Dissolved Oxygen and Temperature Profiles of Tenkiller Reservoir and Tailwaters With Consideration of These Waters as a Possible Habitat for Rainbow Trout[1]

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There are no accounts of the native occurrence of rainbow trout in Oklahoma waters. With the exception of a few areas near the outlets of cold springs which are generally too small or otherwise unsuitable for the support of significant numbers of trout, the major rivers and streams of the state attain temperatures during the critical summer months that are above the lethal limits reported for this species (8, 9, 10).

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The rainbow trout (*Salmo gairdneri*) has been extensively propagated by artificial means and widely distributed over the world, and much has been written about its beauty and sporting qualities. The main factors limiting survival include temperature, dissolved oxygen, and food. Temperature appears to be one outstanding limiting factor in Oklahoma and might be alleviated under certain conditions provided by a deep reservoir with a stable hypolimnion. This should release waters with a temperature of less than 77° F., which according to Embody (2) is the upper limit for feeding and growth of rainbow trout. He cites 55°—60° F. as the optimal range. Such conditions exist in the tailwaters of Norfork Dam, Arkansas, where the growth rate of trout is reported to be phenomenal and the fishery is popular.

Tenkiller Reservoir, and the Illinois River below the dam were chosen as test sites for a comparable habitat in Oklahoma suitable for trout.

Description of Reservoir and River

Tenkiller Reservoir is an impoundment of the Illinois River and the dam is located about 13 miles upstream from its confluence with the Arkansas River. At power pool level (elevation 630), the lake extends in a northeasterly direction for approximately 34 miles to the vicinity of Tahlequah, Oklahoma and has a shore line about 130 miles long and a surface area of 12,500 acres. The storage volume is 630,000 acre-feet, with a total storage capacity of 1,230,000 acre-feet at the top of the flood-control pool (elevation 667). The power pool is long and narrow with a maximum width of approximately 2 miles and a maximum depth of 130 feet (7). The banks near the dam are almost perpendicular from surface to bottom and the surrounding Cookson hills break the full force of the warm south winds to such an extent that thorough water circulation at lower depths during summer is impossible.

The Illinois River has been adequately described (5). Jenkins, *et al.*, (3) refer to it as "a clear, spring-fed stream, flowing through the oak and hickory clad Ozark hills in a succession of sparkling riffles and long, quiet pools." The valley slopes are generally steep and rocky with most of the watershed covered with timber and underbrush, resulting in less sediment than is carried by most Oklahoma streams.

Methods and Materials

In connection with the Oklahoma Fisheries Research Laboratory's 1953 summer survey, two sampling stations were established on Tenkiller Reservoir and three on a seven-mile section of the stream below the dam. The locations and brief descriptions of the stations are as follows:

Station I—Samples taken from platform of Gate Tower near Spillway at dam. Maximum depth of lake at this point, 130 feet.

Station II—At Standing Rock Bridge on Oklahoma Highway 82 across the upper portion of the lake, approximately 20 river miles from Station I. Maximum depth, 33 feet (in old river channel).

Station III—Below dam. Approximately 150 yards below outlet tunnel in pool 4-5 feet deep. Algae-covered rock bottom. Water clear and cold. Strong odor of H_2S permeating the air.

Station IV—About 4 miles downstream from dam. Station located just below riffle. Stream bottom composed of algae-covered rough chert gravel. Depth of stream about 2.5 feet; width 25-30 feet.

Station V—At U. S. Highway 64 bridge near Gore. About 7 miles below dam. Much like Station IV in appearance.

An effort was made to visit each of these check-points at semi-weekly intervals for the collection of temperature and chemical data. The actual days of sampling were: June 16, 18, 22, 26, 29, and July 7, 10, 14, 17, 22. Temperatures were measured with a Whitney underwater thermometer (model 8F10). The thermometer cable was only 120 feet in length which prevented the recording of temperatures below that depth. Methods of determining dissolved oxygen and methyl orange alkalinity were as described by Welch (6). Hydrogen ion concentrations were measured with a Hellige color disc comparator.

Temperatures recorded in Tenkiller Reservoir at Station I showed a drop from an average of 84.8° F. at the surface to an average of 51.8° F. at 120 feet (Table I). A thermo-chemical profile of the lake at this station during June and July, 1953 (Figure 1), showed that the epilimnion reached

TABLE I

Maximum, Minimum, and Average Temperatures and Dissolved Oxygen Concentrations Recorded at Station I, June 16—July 22, 1953.

DEPTH (FT.)	D. O. (PPM.)	TEMP. (°F.)	DEPTH (FT.)	D. O. (PPM.)	TEMP. (°F.)
0	8.1 (7.0—9.4)	84.8 (81.2—88.2)	65		58.8 (58.0—59.5)
5		83.5 (81.2—85.4)	70		57.9 (57.0—58.5)
10		83.0 (80.8—84.7)	75		57.3 (56.5—58.0)
15		82.6 (80.6—84.6)	80		56.8 (56.0—57.7)
20		81.4 (77.8—84.5)	85		56.4 (55.8—57.0)
25	7.3 (6.0—8.5)	79.6 (72.0—84.0)	90	0.9 (0.5—2.0)	55.9 (55.0—56.6)
30		75.9 (66.3—82.0)	95		55.3 (54.1—56.0)
35	1.4 (0.2—4.0)	67.4 (64.0—72.2)	100	0.4 (0.0—0.8)	54.5 (53.3—55.8)
40		64.4 (63.1—66.5)	105		53.9 (52.7—55.2)
45	0.9 (0.4—2.0)	63.1 (61.6—64.5)	110		53.4 (52.2—54.3)
50		61.8 (60.6—63.0)	115		52.2 (51.6—53.0)
55		60.7 (58.5—60.5)	120	0.0	51.8 (51.3—52.4)
60		59.6 (58.5—60.5)	130	0.0	

a depth of 20 feet where the temperature averaged 81.4° F., and a definite thermocline extended from this point to a depth of 40 feet where the temperature averaged 64.4° F. The hypolimnion apparently continued from 40 feet to the bottom of the lake, although 120 feet was the lowest depth attained due to insufficient thermometer cable.

Average dissolved oxygen values from Station I exhibited a trend that corresponded closely with the temperature curve; the sudden decrease of about 6 ppm. from 25-35 feet almost coinciding with the thermocline (Figure 1). The average surface concentration was 8.1 ppm. with a range of 7.0 to 9.4 ppm. while readings at 120 and 130 feet were always 0.0 ppm. (Table I). The hypolimnion had an oxygen deficiency (less than 1.5 ppm.) from 35 to 130 feet.

Data collected at Station II, approximately 20 miles up the lake from the dam, showed the same characteristic thermo-chemical profiles as at Station I with the exception of two samples taken on July 14 and 17

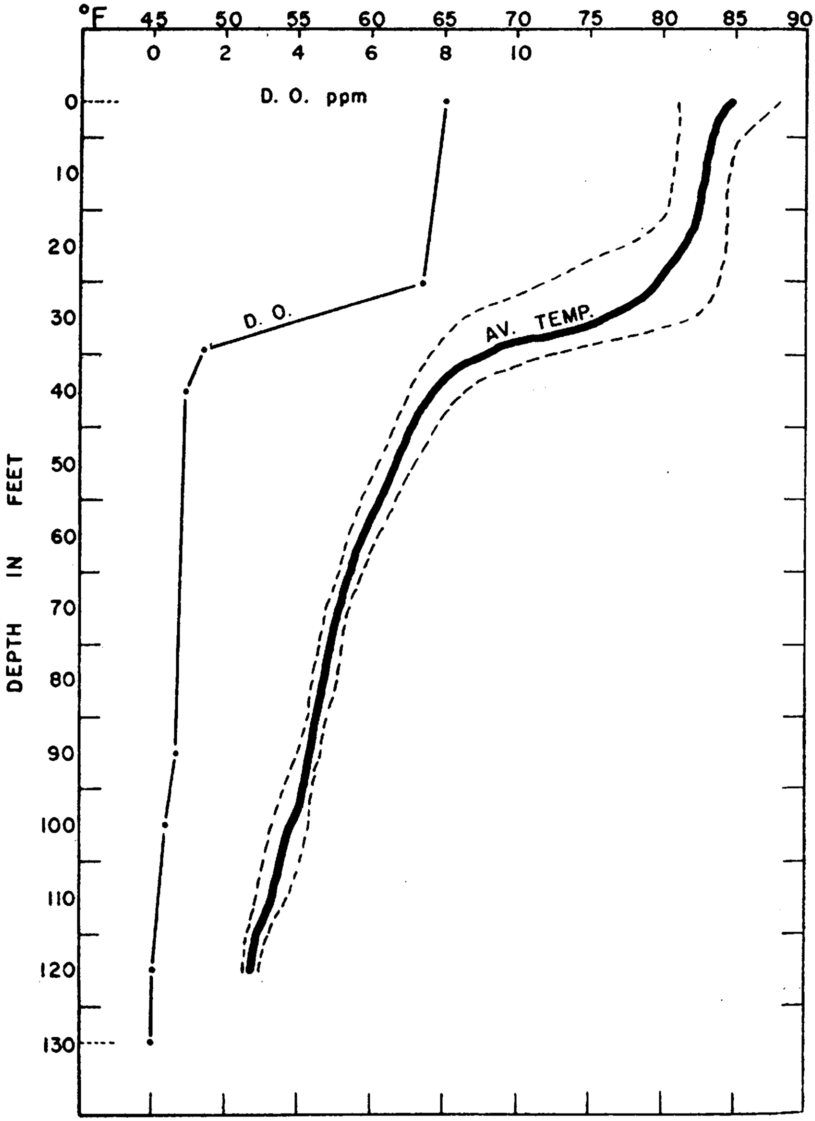

FIGURE 1. Average Summer Thermal and Dissolved Oxygen Profiles of Tenkiller Reservoir at Station I. Dotted lines indicate ranges of recorded temperatures at various depths.

(Table II). On these dates no typical thermocline appeared which may be due to the fact that the lake at this point is not as deep and is more exposed to wind and wave action.

TABLE II

Average Temperature and Dissolved Oxygen Values Taken at Station II, June 16—July 22, 1953.

DEPTH (FT.)	TEMPERATURE (°F.)	D. O. (PPM.)
0	87.7	8.2
5	86.6	—
10	85.8	—
15	84.6	—
20	82.9	5.1
25	77.8	—
30	71.7	—
33	69.7	1.2

Methyl orange alkalinity and *p*H determinations were obtained on various dates at both of these sampling stations. Station I revealed an average alkalinity of 71 (65-76) ppm. at the surface and 93 (90-98) ppm. at 130 feet, while *p*H readings ranged from 7.4 to 7.9 at the surface and 6.8 to 7.0 near the bottom. The surface values at Station II showed a methyl orange alkalinity average of 78 (73-88) ppm. and *p*H varied from 7.2 to 7.8.

During June and July, 1953, while the reservoir was being filled to power pool level, a discharge of only 50 cubic feet per second was allowed and water was released at approximately 120 feet below the surface. Two temperature readings taken at the outlet tunnel were 53.8° and 54.0° F, respectively, as compared with the average in the lake of 51.8° F. at a depth of 120 feet. Although the water came from a level where the dissolvd oxygen was less than 0.5 ppm., the concentrations found at Station III below the outlet averaged 10.3 ppm. (Table III). This figure, when converted at an average temperature of 55.4° F., represents more than 95 per cent saturation and is apparently the result of excellent aeration created by agitation within the outlet tunnel, a fall of six feet at the end of the outlet, and possibly the presence of abundant growths of algae. Stations IV and V further downstream likewise revealed a relatively high dissolved oxygen content with a gradual rise in temperature. Temperatures averaged 66.3° F. at Station IV and 73.8° at Station V (Table III).

TABLE III

Temperature in Degrees F. and Dissolved Oxygen Concentrations in ppm. at Stations III, IV, and V, June 16—July 22, 1953.

	STATION III		STATION IV		STATION V	
DATE	D. O.	TEMP.	D. O.	TEMP.	D. O.	TEMP.
6-16-53	10.8	53.5	—	—	9.6	77.3
6-18-53	10.8	56.0	—	—	10.0	80.0
6-22-53	10.2	54.2	—	66.0	8.6	70.5
6-26-53	10.6	55.7	—	66.1	10.0	73.6
6-29-53	10.0	55.3	—	68.8	9.8	75.0
7- 7-53	10.2	—	—	66.8	8.8	73.8
7-10-53	10.2	56.0	—	65.6	—	73.2
7-14-53	10.0	56.0	—	62.5	10.2	66.8
7-17-53	10.0	56.0	—	68.9	11.4	75.1
7-29-53	9.8	56.4	—	66.1	8.6	73.1
Averages	10.3	55.4	—	66.3	9.7	73.8

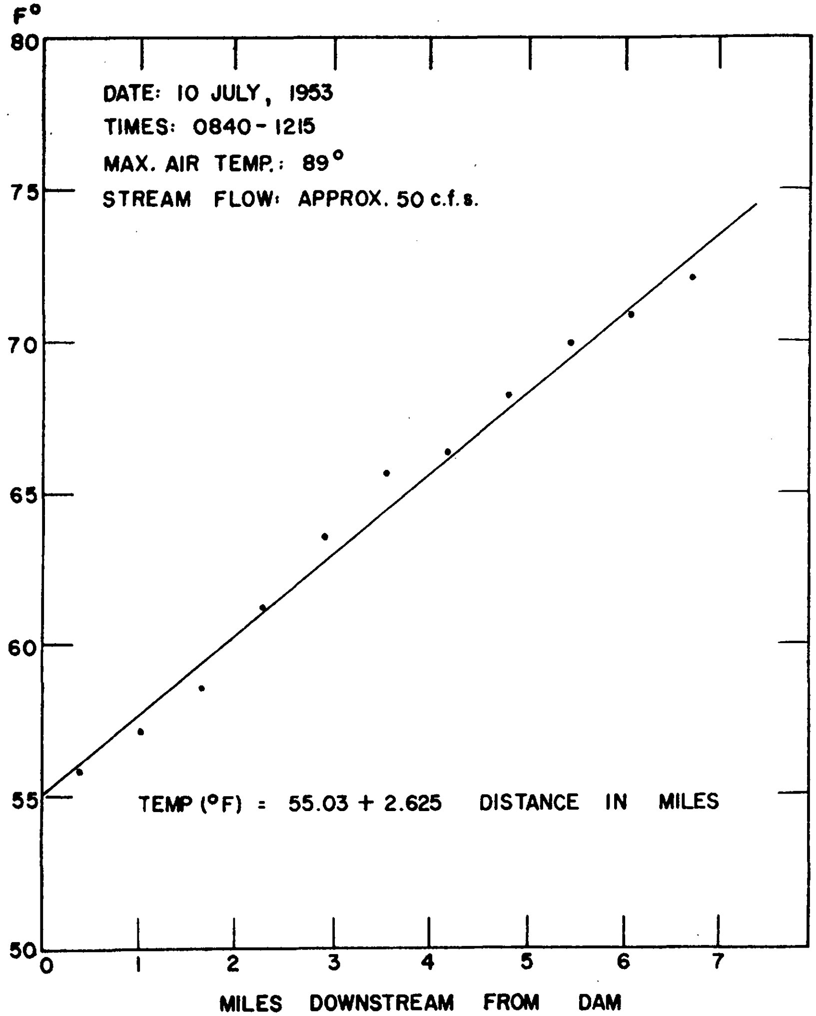

FIGURE 2. Rate of Increase in Temperature Per Mile of River Below Tenkiller Dam.

In order to determine more closely the rate of rise in temperature along this section of the river, a float trip of seven miles was taken on July 10, from the dam downstream to Station V. Temperature readings were recorded every five minutes. Although a few differences in pool and riffle values occurred, there seemed to be no significant pattern of one being consistently colder than the other. However, in some of the deeper pools, a drop of 1° F. was noticed between surface and bottom temperatures. All readings used in calculating the slope line of Figure 2 were taken at a depth of one foot and the average of every four consecutive temperatures plotted on the graph.

Discussion and Conclusions

Tenkiller Reservoir showed a characteristic and pronounced thermocline during the months of June and July, 1953. The greatest ranges in temperatures observed occurred in the epilimnion and thermocline layers. The very stable hypolimnion had a dissolved oxygen concentration of less than 1.5 ppm. from 35 to 130 feet. Above 30 feet the dissolved oxygen concentrations averaged upward from 4 to 8.1 ppm. At other times of the year, especially during the fall and spring turnovers, water circulation should be much greater and result in a more homogeneous temperature and dissolved oxygen content and resultant loss of stratification.

Tenkiller Reservoir had a marked effect upon the temperatures of the Illinois River below the dam for seven miles. Daily temperatures, taken by the U. S. Geological Survey in June and July, 1948 (8) near Gore before impoundment, varied from 72°—89° F. with an average of 81.5°. The average temperature found during this study at the same location (Station V) was only 73.8° F. with a range of 66.8°—80.0°. Although various ranges of temperatures for active feeding have been reported for rainbow trout, the lower and upper limits given by Embody (2) are 40° and 77° F. respectively. Temperatures in this survey below the dam (53.5°—77.3°) generally came within the above limits, with the exception of a single reading of 80.0° at Station V.

The effective distance may increase when the hydroelectric power plant is in operation and an additional discharge of cold water is permitted. With approximately a 50 cubic feet per second release, the curve in Figure 2 demonstrates only about a 3° rise in temperature per mile of stream. The penstock tunnel and outlet tunnel are both at the base of the dam and are the only means of releasing water from the reservoir with the exception of the spillway. It is doubtful that warmer surface waters will be released over the spillway during the critical summer months due to the heavy drawdown expected because of the use of the hydroelectric plant. Thus, as far as temperature is concerned, the Illinois River appears suitable for the existence of the rainbow trout for at least seven miles below Tenkiller Reservoir.

On December 12, 1953, observations were made on the effect of water release through the hydro-electric plant penstock tunnel upon limnological conditions in the river below (Table IV). Water analyses above the dam (Station 1) showed an even distribution of 6.0 ppm. dissolved oxygen from

TABLE IV

Chemical Analyses of Tenkiller Reservoir, and Illinois River, December 12, 1953.

Location	Depth (feet)	Temp. °F.	Dissolved Oxygen O_2 ppm.	Dissolved Oxygen % satura.	pH	MO
Station I	0	55.2	6.0	56	7.2	66
	25	55.1	6.0	55	7.2	—
	75	54.9	6.0	55	7.2	—
	125	54.8	6.0	54	7.3	68
Station III	0	55.2	6.0	56	—	—
Station V	0	55.0	8.4	82	7.4	76
Station II	0	50.0	9.6	84	7.6	78
	25	48.8	9.5	80	—	—

the surface to a depth of 125 feet at the bottom. No thermocline was present, as top and bottom temperatures varied only 0.4° F. Analysis immediately below the penstock tunnel outlet indicated that no aeration was effected during the flow from lake to river (Table IV). Released water does not fall from the penstock tunnel, but wells upward, and the means of aeration afforded by the outlet tunnel are lost. This suggests that during summer months when the oxygen tension of lake bottom waters is near zero little aeration can be expected, and oxygen deficient water will extend for a considerable distance downstream. From these limited observations it is believed that dissolved oxygen, and not temperature or minimum stream flow will be the factor limiting trout survival.

No information was collected concerning the bottom organisms available in the area, but large quantities of filamentous algae were observed. According to Metzelaar (4) these may compose up to 15 per cent of the rainbow trout diet. However, if the productivity below the dam is near that of the Illinois River above, food organisms should be no limiting factor for growth (1).

A total of 5,000 rainbow trout were stocked in the winter of 1952-1953. Of this number, 600 were from 14-16 inches long and the remainder 5-7 inches long. A few catches have since been reported, but only time will tell whether the introduction of this exotic species will be successful below Tenkiller Reservoir. Reproduction is not likely to occur due to constant water fluctuations and future trout fishing will probably depend upon a program of continual replacement.

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