AQUATIC ECOSYSTEM RESEARCH
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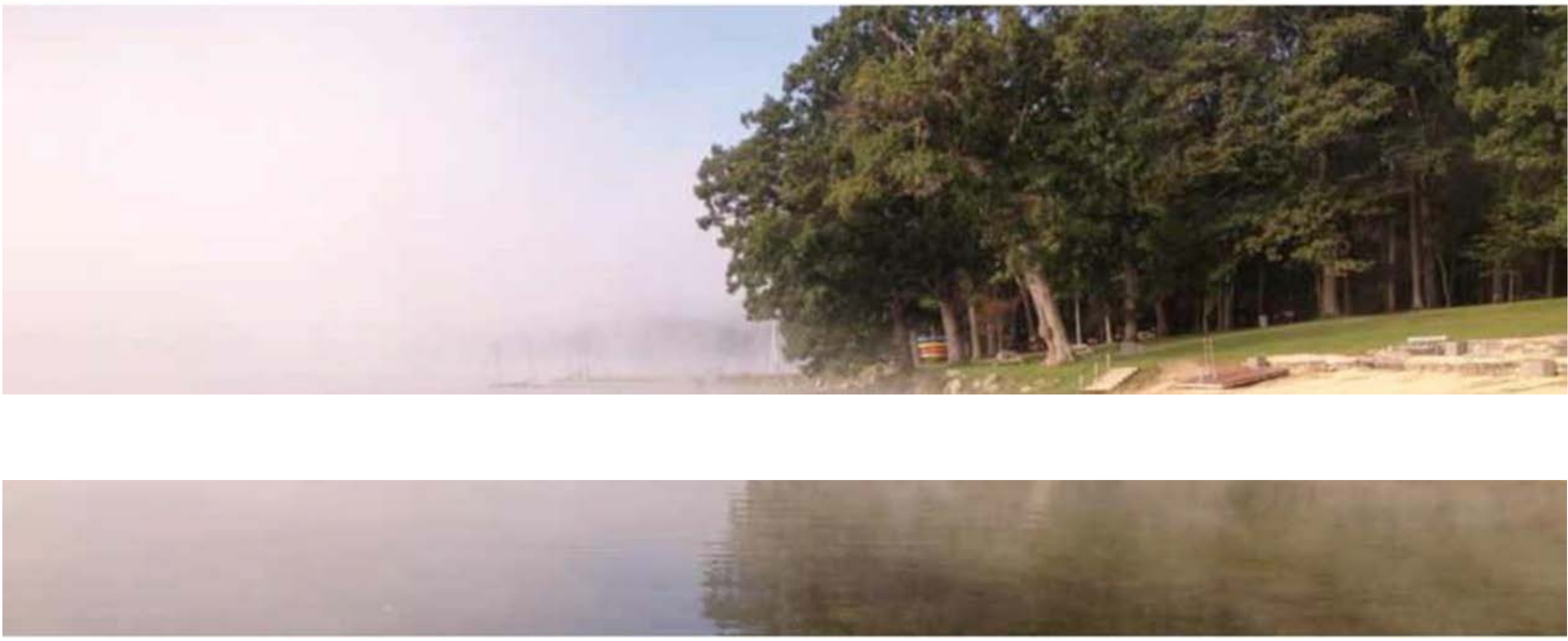

Lake Wononscopomuc 2021 Water Quality Monitoring

Prepared for the
LaRe Wononscopomuc Association
Salisbury, CT
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EXECUTIVE SUMMARY

Aquatic Ecosystem Research (AER) LLC was engaged by the Lake Wononscopomuc Association (LWA) to perform an assessment of water quality in 2021. The biannual monitoring program is one aspect of the LWA's lake management strategy with the goal of developing a scientific database to detect changes – positive and/or negative – within the lake. The following is an outline of findings from the 2021 water quality monitoring program at Lake Wononscopomuc. Several recommendations are provided at the end of the report.

- The lake was thermally stratified by the May 18th sampling date and remained stratified throughout the season, including on October 21st.
    - Resistance to mixing at the thermocline was strong at Site 1 starting on June 16th, and strong at both sites from July 22nd to September 20th.
    - Oxygen concentrations of <1mg/L were first observed at the strata near the bottom of the water column starting on June 16th at both sites.
        - The strata of water with <1mg/L of oxygen expanded upward with time through October 21st until the bottom 19m of the Site 1 water column and the bottom 7m of the Site 2 water column were anoxic.

- The lake exhibited early-mesotrophic to mesotrophic characteristics.
    - Season average and summer average Secchi disk transparency were indicative of early mesotrophic productivity.
    - Monthly epilimnetic total phosphorus measurements spanned oligotrophic to eutrophic concentrations.
        - The highest epilimnetic phosphorus concentrations were measured between May 18th and July 22nd; however, from August 26th through October 21st, concentrations were low or non-detectable.
        - Season averages were indicative of early-mesotrophic to mesotrophic trophic conditions.
        - Average hypolimnetic total phosphorus concentrations were one to two orders of magnitude higher than corresponding epilimnetic levels.
            - Hypolimnetic concentrations increased through August 26th then decreased by September 20th; but, were again elevated by October 21st.
    - Average epilimnetic total nitrogen concentrations were indicative of mesotrophic conditions.
        - Ammonia was not detected in epilimnetic samples. Nitrite and nitrate were only detected once each and at low concentrations.
        - Average hypolimnetic total nitrogen was significantly higher ($p<0.05$) and comprised largely of ammonia.
            - Concentrations increased over time at both sites.

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- Algal cell concentrations were low in the integrated samples of the top three meters of the water column.
    - Relative abundances of cyanobacteria cells were high on October 21st at Site 1; and, on September 20th through October 21st at Site 2.
    - Relative concentrations of phycocyanin suggested that the highest biomass of cyanobacteria existed between the 12 and 15m stratum at Site 1 and the 11 and 14m strata at Site 2 on all sampling dates.
    - The filamentous cyanobacteria, *Planktothrix spp*., was one of two dominant genera; it is known for forming dense layers at or below the thermocline.
        - A sample was collected from Site 1 between the depths of 13 and 14m on June 16th; it had ~30X more cells than the corresponding integrated sample from the surface and was dominated by *Planktothrix spp*.

- Specific conductance was high as it is for most lakes in the Marble Valley of Connecticut.
    - Epilimnetic levels decreased with time from May 18th to August 26th and remained at the relatively low level for the balance of the monitoring season.
    - Hypolimnetic levels increased through August 26th at Site 1 and were slightly lower for the balance of the season
        - At Site 2, hypolimnetic levels gradually increased to the season maximum on October 21st.

- Alkalinity was high as it is for most lakes in the Marble Valley of Connecticut.
    - Epilimnetic levels were higher earlier in the season and decreased to lowest levels by August 26th before modestly increasing through October 21st.
    - Hypolimnetic levels were lowest on May 18th and increased for most of the season. The maxima were reached on August 26th at Site 1 and on October 21st at Site 2.

- The lake water pH was high and not uncommon for lakes in the Marble Valley of Connecticut.
    - In most instances, other than on May 18th, hypolimnetic pH was greater than epilimnetic pH.
        - This is not typical for lakes in the Northeast.
            - We hypothesize that it is related to carbonate-based geology of the Marble Valley of Connecticut.

- Oxidation-reduction potentials (ORP) exhibited different characteristics at the two sampling sites.
    - Site 1 exhibited a pattern more typical to lakes in Connecticut with high ORP in surface waters and low ORP in strata near the bottom after protracted periods of anoxia.

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    - Site 2 ORP levels were only high on May 18th and at the bottom strata. ORP was atypically low with highest levels measured in mid-depth regions of the water column.

- Statistical analyses of water quality trends from data collected in 2015, 2017, 2019, and 2021 revealed that the lake has changed during that time.
    - Changes were detected in the epilimnion, hypolimnion, and in the lake as a whole.
        - Significant negative (decreasing) trends were detected for nitrogen-related variables (e.g., TKN, ammonia)
        - Significant positive (increasing) trends were detected for hypolimnetic total phosphorus.

- Contemporary Lake Wononscopomuc data was compared to that collected in the 1990s.
    - The most conspicuous change was the increase in specific conductance.
        - Many lakes in snowbelt regions of the country are experiencing this type of change and it has been shown to be a result of increasing use of deicing road salts.

- The high pH and high calcium concentrations in the lake water may result in the coprecipitation of phosphorus.
    - This can result in algal productivity that is lower than what the lake could support if phosphorus was not constantly forming insoluble minerals in the water column.
        - This is a feature of lakes with carbonate rich bedrock geology.

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TABLE OF CONTENTS

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INTRODUCTION

Lake Wononscopomuc is a natural 348-acre water body located in Salisbury, Connecticut. It is one of the deepest lakes in Connecticut; it has a maximum depth of 31 meters (m), a mean depth of 11m, and a volume of approximately 4.74×10^9 gallons of water filling two distinct basins. Lake Wononscopomuc is a marl-type lake, which is characterized by calcium rich water and high specific conductance, due to the location of the lake and its watershed within the geological feature known as Connecticut's Marble Valley (Fig. 1; Bell 1985, Canavan and Siver 1995). The type of water chemistry with this geology results in unique features such as marl deposits and lake whitening events. Finally, this type of water chemistry supports specialized algae and plant communities.

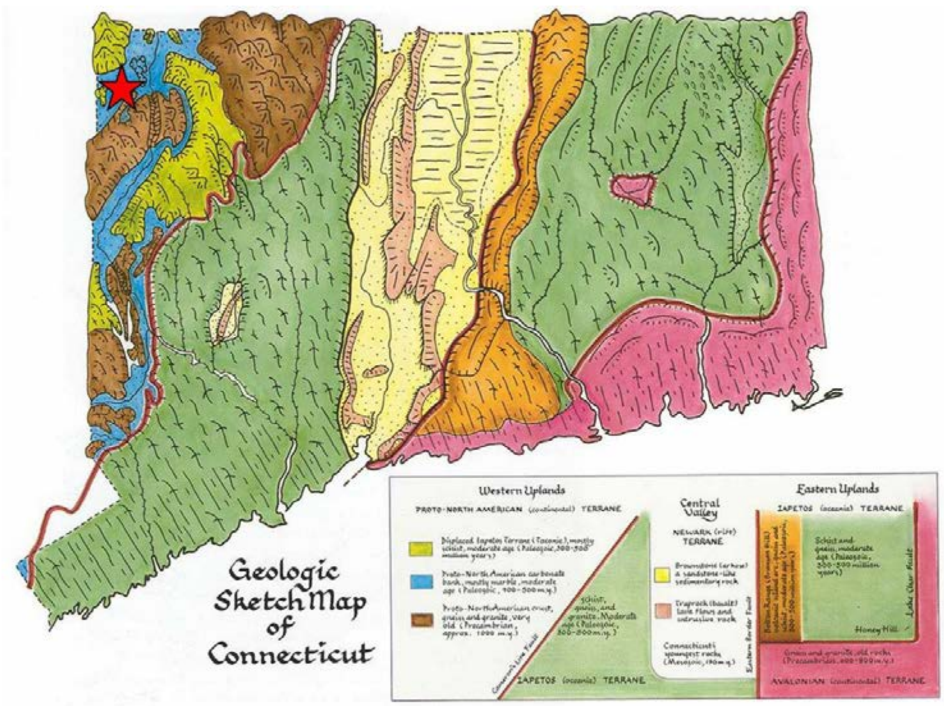

Figure 1. Geological regions of Connecticut as illustrated in Bell (1985) with the approximate location of Lake Wononscopomuc identified by a red star.

The lake's watershed is 1,621 acres and mostly residential land with a small undeveloped wetland to the southeast (Jacobs and O'Donnell 2002). The resulting watershed to lake ratio is 4.7:1. Sucker Brook and one other small stream drain into Lake Wononscopomuc; the lake drains out into Factory Brook, a tributary of Salmon Creek, which ultimately feeds to the Housatonic River. Analyses of historical land use revealed increases in residential/urban and woodlands at the expense of agricultural

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land from 1934 to 1990 (Table 1; Field et.al. 1996). Based on those estimations and models that infer nutrient export, concentrations of in-lake total phosphorus and total nitrogen levels were projected to have increased.

Table 1. Percent coverage of urban-residential (U-R), agricultural-open space (A-O), wooded, and water in the Lake Wononscopomuc watershed (Field et.al. 1996). Also provided are estimated total phosphorus (TP) and total nitrogen (TN) levels predicted from land cover (Norvell et al. 1979, Frink 1991).

Year	U-R	A-O	Wooded	Water	Estimate	
					TP	TN
	(%)	(%)	(%)	(%)	(μg/L)	
1934	1	53	24	22	18	483
1970	16	22	41	22	22	481
1990	27	16	36	22	29	526

Lake Wononscopomuc has been included in several state-wide assessments of Connecticut lakes (Deevey 1940, Frink & Norvell 1984, Canavan and Siver 1994, 1995). Siver et.al. (1996) summarized historical changes in those lakes using data from all three surveys. That study revealed that average Secchi transparency at the Lake Wononscopomuc decreased by 3.9 meters (m) between the 1930s and the early 1990's with much of that occurring between the 1970s and 1990s. Total phosphorus and alkalinity levels increased by approximately 13μg/L and 11mg/L, respectively between 1930s and 1990s with much of that also occurring between the 1970s and 1990s.

Canavan and Siver (1995) characterized Lake Wononscopomuc in the early 1990s as mesotrophic based on total phosphorus and total nitrogen levels. They also noted low chlorophyll-*a* concentrations and high Secchi transparency; they attributed those characteristics to high magnesium and calcium concentrations and coprecipitation.

In 2015, Aquatic Ecosystem Research (AER) was engaged by the Lake Wononscopomuc Association (LWA) to examine the summer season water quality features of Lake Wononscopomuc and to establish a high-quality contemporary database of water quality information. The 2015 water quality assessment established a repeatable design and allowed for a general examination of current water quality for use in future water quality comparisons. One of AER's recommendations was to continue water quality monitoring on an annual or biennial basis. This report is a continuation of the process to develop a high quality, contemporary database.

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METHODS

Field data and water sample collections were performed by AER on May 18th, June 16th, July 22nd, August 26th, September 20th, and October 21st. Collections occurred at two sites on the lake, with each located within the two major basins of the lake (Fig. 2). Secchi disk transparency was measured at the sites by lowering a 22cm black and white disk through the water column and determining the exact distance where it was no longer visible.

Vertical profiles of water quality characteristics were obtained in the field by AER using Eureka Manta II multimeter. Profile data were collected at one-half meter (m) from the surface, and at every meter down to 0.5m above the sediment-water interface. The following variables were measured: Temperature (°C), dissolved oxygen (mg/L), percent oxygen saturation (% O2), conductivity (µS/cm), specific conductance (µS/cm), oxidation – reduction potential (mV), relative cyanobacteria biomass, and pH.

Table 2. Analyses performed and depths of water samples collected.

Analyses	Depth
Total Phosphorus	1m from surface; 0.5m from bottom
Nitrite	1m from surface; 0.5m from bottom
Nitrate	1m from surface; 0.5m from bottom
Ammonia	1m from surface; 0.5m from bottom
TKN	1m from surface; 0.5m from bottom
Alkalinity	1m from surface; 0.5m from bottom
Algae	Integration of top 3m

Water samples were collected at both sites during each visit for analyses of select water quality variables (Table 2) at HydroTechnologies, LLC – a CT State certified laboratory located in New Milford, CT. Samples were collected at 1m of depth (surface) using a horizontal Van Dorn water sampler; samples were similarly collected at approximately 0.5m above the sediment water interface. Water samples for algae identification and enumeration were collected by integrating the top 3m of the water column using a weighted vertical tube sampler at the two sites.

Algae samples were preserved with Lugol's solution shortly after collection and later treated with hydrostatic pressure to collapse the gas vesicles of the cyanobacteria cells (Lawton et al. 1999). Known volumes of the preserved samples were concentrated into smaller volumes with centrifugation and a vacuum pump / filtration flask system. Portions of those concentrates were pipetted into a counting chamber. Then genus-level algal cell enumerations were performed by counting cells in a subset of the chamber's fields using an inverted Nikon Diaphot research microscope. Count data were then corrected to be reflective of the whole water samples.

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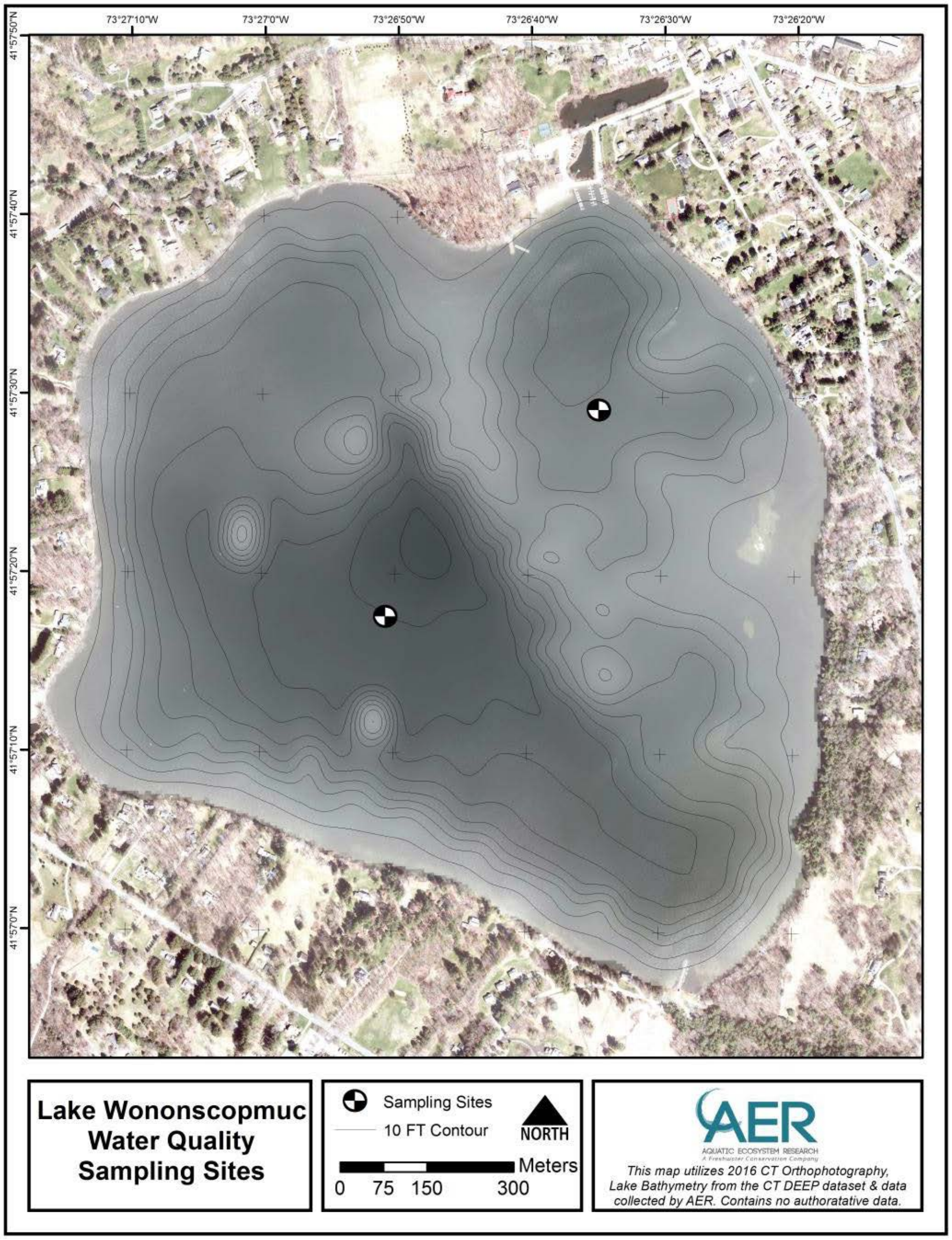

Figure 2. Water quality monitoring sites on Lake Wononscopomuc. Site 1 is located near the center of lake in 30 meters of water. Site 2 is located in the northeastern basin and in 17 meters of water. The lake's bathymetry has been layered into the map.

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To obtain a qualitative view of the entire pelagic zone's phytoplankton community, AER utilized a 10µm mesh plankton net to collect a concentrated algae sample in the field from the photic zone of the water column during each visit. Portions of that concentrated sample were analyzed microscopically before preservation with Lugol's solution, which allowed for the establishment of a qualitative genus list.

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 from temperature profile data using the Relative Thermal Resistance to Mixing (RTRM) formula: $(D1 – D2)/(D' – D^o)$, where D1 is the density of upper water volume, D2 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. The thermocline in the water column is where resistance to mix is greatest, where the RTRM is >30. An RTRM value of ≥80 was used to indictate of strong resistance to mixing (Siver et.al. 2018).

PROFILE DATA

Water quality data measured throughout the water column are provided in Appendix A. We have displayed many of those data below as isopleths where a variable (e.g., temperature) is displayed as shades of colors throughout the water column at each depth and for all dates when data were collected. Values are then interpolated between depth and dates. Variables of the same value (and color) are connected between dates regardless of depth to create a theoretical representation of changes throughout the water column over time.

Temperature and Oxygen

Water temperature data provides a view into the thermal characteristics of the lake and patterns of stratification resulting from temperature/density differences between depths. In shallow New England lakes, or shallow sites in a deep lake, stratification can occur but it may be of short duration because wind energy can mix the water column. In deeper lakes or sites, stratification is not easily broken by wind energy.

When a lake is stratified, a middle transitional layer (aka metalimnion) separates the upper warmer layer (aka epilimnion) from lower colder waters below (aka hypolimnion). Within the boundaries of the metalimnion resides the thermocline, which is the stratum where the temperature/density change and resistance to mixing are the greatest with increasing depth. Stratified conditions will usually persist in deeper lakes or sites for the entire summer and into the fall until turnover mixes the water column.

An oxygen concentration of 5mg/L is generally considered the threshold that delineates favorable conditions for most aerobic organisms in freshwater systems. As concentrations decrease below that threshold, conditions become stressful for many forms of life. Minimum oxygen requirements for fisheries in Connecticut's lakes and

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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 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.

The lake was thermally stratified by May 18th. Surface water temperatures at Site 1 and Site 2 were 17.8°C and 18.0°C, respectively. The small difference on this date and others was likely due to the approximately 40 minutes that transpired between measurements at the surface of the two sites. Above and below the Site 1 thermocline, located between 7 and 8m of depth, temperatures decreased from 11.3 to 9.3°C. Temperatures continued to slowly decrease with depth; between 17m and 30m of depth, temperatures only decreased from 6°C to 5.5°C. Oxygen concentrations increased with depth from 10.7mg/L at the surface to 12.2mg/L at the 9 to 10m strata. Below that, concentrations slowly decreased to 8.0mg/L at the bottom stratum.

At Site 2, temperatures above and below the thermocline, also located between the 7 and 8m strata, were 11.2 and 9.6°C. Temperatures gradually decreased with depth from 6.9 to 6.2mg/L between 12 and 17m of depth. Oxygen concentrations also increased with depth from 10.6 to 12.6mg/L from the surface to 9m of depth before decreasing to 4.2mg/L by the 17m stratum.

By June 16th, surface water temperatures had increased to 21.9°C and 22.4°C at Sites 1 and 2, respectively. Temperatures at the bottom strata remained similar to those observed on May 18th. At Site 1, temperatures were >21°C down to the thermocline situated between the 3 and 4m strata; immediately below the thermocline temperatures were 18.3°C. Temperatures continued to rapidly decrease within the metalimnion, and then gradually decreased from the 9m stratum to the bottom (Fig. 3). Similarly at Site 2, temperatures in the epilimnetic strata were >22°C then rapidly decreased within the metalimnion including a change from 16.0 to 13.0°C above and below the thermocline, which was situated between the 6 and 7m strata. Temperatures decreased slowly below the lower metalimnetic boundary from 10.6 to 6.4°C between 8 and 17m of depth.

June 16th oxygen concentrations increased with depth to the 8m stratum where a maximum of 12.9mg/L was recorded at Site 1. Concentrations decreased afterwards and were <1mg/L at and below 28m of depth. The oxygen maximum at Site 2 was also at the 8m stratum and was 12.8mg/L. Concentrations of <1mg/L were recorded from 15m of depth to the bottom of Site 2.

Surface water temperatures increased through August 26th. July 22nd surface temperatures were between 25 and 26°C. Temperatures decreased from 19.1 to 15.1°C above and below the Site 1 thermocline, which was situated between 6 and 7m of depth. A

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similar temperature gradient was observed at the Site 2 thermocline, located between 7 and 8m of depth, when temperatures at those strata decreased from 16.2 to 12.8°C.

The highest surface water temperatures of the season occurred on August 26th and were 25.5°C and 25.4°C at Sites 1 and 2, respectively. The temperatures continued to remain stable at the bottom and were similar to those measured earlier in the season. Oxygen concentrations at Site 1 were between 8 and 9mg/L down to the thermocline, situated between 7 and 8m of depth. Highest concentrations – between 9.5 and 10mg/L – were measured within the metalimnion and just below it. Oxygen concentrations rapidly decreased from 5.8mg/L at 11m of depth to <1mg/L at 22m of depth then remained <1mg/L to the bottom.

Similar conditions were observed at Site 2 on August 26th. Oxygen concentrations were 9.2 from the surface to the 3m stratum and were between 8 and 9mg/L from the 4m stratum down below the thermocline, which was situated between 6 and 7m of depth. Oxygen increased to 9.7mg/L by the 9m stratum before decreasing to <1mg/L by the 13m stratum down to the bottom stratum.

On September 20th, the Site 1 surface water temperatures of 22.1° C decreased with depth to 20.9°C just above the upper metalimnetic boundary at 6m of depth. Temperatures decreased rapidly from 17.8 to 10.2°C within the metalimnion then slowly from 8.9 to 5.6°C below the metalimnion to the bottom stratum. A similar thermal pattern was observed at Site 2, except temperatures at the bottom were 7°C.

Oxygen concentrations of 8.9 to 9mg/L were measured in the top 5m of the Site 1 water column on September 20th, before slightly decreasing, and then increasing to 9.4mg/L by 9m of depth. Oxygen concentrations decreased below that and were <1mg/L from 18 m stratum to the bottom. Oxygen levels decreased in the first few meters then increased between the 7m and 8m stratum. The thermocline remained around 10 meters of depth at Site 1 then climbed slightly to 9 meters at Site 2.

The Site 2 oxygen levels on September 20th were 9mg/L to the 4m strata, between 7.8 and 8.8mg/L within the metalimnion; and below the lower metalimnetic boundary (10m), oxygen decreased from 5.5 to <1mg/L at 17m of depth.

On October 21st, temperatures from the surface to the 8m stratum decreased from approximately 16.8 to 16.1°C. Within the metalimnion, temperatures decreased from 13.6 to 9.4°C. Just below the lower metalimnetic boundary at 12m of depth, temperatures decreased from 8.2 to 5.7°C at the bottom. The Site 2 temperature profile was similar; but temperatures only decreased to 7.2°C at the bottom.

October 21st, oxygen concentrations were >9mg/L down to the 8m stratum at both sites, decreased rapidly within the metalimnion, and were <1mg/L throughout the hypolimnetic strata.

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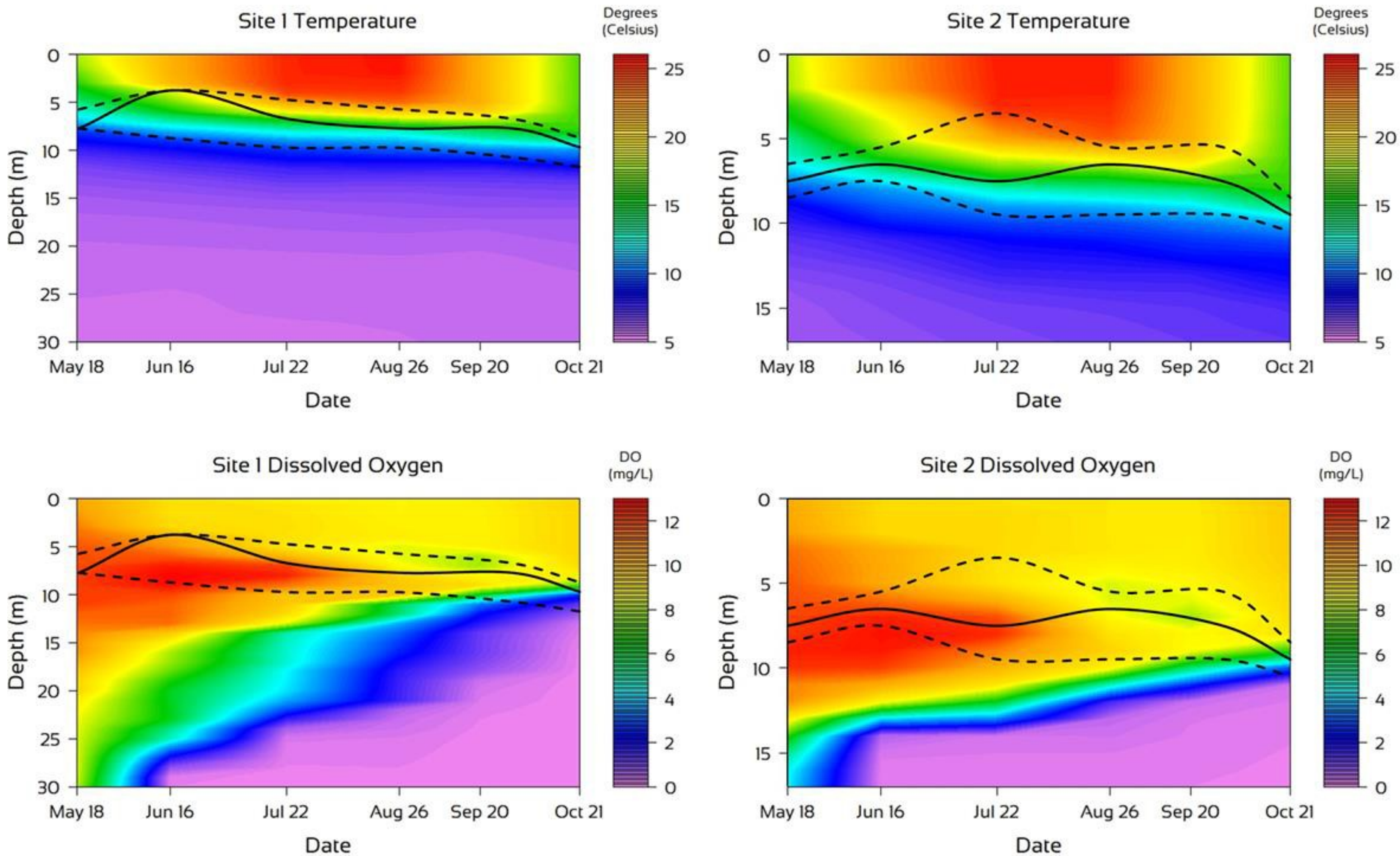

Figure 3. Temperature (top) and dissolved oxygen (bottom) isopleth charts for Site 1 (left) and Site 2 (right) on Lake Wononscopomuc in 2021. The black dashed lines represent the approximate location of the upper and lower metalimnetic boundaries; the solid black line represents the approximate location of the thermocline.

TROPHIC VARIABLES

Secchi Transparency

Secchi disk transparency is a measure of how much light is transmitted through the water column. That transmission is influenced by several variables including the quantity of inorganic and organic particulate material in the water column that absorbs, refracts, or reflects light. In the open water environment, Secchi disk transparency is inversely related to algal productivity.

Light in lakes is important for several reasons including its impact on open water photosynthesis and algal productivity. As light diminishes with depth, so too does maximum photosynthetic potential. As photosynthesis decreases with depth there is a depth where oxygen produced from algal photosynthesis is equaled to the oxygen consumed via cellular respiration. That is referred to as the Compensation Point or Compensation Depth; it is estimated by multiplying the Secchi disk transparency by 2. Compensation Depths are discussed in the *Assessment* section of this report.

Season Secchi transparency averages at Site 1 and Site 2 were 4.99 and 4.82m, respectively. Respective summer month (July – September) averages were 4.58 and 4.50m. Secchi transparencies of >5m on May 18th and June 16th decreased to season minima of 3.81 and 3.90m at Site 1 and Site 2, respectively by July 22nd. Measurements increased to >5m by September 20th at both sites, before decreasing to approximately 4.60m by October 21st.

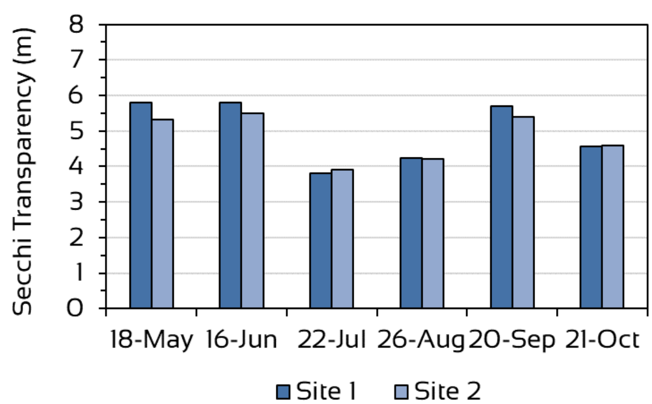

Figure 4. Secchi disk transparencies measured at Site 1 and Site 2 at Lake Wononscopomuc in 2021.

Total Phosphorus

Algae and cyanobacteria require a variety of macro and micronutrients. The nutrient that is least available in proportion to algal requirements is termed the *limiting nutrient*; in freshwater systems, that nutrient is usually phosphorus. It is the *limiting nutrient* because the amount of available phosphorus will limit the amount of algal productivity in the system. In most Limnological studies, total phosphorus is measured; it is the sum of particulate and dissolved forms of phosphorus.

Site 1 epilimnetic phosphorus exhibited a range from below detectable limits, which occurred on both August 26th and September 20th, to a maximum concentration of 40ug/L (June 16th). The seasonal average for the Site 1 epilimnion was 15.7ug/L.

The Site 2 epilimnetic concentrations were generally lower than Site 1 concentrations (Fig. 5) but site averages were not significantly different ($p>0.05$). Concentration below detectable limits were reported for Site 2 samples collected on September 20th and October 21st. The season maximum of 26ug/L occurred on June 16th. The Site 2 seasonal average was 11.2ug/L.

Average hypolimnetic concentrations were one to two orders of magnitude higher than epilimnetic levels. The lake averages for the two strata were significantly different ($p<0.05$). Site 1 and Site 2 hypolimnetic averages were 167.5 and 396.3µg/L, respectively, but not statistically different ($p>0.05$).

Hypolimnetic concentrations on May 18th were similar to corresponding epilimnetic levels (Fig. 5). Site 1 hypolimnetic concentrations fluctuated between 16 and 95ug/L from May 18th through July 22nd before increasing to 300µg/L by August 26th. Concentrations decreased to 140µg/L by September 20th before attaining their highest levels of 400µg/L by October 21st.

At Site 2, hypolimnetic concentrations increased exponentially from 29 to 1,300µg/L between May 18th and August 26th. Like observed at Site 1, the September 20th concentration at Site 2 substantively decreased before increasing to 390µg/L by October 21st.

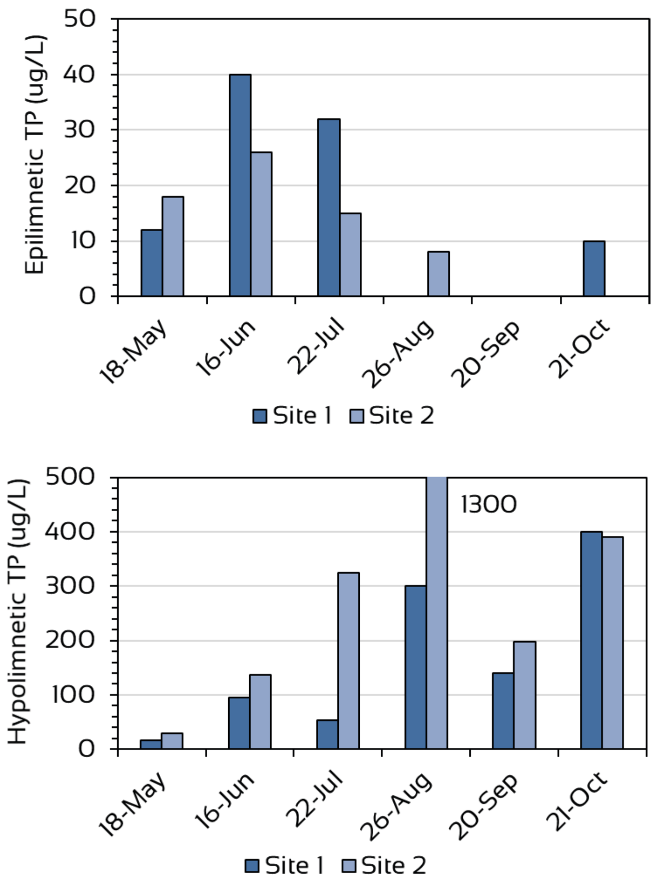

Figure 5. Epilimnetic (top) and hypolimnetic (bottom) total phosphorus (TP) at Site 1 and Site 2 of Lake Wononscopomuc in 2021. Note the difference in scale between epilimnetic and hypolimnetic concentrations.

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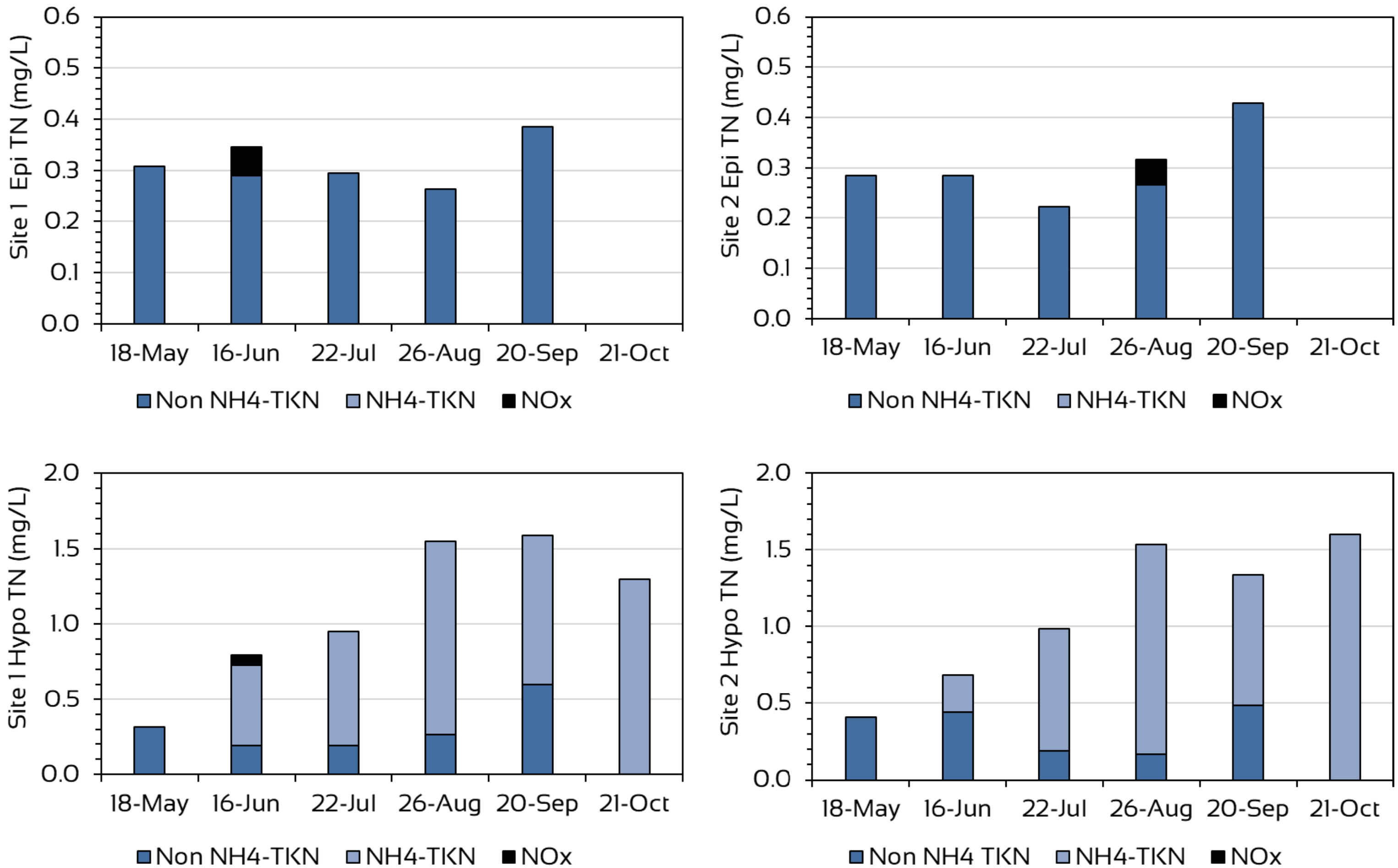

Figure 6. Total nitrogen (TN) in the epilimnion (top) and hypolimnion (bottom) of Site 1 (left) and Site 2 (right) of Lake Wononscopomuc in 2021. Total nitrogen is presented as the sum of its constituents: total Kjeldahl nitrogen that is not ammonia (Non NH4-TKN), TKN that is ammonia (NH4-TKN), and nitrate/nitrite (NOx). Note the difference in scale between epilimnetic and hypolimnetic concentrations.

Total Nitrogen

Total Kjeldahl nitrogen (TKN) is a measure of the reduced forms of nitrogen (including ammonia) and 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 of TKN, nitrate, and nitrite; since the latter two are often below detectable limits, TKN levels are often similar or equal to total nitrogen (TN) levels.

Nitrogen constituents were analyzed in samples collected at one meter below the surface and approximately 0.5m from the bottom during each sampling event. Due to a change in laboratory analyst in October, a higher minimum detection limit was used for TKN. The detection limit was higher than the concentrations found in the samples, and sample concentrations were reported as <0.5mg/L. Those October 21st data are being excluded from our assessment of total nitrogen below.

Epilimnetic total nitrogen levels were low to moderate with season averages of 319 and 307µg/L at Sites 1 and 2, respectively. Ammonia was not detected in epilimnetic samples collected at either site. A small concentration of nitrite was detected at Site 1 on June 16th and a small concentration of nitrate at Site 2 on August 26th (Fig. 6). The highest total nitrogen concentrations at both sites occurred on September 20th.

Average total nitrogen concentrations in the hypolimnion were significantly higher than epilimnetic averages ($p<0.05$). Most of the hypolimnetic total nitrogen after May 18th was in the form of ammonia (Fig. 6). A small amount of hypolimnetic nitrite was also detected at Site 1 on June 16th. Hypolimnetic total nitrogen concentrations, particularly the ammonia faction, increased over the course of the season concurrent with the length of time anoxic conditions persisted in the hypolimnion.

Trophic data and other chemical data discussed below are compiled in a tabular format in Appendix B.

Algal Community Dynamics

Algae have been used in water quality assessments for many years, for multiple reasons, and in a variety of ways. Algae are essential to the aquatic food web, particularly in the open water environment. They are responsive to changes in water quality and chemistry; increasing nutrient levels often result in greater algae cell concentrations and community composition shifts where populations of cyanobacteria become dominant. The quantity of cells, algal biomass, and composition of the community can all be used as diagnostic tools to assess water quality.

In recent years, there has been much attention focused on the cyanobacteria (aka Cyanophyta or blue-green algae). As noted, their dominance in the water column and formation of blooms is a feature of eutrophication. More recently, the toxigenic nature of some taxa of cyanobacteria has prompted state government environmental agencies to provide guidance to municipalities on appropriate actions at public beaches in response to harmful cyanobacteria algae blooms (e.g., CT DPH & CT DEEP 2019).

Samples collected for algae identification and enumeration were an integration of the top three meters of the water column. Some genera of cyanobacteria can regulate their position in the water column by altering cellular buoyancy. High concentrations of such organisms are often found layered near the thermocline. Those populations residing below three meters of depth are not accounted for in integrated samples but are assessed using relative phycocyanin concentrations, which are measured with a multimeter during each visit. At the strata with the highest relative phycocyanin concentration, a sample was collected (13.5m) on June 16th (see below). It would be advantageous add this sample to all future assessments.

Forty-five algal genera were identified and those were asymmetrically distributed among eight taxonomic groups (Appendix C). The taxon with the greatest seasonal richness (i.e., most individual genera) were the Chlorophyta (aka green algae); that group was represented by 20 genera (44% of all genera observed). The Chrysophyta (aka golden algae), Bacillariophyta (aka diatoms), and Cyanophyta were represented by 7, 6, and 5 genera, respectively. Four genera from the Pyrrophyta (aka dinoflagellates) and one in each of three other taxonomic groups were also observed in samples. Observations were made from both concentrated plankton net samples and in samples used for counts.

Total algal cell concentrations were low in all samples from both sites. The season maximum at Site 1 was 4,055 cells/mL (May 18th); cell concentration at Site 2 on that date were also relatively high but the maximum of 4,356 cells/mL occurred on October 21st (Fig. 7). The May 18th Site 1 maxima was co-dominated by cyanobacteria and golden algae, while the October 21st Site 2 maxima was mostly cyanobacteria. For both maxima, the dominant cyanobacterium was *Planktothrix spp*. (formerly *Oscillatoria spp*. Fig. 8).

The high relative abundance of cyanobacteria at Site 2 on October 21st was also observed on the same date at Site 1; this was also the case on September 20th at Site 2 (Fig. 7). Despite the high relative abundance, cyanobacteria cell concentrations were only between 1,000 and 4,300 cells/mL in those samples. For comparison, the State recommends a range of 0 to 20,000 cyanobacteria cells/mL to indicate Visual Rank Category 1 conditions, which generally reflect no public health risk due to cyanobacteria or cyanotoxins (CT DPH & CT DEEP 2019).

The golden algae genus that was co-dominant in the algae community on May 18th was *Dinobryon spp*. (Fig. 8). *Dinobryon spp*. continued to be important through June 16th but not afterwards. The centric diatom *Cyclotella spp*. (Fig. 8) was the genus with the greatest relative abundance on June 16th. The green algae community was also important on June 16th particularly at Site 2 where five genera collectively accounted for 22.5% of total cells in the sample.

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The Chlorophyta, and specifically *Scenedesmus spp*. (Fig. 2), was again important on July 22nd. *Scenedesmus spp.* was a dominant genus on August 26th at both sites, and on September 20th at Site 1. On July 22nd, a second filamentous cyanobacteria genus, *Dolichospermum spp*. (Fig. 8), was secondarily important at both sites and continued to be important at Site 1 through August 26th. The diatom *Cyclotella spp*. was also important at Site 1 on August 26th.

The two sites were most different from each other on September 20th. As noted earlier, the Site 2 sample was dominated by the cyanobacteria *Planktothrix spp*. At Site 1, however, green algae led by *Scenedesmus spp*. still comprised approximately 80% of the algae community. By October 21st, *Planktothrix spp*. was dominant, constituting 83 and 93% of the cell concentrations at Site 1 and Site 2, respectively.

The two important cyanobacteria genus at Wononscopomuc in 2021 were *Planktothrix spp*. and *Dolichospermum spp*.; they are both genera that can regulate buoyancy and can be found concentrated in strata well below the surface. To assess the cyanobacteria spatial and temporal distribution, the photosynthetic pigment unique to the cyanobacteria – phycocyanin – was measured throughout the water column with the fluorimeter incorporated into the sensor array of the Eureka Manta II multimeter. Fluorimeters work on the principal that a particular substance fluoresces at a specific wavelength when light of another wavelength is directed on that substance. The fluorimeter in AER's instrumentation emits a wavelength that interacts with phycocyanin. This sensor is not calibrated to known concentrations of phycocyanin so measurements are not quantitative; instead, the measurements are relative to other measurements in the water column or to other sites.

A persistent layer of high phycocyanin was detected at both sites below thermocline (Fig. 9). Concentrations elsewhere in the water columns of both sites were low. The highest deep water relative phycocyanin concentration was detected between 13 and 14m of depth at Site 1 on June 16th. A successful effort was made to capture a sample from that site on that date at approximately 13.5m of depth for analysis. Cell concentrations were 34,513 cells/mL (compared to 1,045 and 555 cells/mL near the surface of Site 1 and Site 2, respectively). The composition of the deep-water sample was 99.5% *Planktothrix spp*.

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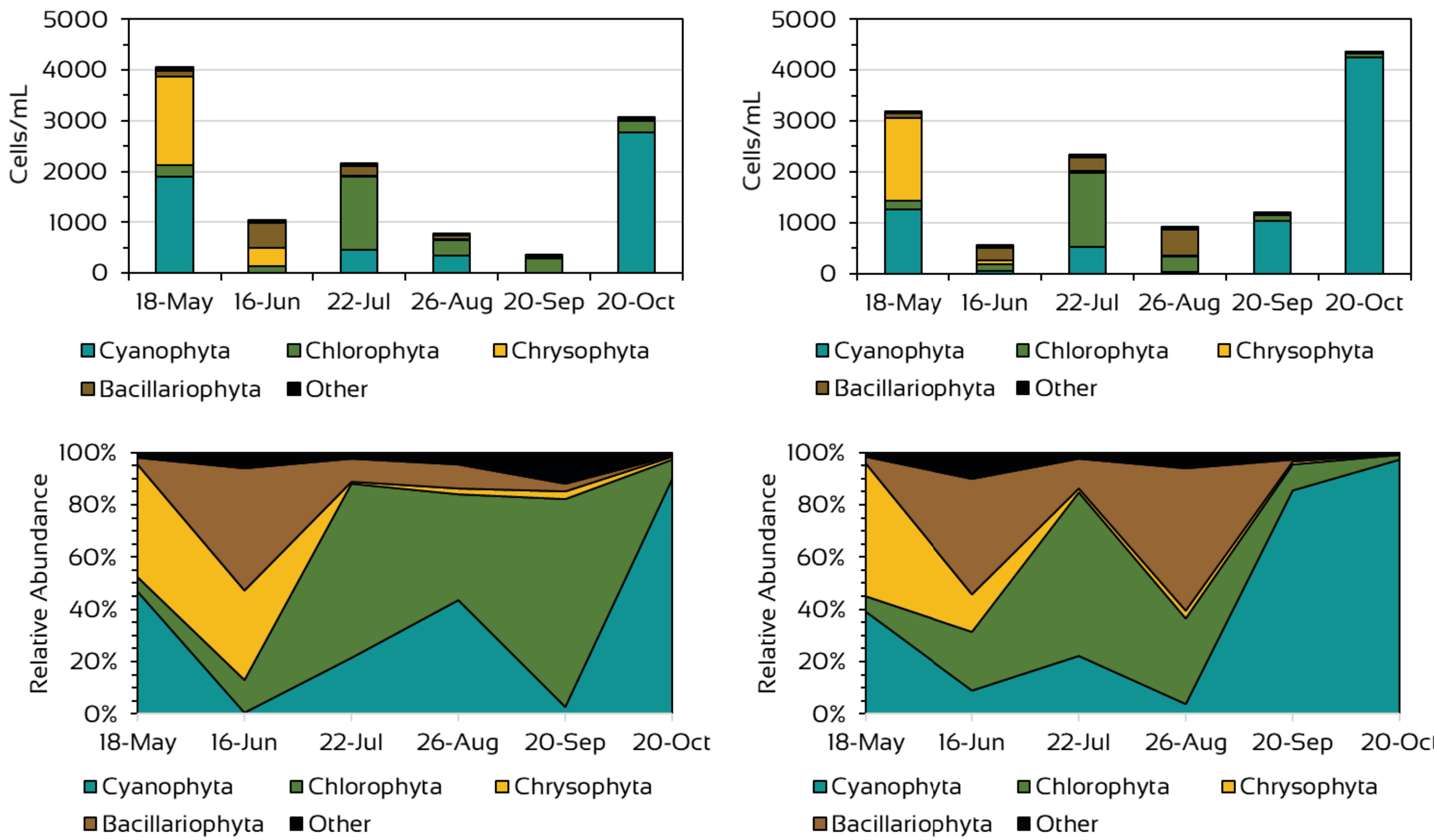


Figure 7. Algae cell concentration by taxonomic group (top) and relative abundance for those groups (bottom) for Site 1 (left) and Site 2 (right) during the 2021 season at Lake Wononscopomuc.

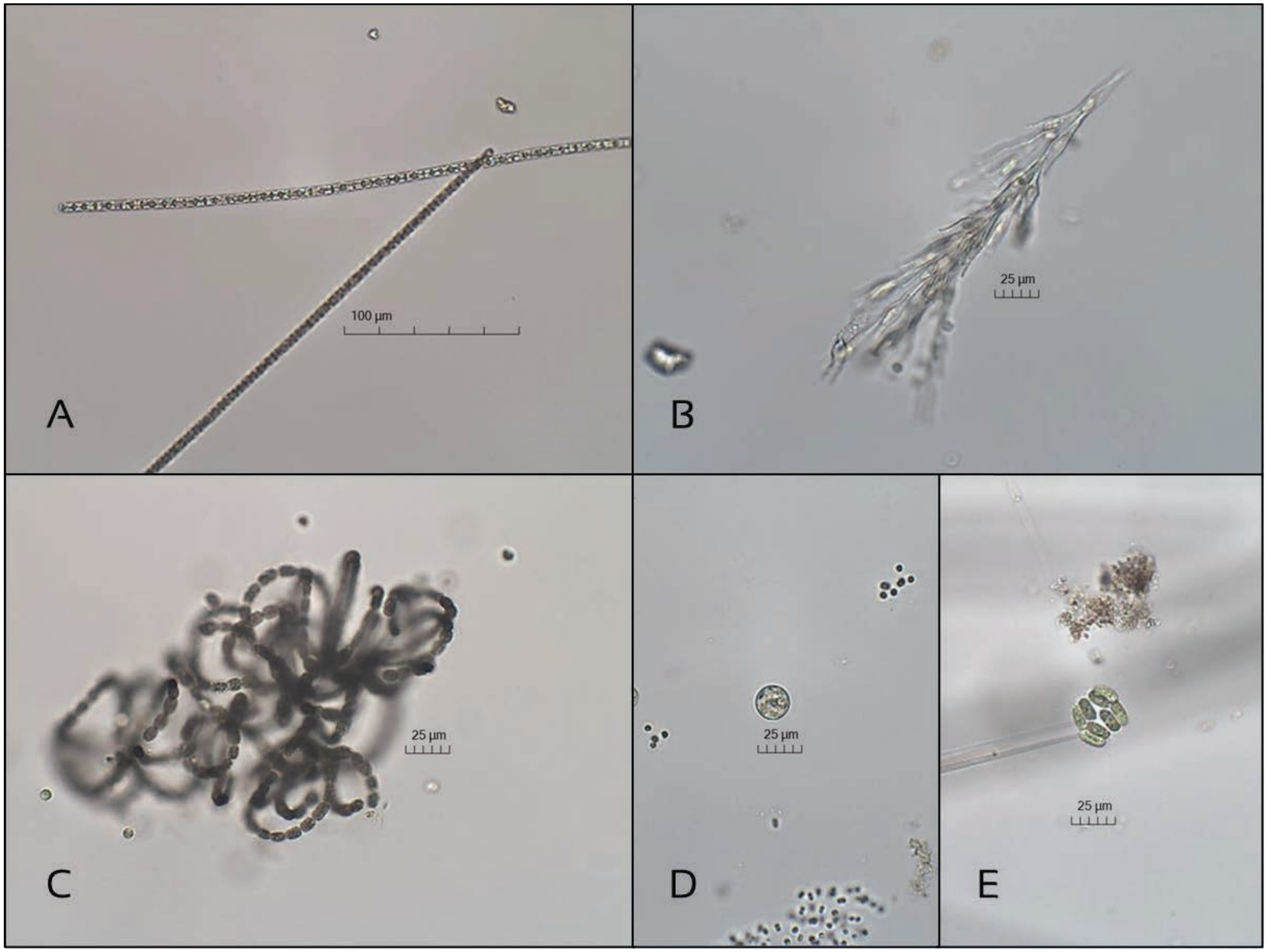
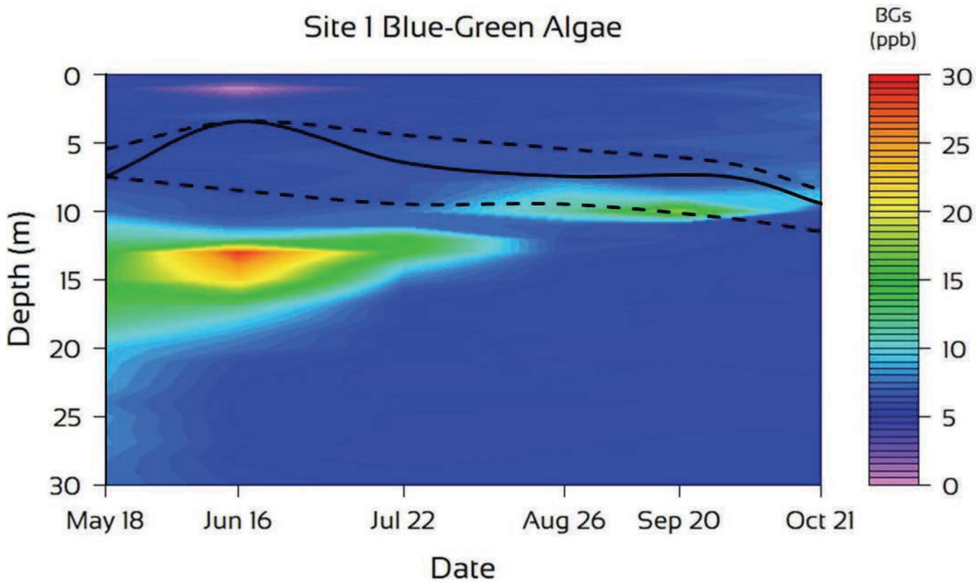


Figure 8. Images of algae collected at Lake Wononscopomuc in 2021. A) the filamentous cyanobacteria *Planktothrix spp*., B) the colonial golden algae *Dinobryon spp*., C) the filamentous cyanobacteria *Dolichospermum spp*., D) the centric diatom *Cyclotella spp*., and the colonial green algae *Scenedesmus spp*. Total magnification is 400X.



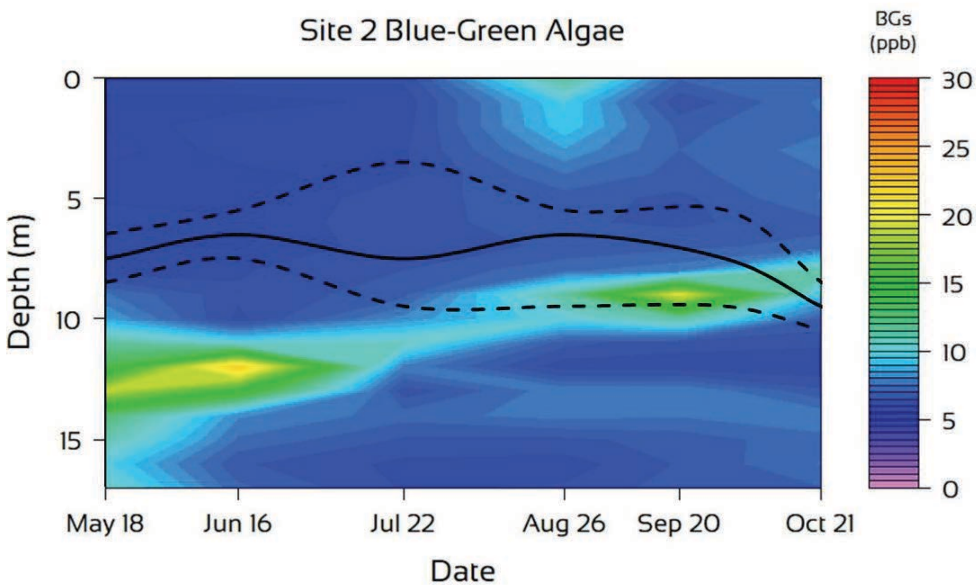


Figure 9. Isopleth charts of relative phycocyanin concentrations in the water columns at Site 1 (top) and Site 2 (bottom) of Lake Wononscopomuc during the 2012 season. The black dashed lines represent the approximate location of the upper and lower metalimnetic boundaries; the solid black line represents the approximate location of the thermocline.

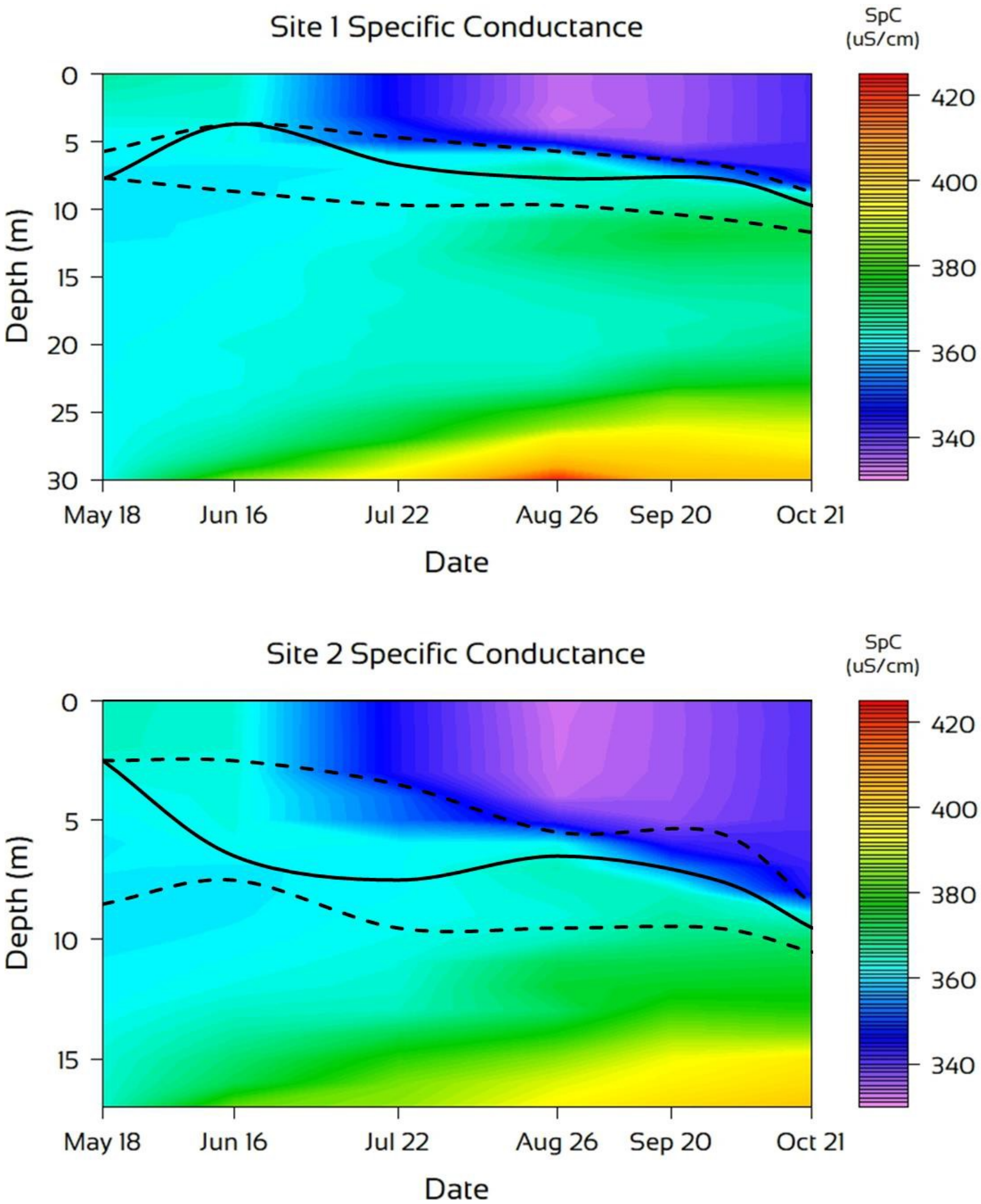


Figure 10. Isopleth charts of specific conductance in the water columns of Site 1 (top) and Site 2 (bottom) of Lake Wononscopomuc during the 2012 season. The black dashed lines represent the approximate location of the upper and lower metalimnetic boundaries; the solid black line represents the approximate location of the thermocline.

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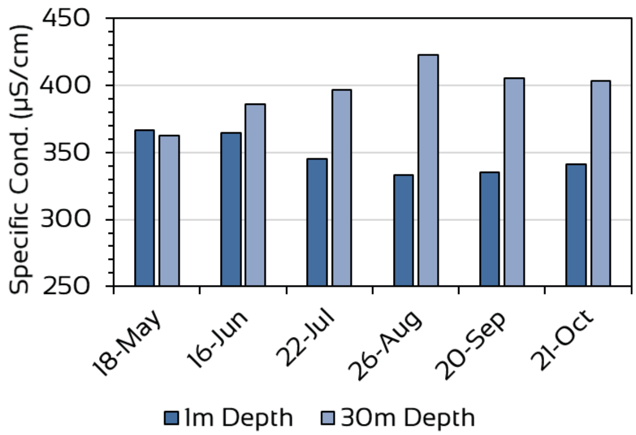
Specific Conductance

Conductivity is a surrogate measurement for the sum of the ionized minerals, metals, and salts in the water. As such, it is also a measure of water's ability to conduct an electrical current. Data collections included measures of both conductivity and specific conductance and were measured in microsiemens per cm (µS/cm). We report below on specific conductance which is the same as conductivity but standardized to a set water temperature (25°C). Temperature influences conductivity and – in the field – temperature varies with depth and date.

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). As was done with temperature and oxygen profile data, specific conductance data have been displayed as isopleth charts (Fig. 10).

The Lake Wononscopomuc specific conductance was high relative to other lakes in Connecticut, and due in part to local geology. Levels were variable over time and depth (Fig. 10, 11). Specific conductance throughout the water column was nearly homogeneous on May 18th, with only slightly higher levels near the surface. Conditions were similar on June 16th but with a notable increase at the bottom of both sites.



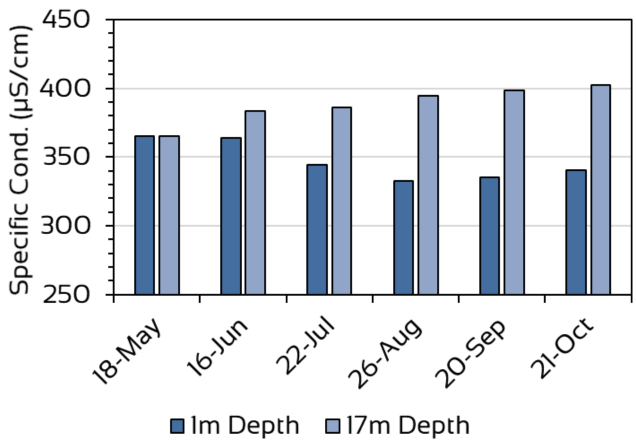


Figure 11. Specific conductance at 1m of depth and the bottom stratum at Site 1 (top) and Site 2 (bottom) of Lake Wononscopomuc in 2021.

Between June 16th and July 22nd, levels decreased in the epilimnetic strata, while continuing to increase in the bottom strata. That trend continued through August 26th when epilimnetic strata decreased to their lowest levels at both sites, and the Site 1 hypolimnetic level increased to its season high. The hypolimnetic season maximum at Site 2 did not occur until October 21st. Also on August 26th, specific conductance in the strata at, or just below, the lower metalimnetic boundary was elevated relative to strata above and below it, particularly at Site 1 (Fig. 10).

Between August 26th and October 21st, epilimnetic specific conductance increased slightly, but only to levels measured previously on July 22nd. Hypolimnetic levels at Site 1 decreased slightly but were still high relative to epilimnetic levels.

Alkalinity and pH

Alkalinity is a measure of calcium carbonate; and, it provides lake water its ability to neutralize acid (i.e., buffering capacity). Alkalinity of surface waters is largely influenced by local geology and other watershed characteristics. Alkalinity at the bottom of the water column can also be generated internally from the biologically mediated reduction of iron, manganese, and sulfate via cellular respiration in the anoxic lake sediments, and denitrification of nitrate to elemental nitrogen (Wetzel 2001).

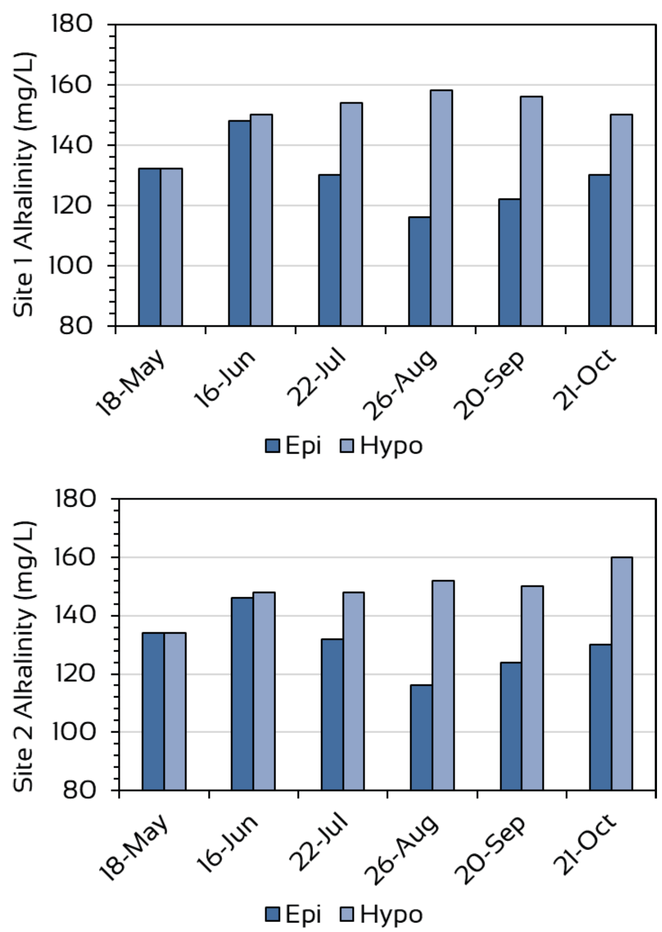


Figure 12. Epilimnetic (Epi) and hypolimnetic (Hypo) alkalinity at Site 1 (top) and Site 2 (bottom) of Lake Wononscopomuc in 2021.

On May 18th, an alkalinity of 132mg/L was measured at both sites and both strata. Levels increased by June 16th but were still similar across sites and depths (Fig. 12). By July 22nd, epilimnetic and hypolimnetic levels began to become more discrete. Epilimnetic concentrations at both sites decreased and reached the season minimum of 116mg/L by August 26th, while hypolimnetic levels increased and reached a season maximum of 158mg/L at Site

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1. The season hypolimnetic maximum for Site 2 would not occur until October 21st when it was measured at 160mg/L. Epilimnetic concentrations experienced a small increase between August 26th and October 21st.

The season epilimnetic averages were 129.7mg/L and 130.3mg/L at Site 1 and Site 2, respectively. The respective hypolimnetic averages were significantly higher at 150mg/L and 148.7mg/L ($p<0.05$).

The pH of surface waters of lakes in the Northeast normally ranges from approximately 6 to 9 SU (standard units). Very low or very high pH levels will not support diverse fauna and flora in freshwater ecosystems.

Algal community composition is influenced by pH. For example, all algae require some form of dissolved carbon for growth; the pH of the water will determine the type of dissolved carbon in the water column. At pH levels greater than 8.3 SU, bicarbonate is the dominant form of carbon available to the pelagic algal community; the cyanobacteria have adaptive advantages over other algal groups under those conditions because they can efficiently utilize that form of carbon. Other algal groups are dependent upon carbon dioxide, which is more readily available in water with a pH below 8.3 SU.

The difference in pH between the epilimnetic and hypolimnetic stratum is largely due to the concentration of carbon dioxide in the two strata. Atmospheric carbon dioxide diffuses into the water and forms carbonic acid, and although a weak acid, is one that decreases pH. In the upper strata of the water column where photosynthesis is occurring, carbon dioxide is used in photosynthesis, resulting in the production of energy storage products (e.g., carbohydrates) and oxygen. Photosynthesis normally decreases with depth, so carbon dioxide levels increase with depth thus lowering pH.

Carbon dioxide is also a metabolic byproduct of cellular respiration. Cellular respiration occurs in both the epilimnion by the aerobic organisms, and in the hypolimnion by aerobic organisms until oxygen is used up. Then anaerobic organisms become more dominant and utilize other molecules for their cellular respiration needs. This combination of factors also mediates carbon dioxide levels and result in the pH in the hypolimnion being lower.

Epilimnetic pH of Lake Wononscopomuc was high. The season minima at Site 1 and Site 2 were 8.6 and 8.7 SU, respectively; the respective maxima were 9.0 and 9.1 SU. Season averages for Site 1 and Site 2 were 8.8 and 9.2 SU. Epilimnetic pH increased over time; this trend was more conspicuous at Site 2 (Fig. 13).

Atypical for lakes of the Northeast, hypolimnetic pH was often higher than corresponding epilimnetic pH (Fig. 13). The season minimum, maximum, and average for Site 1 were 7.8, 10.0, and 9.2 SU. Those data for Site 2 were 8.0, 11.1, and 9.8 SU. At Site

1, the hypolimnetic levels on May 18th and June 16th were lower than epilimnetic levels; those were the lowest of the season. Similar conditions were observed at Site 2 on May 18th. On all other dates, hypolimnetic pH levels exceeded epilimnetic pH levels.

After June 16th at Site 1, hypolimnetic pH increased and was at or near 10.0 SU between August 26th and October 21st. At Site 2, hypolimnetic pH was more variable. Levels increased from 8.0 SU on May 18th to 11.1 SU on July 22nd. Levels decreased to 9.5 SU by August 26th before returning to 11.1 SU by September 20th. By October 21st, hypolimnetic levels decreased again to 9.6 SU.

It is worth recalling that pH is reported in logarithmic units, i.e., each number along the scale of 0 to 14, and each SU represents a 10-fold change in the hydrogen ion concentration of the water. For example, the change in the Site 2 hypolimnion from 8 SU to 11 SU represents a 1,000-fold decrease in the hydrogen ion concentration of the water.

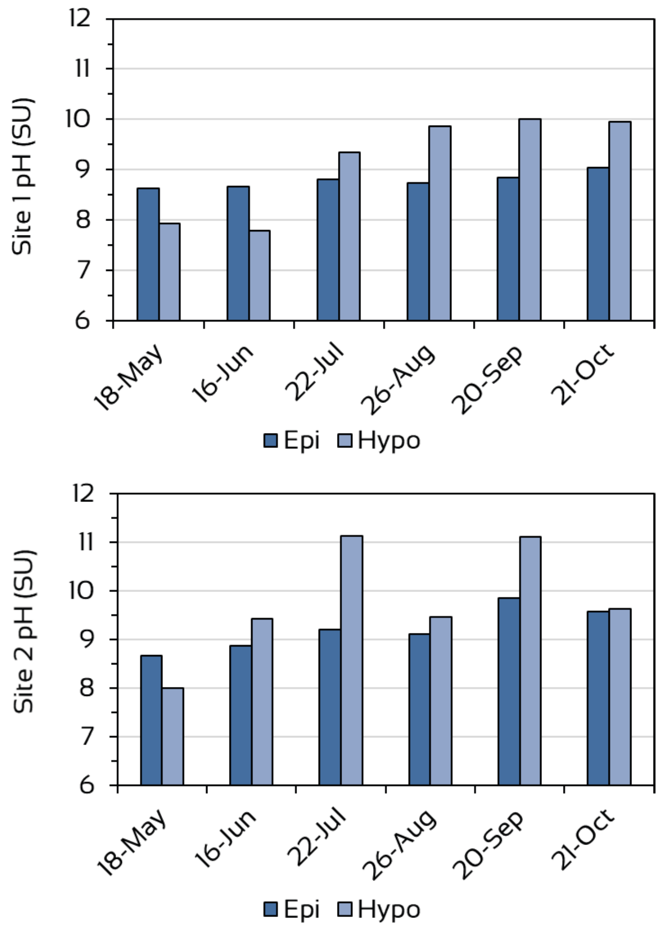
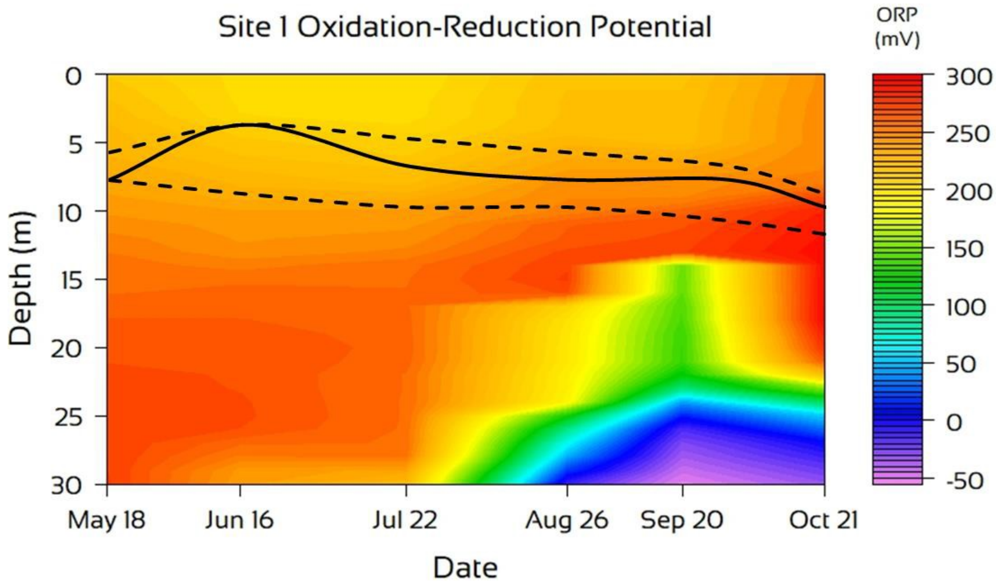


Figure 13. Epilimnetic (Epi) and hypolimnetic (Hypo) pH at Site 1 (top) and Site 2 (bottom) of Lake Wononscopomuc in 2021.

Oxidation-Reduction Potential

The oxidation-reduction potential (aka redox potential or ORP) in lakes refers to the oxidative or reductive state in a particular stratum of the water column; it can provide some insight as to whether phosphorus is changing from an insoluble particulate state in the sediments to a soluble state that readily diffuses to overlying waters and available to lentic algae if mixed into the photic zone (i.e., where algae can harvest it for growth). When OPR is ≥200 millivolts (mV) phosphate remains bound to iron; at ORP values of <200mV, iron can be reduced and the phosphate that is chemically bound to the iron can become soluble (Søndergaard 2009).



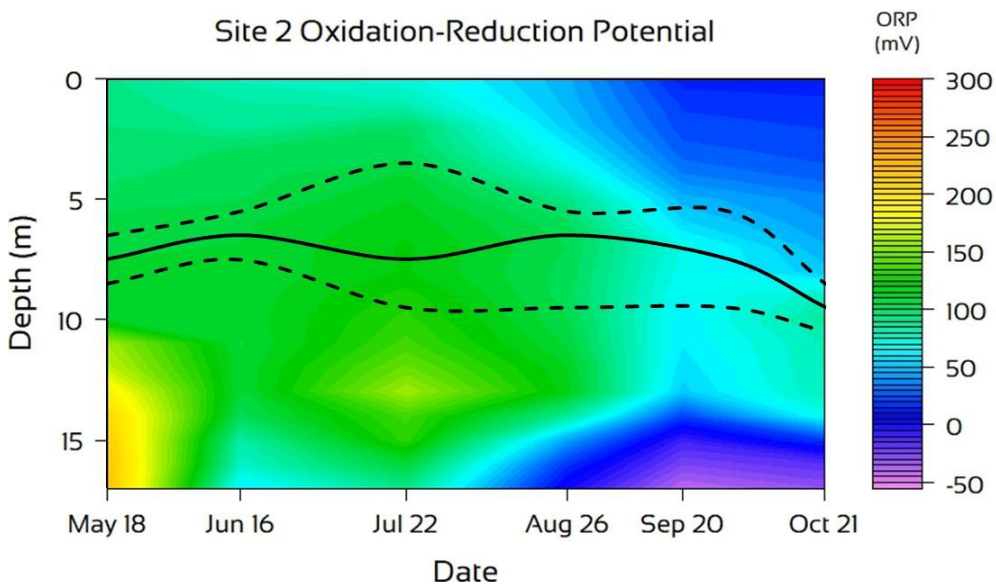


Figure 14. Isopleth charts of oxidation-reduction potential in the water columns of Site 1 (top) and Site 2 (bottom) of Lake Wononscopomuc during the 2012 season. The black dashed lines represent the approximate location of the upper and lower metalimnetic boundaries; the solid black line represents the approximate location of the thermocline.

At Site 1, oxidation-reduction potential was ≥200mV throughout the water column from May 18th through July 22nd. By August 26th, ORP ≥200mV was measured from the surface down to 17m of depth. Between the 18m and 24m strata, ORP measurements decreased from 199mV to 187mV. From the 25m to 30m strata, ORP decreased from

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124mV to -9mV. Those strata of the water column with ORP <200mV increased by September 20th and were measured at 147mV in the 14m stratum down to -52mV at the 30m stratum. Strata with ORP >200mV increased by October 21st from the surface down to the 22m stratum; below that ORP decreased from 153mV at the 23m stratum to -32 at the 30m stratum.

Oxidation-reduction potential dynamics were considerably different at Site 2. Only the Site 2 ORP measurements from the 14m to 17m strata on May 18th were >200mV. ORP measurements the June 16th and July 22nd water columns were between 60 and 159mV. Levels increased with depth to the 10m strata before decreasing with depth to the bottom on June 16th (Fig. 14). On July 22, the depth with maximum ORP was the 13m stratum; afterwards ORP decreased with depth. Similar conditions persisted on August 26th but with a water column minimum of 1.4mV measured at 17m of depth. September 20th and October 21st ORP water column measurements were similar with minimum and maximum measurements of -40 and 70mV, and -30 and 87mV, respectively.

2015 TO 2021 WATER QUALITY TRENDS

Since 2015, AER has been engaged in developing a water quality database on Lake Wononscopomuc. A benefit of a historical database is the ability to detect statistically significant trends in the lake that may be occurring. Below, two approaches were used to assess whether the lake and specific variables were trending, i.e., significantly increasing or decreasing, or not changing. The first approach pooled epilimnetic and hypolimnetic data into one dataset; the second approached leveraged the epilimnetic and hypolimnetic datasets independently.

Two statistical methods were applied to the datasets derived from the two approaches. The first method, Multiple Linear Regression (MLR), was employed to determine if the epilimnion, hypolimnion, and/or the entire water column – based on a collective set of 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. Rejecting the null hypothesis implied that a significant trend was detected based on the collective dataset.

The second method, Analysis of Variance or ANOVA, was utilized to examine each variable independently of others to determine whether a change had occurred in a statistically significant manner over time. The F-statistic was 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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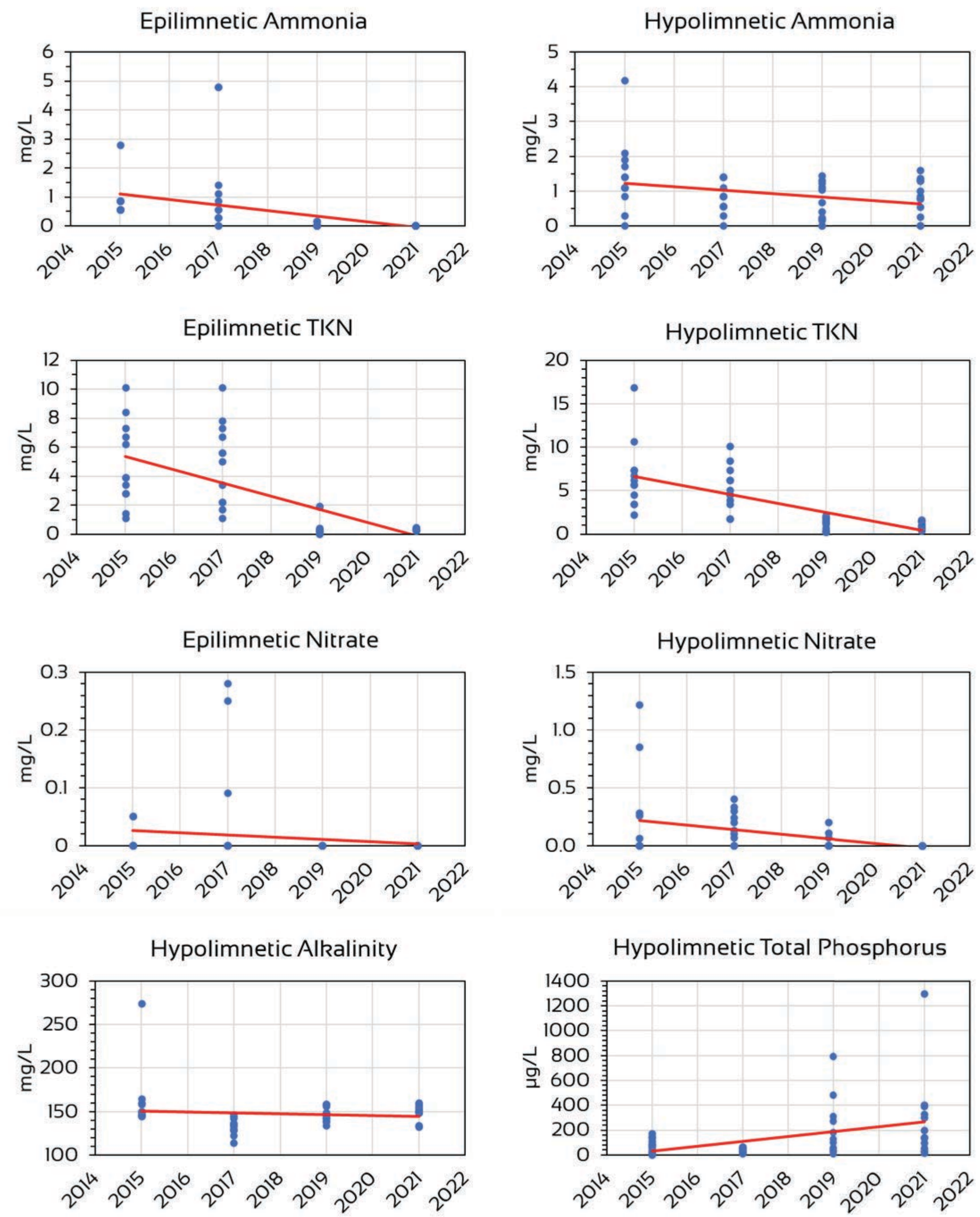

Figure 15. Regressions of variables by year determined to have significantly changed based on ANOVA analyses of data between 2015 and 2021. TKN = Total Kjeldahl Nitrogen.

Multiple Linear Regression

Significant change was detected in water quality of Lake Wononscopomuc based on the pooled, epilimnetic, and hypolimnetic datasets. The variables that contributed most to the significance of the model from the pooled dataset were epilimnetic and hypolimnetic ammonia, hypolimnetic nitrate, hypolimnetic total Kjeldahl nitrogen, and hypolimnetic total phosphorus. The variable that contributed most to the significance of the model from the epilimnetic dataset was total Kjeldahl nitrogen. The variables that contributed most to the significance of the model from the hypolimnetic dataset was ammonia, total Kjeldahl nitrogen, and total phosphorus. See Appendix D for results from analyses.

Analysis of Variance (ANOVA)

ANOVA indicated that multiple variables have significantly changed since 2015. These included the epilimnetic variables of ammonia, nitrate, and total Kjeldahl nitrogen. From the hypolimnion dataset, alkalinity, ammonia, nitrate, total Kjeldahl nitrogen, and total phosphorus were shown to have significantly changed since 2015. See Appendix D for results from analyses.

Variables that exhibited significant change were plotted to detect the direction of change, i.e., increasing or decreasing, since 2015 (Fig. 15). All nitrogen related variables (ammonia, TKN, nitrate) exhibited significant decrease in both the epilimnetic and hypolimnetic strata. A negative (decreasing) trend in hypolimnetic alkalinity was detected, as well. The significant trend for hypolimnetic total phosphorus was positive (increasing).

The same kinds of analyses were performed in 2019 with data collected from 2015 to 2019. Below we have compared the results of ANOVA from 2019 with those that included the 2021 data (Table 3). Results from the two sets of analyses were similar for several variables including epilimnetic variables of ammonia, and TKN, and hypolimnetic variables of alkalinity, ammonia, TKN, and total phosphorus. Trends for some variables were significant for the 2015 to 2019 dataset, but not for the 2015 to 2021 dataset. These included, epilimnetic total phosphorus, epilimnetic pH, and hypolimnetic pH. Trends for epilimnetic and hypolimnetic nitrate were not significant based on the smaller dataset (2015 – 2019), but were for the larger dataset (2015 – 2021).

ASSESSMENT AND MANAGEMENT CONSIDERATIONS

Much of those data collected were used to assess the trophic state of the lake. A lake's trophic state is a determination of the level of productivity the lake supports by assessing the variables that limit or are related to algal productivity, e.g., phosphorus concentration, Secchi transparency, chlorophyll-*a* concentrations, etc. Lakes supporting very little productivity are typically clear and are called oligotrophic lakes; lakes supporting high levels of productivity are more turbid and are termed eutrophic or highly eutrophic. It is generally eutrophic or highly eutrophic lakes that experience algal blooms. Table 4 lists the criteria used to categorize the trophic state of a lake.

Table 3. Comparison of ANOVA results with data collected from 2015 and 2019, and 2015 and 2021. Level of significance is indicated (significant * to highly significant ***).

Variables	Whole		Epilimnion		Hypolimnion	
	2019	2021	2019	2021	2019	2021
Secchi						
Epi Alkalinity						
Epi Ammonia	***	***	*	***		
Epi Nitrate		*				
Epi Nitrite						
Epi TKN	***	***	**	***		
Epi Total Phosphorus	***		**			
Epi pH	***		*			
Hypo Alkalinity	*	*			*	*
Hypo Ammonia					***	**
Hypo Nitrate		**				***
Hypo Nitrite						
Hypo TKN	***	***			***	***
Hypo Total Phosphorus	*	*			**	**
Hypo pH	***				***	

Table 4. 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

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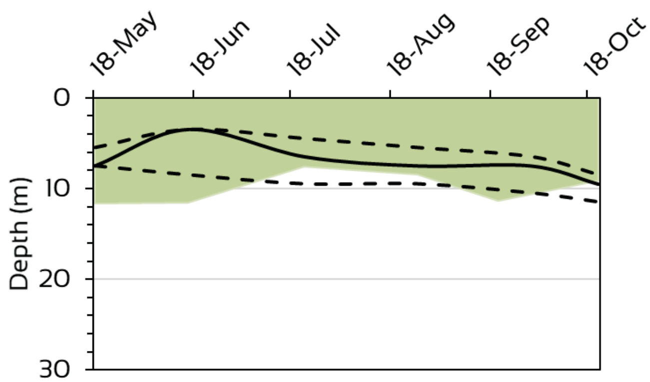
Both season and summer average Secchi disk transparency indicated that the lake supported early mesotrophic productivity (Table 4). Average total phosphorus at Site 2 was also characteristic of early mesotrophic waterbodies. The Site 1 average was characteristic of mesotrophic productivity. Average total nitrogen levels were also characteristic of lakes that supported mesotrophic productivity.

Chlorophyll-*a* is an important trophic variable that is not measured at Lake Wononscopomuc. It is important because it is a direct measure of algal biomass since all algae contain chlorophyll-*a*. Algae cell concentrations do not have adopted standards for trophic levels like those use in Table 4, but there are guidelines for cyanobacteria cell concentrations used to assess public risk due to cyanotoxins at public beaches (CT DPH & CT DEEP 2019). The State of Connecticut recommends a threshold of 20,000 cyanobacteria cells/mL before warranting any intervention. The Lake Wononscopomuc total cell concentrations never exceeded 5,000 cells/mL, are generally considered low, and more consistent with oligotrophic to early mesotrophic productivity.

Scientists (e.g., Kortmann 2015) utilize the position of the Compensation Depth (see *Secchi Transparency* section above) relative to the metalimnion and thermocline as a variable in cyanobacteria positioning in the water column and as a stimulant of cyanobacteria growth. Water quality is likely to be good and unlikely to stimulate cyanobacteria productivity if the Compensation Depth extends below the thermocline. If the Compensation Depth is located within the metalimnion, a layer of cyanobacteria could form within those strata. Lastly, growth of cyanobacteria genera that can regulate buoyancy could be stimulated when the Compensation Depth is within the mixed epilimnetic layer. This implies the extension of anoxic waters into the bottom of the epilimnetic layer.

Throughout the 2021 season, the calculated Compensation Depth (shaded green in Fig. 16) exceeded the depth of the thermocline, and



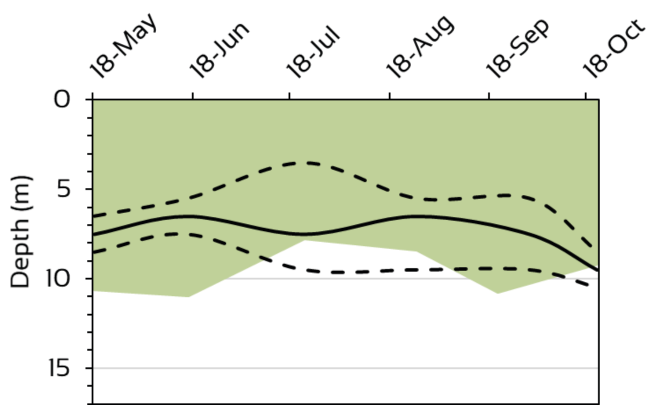


Figure 16. Area of the water column above the Compensation Depth (shaded in green). The black dashed lines and black dots represent the upper and/or lower metalimnetic boundaries. The solid black line represents the location of the thermocline.

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for much of the season, exceeded the lower metalimnetic boundary. This implied that water quality was good, and conditions were not favorable to stimulation of cyanobacteria growth. It is noteworthy that the Compensation Depth was situated below the thermocline but above the lower metalimnetic boundary on July 22nd and August 26th. Those events were contemporaneous with a shift in the highest cyanobacteria biovolume from meters below the lower metalimnetic boundary to that boundary (Fig. 9). It was also on August 26th when an increase in cyanobacteria biovolume was detected near the surface (Fig. 9).

Coprecipitation of Phosphorus

The high pH levels measured at Lake Wononscopomuc favor dominance by cyanobacteria since dissolved carbon shifts at a pH of 8.3 from carbon dioxide to bicarbonate. Cyanobacteria are capable of utilizing bicarbonate for their carbon requirement, while other algal taxa cannot.

High pH is also a prerequisite of a chemical process referred to as coprecipitation of phosphorus. A lake's trophic dynamics can be influenced by calcium concentrations in the water. High calcium concentration in lakes with high pH can result in limited phosphorous availability to the algae via the process of coprecipitation (Wetzel 2001). Simply stated, at high pH levels and calcium concentrations, phosphorus will bind with calcium carbonate, precipitate out of the water column as calcite, and become unavailable to algae.

As noted, pH at Lake Wononscopomuc was high. Calcium concentrations were also high based on alkalinity levels. Average total phosphorus concentrations at Site 1 and Site 2 were characteristic of early mesotrophic to mesotrophic productivity. Algal concentrations were, nonetheless, low.

There was a strong relationship between epilimnetic total phosphorus and alkalinity (Fig. 17). High total phosphorus and alkalinity concentration measured in the first half of the season, shifted to lower total phosphorus and alkalinity concentrations in the latter half of the season. We hypothesize that the shift resulted from the coprecipitation and settlement of phosphorus and calcium out of epilimnetic strata of the water column.

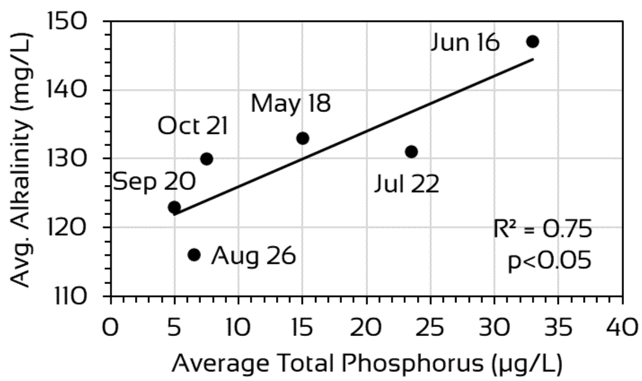

Figure 17. Regression of lake average total phosphorus and alkalinity measured in the epilimnion of Lake Wononscopomuc in 2021.

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Limiting Nutrients

Limnologists frequently use the Redfield ratio of 16 (16:1 nitrogen to phosphorus) to determine whether nitrogen or phosphorus is limiting in a freshwater system (Redfield 1958). The ratio is molar-based and when converted to mass, 7.2µg/L is the threshold; and, values lower than the aforementioned are indicative of nitrogen limitation while ratios above 7.2µg/L indicate phosphorus limitations. Nitrogen limitation in a system will favor dominance by cyanobacteria, particularly those genera capable of utilizing nitrogen gas diffused into the water. Other taxa of algae (see below) are not capable of using nitrogen gas, and rely on other nitrogen compounds, e.g., ammonia, nitrate.

When epilimnetic total phosphorus was below detectable limits (e.g., August 26th and September 20th at Site 1, and September 20th and October 21st at Site 2), a concentration of 5µg/L was used to calculate the Redfield ratio resulting in August 26th and September 20th ratios of ≥40. October 21st ratios could not be determined due to the lack of total nitrogen data on that date. Epilimnetic ratios from earlier in the season were generally lower, and between 9 and 16 except for the May 18th Site 1 ratio of 26. All epilimnetic ratios were >7, but some were close to that threshold.

Ratios based on nutrient levels at the bottom of the water column are less diagnostic since algal growth at those depths at Lake Wononscopomuc is light-limited. But they can provide insight into ratios at mid-ranged depths. Hypolimnetic ratios were <7.2 at Site 1 on August 26th, and at Site 2 from June 16th to September 20th (October 21st data was omitted). Those were favorable to dominance by cyanobacteria. It is conceivable that ratios at depths below the thermocline or lower metalimnetic boundary, where layers of cyanobacteria were detected, were between those calculated from data collected at the surface and at the bottom. If they tended to be closer to hypolimnetic ratios, it might provide some additional rational for the layers of cyanobacteria at those depths.

Internal Loading of Phosphorus

We reported in 2019 that autochthonous phosphorus sources are important to the overall phosphorus budget of the lake. Those sources originate from lake sediments in precipitated forms, and are converted to a dissolved, aqueous form after protracted periods of anoxia. The same lines of evidence observed in 2019 were also observed in 2021. Hypolimnetic total phosphorus greatly increased from May 18th to August 26th. While decreasing by September 20th, concentrations were still high relative to epilimnetic levels, and increased again by October 21st (Fig. 5). These occurrences were concurrent with the increasing time of anoxic conditions in the lower strata of the water column.

Other lines of evidence include increasing ammonia concentrations, alkalinity levels, and specific conductance. These, too, are related to loss of oxygen, the shift in anoxic

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decomposers, and the alternative compounds used in cellular respiration (e.g., iron in iron phosphate, nitrogen compounds, and sulfur compounds).

An important question that has not been addressed is how much of the water column develops high phosphorus concentrations as strata of anoxic waters increases and occupies more of the water column (Fig. 5). It is conceivable that the lens of concentrated cyanobacteria regularly encountered at Lake Wononscopomuc benefits from higher phosphorus concentrations generated from the lake sediments.

Hypolimnetic pH

The high hypolimnetic pH levels, relative to epilimnetic levels, is unusual for most Northeast lakes. Typically, hypolimnetic pH is lower due to greater carbon dioxide concentrations forming greater amounts of carbonic acid, relative to epilimnetic levels. We believe the geology of the Lake Wononscopomuc basin may be one reason for the higher pH levels in the hypolimnion.

We hypothesize that the carbonate rock that characterizes the Marble Valley bedrock is providing a readily available source of carbonate ions. Those could bind free hydrogen ions, form bicarbonate, and increase pH. If there is a carbonate source directly on the lake bottom, the pH there could be higher.

Specific Conductance Trends

In 2019, we provided a data table that displayed lake averages for a set of variables and compared them to corresponding averages for the lake based on a state-wide survey of Connecticut lakes conducted in the early 1990s. The table also provided averages for those variables for the Marble Valley lakes in the 1990s study and for the entire 60 lake set of lakes in that study (Canavan and Siver 1995). That table has been recreated below but also includes the Lake Wononscopomuc averages for 2021.

Of the variables measured in the 1990s and in recent years, the one exhibiting the greatest increase over time appears to be epilimnetic specific conductance. Average specific conductance at Lake Wononscopomuc from the 1990s survey was 274µS/cm. The 2019 average was 323µS/cm and that increased by 2021 to 347µS/cm. The 2021 average was significantly greater than the 2019 average ($p<0.005$).

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Table 4. Comparisons of the Lake Wononscopum averages for selected water quality variables from the early 1990s, 2019, and 2021 to corresponding averages from lakes in the Connecticut Marble Valley geological region and from a statewide survey of 60 lakes (Canavan and Siver 1995) conducted in the early 1990s. All measures with the exception of Secchi transparency were from samples collected at 1 meter depth. Abbreviations: Wononsco. = Wononscopomuc, Nitro. = nitrogen, Phos. = phosphorus, Chloro-*a* = chlorophyll-*a*, Sp. Cond. = specific conductance.

Parameter	**Units**	**Wononscopomuc**			**Marble Valley Lakes**			**60 CT Lake Set**		
		1990s	2019	2021	Min	Max	Mean	Min	Max	Mean
Total Nitro.	µg/L	334	249	313	334	547	449	119	3831	439
Total Phos.	µg/L	21	10.8	13.4	21	42	31	9	334	33
Chloro-*a*	µg/L	1.2	*NA*	*NA*	1.2	7.1	4.3	0.2	71.6	6.5
Secchi Disk	meters	4.9	4.87	4.91	2.0	4.9	3.3	0.9	7.6	3.3
pH	pH units	8.5	8.8	9.0	7.8	8.3	8.2	4.6	8.8	7.1
Sp. Cond.	µS/cm	274	323	347	180	317	258	24	317	102
Alkalinity	mg/L	121	127	130	54.5	120.5	90	0	120.5	14.5
Chloride	mg/L	9.2	*NA*	*NA*	3.2	42.2	21.3	0.7	42.2	10.3
Calcium	mg/L	25.2	*NA*	*NA*	16.6	28.8	22.8	1.2	28.8	7.6
Magnesium	mg/L	15.4	*NA*	*NA*	5.9	15.2	9.8	0.2	15.2	2.5
Sodium	mg/L	6.7	*NA*	*NA*	2.5	24.6	13.1	1.4	24.6	6.9
Potassium	mg/L	1.6	*NA*	*NA*	1.2	2.7	1.9	0.4	2.7	1.2

Recommendations

Recommendation 1. Continue Water Quality Monitoring

The water quality monitoring program is an essential component to successful lake management because it provides a basis of assessing change in the system, both positive and negative change. Those changes can be natural, i.e., the natural lake aging process, due to perturbations in the watershed, or can be related to successful management initiatives in the lake or watershed.

There are several variables we recommended adding to the program. First, chlorophyll-*a* in samples collected near the surface is recommended. This variable is a direct assessment of algal biovolume and will provide additional insight into the trophic dynamics, including coprecipitation of phosphorus, at the lake.

Base cations (sodium, potassium, calcium, and magnesium) and chloride in the epilimnion should also be considered for addition to the monitoring program to develop an understanding of the increasing specific conductance levels. These variables would not have to be measured monthly during a monitoring year, but they should be measured on some regular interval.

AER can intercede with the commercial laboratory to negotiate a favorable pricing for the additional laboratory charges incurred through these proposed modifications.

Recommendation 2. Develop a strategy to better understand the impacts of internal loading of phosphorus.

Total phosphorus levels in samples collected from the bottom of the water column, after a protracted period of anoxia at those strata, were one to two orders of magnitude greater than corresponding levels in samples collected near the surface. The anoxic conditions increased upward as the season progresses reaching the lower metalimnetic boundary by October. Influences of phosphorus enrichment from the bottom at mid-range depths where concentrated layers of cyanobacteria are observed are not well understood.

We proposed developing a cost-effective approach to assessing influences on mid-range depths by internal loading of phosphorus from the sediments.

Recommendation 3. We recommend a publication by the Cary Institute entitled *Road Salt: The Problem, The Solution, and How to Get There.*

As noted, specific conductance has greatly increased since the early 1990s. As has been documented at other waterbodies much of this is due to increased use of winter deicing salts on roads. In the recommended publication, the authors provide insights into the road salt issue, including impacts to lakes, and provide management recommendations, e.g.,

- Anti-icing
- Pre-wetting

- Calibration of equipment
- Variable application rates
- Proper salt storage.

A link to the online publication is provided in the References section of this report.

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APPENDIX A. FIELD DATA

Abbreviations (for both Appendix A and B)

Temp = temperature

DO = dissolved oxygen

BGs = Blue-green Algae (Cyanobacteria) measured as relative phycocyanin concentration

ORP = Oxidation Reduction Potential

Spec. C. = Specific Conductance

Alk = Alkalinity

NH4 = Ammonia

TKN = Total Kjeldahl Nitrogen

NO3 = Nitrate

NO2 = Nitrite

TP = Total Phosphorus

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18-May-2021

Site 1	Depth (m)	Temp (°C)	DO (mg/L)	DO (%)	BGs	Spec C (µS/cm)	ORP (mV)	pH
	0.5	17.83	10.7	114.9	0.44	367.7	214.5	8.62
	1	17.54	10.84	115.7	1.32	366.4	217.5	8.63
	2	16.78	11.03	115.9	1.09	365.1	221	8.64
	3	15.94	11.36	117.3	1.49	364	223.7	8.64
	4	14.87	11.61	117.1	1.36	362.8	226.2	8.65
	5	13.71	11.9	117.1	1.36	361.7	227.5	8.65
	6	12.51	11.92	114.2	1.94	361.5	230.4	8.64
	7	11.26	12.01	111.8	1.63	360.9	234.7	8.58
	8	9.33	12.14	108	2.44	360.4	237.5	8.56
	9	8.53	12.18	106.3	3.27	360	240.9	8.5
	10	7.72	12.19	104.2	3.75	360.3	244.1	8.46
	11	7.14	12.14	102.4	6.46	360.6	247.2	8.41
	12	6.66	11.68	97.3	7.84	360.8	252.4	8.31
	13	6.56	11.49	95.5	10.41	361.2	254.8	8.27
	14	6.31	11.18	92.3	11.56	361.1	257.2	8.23
	15	6.16	11.04	90.8	11.93	361.1	258.7	8.21
	16	6.06	11.04	90.6	10.74	361	259.7	8.19
	17	5.96	10.53	86.1	9.51	361.5	262.3	8.14
	18	5.91	9.96	81.4	8.6	361.5	265.2	8.09
	19	5.83	9.66	78.8	7.03	361.5	266.6	8.06
	20	5.76	9.65	78.6	5.38	361.8	267.2	8.05
	21	5.73	8.98	73.1	5.12	361.8	269.8	8.01
	22	5.69	8.76	71.2	4.92	362	271.4	7.99
	23	5.63	8.53	69.2	4.68	361.9	272.8	7.97
	24	5.61	8.43	68.4	3.87	362	273.6	7.96
	25	5.61	8.34	67.6	4.45	362	274.2	7.95
	26	5.59	8.33	67.5	4.25	362	274.6	7.94
	27	5.59	8.32	67.4	4.38	362.1	274.7	7.94
	28	5.57	8.31	67.4	3.89	362.2	275	7.94
	29	5.55	8.23	66.6	3.66	362.3	275.3	7.93
	30	5.54	7.95	64.4	3.72	362.5	276.3	7.92

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18-May-2021

Site 2	Depth (m)	Temp (°C)	DO (mg/L)	DO (%)	BGs	Spec C (µS/cm)	ORP (mV)	pH
	0.5	17.95	10.63	114.5	1.96	365.7	90.6	8.67
	1	17.85	10.76	115.6	1.63	365.5	92.5	8.66
	2	17.73	10.88	116.6	1.42	365.4	95.4	8.64
	3	15.96	11.49	118.6	0.93	363.1	94.7	8.84
	4	15.13	11.66	118.3	1.62	362.4	98.8	8.7
	5	13.53	11.86	116.2	1.67	361.5	103.1	8.69
	6	12.74	11.96	115.1	2.03	360.6	106.8	8.68
	7	11.23	12.09	112.4	1.81	361.2	108.9	8.75
	8	9.56	12.26	109.7	1.94	360.3	111.3	8.64
	9	8.33	12.55	108.9	3.83	360.6	112.2	8.62
	10	7.78	12.3	105.4	4.78	360.4	114.9	8.53
	11	7.24	11.23	94.9	7.81	361.2	159.1	8.34
	12	6.94	11.08	92.9	9.87	361.2	167.7	8.28
	13	6.69	9.04	75.3	15.19	362.2	189.6	8.09
	14	6.39	6.76	55.9	8.78	363.5	206.1	7.99
	15	6.28	5.39	44.5	7.37	364.3	212.7	7.92
	16	6.22	4.51	37.2	5.89	364.8	217.5	8.02
	17	6.22	4.23	34.8	6.85	365.1	220.2	8

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16-Jun-2021

Site 1	Depth (m)	Temp (°C)	DO (mg/L)	DO (%)	BGs	Spec C (μS/cm)	ORP (mV)	pH
	0.5	21.92	9.38	109.2	3.12	365	203.3	8.65
	1	21.92	9.37	109.2	-3.74	364.9	203.3	8.67
	2	21.89	9.41	109.6	0.76	364.6	203.9	8.71
	3	21.53	9.51	110	3.38	364.4	205.3	8.72
	4	18.31	10.58	114.7	1.19	363	212	8.7
	5	16.9	11.03	116.2	1.86	363.1	217	8.67
	6	15.33	11.79	120.1	2.27	362.3	220.2	8.67
	7	13.06	12.67	122.8	1.76	360.4	225	8.64
	8	11.13	12.9	119.7	1.86	360.4	229.2	8.62
	9	9.27	12.78	113.5	2.29	360.6	233.3	8.55
	10	8.37	12.03	104.5	2.24	361	240	8.43
	11	7.6	11.66	99.4	3.4	361.3	243.7	8.45
	12	7.15	11.65	98.2	7.01	361.2	244.4	8.42
	13	6.68	11.55	96.3	24.82	361.6	246.2	8.34
	14	6.48	9.91	82.2	21.39	361.8	253.2	8.14
	15	6.27	8.72	71.9	18.59	362.1	258.8	8.07
	16	6.14	7.92	65.1	12.83	362.3	261.9	8.01
	17	6.01	7.78	63.7	8.05	362.3	263.1	7.99
	18	5.93	7.33	60	5.85	362.4	265.2	7.94
	19	5.84	6.67	54.4	4.51	362.9	267.5	7.88
	20	5.8	6.23	50.8	3.63	363.2	268.9	7.85
	21	5.73	6.23	50.7	2.21	362.9	269.2	7.85
	22	5.67	6.3	51.2	1.92	362.8	269.5	7.85
	23	5.62	6.31	51.2	1.64	362.9	269.7	7.84
	24	5.61	5.32	43.1	1.65	363.5	270.7	7.79
	25	5.59	4.84	39.2	1.51	364	271.1	7.76
	26	5.58	3.35	27.1	1.7	365.3	269.9	7.7
	27	5.57	1.95	15.8	1.85	367	261.4	7.65
	28	5.56	0.9	7.3	1.5	369.2	254	7.62
	29	5.54	0.15	1.2	1.85	374.7	243.5	7.71
	30	5.52	0.1	0.8	2.19	385.7	241.1	7.79

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16-Jun-2021

Site 2	Depth (m)	Temp (°C)	DO (mg/L)	DO (%)	BGs	Spec C (µS/cm)	ORP (mV)	pH
	0.5	22.37	9.49	111.5	2.47	364.1	79.1	8.89
	1	22.37	9.5	111.6	1.45	364	85.5	8.88
	2	22.28	9.52	111.7	2.1	364	88.2	8.88
	3	19.93	10.6	118.8	2.1	363.9	101.4	8.88
	4	18.47	10.7	116.4	1.51	363.3	103.1	8.89
	5	17.85	10.66	114.5	1.69	363.3	104.8	8.79
	6	15.96	11.52	119	1.78	362.8	109	8.72
	7	13.04	12.53	121.5	1.68	360.6	110.4	8.74
	8	10.62	12.76	117	2.2	360.7	111	8.67
	9	9.7	12.64	113.4	2.34	360.8	111.6	8.93
	10	8.79	12.15	106.7	2.13	361.4	111.9	8.84
	11	7.71	10.56	90.3	6.25	362.2	109.4	8.61
	12	7.31	8.82	74.7	18.58	363.2	111.4	8.38
	13	6.91	4.11	34.4	11.34	365.3	109.9	8.08
	14	6.72	0.58	4.8	4.34	367.7	102.8	7.93
	15	6.6	0.23	1.9	3.69	370.5	84.4	8.96
	16	6.53	0.15	1.2	2.84	372.8	76.9	9.15
	17	6.42	0.1	0.8	3.38	383.4	59.6	9.43

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22-Jul-2021

Site 1	Depth (m)	Temp (°C)	DO (mg/L)	DO (%)	BGs	Spec C (µS/cm)	ORP (mV)	pH
	0.5	25.16	9.08	112.4	1.58	345	199.9	8.77
	1	25.16	9.28	114.9	1.49	345	200.8	8.8
	2	25.15	9.31	115.3	2.02	345	202.2	8.78
	3	25.03	9.34	115.5	0.81	345.1	202.7	8.78
	4	24.54	9.27	113.5	1.69	348.7	206.1	8.72
	5	22.4	9.23	108.5	2.33	349.6	210.9	8.63
	6	19.13	10.31	113.7	2.42	361.2	215.1	8.63
	7	15.12	12.07	122.4	2.48	361.3	220.4	8.64
	8	12.55	12.58	120.6	2.71	362.6	223.4	8.64
	9	10.58	11.47	105	2.58	362.2	233	8.43
	10	9.22	10.04	89.1	3.74	362.9	241.7	8.22
	11	8.48	9.96	86.8	3.73	362.6	243.3	8.22
	12	7.59	9.46	80.6	11.55	363.2	247.3	8.13
	13	7.19	8.44	71.2	10.83	364.1	251.1	8.03
	14	6.75	5.02	41.9	6.26	364.5	258.4	7.83
	15	6.45	4.82	39.9	4.06	364.3	259.6	7.8
	16	6.23	4.72	38.9	2.2	363.9	260.2	7.8
	17	6.09	4.74	38.9	1.52	364	261	7.79
	18	6.02	4.33	35.5	1.81	364.4	262.4	7.77
	19	5.95	4.26	34.8	1.12	364.2	262.7	7.76
	20	5.9	4.14	33.8	1.53	364.3	263.2	7.69
	21	5.73	3.62	29.4	1.24	364.5	262.2	7.65
	22	5.72	2.78	22.6	0.93	365.7	259.8	7.59
	23	5.68	1.73	14	1.04	366	259.8	7.56
	24	5.64	0.63	5.1	1.53	367.9	259.5	7.52
	25	5.63	0.24	1.9	1.2	371.6	259.6	7.54
	26	5.63	0.15	1.2	1.24	373.7	259.4	7.58
	27	5.62	0.13	1	0.95	376.5	259.6	7.68
	28	5.59	0.09	0.7	1	386.4	257	8.45
	29	5.58	0.05	0.4	1.44	391.9	237.8	9.25
	30	5.57	0.05	0.4	1.28	396.8	225.4	9.34

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22-Jul-2021

Site 2	Depth (m)	Temp (°C)	DO (mg/L)	DO (%)	BGs	Spec C (µS/cm)	ORP (mV)	pH
	0.5	25.35	9.28	115.3	2.38	344.2	72.2	9.28
	1	25.29	9.51	118.1	1.93	344.2	80.6	9.21
	2	25.23	9.53	118.2	2.03	344.3	100	8.86
	3	25.18	9.49	117.6	2.17	344.2	102.6	9.26
	4	23.78	9.26	111.8	2.2	352.3	110.5	9.18
	5	22.21	9.31	109.1	2.6	352.7	114.8	9.13
	6	18.86	10.49	115.1	2.7	361.9	118.1	9.21
	7	16.19	11.95	124.1	2.61	361.9	120.8	9.26
	8	12.81	12.44	120	2.76	361.8	120.4	9.3
	9	10.74	11.25	103.5	3.1	362.6	127.1	9.26
	10	9.44	10.42	92.9	4.41	363.1	131.7	9.11
	11	8.5	9.18	80.1	6.84	363.9	136.8	9.2
	12	8.04	6.32	54.5	4.12	364.6	146.3	9.05
	13	7.68	3.31	28.3	2.42	366	159.3	8.9
	14	7.16	0.26	2.2	3.5	373.1	136.8	10.2
	15	6.91	0.2	1.7	2.68	379.5	131.8	10.55
	16	6.79	0.13	1	2.11	384.7	109.7	11.01
	17	6.73	0.1	0.8	2.21	386.4	90.7	11.13

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26-Aug-2021

Site 1	Depth (m)	Temp (°C)	DO (mg/L)	DO (%)	BGs	Spec C (µS/cm)	ORP (mV)	pH
	0.5	25.51	8.89	110.8	0.54	333.3	218.8	8.71
	1	25.51	8.89	110.8	1.62	333.4	219.9	8.73
	2	25.47	8.91	111	1.54	333.3	220.8	8.73
	3	25.09	8.98	111.1	1.74	332.4	220.9	8.76
	4	24.78	9.04	111.1	2.22	333.3	222	8.74
	5	23.79	8.38	101.1	2.15	344.5	228.9	8.58
	6	20.93	8.46	96.7	2.31	361.9	234.6	8.48
	7	17.17	8.71	92.3	2.56	367.9	239.8	8.42
	8	12.89	9.7	93.7	4.78	364.4	248	8.31
	9	11.13	9.97	92.5	6.79	363.8	249.8	8.29
	10	9.72	9.98	89.6	7.91	364.8	251.3	8.28
	11	8.64	5.75	50.3	2.98	370.3	264.6	7.96
	12	7.81	5.59	47.9	2.16	370.4	266	7.94
	13	7.12	3.65	30.8	2.38	371.2	271.4	7.78
	14	6.69	3.02	25.1	1.58	368.6	274.3	7.71
	15	6.46	2.68	22.2	1.51	366.6	276	7.66
	16	6.33	2.45	20.2	1.32	365.6	270.7	7.63
	17	6.21	2.09	17.2	1.44	365.2	208.5	7.58
	18	6.07	1.79	14.6	1.43	364.7	198.9	7.56
	19	5.97	1.68	13.7	1.4	364.4	196.8	7.55
	20	5.88	1.65	13.5	0.99	364.3	195.9	7.55
	21	5.8	1.64	13.4	1.3	364.6	195.3	7.54
	22	5.75	0.56	4.5	1.49	365.6	191.8	7.5
	23	5.73	0.36	2.9	1.04	368.1	190.7	7.5
	24	5.69	0.3	2.4	1.69	374.2	187.1	7.59
	25	5.66	0.18	1.4	1.03	381.3	124.2	8.79
	26	5.65	0.15	1.2	1.03	386	92	9.18
	27	5.62	0.12	0.9	1.19	395.2	66.5	9.44
	28	5.61	0.1	0.8	1.41	399.5	45.6	9.6
	29	5.6	0.08	0.6	1.62	407.3	19.1	9.74
	30	5.59	0.06	0.5	1.48	422.5	-9	9.86

26-Aug-2021

Site 2	Depth (m)	Temp (°C)	DO (mg/L)	DO (%)	BGs	Spec C (µS/cm)	ORP (mV)	pH
	0.5	25.4	9.2	114.4	7.95	332.3	46	9.11
	1	25.4	9.19	114.3	5.82	332.7	48.4	9.11
	2	25.36	9.19	114.2	5.64	332.8	52.9	9.1
	3	24.99	9.2	113.6	4.69	333	63.1	9.09
	4	24.7	8.88	109	3.72	333.8	75.5	9.06
	5	24.02	8.36	101.3	3.03	342.3	92	8.66
	6	20.21	8.38	94.5	2.85	362.8	101.7	8.49
	7	16.33	8.79	91.5	2.81	366.2	104.9	8.99
	8	13.52	9.31	91.2	3.66	364.9	103.1	8.94
	9	11.1	9.65	89.5	7.79	363.4	102.2	8.99
	10	9.62	8.85	79.3	6.26	365.7	105.6	8.76
	11	8.84	4.85	42.6	2.95	372.7	109.1	8.4
	12	8.24	1.59	13.8	1.92	374.4	115.2	8.13
	13	7.76	0.46	3.9	4.13	371.9	117.4	8.01
	14	7.39	0.31	2.6	4.02	378.4	87.3	8.84
	15	7.06	0.2	1.6	2.65	386.1	42.8	9.36
	16	6.92	0.15	1.2	1.99	391.3	17.3	9.44
	17	6.86	0.12	1	2.32	394.3	1.4	9.47

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20-Sep-2021

Site 1	Depth (m)	Temp (°C)	DO (mg/L)	DO (%)	BGs	Spec C (µS/cm)	ORP (mV)	pH
	0.5	22.05	9.03	105.4	-0.12	335.5	218.1	8.89
	1	22.06	8.97	104.7	2.96	335.4	219.7	8.84
	2	22.06	8.94	104.5	1.08	335.4	221	8.81
	3	22.06	8.94	104.4	1.85	335.5	221.8	8.79
	4	22.06	8.93	104.3	2.05	335.5	222.1	8.78
	5	22.05	8.92	104.2	3.02	335.5	222.6	8.77
	6	20.9	7.92	90.4	2.08	341.8	233.6	8.5
	7	17.84	7.88	84.6	2.95	356.7	240.4	8.37
	8	14.35	8.78	87.6	2.77	365.2	247.9	8.27
	9	12.39	9.39	89.7	5.59	366	249.8	8.28
	10	10.2	6.42	58.3	14.58	368.4	262.3	8.7
	11	8.79	3.22	28.2	2.15	372.6	269.1	8.45
	12	7.63	2.28	19.4	2.26	374.7	272.3	8.34
	13	7.13	1.85	15.6	1.78	372.6	274.2	8.28
	14	6.79	1.25	10.4	1.39	370.4	147.2	8.18
	15	6.56	1.23	10.2	1.3	368.6	145.6	8.18
	16	6.41	1.23	10.2	1.42	367.6	144.5	8.17
	17	6.24	1.08	8.9	1.07	366	140.3	8.15
	18	6.02	0.84	6.8	1.23	365.6	138.7	8.13
	19	5.93	0.34	2.7	1.12	366.1	135.4	8.09
	20	5.83	0.23	1.9	1.18	366	134.6	8.08
	21	5.77	0.19	1.5	1.26	368.9	134.4	8.07
	22	5.74	0.13	1	0.9	372.6	121	8.29
	23	5.72	0.1	0.8	1.2	375.5	93.4	8.66
	24	5.7	0.07	0.6	1.11	384.7	42	9.29
	25	5.68	0.06	0.5	1.21	387.8	11.5	9.61
	26	5.67	0.05	0.4	1.23	392	-12.6	9.8
	27	5.66	0.05	0.4	1.44	395.9	-25.6	9.88
	28	5.65	0.05	0.4	1.4	399.5	-34.3	9.92
	29	5.64	0.04	0.3	1.27	401.4	-43.5	9.97
	30	5.63	0.04	0.3	1.46	405.4	-52.2	10.01

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20-Sep-2021

Site 2	Depth (m)	Temp (°C)	DO (mg/L)	DO (%)	BGs	Spec C (µS/cm)	ORP (mV)	pH
	0.5	22.06	9.14	106.8	3.34	335.5	12.4	9.88
	1	22.05	9.11	106.4	2.37	335.4	18.8	9.85
	2	22.05	9.1	106.3	3.14	335.5	22.4	9.86
	3	22.04	9.09	106.1	3.26	335.5	27.2	9.19
	4	22	9.03	105.3	3.11	335.9	35.6	8.93
	5	21.89	8.76	102	2.61	336.7	48	9.94
	6	20.64	8.45	96	2.63	343.3	56.1	9.85
	7	18.15	7.85	84.9	3.14	355.1	69.6	9.77
	8	13.95	8.8	87	4.05	365.8	67.3	10.06
	9	11.73	8.66	81.5	16.16	367.4	65	10.08
	10	10.18	5.53	50.2	7.78	369.5	61.7	9.91
	11	9.24	2.55	22.6	2.45	373.1	60.4	9.78
	12	8.69	0.35	3	1.99	375.6	57.2	9.76
	13	7.81	0.21	1.8	4.25	380.3	53.3	9.9
	14	7.42	0.18	1.5	3.83	387	19.9	10.36
	15	7.19	0.15	1.2	2.93	392.7	-8.7	10.76
	16	7.11	0.13	1.1	2.81	395	-24.6	10.94
	17	7	0.1	0.8	3.03	398.6	-40.4	11.11

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21-Oct-2021

Site 1	Depth (m)	Temp (°C)	DO (mg/L)	DO (%)	BGs	Spec C (µS/cm)	ORP (mV)	pH
	0.5	16.63	9.62	100.8	2.32	341.2	246.9	9.15
	1	16.62	9.6	100.6	2.51	341.3	247.3	9.04
	2	16.61	9.6	100.5	2.89	341.2	248.5	8.9
	3	16.59	9.6	100.5	3.55	341.2	248.8	8.84
	4	16.59	9.6	100.5	2.78	341.2	249.3	8.78
	5	16.57	9.61	100.5	2.72	341.2	249.1	8.76
	6	16.46	9.6	100.2	2.99	341.2	249.7	8.71
	7	16.41	9.43	98.3	3.93	341.8	250.3	8.65
	8	16.14	8.99	93.2	3.9	345.3	253.8	8.53
	9	13.64	7.28	71.5	5.74	365.4	271.6	8.05
	10	10.63	2.57	23.5	2.16	371.7	285.5	7.65
	11	9.49	1.33	11.8	1.54	372.7	288.9	7.53
	12	8.2	0.76	6.6	1.22	373.4	291.2	7.45
	13	7.27	0.27	2.3	1.24	372.3	293.4	7.38
	14	6.85	0.19	1.6	1.49	370	294.3	7.35
	15	6.64	0.1	0.8	1.16	369.2	295	7.35
	16	6.39	0.07	0.6	1.01	367.4	295.3	7.36
	17	6.23	0.06	0.5	1.26	367.4	296	7.35
	18	6.12	0.05	0.4	1.04	367	296.1	7.36
	19	6.08	0.04	0.4	1.07	368.1	287.9	7.42
	20	5.98	0.04	0.3	0.92	369.3	280.8	7.52
	21	5.86	0.04	0.3	0.81	371	266.3	7.73
	22	5.83	0.04	0.3	1.36	373.4	223.3	7.96
	23	5.79	0.04	0.3	1.16	378	152.6	8.5
	24	5.76	0.03	0.3	1.06	382.9	102.8	9.05
	25	5.74	0.04	0.3	1.09	386.8	53.5	9.48
	26	5.72	0.03	0.3	1.3	391.1	30	9.66
	27	5.71	0.04	0.3	1.45	392.8	4	9.8
	28	5.7	0.04	0.3	1.4	395.7	-8.8	9.86
	29	5.68	0.03	0.3	1.48	401.2	-21.1	9.91
	30	5.67	0.03	0.3	1.38	403.3	-31.9	9.96

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21-Oct-2021

Site 2	Depth (m)	Temp (°C)	DO (mg/L)	DO (%)	BGs	Spec C (µS/cm)	ORP (mV)	pH
	0.5	16.75	9.93	104.3	3.33	340.9	11	9.62
	1	16.76	9.87	103.6	3.87	340.8	16.6	9.57
	2	16.73	9.87	103.6	3.64	340.9	19.7	9.54
	3	16.71	9.86	103.4	3.98	340.9	22.6	9.51
	4	16.56	9.77	102.2	3.72	340.9	27.4	9.46
	5	16.49	9.61	100.3	3.79	340.8	37.1	9.38
	6	16.45	9.55	99.6	3.12	341.3	40.9	9.35
	7	16.33	9.41	97.9	3.4	342.2	46	9.3
	8	16.13	9.2	95.3	7.67	343.7	51.9	9.24
	9	14.09	6.77	67.1	5.47	364	77.6	8.71
	10	11.08	2.9	26.9	3.22	371	87	8.42
	11	9.64	0.32	2.8	2.35	373.8	80.4	8.31
	12	8.83	0.19	1.6	1.8	376.1	80.4	8.32
	13	8.52	0.15	1.3	2.92	379	79.7	8.34
	14	7.95	0.11	0.9	4.08	385.5	66.9	8.56
	15	7.44	0.09	0.7	3.62	396.3	18.5	9.23
	16	7.31	0.07	0.6	3.79	398.8	-16.1	9.54
	17	7.18	0.06	0.5	3.24	402.5	-30.1	9.62

APPENDIX B. LABORATORY DATA

Site 1

18-May-21	Depth (m)	Alk (mg/L)	NH4 (mg/L)	TKN (mg/L)	NO3 (mg/L)	NO2 (mg/L)	TP (µg/L)	Secchi (m)
	0.5	132	0	0.307	0	0	0.012	5.81
	30	132	0	0.315	0	0	0.016	

16-Jun-21	Depth (m)	Alk (mg/L)	NH4 (mg/L)	TKN (mg/L)	NO3 (mg/L)	NO2 (mg/L)	TP (µg/L)	Secchi (m)
	0.5	148	0	0.29	0	0.055	0.04	5.80
	30	150	0.537	0.73	0	0.067	0.095	

22-Jul-21	Depth (m)	Alk (mg/L)	NH4 (mg/L)	TKN (mg/L)	NO3 (mg/L)	NO2 (mg/L)	TP (µg/L)	Secchi (m)
	0.5	130	0	0.295	0	0	0.032	3.81
	30	154	0.764	0.953	0	0	0.054	

26-Aug-21	Depth (m)	Alk (mg/L)	NH4 (mg/L)	TKN (mg/L)	NO3 (mg/L)	NO2 (mg/L)	TP (µg/L)	Secchi (m)
	0.5	116	0	0.263	0	0	0	4.24
	30	158	1.285	1.55	0	0	0.3	

20-Sep-21	Depth (m)	Alk (mg/L)	NH4 (mg/L)	TKN (mg/L)	NO3 (mg/L)	NO2 (mg/L)	TP (µg/L)	Secchi (m)
	0.5	122	0	0.386	0	0	0	5.69
	30	156	0.99	1.587	0	0	0.14	

21-Oct-21	Depth (m)	Alk (mg/L)	NH4 (mg/L)	TKN (mg/L)	NO3 (mg/L)	NO2 (mg/L)	TP (µg/L)	Secchi (m)
	0.5	130	0	0	0	0	0.01	4.57
	30	150	1.3	0.66	0	0	0.4	

Site 2

18-May-21	Depth (m)	Alk (mg/L)	NH4 (mg/L)	TKN (mg/L)	NO3 (mg/L)	NO2 (mg/L)	TP (µg/L)	Secchi (m)
	0.5	134	0	0.285	0	0	0.018	5.33
	17	134	0	0.407	0	0	0.029	

16-Jun-21	Depth (m)	Alk (mg/L)	NH4 (mg/L)	TKN (mg/L)	NO3 (mg/L)	NO2 (mg/L)	TP (µg/L)	Secchi (m)
	0.5	146	0	0.284	0	0	0.026	5.50
	17	148	0.243	0.685	0	0	0.137	

22-Jul-21	Depth (m)	Alk (mg/L)	NH4 (mg/L)	TKN (mg/L)	NO3 (mg/L)	NO2 (mg/L)	TP (µg/L)	Secchi (m)
	0.5	132	0	0.222	0	0	0.015	3.90
	17	148	0.792	0.944	0	0	0.324	

26-Aug-21	Depth (m)	Alk (mg/L)	NH4 (mg/L)	TKN (mg/L)	NO3 (mg/L)	NO2 (mg/L)	TP (µg/L)	Secchi (m)
	0.5	116	0	0.266	0.05	0	0.008	4.21
	17	152	1.368	1.533	0	0	1.3	

20-Sep-21	Depth (m)	Alk (mg/L)	NH4 (mg/L)	TKN (mg/L)	NO3 (mg/L)	NO2 (mg/L)	TP (µg/L)	Secchi (m)
	0.5	124	0	0.428	0	0	0	5.40
	17	150	0.849	1.336	0	0	0.198	

21-Oct-21	Depth (m)	Alk (mg/L)	NH4 (mg/L)	TKN (mg/L)	NO3 (mg/L)	NO2 (mg/L)	TP (µg/L)	Secchi (m)
	0.5	130	0	0	0	0	0	4.60
	17	160	1.6	1.5	0	0	0.39	

APPENDIX C. ALGAE DATA

Genera observed in samples collected from Lake Wononscopomuc in 2021.

Taxa	Genus	18-May-21	16-Jun-21	22-Jul-21	26-Aug-21	20-Sep-21	21-Oct-21
Cyanophyta	*Aphanocapsa sp.*				X	X	X
	Chroococcus sp.			X	X	X	
	Dolichospermum sp.		X	X	X	X	X
	Microcystis sp.					X	
	Planktothrix sp.	X	X	X	X	X	X
Chlorophyta	*Coelastrum sp.*		X			X	
	Chodatella sp.			X	X	X	
	Closterium sp.						X
	Crucigenia sp.				X		
	Dictyosphaerium sp.			X			
	Elakatothrix sp.				X		
	Eudorina elegans				X	X	
	Gloeocystis sp.	X		X	X		
	Lagerheimia sp.	X	X				
	Micractinium sp.	X					
	Mougiotia sp.					X	
	Oocystis sp.		X	X	X	X	X
	Pediastrum sp.	X					
	Quadrigula sp.				X		
	Scenedesmus sp.	X	X	X	X	X	X
	Selenastrum sp.	X	X	X	X	X	X
	Spondylosium sp.			X	X	X	

Taxa	Genus	18-May-21	16-Jun-21	22-Jul-21	26-Aug-21	20-Sep-21	21-Oct-21
Chlorophyta (con't)	*Staurastrum sp.*						X
	Tetraedron sp.			X	X	X	
	Treubaria sp.			X	X		
Chrysophyta	*Dinobryon sp.*	X	X	X	X	X	X
	Epipyxis sp.		X				
	Kephyrion sp.	X	X				
	Mallomonas sp.	X	X	X	X	X	X
	Spinifermonas sp.			X			
	Synura sp.		X				X
	Uroglenopsis sp.	X	X	X	X	X	X
Bacillariophyta	*Asterionella sp.*	X					
	Cyclotella sp.	X	X	X	X	X	X
	Fragilaria sp.	X	X	X		X	X
	Rhizosolenia sp.	X	X	X	X	X	X
	Synedra sp.	X	X	X	X	X	X
	Tabellaria sp.	X	X				
Pyrrophyta	*Ceratium sp.*		X	X	X	X	X
	Glenodinium sp.	X	X	X	X	X	X
	Gymnodinium sp.					X	X
	Peridinium sp.	X	X	X	X	X	X
Cryptophyta	*Cryptomonas ovata*	X	X				
Euglenophyta	*Trachelomonas sp.*	X	X	X	X	X	X
Ochrophyta	*Stichogloea sp.*				X		
	Total each month	21	23	24	27	26	21

Algae Count Data

May 18, 2021 – Site 1

Taxa	**Genus / species**	**Cells / mL**	**%**	**Taxa cells / mL**	**Taxa %**
Cyanophyta	*Planktothrix sp.*	1906	47.0	1906	47.0
	Snowella sp.	0	0.0		
	Woronichinia sp.	0	0.0		
Chlorophyta	*Anikistrodesmus sp.*	0	0.0	216	5.3
	Lagerheimia sp.	9	0.2		
	Mougiotia sp.	19	0.5		
	Selenastrum sp.	188	4.6		
Chrysophyta	*Chrysosphaerella sp.*	0	0.0	1755	43.3
	Dinobryon sp.	1690	41.7		
	Kephyrion sp.	66	1.6		
Bacillariophyta	*Asterionella sp.*	19	0.5	103	2.5
	Cyclotella sp.	19	0.5		
	Fragilaria sp.	9	0.2		
	Rhizosolenia sp.	19	0.5		
	Synedra sp.	28	0.7		
	Tabellaria sp.	9	0.2		
Pyrrophyta	*Ceratium sp.*	0	0.0	38	0.9
	Peridinium sp.	38	0.9		
Cryptophyceae	*Cryptomonas sp.*	0	0.0	0	0.0
Euglenophyceae	*Euglena sp.*	0	0.0	0	0.0
	Trachelomonas sp.	0	0.0		
	Unknown	38	0.9	38	0.9
Taxa identified 13	Totals	4055	100	4055	100

May 18, 2021 – Site 2

Taxa	*Genus / species*	Cells / mL	%	Taxa cells / mL	Taxa %
Cyanophyta	*Aphanizomenon sp.*	0	0.0	1254	39.2
	Planktothrix sp.	1254	39.2		
Chlorophyta	*Anikistrodesmus sp.*	0	0.0	181	5.7
	Pediastrum sp.	107	3.4		
	Scenedesmus sp.	13	0.4		
	Selenastrum sp.	60	1.9		
Chrysophyta	*Chrysosphaerella sp.*	0	0.0	1629	50.9
	Dinobryon sp.	1576	49.3		
	Kephyrion sp.	40	1.3		
	Uroglenopsis sp.	13	0.4		
Bacillariophyta	*Asterionella sp.*	7	0.2	80	2.5
	Cyclotella sp.	27	0.8		
	Synedra sp.	47	1.5		
Pyrrophyta	*Ceratium sp.*	0	0.0	27	0.8
	Peridinium sp.	27	0.8		
Cryptophyceae	*Cryptomonas sp.*	13	0.4	13	0.4
	Rhodomonas sp.	0	0.0		
Euglenophyceae	*Euglena sp.*	0	0.0	0	0.0
	Trachelomonas sp.	0	0.0		
	Unknown	13	0.4	13	0.4
Taxa identified					
12	*Totals*	3198	100	3198	100

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June 16, 2021 – Site 1

Taxa	Genus / species	Cells / mL	%	Taxa cells / mL	Taxa %
Cyanophyta	*Aphanizomenon sp.*	0	0.0	6	0.6
	Dolichospermum sp.	3	0.3		
	Planktothrix sp.	3	0.3		
Chlorophyta	*Anikistrodesmus sp.*	0	0.0	129	12.4
	Oocystis sp.	24	2.3		
	Pediastrum sp.	0	0.0		
	Scenedesmus sp.	72	6.9		
	Schroederia sp.	0	0.0		
	Selenastrum sp.	33	3.2		
Chrysophyta	*Chrysosphaerella sp.*	0	0.0	357	34.2
	Dinobryon sp.	252	24.1		
	Epipyxis sp.	54	5.2		
	Kephyrion sp.	3	0.3		
	Mallomonas sp.	3	0.3		
	Uroglenopsis sp.	45	4.3		
Bacillariophyta	*Asterionella sp.*	0	0.0	490	46.8
	Cyclotella sp.	354	33.9		
	Fragilaria sp.	96	9.2		
	Rhizosolenia sp.	33	3.2		
	Synedra sp.	3	0.3		
	Tabellaria sp.	3	0.3		
Pyrrophyta	*Ceratium sp.*	6	0.6	45	4.3
	Glenodinium sp.	21	2.0		
	Peridinium sp.	18	1.7		
Cryptophyceae	*Cryptomonas sp.*	0	0.0	0	0.0
Euglenophyceae	*Euglena sp.*	0	0.0	0	0.0
	Unknown	18	1.7	18	1.7
Taxa identified 18	*Totals*	1045	100	1045	100

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June 16, 2021 – Site 1 @ 13 meters

Taxa	Genus / species	Cells / mL	%	Taxa cells / mL	Taxa %
Cyanophyta	*Aphanizomenon sp.*	0	0.0	34334	99.5
	Planktothrix sp.	34334	99.5		
Chlorophyta	*Anikistrodesmus sp.*	0	0.0	0	0.0
	Coelastrum sp.	0	0.0		
Chrysophyta	*Chrysosphaerella sp.*	0	0.0	0	0.0
Bacillariophyta	*Asterionella sp.*	51	0.1	128	0.4
	Cyclotella sp.	26	0.1		
	Fragilaria sp.	26	0.1		
	Synedra sp.	26	0.1		
Pyrrophyta	*Ceratium sp.*	0	0.0	51	0.1
	Peridinium sp.	51	0.1		
Cryptophyceae	*Cryptomonas sp.*	0	0.0	0	0.0
Euglenophyceae	*Euglena sp.*	0	0.0	0	0.0
	Trachelomonas sp.	0	0.0		
	Unknown	0	0.0	0	0.0
Taxa identified					
6	*Totals*	34513	100	34513	100

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June 16, 2021 – Site 2

Taxa	Genus / species	Cells / mL	%	Taxa cells / mL	Taxa %
Cyanophyta	*Aphanizomenon sp.*	0	0.0	50	9.0
	Dolichospermum sp.	2	0.3		
	Planktothrix sp.	48	8.7		
Chlorophyta	*Anikistrodesmus sp.*	0	0.0	125	22.5
	Coelastrum sp.	53	9.6		
	Lagerheimia sp.	3	0.6		
	Oocystis sp.	7	1.2		
	Scenedesmus sp.	27	4.8		
	Selenastrum sp.	35	6.3		
Chrysophyta	*Chrysosphaerella sp.*	0	0.0	78	14.1
	Dinobryon sp.	32	5.7		
	Kephyrion sp.	5	0.9		
	Mallomonas sp.	5	0.9		
	Synura sp.	8	1.5		
	Uroglenopsis sp.	28	5.1		
Bacillariophyta	*Asterionella sp.*	0	0.0	246	44.4
	Cyclotella sp.	233	42.0		
	Fragilaria sp.	2	0.3		
	Rhizosolenia sp.	12	2.1		
Pyrrophyta	*Ceratium sp.*	0	0.0	48	8.7
	Glenodinium sp.	28	5.1		
	Peridinium sp.	20	3.6		
Cryptophyceae	*Cryptomonas sp.*	0	0.0	0	0.0
Euglenophyceae	*Euglena sp.*	0	0.0	2	0.3
	Trachelomonas sp.	2	0.3		
	Unknown	5	0.9	5	0.9
Taxa identified 18	*Totals*	555	100	555	100

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July 22, 2021 – Site 1

Taxa	Genus / species	Cells / mL	%	Taxa cells / mL	Taxa %
Cyanophyta	*Aphanizomenon sp.*	0	0.0	464	21.6
	Dolichospermum sp.	464	21.6		
Chlorophyta	*Anikistrodesmus sp.*	0	0.0	1436	66.7
	Chodatella sp.	10	0.4		
	Scenedesmus sp.	1398	64.9		
	Spondylosium sp.	10	0.4		
	Tetraedron minimum	10	0.4		
	Treubaria sp.	10	0.4		
Chrysophyta	*Chrysosphaerella sp.*	0	0.0	10	0.4
	Mallomonas sp.	10	0.4		
	Synura sp.	0	0.0		
Bacillariophyta	*Asterionella sp.*	0	0.0	196	9.1
	Cyclotella sp.	148	6.9		
	Fragilaria sp.	5	0.2		
	Rhizosolenia sp.	34	1.6		
	Synedra sp.	10	0.4		
Pyrrophyta	*Ceratium sp.*	0	0.0	43	2.0
	Glenodinium sp.	19	0.9		
	Gymnodinium sp.	0	0.0		
	Peridinium sp.	24	1.1		
Cryptophyceae	*Cryptomonas sp.*	0	0.0	0	0.0
Euglenophyceae	*Euglena sp.*	0	0.0	5	0.2
	Trachelomonas sp.	5	0.2		
	Unknown	0	0.0	0	0.0
Taxa identified					
14	*Totals*	2154	100	2154	100

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July 22, 2021 – Site 2

Taxa	Genus / species	Cells / mL	%	Taxa cells / mL	Taxa %
Cyanophyta	*Aphanizomenon sp.*	0	0.0	518	22.2
	Chroococcus sp	19	0.8		
	Dolichospermum sp.	499	21.4		
Chlorophyta	*Anikistrodesmus sp.*	0	0.0	1464	62.7
	Chodatella sp.	14	0.6		
	Scenedesmus sp.	1373	58.9		
	Selenastrum sp.	52	2.2		
	Spondylosium sp.	14	0.6		
	Tetraedron minimum	5	0.2		
	Treubaria sp.	5	0.2		
Chrysophyta	*Chrysosphaerella sp.*	0	0.0	29	1.2
	Dinobryon sp.	14	0.6		
	Mallomonas sp.	10	0.4		
	Uroglenopsis sp.	5	0.2		
Bacillariophyta	*Asterionella sp.*	0	0.0	266	11.4
	Aulocoseria sp.	0	0.0		
	Cyclotella sp.	223	9.6		
	Rhizosolenia sp.	38	1.6		
	Synedra sp.	5	0.2		
Pyrrophyta	*Ceratium sp.*	0	0.0	38	1.6
	Glenodinium sp.	24	1.0		
	Peridinium sp.	14	0.6		
Cryptophyceae	*Cryptomonas sp.*	10	0.4	10	0.4
Euglenophyceae	*Euglena sp.*	0	0.0	10	0.4
	Trachelomonas sp.	10	0.4		
	Unknown	0	0.0	0	0.0
Taxa identified 18	*Totals*	2334	100	2334	100

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August 26, 2021 – Site 1

Taxa	Genus / species	Cells / mL	%	Taxa cells / mL	Taxa %
Cyanophyta	*Aphanizomenon sp.*	0	0.0	335	43.4
	Dolichospermum sp.	335	43.4		
	Gomphosphaeria	0	0.0		
Chlorophyta	*Anikistrodesmus sp.*	0	0.0	314	40.7
	Chodatella sp.	3	0.3		
	Cosmarium sp.	3	0.3		
	Dictyosphaerium sp.	0	0.0		
	Elakatothrix gelatinosa	3	0.3		
	Oocystis sp.	14	1.8		
	Scenedesmus sp.	256	33.2		
	Selenastrum sp.	13	1.6		
	Spondylosium sp.	16	2.1		
	Tetraedron minimum	6	0.8		
	Treubaria sp.	1	0.2		
Chrysophyta	*Chrysosphaerella sp.*	0	0.0	16	2.1
	Dinobryon sp.	9	1.1		
	Mallomonas sp.	6	0.8		
	Uroglenopsis sp.	1	0.2		
Bacillariophyta	*Asterionella sp.*	0	0.0	71	9.2
	Cyclotella sp.	64	8.3		
	Synedra sp.	8	1.0		
Pyrrophyta	*Ceratium sp.*	3	0.3	9	1.1
	Glenodinium sp.	4	0.5		
	Peridinium sp.	3	0.3		
Cryptophyceae	*Cryptomonas sp.*	0	0.0	0	0.0
Euglenophyceae	*Euglena sp.*	0	0.0	1	0.2
	Trachelomonas sp.	1	0.2		
Ochrophyta	*Stichogloea sp.*	5	0.6	5	0.6
	Unknown	20	2.6	20	2.6
Taxa identified 19	*Totals*	772	100	772	100

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August 26, 2021 – Site 2

Taxa	Genus / species	Cells / mL	%	Taxa cells / mL	Taxa %
Cyanophyta	*Aphanizomenon sp.*	0	0.0	33	3.6
	Dolichospermum sp.	33	3.6		
Chlorophyta	*Anikistrodesmus sp.*	0	0.0	300	33.0
	Chodatella sp.	2	0.2		
	Cruceginia sp.	2	0.2		
	Scenedesmus sp.	256	28.1		
	Selenastrum sp.	10	1.1		
	Spondylosium sp.	27	3.0		
	Tetraedron sp.	4	0.4		
Chrysophyta	*Chrysosphaerella sp.*	0	0.0	25	2.7
	Dinobryon sp.	6	0.6		
	Epipyxis sp.	0	0.0		
	Kephyrion sp.	0	0.0		
	Mallomonas sp.	13	1.5		
	Synura sp.	0	0.0		
	Uroglenopsis sp.	6	0.6		
Bacillariophyta	*Asterionella sp.*	0	0.0	497	54.5
	Cyclotella sp.	493	54.1		
	Synedra sp.	4	0.4		
Pyrrophyta	*Ceratium sp.*	0	0.0	8	0.8
	Glenodinium sp.	6	0.6		
	Peridinium sp.	2	0.2		
Cryptophyceae	*Cryptomonas sp.*	8	0.8	8	0.8
Euglenophyceae	*Euglena sp.*	0	0.0	4	0.4
	Trachelomonas sp.	4	0.4		
Ochrophyta	*Stichogloea sp.*	0	0.0	0	0.0
	Unknown	37	4.0	37	4.0
Taxa identified 16	*Totals*	910	100	910	100

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September 20, 2021 – Site 1

Taxa	Genus / species	Cells / mL	%	Taxa cells / mL	Taxa %
Cyanophyta	*Aphanizomenon sp.*	0	0.0	10	2.7
	Chroococcus sp	9	2.4		
	Dolichospermum sp.	1	0.2		
Chlorophyta	*Anikistrodesmus sp.*	0	0.0	283	79.5
	Chodatella sp.	2	0.5		
	Coelastrum sp.	40	11.2		
	Mougiotia sp.	1	0.2		
	Oocystis sp.	7	2.0		
	Scenedesmus sp.	179	50.4		
	Selenastrum sp.	23	6.6		
	Spondylosium sp.	2	0.5		
	Tetraedron minimum	29	8.1		
Chrysophyta	*Chrysosphaerella sp.*	0	0.0	10	2.9
	Dinobryon sp.	1	0.2		
	Mallomonas sp.	5	1.5		
	Uroglenopsis sp.	4	1.2		
Bacillariophyta	*Asterionella sp.*	0	0.0	10	2.9
	Cyclotella sp.	9	2.4		
	Synedra sp.	2	0.5		
Pyrrophyta	*Ceratium sp.*	2	0.5	21	5.9
	Glenodinium sp.	15	4.2		
	Peridinium sp.	4	1.2		
Cryptophyceae	*Cryptomonas sp.*	0	0.0	0	0.0
Euglenophyceae	*Euglena sp.*	0	0.0	9	2.4
	Trachelomonas sp.	9	2.4		
Ochrophyta	*Stichogloea sp.*	0	0.0	0	0.0
	Unknown	13	3.7	13	3.7
Taxa identified 19	*Totals*	356	100	356	100

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September 20, 2021 – Site 2

Taxa	Genus / species	Cells / mL	%	Taxa cells / mL	Taxa %
Cyanophyta	*Aphanizomenon sp.*	0	0.0	1031	85.6
	Chroococcus sp	17	1.4		
	Dolichospermum sp.	35	2.9		
	Planktothrix sp.	979	81.3		
Chlorophyta	*Anikistrodesmus sp.*	0	0.0	117	9.7
	Scenedesmus sp.	76	6.3		
	Selenastrum sp.	24	2.0		
	Tetraedron minimum	17	1.4		
	Treubaria sp.	0	0.0		
Chrysophyta	*Chrysosphaerella sp.*	0	0.0	13	1.1
	Mallomonas sp.	4	0.4		
	Uroglenopsis sp.	9	0.7		
Bacillariophyta	*Asterionella sp.*	0	0.0	13	1.1
	Cyclotella sp.	9	0.7		
	Synedra sp.	4	0.4		
Pyrrophyta	*Ceratium sp.*	6	0.5	15	1.3
	Glenodinium sp.	6	0.5		
	Peridinium sp.	2	0.2		
Cryptophyceae	*Cryptomonas sp.*	0	0.0	0	0.0
Euglenophyceae	*Euglena sp.*	0	0.0	4	0.4
	Trachelomonas sp.	4	0.4		
Ochrophyta	*Stichogloea sp.*	0	0.0	0	0.0
	Unknown	11	0.9	11	0.9
Taxa identified					
14	*Totals*	1204	100	1204	100

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October 21, 2021 – Site 1

Taxa	Genus / species	Cells / mL	%	Taxa cells / mL	Taxa %
Cyanophyta	*Aphanizomenon sp.*	0	0.0	2772	90.0
	Dolichospermum sp.	215	7.0		
	Planktothrix sp.	2557	83.0		
Chlorophyta	*Anikistrodesmus sp.*	0	0.0	229	7.4
	Closterium sp.	2	0.1		
	Oocystis sp.	5	0.2		
	Scenedesmus sp.	208	6.8		
	Selenastrum sp.	9	0.3		
	Tetraedron minimum	5	0.2		
Chrysophyta	*Chrysosphaerella sp.*	0	0.0	32	1.1
	Dinobryon sp.	9	0.3		
	Mallomonas sp.	9	0.3		
	Synura sp.	5	0.2		
	Uroglenopsis sp.	9	0.3		
Bacillariophyta	*Asterionella sp.*	0	0.0	7	0.2
	Fragilaria sp.	2	0.1		
	Synedra sp.	5	0.2		
Pyrrophyta	*Ceratium sp.*	2	0.1	9	0.3
	Glenodinium sp.	2	0.1		
	Gymnodinium sp.	0	0.0		
	Peridinium sp.	5	0.2		
Cryptophyceae	*Cryptomonas sp.*	7	0.2	7	0.2
Euglenophyceae	*Euglena sp.*	0	0.0	9	0.3
	Trachelomonas sp.	9	0.3		
Ochrophyta	*Stichogloea sp.*	0	0.0	0	0.0
	Unknown	14	0.5	14	0.5
Taxa identified 18	*Totals*	3079	100	3079	100

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October 21, 2021 – Site 2

Taxa	Genus / species	Cells / mL	%	Taxa cells / mL	Taxa %
Cyanophyta	*Aphanizomenon sp.*	0	0.0	4241	97.4
	Dolichospermum sp.	172	4.0		
	Planktothrix sp.	4069	93.4		
Chlorophyta	*Anikistrodesmus sp.*	0	0.0	74	1.7
	Scenedesmus sp.	57	1.3		
	Selenastrum sp.	8	0.2		
Chrysophyta	*Chrysosphaerella sp.*	0	0.0	25	0.6
	Dinobryon sp.	12	0.3		
	Mallomonas sp.	8	0.2		
	Uroglenopsis sp.	4	0.1		
Bacillariophyta	*Asterionella sp.*	0	0.0	4	0.1
	Synedra sp.	4	0.1		
Pyrrophyta	*Ceratium sp.*	0	0.0	12	0.3
	Glenodinium sp.	8	0.2		
	Peridinium sp.	4	0.1		
Cryptophyceae	*Cryptomonas sp.*	0	0.0	0	0.0
Euglenophyceae	*Euglena sp.*	0	0.0	0	0.0
	Trachelomonas sp.	0	0.0		
Ochrophyta	*Stichogloea sp.*	0	0.0	0	0.0
	Unknown	0	0.0	0	0.0
Taxa identified 11	*Totals*	4356	100	4356	100

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APPENDIX D. STATISTICAL ANALYSES

Key: Alk = alkalinity; Amm = ammonia; NO3 = nitrate; NO2 = nitrite; TKN = total Kjeldahl nitrogen; TP = total phosphorus. The ".T" and ".B" following a variable indicates whether the data was from the top of the water column (epilimnion) or bottom of the water column (hypolimnion), respectively.

Whole Lake (Combined) Multiple Linear Regression

	Estimate	**Std. Error**	**t value**	**Pr(>|t|)**	**Significance**
(Intercept)	2.04E+03	6.87E+00	296.194	< 2e-16	***
pH.T	-1.63E+00	8.53E-01	-1.913	0.0653	.
pH.B	4.03E-01	2.08E-01	1.939	0.0619	.
Alk.T	-2.99E-02	2.01E-02	-1.485	0.148	
Amm.T	-7.98E-01	2.53E-01	-3.153	**0.00365**	**
NO3.T	-1.73E+00	4.14E+00	-0.418	0.67881	
NO2.T	-1.84E+01	1.66E+02	-0.11	0.91277	
TKN.T	2.08E-01	1.42E-01	1.461	0.15453	
TP.T	-1.94E-03	1.63E-02	-0.119	0.90585	
Alk.B	-9.57E-03	1.05E-02	-0.91	0.37005	
Amm.B	-1.11E+00	3.93E-01	-2.83	**0.00822**	**
NO3.B	-3.93E+00	1.40E+00	-2.819	**0.00845**	**
NO2.B	4.25E+01	1.33E+02	0.318	0.75252	
TKN.B	-3.51E-01	9.85E-02	-3.564	**0.00125**	**
TP.B	2.23E-03	1.00E-03	2.226	**0.03365**	*
Secchi	2.02E-01	2.33E-01	0.869	0.39155	

r2	0.6735
F	7.189
p	2.59E-06

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Epilimnetic Multiple Linear Regression

	Estimate	Std. Error	t value	Pr(>|t|)	Significance
(Intercept)	2027.08161	7.70289	263.158	< 2e-16	***
pH.T	-0.76467	0.79348	-0.964	0.341458	
Alk.T	-0.01481	0.02424	-0.611	0.544904	
Amm.T	-0.29347	0.29017	-1.011	0.318408	
NO3.T	-2.94565	4.98757	-0.591	0.55838	
NO2.T	45.40371	34.44027	1.318	0.195496	
TKN.T	-0.38499	0.10453	-3.683	**0.000732**	***
TP.T	-0.02495	0.01872	-1.333	0.190828	
Secchi	0.23326	0.27347	0.853	0.399173	
r2	0.4352				
F	5.334				
p	0.0001734				

Hypolimnetic Multiple Linear Regression

	Estimate	Std. Error	t value	Pr(>|t|)	
(Intercept)	2.02E+03	1.74E+00	1162.739	< 2e-16	***
pH.B	7.70E-02	1.47E-01	0.525	0.6026	
Alk.B	-4.12E-03	1.05E-02	-0.393	0.69613	
Amm.B	-9.44E-01	3.07E-01	-3.078	**0.00375**	**
NO3.B	-2.15E+00	1.13E+00	-1.893	0.06565	.
NO2.B	2.72E+01	2.12E+01	1.281	0.20754	
TKN.B	-3.34E-01	6.81E-02	-4.905	**1.60E-05**	***
TP.B	3.14E-03	9.79E-04	3.206	**0.00265**	**
r2	0.616				
F	11.77				
p	5.05E-08				

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Whole Lake ANOVA

	Df	Sum Sq	Mean Sq	F value	Pr(>F)	Significance
pH.T	1	2.98	2.98	1.8568	0.1831326	
pH.B	1	0.432	0.432	0.269	0.6078161	
Alk.T	1	0.796	0.796	0.4957	0.4868301	
Amm.T	1	38.643	38.643	24.0766	**3.03E-05**	***
NO3.T	1	8.529	8.529	5.3139	**0.0282518**	*
NO2.T	1	5.637	5.637	3.5119	0.0707	.
TKN.T	1	53.586	53.586	33.3866	**2.60E-06**	***
TP.T	1	5.905	5.905	3.679	0.0646629	.
Alk.B	1	10.675	10.675	6.6509	**0.0150583**	*
Amm.B	1	0.334	0.334	0.2084	0.6513426	
NO3.B	1	12.823	12.823	7.9893	**0.0082957**	**
NO2.B	1	0.064	0.064	0.04	0.8428577	
TKN.B	1	21.721	21.721	13.5332	**0.0009156**	***
TP.B	1	9.731	9.731	6.0629	**0.0197688**	*
Secchi	1	1.213	1.213	0.7558	0.3915465	

Epilimnetic ANOVA

	Df	Sum Sq	Mean Sq	F value	Pr(>F)	
pH.T	1	2.98	2.98	1.0733	0.3069185	
Alk.T	1	0.716	0.716	0.2579	0.6146133	
Amm.T	1	39.131	39.131	14.0929	**0.0005971**	***
NO3.T	1	8.475	8.475	3.0522	0.0889266	.
NO2.T	1	5.598	5.598	2.0162	0.1639958	
TKN.T	1	53.689	53.689	19.3363	**8.91E-05**	***
TP.T	1	5.873	5.873	2.1152	0.1542738	
Secchi	1	2.02	2.02	0.7275	0.3991729	

Hypolimnetic ANOVA

	Df	Sum Sq	Mean Sq	F value	Pr(>F)	
pH.B	1	0.825	0.825	0.4208	0.520239	
Alk.B	1	2.696	2.696	1.3747	0.247949	
Amm.B	1	19.916	19.916	10.1567	**0.002789**	**
NO3.B	1	45.662	45.662	23.2861	**2.06E-05**	***
NO2.B	1	5.163	5.163	2.6329	0.112525	
TKN.B	1	67.148	67.148	34.243	**7.64E-07**	***
TP.B	1	20.153	20.153	10.2774	**0.002648**	**

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