Paul Smith's College
Adirondack Watershed Institute

Technical Report | Limnology and Water Quality Program

Litchfield Park Lakes

Water Quality Report
Program Update: 2017

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Report # PSCAWI2018-04

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Report Summary

The Adirondack Watershed Institute began monitoring the limnology and water quality of Lake Madeleine and Heavens Lake in 1994. The objectives of this work are to track acid and trophic characteristics of the lakes, and to provide recommendations for acid mitigation and lake management. The lakes have been treated with limestone sand at regular intervals since 1986; however, the lakes have not been limed in last four years. This provides us with an opportunity to examine how the chemistry of the lakes has responded to a reduction in lime application. Understanding the response to decreased management effort is important because amendments to the Clean Air Act in 1990 have resulted in a substantial decrease in acid deposition and recent research reveals that many acid impacted lakes are showing signs of natural recovery.

1. Lake Madeleine provides cold water and high concentration of dissolved oxygen throughout most of the field season. Dissolved oxygen is depleted to low concentrations in the bottom few meters of the deepest section and this pattern is common in the historical data.

2. Heavens Lake provides suitable thermal conditions for brook trout. During the summer months optimal conditions are restricted due to warm surface water and anoxic bottom waters.

3. The average secchi disk transparency of Lake Madeleine in 2017 was the lowest observed value in the historical data set. Overall, the transparency of the lake is exhibiting a significant downward trend. This pattern does not appear to be related to nutrients or algal productivity, as chlorophyll concentration has not exhibited any significant trend and phosphorus concentration has been decreasing over time. Analysis of 122 Adirondack lakes, as well as recent scientific publications, suggests the decreased transparency may be a regional response related to changes in climatic patterns and acid deposition recovery.

4. As expected, the reduction in the rate of lime application to Lake Madeleine has resulted in decreased ANC and calcium concentration. Despite these reductions, the pH of the lake has not been affected; it remains circumneutral with no significant change since liming stopped in 2013.

5. The pattern in Heavens Lake is similar, although Heavens' pH tends to be lower than Lake Madeline's. The higher elevation, low retention time, and shallower soils of Heavens watershed offer less natural buffering ability. We observed a significant reduction in ANC and calcium since the period of biennial lime application. Despite the reductions in buffering, the pH of the lake has actually exhibited a slight, yet significant increase.

6. The lakes provide a suitable chemical environment for the primary species of interest. Brook and lake trout are more acid tolerant than other freshwater fish species. Although the optimal pH range for survival and reproduction appears to be between 6.5 and 8.0, the tolerance range is much wider and likely between 4.0 and 9.0 pH units. The Litchfield park lakes are mildly acidic to circumneutral, suggesting the acidity is not an issue of concern at this time.

7. The Ca:H ratios of both Madeleine and Heavens Lakes rarely fall below the threshold level of 10, in fact during the vast majority of observations they are near the optimal value of 100, suggesting that the chemistry of these lakes is favorable to native trout species.

8. We recommend that the acid mitigation strategy employed at Litchfield Park be changed from biennial application to only when necessary. The liming option should be discussed when the pH of either of the water bodies falls below 6.0 pH units.

Introduction

Lake Madeleine and Heavens Lake are two water bodies in Litchfield Park that are actively managed for cold water fish production and acid mitigation. The negative effects of acid deposition have largely been ameliorated by the application of calcium carbonate sand (lime) at regular intervals beginning in 1986. The water quality objectives for the liming operation have been to maintain an ANC of 100 μeq/L, a pH of ≥6.0 units, and a minimum calcium concentration of 2mg/L (Laxson and Kelting 2014; Martin 1997; Living Lakes 1992). Monitoring of the acid mitigation program was implemented by the Adirondack Watershed Institute in 1994 and was designed to: (1) document acid and trophic characteristics of the lakes, and (2) provide recommendations for acid mitigation and lake management. The data gathered by this program are intended to serve a supporting role in the management of the lakes by Litchfield Park staff.

Historical Perspective

Lake Madeleine and Heavens Lake were two of the 22 lakes selected by Living Lakes Inc. (LLI) in 1986 to participate in a liming evaluation program. Participating lakes were selected based on the criteria of depressed pH, roadside access, and land owner interest. The goal of the LLI program was to demonstrate cost effective liming strategies to neutralize acidified waters and restore acid impacted fisheries (LLI 1992). Living lakes independently developed their own criteria for acid mitigation. Their first strategy, termed mitigative liming, was used for the restoration of an acid impacted fishery and was initiated on ponds with a pH of ≤6 pH units and an ANC ≤10 μeq/L. The second strategy, termed maintenance liming, was used to protect a susceptible fisheries in mildly acidic waters and was initiated on ponds with a pH of ≤6.5 and an ANC ≤100 μeq/L. The final report from Living Lakes provides no scientific rational for these liming criteria and they do not appear to be specific to the native salmonid fishery of the Adirondack region. It's worth noting that Living Lakes was a fairly controversial entity at the time because it was created, funded, and controlled by no less than twenty major power and coal companies with essentially zero citizen input or public discussion (reviewed by Megalli and Friedman 1991). Although the media hailed the group as "*lake savers*" and "*fighters against acid rain*", scientists and environmentalists contented that the power companies were trying to mitigate a problem they created in an effort to undercut the growing support for industry regulations that would eliminate the cause acid deposition.

Initial measurements by LLI staff in the late summer of 1986 revealed the pH, ANC, and calcium concentration in Lake Madeleine to be 6.2 pH units, 32 μmol/L, and 2.7 mg/L respectively. Upstream in the smaller kettle pond known as Heavens Lake, the values were observed to be 6.1 pH units, 37.8 μmol/L, and 2.3 mg/L. Based on these observations the lakes were classified as 'mildly acidic' so the maintenance liming strategy was enacted. In the autumn of 1986, a helicopter was used to apply 90.5 metric tons of calcium carbonate sand to Lake Madeline and 6.5 metric tons to Heavens Lake (LLI 1992). The initial applications were successful at elevating the pH and bolstering the acid neutralizing capacity of the waters. Semi-annual monitoring revealed that the pH and ANC of Heavens Lake had dropped below LLI's reliming criteria so the lake was treated again in August of 1988, this time with 7.3 metric tons of lime was added with a boat mounted slurry box. Lake Madeleine, with its longer retention time and upstream additions from Heavens, did not reach LLI reliming criteria until 1990. On August 14th 1990 Lake Madeline was again treated with 90.5 metric tons of lime.

The Living Lakes Program ended in 1992 and Litchfield Park staff took over the mitigation strategy; however, accurate records of the liming rate in the early 1990's are not available. Historically, lime has been added to

Lake Madeleine (35 tons) and Heavens Lake (5 tons) every other year since 1997. The lakes were due to be limed in 2015, but the application was rescheduled to 2016 due to time constraints and the overall favorable chemical conditions of the lakes. However, unusually low water levels in 2016 prevented the treatment from occurring. In 2017, the chemical conditions of the lakes were again favorable and the decision was made to forego the treatment once again. As a result, lime has not been applied to the lake for four full seasons, the longest cessation of treatment since 1995. This provides us with an opportunity to examine how the chemistry of the lakes has responded to reduced lime application. Understanding the lakes response to decreased management effort is important because the amendments to the Clean Air Act made in 1990 have resulted in a substantial decrease in acid deposition across the Adirondacks. 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 36 years (NADP 2017; Figure 1). Likewise, recent research from the 74 lakes in Northeast (60% in the Adirondacks) illustrate that several acid indicators such as sulfate concentration and ANC are exhibiting significant recovery (Strock et al 2014). Thus it is reasonable to anticipate a time when liming the Litchfield Park lakes may occur infrequently or stop all together.

The objectives of this report are twofold: First, to summarize the historical and current trophic condition of the lakes; and secondly, to assess the impact of reduced lime application on the chemical conditions of the lakes.

Methods

Litchfield Park is located the northern Adirondacks, within the Town of Tupper Lake. Lake Madeleine is 125 hectare (1 hectare ≈ 2.5 acres) oligotrophic lake with 10km of shoreline and a maximum depth of 26 meters. Within the Lake Madeleine watershed is Heavens Lake an 18 hectare oligotrophic water body with 3.4km of shoreline and a maximum depth of 8 meters. Details of the lake and watershed morphology can be found in Laxson and Kelting 2014.

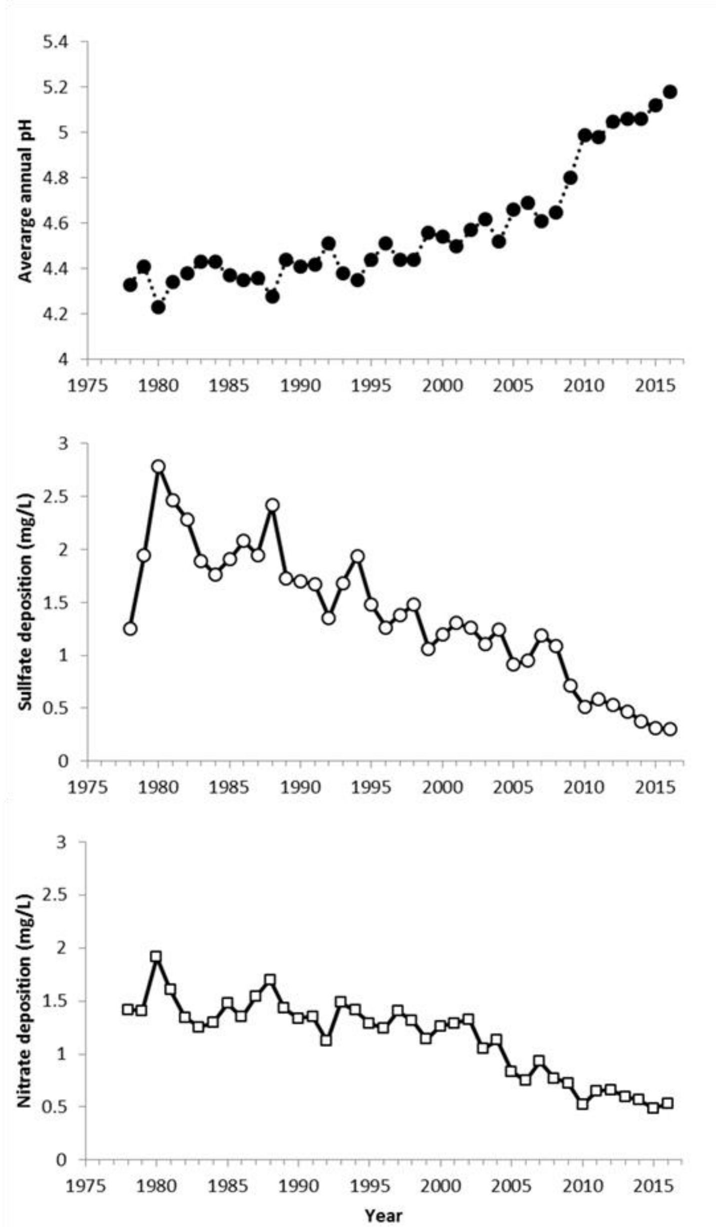


Figure 1. Annual average values for key acid deposition indicators at Huntington Forest in the central Adirondacks.

Field Sampling and Lab Analysis

Data was collected at the deepest point of each lake on two to five occasions during the ice free period, beginning in September of 1996 and continuing until September 2017. Transparency was observed using a 20 cm black and white Secchi disk from the shady side of the vessel. Temperature and dissolved oxygen (DO) were determined every meter from the surface to the bottom with an YSI EXO-1 sonde. Surface water samples were collected using 2 meter integrated tube sampler. The hypolimnetic water was collected with a 1 L Kemmerer Bottle from approximately 1 meter off the bottom. 250 mL of the surface water was immediately passed through a 0.45µm cellulose membrane filter. The filter was collected, wrapped in foil and put on ice for chlorophyll-a analysis. All samples were kept on ice after collection and chemically preserved or stored at 4°C until analysis could be completed. Samples were analyzed for pH, conductivity, alkalinity, total phosphorus, chlorophyll-a, color, sodium, chloride, and calcium at the AWI Environmental Research Lab following the analytical methods described Laxson and Kelting (2014).

Data Analysis

Trend analysis on key trophic indicators was conducted using Kendall's non-parametric correlation to test the hypothesis "there is no relationship between the indicator and time". Simple linear trend lines were fit to data with statistically significant ($P<0.05$) trends and displayed on the corresponding figures. Thus, absence of a line means there was no statistically significant trend in the indicator over time. Average annual values for secchi disk transparency, total phosphorus, and chlorophyll-a in the ponds 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 were 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.

To assess the result of reduced lime application over the last four years we compared pH, ANC, and calcium values from 2014-2017 to the values observed during untreated years within the time period of 1998-2012 with a Mann-Whitney U test. In addition, calcium-to-hydrogen ionic ratios (Ca:H) were calculated for the lakes. Ca:H ratios have been proposed as an effective index for determining suitable water chemistry for brook trout survival, with values ≥ 10 being critical for egg and juvenile survival (Clayton et al. 1998), and values near 100 associated with maximum survival (Petty and Thorne 2005).

Results and Interpretation

Temperature and Dissolved Oxygen

Brook Trout and lake trout prefer temperatures below 16°C and 10°C respectively and oxygen concentration above a threshold of 5 mg/L (Coutant 1977; Smith 1985). Lake Madeleine provides the cold water and high concentration of oxygen required for trout production during most of the year (Figure 2). The maximum temperature of the epilimnion (surface strata of uniform temperature) was observed at 22 ^{o}C in mid-August, but this warm water did not extend past a depth of 4 meters. The dissolved oxygen concentration of the lake exhibited its typical clinograde profile, where oxygen concentrations are elevated in the surface water and decrease under the thermocline. Although the oxygen was depleted in the bottom four meters, the majority of the cold water area had an oxygen concentration greater than 5 mg/L (Figure 2 left).

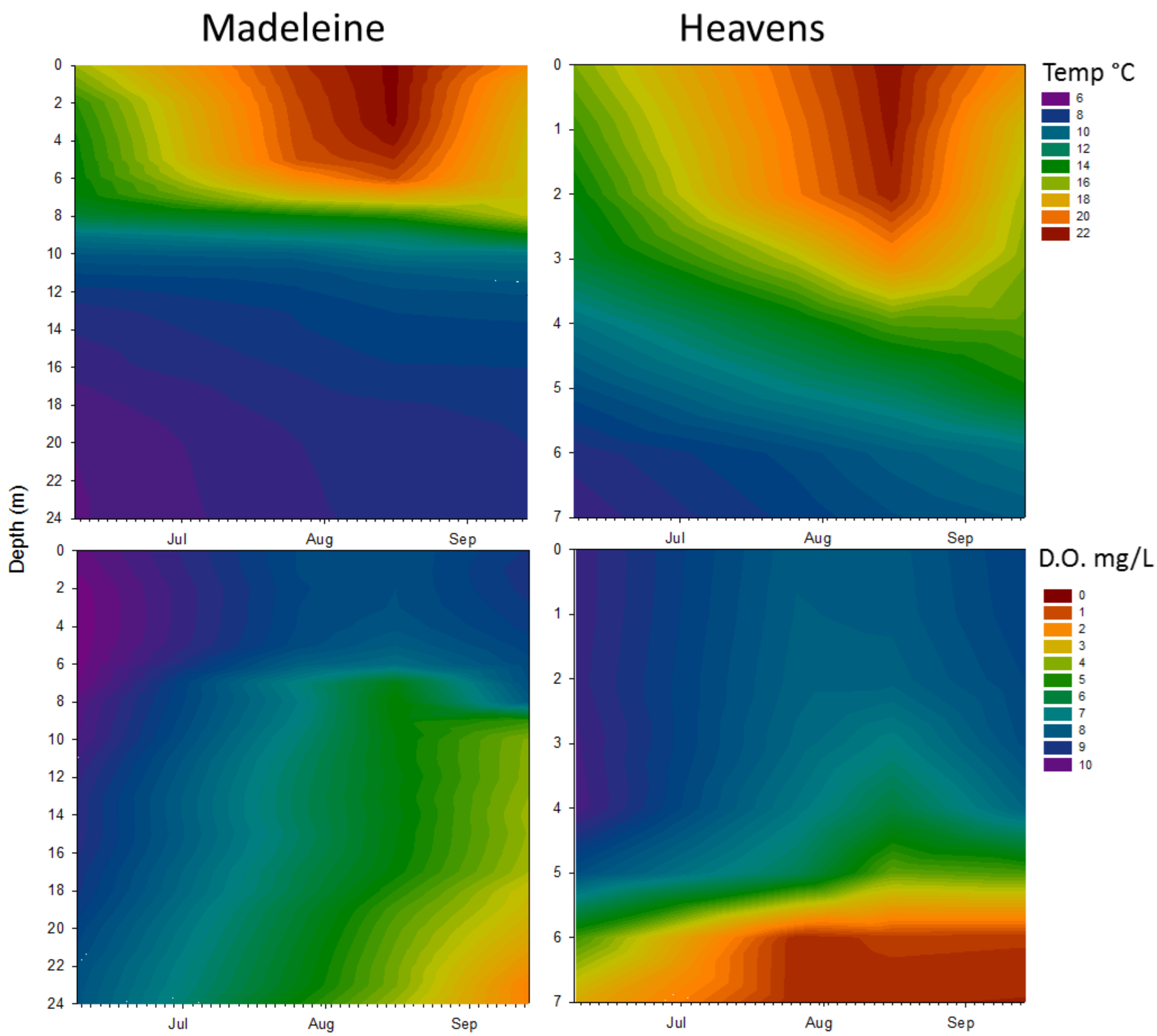


Figure 2. Profiles of temperature (upper panels) and dissolved oxygen (lower panels) for the Litchfield Park study lakes during the field season of 2017.

Table 1. Water quality indicators for Lake Madeleine during the 2017 field season.

Water Quality Indicator	Sampling Date 2017				
	6/8	7/26	8/16	9/14	Avg.
			Surface Water (0-2 meters)		
Secchi Transparency (m)	5.5	3.9	4.7	4.8	4.7
Total Phosphorus (µg/L)	4.0	6.8	8.4	2.1	5.3
Chlorophyll-a (µg/L))	2.8	2.9	2.2	2.8	2.7
Color (Pt-Co)	47.1	21.4	15.0	18.2	25.4
Conductance (µS/cm@25°C)	13.7	14.4	11.6	13.1	13.2
Laboratory pH	7.1	7.4	7.0	6.4	7.0
Field pH	6.8	6.6	7.0	6.5	6.7
Alkalinity (mg/L)	5.0	4.5	4.9	4.9	4.8
ANC (µmol/L)	101.8	90.7	98.6	99.6	97.7
Calcium (mg/L)	1.6	1.6	1.6	1.6	1.6
Ca:H molar ratio	562	947	415	92	504
Chloride (mg/L)	0.4	0.5	0.5	0.6	0.5
Sodium (mg/L)	0.5	0.6	0.5	0.5	0.5
			Bottom Water (~25 meters)		
Total Phosphorus (µg/L)	4.3	10.9	5.9	6.0	6.8
Color (Pt-Co)	18.2	24.6	21.4	47.2	27.9
Conductance (µS/cm@25°C)	14.8	16.5	16.4	19.3	16.7
Laboratory pH	6.3	6.1	6.1	6.2	6.2
Alkalinity (mg/L)	5.8	7.0	7.9	9.4	7.5
ANC (µmol/L)	117.0	140.8	160.3	190.7	152.2
Calcium (mg/L)	1.8	1.8	1.9	2.2	1.9
Ca:H molar ratio	87	63	59	77	71
Chloride (mg/L)	0.2	0.6	0.6	0.6	0.5
Sodium (mg/L)	0.5	0.6	0.6	0.5	0.6

Table 2. Water quality indicators for Heavens Lake during the 2017 field season.

Water Quality Indicator	Sampling Date 2017				
	6/8	7/26	8/16	9/14	Avg.
	Surface Water (0-2 meters)				
Secchi Transparency (m)	5.2	4.4	4.2	4.1	4.5
Total Phosphorus (µg/L)	3.3	3.9	3.5	2.5	3.3
Chlorophyll-a (µg/L))	1.2	1.5	1.2	1.3	1.3
Color (Pt-Co)	18.2	40.7	34.3	31.1	31.1
Conductance (µS/cm@25°C)	10.9	9.0	8.0	9.2	9.3
Laboratory pH	6.1	5.9	6.1	6.3	6.1
Field pH	5.6	5.9	5.9	5.9	5.8
Alkalinity (mg/L)	2.4	1.9	1.8	6.1	3.1
ANC (µmol/L)	48.3	37.8	37.2	124.0	61.8
Calcium (mg/L)	1.1	1.0	1.1	1.1	1.1
Ca:H molar ratio	34.9	20.9	33.4	51.2	35.1
Chloride (mg/L)	0.4	0.4	0.4	0.4	0.4
Sodium (mg/L)	0.5	0.4	0.6	0.4	0.5
	Bottom Water (7 meters)				
Total Phosphorus (µg/L)	11.8	7.0	17.9	17.6	13.6
Color (Pt-Co)	37.3	34.3	66.5	60.0	49.5
Conductance (µS/cm@25°C)	13.1	11.5	15.0	15.2	13.7
Laboratory pH	5.8	5.8	5.8	6.0	5.8
Alkalinity (mg/L)	4.1	4.0	6.4	6.5	5.2
ANC (µmol/L)	82.8	79.8	129.8	130.8	105.8
Calcium (mg/L)	1.6	1.4	2.0	2.0	1.8
Ca:H molar ratio	26.4	23.3	31.3	46.4	31.9
Chloride (mg/L)	0.2	0.4	0.5	0.5	0.4
Sodium (mg/L)	0.5	0.5	0.6	0.5	0.5

In Heavens Lake, the maximum temperature observed was also 22°C in mid-August and this warm water did not extend past a depth 2 meters. The dissolved oxygen concentration was rapidly depleted under the thermocline, with the bottom 1.5 meters of the pond essentially devoid of oxygen by late July (Figure 2 right). The combination of warm surface water and anoxic bottom water likely causes the brook trout to congregate within a depth of 3 to 5 meters (10 – 16 feet) during July and August (Figure 2 right).

Trophic Indicators

Both Madeleine and Heavens are oligotrophic. Oligotrophic lakes are typified by limited dissolved nutrients resulting in low algal productivity and high transparency. The Trophic State Index for Lake Madeleine calculated with secchi transparency (38), chlorophyll (39), and total phosphorus (26) all indicated an oligotrophic classification for the lake in 2017. The trophic state of the lake has been oligotrophic since monitoring began with all three indicators generally in close agreement (Figure 3).

Total phosphorus concentrations were low in the epilimnion in 2017, and ranged from approximately 2 µg/L to 8.4 µg/L, with slightly higher values observed in the bottom water (Table 1). Over the period of AWI monitoring, average annual total phosphorus concentration in the epilimnion has ranged from 1.8 to 9.2 µg/L. with a significant downward trend in data at a rate of approximately 0.1 µg/L/year (Figure 3). Chlorophyll-a concentrations exhibited little variation around the average of 2.7 µg/L in 2017. Historically, average annual chlorophyll-a concentrations have ranged from 1.1 to 4.1 µg/L with no significant trend detected in the data. Secchi transparency averaged 4.7 meters, which was the lowest average observed since the AWI began monitoring the lake. Over the 24 years of monitoring, average annual Secchi transparency has ranged from 4.7 to 11.4 meters, with a significant downward trend at a rate of approximately 12 cm/year (Figure 3; $P < 0.01$). The reason for the downward trend in transparency is unclear. The pattern does not appear to be related to nutrients or algal productivity, as chlorophyll-a has not exhibited any significant trend and phosphorus concentration has been decreasing over time. Analysis of 122 Adirondack lakes, as well as recent scientific publications, suggests the decreased transparency may be a regional response related to changes in climatic patterns and acid deposition recovery.

The Trophic State Index for Heavens calculated with secchi transparency (39), chlorophyll (39), and total phosphorus (35) all indicated an oligotrophic classification the lake in 2017. Similar to Madeleine, the trophic state of the Heavens Lake has been oligotrophic since monitoring began with all three indicators generally in close agreement (Figure 3). Secchi transparency averaged 4.5 meters in 2017. Historically, average annual Secchi transparency have ranged from 3.7 to 5.9 meters, with no observable trend detected in the data ($P = 0.21$). Total phosphorus concentrations were low in the epilimnion in 2017, and ranged from a 2.5 µg/L to 3.9 µg/L (Table 1). We observed the phosphorus concentration in the bottom water to be four times higher, and ranged from 7 to 17.9 µg/L. The elevated phosphorus concentration is due to the anoxic conditions at the bottom of the lake. The absence of oxygen creates a reducing environment along the bottom which allows phosphate to leak out of the lake sediments. Over the period of AWI monitoring, average annual total phosphorus concentration in the surface water has ranged from 2.7 to 18.3 µg/L. with no observable trend detected in the historical data. Surface water chlorophyll-a concentration exhibited little variation around the average of 1.3 µg/L in 2017. Historically, average annual chlorophyll-a concentrations have ranged from 1.2 to 4.6 µg/L with no significant trend detected in the data.

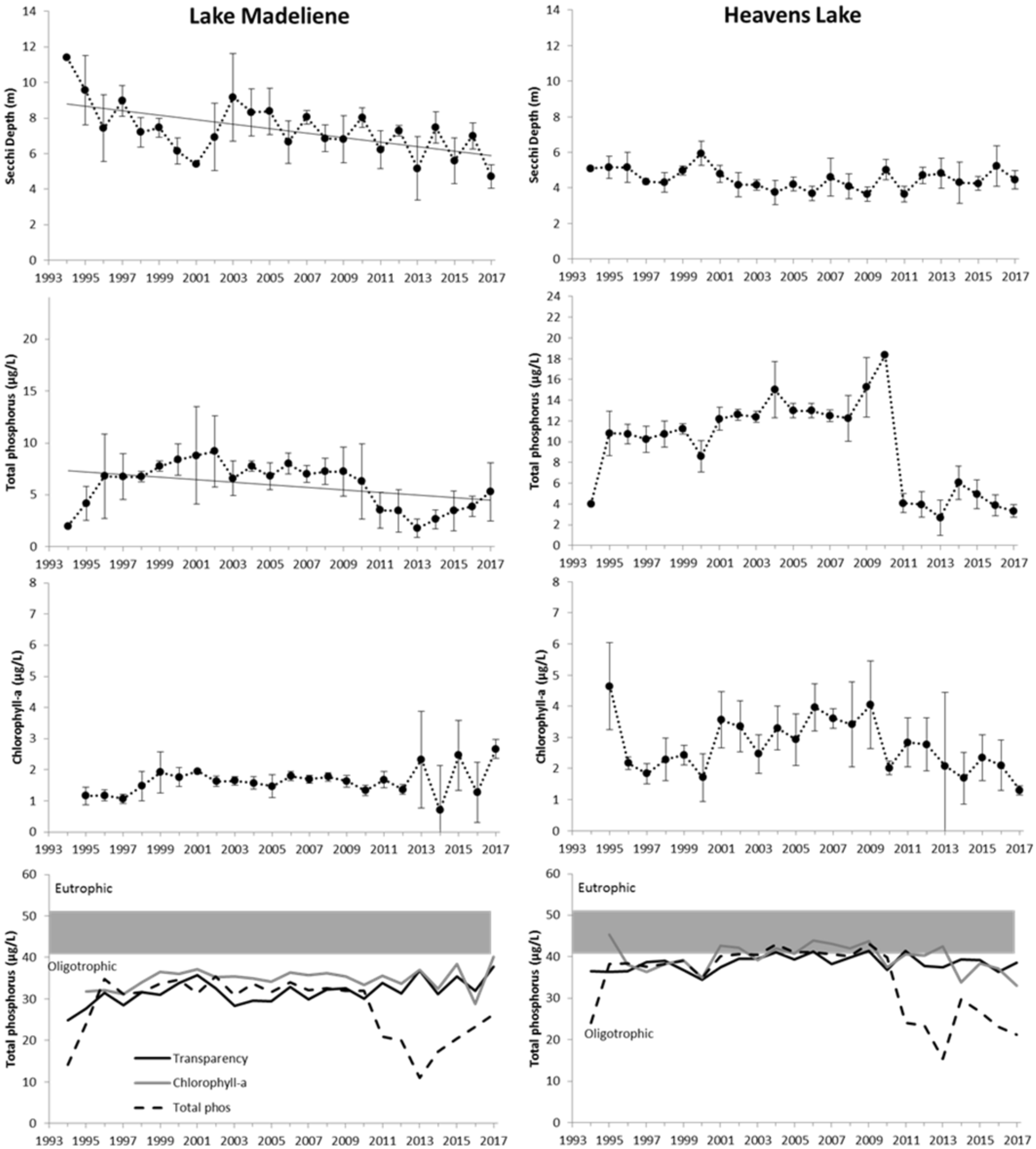
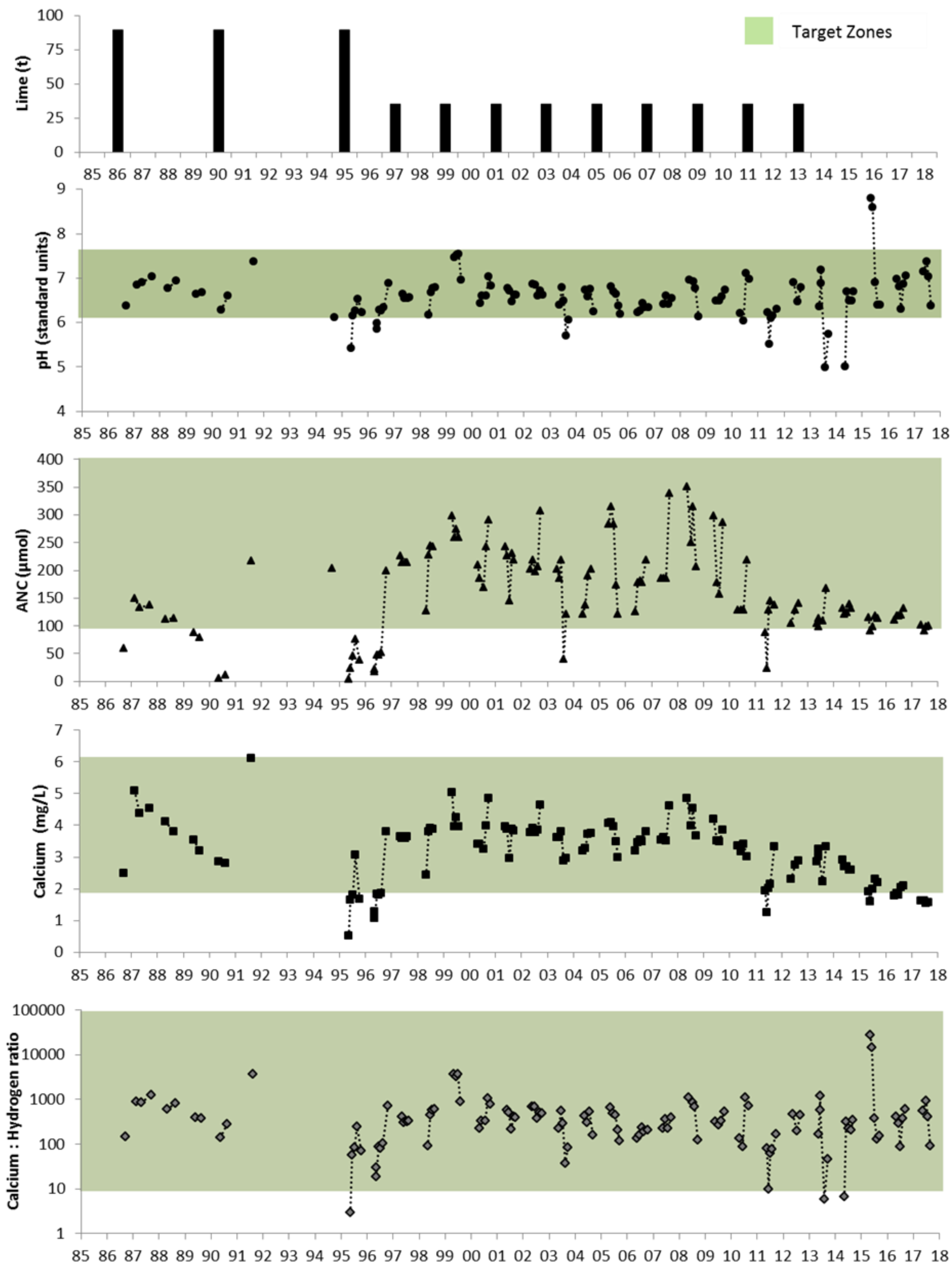


Figure 3. Annual average values for the key trophic indicators for Lake Madeleine (left) and Heavens Lake (right) from 1994-2012. Error bars represent one standard deviation of the mean, solid line denotes a significant historical trend.



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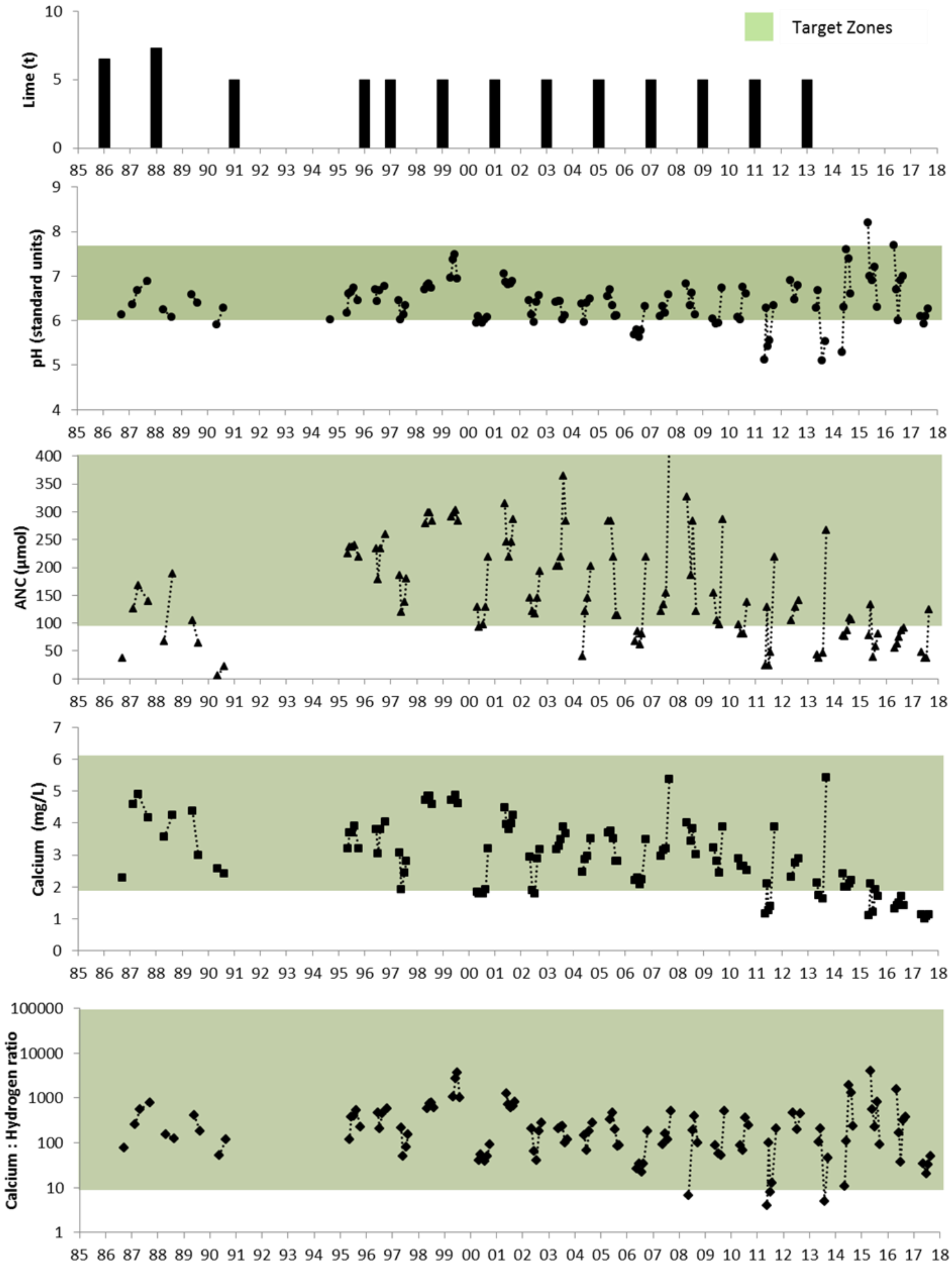

Figure 5. Lime treatment and acidity indicators of Heavens Lake 1986 - 2017. Each point represents an observation on a single sample day. Shaded areas for ANC, pH, and calcium represent target values established by Living Lakes (1992). The shaded area for Ca:H represent critical values above 10 (Clayton et al 1998).

Acidity Indicators

Lime has not been added to either of the study lakes since 2013. As we expected, the reduction in lime application has resulted in a drop in the ANC as well as the calcium concentrations; however, the reduced application has not resulted in an increase in the acidity (Figures 4 and 5)

The acid neutralizing capacity in the surface water of Madeleine ranged from 90.7 to 101.8 µmol/L in 2017, very close to the target value of 100 µmol/L. ANC values were approximately 35% higher in the bottom water, were they ranged from 117 to 190 µmol/L. We found that the ANC of Lake Madeleine has significantly decreased since the last time lime was last added in 2013. The median ANC value for the untreated years between 1998 and 2012 was 200 µmol/L, while the median value for the last four years was 118 µmol/ (Figure 5; $P < 0.001$). The calcium concentration in the surface water exhibited little variation across the season and averaged 1.6 mg/L in the surface water and 1.9 mg/L in the bottom water, slightly below the prescribed target level of 2.0 mg/L. Similar to ANC, we observed a significant decrease in calcium since the last regular lime application in 2013. The median calcium concentration for the untreated years between 1998-2012 was 3.6 mg/L, while the median concentration for the last four years was 2 mg/L (Figure 6; $P < 0.001$).

Despite the reductions observed in the ANC and calcium concentrations, the acidity of the surface water in 2017 was circumneutral, and ranged from 6.4 to 7.4 pH units. In the bottom water the pH values were slightly lower and ranged from 6.1 to 6.3 (Table 1). Depressed pH near the bottom is expected due to the decomposition of accumulated organic material. Interestingly, we observed that the pH of Madeleine has not significantly changed since the last time lime was last added in 2013. The median pH value for the untreated years between 1998 and 2012 was 6.7 pH units. The median pH value for the last four years was 6.8 pH units, with no significant difference between the two treatment efforts (Figure 5; $P=0.12$).

The pattern in Heavens Lake is similar to Madeleine, although Heavens Lake tends to be more acidic than Lake Madeline, its higher elevation, low retention time, and shallower soils offer less natural buffering ability. The acid neutralizing capacity in the surface water in 2017 was typically below the target value of 100, and ranged from 37.8 to 124 µmol/L. ANC values were approximately 40% higher in the bottom water, were they ranged from 82 to 130.8 µmol/L. The calcium concentration in the surface water in 2017 was below the target range of 2.0 mg/L, and averaged 1.1 mg/L.

The pH values of the surface water of Heavens fluctuated around the target value, and ranged from 5.9 to 6.3. In the hypolimnion, the pH values were similar and ranged from 5.8 to 6.0 (Table 2). Regardless of the reduced buffering ability we found that the pH of the lake was slightly, yet statistically greater over the past four years than it was during the regular liming phase. The median pH value for the untreated years between 1998 and 2012 was 6.4 pH units, while the median pH value for the last four years was 6.7 pH units (Figure 6; $P=0.03$).

We believe the acceptable and stable pH values of the study lakes are driven by the sizable decrease in acid deposition in the area. Although the buffering ability of the lake has not been augmented by lime, less acid is being deposited on the watershed from the atmosphere. For example, the acidity of rain water in the central Adirondacks is 8 times less acidic in 2017 than it was in 1986, the first year of lime application (Figure 1; NADP 2018).

Overall, the Litchfield Park Lakes continues to provide a suitable chemical environment for the primary species of interest, brook trout (both lakes) and lake trout (Madeline only). It's important to point out that brook and lake trout are more acid tolerant than other freshwater fish species (Daye and Garside 1975,

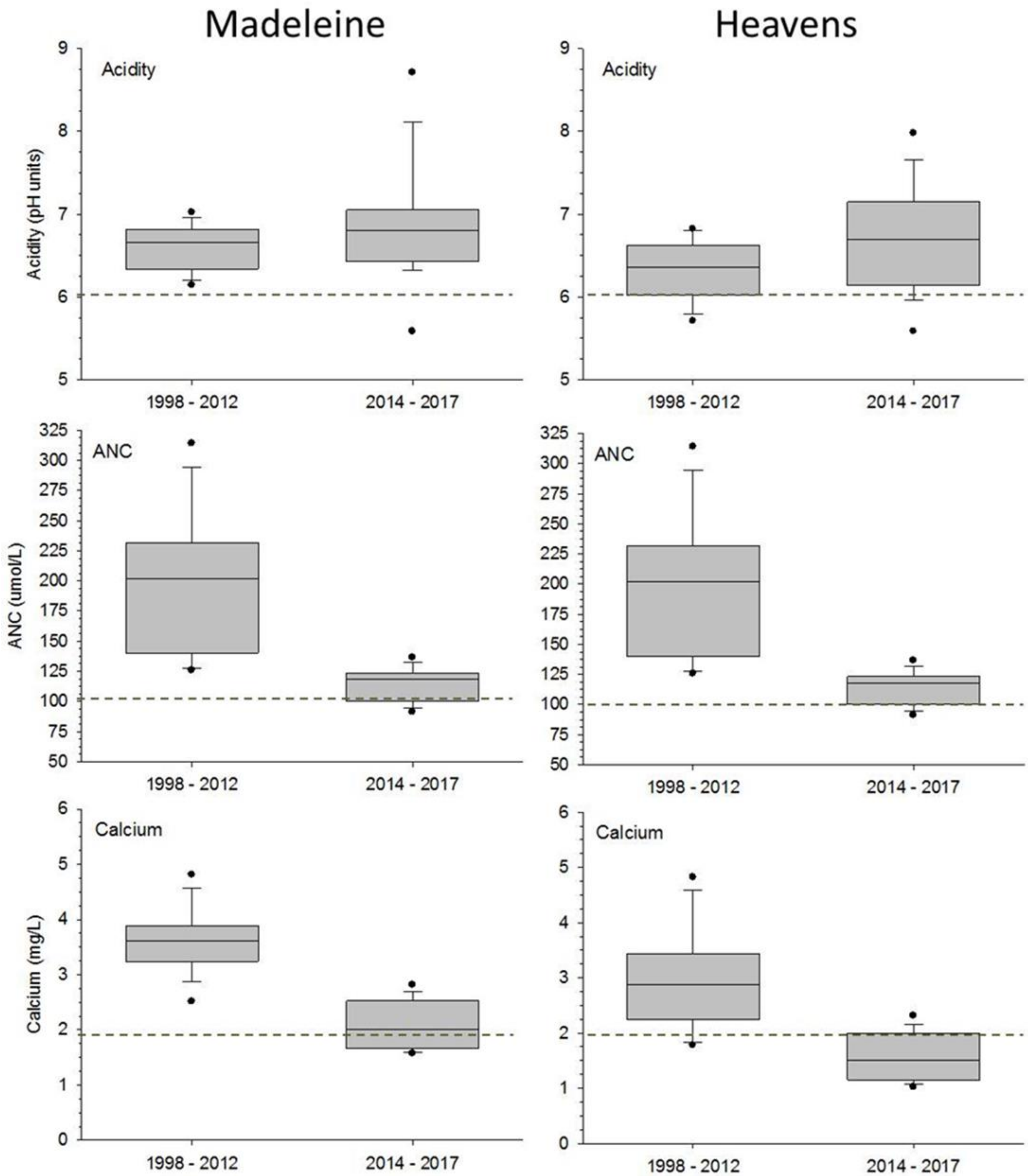

Figure 6. Box plots of acid indicators of Lake Madeleine (left column) and Heavens lake (right column) during the period when lime was added to the study lakes on a biennial bases (1998-2012) and the recent time period when lime has not been applied (2014-2017). The box represents 50% of the data, with the horizontal line indicating the median. The boundary of the box closest to zero indicating the 25th percentile and the boundary furthest from zero indicating the 75th percentile. Whiskers above and below the box equal the 90th and 10th percentiles. Points represent data outside the range described above. The horizontal dashed line indicates the target value for each analyte.

Beemish 1976). Although the optimal pH range for survival and reproduction appears to be between 6.5 and 8.0, the tolerance range is much wider and likely between 4.0 and 9.0 (reviewed by Raleigh 1982). The Litchfield park lakes are mildly acidic to circumneutral, suggesting the acidity is not an issue of concern at this time. Severely acidic lakes are hard on juvenile trout due to the interaction between acidity, low calcium, and high aluminum that ultimately causes problems with sodium balance and oxygen exchange at the gill (Mount et al. 1988, Baker and Schofield 1982, Leivestad et al 1976). The presence of calcium has been shown to increase the tolerance of young brook trout to the harmful effects of toxic aluminum (McClurg et al. 1997 Ingersoll et al. 1990). Because of this, the Ca:H ratio is a useful index for determining suitable chemical conditions for aquatic organisms in relation to acidity. A Ca:H ratio of 10 was suggested by Clayton et al (1998) as a better index for brook trout success than pH, alkalinity or calcium alone. The Ca:H ratios of both Madeleine and Heavens Lakes rarely fall below the threshold level of 10, in fact during the vast majority of observations they are near or above the optimal value of 100 (Petty and Thorne 2005), suggesting that the chemistry of these lakes is favorable to native trout species. It is important to recognize that this analysis of chemical suitability is fairly liberal because data was not collected during spring runoff, when acidity is greatest, nor does it represent stream environments where brook trout tend to spawn.

Conclusion and Recommendations

In conclusion, we recommend that the acid mitigation strategy employed at Litchfield Park be changed from biennial application to only when necessary. The reason for this are: (1) Acid deposition in our area has significantly declined since liming began in the late 1980's. (2) Currently the lakes are only managed for brook and lake trout, and these species are more acid tolerant than species previously stocked, such as rainbow trout. (3) Calcium to hydrogen ratios of the lakes suggests a favorable chemical environment for local trout species. The option to lime should be discussed if the acidify of the lakes falls below a pH 6.0 units.

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