AQUATIC ECOSYSTEM RESEARCH
A Freshwater Conservation Company

EAST TWIN LAKE

2017 Summary Water Quality Report

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2017 SUMMARY WATER QUALITY REPORT

MARCH 7, 2018

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EXECUTIVE SUMMARY

The Twin Lakes Association instituted a volunteer monitoring program in 2017 resulting in lake water quality data collections at a site in the deep basin of East Twin Lake (Lake Washining) on the following dates: July 16th, August 11th, September 8th, and October 2nd. The lake was stratified with strong resistance to mixing during each visit. The strong resistance to mixing prevented replenishment of oxygen to areas of the water column near the bottom after consumption by bacteria resulting in anoxia. Oxygen depletion resulted in higher levels of TKN, specific conductance, and alkalinity at 25m depth vs those encountered at 1m depth. It also resulted in elevated levels of total phosphorus in August. However, the elevated hypolimnetic levels did not result in increases of phosphorus in the epilimnion.

The 2017 Secchi disk transparency and total phosphorus concentration suggests that East Twin's trophic status is early-mesotrophic to mesotrophic. The algal community, however, was dominated by cyanobacteria (blue-green algae) throughout the sampling season. The lowest Secchi transparency corresponded with the highest algal cell concentration which occurred in September, with *Microcystis spp.* comprising 58% of the algal cells in the sample. That genus is capable of regulating buoyancy which can result in high cell concentrations at specific depths and influence transparency. Another rarer blue-green genus, *Rhabdoderma spp.,* was counted in the September and October sample. This genus is found in habitats with high pH and salt content, which is concordant with the conditions encountered at East Twin Lake.

Some simple trend analysis was performed with Secchi transparency the only variable having a significant negative (decreasing) trend over time ($p<0.05$). Other variables including, pH, specific conductivity, and total phosphorus are increasing but the trends are not statistically significant.

TABLE OF CONTENTS

Executive Summary 2
List of Figures 3
Introduction 4
Methods 4
Results 6
Thermal Structure and Dissolved Oxygen 6
Alkalinity, pH, and Specific Conductance 9
Nitrogen and Phosphorus Levels 10
Secchi Transparency and Algal Community Characteristics 12
2017 Water Quality Summary and Trends 14
Recommendations 17
References 18

LIST OF FIGURES

Figure 1. East Twin Lake showing the location of the water quality monitoring sites 5

Figure 2. Vertical profiles of water temperature and dissolved oxygen concentrations (top panel) and relative thermal resistance to mixing throughout the water column (bottom panel) at East Twin Lake during monthly site visits from July to October 7

Figure 3. Epilimnetic (1m depth) and hypolimnetic (25m depth) measures of nutrients (total phosphorus, total Kjeldahl nitrogen (TKN), ammonia, and nitrite, alkalinity, specific conductance, and pH at Site 2. Monthly Secchi transparencies are also compared above 11

Figure 4. Relative abundance of major algal taxa (top) and cell concentrations (bottom) each month from July through October. 13

Figure 5. Comparisons of historic total phosphorus, Secchi transparency, total nitrogen, specific conductance, alkalinity and pH to current levels at East Twin Lake. Blue dots and linear regression line are based on the data compiled in Canavan and Siver (1995) and 2017 data collections. Red dots represent annual averages from 2004 to 2015 as compiled by AER (2016). 16

INTRODUCTION

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

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

This year, the Twin Lakes Association initiated a volunteer monitoring program to collect water quality data on East Twin Lake. The protocols were modeled after AER's field methods. The purpose of this document is to report on the data collected by the Twin Lakes Association, assess it, and compare it to historical data to determine the kinds of changes the lake may be experiencing.

METHODS

A volunteer monitoring program was developed by the Twin Lake Association in conjunction with AER who provided training in field data collection methods. Volunteer monitors conducted monthly site visits to one site on East Twin Lake (73°22'59.999" W 42°1'32.984" N; Fig. 1) between July through October, 2017, on the following dates: July 16th, August 11th, September 8th, and October 2nd. During each visit the following data were collected. A transparency measurement was taken using a standard 20cm Secchi disk. Temperature (°C), oxygen (mg/L), conductivity (µS/cm), specific conductance (µS/cm), and pH were measured just below the surface, at one meter (m), and at every meter to the bottom using a YSI® Professional meter. During each site visit, water samples were collected at a depth of 1.0m from the surface and 0.5 to 1m from the bottom using a Van Dorn horizontal sampler for nutrient analyses. The Van Dorn sampling bottle was also used to collect a water sample each month, July through October, at the depth of greatest oxygen concentration for an analysis of important algal taxa, including algal cell enumerations.

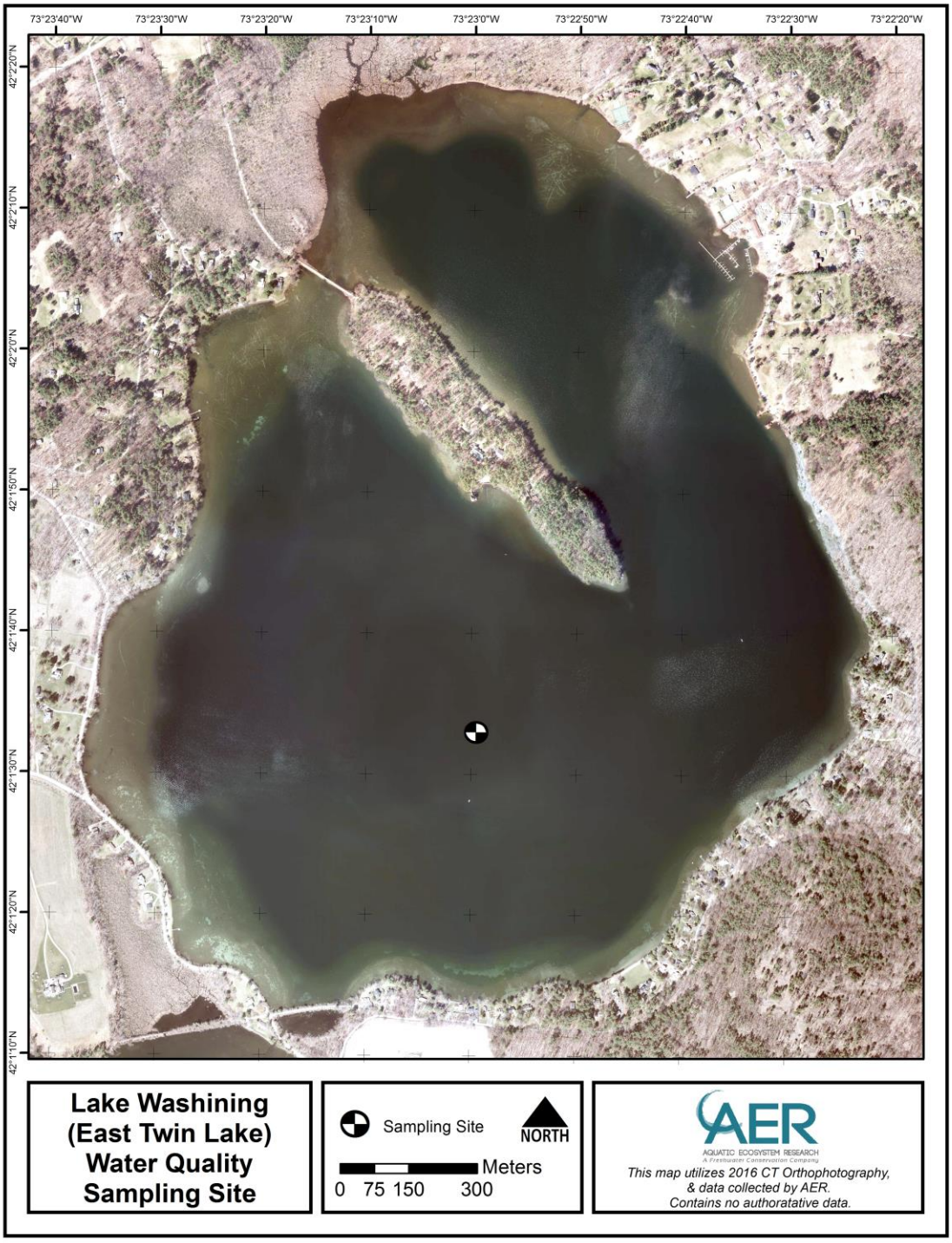

Figure 1. East Twin Lake showing the location of the water quality monitoring sites.

Chemical analyses were performed by a Connecticut State certified laboratory for alkalinity (mg/L), ammonia (mg/L), nitrite (mg/L), nitrate (mg/L), total Kjeldahl nitrogen (mg/L), and total phosphorus (µg/L). AER performed the algae analyses by first concentrating a known volume from the sample collected in the field to a smaller known volume with centrifugation and a vacuum pump / filtration flask system. A portion of that concentrate was pipetted into a counting chamber and genus-level algal cell enumerations were performed by counting cells in a subset of fields in the counting chamber using an inverted Nikon Diaphot research microscope. Those counts were then corrected to be representative of the whole sample.

Using those aforementioned data, resistance to mixing within the water column was calculated. Resistance to mixing, which is an assessment of the ability of two different water volumes – that differ in temperature – 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. The results of all of the aforementioned tests were stored in a database managed by AER.

RESULTS

Thermal Structure and Dissolved Oxygen

The vertical structure of water temperature is influenced by the incident radiation of our sun hitting the surface of the lake and the diffusion and diffraction of that energy through the vertical profile of the water volume. In short, the upper reaches of the lake are heated disproportionately faster compared to the lower reaches of the water body. The result is a warm surface water volume (i.e. epilimnion), a transitional area of rapid temperature decline with depth (i.e. metalimnion), and a cool bottom water volume (i.e. hypolimnion). Differences in temperature, and therefore density, between layers of water create resistance to mixing with the greatest resistance to mixing occurring where the density difference is the greatest (i.e. the thermocline).

As noted in the *Methods* section of the report, relative resistance to mixing (RTRM) was calculated between layers at 1-meter (m) intervals and assesses the resistance to mixing between layers of water. Traditionally, RTRM values >30 are indicative of the metalimnion (i.e. thermocline) region of the water column. RTRM values >80 are indicative of strong resistance to mixing no matter where they exist.

An oxygen concentration of 5mg/L is critical to the distribution of fisheries habitat in lakes. Some cold-water species – like trout – require more oxygen. Concordant with the establishment of the thermal structure is a diminishment of oxygen in the hypolimnion. The decrease in oxygen is due to respiration of bacteria in the deeper waters and the inhibited reintroduction of oxygen to the hypolimnion resulting from the thermal structure of the lake (i.e. high RTRM values in the metalimnion and at the thermocline).

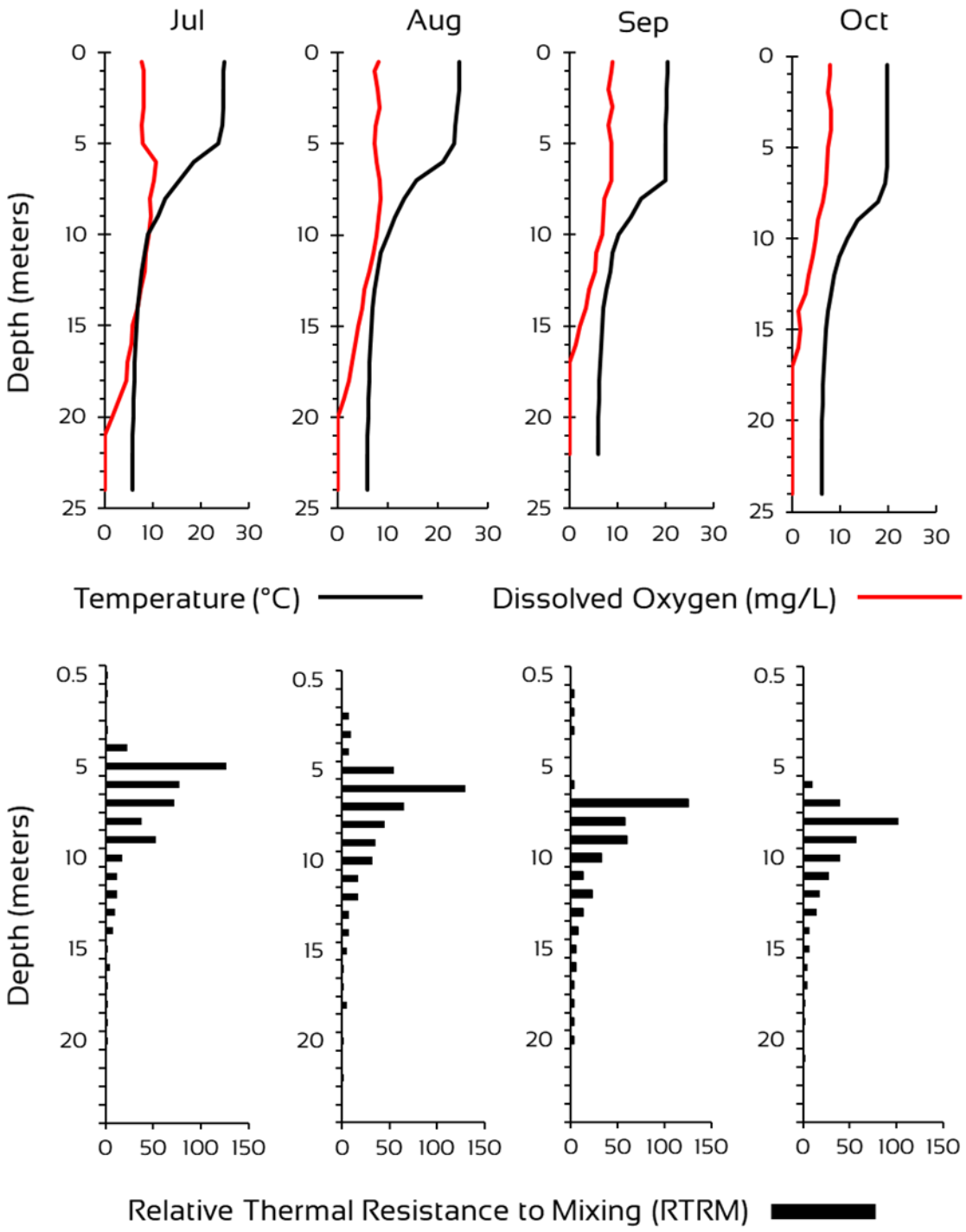

Figure 2. Vertical profiles of water temperature and dissolved oxygen concentrations (top panel) and relative thermal resistance to mixing throughout the water column (bottom panel) at East Twin Lake during monthly site visits from July to October.

A good analogy for the separation of the epilimnion and hypolimnion in the water column is the manner in which oil and water do not mix. The result is minimal exchange of oxygen between layers and loss of oxygen near the sediment / water interface due to microbial aerobic respiration. In short, oxygen does not diffuse to or replenish oxygen-depleted depths when the lake is stratified.

At the time of each site visit the water column was stratified and there was strong resistance to mixing (RTRM > 80). On July 16th the top four meters were very similar in temperature ranging from 24.9 to 24.6°C. Temperature rapidly decreased between the 5 and 11m depths with levels falling from 23.7 to 8.3°C. The greatest water- density-difference occurred between 5 and 6m depth resulting in an RTRM of 127. Temperature gradually decreased from 7.8 to 5.9°C between 12 and 24m depth (Fig. 1).

On August 11th, the temperature of the top five meters of water ranged from 24.2 to 23.2°C. A precipitous decline in temperature occurred between 6 and 11m where temperature fell from 21.0 to 8.7°C. The maximum RTRM value was 130, which occurred between the 6 and 7m strata. Temperature decreased from 8 to 5.9°C from 12 to 24m depth.

The epilimnion increased by another 2m by the September 8th visit with temperatures from the surface to 7m depth ranging from 20.4 to 20.0°C. The greatest RTRM of 125 occurred between 7 and 8m depth where temperature was measured at 15°C. Below that depth, temperature continued to decrease to 6°C at the 22m stratum.

On October 2nd the top seven meters from the surface ranged in temperature from 19.8 to 19.4°C. The greatest RTRM of 102 occurred between 8 and 9m depth where temperatures were 17.8 and 13.7°C, respectively. Temperatures continued to decrease to 8.7°C at 12m depth. From 13 to 24m depth, temperature diminished from 8 to 6.1°C.

During the July site visit, oxygen levels exceeded 5mg/L from the lake surface down to 16m. The highest concentration of 10.6mg/L was observed at the depth of the thermocline between 5 and 6m. From 17 to 20m depth oxygen concentrations were <5 and >1mg/L. From 21 to 24m depth, the oxygen concentrations were <1mg/L.

A similar oxygen profile was observed on August 11th (Fig. 1) with some notable differences. Oxygen concentrations of >5mg/L were observed from the surface to the 14m depth instead of the 16m depth. Concentrations <5 but >1mg/L were observed from 15 to 19m depth; and, below that the oxygen concentrations were <1mg/L.

The trend of decreasing water-volumes with ≥5mg/L of oxygen continued into September and October. Concentrations ≥5mg/L extended down to 12m depth on September 8th and to the 9m depth on October 2nd. Depths at which oxygen concentrations were measured at ≤1mg/L began at 17m depth at both visits.

Alkalinity, pH, and Specific Conductance

Alkalinity regulates the ability of lake water to resist change in pH. It is expressed as mg/L of calcium carbonate ($CaCO_3$) and reflects the buffering capacity or acid neutralizing capacity of water. Lakes with low alkalinity are susceptible to changes in pH. Alkalinity of surface waters is largely influenced by the local geology and other watershed factors. Calcium carbonate concentration at the bottom of a lake can also be generated internally from dissimilatory reduction reactions of sulfate by bacteria found in anoxic lake sediments (Siver et al. 2003).

Alkalinity in the epilimnion of East Twin was generally high compared to other Connecticut Lakes, but similar to other lakes in the Marble Valley geologic region of Connecticut. Alkalinity measured at 1m depth in samples collected in July, August, September and October ranged from 106 to 122mg/L and averaged 112mg/L. In the survey of 56 Connecticut Lakes, Siver and Canavan (1994, 1995) found that in the five examined Marble Valley lakes surface water alkalinity ranged from 54 to 121mg/L and averaged 90mg/L.

Alkalinities measured at 25m depth were elevated compared to the corresponding measurements at the surface on July 16th, August 11th and September 8th, and measured at 134, 138 and 130mg/L (Fig. 2), respectively suggesting internal alkalinity generation. Alkalinity measured in the hypolimnion in October was 116mg/L and similar to that measured in the epilimnion on the same day.

The pH of lake water is important for several reasons. Firstly, very low or very high pH levels will not support diverse aquatic animal life. Algal communities are also influenced by pH due in part to the types of dissolved carbon in the water column at various pH levels. For example, at a pH greater than 8.3, bicarbonate is the dominant form of carbon available to the pelagic algal community. Blue-green algae have an adaptive advantage over other algal groups because they can utilize bicarbonate to fulfill their carbon requirements while other groups are dependent upon carbon dioxide, which is limited at elevated pH. Consequently, higher pH promotes the dominance of blue-green algae because carbon resources are limited for other algal genera.

The pH measured at 1m depth was consistently high, and measured at 8.7 on July 16th and August 11th and 8.8 on September 8th and October 2nd. The pH in epilimnion of Connecticut's Marble Valley lakes in the 1990s ranged from 7.8 to 8.3 and average 8.2. This suggests that pH in East Twin is higher now than it was in the past. The pH measured at 25m depth was highest on July 16th at 7.5 and ranged from 5.9 to 6.1 in subsequent months. The season averages for the epilimnion and hypolimnion were 8.8 and 6.4.

Specific conductance (hereafter conductivity) is a measure of lake water's ability to transmit an electrical current at a specific temperature. Dissolved materials (i.e. nutrients and salts) have a distinct impact on conductivity measurements where higher concentrations of nutrients and salts result in higher conductivity readings. Because

conductivity is also representative of the total concentration of ions in lake water, it can be used to identify sources of nutrient loading or pollutants. Differences in conductivity can also impact the algal community, e.g. hard water lakes with high conductivity tend to have more blue-green algae. Moreover, vertical differences can be observed in conductivity profiles, particularly during the periods of hypolimnetic anoxia because nutrients and metal ions are diffusing from the sediment to the water column during periods of oxygen limitation.

The highest epilimnetic conductivity measured was on July 5th at 241µS/cm. Levels decreased modestly to 236µS/cm by August 11th, and then to 231µS/cm by September and October. The average for the season was 235µS/cm. The range of conductivities measured in the epilimnion of Mable Valley Lake in the 1990s was 180 to 317µS/cm and the average was 233µS/cm.

Average conductivity at 25m depth was significantly higher than that measured at 1m depth ($p<0.05$). It increased from the July 16th level of 265µS/cm to 277 and 293µS/cm on August 11th and September 8th, respectively before decreasing back to 277µs/cm by October 2nd. The average for the season was 278µS/cm.

Nitrogen and Phosphorus Levels

Nitrogen can be present in a number of forms in lake water. Ammonia – a reduced form of nitrogen – is important because it can affect the productivity, diversity, and community dynamics of the algal and plant communities. Ammonia can be an indicator of internal nutrient loading since bacteria will utilize other forms of nitrogen (e.g. nitrite and nitrate) in lieu of oxygen under anoxic conditions, which results in ammonia enrichment of the hypolimnion.

Other forms of nitrogen in lake waters are nitrite and nitrate. These forms of nitrogen are often below detectable levels in natural systems because they are quickly cycled by bacteria and aquatic plants. Total Kjeldahl nitrogen (i.e. TKN) is a measure of the reduced forms of nitrogen (i.e. ammonia) and total organic proteins in the water column; therefore, it is useful in assessing the productivity of the lentic system because it accounts for biologically derived proteins in the water column. Total nitrogen is the sum of TKN, nitrate and nitrite; because the latter two are often below detectable limits, TKN levels are often the same as total nitrogen levels.

Ammonia at 1m depth was measured at 0.84mg/L on August 11th and October 2nd but not detected in the sample collected on July 16th and September 8th. Ammonia at 25m depth was not detected in the July 16th sample but was detected in samples collected in August through October; detected levels were lowest on August 11th and September 8th at 0.28mg/L; and was highest on October 2nd at 1.1mg/L. Season averages at 1 and 25m depth were both 0.42mg/L.

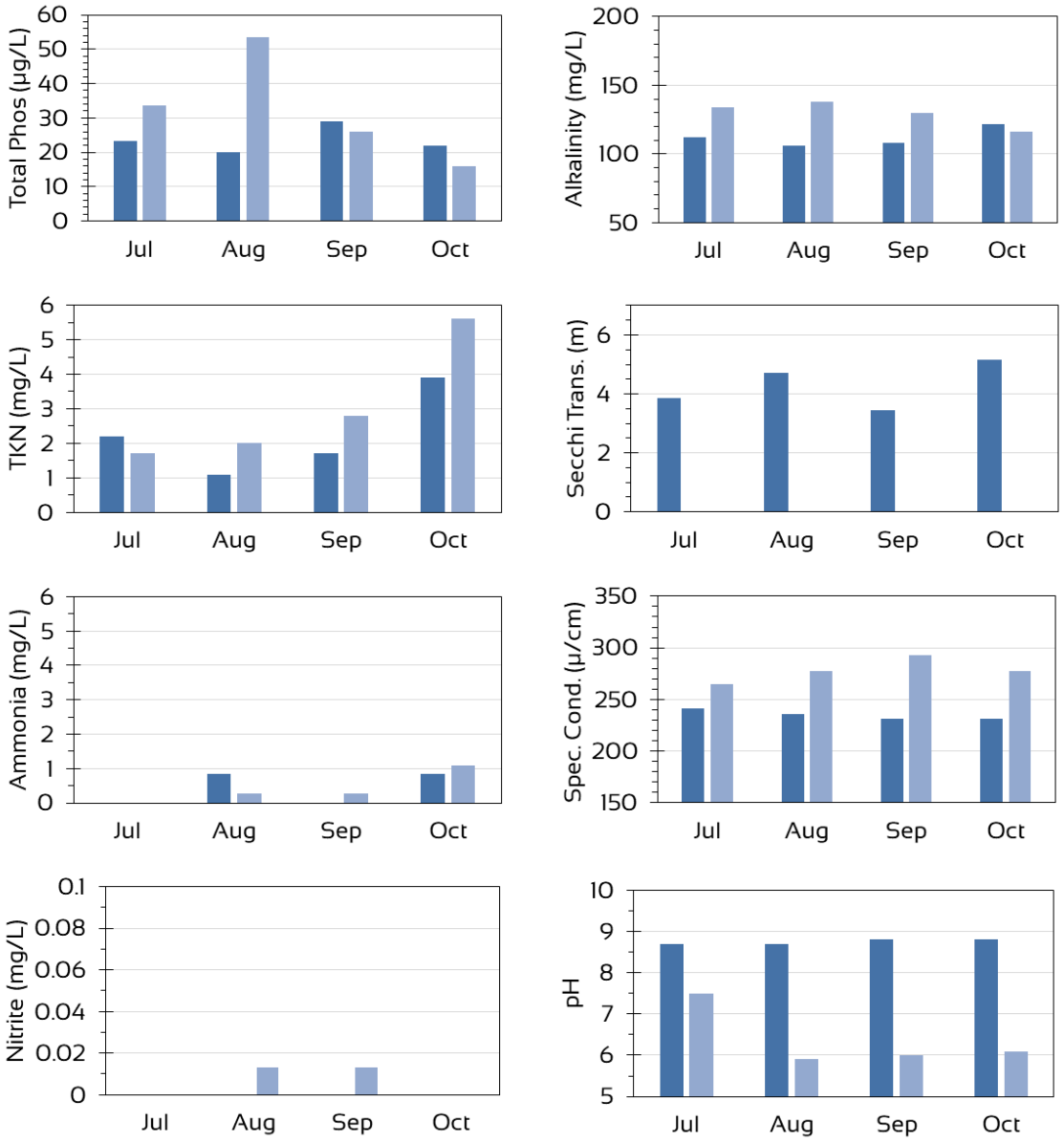

Figure 3. Epilimnetic (1m depth) and hypolimnetic (25m depth) measures of nutrients (total phosphorus, total Kjeldahl nitrogen (TKN), ammonia, and nitrite, alkalinity, specific conductance, and pH at Site 2. Monthly Secchi transparencies are also compared above.

TKN steadily increased at both 1m and 25m depth from August 11th to October 2nd (Fig. 2). The TKN concentration at 1m depth on July 16th was 2.2mg/L, was modestly lower on August 11th at 1.1mg/L, then increased to 1.7 and 3.9mg/L by September 8th and October 2nd, respectively. The season average was 2.23mg/L. At 25m depth concentrations steadily increased from 1.7mg/L measured in the July sample to

5.6mg/L in the sample collected in October (Fig. 2). The average for the season was 3.03mg/L.

Nitrate was detected only once and at a concentration of 0.07mg/L at 25m depth on July 16th. Nitrite was detected at 0.013mg/L at samples collected at 25m depth on both August 11th and September 8th.

Total phosphorus concentrations at 1 and 25m depth on July 16th were 23.3 and 33.5µg/L, respectively. By August 11th total phosphorus concentrations at 1 and 25m depth were 20.1 and 53.5µg/L and indicative of internal nutrient loading under anoxic conditions. On August 11th, however, concentrations at 1 and 25m depth were not appreciably different at 28.9 and 26.1µg/L, respectively (Fig. 2). This suggests a mixing event between the two dates that increased concentrations at 1m and lowered them at 25m depth. Concentrations measured on October 2nd at 1 and 25m depth were modestly lower than those on September 8th at 22.0 and 16.0µg/L, respectively. The averages at 1 and 25m depth for the season were 23.6 and 32.3µg/L, respectively.

Secchi Transparency and Algal Community Characteristics

While phosphorus and nitrogen are important to the understanding of algal productivity, Secchi transparency is a direct indicator of algal influence on water clarity. Secchi transparency is a measure of the penetration of light into the water column, which is reduced as particulate matter – including algae – increases.

Secchi transparecy at East Twin Lake in 2017 averaged 4.29m for the season and ranged from a low of 3.45m measured on September 8th to a high of 5.15m measured on October 2nd (Fig. 2). These measures are characteristic of lakes with early mesotrophic to mesotrophic productivity based on a trophic classification system commonly used in Connecticut (Table 1).

The algal community was dominated by blue-green (cyanobacteria) from July through October (Fig. 3). On July 5th blue-green algae comprised 77% of the community with *Chroococcus spp.*, *Microcystis spp.*, and *Woronchinia spp*. the most common genus. Diatoms comprised approximately 11% of the community with *Stephanodiscus spp*. and *Fragilaria spp*. the most common. Green algae constituted approximately 10% of the community with *Gleoecystis spp*. being the most common genus of that group observed.

Greater than 95% of all cells counted in samples collected in August, September, and October were blue-green algae. On August 11th, *Microcystis spp.* and *Woronchinia spp.* were the most abundant genera followed in importance by *Aphanothece spp.* and *Chroococcus spp.*. On September 8th, *Microcystis spp.* and *Aphanothece spp.* were the most abundant blue-green, followed in importance by *Rhabdoderma spp.*, *Gomphosphaeria spp.* and *Chroococcus spp*. The University of New Hampshire Phyco Key (Baker et al. 2012) describes species of *Rhabdoderma spp.* as common constituent

of the phytoplanktonic community of large lakes, although not in abundance, and found in lakes with high pH and salt content. A similar species composition was observed in the October 2nd sample.

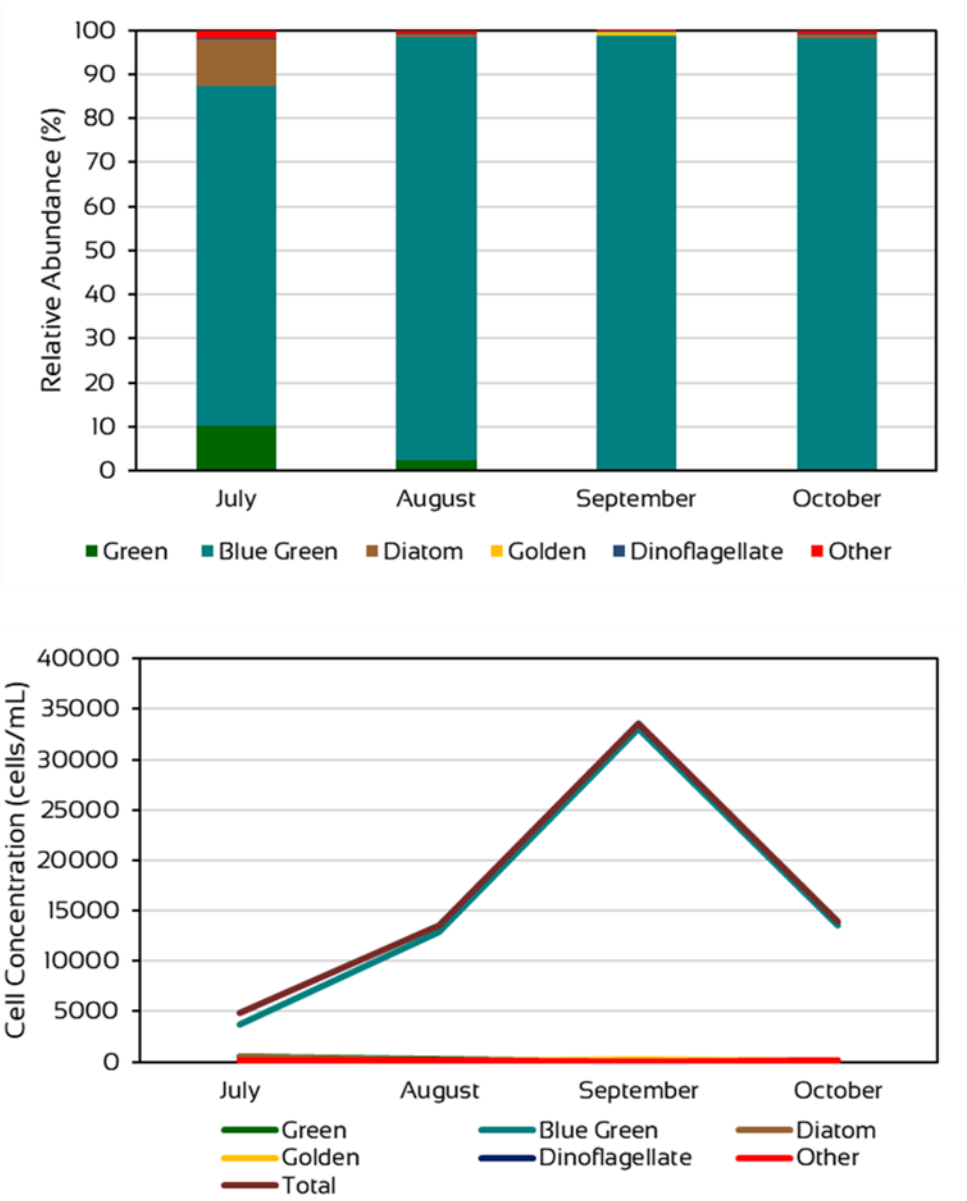

Figure 4. Relative abundance of major algal taxa (top) and cell concentrations (bottom) each month from July through October.

Cell concentrations ranged from a low of 4,798cells/mL in the July 16th sample to 33,612cells/mL in the September 8th sample. Nearly two-thirds of the September 8th flora was *Microcystis* which is found as amorphous masses of numerous minute cells. This morphology can often inflate cell concentrations.

2017 WATER QUALITY SUMMARY AND TRENDS

East Twin Lake lies within the Marble Valley geological region of Connecticut which has a bedrock largely comprised of limestone (Bell 1985). This predisposes surface runoff and results in the lakes like East Twin Lake, Lake Wononscopomuc, Candlewood Lake, and Ball Pond having higher alkalinity, pH, and conductivity levels. The differences observed between conductivity at 1m and 25m depth at East Twin Lake appears to be a result of anoxic conditions at the bottom due to the stratification and strong resistance to mixing that prevents diffusion of oxygen to depths near the bottom. A similar "*lower concentration in the epilimnion and higher concentration in the hypolimnion"* occurred for TKN and alkalinity.

On August 11th, hypolimnetic total phosphorus was almost three times higher than epilimnetic concentrations, and most likely due to internal loading resulting from anoxic conditions at the sediment-water interface. However, on both September 8th and October 2nd concentrations at the two depths were similar. The reason for this is unclear since the water column was stratified with strong resistance to mixing on both sampling dates in September and October. Also unclear is the greatly increased TKN levels on October 2nd at both 1m and 25m depth.

Secchi transparency and total phosphorus concentrations indicated that East Twin Lake is early-mesotrophic to mesotrophic with regards to productivity. Even with moderate productivity, the algal community was dominated by the blue-green algae and on one occasion (September 8th), the cell concentration was moderately high. The pH and conductivity of East Twin may have an important influence on the structure of the community. As noted above, lake water pH above 8.3 puts algal taxa other than blue-green algae at a disadvantage because they can't utilize bicarbonate whereas blue-greens can. The higher cell concentration in September was likely due to the dominant genus, *Microcystis spp.*, which was observed in amorphous colonies of minute cells (2-3µm in diameter) and difficult to enumerate.

We do note that TKN levels reported here, and therefore total nitrogen levels, are quite high and not aligned with Secchi transparency and total phosphorus levels (Table 1). We believe this to be laboratory error but cannot be quite sure if it is an analytical or mathematical issue. Above we reported epilimnetic TKN averages of 2.23mg/L. By converting units of measure from mg/L to µg/L, the averages become 2,230 which is characteristic of highly eutrophic conditions (Table 1). If these were mathematically off by one decimal place and adjusted accordingly, then the concentrations might be 223µg/L and closer to the trophic class that is suggested by the Secchi transparency

and total phosphorus. They would also be closer to historic levels (Fig. 4). AER has already chosen a different Connecticut State Certified Laboratory to provide nutrient and chemical analyses in 2018.

To put the 2017 water quality conditions into context, AER has provided a comparison of some of variables measured this year to historical levels. These variable included Secchi transparency, total phosphorus, total nitrogen, specific conductivity, alkalinity, and pH (Fig. 4). Data used for this analysis prior to 2017 were from those compiled and taken from Canavan and Siver (1995) who used the research of Deevey (1940), Frink and Norvell (1984), CT DEP (1991), and Canavan and Siver (1994, 1995). Annual averages between 2004 and 2015 were also used in this analysis (AER 2016).

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

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

Two of the three trophic indicators (Secchi transparency and total phosphorus) indicated a gradual increase in the trophic state of the lake based on the data compiled by Canavan and Siver (1995) and the 2017 data. As noted above, we believe the TKN data collected this year is erroneous and are therefore did not consider it in this analysis. Total phosphorus is trending upward since the 1930s but the trend is not significant ($p>0.05$). Secchi transparency is trending downward since the 1930s and that trend is significant ($p<0.05$). However, it does appear that there has not been much change since the early 1990s.

Conductivity, alkalinity, and pH are also gradually trending upward over time but none of these are significant ($p>0.05$) and in some cases historical data is limited (e.g. conductivity and pH).

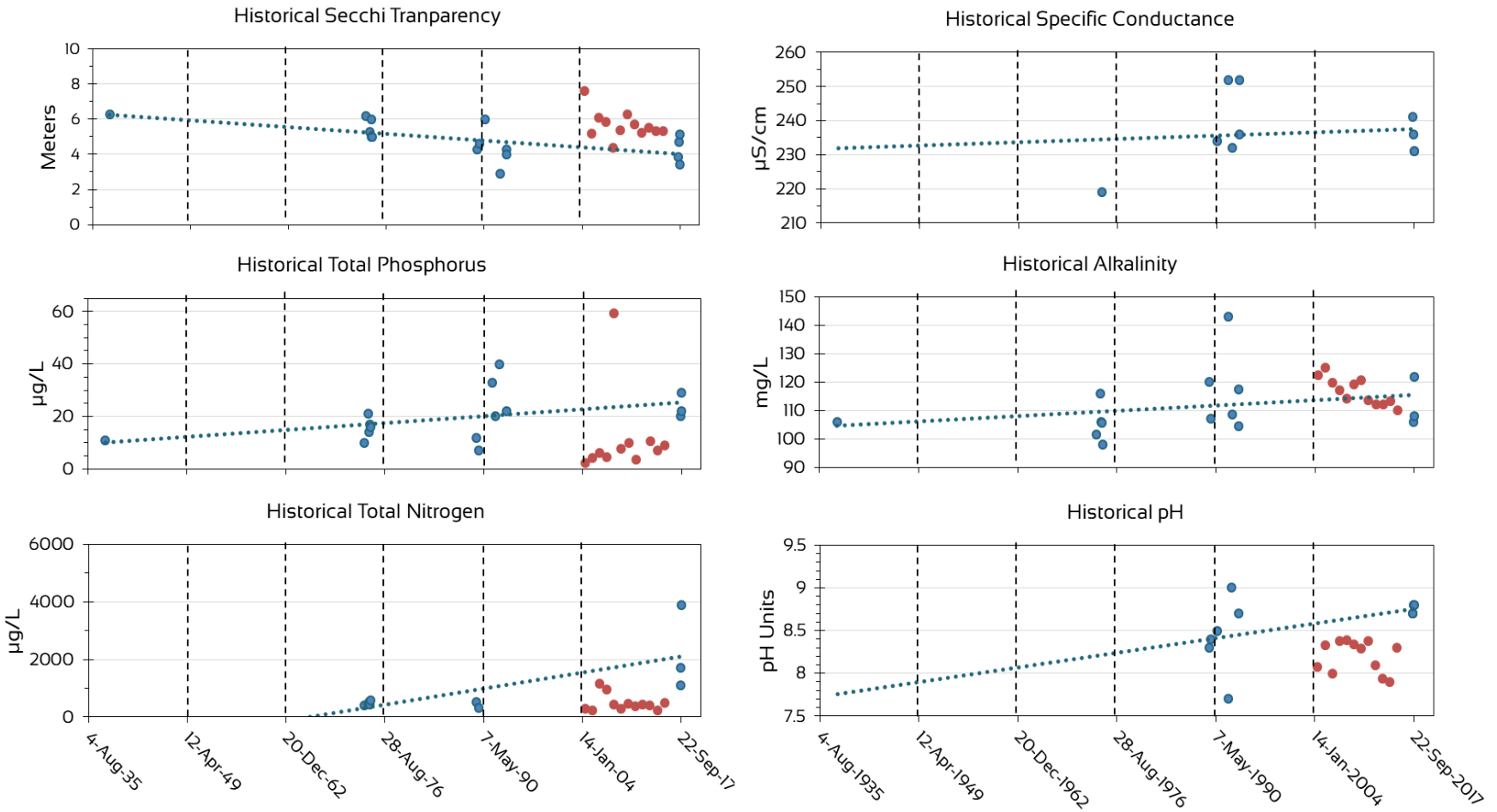

Figure 5. Comparisons of historic total phosphorus, Secchi transparency, total nitrogen, specific conductance, alkalinity and pH to current levels at East Twin Lake. Blue dots and linear regression line are based on the data compiled in Canavan and Siver (1995) and 2017 data collections. Red dots represent annual averages from 2004 to 2015 as compiled by AER (2016a).

RECOMMENDATIONS

The following are recommendations for future water quality management initiatives:

1. Continue Water Quality Monitoring
    a. Ideally, this should be conducted on a yearly basis to develop a comprehensive database for statistical modeling and real-time water quality management decision-making. This should always be conducted following the protocol outlined in this report and in the Water Quality Monitoring Standard Operating Procedure (AER 2016b).
        i. Consider expanding the scope to include the months of April or May through October with samples collected each month for analyses, in addition to collecting profile and Secchi data.
    b. Consider constructing a Quality Assurance Program Protocol to ensure the protocol is documented completely in case there is a change in the lake management entity.

2. Consider a paleolimnological study to develop data on past conditions including trophic levels. Sediment cores already exist and a cursory analysis has been performed

3. GIS Analysis of Current and Historic Land Use
    a. Geographic Information Systems (GIS) have become a powerful tool in lake and watershed management. Additionally, it is well known that changing land use within a watershed results in changes in water quality.
        i. An analysis of current land use conditions already completed by AER would be used and compared to historic land use and applied to nutrient export models to estimate nutrient loading from the watershed.

REFERENCES

Aquatic Ecosystem Research (AER). 2016a. Twin Lakes: Historical Data Analysis and Lake Management Plan. Prepared for the Twin Lakes Association. 105 pp.

Aquatic Ecosystem Research (AER). 2016b. Twin Lakes – Salisbury, CT: Water Quality Monitoring Standard Operation Procedure. Prepared for the Twin Lakes Association. 9 pp.

Baker, A.L. et al. 2012. Phycokey -- an image based key to Algae (PS Protista), Cyanobacteria, and other aquatic objects. University of New Hampshire Center for Freshwater Biology. http://cfb.unh.edu/phycokey/phycokey.htm 6 Mar 2018.

Bell, M. 1985. The Face of Connecticut. State Geological and Natural History Survey of Connecticut. Bull. 110.

Canavan RW, Siver PA. 1994. Chemical and physical properties of Connecticut lakes, with emphasis on regional geology. LAKE RESERV MANAGE. 10(2):175-188.

Canavan RW, Siver PA. 1995. Connecticut Lakes: A study of the chemical and physical properties of fifty-six Connecticut Lakes. New London (CT): Connecticut College Arboretum.

Connecticut Department of Energy and Environmental Protection (CT DEEP). 1991. Trophic Classifications of Forty-nine Connecticut Lakes. CT DEEP, Hartford, CT. 98 pp.

Deevey ES Jr. 1940. Limnological studies in Connecticut. V. A contribution to regional limnology. AM J SCI. 238(10):717-741.

Frink CR, Norvell WA. 1984. Chemical and physical properties of Connecticut lakes. New Haven (CT): Connecticut Agricultural Experiment Station. Bulletin 817. 180 pp

Kohli, P., Siver, P.A., Marsicano, L.J., Hamer, J.S. and A. Coffin. 2017. Assessment of long-term trends for management of Candlewood Lake, Connecticut, USA. LAKE RESERV MANAGE. 33: 280-300.

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.

Siver, P.A., Ricard, R., Goodwin, R. and A.E. Giblin. 2003. Estimating historical in-lake alkalinity generation and its relationship to lake chemistry as inferred from algal microfossils. J. Paleolimnology 29: 179-197.