Acid precipitation and the Adirondacks: Acid effects on the biota indigenous to Lake George

Completed by

D.A. Roberts, C.W. Boylen, and R.A. Singer

FWI #82-2

ACID PRECIPITATION AND THE ADIRONDACKS: ACID EFFECTS ON THE BIOTA INDIGENOUS TO LAKE GEORGE

Deborah A. Roberts, Charles W. Boylen and
Robert Singer

Fresh Water Institute
Rensselaer Polytechnic Institute
Troy, New York 12181

and

Colgate University
Hamilton, New York 13346

ABSTRACT

Acid precipitation has been considered by many to be one of the major environmental problems of the century. Interest in the impact of acid deposition on Adirondack lakes prompted a study using macrophytic species indigenous to Lake George as well as the Adirondacks as a whole. Aquarium microcosms were set up in which sediment and water from Lake George were systematically adjusted to pH values between 7 and 4. Growth rates of the predominant lake macrophytes, Vallisneria americana and Potamogeton robbinsii dropped by approximately 70% between pH 7 and pH 4. Concomitant results were shown by a drop in actual photosynthetic rate as determined by oxygen evolution experiments. These results indicate that these species are severely affected by acid conditions and that the ecology of a lake with these communities would be severely altered if acid stressed. Such a conclusion correlates with distribution data collected for these species elsewhere in the Adirondacks. The susceptibility of a particular lake to become acid stressed is largely dependent on the geology of its basin. Therefore considerable variability exists in proximal lakes receiving similar inputs of acid depostion. Results from acid stressed Adirondack lakes allow us to postulate the effects of acid stress on submerged macrophyte ecology. An ecological successional scheme is presented.

INTRODUCTION

Acid rain is a serious environmental problem that is the cause of widespread concern. However, a serious lack of information exists on the effects of acid precipitation on food chain dynamics in aquatic systems. Until very recently the major focus of acid precipitation research has been on the chemistry of acidification and the effects on fish populations. The effects of acidic deposition on other components of the food chain has been investigated in Scandinavia (summarized by Overrein, et al., 1980), but similar data are largely lacking for affected regions in the U.S.

One area of interest is the effect of acid precipitation on the distribution of aquatic plants. Some research has been done in Scandinavia to characterize plant communities in acid lakes (Grahn, 1977; Halvorsen, 1977) and to characterize the nature of the physiological effects of acidic conditions on plants (Søndergaard and Sand-Jensen, 1979; Halvorsen, 1977). With the exception of work done by Hendrey and Vertucci (1980) which characterized the plant community in one high altitude Adirondack lake, almost no published data exist on the distribution of plant species in the Western hemisphere with respect to lake pH.

The purpose of our study has been to characterize the distribution of aquatic plant communities in lakes under varying degrees of acidification. These plant distribution data can then be correlated to individual species tolerances to acidic conditions. Preliminary laboratory studies on the growth of several macrophyte species at different pH levels were conducted to determine if a short term response in growth rate to low pH conditions could be measured.

MATERIALS AND METHODS

Three species of aquatic plants, Myriophyllum sp., Potamogeton robbinsii Oakes, and Vallisneria americana Michx., were collected from Lake George. Twenty specimens of each species were planted in each of four glass tanks (20 gal each) containing sediment and water collected from Smith Bay. The total length and wet weight of each plant was recorded at the time of transplanting into the aquaria. The plants were allowed to adapt to tank conditions for one week prior to acidification.

All tanks were exposed to the same light and temperature conditions: temperature was maintained at approximately 21^{o}C and a light/dark cycle of 14/10. All tanks were continuously aerated with water circulating through each tank into a reservoir and back again into the culture tank.

The pH of one tank was maintained at an original level of 7.4 throughout the experiment. The pH of the other three tanks were lowered to pH 6, pH 5 and pH 4, respectively. Acidification was accomplished by adding dilute H_2SO_4 to each reservoir and slowly circulating the reservoir water through the culture tank. Acidification to pH 6 was attained after two days, pH 5 after one additional day and the remaining tank reached pH 4 after one more day of acid addition. Due to the high buffering capacity of Lake George sediments, all of the acidified tanks at pH 6, 5 and 4 required daily addition of acid to the reservoirs to keep the pH in each tank at the appropriate level.

After three weeks at the adjusted pH levels, the plants were harvested and their wet weights and lengths were measured. The average increase in length and net weight of each species was calculated for each pH treatment.

A preliminary study was also done to measure the gross photosynthetic rate of Myriophyllum sp. at various levels of artificial acidification. Growing shoots of Myriophyllum were placed in glass-stoppered bottles which were then filled with Lake George water, adjusted to the appropriate pH with dilute H_2SO_4. Five light bottles and five dark bottles for each pH (7, 6, 5, and 4) were incubated for six hours. The final dissolved oxygen content of the water was measured by the Winkler method (APHA, 1981). The samples were fixed while each plant was still in the bottle. The plants were then removed and dried at 60°C for dry weight determinations prior to titration. Initial dissolved oxygen content for water used in each pH treatment was measured on triplicate samples taken from the large reservoir of water used to fill the incubation bottles.

Field distribution studies

During August 1981, a field survey of 9 small Adirondack lakes was conducted. The lakes were chosen to lie in the same geographical region and altitude, to be approximately the same size, exhibit a minimum of human habitation and represent a range of pH from 7.0 to <4.0. These lakes provided crucial information on the distributional patterns of submerged macrophytes indigenous to the Adirondack region in which Lake George is geographically located. Divers equipped with both snorkel and scuba gear observed and mapped completely the macrophyte species found in each lake. The percent cover of each species was estimated as each lake bottom was surveyed. These data were recorded on a map of each lake by one of us in the boat. Observations by SCUBA divers were recorded on etched plastic plates and depths were noted with a wrist depth gauge which was previously calibrated against a marked line.

RESULTS AND DISCUSSION

Laboratory Studies

The results of the three week growth experiments are shown in Fig. 1 & 2. Both measurements of growth, average change in length and wet weight, show similar trends for Vallisneria americana. A significantly lower growth rate at the lower pH levels are seen. Similar responses are seen with the other two species (Fig. 2). Both Potamogeton robbinsii and Myriophyllum sp. showed decreased growth rate, measured as change in length, over the 21-day period. The magnitude of the effect is related to the plant's normal growth rate. Myriophyllum is a much faster growing species and the total increase in length for all pH treatments is nearly an order of magnitude greater than that of P. robbinsii.

Gross productivity measurements with Myriophyllum sp. also show significantly lower values at the lower pH levels (Fig. 3). Further experimentation is necessary to determine the significance of the somewhat elevated value of gross oxygen production at pH 6 relative to that observed at pH 7.0.

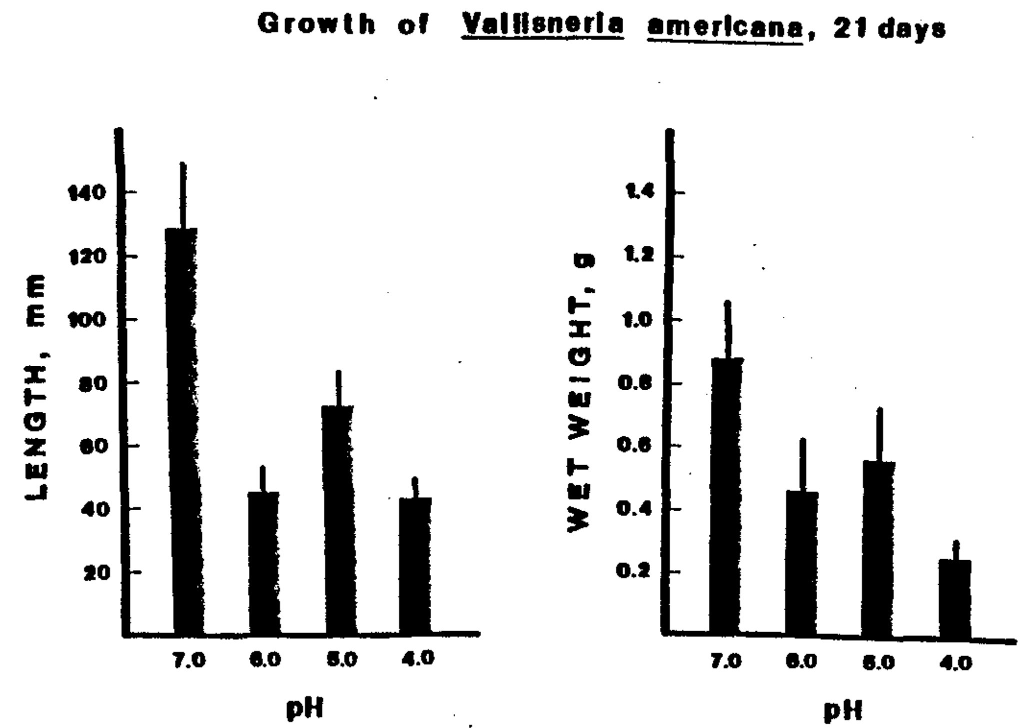

Fig. 1. Growth of V. americana under varying pH conditions.

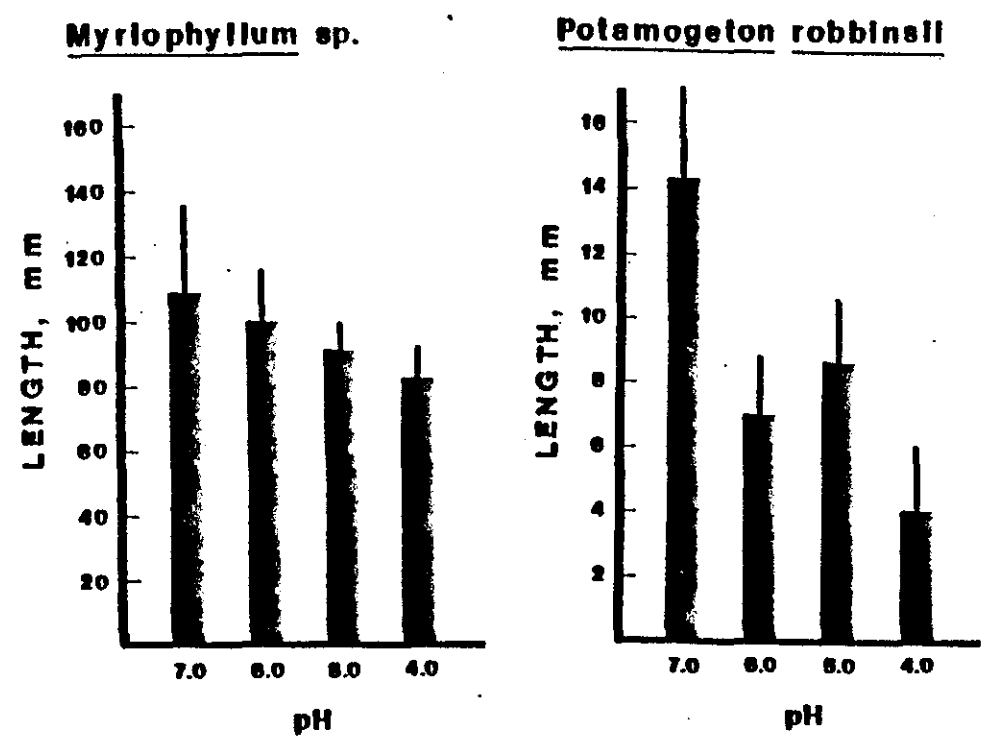

Fig. 2. Growth of Myriophyllum sp. and P. robbinsii under varying pH conditions.

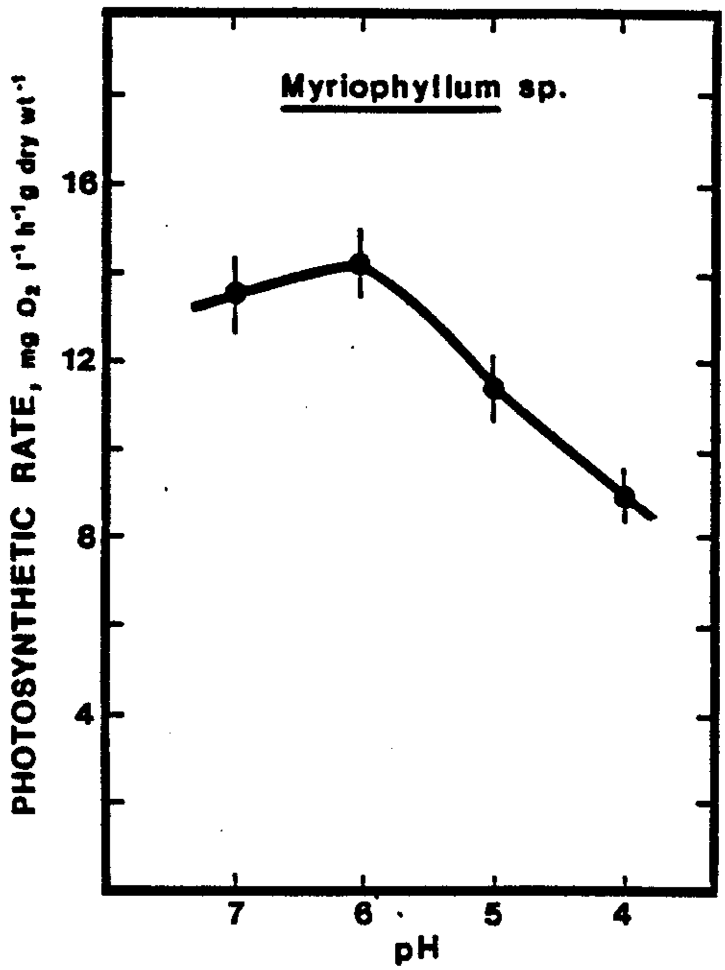

Fig. 3. Photosynthetic rate of Myriophyllum sp. under varying pH conditions.

Together these preliminary laboratory data indicate that a response to artificial acidification under laboratory conditions could be measured at levels of acidity currently found in Adirondack lakes. Further investigations are necessary to differentiate between the direct effects of increased hydrogen ion concentration and possible secondary effects of acid condition such as changes in nutrient availability and metal solubility. The importance of these variables in natural environments must also be verified.

The results of our field survey are summarized in Fig. 4. Thirty-five species (of submersed and floating-leaved plants) were found in the 9 surveyed lakes. Of these species, 28 are also found in Lake George. The relative importance of each species in a particular lake was evaluated according to its contribution to the total bottom cover and was assigned a designation of dominant, frequent or occasional. The species designated in the figure as numbers 1-15, which include six species of the pondweed genus, Potamogeton, were present in this study only in lakes with a pH above 6.0. Another group of plants, numbers 31-35, were found to occur frequently only in the lakes with a pH below 5. These include Potamogeton confervoides Reichenb and Utricularia geminiscapa Benj.

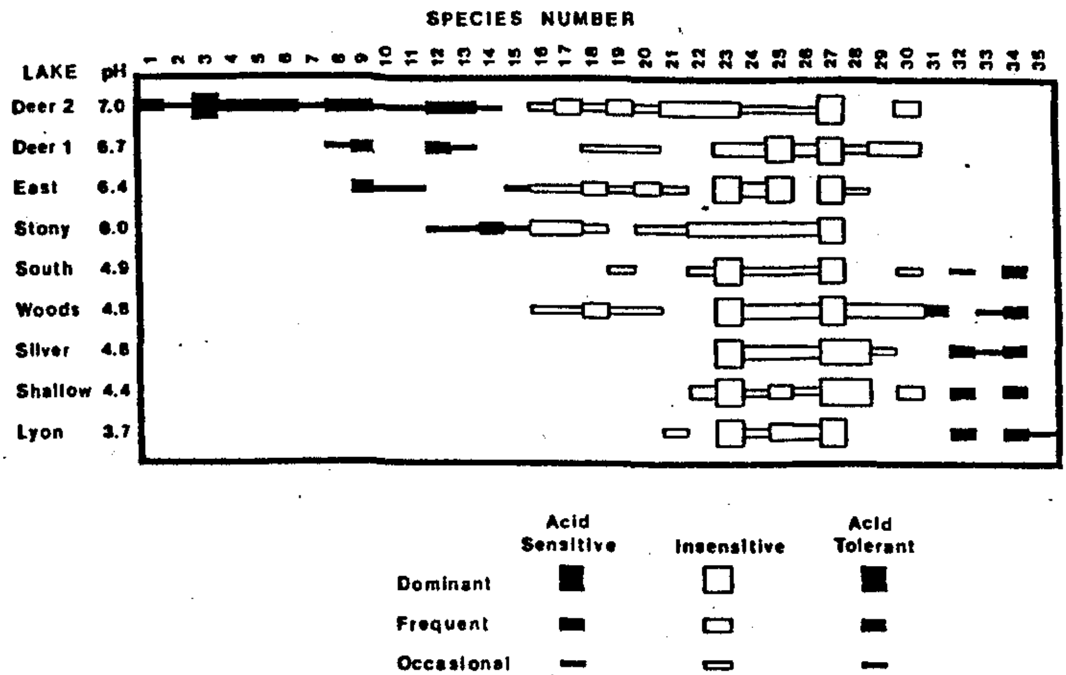

Fig. 4. Presence and relative abundance of macrophyte species in 9 Adirondack lakes studied and their distribution in relation to water pH.

It is apparent from Fig. 4 that the dominant species in most of the lakes are present throughout the pH gradient. These widely tolerent species are a major component of the communities in the acid lakes surveyed (pH below 5).

Grahn (1977) and Halversen (1977) have reported extensive expansion in Sphagnum communities in Scandinavian lakes. Similarly, dense mats of Sphagnum pylaesii in Lake Colden in the Adirondacks have been reported (Hendrey and Vertucci, 1980). In our study Sphagnum was found to be a major component of only two of the five lakes having pH values below 5.

V. americana, a species used in the laboratory study, was found only in the lake with a pH of 7. This shows a tentative correlation between the findings of the preliminary laboratory growth experiments and the field distribution data.

The field data presented in Fig. 4 does indicate a shift in aquatic plant communities in lakes possessing varying degrees of acidification. This indicates what type of community changes might be expected as a lake undergoes acidfication. The effects of this change in plant communities on the role of macrophytes in nutrient cycling in acid lakes is not known. However, the low productivity of planktonic algae and development of extensive benthic algal communities observed in this study and by others (Stokes, 1981) coupled with a decrease in bacterial decomposition rates observed in acid lakes (Laake, 1976) may magnify the role of macrophytes in nutrient cycling and biomass accumulation under these conditions.

The overall effect of acidification to the aquatic food chain is summarized in Fig. 5. As fish disappear in acid waters, shifts in invertebrate predator and zooplankton communities occur. The drop in soluble CO_2 concentrations shows a concomitant drop in phytoplankton productivity. Decreased bacterial metabolic activity is reflected in decreased levels of decomposition lowering soluble nutrient availability in the water column.

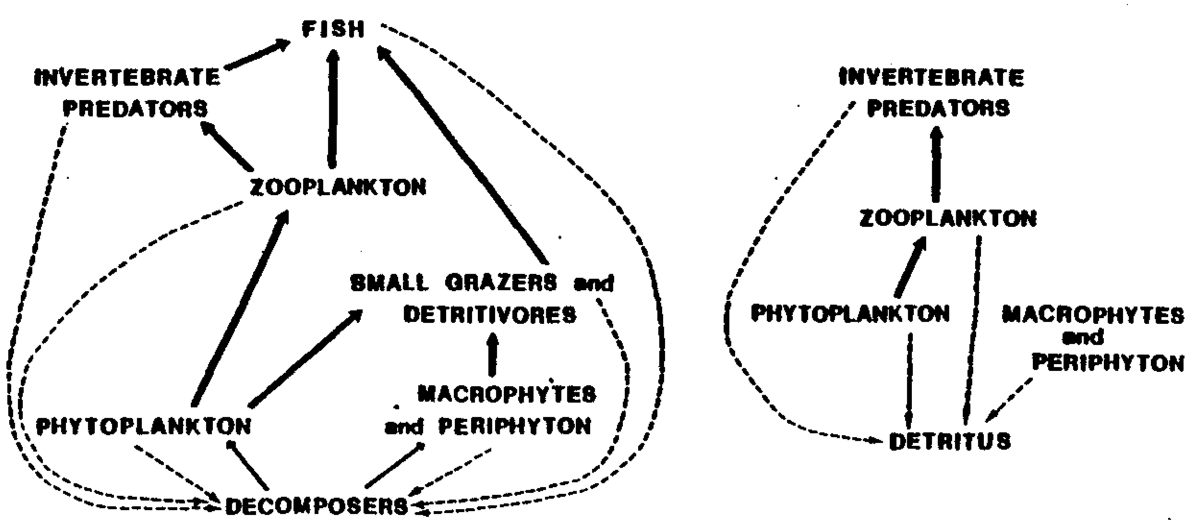

Fig. 5. A scheme showing the effect of acidification on aquatic food chains; pH 7.0 shown on the left, pH 4.0 on the right.

REFERENCES

American Public Health Association. 1981. Standard Methods for the Examination of Water and Wastewater, 15th ed. American Public Health Association, Washington, D.C. 1134 pp.

Grahn, O. 1977. Macrophyte succession in Swedish lakes caused by deposition of airborne acid substances. Water, Air and Soil Poll. 7:295-305.

Halvorsen, K. 1977. Makrofyttvegetajonen i endel vann på Adg er. SNSF-project, TN 36/77, 154 pp.

Hendrey, G.R. and Vertucci, F. 1980. Benthic plant communities in acid Lake Colden, New York: Sphagnum and the algal mat. pp. 315-315 In D. Drablos and A. Tollan, (eds.), Proc. Int. Conf. Ecol. Impact Acid Precip. Norway SNSF project, Oslo.

Laake, M. 1976. Effekter av lav pH på produksjon, nedbrytning og stoffkretsløp i littoralsonen. SNSF-project, IR29/76, 75pp.

Overrein, L.N., H.M. Seip and A. Tollan. 1980. Final report of the SNSF-project 1972-1980. Oslo, 175p pp.

Søndergaard, M. and Sand-Jensen, K. 1979. Carbon uptake by leaves and roots of Littorella uniflora (L.) Aschers. Aquat. Bot., 6: 1-12.

Stokes, P.M. 1981. Benthic algal communities in acid lakes. pp. 119-138 In R. Singer, (ed.), Effects of Acidic Precipitation on Benthos. North American Benthological Society.

DISCUSSION

Morton - To what do you attribute the death of fish?
Roberts - Increase levels of metals have a direct effect on fish. Large changes in the food chain also effect fish.

George - What are the characteristics of acidophiles?
Roberts - Survey suggests that plants are carbon limited (no HCO_3) There is a selection for plants that can use CO_2 as a carbon source.

Heimke - How do you keep the media buffered in the 21-day growth source?
Roberts - The pH is maintained by using a flow-through system.

Armstrong - Did you do any water chemistry analysis in the tanks?
Roberts - No.

Fuhs - Was there any macroalga present in the acid lakes?
Roberts - Yes, 3 communities of mat-forming algae and there was a shift to benthic algae.