Toole, Marion. 1951. Channel catfish culture in Texas. Progr. Fish-Cult., 13(1): 3-10.
Trautman, Milton B. 1957. The fishes of Ohio. Ohio State Univ. Press, Baltimore. xvii + 683 pp.
Turnbull, Harry, J. G. DeMann, and R. F. Weston. 1954. Toxicity of various refinery materials to fresh water fish. Indus. and Engr. Chem., 46(2): 324-333.
U. S. Public Health Service. 1961. Pollution-caused fish kills in 1960. U. S. Publ. Hlth. Serv., Publ. No. 847. 20 pp.
Vincent, Robert E. 1960. Some influences of domestication upon three stocks of brook trout *(Salvelinus fontinalis* Mitchill). Trans. Am. Fish. Soc., 89(1): 35-52.
Weiss, Charles M. 1958. The determination of cholinesterase in the brain tissue of three species of fresh water fish and its inactivation in vivo. Ecol., 39(2): 194-199.
————. 1959. Response of fish to sub-lethal exposures of organic phosphorus insecticides. Sew. and Indus. Wastes, 31(5): 580-593.
Weiss, Charles M., and James L. Botts. 1957. Factors affecting the response of fish to toxic materials. Sew. and Indus. Wastes, 29(7): 810-818.
Wells, Morris M. 1916. Starvation and the resistance of fishes to lack of oxygen and to KCN. Biol. Bull., 31(6): 441-452.
————. 1918. The reactions and resistance of fishes to carbon dioxide and carbon monoxide. Bull. Illinois State Lab. Nat. Hist., 11: 557-571.
Witt, Arthur, Jr., and Richard C. Marzolf. 1954. Spawning and behavior of the longear sunfish, *Pepomis megalotis megalotis.* Copeia, 1954(3): 188-190.

SAMPLING IN THE ADCLAUSTRAL ZONE OF A POWER RESERVOIR

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ABSTRACT

Spot checking the stratification pattern existing within a power reservoir generally consists of a single series of oxygen and temperature determinations taken vertically at the point of maximum depth. The point of maximum depth ordinarily is found immediately upstream from the impounding structure.

Data secured from a series of observations in the John H. Kerr Reservoir, Virginia, are presented which confirm Ellis' warning of 1936 that reservoir stratification in the immediate proximity of a power dam is very unstable and samples collected therefrom may yield entirely different results from samples taken at the same depth but beyond the limits of the adclaustral zone.

When determining the stratification pattern within a power reservoir, a series of vertical profiles is indicated. These observations should be spaced along the inundated stream bed as closely as circumstances will permit. When only a single profile is possible for determining the stratification pattern, that profile should be secured at a considerable distance from the impounding structure.

INTRODUCTION

In 1936, Ellis[1] described as the "adclaustral zone" that mass of deep water in a power reservoir lying upstream from the face of the impounding structure wherein stratification may be seriously deranged by vertical water movements. Ellis warned that water samples collected therein could yield very different results from those taken at the same depths in the reservoir beyond the limits of the adclaustral zone.

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[1] Ellis, Max M., "Water Conditions Affecting Aquatic Life in Elephant Butte Reservoir". Bulletin No. 34, U. S. Department of the Interior, Bureau of Fisheries, 47 pages.

In spite of Ellis' warning, many workers continue to spot-check the stratification pattern of a power reservoir through a single series of vertical observations taken at the point of maximum depth. The maximum depth is encountered, with few exceptions, immediately upstream from the impounding structure and well within the adclaustral zone. This practice may be expected to yield some highly atypical results at times and, with only a single series of observations, the investigator has no way of recognizing whether or not his data so colllected are in any way representative of the reservoir as a whole.

The confused stratification within the adclaustral zone, according to Ellis, resulted from a down-reservoir movement of a large volume of surface water propelled by wind action, or from a similar movement of warm surface water following heavy precipitation. In a river impoundment, descriptively termed a "half-lake" by Ellis, the down-reservoir surface water movements do not encounter the usual feathering shore line of a natural lake against which their inertia would be dissipated by creation of a seiche that does not significantly affect stratification. Instead, such water movements encounter the vertical upstream face of the impounding structure. In such a circumstance, Ellis described the piling up of surface waters against the dam thus forcing the epilimnial waters down, breaking such thermal stratification as may exist, and finally driving these surface waters in an upstream direction back through what would have been the upper hypolimnial or lower epilimnial zone. As a consequence, conditions within the mass of deep water in close proximity to the dam are very unstable.

The same effect, but resulting from the down-river movement of a bottom current rather than surface water movement as described by Ellis, was encountered by the writer during an investigation of a report that "Kerr Reservoir had less than one part per million dissolved oxygen from top to bottom".

The John H. Kerr Dam, a Corps of Engineers, U. S. Army, hydroelectric power and flood control project, is located on the Roanoke River about 179 miles above the mouth and 20 miles upstream from the North Carolina-Virginia state line. The reservoir covers some 39 miles of stream channel, contains about 1.5 million acre-feet of water at normal surface elevation and, at this elevation, has a maximum depth of 110 feet immediately above the dam. Because water quality is very important to downriver interests, the development and ultimate dissipation of stratification and the attending deoxygenation within the reservoir has been checked for many years through a single vertical profile periodically determined at a sampling station located 1,000 feet upstream from the dam.

A report was received that an oxygen profile secured at the usual sampling station on August 10, 1955, had revealed 0.4 ppm to be the highest dissolved oxygen concentration in Kerr Reservoir and this concentration was found at the depth of 48 feet. The writer visited Kerr Reservoir on September 14, 1955, and ran temperature and dissolved oxygen profiles at the same station from which the August 10 results had been recorded. Similar determinations also were made at three additional stations located 1.25, 2.5, and 5.5 miles, respectively, upriver from the dam. The results are recorded in Table 1. These data, except those from Station 4, show atypically low dissolved oxygen concentrations with the maximum values again found at a considerable depth. The exact pattern of dissolved oxygen concentrations shown by these samples was not clear until the isopleths were plotted in vertical section as shown in Figure 1.

The temperature data, plotted in Figure 2, show the reservoir was essentially homothermous at the time of sampling. Comparing these data with the prevailing dissolved oxygen concentrations leads to the conclusion that conventional "text book" horizontal stratification, if it existed at all in the reservoir, was well beyond the upstream limits of the observations—except for a small pocket adjacent to the dam at depths exceeding 80 feet—and a similar pocket at Station 4. When these data were obtained, the adclaustral zone extended more than 2.5 miles upstream from the dam.

It is very clear from the figured data that, within the adclaustral zone, a large volume of water was in motion. This movement was not a simple horizontal drawoff current leading directly into the powerhouse penstocks. These data indicate the direction of water movement was more or less along a slope extending between the center line of the penstocks and the reservoir surface some three or four miles upstream from the dam. Likewise, the volume and momentum contained in the drawoff current exceeded the powerhouse demand sufficiently to cause a vertical upwelling along the upstream face of the dam. The inertia of the rollback so produced was sufficient to force upstream for several miles at least, the better oxygenated surface waters of the reservoir. The pattern of water movement observed in the adclaustral zone was quite comparable to that described by Ellis although, in this case, it was a deep current forced upward by the impounding structure rather than a surface movement forced downward.

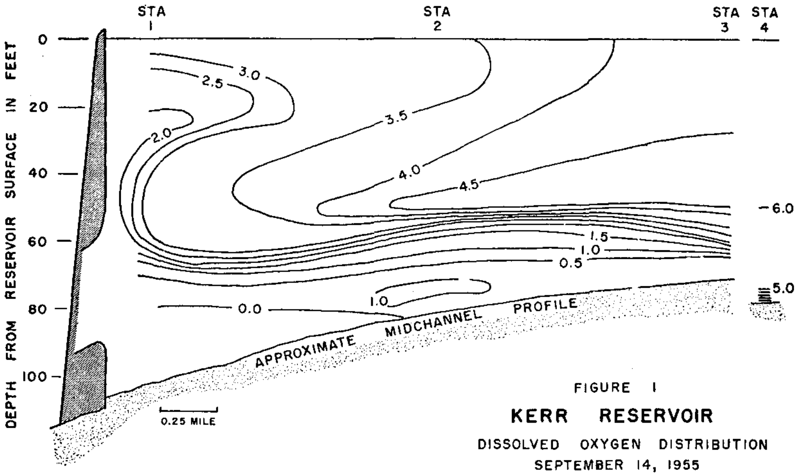

FIGURE I

KERR RESERVOIR

DISSOLVED OXYGEN DISTRIBUTION
SEPTEMBER 14, 1955

TABLE 1.

DISSOLVED OXYGEN AND TEMPERATURE PROFILES, JOHN H. KERR RESERVOIR, SEPTEMBER 14, 1955.

	Station 1		*Station 2*		*Station 3*		*Station 4*	
Approximate Distance from Dam	*0.25 mile*		*1.25 miles*		*2.50 miles*		*5.5 miles*	
Depth from Surface (feet)	*D. O. ppm*	*Temp. °F.*	*D. O. ppm*	*Temp. °F.*	*D. O. ppm*	*Temp. °F.*	*D. O. ppm*	*Temp. °F.*
5	3.0	74.5	3.3	73.5	4.1	75.0	6.8	75.0
10	2.4	74.5		73.5	4.1	75.0	6.7	75.0
20	2.4	74.5	3.5	73.5		75.0	6.0	75.0
30	2.0	74.0	3.7	73.5	4.5	75.0	5.8	75.0
40	3.0	74.0	4.2	73.5	4.5	74.5		75.0
45		74.0		73.5	4.2	74.5		75.0
50	3.0	74.0	4.7	73.5		74.5	6.1	74.5
55		74.0	3.6	73.5	3.6	74.5		74.0
60	3.0	74.0	1.3	73.0	2.1	74.5	5.9	74.0
65		74.0		73.0	0.3	74.0		74.0
70	0.6	73.5	0.3	72.5	0.2	74.0	5.6	74.0
75							0.0	67.5
80	0.0	72.5	1.4	71.0			0.0	67.0
90	0.0	67.5						
100	0.0	62.5						

Figure 2. Kerr Reservoir temperature distribution September 14, 1955.