biovolume (mm^3/m^3)	28,400	1,967	*18,307*	*12,128*	40,965	8,297	*1,011*	*13,974*	*11,296*
Dominant Taxa (Biovolume)	*Unidentified green* (99%)	*Gonatozygon* (53%)	*Staurastrum* (79%)	*Staurastrum* (61%)	*Staurodesmus* (82%)	*Cosmarium* (21%) *Staurastrum* (15%)	*Cosmarium* (23%)	*Staurodesmus* (89%)	*Staurastrum* (75%)
pH Range (su)	8.0-8.3	6.6-6.8	6.5-6.9	6.5-6.6	6.9-7.0	6.9-7.3	6.9-7.0	8.3-8.5	6.9-6.9
Total Nitrogen (µg/L)	410	610	700	616	641	679	860	725	659
Total Phosphorus (µg/L)	20	20	20	18	24	23	25	24	20

NCDEQ reported turbidity as µmhos/cm and LIMNOSCIECES reported turbidity as NTU

6. <u>Nutrient and Phytoplankton Comparisons Between White Lake and Singletary Lake</u>

The earliest nutrient data for the Bay Lakes was collected in 1974-1975, as part of a statewide survey of lakes and reservoirs (Weiss and Kuenzler 1976). Samples were collected in February and June in each year for most of the lakes, although White Lake was sampled only in 1974. Comparisons with recent June data for both White Lake and Singletary Lake show the same trend of increased TN compared with 1974 data, resulting in higher TN:TP mass ratios over the period. Total Phosphorus (TP) levels have not changed substantially in either lake over time, but it should be noted TP levels are generally higher in Singletary Lake compared to White Lake, and the same holds for soluble reactive phosphorus (SRP) levels.

Despite the lower water clarity and pH, phytoplankton biomass (as measured both by chlorophyll *a* levels and algal biovolume calculations) can be higher in Singletary Lake than in White Lake (which was the case in 2023; Fig. 13), although diversity is much lower in Singletary (e.g., LIMNOSCIENCES 2023). In June 2024, the small desmid *Cosmarium tinctum* dominated the biovolume at White Lake (91%) while the cryptomonad *Cryptomonas* sp. (39%) dominated Singletary biovolume.

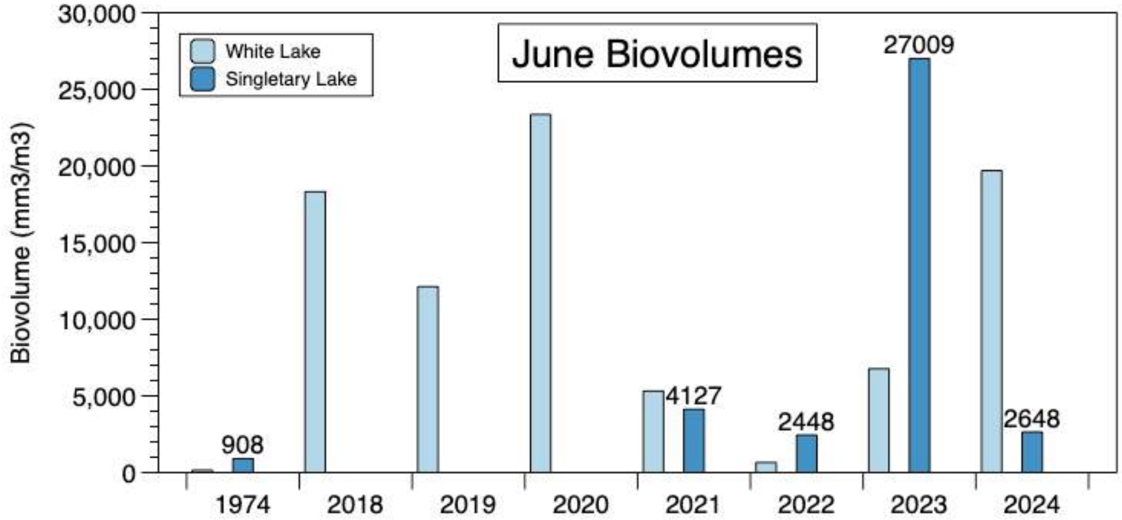


Figure 13. Phytoplankton biovolume (mm^3/m^3) comparisons between White Lake and Singletary Lake in the month of June, 1974-2023 (data from Table 3 and Table 4).

Singletary Lake is an acidic blackwater lake with an undeveloped shoreline which is sampled as a reference lake.

7. <u>At the Lake Bottom</u>

The individual cells of the cyanobacterial taxon *Aphanothece* contain polyphosphate granules, which are distinctive phosphorus storage particles (e.g., Sanz-Luque et al. 2020). Polyphosphate accumulating organisms, or PAOs, can thus be important in phosphorus removal in aquatic ecosystems, as they can accumulate large amounts of intracellular polyphosphate (Chen et al. 2020, referenced in Trebuch et al. 2023). The relative abundance of this cyanobacteria in White Lake (observed since 2022 and in decades past as well) is another example of the fierce competition for nutrients by primary producers.

This material can be collected by lowering a Van Dorn sampling bottle to the bottom in the deeper benthic zone of White Lake, or by collecting clumps of colonies that are sometimes seen floating on the lake surface. Boating activity which stirs up the lake bottom is stirring up these cyanobacteria balls as well as muddy sediments and rooted aquatic vegetation, which collects along the lakeshore (Fig. 14).

Figure 14. Colonial cyanobacteria identified as *Aphanothece stagnina*. Small cells are embedded in a mucilaginous matrix, and these individual colonies are large enough to distinguish with the naked eye. Flocs generally appear more frequently around the marina boat landing on the northern shore of the lake and along the western shore.

In addition to the balls of cyanobacteria, one of the most common aquatic plants found in White Lake can be seen at the top of the photo—spikerush. It is a low-growing fragile-appearing rooted plant, and while it is typically the most abundant in the deeper portion of the lake, it can grow elsewhere as well, such as at the shoreline at Lake Place (Fig. 15).

Figure 15. Spikerush (*Eleocharis baldwinii*) which has been dislodged and washes ashore can either root, which it has done in this photo taken in August 2024 (when lake levels were high), or rot, particularly when it is smothered by muddy sediments which have also washed ashore.

In addition to spikerush, other commonly seen submerged aquatic plants include aquatic moss (Fig. 16a), dwarf milfoil (considered to be critically imperiled and endangered in NC by the Natural Heritage Program); Fig. 16b), and bladderwort (Fig. 16c) which is a type of carnivorous plant that does not form roots.

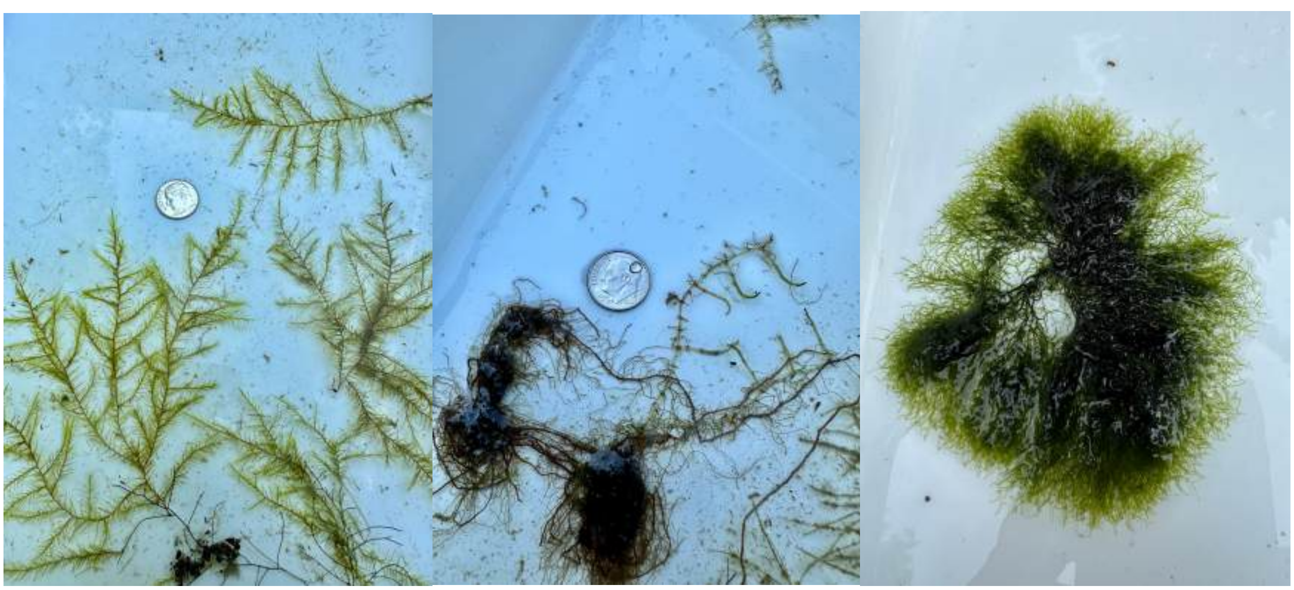
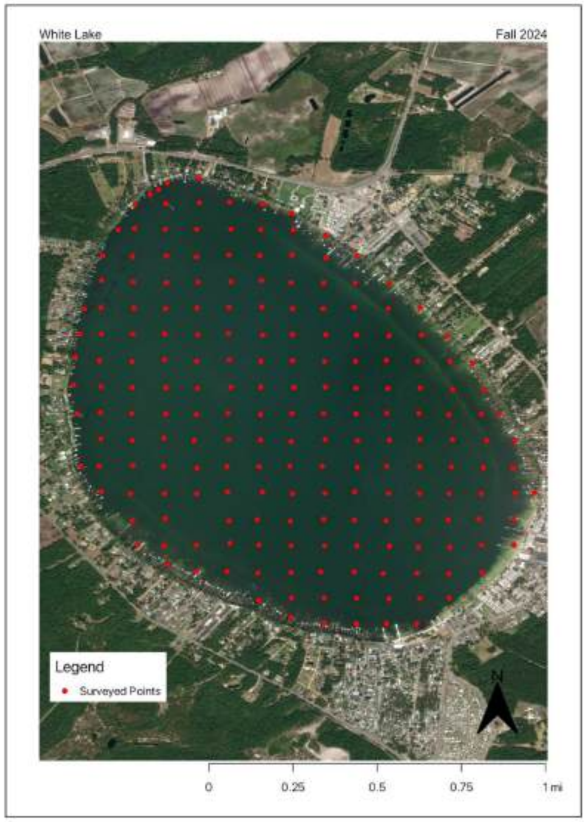


Figure 16. Three of the aquatic plants found in White Lake in April 2024: a) aquatic moss (*Fontinalis* sp.); b) dwarf milfoil (*Myriophyllum tenellum*); and bladderwort (*Utricularia purpurea*).

Personnel from NC State University's Aquatic Plant Management program conducted an annual whole-lake survey of White Lake (Fig. 17) on October 10, 2024.

a.



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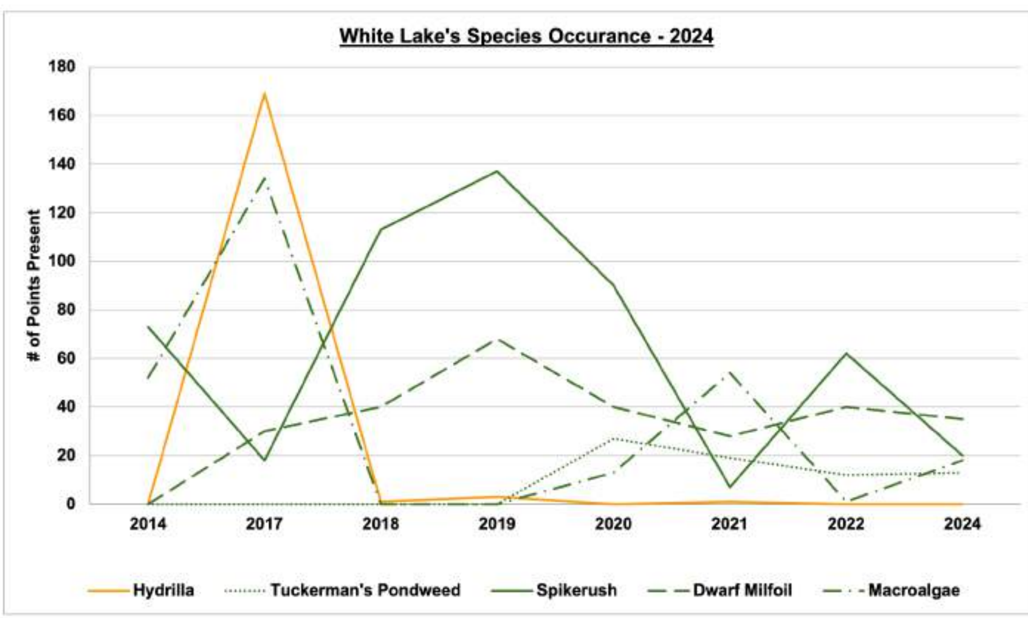

Figure 17. NC State survey of White Lake: a) map of 197 survey points for sampling aquatic vegetation; and b) number of locations where vegetation was found in the years when this survey was conducted (map and data from NCSU Aquatic Plant Management 2024 White Lake Vegetation Survey report).

This survey found five different aquatic vegetation species (they did not collect aquatic moss in 2024 but it it was seen in the lake, so there were at least six; Fig. 16). No hydrilla has been found since 2021. The NCSU report concludes: "in 2024, White Lake's aquatic plant community was represented entirely by native, beneficial aquatic plant species". The presence and abundance have varied from year to year, much like the phytoplankton community is variable from year to year.

The NCSU Aquatic Plant Management program also conducts annual vegetation surveys at Lake Waccamaw. Hydrilla was last seen there in 2017, and treatment of the lake was concluded in 2019. In 2024, 9 species were found (with only two common species groups between White Lake and Lake Waccamaw), and the filamentous cyanobacteria lyngbya was found at sites around the NC Wildlife Resources boat landing for the first time since 2021. Because it can produce toxins that create skin irritations, lyngbya is considered harmful, and it is something to watch out for in White Lake, given that it as well as hydrilla have the potential to be introduced by fishing boats and trailers and ballast water boats.

<u>Summary</u>

1. Total rainfall in 2024 was above average, and the pattern of rainfall—very high in several months and very low in others—resulted in a 20+ inch variation in lake levels over a five-week period of time.

2. Flushing of the lake does not occur in the same way that it does in drainage lakes with significant surface inflow and outflow. Water loss is a result of evaporation and groundwater seepage (Shank and Zamora 2019) as groundwater flows through the lake (which can influence nitrogen dynamics, e.g., Stoliker et al. 2016). The small outlet at Turtle Cove should be maintained as a flood control device (which is why and how it was designed), as it does not serve to either regulate lake levels or facilitate flushing of the lake. The high rainfall in 2024 and rapid increase in lake level to flood conditions serves as a reminder of this.

3. Natural processes can help regulate nutrient levels. Incorporation of nutrients into the aquatic food web—microscopic to macroscopic life—and chemical transformations such as denitrification (e.g., Qin et al. 2020) influence the availability of water column nutrients.

4. White Lake has always been a relatively productive lake, with most of the productivity associated with the lake bottom, as the sediments are a source of nutrients. Variability in the relative abundance of bottom algae/cyanobacteria and/or aquatic vegetation both seasonally and annually has been substantial both historically and recently. Since 2022, benthic/pelagic cyanobacterial flocs have been observed in the summer and fall, and this material may serve as a rich food supply for invertebrates such as grass shrimp, and fish.

5. White Lake nitrogen levels are substantially higher than historical levels (the same is true in Singletary Lake), and levels can vary considerably from month to month, with the lowest levels generally found in October. Rainfall is a significant source of both organic and inorganic nitrogen to the lake. Inorganic nitrogen fluxes to the biosphere from agricultural activities have increased five-fold in the past sixty years (Battye et al. 2017). The increase has been even more dramatic in the region around White Lake (as measured at the Clinton NADP monitoring station [NC35]). Using 2022 NADP data as an example, the annual deposition of DIN (NH_x and NO_x) in 2022 totaled 9.257 kg/ha (a map of ammonium wet deposition for 2022

is included in the appendix). So, for White Lake, at an area of 836.485 ha, this loading is equivalent to 7,743.3 kg of DIN to the lake from rainfall in 2022. Dry deposition of N can also be high in this region (e.g., Wiegand et al. 2022).

6. Water column phosphorus levels in White Lake are equivalent to historical levels, except during phytoplankton blooms (e.g., the 2017-2018 cyanobacteria bloom and the desmid bloom in Feb.-April 2021).

7. As a result of atmospheric nitrogen deposition, the N:P ratios in White Lake have changed substantially (this has been seen in many lakes around the world [e.g., Bergström and Jansson 2006, Li et al. 2016]).

8. There are several natural means for sequestering P in White Lake: the P-binding capacity of aluminum found in the muddy sediments, and primary producers such as cyanobacteria, which have strategies for excess, or luxury P storage (e.g., Xiao et al. 2022). Very small cyanobacteria (picoplankton) are often numerically dominant in White Lake, and Canadian researchers have found that picocyanobacteria abundance is much higher in oligotrophic to mesotrophic lakes with lower total phosphorus levels (Lavallée and Pick 2002).

9. Other life forms in White Lake that are adapted to low-nutrient conditions include the carnivorous bladderwort *Utricularia purpurea* (which utilizes the nutrients in its prey) as well as the colonial cyanobacteria *Aphanothece stagnalis*.

10. White Lake's phytoplankton community continues to be healthy and quite dynamic, with general trends including the dominance of desmids (different desmid taxa may dominate at different times), slight increases in phytoplankton diversity, and low filamentous cyanobacterial biovolume since the 2018 alum treatment.

11. Singletary Lake has higher levels of bioavailable phosphorus and nitrogen, and at times has more phytoplankton biovolume than does White Lake. It is a much less diverse system, however.

12. Lake clarity can at times be very good (such as May 2024), although there are also times when the lake appears to be cloudy or green. Boating activity which stirs up the muddy sediments can influence the appearance of the water, and churned up vegetative matter and sediments can cause degraded conditions in places along the lake shore, particularly where there are seawalls. This has been a long-standing issue.

13. Stewardship actions which can improve nearshore conditions include removal of seawalls and first and foremost, responsible boating practices which can reduce the amount of material stirred up from the lake bottom.

14. Bass fishing tournaments attract many fishers, and boat/trailer inspections would help to ensure that invasive weeds such as hydrilla and the filamentous cyanobacteria lyngbya are not re-introduced into the lake. The 2024 aquatic vegetation survey found that the lake is home to natural, beneficial vegetation, with no hydrilla or lyngbya found.

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