AQUATIC ECOSYSTEM RESEARCH
A Freshwater Conservation Company

East Twin Lake

2020 Water Quality Monitoring

Prepared for the
Twin Lake Association
Salisbury, CT
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EXECUTIVE SUMMARY

Aquatic Ecosystem Research was engaged by the Twin Lakes Association to compile and report on the 2020 water quality data collected by volunteers from the Association. One deep water site on the lake was visited on May 26th, June 22nd, July 21st, August 24th, September 24th, and October 19th where field data and water samples were collected. Field data collected on those dates and results from laboratory analyses of water samples were conveyed to AER for assessment. A summary of those data is provided below.

- East Twin Lake exhibited characteristics of an early mesotrophic lake (low to moderate levels of productivity).
    - The 2020 average Secchi disk transparency was 5.46 meters (m).
        - The greatest water clarity was recorded on June 22nd and was 7.83m.
            - This reading represented the deepest value recorded since 2004.
        - The lowest transparency of the season was 4.00m and was recorded on July 21st.
    - The average total phosphorus at 1m of depth was 9.7µg/L
        - Results from three of the six total phosphorus analyses on samples collected in the epilimnion were <10µg/L, with one of those below detectable limits.
        - The June 22nd and September 24th levels were 19 and 22µg/L, respectively.
    - Average hypolimnetic total phosphorus concentrations were significantly higher ($p<0.05$) than the epilimnetic average.
        - Greatest differences between the two strata occurred from July 21st to October 19th.
    - The average total nitrogen concentration in the epilimnion was 419µg/L.
        - Levels in the epilimnion were all below 413µg/L on all dates with the exception of September 24th when the concentration was 674µg/L.
    - The average total nitrogen in the hypolimnion was significantly higher ($p<0.05$) than the epilimnetic average.
        - Much of the difference between the strata occurred between July 21st and October 19th.
            - Much of that difference within those dates was driven by the loading of ammonia to the hypolimnion from bottom sediments.

- Algae cell concentrations (including cyanobacteria) were low and commensurate with high Secchi transparencies and low nutrient concentrations in the epilimnion.
    - Cell concentrations in four of the six counts were <2,000 cells/mL
    - The highest cell concentrations were from the samples collected on July 21st and August 24th at 7,913 and 5,315 cells/mL, respectively.

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        - Cyanobacteria cell concentrations peaked on those two midsummer dates, constituted most of the cells counted, but were well below the threshold of 20,000 cyanobacteria cells/mL recommended by the State of Connecticut for initiating mitigating steps in the interest of public health.
        - Cyanobacteria (aka blue-green algae), followed by Chlorophyta (aka green algae), were the most important taxa in the midsummer months.
        - Bacillariophyta (aka diatoms) and Chrysophyta (aka golden algae) were codominant with Cyanobacteria earlier in the season
            - The October 19th algae community was very diverse.

- The water column was stratified during each site visit from May through October.
    - Resistance to mixing at the thermocline was strong (RTRM ≥ 80) during all visits between June and September.
    - The warmest surface water temperatures were measured on June 22nd and July 21st; both were approximately 27°C (81°F).
        - Temperatures at the bottom remained constant and low (approximately 6°C or 43°F) throughout the season.
    - The volume of the epilimnion increased over the season as a result of wind driven mixing.
    - Oxygen concentrations above the thermocline were always >5mg/L.
        - Highest concentrations were found within the metalimnion for much of the season.
        - Concentrations <1mg/L were first observed at the bottom 2m of the water column on June 22nd
            - The volume of water with <1mg/L of oxygen expanded upward until it occupied the bottom 12m of the water column by October 19th.

- Specific conductance was significantly ($p<0.05$) higher at the bottom than it was at the top, which is most likely due to the solutes loading to waters above the bottom sediments during periods of anoxia.
    - The thermocline acted as a boundary between higher specific conductance below and lower specific conductance above it.
    - At the surface, the highest specific conductance was measured on May 26th, then decreased to lowest levels by August 24th before a small increase by October 19th.
        - This pattern is consistent with that observed since 2018.
            - The decrease in specific conductance during the season may be due to coprecipitation of calcium with phosphorus.

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- A significant change in water chemistry has occurred in East Twin Lake since 2004.
    - Multiple Linear Regression analyses indicated that significant changes have occurred in the epilimnion, hypolimnion, and in the entire water column.
        - The variables of pH, ammonia, and nitrate were those contributing most to model significance in both the whole lake and hypolimnetic analyses.
        - Alkalinity was also an important contributor to the whole lake and epilimnetic models.
        - Other variables contributing to the significance of the epilimnetic model included pH and nitrate.
    - Analyses of Variance (ANOVA) indicated that specific variables have changed significantly since 2004.
        - In the epilimnion alkalinity and nitrate concentrations have significantly decreased, while pH had significantly increased.
            - Secchi transparency, an indicator of trophic state, has significantly decreased, indicating a possible increase in average algal productivity.
        - Based on hypolimnetic data, as well as the combined epilimnetic and hypolimnetic dataset, average ammonia and TKN levels have significantly increased while average nitrate decreased.
            - This suggests more influence of anoxic conditions near the lake bottom, which can cause more loading of nitrogen and phosphorus in overlying waters.

- Because of the active aquatic plant management program at East Twin Lake, it will be important to continue to monitor the water quality to track indicators of increasing trophic levels.

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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. These included surveys conducted in the 1930s (Deevey 1940), the 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 that compilation, East Twin Lake had experienced an increase in algal productivity. Lines of evidence included an average decrease in summer Secchi transparency of 2.0m between the 1930s and 1990s with approximately half of that decrease occurring between the 1970s and 1990s (Siver et al. 1996). A 21µg/L increase in total phosphorus between the 1930s and 1990s also occurred and included a 16µg/L increase between 1970 and 1990. Alkalinity also increased since the 1930s, but almost all of the 13mg/L increase occurred between 1970 and 1990.

Last year, AER reported that significant ($p<0.05$) changes had occurred at East Twin Lake between 2004 and 2019. These included a decrease in Secchi disk transparency, decrease in hypolimnetic nitrate, and increase in hypolimnetic ammonia. The pH had also significantly increased in that timeframe.

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

METHODS

A volunteer monitoring program was developed by the Twin Lake Association with guidance from AER in 2017. For the third year, Peter and Kathy Neely conducted monthly site visits to a site on East Twin Lake (73°22'59.999" W 42°1'32.984" N; Fig. 1) between May and October. The 2020 visits occurred on the following dates: May 26th, June 22nd, July 21st, August 24th, September 24th, and October 19th. During each visit the following data were collected:

- A water clarity measurement was taken with a standard 20cm Secchi disk.
- Temperature (°C), oxygen (mg/L), conductivity (µS/cm), specific conductance (µS/cm), and pH were measured at 0.5m below the surface, at one meter (m), and at every meter to the bottom using a YSI® Professional meter and recorded.

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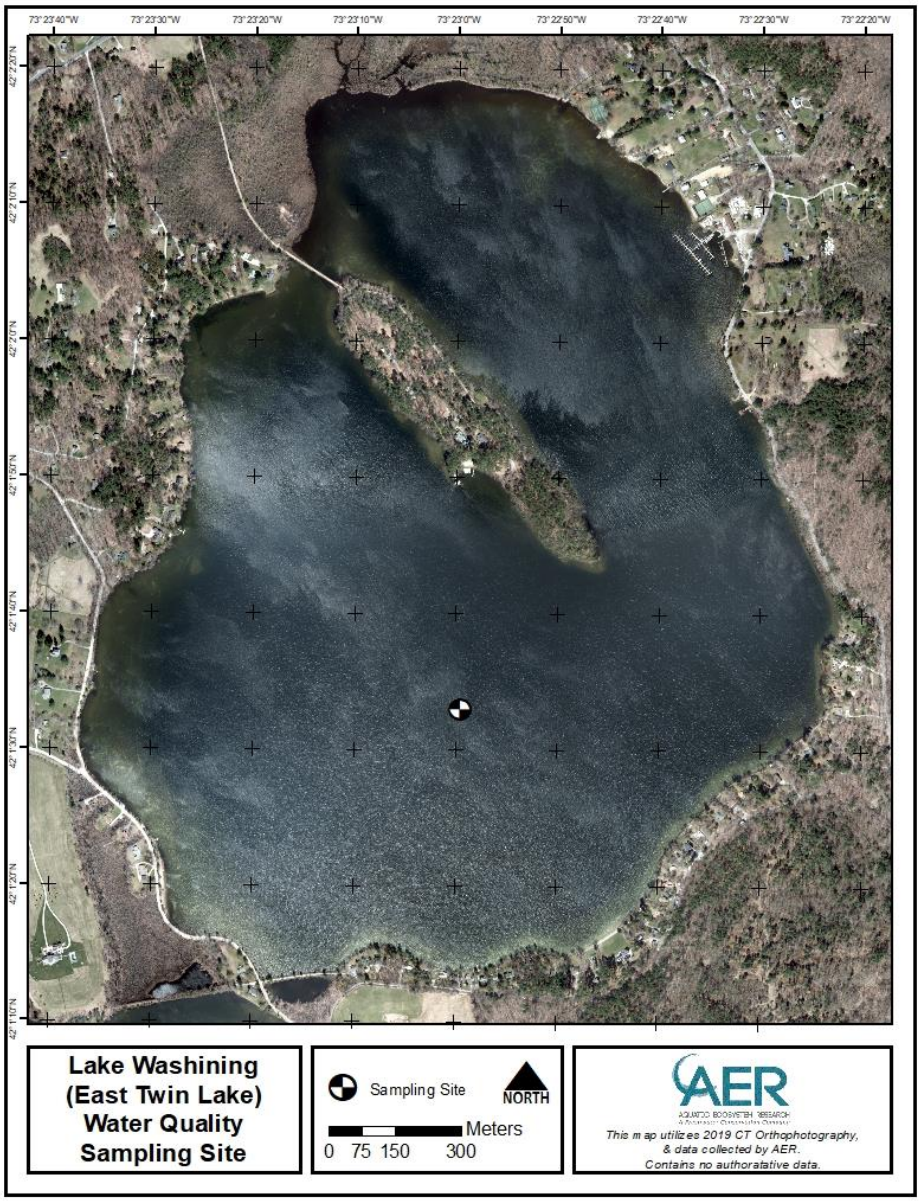

Figure 1. Map of East Twin Lake showing the location of the water quality sampling site.

In addition, 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. Samples were kept at approximately 3°C and delivered to HydroTechnologies, LLC, a Connecticut State certified laboratory located in New Milford, CT.

An additional sample was collected for phytoplankton analyses. The sample was an integration of the top 3m of the water column and collected with a 3m tube sampler. Samples were treated with Lugol's solution before transferring them to AER.

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Hydrostatic pressure was then applied to samples to collapse the gas vesicles that might be contained within cyanobacteria cells (Lawton et al. 1999). Known volumes of the 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, and 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.

Field and laboratory data were conveyed to AER for analyses. Temperature profile data was utilized to determine thermal resistance to mixing scores, which were used 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 mean that layers are mixed; scores of ≥30 between strata are characteristic of the transitional metalimnion layer. RTRM scores of ≥80 between strata characterizes strong resistance to mixing (Siver et.al. 2018).

TEMPERATURE AND OXYGEN DYNAMICS

Temperature profile data allow for the assessment of thermal characteristics of the water column by providing the means to calculate where layers of water were and were not mixing as a result of 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 early fall until weak thermal separation affords bottom to top mixing.

An understanding of oxygen concentrations is important for several reasons. An oxygen concentration of 5mg/L is generally thought to be the threshold limit of sustainable conditions for most aerobic organisms in freshwater systems. As concentrations drop below the threshold, conditions become progressively 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).

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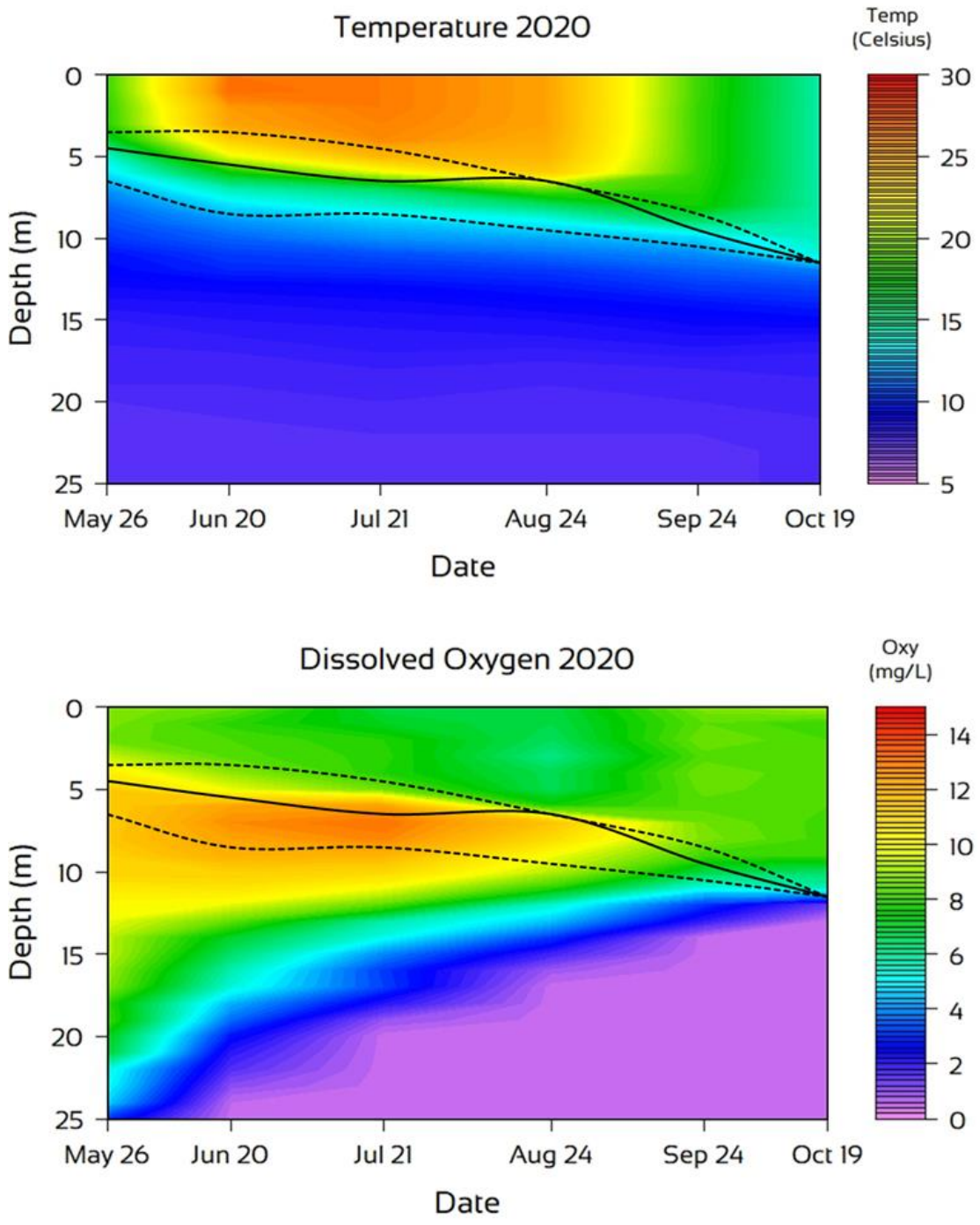

Figure 2. Temperature (top) and dissolved oxygen (bottom) isopleth diagrams for East Twin Lake based on data collections in 2020. The dashed black lines represent the depths of the upper and lower boundary of the metalimnion; and the solid black lines represents the depth of the thermocline.

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The loss or absence of oxygen at the bottom of the water column modifies the chemical environment as compared to conditions where oxygen is present. These modification result in the dissolution of compounds (e.g., iron phosphate) in the sediments that can then dissolve in the interstitial waters and then, by diffusion, into the waters above the sediments.

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.

The water column on May 26th was stratified with the upper boundary of the metalimnion located between 3 and 4m of depth. Temperatures above the upper boundary (i.e. the epilimnion) were between 18.0 and 18.5°C. The lower boundary of the metalimnion was between 6 and 7m of depth. Within the metalimnion, temperatures decreased from 16.6 to 13.0°C. The thermocline was located between 4 and 5m of depth. Temperatures below the metalimnion decreased to 7.6°C at the bottom of the water column.

Oxygen concentrations in the water column on May 26th exceeded 5mg/L to a depth of 23m and were ≥3mg/L below that to the bottom. A metalimnetic oxygen maxima was observed on this and all dates through August 24th. That means that higher oxygen concentrations were found within the metalimnetic strata rather than in the epilimnion. That phenomenon is a result of algae's photosynthetic influence on the state of oxygen where they are highly concentrated and the cooler temperatures at these depths which increases oxygen solubility. Concentrations above the upper boundary of the metalimnion were between 8.5 and 9.4mg/L; metalimnetic oxygen concentrations were between 10.4 and 11.4mg/L. The highest concentrations of 11.5mg/L was measured at 8m of depth, which then gradually decreased to 3mg/L at the bottom.

The epilimnetic layer was warmest on June 22nd and July 21st when surface water temperatures were approximately 27°C. The upper boundary of the metalimnion was still between 3 and 4m on June 22nd but the lower boundary was located between 8 and 9m. The temperature gradient within the metalimnion was greater, with a temperature range between 23.9 and 12.9°C. The thermocline on June 22nd, which exhibited strong resistance to mixing (RTRM = 95), was detected between 5 and 6m of depth. Temperatures of the hypolimnion decreased to 7.7°C at the bottom of the water column.

The metalimnion continued to exhibit the highest oxygen concentrations during the June 22nd sampling event with levels between 12.4 and 12.8mg/L at depths between 6 and 8m. Above the metalimnion concentrations were between 8 and 8.5mg/L. Below the metalimnion, concentrations decreased from 12.1 at 9m of depth to 1.1mg/L at 23m of depth. Concentrations at 24m of depth and below were <1mg/L.

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By July 21st the upper boundary of the metalimnion had started to descend and would continue to do so for the remainder of the season (Fig. 2). Temperature differences within the metalimnion were similar to those on June 22nd, albeit the July 21st range of temperatures was wider. The result was the strongest resistance to mixing (RTRM = 135) of the season at the thermocline located between 6 and 7m of depth.

Oxygen concentrations in epilimnetic waters decreased as temperatures remained warm. The July 21st metalimnetic strata continued to exhibit the highest concentrations of oxygen, which ranged between 12.5 and 13.2mg/L between 6 and 8m of depth. Concentration below the metalimnion decreased to 1mg/L by 19m of depth and were <1mg/L from 20m of depth to the bottom.

Surface water temperature decreased by 1°C between July 21st and August 24th. The upper boundary of the metalimnion had descended while the depth of the thermocline had not changed since July 21st, resulting in the thermocline position at the same depth as the metalimnetic upper boundary (Fig. 2). Resistance to mixing at the thermocline, located between 6 and 7m of depth, continued to remain high (RTRM = 119). Temperatures in the bottom 10m of the water column were consistent with those measured since May 26th; temperature in those strata were between 8.6 and 7.6°C.

August 24th oxygen concentrations in the epilimnion were between 6 and 7mg/L. Oxygen concentrations were 11.6mg/L below the upper metalimnetic boundary; it decreased to 9.9mg/L just above the lower metalimnetic boundary. Concentrations decreased further to 1.9mg/L at 15m of depth and were <1mg/L from 16m to the bottom of the water column.

By September 24th, temperatures in the epilimnion had decreased by approximately 7°C since August 24th; and, were between 18.5°C measured at 0.5m of depth and 17.8°C measured at 8m of depth. Temperatures decreased from 15.8°C below the upper boundary of the metalimnion to 12.7°C above the lower metalimnetic boundary. Temperatures below that diminished to 7.7°C at the bottom of the water column.

With the decrease in epilimnetic temperatures, epilimnetic oxygen concentrations on September 24th increased and were between 8 and 9mg/L. Metalimnetic oxygen concentrations were within that same range with the exception of the 6.9mg/L measured just above the lower metalimnetic boundary, which was located between 10 and 11m of depth. Concentrations decreased below that to 2.1mg/L at 13m of depth; and, were <1mg/L from 14m of depth to the bottom of the water column.

Epilimnetic temperatures on October 19th were between 14 and 15°C. Below the thermocline, positioned at 12m of depth, temperature was 11.2°C. Temperatures continued to diminish to the bottom of the water column where they were 7.9°C. Oxygen concentrations were 9.2mg/L at 0.5m of depth, were 8.0 to 8.3mg/L from 1 to 9m of depth, decreasing to 1.6mg/L by 12m of depth, and were <1mg/L from 13m of depth to the bottom of the water column.

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NUTRIENTS

Total Phosphorus

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

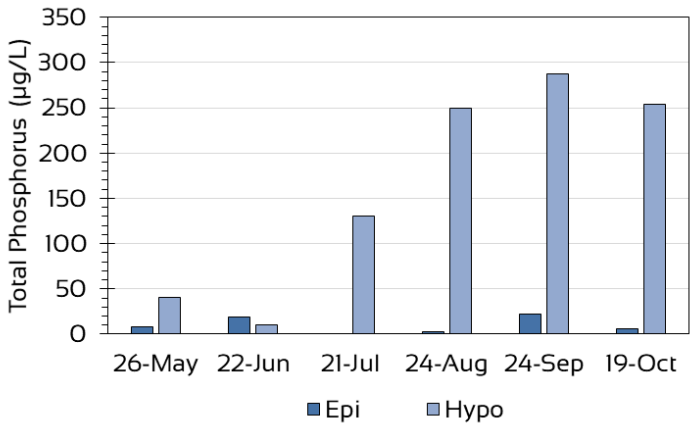

Figure 3. Total phosphorus concentrations measured in the epilimnion (Epi) and hypolimnion (Hypo) in East Twin Lake durng the 2020 season.

Concentrations in the epilimnion were generally low (Fig. 3). The season average was 9.7µg/L, the season low was 0µg/L (below detectable limits) on July 21^{s}, and the high was 22µg/L on September 24th. The epilimnetic level on June 22nd was 19µg/L. All others were <10µg/L.

The average hypolimnetic level of 162.2µg/L was significantly higher than the epilimnetic average ($p<0.05$). Concentrations were relatively low on May 26th and June 22nd (Fig. 3). The season low of 10µg/L on June 22nd increase by 120µg/L July 21st. By August 24th and for the remainder of the season, hypolimnetic concentrations were ≥250µg/L

Nitrogen

Nitrogen is regularly 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 as-

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sessing 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.

Nitrite (NO_2^-) was not detected in either epilimnetic or hypolimnetic samples collected during the 2020 season. Nitrate (NO_3^-) was measured above detection levels only once. This oxidized form of nitrogen was measured in the hypolimnetic sample collected on May 26th and was 51µg/L.

The 2020 average total Kjeldahl nitrogen in the epilimnion was 419µg/L. Epilimnetic concentrations in five of the six months were between 299 and 413µg/L. The September 24th concentration was higher at 674µg/L.

The average hypolimnetic concentration of 838µg/L was significantly higher ($p<0.05$) than the epilimnetic average. Lowest hypolimnetic concentrations were measured on May 26th and June 22nd; those values were similar to their corresponding epilimnetic levels (Fig. 4). By July 21st and for the remainder of season, the concentrations in the hypolimnion were notably higher than epilimnetic concentrations. During that time, hypolimnetic concentrations steadily increased and were highest on September 24th/October 19th at 1,370 and 1,220µg/L, respectively.

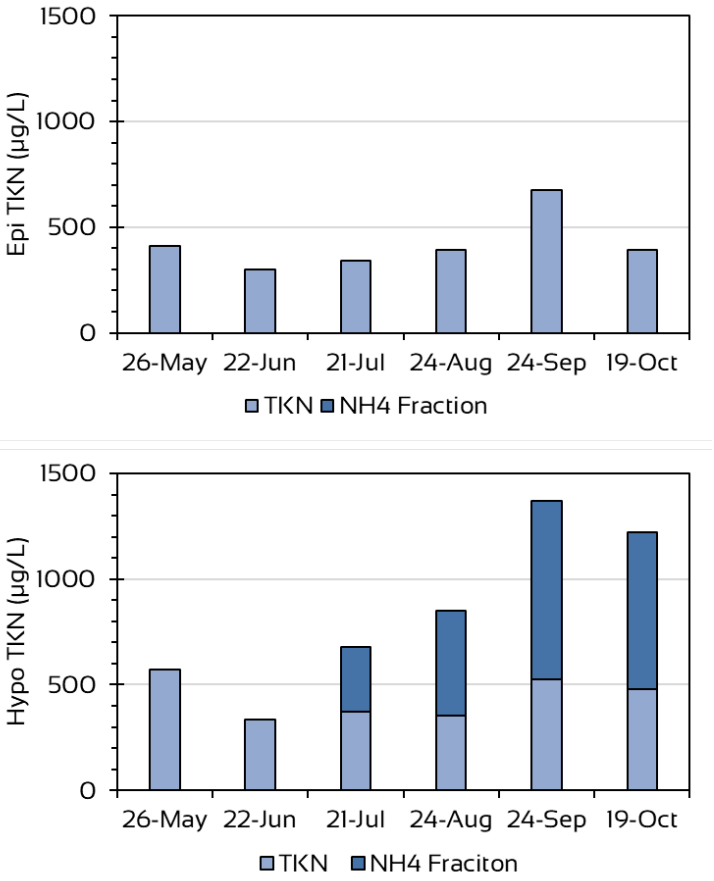

Figure 4. Total Kjeldahl nitrogen (TKN) and the ammonia (NH4) fraction of the TKN in the epilimnion (Epi; top panel) and hypolimnion (Hypo; bottom panel) during the 2020 season.

The ammonia (NH_4^+) fraction of epilimnetic TKN was below detectable limits throughout the 2020 season. In the hypolimnion, ammonia levels were undetectable on May 26th and June 22nd. By July 21st, approximately half of the hypolimnetic TKN was in the

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form of ammonia and half was other forms of organic nitrogen (Fig. 4). By August 24th, ammonia was the dominant constituent (58%) of TKN in the hypolimnion. Ammonia comprised approximately 61% of TKN on September 24th and October 19th.

Total nitrogen levels in both the epilimnion and hypolimnion were identical to TKN levels for the season with one exception. Since 51µg/L of nitrate was measured in the hypolimnion on May 26th, the total nitrogen was 622µg/L rather than the TKN concentration of 571µg/L.

SECCHI DISK TRANSPARENCY

Secchi disk transparency is a measure of how much light is transmitted through the water column. That amount of light is influenced by a number of variables including the amounts of inorganic and organic particulate material in the water column that absorbs or reflects light. In the open water environment, Secchi disk transparency is inversely related to algal productivity, i.e., the more algae in the water, the less Secchi transparency is; and less algal productivity results in greater Secchi transparency.

Light in lakes is important for several reasons including its impact on pelagic photosynthesis and the aforementioned algal productivity. As light diminishes with depth, so too does maximum photosynthetic potential. As photosynthesis decreases with depth, there eventually is a stratum where oxygen production from photosynthesis equals oxygen consumed via respiration. That is referred as the compensation depth; it is estimated by multiplying the Secchi disk transparency by 2.

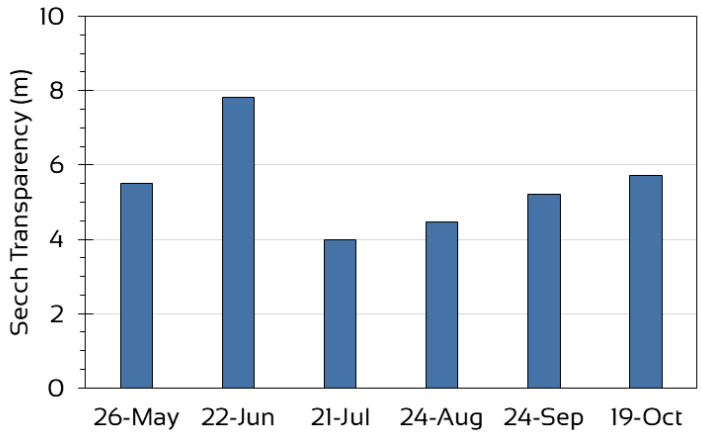

Figure 5. Secchi disk transparencies measured in East Twin Lake during the 2020 season.

Secchi disk transparencies were 5.50 and 7.83m on May 26th and June 22nd, respectively. On July 21st, the lowest 2020 measurement of 4.00m was taken. Afterwards, Secchi transparency measurements progressively increased until they reached 5.73m by October 19th (Fig. 5). The season average 5.46m.

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ALGAL DYNAMICS

This season, samples for algae analyses were collected by integrating the top three meters of the water column. In the past, samples were collected at the depths of maximum oxygen concentrations within the water column. The new protocol was adapted from the US EPA's Cyanomonitoring Program (US EPA 2020).

Total algae cell concentrations were low throughout the season. Lowest concentrations were from samples collected on May 26th, June 22nd, and October 19th and were 444, 491, and 268 cells/mL, respectively. Samples collected on July 21st and August 24th contained the highest cell concentrations with 7,913 and 5,315 cells/mL.

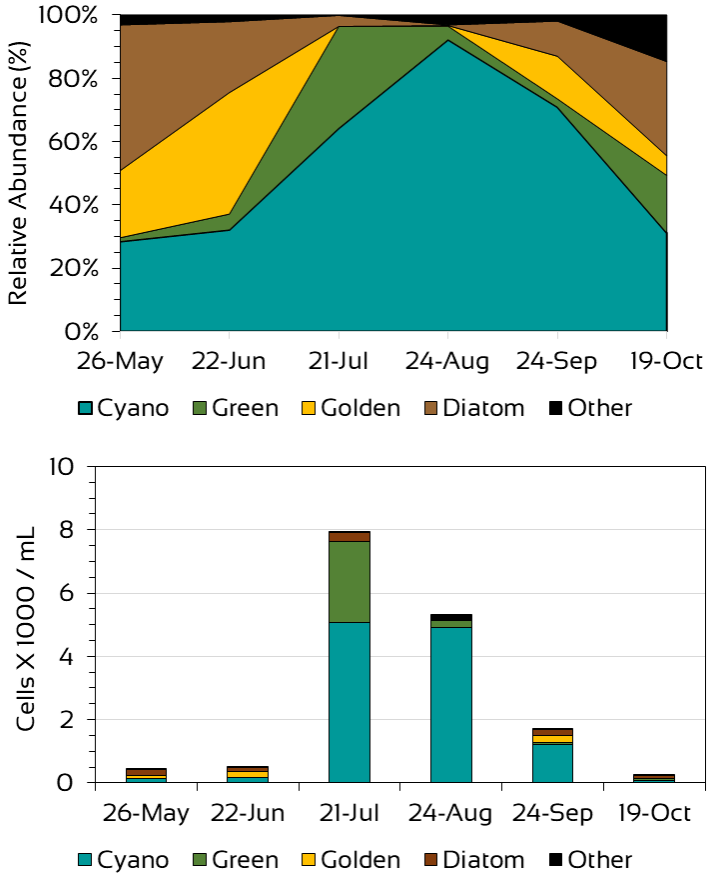

Figure 6. Relative abundance (top) and cell concentrations (bottom) of major taxonomic groups of the algae observed in East Twin Lake in the 2020 season.

In both samples with higher cell concentrations, the cyanobacteria (aka blue-green algae) were the most abundant. In the July 21st sample, the Chlorophyta (green algae) were also important (Figs. 6). Cyanobacteria were the most abundant in the September 24th sample, but the cell concentration was low (i.e., 1,724 cells/mL).

On May 26th, the cyanobacteria comprised 28.5% of the total cell concentration with *Dolichospermum spp*. (Fig. 7b) accounting for the majority of that. The Chrysophyta (aka golden algae) were 21% of the cells counted with *Dinobryon spp*. (Fig. 7d) and *Uroglenopsis spp*. the most important genera from that taxonomic group. The Bacillariophyta (aka diatoms) were the most abundant taxa on May 26th at 46.1% of the total with *Cyclotella spp*. and *Asterionella spp.* the most abundant genera of that taxon.

The relative abundances of the June 21st algae community were similar to that observed in samples collected on May 26th. Cyanobacteria were 32% of the total cell concentration with *Aphanocapsa spp*. (Fig. 7a) accounting for most of that. The golden al-

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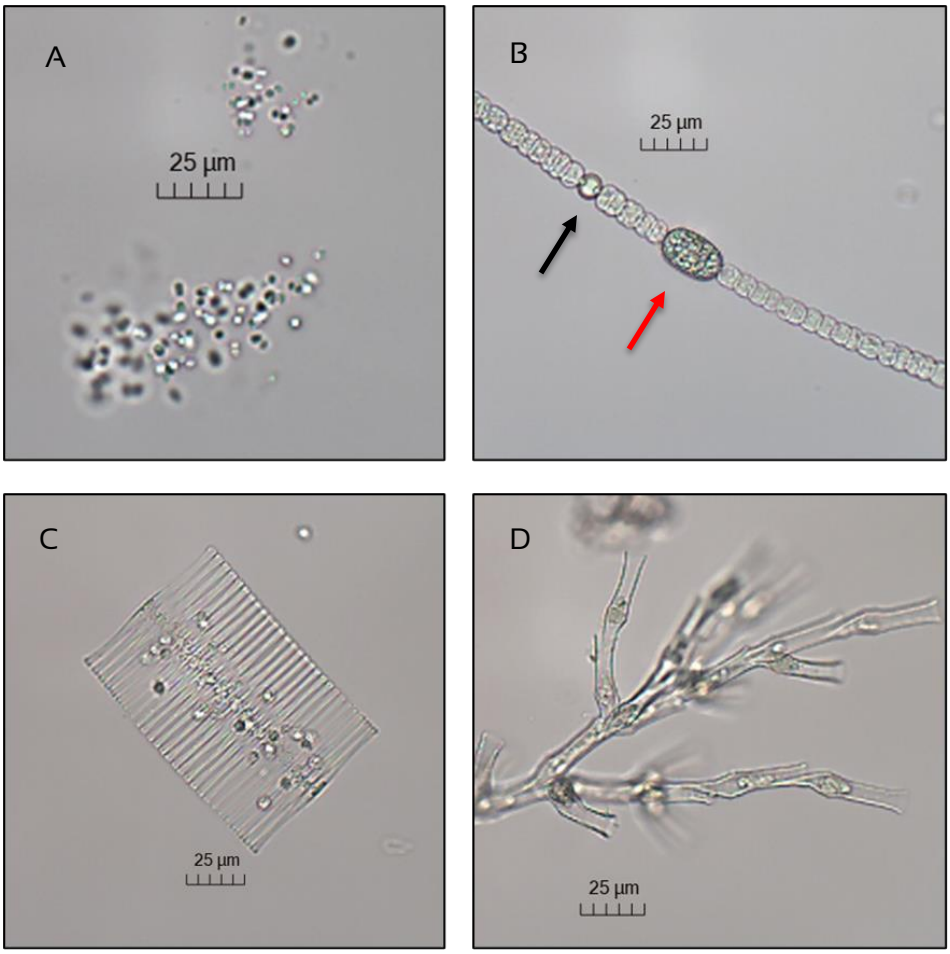

Figure 7. Micrographs of selected algae specimens in samples collected at East Twin Lake. A) the colonial cyanobacteria Aphanocapsa spp.; B) the filamentous cyanobacteria Dolichospermum spp. The black arrow points to a heterocyst, a specialized cell that is the site of nitrogen fixation. The red arrow points to an akinete, another specialized cell which overwinters in the sediments, and germinates the following season. C) the colonial diatom Fragilaria spp., and D) the colonial golden algae Dinobryon spp. Total magnification for all images is 400X.

gae increased to 38.5% of the community with the colonial *Chrysosphaerella spp.* joining *Dinobryon spp*. as the most abundant genera of that taxon. Diatoms decreased to 22.4% of the community and were largely of the genus *Fragilaria spp*. (Fig. 7c).

On July 21st, the community was dominated by cyanobacteria (64%) and, to a lesser extent, green algae (32.2%). *Aphanocapsa spp*. continued to be the most abundant on a cell number basis. It is worth noting the very small cell size of this genus with a cell diameter of ≤2µm (Fig. 7a). Other cyanobacteria genus observed at East Twin Lake, e.g., *Dolichospermum spp.*, have cell diameters of 5+ µm meaning that the cellular volume is approximately 16 or more time greater than that of *Aphanocapsa spp*.

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Other important genus on July 21st included the cyanobacteria *Chroococcus spp*. and the green algae genus *Gloeocystis spp*. This was the only time during the season that the Chlorophyta were an important constituent of the planktonic algae.

Aphanocapsa spp. was estimated to comprise 75% of all cells in the August 24th sample, and were followed in importance by the cyanobacteria *Dolichospermum spp*. and *Rhabdoderma spp*. Collectively, the cyanobacteria were 92.2% of the total cell concentration.

The cyanobacteria *Woronichinia spp*., which accounted for 23.7% of all cells, joined *Aphanocapsa spp*. at 38.9%, as the dominant genera in the September 24th planktonic algae community. The golden algae *Dinobryon spp*. and diatom *Synedra spp*. were also important contributors at relative abundances of 13.3 and 10.4%, respectively.

The cyanobacteria were codominant with the diatoms in the dilute October 19th sample. The two taxa comprised 31.1 and 29.8% of the community, respectively. *Dolichospermum spp*. replaced *Aphanocapsa spp*. as the dominant cyanobacteria genus. *Cyclotella spp*., followed by *Fragilaria spp*. and *Synedra spp*. were the most abundant diatom genera. Seven different genera of green algae collectively accounted for 18.2% of the flora.

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 watershed characteristics including land use. Alkalinity can also be generated internally from the dissimilatory reduction reactions during cellular respiration by bacteria found in anoxic lake sediments (Siver et al. 2003).

The pH of lake water is a response to several variables including the pH of precipitation falling in the lake and watershed, the buffering capacity (i.e., alkalinity) in the lake, geology, influences from surrounding wetlands, and levels of productivity in the lake. The measurement is important for several reasons. Firstly, very low (<5) or very high (>9) pH levels will not support diverse lentic flora and fauna.

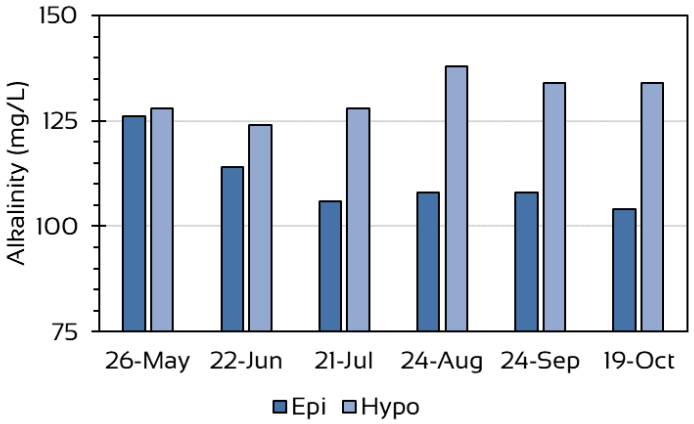

Figure 8. Epilimnetic (Epi) and hypolimnetic (Hypo) alkalinity in East Twin Lake during the 2020 season.

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Algal communities both influence and are influenced by pH. Algal photosynthesis lowers the dissolved carbon and carbonic acid levels, thus increasing pH. In turn, pH will determine 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.

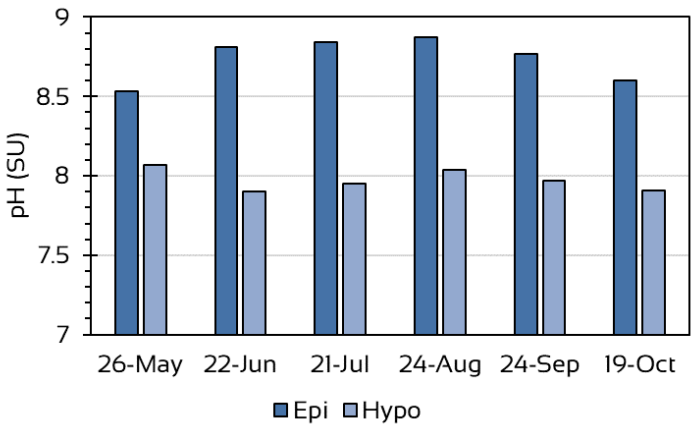

Figure 9. Epilimnetic (Epi) and hypolimnetic (Hypo) pH in East Twin Lake during the 2020 season.

The highest epilimnetic alkalinity of 126mg/L on May 26th decreased to 106mg/L by July 21st and was stable for the remainder of the season. The epilimnetic average for 2020 was 111mg/L. The hypolimnetic average of 131mg/L was significantly different ($p<0.01$). Alkalinity of the two strata were similar on May 26th but became increasingly different as the season progressed (Fig. 8). Hypolimnetic levels were between 124 and 128mg/L during the first half of the season, and between 134 and 138mg/L for the remainder of the season.

Average epilimnetic and hypolimnetic pH levels of 8.7 and 8.0 standard units (SU), respectively, were also significantly different ($p<0.005$). Epilimnetic levels increased from a low of 8.5SU on May 26th to highs of 8.8 and 8.9SU between June 22nd and September 24th (Fig. 9). The October 19th pH in the epilimnion was 8.6SU. Hypolimnetic pH levels exhibited little variability and only ranged from 7.9 to 8.1SU during the season.

SPECIFIC CONDUCTANCE

Conductivity is a surrogate measurement of the dissolved salt or ion concentration in water; as the name suggests, it is a measure of water's ability to conduct an electrical current. Data collection is started with a measure of conductivity. That datum is converted to specific conductance by mathematically standardizing it to a set water temperature (25°C) because – in the field – temperature varies with depth and/or date and alters the ability of water to conduct an electrical current.

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Specific conductance 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 regions 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.

Specific conductance data collected throughout the water column over the 2020 season were utilized in the development an isopleth diagram and subsequent interpretation. Specific conductance measured at 1m of depth and 0.5m above the bottom were compared in the proceeding.

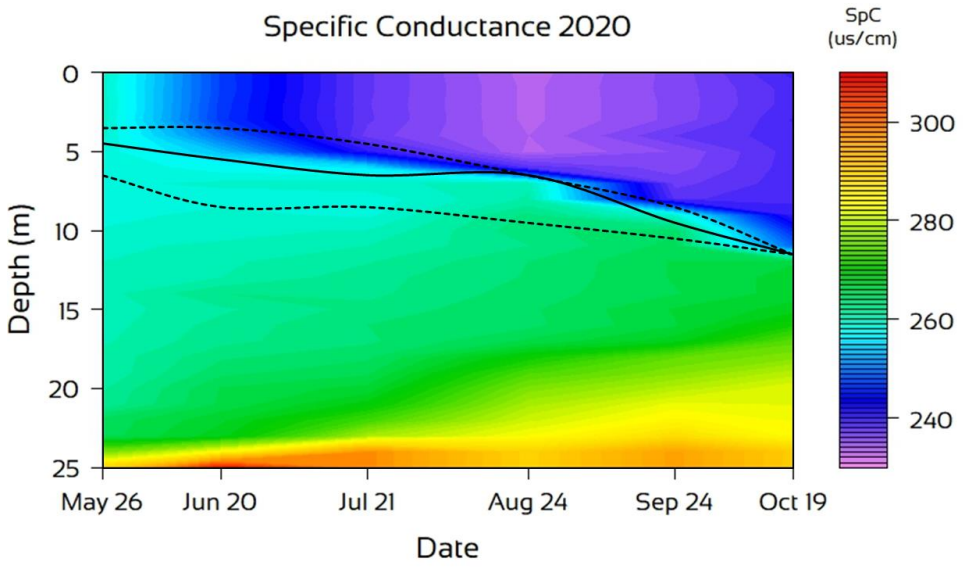

Figure 10. Isopleth diagram of specific conductance in East Twin Lake based on data collections in 2020. The dashed black lines represent the depths of the upper and lower boundary of the metalimnion; and the solid black lines represents the depth of the thermocline.

With the exception of the bottom 4m of the water column, the May 26th specific conductance throughout the water column was 258 to 262µS/cm. From 22 to 25m of depth, specific conductance increased from 265 to 289µS/cm. Epilimnetic specific conductance decreased through August 24th to approximately 234µS/cm, while

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measures of ≥265µS/cm were observed from 14m of depth to the bottom of the water column (Fig. 10). Those values extended upwards to 10m from the surface by September 24th, while levels at the bottom increased to 297µS/cm. Specific conductance levels at the bottom of the water column fluctuated from 289 (May 26th) to 310µS/cm (June 21st). By October 19th, epilimnetic specific conductance increased to 239µS/cm. Between 10 and 12m of depth, values sharply increased from 246 to 267µS/cm, and then to 291µS/cm at 24m of depth.

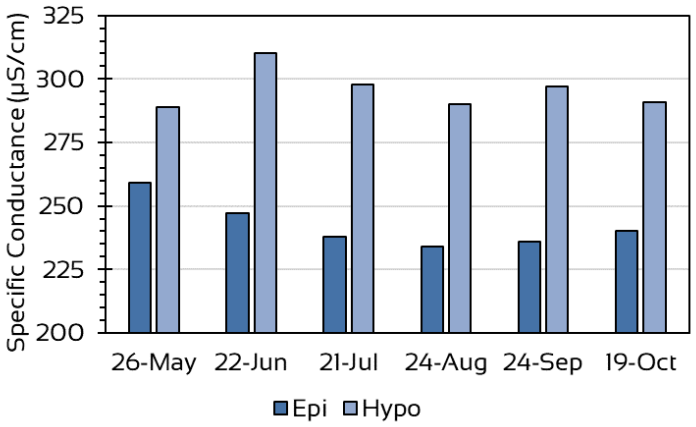

Figure 11. Epilimnetic (Epi) and hypolimnetic (Hypo) specific conductance in East Twin Lake during the 2020 season.

Average specific conductance at the top and bottom of the water column of 242 and 296µS/cm, respectively, were significantly different ($p<0.05$). There was a 30µS/cm difference between top and bottom of the water column specific conductance on May 26th, and a difference ranging from 56 to 63µS/cm for the balance of the sampling season (Fig. 11).

WATER QUALITY TRENDS

Similar to last year, trends in East Twin Lake water quality since 2004 were examined using two approaches. The first approach pooled each year's epilimnetic and hypolimnetic data; the second leveraged the epilimnetic and hypolimnetic datasets independently. Specific variables used in analyses included total phosphorus, total Kjeldahl nitrogen (TKN), nitrate, ammonia, alkalinity and pH. Secchi transparency data was analyzed separately. A difference between analyses this year vs. last year, other than the addition of the 2020 data, was the exclusion of the 2017 nitrogen data. Last year those data were included despite concerns of its anomalous nature relative to levels in TKN and ammonia in other years; the analysis outlined below exclude 2017 nitrogen data.

Two statistical methods were used. First, a multiple linear regression (MLR) 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.

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The second analysis performed was analysis of variance or ANOVA. With ANOVA each variable was examined independently to determine whether a change had occurred 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.

Multiple Linear Regression

Results from MLR indicated that significant ($p<0.005$) changes occurred in the epilimnion, hypolimnion, and the water column in its entirety (i.e., the whole lake) between 2004 and 2020.

The variables of pH, ammonia, and nitrate were those contributing to the significance of both the whole lake and hypolimnetic models. Alkalinity was also an important contributor to the whole lake model and the epilimnetic model. Other variables contributing to the significance of the epilimnetic model included pH and nitrate.

ANOVA

Results of ANOVA analyses on epilimnetic data indicated that significant changes had occurred in pH, alkalinity, and nitrate levels (Fig. 12). The epilimnetic pH in East Twin Lake has significantly increased, while epilimnetic alkalinity and nitrate has decreased since 2004. The loss of alkalinity would make the lake more susceptible to changes in pH. The change in epilimnetic nitrate appeared to be due to elevated levels measured prior to 2008.

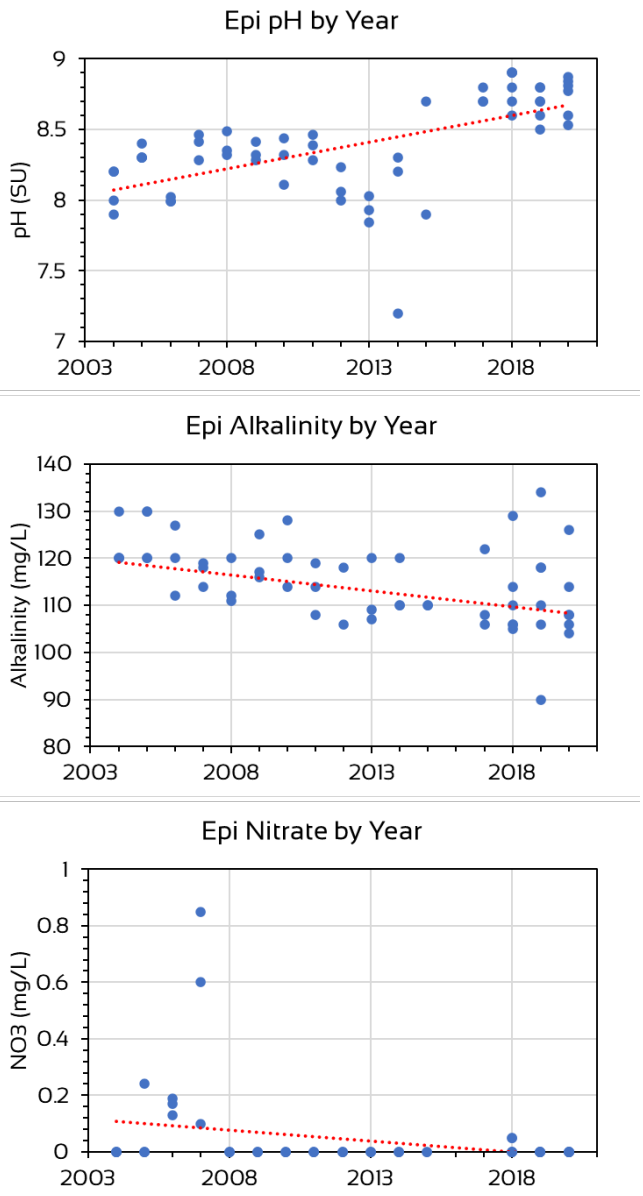

Figure 12. Regressions from ANOVA analyses of pH, alkalinity, and nitrate measured in the epilimnetic (Epi) since 2004.

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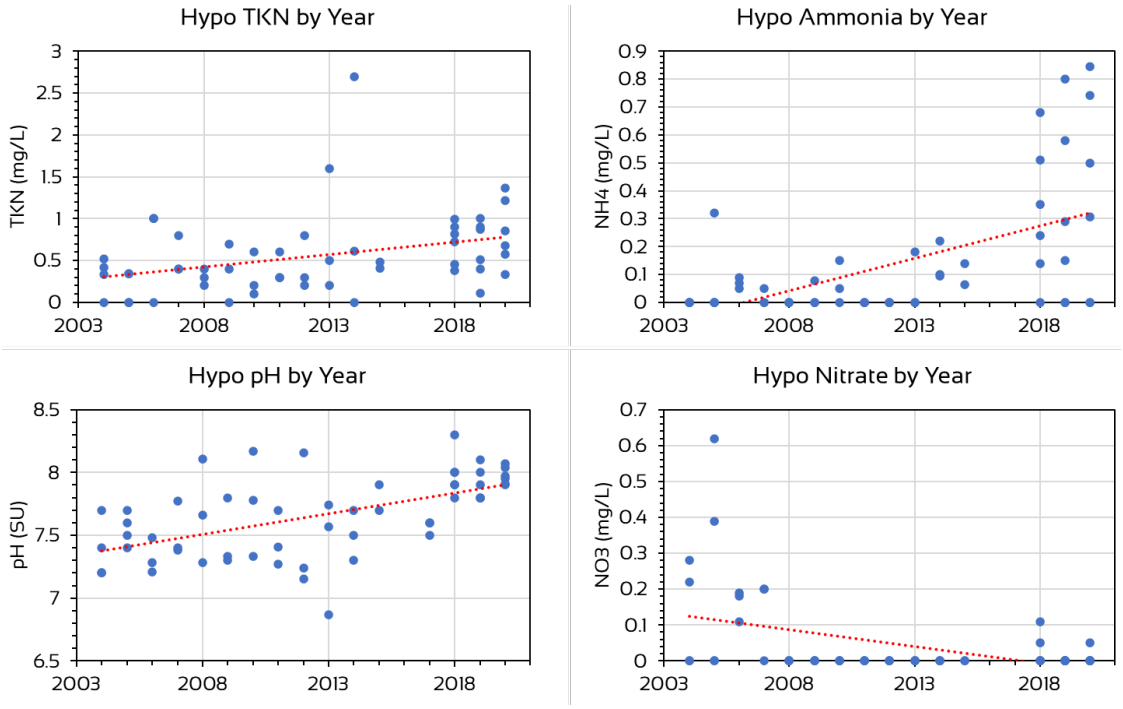

Figure 13. Regressions from ANOVA analyses of TKN, pH, ammonia, and nitrate, measured in the hypolimnion (Hypo) since 2004.

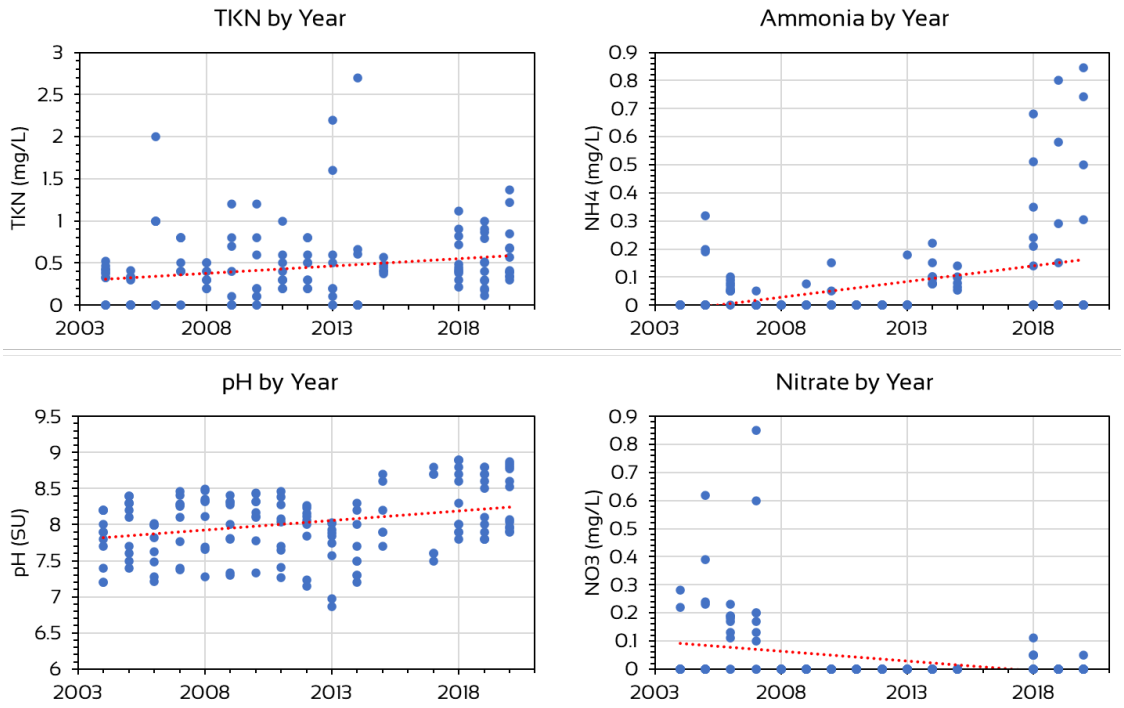

Figure 14. Regressions from ANOVA analyses of TKN, pH, ammonia, and nitrate, measured in the both the epilimnion and hypolimnion since 2004.

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Results from ANOVA on hypolimnetic data and from pooled epilimnion and hypolimnion data were the same in that the same variables have significantly changed in both datasets, namely TKN, ammonia, nitrate, and pH. The trajectories for each variable were the same in both datasets (Figs. 13 & 14). TKN, ammonia, and pH have significantly increased, while nitrate has decreased. This implies that hypolimnetic changes are driving much of the change throughout the lake.

Secchi Disk Transparency Trends

Results of both MLR and ANOVA indicated that average Secchi disk transparency significantly decreased since 2004. Average monthly trends were also assessed and exhibited a significant decrease between May and October (Fig. 15).

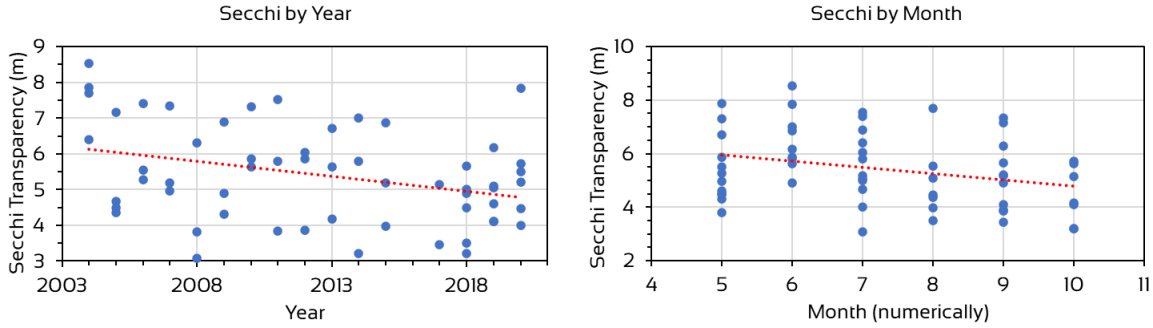

Figure 15. Regressions from ANOVA analyses of Secchi disk transparency by year (left) and by month (right) from data collected since 2004.

DISCUSSION

A lake's trophic state or status is an account of the level of productivity, particularly open water algal productivity, that a lake supports. Average summer chlorophyll-*a* concentration and Secchi disk transparency provide direct measures of productivity and are used in conjunction with the average levels of nutrients that can limit algal productivity (i.e., total phosphorus and total nitrogen). Table 1 provides a standard framework of how those variables are used to assess trophic status developed in Connecticut.

Average Secchi disk transparency for the season was 5.46m. The average transparency based on measurements taken from June through September was 5.38m. In both instances, Secchi disk transparency was within the early mesotrophic range.

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Table 1 . Trophic classification criteria used by the Connecticut Experimental Agricultural Station (Frink and Norvell 1984) and the CT DEP (1991) to assess the trophic status of Connecticut lakes. The categories range from oligotrophic or least productive to highly eutrophic or most productive.

Trophic Category	Total Phosphorus (µg / L)	Total Nitrogen (µg / L)	Summer Chlorophyll-*a* (µg / L)	Summer Secchi Disk Transparency (m)
Oligotrophic	0 - 10	0 - 200	0 - 2	>6
Early Mesotrophic	10 - 15	200 - 300	2 - 5	4 - 6
Mesotrophic	15 - 25	300 - 500	5 - 10	3 - 4
Late Mesotrophic	25 - 30	500 - 600	10 - 15	2 - 3
Eutrophic	30 - 50	600 - 1000	15 - 30	1 - 2
Highly Eutrophic	> 50	> 1000	> 30	0 - 1

The average epilimnetic total phosphorus in 2020 was 9.7µg/L. This average was at the high end of the oligotrophic category for that variable. The total nitrogen average for 2020 was 419µg/L and characteristic of mesotrophic productivity. Chlorophyll-*a* concentration is not included in the variables measured at Twin Lake.

As indicated above, there has been an overall decrease in water clarity since 2004. Secchi transparency over the last several years, however, appears to be stable (Fig. 12). It is also worth noting that the 2020 Secchi transparency high of 7.83m on June 22nd marked the greatest measured clarity since 2004. However, the overall trend indicates an increase in the trophic state of the lake.

The significant and concurrent trends of decreasing nitrate and increasing ammonia in the hypolimnion since 2004 does also suggest that trophic conditions are evolving. Organic matter accumulates at the bottom of a lake as it naturally ages, increasing oxygen demand there. Accumulation can also be accelerated as a result of the treatment of aquatic plants. Treated plants eventually become part of the organic matter at the bottom and that organic material can be transported from the bottom of the littoral zone to the bottom of the open water or pelagic zone.

Increased oxygen demand at the bottom results in depletion of oxygen there. Bacterial cellular respiration then shifts to the use of nitrate in the sediments at the bottom as the oxidizing agent in cellular respiration with ammonia as one of the biproducts of that metabolic reaction. The trends of decreasing nitrate and increasing ammonia at the bottom of the water column suggests that the anaerobic metabolism at the bottom is increasing. Loading of ammonia in the hypolimnion was clearly evident at East Twin Lake in 2020 (Fig. 4).

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Once nitrates are depleted, compounds of iron that contain phosphates are used in cellular respiration, which results in a buildup of phosphorus in the hypolimnion. This also occurs at East Twin Lake as evidenced this season (Fig. 3). Trends in hypolimnetic total phosphorus since 2004 were not statistically significant but the trendline was positive, i.e., increasing over time. Reasons for a lack of a significant trend may be due to the seasonality of hypolimnetic total phosphorus which are generally low early in the season, and increase in the mid to late season months of the season.

We examined historical specific conductance trends by comparing levels measured at 1m of depth from the early 1970s through the early 1990s (Canavan and Siver 1995) to those measured in recent years. There has been a gradual increase in specific conductance, with much of that occurring between the early 1970s and the early 1990s (Fig. 16).

A closer examination at specific conductance at 1m of depth since 2018 revealed a consistent pattern of highest levels measured in May followed by a decrease to lowest levels of the season by August or September (Fig. 17). A slight increase was observed in the final months of the season in 2019 and 2020.

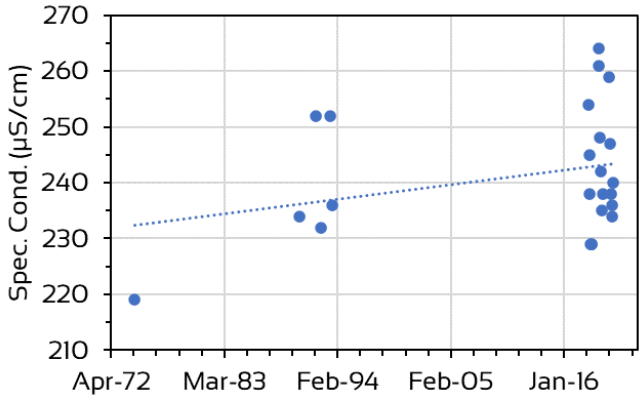

Figure 16. Historic specific conductance at 1m of depth since 1974.

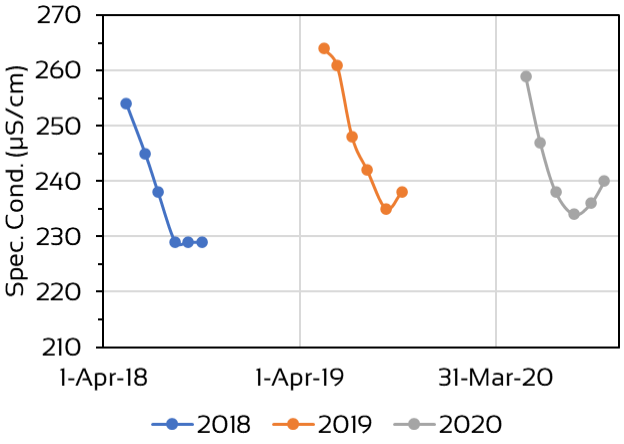

Figure 17. Specific conductance measured at 1m of depth in May through October of 2018, 2019, and 2020.

Calcium levels at East Twin Lake are some of the highest in the State due to is position in the Marble Valley geologic region of Connecticut (Canavan and Siver 1994, 1995). Coprecipitation of phosphorus by calcium is known to occur in lakes with high calcium levels and high pH level, both of which are characteristic of East Twin Lake. The decrease of specific conductance over the course of the season may be a result of the precipitation of calcium.

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RECOMMENDATIONS

Although there are indications of the eutrophication process occurring at East Twin Lake, the overall water quality is still good. An important question to consider in the future is how much of the lake aging process is natural vs. and how much might be due to management activities.

If not implemented carefully, management of aquatic plant with herbicides can result in symptoms of eutrophication. Nutrients incorporated in the plant tissue can become available to algae once plant cells are senesced. Dead plant mater that becomes part of the sediments increases oxygen demand due to the decomposition process that ultimately leads to loading of nutrients back to the water column from the sediments under anoxic conditions. The internal loading process already occurs at East Twin Lake.

The following recommendations are provided for consideration:

- Continue the water quality monitoring program
    - Additions for consideration
        - Chlorophyll-*a* in the epilimnion (see Table 1)
        - Base cation and chloride concentrations in the epilimnion
            - These would aid in understanding the drivers of increasing specific conductance trends. There is already historical data that contemporary data can be compared to.

- Have pretreatment plant survey mappings conducted for careful targeting of treatments for invasive plants.

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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

Date	Depth (m)	Alk (mg/L)	NH4 (mg/L)	TKN (mg/L)	NO3 (mg/L)	NO2 (mg/L)	TP (mg/L)	TN (mg/L)
26-May-20	1	126	0	0.413	0	0	0.008	0.413
	23.5	128	0	0.571	0.051	0	0.041	0.622

Date	Depth (m)	Alk (mg/L)	NH4 (mg/L)	TKN (mg/L)	NO3 (mg/L)	NO2 (mg/L)	TP (mg/L)	TN (mg/L)
22-Jun-20	1	114	0	0.299	0	0	0.019	0.299
	23.5	124	0	0.334	0	0	0.01	0.334

Date	Depth (m)	Alk (mg/L)	NH4 (mg/L)	TKN (mg/L)	NO3 (mg/L)	NO2 (mg/L)	TP (mg/L)	TN (mg/L)
21-Jul-20	1	106	0	0.343	0	0	0	0.343
	23	128	0.306	0.68	0	0	0.13	0.68

Date	Depth (m)	Alk (mg/L)	NH4 (mg/L)	TKN (mg/L)	NO3 (mg/L)	NO2 (mg/L)	TP (mg/L)	TN (mg/L)
24-Aug-20	1	108	0	0.391	0	0	0.003	0.391
	23	138	0.499	0.852	0	0	0.25	0.852

Date	Depth (m)	Alk (mg/L)	NH4 (mg/L)	TKN (mg/L)	NO3 (mg/L)	NO2 (mg/L)	TP (mg/L)	TN (mg/L)
24-Sep-20	1	32	0	0.674	0	0	0.022	0.674
	22.5	134	0.846	1.37	0	0	0.288	1.37

Date	Depth (m)	Alk (mg/L)	NH4 (mg/L)	TKN (mg/L)	NO3 (mg/L)	NO2 (mg/L)	TP (mg/L)	TN (mg/L)
19-Oct-20	1	104	0	0.391	0	0	0.006	0.391
	23	134	0.743	1.22	0	0	0.254	1.22

26-May-20

Depth m	Temp °C	DO mg/L	Cond µS/cm	Spec C µS/cm	pH SU
0.5	18.4	8.7	227	260	8.5
1	18.4	8.7	226.5	259	8.6
2	18.2	8.5	226.2	260	8.6
3	18.1	9.4	225.5	260	8.6
4	16.6	10.4	217.9	259	8.6
5	14.1	11.4	204.8	259	8.6
6	13.0	11.4	199.6	259	8.6
7	11.7	11.4	192.9	259	8.6
8	10.9	11.5	188.6	258	8.6
9	10.5	11.2	186.8	259	8.6
10	10.1	11.2	185.5	259	8.5
11	9.5	10.5	182.9	260	8.5
12	9.3	10.1	181.8	260	8.4
13	9.0	9.8	180.7	260	8.4
14	8.7	9.3	179.4	261	8.3
15	8.4	9.3	178	261	8.3
16	8.3	9.0	177.4	261	8.3
17	8.1	8.8	176.5	261	8.3
18	8.0	7.9	176.4	261	8.2
19	8.0	8.1	176.1	261	8.2
20	7.8	7.3	176.1	262	8.2
21	7.8	7.0	176.2	262	8.2
22	7.7	5.3	177.7	265	8.2
23	7.7	5.1	177.8	266	8.2
24	7.7	4.6	184.6	276	8.1
25	7.6	3.0	193.3	289	8.1

22-Jun-20

Depth m	Temp °C	DO mg/L	Cond µS/cm	Spec C µS/cm	pH SU
0.5	27.0	8.5	256	247	8.8
1	27.2	7.9	257	247	8.8
2	26.0	8.2	252	247	8.8
3	25.8	8.3	250	246	8.8
4	23.9	8.9	244	249	8.9
5	21.2	9.8	235	254	8.9
6	17.4	12.4	220	257	9.0
7	14.5	12.8	207	259	9.0
8	12.9	12.4	199	258	9.0
9	11.6	12.1	193	259	9.0
10	10.8	11.2	189	260	8.9
11	10.2	10.7	187	260	8.8
12	9.8	9.8	185	261	8.7
13	9.1	8.5	182	261	8.6
14	8.8	7.1	182	263	8.5
15	8.6	6.5	180	262	8.4
16	8.4	5.8	179	262	8.3
17	8.2	5.4	178	263	8.2
18	8.1	4.3	179	264	8.1
19	8.0	3.6	179	265	8.1
20	7.9	2.7	179	266	8.0
21	7.8	2.1	179	266	8.0
22	7.8	1.7	180	268	8.0
23	7.8	1.1	180	269	8.0
24	7.7	0.6	190	284	7.9
25	7.7	0.5	207	310	7.9

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21-Jul-20

Depth m	Temp °C	DO mg/L	Cond µS/cm	Spec C µS/cm	pH SU
0.5	26.8	6.9	246	238	8.8
1	26.8	7.2	246	238	8.9
2	26.8	7.8	246	238	8.9
3	26.6	7.9	246	238	8.9
4	26.4	7.8	244	238	8.9
5	24.9	8.6	241	241	8.9
6	21.2	12.5	237	256	9.0
7	15.8	13.2	214	260	9.1
8	14.1	12.9	205	258	9.0
9	12.5	12.0	197	259	8.9
10	11.6	11.0	193	260	8.7
11	10.5	9.9	189	261	8.6
12	9.9	8.4	187	262	8.5
13	9.3	5.9	184	263	8.4
14	8.9	5.2	182	263	8.3
15	8.7	3.9	181	263	8.3
16	8.5	3.1	181	264	8.2
17	8.4	3.2	180	264	8.1
18	8.2	2.2	180	265	8.1
19	8.0	1.0	180	266	8.0
20	8.0	0.5	180	267	8.0
21	7.9	0.5	182	270	8.0
22	7.8	0.5	184	273	8.0
23	7.7	0.5	187	279	8.0
24	7.7	0.5	200	299	8.0
25					

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24-Aug-20

Depth m	Temp °C	DO mg/L	Cond µS/cm	Spec C µS/cm	pH SU
0.5	25.8	6.9	237	234	8.9
1	25.8	6.8	237	234	8.9
2	25.8	6.6	237	234	8.9
3	25.8	6.2	237	234	9.0
4	25.5	6.7	236	234	9.0
5	25.1	6.7	234	234	9.0
6	24.0	7.7	234	239	9.0
7	19.2	11.6	232	261	9.0
8	15.8	10.9	215	261	9.0
9	13.3	9.9	204	263	9.0
10	12.0	9.3	198	264	8.9
11	11.0	7.9	193	263	8.8
12	10.1	5.5	189	264	8.7
13	9.6	4.5	187	264	8.6
14	9.2	3.1	185	265	8.5
15	8.8	1.9	183	265	8.4
16	8.6	0.9	182	265	8.3
17	8.3	0.5	181	266	8.3
18	8.1	0.5	183	270	8.2
19	8.0	0.5	185	274	8.2
20	7.9	0.5	186	277	8.1
21	7.9	0.5	187	279	8.1
22	7.8	0.5	188	281	8.1
23	7.7	0.5	190	283	8.1
24	7.7	0.5	194	290	8.0

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24-Sep-20

Depth m	Temp °C	DO mg/L	Cond µS/cm	Spec C µS/cm	pH SU
0.5	18.5	8.7	207	236	8.8
1	18.5	8.4	207	236	8.8
2	18.4	8.6	207	236	8.8
3	18.4	8.3	207	236	8.8
4	18.4	8.6	208	238	8.8
5	18.4	8.5	206	236	8.9
6	18.3	8.3	206	236	8.9
7	18.1	8.6	206	238	8.9
8	17.8	8.7	206	239	8.9
9	15.8	8.1	213	259	8.7
10	12.7	6.9	203	265	8.6
11	11.5	5.2	197	265	8.4
12	10.7	3.1	193	266	8.3
13	10.1	2.1	190	266	8.3
14	9.5	0.5	187	266	8.2
15	9.1	0.5	186	267	8.2
16	8.8	0.5	184	267	8.2
17	8.5	0.5	184	269	8.2
18	8.2	0.5	187	275	8.1
19	8.1	0.5	187	277	8.1
20	8.0	0.5	189	279	8.1
21	7.9	0.5	190	282	8.0
22	7.8	0.5	191	284	8.0
23	7.7	0.5	193	288	8.0
24	7.7	0.5	199	297	8.0

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19-Oct-20

Depth m	Temp °C	DO mg/L	Cond µS/cm	Spec C µS/cm	pH SU
0.5	14.8	9.2	194	240	8.6
1	14.8	8.0	193	240	8.5
2	14.8	8.2	193	240	8.5
3	14.8	8.3	193	240	8.5
4	14.8	8.2	193	240	8.5
5	14.8	8.2	193	240	8.5
6	14.8	8.2	193	240	8.6
7	14.8	8.1	193	240	8.6
8	14.8	8.1	193	240	8.6
9	14.7	8.0	194	241	8.6
10	14.4	6.5	196	246	8.5
11	14.0	5.8	196	249	8.5
12	11.2	1.6	197	267	8.3
13	10.3	0.5	193	267	8.2
14	9.8	0.5	190	268	8.1
15	9.3	0.5	188	268	8.1
16	8.7	0.5	187	271	8.1
17	8.4	0.5	188	275	8.0
18	8.3	0.5	188	277	8.0
19	8.1	0.5	189	280	8.0
20	8.0	0.6	190	282	8.0
21	8.0	0.5	190	282	8.0
22	7.9	0.6	191	283	7.9
23	7.9	0.6	191	284	7.9
24	7.9	0.6	196	291	7.9

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APPENDIX B. ALGAE DATA

May 26, 2020

Taxa	*Genus / species*	Cells / mL	%	Taxa cells / mL	Taxa %
Cyanophyta	*Aphanizomenon sp.*	0	0.0	127	28.5
	Dolichospermum sp.	99	22.2		
	Microcystis sp.	28	6.3		
	Woronichinia sp.	0	0.0		
Chlorophyta	*Anikistrodesmus sp.*	1	0.3	6	1.3
	Oocystis sp.	2	0.5		
	Scenedesmus sp.	2	0.5		
	Tetraedron sp.	0	0.0		
Chrysophyta	*Chrysosphaerella sp.*	0	0.0	94	21.2
	Dinobryon sp.	52	11.6		
	Mallomonas sp.	2	0.5		
	Uroglenopsis sp.	40	9.1		
Bacillariophyta	*Asterionella sp.*	52	11.6	205	46.1
	Aulocoseria sp.	0	0.0		
	Cyclotella sp.	129	29.0		
	Fragilaria sp.	1	0.3		
	Synedra sp.	1	0.3		
	Tabellaria sp.	22	5.0		
Dinophyceae	*Ceratium sp.*	1	0.3	3	0.8
	Gymnodinium sp.	2	0.5		
	Peridinium sp.	0	0.0		
Cryptophyceae	*Cryptomonas ovata*	4	1.0	4	1.0
Euglenophyceae	*Trachelomonas sp.*	1	0.3	1	0.3
	Unknown	4	1.0	4	1.0
Taxa identified 17	*Totals*	446	100	446	100

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June 22, 2020

Taxa	Genus / species	Cells / mL	%	Taxa cells / mL	Taxa %
Cyanophyta	*Aphanocapsa sp.*	116	23.5	159	32.1
	Chroococcus sp.	41	8.2		
	Woronichinia sp.	1	0.3		
Chlorophyta	*Anikistrodesmus sp.*	0	0.0	25	5.0
	Elakatothrix sp.	6	1.2		
	Gloeocystis sp.	6	1.2		
	Quadrigula sp.	4	0.9		
	Scenedesmus sp.	6	1.2		
	Tetraedron sp.	3	0.6		
Chrysophyta	*Chrysosphaera sp.*	96	19.4	191	38.5
	Dinobryon sp.	70	14.1		
	Mallomonas sp.	1	0.3		
	Uroglenopsis sp.	23	4.7		
Bacillariophyta	*Cyclotella sp.*	6	1.2	111	22.4
	Fragilaria sp.	102	20.6		
	Synedra sp.	3	0.6		
Dinophyceae	*Ceratium sp.*	1	0.3	1	0.3
Cryptophyceae	*Cryptomonas ovata*	4	0.9	4	0.9
Euglenophyceae	*Euglena sp.*	0	0.0	0	0.0
	Unknown	4	0.9	4	0.9
Taxa identified					
17	*Totals*	495	100	495	100

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Taxa	Genus / species	Cells / mL	%	Taxa cells / mL	Taxa %
Cyanophyta	*Aphanocapsa sp.*	3770	47.6	5083	64.2
	Chroococcus sp.	985	12.4		
	Dolichospermum sp.	71	0.9		
	Oscillatoria sp.	9	0.1		
	Rhabdoderma sp.	248	3.1		
Chlorophyta	*Anikistrodesmus sp.*	0	0.0	2546	32.2
	Elakatothrix sp.	71	0.9		
	Gloeocystis sp.	2271	28.7		
	Nephrocytium sp.	35	0.4		
	Oocystis sp.	18	0.2		
	Quadrigula sp.	9	0.1		
	Sphaerocystis sp.	142	1.8		
	Staurastrum sp.	0	0.0		
Chrysophyta	*Chrysosphaerella sp.*	0	0.0	0	0.0
Bacillariophyta	*Asterionella sp.*	0	0.0	275	3.5
	Fragilaria sp.	275	3.5		
Dinophyceae	*Ceratium sp.*	9	0.1	9	0.1
Cryptophyceae	*Cryptomonas sp.*	0	0.0	0	0.0
Euglenophyceae	*Euglena sp.*	0	0.0	0	0.0
	Unknown	0	0.0	0	0.0
Taxa identified					
13	*Totals*	7913	100	7913	100

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August 24, 2020

Taxa	*Genus / species*	Cells / mL	%	Taxa cells / mL	Taxa %
Cyanophyta	*Aphanocapsa sp.*	3988	75.0	4906	92.2
	Chroococcus sp.	64	1.2		
	Dolichospermum sp.	489	9.2		
	Rhabdoderma sp.	364	6.8		
Chlorophyta	*Gloeocystis sp.*	210	3.9	229	4.3
	Oocystis sp.	11	0.2		
	Selenastrum sp.	3	0.0		
	Tetraedron sp.	5	0.1		
Chrysophyta	*Mallomonas sp.*	3	0.0	5	0.1
	Uroglenopsis sp.	3	0.0		
Bacillariophyta	*Asterionella sp.*	0	0.0	5	0.1
	Cyclotella sp.	3	0.0		
	Synedra sp.	3	0.0		
Dinophyceae	*Glenodinium sp.*	5	0.1	5	0.1
Cryptophyceae	*Cryptomonas sp.*	3	0.0	3	0.0
Euglenophyceae	*Euglena sp.*	0	0.0	0	0.0
Ochrophyta	*Stichogloea sp.*	162	3.0	162	3.0
	Unknown	0	0.0	0	0.0
Taxa identified					
15	*Totals*	5320	100	5320	100

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September 24, 2020

Taxa	*Genus / species*	Cells / mL	%	Taxa cells / mL	Taxa %
Cyanophyta	*Aphanocapsa sp.*	670	38.9	1222	70.9
	Dolichospermum sp.	143	8.3		
	Woronichinia sp.	409	23.7		
Chlorophyta	*Anikistrodesmus sp.*	0	0.0	45	2.6
	Gloeocystis sp.	18	1.0		
	Oocystis sp.	7	0.4		
	Scenedesmus sp.	18	1.0		
	Selenastrum sp.	2	0.1		
Chrysophyta	*Chrysosphaerella sp.*	0	0.0	232	13.5
	Chrysosphaera sp.	0	0.0		
	Dinobryon sp.	230	13.3		
	Mallomonas sp.	2	0.1		
Bacillariophyta	*Cyclotella sp.*	9	0.5	192	11.1
	Fragilaria sp.	4	0.3		
	Synedra sp.	179	10.4		
Dinophyceae	*Glenodinium sp.*	2	0.1		
	Gymnodinium sp.	2	0.1	11	0.6
	Peridinium sp.	7	0.4		
Cryptophyceae	*Cryptomonas ovata*	0	0.0	0	0.0
Euglenophyceae	*Euglena sp.*	0	0.0	0	0.0
Ochrophyta	*Stichogloea sp.*	0	0.0	0	0.0
	Unknown	22	1.3	22	1.3
Taxa identified					
15	*Totals*	1724	100	1724	100

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October 19, 2020

Taxa	*Genus / species*	Cells / mL	%	Taxa cells / mL	Taxa %
Cyanophyta	*Aphanizomenon sp.*	7	2.7	83	31.1
	Dolichospermum sp.	60	22.2		
	Rhabdoderma sp.	17	6.2		
Chlorophyta	*Coelastrum sp.*	10	3.6	49	18.2
	Cruceginia sp.	10	3.6		
	Closterium sp.	1	0.4		
	Oocystis sp.	5	1.8		
	Scenedesmus sp.	14	5.3		
	Selenastrum sp.	6	2.2		
	Tetraedron sp.	4	1.3		
Chrysophyta	*Chrysosphaera sp.*	0	0.0	17	6.2
	Dinobryon sp.	5	1.8		
	Mallomonas sp.	2	0.9		
	Uroglenopsis sp.	10	3.6		
Bacillariophyta	*Asterionella sp.*	0	0.0	80	29.8
	Aulocoseria sp.	0	0.0		
	Cyclotella sp.	43	16.0		
	Fragilaria sp.	20	7.6		
	Synedra sp.	17	6.2		
Dinophyceae	*Ceratium sp.*	5	1.8	13	4.9
	Glenodinium sp.	8	3.1		
Cryptophyceae	*Cryptomonas sp.*	5	1.8	5	1.8
Euglenophyceae	*Euglena sp.*	0	0.0	0	0.0
	Unknown	21	8.0	21	8.0
Taxa identified					
19	*Totals*	268	100	268	100

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APPENDIX C. STATISTICAL DATA

Multiple Linear Regression: Pooled Epilimnion and Hypolimnion				
	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	1987.65635	8.23344	241.413	< 2e-16
pH	3.72066	0.83104	4.477	**1.58E-05**
Alkalinity	-0.05902	0.02649	-2.228	**0.02753**
TKN	1.62581	0.85874	1.893	0.06043
NH4	13.09587	3.8148	3.433	**0.00079**
NO3	-10.33527	3.09512	-3.339	**0.00108**
Tphos	3.12773	9.93554	0.315	0.75339
p	1.59E-12			
r2	0.3562			
F	14.19			

Multiple Linear Regression: Epilimnion				
	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	1961.13109	19.41506	101.011	< 2e-16
pH	8.76352	1.8119	4.837	**1.46E-05**
Alkalinity	-0.18969	0.07149	-2.653	**0.0108**
TKN	1.41764	1.61727	0.877	0.3852
NH4	1.72028	12.45892	0.138	0.8908
NO3	-9.9568	3.98854	-2.496	**0.0161**
Tphos	-46.9372	35.97331	-1.305	0.1983
p	2.93E-06			
r2	0.4588			
F	8.489			

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Multiple Linear Regression: Hypolimnion				
	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	1976.67009	17.52759	112.775	< 2e-16
pH	7.05737	1.60973	4.384	**6.51E-05**
Alkalinity	-0.15526	0.08152	-1.905	0.063
TKN	0.70857	1.17862	0.601	0.5506
NH4	12.11199	4.7036	2.575	**0.0132**
NO3	-9.47788	4.62262	-2.05	**0.0459**
Tphos	1.39873	10.19366	0.137	0.8914
p	3.14E-09			
r2	0.6024			
F	14.39			

Multiple Linear Regression: Secchi				
	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	2019.919	2.8168	717.09	< 2e-16
Secchi	-1.3655	0.5055	-2.701	0.00912
p	0.009121			
r2	0.09949			
F	7.297			

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Multiple Linear Regression: Secchi 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			

Multiple Linear Regression: Secchi By Month & Year				
	Estimate	Std. Error	t value	p
(Intercept)	-293.21103	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			

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ANOVA: Pooled Epilimnion and Hypolimnion						
	Df	Sum Sq	Mean Sq	F value	Pr(>F)	
pH	1	383.82	383.82	21.1758	9.45E-06	***
Alkalinity	1	29.12	29.12	1.6068	0.2070913	
TKN	1	243.43	243.43	13.4304	0.000353	***
NH4	1	679.27	679.27	37.4762	9.17E-09	***
NO3	1	205.38	205.38	11.3308	0.0009895	***
Tphos	1	1.8	1.8	0.0991	0.753391	

ANOVA: Epilimnion						
	Df	Sum Sq	Mean Sq	F value	Pr(>F)	
pH	1	568.65	568.65	33.834	5.09E-07	***
Alkalinity	1	159.12	159.12	9.4672	0.003483	**
TKN	1	1.55	1.55	0.0923	0.762624	
NH4	1	1.84	1.84	0.1097	0.74199	
NO3	1	96.29	96.29	5.729	0.020731	*
Tphos	1	28.61	28.61	1.7024	0.198321	

ANOVA: Hypolimnion						
	Df	Sum Sq	Mean Sq	F value	Pr(>F)	
pH	1	599.66	599.66	48.5671	9.11E-09	***
Alkalinity	1	0.16	0.16	0.0131	0.909236	
TKN	1	127.77	127.77	10.3482	0.002348	**
NH4	1	285.8	285.8	23.1472	1.59E-05	***
NO3	1	52.05	52.05	4.2158	0.045637	*
Tphos	1	0.23	0.23	0.0188	0.891447	

ANOVA: Secchi						
	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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