The State of Hamilton County Lakes: A 25-Year Perspective

1993 - 2017

Prepared for the Hamilton County Soil and Water Conservation District by the Paul Smith's College Adirondack Watershed Institute

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Cover Photograph: Fawn Lake, by Caitlin Stewart

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Opposite Photograph: Indian Lake, Courtesy of Jamie Parslow

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Executive Summary

It is widely acknowledged that long-term monitoring programs are incredibly important for understanding lake ecology and detecting ecosystem change. Twenty-five years of limnological monitoring on Hamilton County lakes has informed us that the lakes support relatively low algal productivity and stable trophic characteristics. Many of the lakes are exhibiting a clear signal of recovery from acid deposition, including elevated pH and acid neutralizing ability. This study has also identified areas of concern, most notably, a trend toward depressed transparency and increased salinity. This report synthesizes the current and historical water quality data for these 21 lakes and provides interpretations of the findings where possible. The report can be summarized in the following key points:

1. We observed a wide variety of oxygen content in the bottom water of the study lakes. Eleven of the study lakes (51%) had adequate oxygen during the month of August, while seven lakes (33%) exhibited a propensity for either hypoxic or anoxic conditions. Lake depth, and thereby hypolimnion volume, likely drives the rapid depletion in many of the lakes.

2. The pH of the study lakes were all within the circumneutral range, indicating that they were not particularly impacted by acid deposition. The observed circumneutral condition may partially be due to the sampling regime, which only examines the surface water condition during the summer months. Analysis of the historical data indicated the majority of the lakes (86%) experienced stable pH values and two of the lakes (10%) experienced an increasing pH trend. Although the lakes were variable in their acid neutralizing ability, the majority of lakes (81%) exhibited a trend toward increasing alkalinity.

3. The concentrations of total phosphorus in the surface water tended to be quite low, and ranged from less than 4 µg/L in Blue Mountain Lake to as high 14 µg/L in Adirondack Lake. We observed that 19 of the lakes (90%) exhibited a significant downward trend in total phosphorus concentration. We believe that significant method changes over the past 25-years influenced the observed decrease in phosphorus, and therefore recommend cautious interpretation of these trends.

4. The photosynthetic pigment chlorophyll-a was variable between and within lakes. Generally, concentration was lowest in Blue Mountain Lake, and greatest in Oxbow Lake. Historically, the concentration of chlorophyll in the HC lakes had been stable, with 19 lakes (90%) exhibiting no discernable trend over time.

5. The transparency of the lakes ranged from a low of 2.4 meters in Oxbow Lake to a maximum of 7.8 meters in Blue Mountain Lake. Analysis of the 25-year dataset revealed that 17 of the lakes (81%) experienced a significant downward trend in transparency. Evidence from published research as well as regional observation by the AWI suggests that decreased transparency relates to changes in regional climate variables and/or acid deposition recovery.

6. We classified five lakes as oligotrophic (24%), 14 lakes as mesotrophic (67%), and two lakes (9%) as eutrophic. Assessment of trophic state using Carlson's TSI supports the opinion that the majority of lakes in the HC dataset are limited by phosphorus availability.

7. Nineteen of the study lakes (91%) exhibited a clear signal of road salt influence. We found that 93% of the variation in chloride concentration across HC study lakes could be explained by state road density. Routine monitoring of chloride and sodium began in 2013, so we were limited in our ability to analyze historical trends. Despite the lack of historical data, we know that HC lakes with paved roads in their watershed have experienced substantial salt enrichment because concentrations of chloride range from 4 to 70 times greater than background values for Adirondack lakes.

8. The calcium concentration of the study lakes was generally low, with the majority of lakes having a concentration less than 4 mg/L of chloride. Calcium concentration in all of the study lakes was below the threshold needed to support a viable zebra mussel population.

9. The average total aluminum concentration for the HC lakes was low, and ranged from below detection values in Adirondack Lake to 54 µg/L in Limekiln Lake. Morehouse Lake was the only exception to this range, where the average aluminum concentration over the past three years averaged 123 µg/L. In general, HC lakes with lower alkalinity and greater acidity tended to have greater concentrations of aluminum, supporting the observations made by numerous researchers over the last three decades.

Introduction

Recognizing the need to protect water resources, the Hamilton County Board of Supervisors contracted with the Hamilton County Soil and Water Conservation District (HCSWCD) in 1993 to initiate a comprehensive water-monitoring program. Initially, the program was limited in equipment and resources, and relied heavily on volunteer efforts. In 1996, the HCSWCD became a member of the Finger Lakes – Lake Ontario Watershed Protection Alliance (FLOWPA), resulting in a reliable stream of NYS funds to support the program. Twenty lakes from around the county were chosen for inclusion in the program. In 1997, Lake Durant was dropped and Fawn Lake was added. The addition of Lake Abanakee in 1998 finalized the number of study lakes at 21 (Figure 1). Twenty-five years later, the Hamilton County Lake Monitoring Program is an incredibly valuable long-term data set and one of only a few like it in the Northeast. Sustained research and long-term monitoring programs like this one are essential for understanding lake ecology, particularly in the ever-growing shadow of human activities.

The purpose of this report is to: (1) provide an informative description of the chemical ecology of lakes, (2) deliver a countywide assessment of the current and historical water quality status, and (3) synthesis the limnological data of each of the 21 study lakes.

Report Format

This report is designed to provide information to the informed layperson, scientific community, lake managers, and other interested individuals. As such, it is written in a way to provide something for everyone. The section titled *Methods* provides a general description of the field and laboratory methods used to collect and analyze the data. Readers that desire descriptions that are more detailed should contact the report authors. The section titled *Results and Discussion* is intended to deliver information in three areas. First, we provide the readers with background information on lake science and a basic understanding of how to interpret lake data; this section is based on information from over 50 scientific texts and peer-reviewed publications related to lake science. Second, we provide a countywide summary of key water quality variables and historical trends for the study lakes. Finally, this section offers interpretation of the results were possible. The last section of the report, titled *Individual Lake Reports*, takes a detailed look at the limnology and water quality of the 21 individual lakes in the program.

The data in this document are reported in metric units. Although this system has not been fully adopted in the United States, it is the standard system of measurement used by scientists and lake managers throughout the world. Information on converting the metric units of measurement to imperial units are readily available through internet searches and mobile apps. The amount of chemical elements dissolved in lake water are always expressed in metric units, typically as mg/L (miligrams per liter) or µg/L (micrograms per liter). One mg/L is equal to one part analyte to one million parts water. One µg/L is equal to one part analyte to one billion parts water.

Lake Eaton. Photograph by HCSWCD

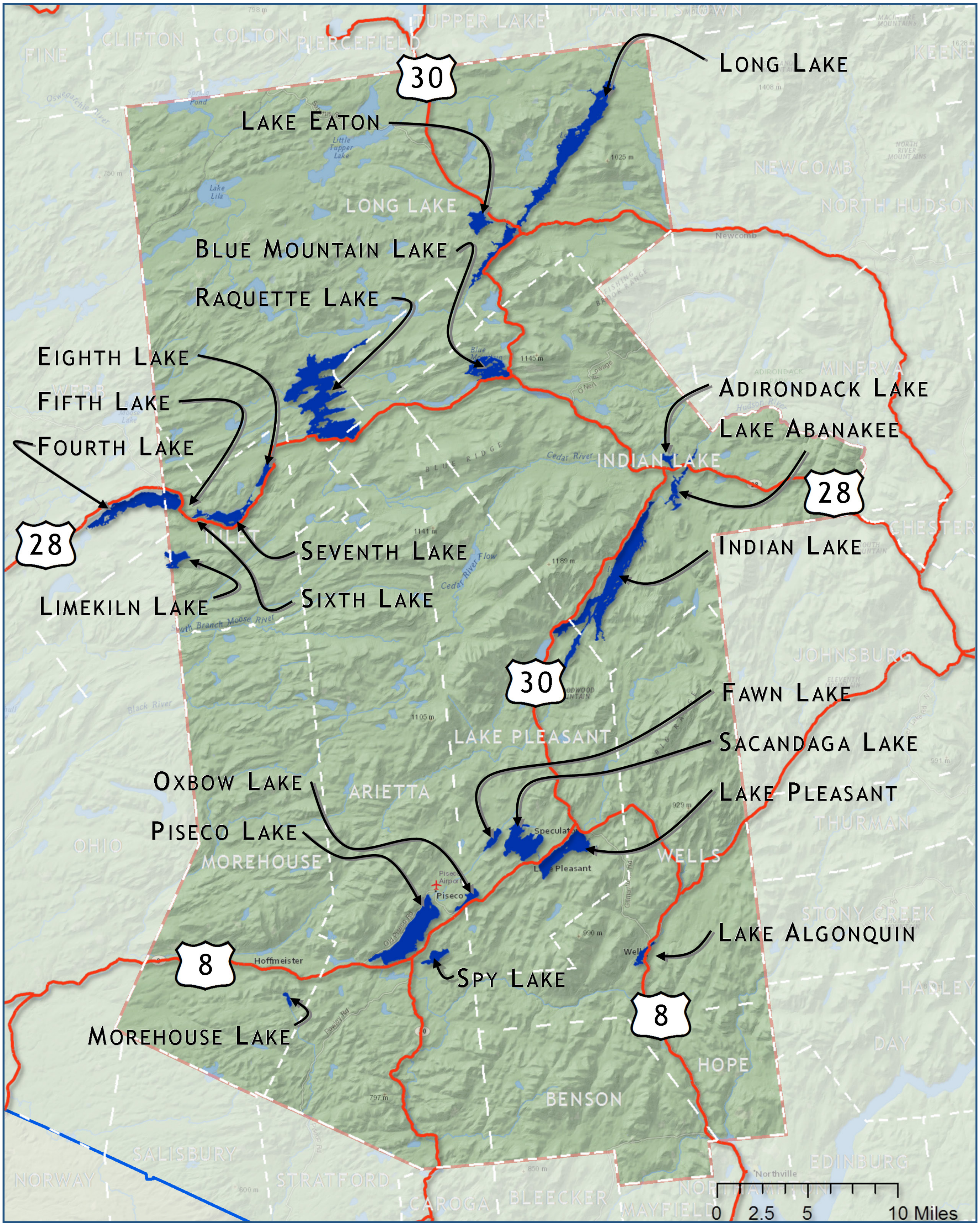


Figure 1. Lakes of the Hamilton County Monitoring Program.

Methods

Study Region

Hamilton is a 4,662 km^2 county (1,802 mi^2) located in upstate New York and is one of only two counties to exist entirely within the Adirondack Park. Hamilton is the least populous county in New York and is quintessentially rural. The county is 67% state land, covered almost exclusively by forest, and encompasses 385 lakes. The region possesses a humid continental climate, typified by large seasonal temperature differences, warm humid summers, cold winters, and precipitation that is evenly distribution throughout the year. Table 1 describes the climatic patterns observed at the National Climatic Data Center in Indian Lake over the last 117 years, noting that the wettest and warmest years on record occured during the study period.

Field Methods

Data collection occurred monthly at the deepest location of each lake, three to five times per year. From years 1993 to 2000, the data was collected between May and October. HCSWCD reduced the sampling regime to June through September for the years 2001 to 2005, and June through August for years 2006 to 2017. During each sampling event, a representative surface sample was collected for chlorophyll-a analysis by lowering an integrated tube sampler to a depth of 2 meters. A 250 mL aliquot of the integrated sample was then filtered through a 0.45 µm cellulose-acetate filter. The filter was wrapped in aluminum foil and frozen for later chlorophyll analysis. A second surface water sample was collected for chemical analysis by lowering a discrete sampler to a depth of 1.5 meters. The sample was stored in a 250 mL HDPE bottle and frozen for transport to the lab. While on location, staff observed the transparency by lowering a 20 cm Secchi disk to a depth where it could no longer be seen. Field measurements of temperature and dissolved oxygen were made at 1-meter intervals with calibrated YSI multi-probes, with the addition of pH in 1999, and conductivity, turbidity and total dissolved solids in 2017.

Laboratory Methods

Numerous analytical changes have occurred over the 25-year study period. HCSWCD performed laboratory analysis of pH, alkalinity, total phosphorus, nitrate + nitrite, and chlorophyll in their laboratory from the onset of the study until 2008. The study expanded to include aluminum and calcium in 1997, which were analyzed at the Adirondack Watershed Institute (AWI) laboratory at Paul Smith's College. The AWI took over all of the laboratory analysis in 2008, with the exception of pH and alkalinity, which occurred in 2012. A complete description of laboratory methods used by the AWI can be found in Table 2.

Data Analysis

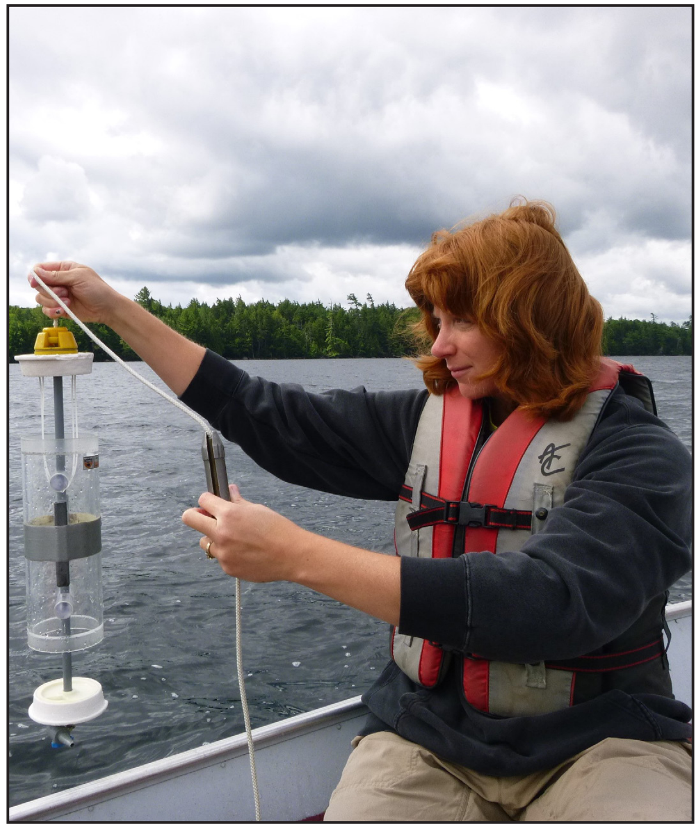
Current lake status was assessed by summarizing the descriptive statistics (average and range) of key water quality variables between 2015 and 2017, and comparing them to known indices or regional data. Trend analysis was conducted on the annual average value of key water quality indicators between 1993 and 2017. Because water quality data typically lacks independence between years, we used Kendall's Tau, a rank correlation coefficient used to test the null hypothesis that there is no association between a particular water quality variable and the passage of time. Significant trends over time were indicated for p-values less than 0.05.

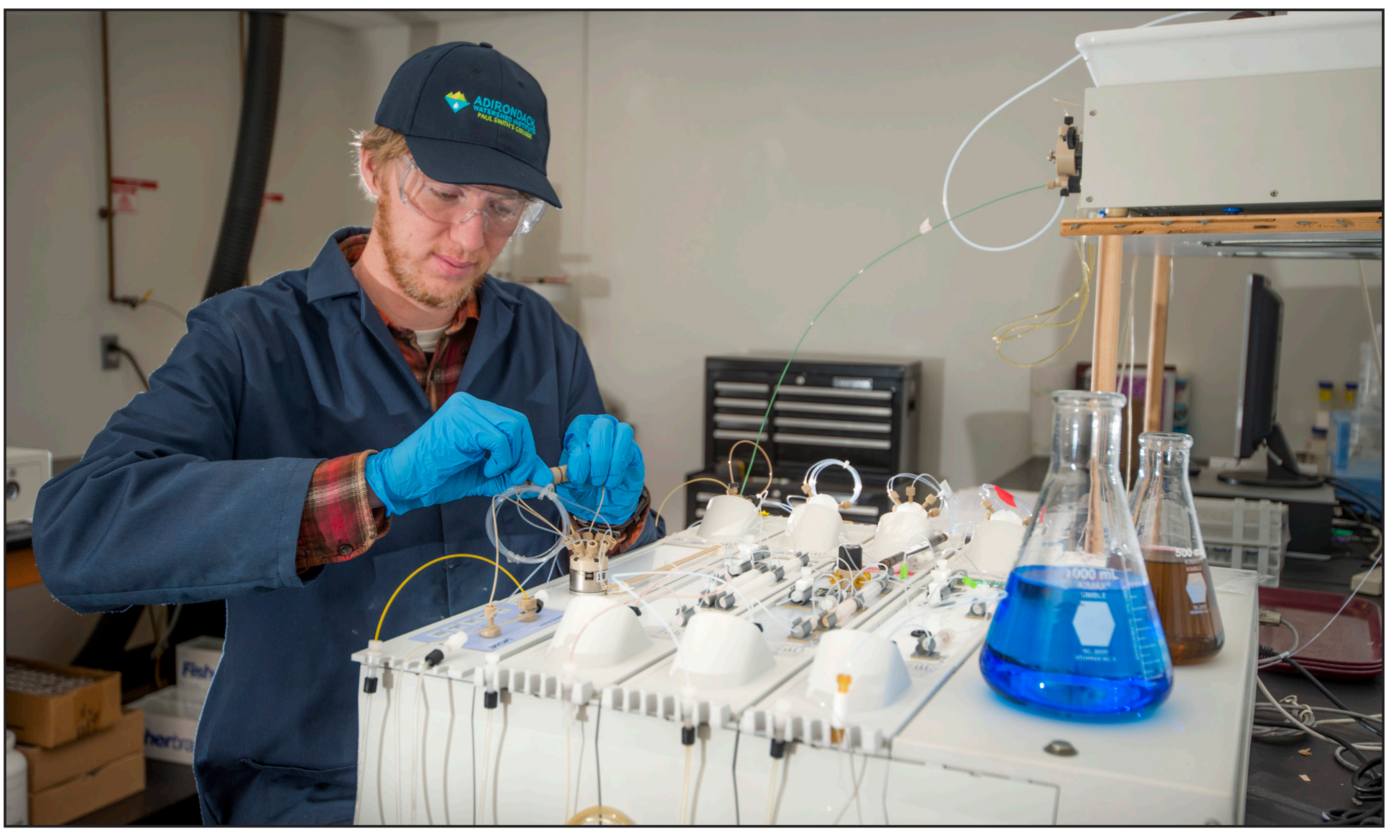
Average annual values for transparency, total phosphorus, and chlorophyll-a were used to calculate Carlson's Trophic State Index (TSI), a commonly used quantitative index for classifying the trophic status of lakes (Carlson 1977). Lakes with a TSI value less than 40 are classified as oligotrophic, a TSI value between 40 and 50 are classified as mesotrophic, and a values greater than 50 are classified as eutrophic.

The propensity for lakes to experience bottom water anoxia was analyzed by examining the oxygen content of the water 1-meter off the bottom during each visit in June, July, and August. Each lake was individually assessed based on the proportion of observations that were anoxic (D.O < 0.5), hypoxic (D.O < 2.0) or experiencing noted oxygen depletion (D.O < 4.0).

Table 1. Summary of weather statistics from the National Climate Data Center in Indian Lake, 1900 – 2017 (NCDC station: USC00304102).

	Years: 1900 - 2017			Record Years	
Parameter	Minimum	Average	Maximum	Minimum	Maximum
Precipitation (mm)	630	1,003	1,520	1963	2011
Precipitation Days	59	108	153	1926	2008
Average Temperature °C	-1	5	7	1943	1990
Growing Degree Days °C	682	1,472	1,934	1943	2011
Number of Days Above 15°C	33	69	100	1963	2011





HCSWCD and AWI staff collecting and analyzing data from the Hamilton County study lakes. Clockwise from upper left: (1) HCSWCD Intern, Alex Bielli, collecting temperature and dissolved oxygen data. (2) HCSWCD Manager, Caitlin Stewart, preparing to collect a surface water sample with a Kemmerer bottle. (3) AWI Research Technician, Hunter Favreau, analyzing water samples through flow injection analysis.

Table 2. Analytical methods used at the Paul Smith's College Adirondack Watershed Institute.

Analyte	Method Description	Reference
Laboratory pH	Mettler Toledo standard pH electrode	APHA
Spec. Conductivity	Conductance at 25°C via conductivity cell	APHA 2510 B
Chlorophyll-a	In-vitro fluorescence, non-acidification optical kit	EPA 445
Total Phosphorus	Acid-persulfate digestion, ascorbic acid reduction	APHA 4500 - P H
Nitrate + Nitrite	Automated cadmium reduction	APHA4500 - NO_3 I
Alkalinity	Automated methyl orange method	EPA 301.2
Chloride	Automated ion chromatography	EPA 300.0
Metals	Inductively coupled optical emission spectrophotometry	EPA 200.7

Results and Discussion

Temperature and Thermal Stratification

Vertical mixing of a lake is driven by the relationship between the density and temperature of water. Simply put, as water warms it becomes less dense and floats on top of the colder, more dense water. When the lake ice melts in the spring, the water column is all the same temperature from top to bottom, a condition referred to as isothermal (Greek: *iso* = equal, *thermo* = heat). When a lake is isothermal, it is also the same density throughout, allowing the water to vertically mix without impediment. Limnologists refer to this period of complete mixing as spring turnover. As spring progresses, energy from the sun heats the surface water faster than the heat can be distributed through the water column. The thermal resistance to mixing increases between the warm surface water and the colder and denser bottom water. If the lake is deep enough, the water column will become separated into three distinct strata. The epilimnion is the upper stratum that is uniformly warm and turbulent. The hypolimnion is the bottom stratum that is uniformly cold and still. Between the two strata is the metalimnion, a zone of sharp thermal change that prevents mixing between the surface and the bottom. As the lake loses heat in the autumn, the epilimnion becomes cooler and deeper. Eventually the lake is once again isothermal and freely mixes, a period referred to as fall turnover (Figure 2).

Dissolved Oxygen

In his seminal textbook, *Limnology: Lake and River Ecosystems,* Robert Wetzel describes oxygen as the most fundamental parameter of a lake aside from the water itself (Wetzel 2001). Dissolved diatomic oxygen (O_2) is essential for the metabolism of aerobic organisms as well as numerous non-biotic chemical reactions. In addition, the presence or absence of oxygen directly affects the solubility of a number of important inorganic nutrients such as phosphorus. The primary source of oxygen in a lake is the atmosphere. During thermal stratification the thermocline serves as a barrier to vertical oxygen transport from the atmosphere; as a result, the hypolimnion is a closed oxygen system, which means it only has as much oxygen as moved in during the period of spring turnover. When lake sediments contain high amounts of organic material, bacterial decomposition consumes all of the dissolved oxygen resulting in hypolimnetic hypoxia (very low O_2, < 2.0 mg/L) or anoxia (essentially no O_2, <0.5 mg/L). Nutrient enrichment resulting from human activities stimulates algal productivity and subsequent algal settlement, decomposition, and oxygen loss.

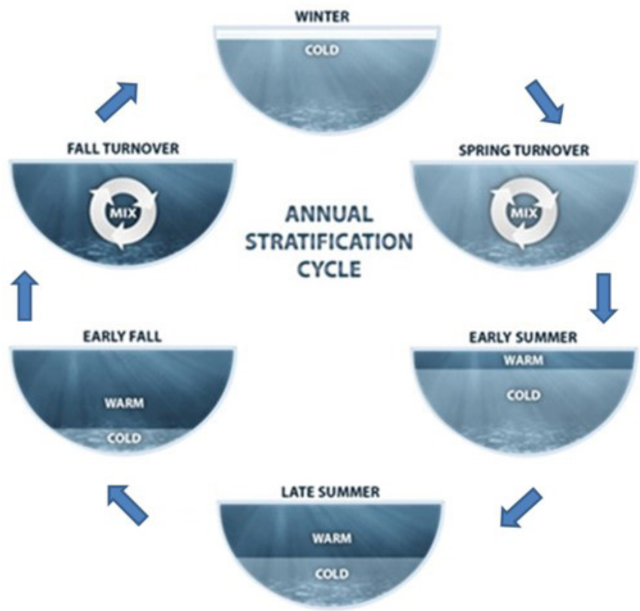


Figure 2. The typical stratification cycle of an Adirondack lake.

Several ecological processes are influenced by hypolimnetic hypoxia. The most obvious impact is loss of biological diversity, particularly fish and invertebrates. Hypoxia has been shown to have a negative effect on fish reproduction by interfering with essential processes such as behavior, gonad and embryonic development, hatching success, and overall fitness (Wu 2009). In addition, reduced oxygen concentration restricts metabolic activity at the cellular level, which in turn inhibits important activities of juveniles and adults, such as swimming, feeding, predator avoidance, and growth (Evans 2006). Lake trout (*Salvelinus namaycush*), the symbol of clean Adirondack waters, are often used as an example of the importance of adequate hypolimnetic oxygen. Lake trout favor cold, highly oxygenated water. Over the years researchers have proposed various criteria to gauge habitat suitability for lake trout, with the most popular ones combing the generalized oxygen criteria of 6 mg/L used for family Salmonidae with the lake trout median preferred temperature of 10°C (reviewed by Evans 2006). Recently, increased understanding of metabolic activity and the spatial distribution of juvenile lake trout spurred Evans (2006) to recommend the minimum dissolved oxygen criteria for the protection of viable lake trout populations be 7.0 mg/L. A second important impact of bottom water hypoxia is that it results in internal loading of phosphorus. Lack of oxygen in the hypolimnion influences the solubility of inorganic phosphorus and allows the release of dissolved reactive phosphate from the lake sediments, resulting in phosphorus enrichment in the bottom strata of the lake. The phosphorus can then be distributed to the entire water column during fall turnover (Wetzel 2001).

Overall, we observed a wide variety of oxygen content in the bottom water of HC study lakes. Eleven of the study lakes (51%) had an adequate supply of oxygen in the bottom meter of the water column during the month of August, while seven lakes (33%) exhibited a propensity for either hypoxic or anoxic conditions (Table 3).

Although it is tempting to use oxygen content as a metric for human impact on the watershed, the relationship between oxygen depletion and lake productivity is far more complex than that. In some lakes, notable oxygen depletion and even anoxia may be a natural occurrence. Natural anoxia is common in relatively shallow lakes where the volume of the hypolimnion is small in relation to the sediment surface area were microbial decomposition occurs; this skewed ratio results in rapid oxygen

Table 3. Hypolimnetic oxygen content (HOC) of the Hamilton County study lakes. The HOC was classified as adequate, marginal, or depleted based on the proportion of observations where the water 1-meter off the bottom was hypoxic during the month of August. Adequate = no observations, Marginal < 50% of observations, Depleted > 50% of observations.

			Percent of August observations: 1993-2017	
HOC	**Waterbody**	**Max Depth (m)**	**Hypoxic**	**Anoxic**
Adequate	Blue Mountain Lake	30	0	0
	Eighth Lake	25	0	0
	Fawn Lake	19	0	0
	Fourth Lake	19	0	0
	Indian Lake	26	0	0
	Lake Abanakee	8	0	0
	Lake Algonquin	3	0	0
	Limekiln Lake	22	0	0
	Piseco Lake	38	0	0
	Raquette Lake	29	0	0
	Seventh Lake	27	0	0
Marginal	Oxbow Lake	3	11	0
	Sacandaga Lake	22	31	6
	Morehouse Lake	11	42	5
	Fifth Lake	5	37	15
Depleted	Lake Adirondack	6	50	8
	Lake Pleasant	21	45	18
	Lake Eaton	17	50	19
	Long Lake	13	57	30
	Sixth Lake	13	42	50
	Spy Lake	9	35	65

depletion (Fulthorpe and Paloheimo 1985; Charlton 1980; Mathias and Barica 1980). For example, Molot et al. (1992) examined 33 lakes in Ontario and determined that lake morphometry exerted a particularly strong influence on oxygen profiles, and that the influence was greatest in shallow lakes (<20 meter max depth). We found similar results in the HC data, as lakes with adequate oxygen content tended to have maximum depths greater than 20 meters, while lakes with notable depletion had maximum depths between 6 to 21 meters (Table 3). There are a few exceptions to this observation, most notability lakes Abanakee (8-meter max depth) and Algonquin (3-meter max depth). It is likely that oxygen depletion in Lake Abanakee is rare because it is a low-retention reservoir with an estimated flush rate of over eight times per year. In addition, the Abanakee Dam has regularly scheduled releases of water to support white water rafting on the Indian River during the summer months. Lake Algonquin is also a low-retention reservoir; its high flush rate (25 times per year) and shallow depth support the mixing of oxygen throughout the water column.

Acidity: pH and Alkalinity

In chemistry, pH is used to communicate acidity. Technically, pH is a surrogate measure of the concentration of hydrogen ions in water. Hydrogen ions are very active, and their interaction with other molecules determines the solubility and biological activity of gasses, nutrients, and heavy metals; thus pH is considered a master variable for its influence on chemical processes and aquatic life. The pH unit exists on a logarithmic scale from 0-14, with 7 being neutral. pH values less than 7 indicate increasing acidity, whereas pH values greater than 7 indicate increasingly alkaline conditions. Because pH exists on a logarithmic scale, a decrease in 1 pH unit represents a 10 fold increase in hydrogen ion activity. Acidification occurs through the introduction of organic acids from wetland, or acidic deposition. Acid deposition is the addition of sulfuric and nitric acids to watersheds from the atmosphere. The acidic compounds are the result of chemical reactions between water, oxygen and the oxides of sulfur and nitrogen emitted to the atmosphere from the burning of fossil fuels. The deposition of acidic compounds has resulted in adverse ecological effects to the aquatic and terrestrial environment of the region (reviewed by Driscoll et al. 2003) In the Adirondacks, acidification status can be generally assed from pH values based on the guidelines outlined in Table 4.

Alkalinity (or acid neutralizing ability) is the capacity of a water body to neutralize acids and thereby resist changes in pH. The amount of alkalinity plays a major role in whether or not acidic deposition will negatively influence a lake. Alkalinity is a function of the amount of calcium carbonate in the water, which is derived mainly from the watershed. Most Adirondack lakes exist on slowly weathering granitic bedrock that has a slow rate of calcium carbonate generation, and therefore lower acid neutralizing ability. For example, 52% of the lakes analyzed in the Adirondack Lake Assessment Program had alkalinity values that would characterize the water as having moderate or extreme sensitivity to acidification (Laxson et al. 2018a). The opposite is true for lakes that exist on bedrock derived from ancient ocean deposits, such as limestone or dolomite. Soil depth also plays a role in acid neutralizing capacity, with deeper soils offering more buffering ability than shallower soils. A general assessment of the acid neutralizing ability of a lake follows the parameters presented in Table 5.

Table 4. Assessment of lake acidification based on pH values.

Lake acidity	Assessment
pH < 5.0	Acidic: critically impaired
pH 5.0 – 6.0	Acidic: threatened
pH 6.0 – 6.5	Acidic: acceptable
pH 6.5 – 7.5	Circumneutral: non-impacted
pH >7.5	Alkaline: non-impacted

Table 5. Assessment of sensitivity to acid deposition based on alkalinity (mg/L).

Alkalinity	Neutralizing ability	Acidification Status
0	None	Acidified
0 - 2	Low	Extremely sensitive
2 - 10	Moderate	Moderately sensitive
10 - 25	Adequate	Low sensitivity
> 25	High	Not sensitive

Using the data from 2015-2017, we found that the HC lakes are not currently impacted by acid deposition (Table 6, Figure 3). The average pH was similar between lakes, and ranged from a low of 6.7 in Morehouse Lake to a high of 7.5 in Eighth Lake. Overall, 15 of the study lakes (71%) had average pH values between 7.0 and 7.2 units. The average alkalinity for the same period ranged from a low of 2 mg/L in Morehouse Lake to a high of 27 mg/L in Adirondack Lake (Table 6 and Figure 4).

The pH of the majority of HC lakes has been stable over the 25-year study. We found that 18 of the lakes (86%) had no statistical trend in the historical pH data, while two lakes (10%) exhibited a trend for increasing pH, and one lake exhibited a downward trend in pH. Although the pH has been historically stable, the acid neutralizing ability

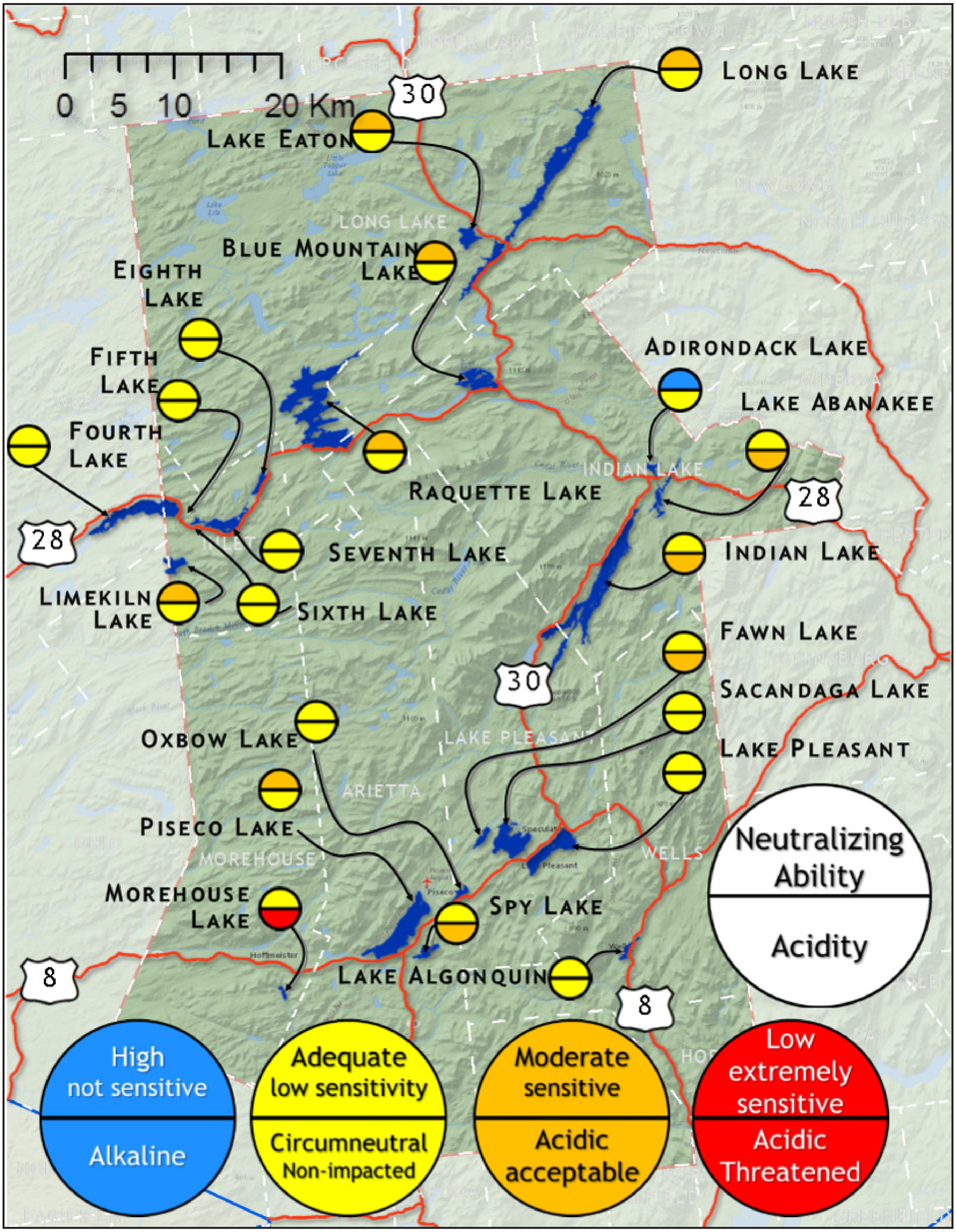


Figure 3. Spatial representation of Hamilton County lakes based on their acidity and acid neutralizing ability.

*Table 6. Current status, historical trends, and overall assessment of the acidity and acid neutralizing capacity of the Hamilton County study lakes. * denotes significance at the 0.05 level, ^ denotes significance at the 0.01 level.*

Waterbody	pH Status 2015-2017		pH trend	Alkalinity Status 2015-2017		Alkalinity trend	Acidity Assessment
	Avg.	Range	1993-2017	Avg.	Range	1993-2017	
Blue Mnt	7.2	5.7, 7.8	no trend	9	8, 10	increasing^	Circumneutral, moderate sensitivity
Eighth	7.5	5.8, 8.7	no trend	17	16, 18	increasing^	Circumneutral, low sensitivity
Fawn	7.1	6.4, 7.8	no trend	5	2, 6	increasing^	Circumneutral, extreme sensitivity
Fifth	7.0	6.0, 7.4	no trend	15	12, 19	no trend	Circumneutral, low sensitivity
Fourth	7.1	6.3, 7.6	no trend	14	12, 15	increasing^	Circumneutral, low sensitivity
Indian	7.0	6.5, 7.4	no trend	6	5, 7	no trend	Circumneutral, low sensitivity
Abanakee	6.9	6.1, 7.4	decreasing^	7	5, 8	increasing^	Circumneutral, moderate sensitivity
Adirondack	7.4	6.2, 8.4	no trend	27	23, 31	no trend	Circumneutral, no sensitivity
Algonquin	7.1	6.5, 7.7	no trend	16	9, 20	no trend	Circumneutral, low sensitivity
Eaton	7.1	6.5, 7.7	no trend	6	5, 7	increasing^	Circumneutral, moderate sensitivity
Pleasant	7.2	6.5, 7.7	no trend	12	11, 13	increasing^	Circumneutral, low sensitivity
Limekiln	7.1	6.6, 7.6	no trend	4	3, 6	increasing^	Circumneutral, extreme sensitivity
Long	7.0	6.5, 7.4	no trend	6	4, 8	increasing^	Circumneutral, moderate sensitivity
Morehouse	6.7	5.9, 7.4	increasing^	2	1, 3	increasing^	Circumneutral, extreme sensitivity
Oxbow	6.9	6.4, 7.4	no trend	10	9, 12	increasing^	Circumneutral, moderate sensitivity
Piseco	7.0	6.7, 7.4	no trend	7	5, 8	increasing^	Circumneutral, moderate sensitivity
Raquette	6.9	6.6, 7.4	no trend	5	3, 6	increasing^	Circumneutral, moderate sensitivity
Sacandaga	7.1	6.5, 7.5	no trend	11	4, 13	increasing^	Circumneutral, moderate sensitivity
Seventh	7.1	6.5, 7.5	no trend	12	10, 13	increasing^	Circumneutral, low sensitivity
Sixth	7.0	6.0, 7.5	no trend	13	10, 14	increasing*	Circumneutral, low sensitivity
Spy	6.9	6.2, 7.5	increasing*	6	5, 10	increasing^	Circumneutral, moderate sensitivity

of the lakes has shown considerable improvement over time. Seventeen of the lakes (81%) have exhibited an increasing trend in alkalinity, while the remaining four lakes have exhibited no statistical change over time (Table 6)

Because only the surface water samples from the summer months were analyzed, the assessment of the pH of HC lakes may underestimate overall acidity. The most acidic pulse of water from the watershed is usually associated with spring snowmelt, which is not captured in this sampling regime. In addition, photosynthesis is greatest in the summer months, which increases the pH of the water due to the removal of CO_2. On a regional scale, there is plenty of evidence to support that lakes are recovering from acidification. Over the last several decades, implimentaion of national and international environmental regulations has resulted in significant declines in the rate of acid deposition. The most influential of these regulations for the Adirondacks was the 1990 amendments to the Clean Air Act (enacted in 1994). Analysis of historical acid deposition data from the National Atmospheric Deposition Program in Huntington Forest (NADP - NTN) reveals a significant downward trend in annual sulfate deposition, with a 84% reduction between the years 1994 and 2017 (p-value < 0.001; R^2 = 0.84, slope = -0.63). Nitrate deposition over that same period decreased by 54% (p-value < 0.001; R^2 = 0.89, slope = -0.46), and precipitation acidity decreased by a factor of nearly 10 (p-value < 0.001; R^2 = 0.85, slope = -0.04; Figure 5; NADP NTN 2018). Likewise, recent research from 74 lakes in the Northeast (60% in the Adirondacks) illustrate that several acid indicators such as sulfate concentration and acid neutralizing capacity have exibited significant recovery (Strock et al 2014).

Phosphorus

Phosphorus is of major importance to structure and metabolism of all organisms. Decades of experimental and observational research have demonstrated that phosphorus is typically the limiting nutrient for algal productivity in lakes (Hecky and Kilham 1988). In freshwater systems, phosphorus exists in relatively small amounts compared to other essential nutrients such as carbon, nitrogen, oxygen, and sulfur. The addition of extra phosphorus allows production to increase greatly because all other essential elements are usually available in excess (Schindler 1977). Natural weathering slowly releases phosphorus from rocks and soils into aquatic systems; however, phosphorus can rapidly enter water through fertilizer application, wastewater effluent, and agricultural runoff. Phosphorus exists in a number of forms in aquatic systems, including readily available dissolved phosphate, and organically and inorganically bound phosphorus.

Total phosphorus is all of the forms of phosphorus combined and serves as an important indicator of overall

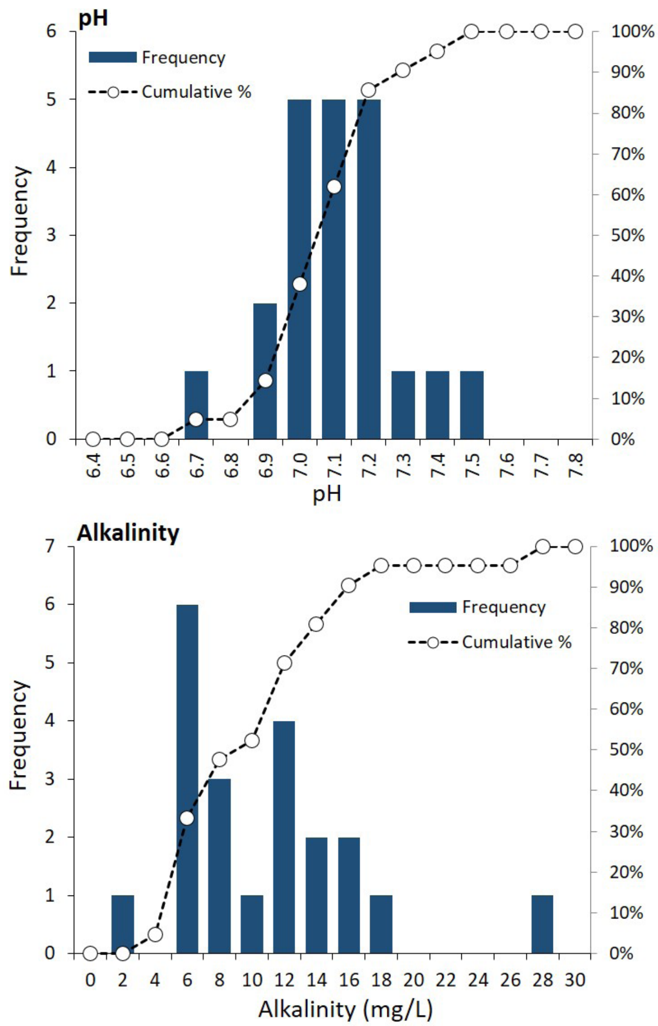


Figure 4. Frequency histogram of the average pH (upper) and alkalinity (lower) of the Hamilton County study lakes for the years 2015 to 2017.

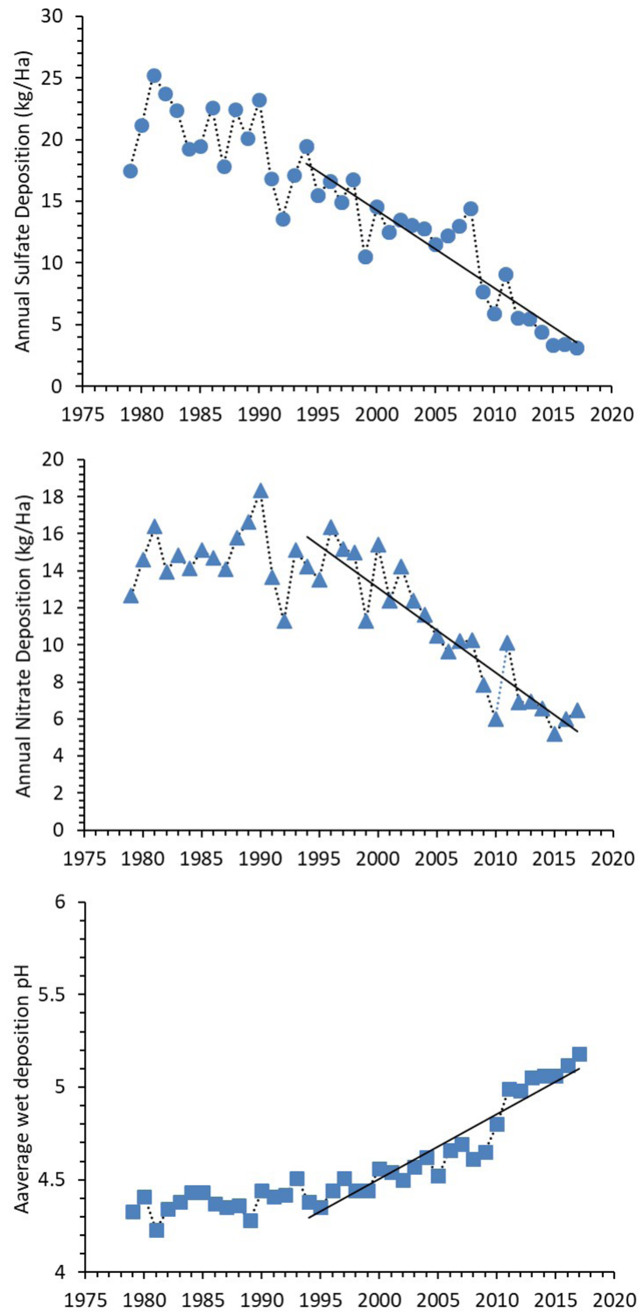


Figure 5. Acid deposition data collected at the National Atmospheric Deposition Monitoring Program station in Huntington Forest, Newcomb NY, 1979 – 2017. Solid lines denote statistically significant trends ($p < 0.05$) since the enactment of the 1990 amendments to the Clean Air Act.

*Table 7. Current status and historical trends in total phosphorus concentration for the Hamilton County study lakes. * denotes significance at the 0.05 level, ^ denotes significance at the 0.01 level.*

Waterbody	TP Status: 2015-2017 Avg. (µg/L)	Range	Trend 1993-2017
Blue Mnt	3.0	1.7, 4.6	decreasing*
Eighth	3.4	2.5, 4.8	decreasing^
Fawn	5.9	4.0, 10.3	decreasing*
Fifth	5.2	3.3, 6.9	decreasing*
Fourth	5.4	3.0, 8.5	decreasing^
Indian	5.1	3.5, 7.5	decreasing*
Abanakee	7.9	5.0, 8.2	decreasing*
Adirondack	14.0	11.5, 20.5	no trend
Algonquin	8.4	5.4, 12.1	no trend
Eaton	4.0	2.4, 6.3	decreasing^
Pleasant	6.0	4.3, 8.0	decreasing^
Limekiln	3.9	3.0, 4.6	decreasing^
Long	5.6	4.0, 7.3	decreasing*
Morehouse	5.4	4.2, 7.4	decreasing*
Oxbow	12.1	8.2, 16.2	no trend
Piseco	6.7	4.9, 10.0	decreasing^
Raquette	4.9	3.8, 6.3	decreasing^
Sacandaga	5.7	4.6, 6.9	decreasing^
Seventh	3.3	2.5, 5.0	decreasing^
Sixth	3.9	3.1, 4.8	decreasing^
Spy	6.4	3.7, 8.1	decreasing^

trophic status of a lake. Generally speaking, lakes of low productivity (oligotrophic) have total phosphorus concentrations less than 10 µg/L, while highly productive lakes (eutrophic) have total phosphorus concentrations greater than 20 µg/L (New York State Department of Environmental Conservation {NYSDEC} assessment criteria).

In order to assess the status of phosphorus in HC lakes we analyzed the total phosphorus concentration for each lake over the three-year period of 2015-2017. Overall, average total phosphorus concentrations in the surface water of HC lakes were low, and ranged from less than 4 µg/L in Blue Mountain Lake to as high 14 µg/L in Adirondack Lake (Table 7). The vast majority of lakes (90%) had average concentrations of less than 10 µg/L, suggesting that they lean toward oligotrophy (Figure 6).

Analysis of the 25-year data set revealed that 19 of the study lakes (90%) have experienced a significant downward trend in total phosphorus concentration over time (Table 7). As an example, the total phosphorus concentration of Sacandaga Lake ranged from 13 to 17 µg/L in the period from 1995-1997. Twenty years later

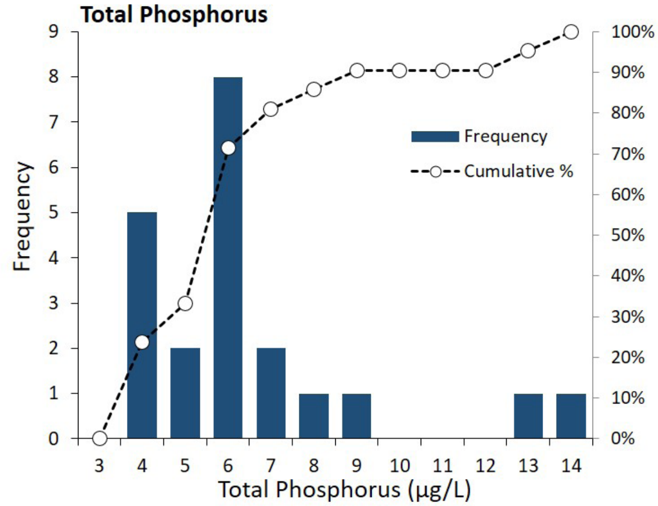


Figure 6. Frequency histogram of the average concentration of total phosphorus in the Hamilton County study lakes for the years 2015 to 2017.

the concentration ranged from 5 to 6 µg/L. Although these statistics suggest a regional decrease in phosphorus availability, data interpretation should proceed with caution. The method used to analyze phosphorus on the HC lakes has undergone numerous changes since the project began. The analytical modifications have certainly had a positive influenced on quality control, including detection limits, accuracy, precision, and probability of contamination. Most recently, the AWI implemented substantial changes to the total phosphorus methodology in 2010 by switching from a manual benchtop method to fully automated flow injection analysis. The history of method changes may be responsible for the decreasing trend in phosphorus observed in the HC data. Though, it is worth noting that the decadal analysis of the HC data performed in 2003 also detected a significant downward trend in total phosphorus across the county (HCSWCD 2003).

Nitrogen

Nitrogen is an essential element that can be the limiting nutrient for algal productivity in lakes, but it is generally the second most limiting nutrient after phosphorus. Nitrogen does not typically receive the attention that phosphorus does because it is more abundant and has a variety of sources in the watershed. The ultimate source of nitrogen in the ecosystem is nitrogen gas (N_2), which is triple bonded inert gas, and thereby unusable by the vast majority of organisms. Only some species of cyanobacteria can "fix" nitrogen gas into a form they can utilize, giving cyanobacteria a competitive edge in environments with limited useable nitrogen. Cyanobacteria are an important link in the nitrogen cycle because they release excess nitrogen in the usable form of ammonium.

*Table 8. Current status and historical trends in nitrate concentration of the Hamilton County study lakes. * denotes significance at the 0.05 level, ^ denotes significance at the 0.01 level.*

Waterbody	NO_x Status: 2015-2017 Avg. (µg/L)	Range	Trend 1993-2017
Blue Mnt	14	BD, 49	decreasing*
Eighth	42	BD, 124	no trend
Fawn	BD	BD	decreasing^
Fifth	103	40, 22	no trend
Fourth	65	BD, 151	decreasing*
Indian	49	BD, 168	decreasing*
Abanakee	41	BD, 120	no trend
Adirondack	18	BD, 155	no trend
Algonquin	17	3, 43	no trend
Eaton	18	BD, 168	no trend
Pleasant	BD	BD	increasing^
Limekiln	72	29, 160	no trend
Long	32	BD, 155	no trend
Morehouse	2	BD, 11	decreasing^
Oxbow	BD	BD	decreasing^
Piseco	8	BD, 30	decreasing^
Raquette	39	5, 85	no trend
Sacandaga	14	BD, 124	decreasing^
Seventh	124	21, 197	decreasing*
Sixth	118	67, 235	no trend
Spy	24	BD, 216	no trend

Plants and algae can only assimilate inorganic forms of nitrogen, with a preference for ammonium (NH^{+4}), followed by nitrate (NO_3), and nitrite (NO_2). These forms of inorganic nitrogen enter the lake though the decomposition of organic matter within the lake or the watershed, as well as through precipitation and atmospheric deposition. Because phytoplankton can rapidly assimilate inorganic nitrogen, summer concentrations in the surface water of Adirondack lakes is typically low. Lake managers are interested in inorganic nitrogen because unusually high concentrations of nitrate or ammonia are indicative of human impacts such as wastewater discharge, agricultural runoff, and acid deposition.

Of the three forms of inorganic nitrogen, HCSWCD only monitored nitrate and nitrite as one analyte, known collectively as NOx, but herein referred to as nitrate. We made two relevant observations about nitrate in the HC data set. The first was that the nitrate concentrations in the study lakes were relatively low, with average concentrations for the 2015-2017 period falling below analytical detection in Fawn, Pleasant, and Oxbow Lakes, to a maximum of 124 µg/L in Seventh Lake (Table 8). The majority of lakes (76%) had average concentrations of less than 50 µg/L (Figure 7). The low summer average in the HC lakes was within the range we found in the surface water of several other Adirondack Lakes during the same time period. For example, average concentration in nine lakes monitored by the AWI in Franklin and Essex Counties ranged from below analytical detection to 50 µg/L. To put these values in perspective, lakes with elevated nitrate concentration, such as Cayuga and Owasco in the western Finger Lakes, had average values of 712 and 608 µg/L, respectively, in 2017 (NYSDEC 2018). Our second observation, which we expected, was that nitrate concentrations are highly variable across the HCSWCD sampling season. In general, a combination of spring snow melt and low algal productivity results in the greatest nitrate concentration in the spring. By August, decreased precipitation and increased biological demand results in the very low concentrations that are evident in Table 8.

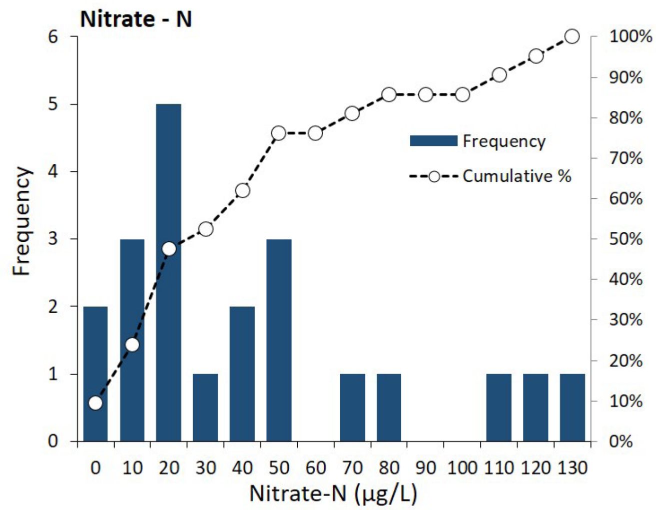


Figure 7. Frequency histogram of the average nitrate concentration of the Hamilton County study lakes for the years 2015 to 2017.

Analysis of the 25-year data set revealed that 9 of the study lakes (48%) have experienced a significant downward trend in nitrate concentration. It is reasonable to assume the regional decrease in acid deposition was responsible for the negative trend in nitrate concentrations (as observed by Strock et al. 2014). Acid deposition has an influence on nitrate concentration because it is comprised of both sulfuric and nitric acid. Prior to being deposited on the landscape, nitric acid fully dissociates in atmospheric water into a free acid proton (H+) and its conjugate base nitrate (NO_3). As previously stated, analysis of historical acid deposition data from the NADP station in Huntington Forest reveals a significant downward trend in annual nitrate deposition since the enactment of the 1990 amendments to the Clean Air Act (see Figure 5).

As with the phosphorus data, we should exercise cau-

*Table 9. Current status and historical trends in chlorophyll-a concentration of the Hamilton County study lakes. * denotes significance at the 0.05 level, ^ denotes significance at the 0.01 level.*

Waterbody	Chl-a Status: 2015-2017		Trend
	Avg. (µg/L)	Range	1993-2017
Blue Mnt	1.7	0.5, 3.6	no trend
Eighth	2.3	0.1, 4.4	no trend
Fawn	3.6	2.1, 5.5	no trend
Fifth	3.0	1.5, 4.1	no trend
Fourth	4.7	1.7, 10	no trend
Indian	5.7	1.7, 10.8	no trend
Abanakee	4.6	1.6, 7.4	no trend
Adirondack	9.0	4.7, 11.2	no trend
Algonquin	4.8	1.3, 7.3	increasing*
Eaton	2.9	0.4, 7.6	no trend
Pleasant	4.2	1.2, 6.3	no trend
Limekiln	2.8	0.7, 10.5	no trend
Long	6.0	2.8, 9.9	no trend
Morehouse	1.8	0.5, 5.2	no trend
Oxbow	9.4	3.8, 14.9	increasing*
Piseco	4.1	0.9, 7.5	no trend
Raquette	3.7	1.6, 6.3	no trend
Sacandaga	4.6	1.1, 8.7	no trend
Seventh	1.6	0.5, 3.3	no trend
Sixth	2.3	1.2, 4.0	no trend
Spy	2.7	0.5, 5.9	no trend

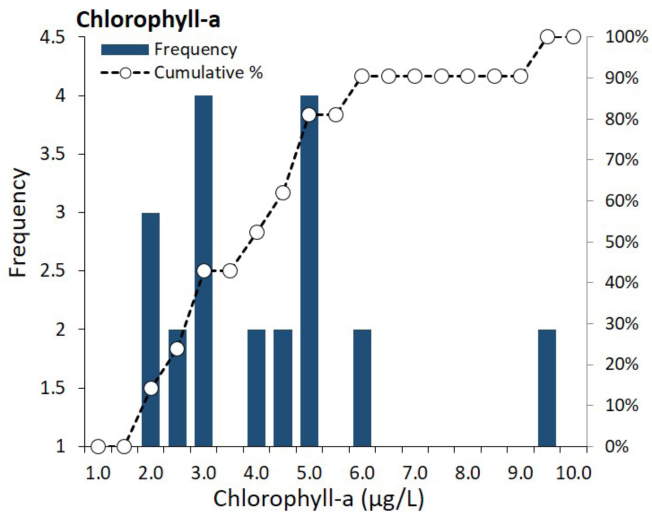


Figure 8. Frequency histogram of the average concentration of chlorophyll -a in the Hamilton County study lakes for the years 2015 to 2017.

tion when interpreting nitrate trends. Because nitrate concentration exhibit significant inter-annual variation and are strongly related to hydrologic events, HCSWCD's approach of analyzing three samples per annum may not be robust enough to assess long-term trends. Changes to the sampling regime may also have influenced the historical trends. Prior to 2000 samples were taken during the month of May, and these spring samples typically have greater nitrate concentrations from snowmelt.

In addition, nitrate is just one form of nitrogen that is important to lake ecology. Adding other nitrogenous analytes to the monitoring program, particularly ammonium and total nitrogen, would improve our understanding of the role nitrogen plays in HC lakes.

Chlorophyll-a

Chlorophyll-a is the primary photosynthetic pigment found in all freshwater species of algae and cyanobacteria. Quantifying algal biomass in a lake is a difficult undertaking; however, a measurement of chlorophyll is a relatively simple and inexpensive analysis that can provide a surrogate measure of algal productivity (Wetzel 2001). Chlorophyll is not a direct measure of algal biomass as the concentration of chlorophyll varies somewhat by species and environmental conditions. This said, increases in chlorophyll are generally associated with increased algal production, and the concentration of chlorophyll is widely considered as the most direct measure of the trophic state of lakes (Calson 1977). Generally speaking, lakes of low productivity (oligotrophic) tend to have chlorophyll-a concentrations less than 2 µg/L, while highly productive lakes (eutrophic) often have chlorophyll concentrations greater than 8 µg/L (NYS DEC assessment criteria). Typically, major changes in algal biomass (e.g. an algae bloom) are related to changes in the availability of nutrients, primarily phosphorus or nitrogen, or at times, silica or inorganic carbon (Wetzel 2001).

Concentration of chlorophyll-a was variable between HC lakes, with average concentrations that stretched from a low of 1.7 µg/L in Blue Mountain Lake, to a maximum of 9.4 µg/L in Oxbow Lake during the 2015-2017 period (Table 9). Over 40% of the lakes had average concentrations less than 3 µg/L, while nearly 50% of the lakes had average concentrations between 3.5 and 6 µg/L (Figure 8). Seasonal variation of chlorophyll concentration was evident in all of the study lakes. For example, we observed chlorophyll concentrations in Limekiln Lake as low as 0.7 and as high as 10.5 µg/L. The interaction of nutrient availability, light, water temperature, and grazing all affect algal biomass, so variation in chlorophyll concentrations throughout the year is expected depending on which of these factors is limiting growth at a particular time.

Chlorophyll-a concentration in the HC lakes has remained stable over the 25-year program, with 19 lakes (90%) exhibiting no discernable trend in the historical data. Only Lake Algonquin and Oxbow lake exhibited an increasing trend in chlorophyll concentration (Table 9). The absence of chlorophyll trends in HC lakes is consistent with the findings of the Adirondack Lake Assessment Program, where 80% of the 67 lakes had no statistical trend in chlorophyll concentration (Laxson et al. 2018a).

Transparency

Transparency depth is a simple and inexpensive measurement of water clarity and light penetration. It is measured by lowering a 20 cm black and white disk, called a Secchi disk, through the water to the depth where it is no longer visible from the surface. The Secchi disk is the most widely used limnological tool because it integrates many characteristics of a lake into a simple metric.

The depth to which the Secchi disk can be seen is ultimately a function of light penetration through the water. Pure H_2O absorbs light and transforms it into heat in a predictable and relatively slow pattern. The amount of light that is absorbed (or scattered) rapidly increases as the amount of dissolved and suspended materials rises, resulting in suppressed transparencies. Transparency data is used most often to assess the productivity of a lake. In general, lakes that have low productivity and low algal abundance have greater transparency. As algal productivity increases the transparency of the water body tends to decrease (see Trophic State). Many other factors can affect transparency, such as turbidity, suspended sediment, and dissolved chemicals. For example, the transparency of many lakes is influenced by the quality and quantity of dissolved organic matter (DOM), which can selectively attenuate solar radiation and reduce transparency (Zhang et al. 2010; Williamson et al. 1999).

Average transparency depth for the period of 2015-2017 ranged from a low of 2.4 meters in Oxbow Lake to a maximum of 7.8 meters in Blue Mountain Lake (Table 10). The majority of lakes (67%) had an average transparency values greater than 3.5 meters (Figure 9). Analysis of the 25-year dataset revealed that that 17 of the HC study lakes (81%) have experienced a significant downward trend in transparency. As an example, during the first three years of the study (1993-1995) the average transparency of Seventh Lake ranged from 5.6 to 7.0 meters, while more recently (2015-2017) it has ranged from 3.3 to 5.3 meters.

Reduction in water transparency appears to be a regional phenomenon. The Adirondack Watershed Institute has observed statistically significant downward trends

*Table 10. Current status and historical trends in transparency depth of the Hamilton County study lakes. * denotes significance at the 0.05 level, ^ denotes significance at the 0.01 level.*

Waterbody	Transp: 2015-2017 Avg. (m)	Range	Trend 1993-2017
Blue Mnt	7.8	4.7, 10.9	no trend
Eighth	5.0	4.1, 6.1	no trend
Fawn	4.5	3.8, 6.0	no trend
Fifth	4.0	2.9, 4.9	decreasing*
Fourth	4.8	3.0, 6.6	decreasing*
Indian	3.8	2.9, 4.4	decreasing*
Abanakee	3.0	2.5, 3.6	decreasing^
Adirondack	2.5	2.1, 3.0	decreasing*
Algonquin	2.3	1.4, 2.8	decreasing^
Eaton	5.3	4.5, 6.7	decreasing*
Pleasant	3.3	2.6, 4.4	decreasing^
Limekiln	5.7	4.2, 6.7	decreasing^
Long	3.0	2.4, 3.6	decreasing*
Morehouse	4.0	2.1, 5.3	decreasing^
Oxbow	2.4	2.0, 3.0	decreasing^
Piseco	3.5	2.5, 4.3	decreasing*
Raquette	3.7	3.1, 4.9	decreasing^
Sacandaga	3.6	2.7, 4.9	increasing^
Seventh	4.4	3.3, 5.3	decreasing^
Sixth	4.3	3.2, 5.7	decreasing^
Spy	3.9	2.4, 5.3	no trend

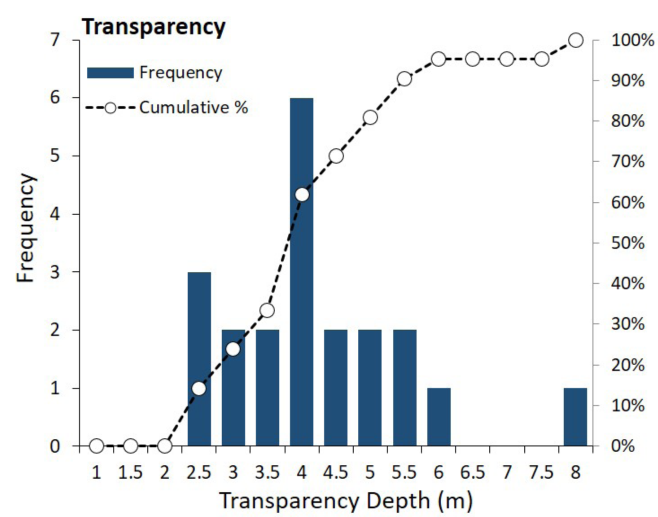
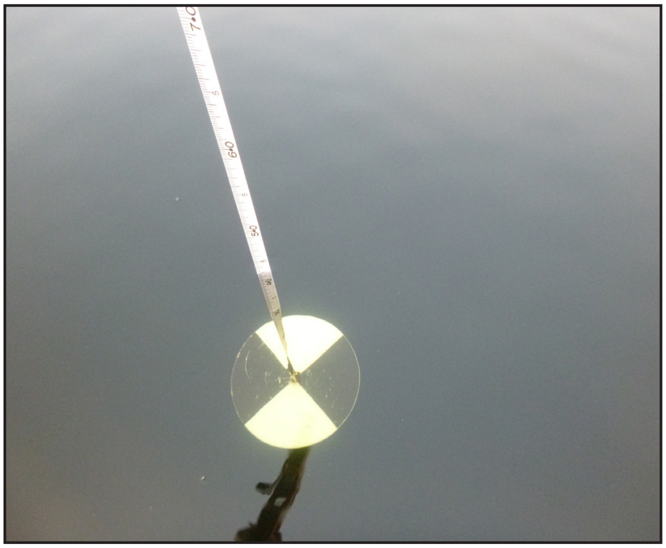


Figure 9. Frequency histogram of the average transparency depth of the Hamilton County study lakes for the years 2015 to 2017.



Measuring transparency depth with a Secchi disk.

in several lakes in the Adirondack region, including Upper Saranac Lake, the Rainbow Lake Chain, Litchfield Park Lakes, as well as 15% of the lakes participating in the Adirondack Lake Assessment Program (Laxson et al. 2018a; Laxson et al. 2018b; Laxson et al. 2018c). Current research suggests that increased dissolved organic carbon concentration (DOC) is responsible for the observed downward trend in transparency (Williamson et al. 2014). Because DOC has a strong ability to absorb light, DOC enrichment results in depressed transparency.

Two popular hypothesis that attempt to explain increased concentrations of DOC in lakes are the reduction in acidic deposition (Montieth et al. 2007), and increased precipitation from climate change (Shindler et al. 1996; Pace and Cole 2002; Gaiser et al. 2009). It is clear that both of these interacting environmental stressors are at work in the Adirondack Region and may be influencing the transparency of lakes in Hamilton County. For example, a wide range of research has clearly demonstrated that DOC concentrations are on the rise in Adirondack lakes recovering from acidification (Montieth et al. 2007; Lawrence et al. 2013; Driscoll et al. 2003). Concurrently, both precipitation and temperature recorded at the Indian Lake weather station have exhibited significant increases during the study period of 1993-2017 (precip: p = 0.002; temp: p = 0.002; Figure 10).

Trophic Status

Trophic status, a term derived from the Greek word *trophi* (meaning food or nourishment), is used by limnologists to explain the overall lake productivity. Lake productivity is naturally influenced by the rate of nutrient supply from the watershed, climatic condition, and lake and watershed morphology. Human activities and development within a watershed have the potential to increase the rate of nutrient supply into the lake and thereby accelerate lake productivity, a process known as cultural eutrophication. Most Lakes in the Adirondacks can be assigned into one of three trophic classes: oligotrophic, mesotrophic, or eutrophic based on their overall level of biological productivity.

Oligotrophic - From the Greek words *oligo* (meaning few) and *trophi* (meaning nourishment), oligotrophic lakes have low biological productivity due to relatively low nutrient content. As a result of low nutrients oligotrophic lakes have high transparency, low algal abundance, low organic matter in the sediments, sparse aquatic plant growth, and abundant dissolved oxygen throughout the water column the entire year. Oligotrophic lakes are most likely to support a cold-water fishery (trout and salmon).

Eutrophic - From the Greek root *eu* (meaning good), eutrophic lakes have high biological productivity due to abundant levels of nutrients. As a result of high nutrient availability eutrophic lakes are typified by high algal productivity, low transparency, high organic matter in the sediments, and periods of anoxia in the bottom of the water column (the hypolimnion). Eutrophic lakes tend to support dense aquatic plant growth in the littoral zone. Eutrophic lakes are unlikely to support a viable cold-water fishery

Mesotrophic - from the Greek word *meso* (meaning middle), mesotrophic is an intermediate trophic classification on the continuum between oligotrophy and eutrophy.

Trophic status is typically determined by analyzing lake data on transparency, chlorophyll and total phosphorus and employing one of the two most commonly used classification approaches, the fixed boundary method or a trophic index method. Fixed boundary methods use

Table 11. Fixed boundary trophic status determination method used by the NYSDEC.

Parameter	Oligotrophic	Mesotrophic	Eutrophic
Transparency (m)	>5	2 - 5	<2
Total phosphorus (µg/L)	<10	10 - 20	>20
Chlorophyll-a (µg/L)	<2	2 - 8	>8

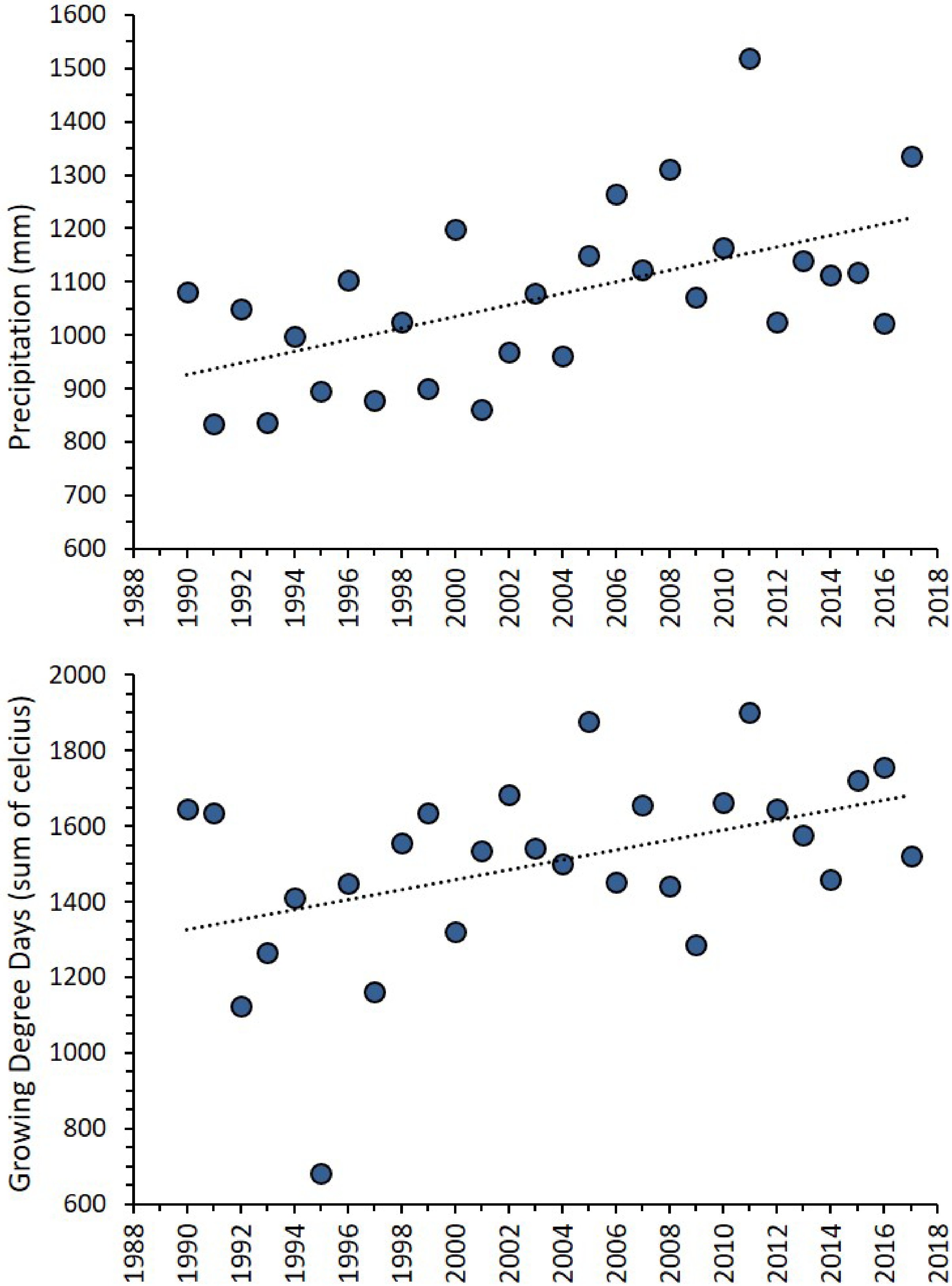


Figure 10. Total annual precipitation (upper panel) and growing degree days (lower panel) recorded at the National Climate Data Center in Indian Lake, 1990 – 2017 (NCDC station: USC00304102). Growing degree days are based on the base temperature of 10°C (50°F). Dashed lines denote a statistically significant trend over time (P < 0.05).

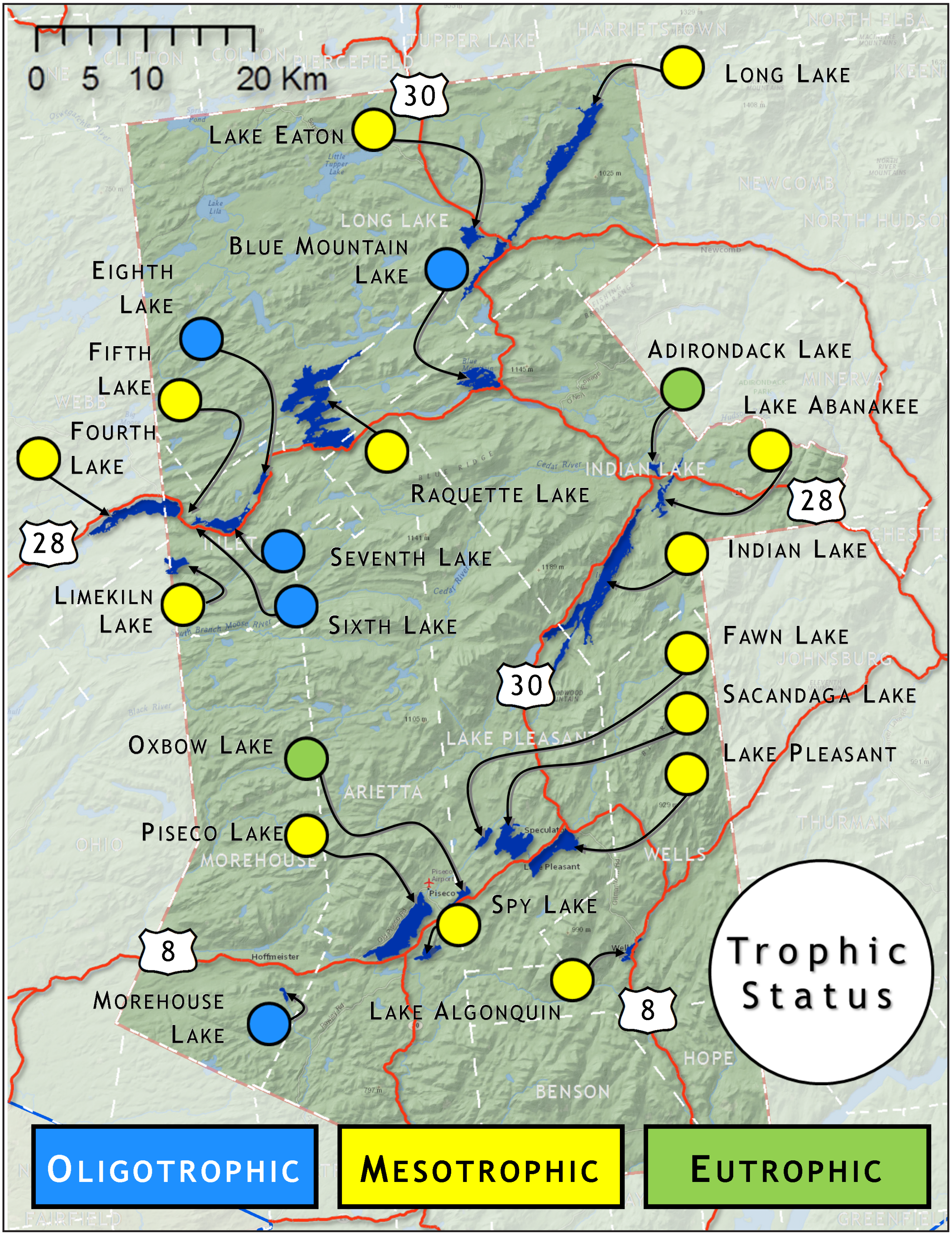


Figure 11. Spatial representation of the trophic status of the Hamilton County study lakes. Trophic state calculated from the NYSDEC guidelines for chlorophyll-a.

Table 12. Trophic classification of lakes based on Carlson's Trophic State Index (TSI).

TSI Value	Trophic Classification	Likely Attributes
<30	Oligotrophic	Clear water, high oxygen throughout hypolimnion during the entire year.
30-40	Oligotrophic	Clear water, periods of hypolimnetic anoxia possible during the summer in relatively shallow lakes.
40-50	Mesotrophic	Moderately clear, increased probability of hypolimnetic anoxia during the summer.
50-60	Eutrophic	Mildly eutrophic. Decreased transparency, hypolimnetic anoxia and warm water fishery only. Supports all recreational and aesthetic uses but threatened.
60-70	Eutrophic	Dominance of blue-green algae likely, extensive macrophyte growth in shallow water.
70-80	Hyper-eutrophic	Heavy algal blooms possible throughout summer. Recreational and aesthetic uses greatly impacted.
>80	Hyper-eutrophic	Algal scum, summer fish kills, few macrophytes due to algal shading.

predetermined ranges of transparency, total phosphorus, and chlorophyll to classify the lake's trophic status, although most lake managers consider chlorophyll to be the most direct measure. A good example of a fixed boundary is the traditional method employed by the NYSDEC that appears in Table 11 (NYSDEC Clean Lakes Assessment). Using recent data from 2015-2017 and the NYSDEC guidelines for chlorophyll, we classified five lakes (24%) of the HC lakes as oligotrophic, 14 lakes (67%) as mesotrophic, and two lakes (9%) as eutrophic (Figure 11).

The most commonly used tropic index (TSI) is Carlson's TSI (Carlson 1977). This index is based on algal biomass as determined by the three variables of transparency, total phosphorus, and chlorophyll as the basis for the trophic state classification. The range of the index is from approximately zero to 100, although technically there are no upper or lower bounds. Each major TSI division (10, 20, 30, etc.) represents a doubling in algal biomass. The traditional trophic classification scheme can be overlaid on the index as follows: TSI < 40 = oligotrophic, TSI 40-50 = mesotrophic, TSI > 50 = Eutrophic (Table 12).

The strength of Carlson's TSI is that resource managers can use it to detect unusual conditions and interesting lake dynamics. TSI values for phosphorus, for example, may not lead to the same trophic classification as the TSI for transparency or chlorophyll under phosphorus-limited conditions (known as TSI deviations, Carlson and Havens 2005). TSI deviations for the HC study lakes are illustrated in Figure 12. All 21 lakes have a greater TSI score derived from chlorophyll than from total phosphorus concentration, suggesting that phosphorus limits algal biomass. Three lakes (Algonquin, Morehouse, and Seventh) have TSI values calculated from transparency that overestimate the productivity as calculated by chlorophyll, suggesting that other particles besides algae attenuate light and reduce transparency. In Adirondack lakes, colored dissolved organic matter is typically responsible for this scenario. The remaining 19 lakes have greater TSI values calculated from chlorophyll than would be expected based on the transparency data. This scenario may occur when large-bodied species dominate the algal community. Large algal species contain a greater pool of chlorophyll, but do not atteneuate light as rapidly as numerouse small - bodied species.

Regardless of the lakes trophic classification, it is important to remember that "trophic state" is just an organizing concept limnologists use to locate a particular waterbody on a continuum of productivity, thereby connecting the lake to previous information and knowledge from other lakes. An oligotrophic lake and its biota do not possess a distinct identity or wholeness that separates it from a mesotrophic lake. The physical variables of a lake system are dynamic and exist across a wide gradient and the biological components of a lake change continuously as well (Carlson and Simpson 1996).

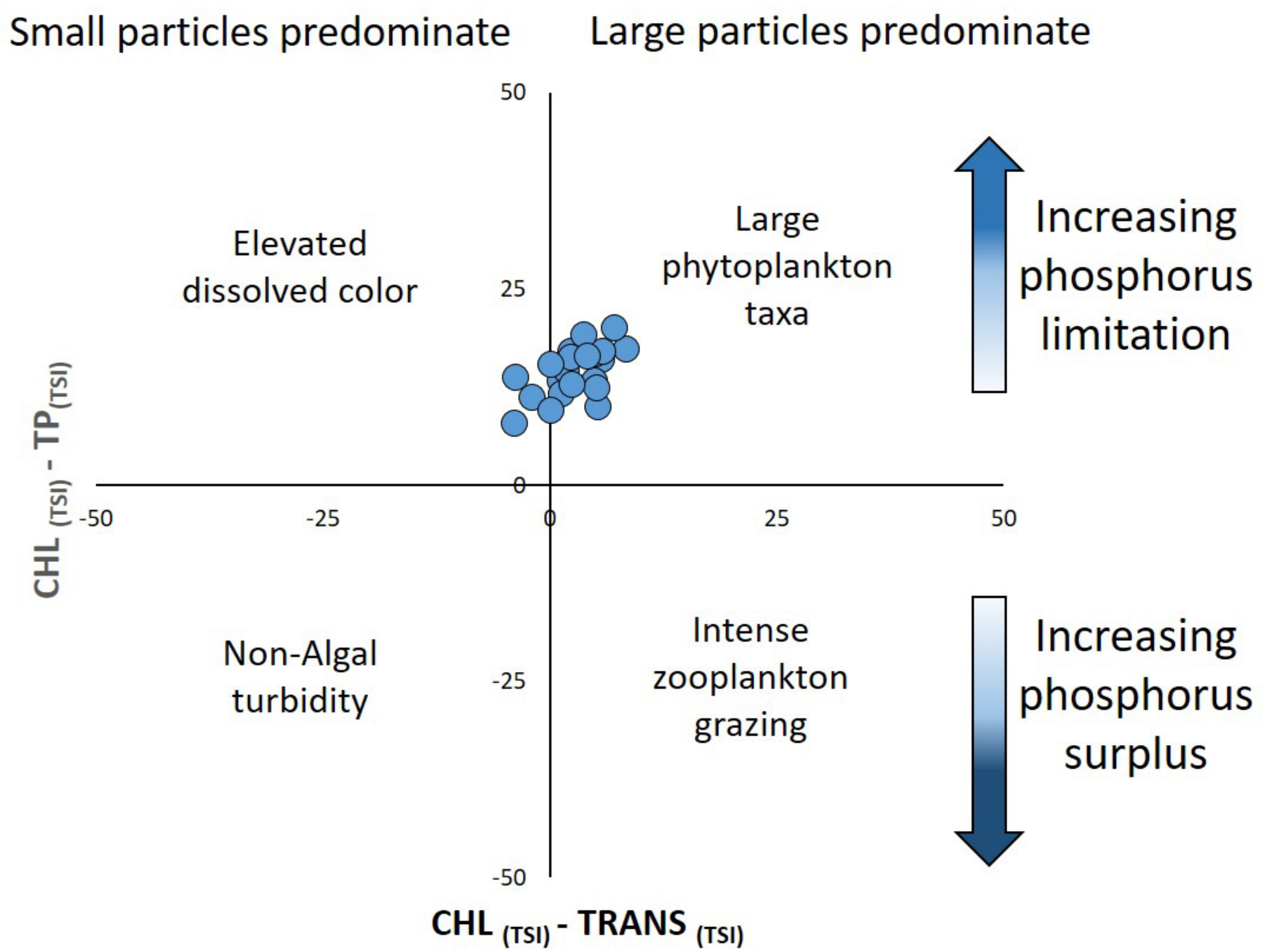


Figure 12. Trophic state deviation plot for the Hamilton County study lakes (blue circles) that illustrates the likely conditions experienced by the lakes (based on Carlson and Havens 2005).

Road Salt Influence

Lakes in the Adirondack region have naturally low concentrations of both chloride and sodium, with median background concentrations of 0.3 mg/L and 0.5 mg/L respectively (Kelting et al. 2012). Wide spread use of road salt (primarily sodium chloride) over the last several decades has significantly increased the concentration of these ions in the environment. Many lakes in the Adirondacks now contain anywhere from 10 to 170 times the background concentration of chloride (Laxson et al. 2018). Adirondack roads receive approximately 208,000 metric tons of road deicers each year, with an annual average of 23 tons of salt applied to each lane kilometer of state roads (NYSSOGS 2013). At a regional scale, salted roads are hydrologically connected to 77% of the surface water in the Adirondack Park (Regalado and Kelting 2015). Recent research has highlighted that road salt application has significantly elevated the concentrations of sodium and chloride in Adirondack lakes, and that the extent of concentration increase is directly proportional to the density of state roads within the watershed (Kelting et al. 2012).

Road salt can have direct and indirect effects on aquatic ecosystems and drinking water supply. It is clear that the direct impact of road deicers on organisms is not well understood, and is highly variable across taxa. Based on laboratory studies, the lethal concentration for most aquatic organisms is much higher than concentrations encountered in a lake environment; however, at times lethal concentrations can be encountered in near-road environments that receive direct runoff such as roadside streams or vernal pools (reviewed by Findlay and Kelly 2011; Kelting and Laxson 2010). Researchers have also documented indirect effects to aquatic systems. For example, sodium actively displaces base cations (Ca, K, and Mg) as well as heavy metals from the soil, elevating their concentration in surface waters (Kelting and Laxson 2018). In some extreme cases, the sheer volume of road salt runoff that enters a lake can interfere with lake stratification, causing numerous negative consequences for oxygen availability, nutrient cycling and habitat availability (Wiltse et al. 2018; Bubeck et al. 1971; Kjensmo 1997). Sodium and chloride can impart an undesirable taste to drinking water, the United States Environmental Protection Agency has a guideline of 250 mg/L for chloride and 20 mg/L for sodium, but these are for public drinking water supplies only and are not enforceable standards.

Although it is difficult to use sodium and chloride concentration to assess impact to the aquatic environment, the concentration of these chemicals serves as a reliable index for the level of hydrologic connectivity a lake has with salted roads in its watershed. We propose the boundaries presented in Table 13 as a general guideline for gauging road salt influence on a lake.

During the 2015-2017 period, the concentration of chloride ranged from a low of 0.5 mg/L in Morehouse Lake to a maximum of 20.5 mg/L in Oxbow Lake. Sodium concentration ranged from a low of 0.4 mg/L in Morehouse Lake to a high of 11.7 mg/L in Eighth Lake. Only two of the study lakes were free of road salt influence. Five of the lakes (24%) exhibited low-level influence, 13 lakes (62%) presented moderate influence, and one lake was characterized as having a high amount of road salt influence (Table 14, Figure 13). The density of New York State roads in each of the lake's watershed (lane-kilometers / hectare) clearly dictates the concentraion of chloride and sodium in the HC study lakes. We found that 93% of the variation in chloride and 92% of the variation in sodium between study lakes was explained by the state road density alone (Figure 14, chloride: $P < 0.001$, $R^2 = 0.928$, sodium: $P < 0.001$, $R^2 = 0.917$).

Routine monitoring of chloride and sodium began in 2013, so we are limited in our ability to analyze historical trends. Only Eighth Lake exhibited an increasing trend in road salt ions, with a slight, yet significant increase in chloride between 2013 and 2017. Despite the lack of historical data, we know that HC lakes with paved roads in their watershed have experienced substantial salt enrichment because concentrations of chloride are 4 to 70 times greater than background values for Adirondack lakes (Kelting et al. 2012).

Table 13. General assessment of road salt influence based on chloride concentration.

Chloride (mg/L)	Road Salt Influence
Less than 1.0	Not significant
1 - 5	Present – low
5 - 20	Moderate
20 – 50	High

Conductivity

Conductivity is a measurement of the ability of a water sample to conduct electricity. Pure H2O is a poor conductor of electricity. The ability of water to conduct electricity increases as the concentration of dissolved ions in the water increases. Thus, conductivity is a strong indicator of the amount of dissolved ions in water. Typically, the conductivity of least-impacted and undeveloped lakes in the Adirondacks is quite low, and typically in the range of 10 to 25 µS/cm. Elevated conductivity may be indicative of road salt pollution, faulty septic systems or the influence of bogs and wetlands in the watershed.

During the 2015 to 2017 period, average conductivity ranged from a minimum of 7.1 µS/cm in Morehouse Lake to a maximum of 95.2 µS/cm in Eighth Lake. Conductivity data only exists as far back as 2013. Analysis of the five-year data set did not reveal any significant trends (Table 15). Overall, chloride concentration is the predominate driver of conductivity in HC lakes. Analysis of the pooled data for all lakes over the period of 2013-2017 (n = 316) revealed that chloride concentration explained 86% of the variation in conductivity.

AWI technician, Hunter Favreau, collecting salt loading data from an inlet stream to Blue Mountain Lake. Spring melting conditions, such as the one pictured above, can result in as much as 5,000 Kg/day of chloride entering Blue Mountain Lake from NYS 28/30 (Laxson et.al 2018d).

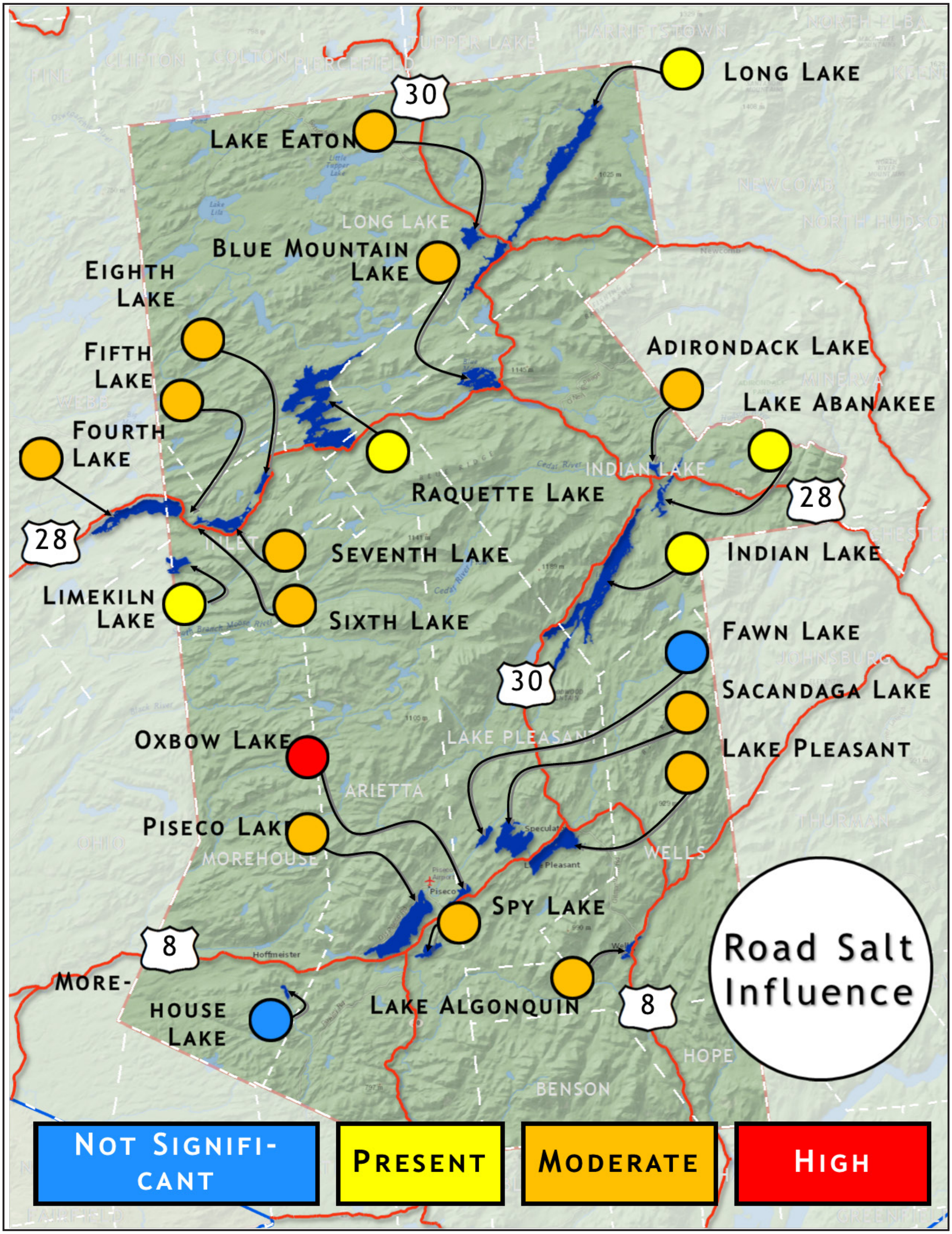


Figure 13. Spatial representation of the degree of road salt influence on the Hamilton County study lakes based on chloride concentration.

*Table 14. Current status, historical trends, and overall assessment of road salt influence on the Hamilton County study lakes. * denotes significance at the 0.05 level, ^ denotes significance at the 0.01 level.*

Waterbody	Chloride 2015-2017 Avg.	Chloride 2015-2017 Range	Chloride Trend 2013-2017	Sodium 2015-2017 Avg.	Sodium 2015-2017 Range	Sodium Trend 2013-2017	Road Salt Influence
Blue Mnt	16.2	15, 18	no trend	9.8	9, 12	no trend	Moderate
Eighth	19.4	18, 20	increasing*	11.7	10, 15	no trend	Moderate
Fawn	0.6	< 1	no trend	0.6	< 1	no trend	Not significant
Fifth	13.8	12, 20	no trend	8.3	6, 11	no trend	Moderate
Fourth	10.9	10, 12	no trend	6.4	5, 8	no trend	Moderate
Indian	3.2	2, 4	no trend	2.1	2, 3	no trend	Low
Abanakee	3.4	3, 4	no trend	2.2	2, 3	no trend	Low
Adirondack	11.1	9, 12	no trend	6.5	5, 8	no trend	Moderate
Algonquin	8.3	5, 13	no trend	5.0	3, 7	no trend	Moderate
Eaton	11.6	11, 13	no trend	6.8	6, 8	no trend	Moderate
Pleasant	10.5	9, 12	no trend	5.7	5, 7	no trend	Moderate
Limekiln	1.2	1, 2	no trend	0.8	<1	no trend	Low
Long	3.8	3, 4	no trend	2.6	2, 3	no trend	Low
Morehouse	0.5	< 1	no trend	0.4	< 1	no trend	Not significant
Oxbow	20.3	18, 23	no trend	11.4	10, 13	no trend	High
Piseco	5.6	5, 8	no trend	3.2	3, 4	no trend	Moderate
Raquette	4.4	4, 5	no trend	2.7	2, 3	no trend	Low
Sacandaga	8.0	7, 10	no trend	4.4	4, 5	no trend	Moderate
Seventh	10.8	10, 12	no trend	6.5	6, 7	no trend	Moderate
Sixth	11.5	11, 13	no trend	6.9	6, 7	no trend	Moderate
Spy	15.2	14, 17	no trend	7.7	2, 9	no trend	Moderate

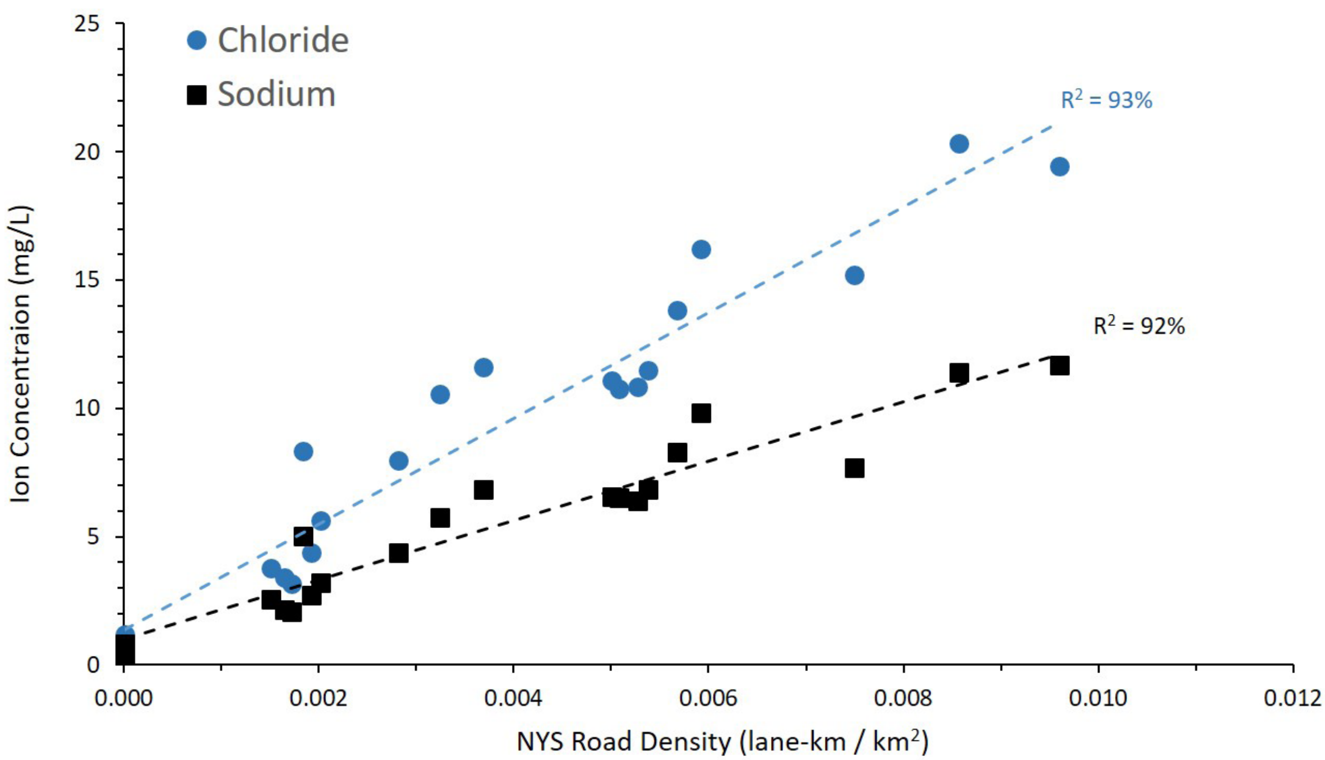


Figure 14. Relationship between chloride and sodium concentration in Hamilton County study lakes and the density of New York State roads in the watershed (lane-km / km2). Dashed lines denote a statistically significant relationship (P < 0.001 for both ions).

*Table15. Current status and historical trends in specific conductivity (25 degrees C) of the Hamilton County study lakes. * denotes significance at the 0.05 level, ^ denotes significance at the 0.01 level.*

Waterbody	Cond. Status: 2015-2017 Avg. (µS/cm)	Range	Trend 2013-2017
Blue Mnt	67.5	62, 74	no trend
Eighth	95.2	91, 98	no trend
Fawn	12.5	11, 15	no trend
Fifth	72.8	66, 95	no trend
Fourth	61.5	59, 64	no trend
Indian	21.9	19, 25	no trend
Abanakee	24.7	21, 28	no trend
Adirondack	83.4	75, 89	no trend
Algonquin	51.9	34, 64	no trend
Eaton	54.0	48, 75	no trend
Pleasant	54.6	52, 58	no trend
Limekiln	12.2	10, 15	no trend
Long	24.8	24, 26	no trend
Morehouse	7.1	6, 8	no trend
Oxbow	84.7	73, 91	no trend
Piseco	30.5	29, 33	no trend
Raquette	26.3	23, 30	no trend
Sacandaga	46.6	43, 50	no trend
Seventh	58.6	57, 60	no trend
Sixth	61.8	59, 65	no trend
Spy	57.8	54, 61	no trend

*Table16. Current status and historical trends in calcium concentraion of the Hamilton County study lakes. * denotes significance at the 0.05 level, ^ denotes significance at the 0.01 level.*

Waterbody	Calcium Status: 2015-2017 mg/L	Range	Trend 1997-2017
Blue Mnt	3.4	3.0, 3.7	no trend
Eighth	6.3	5.6, 6.6	increasing*
Fawn	1.6	1.4, 1.8	decreasing*
Fifth	5.4	4.6, 7.2	no trend
Fourth	4.9	4.4, 5.1	no trend
Indian	2.0	1.6, 2.4	no trend
Abanakee	2.4	2.0, 2.7	decreasing^
Adirondack	9.2	7.2, 11.7	no trend
Algonquin	5.0	3.2, 6.7	no trend
Eaton	2.8	2.4, 3.6	no trend
Pleasant	4.1	3.6, 4.9	no trend
Limekiln	1.6	1.3, 2.0	decreasing^
Long	2.2	1.9, 2.7	no trend
Morehouse	1.0	0.7, 1.1	decreasing*
Oxbow	3.8	3.0, 4.5	no trend
Piseco	2.4	2.0, 2.8	increasing*
Raquette	2.3	1.9, 2.9	increasing*
Sacandaga	4.0	3.5, 4.5	decreasing*
Seventh	4.5	4.0, 5.0	no trend
Sixth	4.7	4.1, 5.1	no trend
Spy	2.3	1.9, 3.2	no trend

Calcium

Calcium plays an important role in lake ecology because it is an essential element for the structure and physiology of all organisms. For example, calcium is needed for bones and teeth in vertebrates, exoskeletons and shells in invertebrates, and biochemical regulation in plants to name a few. The ultimate source of calcium in lakes is weathering of the bedrock, and to a lesser extent atmospheric deposition (dust). Many lakes in the Adirondacks have low concentrations of calcium, typically between 2 and 5 mg/L. The reason for the relatively low concentration is that the granite bedrock underlying most of the Adirondack region weathers slowly, resulting in a low rate of calcium generation. There are, however, many lakes in the Adirondacks where calcium rich bedrock results in elevated calcium concentrations, examples include Lake George (Ca = 12 mg/L), Augur Lake (Ca = 11 mg/L), Long Pond (Ca = 13 mg/L), and Lake Champlain (Ca = 12 mg/L).

Calcium concentration is a good indicator of the overall habitat suitability for the zebra mussel, a non-indigenous species from Eurasia that has been spreading globally. Relatively low calcium concentration serves to insulate the majority of Adirondack lakes from invasion by the zebra mussel. Researchers have reported that the minimum calcium concentrations needed to support a viable zebra mussel population is in the range of 12-20 mg/L, much higher than most lakes in the Adirondacks (Whittier et al. 2008).

We found the average calcium concentration during the 2015-2017 period to range from a low of 1.0 mg/L in Morehouse Lake to a high of 9.2 mg/L in Adirondack Lake. Overall, the majority of lakes had less than 4 mg/L of chloride (Figure 14). Analysis of the twenty years of available data revealed that three lakes (14%) exhibited an increasing trend (24%) and five lakes exhibited a decreasing trend (Table 16).

For this report, we did not explore the specific mechanisms responsible for the observed trends in calcium concentration; however, we know that several environmental stressors can affect the calcium concentration of lakes (Jeziorski et al. 2008). Research in the northeastern United States, southern Ontario, and northern Europe has demonstrated that acid deposition has leached calcium and other cations from sensitive soils, severely depleting calcium stores in the watershed. The leaching of calcium by acidic deposition may result in an initial increase of calcium concentration in surface water followed by long term calcium decline over time (Stoddard et al. 1999; Strock et al. 2014; Keller et al. 2001). The influence that road salting has on calcium concentrations is an emerging research area. Some

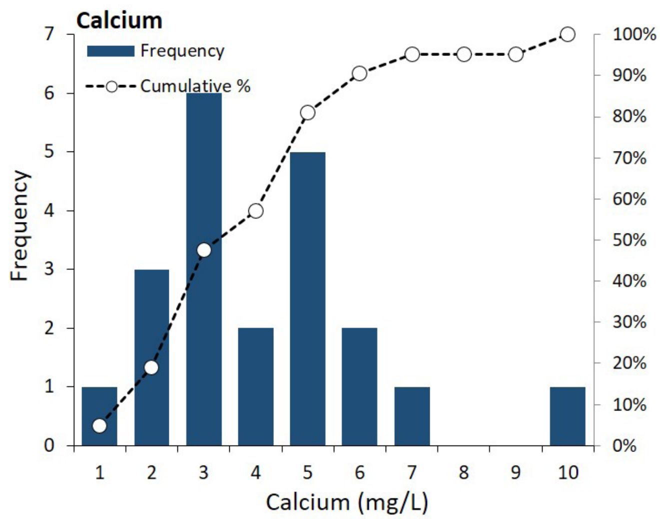


Figure 15. Frequency histogram of the average calcium concentration of the Hamilton County study lakes for the years 2015 to 2017.

municipalities utilize calcium chloride to deice roads, thereby increasing the calcium content of the watershed. When rock salt is used as a deicer, the sodium can displace calcium in the soil, potentially leading to increased calcium concentrations in the ground and surfaces water. Kelting and Laxson (2018) observed that calcium export from watersheds with salted roads was 31% higher than watersheds without salted roads.

Aluminum

Aluminum is the most abundant metal in the earth's crust and the third most abundant element on the planet. Although aluminum is numerically important, it is not an essential element for organisms. Despite its lack of biological function, high concentrations of aluminum can interfere with physiological processes, making it potentially toxic (Gensemer and Playle 1999; Driscoll and Schecher 1990). Environmental scientists are interested in aluminum in the Adirondacks because acidic deposition can facilitate the leaching of aluminum from the soil in poorly buffered watersheds, resulting in elevated aluminum concentrations in the surface water.

Aluminum chemistry is very complex and poorly understood, making environmental research and data interpretation difficult. The metal is largely insoluble between the pH of 6 and 8, and it forms numerous complexes with components such as fluoride (F), sulfate ($SO4^{-2}$), phosphate ($PO_4^{-3)}$ hydroxide (OH^-), and dissolved organic carbon (DOC), the proportion of which vary greatly depending on pH, temperature, and redox potential (Gensemer and Playle 1999). There are numerous analytical methods available to measure aluminum, resulting in a wide variety of reported values. For example, aluminum may be analyzed as total aluminum (Al_{tot}), inorganic monomeric (Al_{im}), organic monomeric (Al_{om}) or dissolved (Al_d), with total aluminum being the most widely reported due to low cost and ease of analysis. The inorganic monomeric form of aluminum (Al_{im}) is of most concern in Adirondack lakes for at least two reason. Aluminum serves as a coagulant that expedites the removal of light attenuating dissolved organic carbon from the lake, resulting in increased water clarity and decreased thermal stability (Effler et al. 1985). In addition, the combination of low pH and elevated Alim is toxic to aquatic organisms, particularly the survival and growth of young fish. The mechanism for Alim toxicity in fish revolves around osmoregulatory dysfunction related to aluminum precipitation on the gills (Baker and Schofield 1982; Cleveland et al. 1986).

HCSWCD only monitors total aluminum, limiting our ability to interpret potential biological impact. The average total aluminum concentration for the HC lakes was low, and ranged from a low of 2 µg/L in Adirondack Lake to a high of 54 µg/L in Limekiln Lake. Morehouse Lake was the only exception to this range, where the average aluminum concentration was 123 µg/L over the past three years (Figure 15, Table 17). In general, HC lakes with lower alkalinity and pH tended to have higher concentrations of aluminum ($p = 0.002$; $R^2 = 0.39$), supporting the observations made by numerous researchers over the last three decades (reviewed by Driscoll and Schecher 1990). For example, Adirondack Lake had the lowest concentration of aluminum and it is the least acid impacted in terms of pH, alkalinity, and calcium concentration. The opposite occurred in Morehouse Lake, which had

Preparing for field work on Fawn Lake. Photo by Caitlin Stewart

Table 17. Current status and historical trends in aluminum concentration of the Hamilton County study lakes.

Waterbody	Aluminum Status: 2015-2017 µg/L	Range	Trend 1997-2017
Blue Mnt	12	BD, 28	increasing*
Eighth	18	BD, 31	increasing*
Fawn	24	BD, 42	increasing*
Fifth	24	BD, 59	no trend
Fourth	15	BD, 36	increasing*
Indian	28	BD, 68	increasing^
Abanakee	34	BD, 67	increasing*
Adirondack	2	BD, 21	no trend
Algonquin	35	BD, 84	no trend
Eaton	14	BD, 28	no trend
Pleasant	11	BD, 29	no trend
Limekiln	54	14, 96	no trend
Long	52	BD, 103	no trend
Morehouse	123	50, 174	no trend
Oxbow	15	BD, 34	no trend
Piseco	27	BD, 47	no trend
Raquette	46	16, 70	no trend
Sacandaga	10	BD, 26	no trend
Seventh	46	22, 63	increasing*
Sixth	26	BD, 50	increasing*
Spy	13	BD, 34	no trend

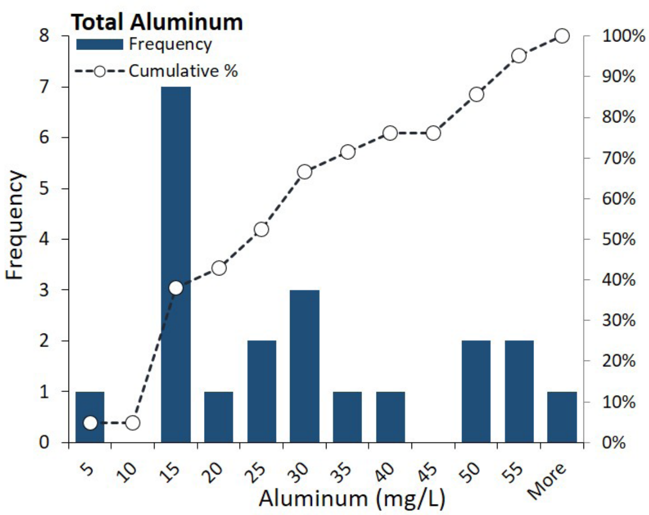


Figure 15. Frequency histogram of the average total aluminum concentration of the Hamilton County study lakes for the years 2015 to 2017.

significantly more aluminum than the other study lakes.

Scientists have not offered a well-defined water quality guideline for total aluminum, as the toxicity of the metal is strongly influenced by pH, dissolved organic carbon (DOC), and the predominate form of aluminum present in solution. For example, the Canadian Environmental Quality Guidelines identified the critical concentration of total aluminum in the range of 75 to 100 µg/L for slightly acidic lakes with low concentrations of DOC (CCME 2003). Recently, the Canadian government withdrew these guidelines for lack of clear evidence, and replaced them with a guideline of "variable" and lists pH, calcium, and DOC as modifiers (CCME 2018). The total aluminum values we observed in the HC lakes are below, or within the lower range reported for acid-sensitive Adirondack lakes in the Eastern Lake Survey of 1985 (8 – 750 µg/L; Driscoll and Schecher 1990).

Analysis of the historical data reveals that eight of the HC lakes (38%) have exhibited an increasing trend in aluminum concentration (Table 17). Although these statistics suggest a regional increase in total aluminum, data interpretation should proceed with caution. We observed a substantial increase in the concentration of aluminum in all study lakes during the 2012 and 2013 season, which greatly influences the statistical outcome. The reason for these elevated concentrations is not well understood. A large proportion of water column aluminum is in a particulate form, the concentration of which can be influenced by changes in surface water runoff. Years 2011 and 2013 where wet years (see Figure 10), which may have resulted in elevated total aluminum in the water column. We also encountered a high proportion of analytical control issues with aluminum during this period, suggesting that some of the values may be high biased.

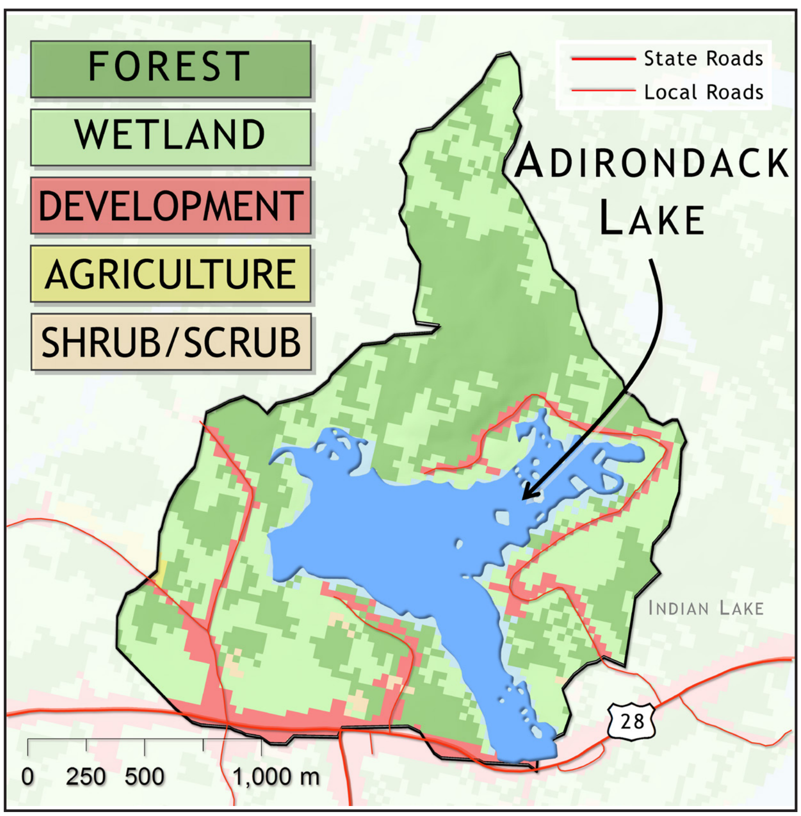
ADIRONDACK LAKE

SUMMARY

Adirondack Lake is a 78-hectare waterbody, located within a 379-hectare watershed that is co-dominated by forest cover (33%) and wetlands (33%). Long term monitoring by HCSWCD produced the following findings.

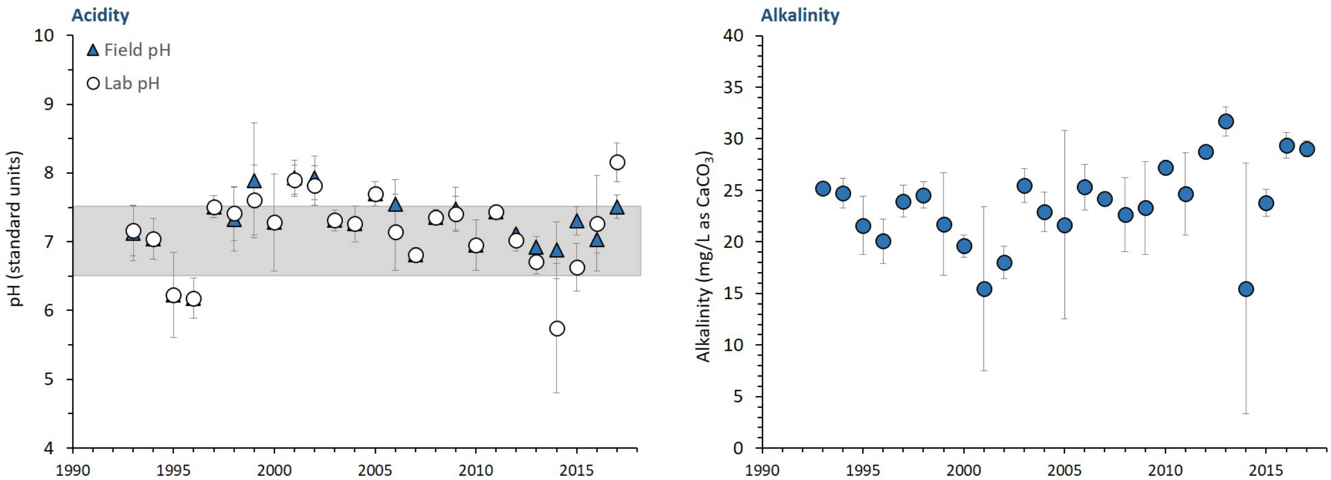
The surface water of the lake is best classified as circumneutral to slightly alkaline, with average annual pH values that were typically in the range of 6.5 to 7.9 standard units. Between the years 2015 and 2017, alkalinity was in the range of 23 to 31 mg/L, indicating that the lake was adequately buffered, and not currently sensitive to acid deposition. The lake is best classified between eutrophic and mesotrophic, with a statistically significant decrease in transparency over time. Adirondack Lake had the highest calcium concentration in the dataset during the 2015 to 2017 period at 9.2 mg/L. The chemistry of the lake was moderately influenced by the 6.3 km of roads in the watershed. The concentration of chloride and sodium between the years 2015 and 2017 averaged 11.1 and 6.5 mg/L respectively, which is approximately 37 times greater than background concentrations for lakes in the Adirondack region. The bottom water of Adirondack Lake experienced significant oxygen depletion, with anoxic or hypoxic water encountered on 58% of sampling trips during the month of August.

MORPHOMETRY



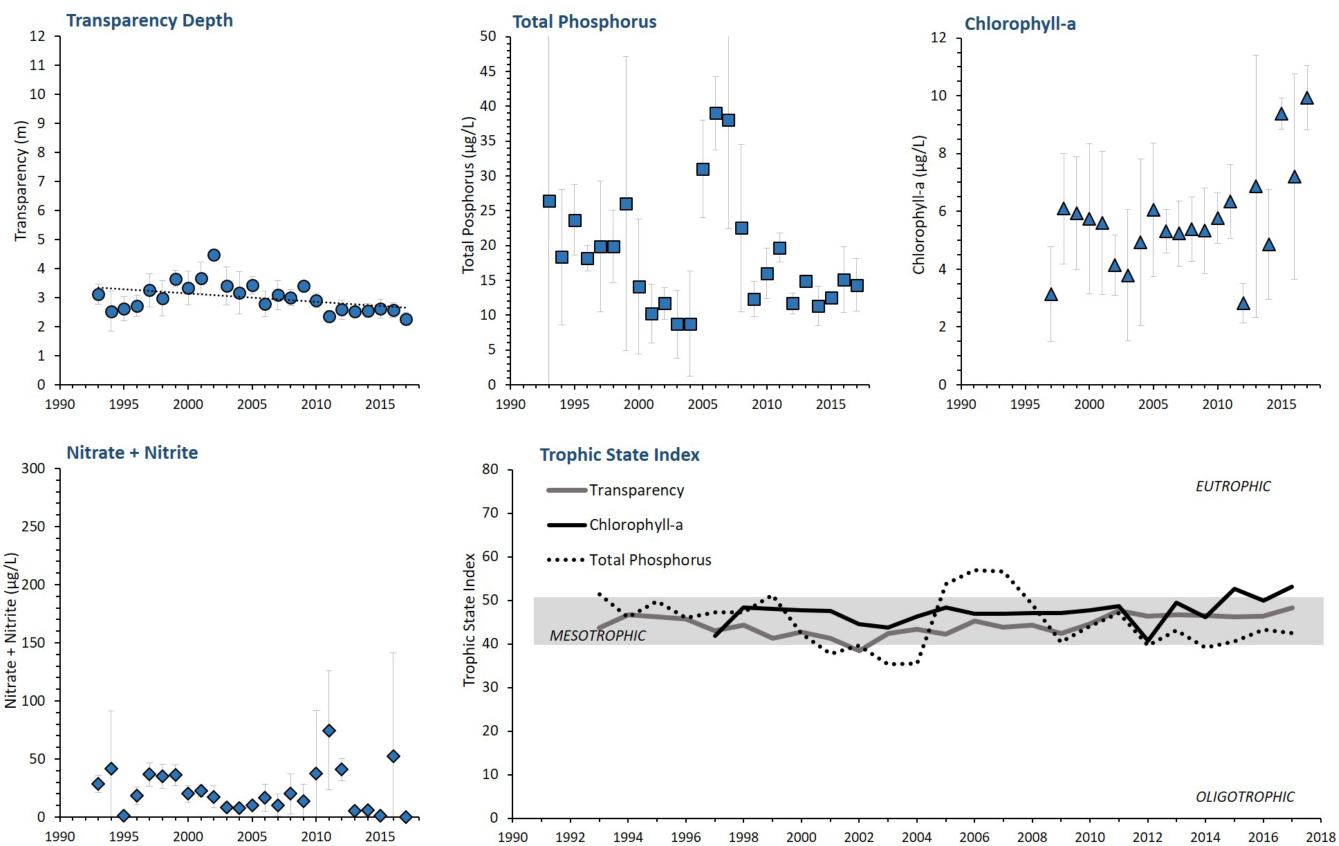
Lake Area (ha)	78
Max Depth (m)	5.8
Volume (m^3 x 10^6)	1.7
Shoreline (km)	10.4
Watershed Area (ha)	379
Retention Time (yrs)	0.8
Surface Water Area (%)	26
Forested Area (%)	33
Developed Area (%)	7
Wetland Area (%)	33
State Road Length (km)	1.0
Local Road Length (km)	5.3

ACIDITY



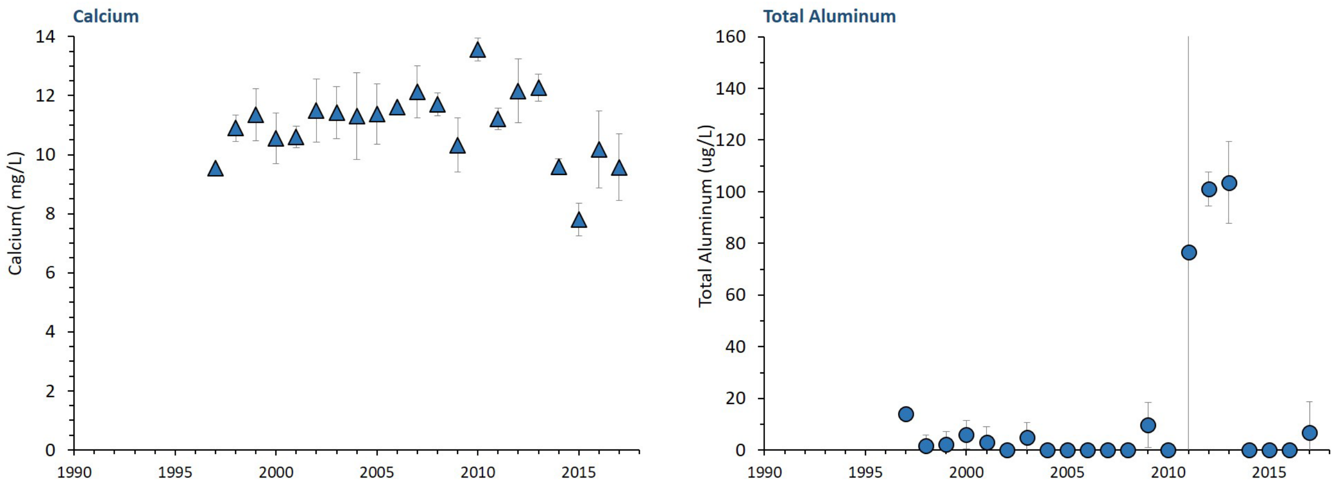
Annual average acidity (left panel) and alkalinity (right panel) of Adirondack Lake, 1993 - 2017. Shaded box denotes range of circumneutral condition (pH 6.5-7.5). Error bars denote one standard deviation of the mean.

TROPHIC STATE



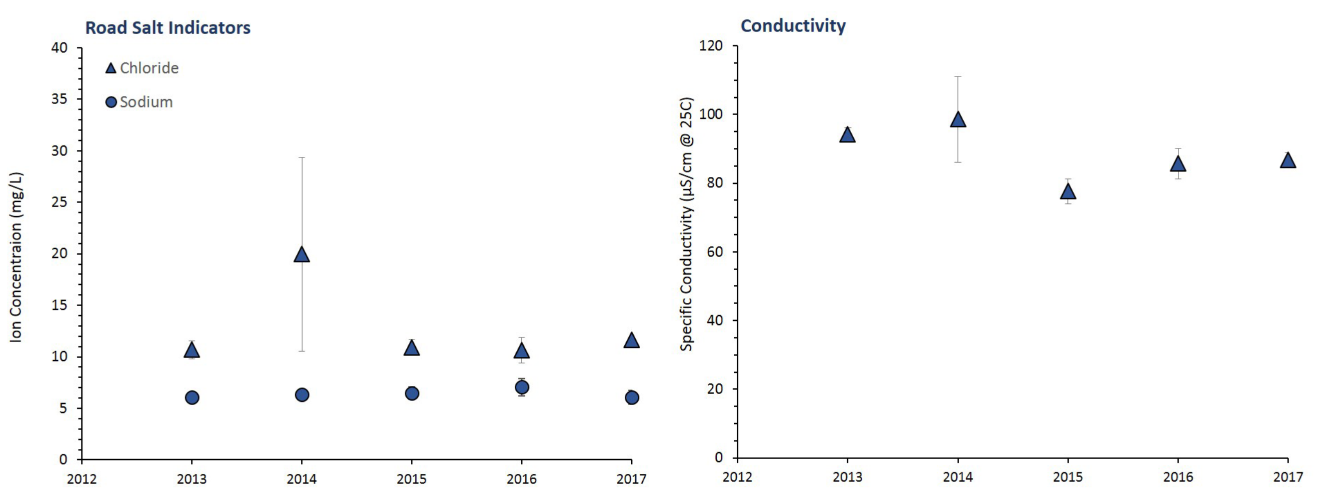
Average values for key trophic state indicators of Adirondack Lake, 1993-2017. Error bars represent one standard deviation of the mean. Transparency has exhibited a decreasing trend since 1993 (p = 0.006, tau = 0.40).

Metals



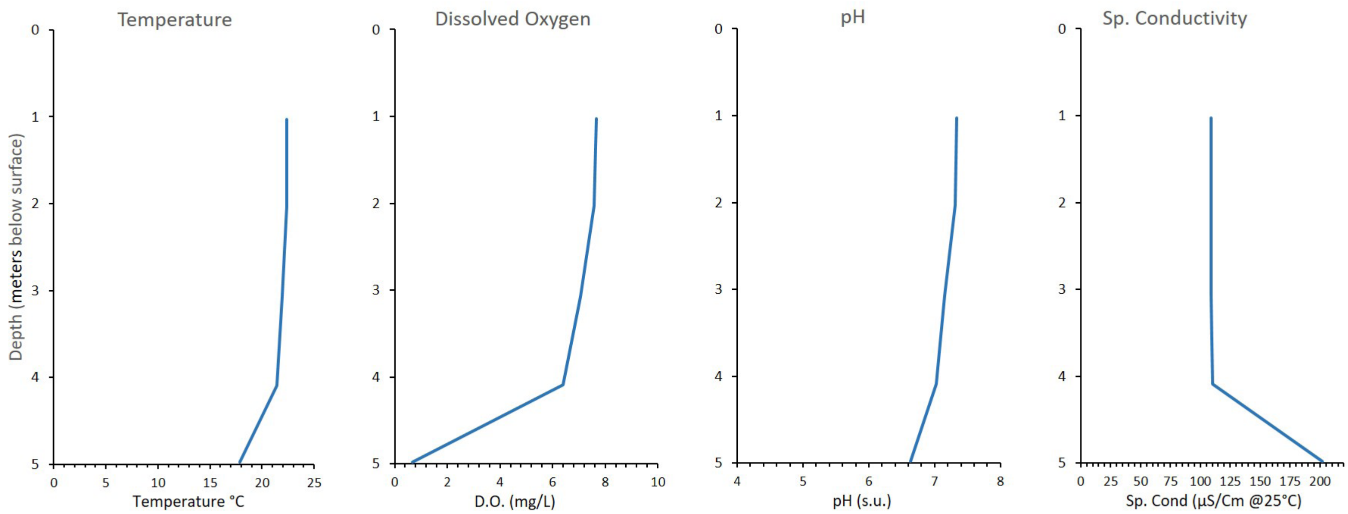
Annual average concentration of calcium and total aluminum in Adirondack Lake, 1997-2017. Error bars represent one standard deviation of the mean. Aluminum values for 2010 to 2013 represent statistical outliers.

Road Salt



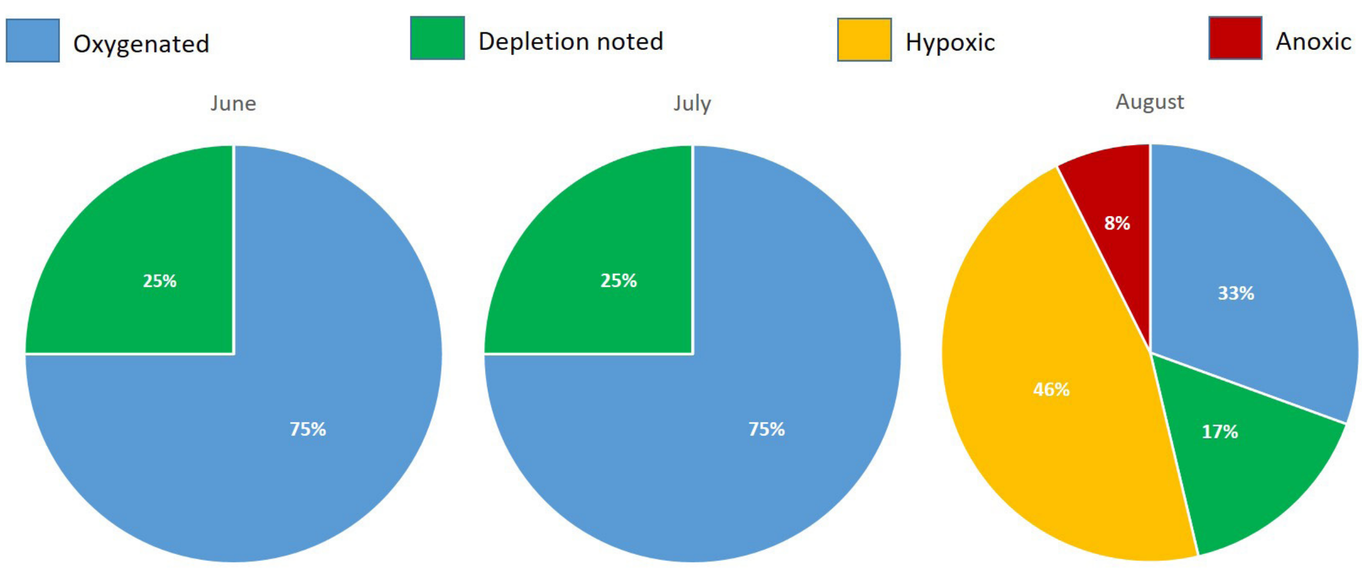
Annual average values of sodium and chloride ions (left panel) and specific conductivity (right panel) in Adirondack Lake, 2013-2017. Error bars represent one standard deviation of the mean.

Lake Profile - August 2017



Depth profiles of temperature, dissolved oxygen, pH, and specific conductivity in Adirondack Lake during the August 2017 sampling trip.

Dissolved Oxygen Content



Proportion of monthly sampling trips where the bottom water of Adirondack Lake (1 meter off bottom) was observed to be oxygenated (D.O. > 4.0 mg/L), experiencing noted depletion (< 4.0 mg/L), hypoxic (< 2.0 mg/L) or anoxic (< 0.5 mg/L). Data is from the period of 1993 to 2017.

BLUE MOUNTAIN LAKE

Summary

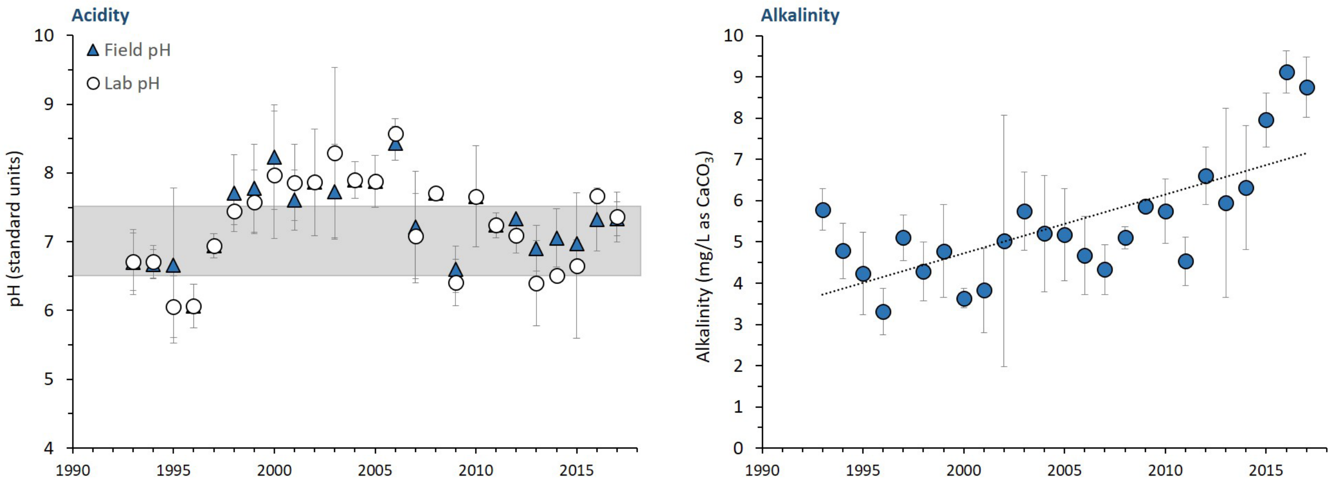
Blue Mountain Lake is a 509 hectare waterbody, located within a 2,803 hectare watershed that is dominated by forest cover. Long term monitoring by HCSWCD produced the following findings.

The surface water of the lake is best classified as circumneutral to slightly alkaline, with average annual pH values that were typically in the range of 6.5 to 7.9 standard units. Between the years 2015 and 2017, alkalinity was in the range of 6 to 9 mg/L, indicating that the lake was moderately buffered against acidic deposition. The alkalinity of the lake has exhibited a statistical increase since monitoring began in 1993. The lake was best classified as oligotrophic, with high transparency and low concentrations of nutrients and chlorophyll-a. A significant downward trend existed in the total phosphorus data. The chemistry of the lake was influenced by the 12.4 km of roads in the watershed. The concentration of chloride and sodium between the years 2015 and 2017 averaged 16.2 and 9.8 mg/L respectively, which is approximately 54 times greater than background concentrations for Adirondack lakes. The bottom water of Blue Mountain Lake was well oxygenated during the sampling period. Only 8% of observations during the month of August had notable oxygen depletion.

Morphometry

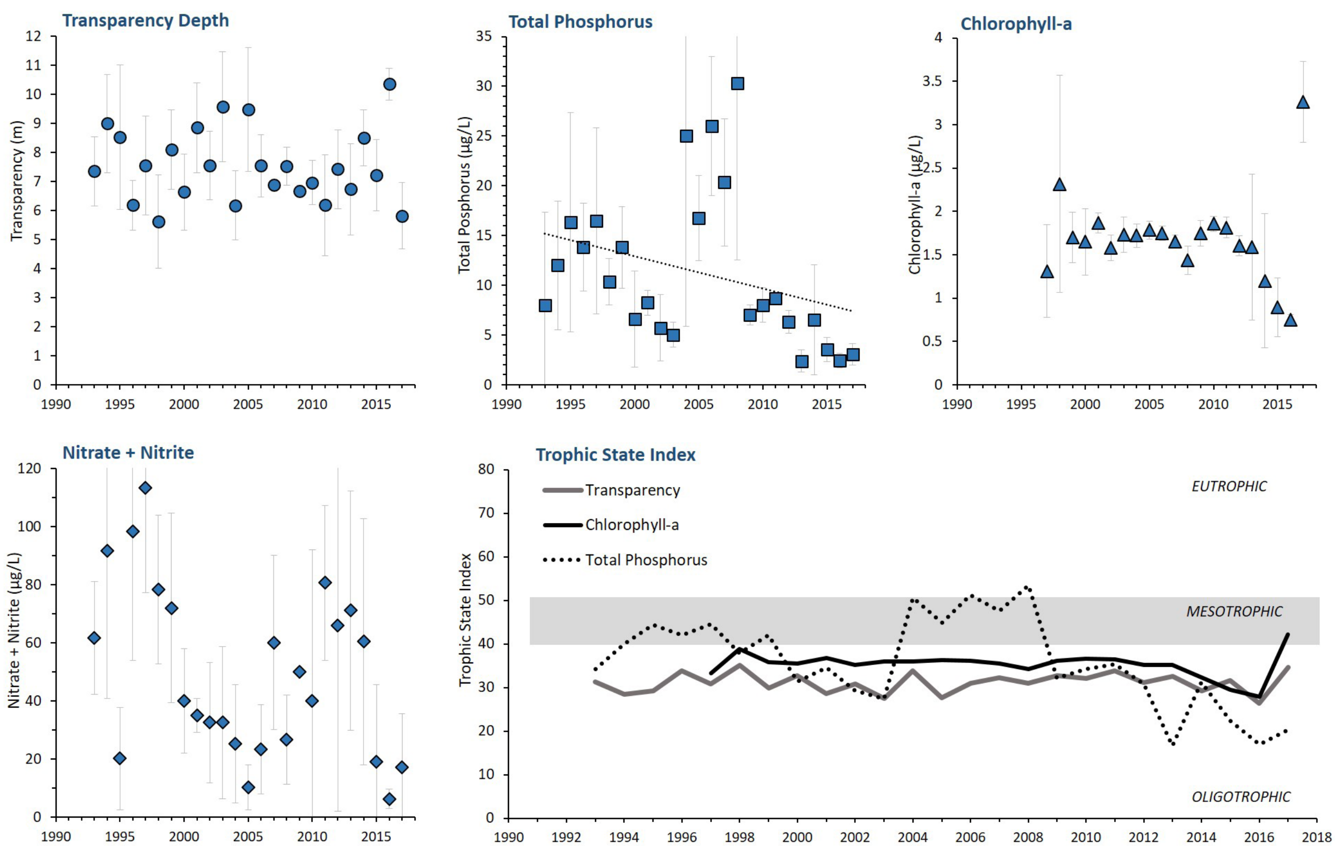
Lake Area (ha)	509
Max Depth (m)	33
Volume (m^3 x 10^6)	76.6
Shoreline (km)	24
Watershed Area (ha)	2,803
Retention Time (yrs)	3.5
Surface Water Area (%)	23
Forested Area (%)	69
Developed Area (%)	3
Wetland Area (%)	5
State Road Length (km)	8.3
Local Road Length (km)	4.1

Acidity



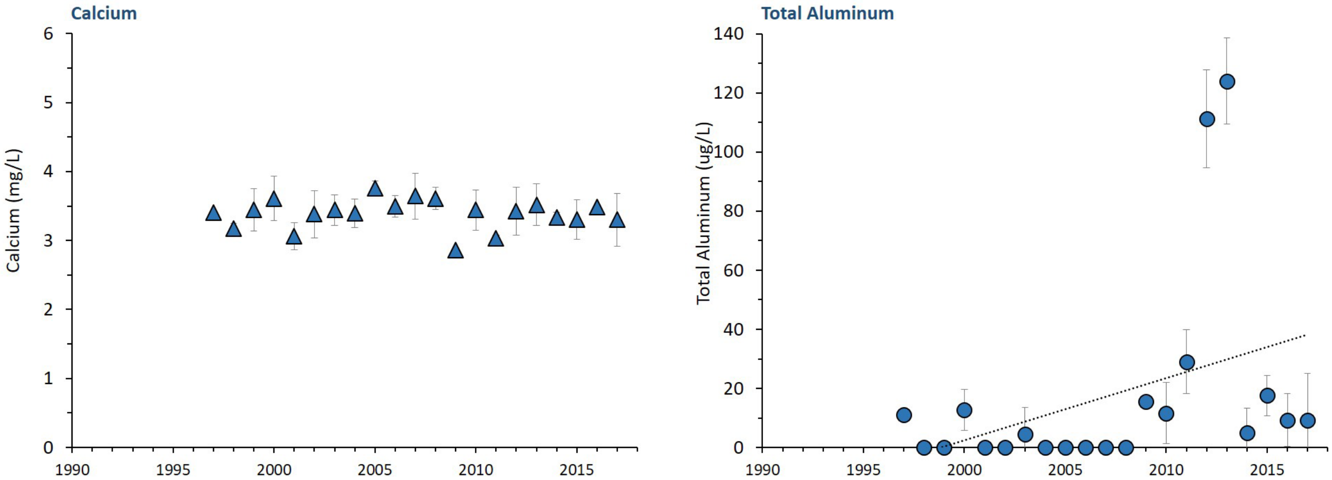
Annual average acidity (left panel) and alkalinity (right panel) of Blue Mountain Lake, 1993 - 2017. Shaded box denotes range of circumneutral condition (pH 6.5-7.5). Error bars denote one standard deviation of the mean. Alkalinity has exhibited an increasing trend since 1993 ($p = 0.002$, tau = 0.53).

Trophic State



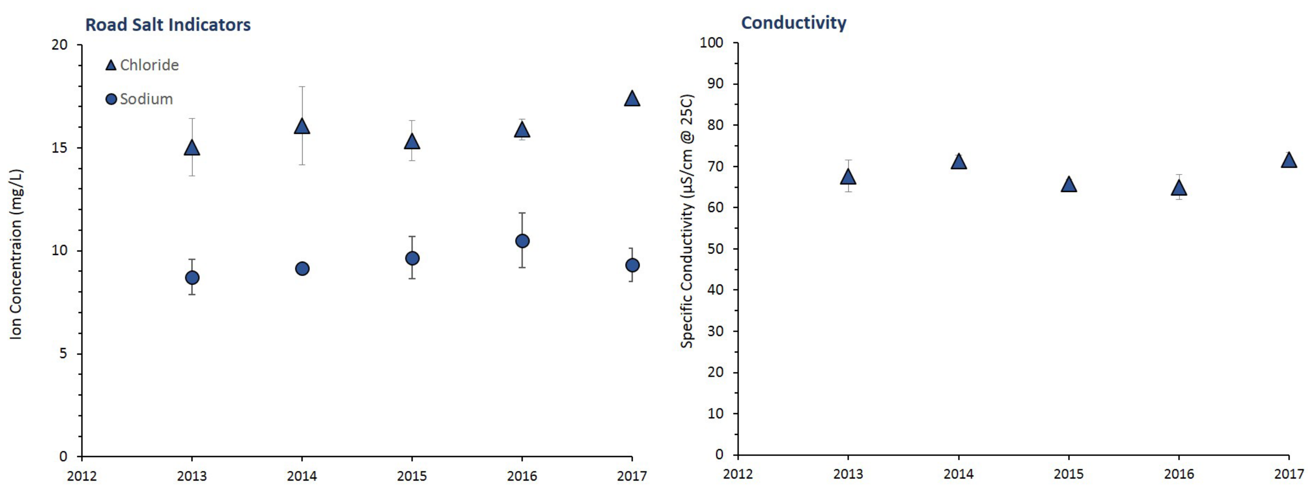
Average values for key trophic state indicators of Blue Mountain Lake, 1993-2017. Error bars represent one standard deviation of the mean. Total phosphorus has exhibited a decreasing trend since 1993 ($p = 0.02$, tau = 0.32), although a portion of this trend may be explained by changes in sampling regime and laboratory methods.

Metals



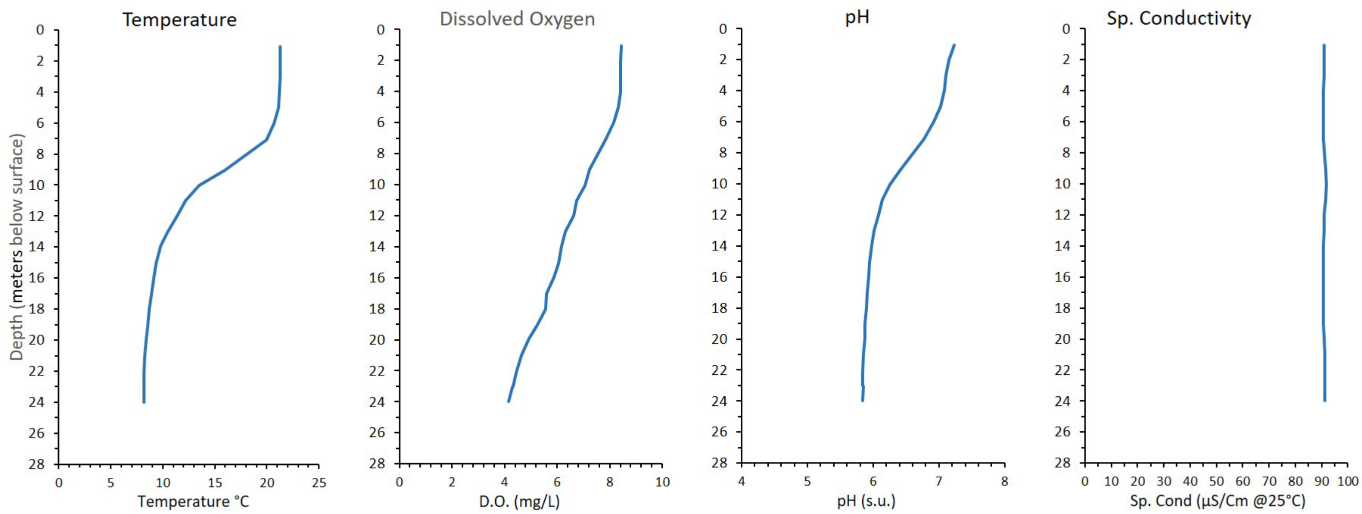
Annual average concentration of calcium and total aluminum in Blue Mountain Lake, 1997-2017. Error bars represent one standard deviation of the mean. Total aluminum has exhibited an increasing trend since 1997, although the trend appears to be driven by two unusually high measurements (see page 30; p = 0.03, tau = 0.37).

Road Salt



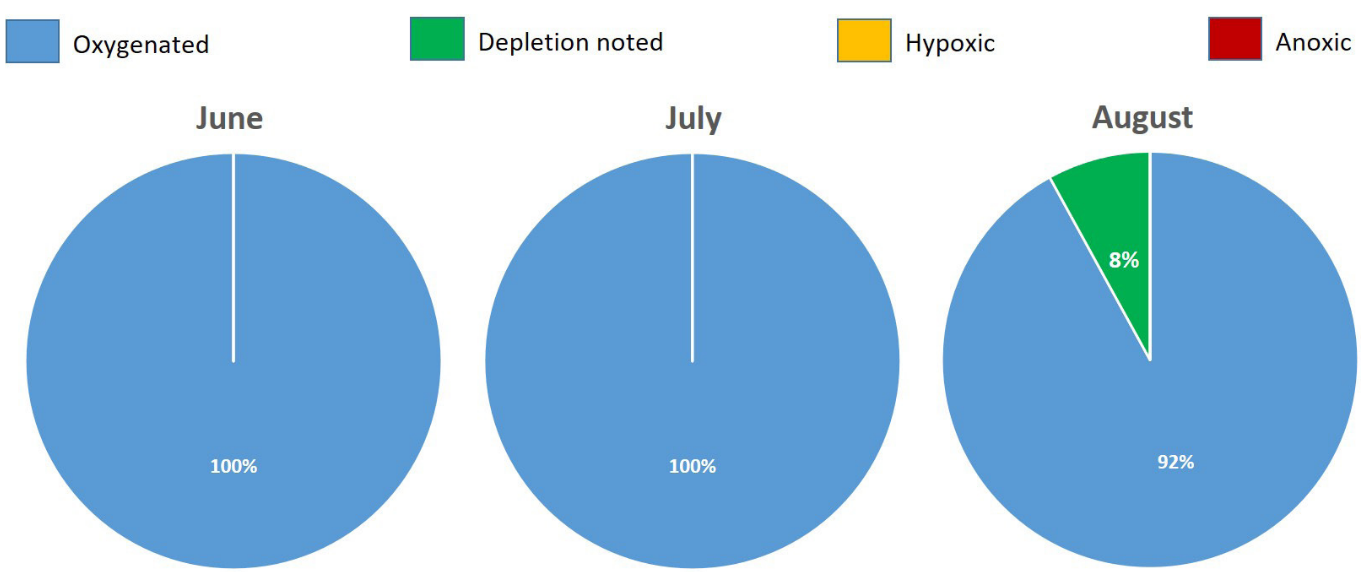
Annual average values of sodium and chloride ions (left panel) and specific conductivity (right panel) in Blue Mountain Lake, 2013-2017. Error bars represent one standard deviation of the mean.

Lake Profile - August 2017



Depth profiles of temperature, dissolved oxygen, pH, and specific conductivity in Blue Mountain Lake during the August 2017 sampling trip.

Dissolved Oxygen Content



Proportion of monthly sampling trips where the bottom water of Blue Mountain Lake (1 meter off bottom) was observed to be oxygenated (D.O. > 4.0 mg/L), experiencing noted depletion (< 4.0 mg/L), hypoxic (< 2.0 mg/L) or anoxic (< 0.5 mg/L). Data is from the period of 1993 to 2017.

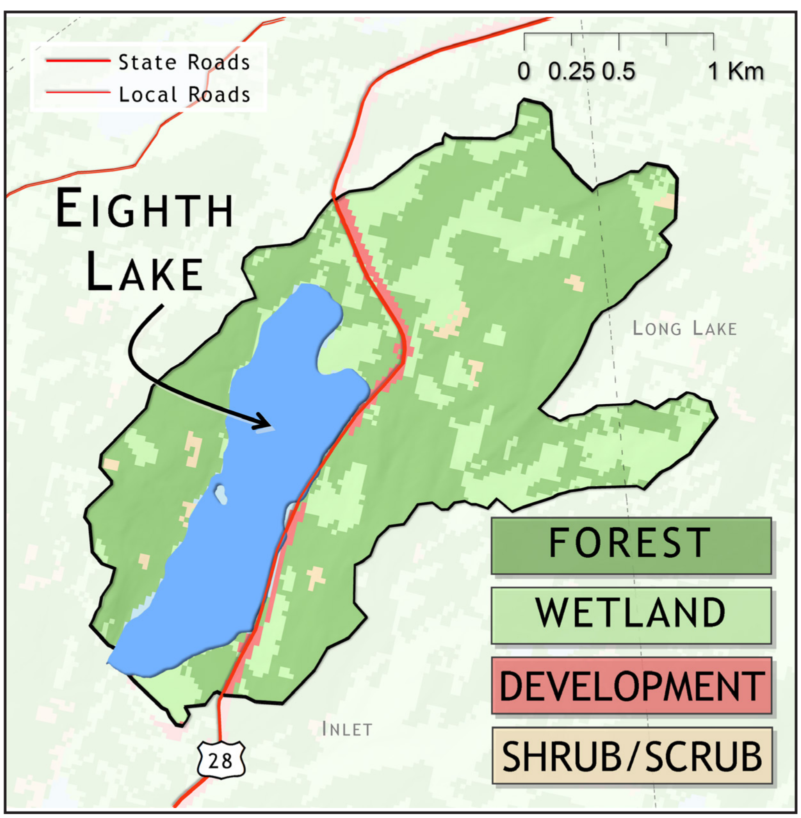
EIGHTH LAKE

Summary

Eighth Lake is a 124-hectare waterbody, located within a 702-hectare watershed that is dominated by forest cover. Long term monitoring by HCSWCD produced the following findings.

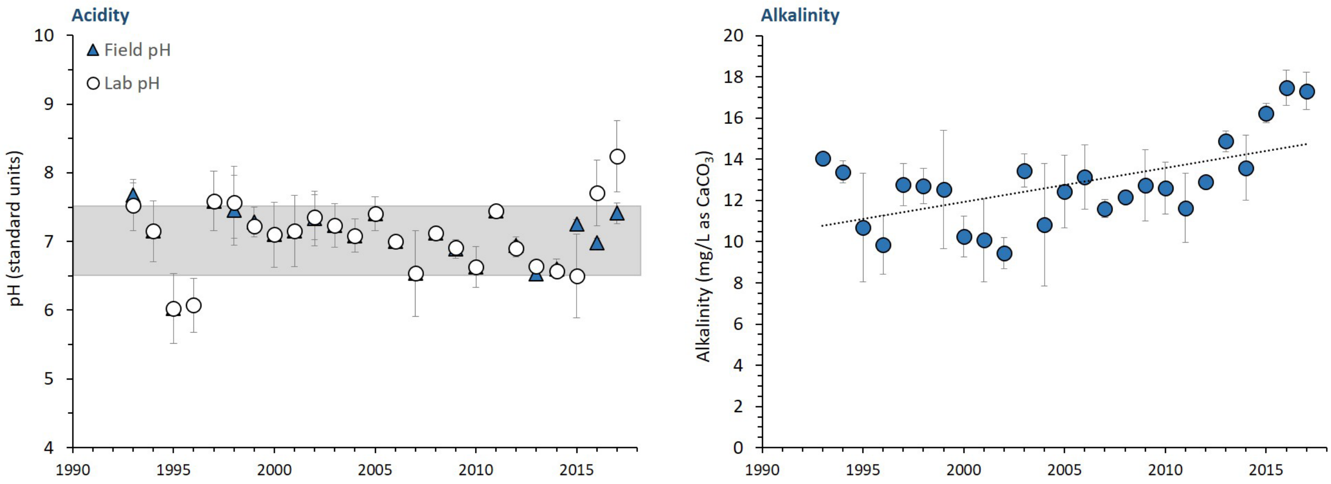
The surface water of the lake is best classified as circumneutral to slightly alkaline, with average annual pH values that were typically in the range of 6.5 to 7.5 standard units. Between years 2015 and 2017, alkalinity was in the range of 16 to 18 mg/L, indicating that the lake had low sensitivity to acidic deposition. The alkalinity of the lake has exhibited a statistical increase since monitoring began in 1993. The lake was best classified as oligotrophic, with high transparency and low concentrations of nutrients and chlorophyll-a. A significant downward trend existed in the total phosphorus data. The chemistry of the lake was influenced by the 3.4 km of NYS roads in the watershed. The concentration of chloride and sodium between the years 2015 and 2017 averaged 19.4 and 11.7 mg/L, respectively, which is approximately 65 times greater than background concentrations for Adirondack lakes. Althought the bottom water of Eighth Lake did not exhibit anoxia or hypoxia during any of the sampling visits, it was common to find notable oxygen depletion during the month of August (28% of observations).

Morphometry



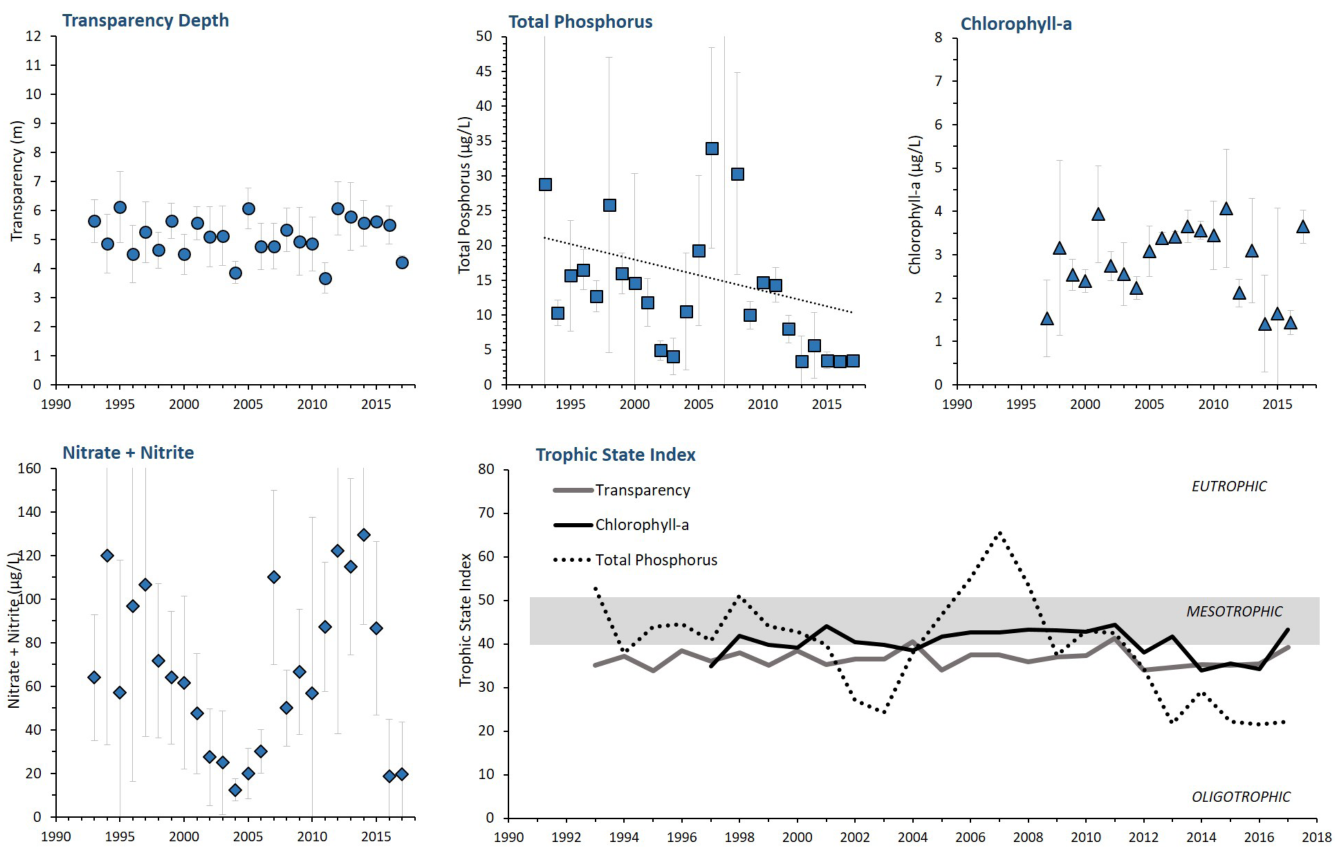
Lake Area (ha)	124
Max Depth (m)	25
Volume (m^3 x 10^6)	14.6
Shoreline (km)	6.6
Watershed Area (ha)	702
Retention Time (yrs)	2.5
Surface Water Area (%)	20
Forested Area (%)	57
Developed Area (%)	2
Wetland Area (%)	20
State Road Length (km)	3.4
Local Road Length (km)	0

ACIDITY



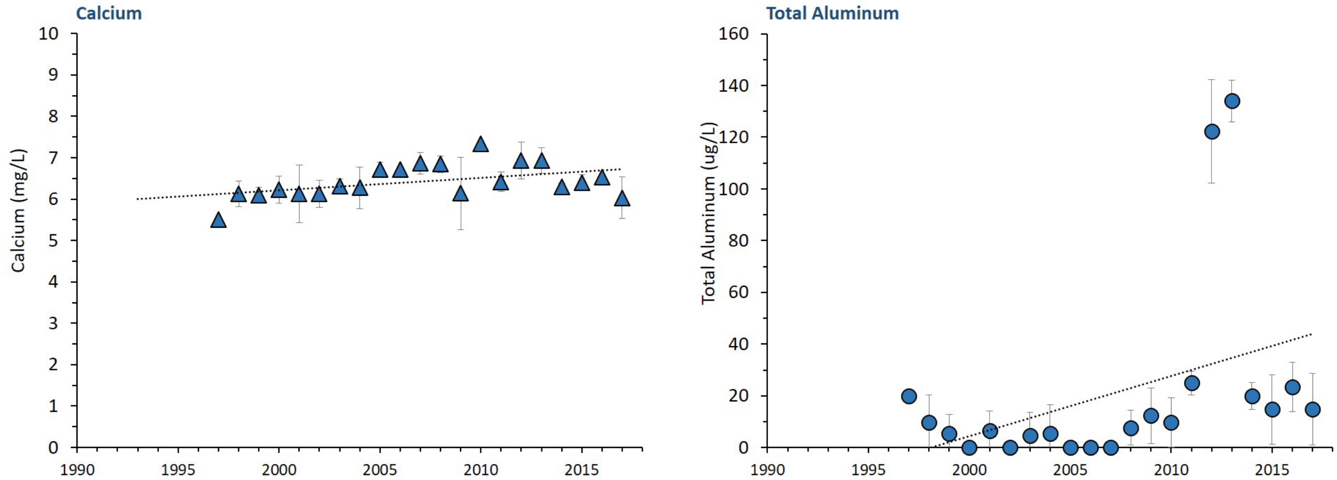
Annual average acidity (left panel) and alkalinity (right panel) of Eighth Lake, 1993 - 2017. Shaded box denotes range of circumneutral condition (pH 6.5-7.5). Error bars denote one standard deviation of the mean. Alkalinity has exhibited an increasing trend since 1993 ($p = 0.02$, tau = 0.34).

TROPHIC STATE



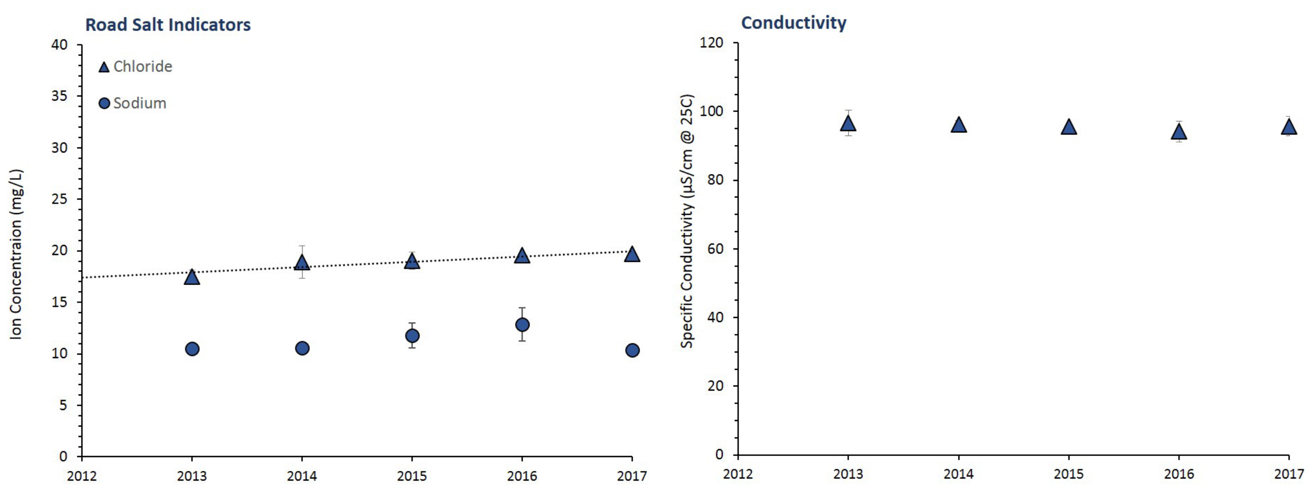
Average values for key trophic state indicators of Eighth Lake, 1993-2017. Error bars represent one standard deviation of the mean. Total phosphorus has exhibited a decreasing trend since 1993 ($p = 0.01$, tau = 0.39), although a portion of this trend may be explained by changes in sampling regime and laboratory methods.

Metals



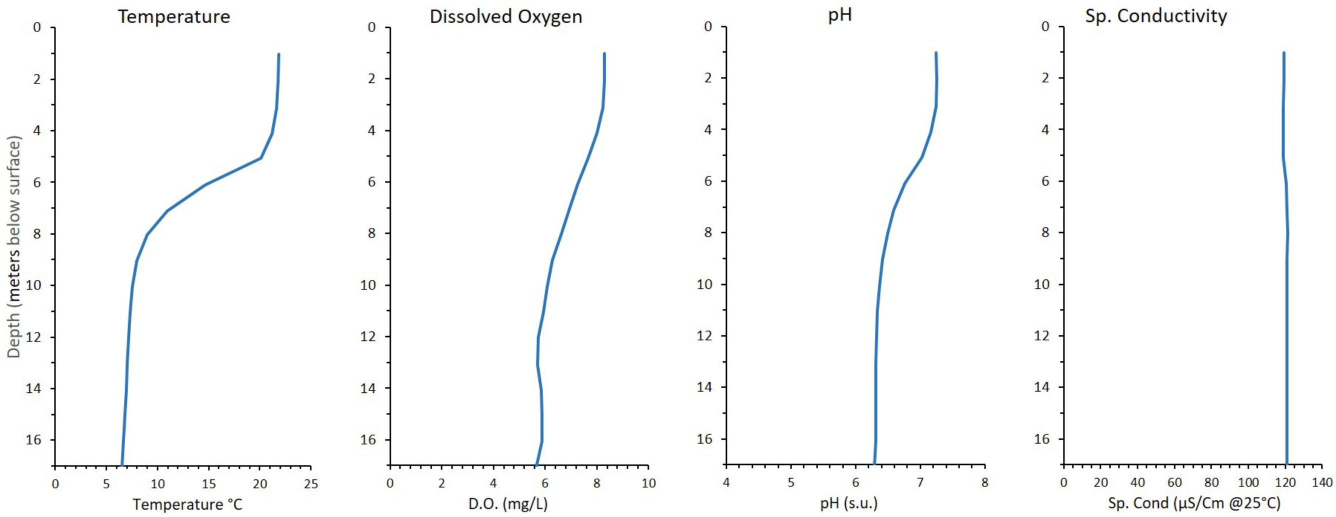
Annual average concentration of calcium and total aluminum in Eighth Lake, 1997-2017. Error bars represent one standard deviation of the mean. Calcium exhibited a slight, yet significant, increasing trend since 1997 (p = 0.01, tau = 0.40). Total aluminum has also exhibited an increasing trend since 1997, although the trend appears to be driven by two unusually high measurements (see page 30; p = 0.03, tau = 0.37).

Road Salt



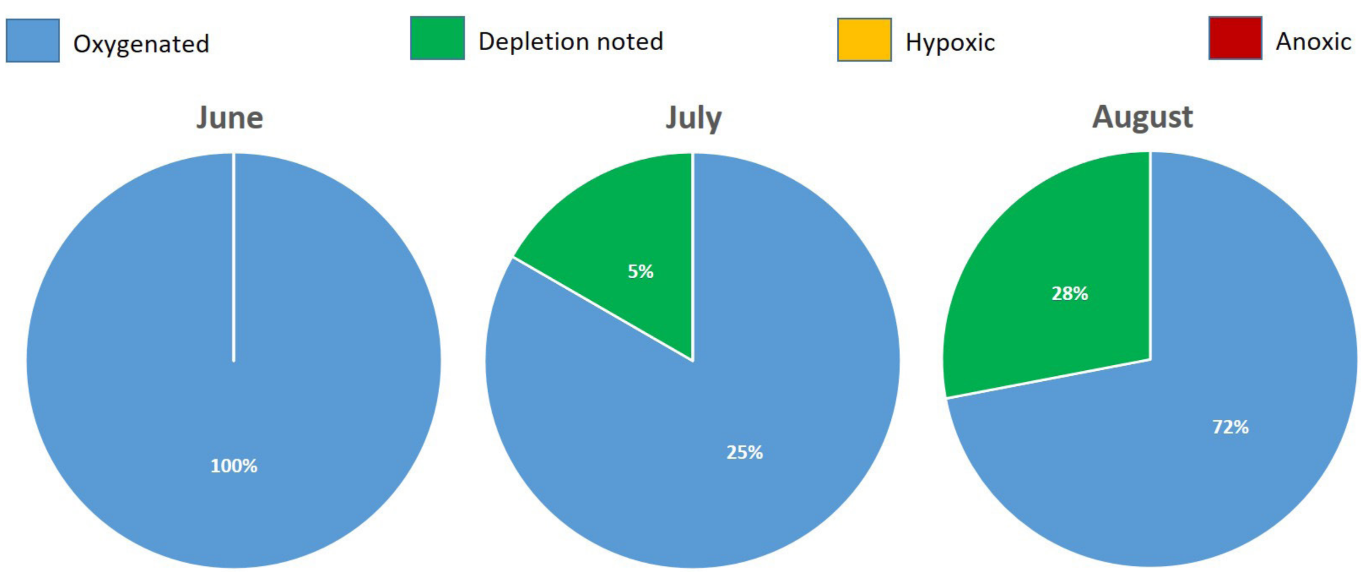
Annual average values of sodium and chloride ions (left panel) and specific conductivity (right panel) in Eighth Lake, 2013-2017. Error bars represent one standard deviation of the mean. Chloride exhibited a slight, yet significant, increasing trend since 2013 (p = 0.01, tau = 1.0).

LAKE PROFILE - AUGUST 2017



Depth profiles of temperature, dissolved oxygen, pH, and specific conductivity in Eighth Lake during the August 2017 sampling trip.

DISSOLVED OXYGEN CONTENT



Proportion of monthly sampling trips where the bottom water of Eighth Lake (1 meter off bottom) was observed to be oxygenated (D.O. > 4.0 mg/L), experiencing noted depletion (< 4.0 mg/L), hypoxic (< 2.0 mg/L) or anoxic (< 0.5 mg/L).

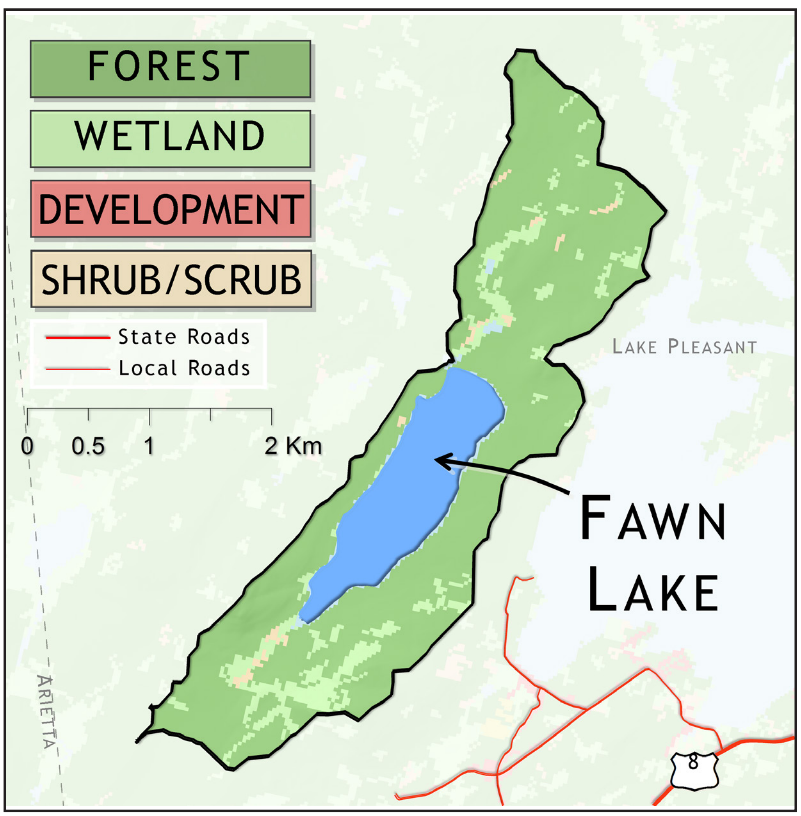
FAWN LAKE

Summary

Fawn Lake is a 117-hectare waterbody, located within a 451-hectare watershed that is dominated by forest cover. Long term monitoring by HCSWCD produced the following findings.

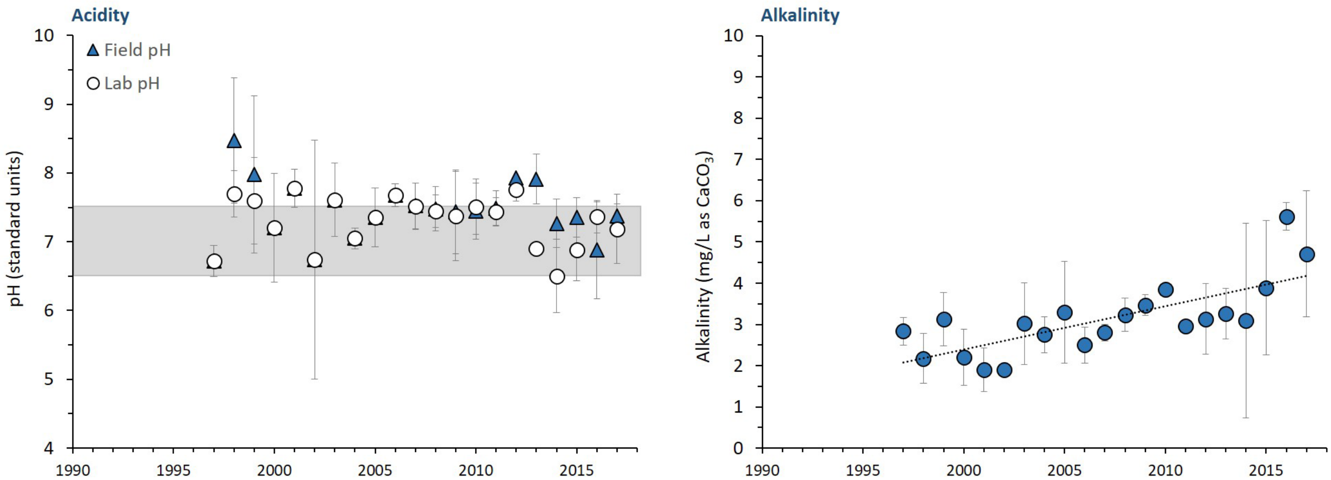
The surface water of the lake is best classified as circumneutral to slightly alkaline, with average annual pH values that were typically in the range of 6.6 to 7.7 standard units. Alkalinity ranged from 2 to 6 mg/L between years 2015 and 2017, indicating that the lake had moderate sensitivity to acidic deposition. Overall, alkalinity of the lake has exhibited a statistical increase since monitoring began in 1997. The lake was best classified as oligotrophic, with relatively high transparency and typically low concentrations of nutrients and chlorophyll-a. A significant downward trend existed in both the total phosphorus and nitrate data. The chloride concentration averaged 0.6 mg/L between the years 2015 and 2017, a concentraion that is within the range we would expect for a lake that lacks salted roads in it watershed. Although the bottom water of Fawn Lake did not exhibit anoxia or hypoxia during any of the sampling visits, it was common to find notable oxygen depletion during the month of August (50% of observations).

Morphometry



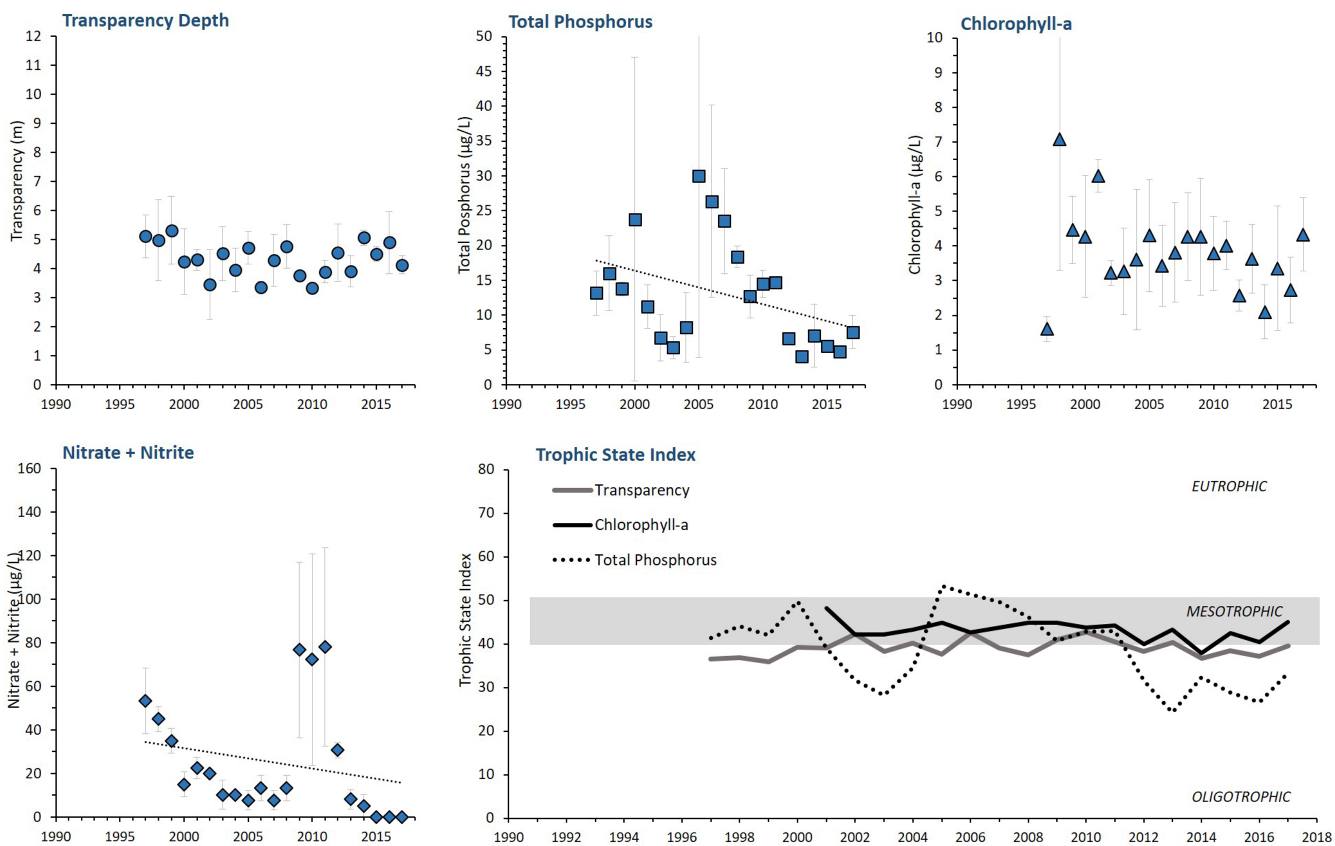
Lake Area (ha)	117
Max Depth (m)	19
Volume (m^3 x 10^6)	10.2
Shoreline (km)	5.6
Watershed Area (ha)	451
Retention Time (yrs)	2.3
Surface Water Area (%)	18
Forested Area (%)	75
Developed Area (%)	0
Wetland Area (%)	8
State Road Length (km)	0
Local Road Length (km)	0

Acidity



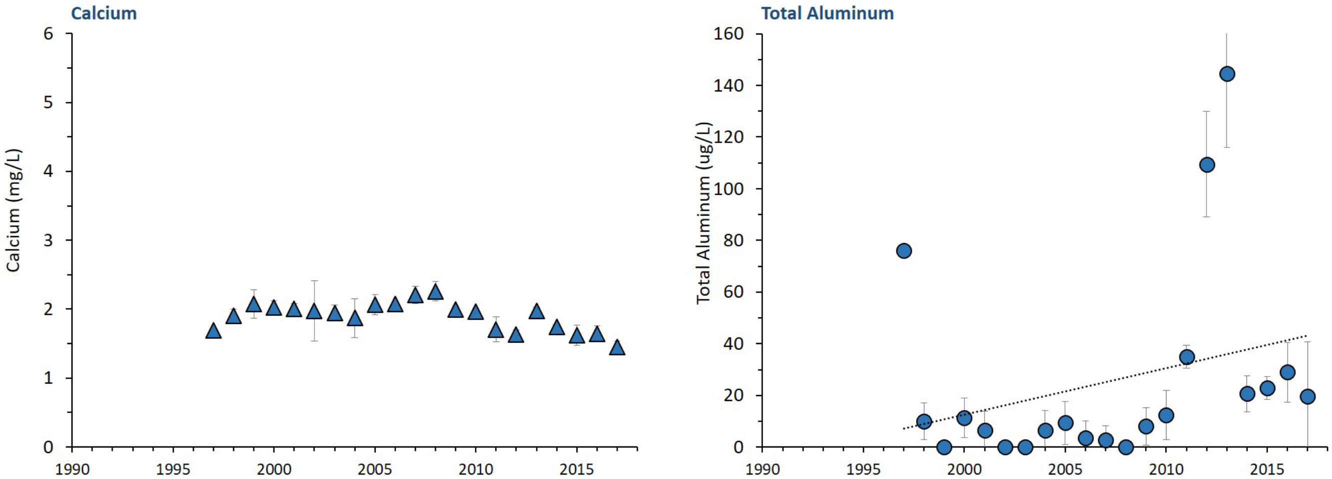
Annual average acidity (left panel) and alkalinity (right panel) of Fawn Lake, 1997 - 2017. Shaded box denotes range of circumneutral condition (pH 6.5-7.5). Error bars denote one standard deviation of the mean. Alkalinity has exhibited an increasing trend since 1993 ($p < 0.01$, tau = 0.56).

Trophic State



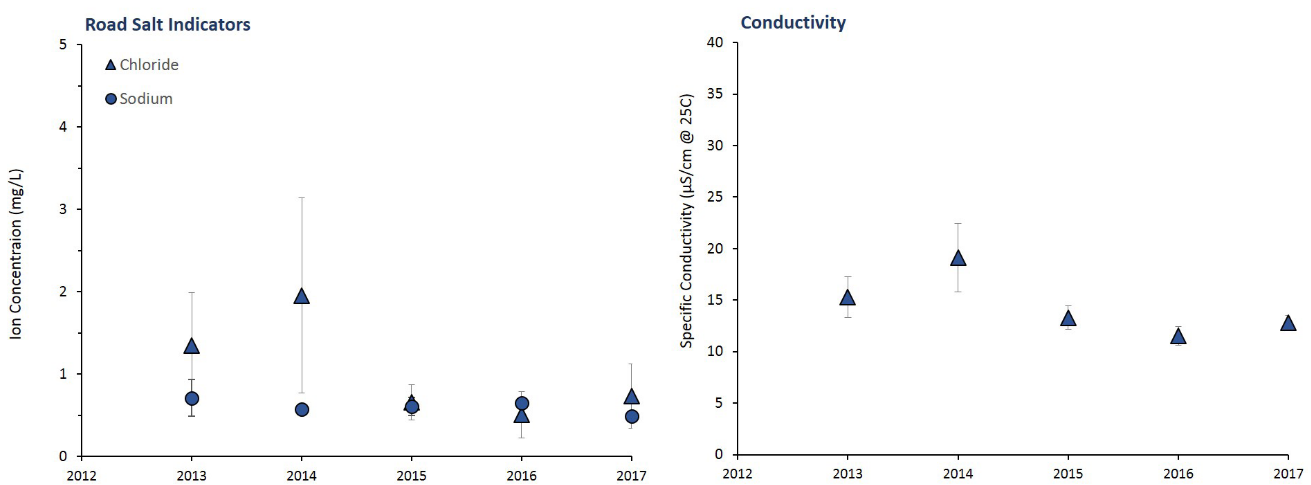
Average values for key trophic state indicators of Fawn Lake, 1997-2017. Error bars represent one standard deviation of the mean. Total phosphorus and nitrate have exhibited a decreasing trend since 1997 (Total P: $p = 0.01$, tau = 0.39; Nitrate: $p = 0.01$, tau = 0.43), although a portion of both of these trends may be explained by changes in sampling regime and laboratory methods.

Metals



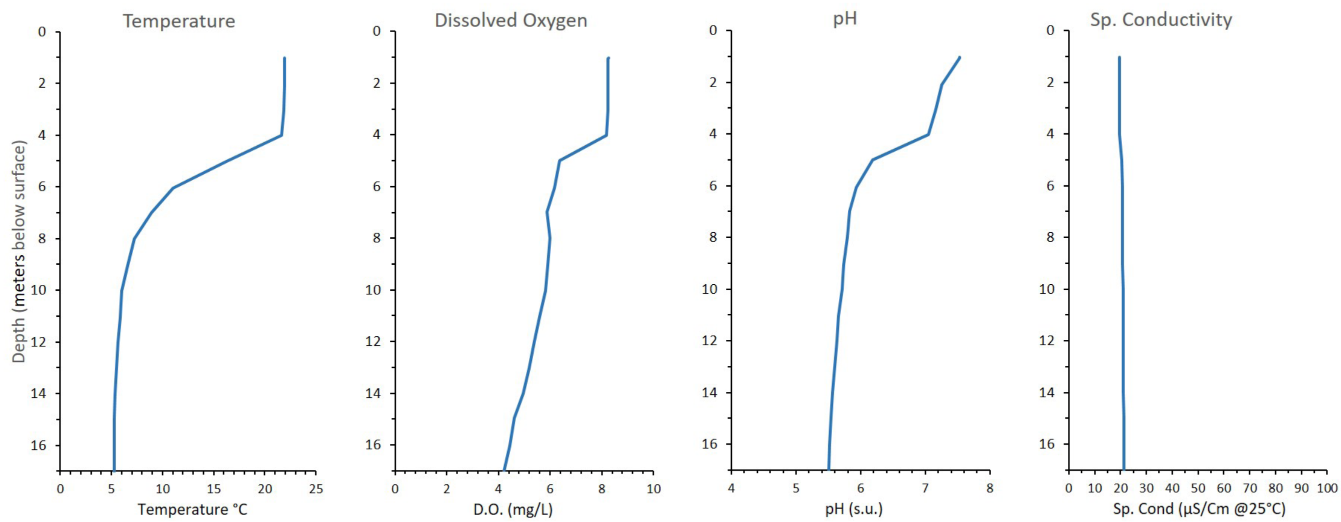
Annual average concentration of calcium and total aluminum in Fawn Lake, 1997-2017. Error bars represent one standard deviation of the mean. Total aluminum has exhibited an increasing trend since 1997, although the trend appears to be driven by two unusually high measurements (see page 30; p = 0.04, tau = 0.33).

Road Salt



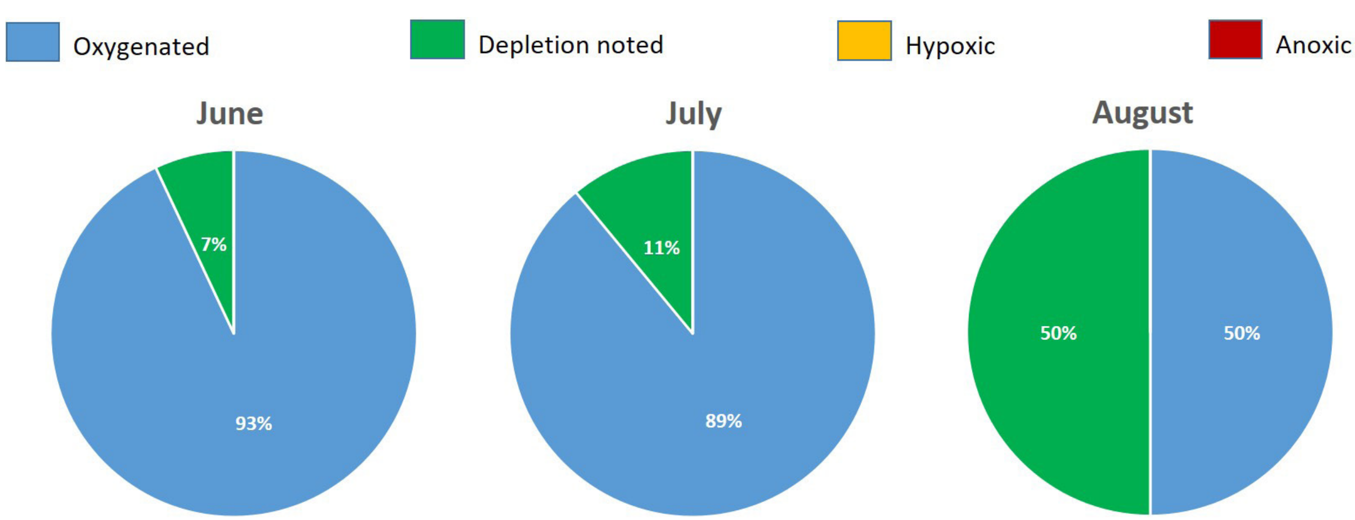
Annual average values of sodium and chloride ions (left panel) and specific conductivity (right panel) in Fawn Lake, 2013-2017. Error bars represent one standard deviation of the mean.

Lake Profile - August 2017



Depth profiles of temperature, dissolved oxygen, pH, and specific conductivity in Fawn Lake during the August 2017 sampling trip.

Dissolved Oxygen Content



Proportion of monthly sampling trips where the bottom water of Fawn Lake (1 meter off bottom) was observed to be oxygenated (D.O. > 4.0 mg/L), experiencing noted depletion (< 4.0 mg/L), hypoxic (< 2.0 mg/L) or anoxic (< 0.5 mg/L).

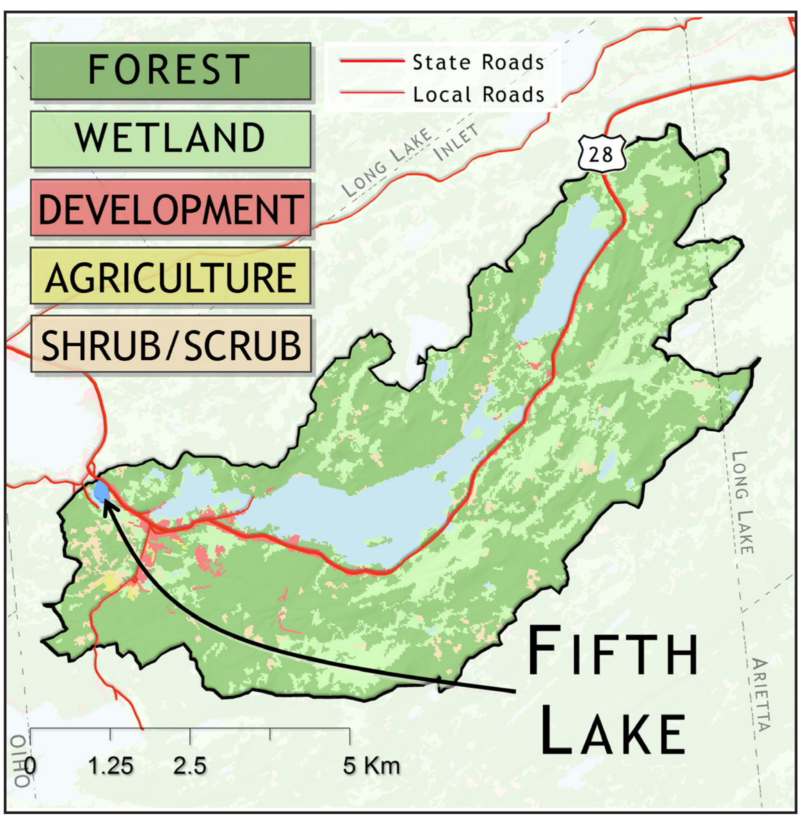
FIFTH LAKE

Summary

Fifth Lake is a 5.6-hectare waterbody, located within a 4,526-hectare watershed that is dominated by forest cover. The ratio of lake-volume to watershed area results in a rapid flushing rate, calculated at over 17 times per year. Long term monitoring by HCSWCD produced the following findings.

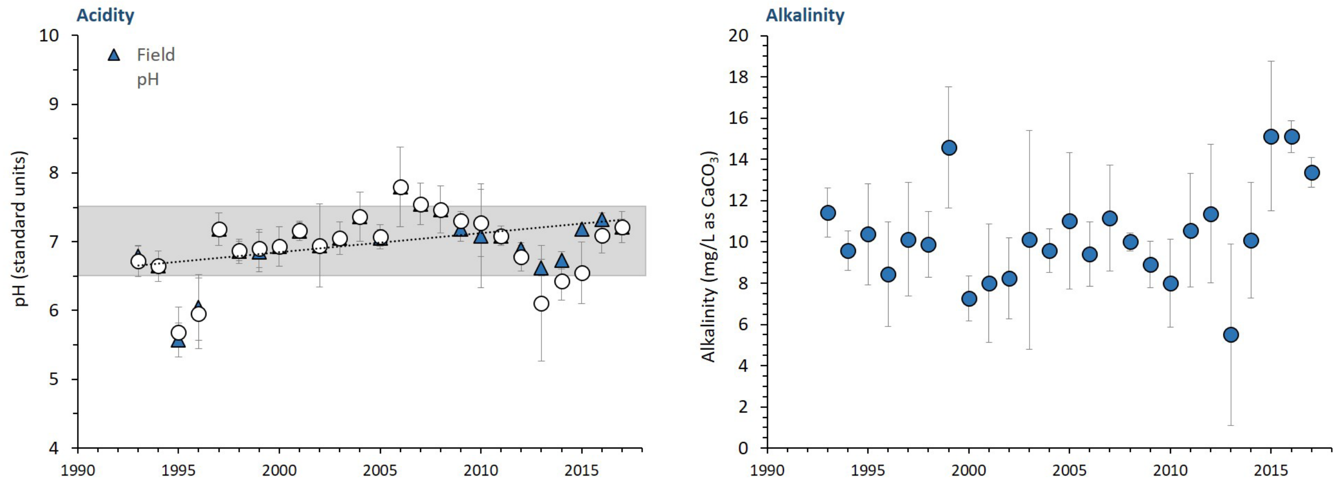
The surface water of the lake is best classified as slightly acidic to circumneutral, with average annual pH values that were typically in the range of 6.0 to 7.5 standard units. Alkalinity ranged from 12 to 19 mg/L between years 2015 and 2017, indicating that the lake had a low sensitivity to acidic deposition. The lake was best classified as mesotrophic, with moderate concentrations of nutrients and chlorophyll-a. A slight, yet significant, downward trend existed for transparency depth since 1993. The chloride concentration averaged 13.8 mg/L between the years 2015 and 2017, indicating that the chemistry of the lake is influenced by the 17 km of paved roads in the watershed. Oxygen depletion is common in the bottom water of Fifth Lake, as hypoxic or anoxic conditions were encountered on 48% of sampling visits during the month of August.

Morphometry



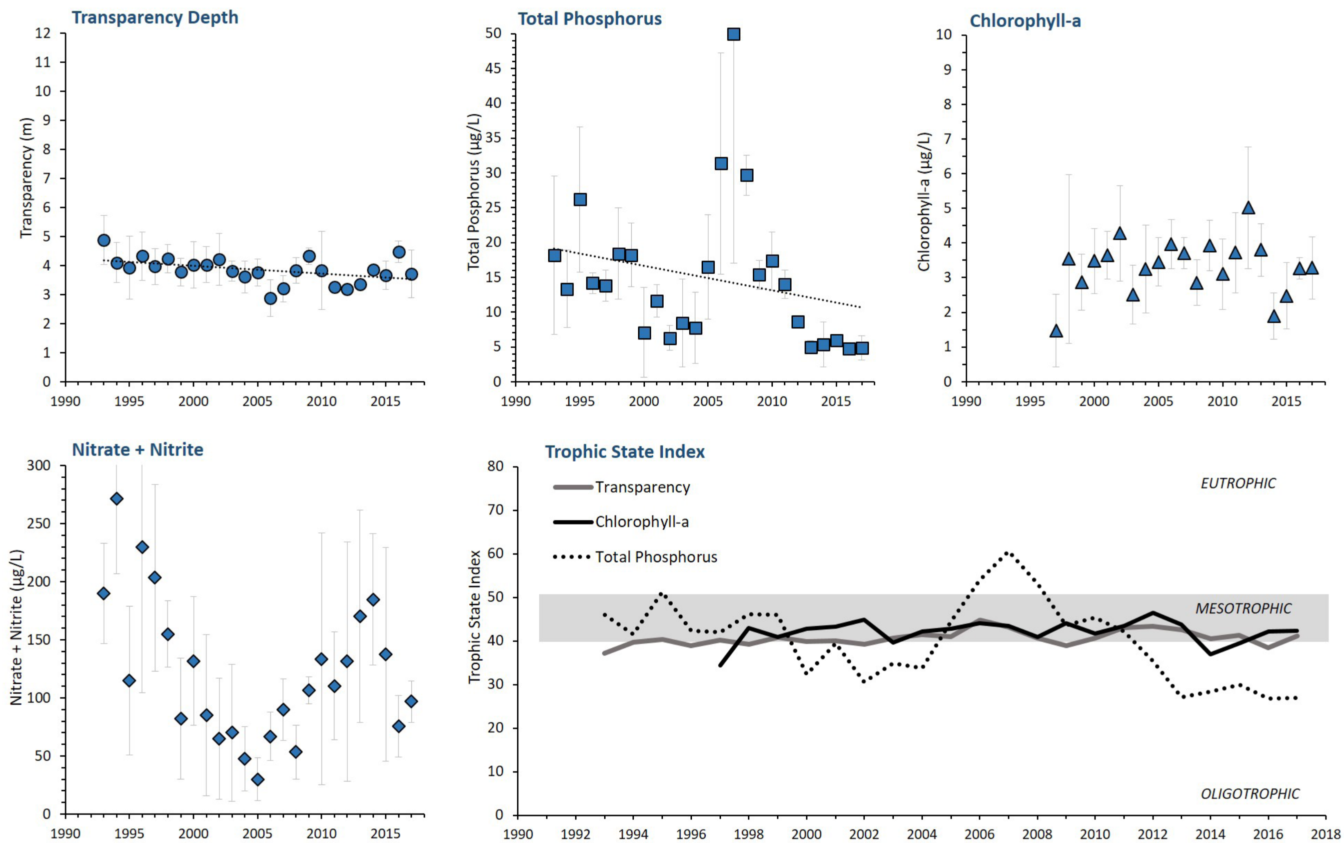
Lake Area (ha)	5.6
Max Depth (m)	5
Volume (m^3 x 10^6)	0.12
Shoreline (km)	1.0
Watershed Area (ha)	4,562
Retention Time (yrs)	0.06
Surface Water Area (%)	14
Forested Area (%)	61
Developed Area (%)	3
Wetland Area (%)	20
State Road Length (km)	12.9
Local Road Length (km)	4.4

Acidity



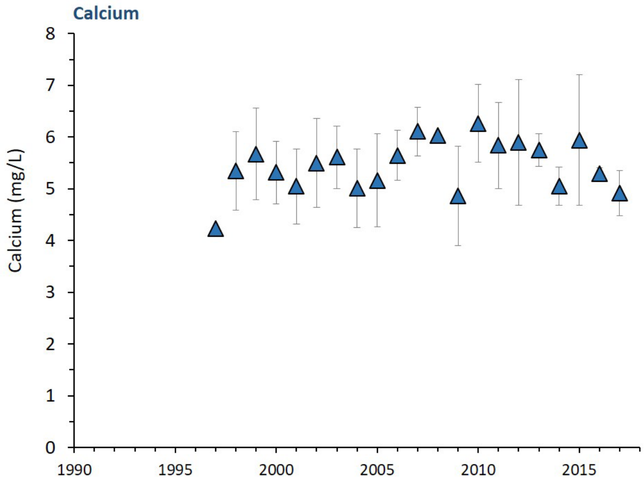
Annual average acidity (left panel) and alkalinity (right panel) of Fifth Lake 1993 - 2017. Shaded box denotes range of circumneutral condition (pH 6.5-7.5). Error bars denote one standard deviation of the mean. pH has exhibited an increasing trend since 1993 (p = 0.02, tau = 0.33).

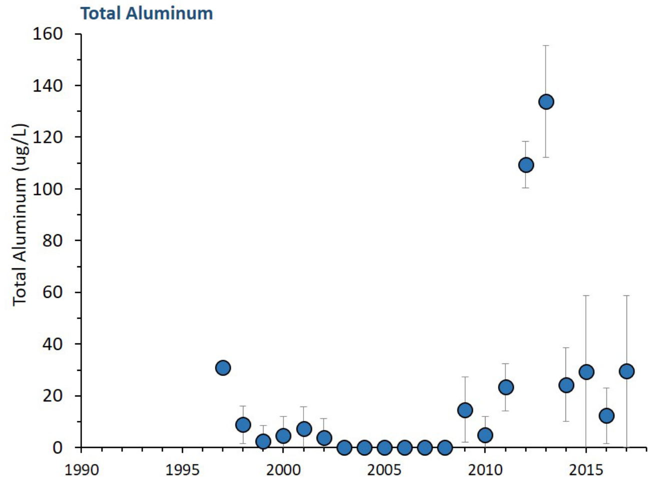
Trophic State



Average values for key trophic state indicators of Fifth Lake, 1993-2017. Error bars represent one standard deviation of the mean. Total phosphorus has exhibited a decreasing trend since 1993 (p = 0.02, tau = 0.33), although a portion of this trend may be explained by changes in sampling regime and laboratory methods.

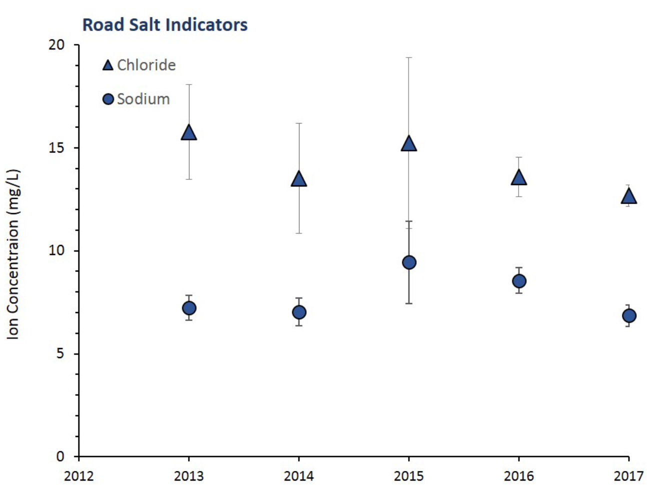
Metals

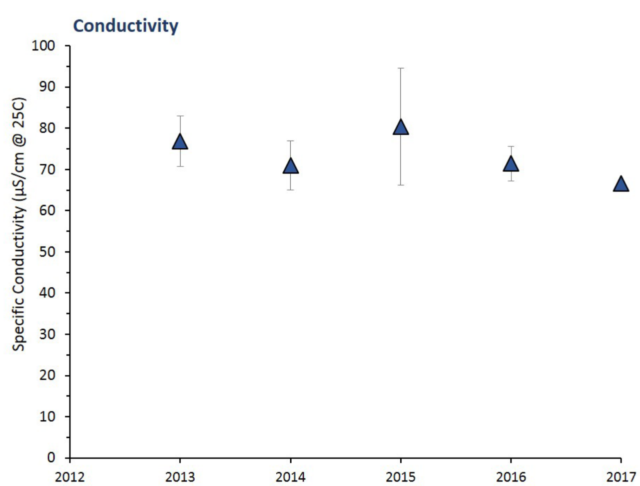




Annual average concentration of calcium and total aluminum in Fifth Lake, 1997-2017. Error bars represent one standard deviation of the mean.

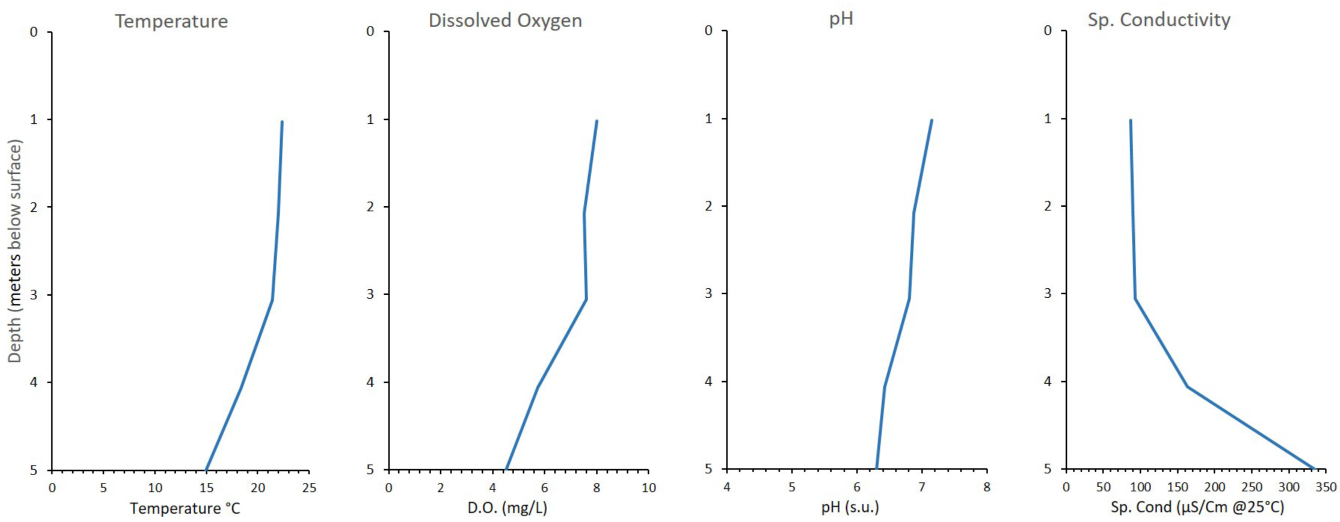
Road Salt





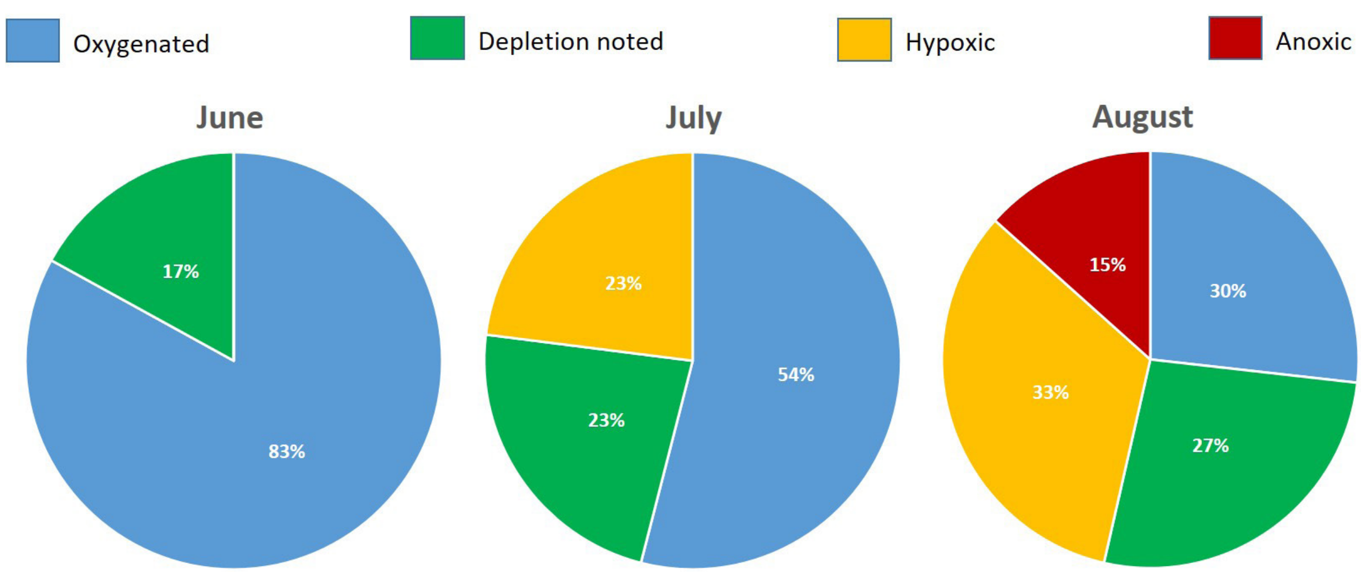
Annual average values of sodium and chloride ions (left panel) and specific conductivity (right panel) in Fifth Lake, 2013-2017. Error bars represent one standard deviation of the mean.

LAKE PROFILE - AUGUST 2017



Depth profiles of temperature, dissolved oxygen, pH, and specific conductivity in Fifth Lake during the August 2017 sampling trip.

DISSOLVED OXYGEN CONTENT



Proportion of monthly sampling trips where the bottom water of Fifth Lake (1 meter off bottom) was observed to be oxygenated (D.O. > 4.0 mg/L), experiencing noted depletion (< 4.0 mg/L), hypoxic (< 2.0 mg/L) or anoxic (< 0.5 mg/L).

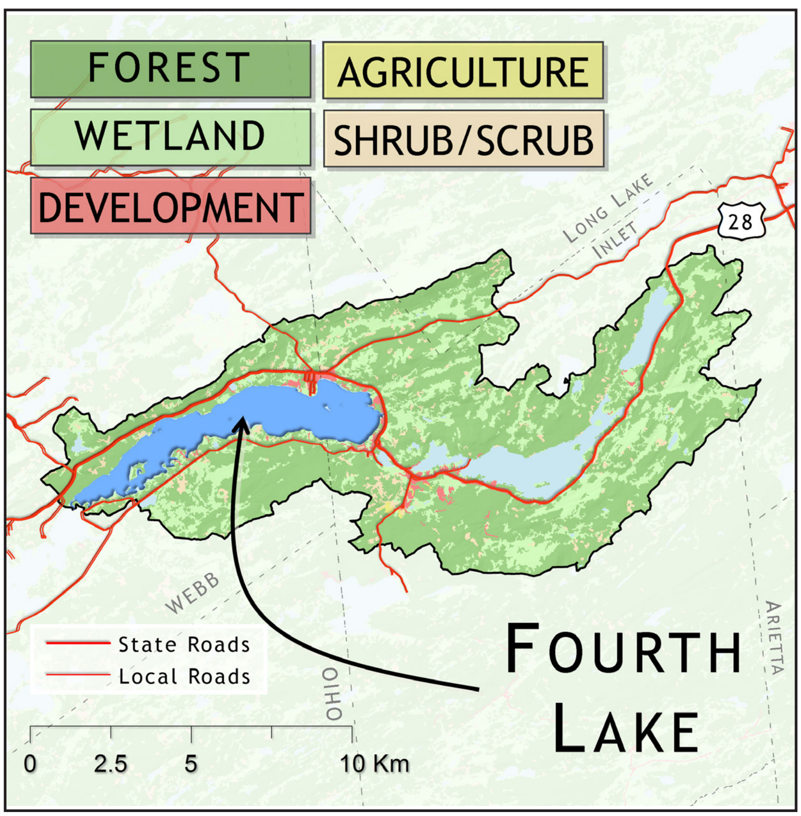
FOURTH LAKE

SUMMARY

Fourth Lake is an 830-hectare waterbody, located within a 9,364-hectare watershed that is dominated by forest cover. Long term monitoring by HCSWCD produced the following findings.

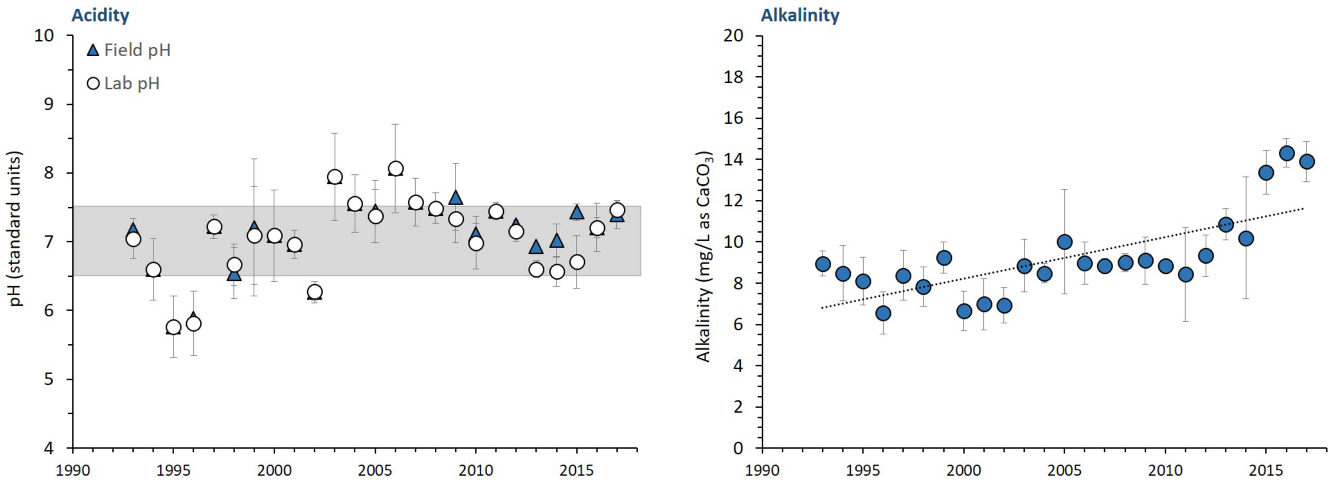
The surface water of the lake is best classified as circumneutral, with average annual pH values that were typically in the range of 6.3 to 7.6 standard units. Between the years 2015 and 2017, alkalinity was in the range of 12 to 15 mg/L, indicating that the lake had low sensitivity to acidic deposition. The alkalinity of the lake has exhibited a statistical increase since monitoring began in 1993. The lake was best classified as mesotrophic, with moderate transparency depths and chlorophyll-a concentrations. A significant downward trend existed in the transparency data, with a reduction of approximatly 1-meter since 1993. The chemistry of the lake was influenced by the 47 km of roads in the watershed. The concentration of chloride and sodium between the years 2015 and 2017 averaged 10.9 and 6.4 mg/L respectively, which is approximately 36 times greater than background concentrations for Adirondack lakes. In most cases, the bottom water of Fourth Lake was well oxygenated during the period of summer stratification. Only 25% of observations during the month of August had notable oxygen depletion.

MORPHOMETRY



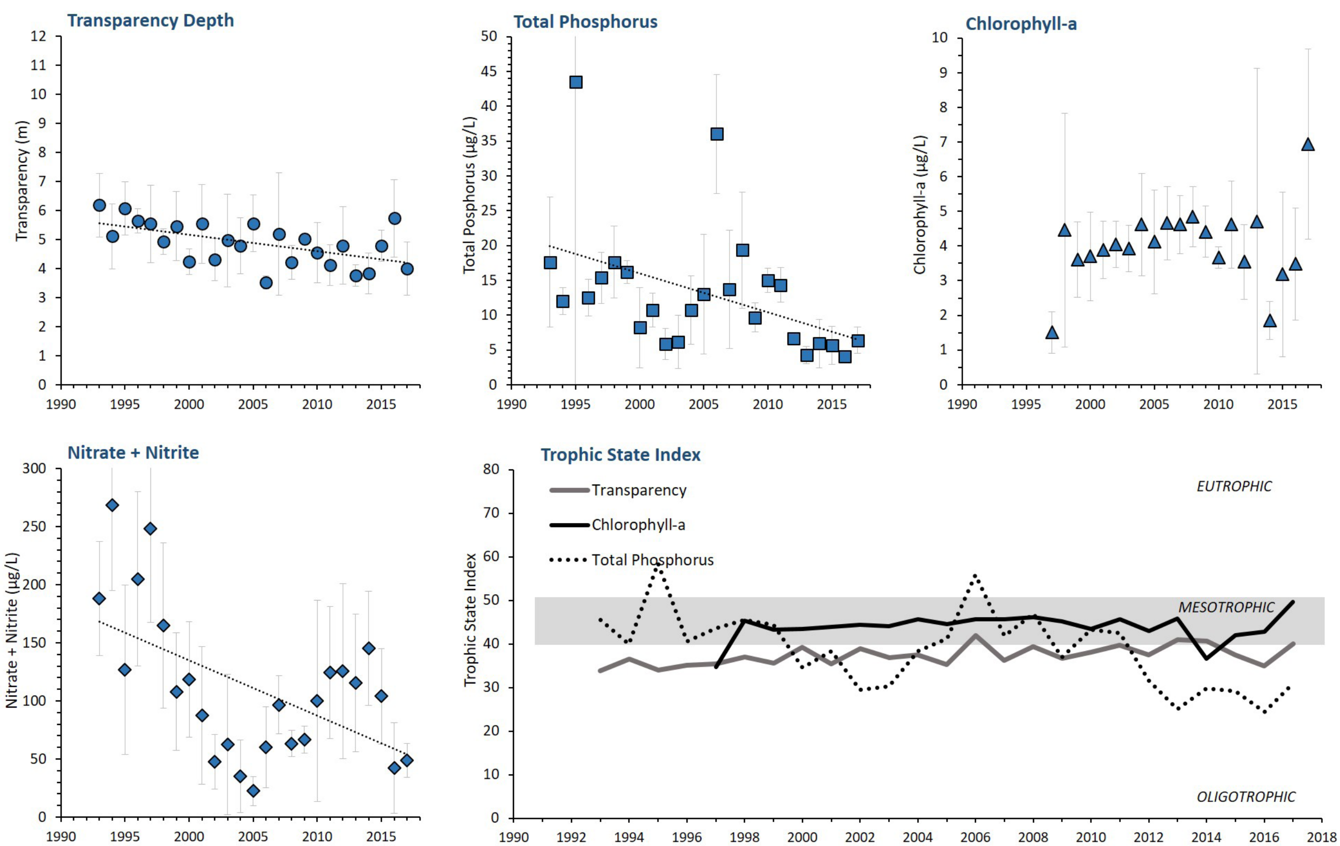
Lake Area (ha)	830
Max Depth (m)	19
Volume (m^3 x 10^6)	77.4
Shoreline (km)	31
Watershed Area (ha)	9,364
Retention Time (yrs)	0.96
Surface Water Area (%)	17
Forested Area (%)	59
Developed Area (%)	3
Wetland Area (%)	20
State Road Length (km)	24.6
Local Road Length (km)	23.0

ACIDITY



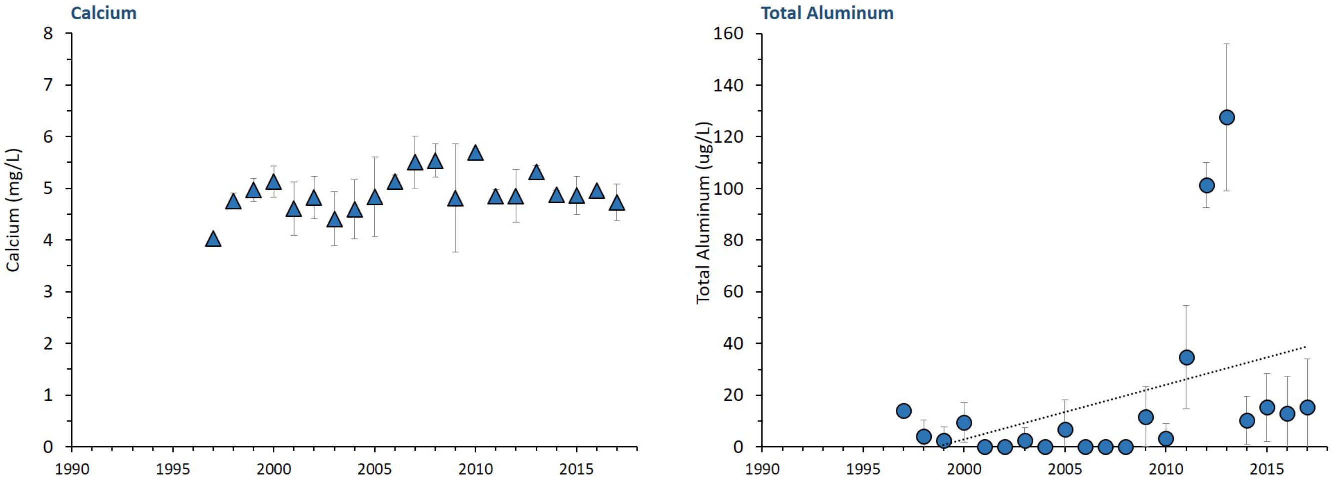
Annual average acidity (left panel) and alkalinity (right panel) of Fourth Lake 1993 - 2017. Shaded box denotes range of circumneutral condition (pH 6.5-7.5). Error bars denote one standard deviation of the mean. Alkalinity has exhibited an increasing trend since 1993 ($p = 0.01$, tau = 0.55).

TROPHIC STATE



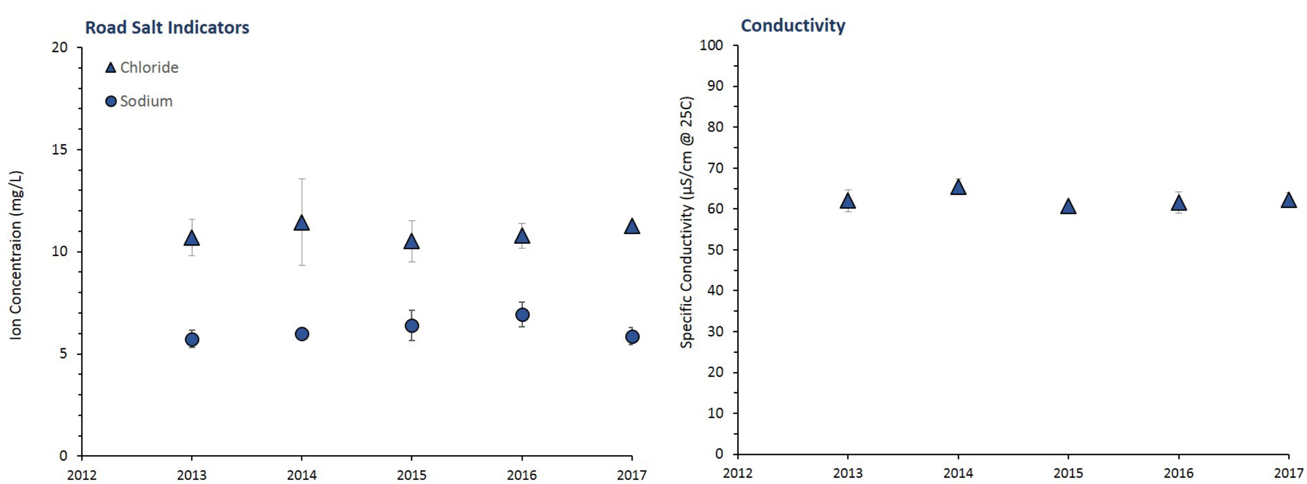
Average values for key trophic state indicators of Fourth Lake, 1993-2017. Error bars represent one standard deviation of the mean. Total phosphorus and nitrate have exhibited a decreasing trend since 1993 (Total P: $p = 0.01$, tau = 0.39; Nitrate: $p = 0.04$, tau = 0.29), although a portion of both of these trends may be explained by changes in sampling regime and laboratory methods.

METALS



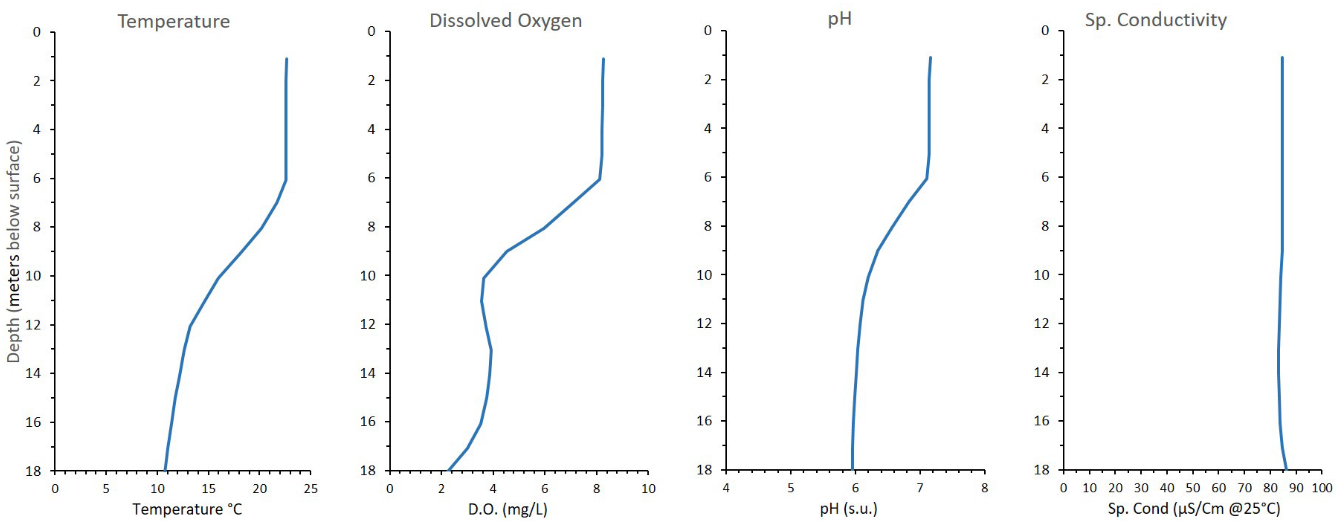
Annual average concentration of calcium and total aluminum in Fourth Lake, 1997-2017. Error bars represent one standard deviation of the mean. Total aluminum has exhibited an increasing trend since 1997, although the trend appears to be driven by two unusually high measurements (see page 30; p = 0.03, tau = 0.35).

ROAD SALT



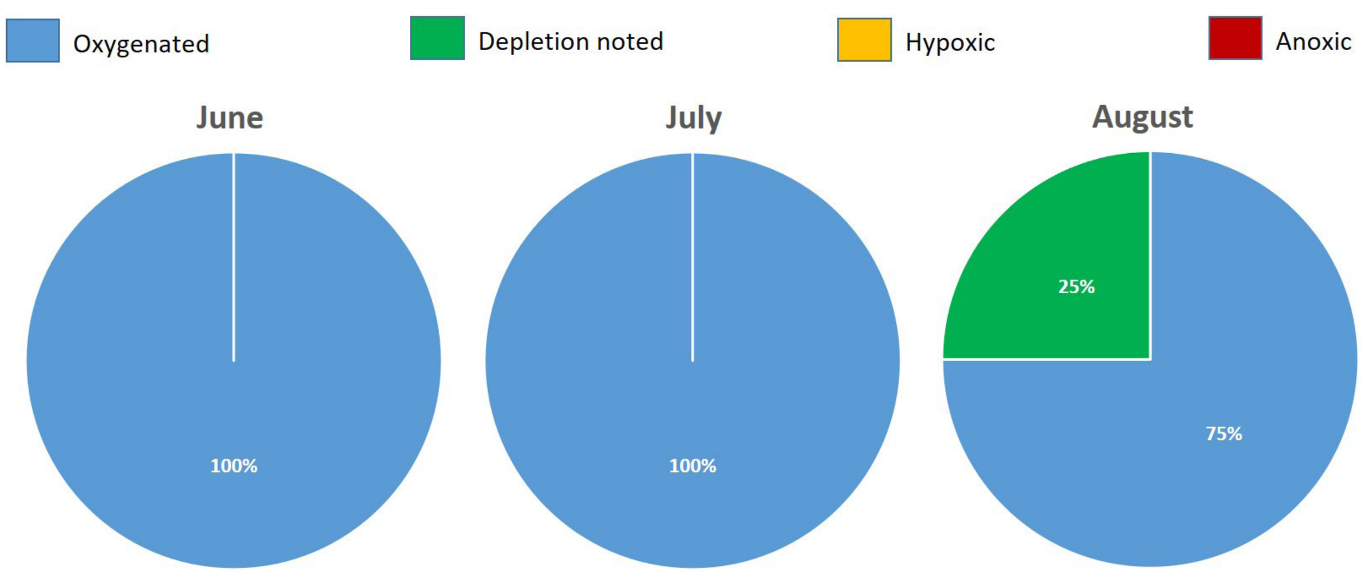
Annual average values of sodium and chloride ions (left panel) and specific conductivity (right panel) in Fourth Lake, 2013-2017. Error bars represent one standard deviation of the mean.

LAKE PROFILE - AUGUST 2017



Depth profiles of temperature, dissolved oxygen, pH, and specific conductivity in Fourth Lake during the August 2017 sampling trip.

DISSOLVED OXYGEN CONTENT



Proportion of monthly sampling trips where the bottom water of Fourth Lake (1 meter off bottom) was observed to be oxygenated (D.O. > 4.0 mg/L), experiencing noted depletion (< 4.0 mg/L), hypoxic (< 2.0 mg/L) or anoxic (< 0.5 mg/L). Data is from the period of 1993 to 2017.

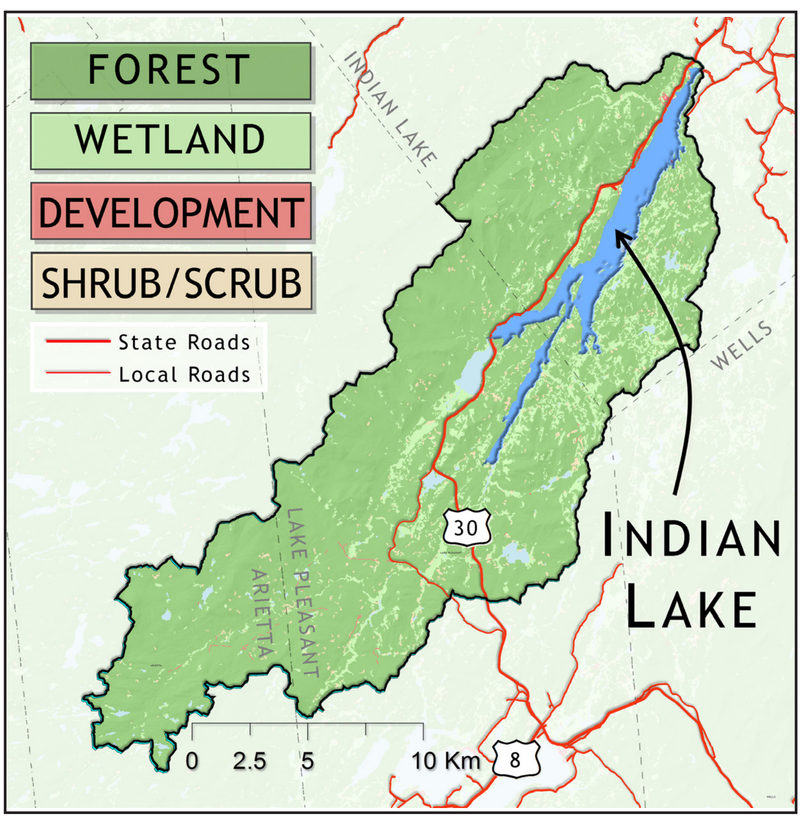
INDIAN LAKE

Summary

Indian Lake is a 1,740-hectare waterbody, located within a 33,586-hectare watershed that is dominated by forest cover. Long term monitoring by HCSWCD produced the following findings.

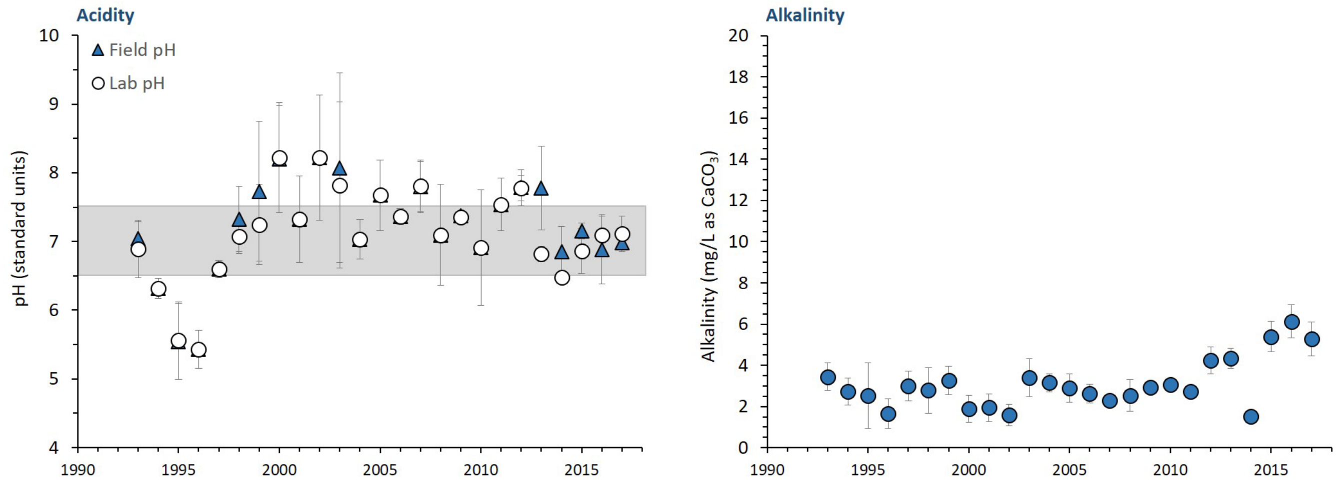
The surface water of the lake is best classified as circumneutral, with average annual pH values that were typically in the range of 6.5 to 7.4 standard units. Between the years 2015 and 2017, alkalinity was in the range of 5 to 7 mg/L, indicating that the lake had moderate sensitivity to acidic deposition. The lake was best classified as mesotrophic, and has been fairly stable since monitoring began in 1993. A slight, yet statistically significant downward trend in transparency was detected in the historical data. The chemistry of the lake was slightly influenced by the 39 km of roads in the watershed. The concentration of chloride and sodium between the years 2015 and 2017 averaged 3.2 and 2.1 mg/L respectively, which is approximately 11 times greater than background concentrations for Adirondack lakes. Although the bottom water of Indian Lake did not exhibit anoxia or hypoxia during any of the sampling visits, it was common to find notable oxygen depletion during the month of August (60% of observations).

Morphometry



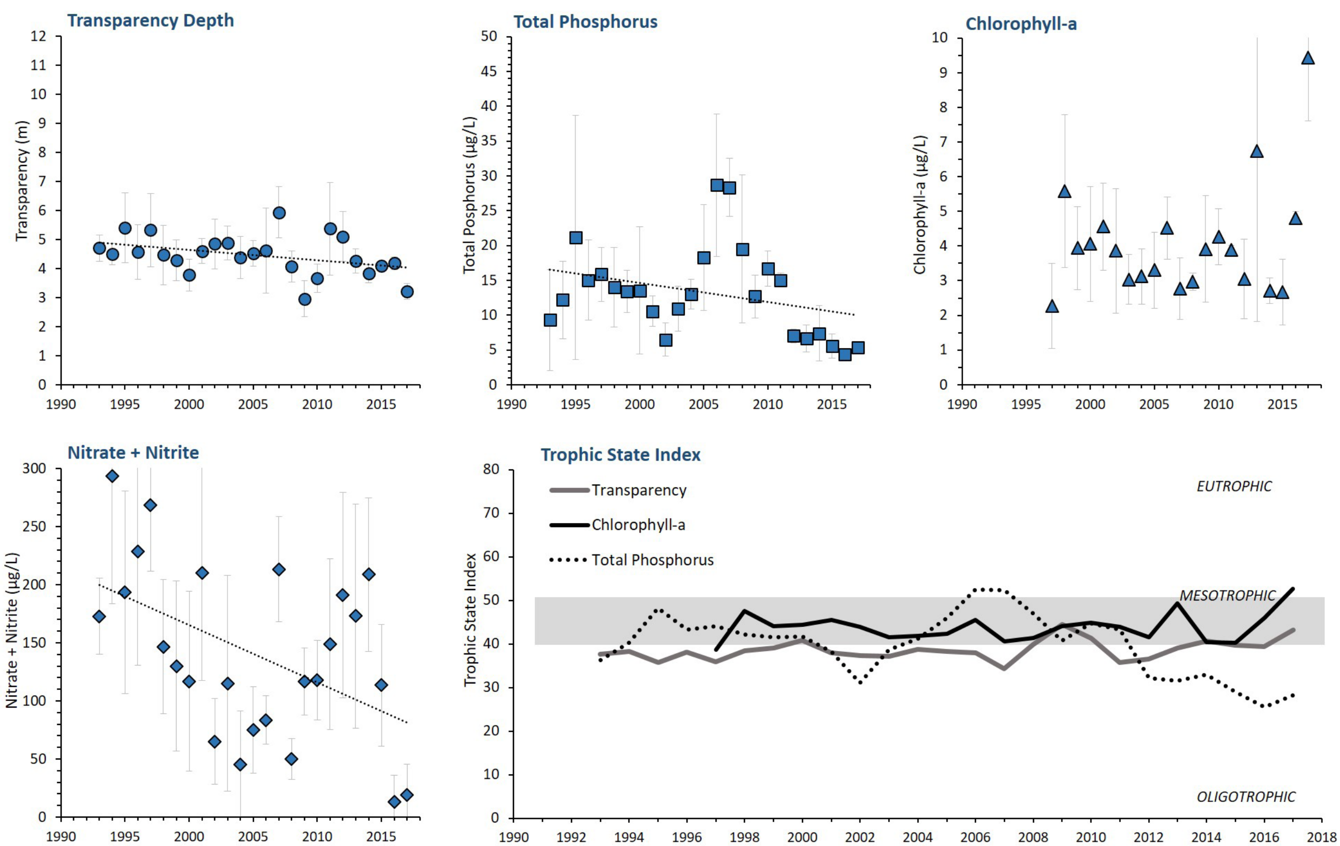
Lake Area (ha)	1,740
Max Depth (m)	25
Volume (m^3 x 10^6)	209
Shoreline (km)	106
Watershed Area (ha)	33,586
Retention Time (yrs)	0.9
Surface Water Area (%)	7
Forested Area (%)	83
Developed Area (%)	1
Wetland Area (%)	8
State Road Length (km)	28.8
Local Road Length (km)	10.4

Acidity



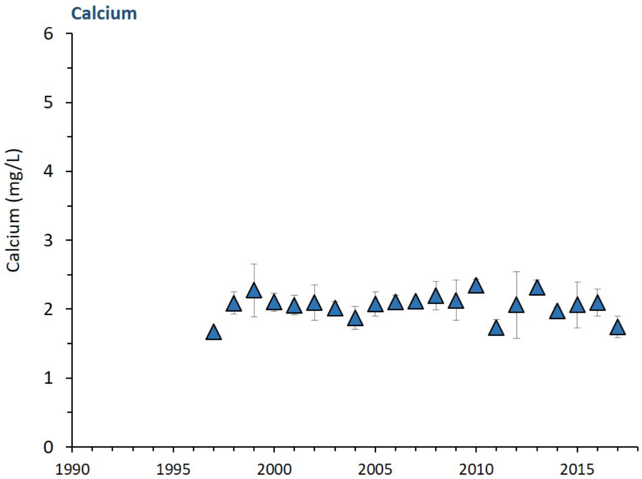
Annual average acidity (left panel) and alkalinity (right panel) of Indian Lake 1993 - 2017. Shaded box denotes range of circumneutral condition (pH 6.5-7.5). Error bars denote one standard deviation of the mean.

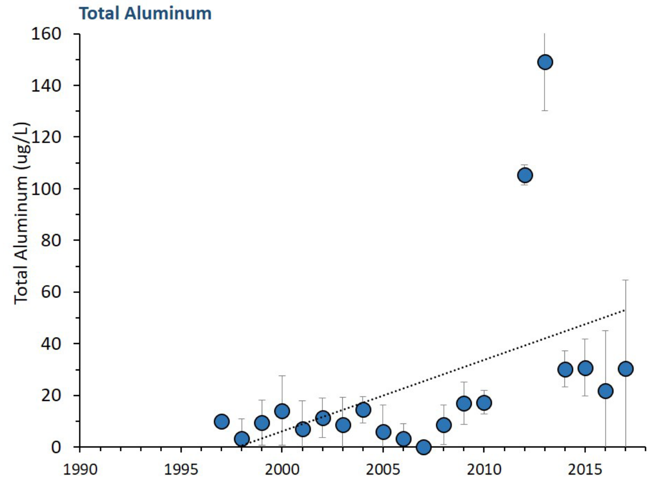
Trophic State



Average values for key trophic state indicators of Indian Lake, 1993-2017. Error bars represent one standard deviation of the mean. Transparency, total phosphorus and nitrate have all exhibited a decreasing trend since 1993 (Transparency: p = 0.04, tau = 0.29; Total P: p = 0.04, tau = 0.30; Nitrate: p = 0.03, tau = 0.31), although a portion of the TP and nitrate trends may be explained by changes in sampling regime and laboratory methods.

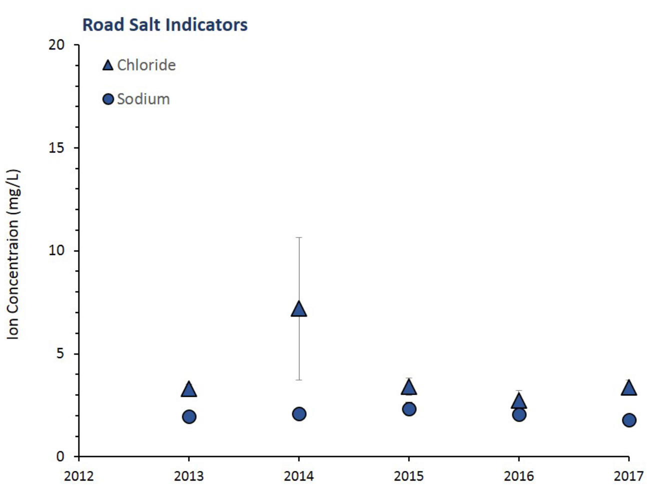
Metals

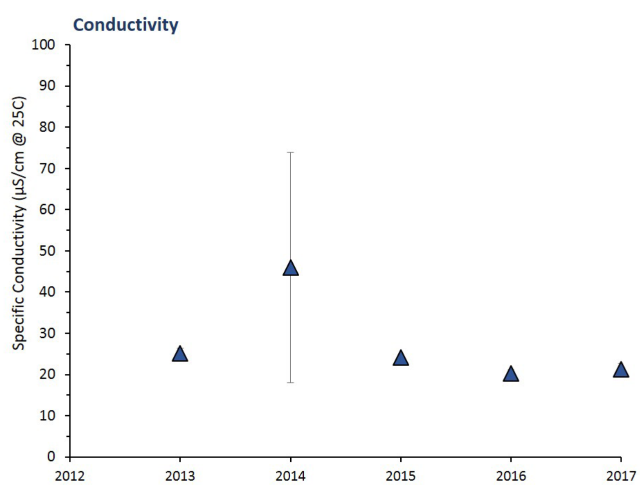




Annual average concentration of calcium and total aluminum in Indian Lake, 1997-2017. Error bars represent one standard deviation of the mean. Total aluminum has exhibited an increasing trend since 1997, although the trend appears to be driven by two unusually high measurements (see page 30; $p = 0.005$, $tau = 0.5$).

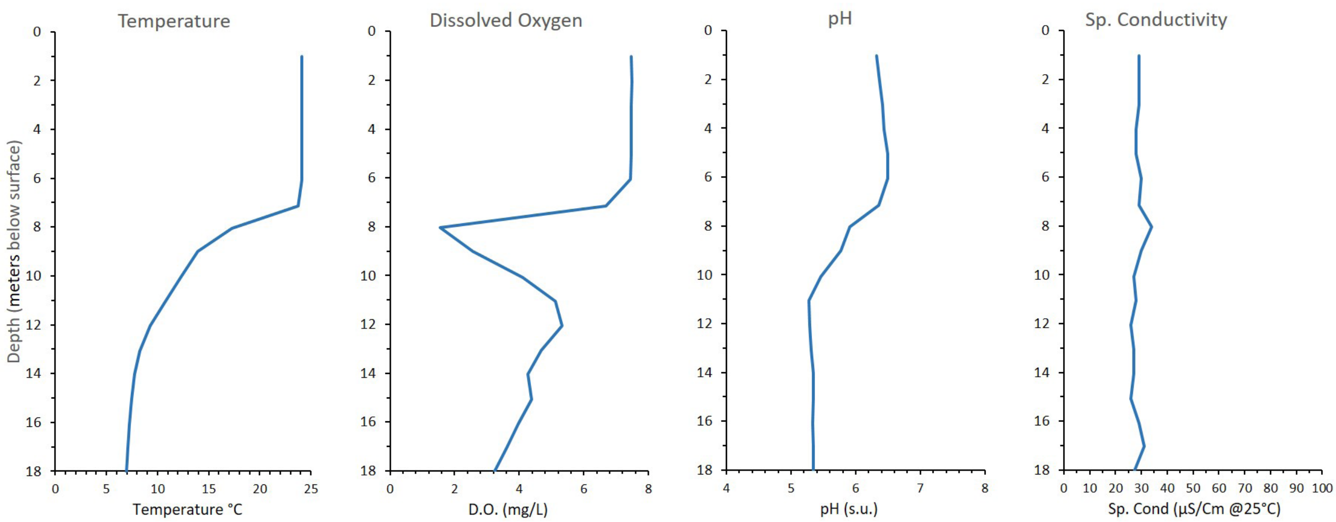
Road Salt





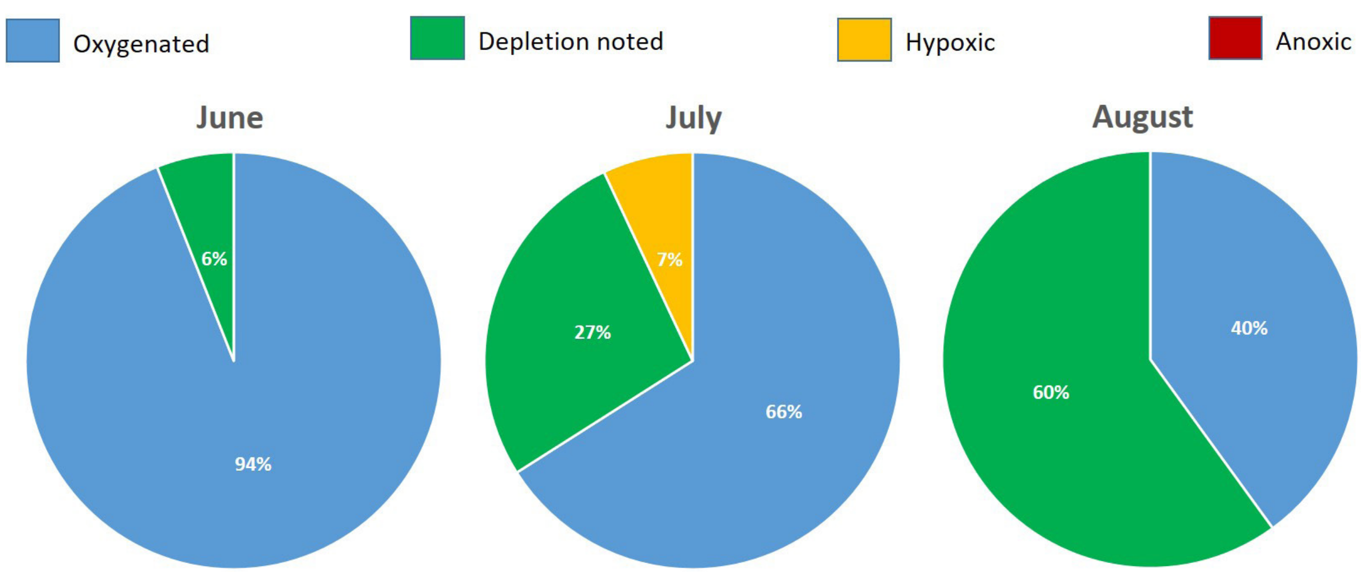
Annual average values of sodium and chloride ions (left panel) and specific conductivity (right panel) in Indian Lake, 2013-2017. Error bars represent one standard deviation of the mean.

Lake Profile - August 2017



Depth profiles of temperature, dissolved oxygen, pH, and specific conductivity in Indian Lake during the August 2017 sampling trip.

Dissolved Oxygen Content



Proportion of monthly sampling trips where the bottom water of Indian Lake (1 meter off bottom) was observed to be oxygenated (D.O. > 4.0 mg/L), experiencing noted depletion (< 4.0 mg/L), hypoxic (< 2.0 mg/L) or anoxic (< 0.5 mg/L). Data is from the period of 1993 to 2017.

LAKE ABANAKEE

Summary

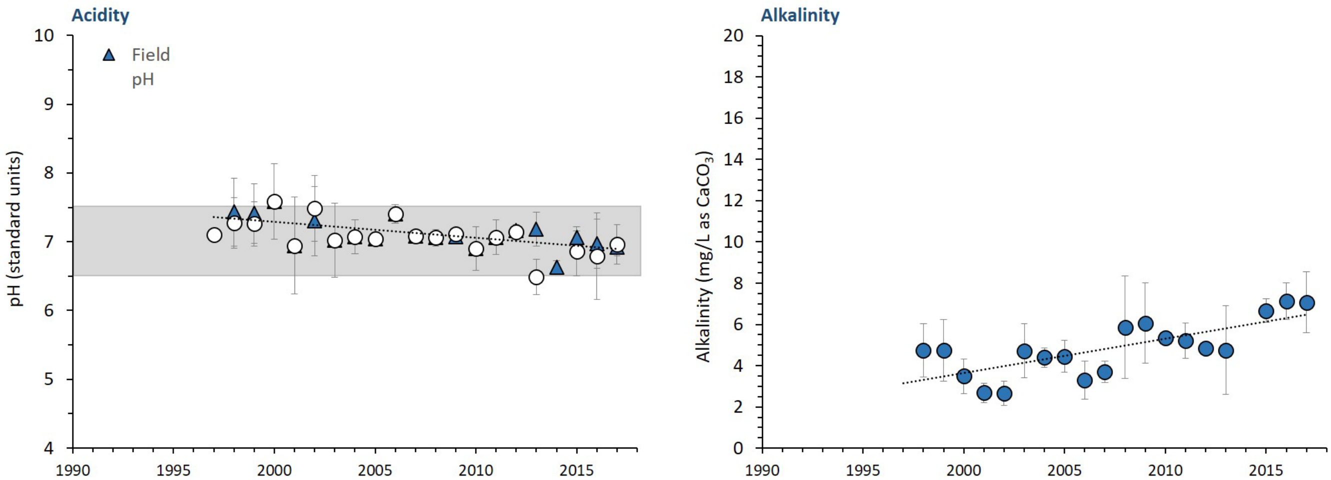
Lake Abanakee is a 215-hectare waterbody, located within a 50,541-hectare watershed that is dominated by forest cover. The ratio of lake-volume to watershed area results in a rapid flushing rate, calculated at over 12 times per year. Long term monitoring by HCSWCD produced the following findings

The surface water of the lake is best classified as circumneutral, with average annual pH values that were typically in the range of 6.5 to7.5 standard units. Between the years 2015 and 2017, alkalinity was in the range of 5 to 8 mg/L, indicating that the lake had moderate sensitivity to acidic deposition. Despite a slight downward trend in pH values, the alkalinity of the lake has exhibited a significant increase since the mid-1990s. The lake is best classified as mesotrophic, with a slight downward trend in transparency. The chemistry of the lake was slightly influenced by the 95 km of roads in the watershed. The concentration of chloride and sodium between the years 2015 and 2017 averaged 3.4 and 2.2 mg/L, respectively, which is approximately 11 times greater than background concentrations for Adirondack lakes. The bottom water of Lake Abanakee did not exhibit anoxia or hypoxia during any of the sampling visits.

Morphometry

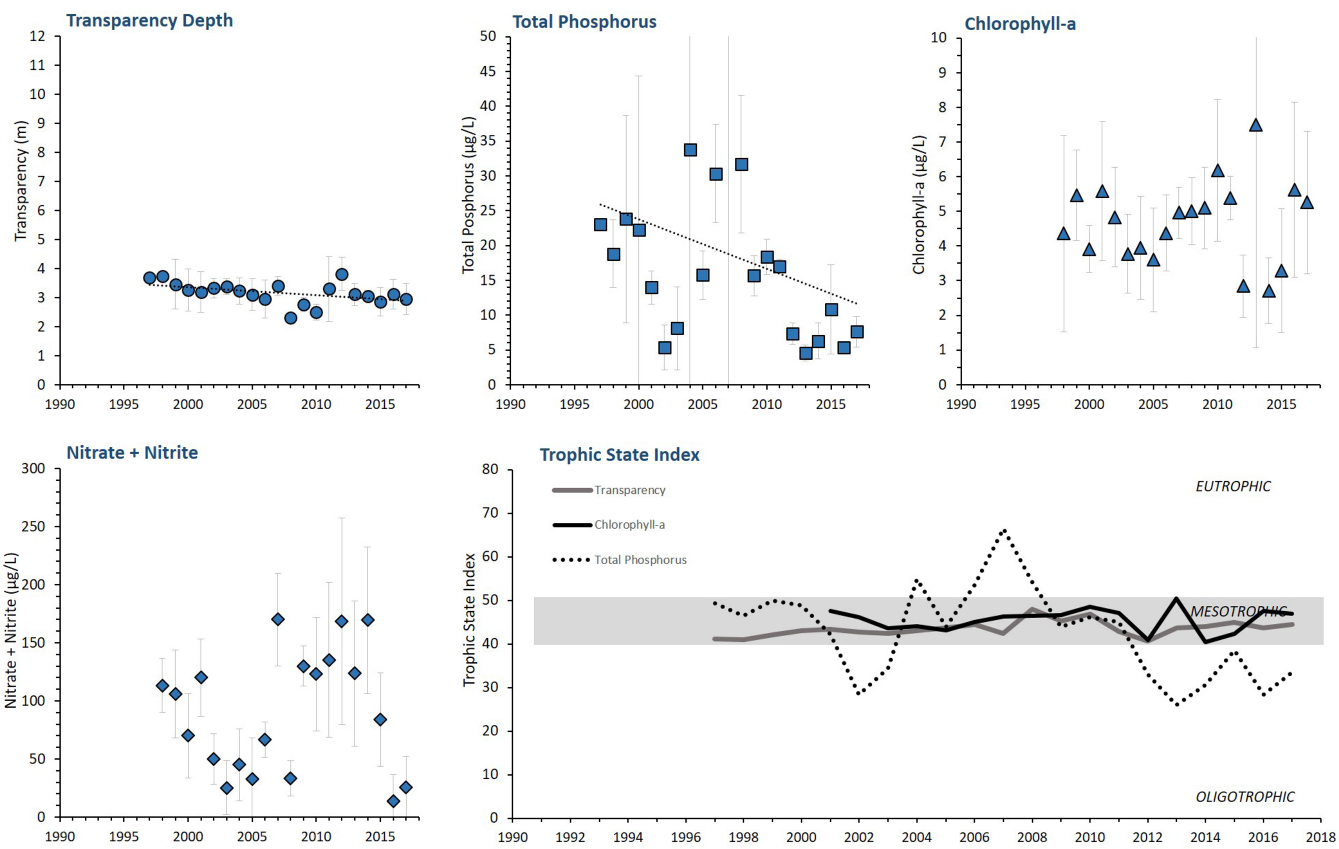
Lake Area (ha)	215
Max Depth (m)	8.2
Volume (m^3 x 10^6)	182
Shoreline (km)	36.7
Watershed Area (ha)	50,541
Retention Time (yrs)	0.12
Surface Water Area (%)	7
Forested Area (%)	81
Developed Area (%)	1
Wetland Area (%)	11
State Road Length (km)	41.4
Local Road Length (km)	54.0

ACIDITY



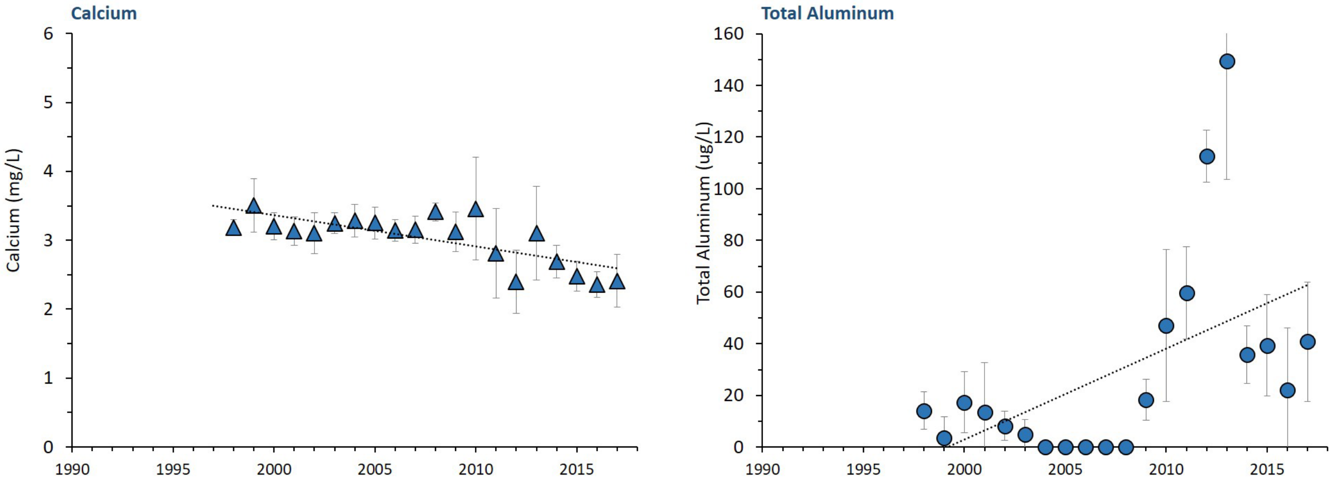
Annual average acidity (left panel) and alkalinity (right panel) of Lake Abanakee, 1997 - 2017. Shaded box denotes range of circumneutral condition (pH 6.5-7.5). Error bars denote one standard deviation of the mean. The pH of the lake has exhibted a signifcant decrease while the alkalinity has exhibited a significant increase (pH: p = 0.007, tau = 0.43; Alkalinity: p = 0.02, tau = 0.38).

TROPHIC STATE



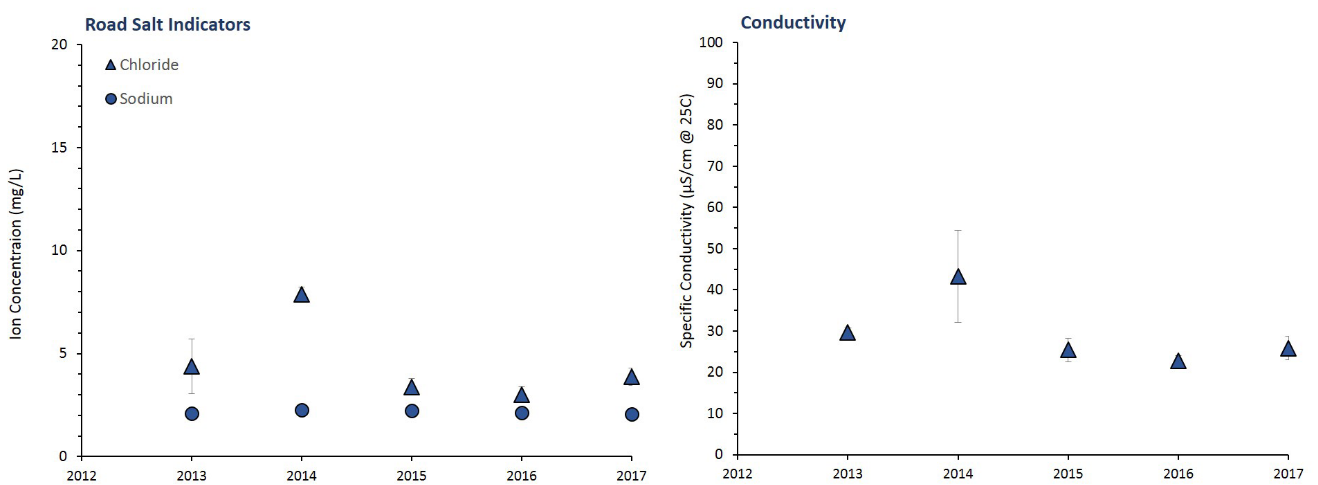
Average values for key trophic state indicators of Lake Abanakee, 1997-2017. Error bars represent one standard deviation of the mean. Transparency and total phosphorus have both exhibited a decreasing trend since 1997 (Transparency: p = 0.01, tau = 0.40; Total P: p = 0.03, tau = 0.35), although a portion of the TP trend may be explained by changes in sampling regime and laboratory methods.

METALS



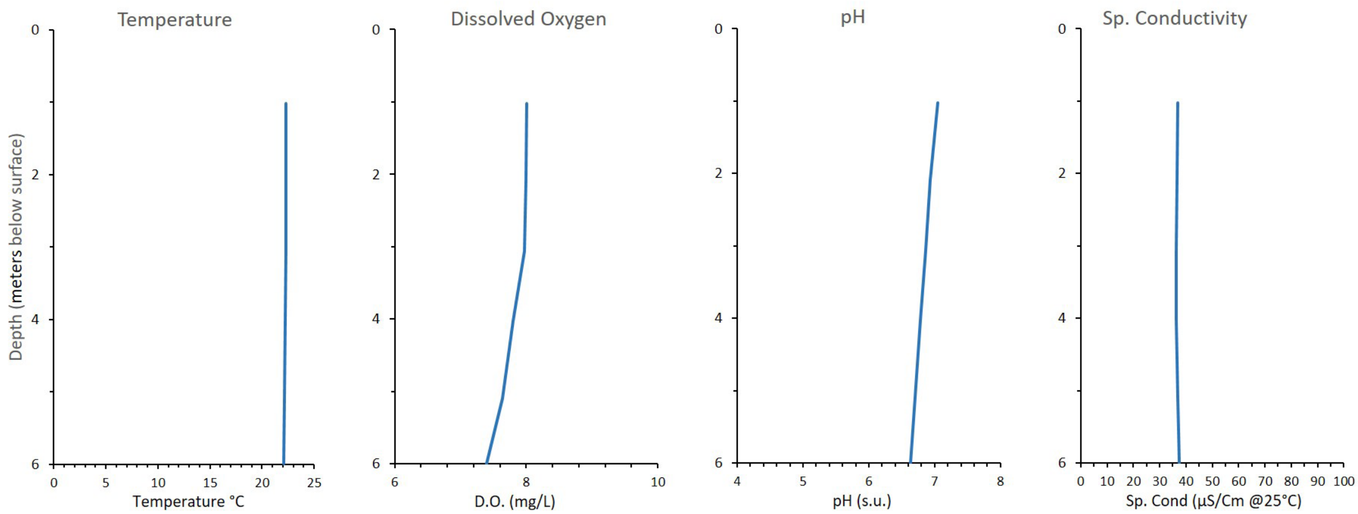
Annual average concentration of calcium and total aluminum in Lake Abanakee, 1997-2017. Error bars represent one standard deviation of the mean. Calcium exhibited a slight, yet significant, downward trend since 1997 ($p = 0.02$, tau = 0.51). Total aluminum has exhibited an increasing trend since 1997 (see page 30; $p = 0.04$, tau = 0.35).

ROAD SALT



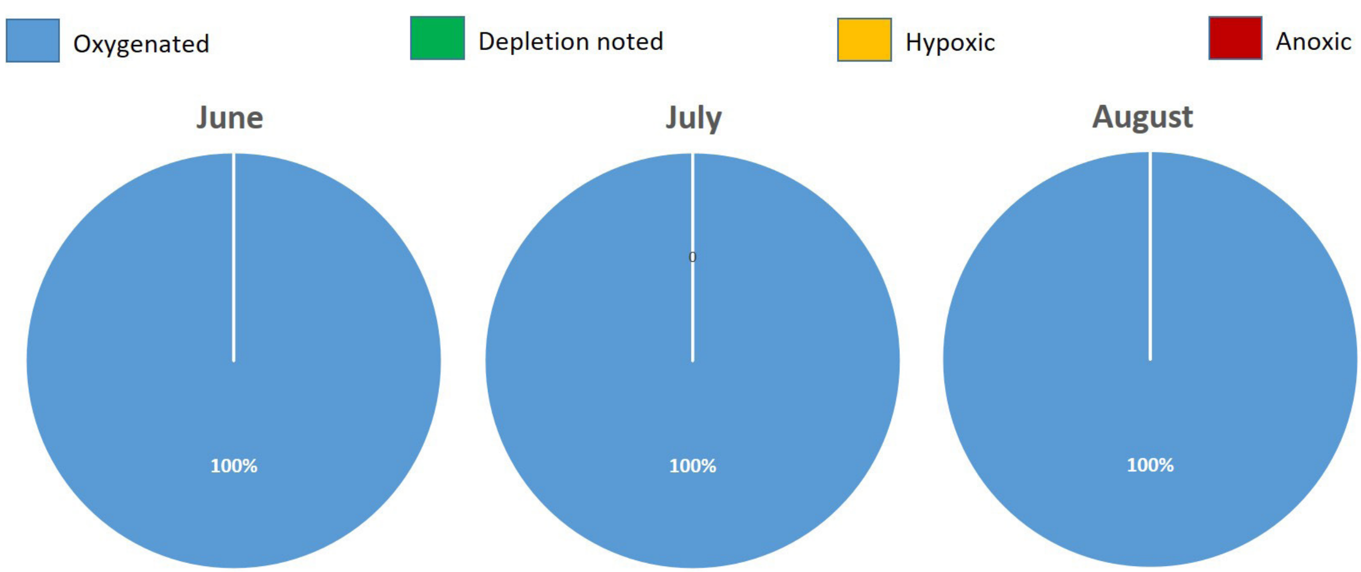
Annual average values of sodium and chloride ions (left panel) and specific conductivity (right panel) in Lake Abanakee, 2013-2017. Error bars represent one standard deviation of the mean.

Lake Profile - August 2017



Depth profiles of temperature, dissolved oxygen, pH, and specific conductivity in Lake Abanakee during the August 2017 sampling trip.

Dissolved Oxygen Content



Proportion of monthly sampling trips where the bottom water of Lake Abanakee (1 meter off bottom) was observed to be oxygenated (D.O. > 4.0 mg/L), experiencing noted depletion (< 4.0 mg/L), hypoxic (< 2.0 mg/L) or anoxic (< 0.5 mg/L). Data is from the period of 1993 to 2017.

LAKE ALGONQUIN

Summary

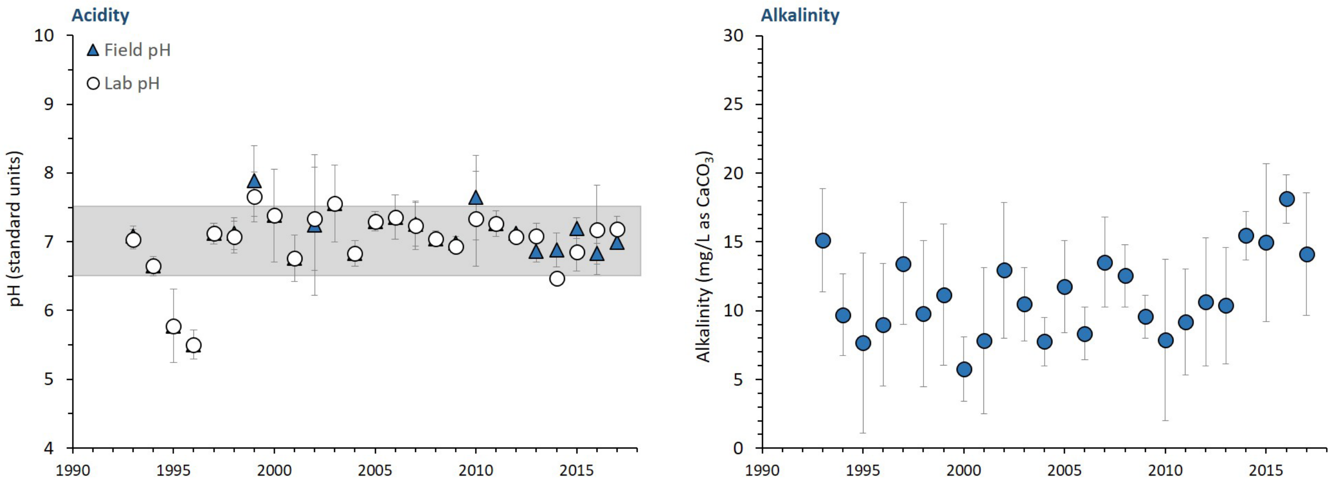
Lake Algonquin is a 104-hectare waterbody, located within a 67,161-hectare watershed that is dominated by forest cover. The ratio of lake-volume to watershed area results in a rapid flushing rate, calculated at over 25 times per year. Long term monitoring by HCSWCD produced the following findings.

The surface water of the lake is best classified as circumneutral, with average annual pH values that were typically in the range of 6.5 – 7.5 standard units. Between the years 2015 and 2017, alkalinity was in the range of 9 to 20 mg/L, indicating that the lake had low sensitivity to acidic deposition. The lake is best classified as mesotrophic, with a statistically significant increase in chlorophyll-a concentration over time. Despite the increase in chlorophyll concentration, we detected a slight, yet significant, downward trend in transparency. The chemistry of the lake was moderately influenced by the 156 km of roads in the watershed. The concentration of chloride and sodium between the years 2015 and 2017 averaged 8.3 and 5.0 mg/L respectively, which is approximately 28 times greater than background concentrations for Adirondack lakes. The bottom water of Lake Algonquin did not exhibit anoxia or hypoxia during any of the sampling visits.

Morphometry

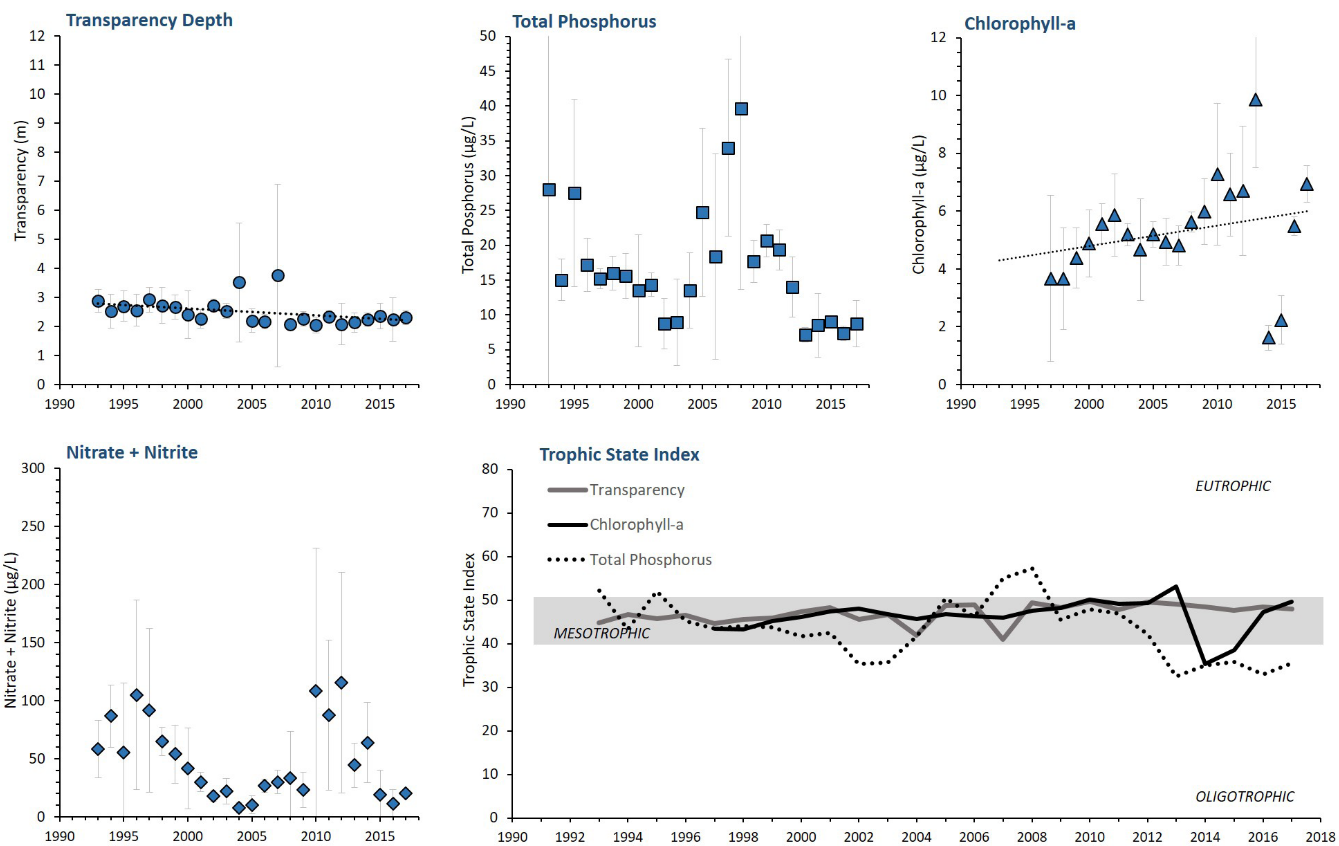
Lake Area (ha)	104
Max Depth (m)	3.0
Volume (m^3 x 10^6)	12.9
Shoreline (km)	10.4
Watershed Area (ha)	67,161
Retention Time (yrs)	0.04
Surface Water Area (%)	4
Forested Area (%)	89
Developed Area (%)	1
Wetland Area (%)	6
State Road Length (km)	61.7
Local Road Length (km)	94.1

Acidity



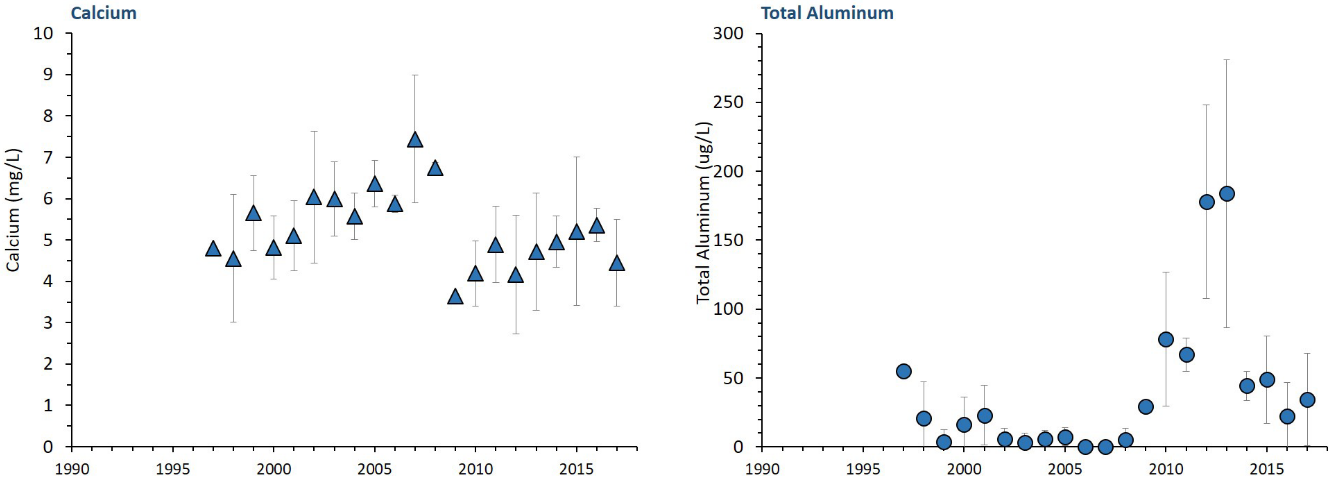
Annual average acidity (left panel) and alkalinity (right panel) of Lake Algonquin, 1993 - 2017. Shaded box denotes range of circumneutral condition (pH 6.5-7.5). Error bars denote one standard deviation of the mean.

Trophic State



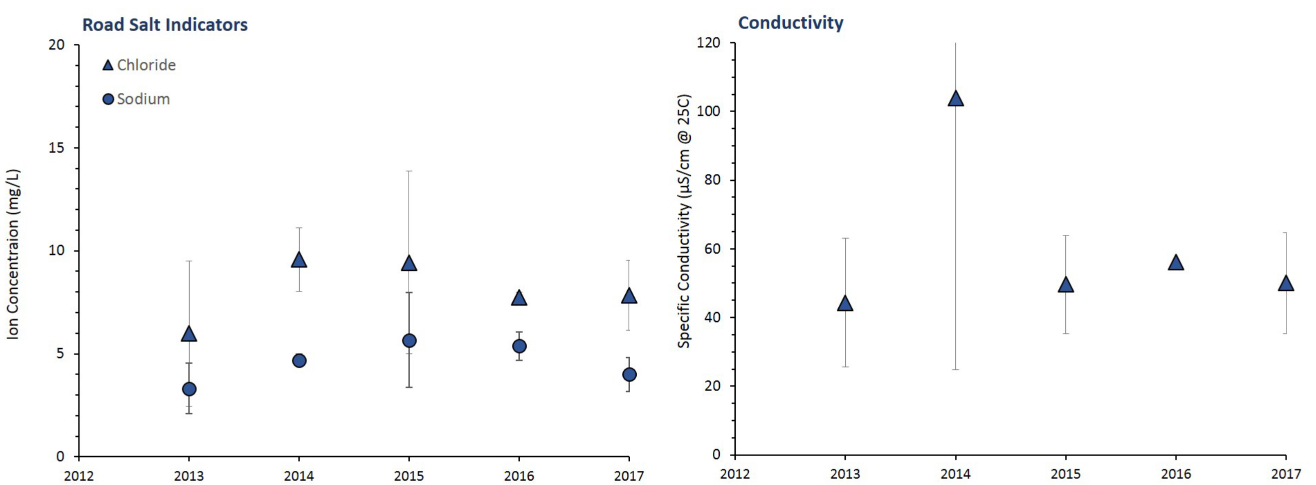
Average values for key trophic state indicators of Lake Algonquin, 1993-2017. Error bars represent one standard deviation of the mean. Transparency has exhibited a decreasing trend since 1993, while chlorophyll-a has experienced an increasing trend (Transparency: p = 0.006, tau = 0.40; Chlorophyll-a: p = 0.02, tau = 0.37).

METALS



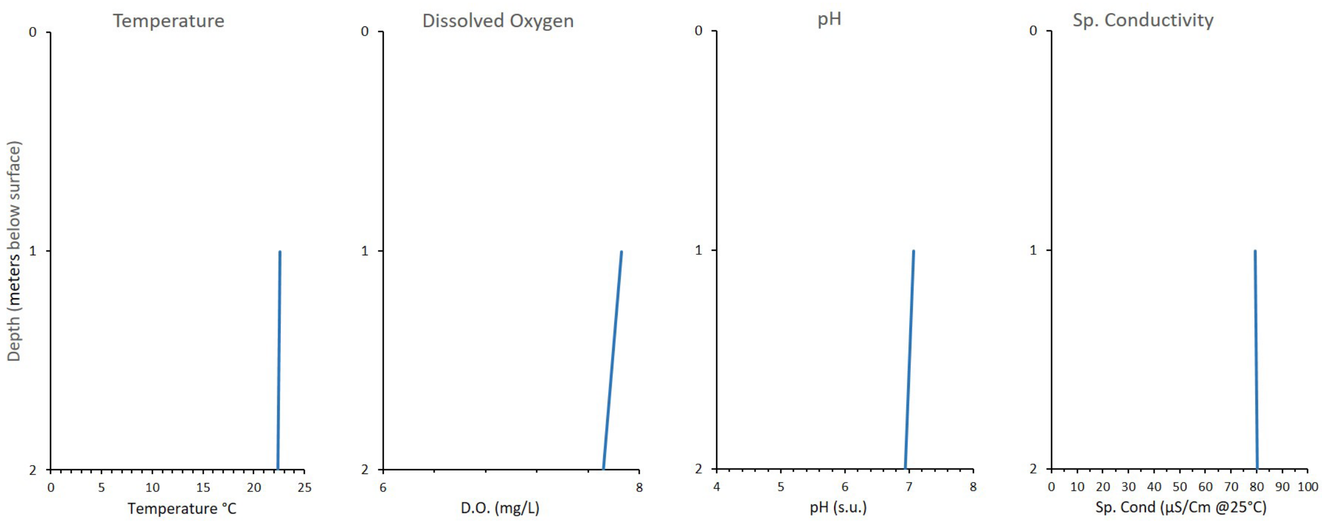
Annual average concentration of calcium and total aluminum in Lake Algonquin, 1997-2017. Error bars represent one standard deviation of the mean. Calcium exhibited a slight, yet significant, downward trend since 1997 ($p = 0.02$, tau = 0.51).

ROAD SALT



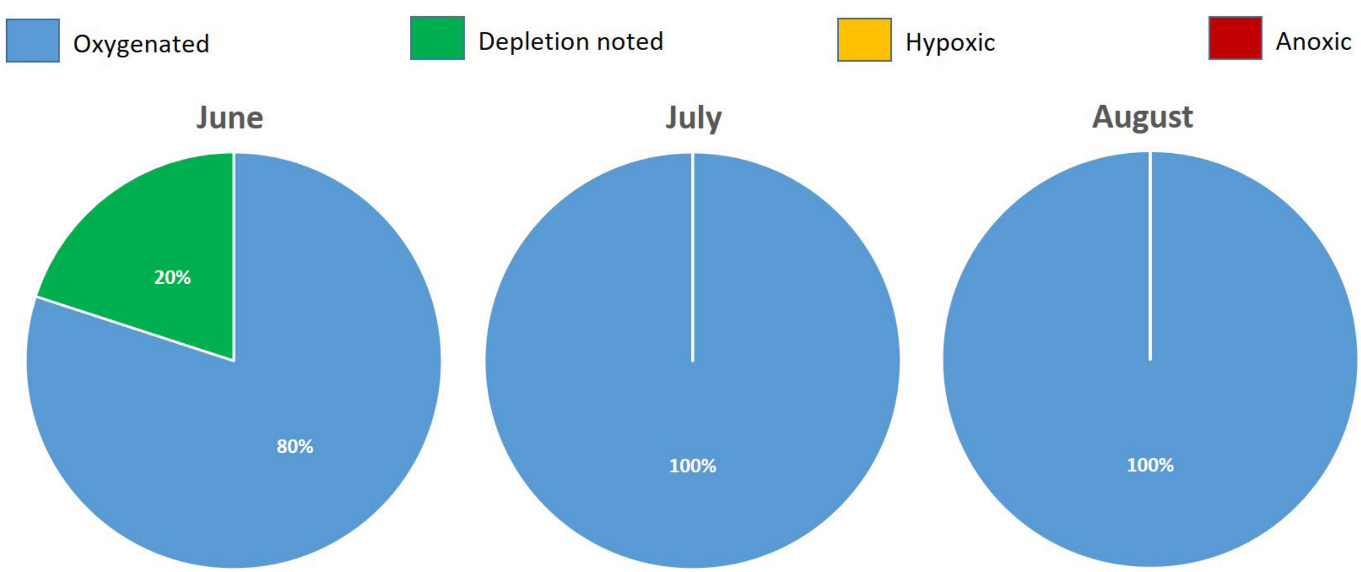
Annual average values of sodium and chloride ions (left panel) and specific conductivity (right panel) in Lake Algonquin, 2013-2017. Error bars represent one standard deviation of the mean.

LAKE PROFILE - AUGUST 2017



Depth profiles of temperature, dissolved oxygen, pH, and specific conductivity in Lake Algonquin during the August 2017 sampling trip.

DISSOLVED OXYGEN CONTENT



Proportion of monthly sampling trips where the bottom water of Lake Algonquin (1 meter off bottom) was observed to be oxygenated (D.O. > 4.0 mg/L), experiencing noted depletion (< 4.0 mg/L), hypoxic (< 2.0 mg/L) or anoxic (< 0.5 mg/L). Data is from the period of 1993 to 2017.

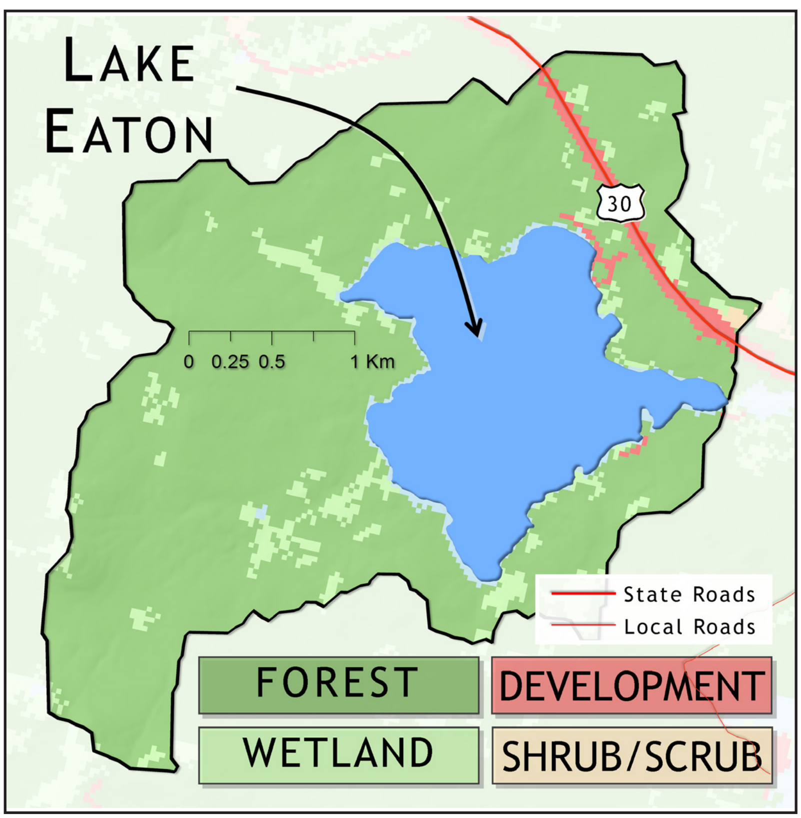
LAKE EATON

SUMMARY

Lake Eaton is a 232-hectare waterbody, located within a 1,100-hectare watershed that is dominated by forest cover. Long term monitoring by HCSWCD produced the following findings.

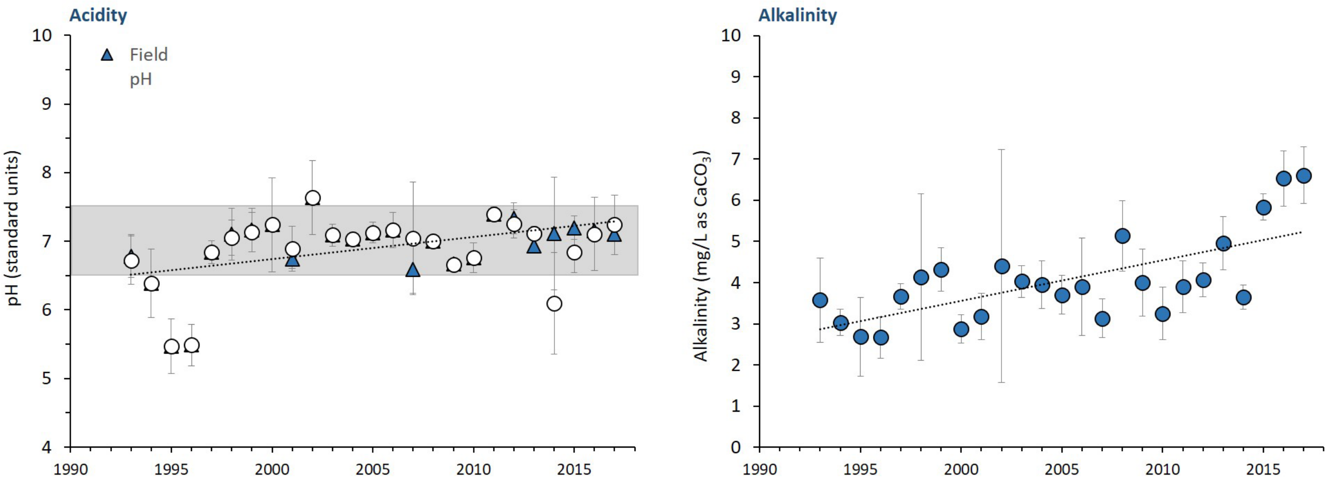
The surface water of the lake is best classified as circumneutral to slightly alkaline, with average annual pH values that were typically in the range of 6.5 to 7.5 standard units. Between the years 2015 and 2017, alkalinity was in the range of 5 to 7 mg/L, indicating that the lake was moderately sensitive to acidic deposition. The lake is best classified as mesotrophic, with a statistically significant decrease observed in transparency and total phosphorus since monitoring began. The chemistry of the lake was moderately influenced by the 7.1 km of roads in the watershed. The concentration of chloride and sodium between the years 2015 and 2017 averaged 11.6 and 6.8 mg/L respectively, which is approximately 37 times greater than background concentrations for lakes in the Adirondack region. The bottom water of Lake Eaton experienced significant oxygen depletion, with anoxic or hypoxic water encountered on 69% of sampling trips during the month of August.

MORPHOMETRY



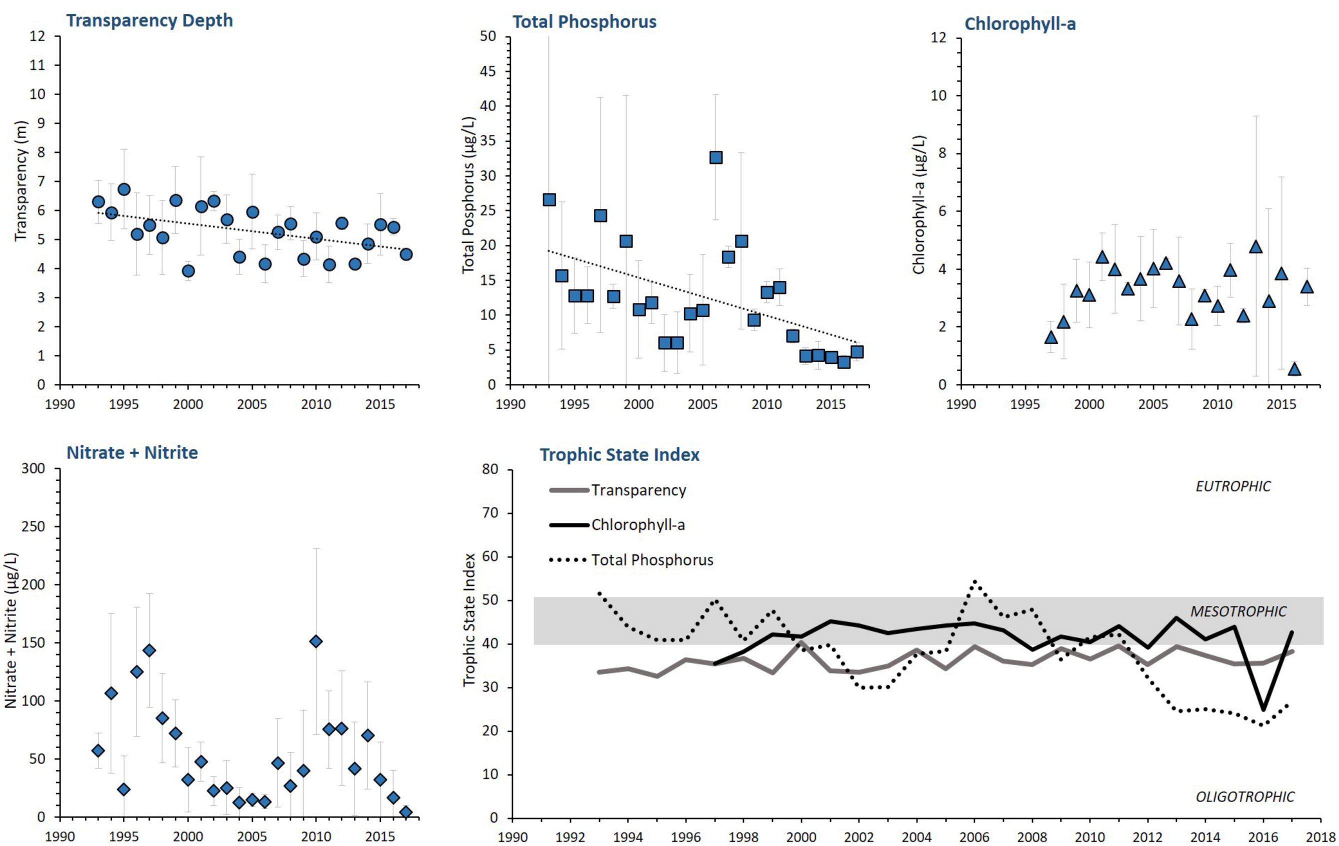
Lake Area (ha)	232
Max Depth (m)	17
Volume (m^3 x 10^6)	17.8
Shoreline (km)	9.1
Watershed Area (ha)	1,111
Retention Time (yrs)	1.0
Surface Water Area (%)	23
Forested Area (%)	71
Developed Area (%)	2
Wetland Area (%)	5
State Road Length (km)	2.1
Local Road Length (km)	0

ACIDITY



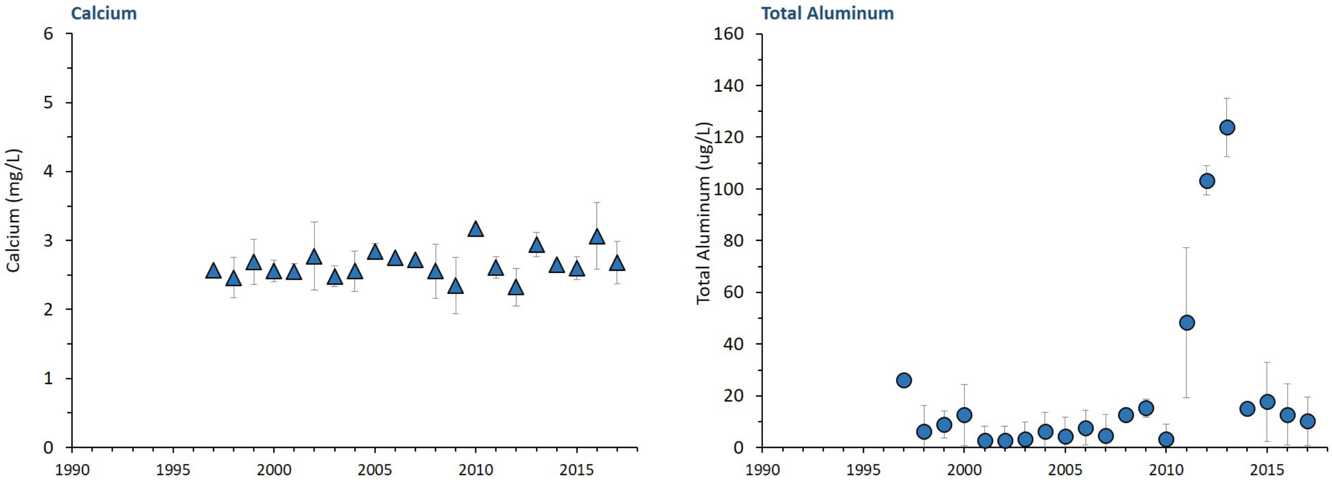
Annual average acidity (left panel) and alkalinity (right panel) of Lake Eaton, 1993 - 2017. Shaded box denotes range of circumneutral condition (pH 6.5-7.5). Error bars denote one standard deviation of the mean. Both pH and alkalinity exhibited an increasing trend since 1993 (pH: $p = 0.05$, tau = 0.28, Alaklinity: $p = 0.002$, tau = 0.4).

TROPHIC STATE



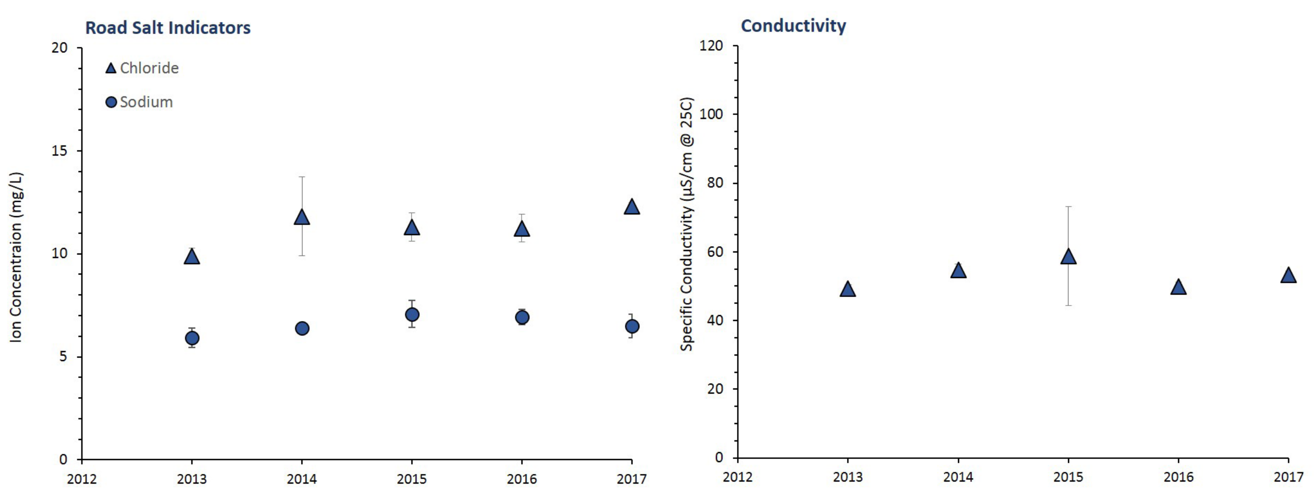
Average values for key trophic state indicators of Lake Eaton, 1993-2017. Error bars represent one standard deviation of the mean. Transparency and total phosphorus have exhibited a decreasing trend since 1993 (Transparency: $p = 0.02$, tau = 0.32; Total phosphorus: $p < 0.001$, tau = 0.47).

Metals



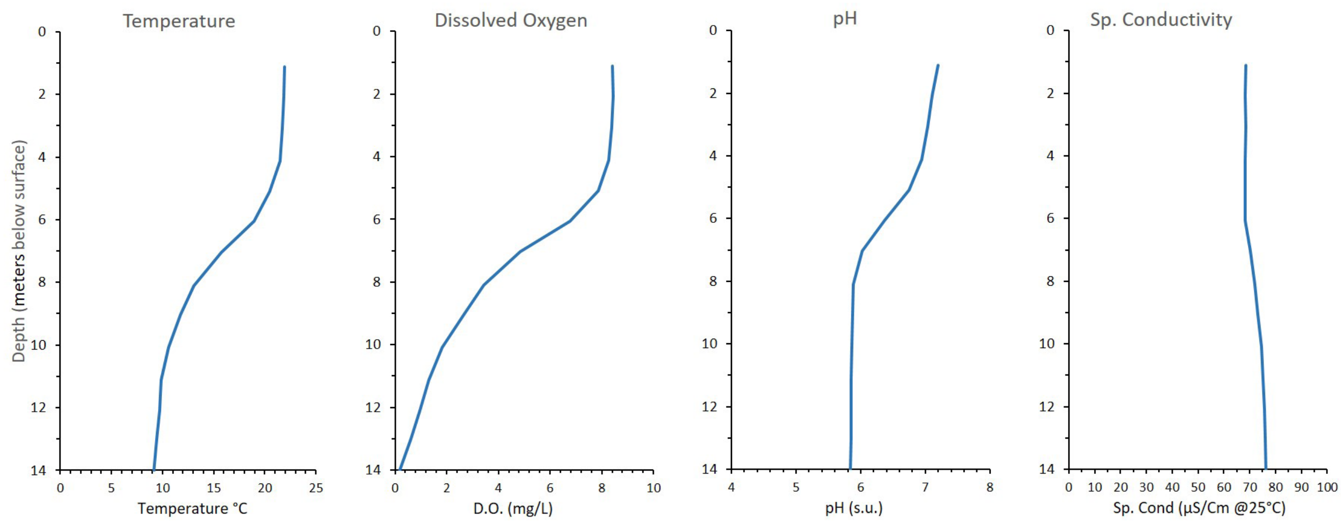
Annual average concentration of calcium and total aluminum in Lake Eaton, 1997-2017. Error bars represent one standard deviation of the mean. Aluminum values in 2012 - 2013 were statistical outliers.

Road Salt



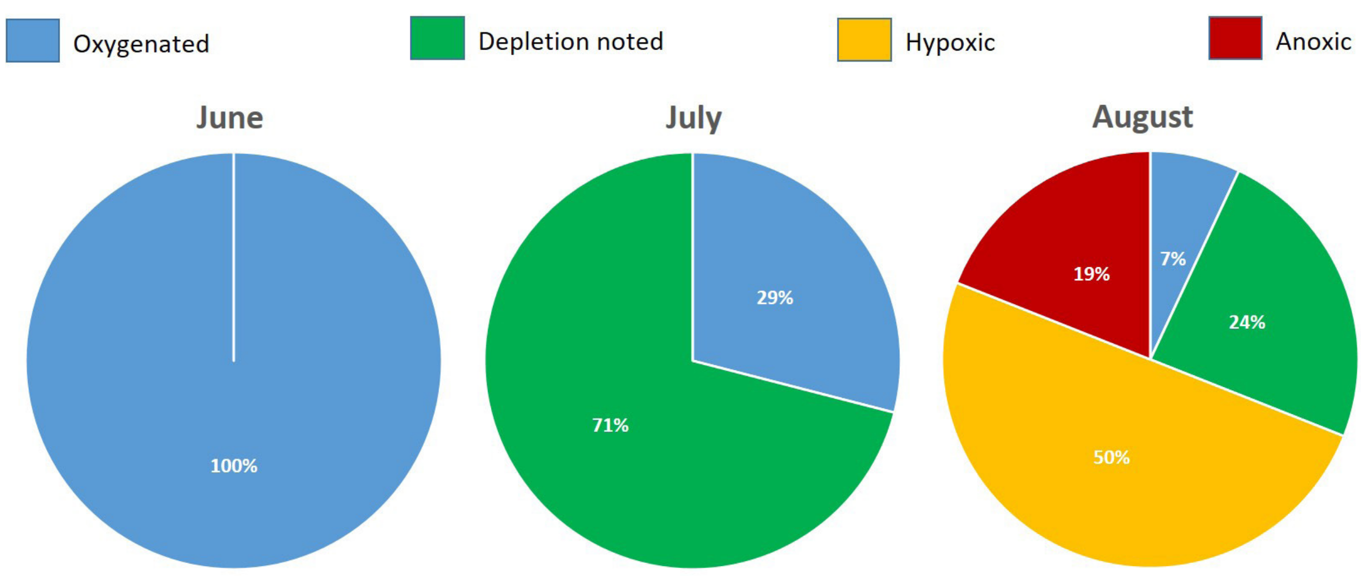
Annual average values of sodium and chloride ions (left panel) and specific conductivity (right panel) in Lake Eaton, 2013-2017. Error bars represent one standard deviation of the mean.

Lake Profile - August 2017



Depth profiles of temperature, dissolved oxygen, pH, and specific conductivity in Lake Eaton during the August 2017 sampling trip.

Dissolved Oxygen Content



Proportion of monthly sampling trips where the bottom water of Lake Eaton (1 meter off bottom) was observed to be oxygenated (D.O. > 4.0 mg/L), experiencing noted depletion (< 4.0 mg/L), hypoxic (< 2.0 mg/L) or anoxic (< 0.5 mg/L). Data is from the period of 1993 to 2017.

LAKE PLEASANT

Summary

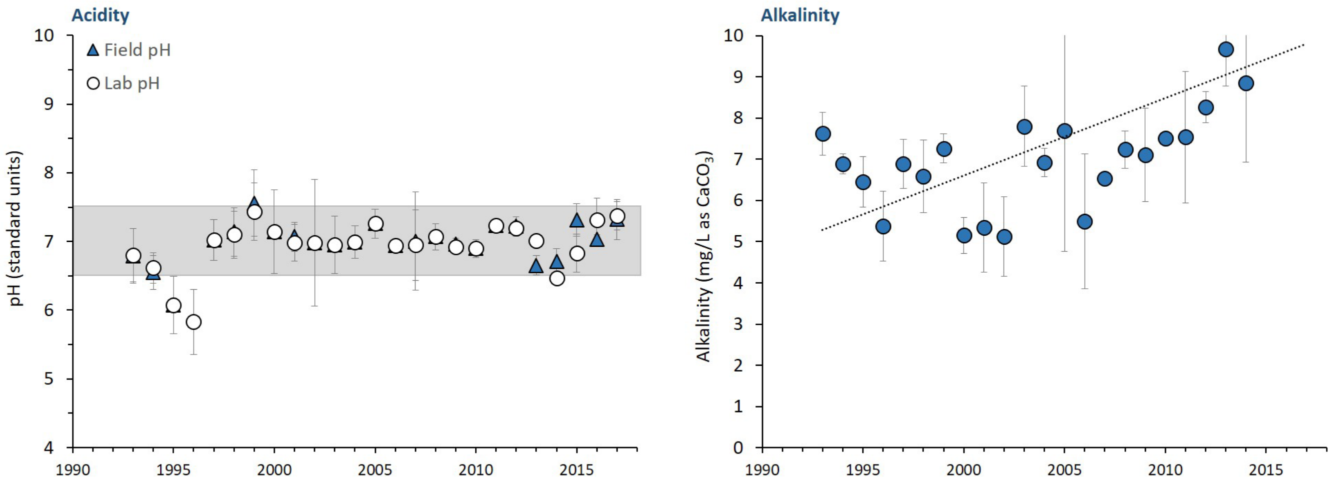
Lake Pleasant is a 597-hectare waterbody, located within an 8,530-hectare watershed that is dominated by forest cover. Long term monitoring by HCSWCD produced the following findings.

The surface water of the lake is best classified as circumneutral to slightly alkaline, with average annual pH values that were typically in the range of 6.5 to 7.5 standard units. Between the years 2015 and 2017, alkalinity was in the range of 11 to 13 mg/L, indicating that the lake had low sensitivity to acidic deposition. The lake is best classified as mesotrophic, with modest concentrations of nutrients and chlorophyll-a in the surface water. Since 1993, the transparency of Lake Pleasant has decreased by over 1 meter. The chemistry of the lake was moderately influenced by the 7.1 km of roads in the watershed. The concentration of chloride and sodium between the years 2015 and 2017 averaged 10.5 and 5.7 mg/L respectively, which is approximately 35 times greater than background concentrations for lakes in the Adirondack region. The bottom water of Lake Pleasant experienced significant oxygen depletion during the summer months, with anoxic or hypoxic water encountered on 63% of sampling trips during the month of August.

Morphometry

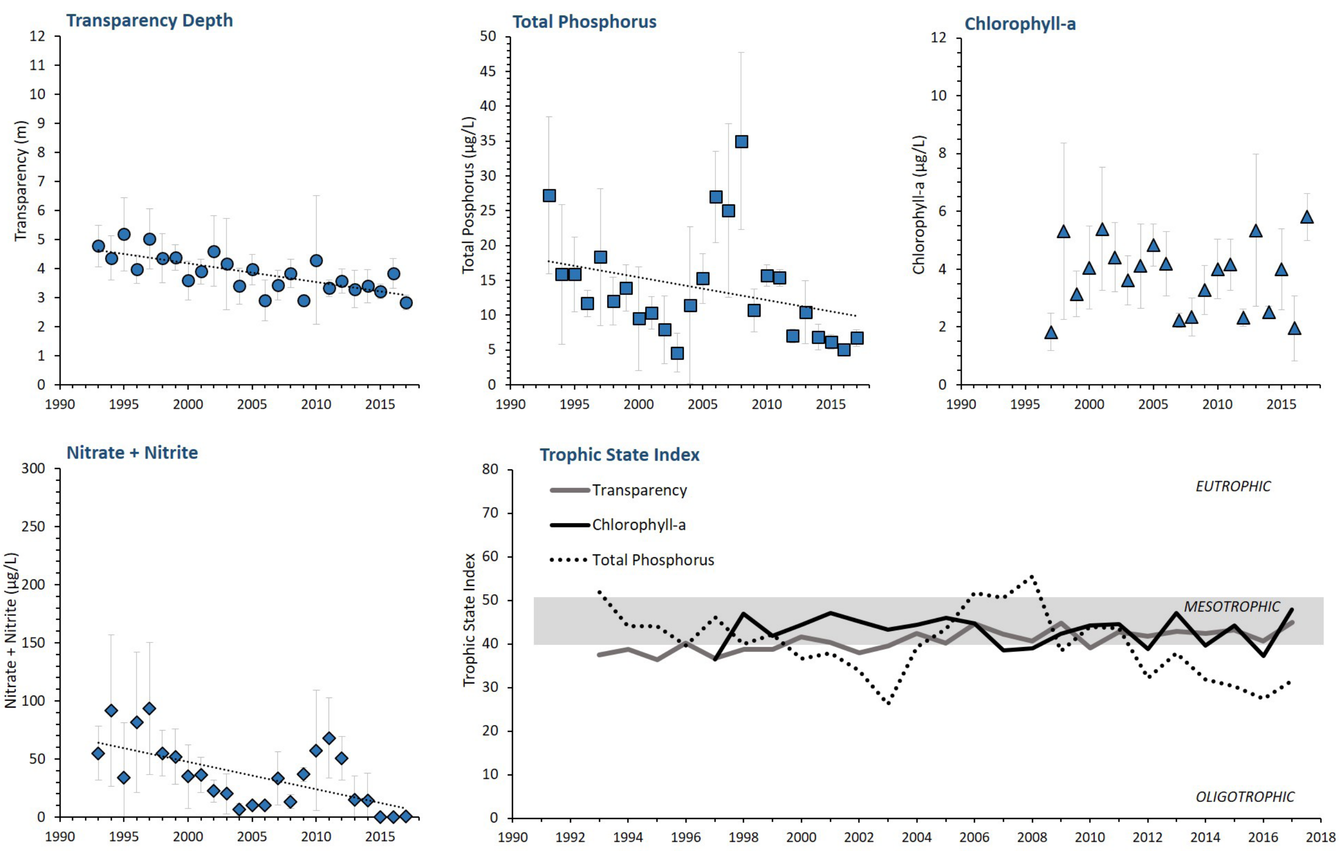
Lake Area (ha)	597
Max Depth (m)	21
Volume (m^3 x 10^6)	55.3
Shoreline (km)	17.1
Watershed Area (ha)	8,530
Retention Time (yrs)	2.0
Surface Water Area (%)	18
Forested Area (%)	69
Developed Area (%)	3
Wetland Area (%)	10
State Road Length (km)	13.8
Local Road Length (km)	34.7

Acidity



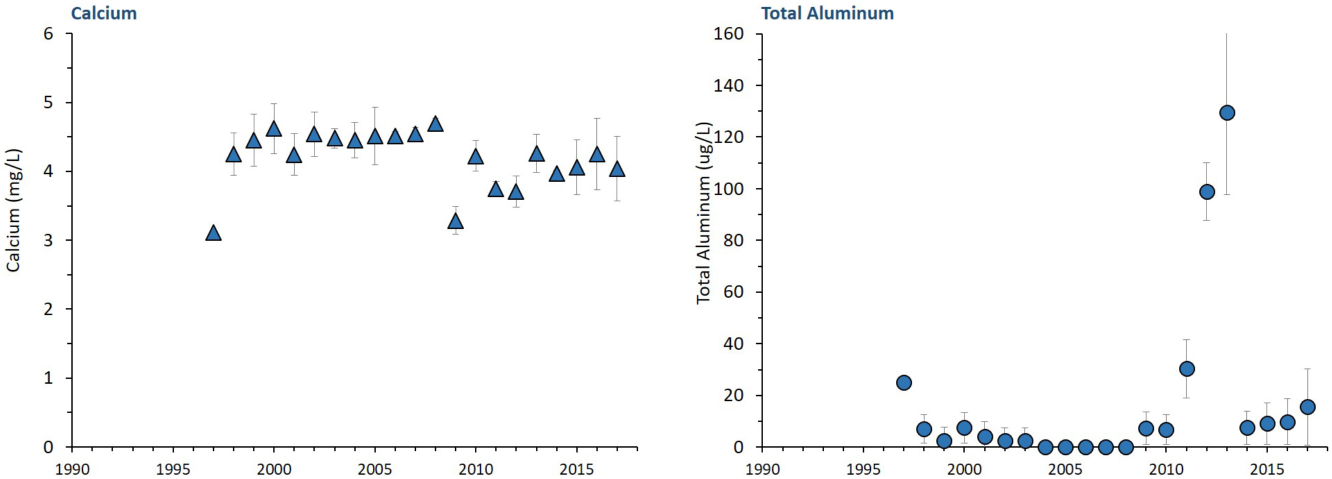
Annual average acidity (left panel) and alkalinity (right panel) of Lake Pleasant, 1993 - 2017. Shaded box denotes range of circumneutral condition (pH 6.5-7.5). Error bars denote one standard deviation of the mean. Alkalinity has exhibited an increasing trend since 1993 (Alkalinity: $p = 0.002$, tau = 0.52).

Trophic State



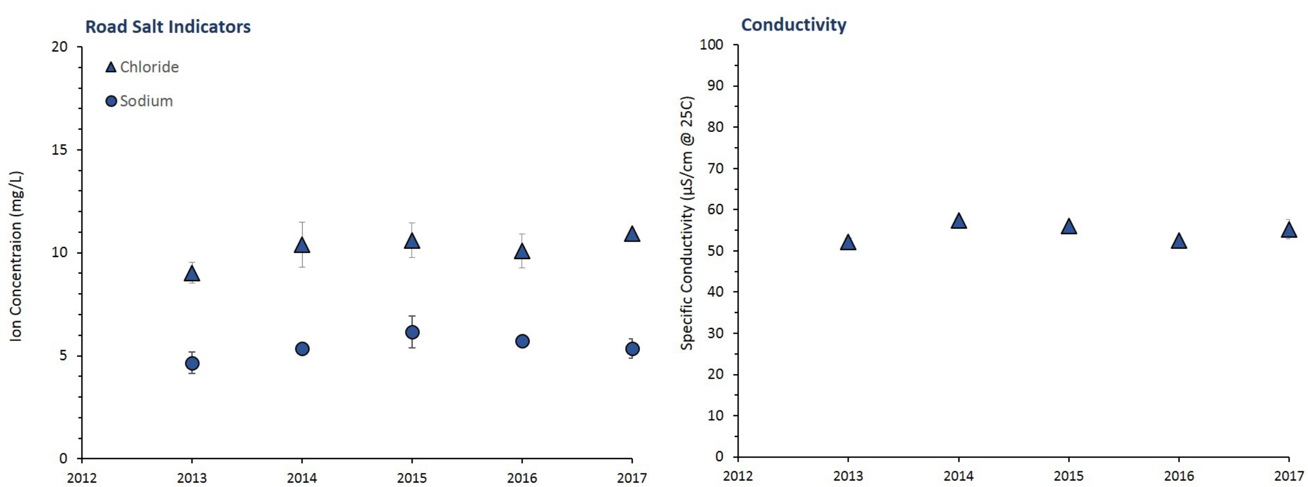
Average values for key trophic state indicators of Lake Pleasant, 1993-2017. Error bars represent one standard deviation of the mean. Transparency, total phosphorus, and nitrate have all exhibited a decreasing trend since 1993 (Transparency: $p < 0.001$, tau = 0.57; Total phosphorus: $p < 0.01$, tau = 0.37; Nitrate: $p < 0.001$, tau = 0.45).

Metals



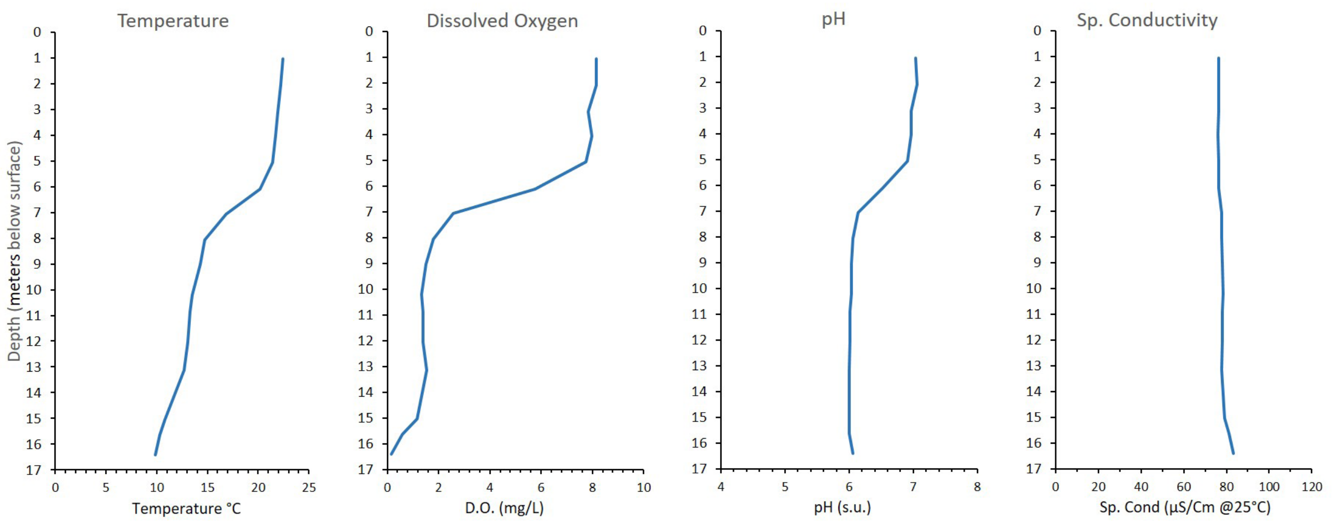
Annual average concentration of calcium and total aluminum in Lake Pleasant, 1997-2017. Error bars represent one standard deviation of the mean. Aluminum values in 2012 - 2013 were statistical outliers.

Road Salt



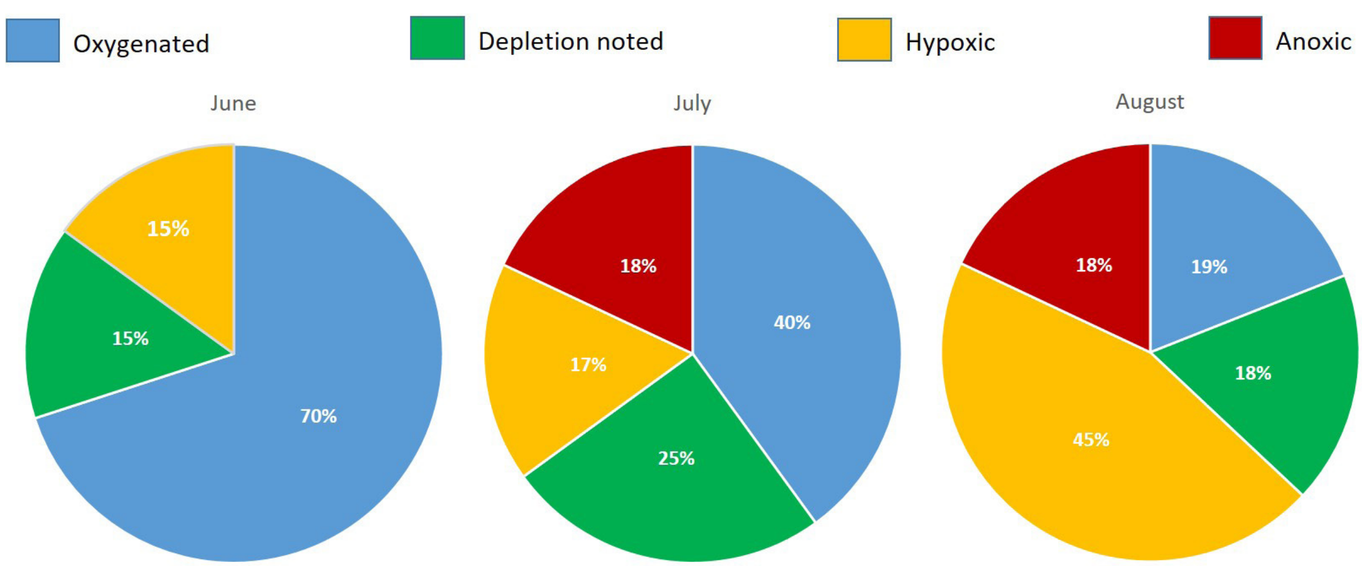
Annual average values of sodium and chloride ions (left panel) and specific conductivity (right panel) in Lake Pleasant, 2013-2017. Error bars represent one standard deviation of the mean.

Lake Profile - August 2017



Depth profiles of temperature, dissolved oxygen, pH, and specific conductivity in Lake Pleasant during the August 2017 sampling trip.

Dissolved Oxygen Content



Proportion of monthly sampling trips where the bottom water of Lake Pleasant (1 meter off bottom) was observed to be oxygenated (D.O. > 4.0 mg/L), experiencing noted depletion (< 4.0 mg/L), hypoxic (< 2.0 mg/L) or anoxic (< 0.5 mg/L). Data is from the period of 1993 to 2017.

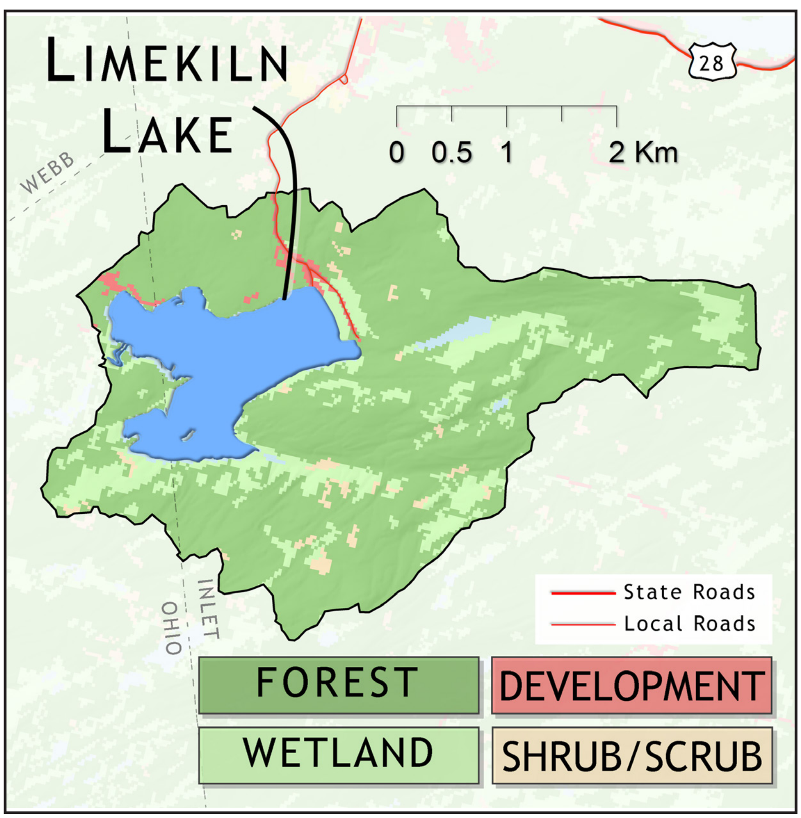
LIMEKILN LAKE

Summary

Limekiln Lake is a 188-hectare waterbody, located within a 1,413-hectare watershed that is dominated by forest cover. Long term monitoring by HCSWCD produced the following findings.

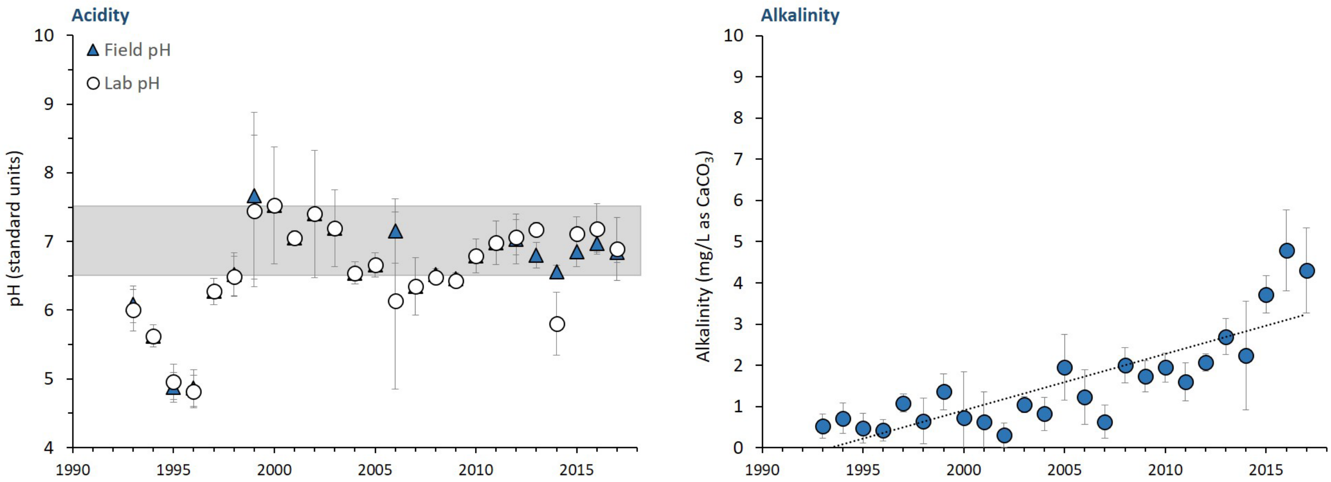
The surface water of the lake is best classified as slightly acidic to circumneutral, with average annual pH values that were typically in the range of 6.2 to 7.5 standard units. Between the years 2015 and 2017, alkalinity averaged 4 mg/L, indicating that the lake was extremely sensitivity to acidic deposition. The alkalinity of Limekiln Lake has exhibited a significant upsurge over time, and has increased by a factor of five since 1993. The lake is best classified as mesotrophic, on the border of oligotrophy. The annual average transparency of the lake has decreased by 3 meters since the early 1990s. The concentration of chloride and sodium between the years 2015 and 2017 averaged 1.2 and 2.8 mg/L respectively, which is in the range we would expect for an Adirondack lake that lacks state roads in its watershed. The bottom water of Limekiln Lake was not observed to be anoxic or hypoxic during any of the sampling trips between 1993 and 2017.

Morphometry



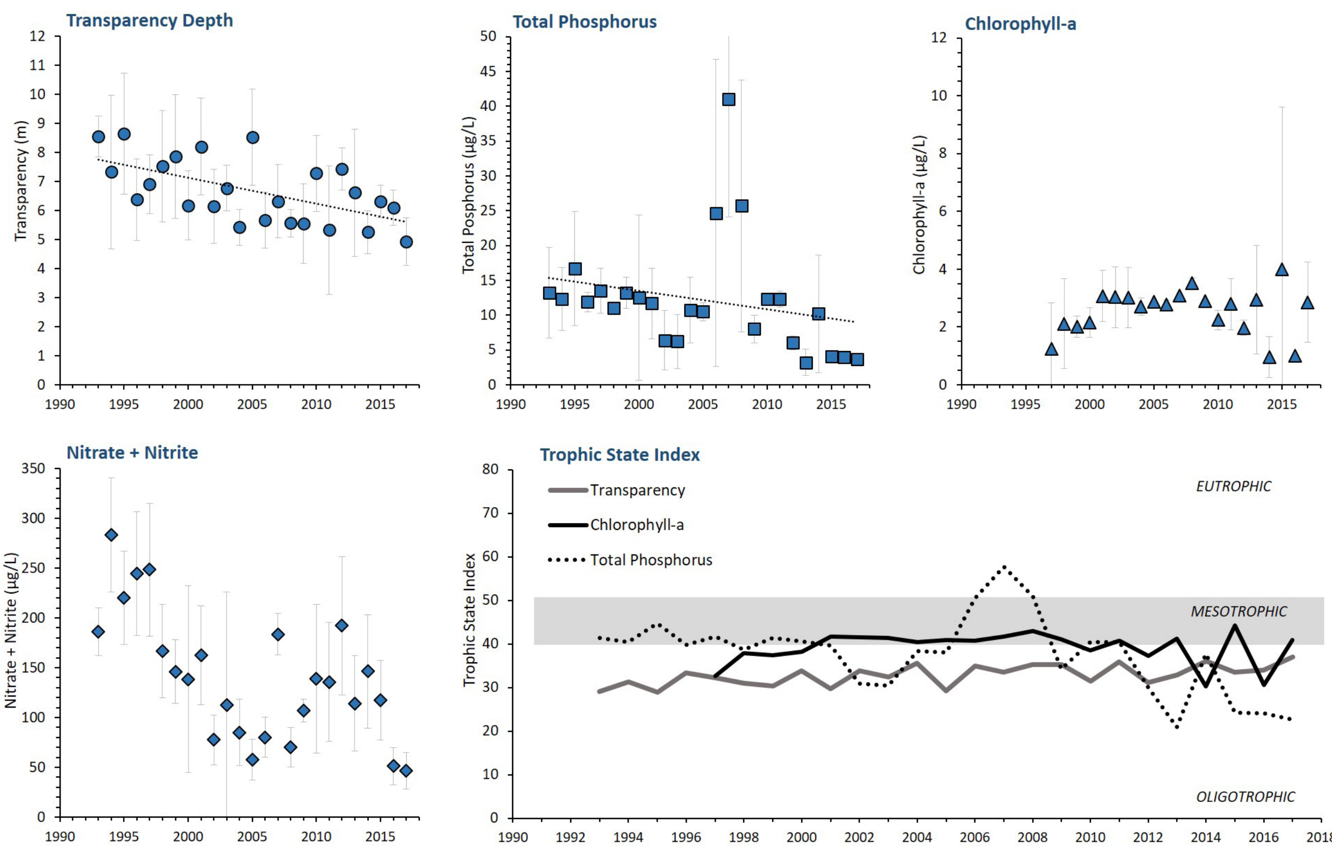
Lake Area (ha)	188
Max Depth (m)	22
Volume (m^3 x 10^6)	11.4
Shoreline (km)	10.5
Watershed Area (ha)	1,413
Retention Time (yrs)	1.4
Surface Water Area (%)	15
Forested Area (%)	72
Developed Area (%)	1
Wetland Area (%)	10
State Road Length (km)	0
Local Road Length (km)	1.8

Acidity



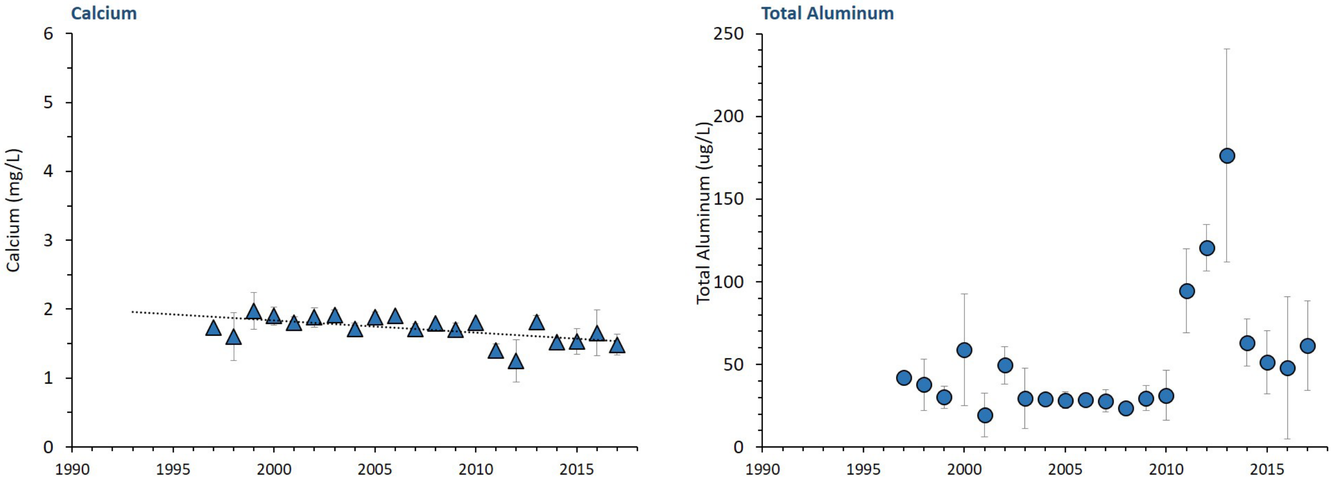
Annual average acidity (left panel) and alkalinity (right panel) of Limekiln Lake, 1993 - 2017. Shaded box denotes range of circumneutral condition (pH 6.5-7.5). Error bars denote one standard deviation of the mean. Alkalinity has exhibited an increasing trend since 1993 (Alkalinity: $p < 0.001$, tau = 0.68).

Trophic State



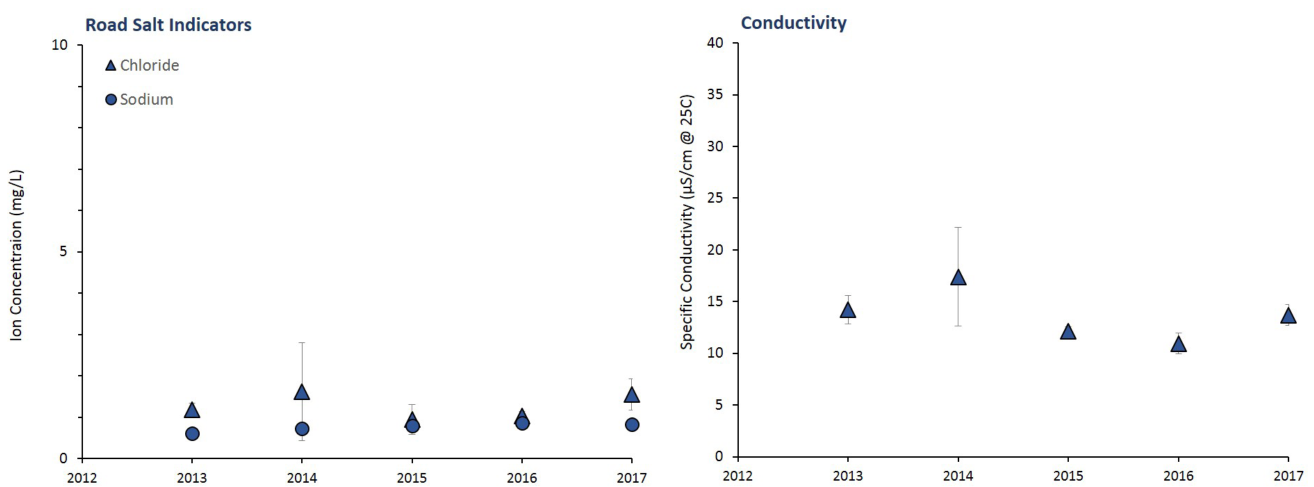
Average values for key trophic state indicators of Limekiln Lake, 1993-2017. Error bars represent one standard deviation of the mean. Transparency depth and total phosphorus concentration have both exhibited a decreasing trend since 1993 (Transparency: $p < 0.001$, tau = 0.45; Total phosphorus: $p < 0.01$, tau = 0.44).

Metals



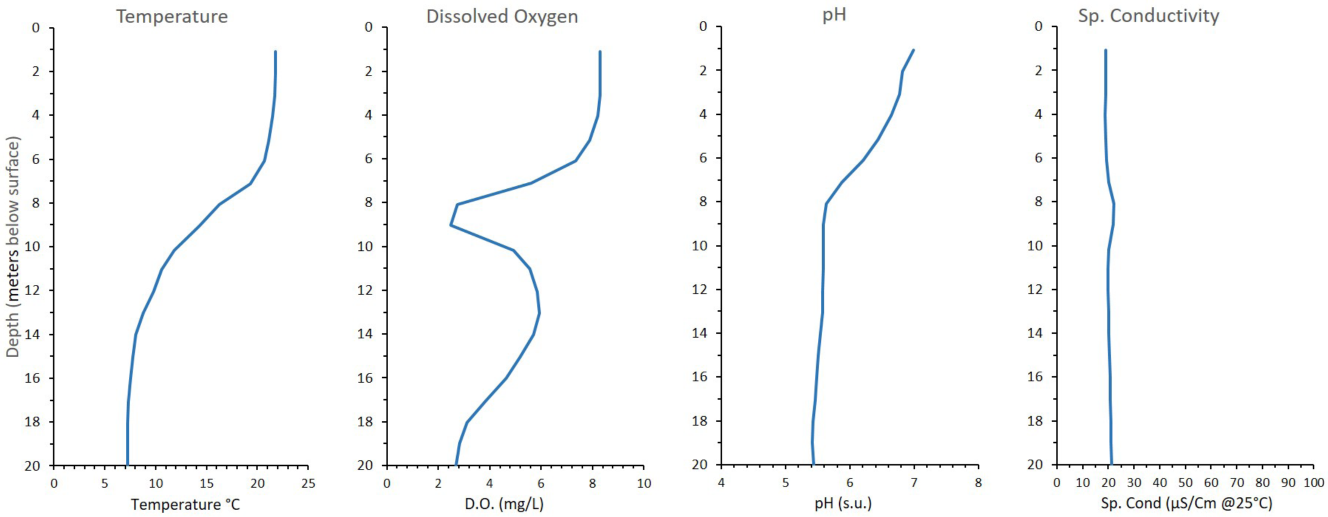
Annual average concentration of calcium and total aluminum in Limekiln Lake, 1997-2017. Error bars represent one standard deviation of the mean. Calcium concentration has exhibited a statistical decrease since 1997 (p = 0.008, tau = 0.42).

Road Salt



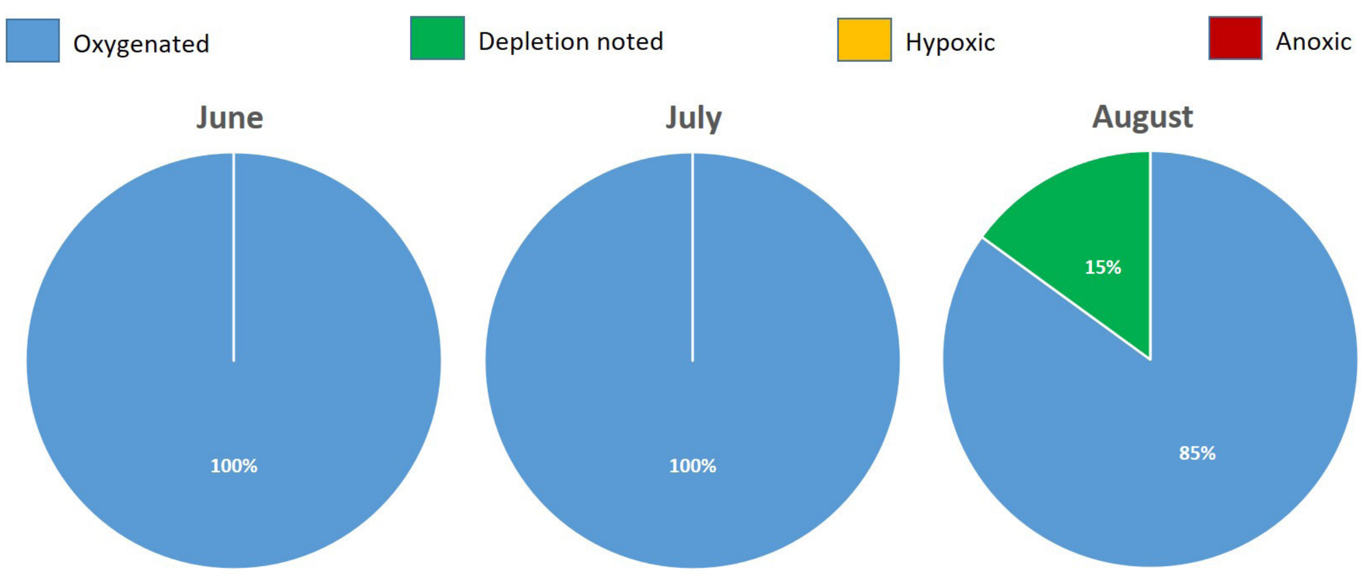
Annual average values of sodium and chloride ions (left panel), and specific conductivity (right panel) in Limekiln Lake, 2013-2017. Error bars represent one standard deviation of the mean.

Lake Profile - August 2017



Depth profiles of temperature, dissolved oxygen, pH, and specific conductivity in Limekiln Lake during the August 2017 sampling trip.

Dissolved Oxygen Content



Proportion of monthly sampling trips where the bottom water of Limekiln Lake (1 meter off bottom) was observed to be oxygenated (D.O. > 4.0 mg/L), experiencing noted depletion (< 4.0 mg/L), hypoxic (< 2.0 mg/L) or anoxic (< 0.5 mg/L). Data is from the period of 1993 to 2017.

LONG LAKE

Summary

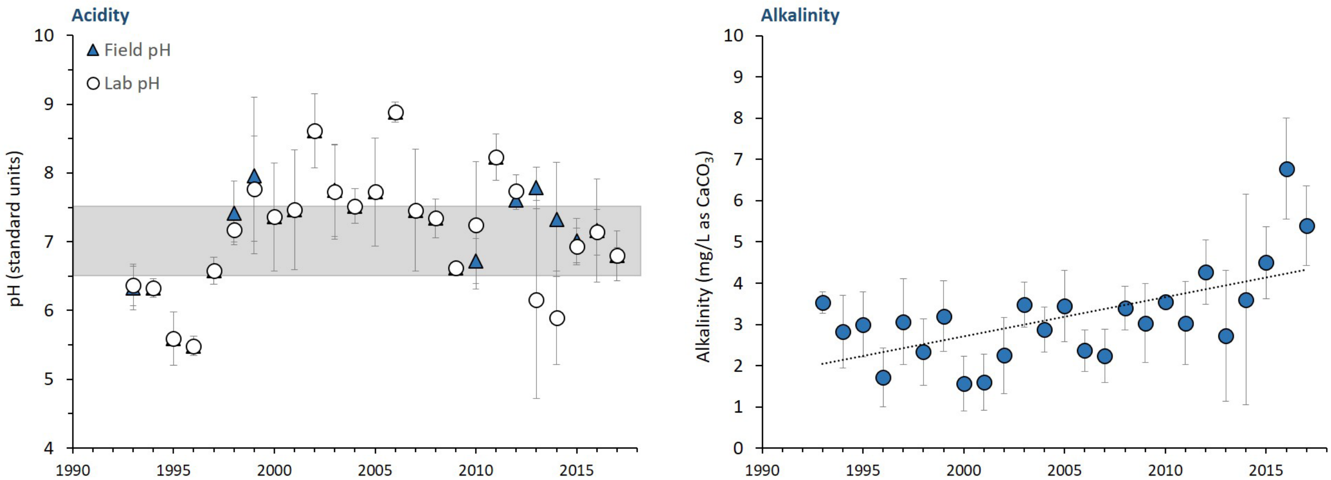
Long Lake is a 1,685-hectare waterbody, located within a 79,417-hectare watershed that is dominated by forest cover. The ratio of lake-volume to watershed area results in rapid water replacement, estimated at over 10 times per year. Long term monitoring by HCSWCD produced the following findings.

The average annual pH of the lake has exhibited a great deal of variability over the study period, with the majority of water samples found to be in the range of 6 to 8 pH units. The alkalinity of Long Lake has experienced a statistically significant increase since 1993. Between the years 2015 and 2017, alkalinity averaged 6 mg/L, indicating that the lake had moderate sensitivity to acidic deposition. The lake is best classified as mesotrophic, with a significant downward trend observed in both transparency depth and total phosphorus concentration. The concentration of chloride and sodium between the years 2015 and 2017 averaged 3.8 and 2.6 mg/L respectively, indicating that road salt has influenced lake chemistry, but the impact was relatively low. The bottom water of Long Lake experienced significant oxygen depletion. Since 1993, 87% of the August sampling trips encountered anoxic or hypoxic conditions 1-meter off the bottom.

Morphometry

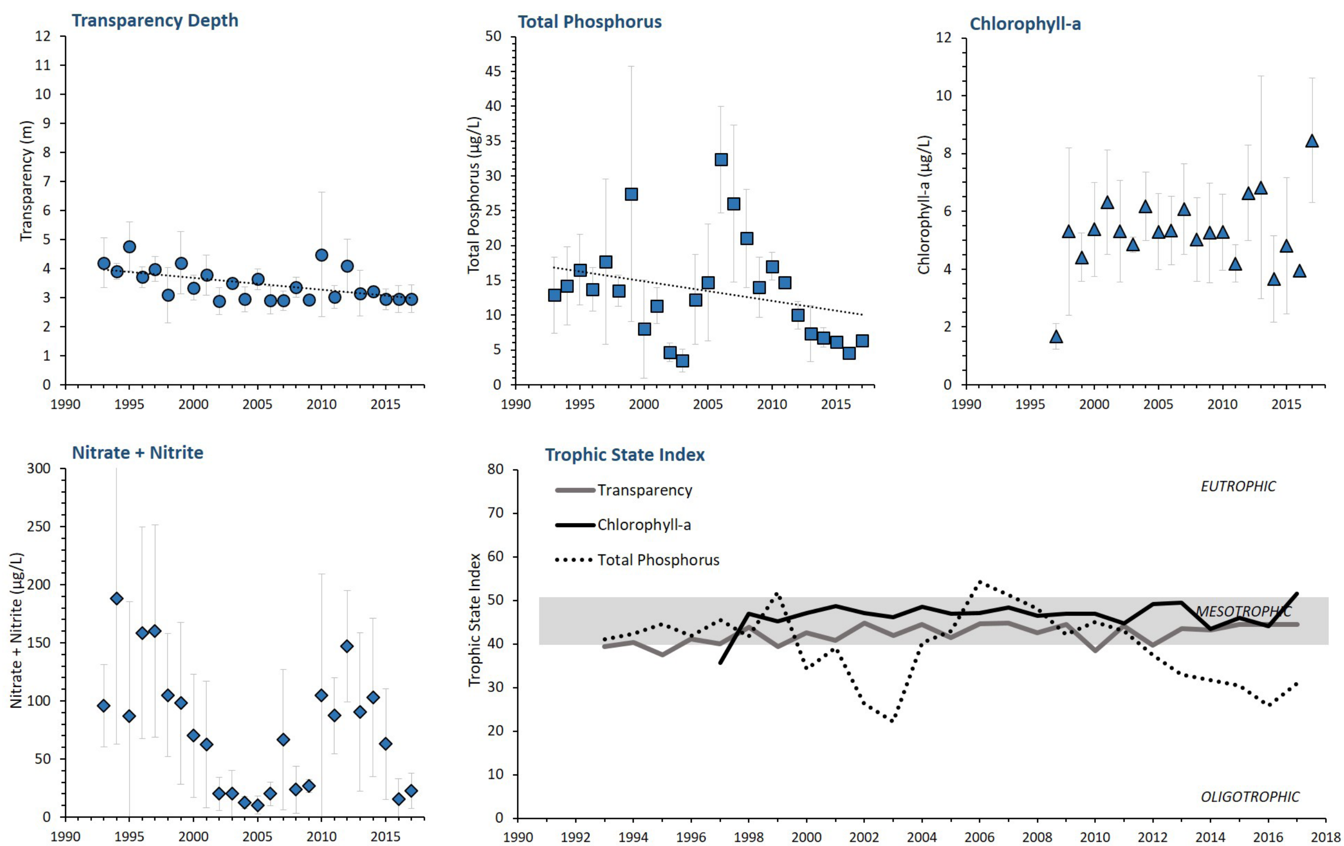
Lake Area (ha)	1,685
Max Depth (m)	13
Volume (m^3 x 10^6)	65.3
Shoreline (km)	78
Watershed Area (ha)	79,417
Retention Time (yrs)	0.1
Surface Water Area (%)	12
Forested Area (%)	71
Developed Area (%)	1
Wetland Area (%)	16
State Road Length (km)	59.7
Local Road Length (km)	61.8

Acidity



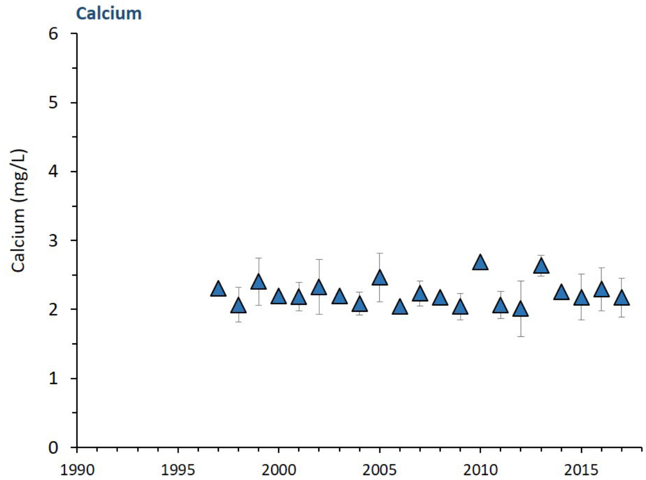
Annual average acidity (left panel) and alkalinity (right panel) of Long Lake, 1993 - 2017. Shaded box denotes range of circumneutral condition (pH 6.5-7.5). Error bars denote one standard deviation of the mean. Alkalinity has exhibited an increasing trend since 1993 (Alkalinity: $p < 0.005$, tau = 0.40).

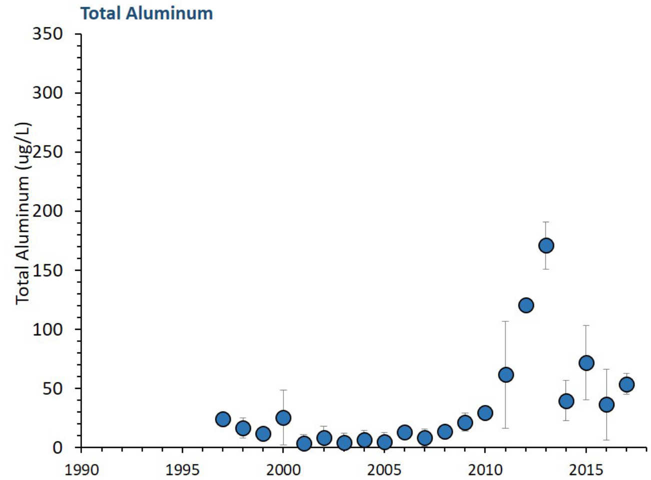
Trophic State



Average values for key trophic state indicators of Long Lake, 1993-2017. Error bars represent one standard deviation of the mean. Transparency depth and total phosphorus concentration have both exhibited a decreasing trend since 1993 (Transparency: $p = 0.002$, tau = 0.34; Total phosphorus: $p < 0.05$, tau = 0.30).

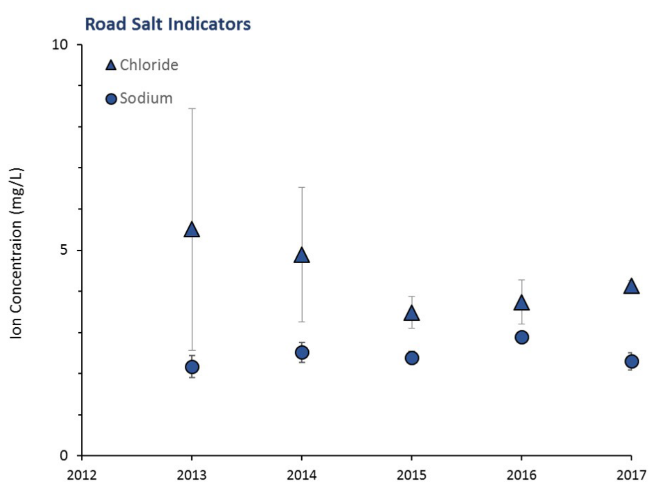
Metals

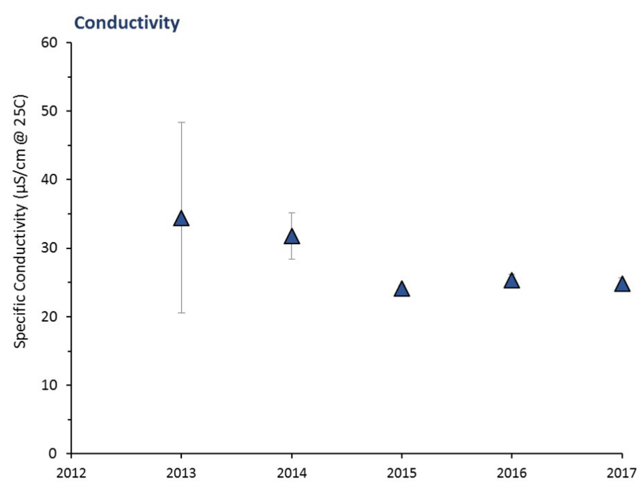




Annual average concentration of calcium and total aluminum in Long Lake, 1997-2017. Error bars represent one standard deviation of the mean.

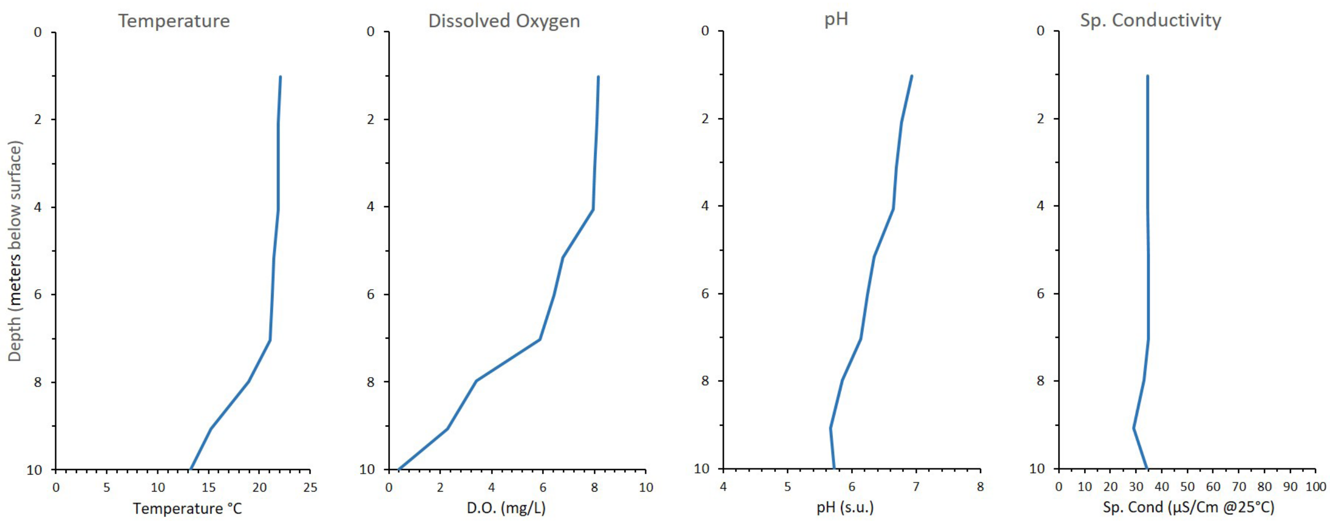
Road Salt





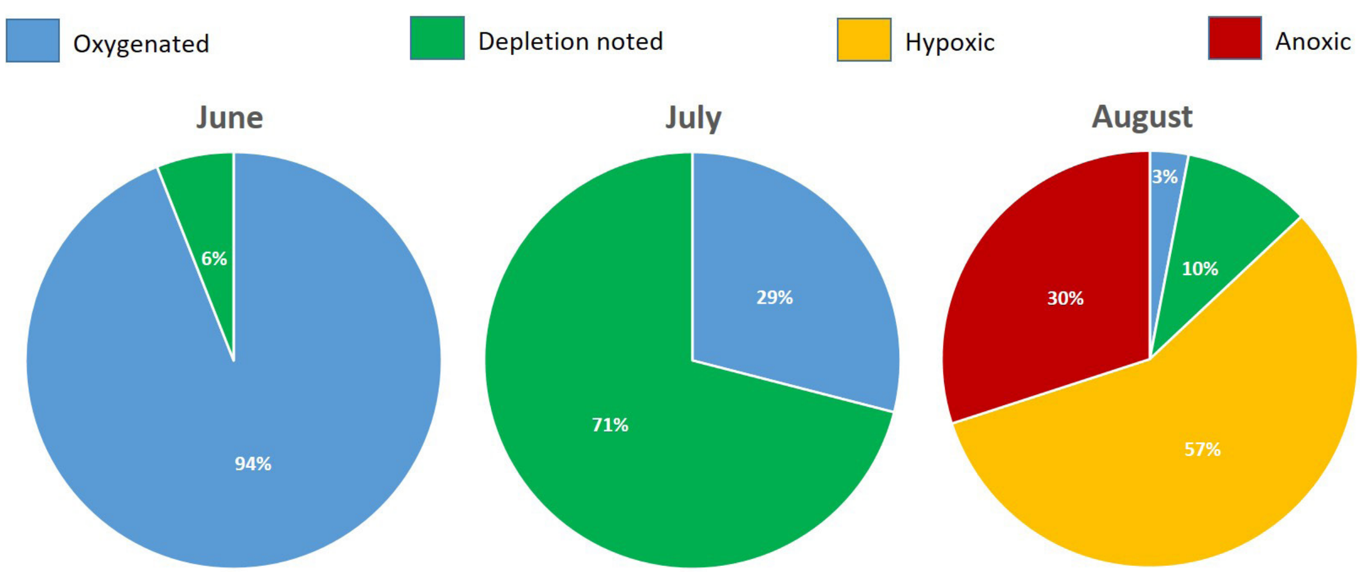
Annual average values of sodium and chloride ions (left panel), and specific conductivity (right panel) in Long Lake, 2013-2017. Error bars represent one standard deviation of the mean.

Lake Profile - August 2017



Depth profiles of temperature, dissolved oxygen, pH, and specific conductivity in Long Lake during the August 2017 sampling trip.

Dissolved Oxygen Content



Proportion of monthly sampling trips where the bottom water of Long Lake (1 meter off bottom) was observed to be oxygenated (D.O. > 4.0 mg/L), experiencing noted depletion (< 4.0 mg/L), hypoxic (< 2.0 mg/L) or anoxic (< 0.5 mg/L). Data is from the period of 1993 to 2017.

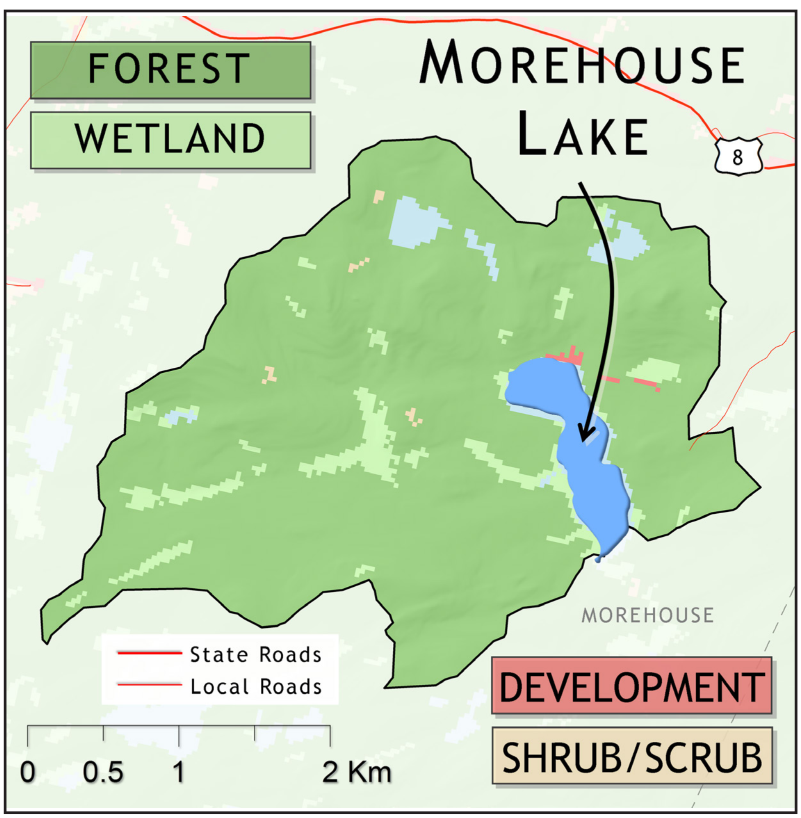
MOREHOUSE LAKE

SUMMARY

Morehouse Lake is a 43-hectare waterbody, located within a 975-hectare watershed that is dominated by forest cover. Long term monitoring by HCSWCD produced the following findings.

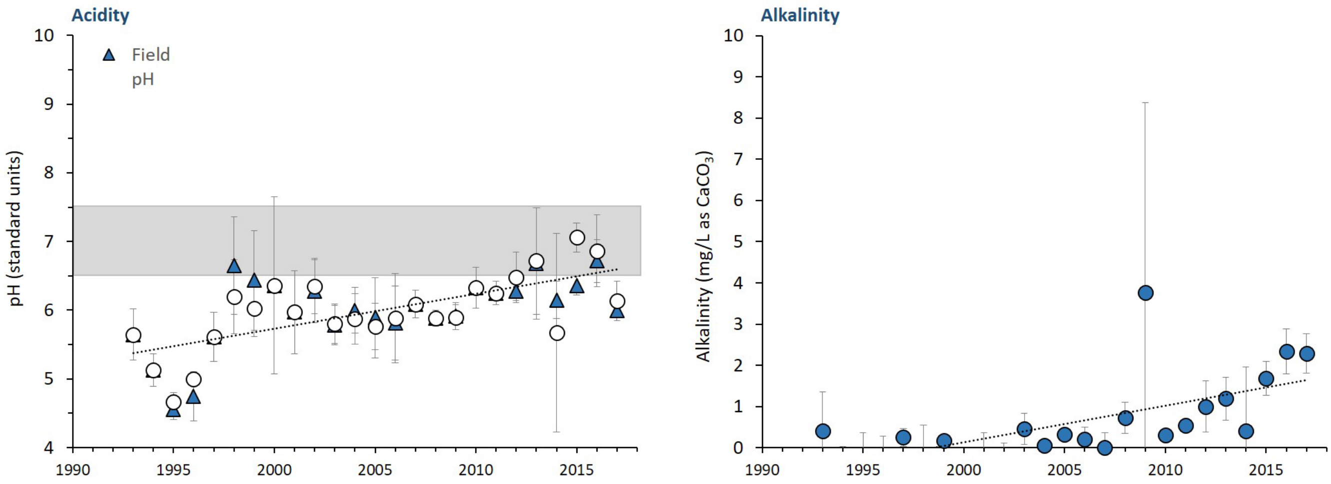
Historically, Morehouse Lake had been the most acid impacted lake in the HC dataset. Although the lake is still extremely sensitive to acidification, the water has exhibited a significant increase in both pH and acid neutralizing ability. The lake is best classified as oligotrophic, with low concentrations of phosphorus and chlorophyll-a in the surface water. The transparency depth of the lake has decreased by approximately 2 meters over the last 25 years. The concentration of chloride and sodium between the years 2015 and 2017 averaged 0.5 and 0.4 mg/L respectively, which is within the range we would expect for a lake that lacks salted roads in its watershed. Oxygen depletion is common in the bottom water of the lake. Since 1993, 36% of the August observations found the bottom water to be either anoxic or hypoxic.

MORPHOMETRY



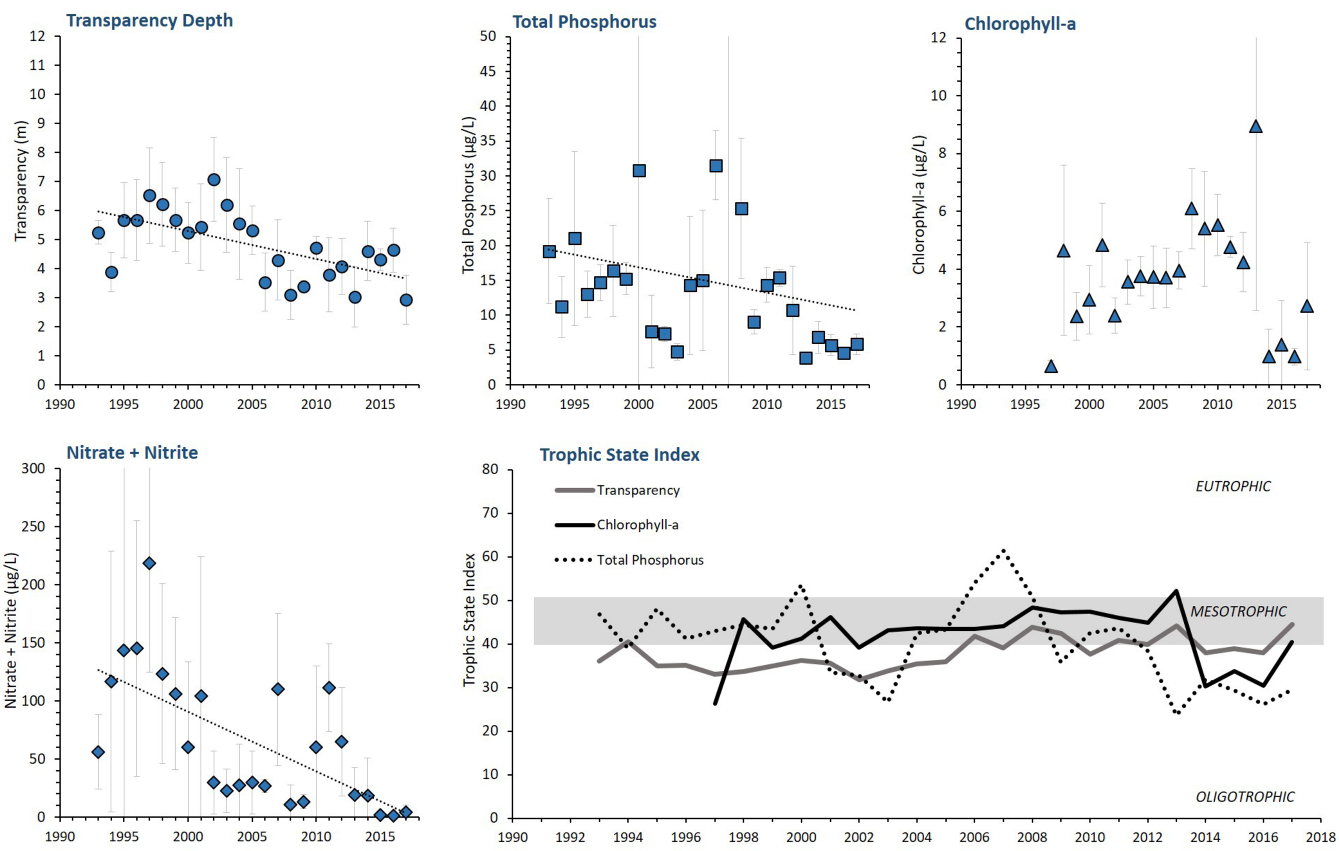
Lake Area (ha)	42.9
Max Depth (m)	11.5
Volume (m^3 x 10^6)	2.5
Shoreline (km)	3.7
Watershed Area (ha)	975
Retention Time (yrs)	1.2
Surface water Area (%)	7
Forested Area (%)	88
Developed Area (%)	0.1
Wetland Area (%)	4
State Road Length (km)	0
Local Road Length (km)	0.2

ACIDITY



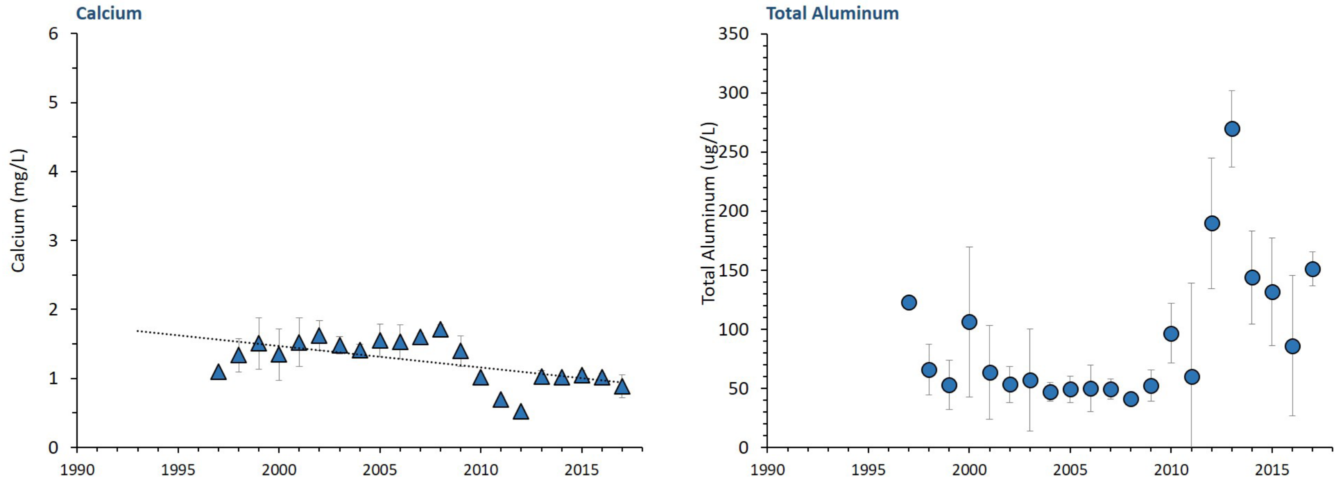
Annual average acidity (left panel) and alkalinity (right panel) of Morehouse Lake, 1993 - 2017. Shaded box denotes range of circumneutral condition (pH 6.5-7.5). Error bars denote one standard deviation of the mean. Both the pH and alkalinity have exhibited an increasing trend since 1993 (pH: $p = 0.001$, tau = 0.47; Alkalinity: $p < 0.001$, tau = 0.56).

TROPHIC STATE



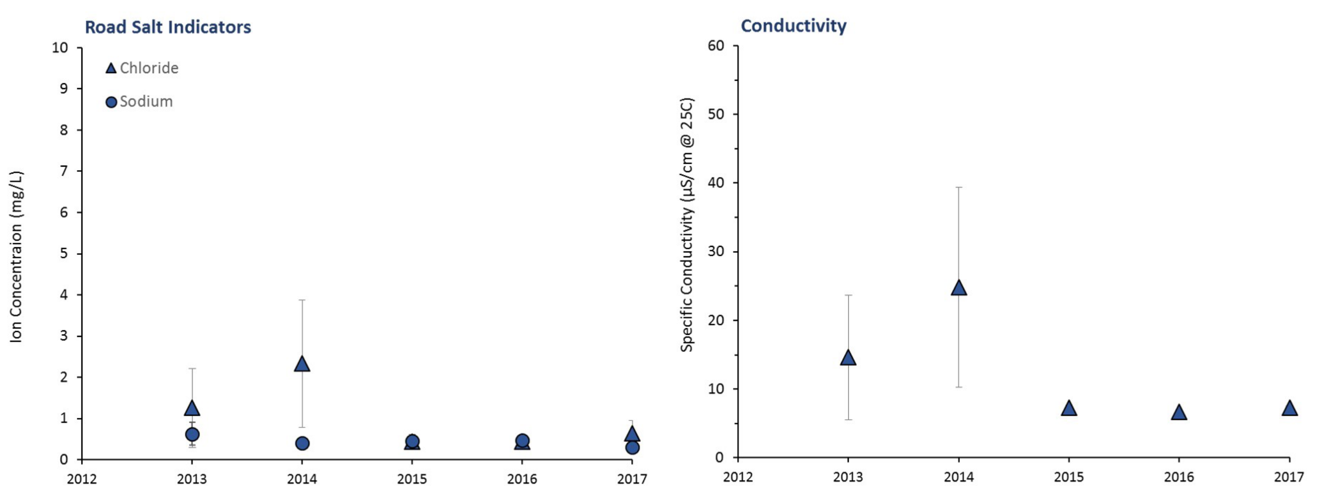
Average values for key trophic state indicators of Morehouse Lake, 1993-2017. Error bars represent one standard deviation of the mean. Transparency depth, and the concentraions of total phosphorus and nitrate have all exhibited decreasing trends since 1993 (Transparency: $p = 0.002$, tau = 0.43; Total phosphorus: $p = 0.03$, tau = 0.31; Nitrate: $p < 0.001$, tau = 0.45).

Metals



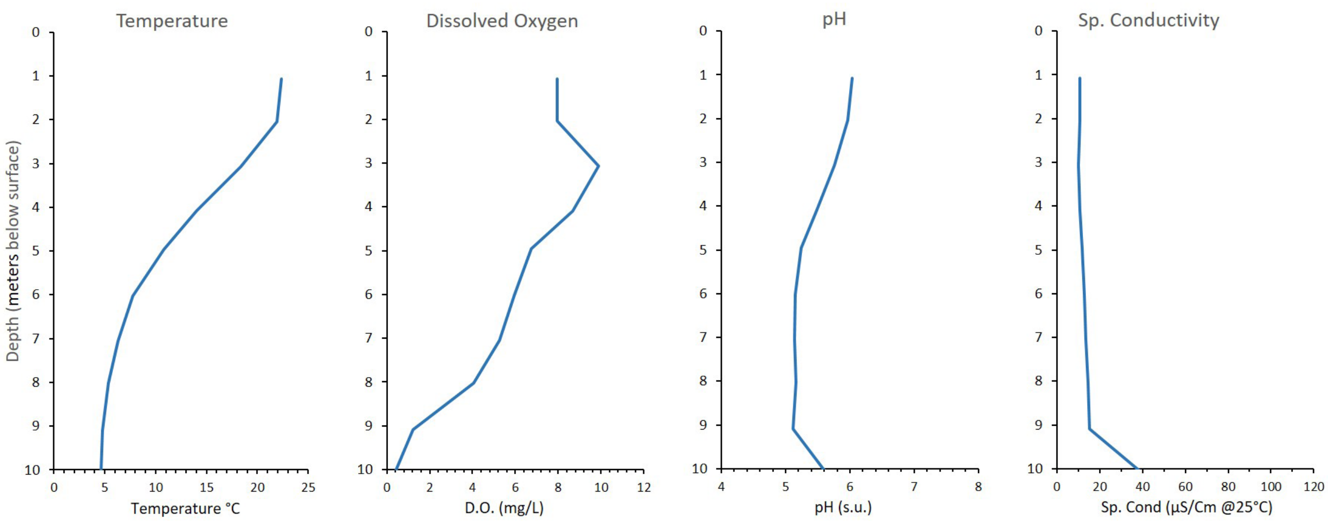
Annual average concentration of calcium and total aluminum in Morehouse Lake, 1997-2017. Error bars represent one standard deviation of the mean. Calcium concentration has experienced a significant decrease since 1997 ($p = 0.05$, tau = 0.32).

Road Salt



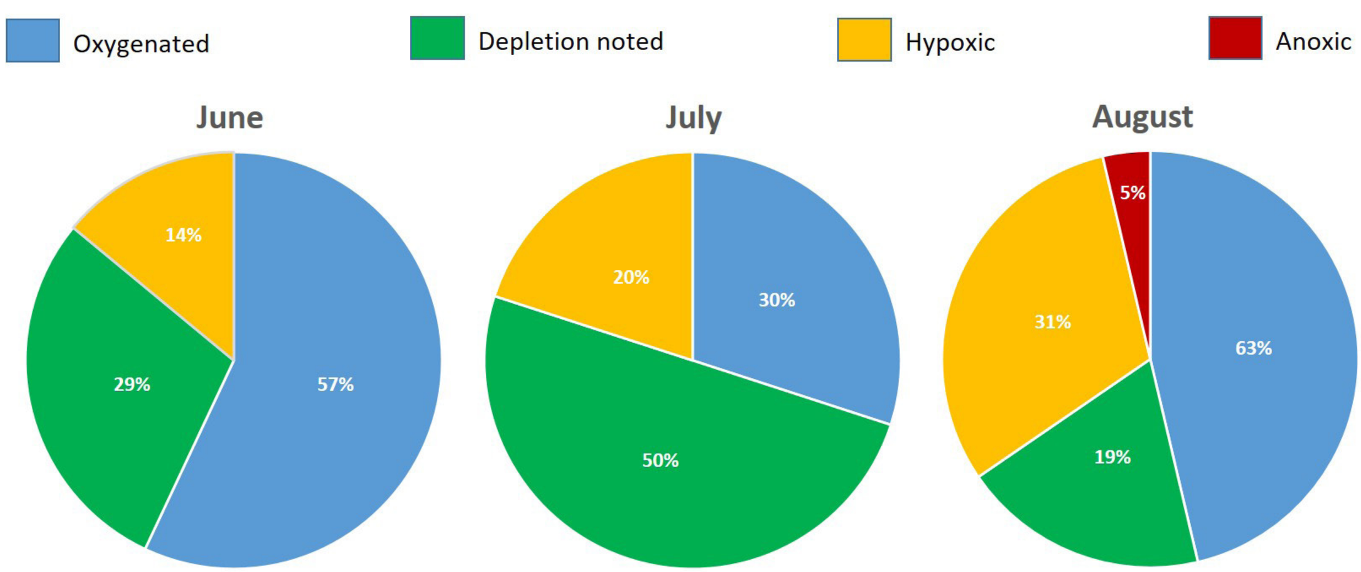
Annual average values of sodium and chloride ions (left panel), and specific conductivity (right panel) in Morehouse Lake, 2013-2017. Error bars represent one standard deviation of the mean.

LAKE PROFILE - AUGUST 2017



Depth profiles of temperature, dissolved oxygen, pH, and specific conductivity in Morehouse Lake during the August 2017 sampling trip.

DISSOLVED OXYGEN CONTENT



Proportion of monthly sampling trips where the bottom water of Morehouse Lake (1 meter off bottom) was observed to be oxygenated (D.O. > 4.0 mg/L), experiencing noted depletion (< 4.0 mg/L), hypoxic (< 2.0 mg/L) or anoxic (< 0.5 mg/L). Data is from the period of 1993 to 2017.

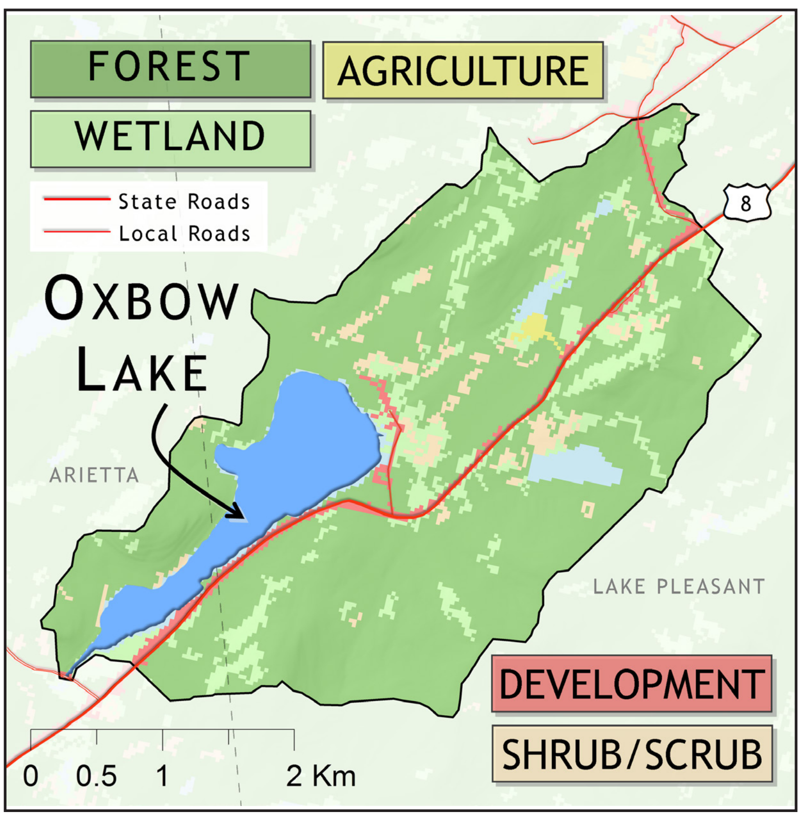
OXBOW LAKE

SUMMARY

Oxbow Lake is a 126-hectare waterbody, located within a 1,139-hectare watershed that is dominated by forest cover. The ratio of lake-volume to watershed area results in rapid water replacement, estimated at over 10 times per year. Long term monitoring by HCSWCD produced the following findings.

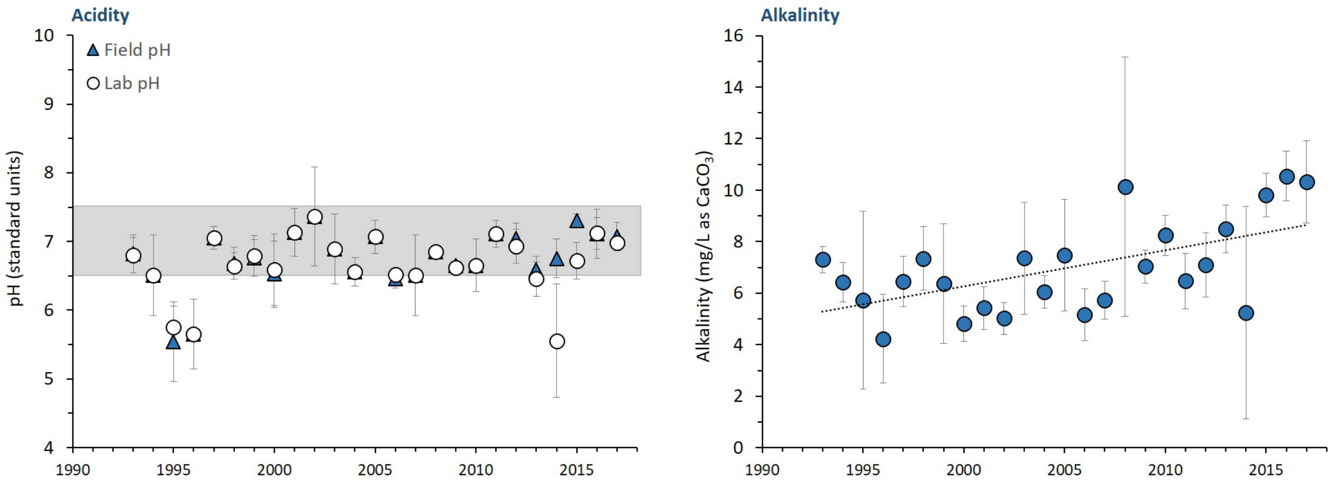
The surface water of the lake is circumneutral, with annual average pH values typically in the range of 6.5 to 7.4 units. The alkalinity of Oxbow Lake has experienced a statistically significant increase since 1993. Between the years 2015 and 2017, alkalinity averaged 10 mg/L, indicating that the lake had low sensitivity to acidic deposition. Based on chlorophyll-a concentration, which has exhibited a significant increase, the lake is best classified as eutrophic. The average transparency has decreased by nearly 1 meter over the last 25 years. The chemistry of the lake was highly influenced by the 8.1 km of roads in the watershed. The concentration of chloride and sodium between the years 2015 and 2017 averaged 20.3 and 11.4 mg/L, respectively, which is approximately 68 times greater than background concentrations for lakes in the Adirondack region. Oxygen depletion was commonly noted in the bottom water of the lake, but hypoxic conditions were only encountered in 10% of the sampling trips.

MORPHOMETRY



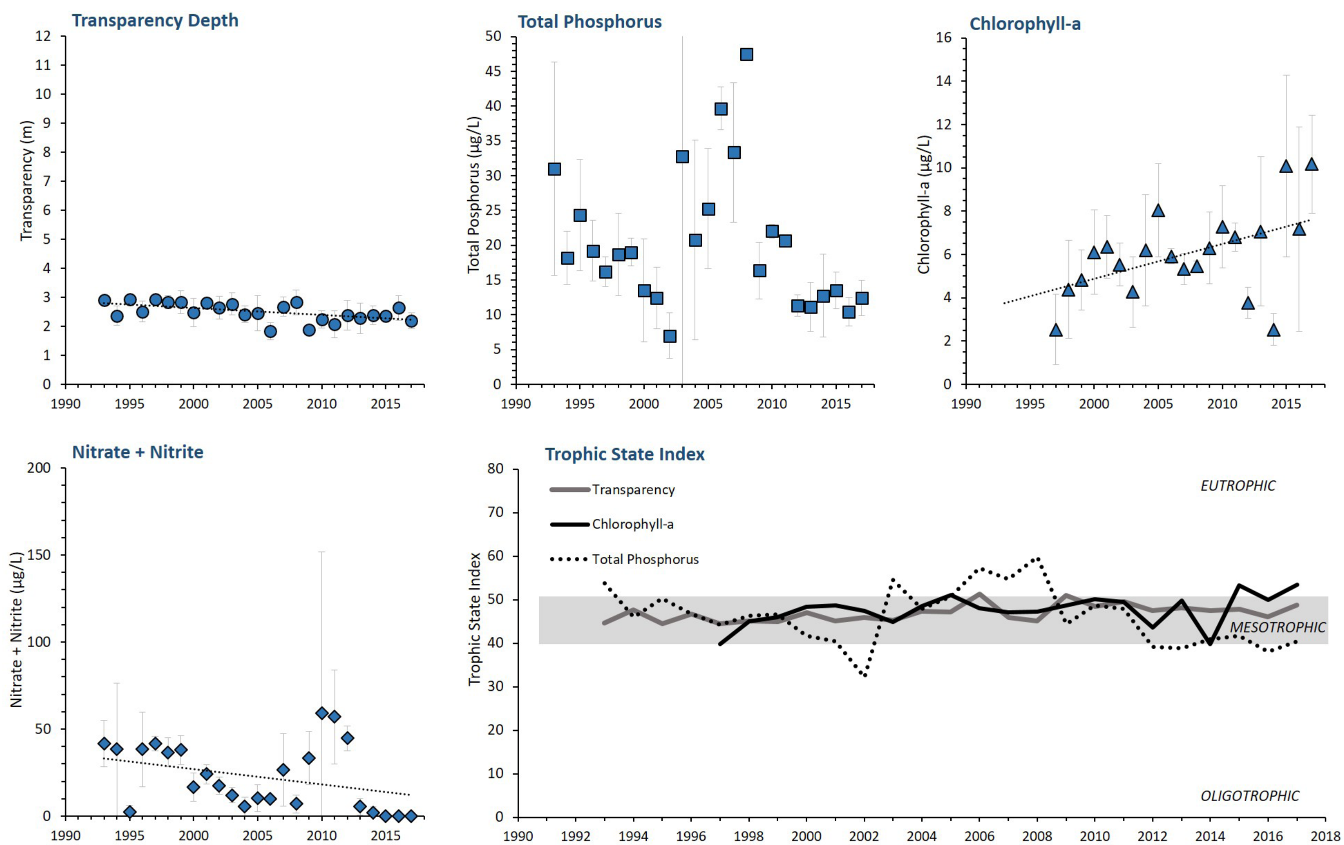
Lake Area (ha)	126
Max Depth (m)	3
Volume (m^3 x 10^6)	1.6
Shoreline (km)	7.9
Watershed Area (ha)	1,339
Retention Time (yrs)	0.1
Surface Water Area (%)	12
Forested Area (%)	74
Developed Area (%)	4
Wetland Area (%)	9
State Road Length (km)	5.7
Local Road Length (km)	2.4

ACIDITY



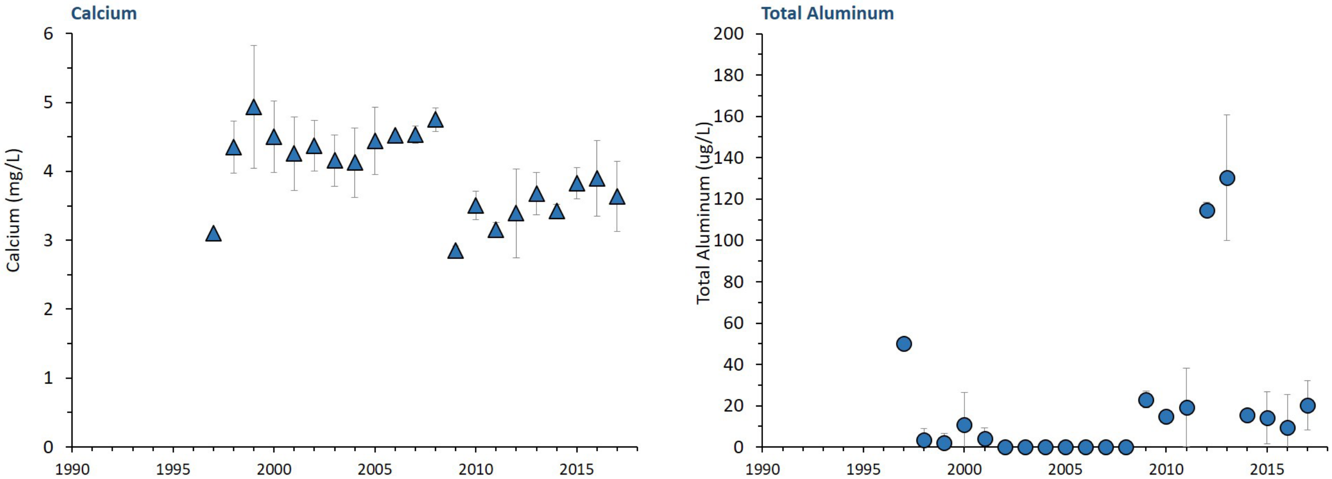
Annual average acidity (left panel) and alkalinity (right panel) of Oxbow Lake, 1993 - 2017. Shaded box denotes range of circumneutral condition (pH 6.5-7.5). Error bars denote one standard deviation of the mean. Alkalinity has exhibited an increasing trend since 1993 ($p < 0.001$, tau = 0.56).

TROPHIC STATE



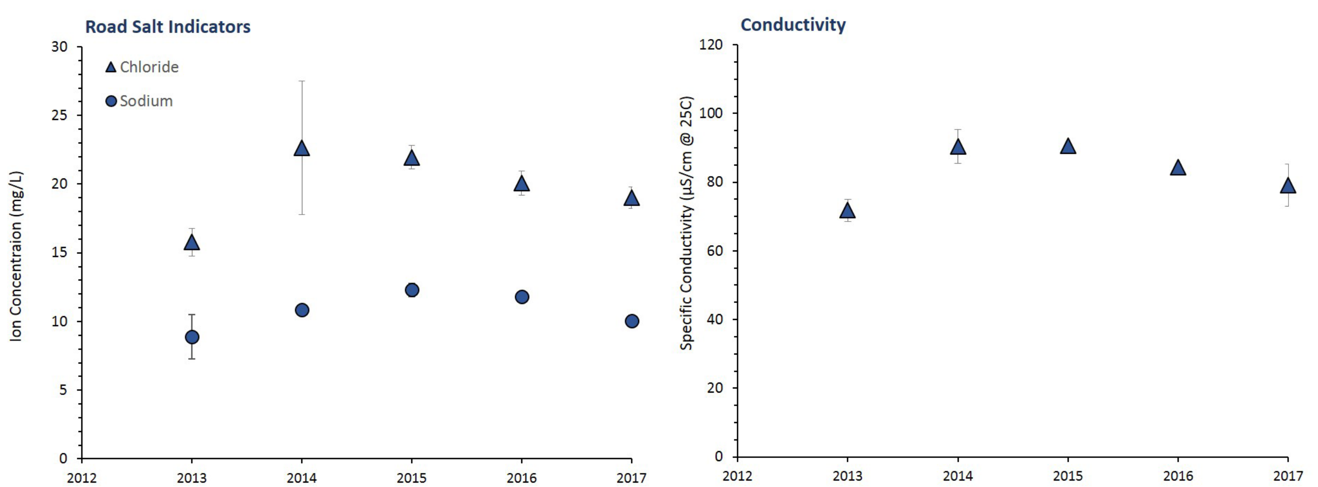
Average values for key trophic state indicators of Oxbow Lake, 1993-2017. Error bars represent one standard deviation of the mean. Transparency depth, and nitrate concentration have exhibited a decreasing trend since 1993, while chlorophyll-a has increased (Transparency: $p = 0.002$, tau = 0.44; Nitrate: $p < 0.01$, tau = 0.40; Chlorophyll-a: $p = 0.02$, tau = 0.40).

Metals



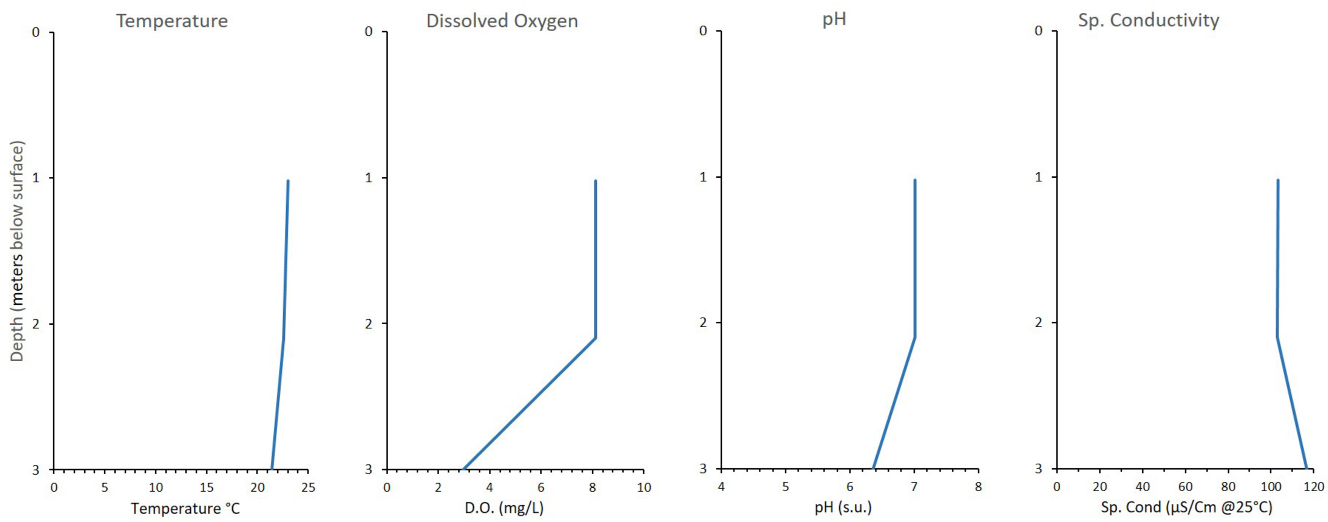
Annual average concentration of calcium and total aluminum in Oxbow Lake, 1997-2017. Error bars represent one standard deviation of the mean.

Road Salt



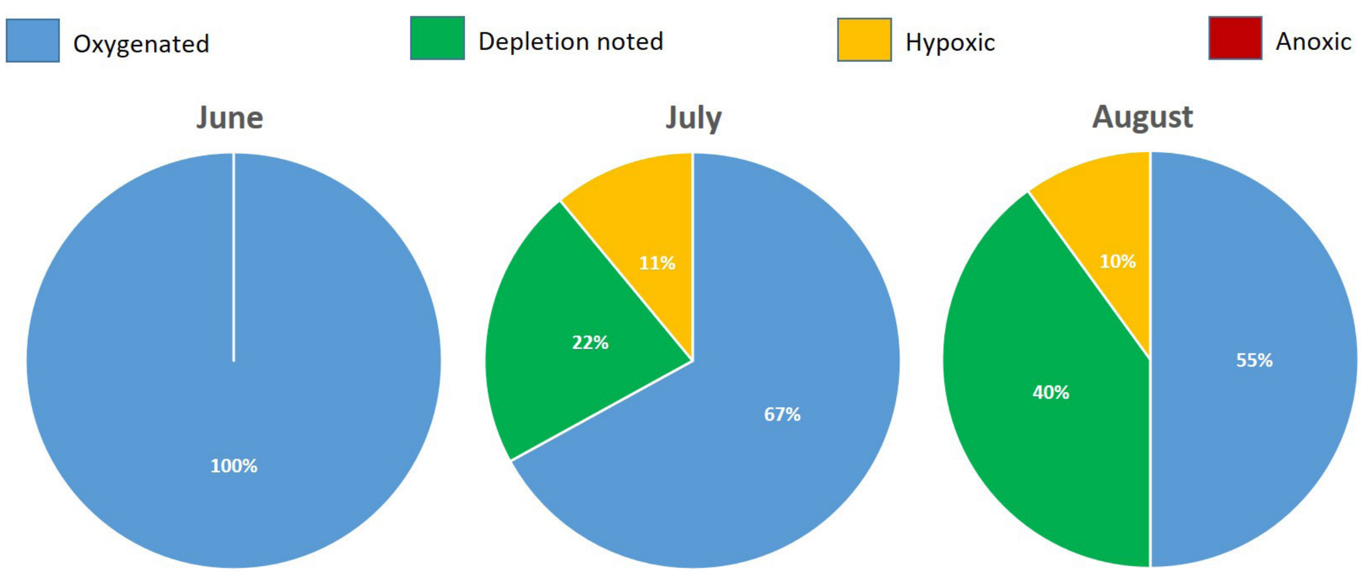
Annual average values of sodium and chloride ions (left panel), and specific conductivity (right panel) in Oxbow Lake, 2013-2017. Error bars represent one standard deviation of the mean.

Lake Profile - August 2017



Depth profiles of temperature, dissolved oxygen, pH, and specific conductivity in Oxbow Lake during the August 2017 sampling trip.

Dissolved Oxygen Content



Proportion of monthly sampling trips where the bottom water of Oxbow Lake (1 meter off bottom) was observed to be oxygenated (D.O. > 4.0 mg/L), experiencing noted depletion (< 4.0 mg/L), hypoxic (< 2.0 mg/L) or anoxic (< 0.5 mg/L). Data is from the period of 1993 to 2017.

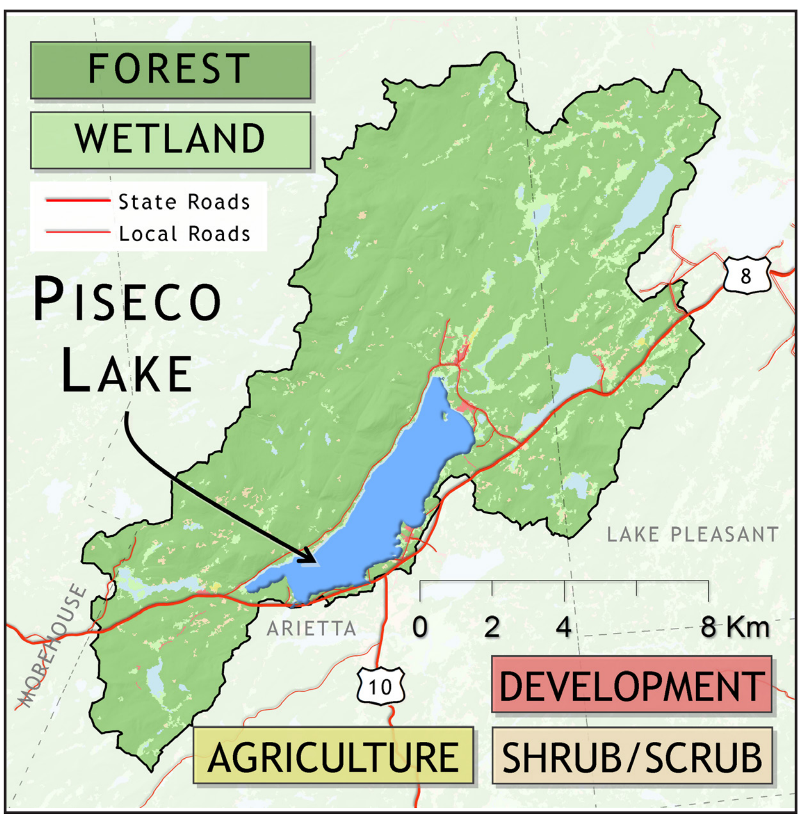
PISECO LAKE

SUMMARY

Piseco Lake is a 1,066-hectare waterbody, located within a 14,490-hectare watershed that is dominated by forest cover. Long term monitoring by HCSWCD produced the following findings.

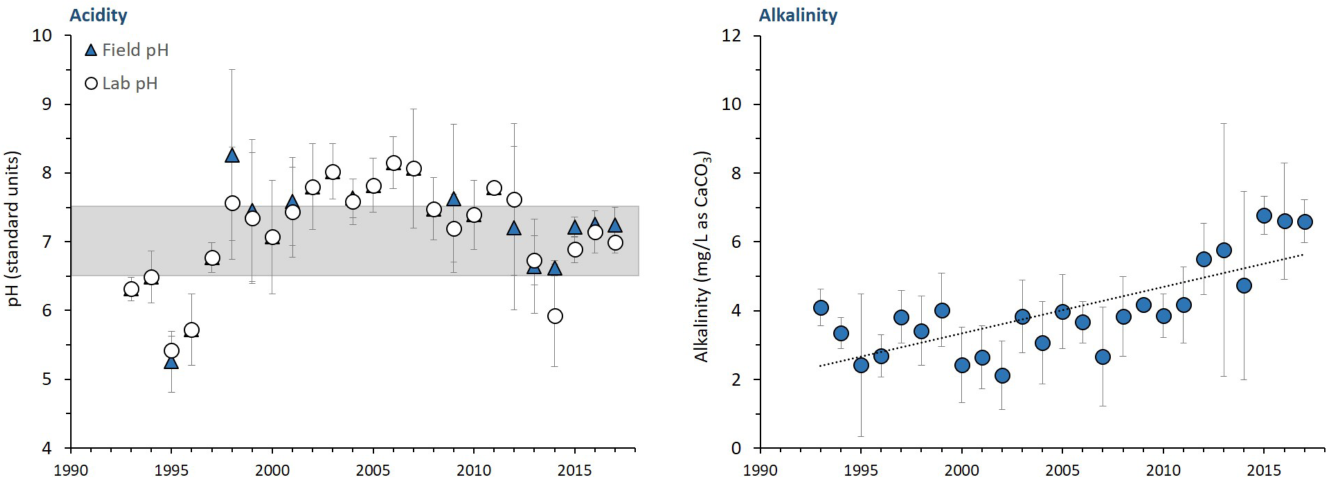
The surface water of the lake is best classified as circumneutral to slightly alkaline, with average annual pH values that were typically in the range of 6.5 to 8.0 standard units. Between the years 2015 and 2017, alkalinity was in the range of 5 to 8 mg/L, indicating that the lake was moderately buffered against acidic deposition. The alkalinity of the lake has exhibited a statistical increase since monitoring began in 1993. The lake was best classified as mesotrophic, with a significant downward trend in transparency depth and total phosphorus concentration. The chemistry of the lake was influenced by the 42 km of roads in the watershed. The concentration of chloride and sodium between the years 2015 and 2017 averaged 5.6 and 3.2 mg/L respectively, which is approximately 19 times greater than background concentrations for Adirondack lakes. The bottom water of Piseco Lake was well oxygenated and no hypoxic or anoxic water was encountered during the sampling period.

MORPHOMETRY



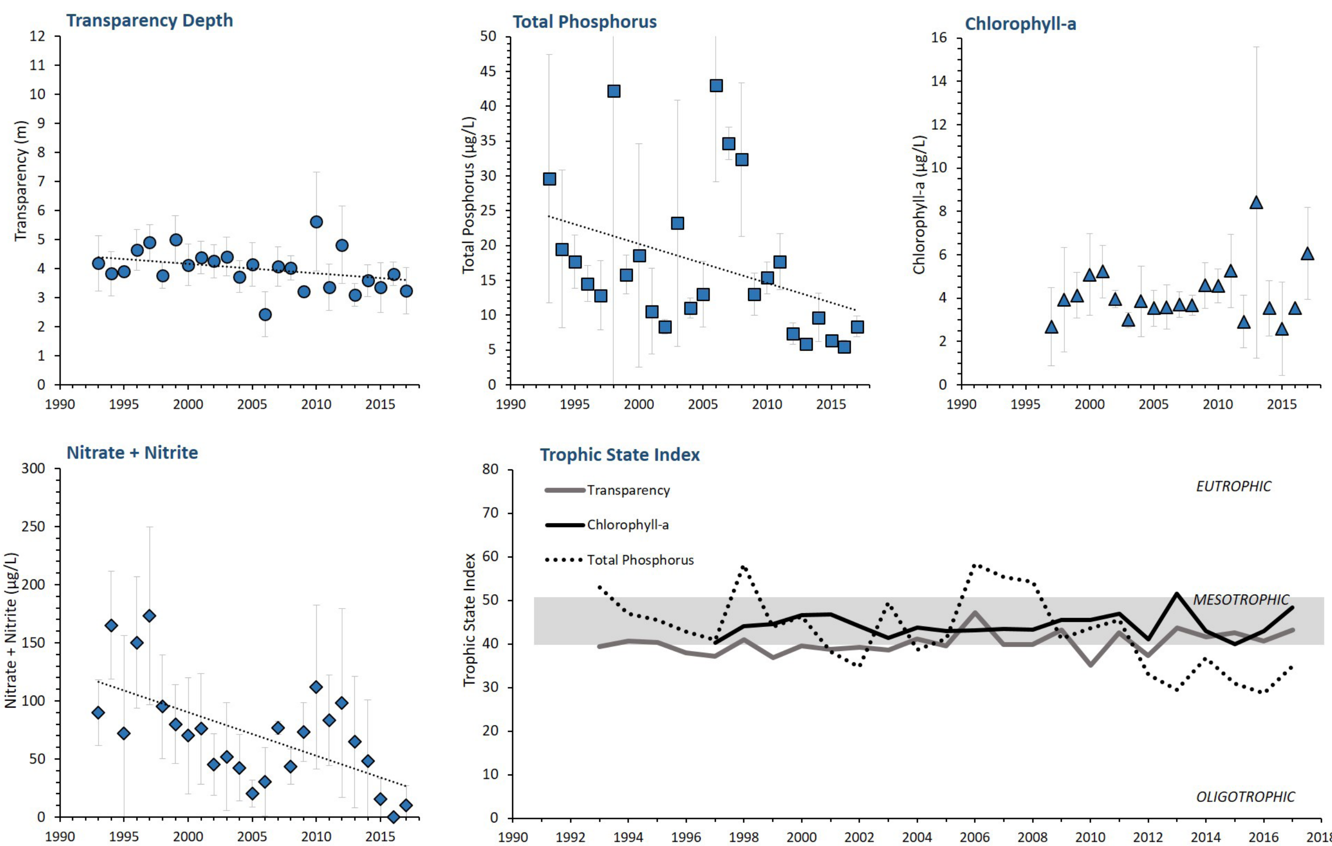
Lake Area (ha)	1,066
Max Depth (m)	38
Volume (m^3 x 10^6)	203
Shoreline (km)	25
Watershed Area (ha)	14,490
Retention Time (yrs)	1.5
Surface Water Area (%)	11
Forested Area (%)	83
Developed Area (%)	1
Wetland Area (%)	5
State Road Length (km)	15.6
Local Road Length (km)	26.3

Acidity



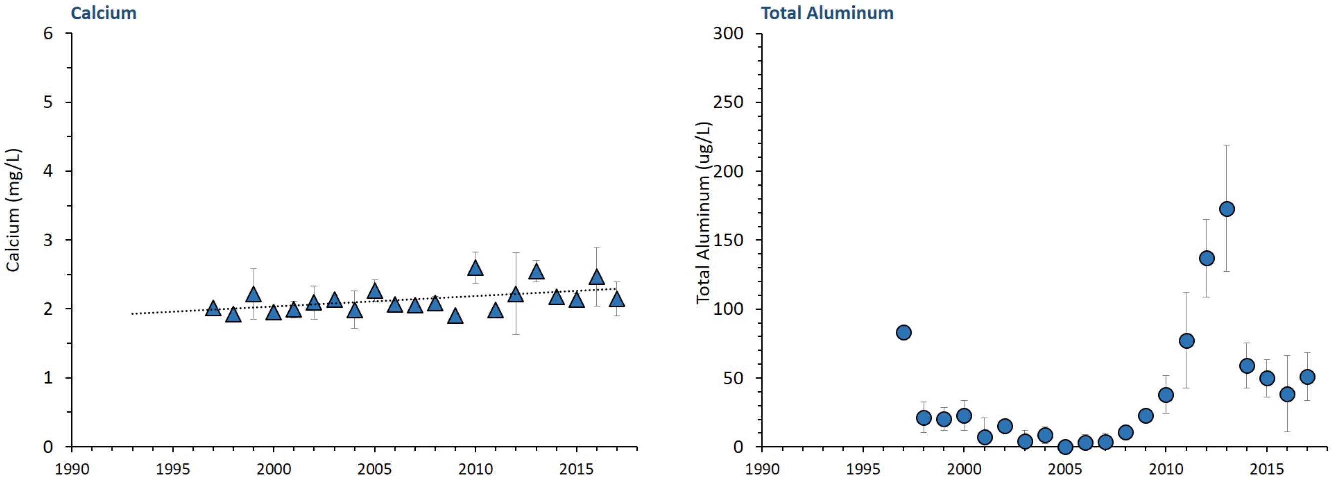
Annual average acidity (left panel) and alkalinity (right panel) of Piseco Lake, 1993 - 2017. Shaded box denotes range of circumneutral condition (pH 6.5-7.5). Error bars denote one standard deviation of the mean. Alkalinity has exhibited an increasing trend since 1993 ($p < 0.001$, tau = 0.54).

Trophic State



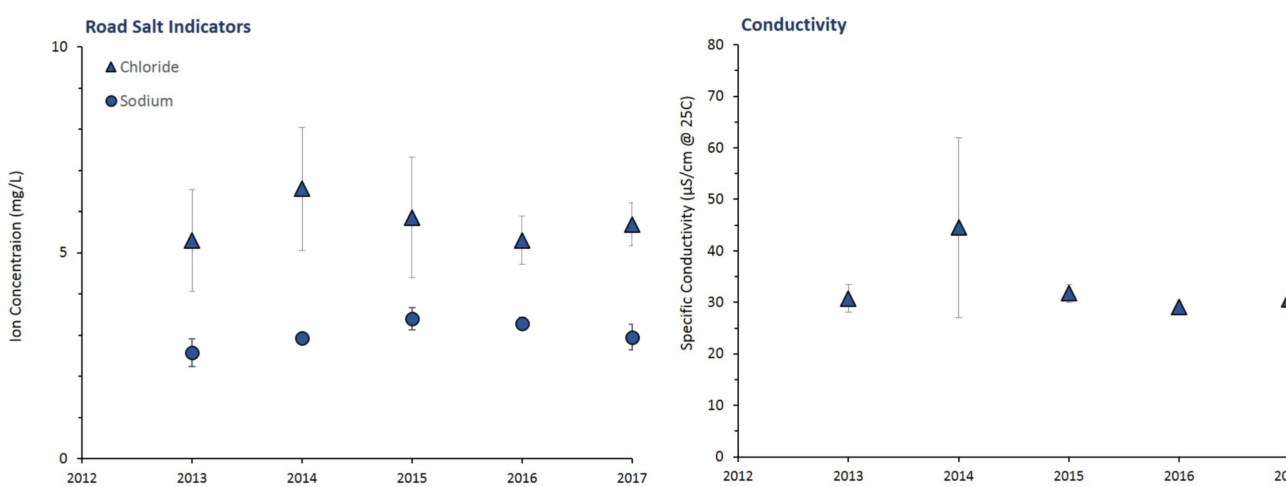
Average values for key trophic state indicators of Piseco Lake, 1993-2017. Error bars represent one standard deviation of the mean. Transparency depth, and the concentrations of total phosphorus and nitrate have all exhibited a decreasing trend since 1993 (Transparency: $p = 0.03$, tau = 0.31; Total phosphorus: $p < 0.001$, tau = 0.39; Nitrate: $p = 0.01$, tau = 0.43).

Metals



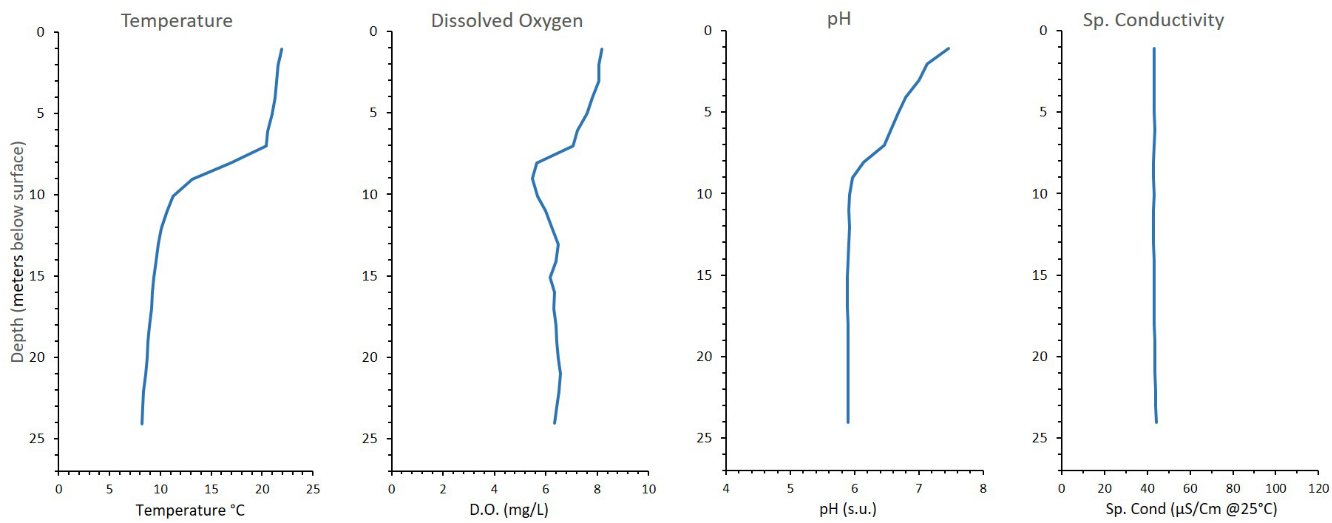
Annual average concentration of calcium and total aluminum in Piseco Lake, 1997-2017. Error bars represent one standard deviation of the mean. Calcium concentration has exhibited an increasing trend since 1993 ($p = 0.08$, tau = 0.42).

Road Salt



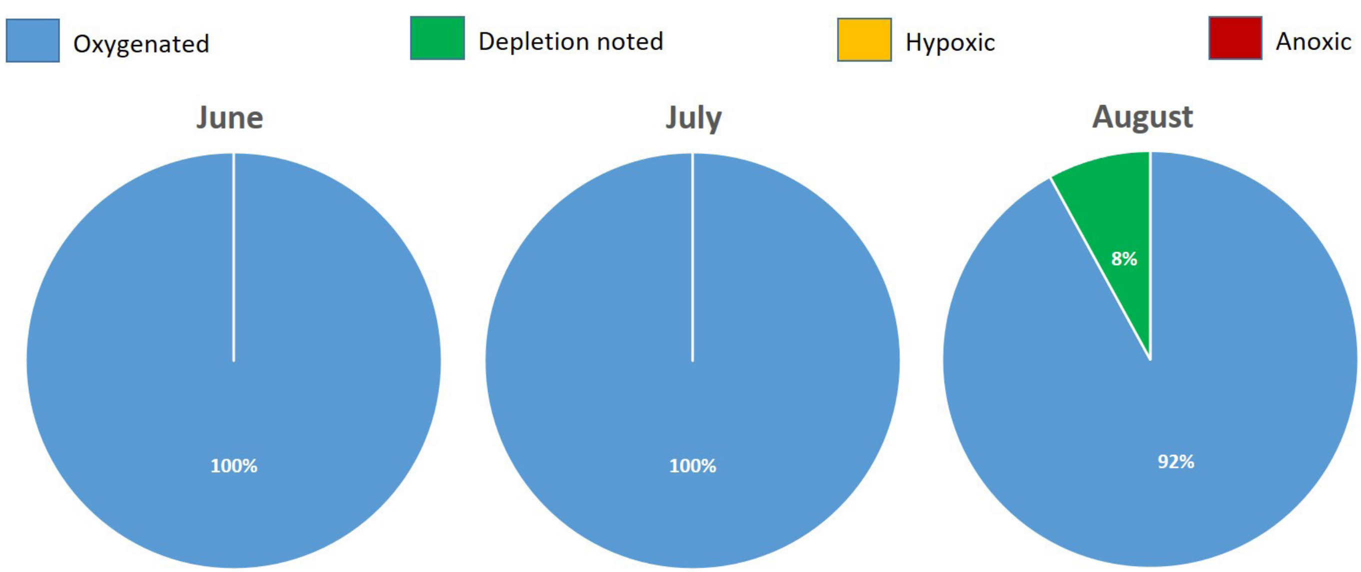
Annual average values of sodium and chloride ions (left panel), and specific conductivity (right panel) in Piseco Lake, 2013-2017. Error bars represent one standard deviation of the mean.

Lake Profile - August 2017



Depth profiles of temperature, dissolved oxygen, pH, and specific conductivity in Piseco Lake during the August 2017 sampling trip.

Dissolved Oxygen Content



Proportion of monthly sampling trips where the bottom water of Piseco Lake (1 meter off bottom) was observed to be oxygenated (D.O. > 4.0 mg/L), experiencing noted depletion (< 4.0 mg/L), hypoxic (< 2.0 mg/L) or anoxic (< 0.5 mg/L). Data is from the period of 1993 to 2017.

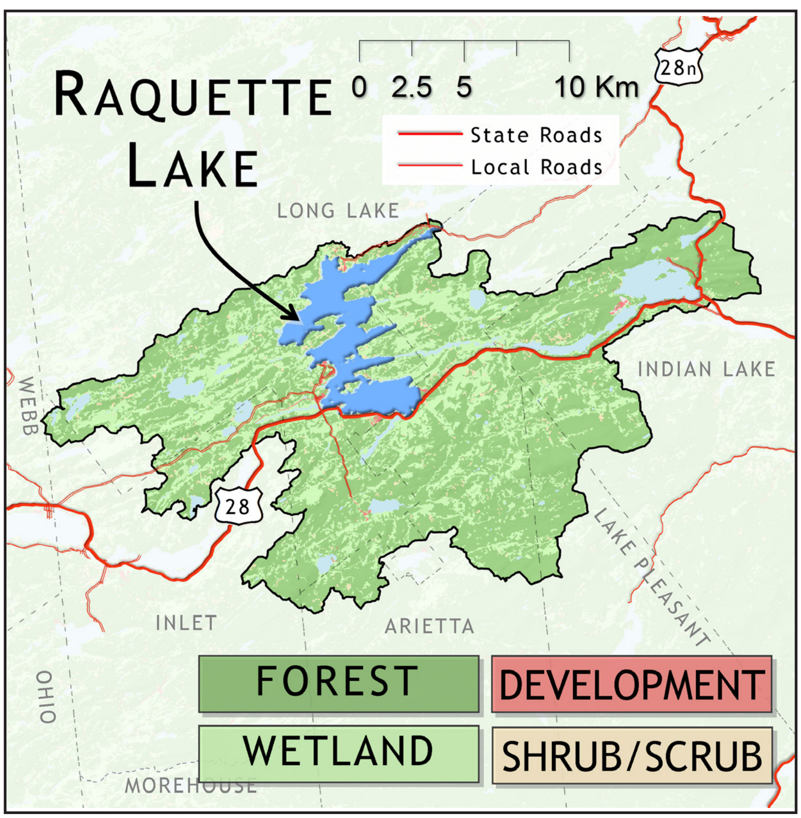
RAQUETTE LAKE

Summary

Raquette Lake is a 2,174-hectare waterbody, located within a 31,123-hectare watershed that is dominated by forest cover. Long term monitoring by HCSWCD produced the following findings.

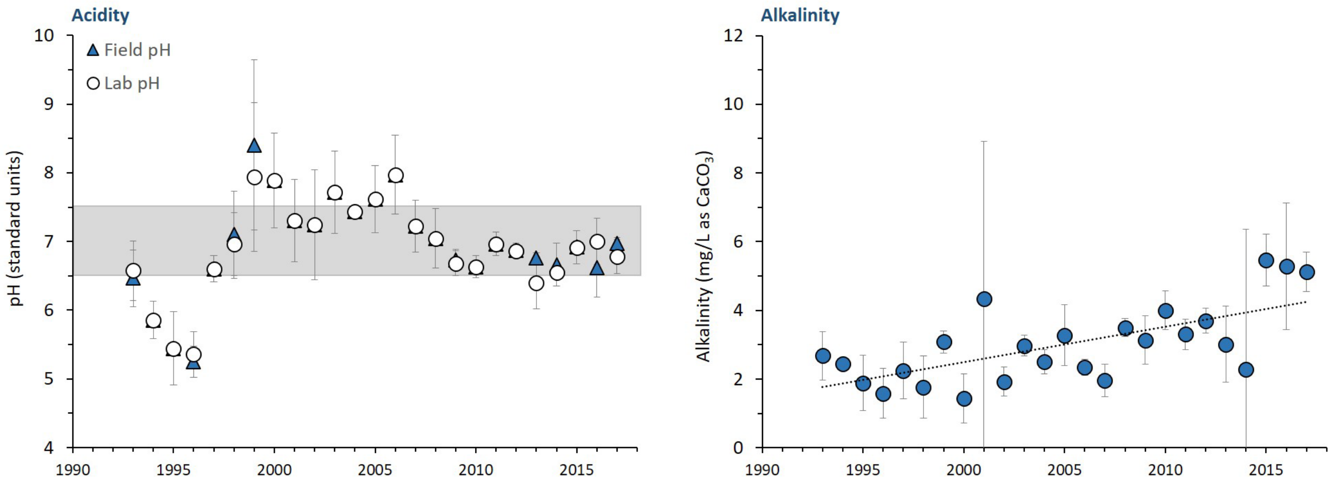
The surface water of the lake is best classified as circumneutral to slightly alkaline, with average annual pH values that were typically in the range of 6.5 to 8.0 standard units. Between the years 2015 and 2017, alkalinity was in the range of 3 to 6 mg/L, indicating that the lake was moderately sensitive to acidic deposition. The alkalinity of the lake has exhibited a statistical increase since monitoring began in 1993. The lake was best classified as mesotrophic, with a significant downward trend in transparency depth and total phosphorus concentration. The chemistry of the lake was influenced by the 56 km of roads in the watershed. The concentration of chloride and sodium between the years 2015 and 2017 averaged 4.4 and 2.7 mg/L respectively, which is approximately 15 times greater than background concentrations for Adirondack lakes. The bottom water of Raquette Lake was well oxygenated and no hypoxic or anoxic water was encountered during the sampling period.

Morphometry



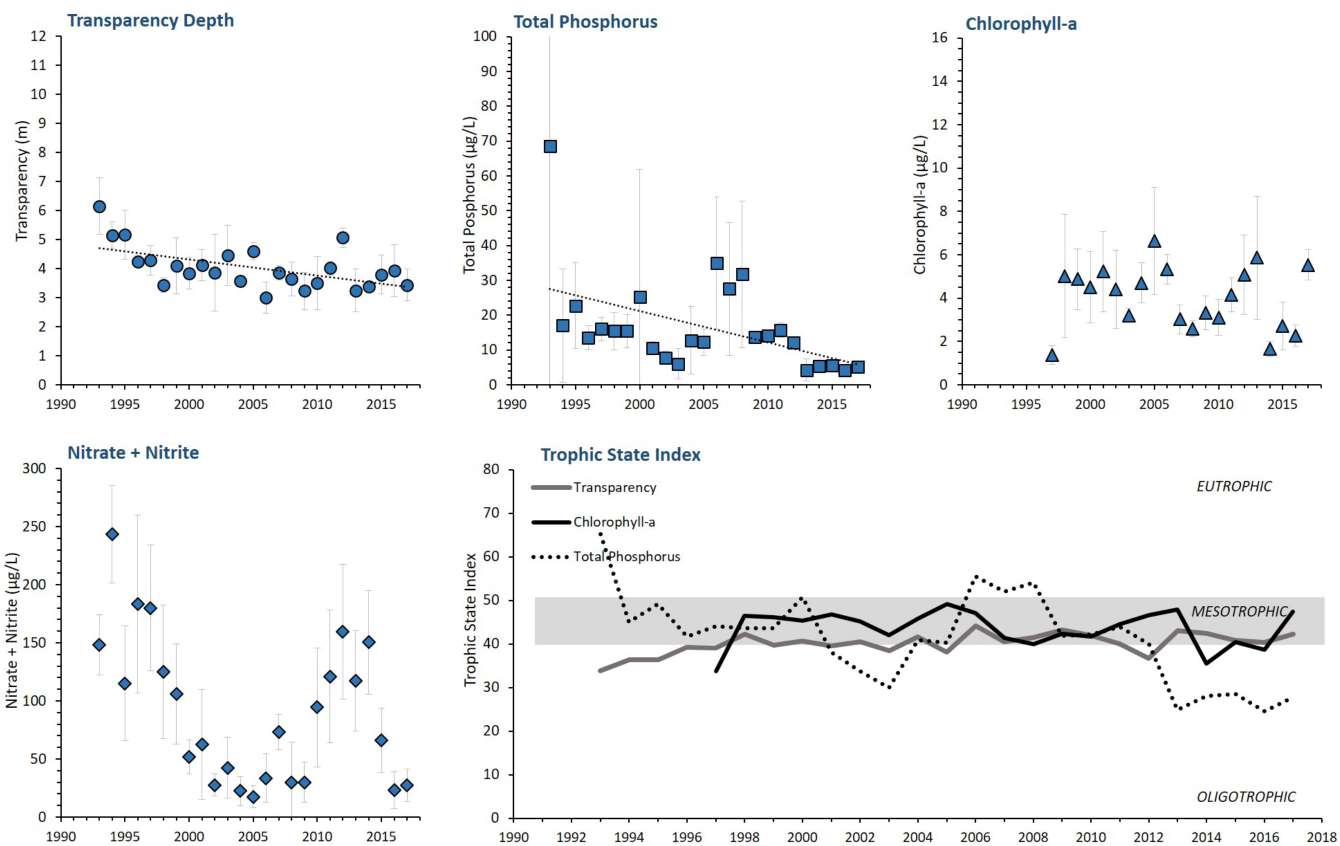
Lake Area (ha)	2,174
Max Depth (m)	29
Volume (m^3 x 10^6)	285
Shoreline (km)	76
Watershed Area (ha)	31,123
Retention Time (yrs)	1.1
Surface Water Area (%)	13
Forested Area (%)	59.5
Developed Area (%)	1.2
Wetland Area (%)	25.1
State Road Length (km)	30.2
Local Road Length (km)	25.3

Acidity



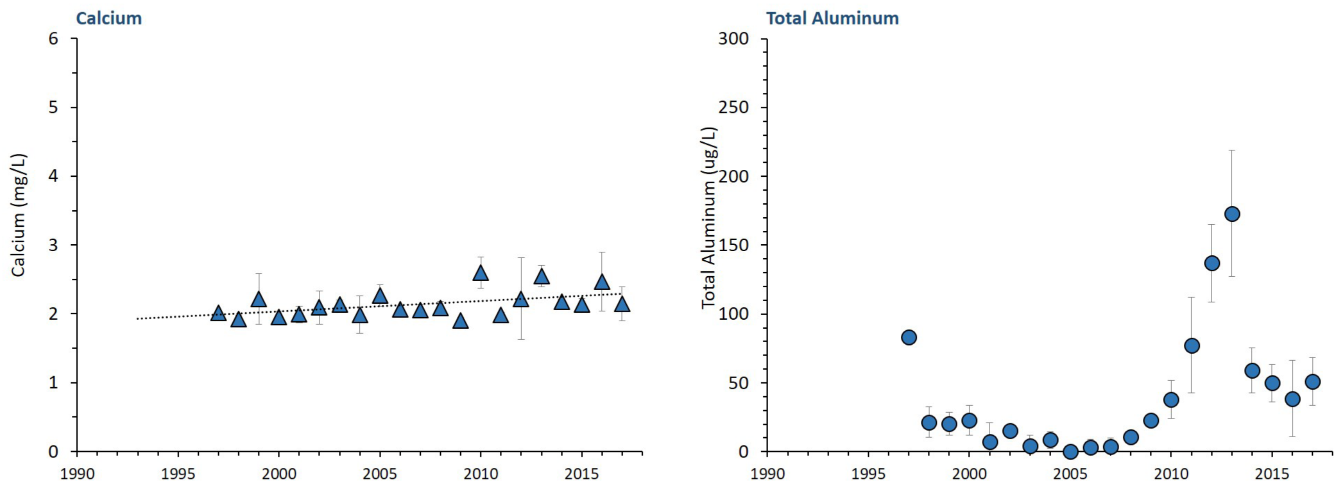
Annual average acidity (left panel) and alkalinity (right panel) of Raquette Lake, 1993 - 2017. Shaded box denotes range of circumneutral condition (pH 6.5-7.5). Error bars denote one standard deviation of the mean. Alkalinity has exhibited an increasing trend since 1993 ($p = 0.04$, tau = 0.54).

Trophic State



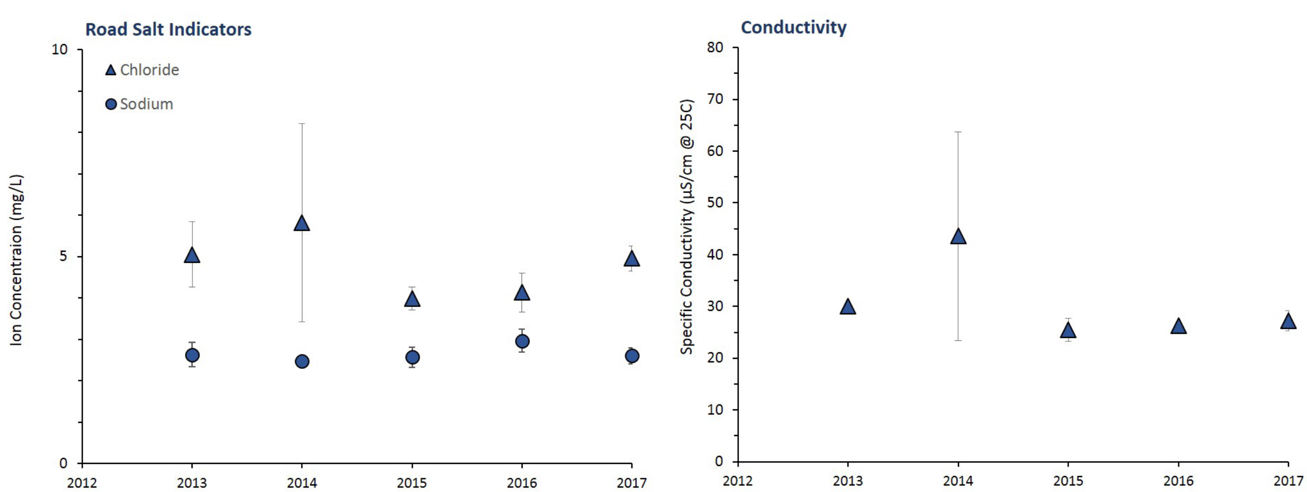
Average values for key trophic state indicators of Raquette Lake, 1993-2017. Error bars represent one standard deviation of the mean. Transparency depth and total phosphorus concentration have both exhibited a decreasing trend since 1993 (Transparency: $p = 0.006$, tau = 0.39; Total phosphorus: $p < 0.001$, tau = 0.44).

Metals



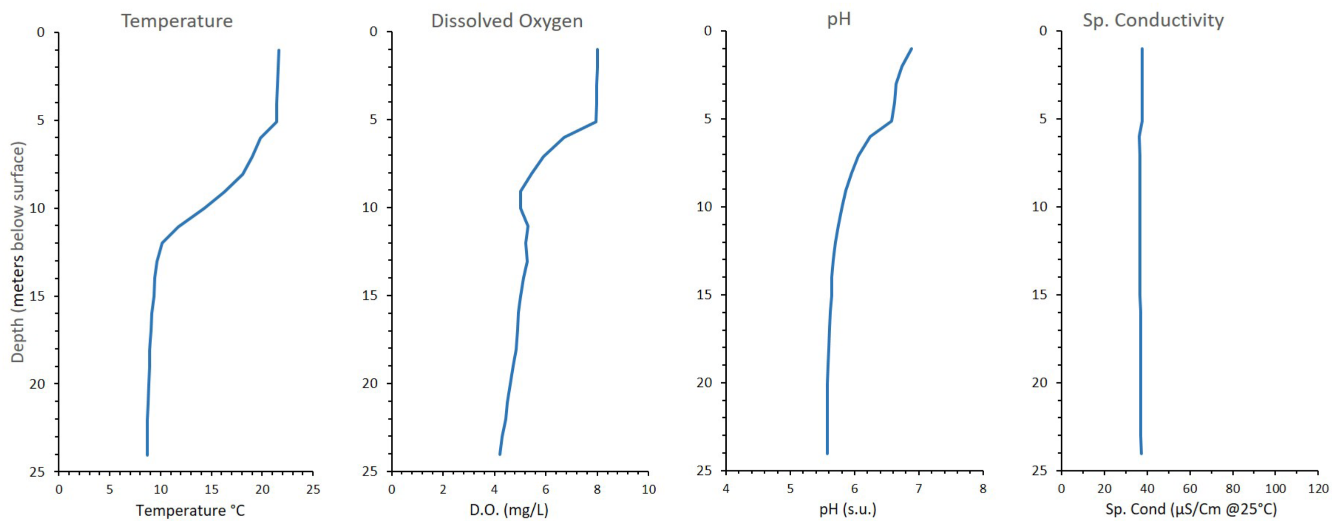
Annual average concentration of calcium and total aluminum in Raquette Lake, 1997-2017. Error bars represent one standard deviation of the mean. Calcium concentration has exhibited an increasing trend since 1993 ($p = 0.05$, tau = 0.31).

Road Salt



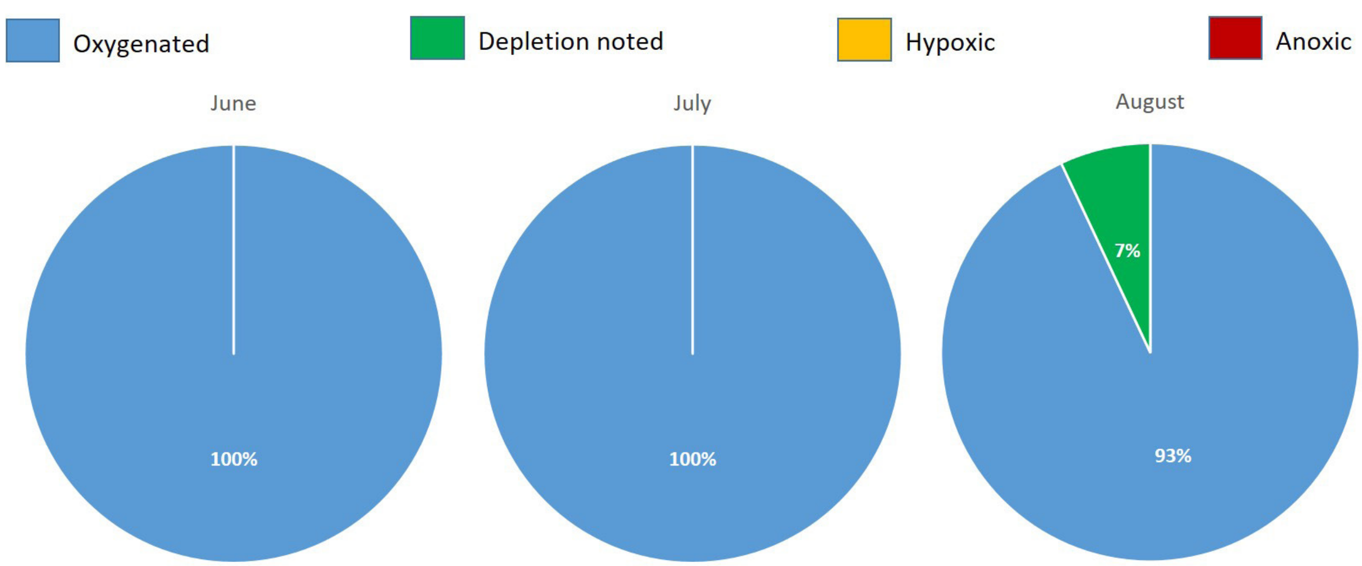
Annual average values of sodium and chloride ions (left panel), and specific conductivity (right panel) in Raquette Lake, 2013-2017. Error bars represent one standard deviation of the mean.

LAKE PROFILE - AUGUST 2017



Depth profiles of temperature, dissolved oxygen, pH, and specific conductivity in Raquette Lake during the August 2017 sampling trip.

DISSOLVED OXYGEN CONTENT



Proportion of monthly sampling trips where the bottom water of Raquette Lake (1 meter off bottom) was observed to be oxygenated (D.O. > 4.0 mg/L), experiencing noted depletion (< 4.0 mg/L), hypoxic (< 2.0 mg/L) or anoxic (< 0.5 mg/L). Data is from the period of 1993 to 2017.

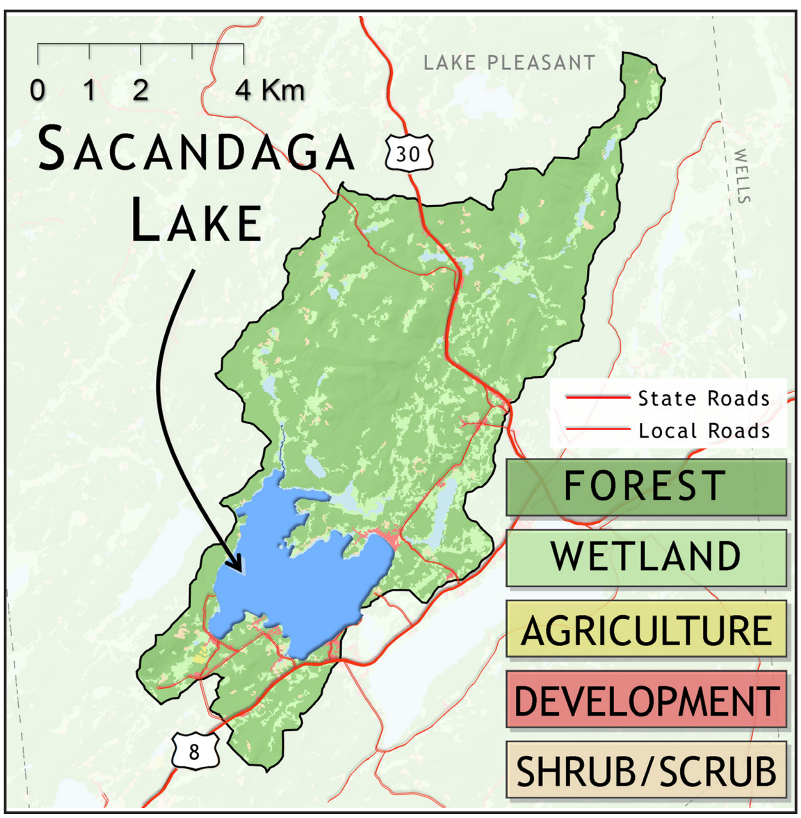
SACANDAGA LAKE

Summary

Sacandaga Lake is a 650-hectare waterbody, located within a 5,266-hectare watershed that is dominated by forest cover. Long term monitoring by HCSWCD produced the following findings.

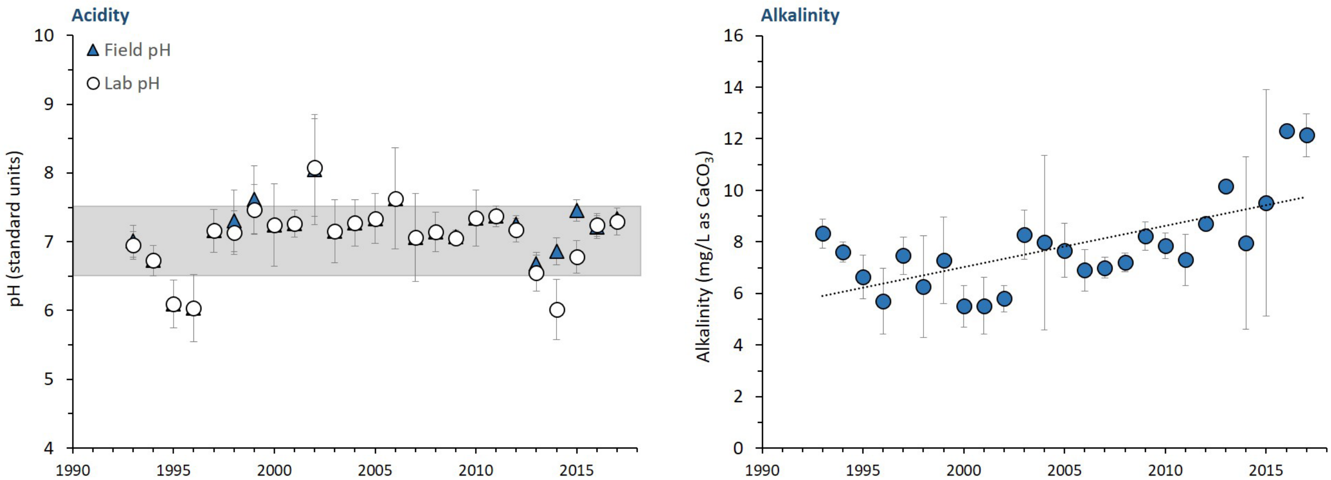
The surface water of the lake is best classified as circumneutral, with average annual pH values that were typically in the range of 6.5 to 7.5 standard units. The alkalinity of the lake has exhibited a significant increase, and has nearly doubled since 1993. Between the years 2015 and 2017, alkalinity averaged 11 mg/L, indicating that the lake had moderate sensitivity to acid deposition. The lake is best classified as mesotrophic, with a statistically significant decrease in transparency, phosphorus, and nitrogen over time. The chemistry of the lake was moderately influenced by the 24 km of roads in the watershed. The concentration of chloride and sodium between the years 2015 and 2017 averaged 8.0 and 6.5 mg/L respectively, which is approximately 27 times greater than background concentrations for lakes in the Adirondack region. The bottom water of Sacandaga Lake was found to be hypoxic or anoxic during 37% of the August sampling trips.

Morphometry



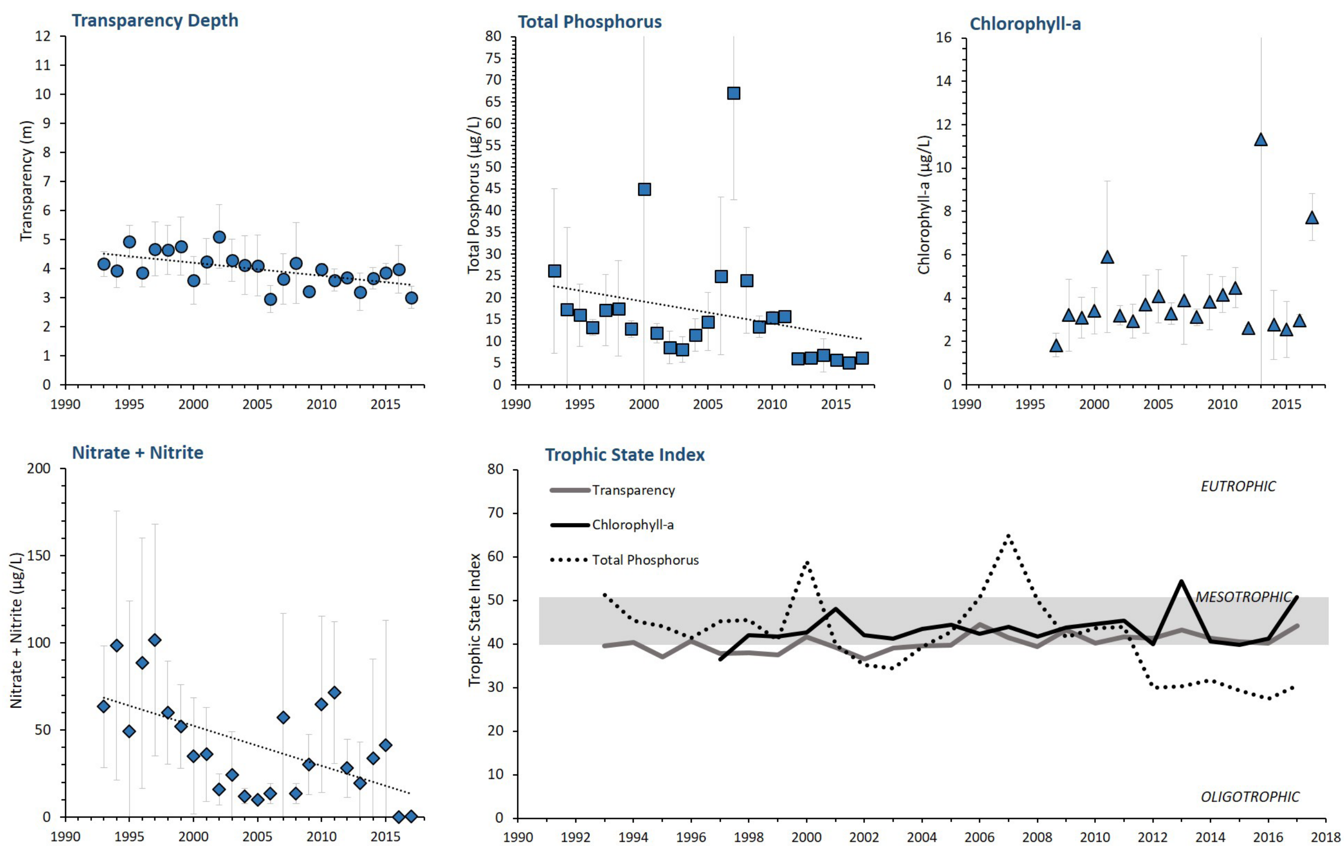
Lake Area (ha)	650
Max Depth (m)	23
Volume (m^3 x 10^6)	42
Shoreline (km)	22
Watershed Area (ha)	5,266
Retention Time (yrs)	0.5
Surface Water Area (%)	16
Forested Area (%)	72
Developed Area (%)	2
Wetland Area (%)	9
State Road Length (km)	7.4
Local Road Length (km)	17

Acidity



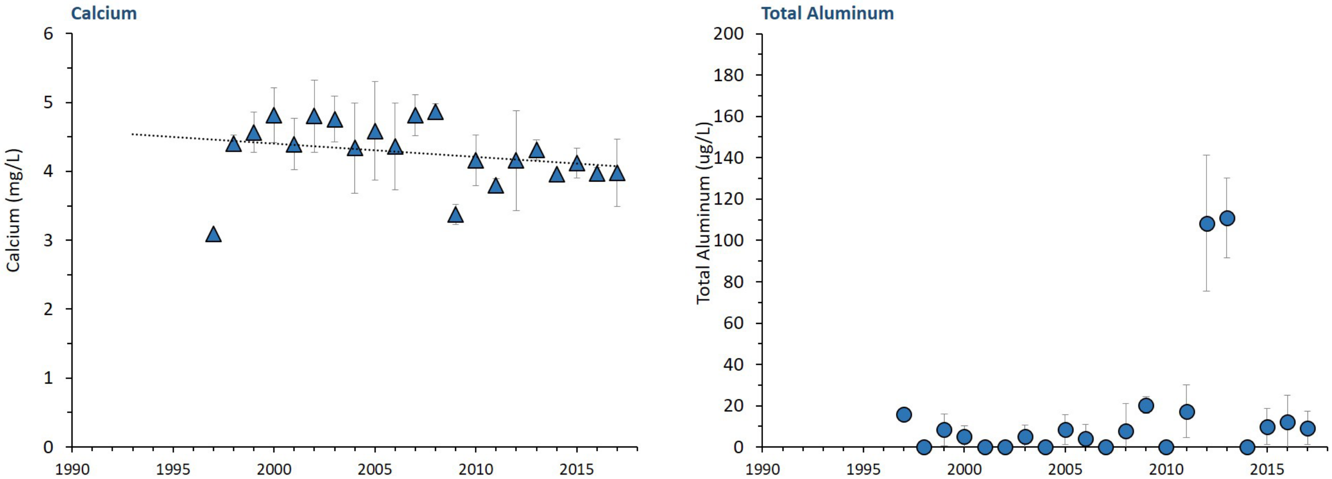
Annual average acidity (left panel) and alkalinity (right panel) of Sacandaga Lake, 1993 - 2017. Shaded box denotes range of circumneutral condition (pH 6.5-7.5). Error bars denote one standard deviation of the mean. Alkalinity has exhibited an increasing trend since 1993 (p = 0.04, tau = 0.54).

Trophic State



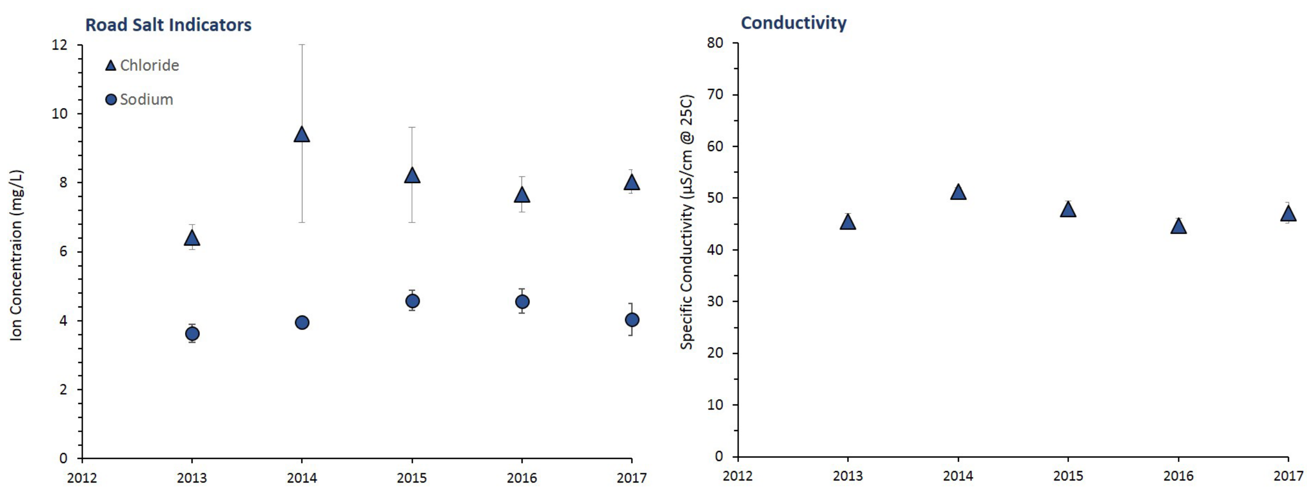
Average values for key trophic state indicators of Sacandaga Lake, 1993-2017. Error bars represent one standard deviation of the mean. Transparency depth, and the concentration of total phosphorus and nitrate have all exhibited a decreasing trend since 1993 (Transparency: p = 0.005, tau = 0.40; Total phosphorus: p < 0.001, tau = 0.42; Nitrate: p = 0.01, tau = 0.38).

Metals



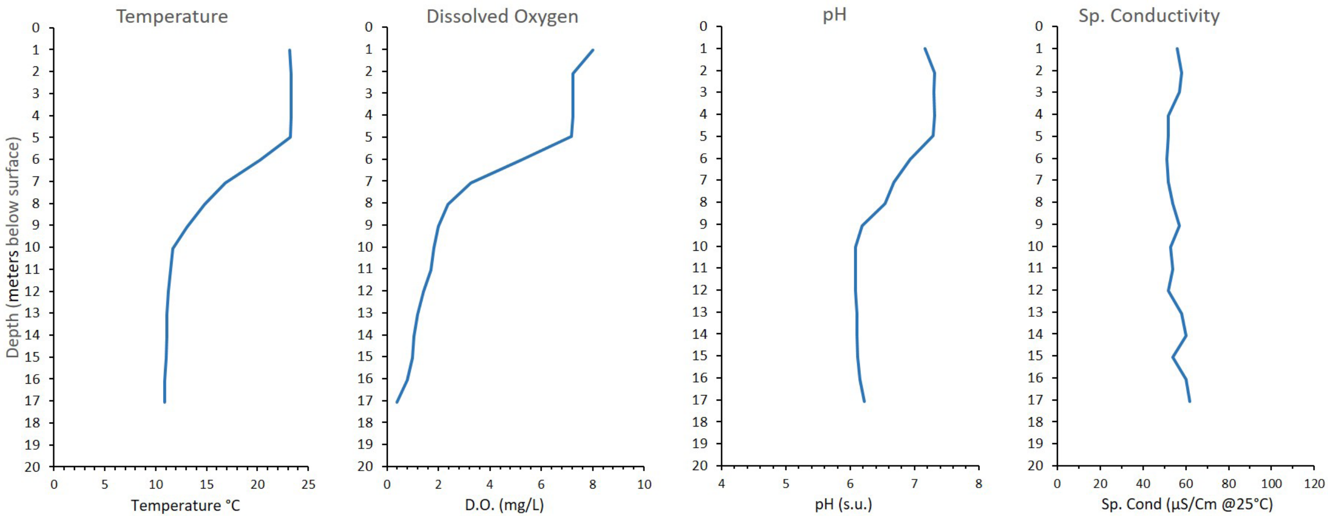
Annual average concentration of calcium and total aluminum in Sacandaga Lake, 1997-2017. Error bars represent one standard deviation of the mean. Calcium concentration has exhibited a decreasing trend since 1993 (p = 0.05, tau = 0.31).

Road Salt



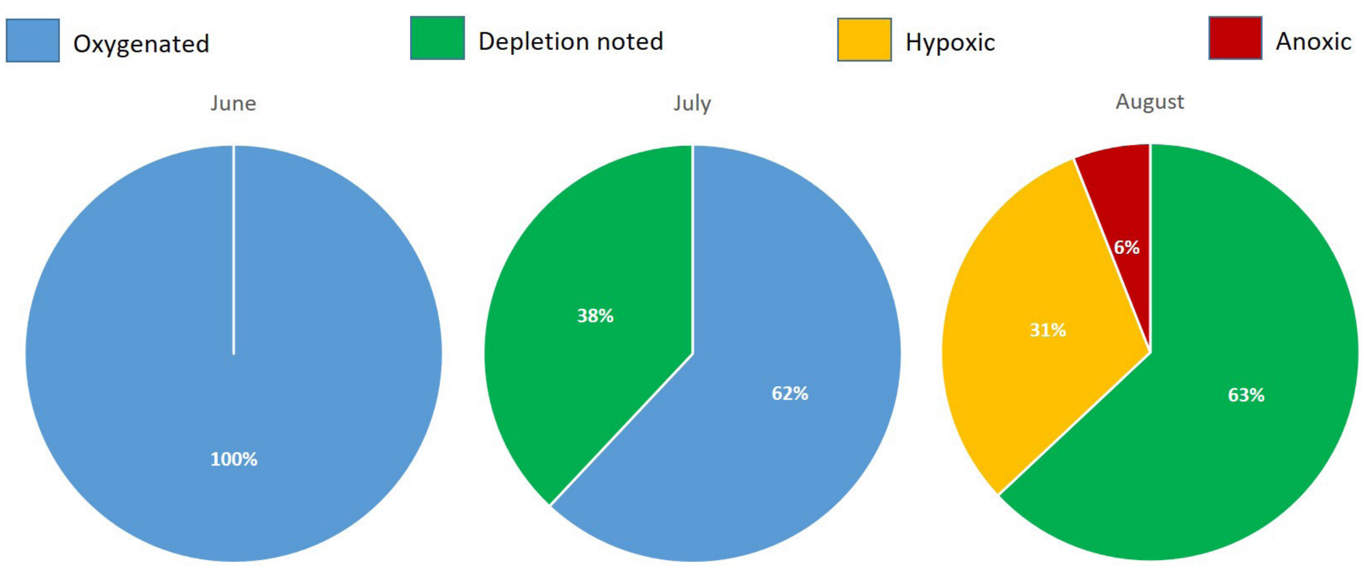
Annual average values of sodium and chloride ions (left panel), and specific conductivity (right panel) in Sacandaga Lake, 2013-2017. Error bars represent one standard deviation of the mean.

Lake Profile - August 2017



Depth profiles of temperature, dissolved oxygen, pH, and specific conductivity in Sacandaga Lake during the August 2017 sampling trip.

Dissolved Oxygen Content



Proportion of monthly sampling trips where the bottom water of Sacandaga Lake (1 meter off bottom) was observed to be oxygenated (D.O. > 4.0 mg/L), experiencing noted depletion (< 4.0 mg/L), hypoxic (< 2.0 mg/L) or anoxic (< 0.5 mg/L). Data is from the period of 1993 to 2017.

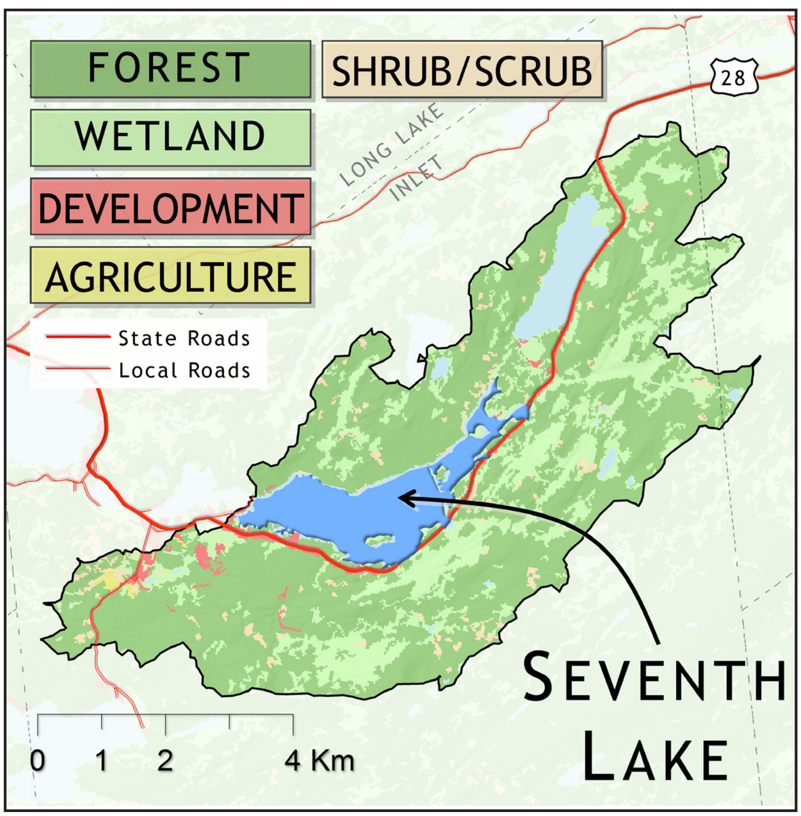
SEVENTH LAKE

Summary

Seventh Lake is a 334-hectare waterbody, located within a 4,220-hectare watershed that is dominated by forest cover. Long term monitoring by HCSWCD produced the following findings.

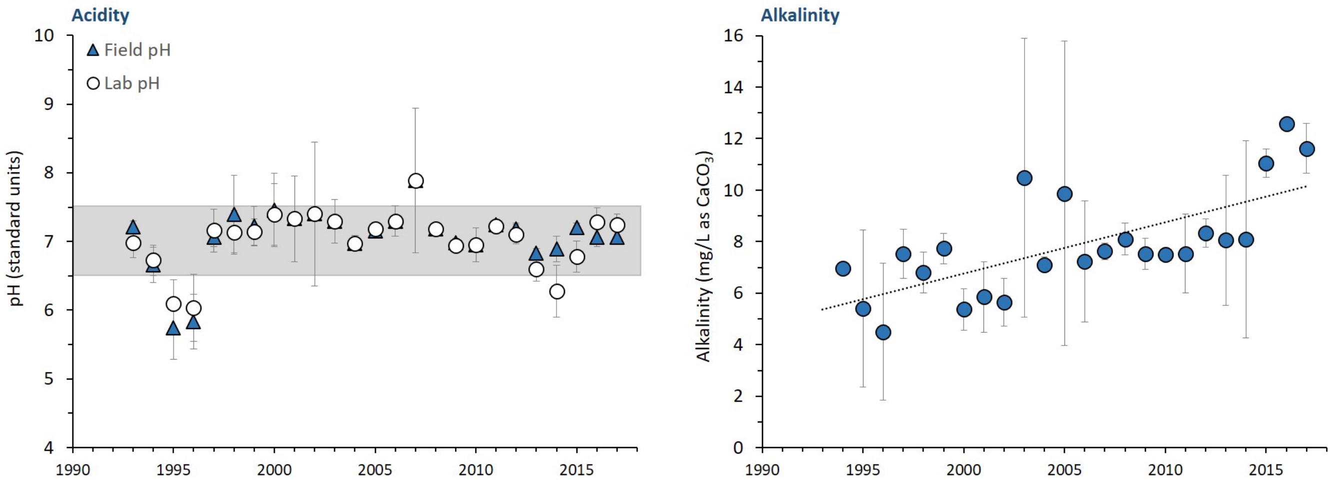
The surface water of the lake is best classified as circumneutral, with average annual pH values that were typically in the range of 6.5 to 7.5 standard units. The alkalinity of the lake has exhibited a significant increase, and has nearly doubled since 1993. Between the years 2015 and 2017, alkalinity averaged 12 mg/L, indicating that the lake had low sensitivity to acid deposition. The lake is best classified as oligotrophic and has low concentrations of nutrients and chlorophyll-a. The transparency of the lake has experienced a significant decline over the study period, and has decreased by an average depth of 1.5 meters since the early 1990s. The chemistry of the lake was moderately influenced by the 13 km of roads in the watershed. The concentration of chloride and sodium between the years 2015 and 2017 averaged 10.8 and 6.5 mg/L respectively, which is approximately 36 times greater than background concentrations for lakes in the Adirondack region. The bottom water of seventh Lake was adequately oxygenated during the study period.

Morphometry



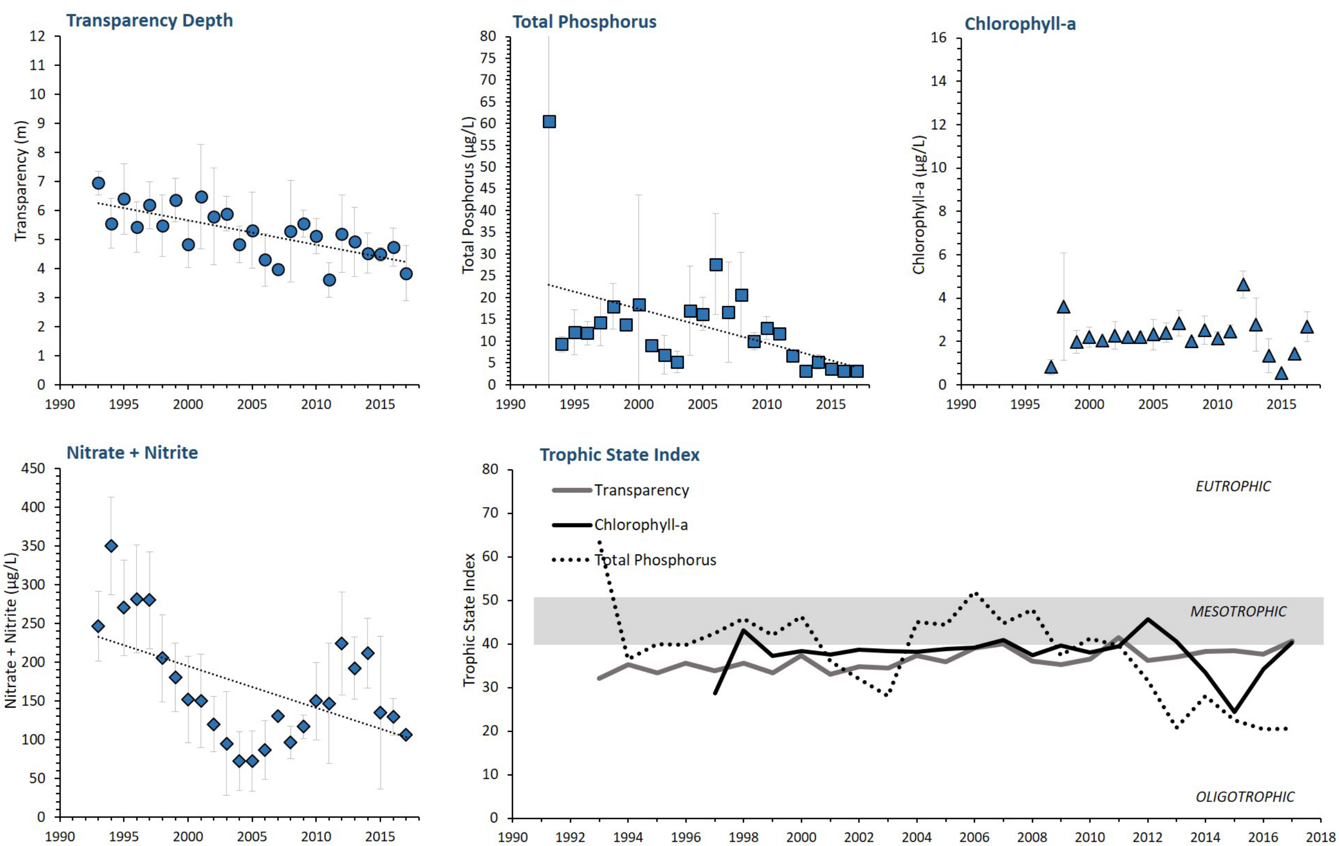
Lake Area (ha)	334
Max Depth (m)	27
Volume (m^3 x 10^6)	42
Shoreline (km)	21
Watershed Area (ha)	4,220
Retention Time (yrs)	0.8
Surface Water Area (%)	13
Forested Area (%)	62
Developed Area (%)	3
Wetland Area (%)	20
State Road Length (km)	10.7
Local Road Length (km)	2.3

Acidity



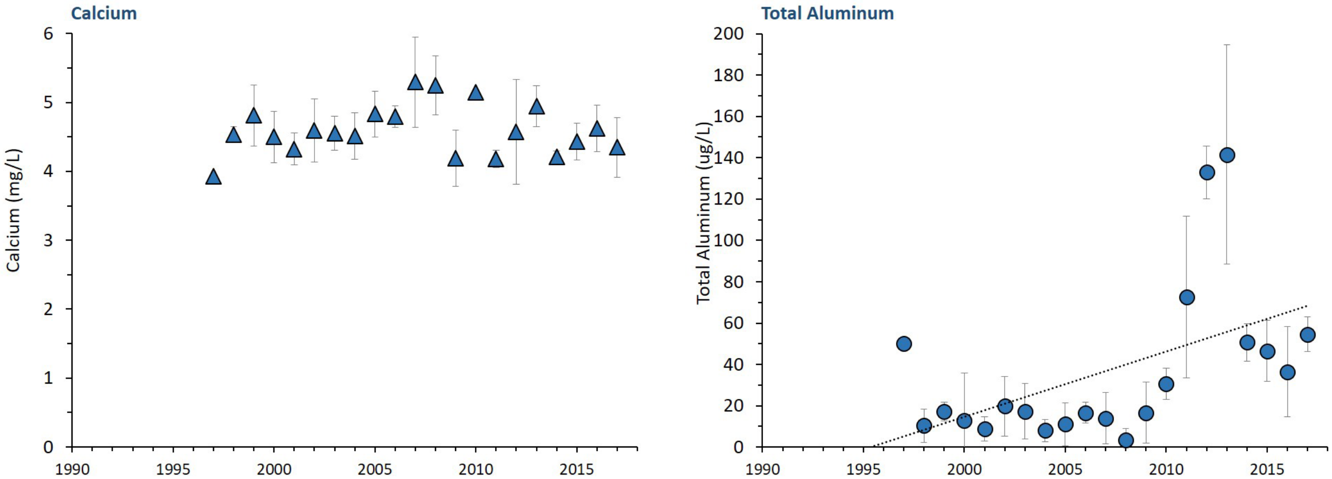
Annual average acidity (left panel) and alkalinity (right panel) of Seventh Lake, 1993 - 2017. Shaded box denotes range of circumneutral condition (pH 6.5-7.5). Error bars denote one standard deviation of the mean. Alkalinity has exhibited an increasing trend since 1993 ($p = 0.001$, tau = 0.56).

Trophic State



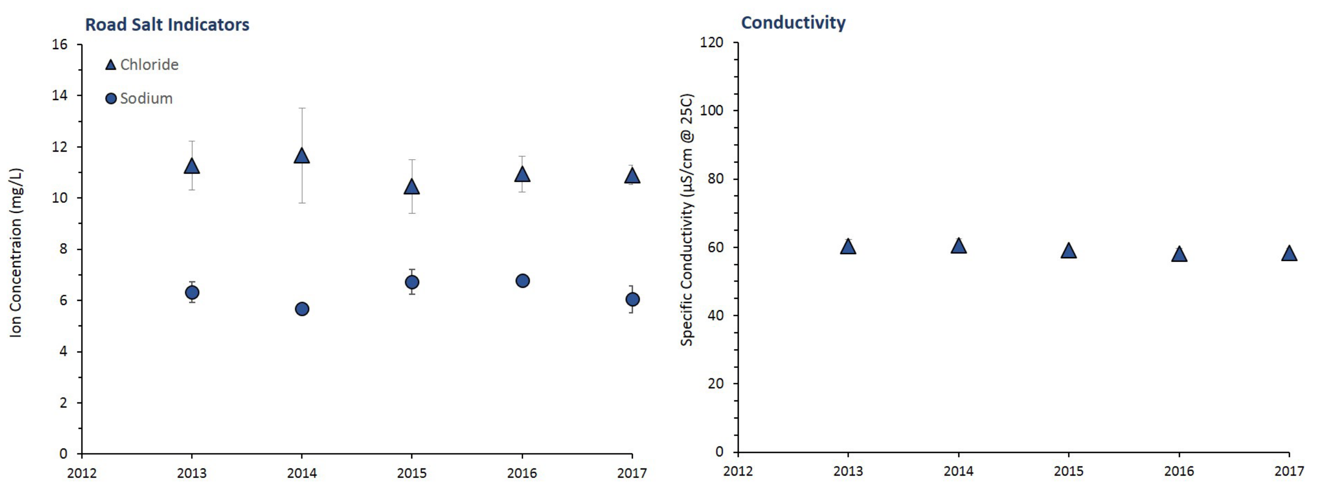
Average values for key trophic state indicators of Seventh Lake, 1993-2017. Error bars represent one standard deviation of the mean. Transparency depth, and the concentration of total phosphorus and nitrate have all exhibited a decreasing trend since 1993 (Transparency: $p < 0.005$, tau = 0.56; Total phosphorus: $p < 0.001$, tau = 0.41; Nitrate: $p = 0.02$, tau = 0.33).

METALS



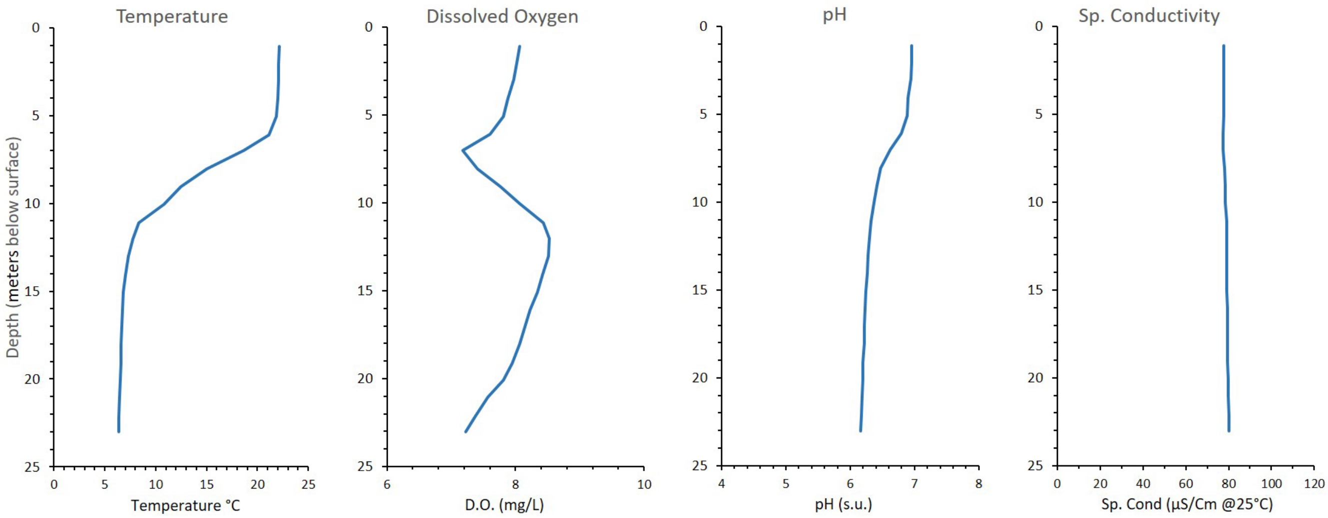
Annual average concentration of calcium and total aluminum in Seventh Lake, 1997-2017. Error bars represent one standard deviation of the mean. Total aluminum has exhibited a significant increase since 1993 (p = 0.01, tau = 0.38).

ROAD SALT



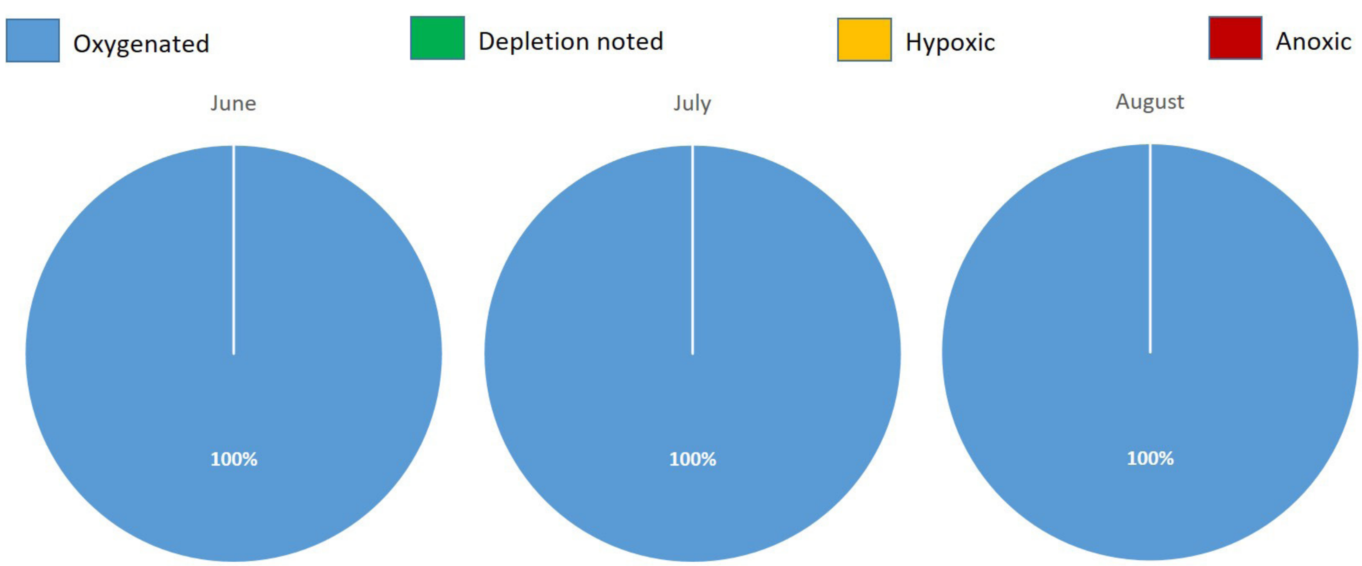
Annual average values of sodium and chloride ions (left panel), and specific conductivity (right panel) in Seventh Lake, 2013-2017. Error bars represent one standard deviation of the mean.

Lake Profile - August 2017



Depth profiles of temperature, dissolved oxygen, pH, and specific conductivity in Seventh Lake during the August 2017 sampling trip.

Dissolved Oxygen Content



Proportion of monthly sampling trips where the bottom water of Seventh Lake (1 meter off bottom) was observed to be oxygenated (D.O. > 4.0 mg/L), experiencing noted depletion (< 4.0 mg/L), hypoxic (< 2.0 mg/L) or anoxic (< 0.5 mg/L). Data is from the period of 1993 to 2017.

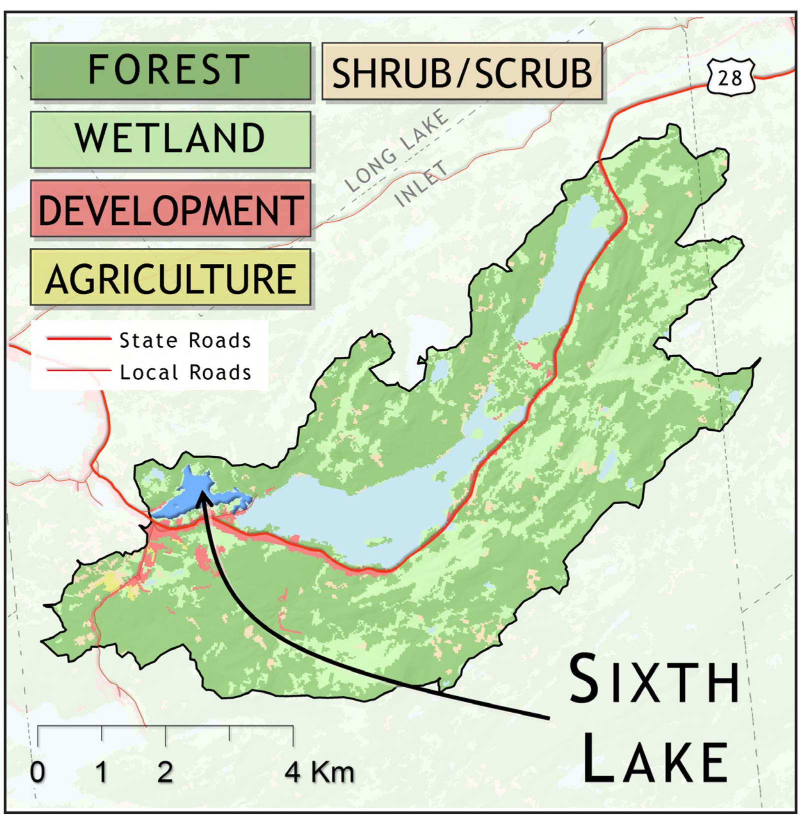
SIXTH LAKE

Summary

Sixth Lake is a 47-hectare waterbody, located within a 4,407-hectare watershed that is dominated by forest cover. The ratio of lake-volume to watershed area results in rapid water exchange, estimated at 25 times per year. Long term monitoring by HCSWCD produced the following findings.

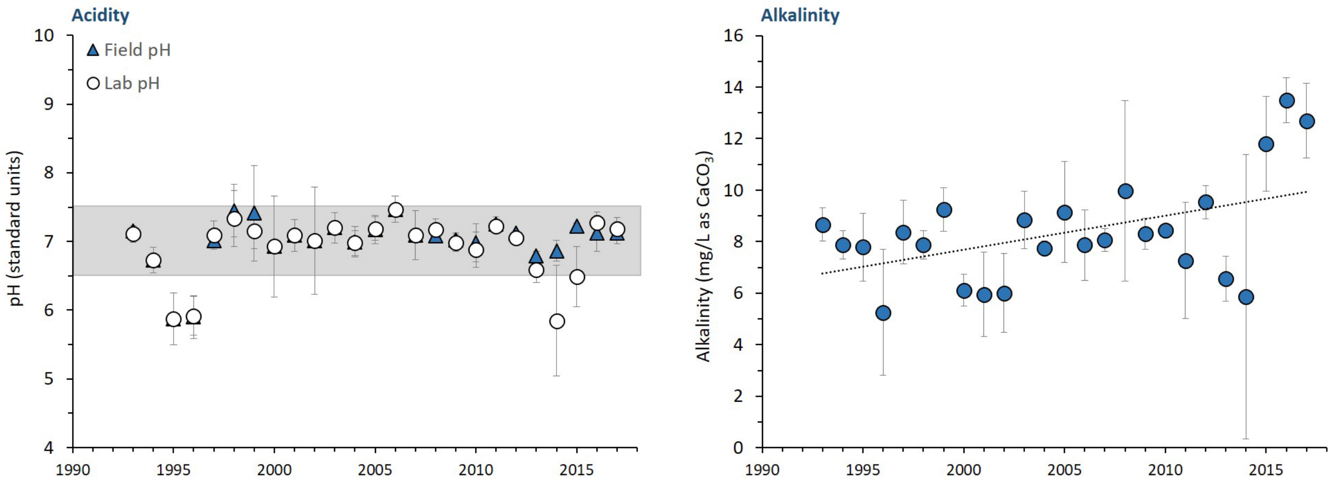
The surface water of the lake is best classified as circumneutral, with average annual pH values that were typically in the range of 6.5 to 7.5 standard units. The alkalinity of the lake has exhibited a slight, yet significant, increase since 1993. Between the years 2015 and 2017, alkalinity averaged 13 mg/L, indicating that the lake had low sensitivity to acid deposition. The lake is best classified as mesotrophic. The transparency of the lake has experienced a significant decline over the study period, and has decreased by an average depth of 1 meter since the early 1990s. The chemistry of the lake was moderately influenced by the 15 km of roads in the watershed. The concentration of chloride and sodium between the years 2015 and 2017 averaged 11.5 and 6.9 mg/L respectively, which is approximately 38 times greater than background concentrations for lakes in the Adirondack region. The bottom water of Seventh Lake experienced rapid oxygen depletion during the summer months. Hypoxic or anoxic water was encountered during 92% of the August sampling trips.

Morphometry



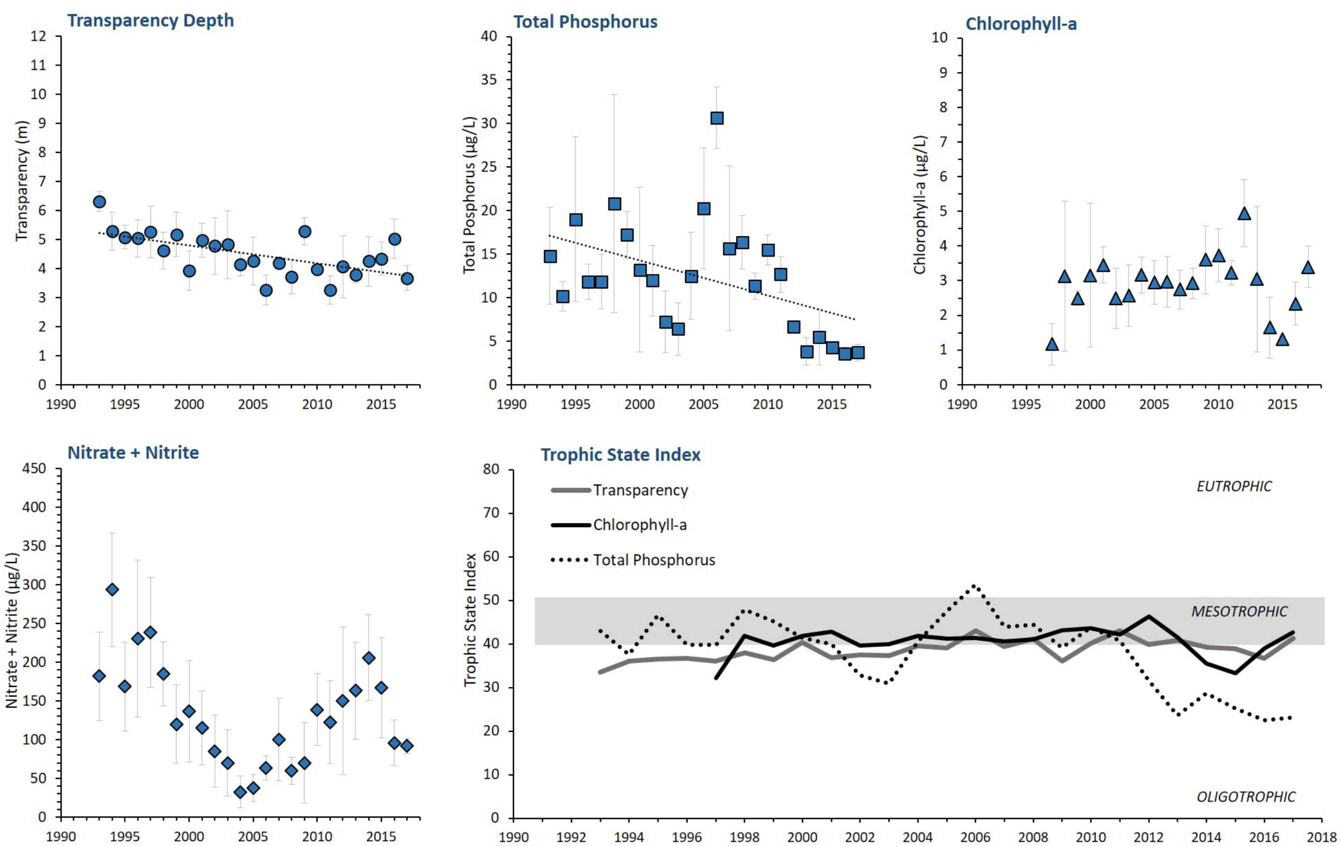
Lake Area (ha)	47
Max Depth (m)	13
Volume (m^3 x 10^6)	1.5
Shoreline (km)	6.2
Watershed Area (ha)	4,407
Retention Time (yrs)	0.04
Surface Water Area (%)	14
Forested Area (%)	61
Developed Area (%)	3
Wetland Area (%)	20
State Road Length (km)	11.8
Local Road Length (km)	3.5

ACIDITY



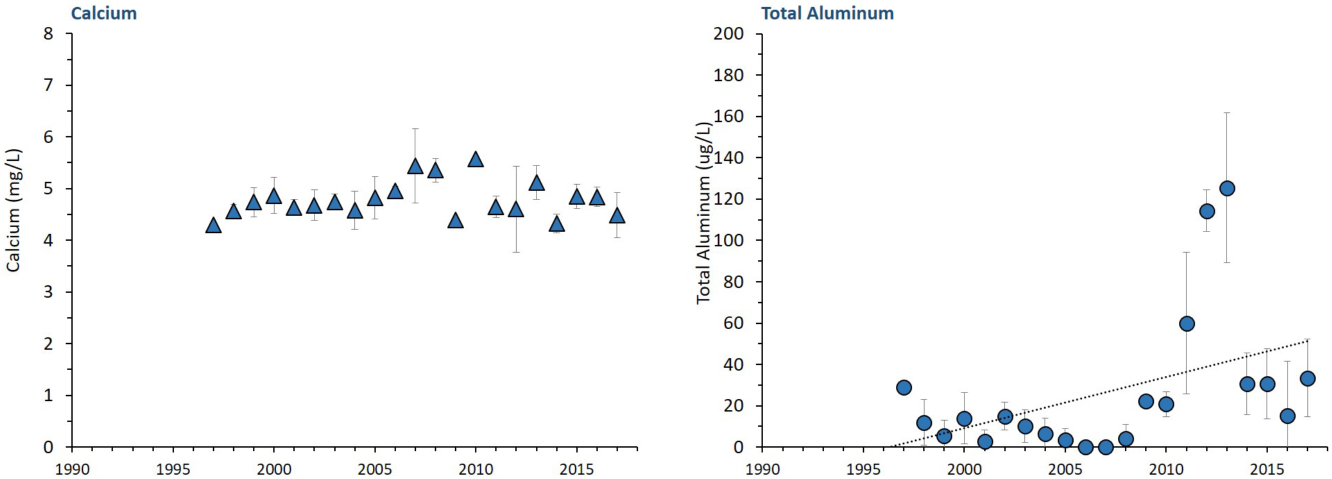
Annual average acidity (left panel) and alkalinity (right panel) of Sixth Lake, 1993 - 2017. Shaded box denotes range of circumneutral condition (pH 6.5-7.5). Error bars denote one standard deviation of the mean. Alkalinity has exhibited an increasing trend since 1993 ($p = 0.05$, tau = 0.30).

TROPHIC STATE



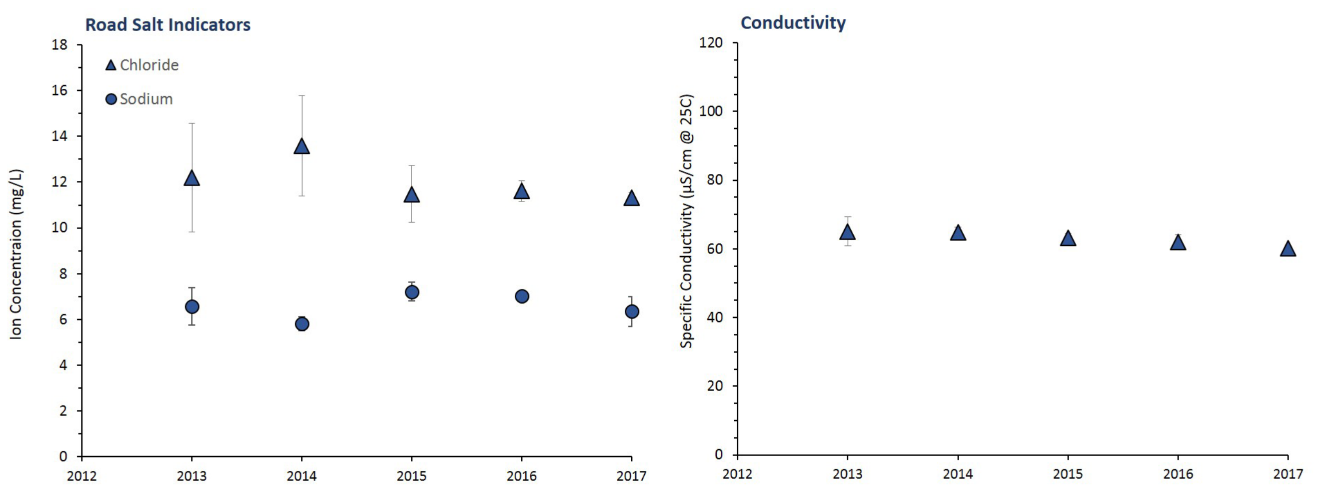
Average values for key trophic state indicators of Sixth Lake, 1993-2017. Error bars represent one standard deviation of the mean. Transparency depth, and total phosphorus concentration have both exhibited a decreasing trend since 1993 (Transparency: $p < 0.002$, tau = 0.44; Total phosphorus: $p < 0.01$, tau = 0.38).

METALS



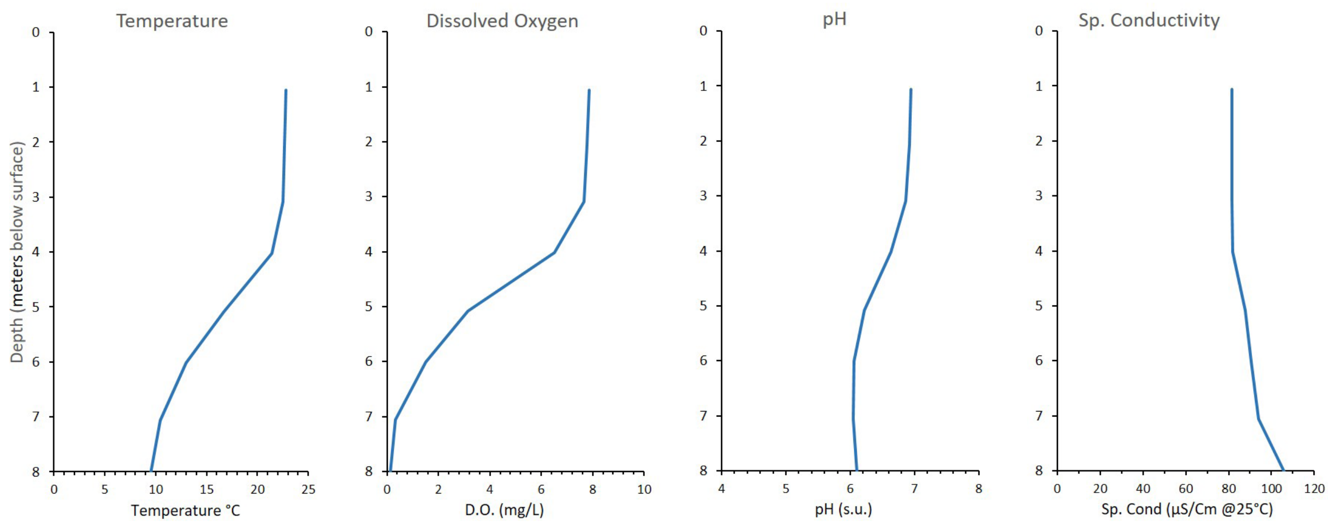
Annual average concentration of calcium and total aluminum in Sixth Lake, 1997-2017. Error bars represent one standard deviation of the mean. Total aluminum has exhibited a significant increase since 1993 (p = 0.04, tau = 0.333).

ROAD SALT



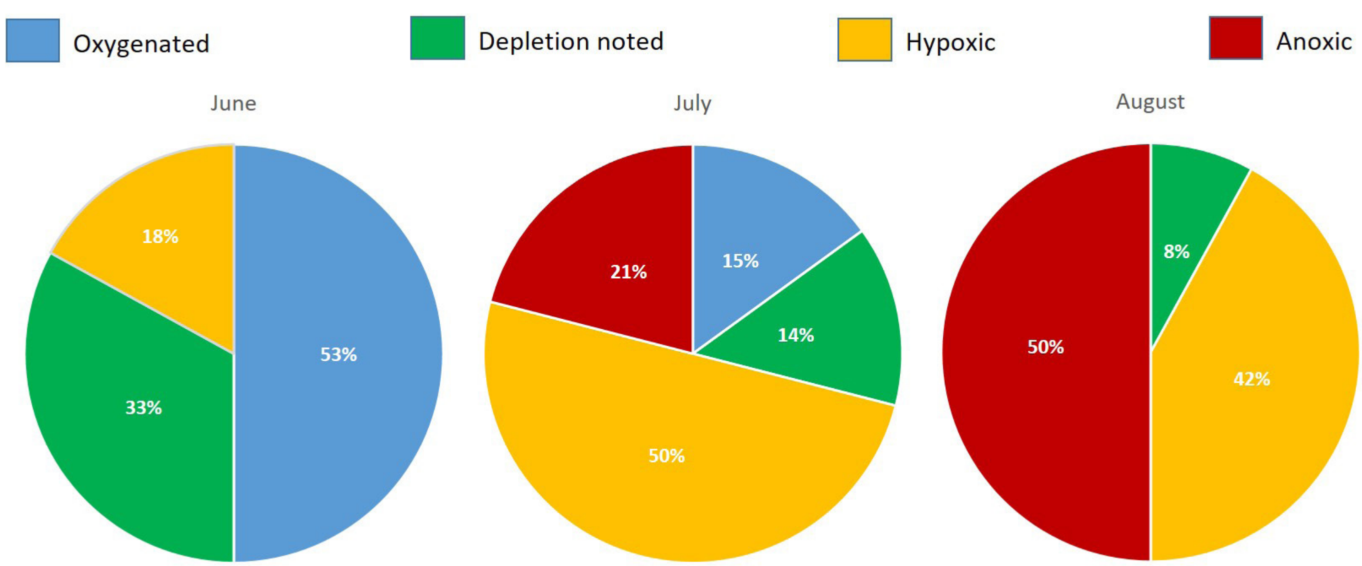
Annual average values of sodium and chloride ions (left panel), and specific conductivity (right panel) in Sixth Lake, 2013-2017. Error bars represent one standard deviation of the mean.

Lake Profile - August 2017



Depth profiles of temperature, dissolved oxygen, pH, and specific conductivity in Sixth Lake during the August 2017 sampling trip.

Dissolved Oxygen Content



Proportion of monthly sampling trips where the bottom water of Sixth Lake (1 meter off bottom) was observed to be oxygenated (D.O. > 4.0 mg/L), experiencing noted depletion (< 4.0 mg/L), hypoxic (< 2.0 mg/L) or anoxic (< 0.5 mg/L). Data is from the period of 1993 to 2017.

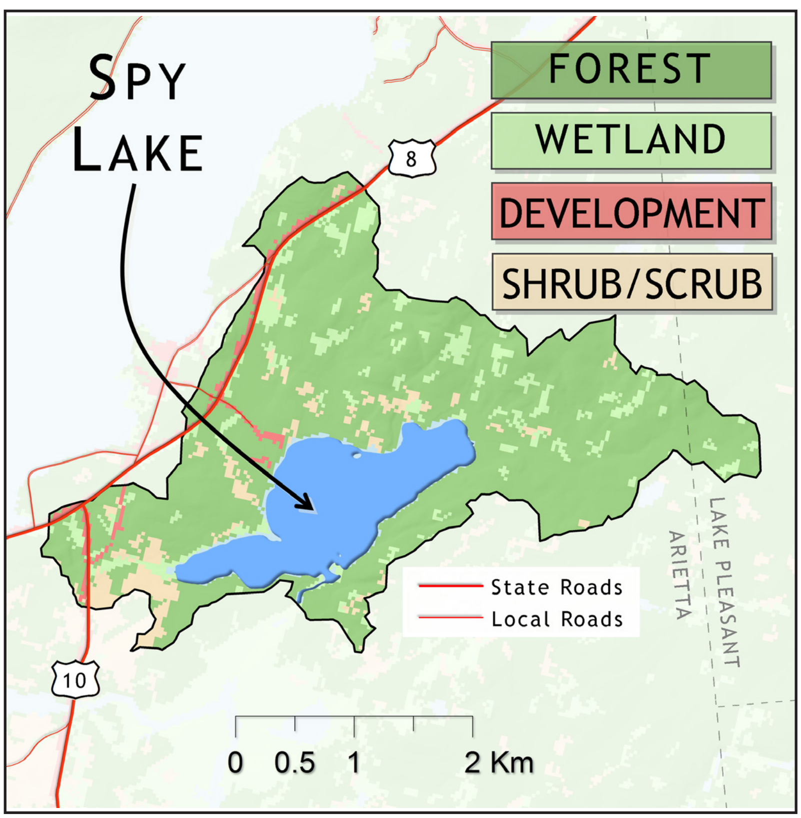
SPY LAKE

SUMMARY

Spy Lake is a 154-hectare waterbody, located within a 1,039-hectare watershed that is dominated by forest cover. Long term monitoring by HCSWCD produced the following findings.

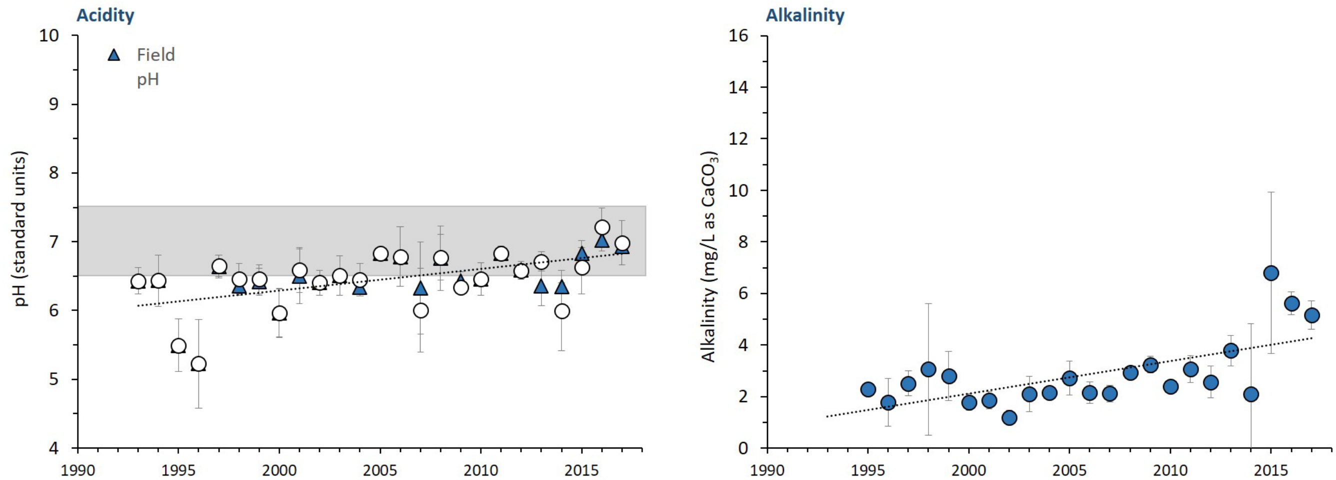
The surface water of the lake is slightly acidic, but it has exhibited a significant increase in both pH and alkalinity since the monitoring program began in 1993. Between the years 2015 and 2017, alkalinity averaged 6 mg/L, indicating that the lake had moderate sensitivity to acid deposition. The lake is best classified as mesotrophic, and it has experienced a significant decline in total phosphorus concentration. Spy Lake was moderately influenced by the 5 km of roads in the watershed. The concentration of chloride and sodium between the years 2015 and 2017 averaged 15.2 and 7.7 mg/L respectively, which is approximately 50 times greater than background concentrations for lakes in the Adirondack region. The bottom water of Spy Lake experienced rapid oxygen depletion during the summer months. Hypoxic or anoxic water was encountered on 87% of the July sampling trips and 100% of the August trips.

MORPHOMETRY



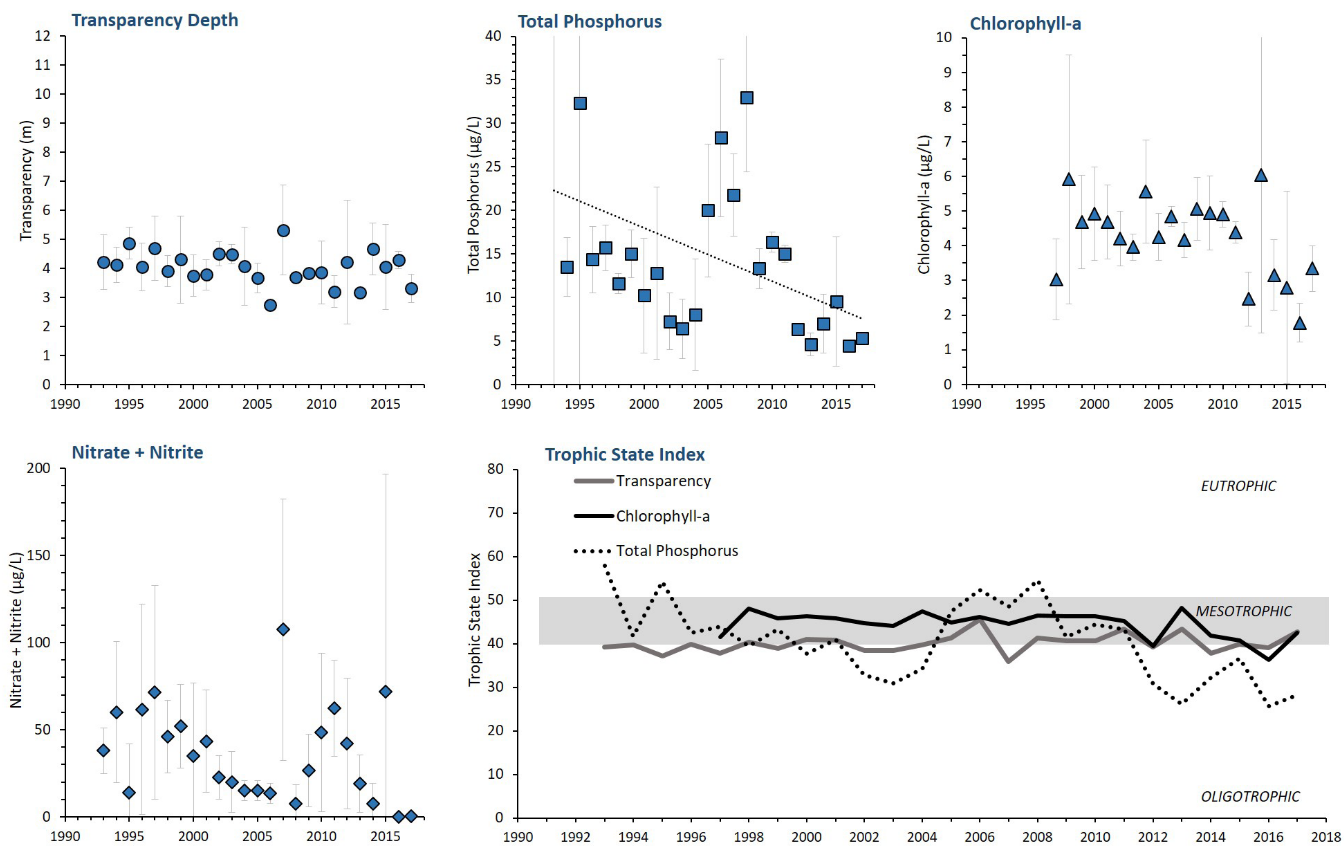
Lake Area (ha)	154
Max Depth (m)	9
Volume (m^3 x 10^6)	7.8
Shoreline (km)	8.4
Watershed Area (ha)	1,039
Retention Time (yrs)	1.0
Surface Water Area (%)	17
Forested Area (%)	73
Developed Area (%)	2
Wetland Area (%)	5
State Road Length (km)	3.9
Local Road Length (km)	0.8

Acidity



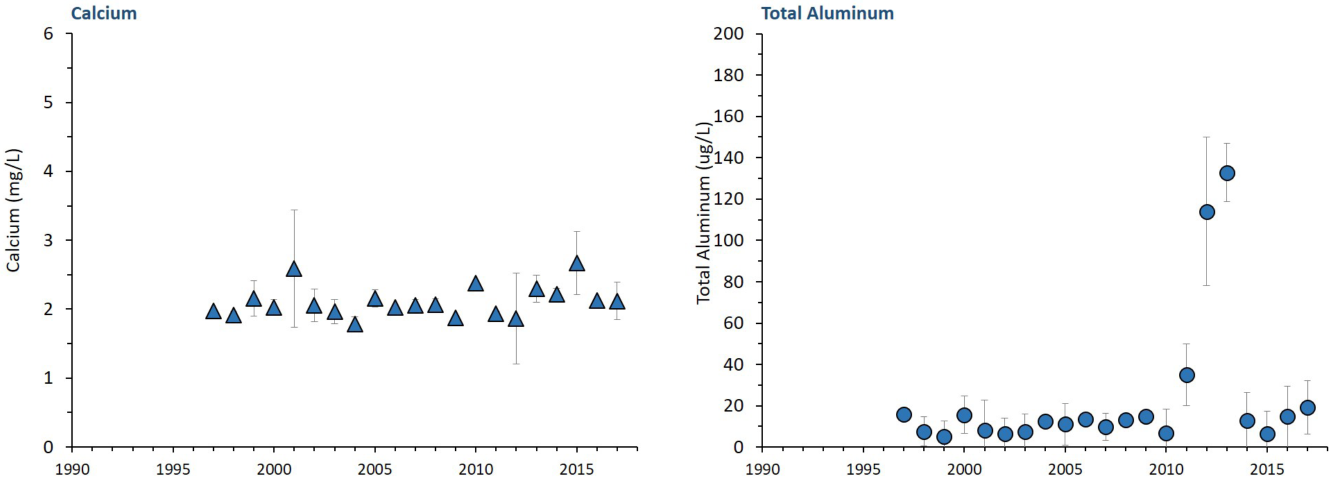
Annual average acidity (left panel) and alkalinity (right panel) of Spy Lake, 1993 - 2017. Shaded box denotes range of circumneutral condition (pH 6.5-7.5). Error bars denote one standard deviation of the mean. The pH and alkalinity of the lake have exhibited increasing trends since 1993 (pH: $p = 0.01$, tau = 0.37; Alkalinity: $p = 0.03$, tau = 0.40).

Trophic State



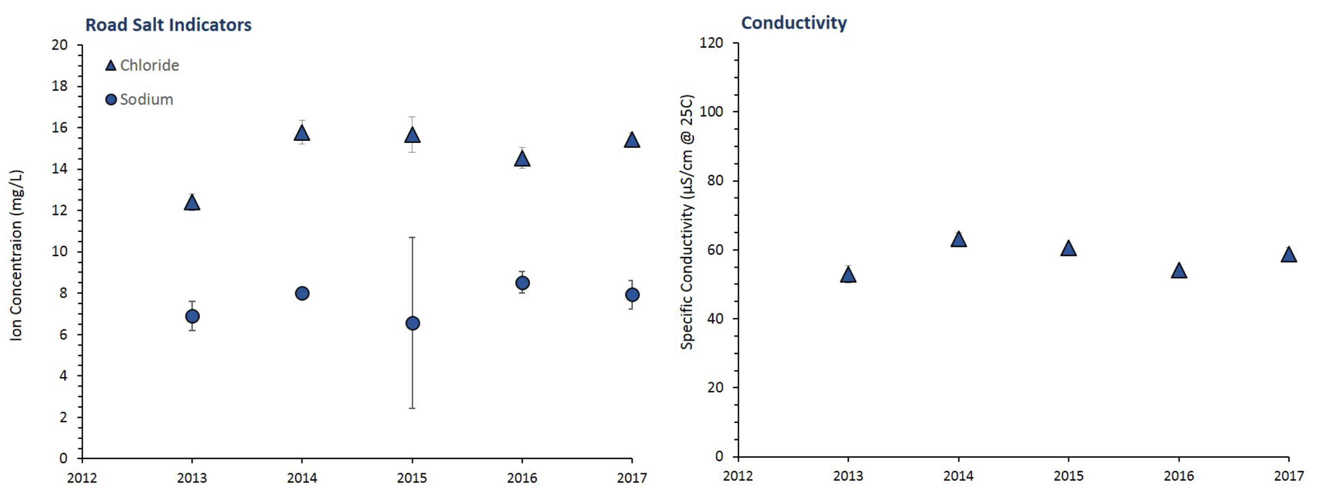
Average values for key trophic state indicators of Spy Lake, 1993-2017. Error bars represent one standard deviation of the mean. Total phosphorus concentration has exhibited a decreasing trend since 1993 ($p < 0.01$, tau = 0.37).

Metals



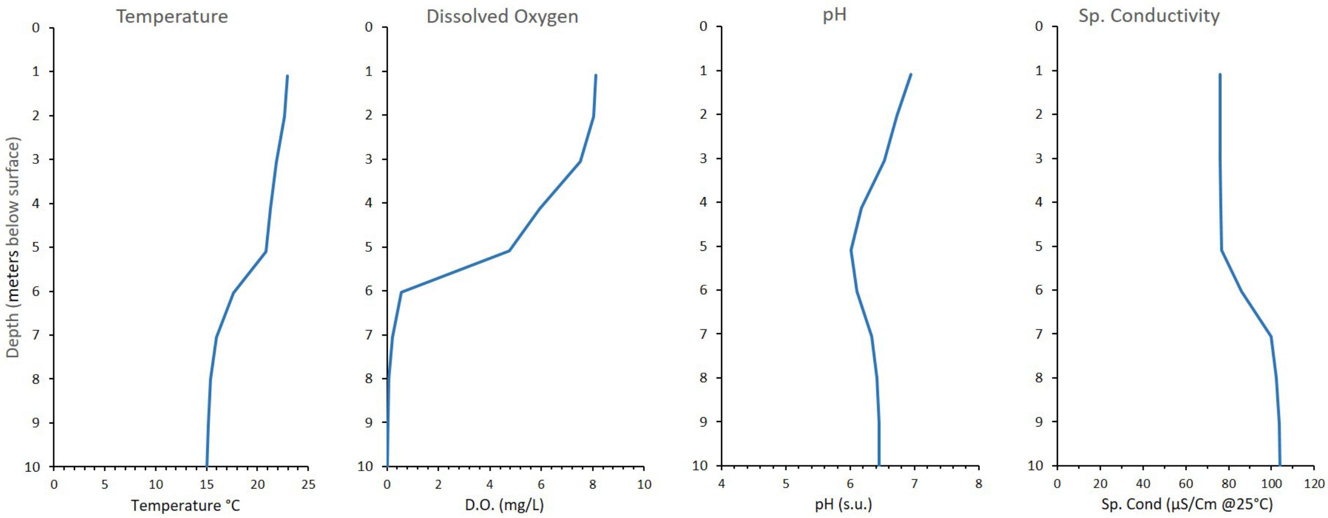
Annual average concentration of calcium and total aluminum in Spy Lake, 1997-2017. Error bars represent one standard deviation of the mean.

Road Salt



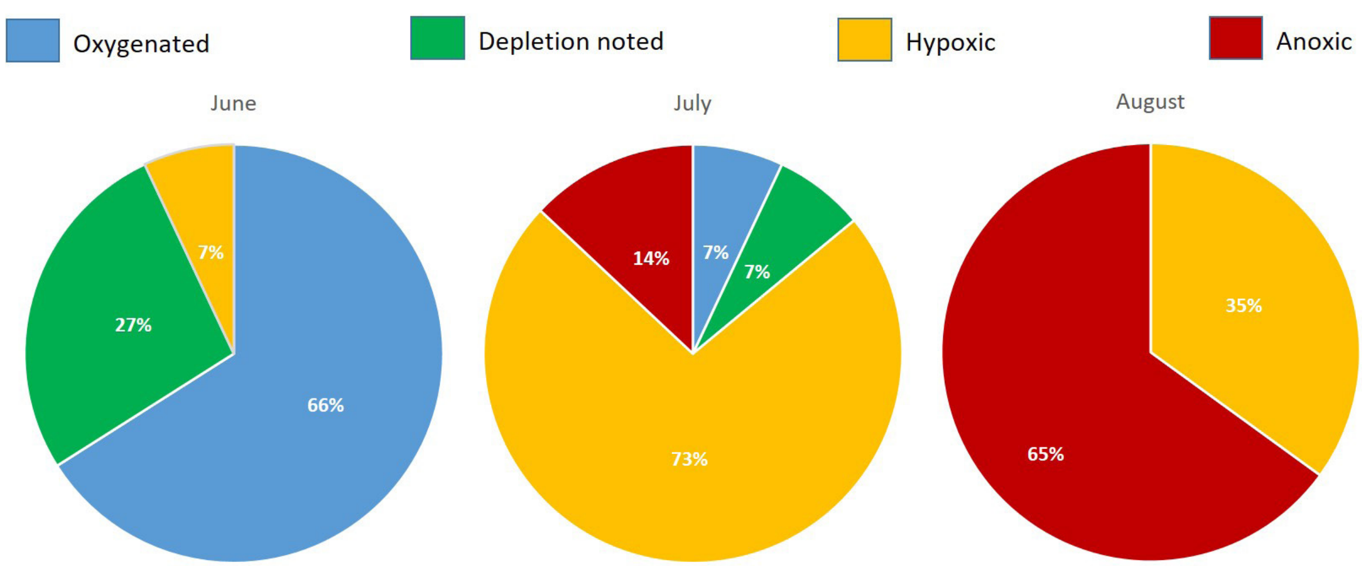
Annual average values of sodium and chloride ions (left panel), and specific conductivity (right panel) in Spy Lake, 2013-2017. Error bars represent one standard deviation of the mean.

LAKE PROFILE - AUGUST 2017



Depth profiles of temperature, dissolved oxygen, pH, and specific conductivity in Spy Lake during the August 2017 sampling trip.

DISSOLVED OXYGEN CONTENT



Proportion of monthly sampling trips where the bottom water of Spy Lake (1 meter off bottom) was observed to be oxygenated (D.O. > 4.0 mg/L), experiencing noted depletion (< 4.0 mg/L), hypoxic (< 2.0 mg/L) or anoxic (< 0.5 mg/L). Data is from the period of 1993 to 2017.

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