FISHERIES DIVISION

TECHNICAL REPORT

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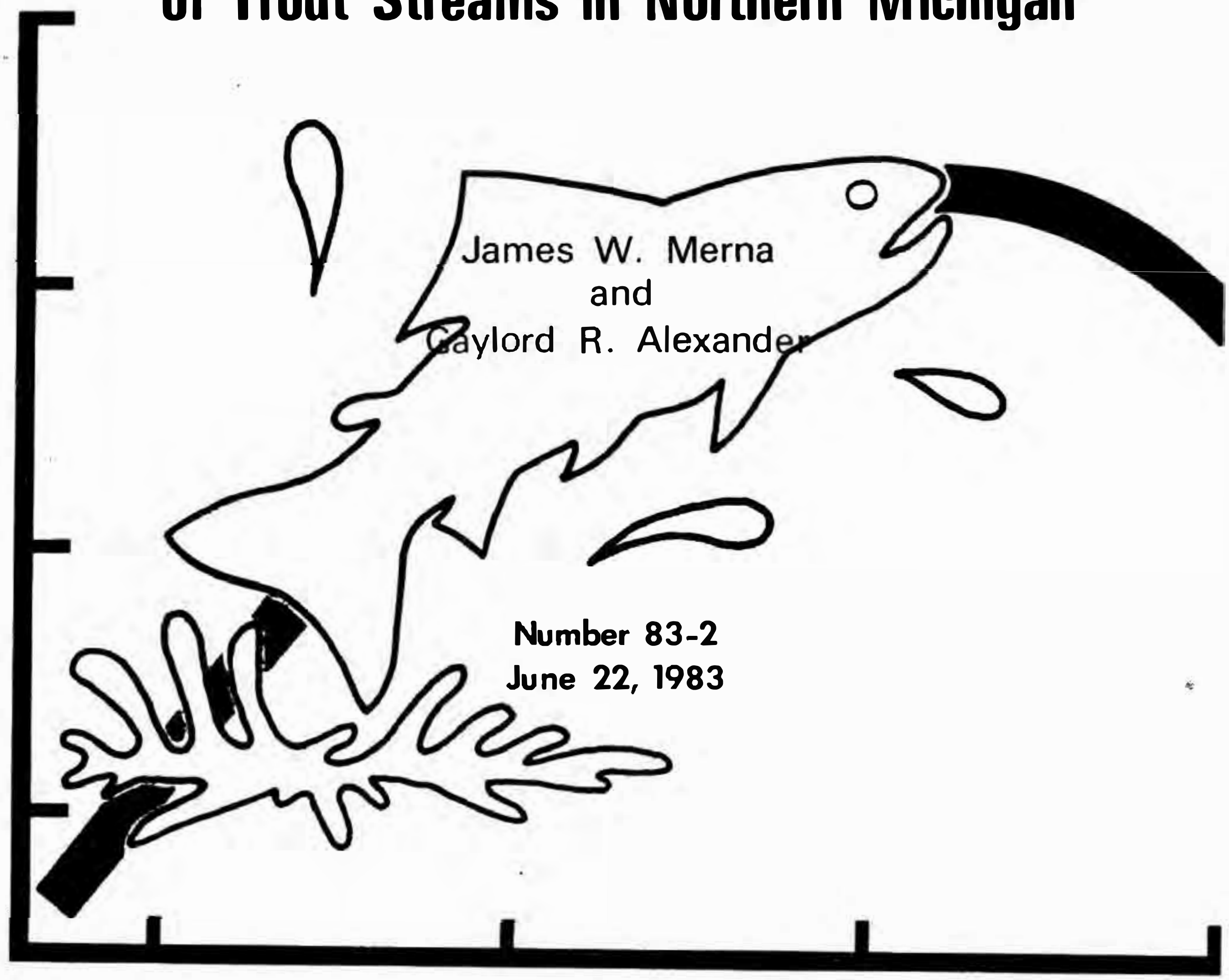

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Number 83-2
June 22, 1983

Michigan Department of
Natural Resources

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EFFECTS OF SNOWMELT RUNOFF ON pH AND ALKALINITY OF TROUT STREAMS IN NORTHERN MICHIGAN

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Introduction

The objective of this study was to determine the effect of snowmelt and spring runoff on pH and alkalinity of northern Michigan trout streams, with emphasis on streams of the Upper Peninsula, known to contain very soft water. The soft-water streams would be expected to be affected most by runoff containing acids from various sources. Naturally produced acids from decay of organic matter leach continuously into our water courses and have done so for ions. However, in the past century, greatly increased acid loads have been contributed to lakes and streams by acidified precipitation and dry deposition. This additional acidity has degraded water quality for fish and other aquatic organisms in many parts of the world, particularly the Scandinavian countries of Europe and the northeastern portions of the United States and Canada. Our concern for the impact of this abnormal, man-made acid precipitation and deposition resulted in this investigation.

The pH of precipitation in Michigan during 1981, collected by volunteer cooperators as part of the Great Lakes Atmospheric Deposition sampling network (G.L.A.D.), is presented in Table 1 (Terkeurst 1982). These data represent the high, low, and average pH values from 238 samples collected at various collection sites throughout the year. Precipitation with a pH of less than 5.6 is considered to be acidic. Of the 238 samples collected, 230 were acidic.

It has been reported by a number of investigators (Jefferies et al. 1979) that acidity of waters increases at snowmelt and spring runoff. Further, Johannessen et al. (1977) observed in laboratory studies that the first 30% of the meltwater from a snow sample contained 70-80% of the H, SO_4, and NO_3 ions. Thus, the first snowmelt can be more acidic than the snow itself.

Trout streams of Michigan are of special significance because they support important fisheries for native brook trout (*Salvelinus fontinalis*) and introduced brown trout (*Salmo trutta*) and rainbow trout (*Salmo gairdneri*). Brook and brown trout spawn in the fall. Their eggs develop in the stream overwinter, and the fry emerge from the redds in late winter and early spring. In some streams newly hatched and emerging fry may be subjected to a sudden increase in acidity at a very sensitive stage in their life cycle. Further, rainbow trout eggs, which are deposited in the spring, can be subjected to changes in water acidity as it percolates through the redds during incubation.

The yolk-sac stage appears to be the most sensitive life period for salmonids (Hendry and Wright 1976). Trojnar (1977) demonstrated that the shock of low pH at the time of emergence of brook trout fry from the redd, following incubation in areas of groundwater of higher pH, can effect survival. Fry incubated at pH 8.07 suffered 100% mortality when transferred to a pH of 4.0. Fry transferred from incubation pH of 4.65 and 5.64 to post emergence pH of 4.0 had mean survival rates of 60-76%. Survival ranged from 95-98% for fry maintained at incubation pH. Also, under certain conditions older trout can be adversely affected, not only by low pH, but by the effect of pH on the solubility of metal ions like Al, Zn, Cu, etc.

We selected streams from two different areas of the Upper Peninsula and one from the Lower Peninsula of Michigan for this study (Table 2). Fifteen streams were chosen in the eastern end of the Upper Peninsula (Schoolcraft, Luce, and Chippewa counties). Three streams were sampled in the western half of the Upper Peninsula (Baraga and Marquette counties). Four streams were sampled in the northern Lower Peninsula (Montmorency County).

Streams were first sampled in mid-March prior to snowmelt to obtain winter baseline conditions for alkalinity, pH, and stream flow (Table 2). Rough estimates of stream discharge were made by visual inspection throughout the study. Values of pH were measured in the field with a portable pH meter. Concentrations of total alkalinity were determined in the field by standard methods using methyl orange indicator (M.O.). All samples were processed immediately at the stream, except those from Baraga and Marquette counties, which were collected and returned to the laboratory for M.O. total alkalinity determination. Water was taken to the Marquette Wastewater Treatment Plant for pH measurements on a laboratory pH meter. All sample bottles were packed in snow until analyzed.

Results

Snowmelt in the Upper Peninsula was intermittent throughout April, with alternate periods of refreezing and even additional snowfall after the first thaw. Warm temperatures and rain on March 31 resulted in an initial runoff and the loss of 10-20% of the snow cover. When the streams were sampled on April 1, they were higher than normal, however, the temperature had again dropped to below freezing and there was no active runoff. There was little additional snowmelt until April 12 and peak runoff was about April 25-27. The snow was estimated to be 80-90% melted on April 27, and the streams were mostly high and colored. The discharge of snowmelt water was probably nearly complete by May 1. Flows increased periodically during May following the onset of spring rains.

Alkalinity and pH values for the Sturgeon, Peskekee, and Escanaba rivers are listed in Table 3. All three rivers show the results of dilution and acid addition from April 12 to May 12. They all dropped in pH by at least one full pH unit. Alkalinity of all three rivers on April 26 was approximately 30% of the values measured in March prior to runoff. The rivers were still reduced in pH and alkalinity on May 5 and 12, but had returned to near normal summer values by May 20. The early May concentrations could have reflected either extended snowmelt, spring rains, or most likely a combination of both.

Alkalinity and pH values measured in the rivers of the eastern end of the Upper Peninsula are listed in Table 4. Values recorded on March 18 were believed to be representative of mid-winter flow concentrations prior to spring runoff.

All alkalinity and pH values were reduced on April 27, but some more than others. Alkalinity values from most streams were approximately 50% lower than on March 18, but concentrations in Little Dawson Creek and Shelldrake River were only 25% of the values recorded in March. These two streams were very high and colored, and apparently were receiving heavy runoff from swamp areas. The decrease in pH recorded in these two streams has the potential of being damaging to their biota. However, data from May 1 indicated that the maximum effect of heavy snowmelt runoff was of short duration.

Streams of the northern Lower Peninsula had much higher alkalinities and pH than streams of the Upper Peninsula. Alkalinities in these streams were depressed 20 to 30 ppm, similar to those in the Upper Peninsula, but in terms of proportional decrease they were reduced by only 10-15%. The pH values were depressed only slightly in these obviously highly buffered waters.

It is evident that alkalinity generally decreases from south to north in Michigan's trout country. Streams of the Lower Peninsula ranged between 160 and 210 ppm. Streams of the southern portion of the Upper Peninsula were not used in this study but are known to contain 80 to 120 ppm. The streams of the northern portion of the Upper Peninsula generally averaged 40 to 60 ppm, although there are a scattered number of streams with concentrations of only 20 to 30 ppm. Those Upper Peninsula streams, draining areas with perched water tables and considerable swamp vegetation, tend to have flashy discharge, lower pH, and alkalinity, and generally reddish stained water. Streams with higher alkalinity and pH were generally less flashy, less colored, and contained less swamp in their drainage.

The East Branch of the Fox River contains both stream types. At the station chosen for study (M77 bridge), it has clear, relatively unstained, moderately hard water (50 ppm M.O.). However, within the next 10 miles, the river passes through an area known as "The Spreads" where it picks up considerable swamp and marsh drainage. At the time of snowmelt, stream discharge was up slightly at the study site, however, at the M28 bridge, east of Seney, the river was at flood stage, highly colored, and reduced in alkalinity and pH. Unfortunately, this site was not sampled on previous sampling dates since this change in character was not anticipated.

It is evident that snowmelt water containing nearly zero alkalinity results in direct dilution of alkalinity in all streams. The pH was also depressed by 0.8 to 2.5 pH units at snowmelt in all streams. However, the pH was depressed most in streams with the greatest dilution of snowmelt water. These streams also tended to have the flashiest discharge and the highest intensity of stain colored water. The stain color is presumably related to organic leachate which contains organic acids (humic, tannic, etc.). The depressions of pH are undoubtedly a result of both organic acids being flushed out of the wetlands and inorganic acids being released from the snowpack and previous dry deposition from the atmosphere. From this study, we could not determine the magnitude of acidic contribution from each of these sources. However, it is reasonable to assume that contributions from organic acids have not increased in recent years. Thus, the increased acidity of lakes and rivers throughout industrialized regions of the world must reflect an increased contribution from atmospheric deposition.

Several of the streams studied dropped about two pH units to levels below 6.0. A reduction of this extent has been demonstrated to result in reduced survival of emerging brook trout fry (Trojnar 1977). However, streams with normal flows, alkalinity values in excess of 40 ppm, and pH values of 7.4 and higher appear to be sufficiently well buffered to prevent damage by acid snowmelt and runoff at present day acidity levels. Most streams of this nature were able to maintain a pH above 6.5 during the peak of snowmelt. Exceptions which will bear watching in the future are streams with alkalinity of 30 ppm or less, which receive water from extensive wetland areas and thus pick up considerable acidity.

Table 1. Values of pH of precipitation samples collected at various sites in Michigan in 1981 (Terkeurst 1982).

Site	Number of readings	pH values		
		High	Low	Logarithimic average
Bay City	24	5.4	4.0	4.4
Beaver Island	7	4.6	3.7	4.0
Benton Harbor	35	6.8	4.0	4.4
Copper Harbor	4	4.9	4.0	4.2
Empire	14	6.3	3.8	4.1
Escanaba	17	4.8	3.1	4.0
Grand Marais	13	4.8	3.7	4.2
Mt. Clemens	30	4.8	3.8	4.1
Muskegon	17	4.3	3.4	3.7
Ontonagon	16	5.3	4.1	4.5
Port Austin	16	6.7	3.9	4.4
Port Sanilac	31	7.0	3.8	4.1
Tawas Point	13	4.7	3.7	4.1

Table 2. Location and flow of Michigan streams studied for effect of snowmelt on alkalinity and pH.

Stream	County	Location of study site	Estimated winter flow (cfs)
Fox River (M28)	Schoolcraft	T46N R13W Sec 29	60
Fox River E. Br. (M77)	Schoolcraft	T46N R13W Sec 4	20
Clear Creek (M77)	Schoolcraft	T47N R13W Sec 21	8
Little Dawson Creek	Luce	T48N R10W Sec 32	3
Shelldrake River (Betsy)	Chippewa	T49N R6W Sec 3	--
Galloway (M123)	Chippewa	T48N R6W Sec 29	5
Roxbury Creek	Chippewa	T47N R6W Sec 9	15
Ankodosh Creek	Chippewa	T47N R6W Sec 8	15
Noamikong Creek	Chippewa	T47N R5W Sec 18	20
Water Wheel Creek (Mill)	Chippewa	T47N R5W Sec 15	3
Halfaday Creek	Chippewa	T47N R5W Sec 14	20
Grant Creek	Chippewa	T47N R5W Sec 13	8
Ward Creek	Chippewa	T46N R5W Sec 19	8
Tahquamenon River E. Br.	Chippewa	T46N R5W Sec 30	30

Table 2. Continued.

Stream	County	Location of study site	Estimated winter flow (cfs)
Pine River	Chippewa	T44N R5W Sec 2	15
Sturgeon River (US41)	Baraga	T49N R33W Sec 12-20	--
Peshekee River (US41)	Marquette	T48N R30W Sec 25	--
Escanaba River Middle Br.	Marquette	T47N R29W Sec 1	--
Avery Creek	Montmorency	T29N R2E Sec 9	3
Yonkers Creek	Montmorency	T29N R2E Sec 4	3
Hunt Creek	Montmorency	T29N R2E Sec 36	25
Fuller Creek	Montmorency	T29N R2E Sec 35	6

Table 3. Values of pH and alkalinity for the Sturgeon, Peskekee, and Escanaba rivers, March 26 - May 29, 1982.

Date	River					
	Sturgeon		Peshekee		Escanaba	
	pH	MO	pH	MO	pH	MO
March 26	7.5	28	--	--	7.2	30
March 29	7.2	24	6.8	22	7.0	28
April 12	6.8	12	6.3	11	6.6	14[a]
April 19	6.8	11[a]	6.2	12	6.6	12
April 26	6.2	8	5.8	6[b]	6.1	9
May 5	6.4	13	5.8	8	6.2	14
May 12	6.7	11	6.2	9	6.4	13
May 20	7.0	19	6.5	15	6.7	21

[a] Ice free: partial ice cover prior to this date.

[b] Ice breaking up: complete prior to this date.

Table 4. Values of pH and alkalinity of some streams in Schoolcraft, Luce, and Chippewa counties, 1982.

River	3/18/82		4/01/82		4/08/82		4/27/82		5/10/82	
	pH	MO	pH	MO	pH	MO	pH	MO	pH	MO
Fox River	7.6	50	7.3	43	7.3	43	5.9	21	--	--
Fox River E. Br. (M77)	7.8	46	7.5	45	7.6	42	6.9	37	--	--
Fox River E. Br. (M28)	--	--	--	--	--	--	6.4	18	--	--
Clear Creek	7.9	37	7.4	39	7.7	44	7.0	32	--	--
Little Dawson Creek	7.0	27	6.5	22	5.7	14	5.3	6	6.1	12
Shelldrake River	7.4	32	7.3	28	6.7	14	4.9	8	6.7	16
Galloway River	7.3	32	7.2	24	7.1	28	6.0	18	7.2	29
Roxbury Creek	7.4	51	7.1	28	6.9	25	6.0	16	7.2	25
Ankodosh Creek	7.4	63	7.5	48	7.1	41	6.5	25	7.2	47
Naomikong Creek	7.7	60	7.2	36	6.7	30	6.6	23	7.1	50
Mill Creek	7.6	59	7.1	39	7.0	34	--	--	7.2	50
Halfaday Creek	7.7	51	7.2	38	7.2	35	6.9	31	7.1	48
Grant Creek	7.6	31	6.9	14	6.9	14	6.5	13	6.9	24
Ward Creek	6.7	23	7.1	15	6.6	15	5.9	8	5.8	13
Tahquamenon River E. Br.	7.6	60	7.5	52	7.1	46	6.8	30	7.2	46
Pine River	7.6	57	7.7	43	6.5	14	6.4	12	--	--

Table 5. Values of pH and alkalinity for Hunt, Fuller, Avery, and Yonkers creeks, March 18 - May 20, 1982.

Date	Hunt		Fuller		Avery		Yonkers	
	pH	MO	pH	MO	pH	MO	pH	MO
March 18	8.2	185	8.1	176	8.2	202	8.1	205
March 24	8.2	174	8.0	175	8.1	195	8.0	198
March 30	8.1	173	7.9	170	7.9	200	7.9	207
April 8	8.0	174	7.9	171	8.1	198	8.1	204
April 18	7.8	161	7.7	156	7.9	192	7.9	196
April 24	7.9	165	7.8	159	8.0	193	8.0	196
April 29	8.0	176	8.0	172	8.1	199	8.1	203
May 3	7.9	170	7.8	168	7.9	198	7.9	200
May 14	7.7	151	7.7	155	7.8	187	7.8	195
May 15	8.0	174	7.9	163	7.9	188	7.7	207
May 20	7.8	157	7.8	160	7.9	200	7.9	205
May 24	8.0	176	8.0	174	8.1	202	8.1	203
May 30	8.0	179	7.9	175	8.1	202	8.1	205

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