CHEMICAL STUDIES OF WATERS OF REELFOOT LAKE[1]

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INTRODUCTION

In a number of ways the chemical properties of water are important and often are of especial value when used to interpret distribution and life habits of fish and other aquatic animals. The aquatic plant life and the humus and silt accumulations in Reelfoot Lake, especially in the marsh and submerged vegetation zones, contribute to the chemical nature of the water surrounding them. A few general conclusions will be drawn from the data presented and it is hoped that the conclusions will be of service to animal and plant ecologists in the better interpretation of their studies of distribution and life habits of fish.

Bodies of water may be separated into two general classes: Those in which there is a continuous directional flow are termed rivers or streams; those in which there is little or no directional motion and in which the water movements are due largely to changes in temperature and winds are called lakes or ponds. Reelfoot Lake is of the pond type and therefore chemical studies, particularly of dissolved oxygen, are very important in determining the optimum requirements for life. Running water may obtain a plentiful supply of oxygen by its own inherent mechanical agitation, whereas the waters of lakes and ponds depend upon winds, temperature changes, currents, etc., for the distribution of oxygen through the body of the system.

In situations such as found here, where temperature, currents, and wind action are at a minimum, the submerged plants contribute most of the oxygen. Also many currents that would distribute oxygen, carbon dioxide, and other dissolved chemical compounds to help establish uniformity are hindered to no little extent by the submerged masses of aquatic vegetation and the blanketing effect of the phytoplankton (Davis, 1936).

The hard water condition of this lake, as expressed by the great amount of normal carbonate found at all stations, the strongly alkaline condition of the water with a pH average of over 7.8, and the sporadic but in many cases large amounts of carbon dioxide and bicarbonate, are all conditions that are applicable to many interpretations and correlations. The soft sand and clays of the Gulf Embayment region,

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in which Reelfoot Lake lies, rest upon a hard limestone of Paleozoic age, and thin indurated beds of calcareous character occur in the overlying rocks. These conditions probably account for the hardness of the water. In some places slight acidities, *i. e.*, pH 6.8, were noted over the marsh areas where the soil was nearly peaty. The carbon dioxide was highest in the duckweed Pleuston, and the occurrence of bicarbonates was too irregular to warrant any definite correlations.

In a pond of this type it is necessary, if there is to be an abundance of fish life, to have a plentiful supply of vegetation which can furnish oxygen. In the areas of submerged aquatics, particularly where *Ceratophyllum* was abundant, a high concentration of oxygen was found. From these preliminary data it is obvious that the vegetation plays an important role in the oxygen supply, but more extensive studies are needed to determine the inter-relationships between oxygen supply and the aquatic plant zones. There seems to be a plentiful supply of essential elements (N, K, Ca, P, etc.) for plant growth and the proper development of fish.

The data presented below is meager, but an attempt has been made to arrange it in regard to the vegetation conditions where the samples were taken. More data and future work should lead to adequate interpretations of the chemical nature of these waters in relation to the total biota of the lake, and to specific animals and plant communities.

The five tables included have been compiled from analyses[2] of 62 of the 102 samples taken. Some of the analyses could not be conveniently grouped under any one of the five types of stations and have been omitted. The number of the sample refers to the number given in the field notes where more detailed descriptions are recorded for future use.

The analysis of sixteen samples of water from the surface of the open stretches of Reelfoot Lake (Table 1) show the following results:

Oxygen ranges from 5.2 to 8.4 p.p.m. to show an average in sixteen samples of 7.7. Samples collected immediately after a heavy rainfall ran as high as 10.2 p.p.m. This increase in oxygen concentration at the surface is transitory, however, and is quickly equalized by diffusion into the lower levels of the pond.

The free carbon-dioxide was very low. The analyses resulted in a range of from 0 to 4 p.p.m., giving an average of 0.6 p.p.m. Since

[2]Procedure employed for chemical analysis: *Dissolved oxygen.* Manganous sulphate and alkaline potassium iodide were added, then concentrated sulphuric acid was added until the precipitate just dissolved. Titration was then carried out with sodium thio-sulphate solution using starch as indicator. (For methods in detail see Mason, *Examination of Water.*) Per cent of oxygen saturation cannot be reported since there is no record of barometric readings at the time the samples were collected.

Alkalinity. Reported as parts per million of carbonate and bicarbonate. The sample was titrated with 0.02 N. sulfuric acid using methyl orange as indicator, and the titration repeated using phenolpthalein as indicator.

The pH determinations were made with the LaMotte colorimetric apparatus.

eleven of the samples showed no concentration of free dissolved carbon-dioxide, this substance may be assumed to be practically nil.

The bicarbonates ranged between 0 and 30, with an average of 6 p.p.m., while the average concentration of carbonates proved to be 115 p.p.m., with the extremes marked at 160 and 82. Determinations

TABLE 1

Open water: no aquatic vegetation

Sample Number	Depth	Temperature of Water	Dissolved Oxygen	Free Carbon Dioxide	Bicarbonates	Carbonates	pH	Remarks
Near Surface:	feet	°C.	p.p.m.	p.p.m.	p.p.m.	p.p.m.		
5	7.0	26.0	5.2	4.0	0.0	160	7.8	O†
24	2.0	25.5	5.9	0.0	10.0	116	8.0	O
39	4.0	26.0	6.6	0.0	0.0	104	8.1	O,G
40	4.0	26.0	8.2	0.0	0.0	104	8.1	O,S
49	5.0	26.5	5.4	2.0	0.0	132	7.6	O
50	11.0	24.0	5.0	2.0	0.0	132	7.6	O,G
59	3.5	23.5	7.0	0.0	10.0	102	8.0	C,G
69	4.0	24.5	7.0	0.0	30.0	82	8.5	O
73*	5.0	27.0	10.2	0.0	8.0	118	8.0	S
75*	6.0	26.0	9.8	0.0	0.0	126	8.0	O
77	7.0	26.0	5.4	2.0	0.0	140	7.9	O,S
89	4.0	27.0	9.6	0.0	14.0	92	8.2	G,M
91	4.0	27.0	8.4	0.0	2.4	110	8.0	O,G
93	3.0	28.0	8.2	0.0	14.0	100	8.2	O,G,S
95	16.0	28.0	5.2	0.0	2.0	108	8.0	X
97	25.0	28.0	7.0	0.0	6.0	110	8.0	O,G
Near bottom:								
6	7.0	26.0	4.2	4.0	0.0	156	7.7	O
11	1.0	28.0	4.0	14.0	0.0	218	7.1	O
37	4.0	24.0	5.0	0.0	8.0	122	8.0	M
38	2.0	25.0	5.0	0.0	12.0	130	8.1	C,G
48	3.0	24.0	4.4	3.0	0.0	130	7.8	O
60	3.5	24.0	5.6	0.0	1.0	100	8.1	C,G
70	4.0	24.0	3.3	4.0	0.0	106	7.4	O
74*	5.0	25.5	5.0	2.0	0.0	126	7.8	S
76	6.0	25.5	3.0	8.0	0.0	142	7.8	O
78	8.0	25.0	3.6	2.0	0.0	124	7.8	S
92	4.0	27.0	5.4	5.0	0.0	116	7.7	O,G,S
96	18.0	27.0	4.2	2.0	0.0	114	7.8	O,G
98	25.0	26.5	5.0	2.0	0.0	110	7.6	O,G

*After a heavy rain.
†Conditions of water: "O" is open water; "S" is stumps; "G" is greenish water; "M" is murky water; "X" is saw-grass area.

showed the water as being slightly alkaline, with an average pH of 8.0 and extremes of 7.6 and 8.5.

Analyses of water collected approximately five feet below the surface showed the following results: oxygen, average 4.5 p.p.m (maximum 5.4, minimum 3.0); free carbon-dioxide, average 3.4 (maximum

TABLE 2

Duckweed on surface: no submerged vegetation

SAMPLE NUMBER	DEPTH	TEMPERATURE OF WATER	DISSOLVED OXYGEN	FREE CARBON DIOXIDE	BICARBONATES	CARBONATES	pH	REMARKS
Near Surface:	feet	°C	p.p.m.	p.p.m.	p.p.m.	p.p.m.		
28	10.0	20.0	0.6	16.0	0.0	200	6.8	D,M†
30	9.0	19.5	0.8	16.0	0.0	204	6.8	D,M,X
42*	10.0	20.5	1.4	16.0	0.0	190	7.2	D,M
43*	10.0	20.5	2.0	16.0	0.0	184	7.2	D,M,X
72	1.0	25.0	1.6	5.0	0.0	128	7.8	D
82*	10.0	24.0	3.4	6.0	0.0	196	7.5	D,M
29	10.0	21.0	2.5	12.0	0.0	212	6.8	D,M
54	6.0	22.0	0.8	18.0	0.0	136	7.3	D

*After a heavy rain.
†Conditions of water: "D" is duckweed; "M" is murky water; "X" is saw grass nearby; "L" is numerous lilies on surface; "G" is green water; "S" is stumpy area

14, minimum 0); bicarbonates, average 3.2 (maximum 12, minimum 0); carbonates, average 130 (maximum 218, minimum 100); pH, average 7.7 (maximum 8.1, minimum 7.1).

The table shows a very definite variation between water at the surface and water at a five-foot level. With an increase in depth there

TABLE 3

Bonnets and lilies on surface: no submerged vegetation

SAMPLE NUMBER	DEPTH	TEMPERATURE OF WATER	DISSOLVED OXYGEN	FREE CARBON DIOXIDE	BICARBONATES	CARBONATES	pH	REMARKS
Near Surface:	feet	°C.	p.p.m.	p.p.m.	p.p.m.	p.p.m.		
15	4.0	30.0	10.2	0.0	32.0	92	8.3	L,G,M*
16	4.0	29.0	11.4	0.0	44.0	84	8.8	L,G,M
17	5.0	29.0	11.4	0.0	18.0	105	8.2	L,G,M,S
19	6.0	28.0	15.4	0.0	32.0	94	8.5	L,M,G,S
34	6.0	29.5	5.0	0.0	24.0	104	8.2	L,G
35	5.0	26.0	8.8	0.0	22.0	166	8.2	L,G
67	6.0	24.0	3.8	5.0	0.0	122	7.8	L
31	3.5	26.0	8.0	0.0	22.0	104	8.3	L
32	2.0	27.0	8.8	0.0	8.0	116	8.0	L
Near Bottom								
20	5.0	28.0	7.0	0.0	3.0	124	8.0	L,G,M,S
36	3.5	25.0	4.0	0.0	2.0	124	8.0	L,D
68	6.0	24.5	3.0	5.0	0.0	122	7.8	L

*Conditions of water: "D" is duckweek; "M" is murky water; "X" is saw-grass nearby; "L" is numerous lilies on surface; "G" is green water; "S" is stumpy are a.

TABLE 4

Duckweed on surface: submerged vegetation

Sample Number	Depth	Temperature of Water	Dissolved Oxygen	Free Carbon Dioxide	Bicarbonates	Carbonates	pH	Remarks
Near Surface:	feet	°C.	p.p.m.	p.p.m.	p.p.m.	p.p.m.		
10	2.0	26.0	1.1	10.0	0.0	216	7.2	D,P,†
12	1.5	26.0	0.0	20.0	0.0	252	7.1	D,P M
25	2.0	24.0	0.1	34.0	0.0	116	6.3	D,P
27	3.0	24.5	0.2	12.0	0.0	150	7.0	D,P

†Conditions of water. "D" is Duckweed covering; "P" is Ceratophyllum; "M" is murky.

is a decrease in free oxygen, bicarbonates, and pH. On the other hand free carbon-dioxide and carbonates are increased with an increase in depth.

With the surface of the water covered with vegetation consisting principally of duckweed (Table 2), the dissolved gases are very greatly altered. The dissolved oxygen is extremely low, averaging 1.5 p.p.m. with extremes at 0.6 and 3.4; the duckweed furnishing little or no oxygen for the waters it covers. Free carbon-dioxide averages 14 p.p.m., with a maximum in eight samples of 16 and a minimum of 5.0. Careful analysis revealed no bicarbonates in any of the samples. Carbonates ranged between 128 and 212, with an average of 181 p.p.m. The average pH was 7.2, very near the point of neutrality. The individual samples showed a variation of from 6.8 to 7.8.

With a surface vegetation consisting of lilies and bonnets (Table 3), there is again a decided shift in oxygen and carbon-dioxide concentration. The dissolved oxygen ranges between 3.8 and 15.4 p.p.m., with the nine samples having an average of 9.2. The free dissolved

TABLE 5

No surface vegetation: submerged vegetation

Sample Number	Depth	Temperature of Water	Dissolved Oxygen	Free Carbon Dioxide	Bicarbonates	Carbonates	pH	Remarks
Near Surface:	feet	°C.	p.p.m.	p.p.m.	p.p.m.	p.p.m.		
9	4	26.0	16.8	0.0	40.0	84	8.8	C,S†
26	5	25.5	10.4	8.0	0.0	160	7.0	C,S
44*	1	21.0	12.4	10.0	0.0	146	7.3	M,C
80*	2	24.0	10.6	0.0	10.0	114	8.2	C

*After a heavy rain.

†Condition of water. "C" is cypress trees; "S" is stumps; "M" is murky water.

carbon-dioxide is essentially zero. Bicarbonate is more nearly constant than in Tables 1 and 2, average 22.4 with extremes at 0 and 44. The carbonate is also fairly uniform, with an average of 110; a maximum of 122 and a minimum of 9.4. The pH shows the water to be definitely on the alkaline side with an average of 8.3. The extremes were set at 7.8 and 8.5.

Samples collected approximately five feet below the surface of the water showed the same variation as is indicated in Table 1. The average oxygen drops to 4.7, the bicarbonate to 1.7, and the pH to 7.9; while the carbon-dioxide increases to 1.7, and the carbonate to 123.

Table 4 presents data obtained from analyses of water which contained abundant surface duckweed and submerged *Ceratophyllum*. The oxygen concentration is very low, averaging 0.4 p.p.m., while the free dissolved carbon-dioxide is relatively high, averaging 19. No bicarbonate was found to be present, while the average concentration of carbonate in the four samples was found to be 184. The pH was practically neutral, averaging 6.9.

Analyses of water from areas having no surface vegetation but a dense growth of submerged *Ceratophyllum* (Table 5) indicate a very significant increase in dissolved oxygen; an average of 12.6 p.p.m., with individual samples ranging between 10.4 and 16.8. Free carbon-dioxide averages 4.5 p.p.m., with extremes at 0 and 10 p.p.m. This high carbon-dioxide content invariably occurs in shallow water after a heavy rain and does not represent a true *Ceratophyllum* condition. Bicarbonate concentration reflects a considerable range of concentrations from 0 to 40, with a median of 12.5 p.p.m. The carbonate is more nearly constant, showing an average of 126, and varying between 84 and 160. The water is slightly alkaline, having an average pH of 7.8 with extremes of 8.8 and 7.0.

Summary

Despite the fact that very little is known regarding the oxygen requirements of various types of fishes and the chemical factors of waters that are detrimental, we believe that certain conclusions can be drawn from this study.

The data recorded from chemical analyses of waters of Reelfoot Lake indicate that certain chemical conditions are favorable for game fish while other environments are decidedly unfavorable. An abundance of oxygen is available where there is no surface duckweed. In open water with no submerged plants, in waters with an abundance of submerged *Ceratophyllum* with no floating duckweed, and in waters with dense patches of water-lilies and bonnets, the oxygen content is favorable (Wiebe, 1935). The presence of duckweed with or without submerged vegetation lowers the oxygen content of the water to a degree which is not favorable for fish life. This is due to the

blanketing action of these plants which cuts off the sunlight from the water below.

Four parts per million of oxygen is usually conceded as the standard limit for fishes, although the killing limit varies with temperature directly and an additional amount of oxygen is necessary if the carbon-dioxide increases (Krogh and Leitch, 1919; Hubbs, 1933). It has also been found that other factors may control this minimum oxygen requirement. For example, certain fish may live in one part per million of oxygen in pure water yet die in water which contains five or six parts per million accompanied by considerable organic waste. In some cases an abundance of decaying aquatic vegetation may kill fish even in four parts per million of oxygen. "It is possible, of course, to determine for fish of a given species, age, sex, and season, just how little dissolved oxygen is necessary to support life, under any given conditions." (Hubbs, 1933.) Until such experiments are conducted we may only generalize on specific requirements for fishes.

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