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SEASONAL CYCLE IN THE GONADS OF THE WHITE BASS, (*ROCCUS CHRYSOPS*), IN LAKE TEXOMA, OKLAHOMA

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SEASONAL CYCLE IN THE GONADS OF THE WHITE BASS,

(ROCCUS CHRYSOPS), IN LAKE TEXOMA, OKLAHOMA

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CHAPTER I

INTRODUCTION

Studies of sex cycles of fishes are not numerous. James (1947) tabulated a list of twenty fishes for which seasonal studies of the gonads had been made. There have been few additions since that time. Although Sigler (1949), and Riggs (1955) both discussed the reproduction of the white bass, *Roccus chrysops*, no data are available on the seasonal cycle of the gonads of this species. This study was made to provide such data, as well as to test the feasibility of the use of gonad smears as a field method for the study of the seasonal cycles in fish gonads. Since the preparation of microscopic sections is time consuming, smears from gonads are a rapid but effective method for field and laboratory use. Smears are particularly useful for the rapid determination of sex in immature fish and for the determination of sex in those fishes in which sex determination by gross inspection is difficult.

MATERIALS AND METHODS

This study is based on the examination of gonads of 540 white bass collected in Lake Texoma from June 8, 1949 to October 22, 1955.

There were three collecting periods: (1) June 8, 1949 to August 9, 1950 -- 229 fish collected, (2) October 19, 1951 to December 13, 1952 -- 58 fish collected, and (3) November 6, 1954 to October 22, 1955 -- 253 fish collected. Most (385) were taken in gill nets; one collection of six fish was made with a bag seine, and the remainder (149) was taken by angling.

The weight of the fish (in grams), and the total- and standard-length (in millimeters) were recorded on standard scale envelopes in which scale samples were placed. The gonads were fixed in Bouin's fixative, FAA, or 10 percent formalin, and each of these was found to provide adequate fixation for the purposes of this study. The gonads were stored in 70 per cent ethyl alcohol, and were blotted dry on paper towelling before they were weighed. A chainomatic, magnetic-damped balance was used for all but the extremely large gonads; these were weighed on a torsion balance.

The ages of the fish were determined by identifying annuli on the magnified (45x) scale image, using the scale-reader at the Oklahoma Fishery Research Laboratory, Norman, Oklahoma.

Outline drawings were made by tracing each gonad. Smears were made by macerating a small piece of the gonad in a drop of acetocarmine on a microscope slide. The piece was obtained from the central region of the gonad, after preliminary work indicated that there were no essential differences in smears from various regions of the gonads. The stages of spermatogenesis in each testis were determined and tabulated. The largest ova in each of ten fields from smears of each ovary were measured with an ocular micrometer and the average size of the largest ova for those ovaries was determined.

CHAPTER II

SEASONAL CYCLE OF THE TESTES

Testes Size

The size of the testes in those white bass examined exhibits a distinct seasonal variation. The 1954-55 collections are used to illustrate the seasonal cycles of the different year-classes of fish; the two earlier collections are used for very limited comparison, because an early analysis of them, made after the ages of the fish were determined, indicated that they were inadequate for a study of the seasonal cycle. The 1954-55 collections were then made in an attempt to obtain a more adequate sample. In spite of concerted efforts, I was unable to obtain the desired number of fish of certain age-groups in several of the monthly collections made in 1954-55.

Drawings of testes of average size for each month of each year-class illustrate the seasonal variations in size (Figure 1). The testes of young-of-year fish (1955 year-class) were small and thread-like in July. The only other collection of fish of this year-class was made in October, and a large increase in the size of the testes was apparent.

The size of testes from yearling fish (1954 year-class) remained fairly constant through most of the year (Figure 1). The testes began to enlarge in September and continued this increase in size through October.

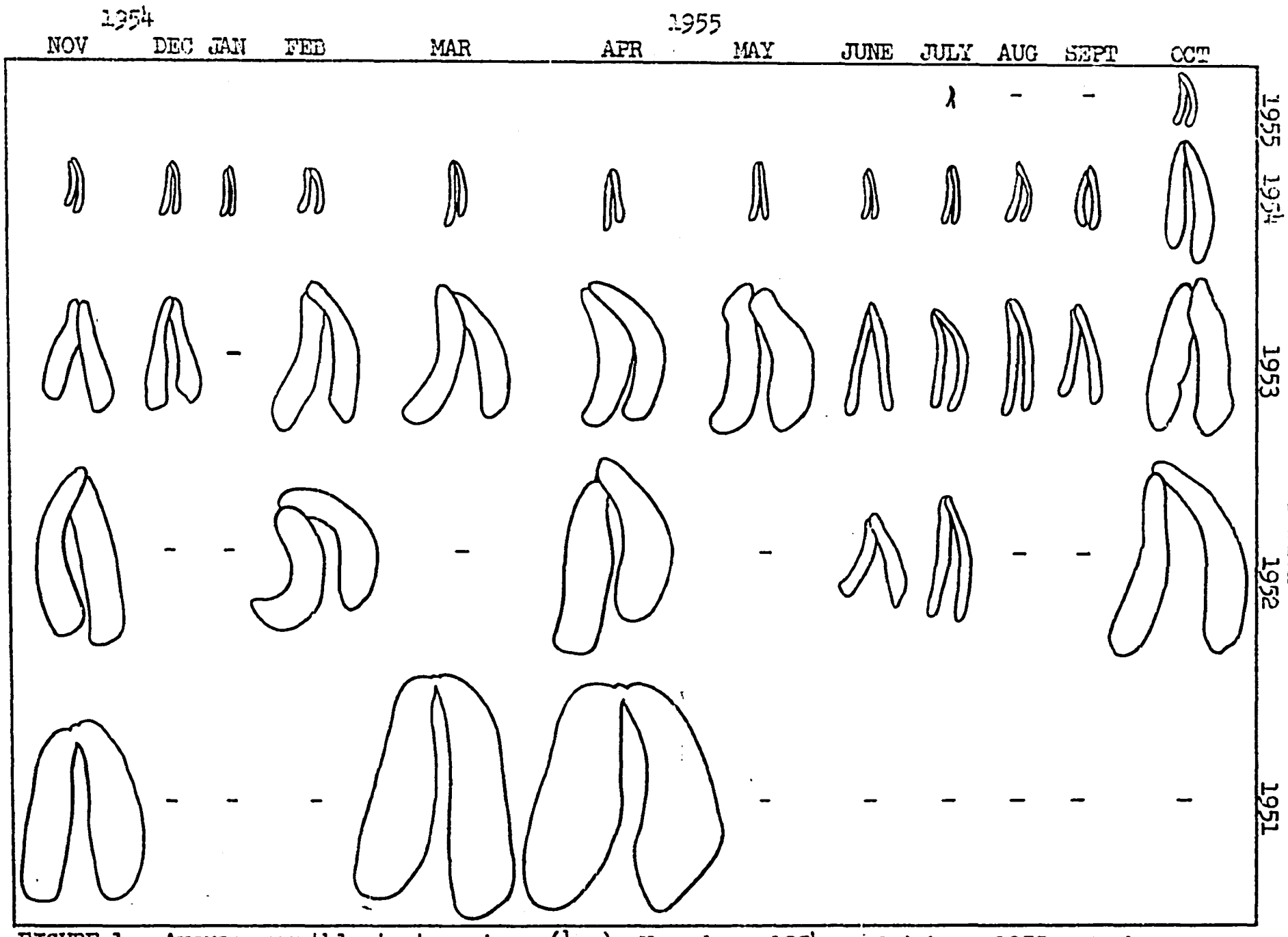


FIGURE 1. Average monthly testes size, -($\frac{1}{2}$ x), November, 1954 to October, 1955. Dash indicates that no fish of this year-class were collected in the month.

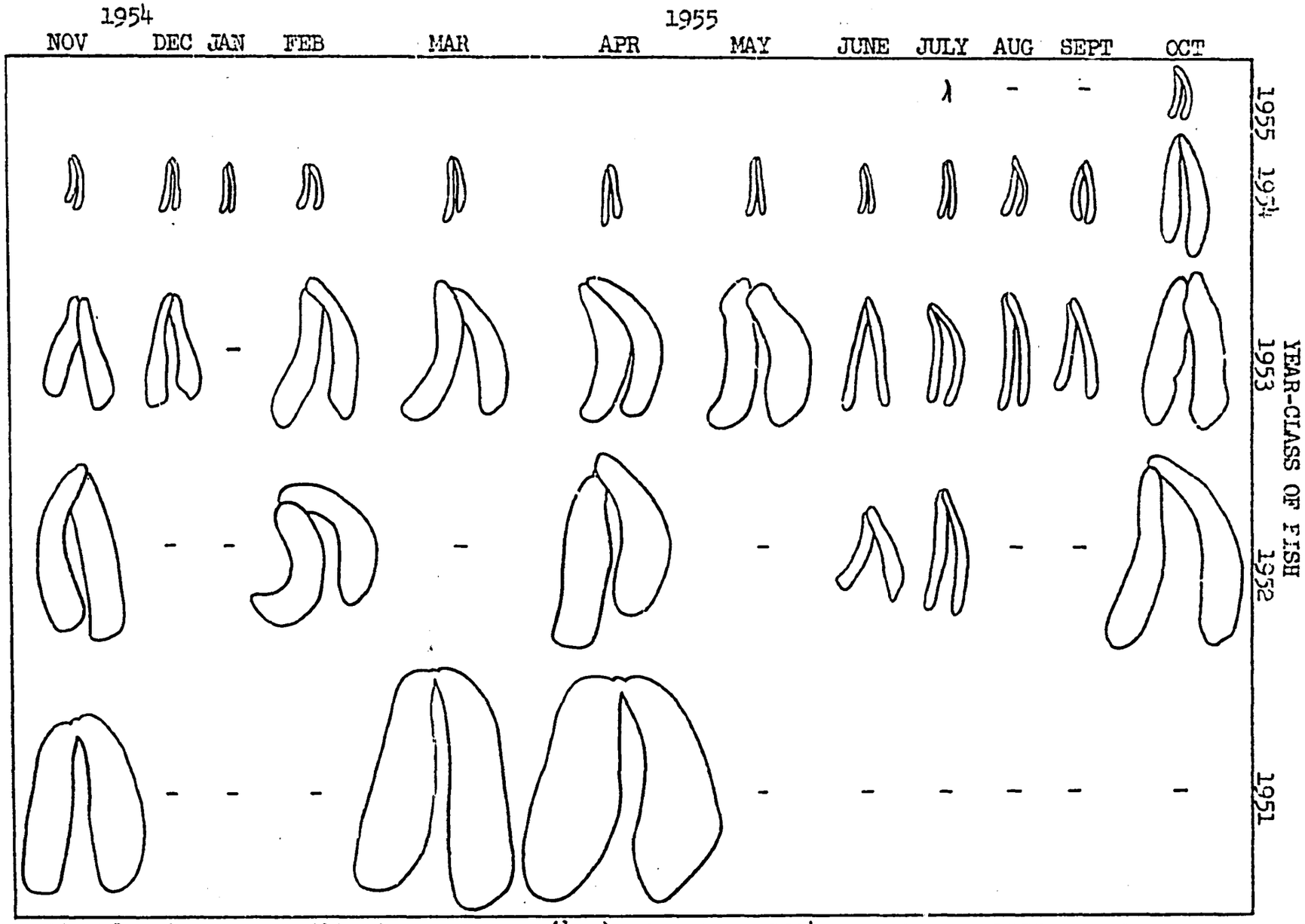


FIGURE 1. Average monthly testes size, -($\frac{1}{2}$ x), November, 1954 to October, 1955. Dash indicates that no fish of this year-class were collected in the month.

The average testes sizes of fish of the 1953 year-class (two years old in 1955) increased gradually from November through May. Based on the specimens used, these fish spawned for the first time in early May. The average size of testes collected in late May after spawning had occurred was much smaller than the size of testes collected in early May. The average size remained small until September when a small increase in size became apparent. There was a large increase in testes size in October.

The testes of fish of the 1952 year-class increased in average size from November to April. They were much smaller in June and July after spawning in late April or early May. The three-year-old fish also displayed the large increase in testes size in October which was characteristic of all year-classes.

The four-year-old males, whose average testes sizes are represented by the November, March, and April drawings of the testes of fish of the 1951 year-class (Figure 1), illustrate the same gradual increase in testes size, November through April. No four-year-old males were collected after April, 1955, or at any time in the earlier collections.

The average testes sizes from fish of the 1951-52 collections were larger than those from fish of the same age collected in 1954 and 1955. But the number of fish collected in 1951 and 1952 was so small that it is only an indication and no valid conclusions can be drawn from the comparison. There were only small variations in size when the testes of the 1949-50 collections were compared with the testes of the fish collected in 1954 and 1955.

Testes Weight

As expected, the seasonal variations in the weight of the testes essentially followed the variations in size (Table 1; Figure 2). The weight of the testes of fish of the 1954 year-class was small from November, 1954 through August, 1955. In September there was an increase in weight which continued through October. In all other year-classes of fish collected, the testes weight increased from November to the spawning period in late April or early May. The changes in the average weight of the testes of fish of the 1953 year-class show some irregularities, but these are probably due to the small samples. To determine whether the apparently upward trend in this year-class was real; a regression line was fitted to the data. The regression coefficient was .83 (t - 4.61) which differs significantly from zero with a probability equal to or less than .01. Regression coefficients for the other year-classes were all significantly greater than zero at levels of probability less than .025. The weight of the testes in all year-classes was the least during June, July, and August. The testes showed a small increase in weight in September and a large increase in October.

Valid comparisons of the average testes weights cannot be made among the three collections, since the two earlier collections were inadequate. The data do indicate (Table 2), however, that the average testes weights of fish collected in 1954 and 1955 were less than those collected in 1951 and 1952, and about the same as those taken in 1949 and 1950 for fish of the same age.

TABLE 1. Averages of body weight, testes weight, and weights of testes as percent of body weight for 108 male white bass, collected November, 1954 to October, 1955.

Date collected	Year-class	Number of fish	Average body weight (grams)	Average testes weight (grams)	Average weight of testes as percent of body weight
1954 Nov	1954	2	121	.13	.11
	1953	7	271	3.24	1.12
	1952	3	415	7.98	1.92
	1951	2	631	16.47	2.66
Dec	1954	1	96	.06	.06
	1953	1	225	1.76	.78
1955 Jan	1954	2	46	.03	.05
Feb	1954	5	75	.04	.05
	1953	6	259	3.35	1.23
	1952	1	366	9.03	2.47
Mar	1954	3	111	.11	.08
	1953	3	331	5.27	1.42
	1951	3	614	22.51	3.68
Apr	1954	3	131	.09	.07
	1953	4	258	4.35	1.69
	1952	3	451	15.09	3.35
	1951	1	623	35.49	5.90
May	1954	1	125	.03	.02
	1953	8	257	6.02	2.19
	1953*	7	237	.97	.41
June	1954	2	135	.05	.04
	1953	6	245	.25	.10
	1952	1	506	.46	.09
July	1955	1	28	.003	.01
	1954	8	207	.05	.02
	1953	5	448	.27	.06
	1952	6	533	.33	.06
Aug	1954	1	208	.04	.02
	1953	1	535	.08	.02
Sept	1954	1	282	.16	.06
	1953	1	566	.36	.06
Oct	1955	3	113	.03	.03
	1954	1	291	.83	.29
	1953	4	462	5.46	1.18
	1952	1	708	9.74	1.38

* After spawning.

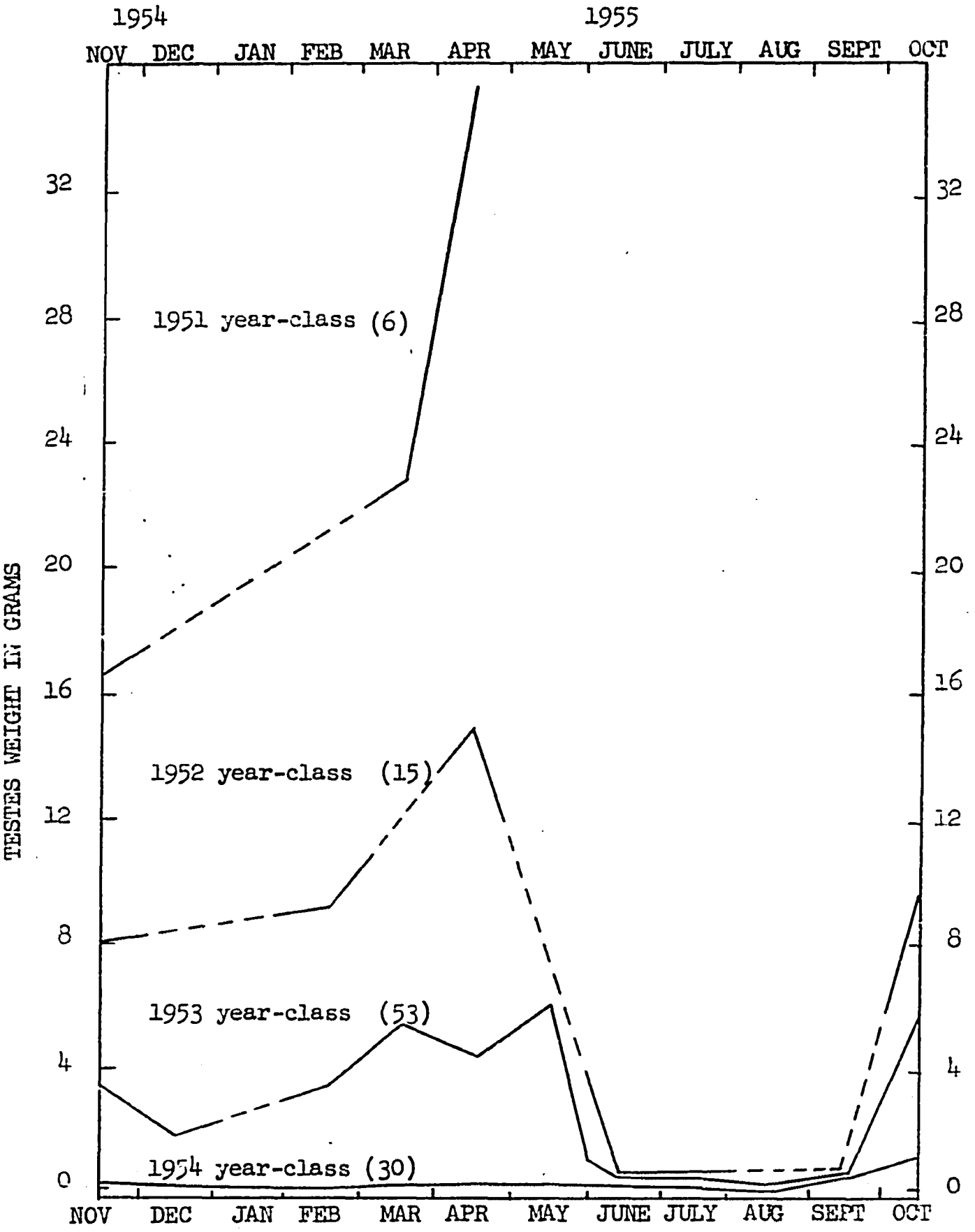


FIGURE 2. Average monthly testes weight, November, 1954 to October, 1955. Dashed line indicates that no fish of this year-class were collected in the month. Number of fish in parenthesis.

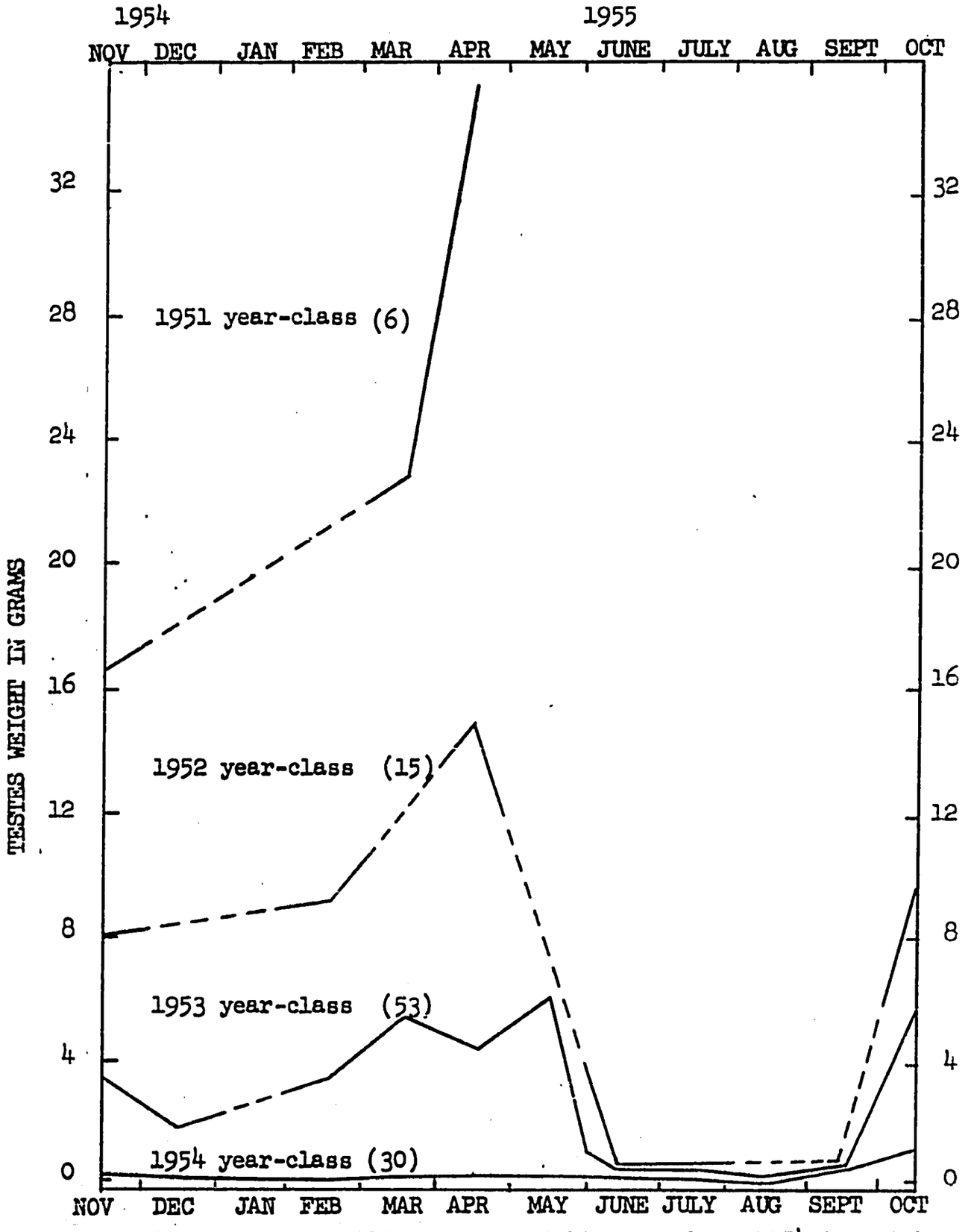


FIGURE 2. Average monthly testes weight, November, 1954 to October, 1955. Dashed line indicates that no fish of this year-class were collected in the month. Number of fish in parenthesis.

TABLE 2. Averages of body weight, testes weight, and weight of testes as percent of body weight for 23 male white bass, collected October, 1951 to December, 1952, and 115 male white bass, collected June, 1949 to August, 1950.

Date collected	Year-class	Number of fish	Average body weight (grams)	Average testes weight (grams)	Average weight of testes as percent of body weight
1951 Oct	1951	1	60	.006	.01
	1950	2	267	1.50	.50
Nov	1950	2	304	5.29	1.66
	1949	1	418	10.43	2.50
1952 Apr	1950	1	267	5.30	1.99
June	1951	1	121	.007	.01
	1950	4	256	.49	.17
July	1951	2	159	.05	.03
	1950	3	368	.26	.07
Aug	1951	3	208	.05	.02
	1950	1	337	.31	.09
Dec	1951	2	252	3.58	1.33
1949 June	1949	1	33	.004	.01
	1948	4	186	.05	.03
	1947	5	239	.06	.03
	1946	1	600	.09	.02
July	1949	8	8	.001	.01
	1948	25	222	.06	.03
	1947	26	425	.16	.04
	1946	3	630	.37	.06
Aug	1949	1	29	.003	.01
	1948	3	257	.05	.02
	1947	4	411	.10	.03
Oct	1948	1	260	.93	.36
	1947	1	566	4.16	.73
Dec	1949	1	94	.04	.04
	1947	3	499	11.47	2.30
1950 Jan	1949	1	92	.02	.02
	1947	3	501	13.82	2.81
Feb	1949	1	53	.02	.04
Apr	1949	12	80	.04	.05
May	1948	1	239	5.52	2.30
	1948*	2	259	2.18	.90
	1947*	2	420	2.09	.50
June	1949	4	176	.11	.07
	1948	1	436	.99	.23
Aug	1949	1	220	.14	.06

* After spawning.

Weights of Testes as Percentage of Body Weight

The percentage of the body weight which is testes weight is a better measure of seasonal variation in the testes than the testes weights alone, (Turner, 1919; Matthews, 1938; James, 1947). Generally, the larger fish taken at any one time have larger testes than the smaller fish, but the individual differences in the sizes of the testes of fish in a particular year-class are not as great when expressed as a percentage of the body weight. The testes weight percentage of body weight disclosed a very distinct seasonal cycle for the white bass (Tables 1, 2; Figure 3) for all but yearling fish increasing through late April or early May when spawning took place, then decreasing sharply after spawning to a percentage similar to that of immature testes. In June, July, and August, there was an additional slight decrease, in September a slight increase, and in October a decided increase.

The data indicate (Tables 1, 2) that the testes weight percentages of body weights in 1954 and 1955 were less than those in 1951 and 1952, and about the same as those in 1949 and 1950 for fish of the same age.

Histological Changes in the Testes

Smears made identification of sex in immature fish easy and accurate. Identification of the sex in the field as the gonads were removed is relatively easy for this species. My identifications were reversed for only eleven immature fish of the 540 fish used in the study.

The study of smears was considered to be an effective method for determining the state of spermatogenetic activity. The stages of spermatogenesis could be readily identified, and the tabulation of the frequency

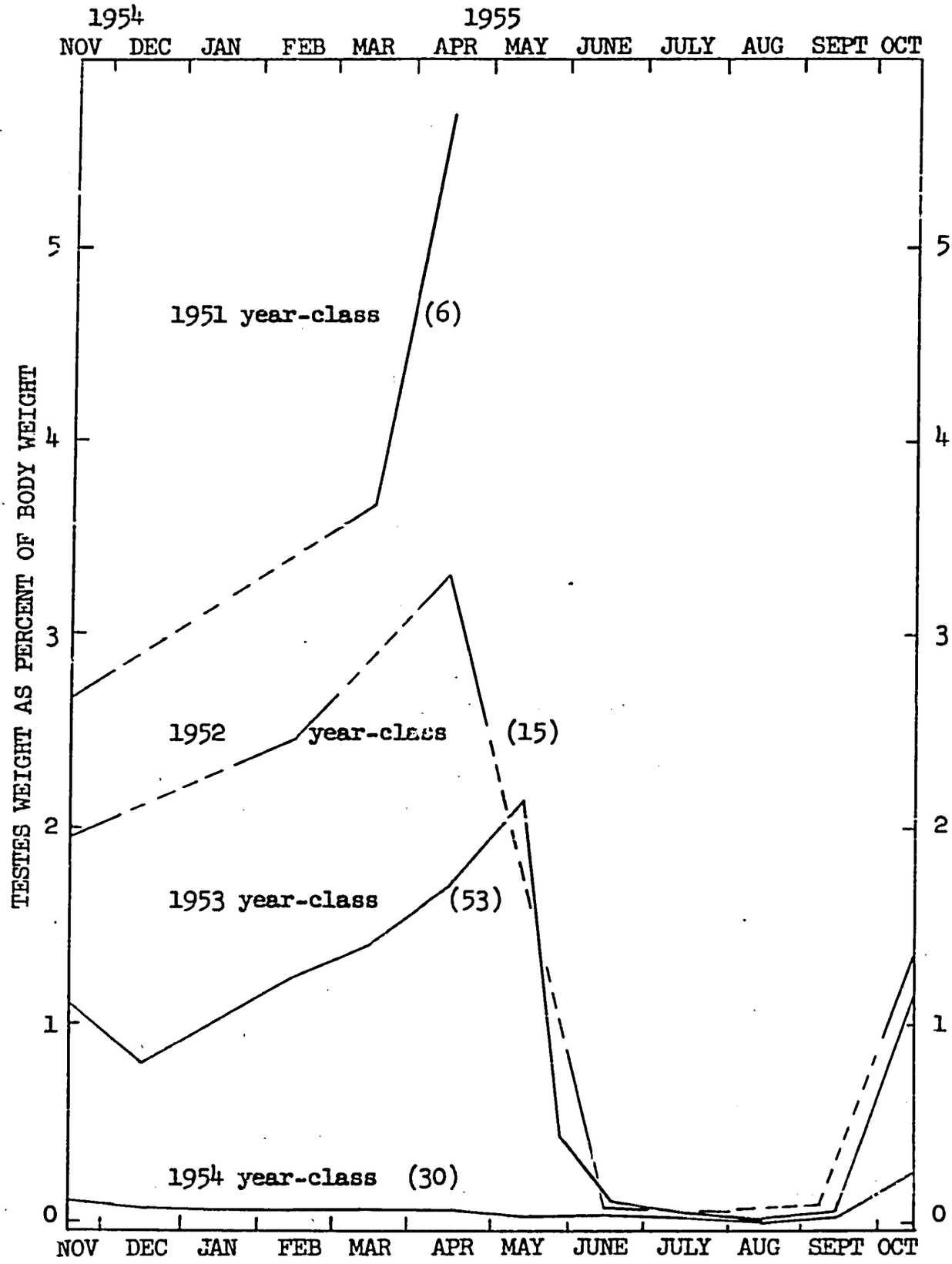


FIGURE 3. Average monthly weight of testes as percent of body weight, November, 1954 to October, 1955. Dashed line indicates that no fish of this year-class were collected in the month. Number of fish in parenthesis.

of their occurrence presented a good picture of the activity within the testes. Smears and sections from the same testes were compared in several cases and the results in comparing tabulated stages of spermatogenesis from each were nearly identical. Sections did show increases in the size of cysts of developing germ cells which smears did not show, but this did not provide any information essential for this study.

The testes were divided into three groups according to the histological condition determined by examination of the smears: (1) the early stages of spermatogenesis (spermatogonia and primary spermatocytes), (2) the middle stages of spermatogenesis (leptotene through the secondary spermatocyte division), (3) the late stages of spermatogenesis (spermatid transformation and spermatozoa).

None of the white bass males matured and spawned until they were two years old. Tabulations of the stages of spermatogenesis (Table 3) show only the early stages through the spawning period in 1955 for the 1954 year-class fish, while fish of the 1953 year-class had a few middle and a great number of the late stages and were in spawning condition from February through May. This is in agreement with Hann (1927) for Cottus bairdii, and James (1947) for Micropterus salmoides. Although Riggs (1955) did not examine the testes of yearling Roccus chrysops histologically, he found them to be in a ripe condition. Sigler (1949) reported only 36 percent of the two-year-old male white bass sexually mature in Spirit Lake, Iowa, based on macroscopic observations. Van Oosten (1942), Eschmeyer and Manges (1945), Howell (1945), Tompkins and Peters (1951), and Riggs (1955) all found fairly large percentages of male white bass mature as yearlings, while Sigler (1949) found no yearlings to be mature

TABLE 3. Histological changes in the testes of 108 white bass, collected November, 1954 to October, 1955.

Date collected	Year-class	Number of fish	Stages of spermatogenesis (Early)	(Middle)	(Late)
1954 Nov	1954	2	XXX*		
	1953	7		X	XX
	1952	3		X	XX
	1951	2		X	XXX
Dec	1954	1	XXX		
	1953	1		X	X
1955 Jan	1954	2	XXX		
Feb	1954	5	XXX		
	1953	6		X	XXX
	1952	1		X	XXX
Mar	1954	3	XXX	X	few
	1953	2		X	XXX
	1952	1		X	XXX
	1951	3		X	XXX
Apr	1954	3	XXX		
	1953	4		X	XXX
	1952	3		X	XXX
	1951	1		X	XXX
May	1954	1	XXX		
	1953	15		X	XXX
June	1954	2	XXX		
	1953	6	XX	X	(RBC)**
	1952	1	XX		(RBC)
July	1955	1	XXX		
	1954	8	XXX		
	1953	3	XXX		
	1952	8	XXX		
Aug	1954	1	XX		
	1953	1	XXX		
Sept	1954	1	XX	XX	
	1953	1	X	XXX	
Oct	1955	3	XXX		
	1954	1	XX	XX	XX
	1953	4	XX	XX	XXX
	1952	1	X	XX	XXX

* X represents the frequency of the stages of spermatogenesis found in the smears.

** (RBC) red blood cells.

upon macroscopic observation of their testes.

The histolocical cycle in the immature testes was illustrated by the fish of the 1954 year-class. From November, 1954 through July, 1955, only the early stages of spermatogenesis were found in the smears of the testes of this year-class, but in August early stages and a few middle stages were found. Spermatogenic activity increased in September as shown by the presence of approximately equal numbers of early and middle stages of spermatogenesis in the smears. This increased activity continued in October and a great number of all stages were found in the smears. These fish were reaching sexual maturity and it it presumed that they would have spawned in 1956.

Testes from fish of the 1953 year-class collected in November, 1954, displayed active spermatogenesis. Great numbers of the late stages of spermatogenesis were present. This was expected, since I had squeezed milt from one fish when it was collected. Examination of the smears indicated that by February the testes were nearly filled with spermatozoa. This condition continued through late April and early May when spawning occurred, resulting in a sharp decline in testes weight (Figure 3). In June the early stages of spermatogenesis were found to be mixed with a great number of red blood cells and some spermatozoa residue. The resorption of the residue, red blood cells, and probably some connective tissue would account for the slight additional decline in testes weight that was found in June. In July and August only the early stages of spermatogenesis were found in the smears. The smears of testes collected in September disclosed the early and middle stages of spermatogenesis. Foley (1926) described the beginning of testes activity in Umbra limi in late July,

and Turner (1919) reported that spermatogenesis began in late August for Perca flavescens. Hann (1927), and Matthews (1938), found that the testes activity began in September for Cottus bairdii, and Fundulus heteroclitus, respectively; James (1947) reported the beginning of testes activity for Lepomis macrochirus in October.

I found very active spermatogenesis in the smears of the testes collected in October. Great numbers of all stages of spermatogenesis were present in all fields of view studied. This increased spermatogenic activity accounts for the great increase in the size of the testes in October. Study of the smears of testes from three-year-old and four-year-old males revealed that the histological cycles were nearly identical with those of the testes from two-year-old males, although the older testes were much larger. There were no histological differences in the smears of the testes from the fish collected in 1951 and 1952 or 1949 and 1950 (Table 4).

Discussion

Seasonal reproductive cycles have been reported in several North American fresh-water fish, Turner (1919) Perca flavescens, Geiser (1922) Gambusia affinis, Foley (1926) Umbra limi, Hann (1927) Cottus bairdii, Matthews (1938) Fundulus heteroclitus, Bullough (1939) Phoxinus laevis, James (1947) Lepomis macrochirus and Micropterus salmoides, Sigler (1949), and Riggs (1955) Roccus chrysops. The seasonal variation in the gonads of the white bass is a conspicuous feature. This cycle is very similar to the cycle described for the yellow perch, Perca flavescens, by Turner (1919); however, he made no attempt to separate the fish into year-classes

TABLE 4. Histological changes in the testes of 23 white bass, collected October, 1951 to December, 1952, and 115 white bass, collected June, 1949 to August, 1950.

Date collected	Year-class	Number of fish	Stages of spermatogenesis (Early)	(Middle)	(Late)
1951 Oct	1951	1	XXX*		
	1950	2	XX	XX	X
Nov	1950	2	X	XX	XX
	1949	1	X	X	XX
1952 Apr	1950	1			XXX
June	1951	1	XXX		
	1950	4	XXX		(CT)**
July	1951	2	XXX		
	1950	3	XXX		(CT)
Aug	1951	3	XXX		
	1950	1	XXX		
Dec	1951	2		X	XXX
1949 June	1949	1	XXX		
	1948	4	XXX		
	1947	5	XXX		
	1946	1	XXX		
July	1949	8	XXX		
	1948	25	XXX		
	1947	26	XXX		
	1946	3	XXX		
Aug	1949	1	XXX		
	1948	3	XXX		
	1947	4	XXX		
Oct	1948	1		XX	X
	1947	1			XX
Dec	1949	1	XXX		
	1947	1			XXX***
1950 Jan	1949	1	XXX		
	1947	3			XXX***
Feb	1949	1	XX	X	
Apr	1949	12	X	X	XX
May	1948	3		X	XXX
	1947	2		X	XX
June	1949	4	XX	X	X
	1948	1			XX
Aug	1949	1	XX	X	

* X represents the frequency that the stages of spermatogenesis are found in the smears.

** (CT) connective tissue.

*** testes exuded sperm with pressure.

when he reported the weight and size of the testes as a proportionate part of the weight and size of the body. He noted no essential differences in the testes weight percentage of body weight in fish varying in weight from 60 to 300 grams. There is, by contrast, a considerable variation in this percentage for white bass of different ages, and older fish have proportionately larger testes than the younger ones. This variation is most noticeable from October through May, since the testes weight makes up a progressively greater proportion of the body weight in each successive month of this period. The testes of white bass reached a maximum size in late April or early May, those of the three- and four-year-old fish attain maximum sizes earlier than do those of the two-year-old fish. Maximum testes sizes in May were reported by Matthews (1938) for Fundulus heteroclitus, and by James (1947) for Lepomis macrochirus; James (1947) found that the testes of Micropterus salmoides reached maximum size in early April. My data which indicate that Lake Texoma white bass spawn in late April and early May are in agreement with Riggs (1955), who reported a similar spawning time for Lake Texoma white bass. Riggs (1955) tabulated the spawning dates for the white bass as reported by twelve workers in various parts of the country and there were variations from April to the end of June.

The testes were smallest in all year-classes during June, July, and August. In testes from fish collected in these months, only the early stages of spermatogenesis were found. In September active spermatogenesis began, except in the young-of-year fish. The middle stages of spermatogenesis were found in all smears made from the testes of fish collected in September. Very active spermatogenesis took place in

October and there was a large increase in the size of the testes of all year-classes of fish.

Riggs (1955) reported that by late October and early November the testes of Lake Texoma white bass appear to be as large as they were immediately preceding spawning, and that some males would emit milt when moderate pressure was applied. My earliest records of any testes in this condition were November 11, 1951 and November 6, 1954.

CHAPTER III

SEASONAL CYCLE OF THE OVARIES

Size of the Ovaries

Although the seasonal variation in the size of the ovaries is very similar to the seasonal cycle in the size of the testes, the former is more striking because the average sizes of the ovaries are larger than the average sizes of the testes from fish of the same age. In all but the very young fish, up to 3.5 inches in total-length, the ovaries can be distinguished readily from the testes. The ovaries are shorter and thicker than the testes, and they become yellow in color as they mature, while the testes become white. The outline drawings of the average ovaries for each year-class during the months of the year illustrate the seasonal changes in the size of the ovaries (Figure 4). The ovaries of fish of the 1954 year-class remained small until the fall of their second year of life. They were larger, however, than the testes from fish of the same age.

Ovaries from fish of the 1953 year-class became progressively larger from November, 1954, through early May, 1955, when spawning occurred, producing the natural sudden decrease in ovary size. They remained small in June but began to increase in size in July, much earlier than the corresponding increase in testes size. The same cyclic changes were found in the ovaries of the older fish, but the average size of the

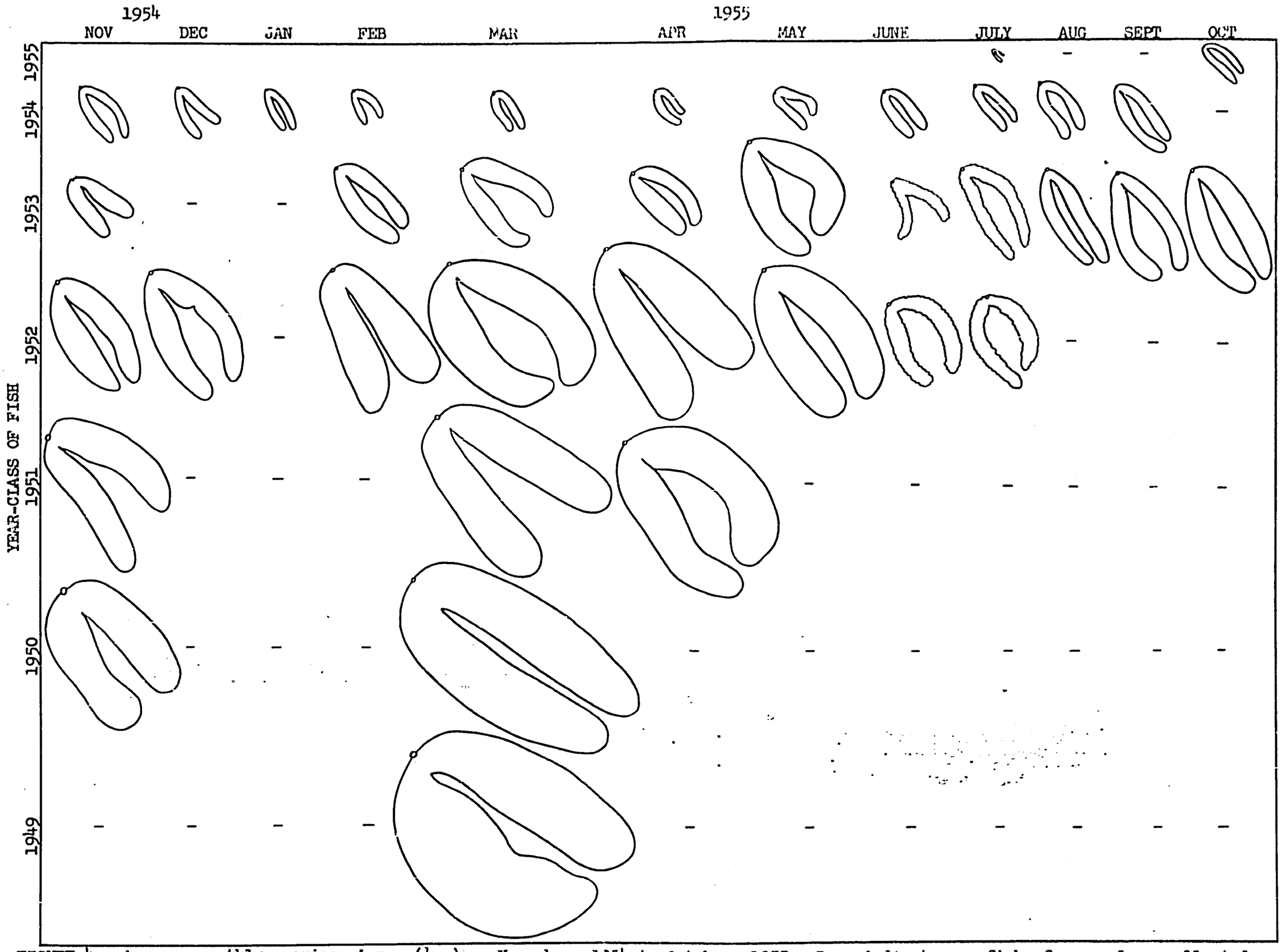


FIGURE 4. Average monthly ovaries size, ($\frac{1}{2}$ x), November, 1954 to October, 1955. Dash indicates no fish of year-class collected.

ovaries was proportionally larger in each successive month.

The ovaries collected in 1954 and 1955 were smaller than those from fish of comparable size collected in 1951 and 1952, but were larger than those of the one- and two-year-old fish and smaller than those of the three-year-old fish collected in 1949 and 1950.

Weight of the Ovaries

The seasonal variation in the weight of the ovaries is represented graphically in Figure 5, and tabulated in Table 5. The weights of the ovaries from yearling fish were relatively small during most of 1955. There were variations in the weights of the ovaries due to the differences in the size ranges of the fish collected in small samples during the different months. A regression line was fitted to the data and the regression coefficient was .08, which differs significantly from zero with a probability equal to or less than .01.

Ovaries from fish of the other year-classes gradually increased in weight from November to the spawning season in late April or early May. To determine whether the apparently upward trends were real, regression lines were fitted to the data. The regression coefficients were significantly greater than zero at levels of probability equal to or less than .01. There was a marked drop in average weight of the ovaries after spawning, and this decline continued in June, as unspawned ova and connective tissue were resorbed. From July through September the ovaries gradually increased in weight, followed by a decided increase in October.

Although there were not enough fish collected in the two earlier

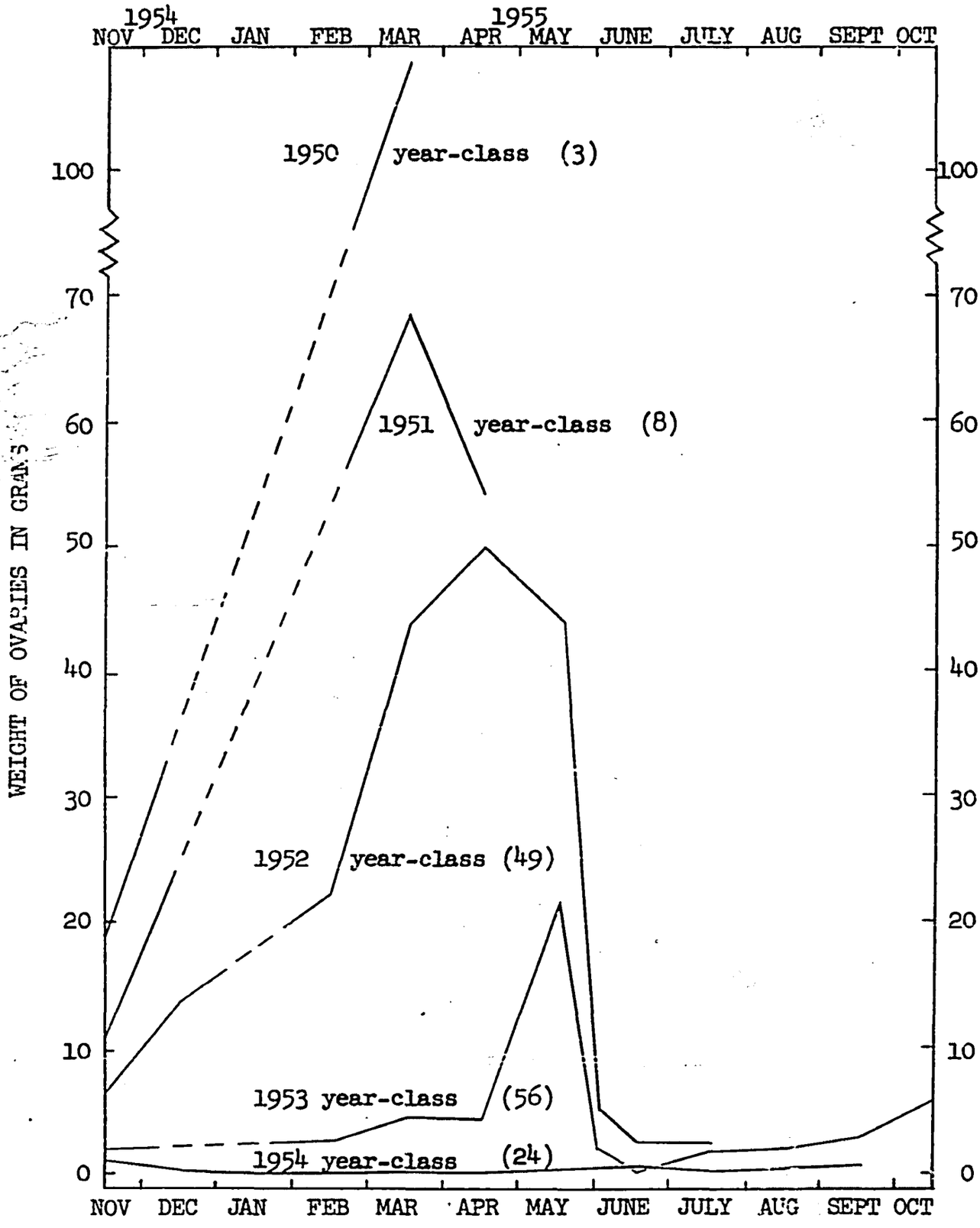


FIGURE 5. Average weight of ovaries, November 1954, to October, 1955. Dashed line indicates that no fish of this year-class were collected in the month. Number of fish in parenthesis.

TABLE 5. Averages of body weight, weight of the ovaries, and weight of the ovaries as percent of body weight for 145 female white bass, collected November, 1954 to October, 1955.

Date collected	Year-class	Number of fish	Average body weight (grams)	Average weight of ovaries (grams)	Average weight of ovaries as percent of body weight
1954 Nov	1954	1	169	1.00	.59
	1953	7	278	2.04	.73
	1952	8	475	6.29	1.32
	1951	2	647	10.42	1.60
	1950	2	963	18.44	1.92
Dec	1954	1	120	.48	.40
	1952	3	464	13.49	2.91
1955 Jan	1954	3	56	.24	.42
Feb	1954	1	38	.15	.40
	1953	2	258	2.87	1.12
	1952	6	442	22.13	4.64
Mar	1954	3	69	.27	.38
	1953	1	280	4.57	1.63
	1952	3	548	43.68	7.95
	1951	1	651	68.34	10.18
	1950	1	849	108.40	12.77
	1949	2	1316	175.90	13.34
Apr	1954	3	56	.22	.45
	1953	8	241	4.36	1.56
	1952	7	533	49.91	9.68
	1951	5	702	54.07	7.72
May	1954	1	125	.55	.44
	1953	11	322	21.85	6.39
	1953*	12	263	2.06	.75
	1952	2	498	44.03	8.82
	1952*	5	463	5.29	1.12
June	1954	2	217	.74	.34
	1953	1	256	.69	.27
	1952	7	564	2.97	.51
July	1955	1	30	.011	.04
	1954	7	214	.58	.27
	1953	9	493	1.91	.38
	1952	8	544	2.51	.46
Aug	1954	1	266	.75	.28
	1953	1	441	2.12	.48
Sept	1954	1	271	1.00	.37
	1953	1	570	3.18	.56
Oct	1955	2	115	.32	.28
	1953	3	551	6.22	1.12

* After spawning.

collections to make valid comparisons, the data do indicate differences. The ovaries collected in 1954 and 1955 weighed less than those from fish of comparable ages collected in 1951 and 1952, but weighed more than those from one- and two-year-old fish and less than those from three-year-old fish collected in 1949 and 1950 (Tables 5, 6, and 7).

Weight of Ovaries as Percentage of Body Weight

The percentage of body weight which is the weight of the ovaries is more indicative of seasonal variation in the ovarian cycle than either the sizes or weights of the ovaries alone. The work of Hann (1927), Matthews (1938), James (1947), and Cooper (1952) concurs. The variations in the white bass ovaries were more striking than similar changes in the testes (Table 5, Figure 6). The percentage of body weight which was the weight of the ovaries for fish of the 1954 year-class (yearlings) was small and varied only slightly during the second year of life. In all other ages of fish there was an increase in the percentage of body weight which was the weight of the ovaries from November, 1954 up to the time of spawning in late April or early May in 1955, followed by a sharp decrease for the fish collected after spawning. This decrease continued in June, but in July there was an increase which continued through October when the collections were terminated. The July increase in percentage of body weight which was the weight of the ovaries occurred two months earlier than similar increases in the testes.

The percentage of body weight which was the weight of the ovaries for fish collected in 1954 and 1955 was less than the percentages in 1951 and 1952, but greater than the percentages in 1949 and 1950

TABLE 6. Averages of body weight, weight of the ovaries, and weight of the ovaries as percent of body weight for 35 female white bass, collected October, 1951 to December, 1952.

Date collected	Year-class	Number of fish	Average body weight (grams)	Average weight of ovaries (grams)	Average weight of ovaries as percent of body weight
1951 Oct	1950	1	248	1.03	.42
Nov	1950	1	267	2.04	.76
	1949	2	543	18.80	3.43
1952 Apr	1951	4	129	.69	.49
	1949	1	436	21.47	4.89
June	1951	2	167	.57	.34
	1950	1	402	44.68	11.11
	1950*	2	407	3.36	.80
July	1951	4	208	.77	.37
	1950	1	382	2.29	.60
Aug	1951	7	233	.79	.34
	1950	5	553	2.81	.52
Dec	1951	2	250	3.61	1.36
	1950	2	567	31.08	5.38

* After spawning.

TABLE 7. Averages of body weight, weight of the ovaries, and weight of the ovaries as percent of body weight for 114 female white bass, collected June, 1949 to August, 1950.

Date collected	Year-class	Number of fish	Average body weight (grams)	Average weight of ovaries (grams)	Average weight of ovaries as percent of body weight
1949 June	1949	1	36	.004	.01
	1948	6	208	.42	.19
	1946	2	545	2.47	.43
July	1949	7	20	.02	.08
	1948	21	243	.63	.25
	1947	32	470	1.71	.37
	1946	4	654	2.55	.39
	1945	5	792	4.69	.60
	1945*	1	950	32.74	3.45
	1944	2	1220	7.74	.64
	1943	1	1450	10.53	.73
Aug	1948	4	253	.24	.09
	1947	1	496	1.64	.33
	1946	1	670	1.20	.18
Oct	1949	1	142	.19	.13
	1947	1	476	1.52	.32
	1946	2	680	10.84	1.62
Dec	1949	3	98	.34	.36
	1947	1	545	32.02	5.91
1950 Jan	1949	1	90	.12	.13
	1948	1	315	6.14	1.95
	1947	1	535	52.36	9.79
Mar	1948	1	253	3.18	1.26
Apr	1949	4	72	.21	.30
May	1949	1	187	.32	.17
	1948	4	289	8.89	3.15
June	1949	3	222	.97	.43
Aug	1949	2	185	.78	.42

* Abnormal ovary, one-half large, bloody.

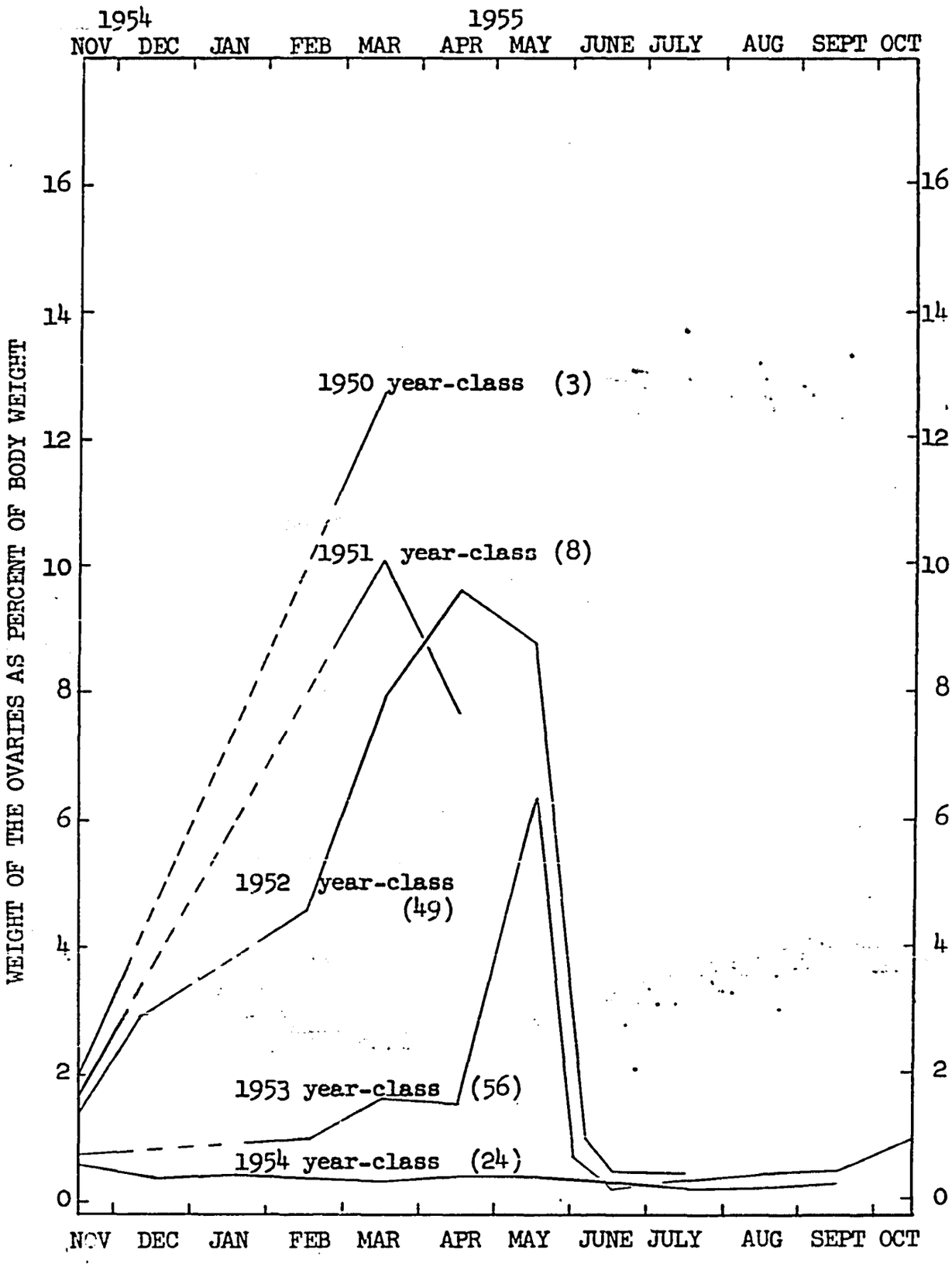


FIGURE 6. Average weight of ovaries as percent of body weight, November, 1954 to October, 1955. Dashed line indicates that no fish of this year-class were collected in the month. Number of fish in parenthesis.

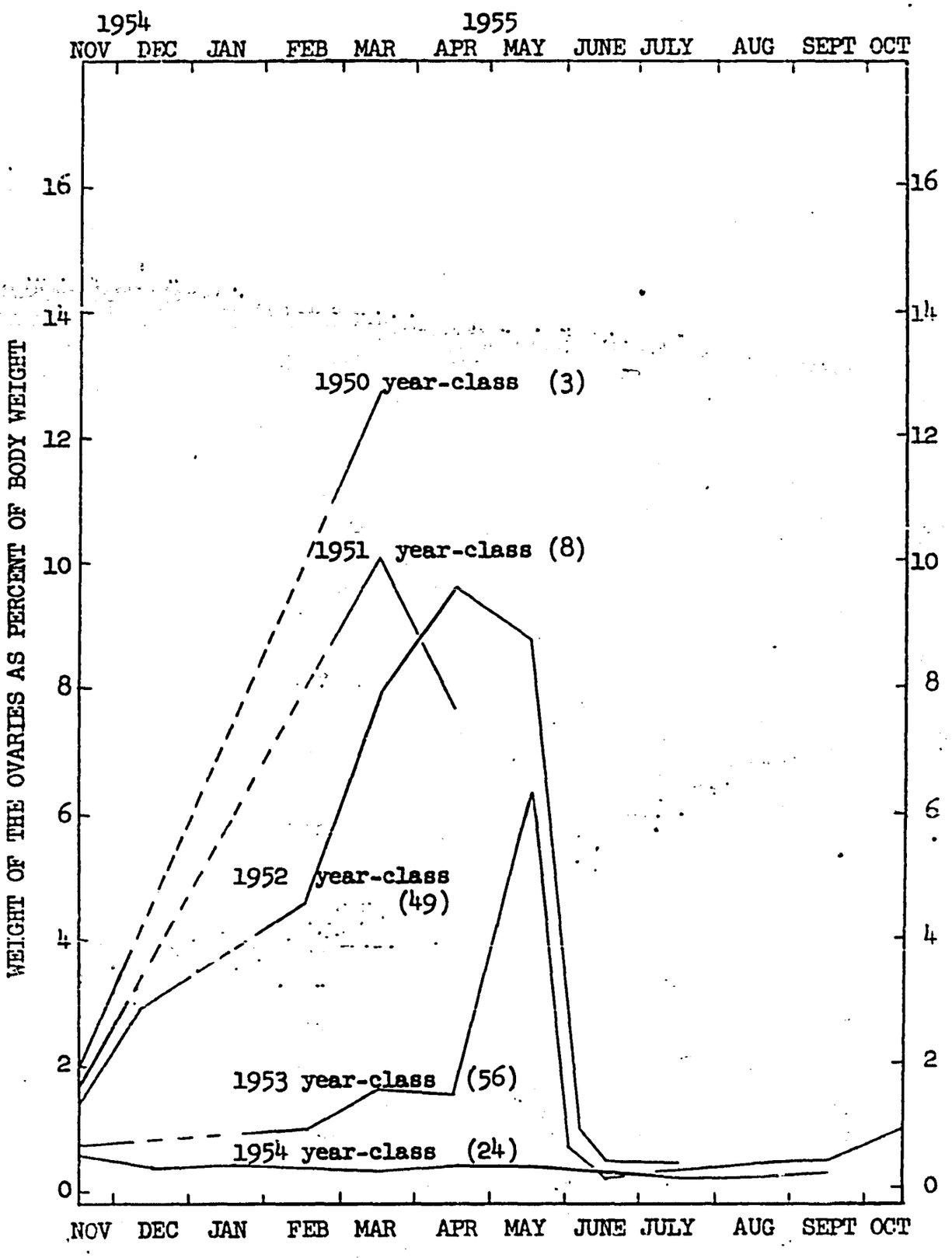


FIGURE 6. Average weight of ovaries as percent of body weight, November, 1954 to October, 1955. Dashed line indicates that no fish of this year-class were collected in the month. Number of fish in parenthesis.

except in November and December (Tables 5, 6, and 7).

Histological Changes in the Ovaries

The average diameters of the largest oöcytes in the smears from the ovaries were recorded for each age of fish (Table 8). The histological changes in the ovaries of yearling fish were shown by fish of the 1954 year-class. From November, 1954 through February, 1955, the largest oöcytes averaged .10 millimeter in diameter but only about one-third of the oöcytes in a smear reached that size. The ovaries were flabby with large lumens and remained so in March and April when about one-half of the oöcytes averaged .11 millimeter in diameter. The average diameter increased to .13 millimeter in one-half of the oöcytes, the lumens remained large, and the ovaries were flabby in May and June. Blood vessels and blood cells appeared in the smears of ovaries collected in June and July, but did not appear to be associated with spawning, since the connective tissue found in the smears of spent ovaries of older fish was not present. In July the average diameter had increased to .14 millimeter in one-half of the oöcytes, the lumens were smaller, and the ovaries were not as flabby. The diameter increased to .15 millimeter in August and .19 millimeter in September, while the ovaries remained fairly flabby and the lumens were small.

The ovaries of fish of the 1953 year-class were flabby with large lumens in November, 1954, and the average diameter of the oöcytes was .16 millimeter. By February, 1955, the average diameter of the oöcytes had increased to .30 millimeter, then to .34 millimeter in March when in some ovaries the lumens were obliterated by being filled with oöcytes. Four

TABLE 8. Average diameters of the oöcytes from 145 white bass, collected November, 1954 to October, 1955.

Date collected	Year-class of fish (Average diameter of oöcytes in millimeters)					
	1954	1953	1952	1951	1950	1949
1954 Nov	.09	.16 (.16)	.32 (.38)	.38	.41	
Dec	.10 (.10)	(.24)	.52 (.51) (.55)			
1955 Jan	.10	(.45)	(.62)			
Feb	.10	.30	.50			
Mar	.11	.34 (.30)	.62	.59	.64	.69
Apr	.11 (.13) (.10)	.63 .21*	.67 (.56)	.69		
May	.13	.62 (.62) .19*	.67 .15*			
June	.13 (.16) (.13)	.15 (.15)	.15	.15		
July	.14 (.16) (.16)	.14 (.16) (.16)	.15 (.16)	.15 (.15)	(.15)	
Aug	.15 (.16) (.14)	.18 (.18) (.15)				
Sept	.19	.20				
Oct	(.16)	.28	(.30)			

* After spawning. 1951-52 oöcytes in first column in parenthesis, 1949-50 oöcytes in second column in parenthesis.

of five fish collected from the fifth to the thirteenth of April, 1955, had immature ovaries with oöcytes that averaged .24 millimeter in diameter, while the remaining fish had ripe ovaries which were packed solidly with mature ova averaging .62 millimeter in diameter. Three fish collected April 25, 1955 were spent and their flabby ovaries contained oöcytes that averaged .21 millimeter in diameter. In early May eleven fish had ovaries packed with mature ova that averaged .62 millimeter in diameter, which indicated that they had not spawned. Twelve fish had very flabby ovaries with large lumens, and the smears showed old fragile ova, a large number of blood cells and connective tissue, as well as a great number of very small oöcytes. The average diameter of the largest oöcytes was .19 millimeter. Spent females were not collected before April 25, 1955, and all of the mature females collected after May 7, 1955 were spent. So the spawning season as indicated by the smears was from April 25, 1955 to May 7, 1955 for the fish in this study. The ovaries from the fish collected in June and July were bloody, very flabby, and wrinkled. Smears from these ovaries contained a number of blood cells, and the average diameter of the largest oöcytes was .15 millimeter, but there were great numbers of very small oögonia. These ovaries were the type which I had listed as "resorbing" in the field, as did James (1947) for the ovaries of Lepomis macrochirus. The bloody condition seemed to be due to the resorption of the mature ova which had not been ovulated and were present in small numbers. This was also a period of very active division of the oögonia as evidenced by the great numbers of very small oögonia. Active oögenesis thus began immediately after spawning and the subsequent increase in the size of the ovaries was

primarily the result of an increase in the size of the oöcytes which were produced by these divisions. In August the average diameter of the oöcytes had increased to .18 millimeter, and the ovaries were fairly solid and had small lumens. The average diameter of the oöcytes increased to .20 millimeter in September. In October the ovaries were solid, had no lumens, and the average diameter of the oöcytes had increased to .28 millimeter. This increase in diameter accounted for the sharp rise in the size and the weight of the ovaries in October.

The three-, four-, and five-year-old fish had oöcytes with average diameters of .32, .38, and .41 millimeters respectively in November, and the ovaries were packed with oöcytes. The average diameter of the oöcytes had increased to .52 millimeter in December. The ovaries continued to be packed with oöcytes until spawning occurred. The average diameters of the oöcytes were .62 millimeter, .59 millimeter, .64 millimeter, and .69 millimeter for the three- to six-year-old fish in March. The average diameters of the oöcytes from three- and four-year-old fish were .67 millimeter and .69 millimeter in April. In May the average diameters of the oöcytes from three-year-old fish were .67 millimeter before spawning and .15 millimeter after spawning. The average diameter of the oöcytes in June and July for the two- and three-year-old fish was .15 millimeter. The ovaries were very flabby and had large lumens. Old ova, blood cells, and connective tissue, as well as large numbers of very small oögonia were found in the smears.

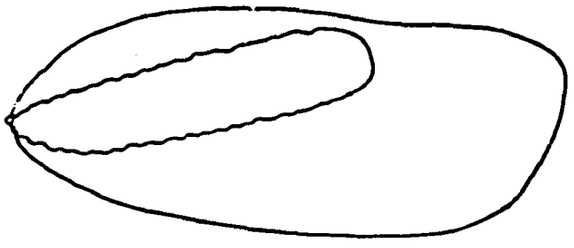
Comparison of the average diameters of the oöcytes from ovaries of the fish taken during the three collecting periods showed only small variations (Table 8).

Discussion

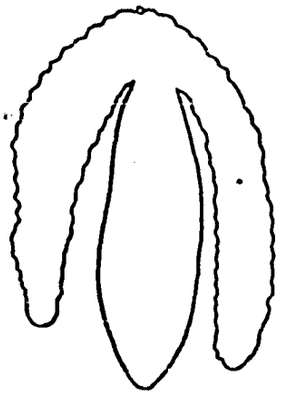
The seasonal changes in the ovaries of the white bass are much greater than similar changes in the testes. Matthews (1938) reported the same differences in Fundulus. The "ripe" ovaries are much larger and the decreases in size after spawning are much greater than similar changes in the testes. This decrease in size after spawning is shown very effectively by the ovaries which were taken from a four-year-old female collected July 27, 1949 (Figure 7A). One of the ovaries was large and packed with mature ova, the characteristic appearance of the ripe ovary, while the other ovary was soft, flabby, and wrinkled, the characteristic appearance of the spent ovary.

The ovaries exhibited a gradual increase in size from November to March, then a rapid increase in April. This was similar to the condition reported in the largemouth bass, Micropterus salmoides, (James, 1947), but differed from the report of Cooper (1952) for both the black and white crappies, Pomoxis nigromaculatus, and P. annularis, which had no extreme separation of stages.

The ovaries reached maturity after two years of growth. Similar ages for maturity were reported by Hann (1927) for Cottus bairdii, James (1947) for Micropterus salmoides, and Cooper (1952) for Pomoxis nigromaculatus and P. annularis. Sigler (1949) and Riggs (1955), after macroscopic examination, reported that white bass females reached maturity in their second or third year. Spawning in Lake Texoma white bass took place in late April or early May. Riggs (1955) reported a similar spawning period for Lake Texoma white bass, but Sigler (1949) listed late



A.



B.

FIGURE 7. Abnormal ovaries. A. Only one ovary had spawned. B. Three ovaries, the middle ovary had not spawned.

May and early June as the spawning period for this species in Spirit Lake, Iowa.

The ovaries exhibited their smallest weight and percentage of body weight in June. The rapid division of the oöcytes produced an increase in the size, weight, and percentage of body weight of the ovaries in July. Thus the preparation for the next spawning period began very early in the cycle of the ovaries. Similar development in the ovaries was reported by Hann (1927) in Cottus bairdii, and James (1947) in Lepomis macrochirus and Micropterus salmoides. The oöcytes then increased in size during the months before the next spawning season as yolk was deposited, and caused the observed increases in size and weight of the ovaries.

All the ovaries were examined carefully as the smears were being prepared to determine if there was a histological closing of the oviducts similar to that reported by Bullough (1939) for the minnow, Phoxinus laevis. No evidence of histological closing of the oviducts was found in any of the 294 females examined.

Early in the study it appeared that a number of mature females did not spawn. Ovaries from fish collected in June and July were still large, but hard, usually flattened laterally, and apparently in a pathogenic condition. This was not a common occurrence however, since only two fish out of 82 mature females collected in June and July had ovaries in this condition, and it evidently has little effect upon the reproductive potential in this species.

A female with three ovaries (Figure 7B) was collected July 22, 1955. The two lateral ovaries, in the normal position for paired ovaries, were flabby and wrinkled like spent ovaries, while the middle ovary

was packed with mature ova being resorbed and had apparently failed to ovulate.

CHAPTER IV

SUMMARY AND CONCLUSIONS

1. This study of the seasonal gonadal cycle in Lake Texoma white bass was based on 540 fish taken from June 8, 1949 to October 22, 1955.

2. Acetocarmine smears of fixed gonads were found to be a quick and adequate method for the study of gonadal activity.

3. There was a pronounced seasonal variation in the size and development of the white bass gonads. The gonads exhibit their smallest size shortly after spawning, then show a gradual increase up to the time of the next spawning period. Both the ovaries and the testes form a greater percentage of the body weight in older and larger fish.

4. Study of the smears of testes show that spermatogenesis began in September and became very active in October.

5. Active oögenesis began immediately after spawning when very active division of the oögonia took place. This was followed by an increase in size of oögonia until maturity was attained shortly before spawning.

6. Study of smears showed that no yearling white bass reached maturity and spawned.

7. Spawning of Lake Texoma white bass took place in late April or early May and the spawning was complete.

LITERATURE CITED

Bullough, W. S.
1939 A study of the reproductive cycle of the minnow in relation to the environment. Proc. Zool. Soc. of London, Ser. A., 109 (1): 79-102.

Cooper, John Lloyd
1952 A histological study of the reproductive organs of crappies, Pomoxis nigro-maculatus and Pomoxis annularis. Trans. Amer. Micros. Soc., 71 (4): 393-404.

Eschmeyer, R. W. and D. E. Manges
1945 Fish migrations into the Norris Dam tail-water in 1943. Rept. Reelfoot Lake Biol. Sta., 9: 92-97.

Foley, James O.
1926 The spermotogenesis of Umbra limi with special reference to the behavior of the spermatogonial chromosomes and the first maturation division. Biol. Bull., 50 (2): 117-147.

Geiser, S. W.
1922 Seasonal changes in the testis of Gambusia affinis, the top-minnow. Anat. Rec., 23 (1): 104-105.

Hann, Harry W.
1927 The history of the germ cells of Cottus bairdii (Girard). Jour. Morph., 43 (2): 427-498.

Howell, H. H.
1945 The white bass in TVA waters. Rept. Reelfoot Lake Biol. Sta., 9: 41-48.

James, Marian F.
1947 Histology of gonadal changes in the bluegill, Lepomis macrochirus (Rafinesque), and the largemouth bass, Huro salmoides (Lacepede). Jour. Morph., 79 (1): 63-91.

Matthews, Samuel A.
1938 The seasonal cycle in the gonads of Fundulus. Biol. Bull., 75 (1): 66-74.

Riggs, Carl D.
1955 Reproduction of the white bass, Morone chrysops. Invest. Indiana Lakes and Streams, 4 (3): 87-110.

Sigler, William F.
1949 Life history of the white bass, Lepibema chrysops (Rafinesque), of Spirit Lake, Iowa. Iowa State Coll. Res. Bull., 366: 201-244.

Tompkins, W. A. and M. M. Peters
1951 The age and growth of the white bass, Lepibema chrysops, of Herrington Lake, Kentucky. Kentucky Div. Fish and Game, Fish. Bull. No. 8: 1-12. (mimeo.)

Turner, Clarence L.
1919 The seasonal cycle of the spermary of the perch. Jour. Morph., 32 (3): 681-705.

Van Oosten, John
1942 The age and growth of the Lake Erie white bass, Lepibema chrysops (Rafinesque). Michigan Acad. Sci., Arts., Lett., 27: 307-334.

APPENDIX I. Body weight, testes weight, and testes weight as a percentage of body weight for 108 male white bass, collected November, 1954 to October, 1955.

Date taken	Year-class	Body weight (Ind.)	Body weight (Av.)	Testes weight (Ind.)	Testes weight (Av.)	Testes weight as percent of body weight (Ind.)	Testes weight as percent of body weight (Av.)
1954							
Nov	1954	131		.10		.08	
		111	121	.16	.13	.14	.11
	1953	325		6.69		2.06	
		318		5.52		1.74	
		267		2.67		1.00	
		260		1.76		.68	
		254		2.88		1.13	
		261		2.60		1.00	
		209	271	.55	3.24	.26	1.12
	1952	480		9.88		2.06	
		383		5.78		1.51	
		381	415	8.29	7.98	2.18	1.92
	1951	708		16.26		2.30	
		554	631	16.67	16.47	3.01	2.66
Dec	1954	96	96	.06	.06	.06	.06
	1953	225	225	1.76	1.76	.78	.78
1955							
Jan	1954	65		.04		.06	
		26	46	.01	.03	.04	.05
Feb	1954	113		.05		.04	
		105		.05		.05	
		65		.03		.05	
		50		.03		.05	
		44	75	.03	.04	.07	.05
	1953	276		3.68		1.33	
		307		6.54		2.26	
		281		4.15		1.48	
		255		4.00		1.57	
		208		.27		.13	
		226	259	1.43	3.35	.63	1.23
	1952	366	366	9.03	9.03	2.47	2.47
Mar	1954	143		.28		.20	
		136		.03		.02	
		52	111	.01	.11	.02	.08
	1953	445		10.32		2.32	
		307		3.95		1.29	
		240	331	1.55	5.27	.65	1.42
	1951	651		22.10		3.39	
		595		23.30		3.92	
		595	614	22.14	22.51	3.72	3.68

APPENDIX I (Continued)

Date taken	Year-class	Body weight (Ind.)	Body weight (Av.)	Testes weight (Ind.)	Testes weight (Av.)	Testes weight as percent of body weight (Ind.)	Testes weight as percent of body weight (Av.)
Apr	1954	168		.13		.08	
		158		.10		.06	
		68	131	.04	.09	.09	.07
	1953	386		6.39		1.66	
		230		4.73		2.06	
		206		3.06		1.49	
		208	258	3.23	4.35	1.55	1.69
	1952	465		12.02		2.58	
		449		19.70		4.39	
		439	451	13.55	15.09	3.09	3.35
	1951	623	623	35.49	35.49	5.70	5.70
May	1954	125	125	.03	.03	.02	.02
	1953	375		13.19		3.52	
		271		10.35		3.82	
		277		5.95		2.15	
		263		6.57		2.50	
		227		2.76		1.22	
		213		3.07		1.44	
		250		3.86		1.55	
		179	257	2.37	6.02	1.32	2.19
	1953*	250		.41		.16	
		245		1.02		.42	
		238		.78		.33	
		235		1.30		.56	
		236		1.02		.43	
		220		1.47		.67	
		237	237	.76	.97	.32	.41
June	1954	142		.03		.02	
		128	135	.06	.05	.05	.04
	1953	340		.51		.15	
		276		.24		.09	
		265		.29		.11	
		215		.26		.12	
		185		.10		.05	
		189	245	.10	.25	.05	.10
	1952	506	506	.46	.46	.09	.09
July	1955	28	28	.003	.003	.01	.01
	1954	240		.05		.02	
		242		.05		.02	
		225		.05		.02	
		219		.04		.02	
		214		.05		.02	

APPENDIX I (Continued)

Date taken	Year-class	Body weight (Ind.)	Body weight (Av.)	Testes weight (Ind.)	Testes weight (Av.)	Testes weight as percent of body weight (Ind.)	Testes weight as percent of body weight (Av.)
		209		.05		.02	
		154		.04		.03	
		153	207	.04	.05	.03	.02
	1953	473		.38		.08	
		481		.32		.07	
		484		.22		.05	
		424		.32		.08	
		378	448	.13	.27	.03	.06
	1952	595		.33		.06	
		556		.62		.11	
		580		.24		.04	
		549		.25		.05	
		565		.27		.05	
		487	555	.24	.33	.05	.06
Aug	1954	208	208	.04	.04	.02	.02
	1953	535	535	.08	.08	.02	.02
Sept	1954	282	282	.16	.16	.06	.06
	1953	566	566	.36	.36	.06	.06
Oct	1955	119		.03		.03	
		121		.03		.02	
		98	113	.03	.03	.03	.03
	1954	291	291	.83	.83	.29	.29
	1953	514		6.80		1.32	
		462		7.02		1.52	
		485		3.75		.77	
		387	462	4.25	5.46	1.10	1.18
	1952	708	708	9.74	9.74	1.38	1.38

* After spawning.

APPENDIX II. Body weight, ovaries weight, and ovaries weight as a percentage of body weight for 145 female white bass, collected November, 1954 to October, 1955.

Date taken	Year-class	Body weight (Ind.)	Body weight (Av.)	Ovaries weight (Ind.)	Ovaries weight (Av.)	Ovaries weight as percent of body weight (Ind.)	Ovaries weight as percent of body weight (Av.)
1954							
Nov	1954	169	169	1.00	1.00	.59	.59
	1953	306		2.56		.84	
		337		2.45		.73	
		316		2.36		.75	
		276		2.25		.82	
		268		1.82		.68	
		230		1.39		.60	
		215	278	1.48	2.04	.69	.73
	1952	497		6.07		1.22	
		525		6.71		1.28	
		467		6.68		1.43	
		508		6.45		1.27	
		497		7.63		1.54	
		458		7.63		1.67	
		421		5.37		1.28	
		429	475	3.75	6.29	.87	1.32
	1951	671		11.37		1.69	
		623	647	9.47	10.42	1.52	1.60
	1950	991		17.46		1.76	
		934	963	19.41	18.44	2.08	1.92
Dec	1954	120	120	.48	.48	.40	.40
	1952	452		13.14		2.91	
		497		14.85		2.99	
		443	464	12.48	13.49	2.82	2.91
1955							
Jan	1954	81		.34		.42	
		55		.22		.40	
		33	56	.15	.24	.45	.42
Feb	1954	38	38	.15	.15	.40	.40
	1953	256		3.75		1.46	
		259	258	1.99	2.87	.77	1.12
	1952	583		51.26		8.79	
		464		15.88		3.42	
		488		32.40		6.64	
		370		6.27		1.70	
		396		12.70		3.21	
		353	442	14.28	22.13	4.05	4.64
Mar	1954	85		.36		.42	
		62		.24		.39	
		59	69	.20	.27	.34	.38

APPENDIX II (Continued)

Date taken	Year-class	Body weight (Ind.)	Body weight (Av.)	Ovaries weight (Ind.)	Ovaries weight (Av.)	Ovaries weight as percent of body weight (Ind.)	Ovaries weight as percent of body weight (Av.)
	1953	280	280	4.57	4.57	1.63	1.63
	1952	595		46.52		7.82	
		553		49.00		8.86	
		496	548	35.53	43.68	7.16	7.95
	1951	651	651	68.34	68.34	10.18	10.18
	1950	849	849	108.40	108.40	12.77	12.77
	1949	1246		160.50		12.88	
		1387	1316	191.30	175.90	13.79	13.34
Apr	1954	80		.24		.30	
		54		.22		.41	
		33	56	.21	.22	.64	.45
	1953	330		21.21		6.43	
		250		2.35		.94	
		243		1.73		.71	
		233		3.38		1.45	
		227		1.81		.80	
		239		1.21		.51	
		221		1.11		.50	
		188	241	2.10	4.36	1.12	1.56
	1952	559		29.96		5.36	
		623		32.01		5.14	
		623		52.40		8.41	
		463		59.02		12.75	
		524		62.51		11.93	
		459		42.47		9.25	
		477	533	71.03	49.91	14.89	9.68
	1951	793		44.45		5.61	
		680		40.81		6.00	
		708		88.20		12.46	
		708		52.46		7.41	
		623	702	44.39	54.07	7.13	7.72
May	1954	125	125	.55	.55	.44	.44
	1953	238		9.99		4.20	
		272		12.04		4.43	
		302		22.57		7.48	
		311		26.32		8.46	
		295		7.98		2.71	
		285		7.83		2.75	
		312		25.35		8.12	
		334		13.66		4.09	
		355		21.26		5.99	
		394		35.52		9.02	
		444	322	57.88	21..85	13.04	6.39

APPENDIX II (Continued)

Date taken	Year-class	Body weight (Ind.)	Body weight (Av.)	Ovaries weight (Ind.)	Ovaries weight (Av.)	Ovaries weight as percent of body weight (Ind.)	Ovaries weight as percent of body weight (Av.)
	1953*	226		1.48		.65	
		221		1.97		.89	
		243		.84		.34	
		269		2.06		.77	
		218		.78		.36	
		236		2.11		.89	
		269		.96		.36	
		263		2.14		.81	
		253		.88		.35	
		303		1.73		.57	
		318		3.96		1.25	
		342	263	5.98	2.06	1.75	.75
	1952	463		38.75		8.37	
		532	498	49.30	44.03	9.27	8.82
	1952*	394		2.11		.54	
		483		4.00		.83	
		485		8.07		1.67	
		457		3.37		.74	
		494	463	8.90	5.29	1.80	1.12
June	1954	240		.81		.34	
		194	217	.66	.74	.34	.34
	1953	256	256	.69	.69	.27	.27
	1952	623		2.96		.48	
		793		6.55		.83	
		584		3.16		.56	
		508		2.10		.41	
		452		2.44		.56	
		476		1.69		.36	
		514	564	1.88	2.97	.37	.51
July	1955	30	30	.011	.011	.04	.04
	1954	272		.84		.31	
		243		.74		.30	
		229		.65		.28	
		213		.49		.23	
		205		.58		.28	
		198		.45		.23	
		140	214	.32	.58	.23	.27
	1953	546		1.97		.36	
		550		2.55		.46	
		526		1.86		.35	
		549		2.51		.46	
		453		1.74		.38	
		482		1.72		.36	

APPENDIX II (Continued)

Date taken	Year-class	Body weight (Ind.)	Body weight (Av.)	Ovaries weight (Ind.)	Ovaries weight (Av.)	Ovaries weight as percent of body weight (Ind.)	Ovaries weight as percent of body weight (Av.)
		476		2.21		.46	
		450		1.36		.30	
		408	493	1.31	1.91	.32	.38
	1952	595		2.05		.35	
		567		2.73		.48	
		586		4.66	(3 ovaries)	.80	
		562		2.12		.40	
		534		2.26		.42	
		483		1.66		.34	
		469		1.81		.39	
		552	544	2.79	2.51	.51	.46
Aug	1954	266	266	.75	.75	.28	.28
	1953	441	441	2.12	2.12	.48	.48
Sept	1954	271	271	1.00	1.00	.37	.37
	1953	570	570	3.18	3.18	.56	.56
Oct	1955	112		.33		.30	
		118	115	.31	.32	.26	.28
	1953	623		6.93		1.11	
		530		8.51		1.61	
		501	551	3.22	6.22	.64	1.12

* After spawning.