CHANGING BIOGEOCHEMICAL RELATIONSHIPS IN MAINE HIGH ELEVATION LAKES AND WATERSHEDS AS PART OF RECOVERY FROM ACID RAIN

Plymouth State University
Center for the Environment

Baumann, Adam[1], Kahl, Steve[1], Scott, Matthew[2]

(1) Center for the Environment, Plymouth State University, 17 High St. MSC 63, Plymouth, NH 03264 (2) Maine DEP (retired)

INTRODUCTION

The 1990 **Clean Air Act Amendments** (CAAA) set target reductions in both sulfur and nitrogen emissions from industrial sources to reduce acidic deposition. SO_2 and NO_X controls were enacted in two phases, the first focusing on the biggest contributors to acidic deposition, the second more broadly targeting utility companies using fossil fuels.

One important purpose of the 1990 CAAA was to improve the biological status of low alkalinity surface waters in the United States. Many papers have published assessments of trends in surface water chemistry, in order to asses the effectiveness of the CAAA. These projects have focused on the northeast and mid-Atlantic regions where acidic deposition has had the most obvious effects. Statistical sampling programs supported by the EPA have evaluated general populations of lakes and streams (e.g. Stoddard et al., 2003). Other projects have evaluated specific subpopulations of surface waters thought to be the most sensitive to acidic deposition. This poster highlights results from the **High Elevation Lake Monitoring** (HELM; e.g. Kahl and Scott, 1988) program in Maine between 1986 and 2004.

The HELM lake population. In 1984 the EPA began monitoring the status of lakes in the northeast by starting the Eastern Lake Survey (ELS). The HELM project was designed with the intent to enhance the relevance of the data coming from Maine by monitoring lakes at the high elevations that ELS had neglected. In 1986, 90 Maine lakes, ≥ 600m elevation, ≥ 0.4ha, and ≥ 1m deep, were targeted and have been sampled periodically over the past 20 years.

On average the HELM lakes are more acidic than the rest of Maine's lakes because they:

- Receive higher amounts of precipitation
- Receive more acidic precipitation
- Have a larger input of organic acids
- Have low ANC's due to geology (steep slopes, shallow soils, resistant bedrock)

All of these factors, coupled with pre-industrial acidity, and general absence of land use disturbance makes the population of HELM lakes preferably suited as an indicator of recovery from acidic deposition.

(a)

(b)

Figure 1. Aerial photographs of (a) Klondike Pond and (b) Tumbledown Pond, two of the HELM lakes

(a)

(b)

Figure 2. (a) Map of acid sensitive regions of the U.S. (b) Map of Maine, with HELM sampling locations

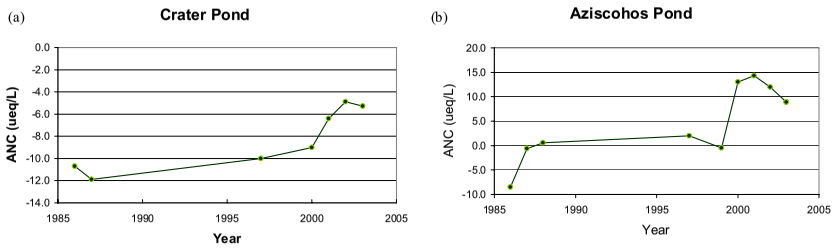

Figure 3. Temporal plot of ANC for (a) Crater Pond and (b) Azicohos Pond, two acidic HELM ponds, both showing an increase in ANC (recovery) over the past 20 years.

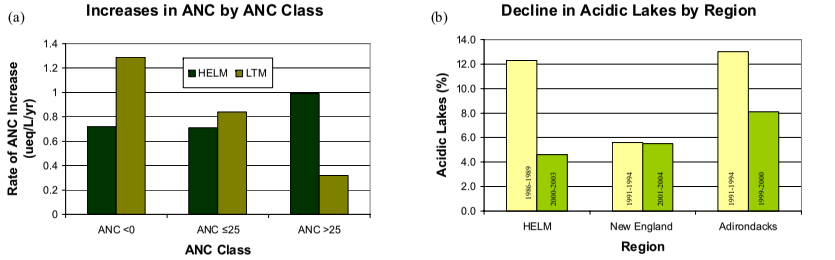

Figure 4. (a) Comparison of acidity class and ANC rate of increase (ueq/L/yr) for HELM and Long Term Monitoring (LTM) lakes (a sample set from the regions outlined in Figure 2a) highlighting the difference in class dependence between the two. (b) Decline in the percentage of acidic lakes (ANC < 0) in the northeastern regions over the period of record indicated. HELM lakes show a similar recovery percentage to the lakes of the Adirondack region.

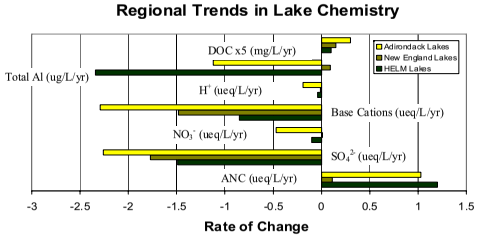

Figure 5.

Regional surface water rates of change as reported by Stoddard et al., 2003 with HELM data added. HELM lakes are recovering (increasing ANC) comparable to Adirondack lakes, however, HELM lakes are showing a slower decline in base cations (Ca^{2+} and Mg^{2+}) and SO_4^{2-}, and a faster decrease in aluminum.

OVERVIEW OF METHODS

pH: Orion EA 920m, with Ross electrodes, samples analyzed (a) in closed-cell system, and (b) after equilibration with 300ppm CO_2 air; ANC: Radiometer ARAS™ Gran-Plot titrator; Dissolved Organic Carbon (DOC): Oceanography International IR Spectrophotometer; Anions: Dionex 2020i Ion Chromatograph; Cations: Perkin-Elmer 703 flame AAS prior to 2002, Dionex ICS-2000 Ion Chromatograph (simultaneous determination with anions) 2002 - present

PRELIMINARY RESULTS

- Lakes in acid sensitive regions of the country are responding positively to the CAAA emission reductions.
- As a population, HELM lakes are as acidic as those in the Adirondacks, indicating that local landscape position, not regional geographic position, is the most important factor for aquatic response to acidic deposition.
- HELM lakes show a comparable rate of increase in ANC (recovery) to the Adirondack lakes, but a slower rate of decline in concentrations of SO_4^{2-} and base cations (Ca^{+2} and Mg^{+2}). HELM lakes are also showing a higher rate of decrease of aluminum than other northeastern lakes.
- HELM lakes have shown a higher percentage of lakes recovering from subzero ANC levels than have other lakes in New England. This recovery is also similar to lakes in the Adirondacks.
- Kahl et al reported that the most acidic lakes exhibited the largest increases in ANC between 1990 and 2000, suggesting that waters in the north east have a greater ability to recovery from acidic deposition than suggested by some authors. In contrast to the regional pattern, HELM lakes have shown a class-dependant increase in ANC levels in which the highest ANC lakes have shown the greatest increase in ANC. This is especially apparent in the high ANC lakes (ANC > 25ueq/L). This relationship is still being investigated.

FUTURE WORK

Through exploration of long term data sets for the northeast and mid-Atlantic regions of the U.S., as well as the HELM population, the intention is to show unique biogeochemical relationships and trends in the HELM population to better understand the effectiveness of the current policy on emission standards. It is clear that the current policy has been effective in reducing acidic deposition, but policy makers need quantification of "recovery" to support future environmental regulatory decisions and legislation.

Given the remote, generally undeveloped nature and geologic distinctiveness of the HELM population, the possibility of HELM lakes as a more relevant indicator of "recovery" will be the topic of further investigation for this lake population.

RESOURCES

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