

White Lake Algae: Just Give Us A Little Respect

Summary

Different types of algae can respond quickly to changing conditions. Cyanobacteria (=blue-green algae) prefer the conditions that are found in lakes in the summer and fall. In White Lake, a filamentous cyanobacterial bloom started in the fall of 2017 and persisted into 2018; the bloom created conditions—particularly high pH levels—that are well-known for maintaining cyanobacterial dominance. Such blooms end only when resources (light, nutrients) run out, and then there is an abrupt (and decidedly unpleasant) end to it.

It is important to recognize that White Lake is not going off the rails every summer. The same filamentous cyanobacteria species that dominated the bloom before the May 2018 alum treatment have been present since then, but their natural inclination to dominate has been subdued.

The variety of other phytoplankton present in the lake are utilizing the same resources—sunlight and nutrients—which are abundant in this shallow lake. This diversity—which has been increasing—means that they all tend to be better-behaved. And because many of the algae are very small, their growth does not result in elevated pH levels.

Sampling of rainfall indicates that it is a diffuse source of readily available nitrogen as well as phosphorus. Algae are responding to these high rainfall/nutrient events, particularly tiny, single-celled forms that are good competitors for nutrients.

The relatively rapid change in rainfall pH (2003-2013) resulted in a relatively rapid change in lake pH, as rainfall is the primary source water for the lake. There has been a substantial increase in nitrogen levels in the lake over the same period, and most of this nitrogen is coming from the rainfall. The lake is establishing a new equilibrium under these changed conditions, which indicates that there is an inherent resiliency to the system.

White Lake, and the life in it deserves our collective understanding and respect, as this is a system that is increasingly impacted by human actions. Continuing monitoring of the lake will give us insight as to how stable the system is (healthy algae vs. harmful cyanobacteria) and how it is responding to weather variability and the effects of climate change (big storms, droughts).

Background Information

Like most lakes, White Lake teems with life—and always has, even during periods when the water has been crystal clear. What varies is how much: how much phytoplankton (the algae that are suspended in the water column) and how much filamentous benthic algae (the threadlike filaments form mats which are visible in shallow areas).

Algae and cyanobacteria (blue-green algae) are referred to as primary producers, since they use the sun's energy and pigments inside their cells (chlorophylls) to produce their own energy (the process is called photosynthesis). Measuring the amount of the pigment chlorophyll a in a water sample is a relatively easy way to assess the amount of phytoplankton present. A more time-consuming method is to identify, count and measure the size of all of the different phytoplankton found in a sample; the results are expressed as the number of cells per liter, and as biovolume (chlorophyll a concentration is a proxy for biovolume). White Lake monitoring includes monthly sampling for chlorophyll a and monthly or bimonthly sampling for algal identifications, with samples taken at three long-term monitoring stations located along the midline of White Lake.

A simple device called a Secchi disk is used to assess water clarity; it is a relative measure of the concentration of suspended particles in the water column, including phytoplankton, sediments that get stirred up, and materials that originate in the landscape and wash into the lake in stormwater. In shallow lakes such as Lake Mattamuskeet, reduced clarity can be a result primarily of sediment resuspension; this can be the case at White Lake at times, particularly after storms, but generally turbid conditions do not last long, so that Secchi readings often correlate fairly well with chlorophyll concentrations.



Figure 1. Windy conditions the day after a large rainfall, which introduced highly-stained stormwater into the lake. The wind also churned up the bottom, resulting in the suspension of organic sediments. Photo taken February 7, 2020.

Looking at Phytoplankton, Clarity and pH Trends Over Time

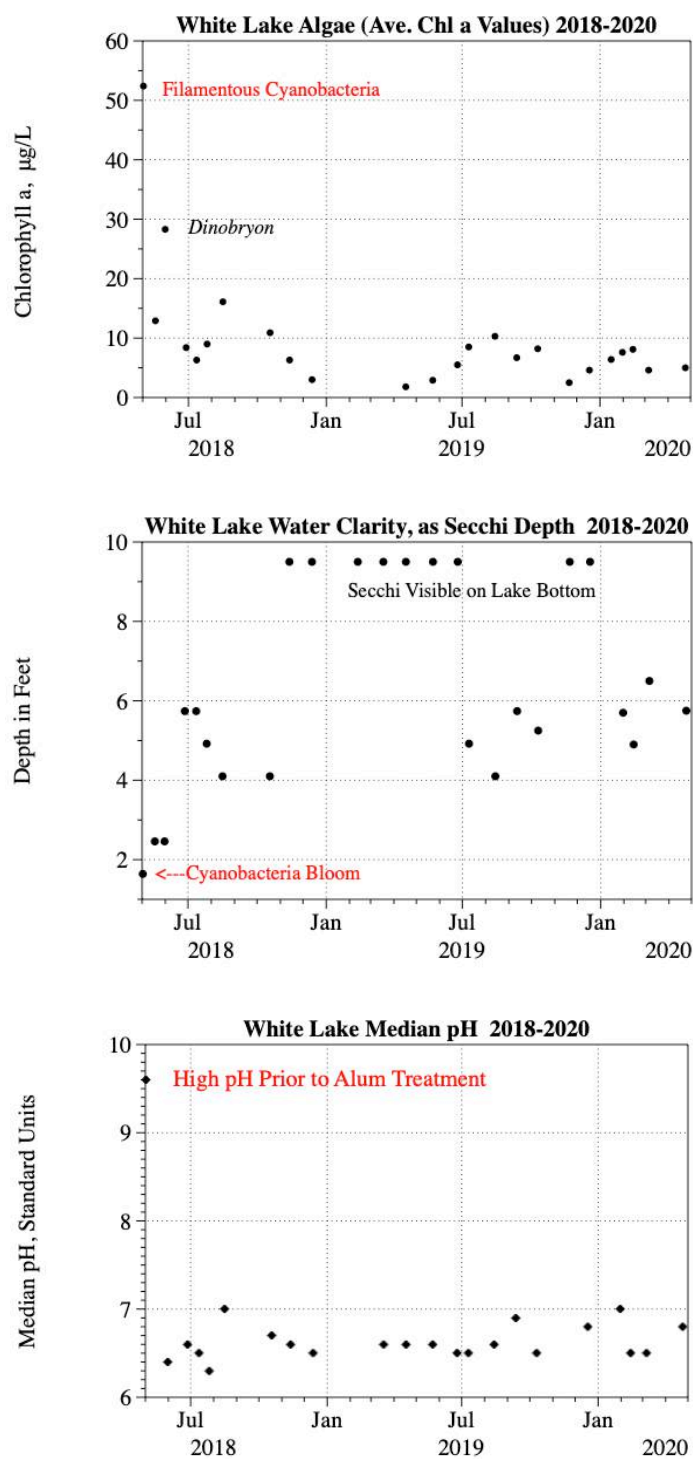


Figure 2. White Lake chlorophyll *a* means (µg/L), Secchi depths (ft), and median pH levels for the period May 2, 2018 (prior to alum treatment) through April 2020.

The following points can be noted by comparing the graphs of chlorophyll concentrations, Secchi depths and pH levels in Figure 2:

- Chlorophyll and pH levels were quite high, and clarity was low (Secchi disk disappeared at 1.5 ft) prior to the alum treatment (which began on May 3, 2018).
- The alum treatment did not remove all algae from the water column, but it did remove the filamentous cyanobacteria that dominated the bloom. Once they were bound up in the floc the pH levels dropped, and more typical algae prospered. As a result, water clarity was improved over pre-treatment conditions, but it was only when temperatures dropped in November 2018 that the lake's clarity was transformed—algae were not gone, but had declined to a mean chlorophyll level of 6.3 µg/L. This was when the filamentous bottom algae mats started to appear.
- Chlorophyll levels stayed within a fairly tight range in the summer of 2019, and clarity ranged from 4-6 feet over the period July-October. In the other months of the year the Secchi disk was visible on the lake bottom. The filamentous benthic mats disappeared in the summer and did not reappear in early winter as they had the previous year.
- Early 2020: there was more variability in conditions over the January-March time frame, with above average rainfall (and one three-inch rain), so more nutrients entering the lake; and warmer temperatures (which could also stimulate algae growth). Stormy weather churned up the lake (Fig. 1) and this was reflected in higher turbidity levels. Chlorophyll and clarity were similar to what was seen in the summer of 2019.

Another way of assessing the differences is by looking at photos taken from the same spot in March of 2018-2020 (Fig. 3).



Figure 3. Photos of White Lake, taken from the same pier on March 15, 2018 (clarity 1.5 ft.), March 18, 2019, (clarity to lake bottom) and March 6, 2020 (clarity 6.5 ft). The yellow material floating on the lake surface is pine pollen.

The phytoplankton analysis done in 2018 and 2019 tells us more about what was in the lake:

- Less dominance, more diversity: while the biomass of phytoplankton was relatively low in April 2019, there were 71 different phytoplankton taxa found that month, indicating a healthy diversity (Appendix 1). The number of different taxa increased to 86 by August 2019. By comparison, there were more cyanobacterial taxa found in 2018, but much lower overall diversity (32 phytoplankton taxa before treatment and 29-50 taxa after the alum treatment; Spirogyra 2018).
- Less abundance: Lower phytoplankton densities were seen in 2019 compared to 2018 (Appendix 2).
- Algal mats come and go: filamentous mats were seen all around the lakeshore from November 2018 through the first half of 2019. This alga was also identified in the phytoplankton samples from August 2018 through May 2019, indicating that filaments can become suspended. They also grow attached to aquatic vegetation, creating the appearance of “furry plants”.



Figure 4. The filamentous green algae *Mougeotia* sp. along the White Lake shoreline. Photo taken January 24, 2019.

A Closer Look at Some White Lake Algae

There are many different kinds of algae found in the lake; one of the most interesting in appearance is a colony-forming golden alga called *Dinobryon*. Single cells are contained in tiny vase-shaped structures that are attached together with stalks (Fig. 5). This alga was very happy for a brief period after the May 2018 alum treatment (note the point labeled as *Dinobryon* on the chlorophyll graph in Fig. 2).



Figure 5. A magnified view of a *Dinobryon* sp. colony, showing the oblong cells inside structures called loricas (photo downloaded from: <http://ohapbio12.pbworks.com/w/page/51731561/Dinobryon>).

Another common algal group in White Lake are desmids, and their shapes—such as the elongation of portions of a cell seen in *Staurastrum* (Fig. 6)—help keep them afloat.



Figure 6. A magnified view of *Staurastrum* sp., showing the bilateral symmetry of its cell (photo downloaded from: http://protist.i.hosei.ac.jp/pdb/Images/Chlorophyta/Staurastrum/Eustaurastrum/Processiformes/2_arms/tetracerm/sp_01.html).

The sizes as well as shapes of phytoplankton vary considerably—the tiniest phytoplankton are referred to as picoplankton (they are roughly $1/50^{\text{th}}$ of the diameter of a human hair), and one type is abundant in White Lake: the single-celled cyanobacteria *Synechococcus* (Fig. 7). In terms of cell counts it ranks high, but in terms of biomass it doesn't amount to much because of its small size.

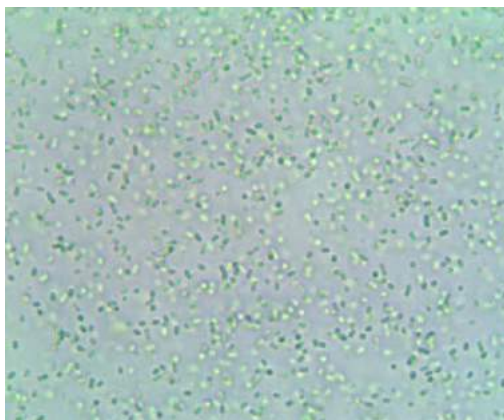


Figure 7. A magnified view of the single-celled cyanobacterium Synechococcus sp. (photo by John A. Strand, downloaded from the Research Gate website on May 18, 2020).

A series of photomicrographs was included in the 2017 White Lake Algae Report, which provides a good visual comparison of changes in phytoplankton abundance over the summer, with the photo on the right showing the dominance of the filamentous cyanobacterium Planktolyngbya limnetica (Fig. 8). After the May 2018 low-dose alum treatment, cyanobacterial filaments in samples were visibly impacted, with fragmented filaments and non-living cells, which gradually disappeared from the water column (Spirogyra 2018).



Figure 8. Algal assemblages in White Lake from June to September 2017 (magnified 100x). Photos by Leigh Stevenson, NC DWR.

References

LIMNOSCIENCES, 2019. Physio-chemical data for White Lake, May-December 2018. Report to the Town of White Lake.

LIMNOSCIENCES, 2020. 2019 White Lake Monitoring Results. Report to the Town of White Lake.

NCDEQ, 2014. White Lake Monitoring, 2013. NC Division of Water Resources, Division of Environmental Quality.

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Spirogyra, 2018. White Lake Phytoplankton Survey, May 2018. Report to the Town of White Lake. Spirogyra Diversified Environmental Services.

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Appendix 1. Phytoplankton taxa found in White Lake, 2019. Sample dates analyzed: April 17, May 23, July 10, and September 12. Richness averages determined from three grab samples/month.

	4/17/19	5/23/19	7/10/19	9/12/19
Richness	0.54193737		0.48634036	0.33576335
greens	35	40	53	53
	4/17/19	5/23/19	7/10/19	9/12/19
<i>Synechococcus</i> sp.		<i>Synechococcus</i> sp.	<i>Synechococcus</i> sp.	<i>Synechococcus</i> sp.
<i>Cyanogranis ferruginea</i>		<i>Cyanogranis ferruginea</i>	<i>Aphanizomenon</i> sp.	<i>Planktolyngbya crassa</i>
<i>Aphanocapsa</i> sp.		<i>Aphanocapsa delicatissima</i>	<i>Planktolyngbya</i> sp.	<i>Chroococcus aphanocapsoides</i>
<i>Raphidiopsis curvata</i>		<i>Aphanizomenon</i> sp.	<i>Jaaginema</i> sp.	<i>Aphanocapsa</i> sp.
<i>Limnolyngbya circumcreta</i>		<i>Desmodesmus</i> sp.	<i>Desmodesmus</i> sp.	<i>Planktolyngbya limnetica</i>
<i>Merismopedia tenuissima</i>		<i>Monoraphidium contortum</i>	<i>Monoraphidium contortum</i>	<i>Aphanocapsa delicatissima</i>
<i>Planktolyngbya limnetica</i>		<i>Monoraphidium arcuatum</i>	<i>Tetraedron constrictum</i>	<i>Aphanizomenon</i> sp.
<i>Staurastrum americanum</i>		<i>Dictyosphaerium</i> sp.	<i>Pediastrum biradiatum</i>	<i>Cyanogranis ferruginea</i>
<i>Desmodesmus</i> sp.		<i>Tetraedron constrictum</i>	<i>Staurastrum tetracerum</i>	<i>Chroococcus aphanocapsoides</i>
<i>Oocystis</i> sp.		<i>Pediastrum biradiatum</i>	<i>Staurodesmus</i> sp.	<i>Raphidiopsis curvata</i>
<i>Monoraphidium contortum</i>		<i>Pediastrum duplex</i>	<i>Staurastrum apiculatum</i>	<i>Dolichospermum</i> sp.
<i>Tetraedron minimum</i>		<i>Staurastrum tetracerum</i>	<i>Pediastrum tetras</i>	<i>Dictyosphaerium</i> sp.
<i>Mougeotia</i> sp.		<i>Staurodesmus</i> sp.	<i>Cosmarium achondrum</i>	<i>Monoraphidium arcuatum</i>
<i>Elakatothrix viridis</i>		<i>Staurastrum apiculatum</i>	<i>Closterium acutum</i>	<i>Ankistrodesmus falcatus</i>
<i>Staurastrum tetracerum</i>		<i>Pediastrum tetras</i>	<i>Selanastrum</i> sp.	<i>Desmodesmus</i> sp.
<i>Monoraphidium minutum</i>		<i>Cosmarium regnesi v. montanum</i>	<i>Ankistrodesmus falcatus</i>	<i>Tetraedron constrictum</i>
<i>Pediastrum biradiatum</i>		<i>Eutetramorus planktonica</i>	<i>Tetraedron caudatum</i>	<i>Ankistrodesmus spiralis</i>
<i>Crucigenia tetrapedia</i>		<i>Koliella</i> sp.	<i>Selanastrum gracile</i>	<i>Staurastrum apiculatum</i>
<i>Pediastrum tetras</i>		<i>Cosmarium achondrum</i>	<i>Elakatothrix viridis</i>	<i>Staurastrum tetracerum</i>
<i>Staurastrum margaritaceum</i>		<i>Cosmarium phaseolus</i>	<i>Coenochloris</i> sp.	<i>Staurodesmus</i> sp.
<i>Staurastrum apiculatum</i>		<i>Closterium acutum</i>	<i>Sorastrum americanum</i>	<i>Staurastrum margaritaceum</i>
<i>Staurodesmus</i> sp.		<i>Selanastrum</i> sp.	<i>Monoraphidium convolutum</i>	<i>Pediastrum tetras</i>
<i>Coelastrum cambricum</i>		<i>Ankistrodesmus falcatus</i>	<i>Staurastrum americanum</i>	<i>Pediastrum biradiatum</i>
<i>Scoenodesmus acutus</i>		<i>Kirchneriella</i> sp.	<i>Staurastrum margaritaceum</i>	<i>Tetraedron caudatum v. longum</i>
<i>Tetraedron caudatum v. longum</i>		<i>Tetraedron caudatum v. longum</i>	<i>Crucigenia tetrapedia</i>	<i>Coelastrum piboscideum</i>
<i>Chlorella</i> sp.		<i>Monoraphidium minutum</i>	<i>Closterium venus</i>	<i>Monoraphidium convolutum</i>
<i>Monoraphidium arcuatum</i>		<i>Tetraedron trigonum</i>	<i>Tetraedron minimum</i>	<i>Elakatothrix viridis</i>
<i>Ankistrodesmus falcatus</i>		<i>Selanastrum gracile</i>	<i>Selanastrum bibraium</i>	<i>Selanastrum</i> sp.
<i>Ankistrodesmus spiralis</i>		<i>Elakatothrix viridis</i>	<i>Coelastrum piboscideum</i>	<i>Selanastrum gracile</i>
<i>Tetraedron trigonum</i>		<i>Ankistrodesmus spiralis</i>	<i>Tetraedron victorae</i>	<i>Monoraphidium minutum</i>
<i>Dodidium</i> sp.		<i>Coenochloris</i> sp.	<i>Cosmarium</i> sp.	<i>Staurastrum americanum</i>
<i>Quadrigula lacustris</i>		<i>Sorastrum americanum</i>	<i>Microspora</i> sp.	<i>Sorastrum americanum</i>
<i>Cosmarium achondrum</i>		<i>Mougeotia</i> sp.	<i>Coelastrum cambricum</i>	<i>Microspora</i> sp.
<i>Sorastrum americanum</i>		<i>Monoraphidium convolutum</i>	<i>Oocystis</i> sp.	<i>Monoraphidium contortum</i>
<i>Cosmarium regnesi v. montanum</i>		<i>Dodidium</i> sp.	<i>Golenkinia radiata</i>	<i>Oocystis</i> sp.
<i>Selanastrum gracile</i>		<i>Selanastrum bibraium</i>	<i>Selanastrum</i> sp.	<i>Cosmarium achondrum</i>
<i>Tetraedron caudatum</i>		<i>Golenkinia radiata</i>	<i>Tetraedron incus</i>	<i>Kirchneriella</i> sp.
<i>Gonatozygon</i> sp.		<i>Chlamydomonas</i> sp.	<i>Monoraphidium minutum</i>	<i>Coelastrum cambricum</i>
<i>Dictyosphaerium</i> sp.		<i>Staurastrum margaritaceum</i>	<i>Ankistrodesmus spiralis</i>	<i>Staurastrum chaetoceras</i>
<i>Coelastrum microporum</i>		<i>Closterium gracile</i>	<i>Monoraphidium arcuatum</i>	<i>Closterium</i> sp.
<i>Quadrigula lacustris</i>		<i>Tetraedron minimum</i>	<i>Kirchneriella</i> sp.	<i>Gonatozygon</i> sp.
<i>Staurodesmus</i> sp.		<i>Cosmarium</i> sp.	<i>Botryococcus</i> sp.	<i>Quadrigula lacustris</i>
<i>Aulacoseira granulata</i>		<i>Sphaerotosma</i> sp.	<i>Cosmarium regnesi v. montanum</i>	<i>Tetraedron trigonum</i>
<i>Navicula</i> sp.		<i>Cyclotella</i> sp.	<i>Tetraedron limneticum</i>	<i>Cosmarium regnesi v. montanum</i>
<i>Cyclotella</i> sp.		<i>Navicula</i> sp.	<i>Closterium</i> sp.	<i>Eutetramorus planktonica</i>
<i>Achnantheidium minutissima</i>		<i>Achnantheidium minutissima</i>	<i>Nephroclytium</i> sp.	<i>Coenochloris</i> sp.
<i>Fragilaria longifusiformis</i>		<i>Pinnularia</i> sp.	<i>Pleurosigma</i> sp.	<i>Golenkinia radiata</i>
<i>Fragilaria</i> sp.		<i>Fragilaria</i> sp.	<i>Tetraedron trigonum</i>	<i>Closterium gracile</i>
<i>Synedra rumpens</i>		<i>Dinobryon sertularia</i>	<i>Schroederia setigerum</i>	<i>Chlorella</i> sp.
<i>Stauroneis</i> sp.		<i>Centritractus belanophorus</i>	<i>Eutetramorus planktonica</i>	<i>Closterium acutum</i>
<i>Melosira italica</i>		<i>Dinobryon</i> sp.2	<i>Staurastrum chaetoceras</i>	<i>Pediastrum tetras</i>
<i>Pinnularia</i> sp.		<i>Synura</i> sp.	<i>Closteriopsis longissima</i>	<i>Schroederia setigerum</i>
<i>Achnanthes exiguum</i>		<i>Cryptomonas</i> sp.	<i>Dictyosphaerium</i> sp.	<i>Tetraedron trigonum</i>
<i>Synedra actinastroides</i>		<i>Komma caudata</i>	<i>Pediastrum duplex</i>	<i>Coelastrum microporum</i>
<i>Caloneis ventricosa</i>		<i>Euglena</i> sp.	<i>Kirchneriella</i> sp.	<i>Tetrastrum helentacanthum</i>
<i>Dinobryon sertularia</i>		<i>Trachelomonas volvocina</i>	<i>Coelastrum microporum</i>	<i>Tetraedron limneticum</i>
<i>Centritractus belanophorus</i>		<i>Phacus agilis</i>	<i>Kirchneriella obesa</i>	<i>Pediastrum duplex</i>
<i>Dinobryon</i> sp.2		<i>Peridiniopsis</i> sp.	<i>Pinnularia</i> sp.	<i>Cosmarium</i> sp.
<i>Synura</i> sp.		<i>Peridinium</i> sp.	<i>Melosira italica</i>	<i>Pediastrum duplex</i>
<i>Chrysochromulina</i> sp.		<i>Cystodinium</i> sp.	<i>Aulacoseira granulata</i>	<i>Tetraedron minimum</i>
<i>Chrysochromulina parva</i>			<i>Cymbella</i> sp.	<i>Radiococcus nimbus</i>
<i>Cryptomonas</i> sp.			<i>Cyclotella</i> sp.	<i>Quadrigula lacustris</i>
<i>Komma caudata</i>			<i>Navicula abruptum</i>	<i>Cosmarium regnesi v. montanum</i>
<i>Plagioselmis nannoplanktonica</i>			<i>Eunolia</i> sp.	<i>Botryococcus</i> sp.
<i>Chilomonas</i> sp.			<i>Gomphonema</i> sp.	<i>Cyclotella</i> sp.
<i>Euglena</i> sp.			<i>Nitzschia</i> sp.	<i>Eunolia</i> sp.
<i>Trachelomonas varians</i>			<i>Dinobryon sertularia</i>	<i>Urosolenia eriensis</i>
<i>Euglena minutus</i>			<i>Dinobryon cylindricum</i>	<i>Navicula</i> sp.
<i>Phacus</i> sp.			<i>Mallomonas acaroides</i>	<i>Synedra rumpens</i>
<i>Peridiniopsis</i> sp.			<i>Komma caudata</i>	<i>Melosira varians</i>
<i>Parvodinium</i> sp.			<i>Cryptomonas platyuris</i>	<i>Synedra ulna</i>
			<i>Cryptomonas reflexa</i>	<i>Dinobryon cylindricum</i>
			<i>Euglena</i> sp.	<i>Dinobryon sertularia</i>
			<i>Trachelomonas varians</i>	<i>Mallomonas acaroides</i>
			<i>Phacus agilis</i>	<i>Mallomonas pseudocoronata</i>
			<i>Parvodinium</i> sp.	<i>Cryptomonas</i> sp.
			<i>Peridiniopsis</i> sp.	<i>Cryptomonas reflexa</i>
			<i>Cystodinium</i> sp.	<i>Euglena</i> sp.
				<i>Lepocinctus acuta</i>
				<i>Trachelomonas varians</i>
				<i>Trachelomonas intermedia</i>
				<i>Phacus agilis</i>
				<i>Peridiniopsis</i> sp.
				<i>Cystodinium</i> sp.
				<i>Peridinium</i> sp.
				<i>Parvodinium</i> sp.

Appendix 2. A comparison of White Lake physio-chemical data and algae data for the month of July, from 2013 to 2019 (data for 2013 and 2017 from NC DEQ, and 2018-2019 from LIMNOSCIENCES, and Spirogyra Diversified Environmental Services).

A Comparison of White Lake Water Quality Data for July, From 2013-2019

	7/15/2013	7/20/2017	7/12/2018	7/10/2019
Mean Temperature (C)	28.6	30.4	29.2	29.0
Water Clarity, Measured as Secchi Depth (m)	1.25	1.5	1.75	1.5
Turbidity (NTU)	4.3	3.0		1.9
Mean Algae Abundance, Measured as Chlorophyll a Concentration (µg/L)	27.7	9.6	6	8.5
Mean # Algal Cells/ml			150,643	38,001
# of Algae Taxa			50	78
Mean Algal Biovolume (mm³/m³)			18,306	
pH Range (std. units)	8.0-8.3	6.6-6.8	6.5-6.9	6.5-6.6
Dissolved Oxygen, Mean % Saturation	103	92.5	94	93.5
Mean Total Nitrogen (mg/L)	0.41	0.61	0.70	0.62
Mean Total Phosphorus (mg/L)	0.02	0.02	0.02	<0.02
Number of Samples	3	3	7	6