Cambridge Water Department 2019 Algae Monitoring Report

Hobbs Brook Reservoir Upper Basin on August 6, 2019

July 2020

Contents

1 EXECUTIVE SUMMARY

This report presents the 2019 results of the City of Cambridge Water Department (CWD)'s Algae Monitoring Program, part of an ongoing study to assess source water quality in Cambridge reservoirs. This report is intended to aid city managers and decision makers and to educate those who are interested in the Cambridge water supply.

The 2019 algae results generally followed expected seasonal patterns for overall abundance. At all three reservoirs, the overall cellular concentration of algae was highest in the middle of the summer and waned with cooling temperatures and after fall mixing. Smaller secondary peaks in algae cellular concentrations at all three reservoirs corresponded with additional nutrients being released during spring and fall turnover. Although the October Golden algae concentration was the highest of any phylum at Stony Brook Reservoir in 2019, the October total concentration of all algae phyla was still lower than during the summer peak in August.

Fresh Pond Reservoir most closely followed the expected prevalence of Diatoms in the spring and fall, and Green algae in the summer. Interestingly, the Hobbs Brook Reservoir was mainly dominated by Diatoms for the whole year. The Stony Brook Reservoir was mainly dominated by a Golden algae called *Dinobryon*, but did have a peak of Green algae in August. *Dinobryon* can become abundant in colder waters and can change the color and odor of water (Mattson and others, 2004).

More years of study are required to determine if the 2019 algae growing season is representative of an average year at the three Cambridge Reservoirs.

2 INTRODUCTION

Algae are a group of photosynthetic plants that are either free-floating (phytoplankton) or attached to a substrate (periphyton). They have no roots, stems, or leaves, and most are microscopic. They are naturally found in most lakes. Some types are single-celled while others are more complex (Mattson and others, 2004). Algae is an important food source for many aquatic animals, but an excess of algae can cause water quality issues.

Algae is important to monitor in surface water drinking supply reservoirs mainly because of aesthetic reasons. An excess of algal growth in our drinking water supply could contribute to the water having an unpleasant odor or taste. One type of algae, Blue-Green algae, known as Cyanobacteria, can also be toxic and harmful to human and animal health (Rosen and St. Amand, 2015). Currently, algal blooms are uncommon in the Cambridge reservoirs. However, given climate change, it is possible that warmer and longer summers will contribute to more algae growth in the future which could expedite the eutrophication of our surface water reservoirs.

In 2019, CWD conducted algae sampling from April - December in the City's three reservoirs: Hobbs Brook Reservoir, Stony Brook Reservoir, and Fresh Pond Reservoir (Figures 1 and 2). Algae samples were collected by taking grab samples from the surface of the reservoirs. Additional grab samples were collected 1 meter from the bottom of the HB @ DH, SB @ DH, and FP @ DH sites during periods of thermal stratification using a pump. CWD also measured Chlorophyll-*a* every 1-2 meters in the water column profile with a water quality probe at all sites except for HB @ Middle and HB @ Upper. If the water quality probe showed a spike in Chlorophyll-*a* in the profile, then CWD collected an additional alga grab sample at the depth indicated by the probe. The algae collected using this method is of the free-floating (phytoplankton) variety. The sample bottles were dark brown glass to avoid light penetration. The samples were sent to a contract laboratory for identification by genera, which is a distinction more specific than phylum, but less specific than species. In addition to collecting algae grab samples, CWD also collected Secchi disk data and measured additional water samples for total phosphorous (TP).

Secchi disks are used to measure visibility in a water column. Low visibility points to an excess of algal growth. All three of the Cambridge reservoirs are phosphorus limited, meaning that increases in algae growth and productivity are more governed by phosphorus inputs than by nitrogen inputs (CWD, 2019; Waldron and Bent, 2001). Higher amounts of phosphorous are expected to correlate with higher amounts of primary productivity, thus greater amounts of algae and less visibility.

Sources of phosphorous in watersheds include soils, weathered minerals, and decomposing organic matter that are introduced into waterways. The accumulation of nutrients is part of the process of eutrophication, which is the natural long-term aging process of lakes. As a lake ages, it evolves from a lower to higher capacity to support biological productivity. An oligotrophic (very clear) lake will eventually become eutrophic and fill in to become a marsh, bog, or swamp. In the natural world, this process happens over the course of hundreds or thousands of years (Olem and Flock, 1990). However, human activity can greatly expedite this process by introducing an excess of nutrients to waterways. Disturbances in the watershed like construction that removes vegetation can greatly increase the amount of silt and nutrients introduced into the water (Olem and Flock, 1990). Phosphorous from lawn fertilizers may enter the reservoirs from runoff and leaking sewage systems can also contribute phosphorus (Olem and Flock, 1990; Mattson and others, 2004). An overabundance of nutrients can lead to harmful algae blooms, overgrowth of plant life, reduced visibility, and an overall hostile environment to aquatic animal life due to lack of oxygen (Massachusetts Department of Environmental Protection, 2013).

It is important for CWD to monitor algae concentrations, TP concentrations, and Secchi disk depths to keep an eye out for signs that there may be inputs to the reservoirs that are speeding up the process of eutrophication. When excess nutrients result in loss of visibility as measured by Secchi depth (SD) and excessive plant or algae growth, waters can be considered impaired for aesthetics and recreational uses.

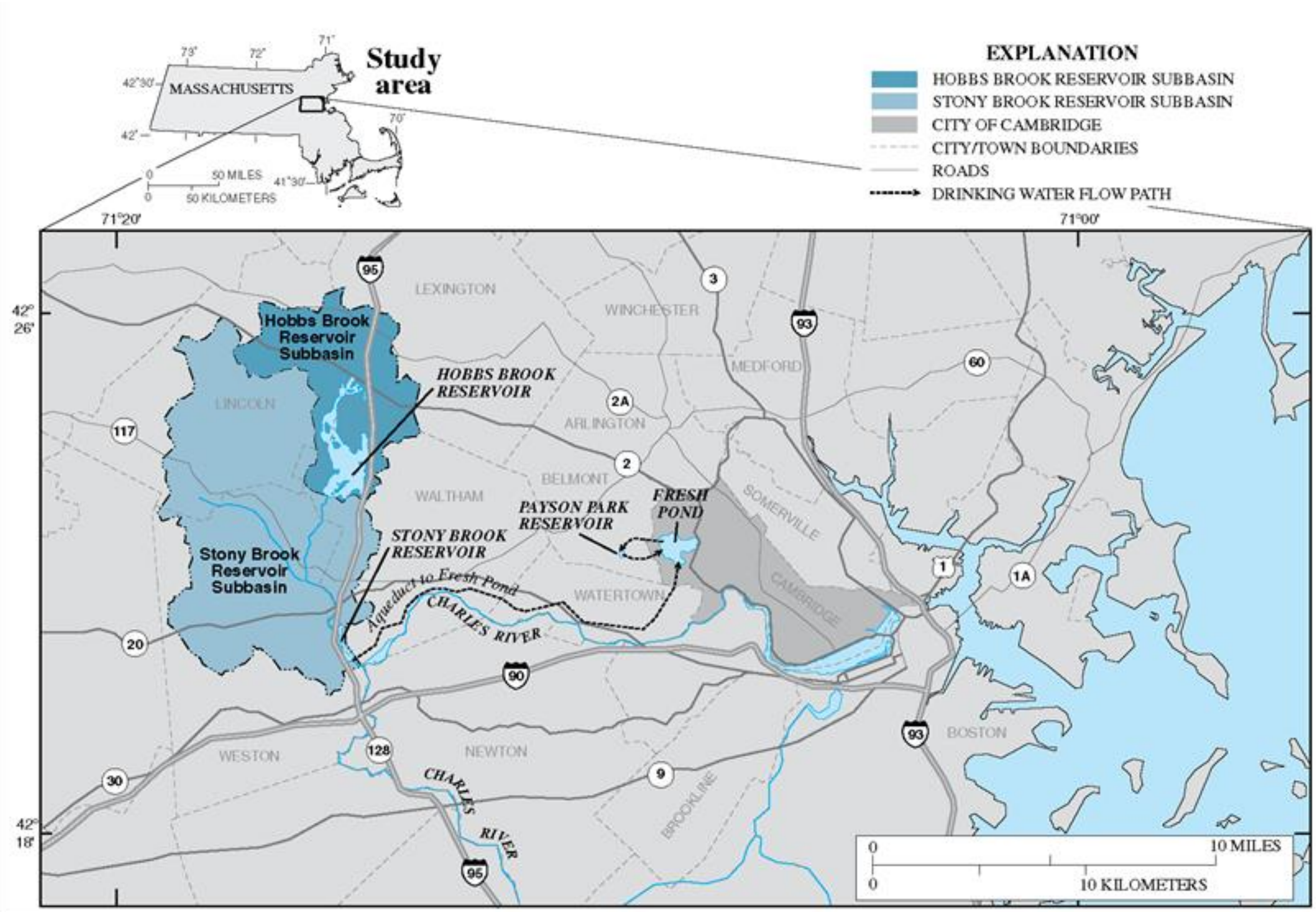


Figure 1: Cambridge Water Supply Source Area (Figure source: Waldron and Bent, 2001)

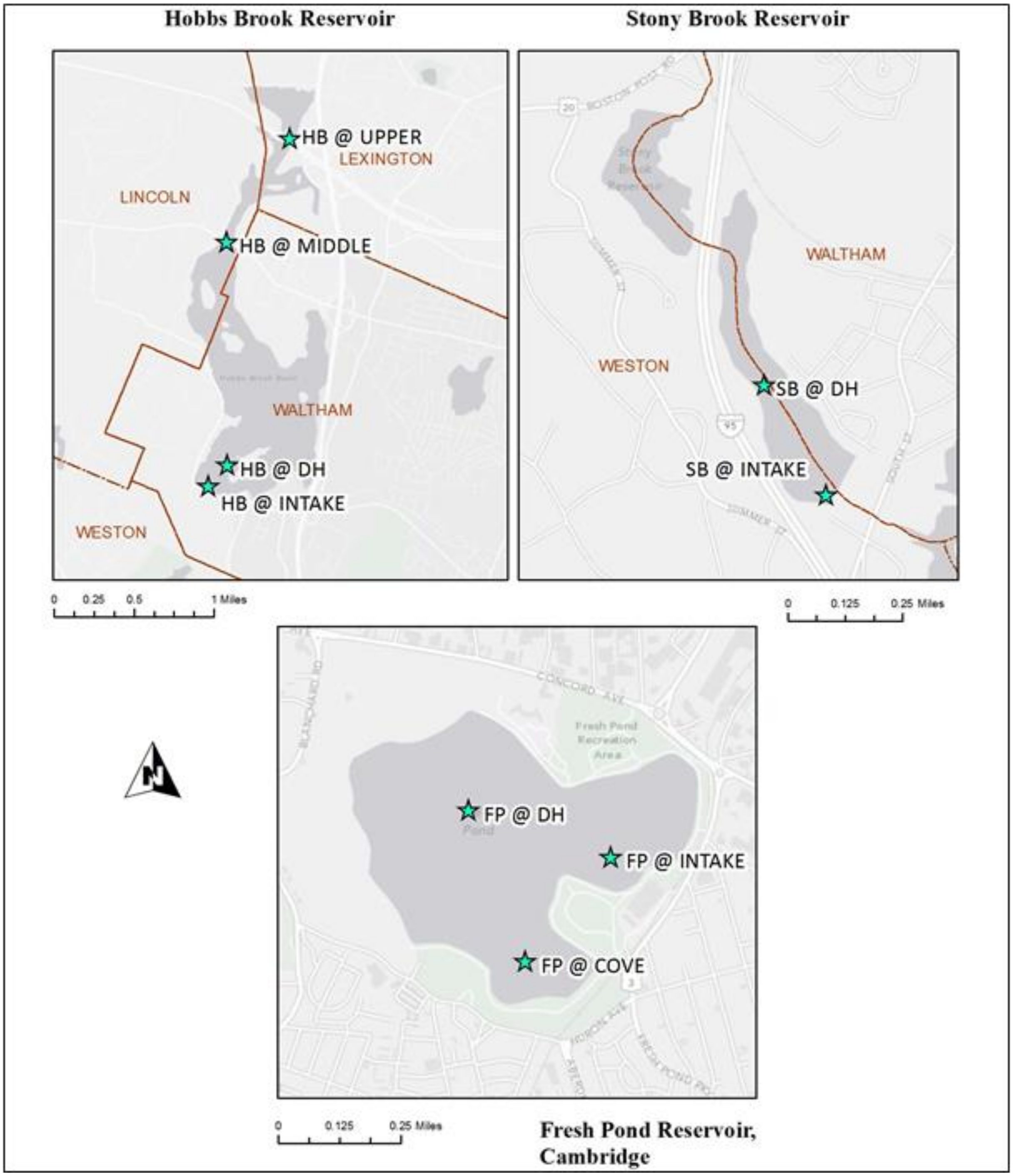


Figure 2: Reservoir Sampling Locations

Reservoir Sampling Locations. Algae samples from HB @ Intake, SB @ Intake, and FP @ Cove are only collected if the Chlorophyll-*a* water quality probe indicates an unusual spike; algae samples were not collected from those sites in 2019.

3 SEASONAL ALGAE CYCLING

The seasonal cycle of algal growth is driven by the phenomenon of lake turnover. Lakes in temperate regions like Massachusetts become stratified in the summer and winter (Robinson, 2004).

During the summer, heat from the sun warms the top layer of water. Since warm water is less dense than cool water, this top layer (called the epilimnion) sits on top of a bottom layer of cool water (called the hypolimnion). The depth where the two layers separate is called the thermocline. Fall turnover occurs when the surface layer of water begins to cool and sink. This promotes circulation throughout the water column and the temperature becomes more uniform throughout. During the winter, the top layer of water freezes and floats because ice has a very low density. This results in inverse stratification, with the coldest water being right under the ice, followed by a slightly warmer layer. As this ice melts in the spring, the stratification is broken allowing the layers of water to mix together again (Mattson and others, 2004).

Aquatic animals and plants have adapted to this seasonal turnover, and algae is no exception. As explained by Olem and Flock (1990), phytoplankton biomass is often highest in the spring and early summer as water temperatures increase and light availability becomes more abundant. Grazing pressure from aquatic animals and declining nutrient availability causes the algal biomass to decrease by midsummer. It rises again when temperatures cool and the water column mixes, releasing a fresh supply of nutrients from the lake bottom. Algal production is typically low in the winter due to cool temperatures and low light availability.

Different types of algae flourish in different parts of the lake turnover cycle. Typically, these phytoplankton follow a community succession of relative abundance. There are several major taxonomic groups, or phyla, of algae commonly found in Northeastern lakes. The three most common are Diatoms (Bacillariophyta), Green algae (Chlorophyta and Charophyta), and Cyanobacteria (Cyanophyta) (Mattson and others, 2004). Cyanobacteria, also known as Blue-Green algae, are not true algae but are actually photosynthetic bacteria (Mattson and others, 2004). Diatoms typically dominate during the early spring, then Green algae and Cyanobacteria thrive when the water becomes warmer and stratified (Olem and Flock, 1990; Mattson and others, 2004). Another spike of Diatoms often occurs in the fall when the water is mixed again (Olem and Flock, 1990; Mattson and others, 2004). Other phyla of algae that may be found throughout the year with the potential to cause blooms include Golden algae (Chrysophyta), Dinoflagellates (Pyrrophyta), and Euglenoids (Euglenozoa).

4 TYPES OF ALGAE IN CAMBRIDGE RESERVOIRS

The four most common phyla of algae found in the Cambridge reservoirs in 2019 were Diatoms, Green algae, Cyanobacteria, and Golden algae. Dinoflagellates and Euglenoids were also found, but not as commonly.

Diatoms (Bacillariophyta) are found in waterways worldwide. According to Baker and others (2012), diatoms make up a huge portion of the earth's primary producers, responsible for 50% of all photosynthesis that occurs on earth. Diatoms live in distinctive "glass houses", made from the silica that they build around themselves. They typically lack flagella, which look like appendages, and are mostly yellowish-green in color. Diatoms tend to prefer times of high mixing, when water temperatures are cooler and silica is more readily available (Mattson and others, 2004). While often abundant, especially in cold waters and oligotrophic lakes, Diatom blooms are not usually recreationally or ecologically problematic (Mattson and others, 2004). However, Diatoms can be a nuisance for drinking water suppliers by clogging filters or causing odors (Mattson and others, 2004).

Green algae (Chlorophyta and Charophyta), as the name suggests, are small organisms that are green in color due to the chlorophylls contained in their cellulose cell walls. Green algae are another very large group, with lots of variation in cell structure across different genera (types). Certain types of Green algae that have more evolutionarily advanced characteristics are elevated to the class Charophyta but are still classified as being in the same phylum. Most types of Green algae are found in fresh water and are considered to be evolutionary ancestors of land plants (Baker and others, 2012). Green algae blooms are most likely to occur in waters with high nitrogen contents (Mattson and others, 2004). Green algae are less of a public health concern than Cyanobacteria, although thick mats of Green algae can cause aesthetic, ecological, and recreational problems. Many Green algae cells derive nutrients from the lake sediments, later floating to the surface using photosynthetically produced gases (Mattson and others, 2004).

Cyanobacteria are not true algae but are actually photosynthetic bacteria. Cyanobacteria can produce a range of toxins that are harmful to human health, and therefore this type of algae makes the news a lot. Cyanobacteria are thought to be among oldest life forms on earth, first appearing in fossils that date back to 3.5 billion years ago (Baker and others, 2012). They typically appear blue or green in color, though some Cyanobacteria can look red. They do not have any flagella, but some still have a small amount of mobility (Baker and others, 2012). Some Cyanobacteria can fix atmospheric nitrogen, gaining a competitive advantage during periods of low nitrogen availability, such as the summer (Matson and others, 2004). Certain Cyanobacteria species also use gas vacuoles to travel vertically in the water column, an advantage in avoiding predation. Many species also have morphological traits to help resist predation (Matson and others 2004).

Golden algae (Chrysophyta), sometimes referred to as Golden-Brown algae, is a very large group that is an umbrella term for many different subgroups. Some types of algae in this phylum form colonies and have distinctive flagella that are used to “swim” around (Baker and others, 2012). Certain genera of Golden algae, such as *Dinobryon*, can cause color or odor issues in drinking water (Matson and others, 2004).

Dinoflagellates (Pyrrophyta), have flagella as their distinctive feature. They are classified as “heterokonts”, meaning that they have two appendages that they use to move around (Baker and others, 2012). In marine environments, large blooms of Dinoflagellates colloquially referred to as “red tides” can produce toxins and are responsible for fish kills, although freshwater varieties are not known to produce toxins (Baker and others, 2012). Dinoflagellates are less common in freshwater than in marine environments (Mattson and others, 2004).

Euglenoids (Euglenozoa) generally appear green in color and often have flagella (Matson and others, 2004). They thrive in eutrophic water bodies so high levels of euglenoids can indicate poor water quality (Matson and others, 2004).

5 ANALYSIS OF FINDINGS BY RESERVOIR

The Cambridge reservoirs were tested for algae from April through December of 2019. Ice formation on the reservoirs and weather limitations prohibited sampling from January through March. All three reservoirs are phosphorus limited, meaning that increases in algae growth and productivity are more governed by phosphorus inputs than by nitrogen inputs (CWD, 2019; Waldron and Bent, 2001).

In 2019, CWD conducted algae sampling at sites in the City's three reservoirs: Hobbs Brook Reservoir, Stony Brook Reservoir, and Fresh Pond Reservoir (Figures 1 and 2). The reservoirs are in sequence and all have different capacities and residence times. Residence times determine how long algae have to take advantage of available nutrients before the water is flushed out (Mattson and others, 2004). In total, 57 algae samples and three field duplicate (FDUP) samples were collected the Cambridge reservoirs in 2019. Forty-three unique algal genera were identified (Table 1). When both a sample and a field duplicate were collected, results were averaged and reported as a single sample. See Appendix A for a comparison of duplicate samples.

Table 1: Unique Genera of Algae found in Cambridge Reservoirs, 2019

Phylum	Unique Genera
Diatoms	11
Green algae	16
Cyanobacteria	10
Golden algae	3
Dinoflagellates	2
Euglenoids	1
Total Genera	43

In the following sections, algae sample results from each of the three reservoirs are analyzed separately. TP, which is the sum of all types of phosphorus found in a water sample, is also reported. Monitoring the rising and falling of TP in a water body can give clues as to how much of the nutrient is available, and therefore how much algae might be able to grow. Likewise, SD readings are reported to show the effect of algae growth on reservoir transparency.

5.1 Hobbs Brook Reservoir

The first reservoir in the sequence is the Hobbs Brook Reservoir (Figure 1). It is the largest of the three reservoirs, with a capacity to hold 2.5 billion gallons of water. It also has the longest residence time at 15 months (CWD, 2019). Algae grab samples were collected from three sites in the reservoir: HB @ Upper, HB @ Middle, and HB @ DH (Figure 2). HB @ DH stands for Hobbs Brook at Deep Hole and is the deepest point in the reservoir. When the water warms and begins stratifying, algae samples were also collected 1 meter from the bottom (HB @ DH_m) using a pump. A total of 22 samples were taken in the Hobbs Brook Reservoir from April through December, excluding the month of November. Bottom samples were not taken in April or in October because the water column was not stratified. A total of 34 unique genera of algae were found across all of the Hobbs Brook Reservoir sites in 2019 (Table 2).

Table 2: Genera of Algae found in Hobbs Brook Reservoir, 2019

Phylum	Genera
Diatoms	10
Green algae	12
Cyanobacteria	7
Golden algae	2
Dinoflagellates	2
Euglenoids	1
Total Genera	34

Figure 3 compares algae concentrations (cells/ml) by phylum for the Hobbs Brook Reservoir deep hole sampling location surface (HB @ DH) and bottom (HB @ DH_m) depths in 2019. Typical algal succession in northeastern lakes begins with Diatoms dominating in the early spring, followed by Green algae and Cyanobacteria when the water warms and becomes stratified, followed by another peak of Diatom abundance following fall turnover (Olem and Flock, 1990). Interestingly, at HB @ DH, Golden algae seemed to be dominant in the early spring, and then this gave way to a huge surge of Diatoms in August, the warmest part of the year. Cyanobacteria and Green algae bottom concentrations increased slightly production in August and September, respectively. However, Cyanobacteria and Green algae concentrations remained relatively low throughout the year. The Cyanobacteria concentration in bottom samples was highest in August at 390 cells/ml, while surface concentrations remained at or near zero year-round.

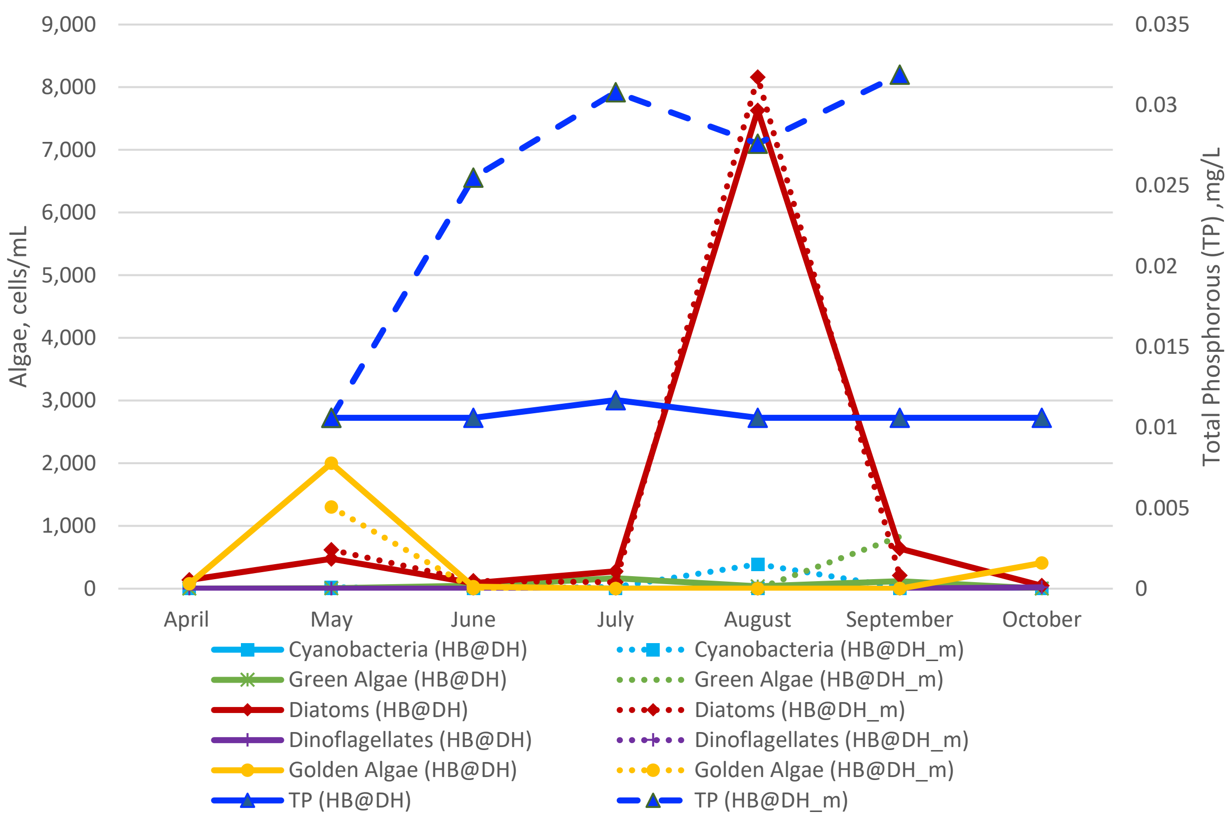


Figure 3: Total Cellular Concentration of Algae Phyla at HB @ DH (Surface) and HB @ DH_m (1m from Bottom), 2019

The surface and bottom algae samples seemed to mirror each other fairly closely at HB @ DH. TP levels were a lot higher in bottom samples than in surface samples. The lab detection limit for TP is 0.0106 mg/L. This was only exceeded in surface samples in July of 2019, so for the rest of the year the TP available for algae production was either at or below 0.0106 mg/L. Higher TP concentrations at the bottom of the reservoir did not encourage more algae growth, probably because of limited sunlight.

At the HB @ Upper sampling site, upstream of HB @ DH and HB @ Middle, the same basic pattern of overall seasonal productivity was shown (Figure 4). The largest cellular concentrations of algae were found in the warmer months. However, different algae genera were more abundant at different times. For example, Golden algae was most abundant at HB @ Upper in July but peaked at HB @ DH in May. Both sites showed a spike of Diatoms in August. Green algae were largely absent from samples taken at HB @ DH but spiked at HB @ Upper in August along with the Diatoms; however, the Green algae spike was lower than the diatom spike. Green algae were also relatively abundant in September, although the concentration dropped by almost 1,000 cells/ml compared to August. December algae results at HB @ Upper seem to show a recovery from September numbers for Diatoms, perhaps due to a competitive advantage in cooler waters. The Green algae concentration fell to near zero in December, following the expected seasonal pattern. This site is not sampled monthly, so there are gaps in the monthly timeline. No algae samples were collected in June, October, and November.

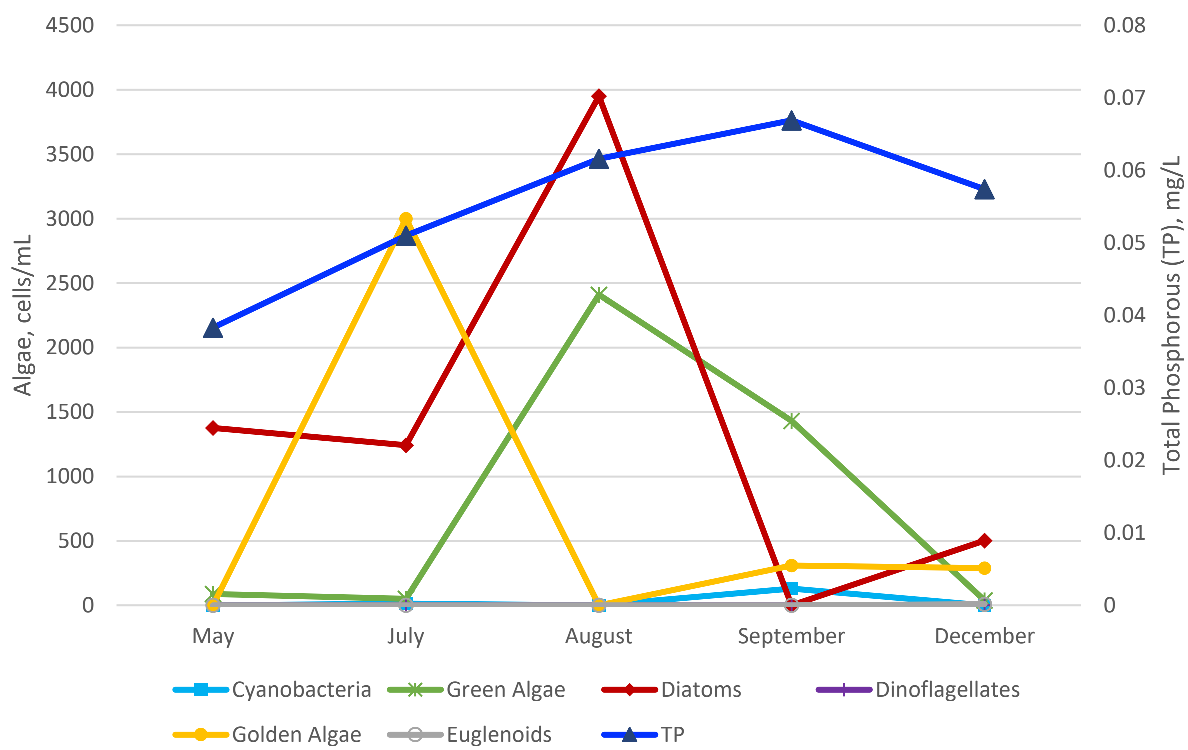


Figure 4: Total Cellular Concentration of Algae Phyla at HB @ Upper

HB @ Middle is also not sampled monthly, so the months of June, October, and November are missing from the timeline as well. TP at this site peaked in August, which was also the peak for 4 out of the 5 algae phyla found here (Figure 5). Diatoms were dominant (3,490 cells/ml), but the algal concentration of Green algae was not far behind (3,400 cells/ml) in August. Concentrations of Diatoms and Green Algae were similar from August onward. Cyanobacteria was the least abundant phylum here overall, although was the most abundant phyla in September (130 cells/ml). There was also an increase in algae abundance from September to December, perhaps due to fall turnover as well.

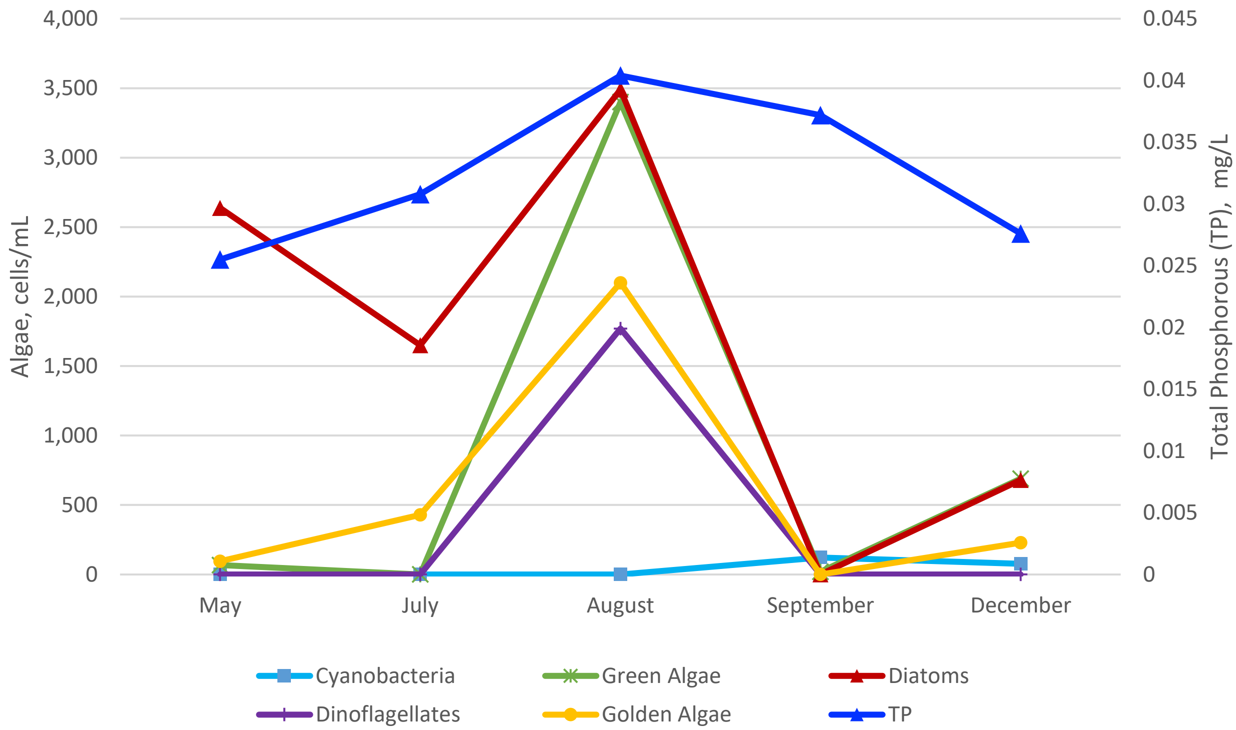


Figure 5: Total Cellular Concentration of Algae Phyla at HB @ Middle

Overall, algae populations at the Hobbs Brook Reservoir sites followed the expected pattern of being most populous in the warm summer months, albeit during the middle of summer, and following spring and fall turnover. However, the expected spring dominance of Diatoms and summer dominance of Green algae and Cyanobacteria did not happen. Diatoms seem to dominate here throughout the season, and Green algae were in competition with Golden algae for second place. More years of study are needed to determine if this is a normal seasonal algal cycle for the Hobbs Brook Reservoir. Figure 6 shows the relationship between the overall cellular surface concentration of algae and SD at HB @ DH. Visibility was lowest in May, when the overall cellular concentration at HB @ DH was the second highest for 2019. However, visibility was highest in August, which was the month with the highest cellular concentration at this site. It seems that SD is not a good indicator of overall algae concentration at this site.

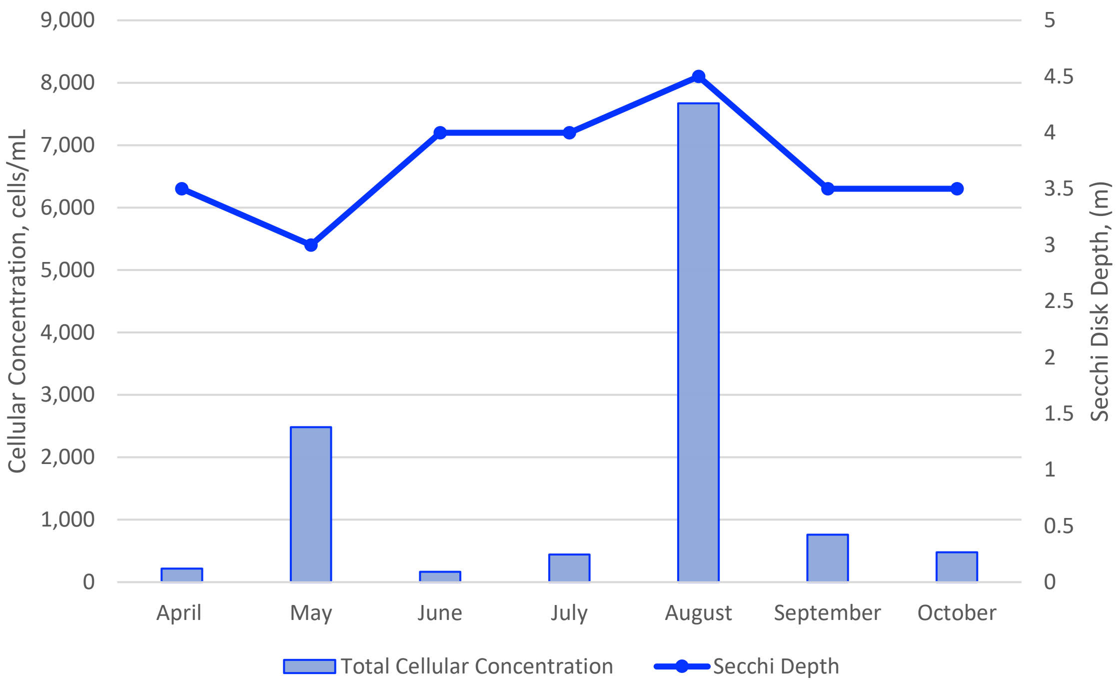


Figure 6: Total Cellular Concentration of Algae Surface Samples at HB @ DH and Secchi Disk Depth (SD), 2019

5.2 Stony Brook Reservoir

Water released from Hobbs Brook Reservoir flows downstream into the Stony Brook Reservoir (Figure 1). Stony Brook Reservoir is the smallest reservoir, holding up to 425 million gallons of water. It has the shortest residence time, averaging at 15 days (CWD, 2019). Algae grab samples were collected at the deepest point of the reservoir, SB @ DH, and also 1 meter from the bottom (SB @ DH_m) when the reservoir was stratified (Figure 2). A total of 14 samples were collected from April through October of 2019. Bottom samples were not collected in April or October because the water column was not stratified. In October, two additional samples were taken from the reservoir due to unusual circumstances. The first was taken at SB @ DH, 1 meter below the surface due to an apparent spike in Chlorophyll-*a* shown by the water quality probe. The second was taken from the right bank of the reservoir (SB @ RB) because of a visible green algal mat (Figure 8). Twenty-eight total unique algal genera were identified in water samples taken from the Stony Brook Reservoir in 2019 (Table 3).

Table 3: Genera of Algae found in Stony Brook Reservoir, 2019

Phylum	Genera
Diatoms	9
Green algae	10
Cyanobacteria	5
Golden algae	3
Dinoflagellates	1
Euglenoids	0
Total Genera	28

Figure 7 compares algae results from the surface (SB @ DH) and bottom (SB @ DH_m) of Stony Brook Reservoir in 2019. There was a bigger difference between surface and bottom samples here than in the Hobbs Brook Reservoir. Algae here also did not follow the expected dominance of Diatoms in the spring and fall and Green and Cyanobacteria in the summer. Instead, Golden algae was the most populous phylum of algae. In the surface samples, Golden algae dominated following spring turnover in May, showed a spike in production in August, and then another even larger spike following fall turnover. However, Golden algae were almost non-existent in the Stony Brook bottom samples, occurring in low numbers only in the May and June samples (148 cells/ml and 15 cells/ml, respectively).

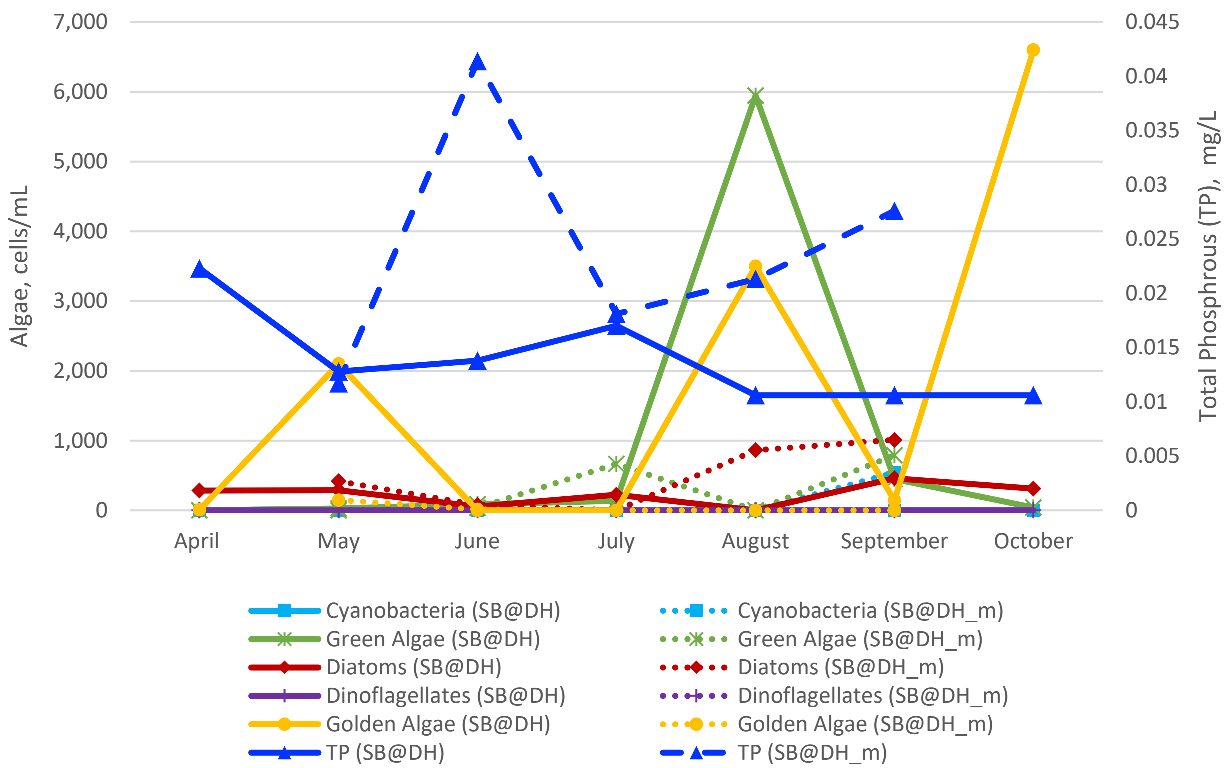


Figure 7: Cellular Concentrations of Algae Phyla at SB @ DH (Surface) and SB @ DH_m (1m from bottom)

Green algae had the highest relative abundance in August at the surface, perhaps taking advantage of the July TP increase, but Diatoms were the most populous phylum on the reservoir bottom.

Diatoms overall were not a dominant phylum in Stony Brook in 2019 (Figure 7). Cyanobacteria and Dinoflagellates were not a big component of the total algal concentration in this reservoir either. The highest cell count for Cyanobacteria occurred in the September bottom sample (540 cells/ml). All other surface and bottom Cyanobacteria concentrations were zero except for a cell count of only 25 cells/ml in the May surface sample. Like in Hobbs Brook, the TP available at the bottom was higher than at the top of the water column, but there were overall fewer algae cells/mL found at the bottom.

One bloom was observed at the Stony Brook Reservoir just after fall turnover in October of 2019. Figure 6 shows a huge spike in Golden algae, consisting entirely of *Dinobryon*, in October after a sharp decline occurred in September. This is likely in response to fall turnover releasing nutrients, but the TP is at or below the detection limit of 0.0106 mg/L from August to October at the surface of the reservoir. Two extra samples were taken during this sampling event in response to visual clues and Chlorophyll-*a* data. SB @ DH_1m is the sample taken from 1 meter from the surface, and SB @ RB was taken from the right bank of the reservoir where a green algal mat was visible (Figure 8).

Figure 8: Green Algae Mat Observed at Stony Brook in October, 2019

Figure 9 explores the compositions of the three different algae samples taken from the Stony Brook Reservoir on the same day in October. The samples collected at the surface (SB @ DH) and from one meter down (SB @ DH_1M) were similar in composition in regard to Diatoms and Golden algae, but the surface sample also included Green algae. The sample taken from the right bank of the reservoir (SB @ RB) was comprised of only Cyanobacteria and Diatoms. Cyanobacteria is of particular concern because it can produce harmful toxins. This was the highest concentration of Cyanobacteria sampled in 2019, but at 2,580 cells/mL, it is still nowhere near the 70,000 cells/mL threshold that the Massachusetts Department of Public Health (MA DPH) designates as dangerous to human health. The Cyanobacteria concentration consisted of *Anabaena* (1,700 cells/ml), *Cylindospermum* (820 cells/ml), and *Mirocystis* (60 cells/ml). The Diatoms in this sample had the highest cells/mL of any phylum in any sample CWD collected in 2019 at 35,300 cells/mL, comprised of *Diatoma*, *Navicula*, and *Synedra*. However, Diatoms are not considered dangerous to human health and have only aesthetic impacts on water quality.

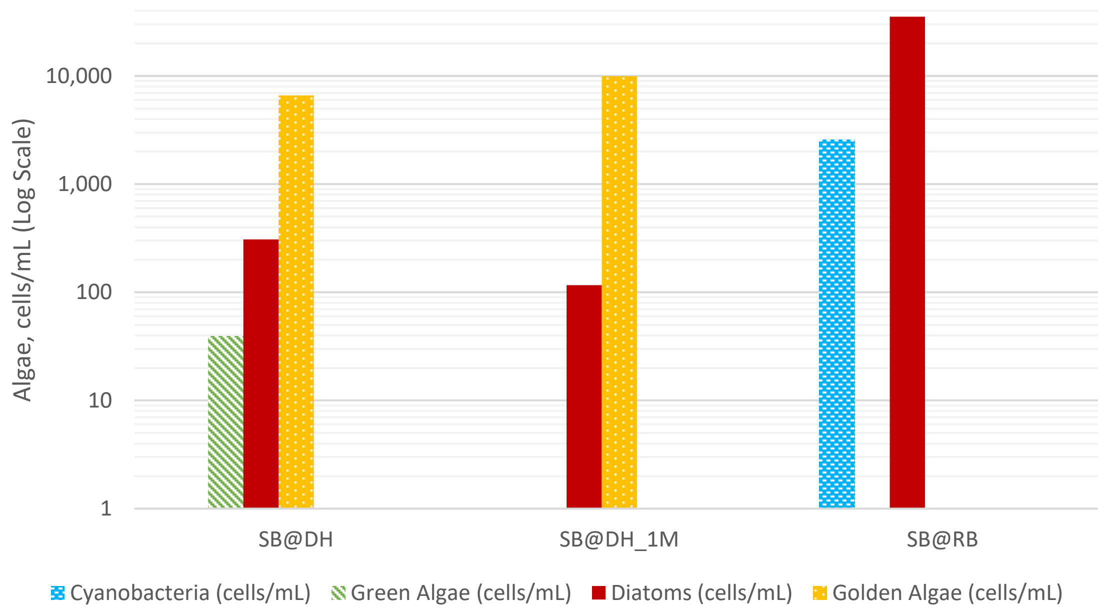


Figure 9: October 2019 Algae Cellular Concentration of Phyla in 3 different samples at Stony Brook Reservoir

Secchi disk visibility was highest in July, which corresponded with a low overall algae cellular concentration. Visibility dropped in August, which makes sense since that was the month with the highest cellular concentration of algae. It dropped again in October in response to another spike in algae abundance and makes sense with the excess algae observed during the sampling mission (Figure 10).

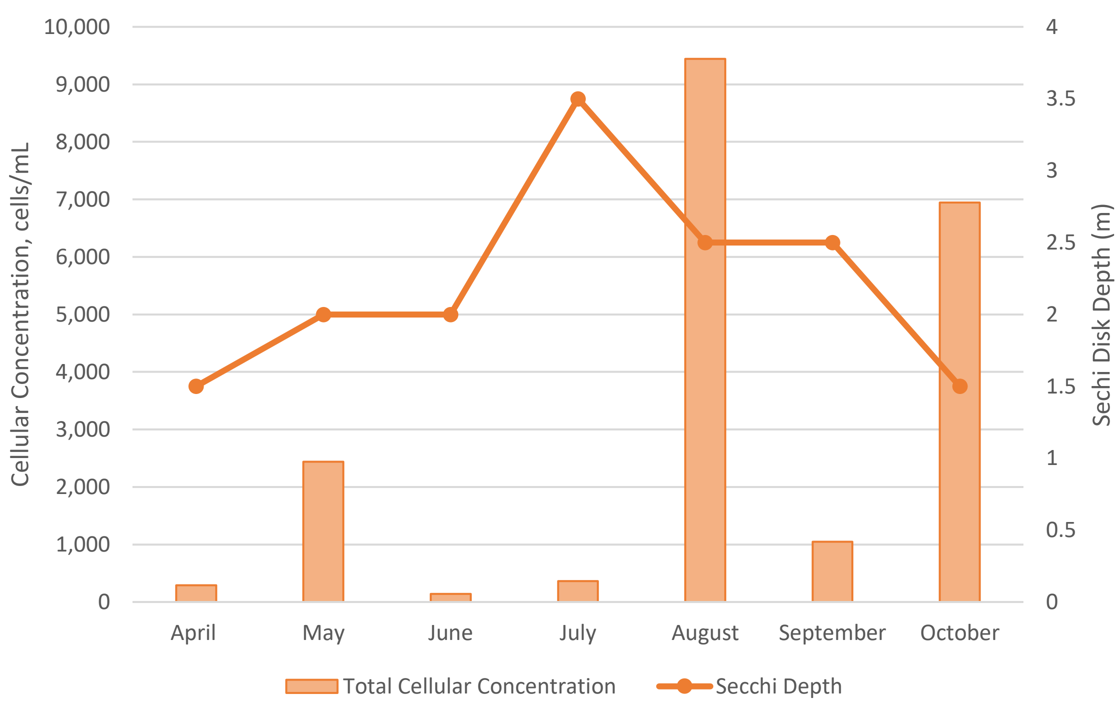


Figure 10: Total Cellular Concentration of Algae Surface Samples at SB @ DH and Secchi Disk Depth (SD), 2019

5.3 Fresh Pond

Water from the Stony Brook Reservoir flows through an underground aqueduct to its final stop at Fresh Pond (Figure 1). Fresh Pond has the capacity to hold 1.5 billion gallons of water and has a residence time of 3.8 months (CWD, 2019). Fresh Pond has an aeration system to keep dissolved oxygen high which prohibits some metals from turning to their aqueous forms. This in turn helps avoid internal phosphorus loading by preventing the release of phosphorous sorbed to iron compounds in the sediments to discourage or diminish algae growth. Twenty-one samples were taken from Fresh Pond sites in 2019 from April through November. Bottom samples were not collected in April or October because the water column was not stratified. In total, 26 distinct types of algae were identified in samples taken from Fresh Pond in 2019 (Table 4).

Table 4: Genera of Algae found in Fresh Pond Reservoir, 2019

Phylum	Genera
Diatoms	9
Green algae	11
Cyanobacteria	2
Golden algae	3
Dinoflagellates	1
Euglenoids	0
Total Genera	26

Of the three reservoirs, Fresh Pond most closely followed the expected seasonal succession of algae phyla. Typically, Diatoms dominate the spring and fall seasons when water is cooler and lake turnover delivers an influx of nutrients, and Cyanobacteria and Green algae dominate summer seasons (Olem and Flock, 1990). At Fresh Pond, this seemed to be generally true.

Figure 11 compares surface samples taken at FP @ DH and at FP @ Intake in 2019. Cellular concentrations of algae phyla at both surface sites mirrored each other closely. In April, May, and June, Diatoms were the taxonomic group with the highest concentration. In July, there was a sharp increase of all taxonomic groups, but especially of Green algae, which is expected in the early summer. The FP @ DH July surface sample also had the highest concentration of Cyanobacteria of the year, although still well below the MA DPH 70,000 cells/mL threshold. A small spike in TP measured in the October surface sample from FP @ DH corresponded with an increase in abundance of all taxonomic groups compared to September, but mainly for Green algae at the FP @ Intake site. A fall increase in diatom abundance was not observed at Fresh Pond Reservoir. This may be because the aeration system prevented significant stratification in the reservoir, thereby limiting the amount of nutrients available for release during fall mixing.

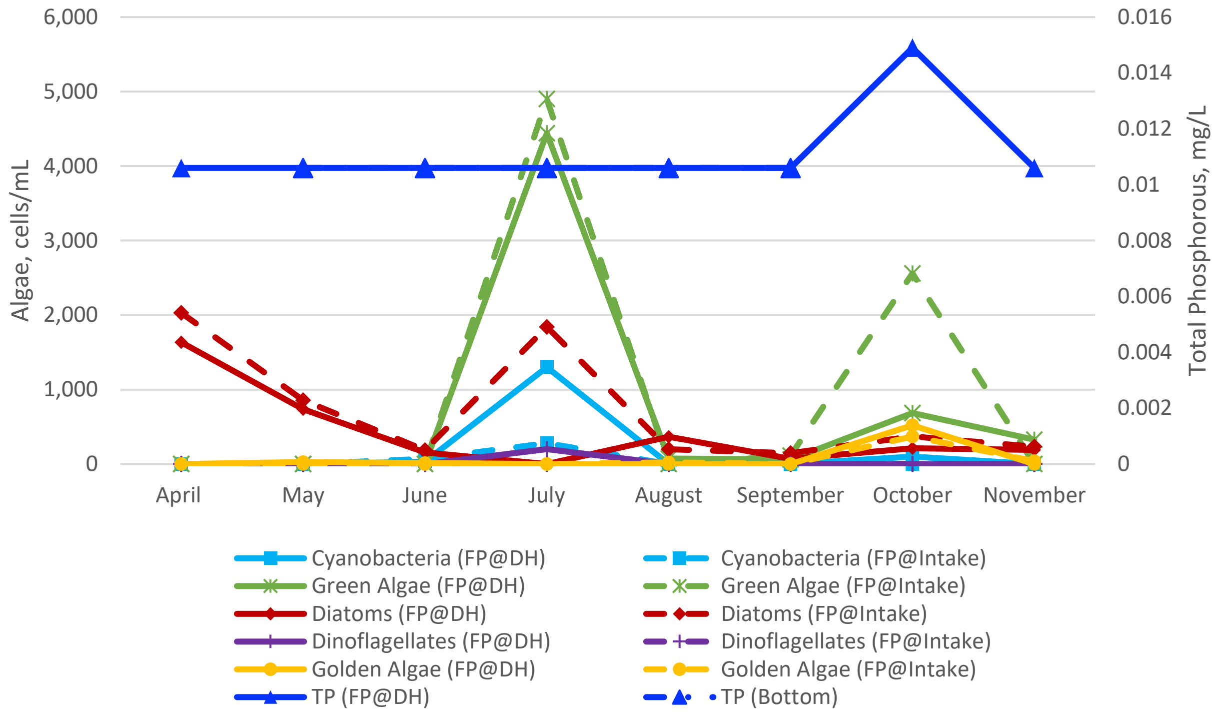


Figure 11: Cellular Concentration of Algae Phyla at Fresh Pond Surface Sites (FP @ DH and FP @ Intake) 2019

Figure 12 compares samples taken at the surface and 1 meter from the bottom of the FP @ DH site. Bottom algae and TP samples were only collected from May through September due to limited thermal stratification. Bottom and surface samples were similar throughout the year, except in July when Green algae and Cyanobacteria were more abundant at the surface than at the bottom of the water column and Dinoflagellates were 1,400 cells/ml higher in the bottom than at the surface. Summer months are typically productive for algae, especially Green algae and Cyanobacteria. All phyla of algae plummeted after the July peak. Since Fresh Pond feeds directly into the water treatment plant, it is outfitted with an aeration line that is used during the summer for a few reasons, including to dissuade algae blooms. It is possible that the water was being mixed enough at this point where algae could not grow effectively during August. It is also possible that grazing pressure from other aquatic organisms lowered the overall algae biomass (Mattson and others, 2004). All taxonomic groups seem to have had a comeback in October, which correlates with fall turnover and a small spike in TP at the surface likely brought up from the bottom of Fresh Pond, although TP concentrations at the bottom of the reservoir in September were below the detection limit. TP surface concentrations for the rest of the year were at or below the detection limit of 0.0106 mg/L. TP concentrations at the bottom were below the detection limit all year.

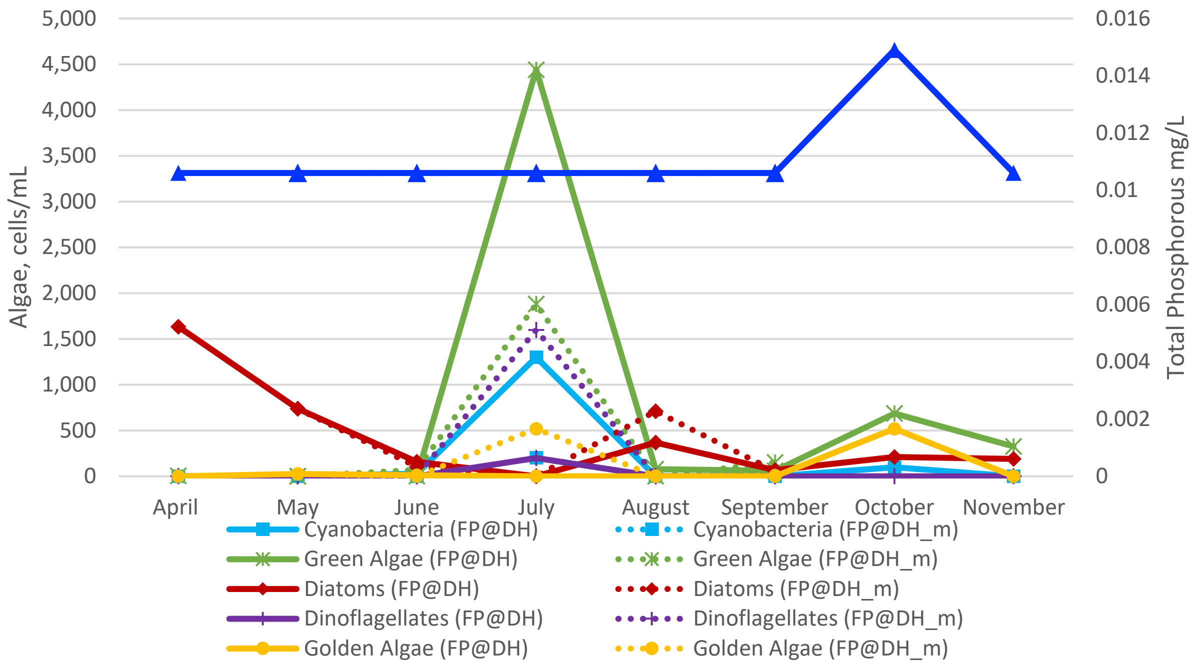


Figure 12: Cellular Concentration of Algae Phyla at Fresh Pond Surface and Bottom Sites (FP @ DH and FP @ DH_m) 2019

Figure 13 compares measured SD to overall total cellular concentration of algae phyla found at the two Fresh Pond surface sites. The SDs recorded were very close at both FP @ DH and FP @ Intake. Visibility was lowest in April, May, and July at both sites. However, visibility was lower in April than July despite the higher July cell counts. The October algae samples do not have a corresponding SD reading because the disk was unavailable on the day of the sampling mission. Visibility was highest in November, the end of the growing season.

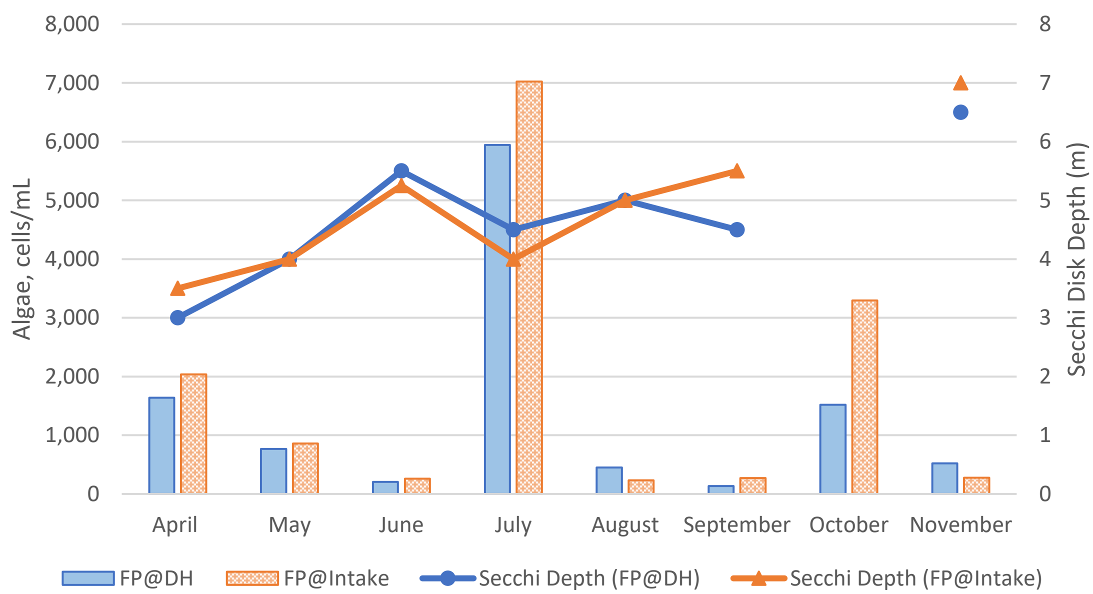


Figure 13: Overall Cellular Concentration of Algae at Fresh Pond Surface Sites (FP @ DH and FP @ Intake) and Secchi Disk Depth (SD), 2019

6 OVERALL TRENDS AND COMMON GENERA

Overall, all three reservoirs were most productive in the summer months. Hobbs and Stony Brook reservoir algal concentrations peaked in August and Fresh Pond peaked in July (Figures 3 – 13). With the exception of HB @ DH, all sites also showed evidence of a second surge in algal production after or around fall turnover, when the water column begins to mix and extra nutrients are released.

Only Fresh Pond followed the expected seasonal succession of algae groups. In surface samples collected from FP @ DH and FP @ Intake, Diatoms were generally dominant in the spring, followed by Green algae dominance in the summer, although the fall peak was dominated by Green algae rather than Diatoms (Figures 11 and 12). Samples from the surface of Hobbs Brook Reservoir (HB @ DH) revealed that Diatoms were overwhelmingly dominant throughout the growing season, followed by Golden algae (Figure 3). At the Stony Brook Reservoir (SB @ DH), excluding the two extra samples from October, Golden algae proved to be the dominant algae group overall, but Green algae was more populous in August (Figure 7).

From an annual perspective, the relative abundance of algae phyla differed between the three reservoirs (Figure 14). Diatoms contributed over 75 percent of the relative abundance at Hobbs Brook Reservoir, followed by Golden algae at just over 20 percent. At Stony Brook Reservoir, Golden algae accounted for the highest proportion of the algal population, followed by Green algae, whereas Green algae were dominant at Fresh Pond, followed by Diatoms. Fresh Pond was the only reservoir with a noticeable proportion of Cyanobacteria, although it was less than 20% of the relative abundance. At all three reservoirs, Cyanobacteria and Dinoflagellates made up a relatively small portion of the total algal community. Euglenoids did not appear in any surface samples collected from the deep hole sites at any of the three reservoirs.

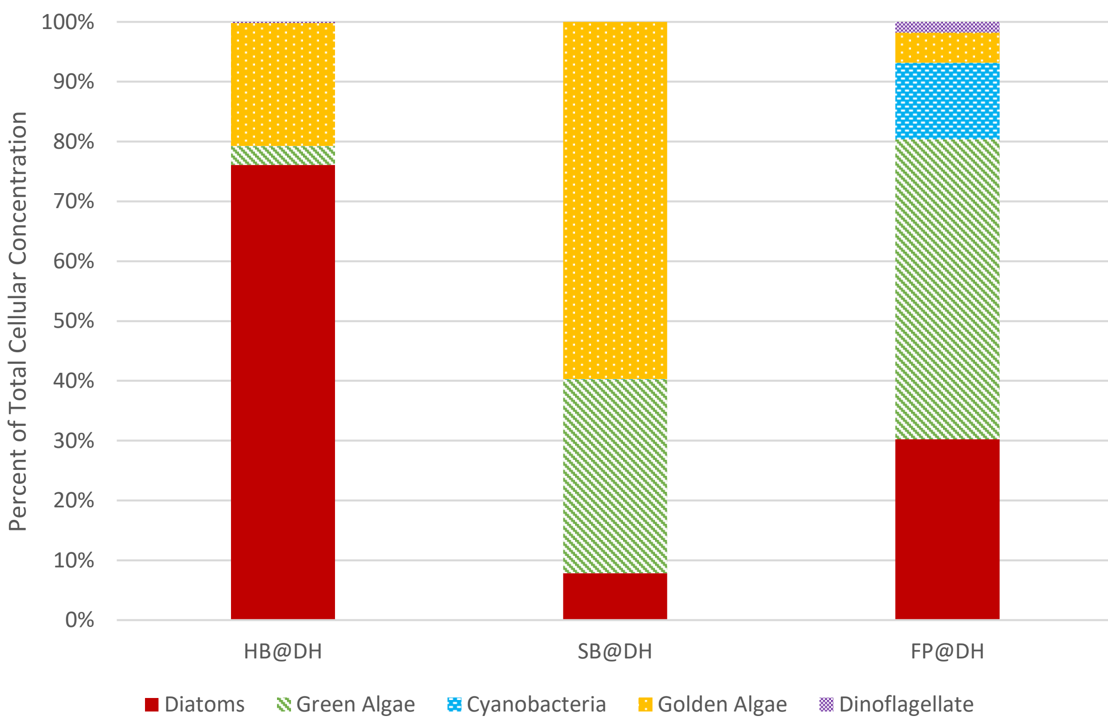


Figure 14: Distribution of Algae Phyla by Cellular Concentration from Surface Samples at the Deep Hole Sites at Hobbs Brook, Stony Brook, and Fresh Pond Reservoirs, 2019

Guidelines for algae in Massachusetts focus on Cyanobacteria because they are what can cause toxic algae blooms. According to the Massachusetts Department of Public Health (2019), Cyanobacteria are known to produce toxins such as microcystin which can be dangerous to human and animal health. These toxins can cause human illness but can be fatal to dogs. Massachusetts Department of Public Health (2019) guidance states that health advisories should be issued for water bodies used for recreational use if the concentration of cyanobacterial algae types exceeds 70,000 cells/mL.

The two highest concentrations of cyanobacteria found in Cambridge reservoirs in 2019 were at Fresh Pond in July and at Stony Brook in October after the fall turnover. The total concentrations of Cyanobacteria in those samples were 1,300 cells/mL and 2,580 cells/mL, respectively. These concentrations are not high enough to cause concern, especially since Cambridge reservoirs are not used for recreation.

Other types of algae cause only aesthetic issues impacting the color and odor of water. Since Cambridge has a robust water treatment system, algae are removed from the final drinking water product during the purification process.

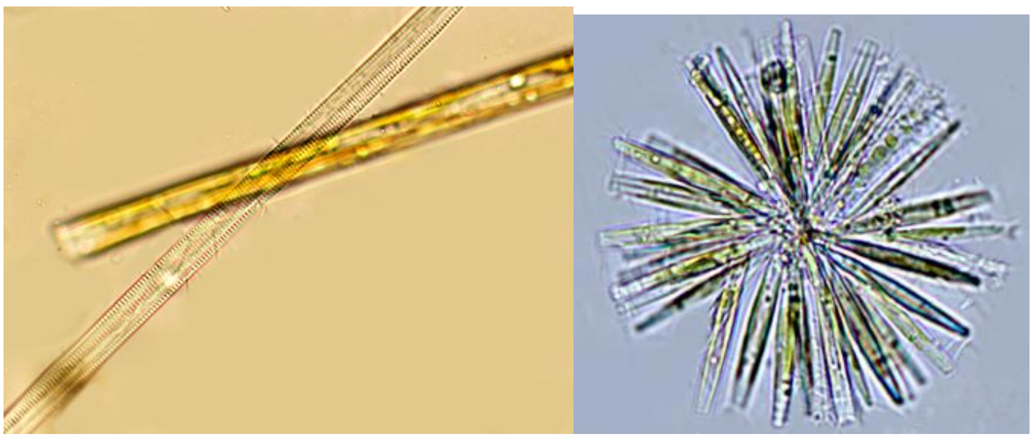
The five most common genera of algae found in each reservoir are listed in Table 5 below. There were 43 total genera found in the surface and bottom samples taken from the three reservoirs in 2019 (Table 1). Many of the genera appeared in multiple samples from the same reservoirs.

Table 5: Most Common Genera found in Cambridge Reservoirs, 2019

Genus	Phylum	# of Appearances	Max. Concentration (cells/mL)
Hobbs Brook			
Synedra	Diatoms	15	4,200
Tabellaria	Diatoms	15	490
Navicula	Diatoms	12	2,300
Coelastrum	Green algae	13	1,500
Dinobryon & Cyclotella	Golden algae / Diatoms	11	3,000 / 736
Stony Brook			
Synedra	Diatoms	8	21,000
Dinobryon	Golden algae	7	9,700
Navicula	Diatoms	7	12,000
Cyclotella	Diatoms	7	410
Coelastrum	Green algae	5	190
Fresh Pond			
Synedra	Diatoms	18	950
Tabellaria	Diatoms	10	675
Scenedesmus	Green algae	9	1,800
Dinobryon	Golden algae	8	520
Navicula	Diatoms	7	280

The most common genus overall was *Synedra*. It appeared in the most samples in all three of the reservoirs. *Dinobryon* and *Navicula* also were among the five most commonly appearing algae genera in all three reservoirs. *Synedra* and *Navicula* are both Diatoms, and *Dinobryon* is a type of Golden algae. Coelastrum, a type of Green algae, was the fourth and fifth most common algae type at Hobbs Brook and Stony Brook reservoirs, respectively. *Tabellaria*, a genus of Diatom, was tied for the most common algae type at Hobbs Brook Reservoir and was the second most populous algae type at Fresh Pond Reservoir. *Scenedesmus*, another type of Green algae, was found in nine out of 22 samples taken at Fresh Pond but did not make the top 5 most common types of algae at the other two reservoirs. *Cyclotella* appeared in seven samples at Stony Brook Reservoir and 11 samples at Hobbs Brook Reservoir but was not in the top five most common algae types found in samples collected at Fresh Pond. *Synedra*, *Dinobryon*, and *Navicula*, the three genera of algae found among the top five most common genera at all three reservoirs, are discussed in further detail below.

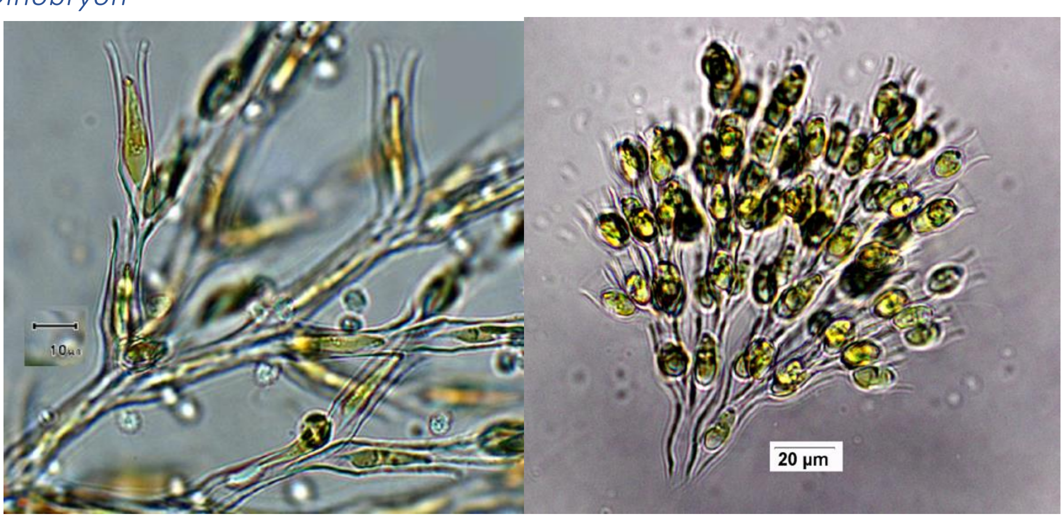
6.1 Synedra



Photos of Sydenra, Source: Baker and others, 2012

Synedra is a genus of Diatom. Its name comes from Greek *syn* and *hedra*, meaning "seated together." Synedra has long, needle-like cells that exist alone or form colonies (Baker and others, 2012). The colonies are clumped together at one point with a pad of mucilage. Synedra thrives in freshwater bodies (Baker and others, 2012). Although *Synedra* is a common diatom and can cause odor issues and clog filters, blooms rarely cause recreational or ecological issues in lakes (Mattson and others, 2004).

6.2 Dinobryon



Photos of Dinobryon, Source: Baker and others, 2012

Dinobryon are a genus of Golden algae. They form large colonies and have two distinctive "flagella" that come off of each cell (Baker and others, 2012). Each cell also has a prominent eyespot or "stigma" (Baker and others, 2012). It can be taken as a compliment that *Dinobryon* is so abundant in Cambridge reservoirs. *Dinobryon* thrives in cool freshwater lakes and competes particularly well in low-phosphorous lakes (Baker and others, 2012; Mattson and others, 2004). Large blooms of *Dinobryon* can cause discoloration and odor in water (Mattson and others, 2004).

6.3 Navicula

Photos of Navicula, Source: Baker and others, 2012

Navicula is another genus of Diatom. Its name comes from Latin *navi* and *cula,* meaning "small ship" (Baker and others, 2012). These cells are solitary and do not form large colonies like *Synedra* and *Dinobryon* (Baker and others, 2012). They have a distinctive canoe shape, wider in the middle and tapered towards the ends. *Navicula* are a common Diatom and are found in both freshwater and saltwater habitats (Baker and others, 2012; Mattson and others, 2004). While all Diatoms can cause odor or filter clogging problems in water supplies, *Navicula* is not known for causing recreational or ecological problems in lakes and reservoirs (Mattson and others, 2004).

7 Appendix A: Field Duplicates

Three field duplicate samples were collected in 2019 at HB @ Middle, FP @ DH, and HB @ Upper. The relative percent difference (RPD) for the genera of algae identified in the sample pairs ranged from 0 percent to 200 percent (Table 6). Duplicate samples with 200 percent RPDs occurred when genera were found in one sample but not the second sample. However, algae concentrations were generally low in the non-zero samples, usually less than 100 cells/ml. The RPD for the total cellular concentration of all genera combined ranged from 23 to 41 percent.

Table 6: Field Duplicate Results and Relative Percent Difference (RPD) calculations, 2019

HB @ Middle (5/1/2019)			
Genera	**Sample (cells/ml)**	**Duplicate (cells/ml)**	**RPD (%)**
Asterionella	110	48	78
Chlamydomonas	3	0	200
Coelastrum	68	0	200
Cyclotella	98	0	200
Diatoma	0	3	200
Dinobryon	13	180	173
Navicula	0	18	200
Staurastrum	0	30	200
Synedra	2,800	2,200	24
Ulothrix	35	0	200
Total	**3,127**	**2,479**	**23**
FP @ DH (8/13/2019)			
Navicula	140	160	13
Nitzschia	13	0	200
Scenedesmus	13	25	63
Staurastrum	13	100	154
Synedra	160	140	13
Tabellaria	13	110	158
Ulothrix	2	0	200
Total	**354**	**535**	**41**
HB @ Upper (12/19/2019)			
Asterionella	0	440	200
Dinobryon	190	390	69
Navicula	230	19	169
Pediastrum	19	0	200
Peridinium	19	0	200
Scenedesmus	19	19	0
Staurastrum	0	19	200
Synedra	120	120	0
Tabellaria	77	0	200
Trachelomonas	19	0	200
Total	**693**	**1,007**	**37**

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