# **Evaluating Changes in Water Quality in Adirondack Lakes from** the Adirondack Long-Term Monitoring (ALTM) Program K. Roy<sup>1</sup>, J. Dukett<sup>2</sup>, N. Houck<sup>2</sup>, P. Snyder<sup>2</sup>, and S. Capone<sup>2</sup>

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#### **Abstract**

Long term changes in the chemistry of wet deposition and lake water were investigated in the Adirondack region between 1992 and 2004. Marked decreases in concentrations of  $SO_4^{-2}$  and  $H^+$  have occurred in wet deposition since the late 1970s. These decreases are consistent with long-term declines in emissions of SO<sub>2</sub> in the eastern US. Changes in wet NO3 deposition and NO3 emissions have been minor over the same interval. Virtually all Adirondack lakes have exhibited large decreases in concentrations of SO42, which coincide with decreases in atmospheric S deposition. Since 1992, concentrations of NO.

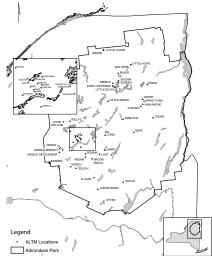


Figure 1. Distribution of Long Term Monito

have also decreased in many (27 of 48) Adirondack lakes (Fig.1). As atmospheric N deposition has not changed appreciably over this period (1992-2004), the mechanism contributing to this apparent increase in lake/watershed N retention is not evident. Decrease in concentrations of SO<sub>4</sub>2 + NO<sub>3</sub> have resulted in increases in acid neutralizing capacity (ANC; 37 of 48 lakes), and decreases in concentrations of inorganic monomeric Al, particularly in acid sensitive lakes. Concentrations of dissolved organic carbon (DOC) have also increased in some (15 of 48) lakes coinciding with decreases in acid deposition. Examination of changes in lake chemistry by hydrologic classes showed that drainage lakes in watersheds with thin deposits of glacial till and mounded seepage lakes have generally been the most responsive to decreases in acidic deposition.

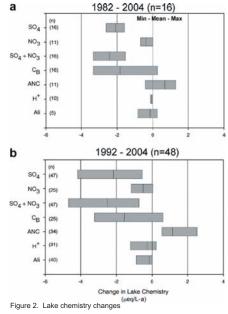
Fish populations from 45 Adirondack Long Term Monitoring (ALTM) lakes were resurveyed during 1994–2005 following the 1984–1987 Adirondack Lakes Survey (ALS) methods. The mean number of fish populations in each lake was 3.27 in the ALS survey and 3.91 in the ALTM resurvey. There have been improvements in the intervening 14 vears between surveys, but results have been mixed and moderate.

Additional components of the ALTM program include: bi-weekly and event-based chemistry monitoring of Buck Creek and its tributaries; weekly snow melt monitoring at twelve ALTM lake outlets; hydrologic gaging at select ALTM lake outlets; an investigation of eight original ALTM sampling points data records with up-stream lake sampling data records; and a comparative evaluation of chemistry and discharge from two independent sampling programs at Arbutus Lake outlet.

#### Sulfate Trends

Despite declines in SO<sub>4</sub><sup>2</sup> over the course of the ALTM, declines in Adirondack lake SO,2- have not been uniform within the monitoring period. Declines were moderate in the 1980s and increased in the 1990s presumably in response to SO, emission controls from the 1990 Amendments to the Clean Air Act. Over the last 4 years rates of decline in lake  $SO_4^{2}$  have been reduced. This slower rate is probably in response to leveling off of SO<sub>2</sub> and SO<sub>4</sub><sup>2</sup> emissions.

Since 1982, all of the original 16 ALTM lakes show significant declines ( $\rho$ <0.05) in SO<sub>4</sub><sup>2</sup> concentration, with a



mean rate of decline of 2.09  $\mu eq~L^{_{\rm 1}}\,year^{_{\rm 1}}$  from 1982 through 2004. The uniform range of decline across the region suggests decreases in  $SO_2$ emissions and atmospheric SO<sub>4</sub><sup>2-</sup> deposition are responsible. (Figs. 2a

Since 1992 similar decreases in concentration of SO<sub>4</sub><sup>2-</sup> are evident for the acid base status of Adirondack lakes.

remaining 32 ALTM Lakes, although the rate of SO<sub>4</sub>2- decline was more variable. Nevertheless, the mean rate of decline for those lakes was similar to the declines in the original 16 lakes.

# **Nitrate Trends**

Many of the ALTM lakes show significant decreases in NO<sub>2</sub>. This decrease is not what is expected if the Adirondacks are approaching a condition of N saturation. With no change in NO emissions and atmospheric  $NO_3$  deposition since 1982, it is speculated this pattern is associated with increased retention of N due to a fertilization effect from increases in atmospheric  $\mathrm{CO}_2$ , effects from hydrologic or climate change, or shifts in forest tree species with decreases in species where mineralization and/or nitrification of litter occur.

Of the original ALTM lakes, 10 showed a significant decrease in NO<sub>3</sub> (p<0.12). Twenty seven of the 48 had small but significant increases in concentration of NO<sub>3</sub> (p<0.05).



Two ponds, a mounded seepage pond and a lake draining a watershed of deep stratified drift, had small but significant (p<0.05) increases in concentrations of NO.

### Trends in Acid Neutralizing Capacity (ANC)

The majority ALTM Lakes show an increase in ANC indicative of the success of emission control strategies to curtail surface water acidification. However, the rates of ANC increase are slow. At current rates it will take decades before chemical recover will support a diverse biological community in acid impacted lakes.

Thirty-seven of the 48 ALTM lakes show significant increases in ANC (p<0.13). Eleven of the 16 original lakes show a significant increase in ANC (p<0.1). The measured reate of increase in lakes showing a significant increasing trend was 0.76 ueq  $\mathrm{L}^{\text{-}1}$  year  $^{\text{-}1}$  . This increase was primarily evident in lakes with thin till. Twenty-four of the 26 thin till lakes showed a significant increase in ANC (p<0.07).

In 2000, the linear rates of ANC increase from time series analysis were used to extrapolate how much time it would take for impoverished lakes to reach 50 µeq L-1 of ANC, a value generally considered to be protect aquatic biota.

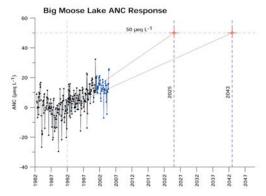


Figure 3. Projected ANC values

Big Moose Lake is a chronically acidic water. Using the data from the period 1992–2000 the projected ANC target of  $\mu eq~L^{\text{-}1}$  of ANC is 25 years; this projects to 2025. However, when the more recent 1992-2004 rates are applied, the 50  $\mu eq~L^{\cdot 1}~$  target takes 39 years; this projects to the year 2043 (Fig. 3).

# **Changes in DOC**

DOC has important implications for lake ecosystems, but the mechanism involved is not evident. Long term temperature and precipitation change could affect DOC concentrations. Variation in DOC is an important control in the attenuation of light and thermal stratification of Adirondack lakes. An increase in DOC in response to decreases in acidic deposition will limit increases in the pH and ANC due to DOCs role in controlling the



#### **Recent Fish Surveys**

Fish populations (i.e., species) from 45 ALTM lakes were re-surveyed during 1994-2005 following 1984-1987 ALS methods. The total fish population increased by 29 from 147 to 176 between the two periods.

The mean number of fish species in each lake was 3.27 in the ALS and 3.91 in the ALTM resurvey. The median pH was 5.41 in the first survey and 5.66 in the second survey. Overall, 20 lakes showed a net gain in fish populations, 6 lakes showed a net loss and 19 lakes showed no change in species.

#### **Field Operations**

Each month the Adirondack Long-Term Monitoring (ALTM) project collects water samples from 52 lakes. On a bi-weekly basis samples are also collected from three streams. Sample sites lie throughout the Adirondack Park and reflect the broad range of watersheds found within the park. Field crews work in pairs and visit sites by foot, canoe or helicopter. Crews have anywhere from quick roadside stops to more time intensive twelve-mile hikes during the course of sampling. Winter brings the added effort of snowshoes, skis, snowmobiles, and the pack weight of augers and additional winter saftey gear - as well as the additional time and



effort required to bore through thick ice to gather samples and deal with harsh weather conditions. Seventeen waters are sampled from a New York State Police Bureau of Aviation helicopter. When a helicopter is not available, crews hike to the remote ponds by foot. In all, each monthly round of samples requires 11 to 20 trips – accomplished in varied weather conditions. No samples are taken in the last seven days of any month to ensure a break between sample periods.



The ALTM uses two sampling protocols. Hikeable streams and ALTM sites with outlets are sampled by hand dipping a sample from the outlet. Seepage waters, ponds with no outlets, and helicopter waters are sampled from a canoe or helicopter pontoon with a Kemmerer sampler at a depth of 0.5 m. Samples are taken where there is good mixing, depth to collect the sample without

disturbing bottom sediments or organic material, and located such that the sample is representative of the pond. Samples are placed on ice and returned to the ALSC laboratory in Ray Brook, New York and analyzed for 20 different chemical parameters.

The ALSC also manages a number of seasonal and more intensive sampling efforts. Snow core samples are collected from a study basin in three ALTM lake watersheds (Grass Pond, G Lake and Constable Pond). The objective of this sampling is to index changes in snow pack water equivalent and snow pack chemistry as indices of episodic potential at each study watershed.

In addition, spring snow melt samples are taken from 12 waters each week from March through the first week of May. The objective of this sampling is to evaluate LTM chemistry during snow melt. This period is of interest as the melting snow pack delivers an acid pulse to the watersheds during a critical time for certain aquatic organisms.

#### **Recent Investigations**

The ALSC established an hydrology monitoring network in the winter~spring of 2005-2006 to investigate the feasibility of gaging the outlets of remote waters. The discharge rating curves developed from the initiative will support future analysis of the ALTM chemistry data. Staff worked with Dr. Chris Cirmo and Dr. Edwin Romanowicz in the



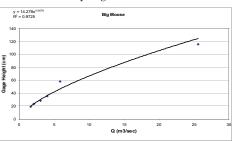
initial siting investigation. Dr. Romanowicz led the final selection and instrumentation of three sites with  $\mathsf{Drucker^{TM}}$  pressure transducers and Telog™ data loggers. Instruments overwintered without failure. One site was eventually abandoned due to site conditions. Two remain and continue to provide valuable discharge measurements (Fig. 4).

Staff worked with C. Cirmo and K. Civerolo in a statistical comparison of ALTM chemistry samples taken at paired ALTM sites. This work

resulted in the discontinuation of one sample location within the paired study group. Additional research based upon this study is underway.

Dr. Myron Mitchell and his graduate student Matthew Domser, compared ALSC LTM with SUNYESF sampling efforts at Arbutus

Lake. Results confirm that monthly sampling is adequate for examining long-term effects on the chemistry of lakes associated with changes in atmospheric inputs. The availability of discharge data improved the accuracy of monthly data. This comparison demonstrates how an intensive study site within a more regional monitoring response program compliments the coarser temporal records. Likewise, how a single lake type responds within the greater regional context.



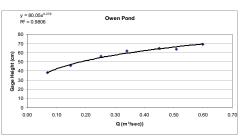


Figure 4. Discharge rating curves developed at two LTM sites

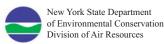
# Website and Data Availability

The ALSC maintains a website at www.adirondacklakessurvey.org where the public is invited to learn more about the ALSC. The web portal is a place researchers and the public can access and download chemistry data. The website also features a searchable database of historic fish and chemistry data from the original ALS. We invite you to visit the website and encourage you to take advantage of the data available there.









# **Research Contributors**

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