The Relationship of Turbidity to Temperature of Some Farm Ponds[1]

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The relationship of water temperature to substances in suspension has been considered by many authors with varying conclusions. Welch (16), after a survey of the then published literature, concluded that turbid waters are "warmer" than clear waters and indicated that "substances in suspension" should be taken into account in comparisons of heat budgets of bodies of water.

Studies by Birge (3) with stained water and Eicher (13) with nigrosine indicate that color in water absorbs light nearer to the surface and may result in reduced temperature in deeper layers. Turbidity was responsible for changes in light penetration in Lake Erie (6). Ball (1) noted that temperature in a fertilized lake was lower than temperature in an unfertilized lake, and he attributed the reduction to increased light absorption by plankton. Ellis (11) studied clear and turbid waters in containers in the laboratory and concluded that stratification of erosion silt particles produced a skew lag in the warming and cooling curves of water. The writer kept turbid aquaria (as much as 200,000 ppm. of silt-clay turbidity) and clear aquaria (less than 25 ppm of silt-clay turbidity) side by side in a laboratory and found that turbid aquaria sometimes had temperatures as much as two degrees centigrade cooler throughout than adjacent clear aquaria.

This study was undertaken to determine the vertical temperatures of comparable ponds with and without silt-clay turbidity. The ponds selected were located on a south slope. They receive water from three convergent gullies into 8 separate ponds, locally known as Berry's Jack Farm ponds. In this group two sets of ponds were available that afforded the contrasting conditions sought.

Two of the ponds were well protected from wave action in the upper ends of two main gullies. One of these ponds, hereafter called Pond No. 1, drains a dirt road and has been turbid since its construction. Its turbidity averaged 139 ppm during the study period (Table I). The comparable pond, hereafter called Pond No. 6, has been clear with rare exceptions (less than 25 ppm with 2 exceptions in 21 visits), since its construction. Ponds No. 1 and No. 6 are each about five feet in maximum depth and each is approximately ¼ acre in surface area.

The other two comparable ponds are in a series. Pond No. 5 is a settling pond for Pond No. 4, and each has a maximum depth of about 6 feet. Pond No. 5 is usually turbid (average 62 ppm during the study, Table I) and Pond No. 4 is usually clear (less than 25 ppm during the study with four exceptions). Each is about ¼ acre in size and both are more exposed than the first two comparable ponds.

Three other ponds in the immediate area were visited and data collected at each trip to the contrasting ponds. The three ponds differed in depth (4-13 ft.) and area (½ to 2 acres), but all were clear. Data collected on these ponds in no way disagreed with the general conclusions of this paper concerning clear waters.

The ponds were visited throughout a year at varying intervals. Temperatures were measured at each foot of depth with a Whitney direct reading thermometer. The sensitive element on the thermometer model used was 2 inches in depth so that the registered temperature data is taken from a layer of water two inches thick. Turbidity samples were secured

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near the surface. Turbidity was measured with the Jackson turbidimeter (15) except that Secchi Disk readings aided in turbidity readings. Any pond with a Secchi Disk visibility of two feet or more was assumed to have less than 25 ppm of turbidity.

Surface and bottom temperatures of the comparable ponds are shown in Figures 1-4. The bottom temperature used here was taken just above the mud, in the water. It can be noted that surface temperatures in general were not significantly higher in turbid ponds than in clear ponds. It is apparent that bottom temperatures were usually lower in turbid than in clear ponds.

TABLE I

Turbidities of Four Ponds during one Year

Date		Pond Turbidities in ppm			
		1	4	5	6
1950					
Nov.	18	140	<25	130	—
	30	120	<25	55	<25
Dec.	7	125	<25	47	<25
	14	66	<25	<25	<25
	21	59	<25	<25	<25
1951					
Jan.	6	60	38	<25	<25
	11	38	<25	42	<25
	20	56	<25	65	<25
	26	48	<25	42	<25
Feb.	22	320	28	140	125
Mar.	1	165	<25	72	48
	6	145	<25	85	<25
	20	130	<25	85	<25
Apr.	10	67	<25	97	<25
	18	48	<25	26	<25
	25	85	<25	95	<25
May	8	310	31	137	<25
Jun.	23	325	<25	52	<25
Sep.	1	30	<25	<25	<25
	25	290	<25	<25	<25
Oct.	16	300	29	<25	<25
Nov.	20	320	<25	26	<25

Computations of the data in Figures 1-4 were made in terms of the vertical difference in temperature as a means of showing the degree of stratification of turbid versus clear ponds. Such an average temperature difference for the period of study is 5.1°C. in turbid Pond No. 1 as contrasted to 4.2°C. in clear Pond No. 6. Similarly the average temperature difference was 4.3°C. in turbid Pond No. 5 as contrasted to 2.8°C. in clear Pond No. 4. The difference in actual readings of the comparable ponds is evidence of the importance of wind action in warming the ponds since the ½ acre ponds were deeper, but less stratified than the ¼ acre ponds.

The maximum decline in temperature for depth occurred on June 23 when a decline of 12.0°C. was present in the first 3 feet of turbid Pond No. 1. Pond No .6 had a drop of 8.1°C. on this date while the turbid Pond No. 5 showed a decline of 7.1°C. and clear Pond No. 4 had a uniform temperature to 3 feet.

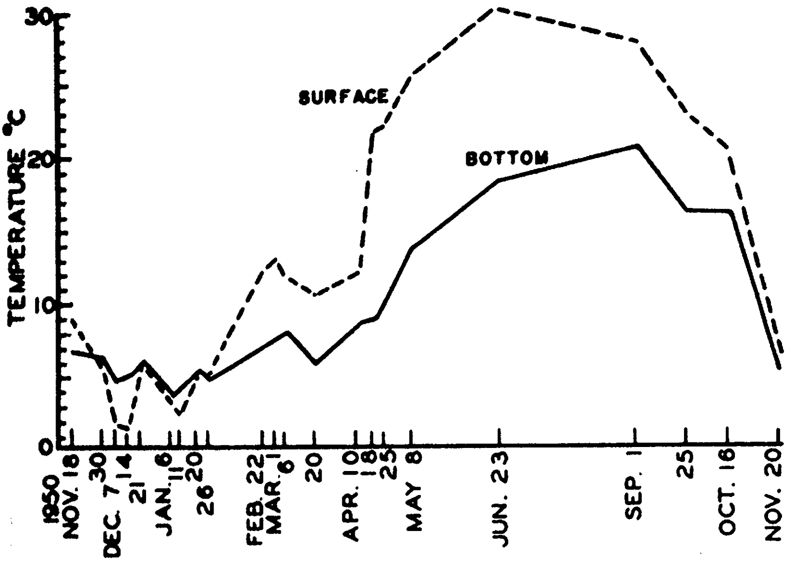

FIGURE 1. SURFACE AND BOTTOM TEMPERATURES OF BERRY POND NUMBER 1.

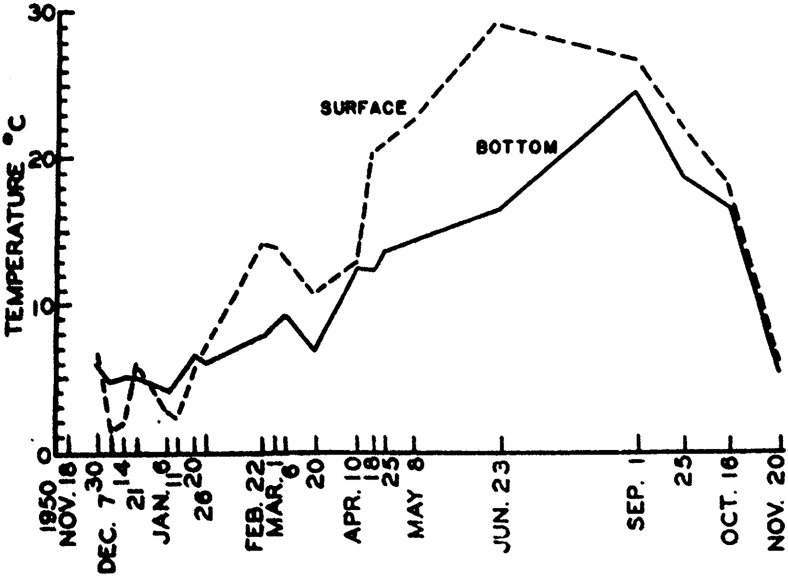

FIGURE 2. SURFACE AND BOTTOM TEMPERATURES OF BERRY POND NUMBER 6.

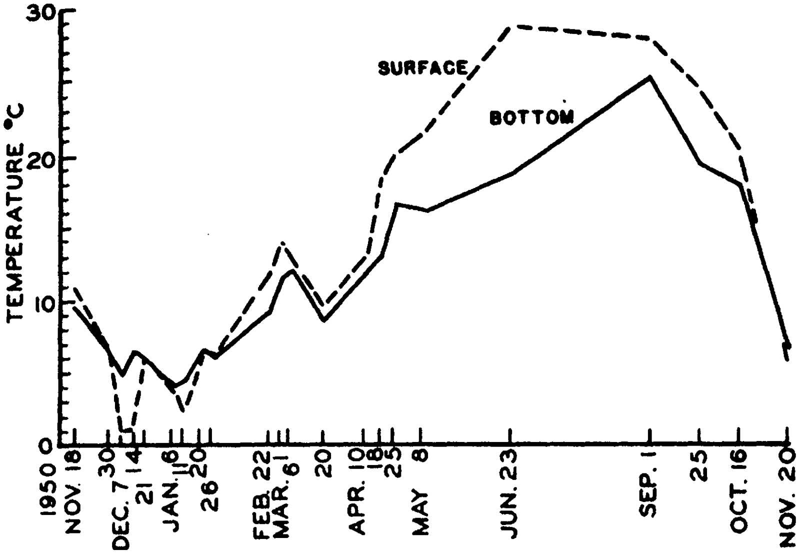

FIGURE 3. SURFACE AND BOTTOM TEMPERATURES OF BERRY POND NUMBER 4.

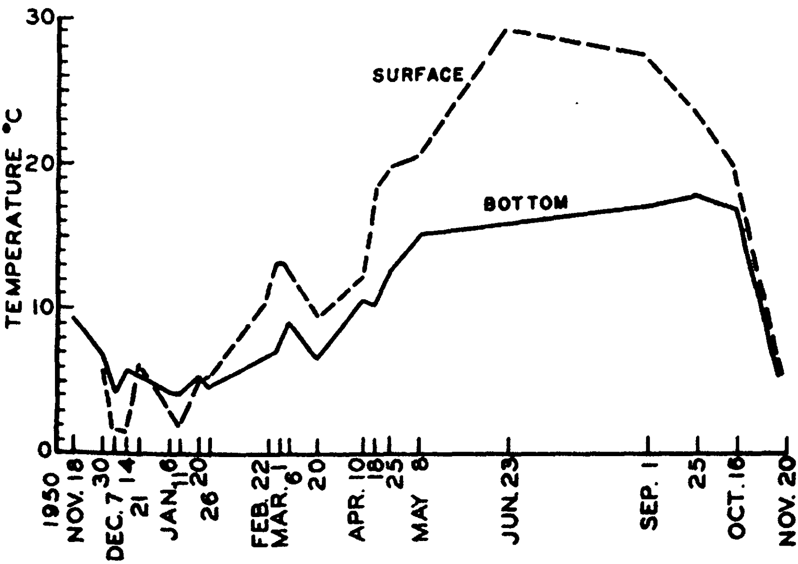

FIGURE 4. SURFACE AND BOTTOM TEMPERATURE OF BERRY POND NUMBER 5.

Since the ponds were of comparable sizes the vertical series of temperatures taken in each pond were totaled and averaged for comparison. These "average" temperatures are given in Table II.

TABLE II

Average Temperatures of Berry's Jack Farm Ponds, Nov. 18, 1950 through Nov. 20, 1951

	1950						1951						
	NOV.		DEC.				JAN.			FEB.		MAR.	
POND NO.	18	30	7	14	21	6	11	20	26	22	1	6	20
1	7.6	5.5	2.9	4.4	5.4	3.1	3.7	5.1	4.9	8.6	9.3	10.1	7.6
6		6.4	3.7	4.3	5.5	2.8	3.8	5.7	6.6	9.3	11.6	12.1	8.9
5	10.0	6.2	2.6	4.6	5.2	3.4	3.4	5.4	5.0	8.7	10.7	11.4	7.9
4	10.2	7.1	2.9	5.3	6.1	3.7	3.5	6.3	6.1	11.1	13.1	12.9	9.1

	1951									
	APRIL			MAY	JUNE	SEPT.		OCT.	NOV.	
	10	18	25	8	23	1	25	16	20	AVERAGE
1	11.0	13.0	15.0	16.7	22.4	25.6	17.9	17.4	5.4	10.1
6	13.4	16.0	18.0	17.7	24.1	27.3	20.8	18.5	5.5	11.5
5	10.8	14.1	17.4	18.2	22.5	24.3	20.6	18.3	5.3	10.8
4	12.9	15.3	18.6	19.6	24.9	27.8	21.8	19.1	5.9	12.0

As shown in the table, the "average" temperatures computed for the ponds indicate that turbid ponds are cooler than adjacent clear ponds, the average of temperatures of turbid Ponds No. 1 being 1.4°C. cooler than clear Pond No. 6, and 1.2°C. cooler in turbid Pond No. 5 than in clear pond No. 4. Annual increase of "average" temperatures are also indicative in the same way. Pond No. 1 increased from a winter minimum of 2.9°C. to a summer maximum of 25.6°C. while Pond No. 6 increased from 2.8°C. to 27.3°C. Similarly Pond No. 5 increased from 3.4°C. to 24.3°C. in contrast to an increase in Pond No. 4 of 3.5°C. to 28.8°C.

An ice cover was present at the times of three visits to the ponds. Chandler (5) found that temperatures in Lake Erie did not vary more than 0.5°C. from top to bottom while an ice cover existed from January 25 to April 1, 1939. Winter temperatures were never lower than 2.2°C. at depths of 1 foot in Berry's Jack Farm Ponds and never lower than 3.8°C. just above the bottom.

TABLE III

Vertical Temperatures of Berry's Jack Farm Ponds under an Ice Cover Showing Surface and Bottom Heating during One Week.

	POND NUMBERS							
DEPTH	DEC. 7				DEC. 14			
FEET	1	6	5	4	1	6	5	4
0	1.4	1.5	1.6	0.7	1.2	2.0	1.4	0.9
1	2.5	3.9	2.2	2.2	5.7	4.8	5.6	6.3
2	2.5	4.1	2.2	2.4	5.2	4.8	5.0	6.0
3	2.5	4.1	2.2	2.8	4.7	4.7	4.8	5.9
4	2.9	4.7	2.6	3.5	4.8	5.3	4.7	5.9
5	3.8		3.3	3.8	5.0		4.7	5.8
6			4.5	4.8			6.0	6.4

Heating of the water was effective through an ice cover during the two week period, December 7 through 14, 1950 (Table III). Heating also occurred from the bottoms as shown in the table. Surface temperatures were taken in the afternoons by breaking the ice (1½ inches on Dec. 7 and ¼ to ½ inches on Dec. 14) and just submerging the sensitive element. The lowest temperature in the table is of water just above the bottom mud. Ide (14) found that in isolated pools a bright sun could heat the water to a much higher (10°C.) temperature than the air and the condition seems to be somewhat similar here.

Temporary stratification was established in turbid ponds even in midwinter. When the ponds were visited on Dec. 21 the ice cover had disappeared. The turbid ponds (No. 1 and No. 5) had declines of 1.2°C. respectively in the first 3 feet while all clear ponds had between 0.1°C. and 0.8°C. decline in comparable depths.

Thermal stratification in (Michigan) bog lakes (17) became well established in early summer after the ice cover was gone, but, with only small depths involved, thermal resistance was low and easily interrupted. The warming of a lake is accomplished by absorption of heat in the surface water and wind agitation with resultant mixing of the water (4). Protected turbid waters warm more slowly than protected clear waters due to low light penetration (3). Slower warming of turbid waters continues due to the influence of temperature on density (2).

Rises in temperature to as much as 40° C. have been recorded in a small lake in Michigan (17) with disastrous effects to clams, plankton organisms, other invertebrates, and some fishes. In excessively turbid waters the rapid shutting out of effective light may limit chlorophyll-bearing plants to a very thin surface stratum (16). It is possible that a layer of turbid water would blanket the surface of a farm pond, eliminating all except surface increase of temperature and allowing organisms to retreat to a satisfactory temperature. At one time (June 23), Berry's Jack Farm Pond No. 1 had a temperature of 31.6°C. at the surface, 24.1°C. at 1 foot, 20.9°C. at 2 feet, and 19.6°C. at 3 feet depths. At the same time Pond No. 6 had comparable temperatures of 30.2°, 29.6°, 25.7°, and 22.1° at the same depths. Light may also cause retreat of animals (16) and a reduction of light was probably also helpful under these conditions.

Pearse has shown that turbid lakes produce their greatest variety and quantity of fish life in the 0.5 meter stratum while in clear lakes more species and a greater number of fish occur in the 5-10 meter stratum (16). Fishes have been located and fishing success increased by locating the depth to fish with a thermometer (7, 8, 9). A discussion of warm water fisheries versus cold water fisheries (12) in a borderline condition would certainly require the consideration of erosion silt turbidity in its analysis if the condition existed as it does in much of the mid-west.

Air temperatures have been shown to be correlated with surface lake temperatures of Lake Erie (10). The temperature of the deeper water does not tend to fluctuate as rapidly. In general the deeper water temperatures lag behind air temperatures more in a turbid pond than in a corresponding clear one. Cooler waters have less tendency to mix than warmer waters so that as warming takes place the water is more easily mixed by storms. Later in the summer and fall cooling and mixing of the water is alternated with surface warming and temporary stratification. And even during this period the stratification is greater in turbid than in clear ponds.

SUMMARY

1. Data are given to compare the temperatures of two turbid ponds with two otherwise similar clear ponds during a year.

2. Bottom temperatures were generally lower in turbid ponds than in clear ponds.
3. The average surface to bottom temperature was lower in turbid than in clear ponds.
4. Surface and bottom heating of water was recorded under an ice cover that existed for two weeks in early December, 1950.
5. Thermal stratification was more pronounced in turbid than in clear ponds.

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