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POPULATION DYNAMICS OF WHITE BASS IN BEAVER RESERVOIR, ARKANSAS

by

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ABSTRACT

Age and growth, mortality and population structure of white bass from Beaver Reservoir were studied. The number of scale radii increased with age of fish and were useful in the identification of annuli.

Growth histories for year classes 1958-1970 showed increased growth during the reservoir formation. Analysis of growth data by the von Bertalanffy growth formula indicated that the postimpoundment white bass attained larger asymptotic lengths than the preimpoundment fish. The factors influencing the asymptotic size were discussed.

The population structure revealed that the Beaver Reservoir white bass population was of a declining population with a dominance of older age groups. On the basis of this study, it was recommended that catch limit on white bass be removed and effective January 1974, by the action of the Arkansas Game and Fish Commission, there has been no catch limit on white bass in Beaver Reservoir.

INTRODUCTION

The white bass, *Morone chrysops* (Rafinesque) is an important sport fish in Beaver Reservoir, the latest impoundment on the White River in Northwest Arkansas. The distribution of the white bass extends from Minnesota, Wisconsin, and Michigan south to the Gulf States, Florida, Alabama, Mississippi, and Texas (Blair et al. 1968). Due to construction of impoundments and subsequent stocking, white bass spread rapidly into other areas, with a resultant southward shift in their center of abundance and became important sport fish of southern and southwestern states (Chadwick et al. 1966; Riggs 1955).

White bass comprises an important portion of the annual sport fish harvest from Beaver Reservoir. From 1965 to 1971, the white bass harvest comprised 4 to 23% of all sport fish and they appear to reach a peak abundance every four years (Yellayi 1972). With the exception of studies on maturity and fecundity (Newton and Kilambi 1969; 1973) and feeding biology (Olmsted and Kilambi 1969; 1971), there has been no published information pertaining to white bass from Beaver Reservoir. The objectives of this investigation were to study age and growth, mortality and population structure of Beaver Reservoir white bass, and to evaluate the effects of impoundment on these parameters.

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MATERIALS AND METHODS

Beaver Reservoir (36°05′ to 36°27′ N and 93°47′ to 94°06′ W) was the latest in the series of impoundments on the White River in the state of Arkansas. The construction of Beaver Dam began in 1960 and was completed in 1963. The reservoir became operational in 1966. The reservoir attained its designed operating pool area of 28,200 acres (11,400 hectares) in 1968. Fastest rate of increase in surface area was generally up to June 1966, particularly between June 1965 and June 1966, with a

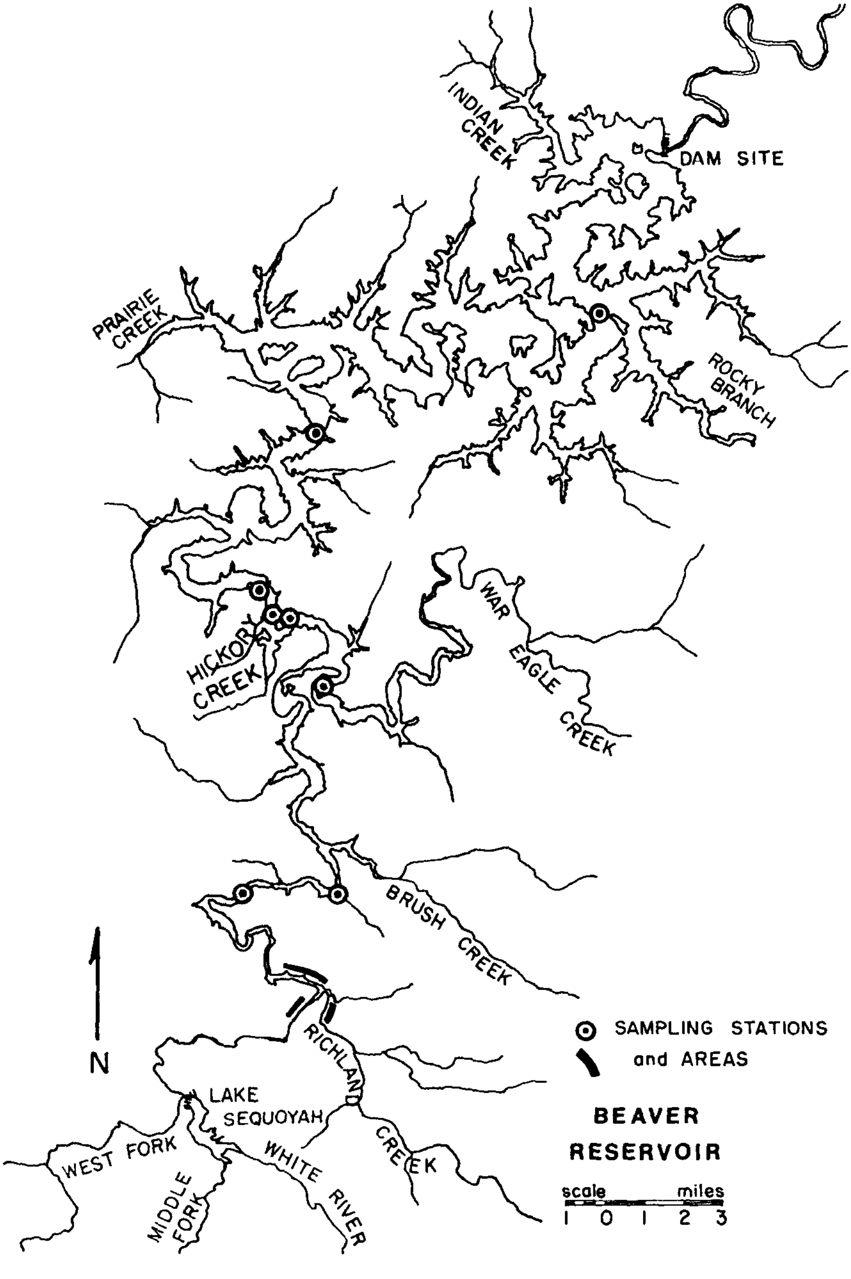

Figure 1. Beaver Reservoir with sampling stations and areas.

slower rate thereafter. The reservoir had three recognizable zones; the lower zone up to Prairie Creek, upper zone up to Brush Creek and riverine zone extending beyond Brush Creek. Sampling stations were selected to represent these three sectors. (Figure 1).

Trap nets, electrofishing, angling, and gill nets were used for obtaining samples of adult white bass during 1968-71. Early stages were obtained from midwater trawl, rotenone, and meter nets. Gill nets (100′ × 6′), each of ¾, 1, 1½, 2, 2½, 3, and 4″ stretch mesh size, were utilized and two sets of nets of 2 and 3″ mesh size were constantly used at Hickory Creek for four days a month and randomly at other places. The fish were taken out of the nets before noon of each day with a fishing effort of 24-hour duration. Electrofishing was done by means of a boat-mounted 230-volt AC generator. This method yielded samples mainly from migrating spawning populations in daylight and early dusk during March and April with little or no catches in other periods of the year.

Fish were collected daily from trap nets set during January and February in the upper reaches of the reservoir. A few fish were obtained from midwater trawl samples from all over the reservoir. Samples of juveniles during fall of 1969 and 1970 were obtained by this gear. Three to five acres of cove areas were treated by rotenone once a month during summer of each year which yielded mainly juveniles during 1970 with no significant numbers of white bass in 1968 or 1969. Meter net collections yielded data on post larvae during 1970 and 1971 from 30 stations all over the reservoir. Data from the Bureau of Sports Fisheries since 1963 mostly obtained by all these gears were utilized in the study wherever needed.

Total length was measured to the nearest millimeter. The scales were obtained from a region below the lateral line at the tip of the appressed left pectoral fin. Five to seven scales were selected from each fish, and impressions of these were made on 1″ × 3″ plastic strips. These were magnified (40X) on a scale projector, and the best scale impression of the strip was selected for study. The largest measure from focus to edge of the anterior field was taken to the nearest millimeter and distances to each annulus were measured on the same radius.

An annulus was assumed at the edge of the scales obtained from late fall onwards until February. Total length of fish and scale radius were fitted with linear relationship $L = A + BS$, where L is the total length and S the radius of scale. In order to eliminate influence of annual fluctuations, all the 740 scale observations were pooled and a general equation was derived.

Fish from 7 to 50mm were designated as post larvae and those between 50 to 150mm were referred to as juveniles. The term young-of-the-year was used for fish up to 200mm.

RESULTS

Age and Growth

Growth of post larval and juvenile fish

The distribution of the larvae and juveniles during July 1970 had four modes suggesting four broods from the spawning season. From the combined data, progression of modes (Figure 2) from April through August indicated the first batch of post larvae occurred late in April and grew to 40mm by May. However, the mode remained at less than 20mm and by June this progressed to 35mm. It is possible the larger groups might have escaped the meter nets. Therefore, the full complement of the juveniles could be ascertained by the frequency curves of July which showed the oldest brood with a mode at 145mm, the next one with a mode at 110mm and followed by two pronounced broods with modes at 65mm and 35mm. Each brood was observed to lag by at least 30mm. The August 1970 distribution of juveniles showed only two modes; one at 65mm and the other at 115mm. The larger ones from the earlier broods had obviously grown beyond 150mm. Meter net collections of May 1971 and June 1971 in comparison with similar months of 1970 indicate a lesser growth.

Total Length – Scale Radius Relationship

Scales from 740 fish pooled over the years 1968 through 1971, were used to determine the relation between total length and scale radius. A linear relationship was fitted as $L = 51.29405 + 1.0614S$ with variances of 10.51119 and 0.0001921 for intercept and slope, respectively. Earliest scale rudiments were observed from post larvae of 40-50mm length. This is in agreement with the intercept value of the total length-scale radius relationship.

The criteria utilized in locating annuli (Lagler 1956; van Oosten 1945; Regier 1962) were applicable to white bass also. However, the occurrence of accessory checks made it difficult to locate the true annuli without bias. In order to minimize the subjectivity involved in distinguishing between true and false annuli, the relation of scale radii, the grooves radiating from near the focus to the margin in anterior field, and age of white bass was investigated.

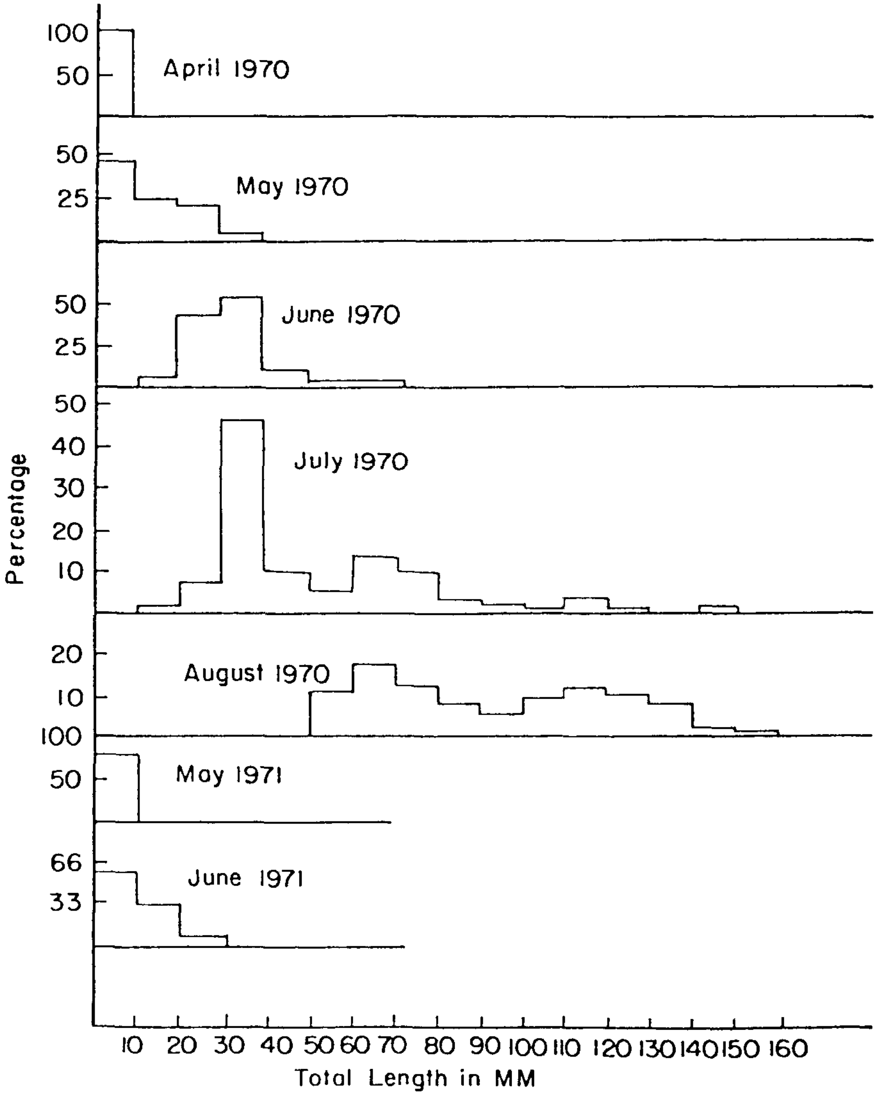

Figure 2. Length frequency distribution of early life history stages.

Radii were observed to originate for the first time very near the focus. In 62 per cent of scales, radii were added only at an annulus. Of the rest of the scales, 28.2 per cent had new radii originating midway between the focus and the first annulus. Irregular addition before the first annulus occurred in 1.8 per cent of scales. New radii originated irregularly in 6.4 per cent of scales between first and second, and 0.9 per cent between second and third annuli. Thus, irregular addition was found to occur in 9.1 per cent of scales.

In 95.8 per cent of scales there was no termination of radii. In 2.7 per cent the radii terminated at an annulus. In 1.5 per cent, termination occurred a little after or before an annulus. Of all the scales, 11.8 per cent had no additional radii. Scales with indistinct annuli but with specific pattern of radii constituted 6.1 per cent, and in 82.1 per cent a definite association between the annuli and radii was noted. Generally, new radii were added in the spring. In a few, however, additions occurred during the early summer. Scales with the same number of annuli were grouped together, and the frequencies of scales with stated number of radii are presented in Table 1, and was expressed by the relationship:

$$\text{Total No. of Radii} = 9.07 + 2.32t - 0.24t^2$$

where t = no. of annuli.

Table 1A. Frequency of Radii Observed in Scales with Different Numbers of Annuli, and Mean Radii for Each Group.

No. of Radii in Each Scale	*Frequency of Scales with Annuli* 0	1	2	3	4
8	2	1	1	—	—
9	7	4	1	—	—
10	16	16	2	1	—
11	17	31	7	1	1
12	18	34	8	4	—
13	2	27	8	5	—
14	1	26	6	6	—
15	—	13	14	4	—
16	—	11	2	2	2
17	—	2	3	2	—
18	—	4	4	1	—
19	—	1	1	1	1
20	—	—	1	1	1
21	—	—	—	1	—
Mean No. of Radii in Each Group	10.82	12.80	13.98	14.55	
Increase in No. of Radii Between Successive Groups —		1.93	1.18	0.57	

Table 1B. Mean Numbers of Different Categories Observed in Scales of Different Year Classes from 1962 to 1967.

Year Class	*Primary*	*Secondary*	*Tertiary*	*Quarternary*
1962 and earlier	9.88	1.86	2.21	1.04
1963	10.27	1.91	1.20	—
1964	10.38	2.80	1.28	—
1965	10.52	1.97	2.29	—
1966	10.90	2.28	1.83	—
1967	10.88	5.58	—	—
Average for All years	10.45	2.73	1.76	—

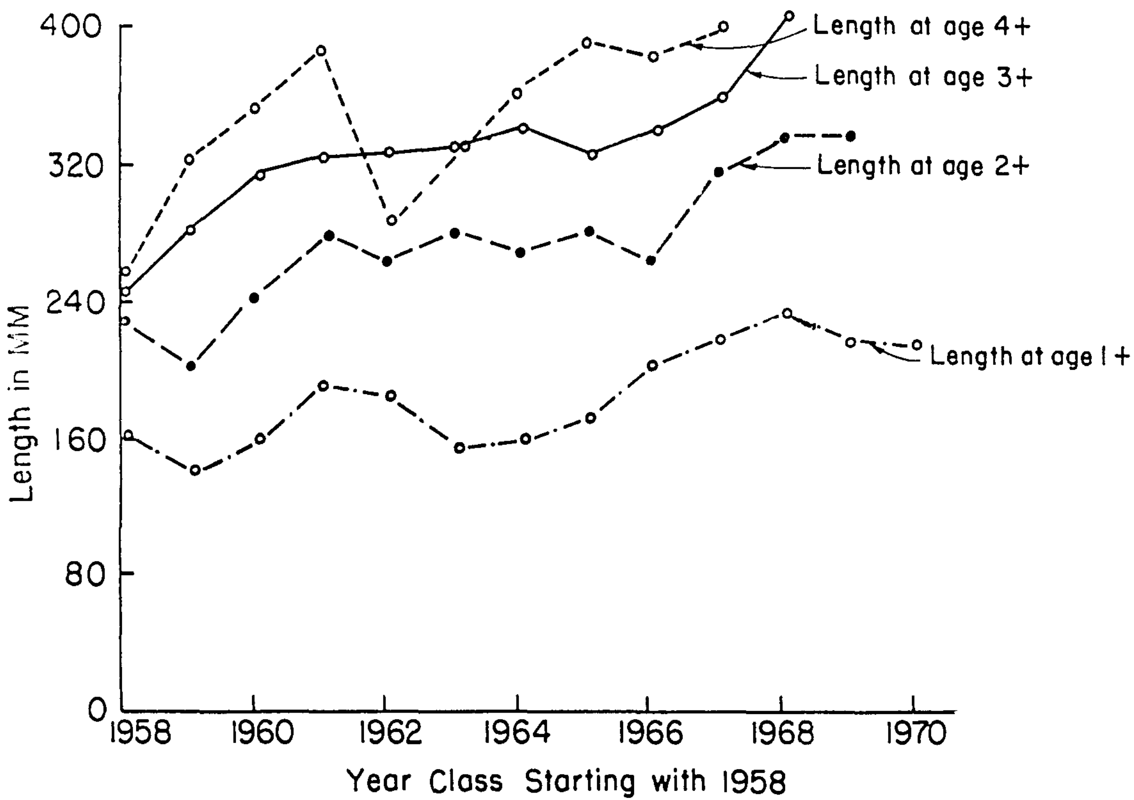

Figure 3. Trends in growth attained at formation of successive annuli in different year classes through years.

As radii generally arose after an annulus, they were categorized as primary, secondary, tertiary, quarternary, etc. The average number of different categories of radii observed in scales from year classes are presented in Table 1. Even with this, the age determination of older age groups, particularly beyond four years, was extremely difficult because of little growth in scales after four years and also due to sparse occurrence of older fish during some of the years.

Growth histories of year classes

The lengths attained by different year classes at successive ages were estimated using the total length-scale radius relationship and are shown in Figure 3. The first year growth oscillated up to 1963 and these fish were considered as from the White River representing the preimpoundment period. The postimpoundment fish (1964-1970 year classes) growth was faster than these of the preimpoundment fish. The growth of the two-year and three-year-olds followed the same trend and it was true for the four-year-olds also, although not well pronounced. On average the postimpoundment fish growth increased by 42mm.

The growth rates estimated from each year's catch from 1965 through 1971 (Table 2) indicated that excluding the one-year-olds, the growth rates calculated from the 1968 catch were lower than in the other years. It suggested that conditions during 1967 were unfavorable.

Growth Parameters and Annual Growth

The growth parameter of white bass were estimated by the von Bertalanffy growth equation

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

Table 2. Growth Rates of Different Age Groups in Various Calendar Years.

Year of Catch	*Rate of Growth (mm) in Age Groups*			
	1^+	2^+	3^+	4^+
1965	159	128	63	59
1966	173	111	47	—
1967	206	110	65	—
1968	219	61	44	17
1969	233	97	77	64
1970	218	104	44	17
1971	215	119	71	39

where L_{∞} = asymptotic length
K = coefficient of catabolism
t_0 = age when length is zero
L_t = length at age t years

The data were analyzed by Walford growth transformation:

$$L_{t+1} = L_{\infty} (1-e^{-K}) + L_t e^{-K}$$

The growth data for the year classes (1958-1963) representing the preimpoundment and the year classes (1964-1970) representing the postimpoundment period were analyzed by the Walford formula. Covariance analysis showed that there was no significance in the slopes ($F1,4 = 0.97$) but the intercepts were significantly different ($F1,5 = 51.88$). It was, therefore, concluded that the preimpoundment white bass had smaller asymptotic length (335mm) than the postimpoundment white bass (441mm).

The von Bertalanffy growth equations were derived (Ricker 1958) for the preimpoundment and postimpoundment periods and were:

Preimpoundment: $L_t = 335 \{1-e^{-0.59(t+0.23)}\}$

Postimpoundment: $L_t = 441 \{1-e^{-0.48(t+0.27)}\}$

The life span required to attain 95 per cent of the asymptotic length was estimated for the pre- and postimpoundment periods as 4.9 and 6.0 years, respectively.

Beaver Reservoir filled rapidly from 1964 through 1966 and slowly after 1967. On this basis, the postimpoundment growth data were further divided into early postimpoundment (1964-1966 year classes) representing the rapid filling phase, and early stabilization (1967-1970 year classes) representing the period from 1967. The data were fitted with the von Bertalanffy formula and the resulting growth equations were:

Early impoundment: $L_t = 462 \{1-e^{-0.40 (t+0.27)}\}$

Early stabilization: $L_t = 418 \{1-e^{-0.78 (t-0.02)}\}$

The lengths attained in the first three years of life in Beaver Reservoir were compared with some selected localities (Table 3). The Beaver Reservoir white bass growth was faster in the first year of life than many other large bodies of water. In general the fish in northern lakes were observed to live longer, up to eight years (Chadwick et al. 1966) but fish of five years or more are rare in Beaver Reservoir. However a three-year-old white bass tagged in 1969 was recaptured in 1975 as a nine-year-old fish (Northwest Arkansas Times, July 3, 1975).

Population Structure

Size Group Distribution Through Years

The length group distributions through different years were compared as pyramids of numbers. Since the length bears a definite relationship to age, a comparison of length distributions was presumed to represent age distributions. The catches during January of each year were utilized for this purpose, since the total growth attained was maximum, the rate of growth was minimum, movement of fish was random, and stratification was minimum during this month. Besides, all age groups of preceding year were represented in the catches. The size distributions are shown in Figure 4.

January 1966, catch representing the distribution of 1965, had dominant and continuous early broods suggesting continuous spawning activity (Figure 4A). However, due to smaller sizes attained, many young-of-the-year could have escaped capture. The 1966 population (January 1967 catch) included the largest percentage of 0^+ age group compared to the rest of the years and a reduced frequency of oldest age group. A discontinuous group was located in smallest size range. The dominant older sizes were observed to be in 310 through 350mm groups (Figure 4B). The 1967 population (Figure 4C) contained no fish less than 200mm in the sample and were dominated by size groups between 200 and 300mm. The reduction in the dominant size groups above 300mm of the preceding two years suggested a retarded growth and/or a drastic reduction in the numbers of the older age group fish. If young-of-the-year were not considered, this appeared to suggest that a broad-based pyramid, mostly dominated by 1^+ age group. In 1968 population (Figure 4D) 34 per cent consisted of 0^+ age group, indicating a good survival of young-of-the-year with extensive distribution of size groups from 170 to 270mm. These were predominantly from middle broods with distribution pattern similar to that of 1965 population. The dominance of the 1966 year class was very pronounced at 330 to 360mm. The 1967 year class contributed only 3 per cent. Young-of-the-year consisted of 27 per cent of the 1969 population (Figure 4E). Presumably, the year classes of 1966, 1967, and 1968 represented by fish of the range 310-390mm, were dominant in the distribution. The poor occurrence of the 360-370mm group suggested the meager contribution by the 1967 year class.

The 1970 distribution (Figure 4F), with continuous and large range (170-270mm), presented a success of the young-of-the-year. The discontinuous pattern of earlier age group was still marked at 290-300mm. The year classes of 1966 and 1968 were very dominant in the catches. The proportion of the 0^+ age group was further reduced to 24 per cent and the next higher ranking groups formed 15 to 12 per cent of the total population.

Mortality and Survival Rates

The instantaneous mortality (i) and annual survival (S) rates were estimated from the abundance of various age groups from the expression

$$i = \log_e (N_t/N_t+1) \text{ and } S = e^{-i}$$

The mortality and survival rates were estimated for the pre- and postimpoundment white bass (Table 4). The postimpoundment white bass had greater survival than the preimpoundment fish.

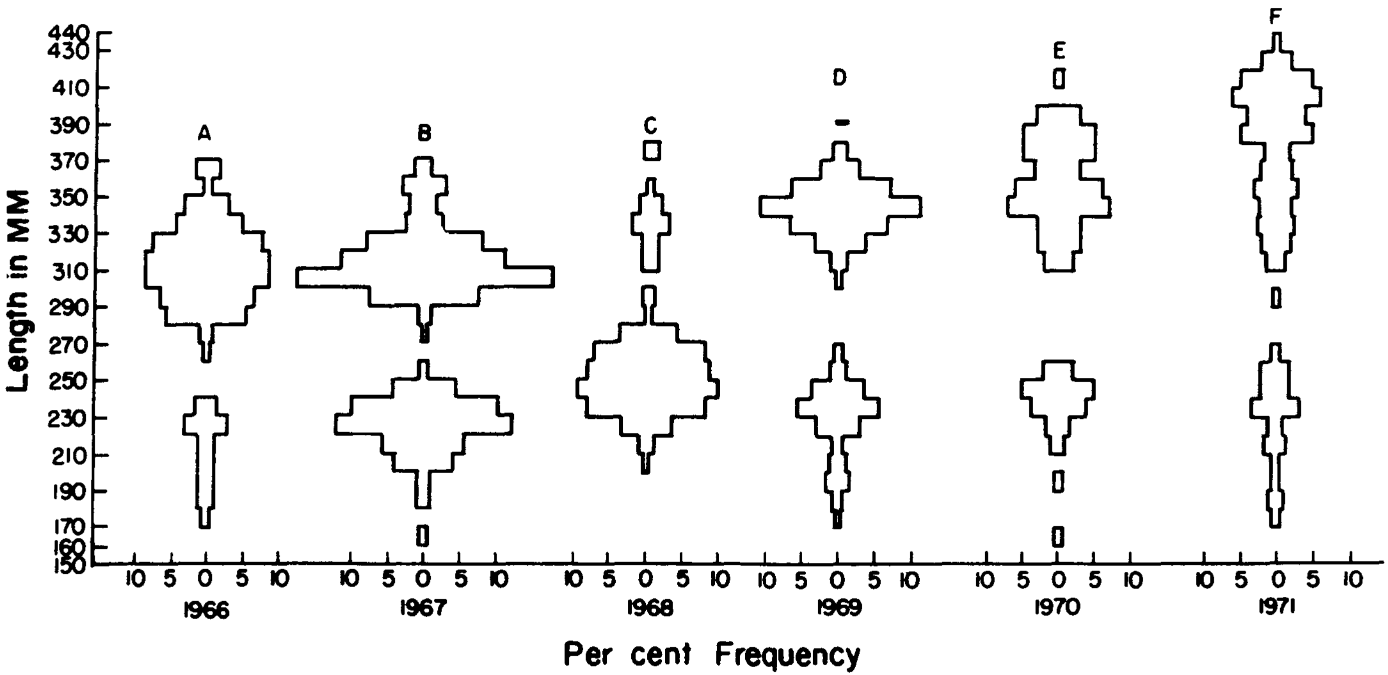

Figure 4. Size distribution in catches of January of each year. Populations of 1965 to 1970 in pyramids A to F.

Table 3. Comparison of white bass growth from different waters in the first three years of life.

Area	Length (mm) at end of year of life 1	2	3	Reference
Oklahoma waters	190	310	370	Jenkins and Elkin (1957)
Lake Duncan, Okla. (standard lengths)	190	230	270	Ward (1951)
Center Hill Reservoir, Tennessee	212	364	401	Webb and Moss (1967)
Lake Overholser, Okla. (standard lengths)	140	200	220	Thompson (1951)
Spirit Lake, Iowa (standard lengths) (Mean for both sexes)	100	190	250	Thompson (1951)
Oneida Lake, New York	130	260	310	Forney and Taylor (1963)
Clear Lake, Iowa	150	270	330	Lewis (1959)
Lake Erie	216	270	310	Van Oosten (1942)
Bull Shoals Reservoir (means for 2 years)	190	330	370	Houser and Bryant (1968)
White River (preimpoundment)	170	242	295	Present study
Beaver Reservoir	202	293	350	Present study

Table 4. Mortality and Survival for Successive age groups of Preimpoundment and Postimpoundment white bass.

Age	Preimpoundment i	Preimpoundment S	Postimpoundment i	Postimpoundment S
1-2	—	—	0.47	0.63
2-3	0.55	0.57	0.40	0.67
3-4	1.56	0.21	1.55	0.21
4-5	2.08	0.12	1.30	0.27
Average	1.40	0.25	0.93	0.40

DISCUSSION AND CONCLUSION

Age and Growth

The early recruitment phase forms the basis of a population structure. The early life history stages are highly vulnerable to environmental changes and their success or failure determine to a large extent the future status of the population. The length frequency distributions of the juveniles (Figure 2) indicated that the recruitment phase included three or four broods. These occurred during a period of one to two months with spawning commencing in March and extending into April. From the nature of the juvenile structure there appeared considerable variation in spawning activity. Yellayi and Kilambi (1969) found the early developmental stages to be sensitive to temperature with developmental rates to be too slow at 55 F. and too fast at 68 F. Increase in temperature increased the rate of mortality of eggs and fry of striped bass, a closely related species (Shannon 1969). Recruitment from 1970 spawning appeared to be large because of the relative abundance of juveniles, when the average water temperature in the upper 10 meters gradually increased from 40 F. in February and therefore the temperatures between 45-55 F. during March-April were conducive to the successful recruitment (Yellayi 1972). The rapid increase in water temperature during last phase of spawning season could perhaps account for lesser abundance of the latest broods.

The assignment of age was based on the number of annuli on the scales. It was known that annuli fail to form in some species of fish (Buchholz and Carlander 1963) and in white bass of older age groups (Ruelle 1971). In Beaver Reservoir white bass, six per cent of the scales exhibited indistinct annuli, beside frequent occurrence of false annuli. The addition of radii on white bass scales followed a specific pattern, thus was a valuable accessory method in aging the fish. Van Oosten (1945) stated that in some species of fish the radii increase in number with age and recognized some types of them as those that arise near the focus and those that arise subsequently. Larreneta (1964) observed that in some fish the radii end or bend at the annual mark. Beyond this, there was little work available to evaluate their efficacy in age determination. With the exception of those commencing midway between focus and first annulus new radii generally originated immediately after a new annulus. These radii numbered more than two after first annulus, one or two after second annulus and rarely more than one after the third annulus. Even though van Oosten (1945) recognized only two groups, it appeared useful to classify these according to the age zones in which they started. Accordingly, the terms primary, secondary, tertiary, etc. . . . were used here to indicate the radii that have originated in the first-, second-, and third-year zones of the scale.

The characteristic that the later radii arose at an annulus enabled to distinguish between the true and false annuli, particularly in the earlier years. Similarly the terminations of these at an annulus could also help to locate annuli (Larreneta 1964). Besides, the fact that radii were associated clearly in 82 per cent of scales, their value as accessory criteria in age studies was obvious. Thus, it appeared that the origin of radii was annual and marked the beginning of a new growth period. Therefore, this method appeared valuable in locating true annuli.

The progressive increase in total number of radii with age was also suggestive of its independent use in age determinations (Table 1). The large scatter observed within an age group could be due to the addition of variable number of radii in different calendar years, and also due to non addition or termination of radii in some of the scales. The increasing trend in the number of radii with age was clear from the mean numbers for different age groups, and compared satisfactorily with those observed for different categories of radii. The rate of increase in radii is inversely related to age. Ignoring the very few scales having four annuli, maximum number of radii was estimated to be about 16, which fits well with observations. From the relation of age either to the rate of increase or to the total number of radii, the age up to which the radii increase in number could be estimated, and in the present study it was observed to be 4^{+} years.

The increase in number of different categories of radii through different years was probably significant in the light of the history of Beaver Reservoir. The mean number of primary radii was less that 9.9 in fish of the year classes prior to 1963, i.e., up to the completion of the dam, the mean number of these increased gradually from 10.3 in 1963 year class through 10.4 in 1964 to 10.5 in 1965 year class. After the reservoir became almost full the mean number or primary radii increased to 10.9 in both the 1966 and 1967 year classes. The trend in mean numbers of secondary radii was similar being 1.9, 2.2, and 3.9 for the three periods, respectively. This progressive increase appears to be a consequence of impoundment.

The growth of various year classes (Figure 3) indicated that the lengths of one-year-olds prior to impoundment oscillated between 156-192mm, and in the postimpoundment period the lengths increased gradually with a maximum for the 1968 year class. In general the older age groups registered accelerated growth after impoundment.

Of the preimpoundment year classes, the 1961 year class attained maximum growth for all the age groups. This was probably a consequence of new environment with numerous shallow pools during the time when the dam was being built. The increase in growth of the one-year-olds in the postimpoundment period continued up to the 1969 year class indicating the influence of the expanding reservoir. The trend was observed to level off in growth of one- and two-year-olds, and could be expected to level off soon in the older groups.

A comparison of growth of white bass in 1968 catches with those in 1965-67 and 1969-71 catches indicated that during growth in 1967 for all the age groups was slow with the exception of the one-year-olds (Table 2). The juvenile threadfin shad suffered a drastic reduction during 1967 (Houser 1969, personal communication). It was therefore concluded that the reduced biomass of juvenile shad adversely affected the growth of white bass. Since the immature white bass fed more heavily on insects during spring and on fishes in the other seasons (Olmsted and Kilambi 1971), their growth was not greatly affected by the reduction in the biomass of shad. In contrast, the growth rates estimated from 1969-71 catches showed an increase for all the age groups. This fast growth could be partly due to the consequences of reduced numbers, particularly the later broods of 1967 class and the abundance of the juvenile shad. These two factors obviously served the same purpose as the expanding environment. This also suggests that the population of white bass attempts at a recovery even as immediately as the succeeding year, if other conditions are favorable.

The analysis of pre- and postimpoundment growth data by the von Bertalanffy growth equation showed that the white bass attained a significantly larger asymptotic length in the postimpoundment period than during the preimpoundment period. According to Beverton and Holt (1957) the asymptotic size is greatly modified by the supply of food available. Both the gizzard shad and the threadfin shad are considered to be excellent as forage fishes. In the postimpoundment period both the gizzard and threadfin shad were available as forage due to the introduction of threadfin shad into Beaver Reservoir in 1964 by the Arkansas Game and Fish Commission. Due to greater availability of forage fishes, the asymptotic size of the postimpoundment white bass had significantly increased. Within the postimpoundment period, the white bass of early postimpoundment had a larger asymptotic length than those of the early stabilization period. Shad production in Beaver Reservoir showed a decline from 1968 through 1970 (Houser and Netsch 1971). Assuming this decline beginning in the early postimpoundment period, the increase in the older age groups of white bass in the population after 1968 (Figure 4) would result in decrease in availability of food. The decrease in available food in the early stabilization period was reflected in the lower asymptotic length reached by white bass.

Population Structure

Usually a rapidly expanding population will contain a large proportion of young individuals, a stationary population a more even distribution of age groups, and a declining population a large proportion of old individuals (Odum 1971). The concept that a population would tend to be stationary for a given set of conditions and would return to that state after recovering from the impact of disturbing influences was proposed by Lotka (1956). In the present study, the 1966 population (Figure 4B) structure approached the definition of an expanding population with a large proportion of young fish. The closest to a stationary population would be located in the 1968 catch (Figure 4C) with exception of the failure of 1967 year class and the dominance of 1966 year class. The 1968, 1969 and 1970 populations (Figures 4D, E and F) suggested a declining population with a dominance of older age groups. The success of 1966 year class and the failure of 1967 class, and the increase in survival of the postimpoundment fish appeared to have contributed to this trend.

If this population structure is not corrected it would result in further deterioration leading to a senile population. This could be corrected to a large extent by exploiting the older age groups more intensively. It was recommended that catch limit on white bass be removed, and effective January 1974, by the action of the Arkansas Game and Fish Commission, there was no limit on white bass in Beaver Reservoir. It is further important that statistics on the composition of the age groups be monitored every year to evaluate the changes in population structure.

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