Cyanobacteria Blooms and Water Quality Parameters in Two Mecklenburg County Park and Recreation Ponds in Charlotte, NC

By

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Abstract

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As Harmful Algal Blooms (HABs) become an increasing concern in small bodies of water, such as ponds, effective management strategies become more necessary. The most common group of algae to produce HABs in small bodies of water are the photosynthetic bacteria, Cyanobacteria (Blue-Green Algae). Some kinds of Cyanobacteria, such as *Microcystis* spp., can produce toxins that are harmful to humans and animals. Unfortunately, HABs caused by Cyanobacteria are becoming more frequent. To gain a better understanding of algal community dynamics, a comparison of two urban ponds was conducted in Charlotte, NC in the summer of 2020. Sampling events to collect algae from the water body, algae from a bloom, and water quality data were conducted every two weeks between June 9th and October 20th, producing a total of 10 samples. Pond management routines for both ponds were also documented during the same season. The two ponds exhibited different ecological dynamics, with differences in algal community, bloom status, and water quality parameters. Both ponds experienced a *Microcystis* spp. bloom at some point in the season, though the intensity of the bloom was greater in Freedom Park Pond. Cyanobacteria density and/or biovolume were significantly correlated with nutrients (total phosphorus and total Kjeldahl nitrogen), conductivity, and temperature. Pond treatments for both ponds during the sampling season did not follow the product-recommended practices. Reducing nutrient inputs and implementing effective pond management strategies could be the most effective way of minimizing or eliminating HABs in urban ponds.

Biography

Lauren Goyne was born in Dallas, TX on July 1, 1979. After receiving an A.S in Biology, she transferred to the University of North Carolina at Charlotte in the spring semester of 2015. In December of 2016 she graduated magna cum laude with a B.S. in Environmental Science. In January of 2017 she began her career in the Charlotte-Mecklenburg Stormwater Services (CMSWS) Water Quality Program. While continuing to work for CMSWS, in 2019 she decided to continue her pursuit of knowledge and began the graduate program at North Carolina State University to earn her Master of Environmental Assessment.

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Introduction

Algae are a significant part of Earth's environment, producing approximately fifty percent of the oxygen in the atmosphere (Vidyasagar 2016). As primary producers, they form the foundation for the diverse food webs in both ocean and freshwater ecosystems, generating biomass and providing nutrients for a variety of aquatic consumers (Bellinger and Sigee 2015, Dyhrman 2020). The ability of algae to provide an ecosystem with a food source is vital, but when an abundance of nutrients are available in a waterbody, algae can suddenly increase in concentration and become overgrown, creating an algal bloom (Denchak and Sturm 2019).

Though most freshwater algal blooms are not harmful, a growing number of blooms that occur in ponds, lakes, and rivers are toxic (Denchak and Sturm 2019). When an algal bloom becomes harmful to the environment or to human health, it is then classified as a Harmful Algal Bloom (HAB) (DeBruyn et al. 2021). Now an environmental concern in all 50 states, the occurrence of freshwater HABs has drastically increased in the last 40 years (Denchak and Sturm 2019). HABs can be harmful to aquatic life, both directly and indirectly (Magnolia Fisheries 2021). Some toxins produced by algal blooms can be directly noxious to aquatic wildlife, causing distress or death (Magnolia Fisheries 2021) Algal blooms can also be indirectly detrimental to aquatic life by causing a dead zone, a drop in oxygen levels below the threshold for fish survival (Magnolia Fisheries 2021). There is an economic loss of over $4 billion dollars annually in the United States alone due to impacts on recreation and tourism, aquatic food production, and drinking water supplies, all resulting from freshwater algal blooms (Ho et al. 2019).

Though almost any type of algae in freshwater can produce a bloom, the most common type to do so in the United States is cyanobacteria; a photosynthetic bacterium also known as blue-green algae (Denchak and Sturm 2019). Cyanobacteria are present in all varieties of aquatic ecosystems around the world and have existed on the earth for hundreds of millions of years (Buratti et al. 2017). Some taxa of cyanobacteria, such as *Microcystis* spp., can produce toxins called Microcystins, or more broadly cyanotoxins (Buratti et al. 2017). These toxins pose a health risk to the humans and animals who come in contact with a toxin-producing HAB (Buratti et al. 2017). Cyanotoxins can have chronic or acute negative health impacts, depending on the concentration of the toxins, the duration of exposure, and size of the human or animal receptor (DeBruyn et al. 2021). However, the presence of a toxin-producing cyanobacteria species does not guarantee that a toxin is or will be produced (Buratti et al. 2017). Additionally, the toxin can still be released even if the recession of a bloom is occurring, as toxins can be released during cell lysis (Buratti et al. 2017). The exact mechanism of cyanotoxin release by the cyanobacteria is currently unknown.

In urban areas, many ponds are engineered rather than naturally occurring. Often used as Stormwater Control Measures (SCMs) for retaining stormwater runoff and pollution sedimentation, many urban pond SCMs are incorporated into neighborhoods, commercial properties, and green spaces such as parks and greenways, increasing the potential for human and pet exposure to cyanobacteria and possibly cyanotoxins. Because urban ponds are designed for the specific area they service, they tend to be unique in shape and size (Rouge Project 2021). Frequently shallow with prolonged water retention times and limited tree canopy cover, such ponds create an environment that is ideal for the growth of nuisance algae, such as cyanobacteria (Buratti et al. 2017). If suitable environmental conditions occur, cyanobacteria can begin to rapidly reproduce and form a bloom. Summer is the most common season for blooms, as ideal conditions for cyanobacteria growth include warm temperatures, extended exposure to direct sunlight, and increased nutrient availability (DeBruyn et al. 2021). However, the exact combination and characteristics of the factors which can trigger a cyanobacteria bloom are currently unknown (Indiana University 2021).

The objective of this study was to gain a better understanding of algal community dynamics in two ponds in Charlotte, North Carolina and to determine if water quality parameters that influence a cyanobacteria bloom could be identified. A better understanding of the dynamics and driving factors that influence a bloom in a small body of water could potentially lead to better management and treatment options, allowing pond management staff to take proactive measures to prevent and/or eliminate a potentially harmful algal bloom.

Methodology

Study Locations

To better understand the dynamics and seasonality of cyanobacteria blooms in urban ponds, two urban park ponds, Park Road Park Pond and Freedom Park Pond both located in Charlotte, Mecklenburg County, North Carolina, were monitored. The monitoring efforts were implemented by Mecklenburg County Stormwater Services (MCSWS). Both ponds have experienced recurring algal blooms, including cyanobacteria blooms, in previous summers. Both ponds are highly frequented by Mecklenburg County residents. Mecklenburg County Park and Recreation (MCPR) staff are responsible for the management and treatment of both ponds.

Incorporated in a 72-acre park, the 6.6-acre Park Road Park Pond (Figure 1) receives runoff from the surrounding neighborhood and streets, as well as from a small tributary to Little Sugar Creek. This pond, therefore, has constant influence and consistent flow through. The effluent from the pond flows approximately 440 m before confluence with Little Sugar Creek. Park Road Park Pond has several wooden piers and is accessible for its entire perimeter via a gravel walking path. This pond has a depth of approximately 4.5 – 5.5 m at its deepest point, has a completely natural bed, and is equipped with several submerged aeration features and fountains.

Incorporated in a 98-acre park, the 5.25-acre Freedom Park Pond (Figure 2) receives runoff from the surrounding neighborhood and streets, as well as a pipe from Dairy Branch Creek. Dairy Branch Creek, which runs along the northern edge of the pond, is a tributary to Little Sugar Creek. However, Freedom Park Pond does not have constant influence from Dairy Branch Creek, and has almost no flow through, except during heavy rain events. Water is added to the pond from Dairy Branch Creek by MCPR during prolonged dry periods. The effluence from Freedom Park Pond then discharges into the adjacent Little Sugar Creek. This pond is approximately 1.8 m at its deepest point and is entirely concrete lined. It is also accessible for its entire perimeter via a gravel walking path. The pond is equipped with several submerged aeration features and fountains.

Sampling Protocol

The study of Park Road Park Pond and Freedom Park Pond began in June 2020 and concluded in October 2020, with a total of 10 sampling events in both ponds. Samples were collected twice a month from each pond, between 10:00 AM and 3:00 PM when algae were expected to be most active. All water and algae samples were grab samples collected from the bank using a telescoping stainless-steel collector. Prior to mobilizing to the first pond, the stainless-steel collector was decontaminated using a phosphate-free soap and deionized (DI) water. Water and algae samples were collected from the mid-point of each pond: a small stone platform at Freedom Park Pond and the main, center fishing pier at Park Road Park Pond. Nutrient samples were collected from the upper/influent end of each pond. If a cyanobacteria bloom was visibly present, additional samples for both algae identification and toxin testing were collected in the area where the bloom was most concentrated.

Water Quality Parameters

Physical parameters, including temperature (°C), pH, dissolved oxygen (mg/L; % saturation), conductivity (µS/cm), turbidity (NTU), chlorophyll-*a* (µg/L), and phycocyanin (µg/L), were measured during each sampling event. All measurements were taken with a YSI water quality sampling meter (model number EXO2) and recorded on a field data sheet (Appendix A). After each sampling event, the YSI was rinsed with tap water

Figure 1. Park Road Park Pond, Mecklenburg County, North Carolina. Red circles indicate sampling sites for algae and water quality parameter collection.

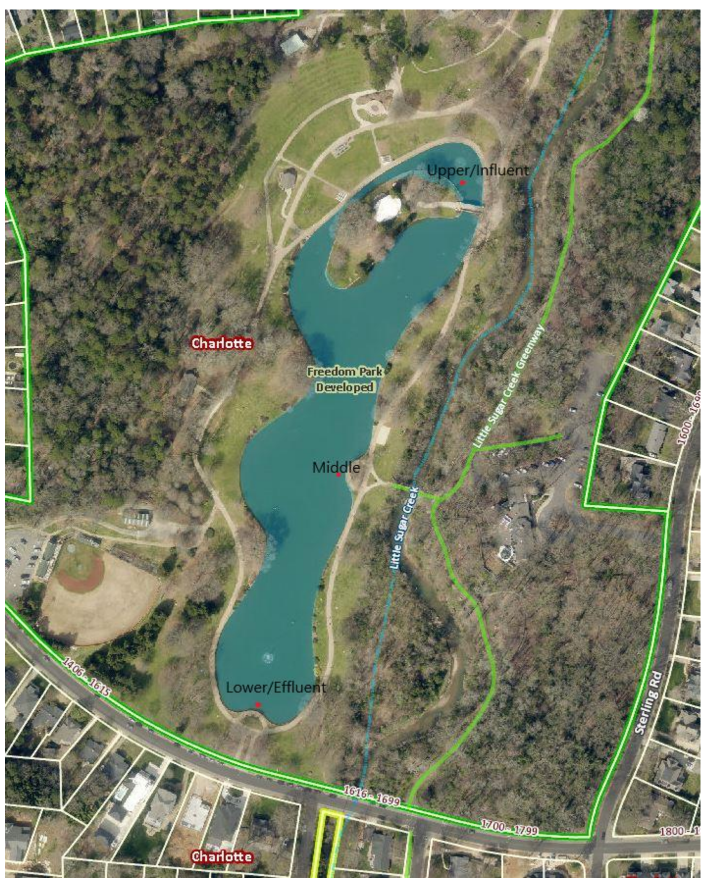

Figure 2. Freedom Park Pond, Mecklenburg County, North Carolina. Red circles indicate sampling sites for algae and water quality parameter collection.

from a 5-gal carboy to prevent cross contamination. One sample for nutrient analysis was collected from the upper/influent end of each pond in a 500mL plastic bottle preserved with sulfuric acid. After collection, the samples were put on ice and delivered to the Charlotte Water Laboratory (Charlotte, NC) for analysis of total Kjeldahl nitrogen (TKN), total phosphorus (TP), and nitrate and nitrite (NOX-N).

An equipment blank was collected once a month from one of the ponds for quality assurance purposes. To collect the blank, DI water was poured into the decontaminated, telescoping, stainless-steel collector and then poured into a 500mL plastic bottle preserved with sulfuric acid.

Algae Identification

Three algae samples were collected from each pond on the first sampling event, which allowed for an assessment of the overall algae community. The first samples were collected at the upper/influent end, middle, and lower/effluent end of each pond (Figures 1 and 2). It was determined that the algal community was consistent throughout each pond and therefore, only one representative algae sample was collected at each pond thereafter. The algae samples were collected in a 250 mL glass bottle containing a modified Lugol's solution preservative. After collection, the samples were placed in the MCSWS algae laboratory where the algae were allowed to settle for condensing purposes and enumerated at 400x to the lowest practicable taxonomic level using the guidelines set forth in the Phytoplankton Sample Processing and Analysis SOP (NCDEQ 2016). Following U.S. Environmental Protection Agency and World Health Organization guidelines, we set the designation of a *Cyanobacteria* algal bloom at 20,000 cells/ml or greater (EPA 2003).

If an active cyanobacteria bloom was observed, one grab sample in an unpreserved 250 mL plastic bottle was collected where the bloom appeared most concentrated and the additional Field Assessment Form for an active cyanobacteria bloom (Appendix B) was also completed. Coinciding with the algal bloom sample, an additional grab sample in an unpreserved 250 mL plastic PETG bottle was also collected for the purpose of testing for cyanotoxins. After collection, all samples were stored in a cooler of ice. The active bloom sample was identified the same day as collection and screened for the presence of cyanobacteria species, particularly *Microcystis* spp., *Anabaena* spp., and *Aphanozominon flos-aque,* which all have the potential to produce toxins. If a *Microcystis* spp. bloom was confirmed, an Algal Toxin Test Strip (Eurofins Abraxis) was performed using the sample from the 250mL PETG bottle.

Data Analysis

Algae were evaluated at the group level with the following designations: *Bacillariophyceae* (Diatoms), *Chlorophyceae* (Green algae), *Chrysophyceae* (Golden algae), *Cryptophyceae*, *Cyanophyceae* (Cyanobacteria/Blue-Green algae), *Dinophyceae* (Dinoflagellates), and *Euglenophyceae*. Two Cyanobacteria groups, *Microcystis* spp. and Other Toxic Cyanobacteria (*Anabaena* spp. and *Aphanozominon flos-aque*), were assessed independently due to their ability to produce toxins. Algal group biovolume and density were calculated for further analysis. Cell count and cell size was used to calculate biovolume (mm^3/m^3) for each algal group. Natural Units, the forms that naturally occur in the water, such as a colony, were used for calculating algal density (units/mL) (NCDEQ 2016). A non-parametric Wilcoxon rank-sum test was performed to identify differences in algal group data and water quality parameters between the two ponds. A Spearman Rank-Order Correlation analysis was performed to identify significant relationships between algal group biovolume and density and water quality parameters within each pond. Significance was defined as a coefficient less than -0.5 or greater than 0.5 and a p-value of less than 0.05.

Pond Treatment

MCPR retained pond management services from Granite Ridge Aquatic Services in the summer of 2020 to treat nuisance algae and vegetation in both Park Road Park Pond and Freedom Park Pond. These services included the application of the copper-based algaecide Captain XTR (SePro corporation), the herbicide Diquat, and the beneficial bacteria Summer Slam. Copper based algaecides, such as Captain XTR, are frequently used and are the most common type of algaecide. Diquat (diquat dibromide) is commonly mixed with other products as an adjuvant. When mixed, Diquat helps copper-based algaecides penetrate the algal cells by damaging the mucilage sheath or cell wall associated with many algal species. Summer slam is a beneficial bacterium which help to reduce the organic sediment, thereby reducing the available nutrients in the water body.

According to the SePro corporation, manufacturer of Captain XTR, a standard of 4 ft is used for the average depth when calculating a pond's acre/ft, therefore, Park Road Park Pond with 6.6 surface acres X 4 ft average depth = 26.4 acre/ft, and Freedom Park Pond with 5.25 surface acres X 4 ft average depth = 21 acre/ft. Label recommendations for the application rate of Captain XTR to be effective in treating algal growth is 0.6 – 3.0-gal of product per acre/foot. Diquat can be used at a rate of 0.5 – 2.0 gal per surface acre, according to the label, and can be mixed with copper algaecides at a 2:1 ratio (e.g., 2-parts Captain XTR:1-part Diquat). According to the product information, beneficial bacteria (Summer Slam) application is recommended when water temperatures are between 75°F-120°F, so application typically begins in the spring when water temperatures warm and is then stopped in the fall when the water temperatures cool off. It is also recommended that the initial dose be larger to build up the live bacterial units within the pond and a twice monthly maintenance application of a lower dose be applied for the remainder of the season. Recommended application rates for Summer Slam are 3 lbs per acre/ft for initial treatment and 2 lbs per acre/ft for the maintenance applications. Summer Slam is commonly sold in containers where the product has been pre-packaged into 1 lb packs.

Results

Algal Biovolume

Park Road Park Pond had an average community biovolume (Figure 3) of 2,627 mm^3/m^3 with the highest sampled biovolume of 7,635 mm^3/m^3 occurring on September 16, 2020. The Green algae group, *Chlorophyceae*, had the highest biovolume in the first two samples (June 9th and July 23rd) accounting for approximately 85% and 53% of the total community biovolume, respectively. *Microcystis* spp. was only minimally present in the first two samples, accounting for about 8% of the overall biovolume in those samples. In contrast, for all other samples later in the season, *Microcystis* spp. constituted an average of 67% of the community biovolume and had a mean biovolume of 1,687 mm^3/m^3. The Cyanobacteria group, *Cyanophyceae*, had a minor presence but increased in biovolume on August 6th and September 16th with biovolumes of 330 mm^3/m^3 and 470 mm^3/m^3, respectively. For the Other Toxic Cyanobacteria group, cells were only observed in half the samples with the remaining samples showing an average biovolume of 38 mm^3/m^3. *Euglenophyceae* had an inconsistent presence, with no cells found in the June 22nd and October 20th samples, a moderate biovolume in the July 23rd and August 19th samples, and the highest biovolume of 699 mm^3/m^3 in the September 16th sample. *Bacillariophyceae* had a slight presence in most samples except the September 16th and October 8th samples where it was elevated to 387 mm^3/m^3 and 242 mm^3/m^3, respectively. *Cryptophyceae* also had insignificant biovolumes overall but increased on July 23rd with 241 mm^3/m^3 and August 19th with 247 mm^3/m^3. *Chrysophyceae* and *Dinophyceae* were both present with minimal biovolumes throughout the sampling season.

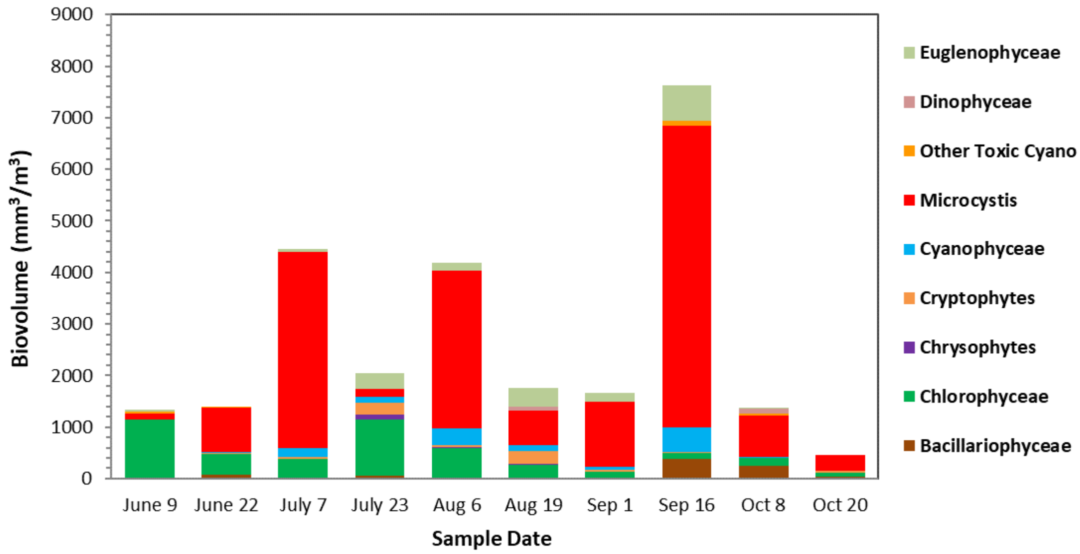

Figure 3. Algal group biovolumes in the 2020 sampling season at Park Road Park Pond, Mecklenburg County, NC.

The Freedom Park Pond community was monopolized by *Microcystis* spp. for all sampling events, with the exception of the first sample (June 9th) which was dominated by the Green algal group, *Chlorophyceae. Microcystis* spp. had a mean biovolume of 18,935 mm^3/m^3 throughout the sampling season, reaching a maximum of 28,887 mm^3/m^3 on July 7th. Except for the first sample where it only accounted for a little over 30% of the algal biovolume, *Microcystis* spp. contributed over 90% of the overall community biovolume for the entire season. *Cyanophyceae* was elevated in the first sample (June 9th) at a biovolume of 3,069 mm^3/m^3 but was drastically reduced in the next sample (June 22nd) to 28 mm^3/m^3. *Cyanophyceae* was minimal and intermittent for the remainder of the sampling events with an average biovolume of 117 mm^3/m^3. The Other Toxic Cyanobacteria group was also elevated in the June samples with biovolumes of 421 and 541 mm^3/m^3, respectively. However, the Other Toxic Cyanobacteria group was also nominal and intermittent for the remainder of the season, with an average biovolume of 114 mm^3/m^3. Green algae, *Chlorophyceae,* had higher biovolumes in the beginning of the season with its highest occurring in the June 22 sample at 924 mm^3/m^3, and an average of 259 mm^3/m^3 for the remainder of the sampling events. At its highest, *Chlorophyceae* only accounted for approximately 8% of the June biovolume samples and maintained an average of 1% of the overall biovolume for the remainder of the season. *Bacillariophyceae* had a low biovolume of only 188 mm^3/m^3 for the first sample at the beginning of the season. *Bacillariophyceae* increased as the season progressed with a biovolume over 2000 mm^3/m^3 for the final three samples, and accounting for 16% of the biovolume in the September 16th sample. *Chrysophyceae*, *Cryptophyceae, Dinophyceae,* and *Euglenophyceae* were all observed to have minimal biovolumes and were only present intermittently throughout the sampling season.

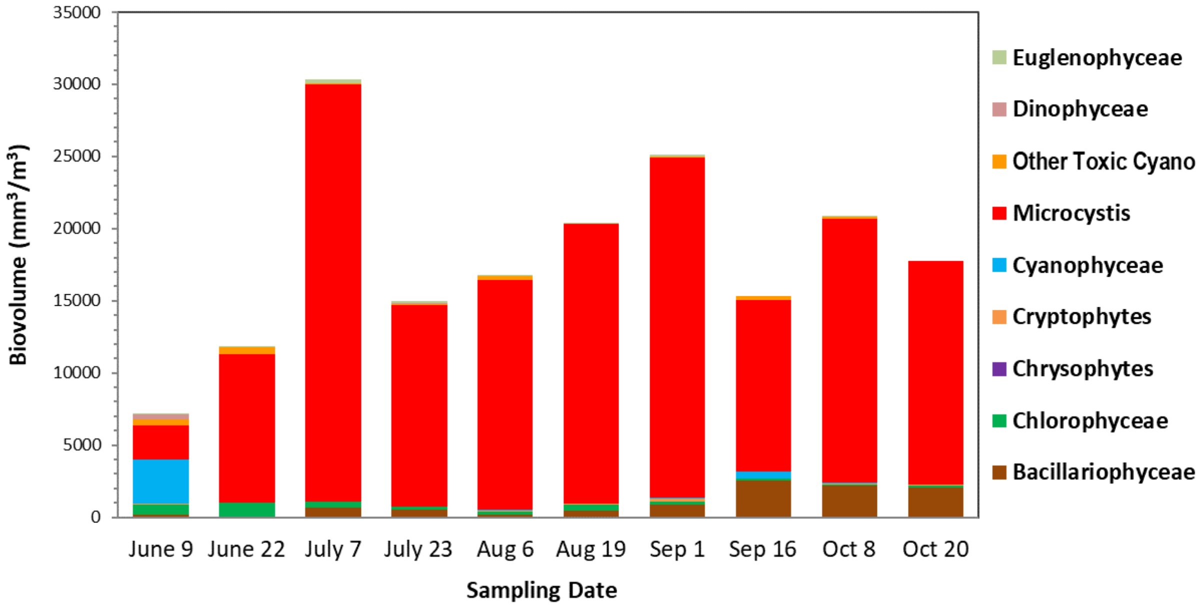

Figure 4. Algal group biovolumes in the 2020 sampling season at Freedom Park Pond, Mecklenburg County, NC.

Algal Density

Except for the September 16th sample, all sampling events for Park Road Park Pond were dominated by the Green algal group *Chlorophyceae,* with a mean density of 1,572 units/ml and a maximum density of 3,117 units/ml occurring on July 23rd (Figure 5). *Chlorophyceae* accounted for an average of almost 69% of the community density through the season and was as high as 80% in the August 6th sample. All other algal groups, including the Cyanobacteria groups: *Cyanophyceae,* Other Toxic Cyanobacteria, and *Microcystis* spp.*,* had variable density throughout the summer. The Cyanobacteria groups had a combined mean density of 654 units/ml and accounted for about 22% of the community density. *Cyanophyceae* had the second highest single sample density of any other group with 1,992 units/ml on September 16th, though for all other sampling events *Cyanophyceae* had a mean density of just 472 units/ml. *Microcystis* spp*.* density was minimal through the season with a mean density of 139 units/ml. The Other Toxic Cyanobacteria group had a minor presence in Park Road Park Pond and was found in only half the samples with a mean density of 48 units/ml, when they were present. The highest individual densities for both *Cyanophyceae* and *Microcystis* spp. of 1,992 units/ml and 391 units/ml, respectively, as well as the highest combined density for the Cyanobacteria groups with 2,506 units/ml occurred on September 16th. Though *Chrysophyceae* and *Cryptophyceae* had elevated densities during the July 23 and August 19th samples, these groups as well as all the others, had a minimal and variable presence during the sampling season. The highest densities for both *Chrysophyceae* and *Cryptophyceae* occurred during the July 23rd sample with densities of 476 units/ml and 806 units/ml, respectively.

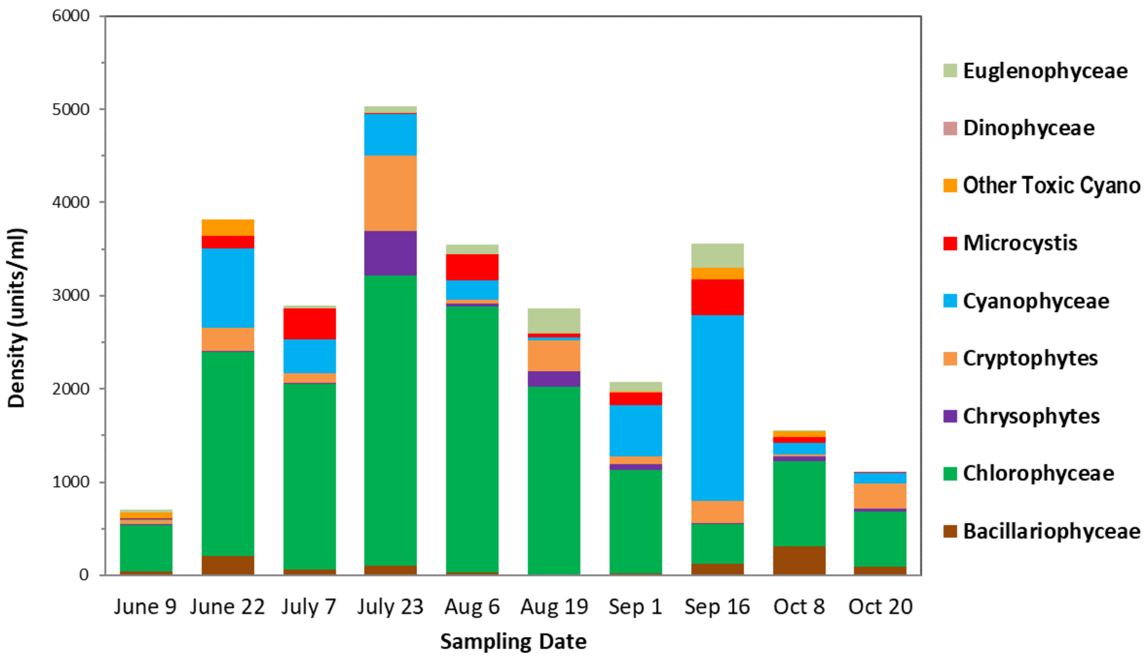

Figure 5. Algal group densities in the 2020 sampling season at Park Road Park Pond, Mecklenburg County, NC.

In contrast to Park Road Park Pond, only the first two samples (June 9 and June 22) in Freedom Park Pond were dominated by the Green algal group *Chlorophyceae* with densities of 1,735 units/ml and 2,090 units/ml, respectively (Figure 6). *Cyanophyceae* was already prevalent at a density of 782 units/ml in the first June sample from Freedom Park Pond, in comparison to only 18.3 units/ml for Park Road Park Pond. Other Toxic Cyanobacteria and *Microcystis* spp. were also observed in the first sample from Freedom Park Pond with densities of 366 units/ml and 244 units/ml, respectively. *Chlorophyceae* remained abundant through the sampling period with a density > 1,000 units/ml for each sample and contributing an average of 26% of the algal community. However, the combined Cyanobacteria groups of *Cyanophyceae,* Other Toxic Cyanobacteria, and *Microcystis* spp. dominated the community density in Freedom Park Pond for the summer. With combined densities averaging around 2,600 units/ml and the greatest combined density of 3,740 units/ml occurring on September 16th, the consolidated densities for all Cyanobacteria groups accounted for approximately 60% of the community density on average. Though *Microcystis* spp. contributed only 7% of the total community density in the first sample, it increased from 244 units/ml to 735 units/ml by the second sample and maintained an average of 25% of the community density with a mean of 972 units/ml. *Microcystis* spp. density was at its highest in the July 7th sample, contributing 38% of the overall density. *Cyanophyceae* had a variable density throughout the summer with no cells observed in the July 7th sample, and a mean density of 949 units/ml for the other sampling events. In October, *Cyanophyceae* density decreased drastically, going from over 2,800 units/ml on September 16th to less than 150 units/ml on October 8th. The Other Toxic Cyanobacteria group was also variable in density with no cells found in the August 19th or October 12th samples but a mean density of 142 units/ml when they were present. *Bacillariophyceae* density was low until September 16th when it went up to 978 units/ml compared to the average density of 475 units/ml and stayed elevated through the end of the sampling season. *Chrysophyceae*, *Cryptophyceae, Dinophyceae,* and *Euglenophyceae* were all observed in low densities and were only present intermittently throughout the sampling season.

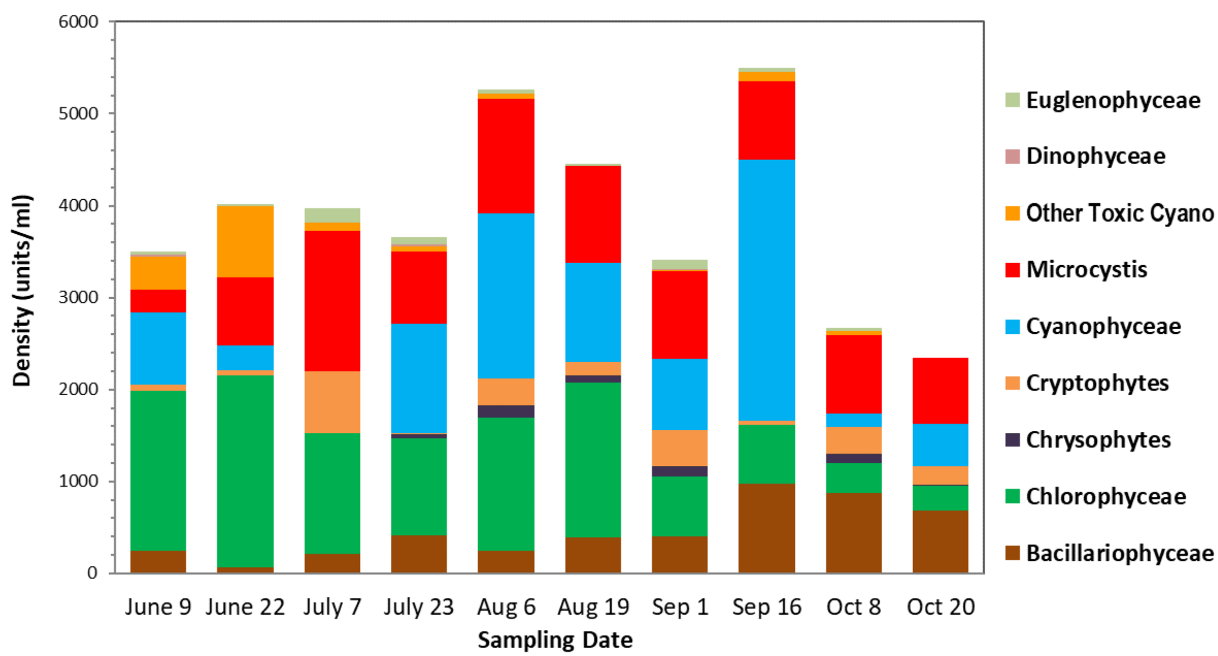

Figure 6. Algal group densities in the 2020 sampling season for Freedom Park Pond, Mecklenburg County, NC.

Algal Blooms

No blooms were observed in either pond during the first sampling event on June 9th, and Park Road Park Pond did not reach bloom status until the July 23rd sampling event (Table 1; Figure 7). Freedom Park Pond was in a bloom state for the remainder of the sampling season, while Park Road Park Pond only bloomed through the October 8th sample. *Microcystis* spp. bloom concentrations in Freedom Park Pond were variable throughout the season with an extreme spike of 15,591,614 cell/ml in the final sample on October 20th. Park Road Park Pond had its highest *Microcystis* spp. bloom count in the pond's first detectable bloom of the season at 677,246 cells/ml and steadily dropped in bloom cell count during the remainder of the season. *Anabaena* spp. was found in two sample events in Park Road Park Pond and four sample events in Freedom Park Pond but only reached bloom concentrations once in each pond, on September 16th and September 1st, respectively. *Aphanozominon flos-aque* was found in one sample in each pond but never reached bloom status in either. Park Road Park Pond only had detectable Microcystin toxin concentrations for three sampling events, whereas toxin concentrations were detected in four sampling events for Freedom Park Pond (Table 1).

Table 1. *Microcystis* spp. bloom cell counts and Microcystin concentrations from the 2020 sampling season for both Park Road Park and Freedom Park ponds, Mecklenburg County, NC. Microcystin toxin tests were conducted when an active bloom was confirmed. BDL= below detection limit.

	***Microcystis* spp. Bloom Count (cell/mL)**		**Microcystin Concentrations (ppb)**	
Date	Park Road Park Pond	Freedom Park Pond	Park Road Park Pond	Freedom Park Pond
6/9/20	No bloom detected	No bloom detected	No Bloom	No Bloom
6/22/20	No bloom detected	49,416	No Bloom	BDL
7/7/20	No bloom detected	107,000	No Bloom	BDL
7/23/20	No bloom detected	26,429	No Bloom	BDL
8/6/20	677,246	374,789	BDL	BDL
8/19/20	430,178	3,071,838	7ppb	>10ppb
9/1/20	472,915	1,082,474	>10ppb	5ppb
9/16/20	324,320	157,521	7ppb	BDL
10/8/20	214,808	1,372,582	BDL	2.5ppb
10/20/20	28,116	15,591,614	BDL	2.5ppb

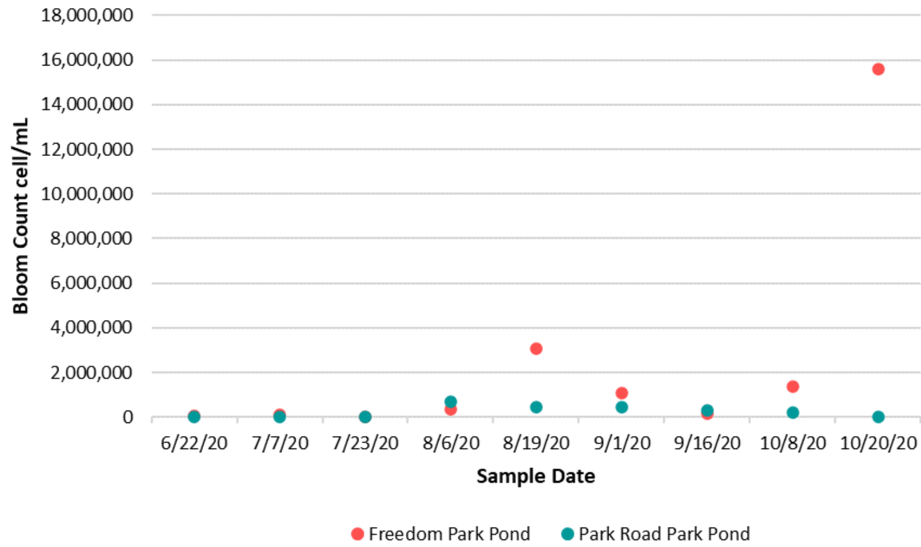

Figure 7. *Microcystis* spp. bloom cell counts for both Park Road Park and Freedom Park ponds, Mecklenburg County, NC from the first bloom event in June 2020 through the final sample collection in October 2020.

Water Quality Parameters

Park Road Park Pond had a relatively consistent TKN concentration, with an average of 0.86 mg/L (range = 0.56 – 1.10 mg/L) (Table 2). TP was also comparatively consistent with an average concentration of 0.09 mg/L (range = 0.07 – 0.14 mg/L). NOX-N was moderately variable with concentrations ranging from less than 0.05 mg/L to the highest concentration of 0.18 mg/L observed on October 20th. Throughout the sampling season, Park Road Park Pond had an average temperature of 26.70 °C. The sampling season began with temperatures at 29.10 °C and cooled off as the season progressed with the lowest recorded temperature of 18.00 °C at the end of season. The average conductivity for the season was 120.07 µS/cm (range = 80.00 – 149.50 µS/cm), with slightly higher levels of conductivity in the first few sampling events compared to the rest of the season. Dissolved oxygen had an average percent saturation of 95% (range = 56.2 – 159%) and an average concentration of 7.60 mg/L (range = 4.58 – 12.37 mg/L), with higher readings in the first couple of sampling events. An average pH of 7.70 (range = 7.06 – 9.03) was observed for the sampling season with the highest pH in the first three sampling events. Turbidity was quite variable with a range from 6.5 to 34.73 NTU, though the seasonal average was 16.64 NTU. There was an average chlorophyl-*a* concentration of 8.35 µg/L throughout the season. However, chlorophyl-*a* concentrations were inconsistent, with a range from 1.96 to 20.06 µg/L. Phycocyanin was also variable in concentrations with a seasonal average concentration of 17.46 µg/L (range = 3.87 – 58.52 µg/L). The average Secchi depth disk reading for Park Road Park Pond was 0.7 m (range = 0.3 –

1.2 m), with the longest measurements occurring during the first three sampling events, indicating greater light penetration.

Freedom Park Pond had an average TKN concentration of 1.47 mg/L, though it did show a spike in two samples: 2.40 mg/L on August 19th and the highest reading of 3.60 on October 20th (range = 0.90 – 3.60 mg/L) (Table 3). The highest TP concentrations also occurred on August 19th and October 20th with concentrations of 0.14 mg/l and 0.21 mg/L, respectively (range = 0.04 – 0.21 mg/L). NOX-N concentrations never exceeded 0.05 mg/L, which is the detection limit. The temperature was warmest in Freedom Park Pond on July 23rd at 30.90 °C, with an average seasonal temperature of 26.46 °C in a range of 18.60 to 30.90 °C. Conductivity was consistent with an average of 184.85 µS/cm and the highest record occurring during the August 6th sample (range = 173.80 – 200.90 µS/cm). Dissolved oxygen was highest for both percent and concentration on June 22nd of 196.40% and 15.62 mg/L. Dissolved oxygen had an average percent saturation of 127.45% (range = 83.40 – 196.00%) and an average concentration of 10.34 mg/L (range = 6.40 – 15.62 mg/L). Freedom Park Pond had an average pH for the season of 8.37 in a range from 7.51 to 9.26 and was also highest on June 22nd. Turbidity (NTU) was highest on July 7th in a range of 9.66 to 42.80 NTU and an average seasonal concentration of 24.74 NTU. Chlorophyll-*a* maintained an average of 8.33 µg/L for the sampling season but was elevated during two sampling events: June 9th and October 20th at 15.23 µg/L and 12.62 µg/L, respectively (range = 4.90 – 15.23 µg/L). Phycocyanin was also highest on July 7th and had a seasonal average concentration of 72.65 µg/L (range = 44.30 – 125.50 µg/L). The Secchi disk readings were extremely consistent with an overall average of 0.4 m in a range of 0.3 to 0.6 m.

Concentrations of TKN were higher than concentrations of TP in both ponds, and both TKN and TP were higher in Freedom Park Pond than in Park Road Park Pond (Figure 8). Average TKN concentrations were higher in both ponds during a bloom event than when no bloom was confirmed, with both ponds showing comparable concentration changes in relation to a bloom event (Figure 9). TP concentrations were more consistent between the two bloom states in Park Road Park Pond than in Freedom Park Pond (Figure 10). During a bloom event in Freedom Park Pond, TP concentrations were distinctly higher than during sampling events when a bloom was not confirmed (Figure 10).

Table 2. Water quality parameters collected at each 2020 sampling event for Park Road Park Pond, Mecklenburg County, NC.

Date	Temperature (°C)	Conductivity (µS/cm)	DO (%)	DO (mg/L)	pH	Turbidity (NTU)	Chlorophyll-A (µg/L)	Phycocyanin (µg/L)	Secchi depth (m)	TKN (mg/L)	TP (mg/L)	NOX-N (mg/L)
6/9/20	29.10	146.00	114.30	8.77	8.43	10.27	5.94	9.96	1.1	0.83	0.08	<0.05
6/22/20	28.40	140.60	159.20	12.37	9.03	6.50	6.46	6.50	1.2	0.56	0.07	<0.05
7/7/20	29.90	149.50	107.40	8.12	8.69	7.10	3.51	18.92	1.1	0.68	0.09	<0.05
7/23/20	29.00	87.50	59.60	4.58	7.40	32.64	6.64	10.36	0.3	0.70	0.09	0.11
8/6/20	29.70	116.30	110.60	8.40	7.45	9.16	13.67	18.35	0.9	1.10	0.09	<0.05
8/19/20	27.60	80.00	80.20	6.32	7.06	34.73	7.79	8.20	0.4	1.10	0.14	0.10
9/1/20	280.00	99.40	77.70	6.08	7.11	15.10	20.06	19.31	0.8	0.97	0.09	0.08
9/16/20	25.80	113.10	88.30	7.19	7.19	18.88	14.96	58.52	0.4	1.10	0.07	<0.05
10/8/20	20.90	92.00	99.10	8.85	7.88	12.12	2.52	20.63	0.7	0.60	0.06	<0.05
10/20/20	18.70	96.30	56.20	5.25	7.22	19.88	1.96	3.87	0.5	0.91	0.10	0.18

Table 3. Water quality parameters collected at each 2020 sampling event for Freedom Park Pond, Mecklenburg County, NC.

Date	Temperature (°C)	Conductivity (µS/cm)	DO (%)	DO (mg/L)	pH	Turbidity (NTU)	Chlorophyll-A (µg/L)	Phycocyanin (µg/L)	Secchi depth (m)	TKN (mg/L)	TP (mg/L)	NOX-N (mg/L)
6/9/20	29.40	174.60	116.30	8.87	8.72	9.66	15.23	44.30	0.6	0.71	0.04	<0.05
6/22/20	27.10	183.90	196.40	15.62	9.26	22.04	5.74	60.00	0.5	1.40	0.08	<0.05
7/7/20	28.90	192.10	131.50	10.12	8.75	42.80	6.35	125.47	0.5	1.40	0.13	<0.05
7/23/20	30.90	190.60	109.90	8.18	8.51	27.03	7.00	56.74	0.4	0.90	0.09	<0.05
8/6/20	29.10	200.90	83.40	6.40	7.51	24.98	4.79	62.09	0.4	0.96	0.08	<0.05
8/19/20	28.03	182.70	136.50	10.68	8.18	29.43	9.96	69.01	0.3	2.40	0.14	<0.05
9/1/20	27.70	182.70	101.70	7.99	7.97	22.29	5.96	50.23	0.3	1.00	0.08	<0.05
9/16/20	24.22	190.20	113.50	9.42	8.11	20.89	10.59	79.07	0.4	1.10	0.06	<0.05
10/8/20	20.60	173.80	154.30	13.85	8.60	23.75	5.07	96.80	0.5	1.20	0.08	<0.05
10/20/20	18.60	177.00	131.00	12.25	8.16	24.57	12.62	82.77	0.5	3.60	0.21	<0.05

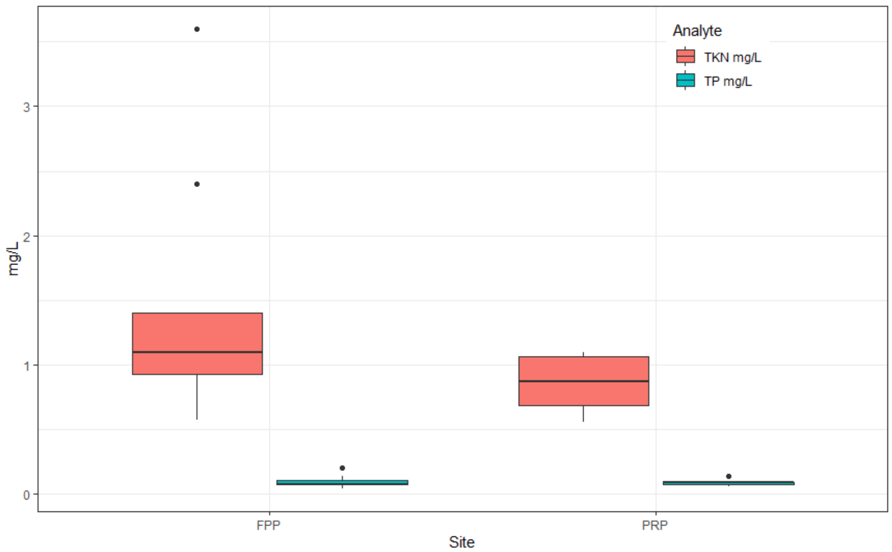

Figure 8: Average of the TKN and TP for Freedom Park Pond (FPP) and Park Road Park Pond (PRP) from the 2020 sampling season, Mecklenburg County, NC. Credit: Dr. Robert Sowah, MCSWS.

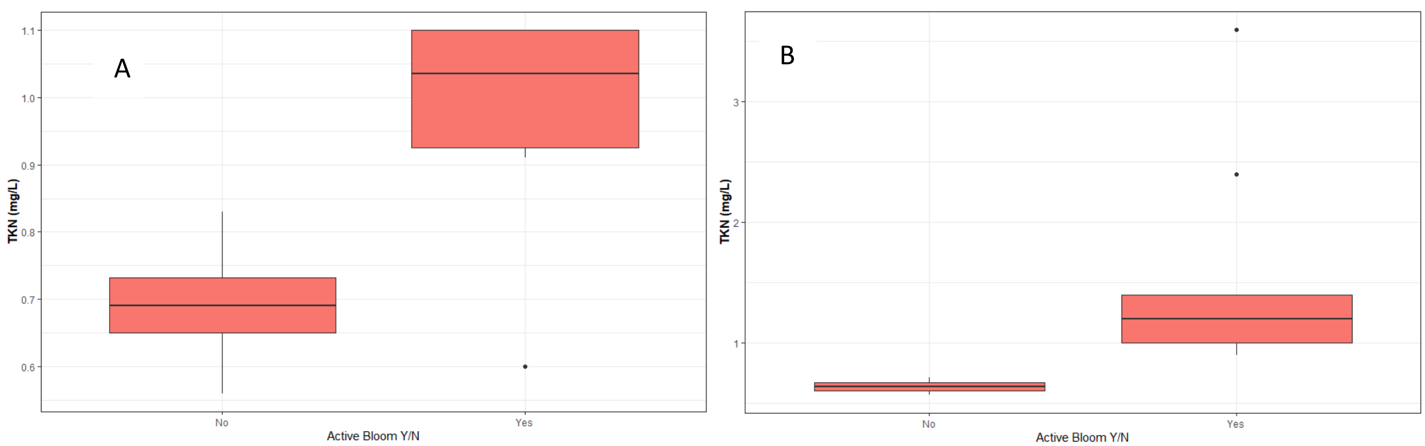

Figure 9: Average of TKN in Park Road Park Pond (A) and Freedom Park Pond (B) from the 2020 sampling season as a function of algal bloom state, Mecklenburg County, NC. Credit: Dr. Robert Sowah, MCSWS.

Park Road Park Pond had lower average conductivity, dissolved oxygen, turbidity, and phycocyanin than Freedom Park Pond (Figure 11). Chlorophyll-*a,* pH, and the Secchi disk measurement averages were comparable between the two ponds. Temperature was the only water quality parameter that had a lower average in Freedom Park Pond than Park Road Park Pond, though the averages were comparable.

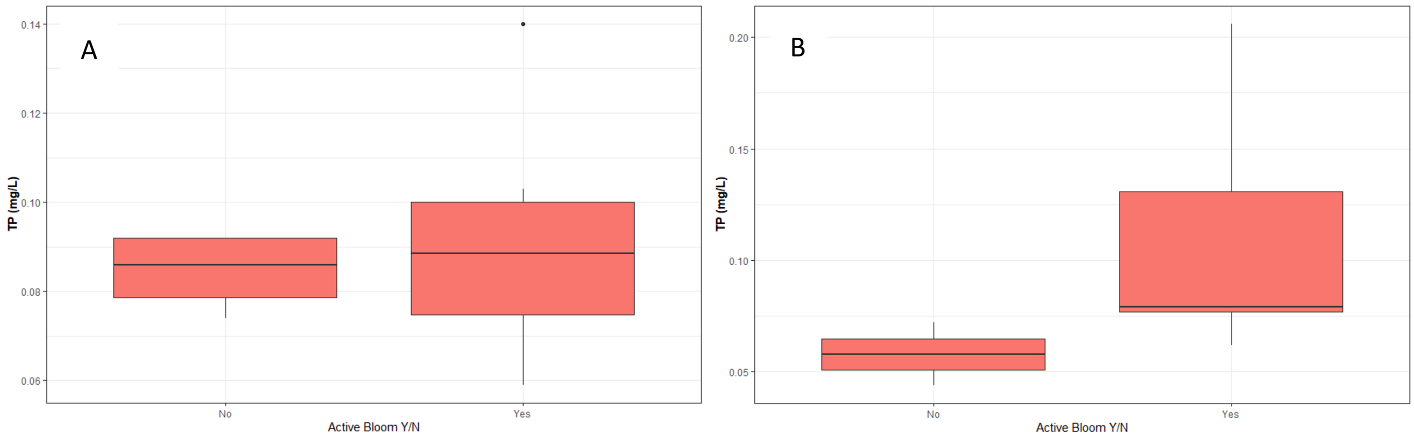

Figure 10: Average of TP in Park Road Park Pond (A) and Freedom Park Pond (B) from the 2020 sampling season as a function of algal bloom state, Mecklenburg County, NC. Credit: Dr. Robert Sowah, MCSWS.

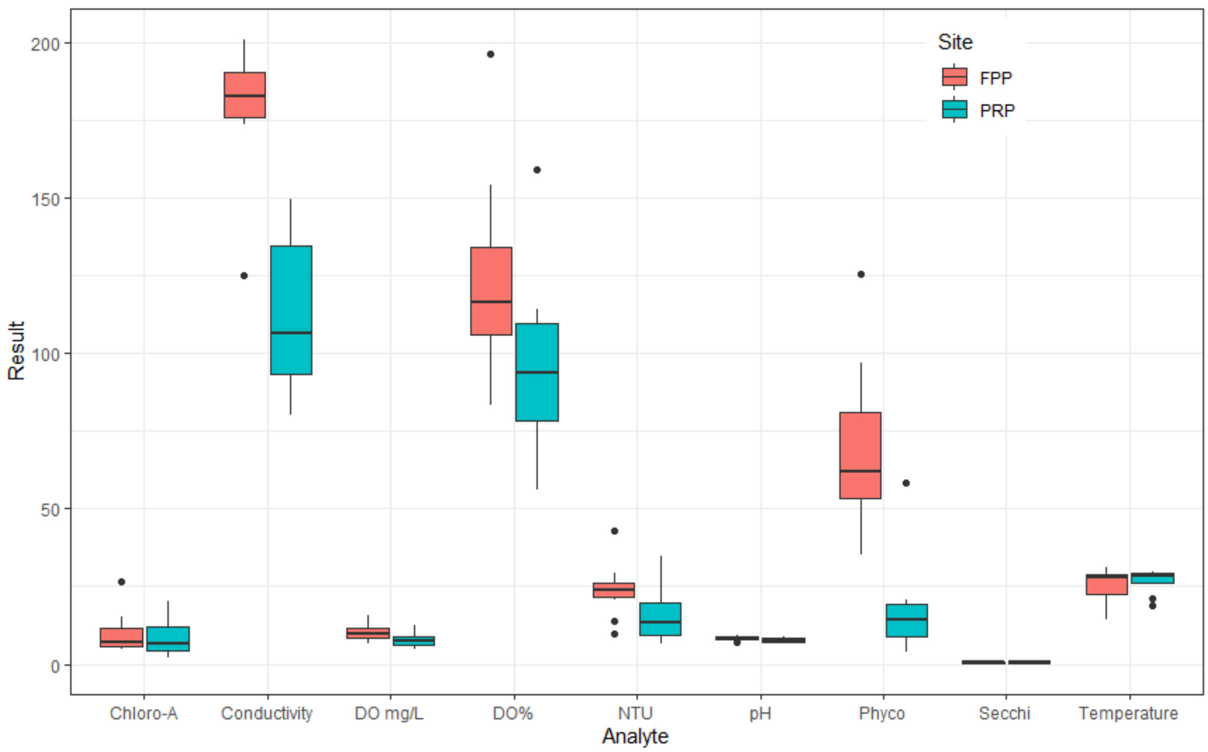

Figure 11: Average of water quality parameters for Freedom Park Pond (FPP)and Park Road Park Pond (PRP) from the 2020 sampling season, Mecklenburg County, NC. Credit: Dr. Robert Sowah, MCSWS.

Data Analysis

A direct comparison of water quality parameters and Cyanobacteria groups between Freedom Park Pond and Park Road Park Pond indicated some significant differences (Table 4). Conductivity, dissolved oxygen, pH, turbidity, phycocyanin, TKN, and NOX-N were significantly different ($p < 0.05$) between the ponds. Cell counts for the Cyanobacteria group *Cyanophyceae*, cell counts for *Microcystis* spp., *Microcystis* spp. density and *Microcystis* spp. biovolume were also significantly different between the two ponds.

Table 4. Wilcoxon rank-sum test of differences in water quality parameters and Cyanobacteria groups between Freedom Park Pond and Park Road Park Pond, Mecklenburg County, NC. Significant p-values ($p < 0.05$) are indicated in bold.

Parameter	p-value
Conductivity	**0.0002**
Temperature	0.8205
DO	**0.0232**
pH	**0.0355**
NTU	**0.0433**
Chlorophyll-A	0.8534
Phycocyanin	**<0.0001**
TKN	**0.0206**
TP	0.8203
NOX-N	**0.0306**
Microcystis Bloom Count	0.1704
Microcystis Count	**0.0009**
Microcystis Density	**0.0004**
Microcystis Biovolume	**<0.0001**
Cyanophyceae Count	**0.0342**
Other Toxic Cyano Count	0.0741

The only water quality parameter to have a significant relationship with *Microcystis* spp. bloom counts in Park Road Park Pond was temperature ($p = 0.0$) (Table 5; Appendices C and E). Temperature also had a significant impact on *Microcystis* spp. density ($p = 0.0144$), as well as both density ($p = 0.0381$) and biovolume ($p = 0.0075$) for the Green algal group, *Chlorophyceae*. TP had a significant impact on the following algal groups: *Microcystis* spp. density ($p = 0.0318$), Cyanophyceae density ($p = 0.0359$), Other Toxic Cyanobacteria group density ($p = <0.0001$) and biovolume ($p = 0.0009$), and Chlorophyceae density ($p = 0.0059$). Whereas, TKN only had a significant influence on the Other Toxic Cyanobacteria group density ($p = 0.0006$). Conductivity had a significant impact on density for both *Microcystis* spp. (p = 0.0078) and Other Toxic Cyanobacteria (p = 0.0006).

Table 5. Spearman Rank-Order Correlation analysis of algal group and water quality data from the Park Road Park Pond, Mecklenburg County, NC 2020 sampling season. Significant p-values ($p < 0.05$) are indicated in bold.

Algal Group	Water Quality Parameter	Correlation Coefficient	p-value
Microcystis Biovolume	TP mg/L	-0.2918	0.4133
Microcystis Biovolume	TKN mg/L	0.2270	0.5282
Microcystis Bloom Count	Temperature	1	**0**
Microcystis Bloom Count	TKN mg/L	0.4028	0.0631
Microcystis Bloom Count	TP mg/L	0.2331	0.2965
Microcystis Density	Conductivity	0.5514	**0.0078**
Microcystis Density	Temperature	0.5141	**0.0144**
Microcystis Density	TP mg/L	-0.4588	**0.0318**
Microcystis Density	TKN mg/L	0.1412	0.5307
Cyanophyceae Biovolume	TKN mg/L	0.5338	0.1120
Cyanophyceae Biovolume	TP mg/L	0.0304	0.9336
Cyanophyceae Density	TP mg/L	-0.4493	**0.0359**
Cyanophyceae Density	TKN mg/L	-0.0136	0.9522
Other Toxic Cyano Biovolume	TP mg/L	-0.8754	**0.0009**
Other Toxic Cyano Biovolume	TKN mg/L	-0.1636	0.6515
Other Toxic Cyano Density	TP mg/L	-0.9650	**<0.0001**
Other Toxic Cyano Density	TKN mg/L	-0.6757	**0.0006**
Other Toxic Cyano Density	Conductivity	0.6723	**0.0006**
Chlorophyceae Biovolume	Temperature	0.7818	**0.0075**
Chlorophyceae Biovolume	TKN mg/L	-0.2638	0.4614
Chlorophyceae Biovolume	TP mg/L	-0.0486	0.8939
Chlorophyceae Density	TP mg/L	0.5676	**0.0059**
Chlorophyceae Density	Temperature	0.4449	**0.0381**
Chlorophyceae Density	TKN mg/L	0.2668	0.2300

Freedom Park Pond had fewer significant correlations than Park Road Park Pond, and the only significant correlations were associated with *Microcystis* spp. (Table 6; Appendices D and F). Conductivity had a significant relationship with *Microcystis* spp. bloom counts (p = 0.0412) and density (p = 0.0014). TP had a significant relationship with both *Microcystis* spp. density (p = 0.0302) and biovolume (p = 0.0122), whereas

TKN only significantly related to biovolume (p = 0.0303). Finally, temperature significantly correlated with *Microcystis* spp. density (p = 0.0208).

Table 6. Spearman Rank-Order Correlation analysis of algal group and water quality data from the Freedom Park Pond, Mecklenburg County, NC 2020 sampling season. Significant p-values ($p < 0.05$) are indicated in bold.

Algal Group	Water Quality Parameter	Correlation Coefficient	p-value
Microcystis Biovolume	TP mg/L	0.6947	**0.0122**
Microcystis Biovolume	TKN mg/L	0.6235	**0.0303**
Microcystis Bloom Count	Conductivity	-0.6862	**0.0412**
Microcystis Bloom Count	TKN mg/L	0.5439	0.1301
Microcystis Bloom Count	TP mg/L	0.4202	0.2602
Microcystis Density	Conductivity	0.8105	**0.0014**
Microcystis Density	Temperature	0.6550	**0.0208**
Microcystis Density	TP mg/L	0.6239	**0.0302**
Cyanophyceae Biovolume	TP mg/L	-0.3088	0.3289
Cyanophyceae Biovolume	TKN mg/L	-0.0806	0.8035
Cyanophyceae Density	TKN mg/L	-0.2382	0.4560
Cyanophyceae Density	TP mg/L	-0.1544	0.6319
Other Toxic Cyano Biovolume	TP mg/L	-0.3465	0.2699
Other Toxic Cyano Biovolume	TKN mg/L	0.0321	0.9211
Other Toxic Cyano Density	TKN mg/L	-0.1025	0.7513
Other Toxic Cyano Density	TP mg/L	-0.3504	0.2641
Chlorophyceae Biovolume	TKN mg/L	0.2207	0.4907
Chlorophyceae Biovolume	TP mg/L	-0.0140	0.9655
Chlorophyceae Density	TKN mg/L	-0.3363	0.2852
Chlorophyceae Density	TP mg/L	-0.2877	0.3645

Pond Treatment

The treatment schedule for both Park Road Park Pond and Freedom Park Pond for the 2020 summer season included the following chemical products: Captain XTR, Diquat, and Summer Slam (Table 7). For both ponds, the copper algaecide treatment of Captain XTR varied, with a 1 – 2-gal treatment occurring every 2 weeks, and no treatments occurring in Park Road Park Pond after September 2nd. The herbicide Diquat was applied inconsistently in both ponds; with treatments occurring only once some months and no treatments occurring in Park Road Park Pond after August 26th. A onetime treatment of 2 quarts of Diquat was applied to Freedom Park Pond on August 6th. The beneficial bacteria, Summer Slam was applied to Freedom Park Pond using three 1 lb "Packs" on two occasions, June 12th and July 10th. No Summer Slam was applied to Park Road Park Pond during the 2020 sampling season.

The recommended treatment schedule based on manufacturer guidelines for Park Road Park Pond using the lowest recommended application rates twice monthly would have been as follows: 15.8-gal of Captain XTR, 7.9-gal of Diquat using the 2:1 recommended ratio, and 79lbs of Summer Slam for the initial dose and 53lbs for the remaining treatments (Table 8). For Freedom Park Pond the suggested alternating treatment schedule on a weekly basis while only treating half the pond at a time would have been as follows: 6.3-gal of Captain XTR, 3.2-gal of Diquat using the 2:1 recommended ratio, and 31.5lbs of Summer Slam for the first two initial doses and 21lbs for the remaining treatments. When the algal bloom is ubiquitous, which was the case in Freedom Park Pond, it is recommended to treat only half the water body at a time once a week, instead of the entire pond twice monthly, in an effort to reduce a fish kill which could result from depleted dissolved oxygen due to the decomposing algae (Pond Informer 2021).

Table 7. Pond treatments for Freedom Park Pond (FPP) and Park Road Park Pond (PRPP) by Mecklenburg County Park and Recreation for the summer of 2020, Mecklenburg County, NC.

Date	**Captain XTR (Gal)**		**Diquat (Quart)**		**Summer Slam (1lb Pack)**	
	FPP	PRPP	FPP	PRPP	FPP	PRPP
6/12/20	1.5	2	0	1	3	0
6/29/20	2	2	1	0	0	0
7/10/20	2	1.5	1	0	3	0
7/22/20	2	1.5	1	1	0	0
8/6/20	1.5	1	2	0	0	0
8/26/20	1.5	2.5	1	1	0	0
9/2/20	2	1.5	0	0	0	0
9/18/20	1.5	0	1	0	0	0
10/9/20	2	0	0	0	0	0

Table 8. Pond treatments based on product recommendations for Freedom Park Pond (FPP) and Park Road Park Pond (PRPP), Mecklenburg County, NC. Park Road Park Pond would be treated on a bi-monthly basis and half of Freedom Park Pond would be treated weekly.

Date	**Half of Freedom Park to be Treated (North or South)**	**Captain XTR (Gal)**		**Diquat (Gal)**		**Summer Slam (1lb Pack)**	
		FPP	PRPP	FPP	PRPP	FPP	PRPP
6/12/20	N	6.3	15.8	3.2	7.9	31.5	79
6/19/20	S	6.3	0	3.2	0	31.5	0
6/26/20	N	6.3	15.8	3.2	7.9	21	53
7/03/20	S	6.3	0	3.2	0	21	0
7/10/20	N	6.3	15.8	3.2	7.9	21	53
7/17/20	S	6.3	0	3.2	0	21	0
7/24/20	N	6.3	15.8	3.2	7.9	21	53
7/31/20	S	6.3	0	3.2	0	21	0
8/07/20	N	6.3	15.8	3.2	7.9	21	53
8/14/30	S	6.3	0	3.2	0	21	0
8/21/20	N	6.3	15.8	3.2	7.9	21	53
8/28/20	S	6.3	0	3.2	0	21	0
9/04/20	N	6.3	15.8	3.2	7.9	21	53
9/11/20	S	6.3	0	3.2	0	21	0
9/18/20	N	6.3	15.8	3.2	7.9	21	53
9/25/20	S	6.3	0	3.2	0	21	0
10/02/20	N	6.3	15.8	3.2	7.9	21	53
10/09/20	S	6.3	0	3.2	0	21	0
10/16/20	N	6.3	15.8	3.2	7.9	21	53

Discussion

Freedom Park Pond had considerably more algal growth than Park Road Park Pond in the 2020 sampling season; with an average community seasonal biovolume of 20,477 mm^3/m^3, Freedom Park Pond was almost 10 times more productive than Park Road Park Pond. Though bloom counts of *Microcystis* spp. were not significantly different between the two ponds, algal blooms were observed more often in Freedom Park Pond and a number of those bloom concentrations were markedly higher than any observed in Park Road Park Pond during the 2020 sampling season. Furthermore, average density and biovolume of *Microcystis* spp. was significantly greater in Freedom Park Pond than Park Road Park Pond. Moreover, several significant correlations were observed in Park Road Park Pond between water quality parameters and algal groups, whereas the only significant correlations observed in Freedom Park Pond were in association with *Microcystis* spp.

In the summer months, Cyanobacteria are able to "out-compete" other algal groups creating an imbalanced ecosystem (Bellinger and Sigee 2015). Additionally, the presence of a Cyanobacteria bloom could be used as an indicator that the system has become eutrophic (Bellinger and Sigee 2015). Therefore, the higher algal productivity, higher concentrations of *Microcystis* spp., and lack of significant correlations between water quality parameters and other algal groups in Freedom Park Pond could be explained by the higher nutrient concentrations observed. This could also indicate that Freedom Park Pond's phytoplankton community had become imbalanced.

Though nutrients such as phosphorus and nitrogen are naturally found in the environment, stormwater containing excess amounts of nutrients, typically from anthropogenic sources like chemical fertilizers and animal waste, can cause the eutrophication of water bodies (Denchak and Sturm 2019). Studies have shown that eutrophication can cause an increase in Cyanobacteria concentrations and lead to an algal bloom (Denchak and Sturm 2019; Jankowiak et al. 2019). For example, a study conducted in 2015 in Lake Erie regarding the relationship between HABs and anthropogenic nutrient loading, found that the abundance of Cyanobacteria was strongly influenced by nutrient availability (Jankowiak et al. 2019). In Freedom Park Pond, a notable spike in both TP and TKN was observed during two sampling events: August 19th and October 20th, with a corresponding spike in *Microcystis* spp. bloom concentrations during the same sampling events. Both TP and TKN were observed to be higher in Freedom Park Pond than Park Road Park Pond, with TKN concentrations being significantly higher. Additionally, TP was significantly correlated to *Microcystis* spp. in both ponds (Table 4 and Figure 8). Due to the ability of many Cyanobacteria species, including *Microcystis* spp., to fix atmospheric nitrogen, they are considered to be phosphorus limited (Jankowiak et al. 2019). As illustrated in Figure 10, Freedom Park Pond presents elevated concentrations of TP during a bloom event, which could indicate that TP is the limiting nutrient for *Microcystis* spp. in Freedom Park Pond. Furthermore, the significantly higher TKN concentrations observed in Freedom Park Pond could be exacerbated due to nutrient loading in the system from nitrogen fixation by *Microcystis* spp. (Lu et al. 2019).

Another factor that has the potential to impact the production of algal blooms, is water flow. Water evaporation in the summer months can cause ponds to lose a substantial amount of water. A pond with constant flow, such as Park Road Park Pond, will stay full and have better nutrient balance because excess nutrients are flushed out through the pond effluent (Swistock 2013). Conversely, a pond with little to no flow through, such as Freedom Park Pond, can only eliminate excess nutrients during major storm events and will lose water to evaporation but continue to accumulate nutrients (Swistock 2013). Therefore, ponds with minimal flow have reduced water qualities and are susceptible to excess nutrient accumulation leading to increased vegetation and algal growth (Swistock 2013). Periodically flushing Freedom Park Pond, in an effort to moderate accumulated nutrients in the pond, could potentially have a positive impact on reducing algal blooms.

Temperature and conductivity were also significantly correlated with *Microcystis* spp. in both ponds. As the climate continues to change and the planet warms, global and local environmental conditions will also be altered (Wells et al. 2020). These environmental changes such as water temperature, nutrient cycling, and precipitation are likely to substantially modify algae assemblage distribution and patterns (Wells et al. 2020). These impacts to algae assemblages could also alter HABs in a number of ways: increases in HAB species biovolume, HAB species out competing non-HAB species in algal communities, and the potential of increases in toxin-producing HAB species (Wells et al. 2020). Therefore, it is imperative that effective pond management strategies are developed and implemented in order to reduce Harmful Algal Blooms in small bodies of water.

Chemical applications are commonly used in pond management to treat algal blooms, which was the treatment method used for both Freedom Park and Park Road Park Ponds in the summer of 2020. However, there was a discrepancy in the recommended application rates and the actual doses used. No more than 2-gal of Captain XTR was used in a single treatment for either pond, which is less than 15% of the recommended dose (Table 7 and 8). Diquat was used intermittently in both ponds and only a single quart was ever applied; the application of 1-qt of Diquat is less than 5% of the recommended dose for both ponds (Table 7 and 8). Being that Diquat is an accessory product which increases the efficacy of the copper-based algaecide, Captain XTR, using the 2:1 ratio dose for the application of those products is ideal. Summer slam was only used on Freedom Park Pond and only two treatments occurred in the beginning of the season (Table 7 and 8). For the two Summer Slam treatments applied to Freedom Park Pond, less than 5% of the initial recommended dose was used (Table 7 and 8). A pond management regime which follows the recommended doses and application frequency for treatment products could have made pond treatments much more effective in managing the algal blooms in both Park Road Park and Freedom Park Ponds, specifically *Microcystis* spp. blooms.

Some alternate treatment methods for controlling algal blooms have been studied or are already available. Barley straw and barley straw extract have been used to treat algal blooms as an alternative to harsh chemicals and have shown success in reducing concentrations of *Microcystis* spp., as well as other forms of Cyanobacteria (Islami et al. 2010). Though the exact mechanism which allows barley straw to have an impact on algae concentrations is unknown, it has been hypothesized that oxidized phenolics act as an inhibitor when they are released during barley straw decomposition (Islami et al. 2010). The use of potassium ions could be another treatment option; a study done in India demonstrated that potassium salts inhibited the growth of *Microcystis* spp. (Parker et al. 1997). The study suggested that potassium ions could be a better alternative to copper sulfate because other organisms are un-harmed by the concentrations of potassium salts that are toxic to *Microcystis* spp. (Parker et al. 1997).

Having a better understanding of the dynamics and driving factors that could be influencing the phytoplankton community and triggering *Microcystis* spp. blooms in Freedom Park and Park Road Park Ponds will allow MCPR staff to make more informed decisions, leading to better management and treatment options to prevent or eliminate harmful algal blooms. Further investigation into this topic, such as a comparison of urban and forested ponds, studying a greater number of ponds, or collecting more samples over a longer period of time, could provide more insight into the unique dynamics leading to algal blooms in these individual ponds.

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Appendices

Appendix A

Phytoplankton Sampling – Field Evaluation Form

(walk around entire waterbody before completing this form)

Sampled by:_______________________________________ Date Sampled:__________________

Time: ________________

Park/Neighborhood/Facility:_____________________________

Weather conditions at time of sampling: ____

YSI Readings:

Temp	Sp. Cond	DO%	DO mg/L	pH	NTU	Chloro-a	Phyco	Secchi

Notes:

Appendix B

Cyanobacteria Bloom Evaluation Form

(only complete this form if an active bloom is observed and sampled)

Sampled by:_______________________________________ Date Sampled:__________________

Time: ________________

Park/Neighborhood/Facility:_____________________________

YSI Readings:

Temp	**Sp. Cond**	**DO%**	**DO mg/L**	**pH**	**NTU**	**Chloro-a**	**Phyco**

Location of bloom/% coverage (center, perimeter, upper end, lower end, etc.):

Description of bloom (surface scum, grass clippings, green cheese curds, filaments, spilled paint, etc.)

Circle any colors you see:

Green Blue Red Rust Brown Milky White

Purple Black Other ___________

Aquatic vegetation observed? YES / NO

Stressed/dead aquatic organisms? YES / NO

Notes:

Appendix C

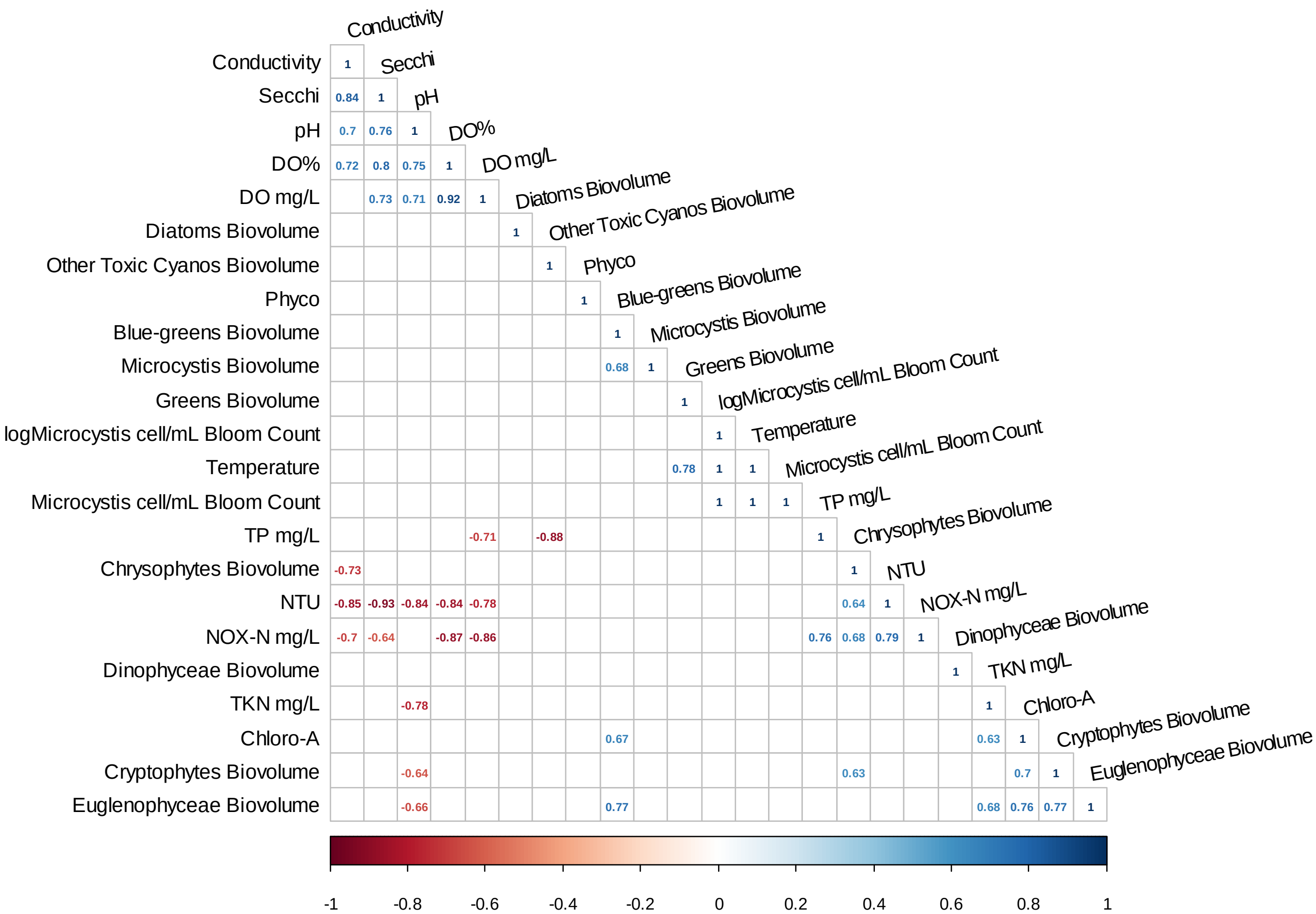

Figure of the Spearman Rank-Order Correlation for Algae Biovolume vs Water Quality Parameters for Park Road Park Pond for the 2020 sampling season, Mecklenburg County, NC. Credit: Dr. Robert Sowah.

Appendix D

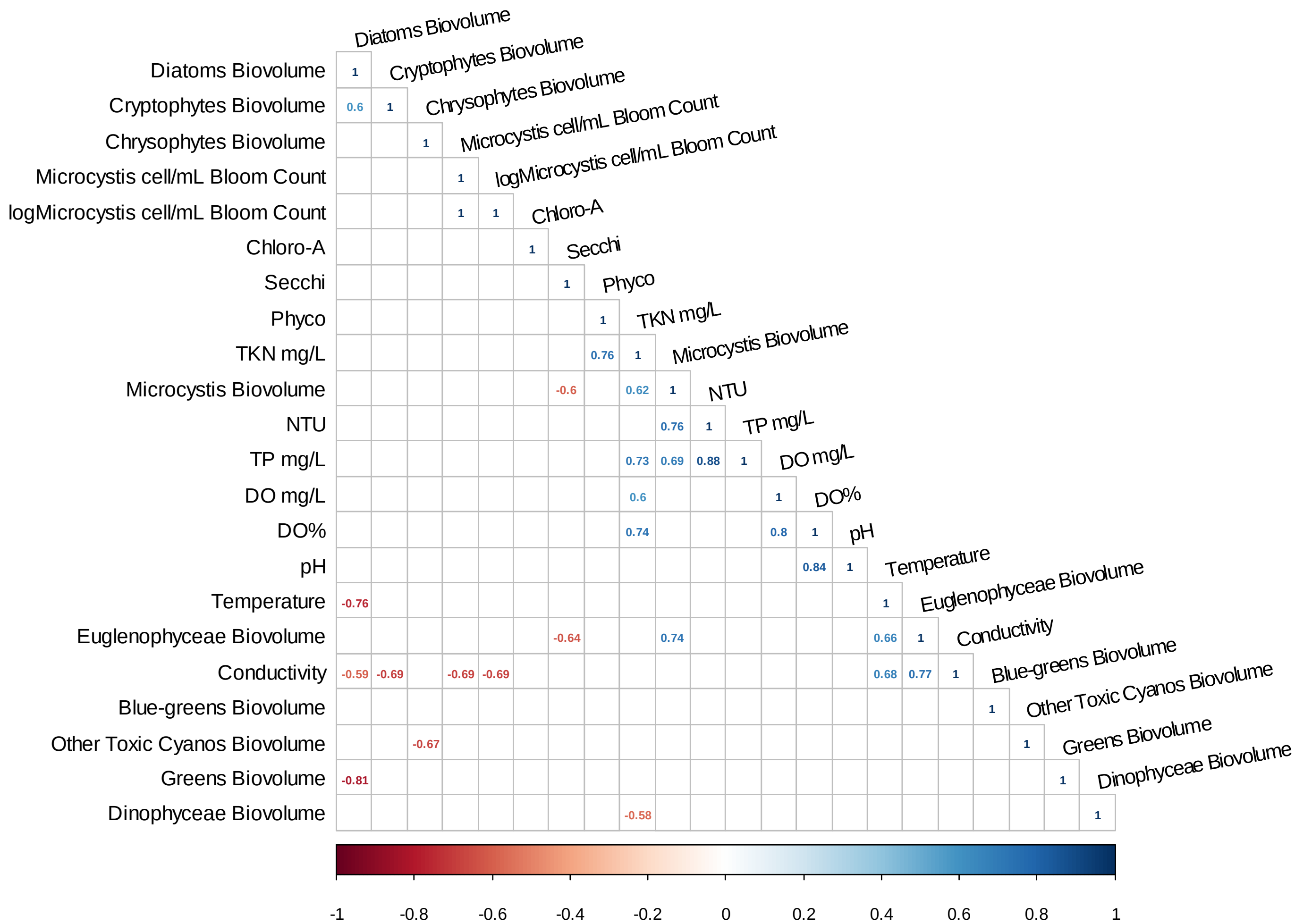

Figure of the Spearman Rank-Order Correlation for Algae Biovolume vs Water Quality Parameters for Freedom Park Pond for the 2020 sampling season, Mecklenburg County, NC. Credit: Dr. Robert Sowah.

Appendix E

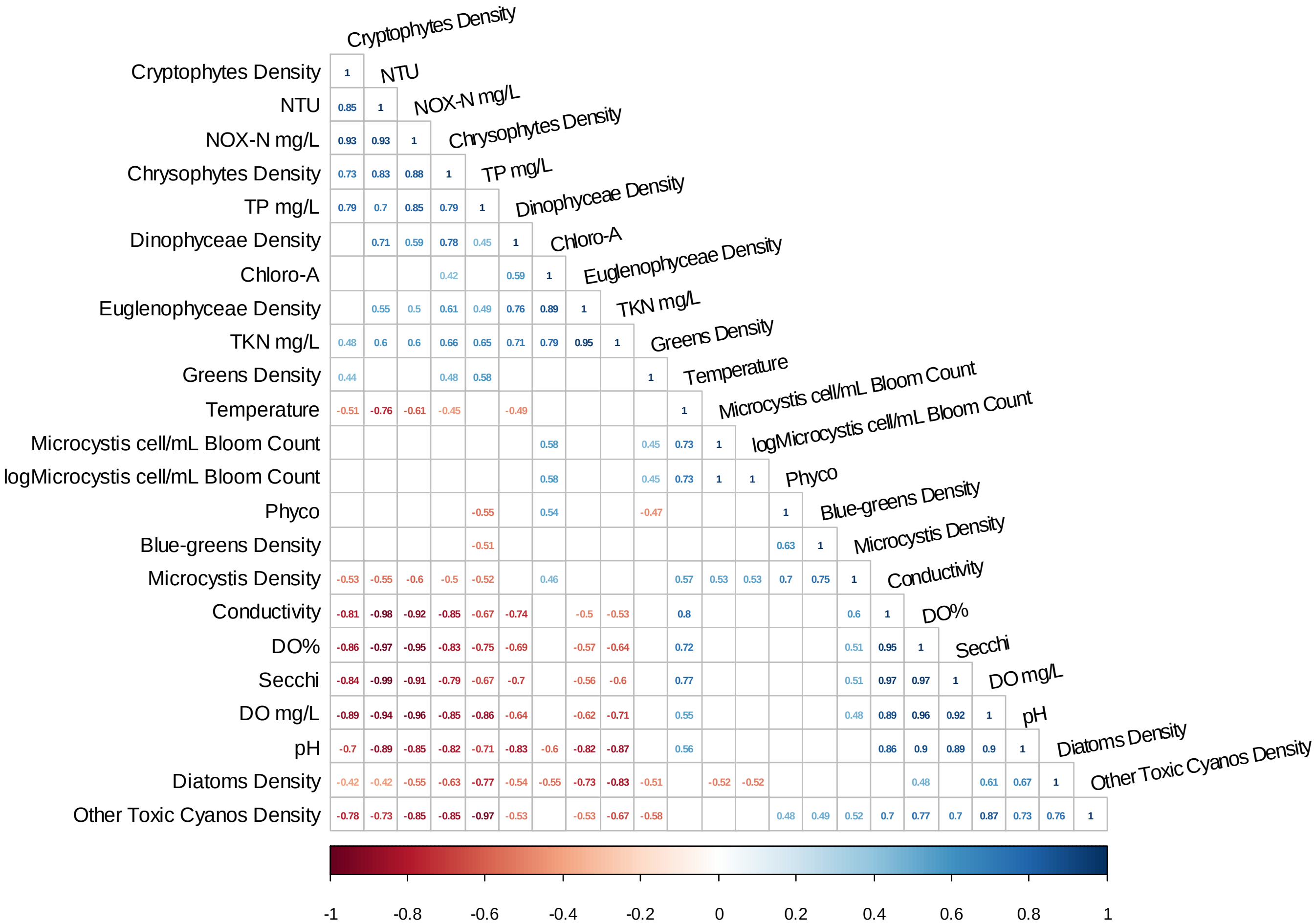

Figure of the Spearman Rank-Order Correlation for Algae Density vs Water Quality Parameters for Park Road Park Pond for the 2020 sampling season, Mecklenburg County, NC. Credit: Dr. Robert Sowah.

Appendix F

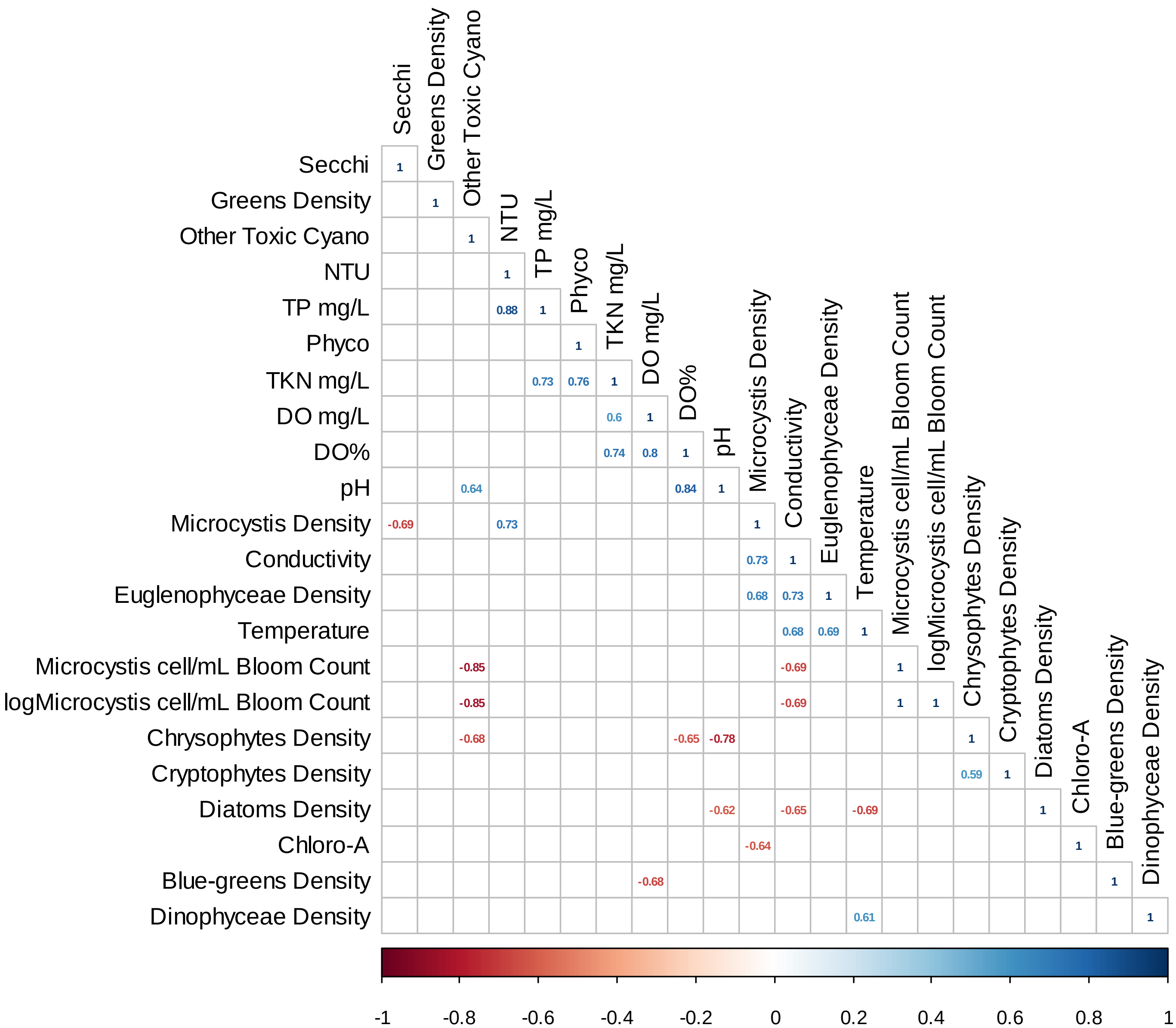

Figure of the Spearman Rank-Order Correlation for Algae Density vs Water Quality Parameters for Freedom Park Pond for the 2020 sampling season, Mecklenburg County, NC. Credit: Dr. Robert Sowah.