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Jacob J. Hogue
*University of Arkansas, Fayetteville*

Raj V. Kilambi
*University of Arkansas, Fayetteville*

# Age and Growth of Bluegill, *Lepomis Macrochirus* Rafinesque, from Lake Fort Smith, Arkansas

JACOB J. HOGUE, JR.[1], and RAJ V. KILAMBI
Department of Zoology, University of Arkansas, Fayetteville, Arkansas 72701

## ABSTRACT

A total of 337 bluegill from Lake Fort Smith were used for this study. Annuli were formed between late February and early June, the younger fish forming annuli earlier than older fish. Total length-scale radius and length-weight relationships were determined. Growth of bluegill was compared with that reported in other studies. Growth curves were analyzed by the Von Bertalanffy growth formula and the parameters were evaluated in terms of physical and biological factors.

## INTRODUCTION

The bluegill is widely distributed in the Great Lakes regions to the St. Lawrence drainage, throughout the Mississippi Valley and from Mexico to Virginia (Blair et al., 1968). In Arkansas, it is common in lakes, rivers, streams and ponds where it is an important sport and forage fish. Olmsted and Kilambi (1971) reported that during the late summer and fall *Lepomis* spp., particularly bluegill, carried the heaviest burden of predation by white bass *Morone chrysops* (Rafinesque) in Beaver Reservoir. Applegate et al. (1966) found that the longear sunfish *Lepomis megalotis* (Rafinesque), green sunfish *Lepomis cyanellus* Rafinesque, and bluegill constituted 10% of the food for black basses *Micropterus* spp. in Bull Shoals Reservoir. In Lake Fort Smith, bluegill was the major forage fish for largemouth bass *Micropterus salmoides* (Lacepede) and spotted bass *Micropterus punctulatus* (Rafinesque) (Hoffman et al., 1974). Published information concerning age and growth of the bluegill is considerable. Most of the studies were conducted in northern waters, except those in Oklahoma and Tennessee, and there were only limited studies in the southern tier of these states. A previous age and growth study of bluegill from Lake Fort Smith was performed by Trenary (1958).

Knowledge of the age and growth of fishes in a particular body of water is essential to fishery management. The growth stanzas of fishes reflect inherent growth patterns as well as environmental influences on growth. The objectives of the present study were to determine the time of annulus formation and the growth rates of males and females, and to estimate maximum attainable size and age by the Von Bertalanffy growth formula.

## DESCRIPTION OF STUDY AREA

Lake Fort Smith is an artificial impoundment about 1.6 km north of Mountainburg, Arkansas, and it serves as a water supply reservoir for the city of Fort Smith. Its watershed of about 168.35 $km^2$ is covered primarily with oak-hickory forest. The lake is surrounded by a steep slope on its eastern shore, and by a slightly less steep western slope. It was impounded in 1936 and attained a flood pool surface area of 212.83 ha, a mean depth of 6.99 m and a maximum depth of 21.94 m (Hoffman, 1951). Nelson (1951) reported additional morphometric data in that the lake was turbid from early fall to midsummer, creating conditions for considerable siltation and change in morphometric character since 1952. Lake Shepherd Springs, about 1.6 km upstream, has not acted as a settling basin for many of these sediments.

[1] Present address: Tennessee Valley Authority, Division of Forestry, Fisheries and Wildlife Development, Norris, Tennessee 37828.

## MATERIALS AND METHODS

A total of 337 bluegill (166 males and 171 females) was collected by a 230-v electroshocker, gill nets and rod and line from October 1970 to September 1971 and by rotenone sampling on 8 July 1971. Specimens were placed on ice and transported to the laboratory where total lengths to the nearest millimeter and weights to the nearest 0.1 g were taken. Scale samples were taken posterior to the tip of the depressed pectoral fin below the lateral line on the left side. Fish were assigned sex on the basis of gonad inspection. Individuals identified as male or female included both immature and mature fish.

Five to 10 scales from each fish were pressed on cellulose acetate strips by means of a Carver laboratory press. A numerical age designation was adopted, and a plus sign was used to refer to growth beyond the annual mark. Scale impressions were projected (43x) on an Eberach scale projection apparatus. Scale measurements were made along a line from the center of the focus anterolaterally to the ventral edge. The distance to each annulus and to the outer edge was recorded to the nearest millimeter. To investigate the validity of the assumption that the annulus was forming during a specific short period of time each year, measurements were made of the marginal scale increments throughout the year. The distance from the last formed annulus to the anterolateral scale edge was recorded for each fish, and measurements were grouped by month.

Date of capture, total length, weight, sex, age, distance to each annulus if present and scale radius for each fish were recorded on data sheets and IBM cards. The analyses of the data were accomplished by use of a Friden electronic desk calculator and an IBM 360-50 computer. All statistical tests for significance are reported at the 0.05 level of probability, unless otherwise stated.

## RESULTS AND DISCUSSION

*Age Determination and Time of Annulus Formation.* The number of scale annuli indicated that ages ranged from zero (young-of-the-year) to 9+ years. Accessory checks were noted close to the focus on some late-spawned bluegill. A few spawning checks were noted after the third annulus on some fish. Clumping of annuli and resorption of the anterior field may have obliterated previous annuli. Thus, bluegill aged 9+ possibly could have been older.

The time of annuli formation was determined on the basis of monthly average marginal scale increments for the age groups 1+, 4+ and 6+ (Fig. 1). Annuli formed from late February to

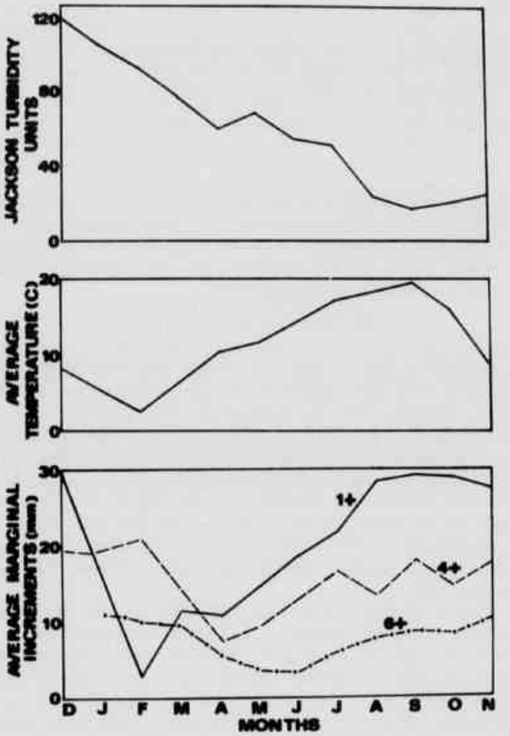


Figure 1. Monthly average marginal scale increments for selected age groups, and average temperature and turbidity of Lake Fort Smith.

early June. The older fish formed the annuli later than the younger bluegill. The average temperature and turbidity (JTU) data of Lake Fort Smith for 1971-72 (Hoffman et al., 1974) are shown in Figure 1. It appears that low temperature and high turbidity were responsible for the formation of annuli in one-year-old bluegill. Although exposed to similar environmental factors, the older bluegill formed annuli at a later time. Because all the 3+ and older fish were sexually mature, spawning and physiological stress may be responsible for annulus formation in the older bluegill.

*Total Length-Scale Radius Relationship.* The total length-scale radius relationship was derived by a stepwise polynomial technique from the general model:

$$L = \theta_0 + \theta_1 S + \theta_2 S + \ldots + \theta_n S^n$$

(Graybill, 1961) where L is the total length in millimeters, S is the scale radius (43x) in millimeters and $\theta_0$ to $\theta_n$ are constants. The relationships for the male and female bluegill were calculated separately.

Covariance analysis showed that the difference between the males and females was not significant ($F_{4,329} = 0.67$) and therefore the data for the sexes were combined. The resulting total length-scale radius relationship was:

$$L = 19.319 + 1.227S - 0.002S^2$$

*Length-Weight Relationship.* The length-weight relationship was calculated by the formula

$$\log W = \log a + b \log L$$

where

W = weight in grams

L = total length in millimeters

a and b = constants.

Because there were no differences between sexes either in slopes ($F_{1,333} = 1.17$) or in the intercepts ($F_{1,334} = 6.0$), the data was combined and the resulting relationship was:

$$\log W = 3.21 \log L - 5.2207$$

The average calculated and observed weights at each year of life are given in Table I.

**Table 1. Average calculated and observed weights in grams at the end and during each year of life, respectively.**

| | | Age-Group | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 1+ | 2+ | 3+ | 4+ | 5+ | 6+ | 7+ | 8+ | 9+ |
| MALES | Calculated Weight | 2.3 | 10.7 | 24.9 | 41.9 | 62.8 | 82.1 | 105.7 | 128.2 | -- |
| | Observed Weight | 6.8 | 14.9 | 30.1 | 46.9 | 67.0 | 96.0 | 128.6 | 148.5 | -- |
| FEMALES | Calculated Weight | 2.2 | 10.5 | 24.0 | 42.4 | 60.8 | 82.1 | 103.0 | 132.1 | 162.3 |
| | Observed Weight | 5.6 | 15.7 | 26.7 | 46.0 | 64.7 | 95.5 | 130.1 | 153.8 | 187.9 |

**Table 2. Average calculated growth rate of male bluegill.**

| | Total Length at each annulus (mm) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Age-Group | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 1 | 42.1 | | | | | | | |
| 2 | 46.7 | 81.7 | | | | | | |
| 3 | 46.4 | 80.7 | 109.5 | | | | | |
| 4 | 48.5 | 81.6 | 107.6 | 129.6 | | | | |
| 5 | 57.8 | 89.9 | 114.0 | 132.2 | 145.2 | | | |
| 6 | 66.3 | 99.2 | 121.3 | 140.1 | 153.2 | 162.9 | | |
| 7 | 69.9 | 101.7 | 125.3 | 145.6 | 160.4 | 171.1 | 179.1 | |
| 8 | 62.1 | 94.1 | 122.0 | 146.9 | 163.6 | 176.6 | 185.4 | 191.9 |
| Weighted mean | 54.8 | 88.4 | 115.2 | 137.4 | 153.6 | 167.0 | 180.7 | 191.9 |
| Number of fish | 166 | 163 | 134 | 97 | 74 | 55 | 23 | 6 |

*Growth in Length.* By use of the total length-scale radius relationship, the length attained at each annulus was calculated (Tables II, III). The average lengths at the end of one and two years were weighted means based on back calculations for immature and mature bluegill.

Table 3. Average calculated growth rate of female bluegill.

| Age-Group | Total length at each annulus (mm) 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 42.6 | | | | | | | | |
| 2 | 49.1 | 85.9 | | | | | | | |
| 3 | 42.9 | 76.5 | 105.0 | | | | | | |
| 4 | 49.2 | 82.8 | 109.2 | 131.0 | | | | | |
| 5 | 59.7 | 90.4 | 112.9 | 130.0 | 143.7 | | | | |
| 6 | 63.6 | 97.8 | 121.4 | 139.0 | 152.5 | 162.2 | | | |
| 7 | 65.7 | 97.7 | 120.9 | 140.2 | 155.1 | 166.7 | 174.3 | | |
| 8 | 65.8 | 99.7 | 127.7 | 146.9 | 160.4 | 171.5 | 180.8 | 185.7 | |
| 9 | 71.8 | 109.8 | 140.2 | 163.4 | 179.9 | 192.5 | 198.9 | 203.6 | 206.5 |
| Weighted mean | 54.3 | 88.0 | 113.9 | 135.9 | 152.1 | 167.0 | 179.2 | 193.7 | 206.5 |
| Number of fish | 171 | 169 | 146 | 112 | 77 | 51 | 27 | 9 | 4 |

Growth patterns for male and female bluegill were analyzed by the Von Bertalanffy equation:

$$L_t = L_{oo}(1 - e^{-K(t-t_0)})$$

where

$L_t$ = length at age t

$L_{oo}$ = asymptotic length

$K$ = coefficient of catabolism

$t_o$ = age at which the length is zero.

Initially the data were analyzed by Walford's transformations (Beverton and Holt, 1957). Covariance analysis showed that both sexes can be represented by a single line ($F$ 2, 11 = 1.02) indicating that males and females attain the same asymptotic length with similar coefficients of catabolism. The combined data for sexes were analyzed further (Richer, 1958) and the growth curve can be represented by the equation:

$$L_t = 253\ (1-e^{-0.18(t+0.42)})$$

The asymptotic weight, $W_{oo}$, computed by use of the length-weight relationship, was 311.4 g. The age ($t_i$) at which 95% (P) of asymptotic length could be attained was estimated by the equation:

$$t_i = t_o - \{ \frac{\ln(1 - P)}{K} \}$$

and this age was 16.7 years. The weight at $t_i$ was calculated to be 263 g. Bluegill as old as 13 years have been reported, and the largest bluegill reported weighed 2156g (Snow et al., 1960). Therefore, the projected values of $t_i$, $L_{oo}$ and $W_{oo}$ for Lake Fort Smith bluegill seem reasonable.

The growth data for bluegill from Lake Fort Smith from an earlier study (Trenary, 1958) were fitted by the Von Bertalanffy growth formula as

$$L_t = 303\ (1-e^{-0.21(t + 0.04)})$$

and the projected age at which 95% of asymptotic length could be attained was 14 years.

Comparison of growth parameters of Trenary's data and of the present study by Walford transformation showed that the slopes were not significantly different ($F$ 1, 8 = 0.12) but the differences in the intercepts were significant ($F$ 1, 9 = 16.92) at the 0.01 level. It is concluded that the bluegill of this study would attain significantly smaller asymptotic length (253 mm) than those of Trenary's study (303 mm).

Of the two growth parameters $L_{oo}$ ($W_{oo}$) and the coefficient of catabolism, K, the latter was regarded as independent of the level of feeding but varied with certain environmental factors such as temperature, whereas $W_{oo}$ was influenced by food consumption (Beverton and Holt, 1957). Felin (1951) stated that the rate of deceleration of growth is the more stable of the two growth characteristics and that, with relatively constant environments, slope is a physiological character of genetic meaning.

The mean temperatures of Lake Fort Smith at 1 m depth between 1959-1960 (Rorie, 1961) and 1972 (Hoffman et al., 1974) for the period February through September were not significantly different ($F$ 1, 14 = 0.08), and the overall mean temperature was 19.5C. The similarity of coefficients of catabolism for bluegill of Trenary's study and for those of this investigation is due to constant environmental temperature.

According to Hoffman et al. (1974), the composition and standing crop of Lake Fort Smith plankton have not changed since 1938. However, no information on insects was available. It was assumed that availability of food for bluegill remains the same as in the earlier years. The population sizes of adult bluegill and largemouth bass from rotenone samples during 1957-1958 and 1971 were reported by Cole (1959) and Hoffman et al. (1974), respectively. The adult bluegill population sizes were 18,030 in June 1957, 16,710 in June 1958 and 17,782 in July 1971. In July 1971, the population size of juvenile and intermediate-size bluegill was estimated to be 1,235,105 on the basis of the rotenone sample. The population sizes of largemouth bass in June 1957, June 1958 and July 1971 were 9,921, 9,085 and 5,589, respectively. These figures indicate a drastic reduction in the largemouth bass population for which the bluegill forms a major forage in Lake Fort Smith. The decrease in predation would result in greater numbers of juvenile and intermediate-size bluegill that compete with adult bluegill for food. During May and June the juvenile bluegill of Lake Fort Smith fed on insects, which were the main food item for the adults (Henderson, 1972). This competition and the recruitment of young fish to adult size would result in intense competition for food and thus in a smaller amount of available food. These factors probably resulted in slower growth (Table IV) and smaller $L_{oo}$, in contrast with those of the previous study (Trenary, 1958).

Table 4. Average total length of Lake Fort Smith bluegill and other waters.

| Locality | Calculated length in mm at each age 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Lake Fort Smith (Present study) | 55 | 88 | 115 | 137 | 153 |
| Lake Fort Smith (Trenary 1958) | 61 | 103 | 135 | 177 | 194 |
| Bull Shoals Reservoir (Applegate et al. 1966) | 48 | 84 | 102 | 123 | 150 |
| Oklahoma (Jenkins et al. 1955) | 81 | 124 | 151 | 172 | 182 |
| Homewood Lake (Ill.) (Carlander and Smith 1953) | 71 | 114 | 135 | 142 | 147 |
| Alma Lake (Ohio) (Carlander and Smith 1953) | 41 | 91 | 140 | 178 | 203 |

Growth of Lake Fort Smith bluegill through the first five years of life was compared with growth in other bodies of water and to that reported in an earlier study of Lake Fort Smith (Table IV). The bluegill growth of the present study was slower than that reported in Trenary's study. The factors contributing to this change have been discussed. The growth of Bull Shoals Reservoir bluegill was similar to that found in the present study. It was also evident that Lake Fort Smith bluegill growth was slower than that in Oklahoma and Ohio (Alma Lake), but similar to that in Homewood Lake, Illinois. Eschmeyer (1940) stated fisheries workers generally assume that fish growth is progressively more rapid with decrease in latitude. This phenomenon is attributed to difference in length of growing season (Gerking, 1966). The present study indicates that bulegill do not necessarily grow faster at lower latitudes or grow at the same rate in the same lake at different times. The condition of the lake and available food more aptly dictate the growth rate.

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