COMPLETION REPORT

FISH GROWTH RESPONSE TO MECHANICAL MIXING OF LAKE ARBUCKLE, OKLAHOMA

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ABSTRACT

Fish were sampled from 1973-75 to determine the effect of mechanical mixing of Lake Arbuckle, Oklahoma on the growth rate and depth distribution of gizzard shad, white crappie, freshwater drum, black bullhead and channel catfish. The vertical depth distribution, annual growth rate, instantaneous growth rate, seasonal growth rate and condition factors were determined for the above species. The vertical depth distributions of all species were compressed into the upper water layers by an anoxic hypolimnion during summer stratification and the distributions deepened substantially after fall overturn. No positive conclusions about annual growth rates could be resolved, but it appeared that growth was generally larger in 1974 when the lake was partially mixed than in previous nonmixed years. Seasonal growth rates indicated that generally the major portion of the population growth occurred during the destratified overwinter period rather than the stratified summer period. Condition factors often decreased during the stratified summer interval and increased during the destratified period indicating better fish conditions when the lake was destratified.

PREFACE

This study is one component of the Oklahoma State University interdisciplinary, destratification project on Arbuckle Lake which included concomitant studies by faculty in Mechanical Engineering (Moretti and McLaughlin), Agricultural Engineering (Garton) and Biological Sciences (Summerfelt, Toetz, and Wilhm):

(1) "Effects of artificial destratification on populations of benthic macroinvertebrates and zooplankton in Ham's Lake and Arbuckle Reservoir" by Jerry Wilhm (A-059-OKLA);

(2) "Biological and water quality effects of artificial destratification of Lake of the Arbuckles" by Dale W. Toetz (A-049-OKLA);

(3) "Improving the quality of reservoir releases by means of a large diameter pump" by James E. Garton, OKLA-C-5228 (Title II);

(4) "Hydraulic model studies of mechanical mixing devices in stratified lakes" by P. M. Maretti and D. K. McLaughlin (A-064-OKLA);

(5) "Fish growth response to mechanical mixing of Lake Arbuckle, Oklahoma" by Robert C. Summerfelt (A-049-OKLA).

The present is one of three reports emphasizing biological impact and effects of reservoir destratification. At the time of this writing plans were being made for another year's biological monitoring to evaluate additional efforts by James E. Garton to use an axial flow mechanical pump to prevent the lake from stratifying.

INTRODUCTION

This report presents observations on depth distribution, growth and a measure of condition on five species of fish collected from Lake-of-the-Arbuckles (hereinafter referred to as Lake Arbuckle), Oklahoma, 1973 through 1975. This investigation was undertaken to describe certain responses of the fish community which might be expected as an ecological consequence from engineering efforts to artificially prevent summer stratification. Destratification was attempted as a means for in situ improvement of reservoir water quality since there was a history of taste and odor problems when hypolimnetic water from this reservoir was used for a municipal water supply.

Fish growth is highly plastic and effected by food, space, temperature, and other factors (Weatherly 1962). Because artificial aeration, or destratification, is thought to influence the production processes (Toetz, Summerfelt and Wilhm 1972), fish growth should characterize the response of certain segments of the fish community to this type of environmental perturbation. Primary production (photosynthesis) and intermediate production (invertebrates) provide food for fish growth; factors which affect these processes are vital to terminal production or yield of fishes. Also, it has been suggested that a short-term study of fish growth rate can serve as an overall indication of environmental quality (Gunning and LaNasa 1973).

Fish production in aquatic ecosystems has been the subject of considerable biological research which has engendered recent reviews such as Nikolskii's (1969) "Theory of Fish Population Dynamics," Gerking's (1967), "The Biological Basis of Freshwater Fish Production," and Ricker's (1968) "Methods for Assessment of Fish Production in Freshwaters." Fish growth is one of two major factors used in computation of production (P), $P = G\bar{B}$, where G equals instantaneous growth coefficient and B equals average population biomass. Average population biomass, however, is very difficult to obtain in large reservoirs, because an estimation of the number of fish present in the population must be obtained for at least two time intervals. Numerical estimates of fish population numbers requires an intensive mark-and-recapture effort. Fish growth alone appears to be the most practical aspect of the production process for study of effects of an environmental perturbation upon production in an aquatic ecosystem.

Although descriptive studies on fish growth are numerous, the effect of stratification on fish growth has been poorly documented; for warm-water fish, only the study by Mayhew (1963) specifically addressed this problem. Mayhew (1963) postulated, from observing growth checks on scales associated with the onset of stratification, that fish growth is retarded by stratification. Gerking (1966) noted that bluegill sunfish (Lepomis macrochirus) growth rates were highest in the spring followed by progressively declining growth rates in late summer and autumn. He did not examine the relationship between growth rates to any conditions of stratification, but he did find that the annual rate of growth and length of the growing season were directly related. Johnson (1966) measured fish growth before and after destratification of a lake used to rear coho salmon (Oncorhynchus kisutch). Average fish growth decreased slightly after destratification, probably due to an increase in smolt survival from 12.9% before destratification to 42.1% during the years of destratification. This increased survival resulted in an increased total production of over 300%.

Numerous laboratory studies show that activity, growth, and production of both cold-water and warm-water fishes can be restricted by the lack of suitable levels of dissolved oxygen (DO) (Doudoroff and Shumway 1970), but the impact of stratification or destratification on fish is mostly limited to descriptions of vertical distribution. A DO depletion or development of anoxia in the hypolimnion associated with stratification limits fish distribution and removes a substantial portion of the lake from use by fish during the major part of the growing season (Borges 1950, Byrd 1951, Dendy 1945, Fast 1968, Mayhew 1963, Sprugel 1951, Summerfelt and Hover 1968, Ziebell 1969).

OBJECTIVES

The objectives of this project were

1. to estimate by back-calculation procedures, the average annual growth rates of carp (Cyprinus carpio), white crappie (Pomoxis annularis), channel catfish (Ictalurus punctatus), black bullhead (Ictalurus melas), freshwater drum (Aplodinotus grunniens), and gizzard shad (Dorosoma cepedianum), through age 6 for 1967-1973;
2. to compare the annual growth rates of the selected fishes for the period 1967-1972 to growth in 1973; and
3. to estimate at biweekly intervals the instantaneous growth rates of the same species from 28 May through 24 August 1973.

The first objective was accomplished except carp was dropped from the analysis due to insufficient numbers in the catch. We could not back-calculate growth histories of white crappie, freshwater drum, or black bullhead back to 1967 since fish of these older year-classes were not captured. Annual growth rates for 1973 and 1974 were compared to growth in previous years. Annual growth for 1975 is not given because it cannot be calculated until spring of 1976 when the annulus is formed and total annual growth for 1975 is complete. Instantaneous growth rates were estimated at triweekly intervals instead of biweekly intervals to increase, for sake of more statistical reliability, the sample size of each interval. Instantaneous growth rates were calculated at triweekly intervals in the summers of 1973, 1974, and 1975 and between the sampling dates for the rest of the year. In addition, the vertical depth distribution of fish was monitored at weekly intervals to determine usable habitat and relate growth rates to depth distribution.

DESCRIPTION OF THE RESERVOIR

Lake Arbuckle is located in the Arbuckle Mountains in south central Oklahoma on Rock Creek in Murray County, Oklahoma (Figure 1). This is a region of low rolling hills which creates a relatively steep sided and deep lake: surface area 951 ha, capacity 89,300,000 m^3, average depth 9.39 m, and a maximum depth of 27.4 m[1]. Arbuckle Dam was closed in January 1967 and the reservoir was filled to near the top of the active conservation pool level by April 1968. The watershed receives an annual precipitation of about 96 cm and the average length of the frost-free period is 218 days. The lake is thermally stratified from May to October with a thermocline established at a depth of approximately 7 m.

METHODS AND MATERIALS

The growth and distribution of fish was studied to establish effects of destratifying the reservoir with *in situ* mixing devices. During the summer of 1973, the Bureau of Reclamation attempted destratification with use of a compressed air gun similar to one described by Bryan (1965). The device had a pumping capacity of 42 to 50 m^3/min. The pump was started 10 July 1973 and operated continuously, barring a few minor shutdowns, until 1 October 1973. During the summers of 1974 and 1975 an attempt was made

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[1]According to personnel of the National Park Service maximum depth is 29.0 m over an old quarry located somewhere in the central pool.

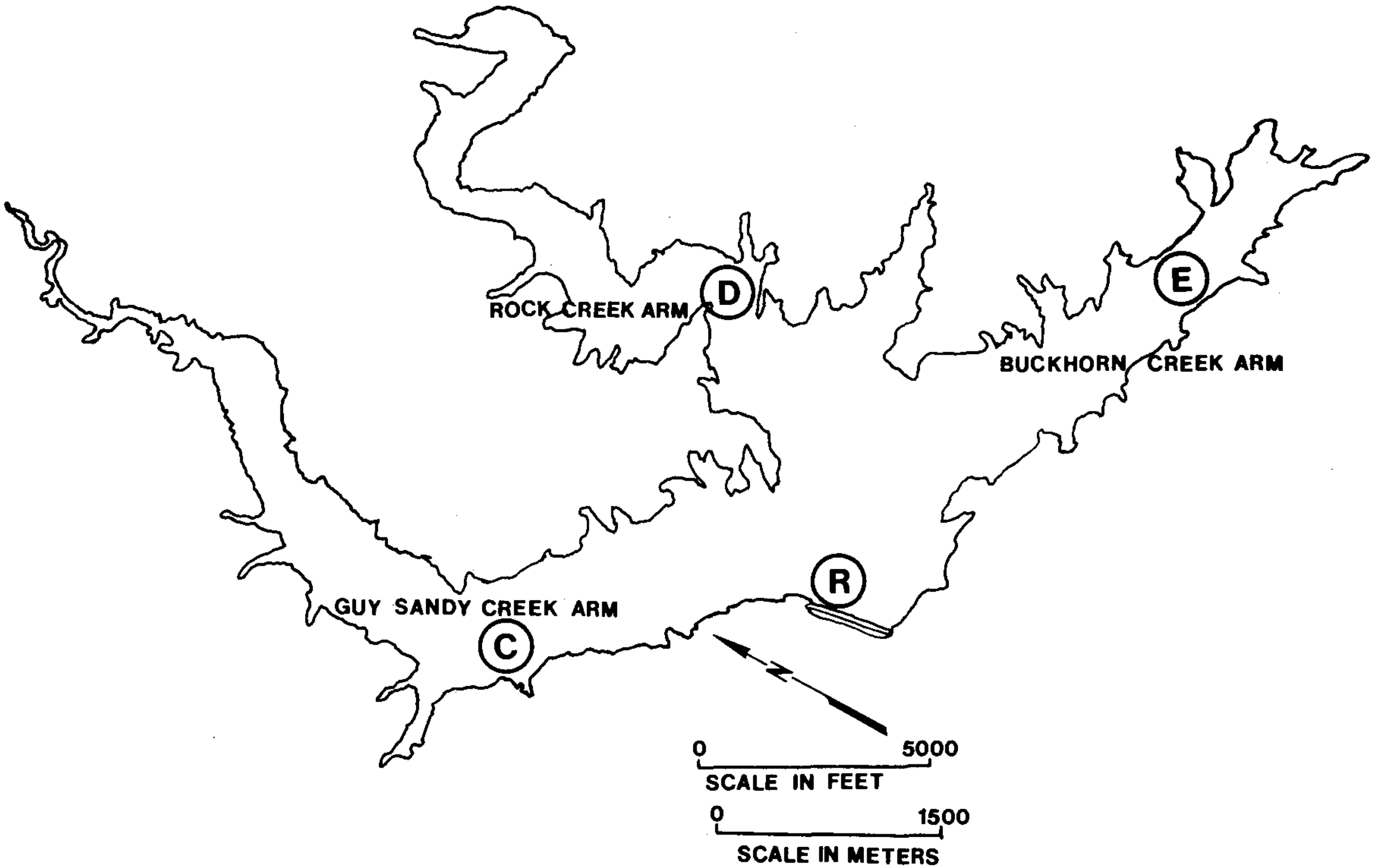

Figure 1. Lake of the Arbuckles, showing four fish collection sites.

by J. E. Garton of Oklahoma State University to destratify the reservoir using an axial flow pump, larger but similar to one described by Quintero and Garton (1973). In 1974, a 5.03 m diameter propeller pump was operated for 46 days, 17 July thru 31 August, at a rotative speed of 5 to 12 RPM, pumping capacity of 196.0 to 832.7 m^3/minute, respectively. In 1975, the device was operated at 18 RPM, a pumping capacity of 704.0 m^3/minute for 30 days from 2 June thru 1 July, and at 20 RPM, pumping capacity of 783.5 m^3/minute, for 73 days from 2 July thru September 12. Thus, in 1975 the pump was operated 57 days more than in 1974 and at a higher average capacity.

Four sites, three control sites (C, D and E) and one experimental site (R) were used to make the fish collections needed to describe the vertical distribution and growth of fish (Figure 1): site R was located at the dam within 200 m of the mixing device; site C was located in Guy Sandy Creek arm, 2,067 m from the mixing device; site D was located in Rock Creek arm, 2,250 m from the mixing device; site E was located in Buckhorn Creek arm, 3,033 m from the mixing device. Site R, the experimental site, was located near the mixing device to measure any local effects of the mixing device on the fish population. The three control sites (C, D and E) were located as far up the respective major arms of the lake as possible where the lake was still of sufficient depth to allow for fishing nets at all depth intervals. Three control sites were selected to allow for statistical analysis of the sampling variation within the control area. Fish catch 1973-75 by site of capture is given in Appendix Tables A-1 thru A-3.

Fish were sampled by use of experimental gill nets, 3.05 m deep by 45.73 m long, divided into six 7.62 m panels with individual panel square mesh sizes of 1.27 cm, 2.54 cm, 3.81 cm, 6.35 cm, and 7.62 cm. Nets were fished in a horizontal position on the bottom at depths of 0-5 m, 5-10 m, 10-15 m, and 15-20 m. The nets were set at the specified intervals with the aid of a recording ecosounder. These depth intervals were chosen to sample the epilimnion, metalimnion, and hypolimnion. One series of nets (one 45.73 m net fished at each of the four depth contours) was set at each of sites C, D and E each week. Three series of nets were set at site R each week. Therefore, one-half of the sampling effort took place at the mixing device. Nets were fished for approximately 24-hour intervals and catch was adjusted to express number of fish per 24 hours.

In 1973, fish collections were made for 15 continuous weeks from 14 May to 24 August and an additional collection was obtained 18-21 October 1973. In 1974, collections commenced 10-14 March 1974 with the weekly collection schedule beginning 20 May and continuing through 23 August 1974. A final 1974 collection was made 9-13 September to monitor growth and distribution after the lake had destratified. In 1975, weekly collections commenced 12 May and continued through 22 August; a collection was obtained 22-26 September after the lake had destratified.

Fish were weighed and measured and scales were taken from scaled fish, and spines were taken from the catfish. The scales and spines were examined to determine the age of the fish and to back-calculate growth for previous years of life from use of the body-scale relationship as described by Tesch (1971). The body-scale relationships were established using a step-wise 5th degree polynomial regression of length on total scale radius. The step ("degree") which gave the best fit, i.e., least deviation of the calculated lengths from the observed, was used to back-calculate the growth. The fifth degree polynomial equation was:

$$Y = \hat{\alpha} + \hat{\beta}_1 (X) + \hat{\beta}_2[(X^2)(10^{-3})] + \hat{\beta}_3[(X^3)(10^{-5})] + \hat{\beta}_4[(X^4)(10^{-7})] + \hat{\beta}_5[(X^5)(10^{-9})]$$

where: X = focus to annulus measurement,

Y = estimated total length at age X,

$\hat{\alpha}$ = the Y axis intercept and

$\hat{\beta}_{1-5}$ = the stepwise regression coefficients

The body-scale relationships for the scaled fishes (white crappie, freshwater drum and gizzard shad) were established using combined data from all three years of study. The body-scale regression was used to back-calculate the growth for each year's collection, calculated separately, giving three estimates of the growth increment for each year class. The three estimates were then subjected to an analysis of variance test. In most cases there was no significant difference between the three estimates, therefore, the three estimates were pooled by a weighted mean procedure for a single estimate of each growth increment.

Growth histories for the scaleless fish, channel catfish and black bullhead, were established using spine sections. Because the spine sections were cut and read in a slightly different manner over the three years of study, the growth history for the same year-class was substantially different among the three years. To eliminate this inconsistency, the 1975 collection was selected for back-calculating growth because it included annual growth in 1973 and 1974 which could not be measured by the 1973 and 1974 collections themselves.

Annual growth increments of the five selected species were described for each year of life for the interval 1967-1974, and the significance of difference in annual growth among these years was tested statistically by an analysis of variance procedure. If the analysis of variance test showed a significant difference among years, then each year was tested against all other years using a least significant difference test (Steel and Torrie 1960:106, 114). If the analysis of variance test did not show a significant difference among years then according to accepted statistical procedure the least significant difference test or t-test cannot be applied to test the differences (Steel and Torrie 1960:107), and it is assumed that there is no significant difference between growth in any of the years.

Instantaneous growth rates were calculated at three-week intervals for all age groups of the five selected species that were adequately represented in the sample. The instantaneous growth coefficient, G, was measured using the equation:

$$G = \frac{(\log_e \bar{w}_2 - \log_2 \bar{w}_1)}{\Delta t}$$

where $\bar{w}_1$ and $\bar{w}_2$ = mean weights of fish at time t_1 and t_2 (Chapman 1968:187). Instantaneous growth coefficients (G values) were also calculated for the interval between the last summer collection and the fall collection, and for the interval between the fall collection and the spring (i.e., the over-wintering period). These G values were then examined in relation to conditions of stratification to establish a causal relation between growth and environmental changes within the lake. It should be noted that the G value is the mean population growth rate and not a mean growth rate of individual fish. The latter could not be obtained since it would require recapture of marked fish; the population growth is generally lower than the individual fish growth rate for fish older than age 1 or 2 (Ricker 1971:129).

Condition factors were also calculated at three-week intervals for the age groups of fishes that were adequately represented in the collection using the basic equation:

$$K = \frac{10^5 W}{L^3}$$

where W = weight in grams and L = total length in millimeters. The condition factor relates weight to length and is an expression of relative robustness or degree of well-being of the fish. Condition factors have been employed to measure the effects of environmental changes upon fish stocks (Cooper and Benson 1951).

The objective of the condition factors, also called the coefficient of condition or ponderal index, is to express the degree of well-being of the fish in numerical terms. Condition factors are calculated by dividing weight by length; therefore, the higher the condition factor, the heavier the fish in proportion to its length, and the better its condition. Condition factors are calculated for individual fish, thereby avoiding the inherent problems of non-random sampling associated with the calculations of instantaneous growth rates. As a rule, condition factors increase slightly as the size of the fish increases; therefore, we have separated the fish by age group for the condition factor analysis. In some cases, the condition factors may decrease early in the summer due to a loss of spawning products, but most fish have already spawned by this time.

Vertical distributions of five species, those adequately represented in the collection, are described using weekly gill net catches 0-5 m, 5-10 m, 10-15 m, and 15-20 m for each site separately and for all sites combined. A mean depth of capture was calculated for each species, at each week, for each site, and for all sites combined. This calculation, basically a weighted mean, assumes that all fish were captured at the mid-point of each depth interval. The vertical distribution of each species was considered in relation to the degree of stratification. The mean depth distribution was plotted against selected temperature and DO isopleths in an attempt to ascertain the correlation between depth distribution and temperature and DO. Temperature and DO measurements were taken weekly at 1 m intervals at all sites using a DO probe and thermistor (Appendix Tables A-4 thru A-6). Secchi disc transparency was measured once each week in 1974 and 1975.

RESULTS

Habitat Analysis

The literature survey by Doudoroff and Shumway (1970) reviewed studies by several investigators which indicate that fish generally avoid water containing less than 2 mg/l DO. In our study, therefore, we used the 2 mg/l DO isopleth (the lake contour at which 2 mg/l DO was present) as the lower level of suitable fish habitat; generally, the water became anoxic within two meters below the 2 mg/l DO isopleth. In each of the three years of study, 1973-75, Arbuckle Lake was thermally stratified by mid-May and DO profiles were clinograde (Figure 2). The area and volume of suitable fish habitat in Arbuckle Lake was calculated weekly for each of the three years of study (Table 1). In 1973, the volume of the lake with more than 2 mg/l DO declined from 100% on 18 May to 89% on 31 May (Table 1); in 1974, oxygen depletion had begun as early as 19 May, and depletion reduced available habitat to 81% of the total volume by 3 June (Table 1). In 1975, 98% of the volume contained more than 2 mg/l DO on 12 May, but by 2 June only 70% of the lake's volume contained more than 2 mg/l DO (Table 1).

Available fish habitat was substantially reduced in Arbuckle Lake during summer stratification: (i) in 1973 as much as 48% of the total volume of habitat was unavailable (20 July) and between 13 July and 24 August the average volume of available habitat (water containing > 2 mg/l DO) was 55.3% of the total lake volume; (ii) in 1974, with the Garton pump operating for 46 days between 17 July thru 31 August, the suitable volume of space never was less than 61% (iii) in 1975, with the Garton pump operating for 104 days between 2 June thru 12 September, the volume of suitable habitat was as little as 41% and it averaged only 47% between 21 July and 18 August. By early June,

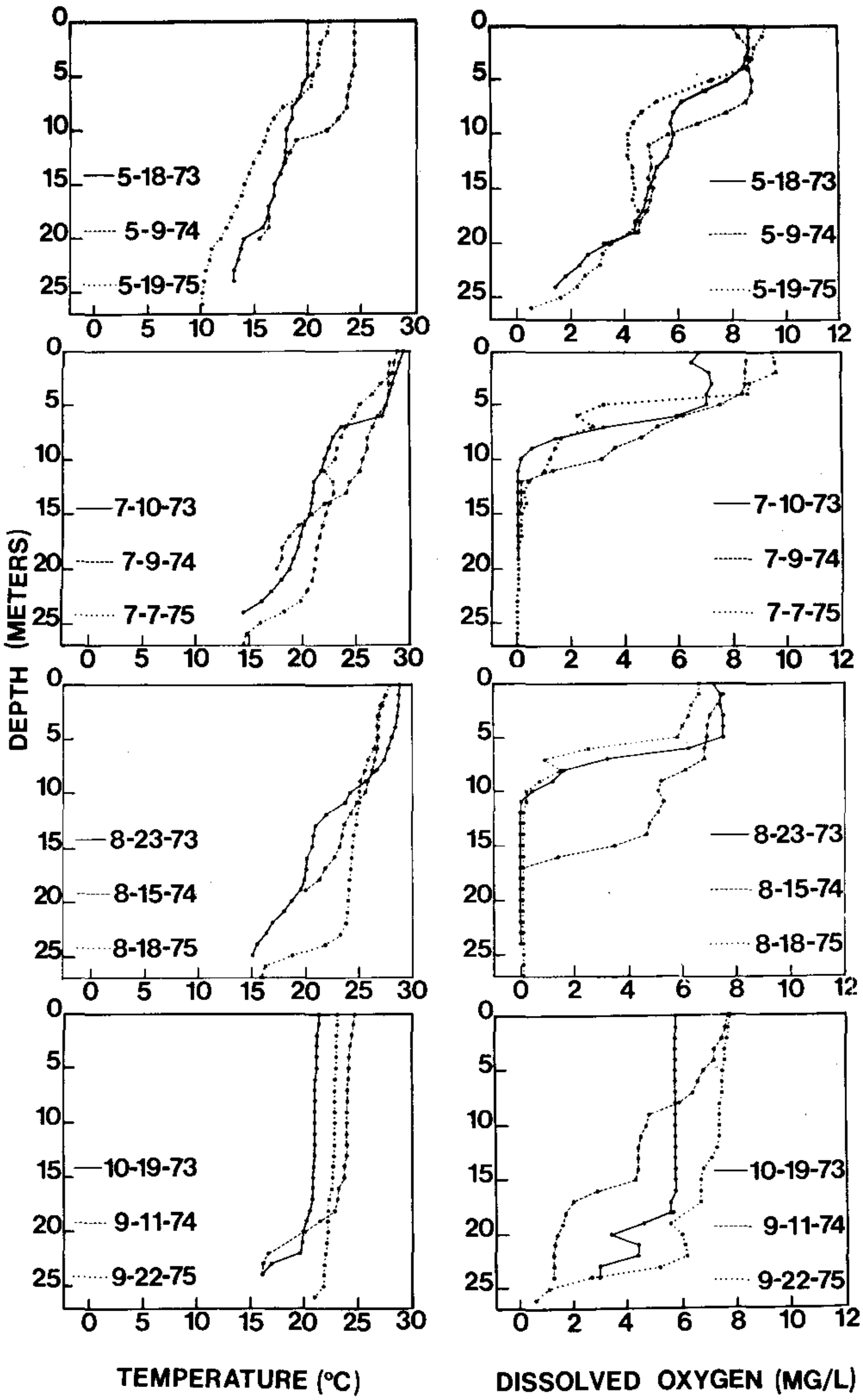

Figure 2. Temperature and dissolved oxygen profiles for Arbuckle Lake (site R, Figure 1) on selected dates, 1973-75.

Table 1. Volume of Lake Arbuckle with more than 2 mg/l DO in 1975 and the area of the lake's basin overlaid with water containing more than 2 mg/l DO.

1973			1974			1975		
Day month	Area (hectares)[a]	Volume (m^3 X 1000)	Day month	Area (hectares)	Volume (m^3 X 1000)	Day month	Area (hectares)	Volume (m^3 X 1000)
-	-	-	-	-	-	12 May	893(94)	87,970(98)
18 May	950(100)[b]	89,304(100)[b]	12 May	770(81)	81,600(91)	19 May	770(82)	82,067(92)
23 May	823(87)	84,928(95)	27 May	703(74	76,049(85)	26 May	702(74)	77,466(87)
31 May	742(78)	79,778(89)	3 June	640(67)	72,049(81	2 June	527(56)	62,186(70)
8 June	677(71)	78,715(88)	10 June	648(68)	72,660(81)	9 June	533(56)	62,618(70)
15 June	624(66)	70,827(79)	17 June	582(61)	66,957(75)	16 June	582(61)	66,930(75)
22 June	544(57)	63,510(71)	24 June	533(56)	62,644(70)	23 June	538(57)	63,051(71)
29 June	507(53)	60,481(68)	1 July	528(56)	62,211(70)	30 June	400(42)	50,633(57)
6 July	438(46)	54,257(61)	8 July	496(52)	59,615(67)	7 July	337(35)	44,128(49)
13 July	383(40)	48,937(55)	15 July	507(53)	60,480(68)	14 July	314(33)	41,735(47)
20 July	363(38)	46,841(52)	22 July	438(46)	54,258(61)	21 July	344(36)	44,727(50)
27 July	378(40)	48,338(54)	29 July	448(47)	55,287(62)	28 July	320(34)	42,332(47)
4 Aug.	438(46)	54,257(61)	5 Aug.	574(60)	66,230(74)	4 Aug.	291(31)	39,097(44)
10 Aug.	432(45)	53,742(60)	12 Aug.	671(71)	74,492(83)	11 Aug.	276(29)	37,048(41)
17 Aug.	372(39)	47,739(53)	19 Aug.	671(71)	74,492(83)	18 Aug.	366(39)	47,123(53)
24 Aug.	363(38)	46,841(52)	-	-	-	-	-	-
31 Aug.	-	-	-	-	-	-	-	-
-	-	-	8 Sept.	775(82)	81,939(92)	-	-	-
-	-	-	-	-	-	22 Sept.	940(99)	89,134(99)
29 Sept.	-	-	-	-	-	-	-	-
7 Oct.	-	-	-	-	-	-	-	-
14 Oct.	-	-	-	-	-	-	-	-
20 Oct.	950(100)	89,304(100)	-	-	-	-	-	-

[a]The surface area of the lake minus the surface area of a horizontal plane at the depth of the 2 mg/l Do isopleth.

[b]% total area (951 hectares) and total volume (89,304,166)

1975 the water below about 10 m was anoxic (Figure 2).

We also calculated the volume of stored water in Lake Arbuckle containing more than 2 mg/l DO for 1973 thru 1975 in the 163-day interval from 11 May thru 20 October. During a typical year (when efforts are not underway to artificially destratify the reservoir) this interval should encompass the totality of the summer stratification period, including a few days of spring overturn (prior to the onset of stratification) through summer stratification (stagnation) and a few days after the natural fall overturn. We assumed that 100% of the volume of the lake would contain more than 2 mg/l DO between 20 October and 11 May. Our calculations of available fish habitat for the interval 11 May thru 20 October were accomplished by (i) interpolation from the weekly summaries (Table 1) of available habitat, (ii) by extrapolation from the first sample each year back to 11 May, and (iii) by extrapolation from the last sample each year to 20 October.

The average volume of Lake Arbuckle with more than 2 mg/l DO present in the 163-day interval 1973-75 was 72.9%, 82.7% and 72.67%, respectively of a total of 89,304,166 cubic meters (8930.4 ha-m) of total lake volume. Thus, there was little difference between 1973 and 1975, but both years differed substantially from 1974.

In 1974, the pump was operated at 5 RPM (196 m^3/minute) from 17 July thru 23 July. Temperature and DO profiles collected 8, 15 and 22 July (Appendix Table A-5) indicated pronounced thermal and chemical stratification for those three sample dates, and in fact the degree of chemical stratification actually intensified over this interval for the depth of the 2 mg/l DO isopleth decreased. It was 10.6 m on 8 July, 8.9 m on 15 July, and 8.0 m on 22 July. On 24 July the RPM was increased to 9 (352.8 m^3/minute) and maintained at that speed thru 1 August. Although the pumping volume increased by a factor of 1.8; after 6 days of pumping, the 2 mg/l DO isopleth remained at 8 m, the same as on 22 July. On 2 August the pumping rate was increased by a factor 1.33 by increasing the RPM from 9 to 12 (capacity from 352.8 to 470.4 m^3/minute). Four days later, the depth of the 2 mg/l DO isopleth went down to 15.41 m, a substantial increase in fish habitat.

In 1975, the lake stratified by 15 May. The volume of water containing more than 2 mg/l DO between 11 May and 20 October 1975 was 72.6%, compared with 72.9% in 1973. In 1975, the pump was started 2 June at 18 RPM (705.6 m^3/minute); it was operated at this rate for 30 days thru 1 July. The 2 mg/l DO isopleth was 20.7 on 28 May, 16.0 m on 5 June, 11.7 m on 13 June, 10.6 m on 20 June, and 10.0 m on 25 June. The operation of the pump at this capacity did not prevent the expected decrease in the depth of the 2 mg/l DO isopleth for this season. On 2 July the rotational speed was increased to 20 RPM (784.0 m^3/minute); it was operated at this rate thru 12 September. The 2 mg/l DO isopleth was 7.8 m on 7 July, 5.2 m on 14 July, 5.7 m on 21 July, 5.4 m on 25 July, 4.8 m on 4 August, and 4.5 m on 11 August. Thus, the increase in pumping capacity on 2 July did not prevent a reduction in fish habitat. In 71 days of pumping, the depth of the 2 mg/l DO isopleth decreased from 20.7 m on 28 May, prior to any pumping to 4.5 m on 11 August. On 8 July 1974 the 2 mg/l DO isopleth was at 10.6 m compared with 7.8 m depth for this isopleth on 7 July 1975. Similar comparisons between 1974 and 1975, indicate that the depth of 2 mg/l DO isopleth was greater (i.e., deeper) in 1974 compared with 1975. The differences in depth of the 2 mg/l DO isopleth between 1974 and 1975 appeared to be an affect of the increased pumping capacity (the pump was operated at a higher average RPM in 1975). Since Garton's pump was moving more water in 1975 than 1974, why then was there less fish habitat available?

Garton's pump appeared to have reduced the temperature difference from top to bottom by early July 1975 and by 18 August the temperature profile was nearly orthograde from the surface to 22 m (Figure 2). Operation of the pump in 1975 substantially increased the water temperature below 12 meters compared to 1973 and 1974 (Figure 2). This increase in water temperature appears to explain the decreased depth of the 2 mg/l DO isopleth in 1975 compared to 1974 because higher temperatures should substantially increase bacterial metabolism. It appears that Garton's axial flow pump influenced temperature and DO profiles in 1974 and 1975 because the lake was vertically more homogeneous for temperature and DO by 12 September 1975 than in 1968-69 and 1973. Do profiles (Duffer and Harlin 1971) (Figures 31-32 of their report) for Lake Arbuckle on 16 October 1968 and 15 October 1969 indicate the 2 mg/l DO isopleth at 19.5 and 21.0 m, respectively, compared with 24.4 m on 22 September 1975.

In regards to our definition of what constitutes suitable fish habitat, 1974 would have been a better year for fish than either 1973, or 1975. Notwithstanding the smaller volume of suitable habitat in 1975, we believe the operation of the Garton pump was responsible for the increase in habitat in 1974.

High epilimnetic surface water temperatures, often exceeding the preferred temperature of most species of fish (Ferguson 1958), also decreased habitable water concurrent with the progressive expansion in the volume of the anoxic hypolimnion (Figure 2). Species like white crappie responded by avoiding the high temperature of the upper strata of the epilimnetic zone. Summer stratification in this case has the effect of compressing the vertical depth distribution of certain fish into a narrow layer of water between the anoxic hypolimnion and the thermally oppressive temperatures in the upper epilimnion. It was not possible to elucidate fish depth distribution within the 0-5 m contour, however, observations in the field indicated that during the warmest part of mid-summer, most of the fish catch in the 0-5 m contour was in the lower portion of the net.

Species Composition

The total number of species of fish captured each year, 1973-75, was 19 in 1973 and 18 in 1974 and 1975. In 384 gill net days of effort each year, the numerical catch rate (C/f) declined from 13.13 fish per gill net day in 1973 to 8.72 in 1974 and 7.61 in 1975 (Table 2). A substantial part of the decline in the C/f between 1973 and 1975 is due to the decline in catch (i.e., abundance) of gizzard shad; the catch rate of shad in 1975 was only 20% of the C/f value in 1973. Removing the number of shad from the total number captured in 1973 and 1975 (5046-2522 for 1973, and 2926-510), the overall C/f value would be 6.57 in 1973 and 6.29 in 1975.

The numerical abundance of individual species of fish in the gill net catch dictated which species would be described in the growth study. Determinations of instantaneous growth rates required large numbers of fish in order to overcome sample error caused by individual size variation. The five most numerous species captured in 1973, together they made up 92.23% of the total catch, were gizzard shad (*Dorosoma cepedianum*), white crappie (*Pomoxis annularis*), black bullhead (*Ictalurus melas*), freshwater drum (*Aplodinotus grunniens*), and channel catfish (*Ictalurus punctatus*) (Table 2). These same five species predominated in the catch in 1974 and 1975 with the exception that compared with 1973, the catch of channel catfish dropped from fifth to sixth ranking in abundance in 1974 and 1975 behind white bass (*Morone chrysops*). For the sake of continuity, the five most abundant species of fishes in the 1973 catch were studied in all three years.

Growth rates vary among species and each has a different behavioral response to the same environmental factors; therefore, the results are presented by species.

Gizzard Shad

Depth Distribution

The depth distribution of gizzard shad was calculated from collections of 2522 fish in 1973, 1005 fish in 1974, and 510 fish in 1975. Gizzard shad were distributed throughout the water column in the early summer during all three years of study (Figure 3). In 1973, mean depth of capture ($\bar{X}$) declined from 6.4 (14 May - 1 June) to 4.9 (25 June - 13 July) corresponding to a decline in mean depth of the 2 mg/l DO isopleth; the depth distribution of gizzard shad and the 2 mg/l DO isopleth remained fairly uniform in the next two intervals (16 July - 3 August, 6-24 August). After the fall overturn (18-21 October) the mean depth distribution of shad deepened substantially ($\bar{X}$ = 7.9). The 1974 and 1975 data show similar trends, however, in mid-summer (1 June - 9 August) the relative abundance of shad in the 10-15 and 15-20 m depth intervals was substantially greater in 1974 and 1975 compared with 1973. Operation of Garton's pump in 1974 increased fish habitat to 82.7% of total lake volume compared with 72.9% in 1973, before Garton's pump was operated. In 1975, with Garton's pump operating, the percentage of available habitat averaged 72.6%, about the same as 1973. In July and August, 1975 the depth of the 2 mg/l DO isopleth was less than in 1973-74, apparently causing the concentration of shad (64-90% of the catch) in the 0-5 m depth interval (Figure 3). The depth distribution of gizzard shad included the entire water column after the fall overturn (Figure 3).

Annual Growth Rates

Annual first-year (age group 1) growth increments of gizzard shad, back-calculated from fish of ages 2-7, are described for eight years, 1967 to 1974;

Table 2. Numerical abundance, percent of total catch, and catch per gill net day of 20 species of fishes collected by gill netting in Lake Arbuckle in 1973-75.

Species	1973 No.	1973 %	1973 C/f[a]	1974 No.	1974 %	1974 C/f[a]	1975 No.	1975 %	1975 C/f[a]
Gizzard shad	2522	49.98	6.57	1005	29.99	2.62	510	17.43	1.33
White crappie	833	16.51	2.17	977	29.16	2.54	843	28.81	2.20
Black bullhead	579	11.47	1.51	506	15.10	1.32	470	16.06	1.22
Freshwater drum	409	8.11	1.07	299	8.92	0.78	431	14.73	1.12
Channel catfish	311	6.16	0.81	176	5.25	0.46	113	3.86	0.29
White bass	159	3.15	0.41	266	7.94	0.69	277	9.47	0.72
Carp	89	1.76	0.23	32	0.95	0.08	32	1.09	0.08
Walleye	49	0.97	0.12	36	1.07	0.09	19	0.65	0.05
Largemouth bass	28	0.55	0.07	20	0.60	0.05	14	0.48	0.04
River carpsucker	23	0.46	0.06	7	0.21	0.02	28	0.96	0.07
Black crappie	22	0.44	0.06	11	0.33	0.03	9	0.31	0.02
Longnose gar	8	0.16	0.02	4	0.12	0.01	1	0.03	0.00
Flathead catfish	4	0.08	0.01	8	0.24	0.02	12	0.41	0.03
Yellow bullhead	5	0.10	0.01	0	0.00	0.00	0	0.00	0.00
Warmouth	0[b]	-	-	0[b]	-	-	26	0.89	0.07
Green sunfish	0[b]	-	-	0[b]	-	-	9	0.31	0.02
Longear	0[b]	-	-	0[b]	-	-	15	0.51	0.04
Golden redhorse	0	0.00	0.00	0	0.00	0.00	3	0.10	0.01
Bluegill	0[b]	-	-	0[b]	-	-	114	3.90	0.30
Blue catfish	5	0.10	0.01	4	0.12	0.01	0	0.00	0.00
Total	5046	100.00	13.13	3351	100.00	8.72	2926	100.00	7.61

[a]Catch per unit of effort: the catch of fish, in numbers, taken in one gill net fished for 24 hours.

[b]These species were collected but not recorded due to time limitations.

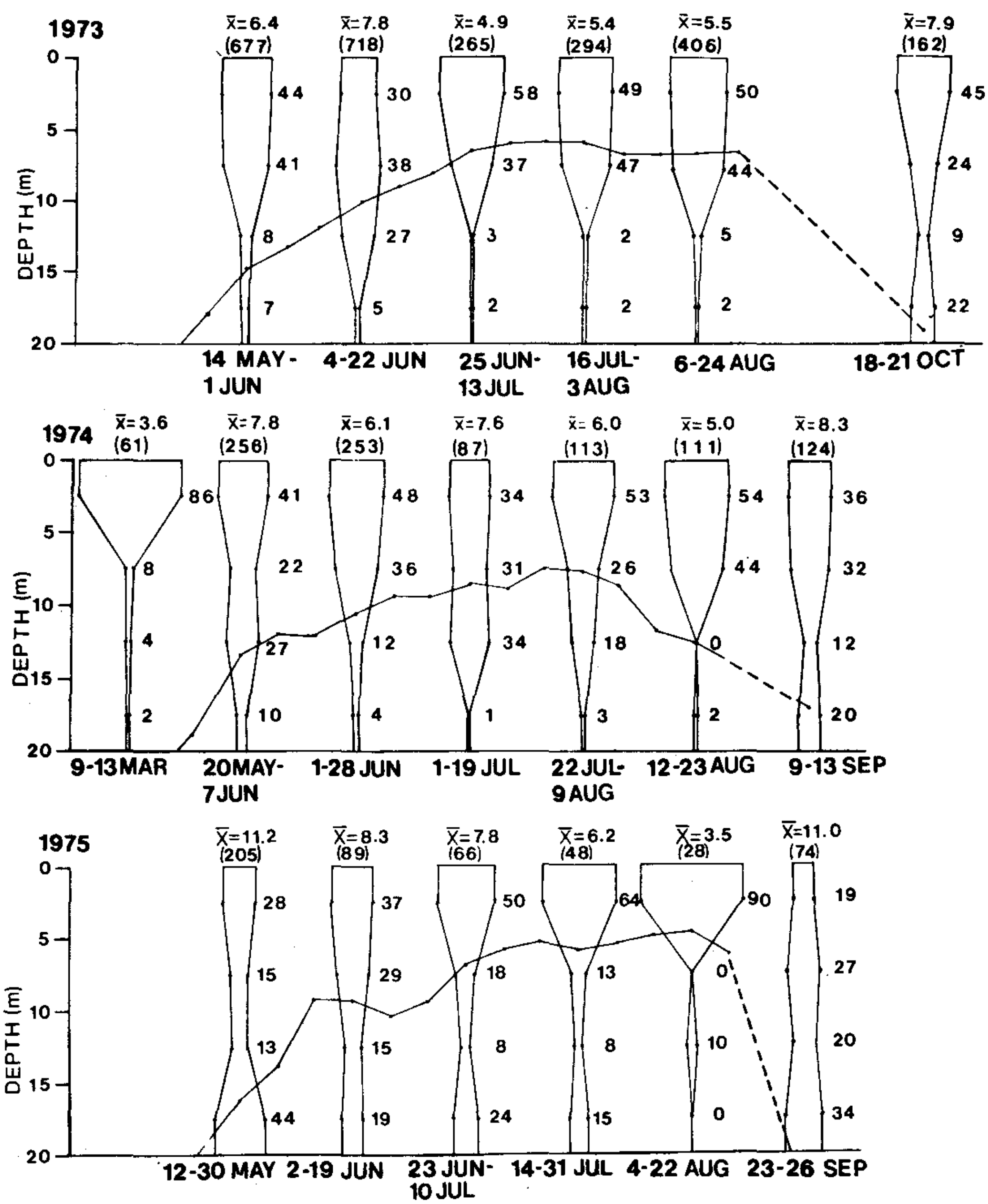

Figure 3. Depth distribution of gizzard shad, represented by polygons that approximate the percentage (shown alongside the polygon) of fish captured at each depth interval, in relation to the 2 mg/l DO isopleth (curve); the $\bar{X}$ represents the mean depth (m), and the value in ( ) the total adjusted number caught in that interval.

Table 3. Mean annual growth increments (mm) (± 95% confidence interval) for gizzard shad in Lake Arbuckle, 1967-1974.

Year of growth	Age[a] 1	2	3	4	5	6	7
1967	154.6±4.6 (9)						
1968	151.8±1.0 (46)	19.4±11.8 (9)					
1969	152.4±1.2 (73)	22.8±2.4 (46)	31.1±11.7 (9)				
1970	153.4±0.7 (169)	24.9±1.8 (73)	22.2±2.4 (46)	27.2±7.9 (9)			
1971	151.7±1.3 (54)	25.6±1.0 (169)	28.5±2.5 (73)	36.0±3.6 (46)	26.2±6.2 (9)		
1972	155.8±2.8 (34)	23.9±1.6 (54)	21.6±1.0 (169)	26.7±2.7 (73)	21.6±2.4 (46)	14.7±5.0 (9)	
1973	164.0±4.7 (17)	21.5±3.1 (34)	21.4±1.6 (54)	19.7±1.5 (91)	20.3±2.0 (62)	15.9±1.9 (39)	11.3±6.4 (4)
1974	159.2±5.4 (18)	31.1±9.2 (13)	20.8±4.1 (31)	25.1±2.9 (28)	22.6±2.4 (31)	12.6±12.1 (25)	12.1±8.1 (3)

[a]Value in ( ) indicates number of fish.

annual growth increments varied from 151.7-164.0 mm over the 8 years with a weighted mean of 153.6 (3.62 S.D.) (Table 3). The differences among the mean annual growth increment for age group 1 gizzard shad were significant ($P<.05$) when tested with the analysis of variance (AOV). The least significant difference (LSD) test indicates that the means for 1973 and 1974 differed significantly (were larger than) from all other years. Also significant are the differences in size between the 1973 and 1974 year-classes, and between the 1972 and the 1969-71 year-classes.

The AOV of the differences in the mean annual growth increment of gizzard shad in their second year of life among seven years, 1967-1974 (Table 3) indicate that each of the years as a group differ from each other more than might be expected as a result of sampling error at a probability smaller than 0.05. The LSD test indicated that the increment in 1974 for fish in their second year of growth was significantly greater than for any other year, 1968-1973 (Table 4). This test also indicated that the second year increment in 1973 was significantly different (less than) than the increment for 1970 and 1971 but not greatly different from growth in 1968, 1969 or 1972 than might be expected from sampling error at the 5% level.

Growth of age 3 gizzard shad varied from 20.8 to 31.1 mm (Table 3) and the AOV difference among the years was significant. The LSD test indicated that the growth increment in 1969 was significantly larger than the increments obtained by age group 3 fish in 1970, 1972-74 (Table 5). The AOV of the difference among all years for growth of age 4 gizzard shad was significant; the LSD test indicated that 1971 was significantly larger than all other years (Table 5). There was not a significant difference among years for ages 5, 6 and 7.

Table 4. Differences in annual growth increments of gizzard shad among years was significant (0.05 level) for first and second year growth by the analysis of variance test. Differences in growth increments between years are shown; the least significant difference test indicates which differences were significant at the 0.05 level (*).

Year of growth	First year growth							
	1967	1968	1969	1970	1971	1972	1973	1974
1967	-							
1968	2.78	-						
1969	2.24	0.54	-					
1970	1.19	1.59	1.05	-				
1971	2.91	0.13	0.67	1.72*	-			
1972	1.14	3.92	3.38*	2.33*	4.05*	-		
1973	9.35*	12.13*	11.59*	10.54*	12.26*	8.21*	-	
1974	4.63*	7.41*	6.87*	5.82*	7.54*	3.49*	4.72*	-

Year of growth	Second year growth						
	1968	1969	1970	1971	1972	1973	1974
1968	-						
1969	3.31	-					
1970	5.48*	2.17	-				
1971	6.20*	2.89	0.72	-			
1972	4.47	1.16	1.01	1.73	-		
1973	2.09	1.22	3.39*	4.11*	2.38	-	
1974	11.66*	8.35*	6.18*	5.46*	7.19*	9.57*	-

Table 5. Differences in annual growth increments of gizzard shad among years was significant (0.05 level) for third and fourth year growth by the analysis of variance test. Differences in growth increments between years are shown; the least significant difference test indicates which differences were significant at the 0.05 level (*).

Year of growth	Third year growth					
	1969	1970	1971	1972	1973	1974
1969	-					
1970	8.96*	-				
1971	2.65	6.31*	-			
1972	9.51*	0.55	6.86*	-		
1973	9.66*	0.70	7.01*	0.15	-	
1974	10.31*	1.35	7.66*	0.80	0.65	-

	Fourth year growth				
	1970	1971	1972	1973	1974
1970	-				
1971	8.89*	-			
1972	0.47	9.36*	-		
1973	7.43*	16.32*	6.96*	-	
1974	2.03	10.92*	1.56	5.40*	-

For age group 1 gizzard shad, the annual growth increment in Arbuckle Lake, 1967-1974, was larger than the median rates for Kansas and Oklahoma, but for age groups 2-7, the annual increments were less than the median rates for Kansas and Oklahoma (Carlander 1969).

The 1973 Bureau of Reclamation effort to destratify the reservoir with an air gun was considered ineffective on the basis of temperature and dissolved oxygen profiles. Operation of Garton's pump in 1974, however, increased the average percentage of available habitat from 72.9% in 1973 to 82.7% in 1974. The objective of analyzing fish growth was to ascertain whether annual growth rates might be effected by operation of the pump. There was nearly 10% more habitat in 1974 compared to 1973 and the reservoir destratified about one month earlier than in 1968-69 and 1973. There was a significantly better growth rate for age group 2 gizzard shad in 1974 compared with all other years, and growth of age group 1 gizzard shad in 1974 was better than all other years except in 1973. For age group 3 growth rate in 1974 was less than in 1969-73 but the difference was significant only in comparison to 1969 and 1972. For age group 4, growth was greater in 1974 than in 1973, less than in 1971 and not significantly different from 1970 and 1972. Thus, the effect of the pumping in 1974 on annual growth increments of gizzard shad were age specific, perhaps not directly related to changes in habitat or operation of the pump. Overall, therefore, growth rates were neither benefited, nor harmed from the pump when considering year-to-year variations observed over all age groups 1967-74.

Instantaneous Growth Rates

Instantaneous growth rates, or growth coefficients (G values) were calculated at three-week intervals during the summer sampling period and between the other sampling periods, 1973-75 for the age groups 3, 4 and 5, which were adequately represented in the collections (Appendix Tables A-7, A-8, and A-9). The G value is expressed as grams per day to facilitate comparisons over intervals representing a different number of days; and they are presented in scientific notation ($\chi\ 10^{-3}$) to eliminate an excessive number of zeroes.

Instantaneous growth rates are shown in relation to available habitat, and the correlation between the G values and available habitat are given for age group 3, 4 and 5 gizzard shad for 1973-74 (Table 6). None of the correlation coefficients (r values in Table 6) were significant (P less than 0.05) indicating that the correlation coefficients were not large enough to be distinguished from mere sample error.

For age group 3 gizzard shad, most population growth and the larger G values were obtained for the over-winter intervals when the lake was destratified (Table 7):over the 149-day summer interval of 1973 (data given in Appendix Table A-7) mean weight gain was -2.0 g compared to 31.1 g over the 221.5-day winter interval of 1973-74; in the summer of 1974 the mean weight gain was 8.7 g compared to 31.4 over the winter interval of 1974-75 when the lake was destratified. The G values also show substantially better growth rate during the destratified intervals than during the summer. The mean weight gain and G values for the summer of 1974 were larger than the summers in 1973 and 1975.

For age group 4, mean weight gain per fish was better in the summer of 1973 than for the winter interval; also, the G value was larger for the summer than the winter interval. Although these data did not substantiate the summer-winter growth differences observed for fish of age group 3 in the 1973-74 interval, the age group 4 gizzard shad did have a larger G value in the summer of 1974 than 1973. The growth coefficient of 1.69 for age group 4 shad for

Table 6. Relationship between the instantaneous growth coefficient (G) for gizzard shad and mean percentage of the lake's volume containing ≥ 2 mg/l DO.

Median collection date	Interval (days)	Available habitat (%)	G values by age group 3	4	5
		1973			
5-23[a]					
	19.5	88.4	-2.00	3.89	-0.85
6-12					
	21.0	71.9	-7.31	-14.14	-5.44
7-3					
	21.0	55.8	1.20	10.98	-0.72
7-24					
	21.0	58.0	3.02	-9.85	-2.27
8-14					
	66.5	73.4	1.16	5.63	2.61
10-19[a]					
	221.5	99.2	1.58	0.54	0.34
5-29-74					
			r = -0.13	0.06	0.26
		1974			
5-29					
	20.0	79.9	-2.69	2.22	-3.47
6-18					
	21.0	69.8	0.82	-3.42	-0.65
7-9					
	21.0	64.2	0.06	9.60	-0.06
7-30					
	17.5	77.1	0.15	-	-3.12
8-16[a]					
	26.0	87.9	6.56	-0.60	2.10
9-11					
	252.0	99.2	1.20	1.70	-
5-21-75					
			r = 0.42	-0.30	0.14
		1975			
5-21					
	19.5	80.7	7.42	-4.63	0.67
6-9[a]					
	21.5	69.4	4.68	8.40	0.22
6-30					
	21.0	49.6	0.69	-8.76	-4.17
7-21					
	19.5	45.4	0.86	8.48	14.28
8-9[a]					
	46.5	72.9	-3.97	1.59	-9.23
9-24[a]			r = 0.34	-0.10	-0.51

[a]The exact median collection date was between this date and the following day.

Table 7. Comparison of growth rates (G) and mean weight gain (g) for gizzard shad for summer (stratified) and winter (destratified) intervals, 1973-75.

Median Collection Date	Interval	Days	Weight gain and (G) for age groups shown 3	4	5
5-23-73					
	summer	149.0	-2.0(-0.17)	29.2(1.33)	-3.8(-0.13
10-19-73					
	winter	221.5	31.1(1.58)	20.5(0.53)	14.5(0.33)
5-29-74					
	summer	105.5	8.7(0.98)	16.8(1.40)	-14.7(-0.79)
9-11-74					
	winter	252.0	31.4(1.20)	65.1(1.69)	-----
5-21-75					
	summer	128.0	7.2(0.71)	18.8(1.13)	-37.0(-1.72)
9-24-75					

the 252-day overwinter interval from 9-11-74 to 5-21-75, was larger than that of any previous interval.

Age group 5 gizzard shad had negative growth rates (-G values) in the summer of 1973-75; the only positive G value was calculated for overwinter growth for 1973-74 (Table 7).

Instantaneous growth rates, when compared for intervals when the lake is stratified to intervals when the lake is destratified, generally indicate better growth during the overwinter intervals; also, growth in 1974 was better than in the summers of 1973 and 1975 which coincides to differences in available habitat between these years.

Condition Factors

The curve of temporal variation in the K factor of age group 3 gizzard shad in 1973 and 1974 indicates an annual pattern characterized by (i) large K factor preceeding spawning; (ii) a sharp decline immediately following spawning; (iii) small K factors prevailing during the summer, with lowest values occurring in mid-summer when the amount of habitat with 2 mg/l DO was the least; and (iv) a rise in the K factor in the fall after destratification (Figure 4).

The seasonal trend in the K factor for age group 4 gizzard shad in 1973-74 generally paralleled the trend observed for the age group 3 fish, i.e., a sharp decline following spawning, and generally low K factors throughout the summer. There were two notable differences between the trends in K factors for age group 3 and 4: (i) the K value shown for age group 4 on 7-30-74 was unusually large for mid-summer, especially in contrast to the low K factor for age group 3 on a similar date; (ii) the K factor for age group 4 fish on

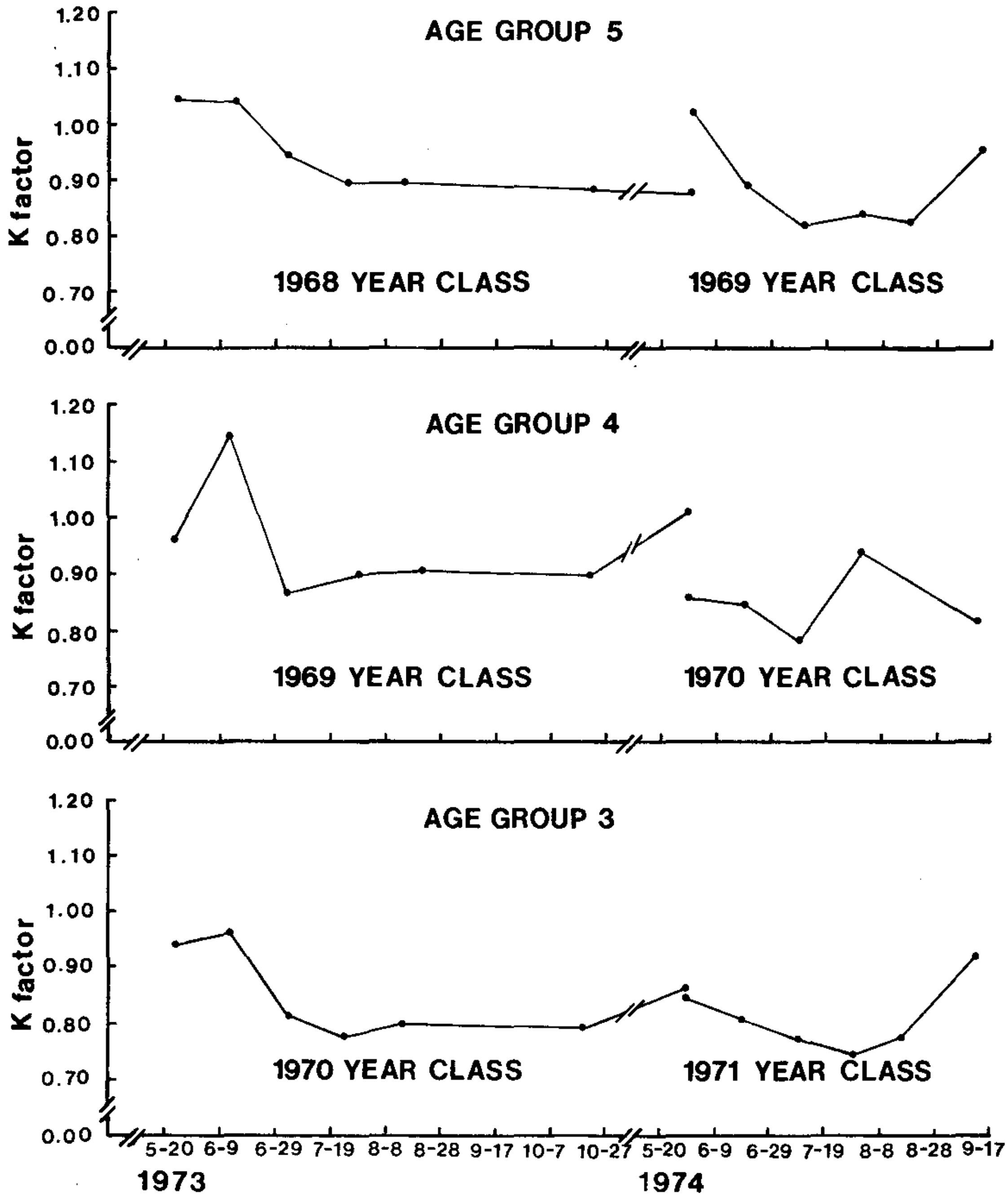

Figure 4. Temporal variation in condition factors (K factors) of age group 3-5 gizzard shad, Arbuckle Lake, 1973-74.

9-11-74 was lower than for age group 3, whereas on all other dates the K factors for age group 4 fish were larger than the K factors for the age group 3 fish.

In 1973, the seasonal trend in K factors of age group 5 gizzard shad paralleled that for age groups 3 and 4 through 10-18-73, however, the K factor of the 1968 year-class in the spring of 1974, instead of being greater than 1.00, as for most ripening fish, the K factor was only 0.88. The 1968 year-class which would become age group 6 in 1974 may have been showing signs of senility. The 1969-year-class had a K factor of 1.02 on 5-29-74 indicating appropriate gonadal development for pre-spawning fish, and they apparently spawned in early June as indicated by the decline in mean K factor between 5-29 and 6-18-74. As was the general pattern for most age groups in both 1973 and 1974, the K factors of the 1969 year-class of age group 5 shad were low during the summer of 1974, but condition increased in the fall (9-24-74) collection interval (Figure 4).

The relationship between variation in the K factor of gizzard shad and the percentage of available habitat was examined for each age group in 1973 and 1974 (Table 8). Only one (age group 4 in 1974) correlation coefficient (r) was negative suggesting that as a general case the K factor tended to increase with increasing percentage of available habitat. However, only the r of 0.85 for age group 3 gizzard shad in 1973 was significant ($P<.05$).

Table 8. Relationship between the condition factor (K ± 95% confidence interval) for age group 3-5 gizzard shad and mean percentage of the lake's volume containing ≥ 2 mg/l DO.

Collection date	Available habitat (%)	Age group 3		Age group 4		Age group 5	
		Sample size	K factor	Sample size	K factor	Sample size	K factor
				1973			
5-15 to 6- 1	94.8	151	0.94±0.02	60	0.96±0.03	6	1.04±0.12
6- 2 to 6-22	81.9	63	0.96±0.02	18	1.15±0.14	10	1.04±0.14
6-23 to 7-13	63.6	50	0.81±0.02	5	0.87±0.37	4	0.94±0.20
7-14 to 8- 3	54.7	38	0.78±0.03	2	0.90±1.56	4	0.89±0.10
8- 4 to 8-24	56.3	60	0.80±0.02	1	0.91±0.00	6	0.89±0.08
10-18 to 10-21	99.4	86	0.79±0.02	28	0.90±0.03	15	0.88±0.04
5-20 to 6- 7	84.4	6	0.86±0.07	18	1.02±0.12	11	0.88±0.06
		r =	0.49		0.34		0.33
				1974			
5-20 to 6- 7	84.4	72	0.84±0.02	6	0.86±0.07	18	1.02±0.12
6- 8 to 6-28	74.8	100	0.80±0.02	13	0.85±0.03	11	0.89±0.05
6-29 to 7-19	67.8	85	0.77±0.02	12	0.79±0.06	7	0.82±0.08
7-20 to 8- 9	67.0	46	0.74±0.02	1	0.95±0.00	9	0.84±0.05
8-10 to 8-23	83.0	88	0.77±0.01	-	-	3	0.83±0.01
9- 9 to 9-13	92.6	16	0.92±0.05	9	0.83±0.23	3	0.96±0.21
		r =	0.85*		-0.27		0.68

*Significant at P≤ 0.05

White Crappie

Depth Distribution

The depth distribution of white crappie was described from collections of 833 fish in 1973, 977 in 1974, and 843 in 1975 (Figure 5). Our working hypothesis for white crappie, as for other species, was that they would be found at all depth contours sampled with the gill nets when the 2 mg/l DO isopleth reached the bottom. In 1973 and 1975 the first collection intervals (14 May - 1 June 1973, 12-30 May 1974) were after the lake evidenced a degree of stratification and the 2 mg/l DO isopleth was already above the lowest (15-20 m) depth interval. Thus, in 1973 and 1975 white crappie had already abandoned the deepest contour on the first collection interval. In 1974, the first collection interval (9-13 March) preceeded lake stratification, and 2 mg/l DO was present near the bottom. At that time, 4.0% of the adjusted catch of white crappie were caught in the nets set at 15-20 meter interval.

Throughout most (13 of 15) of the collection intervals when the lake was stratified, white crappie were not collected in the 15-20 meter depth contours; the two exceptions were 16 July to 3 August 1973, and 23 June to 10 July 1975. The mean depth distribution of white crappie was closely correlated ($r = 0.84$, $P<0.01$) to the depth of the 2 mg/l DO isopleth in 1975; for 1974 the correlation was 0.60 but it was not significant at the 5% level (Gebhart and Summerfelt 1975).

During August 1975, when the 2 mg/l DO isopleth was about 5 meters, white crappie were limited to the epilimnion and only caught in the 0-5 m interval. In each year after the fall overturn the mean depth of capture of white crappie was substantially deeper than it had been prior to the overturn. The early fall overturn in 1974 and 1975, presumably brought about by the pumping, had a

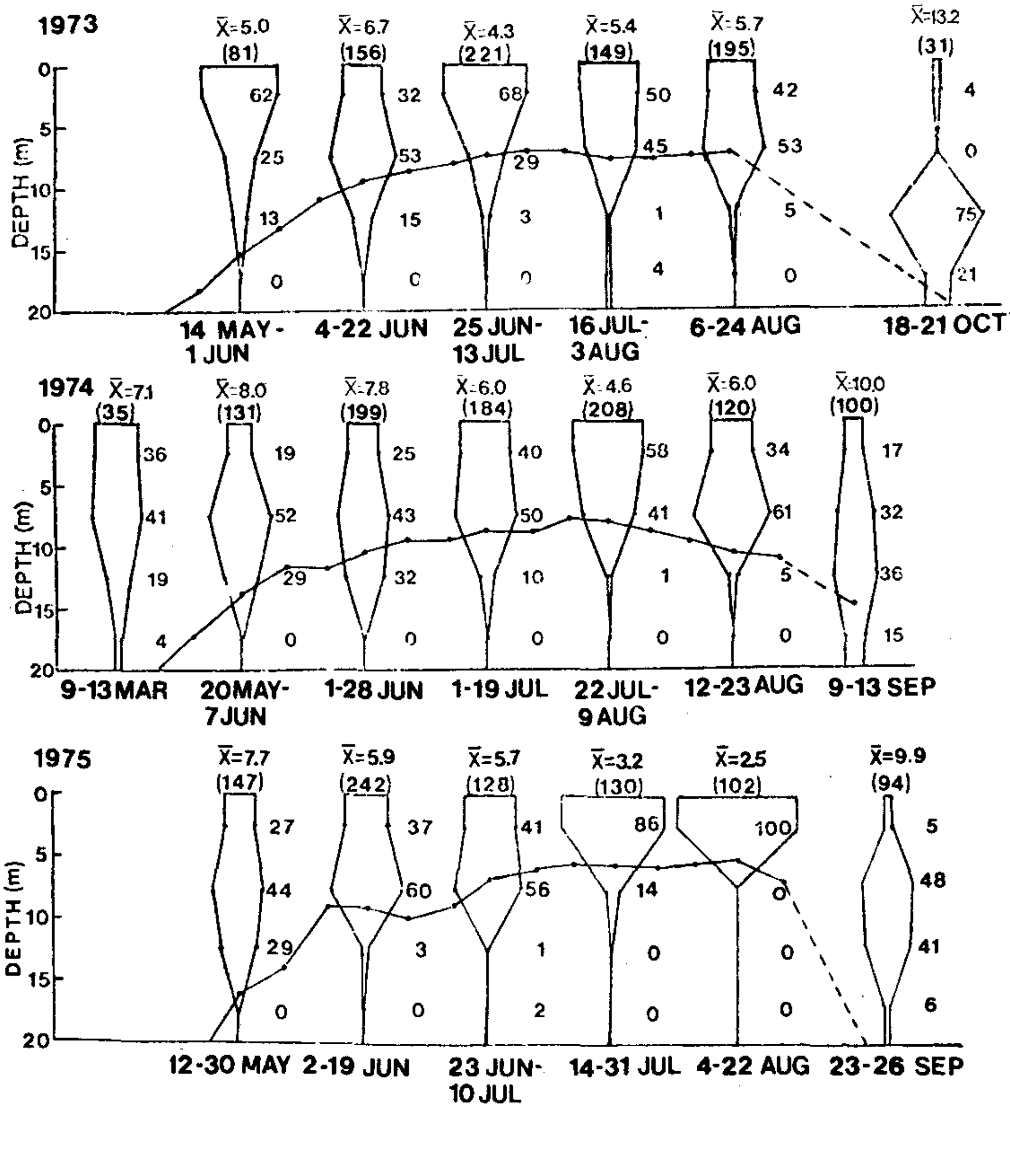

Figure 5. Depth distribution of white crappie, represented by polygons that approximate the percentage (shown alongside the polygon) of fish captured at each depth interval, in relation to the 2 mg/l DO isopleth (curve); the $\bar{X}$ represents the mean depth (m), and the value in ( ) the total adjusted number caught in that interval.

significant effect upon the depth distribution of white crappie because they occupied deeper water after the lake destratified and oxygen was available to all depths.

Annual Growth Rates

Mean annual growth increments for white crappie, ages 1-5 for 1968-74 (Table 9), were generally higher than the state average for Oklahoma (Houser and Bross 1963). In their first year of life (age group 1), the annual mean growth increment varied less than 5 mm among the five years 1968-72, the weighted annual average for 1968-72 was 80.1 mm. In 1973 the mean growth in the first year of life increased 35.6 mm to 115.7 mm, and in 1974 it increased to 140.0 mm.

The AOV of the differences among the means of first year growth increments was significant, and the least significant difference test (Table 10) indicated that growth of white crappie in 1974 was greater than all other prior years, likewise, 1973 was also greater than all prior years. The differences among the years 1968-72, as expected, were not statistically significant ($P>.05$).

The first year crappie growth rates in 1973 can not be directly attributed to the operation of the air gun in that year since its effectiveness was very limited. The exceptional growth rate for 1974 cannot be directly attributed to operation of the Garton pump, but it was substantially greater than the range in annual variation 1968-73. Growth rate of age 1 crappie in 1974, when Garton's pump increased fish habitat, was significantly larger than any previous year. The population density of white crappie during the course of the summer of 1973 and 1974, as indicated by the catch per unit of gill netting effort (c/f) (Table 2), 2.17 fish in 1973, 2.54 fish in 1974, does not indicate any

Table 9. Mean annual growth increments (mm) (± 95% confidence interval) for white crappie in Lake Arbuckle, 1968-1974.

Year of growth	Age[a]				
	1	2	3	4	5
1968	84.6±14.6 (4)				
1969	84.6±0.0 (1)	43.9±18.6 (4)			
1970	81.8±3.5 (19)	61.8±0.0 (1)	61.4±25.0 (4)		
1971	79.6±2.3 (105)	81.7±10.2 (19)	63.2±0.0 (1)	40.5±26.56 (4)	
1972	81.7±6.1 (47)	124.3±4.4 (105)	73.0±9.4 (19)	57.7±0.0 (1)	38.4±12.4 (4)
1973	115.7±8.2 (59)	122.9±8.7 (36)	73.2±8.2 (18)	54.6±25.4 (5)	
1974	140.0±11.2 (31)	82.3±8.5 (29)	46.9±21.2 (6)		

[a]Value in ( ) indicates number of fish.

Table 10. Differences in annual growth increments of white crappie among years was significant (0.05 level) for first and second year growth by the analysis of variance test. Differences in growth increments between years are shown; the least significant difference test indicates which differences were significant at the 0.05 level (*).

Year of growth	First year growth						
	1968	1969	1970	1971	1972	1973	1974
1968	-						
1969	0.00	-					
1970	2.89	2.89	-				
1971	5.07	5.07	2.18	-			
1972	2.98	2.98	0.09	2.09	-		
1973	31.09*	31.09	33.98*	36.16*	34.07*	-	
1974	55.31*	55.31*	58.20*	60.38*	58.29*	24.22*	-

Year of growth	Second year growth					
	1969	1970	1971	1972	1973	1974
1969	-					
1970	17.85	-				
1971	37.79*	19.94	-			
1972	80.38*	62.53*	42.59*	-		
1973	78.95*	61.10*	41.16*	1.43	-	
1974	38.35*	20.50*	0.56	42.03*	40.60*	-

basis for suspecting a smaller density in 1974 than in 1973.

Annual variation in growth increments of white crappie in their second year of life was substantial; the range in annual increments was from 43.9 to 122.9, and the AOV for the differences among the means was significant. Growth increments increased each year 1969-72, an interesting trend which may be due to Lee's phenomenon which is a case where growth when back-calculated shows an apparent trend such as this due to differential mortality of the faster growing fish (Tesch 1971). The large number of significant differences (LSD test) observed between years (Table 10) seem unrelated to the effect of operation of the Garton pump in 1974. Growth differences in 1973 and 1974, which are least likely to be affected by Lee's phenomenon, were significant, 1973 was larger than 1974. If the differences between 1973 and 1974 were related to the pumping in 1974, it would indicate, compared to the difference in growth of crappie in their first year of life, that the effect of the increased habitat on growth of white crappie was age specific, with a beneficial affect in the first year of life, and a negative effect in the second and third year of life. However, judging from the overall array of differences over all years (Table 10), the present analysis provides an inconclusive assessment of the impact of the pumping in 1974 on annual population growth of white crappie.

Instantaneous Growth Rates

The instantaneous growth rates, growth coefficients (G values) calculated over various intervals, 19.5-250.0 day lengths, 1973-75 were generally positive for age group 1 white crappie (Table 11), but substantial loss in mean weight, 22.1 g or 56%, was observed in a 19.5-day interval in late spring of 1975

Table 11. Relationship between the instantaneous growth coefficient (G) for white crappie and mean percentage of the lake's volume containing ≥ 2 mg/l DO.

Median collection date	Interval (days)	Available habitat (%)	G values by age group		
			1	2	3
		1973			
5-23[a]					
	19.5	88.4	-	7.49	-47.58
6-12					
	21.0	71.9	10.94	5.09	19.59
7-3					
	21.0	55.8	0.59	2.20	-5.77
7-24					
	21.0	58.0	7.38	-11.50	14.14
8-14					
	66.5	73.4	-	2.32	5.30
10-19[a]					
	221.5	99.2	0.90	-	-
5-29-74			r = -0.19	0.68	0.32
		1974			
5-29					
	20.0	79.9	19.18	6.15	-
6-18					
	21.0	69.8	8.38	6.94	8.33
7-9					
	21.0	64.2	7.12	4.94	0.28
7-30					
	17.5	77.1	6.06	4.15	6.54
8-16[a]					
	26.0	87.9	1.98	8.76	-1.70
9-11					
	252.0	99.2	4.39	0.65	-
5-21-75			r = -0.27	-0.40	-0.34
		1975			
5-21					
	19.5	80.7	-29.52	-13.67	-5.44
6-9[a]					
	21.5	69.4	14.63	2.00	-15.23
6-30					
	21.0	49.6	25.17	-6.86	25.17
7-21					
	19.5	45.4	-11.54	4.37	-
8-9[a]					
	46.5	72.9	-0.58	3.58	-
9-24[a]			r = 0.43	-0.36	-0.82

[a]The exact median collection date was between this date and the following day.

(Appendix Table A-10). This was not apparently related to sampling error as the collections made between 5-12 and 5-30 were represented by 114 fish and the collection 5-31 to 6-19 by 223 fish. The age group 2 and 3 white crappie also lost weight between these two collecting intervals, and for the 2 and 3 year old fish, this weight loss might be related to loss of gametes during spawning which might have taken place at this time. White crappie spawn when water temperatures are about 17-20^{o}C (64-68^{o}F) (Goodson 1966), and the 5-18-73 temperature profile (Figure 2) shows the temperature of 20^{o}C from 0-5 meters. However, it would be surprising to find yearling (age group 1) white crappie, mean weight of 50.5 g for fish collected 5-12 to 5-30-75, spawning, because their sexual maturity is usually at 2 to 3 years of age (Goodson 1966).

In 1973 and 1974, there was substantial overwinter growth of age 1 white crappie: (i) between 10-19-73 and 5-29-74 (median collection dates), crappie increased 302.4%, from 66.2 to 85.9 g mean size; (ii) between 9-11-74 and 5-21-75, their mean weight went from 73.6 to 222.6 g (Appendix Table A-10). The correlation coefficients for the relation between G values and percentage of available habitat were all non-significant (P>.05) (Table 11).

For age group 1 white crappie, growth rates (G values) for summer and winter intervals did not indicate better winter than summer growth. In the summer of 1973, the G value was 6.3 for 149 days, compared with 0.9 for the 221.5 days (1973-74) overwinter interval. The comparison for the summer-winter intervals 1974-75 were similar, G of 8.25 for the summer and 4.39 for the winter. Relevant to our evaluation, is that the G values of age group 1 white crappie in 1974, summer and winter, were substantially larger than those for summer and winter intervals 1973 and summer of 1975. The latter G value, 0.12, was very poor relative to the G values of 6.3 and 8.25 for 1973 and 1974, respectively (Table 12).

Table 12. Comparison of growth rates (G) and mean weight gain (g) for white crappie for summer (stratified) and winter (destratified) intervals, 1973-75.

Median Collection Date	Interval	Days	Weight gain and (G) for age groups shown		
			1	2	3
5-23-73					
	summer	149.0	21.7(6.30)	30.2(1.42)	2.9(0.08)
10-19-73					
	winter	221.5	19.7(0.90)[a]	102.0(2.06)	-----
5-29-74					
	summer	105.5	42.8(8.25)	142.3(6.37)	74.2(2.93)[b]
9-11-74					
	winter	252.0	149.0(4.39)	51.7(0.64)	-----
5-21-75					
	summer	128.0	0.8(0.12)	-24.4(-0.90)	34.3(1.54)[c]
9-24-75					

[a] Interval was 241.5 days in length

[b] Interval was 85.5 days in length

[c] Interval was 62.0 days in length

For age group 2 white crappie, G values were smaller, as expected, than those of the age group 1 fish. The summer-winter comparisons in 1973 are reverse of the case for the age group 1 white crappie; in that year the G values for age group 2 fish were higher for the winter intervals than the summer intervals. However, in 1974, the summer growth rate was larger than the rate for the winter interval. For all age groups, summer growth rates in 1974 were larger than summer growth rates in 1973 or 1975, the difference suggests that available habitat may have some effect on summer growth rate. As noted previously, the operation of the pump in 1975 actually caused a reduction in lake volume with more than 2 mg/l DO (Table 1).

Condition Factors

The condition factors of age group 1 white crappie in 1973 were represented by small samples (2-4, Table 13) but in 1974, when large samples (48-128) were collected, the condition factors of age 1 white crappie declined as the summer progressed (Figure 6). The condition factor increased slightly in the 9-9 to 9-19 interval when the lake was homothermal and with a more than 2 mg/l DO near the bottom. The condition factors of age 2 white crappie varied from 1.35 to 1.42 throughout the summer of 1973 (5-15 to 8-24) but there was a decline in condition in the fall collection (10-18 to 10-21) although this sample was of only 3 fish (Table 13). The condition factors of age group 2 white crappie were fairly uniform during the summer of 1974, but the value for the fall collection increased substantially.

The mean condition factors for age group 3 white crappie varied irregularly

Table 13. Relationship between the condition factor (K ± 95% confidence interval) for age group 1-3 white crappie and mean percentage of the lake's volume containing ≥ 2 mg/l DO.

Collection date	Available habitat (%)	Age group 1		Age group 2		Age group 3	
		Sample size	K factor	Sample size	K factor	Sample size	K factor
				1973			
5-15 to 6- 1	94.8	-	-	47	1.39±0.99	4	1.25±0.24
6- 2 to 6-22	81.9	2	1.38±0.43	76	1.39±0.03	86	0.95±0.04
6-23 to 7-13	63.6	2	1.41±2.51	66	1.35±0.05	112	1.09±0.06
7-14 to 8- 3	54.7	3	1.17±0.96	29	1.42±0.07	106	1.02±0.06
8- 4 to 8- 3	56.3	4	1.36±0.16	19	1.37±0.06	148	1.11±0.03
10-18 to 10-21	99.4	-	-	3	1.31±0.22	22	1.32±0.05
5-20 to 6- 7	84.4	15	1.29±0.15	-	-	-	-
		r =	0.27		-0.46		0.65
				1974			
5-20 to 6- 7	84.4	48	1.30±0.11	15	1.29±0.15	-	-
6- 8 to 6-28	74.8	84	1.25±0.05	33	1.25±0.03	2	1.34±1.34
6-29 to 7-19	67.8	94	1.18±0.03	-	-	3	1.41±0.08
7-20 to 8- 9	67.0	128	1.19±0.02	-	-	4	1.32±0.06
8-10 to 8-23	83.0	87	1.14±0.03	17	1.26±0.04	3	1.29±0.07
9- 9 to 9-13	92.6	55	1.15±0.05	12	1.47±0.09	-	-
		r =	-0.08		0.91		-0.65

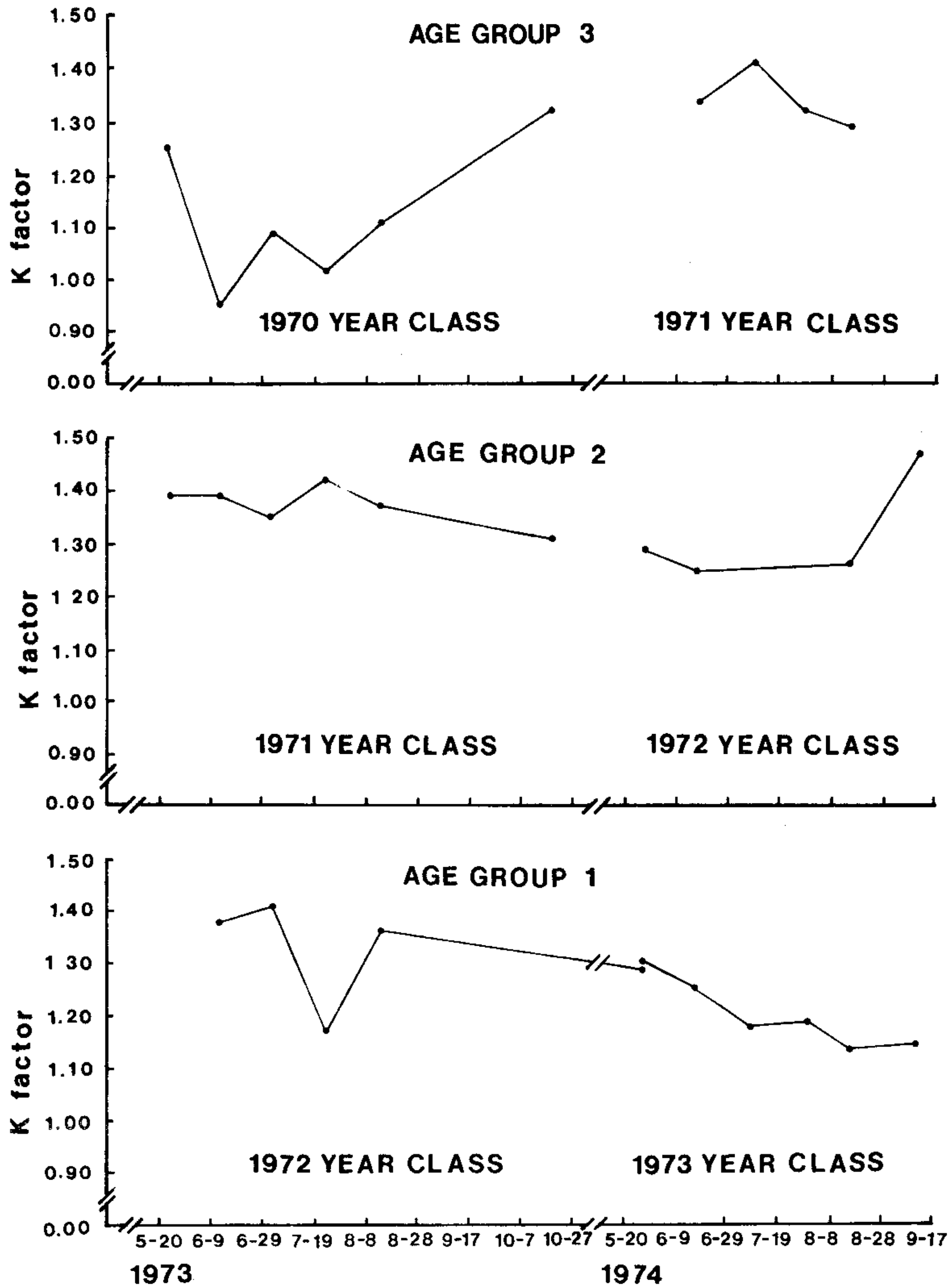

Figure 6. Temporal variation in condition factors (K factors) of age group 1-3 white crappie, Arbuckle Lake, 1973-74.

during the 1973 summer collections, first decreasing at the beginning of the summer, possibly due to the loss of spawning products, then increasing sharply during the fall overturn period (Figure 6). The 1974 data for age group 3 white crappie differed substantially from the 1973 collection, being much larger, and it did not include a fall 1974 collection. Temporal variation in the K factors of the 1974 collection does not reveal a response to stratification.

Over-all age groups, the temporal variation in the K factors of white crappie do not show a consistent pattern in temporal variation which can be related to summer stratification or in terms of differences between 1973 and 1974.

Freshwater Drum (*Aplodinotus grunniens*)

Depth Distribution

The depth distribution of freshwater drum was calculated from a collection of 409 fish in 1973, 299 fish in 1974, and 431 fish in 1975. The depth distribution of drum appeared highly responsive to conditions of stratification and destratification (Figure 7). A 9-13 March collection in 1974 did not contain enough drum to describe their depth distribution at that time. In the first collection intervals in 1973-75, the reservoir already evidenced some degree of stratification and the 2 mg/l DO isopleth was above the bottom. A few drum were captured in the 15-20 m depth interval in the first two collection intervals in 1973-75. In the mid-summer collections, drum showed an obvious avoidance of the anoxic 15-20 m interval, and the catch in the 10-15 m interval was generally a small percentage of the total. Drum were most abundant in the 15-20 m depth contour after fall turnover (18-21 October 1973, 9-13 September 1974, 23-26 September 1975) when the DO content in the water in

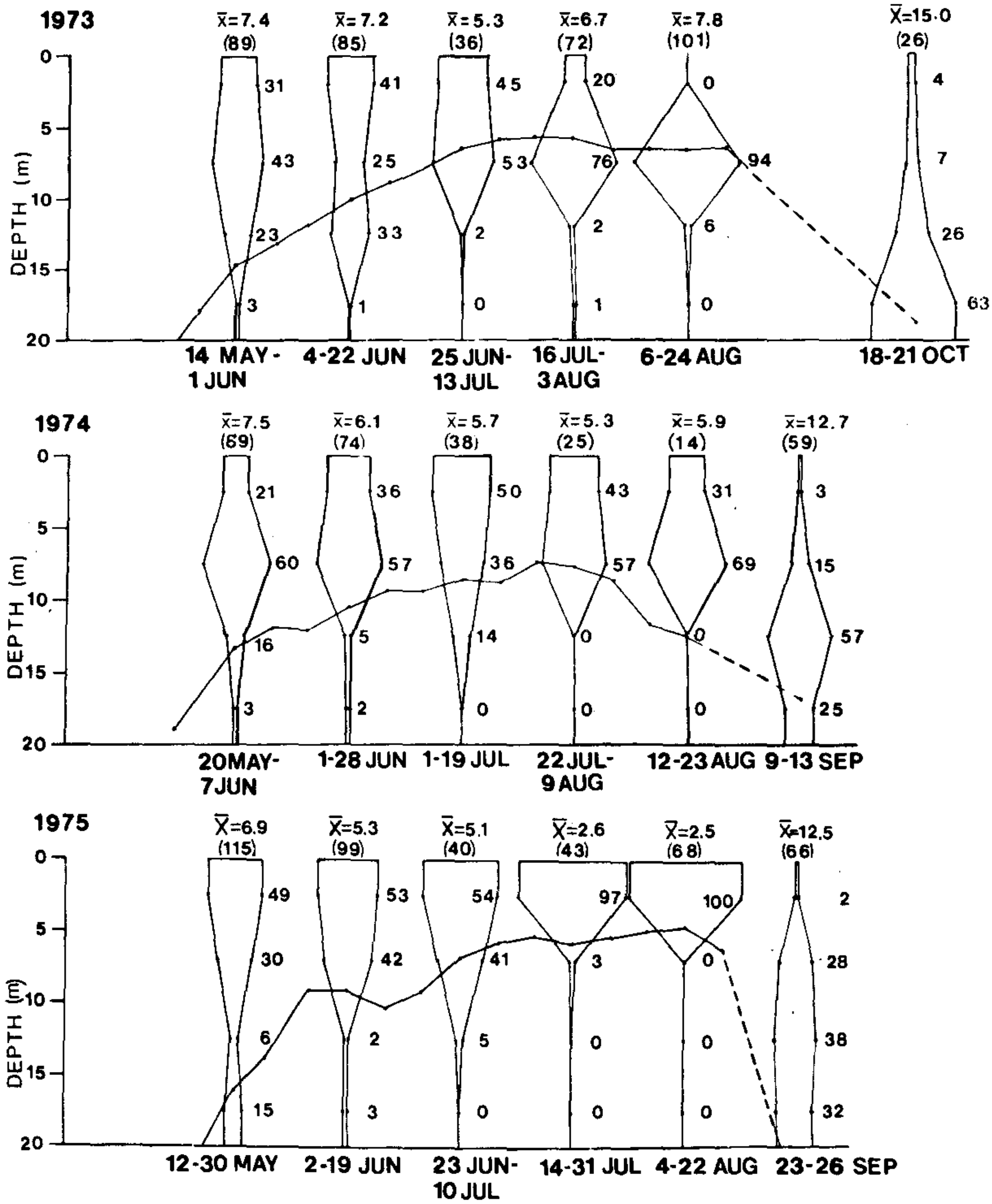

Figure 7. Depth distribution of freshwater drum, represented by polygons that approximate the percentage (shown alongside the polygon) of fish captured at each depth interval, in relation to the 2 mg/l DO isopleth (curve); the $\bar{X}$ represents the mean depth (m), and the value in ( ) the total adjusted number caught in that interval.

the 15-20 m depth interval was more than 2 mg/l. In the last 6 weeks of the summer of 1975 (14 June thru 22 August), when the 2 mg/l DO isopleth was never deeper than 6 meters, only 1 drum was captured in a net set deeper than 5 m.

In 1974, only one (the 6 mg/l DO isopleth) correlation coefficient was significant ($r = 0.63$, $P<.05$) for the relationship between mean depth of capture of drum and mean depth of the 2, 4, 6 and 8 mg/l DO isopleths; in 1975, when DO depletion was more prevalent, the correlations between depth distribution of drum and DO isopleths were highly significant ($P<.01$) for the 2, 4 and 6 mg/l DO isopleths ($r = 0.87$, 0.90, and 0.85, respectively) (Gebhart and Summerfelt 1975). In contrasting the results over two years, the results appear to show that when drum have less habitat because of the larger volume of the anoxic hypolimnion, drum depth distribution was closely associated with the chemocline.

Annual Growth Rates

Mean annual growth increments are described for freshwater drum, ages 1-5, for seven years, 1968 to 1974 (Table 14). The first year growth of freshwater drum was greater in all years than the average Oklahoma rate for freshwater drum in Oklahoma and the growth in 1968-70 was higher than the fastest growth recorded for Oklahoma (Houser and Bross 1963). However, growth of age 2-5 drum in Lake Arbuckle was lower than the state average in all but one case.

The average length (weighted, mean of the annual means) of drum to the end of the first year of life 1968 thru 1972 was 163.5 mm (± 5.2 mm, 95% confidence interval for annual mean); therefore, 1973 was within the expected average but growth in 1974 was substantially less than the expected annual variation.

Table 14. Mean annual growth increments (mm) (± 95% confidence interval) for freshwater drum in Lake Arbuckle, 1968-1974.

Year of growth	Age[a]				
	1	2	3	4	5
1968	207.0±0.0 (1)				
1969	174.9±19.9 (11)	77.5±0.0 (1)			
1970	169.7±6.3 (51)	76.5±15.0 (11)	8.9±0.0 (1)		
1971	161.6±5.5 (53)	87.5±5.0 (51)	24.6±12.5 (11)	50.4±0.0 (1)	
1972	157.7±4.4 (65)	88.6±5.3 (53)	18.0±3.2 (51)	8.8±3.2 (11)	138.2±0.0 (1)
1973	163.4±5.5 (55)	82.2±4.0 (65)	16.5±5.0 (26)	6.1±2.2 (25)	4.2±3.7 (4)
1974	141.9±3.3 (25)	44.8±10.8 (28)	43.8±12.4 (34)		

[a]Value in ( ) indicates number of fish.

The analysis of variance test showed a significant difference among all years for age 1 drum. The least significant difference test indicated a significant difference between 1970 and 1972, and a significant difference in growth between 1974 and all other years (Table 15), growth in 1974 was less than all other years.

The analysis of variance test showed a significant difference among all years growth for age 2 drum, growth in 1974, as for age group 1 drum, was again lower than all other years (Table 15). Growth of age 3 drum was greater in 1974 than in 1970-73. The analysis of variance test indicated a significant difference in growth among all years for age 3 drum (Table 16). The least significant difference test revealed a significant difference between growth in 1974 versus all other years except 1970 which was represented by a single specimen. Growth rates for age group 4 drum were larger in 1971 than 1972-73 and for age group 5, only two years were available for comparison and for 1972, only one specimen.

Instantaneous Growth Rates

Temporal variation in instantaneous growth rates of age 2 and 3 drum were irregular; negative growth occurred in many of the intervals (Table 17). The mean weights, from which the instantaneous growth rates were calculated, have confidence limits which are larger than the differences between mean weights in most cases (Appendix Table A-13). This indicates that sampling variation could be the cause of the irregular growth patterns. None of the correlation coefficients between temporal variation in percent available habitat and instantaneous growth coefficients were statistically significant (Table 17).

The major portion of the population growth of age 2 drum in 1973 and 1974 occurred between the time of the fall sample and the first sample the next

Table 15. Differences in annual growth increments of freshwater drum among years was significant (0.05 level) for first and second year growth by the analysis of variance test. Differences in growth increments between years are shown; the least significant difference test indicates which differences were significant at the 0.05 level (*).

Year of growth	First year growth						
	1968	1969	1970	1971	1972	1973	1974
1968	-						
1969	32.02	-					
1970	37.29	5.27	-				
1971	45.39	13.37	8.10	-			
1972	49.26	17.24	11.97*	3.87	-		
1973	43.54	11.52	6.25	1.85	5.72	-	
1974	65.08*	33.06*	27.79*	19.69*	15.82*	21.54*	-

Year of growth	Second year growth					
	1969	1970	1971	1972	1973	1974
1969	-					
1970	1.00	-				
1971	9.94	10.94*	-			
1972	11.08	12.08*	1.14	-		
1973	4.65	5.65	5.29	6.43*	-	
1974	32.70*	31.70*	42.64*	43.78*	37.35*	-

Table 16. Differences in annual growth increments of freshwater drum among years was significant (0.05 level) for third, fourth, and fifth year growth by the analysis of variance test. Differences in growth increments between years are shown; the least significant difference test indicates which differences were significant at the 0.05 level (*).

Year of growth	Third year growth 1970	1971	1972	1973	1974
1970	-				
1971	15.75	-			
1972	9.09	6.66	-		
1973	7.58	8.17	1.51		
1974	34.90	19.15*	25.81*	27.22*	-

Year of growth	Fourth year growth 1971	1972	1973
1971	-		
1972	41.66*	-	
1973	44.29*	2.63	-

Year of growth	Fifth year growth 1972	1973
1972	-	
1973	134.05*	-

Table 17. Relationship between the instantaneous growth coefficient (G) for freshwater drum and mean percentage of the lake's volume containing $\geq$ 2 mg/l DO.

Median collection date	Interval (days)	Available habitat (%)	G values by age group 2	G values by age group 3
		1973		
5-23[a]				
	19.5	88.4	0.10	-5.50
6-12				
	21.0	71.9	-5.87	-0.67
7-3				
	21.0	55.8	2.83	-3.89
7-24				
	21.0	58.0	0.33	6.82
8-14				
	66.5	73.4	-2.09	-3.85
10-19[a]				
	221.5	99.2	1.44	0.65
5-29-74				
			r = -0.02	-0.41
		1974		
5-29				
	20.0	79.9	4.30	-0.93
6-18				
	21.0	69.8	-0.39	-3.54
7-9				
	21.0	64.2	-4.07	-1.35
7-30				
	17.5	77.1	1.89	10.08
8-16[a]				
	26.0	87.9	2.07	0.44
9-11				
	252.0	99.2	0.72	-
5-21-75				
			r = 0.53	0.26
		1975		
5-21				
	19.5	80.7	-0.65	-2.33
6-9[a]				
	21.5	69.4	7.79	0.20
6-30				
	21.0	49.6	-12.43	1.57
7-21				
	19.5	45.4	24.73	0.86
8-9[a]				
	46.5	72.9	6.42	0.26
9-24[a]			r = -0.22	-0.82

[a]The exact median collection date was between this date and the following day.

Table 18. Comparison of growth rates (G) and mean weight gain (g) for freshwater drum for summer (stratified) and winter (destratified) intervals, 1973-75.

Median Collection Date	Interval	Days	Weight gain and (G) for age groups shown 2	3
5-23-73				
	summer	149.0	-34.7(-1.29)	-59.9(-1.52)
10-19-73				
	winter	221.5	61.1(1.44)	36.6(0.65)
5-29-74				
	summer	105.5	14.7(0.75)	15.4(0.63)
9-11-74				
	winter	252.0	38.2(0.71)	-----
5-21-75				
	summer	128.0	99.0(5.26)	4.8(0.16)
9-24-75				

summer (Table 18), however, in 1975, average weight gain and rate of weight gain (G values) were better than in the summer of 1973 and 1974. The instantaneous population growth rate of age 3 drum was negative in the summer of 1973; the highest summer growth rate for the age group 3 drum occurred in the summer of 1974. The 1973-74 overwinter growth for the age group 3 drum was larger than that for the three summer intervals.

Condition Factors

The condition factors for age group 2 freshwater drum in 1973 declined abruptly between the 6-2 thru 6-22 collection interval to the 6-23 thru 7-13 collection interval, perhaps reflecting a post-spawning change due to loss of gametes (Table 19, Figure 8). The K factor of fish collected in August 1973 was higher than preceeding samples but K factor declined in the fall 1973 collection (Figure 8). The age group 2 drum in 1974 (1972 year-class) also exhibited an apparent post-spawning decline, the K factor of the 1972 year-class stayed low throughout the summer of 1974. The weighted mean condition factor of age group 2 drum collected in the summer of 1973 (excluding the 10-18 thru 10-21 collection) was 1.11 compared with 1.0 the summer of 1974 (excluding the 9-9 thru 9-13 collection), the difference in the weighted means, using a pooled variance, was non-significant. The correlations between K factors of age group 2 drum and seasonal variation in available habitat in 1973 and 1974 were also non-significant (Table 19).

The mean condition factors for age group 3 freshwater drum decreased fairly consistently from the first through the fourth collection in both 1973 and 1974 (Figure 8). For age group 3 drum, the weighted mean K factor in the summer of 1974 was 1.12 compared with 1.05 for the summer of 1973; the difference was statistically significant ($P<.01$). The difference between the

Table 19. Relationship between the condition factor (K $\pm$ 95% confidence interval) for age group 2-3 freshwater drum and mean percentage of the lake's volume containing $\geq$ 2 mg/l DO.

Collection date	Available habitat (%)	Age group 2 Sample size	Age group 2 K factor	Age group 3 Sample size	Age group 3 K factor
			1973		
5-15 to 6- 1	94.8	26	1.16±0.04	35	1.17±0.04
6- 2 to 6-22	81.9	28	1.17±0.03	17	1.11±0.03
6-23 to 7-13	63.6	38	1.06±0.03	13	1.10±0.05
7-14 to 8- 3	54.7	27	1.08±0.03	8	1.06±0.04
8- 4 to 8-24	56.3	35	1.13±0.06	10	1.07±0.03
10-18 to 10-21	99.4	7	1.00±0.08	12	1.09±0.05
5-20 to 6- 7	84.4	41	1.11±0.04	9	1.09±0.08
		r =	-0.06		0.64
			1974		
5-20 to 6- 7	84.4	1	1.11±0.00	41	1.11±0.04
6- 8 to 6-28	74.8	24	1.16±0.24	17	1.05±0.04
6-29 to 7-19	67.8	14	1.01±0.07	21	1.01±0.03
7-20 to 8- 9	67.0	6	0.99±0.05	11	0.98±0.04
8-10 to 8-23	83.0	5	0.98±0.02	11	0.98±0.05
9- 9 to 9-13	92.6	13	1.00±0.03	10	0.98±0.06
		r =	0.01		0.09

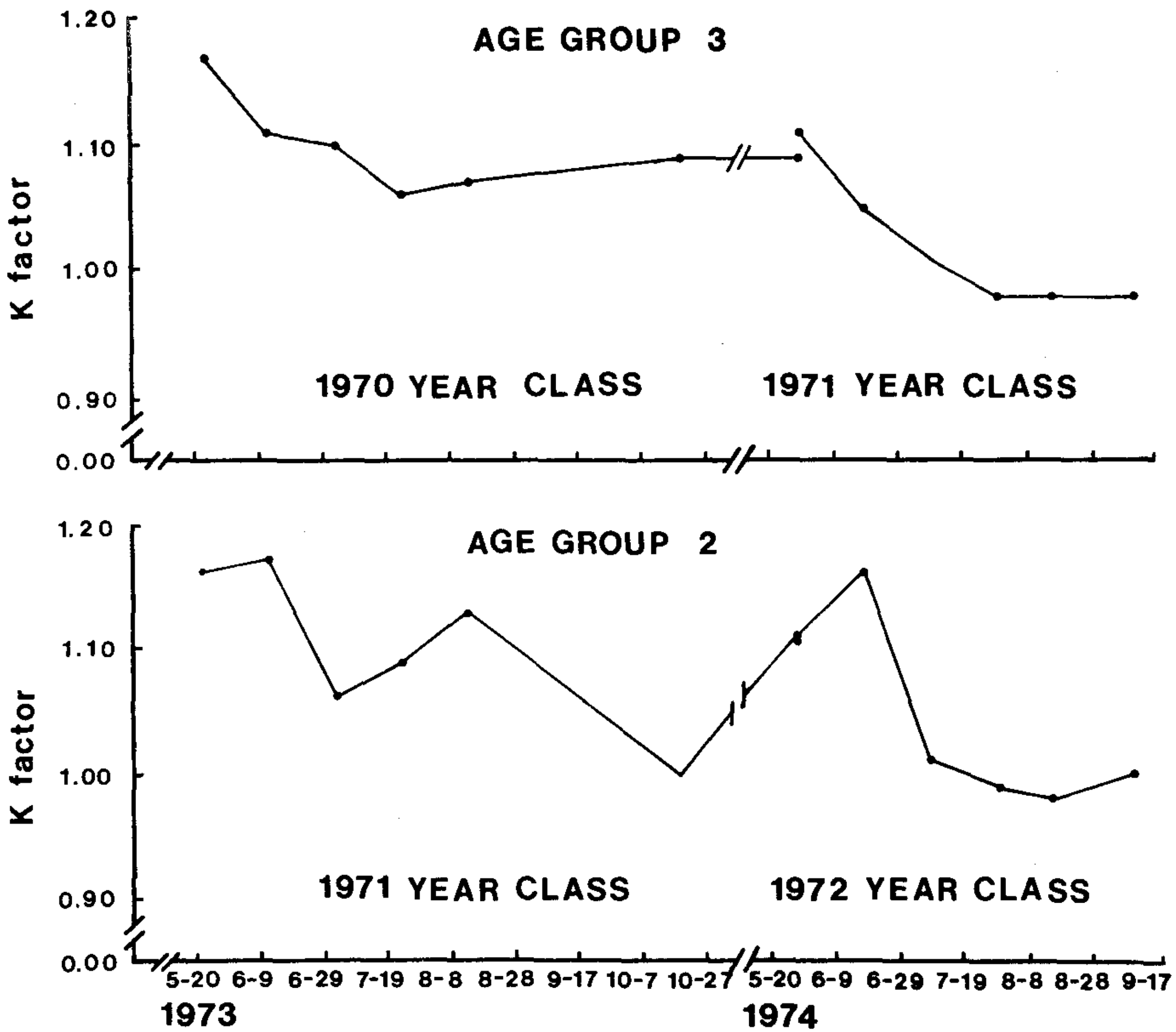

Figure 8. Temporal variation in condition factors (K factors) of age group 2-3 fresheater drum, Arbuckle Lake, 1973-74.

weight mean K factor for age group 2 and 3 in 1973 and 1974 was not significant. None of the correlation coefficients between percent available habitat and condition factor were statistically significant at the 0.05 level.

Black Bullhead (*Ictalurus melas*)

Depth Distribution

The depth distribution of the black bullhead was determined from a collation of 579 fish in 1973, 506 fish in 1974, and 470 fish in 1975. The mean depth of capture of the black bullhead was consistently greater than any other species. They were distributed to all depths of the lake during the entire study period (Figure 9), obviously tolerant to low oxygen as evidenced by their high frequency of catch in the anoxic hypolimnion. Their mean depth distribution did decrease, however, as the anoxic hypolimnion expanded, as seen in the intervals 16 July - 3 August 1973, 22 July - 9 August 1974, and the interval 4-22 August 1975. Bullheads were captured at greater depths when the lake destratified and dissolved oxygen was available throughout the water column. In 1974 the correlations between the depth distribution of the black bullhead and the depth of the 2, 4, 6 and 8 mg/l DO isopleth was non-significant, but in 1975, the correlation was significant between the 2 mg/l, 4 and 6 mg/l DO isopleths: $r = 0.65$ for the 2 mg/l, 0.70 for the 4 mg/l, and 0.78 for the 6 mg/l isopleths (Gebhart and Summerfelt 1975).

Annual Growth Rates

The mean annual growth increments are described for ages 1-4, 1971 to 1974 (Table 20). The growth of black bullhead in the first year of life in Lake Arbuckle was much greater than the average growth reported for Oklahoma,

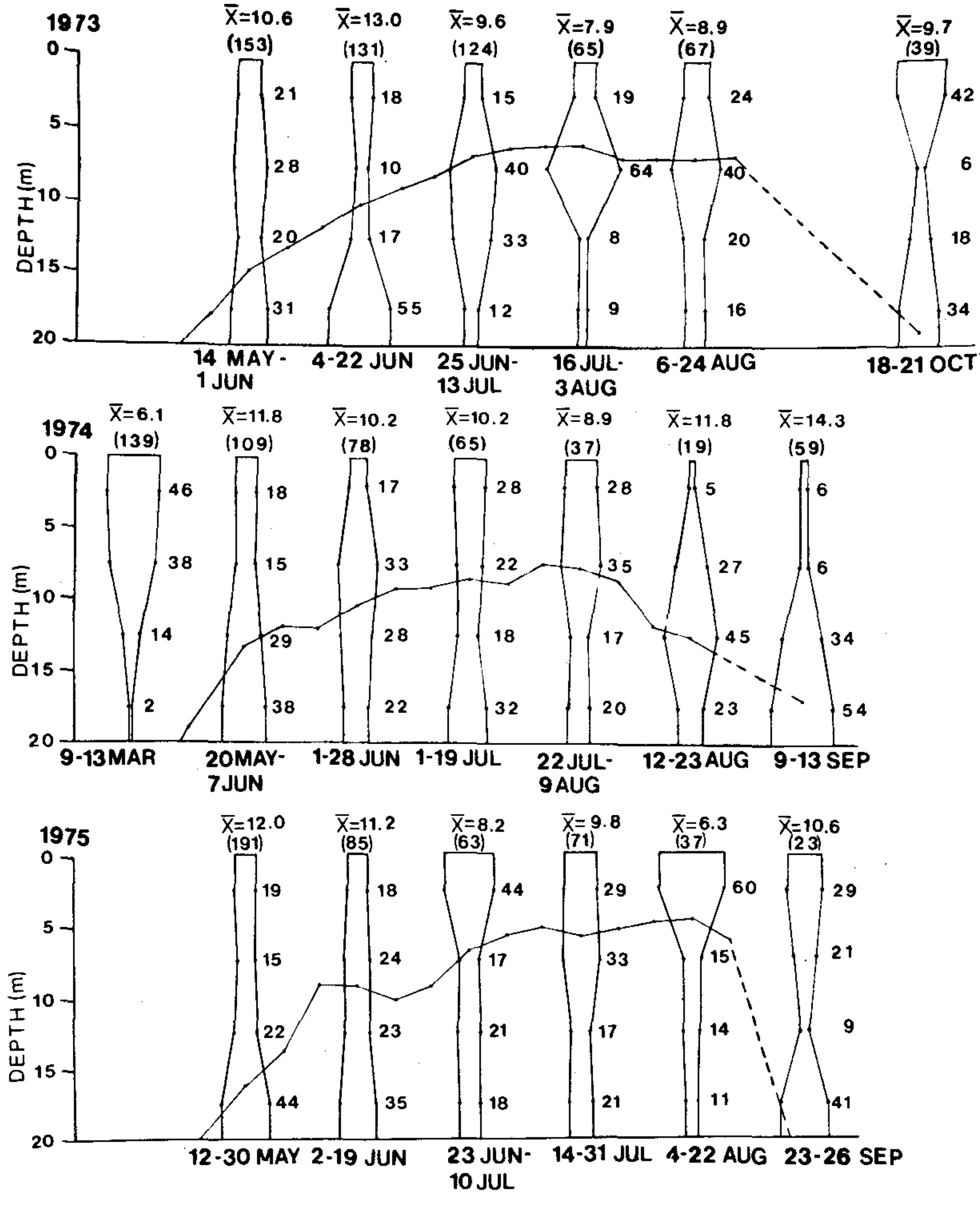

Figure 9. Depth distribution of black bullhead, represented by polygons that approximate the percentage (shown alongside the polygon) of fish captured at each depth interval, in relation to the 2 mg/l DO isopleth (curve); the $\bar{X}$ represents the mean depth (m), and the value in ( ) the total adjusted number caught in that interval.

Table 20. Mean annual growth increments (mm) (± 95% confidence interval) for black bullhead in Lake Arbuckle, 1971-1974.

Year of growth	Age[a] 1	2	3	4
1971	181.1±9.8 (26)			
1972	184.8±11.8 (27)	41.2±5.3 (26)		
1973	179.4±13.0 (26)	51.7±5.4 (27)	24.0±5.2 (26)	
1974	202.9±0.0 (1)	56.6±7.1 (26)	22.3±5.5 (27)	15.7±3.9 (26)

[a]Value in ( ) indicates number of fish.

but not as great as the fastest growth reported for Oklahoma (Houser and Bross 1963). The growth of age 2-4 black bullhead in Lake Arbuckle was less than the state average in all instances. The growth of bullhead in their first year of life may be overestimated.

The analysis of variance test showed no significant difference in growth increments for the first thru third year of life among all years of study, therefore, the least significant difference test was not used to test the differences between years. There was not a large difference in growth between any of the years except those involving the age 2 fish which indicated better growth in 1974 than 1972 and 1973. The age 2 growth exhibits Lee's phenomenon with fish showing slower growth the farther back that growth is back-calculated. This makes it difficult to ascertain whether a difference in growth between years is due to some environmental perturbation or selective mortality. The growth of age 4 black bullhead was represented by only one year, follows the trend of growth in length decreasing as the fish gets older (Table 20).

Instantaneous Growth Rates

The instantaneous growth rates of black bullhead are given for 1974 and 1975 for age groups 2 and 3 which had the best representation in the total collection (Table 21). The instantaneous growth rates of black bullhead could not be calculated in 1973 because field personnel cut the spine from the body rather than dearticulating it, as a result, the section could not be made through the basal process which we believed would result in frequent errors in age determination.

The instantaneous growth rates of age 2 black bullhead were positive in

Table 21. Relationship between the instantaneous growth coefficient (G) for black bullhead and mean percentage of the lake's volume containing $\geq$ 2 mg/l DO.

Median collection date	Interval (days)	Available habitat (%)	G values by age group 2	3
		1974		
5-29				
	20.0	79.9	19.70	3.03
6-18				
	21.0	69.8	9.37	-1.36
7-9				
	21.0	64.2	-0.87	17.43
7-30				
	17.5	77.1	-5.79	-11.86
8-16[a]				
	26.0	87.9	-5.06	-10.58
9-11				
	252.0	99.2	0.99	1.77
5-21-75			r = -0.13	-0.41
		1975		
5-21				
	19.5	80.7	1.83	-0.09
6-9[a]				
	21.5	69.4	1.43	0.14
6-30				
	21.0	49.6	3.13	-0.55
7-21				
	19.5	45.4	-0.66	1.71
8-9[a]				
	46.5	72.9	-5.44	-1.23
9-24[a]			r = -0.21	-0.53

[a]The exact median collection date was between this date and the following day.

the early summer of both years but negative in the mid- to late-summer, when the lake was strongly stratified (Table 21). A substantial part of the total annual growth of age 2 and 3 black bullhead in 1974 occurred between September 1973 and May 1974; the 2-year-old fish went from 173.7 to 260.7 mm length and the 3-year-old fish went from 228.4 to 328.3 mm (Appendix Tables A-15 and A-16). The instantaneous growth rates of age 3 black bullhead in 1973 and 1974 were irregular, with positive growth interspersed with negative population growth for both years of study (Table 24). The confidence limits on the mean weights, from which the growth coefficients were calculated, are fairly large, indicating that sampling variation may be responsible for the fluctuating growth rates (Appendix Table A-16). None of the correlation coefficients between the percent available habitat and the instantaneous growth rates were statistically significant and in fact, all of the r values were negative.

The population growth rage for age group 2 fish in the summer period of 1974 was 3.21 compared with -1.04 in the summer of 1975, but winter (1974-75) growth rate was less than the growth rate in the summer of 1974 for both age group 2 and 3 black bullheads, growth rates in the summer of 1974 were better than 1975.

Condition Factors

Condition factors were not calculated for black bullhead in 1973 due to difficulties encountered in aging the fish. In the summer of 1974, the condition factors for age group 2 black bullhead varied irregularly, increasing during the first half of the summer and then decreasing during late summer and fall (Figure 10). The mean condition factors for age group 3 black bullhead also varied irregularly during the summer and fall of 1974 but showed

Table 22. Comparison of growth rates (G) and mean weight gain for black bullhead for summer (stratified) and winter (destratified) intervals, 1974-75.

Median Collection Date	Interval	Days	Weight gain and (G) for age groups shown: 2	3
5-29-74				
	summer	105.5	50.0(3.21)	-20.1(-0.79)
9-11-74				
	winter	252.0	87.0(1.61)	99.9(1.43)
5-21-75				
	summer	128.0	-29.9(-1.04)	-8.8(-0.26)
9-24-75				

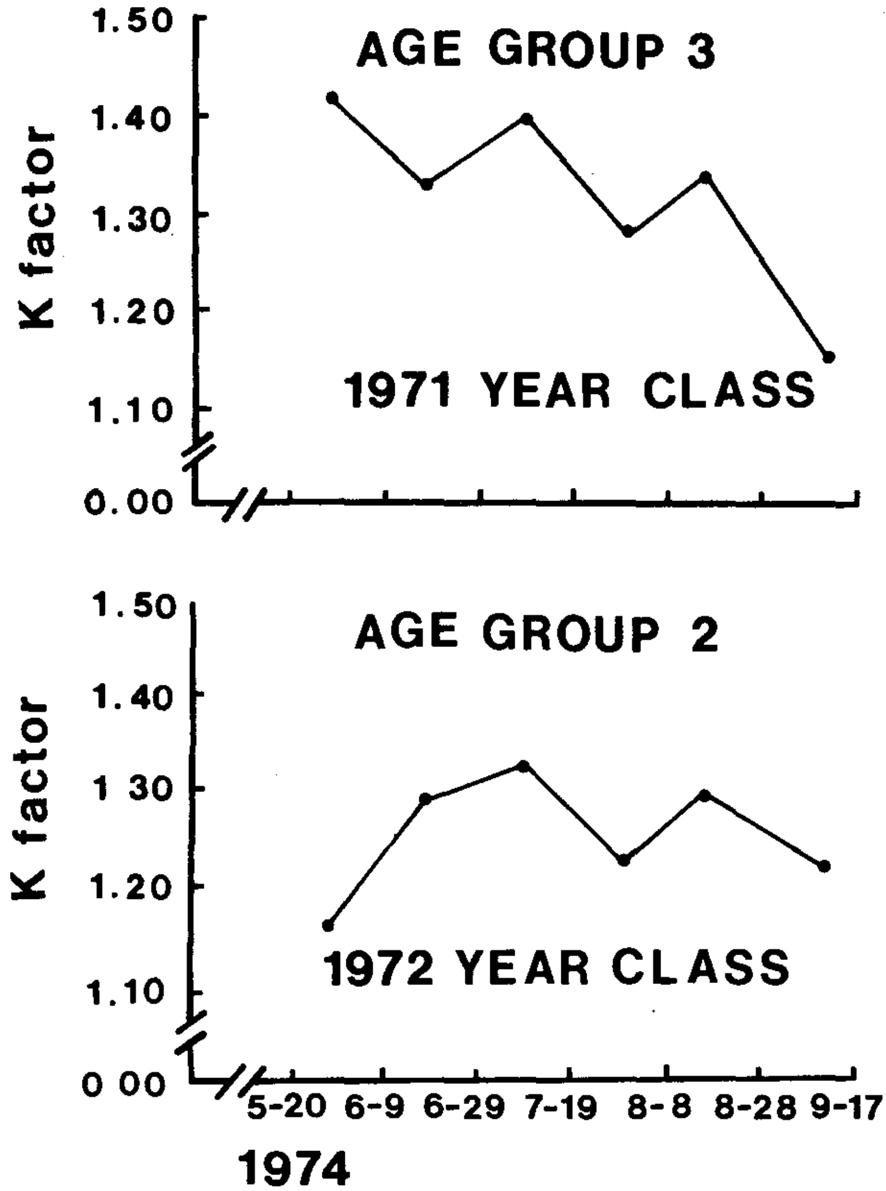

Figure 10. Temporal variation in condition factors (K factors) of age group 2-3 black bullhead, Arbuckle Lake, 1974.

a general downward trend over the summer (Figure 10). The mean K factor of the age group 2 black bullhead collected in 1974 was 1.26 compared with 1.36 (S.D. = 0.07) for age group 3; the difference between the age groups was significant, indicating that weight increases faster than length as they age.

Black bullhead do not appear to experience the decline in condition characteristic of other species until late in the summer. This agrees with their depth distribution which in contrast with the distributions of other species is not substantially effected by conditions of stratification.

Channel Catfish (*Ictaluris punctatus*)

Depth Distribution

The depth distribution of channel catfish was calculated from a collection of 311 fish in 1973, 176 fish in 1974, and 113 fish in 1975 (Table 2). Channel catfish were intermediate in depth distribution between crappie and black bullhead. Channel catfish are distributed throughout most of the water column during the early summer, often occurring below the depth of the 2 mg/l DO isopleth (Figure 11). Mean depth distribution of channel catfish was less, therefore, the fish were closer to the surface during mid- to late-summer. Channel catfish were distributed deeper when the lake destratified in the fall, perhaps indicating that the fish would show a preference for deeper water during the summer than allowed by the anoxic hypolimnion.

Annual Growth Rate

The mean annual growth increments are described for channel catfish ages 1-8 for 1967 to 1974 (Table 24). The growth of age 1 and 2 channel catfish in Lake Arbuckle was generally greater than the average growth rates for

Table 23. Relationship between the condition factor (K ± 95% confidence interval) for age group 2-3 black bullhead and mean percentage of the lake's volume containing ≥ 2 mg/l DO.

Collection date	Available habitat (%)	Age group 2 Sample size	Age group 2 K factor	Age group 3 Sample size	Age group 3 K factor
			1974		
5-20 to 6- 7	84.4	6	1.16±0.09	33	1.42±0.05
6- 8 to 6-28	74.8	5	1.29±0.22	27	1.33±0.08
6-29 to 7-19	67.8	21	1.33±0.10	41	1.40±0.06
7-20 to 8- 9	67.0	27	1.23±0.08	1	1.28±0.00
8-10 to 8-23	83.0	7	1.30±0.13	3	1.34±0.40
9- 9 to 9-13	92.6	3	1.22±0.45	8	1.15±0.10
		r =	-0.47		-0.44

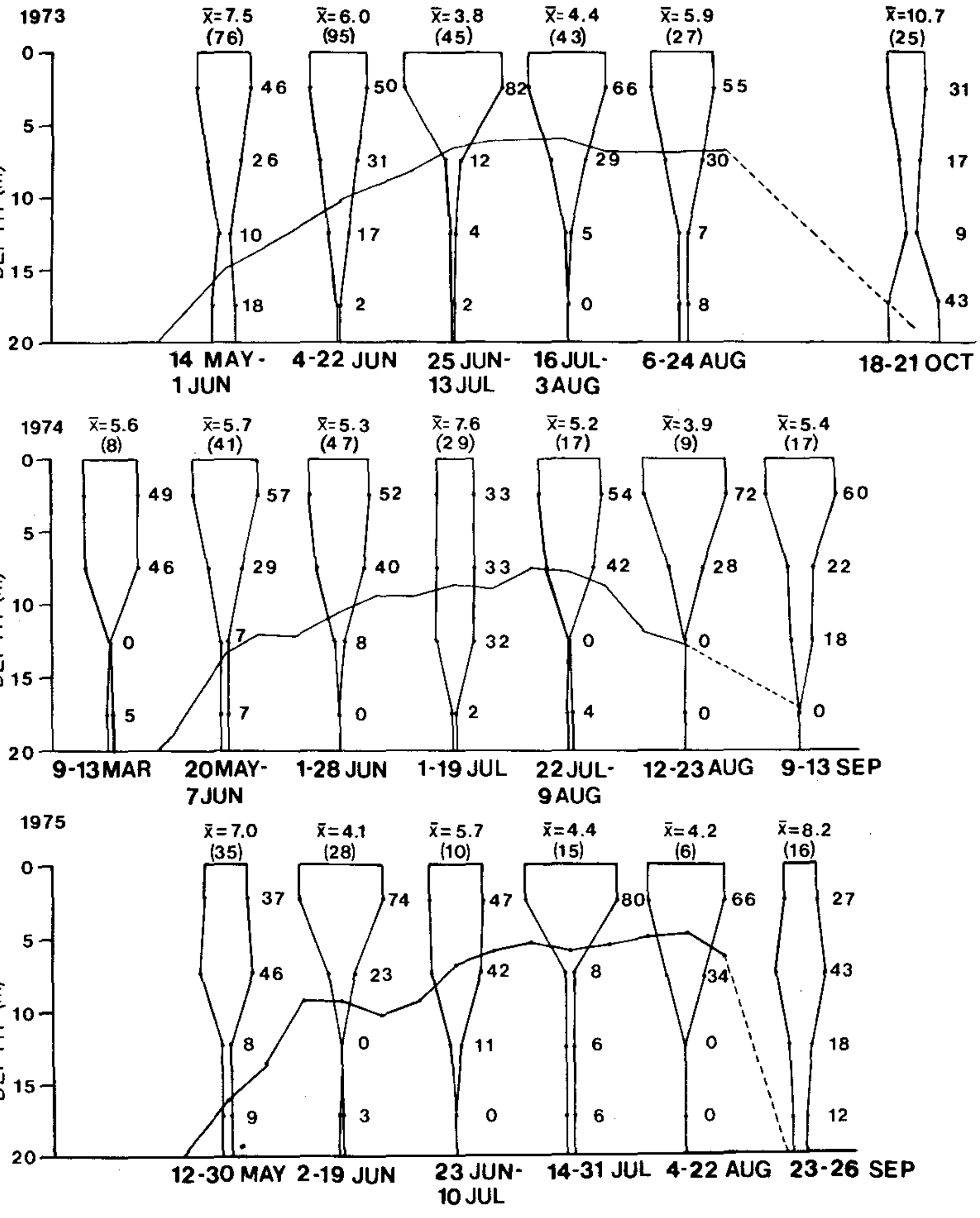

Figure 11. Depth distribution of channel catfish, represented by polygons that approximate the percentage (shown alongside the polygon) of fish captured at each depth interval, in relation to the 2 mg/l DO isopleth (curve); the $\bar{X}$ represents the mean depth (m), and the value in ( ) the total adjusted number caught in that interval.

Table 24. Mean annual growth increments (mm) (± 95% confidence interval) for channel catfish in Lake Arbucklc, 1967-1974.

Year of growth	Age[a] 1	2	3	4	5	6	7	8
1967	102.4±80.4 (4)							
1968	137.4±22.9 (4)	118.4±33.9 (4)						
1969	106.3±37.5 (5)	93.1±36.8 (4)	43.4±16.8 (4)					
1970	121.5±322.6 (2)	95.6±33.2 (5)	57.1±29.8 (4)	34.0±11.6 (4)				
1971	141.4±36.5 (7)	118.4±61.3 (2)	56.7±8.0 (5)	41.2±35.3 (4)	39.1±11.5 (4)			
1972	124.7±32.9 (8)	114.8±22.3 (7)	63.4±228.1 (2)	49.9±21.8 (5)	44.4±35.4 (4)	32.8±20.8 (4)		
1973	119.4±17.8 (8)	135.9±15.6 (8)	76.1±14.5 (7)	67.7±0.0 (2)	56.7±16.9 (5)	41.2±34.5 (4)	46.5±27.5 (4)	
1974		135.4±27.0 (8)	61.3±10.7 (8)	70.1±28.9 (7)	59.2±107.5 (2)	39.8±9.6 (5)	33.8±5.5 (4)	28.5±11.5 (4)

[a]Value in ( ) indicates number of fish.

Oklahoma (Houser and Bross 1963). The growth of age 3-8 channel catfish in Lake Arbuckle is generally below the state averages for those age groups with only 5 of the 21 growth estimates being higher than the state averages. The yearly growth estimates are characterized by small samples sizes and large variances which results in wide confidence intervals, as a result, the analysis of variance test did not indicate a significant difference among years for any of the age classes of channel catfish. Consequently, the least significant difference test was not used for testing for significant differences between years.

The numerical differences in first year growth between years is fairly large in most cases (Table 24). There were no consistent trends evident in the first year growth of channel catfish. The differences between years in second year growth are also quite large in most cases, but 1973 and 1974 growth was substantially greater than other years. The age 4 and 5 channel catfish show a definite Lee's phenomenon trend in their yearly growth rates (Table 24). There are sizable differences in growth rates between years for the older age channel catfish, but the wide confidence intervals and Lee's phenomenon effect make it difficult to place any significance upon the differences between growth in different years.

Instantaneous Growth Rates

Temporal variation in instantaneous growth rates of channel catfish were highly variable because of small sample sizes for each individual age class (Appendix Table A-17). This produced wide confidence intervals and made it difficult to draw any positive conclusions from the data. For age group 3 channel catfish, for which adequate samples were available, variation in G values did not follow a consistent pattern in all three years of the study

Table 25. Relationship between the instantaneous growth coefficient (G) for channel catfish and mean percentage of the lake's volume containing $\geq$ 2 mg/l DO.

Median collection date	Interval (days)	Available habitat (5)	G values by age group 3
		1973	
5-23[a]			
	19.5	88.4	11.87
6-12			
	21.0	71.9	7.76
7-3			
	21.0	55.8	-23.73
7-24			
	21.0	58.0	11.51
8-14			
	66.5	73.4	2.47
10-19[a]			
	221.5	99.2	-
5-29-74			r = 0.45
		1974	
5-29			
	20.0	79.9	-0.66
6-18			
	21.0	69.8	2.98
7-9			
	21.0	64.2	4.88
7-30			
	17.5	77.1	2.76
8-16[a]			
	26.0	87.9	3.05
9-11			
	252.0	99.2	1.98
5-21-75			r = -0.42
		1975	
5-21			
	19.5	80.7	17.93
6-9[a]			
	21.5	69.4	-23.79
6-30			
	21.0	49.6	-
7-21			
	19.5	45.4	-4.03
8-9[a]			
	46.5	72.9	-
9-24[a]			r = 0.60

[a]The exact median collection date was between this date and the following day.

(Table 25). In 1973, the growth rate was positive and fairly large except for the July sample when a substantial loss in weight occurs. The growth rate was negative during the first sampling period in 1974 and then positive for the rest of the summer. In 1975, the growth rate was positive during the first sampling period and then negative for the rest of the summer. The correlation coefficients between percent available habitat and the instantaneous growth coefficients were not statistically significant for any of the three years; the coefficients were positive in 1973 and 1975 but negative in 1974.

The seasonal growth rates for age 3 channel catfish indicate that the major portion of the total population growth occurs during the destratified winter period (Table 26). The weight gain during the summer period was less than the winter weight gain in all cases. Instantaneous growth rate in the summer of 1974 was better than in the summer of 1973 or 1974.

Condition Factors

The condition factors of age 3 channel catfish declined during the summer of 1973 and increased during the overwinter period, but in 1974 the condition factors remained fairly constant (Figure 12). The weighted mean K factor for the age group 3 channel catfish in the summer of 1973 (May thru August) was 0.74 compared with 0.70 for the summer of 1974; the difference between the mean of means was significant at the 5% level. There was a significant correlation between temporal variation in K factor of age group 3 channel catfish and available habitat in 1973 ($r = 0.96$, $P<.01$) but the correlation in 1974 was non-significant (Table 27).

The mean condition factors for age 6 channel catfish declined in the early summer of 1973, increased during mid-summer and declined again in the

Table 26. Comparison of growth rates (G) and mean weight gain (g) for age group 3 channel catfish for summer (stratified) and winter (destratified) intervals, 1973-75.

Median collection date	Interval	Days	Weight gain (G) 3
5-23-73			
	summer	82.5	21.0(1.67)
10-19-73			
	winter	288.0	169.0(2.47)
5-29-74			
	summer	105.5	90.2(2.64)
9-11-74			
	winter	252.0	240.4(1.98)
5-21-75			
	summer	128.0	-103.1(-4.00)
9-24-75			

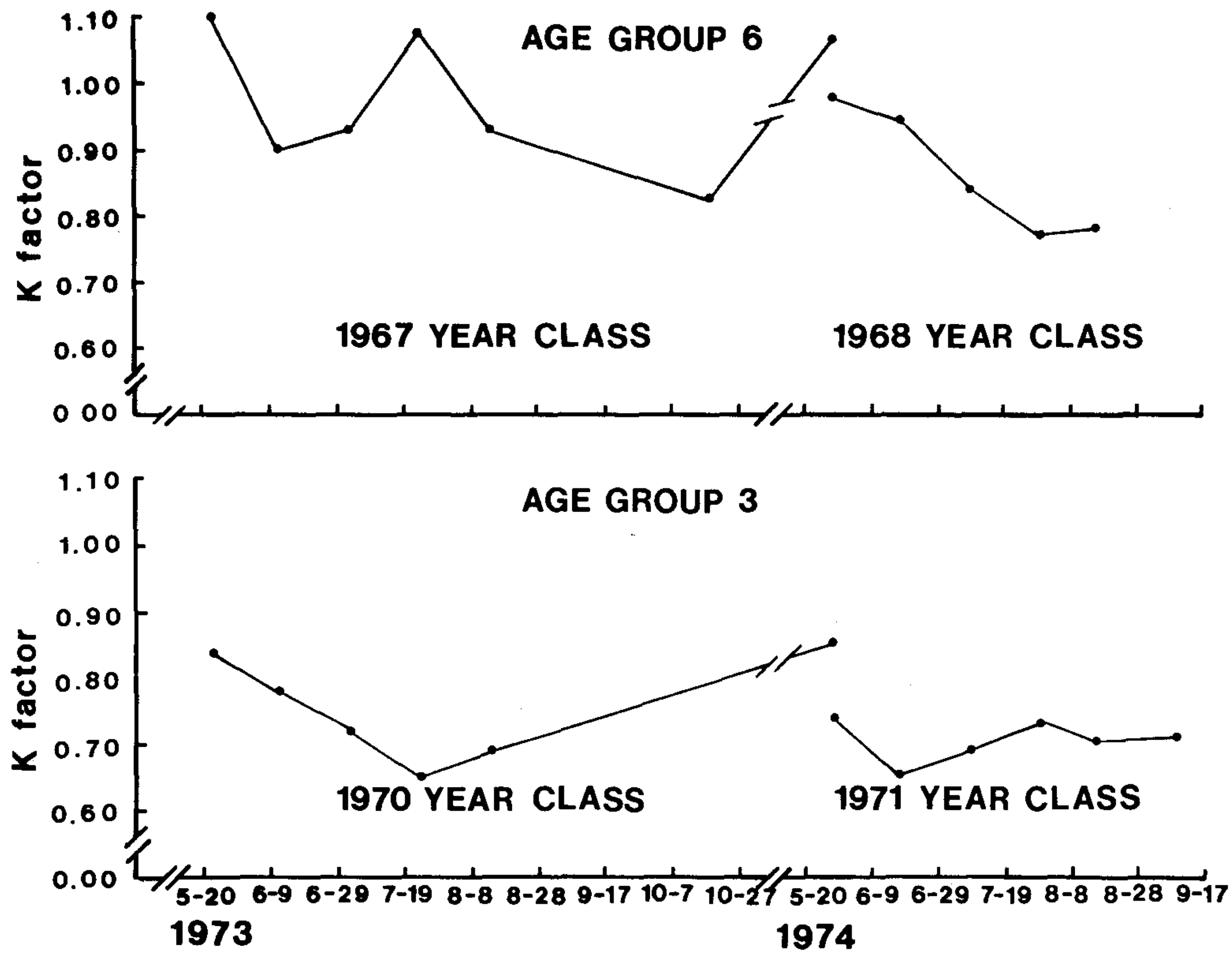

Figure 12. Temporal variation in condition factors (K factors) of age group 3 and 6 channel catfish, Arbuckle Lake, 1973-74.

Table 27. Relationship between the condition factor (K ± 95% confidence interval) for age group 3 and 6 channel catfish and mean percentage of the lake's volume containing ≥ 2 mg/l DO.

Collection date	Available habitat (%)	Age group 3		Age group 6	
		Sample size	K factor	Sample size	K factor
			1973		
5-15 to 6- 1	94.8	2	0.84±0.48	15	1.10±0.11
6- 2 to 6-22	81.9	3	0.78±0.10	17	0.90±0.08
6-23 to 7-13	63.6	3	0.72±0.17	11	0.93±0.09
7-14 to 8- 3	54.7	1	0.65±0.00	9	1.08±0.26
8- 4 to 8-24	56.3	2	0.69±0.69	5	0.93±0.31
10-18 to 10-21	99.4	-	-	8	0.83±0.12
5-20 to 6- 7	84.4	1	0.85±0.00	2	1.07±0.23
		r =	0.96**		-0.13
			1974		
5-20 to 6- 1	84.4	1	0.74±0.00	2	0.98±1.46
6- 8 to 6-28	74.8	3	0.65±0.14	8	0.95±0.09
6-29 to 7-19	67.8	6	0.69±0.05	10	0.84±0.13
7-20 to 8- 9	67.0	10	0.73±0.05	2	0.77±0.23
8-10 to 8-23	83.0	3	0.70±0.08	3	0.78±0.07
9- 9 to 9-13	92.6	6	0.71±0.04	-	-
		r =	0.20		0.42

** Significant at $P \leq 0.01$

the fall (Figure 12). The condition factor increased during the destratified overwinter period in 1973-74. In 1974, the mean condition factor of the 1968 year-class and age group 6 fish declined continuously over the stratified summer period. The mean condition factor for age group 6 channel catfish in the summer (May thru August) of 1973 was 0.96, in 1974 it was 0.87, the difference between these two weighted mean of means was significant at the 1% level. There was also a highly significant difference between the age group 3 and age group 6 channel catfish each year, indicating that with increasing age, they increase weight faster than length.

CONCLUSIONS

1. Using the 2 mg/1 DO isopleth as a boundry defining the limit of suitable fish habitat, there was more suitable fish habitat available in 1974 compared with 1973 and 1975.

   a. Operation of a compressed air gun for 83 days, 10 July thru 10 October in 1973 did not disrupt stratification, the effects, if any were very localized; as much as 48% (20 July) of the total volume of Lake Arbuckle contained less than 2 mg/1 DO.

   b. In 1974 and 1975 an axial flow pump of the Garton design was operated. In 1974 the pump ran for 46 days (17 July thru 31 August) during which time the volume of the lake with less than 2 mg/1 DO was never more than 39%; in 1975 the pump ran for 104 days (2 June thru 12 September) and as much as 59% of the volume contained less than 2 mg/1 DO.

   c. The average volume of Lake Arbuckle containing more than 2 mg/1 DO during 1973-75 was 72.9%, 82.7% and 72.6%. In 1975, with a faster RPM, therefore, a greater pumping capacity and a longer running interval, the temperature differential from top to bottom was lowered, but the volume of the lake with more than 2 mg/1 DO was less than in 1974. The temperature of the hypolimnion was increased over 1974, perhaps increasing bacterial respiration which resulted in a decrease in the oxygen concentration; alternately, the increased mixing in 1975 could have transported algal cells out of the euphotic zone thereby reducing the P/R ratio, however, neither bacterial respiration nor primary production was measured.

   d. Compared with 1968-69 and 1973, Lake Arbuckle was more nearly orthograde in September 1974 and 1975, which, along with observations on DO profiles, indicates that the operation of the Garton pump substantially influenced physicochemical profiles.

2. Gill net catch indicated a decline in abundance of gizzard shad during 1973 thru 1975 (49.98 to 17.43%) which coincided with an increase in abundance of white bass (3.15 to 9.47%), but there was no major change in species composition which might be attributed to perturbations from efforts to destratify the reservoir.
3. Depth distributions of gizzard shad, white crappie, freshwater drum, black bullhead and channel catfish were influenced by physicochemical conditions of lake stratification. The mean depth of capture of all species was substantially greater in September and October collections when the depth of the 2 mg/l DO isopleth deepened.
4. Our assessment of the effect of the artificial mixing upon annual fish growth is confounded by two factors; (i) a significant amount of natural variation between years of growth during uears when no artificial efforts were made to aerate or destratify the lake; (ii) the impact of Lee's phenomenon in back-calculating growth histories of fish in previous years which, if operating, indicates a larger growth occurring in the most recently back-calculated years of growth than for earlier years.
   a. An analysis of variance test indicated significant differences among years for many age groups, and a least significant difference test often indicated significant differences between annual growth in 1974 compared to other years for a given age group. Although growth in 1974 was sometimes greater than in other years in one age group, it was lower in 1974 for other age groups. The effect on

annual growth gave positive and negative effects within and among species that no conclusive evaluation can be made regarding the impact of the aeration apparatus.

b. Including all species and age groups and differences which were not statistically significant at the 5% level, there were high frequency of occurrences where growth in 1974 was greater than in any previous years. A Chi-square analysis was made of the observed frequency (f_o) of cases in which growth in 1974 for an age group was greater than growth in other years for that age group, assuming that the expected frequency (f_e) of first rank by chance alone would be only once out of the number of years in which growth was obtained for each age group. A total of 22 age groups were examined for the five species, which represented 107 age group-years. The observed frequency (f_o) of times when growth in 1974 was larger than the others of the age group was 37% compared with an expected frequency (f_e) of 22%; the difference (f_o-f_2) was highly significant (X^2 = 10.23, p + 0.0018). Thus, there was a trend over all species for growth in 1974 to be larger than the annual growth before the operation of the Garton pump.

5. In many age groups for most species, instantaneous growth rates indicated that the major portion of the population growth occurred during the destratified overwinter period. In fact, the population growth rate is negative in many cases during the stratified summer period. This could be due to selective mortality operating on the larger fish of an age class during the summer months or the negative growth rate could be an actual individual weight loss resulting from the higher maintenance energy

required at the high summer water temperatures, especially when fish are forced into the hot epilimnion by the anoxic waters of the hypolimnion. Feeding efficiency of fish may decrease when they are forced to live in water which produces thermal stress and excess metabolic demand. Also, the fish may exhaust their food supply as the summer progresses and stratification shrinks the available habitat of the prey organisms.

6. The mean condition factors by age groups showed a trend of decreasing through the summer when the lake was stratified. The condition factors were generally larger in the fall and spring period reflecting in part gonadal development and improved condition in the destratified part of the year.
7. It appears from our analysis that stratification has a negative impact on fish growth and well-being; complete mixing and destratification of the lake for an entire year should improve fish growth, however, we still do not have an assessment of the overall ecological impact of aeration and artificial destratification on the productivity of the whole lake ecosystem.

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APPENDIX

Table A-1. Numerical abundance in Lake Arbuckle of 15 species of fishes collected by gill netting in 1973. Sites C, D and E are locations outside the influence of the aerator; site R was in the proximity of the aerator. Species abundance is also shown as a percent of the total number collected by site.

Species	Site C		Site D		Site E		Site R		Grand total	
	No.	%	No.	%	No.	%	No.	%	No.	%
Gizzard shad	647	44.93	656	54.17	396	41.16	823	57.51	2522	49.98
White crappie	267	18.54	189	15.61	152	15.80	226	15.79	833	16.51
Black bullhead	166	11.53	79	6.52	225	23.39	106	7.41	579	11.47
Freshwater drum	148	10.28	104	8.42	81	8.42	78	5.45	409	8.11
Channel catfish	87	6.04	88	7.27	52	5.41	84	5.87	311	6.16
White bass	56	3.89	33	2.73	11	1.14	59	4.12	159	3.15
Carp	28	1.94	36	2.97	19	1.98	6	0.42	89	1.76
Walleye	17	1.18	15	1.24	10	1.04	7	0.49	49	0.97
Largemouth bass	10	0.69	5	0.41	4	0.42	9	0.63	28	0.55
River carpsucker	6	0.42	6	0.50	3	0.31	8	0.56	23	0.46
Black crappie	3	0.21	0	0.00	3	0.31	16	1.12	22	0.44
Longnose gar	2	0.14	1	0.08	5	0.52	0	0.00	8	0.16
Blue catfish	3	0.21	0	0.00	1	0.10	1	0.07	5	0.10
Yellow bullhead	0	0.00	0	0.00	0	0.00	5	0.35	5	0.10
Flathead catfish	0	0.00	1	0.08	0	0.00	3	0.21	4	0.08
	1440	100.00	1213	100.00	962	100.00	1431	100.00	5046	100.00
Site totals as % of grand total	28.54		24.04		19.06		28.36		100.00	

Table A-2. Numerical abundance in Lake Arbuckle of 14 species of fishes collected by gill netting in 1974. Sites C, D and E are locations outside the influence of the aerator; site R was in the proximity of the aerator. Species abundance is also shown as a percent of the total number collected by site.

Species	Site C No.	Site C %	Site D No.	Site D %	Site E No.	Site E %	Site R No.	Site R %	Grand total No.	Grand total %
Gizzard shad	252	26.22	145	24.66	132	24.22	476	37.87	1005	29.99
White crappie	328	34.13	133	22.62	140	25.69	376	29.91	977	29.16
Black bullhead	122	12.70	98	16.67	145	26.61	141	11.22	506	15.10
Freshwater drum	94	9.78	63	10.71	69	12.66	73	5.81	299	8.92
Channel catfish	62	6.45	37	6.29	29	5.32	48	3.82	176	5.25
White bass	66	6.87	90	15.31	12	2.20	98	7.80	266	7.94
Carp	12	1.25	6	1.02	7	1.28	7	0.56	32	0.95
Walleye	13	1.35	10	1.70	4	0.73	9	0.72	36	1.07
Largemouth bass	8	0.83	2	0.34	4	0.73	6	0.48	20	0.60
River carpsucker	1	0.10	2	0.34	0	0.00	4	0.32	7	0.21
Black crappie	0	0.00	1	0.17	0	0.00	10	0.80	11	0.33
Longnose gar	1	0.10	1	0.17	2	0.37	0	0.00	4	0.12
Blue catfish	2	0.21	0	0.00	1	0.18	1	0.08	4	0.12
Flathead catfish	0	0.00	0	0.00	0	0.00	8	0.64	8	0.24
	961	99.99	588	100.00	545	99.99	1257	100.00	3351	100.00
Site totals as % of grand total	28.68		17.53		16.26		37.51		99.98	

Table A-3. Numerical abundance in Lake Arbuckle of 18 species of fishes collected by gill netting in 1975. Sites C, D and E are locations outside the influence of the aerator; site R was in the proximity of the aerator. Species abundance is also shown as a percent of the total number collected by site.

Species	Site C		Site D		Site E		Site R		Grand total	
	No.	%	No.	%	No.	%	No.	%	No.	%
Gizzard shad	112	17.28	78	18.66	67	11.45	253	19.84	510	15.92
White crappie	154	23.77	102	24.40	151	25.81	436	34.20	843	26.32
Black bullhead	129	19.91	61	14.59	170	29.06	110	8.63	470	14.67
Freshwater drum	85	13.12	77	18.42	113	19.32	156	12.24	431	13.46
Channel catfish	27	4.17	24	5.74	22	3.76	40	3.14	113	3.53
White bass	111	17.13	58	13.88	35	5.98	73	5.73	277	8.65
Carp	3	0.46	5	1.20	15	2.56	9	0.71	32	9.65
Walleye	9	1.39	3	0.72	2	0.34	5	0.39	19	0.59
Largemouth bass	6	0.93	2	0.48	1	0.17	5	0.39	14	0.44
River carpsucker	5	0.77	2	0.48	2	0.34	19	1.49	28	0.87
Black crappie	0	0	3	0.72	0	0	6	0.47	9	0.28
Longnose gar	1	0.15	0	0	0	0	0	0	1	0.03
Flathead catfish	0	0	0	0	1	0.17	11	0.86	12	0.37
Warmouth	3	0.46	0	0	0	0	23	1.80	26	0.81
Green sunfish	0	0	0	0	0	0	9	0.71	9	0.28
Longear	0	0	0	0	0	0	15	1.18	15	0.47
Golden redhorse	0	0	0	0	3	0.51	0	0	3	0.09
Bluegill	3	0.46	3	0.72	3	0.51	105	8.24	114	3.56
	648	100.00	418	100.01	585	99.98	1275	100.02	2926	99.99
Site totals as % of grand total	22.15		14.29		19.99		43.57		100.00	

Table A-4. Temperature (°C) and dissolved oxygen (mg/l) at site R, Lake Arbuckle, 1973.

	17 May[1]	3 July		10 July		17 July		24 July		1 Aug		8 Aug		16 Aug		24 Aug	
Depth(m)	Temp	Temp	DO	Temp	DO	Temp	DO	Temp	DO	Temp	DO	Temp	DO	Temp	DO	Temp	DO
Surface	25.3	28.2	6.2	29.5	7.6	28.6	8.1	29.3	8.0	28.0	7.8	27.9	7.6	28.3	8.0	28.0	8.1
1	25.3	28.2	6.2	29.2	7.6	28.2	8.1	29.0	8.0	28.0	7.7	27.8	7.6	28.2	8.0	28.0	8.1
2	24.9	27.8	6.1	28.8	7.5	27.5	7.8	28.7	8.0	27.9	7.7	27.8	7.6	28.1	8.0	28.1	8.0
3	24.5	27.8	6.0	28.5	7.4	27.0	7.5	28.2	7.8	27.8	7.7	27.2	7.5	28.0	7.7	28.0	7.9
4	24.3	27.5	6.0	28.3	7.3	27.0	7.2	28.1	7.1	26.7	7.6	27.2	7.4	28.0	7.7	28.0	7.8
5	23.9	27.5	6.0	28.1	4.1	26.7	6.4	27.7	6.3	27.5	7.6	27.0	7.2	27.8	7.1	28.0	7.6
6	23.9	26.2	3.0	27.5	2.6	26.2	2.4	26.8	3.5	27.1	7.6	27.0	6.4	27.5	5.3	27.9	7.4
7	22.5	23.9	0.8	23.6	0.5	25.5	1.3	26.0	1.2	27.0	7.4	27.0	5.9	27.3	3.3	27.6	1.8
8	21.8	23.2	0.6	22.9	0.1	23.8	0.2	24.6	0.1	26.4	5.2	26.6	3.4	26.5	1.7	26.8	0.1
9	21.5	22.5	0.4	22.5	0	21.7	0.1	22.0	0.1	23.1	0.4	25.3	0.2	26.0	0.9	25.8	0.1
10	21.2	21.8	0.4	22.1	0	21.4	0.1	21.3	0.1	22.0	0.4	23.7	0.2	24.6	0.7	24.5	0.1
11	20.9	21.2	0.4	21.7	0	20.5	0.1	20.7	0.1	21.3	0.5	22.2	0.2	22.7	0.6	23.0	0.1
12	20.9	20.9	0.4	21.1	0	20.4	0.1	20.5	0.2	20.6	0.5	21.8	0.2	22.1	0.6	22.2	0.1
13	20.5	20.8	0.3	21.0	0	20.1	0.1	20.3	0.2	20.3	0.5	21.4	0.2	21.3	0.6	21.7	0.1
14	20.2	20.5	0.2	20.8	0	20.0	0.1	20.0	0.2	20.0	0.5	20.9	0.2	21.0	0.6	21.1	0.1
15	19.9	20.3	0.2	20.6	0	19.9	0.1	19.8	0.2	19.9	0.5	20.8	0.2	20.9	0.6	20.9	0.1
16	19.9	20.1	0.2	20.3	0	19.7	0.1	19.5	0.2	19.8	0.5	20.5	0.2	20.7	0.7	20.4	0.1
17	19.9	20.0	0.2	19.9	0	19.4	0.1	19.2	0.2	19.7	0.5	20.0	0.2	20.4	0.7	20.0	0.1
18	19.9	19.8	0.2	19.6	0	19.1	0.1	18.9	0.2	19.2	0.5	19.9	0.2	20.0	0.7	19.9	0.1
19	18.8	19.4	0.2	19.3	0	18.7	0.1	18.6	0.2	18.9	0.5	19.5	0.2	19.5	0.8	19.6	0.2
20	18.2	19.0	0.2	18.9	0	18.4	0.1	18.1	0.2	18.5	0.5	18.9	0.2	19.1	0.9	18.7	0.2
21	17.9	18.5	0.2	18.2	0	17.2	0.1	17.8	0.2	18.1	0.5	18.2	0.3	18.6	1.0	18.0	0.2
22	17.5	16.1	0.2	17.5	0	16.6	0.1	16.4	0.2	17.6	0.5	17.4	0.3	17.4	1.2	17.2	0.5
23	16.9	15.5	0.2	16.2	0	15.6	0.1	15.7	0.2	16.8	0.5	16.4	0.3	16.6	1.4	16.1	0.6
24	16.5	15.0	0.2	14.9	0	14.9	0.1	15.5	0.2	16.0	0.5	15.6	0.3	15.6	1.5	15.6	0.8
25	16.0	14.0	0.2							15.5	0.5			15.3	1.5		
26	16.0	13.6	0.2							14.9	0.5			15.1	1.3		

[1] Dissolved oxygen was not measured on this day

Table A-5. Temperature (°C) and dissolved oxygen (mg/l) at site R, Lake Arbuckle, 1974.

	12 Mar		22 May		29 May		3 June		10 June		20 June		27 June		1 July	
Depth(m)	Temp	DO	Temp	DO	Temp	DO	Temp	DO	Temp	DO	Temp	DO	Temp	DO	Temp	DO
Surface	12.4	9.8	24.5	8.0	25.5	8.0	25.5	7.4	26.5	8.6	27.4	8.2	26.5	9.2	26.5	9.1
1	12.4	9.8	24.5	8.2	25.5	8.0	25.5	7.4	26.5	8.6	27.4	8.2	26.5	9.2	26.5	9.1
2	21.1	10.0	24.5	8.6	25.5	8.3	25.5	8.0	26.3	8.7	27.4	8.6	26.5	9.5	26.5	9.3
3	12.0	10.3	24.5	8.6	25.3	8.3	25.2	8.1	26.1	8.8	27.2	8.8	26.5	9.8	26.5	9.6
4	11.9	10.5	24.5	8.6	25.2	8.3	25.2	8.2	25.8	8.8	27.2	8.8	26.5	9.9	26.5	9.9
5	11.8	10.7	24.2	8.7	25.0	8.3	25.2	8.3	25.8	8.7	27.2	8.8	26.5	9.7	26.5	9.9
6	11.7	10.9	24.0	8.7	24.8	8.1	25.0	8.3	25.6	8.7	27.1	8.1	26.5	9.7	26.5	9.7
7	11.4	11.1	23.8	8.5	24.8	8.1	25.0	8.1	25.6	8.6	27.0	5.6	26.5	9.4	26.4	9.1
8	11.0	11.2	23.8	7.8	24.8	7.8	25.0	6.3	25.5	7.6	26.5	4.8	26.3	6.3	26.4	6.4
9	10.8	11.3	23.0	6.7	24.5	7.3	24.9	6.2	25.3	6.9	25.9	2.8	25.4	2.1	25.4	2.1
10	10.6	11.4	22.0	5.6	24.2	7.0	24.5	3.8	25.0	6.2	25.5	2.2	25.0	0.8	25.0	1.0
11	10.6	11.4	19.0	4.9	23.1	3.5	23.5	2.7	24.8	5.0	25.0	1.7	24.0	0.8	24.1	1.0
12	10.6	11.5	18.5	5.0	20.5	3.5	23.0	1.9	23.8	3.4	24.5	1.2	23.7	0.9	23.6	0.9
13	10.7	11.5	18.0	5.0	19.5	3.7	21.0	1.9	23.1	1.2	23.0	0.4	22.6	0.9	22.6	0.9
14	10.9	11.5	17.5	4.9	19.2	3.7	20.5	2.4	20.1	1.2	23.0	0.4	21.5	0.9	21.4	0.9
15	11.0	11.5	17.0	5.1	18.6	3.7	19.5	2.9	19.4	1.8	21.2	0.4	20.5	1.0	20.4	0.9
16	11.0	11.5	17.0	5.0	18.2	3.5	18.8	2.9	19.1	1.8	20.2	0.4	19.5	1.0	19.4	0.9
17	11.1	11.5	16.5	4.9	18.0	3.4	18.5	2.8	18.9	1.4	19.2	0.4	18.8	1.0	18.9	0.9
18	11.6	11.5	16.5	4.6	18.0	3.4	18.0	2.6	18.0	1.5	18.8	0.4	18.5	1.0	18.5	0.9
19	12.0	11.5	16.5	4.5	17.8	3.4	17.5	1.6	17.9	1.6	18.5	0.4	18.2	1.0	18.2	0.9
20	12.1	11.5	15.5	3.2	17.0	3.1	17.0	1.4	17.6	1.75	18.2	0.4	17.2	1.0	17.2	0.9
21							16.8	1.4								
22																
23																
24																
25																
26																

Table A-5. continued

	8 July		15 July		22 July		29 July		5 Aug		15 Aug		11 Sept	
Depth(m)	Temp	DO	Temp	DO	Temp	DO	Temp	DO	Temp	DO	Temp	DO	Temp	DO
Surface	28.0	8.4	29.1	8.8	31.0	8.6	30.2	8.3	27.5	8.0	27.5	7.5	24.6	7.7
1	28.0	8.4	29.1	8.8	31.0	8.6	30.2	8.3	27.5	8.0	27.5	7.5	24.5	7.6
2	28.0	8.4	29.1	8.6	31.0	8.6	30.0	8.2	27.5	7.8	27.2	7.4	24.4	7.5
3	28.0	8.4	29.0	8.5	30.9	8.5	29.8	8.1	27.5	7.5	26.9	7.0	24.3	7.2
4	28.0	8.3	28.9	8.3	30.5	8.4	29.8	7.9	27.5	7.2	26.8	6.9	24.2	7.2
5	27.8	7.5	28.9	8.3	29.3	8.0	29.5	7.5	27.4	7.0	26.8	6.9	24.1	6.8
6	27.0	6.1	28.8	8.5	28.5	7.8	29.0	7.3	27.2	6.8	26.8	6.8	24.1	6.6
7	26.5	5.2	27.3	8.3	28.2	6.0	27.8	6.5	27.1	6.8	26.5	6.8	24.0	6.4
8	26.0	4.6	27.0	4.1	27.1	1.9	27.2	1.8	27.1	6.6	26.2	6.1	24.0	5.9
9	26.0	3.6	26.0	1.7	26.5	0	26.5	0.5	26.9	6.5	25.9	5.2	24.0	4.8
10	25.5	3.1	25.3	0	25.9	0	25.8	0	25.2	6.1	25.5	5.1	24.0	4.7
11	25.4	1.3	25.1	0	25.4	0	25.4	0	25.1	6.2	24.8	5.3	24.0	4.5
12	24.2	0.1	24.8	0	24.9	0	25.0	0	24.5	6.4	24.2	5.1	24.0	4.4
13	24.0	0.1	23.0	0	23.4	0	24.0	0	24.5	6.4	23.6	4.8	24.0	4.4
14	22.0	0.1	21.1	0	22.0	0	22.5	0	24.0	3.8	23.5	4.7	23.8	4.4
15	20.9	0	20.1	0	20.5	0	21.2	0	22.0	3.4	23.2	3.5	23.7	4.3
16	19.5	0	19.5	0	19.6	0	19.4	0	20.5	0	22.7	1.4	23.2	2.9
17	18.6	0	18.6	0	19.2	0	18.8	0	19.8	0	21.9	0	23.1	2.0
18	18.0	0	17.9	0	18.6	0	18.2	0	18.5	0	21.4	0	22.0	1.7
19	18.0	0	17.4	0	17.8	0	17.8	0	18.0	0	20.0	0	21.5	1.6
20	17.5	0	17.1	0	17.8	0	17.2	0	17.0	0.2			20.0	1.4
21			16.9	0									17.7	1.3
22			15.5	0									16.7	1.3
23			15.0	0									16.2	1.3
24													16.1	1.3
25														
26														

Table A-6. Temperature (^{0}C) and dissolved oxygen (mg/l) at site R, Lake Arbuckle, 1975.

	16 May		19 May		28 May		5 June		13 June		20 June		25 June		7 July	
Depth(m)	Temp	DO	Temp	DO	Temp	DO	Temp	DO	Temp	DO	Temp	DO	Temp	DO	Temp	DO
Surface	23.2	9.0	22.1	9.2	23.9	12.0	24.2	8.4	23.9	7.3	25.5	7.4	26.9	8.7	28.8	9.4
1	23.1	9.2	22.0	9.1	23.8	12.2	24.2	8.4	23.6	7.2	25.2	7.4	26.8	8.6	28.5	9.5
2	21.6	9.4	21.3	8.8	23.5	11.9	23.9	8.2	23.2	7.1	25.0	7.1	26.8	8.6	28.2	9.6
3	21.2	9.2	21.2	8.7	23.3	11.6	23.4	7.6	23.1	6.5	24.8	6.9	26.8	8.6	27.2	8.6
4	21.0	8.8	21.2	8.5	23.2	11.4	23.2	7.4	23.0	5.8	23.4	6.5	26.5	8.4	26.5	6.2
5	20.8	8.5	20.5	7.2	23.3	11.4	23.0	6.7	23.0	5.6	24.2	6.0	26.3	7.9	25.2	3.2
6	20.4	7.8	20.4	7.0	23.2	11.2	23.0	6.5	22.9	4.9	24.2	6.0	26.1	7.2	24.8	2.2
7	18.9	6.0	19.4	5.2	22.7	7.3	22.8	6.0	22.8	4.2	24.0	5.5	24.8	3.5	24.0	2.8
8	21.2	2.9	23.9	5.1	24.0	2.9	22.4	5.3	21.2	2.9	23.9	5.1	24.0	2.9	23.6	1.8
9	18.1	5.2	17.0	4.2	20.8	4.0	21.2	2.4	21.0	2.3	22.5	2.8	23.2	2.1	23.2	1.4
10	17.8	5.1	16.4	4.1	20.3	3.3	20.6	1.6	21.8	2.3	22.2	2.5	22.4	2.0	23.0	1.2
11	16.4	4.8	16.1	4.1	19.2	2.8	19.9	1.4	21.3	2.2	21.6	1.6	22.0	1.7	22.0	0.9
12	15.8	4.9	15.5	4.1	18.6	2.9	19.2	2.2	20.1	1.9	21.0	1.6	22.0	1.8	22.8	0.4
13	15.4	5.0	15.0	4.2	17.7	3.0	19.0	2.0	20.0	1.4	20.8	0.8	21.9	1.4	22.8	0.2
14	15.2	4.8	14.6	4.3	17.2	3.1	18.8	2.2	19.9	1.3	20.5	0.5	21.6	0.6	22.5	0.3
15	14.9	5.0	14.3	4.4	16.9	3.0	18.0	2.6	19.5	0.8	20.2	0.4	21.1	0.1	22.1	0.1
16	14.1	5.0	13.9	4.2	16.6	2.7	17.8	2.0	19.2	0.8	20.1	0.3	21.0	0.1	21.9	0.1
17	13.9	5.0	13.5	4.4	16.2	2.9	17.4	1.4	19.1	0.5	20.0	0.2	20.9	0.1	21.5	0.1
18	13.5	5.2	13.0	4.4	15.8	3.3	16.5	1.1	18.9	0.4	19.9	0.1	20.7	0.1	21.2	0.0
19	12.9	4.8	12.5	4.2	15.0	3.3	16.5	1.1	18.4	0.1	19.8	0.0	20.3	0.0	21.1	0.0
20	12.1	4.8	11.9	3.5	14.3	3.0	16.0	1.0	18.0	0.1	19.5	0.0	20.0	0.0	21.0	0.0
21	11.9	4.3	11.1	3.2	13.2	1.6	15.4	0.8	17.8	0.1	19.1	0.0	20.0	0.0	20.8	0.0
22	11.4	3.8	10.9	3.1	12.6	0.3	14.1	0.2	17.2	0.1	19.0	0.0	19.7	0.0	20.2	0.0
23	11.2	3.0	10.5	2.4	12.4	0.2	13.8	0.1	16.2	0.0	18.2	0.0	19.0	0.0	19.8	0.0
24	11.1	3.0	10.4	2.2	12.1	0.1	12.8	0.1	15.0	0.0	16.8	0.0			18.2	0.0
25	11.0	2.7	10.2	1.6			12.2	0.1	13.5	0.0	14.9	0.0			16.0	0.0
26	11.0	2.0	10.2	0.4			12.0	0.0	13.0	0.0	13.9	0.0			14.8	0.0

Table A-6. (cont.) Temperature and dissolved oxygen measurements taken at site R in Lake Arbuckle during 1975..

	14 July		21 July		28 July		4 Aug		11 Aug		18 Aug		22 Sept	
Depth (m)	Temp	DO	Temp	DO	Temp	DO	Temp	DO	Temp	Do	Temp	DO	Temp	DO
Surface	27.9	7.3	29.3	8.4	28.2	7.2	29.5	8.2	29.2	8.5	28.0	6.6	22.9	7.8
1	27.8	7.3	29.1	8.4	27.8	7.3	29.2	8.3	29.0	8.6	27.5	6.6	22.9	7.7
2	27.0	6.4	28.1	8.4	27.2	7.3	29.1	8.3	28.9	8.4	27.0	6.3	22.9	7.7
3	26.9	6.3	28.0	8.4	27.1	7.2	29.0	8.3	28.4	7.6	27.0	6.2	22.9	7.6
4	26.5	4.4	27.8	8.0	27.1	7.1	27.9	4.2	27.6	3.0	26.9	6.0	22.9	7.6
5	25.6	2.2	27.0	5.5	26.5	2.6	26.9	1.4	26.9	0.9	26.9	5.8	22.9	7.5
6	24.3	1.3	25.1	0.8	25.8	1.0	26.2	0.3	26.0	0.2	26.4	2.5	22.8	7.5
7	24.0	1.0	24.9	1.0	25.0	0.5	25.8	0.2	25.5	0.1	25.9	0.8	22.8	7.5
8	23.8	1.0	24.4	1.2	24.9	0.2	25.2	0.1	25.2	0.1	25.6	1.5	22.8	7.4
9	23.6	0.4	24.2	0.4	24.8	0.1	25.1	0.1	25.1	0.1	25.1	0.6	22.8	7.4
10	23.4	0.1	24.0	0.2	24.4	0.1	25.0	0.1	25.0	0.1	25.0	0.2	22.8	7.4
11	23.2	0.1	23.8	0.1	24.2	0.0	24.9	0.1	25.0	0.1	25.0	0.2	22.8	7.4
12	23.1	0.1	23.8	0.1	24.0	0.0	24.5	0.1	24.8	0.1	24.9	0.1	22.8	7.3
13.	23.0	0.1	23.5	0.1	24.0	0.0	24.2	0.1	24.5	0.1	24.8	0.1	22.7	7.1
14	22.9	0.0	23.2	0.1	23.9	0.0	24.2	0.1	24.2	0.1	24.6	0.1	22.6	6.8
15	22.9	0.0	23.1	0.1	23.8	0.0	24.2	0.1	24.2	0.1	24.5	0.1	22.6	6.7
16	22.8	0.0	23.1	0.1	23.5	0.0	24.0	0.1	24.1	0.1	24.4	0.1	22.5	6.7
17	22.5	0.0	23.0	0.1	23.2	0.0	23.9	0.1	24.0	0.1	24.2	0.1	22.3	6.7
18	22.2	0.0	23.0	0.1	23.1	0.0	23.8	0.1	23.9	0.1	24.1	0.1	22.2	5.7
19	22.0	0.0	22.9	0.0	23.1	0.0	23.5	0.1	23.8	0.1	24.1	0.1	22.2	5.6
20	21.9	0.0	22.7	0.0	23.0	0.0	23.2	0.0	23.5	0.1	24.0	0.1	22.2	6.0
21	21.6	0.0	22.2	0.0	23.0	0.0	23.1	0.0	23.2	0.1	23.9	0.1	22.1	6.1
22	21.1	0.0	22.0	0.0	22.6	0.0	22.9	0.0	23.0	0.0	23.7	0.1	22.1	6.2
23	20.8	0.0	21.8	0.0	22.0	0.0	22.2	0.0	22.8	0.0	23.2	0.1	22.0	5.2
24	19.8	0.0	19.9	0.0	21.2	0.0	21.3	0.0	21.9	0.0	21.9	0.1	21.9	2.7
25	16.5	0.0	17.0	0.0	17.9	0.0	17.8	0.0	18.0	0.0	18.8	0.1	21.8	1.1
26	15.6	0.0	15.2	0.0	16.5	0.0	16.5	0.0	15.6	0.0	16.2	0.1	21.0	0.0

Table A-7. Instantaneous growth rates of age group 3 gizzard shad for 1973-75.

Collection date	Growth interval	Sample size	Mean weight (g) ± 95% confidence interval	Growth rate (g/day X 10^{-3})
		1973		
5-15 to 6- 1		151	75.9± 3.53	
	19.5			-2.00
6- 2 to 6-22		63	73.0± 2.99	
	21.0			-7.31
6-23 to 7-13		50	62.6± 3.17	
	21.0			1.20
7-14 to 8- 3		38	64.2± 5.82	
	21.0			3.02
8- 4 to 8-24		60	68.4± 4.06	
	66.5			1.16
10-18 to 10-21		86	73.9± 2.42	
	221.5			1.58
5-20 to 6- 7		6	105.0± 9.91	
		1974		
5-20 to 6- 7		72	80.0± 2.92	
	2010			-2.69
6- 8 to 6-28		100	75.8± 1.94	
	21.0			0.82
6-29 to 7-19		85	74.5± 2.40	
	21.0			0.06
7-20 to 8-9		46	74.6± 3.14	
	17.5			0.15
8-10 to 8-23		88	74.8± 2.38	
	26.0			6.56
9- 9 to 9-13		15	88.7±17.91	
	252.0			1.20
5-12 to 5-30		32	120.1± 3.59	
		1975		
5-12 to 5-30		14	75.2±10.97	
	19.5			7.42
5-31 to 6-19		10	86.9± 8.81	
	21.5			4.68
6-20 to 7-10		3	96.1±16.14	
	21.0			0.69
7-11 to 7-31		2	97.5±25.34	
	19.5			0.86
8- 1 to 8-18		8	99.1±23.78	
	46.5			-3.97
9-23 to 9-26		34	82.4± 7.33	

Table A-8. Instantaneous growth rates of age group 4 gizzard shad for 1973-75.

Collection date	Growth interval	Sample size	Mean weight (g) ± 95% confidence interval	Growth rate (g/day X 10^{-3})
		1973		
5-15 to 6- 1		60	132.2±16.77	
	19.5			3.89
6- 2 to 6-22		18	145.9±21.50	
	21.0			-14.14
6-23 to 7-13		5	108.4±59.29	
	21.0			10.98
7-14 to 8- 3		2	136.5±298.68	
	21.0			-9.85
8- 4 to 8-24		1	111.0±0.00	
	66.5			5.63
10-18 to 10-21		28	161.4±14.87	
	221.5			0.54
5-20 to 6- 7		18	181.9±21.10	
		1974		
5-20 to 6- 7		6	105.0±9.91	
	20.0			2.22
6- 8 to 6-28		13	109.8±6.92	
	21.0			-3.42
6-29 to 7-19		12	102.2±14.58	
	21.0			9.60
7-20 to 8- 9		1	125.0±0.00	
	17.5			
8-10 to 8-23		-	-	
	26.0			-0.60
9- 9 to 9-13		4	121.8±51.54	
	252.0			1.70
5-12 to 5-30		110	186.9±8.46	
		1975		
5-12 to 5-30		32	120.1±8.11	
	19.5			-4.63
5-31 to 6-19		10	109.7±15.01	
	21.5			8.40
6-20 to 7-10		5	131.4±25.97	
	21.0			-8.76
7-11 to 7-31		3	109.3±44.89	
	19.5			8.48
8- 1 to 8-18		4	129.0±86.79	
	46.4			1.59
9-23 to 9-26		7	138.9±16.97	

Table A-9. Instantaneous growth rates of age group 5 gizzard shad for 1973-75.

Collection date	Growth interval	Sample size	Mean weight (g) ± 95% confidence interval	Growth rate (g/day X 10^{-3})
		1973		
5-15 to 6- 1		6	190.3±20.75	
	19.5			-0.85
6- 2 to 6-22		10	187.2±27.30	
	21.0			-5.44
6-23 to 7-13		4	167.0±61.57	
	21.0			-0.72
7-14 to 8- 3		4	164.5±17.73	
	21.0			-2.27
8- 4 to 8-24		6	156.8±19.78	
	66.5			2.61
10-18 to 10-21		15	186.5±11.91	
	221.5			0.34
5-20 to 6- 7		11	201.0±27.25	
		1974		
5-20 to 6- 7		18	181.9±21.11	
	20.0			-3.47
6- 8 to 6-28		11	169.7±16.39	
	21.0			-0.65
6-29 to 7-19		7	167.4±12.95	
	21.0			-0.06
7-20 to 8- 9		9	167.2±13.83	
	17.5			-3.12
8-10 to 8-23		3	158.3±16.53	
	26.0			2.10
9- 9 to 9-13		7	167.2±41.30	
		1975		
5-12 to 5-30		110	186.9± 6.34	
	19.5			0.67
5-31 to 6-19		51	189.4±10.03	
	21.5			0.22
6-20 to 7-10		37	190.3±16.07	
	21.0			-4.17
7-11 to 7-31		11	174.4±14.11	
	19.5			14.28
8- 1 to 8-18		6	230.3±28.42	
	46.5			-9.23
9-23 to 9-26		10	149.9±13.49	

Table A-10. Instantaneous growth rates of age group 1 white crappie for 1973-75.

Collection date	Growth interval	Sample size	Mean weight (g) ± 95% confidence interval	Growth rate (g/day X 10^{-3})
		1973		
5-15 to 6- 1				
	19.5			-
6- 2 to 6-22		2	44.5±171.58	
	21.0			10.94
6-23 to 7-13		2	56.0±190.65	
	21.0			0.59
7-14 to 8- 3		3	56.7±57.17	
	21.0			7.38
8- 4 to 8-24		4	66.2±14.99	
	66.5			-
10-18 to 10-21			-	
	221.5			0.90
5-20 to 6- 7		15	85.9±38.07	
		1974		
5-20 to 6- 7		48	30.8± 4.26	
	20.0			19.18
6- 8 to 6-28		84	45.2± 4.66	
	21.0			8.38
6-29 to 7-19		94	53.9± 2.42	
	21.0			7.12
7-20 to 8- 9		128	62.6± 2.76	
	17.5			6.06
8-10 to 8-23		87	69.6± 5.27	
	26.0			1.98
9- 9 to 9-13		54	73.6±22.90	
	252.0			4.39
5-12 to 5-30		24	222.6±50.85	
		1975		
5-12 to 5-30		114	50.5± 5.08	
	19.5			-29.52
5-31 to 6-19		223	28.4± 3.46	
	21.5			14.63
6-20 to 7-10		117	38.9± 5.97	
	21.0			25.17
7-11 to 7-31		100	66.0± 8.77	
	19.5			-11.54
8- 1 to 8-18		80	52.7± 6.24	
	46.5			-0.58
9-23 to 9-26		53	51.3± 4.53	

Table A-11. Instantaneous growth rates of age group 2 white crappie for 1973-75.

Collection date	Growth interval	Sample size	Mean weight (g) ± 95% confidence interval	Growth rate (g/day X 10^{-3})
		1973		
5-15 to 6- 1		47	127.8±10.40	
	19.5			7.49
6- 2 to 6-22		76	147.9± 7.31	
	21.0			5.09
6-23 to 7-13		66	164.6± 5.68	
	21.0			2.20
7-14 to 8- 3		29	172.4±13.05	
	21.0			-11.50
8- 4 to 8-24		19	135.4±20.27	
	66.5			2.32
10-18 to 10-21		3	158.0±176.58	
		1974		
5-20 to 6- 7		8	148.3±15.96	
	20.0			6.15
6- 8 to 6-28		21	167.7±10.18	
	21.0			6.94
6-29 to 7-19		12	194.0±29.63	
	21.0			4.94
7-20 to 8- 9		7	215.2±34.70	
	17.5			4.15
8-10 to 8-23		15	231.4±23.58	
	26.0			8.76
9- 9 to 9-13		8	290.6±41.36	
	252.0			0.65
5-12 to 5-30		3	342.3±292.48	
		1975		
5-12 to 5-30		24	222.6±50.85	
	19.5			-13.67
5-31 to 6-19		13	170.5±46.16	
	21.5			2.00
6-20 to 7-10		7	178.0±60.48	
	21.0			-6.86
7-11 to 7-31		15	154.1± 8.13	
	19.5			4.37
8- 1 to 8-18		13	167.8±13.96	
	46.5			3.58
9-23 to 9-26		32	198.2±20.22	

Table A-12. Instantaneous growth rates of age group 3 white crappie for 1973-75.

Collection date	Growth interval	Sample size	Mean weight (g) ± 95% confidence interval	Growth rate (g/day X 10^{-3})
		1973		
5-15 to 6- 1		4	238.0±58.12	
	19.5			-47.58
6- 2 to 6-22		86	94.1±12.57	
	21.0			19.59
6-23 to 7-13		112	142.0±15.76	
	21.0			-5.77
7-14 to 8- 3		106	125.8±15.32	
	21.0			14.14
8- 4 to 8-24		148	169.3±15.36	
	66.5			5.30
10-18 to 10-21		22	240.9±26.67	
		1974		
5-20 to 6- 7		-	-	
	20.0			-
6- 8 to 6-28		2	260.0±76.26	
	21.0			8.33
6-29 to 7-19		3	309.7±138.77	
	21.0			0.28
7-20 to 8- 9		4	311.5±67.38	
	17.5			6.54
8-10 to 8-23		3	39.3±89.73	
	26.0			-1.70
9- 9 to 9-13		4	334.2±41.02	
		1975		
5-12 to 5-30		3	342.3±292.48	
	19.5			-5.44
5-31 to 6-19		1	308.0± 0.00	
	21.5			-15.23
6-20 to 7-10		1	222.0± 0.00	
	21.0			25.17
7-11 to 7-31		2	376.6±686.27	

Table A-13. Instantaneous growth rates of age group 2 freshwater drum for 1973-75.

Collection date	Growth interval	Sample size	Mean weight (g) ± 95% confidence interval	Growth rate (g/day X 10^{-3})
		1973		
5-15 to 6- 1		26	197.1±15.91	
	19.5			0.10
6- 2 to 6-22		28	197.5±13.11	
	21.0			-5.87
6-23 to 7-13		38	174.6± 9.42	
	21.0			2.83
7-14 to 8- 3		27	185.3±12.86	
	21.0			0.33
8- 4 to 8-24		35	186.6±16.50	
	66.5			-2.09
10-18 to 10-21		7	162.4±18.57	
	221.5			1.44
5-20 to 6- 7		41	223.5±14.00	
		1974		
5-20 to 6- 7		1	178.0± 0.00	
	20.0			4.30
6- 8 to 6-28		24	194.0±13.82	
	21.0			-0.39
6-29 to 7-19		14	192.4±20.02	
	21.0			-4.07
7-20 to 8- 9		6	176.7±15.29	
	17.5			1.89
8-10 to 8-23		5	182.6±25.59	
	26.0			2.07
9- 9 to 9-13		13	192.7±14.00	
	252.0			0.72
5-12 to 5-30		64	230.9± 8.01	
		1975		
5-12 to 5-30		20	102.8±15.63	
	19.5			-0.65
5-31 to 6-19		4	101.5±61.61	
	21.5			7.79
6-20 to 7-10		1	120.0±47.40	
	21.0			-12.43
7-11 to 7-31		7	92.4±17.01	
	19.5			24.73
8- 1 to 8-18		7	149.7±32.89	
	46.5			6.42
9-23 to 9-26		12	201.8±36.91	

Table A-14. Instantaneous growth rates of age group 3 freshwater drum for 1973-75.

Collection date	Growth interval	Sample size	Mean weight (g) ± 95% confidence interval	Growth rate (g/day X 10^{-3})
		1973		
5-15 to 6-1		35	295.1±19.65	
	19.5			-5.50
6- 2 to 6-22		17	265.1±15.78	
	21.0			-0.67
6-23 to 7-13		13	261.4±18.01	
	21.0			-3.89
7-14 to 8- 3		8	240.9±21.50	
	21.0			6.82
8- 4 to 8-24		10	278.0±2124	
	66.5			-3.85
10-18 to 10-21		12	235.2±22.98	
	221.5			0.65
5-20 to 6- 7		9	271.8±27.62	
		1974		
5-20 to 6- 7		41	223.5±13.74	
	20.0			-0.93
6- 8 to 6-28		17	219.4±18.08	
	21.0			-3.54
6-29 to 7-19		21	203.7±11.16	
	21.0			-1.35
7-20 to 8- 9		11	198.0±26.90	
	17.5			10.08
8-10 to 8-23		11	236.2±34.62	
	26.0			0.44
9- 9 to 9-13		10	238.9±28.17	
	252.0			
5-12 to 5-30				
		1975		
5-12 to 5-30		64	230.9± 8.01	
	19.5			-2.33
5-31 to 6-19		58	220.7± 9.05	
	21.5			0.20
6-20 to 7-10		24	221.6±14.37	
	21.0			1.57
7-11 to 7-31		25	229.0±13.53	
	19.5			0.86
8- 1 to 8-18		11	232.9±16.76	
	46.5			0.26
9-23 to 9-26		7	235.7±36.50	

Table A-15. Instantaneous growth rates of age group 2 black bullhead for 1974-75.

Collection date	Growth interval	Sample size	Mean weight (g) ± 95% confidence interval	Growth rate (g/day X 10^{-3})
		1974		
5-20 to 6- 7		6	123.7±20.31	
	20.0			19.70
6- 8 to 6-28		5	183.4±68.57	
	21.0			9.37
6-29 to 7-19		21	223.3±16.29	
	21.0			-0.87
7-20 to 8- 9		27	219.3±18.65	
	17.5			-5.79
8-10 to 8-23		7	198.1±49.62	
	26.0			-5.06
9- 9 to 9-13		3	173.7±27.14	
	252.0			0.99
5-12 to 5-30		80	260.7±14.04	
		1975		
5-12 to 5-30		15	206.8± 5.53	
	19.5			1.83
5-31 to 6-19		3	214.3±21.05	
	21.5			1.43
6-20 to 7-10		1	221.0± 0.00	
	21.0			3.13
7-11 to 7-31		3	236.0±49.13	
	19.5			-0.66
8- 1 to 8-18		16	233.0± 9.88	
	46.5			-5.44
9-23 to 9-26		7	180.9±46.24	

Table A-16. Instantaneous growth rates of age group 3 black bullhead for 1974-75.

Collection date	Growth interval	Sample size	Mean weight (g) ± 95% confidence interval	Growth rate (g/day X 10^{-3})
		1974		
5-20 to 6- 7		33	248.5±10.70	
	20.0			3.03
6- 8 to 6-28		27	264.0±10.94	
	21.0			-1.36
6-29 to 7-19		41	256.6± 9.16	
	21.0			17.43
7-20 to 8- 9		1	370.0± 0.00	
	17.5			-11.86
8-10 to 8-23		3	300.7±93.20	
	26.0			-10.58
9- 9 to 9-13		8	228.4±46.00	
	252.0			1.77
5-12 to 5-30		37	328.3±13.50	
		1975		
5-12 to 5-30		80	260.7±14.04	
	19.5			-0.09
5-31 to 6-19		48	260.2±16.90	
	21.5			0.14
6-20 to 7-10		84	261.0±10.00	
	21.0			-0.55
7-11 to 7-31		30	258.0±17.66	
	19.5			1.71
8- 1 to 8-18		15	266.7±23.20	
	46.5			-1.23
9-23 to 9-26		9	251.9±22.74	

Table A-17. Instantaneous growth rates of age group 3 channel catfish for 1973-75.

Collection date	Growth interval	Sample size	Mean weight (g) ± 95% confidence interval	Growth rate (g/day X 10^{-3})
		1973		
5-15 to 6- 1		2	142.0±12.71	
	19.5			11.87
6- 2 to 6-22		3	179.0±80.71	
	21.0			7.76
6-23 to 7-13		3	210.7±111.06	
	21.0			-23.73
7-14 to 8- 3		1	128.0± 0.00	
	21.0			11.51
8- 4 to 8-24		2	163.0±12.71	
	66.5			2.47
10-18 to 10-21		-	-	
	221.5			-
5-20 to 6- 7		1	332.0± 0.00	
		1974		
5-20 to 6- 7		1	280.0± 0.00	
	20.0			-0.66
6- 8 to 6-28		3	276.3±92.57	
	21.0			2.98
6-29 to 7-19		6	294.2±37.47	
	21.0			4.88
7-20 to 8- 9		10	325.9±47.21	
	17.5			2.76
8-10 to 8-23		3	342.0±248.06	
	26.0			3.05
9- 9 to 9-13		6	370.2±54.93	
	252.0			1.98
5-12 to 5-30		9	610.6±121.68	
		1975		
5-12 to 5-30		7	257.1±35.36	
	19.5			17.93
5-31 to 6-19		3	364.7±575.79	
	21.5			-23.79
6-20 to 7-10		3	218.7±237.36	
	21.0			-
7-11 to 7-31		-	-	
	19.5			-4.03
8- 1 to 8-18		-	-	
	46.5			-
9-23 to 9-26		4	154.0±105.43	