AGE AND GROWTH OF THE WHITE CRAPPIE, *POMOXIS ANNULARIS* RAFINESQUE, IN LAKE WACO, TEXAS

A Thesis Submitted to the Faculty of

Baylor University

In Partial Fulfillment of the

Requirements for the Degree

of

Master of Science

in

Biology

By

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Waco, Texas

January 1969

ABSTRACT

Chen, Terry Huei-Hsiung. Age and growth of the White Crappie, Pomoxis annularis Rafinesque, in Lake Waco, Texas. A thesis submitted to the faculty of Baylor University in partial fulfillment of the requirements for the degree of Master of Science.

The major collection of white crappie was from 17 July 1967, to 10 April 1968, by traps and gill nets. Other fish were taken by anglers and seines in June 1968. A total of 1142 fish were included in this study.

Spawning season for Lake Waco crappie was from late February to early May and was at its peak in March and April. White crappie in Lake Waco may spawn after one year.

Growth rate of Lake Waco white crappie was rapid. The average back-calculated total lengths (TL) for Lake Waco crappie for the last 4 years were as follows: 145 mm for the first year's growth, 216 mm for the second age group, 271 mm for the third age group, and 309 mm for the fourth age group.

In the white crappie scales started to develop on the caudal peduncle in fish 16 mm TL. The first fully scaled fish observed was 31 mm TL. The region between the

dorsal fin and pectoral fin was the last place to develop scales.

The mathematical expression of the length-weight relationship for the white crappie of Lake Waco is:

$$\log W = -5.6131 + 3.2954 \log L$$

where W = Body weight in grams

L = Total length in millimeters.

The body-scale relationship demonstrated a parabolar curve. The equation

$$L = 35.506219 + 1.215665\, S + 0.000931\, S^2$$

fitted the body-scale relationship of Lake Waco white crappie well.

Principal food items of white crappie were small fishes (mainly shads, Dorosoma cepedianum and D. petenense), aquatic insects, and small crustaceans.

Lymphocystis was only found in the spring, and about 1.7 percent of the fish were infected. Infection by nematode parasites, Camallanus oxycephalus, was observed in the spring and summer, but infected fish showed no signs of weakness.

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CHAPTER I

INTRODUCTION

Changes in fish populations often occur with aging of a reservoir. Sometimes such fish as largemouth bass or bluegill are numerous in the first few years of the reservoir and are later replaced by crappie or other species (Lane, 1954). In their study of rough fishes, Dalquest and Peters (1966) stated that the history of sport fishing in new reservoirs of Texas has followed a uniform course. A few years after completion of the reservoir, sport fishing is good to excellent. The initial period of good fishing is followed by a period of gradual decline until sport fishing becomes poor, and it remains poor unless the reservoir is reclaimed or rejuvenated. Bass fishing usually is good in the first few years after impoundment, and then, with a decline in bass fishing, crappie fishing improves and becomes the dominant sport.

In new Lake Waco (completed in 1965), however, the situation has been different. Bass fishing has not been as good as in other new reservoirs, whereas crappie fishing has been excellent since impoundment (pers. com. with Texas Parks and Wildlife Department and local anglers.)

The reasons for this phenomenon are not known; therefore, the biologists at the Texas Parks and Wildlife Department in Waco suggested this study.

I. THE PROBLEM

Statement of the problem--It was the purpose of this study: (1) to explain why the white crappie population has become so well established in Lake Waco in the first three years of impoundment; (2) to study the growth dynamics of white crappie in a Texas reservoir; (3) to compare the growth of white crappie in a Texas reservoir with the growth of white crappie in other states; and (4) to study the biology of white crappie in this reservoir.

Importance of the study--For proper management of a fish population, an age and growth analysis is indispensible, since it serves as a measure of the suitability of the environmental conditions acting on that population. From such an analysis, one can determine the age at which a fish attains sexual maturity, at what age a given species will reach catchable size in a given place, and when to harvest the population to maintain the optimum yield. A comparison of fish growth rates in different bodies of water may indicate relative suitability of environmental conditions and suggest steps to be taken for improvement. Age and growth studies are useful in measuring the effects of any attempt to improve the environment. Such studies are also useful in determining the effect of fishing pressure on a body of water.

Old Lake Waco had a good reputation for its crappie fishing before the completion of the new reservoir. At the time of this study, the new reservoir was considered by local anglers to be one of the best crappie fishing waters in Texas. The crappie is one of the more important game fishes in the South and Midwest, because it is numerous, easy to catch, and a good food fish.

Because crappie are easily established in ponds and lakes and have great reproductive potential, they sometimes rapidly overpopulate bodies of water. The result is many stunted fish of little value (Funk, 1964). Proper management can help to prevent such overpopulation.

There is very little literature on the age and growth of any fish in Texas. Whiteside (1964) studied the biology of the white crappie in Oklahoma and found no papers about the life history of white crappie in the southern states. I found no papers on the life history of white crappie in Texas. Age and growth studies of fish in Texas are needed to provide the information necessary for wise management of fish populations in Texas.

II. ACKNOWLEDGEMENTS

I am indebted to my thesis committee, Dr. Owen T. Lind, chairman, Dr. Harley W. Reno, and Dr. Frederick R. Gehlbach, for direction of study and suggestions for improvement.

I wish to express my appreciation to the many individuals and organizations which have helped me in this study. I wish to thank the staff of the Waco branch of the Texas Parks and Wildlife Department, and especially Mr. Dwane Q. Smith, the fishery biologist, for cooperation, information, and suggestions for study, and for allowing me to take fish collected during their routine sampling of Lake Waco fish populations. I would like to thank also the City of Waco Water Department for providing data on the temperature of lake water.

I am grateful to Dr. A. G. Pinkus of the Baylor University Chemistry Department for the use of his hydraulic press.

I wish to thank Mr. Paul Currier of the Baylor University Photography Center for help in developing pictures of scales.

I wish to thank the many biology students at Baylor University who helped in collecting fish and recording data.

III. DESCRIPTION OF HABITAT

Lake Waco is located in McLennan Co., Texas. The dam is about six miles west of the city of Waco. There are four sources of drainage into Lake Waco: the North, Middle, and South Bosque Rivers, and Hog Creek. The spillway opens to the Bosque River, a tributary of the Brazos River which empties into the Gulf of Mexico. The reservoir has an area of 7,500 acres and 60 miles of shoreline. The dam constructed by the Corps of Engineers, U. S. Army, was completed in February 1965. The reservoir filled within a month after the gates were closed. The water level has remained fairly stable at 455 feet above mean sea level during the past three years. The deepest point which has been found is 27 meters. New Lake Waco is a multi-purpose reservoir: It provides 553,300 acre-feet of storage capacity for flood control and is capable of storing 104,100 acre-feet of water for municipal water supply and other beneficial uses at conservation pool level. Besides flood control and water conservation, Lake Waco provides attractive areas for outdoor recreation.

Lind and Kimmel (unpubl. data) have obtained general physical, and chemical limnological data on Lake Waco. Data from a year of their routine sampling are included in Table 1. There are two noteworthy limnological features: (1) Considerable exposure to wind action results in continuous mixing.

Table 1. Range of Selected Chemical Characteristics of Lake Waco, 1967-1968*

	Surface	Bottom
Dissolved oxygen (mg/l)	10.8 - 7.8	11.0 - 5.6
Total alkalinity (mg/l)	159.0 - 107.0	160.0 - 109.0
pH	9.0 - 8.0	8.8 - 7.8
Total hardness (mg/l)	148.0 - 136.0	152.0
Specific conductance (umhos/cm)	300.0 - 250.0	310.0 - 250.0
Calcium (mg/l)	51.0 - 46.0	51.0 - 46.0
Magnesium (mg/l)	5.1	5.1
SiO_2 (mg/l)	10.0 - 7.2	9.6 - 7.2
Sulfate (mg/l)	32.0 - 27.0	32.0 - 27.0
Total iron (mg/l)	0.2 - 0.0	0.2 - 0.0
Phosphate (μg/l)	22.0 - 10.0	19.0 - 10.0
Total residue (mg/l)	294.0 - 188.0	291.0 - 247.0
Volatile residue (mg/l)	56.0 - 40.0	54.0 - 42.0
Chlorophyll _a_ (mg/m^3)	17.3 - 5.8	17.4 - 5.8

* From Lind and Kimmel (unpublished)

Wind action prevents the formation of thermal stratification and brings about relatively uniform chemical conditions in the reservoir throughout the year. Dissolved oxygen, pH, total alkalinity, etc., are about the same from the surface to the bottom of this reservoir. (2) The range of total alkalinity is 107-159 mg per liter for the surface water and 109-160 mg per liter for the bottom stratum. This is considered high (Welch, 1952).

Turbidity of the water is also high (from October 1966 to May 1968, 16 Secchi disk readings were taken with an average visibility of 29 inches). Turbidity is probably due to the strong wind action, lack of emergent vegetation (but woody parts of trees remain in some areas of the reservoir), and the silt brought into the reservoir by its tributaries.

During the last three years, water temperatures have been coldest in January and February (daily average about 11 C) and warmest in July and August (average 29.4 C)(Table 2). The lowest recorded temperature was 6.1 C in February 1966, and the highest was 31.1 C recorded in July 1967 (Fig. 1).

The species list of fish caught by gill nets and their relative abundance in new Lake Waco is given in Table 3. Although blacktail shiner (*Notropis venustus*), red shiner

Table 2. Average Monthly Bottom Water Temperature of Lake Waco, 1965-1968*

	Temperature C				
Month	1965	1966	1967	1968	Average
January	13.9	12.2	11.1	9.4	11.7
February	12.2	10.0	12.7	12.2	11.8
March	12.7	13.3	16.7	13.3	14.0
April	18.8	22.7	18.8	19.4	19.9
May	21.7	22.7	23.9	23.9	23.1
June	26.6	26.6	27.2		26.8
July	29.4	28.9	29.4		29.2
August	28.9	28.9	29.4		29.1
September	27.8	30.0	27.2		28.3
October	22.2	21.7	22.8		22.2
November	19.4	18.8	16.1		18.1
December	16.1	14.4	13.3		14.6

*Data were obtained from Waco Water Plant.

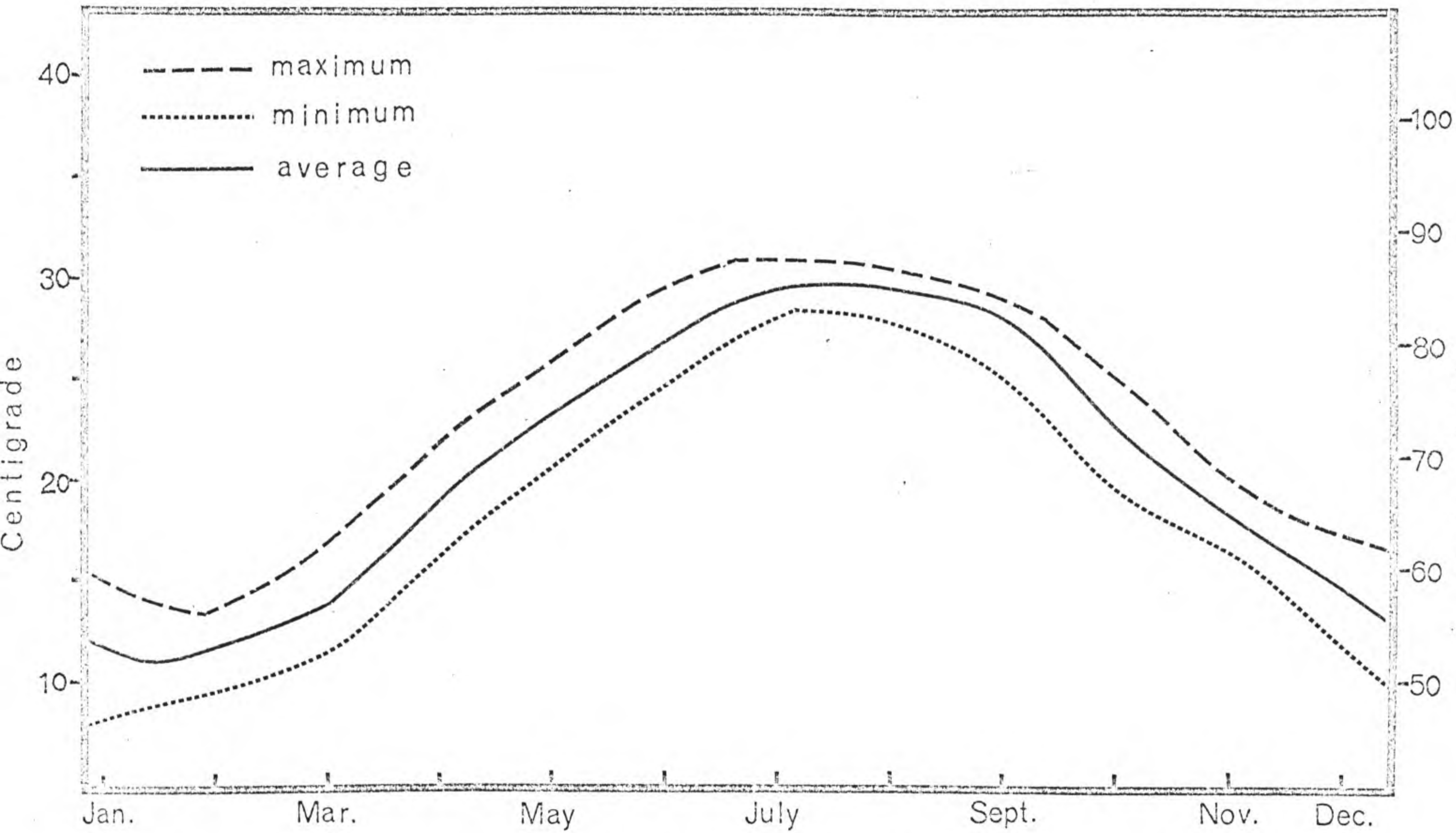


Figure 1. Average monthly water temperature of Lake Waco from January 1965 to May 1968.

Table 3. List of Species and the Relative Abundance of Fish Sampled by Gill Net from July 1967 to January 1968

Scientific Name	Common Name	#	%
Pomoxis annularis Raf.	White crappie	217	25.4
Dorosoma cepedianum (LeSueur)	Gizzard shad	123	14.4
Micropterus salmoides (Lacépède)	Largemouth bass	98	11.5
Ictalurus punctatus (Raf.)	Channel catfish	89	10.4
Ictiobus bubalus (Raf.)	Smallmouth buffalo	84	9.8
Carpiodes carpio (Raf.)	River carpsucker	65	7.6
Lepomis macrochirus Raf.	Bluegill	42	4.9
Cyprinus carpio (L.)	Carp	33	3.9
Moxostoma congestum (Baird and Girard)	Gray redhorse	32	3.7
Notemigonus crysoleucas (Mitchill)	Golden shiner	26	3.0
Aplodinotus grunniens Raf.	Freshwater drum	16	1.9
Lepomis microlophus (Günther)	Redear sunfish	10	1.2
Lepisosteus oculatus Winchell	Spotted gar	8	0.9
Lepisosteus osseus (L.)	Longnose gar	4	0.5
Pylodictis olivaris (Raf.)	Flathead catfish	4	0.5
Lepomis cyanellus Raf.	Green sunfish	2	0.2
Lepomis megalotis (Raf.)	Longear sunfish	1	0.1
Lepomis humilis (Girard)	Orange spotted sunfish	1	0.1
Total		855	100.0

(*Notropis lutrensis*), blackstripe topminnow (*Fundulus notatus*), and threadfin shad (*Dorosoma petenense*) are not caught by gill nets, they are commonly caught by seining.

CHAPTER II

REVIEW OF THE LITERATURE

I. AGE ASSESSMENT AND SCALE METHOD

Assuming growth of scales and body to be directly proportional throughout the entire life of the fish, early workers used the direct proportion formula for back calculation of body lengths (Van Oosten, 1929; Dahl, 1910; Lea, 1910). Dahl-Lea direct proportion method is expressed by the equation:

$$L = cS,$$

where L = body length, S = scale length, and c is a constant. The above formula is based on the assumption that body and scale growth demonstrate a straight-line relationship; i.e., plotting scale length against body length on rectangular coordinates gives a straight line passing through the origin. Using this direct proportion method, many workers found that the calculated body lengths were much lower than the empirical lengths and explained this relationship by the fish's attainment of some body length before the scales were laid down. Lee (1920) introduced a constant "a", the length of the fish at the time of scale formation, and modified the direct proportion formula as:

$$L = a + cS.$$

Fraser (1916) proposed another correction in the direct proportion method:

$$L_n = S_n \frac{L - c}{S} + c,$$

where L_n is the length of the fish at the _n_th year of its life, S_n is the dimension of the scale within the _n_th annulus, L is the length of the fish at capture, S is the dimension of the scale to its margin, and c is the body length of the fish at the time of scale formation (the same as "a" in Lee's formula). When plotted graphically the relationship between scale and body lengths is sometimes curvilinear (Creaser, 1926), or even a sigmoid curve (Carlander, 1945). In these cases the growth curves best fit Monastyrsky's (1930) logarithmic method, Sherriff's (1922) second degree parabolar equation, or Carlander's third degree polynomial equation. Witt (1952) in his study of white crappie found that the third degree polynomial equation best fitted the relationship between body length and scale length.

Although various workers have proposed mathematical relationships to express scale growth and body length relationships of fishes, the body-scale relationship is not subject to generalization and almost certainly varies from one species to another, and it is not improbable that the relationship may vary between races and populations of the same species (Lagler, 1956).

Berg and Grimaldi (1967) described criteria for recognition of annuli on fish scales and also clarified the terminology used in fish growth studies employing the scale method. Cutting over of the circuli at the shoulder of the scale is the best criterion for determining age, but sometimes narrow-spaced circuli preceding "fast growth circuli" aid in recognition of an annulus or year mark.

II. SCALE FORMATION

Witt (1952) found a significant difference in the number of lateral line scales of white crappie from old and new reservoirs. He also demonstrated two different body-scale relationships for white crappie from old and new reservoirs and explained the phenomenon as a result of differences in scalation resulting from different growth rates of fingerlings. Siefert (1965) studied early scale development in white crappie in South Dakota and found no evidence of scale formation in fish less than 16 mm total length. Ward and Leonard (1952) studied the scale development of black crappie and found that the mean body length at the time of scale appearance was 17.7 mm.

III. PREVIOUS STUDIES OF WHITE CRAPPIE

Hansen (1951), in a detailed study of the biology of white crappie in Illinois using the scale method, concluded that fish require two to three years to reach sexual maturity, and that periods of annulus formation ranged from early May to August. Starrett and Fritz (1965) studied the white crappie of Lake Chautauqua, Illinois and found that one year old white crappie ranged from 76 to 102 mm TL and that fish over five years of age were seldom collected. They also found little or no difference in growth rate between the sexes of fish older than three years, but females outlived the males. Stroud (1949) used the Dahl-Lea method in the study of white crappie in Tennessee and found very good growth rates for fish older than one year. Neal (1963) studied the white crappie of Iowa. Roach and Evans (1948) and Morgan (1954) reported the growth and life history of white crappie from 53 lakes in Ohio. Witt (1952) studied the age and growth of white crappie in Missouri. Many biological studies on white crappie have been reported from Oklahoma (Sneed and Thompson, 1950; Wilson, 1951; Hall, Jenkins, and Finnell, 1954; Whiteside, 1964), but no research on the age and growth of white crappie has been done in Texas.

IV. BIOLOGICAL STUDIES OF LAKE WACO

The present Lake Waco is young (3 1/2 years) and no biological research has been completed. Bothner (1957) studied the biology of smallmouth buffalo (Ictiobus bubalus) in old Lake Waco. The Texas Parks and Wildlife Department made a survey from 1 November 1960-31 October 1961 to obtain information about the fish populations and the factors influencing fish population before the construction of a new reservoir. Currently, O. T. Lind and B. L. Kimmel of this laboratory are conducting research on primary production and eutrophication.

CHAPTER III

MATERIALS AND METHODS

I. COLLECTION AND COLLECTION GEAR

The major collection of white crappie for this study started 17 July 1967, and terminated 10 April 1968. Other fish caught by anglers in late May and early June 1968 were examined for spawning coloration and gonad condition. Fish collection methods included seines, gill nets, metal traps, and angling. Early collections were made with experimental gill nets (150 feet long with 1 inch to 3 1/2 inch mesh, changing 1/2 inch every 25 feet) in cooperation with the Texas Parks and Wildlife Department at Waco during their routine sampling of Lake Waco fish populations. Twelve stations were chosen to represent the various environmental areas of the reservoir (Fig. 2). Nets were set in the morning, left overnight, and run on the following morning. All the crappie collected by gill nets were used in this study.

In January 1968, seven metal traps (1 inch mesh chicken wire, 5 feet long, 3 feet in diameter, with either one or two funnel openings, Fig. 3) were set in the area near Midway Park (Fig. 2). The traps were checked twice a week. A total of 1142 fish (185 taken by gill nets, 824 by

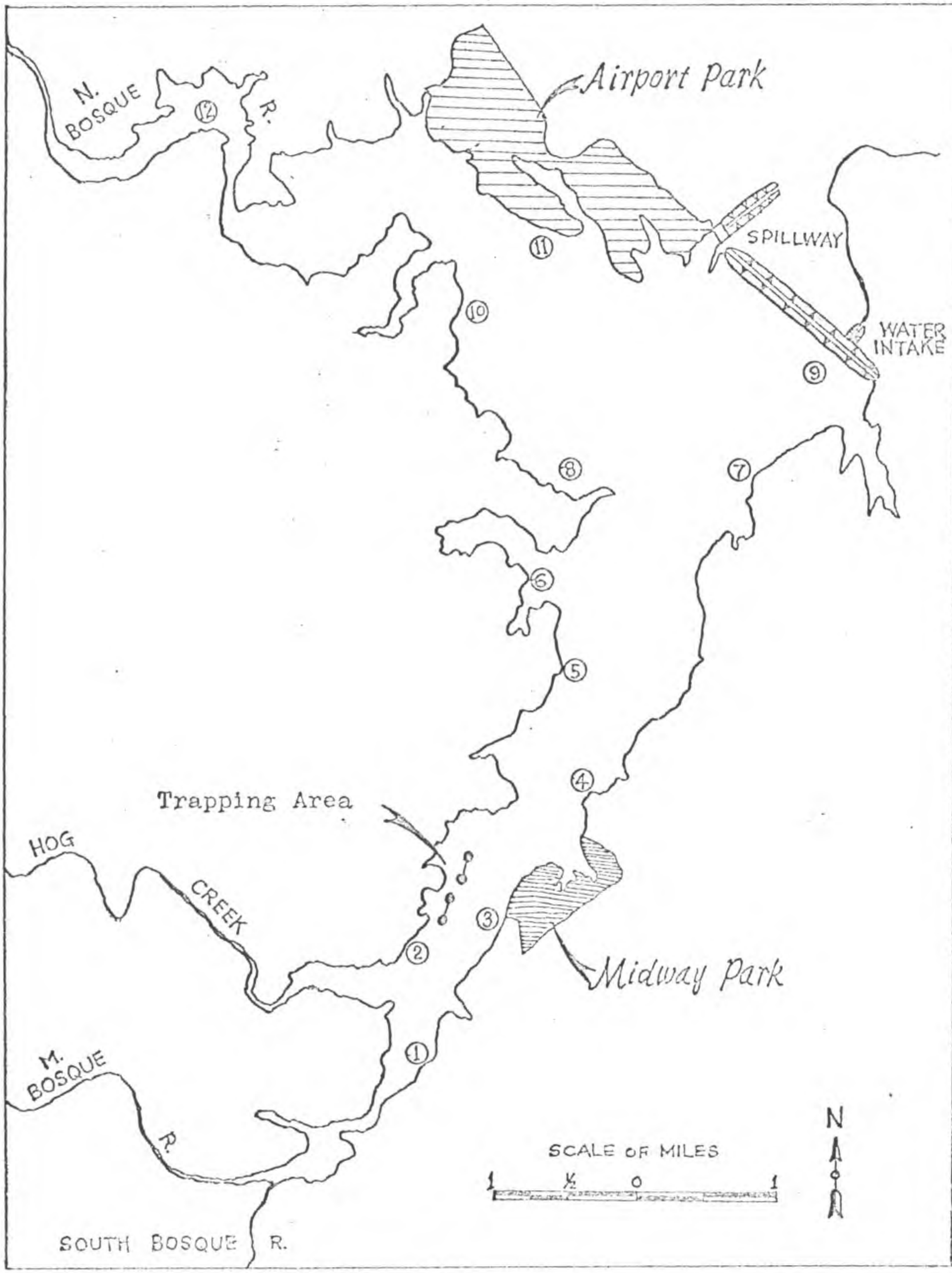


Fig. 2. A map of Lake Waco and its tributaries. The number in the circle indicates gill-net stations.

Fig. 3. The funnel traps used in this study.

traps, and the rest by either angling or seining) were included in this study. In late April and early May unsuccessful attempts were made to collect newly hatched fry. From 8 May-11 May 1968, the Waco area had 6 inches of rain which raised the water level in the reservoir 15 feet above its normal water level (455 feet above mean sea level). A large lake area was flooded and many roads around the reservoir were closed due to this flood. During the time of flooding, two attempts were made to collect young of the year without success. On 9 June 1968, 104 young of the year, ranging from 17 mm to 58 mm TL, were collected with a 26 foot bag seine (1/8 inch mesh) in the shallow inlets close to the marina in Airport Park (Fig. 2). All specimens were preserved in 10% formalin immediately after capture. The 104 young of the year were separated into different size classes (10 mm in range), total weight of each size class was taken, and the average standard and total lengths of each size class were calculated.

All 104 fingerlings collected in June 1968 were carefully examined under a dissecting microscope to determine the pattern and time of scale formation.

The number of dorsal spines of each fish collected from January to April was carefully counted to help determine if any black crappie (Pomoxis nigromaculatus) were present in Lake Waco.

II. MEASUREMENTS AND DATA RECORDING

All fish were measured and examined as soon as possible. Body weight, total and standard lengths of each fish were taken using the measurements commonly employed in fishery research (Lagler, 1956). Body weight was measured in grams to the nearest tenth on a 599 gram Hanson spring scale. Lengths were measured on a fish measuring board in millimeters. Maturity and condition of sexual organs were recorded after the fish were opened. Stomachs were removed, wrapped in gauze squares (15 cm x 15 cm), and numbered with tags. Stomachs were preserved in 10% formalin for two weeks to allow the contents to harden before examination under a dissecting microscope. All recognizable materials were identified as completely as possible and counted. About 20-30 scales between the dorsal fin and lateral-line of the left side of each fish were collected and stored in a numbered coin envelope.

III. PREPARATION OF SCALE IMPRESSION AND AGE ASSESSMENT

Three representative scales from each fish were chosen for impression on plastic plates by a modification of the method described by Campbell and Witt (1953). Before impression, the plastic plates were presoftened by pressing against an acetone-soaked sponge. A pressure of

13,000 pounds per square inch (created by a Carver laboratory hydraulic press) was necessary for good results, and at least three minutes were required for the plastic slides to reharden.

Age assessment and scale measurement were accomplished with a microprojector of 46x magnification. Age determination was based on the year of life completed as indicated by the number of annuli or year marks. Five hundred fish collected in January, February, and March of 1968 were used for the determination of body-scale relationship and the construction of a nomograph for the back calculation of fish length at each annulus (Carlander and Smith, 1944). The anterior scale radius was measured from the focus along the longest, most central interradial space to the edge of the scale. Total length of the fish at each annulus was back calculated using a nomograph constructed from empirical data of body-scale relationship of the 500 fish.

CHAPTER IV

RESULTS AND DISCUSSION

I. THE EFFECTIVENESS OF TRAPS IN CAPTURING FISHES

Traps were placed horizontally close to the bottom in shallow water (range from 12 to 20 feet in depth) where many dead trees emerged from the water. Traps were checked once or twice every week. A total of 940 fish (eight species) were caught in a period of four months (January-April 1968) (Table 4). The biggest catch was on 10 April 1968 (for a period of 7 days), with a total of 171 fish (136 crappie). The best catch per trap was 48 fish (34 crappie, 10 bluegill, 3 gizzard shad, and 1 channel catfish). About 85 percent of the fish caught by the traps were white crappie; 11.7 percent were sunfish (bluegill and redear). The remaining species (largemouth bass, channel catfish, gizzard shad, carp, and freshwater drum) accounted for only 3.2 percent of the total catch. These data show that funnel traps are very effective in catching white crappie in the spring, especially during the spawning season.

Traps with two funnel openings seemed more effective in catching crappie than traps with one funnel. The average

Table 4. Relative Effectiveness of Traps in Capturing Various Species of Fish

Species of Fish		Number of Fish Captured
Pomoxis annularis (white crappie)		807
Lepomis macrochirus (bluegill) Lepomis microlophus (redear)	combined	111
Micropterus salmoides (largemouth bass)		12
Ictalurus punctatus (channel catfish)		12
Dorosoma cepedianum (gizzard shad)		3
Cyprinus carpio (carp)		2
Aplodinotus grunniens (freshwater drum)		1
Total of 8 species		948

number of crappie caught in single funnel traps was 0.71 crappie per trap per day, and the average for dual funnel traps was 1.49 crappie per trap per day; but the difference is insignificant statistically ($t = 1.5668$, $p > 0.1$) when tested by group comparison. The average number of crappie per collection per trap was 4.45 for single funnel traps and 9.57 crappie per collection per trap for traps with two funnel openings.

II. NUMBER OF DORSAL SPINES

Of 561 crappie examined, 504 fish had six dorsal spines, 27 had five dorsal spines, and 30 had seven dorsal spines (Table 5). The fish with seven dorsal spines might have been black crappie since they normally have seven or eight dorsal spines, but the color patterns of these fish were like those of white crappie. I assume that black crappie were not present in Lake Waco.

III. SPAWNING SEASON AND BREEDING COLORATION

Probably the best way to determine the spawning period is to determine the actual seasonal changes in gonad weight of different size classes. Whiteside (1964) used the product of gonad length and width and the average gonad weight to determine the extent of the spawning season and the time and degree of gonad development.

Table 5. Dorsal Spine Count of White Crappie from Lake Waco

Month	Number Examined	Number of Spines		
		Seven	Six	Five
March	331	18	298	15
April	230	12	206	12
Total	561	30	504	27

I determined the spawning period by examining the gonad condition of fish collected from January to June 1968. Gonad conditions were divided into five classes: undeveloped, developed, mature, free, and spent. The gonad was considered to be free when the milt or eggs could be squeezed out freely by gentle pressure on the area slightly anterior to the anus; fish were classed as mature when gonads were ripe, but not free; and fish were classed as developed when the sex of the fish could be determined from the immature gonad. In the January collection 84% of the fish had mature gonads and only 3 percent of the fish were considered to be free (Table 6). Of 160 fish caught in February, 55 percent were free. In the March collection, 84.3% of the fish had free gonads, 10% of the fish had mature gonads, and only 5.7% of the fish had developed immature gonads. In April, 91.5% of the fish had free gonads and only 6.1% of the fish had mature gonads. No fish were taken in May because of high water, resulting from heavy rains. In early June, 29 fish (all larger than 190 mm TL) were caught by anglers. All 29 fish had spent gonads.

On February 24, I first observed spawning coloration on two male crappie. I was able to correctly sex about 90 percent of the white crappie collected in March by external appearance; or, sex was indistinguishable by

Table 6. Sex Ratio and Difference in Gonad Condition of White Crappie Collected in Lake Waco from July 1967 to June 1968

Month	Total Catch	♀/♂ Ratio	Sex not Determin.	Gonad Condition (%) U	D	M	F	S
<u>1967</u>								
July	55	1.429	4	21.8				5.5
Sept.	90	1.154	6	6.7	93.3			
Nov.	24	0.600			79.2	8.3	12.5	
<u>1968</u>								
Jan.	101	1.244			13.0	84.0	3.0	
Feb.	160	1.025			16.2	28.8	55.0	
Mar.	331	0.789			5.7	10.0	84.3	
Apr.	247	1.764		0.4	5.7	2.0	91.5	0.4
June	29	1.294						100.0
Total	1037	1.108						

* U - Undeveloped

D - Developed

M - Mature

F - Free

S - Spent

sight in only 10.87 percent (36 out of 331) of the fish. On April 3, the first spent fish, a male, was observed.

Water temperature is an important factor which determines when the fish will spawn. It is generally believed that the optimum temperature for spawning of white crappie is around 21 C (range from 10 C to 27 C). Spawning season of white crappie varies geographically. Crappie normally spawn in May in most Missouri waters (Funk, 1964). Hansen (1951) observed the spawning season of white crappie in Illinois to be May and June. Morgan (1954) reported that Ohio white crappie start spawning in late April and continue through July at temperatures of 10.5-26.5 C with a peak in May and early June. The spawning period for Lake Texoma, Oklahoma, white crappie was reported to be April and May at water temperatures of 15-25 C with the height during late April and early May (Whiteside, 1964). From observations of spawning coloration and the examination of monthly changes in gonad condition (Table 6), I concluded that the spawning season for white crappie in Lake Waco was from March to early May and was at its peak in late March and April.

IV. SEXUAL MATURITY AND SEX RATIO

It is generally believed that a fish will reach sexual maturity when it attains a certain length. Thus sexual maturity is a matter of growth and is independent of age.

Harper (1938) found 1 year old black crappie spawning in Texas. Eschmeyer, Stroud, and Jones (1944) found that some 2 year old white crappie from one of the reservoirs of the Tennessee River were sexually mature, whereas others were not. Hansen (1951) reported that 2 year old female crappie in Illinois had reached sexual maturity at an average total length of 157.5 mm, but that fish of the same age less than 157.5 mm total length were sexually immature. Carter (1953) found in Kentucky that some 1 year old crappie were sexually mature. Whiteside (1964) reported that white crappie in Lake Texoma, Oklahoma, reached sexual maturity in the second or third year of life after they had attained a total length over 177.8 mm.

Fifty 1 year old white crappie (age determined by scale reading) were caught in March and April 1968. Of these fish, 19 were immature, 8 were mature, and 23 (13 female, 10 male) were free (spawning). The average total length for immature fish was 170.7 mm; 183 mm for mature fish; and 188.3 mm for 1 year old white crappie with free gonads. Ironically, one mature male (TL 175 mm), caught April 10, 1968, had the breeding coloration.

White crappie of Lake Waco may start to spawn after they complete 1 year of growth. One year old fish over 170 mm total length were sexually mature.

The overall male to female ratio in percent was 47:53. The number of males captured exceeded the number of females only in November 1967 and March 1968 (Table 6). The November result might be due to the small sample collected. Striking differences in the March and April collections probably reflected the spawning behavior of white crappie.

V. ORIGIN AND DEVELOPMENT OF SCALES

The origin and development of scales in white crappie from Lake Waco were observed on 104 young of the year, ranging from 13 mm to 58 mm TL. Generally, fish under 15 TL do not have scales. Two fish which measured 20 mm and 24 mm had no scales. Usually, fish 35 mm TL were completely covered by scales.

The origin and pattern of scale development are shown in Fig. 4. The fish started to develop scales in the caudal peduncle at about 16 mm TL. Scales were formed progressively anterior and ventral to the lateral-line as fish grew. The first fully scaled fish observed was 31 mm in total length. The region between the dorsal fin and the pectoral fin was the last place to develop scales. Lateral-line scales started from the caudal region, then scales appeared on the anterior head portion, and grew from both directions to meet in the center of the fish.

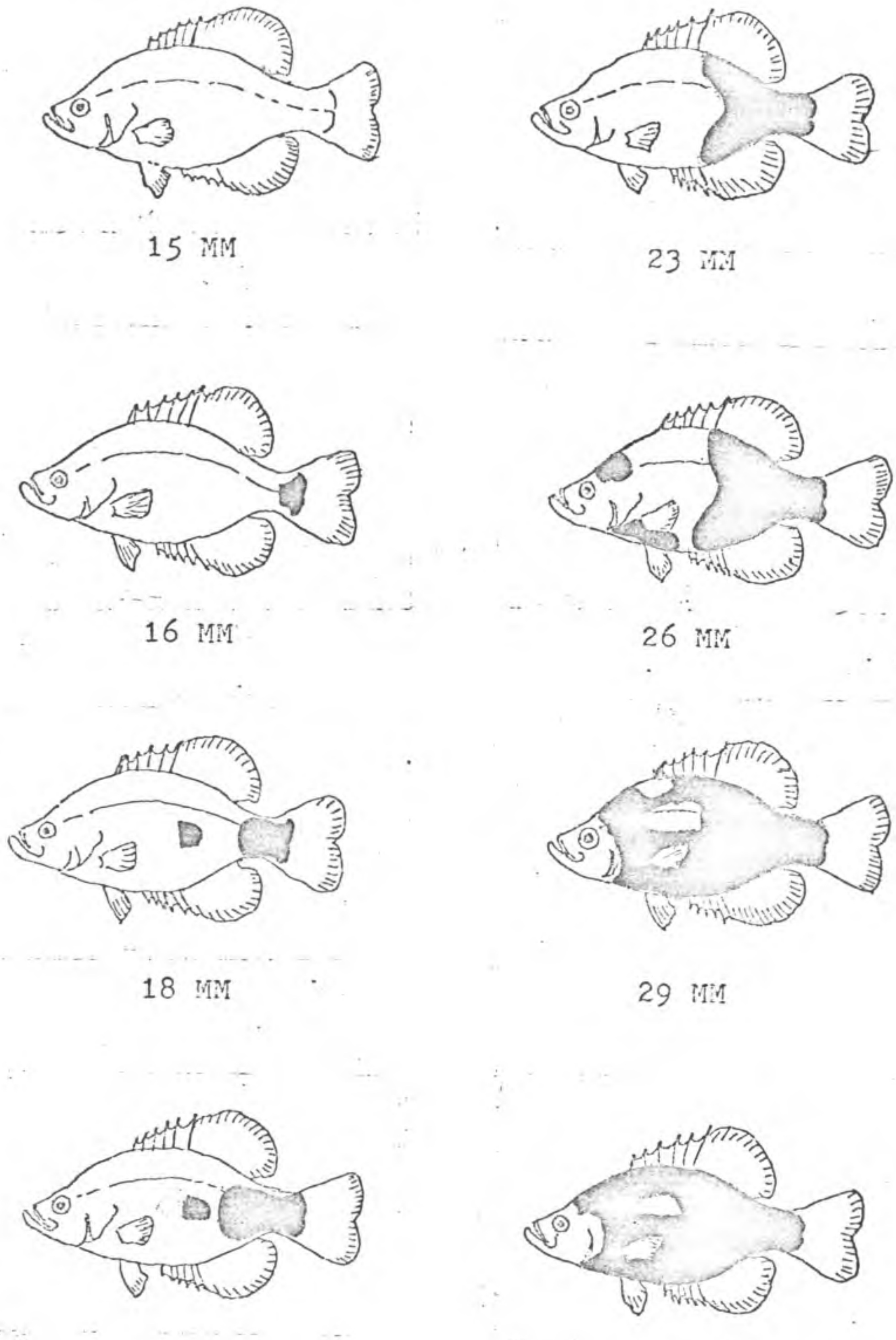


Figure 4. Diagrammatic representation of young white crappie showing origin of scales and development of scale pattern (modified from Ward and Leonard, 1952).

Siefert (1965) studied white crappie in South Dakota and found no evidence of scale formation in fish less than 16 mm in total length, and the first fully scaled fish he observed was 27 mm long. My observations of the scale development pattern of Lake Waco white crappie were quite similar to Siefert's findings. The scale development pattern of black crappie is very similar to that of white crappie, but differs in earlier scale development and faster rate of development than in white crappie (Ward and Leonard, 1952). Since fish of the same size differed in stage of scale development, apparently the age of white crappie is a determining factor in scale development as it is in black crappie (Ward and Leonard, 1952).

VI. LENGTH-WEIGHT RELATIONSHIP

Length-weight relationship of a species of fish in a particular geographic area is useful for creel census work. Usually only the length of the fish is obtained and it is necessary to know a length-weight relationship in order to estimate the weight of fish removed by anglers.

Empirical data from 592 fish were used in developing a length-weight relationship of white crappie in Lake Waco. The fish were divided into 10 mm size-class intervals (Table 7), and their average total body length was plotted against

Table 7. Length-Weight Relation of White Crappie from Lake Waco

Class Interval	Number	Average Weight (gms)	Average TL* (mm)	Average ASRx46** (mm)	TL/ASR	SL/TL***
130-139	1	20.0	135.0	70.0	1.298	0.815
140-149	3	32.0	145.8	86.0	1.659	0.756
150-159	7	38.1	155.8	89.4	1.743	0.733
160-169	9	51.8	165.2	100.3	1.647	0.748
170-179	16	60.7	175.3	104.1	1.684	0.754
180-189	41	74.8	184.5	117.8	1.566	0.756
190-199	47	84.9	194.7	127.4	1.528	0.755
200-209	71	104.7	204.5	133.7	1.530	0.756
210-219	61	128.5	215.4	142.8	1.507	0.759
220-229	80	150.9	225.3	147.2	1.531	0.764
230-239	78	171.9	234.3	150.9	1.553	0.765
240-249	66	193.4	244.3	156.7	1.559	0.763
250-259	43	219.1	253.4	156.4	1.621	0.767
260-269	19	251.7	264.3	167.8	1.575	0.772
270-279	14	283.3	274.9	165.6	1.660	0.775
280-289	13	299.2	283.7	175.7	1.615	0.766
290-299	7	362.0	294.4	182.4	1.614	0.780
300-309	9	387.3	303.8	200.6	1.514	0.768
310-319	3	449.3	317.0	194.7	1.628	0.783
320-329	1	432.0	320.0	202.0	1.584	0.788
330-339	1	482.0	335.0	186.0	1.801	0.782
340-349	1	469.0	340.0	224.0	1.518	0.785
350-359	1	451.0	350.0	225.0	1.556	0.669

*TL = Total length
**ASR = Anterior scale radius
***SL = Standard length

the corresponding body weight to obtain a graphical expression of the length-weight relationship for Lake Waco white crappie (Fig. 5).

Witt (1952) pointed out that the best mathematical formulation for the length-weight relationship of white crappie is:

$$W = cL^n$$

Where W = Body weight

L = Total body length

c = A constant

n = A constant derived empirically

I used the above equation to derive the length-weight relationship of white crappie in Lake Waco. In the solution of equation $W = cL^n$, it was first changed to logarithmic form:

$$\log W = \log c + n \log L;$$

then the logs of average lengths and weights of each size class were obtained. By using this statistical formula (Fuller, 1967), the constants c and n were calculated. If we let $x = \log L$, and $y = \log W$, then:

$$n = \frac{N\Sigma xy - \Sigma x \Sigma y}{N\Sigma x^2 - (\Sigma x)^2}$$

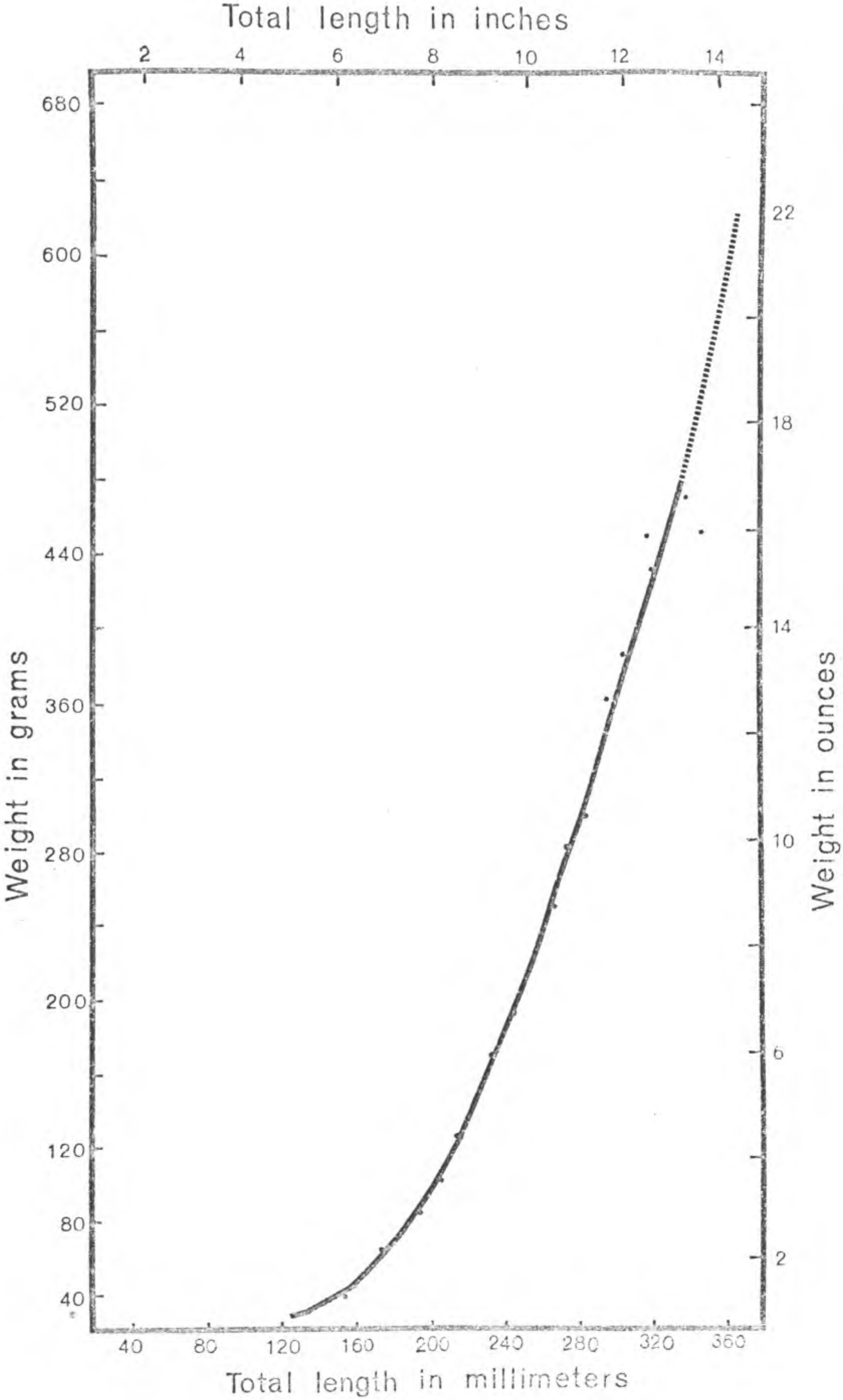


Figure 5. Length-weight relationship of white crappie in Lake Waco.

and

$$\log c = \frac{\Sigma x^2 \Sigma y - \Sigma x \Sigma xy}{N\Sigma x^2 - (\Sigma x)^2}$$

where N = Number of size classes.

The mathematical expression of the length-weight relationship for the white crappie of Lake Waco is:

$$\log W = -5.6131 + 3.2954 \log L.$$

The length-weight relationship of white crappie in Missouri was reported by Witt (1952) as:

$$\log W = -5.5951 + 3.2987 \log L.$$

There is surprising agreement in the body length-weight relationship of the two different bodies of water.

VII. BODY-SCALE RELATIONSHIP

The use of scales in an age and growth study of fish is based on the assumption that the annulus or year mark forms on the scale each year and that scale growth and body growth exhibit a definite reliable relationship.

Pictures of scales taken from Lake Waco crappie (Fig. 6) show evidences of clear annulus formation. The monthly record of water temperatures in Lake Waco (Table 2) shows that between January and February the water temperature dropped to near 11 C for a period of time long enough to retard the growth of the fish and evoke annulus formation.

Figure 6. Scales of white crappie from Lake Waco.

All scale pictures were magnified 9x

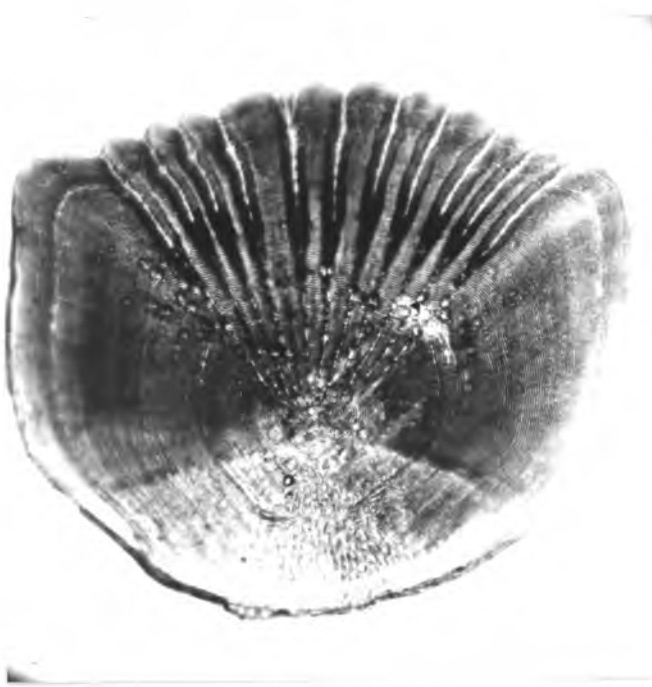
Scale	A	B	C	D
Date of collection	18-VII-67	3-IV-68	10-IV-68	9-VI-68
Sex	Female	Female	Female	Male
Gonad condition	Developed	Free	Free	Spent
Age (years)	1^+	2	2	3
Total length (mm)	181	217	266	335
Body weight (grams)	62	129	236	449

A

B

Figure 6. (continued)

C



D

A length frequency distribution of 592 fish collected from January-March, 1968 was plotted on probability paper (Harding, 1949; Cassie, 1954) to analyze the polymodel frequency distribution of the total population (Fig. 7).

Three subpopulations representing the first three age groups were separated with modes at 155, 208, and 284 mm. These modes were comparable to the calculated mean lengths of the same age groups (age determined by annuli) (Table 9). This seems to support the validity of age assessment by scale annuli. Age group IV is not detected in Fig. 7, probably due to the small number of individuals above 320 mm trapped.

The relationship between body length and scale length was discussed in Chapter II. Witt (1952) demonstrated that the body-scale relationship of white crappie best fitted the third degree polynomial sigmoid curve. Because of the sigmoid character of these relationships, Witt (1952) used Carlander's third degree polynomial equation to fit his data. The general equation for this curve is:

$$L = a + bS + cS^2 + dS^3$$

where L = Body length

S = Scale length

a, b, c, and d are constants.

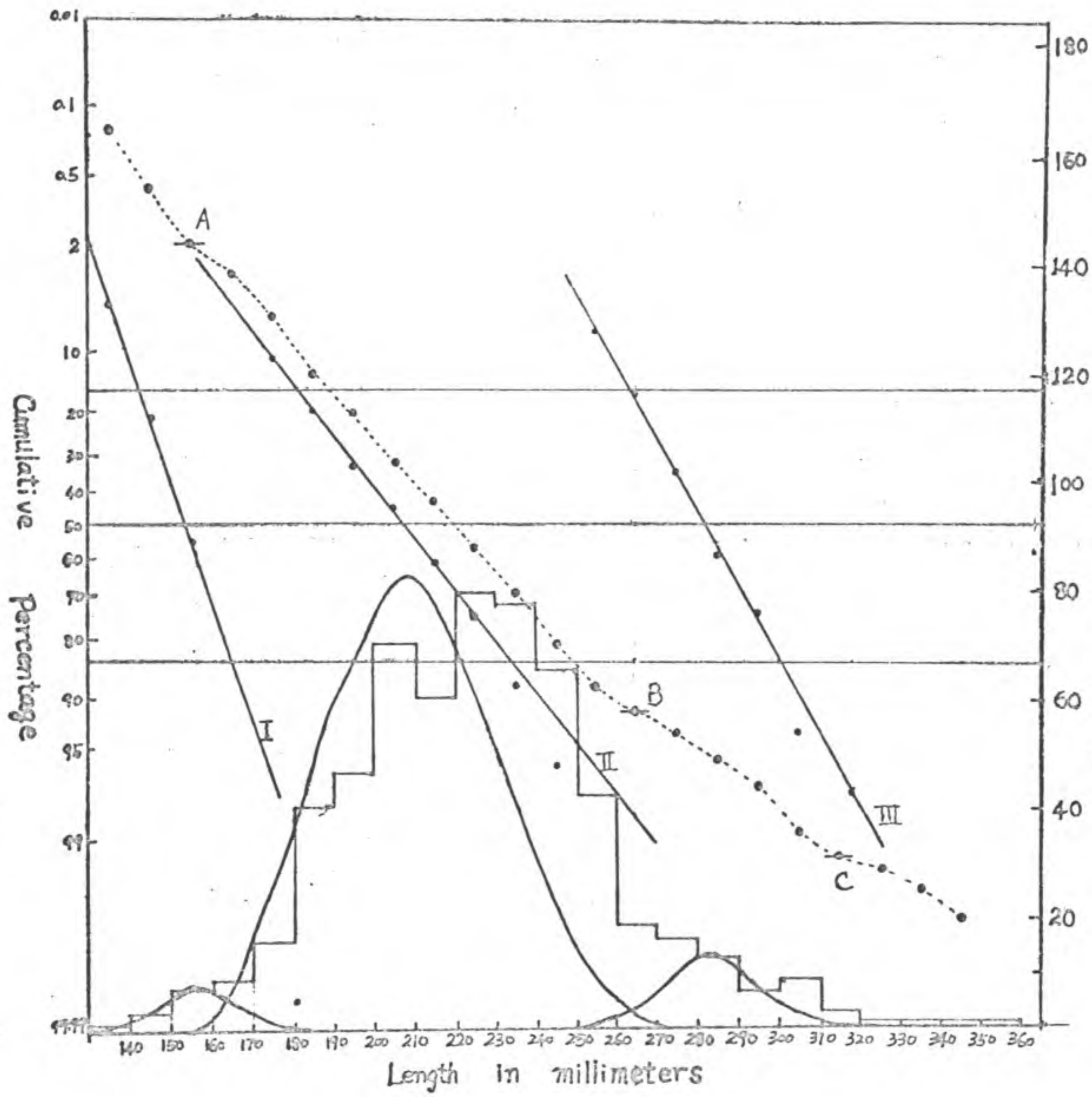


Fig. 7. Length frequency distribution of 592 fish collected from January-March, 1968. (Dotted line represents the total population plotted in percentage of cumulative frequency. A, B, and C are the points of inflextion for age groups I, II, and III respectively.)

Figure 8 represents graphically the empirical body-scale relationship of white crappie from Lake Waco. The empirical total body length in millimeters is on the abscissa; the ordinate represents the anterior radius of the scales in millimeters, magnified 46 times. The curve is not sigmoid. By using the least square method, constants a, b, c, and d of Carlander's equation were calculated by computer. The body-scale relationship calculated by the above equation for white crappie in Lake Waco was:

$$L = 268.825541 - 4.100736\ S + 0.038422\ S^2 - 0.000083 S^3.$$

Calculated lengths and actual lengths were in agreement. However, the intercept at 268.82 mm is in error due to the lack of fish smaller than 135 mm.

Using Sherriff's second degree parabolar equation, an equation

$$L = 35.506219 + 1.215665\ S + 0.000931\ S^2$$

was obtained. Calculated length and empirical data fits quite well. Most of the differences are within 5% (Table 8).

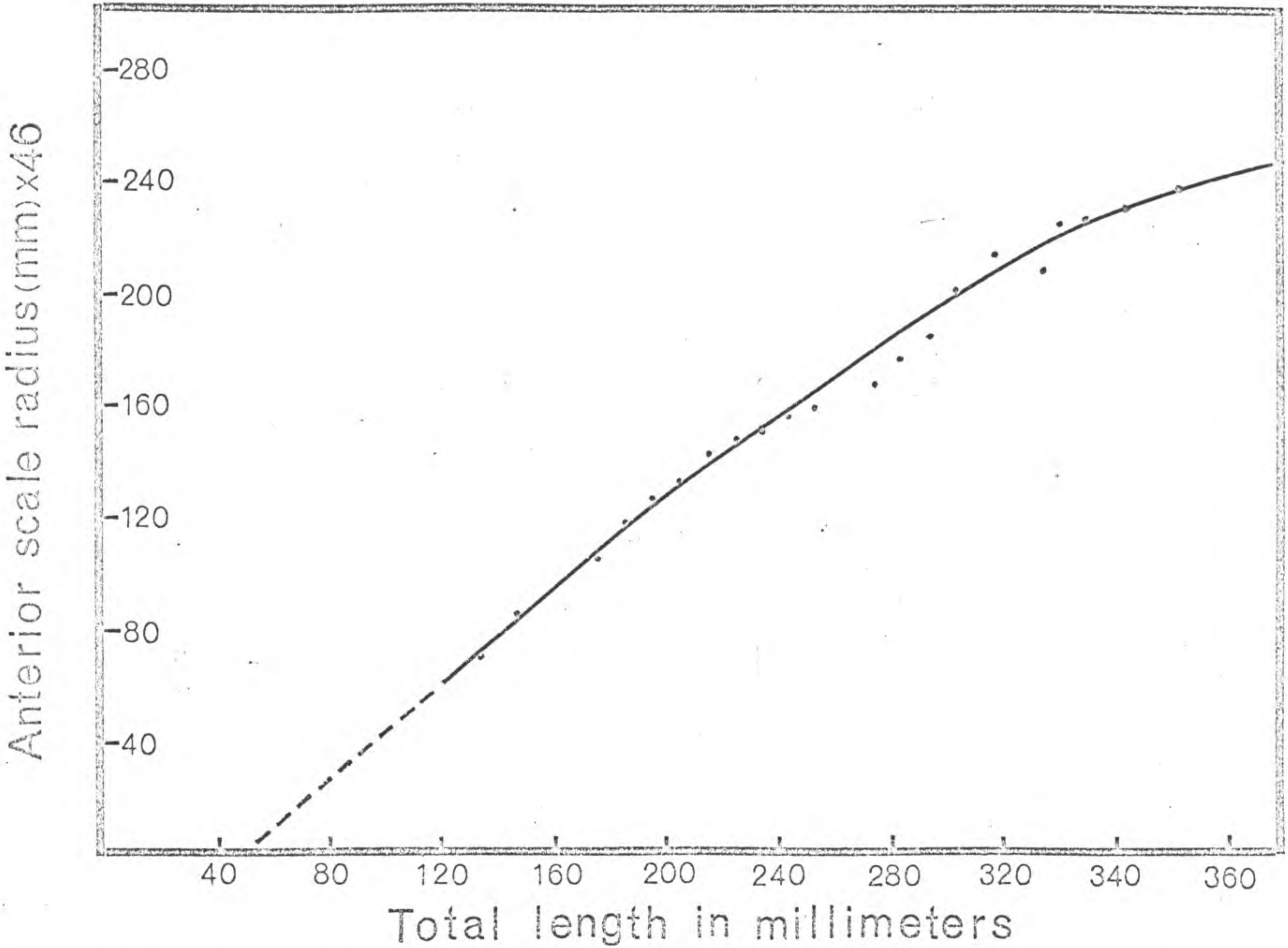


Figure 8. The empirical body-scale relationship of white crappie from Lake Waco.

Table 8. Difference in Empirical Lengths and Calculated Lengths by Use of Equation: $L = 35.506219 + 1.215665\ S + 0.000931\ S^2$

Actual TL mm	Calcul. TL mm	Difference mm	Diff. in % of Actual TL
135.0	125.17	9.83	4.86
145.8	146.94	- 1.14	1.18
155.8	151.63	4.17	3.75
165.2	166.81	- 1.61	3.00
175.3	172.15	3.15	6.09
184.5	191.63	- 7.13	0.72
194.7	205.50	-10.80	1.83
204.5	214.69	-10.19	2.14
215.4	228.09	-12.69	4.40
225.3	234.63	- 9.33	3.34
234.3	240.15	- 5.85	2.24
244.3	248.87	- 4.57	2.38
253.4	248.26	5.14	1.58
264.3	265.71	- 1.41	2.21
274.9	262.36	12.54	3.16
283.7	277.85	5.86	0.09
294.4	288.22	6.18	0.25
303.8	316.84	-13.04	5.96

Table 8. (continued)

Actual TL mm	Calcul. TL mm	Difference mm	Diff. in % of Actual TL
317.0	307.50	9.50	0.97
320.0	319.07	.93	1.15
335.0	293.84	41.16	10.18
340.0	354.54	-14.54	1.36
350.0	356.17	- 6.17	1.37

VIII. AGE AND GROWTH

Nine hundred and thirteen fish were used in age and back-calculation study. The oldest and largest fish caught was a 4 year old female measuring 340 mm TL, and weighing 469 grams. Age was determined by the presence of annuli based on evidence of "cutting over" at the shoulder of the scale or sometimes by a band of wide-spaced circuli. In the latter case, the annulus was considered to be an ideal line running between the last narrow-spaced circulus and the first wide-spaced circulus (Fig. 6).

For each year class, back-calculated total lengths in millimeters at the end of each year of life are given in Table 9. Data showed that, after 1 year of impoundment, the growth rate of white crappie increased rapidly from 116 mm in 1965 to 150 mm in 1966 and 177 in 1967 for the first year growth. There was significant difference ($\chi^2 = 12.63$ $p < 0.01$) between growth rates of the different year classes during the 4 year period from 1964 to 1968.

The overall average total lengths for all year classes of Lake Waco white crappie for the last 4 years were as follows: 145 mm for the first year of growth, 216 mm for the second age group, 271 mm for the third age group, and 309 mm for the fourth age group.

Growth rate of white crappie in Lake Waco was unusual when compared with the growth rate of crappie in

Table 9. Back-Calculated Lengths of White Crappie from Lake Waco

Time of Collection	Year Class	Calculated total length (mm) I	II	III	IV	No. of Specimens
July 1967	1967	141				1
	1966	168	211			35
	1965	139	219	262		9
September	1967	164				6
	1966	163	224			40
	1965	133	245	298		3
November	1967	175				2
	1966	159	220			16
	1965	121	218	259		4
1967 Combined	1967	164				9
	1966	164	218			91
	1965	133	224	268		16
January 1968	1967	175*				37
	1966	147	220			193
	1965	115	203	261		25
	1964	125	185	300	350**	1
March	1967	173				20
	1966	151	222			224
	1965	113	202	263		74
	1964	102	210	274	309	2
April	1967	181				30
	1966	153	220			157
	1965	126	224	268		28
	1964	116	217	279	302	6
1968 Combined	1967	177				87
	1966	150	221			574
	1965	116	207	264		127
	1964	114	212	280	309	9
Grand average		145	216	271	309	913

*Fish had completed first year's growth, but had not resumed their second year of growth; there was no annulus on scales.

**Fish of age group IV were believed to be from old lake.

other waters (Table 10). Only the growth rate of white crappie in Cherokee Lake, Tennessee (Stroud, 1949) exceeded the growth rate of Lake Waco crappie. Reasons for the exceptional growth rate of Lake Waco crappie are: (1) The growing season is longer in the South than in the North. The monthly water temperature of Lake Waco remains above 13 C from March to early December (Fig. 1). Thus fish in this area have about 9 months of growing season. Higher spring water temperatures result in earlier spawning of white crappie and contribute to the fast growth of fish during the first year. (2) Lake Waco is only 3 1/2 years old. The fish population in the reservoir is still expanding, and in an expanding population the growth rate is generally excellent when compared with the growth rate of the same species in an equilibuium or overpopulated population. (3) It is believed that there is ample supply of forage fish for white crappie. Lake Waco has plenty of gizzard shad, threadfin shad, and a few species of shiner (evidence was found by seining, but data are not included). Since Lake Waco crappie spawned early in the year have reached a large enough size by the time shad are spawned, the young crappie may have tremendous food source early in life.

Before the completion of new Lake Waco in February 1965, white crappie were already well established in the old reservoir. Thus with the completion of a new reservoir,

Table 10. A Comparison of Growth in Millimeters of Total Length of White Crappie from Lake Waco and Other Waters*

Body of Water and Reference	Age group							
	I	II	III	IV	V	VI	VII	VIII
Lake Waco, Texas (This study, 1968)	145	216	271	309				
Lake Texoma, Okla. (Whiteside, 1964)	86	153	208	256	295	327	353	366
Okla. State Average (Hall _et al._, 1954)	74	150	198	249	302	335	361	381
Lake of the Ozarks, Mo. (Witt, 1952)	85	152	217	280	329	344	358	366
Cherokee Lake, Tenn. (Stroud, 1949)	38	222	295					
Douglas Lake, Tenn. (Stroud, 1949)	74	186	234					
Lake Marion, S. C. (Stevens, 1958)	48	176	252	284	312	320	332	
Hiwassee Lake, N. C. (Stroud, 1949)	61	173	242	242				
Clear Lake, Iowa (Neal, 1963)	74	153	191	216	236	254	322	
Buckeye Lake, Ohio (Morgan, 1954)	58	107	150	193	232	259	301	
Ohio Lakes (Roach and Evans, 1948)	66	140	193	234	264			
Foots Pond, Ind. (Ricker & Lagler, 1942)	71	148	218	259	292			
Lake Decatur, Ill. (Hansen, 1951)		186	232	266	269	310	312	

* Modified from Whiteside (1964). Some original papers were not seen and most data were converted to millimeters from inches.

an increase in space and feeding area should lead to the active expansion of an already established white crappie population. Expansion of crappie populations probably explains why, in spite of artificial stocking, largemouth bass have not and are not reaching the peak which would be expected in a new reservoir. Since white crappie and largemouth bass occupy similar niches, competition for food and space must exist when the two species occur together. The higher reproductive capacity and earlier establishment of white crappie have forced largemouth bass into an inferior position in Lake Waco.

Few fish from the old reservoir were caught. Some sampling error may have been involved, but most of the fish had probably died, since mortality of fish over 3 or 4 years of age is high.

IX. FOOD HABITS

A total of 865 stomachs were examined for food content, but only 503 (58 percent) of the stomachs contained food. The fish examined ranged from 135 mm to 350 mm in total length and were collected between 18 July 1967-10 April 1968.

The method of fishing and the degree of digestibility of prey organisms should be taken into account in a study of the food habits of an organism. Trapped specimens are more likely to have empty stomachs than specimens taken by other methods, because it is hard for fish to obtain food after they have been trapped. Prey organisms that are hard to digest will remain longer in the stomach.

All fish in the stomachs which could be positively identified were shad. Since two species of shad occurred in Lake Waco, I assumed that both gizzard shad and threadfin shad occurred in the stomachs of white crappie. Shad were easily identified by the black peritoneum, gizzard-like stomach, and ventral scutes. Fish were the most important food item from July through November 1967 (Table 11). Mayfly nymphs and dragonfly naiads also contributed some volume to the food content of the stomachs. Fish were still the most important food item by volume in the spring of 1968. Midge larvae (Chironomidae) started to

Table 11. Food Items and Percent Density by Number in Stomachs of Lake Waco White Crappie Collected from July 1967 to April 1968 (Number in Parentheses Indicates the Number of Individuals of a Given Food Item)

Food Item	1967			1968			
	July	Sept.	Nov.	Jan.	Feb.	Mar.	Apr.
Shad (2 species)	71.4	56.2	64.5	58.2	5.3	8.9	2.8
	(35)	(39)	(20)	(170)	(19)	(28)	(16)
Ephemeroptera	12.3	26.1	22.6	27.7	9.3	17.1	15.1
	(6)	(18)	(7)	(81)	(33)	(54)	(87)
Anisoptera	16.3	17.4			0.3		
	(8)	(12)			(1)		
Diptera							
Chironomidae			9.7	9.9	74.2	52.4	31.5
			(3)	(29)	(265)	(165)	(182)
Chaoboridae						3.2	31.7
						(10)	(183)
Culicidae						2.9	14.7
						(9)	(85)
Hemiptera							
Corixidae			3.3	3.4	8.4	13.3	4.2
			(1)	(10)	(30)	(42)	(24)
Decapoda (shrimp)				0.7	2.5	2.2	0.2
				(2)	(9)	(7)	(1)

Table 11. (continued)

Food Item	1967			1968				
	July	Sept.	Nov.	Jan.	Feb.	Mar.	Apr.	Total
Cladocera and Copepoda*						6625	12300	
# stomachs with food	43	61	17	72	68	135	107	503
# stomachs empty	12	29	7	29	93	114	78	362
Total stomachs Examined	55	90	24	101	161	249	185	865

* Number of Cladocera and Copepoda is a rough estimate and not included in the calculation of percent density.

appear in November and gradually became a common food item from February through April.

Miscellaneous food items included back swimmer (Hemiptera, Notonectidae), cricket (Orthoptera, Gryllidae), water mite (Hydracarina), plant seeds, and filamentous algae. Fish scales were also found in stomachs.

Whiteside (1964) found that 66 percent of the stomachs he examined contained food and that shad and unidentified fish were the main food items from July through January. Marcy (1954), Morgan (1954), and Hansen (1951) concluded that the principal food items of white crappie were small fishes, aquatic insects, and small crustaceans. The food habits of Lake Waco crappie were very similar to those of white crappie in other states.

X. DISEASES AND PARASITES

Lymphocystis (a virus disease) is the only disease known to occur commonly in white crappie (Whiteside, 1964). Witt (1957) studied the seasonal variation in the incidence of lymphocystis in white crappie from Missouri and reported that the infection rate was high in summer (July) and low in spring (April). In fish from Lake Waco, the infection usually occurred on the anal and caudal fins and less frequently on the pectoral, pelvic, and dorsal fins. In two cases of heavy infection, the infected fish were weak and weighed much less than uninfected fish of the same length.

The infection rate of lymphocystis in white crappie is not high. Whiteside (1964) found that lymphocystis occurred from February to June, with an overall average of 3% of the fish infected. Nigrelli (1954) stated that lymphocystis usually appears in the spring, has a peak in the summer, and gradually disappears through the fall. Hansen (1951) reported that in Illinois, lymphocystis infected 1.4% of the crappie in Senachwine Lake (April 1942), 9.5 percent in Lake DePue (April 1943), and 19.5 percent in Lake Chautaugua (September 1943). Borges (1950) reported that lymphocystis occurred in 10.7 percent of the white crappie in Missouri. I found no lymphocystis on the fish collected from July 1967, to January 1968. In February 1968, 3 out of 160 (1.9 percent) of the fish examined were infected with lymphocystis. In March, 5 out of 331 (1.5 percent) were infected, and in the April collection 4 out of 230 (1.7 percent) of the fish examined were infected.

I paid no special attention to fish parasites. The only parasite noticed was Camallanus oxycephalus, a red nematode about 20-30 mm in length, which commonly parasitizes freshwater fish (Hoffman, 1967), and was always found hanging from the anus. The parasites usually occurred in the spring and summer. The incidence of infection was as follows: 3.6 percent (2/55) in July 1967, 1.2 percent (4/331) in March 1968, and 3.9 percent (9/230) in April 1968. Fish infected with nematode parasites showed no signs of weakness and probably tolerated this parasite well.

CHAPTER V

SUMMARY

1. New Lake Waco, located in central Texas near Waco, was completed in February 1965. It has a surface area of 7,500 acres and 60 miles of shoreline. Strong wind action prevents the formation of thermal stratification and brings about relatively uniform chemical conditions through the year. Alkalinity and turbidity of the water are high.

2. The major collection of white crappie for this study started 17 July 1967, and terminated 10 April 1968. Collection methods included seines, gill nets, funnel traps, and angling. A total of 1,142 fish (185 taken by gill nets, 824 by traps, and the rest by either angling or seining) were included in this study.

3. Funnel traps were very effective in catching white crappie in the spring, especially during the spawning season. Traps with two funnel openings seemed more effective in catching crappie than traps with one funnel, but the difference is not statistically significant when tested by group comparison ($t = 1.5668$, $p > 0.1$).

4. On the basis of dorsal spine count and the appearance of color patterns of fish, it was concluded that black crappie were not present in Lake Waco.

5. Spawning season for Lake Waco white crappie was from March to early May, and was at its peak in late March and April.

6. Data show the evidences that some white crappie of Lake Waco may spawn the next spring after they were hatched. Fish of age group I over 170 mm TL. were sexually mature. The overall male to female ratio in percent was 47:53 for Lake Waco crappie.

7. The origin and pattern of scale development were determined from 104 young of the year caught in early June 1968. The fish started to develop scales in the caudal peduncle at a total length of about 16 mm. Then scales were formed progressively anterior and ventral to the lateral-line as fish grew. The first fully scaled fish observed was 31 mm in TL. The region between dorsal fin and pectoral fin was the last place to develop scales. Lateral-line scales started from the caudal region, then scales appeared on the anterior trunk portion, and grew from both directions to meet in the center of the fish.

8. The mathematical expression of the length-weight relationship for the white crappie of Lake Waco is:

$$\log W = -5.6131 + 3.2954 \log L.$$

Where W = Body weight in grams

L = Total length in millimeters

9. The body-scale relationship demonstrated that Sherriff's second degree parabolar equation

$$L = 35.506219 + 1.215665\ S + 0.000931\ S^2$$

fitted the body-scale relationship of Lake Waco white crappie well.

10. A total of 913 fish were used in the age and growth study. Annuli or year marks were used to determine the age of fish. There were no fish over 4 years of age caught during this study. The overall average back-calculated total lengths for Lake Waco white crappie for the last 4 years were as follows: 145 mm for the first year's growth, 216 mm for the second age group, 271 mm for the third age group, and 309 mm for the fourth age group.

The growth rate of white crappie in Lake Waco was unusually fast when compared with the growth rate of crappie in other waters. The reasons for good growth rate are: (1) The high temperature and long growing season. (2) Lake Waco is a new reservoir, and in a new reservoir a fast growth rate is generally expected. (3) It is believed that there is ample supply of food in Lake Waco.

11. A total of 865 fish stomachs were examined for food organisms. Only 58% of the stomachs contained food. Principal food items of white crappie were small fishes (mainly shads), aquatic insects, and small crustaceans.

12. Lymphocystis was only found in the spring, and about 1.7% of fish were infected. Infection by nematode parasites, Camallanus oxycephalus, was observed in the spring and summer, but infected fish showed no signs of weakness.

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