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FACTORS AFFECTING THE VERTICAL DISTRIBUTION OF WHITE CRAPPIE *(POMOXIS ANNULARIS)* IN TWO OKLAHOMA RESERVOIRS

by

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ABSTRACT

Mean depth of capture of the white crappie in horizontal, bottom set gill nets in Arbuckle Reservoir in 1973 was not statistically different from that in this reservoir in 1974, or from that in Eufaula Reservoir (determined by collection in vertical gill nets) in 1968. The white crappie depth distribution was generally similar in these two reservoirs, and there was a seasonal cycle of distribution related primarily to changes in temperature and dissolved oxygen. Lake Arbuckle was acutely stratified by midsummer of both years. Stratification in this reservoir appeared to force white crappie into the thermocline but anoxic conditions excluded them from the hypolimnion. In Eufaula Reservoir, white crappie were distributed deeper when surface temperatures increased but their depth distribution was not limited by anoxic water. White crappie were found nearer the surface in the fall when surface water cooled.

INTRODUCTION

The white crappie *(Pomoxis annularis)* is a valuable game fish in reservoirs of the southeastern U.S. In Oklahoma it has been more widely sought after than any other Oklahoma fish (Wilson 1951). Various aspects of the biology and depth distribution of the white crappie in Oklahoma reservoirs were reported by Carter (1967), Dowell (1956), Grinstead (1969), Whiteside (1964) and Wilson (1951). In Tennessee, studies by Dendy (1945, 1946) indicated that the depth distribution of fish appeared related to dissolved oxygen and temperature profiles. In the Tennessee study, the publication in local newspapers of current information on fish depth distribution (Dendy 1948), apparently helped sport fishermen increase their catches. Some observers reported that white crappies congregate in loose aggregations at certain depths at various times of the year (e.g., Grinstead 1969).

[1]Cooperators are the Oklahoma Department of Wildlife Conservation, the Oklahoma State University and the U.S. Fish and Wildlife Service.

Temperature is one of the most important factors determining the distribution of fishes (Brett 1956). When fish were free to choose from a wide temperature range, their distribution was directly correlated with their preferred temperature (Carter 1967; Dendy 1945, 1946; and Horak and Tanner 1964). Neill and Magnuson (1974) found black crappies *(Pomoxis nigromaculatus)* avoided temperatures lower than 25.5° C or higher than 30.0° C. Hancock (1954) observed at Canton Reservoir, Oklahoma a winter concentration of white crappies in a cove fed by warmer ground water; when he artificially duplicated the results by warming the water in another cove, he observed a similar concentration of white crappies where one did not exist before the experiment. In other Oklahoma reservoirs where vertical temperature profiles were fairly uniform, no relationship between temperature and depth distribution of white crappies was evidenced (Loomis 1951 and Grinstead 1965).

The concentration of DO is also known to affect the vertical distribution of fishes (Borges 1950, Dendy 1945, Grinstead 1969, and Carter 1967). Laboratory studies (Moore 1942, Moss and Scott 1961, and Mount 1961) suggested that DO contents of 1.0 to 3.0 mg/ l or less were critical to most species of warmwater fishes. Whitmore (1960) observed largemouth bass *(Micropterus salmoides)* and bluegill *(Lepomis macrochirus)* markedly avoiding DO levels near 1.5 mg/ l, but not higher concentrations. Kline (1974) found that continuously decreasing DO resulted in significantly increasing activity of yearling smallmouth bass *(Micropterus dolomieui)*, suggesting that the fish were moving about to try to escape from water containing low DO. Inasmuch as fish distribution may not be affected by DO levels that exceeded 3 mg/ l (Dendy 1945 and Grinstead 1969), temperature or other factors probably become important in determining distribution in water with DO above this level.

Turbidity is another factor which may affect the depth distribution of the white crappie. Grinstead (1969) assumed that their depth distribution was influenced by turbidity through its effect on light transmission; he observed white crappies at greater depths when turbidity was low than when it was high. Carter (1967) reported that catches of fish near the surface increased when turbidity increased greatly during a flood. Wallen (1951) found fish responding to high turbidities by swimming at the surface, but turbidities high enough to directly affect survival of fishes usually exceeded the ranges found in nature. However, the effects of turbidity on light penetration and the effects of light penetration on depth distribution of reservoir fishes are less well known than the effects of temperature and DO. Other physicochemical and biological factors such as distribution of food and predators could affect depth distribution of white crappies.

The objective of the present report is to provide additional descriptive data on the depth distribution of the white crappie in two Oklahoma reservoirs, to show that their average depth is generally similar in different environments, and to describe the relationship between their depth distribution, temperature and DO.

We would like to acknowledge the help given us in collecting the fish and tabulating data by R. Hover, J. F. Heitman, and B. Cummins. Financial support for the Eufaula Reservoir study was provided by a Federal Aid Project (Oklahoma, F-24-R-2), and the Arbuckle Reservoir study was financed by the Office of Water Resources Research, U.S. Department of the Interior (Project A-047-Okla.).

DISCRIPTION OF RESERVOIRS

Arbuckle Reservoir (Fig. 1), which is in south central Oklahoma on Rock Creek in Murray County, has an average surface area of 2,349 acres and a capacity of 72,399 acre-feet. The major land use of the basin is for pasture. The area receives an annual precipitation of about 38 inches and the average length of the growing season, or frost-free period, is 218 days. Eufaula Reservoir, which is in east central Oklahoma on the Canadian River in McIntosh, Haskell, and Pittsburg Counties, has a surface area of 102,500 acres and a volume of about 2.8 million acre-feet. The sites selected for study in Eufaula Reservoir were in the central pool (Fig. 1) which has an area of 10,800 acres and a volume of approximately 570,000 acre-feet.

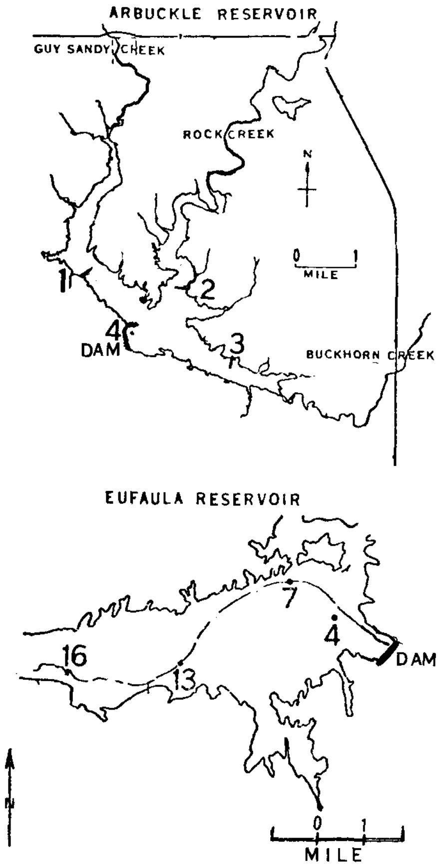

Figure 1. Arbuckle Reservoir and the central pool of Eufaula Reservoir, showing numbered sampling sites.

METHODS

Fish depth distribution was studied in relationship to efforts to destratify the reservoirs with *in situ* aeration devices. Since the artificial aeration apparatus failed to destratify either reservoir, and had only a limited affect within a small segment of the water column adjacent to the aerator, we will not describe it. In Eufaula Reservoir, the proximity of the apparatus to the dam resulted in a substantial increase in DO in penstock discharges, which came from the aerated hypolimnetic waters (Leach et al. 1970).

Of the four collection sites at Arbuckle Reservoir, one was in each of the three major arms of the lake and one near the dam (Fig. 1). Fish were sampled with horizontal gill nets 3.0 m deep and 45.7 m long (Fig. 2). The nets were divided into six 7.6 m panels with individual panel square mesh sizes of 1.27, 2.54, 3.81, 5.08, 6.35, and 7.62 cm. Nets were fished for periods of about 24-hours, and catch was adjusted to number of fish caught per 24-hours. Nets were placed on the bottom at depths of less than 5 m, 5-10 m, 10-15 m, and greater than 15 m at all sites (Fig. 2). We chose these depths to ensure inclusion of the epilimnion, metalimnion, and hypolimnion in the waters sampled.

Samples were collected at Arbuckle Reservoir in 1973 for 15 continuous weeks from 15 May to 24 August, and on 18-21 October; and in 1974 on 9-13 March; weekly from 20 May to 23 August, and on 9-13 September. We made the fall collection in both years to monitor depth distribution of crappies after the lake was expected to have undergone natural destratification.

In calculating depth distribution of fish in Arbuckle Reservoir, we assumed that the fish were captured at the midpoint of the depth interval fished (2.5, 7.5, 12.5, and 17.5 m). The nets were set at the specified depth intervals with the aid of a recording ecosounder. A weighted mean depth distribution for crappies was calculated each week. Temperature and dissolved oxygen measurements were taken weekly at 1-m intervals at all sites, with an electrical DO probe and thermistor. Secchi disc measurements, used to express turbidity, were obtained from D. Toetz (personal communication, Department of Zoology, Oklahoma State Univ., Stillwater).

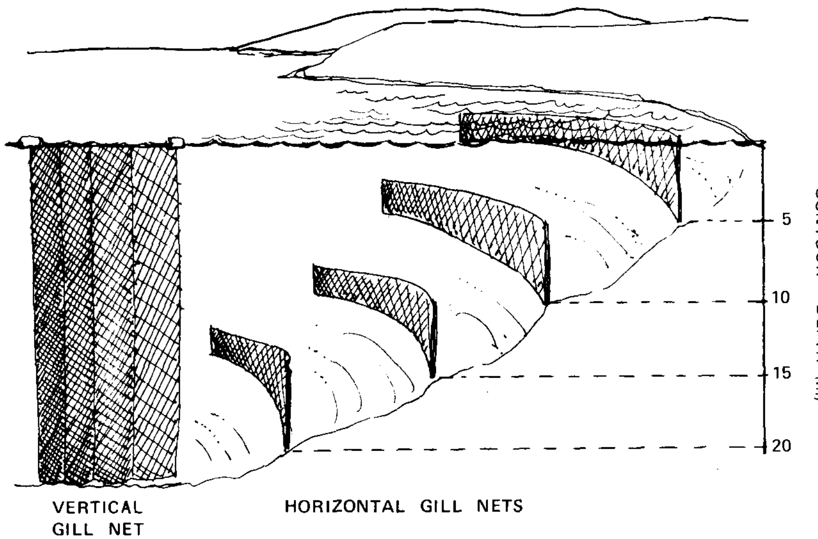

Figure 2. Gill nets as set for sampling the depth distribution of white crappies. Vertical nets were used in Eufaula Reservoir and horizontal nets in Arbuckle Reservoir.

In Eufaula Reservoir, we selected four netting stations over or near the submerged river channel, 0.48 to 10.62 km upstream from the dam, which were of similar depth ranges and free of submerged trees. Average depths for the five stations ranged from 21 to 25 (mean, 23) meters. Fish were collected with vertical gill nets (Fig. 2) which were 4.9 m wide and 30.5 m deep. Each net contained four 1.2 m wide webbing columns of different mesh sizes (2.54, 3.81, 5.08, and 6.35 cm, bar measure), joined at the interfaces. The nets were hung on no. 72 braided nylon lines and marked at 1-m intervals with numbered brass brads. The roller-float assembly used in this study was similar to that described by Carter (1968).

In Eufaula Reservoir, three 2-day net sets were made per netting week at each of the four sampling sites. To reduce error and standardize net sets for comparison, we adjusted all catch rates to catch per 24 hours. The vertical gill nets were fished at sites 7, 4 and 13 from June to October of 1968.

DEPTH DISTRIBUTION OF WHITE CRAPPIE IN ARBUCKLE RESERVOIR

In 1973 the depth distribution was based on a total collection of 639 fish and the 1974 depth distribution was based on a total collection of 996 fish. During the summer, when the reservoir is stratified, the 2 ppm DO contour is an accurate representation of the midpoint of the thermocline, which is then a 1-m thick layer of water where the DO level drops from 5 ppm to near 0 ppm in a 1-m interval; the declining temperature in the thermocline varied. In the early summer of 1973, white crappies were distributed well above the limiting oxygen levels (Fig. 3). In July and August, however, their distribution extended down to the anoxic hypolimnion. During August, the mean depth distribution of crappies (all sites combined) coincided almost exactly with the average depth of the 2 ppm dissolved oxygen contour. When the lake destratified in October 1973 and oxygen levels were uniformly high throughout the lake, white crappies entered substantially greater depths than during summer. Average depth distribution of crappies, all sites combined, increased from 6.4 on 24 August to 13.2 m on 20 October. The greater depths occupied by crappies in August than in earlier months suggests that the fish were avoiding the warm epilimnion (Fig. 4). Depth distribution in August was ultimately limited by low concentrations of DO in the cooler but anoxic hypolimnion. In October, depth distribution was no longer affected by either temperature or DO.

In spring and early summer, the mean depth of white crappie was not as great as in late summer when the lake was fully stratified. We assume that crappies enter shallow water in the spring to spawn, and remain there through the early summer until epilimnetic temperatures become intolerably high (Fig. 5). Neill and Magnuson (1974) found that fishes are distributed within an area according to their temperature preferences. They found the preferred temperature of the related black crappie to be 28.3°C in both laboratory and field experiments. Black crappies avoided temperatures lower than 25.5°C or higher than 30.5°C. Arbuckle Reservoir experienced epilimnetic water temperatures of 31.5°C and surface temperatures averaged 29.4°C in July and August of 1974. Neill and Magnuson (1974) found that fishes made forays for food into water with temperatures either higher or lower than their preferred temperature, but suggested that thermoregulatory behavior was dominant over feeding behavior. Brett (1956) found that the preferred temperature usually corresponds with the optimum temperature for activity.

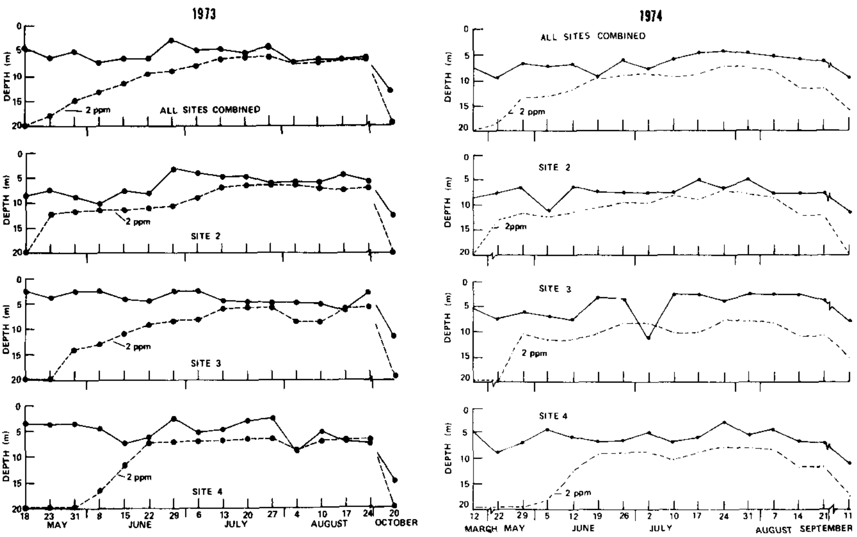

Figure 3. Depth distribution of white crappie (solid line) in relation to the 2-ppm DO contour (broken line) in Arbuckle Reservoir in 1973 and 1974 (no data for September 1973 or April 1974). Site 1 was not shown because during parts of 1973 we did not have oxygen profiles.

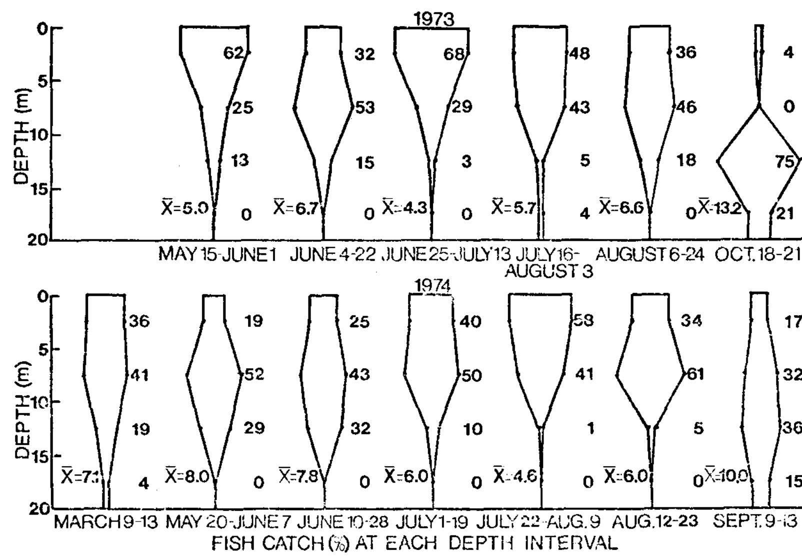

Figure 4. White crappie depth distribution in Arbuckle Reservoir in 1973 (upper panel) and 1974 (lower panel). Numbers beside the polygons show the average depth at which the fish were caught during each interval.

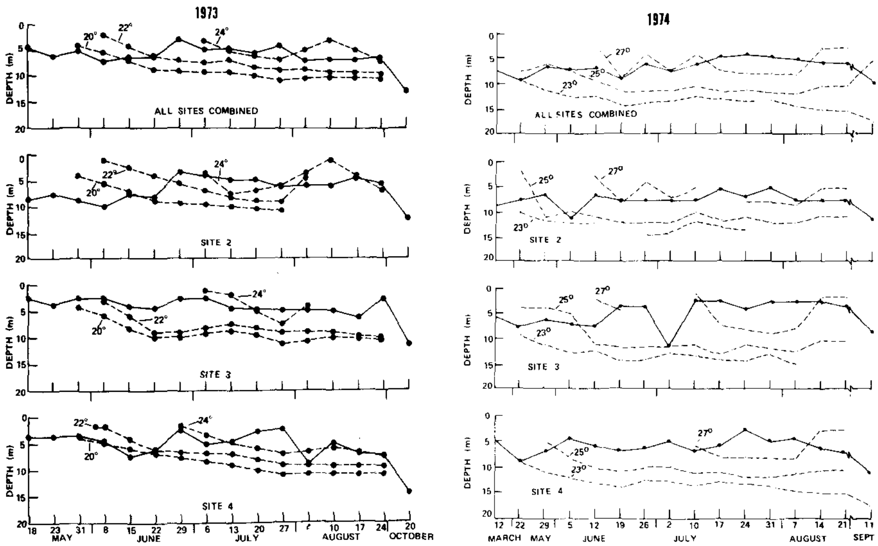

Figure 5. Depth distribution of white crappie (solid line) in relationship to selected temperature contours (as labeled) in Arbuckle Reservoir in 1973 (left panel) and 1974 (no data for September 1973 or April 1974).

A seasonal pattern of white crappie depth distribution appeared to be repeated in the two years in Arbuckle Reservoir (Fig. 4). The percentage of the total catch taken in the 15-m to 20-m interval was near 0, except when the lake was unstratified. The proportion of the total fish catch taken in the 10-m to 15-m depth interval gradually decreased as the summer progressed and the anoxic hypolimnion moved closer to the surface (Fig. 3). The catch for the 5-m to 10-m depth interval varied irregularly. The percentage of the catch taken in 0-m to 5-m depth interval increased from early to midsummer as fish were forced upward from lower depths by low oxygen levels. The temperatures surpassed the thermal preference of white crappies.

White crappies in Arbuckle Reservoir were held within a narrow stratum by high epilimnetic temperatures and the lack of oxygen in the hypolimnion—a situation similar to that reported by Hile (1936) for coldwater fishes. Colby and Brooke (1969) reported mortality of coldwater fishes when they were trapped between two layers, each exceeding their tolerance. Warmwater fish mortality, due to this effect, could occur during an abnormally hot period. The median tolerance limit for bluegill was reported to be 33.8°C (Hart 1952). Even though water temperature may not reach lethal levels, for white crappies, available habitat is substantially reduced in July and August. Dendy (1945, 1946,), Carter (1967), Ferguson (1958), and Horak and Tanner (1964) found a correlation between depth distribution of fish and water temperature.

DEPTH DISTRIBUTION OF THE WHITE CRAPPIE IN EUFAULA RESERVOIR

The average depth distribution of white crappie at four sites in Eufaula Reservoir was examined in relation to selected temperature and oxygen profiles, and is illustrated for site 13 in Fig. 6. The depth distribution for Eufaula Reservoir was calculated from a total collection of 228 fish. As shown, levels of DO in the summer were considerably higher at greater depths in Eufaula Reservoir than in Arbuckle Reservoir.

The temperature of the epilimnion in Eufaula Reservoir increased as the summer progressed in 1968 and gradually cooled in the fall; at site 13 (Fig. 6), as well as at sites 4 and 7, white crappies were nearer the surface in the fall than in the summer, possibly responding to the cooler temperatures. Thus, white crappies apparently abandoned shallow water when temperatures became high and returned when the temperatures moderated. However, temperature was not always sufficiently high to serve as the primary controlling factor. There appears to be a delayed response of depth distribution to temperature fluctuations.

COMPARISON OF DEPTH DISTRIBUTION OF WHITE CRAPPIE IN ARBUCKLE AND EUFAULA RESERVOIRS

The mean depth distribution of white crappie in Eufaula Reservoir in 1968 was compared with that in Arbuckle Reservoir over similar months in 1973 and 1974 (Fig. 7 and Table 1). A paired t-test showed no significant difference ($P>.05$, d.f.=11) in white crappie depth distribution between Eufaula Reservoir in 1968 and Arbuckle Reservoir in 1973, but there was a significant difference (P .05, d.f.=11) in 1974. Depth distribution differed little between reservoirs, or between years in Arbuckle Reservoir, in the present study, and was in general agreement with that reported in Lake Texoma (Grinstead 1965). Computed linear regression lines for depth of capture over time of study for all sites combined in each reservoir indicated no significant increase or decrease in water depth inhabited by white crappies during the summer.

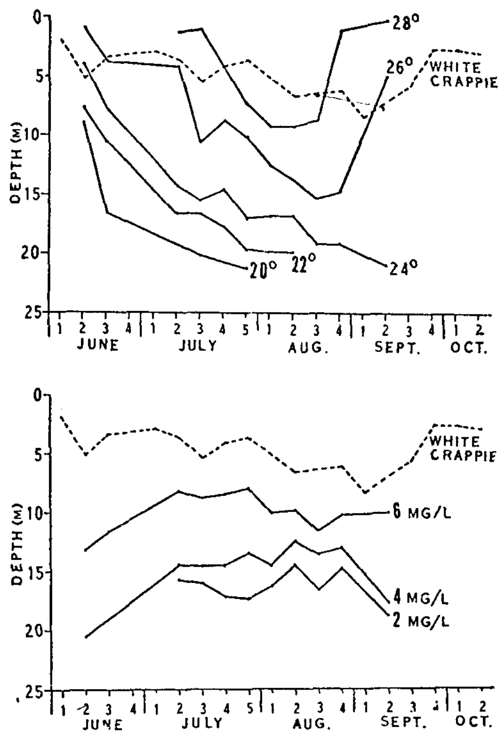

Figure 6. Weekly mean depth of capture for white crappie (broken line) in relation to temperatures and dissolved oxygen concentrations at site 13 (Fig. 1) in Eufaula Reservoir.

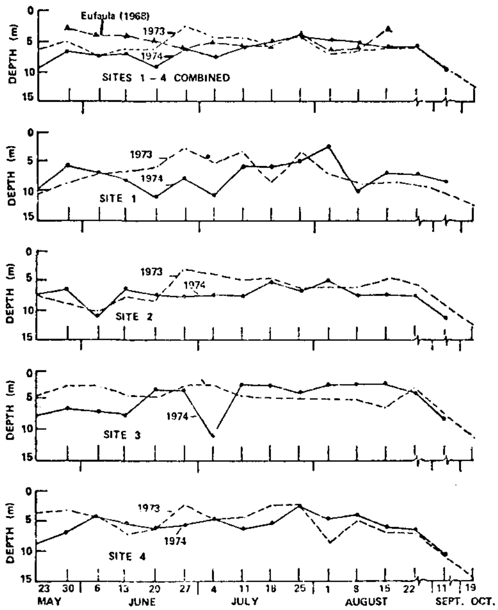

Figure 7. Weekly depth distribution of white crappies in Arbuckle Reservoir in 1973 and 1974 and in Eufaula Reservoir in 1968.

Table 1. Comparison of white crappie depth distribution (m) between reservoirs, between sites within a reservoir, and between years within a reservoir.

Reservoir	June 1	2	3	4	July 1	2	3	4	5	August 1	2	3
Eufaula (1968)	2.9	3.9	3.8	5.1	6.2	5.1	5.7	5.4	3.6	6.9	6.7	3.0
Arbuckle (1973)	5.0	7.2	6.4	6.4	2.9	4.9	4.6	5.6	4.1	7.2	6.7	6.6
Arbuckle (1974)	6.7	7.3	6.9	9.3	6.3	7.8	6.1	5.0	4.3	4.8	5.3	5.9
Texoma (1962-63) (Grinstead 1965)		6.6				7.1				6.1		

Reservoir and Site	t value	Conclusion
Eufaula (1968) vs. Arbuckle (1973)	1.36	No significant difference between reservoirs
Eufaula (1968) vs. Arbuckle (1974)	2.33*	Significant difference
Arbuckle (1973)		
Site 1 vs 2	0.89	No significant difference between sites
Site 2 vs 4	1.36	No significant difference between sites
Site 1 vs 3	4.84*	Significant difference
Site 1 vs 4	2.17*	Significant difference
Site 2 vs 3	3.69*	Significant difference
Site 3 vs 4	2.74*	Significant difference
Arbuckle (1973) vs. Arbuckle (1974)		
Site 1	0.95	No significant difference between years
Site 2	2.04	No significant difference between years
Site 3	0.49	No significant difference between years
Site 4	1.10	No significant difference between years
All sites combined	1.62	No significant difference between years

*Significant values at .05 protection level

A paired t-test showed no significant difference (P .05, d.f.=14) in mean depth of white crappies between sites within Arbuckle Reservoir in 1973 for sites 1 VS 2 and 2 VS 4, but there was a significant difference among the other site combinations (P .05,) in 1973 (Table 1). A paired t-test showed no significant difference (P .05, d.f.=11) in white crappie depth distribution between each of the four sites for Arbuckle Reservoir in 1973 as compared with distribution at the same sites over the same period in 1974. There was also no significant difference between the mean total depth distribution of white crappie for all four sites combined in 1973 versus all four sites combined in 1974 covering the same time periods (Table 1).

A three-way analysis of variance test computed for the 1973 Arbuckle Reservoir data versus the 1974 Arbuckle Reservoir data was used to determine significance of observed differences in white crappie depth distribution between the 2 years at weekly intervals over all four sites (Table 2). There was no significant difference (F .05) between the years by weeks, indicating a similar annual depth distribution of white crappie in Arbuckle Reservoir in 1973 and 1974. The three years of study show a general similarity; the two years of Arbuckle data are strikingly similar in late August when the lake temperature is high and the hypolimnion is completely anoxic, and in September when the lake naturally destratifies and oxygen levels are high throughout the water column (Figure 7). In the fall, white crappie depth distribution in Eufaula Reservoir rises while the Arbuckle Reservoir depth distribution decreases.

Table 2. Summary of three-way analysis of variance comparison of average depth of white crappies at four sites in Arbuckle Reservoir in 1973 and 1974.

Source of variation	d.f.	SS	MS	Fs
Year (Y)	1	16.47	16.47	
Week (W)	13	89.60	8.89	
Site (S)	3	128.69	42.90	
YxW	13	84.26	6.48	1.96 ns
YxS	3	0.95	0.32	0.10 ns
WxS	39	126.66	3.25	0.98 ns
YxWxS	39	128.58	3.30	
Total	111	575.21		

$F_{.05[13,39]} = 1.98$ $F_{.05[3,39]} = 2.85$ $F_{.05[39,39]} = 1.69$

ns denotes not significant

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