# Ball Pond

## 2023 Water Quality Monitoring Report

Prepared for the:

*Ball Pond Advisory Committee*
*New Fairfield, CT*

*Prepared by:*

Brawley Consulting Group, LLC
95 Pilgrim Drive
Windsor, CT 06095
203-525-5991

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## I. Executive Summary

Two issues have emerged from recent water quality monitoring efforts and from reporting by community volunteers. The first is the occurrences of sizeable cyanobacteria blooms in certain areas along the shoreline of Ball Pond. Data from water quality monitoring efforts that may help explain these occurrences and discussed in this report include:

- Ball Pond stratifies and exhibits strong resistance to mixing early in the season, i.e. in April or May. Following stratification, oxygen in the hypolimnion is quickly used up in cellular respiration and not replenished since oxygen cannot diffuse down below the thermocline.

- The anoxic hypolimnion becomes a chemically reduced environment where precipitated compounds in the lake bottom sediments dissolve, i.e., go back into solution, and internally "load" in the waters between sediment particles, and later above the sediments and diffuse up through the hypolimnion. These include soluble phosphorus and nitrogen compound which become highly concentrated in the hypolimnion.

- Coprecipitation of phosphorus appears to occur in the epilimnion due to the high pH and calcium content of those waters. Phosphorus enriched calcite precipitates, i.e., settle out of the water column, and may be contributing to the soluble phosphorus concentrations in the hypolimnion if those precipitates dissolve in the reduced hypolimnetic environment.

- Cyanobacteria concentrations in the surface waters at the deep-water sampling site are typically low. Very high concentrations do occur in the metalimnion below the thermocline, starting in July and continuing into the season. The ability to regulate cellular buoyancy provides cyanobacteria with the adaptive advantage of situating themselves at depths that allow for the utilization of elevated nutrient levels of the lower depths.

- Some cyanobacteria may become positively buoyant and rise to the surface, and with light winds can be "collected" in the downwind shoreline areas of the lake, forming blooms. We believe this is what creates shoreline cyanobacteria blooms at Ball Pond.

The other water quality issue of concern is increasing specific conductance levels. Levels increase each season in the hypolimnion due to the anoxic, reduced environment. However, changes in epilimnion over time implicates watershed-based sources of pollution.

- Past studies indicate that this trend has been ongoing for decades.
- Historical and recent data identify increases in sodium and chloride levels as the main drivers in the increased specific conductance levels.
    - Changes in fauna and flora, and changes in a lake's ability to mix can occur when salt levels become excessively high.

- Although not increasing to the same degree as sodium and chloride, calcium levels are now high enough in Ball Pond to rank it in the *moderate risk of zebra mussel colonization* category if that invasive animal were to be introduced.
    - The nearby Candlewood Lake is now experiencing colonization by zebra mussels. Candlewood's proximity to Ball Pond does pose a risk if vessels, including paddle craft, are used to recreate in both waterbodies.

Recommendations for addressing these water quality issues have been provided at the end of this report. Field and laboratory data have been provided as appendices of this report.

## II. Introduction

Ball Pond is an 89-acre natural kettle lake located in New Fairfield, CT (Canavan and Siver 1995, Frink and Norvell 1984). The lake's origins are glacial in nature and a result of the retreat of the Laurentide Ice Sheet some *ca* 10,000 to 12,000 years before present. Ball Pond is now an important ecological, economic, and recreational asset to the Town of New Fairfield. Stewardship of the lake is largely led by the Town's Ball Pond Advisory Committee (BPAC) and by the Friends of Ball Pond, a not-for-profit advocacy organization. The Connecticut Department of Energy and Environmental Protection maintains a public boat ramp on the lake, annually stocks the lake with trout (Jacobs and O'Donnell 2004), and performs other environmental services (e.g., fish surveys).

Ball Pond is largely spring, or groundwater fed, but also receives some stormwater runoff from its watershed (Fig. 1). Based on Connecticut's Water Quality Standards, Ball Pond is classified as AA. This designation allows for existing or proposed drinking water supplies, habitat for fish and other aquatic life and wildlife, recreation, and water supply for industry/agriculture (NFPC 2014). The lake has a maximum depth of 51 feet (15.4 meters) and a mean depth of 24 ft (7.3 meters).

The 245-acre watershed is relatively small and was reported to lie within the Connecticut Marble Valley geological formation, which is largely metamorphosed calcium carbonate (Canavan and Siver 1995, Jacobs and O'Donnell 2002). Local experts have conversely described the bedrock as metamorphic but of a granitic composition, over a billion years old, and with possible influences of glacial erratics that may potentially provide the carbonate influences to the system (J. Mellett, personal communication, December 4, 2021).

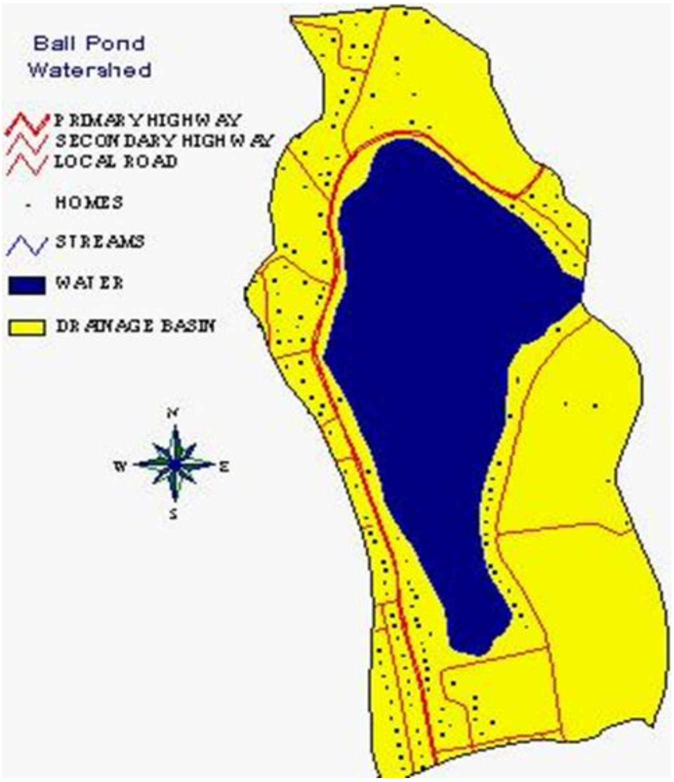

Figure 1. Map of Ball Pond and its watershed (drainage basin). Homes are based on a 1984 map. Image is from the Connecticut College Silica Secchi Disk database (Siver 2024)

An analysis of historical land cover in the Ball Pond watershed (Field et.al. 1996) is presented in Table 1. In summary, changes in the watershed between 1934 to 1990 included an overall increase in wooded/forested and residential cover at the expense of the agricultural cover that – in 1934 – accounted for over half of the watershed area. Field et. al. also applied empirical models developed for lakes in Connecticut to estimate total phosphorus (Norvell et. al. 1979) and total nitrogen (Frink 1991) concentrations in the lake based on land cover. The estimated levels for 1934, 1970, and 1990 are also included in Table 1. Jacobs and O'Donnell (2004) more recently described the watershed as mostly residential.

Table 1. Percent of residential, agricultural, wooded (aka forested), and water (including the lake) coverages of the Ball Pond watershed. Also provided are estimated total phosphorus (eTP) and estimated total nitrogen (eTN) levels predicted from land cover.

| Year | Residential (%) | Agriculture (%) | Wooded (%) | Water (%) | *e*TP (µg/L) | *e*TN (µg/L) |
|---|---|---|---|---|---|---|
| 1934 | 4 | 52 | 9 | 35 | 15 | 417 |
| 1970 | 25 | 18 | 24 | 33 | 25 | 506 |
| 1990 | 37 | 15 | 15 | 33 | 32 | 600 |

In addition to the Field et.al. study, Ball Pond has been included in several state-wide surveys of Connecticut lakes (Deevey 1940, Frink & Norvell 1984, Canavan and Siver 1994, 1995). Siver et.al. (1996) summarized historical changes in 42 lakes, including Ball Pond, using data from those surveys. That study revealed that the average Ball Pond Secchi disk transparency in the lake decreased by 0.1 meter (m) between the 1930s and the early 1990's. Total phosphorus levels increased by 28µg/L between 1934 and the early 1990s, with 19µg/L of that increase occurring since the early 1970s. Canavan and Siver (1995) described Ball Pond as late mesotrophic to eutrophic with total phosphorus levels like those of Bantam Lake and Lake Waramaug.

Ball Pond was also one of 23 study lakes in Connecticut where paleolimnological reconstructions of past water quality were assessed (Siver et.al. 1999). The inferred past conditions were based on assemblages of fossil bearing microalgae chronologically layered in the lake sediments and highly significant inference models. Water quality reconstructions targeted the *ca* 1890 and *ca* 1990 layers of a sediment core that was dated with a lead-210 isotope dating method. In that study, 100-year changes in water quality were correlated with land use changes between 1934 and 1990. Those correlations revealed that lakes with watersheds that have remained over -80% forested have not significantly changed, whereas those that have become over -25% residential have experienced the greatest amount of change.

Ball Pond exhibited the first or second highest increase in specific conductance, depending on which fossil organisms were used, of all 23 lakes in the study. The lake also ranked highly for increased pH and trophic score (Fig 2). Both organismal groups were used to infer specific conductivity and pH; however, only scaled chrysophytes or planktonic diatoms were used to infer trophic score and total nitrogen, respectively. In each panel, lakes are arranged in ascending order based on inferences made with scaled chrysophytes. Ball Pond is #3 and circled in red in each panel. Siver et.al. (1999) also reported a 29% increase in residential land cover between 1934 and 1990.

That land-use change was tied with two other lakes for third in percent increase in residential land cover over the 66-year period. The 1990 forest cover was estimated at 48%

Last year, we characterized Ball Pond as a mesotrophic to late-mesotrophic lake, i.e., moderate algal productivity. However, the lake experiences localized cyanobacteria blooms along the shoreline, a characteristic of lakes that are eutrophic. Additionally, we reported that much of the aquatic vegetative cover has been dramatically reduced, presumably by the stocking of triploid grass carp, although there are cases in the scientific literature where a lake's plant community that is dominated by Eurasian watermilfoil, was decimated by a microscopic pathogen (e.g. Elser 1967, Shearer 1994).

Brawley Consulting Group (BCG) was contracted by the Ball Pond Advisory Committee to perform water quality monitoring in the 2023 season. Data collected will be used in conjunction with historical data to understand the water quality trajectories and develop future lake management strategies.

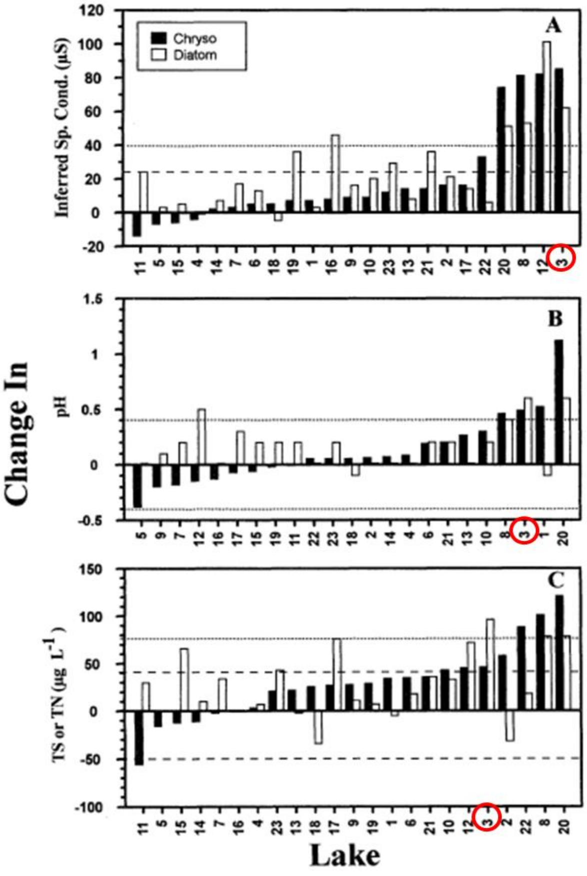

Figure 2. A comparison of 100-yr changes in inferred specific conductivity (A), pH (B), trophic score (C), and total nitrogen (C) of 23 Connecticut lakes based on scaled chrysophyte (solid bars) and planktonic diatom (open bars) remains. From Siver et. al., 1999.

## III. Methods

A water quality monitoring program was supported by the Town of New Fairfield and the BPAC, which included having BCG collect field data and water samples at Ball Pond between the months of May and October. The sampling dates were May 22nd, June 15th, July 25th, August 21st, September 20th, and October 17th. Monthly sampling consisted of visiting one deep-water site (41.46286071, -73.52371949; Fig. 2) where the following field data were collected:

- Site maximum depth measured in meters with a weighted field tape.
- Secchi disk transparency measured in meters (m) with a standard 20cm Secchi disk.
- Temperature (°C), dissolved oxygen (mg/L), percent oxygen saturation (%), specific conductance (µS/cm), pH (SU), and relative phycocyanin concentration (µg/L) measured at 0.5m below the surface, and at each meter from 1m to 15m of depth with a Eureka Manta Multiprobe II.

Water samples were collected with a horizontal Van Dorn water sampler at 1m below the surface (epilimnion), and at approximately 0.5m above the sediment-water interface (hypolimnion). Additional intermediate depth (metalimnion) samples were collected at the approximate depth of the thermocline (see below). Samples were kept at approximately 3°C in an ice-cooler.

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. Epilimnetic samples were also tested for base cations and anions. Those were sodium, potassium, calcium, magnesium, and chloride.

Samples were also collected to evaluate chlorophyll-*a* concentrations and phytoplankton community structure and cell concentrations. For those samples, a weighted tube sampler was used to collect an integrated sample of the top three meters of the water column; those samples were also stored at 3°C. Chlorophyll-*a* analyses were performed by York Analytical Laboratories.

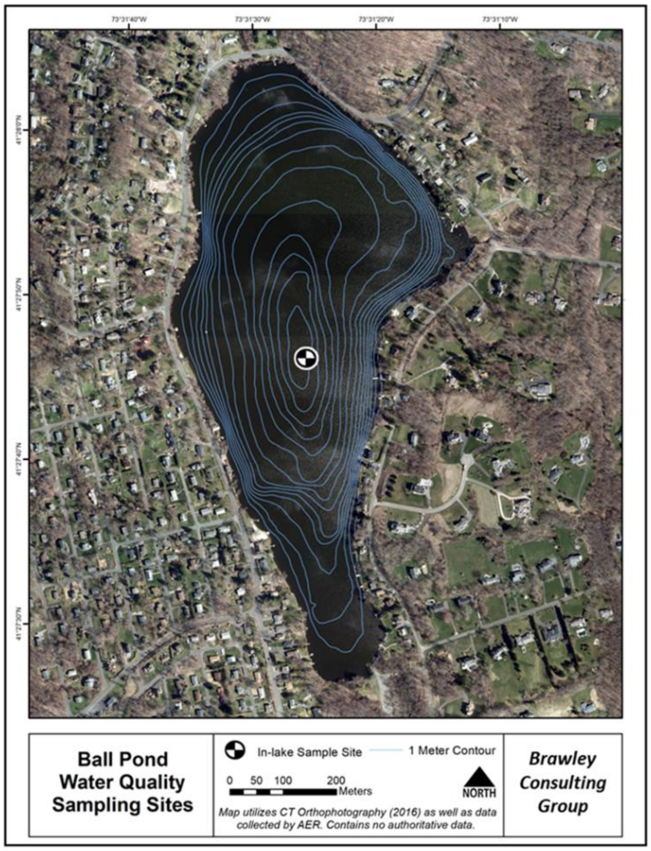

Figure 3. Location of deep-water monitoring site on Ball Pond in 2023.

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 delivery to the laboratory. The sample for chlorophyll-a analysis was prepared before delivery by filtering a known volume through a 25 mm diameter filter with 0.7 µm pore size using a vacuum pump/filtration flask system. Filters were then stored in labelled aluminum foil envelopes until delivered to the UCONN CESE laboratory.

Samples collected for algae / cyanobacteria counts were treated in the field with Lugol's solution for preservation. At BCG facilities, a volume of those samples were treated with hydrostatic pressure to the 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 corrected to be reflective of the whole water samples.

For a qualitative assessment of the entire pelagic zone's phytoplankton community, a 10µm 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 facilities 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: $(D_1 - D_2)/(D' - D^o)$, where $D_1$ is the density of upper water volume, $D_2$ is the density of the lower water volume, D' is the density of water at 5°C, and $D^o$ is the density of water at 4°C. RTRM scores of <30 mean that layers are mixed; scores of ≥30 between strata are characteristic of the transitional metalimnion layer. RTRM scores of ≥80 between strata characterizes strong resistance to mixing (Siver et.al. 2018).

## IV. Temperature and Oxygen Profiles

We have displayed many of the data collected throughout the water column as *isopleths* in the following sections 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 are then interpolated between depth and dates. Variables of the same value (and color) are connected between dates regardless of depth to create a theoretical representation of changes throughout the water column over time.

### A. Temperature & Dissolved Oxygen

The water temperature profile data and isopleth charts provide 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 may be short in duration because wind energy can mix the water column. In deeper lakes or sites, stratification is not easily broken by wind energy.

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

The 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 in the interstitial waters and eventually into the waters above the sediments.

The water column was highly stable throughout the 2023 season. On each sampling event, the water column was stratified and resistance to mixing at the thermocline was very strong (RTRM>80). Epilimnetic waters warmed from 17-18°C in late May and reached highest temperatures of just under 27°C in late July before cooling for through mid-October down to approximately 15°C (Fig. 4).

The strong resistance to mixing precluded heat transfer from warmer upper waters to the lower hypolimnetic waters. Hypolimnetic waters only varied from approximately 6°C to 8.5°C during the season.

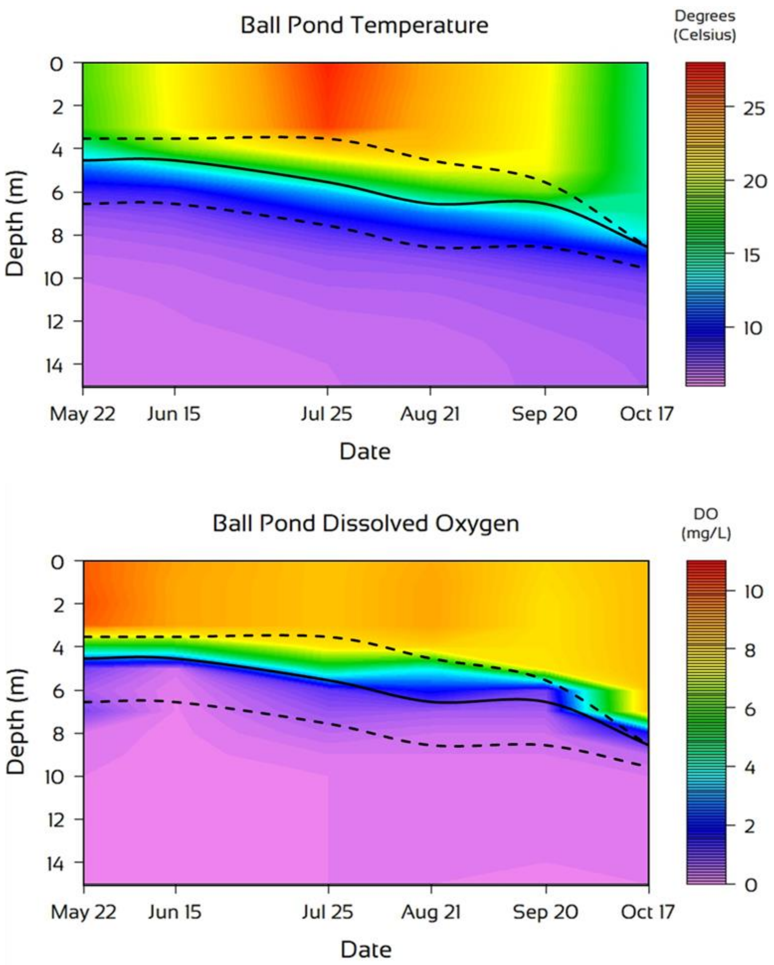

Figure 4. Temperature (top) and oxygen (bottom) isopleth charts for the Ball Pond water column in 2023. The dashed lines represent the position of the upper and lower metalimnetic boundaries; the solid black lines represent the position of the thermocline.

Between the epilimnion and hypolimnion was a metalimnetic layer characterized by a rapid change in temperature. For much of the season, the metalimnetic stratum occupied a 3-to-5-meter region of the water column. That metalimnetic layer trended downward and was only 2 meters .in width by the end of the season.

The same physical processes precluding heat transfer below the thermocline also precluded oxygen diffusion below the thermocline (Fig. 4). Oxygen concentrations in the hypolimnion were ≤1mg/L all season, including in late May when those levels were observed from 5 to 14 meters of depth.

The isopleth data indicated that there may have been an intrusion of low oxygen concentration waters above the thermocline in late August and late September. Concentrations above the upper metalimnetic boundary remained high on those dates but by mid-October had started to decrease.

## V. Trophic Characteristics

Several of the water quality parameters measured were used to assess the trophic status of Bantam 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 are related to algal productivity, including phosphorus concentration, Secchi transparency, and chlorophyll-*a* concentrations (See Table 2). Lakes supporting very little productivity 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 lie within several categories of mesotrophic conditions. Mesotrophic and even oligotrophic lakes can experience an algal bloom but are much less intense and infrequent.

Based on the sampling data and classification criteria in Table 2, the trophic status of Ball Pond in 2022 was mesotrophic to late mesotrophic**.**

Table 2. 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 |

### A. Secchi 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.

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).

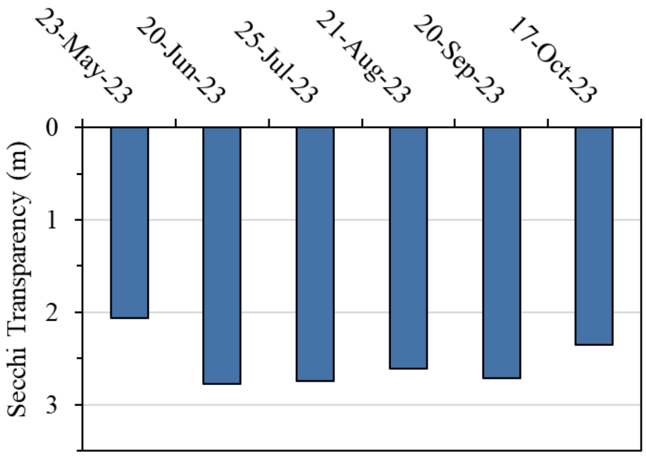

Figure 5. Secchi transparencies at Ball Pond in 2023.

The season minimum Secchi disk transparency was measured in late May at just over 2 meters. By late June and through late September, transparency was 2.6 meters to 2.8 meters. Secchi transparency decreased to 2.35 meters by mid-October (Fig. 5).

The season average was 2.55 meters while the summer average (July – September) was 2.69 meters. These data are characteristic of late-mesotrophic conditions.

## B. Chlorophyll-a Concentrations

Chlorophyll-*a* is the photosynthetic pigment common to all freshwater algae and cyanobacteria and is used as a surrogate measurement for algal biovolume in the water. Concentrations reported here were reflective of the algal productivity in the top three meters of the water column (see Methods).

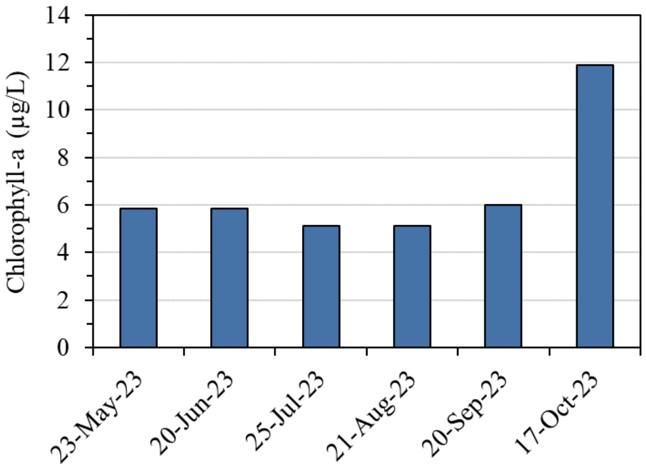

Figure 6. Chlorophyll-*a* concentrations at Ball Pond in 2023.

Chlorophyll-*a* concentrations were very stable from May through September with all concentrations between 5 and 6 µg/L. The mid-October concentration was nearly double that in late September (Fig. 6).

The season averaged chlorophyll-a concentration was 6.6 µg/L. The summer month average was 5.4 µg/L. These data are characteristic of mesotrophic conditions.

## C. Total Phosphorus

Algae and cyanobacteria require a variety of micro- and macronutrients to survive. In freshwater systems, phosphorus is what 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 concentrations began the season relatively high at 20µg/L but by mid-June were at the season low of 7µg/L (Fig 5). Concentrations gradually increased to the season high of 28µg/L by mid-October.

Metalimnetic concentrations were initially low through late June until reaching a season high of 108µg/L in late August. The late September level was more consistent with the corresponding epilimnetic level but by mid-October, was again elevated relative to the epilimnetic levels at 57µg/L.

Apart from the late-August metalimnetic phosphorus concentration, hypolimnetic concentrations were an order of magnitude greater than the concentration in the epilimnetic or metalimnetic strata (Fig. 7). Most hypolimnetic concentrations, including in the late May, were between 400 and 600µg/L. The season high occurred of 680µg/L was measured in the mid-June sample; the season low of 313µg/L was from the mid-October hypolimnetic sample.

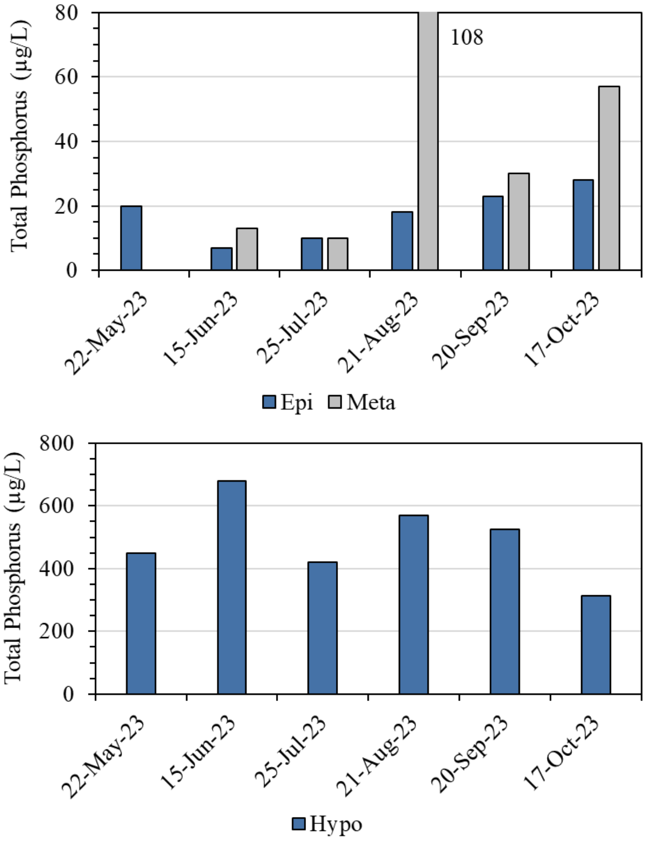

Figure 7. Epilimnetic (Epi) and metalimnetic (Meta) total phosphorus concentrations (top) and hypolimnetic (Hypo) total phosphorus concentrations (bottom) at Ball Pond in 2023.

The differences between the hypolimnetic average of 493µg/L and the averages for the other two strata were highly significant ($p<0.001$). The average for the epilimnion of 17.7µg/L and for the metalimnion of 43.6µg/L were not significantly different ($p>0.05$). The epilimnetic average was consistent with mesotrophic lakes (see Table 1).

## 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.

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.

Epilimnetic total nitrogen levels were modestly higher in May and June than they were in July through October. Those early season epilimnetic levels were 790 and 1,040µg/L. Epilimnetic concentrations in July through October were between 550 and 610µg/L. Metalimnetic concentrations followed a similar pattern with the following exceptions. First, there was no metalimnetic data for May. Secondly, the late-August metalimnetic concentration was nearly 3x that measured in July, September, and October. The epilimnetic and metalimnetic season averages were 690 and 858µg/L, respectively and not significantly different ($p > 0.05$).

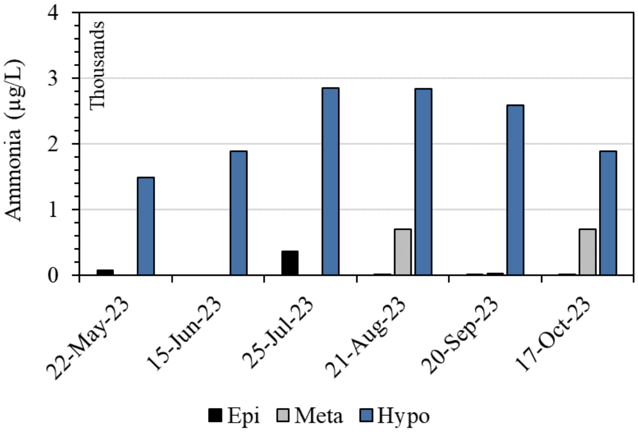

Figure 8. Epilimnetic (Epi), metalimnetic (Meta), and hypolimnetic (Hypo) ammonia concentrations at Ball Pond in 2023.

The differences between the hypolimnetic total nitrogen average of 2,645µg/L and the epilimnetic or metalimnetic averages were highly significant ($p < 0.001$). The hypolimnetic season low of 1,610µg/L occurred in May (Fig. 8). Concentrations rapidly increased to 2,860µg/L by June and were 3,360µg/L in August and September. The concentration decreased by October to 1,880µg/L.

Much of the hypolimnetic total nitrogen was in the form of ammonia (Fig. 8). The hypolimnetic ammonia concentration of 1,480µg/L in May increased up to 2,835µg/L by August. Concentrations decreased to 1,880µg/L by October. Ammonia concentrations in the other strata of the water column were relatively low. On two occasions – August and October – metalimnetic concentrations were 700µg/L. An epilimnetic concentration of 366µg/L was measured in July.

The average epilimnetic total nitrogen concentration of 690µg/L was diagnostic of eutrophic conditions. However, based on total nitrogen to total phosphorus ratios, Ball Pond algal productivity in the epilimnion and metalimnion was phosphorus limited (Table 3).

Limnologists frequently use the Redfield ratio of 16 (16:1 nitrogen to phosphorus) to determine whether nitrogen or phosphorus is limiting in a freshwater system (Redfield 1958). The ratio is molar-based and when converted to mass, 7.2µg/L is the threshold. Values lower than the threshold are indicative of nitrogen limitation while ratios above 7.2µg/L indicate phosphorus limitations. Nitrogen limitation favors cyanobacteria productivity due to the ability of some cyanobacteria to harvest elemental nitrogen dissolved into the water from the atmosphere, aka nitrogen fixation. Other algae taxa do not possess this ability.

Redfield ratios were determined for all dates and strata where nutrient data was available. All ratios from the epilimnetic and metalimnetic were indicative of phosphorus limitation. Hypolimnetic ratios were indicative of nitrogen limitation. Averages for each stratum – epilimnion, metalimnion, and hypolimnion – decreased with depth (Table 3).

Table 3. Total nitrogen to total phosphorus ratios in the epilimnion, metalimnion, and hypolimnion of Ball Pond in 2023.

| Date | **Epilimnion** | **Metalimnion** | **Hypolimnion** |
|---|---|---|---|
| 22-May-23 | 40 | --- | 4 |
| 15-Jun-23 | 149 | 69 | 4 |
| 25-Jul-23 | 57 | 56 | 7 |
| 21-Aug-23 | 32 | 14 | 6 |
| 20-Sep-23 | 27 | 22 | 6 |
| 17-Oct-23 | 20 | 12 | 6 |
| Average | 53.9 | 34.6 | 5.5 |

## VI. Algal Community Dynamics

Algae have been used in ecological assessments for over 100s years (Stevenson 2014). The composition, concentrations, and biomasses of assemblages of algae 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 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 include species from 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.

## B. Algae and Cyanobacteria Cell Concentrations and Relative Abundance

Total algae cell concentrations were lower in May, June, and July, with concentrations ranging from 3,300 cells/mL to 4,800 cells/mL. Of the three, only the May sample contained appreciable concentrations of cyanobacteria, which comprised 46% of all cells counted that month.

The August, September, and October cell concentrations were on average 3x greater than those in the first half of the season. The percentage of those cells in the later half of the season that were cyanobacteria increased and were between 8,300 and 9,500 cells/mL or 64% to 72% of all cells counted (Fig. 9).

Even with the cyanobacteria cell concentration increase in the latter part of the season, all concentrations were still relatively low. 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.

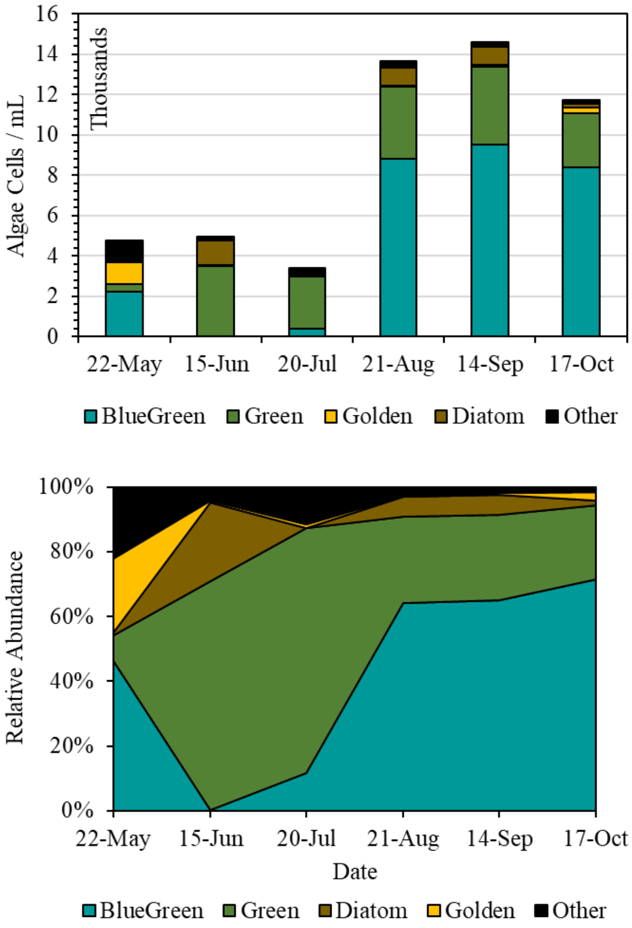

Figure 9. Monthly cell concentrations by taxonomic group (top) and relative abundance of those groups during the 2023 season at Ball Pond.

## C. Algal Taxa and Genera

Forty-three algal genera were identified from the plankton net samples and samples collected for algae counts. Those genera were unequally distributed among seven taxonomic groups. The group with the greatest richness (number of genera) was the Chlorophyta (aka green algae) with 18 genera identified. Cyanobacteria had the next highest richness with 8 genera. Bacillariophyta (aka diatoms) were represented by 7 genera. Four Pyrrhophyta (aka dinoflagellates) and four Chrysophyta (aka golden algae) genera were identified. Euglenophyta and Cryptophyta were represented by one genus each (Table 3).

The filamentous Cyanophyta (aka blue-green algae or cyanobacteria) *Aphanizomenon spp*. was the dominant genus in May (Fig. 9a). The filaments, which are tapered at the ends, are comprised of many cells with the cells on the ends longer than those in the middle. The two other important genera in the May community were the colonial Chrysophyta (aka golden algae) *Uroglenopsis spp*., and the Cryptophyta Cryptomonas spp., which exists as a flagellated unicell (Figs. 9b and 9c, respectively).

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

**CHLOROPHYTA**

*Anikistrodesmus sp.*
*Arthrodesmus sp.*
*Chlamydomonas sp.*
*Closterium sp.*
*Coelastrum sp.*
*Cosmarium sp.*
*Elakatothrix sp.*
*Eudorina sp.*
*Gloeocystis sp.*
*Nephrocytium sp.*
*Oocystis*
*Padorina sp.*
*Pediastrum sp.*
*Scenedesmus sp.*
*Selenastrum sp.*
*Spondylosium sp.*
*Staurastrum sp.*
*Tetraedron sp.*

**CYANOPHYTA**

*Aphanizomenon sp.*
*Aphanocapsa sp.*
*Chroococcus sp.*
*Dolichospermum sp.*
*Lyngbya sp.*
*Planktothrix sp.*
*Snowella sp.*
*Woronichinia sp.*

**BACILLARIOPHYTA**

*Asterionella sp.*
*Aulocoseria sp.*
*Cyclotella sp.*
*Fragilaria sp.*
*Rhizosolenia sp.*
*Synedra sp.*
*Tabellaria sp.*

**CHRYSOPHYTA**

*Dinobryon sp.*
*Mallomonas sp.*
*Synura sp.*
*Uroglenopsis sp.*

**PYRRHOPHYTA**

*Ceratium sp.*
*Glenodinium sp.*
*Gymnodinium sp*
*Peridinium sp.*

**CRYPTOPHYTA**

*Cryptomonas ovata*

**EUGLENOPHYTA**

*Trachelomonas sp.*

By June, the phytoplankton community had shifted to one dominated by Chlorophyta (aka green algae). Of the ten green genera counted, the most abundant was the colonial *Tetraedron spp*. Collectively, the green algae comprised 71% of all cells count. The next highest relative abundance was that of the Bacillariophyta (aka diatoms) at 25%. The most abundant diatom was the colonial *Fragilaria spp*. Cyanobacteria were rare in June.

Cyanobacteria gained in importance by July comprising 12% of all cells counted. The dominant cyanobacteria genus was now the filamentous *Dolichospermum spp*. These filaments are comprised of cells that are larger and rounder than *Aphanizomenon spp*. (Fig. 9x). The July community was still dominated by the green algae which attained its greatest richness with 13 genera counted. The most abundant green algae were the colonial *Scenedesmus spp*. and *Gloeocystis spp*.

The August and September community was similar in that cyanobacteria were the dominant taxon, comprising 64% and 65% of those respective communities. In both months, the green algae were subdominant at 27% of all cells counted each month. *Dolichospermum spp*. was the most abundant genus in August and important in September. However, by September another filamentous cyanobacterium, *Planktothrix spp*., was the most abundant.

Dominance by cyanobacteria at 71% of all cells counted and sub-dominance by green algae at 23% of all cells counted continued into October.  Severn different cyanobacteria genera were counted with *Planktothrix spp.* the most abundant, and followed in importance by *Aphanizomenon spp*. Twelve different green algae genera were counted with the most abundant *Coelastrum spp*. and *Scenedesmus spp*.

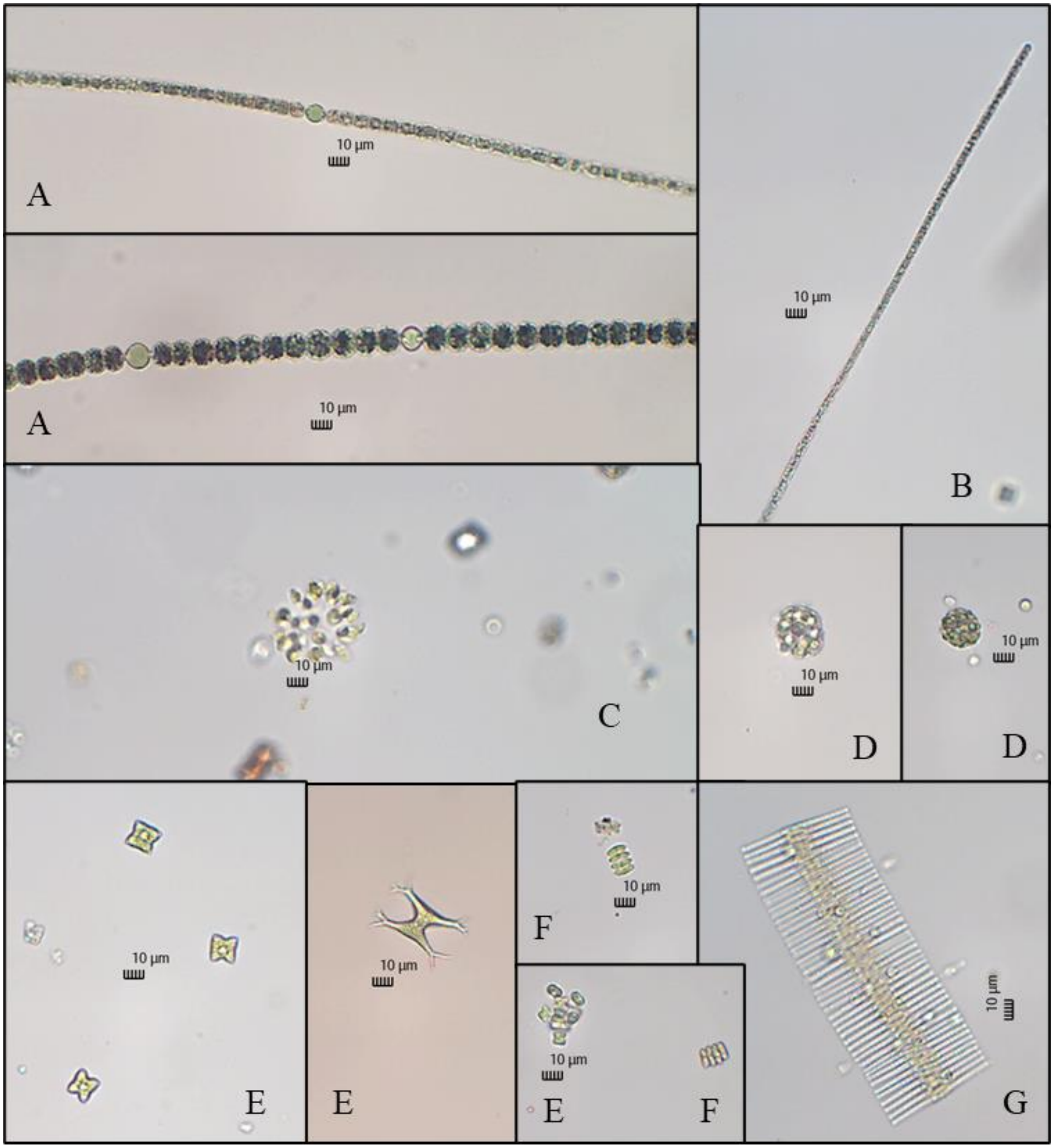

Figure 10. Micrographs of cyanobacteria and algae specimens collected from Ball Pond in 2023. Cyanobacteria A) *Dolichospermum spp*.; and B) *Planktothrix spp*.; C) the Chrysophyta *Uroglenopsis spp*.; Chlorophyta D) Coelastrum spp., E) Tetraedron spp., F) Scenedesmus spp.; and G) the Bacillariophyta *Fragilaria spp*. Total magnification for all images was 400X. Scale bars are a total of 10µm.

Details on the algae communities can be found in Appendix B. Micrographs of specimens collected at Ball Pond in 2023 and discussed above are provided in Figures 10.

### D. Cyanobacteria Spatial and Temporal Distribution

In the same way chlorophyll-*a* is used as a surrogate for total algae biomass, phycocyanin provides a means of assessing cyanobacteria biomass. Phycocyanin is an auxiliary photosynthetic pigment unique to the cyanobacteria and relative concentrations were measured 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.

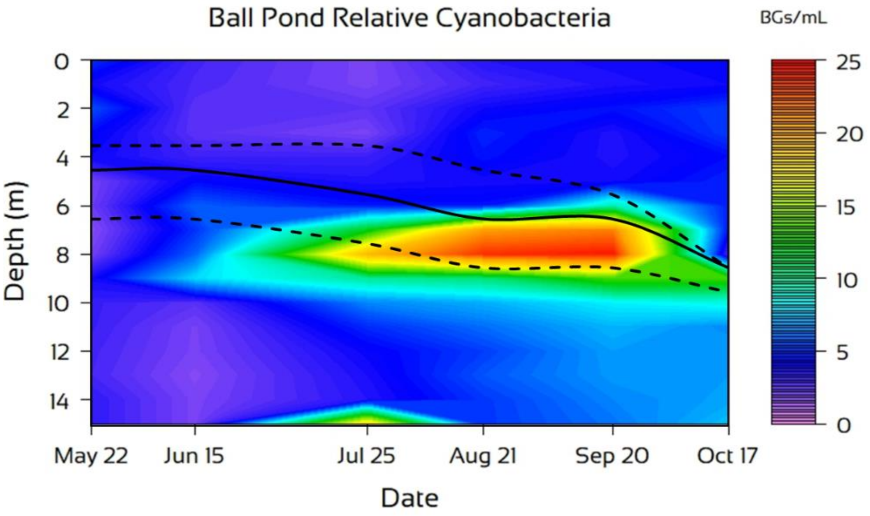

Figure 11. Relative phycocyanin concentration isopleth chart for the Ball Pond water column in 2023. The dashed lines represent the position of the upper and lower metalimnetic boundaries; the solid black lines represent the position of the thermocline.

The genera of cyanobacteria discussed above can regulate buoyancy, i.e., selectively position themselves in the water column. Because of that, we examined the spatial and temporal distribution throughout the water column by creating isopleths chart for each site using measurements taken with the fluorimeter on each sampling event (Fig. 11).

Relative cyanobacteria biomass was low in the epilimnion all season, with lowest levels in June and July. Indications of higher relative concentrations at depth were first observed in mid-June when levels at 9 meters of depth were elevated relative to levels above and below that. From late July through mid-October, the area between the thermocline and the lower metalimnetic boundary was the site of the very high relative cyanobacteria biomass.

Highest relative levels occurred in August and September and were situated between 6 and 8 meters of depth (Fig. 10). Levels within the metalimnion decreased some by mid-October but were will high in comparison to epilimnetic levels. Hypolimnetic concentrations increased modestly after late August.

## VII. Water Chemistry

### 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., June-Wells et.al. 2013, Siver 1993, McMaster & Schindler 2005). As was done with temperature and oxygen profile data, specific conductance data have been displayed as an isopleth chart (Fig. 12).

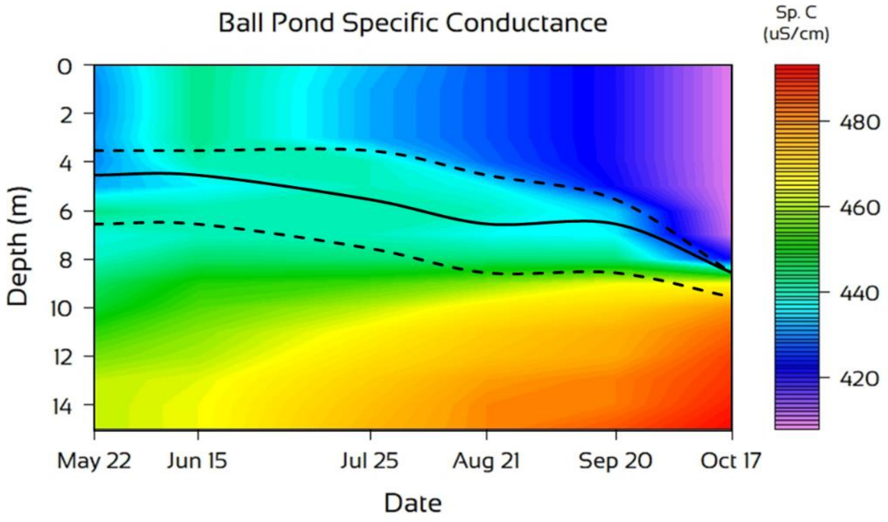

Figure 12. Specific conductance isopleth chart for the Ball Pond water column in 2023. The dashed lines represent the position of the upper and lower metalimnetic boundaries; the solid black lines represent the position of the thermocline.

Specific conductance in the epilimnion of Ball Pond in 2023 was measured between 409 and 443 µS/cm and averaged 424 µS/cm for the season. These are likely some of the highest specific conductance levels in the State of Connecticut (Canavan and Siver, 1995). Highest epilimnetic levels were measured in mid-June and the lowest measured in mid-October (Fig. 12).

Metalimnetic levels were measured between 430 and 464 µS/cm and averaged 440 µS/cm for the season. Most of the measurements were between 435 and 445 µS/cm. Beginning of the season and the end of the season were when the metalimnetic season lows and highs occurred, respectively.

The greatest variability in specific conductance occurred in the hypolimnion where season lows of 438 to 440 µS/cm were recorded in late May and mid-June, and season highs of 490 and 492 µS/cm were recorded in mid-October. The hypolimnetic average was 466 µS/cm. Spatial differences within the hypolimnion were more distinct than those observed in the other layers. Hypolimnetic specific conductance notably increased with depth up through late September. By mid-October most of the hypolimnion had levels of 487 to 492 µS/cm.

### 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 cellular respiration in the anoxic lake sediments, and denitrification of nitrate to elemental nitrogen (Wetzel 2001). For purposes of assessing alkalinity and comparing it between strata and sites, the unit of measure reported by the laboratory, i.e., mg/L, was used.

Epilimnetic alkalinity was higher in the first three months of the season, with levels between 82 and 86 mg/L (Fig. 13). Epilimnetic levels were lower in the latter half of the season, with levels between 59 and 65 mg/L. The season average was 73 mg/L.

The average metalimnetic concentration of 75 mg/L was not significantly different from the epilimnetic average ($p>0.05$). Measures at the two strata were most similar in June and July, and more different from August through October.

Hypolimnetic levels were greater than those at the other strata on each sampling event. The hypolimnetic average of 95 mg/L was significantly greater than the epilimnetic and metalimnetic averages ($p<0.05$). Hypolimnetic levels decreased from 100 mg/L in late July to 82 mg/L by mid-October.

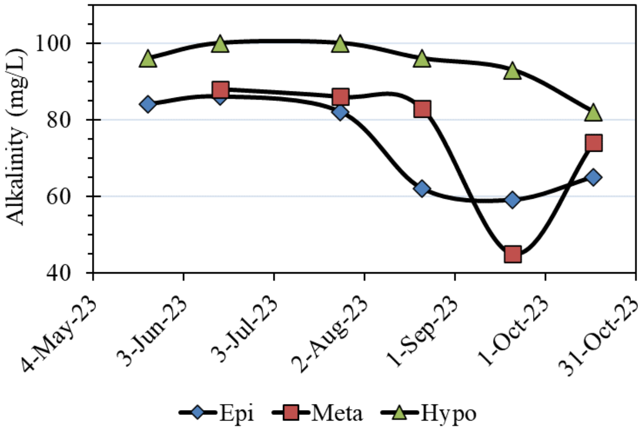

Figure 13. Alkalinity in the epilimnion (Epi), metalimnion (Meta), and hypolimnion (Hypo) of Ball Pond in 2023.

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 in that 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 late-May level of 8.6 increased to 9.1 mid-June before returning to 8.6 by late July. Levels modestly decreased to 8.4 by late September before attaining a season high of 9.4 by mid-October. The season average was 8.8.

Hypolimnetic pH levels were marginally higher and followed a similar pattern with higher early season levels decreasing with time but with no late season increase (Fig. 14). The season hypolimnetic average was 9.0.

Whereas average epilimnetic and hypolimnetic pH levels were not significantly different, the metalimnetic average of 7.7 was significantly lower than the other averages ($p<0.05$). Early season metalimnetic levels of 7.9 and 8.0 decreased through late September to 7.4 before increasing to 7.8 by mid-October.

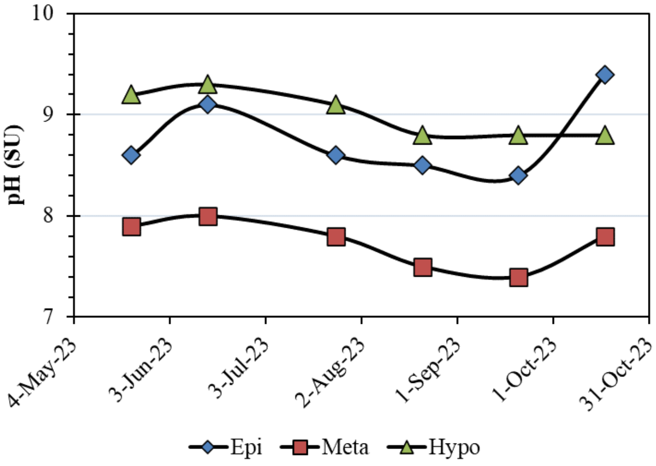

Figure 14. Epilimnetic (Epi), metalimnetic (Meta) and hypolimnetic (Hypo) pH in standard units (SU) at Ball Pond in 2023.

## C. Base Cations and Anions

Base cation and anion concentrations are important in understanding natural influences (e.g., dissolved salts from bedrock geology) as well as anthropogenic influences in the watershed (e.g., road salts). In most lakes, the dominant base cations in lake waters are calcium ($Ca^{2+}$), magnesium ($Mg^{2+}$), sodium ($Na^{+}$) and potassium ($K^{+}$). Dominant anions include chloride ($Cl^{-}$), sulfate ($SO_4^{2-}$), and the alkalinity ions, i.e., carbonate ($CO_3^{2-}$), and bicarbonate ($HCO_3^{-}$). Those cations and anions are what collectively create much of the conductivity levels in lake water. The ratios and other characteristics of those ions can be diagnostic when compared to other lakes, and when compared to levels in the same lake over time.

The laboratories which conducted the analyses reported results on a mass basis (mg/L). We converted those to their electrochemical equivalents or milliequivalents (meq/L).[1] Those were calculated by dividing the measured mass of an ion by its equivalent weight. This provides a meaningful accounting for ionic charge (positive or negative). Accounting for electric charge can be preferable when comparing ion levels to other electrochemical

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[1] See https://en.wikipedia.org/wiki/Equivalent_weight

characteristics of lake water, e.g., specific conductance. Ion levels are reported below in both mass and milliequivalents below.

Table 5. Base cations potassium (K+), sodium (Na+), calcium (Ca2+), magnesium (Mg2+), and anions chloride (Cl-) and alkalinity (Alk). Levels are reported in mass (mg/L) and in milliequivalents (meq/L).

| **Date** | **$K^+$** | | **$Na^+$** | | **$Ca^{2+}$** | |
|---|---|---|---|---|---|---|
| | **mg/L** | **meq/L** | **mg/L** | **meq/L** | **mg/L** | **meq/L** |
| 22-May-23 | 2.2 | 0.06 | 37.7 | 1.6 | 21.3 | 1.1 |
| 15-Jun-23 | -- | -- | 42.9 | 1.9 | 22.8 | 1.1 |
| 25-Jul-23 | 2.4 | 0.06 | 44.2 | 1.9 | 23.7 | 1.2 |
| 21-Aug-23 | 2.6 | 0.07 | 34.7 | 1.5 | 22.3 | 1.1 |
| 20-Sep-23 | 2.7 | 0.07 | 37.8 | 1.6 | 24.3 | 1.2 |
| Average | 2.5 | 0.06 | 39.5 | 1.7 | 22.9 | 1.1 |

| **Date** | **$Mg^{2+}$** | | **$Cl^-$** | | **Alk** | |
|---|---|---|---|---|---|---|
| | **mg/L** | **meq/L** | **mg/L** | **meq/L** | **mg/L** | **meq/L** |
| 22-May-23 | 7.2 | 0.6 | 77.7 | 2.2 | 84 | 1.68 |
| 15-Jun-23 | 7.9 | 0.7 | 82.0 | 2.3 | 86 | 1.72 |
| 25-Jul-23 | 8.3 | 0.7 | 74.6 | 2.1 | 82 | 1.64 |
| 21-Aug-23 | 7.7 | 0.6 | 86.3 | 2.5 | 62 | 1.24 |
| 20-Sep-23 | 8.2 | 0.7 | -- | -- | 59 | 1.18 |
| Average | 7.9 | 0.7 | 80.2 | 2.3 | 74.6 | 1.49 |

There was little variability over the season for each of the base cations (Table 4). Chloride and alkalinity exhibited a little more seasonality but overall were seasonally stable. On a milliequivalent basis, chloride followed by sodium were the biggest contributors to the ionic concentrations and specific conductance in the epilimnion of Ball Pond.

Although not as high as sodium levels, calcium concentrations at Ball Pond were high relative to other lakes (Canavan and Siver 1994).

## VIII. Cyanobacteria Blooms at Ball Pond

Although not part of this monitoring effort, we do receive reports and corroborating photographs from community volunteers of cyanobacteria blooms along the northeastern shoreline (Fig. 15) and just to the west of the State Boat Launch. In 2023, much of that reporting occurred in September and October. We believe circumstances contributing to these events are tied to the physical, chemical, and biological properties of Ball Pond that were described above in monitoring program results, and below in our assessment.

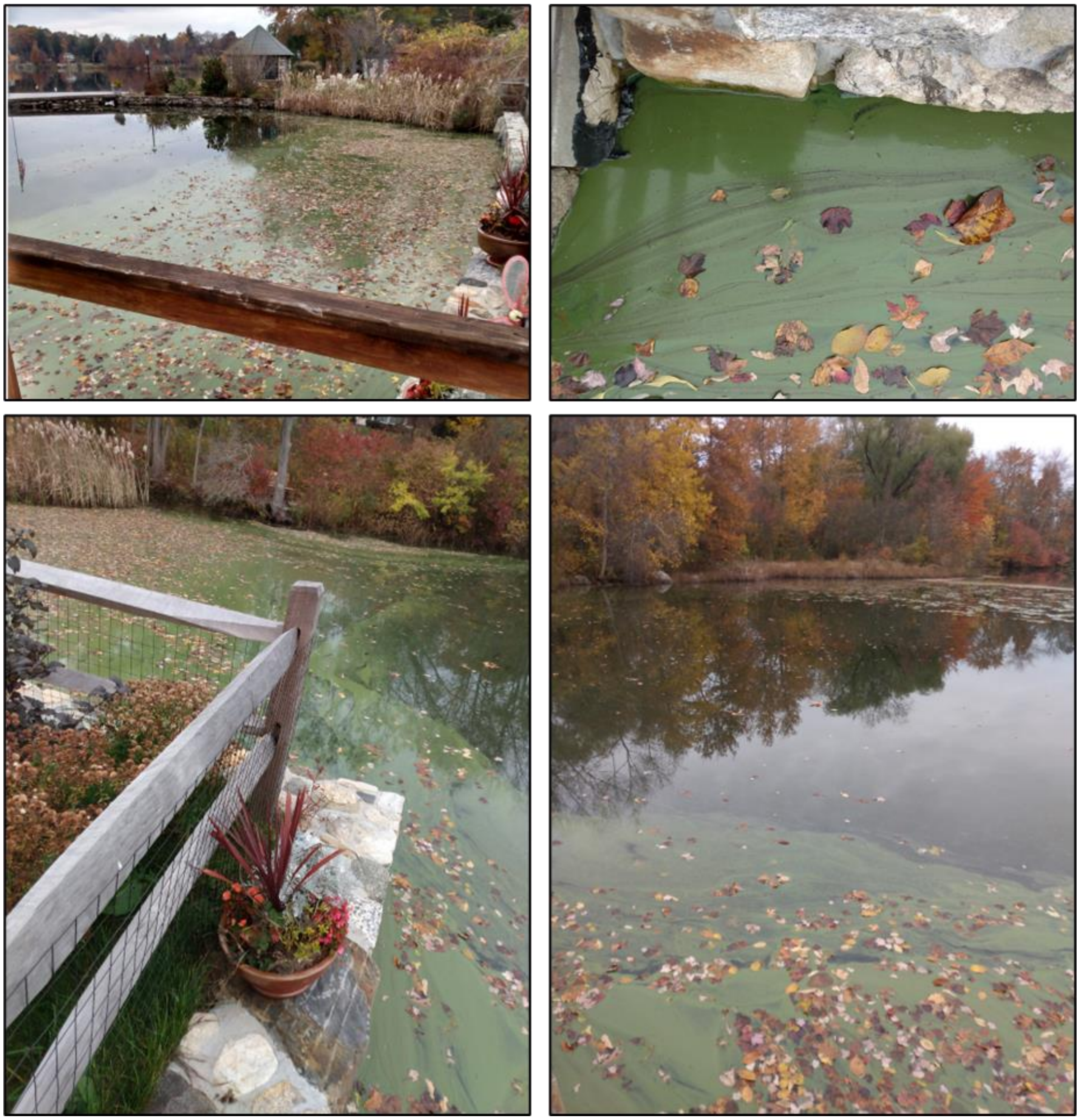


Figure 15. Photographs of a surface bloom of cyanobacteria in October of 2023 along the shoreline in the vicinity of the outlet to Ball Pond Brook. Photographs courtesy of E. Johnson.

### A. Physical and Biochemical Contributors

Ball Pond is relatively small but deep, and much of the bottom is steep sided. The monitoring site, i.e., the deepest site on the lake, is centrally located. These characteristics contribute to the physical process of early stratification with strong resistance to mixing.

There appears to be a substantial hypolimnetic oxygen demand or sediment oxygen demand at Ball Pond. This is evidenced by the volume of water that is anoxic early in the season. An anoxic hypolimnion was also encountered on May 18th of 2022. Hypolimnetic oxygen in 2022 appeared to be depleted quickly between April 20th and May 18th (Fig. 16). The 2021 season exhibited similar conditions.

This protracted period of anoxic conditions in the hypolimnion results in the reduction of chemical compounds in the processes of anaerobic respiration. Resultingly, hypolimnetic specific conductance increases; alkalinity increases; ammonia increases; and perhaps most importantly, phosphate increases.

Based on phosphorus concentrations throughout the water column and the volumes of water delineated by the upper and lower metalimnetic boundaries during the season, we will attempt in the future to create a phosphorus mass balance model for the Ball Pond water column. Currently, the model would assume equal concentration throughout a stratum. For example, we reported a hypolimnetic phosphorus concentration in August of 57μg/L in a hypolimnion that extended from the bottom (approximately 14 meters) to 9 meters of depth. It is conceivable that concentrations decreased at progressively higher levels of the hypolimnion, but equally conceivable that upper hypolimnetic concentrations were still elevated relative to epilimnetic levels.

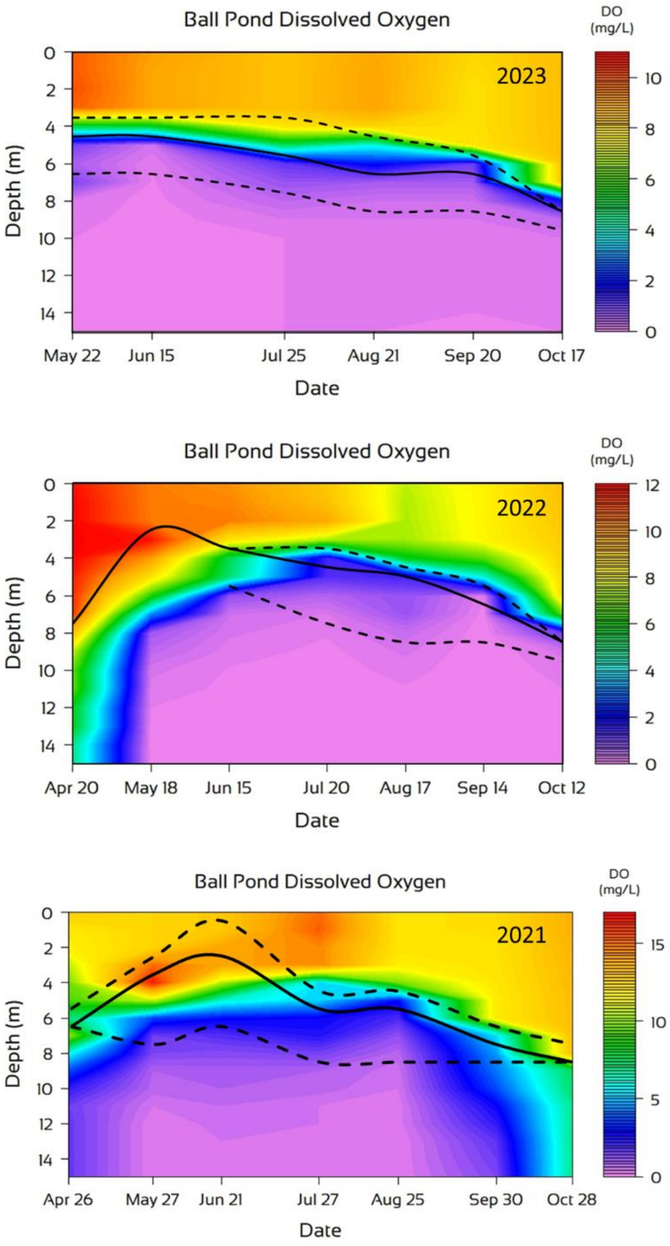


Figure 16. Oxygen isopleth diagrams for the 2023 (top), 2022 (middle), and 2021 (bottom) seasons.

### B. Coprecipitation Contributor

We hypothesize that another chemical process may be contributing to the very high hypolimnetic phosphorus concentrations. In our 2021 report, we discussed the process of coprecipitation of phosphorus in the epilimnion. In lakes with high epilimnetic calcium levels and pH, both characteristic of Ball Pond, phosphorus can bind with calcium carbonate and precipitate out of the epilimnion. This reduces the phosphorus available for algae growth in the epilimnion.

Another noteworthy characteristic of Ball Pond is the higher hypolimnetic pH relative to epilimnetic pH. In most lakes, the epilimnetic pH is higher due to carbon being harvested out of the water by algae, thus reducing levels of carbonic acid. At Ball Pond, this is not the case and may be related to coprecipitation. It is conceivable that the phosphorus-calcium carbonate precipitate sinks to the lower depths of the water column and, when in the reduced/anoxic environment, converts back into a soluble state. This would drive the pH up as carbonate and bicarbonate form, and release phosphate to those bottom waters.

The high hypolimnetic phosphorus levels are likely important to the cyanobacteria bloom-like conditions observed below the thermocline after late July (Fig. 11). As noted earlier, several genera of cyanobacteria can regulate buoyancy which is how highly concentrated layers form. Auxiliary photosynthetic pigments of cyanobacteria, including phycocyanin, provide an adaptive advantage over other algae in that those pigments allow photosynthesis to occur at deeper depths after much of the light has been filtered out. With the ability to photosynthesize at deeper depths, the cyanobacteria can take advantage of higher phosphorus concentrations of the hypolimnion.

### C. Compensation Point Contributor

Above, we discussed the concept of the *Compensation Point* (see Secchi Transparency). The position of the *Compensation Point* (2x the depth of Secchi disk transparency) relative to the positions of the metalimnion and/or thermocline can also be an important variable in the understanding the vertical position of cyanobacteria in the water column and the potential stimulation of cyanobacteria growth. Kortmann (2015) predicted good water quality and no stimulation of cyanobacteria productivity if the *C*ompensation Point was below the metalimnion. However, if the Compensation Point was located within the metalimnion, a layer of cyanobacteria could form within that stratum. In the final

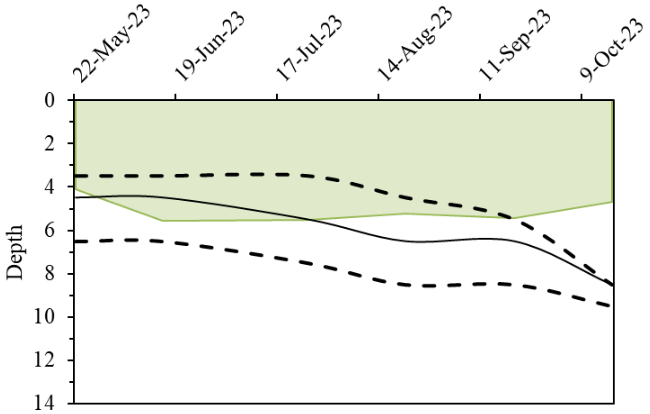


Figure 17. The depth of the Compensation Point (green area) relative to the stratification of the Ball Pond water column in 2023. The dashed lines represent the position of the upper and lower metalimnetic boundaries; the solid black lines represent the position of the thermocline.

theoretical scenario, growth of cyanobacteria that can regulate buoyancy could be stimulated if the Compensation Point was observed within the upper, mixed epilimnetic layer.

At Ball Pond in 2023, the Compensation Point was within the metalimnetic boundaries all season except in mid-October (Fig. 17). Kortmann's model (2015) for cyanobacteria productivity was applicable at Ball Pond.

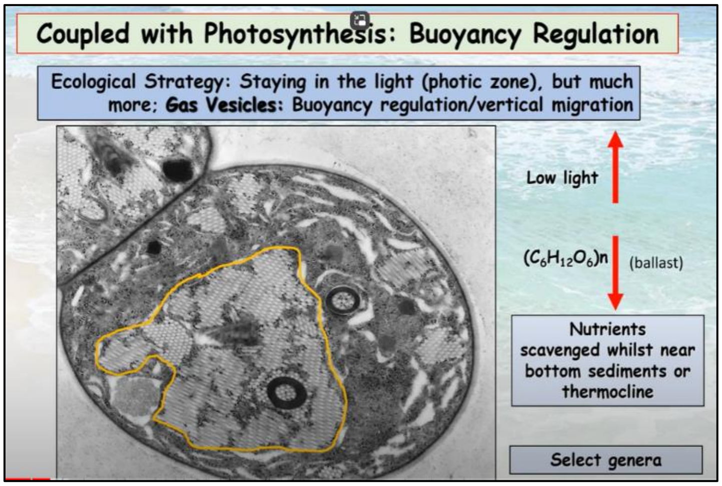
### D. Cyanobacteria Life Processes

As noted earlier, some genera of cyanobacteria can regulate buoyancy. They do that by the formation of gas vesicles within the cells which make them positively buoyant and keeps cells within range of light for photosynthesis. The synthesis of sugars through the process of photosynthesis creates the ballast or makes them negatively buoyant to sink to depths that are nutrient rich (Fig 18).

Some cells will become positively buoyant and reach the surface without creating the ballast to remain submerged. Depending on wind strength and direction, the cyanobacteria colonies and/or filaments can be "swept" into the downwind shoreline or cove (Fig. 19). We hypothesize this is how shoreline blooms form along the shore of Ball Pond.

## IX. Historical Change and Dissolved Salts

As discussed, historical water quality data for Ball Pond had been collected over the last 86 years as part of State-wide surveys of Connecticut Lakes. We have compiled that data along with that collected in the last three years below (Table 6). Those data suggest that algal productivity, i.e. the trophic level of the lake, has not notably changed.



**Coupled with Photosynthesis: Buoyancy Regulation**

Ecological Strategy: Staying in the light (photic zone), but much more: **Gas Vesicles:** Buoyancy regulation/vertical migration

Low light

$(C_6H_{12}O_6)n$ (ballast)

Nutrients scavenged whilst near bottom sediments or thermocline

Select genera

Figure 18. Transmission electron micrograph of a cell of cyanobacteria highlighting the gas vesicles. This slide was from the presentation by Dr. Barry Rosen entitled *Cyanobacteria: What you Need to Know – Part 1: Cyanobacteria Biology and Toxin Formation.* https://www.youtube.com/watch?v=eaUp178DXFQ

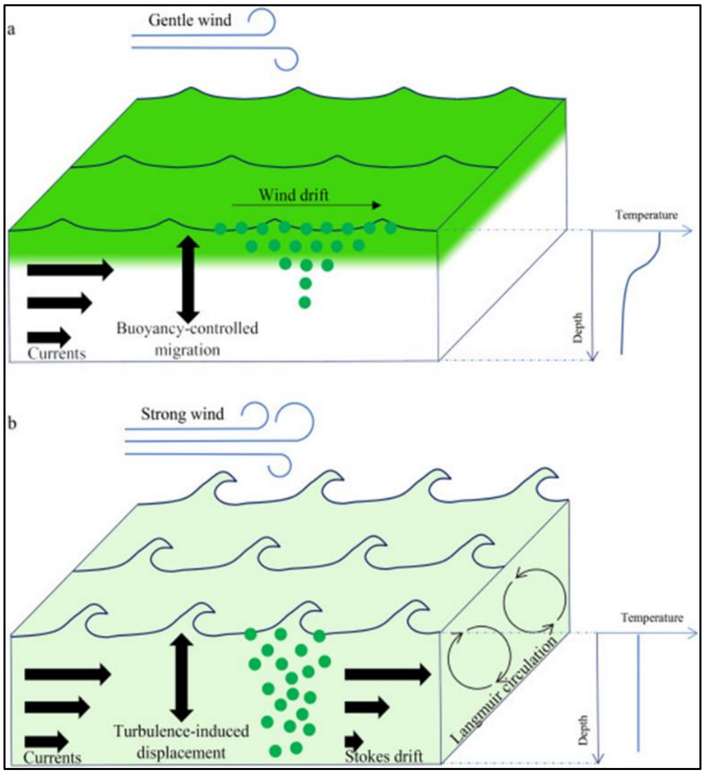


Figure 19. Illustrations of vertical migration and lateral movement of cyanobacteria in different wind speeds. From *Individual-based modelling of cyanobacteria blooms: Physical and physiological processes* (Ranjbar et.al 2021).

Average total phosphorus and total nitrogen levels, chlorophyll-*a* concentrations, and Secchi disk transparency don't appear to be trending up or down.

Table 6. Average water quality characteristics of Ball Pond in the last 1930s (Deevey 1940), 1980 (Frink and Norvell 1984), 1993 (Canavan and Siver 1994), 2021 & 2022 (AER 2022, 2023), and in 2023 (Brawley Consulting Group).

| **Parameter** | **Units** | **2023** | **2022** | **2021** | **1993** | **1980** | **1937-9** |
|---|---|---|---|---|---|---|---|
| Total Nitrogen | µg/L | 690 | --- | 734 | --- | 716 | --- |
| Total Phosphorus | µg/L | 18 | 13 | 34 | 22 | 30 | 14 |
| Chlorophyll-*a* | µg/L | 6.6 | 6.8 | 6.5 | 5.0 | 3.0 | 5.5 |
| Secchi Disk | meters | 2.6 | 2.7 | 2.4 | 2.6 | 1.9 | 2.7 |
| pH | SU | 8.8 | 8.9 | 9.0 | 8.7 | --- | --- |
| Sp. Conductance | µS/cm | 427 | 413 | 417 | 283 | --- | --- |
| Alkalinity | mg/L | 73 | 84 | 82 | 64 | 52 | 28 |
| Chloride ($Cl^-$) | mg/L | 80.2 | 77.6 | --- | 42.2 | --- | --- |
| Calcium ($Ca^{2+}$) | mg/L | 22.5 | 24.4 | 24.1 | 19.7 | 19.6 | --- |
| Magnesium ($Mg^{2+}$) | mg/L | 7.8 | 8.1 | --- | 6.6 | 5.6 | --- |
| Sodium ($Na^+$) | mg/L | 39.9 | 44.6 | --- | 24.6 | 9.2 | --- |
| Potassium ($K^+$) | mg/L | 2.4 | 2.7 | --- | 2.7 | 2.0 | --- |

What did notably change, and appears to still be trending up, are specific conductance levels and the concentrations of ions that determine specific conductance levels in lakes. Since 1990, specific conductance has increased by approximately 50%.

To quantify ion changes in that same period, we determined the percent change for the base cations, chloride, and the alkalinity ions between 1990 levels and 2022/2023 averages (Fig. 20). All ion levels, except potassium, increased. Calcium, magnesium, and alkalinity all increased between 19 and 23%. Sodium and chloride concentrations increased by 71 and 67%, respectively. While the increase in all cations (excluding potassium), and anion contributed to increased specific conductance, it was sodium and chloride that influenced the increase the most.

The nearly 1:1 sodium and chloride increase implicates the increasing use of deicing salts on roads. The trend of increasing specific conductance, sodium and chloride levels in lake water is widespread in the Northeast and in snowbelt regions of the country, has been attributed to the increased use of deicing salts on roads, and is a growing management concern for lakes (Kelly et. al. 2019). Increased salts can alter the biota, and in deeper lakes accumulate at the bottom, impeding or preventing complete turnover because of the elevated density of the “saltier” water. This could create a condition where full oxygenation of bottom waters could be prevented.

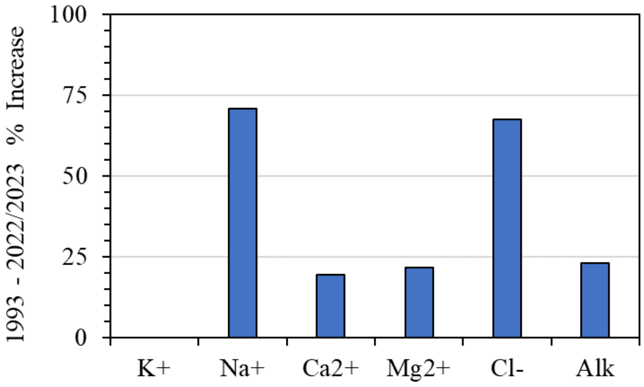


Figure 20. Percent change concentrations of base cations potassium (K+), sodium (Na+), calcium (Ca2+), magnesium (Mg2+), chloride (Cl-), and the alkalinity ions (Alk) between 1993 and 2022/2023 averages.

Although the ions other than sodium and chloride have not increased as much, the increasing calcium levels do present a lake management problem, i.e. the potential for colonization by zebra mussels (*Dreissena polymorpha*). Calcium has been considered a limiting nutrient for colonization of zebra mussels. Whitter et.al. (2008) characterized waters with calcium levels of 20 to 28 mg/L as having moderate risk for zebra mussel invasion. Ball Pond calcium levels are withing that range and zebra mussels are not established in nearby Candlewood Lake.

## X. Recommendations

### A. Deicing Salts

We recommend that the BPAC review the web pages of the Carey Institute on road salts at https://www.caryinstitute.org/our-expertise/freshwater/road-salt. There, a report entitled *Road Salt: The Problem, The Solution, and How to Get There* can be downloaded and reviewed. 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*.” 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 BPAC. Mitigation of salt pollution in those and other educational materials focuses on better road salting practices. From there, planning on how to reduce salt concentrations used in the Ball Pond watershed should be undertaken.

### B. Zebra Mussels

Zebra mussels are introduced into new lakes several ways including on watercraft that have been in infected waterbodies and then used in non-infected waterbodies. Federal and state governments agencies, including the Connecticut Department of Energy and Environmental Protection, have developed aquatic invasive species educational materials that focus on the concept of CLEAN – DRAIN – DRY (CT DEEP 2024). To summarize, all watercraft and trailers that have been in infected waters should be inspected for zebra mussels and other invasive species and cleaned. All water that has collected in the vessel should be drained, including that in bilges, wells, tanks, buckets, etc. Lastly, the vessel, trailer, and associated equipment should be allowed to dry for five days before launching in a new lake or pond.

An informational / educational program on preventing the introduction of zebra mussels and other aquatic invasive species is recommended. This could entail the use of social media or print media, e.g., the Town Tribune. Materials already exist at Federal and State government websites and could be used for local efforts. Educating the community on what zebra mussels look like is also important (Fig. 21). Being able to identify a zebra mussel can result in early detection which can lead to a rapid response.

Developing monitoring programs and a rapid response plan for zebra mussels should also be considered. Inexpensive and easy to make zebra mussel settling samplers could be made, deployed around the lake from docks, and maintained by the community (e.g., see MDNR 2018). A rapid response plan details what steps need to be taken to prevent an introduction and what steps should be taken if zebra mussels were found in Ball Pond. The Invasive Mussel Collaborative website provides great resources for finding existing plans and creating your own (IMC 2018).


**Photo from the United Water Conservation District**
**unitedwater.org**

Figure 21. Zebra mussels with a dime to provide size context.

## C. Cyanobacteria Blooms

Traditionally, responsive measures for cyanobacteria blooms were copper sulfate treatments. When the algicide was released, it worked by breaking down the cells walls of the cyanobacteria. If a bloom was toxic, then those toxins were released directly into the water. The more efficient means of managing cyanobacteria blooms uses a preventative approach.

Recommendations have been proposed in past reports that are still applicable today and we have reproduced recommendations from the 2022 report in Appendix C. Those included:

- Community Bloom Watch on Ball Pond
- Modification of the Cyanotoxin Monitoring Program
- Understanding Phosphorus Levels Below the Thermocline
- Sediment Phosphorus Fractions

A formalized *Community Bloom Watch Program* would develop data to confirm or negate our theory on cyanobacteria blooms at Ball Pond. It would also work hand in hand with the *Modification of the Cyanotoxin Monitoring Program*. There we have recommended testing toxin levels in the concentrated surface scums that form during the blooms.

Understanding *Phosphorus Levels below the Thermocline* is still an important recommendation and would help in understanding the high concentrations of cyanobacteria below the thermocline. In addition to measuring total phosphorus at additional depths in the hypolimnion, we would recommend adding soluble reactive phosphorus (phosphate) to analyses performed in samples from the epilimnion, metalimnion, and hypolimnion. This would shed light on the coprecipitation process and its potential to contribute to hypolimnetic phosphorus discussed above.

A *Sediment Phosphorus Fractions* study would be the first of two studies undertaken in preparation for an alum treatment. Alum is a product that is used in the area where anoxic waters are observed. At Ball Pond, these are any areas deeper than 5 meters. As it sinks to the bottom, it strips phosphorus out of the water column. It then forms a floc on the bottom that prevents the loading of phosphorus from the sediments into overlying waters for up to 15 years.

Alum treatments are effective but expensive. Based on recent work at another client lake and extrapolating for differences in treatment areas, we estimate the costs for a treatment at Ball Pond in the $250,000 to $300,000 dollar range. The Sediment Phosphorus Fraction study and a alum titration study with Ball Pond sediments would aid in narrowing down the costs. For more information, see The Use of Alum for Lake Management on the website of the North American Lake Management Society (https://www.nalms.org/nalms-position-papers/the-use-of-alum-for-lake-management/).

### D. Preventative Algicide Treatments

In recent years, researchers have experimented with preventative algicide treatment rather than reactive copper sulfate treatments. The new approach incorporates the life cycle of bloom-forming cyanobacteria into the treatment strategy. Bloom-forming cyanobacteria overwinter in the sediments of lakes as specialized cells or in some cases as vegetative cells. In the spring when light and temperature regimes change, those cells “germinate” giving rise to the summer population (Fig. 22). This approach lessens the community before going into the rapid growth phase, and in the case of Ball Pond, descend below the thermocline. We will continue to monitor this work and determine if it might be an appropriate approach at Ball Pond.

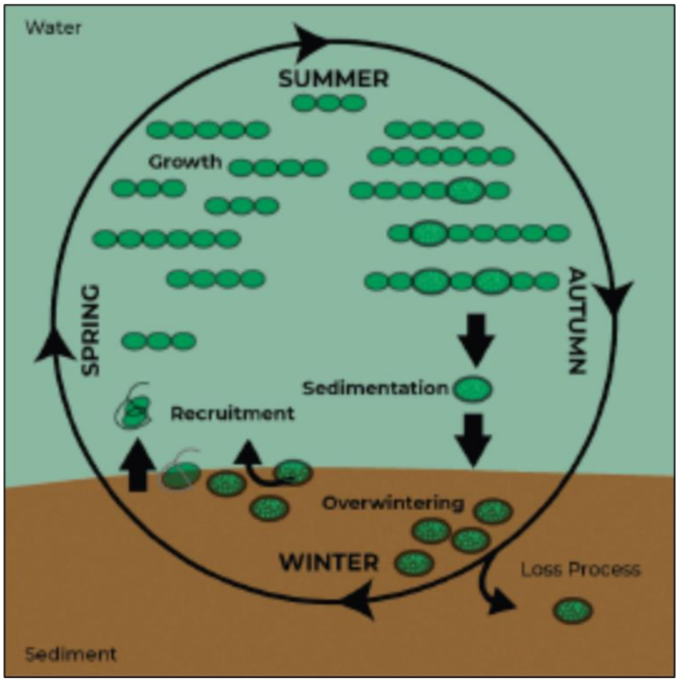


Figure 22. Lifecycle of cyanobacteria from Identification and Preventative Treatment of Overwintering Cyanobacteria in Sediments (Calomeni et.al. 2022).

### E. Monitoring Program

We encourage the BPAC to continue the water quality monitoring program. Because of the consistency of the ion data collected, we believe analyses of potassium, sodium, calcium, magnesium, and chloride can be reduced to three times each year as opposed to monthly as it currently stands.

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## Appendix A. Water Quality Data

Temp = Temperature; DO = Dissolved Oxygen; Rel Phyco = relative phycocyanin; Spec C = specific conductance; ORP = oxidation-reduction potential; Alk = Alkalinity; Epi = epilimnion; Meta = met-alimnion; Hypo = hypolimnion

**May 22, 2023**

| Depth | Temp | DO mg/L | DO % | BGs | Spec C | pH |
|---|---|---|---|---|---|---|
| 0.5 | 18.08 | 9.93 | 109.6 | 5 | 431 | 8.81 |
| 1 | 18.03 | 9.96 | 109.8 | 3.88 | 430 | 8.85 |
| 2 | 17.83 | 10.07 | 110.6 | 5.49 | 430 | 8.87 |
| 3 | 17.75 | 9.91 | 108.6 | 4.36 | 431 | 8.81 |
| 4 | 14.54 | 4.96 | 50.8 | 3.99 | 430 | 7.86 |
| 5 | 11.03 | 0.95 | 9 | 2.2 | 432 | 7.54 |
| 6 | 8.7 | 0.53 | 4.7 | 2.33 | 443 | 8.42 |
| 7 | 7.43 | 0.88 | 7.7 | 1.86 | 438 | 8.37 |
| 8 | 7 | 0.18 | 1.6 | 2.23 | 440 | 8.23 |
| 9 | 6.78 | 0.14 | 1.2 | 3.87 | 445 | 8.31 |
| 10 | 6.61 | 0.1 | 0.8 | 3.27 | 448 | 8.68 |
| 11 | 6.54 | 0.08 | 0.7 | 3.25 | 453 | 8.93 |
| 12 | 6.47 | 0.07 | 0.6 | 3.07 | 457 | 9.11 |
| 13 | 6.43 | 0.06 | 0.5 | 3 | 461 | 9.24 |
| 14 | 6.42 | 0.05 | 0.4 | 3.43 | 461 | 9.3 |

## June 15, 2023

| Depth | Temp | DO mg/L | DO % | BGs | Spec C | pH |
|---|---|---|---|---|---|---|
| 0.5 | 21.02 | 9.18 | 107.4 | 3.07 | 443 | 9.18 |
| 1 | 21.01 | 9.1 | 106.5 | 2.95 | 443 | 9.05 |
| 2 | 20.98 | 9.1 | 106.4 | 2.66 | 443 | 8.98 |
| 3 | 20.94 | 9.1 | 106.4 | 2.66 | 443 | 8.9 |
| 4 | 18.72 | 5.28 | 59 | 3.15 | 441 | 8 |
| 5 | 12.76 | 0.25 | 2.4 | 4.32 | 436 | 7.49 |
| 6 | 9.04 | 0.11 | 1 | 5.8 | 441 | 7.52 |
| 7 | 7.79 | 0.08 | 0.7 | 4.99 | 440 | 7.56 |
| 8 | 7.2 | 0.06 | 0.5 | 5.84 | 445 | 8.6 |
| 9 | 6.87 | 0.05 | 0.4 | 7.86 | 452 | 8.9 |
| 10 | 6.69 | 0.04 | 0.3 | 2.66 | 455 | 9.19 |
| 11 | 6.62 | 0.04 | 0.3 | 2.17 | 458 | 9.25 |
| 12 | 6.58 | 0.04 | 0.3 | 2.14 | 460 | 9.28 |
| 13 | 6.54 | 0.04 | 0.3 | 1.93 | 463 | 9.26 |
| 14 | 6.51 | 0.04 | 0.3 | 2.11 | 464 | 9.27 |

## July 25, 2023

| Depth | Temp | DO mg/L | DO % | BGs | Spec C | pH |
|---|---|---|---|---|---|---|
| 0.5 | 27.21 | 8.5 | 107.3 | 2.1 | 433 | 8.58 |
| 1 | 26.96 | 8.5 | 107 | 2.1 | 432 | 8.59 |
| 2 | 26.78 | 8.5 | 107.2 | 2.6 | 432 | 8.58 |
| 3 | 26.59 | 8.5 | 107.1 | 2.1 | 432 | 8.55 |
| 4 | 22.74 | 7.8 | 90.7 | 3.2 | 440 | 8.3 |
| 5 | 17.9 | 4.9 | 51.6 | 3.7 | 440 | 7.83 |
| 6 | 12.44 | 1.1 | 10.7 | 4.5 | 440 | 7.99 |
| 7 | 9.79 | 0.7 | 6.1 | 12.1 | 440 | 8.1 |
| 8 | 8.19 | 0.4 | 3 | 19.7 | 444 | 8.03 |
| 9 | 7.37 | 0.2 | 1.8 | 10.0 | 454 | 8.4 |
| 10 | 7.1 | 0.1 | 1 | 6.4 | 461 | 8.89 |
| 11 | 6.85 | 0.1 | 0.7 | 4.9 | 466 | 9.04 |
| 12 | 6.74 | 0.1 | 0.6 | 4.1 | 469 | 9.09 |
| 13 | 6.64 | 0.1 | 0.6 | 3.8 | 472 | 9.11 |
| 14 | 6.6 | 0.1 | 0.5 | 3.6 | 474 | 9.11 |
| 14.5 | 6.59 | 0.1 | 0.4 | 18.4 | 475.5 | 9.11 |

## August 21, 2023

| Depth | Temp | DO mg/L | DO % | BGs | Spec C | pH |
|---|---|---|---|---|---|---|
| 0.5 | 24.05 | 9.0 | 108.1 | 3.6 | 427 | 8.46 |
| 1 | 23.99 | 9.1 | 109.3 | 3.1 | 427 | 8.47 |
| 2 | 23.79 | 9.1 | 108.3 | 4.0 | 427 | 8.44 |
| 3 | 23.65 | 9.1 | 107.8 | 4.8 | 427 | 8.44 |
| 4 | 23.18 | 8.2 | 96.2 | 4.5 | 428 | 8.19 |
| 5 | 20.47 | 3.8 | 42.7 | 3.9 | 437 | 7.57 |
| 6 | 16.38 | 2.0 | 20 | 4.5 | 440 | 7.48 |
| 7 | 11.52 | 0.6 | 5.8 | 70.8 | 437 | 7.7 |
| 8 | 9.24 | 0.3 | 2.1 | 23.7 | 444 | 7.78 |
| 9 | 7.67 | 0.2 | 1.2 | 10.6 | 458 | 8.49 |
| 10 | 7.14 | 0.1 | 0.9 | 7.1 | 467 | 8.72 |
| 11 | 6.94 | 0.1 | 0.7 | 6.0 | 472 | 8.79 |
| 12 | 6.8 | 0.1 | 0.5 | 5.2 | 474 | 8.86 |
| 13 | 6.7 | 0.1 | 0.4 | 5.6 | 479 | 8.85 |
| 14 | 6.66 | 0.1 | 0.4 | 5.1 | 481 | 8.83 |

## September 20, 2023

| Depth | Temp | DO mg/L | DO % | BGs | Spec C | pH |
|---|---|---|---|---|---|---|
| 0.5 | 20.99 | 8.1 | 91.5 | 3.9 | 421 | 8.51 |
| 1 | 20.91 | 8.0 | 90.3 | 3.7 | 421 | 8.43 |
| 2 | 20.83 | 7.9 | 89.3 | 4.5 | 421 | 8.25 |
| 3 | 20.78 | 7.9 | 89.2 | 3.7 | 421 | 8.25 |
| 4 | 20.73 | 7.9 | 89.2 | 3.7 | 421 | 8.23 |
| 5 | 20.56 | 7.8 | 87.2 | 3.9 | 422 | 8.29 |
| 6 | 18.67 | 1.0 | 11.1 | 9.7 | 434 | 7.41 |
| 7 | 13.37 | 0.6 | 5.3 | 21.7 | 436 | 7.63 |
| 8 | 10.55 | 0.3 | 2.6 | 24.4 | 444 | 7.65 |
| 9 | 8.42 | 0.2 | 1.3 | 13.7 | 464 | 8.54 |
| 10 | 7.53 | 0.1 | 0.8 | 8.2 | 471 | 8.76 |
| 11 | 7.19 | 0.1 | 0.6 | 7.2 | 477 | 8.79 |
| 12 | 7.05 | 0.1 | 0.5 | 6.8 | 478 | 8.79 |
| 13 | 6.91 | 0.1 | 0.4 | 6.7 | 482 | 8.78 |
| 14 | 6.87 | 0.1 | 0.4 | 6.4 | 482 | 8.77 |
| 14.5 | 6.85 | 0.0 | 0.4 | 6.1 | 485.5 | 8.76 |

## October 17, 2023

| Depth | Temp | DO mg/L | DO % | BGs | Spec C | pH |
|---|---|---|---|---|---|---|
| 0.5 | 15.14 | 8.6 | 86.5 | 4.2 | 409 | 9.53 |
| 1 | 15.1 | 8.6 | 86.3 | 4.0 | 409 | 9.41 |
| 2 | 15.04 | 8.6 | 86 | 5.2 | 409 | 9.29 |
| 3 | 15.02 | 8.6 | 85.9 | 5.2 | 409 | 9.18 |
| 4 | 15 | 8.6 | 85.9 | 4.4 | 409 | 9.06 |
| 5 | 14.98 | 8.6 | 85.8 | 4.8 | 409 | 8.95 |
| 6 | 14.96 | 8.5 | 85.2 | 4.7 | 409 | 8.78 |
| 7 | 14.82 | 8.5 | 84.8 | 4.4 | 410 | 8.71 |
| 8 | 13.7 | 1.7 | 16.7 | 2.8 | 422 | 7.84 |
| 9 | 9.69 | 0.4 | 3.2 | 13.5 | 464 | 8.07 |
| 10 | 7.9 | 0.2 | 1.7 | 8.8 | 480 | 8.68 |
| 11 | 7.49 | 0.1 | 1.1 | 6.5 | 484 | 8.77 |
| 12 | 7.2 | 0.1 | 1 | 6.8 | 487 | 8.79 |
| 13 | 7.14 | 0.1 | 0.8 | 6.8 | 488 | 8.79 |
| 14 | 7.04 | 0.1 | 0.6 | 6.9 | 490 | 8.79 |
| 14.5 | 7.01 | 0.1 | 0.5 | 7.4 | 492.1 | 8.78 |

**Biologicals**

| | 20-May-23 | 15-Jun-23 | 25-Jul-23 | 21-Aug-23 | 20-Sep-23 | 17-Oct-23 |
|---|---|---|---|---|---|---|
| Secchi Transparency | 2.06 | 2.78 | 2.75 | 2.61 | 2.72 | 2.35 |
| Average Relative Phycocyanin* | 4.68 | 2.84 | 2.20 | 3.88 | 4.00 | 4.60 |
| Cyanobacteria Cells | 2195 | 10 | 390 | 8791 | 9496 | 8384 |
| Chlorophyll-*a* | 5.86 | 5.86 | 5.12 | 5.10 | 6.00 | 11.90 |

*Average of the top 3 meters of the water column

**Total Phosphorus**

| | 22-May-23 | 15-Jun-23 | 25-Jul-23 | 21-Aug-23 | 20-Sep-23 | 17-Oct-23 |
|---|---|---|---|---|---|---|
| Epilimnion | 20 | 7 | 10 | 18 | 23 | 28 |
| Metalimnion | --- | 13 | 10 | 108 | 30 | 57 |
| Hypolimnion | 450 | 680 | 420 | 570 | 526 | 313 |

| Total Nitrogen | 22-May-23 | 15-Jun-23 | 25-Jul-23 | 21-Aug-23 | 20-Sep-23 | 17-Oct-23 |
|---|---|---|---|---|---|---|
| Epilimnion | 790 | 1040 | 565 | 583 | 610 | 553 |
| Metalimnion | --- | 900 | 560 | 1467 | 665 | 697 |
| Hypolimnion | 1610 | 2860 | 2800 | 3360 | 3360 | 1880 |

| Ammonia | 22-May-23 | 15-Jun-23 | 25-Jul-23 | 21-Aug-23 | 20-Sep-23 | 17-Oct-23 |
|---|---|---|---|---|---|---|
| Epilimnion | 75 | <50 | 366 | 7 | 7 | 15 |
| Metalimnion | --- | <50 | <50 | 700 | 22 | 697 |
| Hypolimnion | 1480 | 1890 | 2850 | 2835 | 2589 | 1880 |

| Alkalinity | 22-May-23 | 15-Jun-23 | 25-Jul-23 | 21-Aug-23 | 20-Sep-23 | 17-Oct-23 |
|---|---|---|---|---|---|---|
| Epilimnion | 84 | 86 | 82 | 62 | 59 | 65 |
| Metalimnion | --- | 88 | 86 | 83 | 45 | 74 |
| Hypolimnion | 96 | 100 | 100 | 96 | 93 | 82 |

| pH | 22-May-23 | 15-Jun-23 | 25-Jul-23 | 21-Aug-23 | 20-Sep-23 | 17-Oct-23 |
|---|---|---|---|---|---|---|
| Epilimnion | 8.9 | 9.1 | 8.6 | 8.5 | 8.4 | 9.4 |
| Metalimnion | 7.9 | 8 | 7.8 | 7.5 | 7.4 | 7.8 |
| Hypolimnion | 9.3 | 9.3 | 9.1 | 8.8 | 8.8 | 8.8 |

# Appendix B. Algae Data

May 22, 2023

| **Taxa** | **Genus / species** | **Cells / mL** | **%** | **Taxa cells / mL** | **Taxa %** |
|---|---|---|---|---|---|
| Cyanophyta | *Aphanizomenon sp.* | 2195 | 46.2 | 2195 | 46.2 |
| | *Woronichinia sp.* | 0 | 0.0 | | |
| Chlorophyta | *Anikistrodesmus sp.* | 0 | 0.0 | 387 | 8.1 |
| | *Oocystis sp.* | 42 | 0.9 | | |
| | *Scenedesmus sp.* | 105 | 2.2 | | |
| | *Staurastrum sp.* | 21 | 0.4 | | |
| | *Tetraedron sp.* | 219 | 4.6 | | |
| Chrysophyta | *Chrysosphaerella sp.* | 0 | 0.0 | 1076 | 22.6 |
| | *Mallomonas sp.* | 31 | 0.7 | | |
| | *Synura sp.* | 42 | 0.9 | | |
| | *Uroglenopsis sp.* | 1003 | 21.1 | | |
| Bacillariophyta | *Asterionella sp.* | 0 | 0.0 | 42 | 0.9 |
| | *Cyclotella sp.* | 21 | 0.4 | | |
| | *Tabellaria sp.* | 21 | 0.4 | | |
| | *Pennate Diatom* | 0 | 0.0 | | |
| Dinophyceae | *Ceratium sp.* | 10 | 0.2 | 10 | 0.2 |
| | *Peridinium sp.* | 0 | 0.0 | | |
| Cryptophyceae | *Cryptomonas sp.* | 1024 | 21.5 | 1024 | 21.5 |
| | *Rhodomonas sp.* | 0 | 0.0 | | |
| Euglenophyceae | *Euglena sp.* | 0 | 0.0 | 21 | 0.4 |
| | *Trachelomonas sp.* | 21 | 0.4 | | |
| | Unknown | 0 | 0.0 | 0 | 0.0 |
| Taxa identified | | | | | |
| 13 | Totals | 4755 | 100 | 4755 | 100 |

June 15, 2023

| Taxa | *Genus / species* | Cells / mL | % | Taxa cells / mL | Taxa % |
|---|---|---|---|---|---|
| Cyanophyta | *Aphanizomenon sp.* | 0 | 0.0 | 10 | 0.2 |
| | *Dolichospermum sp.* | 10 | 0.2 | | |
| | *Woronichinia sp.* | 0 | 0.0 | | |
| Chlorophyta | *Arthrodesmus sp.* | 29 | 0.6 | 3492 | 70.6 |
| | *Closterium sp.* | 419 | 8.5 | | |
| | *Coelastrum sp* | 156 | 3.2 | | |
| | *Gloeocystis sp.* | 371 | 7.5 | | |
| | *Oocystis sp.* | 156 | 3.2 | | |
| | *Pediastrum sp.* | 39 | 0.8 | | |
| | *Scenedesmus sp.* | 176 | 3.6 | | |
| | *Selenastrum sp.* | 20 | 0.4 | | |
| | *Staurastrum sp.* | 429 | 8.7 | | |
| | *Tetraedron sp.* | 1697 | 34.3 | | |
| Chrysophyta | *Chrysosphaerella sp.* | 0 | 0.0 | 29 | 0.6 |
| | *Mallomonas sp.* | 20 | 0.4 | | |
| | *Uroglenopsis sp.* | 10 | 0.2 | | |
| Bacillariophyta | *Asterionella sp.* | 254 | 5.1 | 1210 | 24.5 |
| | *Aulocoseria sp.* | 166 | 3.4 | | |
| | *Cyclotella sp.* | 98 | 2.0 | | |
| | *Fragilaria sp.* | 576 | 11.6 | | |
| | *Synedra sp.* | 117 | 2.4 | | |
| Dinophyceae | *Ceratium sp.* | 20 | 0.4 | 20 | 0.4 |
| | *Peridinium sp.* | 0 | 0.0 | | |
| Cryptophyceae | *Cryptomonas sp.* | 117 | 2.4 | 117 | 2.4 |
| | *Rhodomonas sp.* | 0 | 0.0 | | |
| Euglenophyceae | *Euglena sp.* | 0 | 0.0 | 10 | 0.2 |
| | *Trachelomonas sp.* | 10 | 0.2 | | |
| | *Unknown* | 59 | 1.2 | 59 | 1.2 |
| Taxa identified<br>21 | *Totals* | 4945 | 100 | 4945 | 100 |

July 20, 2023

| Taxa | *Genus / species* | Cells / mL | % | Taxa cells / mL | Taxa % |
|---|---|---|---|---|---|
| Cyanophyta | *Aphanizomenon sp.* | 8 | 0.2 | 390 | 11.6 |
| | *Aphanocapsa sp.* | 8 | 0.2 | | |
| | *Chroococcus sp.* | 45 | 1.3 | | |
| | *Dolichospermum sp.* | 330 | 9.8 | | |
| | *Woronichinia sp.* | 0 | 0.0 | | |
| Chlorophyta | *Anikistrodesmus sp.* | 8 | 0.2 | 2560 | 75.8 |
| | *Arthrodesmus sp.* | 278 | 8.2 | | |
| | *Closterium sp.* | 38 | 1.1 | | |
| | *Coelastrum sp* | 120 | 3.6 | | |
| | *Cosmarium sp.* | 240 | 7.1 | | |
| | *Elakatothrix sp.* | 30 | 0.9 | | |
| | *Gloeocystis sp.* | 398 | 11.8 | | |
| | *Oocytis sp.* | 293 | 8.7 | | |
| | *Scenedesmus sp.* | 571 | 16.9 | | |
| | *Selenastrum sp.* | 30 | 0.9 | | |
| | *Spondylosium sp.* | 60 | 1.8 | | |
| | *Staurastrum sp.* | 195 | 5.8 | | |
| | *Tetraedron sp.* | 300 | 8.9 | | |
| Chrysophyta | *Chrysosphaerella sp.* | 0 | 0.0 | 38 | 1.1 |
| | *Mallomonas sp.* | 8 | 0.2 | | |
| | *Uroglenopsis sp.* | 30 | 0.9 | | |
| Bacillariophyta | *Asterionella sp.* | 0 | 0.0 | 0 | 0.0 |
| | *Tabellaria sp.* | 0 | 0.0 | | |
| Dinophyceae | *Ceratium sp.* | 0 | 0.0 | 30 | 0.9 |
| | *Gymnodinium sp.* | 8 | 0.2 | | |
| | *Peridinium sp.* | 23 | 0.7 | | |
| Cryptophyceae | *Cryptomonas sp.* | 278 | 8.2 | 278 | 8.2 |
| | *Rhodomonas sp.* | 0 | 0.0 | | |
| Euglenophyceae | *Euglena sp.* | 0 | 0.0 | 30 | 0.9 |
| | *Trachelomonas sp.* | 30 | 0.9 | | |
| | *Unknown* | 53 | 1.6 | 53 | 1.6 |
| Taxa identified | | | | | |
| 23 | *Totals* | 3378 | 100 | 3378 | 100 |

August 21, 2023

| Taxa | *Genus / species* | Cells / mL | % | Taxa cells / mL | Taxa % |
|---|---|---|---|---|---|
| Cyanophyta | *Aphanizomenon sp.* | 15 | 0.1 | 8791 | 64.2 |
| | *Chroococcus sp.* | 92 | 0.7 | | |
| | *Dolichospermum sp.* | 8072 | 59.0 | | |
| | *Woronichinia sp.* | 612 | 4.5 | | |
| Chlorophyta | *Anikistrodesmus sp.* | 0 | 0.0 | 3623 | 26.5 |
| | *Closterium sp.* | 15 | 0.1 | | |
| | *Coelastrum sp* | 550 | 4.0 | | |
| | *Gloeocystis sp.* | 795 | 5.8 | | |
| | *Golenkinia sp.* | 0 | 0.0 | | |
| | *Kirchneriella sp.* | 15 | 0.1 | | |
| | *Oocystis sp.* | 290 | 2.1 | | |
| | *Padorina sp.* | 15 | 0.1 | | |
| | *Scenedesmus sp.* | 1850 | 13.5 | | |
| | *Staurastrum sp.* | 46 | 0.3 | | |
| | *Tetraedron sp.* | 46 | 0.3 | | |
| Chrysophyta | *Chrysosphaerella sp.* | 0 | 0.0 | 46 | 0.3 |
| | *Mallomonas sp.* | 46 | 0.3 | | |
| | *Uroglenopsis sp.* | 0 | 0.0 | | |
| Bacillariophyta | *Asterionella sp.* | 0 | 0.0 | 856 | 6.3 |
| | *Cyclotella sp.* | 443 | 3.2 | | |
| | *Fragilaria sp.* | 382 | 2.8 | | |
| | *Rhizosolenia sp.* | 31 | 0.2 | | |
| Dinophyceae | *Ceratium sp.* | 0 | 0.0 | 15 | 0.1 |
| | *Peridinium sp.* | 15 | 0.1 | | |
| Cryptophyceae | *Cryptomonas sp.* | 31 | 0.2 | 31 | 0.2 |
| | *Rhodomonas sp.* | 0 | 0.0 | | |
| Euglenophyceae | *Euglena sp.* | 0 | 0.0 | 15 | 0.1 |
| | *Trachelomonas sp.* | 15 | 0.1 | | |
| | *Unknown* | 306 | 2.2 | 306 | 2.2 |
| Taxa identified | | | | | |
| 20 | *Totals* | 13683 | 100 | 13683 | 100 |

September 14, 2023

| Taxa | *Genus / species* | Cells / mL | % | Taxa cells / mL | Taxa % |
|---|---|---|---|---|---|
| Cyanophyta | *Aphanizomenon sp.* | 0 | 0.0 | 9496 | 65.0 |
| | *Chroococcus sp.* | 797 | 5.5 | | |
| | *Dolichospermum sp.* | 2285 | 15.6 | | |
| | *Planktothrix sp.* | 4730 | 32.4 | | |
| | *Snowella sp.* | 904 | 6.2 | | |
| | *Woronichinia sp.* | 780 | 5.3 | | |
| Chlorophyta | *Anikistrodesmus sp.* | 53 | 0.4 | 3880 | 26.5 |
| | *Closterium sp.* | 18 | 0.1 | | |
| | *Coelastrum sp* | 283 | 1.9 | | |
| | *Cosmarium sp.* | 18 | 0.1 | | |
| | *Gloeocystis sp.* | 1949 | 13.3 | | |
| | *Oocystis sp.* | 177 | 1.2 | | |
| | *Scenedesmus sp.* | 407 | 2.8 | | |
| | *Selenastrum sp.* | 89 | 0.6 | | |
| | *Spondylosium sp.* | 532 | 3.6 | | |
| | *Staurastrum sp.* | 18 | 0.1 | | |
| | *Tetraedron sp.* | 337 | 2.3 | | |
| Chrysophyta | *Chrysosphaerella sp.* | 0 | 0.0 | 89 | 0.6 |
| | *Mallomonas sp.* | 18 | 0.1 | | |
| | *Uroglenopsis sp.* | 71 | 0.5 | | |
| Bacillariophyta | *Asterionella sp.* | 0 | 0.0 | 886 | 6.1 |
| | *Cyclotella sp.* | 461 | 3.2 | | |
| | *Fragilaria sp.* | 425 | 2.9 | | |
| Dinophyceae | *Ceratium sp.* | 18 | 0.1 | 35 | 0.2 |
| | *Peridinium sp.* | 18 | 0.1 | | |
| Cryptophyceae | *Cryptomonas sp.* | 18 | 0.1 | 18 | 0.1 |
| | *Rhodomonas sp.* | 0 | 0.0 | | |
| Euglenophyceae | *Euglena sp.* | 0 | 0.0 | 0 | 0.0 |
| | *Trachelomonas sp.* | 0 | 0.0 | | |
| | *Unknown* | 213 | 1.5 | 213 | 1.5 |
| Taxa identified | | | | | |
| 23 | *Totals* | 14616 | 100 | 14616 | 100 |

October 17, 2023

| Taxa | *Genus / species* | Cells / mL | % | Taxa cells / mL | Taxa % |
|---|---|---|---|---|---|
| Cyanophyta | *Aphanizomenon sp.* | 2275 | 19.4 | 8384 | 71.5 |
| | *Aphanocapsa sp.* | 11 | 0.1 | | |
| | *Dolichospermum sp.* | 398 | 3.4 | | |
| | *Lyngbya sp.* | 11 | 0.1 | | |
| | *Planktothrix sp.* | 4550 | 38.8 | | |
| | *Snowella sp.* | 455 | 3.9 | | |
| | *Woronichinia sp.* | 683 | 5.8 | | |
| Chlorophyta | *Closterium sp.* | 23 | 0.2 | 2673 | 22.8 |
| | *Coelastrum sp* | 796 | 6.8 | | |
| | *Cosmarium sp.* | 34 | 0.3 | | |
| | *Elakatothrix sp.* | 11 | 0.1 | | |
| | *Eudorina sp.* | 11 | 0.1 | | |
| | *Gloeocystis sp.* | 137 | 1.2 | | |
| | *Pediastrum sp.* | 11 | 0.1 | | |
| | *Scenedesmus sp.* | 830 | 7.1 | | |
| | *Selenastrum sp.* | 102 | 0.9 | | |
| | *Spondylosium sp.* | 11 | 0.1 | | |
| | *Staurastrum sp.* | 11 | 0.1 | | |
| | *Tetraedron sp.* | 694 | 5.9 | | |
| Chrysophyta | *Dinobryon sp.* | 57 | 0.5 | 319 | 2.7 |
| | *Mallomonas sp.* | 102 | 0.9 | | |
| | *Synura sp.* | 46 | 0.4 | | |
| | *Uroglenopsis sp.* | 114 | 1.0 | | |
| Bacillariophyta | *Cyclotella sp.* | 137 | 1.2 | 182 | 1.6 |
| | *Rhizosolenia sp.* | 23 | 0.2 | | |
| | *Synedra sp.* | 23 | 0.2 | | |
| Dinophyceae | *Ceratium sp.* | 23 | 0.2 | 23 | 0.2 |
| Cryptophyceae | *Cryptomonas sp.* | 46 | 0.4 | 46 | 0.4 |
| Euglenophyceae | *Euglena sp.* | 0 | 0.0 | 23 | 0.2 |
| | *Trachelomonas sp.* | 23 | 0.2 | | |
| | *Unknown* | 80 | 0.7 | 80 | 0.7 |
| Taxa identified | | | | | |
| 29 | *Totals* | 11728 | 100 | 11728 | 100 |

## Appendix C. Selected Recommendations from 2022 Report

### *Community Bloom Watch on Ball Pond*

Currently there is a small group of residents who have reported and photo-documented shoreline blooms. We recommend formalizing a Community Cyanobacteria Bloom Watch on Ball Pond. The development of data on shoreline bloom events, including locations, dates, extent, and weather conditions (including wind direction) could be important in understanding the variables associated with blooms and also create the necessary public awareness to develop the momentum to mitigate the problem.

In 2021, the BPAC purchased a microscope and the accessories to photo-document the dominant genera in the blooms. Former BPAC members had developed the necessary microscopic techniques and learned to identify the major cyanobacteria genera. AER reported on these efforts in our 2021 report. This type of data should also be incorporated into a Community Bloom Watch program.

### *Modification of the Cyanotoxin Monitoring Program*

The microcystin monitoring program at Ball Pond, in conjunction with Western Connecticut State University, provides excellent information for the community for making informed decisions regarding the recreational use of the lake. The program could be expanded to measure toxin levels in the surface bloom, where cyanobacteria concentrations are typically much higher.

It was fortuitous that research on saxitoxins in lakes occurred at WCSU in 2022. The findings of elevated saxitoxin levels in the benthic *Lyngbya spp*. mat on August 14th was concerning, even if it was one sample. There was one other sample collected two weeks later when saxitoxin levels were within the acceptable levels for Ohio.

Saxitoxin testing should be incorporated into the annual lake management program and expanded to include several sites that are sampled on a regular basis during the summer. Additionally, a thorough literature search on mitigating benthic cyanobacteria communities in lakes should be undertaken.

### *Understanding Phosphorus Levels Below the Thermocline*

As described above, phosphorus is released from bottom sediments under anoxic conditions and creates high concentrations in the strata near the bottom. Phosphorus concentrations near the thermocline and one meter below the surface are often similar. What is not understood are concentration gradients between the bottom strata and the thermocline. Understanding concentrations, below the thermocline or lower metalimnetic boundary down to the depth of the hypolimnetic sample could shed light on the high cyanobacteria concentrations near the thermocline and possibly in the shoreline booms.

Understanding phosphorus dynamics throughout the water column with higher resolution than the current epilimnetic, metalimnetic and hypolimnetic sampling regime should be developed in conjunction with a phosphorus budget study.

### *Sediment Phosphorus Fractions*

It is highly possible that much of the phosphorus budget of Ball Pond is driven by internal loading. While addressing watershed-generated phosphorus with best management practices and education is important, it will also be important to understand phosphorus in the lake sediment, particularly in the area of the bottom that is anoxic for a protracted period of time (Fig. 21).

Quantifying the phosphorus fractions (e.g., phosphorus bound to iron, aluminum, organics, etc.) in the sediments that experience protracted periods of anoxia is an important step in planning for phosphorus sequestering with alum. Ball Pond has been identified as a candidate for this type of effort since at least the early 1980s (Norvell 1982).

# Appendix D. Preparer's Qualification

## Laurence J. Marsicano

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

### RELEVANT EXPERIENCE

- Over 30 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.
- I was a founding member of the Connecticut Federation of Lakes, have, and continue to serve as a volunteer and an officer of Connecticut's lake advocacy, nonprofit organization.

### PROFESSIONAL EXPERIENCE

- **Principal Partner – Aquatic Ecosystem Research, LLC.** July 2017 to present
- **Adjunct Faculty** – Western Connecticut State University, Biological and Environmental Science Department. 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
- **Certification** by National Project WET as a Teacher Training Facilitator, CT DEP 2002
- **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 educational publication entitled *Candlewood Lake: Watershed Awareness and Lake Preservation* in 1998.

### ORGANIZATIONS

- **Connecticut Federation of Lakes** – Founding member 1995 - present; Treasurer from 1995 – 2001; Vice President from 2009 – 2011, 2018 - present; President from 2011 - 2015
- **Northwest Conservation District** – Board member from 2003 – 2010
- **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

Lonergan, T., L. **Marsicano**, and M. Wagener. 2014. A laboratory examination of the effectiveness of winter seasonal drawdown to control invasive Eurasian watermilfoil (*Myriophyllum spicatum*). Journal of Lake and Reservoir Management. 30:381-392

Moore H.H., Niering W.A., **Marsicano** L.J, and Dowdell M. 1999. Vegetation change in created emergent wetlands (1988–1996) in Connecticut (USA). Wetland Ecology and Management. 7:177-191.

Siver, P.A. A. M. Lott, E. Cash, J. Moss, and L.J. **Marsicano**. 1999. Century changes in Connecticut, USA, lakes as inferred from siliceous algal remains and their relationship to land use changes. Limnology and Oceanography 44:1928-1935.

**Marsicano**, L.J. and A.H. **Brawley**. 1997. Land use, watersheds and aquatic resources. Connecticut Woodlands 62(3): 21-23

Siver, P.A. and L.J. **Marsicano**. 1996. Inferring trophic conditions using scaled chrysophytes. Beiheft zur Nova Hedwigia 114:233-246.

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**
95 Pilgrim Drive, Windsor CT 06095
Mobile: 203-525-5991
hbrawley@gmail.com

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## *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.

Markow, J. and H. Brawley. 2001. Herpetofaunal and Avifaunal Surveys of Vaughn's Neck Peninsula, Candlewood Lake, Connecticut. Report to the Town of New Fairfield, CT. 32 p.

Brawley, A. H. 1998. A Vegetation Survey and Conservation Analysis of Vaughn’s Neck Peninsula. Report to The Candlewood Lake Authority. The National Audubon Society. 11 p.

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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## ***ACTIVITIES***

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

Coverts Project Cooperator, UConn Cooperative Extension System