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

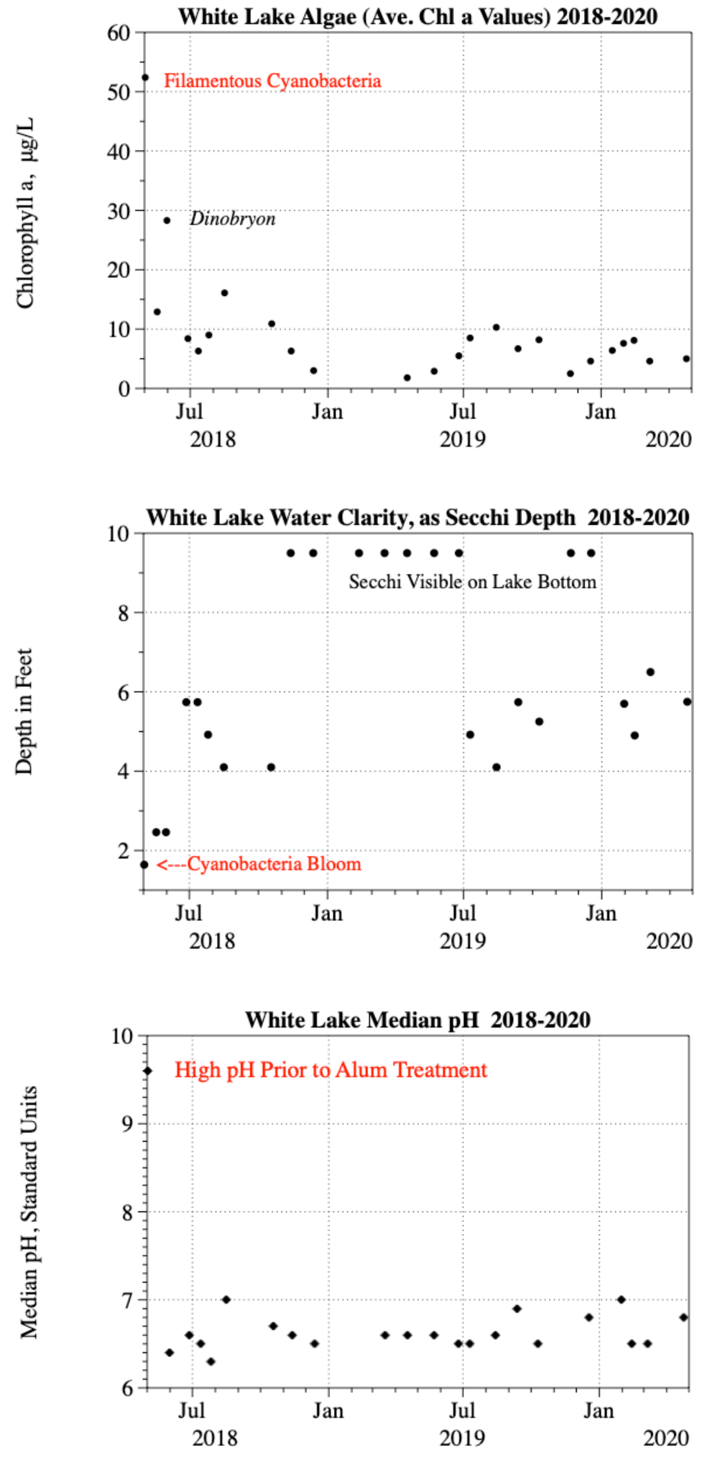

Figure 2. White Lake chlorophyll a means (µg/L), Secchi depths (ft), and median pH levels for the period May 2, 2018 (prior to alum treatment) through April 2020.

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).

<u>2018</u> <u>2019</u> <u>2020</u>

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).

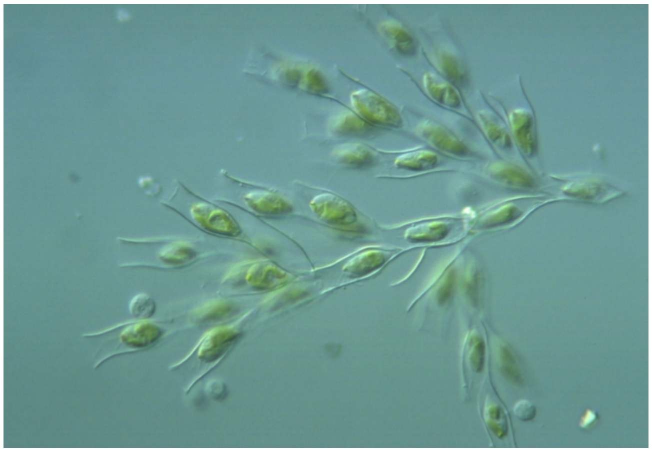

Figure 5. A magnified view of a *Dinobryon* sp. colony, showing the oblong cells inside structures called loricas (photo downloaded from: http://ohapbio12.pbworks.com/w/page/51731561/Dinobryon).

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.

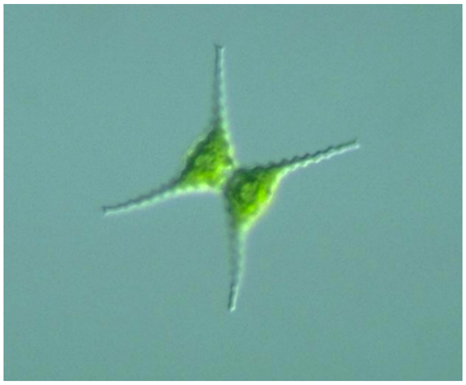

Figure 6. A magnified view of *Staurastrum* sp., showing the bilateral symmetry of its cell (photo downloaded from: http://protist.i.hosei.ac.jp/pdb/Images/Chlorophyta/Staurastrum/Eustaurastrum/Processiformes/2_arms/tetracerum/sp_01.html).

The sizes as well as shapes of phytoplankton vary considerably—the tiniest phytoplankton are referred to as picoplankton (they are roughly 1/50th 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.

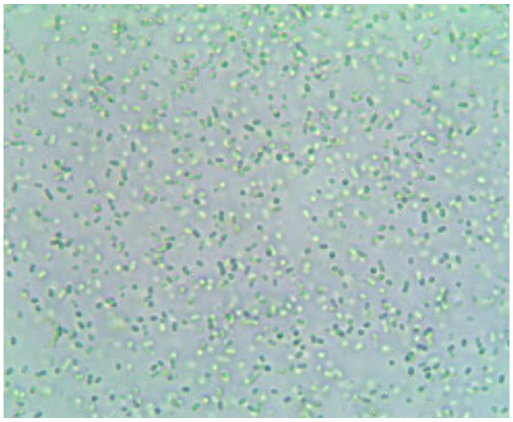

Figure 7. A magnified view of the single-celled cyanobacterium <u>Synechococcus</u> sp. (photo by John A. Strand, downloaded from the Research Gate website on May 18, 2020).

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 <u>Planktolyngbya limnetica</u> (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).

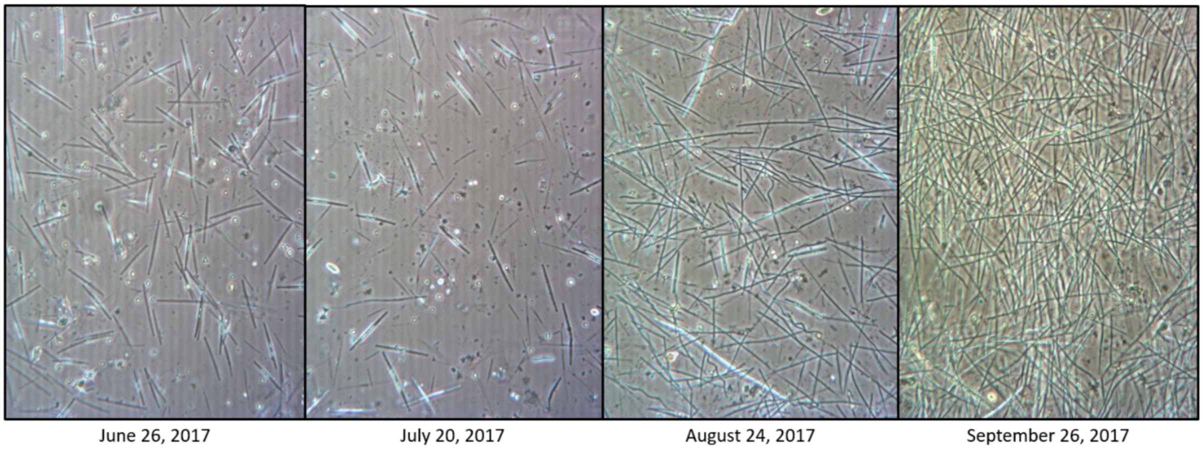

Figure 8. Algal assemblages in White Lake from June to September 2017 (magnified 100x). Photos by Leigh Stevenson, NC DWR.

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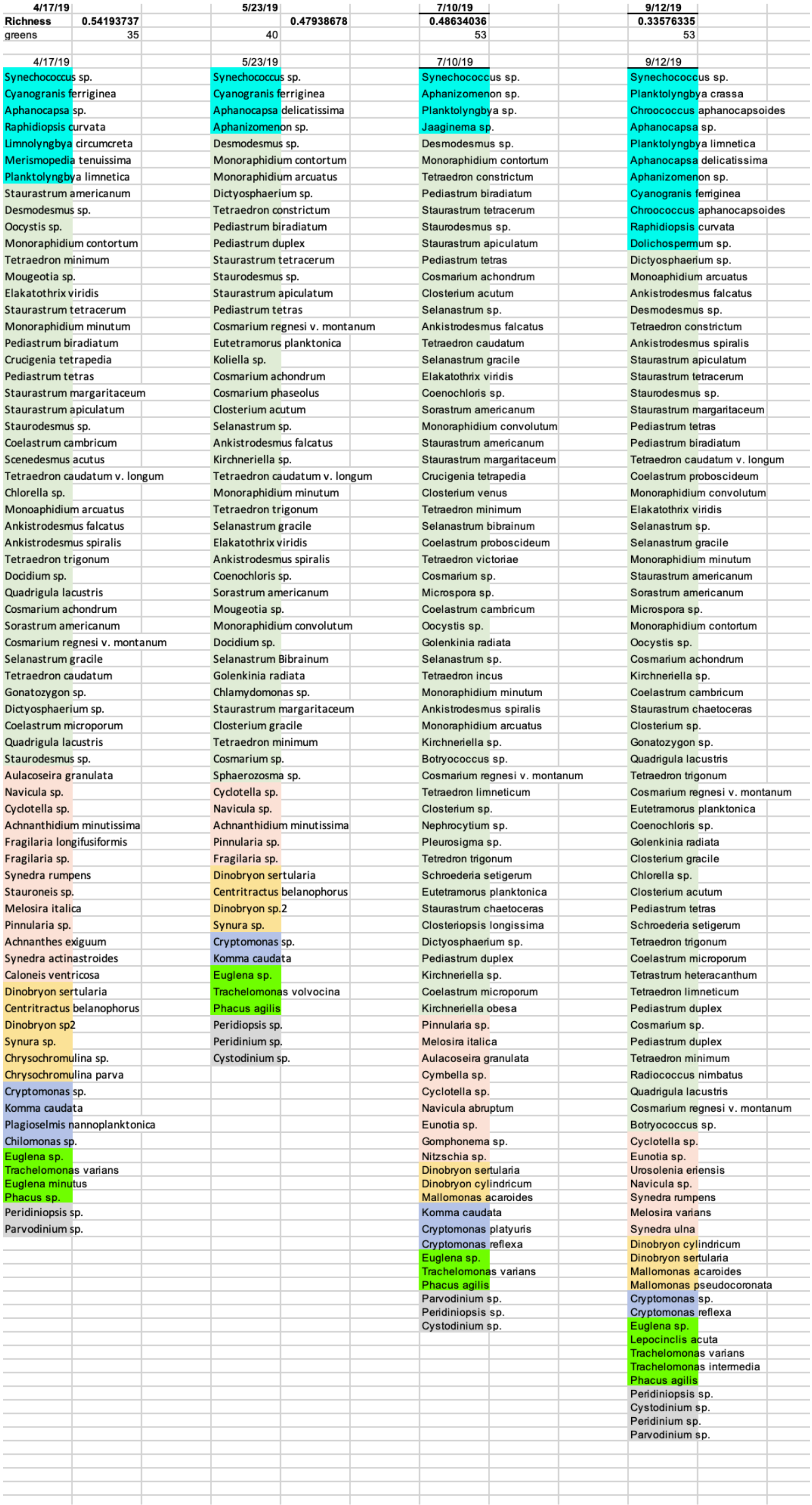
Spirogyra, 2018. White Lake Phytoplankton Survey, May 2018. Report to the Town of White Lake. Spirogyra Diversified Environmental Services.

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

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	0.47938678	0.48634036	0.33576335
greens	35	40	53	53
	4/17/19	5/23/19	7/10/19	9/12/19
	Synechococcus sp.	Synechococcus sp.	Synechococcus sp.	Synechococcus sp.
	Cyanogranis ferriginea	Cyanogranis ferriginea	Aphanizomenon sp.	Planktolyngbya crassa
	Aphanocapsa sp.	Aphanocapsa delicatissima	Planktolyngbya sp.	Chroococcus aphanocapsoides
	Raphidiopsis curvata	Aphanizomenon sp.	Jaaginema sp.	Aphanocapsa sp.
	Limnolyngbya circumcreta	Desmodesmus sp.	Desmodesmus sp.	Planktolyngbya limnetica
	Merismopedia tenuissima	Monoraphidium contortum	Monoraphidium contortum	Aphanocapsa delicatissima
	Planktolyngbya limnetica	Monoraphidium arcuatus	Tetraedron constrictum	Aphanizomenon sp.
	Staurastrum americanum	Dictyosphaerium sp.	Pediastrum biradiatum	Cyanogranis ferriginea
	Desmodesmus sp.	Tetraedron constrictum	Staurastrum tetracerum	Chroococcus aphanocapsoides
	Oocystis sp.	Pediastrum biradiatum	Staurodesmus sp.	Raphidiopsis curvata
	Monoraphidium contortum	Pediastrum duplex	Staurastrum apiculatum	Dolichospermum sp.
	Tetraedron minimum	Staurastrum tetracerum	Pediastrum tetras	Dictyosphaerium sp.
	Mougeotia sp.	Staurodesmus sp.	Cosmarium achondrum	Monoaphidium arcuatus
	Elakatothrix viridis	Staurastrum apiculatum	Closterium acutum	Ankistrodesmus falcatus
	Staurastrum tetracerum	Pediastrum tetras	Selanastrum sp.	Desmodesmus sp.
	Monoraphidium minutum	Cosmarium regnesi v. montanum	Ankistrodesmus falcatus	Tetraedron constrictum
	Pediastrum biradiatum	Eutetramorus planktonica	Tetraedron caudatum	Ankistrodesmus spiralis
	Crucigenia tetrapedia	Koliella sp.	Selanastrum gracile	Staurastrum apiculatum
	Pediastrum tetras	Cosmarium achondrum	Elakatothrix viridis	Staurastrum tetracerum
	Staurastrum margaritaceum	Cosmarium phaseolus	Coenochloris sp.	Staurodesmus sp.
	Staurastrum apiculatum	Closterium acutum	Sorastrum americanum	Staurastrum margaritaceum
	Staurodesmus sp.	Selanastrum sp.	Monoraphidium convolutum	Pediastrum tetras
	Coelastrum cambricum	Ankistrodesmus falcatus	Staurastrum americanum	Pediastrum biradiatum
	Scenedesmus acutus	Kirchneriella sp.	Staurastrum margaritaceum	Tetraedron caudatum v. longum
	Tetraedron caudatum v. longum	Tetraedron caudatum v. longum	Crucigenia tetrapedia	Coelastrum proboscideum
	Chlorella sp.	Monoraphidium minutum	Closterium venus	Monoraphidium convolutum
	Monoaphidium arcuatus	Tetraedron trigonum	Tetraedron minimum	Elakatothrix viridis
	Ankistrodesmus falcatus	Selanastrum gracile	Selanastrum bibrainum	Selanastrum sp.
	Ankistrodesmus spiralis	Elakatothrix viridis	Coelastrum proboscideum	Selanastrum gracile
	Tetraedron trigonum	Ankistrodesmus spiralis	Tetraedron victoriae	Monoraphidium minutum
	Docidium sp.	Coenochloris sp.	Cosmarium sp.	Staurastrum americanum
	Quadrigula lacustris	Sorastrum americanum	Microspora sp.	Sorastrum americanum
	Cosmarium achondrum	Mougeotia sp.	Coelastrum cambricum	Microspora sp.
	Sorastrum americanum	Monoraphidium convolutum	Oocystis sp.	Monoraphidium contortum
	Cosmarium regnesi v. montanum	Docidium sp.	Golenkinia radiata	Oocystis sp.
	Selanastrum gracile	Selanastrum Bibrainum	Selanastrum sp.	Cosmarium achondrum
	Tetraedron caudatum	Golenkinia radiata	Tetraedron incus	Kirchneriella sp.
	Gonatozygon sp.	Chlamydomonas sp.	Monoraphidium minutum	Coelastrum cambricum
	Dictyosphaerium sp.	Staurastrum margaritaceum	Ankistrodesmus spiralis	Staurastrum chaetoceras
	Coelastrum microporum	Closterium gracile	Monoraphidium arcuatus	Closterium sp.
	Quadrigula lacustris	Tetraedron minimum	Kirchneriella sp.	Gonatozygon sp.
	Staurodesmus sp.	Cosmarium sp.	Botryococcus sp.	Quadrigula lacustris
	Aulacoseira granulata	Sphaerozosma sp.	Cosmarium regnesi v. montanum	Tetraedron trigonum
	Navicula sp.	Cyclotella sp.	Tetraedron limneticum	Cosmarium regnesi v. montanum
	Cyclotella sp.	Navicula sp.	Closterium sp.	Eutetramorus planktonica
	Achnanthidium minutissima	Achnanthidium minutissima	Nephrocytium sp.	Coenochloris sp.
	Fragilaria longifusiformis	Pinnularia sp.	Pleurosigma sp.	Golenkinia radiata
	Fragilaria sp.	Fragilaria sp.	Tetredron trigonum	Closterium gracile
	Synedra rumpens	Dinobryon sertularia	Schroederia setigerum	Chlorella sp.
	Stauroneis sp.	Centritractus belanophorus	Eutetramorus planktonica	Closterium acutum
	Melosira italica	Dinobryon sp.2	Staurastrum chaetoceras	Pediastrum tetras
	Pinnularia sp.	Synura sp.	Closteriopsis longissima	Schroederia setigerum
	Achnanthes exiguum	Cryptomonas sp.	Dictyosphaerium sp.	Tetraedron trigonum
	Synedra actinastroides	Komma caudata	Pediastrum duplex	Coelastrum microporum
	Caloneis ventricosa	Euglena sp.	Kirchneriella sp.	Tetrastrum heteracanthum
	Dinobryon sertularia	Trachelomonas volvocina	Coelastrum microporum	Tetraedron limneticum
	Centritractus belanophorus	Phacus agilis	Kirchneriella obesa	Pediastrum duplex
	Dinobryon sp2	Peridiopsis sp.	Pinnularia sp.	Cosmarium sp.
	Synura sp.	Peridinium sp.	Melosira italica	Pediastrum duplex
	Chrysochromulina sp.	Cystodinium sp.	Aulacoseira granulata	Tetraedron minimum
	Chrysochromulina parva		Cymbella sp.	Radiococcus nimbatus
	Cryptomonas sp.		Cyclotella sp.	Quadrigula lacustris
	Komma caudata		Navicula abruptum	Cosmarium regnesi v. montanum
	Plagioselmis nannoplanktonica		Eunotia sp.	Botryococcus sp.
	Chilomonas sp.		Gomphonema sp.	Cyclotella sp.
	Euglena sp.		Nitzschia sp.	Eunotia sp.
	Trachelomonas varians		Dinobryon sertularia	Urosolenia eriensis
	Euglena minutus		Dinobryon cylindricum	Navicula sp.
	Phacus sp.		Mallomonas acaroides	Synedra rumpens
	Peridiniopsis sp.		Komma caudata	Melosira varians
	Parvodinium sp.		Cryptomonas platyuris	Synedra ulna
			Cryptomonas reflexa	Dinobryon cylindricum
			Euglena sp.	Dinobryon sertularia
			Trachelomonas varians	Mallomonas acaroides
			Phacus agilis	Mallomonas pseudocoronata
			Parvodinium sp.	Cryptomonas sp.
			Peridiniopsis sp.	Cryptomonas reflexa
			Cystodinium sp.	Euglena sp.
				Lepocinclis acuta
				Trachelomonas varians
				Trachelomonas intermedia
				Phacus agilis
				Peridiniopsis sp.
				Cystodinium sp.
				Peridinium sp.
				Parvodinium 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