NORTH CENTRAL FOREST EXPERIMENT STATION

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ACIDITY OF LAKES AND IMPOUNDMENTS IN NORTH-CENTRAL MINNESOTA

Elon S. Verry,
Principal Forest Hydrologist,
Grand Rapids, Minnesota

ABSTRACT.—Measurements of lake and impoundment pH for several years, intensive sampling within years, and pH-calcium plots verify normal pH levels and do not show evidence of changes due to acid precipitation. These data in comparison with general lake data narrow the northern Lake States area in which rain or snow may cause lake acidification.

KEY WORDS: Acid rain, acid precipitation, limnology, lake pH.

Acidity has increased in poorly buffered lakes of southern Scandinavia and eastern North America during the last 30 to 40 years (Wright and Gjessing 1976). Acid precipitation is thought to be the cause. It has spread in North America in recent decades (Likens *et al.* 1979), and lakes and streams in some watersheds with low buffering capacity are becoming more acid as a result (Jeffries *et al.* 1979, Henriksen 1979). We studied pH changes in lakes and impoundments in north-central Minnesota to see if lakes in this area showed signs of acidification due to acid precipitation.

METHODS

In the spring of 1974, we measured surface water pH and specific conductance (corrected to 25°C) in 17 lakes near the Marcell Experimental Forest in north-central Minnesota (fig. 1). We used this information in combination with water table maps to classify the lakes as perched, transitional, or strongly groundwater-fed (Hawkinson and Verry 1975). We remeasured these lakes in the fall of 1979 and measured four additional lakes in the same area. In the spring of 1980 we again measured pH and conductance in all 21 lakes and analyzed the water for calcium using atomic absorption (Perkin-Elmer 1973) and apparent color using a [1]Hellige Aqua Testor™ with colored glass discs calibrated to platinum-cobalt standards such that one color unit equals 1 mg Pt/l. True color was determined the same way after passing the water through a 0.45 μm filter. Lake samples were taken by gently lowering a glass beaker into the surface water of the littoral. Acidity (pH) and conductance were measured immediately with field-calibrated instruments and these values were checked the same or following day with laboratory meters. Lakes were in a mixed condition when all samples were taken. Changes in pH (calculations done with hydrogen ion activities) between the three measurement dates were tested for statistical significance at the 5 percent level of confidence using a paired t-test.

Seven shallow waterfowl impoundments in the Chippewa National Forest were measured for pH for 4 years (from April 1975 to May 1979) at least every 2 to 4 weeks throughout the year. One deep water marsh (Goose "Lake") in the Chippewa National Forest was similarly measured for 3 years (from March 1976 to May 1979).

In the spring of 1980, pH and calcium data for some of the 21 lakes were plotted and compared with Henriksen's lake acidification curve.

[1]*Mention of trade names does not constitute endorsement of the products by the USDA Forest Service.*

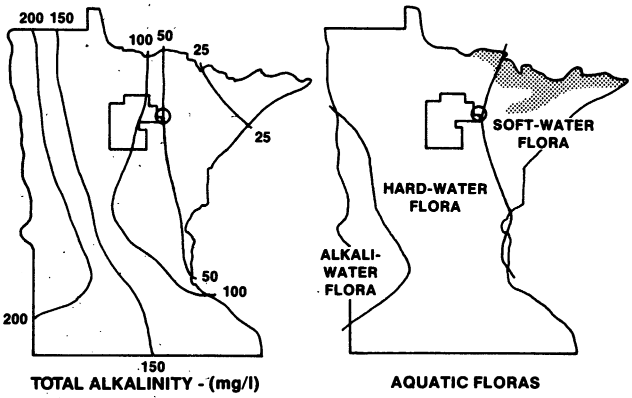

Figure 1.—*Location of sample lakes, Marcell Experimental Forest (circle), and impoundments, Chippewa National Forest (rectangle) in relation to Moyle's (1954) general lake data. Shaded area is exposed formation of Precambrian igneous and metamorphic rocks. These formations extend across the northern half of Minnesota to the Red River Valley but are generally covered with glacial drift.*

RESULTS AND DISCUSSION

Perched lakes in 1980 were 0.3 pH unit higher than in either 1974 or 1979 (table 1). Groundwater lakes were 0.2 pH unit lower in 1979 and 0.6 pH unit lower in 1980 than in 1974. Transitional lakes and data from other years for perched and groundwater lakes showed no statistically significant changes.

The most significant conclusion associated with these lake pH data is that no lake had a pH value below 6.0. Fish are not adversely affected at pH 6.0 and above. Thus, none of these lakes can be considered abnormally acidic. Even though some lake categories showed a statistical change in pH, it is presumptive to conclude that these changes represent a trend because lakes and impoundments normally vary approximately 1 pH unit annually.

The pH of the impoundments we studied ranged from 0.9 to 1.9 units annually (table 2). Such ranges in annual lake pH are also common. Lohammar (1938) measured lake pH at 70 sites in Sweden 3 or 4 times a year in 1933, 1934, and 1937 and found an average range of 0.9 pH units with ranges for individual lakes from 0.2 to 2.6 units. Juday *et al.* (1935) found a range in pH up to 1.4 pH units for 222 lakes measured for a period of 2 to 6 years (from 1925 to 1932) in northeastern Wisconsin and ranges up to 2.5 units in 23 additional lakes. Thus, interpretation of long-term lake pH changes from small sample numbers per year is difficult in light of normal within-year variation. Intensive sampling throughout the year on selected lakes would establish a pH record over several years and would be more easily interpreted.

The pH of snow at the Marcell Experimental Forest ranges from 3.5 to 4.9. Jeffries *et al.* (1979) suggested that stream or lake water may approach these values during and after snowmelt and thus watersheds that are not able to buffer acid snowmelt would be identified.

Impoundment water pH does not show a depression to near snow pH values, but ranges from 5.7 to 7.7 during and after snowmelt (fig. 2). The impoundments we studied covered a range of water quality conditions. Ketchum impoundment is strongly fed by groundwater springs and has abundant water and an average specific conductance of 350 μmhos. Bear Brook has a large organic soil surface watershed but significant amounts of groundwater inflow and an average specific conductance of 190. Cuba impoundment has a small watershed and is totally fed by surface water. It has an average specific conductance of 65. Water supply is not dependable and the impoundment nearly dried up during 1976 and 1977—two severe drought years. The pH of snow may not affect impoundment or lake pH if the snowpack is small. Snow water contents at maximumpack average 13 cm; only 1977 had a small snowpack: 1975, 20 cm; 1976, 13 cm; 1977, 4 cm; 1978, 11 cm; and 1979, 18 cm.

Acidity (pH) of the impoundments is least variable during February and March and generally low at this time. These under-ice values may result from respiration-generated carbon dioxide. Ice-out on these impoundments generally occurs during the third week of April—about 1 to 1½ weeks after snow has

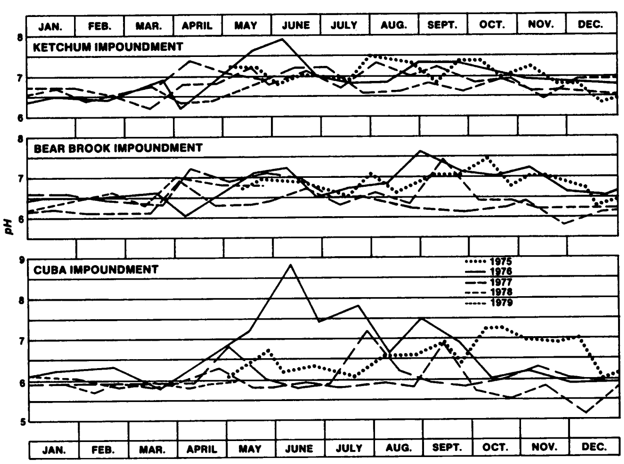

Figure 2.—*pH (25°C) of three impoundments on the Chippewa National Forest.*

Table 1.—*Chemical characteristics of lakes near the Marcell Experimental Forest*[1]

Lake	Spring 1974 Specific conductance	Spring 1974 pH	Fall 1979 Specific conductance	Fall 1979 pH	Spring 1980 Specific conductance	Spring 1980 pH	Spring 1980 Apparent color units	Spring 1980 True color units	Spring 1980 Ca
	μmhos		μmhos		μmhos				mg/1
PERCHED LAKES									
Blandin	16	6.2	15	6.0	14	6.6	30	25	1.0
Willeys	16	6.6	16	6.5	15	7.0	15	7	1.5
White Porky	18	6.6	16	6.3	18	6.9	20	15	1.4
Moss	19	6.8	13	6.5	11	6.7	25	15	1.1
Moon	19	6.4	17	6.6	17	7.3	25	15	1.2
Spring	20	6.4	18	6.5	16	6.4	75	50	1.3
Lum	21	6.3	21	6.3	20	6.6	40	30	1.8
Sawyer	22	6.1	17	6.1	16	6.9	25	20	1.6
Bog	23	6.6	19	6.2	18	6.6	65	45	1.4
Nose	—	—	22	6.2	20	6.6	25	15	1.6
Three Island	—	—	26	6.6	24	6.9	30	20	2.3
Shorty's	—	—	23	6.1	21	6.1	130	110	2.6
Tubby	—	—	19	6.1	18	6.6	45	35	1.2
Average	19	6.2a	19	6.2b	18	6.5a,b	42	31	1.5
TRANSITIONAL LAKES									
Burrow's	31	6.4	23	6.8	22	6.5	10	5	2.6
Lost Moose	55	7.4	41	7.0	52	7.0	25	15	6.4
Burnt Shanty	32	6.9	70	7.0	76	6.7	15	5	10.2
Buckman	95	7.3	102	7.3	96	7.0	30	15	10.8
Average	53	6.8	59	7.0	61	6.7	20	10	7.5
GROUNDWATER LAKES									
Sand	144	7.5	120	7.4	113	6.8	15	7	15.9
Hunter	150	7.5	112	7.3	120	7.0	45	25	15.4
Cutaway	160	7.6	161	7.2	160	6.7	25	15	17.1
Lake 19	192	7.2	181	7.0	202	6.9	30	10	10.0
Average	162	7.4cd	143	7.2d	149	6.8c	29	14	17.1
ALL LAKES									
Average	61	6.7	50	6.4e	51	6.6e	35	24	5.6

[1] pH averages followed by the same letter are significantly different (95 percent level of confidence) on the basis of a paired-test.

Table 2.—*Annual pH range of eight waterfowl impoundments on the Chippewa National Forest*[1]

Impoundment	May 1975 to May 1976	May 1976 to May 1977	May 1977 to May 1978	May 1978 to May 1979	Average range
Ball Club	6.0-7.2	6.1-7.3	5.6-7.5	6.1-6.9	1.3
Bear Brook	6.0-7.4	6.3-7.6	6.1-7.1	6.3-7.4	1.2
Beaver Lodge	6.0-7.5	6.0-7.2	5.7-7.2	6.0-7.0	1.3
Cuba	5.8-7.2	drawn down	5.7-7.2	5.1-6.9	1.6
East Lake	6.4-7.7	6.3-7.6	6.2-7.9	6.4-7.6	1.4
Goose Lake	—	5.2-6.3	4.8-6.3	5.4-6.7	1.3
Ketchum	6.2-7.4	6.8-7.9	6.2-7.2	6.3-7.3	1.1
Sucker Bay	drawn down	drawn down	5.7-6.6	5.3-6.5	1.1
Average annual range	1.3	1.2	1.2	1.2	1.3

[1] pH data were excluded in naturally dry or purposefully drawn-down impoundments.

melted from the uplands. pH varies more in April than under the ice, but generally tends to rise. Thus, these water bodies do not experience a low pH, snowmelt shock as experienced in other areas.

We plotted pH over calcium concentration for 15 lakes and compared these with an empirical curve developed by Henriksen (1979) to show lakes that may be losing bicarbonate ions due to acid precipitation but have not changed greatly in pH. Henriksen's empirical curve was developed with calcium concentrations up to 6 mg/l. Thus six of the lakes we studied are not shown because their calcium concentrations are greater than 10 mg/l (table 1). All but 1 of the 15 lakes plotted well below the empirical line separating lakes that are losing bicarbonate from those that are not (fig. 3). The single point above the line (indicating acidification) represents Shorty's Lake, which receives naturally low pH, highly colored water from surrounding organic soils (table 2). In Henriksen's (1979) words, "When applied to data from such waters (highly colored), the indicator (line) implies an apparent acidification where none has occurred.".

A broader interpretation of these data can be made by reference to figure 1 showing Moyle's (1954) areas of alkalinity and hard water-soft water flora in Minnesota. It is unlikely that lakes to the west of the hard water-soft water line or west of the 50 mg/l $CaCO_3$ line will be changed by acid precipitation because of sufficient buffering capacity in watershed soils and groundwater aquifers. Interpretations of the acidification impact on lakes to the east of these lines need further analysis. It is known that lakes in northeastern Wisconsin have had pH values as low as 4.4 since 1925 when they were first measured (Juday *et al.* 1935). Some of these lakes have color values as low as 16. Thus, interpretations in soft water lakes with low pH values are difficult and should be done with intimate knowledge of the lake, its watershed, and hydrology. General surveys such as Moyle's help us sharpen our perspective.

The data in this paper establish a pH record for some lakes and impoundments in north-central Minnesota. Precipitation in this area is acid—listed snow pH values range from 3.5 to 4.9 and rain pH values range from 3.6 to 6.5. However, lakes and impoundments in this area exhibit normal pH values and do not show evidence of becoming more acidic.

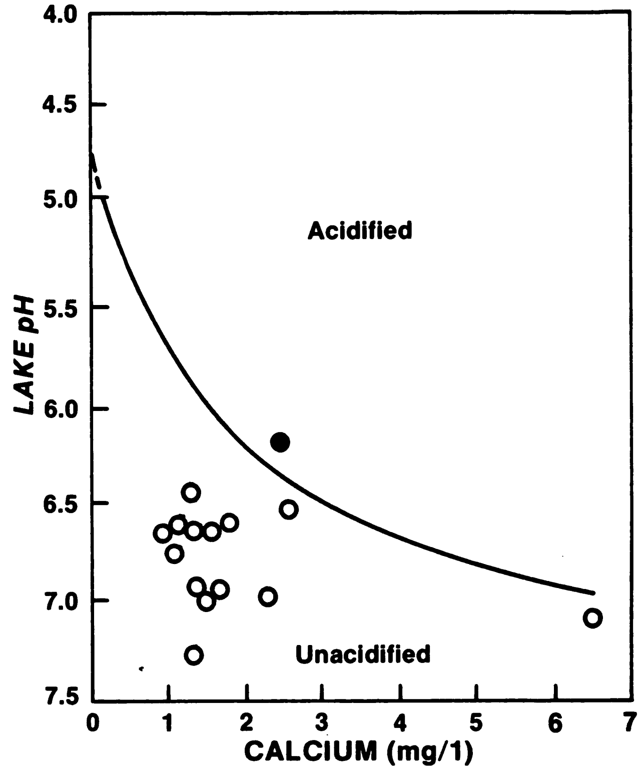

Figure 3.—*pH-calcium plots of 15 lakes in the area of the Marcell Experimental Forest. The solid dot is a highly colored lake. The separation line between acidified and unacidified lakes is from Henriksen (1979).*

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