AQUATIC ECOSYSTEM RESEARCH
A Freshwater Conservation Company

East Twin Lake 2018 & 2019 Water Quality Monitoring

Prepared for the
Twin Lakes Association
Salisbury, CT

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EXECUTIVE SUMMARY

This report summarizes water quality data collected in the field and water chemistry data from East Twin Lake in Salisbury, CT during 2018 and 2019. In situ water quality data and sample collections were performed by volunteers from the Twin Lakes Association. Laboratory analyses were performed by HydroTechnologies, LLC in New Milford, CT. Algal analyses were performed by AER. Additionally, multiple linear regression and ANOVA were performed on historical data to delineate changes in water quality. Highlights include:

- The lake was stratified for the entire sampling season (May – October) in both years and the resistance to mixing was strong (RTRM at thermocline ≥80) for most of each season.
    - The bottom of the lake was always very cold (5 to 6°C).
    - The anoxic zone associated with deep waters increased in size starting on June 8th of 2018, and July 8th of 2019. The region of anoxic waters expanded from the bottom up to the 17m stratum in 2018 and the 15m stratum in 2019.
    - The highest concentration of oxygen was located below the thermocline between 7 and 10m of depth.

- Average total phosphorus concentration in the epilimnion was 17 and 11µg/L in 2018 and 2019, respectively.
    - In 2018, hypolimnetic levels were slightly higher than epilimnetic levels until August 13th at which time hypolimnetic levels were an order of magnitude higher than in the epilimnion.
        - In 2019, that type of phenomenon in the hypolimnion did not occur until October 8th.

- Nitrogen in the form of total Kjeldahl nitrogen (TKN) and total nitrogen were low in the epilimnion of both seasons.
    - Hypolimnetic ammonia, TKN, total nitrogen, and alkalinity increased over epilimnetic levels to a greater degree as the season progressed in concordance with the development of anoxic conditions.

- Average Secchi transparency was 4.46 and 4.86m in 2018 and 2019, respectively.
    - Two of the twelve measurements made during 2018 and 2019 were <4m; two were >5m; all others were between 4 and 5m.

- Specific conductance was high for Connecticut standards but not for lakes in the Marble Valley region of the State.
    - Conductance of the epilimnion decreased as the season progressed in both seasons.
    - For depths from the thermocline down to approximately 20m, the conductance values were higher and more stable over time.

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    - Specific conductance values at the very bottom were highly elevated after July of both seasons when anoxic conditions in the hypolimnion were present.

- The algal community at the depths of highest oxygen concentrations was largely comprised of Cyanobacteria from August to October, with many of the genera observed associated with cyanotoxin production.
    - This is common for many Connecticut Lakes.
    - Cyanobacteria cell concentrations were well below the recommended threshold by the State for public interventions, i.e. Cyanobacteria concentrations near the surface do not pose a threat.
    - Based on oxygen profiles, it appears that the largest population of Cyanobacteria are layered between 8 and 10m of depth.
    - Diatoms and Chrysophyta were codominant with Cyanobacteria in May through July of both seasons.

- Multiple linear regression indicated that the water column as a whole had not significantly changed since 2004.
    - Analyzed separately, the epilimnion and hypolimnion had significantly changed.
        - Changes in pH were found to be significant.

- Results from ANOVA indicated that there were changes in multiple water quality parameters of the epilimnion, hypolimnion, and the water column as a whole
    - In the water column as a whole and separately in hypolimnion, significant increases between 2004 and 2019 were observed for pH, TKN, and ammonia.
        - In the water column as a whole and separately in hypolimnion, a significant decrease in nitrate was observed between 2004 and 2019.
        - The decrease in hypolimnetic nitrate concurrently with the increase in ammonia and TKN suggested an increase in the rate of nitrate reduction under anoxic conditions (i.e. increased oxygen demand).

- Linear regression and analysis of variance (ANOVA) were applied to Secchi transparency data from 2004 to 2019.
    - Linear regression indicated a change to the overall system in the timeframe.
    - ANOVA also resulted in a statistically significant decrease in average Secchi disk transparency from 2004 to 2019.
        - ANOVA analyses also resulted in a significant change in average Secchi transparency from May to October.

- Management recommendations have been provided at the end of the report.

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INTRODUCTION

East Twin Lake (also known as Washining Lake) is a 569-acre (ac) lake located in northwest Connecticut in the Town of Salisbury (Jacobs and O'Donnell 2002). The lake is one of the deepest in Connecticut with a maximum depth of 25 meters. With a watershed of 2,639ac, the lake has a relatively small watershed to lake ratio of 4.6.

East Twin Lake has been included in several state-wide surveys of lakes in Connecticut which provide important baseline information that will be discussed later. These included surveys conducted in the 1930s (Deevey 1940), 1970s (Frink & Norvell 1984), and in the 1990s (Canavan & Siver 1994, 1995). Much of those data from the three initiatives are compiled in Canavan and Siver (1994, 1995). Based on those studies it was reported that East Twin Lake had experienced a decrease in summer Secchi transparency of 2.0m between the 1930s and 1990s and a 1.0m decrease between the 1970s and 1990s (Siver et al. 1996). The same study also revealed: a 21µg/L increase in total phosphorus between the 1930s and 1990s including a 16µg/L increase between 1970 and 1990; and alkalinity also exhibited an increase of 12.3mg/L between 1930s and 1990s with a 13mg/L increase between 1970 and 1990.

The Twin Lakes Association initiated a volunteer monitoring program several years ago to collect water quality data on East Twin Lake. The protocols were modeled after AER's field methods. The purpose of this report is to account on the data collected by the Twin Lakes Association, analyze it, and compare it to historical data to determine if any more recent changes have occurred.

METHODS

A volunteer monitoring program was developed by the Twin Lake Association in conjunction with AER in 2017. Volunteer monitors conducted monthly site visits to one site on East Twin Lake (73°22'59.999" W 42°1'32.984" N; Fig. 1) between May and October in 2018 on the following dates: May 14th, June 18th, July 12th, August 13th, September 5th, and October 1st. Visits in 2019 occurred on the following dates: May 16th, June 10th, July 8th, August 5th, September 9th, and October 8th. During each visit the following data were collected: A transparency measurement was taken using a standard 20cm Secchi disk. Temperature (°C), oxygen (mg/L), conductivity (µS/cm), specific conductance (µS/cm), and pH were measured 0.5m below the surface, at one meter (m), and at every meter to the bottom using a YSI® Professional meter. During each site visit, water samples were collected at a depth of 1.0m below the surface and 0.5 to 1m above the sediment-water interface using a Van Dorn horizontal sampler for nutrient analyses.

For phytoplankton analyses, volunteers collected samples at the depth of the greatest oxygen concentration in the water column. Samples were prepared by treating them with Lugol's solution before transferring them to AER. Hydrostatic pressure was then

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applied to each sample to collapse the gas vesicles that might be contained within cyanobacteria cells (Lawton et al. 1999). Known volumes of the field samples were concentrated into smaller measured volumes with centrifugation and a vacuum pump / filtration flask system. A portion of the concentrates were pipetted into a counting chamber then genus-level algal cell enumerations were performed by counting individual cells in a subset of fields within the counting chamber using an inverted Nikon Diaphot research microscope. Those counts were then corrected to be reflective of the whole sample.

Figure 1. Map of East Twin Lake showing the location of the lake monitoring point where data is collected.

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TEMPERATURE AND OXYGEN DYNAMICS

Temperature profile data allow for the assessment of thermal characteristics by providing the means to calculate where the water column is and is not mixing due to temperature/density differences. In shallow New England lakes stratification can occur but it may be short in duration as energy from wind can mix the water column. In deeper lakes, such as East Twin Lake, a middle transitional layer (aka metalimnion) separates the upper warmer layer (aka epilimnion) from lower, colder waters below (aka hypolimnion). Within the metalimnion resides the thermocline, which is the layer between strata where temperature/density changes are greatest with increasing depth. These conditions will often persist in deeper lakes for the entire summer and into the fall until turnover mixes the water column.

Temperature and oxygen data have been displayed as isopleths where temperature and oxygen are graphically displayed as shades of colors at each depth throughout the water column and between dates (Fig 2). The variables at each depth between the dates when measured are interpolated from the actual measurements. Variables of same value (i.e. color) are connected between dates irrespective of depth to create a theoretical representation of changes at depth over the entire study period.

Thermal resistance to mixing scores were calculated to determine the position of the metalimnion and characterize the strength of the thermocline. Resistance to mixing, which is an assessment of the ability of two different water volumes – that differ in temperature and density – to mix, was calculated using the Relative Thermal Resistance to Mixing (RTRM) formula: $(D_1 - D_2)/(D' - D^o)$, where D_1 is the density of upper water volume, D_2 is the density of the lower water volume, D' is the density of water at 5°C, and D^o is the density of water at 4°C. RTRM scores of <30 means layers are mixed; scores of ≥30 between strata are characteristic of the transitional metalimnion layer. RTRM scores of ≥80 between strata is characterized as strong resistance to mixing (Siver et.al. 2018).

An oxygen concentration of 5mg/L is generally thought to be the threshold that indicates sustainable conditions for most aerobic organisms in freshwater systems. As concentrations drop below the threshold, conditions become stressful. Minimum oxygen requirements for fisheries in Connecticut's lakes and ponds range from 4 to 5mg/L for cold-water fish (e.g. trout), 2mg/L for cool-water fish (e.g. walleye), and 1 to 2mg/L for warm-water fish (e.g. bass and panfish; Jacobs and O'Donnell 2002).

The water column in mid-May of both 2018 and 2019 was stratified. In 2018, temperatures from the surface to a depth of 5m ranged from 15.1 to 13.9°C before a strong thermocline (RTRM = 85) occurred the 5 to 6m strata. In 2019, temperatures from the surface to 6m of depth ranged from 13.5 to 12.6°C before reaching the upper boundary of the metalimnion, which was located between the 6 and 7m strata; additionally, a weak thermocline (RTRM = 35) was located between the 8 and 9m strata. In both years, temperatures ranged from about 9°C just beneath the thermocline to 5 – 6°C at the bottom.

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The entire 2018 mid-May water column had a concentration of >8.8mg/L; in 2019, the entire water column had a concentration of ≥8mg/L except for the very bottom (24m) where a concentration of 0.4mg/L was recorded. In both seasons, strata of water with concentrations between 10.5 and 11.7mg/L was observed layered between masses of water above and below where lower concentrations were recorded (Fig. 2). This pattern would persist through early September in both years and is suggestive of large algal communities.

Temperatures recorded in the upper levels of the water column in June of 2018 and June of 2019 were similar. In 2018, temperatures of 22.1 to 20.1°C were observed from the surface down to the strong thermocline (RTRM = 125) located between 5 and 6m of depth. Below the lower boundary of the metalimnion temperatures decreased from 8.4°C at the 9m strata to 5.6°C at the 23m strata in 2018.

On June 10th of 2019, temperatures from the surface to 4m of depth ranged from 22 to 20.9°Cabove the upper boundary of the metalimnion. Temperatures quickly decreased through the 2019 metalimnion from 19 to 11.6°C; temperatures above and below the strong thermocline (RTRM = 80, 6 and 7m) of depth were 17.4 and 14.2°C, respectively. Temperatures below the lower boundary of the metalimnion decreased from 10°C at the 9m strata to 5.8°C at the 25m strata.

Oxygen concentrations on June 18, 2018 were ≥5mg/L down to a depth of 19m, were 3.7mg/L at the 20m strata, and were 0.1mg/L from the 21m strata to the bottom. The highest concentrations were encountered between 6 and 12m of depth and ranged from 10.5 to 12.8mg/L. On June 10 of 2019, concentration of ≥5mg/L were recorded down to 21m of depth then decreased to 2.7mg/L by the 24m strata and was 0.2mg/L at the 25m strata. The region of the water column with the highest oxygen concentrations, which ranged between 10.2 to 11.3mg/L, was located between 7 and 12m of depth.

The temperature profiles of July 12th and August 13th of 2018 were similar. Temperatures were between 26 and 27°C in the top 4m of the water column on July 12th, and in the top 5m of the water column on August 13th. Much of the metalimnion on both dates exhibited strong resistance to mixing and contained a strong thermocline (RTRM = 127 between the 5 and 6m strata on July 12th; RTRM = 142 between the 6 and 7m strata on August 13th). On July 12th temperatures transitioned from 22.6 to 11.2°C between the 5 and 8m strata then decreased from 9.1 to 5.6°C between 9 and 24m of depth. Similarly on August 13th, a rapid decrease in temperature from 22.0 to 10.7°C occurred within the metalimnion; below the lower boundary of the metalimnion located between 9 and 10m of depth, temperatures decreased from 9.0 to 5.6°C at the bottom.

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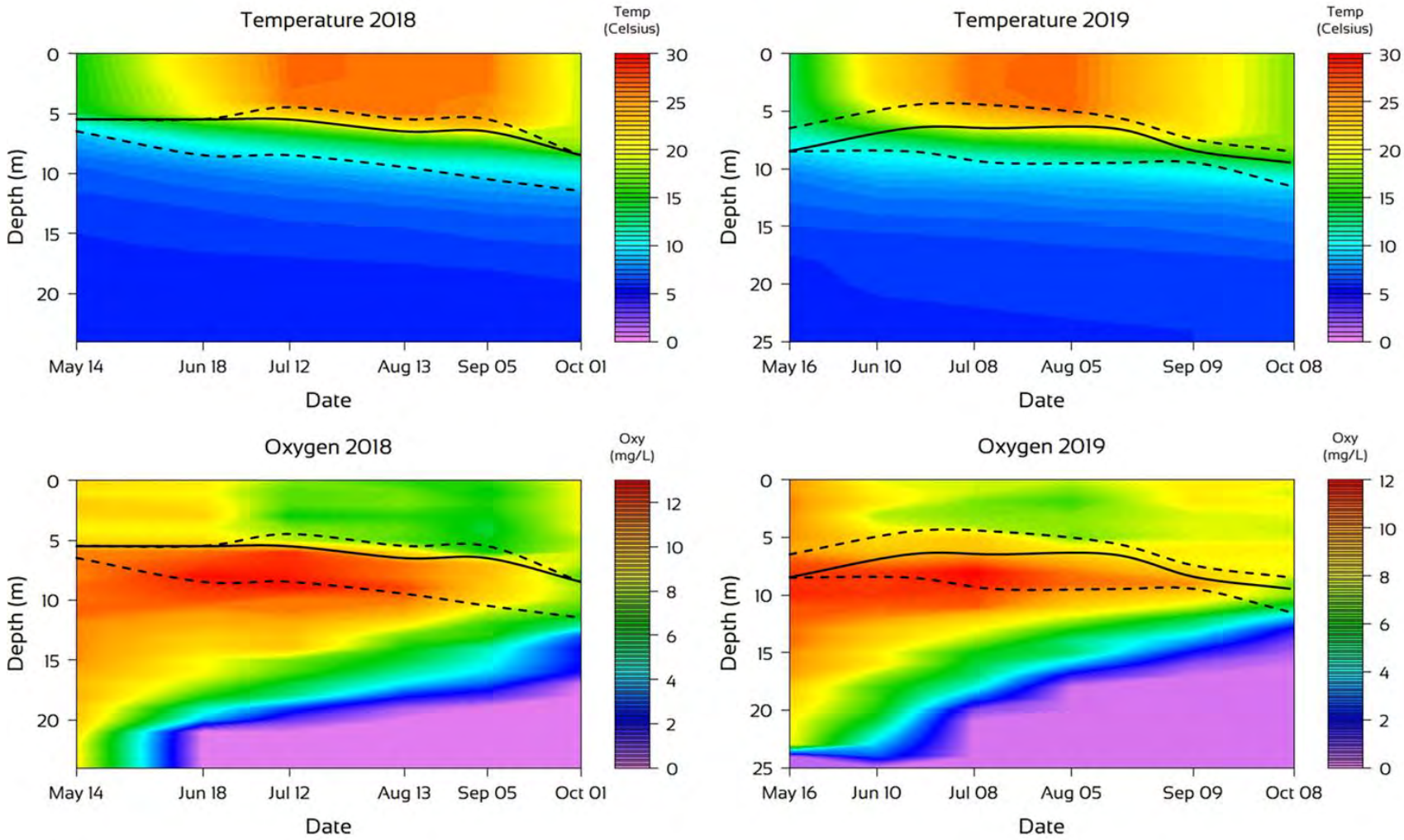

Figure 2. Temperature (top) and oxygen (bottom) isopleths for the 2018 (left) and 2019 (right) seasons at East Twin Lake. The dashed lines represent the upper and lower boundary of the metalimnion; the solid like represents the location of the thermocline.

Oxygen concentrations ≥5mg/L were recorded down to the 18m stratum on July 12th and to the 16m stratum on August 13th. Oxygen concentrations <1mg/L were observed from the 21m stratum to the bottom on July 12th, and from the 19m stratum to the bottom on August 13th. The highest concentrations of oxygen were found to be in middle depths on both 2018 dates (Fig. 2).

Temperature profiles in July 8th and August 5th of 2019 were similar to those in July and August of 2018. In 2019, the same temperature range of 26 to 27°C was observed at the same depths as in the corresponding July and August of 2018. The upper boundary of the metalimnion was located between 4 to 5m and 5 to 6m stratum in July and August, respectively, of both years. Below the lower boundary of the metalimnion, starting at 9m of depth on July 8th and 10m of depth on August 5th, temperatures decreased from 9.8 to 11°C to 5.9°C at the bottom.

There appeared to be a slightly higher oxygen demand in July and August of 2019 compared to corresponding months in 2018. Oxygen levels <1mg/L were observed from 20m of depth to the bottom on July 8th; and, from 18m of depth to the bottom on August 5th.

The water column during September 5, 2018 and September 9, 2019 exhibited some observable differences. In 2018, temperatures in the first 5m of the water column (above the upper boundary of the metalimnion) were found to be between 26.2 and 25.3°C; the thermocline located between the 6 and 7m stratum was highly resistant to mixing (RTRM = 145). In 2019, temperatures in the first 7m of the water column (above the upper boundary of the metalimnion) exhibited a range of 21.6 to 21°C; the thermocline was situated between the 8 and 9m stratum was weaker than that encountered in 2018 (RTRM = 98). Below the lower boundary of the metalimnion (i.e. between the 10 and 11m strata in 2018 and between the 9 and 10m strata in 2019) temperatures gradually decreased to between 5.7 to 6°C at the bottom in both years.

The 2018 and 2019 September oxygen profiles also differed. Oxygen concentrations in the epilimnion of 2018 were between 6 and 7mg/L; in 2019 the epilimnetic range was 7.7 to 8.3mg/L. The highest oxygen concentration of 9 to 10.5mg/L were located between the 7 and 10m strata in 2018, and between the 8 and 9m strata in 2019. In 2018 oxygen concentrations decreased with depth and were <1mg/L at 19m of depth. In 2019, the anoxic zone was found to start at the 17m strata.

The lake remained thermally stratified in October of both seasons. In 2018, the October 1st temperatures from the surface to above the strong thermocline (RTRM = 138, 8-9m) were between 18.9 and 17.6°C. Temperatures then rapidly decreased to 8°C by 12m of depth and gradually decreased to 5.8°C by 24m of depth. Similarly, in 2019, temperature of waters above the upper boundary of the metalimnion were 17.5°C then decreased rapidly to 9°C by the 12m strata; water temperature then gradually decreased to 6.1°C by the 24m strata.

Oxygen concentrations on October 1st of 2018 ranged from 8.7mg/L at the surface to 5.4mg/L at 12m of depth then decreased to 2mg/L at 16m of depth, and were ≤0.3mg/L

at all strata below the 16m stratum. On October 8th of 2019, surface oxygen concentrations of 8.4mg/L decreased to 5.5mg/L by 11m of depth then decreased to 0.6mg/L by the 15m stratum, and were 0.3mg/L from 16m of depth to the bottom.

NUTRIENTS

Phosphorus

Phosphorus in freshwater systems is commonly the nutrient in the shortest supply and in greatest demand by the algae; therefore, it often the nutrient limiting algal productivity. Sources of phosphorus can be imported from the watershed (i.e. allochthonous), or derived internally from anoxic sediments (i.e. autochthonous). Total phosphorus is the analysis frequently conducted; it represents all forms of phosphorus in a sample, i.e. particulate and soluble forms.

Total phosphorus concentrations in the epilimnion were generally low. The average for the 2018 season was 17µg/L; the high for season was 27µg/L on May 14th with concentrations generally decreasing to a low of 5µg/L on October 1st. In 2019, the average epilimnetic concentration was 10.5µg/L, which included 0µg/L (below detectable limits) on August 5th and a high of 28µg/L on September 9th.

In 2018, hypolimnetic total phosphorus levels ranged from 19 to 41µg/L from May 14th to July 12th, but ranged from 120 to 290µg/L between August 13th and October 1st. In 2019, the hypolimnetic levels ranged from 6 to 45µg/L between May 16th and September 9th; but, on October 8th was measured at 234µg/L. Average hypolimnetic concentration for the 2018 and 2019 seasons were 133 and 63µg/L, respectively.

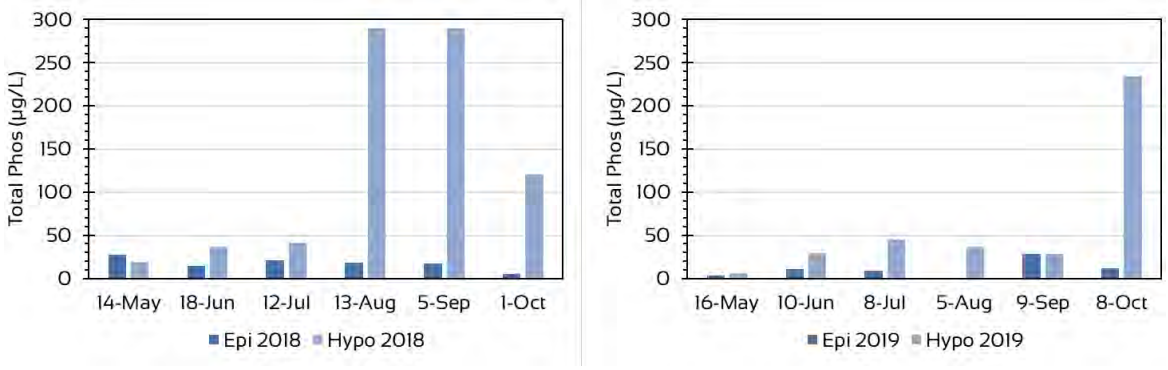

Figure 3. Total phosphorus concentrations in the epilimnion (Epi) and hypolimnion (Hypo) of East Twin Lake in 2018 (left) and 2019 (right).

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Nitrogen

Nitrogen is commonly the second most limiting nutrient for algae growth in freshwater systems. It can be present in a number of forms in lake water. Ammonia – a reduced form of nitrogen – is important because it can affect the productivity, diversity, and dynamics of the algal and plant communities. Ammonia can be indicative of internal nutrient loading since bacteria will utilize other forms of nitrogen (e.g. nitrite and nitrate) in lieu of oxygen for cellular respiration under anoxic conditions, resulting in ammonia enrichment of the hypolimnion.

Total Kjeldahl nitrogen (aka TKN) is a measure of the reduced forms of nitrogen (including ammonia) and total organic proteins in the water column. Since TKN accounts for biologically derived, nitrogen-rich proteins in the water column, it is useful in assessing the productivity of the lentic system. Nitrate and nitrite are often below detectable levels in natural systems because they are quickly cycled by bacteria and aquatic plants. Total nitrogen is the sum total of TKN, nitrate, and nitrite. Since the latter two are often below detectable limits, TKN levels are often similar or equal to total nitrogen levels.

Ammonia was only detected in the epilimnion once over the two-year period, which was 0.21mg/L on October 1st of 2018. In the hypolimnion, low concentrations were detected in June of both season (0.14mg/L in 2018 and 0.15mg/L in 2019). Hypolimnetic ammonia increased up to 0.68mg/L by August 13th in 2018 before decreasing to 0.35mg/L by October 1st. In 2019, concentrations increased to 0.58mg/L by August 5th, were not detected in the September sample, but attained the highest concentration over the two years on October 8th with a value of 0.8mg/L.

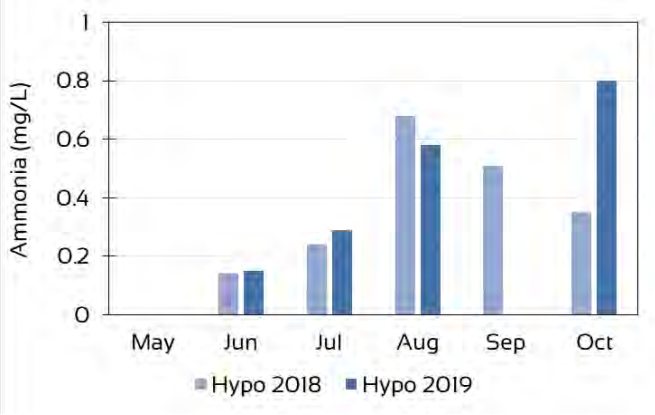

Figure 4. Hypolimnetic ammonia concentrations at East Twin Lake in 2018 and 2019.

To explore the relationship between total nitrogen and TKN at East Twin Lake, the two variables were regressed against each other for all samples where TKN was measured and total nitrogen calculated. A very strong correlation existed between those two sets of data (R^2=0.992; $p<0.005$). Of the 24 total data pairs, on only 4 occasions was total nitrogen different from TKN. On those occasions, nitrate was detected at the following levels on these 2018 dates at these strata: 0.11mg/L on June 18th in the hypolimnion, 0.05mg/L on August 13th in both the epilimnion and hypolimnion and 0.05mg/L on October 1st in the epilimnion. Nitrate was not detected in 2019 samples.

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Average levels of total nitrogen in the epilimnion in 2018 and 2019 were 0.51 and 0.38mg/L, respectively. The average levels in the hypolimnion in 2018 and 2019 were 0.73 and 0.63mg/L, respectively. Epilimnetic and hypolimnetic averages were not significantly different from each other in either year ($p>0.05$). Epilimnetic averages for each season were not significantly different ($p>0.05$). The same was also true for hypolimnetic averages in 2018 and 2019.

The 2018, total nitrogen concentrations in the epilimnion range from a low of 0.27mg/L on August 13th to a high of 1.12mg/L on May 14th. In the hypolimnion, the low was 0.42mg/L on July 12th and the high was 0.99mg/L on May 14th. In 2019 concentrations in the epilimnion ranged from 0.2mg/L on October 8th to 0.79mg/L on June 10th; hypolimnetic concentrations ranged from 0.11mg/L on May 16th to 1.0mg/L on August 5th.

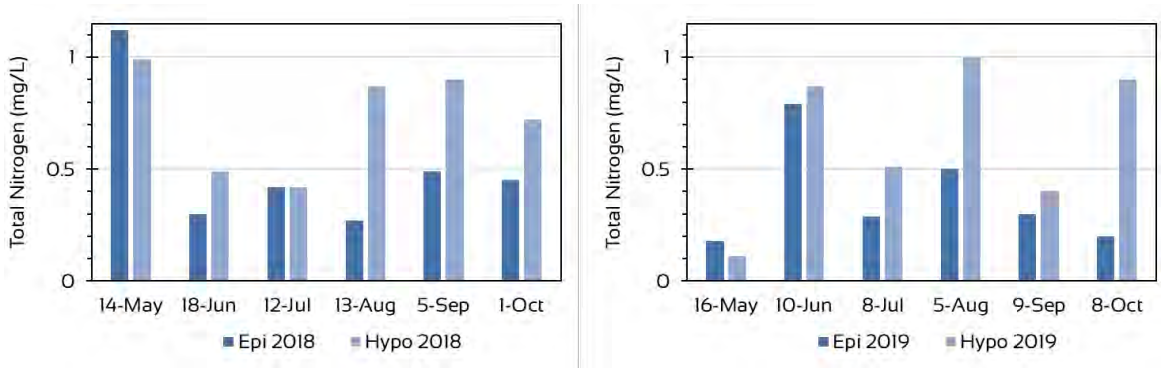

Figure 5. Epilimnetic (Epi) and hypolimnetic (Hypo) total nitrogen concentrations in 2018 (left) and 2019 (right) at East Twin Lake.

SECCHI TRANSPARENCY

Secchi disk transparency is a standard Limnological measurement that assesses how much light is transmitted through the water column. How far light is transmitted down the water column is a response to the amount of particulate matter suspended in the water column that absorbs or scatters the light. The particulate matter can be inorganic (e.g. silts, clays, etc.) or organic (phytoplankton) in nature. Since transparency is more often related to the phytoplankton in the water column, the measurement has historically been used to assess trophic conditions (Table 1).

Secchi disk transparency is also useful in assessing the stratum in the water column where enough light penetrates to yield more oxygen from algal photosynthesis than is consumed in aerobic cellular respiration. This is referred to as the Compensation Depth and is estimated by doubling the Secchi transparency.

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Average Secchi transparency for the 2018 season was 4.46m; in 2019, the season average was 4.86m. Season averages were not significantly different ($p>0.05$). On only two of twelve occasions between the two seasons was Secchi transparency <4m. These were on August 13th and October 1st of 2018 and were 3.5m and 3.2m, respectively. On two occasions Secchi transparency was >5m. These were on September 5th of 2018 and June 18th of 2019 and were 6.17 and 5.65m, respectively. All other measurements were between 4.1 and 5.1m (Fig. 5).

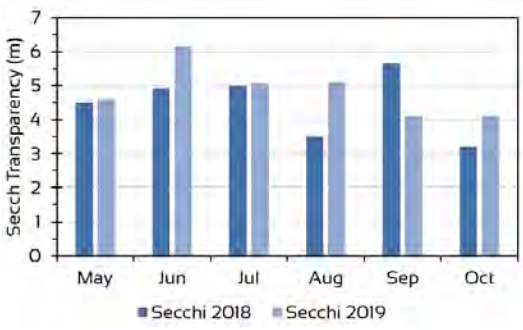

Figure 6. Secchi transparency during the 2018 and 2019 seasons at East Twin Lake.

ALKALINITY AND PH

Alkalinity is a measure of calcium carbonate in the water; it reflects the buffering capacity or acid neutralizing capacity of water. Alkalinity of surface waters is influenced by local geology and other watershed phenomenon. Alkalinity can also be generated internally from the dissimilatory reduction reactions of sulfate by bacteria found in anoxic lake sediments (Siver et al. 2003).

The pH of lake water is important for several reasons. Firstly, very low (<5) or very high (>9) pH levels will not support diverse lentic flora and fauna. Algal communities are influenced by pH due – in part – to its influence on the form of dissolved carbon in the water column. For example, at pH greater than 8.3, bicarbonate is the dominant form of carbon available to the pelagic algal community. Cyanobacteria (aka blue-green algae) have an adaptive advantage over other algal groups because they can more efficiently utilize that form of carbon. Other algal groups are dependent upon carbon dioxide, which much less available in water with a pH above 8.3.

The average epilimnetic alkalinity in 2018 and 2019 was 111.7 and 112.7mg/L respectively. The hypolimnetic averages were 133.8 and 136mg/L, respectively. Differences between the epilimnetic and hypolimnetic averages were significant ($p<0.05$) in both seasons and when data were pooled.

In 2018, the epilimnetic alkalinity was highest on May 14th at 129mg/L, gradually decreased to 105mg/L by August 13th, and remained near that level for the remainder of the season (Fig. 6). The 2018 hypolimnetic alkalinity ranged between 124 to 132 from May 14th through July 12th; it was higher during the last three months of the season with a range of 135 to 143mg/L.

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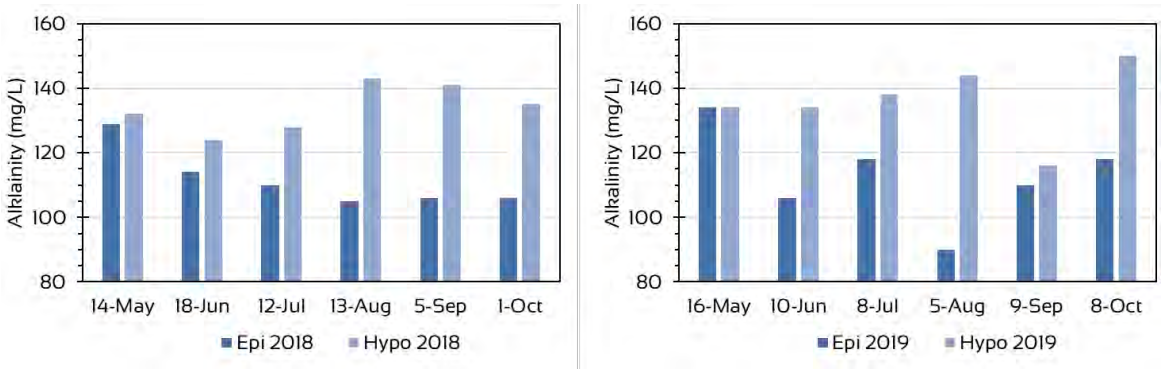

Figure 7. Epilimnetic (Epi) and hypolimnetic (Hypo) alkalinity in the 2018 (left) and 2019 (right) seasons.

In 2019, epilimnetic alkalinity was also highest in May with a value of 134mg/L. Alkalinity ranged between 106 and 118 for the remaining months except for August when it was reported as 90mg/L. The 2019 hypolimnetic levels ranged between 134 and 138mg/L between May 16th and July 8th; the August 5th and October 8th levels were greater at 144 and 150mg/L, respectively. The September 9th hypolimnetic level was the lowest for the 2019 season at 116mg/L.

The pH of the epilimnion between May and October of both seasons exhibited a range spanning 8.5 to 8.9SU. The lowest epilimnetic pH was measured in May of both years; it then gradually increased through August in 2018 and through September in 2019 then decreased through the end of both seasons (Fig. 7). The season averages in 2018 and 2019 were 8.75 and 8.77, respectively.

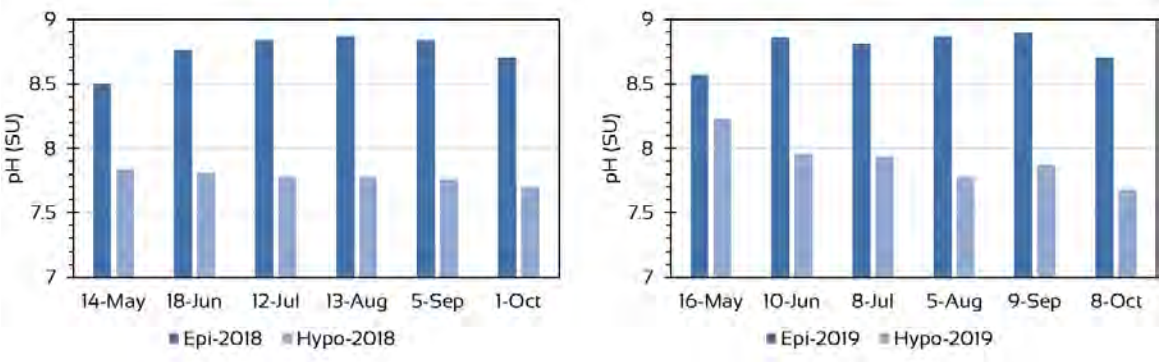

Figure 8. Epilimnetic (Epi) and hypolimnetic (Hypo) pH in the 2018 (left) and 2019 (right) seasons.

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The average hypolimnetic pH for the 2018 and 2019 seasons were 7.78 and 7.94, respectively. In 2018 all hypolimnetic pH levels were between 7.7 and 7.84. In 2019, the May 16th pH in the hypolimnion was 8.23; that value decreased to 7.68 by October 8th.

The epilimnetic pH was significantly higher than hypolimnetic levels in both seasons ($p<0.005$). Differences between epilimnetic and hypolimnetic levels were due to lower levels of carbon dioxide in the epilimnion as a result of photosynthesis by the algae. In the hypolimnion where photosynthesis is limited by light, carbon dioxide enrichment resulted in lower pH.

SPECIFIC CONDUCTANCE

Conductivity is a surrogate measure for ion concentration of water; simply put, it is a measure of water's ability to transmit an electrical current. Data collections included measures of both conductivity and specific conductance. Specific conductance is conductivity standardized to a set water temperature (25°C) because – in the field – temperature varies with depth and/or date. Specific conductance (i.e. conductivity) is an important metric in Limnological studies due to its ability to detect pollutants and/or nutrient loadings. Specific conductance can also have an influence on organisms that inhabit a lake or pond; particularly, algae. The composition of algal communities has been shown to be related, in part, to conductivity levels in lakes (e.g. Siver 1993, McMaster & Schindler 2005).

Specific conductance near the lake bottom sediments can be higher than in other region of the water column nearer the surface, particularly later in the summer after the water column has been stratified and the waters near bottom have been anoxic for protracted periods of time. Under those conditions, minerals and salts in the sediments can undergo chemical transformation and change from a particulate state to a dissolved ionic state, diffuse to the waters above the sediments, and increase the conductivity of the hypolimnion.

AER examined specific conductance isopleths for 2018 and 2019, as well as at specific strata, i.e. at the 1m strata and at the bottom of the water column.

The isopleths for 2018 and 2019 depict three distinct features with regards to specific conductance in the water column. First, in the regions of the water column above the thermocline specific conductance progressively decreased over the course of the season. In 2018, the top 5m of the water column on May 14th had specific conductance levels between 252 and 256µS/cm; epilimnetic levels on October 1st were between 227 and 230µS/cm. Similarly in 2019, the May 16th epilimnetic specific conductance ranged from 263 to 265µS/cm; but by October 8th epilimnetic levels ranged between 237 and 238µS/cm.

Seasonal change below the thermocline down to approximately the 18 to 20m strata were more subtle (Fig. 8). For example, the region of the water column between the 9

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and 17m strata varied between 252 and 260µS/cm in 2018; the range at the same depths was modestly wider in 2019 and between 252 and 273µS/cm. More measurable changes in specific conductance occurred at depths near the bottom. In 2018, specific conductance from the 20m stratum to the bottom ranged from 253 to 326µS/cm; in 2019 at those depths, levels ranged from 266 to 236µS/cm. Highest levels in 2018 were on August 13th while in 2019 highest levels were on July 8th

Comparison of specific conductance at 1m of depth to that at the bottom illustrated the overall higher values in 2019 compared 2018 at both strata (Fig. 9). Also notable were the similarities between epilimnetic and hypolimnetic values in May of 2018, while in May of 2019 differences in specific conductance between the two water-volumes were already occurring.

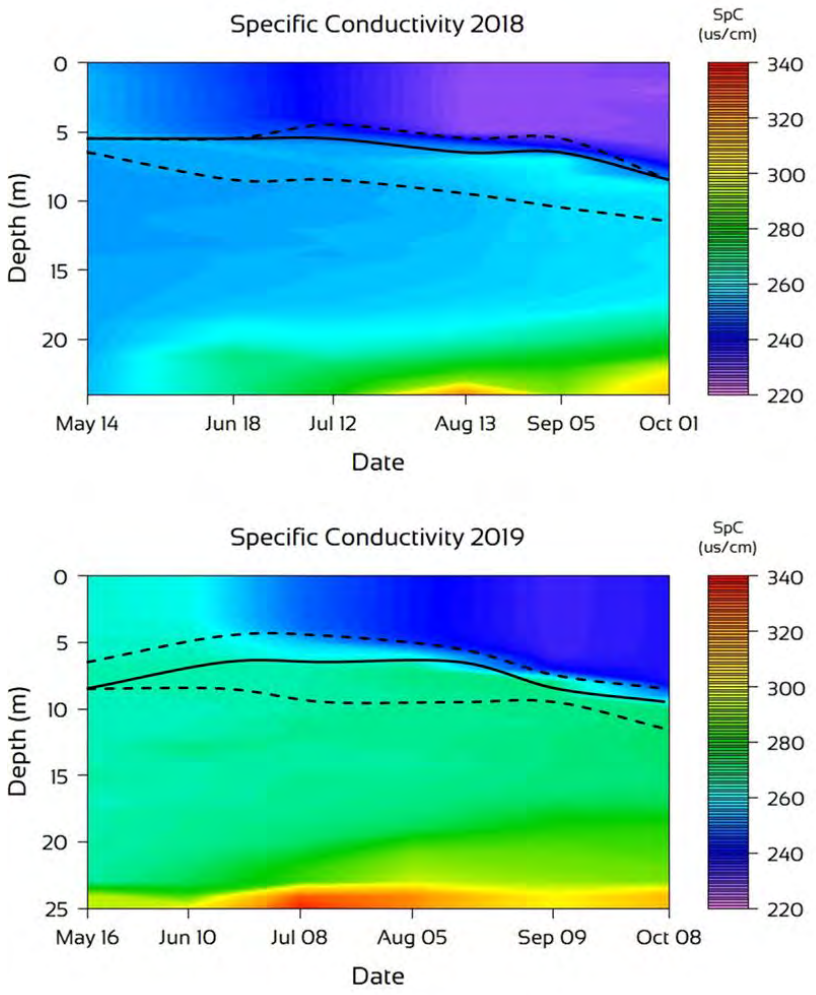

Figure 9. Specific conductance isopleths for the 2018 and 2019 season.

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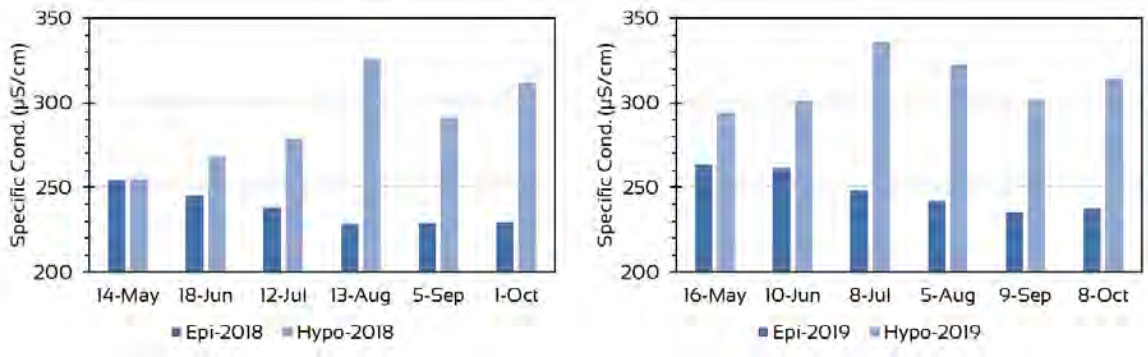

Figure 10. Epilimnetic (Epi) and hypolimnetic (Hypo) specific conductance (Specific Cond.) in the 2018 (left) and 2019 (right) seasons.

ALGAL COMMUNITY DYNAMICS

Algae concentrations at the depths of highest oxygen concentrations in both 2018 and 2019 (Fig. 2; Appendix A) were generally low between May and August, with cell concentration between 700 and 6,200 cells/mL (Fig. 11). In both season, June algae concentrations were lowest with 791 and 1,223 counted in 2018 and 2019, respectively. In 2018, only the October cell count was greater than that range with a value of 8,953 cells/mL. In 2019, the September count reached 18,471 cells/mL then decreased by October to 12,822 cells/mL.

In May of both seasons, cells from the Cyanobacteria (aka Blue-green Algae), followed by Bacillariophyta (aka diatoms), were the most abundant (Fig. 11). The filamentous Cyanobacteria *Aphanizomenon spp*. comprised 52% of all cells in May of 2018; the diatom *Fragilaria spp*. was the second most abundant genus at 15% of the total cells. In May of 2019, the Cyanobacteria *Chroococcus spp*. was the most abundant genus accounting for 70% of the total cell concentration; the diatom *Tabellaria spp*. was the second most abundant genus at 13%.

In June of 2018, diatoms comprised 70% of the algal population with *Fragilaria spp*. increasing from its May concentration to 55% while *Cyclotella spp*. became an important community constituent at 15%. Chrysophyta (aka Golden Algae) were also important in June of 2018 with the colonial *Uroglenopsis spp*. comprising 16% of the total cells. Cyanobacteria were not observed in the June 2018 sample.

The pelagic algal community of June 2019 was diverse with Cyanobacteria, diatoms and Golden Algae each comprising between 28 and 35% of the cells counted. The filamentous Cyanobacteria genus *Dolichospermum spp.* (formerly *Anabaena spp*.), the colonial diatom genus *Asterionella spp*., and the colonial Golden Algae genus *Dinobryon spp.* were the most abundant genera.

July of 2018 was similar to June of 2019 with regards to the diversity of the algal community. In July of 2018, Cyanobacteria comprised 32%, diatoms 36%, Ochrophyta 18%,

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and Golden Algae 7.5% of the algal cells. Important Cyanobacteria genera included *Microcystis spp*. and *Woronichinia spp*.; *Fragilaria spp*. and *Cyclotella spp*. continued to be the dominant diatom genera; *Dinobryon spp*. and *Uroglenopsis spp*. were the most abundant Golden Algae genera; and *Stichogloea spp*. was the most abundant genus from the Ochrophyta. Until recently, *Stichogloea spp*. was grouped with the Chrysophyta, but was taxonomically reclassified because of unique auxiliary pigment combinations. Some phycologists still consider the new Family as "proposed" and retain the original classification.

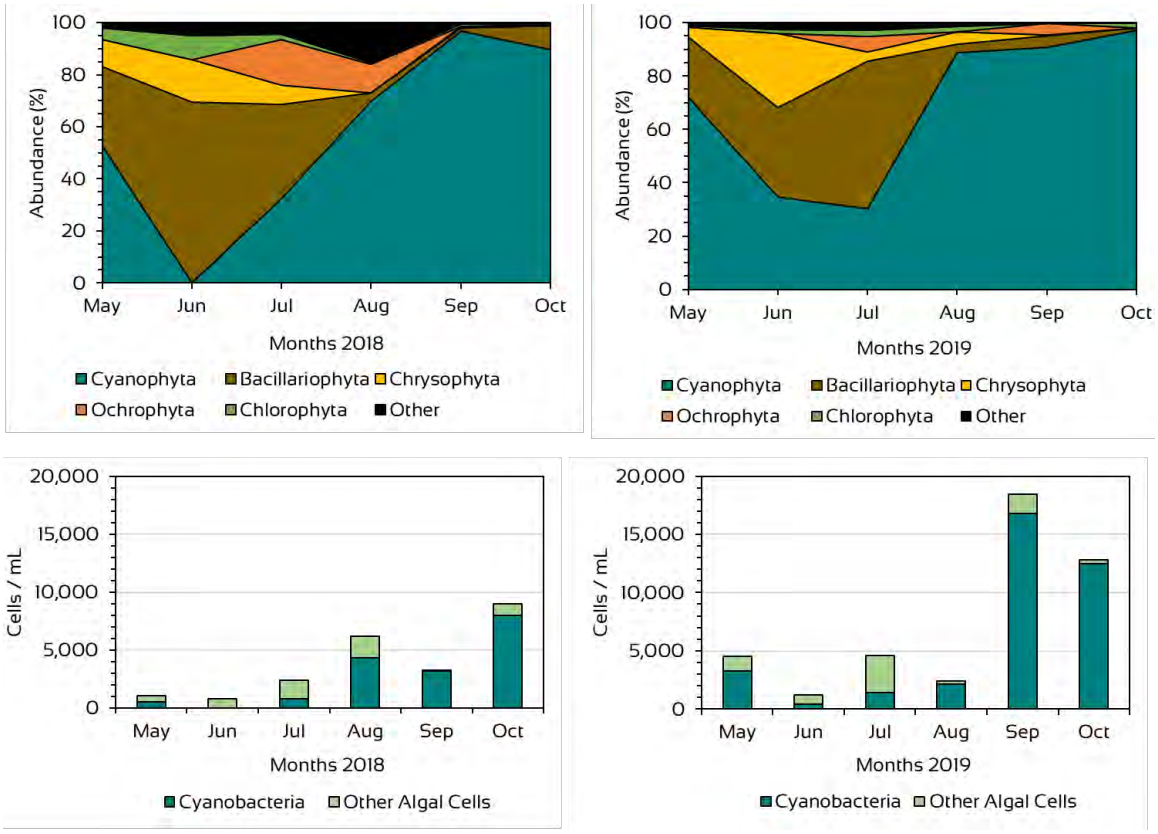

Figure 11. Relative abundance (top) and algal cell concentrations (bottom) in the 2018 (left) and 2019 (right) season at East Twin Lake.

In July of 2019, diatoms comprised 55% of the total cells with *Tabellaria spp*. and *Fragilaria spp*. being the most abundant genera. Cyanobacteria, led by *Aphanocapsa spp.* were the second most abundant taxa at 30%. The same Golden Algae and Ochrophyta genera that were observed in July of 2018 were observed in July of 2019 as well.

In August, September, and October of both 2018 and 2019, the Cyanobacteria were the dominant taxa with a relative abundance range of 70 to 97% of the total. Genera from

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other taxa counted in 2018 that was ≥10% included *Stichogloea spp*. from the Ochrophyta at 11% in August and the diatom *Asterionella spp*. in October at 10%. An unidentified genus attained 15% in August of 2018. In 2019, no genera other than those from the Cyanobacteria were ≥10% of the total August through October. The Cyanobacteria genera observed in all months from May through October of 2018 and 2019 are listed in Table 1.

Table 1. Cyanobacteria genera observed in algae count samples in the 2018 and 2019 seasons by month.

Cyanobacteria Genera	May 2018	Jun 2018	Jul 2018	Aug 2018	Sep 2018	Oct 2018
*Aphanizomenon spp.**	X					
*Aphanocapsa spp. **						
Aphanothece spp.				X	X	X
Chroococcus spp.			X	X	X	X
*Dolichospermum spp. **				X	X	X
Gomphosphaeria spp.						
*Lyngbya spp. **						
*Microcystis spp. **	X		X	X	X	X
*Pseudoanabaena spp. **						
Rhabdoderma spp.			X	X	X	X
*Snowella spp. **					X	
*Woronichinia spp. **			X	X	X	X

Cyanobacteria Genera	May 2019	Jun 2019	Jul 2019	Aug 2019	Sep 2019	Oct 2019
*Aphanizomenon spp. **	X			X	X	X
*Aphanocapsa spp. **			X	X		
Aphanothece spp.			X	X	X	
Chroococcus spp.	X	X		X		X
*Dolichospermum spp. **	X		X			
Gomphosphaeria spp.					X	
*Lyngbya spp. **		X		X	X	
*Microcystis spp. **						
*Pseudoanabaena spp. **		X				
Rhabdoderma spp.						
*Snowella spp. **				X	X	X
*Woronichinia spp. **						

*Cyanobacteria genera associate with cyanotoxin production.

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Eight of the twelve Cyanobacteria genera identified in samples from East Twin Lake have been associated with production of cyanotoxins (Bukowska 2017, CT DPH & CT DEEP 2019, iNaturalist 2019). These were *Aphanizomenon spp*., *Aphanocapsa spp*., *Dolichospermum spp*. (formerly *Anabaena spp*.), *Lyngbya spp*., *Microcystis spp*., *Pseudoanabaena spp*., *Snowella spp*. and *Woronichinia spp*. Of these, *Aphanizomenon spp*., *Microcystis spp.,* and *Woronichinia spp.* were observed four months out of the 2018 or 2019 season while the other genera were observed less frequently (Table 1). As more research is done, it is conceivable that more Cyanobacteria genera will be associated with cyanotoxin production.

In guidance developed for Health Departments in Connecticut municipalities, the State recommends thresholds of 20,000 to 100,000 cells/mL for public interventions that include increased surveillance and posting cautionary signage. At cell concentrations over 100,000 cells/mL beach closing signage is recommended (CT DPH & CT DEEP 2019). On only two occasions in the two seasons did Cyanobacteria cell concentrations exceed 10,000 cells/mL. These were both in 2019: the first was on September 9th when *Aphanocapsa spp*. was the dominant genus; the second was on October 8th when *Woronichinia spp*. was the dominant genus (Fig. 11). In both instances, cell concentrations did not exceed 20,000 cells/mL. On only the latter of the two dates were concentrations reflective of conditions near the surface where most recreational contact occurs. Samples collected from May through September of both years were from depths between 7 and 11m of depth.

HISTORICAL TRENDS

Historical trends since 2004 were analyzed in two contexts. The first strategy used pooled epilimnetic and hypolimnetic data; the second leveraged the two datasets independently. Specific variables used in analyses of nutrients included total phosphorus, total Kjeldahl nitrogen, nitrate, ammonia, alkalinity and pH. Secchi transparency data was analyzed in another set of analyses. In both contexts for nutrient variables, two statistical methods were used. First, a multiple linear regression method was employed to determine if the epilimnion, hypolimnion, and/or the entire water column – based on all the variables – had changed significantly. A p-value was calculated to determine if the null hypothesis (i.e. numbers are randomly distributed in multidimensional space) was accepted or rejected (i.e. there was a pattern in the data set that differed from random) with $p<0.05$ indicating the latter.

The second analysis performed was analysis of variance or ANOVA. ANOVA examines each variable independently to determine if that variable has changed in a statistically significant manner over time. The F-statistic is used to calculate the probability (i.e. p-value) that a dataset's variable pattern differs from a random distribution of values.

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Multiple Linear Regression

Multiple linear regression analyses using the pooled epilimnetic and hypolimnetic data suggested that there was no significant change of the nutrient and alkalinity levels in water column between 2004 to 2019 ($p>0.05$). Using epilimnetic data, there was an overall change ($p<0.05$). The variable that contributed most to the model's significance was pH. A significant change was also detected in the hypolimnion over the 15-year period ($p<0.05$). The variables exhibiting the greatest influence on the model were pH and nitrate.

ANOVA

ANOVA detected multiple variables that exibited significant change throughout the entire water column. Using pooled data, pH, total Kjeldhal nitrogen (TKN), and ammonia has significantly increased while nitrate had significantly decreased over time (Fig. 11). In the epilimnion, pH significantly increased and nitrate significantly decreased (Fig. 12). In the hypolimnion, significant increases occurred for pH, TKN, and ammonia levels, and a significant decrease occurred for nitrate (Fig. 13).

One of the variable that did not significantly change was total phosphorus. This should be viewed as a favorable outcome because it bodes well for the health of East Twin Lake.

There are several relationships between the forms of nitrogen that may explain some of the changes observed through ANOVA. Ammonia is a reduced form of nitrogen that would be included in an analysis of total Kjeldhal nitrogen (TKN). A significant increase in ammonia over time would necessitate an increase in TKN. That relationship was observed in the hypolimnetic data and the pooled epilimnetic/hypolimnetic data, but not in the epilimnetic data.

There is also a relationship between nitrate and ammonia, particularly in the hypolimnion. Once the waters above the sediments are anoxic, nitrogen compounds like nitrate are used in cellular respiration by bacteria; a product of that metabolic process is ammonia. With that in mind, it stands to reason that nitrate would go down in the hypolimnion under anoxic conditions as ammonia goes up. This relationship was observed in the pooled data and in the hypolimnetic data. In the epilimnion, nitrate, but not ammonia, significantly changed over time.

The relationships between ammonia and TKN; and, nitrate and ammonia in the pooled data was driven by the hypolimnetic data based on the lack of change in those variables in the epilimnetic dataset. We hypothesize that as East Twin Lake ages, a reduction in nitrates will coincide with biological oxygen demand. Over time, nitrates will support cellular respiration throughout anoxic periods and other compounds will be used, including iron. At that point, increases in hypolimnetic phosphorus concentration will occur because iron will be reduced to a point where phosphates are

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released fro the sediment. This already occurs in East Twin Lake (Fig. 3) but the rate of internal loading does not appear to have changed over the last 15 years.

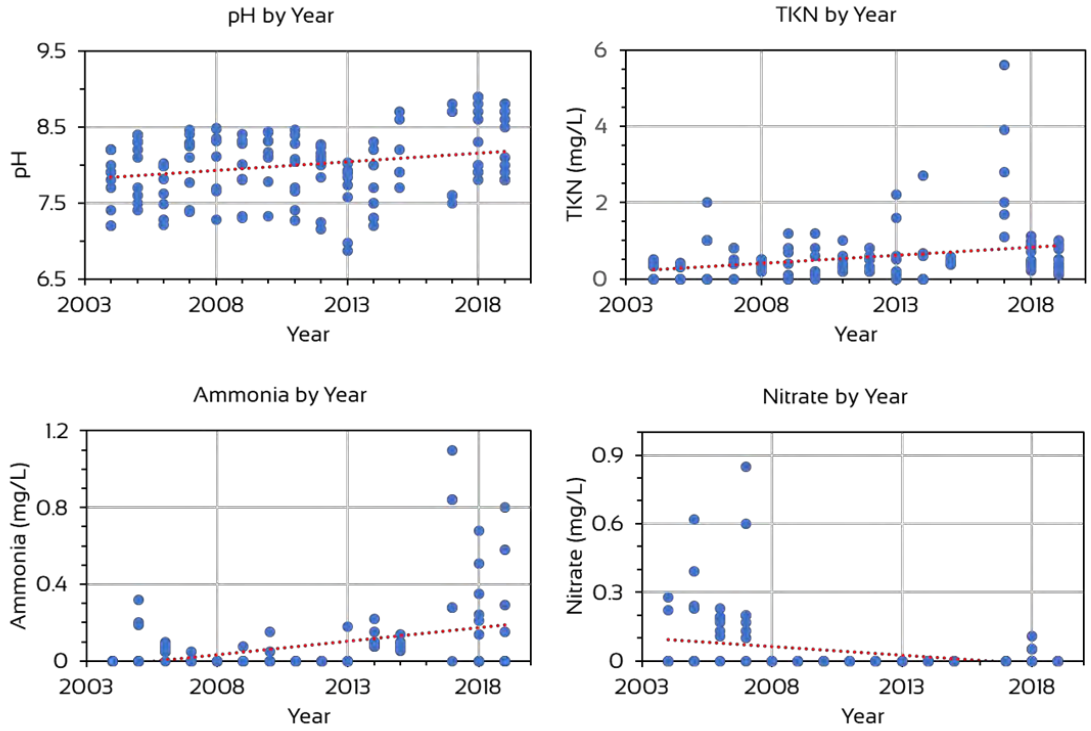

Figure 12. Regressions from ANOVA analyses of pH, total Kjeldahl nitrogen (TKN), ammonia, and nitrate concentrations measured in both the epilimnion and hypolimnion from 2004 to 2019.

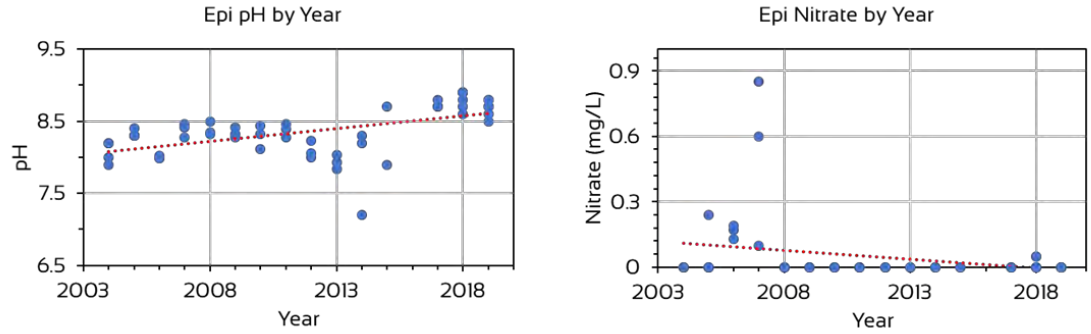

Figure 13. Regressions from ANOVA analyses of pH and nitrate concentrations measured in both the epilimnion (Epi) from 2004 to 2019.

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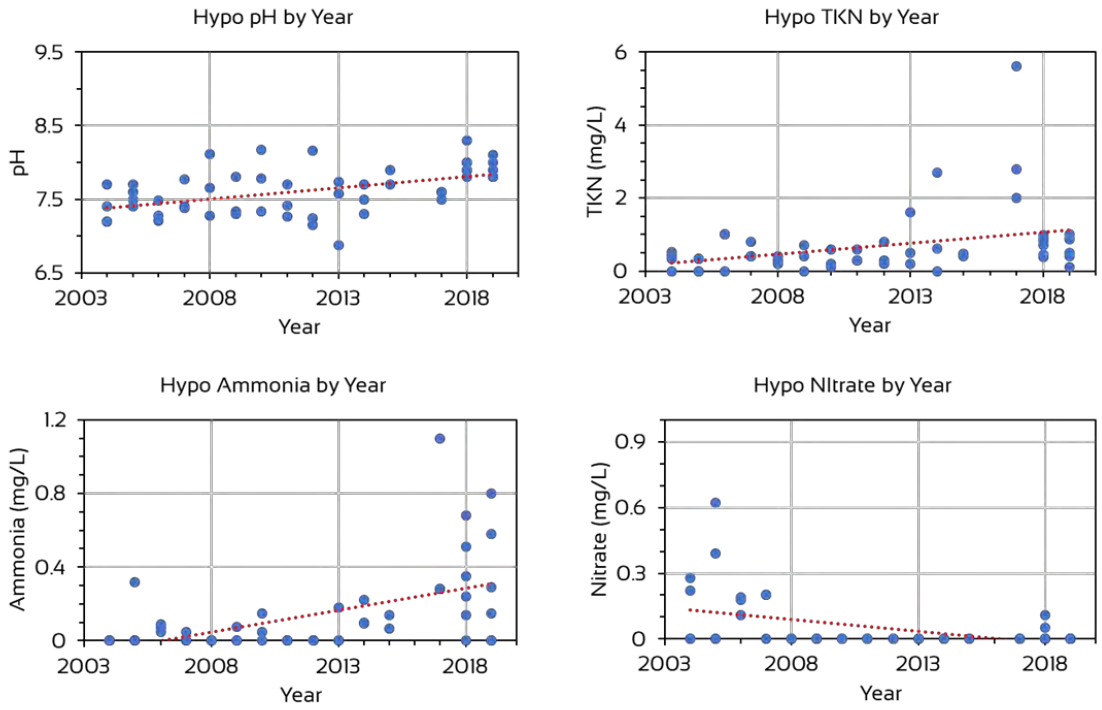

Figure 14. Regressions from ANOVA analyses of pH, total Kjeldahl nitrogen (TKN), ammonia, and nitrate concentrations measured in hypolimnion (Hypo) from 2004 to 2019.

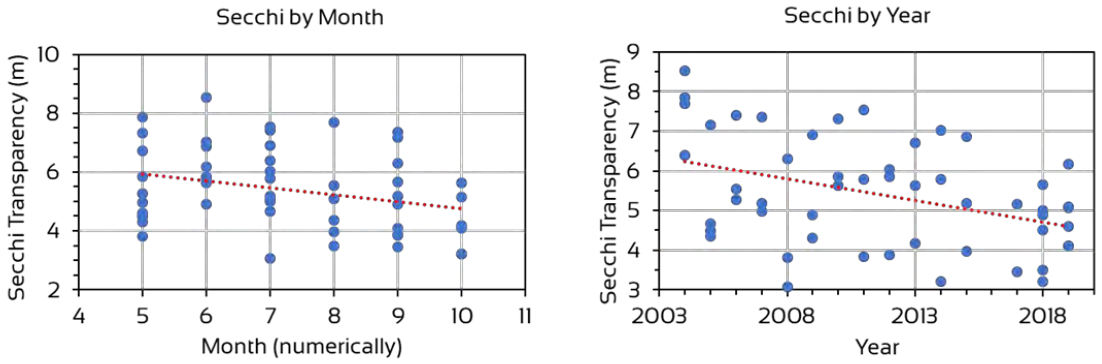

Figure 15. Regressions from ANOVA analyses of Secchi transparency data from 2004 to 2019. The regression for monthly data is on the left; the regression for annual data is on the right.

Linear regression and ANOVA were applied to Secchi data. The variables used in addition to actual Secchi disk transparency, were the season average, and the monthly average over the 15-year period.

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The linear regression analyses did result in a significant change based on the average annual Secchi transparency over time. ANOVA analyses corroborated that finding showing a significant negative (decreasing) trend in average Secchi transparency over time.

RECOMMENDATIONS

Based on the assessment of the 2018 and 2019 data, the following recommendations are presented.

1. For 2020, add an April sampling event. The fact that East Twin Lake was stratified in May in both 2018 and 2019 merits further investigation to answer the question "How soon does the lake stratify?" It is probable that 2020 will be unusual because of the very warm winter and lack of precipitation. We encourage sampling in April to understand the stratification dynamics of the lake.

2. Analyses of algae, including Cyanobacteria, have been on samples collected at the depths of highest oxygen concentrations based on past guidance by AER. These depths are typically where the highest concentrations of Cyanobacteria occur, but are not the depths were greatest recreational contact with the lake water occurs. AER has since changed its algae sampling protocols to be consistent with EPA methods to understand Cyanobacteria concentrations where human recreational contact is the greatest – near the surface. In addition, there has been reporting of algae blooms in certain coves or shorelines of the lake in the past. Given these factors, we recommend modifying the monitoring program in the following manner.

    a. Collect for algae analyses by integrating the top three meters of the water column. This can be accomplished by using the Van Dorn water sample to collect water at 1m, 2m, and 3m; emptying each into a large container (e.g. clean bucket) to integrate the sample; and then collect an integrated sample in the appropriate sample bottle and treating with Lugols Solution. Alternatively, a weighted sampling tube can be used that would collect an integrated sample to store in the sample bottle. AER can provide guidance on where to purchase a weighted tube sampler and obtain instructions on how to use it.

    b. Incorporate into the monitoring program algae counts from samples collected at the site of an algae bloom. This would be on an *as needed* basis. Samples could be collected at or near the surface from a dock, or in shallow water with waders on, then treated with Lugols Solution, and stored on ice until delivered to AER or HydroTechnologies.

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APPENDIX A. WATER QUALITY DATA

Abbreviations for nutrient data

- Alk = alkalinity
- NH4 = ammonia
- NO3 = nitrate
- NO2 = nitrite
- TKN = total Kjeldahl nitrogen
- TN = total nitrogen
- TP = total phosphorus

Abbreviations for profile data

- Temp = temperature
- DO = dissolved oxygen
- Cond = conductivity
- Spec C = specific conductance

Units

- mg/L = milligram per liter
- µg/L = microgram per liter
- µS/cm = microsiemens per centimeter
- m = meters
- °C = degrees in Celsius
- SU = standard units

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Date	Depth (m)	Alk (mg/L)	NH4 (mg/L)	NO3 (mg/L)	NO2 (mg/L)	TKN (mg/L)	TN (µg/L)	TP (ug/L)
14-May-18	1	129	0	0	0	1.12	1.12	0.027
	23	132	0	0	0	0.99	0.99	0.019

Date	Depth (m)	Alk (mg/L)	NH4 (mg/L)	NO3 (mg/L)	NO2 (mg/L)	TKN (mg/L)	TN (µg/L)	TP (ug/L)
18-Jun-18	1	114	0	0	0	0.3	0.3	0.014
	25	124	0.14	0.11	0	0.38	0.49	0.037

Date	Depth (m)	Alk (mg/L)	NH4 (mg/L)	NO3 (mg/L)	NO2 (mg/L)	TKN (mg/L)	TN (µg/L)	TP (ug/L)
12-Jul-18	1	110	0	0	0	0.42	0.42	0.021
	23.3	128	0.24	0	0	0.45	0.45	0.041

Date	Depth (m)	Alk (mg/L)	NH4 (mg/L)	NO3 (mg/L)	NO2 (mg/L)	TKN (mg/L)	TN (µg/L)	TP (ug/L)
13-Aug-18	1	105	0	0.05	0	0.22	0.27	0.018
	23	143	0.68	0.05	0	0.82	0.87	0.29

Date	Depth (m)	Alk (mg/L)	NH4 (mg/L)	NO3 (mg/L)	NO2 (mg/L)	TKN (mg/L)	TN (µg/L)	TP (ug/L)
5-Sep-18	1	106	0	0	0	0.49	0.49	0.017
	22.7	141	0.51	0	0	0.9	0.9	0.29

Date	Depth (m)	Alk (mg/L)	NH4 (mg/L)	NO3 (mg/L)	NO2 (mg/L)	TKN (mg/L)	TN (µg/L)	TP (ug/L)
1-Oct-18	1	106	0.21	0.05	0	0.4	0.45	0.005
	23.3	135	0.35	0	0	0.72	0.72	0.12

Date	Depth (m)	Alk (mg/L)	NH4 (mg/L)	TKN (mg/L)	NO3 (mg/L)	NO2 (mg/L)	TN (mg/L)	TP (mg/L)
16-May-19	1	134	0	0.18	0	0	0.18	0.003
	23.5	134	0	0.11	0	0	0.11	0.006

Date	Depth (m)	Alk (mg/L)	NH4 (mg/L)	TKN (mg/L)	NO3 (mg/L)	NO2 (mg/L)	TN (mg/L)	TP (mg/L)
10-Jun-19	1	106	0	0.79	0	0	0.79	0.011
	23.5	134	0.15	0.87	0	0	0.87	0.029

Date	Depth (m)	Alk (mg/L)	NH4 (mg/L)	TKN (mg/L)	NO3 (mg/L)	NO2 (mg/L)	TN (mg/L)	TP (mg/L)
8-Jul-19	1	118	0	0.29	0	0	0.29	0.009
	23	138	0.29	0.51	0	0	0.51	0.045

Date	Depth (m)	Alk (mg/L)	NH4 (mg/L)	TKN (mg/L)	NO3 (mg/L)	NO2 (mg/L)	TN (mg/L)	TP (mg/L)
5-Aug-19	1	90	0	0.5	0	0	0.5	0
	23	144	0.58	1	0	0	1	0.037

Date	Depth (m)	Alk (mg/L)	NH4 (mg/L)	TKN (mg/L)	NO3 (mg/L)	NO2 (mg/L)	TN (mg/L)	TP (mg/L)
9-Sep-19	1	110	0	0.3	0	0	0.3	0.028
	24.1	116	0	0.4	0	0	0.4	0.028

Date	Depth (m)	Alk (mg/L)	NH4 (mg/L)	TKN (mg/L)	NO3 (mg/L)	NO2 (mg/L)	TN (mg/L)	TP (mg/L)
8-Oct-19	1	118	0	0.2	0	0	0.2	0.012
	24.1	150	0.8	0.9	0	0	0.9	0.234

14-May-18

Depth m	Temp °C	DO mg/L	Cond µS/cm	Spec C µS/cm	pH SU
0.5	15.1	9.8	204.7	252.6	8.57
1	15	9.1	206	254.4	8.59
2	14.9	10	205.4	254.3	8.62
3	14.9	9.5	205.2	254.2	8.62
4	14.9	8.8	205	254.2	8.63
5	13.9	9.5	201.4	255.4	8.57
6	10.5	11.2	183.6	253.6	8.59
7	8.5	11.4	173.3	252.9	8.57
8	7.9	11.2	170.4	252.9	8.55
9	7.1	11.6	166.5	252.6	8.54
10	6.8	11.5	165	252.6	8.53
11	6.6	11.7	163.8	252.7	8.48
12	6.4	11.1	162.5	252.4	8.48
13	6.2	11.2	162.3	252.9	8.47
14	6	11.1	161.4	253	8.46
15	6	11.1	161	253.1	8.43
16	5.9	10.7	160.9	253.2	8.4
17	5.9	10.2	160.6	253.2	8.39
18	5.8	10.5	160.2	253.2	8.38
19	5.7	10	160	253.6	8.35
20	5.6	9.9	159.8	253.7	8.32
21	5.6	9.4	159.8	254	8.29
22	5.6	8.8	160.2	254.8	8.26
23	5.6	8.9	160.3	255	8.23

18-Jun-18

Depth m	Temp °C	DO mg/L	Cond µS/cm	Spec C µS/cm	pH SU
0.5	22.1	9.2	231.3	245.1	8.86
1	22.1	8.8	231.1	244.9	8.86
2	21.8	9.3	230.2	245.4	8.86
3	20.9	9.7	226.5	245.7	8.87
4	20.6	8.7	225	245.6	8.86
5	20.1	9.3	223.7	246.8	8.84
6	15.1	11.5	206.1	254.2	8.75
7	11.5	12.1	188.6	253.8	8.68
8	9.7	12.8	179.1	253.2	8.66
9	8.4	12.3	172.7	252.8	8.62
10	7.5	12	168.5	253	8.56
11	7.1	10.9	166.6	253.5	8.46
12	6.7	10.5	165.3	253.9	8.38
13	6.5	9.7	163.5	252.8	8.32
14	6.3	9.5	163.4	254.2	8.28
15	6.2	8.7	162.9	254.2	8.25
16	6.1	8.7	162.5	254.5	8.21
17	5.9	7.9	162	255	8.17
18	5.8	6.8	162.1	256.3	8.12
19	5.7	5	164.3	260.1	8.06
20	5.7	3.7	165.1	261.7	8.02
21	5.6	0.1	170	269.7	7.97
22	5.6	0.1	169.3	268.5	7.96
23	5.6	0.1	169.2	268.4	7.96

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12-Jul-18

Depth m	Temp °C	DO mg/L	Cond µS/cm	Spec C µS/cm	pH SU
0.5	26.6	7.6	245.3	238.3	8.81
1	26.6	7.2	245.3	238.1	8.82
2	26.6	7.2	245.5	238.4	8.82
3	26.5	6.5	245.3	238.3	8.83
4	26.5	7.6	245.3	238.3	8.84
5	22.6	8.1	233.5	244.4	8.84
6	17.5	12.4	216.8	253.1	8.86
7	13.4	12.4	197.8	254.2	8.8
8	11.2	12.6	186.9	253.8	8.73
9	9.1	12.7	176.2	253.1	8.63
10	8.1	11.3	171.7	253.7	8.53
11	7.4	11.3	168.3	253.4	8.47
12	7	10.5	166.9	254.1	8.38
13	6.7	10.1	165.4	254.1	8.32
14	6.5	10	164.3	253.8	8.29
15	6.4	7.6	164.2	255.1	8.22
16	6.1	7.2	163.3	255.3	8.14
17	6	6.1	162.8	255.6	8.12
18	5.9	5.4	162.7	256.5	8.09
19	5.8	2.8	163.8	259	8.02
20	5.7	1.3	164.7	260.8	7.98
21	5.7	0.1	166.9	264.6	7.95
22	5.6	0.1	171.6	272.5	7.93
23	5.6	0.1	174	276.4	7.93
24	5.6	0.1	175.8	279.2	7.94

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13-Aug-18

Depth m	Temp °C	DO mg/L	Cond µS/cm	Spec C µS/cm	pH SU
0.5	26.4	6.8	235.1	228.9	
1	26.4	7.4	234.8	228.6	
2	26.4	7.5	234.7	228.5	
3	26.4	6.8	234.7	228.5	
4	26.4	7.3	234.7	228.5	
5	26.4	7.1	234.7	228.6	
6	22.3	9.4	236.1	249	
7	16.6	11.5	217.5	258.8	
8	13	11.4	197.5	256.5	
9	10.7	12.1	185.2	255.1	
10	9	11.4	177.1	254.7	
11	8	10.6	171.8	254.7	
12	7.3	9	168.9	255	
13	6.9	7.4	167.2	255.7	
14	6.6	6.6	165.7	255.7	
15	6.4	6.1	164.7	255.8	
16	6.2	5.2	164.2	256.3	
17	6.1	4.2	163.9	256.9	
18	5.9	2.4	164.3	258.4	
19	5.8	0.7	165	260.2	
20	5.8	0.1	167.4	264.5	
21	5.7	0.1	171.7	271.7	
22	5.7	0.1	176.9	280.3	
23	5.7	0.1	183.8	291.5	
24	5.6	0.1	205.2	325.8	

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5-Sep-18

Depth m	Temp °C	DO mg/L	Cond µS/cm	Spec C µS/cm	pH SU
0.5	26.2	6.8	234.2	228.9	8.89
1	26.2	6.3	234.2	228.9	8.9
2	26.2	6.7	234.1	228.9	8.91
3	26.1	6.4	233.7	228.9	8.91
4	25.5	6	230.5	228.2	8.93
5	25.3	6.4	230.1	228.8	8.92
6	23.7	6.5	232.8	238.5	8.79
7	17.9	10.3	225.8	261.3	8.73
8	13.7	10.2	203.1	259.2	8.6
9	11.1	9.9	190.2	259.1	8.54
10	9.5	9.6	180.9	256.9	8.44
11	8.3	8.1	175.4	257.3	8.36
12	7.7	6.9	172.1	257.3	8.28
13	7.1	6.8	169.1	256.8	8.22
14	6.8	5	168	257.4	8.13
15	6.6	4.6	166.9	257.3	8.08
16	6.4	4.1	165.8	257.4	8.06
17	6.2	3	165.5	258	8.01
18	6	1.5	165.3	259.1	7.98
19	5.9	0.1	168.2	265.1	7.94
20	5.8	0.1	170.4	268.9	7.93
21	5.8	0.1	175	276.6	7.92
22	5.7	0.1	178.1	281.8	7.91
23	5.7	0.1	181.2	286.9	7.89
24	5.7	0.1	183.7	290.9	7.87

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1-Oct-18

Depth m	Temp °C	DO mg/L	Cond µS/cm	Spec C µS/cm	pH SU
0.5	18.9	8.7	202.7	229.2	8.7
1	18.9	8.6	202.7	229.3	8.72
2	18.9	8.6	200.9	227.3	8.73
3	18.9	8.5	202.4	229.3	8.73
4	18.9	8.6	202.4	229.3	8.73
5	18.9	8	202.4	229.3	8.73
6	18.8	8.3	202.8	229.8	8.73
7	18.6	8	206.3	235.1	8.66
8	17.6	7.2	212.6	247.7	8.42
9	12.1	7.9	195.5	259.4	8.33
10	10.5	7.6	186.7	258.2	8.27
11	9.2	6.9	180.1	257.9	8.2
12	8	5.4	174	257.7	8.15
13	7.3	2.9	171	258.3	8.06
14	6.9	2.2	169.2	258.3	8.01
15	6.7	2.3	167.8	258.1	7.97
16	6.5	2	167.5	258.9	7.94
17	6.3	0.3	166.4	259.2	7.91
18	6.1	0.1	169.3	264.6	7.87
19	6	0.1	171.1	268.8	7.83
20	5.9	0.1	175.3	276.1	7.79
21	5.8	0.1	178.3	281.3	7.77
22	5.8	0.1	187.9	296.5	7.7
23	5.8	0.1	193.5	305.4	7.69
24	5.8	0.1	197.6	311.8	7.68

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16-May-19

Depth m	Temp °C	DO mg/L	Cond µS/cm	Spec C µS/cm	pH SU
0.5	13.5	10.2	205.7	263.8	8.47
1	13.4	10.1	205.5	263.8	8.5
2	13.3	10.4	204.8	263.9	8.49
3	13.1	10.3	203.8	263.6	8.52
4	13.1	10.2	203.6	263.7	8.51
5	12.7	10.2	202.2	264.2	8.52
6	12.6	9.9	202.2	264.9	8.52
7	11.3	10.9	196.8	266.5	8.47
8	10.3	11.2	191.9	266.8	8.35
9	8.9	11.4	183.4	265.1	8.45
10	8	11.5	179	265.4	8.4
11	7.5	11	176.6	265.3	8.35
12	7.1	10.9	174.8	265.6	8.32
13	7	10.6	174.1	265.6	8.29
14	6.7	10.7	172.8	265.7	8.23
15	6.5	10.3	172.9	267.7	8.22
16	6.2	10.2	170.3	266	8.17
17	6.1	10	169.3	264.9	8.14
18	5.9	9	169.5	266.7	8.11
19	5.9	8.9	169.3	266.7	8.07
20	5.8	8.5	169.2	266.9	8.05
21	5.8	8.1	169.2	267.1	8.03
22	5.8	8.1	169.2	267.2	8.03
23	5.8	8	169.2	267.3	8.04
24	5.7	0.4	185.7	294.5	7.84

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10-Jun-19

Depth m	Temp °C	DO mg/L	Cond µS/cm	Spec C µS/cm	pH SU
0.5	22	7.8	246.6	261.6	8.74
1	22	8.2	246.3	261.3	8.76
2	21.9	8.5	246.1	261.5	8.77
3	21.9	7.4	245.9	261.6	8.78
4	20.9	7.9	242.8	263.3	8.78
5	19	8.8	234.3	264.5	8.75
6	17.4	9.1	227.2	265.8	8.73
7	14.2	10.2	211.8	267.1	8.7
8	11.6	11.3	198.1	266.5	8.65
9	10	11.2	190.1	266.2	8.57
10	9.2	11.3	185	265.2	8.46
11	8.3	10.9	180.7	265.7	8.37
12	7.8	10.2	178.5	266.2	8.28
13	7.2	9.2	178.1	269.9	8.19
14	7	9	174.8	266.6	8.13
15	6.6	8.3	173	266.8	8.08
16	6.4	8.5	172	266.5	8.05
17	6.3	7.3	171.8	267.1	8.02
18	6.2	6.5	171.7	268.1	7.99
19	6.1	6.5	171.4	268.2	7.97
20	6.1	6.2	171.3	268.5	7.98
21	6	5.5	171.6	269.4	7.97
22	5.9	4.5	172.7	271.6	7.96
23	5.9	3.6	173.8	273.6	7.95
24	5.9	2.7	180	283.5	7.93
25	5.8	0.2	191	301.3	7.81

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8-Jul-19

Depth m	Temp °C	DO mg/L	Cond µS/cm	Spec C µS/cm	pH SU
0.5	26.3	7.6	254.7	248.3	8.81
1	26.4	7.6	254.8	248.4	8.84
2	26.4	6.9	254.8	248.3	8.85
3	26.4	7	254.7	248.3	8.86
4	26.2	7.3	255	249.1	8.87
5	23.9	9.1	250.9	256.2	8.88
6	21.6	9.3	243.7	260.4	8.85
7	17.3	10.7	227.4	266.7	8.81
8	13.9	11.9	210	266.8	8.78
9	11	11.7	195.5	267.1	8.71
10	9.5	11.1	188	267.1	8.57
11	8.7	10.9	184.8	268.5	8.48
12	7.8	9	179.9	268.3	8.34
13	7.4	8.1	177.6	267.3	8.24
14	7.1	7.2	176.3	267.7	8.12
15	6.8	6	174.8	268.2	8.03
16	6.5	5.6	173.9	268.7	7.96
17	6.4	5.2	172.9	268.5	7.91
18	6.3	4.3	172.7	269.1	7.88
19	6.1	2.8	172.8	270.3	7.85
20	6.1	0.9	173.4	271.6	7.82
21	6	0.2	176.6	277.2	7.81
22	6	0.2	179.7	282.4	7.81
23	5.9	0.2	180.7	284.1	7.81
24	5.9	0.2	208.7	328.5	7.78
25	5.9	0.2	213.1	335.9	7.78

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5-Aug-19

Depth m	Temp °C	DO mg/L	Cond µS/cm	Spec C µS/cm	pH SU
0.5	26.7	7.5	250	241.9	8.86
1	26.7	6.9	249.9	241.9	8.87
2	26.7	6.4	249.8	241.8	8.87
3	26.7	7	249.8	241.8	8.88
4	26.7	7.1	249.4	241.6	8.88
5	26.5	6.9	250.4	243.6	8.86
6	23.6	8.3	253.9	260.9	8.85
7	18.6	9.6	236.5	269.5	8.82
8	15.3	10.5	219.8	269.4	8.77
9	12.4	10.7	203.7	268	8.71
10	9.8	9.8	190.8	268.7	8.61
11	8.8	9	184.8	267.9	8.51
12	8.2	7.6	182.2	268.4	8.36
13	7.7	6.2	179.7	268.7	8.25
14	7.2	5	176.5	267.3	8.15
15	6.9	5.2	175.7	268.3	8.06
16	6.7	3.6	174.9	269.1	7.96
17	6.4	1.7	174.1	269.9	7.89
18	6.3	0.3	173.9	270.7	7.85
19	6.2	0.2	175.5	273.8	7.82
20	6	0.3	180.2	282.5	7.81
21	6	0.3	184.2	289.1	7.8
22	6	0.3	185.8	291.9	7.8
23	6	0.3	188.1	295.7	7.8
24	5.9	0.3	205.1	322.7	7.78

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9-Sep-19

Depth m	Temp °C	DO mg/L	Cond µS/cm	Spec C µS/cm	pH SU
0.5	21.6	8.4	219.9	235.2	8.81
1	21.6	8.3	219.9	235.2	8.84
2	21.6	8.4	219.8	235.2	8.86
3	21.6	7.7	219.8	235.2	8.86
4	21.6	7.8	219.8	235.3	8.88
5	21.5	7.7	219.8	235.4	8.88
6	21.5	8.3	219.9	235.5	8.89
7	21	8.1	222.5	240.9	8.85
8	17.5	9	231.9	270.4	8.72
9	13.6	10.2	210.7	269.4	8.68
10	10.7	8.8	196	269.5	8.59
11	9.6	7.6	190.1	269.1	8.47
12	8.6	5.6	185.6	270	8.33
13	7.9	4.6	181.7	270	8.22
14	7.4	3.3	179.3	270	8.13
15	7.1	1.9	177.9	270.3	8.02
16	6.9	0.8	176.9	270.5	7.96
17	6.6	0.3	177.1	273.1	7.92
18	6.3	0.3	179	278.3	7.86
19	6.2	0.3	180.6	281.7	7.83
20	6.2	0.3	182.5	285.1	7.8
21	6.1	0.3	184	287.8	7.78
22	6.1	0.3	184.7	289.1	7.78
23	6.1	0.3	186.1	291.6	7.77
24	6	0.3	191.8	300.8	7.76
25	6	0.3	192.4	301.6	7.76

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8-Oct-19

Depth m	Temp °C	DO mg/L	Cond µS/cm	Spec C µS/cm	pH SU
0.5	17.5	8.4	203.7	237.6	8.68
1	17.5	7.6	203.6	237.5	8.7
2	17.5	8.1	203.6	237.5	8.71
3	17.5	7.9	203.6	237.5	8.71
4	17.5	7.6	203.6	237.5	8.71
5	17.5	7.7	203.7	237.5	8.72
6	17.5	8.3	203.7	237.6	8.72
7	17.5	7.9	203.6	237.6	8.72
8	17.5	7.9	203.9	238	8.73
9	16.3	6.9	210.2	252	8.58
10	12.7	7.1	207.1	270.9	8.49
11	10.4	5.5	195.4	271.2	8.22
12	9	3.5	188.7	271.5	8.14
13	8.2	1.8	184.6	271.7	8.09
14	7.7	1	181.9	271.3	8.05
15	7.4	0.6	179.7	270.9	8.02
16	7.1	0.3	179	271.7	7.98
17	6.9	0.3	179.1	273.4	7.98
18	6.5	0.3	180.1	278.5	7.91
19	6.4	0.3	182.2	283	7.87
20	6.3	0.3	182.7	284.2	7.85
21	6.3	0.3	183.4	285.5	7.83
22	6.2	0.3	184.7	288.1	7.8
23	6.2	0.3	185.4	289.4	7.82
24	6.1	0.3	201.1	314.2	7.7

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APPENDIX B. ALGAE DATA

		May 14, 2018			June 18, 2018		
Taxa	Genus / species	Cells / mL	%	Taxa %	Cells / mL	%	Taxa %
Cyanophyta	*Aphanizomenon sp.*	537	52.1	52.1	0	0.0	0
	Aphanothece sp.	0	0.0		0	0.0	
	Chroococcus sp.	0	0.0		0	0.0	
	Dolichospermum sp.	0	0.0		0	0.0	
	Microcystis sp.	4	0.3		0	0.0	
	Rhabdoderma sp.	0	0.0		0	0.0	
	Snowella sp.	0	0.0		0	0.0	
	Woronichinia sp.	0	0.0		0	0.0	
Chlorophyta	*Anikistrodesmus sp.*	0	0.0	4.4	0	0.0	9
	Dictyosphaerium sp.	0	0.0		71	9.0	
	Elakatothrix sp.	0	0.0		0	0.0	
	Gloeocystis sp.	0	0.0		0	0.0	
	Oocystis sp.	0	0.0		0	0.0	
	Scenedesmus sp.	4	0.3		0	0.0	
	Selenastrum sp.	4	0.3		0	0.0	
	Tetraedron sp.	39	3.8		0	0.0	
Chrysophyta	*Dinobryon sp.*	11	1.0	10.3	0	0.0	16.1
	Mallomonas sp.	11	1.0		0	0.0	
	Synura sp.	7	0.7		0	0.0	
	Uroglenopsis sp.	78	7.6		127	16.1	
Ochrophyta	*Stichogloea sp.*	0	0.0		0	0.0	
Bacillariophyta	*Asterionella sp.*	53	5.2	30.4	0	0.0	69.5
	Cyclotella sp.	85	8.3		116	14.6	
	Fragilaria sp.	160	15.5		435	54.9	
	Rhizosolenia sp.	0	0.0		0	0.0	
	Synedra sp.	7	0.7		0	0.0	
	Tabellaria sp.	0	0.0		0	0.0	
	Pennate Diatom	7	0.7		0	0.0	
Pyrrhophyta	*Ceratium sp.*	0	0.0	0.3	2	0.3	0.6
	Glenodinium sp.	0	0.0		0	0.0	
	Gynmodinium sp.	4	0.3		2	0.3	
Cryptophyta	*Cryptomonas ovata*	0	0.0	0	0	0.0	4.5
	Rhodomonas sp.	0	0.0		36	4.5	
Euglenophyta	*Euglena sp.*	0	0.0	0.3	0	0.0	0
	Trachelomonas sp.	4	0.3		0	0.0	
	Unknown	18	1.7	1.7	0	0.0	0
	Totals	1032	100	100	791	100	100

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		July 12, 2018			August 13, 2018		
Taxa	Genus / species	Cells / mL	%	Taxa %	Cells / mL	%	Taxa %
Cyanophyta	*Aphanizomenon sp.*	0	0.0	32.2	0	0.0	69.9
	Aphanothece sp.	0	0.0		2050	33.2	
	Chroococcus sp.	120	5.1		72	1.2	
	Dolichospermum sp.	0	0.0		269	4.4	
	Microcystis sp.	431	18.3		460	7.4	
	Rhabdoderma sp.	25	1.0		26	0.4	
	Snowella sp.	0	0.0		0	0.0	
	Woronichinia sp.	185	7.8		1439	23.3	
Chlorophyta	*Anikistrodesmus sp.*	0	0.0	1.9	0	0.0	0.4
	Dictyosphaerium sp.	0	0.0		0	0.0	
	Elakatothrix sp.	0	0.0		0	0.0	
	Gloeocystis sp.	12	0.5		0	0.0	
	Oocystis sp.	34	1.4		26	0.4	
	Scenedesmus sp.	0	0.0		0	0.0	
	Selenastrum sp.	0	0.0		0	0.0	
	Tetraedron sp.	0	0.0		0	0.0	
Chrysophyta	*Dinobryon sp.*	59	2.5	7.4	0	0.0	0.0
	Mallomonas sp.	3	0.1		0	0.0	
	Synura sp.	31	1.3		0	0.0	
	Uroglenopsis sp.	83	3.5		0	0.0	
Ochrophyta	*Stichogloea sp.*	413	17.5	17.5	677	11.0	11.0
Bacillariophyta	*Asterionella sp.*	43	1.8	36.3	0	0.0	3.2
	Cyclotella sp.	203	8.6		53	0.9	
	Fragilaria sp.	598	25.4		0	0.0	
	Rhizosolenia sp.	0	0.0		145	2.3	
	Synedra sp.	3	0.1		0	0.0	
	Tabellaria sp.	9	0.4		0	0.0	
	Pennate Diatom	0	0.0		0	0.0	
Pyrrhophyta	*Ceratium sp.*	0	0.0	0.1	0	0.0	0.0
	Glenodinium sp.	3	0.1		0	0.0	
	Gynmodinium sp.	0	0.0		0	0.0	
Cryptophyta	*Cryptomonas ovata*	6	0.3	1.9	7	0.1	0.1
	Rhodomonas sp.	37	1.6		0	0.0	
Euglenophyta	*Euglena sp.*	0	0.0	0	0	0.0	0.1
	Trachelomonas sp.	0	0.0		7	0.1	
	Unknown	59	2.5	2.5	946	15.3	15.3
	Totals	2356	100	100	6176	100	100

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		September 5, 2018			October 1, 2018		
Taxa	Genus / species	Cells / mL	%	Taxa %	Cells / mL	%	Taxa %
Cyanophyta	*Aphanizomenon sp.*	0	0.0	96.7	0	0.0	
	Aphanothece sp.	650	19.9		2020	22.6	
	Chroococcus sp.	520	15.9		1174	13.1	
	Dolichospermum sp.	44	1.4		7	0.1	
	Microcystis sp.	221	6.8		7	0.1	
	Rhabdoderma sp.	396	12.1		426	4.8	
	Snowella sp.	106	3.2		0	0.0	
	Woronichinia sp.	1225	37.5		4323	48.3	
Chlorophyta	*Anikistrodesmus sp.*	0	0.0	0.8	0	0.0	0.3
	Dictyosphaerium sp.	0	0.0				
	Elakatothrix sp.	6	0.2		0	0.0	
	Gloeocystis sp.	0	0.0		0	0.0	89.6
	Oocystis sp.	21	0.6		0	0.0	
	Scenedesmus sp.	0	0.0		30	0.3	
	Selenastrum sp.	0	0.0		0	0.0	
	Tetraedron sp.	0	0.0		0	0.0	
Chrysophyta	*Dinobryon sp.*	0	0.0	0.5	0	0.0	0.1
	Mallomonas sp.	3	0.1		7	0.1	
	Synura sp.	0	0.0		0	0.0	
	Uroglenopsis sp.	15	0.5		7	0.1	
Ochrophyta	*Stichogloea sp.*	0	0.0	0.0	60	0.7	0.7
Bacillariophyta	*Asterionella sp.*	0	0.0	1.4	0	0.0	9.7
	Cyclotella sp.	0	0.0		7	0.1	
	Fragilaria sp.	41	1.3		853	9.5	
	Rhizosolenia sp.	0	0.0		0	0.0	
	Synedra sp.	3	0.1		0	0.0	
	Tabellaria sp.	0	0.0		0	0.0	
	Pennate Diatom	0	0.0		0	0.0	
Pyrrhophyta	*Ceratium sp.*	0	0.0	0.0	7	0.1	0.1
	Glenodinium sp.	0	0.0		0	0.0	
	Gynmodinium sp.	0	0.0		0	0.0	
Cryptophyta	*Cryptomonas ovata*	3	0.1	0.1	7	0.1	0.2
	Rhodomonas sp.	0	0.0		7	0.1	
Euglenophyta	*Euglena sp.*	0	0.0	0.1	0	0.0	0.1
	Trachelomonas sp.	3	0.1		7	0.1	
	Unknown	15	0.5	0.5	0	0.0	0.0
	Totals	3272	100	100	8953	100	100

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		16-May-19			10-Jun-19		
Taxa	*Genus / species*	Cells / mL	%	Taxa %	Cells / mL	%	Taxa %
Cyanophyta	*Aphanizomenon sp.*	4	0.1	72.1	0	0.0	34.5
	Aphanothece sp.	0	0.0		0	0.0	
	Chroococcus sp.	3185	70.4		0	0.0	
	Dolichospermum sp.	72	1.6		331	27.1	
	Microcystis sp.	0	0.0		3	0.2	
	Pseudoanabaena sp	0	0.0		88	7.2	
	Rhabdoderma sp.	0	0.0		0	0.0	
	Woronichinia sp.	0	0.0		0	0.0	
Chlorophyta	*Anikistrodesmus sp.*	0	0.0	0.4	0	0.0	1.4
	Elakatothrix sp.	0	0.0		0	0.0	
	Gloeocystis sp.	0	0.0		12	1.0	
	Oocystis sp.	0	0.0		0	0.0	
	Scenedesmus sp.	4	0.1		6	0.5	
	Schroederia sp.	16	0.4		0	0.0	
	Sphaerocystis sp.	0	0.0		0	0.0	
	Tetraedron sp.	0	0.0		0	0.0	
Chrysophyta	*Dinobryon sp.*	0	0.0	4.0	241	19.7	27.8
	Mallomonas sp.	4	0.1		3	0.2	
	Synura sp.	0	0.0		3	0.2	
	Uroglenopsis sp.	175	3.9		94	7.7	
Ochrophyta	*Stichogloea sp.*	0	0.0		0	0.0	
Bacillariophyta	*Asterionella sp.*	0	0.0	22.4	261	21.3	33.6
	Aulocoseria sp.	4	0.1		0	0.0	
	Cyclotella sp.	64	1.4		6	0.5	
	Fragilaria sp.	0	0.0		12	1.0	
	Stephanodiscus sp.	207	4.6		6	0.5	
	Synedra sp.	135	3.0		3	0.2	
	Tabellaria sp.	601	13.3		123	10.1	
Pyrrhophyta	*Ceratium sp.*	0	0.0	0.3	3	0.2	1.0
	Glenodinium sp.	0	0.0		3	0.2	
	Gynmodinium sp.	12	0.3		3	0.2	
	Peridinium sp.	0	0.0		3	0.2	
Cryptophyta	*Cryptomonas sp.*	4	0.1	0.1	6	0.5	0.5
Euglenophyta	*Euglena sp.*	0	0.0	0.1	0	0.0	0.0
	Trachelomonas sp.	4	0.1		0	0.0	
	Unknown	32	0.7	0.7	15	1.2	1.2
	Totals	4522	100	100	1223	100	100

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		8-Jul-19			5-Aug-19		
Taxa	*Genus / species*	Cells / mL	%	Taxa %	Cells / mL	%	Taxa %
Cyanophyta	*Aphanizomenon sp.*	0	0.0	30.4	0	0.0	88.7
	Aphanocapsa sp.	0	0.0		941	39.1	
	Aphanothece sp.	1336	28.9		337	14.0	
	Chroococcus sp.	61	1.3		244	10.2	
	Dolichospermum sp.	0	0.0		3	0.1	
	Gomphosphaeria sp.	6	0.1		0	0.0	
	Microcystis sp.	0	0.0		3	0.1	
	Pseudoanabaena sp	0	0.0		0	0.0	
	Rhabdoderma sp.	0	0.0		11	0.5	
	Woronichinia sp.	0	0.0		595	24.7	
Chlorophyta	*Anikistrodesmus sp.*	0	0.0	2.2	3	0.1	2.1
	Elakatothrix sp.	0	0.0		0	0.0	
	Gloeocystis sp.	91	2.0		11	0.5	
	Oocystis sp.	6	0.1		25	1.1	
	Scenedesmus sp.	0	0.0		0	0.0	
	Schroederia sp.	0	0.0		0	0.0	
	Sphaerocystis sp.	0	0.0		11	0.5	
	Tetraedron sp.	6	0.1		0	0.0	
Chrysophyta	*Dinobryon sp.*	73	1.6	3.5	0	0.0	4.7
	Mallomonas sp.	0	0.0		70	2.9	
	Uroglenopsis sp.	91	2.0		42	1.8	
Ochrophyta	*Stichogloea sp.*	273	5.9	5.9	0	0.0	0.0
Bacillariophyta	*Asterionella sp.*	0	0.0	55.1	0	0.0	3.2
	Aulocoseria sp.	0	0.0		0	0.0	
	Cyclotella sp.	61	1.3		20	0.8	
	Fragilaria sp.	492	10.6		37	1.5	
	Synedra sp.	0	0.0		6	0.2	
	Tabellaria sp.	1992	43.1		14	0.6	
Pyrrhophyta	*Ceratium sp.*	6	0.1	0.3	3	0.1	0.1
	Glenodinium sp.	0	0.0		0	0.0	
	Gynmodinium sp.	6	0.1		0	0.0	
	Peridinium sp.	0	0.0		0	0.0	
Cryptophyta	*Cryptomonas sp.*	67	1.4	1.4	3	0.1	0.1
Euglenophyta	*Euglena sp.*	0	0.0	0.1	0	0.0	0.4
	Trachelomonas sp.	6	0.1		8	0.4	
	Unknown	43	0.9	0.9	20	0.8	0.8
	Totals	4621	100	100	2407	100	100

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		9-Sep-19			8-Oct-19		
Taxa	*Genus / species*	Cells / mL	%	Taxa %	Cells / mL	%	Taxa %
Cyanophyta	*Aphanizomenon sp.*	0	0.0	90.9	0	0.0	97.2
	Aphanocapsa sp.	12610	68.3		1185	9.2	
	Chroococcus sp.	17	0.1		0	0.0	
	Dolichospermum sp.	0	0.0		391	3.0	
	Microcystis sp.	2114	11.4		0	0.0	
	Rhabdoderma sp.	51	0.3		0	0.0	
	Woronichinia sp.	1987	10.8		10890	84.7	
Chlorophyta	*Anikistrodesmus sp.*	0	0.0	0.1	0	0.0	1.7
	Gloeocystis sp.	0	0.0		95	0.7	
	Oocystis sp.	17	0.1		119	0.9	
	Scenedesmus sp.	0	0.0		0	0.0	
	Schroederia sp.	0	0.0		0	0.0	
	Sphaerocystis sp.	0	0.0		0	0.0	
	Tetraedron sp.	0	0.0		0	0.0	
Chrysophyta	*Dinobryon sp.*	0	0.0	0.1	0	0.0	0.0
	Mallomonas sp.	8	0.0		0	0.0	
	Synura sp.	0	0.0		0	0.0	
	Uroglenopsis sp.	17	0.1		36	0.3	
Ochrophyta	*Stichogloea sp.*	812	4.4	4.4	0	0.0	
Bacillariophyta	*Asterionella sp.*	0	0.0	4.3	0	0.0	0.7
	Aulocoseria sp.	0	0.0		0	0.0	
	Cyclotella sp.	17	0.1		0	0.0	
	Fragilaria sp.	617	3.3		12	0.1	
	Stephanodiscus sp.	0	0.0		0	0.0	
	Synedra sp.	8	0.0		0	0.0	
	Tabellaria sp.	152	0.8		83	0.6	
Pyrrhophyta	*Ceratium sp.*	8	0.0	0.1	24	0.2	0.2
	Glenodinium sp.	0	0.0		0	0.0	
	Gynmodinium sp.	8	0.0		0	0.0	
	Peridinium sp.	0	0.0		0	0.0	
Cryptophyta	*Cryptomonas sp.*	0	0.0	0.0	12	0.1	0.1
	Rhodomonas sp.	0	0.0		0	0.0	
Euglenophyta	*Euglena sp.*	0	0.0	0.0	0	0.0	0.0
	Trachelomonas sp.	8	0.0		0	0.0	
	Unknown	0	0.0	0.0	12	0.1	0.1
	Totals	18471	100	100	12858	100	100

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APPENDIX C. STATISTICAL ANALYSES

Multiple Linear Regression Nutrients by Year				
	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	1998.2	66.6068	30	8.14E-05
nut$pH	4.98724	3.38115	1.475	0.237
nut$Alkalinity	-0.0181	0.22473	-0.08	0.941
nut$TKN	11.969	7.98908	1.498	0.231
nut$NH4	46.1631	27.4951	1.679	0.192
nut$NO3	-21.269	31.0049	-0.686	0.542
nut$Tphos	-146.36	189.204	-0.774	0.496
F	3.941			
R	0.74			
p	0.1415	<--	No overall change	

MultipleLinear Regression Nutrients by Year in Epilimnion				
	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	1946.22	25.0485	77.698	< 2e-16
epi$pH	9.50208	2.50439	3.794	**0.00084**
epi$Alkalinity	-0.1031	0.09686	-1.064	0.29745
epi$TKN	1.95567	1.86533	1.048	0.30447
epi$NH4	-1.6558	4.64299	-0.357	0.72436
epi$NO3	-4.6968	5.39047	-0.871	0.39188
epi$Tphos	-76.458	41.1807	-1.857	0.07518
epi$NP	-0.0228	0.02019	-1.128	0.27008
F	4.96			
R	0.462			
p	0.00127	<--	Sig change overall	

Multiple Linear Regressin Nutrients by Year in Hypolimnion				
	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	1968.68	18.8346	104.524	< 2e-16
hyp$pH	6.70821	1.72084	3.898	**0.00042**
hyp$Alkalinity	-0.0663	0.08635	-0.768	0.44791
hyp$TKN	2.42106	1.53309	1.579	0.12329
hyp$NH4	5.50456	4.58607	1.2	0.23809
hyp$NO3	-16.579	7.98844	-2.075	**0.04536**
hyp$Tphos	4.9491	10.5371	0.47	0.6415
hyp$NP	-0.0297	0.01713	-1.734	0.09166
F	8.041			

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R	0.5399		
p	8.21E-06	<--	Overall Change detected

ANOVA
Nutrients by Year

	Df	Sum Sq	Mean Sq	F value	Pr(>F)	
nut$pH	1	274.03	274.028	**40.9613**	**0.007727**	<--
nut$Alkalinity	1	3.07	3.07	0.4589	0.546702	
nut$TKN	1	119.86	119.861	**17.9167**	**0.024129**	<--
nut$NH4	1	277.62	277.621	**41.4984**	**0.007585**	<--
nut$NO3	1	162.66	162.655	**24.3135**	**0.01599**	<--
nut$Tphos	1	39.59	39.585	5.9171	0.09312	.
nut$NP	84	1496.05	17.81	2.6622	0.2292	

ANOVA
Epilimnetic Nuts by Year

	Df	Sum Sq	Mean Sq	F value	Pr(>F)	
epi$pH	1	380.34	380.34	**25.4387**	**3.33E-05**	<--
epi$Alkalinity	1	19.5	19.5	1.3041	0.26428	
epi$TKN	1	0.1	0.1	0.0065	0.93646	
epi$NH4	1	1.73	1.73	0.1159	0.73635	
epi$NO3	1	63.87	63.87	**4.2719**	**0.04925**	<--
epi$Tphos	1	34.57	34.57	2.3123	0.1409	
epi$NP	1	19.02	19.02	1.2721	0.27008	
Residuals	25	373.78	14.95			

ANOVA
Hypolimnetic Nuts by Year

	Df	Sum Sq	Mean Sq	F value	Pr(>F)	
hyp$pH	1	335.35	335.35	27.2355	**8.28E-06**	<--
hyp$Alkalinity	1	9.4	9.4	0.7632	0.388274	
hyp$TKN	1	109.7	109.7	8.9094	**0.005148**	<--
hyp$NH4	1	112.76	112.76	9.1573	**0.004623**	<--
hyp$NO3	1	78.92	78.92	6.4097	**0.015994**	<--
hyp$Tphos	1	9.91	9.91	0.8052	0.375689	
hyp$NP	1	37.04	37.04	3.008	0.091657	.

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By Year					
Response	Secchi				
	Estimate	Std. Error	t value	p	
(Intercept)	226.88603	69.9324	3.244	0.0021	
sec$Year	-0.1101	0.03476	-3.167	**0.00262**	<--
Fstat	10.03				
R	0.1504				

By Month & Year					
	Estimate	Std. Error	t value	p	
(Intercept)	-293.211	317.49952	-0.924	0.36	
sec$MonthNo	68.55723	42.93745	1.597	0.117	
sec$Year	0.14904	0.15781	0.944	0.35	
sec$MonthNo:sec$Year	-0.03416	0.02134	-1.601	0.116	<--
Fstat	5.458				
R	0.2077				

ANOVA Results						
	Df	Sum Sq	Mean Sq	F value	Pr(>F)	
sec$MonthNo	1	8.541	8.5415	5.7355	**0.020576**	<--
sec$Year	1	12.025	12.0247	8.0745	**0.006571**	<--
sec$MonthNo:sec$Year	1	3.816	3.8165	2.5627	0.115971	

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