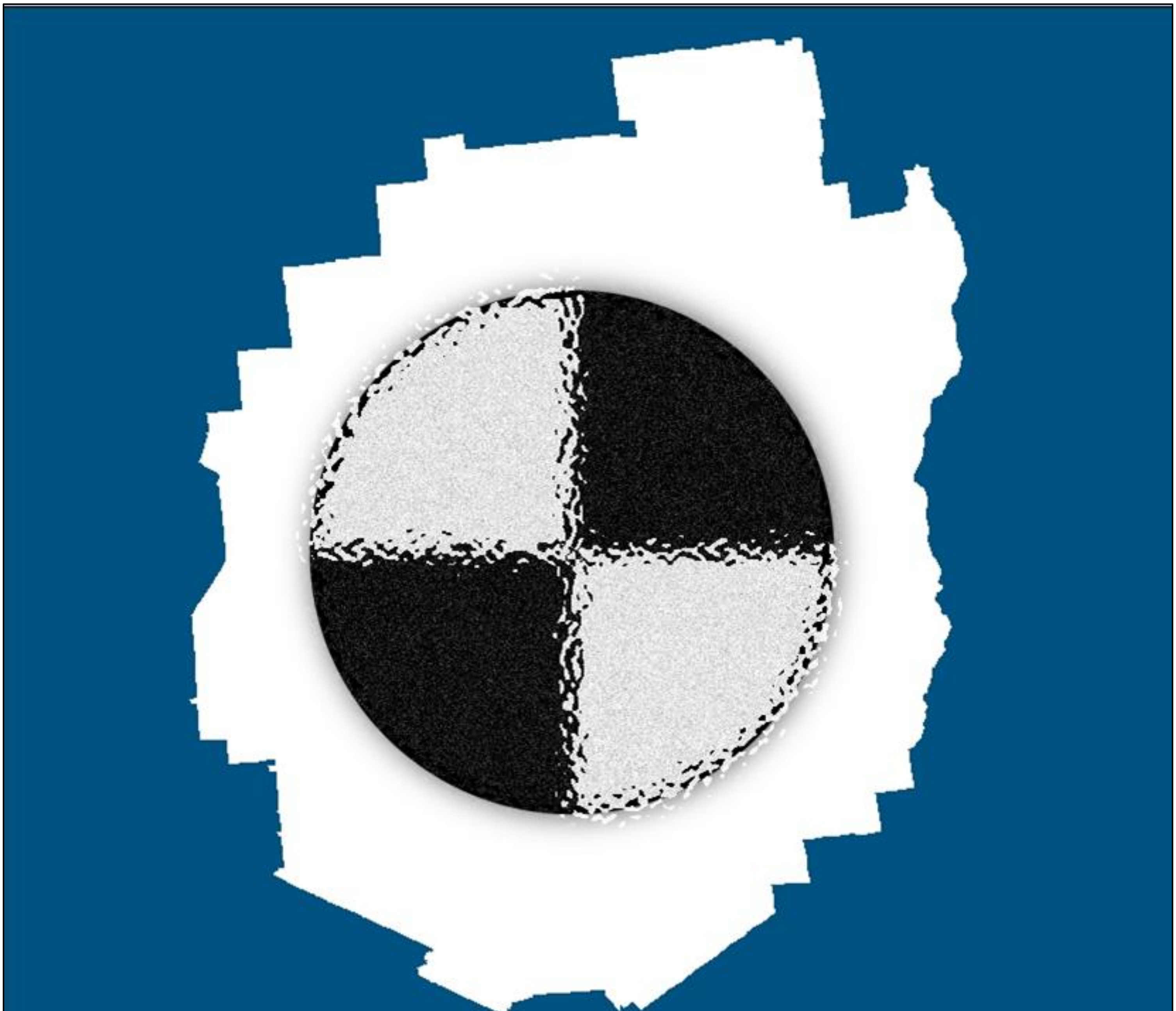
Adirondack Lake Assessment Program

2015 Report

ALAP



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Acknowledgments

The Adirondack Lake Assessment Program (ALAP) is a collaboration between the Paul Smith's College Adirondack Watershed Institute (www.adkwatershed.org) and Protect the Adirondacks (www.protectadks.org). 2015 marked the 18th year of ALAP. The narrative and results presented in this report were produced by Corey Laxson, Elizabeth Yerger, Sean Regalado, and Daniel L Kelting. Laboratory work on samples received from ALAP volunteers was conducted by Elizabeth Yerger, Sean Patton, Corey Laxson, Hunter Favreau, and Dan Kelting. Administrative support, volunteer coordination, and numerous program contributions were provided by Peter Bauer, Nancy Bernstein, Evelyn Greene, and Elizabeth Yerger.

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*Corresponding author Corey Laxson at claxson@paulsmiths.edu

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John and Dorothy Adami
Denise Baer
James Belott
Anya Bickford and Doug Chamberalin
Nancy Gucker Birdsall
Jim Bowen
Harriet and George Burrell
Jacob Burstein
Karl Butz
Robert Colegrove
John and Ellen Collins
C.K. Cunningham
Arlene Davis
Charlotte Demers
Mark Denicore
John Donoghue
Jack Drury
John Duryea
David Ellison
John Englert
Fred Eshelman
Russ Evatt
Rick Findlay
Jim and Nancy Fregoe
Ethan Gingell
John Goddard
Laura Gouthreau
Mark Greene
Evelyn Greene
Peter Halsch
Bob Hammond
Joe Hancock
Marsha and Jerry Hickey
David and James Hoffman
Jocelyn Jerry
John Johanson
Scott and Lynn Johnson
Eileen and John Jungbluth
Lee and Nancy Keet
H. Kemp
Margaret and Henry Kinosian
Lewis Kinter
Ed Kipp
Bruce Kitney
Irene Krotz
Tim and Alice Ladue
Joseph Laundry
George Lee
James McMartin Long
Stuart Lucks
Robert and Carl Manning
Mary Lou Marien
John McGlade
Bill and Ann Marie McKeon
David Meade
John Merriman
Nancy Morrill
Patty Morrison
Anne Moses
Susan Murante
Susan Nettleton
Rose and Tom Neuhard
Judith Peabody
Bruce Peck
Andrew Pickett
Barb Quigley
John Sayles
Bob Schwajlyk
Harold Shippey
Ruth Spina
Steven Stoddard
Ben Strader
Ken and Joanne Strike
Randall Swanson
Peter Taylor
Norine Thibault
Phyllis Thompson
Keith Trombly
Amy Vedder
Mary Wanzer
Terry Warner
David Washburn
Stacy and Joe Webb
Scott Weller
Brendan Wiltse
Alan Woodruff

Table of Contents

List of Figures

List of Tables

How to Use This Report

Welcome to the 2015 ALAP Report! Once again we have enacted a major change to the reporting format. Instead of issuing 75 individual lake reports we have designed a single report that encompasses all the information of the old style reports plus plenty of new material as well. We believe the move to a single report represents a substantial upgrade for the program for several reasons. First, a single report highlighting the water quality across the entire region will attract wider interest than dozens of lake specific reports; and it will be much more useful for academics, government agencies, non-profits, lake associations, and interested individuals. Secondly, ALAP participants will now have easy access to lake information from all of the participating lakes without having to search and download files from a website. Lastly, a single document greatly improves our reporting efficiency, allowing ALAP to be cost effective and affordable.

This report is designed to provide lake information to the informed lay person, scientific community, lake managers, and other interested individuals. As such, it is written in a way to provide something for everyone. New this year is a section titled "*Understanding and Interpreting ALAP Data*". We hope this section will provide readers with greater appreciation for lake science as well as improved ability to interpret the data for their lake. The data for each participating lake has been reduced down to a 2-page description and can be found in the section titled "*Individual Lake Reports*". Participating lakes that wish to have a full stand-alone report produced for them are encouraged to contact the corresponding author.

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 measurements used in this report to English units are readily available through internet searches. The amount of chemical elements dissolved in the lake samples are always described using metric concentration units. The most common ways to express chemical data are milligrams per liter (mg/L) and micrograms per liter (µg/L). One milligram per liter is equal to one part analyte to one million parts water. One microgram per liter is equal to one part analyte to one billion parts water.

Image 1. Sunset on Middle Saranac Lake (photo courtesy of Brendan Wiltse).

Overview of ALAP

The Adirondack Lake Assessment Program (ALAP) is a highly successful citizen science lake monitoring program that combines the enthusiasm of volunteers with the technology and expertise of scientists in the environmental field. Citizen science programs like ALAP are quickly becoming the 21st century model for handling large scale research and monitoring projects. These collaborations are mutually beneficial in that they address the scientific communities need for more researchers, and provide citizens with the benefit of knowing they helped advance the understanding of a cherished resource (Toerpe 2013). There are many citizen science lake monitoring programs across the country, the vast majority of which are administered at the state level. ALAP is the only program to focus on a specific region.

Image 2. Young citizen scientists from Camp Whippoorwill preparing to collect an ALAP sample from Augur Lake (photo courtesy of Nancy Gucker-Birdsall).

ALAP is a cooperative effort between Protect the Adirondacks (Protect) and the Adirondack Watershed Institute (AWI). The objectives of ALAP are to (1) develop a long term water quality database for Adirondack lakes and ponds that can be used by multiple stakeholders, (2) document historical trends in their limnological condition, and (3) engender lake stewardship by providing opportunities for citizens to participate in scientific monitoring.

ALAP continues to be a highly successful program. Established in 1998 with 9 participating lakes, the program has grown to 75 participating lakes in 2015. ALAP lakes are from all across the Adirondack Region (Figure 1 and Table 1). For many lakes the ALAP dataset represents the only available source of information on water quality.

Methods

ALAP volunteers were trained in standard limnological sampling methods by AWI and PROTECT. Data was collected from the deepest location of the lake, 3 to 5 times during the summer months. During each sampling event volunteers observed the secchi transparency reading by lowering a standard 20 cm black and white secchi disk to a depth where it could no longer be seen. This process was repeated and the average secchi depth for that day was recorded. Surface water samples were collected using a 2-meter integrated tube sampler. The contents of the tube were poured into a 1 liter brown bottle and thoroughly mixed. A 250 mL aliquot of the integrated sample was collected for chemical analysis and a second 250 mL aliquot was filtered through a 0.45 µm cellulose membrane filter for chlorophyll-a analysis. The filter was retrieved and wrapped in foil. The water sample and chlorophyll filter were frozen immediately after collection and delivered frozen to the AWI Environmental Research Lab, generally within a 10 day period.

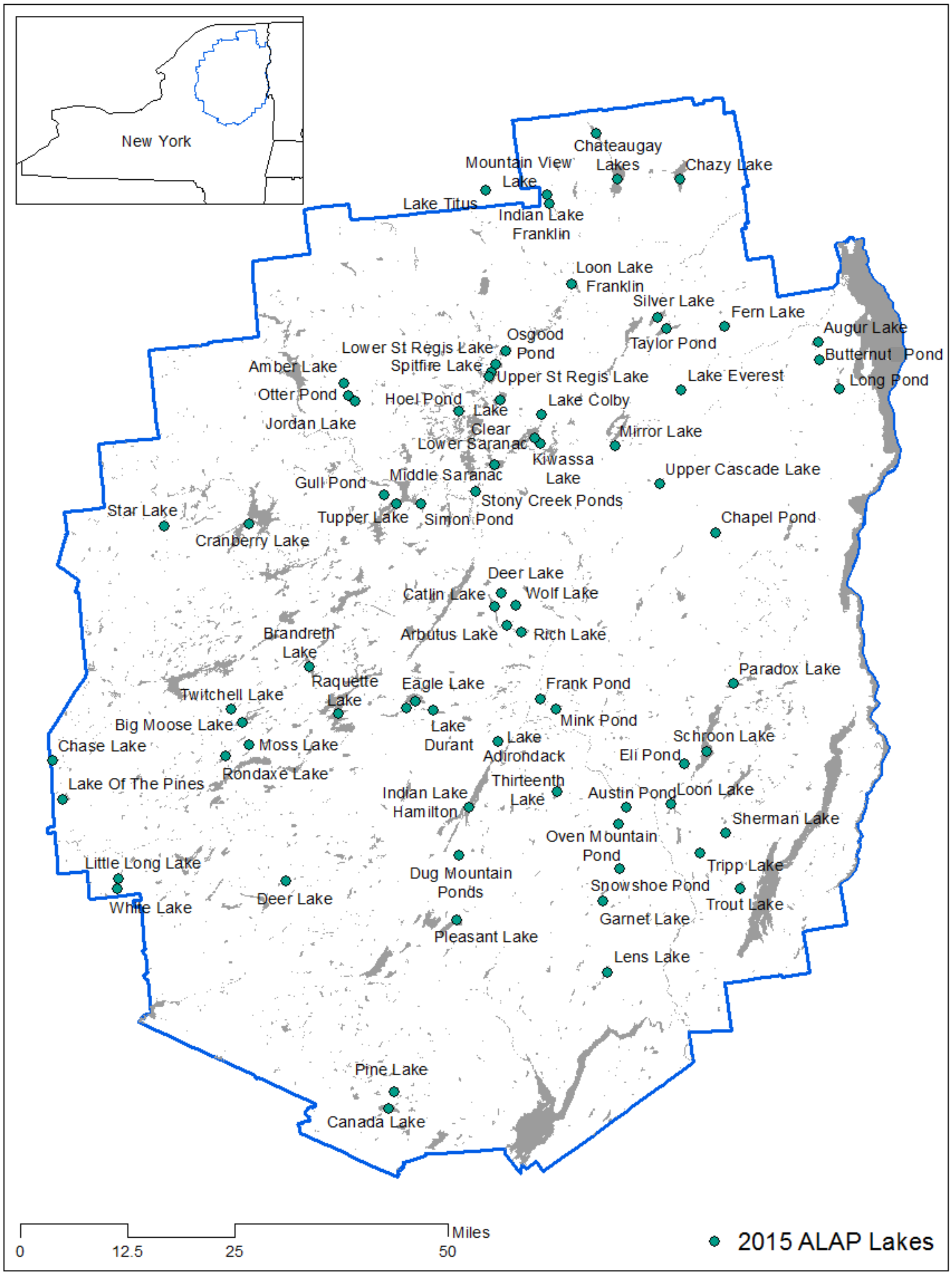


Figure 1 Location of ALAP participants in 2015.

Table 1. 2015 ALAP Lakes organized by the number of years of program participation.

Lake Name	Years	Lake Name	Years	Lake Name	Years
Blue Mt. Lake	18	Thirteenth Lake	15	Lake Adirondack	9
Cranberry Lake	18	Tripp Lake	15	Lower Chateaugay Lake	9
Eagle Lake	18	Twitchell Lake	15	Upper Chateaugay Lake	9
Loon Lake (FC)	18	Wolf Lake	15	Chapel Pond	8
Oven Mt. Pond	18	Garnet Lake	14	Simon Pond	7
Silver Lake	18	Lens Lake	14	Upper Cascade Lake	7
Brandreth Lake	17	Lower Saranac Lake	14	Augur Lake	6
Eli Pond	17	Lower St Regis Lake	14	Jordan Lake	6
Gull Pond	17	Upper St Regis Lake	14	Lake Titus	6
Little Long Lake	17	Canada Lake	13	Otter Pond	6
Austin Pond	16	Kiwassa Lake	13	Amber Lake	5
Middle Saranac Lake	16	Lake Colby	13	Lake Clear	5
Osgood Pond	16	Raquette Lake	13	Lake Durant	5
Stony Creek Ponds	16	Sherman Lake	13	Star Lake	5
Trout Lake	16	Snowshoe Pond	13	Loon Lake (WC)	4
White Lake	16	Spitfire Lake	13	Rondaxe Lake	3
Arbutus Lake	15	Tupper Lake	13	Mirror Lake	2
Catlin Lake	15	Fern Lake	12	Paradox Lake	2
Deer Lake	15	Indian Lake (HC)	12	Schroon Lake	2
Hoel Pond	15	Big Moose Lake	11	Butternut Pond	1
Lake of the Pines	15	Dug Mountain Ponds	11	Chase Lake	1
Long Pond	15	Indian Lake (FC)	11	Frank Pond	1
Pine Lake	15	Moss Lake	11	Lake Everest	1
Pleasant Lake	15	Mountain View Lake	11	Mink Lake	1
Rich Lake	15	Chazy Lake	9	Taylor Pond	1

Samples were analyzed for laboratory pH, conductivity, alkalinity, total phosphorus, nitrate, chlorophyll-a, chloride, calcium and sodium at the AWI Environmental Research Lab following the analytical methods listed in Appendix 1. Results for the current year were tabulated and time series charts were constructed from the annual average value for each indicator. Trend analysis was conducted on lakes with five or more years of data using Kendall's non-parametric regression to test the hypothesis "there is no relationship between the indicator and time". Simple linear trend lines were fit to data with significant trends ($P<0.05$) and displayed on the corresponding chart.

Understanding and Interpreting ALAP Data

Transparency

Transparency 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 was created by the Italian astronomer Pietro Angelo Secchi in the mid-19th century (Image 3).

Transparency is a great indicator of lake condition because it is influenced by many factors related to water quality and human perception. Secchi data is used most often to interpret 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 decreases (see Trophic State). There are a number of other water quality issues that can influence transparency depth such as turbidity (cloudiness of the water), suspended sediment, and dissolved chemicals. For example, the transparency of many lakes in the Adirondacks is influenced by the amount of colored dissolved organic material in the water (see Color).

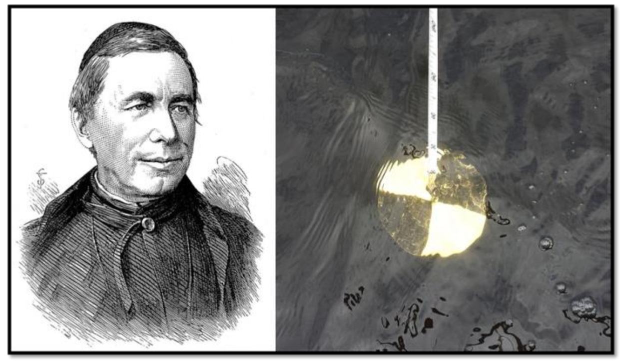


Image 3. Pietro Angelo Secchi (1818 - 1878) and the limnological tool named after him.

In 2015 average ALAP transparencies ranged from less than 1 meter to as high as 8.5 meters in depth. The majority of lakes (63%) had average transparency depths of 4.0 meters or less (Figure 2). Analysis of the historical data reveals that 90% of study lakes had no observable change over time and 9% had a decreasing trend in transparency (less transparent).

Chlorophyll-a

Chlorophyll-a is the primary photosynthetic pigment found in all freshwater species of algae and cyanobacteria. Studying actual algal productivity in a lake is a difficult and expensive undertaking. A measurement of chlorophyll-a however is relatively simple and inexpensive, and provides a surrogate measure of algal productivity (Wetzel 2001). Chlorophyll-a 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. Algal biomass is affected by the interaction of nutrient availability, light, water temperature, and grazing so there can be considerable variation in chlorophyll concentrations throughout the year depending on which of these factors is limiting growth at a particular time. Typically, major changes in algal biomass (e.g. an algae bloom), and thus chlorophyll, are usually related to changes in the availability of phosphorus, nitrogen, silica or inorganic carbon (Wetzel 2001; Klemer 1990).

Image 4. A chlorophyll filter clogged with algae. The sample was taken during a cyanobacteria bloom on Spitfire Lake in August, 2014.

Chlorophyll-a is analyzed by filtering a known volume of lake water through a fine (0.45µm) cellulose-acetate filter, which captures the small photosynthetic organisms (Image 4). In the laboratory the filter is macerated and the chlorophyll- is extracted into acetone and is then analyzed with a spectrophotometer.

In 2015 average chlorophyll-a concentrations ranged from less than 0.5 µg/L to as high as 18 µg/L. The majority of lakes (83%) had values between 1.5 and 6.5 µg/L (Figure 2). Analysis of the historical data reveals that 81% of participating lakes showed no statistical change in algal productivity over time and that 18% had a decreasing trend in chlorophyll-a concentration.

Phosphorus

Phosphorus is of major importance to structure and metabolism of all organisms. However, it exists in relatively small amounts in freshwater systems compared to other essential nutrients such as carbon, hydrogen, oxygen, and sulfur. The addition of extra phosphorus to an aquatic system allows production to increase greatly because all other essential elements are typically available in excess. Thus phosphorus is typically the limiting nutrient in aquatic systems, and widely considered as the most important contributor to reduced water quality in lakes (Schindler 1977; Søndergaard et al. 2003). Natural weathering releases phosphorus from rocks and soils, and it also enters our watersheds in fertilizers, human and animal waste, and atmospheric deposition. Phosphorus exists in a number of forms in aquatic systems, including readily available dissolved phosphorus, and organically and inorganically bound phosphorus. Total phosphorus is a measurement of all of the forms of phosphorus combined and serves as an important indicator of overall 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 20µg/L (NYSDEC Clean Lakes Assessment).

Total phosphorus is analyzed by digesting the lake water sample with a strong acid (sulfuric acid) and an oxidizing agent (ammonia persulfate). All of the numerous forms of phosphorus are converted to phosphate, which is then quantified with an automated spectrophotometer (Image 5)

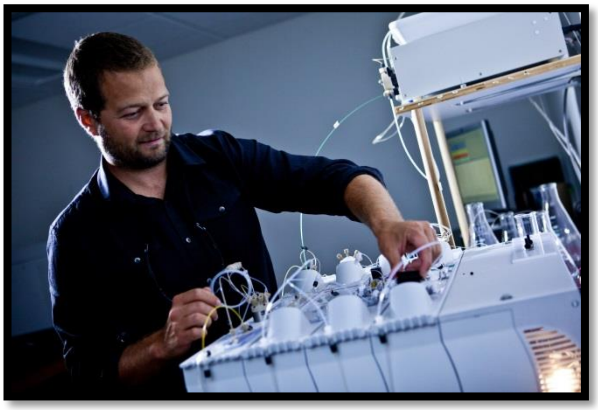


Image 5. Preparing the Lachat QC 8500 for chemical analysis of ALAP samples in the Environmental Research Lab of the AWI.

In 2015 the average total phosphorus concentrations ranged from below detection levels to as high as 30 µg/L. The majority of lakes (72%) had average values less than 12 µg/L (Figure 2). Analysis of the historical data reveals that 66% of participating lakes showed no statistical change in phosphorus concentration over time and that 33% exhibited a decreasing trend. Significant improvements were made to our phosphorus methodology in 2010. The method change may be partially responsible for the decreasing trend exhibited by some lakes.

Trophic State

Trophic status is a term derived from the Greek word *trophi*, meaning food or nourishment, and is used by limnologists to explain the overall productivity of a lake. 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 words *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 words *Meso*, 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 the trophic index method. The fixed boundary method uses predetermined ranges of transparency, total phosphorus, and chlorophyll to classify the lakes trophic status. A good example of a fixed boundary is the traditional method employed by the NYS DEC that appears in Table 2 (NYSDEC Clean Lakes Assessment).

Table 2. Fixed boundary trophic status determination employed by the NYSDEC.

Parameter	Oligotrophic	Mesotrophic	Eutrophic
Transparency	>5	2-5	<2
Total Phosphorus	<10	10-20	>20
Chlorophyll-a	<2	2-8	>8

The most commonly used tropic state index is Carlson's TSI (Carlson 1977). This index uses 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.

Regardless of the lakes trophic state, or the method used to classify it, it's 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).

Of the 76 lakes participating in 2015 we classified 58% as oligotrophic, 39% as mesotrophic, and 3% as eutrophic using Carlson's TSI value for chlorophyll-a (Figure 3).

Image 6. Paddling on Blue Mountain Lake, a classic oligotrophic lake (photo courtesy of Brendan Wiltse).

Color

The observed color of a lake is an optical property that results from light being scattered upwards after selective absorption by water molecules as well as dissolved (metallic ions, organic acids) and suspended materials (silt, plant pigments). For example, alkaline lakes with high concentrations of calcium carbonate scatter light in the green and blue wavelength and thus appear turquoise in color. Lakes rich in dissolved organic matter and humic compounds absorb shorter wavelengths of light such as green and blue and scatter the longer wavelengths of red and yellow, thus these lakes appear to be brown in color (Image 7; Wetzel 2001). Analysis of color can provide us with information about the quantity of dissolved organic matter (DOM) in the water. However, caution should be taken when using color as a surrogate for DOM as color has been shown to behave differently than the total DOM pool in a lake, making it a crude predictor of DOM (Dillon and Molot 1997; Thurman 1985).

Image 7. Dissolved organic matter can make a lake appear different shades of brown due to its selective light absorption.

For objective quantification of apparent color water samples are compared to standards of platinum-cobalt solution (PtCo units) via spectrophotometry. "True color" is the color transmitted by a solution after the removal of suspended material, "apparent color" is the color transmitted without any filtration.

In 2015 the average color values ranged from less than 10 to nearly 200 PtCo, with the majority of lakes (80%) falling between 10 and 50 PtCo units. (Figure 2). Analysis of the historical data reveals that 90% of participating lakes showed no statistical change in color over time and that 9% have exhibited an increasing trend.

pH

In chemistry, pH is used to communicate the acidity or alkalinity of a solution. Technically pH is a surrogate measure of the concentration of hydrogen ions in water (acidity). 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. pH 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.

Table 3. Assessment of lake acidification based on pH

Lake acidity	Status
pH less than 5	Acidic: Critically Impaired
pH 5.0 – 6.0	Acidic: Threatened
pH 6 – 6.5	Acidic: Acceptable
pH 6.5 – 7.5	Circumneutral: non-impacted
pH >7.5	Alkaline: non-impacted

Lakes can become acidified when they are influenced by organic acids from wetlands and bogs or when acidic precipitation falls on a poorly buffered watershed (Driscoll et al. 2003, Wetzel 2001). In the Adirondacks acidification status can be assed from pH values based on the guidelines outlined in Table 3.

In 2015 the average pH values ranged from 5.6 to 8.0. The majority of lakes (94%) fell in the circumneutral range between 6.5 and 7.5 (Figures 3 and 4). Analysis of the historical data reveals that 90% of participating lakes showed no statistical change in pH over time and that 10% have exhibited a increasing trend (less acidic).

Alkalinity

Alkalinity (or acid neutralizing ability) is the capacity of water body to neutralize acids and thereby resist changes in pH. The alkalinity of a lake plays a major role in whether or not a lake is impacted by acid deposition.

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. 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. Alkalinity is quantified by analyzing them amount of dilute acid is required to lower the pH of a lake sample to 4.3 pH units, the point at which all of the carbonate and bicarbonate alkalinity is consumed. The acid neutralizing ability of a lake can be generally assessed following the parameters presented in Table 4.

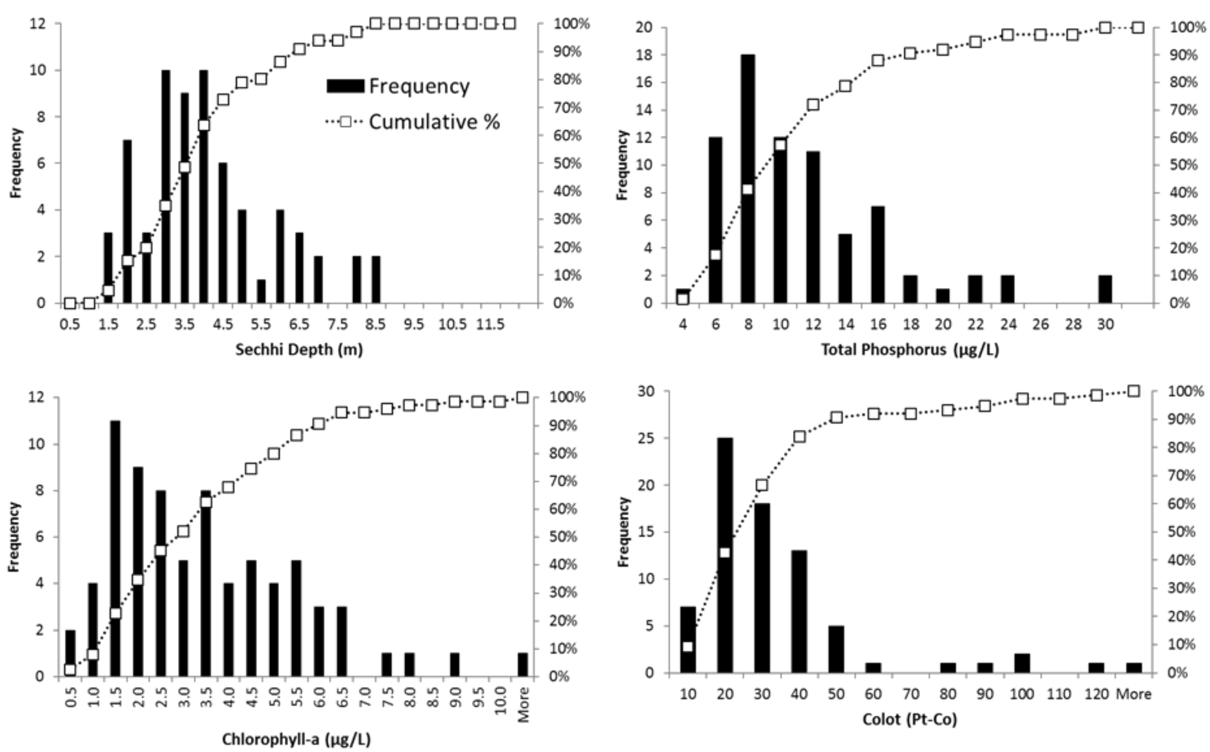


Figure 2. Frequency histograms of average 2015 ALAP values for transparency, total phosphorus, chlorophyll, and color.

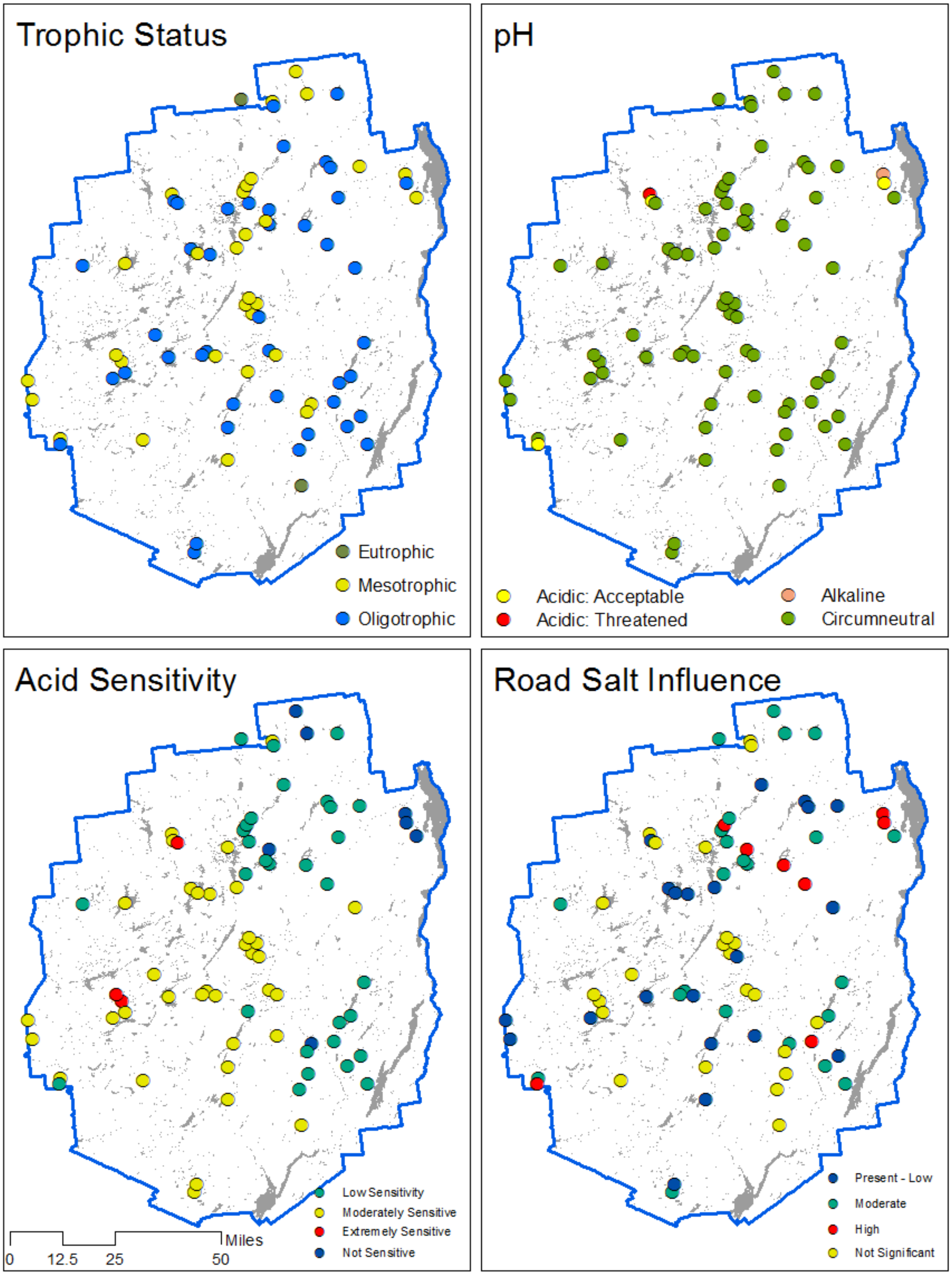


Figure 3. Condition of the 2015 ALAP lakes in terms of trophic state, acidity, acid sensitivity, and road salt influence.

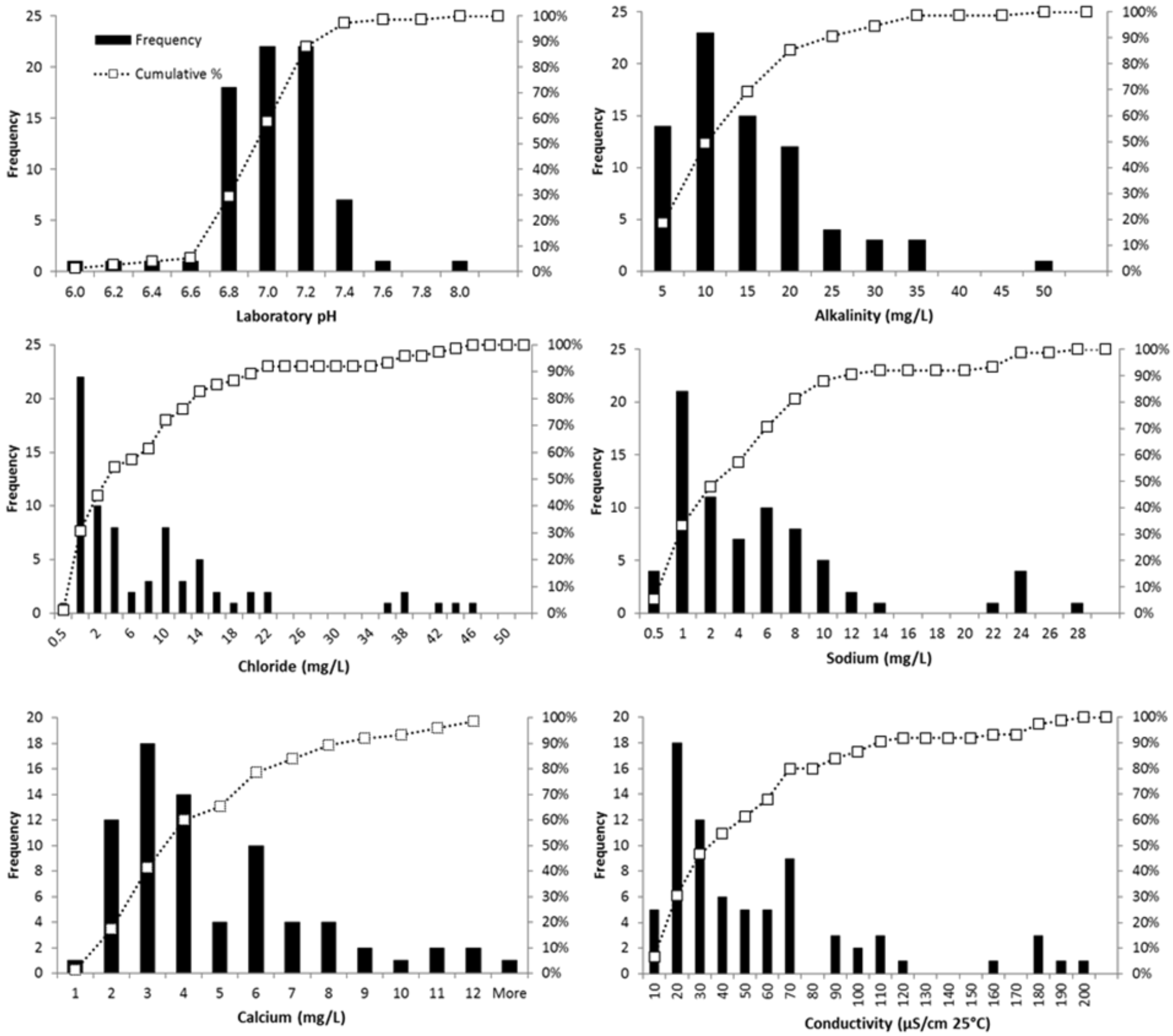


Figure 4. Frequency histograms of average 2015 ALAP values for pH, alkalinity, chloride, sodium, calcium and conductivity.

A wide range of buffering abilities exists across the Adirondack Region. In 2015 the average alkalinity values ranged from less than 2 mg/L to nearly 50 mg/L, with roughly 50% of the lakes exhibiting some acid sensitivity (Figures 3 and 4). Analysis of the historical data reveals that 64% of participating lakes showed no statistical change in alkalinity over time and that 36% have exhibited a negative trend.

Table 4. Acid neutralizing ability and acidification status assessment based on alkalinity concentration (mg/L as $CaCO_3$).

Alkalinity (mg/L)	Buffering 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

Sodium and Chloride

Lakes in the Adirondack region have naturally low concentrations of chloride and sodium, with average background concentrations of 0.2 mg/L and 0.5 mg/L respectively (Kelting et al. 2012). However, wide spread use of road deicers (primarily sodium chloride) have significantly increased the concentration of these chemicals in the environment. Each year approximately 98,000 metric tons of road deicers are spread across state roads in the Adirondacks. (Kelting and Laxson 2014). Recent research by Kelting et al. (2012) highlighted that concentrations of sodium and chloride in Adirondack Lakes are directly proportional to the density of state roads within the watershed.

Road salt can have direct and indirect effects on aquatic ecosystems. 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 run-off such as road side streams or vernal pools (reviewed by Findlay and Kelly 2011; Kelting and Laxson 2010).

Indirect effects to aquatic systems have also been documented. For example sodium actively displaces base cations (Ca, K, and Mg) as well as heavy metals from the soil, potentially elevating their concentration in surface waters. In some extreme cases excessive road salt pollution can interfere with lake stratification due to salts effect on water density (Bubeck et al. 1971; Kjensmo 1997). Sodium and chloride impart an undesirable taste to drinking water. The US EPA has guideline of 250 mg/L for chloride and 20 mg/L for sodium, but these are for drinking water only and are not enforceable standards.

Image 8. Road Salt (NaCl) being loaded into the back of a plow truck (photo by Paul Sancya/AP).

Although it is difficult to use sodium and chloride concentration to assess impact to the aquatic environment, the concentration of these chemicals serve 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 5 as a general guideline for gauging road salt influence on a lake.

Table 5. Assessment of road salt influence based on chloride concentration.

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

Sodium and chloride are analyzed separately from each other in the laboratory using two automated methods. Chloride is measured by injecting the water sample through an ion chromatograph where the chloride is separated from other negatively charged ions by a selective resin and then quantified with a voltmeter. Sodium is analyzed with an atomic emission spectrophotometer. The water sample is introduced into a very hot argon plasma torch that excites the sodium ion into a higher energy state. When the ion relaxes it emits light in a characteristic wavelength, the intensity of which is proportional to the amount of sodium in the sample. Regular analysis of sodium and chloride was initiated by the AWI in 2010. Only a handful of lakes have chloride data that extends before 2010.

As expected, a wide range of salt concentrations existed across the region in 2015, driven primarily by the density of salted roads in the watershed. In 2015 the average chloride concentration ranged from less than 0.5 mg/L to as high as 46 mg/L. Based on these concentrations alone we believe that roughly 70% of the participating lakes are influenced by road salt (Figures 3 and 4). Analysis of the limited historical data reveals that 87% of participating lakes showed no statistical change in chloride over time and that 10% have exhibited an increasing trend.

Image 9. Direct road salt runoff coming off of NYS RT 30 during a thawing event in the spring of 2015. The chloride concentration of this melt water was approaching 5,000 mg/L which is ¼ the concentration of sea water.

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). The majority of 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 under the Adirondacks weathers slowly resulting in a low rate of calcium generation. There are however many lakes in the Adirondacks that reside on calcium rich bedrock resulting in much higher calcium concentrations, examples include Augur Lake (Ca = 12mg/L), Long Pond (Ca = 16 mg/L), and Lake Colby (Ca = 11mg/L).

Environmental stressors can affect the calcium concentration of lakes. Research on northeastern lakes has demonstrated that acid deposition has depleted calcium stores in soils leading to reduced calcium concentrations over time (Strock et al. 2014; Keller et al. 2001). The influence that road salting has on calcium concentrations is an emerging research area. Some 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 increase calcium concentrations in the ground and surfaces water. Kelting and Laxson (2014) observed that the combined concentration of calcium, magnesium and potassium in lakes with paved roads in the watershed was 62% greater than lakes with no paved roads.

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 through the world. 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, lower than most, but not all lakes in the Adirondacks (Whittier et al. 2008).

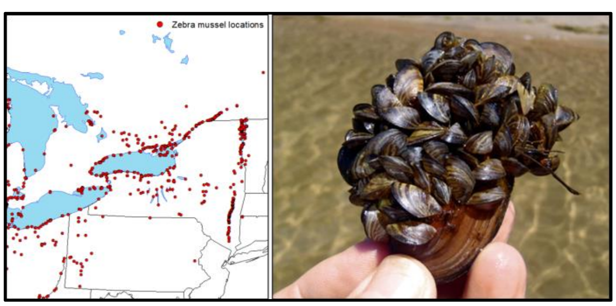


Image 10. Zebra mussel distribution in NYS (left) and an aggregation of zebra mussels growing attached to a native mussel (from USFWS).

Calcium concentration is analyzed alongside sodium and other metals using an atomic emission spectrophotometer and has only been analyzed regularly since 2010 (see Sodium and Chloride). In 2015 the average calcium concentrations values ranged from 1 mg/L to 16 mg/L. The majority of lakes (65%) have calcium concentrations less than 5 mg/L (Figure 4). We found three lakes with calcium concentrations within the minimum range needed to support a viable zebra mussel population (Augur Pond, Austin Pond, and Long Pond). Trend analysis was not performed on calcium concentrations in 2015.

Conductivity

Conductivity is a measurement of the ability of a water sample to conduct electricity. Pure H_2O 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 considered a strong indicator of the amount of dissolved ions in water. Typically the conductivity of a clean undeveloped lake in the Adirondacks is in the range of 10-25 µS/cm. Elevated conductance may be indicative of road salt pollution, faulty septic systems or the influence of bogs and wetlands in the watershed. Conductivity is a very useful surrogate when the relationships between ion concentrations and conductivity are known. For example, conductivity can be used to estimate sodium and chloride concentrations in streams (Daley et al. 2009).

Conductivity is measured in the laboratory with a conductivity meter. The instrument applies an alternating electrical current to two electrodes immersed in the water sample and measures the resulting voltage. Electrical conductance is influenced by water temperature so all measurements are scaled to the conductance at 25° C, known as specific conductivity.

In 2015 the average conductance values ranged from 10µS/cm to 200 µS/cm (Figure 4). We found chloride concentration to be the main driver in lake conductance in the ALAP dataset, chloride concentration explained 91% of the variability in conductivity (Figure 5; $p < 0.001$, $r^2 = 0.91$).

Analysis of the historical data reveals that 70% of participating lakes showed no statistical change in conductivity over time and that 27% exhibited a significant downward trend in conductivity.

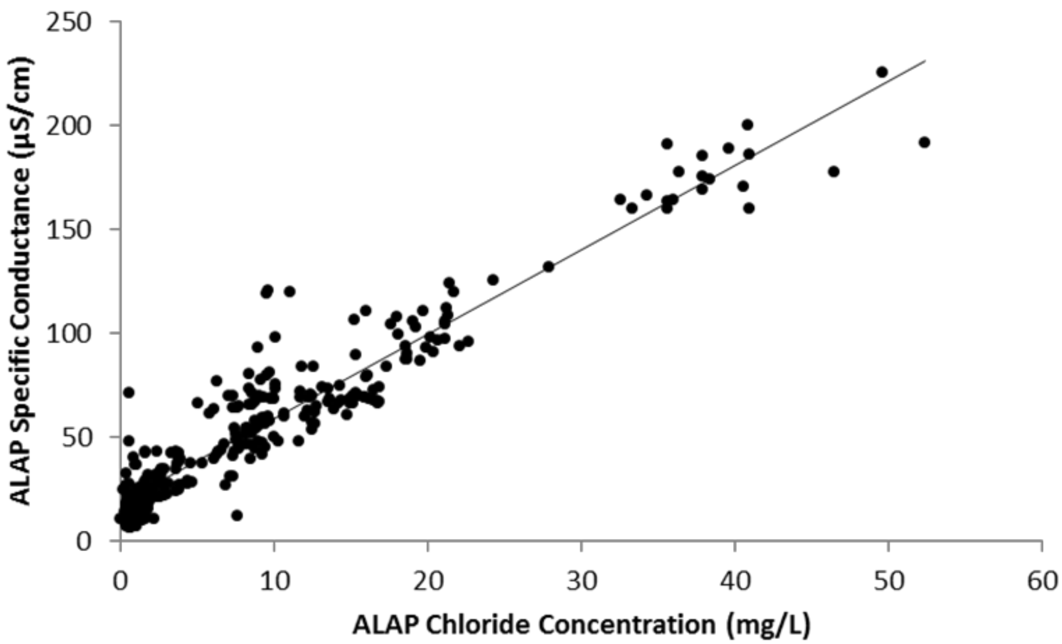
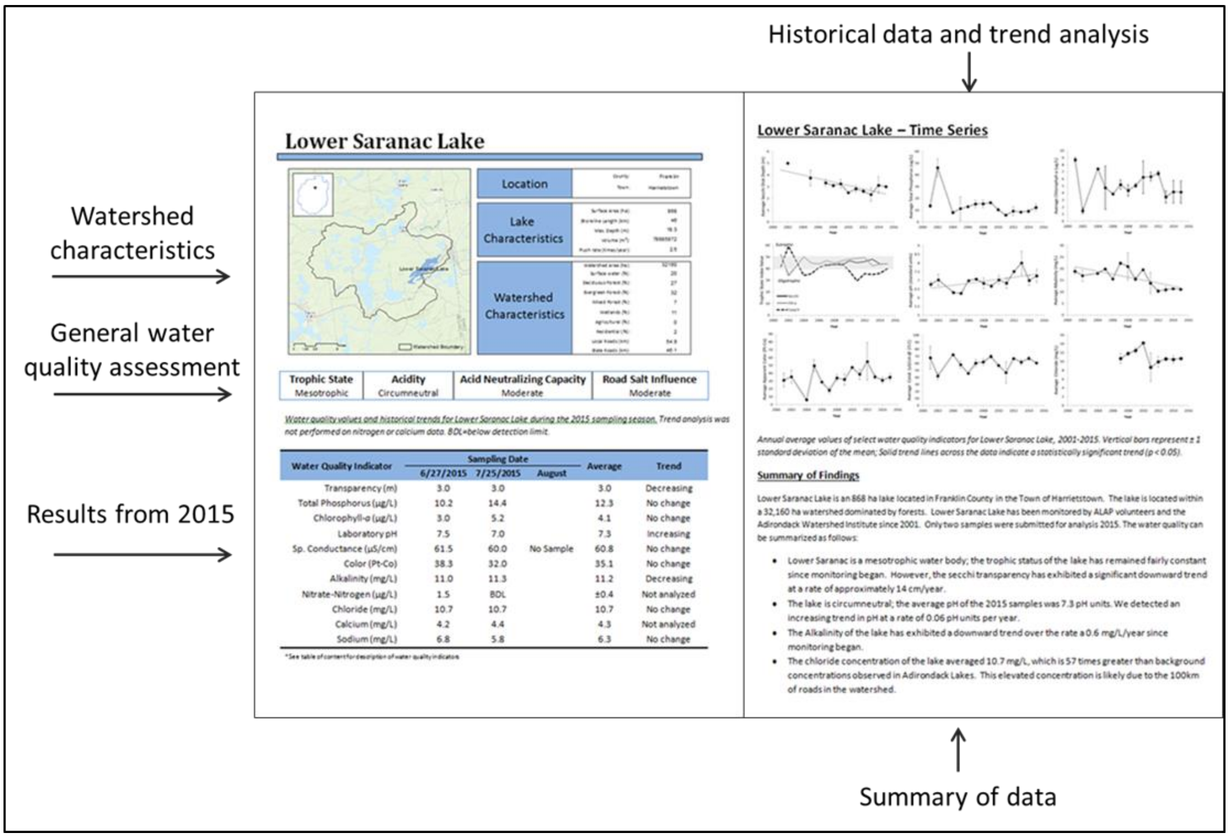


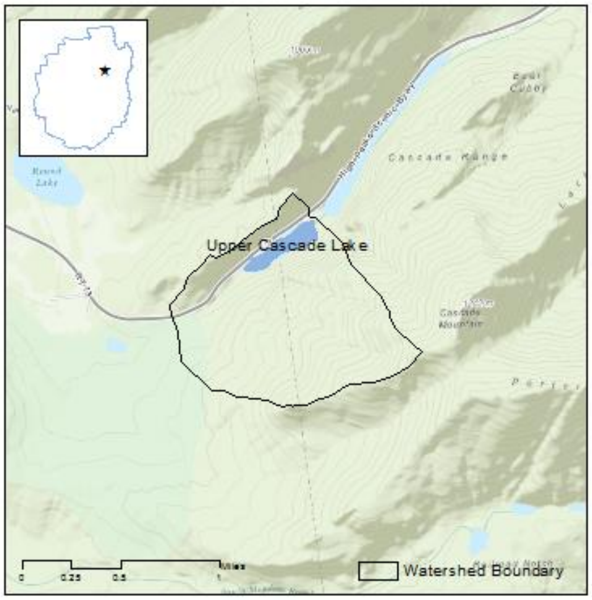
Figure 5. . Relationship between chloride concentration and specific conductance in ALAP lakes from 2015. ($p < 0.001$, $r^2 = 0.91$, n = 305).

Individual Lake Reports

The data and accompanying analysis provided in this report give insight into the water quality of the study lakes, more detailed limnological studies may be necessary to produce management recommendations or specific trend interpretations. Readers interested in additional information or accesses to the raw data are encouraged to contact the corresponding author. Each lake description includes lake and watershed characteristics, general water quality assessment, tabulated 2015 data, historical analysis and a brief summary. An example of the lake report format can be seen below.



Upper Cascade Lake



Location	
County:	Essex
Town:	Keene

Lake Characteristics	
Surface Area (ha):	9
Shoreline Length (km):	2
Max. Depth (m):	19.2
Volume (m^3):	1144425
Flush rate (times/year):	1.5

Watershed Characteristics	
Watershed Area (ha):	213
Surface water (%):	5
Deciduous Forest (%):	43
Evergreen Forest (%):	19
Mixed Forest (%):	27
Wetlands (%):	0
Agricultural (%):	0
Residential (%):	6
Local Roads (km):	0
State Roads (km):	1.4

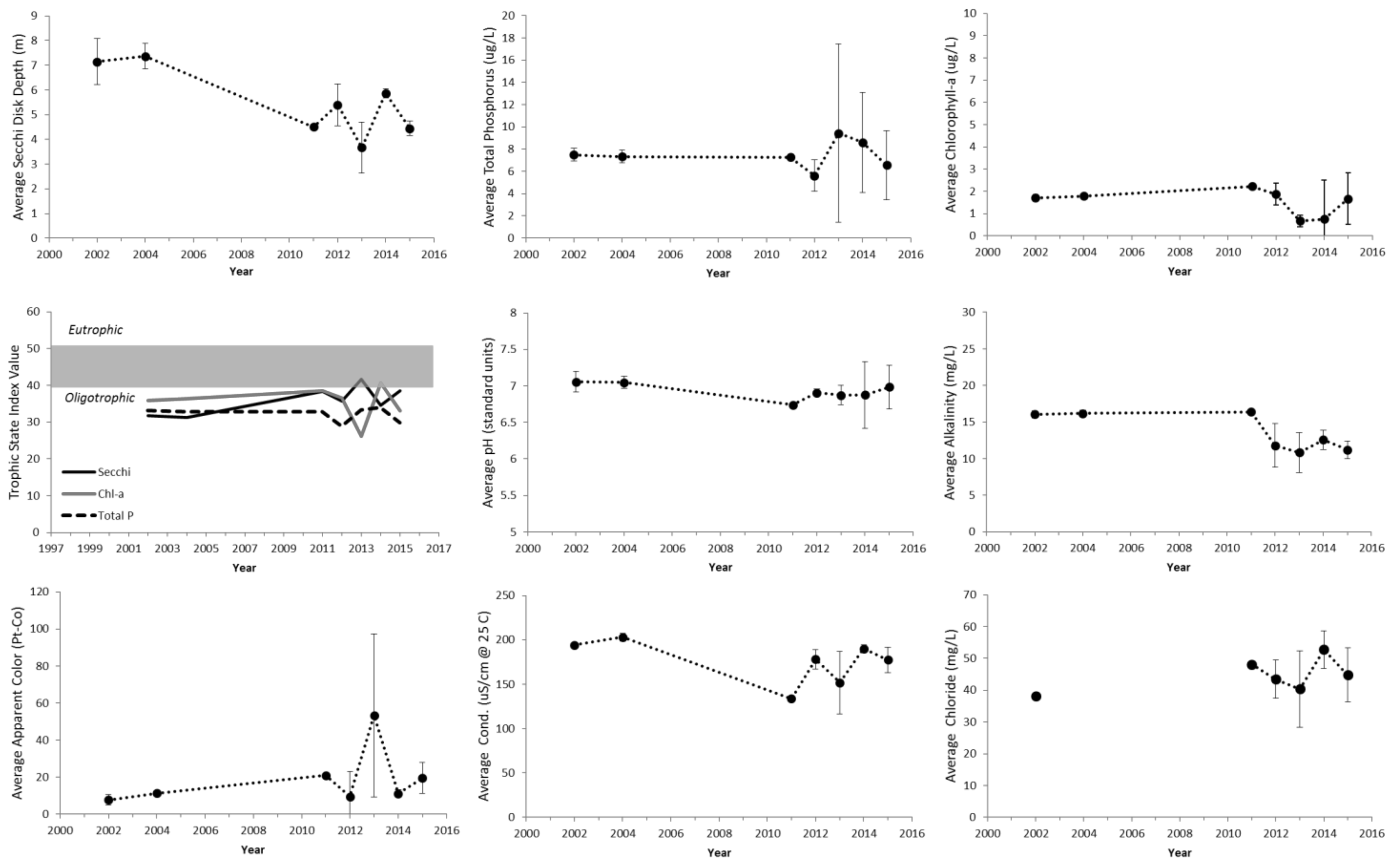
Trophic State	Acidity	Acid Neutralizing Capacity	Road Salt Influence
Oligotrophic	Circumneutral	Adequate – low sensitivity	High

Water quality values and historical trends for Upper Cascade Lake during the 2015 sampling season. Trend analysis was not performed on calcium or nitrogen data. BDL=below detection limit.

Water Quality Indicator	Sampling Date			Average	Trend
	6/26/2015	7/25/2015	10/6/2015		
Transparency (m)		4.3	4.7	4.5	No change
Total Phosphorus (µg/L)	9.0	3.1	7.7	6.6	No change
Chlorophyll-*a* (µg/L)	0.4	2.7	1.9	1.7	No change
Laboratory pH	7.3	6.7	6.9	7.0	No change
Sp. Conductance (µS/cm)	163.1	177.4	191.3	177.3	No change
Color (Pt-Co)	22.7	10.2	25.8	19.6	No change
Alkalinity (mg/L)	10.3	10.7	12.6	11.2	No change
Nitrate-Nitrogen (µg/L)	97.6	43.4	76.7	72.6	Not analyzed
Chloride (mg/L)	35.6	46.5	52.3	44.8	No change
Calcium (mg/L)	5.5	5.6	6.5	5.8	Not analyzed
Sodium (mg/L)	24.8	27.4	26.7	26.3	No change

*See table of content for description of water quality indicators

Upper Cascade Lake – Time Series



Annual average values of select water quality indicators for Upper Cascade Lake, 2002-2015. Vertical bars represent ± 1 standard deviation of the mean; Solid trend lines across the data indicate a statistically significant trend (p < 0.05).

Summary of Findings

Upper Cascade Lake is a 9 ha lake located in Essex County in the Town of Keene. The lake is located within a 213 ha watershed dominated by forests. Upper Cascade Lake has been monitored by ALAP volunteers and the Adirondack Watershed Institute during the years of 2002, 2003 and 2011-2015.

- Upper Cascade Lake is an oligotrophic lake. Trophic indicators have not exhibited any significant positive or negative trends.
- The water samples analyzed in 2015 were found to be circumneutral in terms of their acidity. The alkalinity averaged 11.2 mg/L, indicating low sensitivity to acid deposition.
- Sodium and chloride concentration averaged 26.3 and 44.8 mg/L respectively, indicating that the chemistry of the lake is highly influenced by the 1.4 km of NYS Rt. 73. Upper Cascade Lake has the highest concentration of sodium and chloride in the program.

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Appendix 1. Analytical methods performed on ALAP samples at the AWI Environmental Research Lab.

Analyte	Method Description	Reference
Lab pH	Mettler Toledo standard pH electrode	APHA
Conductivity	Conductivity at 25° C via Mettler Toledo conductivity cell	APHA 2510 B
Apparent Color	Single wavelength method with PtCO standards	APHA 2120 C
Chlorophyll-a	Trichromatic method uncorrected for phaeophyton	APHA 10200 H
Total Phosphorus	Acid-persulfate digestion, automated ascorbic acid reduction	APHA 4500-P H
Nitrate + Nitrite	Automated cadmium reduction	APHA 4500-NO_3 I
Alkalinity	Automated methyl orange method	EPA 301.2
Chloride	Automated ion chromatography	EPA 300.0
Calcium and Sodium	Inductively coupled plasma optical emission spectroscopy	EPA 200.7