2013 Report:

Austin Pond

Adirondack Lake Assessment Program

Adirondack Watershed Institute

Paul Smith's College

P.O. Box 265

Paul Smiths, NY 12970

Report No. PSCAWI 2014-66

Paul Smith's College
THE COLLEGE OF THE ADIRONDACKS

Acknowledgements

The Adirondack Lake Assessment Program (ALAP) represents a collaboration between the Adirondack Watershed Institute (AWI) and Protect the Adirondacks (PROTECT). The AWI is a program of Paul Smith's College that conducts research and service work broadly focused on conservation and protection of water resources. PROTECT is a non-profit organization dedicated to the protection and stewardship of the public and private lands of the Adirondack Park, and to building the health and diversity of its human communities and economies for the benefit of current and future generations. PROTECT recruits volunteers to participate in the program and provides administrative support, while AWI trains volunteers, conducts site visits, analyzes samples, and writes the reports. As such, this report and all results and interpretations contained herein were the sole responsibility of AWI. The narrative and results presented in this report were produced by Daniel L Kelting, Executive Director, and Corey Laxson, Research Associate, both with the AWI. Laboratory work on samples received from ALAP volunteers was conducted by Corey Laxson, Elizabeth Yerger, Sean Patton, Brandon Morey, and Dan Kelting. Sean Regalado produced watershed maps in GIS. Nancy Bernstein and Evelyn Greene from PROTECT provided administrative support. The majority of lake sampling was conducted by volunteers, with some additional sampling by AWI staff. Paul Smith's College provided office and laboratory space. PROTECT is very grateful for the support provide to ALAP from the F.M. Kirby Foundation.

Paul Smith's College
THE COLLEGE OF THE ADIRONDACKS®

PROTECT THE ADIRONDACKS!
LEGACY • LEADERSHIP • VISION

Please cite this report as:

Kelting*, D.L., and C.L. Laxson. 2014. Adirondack Lake Assessment Program: 2013 Report, Austin Pond. Adirondack Watershed Institute of Paul Smith's College. Report No. PSCAWI 2014-66. 23p.

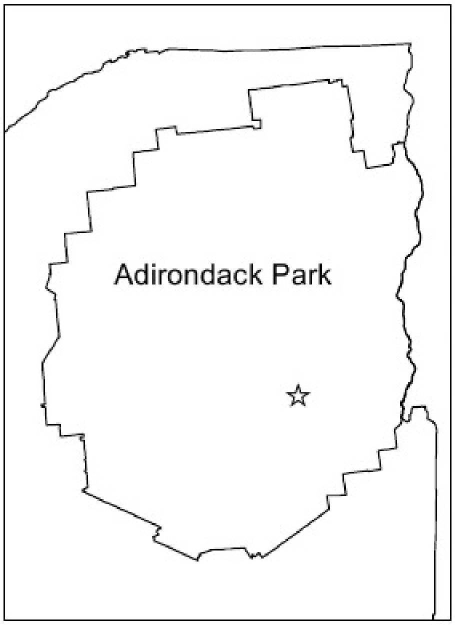
*Corresponding author Dan Kelting at dkelting@paulsmiths.edu

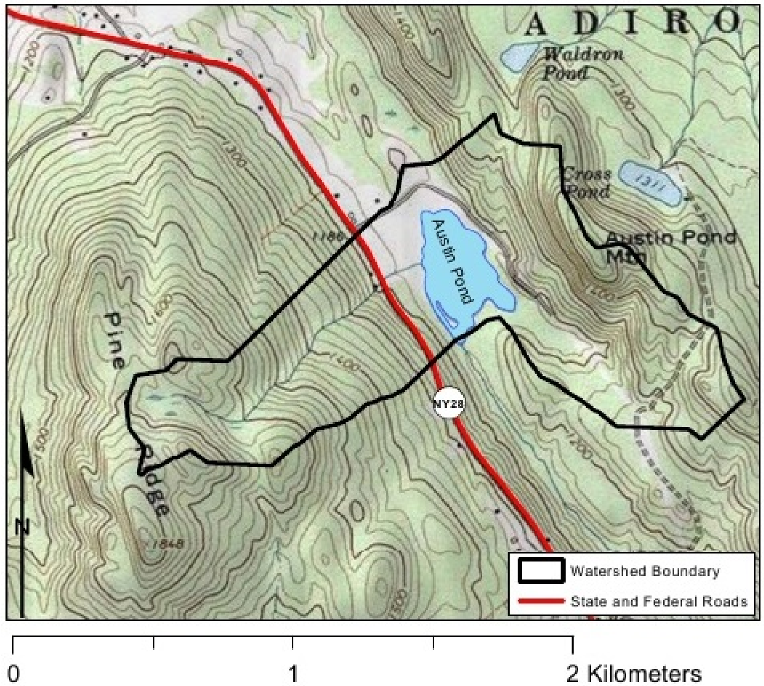
Cover Photo: Lower St Regis Lake taken in front of Spaulding-Paolozzi Environmental Science and Education Center of Paul Smith's College.

Table of Contents

Initial processing of ALAP water samples and pH measurement in the AWI Environmental Research Lab

Quick Facts – Austin Pond





County:	Warren
Town:	North Creek

Lake Area (ha):	128
Watershed Area (ha):	2,915

Trophic Status: Oligotrophic

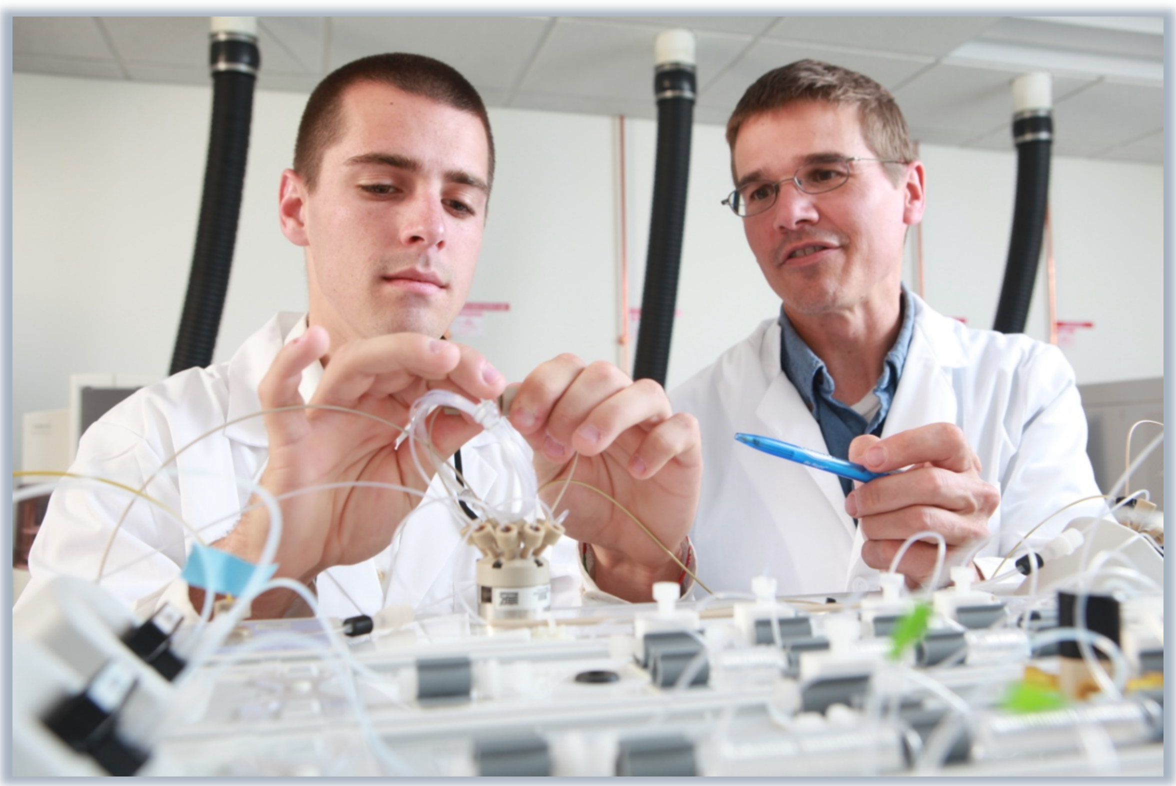
Years in ALAP: 14

2013 Water Quality Indicators and Long-Term Trends:

Indicator	Avg.	Trend
Transparency (m)	2.3	
Total P (µg/L)	13.7	—
Chlorophyll-*a* (µg/L)	6.0	
Laboratory pH	6.1	
Conductance (µS/cm)	85.9	
Color (Pt-Co)	46.0	

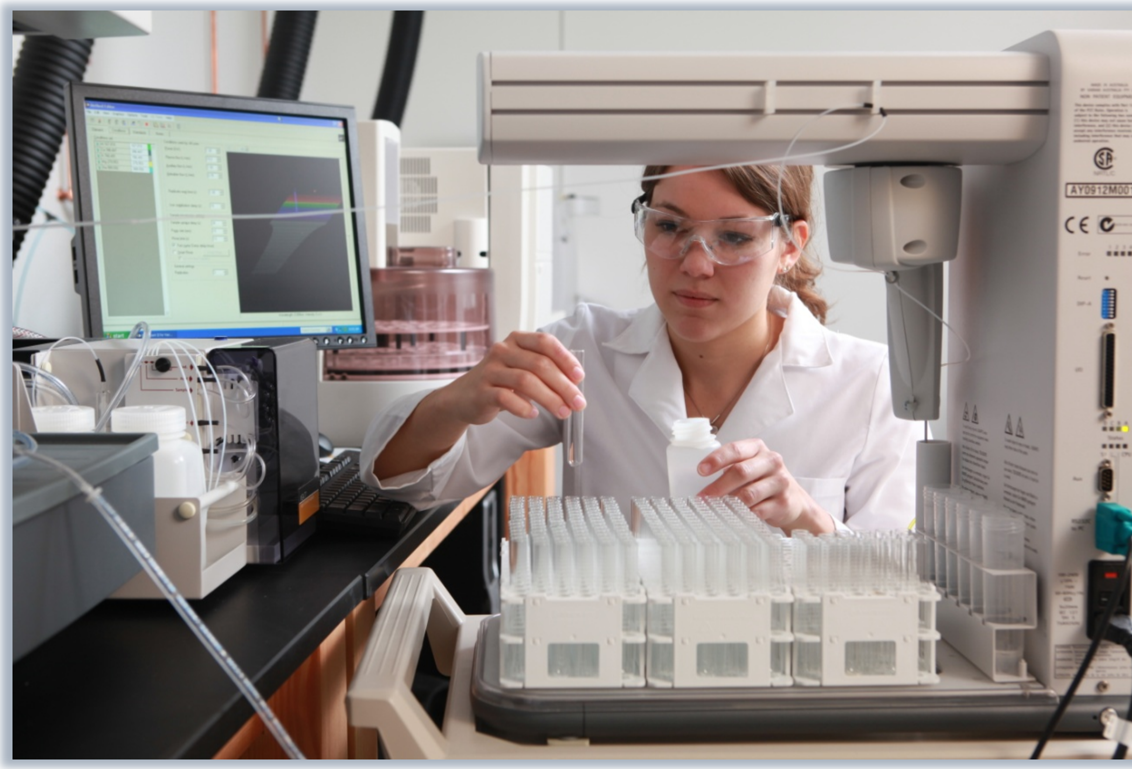
Indicator	Avg.	Trend
Alkalinity (mg/L)	29.2	—
Nitrate (µg/L)	<5.0	
Chloride (mg/L)	11.5	
Calcium (mg/L)	10.1	
Sodium (mg/L)	6.3	

List of Tables



Preparing the Lachat to analyze ALAP water samples for chloride and sulfate via ion chromatography in the AWI Environmental Research Lab.

List of Figures



Transferring ALAP water samples to sample cups in preparation for determining metal concentrations via inductively coupled plasma optical emission spectroscopy in the AWI Environmental Research Lab.

Executive Summary

Austin Pond is a 8.6 ha lake located in Warren County in the Town of North Creek. The lake is located within a 120 ha watershed dominated by forests. Austin Pond has been monitored by ALAP volunteers and the Adirondack Watershed Institute since 2000. Three samples were analyzed in 2013 for transparency, chlorophyll-a, total phosphorus, nitrate, pH, color, alkalinity, conductivity, chloride, calcium and sodium. This report presents the 2013 data and describes long-term trends in water quality for analytes with sufficient data.

1. Total phosphorus has exhibited a significant downward trend in concentration at a rate of approximately 0.6 µg/L/year (P = 0.017). Secchi disk transparency has remained relatively constant over the length of the study and shows no significant positive or negative trend. Chlorophyll a has shown considerably more variability but also showed no significant rend in the data. 2013 marked the lowest average concentrations of chlorophyll-a observed during the 14 years of monitoring.

2. Carlson's Trophic Status Index based on Secchi transparency (49), chlorophyll-a (48), and total phosphorus (41) all point to a mesotrophic classification for Austin Pond. Historically the lake has fluctuated between eutrophic and mesotrophic characteristics.

3. Nitrate levels are low in Austin Pond, and almost below analytical detection. Low nitrate levels may favor blooms of cyanobacteria during the summer months. However, information from lake users and data on transparency and algal abundance does not suggest cyanobacteria blooms have been an issue.

4. Austin Pond is a circumneutral water body with a historical average of 6.9 pH units. The alkalinity of the water (29 mg/l) is high enough to buffer the pond from changes in pH associated with acid deposition (alkalinity >10 mg/L). However, the alkalinity of the pond is exhibiting a significant downward trend at a rate of approximately 1.4 mg/L/year (P = 0.015).

5. Adirondack lakes in watersheds without paved roads typically have sodium and chloride concentrations less than 0.55 and 0.24 mg/L, respectively (Kelting et al 2012). The 2013 concentrations in Austin Pond averaged 6.3 mg/L for sodium and 11.5 mg/L for chloride, suggesting that the chemistry of the lake is influenced in part by road run off. The concentrations of these chemicals are well below the EPA drinking water standard established for sodium (20 mg/L) and the guideline recommended for chloride (250 mg/L).

6. Calcium concentrations in Austin Pond (10.1 mg/l) are within the threshold required for the establishment of a viable zebra mussel population (8-20 mg/L).

The data and accompanying analysis provided in this report give insight into the water quality of Austin Pond, more detailed limnological studies may be necessary to produce management recommendations.

Introduction

The Adirondack Lake Assessment Program (ALAP) is a cooperative citizen science lake monitoring program between Protect the Adirondacks (PROTECT), the Adirondack Watershed Institute of Paul Smith's College (AWI), and numerous dedicated volunteers from across the Adirondack Park and beyond. The objectives of ALAP are to (1) develop a reliable water quality database for Adirondack lakes, (2) document historical trends in their limnological condition, and (3) engender lake stewardship by providing opportunities for citizens to participate in scientific monitoring. To accomplish these objectives participating lakes are sampled throughout the summer by trained volunteers and analyzed by the AWI for indicators of trophic productivity (total phosphorus, chlorophyll, transparency) and water quality (nutrients, pH, alkalinity, color, chloride, and metals). ALAP continues to be a highly successful program. Established in 1998 with 9 participating lakes, the program has grown to 63 lakes in 2013 (Figure 1 and Table 1). For many lakes the ALAP dataset represents the only available source of current water quality information. This report details the results for Austin Pond.

Table 1. Lakes that participated in ALAP in 2013 organized by number of years in the program.

Lake Name	Years	Lake Name	Years	Lake Name	Years
Blue Mountain Lake	16	Lake of the Pines	13	Fern Lake	10
Eagle Lake	16	Long Pond	13	Indian Lake (HC)	10
Loon Lake	16	Pine Lake	13	Big Moose Lake	9
Oven Mountain Pond	16	Pleasant Lake	13	Dug Mountain Pond	9
Silver Lake	16	Rich Lake	13	Hewitt Lake	9
Thirteenth Lake	15	Tripp Lake	13	Indian Lake (FC)	9
Cranberry Lake	15	Twitchell Lake	13	Lake Abanakee	9
Eli Pond	15	Wolf Lake	13	Moss Lake	9
Gull Pond	15	Balfour Lake	12	Mountain View Lake	9
Little Long Lake	15	Garnet Lake	12	Sylvia Lake	8
Stony Creek Ponds	15	Lens Lake	12	Lower Chateaugay	7
Austin Pond	**14**	Lower Saranac Lake	12	Upper Chateaugay Lake	7
Brandreth Lake	14	Lower St Regis Lake	12	Chapel Pond	6
Middle Saranac Lake	14	Snowshoe Pond	12	Simon Pond	6
Osgood Pond	14	Spitfire Lake	12	Lake Adirondack	5
Trout Lake	14	Upper St Regis Lake	12	Upper Cascade Lake	5
White Lake	14	Canada Lake	11	Augur Lake	4
Arbutus Lake	13	Kiwassa Lake	11	Lake Titus	4
Catlin Lake	13	Lake Colby	11	Star Lake	4
Deer Lake	13	Raquette Lake	11	Lake Clear	3
Hoel Pond	13	Tupper Lake	11	Lake Durant	3

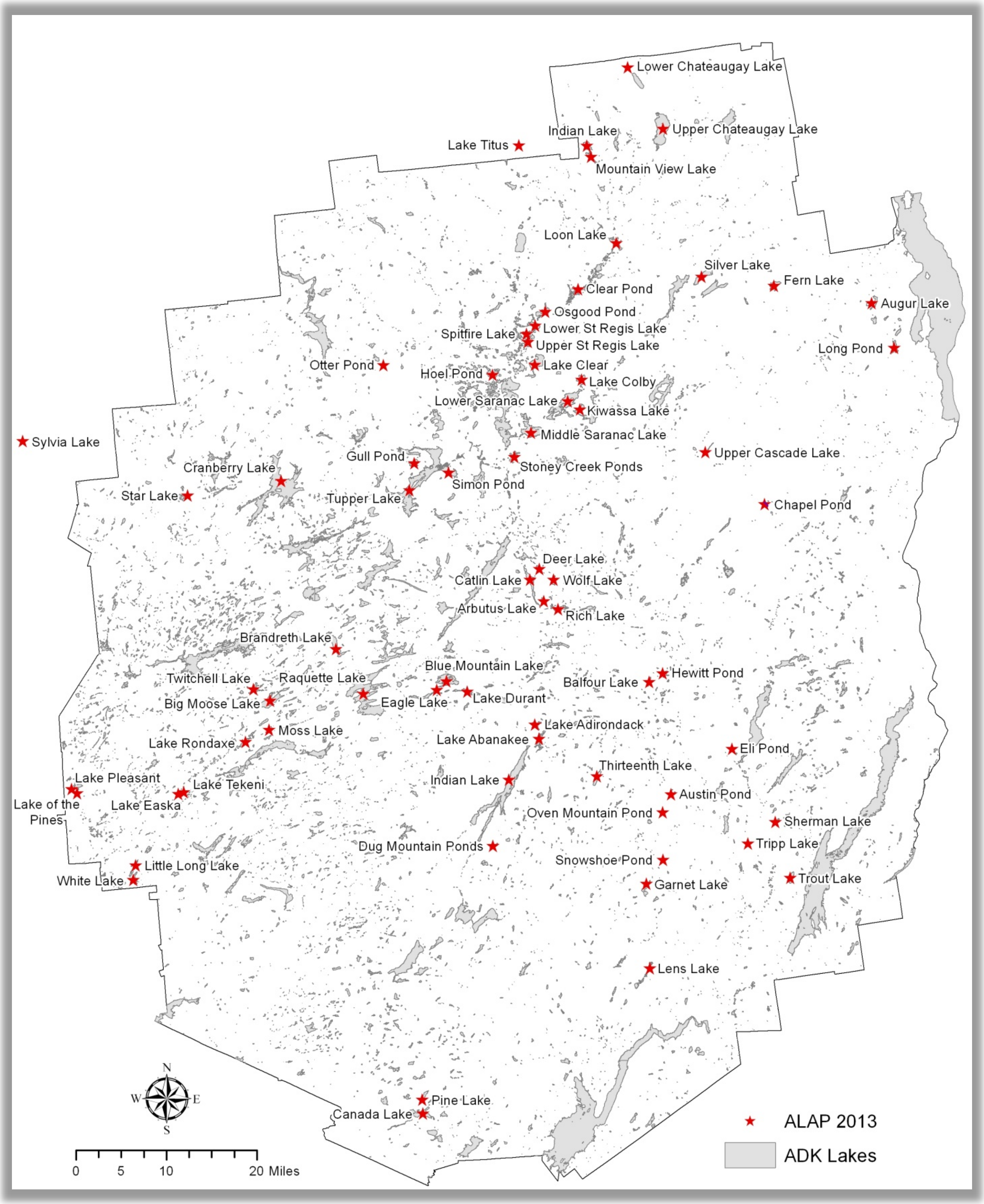


Figure 1. Locations and names of lakes that participated in the Adirondack Lake Assessment Program (ALAP) in 2013.

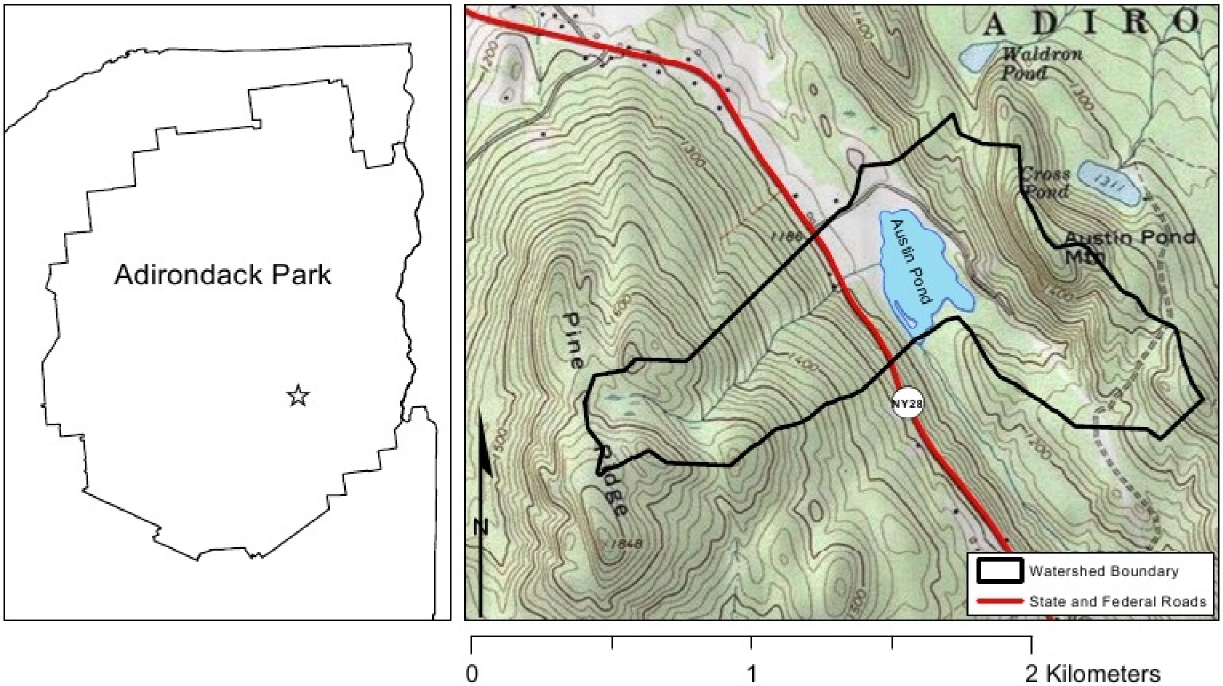


Figure 2. Location and watershed for Austin Pond.

Austin Pond is located in the southern Adirondacks (Figure 2) in Warren County in the Town of North Creek (Table 2). The lake is 8.6ha in surface area and has 1.7km of shoreline. The Austin Pond watershed is 120 ha, 10% of which is surface water. The watershed is dominated by forest cover, with 26% deciduous, 18% evergreen, and 37% mixed forests. The watershed contains 0.8 km of local roads (county, town, and local) and 0.5 km of state roads (state and US highways).

Table 2. Lake and watershed characteristics for Austin Pond.

Location	County:	Warren	Latitude:	43.6765
	Town:	North Creek	Longitude:	-73.9642
Lake Characteristics	Lake Area (ha):	8.6	Z-max (m):	
	Lake Perimeter (km):	1.7	Volume (m^3):	
			Flushing Rate (T/Y):	
Watershed Characteristics	Watershed Area (ha):	120	Residential (%):	
	Surface Water (%):	10	Agriculture (%):	
	Deciduous Forest (%):	26	Commercial (%):	
	Evergreen Forest (%):	18	Local Roads (km):	0.8
	Mixed Forest (%):	37	State Roads (km):	0.5
	Wetlands (%):	3		

Methodology

ALAP volunteers were trained by AWI staff in standard limnological sampling methods. 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 frozen until it could be delivered to the AWI Environmental Research Lab located in the Spaulding-Paolozzi Environmental Science and Education Center on the campus of Paul Smith's College. A second 250 mL aliquot was filtered through a 0.45 µm cellulose membrane filter for chlorophyll-a analysis. The filter was retrieved, wrapped in foil and frozen until delivery to the AWI Environmental Research Lab.

Samples were analyzed for pH, conductivity, alkalinity, total phosphorus, nitrate, chlorophyll-a, chloride calcium and sodium at the AWI Environmental Research Lab following the analytical methods described in Table 3. Descriptive details on each of the analytes and their relation to water quality can be found in Appendix 1. Results for each sampling period were tabulated and annual averages were compared between lakes. Trend analysis was conducted on historical data for lakes with ≥5 years of data using simple linear regression.

Table 3. Analytical methods performed in 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
Metals	Inductively coupled plasma optical emission spectroscopy	EPA 200.7

Average annual values for secchi disk transparency, total phosphorus, and chlorophyll-a were used to calculate Carlson's Trophic Status Index, (TSI), a commonly used quantitative index for classifying lakes based on trophic status (Carlson 1977). TSI values are calculated as follows:

- TSI (Secchi Disk) = 60 – 16.41xln[Secchi Disk (m)]
- TSI (Chlorophyll) = 30.6 + 9.81xln[Chlorophyll a(µg/L)]
- TSI (Total Phosphorus) = 4.15 + 14.42xln[Total Phosphorus (µg/L)]

Typically TSI values are between 0 and 100. Lakes with TSI values less 40 are classified as oligotrophic, TSI values between 40 and 50 are classified as mesotrophic, and TSI values greater than 50 are classified as eutrophic. A detailed description of TSI values and likely lake attributes is found in Table 4.

Table 4. 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, increasing probability of hypolimnetic anoxia during the summer
50-60	Eutrophic	Mildly eutrophic. Decreased transparency, hypolimnetic anoxia, and warm water fishery only. Supports all recreational / aesthetic uses but threatened.
60-70	Eutrophic	Dominance of blue-green algae, algal blooms likely, extensive macrophytes growth in shallow water
70-80	Eutrophic	Heavy algal blooms possible throughout summer, hyper eutrophic
>80	Eutrophic	Algal scum, summer fish kills, few macrophytes due to algal shading

*Definitions for trophic classes are provided in the Appendix

Results for Austin Pond

Transparency

Secchi disk transparency ranged from 1.5 to 3.0 meters and averaged 2.3 meters in 2013 (Table 5). The majority of lakes in the ALAP data set (78%) have an average secchi transparency greater than that of Austin Pond. Over the 14 years of participation in ALAP, transparency of Austin Pond has ranged from 1.5 to 2.3 meters (Figure 3A) with no significant trend in the data (Table 6). Eighty-two percent of ALAP lakes showed no trend in transparency, while 2% showed a positive trend and 16% showed a negative trend. Background information on transparency is provided in the Appendix.

Total Phosphorus

Total Phosphorus concentrations ranged from 6.5 to 18.5 µg/L and averaged 13.7 µg/L in 2013 (Table 5). The majority of lakes in the ALAP data set (83%) have an average total phosphorus concentration less than Austin Pond. Historically, the annual average total phosphorus of Austin Pond has ranged from 8.7 to 23.0 µg/L (Figure 3B), with a significant negative trend in the data (Table 6). Seventy-three percent of ALAP lakes showed no trend in total phosphorus, while the remaining 27% of lakes showed a negative trend. Background information on total phosphorus is provided in the Appendix.

Chlorophyll-a

Chlorophyll-a concentrations ranged from 6.0 to 7.3 µg/L and averaged 6.0 µg/L in 2013 (Table 5). The majority of lakes in the ALAP data set (89%) have an average chlorophyll concentration lower than Austin Pond. Average chlorophyll-a of Austin Pond has ranged from 5.9 to 11.1 µg/L over the past 14 years (Figure 3C) with no significant trend in the data (Table 6). Eighty-five percent of ALAP lakes showed no trend in chlorophyll-a, while 11% of lakes showed a positive trend and the remaining 3% showed a negative trend. Background information on chlorophyll-a is provided in the Appendix.

Carlson's Trophic State Index

The TSI for Austin Pond calculated with secchi transparency (49), chlorophyll (48), and total phosphorus (41) average to a TSI value of 46, suggesting a mesotrophic classification for Austin Pond (Table 4). The trophic state of Austin Pond typically fluctuates around the Mesotrophic-eutrophic boundary with all three indicators of trophic status in close agreement (Figure 3D).

Table 5. Water quality indicators by sampling date and average for Austin Pond in 2013.

Water Quality Indicator	Sampling Date			Average
	6/5/2013	7/6/2013	8/6/2013	
Secchi Transparency (m)	3.00	2.30	1.50	2.27
Total Phosphorus (µg/L)	18.50	16.20	6.45	13.72
Chlorophyll-*a* (µg/L)	6.02	7.32	4.50	5.95
Laboratory pH	6.30	6.04	6.14	6.16
Specific Conductance (µS/cm)	82.40	82.30	92.90	85.87
Color (Pt-Co)	32.00	40.00	66.00	46.00
Alkalinity (mg/L)	28.80	27.20	31.50	29.17
Nitrate-Nitrogen (µg/L)	4.23	2.78	5.35	<5.0
Chloride (mg/L)	13.10	10.70	10.60	11.47
Calcium (mg/L)	9.50	9.69	11.00	10.06
Sodium (mg/L)	7.25	5.66	6.06	6.32

Nitrate-Nitrogen

Nitrate levels for Austin Pond are estimated to be between 4.2 and 5.4 µg/L. These values are considered estimates because they are below the laboratories practical quantitation limit of 5.0 µg/L. Trend analysis on nitrate was not conducted due to insufficient time series data. Background information on nitrogen is provided in the Appendix.

pH

pH ranged from 6.0 to 6.3 and averaged 6.2 in 2013 (Table 5). The majority of lakes in the ALAP data set (83%) have an average pH greater than Austin Pond. Historically, average pH values of Austin Pond have ranged from 6.1 to 7.5 (Figure 4C) with no significant trend in the data (Table 6). Ninety-four percent of

ALAP lakes showed no trend in pH, while the remaining 6% of lakes showed a positive trend. Background information on pH is provided in the Appendix.

Alkalinity

Alkalinity ranged from 27.2 to 31.5 mg/L and averaged 29.2 mg/L in 2013 (Table 5). The majority of lakes in the ALAP data set (88%) have an average alkalinity concentration lower than Austin Pond. Over the 14 years of participation in ALAP, average alkalinity values of Austin Pond have ranged from 28 to 53 mg/L (Figure 4D) with a significant downward trend in the data (Table 6). Seventy-seven percent of ALAP lakes showed no trend in alkalinity, while the remaining 23% showed a negative trend. Background information on alkalinity is provided in the Appendix.

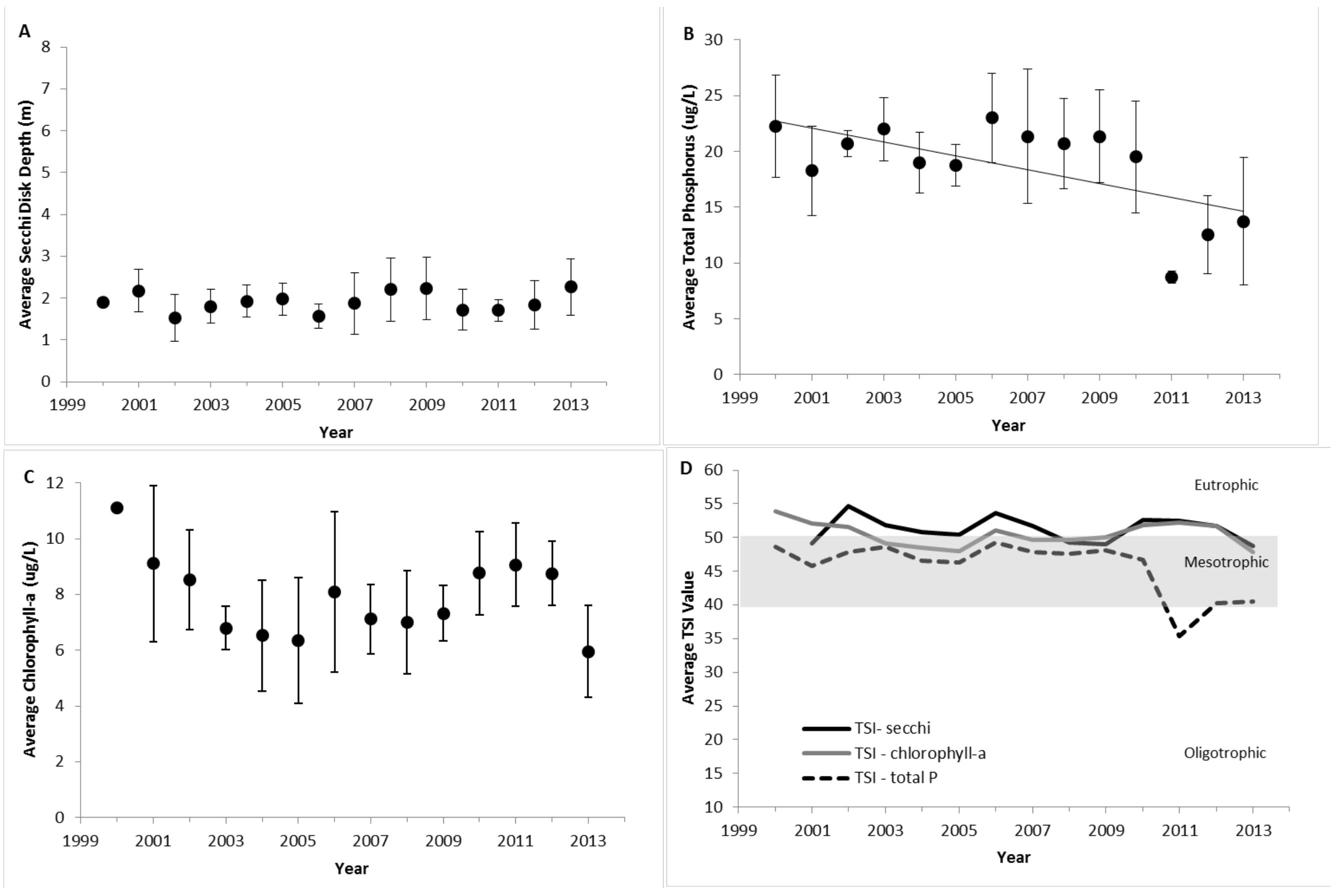


Figure 3. The annual average values of epilimnetic trophic indicators of Austin Pond, 2000-2013. (A) Secchi disk transparency, (B) total phosphorus concentration, (C) chlorophyll-a concentration, and (D) Carlson's Trophic State Index. Vertical bars represent one standard deviation of the mean. Significant trends (*P*<0.05) are noted with a trend line.

Color

Apparent color values ranged from 32 to 66 PtCo units and averaged 46 PtCo units in 2013 (Table 5). The majority of lakes in the ALAP data set (65%) have less coloration than Austin Pond. Over the 14 years, average color values of Austin Pond have ranged from 4 to 55 PtCo units (Figure 4B) with no trend in the data (Table 6). Twenty-three percent of ALAP lakes showed a positive trend in color, while 2% of lakes showed a negative trend and the remaining 75% had no trend in the data. Background information on color is provided in the Appendix.

Specific Conductance

Conductivity values ranged from 82 to 93 µS/cm and averaged 86 µS/cm in 2013 (Table 5). The majority of lakes in the ALAP data set (80%) have a lower conductance value than Austin Pond. Historically, average conductivity of Austin Pond has ranged from 53 to 115 µS/cm (Figure 4A), with no significant trend in the data (Table 6). Eighty-one percent of ALAP lakes showed no trend in conductance, while 3% of lakes showed a positive trend and the remaining 16% showed a negative trend. Background information on specific conductance is provided in the Appendix.

Chloride

Chloride concentrations ranged from 10.6 to 13.1 mg/L and averaged 11.4 mg/L in 2013 (Table 5). The majority of lakes in the ALAP data set (70%) have a chloride concentration lower than that of Austin Pond. Historically, average chloride concentrations of Austin Pond have ranged from 5.1 to 21.0 mg/L (Figure 4E), with no significant trend in the data (Table 6). Eighty-three percent of ALAP lakes showed no trend in chloride, while 12% showed a positive trend and the remaining 5% showed a negative trend. Background information on chloride is provided in the Appendix.

Calcium

Calcium concentrations averaged 10.1 mg/L (Table 5). The majority of ALAP lakes (92%) have calcium concentrations lower than Austin Pond. There is insufficient data at this time for a historical trend analysis of calcium. Background information on calcium is provided in the Appendix.

Sodium

Sodium concentrations averaged 6.3 mg/L (Table 5). The majority of ALAP lakes (72%) have a sodium concentration lower than that of Austin Pond. There is insufficient data at this time for a historical trend analysis of sodium. Background information on sodium is provided in the Appendix.

Table 6. Trend analysis (linear regression) of the water quality indicators of Austin Pond.

Indicator	Slope Coefficient	R-square	P-value
Transparency	0.010	0.029	0.558
Total Phosphorus	-0.622	0.388	0.017*
Chlorophyll-a	-0.104	0.094	0.285
Conductivity	-1.935	0.288	0.048
Apparent Color	2.134	0.078	0.334
pH	-0.029	0.098	0.276
Alkalinity	-1.423	0.397	0.015*
Chloride	0.060	0.003	0.882

*This report defines P-values less than or equal to 0.05 as statistically significant.

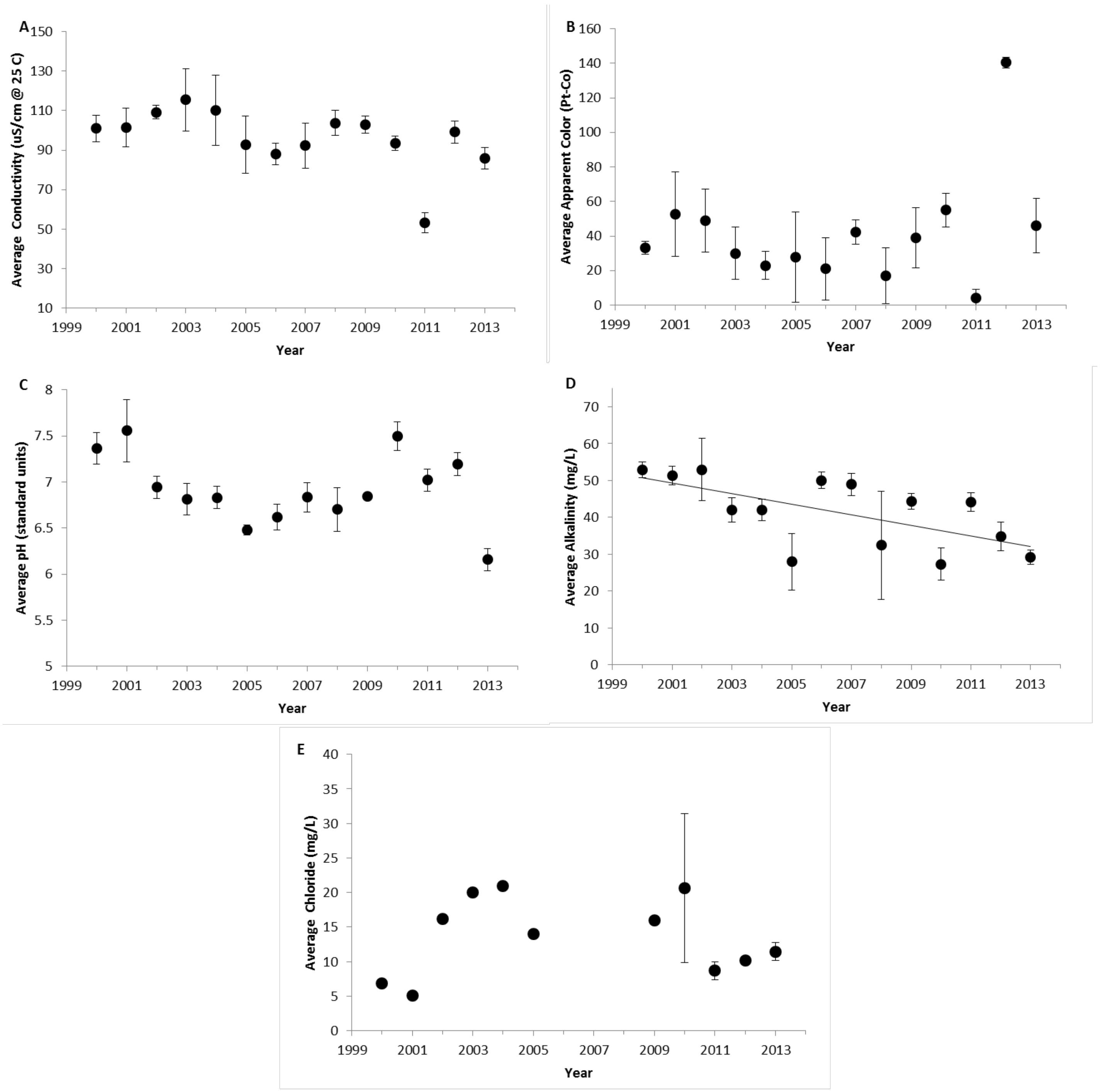


Figure 4. The annual average values of water quality indicators of Austin Pond, 2000-2013. (A) Specific lab conductivity @ 25°C, (B) apparent color, (C) pH, (D) total alkalinity, and (E) chloride concentration. Vertical bars represent one standard deviation of the mean. Significant trends (*P*<0.05) are noted with a trend line.

Literature Cited

Bachmann, R.W., B.L. Jones, D.D. Fox, M. Hoyer, L.A. Bull, and D.E. Canfield. 1996. Relations between trophic state indicators and fish in Florida (U.S.A.) lakes. Canadian Journal of Fisheries and Aquatic Sciences, 53:842-855.

Bertrand-Krajewski, J.L. 2004. TSS concentrations in sewers estimated from turbidity measurements by means of linear regression accounting for uncertainties in both variables. Water Science and Technology, 50(11):81-88.

Carmichael, W.W. 2008. A world overview one-hundred, twenty-seven years of research on toxic cyanobacteria--Where do we go from here? In: Hudnell, H.K. (ed.) *Cyanobacterial Harmful Algal Blooms: State of the Science and Research Needs.* Advances in Experimental Medicine & Biology, Vol. 619. Springer. 500 pp.

Carlson, R.E. 1977. A trophic state index for lakes. Limnology and Oceanography, 22(2):361-369.

Carpenter, S.R., J.F. Kitchell, and J.R. Hodgson. 1985. Cascading trophic interactions and lake productivity. Bioscience, 35(10):634-639.

Cohen, A. 2004. Calcium requirements and the spread of zebra mussels. California Sea Grant, Coastal Ocean Research, San Francisco Estuary Institute. 2p.

Corsi, S.R., Graczyk, D.J., Geis, S.W., Booth, N.L., and Richards, K.D. 2010. A fresh look at road salt: aquatic toxicity and water quality impacts on local, regional, and national scales. Environmental Science and Technology, 44(19):7376-7382.

Daley, M.L., J.D. Potter, and W.H. McDowell. 2009. Salinization of urbanizing New Hampshire streams and groundwater: effects of road salt and hydrologic variability. Journal of the North American Benthological Society, 28(4):929–940.

Davies-Colley, R.J., and D.G. Smith. 2001. Turbidity, suspended sediment, and water clarity: a review. Journal of the American Water Resources Association, 37(5):1085-1101.

Dillon, P.J., and L.A. Molot. 1997. Dissolved organic and inorganic carbon mass balances in central Ontario lakes. Biogeochemistry, 36:29-42.

Driscoll, C.T., K.M. Driscoll, M.J. Mitchell, and D.J. Raynal. 2003. Effects of acidic deposition on forest and aquatic ecosystems in New York State. Environmental Pollution, 123:327–336.

Godfrey, P.J., M.D. Mattson, M.-F. Walk, P.A. Kerr, O.T. Zajicek, and A.Ruby III. 1996. The Massachusetts Acid Rain Monitoring Project: Ten Years of Monitoring Massachusetts Lakes and Streams with Volunteers. Publication No. 171. University of Massachusetts Water Resources Research Center.

Katsev, S., I. Tsandev, I. L'Heureux, and D.G. Rancourt. 2006. Factors controlling long-term phosphorus efflux from lake sediments: Exploratory reactive-transport modeling. Chemical Geology, 234:127-147.

Kelting, D.L., C.L. Laxson, E.C. Yerger. 2012. A regional analysis of the effect of paved roads on sodium and chloride in lakes. Water Research, 46(8):2749-2758.

Lopez, C.B., Jewett, E.B., Dortch, Q., Walton, B.T., Hudnell, H.K. 2008. Scientific Assessment of Freshwater Harmful Algal Blooms. Interagency Working Group on Harmful Algal Blooms, Hypoxia, and Human Health of the Joint Subcommittee on Ocean Science and Technology. Washington, DC.

Monteith, D.T., J.L. Stoddard, C.D. Evans, H.A. deWit, M. Forsius, T. Høgåsen, A. Wilander, B.L. Skjelkvåle, D.S. Jeffries, J. Vuorenmaa, B. Keller, J. Kopácek, and J. Vesely. 2007. Dissolved organic carbon trends resulting from changes in atmospheric deposition chemistry. Nature, 450(22):537-541.

Smeltzer, E., W.W. Walker Jr., V. Garrison. 1989. Eleven years of lake Eutrophication monitoring in Vermont: a critical evaluation. Enhancing States' Lake Management Program, 1989:53-62.

Søndergaard, M., J.P. Jensen, and E. Jeppesen. 2003. Role of sediment and internal loading of phosphorus in shallow lakes. Hydrobiologia, 506-509:135-145.

Wetzel, R.G. 2001. Limnology, Lake and River Ecosystems, 3rd Edition. Academic Press, New York. 1006pp.

White, D.J., M.R. Noll, and J.C. Makarewicz. 2008. Does manganese influence phosphorus cycling under suboxic lake water conditions? Journal of Great Lakes Research, 34(4):571-580.

Appendix 1: Brief Review of Water Quality Indicators

Alkalinity - Alkalinity measures the buffering capacity of a lake, which is the ability of the lake to resist a change in pH. High alkalinity lakes are well buffered against changes in pH, while low alkalinity lakes are poorly buffered against changes in pH. Thus, a high alkalinity lake would have a more stable pH compared to a low alkalinity lake, and a more stable pH is less stressful to aquatic life. Alkalinity largely depends on the concentration of calcium carbonate in the water, and lakes with less than 10 ppm calcium carbonate are highly sensitive to acidification, while lakes with greater than 20 ppm calcium carbonate are not sensitive to acidification (Godfrey et al. 1996).

Calcium, Magnesium, Potassium, Sodium – all essential elements for plant growth, but generally not limiting in aquatic systems and thus do not contribute to algae blooms. Calcium, Magnesium, and Potassium are macronutrients, and Sodium is a micronutrient. All are naturally occurring elements that are released through rock weathering plus smaller quantities from atmospheric deposition. Though, the rocks of the Upper Saranac Lake watershed have low concentrations of these elements, so they are found in low concentrations in lakes under natural conditions. Road salting has elevated the sodium concentration in Adirondack lakes and perhaps the concentrations of the other elements through exchange processes occurring within the soil (Kelting et al. 2012). High concentrations of sodium in drinking water may cause health problems for people with hypertension (Corsi et al. 2010), and thus the US EPA has set a drinking water standard of 20 ppm for sodium, though there is debate over the validity of this standard (it may be too low). Lake calcium concentration also relates to habitat suitability for zebra mussels, as researchers have reported minimum calcium concentrations ranging for 8 to 20 ppm to support a viable population (Cohen 2004). So, calcium is an important indicator to track to assess the risk for zebra mussel infestation. Calcium may also be important to understand internal P loading, Ca-P (Pollman and James 2011).

Carlsons Trophic Status Index (TSI) – a numerical trophic state index that incorporates most lakes into a scale of 0-100. Each major division (10, 20, 30 etc.) represents a doubling of algal biomass. The index can be calculated from Secchi disk transparency, chlorophyll-a, or total phosphorus concentrations.

Chloride – an anion that can have negative effects on aquatic life when at high concentrations (Corsi et al. 2010), and can impart an undesirable taste to drinking water, also when at high concentrations. The US EPA has a drinking water guideline of 250 ppm for salty taste, but this is not an enforceable standard. The principal source of chloride in lakes in our region is road salt (Kelting et al. 2012).

Chlorophyll a – the primary photosynthetic pigment found in all species of algae that is used as an index of algal biomass (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 *a* are generally associated with increased algal production, and the concentration of chlorophyll *a* is widely considered as the most direct measure of the trophic state of lakes. Algal biomass is affected by nutrient availability, water temperature, and light, so there can be considerable variation in chlorophyll *a* concentrations throughout the year depending on which of these three factors is limiting growth at a particular time. Though, major changes in algal biomass (e.g. a bloom) and thus chlorophyll *a* are usually related to changes in the availability of phosphorus, nitrogen, and silica (Wetzel 2001).

Color – can limit light penetration and plant productivity and reduces water clarity. Color is influenced by the types and concentrations of suspended and dissolved particles in the water. Sources of these particles include dissolved organic carbon, algae, minerals and soils. Tannins produced from decomposition of plant and animal matter give water a tea color, particularly when associated with wetlands. Algae produce a variety of colors that range from red to green, depending on the type. Dissolved iron produces red to brown colors and dissolved manganese produces black, both of these metals are abundant in Adirondack waters. True Color, measured on filtered water samples, is used by the NYS DEC when interpreting total phosphorus concentrations in relation to eutrophication. A greater percentage of the total phosphorus is bound to organic matter in darker colored waters, and thus is less available compared to the total phosphorus measured in lighter colored waters.

Conductivity – pure water 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 measured as an indicator of dissolved ions and 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 (Daley et al. 2009).

Dissolved Organic Carbon – a food source for aquatic biota, plays a significant role in lake chemistry, imparts color to the water (e.g. tea colored water is from humic substances), and affects water clarity. Dissolved organic carbon enters streams and lakes from uplands or is produced in lakes and streams. Forested watersheds in particular have been shown to export a significant amount of dissolved organic carbon to lakes (Dillon and Molot 1997). Dissolved organic carbon concentrations in Adirondack lakes have increased over the last 20 years, and this increase may relate to changes in acid deposition (Monteith et al. 2007).

Dissolved Oxygen – needed for survival and health of many forms of aquatic life, as well as affects the availability of phosphorus. Dissolved oxygen is consumed during respiration and decomposition and replenished by photosynthesis and diffusion from the atmosphere. The lack of cycling during summer stratification inhibits the replenishment of dissolved oxygen to bottom waters in the summer, resulting in depletion of dissolved oxygen as previously mentioned. Depletion of dissolved oxygen in bottom waters may result in increased release of phosphorus from the dissolution of iron-phosphates contained in the sediment (Katsev et al. 2006).

Eutrophic – From the Greek words *Eu*, meaning good and *trophi*, meaning nourishment; eutrophic lakes have 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 (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 (Wetzel 2001).

Mesotrophic - From the Greek words *Meso*, meaning the middle and *trophi*, meaning nourishment. Mesotrophic lakes and an intermediate trophic classification on the continuum between oligotrophy and eutrophy.

Nitrogen – a macronutrient that can be the limiting nutrient for algae growth in lakes, but it is generally the second most limiting nutrient after phosphorus. Nitrogen enters our watersheds through biological fixation, atmospheric deposition, fertilizers, and human waste. Nitric acid, a component of acid rain produced by the combustion of fossil fuels, has contributed significantly to lake acidification (reduced pH) in our region (Driscoll et al. 2003). The plant available forms of nitrogen are ammonium and nitrate, which are generally present in very small quantities as they are rapidly assimilated into biomass. Most of the nitrogen is bound in organic matter and is released as ammonium by microbial activity and further converted to nitrate by microbes under aerobic conditions. Total nitrogen is all of the organically bound nitrogen plus the ammonium and nitrate. Under nitrogen limiting conditions, which may occur in lakes with high concentrations of phosphorus, nitrogen fixing cyanobacteria may proliferate (Wetzel 2001). Cyanobacteria are the largest group of toxin producing algae, though not all cyanobacteria produce toxins, and those that do produce toxins don't do so all of the time (Carmichael 2008).

Oligotrophic – From the Greek words *oligo,* meaning few and *trophi,* meaning nourishment; oligotrophic lakes have low levels of available nutrients. 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 (Wetzel 2001).

pH– pH measures the concentration of hydrogen ions in solution, and is considered a master variable for its influence on chemical processes and aquatic life. Neutral waters have a pH of 7, pH's less than 7 are acidic and pHs greater than 7 are basic. The optimum pH range for most aquatic life is between 6.5 and 8.

Phosphorus – a macronutrient that is often the limiting nutrient for algae growth in lakes and widely considered as the most important contributor to reduced water quality in lakes (Søndergaard et al. 2003). Natural weathering releases phosphorus from rocks and soils, and it also enters our watersheds in fertilizers, human waste, and atmospheric deposition. The plant available form is ortho-phosphate, which is generally present in very small quantities as it is rapidly assimilated into biomass. High ortho-phosphate concentrations are indicative of waste inputs (e.g. failing septic systems) or release of bound phosphorus from sediments (internal loading). Soluble total phosphorus is the fraction of total phosphorus that passes through a 0.45 micron filter. Total phosphorus is all of the inorganically and organically bound phosphorus combined, so it represents phosphorus in living tissues, detritus, and ortho-phosphate. The total phosphorus concentration in the surface waters is used as an indicator of lake trophic or productivity status; lakes with less than 10 ppb are considered oligotrophic or low productivity, lakes with 10 to 20 ppb are considered mesotrophic or moderate productivity, and lakes with greater than 20 ppb are considered eutrophic or high productivity. Total phosphorus near the lake bottom (Hypolimnion) is monitored to understand the importance of internal loading, the release of phosphorus accumulated in sediments which replenishes surface water phosphorus when lakes turn over.

Secchi Transparency – widely used measurement of water clarity used as an index of lake trophic state and is important to our perception of water quality. Secchi transparency is influenced by several factors beyond algal productivity, including the eyesight of the reader, time of day of the reading, suspended sediments, and dissolved organic carbon. Increases in suspended sediments from watershed runoff, shoreline erosion, or mixing will reduce Secchi transparency, as will increases in dissolved organic carbon from these same processes. Thus, the potential effects of suspended sediments and dissolved organic carbon should also be considered when interpreting Secchi transparency data.

Trophic Indicators- Lakes are typically assigned into one of three trophic or productivity classes (oligotrophic, Mesotrophic, eutrophic) based on total phosphorus, total nitrogen, chlorophyll *a*, and Secchi transparency (Table 7). These four indicators are known as trophic indicators. Under conditions when water clarity is largely a function of algae biomass, there should be good correlations between chlorophyll *a*, Secchi transparency, and total phosphorus and/or total nitrogen, depending on which of these two nutrients is limiting productivity. For example, Bachmann et al. (1996) reported strong positive correlations between chlorophyll *a* and both total phosphorus and total nitrogen, and strong negative correlations between Secchi transparency and chlorophyll *a*, total phosphorus, and total nitrogen in a study of 65 lakes in Florida. But, if other factors, such as suspended sediments (Davies-Colley and Smith 2001), dissolved organic carbon (Dillon and Molot 1997), or complex food web interactions (Carpenter et al. 1985) are affecting water clarity, then the correlations between trophic indicators can be diminished to non-existent. Thus, it is important to measure all four trophic indicators to assess the trophic state of lakes and to interpret them with full consideration of other factors that can affect water clarity, otherwise the interpretations may be misleading. The NYS DEC uses a true color threshold of 30 Ptu for interpreting total phosphorus and Secchi transparency. The classification thresholds listed in Table 4 are only applied to lakes with true color less than 30 Ptu, in recognition of the relationship between true color and phosphorus availability and between true color and water clarity. The NYS DEC uses chlorophyll *a* to classify lakes with greater than 30 Ptu true color.

Total Suspended Solids (TSS) – Total Suspended Solids is measured as the amount of material retained on a glass fiber filter disk after a known volume of water is filtered. Because turbidity and TSS both measure particles in water, they are related and have been shown to be highly correlated (Bertrand-Krajewski 2004). These particles include silt, clay, organic matter, plankton, and other organisms. Sources of turbidity and TSS include soil erosion in the watershed, algae production, and decomposition of organic matter.

Turbidity – turbidity is a measure of water clarity that is based on the scattering of light by particles in the water.

Table 7. General trophic classification of lakes (adapted from Wetzel 2001) and NYS DEC assessment criteria.

Indicator	Oligotrophic	Mesotrophic	Eutrophic
Total phosphorus (ppb)			
Mean	8.0	26.7	84.4
Range	3.0 - 17.7	10.9 - 95.6	16 – 386
NYS DEC	< 10	10 - 20	> 20
Total nitrogen (ppb)			
Mean	661	753	1875
Range	307 - 1630	361 - 1387	393 - 6100
Chlorophyll a (ppb)			
Mean	1.7	4.7	14.3
Range	0.3 - 4.5	3 – 11	3 – 78
NYS DEC	< 2	2 - 8	> 8
Secchi transparency (m)			
Mean	9.9	4.2	2.45
Range	5.4 - 28.3	1.5 - 8.1	0.8 - 7.0
NYS DEC	> 5	2 - 5	< 2