GROWTH OF WHITE CRAPPIE AND GIZZARD SHAD IN LAKE KEYSTONE, OKLAHOMA

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White crappie, *Pomoxis annularis*, grew more slowly in Keystone Reservoir during the first three years after impoundment than in other newly impounded waters in Oklahoma. The growth of gizzard shad, *Dorosoma cepedianum*, decreased during these first three years. Length-frequency histograms suggest that two discrete populations of gizzard shad coexisted in Salt Creek Cove of the lake during 1967. Gizzard shad exhibited the reverse of Lee's phenomenon.

This study was initiated as a part of a long-term investigation on the productivity of Keystone Reservoir, Oklahoma. The objective was to describe growth of gizzard shad, *Dorosoma cepedianum,* and white crappie, *Pomoxis annularis,* during the first three years after impoundment (1).

Keystone Reservoir is a multipurpose reservoir formed by impoundment of the Cimarron and Arkansas rivers near their confluence, approximately 20 km from Tulsa, Oklahoma. The reservoir began filling in 1964, and reached normal pool level (221 m msl) during November of that year. Physiographic characteristics of the reservoir are: surface area, 10.6 x 10^3 ha; mean depth, 7.7 m; maximum depth, 22.9 m; shoreline length, 531 km at normal power pool level. Because of the large size of the reservoir, the sampling area was limited to Salt Creek cove (Figure 1) which has a surface area of 10^3 ha.

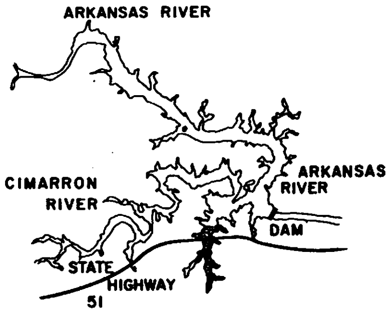

FIGURE 1. Keystone Reservoir, Oklahoma. Dotted area indicates sampling area.

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METHODS

Collection of specimens

Field data were collected during the summer and early autumn of 1966 and 1967. Crappie were collected with 14 barrel nets at depths of 2 to 7 m. Gizzard shad were collected by shoreline electro-fishing.

Measurements and scale preparation

Total length was recorded to the nearest millimeter shortly after capture. In the field, scales were taken, with a pocket knife, from the anterior part of the body just under the tip of the pectoral fin and below the lateral line on the right side. When the scales had been regenerated on the right, the left side of the fish was used.

Impressions of crappie scales were made on clear plastic strips, using a roller press. Scale impressions were projected by a scale projector at a magnification of 80X. Shad scales were placed in watch glasses and allowed to soak overnight in water. Wet mounts were made by placing the scales between two glass microslides. The shad scales were projected at a magnification of 80X.

In all cases more than one scale was examined to verify the presence of the same number of annuli on all scales. The distances between the center of the focus of crappie scales and the respective annuli on the anteriolateral portion of the scale were measured with the same metric ruler, and recorded to the nearest millimeter.

The midpoint of the first circulus was chosen by visual inspection to function as the focus of the shad scales. There was no significant difference between measurements of scale length, which were made from a focus located by visual inspection, and those located with calipers ($t=2.85$, $n=20$, $P=0.01$). Measurements were made on the anterior portion of the scale. Statistical analyses followed methods of Snedecor (2).

RESULTS

Body scale relationships

For both shad and crappie, there was a linear relationship between length of the body and the length of the scale in the size range of the fish captured (1). These results indicate that for shad, and to some extent crappie, curvilinearity existed only for fish less than 100 mm length. Empirical lengths of small fish were usually far less than the length predicted by a curvilinear relationship. Thus, we used the linear relationship between body length and scale length for both species for the purpose of back calculation.

Criteria proposed by Van Oosten (3), Hile (4), and Ricker (5) were used to test the validity of the scale method of aging fish in this study.

Correlation between age and size

(*a*) The regular increase in number of annuli should be accompanied by a similar increase in the size of the fish. This condition verifies that annuli are added systematically as growth proceeds and that occurrence of annuli on scales is not haphazard. Tables 1 and 2 show that such an increase was evident in both species collected in 1966 and 1967.

(*b*) Fish assigned to the same age-group should have similar lengths. This criterion has been met (Tables 1 and 2). The 1967 shad showed some deviation from this criterion which may be due to presence of two populations with different growth rates.

(*c*) Average length of an age-group determined from scale reading and the respective average length established from a length-frequency histogram should agree. The modes for the combined length-frequencies of crappie and shad collected in 1966 and 1967 deviated 1.3 - 2.3 mm and

TABLE 1. *Average calculated total length (mm) and total length at capture of white crappie collected from Keystone Reservoir, Oklahoma, 1966 and 1967.*

Data Collected	Year class	Age group	No. of fish	Calculated total length at annulus 1	2	3	4	Average total length at capture	Marginal growth
1966	1965	I	423	111.5				138.7	27.2
	1964	II	6	122.0	158.5			177.7	19.2
	1963	III	2	95.0	135.0	162.5		176.5	14.0
	1962	IV	3	107.3	155.7	210.7	252.0	269.0	17.0
	Mean			111.5	153.5	191.4	252.0		
Average annual increment				111.5	42.0	37.9	60.6		
1967	1966	I	50	110.9				136.4	25.5
	1965	II	1,264	110.6	143.7			153.7	10.0
	1964	III	10	118.3	158.0	186.5		196.1	9.4
	1963	IV	1	123.0	170.0	202.0	221.0	234.0	13.0
	Mean			110.7	143.8	187.9	221.0		
Average annual increment				110.7	33.1	44.1	33.1		

TABLE 2. *Average calculated total length (mm) and total length at capture of gizzard shad collected from Keystone Reservoir, Oklahoma, 1966 and 1967.*

Data collected	Year class	Age group	No. of fish	Calculated total length at annulus 1	2	3	Average total length at capture
1966	1965	I	1,324	140.6	207.3		165.5
	1964	II	35	141.4	207.3		227.5
	1963	III	1	155.0	219.0	261.0	272.0
	Mean			140.6	207.6	261.0	
Average annual increment				140.6	67.0	53.4	
1967	1966	I	1,443	118.7			151.7
	1965	II	140	122.4	165.7		180.1
	1964	III	2	127.0	183.0	225.5	232.0
	Mean			119.0	165.9	225.5	
Average annual increment				119.0	46.9	59.6	

0.1 - 7.3 mm, respectively, from the average lengths at capture suggested by the modes.

A number of shad scales collected during 1967 had one clear, well-defined annulus. These scales were taken from fish much smaller than those collected in 1966 and most of those collected in 1967. These observations together with an inspection of a length-frequency histogram (Figure 2) suggested that shad collected in 1967 might belong to two populations that apparently overlapped in the 130 to 140 mm range.

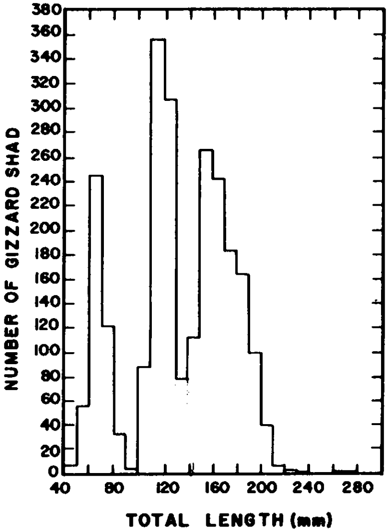

FIGURE 2. Combined length-frequency histogram of gizzard shad, collected from Keystone Reservoir, Oklahoma, 1967.

Agreement among calculated growth histories

(*a*) Lengths at the end of various years of life calculated from scale measurements should agree with corresponding empirical lengths of younger age-groups whose ages were determined by the examination of scales. Tables 1 and 2 show that for crappie and shad at time of capture age I fish were between the average calculated lengths at annulus 1 and 2, while age II fish were between the average calculated lengths at annulus 2 and 3, *etc.*

(*b*) There should also be agreement between calculated length of fish of the same age which were collected in different samples. Back-calculated, average lengths of crappie are consistent for age I in 1966 and age II in 1967 where sufficient numbers of fish were collected (Table 1).

(*c*) There should also be good agreement of growth histories of the same age-groups of different year-classes. For crappie the average calculated total lengths at the first annulus differed by less than 0.9 mm when the sample size was 50 or more fish.

The validity of the age determination for shad can best be tested by comparing the data from various semi-monthly samples. Relatively constant average calculated lengths for each age-group in all the 1966 samples suggest that the scale readings for the 1966 data are valid. For example, age-group I fish had a back-calculated mean length of 140.6 mm at the first annulus; the range of back-calculated lengths at the first annulus was 132.0 - 148.3 mm. When the two shad populations sampled in 1967 are partially separated, the aver-

TABLE 3. *Average total length (mm) of two (small and large size) populations of gizzard shad in the 1967 collection.*[a]

Date (1967)	No. of fish	Small size population Total length (mm) at 1st annulus	capture	No. of fish	Large size population Total length (mm) at 1st annulus	capture
6/1-15	30	106.1	121.6	197	133.7	170.7
6/16-30	19	100.8	126.1	102	129.0	164.2
7/1-15	31	98.9	120.0	52	122.3	161.0
7/16-31	111	99.7	122.4	102	119.0	155.3
8/1-15	108	97.5	120.4	117	127.6	166.2
8/16-31	47	95.7	117.5	175	126.4	166.7
9/1-15	112	98.5	120.6	85	124.7	163.4
9/16-30	38	98.2	121.7	117	133.9	176.2
Total	496					

[a] Small-sized population includes fish 134 mm or less in total length; large-sized population includes fish 135 mm or more in total length.

age back-calculated lengths for the semi-monthly samples of both populations are also relatively constant (Table 3).

(*d*) There should be good agreement among different year classes for relative growth in a year. To illustrate this point, the technique of Hile (4) was used to demonstrate that the growth increments in previous years (1962 to 1966), determined by back-calculation, tended to increase or decrease consistently in comparison with corresponding increments of the preceding year (Table 4).

Persistence, abundance, or scarcity of year classes

The abundance of various year-classes in the samples taken in 1966 and in 1967 show that the age-group I shad (the 1965 year-class or the 1966 year-class) was the most abundant age-group collected in 1966 and 1967, respectively (Table 2). This assumes the same relative mortality in the various year-classes.

The 1965 year-class of crappie was the first to hatch in the reservoir and become the dominant year-class in both the 1966 and the 1967 collections (Table 1). This was also the dominant year-class in all the samples collected in 1966 and 1967. Thus, there is good agreement betwen the technique of identifying an age-group by its numerical abundance and the technique of determining the age of fish by inspecting their scales.

Length at capture during growing season

Ricker (5) used another criterion for the validity of the scale method. There must be a gradual increase in the average length at capture for a particular age-group with the progress of the growing season. Increases in the average lengths at capture of a particular age-group are evident in both 1966 and 1967 for crappie. For example, age-group II fish increased in length steadily from 136.4 mm to 144.7 mm during August and September, 1966. When the two shad populations are examined separately, the same trend emerges (Table 4).

TABLE 4. *Annual increments of growth in length (mm) of white crappie and gizzard shad collected from Keystone Reservoir, Oklahoma, 1966 and 1967.*[a]

Fish and year of capture	Year of life	Increment of growth in calendar year 1962	1963	1964	1965	1966
White	4				44.3	
crappie	3			55.0	27.5—	
1966	2		48.4	40.0—	36.2—	
	1	107.3	95.0—	122.3+	111.5—	
White	4					19.0
crappie	3				32.0	28.5—
1967	2			47.0	39.7—	33.1—
	1		123.0	118.3—	110.6—	110.9+
Gizzard	3				42.0	
shad	2			64.0	65.9+	
1966	1		155.0	141.4—	140.6—	
Gizzard	3					42.5
shad	2				56.0	43.3—
1967	1			127.0	122.4—	118.7—

[a] Minus (—) indicates growth poorer than previous year; plus (+) indicates growth better than previous year.

TABLE 5. *Comparison of growth of white crappie in Keystone Reservoir and in other Oklahoma reservoirs.*[a]

Authority	Locality	Average Total Length (mm) at Annulus I	II	III	IV	V	VI
Buck and Cross (8)	Canton Reservoir	104	198	264			
Hall and Jenkins (9)	Fort Gibson Reservoir	160	236	287			
Hall and Jenkins (9)	Tenkiller Reservoir	127	279	315			
Latta (10)	Wister Reservoir	104	201	269	330		
Mean		124	228	284	330		
Hall, Jenkins and Finnel (11)	State of Oklahoma Reservoirs	84	175	208	251	302	328
Present Study	Keystone Reservoir	111	149	190	236		

[a] All original data; figures for total length originally recorded in inches were converted to millimeters using conversion tables of Carlander (7).

Since growth in some species continues through the autumn months and even during the winter, in any particular year-class the average calculated growth increment for the last annum should exceed, or at least equal, growth between the last annulus and the margin (marginal increment) in the previous year. For example, the average size of the age-group I shad in 1967 was 118.7 mm, 38.7 mm greater than the average total length of the 0 age-group in 1966 and 26.1 mm greater than the greatest length of age-group 0 fish during 1966.

DISCUSSION

Crappie collected in 1966 and 1967 showed greatest growth in length during the first year of life (Table 1). Fish collected during 1966 showed a better rate of growth than those collected in 1967.

A decrease in the growth rate of fish with aging of a reservoir is a typical phenomenon (6). The present data were collected during the first three years after impoundment. Therefore, it is useful to compare these growth rates with data collected on fish living in reservoirs three years old or less (Table 5). These data indicate that the growth rate of crappie in Keystone is lower than the average rate of growth in other newly impounded waters in Oklahoma. Age-group I fish showed better rates of growth than fish of the same age from Canton and Wister Reservoirs. Crappie in the Keystone Reservoir showed the slowest rate of growth relative to fish from other lakes during the second year of life. Most of these fish were from the 1965 year-class (the first to hatch in the lake). This year-class was dominant in both the 1966 and the 1967 collections.

Shad collected during both 1966 and 1967 showed evidence of the reverse of Lee's phenomenon (Table 2), where older fish tend to have greater calculated lengths than do the younger fish at the same annuli. The largest increments in length were made during the first year of life, similar to the growth of crappie. The growth rate of shad showed a gradual decline with the aging of the lake.

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