AGE AND GROWTH OF THE SPOT, *LEIOSTOMUS XANTHURUS* LACÉPÈDE[1]

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Introduction

The spot, *Leiostomus xanthurus,* a common sciaenid fish along the Atlantic and Gulf coasts from Massachusetts to Texas is especially abundant in estuaries and sounds. The commercial fishery is centered in the Chesapeake Bay area and in the Carolinas. Along the coasts of Louisiana and Texas, the spot is not marketed for human consumption to any great extent. Here it is included with trash fish which are used chiefly in making cat and dog food.

The object of the present investigation was to determine the age and growth of the spot in the Lake Pontchartrain area, Louisiana, based on length-frequency polygons, scale, and otolith studies. Otoliths have not been previously used to determine the age of spot.

Previous attempts to determine the age of spot have been based mostly on the interpretation of modes in length-frequency polygons. Welsh and Breder (1923) reported difficulty in reading its scales. Hildebrand and Schroeder (1928) gave a comprehensive account of the life history of the Chesapeake Bay spot and stated that the wide range of length of spot taken throughout the year made determination of growth rate difficult. Pearson (1928) stated that the spawning season for the spot in the Gulf of Mexico extends from late December through March; the peak was reached in January and February. He also reported on the growth and other aspects of the life history. Hildebrand and Cable (1930) described the larval stages. The smallest spot taken at Beaufort, North Carolina was 1.5 mm in total length; it was assumed to be newly hatched. They also stated that the extended spawning season makes for a great variation in sizes and, as a result, the sizes of fish in successive age groups overlap considerably after the second year. Gunter (1938, 1945) reported on the growth and other aspects of the life history of the spot in Texas and Louisiana waters. Townsend (1956) and Pacheco (1957) recently showed that age determination based on scale studies is possible in the spot. Dawson (1958) studied the biology and life history of the spot with special reference to South Carolina.

Materials and Methods

In this study 1,418 specimens were used. The collections were made at monthly intervals; 354 were collected during July 1953 to May 1954, 145 during January 1955 to September 1955, and 919 during October 1958 to September 1959. The first two series of collections (*viz.,* 1953-54 and 1955) were made in Lake Pontchartrain proper. The 1958-59 collections were obtained from Saw Mill Pass at the Rigolets, lat. 30° 09′N and long. 89° 44′W (fig. 1). Trammel nets, seines, otter trawls, and rotenone were used to collect the specimens.

Seine and trawl samples (Suttkus, Darnell, and Darnell, 1954) indicate that young-of-the-year are more abundant in the shallower areas of the lake during the period February through April. Later in the season young spot frequent deeper parts of the lake and the trawl is a more effective type of collecting gear. Thirteen trawl stations and seven seine stations were established in Lake Pontchartrain (fig. 1). The monthly samples from each station were not large enough to allow a critical comparison of growth rate between various stations.

Length Measurements.—Length measurements were made within a few hours after preservation in 10 percent formalin. Total lengths, measured according to the method of Hubbs and Lagler (1947), were used for growth computations throughout this study. For conversion of total length into standard length a ratio of 1:0.816 was computed for specimens from 19 to 49 mm and a ratio of 1:0.773 for specimens from 50 to 270 mm in total length.

Scale studies.—Scales used in the determination of age and growth were removed from the left side of each fish below the

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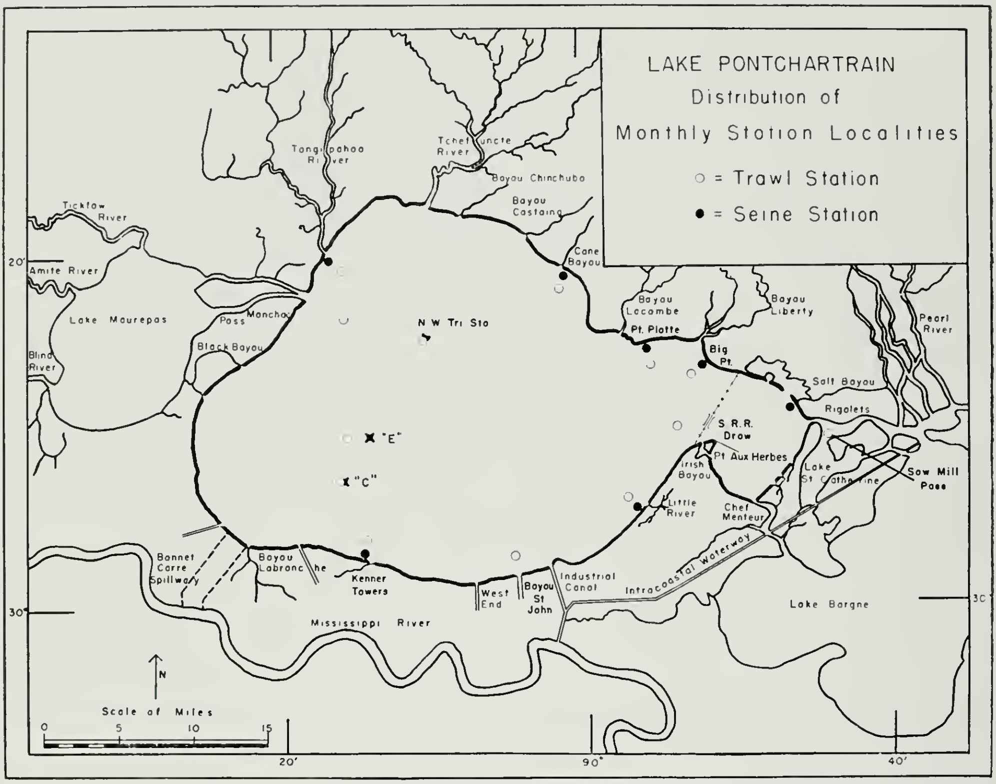


Figure 1. Map of Lake Pontchartrain showing the distribution of monthly trawl and seine stations.

lateral line immediately posterior to the appressed pectoral fin. Regenerated scales were discarded. About 20 scales were removed and rubbed between the fingers to clean off epidermis and slime. The scales were then rinsed in water and stored in scale envelopes. The following information was recorded: total length, date of collection, locality, and method of capture.

In the laboratory, a few scales were removed from each envelope and placed in a 0.5 percent sodium hydroxide solution for a few minutes. Each scale was then cleaned by rubbing between fingers. Impressions of five or six regular scales were made on 3 by 1 inch cellulose acetate strips by use of a roller type press (mfg. William Dixon Inc., Newark, New Jersey). The scale impressions were viewed with a Bausch and Lomb microprojector at a magnification of 57.5 X. Scale images were projected vertically on a sheet of paper. The positions of the projected annuli were marked on strips of paper and these were used for back-calculations. All scales with at least one annulus were read several times until the results were concordant. In addition to the enumeration of annuli, the number of circuii from focus to each annulus and to the anterior margin of the scale were counted.

Otolith studies.—A median sagittal incision was made on the head, in a dorsoventral direction. The two resulting halves were forced outwards and both otoliths removed with a forceps. They were stored dry in their respective scale envelopes. Otoliths were removed only from 1955 and 1958-59 samples.

Some authors have emphasized the importance of not allowing the otoliths to become dry while others stored them dry. Spot otoliths did not lose their clarity after four years of dry storage in this laboratory. Ling (1958) stated that the clarity of the sea garfish, *Reporhamphus melanocheir*, otoliths did not suffer from the effects of

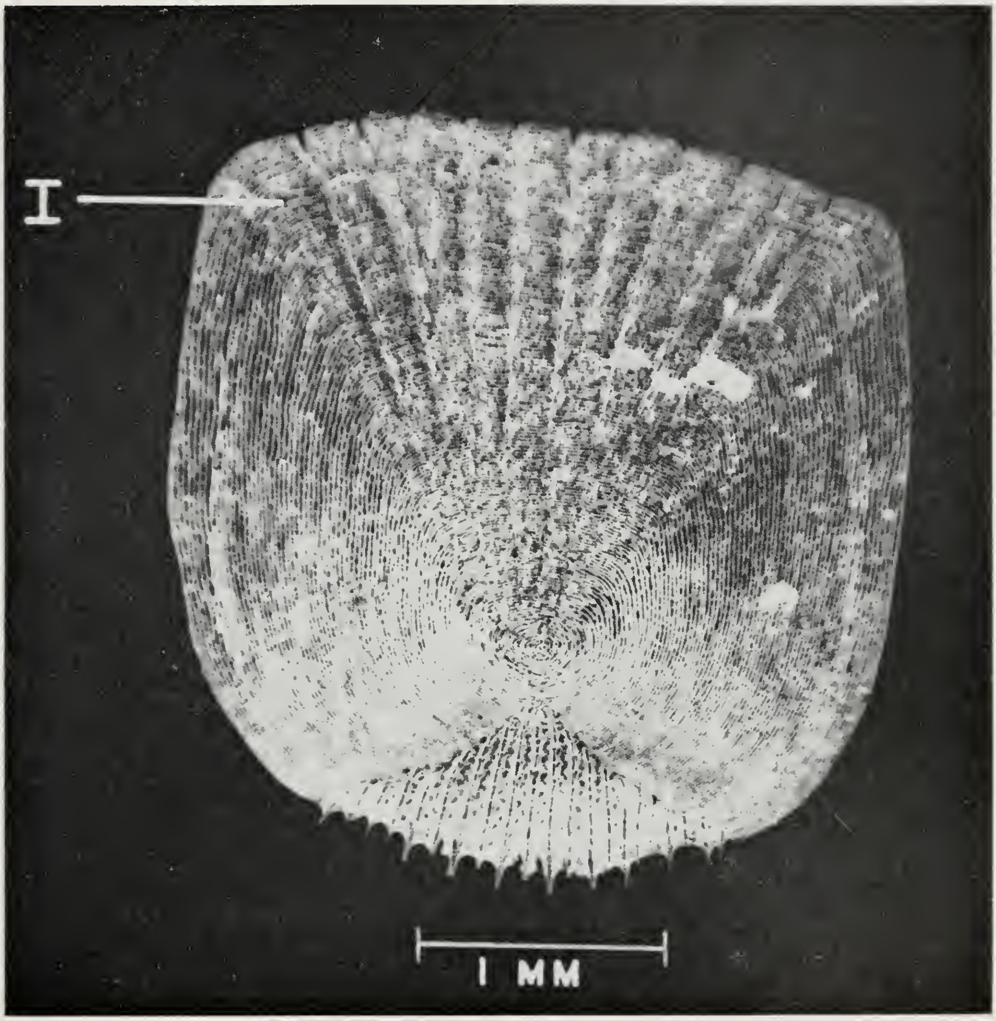


Figure 2. Scale of spot with one annulus (total length 140 mm, March 27, 1954).

drying. However, otoliths of spot preserved in formalin for more than a week were opaque and unusable.

Dakin (1939) and Arora (1951) ground otoliths to show the rings clearly. A few spot otoliths ground on a rotary abrasive wheel were compared with their entire counterparts and no significant difference was noticed in clarity of the rings.

The otoliths were placed in a black bakelite dish filled with water to a depth of about 4 mm and studied under a stereoscopic binocular microscope using reflected light. The translucent bands appeared opaque by reflected light in contrast to opaque zones which appeared white. The radius of the otolith from the center of the nucleus to the anterior edge and to the various annuli was measured by means of an eyepiece micrometer.

Age and Growth

Results of Scale Studies

Description of the spot scale.—Pacheco (1957) gave a brief description of the spot ctenoid scale. Taylor (1916) stated that the radii in *Cynoscion regalis* may afford a supplementary aid in locating annuli, for new radii often originate at an annulus. Pacheco (1957) also subscribed to the same view. Examination of the spot scale revealed that new radii originated at an an-

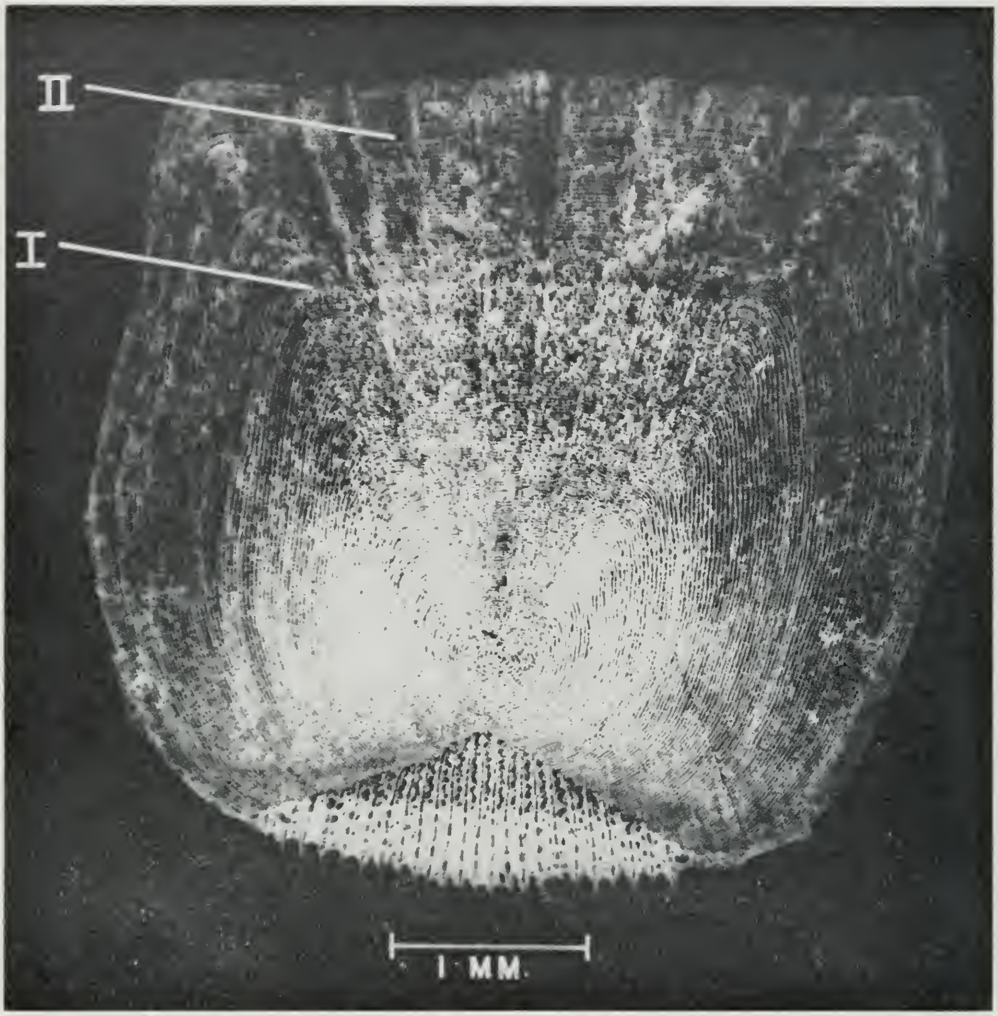


Figure 3. Scale of spot with two annuli (total length 220 mm, March 31, 1955).

nulus (fig. 4), although several exceptions were noted. However, with caution, radii may be used as an additional guide to locate an annulus. New radii usually arise in the antero-lateral field on the outside of the already existing radii. The posterior field of the scale is devoid of circuli and radii (figs. 2-4).

Growth cessation marks.—The characteristics of the spot annulus were determined after examination of about two hundred spot scales. The best character is "crossing over". This is especially evident at the lateral areas of the scale. The circuli in the anterior region of the annulus are broken, incomplete, crooked, or wavy, and stand out prominently from the circuli that precede and succeed them. The annulus is parallel to the general contour of the scale and can be traced around the sculptured part of the scale. Sometimes it can be traced on the unsculptured part of the scale (*i.e.*, in the region of the ctenii). The spot annulus has three characteristics by means of which it can be identified. The so-called crossing over at the lateral areas, the broken or interrupted circuli in the anterior field of the scale, and, at times, closely approximated circuli in the anterior field (figs. 2-4). A check was considered an annulus only when it was present in all scales of the selected sample. My observations agree with Pacheco

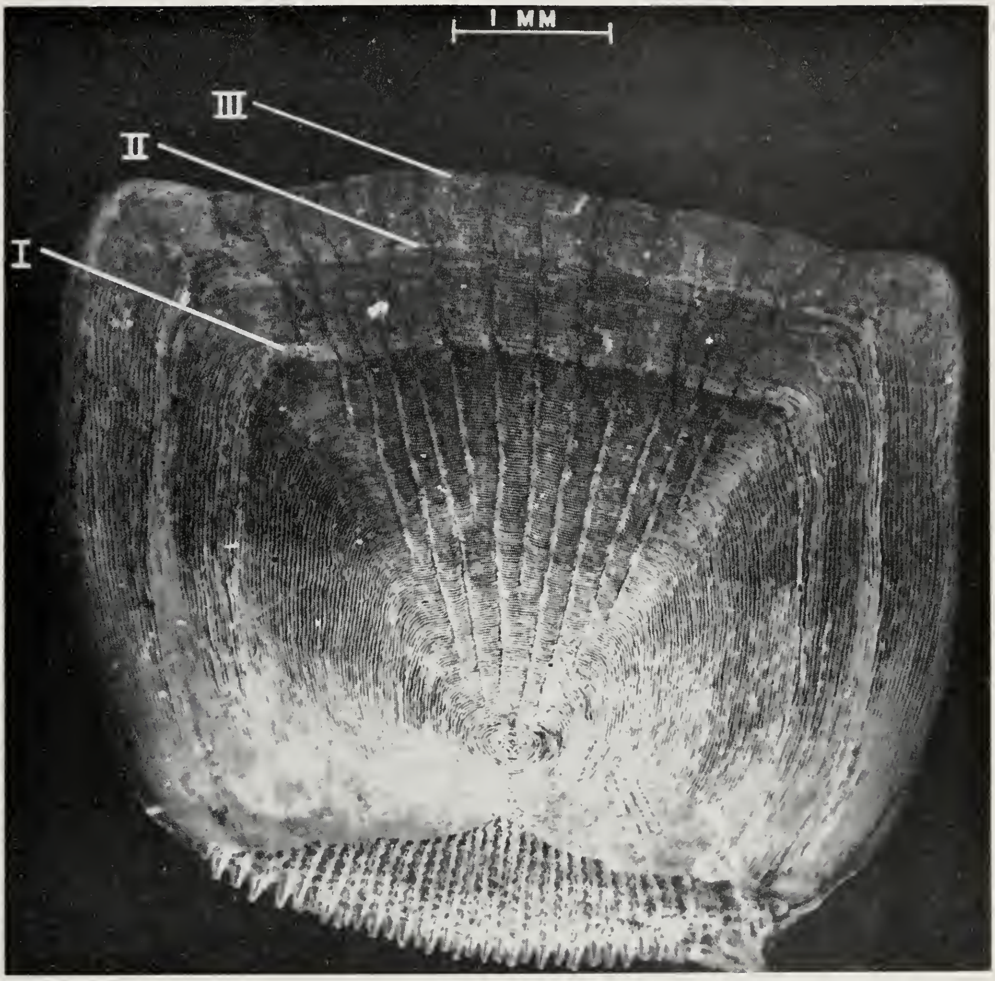


Figure 4. Scale of spot with three annuli (total length 243 mm, May 28, 1954).

(1957) who stated that the usual characteristic of a spot annulus was closer spacing of circuli associated with broken circuli most evident in the postero-lateral area of the scale.

False annuli were often encountered and with some practice they were easily identified. The false annulus is often close to an annulus and is more distinct in the anterior part of the scale than in the lateral areas. Sometimes it is more pronounced than an annulus. Its course cannot be followed all the way around the scale because the false annulus usually merges with the annulus. False annuli may be caused by spawning and/or by some adverse environmental condition.

Period of annulus formation.—Time of annulus formation was determined by measuring the marginal increments for all scales collected between October 1958 and September 1959. The mean marginal increment was minimum in March, and was maximum in January (fig. 5), and indicates that the annulus is formed in February and early March. After March the marginal increments increase very rapidly.

To verify the abovementioned determination all scales collected in January, February, and March of 1959 were re-examined. No annulus was noticed in scales collected in January 1959. An annulus was present in the majority of the scales collected in the latter part of February. The majority of the

TABLE 1.
Mean lengths of the anterior scale radius (X 57.5), mean total length, mean number of circuli, and mean otolith radius of 1,418 spot.

Class Range	Number of Specimens	Mean Anterior Scale Radius	Mean Total Length	Mean Number of Circuli	Mean Otolith Radius in mm
(Total length in mm)					
20- 29	7	9.6	26.7	7.6	—
30- 39	9	12.8	33.1	10.1	—
40- 49	7	22.4	43.1	23.6	1.22
50- 59	20	35.6	55.5	40.6	1.29
60- 69	41	44.9	65.3	48.4	1.42
70- 79	78	55.5	74.3	65.6	1.56
80- 89	90	65.3	84.2	73.6	1.71
90- 99	108	78.4	94.8	87.4	1.85
100-109	182	87.2	104.6	98.0	1.94
110-119	220	98.7	114.2	108.5	2.04
120-129	152	106.4	124.1	114.0	2.16
130-139	97	116.8	133.5	124.0	2.24
140-149	56	125.7	144.5	131.4	2.30
150-159	42	138.4	154.0	138.8	2.50
160-169	46	144.8	164.5	150.0	2.59
170-179	45	152.3	175.0	154.2	2.72
180-189	45	167.0	184.0	163.5	2.85
190-199	29	178.0	194.7	170.0	2.95
200-209	29	183.5	203.2	180.0	3.04
210-219	37	190.6	214.4	184.0	3.24
220-229	37	200.2	223.5	195.5	3.38
230-239	21	210.1	234.5	200.2	3.46
240-249	14	222.5	243.5	206.3	3.63
250-259	5	226.0	252.0	213.0	3.67
260-269	—	—	—	—	—
270-279	1	233.0	270.0	236.0	3.74

scales from March samples showed an annulus plus a small marginal increment; the remainder had an annulus but no marginal increment. Pacheco (1957) stated that annuli of spot in Chesapeake Bay are formed in October and November. The disparity in the time of annulus formation is possibly due to differences in latitude. The temperature does not drop appreciably in the Lake Pontchartrain area until November and December (Suttkus, Darnell, and Darnell, 1954).

Age groups.—The young usually first appear in Lake Pontchartrain in January. Pre-

TABLE 2.
Average calculated total lengths and increments in length of spot collected from July 1953 to May 1954, January 1955 to September 1955, and October 1958 to September 1959, using scales.

Age Group	Number of Specimens	Average Length at Capture in mm	Average Calculated Lengths (in mm) for Previous Years of Life 1	2	3
0	1081	110.0 (21-197)	—	—	—
I	209	163.1 (101-223)	139.1 (90.7-185.8)	—	—
II	90	218.7 (180-247)	151.8 (87.2-191.6)	200.5 (156.8-227.9)	—
III	38	234.5 (210-270)	150.9 (105.7-202.9)	199.1 (168.0-221.0)	223.2 (200.0-248.6)
Number of Records	1418	—	337	128	38
Average Calculated Lengths in mm			143.8	200.1	223.2
Average Increments in mm [2]			143.8	18.7	24.1
Average Total Length in Inches			5.7	7.9	8.8

[2] Only fish completing year of life were used in computing increments.

sumably the eggs were spawned either in December or early January. Thus the biological year and the calendar year appear to coincide closely. The 1958 year class was spawned in late 1957 or early 1958 and formed the first annulus in February-March 1959. Thus a spot in the forementioned group was considered to be young-of-the-year during 1958 and of age group 0 until annulus formation in 1959. Photographs of scales from spot of different ages are presented in Figures 2-4. After all scales were "read" and interpreted the average total length for each age group was determined. The increase in length is greatest during the first year and thereafter the growth rate is a decreasing progression (Table 2).

Determination of the length of the fish at the time of scale formation.—Young fish (17 to 38 mm in total length) collected in February 1954 were used to determine the length of the spot at the time of scale formation. The skin was stripped off from head to tail and adherent muscle tissue was removed. It was streched on a slide and a drop or two of alizarin red was placed on it. After one minute the preparation was drained and the excess stain removed by washing in 70 percent alcohol. The skin was then dehydrated and mounted in Canada balsam.

Scales or scale papillae were not noticed in fish which were 17 mm, 19 mm, and 20 mm in total length. One specimen, 21 mm long (out of three) had scales or scale papillae. Two circuli were observed on caudal peduncle scales from four fish that were 22 mm in total length. Twenty-two millimeters total length was considered to be the length of the fish at the time of scale formation. This value was used in back-calculation of body lengths.

There is a row of scales along the lateral line from the caudal fin to the edge of the operculum of fish 24 mm in total length. A group of scales extends ventrally from the middle of the lateral line system. Scales are absent on either side of the mid-dorsal and mid-ventral line.

Scales are present on either side of the mid-ventral line in 26 mm fish but the scales are not imbricate.

All scales are fully developed and imbricate in 31 mm fish.

Hildebrand and Cable (1930) working at Beaufort, North Carolina, reported that the scales were not visible on spot 25 mm

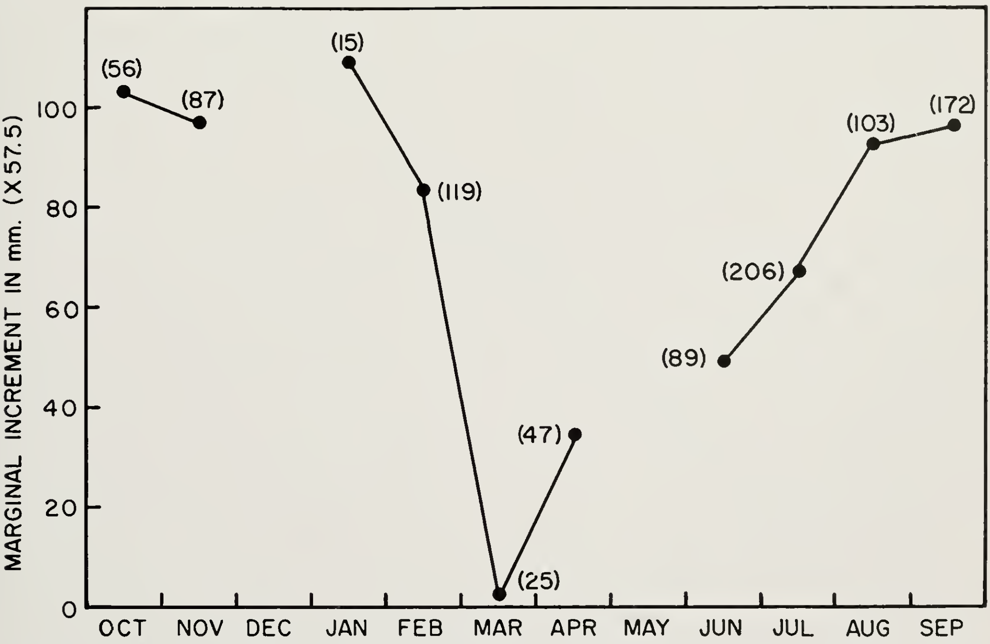


Figure 5. Mean monthly marginal increments of the scale of spot. Figures in parentheses indicate number of specimens.

long but were evident nearly everywhere on fish 30 mm long.

Body length and scale length relationship.—According to Creaser (1926), Graham (1928), Van Oosten (1929), Hile (1941), and Lagler (1956) scales remain constant in number and retain their identity throughout the life of a fish. Johnston (1905) was the first to devise a method of calculating the length of a fish for each year of its life by comparing the widths of the yearly areas of the scale.

The relationship of total length to scale length was determined from measurements of 1,418 spot. The individual measurements of both the total length and the anterior scale radius for each of the 1,418 spot were plotted on millimeter graph paper and a linear distribution was found. The data were grouped by total lengths into 10 mm groups (Table 1, fig. 6). The averages of these groups and the means of their respective scale radii (X 57.5) were then used in computing the linear regression equation (Snedecor, 1957): $Y = 0.98693X + (-18.333)$, where Y = anterior scale radius in millimeters (X 57.5), and X = total length in millimeters.

Estimates of annual growth.—Creaser (1926), Rounsefell and Everhart (1953), and Lagler (1956) list several formulae for back-calculation of body lengths. One frequently used formula is the modified form of Fraser (1916):

$$L' = C.F. + \frac{S'}{S}(L - C.F.).$$

The length of fish at the end of each year of life was computed for all fish with at least one annulus using Fraser's formula. The results are shown in Table 2 and the calculated growth curve based on these data is shown in Figure 7.

The greatest annual increment (143.8 mm) was during the first year of life

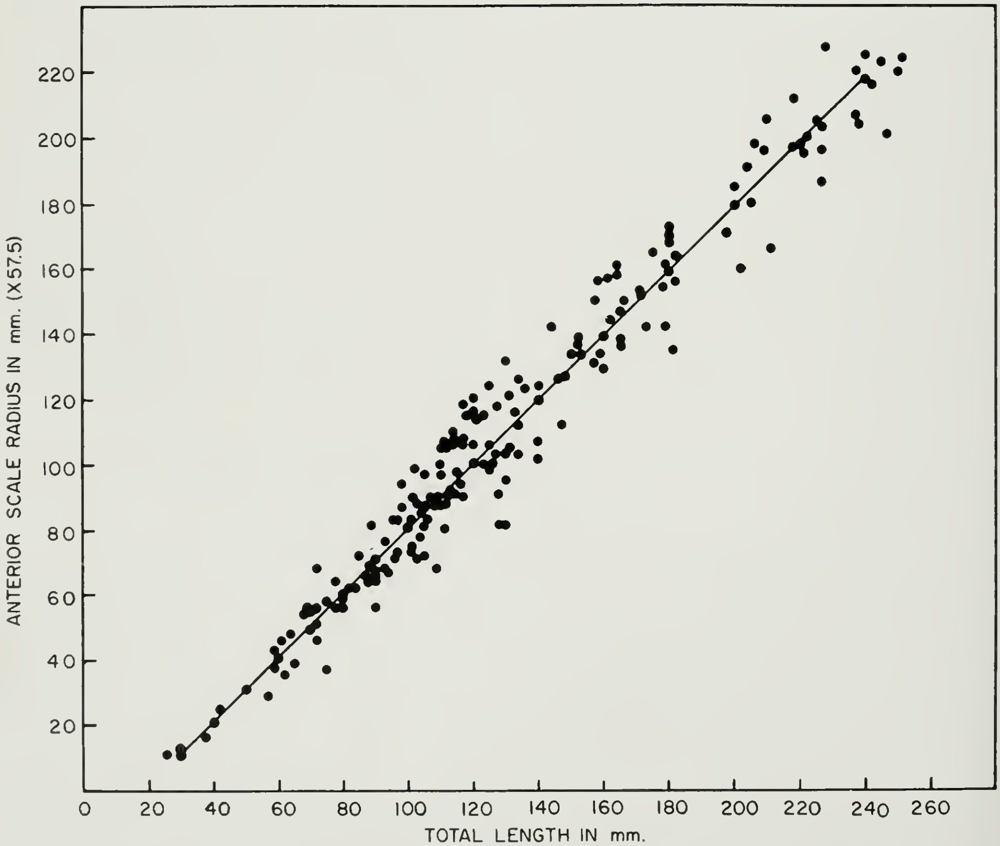


Figure 6. Relationship between total length and anterior scale radius for 1,418 spot. Only 200 random statistics plotted. Line plotted for $Y = 0.98693X + (-18.333)$.

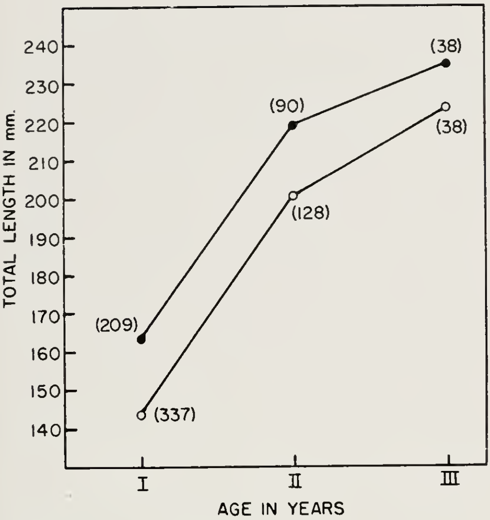


Figure 7. Growth curves of the spot. Dots=observed growth; circles=calculated growth. Figures in parentheses indicate the number of specimens.

(Table 2). During the second and third years of life the increments were 48.6 mm and 24.1 mm respectively.

Calculated lengths are higher than observed lengths of fish collected during the year of growth (Table 2, fig. 7). For instance, the age group 0 consisted mostly of small fish (24 to 197 mm) (Table 2). The calculated length at the end of the first year is higher than the observed length during the year.

Specimens collected in three different years were compared to ascertain differences, if any, in rates of growth. Tables 3, 4, and 5 show the calculated total lengths and increments during the years 1953-54, 1955, and 1958-59 respectively. Average calculated lengths for various age groups during the year 1953-54 agree very closely with the values in Table 2. But, during the year 1955 the calculated lengths at the end of the first year are higher than those during 1953-54. This shows that in 1955 the fish attained larger lengths at the end of the first year of life. Growth was slow during the first year of the one plus individuals for 1958-59 sample (Table 5). The length attained at the end of the first year during 1958-59 was 123.1 mm compared to 145.9 mm during 1953-54 and 156.4 mm during 1955. Further study will be necessary to determine the nature of factors responsible for the disparity in length increments. A comparison of growth rates between Rigolets and Lake Pontchartrain spot is not advisable because the samples were taken in different years.

An analysis of the age and growth of 119 spot collected on October 17 and 22, 1953 is shown in Table 6. These results agree closely with 1953-54 set, and thus substantiate the validity of the use of samples obtained over an extended period of time.

The growth of the various year classes in different calendar years is presented in Table 7. The average annual increments demonstrate that the amount of growth made by fish in a particular year of life varied from year to year. Various factors are probably responsible for these fluctuations in annual growth.

TABLE 3.

Average calculated total lengths and increments in length of spot collected from July 1953 to May 1954, using scales.

Age Group	Number of Specimens	Average Calculated Length (in mm) for Previous Years of Life		
		1	2	3
I	90	142.1	—	—
II	65	149.1	197.5	—
III	32	150.4	197.5	222.5
Number of Records	187	187	97	32
Average Calculated Lengths in mm		145.9	197.5	222.5
Average Increments in mm [3]		145.9	47.9	25.0

[3] Only fish completing year of life were used in computing increments.

TABLE 4.

Average calculated total lengths and increments in length of spot collected from January 1955 to September 1955, using scales.

Age Group	Number of Specimens	Average Calculated Length (in mm) for Previous Years of Life		
		1	2	3
I	52	155.6	—	—
II	23	158.9	207.3	—
III	6	153.9	207.7	226.7
Number of Records	81	81	29	6
Average Calculated Lengths in mm		156.4	207.3	226.7
Average Increments in mm [4]		156.4	49.5	19.4

[4] Only fish completing year of life were used in computing increments.

The average total lengths of young-of-the-year spot collected at almost the same time, at the same locality (Point Aux Herbes, south shore of Lake Pontchartrain) and in different years were compared to ascertain differences in the time of spawning. For example, 1954 year class collected on March 7, 1954 at Point Aux Herbes had attained a mean total length of 35.2 mm, with a range from 20-50 mm. The 1958 year class collected on March 14, 1958 at the same locality had attained a mean total length of 24.8 mm, with a range from 20-32 mm. This would indicate that the 1958 year class was spawned later than the 1954 year class. Further, the 1954 and 1958 year classes attained increments of 155.7 mm and 122.1 mm respectively during the first year of life (Table 7). This disparity in the increments appears to be the result of late spawning of the 1958 year class.

Pearson (1928) found a negligible number of spot over 182 mm in length. Using the age-length ratio of Welsh and Breder (1923) he advanced a hypothesis that spot died before their third year. Gunter (1945) working in Texas waters also corroborated Pearson's hypothesis. Very few spot with three annuli were collected from Louisiana waters and I also assume that the majority of the spot die before they attain three years of age. Welsh and Breder (1923) reported a spot 300 mm in total length which they determined to be 4½ years old. According to them the maximum length recorded for this species is 330 mm. The longest specimen used in this study was 270 mm in total length and the scales had three annuli plus a marginal increment.

Table 5.
Average calculated total lengths and increments in length of spot collected from October 1958, to September 1959, using scales.

Age Group	Number of Specimens	Average Calculated Length (in mm) for Previous Years of Life		
		1	2	3
I	67	122.1	—	—
II	2	157.0	215.9	—
III	—	—	—	—
Number of Records	69	69	2	—
Average Calculated Lengths in mm		123.1	215.9	—
Average Increments in mm [5]		123.1	58.9	—

[5] Only fish completing year of life were used in computing increments.

Table 6.
Average calculated total lengths and increments in length of spot collected on October 17 and 22, 1953, using scales.

Age Group	Number of Specimens	Average Calculated Length (in mm) for Previous Years of Life		
		1	2	3
I	9	143.8	—	—
II	31	153.5	198.2	—
III	9	138.4	191.0	218.0
Number of Records	49	49	40	9
Average Calculated Lengths in mm		148.9	196.5	218.0
Average Increments in mm [6]		148.9	46.4	27.0

[6] Only fish completing year of life were used in computing increments.

Welsh and Breder (1923) found that spot in New Jersey are approximately 80 to 100 mm in total length when one year old, 170 to 220 mm when two years old, 240 to 290 mm when three years old.

Townsend (1956) working on the age and growth of spot in Alligator Harbor, Florida, examined scales from 13 spot of various sizes. Four of them had one annulus each, three had two, one had three, and the rest (five) had no annuli. He did not test the validity of these age marks.

Pacheco (1957) studied scales of Chesapeake Bay spot and found the mean total length attained at the end of first year was about 196 mm, and 247.9 mm at the end of the second year.

The figures of Pacheco (1957) are higher than those of Welsh and Breder (1923) and greater than those obtained in the present study, *i.e.*, the total length attained at the end of the first year is 143.8 mm, 200.1 mm at the end of the second year, and 223.2 mm at the end of the third year. Thus the average size at each age and rate of growth appear to vary greatly throughout the range of this species.

Circuli.—The number of circuli was enumerated from focus to each annulus and to the anterior margin of the scale (Table 8). The increase in the number of circuli is greatest during the first year and thereafter, the number of circuli formed is less. There is a linear relationship between total length and the number of circuli (fig. 8) thus indicating that the circuli are more or less evenly spaced. In age group I, the average number of circuli is 147.6; of this number 128.9 were formed before the formation of the first annulus and 18.5 were formed after it. On the average, 132.1 circuli are laid down from focus to first annulus and 38.3 circuli are laid down from first annulus to second annulus, and second annulus and third between second and third annuli (Table 8). There is good agreement regarding the average number of circuli laid down between focus and first annulus, first annulus and second annulus and about 20.1 are laid down annulus in the different age groups. The range of variation of the number of circuli appears to be considerable (Table 8), but some of this variation is a reflection of range of lengths of the fish. Nevertheless, the number of circuli may be used to determine the approximate age of spot in fractions of a year.

Results of Otolith Studies

Description of the spot otolith.—The otolith is oval, laterally compressed with a convex and a concave surface. The anterior end is bluntish while the posterior end is rounded. When *in situ* the concave surface faces toward the outside in the otic capsule. Each otolith has a central translucent area known as the nucleus. The nucleus is surrounded by alternating bands of wide opaque and narrow translucent bands (figs. 10-12). Usually several radiating bands proceed from the center toward the margin of the nucleus (figs. 10-12) but these bands seldom extend beyond the nucleus. The annuli are clearly seen on the concave side of the otolith. On the convex side a deep groove extends from the center of the otolith towards the anterolateral part.

The otolith of a young spot differs slightly from that of an adult spot. It is oval with the central nucleus surrounded by a wide opaque area. The anterior end is blunt and the posterior end is rounded. In young specimens most otoliths have a translucent ring. Eventually, the translucent ring is not continuous and seldom goes all the way around the nucleus (fig. 9). As spot gets larger radiating translucent lines proceed from the nucleus toward the translucent ring around the nucleus but this ring is joined to the nucleus by means of radiating

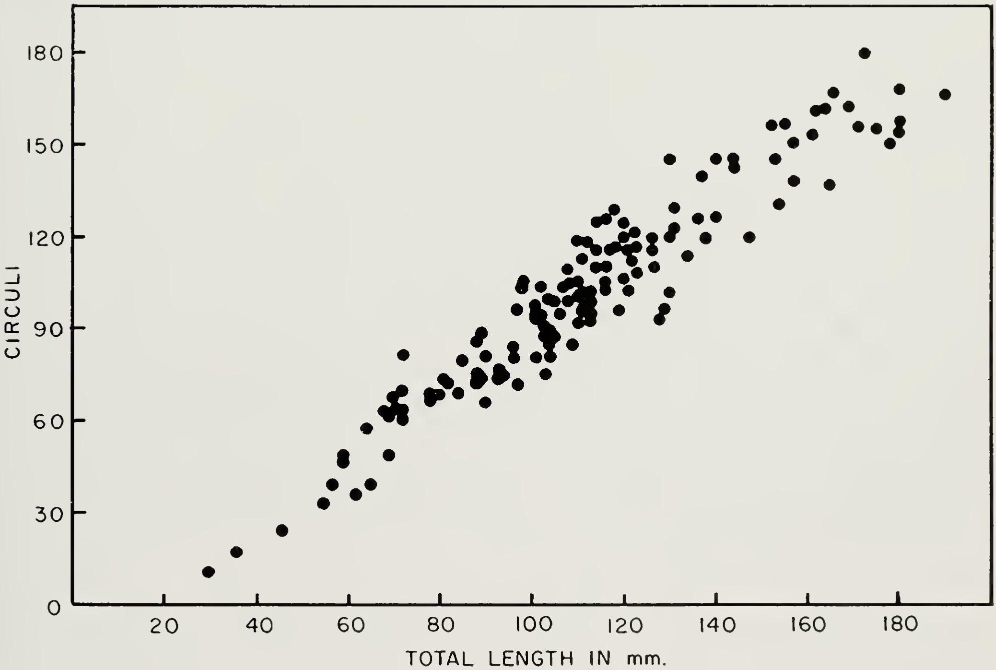


Figure 8. Relationship between total length and the number of circuli for age group 0. Only 145 random statistics plotted.

TABLE 7.

Annual growth increments (in millimeters) of spot in 1950-54, 1957, and 1958 year classes during the calendar years 1950-54, and 1956-58, using scales. Figures in parentheses indicate year of life.

Year Class	Year Collected	Increments of Growth in Calendar Years 1950	1951	1952	1953	1954	1955	1956	1957	1958
1950	1953	146.7 (1)	49.9 (2)	26.0 (3)	—	—	—	—	—	—
1951	1953	—	155.6 (1)	43.2 (2)	—	—	—	—	—	—
1951	1954	—	163.7 (1)	43.8 (2)	14.7 (3)	—	—	—	—	—
1952	1953	—	—	146.3 (1)	—	—	—	—	—	—
1952	1954	—	—	148.5 (1)	42.7 (2)	—	—	—	—	—
1952	1955	—	—	153.9 (1)	53.7 (2)	19.2 (3)	—	—	—	—
1953	1954	—	—	—	143.6 (1)	—	—	—	—	—
1953	1955	—	—	—	158.8 (1)	52.8 (2)	—	—	—	—
1954	1955	—	—	—	—	155.7 (1)	—	—	—	—
1956	1958	—	—	—	—	—	—	157.3 (1)	58.6 (2)	—
1958	1959	—	—	—	—	—	—	—	—	122.6 (1)
Number of Fish in Each Year Class		25	58	44	89	52	—	2	—	67

lines. Before the formation of the first annulus the nucleus merges with the translucent ring. Arora (1951) also described radial lines that run from the core to the periphery in the otoliths of *Citharichthys sordidus*.

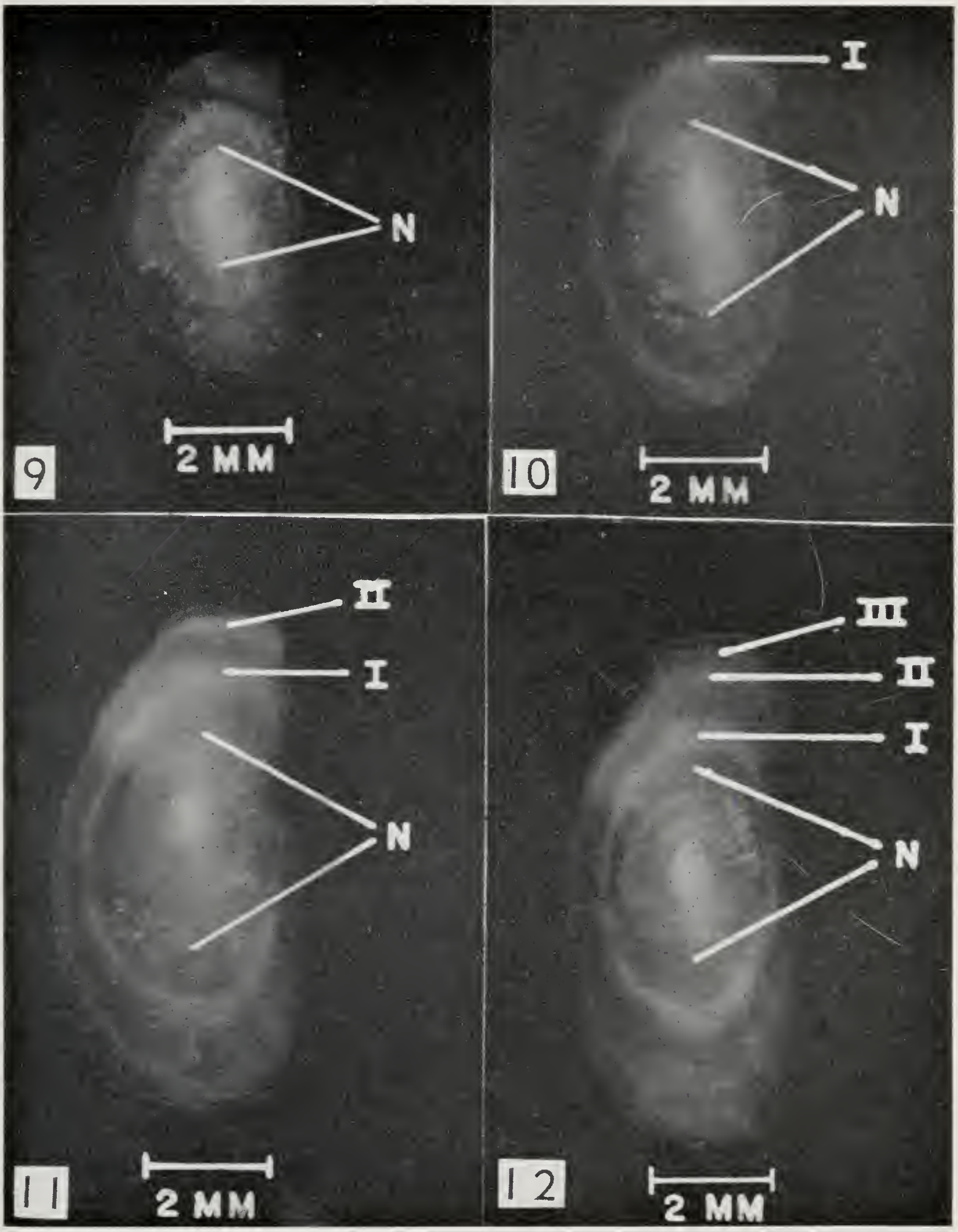
Growth cessation marks.—Cunningham (1905), Hickling (1931, 1933), Molander (1947), and Arora (1951) stated that the opaque bands are due to increased calcification which occurs during summer, the period of rapid growth, and that the translucent bands are formed during winter when growth is slow.

Walford and Mosher (1943) used the following criteria to distinguish annuli in Pacific sardine otoliths. According to them "An annulus is a more or less translucent band concentric with the margin of the otolith, the intervening spaces being opaque. It can usually be traced entirely around the otolith, although it is more easily observed

TABLE 8.

Relationship between number of circuli and age of spot collected from July 1953 to May 1954, January 1955 to September 1955, and October 1958 to September 1959.

Age Group	Average Length at Capture in mm	Average No. of Circuli	Number of Specimens	Average No. of Circuli from Focus to First Annulus	Average No. of Circuli from First Annulus to Second	Average No. of Circuli from Second Annulus to Third
0	110.0	98.8 (4-174)	1081	—	—	—
I	163.1	147.6 (96-199)	209	128.9 (89-175)	—	—
II	218.7	190.0 (145-222)	90	135.3 (85-182)	39.4 (18-75)	—
III	234.5	207.1 (175-236)	38	142.2 (110-181)	35.8 (19-64)	20.1 (11-33)
Number of Records	—	—	1418	337	128	38
Average Number of Circuli				132.1	38.3	20.1



Figures 9-12. Otoliths of spot; N = nucleus. **9**. Without annulus; note the false translucent ring around nucleus (total length 141 mm, October 23, 1958). **10**. With one translucent annulus (total length 180 mm, May 5, 1955). **11**. With two translucent annuli (total length 237 mm, May 5, 1955). **12**. With three translucent annuli (total length 250 mm, May 5, 1955).

Table 9.

Average calculated total lengths and increments in length of spot collected from January 1955 to September 1955 and October 1958 to September 1959, using otoliths.

Age Group	Number of Specimens	Average Calculated Lengths (in mm) for Previous Years of Life		
		1	2	3
I	123	149.2 (109.0-200.0)	—	—
II	21	176.3 (137.2-198.9)	214.7 (199.0-238.0)	—
III	6	158.6 (137.0-183.0)	204.5 (180.0-239.0)	225.1 (197.4-260.1)
Number of Records	150	150	27	6
Average Calculated Lengths in mm		153.3	212.0	225.1
Average Increments in mm [7]		153.3	40.0	20.6
Average Total Length in Inches		6.0	8.3	8.9

[7] Only fish completing year of life were used in computing increments.

at the blunter anterior end than at the sides or posterior end. Annuli tend to be zones rather than lines."

These criteria also apply to spot otoliths. The annuli, as in the Pacific sardine, are very prominent in the anterior blunt end (figs. 10-12).

False annuli were noticed occasionally. They were in the form of translucent bands, but they were always incomplete and hence were easily recognized.

Determination of the period of annulus formation. — The incidence of translucent margins was plotted as a percentage of all otoliths examined during each month of the year (Fairbridge, 1951; Ling; 1958). One thousand and sixty-four spot otoliths collected during the periods January 1955 to September 1955, and October 1958 to September 1959 were used. The otoliths were read without knowledge of the date of collection and were classified as having a translucent or an opaque margin (fig. 13). Annulus formation began in January and con-

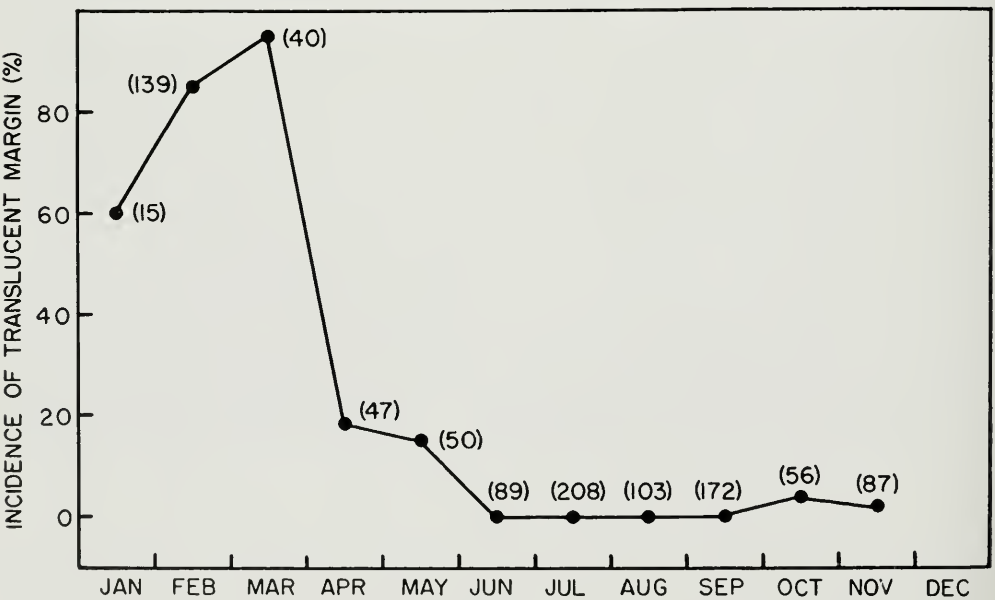


Figure 13. Monthly percentage incidence of translucent otolith margins. Figures in parentheses indicate the number of specimens.

tinued through February and March. During February 85 percent of the otoliths already had the annulus. These data correspond with the period of annulus formation determined by scale examination.

Age groups.—The writer assumed that the nucleus surrounded by the opaque zone covered the period of life from the time of hatching until the formation of the first annulus. The nucleus represents the initial deposition of calcareous material and is comparable to the focus of the scale. Hickling (1933), Moore (1947), and Ling (1958) have, however, counted the nucleus also. All workers agree that the translucent band is formed during winter and the opaque band during summer.

Hickling (1933) and Ling (1958) counted the opaque zones in hake otoliths and in sea garfish otoliths respectively and assigned the age according to the number of these bands. In the sea garfish (Ling, 1958) an annulus is laid down around an opaque nucleus after about the first six months of life and the first opaque band is formed at the end of the first year. Hence he counted the opaque zones and assigned the fish to year groups according to the number of these bands. The spot otolith is a little different. The opaque zone surrounding the nucleus represents the growth during the spring, summer, and fall. The annulus is formed around the opaque zone some time in February. The presence of a translucent annulus indicates that the fish has passed through one winter and hence is a year old; ages were recorded in the number of winters completed. Thus a spot in its first year of life belongs to age group 0 and its otolith has no translucent annulus. A spot in its second year belongs to age group 1 and its otolith has one translucent annulus. Photographs of otoliths from spot of different ages are presented in Figures 9-12.

TABLE 10.
Average calculated total lengths and increments in length of spot collected from January 1955 to September 1955, using otoliths.

Age Group	Number of Specimens	Average Calculated Length (in mm) for Previous Years of Life		
		1	2	3
I	61	165.2	—	—
II	19	176.6	214.6	—
III	6	158.6	204.5	225.1
Number of Records	86	86	25	6
Average Calculated Lengths in mm		167.2	212.0	225.1
Average Increments in mm [8]		167.2	39.8	20.6

[8] Only fish completing year of life were used in computing increments.

TABLE 11.
Average calculated total lengths and increments in length of spot collected from October 1958 to September 1959, using otoliths.

Age Group	Number of Specimens	Average Calculated Length (in mm) for Previous Years of Life		
		1	2	3
I	61	133.4	—	—
II	2	166.8	211.5	—
III	—	—	—	—
Number of Records	63	63	2	—
Average Calculated Lengths in mm		134.4	211.5	—
Average Increments in mm [9]		134.4	44.7	—

[9] Only fish completing year of life were used in computing increments.

Body length and otolith radius relationship.—Hickling (1933) in the hake, Fairbridge (1951) in tiger flathead, Grainger (1953) in Arctic char, Scott (1954) in yellowtail flounder, and Ling (1958) in sea garfish established a relationship between body length and otolith length.

The relationship of total length to otolith radius was determined from measurements of 1,064 spot. The individual measurements of both total length and otolith radius for each of the 1,064 spot were plotted on millimeter graph paper and a linear relationship was found. The data were grouped by total lengths into 10 mm groups (Table 1). The averages of these groups and the means of their respective otolith radii were used in computing the regression equation. Because the distribution was a straight line relationship, linear regression was followed (Snedecor, 1957). The following equation was derived: $Y = 0.16438X - 9.4418$, where Y = otolith radius in micrometer divisions, and X = total length in millimeters. Arbitrary values were substituted for X in the equation and the values for Y were obtained which were used to construct a regression line (fig. 14). Extrapolation of the line indicates a fish of no length has an otolith with a radius of almost 0.68 mm.

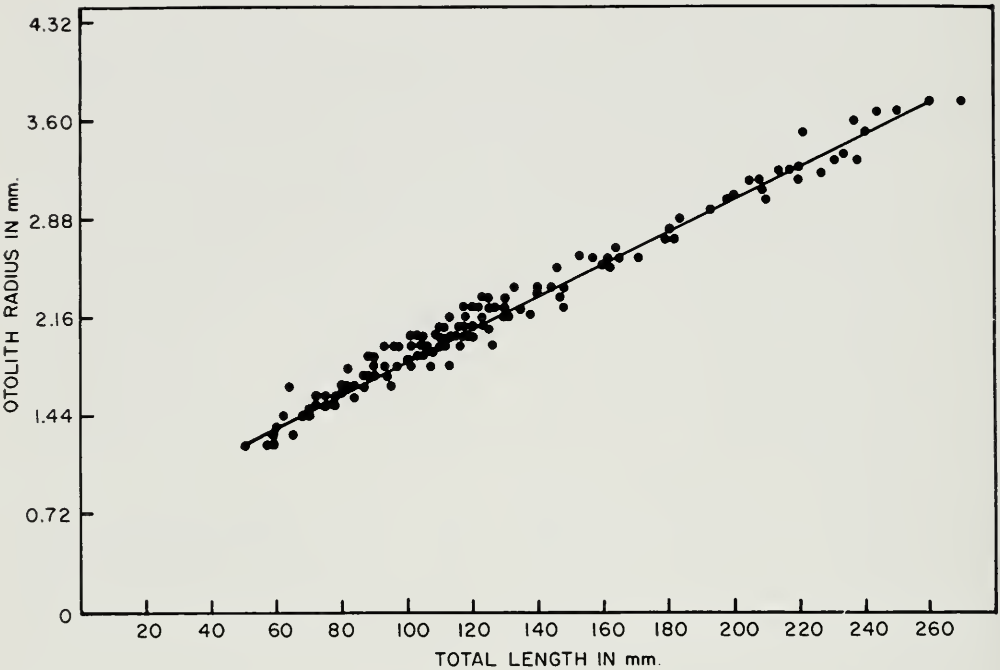


Figure 14. Relationship between total length and otolith radius for 1,064 spot. Only 120 random statistics plotted.

Ling (1958) reported a similar situation in sea garfish. There appears to be a nonlinear relationship between the radius of the spot otolith and the total length of the spot during the early larval period. After a certain period of growth the relationship is linear (fig. 14). No attempt was made to find the length of fish at the time of otolith formation.

Estimates of annual growth.—The calculation of intermediate lengths from otoliths has seldom been attempted. However, Hickling (1933) back-calculated the size of age group 0 hake. Fairbridge (1951) calculated intermediate lengths of New South Wales tiger flathead. Grainger (1953), Scott (1954), and Ling (1958), back-calculated the lengths at previous ages from measurements of otoliths of Arctic char, yellowtail flounder, and sea garfish respectively. All these authors assumed that the growth in fish length is proportional to growth in otolith length. Figure 14 indicates that in spot, growth in fish length is proportional to growth in otolith radius. The concentric bands in the otoliths have already been shown to be annual in formation The formula used for calculating the intermediate lengths was $l = \frac{L}{V} \times v$, where l = intermediate length; L = length of fish at capture; V = total otolith diameter; and, v = distance from center of the nucleus to the annulus. The length of the fish at the end of each year of life was computed for all fish with at least one annulus (Table 9).

The greatest increase in length (153.3 mm) took place during the first year of life. During the second and third years of life the increments were 40.0 mm and 20.6 mm respectively.

Table 9 represents a composite of 1955 and 1958-59 collections; separate tabulations were computed also (Tables 10 and 11 respectively). The increment for the 1955 sample during the first year was 167.2 mm, 39.8 mm during the second and 20.6 mm during the third year. A perusal of Table 11 indicates that the annual increment during the first year of life was very small when compared to that in 1955. Possibly this is correlated with the time of spawning, availability of food, temperature, etc. Obviously growth patterns vary considerably in the same area from year to year and in adjoining areas because of the variations and fluctuations in ecological conditions.

Correlation of Scale and Otolith Readings

Walford and Mosher (1943) advanced the method of age determination in Pacific sardines by correlating the age marks on both scales and otoliths. Moore (1947) correlated the age marks on scales and otoliths of sand flounder, while Arora (1951) did the same in the California sand dab.

Parallel age determination by scales and otoliths were made in 1,064 spot. Age determinations were made separately for the years 1955 and 1958-59 (figs. 15, 16). An inspection of the figures indicates that the calculated lengths based on scales and those based on otoliths are close and either may be used for age determination.

Length-frequency Distributions

The total length measurements of the spot in Lake Pontchartrain taken by Suttkus, Darnell, and Darnell (1954) during 1953, 1954, and 1955 were classified into size groups with a class interval of 5 mm. The

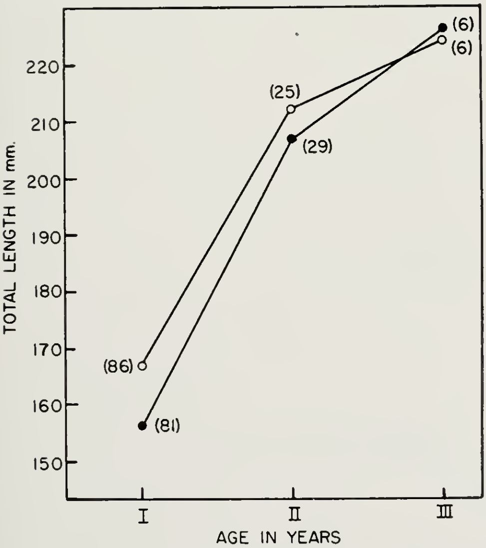


Figure 15. Growth curves of spot showing average calculated lengths from scale and otolith measurements. Dots = calculated lengths based on scales (1955); circles= calculated lengths based on otoliths (1955). Figures in parentheses indicate the number of specimens.

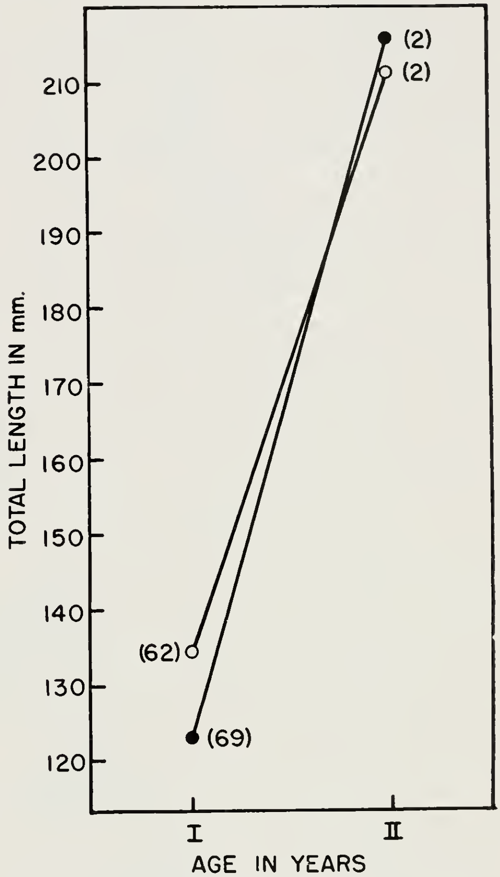


Figure 16. Growth curves of spot showing average calculated lengths from scales and otolith measurements. Dots = calculated lengths based on scales (1958-59); circles= calculated lengths based on otoliths (1958-59). Figures in parentheses indicate the number of specimens.

length-frequency distribution of each sample was prepared and the samples were combined by months (fig. 17).

Age group 0.—Judging from Figure 17 a new group of fish appeared in January 1954 ranging in body length from 15 to 24 mm with a modal peak at 22 mm. The growth of this young-of-the-year group can be followed easily. In February 1954 the range was from 15 to 39 mm with a modal peak at 27 mm. By March 1954, they had attained a modal length of 37 mm with a range from 20 to 74 mm. The modal lengths during April, May, and June were 62, 67, and 92 mm respectively. But in July there are three "peaks", one at 107 mm, a second

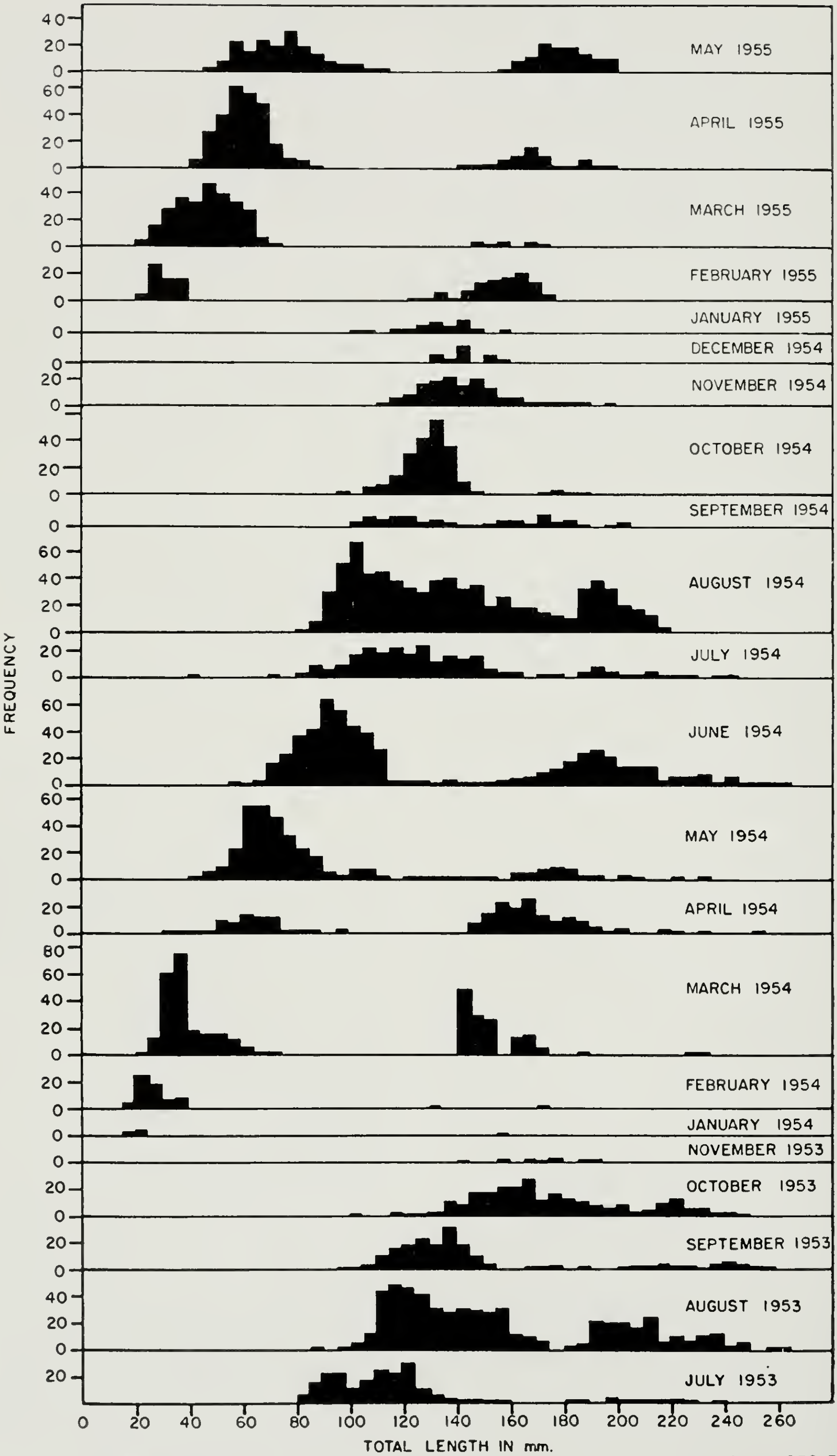


Figure 17. Length-frequency histograms of collections of spot made during 1953-54-55.

at 117 mm, and a third at 127 mm. As the length-frequency distribution is a consolidation of all samples taken at the various stations in Lake Pontchartrain, one might reasonably expect bimodal and trimodal distributions. These differences may be due to differences in nutrition. By December, the young-of-the-year had attained a modal length of 142 mm with a range from 130 to 150 mm. The distribution is bimodal in January with peaks at 132 mm and 142 mm. By the end of January 1955 the group that was spawned in winter of 1953-54 was approximately one year old (*i.e.,* they had passed through one winter). They attained a modal length of 142 mm. The calculated length at the end of first year by means of scales and otoliths is 143.8 mm and 153.3 mm respectively which is reasonable agreement.

A comparison of the monthly station samples of the young-of-the-year spot was made over a period of five months (April 1954 through August 1954). The results indicate that there was a difference in the mean total lengths for the spot taken from the various stations. For example, Bayou St. John spot (June—86.9 mm; August—98.4 mm) averaged smaller than those from South Draw (June—93.0 mm; August—120.3 mm) and Kenner Towers (June—92.5 mm; August—114.9 mm) although collected on or about the same date, with the same kind of gear. The young spot presumably group in the lake after their entry and remain in more or less separate populations throughout spring and summer. Suttkus (1955) reported a consistent difference between the mean lengths for young croakers *(Micropogon undulatus)* taken from various stations in Lake Pontchartrain. Bayou St. John croakers averaged considerably smaller than those from South Draw and Kenner Towers. Data were available for various stations in the lake, but the number of spot collected at these stations was not large enough to warrant a comparison. However, in Lake Pontchartrain, there appear to be great differences in rates of growth. Extrapolation of these results of one study area to another widely separated or adjoining is hazardous.

Age group I.—The growth of age group I can be continued beyond January 1955 by following the modes in February, March, April, and May 1955. Age group I had attained a modal length of 172 mm by May 1955 with a range from 155 to 199 mm. Further growth of age group I can be followed by tracing the modes from July 1953. There is a mode of 197 mm in July 1953 and by October a modal length of 222 mm was obtained.

Age group II.—The growth of the age group II cannot be identified satisfactorily in the length-frequency distributions because of inadequate samples.

Many attempts have been made previously to determine the age of the spot by length-frequency polygons (Welsh and Breder, 1923; Hildebrand and Schroeder, 1928; Pearson, 1928; Hildebrand and Cable, 1930; Townsend, 1956; Pacheco, 1957; and Dawson, 1958). Dawson (1958) summarized the conclusions of various authors.

Pearson (1928) stated that the young-of-the-year from the Texas coast reached a total length of 130 mm by the end of October. Age group I had a modal length of 190 mm in April and showed very little growth. By November and December age group I spot migrated from bays to the Gulf of Mexico for spawning and did not return to the bays in the spring in sufficient numbers. A similar migration occurs in Lake Pontchartrain. The age group 0 spot is the most abundant age group in the lake and they move out of the lake into the Gulf of Mexico by November and December. Age groups I, II, and III spot also move out of the lake into the Gulf of Mexico by November and December, presumably for spawning. No attempt was made to determine the age of spot at maturity. Catch statistics indicate that no spot were taken during December (Suttkus, Darnell, and Darnell, 1954) and this appears to be a case of complete withdrawal of spot from the lake. Age groups II and III are not well represented in the samples from Lake Pontchartrain. A tagging program might yield interesting information on the movements of spot.

Welsh and Breder (1923) assigned a modal length of 140 mm to one year old spot at Fernandina, Florida.

Hildebrand and Cable (1930) studied the growth of spot in the first year. The young-of-the-year appeared in December and by the following November they had attained a total length of 139.3 mm.

Townsend (1956) stated that at an approximate age of one year the spot in Alligator Harbor, Florida, range from 122.8 to 166.8 mm in total length.

Dawson (1958) reported that most South Carolina spot attain between 148.7 to 168.1 mm in total length in their first year. Spot in their second year of life attained between 213.3 to 226.2 mm in total length.

Spot in Lake Pontchartrain attained a modal length of 142 mm at the end of the first year of life; growth of the subsequent age groups is not clear because of insufficient samples.

Summary and Conclusions

This report presents the results of age and growth studies on the spot, *Leiostomus xanthurus* Lacépède, from the Lake Pontchartrain area, Louisiana.

A total of 1,418 spot collected by various methods were used in this investigation. The following conversion ratios were calculated. Between 19 and 49 mm in total length a ratio of 1:0.816 for conversion of total length into standard length. Between 50 and 270 mm a ratio of 1:0.773 for conversion of total length into standard length.

Age and growth of the spot were determined primarily by scales and otoliths but were verified by the length-frequency method.

Spot scales are ctenoid and only one annulus is formed during February and early March each year. New radii often start at an annulus, but a few exceptions were also observed. Nevertheless, the origin of radii may be used as a supplementary guide for the location of an annulus.

Scales made their appearance when the total length of the body was 22 mm.

The relationship between total length and scale radius was determined from measurements of 1,418 spot. The relationship was linear and can be described by the equation $Y = 0.98693X + (-18.333)$.

Fraser's formula was used to back-calculate lengths at previous ages. Spot averaged 143.8 mm at the end of the first year of life, 200.1 mm at the end of second year, and 223.2 mm at the end of third year. The average annual increments were 143.8 mm during the first year, 48.6 mm during the second year, and 24.1 mm during the third year. Increase in length is greatest during the first year and thereafter the growth rate slows down. There was fairly good agreement on calculated growth of fish of the same and different age groups in different years' collections. The length attained at the end of first year of 1958-59 year collection was smaller when compared to that of previous years' collections. Further work will be necessary to determine the nature of factors responsible for slow and fast growth.

Growth of various year classes in different calendar years was evaluated. The amount of growth made by fish in a particular year of life varied from year to year.

An attempt was made to establish a relationship between the number of circuli and the age of the fish. On the average 132.1 circuli are laid down from focus to first annulus, about 38.3 circuli from first to second annulus, and about 20.1 between second and third annuli. The number of circuli may be used to determine the approximate age of spot in fractions of a year. Caution must be exercised in applying this method because the variations in the range are considerable. However, the number of circuli, like the radii, can be used as a supplementary guide to locate an annulus.

The longest specimen was 270 mm in total length, had attained the age of three, and was in its fourth year of life. The vast majority of the spot probably die or migrate after attaining an age of two years. This is evidenced by the fewer number of spot in age group III.

Each otolith has a centrally located nucleus surrounded by alternating bands of opaque and translucent areas. The growth marks are clearly visible on the concave side of the otolith. The annulus which represents winter growth appears as a translucent band and the region in between two annuli which represents summer growth appears opaque in reflected light. Only one annulus is formed each year during late January and February.

The relationship between total length and otolith radius was determined from measurements of 1,064 spot. The relationship was linear and can be described by the equation: $Y = 0.16438X - 9.4418$.

The calculation of intermediate lengths was accomplished by using the direct proportion equation. Spot averaged 153.3 mm at the end of their first year of life, 212 mm at the end of their second, and 225.1 mm at the end of their third.

There was general agreement between the scale year marks and otolith year rings from the same fish. Parallel age determinations by scales and otoliths were made for 1,064 spot. The calculated lengths based on scales and those based on otoliths coincide closely, thereby indicating that either may be used for age determination in the spot.

The length-frequency distributions of the spot show the growth of the young-of-the-year very well. They attain a length of 142 mm by January. This closely corresponds with the calculated lengths based on scales and otoliths. Comparison of the monthly station samples of the young-of-the-year spot showed that there was a difference in mean total lengths for spot taken from various stations. Apparently, young spot group in the lake after their entry and remain more-or-less as discrete populations through spring and summer. Growth of age group I can also be traced, though incompletely, in the length-frequency distributions. Growth of age group II cannot be identified satisfactorily because of insufficient samples.

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ABSTRACT

Age and growth of the spot, *Leiostomus xanthurus* Lacépède, from Lake Pontchartrain area, Louisiana, were determined by the scale and otolith methods and verified by length-frequency method. For the study 1,418 spot obtained by various methods in 1953-54, 1955, and 1958-59 were used. Annuli on scales and otoliths were formed during February and early March. The maximum annual increase in length occurred during the first year. Thereafter, the growth rate decreased. An attempt was made to establish a relationship between the number of circuli and the age of spot. The longest specimen was 270 mm in total length and had attained the age of three and was in its fourth year of life. There was good agreement between scale year marks and otolith year rings from the same fish. The calculated lengths based on scales and those based on otoliths coincide closely, thereby indicating that either may be used for age determination in the spot. The length-frequency distributions of the spot show the growth of the young-of-the-year very well. Young spot taken at various stations in the lake exhibited differences in the growth rate. Presumably, young spot group in the lake after their entry and remain as more or less discrete populations through spring and summer. Growth of age group I could be traced, though incompletely, whereas growth of age group II could not be traced in the length-frequency distributions because of inadequate samples.