to fluctuate locally. Whether environmental factors in these heavily polluted areas prevented survival of the larvae is a matter of speculation.

FOULING

Since crabs with externae are unable to moult, specimens with large or decaying externa are often heavily fouled by a variety of fouling organisms. This is to be expected and many observations of this phenomenon in normal adult crabs have been reported. Among the parasitized crabs collected in Biloxi Bay in 1965, I found several with oysters growing on the ventral side. Occasionally an oyster grows on the carapace of an old crab, but this seems to be the first observation of ventral fouling by oysters. The size of the oysters indicates that the crabs had not accomplished an ecdysis for at least a month.

SUMMARY

Increasing fishing mortality in the Gulf and catastropnic depletion of Atlantic blue crab populations have called attention to all factors that might decrease crab populations. Although *Loxothylacus texanus* does not pose any evident problem at this time, heavy local infestation indicates the possibility that it could become a serious problem.

Loxothylacus texanus has not been observed in *Callinectes similis.* Ventral oyster fouling of parasitized blue crabs was observed in Mississippi estuarine waters. No adults of normal size have been observed with the parasite. *Loxothylacus texanus* apparently infests juvenile blue crabs only in Mississippi waters.

The occurrence of *Loxothylacus* in *Eurypanopeus depressus* and *Rhithropanopeus harrissii* in Mississippi waters was observed.

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GROWTH OF THREADFIN SHAD IN BULL SHOALS RESERVOIR

By Horace E. Bryant and Alfred Houser
South Central Reservoir Investigations
Bureau of Sport Fisheries and Wildlife
Fayetteville, Arkansas

ABSTRACT

Threadfin shad, *Dorosoma petenense,* were first introduced into Bull Shoals Reservoir in 1961. Based on fish collected in 1966 and 1967, weighted average calculated total lengths of females at the end of each successive year of life were 66, 118, 134 and 141 millimeters, and of males 64, 118 and 123 millimeters. Growth of threadfin shad in Bull Shoals was slower than in more southern and temperate regions, but life span was longer. A strong year class in 1964 was indicated by the presence of a relatively high number of 2-year-old fish in 1966 and 3-year-old fish in 1967.

The ratio of females to males in cove rotenone samples was 3.8 to 1, while in midwater trawl samples the ratio was 1.0 to 1. Threadfin shad comprised 80 percent of the total shad population by number, but only 17 percent by weight.

INTRODUCTION

Threadfin shad, *Dorosoma petenense*, is now the most abundant forage species in Bull Shoals Reservoir. Although it does not grow beyond the forage range of the largest predators, age and growth data are needed for a thorough understanding of the life history and population dynamics of this highly important species.

Relatively little information has been published concerning the age and growth of this fish. Parsons and Kimsey (1954) found threadfin shad to be short-lived, with few reaching two years. Berry, Huish and Moody (1956) concluded that mass spawning mortality may account for their relatively short span of life. Some threadfin shad in Bull Shoals Reservoir attain the age of four years (Figure 1).

The range of threadfin shad extends along the Gulf Coast from Florida northward in the Mississippi Valley to Tennessee, southern Arkansas, Oklahoma and south to British Honduras. Recent introductions of this species have been made in California,

Figure 1. Scale of a 151 millimeter female threadfin shad age four years collected August 1967, in Bull Shoals Reservoir.

Arizona and Hawaii. Black (1940) reported this fish as far north as De Valls Bluff on the White River in Arkansas. Its introduction into Bull Shoals Reservoir was made by the Arkansas Game and Fish Commission in 1961 (Mr. Robert Baker, personal communication). This species has flourished since, with cyclic fluctuations in abundance, the lowest occurring in 1966 (Houser and Bryant, 1968).

Bull Shoals is the lowermost of four mainstream reservoirs located on the White River in Arkansas and Missouri. A limnological description of this reservoir is presented by Mullan and Applegate (1966).

MATERIALS AND METHODS

Materials for this age and growth study include 1,926 threadfin shad collected in August 1966 and August-September 1967 in cove rotenone samples and 1,214 age I fish collected in January 1967 and January 1968 by midwater trawl. Additional information used in determining sex ratios and the validity of the annulus as a year mark was obtained from trawl samples. All fish were preserved in 10 percent formalin. No correction was made for shrinkage of preserved specimens.

Date, location, total length, weight, sex and stage of sexual maturity were taken from each fish and recorded on a 3 x 5 scale envelope. Scale samples were taken from the left side below the origin of dorsal fin near the lateral line. Six to eight scales were mounted (dry) between two glass slides and read on a standard microprojector at a magnification of 40 diameters. Scale measurements were made from the estimated focus to each annulus in millimeters. Fish collected after January 1 and before annulus formation time were credited with an annulus at the scale margin since growth for the preceding year was assumed complete by the end of December.

Threadfin shad scales are cycloid and similar to the gizzard shad scale described by Lagler and Applegate (1942). The posterior exposed portion is clear, showing little or no marking with the exception of an annulus. Circuli are crescent shaped, concave posteriorly, and intersect the lateral edge of the scale. Transverse grooves are located in the anterior region (imbedded area), intersecting the lateral fields. The annulus is characterized by discontinuity of circuli in the lateral anterior and lateral fields. Cutting over occurs in the lateral field (Figure 1).

The following criteria were used to validate the annulus as a true year mark (Hile, 1941): 1) An increase in annuli was accompanied by an increase in total length. 2) Calculated values of fish length at the end of the first year closely approximated length of the preceding year when age was known. 3) The persistent abundance of one year class in successive calendar year collections.

The procedure outlined by Houser and Bryant (in press) was used to compute the following: 1) Total body length-scale length relationships were calculated by fitting polynomials of the form $L = \Theta_o + \Theta_1 S + \Theta_2 S^2 + ... + \Theta_k S^k$ using the technique of step-wise polynomial regression (Graybill, 1961), where L = total length of the fish and S = length of scale, Θ and K are constants derived from data. All calculations were made using grouped data. For each sex, the calculations were carried through sixth degree polynomials and tested to determine which equation best fits the data. 2) Length-weight relationship expressed as W = aLn where W = weight, L = total length, and a and n are constants. 3) Back calculation of lengths at each annulus for each age group. Average scale measurements of distance from the focus to each annulus in each age group by sex was computed. These values were substituted in body length-scale length regressions and the body lengths obtained were taken to represent the length at the end of each year of life.

BODY-SCALE RELATIONSHIP

The relationship of the length of the scale radius to total fish length for gizzard shad (*Dorosoma cepedianum*) was shown by Turner (1953) to be represented by a straight line. La Pointe (1957) found plotted body-scale measurements of American shad (*Alosa sapidissima*) indicated a parabolic equation. Plotting points of total body lengths and anterior scale radius demonstrated that the body-scale relationship of Bull Shoals Reservoir threadfin shad followed a curvilinear line (Figure 2).

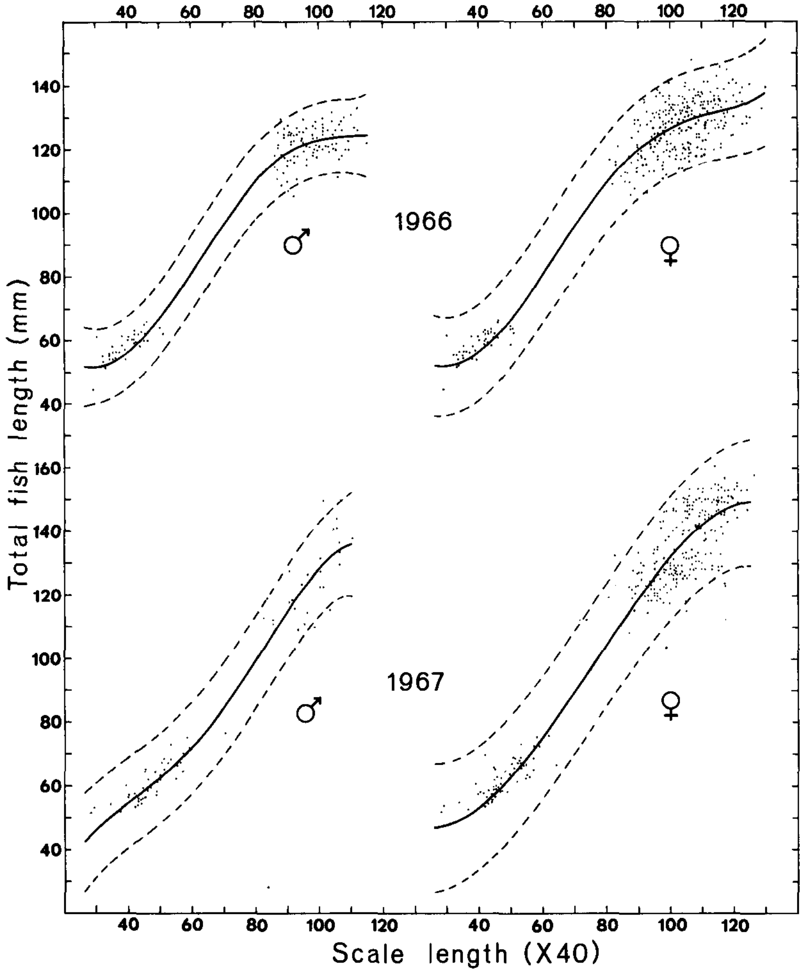

Figure 2. Body-scale relationships of threadfin shad from Bull Shoals Reservoir (95 percent confidence limits indicated by dashed lines).

No effort was made to sex age O fish, but age I fish collected in January of 1967 and 1968 were sexed and showed no difference in length between sexes. Therefore, all young of the year fish in each year's sample were used in the calculation of each body-scale relationship.

Equations obtained which most adequately fit the data were as follows:

Body-Scale Relationship

Males 1966

$$L = 75.662 - 1.266\ S - 0.0103\ S^2 + 0.00127\ S^3 - 0.0000151\ S^4 + 0.0000000519\ S^5$$

Females 1966

$$L = 90.502 - 2.732\ S + 0.0458\ S^2 + 0.000255\ S^3 - 0.00000661\ S^4 + 0.0000000258\ S^5$$

Males 1967

$$L = -24.423 + 4.662\ S - 0.112\ S^2 + 0.00135\ S^3 - 0.00000538\ S^4$$

Females 1967

$$L = 66.488 - 1.738\,S + 0.0427\,S^2 - 0.000188\,S^3$$

An examination of the variation in the body-scale relationship (Figure 2) revealed little difference between male and female threadfin shad in 1966. The sample of 1967 did require a third degree polynomial for females, compared to a fourth degree polynomial for males. This may be attributed to the smaller number of males collected. Body-scale relationships of threadfin shad are best described as a curvilinear function rather than a straight line.

LENGTH-WEIGHT RELATIONSHIP

The relationship between total length and weight of threadfin shad in Bull Shoals Reservoir was calculated for each sex. Since no differences in length between the sexes were observed in yearling fish collected by midwater trawl, all young of the year fish were combined with each sex in calculations. The length-weight relationship expressed in logarithmic form for females is $\log W = -6.60091 + 3.1599 \log L$; for males, $\log W = 6.56021 + 3.1830 \log L$.

The calculated weight plotted against length (Figure 3) shows that males are slightly heavier than females. These collections were made after spawning. In our field observations immediately prior to spawning, we found that females weighed more than males.

AGE COMPOSITION AND SEX RATIO

Age II was the dominant age group in the two rotenone samples. It was evident the 1964 year class was strong by the sequential appearance of a large number of 2-year-olds in 1966 and 3-year-olds in 1967 (Table 1).

A total of 1,917 threadfin shad collected by rotenone and midwater trawl were sexed to determine the ratio of females to males. In all age groups with the exception of yearling fish the ratio was progressively higher with an increase in age. Yearling fish collected by midwater trawl had a ratio of 1:1. In the cove rotenone samples ages one through three, the ratio was 6.6:1, 2.2:1 and 12.1:1. Five females in the collection had reached an age of four years.

To determine time of annulus formation, two collections of threadfin shad were made April 18 and May 27, 1968. No annulus formation had occurred in April, but was visible on scales in the May collection.

GROWTH HISTORY

Growth rates were calculated for 552 females and 147 males. Weighted average calculated total lengths of females at end of successive years of life were 66, 118, 134, and 141 millimeters; for males they were 64, 114, and 123 millimeters (Tables 2 and 3).

Female threadfin shad live longer and attain a greater size than males. Females had a slightly faster growth rate (Figure 4), but differences in length between the sexes were not significant at the end of the first two years of growth. At the end of the third year, mean female total lengths exceeded that of males by 11 millimeters. In the sample of 699 fish, 11 males and 99 females had attained the age of three years, and 5 females had reached the age of four years.

Kimsey (1958) found threadfin shad reached lengths of 101 and 114-117 millimeters at the end of the first and second years of life in the Colorado River. Growth in Bull Shoals was much slower during the first year of life, but by the end of second year the size is comparable with that in the Colorado River.

Bull Shoals threadfin shad live longer, but do not attain lengths recorded elsewhere. McConnell and Gerdes (1964) reported threadfin shad in Pena Blanca Lake, Arizona, reached 175 millimeters in length. Parsons and Kimsey (1954) stated threadfin shad seldom grow beyond seven inches or 179 millimeters. Lambou (1965) collected fish eight inches (203 millimeters) in total length in the Bogue Falaya River, Louisiana. The largest fish collected from Bull Shoals Reservoir was a 161 millimeter female. Shorter growing seasons and possibly more acute interspecific competition may account for the smaller maximum size in Bull Shoals.

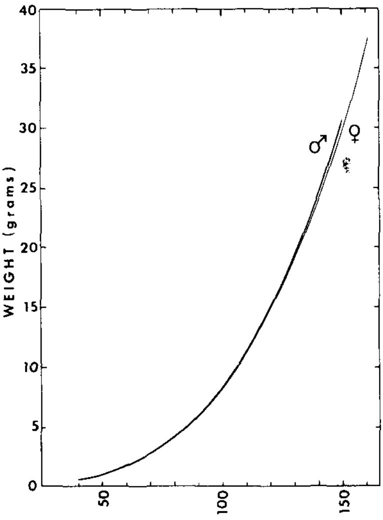

Figure 3. Length-weight relationship of threadfin shad from Bull Shoals Reservoir.

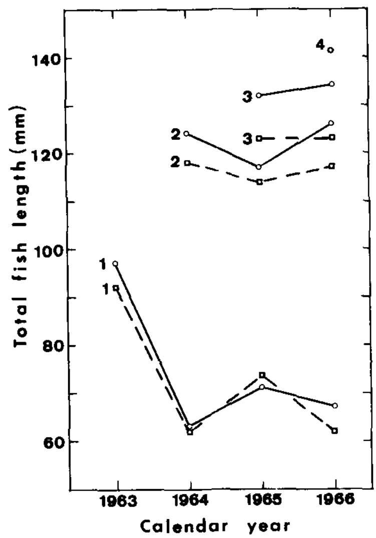

Figure 4. Growth history of female (solid line) and male (broken line) threadfin shad from Bull Shoals Reservoir. Lines connect points representing calculated length attained by each year-class at end of year of life indicated by numeral at left.

Considerable difference in first year growth was observed among the year classes. Deviation in growth in mm. of each year class from the unweighted calculated 4-year average was as follows:

	1963	1964	1965	1966
Females	+22	-12	-4	-8
Males	+19	-11	+1	-9

The fastest growth occurred in 1963 for both sexes and the slowest in 1964. The fast growth in 1963 may bave been due to an expanding population at that time when competition was not as keen within the species. The slow growth in 1964 may be attributed to intraspecific competition within the large 1964 year class.

Some of this difference in growth could be due to the success or failure of second or third hatches during the summer. A successful second spawn would produce more small fish in the year class. A failure would result in more large fish from the first spawning period. Another factor which may influence the size of fish during the first year would be the time and location of spawning. We found that spawning occurred at least a week earlier in the upper region than in the lower region of the reservoir. Threadfin shad were significantly larger in the upper region and smaller in the lower region of the reservoir throughout the summer. A successful spawn in the upper region and failure in the lower region of the reservoir would produce larger fish. Conversely, a successful spawn in lower region and failure in the upper region of reservoir would produce smaller fish.

Since introduction in 1961, threadfin shad have become increasingly abundant in Bull Shoals Reservoir. Annual rotenone samples conducted by Mr. Robert Baker, Arkansas Game and Fish Commission Fishery Manager, since impoundment in 1952 indicate that threadfin shad numbers increased from 1962 through 1965 and decreased in 1966. Population studies made in ,1966 and 1967 by South Central Reservoir Investigations show that threadfin shad surpassed the gizzard shad, *Dorosoma cepedianum*, in numbers but not in weight. The dominance in weight by gizzard shad is due to fewer, but much larger individuals in the population.

TABLE 1
Age composition of threadfin shad by sex

Sample date	*Midwater Trawl*		*Cove Rotenone*							
	I		*I*		*II*		*III*		*IV*	
	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂
August 1966	--	--	76	14	213	102	9	2	--	--
January 1967	337	255	--	--	--	--	--	--	--	--
August-September 1967	--	--	135	18	24	5	90	6	5	0
January 1968	267	359	--	--	--	--	--	--	--	--
Totals	604	614	211	32	237	107	99	8	5	0
Ratio of females to males	1:1		6.6:1		2.2:1		12.1:1			

TABLE 2

Average calculated growth rate of female threadfin shad from Bull Shoals Reservoir.

Year class	*Number of fish, age groups I through IV*	*Total length (mm) at each annulus* 1	2	3	4
1966	135	67			
1965	100, 24	71	126		
1964	303, 303, 90	63	117	134	
1963	14, 14, 14, 5	97	124	132	141
Weighted mean		66	118	134	141
Annual increment		66	52	16	7
Number of fish		552	341	104	5

TABLE 3

Average calculated growth rate of male threadfin shad from Bull Shoals Reservoir.

Year class	*Number of fish, age groups I through IV*	*Total length (mm) at each annulus* 1	2	3	4
1966	18	62			
1965	19, 5	74	117		
1964	108, 108, 6	62	114	123	
1963	2, 2, 2	92	118	123	
Weighted mean		64	114	123	
Annual increment		64	50	9	
Number of fish		147	115	8	

An indication that threadfin shad are suppressing gizzard shad survival is shown by four rotenone samples taken in 1966 and 1967. The average number of shad recovered was 1,983 per acre, weighing 110.4 pounds per acre. Threadfin shad constituted 80 percent of the number and 17 percent of the weight of the clupeid crop. Similarly, Wyatt and Zeller (1962) reported threadfin shad made up 67 percent of the total shad population, but only 4 percent of the weight in Lake Blackshear, Georgia.

Threadfin shad appear to be an excellent forage fish in Bull Shoals. This fish is short-lived, prolific, does not grow out of the forage range, and winter kills keep the population in check. Although increased growth rates of white bass have resulted since introduction of this fish, further studies are being undertaken to determine its interspecific competition effects on other fishes.

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THE 1957-61 SPORT FISHERY IN AN ARKANSAS WATER SUPPLY RESERVOIR[1]

By Charles F. Cole
Department of Forestry and Wildlife Management,
University of Massachusetts
Amherst, Massachusetts

ABSTRACT

A year-round creel census was conducted on Lake Fort Smith, Arkansas from August, 1957 through December, 1961. Typically, maximal fishing pressure began in March and April and terminated in May when turbidity from heavy runoffs made the lake less desirable for fishing; substantial pressure returned in July but dwindled by October. Yearly pressure varied from 12.72 to 28.70 man-hours/acre/year; largemouth bass dominated the catch. Fishing pressure was correlated with fishing success indicating the localized nature of the fishermen using the lake.

[1]Presented to: The Annual Meeting of the Southern Division of the American Fisheries Society and the Southeastern Association of Game and Fish Commissioners, Baltimore, Maryland, October 21-23, 1968.