Mirror Lake

2017 Water Quality Report

Ausable River Association

Adirondack Watershed Institute
Paul Smith's College

Acknowledgments

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We would also like to acknowledge the Adirondack Mountain Club for co-running a five-day teen aquatic stewardship program with the Ausable River Association. As part of this program, high-school age youth conduct a comparative study of Mirror Lake and Heart Lake. Photographs on pages 4, 12, and 25 show participants in this program participating in water quality data collection on Mirror Lake. We appreciate and thank the many youth that have participated in this program.

Photos by Brendan Wiltse.

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Title 11 Environmental Protection Fund

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2017 Water Quality Report

Brendan Wiltse[*1]

Corey L. Laxson[2]

Nicole C. Pionteck[1]

Elizabeth C. Yerger[2]

[1]**Ausable River Association**
1181 Haselton Road, PO Box 8
Wilmington, NY 12997
www.ausableriver.org

[2]**Paul Smith's College Adirondack Watershed Institute**
PO Box 265
Paul Smiths, NY 12970
www.adkwatershed.org

[*]Corresponding Author: Brendan Wiltse, brendan@ausableriver.org, 518-637-6859, PO Box 8, Wilmington, NY 12997

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Executive Summary

This is the second annual report on the limnology and water quality of Mirror Lake issued by the Ausable River Association and the Adirondack Watershed Institute. Our research on Mirror Lake and threats to its water quality continues to yield new insights about the lake. Our goal is to provide stakeholders with the data and science necessary to make informed and effective decisions about how best to protect Mirror Lake. Road salt has emerged as the top threat to the lake, but we have much more work to do before identifying a solution that both protects the lake and provides safe surfaces for people to drive and walk on. This report highlights our most current knowledge of the impacts of road salt to the lake and outlines future work needed to effectively identify solutions.

Key findings include:

1. Measures of the lake's trophic status (total phosphorus, nitrate, ammonium, total nitrogen, chlorophyll-a, transparency, and trophic state index) continue to show no significant long-term trends. While many lakes across the state and country are facing threats related to eutrophication, this is not a concern for Mirror Lake at this time. The lake is oligotrophic (low nutrients) and has remained that way over the period of record.
2. There is a significant long-term increase in calcium, this may be the result of soil cation exchange as a result of road salt and/or the maintenance of a crushed limestone beach on the lake. Increased calcium poses no specific threat to the water quality of the lake, other than an increased likelihood that zebra mussels could become established in the lake if they were introduced.
3. Significant long-term trends in conductivity, sodium, and chloride remain a concern. Elevated bottom water chloride concentrations were documented and evidence exists that these concentrations are impeding the natural turnover of the lake in the spring. The disruption of this important physical process has the potential for a significant negative effect on aquatic life.
4. A prolonged period of bottom water hypoxia was documented throughout 2017. This condition is likely natural for Mirror Lake, but it is worsened by the lack of spring turnover. If fall turnover were also not to occur, a die-off of many aquatic organisms – as a result of low dissolved oxygen – would be likely.
5. Additional work is necessary to determine the reduction in road salt necessary to protect Mirror Lake and set it on a path of recovery. In order to accurately estimate the reduction in salt necessary to achieve this, we need the entire community within the Mirror Lake watershed to be engaged participants in the study of this problem. The more we know and understand how much salt is applied within the watershed, and where, the better we can understand how much of a reduction is necessary to protect the lake.

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Introduction

Mirror Lake is an iconic Adirondack waterbody located adjacent to downtown Lake Placid. The lake is a focal point for activities in the Village of Lake Placid. In the summer months, residents and visitors ply the waters in canoes, kayaks, and stand up paddle boards or swim at the public beach. The lake is home to the swim portion of the IRONMAN triathlon held each year in Lake Placid. In the winter months, there is a flurry of activity including ice skating, hockey tournaments, tobogganing, and dog sled rides. Throughout the year, Mirror Lake serves as a valuable resource to the Village of Lake Placid.

Mirror Lake is in western Essex County in the Town of North Elba and Village of Lake Placid. The lake has a surface area of 50 ha (124 acres) and watershed area of 301 ha (741 acres). The watershed is mostly covered by several forest types (Figure 1; Table 1). Although 27% of the total watershed area is developed, the percentage of developed area rises to 34% if we only consider land area (Table 1). Much of the developed area is covered in impervious surfaces (Figure 2). Mirror Lake has more than twice the percentage of developed land compared to any other lake in the Adirondack Lake Assessment Program (ALAP; Laxson et al. 2016). As a more direct comparison, 1% of Lake Placid's watershed is developed, and 8% of Lake George's watershed is developed (Laxson et al. 2015; The Lake George Association 2016). While this percentage may seem small, when viewed in the context of other Adirondack lakes, Mirror Lake is one of the most developed lakes in the Adirondack Park.

The headwaters of the watershed include Echo Lake which drains into the north bay of Mirror Lake. This upper portion of the watershed is mostly forested, while the area surrounding Mirror Lake is mostly developed (Figure 1). The lake drains to the south, into the Chubb River which flows into the West Branch of the Ausable River. Mirror Lake's outlet stream has been manipulated to run underground for much of its length and is connected to a network of storm drains. The outlet comes above ground just before it enters the Chubb River at Mill Pond.

The entire shoreline of the lake is developed and encompassed by roads. 1.1 km (0.68 mi) of state roadway and 7.6 km (4.72 mi) of local roadway drain into Mirror Lake. For the most part, the roads and impervious surfaces around the lake flow directly into the lake through more than 20 stormwater outfalls. The Village of Lake Placid, with the encouragement of the Mirror Lake Watershed Association, has been proactive in installing hydrodynamic separator units for stormwater from the roads around Mirror Lake. The Village retrofitted several stormwater outfalls along Main Street to flow through these units. The Village has also sought funding to consolidate the stormwater collection along Main Street and divert it away from the lake. A project for stormwater consolidation along the southeast side of the

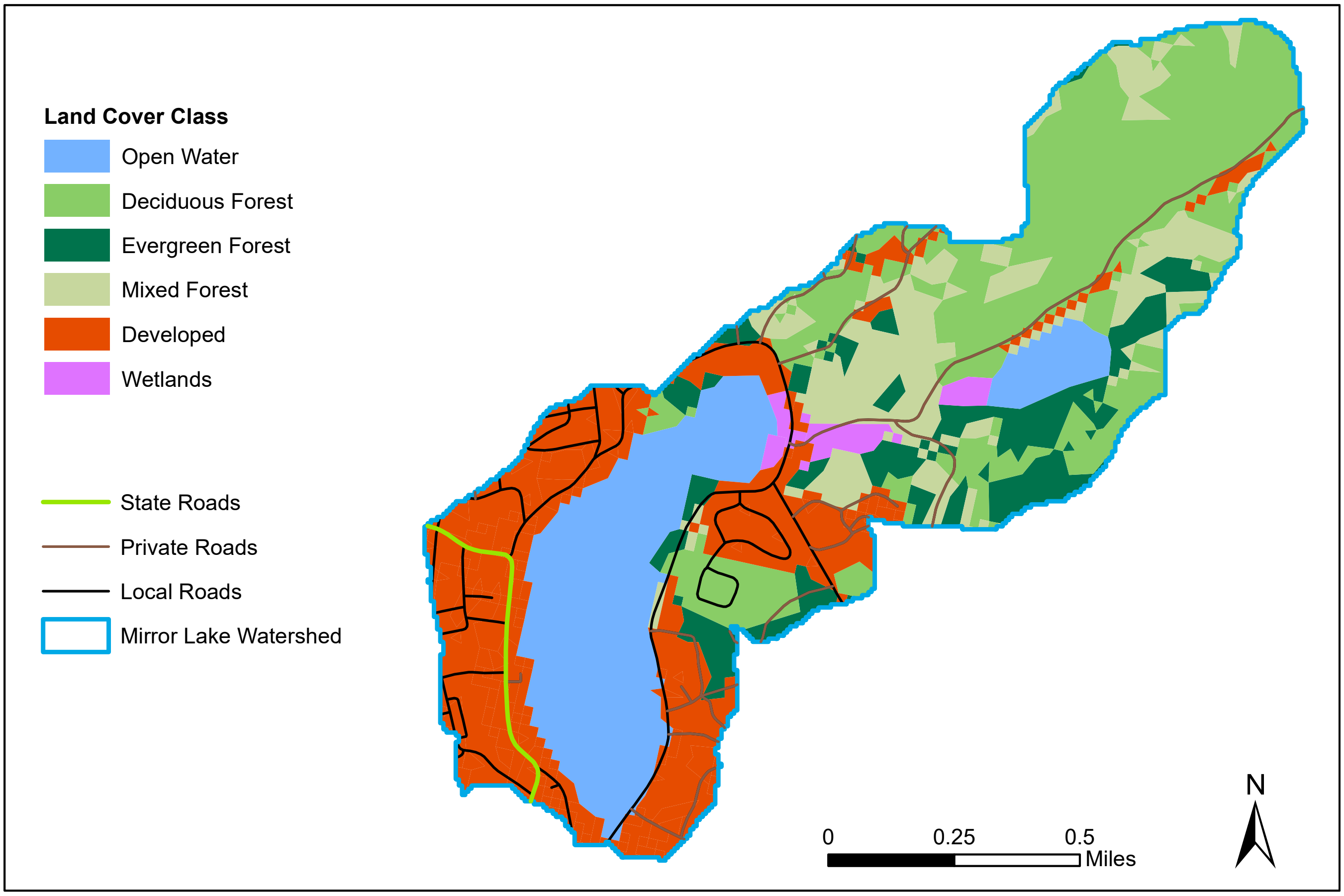


Figure 1. Distribution of land cover class and road types within the Mirror Lake watershed.

lake was completed in July 2017. That stormwater is now directed away from Mirror Lake and enters the Chubb River just below the municipal wastewater treatment plant.

The water quality and health of Mirror Lake has been a topic of interest to residents and scientists alike for many years (Table A1). The first known report on the water quality of Mirror Lake was published by Ray Oglesby (1971). The report was commissioned by the Lake Placid Shore Owners' Association as part of a study of Lake Placid. Its objectives were specific. "(1) To establish a baseline scientific description of Lake Placid and Mirror Lake by means of which future significant changes in water quality could be assessed through comparison with the present state. (2) To obtain evidence as what substance or substances are now critical to the growth of phytoplankton (free-floating algae) in the lake. In other words, what would increase the growth of algae if added to the water in increased amounts. (3) Based on the data available, to make recommendations for the protection and/or improvement of water quality in the two lakes." Oglesby conducted a previous study in March 1971, which we have not been able to obtain. The initial study was followed up by Oglesby in 1974 with a second report (Oglesby & Mills 1974). The objectives of this report were to "further establish baselines" and "determine what, if any, actions should be taken to safeguard or improve the water quality of the two lakes."

Following Ogelsby's initial studies there was a long period when no data was collected on the lake. Although, a few visits to the lake were made by Don Charles in 1976 and 1978 as part of work he was doing with the Paleoecological Investigation into Recent Lake Acidification (PIRLA) project to study recent lake acidification (Whitehead et al. 1990). Paul Smith's College students did a series of reports on

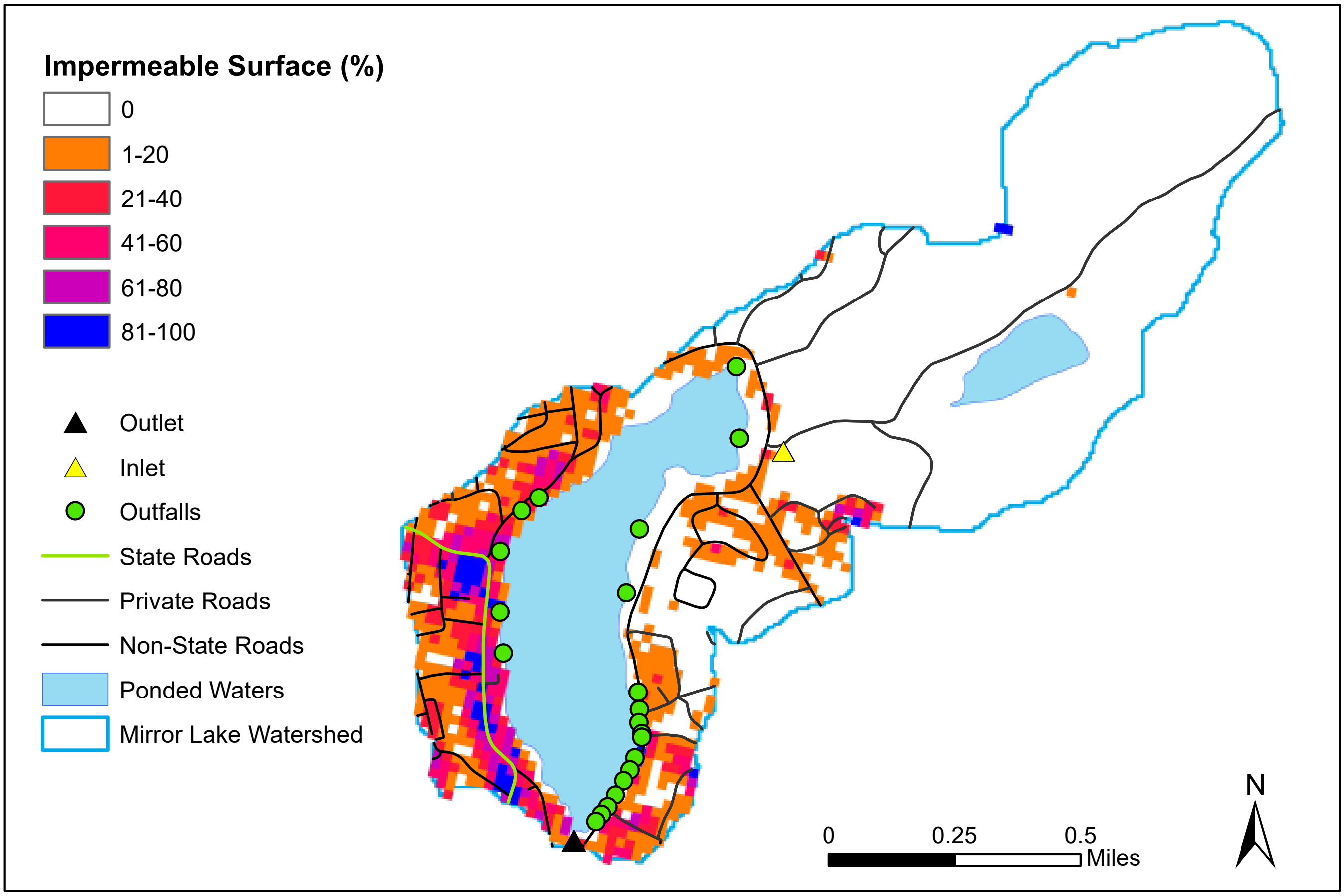


Figure 2. Distribution of impermeable surfaces and stormwater outfalls within the Mirror Lake watershed as of 2016. Many of the outfalls along the southeast side of the lake are no longer in place.

the lake during the winters of 1996, 1998, and 2000 (Martin 1998; Murray et al. 2000; Schmall et al. 1997). In 2001, the lake was studied by Upstate Freshwater Institute as part of a study of Lake Placid funded by the Lake Placid Shoreowners Association (UFI 2002). In 1998, a volunteer started monitoring the lake through the Citizens Statewide Lake Assessment Program (CSLAP) (Kishbaugh 2016). That monitoring effort has continued through 2017 with the exceptions of 2002 and 2012. In 2014, the lake was enrolled in the Adirondack Lake Assessment Program (ALAP). The lake remained enrolled in this program in 2015 but the monitoring was taken over by the Ausable River Association, which added additional parameters to the standard ALAP sampling.

In 2016, the Ausable River Association (AsRA) and the Adirondack Watershed Institute (AWI) initiated a partnership to expand the monitoring of the lake. This effort was supported by the Mirror Lake Watershed Association, Village of Lake Placid, Town of North Elba, IRONMAN Foundation, and NYS Department of State. In 2017, additional support was received from Golden Arrow Lakeside Resort, Mirror Lake Inn, and Branch Creek. Mirror Lake is an iconic, valuable resource that faces challenges from the ring of urban development that surrounds it. The goal of this partnership is to develop a more comprehensive understanding of Mirror Lake's water quality so the community can make scientifically informed management choices essential to ensuring its health.

Objectives

The objectives of the current monitoring program and this report are to: 1) establish a comprehensive picture of Mirror Lake that incorporates all known historical water quality data; 2) develop a better understanding of the impacts of road salt, and elevated sodium and chloride concentrations on the lake; 3) lay the groundwork necessary to establish a scientifically rigorous monitoring program to provide baseline data about Mirror Lake; and, 4) collect the data necessary to help stakeholders identify the best management practices to protect the lake.

A participant in Discovering the Ausable: An Aquatic Stewardship Program collecting data on the temperature, dissolved oxygen, conductivity, and pH throughout the water column of Mirror Lake.

Methods

2017 field data were collected from a canoe over the deepest location of the lake bi-weekly during the open-water season, and monthly when the lake was covered with ice of sufficient thickness for access by foot. During each sampling visit a surface water sample, hypolimnetic sample, and profiles of temperature, dissolved oxygen, specific conductance, and pH were collected. The surface water samples were collected from a depth of 0 to 2 meters with an integrated tube sampler. The tube sampler was emptied into a field rinsed 1L sample bottle. A portion was poured off into an acid-washed and field-rinsed sample bottle for laboratory analysis, and 250ml was filtered through a 0.45 µm cellulose membrane filter. The filter was folded in half twice, wrapped in foil and stored on ice for chlorophyll-*a* analysis. Hypolimnetic samples were collected using a 1.5L Kemmerer bottle from approximately 1 meter above the bottom. This sample was immediately transferred to an acid-washed and field-rinsed sample bottle and stored on ice. All water samples and the chlorophyll-*a* sample were transported on ice until they could be frozen before being transported to the Adirondack Watershed Institute. Samples were analyzed for pH, conductivity, alkalinity, total phosphorus, nitrate, ammonium, total nitrogen, chlorophyll-*a*, chloride, sodium, and calcium at the Adirondack Watershed Institute Environmental Research Lab following the analytic methods described in Table A2. Transparency was measured during the ice-free period using a 20cm black and white Secchi disk from the shady side of the boat. Profiles of temperature, dissolved oxygen, specific conductance, and pH were collected at 1m intervals from the surface to 17m using a YSI Professional Plus handheld sonde.

Field and laboratory data have been combined from multiple sources for this report to provide a record of water quality from 1971 to 2017. Sampling frequency and methodology, as well as laboratory methodology, is slightly different between these sources. Data points in each figure have been categorized into those following the methodology outlined in this report (circles) and those that have not (triangles). Nevertheless, as an exploratory analysis, linear regressions were fit to the annual average data for each parameter and plotted if a significant trend was detected. This analysis should be approached cautiously due to the inconsistency in the data throughout the period of record.

Table 1. Summary of land area of different cover classes for the Mirror Lake watershed, values are also represented as percentage of the total watershed area (301.23 ha) and percentages of the watershed land area (236.93 ha). Percentage of land area is useful when considering the amount of a particular land cover class, such as development, compared to the potential area that cover class could occupy.

Cover Type	Area (ha)	% Watershed Area	% Land Area
Evergreen	29.99	9.96	12.66
Deciduous	87.06	28.90	36.74
Mixed Forest	38.73	12.86	16.35
Wetlands	5.34	1.77	-
Surface Water	58.95	19.57	-
Developed	81.16	26.94	34.25
Agriculture	0.00	0.00	0.00
Commercial	0.00	0.00	0.00
Total	301.23	100.00	100.00

Findings

Total Phosphorus

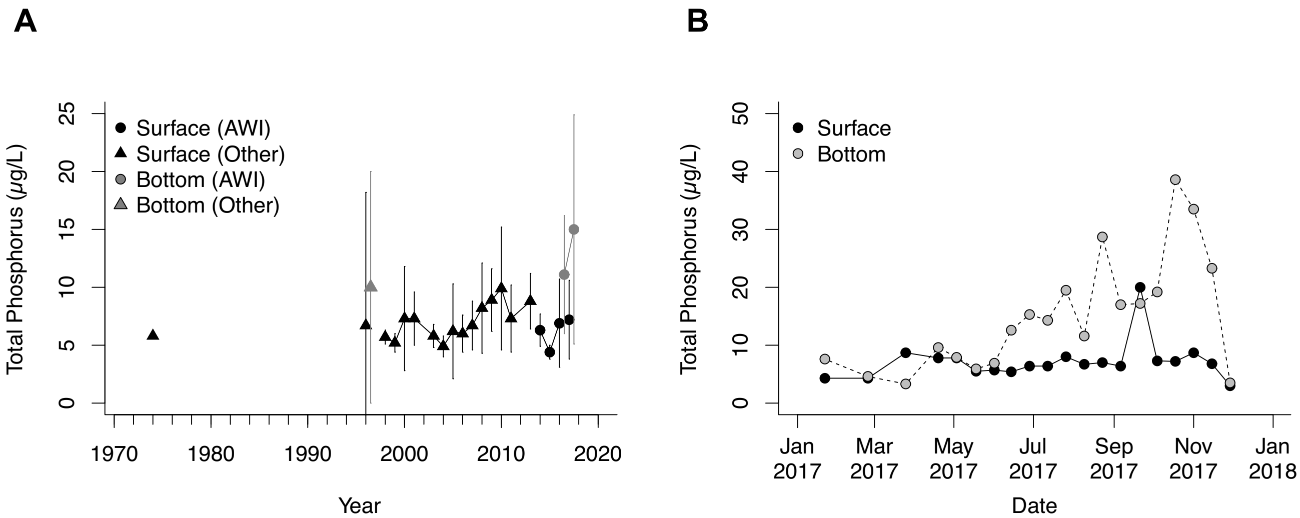


Figure 3. Annual average (a) and 2017 (b) total phosphorus. Black triangles represent data collected by other programs from the epilimnion, black circles represent 2m integrated samples collected by AsRA and AWI. The gray triangles and circles are from discrete samples collected 1m above the lake bottom. Vertical bars represent one standard deviation of the mean. Annual bottom water samples have been offset by +0.5 years for ease of viewing.

Phosphorus is relatively common in igneous rocks such as those found in the Adirondacks and is also abundant in sediments. The concentration of phosphorus in natural waters is low, however, because of the low solubility of these inorganic forms (Wetzel 2001). Phosphorus is also a component of wastewater and is a primary source of phosphorus in many waters. Typical concentrations of phosphorus in surface water are a few micrograms per liter. Additions of phosphorus to the aquatic environment enhance algal growth and accelerate eutrophication that leads to depletion of dissolved oxygen (Schindler 1977; Wetzel 2001).

Phosphorus is also added to surface waters from non-point sources such as eroding soils, stormwater, runoff from fertilized fields, lawns, and gardens, and runoff from livestock areas or poorly managed manure pits. Poorly maintained or sited septic systems can also add phosphorus to surface waters. In addition, analyses of water chemistry in Adirondack upland streams shows that streams coming off old growth forest have higher phosphorus concentrations than those flowing off managed forests (Myers et al. 2007).

Phosphorus plays an important role in biology and is an important nutrient in aquatic ecosystems. Phosphorus is often a limiting nutrient in lakes, meaning that it is a lack of phosphorus that limits aquatic primary production (Schindler 1977). Phosphorus normally enters a lake bound to soil and sediment through overland flow. In developed or urban areas, excess phosphorus can enter a lake due to application to the land as fertilizer or through poor wastewater management. This increase in phosphorus may lead to increased primary production, resulting in aesthetic changes to the lake. If the increase in primary production is large enough, there may be subsequent problems with oxygen depletion because of decomposition. The reduction in oxygen can lead to fish kills and other negative impacts (Carpenter et al. 1998).

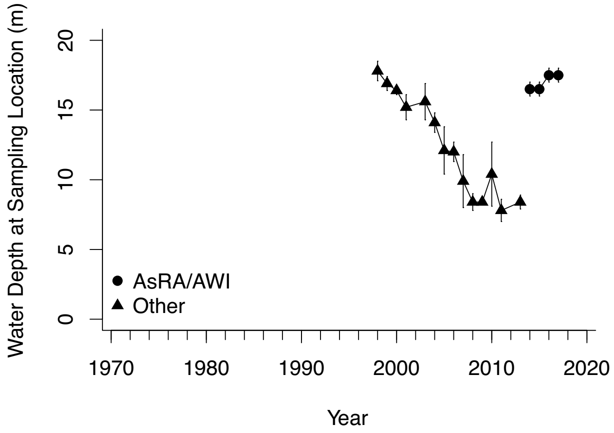


Figure 4. Water depth at the water sampling location. CSLAP samples are represented as closed triangles, ALAP data are closed circles.

Interpreting long-term trends in water quality parameters for Mirror Lake is challenging due to inconsistency in sampling location in the CSLAP data set. A detailed discussion of this is presented in the 2016 Mirror Lake Water Quality Report (Wiltse et al. 2017). It is important to interpret changes in water quality from the period of roughly 2003 to 2014 with caution.

In 2017, total phosphorus concentrations at the surface were generally low and consistent with an oligotrophic lake (Figure 3b). A much higher total phosphorus concentration was recorded in late September, which is consistent with the timing of a sewage leak that occurred. This event was brought to AsRA's attention by a resident, who noticed black water in the outlet pool of the stormwater discharge pipe at the bottom of Saranac Avenue. Testing conducted by AsRA and AWI indicated a total phosphorus concentration of >4 mg/L, E. coli concentration of >2,320 MPN/100mL, and the presence of optical brighteners in the water. All of these indicated a cross connection between the sewer and stormwater systems was likely. Increased algal productivity was observed in the area adjacent to the stormwater discharge pipe, but not in the open water portion of the lake. The Village of Lake Placid responded rapidly upon notification of these results and identified and resolved the issue within 24 hours. This incident is a good reminder of the advantage of having an established monitoring program in place that is capable of rapidly testing and responding to possible water quality concerns.

The elevated bottom water concentrations observed from mid- to late-summer through fall turnover is the result of the release of phosphorus from lake sediments under anaerobic conditions (Figure 3b). During this period bottom water of the lake was anoxic (Figure 10a), resulting in inorganic exchange of phosphorus from the sediments to the water above. In some lakes, prolonged periods of anoxic conditions at the lake bottom can result in significant internal phosphorus loading.

Excessive algal growth in the area of the lake near the stormwater discharge pipe that contained wastewater effluent.

Nitrogen

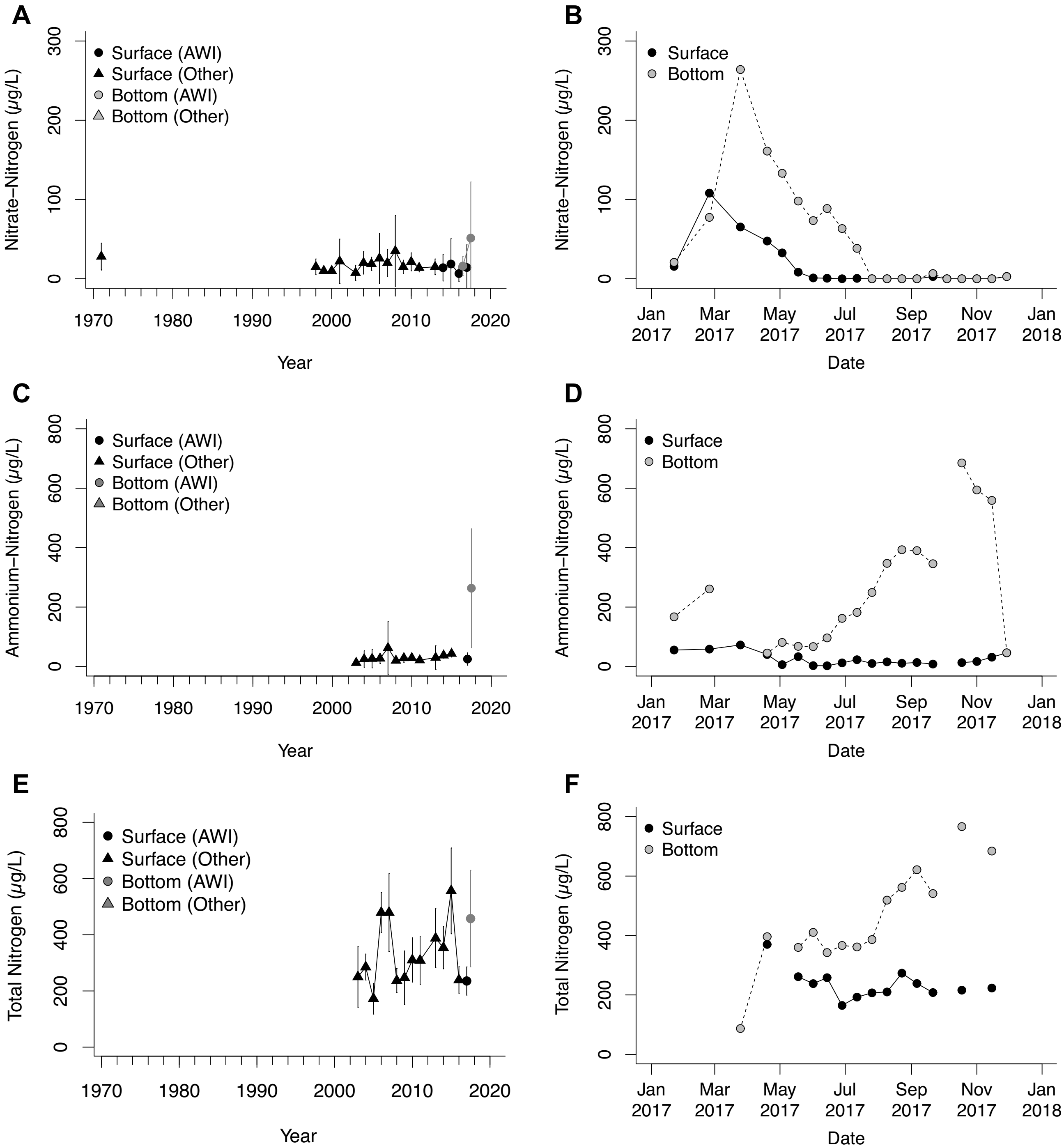


Figure 5. Annual average (a) and 2017 (b) nitrate, annual average (c) and 2017 (d) ammonium, and annual average (e) and 2017 (f) total nitrogen. Black triangles represent data collected by other programs from the epilimnion, black circles are 2m integrated samples collected by AsRA and AWI. The gray triangles and circles are from discrete samples collected 1m above the lake bottom. Vertical bars represent one standard deviation of the mean. Annual bottom water samples have been offset by +0.5 years for ease of viewing.

Nitrogen is present in many forms in the atmosphere, hydrosphere, and biosphere, and is the most common gas in the earth's atmosphere. The behavior of nitrogen in surface waters is strongly influenced by its vital importance to plant and animal nutrition. Nitrogen occurs in water as nitrite (NO_2-) or nitrate (NO_3-) anions, ammonium (NH_4+) cations, or organic nitrogen. Excessive, or high levels of nitrite are an indicator of organic waste or sewage. Nitrate or ammonium may also be from a pollutant source, but, generally, are introduced at a site far removed from the sample point. This is because nitrate is stable over a range of conditions, but nitrite rapidly volatilizes in oxygenated water. Ammonium is an important nutrient for primary producers, but, at high concentrations, is a dangerous pollutant in lakes and rivers, because the bacterial conversion of NH_4 to NO_3 robs water of oxygen. Generally, nitrogen is not a limiting nutrient in aquatic ecosystems (Schindler 1977).

In 2017, ammonium and total nitrogen were added as analytes to provide a complete understanding of nitrogen availability in the lake. There are no long-term trends in any forms of nitrogen in Mirror Lake (Figure 5a, c, e). Nitrate concentrations are low, indicating it is not likely the lake is receiving significant additional inputs of nitrogen from the watershed. Throughout the year, nitrate varies considerably due to rapid utilization by primary producers in the water column (Figure 5b). Concentrations of nitrate were higher in the hypolimnion than the epilimnion through the spring and early summer months. This is a common pattern for lakes in our area. The nitrification process carried out by chemoautotrophic bacteria convert ammonium to nitrate in the presence of oxygen. Production by photosynthetic organisms is substantially lower in the hypolimnion so the concentration of nitrate builds while there is oxygen in the hypolimnion. When the hypolimnion goes anoxic in the early- to mid-summer, the nitrification process works in reverse, resulting in a sharp decrease in nitrate in the hypolimnion that persists until the late fall when the water completely mixes, returning oxygen to the bottom of the lake.

Ammonium (NH_4) is even more bioavailable to photosynthetic organisms than nitrate and therefore remains low in the upper portion of the water column. In the bottom waters, ammonium is rapidly converted to nitrate in the presence of oxygen. Under anoxic conditions bacteria stop converting ammonium to nitrate, therefore concentrations in hypolimnion begin to build (Figure 5d). Sediment absorption of ammonium is also reduced under anoxic conditions, at which point a release of ammonium from the sediments can occur (Wetzel 2001). Additionally, ammonium is generated by the decomposition of organic matter and therefore adds to the accumulation of ammonium in the hypolimnion in the early-summer through fall. At periods of turnover, early spring and late fall, when the water column is well oxygenated, ammonium concentrations are uniform and low throughout the water column (Figure 5d). Total nitrogen largely reflects the combined trends in nitrate and ammonium, but with absolute numbers higher due to the inclusion of organically bound nitrogen (Figure 5e,f).

Nitrogen to Phosphorus Ratio

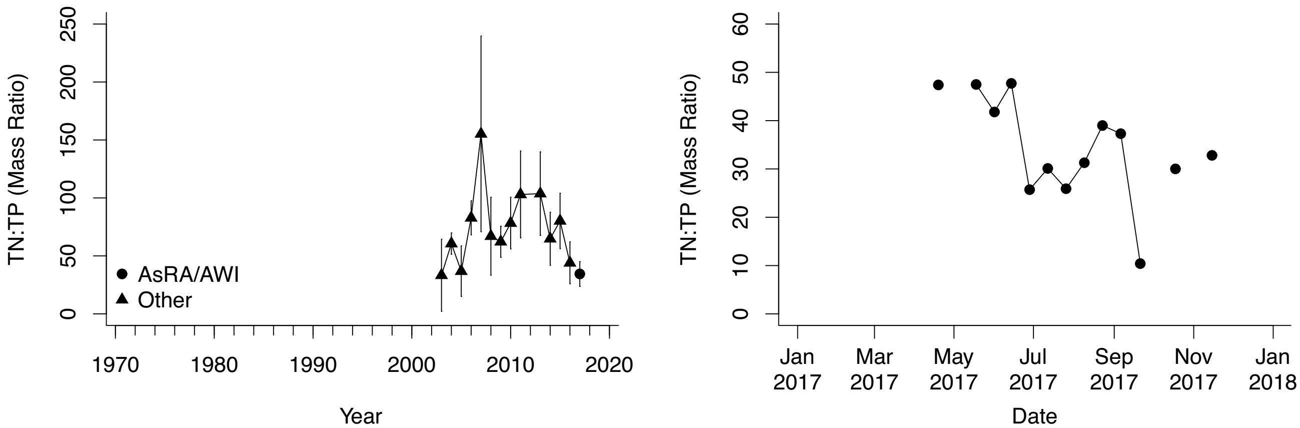


Figure 6. Annual average (a) and 2017 (b) nitrogen to phosphorus mass ratio. Black triangles represent data collected by other programs from the epilimnion, black circles 2m integrated samples collected by AsRA and AWI. Vertical bars represent one standard deviation of the mean. Annual bottom water samples have been offset by +0.5 years for ease of viewing.

As the two primary nutrients in aquatic ecosystems, the ratio of nitrogen to phosphorus (TN:TP) can indicate which is the limiting nutrient and which phytoplankton species are likely to be dominant. Increasing occurrence of harmful algal blooms has renewed interest in lake nutrient cycling and how that relates to the occurrence of toxic blooms. The importance of TN:TP to cyanobacterial blooms is debated, but there is evidence that low TN:TP mass ratios favor both nitrogen fixing and non-nitrogen fixing cyanobacteria (Smith 1983). A TN:TP mass ratio of 22:1 appears to be a threshold under which lakes are more likely to be dominated by N-fixing cyanobacteria (Smith et al. 1985). Laboratory experiments have shown that non-nitrogen fixing *Microcystis* dominates below ratios of 44:1 (Fujimoto & Sudo 1997). While TN:TP ratios may be an important driver of cyanobacterial blooms, it is important to recognize that other factors are important as well, such as temperature, salinity, NO_3:NH_4 mass ratios, and pH (Liu et al. 2011).

In Mirror Lake, there is no long-term trend in TN:TP ratios. For much of the record mean annual ratios are above 50:1. Although mean annual ratios aren't as important as the seasonal variation because blooms occur at specific times of the year when conditions are favorable. For much of 2017, TN:TP ratios were below 44:1 indicating the potential for *Microcystis* to bloom, but only dipped below 22:1 in September when a large input of phosphorus occurred due to a sewage leak.

Chlorophyll-a

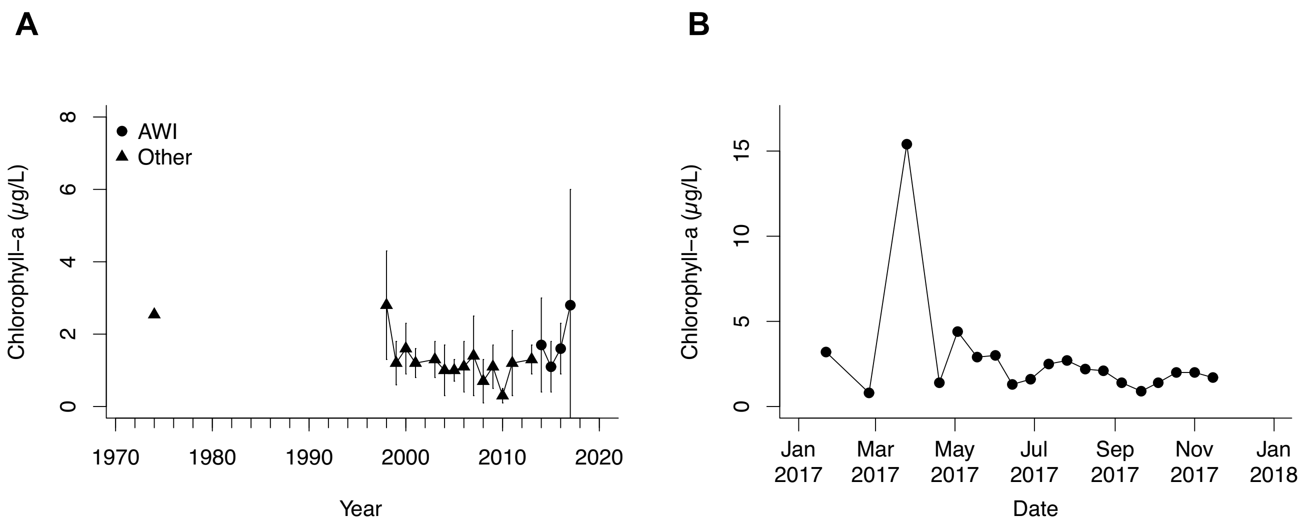


Figure 7. Annual average (a) and 2016 (b) chlorophyll-a. Black triangles represent data collected by other programs from the epilimnion, black circles 2m integrated samples collected by AsRA and AWI. Vertical bars represent one standard deviation of the mean.

Chlorophyll-*a* is the primary photosynthetic pigment in all photosynthetic organisms including algae and cyanobacteria. The concentration of chlorophyll-*a* is used as an index for algal biomass, or productivity. Nutrient concentrations, light, and water temperature all control algal productivity. Depending on the time of year, these three variables change and can limit algal production. Therefore, we expect to see variability in chlorophyll-*a* throughout the year. Major shifts in chlorophyll-*a* concentration over many years can usually be attributed to changes in nutrients (phosphorus, nitrogen, and silica) (Wetzel, 2001).

In Mirror Lake, chlorophyll-*a* concentrations vary throughout the year (Figure 7b), with the highest concentrations occurring in the spring. This time of the year typically sees the highest productivity in the surface waters due to increased nutrient availability and relatively low zooplankton herbivory. During this time of the year, lake turnover, complete mixing of the water column, redistributes the nutrient-rich bottom waters up to the lake surface where there is plenty of light.

Analysis of the annual data shows no significant trend in chlorophyll-*a* (Figure 7a). There was a particularly high concentration reported in 1971 (Oglesby 1971). It is possible that these measurements were inaccurate as there are not corresponding low Secchi readings or high total phosphorus concentrations, both of which would be expected if there was significantly higher primary production during that time. Therefore, we have omitted this measurement from Figure 6a.

Transparency

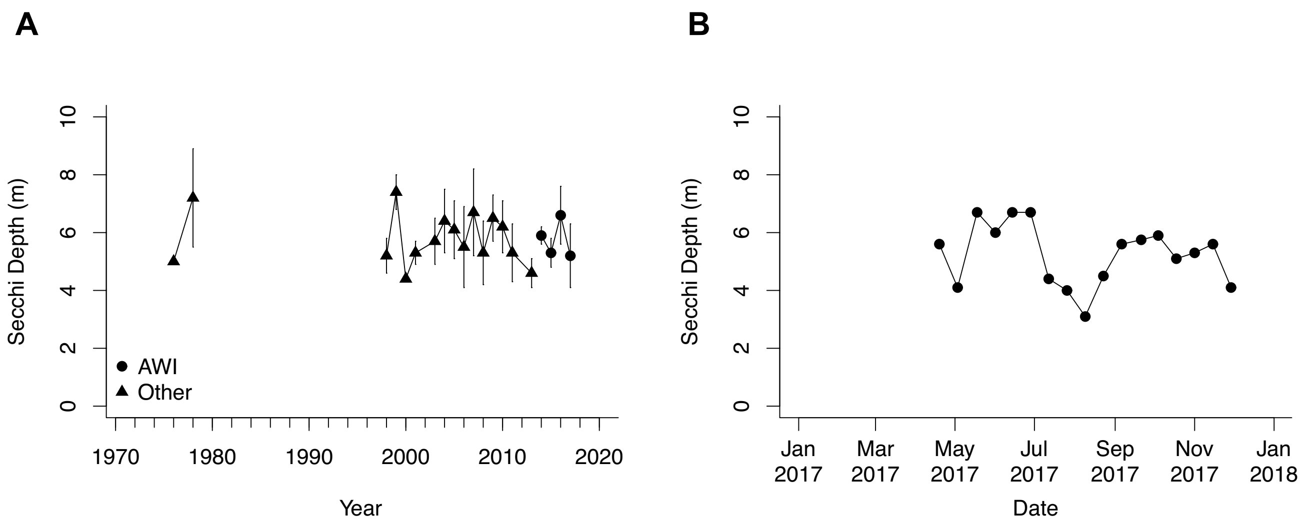


Figure 8. Annual average (a) and 2016 (b) transparency. Black triangles represent data collected by other programs from the epilimnion, black circles 2m integrated samples collected by AsRA and AWI. Vertical bars represent one standard deviation of the mean.

Water column transparency is a simple measure of lake productivity. Generally, Secchi depth is lower in highly productive eutrophic lakes and higher in less productive oligotrophic lakes. Secchi depth can also be influenced by other water quality parameters that impact clarity, such as dissolved organic carbon, total suspended solids, colloidal minerals, and water color. Therefore, it is valuable to keep other water quality parameters, such as total phosphorus and chlorophyll-*a*, related to lake productivity in mind when looking at changes in transparency. Changes in watershed characteristics, such as the amount of runoff from precipitation or the export of organic matter, can also influence transparency.

No significant change in lake water transparency was detected in Mirror Lake (Figure 8a). The highest water column transparency during 2017 was observed in spring and early summer. During the remainder of the year, transparency measurements are consistent. In some Adirondack lakes, water column transparency is declining as a result of dissolved organic carbon (DOC) increasing due to recovery from acid deposition (Warren et al. 2016). The exact mechanism driving regional increases in DOC is not fully understood. Cultural eutrophication can also lead to a decline in water column transparency (Wetzel 2001). Neither appears to be the case in Mirror Lake (Figure 8a).

Trophic Status

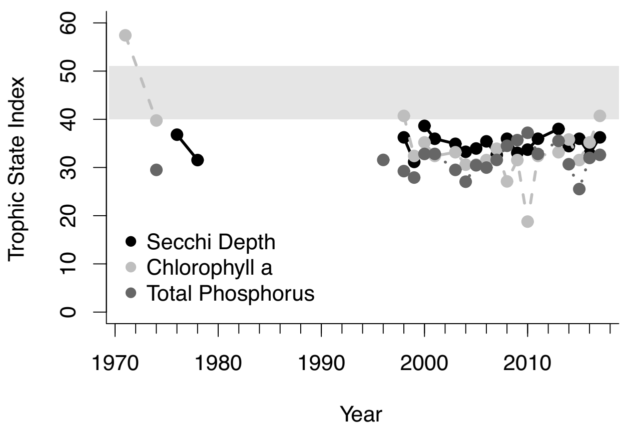


Figure 9. Annual average trophic state index based on secchi depth (black), chlorophyll-a (light gray), and total phosphorus (dark gray).

Trophic status is used by limnologists to refer to the overall productivity of a lake. Lake productivity is influenced by the nutrient supply, light availability, regional climate, watershed characteristics, and lake morphology. The term cultural eutrophication is often used to describe the process whereby human activities increase lake productivity through an increase in the nutrient supply. This process usually results in unwanted outcomes such as declines in lake aesthetics, an increased chance of harmful algal blooms, and fish kills due to elevated bacterial decomposition utilizing all the available oxygen in the water column.

Lakes can be assigned to three main classification categories based on their overall productivity: oligotrophic, mesotrophic, or eutrophic. Oligotrophic lakes have the lowest productivity due to low nutrient content. These lakes are often characterized by clear, highly transparent water, with low phytoplankton biomass. The entire water column is often well oxygenated, making these lakes capable of supporting cold water fish species such as lake trout. Mesotrophic lakes are an intermediate state between oligotrophy and eutrophy. Eutrophic lakes are characterized by high productivity and high nutrient content. As a result, the water column is less clear due to increased phytoplankton production. The greater production of organic matter leads to higher rates of bacterial decomposition at the bottom of the lake. Bacteria utilize oxygen, resulting in a decrease in oxygen availability in the bottom waters during the summer stratified period. This reduction in oxygen is referred to hypoxic (low oxygen) or anoxic (no oxygen) conditions and is not conducive to supporting cold water fish.

Carlson's Trophic Status Index (TSI) can be used to identify which of these trophic classifications a lake belongs to. TSI uses phytoplankton biomass as a measure of the trophic state of the lake. It utilizes independent estimates of phytoplankton biomass using chlorophyll-*a* pigment concentrations, Secchi depth, and total phosphorus concentrations (Carlson 1997). Values of less than 40 are common among oligotrophic lakes, 40-50 is common for mesotrophic lakes, and greater than 50 is common for eutrophic lakes.

TSI has been calculated based on annual averages of chlorophyll-*a*, Secchi depth, and total phosphorus for Mirror Lake (Figure 9). Over the period of record, Mirror Lake has consistently stayed within the oligotrophic classification with no significant trends over time. An early estimate using chlorophyll-*a* placed the lake in the eutrophic category, but as discussed in the chlorophyll-*a* section this is likely an erroneous measurement. The estimate using total phosphorus indicated an increasing trend during the period which showed an increase in this parameter. As discussed in the total phosphorus section, these data are questionable due to the inconsistency in the sample location. Mirror Lake does not show evidence of cultural eutrophication or any obvious shifts in its trophic status since the late 1970's.

Dissolved Oxygen

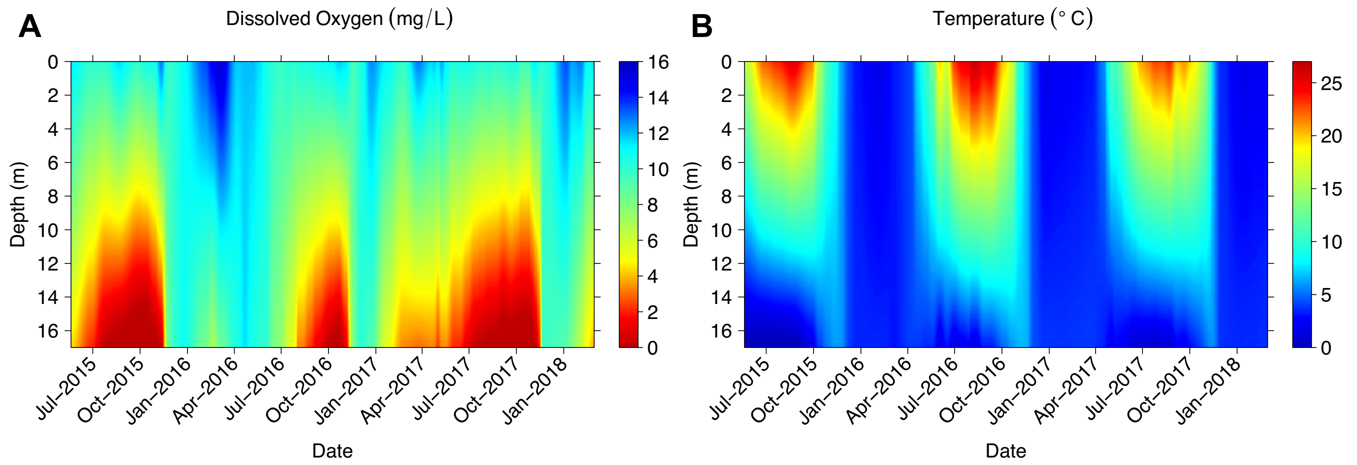


Figure 10. Dissolved oxygen (a) and temperature (b) from vertical profiles collected at 1m intervals over the deepest location of the lake during 2015-2017. A first-order loess smoother was fit to the data to create the continuous plots depicted above.

The primary sources of dissolved oxygen in lakes occur through diffusion from the atmosphere and primary production. Dissolved oxygen is consumed through respiration and decomposition. The solubility of oxygen in water is directly related to temperature and salinity and decreases as both increase. Oxygen is vital to aerobic forms of life such as aquatic insects, zooplankton, and fish. Oxygen availability from the atmosphere and primary production vary throughout the year. During periods of lake turnover (spring and fall), oxygen is redistributed throughout the water column. During the summer stratified period, warm water at the surface of the lake prevents the cold bottom waters from mixing and cuts off the source of atmospheric oxygen. Similarly, during the winter months, while the lake is covered with ice, the supply of atmospheric oxygen is cut off and contributions from primary production are low.

Generally, oxygen depletion in the hypolimnion is a problem in eutrophic lakes with high rates of decomposition. It can also be prevalent in lakes that have a shallow hypolimnion and a large sediment surface area to volume ratio. Reductions in hypolimnetic dissolved oxygen are of primary concern to native salmonid species. During the summer months, these fish species seek out an optimal zone in the lake, an area which is both cool (<18 °C) and well oxygenated (>7 mg/L). In lakes with low hypolimnetic dissolved oxygen, this often pushes these species into a narrow range of depths as oxygen concentrations decline throughout the summer. Many lakes are experiencing longer periods of stratification due to climate change (De Stasio et al. 1996). This is causing the cold hypolimnetic waters to be cut off from atmospheric sources of oxygen for longer periods of time and threatening the ability of cold water fish species to find both cold and well-oxygenated water.

Mirror Lake experienced hypoxic conditions (<2 mg/L dissolved oxygen) in the hypolimnion during the summer in 2015, 2016, and 2017 (Figure 10a). By the end of the summer stratified period, only a few meters of the water column fit the optimal criteria for cold water fish (Figure 10a & b). When sampling started in June 2015, the bottom waters were low in dissolved oxygen and the size of the hypoxic zone in the lake during the summer of 2015 was extensive. In the fall of 2015, the lake turned over, redistributing oxygen throughout the water column. Oxygen concentrations declined slightly throughout the winter, but the water column remained well oxygenated. This is typical for an oligotrophic lake with low rates of decomposition. In the spring of 2016, the lake turned over, again redistributing oxygen throughout the water column. During the summer of 2016, hypoxic conditions again appeared in the hypolimnion but to a lesser extent than in 2015. In the fall of 2016, the lake turned over and again the entire water column was well oxygenated. During the winter of 2017, a hypoxic zone began to form and persisted into the summer due to a lack of spring turnover. The lack of turnover resulted in a hypoxic zone much larger in both duration and spatial extent than what was observed in 2016.

The hypoxic conditions in the hypolimnion of Mirror Lake are a concern for the long-term survival of lake trout within the lake. This problem is expected to worsen as the regional climate warms and the period of stratification lengthens (De Stasio et al. 1996). The ice record for Mirror Lake shows a three-week increase in the open water season over the past 100 years (Figure 11). If the longer open water season is also resulting in a longer period of stratification, the lake may reach a point where there is no lake trout habitat left at the end of the summer stratified season. Dissolved oxygen concentrations and temperature profiles in Mirror Lake should continue to be monitored closely. A further discussion on the internal mixing dynamics of the lake is discussed on page 22 of this report.

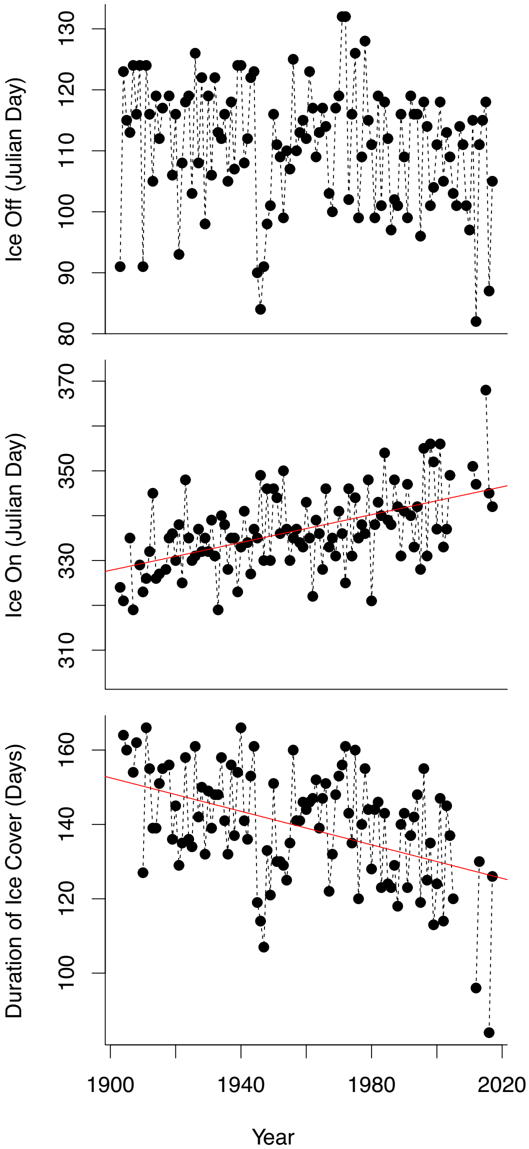


Figure 11. Ice record for Mirror Lake. There is no significant trend in ice off. Ice on ($y=0.16x-33$, $R^2=0.29$, $p<0.01$) and duration of ice cover ($y=-0.23x+580$, $R^2=0.20$, $p<0.01$) both show significant trends.

Acidity

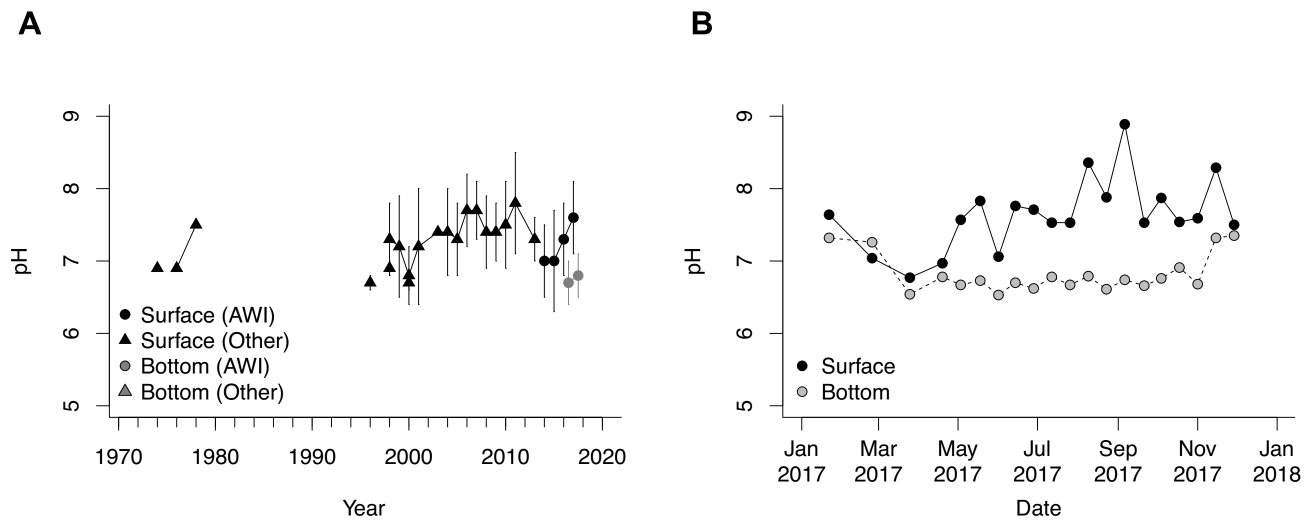


Figure 12. Annual average (a) and 2016 (b) pH. Black triangles represent data collected by other programs from the epilimnion, black circles 2m integrated samples collected by AsRA and AWI. The gray triangles and circles are from discrete samples collected 1m above the lake bottom. Vertical bars represent one standard deviation of the mean. Annual bottom water samples have been offset by +0.5 years for ease of viewing.

pH is an index of the hydrogen ion activity in solution, it is defined as the logarithm of the reciprocal of the concentration of free hydrogen ions in solution. Therefore, high pH values represent lower hydrogen ion concentrations than low pH values, and there is a 10-fold difference in hydrogen ion concentration across a single pH unit. The pH scale extends from 0 to 14, with 7 being neutral. pH values below 7 indicate acidic conditions and pH values greater than 7 indicate alkaline conditions.

Acidity in Adirondack surface waters has two sources: acid deposition (rain, snow, and dry deposition) and organic acids from evergreen needles and other plant matter. Long-term monitoring by the Adirondack Lakes Survey Corporation shows that 25% of lakes in the Adirondacks have a pH of 5.0 or lower and another 25% are vulnerable to springtime acidification (ALSC, 1990).

Shifts in pH can have major effects on the dominant biological and chemical process present within a lake. Many organisms have narrow pH tolerances, resulting in significant declines in individual health and population numbers if pH values stray outside of their tolerances. Changes in pH also influence the mobility of ions and heavy metals which can result in issues related to nutrient availability and toxicity (Driscoll 1985; Schindler et al. 1985).

Over the period of record, Mirror Lake has stayed within the circumneutral (6.5-7.5) to slightly alkaline (>7.5) range (Figure 12a). There is no long-term trend in pH present in Mirror Lake, but pH appeared to increase from 2003 to 2012. Data from the National Atmospheric Deposition Monitoring Program in Huntington Forest (central Adirondacks) reveals that the primary indices of acid deposition, pH, and the acid anions sulfate and nitrate, are all exhibiting significant reductions over the past 35 years. Likewise, recent research from 74 lakes in Northeast (60% in the Adirondacks) illustrates that several acid indicators such as sulfate concentration and ANC are exhibiting significant recovery (Strock et al 2014). Thus, it is reasonable to expect an acid reduction in Mirror Lake.

Alkalinity

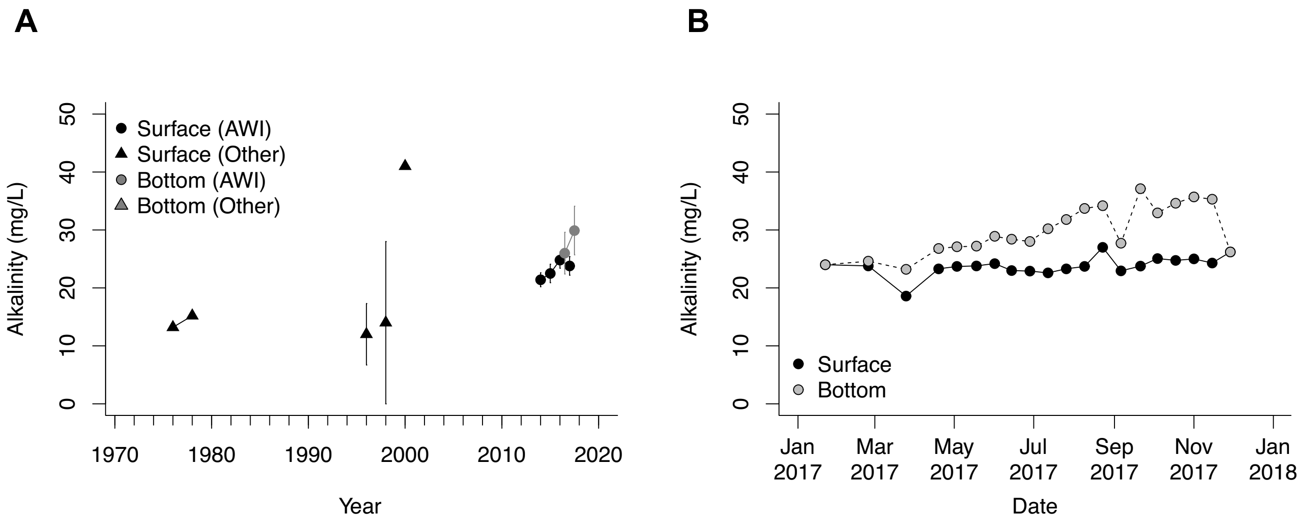


Figure 13. Annual average (a) and 2016 (b) alkalinity. Black triangles represent data collected by other programs from the epilimnion, black circles 2m integrated samples collected by AsRA and AWI. The gray triangles and circles are from discrete samples collected 1m above the lake bottom. Vertical bars represent one standard deviation of the mean. Annual bottom water samples have been offset by +0.5 years for ease of viewing.

Alkalinity is a measure of buffering capacity of a waterbody, typically expressed as mg/L of calcium carbonate ($CaCO_3$). The amount of calcium carbonate in a waterbody is primarily related to the bedrock geology of its watershed. Lakes with watersheds underlain by granitic bedrock tend to have low alkalinity due to slow rates of weathering of the bedrock and low amounts of calcium carbonate in the rock. Conversely, lakes underlain by sedimentary rocks such as limestone tend to both weather faster and contain more calcium carbonate. Many lakes in the Adirondacks are underlain by granitic bedrock and therefore have lower alkalinity.

While there appears to be an increase in alkalinity, we detected no significant trend over the period of record (Figure 13a). Mirror Lake's current alkalinity indicates that it has low sensitivity to acidification (Figure 13b). In other words, Mirror Lake has sufficient buffering capacity to resist acidification. The potential long-term increase may be a result of regional declines in acid deposition or may be related to development within the watershed. Increases in limestone-based concrete associated with the development around the lake may be associated with an increase in alkalinity.

Calcium

The primary source of calcium in lakes is $CaCO_3$, thus the discussion of calcium is closely tied to that of alkalinity. $CaCO_3$ is not very soluble in water, but in the presence of carbonic acid, it is converted to more soluble forms. The primary source of calcium in lakes is from weathering of parent material. Calcium is an important element in biology because it serves a role in the structure and physiology of many organisms. In the Adirondacks, the granitic parent material contains little calcium, and therefore Adirondack lakes tend to be low in calcium. Regionally, lakes are showing calcium declines, in part because of acid deposition. Acid deposition resulted in increased calcium leaching from watershed

Calcium continued

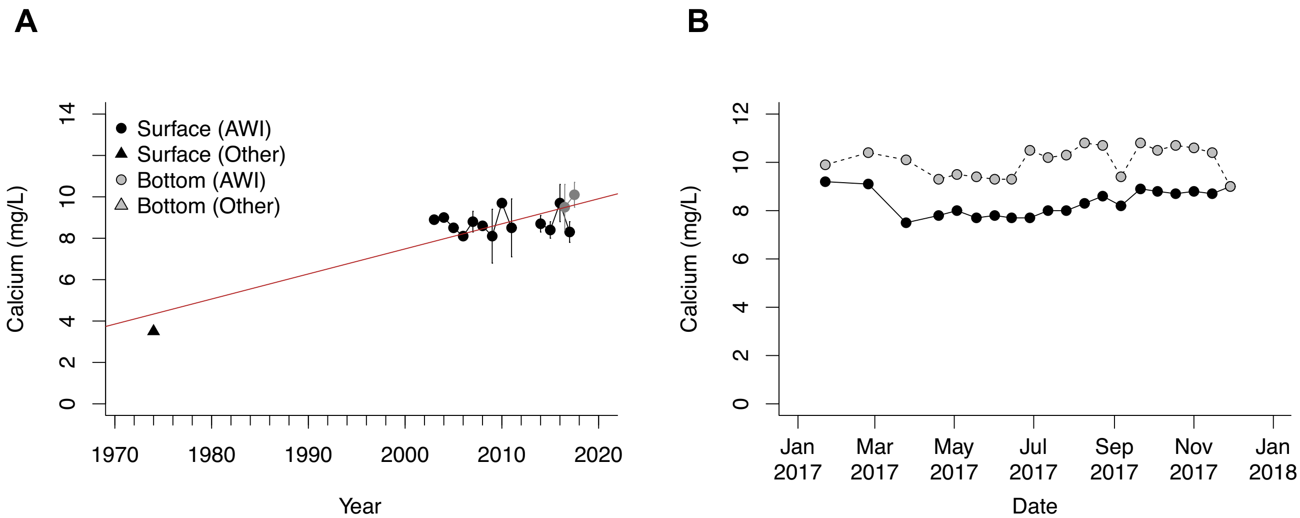


Figure 14. Annual average (a) and 2016 (b) calcium. Black triangles represent data collected by other programs from the epilimnion, black circles 2m integrated samples collected by AsRA and AWI. The gray triangles and circles are from discrete samples collected 1m above the lake bottom. Vertical bars represent one standard deviation of the mean. Annual bottom water samples have been offset by +0.5 years for ease of viewing. Calcium shows a significant trend over the period of record (y=0.12x-234.7, R^2=0.74, p=<0.001).

soil, eventually reducing the pool available for export to lakes (Keller et al. 2001). Concentrations are low enough in some lakes (<2 mg/L) to cause declines in zooplankton that utilize calcium to build their carapace (Jeziorski et al. 2008).

Contrary to regional declines in calcium, Mirror Lake has exhibited an increase over time (Figure 14a). Current concentrations are well above other Adirondacks lakes (Figure 14b). Mirror Lake is above the 90th percentile for lakes monitored as part of the Adirondack Lake Assessment Program (Laxson et al. 2016). Kelting and Laxson (2017) observed 62% higher concentrations of calcium, magnesium, and potassium in lakes with paved roads in their watersheds. Application of sodium chloride (NaCl) as a road deicer results in increased export of these ions from the watershed to the lake when sodium replaces calcium, magnesium, and potassium on soil cation exchange sites (Kelting and Laxson 2017; Mason et al. 1999). In addition, these ions are commonly used with alternative road deicing agents (calcium chloride, magnesium chloride, and calcium magnesium acetate). It is also possible that the elevated calcium concentrations in Mirror Lake are the result of development. The import of calcium-rich materials for construction, primarily limestone-based concrete, and the subsequent weathering may be a significant source of calcium to Mirror Lake. A crushed limestone beach maintained on the lake is also a likely source of calcium to the lake.

Calcium is an important, and sometimes limiting, nutrient to mussels such as the zebra mussel. In many Adirondack lakes, calcium concentrations are too low (<12 mg/L) to support zebra mussel populations (Whittier et al. 2008). Calcium concentrations measured by Oglesby in 1971 were well below this threshold, but recent concentrations are high enough where it may be possible for a zebra mussel population to become established if they were introduced to Mirror Lake (Oglesby 1971; Whittier et al. 2008).

Conductivity

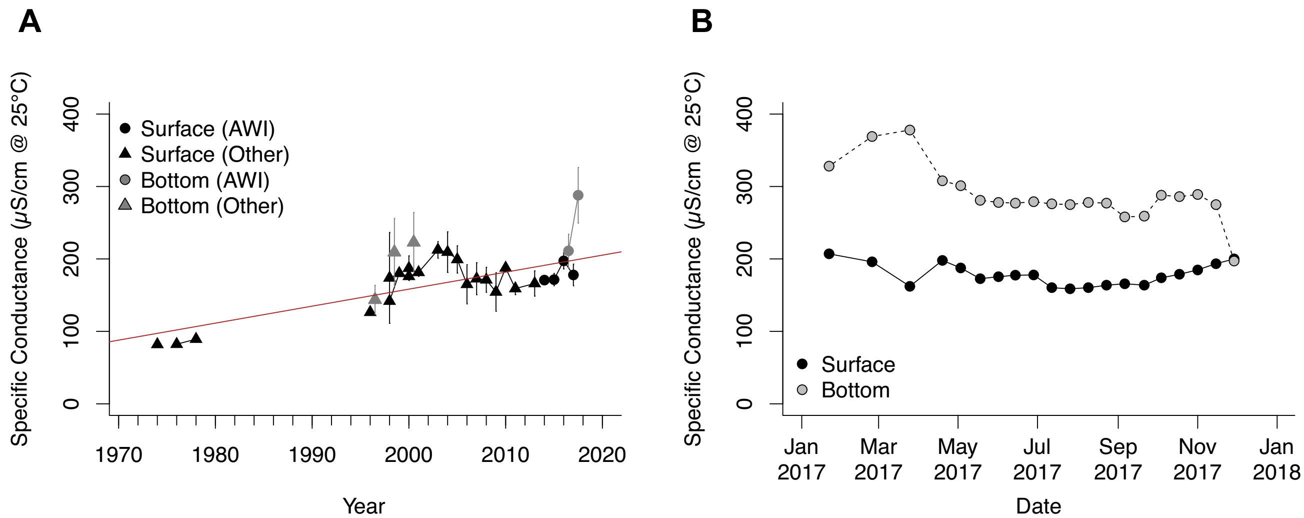


Figure 15. Annual average (a) and 2016 (b) nitrate-nitrogen. Black triangles represent data collected by other programs from the epilimnion, black circles 2m integrated samples collected by AsRA and AWI. The gray triangles and circles are from discrete samples collected 1m above the lake bottom. Vertical bars represent one standard deviation of the mean. Annual bottom water samples have been offset by +0.5 years for ease of viewing. Conductivity shows a significant trend over the period of record ($y=2.35x-4534$, $R^2=0.60$, $p<0.01$).

Conductivity—the ability of water to pass an electrical current because of the presence of dissolved ions—is often called the "watchdog" environmental test since it is informative and easy to perform. Calculations of specific conductance standardize conductivity measurements to the temperature of 25 °C for the purposes of comparison. Rain, erosion, snowmelt, runoff carrying livestock waste, failing septic systems, and road salt raise conductivity because of the presence of ions such as chloride, phosphate, nitrite etc. Oil spills lower water conductivity. Temperature, shade, sunlight, and sampling depth all affect conductivity. A conductivity probe does not identify the specific ions in a water sample—it simply measures the level of total dissolved solids (TDS) in the water body.

Mirror Lake has experienced a significant increase in conductivity over the period of record (Figure 15a). This trend is indicative of the lake being affected by the application of rock salt to roads and sidewalks in the watershed, and the subsequent runoff into Mirror Lake. The data from the early 1970s pre-dates the widespread increase in the use of rock salt on Adirondack roadways and is at the early period of widespread use of road salt nationally (Langen et al. 2006; TRB 1991). Over the course of 2017, we saw a difference in conductivity between the lake's surface and its hypolimnion during almost the entire year (Figure 15b). This indicates an accumulation of dense salt-laden water at the lake bottom. During the fall of 2017, the lake turned over, returning the water column to uniform conductivity.

Sodium & Chloride

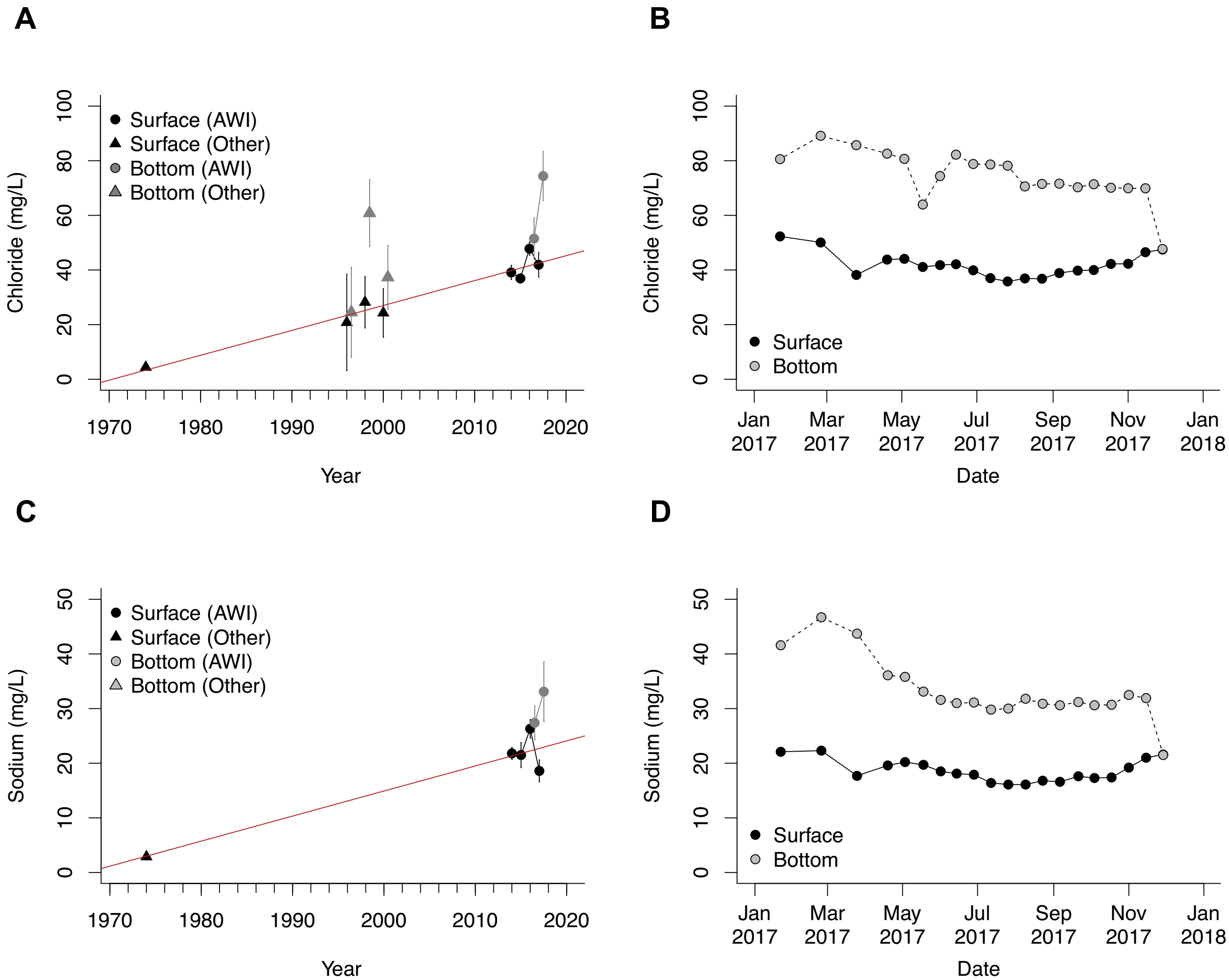


Figure 16. Annual average (a) and 2016 (b) chloride and annual average (c) and 2016 (d) sodium. Open squares represent data collected by other programs from the epilimnion, closed black circles 2m integrated samples collected by AsRA and AWI. The closed gray circles are from discrete samples collected 1m above the lake bottom. Vertical bars represent one standard deviation of the mean. Annual bottom water samples have been offset by +0.5 years for ease of viewing. Both chloride (y=0.91x-1795, R^2=0.94, p=<0.01) and sodium (y=0.46x-902, R^2=0.89, p=0.02) show a significant trend over the period of record.

The element chlorine can occur in various forms or states of oxidation, but the chloride form (Cl-) is most common in surface waters. There are several natural sources of sodium and chloride, including various rocks that contain sodium- and chlorine-bearing minerals. The most abundant natural mineral form of sodium and chloride is NaCl or Halite, also known as rock salt. Large halite deposits form when ocean water evaporates and mineral deposits are buried, eventually becoming rock.

Chloride is present in most natural waters at very low concentrations, except where surface or groundwater mixes with ocean water. Minimally impacted Adirondack lakes have median chloride and sodium concentrations of 0.2 mg/L and 0.5 mg/L, respectively (Kelting et al. 2012). Another source

Sodium & Chloride continued

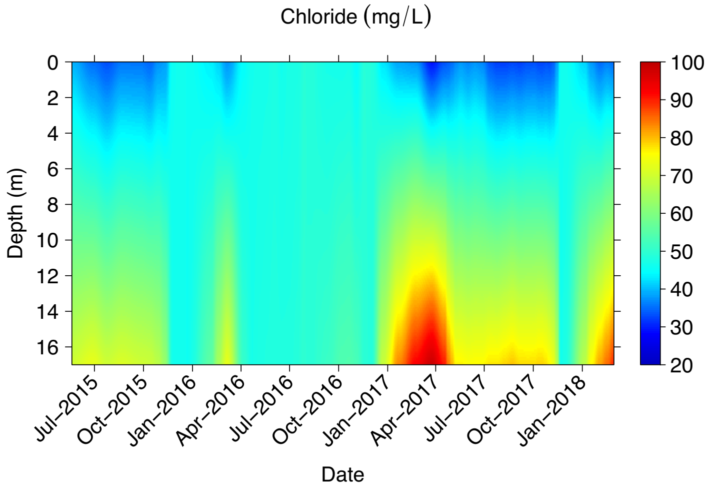


Figure 17. Chloride concentration inferred from conductivity measurements taken at 1m intervals over the deepest location of the lake during 2015 and 2016. A second order loess smoother was fit to the data to create the continuous plots depicted above.

of chloride is road runoff, in regions where rock salt is used as a road deicing agent in winter. New York has one of the highest rock salt application rates per lane mile in the United States (Kelting & Laxson 2010). These application rates are applied on state roads across the state, regardless of proximity to surface waters. Within the Village of Lake Placid, significant amounts of rock salt are applied to the sidewalk around Mirror Lake. The runoff from this area and the adjacent roadways goes directly into Mirror Lake. For a more detailed discussion of chloride toxicity see the Mirror Lake 2016 Water Quality report (Wiltse et al. 2017).

Sodium and chloride concentrations have increased significantly over the period of record (Figure 16a & c). The surface water samples collected by Oglesby in 1974 had sodium and chloride concentrations of 2.9 and 4.4 mg/L, respectively. In 2017, average concentrations were 18.6 and 41.9 mg/L, respectively.

To better understand the distribution of chloride throughout the water column we modeled chloride concentrations based on conductivity measurements. Under a linear model, field specific conductance explains 78% of the variation in chloride concentration ($y=0.27x-11.59$, $R^2=0.78$, $p<0.01$). Using this relationship, we modeled chloride concentrations at 1-m intervals throughout the water column on a bi-weekly basis during the open water season, and monthly while the lake was frozen.

The chloride data show that during the summer of 2015, the chloride concentrations in the hypolimnion were 60-70 mg/L while surface water concentrations were 35-40 mg/L (Figure 17). During the winter of 2015-16, elevated chloride concentrations were observed in the hypolimnion (Figure 17). The onset of this rise in concentration coincides with two runoff events in late-February and early-March. The water column mixed completely in the spring of 2016 and stayed relatively uniform in concentration until early 2017 when chloride began to build in the bottom waters of the lake. High chloride concentrations persisted through 2017 due to a lack of complete mixing in the spring. The lake mixed in the fall of 2017, but immediately afterward chloride again began to build at the bottom of the lake (Figure 17).

Chloride builds in the bottom waters of the lake during the winter because the stormwater runoff has concentrations as high as 2,400 mg/L. The high concentration of salt in the stormwater makes it denser than the lake water, it appears that the dense salt-laden water flows along the lake bottom and accumulates in the deep waters. These density differences result in an increased amount of energy needed to completely mix the water column during spring turnover (Figure 18). In 2016, a combination of a mild winter and use of alternative deicing practices by the village resulted in much less salt building at the bottom of the lake. As a result, the increase in energy required to mix the lake in the spring was 2.8

Sodium & Chloride continued

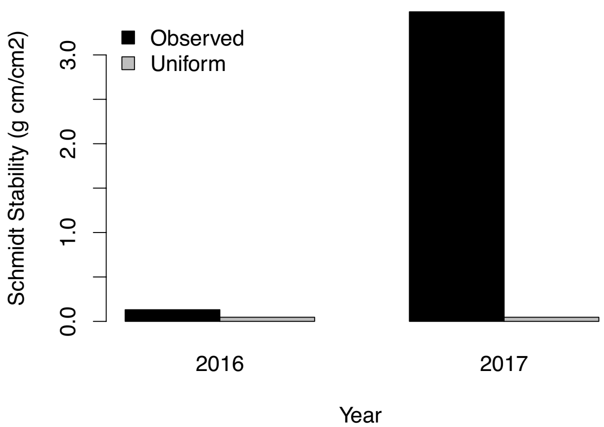


Figure 18. Schmidt stability is a measure of the energy required to mix a water column to uniform density. The observed values represent the lake stability immediately after ice off, the uniform values represent the stability immediately after ice off assuming the salt is evenly distributed throughout the water column.

times greater than what would be required if the salt was evenly distributed. In comparison, 2017 saw much more salt build at the bottom of the lake. As a result, the energy required to mix the lake was 75.5 times higher than would be required if the salt were evenly distributed. This additional energy requirement is likely the reason why Mirror Lake did not mix in the spring of 2017.

Lake Flushing Rates

In 2016, the surface water chloride concentration was higher than both 2015 and 2017 even though the lake didn't experience as much of a buildup of chloride on the lake bottom and completely turned over in both the spring and fall (Figure 17). We believe this is due to a combination of the turnover in the fall of 2015 distributing chloride throughout the water column and the apparent lack of flushing that occurred in 2016.

2016 was a particularly dry year in the spring and summer. Spring and summer rainfall totals were 43% and 27% below the 10-year average respectively (USHCN 2018). During this period the area also experienced above-average temperature. As a result, there were prolonged periods of time in 2016 when there was no discharge at the outlet of the lake. As the flushing rate of the lake dropped, the lake lost the ability to export chloride, thus the surface water concentrations remained high throughout the year. In 2017, spring and summer rainfall was 6% below and 35% above the 10-year average respectively (USHCN 2018). During this period, we saw surface water chloride decline from 52.3 mg/L to 36.8 mg/L, before rising as stratification broke down and the lake began to mix (Figure 16b).

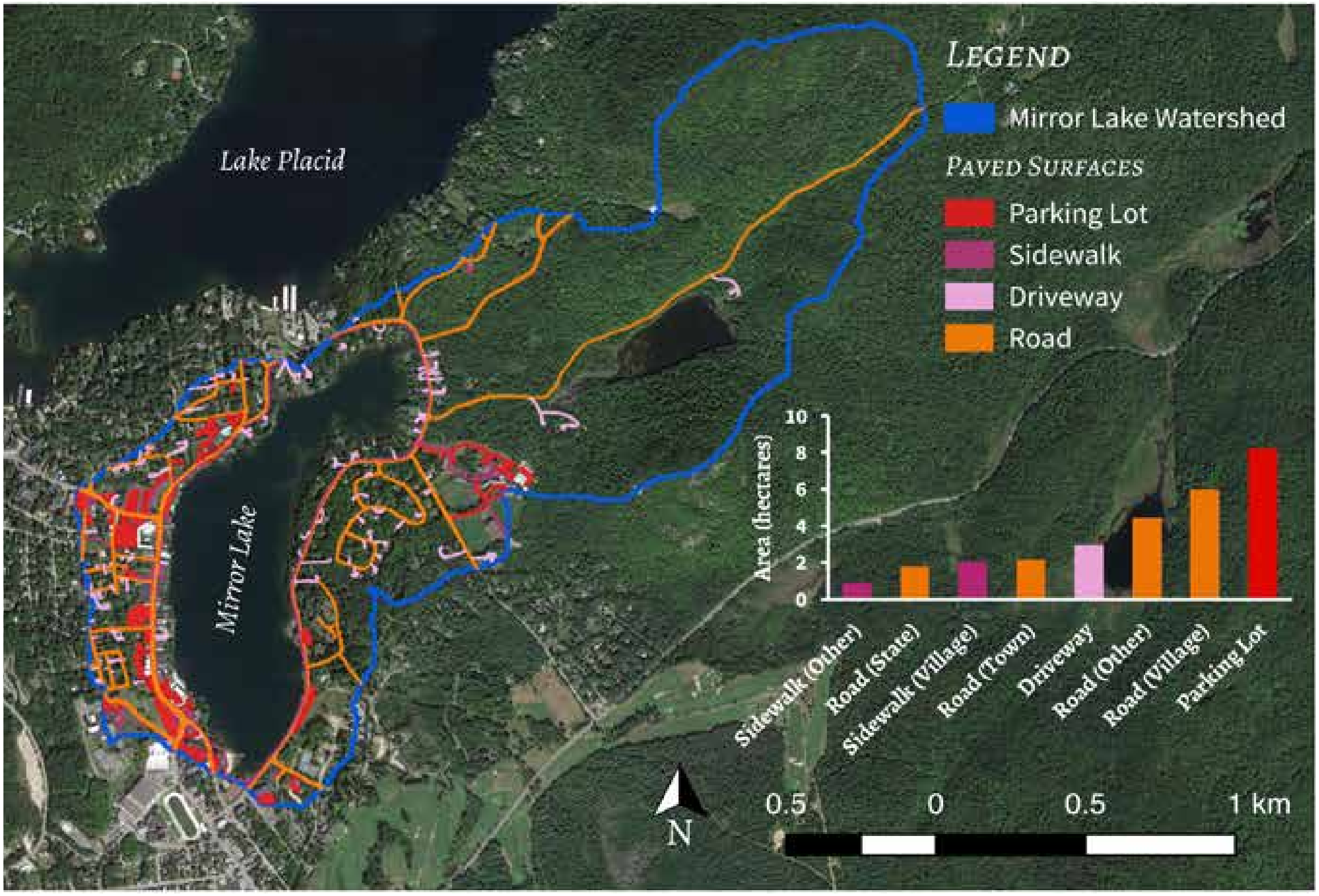
This two-year comparison highlights the potential impact that climate change or alterations to the water balance of Mirror Lake could have on the recovery of the lake. An increased occurrence of hot dry summers may delay the ability of Mirror Lake to recover from reductions in the salt load. Similarly, plans to divert stormwater away from the lake may alter the flushing rate of the lake and delay recovery. While stormwater delivers the salt load to the lake in the spring, that water has almost no salt in it during the summer and fall, therefore aiding in flushing salt from the lake. Diverting stormwater away from the lake may reduce the salt input, but it may also reduce the capacity of the lake to export the salt currently retained in the lake. Further investigation into the water and chloride mass balance of the lake needs to be completed for us to understand the potential impact of both climate change and stormwater diversions on the recovery of Mirror Lake.

Analysis of Potentially Salted Surfaces

In order to effectively address problems related to road salt runoff entering Mirror Lake, we need to understand the total annual load of salt applied to the watershed, where that salt is applied and by whom, and how it moves to and through Mirror Lake. In 2017, we completed a preliminary assessment of potential sources of salt application in the Mirror Lake watershed. Surfaces that may receive winter maintenance were visually delineated from aerial imagery and classified as roads, sidewalks, driveways, and parking lots. This method provides an estimate of the different surface types within the watershed. Delineation from aerial imagery results in a certain amount of error, most notably driveways and residential sidewalks are likely underestimated due to them being obscured from view by tree cover. It is important to recognize that within each category there is significant variability in how much salt is applied. For instance, some parking lots may not be maintained in the winter, some may be plowed and sanded, while others may be plowed and salted.

The results of this analysis show that roads are the largest area of potentially salted surface in the watershed, followed by parking lots, sidewalks, and driveways (Figure 19). After breaking down roads and sidewalks by state, village, or town, we see that the combined parking lot area is larger than any single category of road. This highlights the need to assess private and commercial salt application in addition to addressing this issue at the village, town, and state level. We also see that private roads are a

Figure 19. Distribution of different paved surfaces in the Mirror Lake watershed based on visual delineation from aerial imagery.



substantial area within the watershed and should also be assessed. Finally, both the village sidewalk and state road, two surfaces that are both salted, are of similar size. This suggests that the total chloride load from these two areas may be similar.

AsRA is currently seeking funding to estimate the load of salt applied to each of these sources on an annual basis, conduct stormwater monitoring to understand how the salt moves to Mirror Lake and expand our continuous monitoring stations in the Chubb River watershed to better understand the water and chloride mass balance for Mirror Lake. All of these components together will allow us to estimate the reduction in salt necessary to restore turnover to Mirror Lake and set the lake on a path of recovery. Additionally, we will be able to determine target salt reductions and which best management practices will allow us to achieve the reductions necessary to protect the lake. Without this work being completed, we are left guessing as to how much of a reduction in salt is necessary to protect Mirror Lake and how effective particular efforts are at achieving those reductions. Finally, the monitoring programs that will be established through these efforts will also allow us to track the long-term recovery of the lake.

In 2018 the Town of North Elba purchased a Live Edge plow to use on the portion of Mirror Lake Drive they maintain. The blade of this plow is broken into small sections that move to conform to the shape of the road, resulting in more material being removed with each pass of the plow. Additionally, the town committed to reducing the application of sand, which contains a small amount of salt mixed in. Through these efforts, they have been able to drastically reduce the application of sand on most sections of the road, with the exception of intersections.

Conclusions

The lack of spring turnover in Mirror Lake is a significant threat to the long-term health of the lake. If fall turnover is interrupted as well, there would be significant negative impacts to much of the life in the lake. Therefore, it is imperative that we move to quickly identify the reduction in road salt necessary to restore this important physical process in the lake. In order to accurately estimate the reduction in salt necessary to achieve this, we need the entire community within the Mirror Lake watershed to be engaged participants in the study of this problem. The more we know and understand how much salt is applied within the watershed, and where, the better we can understand how much of a reduction is necessary to protect the lake.

Mirror Lake is central to the identity of Lake Placid. Many people, both residents, and visitors have meaningful connections to the lake. Protecting the lake requires the entire community to serve as its stewards, understanding its value and the essential components of its health, and recognizing the actions necessary to preserve it. The Village of Lake Placid, Town of North Elba, IRONMAN Foundation, Mirror Lake Watershed Association, Golden Arrow Lakeside Resort, and Mirror Lake Inn have all shown a commitment to using science to inform the protection of the lake. As we continue to study Mirror Lake and the threats it faces, it has become increasingly apparent that a much broader community-oriented approach needs to be taken to address those threats.

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Appendix

Table A1: History of water quality research on Mirror Lake

Year(s)	Researchers/Program	Report
1971	Oglesby	A study of Lake Placid and Mirror Lake during 1971.
1974	Oglesby & Mills	A further study of Lake Placid and Mirror Lake, August 5-6, 1974
1976 & 1978	Don Charles	Personal communication
1996	Schmall et al. / Paul Smith's College	Mirror Lake
1998	Martin / Paul Smith's College	Mirror Lake
2000	Murray et al. / Paul Smith's College	Mirror Lake
2001	Upstate Freshwater Institute	Lake Placid and Mirror Lake, Synoptic Survey - August 10 -12, 2001: Water Quality Monitoring Results
1998-2001, 2003-2011, 2013-2016	CSLAP	Annually issued reports
2014	ALAP	Annually issued reports
2015-2016	Wiltse et al. / AsRA & AWI	Mirror Lake: 2016 Water Quality Report
2017	Wiltse et al. / AsRA & AWI	Mirror Lake: 2017 Water Quality Report

Table A2: Analytical methods performed on water 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	EPA 445.0
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