Lake Wononscopomuc

2023 Water Quality Monitoring Report

Prepared for the:

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TABLE OF CONTENTS

I. Executive Summary

Brawley Consulting Group, LLC (BCG) was engaged by the Lake Wononscopomuc Association (LWA) to perform an assessment of water quality in 2023. 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 2023 water quality monitoring program at Lake Wononscopomuc. Several recommendations are provided at the end of the report.

- The water columns at two sampling sites were highly stable, stratified, and exhibited strong resistance to mixing at the thermocline throughout the season. This resulted in anoxic conditions at the bottom which expanded upward in the water column with time. By mid-October at Site 1, the bottom 15 meters of the 30-meter water column, had oxygen concentrations of <1 mg/L.
- The lake exhibited mostly early mesotrophic to mesotrophic characteristics in 2023. Epilimnetic total phosphorus levels were within the early mesotrophic range, while epilimnetic total nitrogen levels were characteristic of mesotrophic conditions. Average summer Secchi disk transparency was just above the early mesotrophic range and within the mesotrophic range. Algae and cyanobacteria cell concentrations indicated even less productivity, i.e., were more characteristic of oligotrophic conditions. Relative phycocyanin was also indicative of low cyanobacteria growth.
- Nutrient and other chemical characteristics of the hypolimnion differed from those in the epilimnion and were an outcome of the anoxic / highly reduced environment at the lower depths. On average, total phosphorus, total nitrogen, and ammonia levels in the hypolimnetic were higher than those in the epilimnion at least partly due to internal loading processes. Hypolimnetic alkalinity was also on average higher than epilimnetic alkalinity, but not as high as might be anticipated given the protracted period of anoxia at the bottom. The pH at the bottom was often higher than corresponding epilimnetic pH which is uncommon. The hypolimnetic pH, alkalinity and phosphorus levels were likely impacted by the co-precipitation process (see below) that we believe occurs in the lake.
- The two most abundant cyanobacteria genera observed in the top three meters of the water column were genera capable of regulating buoyancy and were likely responsible for the lake's highest cyanobacteria biomass observed in the upper levels of the hypolimnion at 10 to 13 meters of depth. They are also morst likely the genera that occasionally form shoreline blooms after becoming positively buoyant, reach the surface, and moved to the shore by light winds. Diatoms and golden algae were dominant or co-dominant up through July before cyanobacteria became the dominant taxon.

- Statistical analyses using 2015 to 2023 data indicate that the lake had significantly changed, but much of statistical models were driven by measurements of nitrogen-related variables, which were reported in 2015 and 2017 as much higher, and much lower since then. Total phosphorus in the epilimnion appears to be decreasing in a statistically significant fashion, but another trophic-related variable – Secchi disk transparency – has not exhibited significant change over the last 8 years. Specific conductance continued to trend up and was the variable showing the most change since the early 1990s.
- Co-precipitation is a phenomenon that likely occurs at Lake Wononscopomuc due to high pH and calcium levels. The process precipitates soluble reactive phosphorus out of the water column, making it unusable by algae and cyanobacteria. We hypothesize that once the precipitate reaches lower, anoxic depths, the compound coverts back into the soluble form and increases carbonate and bicarbonate thus increasing pH. The process would also increase soluble reactive phosphorus in the hypolimnion. This could provide a supplemental source of hypolimnetic phosphorus in addition to that released from sediments as part of the internal loading process. These higher hypolimnetic levels may contribute to the cyanobacteria productivity in the upper levels of the hypolimnion.

II. Introduction

Lake Wononscopomuc is a natural 348-acre water body located in Salisbury, Connecticut. It is one of the deepest lakes in Connecticut; with 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, which is often associated with Connecticut's Marble Valley lakes. The type of water chemistry associated with this geology can produce unique lake features such as marl deposits and lake whitening events. This type of water chemistry can also support specialized algae and plant communities.

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 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	Estimated	
					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 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 2023, Brawley Consulting Group, LLC (BCG) was engaged by the Lake Wononscopomuc Association (LWA) to examine the summer season water quality features of Lake Wononscopomuc and to continue the process of establishing a high-quality contemporary database of water quality information. The water quality assessment followed a repeatable design and allowed for a general examination of water quality for use in future water quality comparisons. One of the past 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.

III. Methods

Field data and water sample collections were performed by BCG on May 30th, June 29th, July 24th, August 23rd, September 21st, and October 18th. Collections occurred at two sites on the lake, each located within one of the two major basins of the lake (Fig. 1). Site depth was determined to the nearest centimeter (cm) using a weighted field tape. 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 BCG using a 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), relative phycocyanin concentration, and pH. Each is discussed in the following report sections.

Water samples were collected at both sites during each visit for analyses of selected water quality variables (Table 2). Samples were collected at 1 meter (m) of depth (aka surface or epilimnion) using a horizontal Van Dorn water sampler; samples were collected at approximately 0.5m above the sediment water interface (hypolimnion). Samples collected in May through July were delivered the same day of collection to York Analytical Laboratories, a Connecticut State-certified laboratory located in Newtown, CT. Concentrations of total phosphorus, total Kjeldahl nitrogen, nitrite, nitrate, ammonia, and alkalinity were analytically determined.

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
Total Nitrogen	1m from surface; 0.5m from bottom
Alkalinity	1m from surface; 0.5m from bottom
Algae	Integration of top 3m

A change in laboratory was made prior to the August sample collection. Samples collected in August through October were analyzed at the UCONN Center for Environmental Science and Engineering (CESE) in Storrs, CT. Samples collected in the field were kept frozen at BCG facilities until delivered to the laboratory.

Samples collected for algae cyanobacteria counts were treated in the field with Lugol's solution for preservation. Those samples were later treated with hydrostatic pressure to collapse the gas vesicles within the cyanobacteria cells (Lawton et al. 1999). Known volumes of those preserved samples were concentrated into smaller volumes with centrifugation and a vacuum pump /filtration flask system. Portions of those concentrates were transferred to a counting chamber. Genus-level algal cell enumerations were then performed by counting cells in a subset of the chamber's fields using an inverted Nikon Diaphot research microscope; those counts were then mathematically corrected to be reflective of the whole water samples.

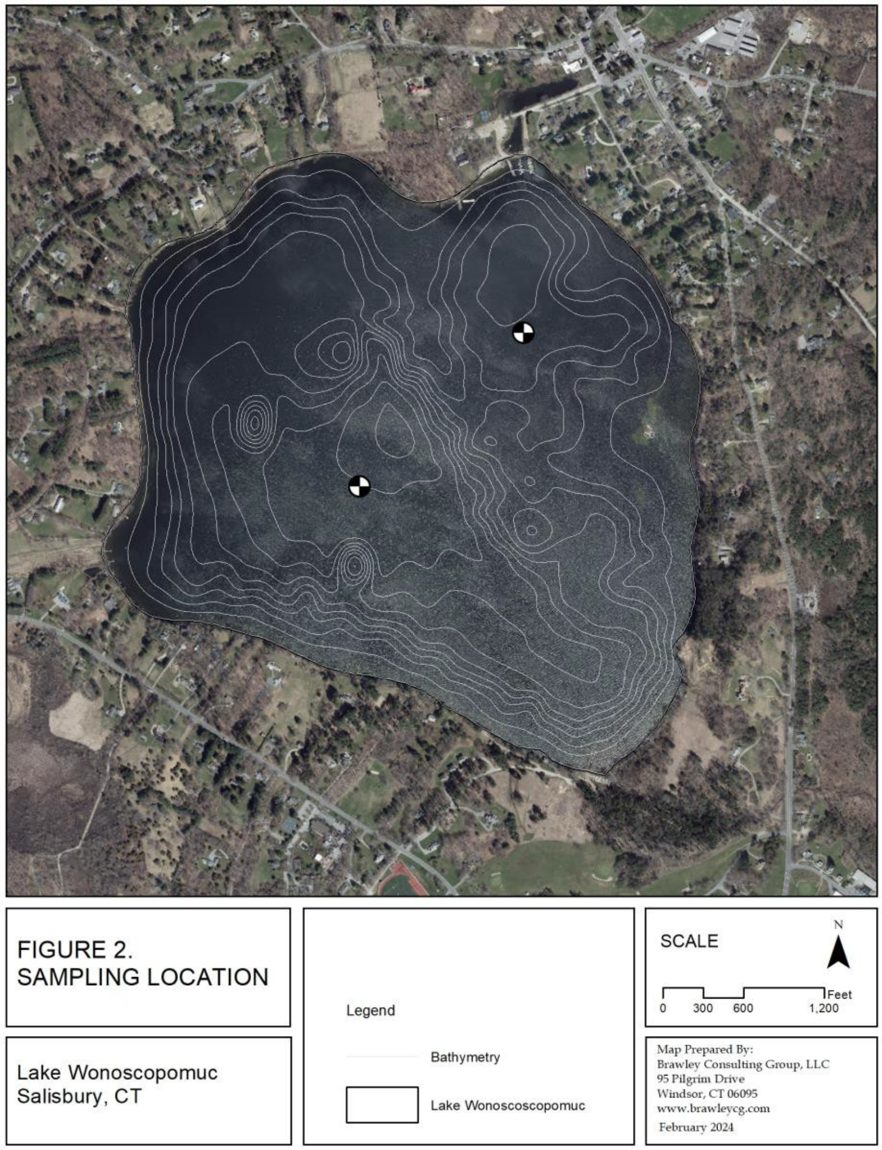


Figure 1. Water quality monitoring sites on Lake Wononscopomuc. Site 1 was located near the center of lake in 30 meters of water. Site 2 was in the northeastern basin and in 17 meters of water.

For a qualitative assessment of the entire pelagic zone phytoplankton community, a 10 micrometer (µm) mesh plankton net was used to collect a concentrated algae sample in the field from the top three meters of the water column. Those samples were examined, and important genera photographed in BCG offices using a Wolfe DigiviTM CVM Microscope with Motic Images Plus 3.0 software.

Water temperature data were utilized to determine thermal resistance to mixing scores, which were used to determine the position of the metalimnion and characterize the strength of the thermocline. Resistance to mixing, which is an assessment of the ability of two different water volumes – that differ in temperature and density – to mix, was calculated using the Relative Thermal Resistance to Mixing (RTRM) formula: (D1 – D2)/(D' – Do), 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 Do is the density of water at 4°C. RTRM scores of <30 mean that layers are mixed; scores of ≥30 between strata are characteristic of the transitional metalimnion layer. RTRM scores of ≥80 between strata are indicative of strong resistance to mixing (Siver et.al. 2018).

IV. Temperature and Oxygen Dynamics

A. Isopleth Plots

We have displayed many of the data collected throughout the water column as isopleths where a variable (e.g., temperature) is displayed as shades of colors throughout the water column at each depth and for all applicable collection dates. Values were 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 (e.g., Fig. 2).

B. Temperature & Dissolved Oxygen

The water temperature profile data and isopleth charts provided a view into the thermal and oxygen dynamics of the lake and seasonal stratification resulting from temperature/density differences between depths. In shallow New England lakes, or shallow sites in a deep lake, stratification can occur. When a lake is thermally stratified, a middle transitional layer (known as the metalimnion) separates the upper warmer layer (epilimnion) from lower colder waters below (hypolimnion). Within the boundaries of the metalimnion is the thermocline, which is the stratum where the temperature/density change and resistance to mixing are the greatest. This stratification in shallow lakes or sites may be short in duration because wind energy can mix the water column. In deeper lakes or sites, stratification is not easily broken down by wind energy.

An oxygen concentration of 5 mg/L is generally considered the threshold that delineates favorable very conditions for most aerobic organisms in freshwater systems. As concentrations decrease below that threshold, conditions become stressful for aquatic organisms. Minimum oxygen requirements for fisheries in Connecticut's lakes and ponds range from 4 to 5 mg/L for cold-water fish (e.g., trout), 2 mg/L for cool-water fish (e.g., walleye), and 1 to 2 mg/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 compared to conditions where oxygen is present. These anoxic conditions result in the dissolution of compounds (e.g., iron phosphate) in the sediments that can then dissolve into the interstitial waters and eventually diffuse into the waters above the sediments.

The water columns at both sites were very stable throughout the 2023 season. On each sampling event, the water columns were stratified. Resistance to mixing at the thermocline was very strong (RTRM>80) on each visit except October when stratification began to weaken. Epilimnetic waters warmed from 18.5-20.5°C in late May and reached highest temperatures of 26-27°C in late July before cooling through mid-October down to approximately 14-15°C (Fig. 4).

The metalimnetic layer in the first part of the season was generally between 4 and 8 meters of depth. Within the metalimnion, temperatures rapidly decreased with depth. As the season progressed, metalimnetic water temperatures continued to rapidly decrease but the layer migrated downward as more of the water column became part of the epilimnion due to wind-driven mixing (Fig. 2).

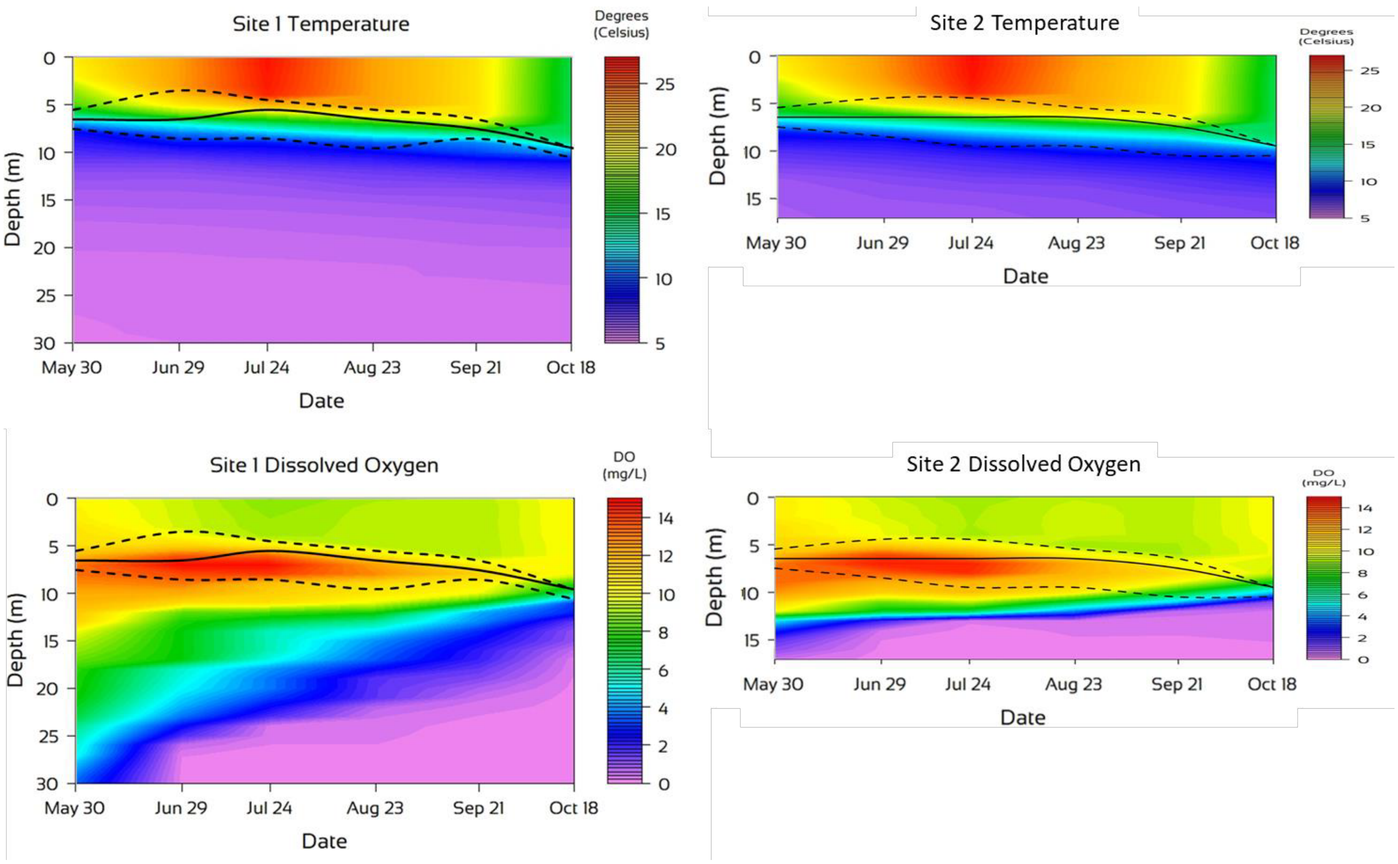


Figure 2. Temperature (top panels) and oxygen (bottom panels) isopleth charts for Site 1 (left panels) and Site 2 (right panels) at Lake Wononscopomuc in 2023.

Temperatures in the hypolimnion were highly stable over depth and time. Temperatures just below the lower metalimnetic boundary were mostly in the 8-10°C range. At Site 1, temperatures decreased with depth to lows of 5-6°C. Those temperatures were observed starting at 16m of depth in May and June, but only starting at 19m of depth in October as upper hypolimnetic temperature modestly increased. As observed at Site 1, upper hypolimnetic temperatures at Site 2 increased modestly as the season progressed.

Epilimnetic oxygen concentrations were greater than 8mg/L all season at both sites. Highest oxygen concentrations were observed within the metalimnion and below the thermocline from May through September.

Oxygen saturation that regularly exceeded 120% in these “metalimnetic oxygen maximum” zones were likely to due to several factors including the higher solubility of oxygen in colder waters, the strength of resistance to mixing at the thermocline, and high concentration of cyanobacteria below the thermocline (see *Algal Community Dynamis* below).

Oxygen concentrations in the hypolimnion decreased with depth. At Site 1, concentrations decreased to 3.5 mg/L at 30 meters of depth by late May. By late June concentrations of <1 mg/L occupied the bottom five meters (26 to 30 meters of depth). By mid-October, the bottom 15 meters, i.e. the bottom half of the water column, exhibited oxygen concentrations of <1 mg/L. At Site 2, concentrations of <1 mg/L were observed in the water column from May through October. In late May, that concentration was only observed at the very bottom of the water column (17 meters). Those concentrations expanded to more of the water column as the season progressed. By mid-October, concentrations of <1 mg/L were measured in the bottom six meters of the water column (12 to 17 meters of depth).

V. Trophic Characteristics

Several of the water quality variables measured in this program were used to assess the trophic status of the lake. A lake’s trophic status is a based on the level of primary productivity it can support and is determined with variables that limit or express algal productivity, including total phosphorus and total nitrogen concentrations, Secchi transparency, and chlorophyll-*a* concentrations (See Table 3). Lakes supporting very little algal are typically clear and are referred to as oligotrophic lakes; lakes supporting high levels of productivity are more turbid and are termed eutrophic or highly eutrophic. It is generally those eutrophic or highly eutrophic lakes that experience regular and intense algal blooms. Lakes with characteristics between oligotrophic and eutrophic conditions can be described as one of several subcategories of mesotrophic conditions. Mesotrophic and even oligotrophic lakes can experience algal blooms but those are much less intense and infrequent.

Table 3. Trophic classification criteria used by the Connecticut Experimental Agricultural Station (Frink and Norvell, 1984) and the CT DEEP (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

Based on the trophic data collected and classification criteria in Table 3, the trophic status of Lake Wononscopomuc in 2023 was early mesotrophic to mesotrophic**.**

A. Secchi Disk Transparency

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

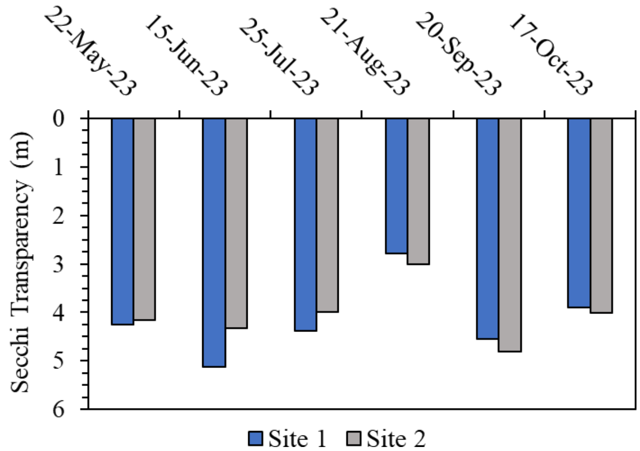


Figure 3. Secchi disk transparencies at Site 1 and Site 2 of Lake Wononscopomuc in 2023.

Light in lakes is important for several reasons, particularly for its role in open water photosynthesis and algal productivity. As light diminishes with depth, so does photosynthetic potential. Since photosynthesis decreases with depth, there is a depth where oxygen produced from algal photosynthesis is equal to the oxygen consumed via algal cellular respiration. That is referred to as the *Compensation Point* and is estimated by multiplying the Secchi disk transparency by 2 (see below).

Secchi disk transparencies were characteristic of early mesotrophic to mesotrophic algal productivity. Of the 12 readings taken in 2023, 9 were ≥4 meters in length (Fig. 3). Two of the 12 were ≥3 to 3.99 meters in length. The August readings were the lowest at 2.78 and 3.00 meters at Sites 1 and 2, respectively. The season averages were 4.17 and 4.05 meters at Sites 1 and 2, respectively; and the respective summer averages (July – September) were 3.91 and 3.93.

B. Relative Phycocyanin Concentrations

Measuring phycocyanin provides a means of assessing cyanobacteria (aka blue-green algae) biomass. Phycocyanin is an auxiliary photosynthetic pigment unique to the cyanobacteria and relative concentrations were measured throughout the water column with a fluorimeter incorporated into the sensor array of the Eureka Manta II multiprobe. Fluorimeters work on the principle that a particular substance fluoresces at a specific wavelength when light of another wavelength is directed on that substance. The fluorimeter in our instrumentation emits a wavelength that interacts with phycocyanin. This sensor is not calibrated with known concentrations of phycocyanin, so measurements are not quantitative; instead, the measurements are relative to other measurements in the water column and to measurements on other dates. Relative measurements are recorded throughout the water column. Spatial distributions of cyanobacteria are reported later in this report (see Algae and Cyanobacteria Dynamics). Here, monthly measurements at both sites were the averages of the top three meters of the water columns.

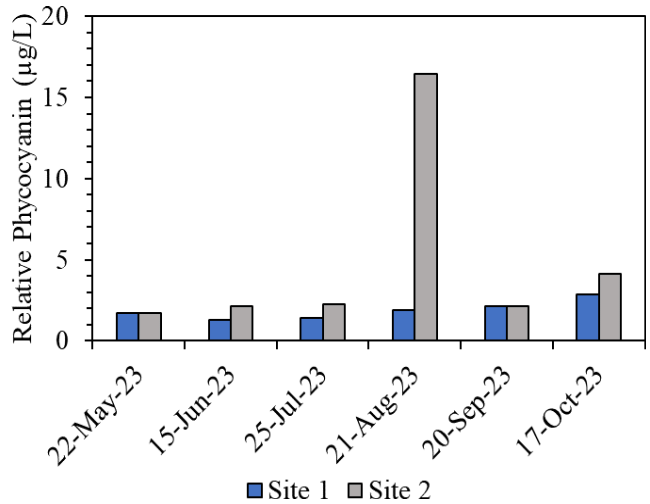


Figure 4. Relative phycocyanin averages from the top three meters of the water column at Site 1 and Site 2 at Lake Wononscopomuc in 2023.

Except for the August average at Site 2, all averages were low and indicative of low cyanobacteria concentrations in the top three meters of the water column. Lowest averages were generally from the May through July when average relative phycocyanin concentrations at both sites were between 1.3 and 2.2 µg/L (Fig. 4). The average remained low in August at Site 1 but increased to 16 µg/L at Site 2 indicating that a cyanobacteria bloom had developed. By September, average relative concentrations were low again and increased only slightly at Site 2 by October.

C. Total Phosphorus

Algae and cyanobacteria require a variety of micro- and macronutrients to maintain a population. In freshwater systems, phosphorus is the nutrient that most often limits algae growth (the *limiting nutrient).* Therefore, total phosphorus (the sum of particulate and dissolved forms of phosphorus) also serves as a measure of productivity in most lake studies.

Epilimnetic total phosphorus concentrations from May through August were all <10 µg/L with the exception of the Site 2 concentration of 20 µg/L in May (Fig. 5).[1] Epilimnetic concentrations increased through the remainder of the season reaching by mid-October 15 and 17 µg/L at Site 1 and Site 2, respectively.

Average epilimnetic levels with only detectable data were 10.7 and 14.0 µg/L. Using the MDL of 10 µg/L when levels were reported by York Environmental as less than the MDL, respective averages were 10.3 and 12.7 µg/L. All epilimnetic averages were within the early mesotrophic range (see Table 3).

Hypolimnetic total phosphorus levels were always greater than minimum detection levels, regardless of laboratory. Hypolimnetic concentrations in the first three months of the season were low and between 15 and 40 µg/L regardless of site. By August, concentrations increased by an order of magnitude and remained high at Site 1 for the remainder of the season. At Site 2, concentrations decreased to early season levels by mid-September before becoming highly elevated by mid-October. Season averages for Site 1 and Site 2 were 146.4 µg and 112.8 µg/L, respectively.

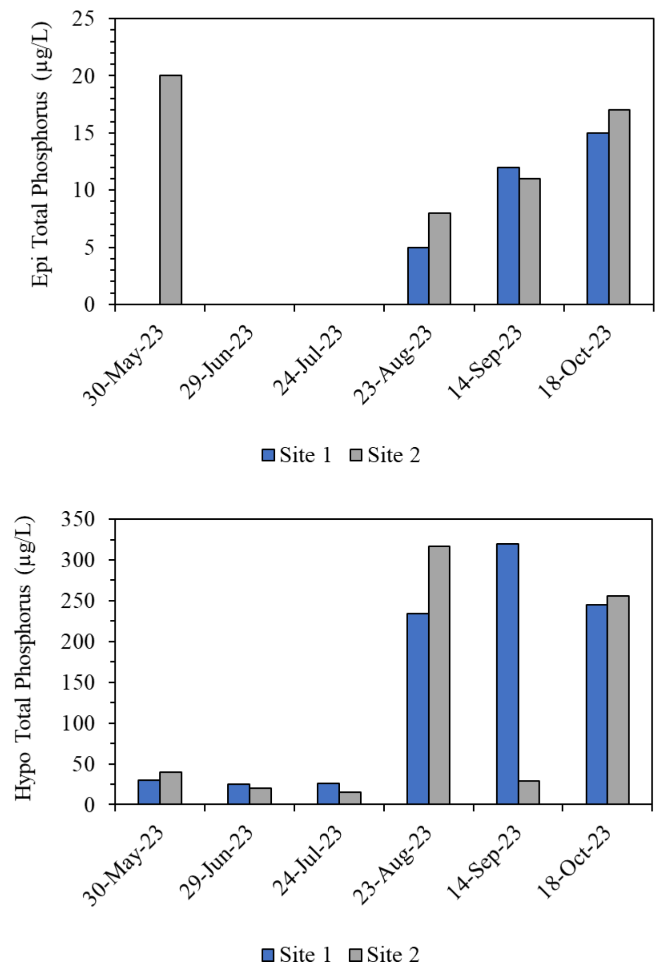


Figure 5. Total phosphorus concentrations in the epilimnion (Epi: top panel) and in the hypolimnion (Hypo; bottom panel) at Site 1 and Site 2 of Lake Wononscopomuc in 2023.

D. Nitrogen

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

[1] Note that the minimum detection limit for total phosphorus for York Environmental was 10µg/L and 2µg/L for UCONN CESE.

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

Differences in laboratory analytical methods and reporting standards were most noticeable in the nitrogen-related data. Several anomalous results were also detected in the data from the first three months of the season. We have reported and displayed the data below as was reported to us, but we have noted anomalous or questionable data below.

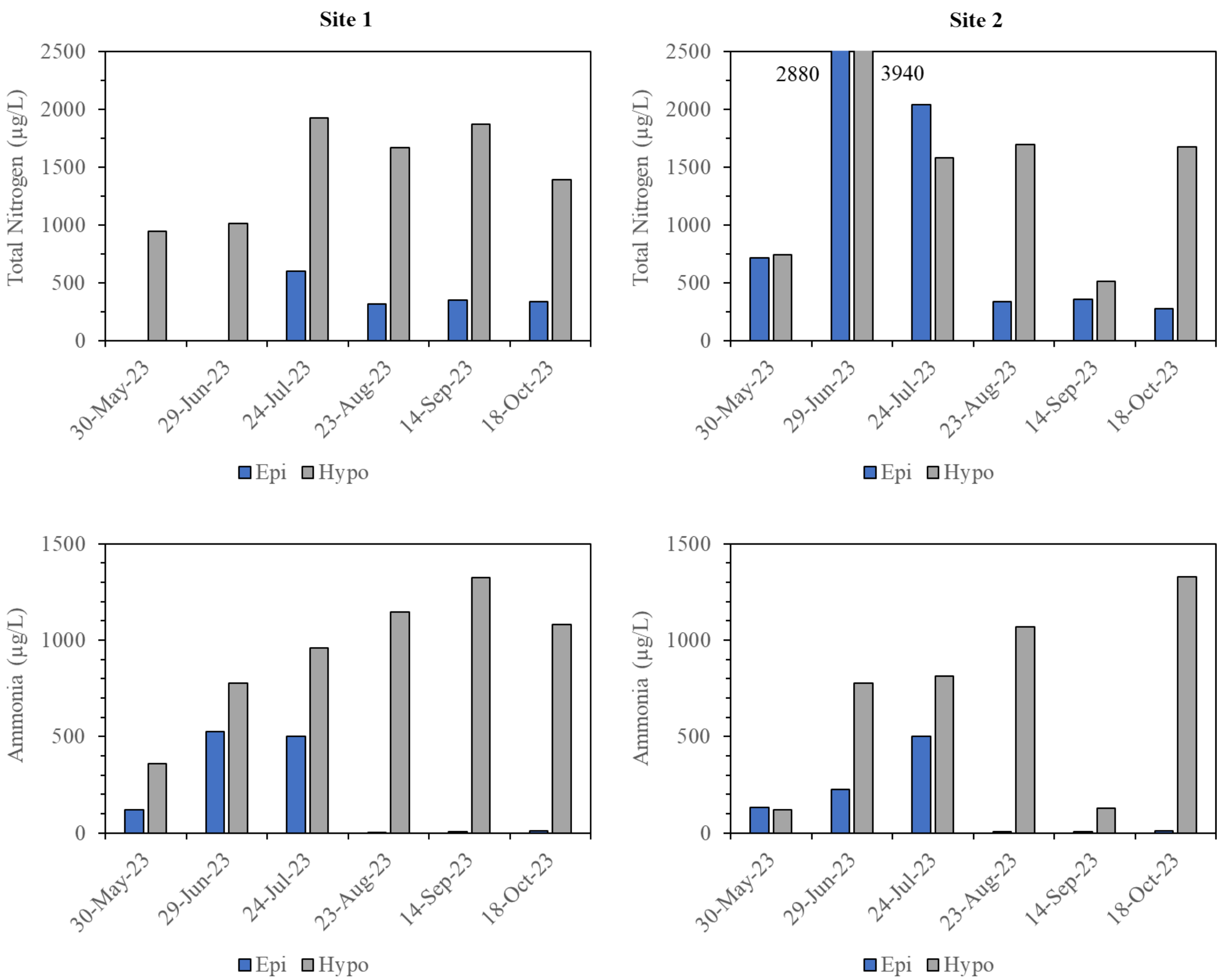


Figure 6. Epilimnetic and hypolimnetic total nitrogen (top panels) and ammonia concentration (bottom panels) at Site 1 (left).

Epilimnetic total nitrogen data in the first half of the season were either reported as below detectable levels (e.g., May and June concentrations at Site 1) or were anomalous (e.g. June and July concentrations at Site 2). All other epilimnetic data were between 272 and 710 µg/L. Based on available data and the removal of anomalies, the season epilimnetic averages were 398 and 417 for Site 1 and Site 2, respectively, and 407 µg/L for the lake. Those all are within the mesotrophic range (Table 3).

Hypolimnetic total nitrogen data appeared to have one anomaly, which was the June Site 2 concentration of 3,940 µg/L. Excluding that data, Site 1, Site 2, and lake averages were 1,467 µg/L, 1,239 µg/L, and 1,363 µg/L, respectively. Concentrations in the latter half of the season were generally higher than those in the first half of the season implicating loading from lake sediments after protracted periods of anoxia. That was supported by the corresponding hypolimnetic ammonia concentration that generally increased as the season progressed (Fig. 6).

High epilimnetic ammonia concentrations were reported in the first half of the season at both sites but were negligible in the second half of the season. Like nitrate and nitrite, ammonia tends to be scarce in the epilimnion because it is rapidly used up in plant and algae growth. We suspect that the high epilimnetic concentrations in the first part of the season were anomalous.

VI. Algal Community Dynamics

Algae has been used in ecological assessments for over 100 years (Stevenson 2014). The composition, concentration, and biomass of algae assemblages in the water column (i.e., phytoplankton) are reflective of environmental conditions in that lake. For example, a lake that is high in nutrients can often be dominated by Cyanophyta (aka cyanobacteria or blue-green algae) with corresponding high cell concentrations and biomass. High concentrations of cyanobacteria can form harmful algal blooms, which can present public health risks due to toxins that some cyanobacteria can produce (CT DPH & CT DEEP 2021). Algae communities that are more diverse can be dominated or co-dominated by the Bacillariophyta (aka diatoms), Chrysophyta (aka golden algae), and Chlorophyta (aka green algae) and typically have lower cell concentrations and biomasses, reflect lower nutrient conditions, and are not toxigenic.

E. Algae and Cyanobacteria Cell Concentrations and Relative Abundance

Algae cell concentrations, including cyanobacteria, were low throughout the season in Lake Wononscopomuc. Lowest algae cell concentrations were observed in May and June and were <1,000 cells/mL. At Site 1, those increased through September to just under 2,800 cells/mL (Fig. 7). At Site 2, the July cell concentration was elevated, decreased by late August, then peaked in late September to just under 3,600 cells/mL.

Cyanobacteria cell concentrations were greater toward the latter part of the season with August and September concentrations of 1,285 and 1,959 cells/mL, respectively at Site 1. At Site 2, the September concentration of 3,010 cyanobacteria cells/mL was the greatest concentration measured in 2023. For comparative purposes, the CT DPH and CT DEEP (2021) equate cyanobacteria cell concentrations of up to 20,000 cells/mL as posing little to no public health risks at public beach areas on lakes. Cyanobacteria cell concentrations of >100,000 cells/mL are equated with high risk to public health due to harmful cyanobacteria blooms.

When cell concentrations were lowest, diatoms and golden algae were the dominant algal taxa. In July when cell concentrations were elevated at Site 2, diatoms were the dominant algal group. Although green algae were seasonally the richest (the greatest number of genera for the season) group, their abundance relative to other groups was low. When the cell concentrations increased in August and September, the cyanobacteria were the clear dominant taxa in the water column (Fig. 7).

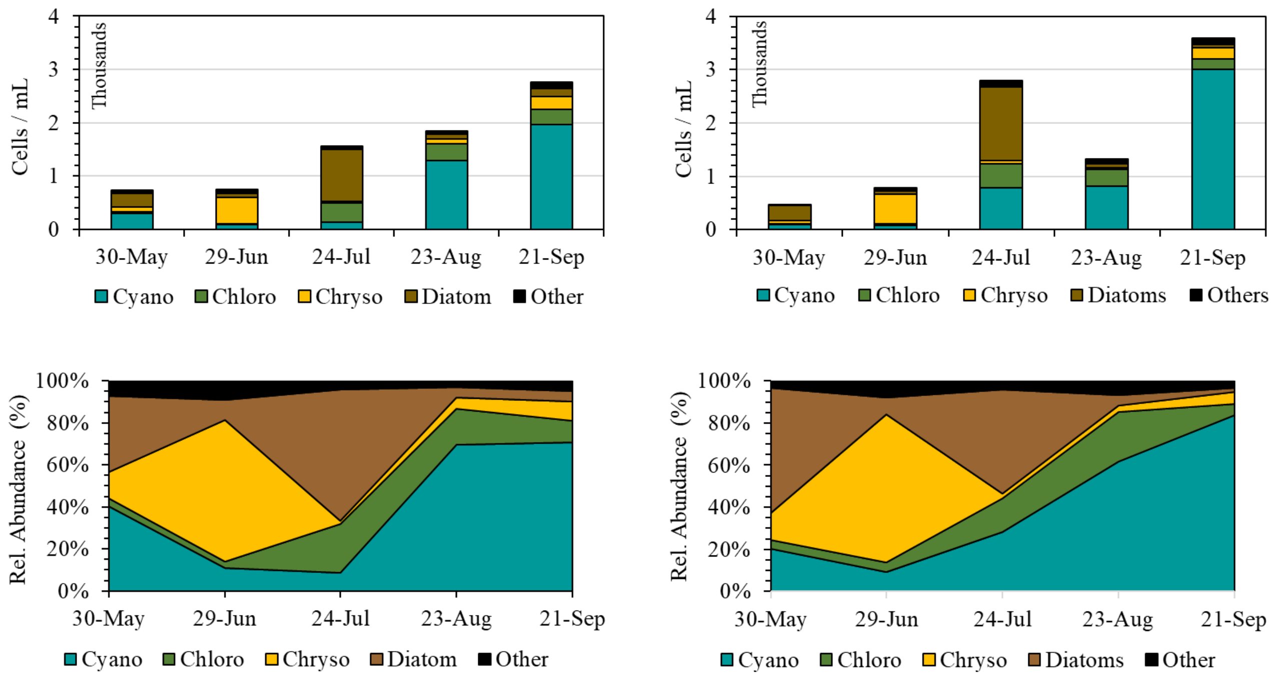


Figure 7. Monthly cell concentrations by taxonomic group (top) and relative abundance of those groups (bottom) at Site 1 (left) and Site 2 (right) during the 2023 season at Lake Wononscopomuc.

F. Algal Taxa and Genera

Thirty-eight genera of algae were observed in plankton net samples and/or the samples used for the algae counts. Of those, 14 genera were from the Chlorophyta (aka green algae). Six genera were from the Chrysophyta (aka golden algae). Five genera from both the Cyanophyta (aka blue-green algae or cyanobacteria) and Bacillariophyta (aka diatoms) were identified. Four genera from the Pyrrophyta (aka dinoflagellates) were observed. One to two genera were observed in three other taxonomic groups (Table 4).

The dominant cyanobacteria genera, particularly in the latter half of the season, were the filamentous *Dolichospermum spp*. and *Planktothrix spp*. (Fig 8a, 8b). Both genera can regulate buoyancy, i.e. can form layers with high cell concentration at depth in the water column. This phenomenon is regularly observed at Lake Wononscopomuc (see below). Both genera are also potentially toxigenic (CT DPH & CT DEEP 2023). However, cell concentrations of these genera in the top three meters of the water column where samples are collected for algae counts, and where contact with swimmers occurs, were always well below the threshold for a risk to public health.

Table 4. Algal genera identified from the plankton net samples and whole water samples collected Lake Wononscopomuc in 2023

Chlorophyta	**Cyanophyta**	**Bacillariophyta**
Anikistrodesmus sp.	*Aphanocapsa sp.*	*Asterionella sp.*
Carteria sp.	*Aphanothece sp.*	*Cyclotella sp.*
Closterium sp.	*Dolichospermum sp.*	*Rhizosolenia sp.*
Coelastrum sp.	*Chroococcus sp.*	*Fragilaria sp.*
Cosmarium sp.	*Planktothrix sp.*	*Synedra sp.*
Crucigenia sp.		
Eudorina sp.	**Chrysophyta**	**Pyrrophyta**
Gloeocystis sp.	*Dinobryon sp.*	*Ceratium sp.*
Oocystis sp.	*Kephyrion sp.*	*Glenodinium sp.*
Scenedesmus sp.	*Mallomonas sp.*	*Gymnodinium sp.*
Selenastrum sp.	*Spinifermonas sp.*	*Peridinium sp.*
Staurastrum sp.	*Synura sp.*	
Tetraedron sp.	*Uroglenopsis sp.*	**Cryptophyta**
Treubaria sp.		*Cryptomonas sp.*
	Ochrophyta	
Euglenophyta	*Gonystromum sp.*	
Trachelomonas sp.	*Stichogloea sp.*	

The early season algae communities were characterized by low cell concentrations but high relative abundance of golden algae and diatoms. In June, the colonial golden alga *Dinobryon spp*. (Fig. 8c) comprised 60 and 66% of all cells counted at Site 1 and Site 2, respectively. In May and July, the centric diatom *Cyclotella spp*. was an important genus. This genus is common in oligotrophic lakes. These *Cyclotella* were small, i.e., in the 3 to 5 µm in diameter range. Also in May, the filamentous diatom *Fragilaria spp*. (Fig. 8d) constituted 41% of all cells counted at Site 2. This genus is larger and common in temperate, mesotrophic lakes in North America.

G. Spatial and Temporal Distribution of Cyanobacteria

In the *Trophic Characteristics* section above, average relative phycocyanin concentrations from the top three meters of the water column were reported. This data was collected throughout the water column. Phycocyanin is the auxiliary photosynthetic pigment unique to cyanobacteria and a good indicator of cyanobacteria biomass. As with other data collected throughout the water column, isopleth charts depicting spatial and temporal distributions of cyanobacteria biomass were created for Site 1 and Site 2 (Fig. 9).

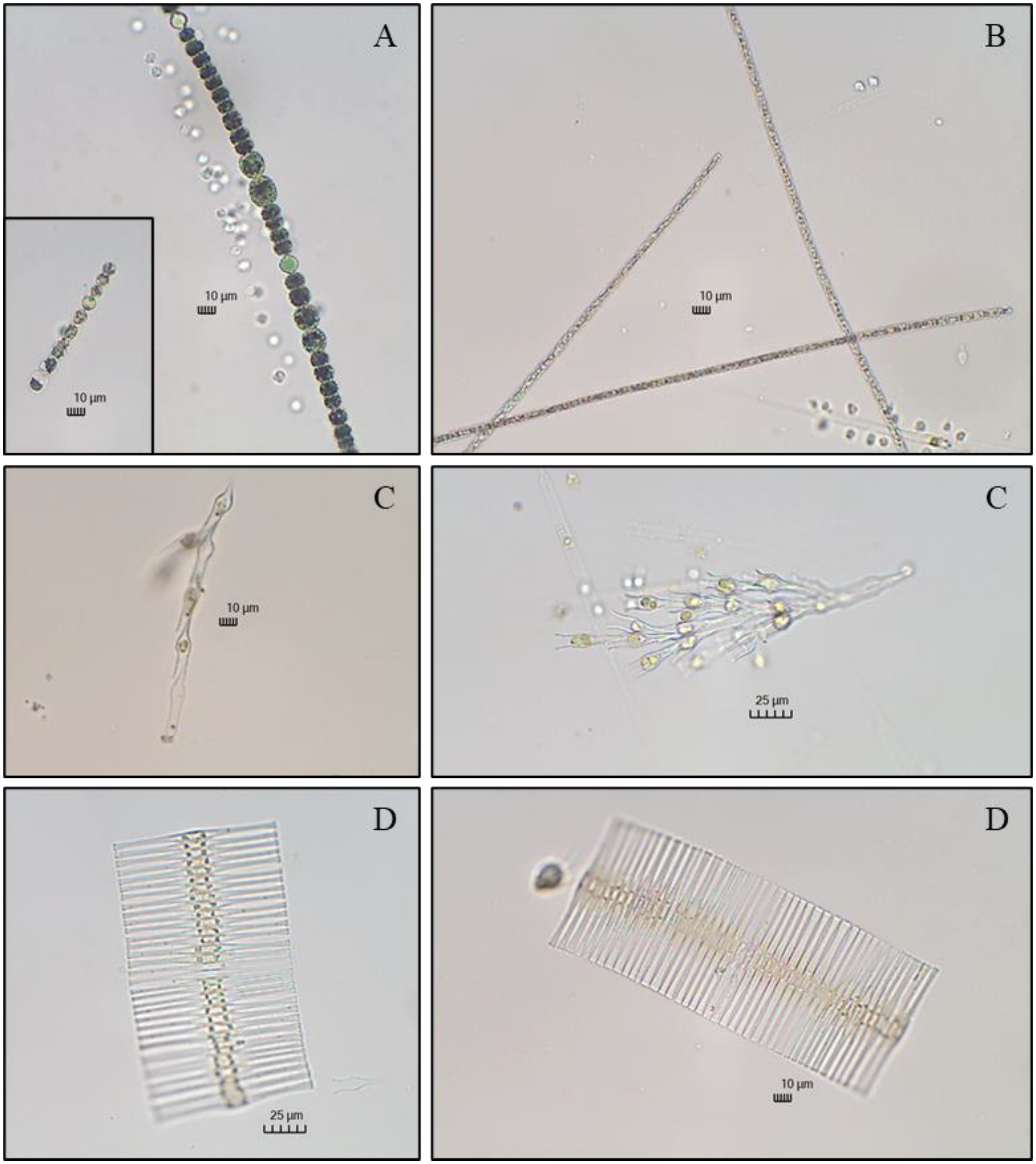


Figure 8. Micrographs of selected algae specimens from Lake Wononscopomuc collected in 2023. From the Cyanophyta (cyanobacteria): A) *Dolichospermum spp*. and B) *Planktothrix spp*. From the Chrysophyta (golden algae) C) *Dinobryon spp*. From the Bacillariophyta (diatoms) D) *Fragilaria spp*. Total magnification for all images was 400X.

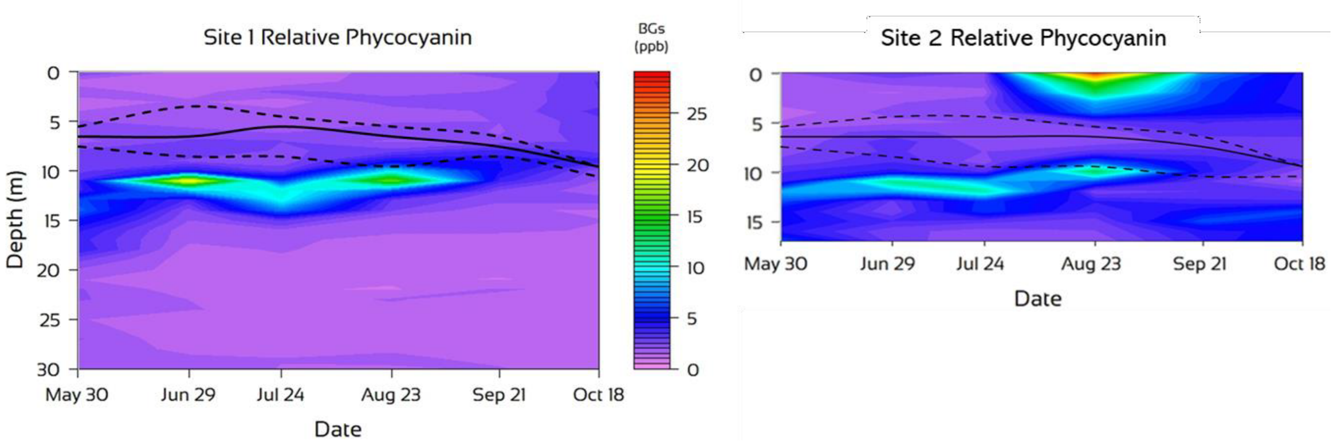


Figure 9. Relative phycocyanin concentration isopleth chart for the Lake Wononscopomuc water columns at Site 1 (left) and Site 2 (right) in 2023. The dashed lines represent the position of the upper and lower metalimnetic boundaries; the solid black lines represent the position of the thermocline.

Based on the phycocyanin isopleth charts, highest cyanobacteria biomass was normally below the lower metalimnetic boundary between 10 and 13 meters of depth, particularly between June through August. This was consistent across the lake despite the different maximum depths at the two sampling sites. The one exception occurred on August 23rd at Site 2 when the highest relative biomass was at the surface. That event corresponds with the lowest Secchi disk transparency measured at the lake in the 2023 season and may have detected the formation of a algal bloom. The buoyancy regulating cyanobacteria *Dolichospermum spp*. and *Planktothrix spp*. can create the types of layers at depth in the water column (e.g., between 10 and 13 meters), as well as form surface blooms.

VII. Chemical Characteristics

A. Specific Conductance

Conductivity is a surrogate measurement for the sum of the ionized minerals, metals, and salts in the water and a measure of water's ability to transmit an electrical current. Data collections included measures of both conductivity and specific conductance and were measured in microsiemens per cm (µS/cm). Specific conductance is conductivity standardized to a set water temperature of 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 plant and algal communities has been shown to be related, in part, to conductivity levels in lakes (e.g., Siver 1993, McMaster & Schindler 2005, June-Wells et.al. 2013). Here, we have compared epilimnetic and hypolimnetic specific conductance levels from both sites (Fig. 10). Additionally, and as was done with temperature, oxygen, phycocyanin profile data, specific conductance data were displayed in isopleth charts (Fig. 11).

Highest epilimnetic specific conductance at the two sites occurred in May when levels of 380 µS/cm were measured at both sites (Fig. 11). Levels gradually decreased to between 347 and 350 µS/cm from August through October at both sites. Epilimnetic season averages at both sites were 358 µS/cm.

While epilimnetic levels decreased over time, levels in the metalimnion and in much of the hypolimnion remained relatively constant. Specific conductance at the bottom of the water column did increase with time and were concurrent with the protracted period of anoxic conditions at those depths.

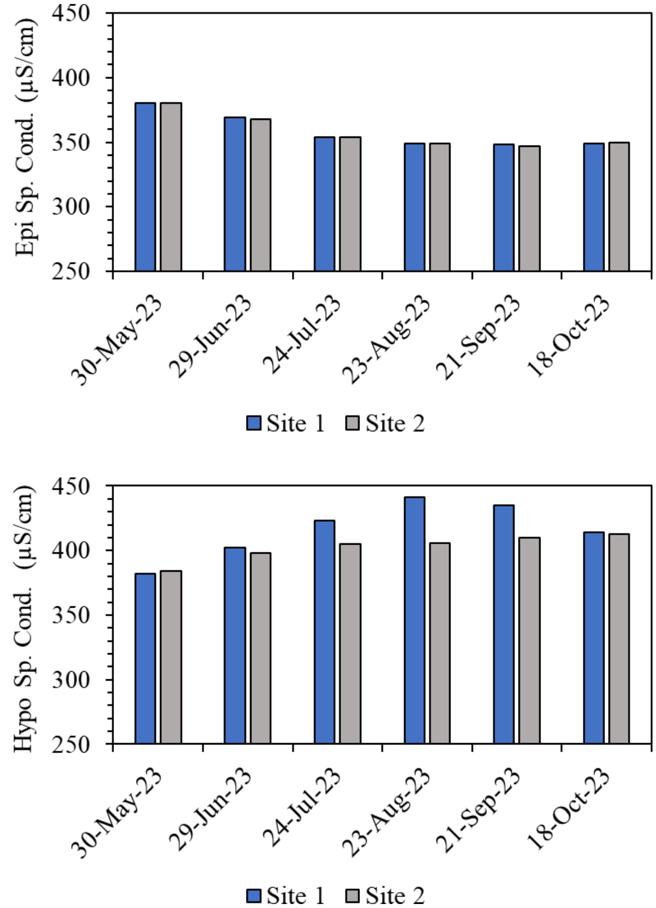


Figure 10. Epilimnetic specific conductance (Epi. Sp. Cond.; top panel) and hypolimnetic specific conductance (Hypo. Sp. Cond.; bottom panel) at Site 1 and Site 2 of Lake Wononscopomuc in 2023.

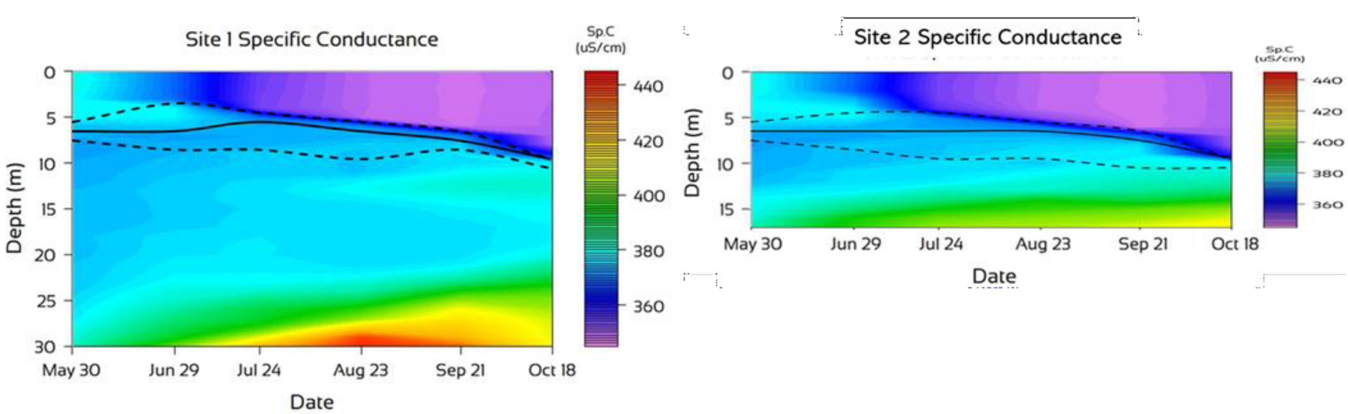


Figure 11. Specific conductance isopleth charts for Site 1(left) and Site 2 (right) at Lake Wononscopomuc in 2023. Dashed black lines represent the upper and lower metalimnetic boundary. The solid black line represents the thermocline.

B. Alkalinity and pH

Alkalinity is a measure of calcium carbonate and provides lake water and 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 anoxic cellular respiration in the lake sediments, and denitrification of nitrate to elemental nitrogen (Wetzel 2001).

Epilimnetic alkalinity was reported higher in May through July than that reported in August through October. Concentrations in the first three months at both sites were 130 to 140 mg/L, while during the latter half of the season concentrations were between 89 and 112 mg/L. The season averages at Site 1 and Site 2 were 123 and 116 mg/L, respectively, and not significantly different ($p>0.05$).

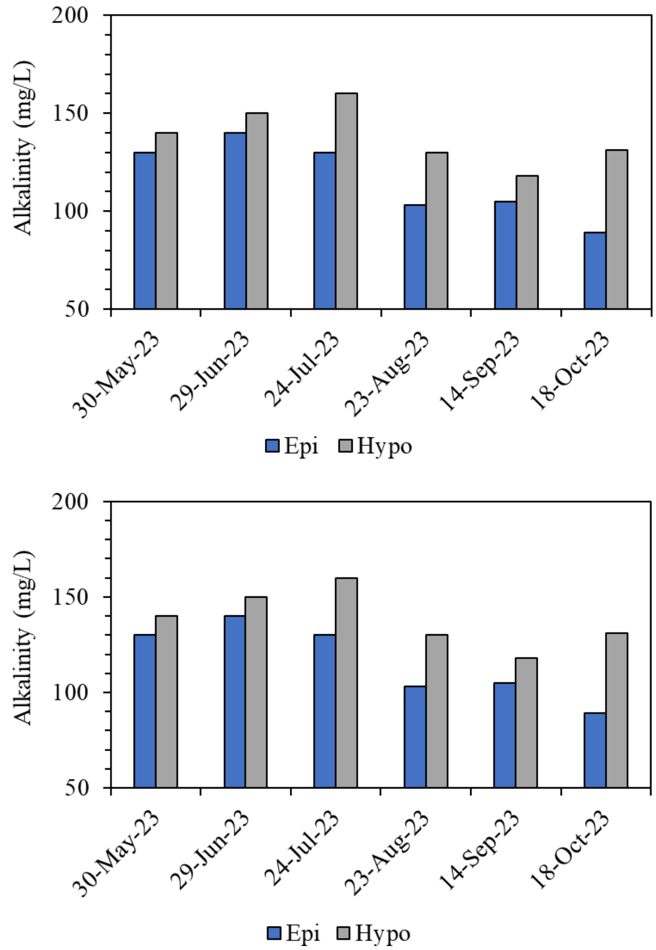


Figure 12. Epilimnetic (Epi) and hypolimnetic (Hypo) alkalinity at Site 1 (top panel) and Site 2 (bottom panel) at Lake Wononscopomuc in 2023.

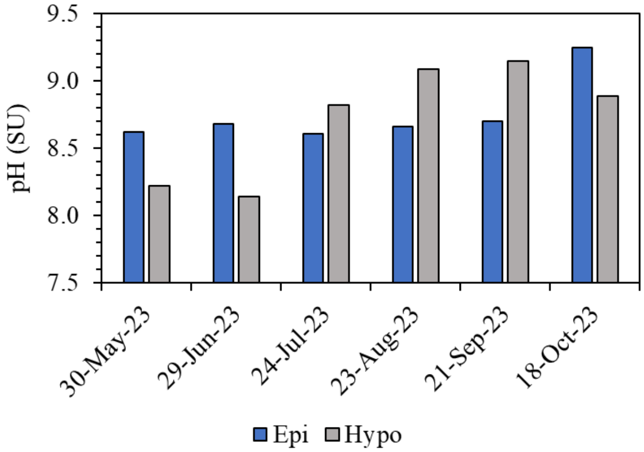
Monthly hypolimnetic alkalinity levels were higher than corresponding epilimnetic levels but followed the same general seasonal trend with higher concentrations reported in May through July, and lower concentrations reported in August through October (Fig. 12). Hypolimnetic concentrations in the first half of the season were between 140 and 160 mg/L. In the latter half of the season, concentrations were between 118 and 138 mg/L except for the October concentration at Site 1 which was 169 mg/L. Averages at Site 1 and Site 2 were 147 and 138 mg/L, respectively.

The normal pH of surface waters of lakes in the Northeast can range 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, the pH of the water will influence algae community characteristics by determining the type of dissolved carbon in the water column. At pH levels greater than 8.3, bicarbonate is the dominant form of carbon available to the pelagic algal community; the blue-green algae have adaptive advantages over other algal groups in those conditions since they can efficiently utilize that form of carbon. Other algal groups are dependent upon carbon dioxide, which is more readily available in water below a pH of 8.3.

The pH near the top of the water column is often higher than the corresponding pH near the bottom, particularly later in the season. That is often due to carbon being harvested more rapidly by the algae community in waters near the surface, reducing the levels of carbonic acids capable of being formed. Carbonic acid is a weak acid but can change the pH of water.

At Site 1, epilimnetic concentrations from May through September were 8.6 to 8.7. Hypolimnetic pH levels were lower than epilimnetic levels in May and June (8.2 and 8.1, respectively), and higher than epilimnetic levels in July, August, and September (range of 8.8 to 9.2; see Fig. 13). In October, epilimnetic and hypolimnetic levels were 9.3 and 8.9, respectively. Site 1 epilimnetic and hypolimnetic averages were 8.8, and 8.7, respectively,

At Site 2, epilimnetic levels ranged between 8.5 and 8.9. Hypolimnetic pH levels were more variable and ranged from 8.6 and 9.4. The hypolimnetic season high of 9.4 in June gradually decreased to 8.7 in October. The June and July levels were notably higher than corresponding epilimnetic levels. The pH at the two levels in the water column were more similar in May, August, September, and October. Site 2 epilimnetic and hypolimnetic averages were 8.8 and 8.9, respectively.



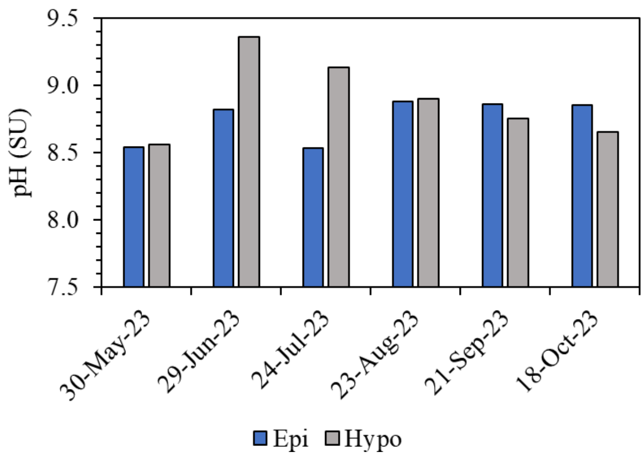


Figure 13. Epilimnetic (Epi) and hypolimnetic (Hypo) pH at Site 1 (top panel) and Site 2 (bottom panel) at Lake Wononscopomuc in 2023.

VIII. Water Quality Trends 2015 to 2023

One of the goals of the biannual water quality monitoring program was to develop a database from which to assess trends. A robust database provides the ability to detect statistically significant trends that may be occurring in the lake. Below, two approaches were used to assess whether the lake and specific variables were trending, i.e., significantly increasing or decreasing, or not significantly changing. The first approach pooled epilimnetic and hypolimnetic data into one dataset; the second approached leveraged the epilimnetic and hypolimnetic datasets independently. The result was three independent datasets.

Two statistical methods were applied to each of the three datasets. The first method, *Multiple Linear Regression* (MLR), was employed to determine if the epilimnion, hypolimnion, and/or the lake as a whole (based on the pooled data) had changed significantly based on variables in each dataset. A p-value statistic was calculated to determine whether the epilimnion, hypolimnion, or whole lake was experiencing statistically significant change or not with $p<0.05$ indicating the former.

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 differed from a random distribution of values, i.e. exhibiting a statistically significant change.

A. 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 pooled dataset were epilimnetic alkalinity and hypolimnetic total nitrogen (formerly total Kjeldahl nitrogen). The variable that contributed most to the significance of the model from the epilimnetic dataset was alkalinity, total nitrogen, and total phosphorus. The variable that contributed most to the significance of the model from the hypolimnetic dataset was total nitrogen. See Appendix D for results from analyses.

In the past, total Kjeldahl nitrogen, nitrate, and nitrite were measured and used in this analysis. Those are the analytes that collectively comprise total nitrogen. The UCONN CESE Laboratory can directly measure total nitrogen. Therefore, starting in August we discontinued having TKN, nitrate, and nitrite measured, and only total nitrogen measured. For any data collected prior to that, we added up TKN, nitrate and nitrite to use as total nitrogen for this analysis.

B. Analysis of Variance

In many ways, results from ANOVA were reflective of those from Multiple Linear Regression. Results from ANOVA from 2015 to 2023 are provided in Table 5, along with results from analyses of data from 2015 to 2019 and data from 2015 to 2021. Several nitrogen-related variables were shown to have significantly changed from both the epilimnion and hypolimnion.

Table 5. Comparison of ANOVA results with data collected from 2015 through 2023. Level of significance is indicated (significant * to highly significant ***).

Variables	Whole			Epilimnion			Hypolimnion		
	2019	2021	2023	2019	2021	2023	2019	2021	2023
Secchi									
Epi Alkalinity									
Epi Ammonia	***	***	***	*	***	***			
Epi Nitrate		*	NA			NA			
Epi Nitrite			NA			NA			
Epi TN	***	***	*	**	***	***			
Epi Total Phosphorus	***			**		*			
Epi pH	***			*					
Hypo Alkalinity	*	*					*	*	
Hypo Ammonia			*				***	**	*
Hypo Nitrate		**	NA					***	NA
Hypo Nitrite			NA						NA
Hypo TN	***	***	*				***	***	***
Hypo Total Phosphorus	*	*					**	**	
Hypo pH	***						***		

C. Interpretation of Analyses

Ammonia and total nitrogen were important in Multiple Linear Regression and ANOVA analyses. However, an examination of those variables plotted on a timeline shows a very clear pattern of high concentrations in 2015 and 2017, and lower concentrations in 2019, 2021, and 2013 (Fig. 14). Levels of those nutrients were also found to be very high in 2015 and 2017 at other client lakes. That suggests that nitrogen-related data collected in those years may have been erroneous.

The significant change in epilimnetic total phosphorus may be a welcomed result since levels appear to be trending down (Fig. 15). Like nitrogen-related analyses, measuring total phosphorus can be challenging for some laboratories and several of the 2015 data appear anomalous so interpretations should be made cautiously. Total phosphorus is one of the variables often used to assess trophic levels in lakes and are often correlated with other trophic variables like chlorophyll-*a* concentration and Secchi disk transparency. The result of ANOVA for Secchi transparency (Table 5) and linear regression of those data does not indicate a significant change over time (Fig. 15). Trophic variables in lakes like Lake Wononscopomuc can be influenced by chemical characteristics (see *Phosphorus Co-Precipitation* below).

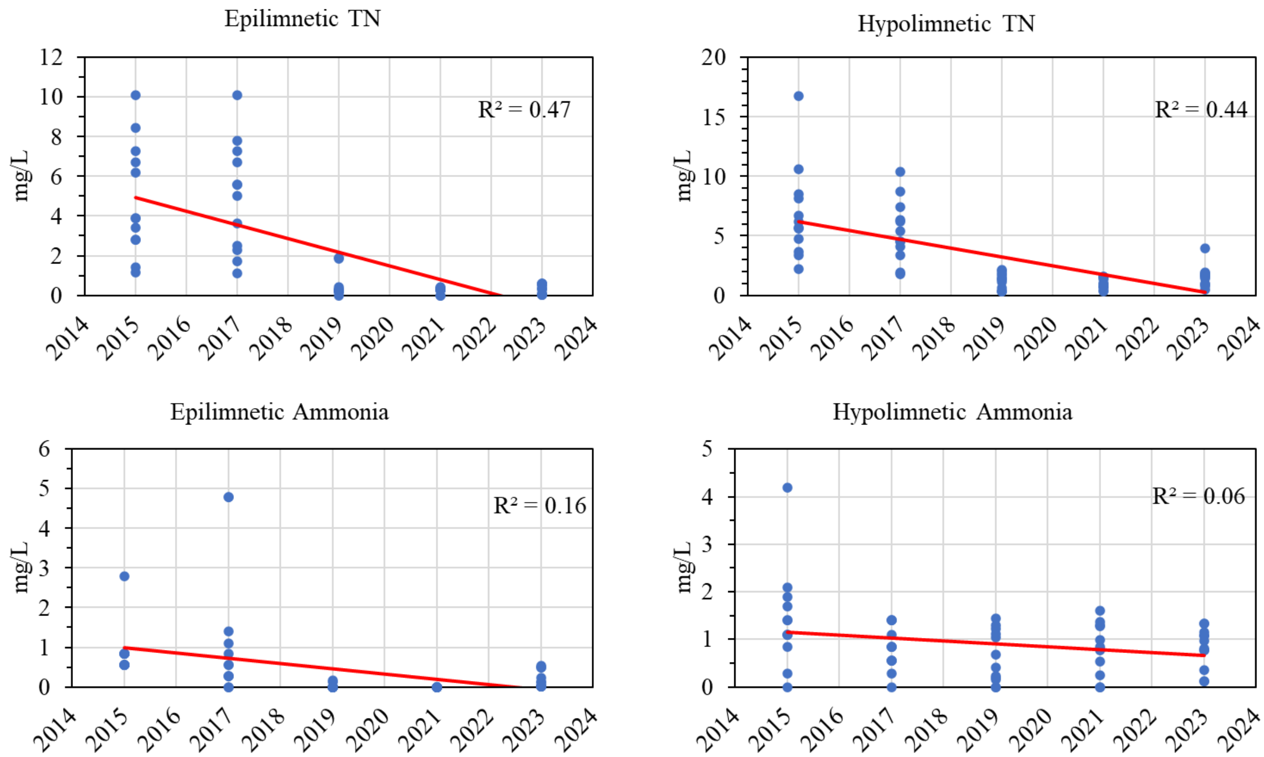


Figure 14. Biannual measurements of total nitrogen (top panels) and ammonia (bottom panels) in the epilimnion (left panels) and hypolimnion (left panels) in Lake Wononscopomuc between 2015 and 2023.

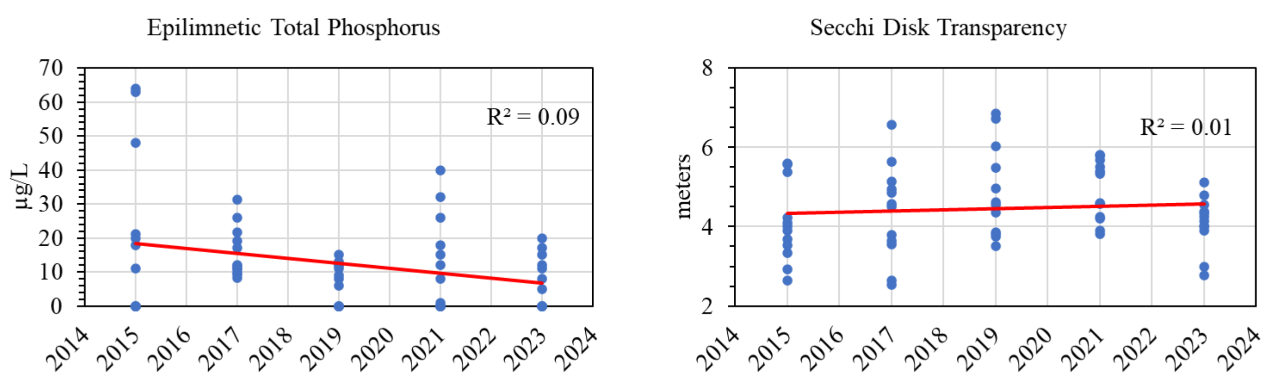


Figure 15. Biannual measurements of epilimnetic total phosphorus (left) and Secchi disk transparency (right) in Lake Wononscopomuc between 2015 and 2023.

IX. Other Assessments and Management Considerations

Since 2019, a data table has been provided in water quality reports that displayed Lake Wononscopomuc averages for a set of variables and compared them to corresponding averages for lakes from 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, of which Lake Wononscopomuc belongs, and for the entire 60 lake set of lakes in that study (Canavan and Siver 1995). That table has been recreated below and now includes Lake Wononscopomuc averages for 2019, 2021, and 2023 (Table 6).

Table 6. Comparisons of the Lake Wononscopomuc averages for selected water quality variables from the early 1990s, 2019, 2021, and 2023 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 except for Secchi transparency were from samples collected at 1 meter depth. Abbreviations: Nitro. = nitrogen, Phos. = phosphorus, Chloro-a = chlorophyll-a, Sp. Cond. = specific conductance.

Parameter	**Units**	**Lake Wononscopomuc**				**Marble Valley Lakes**			**60 CT Lake Set**		
		1990s	2019	2021	2023	Min	Max	Mean	Min	Max	Mean
Total Nitro.	µg/L	334	249	313	407	334	547	449	119	3831	439
Total Phos.	µg/L	21	10.8	13.4	12.6	21	42	31	9	334	33
Chloro-*a*	µg/L	1.2	*NA*	*NA*	*NA*	1.2	7.1	4.3	0.2	71.6	6.5
Secchi Disk	meters	4.9	4.87	4.91	4.11	2.0	4.9	3.3	0.9	7.6	3.3
pH	pH units	8.5	8.8	9.0	8.8	7.8	8.3	8.2	4.6	8.8	7.1
Sp. Cond.	µS/cm	274	323	347	358	180	317	258	24	317	102
Alkalinity	mg/L	121	127	130	120	54.5	120.5	90	0	120.5	14.5
Chloride	mg/L	9.2	*NA*	*NA*	*NA*	3.2	42.2	21.3	0.7	42.2	10.3
Calcium	mg/L	25.2	*NA*	*NA*	*NA*	16.6	28.8	22.8	1.2	28.8	7.6
Magnesium	mg/L	15.4	*NA*	*NA*	*NA*	5.9	15.2	9.8	0.2	15.2	2.5
Sodium	mg/L	6.7	*NA*	*NA*	*NA*	2.5	24.6	13.1	1.4	24.6	6.9
Potassium	mg/L	1.6	*NA*	*NA*	*NA*	1.2	2.7	1.9	0.4	2.7	1.2

C. Specific Conductance

In 2021, it was reported that specific conductance of Lake Wononscopomuc was one of the water quality characteristics changing at a higher rate than others based on historical data. It was also reported that the 2021 average specific conductance measured at one meter of depth was significantly greater than the 2019 average ($p<0.005$). Annual means were compared again using ANOVA. Like the 2021 average, the 2023 average was significantly greater than the 2019 average ($p<0.005$). However, the 2021 and 2023 averages were not statistically different.

To provide an additional simple, but effective way of assessing biannual specific conductance trends, "box and whisker" plots (aka Box Plots) of data collected in 2019, 2021, and 2023 were created. Box plots mathematically separate a dataset into quartiles with each quartile representing one-fourth of all points: the two inner boxes represent the second and third quartile and are separated by the median – the value in the middle of a dataset. The whiskers represent the first and fourth quartiles. A mean – or the average – is also displayed by an X. A box plot was created for each dataset from 2019, 2021, and 2023. Each dataset consists of 12 values – two for each month, since there are two sites, from May through October.

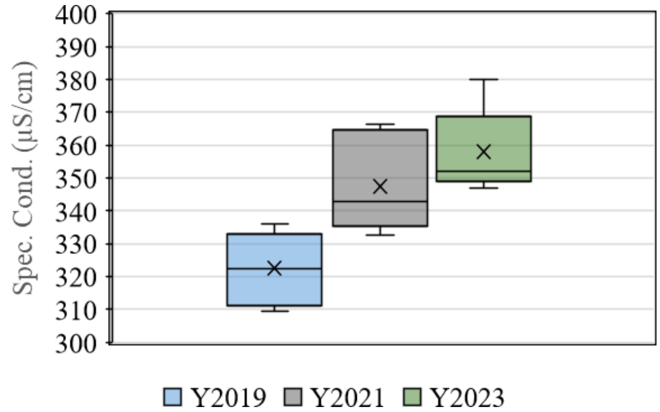


Figure 16. Box and whisker plots of specific conductance (Spec. Cond.) data collected in 2019, 2021, and 2023.

Although means in 2021 and 2023 were not statistically different, the 2023 median and mean were higher than the corresponding 2021 counterparts (Fig. 16). All points in the 2023 fourth quartile were greater than the maximum value in 2021. All 2023 measurements were greater than all 2019 measurements.

Many lakes in Connecticut, the Northeast, and other snowbelt regions are experiencing increasing specific conductance levels. This trend is most often due to increasing use of deicing road salts in the winter (Kelly et. al. 2019). Those deicing salts are transported to the lake by stormwater. As implied earlier, changes in dissolved salt levels can change the biological community over time. In extreme cases, the "saltiest" waters will reside at the bottom of the lake due to greater density and prevent complete mixing or turnover in the fall and spring. This could result in bottom waters never becoming oxygenated as normally would occur from the mixing process.

D. Phosphorus Coprecipitation

In the 2021 report, the process of coprecipitation of phosphorus was described as likely occurring at Lake Wononscopomuc. In lakes with high epilimnetic calcium levels and pH, both characteristic of Lake Wononscopomuc, phosphorus can bind with calcium carbonate, become unavailable for algae growth, and precipitate out of the epilimnion. The bound phosphorus will still be accounted for in analyses since it is part of total phosphorus. Soluble reactive phosphorus is the form used by plants and algae, is currently not measured, but can be measured separately from total phosphorus.

The phosphorus/calcite precipitate can also reduce Secchi disk transparency before settling out of the water column. As it settles, those waters receiving the precipitate, i.e. the bottom waters, will become enriched with total phosphorus. The process can obfuscate standard trophic indicators, except those that are a direct measure of algae productivity, e.g. chlorophyll-*a*, phycocyanin, and algae cell concentrations. As noted above, relative phycocyanin levels were low except for the August measurement at Site 2. We also reported above low algae and cyanobacteria cell concentrations. Chlorophyll-*a* is not measured at Lake Wononscopomuc.

E. Hypolimnetic pH and Alkalinity

As noted above, the pH of epilimnetic waters is generally higher than the pH of hypolimnetic waters due to the utilization of carbon by algae in the epilimnion. The biologically mediated carbon reduction equates to reduced epilimnetic carbonic acids and higher pH. However, at Lake Wononscopomuc the pH of hypolimnetic waters was often greater than or similar to the epilimnetic pH.

Hypolimnetic alkalinity in deeper stratified lakes can often be significantly higher than epilimnetic alkalinity. At Lake Wononscopomuc, average hypolimnetic alkalinity at each site was higher, but not significantly different ($p>0.05$) from average epilimnetic alkalinity at corresponding sites.

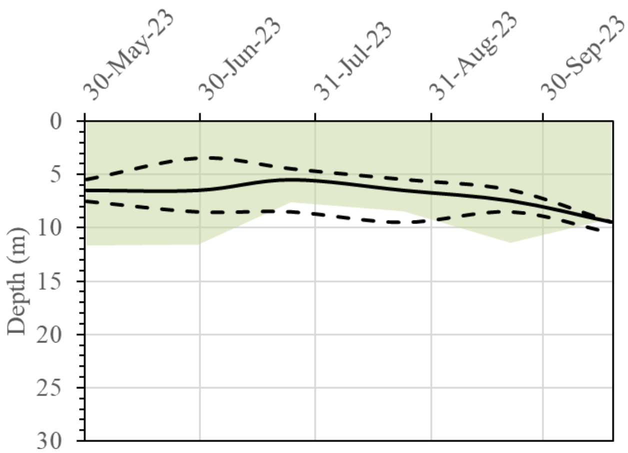
We believe that the higher hypolimnetic pH and lower than anticipated hypolimnetic alkalinity is related to the coprecipitation process discussed above. As the phosphorus-calcium carbonate precipitate settles out, it eventually reaches the anoxic, highly reduced bottom waters of the hypolimnion. Those conditions result in the conversion of the calcium carbonate in a precipitated state back into a soluble state. This would drive the pH up and mediate changes in alkalinity as carbonate, bicarbonate and soluble phosphate are released to those bottom waters.

F. Deep-Water Cyanobacteria Community

In the *Secchi Disk Transparency* section above, the concept of *Compensation Point* was described as the depth in the water column where oxygen consumed in algal cellular respiration was equal to the oxygen produced by algal photosynthesis. The position of the Compensation Point relative to the layers in the water column from stratification is predictive of water quality and positioning of cyanobacteria layers (Kortmann 2015). Water quality is likely to be good and unlikely to stimulate cyanobacteria productivity if the Compensation Point extends below the thermocline. If the Compensation Point 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 Point is within the mixed epilimnetic layer. This implies the extension of anoxic, nutrient-laden waters into the bottom of the epilimnetic layer.

The Compensation Point in the Lake Wononscopomuc water column was estimated for the season at Site 1 and Site 2 and graphically displayed (Fig. 17). Except in mid-October, the Compensation Point was estimated to be below the thermocline for the season at both sites suggesting good water quality and low probability of cyanobacteria productivity. As described above, cyanobacteria productivity was low in epilimnetic and metalimnetic layers, but there is an increase in cyanobacteria biomass for much of the season in the upper levels of the hypolimnion (see Fig. 9).

The important genera of cyanobacteria identified in algal analyses were *Dolichospermum spp*. and *Planktothrix spp*., both of which can regulate buoyancy. The relative phycocyanin isopleths indicated that the greatest cyanobacteria productivity occurred in the upper levels of the hypolimnion. The unique auxiliary photosynthetic pigments like phycocyanin provide cyanobacteria with the adaptive advantage of utilizing the wavelengths of light that can travel further down into the water column for photosynthesis.



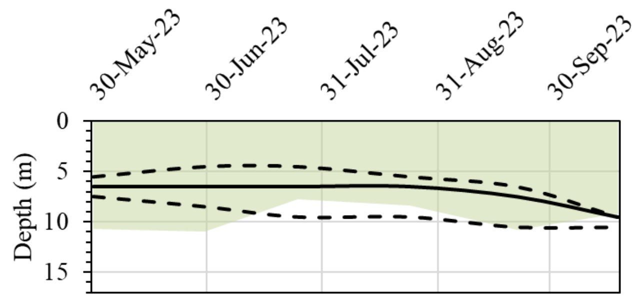


Figure 16. Area above the Compensation Point (green shade) for Site 1 (left) and Site 2 (right) of Lake Wononscopomuc in 2023. The dashed black lines represent the upper and lower metalimnetic boundaries. The solid black lines represent the position of the thermocline.

The advantage to cyanobacteria of layering in the hypolimnion may be elevated concentrations of phosphorus in the hypolimnion. It is worth noting that the hypolimnetic phosphorus measurements are from samples collected approximately ½ meters above the bottom so we can only hypothesize that phosphorus is higher throughout and up to the top of the hypolimnion. We must also hypothesize that the phosphorus being taken advantage of is soluble reactive phosphorus. In this monitoring program, total phosphorus is measured which would include soluble reactive phosphorus, and other forms that are unusable by cyanobacteria like that bound to calcite resulting from coprecipitation.

Periodically, cyanobacteria blooms along the shoreline are reported at Lake Wononscopomuc. It is likely that those events result from a portion of the cyanobacteria population layered below the thermocline becoming positively buoyant, reaching the surface, and then becoming concentrated downwind on the shoreline from light winds forming the bloom conditions.

X. Conclusions and Recommendations

Lake Wononscopomuc continues to exhibit the good water quality that has been observed in the past. We have proposed a mechanism for the seemingly rare algae bloom conditions experienced in the lake by the community. The first set of recommendations below are proposed to further understand and test that mechanism. The second recommendation has been shared in the past with the Lake Wononscopomuc Association. We share it again with additional resources to understand and plan for increasing specific conductance, i.e., salt levels, in the lake.

A. Cyanobacteria Blooms and Phosphorus

First, we recommend a formalized *Community Bloom Watch Program* for Lake Wononoscopomuc. A formalized program would develop data to provide a better understanding of bloom events, e.g., frequency, intensity, and environmental conditions like weather. There exist programs that could be incorporated into the management efforts at Lake Wononscopomuc like BloomWatch (CMC 2024). The BloomWatch Program is a national effort that utilizes a mobile phone app to collect community reports of blooms and compile those reports. The effort is led by the US EPA.

Secondly, we recommend expanding the phosphorus data collections by adding soluble reactive phosphorus as a new variable measured at the top and bottom of the water column. This measure will contribute to our understanding of the coprecipitation process, which we hypothesize is transferring epilimnetic phosphorus to the hypolimnion. We also recommend adding a sample to those already collected at the upper layer of the hypolimnion where the highest concentrations of cyanobacteria are commonly encountered.

B. Deicing Salts

In the past, we have recommended reviewing a report entitled *Road Salt: The Problem, The Solution, and How to Get There.* The report provides important information on the issue and provides recommendations that can be implemented. The report can be found at the Carey Institute website at https://www.caryinstitute.org/our-expertise/freshwater/road-salt.

Additionally, a Western Connecticut State University seminar that occurred on October 17, 2022 featured Vicky Kelly, author of that report. It also featured Robert Wyant, Highway Superintendent for the Town of Rhinebeck NY, who presented "*An introduction to available resources and expert support*." His presentation was a "boots on the ground" approach of reducing road salt use at the municipal level. The seminar was recorded and available at https://www.wcsu.edu/biology/lake-symposium-2022-recordings/ and should be viewed by the members of the LWA. Afterwards, a plan on how to reduce salt concentrations used in the Lake Wononscopomuc watershed should be developed.

XI. References

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Appendix A - Field and Laboratory Data

Abbreviations (for both Appendix A and B)

Temp = temperature
DO = dissolved oxygen
BGs = Blue-green Algae (Cyanobacteria) measured as relative phycocyanin concentration
Spec. C. = Specific Conductance
Alk = Alkalinity
NH4 = Ammonia
TKN = Total Kjeldahl Nitrogen
TN = Total Nitrogen
TP = Total Phosphorus
ND = Below Detectable Limits
NA = Not Applicable

30-May-2023

Site 1	Depth (m)	Temp (°C)	DO (mg/L)	DO (%)	BGs	Spec C (µS/cm)	pH
	0.5	20.31	10.08	116.4	2.68	380.2	8.8
	1	20.11	10.25	117.9	1.24	380.4	8.6
	2	19.87	10.3	117.9	1.84	379.7	8.6
	3	18.59	10.64	118.7	1.21	378.9	8.6
	4	17.82	10.73	117.8	1.52	378	8.6
	5	17.15	10.77	116.6	2.05	378.6	8.6
	6	14.4	11.83	120.8	2.25	374.4	8.6
	7	10.93	13.2	124.6	1.84	373.1	9.2
	8	8.53	13.25	118.2	2.58	372.2	9.1
	9	8.01	12.79	112.6	2.95	372.5	9.0
	10	7.53	12.24	106.5	2.78	373.1	8.9
	11	7.03	11.95	102.7	3.54	373.2	8.9
	12	6.63	11.44	97.4	3.79	373.2	8.8
	13	6.39	11.19	94.6	6.25	374	8.8
	14	6.19	9.91	83.4	6.82	374	8.6
	15	6.04	9.35	78.4	5.21	374	8.6
	16	5.97	8.93	74.7	4.12	374.2	8.5
	17	5.81	8.51	70.9	3.72	374.2	8.5
	18	5.74	7.95	66.1	3.99	374.6	8.5
	19	5.67	7.78	64.6	2.64	374.4	8.4
	20	5.63	7.72	64	1.94	374.5	8.4
	21	5.54	7.57	62.6	1.52	375	8.4
	22	5.49	7.25	59.9	2.06	375	8.4
	23	5.46	6.89	56.9	2.07	375	8.4
	24	5.42	6.2	51.1	1.75	375.5	8.3
	25	5.41	5.79	47.8	1.56	376.3	8.3
	26	5.41	5.46	45	1.6	376.8	8.3
	27	5.4	5.26	43.4	2.06	377.5	8.3
	28	5.39	4.48	36.9	1.65	379	8.3
	29	5.38	3.88	31.9	1.66	380.9	8.2
	30	5.37	3.5	28.8	1.69	381.8	8.2

30-May-2023

Site 2	Depth (m)	Temp (°C)	DO (mg/L)	DO (%)	BGs	Spec C (µS/cm)	pH
	0.5	20.49	10.36	120	1.91	379.9	8.6
	1	20.09	10.39	119.5	1.54	380.1	8.5
	2	19.82	10.32	118	1.61	380.3	8.6
	3	18.58	10.71	119.5	1.75	378.1	8.6
	4	17.92	10.79	118.7	1.13	378.2	8.6
	5	17.02	10.85	117.1	1.57	377.3	8.6
	6	15.35	11.65	121.4	2.18	375.1	8.6
	7	11.57	13.14	125.9	2.01	372	9.0
	8	9.15	13.36	120.9	2.34	371.8	9.0
	9	8.23	13.33	118	2.64	373.1	9.0
	10	7.46	12.65	109.9	3.43	373.5	8.8
	11	7.1	11.26	96.9	3.8	373.4	8.7
	12	6.7	9.95	84.8	8.41	374.1	8.5
	13	6.36	4.89	41.3	6.43	376.9	8.2
	14	6.24	2.91	24.5	4.75	378.7	8.2
	15	6.22	1.6	13.4	4.8	379.5	8.1
	16	6.18	1.08	9	4.29	380.8	8.1
	17	6.14	0.44	3.7	6.31	383.7	8.6

29-June-2023

Site 1	Depth (m)	Temp (°C)	DO (mg/L)	DO (%)	BGs	Spec C (µS/cm)	pH
	0.5	23.36	9.48	112	1.3	368.6	8.7
	1	23.36	9.49	112.1	1.11	368.6	8.7
	2	23.36	9.5	112.2	1.17	368.7	8.7
	3	23.35	9.51	112.3	1.59	368.6	8.6
	4	22.05	10.01	115.4	1.69	378.5	8.6
	5	20.36	11.19	124.8	1.53	378.3	8.7
	6	17.59	13.6	143.4	2.24	375.5	8.8
	7	12.76	14.75	140.2	2.58	372.1	8.8
	8	10.47	13.82	124.6	2.94	373.5	9.1
	9	8.98	13.08	113.8	2.4	374	8.9
	10	7.95	12.18	103.3	4.48	374.4	8.8
	11	7.07	10.93	90.8	20.57	374.9	8.6
	12	6.64	8.45	69.4	8.5	375.4	8.4
	13	6.34	7.74	63.1	3.42	375.6	8.3
	14	6.21	7.45	60.6	2.3	375.4	8.2
	15	6.11	7.44	60.3	2	375.3	8.2
	16	5.99	7.44	60.1	1.61	375.2	8.2
	17	5.85	7.43	59.8	1.6	375.5	8.2
	18	5.77	5.5	44.2	1.29	376.6	8.1
	19	5.68	5.31	42.5	1.21	376.7	8.1
	20	5.63	5.05	40.4	1.29	376.9	8.1
	21	5.58	4.65	37.2	1.21	377.4	8.1
	22	5.54	4.27	34.1	1.18	377.9	8.0
	23	5.53	3.7	29.5	1.49	378.7	8.0
	24	5.51	2.6	20.7	1.57	380.7	8.0
	25	5.47	1.77	14.1	1	381.7	8.0
	26	5.45	0.58	4.6	1.31	384.4	7.9
	27	5.43	0.21	1.7	1.1	387	7.9
	28	5.42	0.17	1.3	1.44	389.6	7.9
	29	5.42	0.14	1.1	1.54	392.9	8.0
	30	5.4	0.12	0.9	1.76	401.7	8.1

29-June-2023

Site 2	Depth (m)	Temp (°C)	DO (mg/L)	DO (%)	BGs	Spec C (µS/cm)	pH
	0.5	23.59	9.45	112.2	2.95	368.4	8.82
	1	23.58	9.58	113.6	2.17	368.2	8.82
	2	23.52	9.61	113.9	1.47	367.9	8.64
	3	23.21	9.78	115.3	1.91	374.2	8.6
	4	22.23	9.83	113.7	2.22	378	8.58
	5	20.4	11.1	123.9	1.84	378.1	8.64
	6	16.96	13.79	143.5	2.71	373.7	9.02
	7	13.05	14.5	138.6	3.3	372.2	9.04
	8	10.47	13.5	121.7	3.1	375.2	8.91
	9	8.39	12.1	103.8	3.46	374.6	8.72
	10	7.79	11.22	94.9	4.19	374.4	8.62
	11	7.33	8.6	71.9	12.05	376.6	8.38
	12	6.93	7.24	59.9	8.09	376.6	8.25
	13	6.66	1.96	16.1	2.92	377.9	8.04
	14	6.5	0.37	3	2.61	383.1	8.73
	15	6.4	0.2	1.6	3.52	387.5	9.04
	16	6.32	0.15	1.2	2.64	395.6	9.22
	17	6.3	0.12	0.9	2.75	397.5	9.36

24-July-2023

Site 1	Depth (m)	Temp (°C)	DO (mg/L)	DO (%)	BGs	Spec C (µS/cm)	pH
	0.5	26.5	8.77	109.8	1.21	354.7	8.7
	1	26.47	8.87	111	1.08	354.4	8.6
	2	26.39	8.99	112.3	2.23	354.3	8.6
	3	26.33	9.03	112.7	1.19	354	8.6
	4	26.14	9.08	113	1.63	353.8	8.6
	5	22.59	10.46	121.8	1.77	369.2	8.6
	6	18.27	13.35	142.7	1.88	373.3	8.7
	7	14.47	14.75	145.5	2.51	373.1	8.7
	8	11.44	14.06	129.6	2.43	373.4	8.8
	9	9.03	11.6	101	2.09	375.6	8.6
	10	8.24	11.23	96	2.81	375.3	8.5
	11	7.48	10.78	90.4	6.04	375.4	8.4
	12	6.86	8.14	67.2	10.27	376.3	8.2
	13	6.49	6.91	56.5	9.98	376.4	8.1
	14	6.3	5.68	46.2	7.27	376.7	8.0
	15	6.15	5.7	46.3	3.09	376.2	8.0
	16	6.01	5.72	46.3	1.98	376.6	8.0
	17	5.89	5.25	42.3	1.74	376.5	8.0
	18	5.81	4.07	32.7	1.56	377	7.9
	19	5.75	3.7	29.7	1.39	377.2	7.9
	20	5.66	3.72	29.8	1.46	377.1	7.9
	21	5.61	3.15	25.2	1.18	377.6	7.9
	22	5.55	2.5	20	1.08	378	7.9
	23	5.53	1.77	14.1	1.29	378.5	7.8
	24	5.53	0.3	2.4	1.16	382	7.8
	25	5.49	0.26	2	1.19	386.7	7.8
	26	5.48	0.2	1.6	1.25	390.7	7.8
	27	5.47	0.17	1.3	1.45	392.1	7.9
	28	5.45	0.13	1	1.3	397.9	8.2
	29	5.43	0.11	0.9	1.52	409.4	8.6
	30	5.42	0.1	0.8	1.48	423.4	8.8

24-July-2023

Site 2	Depth (m)	Temp (°C)	DO (mg/L)	DO (%)	BGs	Spec C (µS/cm)	pH
	0.5	26.65	9.03	113.3	2.41	354.2	8.6
	1	26.6	9.14	114.6	2.36	353.7	8.5
	2	26.53	9.17	114.8	1.71	353.6	8.5
	3	26.37	9.19	114.8	2.48	353.8	8.5
	4	26.02	9.12	113.2	2.22	356.1	8.5
	5	22.17	10.37	119.8	2.06	370.9	8.5
	6	19.27	12.55	136.9	2.27	372.6	8.7
	7	14.49	14.42	142.3	2.24	373.9	8.9
	8	11.74	14.21	131.9	2.49	374.9	8.8
	9	9.59	11.91	105.2	2.2	374.9	8.6
	10	8.26	11.65	99.7	3.43	376.4	8.5
	11	7.59	9.37	78.9	8.25	376.4	8.3
	12	7.27	6.77	56.5	11.5	377.4	8.1
	13	6.88	0.22	1.8	5.8	382.7	8.0
	14	6.64	0.15	1.2	5.97	386.7	8.4
	15	6.47	0.13	1	3.15	395.3	8.8
	16	6.37	0.11	0.9	2.3	401.5	9.0
	17	6.33	0.09	0.7	2.09	405	9.1

23-August-2023

Site 1	Depth (m)	Temp (°C)	DO (mg/L)	DO (%)	BGs	Spec C (µS/cm)	pH
	0.5	23.34	9.15	108.1	1.65	349.1	8.7
	1	23.33	9.29	109.6	1.89	349.1	8.7
	2	23.32	9.3	109.8	1.68	349.1	8.6
	3	23.31	9.31	109.9	2.29	349.1	8.6
	4	23.27	9.32	109.9	1.66	349.1	8.6
	5	23.25	9.32	109.9	1.89	349	8.6
	6	20.21	10.54	117.2	2.47	371.4	8.4
	7	16.17	12.49	127.8	1.9	373.7	8.5
	8	13.1	12.81	122.6	2.7	375.2	8.5
	9	9.98	10.87	96.9	4.53	374.8	8.3
	10	8.68	10.54	91.1	9.47	374.9	8.3
	11	7.81	9.74	82.4	16.87	374.9	8.1
	12	7.09	7.64	63.5	6.51	378	8.0
	13	6.78	6.05	49.8	3.01	379	7.8
	14	6.53	4.92	40.3	2.54	377.3	7.7
	15	6.24	3.98	32.3	1.5	376	7.7
	16	6.11	3.65	29.6	1.72	376	7.7
	17	5.96	3.41	27.5	1.1	376	7.6
	18	5.87	2.55	20.5	1.13	376	7.6
	19	5.79	1.66	13.3	1.18	376.1	7.5
	20	5.71	1.62	13	1.25	376.4	7.5
	21	5.65	1.61	12.9	1.1	376.6	7.5
	22	5.58	0.65	5.2	0.94	377.4	7.5
	23	5.58	0.42	3.3	1.54	381.2	7.5
	24	5.56	0.29	2.3	1.41	384	7.5
	25	5.54	0.25	2	1.17	390.2	7.8
	26	5.5	0.2	1.6	1.19	397.6	8.3
	27	5.48	0.15	1.2	1.24	404.1	8.6
	28	5.45	0.13	1	1.44	419.8	8.8
	29	5.43	0.11	0.9	1.61	438.1	8.9
	30	5.43	0.1	0.8	1.44	440.7	9.1

23-August-2023

Site 2	Depth (m)	Temp (°C)	DO (mg/L)	DO (%)	BGs	Spec C (µS/cm)	pH
	0.5	23.48	9.37	110.9	28.49	348.9	8.9
	1	23.54	9.47	112.2	16.01	349	8.9
	2	23.35	9.5	112.2	12.93	348.9	8.9
	3	23.3	9.5	112.1	8.23	348.8	8.7
	4	23.27	9.51	112.1	7.09	348.8	8.8
	5	23.07	9	105.7	3	352.4	8.5
	6	20.91	10.11	114	2.16	369.9	8.6
	7	16.36	12.24	125.8	2.23	373.9	8.5
	8	12.82	11.98	114	3.15	376.1	8.6
	9	10.71	11.38	103.2	6.6	377.1	8.5
	10	8.97	10.43	90.7	13.12	375.4	8.4
	11	8.04	6.94	59	6.32	378.5	8.1
	12	7.53	3.77	31.7	2.53	381	7.9
	13	7.01	0.33	2.7	4.07	382	7.8
	14	6.69	0.22	1.8	3.55	394.7	8.5
	15	6.61	0.19	1.5	2.76	398.3	8.7
	16	6.51	0.11	0.9	2.48	403.9	8.9
	17	6.45	0.1	0.8	2.1	406.2	8.9

21-September-2023

Site 1	Depth (m)	Temp (°C)	DO (mg/L)	DO (%)	BGs	Spec C (µS/cm)	pH
	0.5	20.84	9.24	104	2.35	347.7	8.8
	1	20.83	9.2	103.6	1.75	347.7	8.7
	2	20.82	9.21	103.6	2.07	347.6	8.7
	3	20.81	9.21	103.6	2.25	347.7	8.7
	4	20.81	9.2	103.5	2.11	347.7	8.6
	5	20.79	9.2	103.4	2.01	347.7	8.6
	6	20.77	9.19	103.3	1.95	347.8	8.6
	7	18.86	10.28	111.2	2.08	369.9	8.4
	8	14.4	11.2	110.4	3.7	375.6	8.5
	9	10.63	10.35	93.6	4.49	377.1	8.5
	10	9.66	9.9	87.6	4.59	376.7	8.4
	11	8.3	7.44	63.7	3.79	378.6	8.1
	12	7.39	4.26	35.6	2.36	381	8.0
	13	6.89	3.94	32.5	2.13	381	8.0
	14	6.52	2.96	24.2	1.63	379.1	7.9
	15	6.35	2.47	20.1	1.73	377.8	7.8
	16	6.19	2.09	17	1.65	377.1	7.8
	17	6.06	1.99	16.1	1.11	376.4	7.8
	18	5.95	1.54	12.4	1.21	376.6	7.8
	19	5.85	1.22	9.8	1.15	376.4	7.7
	20	5.79	0.77	6.2	1.12	376.7	7.7
	21	5.71	0.45	3.6	0.96	377.3	7.7
	22	5.64	0.3	2.4	1.58	381.4	7.7
	23	5.62	0.19	1.5	1.26	386.8	8.2
	24	5.55	0.11	0.8	1.48	395.9	8.6
	25	5.52	0.08	0.6	1.35	404.7	8.8
	26	5.51	0.07	0.5	1.37	411.4	8.9
	27	5.49	0.06	0.5	1.42	415.7	9.0
	28	5.48	0.06	0.5	1.08	420.3	9.1
	29	5.47	0.06	0.4	1.39	424.5	9.1
	30	5.46	0.06	0.4	1.54	434.7	9.2

21-September-2023

Site 2	Depth (m)	Temp (°C)	DO (mg/L)	DO (%)	BGs	Spec C (µS/cm)	pH
	0.5	20.93	9.27	104.5	7.77	347.5	8.9
	1	20.87	9.28	104.5	6.39	347.3	8.9
	2	20.82	9.29	104.5	6.16	347.4	8.8
	3	20.77	9.29	104.5	5.89	347.3	8.8
	4	20.73	9.29	104.3	4.93	347.5	8.6
	5	20.72	9.19	103.1	3.56	347.2	8.6
	6	20.64	9.16	102.7	3.24	347.4	8.6
	7	18.87	9.99	108.1	2.67	368.4	8.4
	8	14.19	10.93	107.2	3.18	376.9	8.6
	9	11.37	9.81	90.3	4.04	377.5	8.4
	10	9.58	7.39	65.2	4.23	379.8	8.2
	11	8.39	4.64	39.8	3.09	381.1	8.0
	12	7.86	0.47	3.9	3.02	382.6	7.8
	13	7.36	0.33	2.7	3.64	384.9	7.8
	14	7.1	0.23	1.9	4.91	390.8	8.1
	15	6.82	0.17	1.4	6.32	401.1	8.6
	16	6.72	0.13	1	4.28	404.8	8.7
	17	6.62	0.12	1	3.98	410.4	8.8

18-October-2023

Site 1	Depth (m)	Temp (°C)	DO (mg/L)	DO (%)	BGs	Spec C (µS/cm)	pH
	0.5	15.07	10.16	101.5	2.6	349.2	9.4
	1	14.98	10.12	101	3.06	349	9.3
	2	14.96	10.12	100.9	3	349	9.2
	3	14.94	10.12	100.8	2.77	349	9.1
	4	14.93	10.11	100.7	3.18	349.1	9.0
	5	14.92	10.05	100.1	2.81	349.2	8.9
	6	14.91	10.04	100	2.87	349.2	8.8
	7	14.89	9.94	98.9	2.68	349.4	8.7
	8	14.87	9.79	97.4	2.84	349.6	8.6
	9	13.97	7.9	77.1	3.68	361.7	8.3
	10	11	6.28	57.4	2.27	377.2	8.0
	11	8.6	3.18	27.4	1.96	380.2	7.8
	12	7.67	2.88	24.2	1.77	381.4	7.8
	13	7.16	1.58	13.1	2.27	381.3	7.7
	14	6.59	1.06	8.7	1.39	379.6	7.7
	15	6.46	1.04	8.5	1.53	378.4	7.7
	16	6.32	0.56	4.5	1.43	378.5	7.6
	17	6.18	0.28	2.3	1.24	377.9	7.6
	18	6.01	0.25	2	1.49	377.8	7.6
	19	5.89	0.18	1.4	1.21	378.2	7.6
	20	5.8	0.15	1.2	1.33	380	7.6
	21	5.73	0.13	1	1.17	384.5	7.9
	22	5.68	0.12	0.9	1.27	387.9	8.0
	23	5.65	0.1	0.8	1.37	393.5	8.3
	24	5.6	0.09	0.7	1.41	399.6	8.4
	25	5.58	0.08	0.6	1.07	403.2	8.6
	26	5.57	0.08	0.6	1.19	405.4	8.7
	27	5.56	0.07	0.6	1.1	408.4	8.7
	28	5.55	0.07	0.5	1.23	409.6	8.8
	29	5.55	0.06	0.5	1.11	409.8	8.8
	30	5.54	0.06	0.5	1.18	413.6	8.9

18-October-2023

Site 2	Depth (m)	Temp (°C)	DO (mg/L)	DO (%)	BGs	Spec C (µS/cm)	pH
	0.5	15.08	10	100	4.26	349.8	8.8
	1	15.04	9.98	99.7	4.2	349.7	8.9
	2	14.9	9.98	99.4	4.12	349.6	8.8
	3	14.88	9.97	99.3	4	349.6	8.8
	4	14.87	9.94	98.9	4.57	349.6	8.8
	5	14.87	9.84	98	3.1	349.7	8.7
	6	14.85	9.84	97.9	3.17	349.9	8.7
	7	14.76	9.61	95.4	2.84	350.8	8.6
	8	14.73	9.48	94.1	2.53	351.2	8.6
	9	14.18	7.38	72.4	3.09	358.4	8.3
	10	10.46	4.6	41.4	2.26	378.1	7.9
	11	8.94	1.16	10.1	1.83	381.5	7.7
	12	8.29	0.39	3.3	3.02	383.8	7.7
	13	7.8	0.34	2.8	3.57	388.1	7.7
	14	7.37	0.26	2.1	6.27	395.5	8.1
	15	7	0.21	1.7	5.06	404.1	8.3
	16	6.85	0.16	1.3	4.79	409.5	8.5
	17	6.77	0.11	0.9	5.63	412.9	8.7

Site 1	TKN	TKN	NH4	NH4	TN	TN	TP	TP	Alk	Alk	Secchi
	Epi	Hypo	Epi	Hypo	Epi	Hypo	Epi	Hypo	Epi	Hypo	
	mg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	mg/L	mg/L	meters
30-May	ND	0.94	120	360	0	940	ND	30	130	140	4.26
29-Jun	ND	1.01	525	775	0	1010	ND	25	140	150	5.12
24-Jul	0.595	1.92	500	961	595	1920	ND	26	130	160	4.39
23-Aug	NA	NA	4	1145	315	1668	5	234	103	130	2.78
14-Sep	NA	NA	7	1324	348	1872	12	320	105	118	4.55
18-Oct	NA	NA	10	1079	333	1392	15	245	89	131	3.90

Site 2	TKN	TKN	NH4	NH4	TN	TN	TP	TP	Alk	Alk	Secchi
	Epi	Hypo	Epi	Hypo	Epi	Hypo	Epi	Hypo	Epi	Hypo	
	mg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	mg/L	mg/L	meters
30-May	0.71	0.74	130	120	710	740	20	40	130	140	4.15
29-Jun	2.88	3.94	225	775	2880	3940	ND	20	140	150	4.33
24-Jul	2.04	1.58	500	812	2040	1580	ND	15	130	160	4.00
23-Aug	NA	NA	5	1070	332	1696	8	317	103	130	3.00
14-Sep	NA	NA	7	126	354	509	11	29	105	118	4.80
18-Oct	NA	NA	9	1326	272	1671	17	256	89	131	4.01

Appendix B - Algae Data

May 30, 2023; Site 1

Taxa	Genus / species	Cells / mL	%	Taxa cells / mL	Taxa %
Cyanophyta	*Aphanizomenon sp.*	0	0.0	296	40.2
	Aphanocapsa sp.	45	6.1		
	Dolichospermum sp.	188	25.6		
	Planktothrix sp.	63	8.5		
Chlorophyta	*Anikistrodesmus sp.*	0	0.0	27	3.7
	Oocystis sp.	13	1.8		
	Pediastrum sp.	0	0.0		
	Scenedesmus sp.	9	1.2		
	Schroederia sp.	0	0.0		
	Selenastrum sp.	4	0.6		
Chrysophyta	*Chrysosphaerella sp.*	0	0.0	94	12.8
	Dinobryon sp.	0	0.0		
	Kephyrion sp.	90	12.2		
	Uroglenopsis sp.	4	0.6		
Bacillariophyta	*Asterionella sp.*	0	0.0	264	36.0
	Cyclotella sp.	188	25.6		
	Fragilaria sp.	45	6.1		
	Synedra sp.	31	4.3		
Dinophyceae	*Ceratium sp.*	4	0.6	31	4.3
	Glenodinium sp.	9	1.2		
	Gymnodinium sp.	0	0.0		
	Peridinium sp.	18	2.4		
Cryptophyceae	*Cryptomonas sp.*	4	0.6	4	0.6
	Rhodomonas sp.	0	0.0		
Euglenophyceae	*Euglena sp.*	0	0.0	0	0.0
	Unknown	18	2.4	18	2.4
Taxa identified					
15	Totals	735	100	735	100

May 30, 2023; Site 2

Taxa	Genus / species	Cells / mL	%	Taxa cells / mL	Taxa %
Cyanophyta	*Aphanizomenon sp.*	0	0.0	95	20.2
	Dolichospermum sp.	60	12.8		
	Planktothrix sp.	35	7.4		
Chlorophyta	*Anikistrodesmus sp.*	0	0.0	19	4.1
	Closterium sp.	4	0.8		
	Cosmaria	4	0.8		
	Oocystis sp.	4	0.8		
	Selenastrum sp.	6	1.2		
	Staurastrum sp.	2	0.4		
	Tetraedron sp.	0	0.0		
Chrysophyta	*Chrysosphaerella sp.*	0	0.0	62	13.2
	Dinobryon sp.	0	0.0		
	Kephyrion sp.	62	13.2		
Bacillariophyta	*Asterionella sp.*	0	0.0	279	59.3
	Cyclotella sp.	29	6.2		
	Fragilaria sp.	194	41.2		
	Synedra sp.	56	11.9		
Dinophyceae	*Ceratium sp.*	0	0.0	6	1.2
	Peridinium sp.	6	1.2		
Cryptophyceae	*Cryptomonas sp.*	0	0.0	0	0.0
	Rhodomonas sp.	0	0.0		
Euglenophyceae	*Euglena sp.*	0	0.0	0	0.0
	Trachelomonas sp.	0	0.0		
	Unknown	10	2.1	10	2.1
Taxa identified 12	*Totals*	472	100	472	100

June 29, 2023; Site 1

Taxa	Genus / species	Cells / mL	%	Taxa cells / mL	Taxa %
Cyanophyta	*Aphanizomenon sp.*	0	0.0	82	11.1
	Dolichospermum sp.	82	11.1		
Chlorophyta	*Anikistrodesmus sp.*	0	0.0	22	3.0
	Cosmarium sp.	4	0.5		
	Oocystis sp.	2	0.3		
	Selenastrum sp.	16	2.2		
Chrysophyta	*Chrysosphaerella sp.*	0	0.0	500	67.3
	Dinobryon sp.	439	59.2		
	Epipyxis sp.	0	0.0		
	Kephyrion sp.	52	7.0		
	Uroglenopsis sp.	8	1.1		
Bacillariophyta	*Asterionella sp.*	0	0.0	72	9.7
	Cyclotella sp.	8	1.1		
	Fragilaria sp.	60	8.1		
	Synedra sp.	4	0.5		
Dinophyceae	*Ceratium sp.*	2	0.3	38	5.1
	Glenodinium sp.	4	0.5		
	Peridinium sp.	32	4.3		
Cryptophyceae	*Cryptomonas sp.*	0	0.0	0	0.0
	Rhodomonas sp.	0	0.0		
Euglenophyceae	*Euglena sp.*	0	0.0	2	0.3
	Trachelomonas sp.	2	0.3		
Ochrophyta	*Gonystromum sp.*	4	0.5	4	0.5
	Unknown	22	3.0	22	3.0
Taxa identified					
14	*Totals*	742	100	742	100

June 29, 2023; Site 2

Taxa	Genus / species	Cells / mL	%	Taxa cells / mL	Taxa %
Cyanophyta	*Aphanizomenon sp.*	0	0.0	74	9.3
	Dolichospermum sp.	74	9.3		
Chlorophyta	*Anikistrodesmus sp.*	0	0.0	36	4.5
	Cosmaria	2	0.3		
	Gloeocystis sp.	4	0.5		
	Oocystis sp.	2	0.3		
	Scenedesmus sp.	20	2.5		
	Selenastrum sp.	8	1.0		
	Tetraedron sp.	0	0.0		
Chrysophyta	*Chyrsosphaerella sp.*	0	0.0	553	70.2
	Dinobryon sp.	518	65.7		
	Epipyxis sp.	0	0.0		
	Kephyrion sp.	24	3.0		
	Mallomonas sp.	0	0.0		
	Synura sp.	0	0.0		
	Uroglenopsis sp.	12	1.5		
Bacillariophyta	*Asterionella sp.*	0	0.0	62	7.8
	Cyclotella sp.	4	0.5		
	Fragilaria sp.	44	5.6		
	Rhizosolenia sp.	2	0.3		
	Synedra sp.	12	1.5		
Dinophyceae	*Ceratium sp.*	4	0.5	44	5.6
	Glenodinium sp.	14	1.8		
	Peridinium sp.	26	3.3		
Cryptophyceae	*Cryptomonas sp.*	0	0.0	0	0.0
	Rhodomonas sp.	0	0.0		
Euglenophyceae	*Euglena sp.*	0	0.0	0	0.0
	Trachelomonas sp.	0	0.0		
	Unknown	20	2.5	20	2.5
Taxa identified					
16	*Totals*	788	100	788	100

July 24, 2023; Site 1

Taxa	***Genus / species***	**Cells / mL**	**%**	**Taxa cells / mL**	**Taxa %**
Cyanophyta	*Aphanizomenon sp.*	0	0.0	137	8.8
	Chroococcus sp.	21	1.4		
	Dolichospermum sp.	116	7.4		
Chlorophyta	*Anikistrodesmus sp.*	0	0.0	359	23.0
	Cosmarium sp.	4	0.2		
	Cruceginia sp.	14	0.9		
	Gloeocystis sp.	85	5.4		
	Oocystis sp.	74	4.7		
	Pediastrum sp.	0	0.0		
	Scenedesmus sp.	158	10.2		
	Selenastrum sp.	7	0.5		
	Tetraedron sp.	14	0.9		
	Treubaria sp.	4	0.2		
Chrysophyta	*Chrysosphaerella sp.*	0	0.0	25	1.6
	Dinobryon sp.	14	0.9		
	Uroglenopsis sp.	11	0.7		
Bacillariophyta	*Asterionella sp.*	0	0.0	972	62.3
	Cyclotella sp.	972	62.3		
Dinophyceae	*Ceratium sp.*	0	0.0	28	1.8
	Glenodinium sp.	4	0.2		
	Peridinium sp.	25	1.6		
Cryptophyceae	*Cryptomonas sp.*	11	0.7	11	0.7
	Rhodomonas sp.	0	0.0		
Euglenophyceae	*Euglena sp.*	0	0.0	0	0.0
	Trachelomonas sp.	0	0.0		
	Unknown	28	1.8	28	1.8
Taxa identified 16	*Totals*	1560	100	1560	100

July 24, 2023; Site 2

Taxa	*Genus / species*	Cells / mL	%	Taxa cells / mL	Taxa %
Cyanophyta	*Aphanizomenon sp.*	0	0.0	783	28.1
	Dolichospermum sp.	619	22.2		
	Planktothrix sp.	164	5.9		
Chlorophyta	*Anikistrodesmus sp.*	0	0.0	454	16.3
	Gloeocystis sp.	157	5.6		
	Oocystis sp.	94	3.4		
	Scenedesmus sp.	164	5.9		
	Selenastrum sp.	16	0.6		
	Tetraedron sp.	23	0.8		
	Treubaria sp.	0	0.0		
Chrysophyta	*Chrysosphaerella sp.*	0	0.0	55	2.0
	Dinobryon sp.	47	1.7		
	Kephyrion sp.	8	0.3		
Bacillariophyta	*Asterionella sp.*	0	0.0	1386	49.7
	Cyclotella sp.	1386	49.7		
Dinophyceae	*Ceratium sp.*	0	0.0	0	0.0
	Glenodinium sp.	0	0.0		
Cryptophyceae	*Cryptomonas sp.*	16	0.6	16	0.6
	Rhodomonas sp.	0	0.0		
Euglenophyceae	*Euglena sp.*	0	0.0	0	0.0
	Trachelomonas sp.	0	0.0		
	Unknown	94	3.4	94	3.4
Taxa identified					
11	*Totals*	2787	100	2787	100

August 23, 2023; Site 1

Taxa	Genus / species	Cells / mL	%	Taxa cells / mL	Taxa %
Cyanophyta	*Aphanizomenon sp.*	0	0.0	1285	69.6
	Aphanocapsa sp.	5	0.3		
	Chroococcus sp	68	3.7		
	Dolichospermum sp.	1213	65.7		
Chlorophyta	*Anikistrodesmus sp.*	0	0.0	314	17.0
	Cosmarium sp.	24	1.3		
	Gloeocystis sp.	63	3.4		
	Oocystis sp.	58	3.1		
	Scenedesmus sp.	155	8.4		
	Selenastrum sp.	5	0.3		
	Tetraedron sp.	10	0.5		
	Treubaria sp.	0	0.0		
Chrysophyta	*Chrysosphaerella sp.*	0	0.0	101	5.5
	Dinobryon sp.	82	4.5		
	Kephyrion sp.	5	0.3		
	Mallomonas sp.	14	0.8		
Bacillariophyta	*Asterionella sp.*	0	0.0	87	4.7
	Fragilaria sp.	72	3.9		
	Synedra sp.	14	0.8		
Dinophyceae	*Ceratium sp.*	5	0.3	14	0.8
	Peridinium sp.	10	0.5		
Cryptophyceae	*Cryptomonas sp.*	5	0.3	5	0.3
	Rhodomonas sp.	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	39	2.1	39	2.1
Taxa identified 17	*Totals*	1845	100	1845	100

August 23, 2023; Site 2

Taxa	Genus / species	Cells / mL	%	Taxa cells / mL	Taxa %
Cyanophyta	*Aphanizomenon sp.*	0	0.0	815	61.8
	Chroococcus sp	15	1.1		
	Dolichospermum sp.	800	60.7		
Chlorophyta	*Anikistrodesmus sp.*	0	0.0	308	23.4
	Cosmarium sp.	38	2.8		
	Gloeocystis sp.	45	3.4		
	Oocystis sp.	79	6.0		
	Scenedesmus sp.	135	10.3		
	Tetraedron sp.	11	0.9		
	Treubaria sp.	0	0.0		
Chrysophyta	*Chrysosphaerella sp.*	0	0.0	41	3.1
	Dinobryon sp.	34	2.6		
	Mallomonas sp.	8	0.6		
Bacillariophyta	*Asterionella sp.*	0	0.0	64	4.8
	Cyclotella sp.	38	2.8		
	Fragilaria sp.	8	0.6		
	Synedra sp.	19	1.4		
Dinophyceae	*Ceratium sp.*	8	0.6	19	1.4
	Glenodinium sp.	8	0.6		
	Peridinium sp.	4	0.3		
Cryptophyceae	*Cryptomonas sp.*	0	0.0	0	0.0
	Rhodomonas sp.	0	0.0		
Euglenophyceae	*Euglena sp.*	0	0.0	4	0.3
	Trachelomonas sp.	4	0.3		
Ochrophyta	*Stichogloea sp.*	0	0.0	0	0.0
	Unknown	68	5.1	68	5.1
Taxa identified					
16	*Totals*	1318	100	1318	100

September 14, 2023; 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		
	Nephrocytium sp.	0	0.0		
	Oocystis sp.	7	2.0		
	Scenedesmus sp.	179	50.4		
	Selenastrum sp.	23	6.6		
	Spondylosium sp.	2	0.5		
	Tetraedron sp.	29	8.1		
	Treubaria sp.	0	0.0		
Chrysophyta	*Chrysosphaerella sp.*	0	0.0	10	2.9
	Dinobryon sp.	1	0.2		
	Kephyrion sp.	0	0.0		
	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		
Dinophyceae	*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
	Rhodomonas sp.	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

September 14, 2023; 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		
	Schroederia sp.	0	0.0		
	Selenastrum sp.	24	2.0		
	Tetraedron sp.	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		
Dinophyceae	*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
	Rhodomonas sp.	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

Multiple Linear Regression: Combined Epi and Hypo

	Estimate	Std. Error	t value	Pr(>|t|)	
(Intercept)	2.04E+03	7.99E+00	255.521	<2e-16	***
pH.T	-1.55E+00	9.56E-01	-1.617	0.1125	
pH.B	1.95E-01	2.12E-01	0.919	0.3628	
Alk.T	-4.78E-02	2.10E-02	-2.276	0.0273	*
Alk.B	-9.02E-03	1.48E-02	-0.611	0.544	
Amm.T	-5.74E-01	3.48E-01	-1.649	0.1056	
Amm.B	-4.74E-01	5.32E-01	-0.89	0.3777	
TN.T	-1.93E-01	1.93E-01	-1.001	0.3217	
TN.B	-3.43E-01	1.40E-01	-2.457	0.0177	*
TP.T	-3.20E-02	2.12E-02	-1.507	0.1383	
TP.B	8.63E-04	1.44E-03	0.6	0.5514	
Secchi	-9.51E-02	2.62E-01	-0.363	0.7184	

r2	0.6282
F	7.374
p	3.37E-07

Multiple Linear Regression: Epilimnion

	Estimate	Std. Error	t value	Pr(>|t|)	
(Intercept)	2037.85765	7.8205	260.579	<2e-16	***
pH.T	-1.31339	0.83672	-1.57	0.1224	
Alk.T	-0.04091	0.0202	-2.025	0.0479	*
Amm.T	-0.31323	0.34574	-0.906	0.3691	
TN.T	-0.57353	0.11867	-4.833	1.19E-05	***
TP.T	-0.04251	0.02007	-2.118	0.0389	*
Secchi	-0.01767	0.26246	-0.067	0.9466	

r2	0.5545
F	10.99
p	6.33E-08

Multiple Linear Regression: Hypolimnion

	Estimate	Std. Error	t value	Pr(>|t|)	
(Intercept)	2.02E+03	2.50E+00	808.368	<2e-16	***
pH.B	4.71E-02	1.88E-01	0.251	0.8029	
Alk.B	-4.02E-03	1.47E-02	-0.273	0.7862	
Amm.B	-8.71E-01	4.53E-01	-1.922	0.0599	.
TN.B	-5.26E-01	9.08E-02	-5.796	3.61E-07	***
TP.B	2.26E-03	1.43E-03	1.578	0.1203	

r2	2.132
F	10.32
p	5.61E-07

Analysis of Variance: Combined Epi and Hypo

	Df	Sum Sq	Mean Sq	F value	Pr(>F)	
pH.T	1	11.778	11.778	3.1681	0.08142	.
pH.B	1	5.348	5.348	1.4385	0.23628	
Alk.T	1	13.516	13.516	3.6356	0.06255	.
Alk.B	1	5.827	5.827	1.5674	2.17E-01	
Amm.T	1	101.226	101.226	27.2291	3.82E-06	***
Amm.B	1	17.754	17.754	4.7756	0.03378	*
TN.T	1	112.118	112.118	30.1589	1.48E-06	***
TN.B	1	22.602	22.602	6.0798	0.01730	*
TP.T	1	9.861	9.861	2.6525	0.10993	
TP.B	1	1.037	1.037	0.2789	0.59983	
Secchi	1	0.489	0.489	0.1316	0.71839	

Analysis of Variance: Epilimnion

	Df	Sum Sq	Mean Sq	F value	Pr(>F)	
pH.T	1	11.778	11.778	2.919	0.09339	.
Alk.T	1	12.91	12.91	3.1998	0.07937	.
Amm.T	1	89.448	89.448	22.1691	1.84E-05	***
TN.T	1	133.918	133.918	33.1907	4.33E-07	***
TP.T	1	18.081	18.081	4.4813	0.03898	*
Secchi	1	0.018	0.018	0.0045	0.94659	

Analysis of Variance: Hypolimnion

	Df	Sum Sq	Mean Sq	F value	Pr(>F)	
pH.B	1	0.005	0.005	0.0011	0.97342	
Alk.B	1	9.18	9.18	2.0192	0.16107	
Amm.B	1	23.241	23.241	5.1119	0.02781	*
TN.B	1	190.733	190.733	41.9516	2.91E-08	***
TP.B	1	11.328	11.328	2.4916	0.12029	

Appendix D - Preparer's Qualification

Laurence J. Marsicano
25 Nutmeg Drive, New Milford, CT 06776, (860) 354-5969, larry.marsicano@gmail.com

RELEVANT EXPERIENCE

- Thirty years as a lake ecologist, manager, advocate, educator, and leader in Connecticut. Successful in the academic, public, and private sectors.
- Advanced the mission of the Candlewood Lake Authority from 1998 through 2017 with the last 14 of those as Executive Director. The board and staff of that agency served the five municipalities surrounding Candlewood Lake, the largest lake in the State and one of Connecticut's most important inland water resources.
- Developed meaningful relationships and worked with the general CT lake community, local and state environmental agency staff, academic researchers, elected leaders at all levels of government, and educators from middle school through college/university levels.
- Co-directed an interdistrict grant program that utilized Candlewood Lake as a living, learning laboratory. The program ran for 10+ years and engaged ~150 high school students and teachers each year.
- Have trained and supervised employees and/or students in Limnological and Paleolimnological field and laboratory methods.
- Founding member of the Connecticut Federation of Lakes, have, and continued to serve as a volunteer and an officer of Connecticut's lake advocacy, nonprofit organization until 2022.

PROFESSIONAL EXPERIENCE

- **Principal Limnologist – Brawley Consulting Group, LLC.** 2023 to present
- **Principal Partner – Aquatic Ecosystem Research, LLC.** July 2017 to 2022
- **Adjunct Faculty** – Western Connecticut State University, Biol. and Enviro. Science Dept. August 2011 to present.
- **Executive Director –** Candlewood Lake Authority, Sherman, CT 06784. April 2003 to July 2017
- **Lake Preservation Director –** Candlewood Lake Authority, Sherman, CT 06784. April 1998 to Oct. 2002
- **Academic Research Associate –** Connecticut College, New London, CT 06320. Sept. 1989 to Jan. 1998
- **Visiting Lecturer –** Connecticut College, New London, CT 06320. August 1997 to January 1998
- **Research Assistant** – Western Connecticut State University, Danbury, CT 06810. 1987 to 1989

CERTIFICATION, EDUCATION, AND TRAINING

- **Certified Lake Manager**, North American Lake Management Society, 2017
- **Professional Certification** in GIS, Pace University, 2014
- **Graduate Certification** in GIS Technology, University of New Haven 2001
- **M.A. in Botany**, Connecticut College 1993
- **B.A. in Biology**, Western Connecticut State University 1988

AWARDS

- **Excellence in Environmental Stewardship** from the **Connecticut Outdoor and Environmental Education Association** in 2018
- **Recognition of Service** in the **Congressional Record** by **US Rep. Elizabeth Esty** on June 14, 2017
- **Watershed Conservationist Award** from the **Housatonic Valley Association** in 2011
- **Conservation Professional of the Year** from the **Litchfield County Conservation District** in 2002
- **Honor Award**, **Southern New England Chapter of the Soil and Water Conservation Society** in 2000.
- **Green Circle Award** from the **Connecticut Department of Environmental Protection** in 1999.
- **Conservation Award** from **Housatonic Valley Association** for publication entitled *Candlewood Lake: Watershed Awareness and Lake Preservation* in 1998.

ORGANIZATIONS

- **Connecticut Federation of Lakes** – Founding member 1995; Treasurer from 1995 – 2001; Vice President from 2009 – 2011, 2018 - present; President from 2011 - 2015
- **Connecticut Forest and Park Association** – Board member from 1994 – 2002
- **North American Lakes Management Society** – Member since 1990

SELECTED PUBLICATIONS

PEER-REVIEWED SCIENTIFIC PAPERS

Siver, P.A., Sibley, J., Lott, AM., **Marsicano**, L.J. Temporal changes in diatom valve diameter indicate shifts in lake trophic status. J Paleolimnology 66, 127–140 (2021). https://doi.org/10.1007/s10933-021-00192-y

Siver, P., L. **Marsicano**, A. Lott, S. Wagener, N. Morris. 2018. Wind Induced Impacts on Hypolimnetic Temperature and Thermal Structure of Candlewood Lake (Connecticut, U.S.A.) from 1985-2015. Geo: Geography and the Environment. 5(2). https://doi.org/10.1002/geo2.56

Kohli, P., Siver, P.A., **Marsicano**, L.J., Hamer, J.S., and Coffin, A.M. 2017. Statistical Assessment of Long-term Trends for Management of Candlewood Lake, Connecticut, USA. Journal of Lake and Reservoir Management. 33:280-300

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Siver, P.A., Canavan, R.W. IV, Field, C., **Marsicano**, L.J. and A.M. Lott. 1996. Historical changes in Connecticut lakes over a 55-year period. Journal of Environmental Quality 25: 334-345

Marsicano, L.J., J.L. Hartranft, P.A. Siver, and J.S. Hamer. 1995. An historical account of water quality changes in Candlewood Lake, Connecticut, over a sixty-year period using paleolimnology and ten years of water quality data. Journal of Lake and Reservoir Management 11:15-28.

Lott, A.M., Siver, P.A., **Marsicano**, L.J., Kodama, K.P. and R.E. Moeller. 1994. The paleolimnology of a small waterbody in the Pocono Mountains of Pennsylvania, USA: reconstructing 19th-20th century specific conductivity trends in relation to changing land use. Journal of Paleolimnology 12: 75-86.

Marsicano, L.J. and P.A. Siver. 1993. A paleolimnological assessment of lake acidification in five Connecticut lakes. Journal of Paleolimnology 9:202-221.

Siver, P.A. and L.J. **Marsicano**. 1993. *Mallomonas connensis* sp. nov., a new species of Synurophyceae from a small New England lake. Nordic Journal Botany. 13: 337-342

Siver, P.A. and L.J. **Marsicano**. 1991. Assessing acidification trends in Connecticut lakes using a paleolimnological approach. CT. Department of Environmental Protection Bulletin, 44 pp. + appendices

POLICY PAPERS AND SUBMITTALS

Marsicano, LJ. 2009. An Examination of Recreational Pressures on Candlewood Lake, CT. Candlewood Lake Authority. Sherman, CT. 68 pp.

Marsicano, L.J., et al. 2000 – 2017. Submittals of the Candlewood Lake Authority to the Federal Energy Regulatory Commission during license renewal and management plan processes for Housatonic Hydro, FERC Docket No. P-2576.

A. Hunter Brawley
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Mobile: 203-525-5991
hbrawley@gmail.com

PROFESSIONAL EXPERIENCE

Owner/Manager, Brawley Consulting Group LLC, Windsor, CT
(January 2008 to present).
Provides land conservation and management services to local land trusts and conservation organizations, including designing and implementing habitat restoration projects, grant writing, trail design and construction, crafting and monitoring conservation easement, boundary posting, Baseline Documentation Reports and developing property management plans. www.brawleycg.com

Land Manager, Naromi Land Trust, Sherman, CT
(March 2004 to present).
Manage all land trust properties and help acquire, monitor and enforce conservation easements. Responsibilities also include designing and building trails, securing funding for habitat restoration projects, and assisting with organizational and administrative tasks. Work cooperatively with the town and other conservation organizations to identify and prioritize lands for future acquisition. www.naromi.org

Land Manager, Kent Land Trust, Kent, CT
(September 2008 to August 2014).
Manage all land trust properties and help acquire, monitor and enforce conservation easements. Responsibilities also include securing funding for habitat restoration projects and preparing Baseline Documentation Reports (BDRs) and property management plans. Addressed backlog of stewardship items required for Kent Land Trust to become the second land trust in Connecticut accredited by the Land Trust Alliance.

Project Manager, Northeast Instream Habitat Program, Amherst MA.
(January 2004 to March 2005).
Coordinated all facets of two fisheries habitat assessment projects working with researcher at the University of Massachusetts, including project planning, data collection, hiring and overseeing seasonal staff, data analysis and report preparation. http://www.neihp.org/index.htm

Executive Director, Pomperaug River Watershed Coalition, Southbury, CT
(July 2001 to May 2003).
Managed all activities of non-profit watershed management organization dedicated to conserving regional water resources, including research, outreach, budgets, grant writing, website development, fundraising, and volunteer relations. www.pomperaug.org

Senior Project Manager, LabLite, LLC, New Milford, CT
(January 2000 to June 2001).
Product development, testing, sales, and customer service for a software company that provides Laboratory Information Management Software (LIMS) to environmental and other laboratories. www.lablite.com

Research Coordinator, The National Audubon Society, Southbury, CT
(March 1998 to January 2000).
Designed and implemented all research on birds and other wildlife at the 625-acre wildlife sanctuary. Conducted natural resources inventory, created checklists of wildlife and plants, established environmental education programs, and coordinated cooperative research projects with state agencies and regional conservation organizations.
http://ct.audubon.org/IBA_BOR.html

Environmental Analyst, Land-Tech Consultants, Inc., Southbury, CT

(November 1996 to February1998).
As Project Manager conducted environmental impact statements, wetland assessments, and wildlife surveys; prepared federal, state and local permit applications; designed pond and tidal wetland restoration projects; and conducted lake diagnostic studies. Worked with state agencies and local land use agencies to mitigate impacts of residential and commercial development projects. www.landtechconsult.com

Wetland Ecologist, The Deep River Land Trust, Deep River, CT.
(July to October 1995).
Worked in association with The Nature Conservancy Connecticut Chapter on a conservation project at two freshwater tidal marshes in the lower Connecticut River. Position entailed mapping dominant vegetation communities, identifying potential environmental impacts, researching information on appropriate buffer zones and recommending methods for long-term monitoring of the system.

Research Assistant, The Nature Conservancy CT Chapter, Weston, CT.
(May to July 1995).
Assisted with research on the productivity and survivorship of Worm-eating Warblers at the 1700-acre Devil's Den Preserve in Weston, CT. Responsibilities included mist-netting, bird banding, and locating and monitoring approximately 25 nest sites throughout the breeding season.
http://www.nature.org/wherewework/northamerica/states/connecticut/

Master's Thesis Research, Connecticut College, New London, CT.
(September 1993 to May 1995).
Conducted two-year study investigating relationships between bird populations and environmental conditions in tidal wetlands of Connecticut. Quantified bird use, vegetation, and selected environmental parameters in eight tidal marsh systems on the Long Island Sound to assess the use of birds as indicators of environmental quality.
http://www.conncoll.edu/departments/botany/index.htm

Research Associate, Connecticut College Arboretum, New London, CT.
(Sept. 1992 to January 1994).
Conducted a natural resources inventory of The Harriet C. Moore Foundation property in Westerly, RI, including producing lists of all plants and animals (flora and fauna), conducting a breeding bird census, and identifying and tagging over 100 ornamental trees. Developed a five-year plan for the management and use of this 35-acre public land preserve.
http://arboretum.conncoll.edu/

Principal Investigator, The Nature Conservancy CT Chapter, Middletown, CT
(Summer 1994).
Studied five marshes in the tidelands of the lower Connecticut River to assess the impacts of the spread of common reed (*Phragmites australis*) on bird populations. Designed project that included the systematic collection of data on bird use, vegetation sampling and an analysis of physical site characteristics.
http://www.nature.org/wherewework/northamerica/states/connecticut/

EDUCATION

Connecticut College, New London, CT. Master of Arts in Botany, 1995.

Connecticut College, New London, CT. Bachelor of Arts in American History, 1982.

The Loomis Chaffee School, Windsor, CT. Graduated 1978.

PUBLICATIONS

Brawley, A. H., Zitter, R. and L. Marsicano, Editors. 2005. Candlewood Lake Buffer Guidelines. Candlewood Lake News *Special Edition*, Vol 1:21.

Warren, R.S., P. E. Fell, R. Rozsa, A. H. Brawley, A. C. Orsted, E. T. Olson, V. Swamy and W. A. Niering. 2002. Salt Marsh Restoration in Connecticut: 20 years of Science and Management. *Restoration Ecology* 10 (3) 497-513.

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Brawley, A. H., R. S. Warren and R. A. Askins. 1998. Bird Use of Restoration and Reference Marshes Within the Barn Island Wildlife Management Area, Stonington, Connecticut, USA. *Environmental Management* 22(4): 625-633.

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Niering, W. A., and A. H. Brawley. 1996. Functions and Values Assessment of Area A Downstream Wetlands and Watercourses. Naval Submarine Base New London, Groton, CT. Report to Brown & Root Environmental, The Environmental Protection Agency, and The United States Navy. 36 p.

Brawley, A.H. 1995. Pratt and Post Coves: A Vegetation Survey and Conservation Analysis. Report to the Deep River Land Trust, Deep River, CT. 62 p.

Brawley, A.H. 1995. Birds of Connecticut's Tidal Wetlands: Relating Patterns of Use to Environmental Conditions. Master's Thesis, Connecticut College, New London, CT. 87 p.

Brawley, A.H. 1994. Birds of the Connecticut River Estuary: Relating Patterns of Use to Environmental Conditions. Report to the Nature Conservancy Connecticut Chapter Conservation Biology Research Program, Middletown, CT. 23 p.

Brawley, A.H., G.D. Dreyer. 1994. Master Plan for the Future Management and Use of Moore Woods. Connecticut College Arboretum Publication. New London, CT. 65 p.

Brawley, A.H., G.D. Dreyer and W.A. Niering. 1993. Connecticut College Arboretum Phase One Report to the Harriet Chappell Moore Foundation. Connecticut College Arboretum Publication. New London, CT. 100 p.

ACTIVITIES

Forest and Trails Conservation Committee, Connecticut Forest & Park Association (CFPA)

Coverts Project Cooperator, UConn Cooperative Extension System