FECUNDITY, FOOD HABITS, AGE AND GROWTH, LENGTH-WEIGHT RELATIONSHIPS AND CONDITION OF CHANNEL CATFISH, *ICTALURUS PUNCTATUS* (RAFINESQUE), IN A 3300-ACRE TURBID OKLAHOMA RESERVOIR

By

AMBROSE JEARLD, JR.

Bachelor of Science

Maryland State College

Princess Anne, Maryland

1965

Submitted to the Faculty of the Graduate College
of the Oklahoma State University
in partial fulfillment of the requirements
for the Degree of
MASTER OF SCIENCE
May, 1970

FECUNDITY, FOOD HABITS, AGE AND GROWTH, LENGTH-
WEIGHT RELATIONSHIPS AND CONDITION OF CHANNEL
CATFISH, ICTALURUS PUNCTATUS (RAFINESQUE),
IN A 3300-ACRE TURBID OKLAHOMA RESERVOIR

Thesis Approved:

Robert C. Summerfelt
Thesis Adviser

Dale Toetz

Rudolph J. Miller

D. Durham
Dean of the Graduate College

PREFACE

The present study was conducted from September, 1967, through September, 1968. Its objectives were to obtain life history information which can be useful to management designed to aid in the improvement of the sport fishery in this and similar bodies of water.

Helpful criticism in preparation of the text was given by my Advisory Committee: Drs. R. J. Miller, D. W. Toetz, and R. C. Summerfelt, Leader of the Oklahoma Cooperative Fishery Unit, who served as advisor and committee chairman.

Special thanks are given to Dr. B. E. Brown for his patient help in statistical procedure, reviewing the manuscript and constructive criticism. I wish to thank the personnel of the Oklahoma Cooperative Fishery Unit for aiding in the collection of samples and especially to R. D. Spall for helpful criticism during this study.

Basic equipment and supplies were provided by the Oklahoma Cooperative Fishery Unit. Cooperators are the Oklahoma Department of Wildlife Conservation, the Oklahoma State University Research Foundation, and the U.S. Bureau of Sport Fisheries and Wildlife. Field collections and my assistantship were financed by contracts (#14-17-0007-769 and #14-17-0004-356) from the Bureau of Commercial Fisheries.

TABLE OF CONTENTS

LIST OF TABLES

Table | Page

LIST OF FIGURES

CHAPTER I

INTRODUCTION

The channel catfish, <u>Ictalurus punctatus</u> (Rafinesque), is present in most Oklahoma streams and rivers, mainstream reservoirs, and has been stocked in many Oklahoma farm ponds. It ranks very high in popularity as a sport and food fish. Commercial pond culture of the species recently has expanded in Oklahoma as in many parts of the United States.

Studies of the channel catfish in Oklahoma waters have dealt primarily with age and growth. Studies elsewhere on channel catfish have been concerned with its distribution in various rivers and streams, observation on feeding, pond culture and reproduction. The general lack of information on the life history of channel catfish in reservoirs stimulated the present study.

The present study was conducted from September, 1967, through September, 1968. Its objectives were to obtain life history information which can be useful to management designed to aid in the improvement of the sport fishery in this and similar bodies of water. Data was collected to show seasonal variation in food habits and gonadal weight of this catfish. Furthermore, information on age and growth relationships and the general condition (length-weight relationships) of channel catfish from Lake Carl Blackwell was obtained. A can-trap technique effective elsewhere for capture of spawning channel catfish was evaluated.

Literature Review

Hubbs and Lagler (1958) reported that the channel catfish is typically found in large rivers and lowland lakes. Its native range extends from the southern portion of Canada, and from the southern part of the Hudson Bay drainage southward through the Great Lakes, through the St. Lawrence basin to the Ottawa River and through most of the Mississippi Valley as far west as eastern Colorado. It extends to Florida and northeastern Mexico and also to the Potomac River, possibly as a canal immigrant. Channel catfish have been introduced into Atlantic and Pacific drainages and are an important game fish in the Midwest, South, and Southwest. Channel catfish were first introduced in California in 1874 (Shebley, 1917) and more recently they have also been introduced into many California reservoirs where they created a good fishery in several areas in Southern California (Miller, 1966).

Aspects of the morphology of the channel catfish useful in taxonomy have been described by Speirs (1952), Taylor (1954), Harlan and Speaker (1956), Trautman (1957), Moore (1957), Hubbs and Lagler (1958), Davis (1959), Jordan and Everman (1896), and Cross (1967).

Results of numerous food habit studies of channel catfish indicate that this species is omnivorous in its feeding habits as it eats all manner of living and dead materials (Hankinson, 1908); Forbes and Richardson, 1920; Kuhne, 1939; Dill, 1944; Eddy and Surber, 1947; Bernen, 1947; and Bailey and Harrison, 1948). The principal diet of young channel catfish apparently is invertebrates, while larger fish are mostly piscivorous. Dill (1944), Clemens (1952), Hoopes (1960), Brown (1965), Russell (1965), and Perry (1969) found that channel catfish under 300 mm usually feed primarily on invertebrates. Bailey and Harrison (1948), Stevens (1959), Busbee (1968) and Swingle (1954) found channel catfish over 15 inches to be largely piscivorous. No size class analyzed contained exclusively one food type, indicating that usage is perhaps dependent upon availability. Berner (1947) reported mice to be 28% by volume and to have occurred in 22% of stomachs examined. Heard (1958) found that 33% of 21 channel catfish taken from Lake Carl Blackwell, Oklahoma, contained at least one cotton rat, *Sigmodon hispidus*.

Seasonal periodicity of fish growth was observed in osseous structures and scales as early as 1759 (Classen, 1944). Since the initiation of age and growth calculations from such structures, other organs have been used. Otoliths (Cunningham, 1905; Barney, 1925), the dentary bone (Adams, 1942) and fin rays (Chugunov, 1926; Cuerrier, 1951) have been used to age fish. Hall and Jenkins (1954) and Jenkins, Leonard and Hall (1952) stated that data obtained from the examination of dorsal spines of channel catfish were more uniform than those obtained from pectoral spines of the same individuals. Age and growth determinations from the vertebrae of catfish have been made by Lewis (1949), Hooper (1949), Appelget and Smith (1951), Barnickol and Starrett (1951).

Studies by Appelget and Smith (1951), Sneed (1951), and Marzolf (1955) confirmed the accuracy of various methods used to calculate age and growth of channel catfish through the use of known age fish. Sneed (1951) stated that more accurate measurements of the annuli could be determined if measurements were made along the expanded edge of the spine cross-sections. Marzolf (1955) made comparisons of age and growth measurements using pectoral spines and vertebrae. He stated that from the standpoint of collection, preparation, and reading, pectoral spine sections were preferred over the vertebrae as they required the least expenditure of time and effort in preparation and were more reliable for age determination because they showed fewer false marks. Marzolf (1955) also reported that growth data derived from vertebral measurements were thought to be a better approximation of growth history because growth was more uniform and in better agreement with empirical data and due to an "unavoidable error" that caused calculated length to be too short by the spine method.

Further studies of age and growth of channel catfish have been reported by Carlander (1950-53) and Muncy (1959) in Iowa waters; Jenkins and Leonard (1954), Finnell and Jenkins (1954), and Sneed and Leonard (1959) in Oklahoma; Davis (1959) and Tiemeier and Elder (1960) in Kansas; MaCamman and LeFaunce (1961) in California; DeRoth (1965) in Ohio; and Schoffman (1967) in Tennessee.

Several techniques have been devised to prepare and mount spine sections for immediate or later reading. Leonard and Sneed (1951), Witt (1961), Carlton and Jackson (1964), School (1968), and Ihm (1968) contributed to the design of instruments for sectioning catfish spines, to the methods of sectioning and mounting catfish spines, and the refinement of these skills.

Aspects of reproduction of channel catfish, including fecundity, embryology, spawning behavior, place of spawning, and the age and size at time of spawning have been reported by several workers. Murphree (1940), Lenz (1947), Clemens and Sneed (1957), and Saksena et al. (1961) studied the embryonic development and spawning behavior of channel catfish. Channel catfish have been reported to reproduce from mid-May to mid-July (Harlan and Speaker, 1956; Marzolf, 1957; Davis, 1959;

Eddy and Surber, 1947; Cross, 1967). Davis (1959) and Moen (1959) reported that channel catfish can be sexed by an external examination of the urogenital region.

Male channel catfish were found to reach sexual maturity at sizes from 7.0 to 17 inches in Louisiana (Davis and Posey, 1958). Harlan and Speaker (1956) reported that females in Iowa mature when 13 to 16 inches in length. Appelget and Smith (1951) found that channel catfish from the Mississippi River near Lansing, Iowa, do not mature before age five, and that all males and 90 percent of the females are mature by age eight.

The site of spawning is variable but nesting usually occurs in secluded, somewhat darkened sites. Brown (1942), Davis (1959), Harlan and Speaker (1956), Geibel and Murray (1961), and Deacon (1959) reported that spawning may take place under rocks, in log jams, in holes, in abandoned burrows of muskrats or directly on the unprotected bottom.

CHAPTER II

METHODS AND MATERIALS

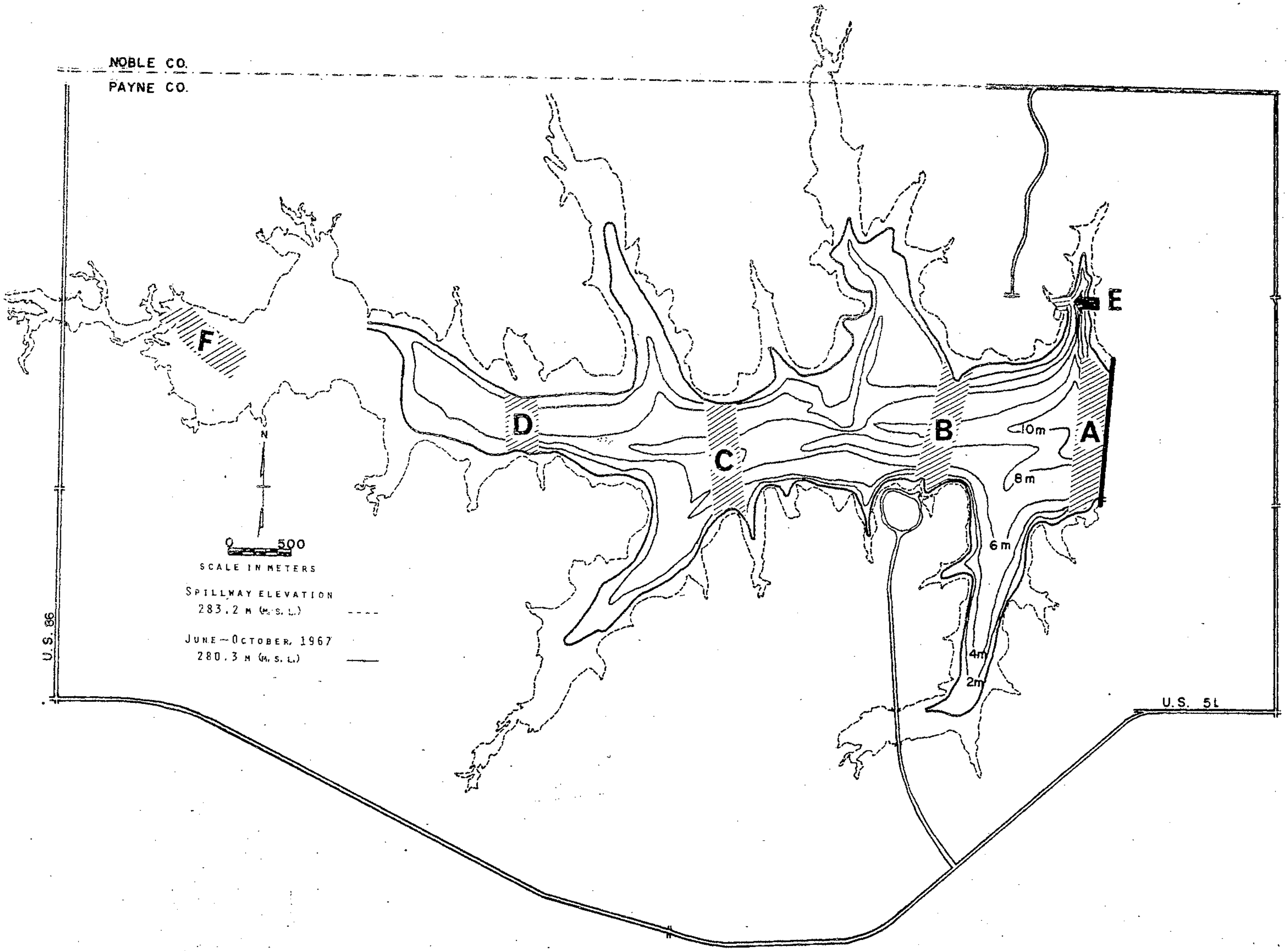
Description of the Study Area

The long axis of Lake Carl Blackwell (Figure 1) extends approximately six miles westward from Sections 10, Township 19 N, Range 1E to Section 3, Township 19 N, Range 1W in Payne County, Oklahoma, nine miles northwest of Stillwater, Oklahoma. Reservoir construction was initiated in 1936 by damming Stillwater Creek at Section 10, Township 19 N, Range 1E in Payne County, Oklahoma. Construction of the earth-and-rockfill dam was completed in 1937, at which time the basin began filling until it reached spillway level at an elevation of 283.2m, m.s.l. in 1945 with an approximate capacity of 80 million cubic meters (65,000 acre feet, 3,700 acres maximum surface area; Norton, 1968).

The reservoir at spillway level has a shoreline of about 100 miles. The north shore is wind swept with regular, gently sloping contours while much of the south shore is rocky and irregular. The deepest section of the reservoir is near the dam and the shallowest section is in the west end which terminated during this study in wide mud flats at the low water levels. The reservoir is now used as a recreation area and as a water supply for the City of Stillwater.

The drainage area is approximately 14 times the size of the reservoir surface area at spillway elevation. The flood plain of the reservoir is quite level with few irregularities except for the former

Figure 1. Contour map of Lake Carl Blackwell with six major collection sites.


NOBLE CO.
PAYNE CO.
U.S. 86
U.S. 51
A
B
C
D
E
F
10m
8m
6m
4m
2m
N
0 500
SCALE IN METERS
SPILLWAY ELEVATION
283.2 M (M.S.L.)
JUNE–OCTOBER, 1967
280.3 M (M.S.L.)

stream channels, which form narrow, steeply sloping trenches through the middle of the lake and the larger coves. The stream channel lies one to three meters below the flood plain. The long axis of the lake extends east and west with several shallow arms extending north and south (Figure 1). As a result, the main axis is at right angles to the prevailing winds from the south. The relatively shallow water depth and low surrounding landscape permits the prevailing winds to keep the lake circulating almost continuously. This circulation keeps the water turbid and causes nearly uniform physical and chemical conditions from top to bottom in most seasons.

The reservoir lies in the Redbed Plains which is one of the eleven distinct physiographic provinces which make up the topography of Oklahoma (Bruner, 1931). The Redbed Plains traverse the entire state from north to south to form the most extensive region of the state. The soils of the region are fine and were derived from red Permian clays and shale. The area has been weathered into gently rolling hills with alternations of prairie and wooded areas. Much of the area is used for agricultural purposes, primarily grazing.

Collection of Fish

Channel catfish included in this study were collected in October 1967, through August 1968. The major portion of the fish were collected by the use of gill nets and to a lesser extent by the use of a Great Lakes trap net, barrel traps, wire traps, rotenone cove samples and electrofishing gear.

A variety of collecting methods were used and each was assumed to have an inherent bias associated with it. It was assumed that gill nets would be selective for faster growing fish of the younger age groups. Barrel and wire traps would probably contain the larger piscivorous catfish since these traps perhaps also attract forage fish. This would also bias the food habit data. Also, as stated elsewhere rotenone poisoning samples could not be included in the food habit study.

Gill Netting

Gill nets were 150 ft. (45.7 m) long with three 50 ft. (15.2 m) sections, each of 1-, 2-, and 3-inch (75 mm) mesh (except for a few samples) collected in a study by the Oklahoma Cooperative Fishery Unit of seasonal distribution of reservoir fishes, using net transects made in four major habitat areas (Figure 1). Three nets were set at each transect for approximately 24 hours during each month. Four areas (A, B, C, and D) were sampled along north and south transects extending from shore to shore (Figure 1).

Area A, located thirty meters west and parallel to the earth-and-rockfill dam represented the deepest sampling area. During this study Area A had an average depth of 8 meters. Area B was a more shallow, open water area with an average depth of approximately 4 m. Area C had an average depth of 3 m and included an area with large trees and snags left when the wooded banks of the former stream channel were inundated. Area D was located at the west end of the lake and was characterized by having an average depth of less than two meters, except in the stream channel.

Trapping

Channel catfish were trapped by the use of a Great Lakes trap net, barrel traps and wire traps. The Great Lakes trap net had a pocket

9 ft. (2.7 m) long, 5 ft. (1.5 m) wide and 4 ft. (1.2 m) deep. The central lead was 150 ft. (45.7 m) long, while the two lateral wings were 50 ft. (15.2 m) in length. This trap was set between area A and B and tangent to area B. The trap was set during the months of February and March, 1968, and was raised approximately every 48 hours. Channel catfish caught by this method were mostly larger than gill netted fish and had an average length of 264 mm, with a range from 187 mm to 527 mm.

Barrel traps (Houser, 1960), made of collapsible nylon, one-inch bar mesh, were 7.5 ft. (2.3 m) long with a 3 ft. (1 m) diameter. These traps, along with similar sized wire traps with 1-inch mesh, were used during the period June, 1968, through August, 1968, in the extreme, uppermost part of the lake (area F). This area was far west of area D and between it and area D the lake is very shallow. Catch rate for channel catfish in gill nets was very low during this time. The barrel and wire trap setting was about three meters (approximately in the stream channel) while that of some wire traps was less than two meters. In the area of barrel and wire-trapping, the water was very turbid and had an average temperature of 26.1°C (79°F) during the settings.

Channel catfish were less vulnerable to the gill nets which were set in areas other than F in the summer months. The success of trapping gear in this area was attributed to increases in the inflow of water from the watershed due to rains west of the lake which presumably resulted in local improvements in available food and cover due to increases in the amounts of allochthonous materials, expansion of habitat and availability of terrestrial invertebrates from the temporary inundation of the surrounding landscape and concomitant deepening of the lake.

Beginning in the spring of 1968, additional samples with can-type traps[1] were attempted (Figure 2). The cans used were 5 gal. (18.9 L.) military type water cans fitted with a line attached to a door which shut over the opening when lifted through the water. The line was attached to a marker buoy. The can bottom was perforated to allow water to drain when lifting from the water. These cans were first set approximately one month before spawning was believed to begin. The purpose of such can traps was to simulate spawning sites for spawning channel catfish and hiding places to capture yearling channel catfish.

Thirty-two cans were distributed from April 20 to July 8, 1968, in shallow areas, deep water areas, sandy bottom areas, mud bottom areas around the bases of trees in areas D, in rocky areas and in areas with least wave action. The cans were raised to check for use by fish and to see if the trap door was open every four to five days. The amount of sampling of this type, for the most part, was determined by the success observed.

Rotenone Samples

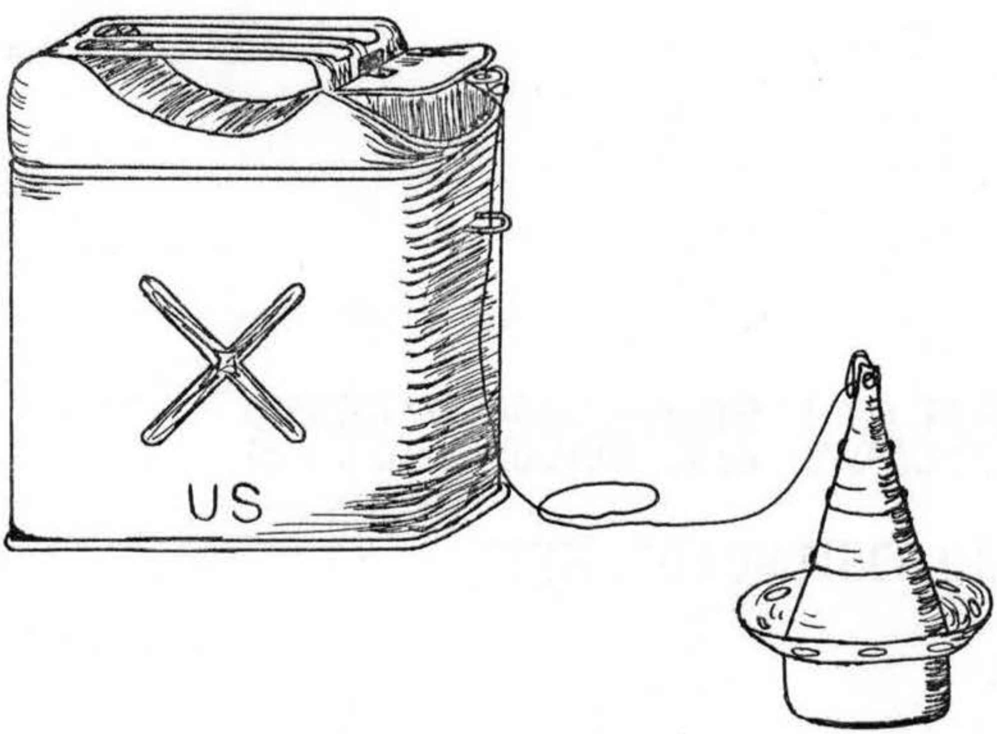
Rotenone samples were taken from a 1.3 acre cove (Area E, Figure 1) with an average depth of 2.2 m. One sample was taken during the first quarter of the study in October, 1967, two samples the second quarter (January and March, 1968), two samples the third quarter (May and June, 1968), and one sample the final quarter (August, 1968).

The rotenone cove extends east and west from one of the larger arms on the north side of the reservoir and escapes much of the wind action

---

[1]The design of this can-trap was developed by Dr. R. C. Summerfelt, Leader, Oklahoma Cooperative Fishery Unit, Stillwater, Oklahoma.

Figure 2. Can-trap.


US

characteristic of the other sampling areas. The shoreline of this particular cove is steep sided, partly rocky and sandy with an appreciable amount of vegetation; thus this small cove is shaded much of the time.

Electrofishing

Catfish were collected by electrofishing in conjunction with studies on the shoreline distribution of fishes conducted by the Fishery Unit. The areas of collection included 450 ft. (37.2 m) sections on the north and south shores of the reservoir, centering on the gill net transects (Area A, B, C, D). Sampling was conducted each month and included both day and night collections.

Laboratory Methods

Channel catfish collected for this study were taken immediately from the lake to the laboratory for processing. Total length and weight were recorded and the left pectoral spine was taken from each fish. The gonads were removed and preserved in 10 percent formalin, and where possible the sex of each fish was determined. Stomachs were removed from fish collected by all methods except those recovered from the rotenone cove samples.

Food Habits

Stomachs from 196 fish were used for food habit analysis. These were primarily of fish caught by gill netting, although some fish were captured in wire and barrel traps. Fish collected from rotenone poisoning samples were not used since the channel catfish were affected by the poison at a slower rate than other forage species present. This being evident, the channel catfish were assumed to feed on the dying fish and this would cause a bias in the food habit data.

After stomachs were removed they were then preserved in a 10 percent formalin solution for later analysis. Identifications of the stomach contents were made by microscopic examination. Volumetric determinations were made in graduated cylinders for large stomach volumes and in graduated centrifuge tubes for small stomach volumes. The frequency of occurrence of each kind of food item was determined. The percentage of volume and the percentage of occurrence for major items were calculated.

Gonadal-Body Weight Relationships

Gonadal-body weight relationships were determined from 106 females and 70 male channel catfish collected by all methods from October, 1967, through August, 1968. Body weight was determined in the laboratory soon after being collected and the gonad weight was recorded during autopsy of the fish.

The gonadal weight of the fish was determined to the nearest 0.1 gram. Sex was determined by gross examination, or where necessary by microscopic examination of wet mounts of squash preparation. These data were recorded and the gonadal-somatic index was determined by expressing the gonadal weight as a percentage of body weight.

Estimation of Fecundity

Females, regardless of size, which had relatively large ovaries were used to estimate fecundity. Ovaries were removed and weighed and preserved in 10% formalin.

The preserved ovaries were removed from the 10% formalin, excess moisture was blotted off and the total weight was taken to the nearest 0.1 gram. This weight was somewhat greater than the weight of the ovaries when first removed from fish due to absorption of formalin.

The formalin hardened the ovary and made it difficult to separate individual eggs from other eggs and from the ovarian tissue.

The left ovary was used to estimate fecundity. The left ovary was weighed and sectioned into three portions (anterior, middle, posterior) in the event the number and size of ova was not uniform throughout. The weight of each section was also taken. The ovarian tissue was removed and weighed and each section was teased apart. A random sample of eggs was selected from each section and weighed. Ova from these samples were counted, weighed and measured to the nearest 0.05 mm with an ocular micrometer under a 40X dissecting microscope. The mean weight of an average egg in each section was determined.

The number of ova was estimated by the following formula:

$$E = W/\left[W_i / \sum_{j=1}^{3} [W_{ij}/\bar{w}_{ij}]\right],$$

where E = number of ova per dish

W_i = weight of left ovary in grams

j = 1, 2, 3 = anterior, center, and posterior sections

W_{ij} = weight in grams of jth section of left ovary

$\bar{w}_{ij}$ = mean weight of egg in jth section of left ovary,

and W = weight in grams of both ovaries.

Age and Growth

Data for age and growth estimation were taken from fish captured by all methods throughout the study period. Total length was measured to the nearest 0.05 mm and weight to the nearest 0.1 gram. The entire pectoral spine was removed from each fish and used to determine the age and rate of growth of the channel catfish. The spines were loosened from a locked condition in the pectoral girdle by rotation until the spine was completely dislocated from the fish. They were then placed in coin envelopes with data concerning the fish from which it was removed.

A small power saw on a stationary platform, similar to the apparatus of Witt (1961) was used to section spines. The instrument consisted of a fixed saw which could be elevated, a mechanical table that could regulate the thickness of the sections, and a sliding table to which a V-block and clamp were attached to hold the spine immovable. Cross-sections of the spines were cut at the base of the articulation (distal end of the basal groove), which served as a reference point to insure consistency in the location of each section. This follows the procedures outlined by Marzolf (1955), Morris (1960), and Russell (1965).

Serial sections were cut as thin as possible. Small spines were glued to pieces of plastic slides used for scale impressions before sectioning. While cutting, coolant water was applied between the spine and the blade with a dropper to keep the section from burning and curling.

The sections were glued on to glass slides with Permount, a commercial histological mounting media. The sections were viewed and measured under a binocular dissecting microscope containing an ocular micrometer at a magnification of 25X. Measurements were made to each annulus from the center of the lumen along the longest spine radius as the annuli were more distinct and well separated from each other at that location, thus insuring more accurate measurement.

CHAPTER III

RESULTS AND DISCUSSION

Can Fishing

Schafer, Posey, and Davidson (1966) evaluated the effectiveness of cans for harvesting catfish from Lake Lac Des Allemands, Louisiana, during the spawning season. The study was undertaken because concern had been expressed by the Louisiana Wildlife and Fisheries Commission that the use of cans by commercial fishermen could deplete the catfish resource by selectively removing brood fish, their eggs, and fry. Grease cans ranging from 5 to 15 gallons in capacity (most were the 5-gallon size) were used in that study. They found that cans were extremely selective, capturing channel catfish almost exclusively; fish examined were sexually mature, females slightly outnumbered males in total catch; and eggs were not found in significant quantities until the cans remained undisturbed for five or more days.

The can sampling technique was investigated in this study as a possible means of capturing mature channel catfish, collecting eggs and/or capturing yearling channel catfish. Can trapping was initiated in Lake Carl Blackwell May 1, 1967, as part of the fish distribution study by the Oklahoma Cooperative Fishery Unit. The 32 cans used in this study were of the same design used in the initial study by the Fishery Unit in 1967 (Figure 2). Twelve cans were set at four locations with a depth range of 0.9 to 9.1 meters and an average depth of 3.4

meters. The cans remained in place May 1 through June 23, 1967, and were examined for fish every two to four days. The experiment was then terminated because it was believed that the channel catfish had ended spawning. The bottom temperature for May, 1967, in the location of can sets ranged from 16.0°C to 20.0°C with an average of 17.8°C, while the temperature during June had a range of 17.8°C to 29°C and an average of 23.6°C. According to Clemens and Sneed (1957) channel catfish spawn at temperatures 21.1°C to 29.4°C with 26.6°C being optimum temperature.

The total hours fished by the 12 cans was 8,920 during May and 6,620 during June. No channel catfish were caught in either month.

In the present study, can sampling for channel catfish began April 29, 1968, before spawning activities commenced and continued until July 8, 1968, when spawning was believed to have terminated. Thirteen cans were placed in the water in April, although the temperatures were below spawning temperature and fish were not in spawning or gravid condition. By May 15, 1968, 32 cans had been set at various locations thought to be possible spawning sites. The cans were in depths ranging from 0.3 to 10.6 meters with an average of 1.6 meters. Schafer, Posey, and Davidson (1966) indicated that the choice of bottom type in placing the cans was important, with shallow (2.5 to 4.0 ft.) hard bottoms being preferable sites. The former substrate was advantageous in can fishing because in softer areas of the lake cans may become rapidly covered with silt. They also indicated that depth is not as important as bottom type.

In the present study sites chosen were usually in moderately shallow waters, where temperatures were within the spawning range of channel catfish. At times from 1 to 9 cans were placed at a particular site. If a particular area was found to be undesirable due to siltation or unfavorable temperatures below the spawning threshold or because of wave action, the cans were relocated. Water temperature for an average depth of 4.6 meters averaged 14.1°C in April; 17.4°C in May; 22.2°C in July. Can site locations were much more shallow (average 1.6 meters), therefore the average water temperature there was higher: May, 22.2°C; June, 25.5°C; July, 30.6°C.

A total of 38,904 can-hours were fished without capturing a single catfish. Unlike the can experiment by Schafer et al. (1966), this experiment was conducted with the can positions marked by a buoy attached to each can. The marked cans were subject to a high incidence of vandalism and were commonly removed or the marker buoys were detached, making their recovery impossible. The high number of cans stolen or lost decreased the number of cans to 9 out of 32 by July 8, 1968, closing date of the can sampling technique. The removal of these cans and the possible removal of fish from the remaining few cans decreased the chance of obtaining channel catfish by this method.

Food Habits

Stomach contents were grouped into four major categories or types: invertebrates, fish, detritus and vegetation (Table I). These four major categories were then classified into even smaller taxa for detailed comparisons. The category "detritus" included sand, mud, zooplankton, phytoplankton, and unrecognizable, partially digested organisms. The percent frequency of detritus present in the stomach analyses remained at a fairly constant level for all size groups. However, size groups ranging from 170 mm to 360 mm had a greater percent by volume than larger size groups. The percent detritus ranged from

TABLE I

SUMMARY OF MAJOR CATEGORIES OF STOMACH CONTENTS OF CHANNEL CATFISH FROM LAKE CARL BLACKWELL N = 128

Category	Number of stomachs containing organisms	Stomachs with food (% total N)	Average number organisms	Percent frequency of occurrence	Percent total volume
Detritus	41	21.46	1.00	4.64	2.85
Fish	76	39.79	1.38	11.90	87.13
Vegetation	9	4.71	1.00	1.02	.91
Mammals	1	.52	1.00	.11	5.71
Invertebrates	64	33.49	26.78	82.30	3.37
		99.97		99.97	

20% to 67% for fish from 170 mm to 360 mm with an average of 45% by volume. Larger size groups ranging from 370 mm to 840 mm had an average of only 5.5% detritus by volume.

Bailey and Harrison (1948) reported that channel catfish are omnivorous and consume a wide variety of food. This study also revealed that food habits of the channel catfish were quite varied. Small catfish primarily consumed various invertebrates and larger fish were more piscivorous. In no size groups of the 128 (65%) fish stomachs with food contents present, was there exclusively one food type (Table II).

Seasonal changes were observed for the four major categories in percent by volume of organisms and in percent frequency of occurrence of organisms. Plant material was almost absent from the diet except for the months of October, November, and December and then it was only a small percentage of the food contents present. There was no real monthly cycle shown in the frequency of occurrence of fish. In the first quarter, during the months of January, February, and March the channel catfish were relatively large in size. Fish comprised 91% of the volume of food eaten by catfish during this period. This is not representative of all channel catfish at this time because larger fish are more piscivorous than small or intermediate size catfish.

On the other hand, there was a distinct seasonal cycle in the percent frequency of occurrence of invertebrates present in the stomachs analyzed. The frequency of occurrence of invertebrates increased during the spring and summer reaching a peak of 99% in June with lowest frequency in winter. The size of the decrease could have been influenced by the fact that there was an abundance of larger fish caught during the colder season as well as to the expected lesser abundance of

TABLE II

STOMACH CONTENTS OF CHANNEL CATFISH, (*ICTALURUS PUNCTATUS*) RAFINESQUE, FROM LAKE CARL BLACKWELL, OCTOBER, 1967, THROUGH AUGUST, 1968

Food item	Stomachs with food (% total N)	Average number organisms	Percent frequency of occurrence	Percent total volume
Decapoda (crayfish)	5.2	3	2.9	2.30
Isopoda (sow bug)	.5	1	.1	*
Mollusca (Pelecypoda)	.5	1	.1	*
Insecta				
Ephemeroptera	7.3	6	9.1	.40
Odonata	.5	1	.1	*
Diptera				
Culicidae	.5	4	.5	.05
Chironomidae	8.9	35	66.7	.2
Coleoptera	3.7	2	1.2	.05
Terrestrial Insect Remains	.5	3	.3	.07
Unidentified Insect Remains	5.9	1	1.2	.30
Fish				
Dorosoma cepedianum (Gizzard Shad)	12.0	2	5.2	33.60
Pomoxis annularis (White Crappie)	3.1	2	1.0	17.50
Roccus chrysops (White Bass)	.5	1	.1	1.30
Unidentified Centrarchidae Remains	5.5	1	1.5	22.50
Unidentified Fish Remains	18.9	1	4.3	12.10
Vegetation	4.7	1	1.0	1.00
Detritus	21.5	1	4.6	2.90
Neotoma floridans (Woodrat)	.5	1	.1	5.70

*Trace .05%

Total number of stomachs examined--196; total number of stomachs containing food--128 (65.3%)

invertebrates at that time. It was assumed that channel catfish eat less during the colder months than during the warmer months, but the average volume of food remained about the same or increased in the winter months compared with other seasons. Since channel catfish captured in the winter were on the average larger than in other seasons, and it is expected that digestion rates are slower. They may be actually eating less but retain a larger volume of undigested food.

Vegetation, except for phytoplankton and material digested beyond recognition was considered a separate category. This vegetation consisted of terrestrial and aquatic macrophytes and algae. It represented only 1% of the total food volume and frequency of occurrence. The low percentage of vegetation in the stomachs was perhaps due to sparseness of aquatic macrophytes. This condition may be due to the turbid nature of the lake. Also the drought conditions present during this study limited the amount of allochthonous vegetation entering the lake.

The major foods eaten by the channel catfish by frequency of occurrence were insects, fish and detritus (Table II). Fish occurred in 40% of the stomachs containing organisms; insects occurred in 27.3% of the stomachs, and detritus occurred in 21.5% of the stomachs. Observation of food habits by percent frequency of numbers of organisms present showed that insects were most common with 79.1%. On the other hand, fish had a greater percentage by total volume than any other category present.

Insects most frequently consumed as food by channel catfish were chironomid larvae and Ephemeroptera (mayfly) nymphs (Table II). Chironomids had an occurrence of 66.7% and mayfly nymphs had an occurrence of 9.1%. Chironomids larvae also constituted the highest average number of any organism found, with a mean value of 35 per stomach in fish containing them. Coleoptera and unidentified insects made up the third most frequent insect category eaten with 3.7% and 5.9%, respectively, in stomachs containing organisms. Other insects occurring less frequently in stomachs examined were: Odonata, Culicidae, and terrestral insects.

The most frequently eaten crustacean was crayfish (Table II). They were present in 10 stomachs and made up 2.3% by volume of the total food organisms. One fish was found gorged with 17 undigested crayfish in its stomach.

Fish or fish remains were present in stomachs examined during all seasons and in all size groups. However, for the most part, whole fish were found in the larger size groups while the smaller size groups contained fish scales and bone fragments. Identifiable as well as unidentifiable fish represented 87% of the total volume of food content in stomachs analyzed (Table II).

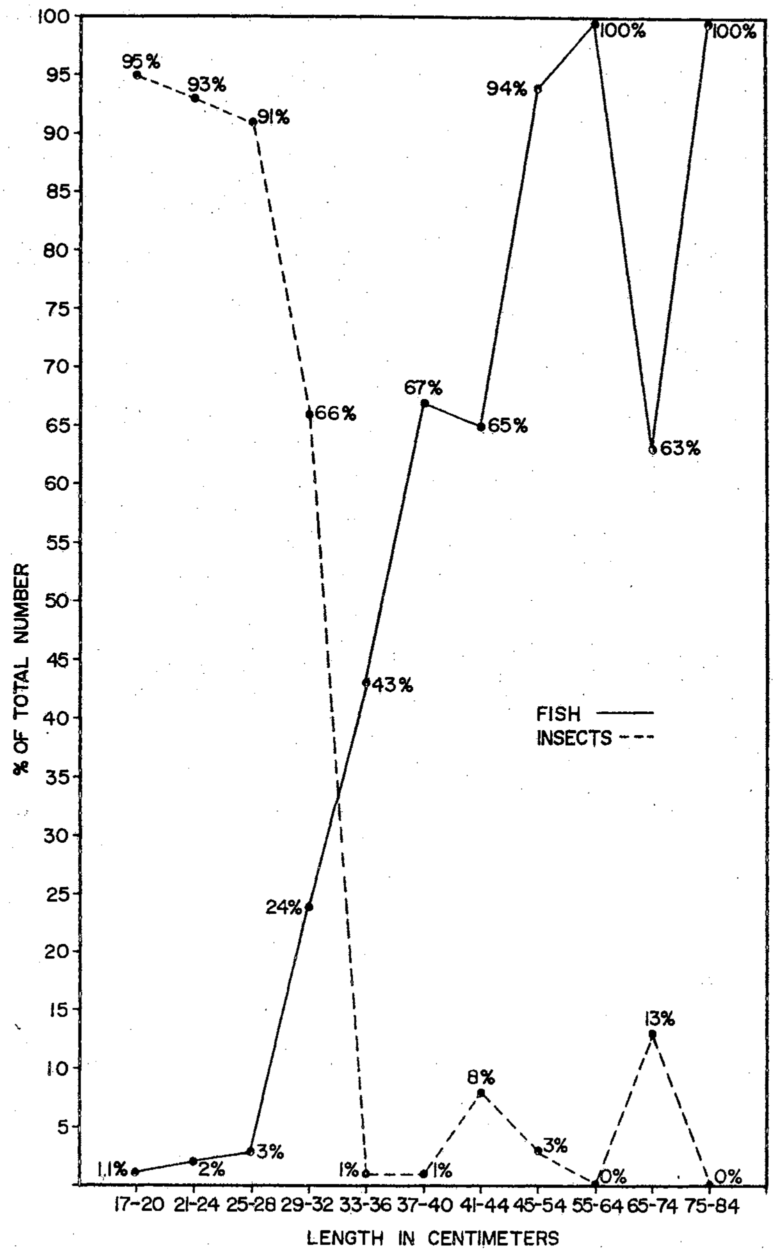
Gizzard shad, Dorosoma cepedianum, comprised 33.6% of the total volume of all food eaten. Identifiable portions of the gizzard shad were also present in the fish remains (Table II). The largest gizzard shad occurred in a 498 mm channel catfish and had a total length of 154 mm and a standard length of 117 mm. This was one of 7 gizzard shad present in that stomach. The second most abundant species was white crappie (Pomoxis annularis). It represented a total volume of 17.5%. This does not suggest that while crappie is a major fish consumed by channel catfish in Lake Carl Blackwell because 55% of the white crappie were in stomachs taken from fish captured in wire and barrel traps. One white bass (Roccus chrysops) was the only other fish classified to the species. Unidentifiable centrarchidae made up 22.5% by volume of the fish contents present in stomachs containing food. The remainder of the fish were unidentifiable and made up 12.1% by volume of unidentifiable fish remains.

The only terrestrial vertebrate present in the stomach contents analyzed was one woodrat (Neotoma floridoma). It had a volume of 170 ml and was 5.7% of the total food volume. This organism was of special interest since Heard (1959) reported that 33% of 21 channel catfish taken from Lake Carl Blackwell from September 23 to November 29, 1958, contained at least one cotton rat, Sigmodon hispidus. Berner (1947) found mice to be 20.7% by volume and 22% by frequency of occurrence in stomach contents of channel catfish from the Missouri River.

Percent frequency of occurrence of total number of organisms and percent by volume of total stomach contents were examined by length classes (Figures 3 and 4). Size classes were arranged in groups of 4 cm from 17 cm to 44 cm and in groups of 10 cm from 45 cm to 84 cm. The latter length groups were expanded as the diet of the channel catfish became less variable with increased length.

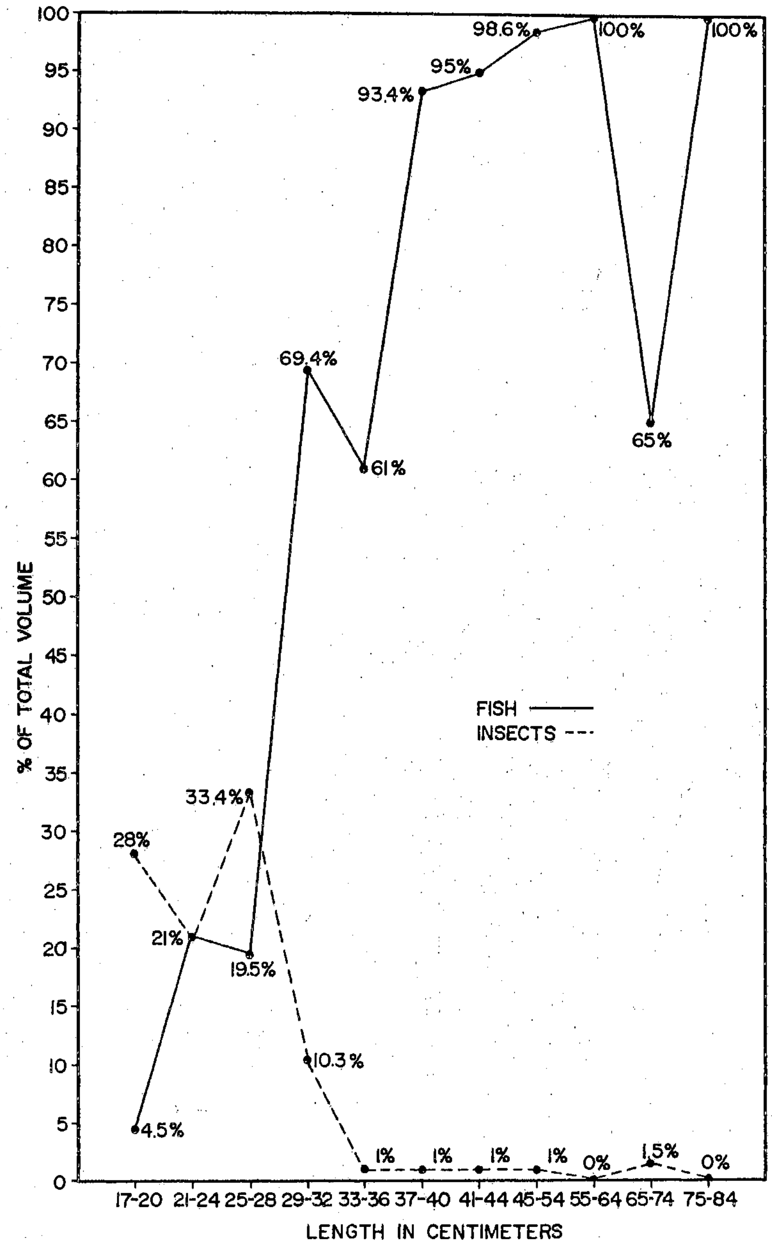
Stomachs analyzed for the four length classes 17-20 cm, 21-24 cm, 25-28 cm and 29-32 cm by percent frequency were dominated by insects (Figure 3). However, the 29-32 cm group contained more fish by percent by volume (Figure 4). It is in this length class, at approximately 300 mm, that channel catfish in Lake Carl Blackwell became more dependent on fish for their diet. Russell (1965) found this to be the size at which channel catfish first began to utilize more fish material from the Ponca section of the Missouri River, Nebraska. However, this is a smaller size than reported by Bailey and Harrison (1948), Stevens (1959),

Figure 3. Percent frequency of total number of major groups of organisms in stomachs of channel catfish.



100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
% OF TOTAL NUMBER
95%
93%
91%
66%
1%
1%
8%
3%
0%
13%
0%
1.1%
2%
3%
24%
43%
67%
65%
94%
100%
63%
100%
FISH
INSECTS
17-20
21-24
25-28
29-32
33-36
37-40
41-44
45-54
55-64
65-74
75-84
LENGTH IN CENTIMETERS

Figure 4. Percent of total food volume composed of major groups of organisms in stomachs of channel catfish collected.



100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
% OF TOTAL VOLUME
98.6%
100%
100%
95%
93.4%
69.4%
61%
65%
FISH
INSECTS
33.4%
28%
21%
19.5%
10.3%
4.5%
1%
1%
1%
1%
0%
1.5%
0%
17-20
21-24
25-28
29-32
33-36
37-40
41-44
45-54
55-64
65-74
75-84
LENGTH IN CENTIMETERS

Busbee (1968) and Swingle (1954), who found that channel catfish were about 380 mm before becoming piscivorous.

At the length of channel catfish progressively exceeded 300 mm, the stomach contents were increasingly dominated by fish and partially digested fish organs. Length classes from 37-40 cm through 75-84 cm would have an average fish content greater than 90% both by frequency of occurrence and by volume if detritus, crayfish and vegetation were overlooked. Detritus, crayfish and vegetation in these size classes made up less than 8% of the food content. The sharp decline in the relative contribution of fish in the diet of catfish in the 65-74 cm length class (Figures 3 and 4) was due to the presence of the Eastern Woodrat which displaced 170 ml of water, and the presence of a number of mayfly nymphs in a single catfish stomach. Swingle (1954) suggested that channel catfish are piscivorous in the 15.5 inch (394 mm) group and larger. This appears to hold true for channel catfish included in this study. Although it should be pointed out as was stated by Busbee (1968) that no size class analyzed was found to contain exclusively one food type including those size classes found to be piscivorous. Even though stomachs were not analyzed by age classes, it can be implied here that older age groups which were made up of greater length classes, contained a greater percentage of fish than the younger age class.

Gonadal-Body Weight Relationships and Time of Spawning

Gonadal-body weight index was calculated from 106 female and 71 male channel catfish collected throughout the study period. The 177 specimen used in the calculation of the gonadal-body weight relationship did not include the immature age groups I through III. The age of 12%

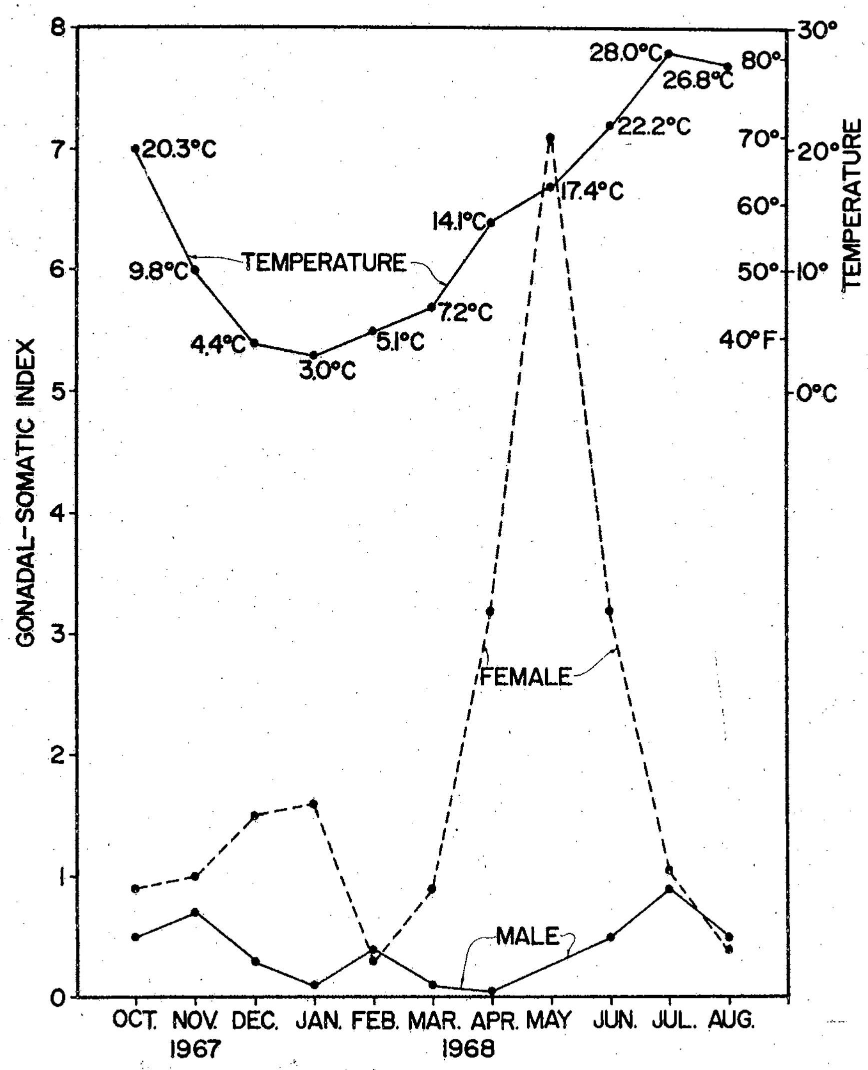
of the total specimens included in the gonadal-somatic index could not be assessed because of difficulties in age determination and of cases where spines were not available. The percentage age composition of those specimens which could be aged was 2% age IV, 9% age V, 16% age VI, 15% age VII, 12% age VIII, 16% age IX, 11% age X, 5% age XI, 1% XII, and 2% age XIII.

The gonadal-somatic index for females was less than 2% from the middle of June through January (Figure 5). In February the gonadal-somatic index for females increased sharply commencing a rise to a peak of approximately 7.1% on May 20 (Figure 5). The sharp ascending limb of the gonosomatic ratio seasonal curve occurred for females prior to spawning. Spawning occurs in May and early June as the average index was less than 2% in mid-June.

Changes in the male gonadal-somatic index were of little magnitude throughout the study period. This could have been due to the small percentage of mature males in the samples. However there was a noticeable steady increase in the gonadal-somatic indices for males beginning in April through July followed by a decrease (Figure 5). The increase in gonosomatic index and its peak did not coincide with that for females. Perhaps this was due to lower vulnerability of maturing and mature males from March through May. The low magnitude of gonosomatic ratios in males as shown in that figure indicated that gonadal development apparently exerted little influence on condition factor.

This assumption was based on seasonal changes in the gonosomatic ratios which reached a peak of 7.1 in May and began sharply declining to 1.1 in July (Figure 5). The same trend was observed in the condition factors for females with the highest peak in May (Table V). From

Figure 5. Seasonal change in gonadal-somatic index of channel catfish from Lake Carl Blackwell.



GONADAL-SOMATIC INDEX
TEMPERATURE
20.3°C
9.8°C
4.4°C
3.0°C
5.1°C
7.2°C
14.1°C
17.4°C
22.2°C
28.0°C
26.8°C
TEMPERATURE
FEMALE
MALE
30°
80°
70°
20°
60°
50°
10°
40°F
0°C
0
1
2
3
4
5
6
7
8
OCT. NOV. DEC. JAN. FEB. MAR. APR. MAY JUN. JUL. AUG.
1967
1968

Table III it can be seen that weight of the ovaries collected increased from March to May. Further support of this assumption was added by observations of sexual dimorphism and the collection of spent females.

Sexual dimorphism was noted as early as early May in several specimen collected in this study. The male channel catfish could be distinguished from the female by having a broader head that appeared to be swollen above and behind the eyes. During the spawning period fish could be sexed with approximately 99% accuracy by examining the genital pore. In males the genital papilla extended posteriorly while in females the genital opening scarcely protruded from its ventral surface. These changes in morphological appearance as described by Davis (1959) were observed throughout the spawning period. Mature females examined during the spawning period were observed to be gravid or spent.

Fecundity

Attempts made to locate spawning sites as well as young-of-the-year channel catfish by a can sampling technique were unsuccessful. However, channel catfish which were absent in other quarterly rotenone samples were present in large number during the third quarterly rotenone cove poisoning in May and June 1968. These fish were sexually mature and some females were recorded as "spent females." This particular cove has an average depth of 2.2 meters, a relatively sandy bottom and a semi-steep rocky bank. The cove is basically free of heavy wave action and this combined with heavy shore vegetation makes for a relatively less turbid area than the mud flats which occur over much of the lake. It is likely that spawning occurred in this cove and possibly in other similar areas.

Ovaries were collected from twenty fish from March through June 1968. Specimen age ranged from V to XI. A total of 2% of the fish could not be aged. The percentage age composition was 10% age V, 25% age VI, 10% age VII, 5% age VIII, 20% age IX, 10% age X, and 10% age XI. An increase of ovary weight of 1% occurred after collection due to absorption of fluids by the eggs preserved in formalin. Mean ovary weight was 7% of the body weight, sample size was 20 fish. Muncy (1959) in a study of channel catfish from the Des Moines River, Iowa, reported a mean ovary weight of approximately 15% of the body weight. However, the fish he examined were considerably larger than fish in the same size range in this study. The estimated egg number was considerably higher for fish from Lake Carl Blackwell than channel catfish Muncy (1959) worked with in Iowa. Channel catfish from Lake Carl Blackwell had a mean length of 388 mm with a range from 201 to 653 mm and a mean count of 13,177 eggs with a range from 1,052 to 64,629. Channel catfish Muncy observed had a mean length of 399 mm with a range from 299 to 512 mm and a mean count of about 6,123 eggs with a range from 2,682 to 9,721.

The number of eggs in the ovaries from the 20 mature female channel catfish increased with the age and length (Table III). Egg number did not increase with the body weight. The failure of egg number to increase as body weight increased is assumed to be due to time ovaries were collected as some of the older and heavier fish were taken when their ovaries were in prespawning condition.

Linear and curvilinear regressions were computed to relate egg number to fish length and egg number to fish weight. The mathematical expressions of the regression of number of eggs (Y) on total length of

TABLE III

EGG COUNTS OF CHANNEL CATFISH COLLECTED FROM LAKE CARL BLACKWELL IN 1968

Date	Age	Standard length (mm)	Total length (mm)	Body weight (grams)	Weight eggs (grams)	Number eggs
March	V	167	201	66	18.06	1052
March	V	227	273	158	25.52	2759
April	VI	190	228	88	2.62	1917
June	VI	228	274	132	11.37	2580
June	VI	229	275	142	13.19	3111
June	VI	260	312	204	5.60	6334
April	VI	348	418	671	13.32	17789
March	VII	235	282	170	2.47	1857
May	VII	273	328	354	8.13	7391
March	VIII	338	406	636	8.72	11369
June	IX	237	284	173	10.55	1368
May	IX	356	427	726	24.40	17079
May	IX	364	437	1090	94.00	12358
April	IX	444	533	1407	50.70	25350
May	X	431	518	1362	207.19	16518
March	X	544	653	2860	82.73	31492
June	XI	357	429	998	84.33	10812
March	XI	491	590	2315	47.24	64629
March		174	209	62	.96	1524
May		479	575	2179	217.47	27480

Standard length computed from the following equation: S.L. = (1/1.201) T.L. (Carlander, 1950).

fish in mm (X) are: $Y = 22{,}963 + 94.5X$ (linear); $Y = 366 - 28.6X + 0.15X^2$ (curvilinear); where Y = egg number, and X = length in millimeters. The linear correlation coefficient (r) was 0.84 which was significant at the 0.05 level. Both the linear and curvilinear regressions were significant at the 0.005 level but the curvilinear term did not significantly (0.05 level) improve the fit of the line (Table IV).

The regressions of number of eggs on weight of the fish in grams are: $Y = 10{,}655 + 11.0X$ (linear); $Y = 10{,}175 + 12.7X - 0.0068X^2$ (curvilinear); where Y = egg number, and X = weight in grams with a linear correlation coefficient (r) of .41 which was not significant at the 0.05 level. Neither the linear or curvilinear equations were significant at the 0.05 level (Table IV).

Coefficient of Condition

The coefficient of condition (also called condition factor or ponderal index) is used as an indicator of the plumpness of fish in numerical terms. This is assumed to represent degree of well-being or relative robustness of fish. The coefficient of condition may vary with several biological and environmental conditions.

The condition factor K was computed for all fish when length and weight measurements were available as follows:

$$K = \frac{1{,}000{,}000\ W}{L^3}$$

where W = weight in grams, and L = total length in millimeters.

Seasonal changes in the coefficient of condition of channel catfish from Lake Carl Blackwell were calculated separately and combined for males, females, and unidentified fish (Table V). The total sample size

TABLE IV

ANALYSIS OF VARIANCE FOR EGG NUMBER VERSUS TOTAL LENGTH IN MILLIMETERS AND EGG NUMBER VERSUS BODY WEIGHT IN GRAMS

Source of variation	Degree of freedom	Length		Weight	
		F	Probability	F	Probability
Total	19				
Linear Regression	1	41.98	$P < 0.005$	3.59	$0.1 < P < 0.05$
Residual	18				
Curvilinear Regression	2	22.47	$P < 0.005$	1.70	$P > 0.1$
Curvilinearity	1	1.59	$P > 0.1$	.007	$P > 0.1$
Residual	17				

TABLE V

SEASONAL CHANGES IN CONDITION FACTOR WITH 95% CONFIDENCE INTERVALS FOR LAKE CARL BLACKWELL CHANNEL CATFISH

Month	Year	Male	Female	Unidentified	Unknown	Total
October	1967	7.4± .8 (10)	7.7±0.9 (7)	6.5± .81 (4)		7.3±0.1
November	1967	8.3± .3 (11)	6.6±0.4 (13)			7.4±0.1
December	1967	8.7±1.8 (7)	6.6±1.6 (11)			7.4±0.1
January	1968	7.4± .5 (6)	8.3±0.3 (4)			7.8±0.2
February	1968	8.3±1.1 (13)	7.8±1.2 (15)	6.8±0.3 (7)		7.8±0.1
March	1968	8.4±1.3 (12)	8.4±0.8 (15)			8.4±0.1
April	1968	7.6±1.2 (10)	7.2±1.7 (8)			7.3±0.1
May	1968		10.7±0.2 (5)			10.7±0.2
June	1968	7.8±0.4 (30)	8.2±1.4 (33)	6.8±0.9 (4)		7.9±0.1
July	1968	8.0±0.7 (18)	5.9±1.0 (8)	6.8±0.4 (3)	7.7±.7 (3)	7.9±0.1
August	1968	7.2±3.3 (3)	7.3±2.3 (6)			7.3±0.1

of 266 channel catfish included 120 (45%) males, 125 (47%) females, and 21 (8%) unidentified.

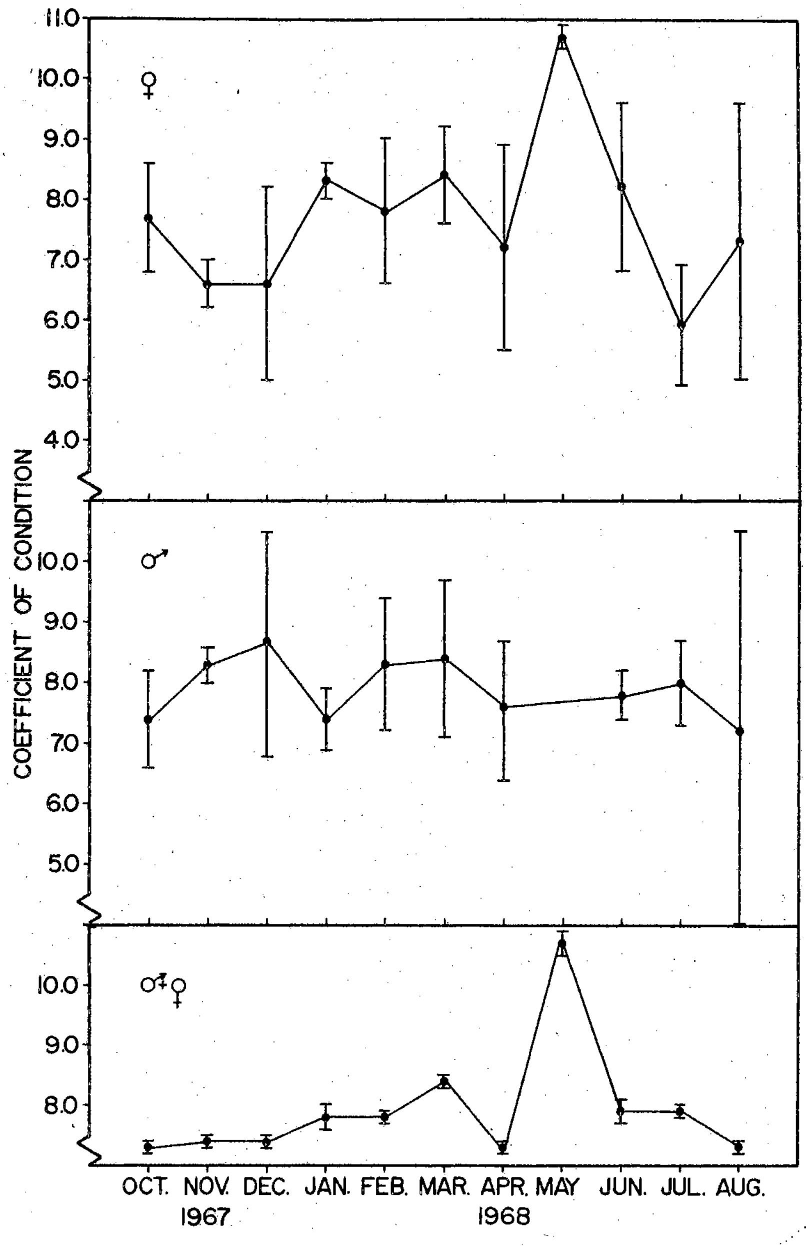
The seasonal variation in coefficient of condition for males and females is shown in Figure 6. There was no appreciable difference in K seasonally for males and no conspicuous seasonal trends. There was also no gross difference seasonally for males compared with females except during the spawning period. The curve representing the female coefficient of condition increased rapidly prior to spawning and declined sharply thereafter as did the gonadal-somatic index curve (Figure 5) for females. The K values with 95 percent confidence intervals for females increased from 7.2±1.7 in April to a peak of 10.7±0.2 in May and began sharply declining from 8.2±1.4 in June to its lowest 5.9±1.0 in July. There was a similar change in the combined sexes for seasonal change in the condition factors (Figure 6).

The mean condition factor for males, females, and unidentified channel catfish was 7.74±.27. This value fell below values of condition factors computed for the same size Oklahoma channel catfish, using the state wide length-weight values reported by Finnell and Jenkins (1954). Channel catfish in this study were also in poor condition as compared with values from Reelfoot Lake, Tennessee (Schoffman, 1967) and the Ponca and Plattsmouth section of the Missouri River (Russell, 1965).

Length-Weight Relationship

Calculation of total length-weight relationships for channel catfish from Lake Carl Blackwell were determined by combining both sexes since there was no apparent over all difference in condition factors for males and females. This also aided in obtaining as large a sample in each size group as possible.

Figure 6. Seasonal changes in channel catfish condition factor with 95% confidence intervals for males, females, and combined.



11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
♀
♂
♂+♀
COEFFICIENT OF CONDITION
OCT.
NOV.
DEC.
JAN.
FEB.
MAR.
APR.
MAY
JUN.
JUL.
AUG.
1967
1968

The length-weight relationship can be described by the following formula:

$$\log_e W = 13.63738 + 3.3239 \log_e L$$

where $W = .0000011949\ 72\ L^{3.3239}$

W = weight in grams

L = length in mm,

and $\log_e$ = natural logarithm.

The regression line was calculated by the method of least squares and the regression coefficient b was 3.323 which is close to 3. The value b = 3 indicates that the fish grew symmetrically or isometrically.

Table VI contains total length-weight relations for fish from 50 mm and 2 grams to 700 mm and 3408 grams in size. This table can be used to obtain a total length or weight value when only one is known.

Body-Spine Relationship

The body-spine relationship in this study was calculated from 255 channel catfish with an age range of I to XIII and a total length range of 170 to 686 mm. Both a linear and curvilinear regression were computed for these fish. The linear and the curvilinear regressions were significant at the 0.05 level and there was significant reduction due to the curvilinear term (Table VII).

The mathematical expression of the linear regression of the total body length in millimeters (L) on radius of the expanded edge of the left pectoral spine (X) in ocular units is: $L = 41.2 + 2.41X$ with a correlation coefficient (r) of .80. The curvilinear regression can be described as $L = 203.5 - .96X + .015X^2$. These equations are plotted in Figure 7. The linear regression was the body-spine relationship used for the back calculations.

TABLE VI

LENGTH-WEIGHT VALUES FOR CHANNEL CATFISH
FROM LAKE CARL BLACKWELL

Length (mm)	Weight (gms.)	Length (mm)	Weight (gms.)	Length (mm)	Weight (gms.)	Length (mm)	Weight (gms.)
80	2	182-183	39	224	77	261	128
81-88	3	184	40	225	78	262	130
89-95	4	185	41	226	80	263	132
96-101	5	186-187	42	227	81	264	133
102-106	6	188	43	228	82	265	135
107-111	7	189	44	229	83	266	137
112-115	8	190-191	45	230	84	267	138
116-119	9	192	46	231	86	268	140
120-122	10	193	47	232	87	269	142
123-126	11	194	48	233	88	270	144
127-129	12	195	49	234	89	271	145
130-132	13	196-197	50	235	91	272	147
133-135	14	198	51	236	92	273	149
136-138	15	199	52	237	93	274	151
139-140	16	200	53	238	94	275	153
141-143	17	201	54	239	96	276	155
144-145	18	202	55	240	97	277	156
146-148	19	203	56	241	98	278	158
149-150	20	204	57	242	100	279	160
151-152	21	205	58	243	101	280	162
153-154	22	206-207	59	244	103	281	164
155-156	23	208	60	245	104	282	166
157-158	24	209	61	246	105	283	168
159-160	25	210	62	247	107	284	170
161-162	26	211	63	248	108	285	172
163-164	27	212	64	249	110	286	174
165	28	213	65	250	111	287	176
166-167	29	214	66	251	113	288	178
168-169	30	215	67	252	114	289	180
170-171	31	216	68	253	116	290	182
172	32	217	69	254	117	291	184
173-174	33	218	71	255	119	292	186
175	34	219	72	256	120	293	188
176-177	35	220	73	257	122	294	191
178	36	221	74	258	123	295	193
179-180	37	222	75	259	125	296	195
181	39	223	76	260	127	297	197

TABLE VI (Continued)

Length (mm)	Weight (gms.)	Length (mm)	Weight (gms.)	Length (mm)	Weight (gms.)	Length (mm)	Weight (gms.)
298	199	344	321	390	488	436	706
299	202	345	324	391	492	437	712
300	204	346	328	392	496	438	717
301	206	347	331	393	500	439	723
302	208	348	334	394	505	440	728
303	211	349	337	395	509	441	734
304	213	350	340	396	513	442	739
305	215	351	344	397	517	443	745
306	218	352	347	398	521	444	750
307	220	353	350	399	526	445	756
308	223	354	353	400	531	446	762
309	225	355	357	401	535	447	767
310	227	356	360	402	539	448	773
311	230	357	364	403	544	449	779
312	232	358	367	404	548	450	785
313	235	359	370	405	553	451	791
314	237	360	374	406	557	452	796
315	240	361	377	407	562	453	802
316	242	362	381	408	567	454	808
317	245	363	384	409	571	455	814
318	247	364	388	410	576	456	820
319	250	365	391	411	581	457	826
320	253	366	395	412	585	458	832
321	255	367	398	413	590	459	838
322	258	368	402	414	595	460	844
323	261	369	406	415	600	461	850
324	263	370	409	416	604	462	856
325	266	371	413	417	609	463	863
326	269	372	417	418	614	464	869
327	272	373	421	419	619	465	875
328	274	374	424	420	624	466	881
329	277	375	428	421	629	467	888
330	280	376	432	422	634	468	894
331	283	377	436	423	639	469	900
332	286	378	440	424	644	470	907
333	288	379	443	425	649	471	913
334	291	380	447	426	654	472	920
335	294	381	451	427	659	473	926
336	297	382	455	428	664	474	933
337	300	383	459	429	669	475	939
338	303	384	463	430	675	476	946
339	306	385	467	431	680	477	952
340	309	386	471	432	685	478	959
341	312	387	475	433	690	479	966
342	315	388	479	434	696	480	972
343	318	389	484	435	701	481	979

TABLE VI (Continued)

Length (mm)	Weight (gms.)	Length (mm)	Weight (gms.)	Length (mm)	Weight (gms.)	Length (mm)	Weight (gms.)
482	986	528	1335	574	1762	621	2289
483	993	529	1343	575	1772	622	2301
484	1000	530	1352	576	1783	623	2314
485	1007	531	1360	577	1793	624	2326
486	1013	532	1369	578	1803	625	2338
487	1020	533	1377	579	1814	626	2351
488	1027	534	1386	580	1824	627	2363
489	1034	535	1395	581	1835	628	2376
490	1041	536	1403	582	1845	629	2388
491	1049	537	1412	583	1856	630	2401
492	1056	538	1421	584	1866	631	2414
493	1063	539	1430	585	1877	632	2427
494	1070	540	1439	586	1888	633	2439
495	1077	541	1447	587	1898	634	2452
496	1084	542	1456	588	1909	635	2465
497	1092	543	1465	589	1920	636	2478
498	1099	544	1474	590	1931	637	2491
499	1106	545	1483	591	1942	638	2504
500	1114	546	1492	592	1953	639	2517
501	1121	547	1501	593	1964	640	2530
502	1129	548	1510	594	1975	641	2543
503	1136	549	1520	595	1997	642	2557
504	1144	550	1529	596	2008	643	2570
505	1151	551	1538	597	2019	644	2583
506	1159	552	1547	598	2030	645	2596
507	1166	553	1557	599	2042	646	2610
508	1174	554	1566	600	2053	647	2623
509	1182	555	1576	601	2064	648	2637
510	1190	556	1585	602	2076	649	2650
511	1197	557	1595	603	2087	650	2664
512	1205	558	1604	604	2099	651	2678
513	1213	559	1614	605	2110	652	2691
514	1221	560	1623	607	2122	653	2705
515	1229	561	1633	608	2134	654	2719
516	1237	562	1643	609	2145	655	2733
517	1245	563	1652	610	2157	656	2747
518	1253	564	1662	611	2169	657	2761
519	1261	565	1672	612	2181	658	2774
520	1269	566	1682	613	2192	659	2789
521	1277	567	1692	614	2204	660	2803
522	1285	568	1702	615	2216	661	2817
523	1293	569	1712	616	2228	662	2831
524	1302	570	1722	617	2250	663	2845
525	1310	571	1733	618	2252	664	2859
526	1318	572	1742	619	2265	665	2874
527	1327	573	1752	620	2277	666	2888

TABLE VI (Continued)

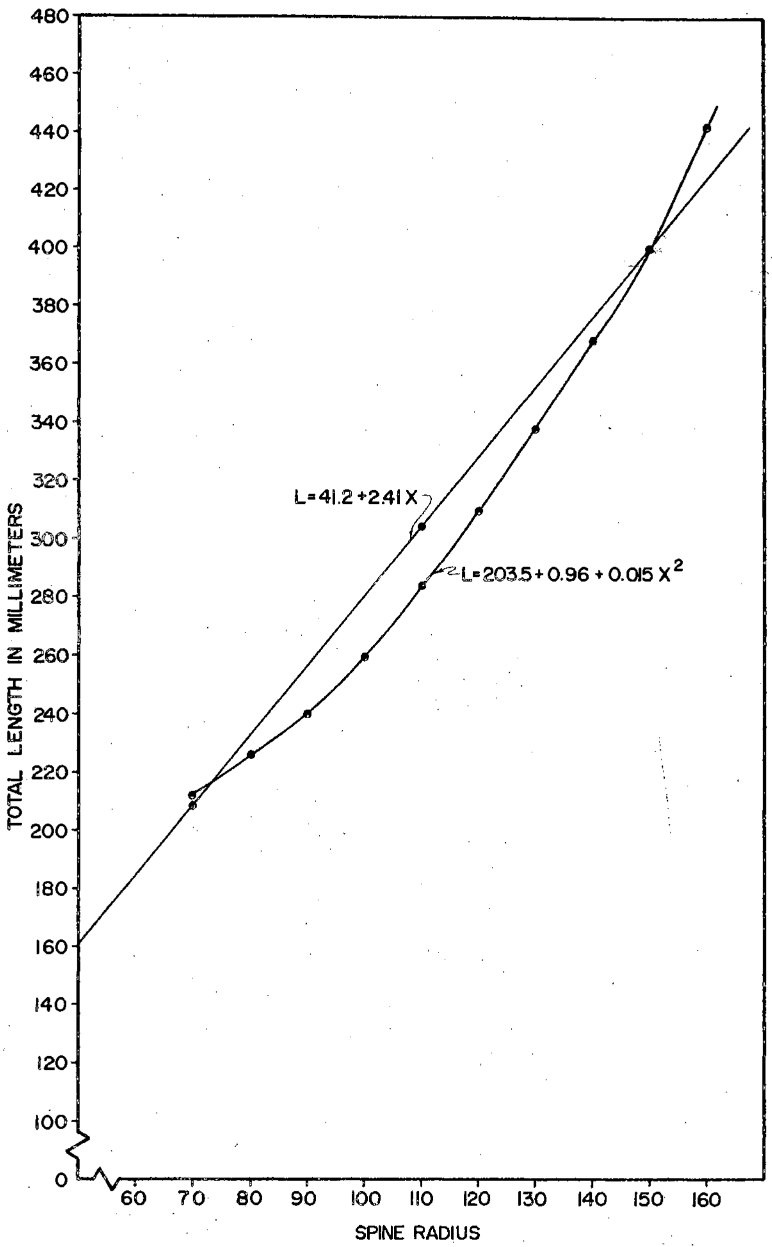
Length (mm)	Weight (gms.)	Length (mm)	Weight (gms.)	Length (mm)	Weight (gms.)	Length (mm)	Weight (gms.)
667	2903	676	3035	685	3171	693	3296
668	2917	677	3050	686	3187	694	3312
669	2932	678	3065	687	3202	695	3328
670	2946	679	3080	688	3218	696	3344
671	2961	680	3095	689	3233	697	3360
672	2976	681	3110	690	3249	698	3376
673	2990	682	3125	691	3265	699	3392
674	3005	683	3145	692	3280	700	3408
675	3020	684	3156				

TABLE VII

ANALYSIS OF VARIANCE FOR RELATIONSHIPS BETWEEN TOTAL LENGTH IN MILLIMETERS AND SPINE RADIUS IN OCULAR UNITS FOR CHANNEL CATFISH FROM LAKE CARL BLACKWELL

Source of variation	Degrees of freedom	F	Probability
Total	84		
Linear Regression	1	151.67	P < .005
Residual	83		
Curvilinear Regression	2	160.35	P < .005
Curvilinearity	1	60.43	P < .005
Residual	82		

Figure 7. Relation of spine radius in ocular units (X) to body lengths in millimeters (L).



L=41.2+2.41X
L=203.5+0.96+0.015X²
TOTAL LENGTH IN MILLIMETERS
SPINE RADIUS
480
460
440
420
400
380
360
340
320
300
280
260
240
220
200
180
160
140
120
100
0
60
70
80
90
100
110
120
130
140
150
160

The body-spine relationship has been described as a linear relationship by some and as a curvilinear relationship by others. Sneed (1951) found the body-spine relationship of channel catfish to be a straight line, but indicated that it could be curvilinear. Marzolf (1955), Morris (1960), and Russell (1965) found the relationship to be curvilinear. Sneed and Leonard (1956) found channel catfish in Lake Texoma, Oklahoma, to approximate a linear relationship between total length and radius of the ventral lip of the spine also.

Age and Growth

Calculated age and growth information was determined from cross-sections of the left pectoral spine of 255 channel catfish collected from Lake Carl Blackwell from October, 1967, to August, 1968. Measurements of the sections from the left pectoral spine were taken along the expanded edge (longest spine radius), using the method of Sneed (1951), Muncy (1959), and Russell (1965).

Back calculated values of lengths at earlier ages from the spine sections were computed as follows:

$$L_i = a \frac{S_i}{S} (L-a),$$

where L = length at capture

L_i = estimated length of fish at time of formation of annulus i

S = spine radius

S_i = spine radius to the end of the ith winter ring,

and a = hypothetical length of fish before the appearance of its spine estimated from intercept value of the linear body-spine regression.

Lengths were back calculated for individual fish by the above equation. The means for each age group separately for each year class were then computed and an unweighted mean was then calculated for these values. This was done separately for males and females and then for both sexes combined (Table VIII, X, and XII). The corresponding variances of these calculated lengths were also calculated (Tables IX, XI and XIII). Ricker (1969) indicated that few people take the trouble to compute the variance in length of the fish they are studying. He stated that frequently the pattern of variance in size at age in fish populations shows first an increase with age and later a decrease and that this might be indicative of compensatory growth. However, there was no pattern to the distributions of the variances present in these values.

The annual average calculated growth increments for all age groups are shown in Table VIII. As there was no obvious difference in growth between sexes the combined values will be discussed. It can be seen from Table VIII that there is a progressive increase in length in millimeters at each succeeding annulus. The fish grew faster in the older age groups. This could be due to selection of sampling gear which favored larger fish or to increased incidence of fish in the diet.

Fish between ages five and nine constituted 75% of the total number. In the present study 40% of the channel catfish were over 7 years old. Other investigators have reported that channel catfish seldom live longer than 7 years (Davis, 1959, Kansas; Finnell and Jenkins, 1954, Oklahoma). The 1962 year class (age group VI) was the most abundant single year class. Sneed and Leonard (1959) in their study of channel catfish from Lake Texoma, Oklahoma, reported that each successive year class showed a greater growth for each year of life than had the

TABLE VIII

MEAN CALCULATED TOTAL LENGTHS IN MILLIMETERS WITH 95% CONFIDENCE LIMITS OF CHANNEL CATFISH FROM LAKE CARL BLACKWELL

Year Class	Age Group	Number of Fish	Size at Annulus 1	2	3	4	5	6	7	8	9	10	11	12	13
1967	I	3	54 ± 19												
1966	II	2	73 ±165	110 ±135											
1965	III	6	71 ± 7	117 ± 28	152 ±19										
1964	IV	21	74 ± 3	116 ± 9	154 ± 5	181 ± 5									
1963	V	34	79 ± 4	122 ± 7	159 ± 7	187 ± 8	213 ± 9								
1962	VI	52	82 ± 3	123 ± 5	159 ± 5	187 ± 8	210 ± 9	235 ±10							
1961	VII	36	82 ± 3	136 ± 24	156 ± 7	189 ± 9	216 ±11	242 ±13	267 ±15						
1960	VIII	34	88 ± 4	129 ± 6	166 ± 7	199 ±10	230 ±13	260 ±16	288 ±19	313 ±22					
1959	IX	35	92 ± 5	129 ± 8	166 ± 7	206 ±10	238 ±12	267 ±15	297 ±19	328 ±22	358 ±24				
1958	X	18	100 ± 8	139 ± 11	181 ±13	213 ±12	242 ±15	270 ±20	304 ±25	336 ±31	373 ±41	407 ±47			
1957	XI	10	116 ± 10	151 ± 13	189 ±16	227 ±26	266 ±32	304 ±29	343 ±34	376 ±38	424 ±47	480 ±55	514 ±56		
1956	XII	1	134	153	195	220	254	293	335	360	433	517	601	635	
1955	XIII	3	135 ± 13	184 ± 25	227 ±18	269 ±28	302 ±31	341 ±58	371 ±43	403 ±17	445 ±50	484 ±19	535 ±41	576 ±47	617 ±99
Unweighed Means			91	134	173	208	241	277	315	353	407	472	550	606	617
Mean Annual Increment			91	43	39	35	33	36	38	38	54	65	78	56	11
Number of Fish			255	252	250	244	223	189	137	101	67	32	14	4	3

TABLE IX

VARIANCE OF CALCULATED LENGTHS IN MILLIMETERS OF CHANNEL CATFISH FROM LAKE CARL BLACKWELL

Year Class	Age Group	Number of Fish	Size of Annulus 1	2	3	4	5	6	7	8	9	10	11	12	13
1967	I	3	60												
1966	II	2	338	1625											
1965	III	6	39	699	335										
1964	IV	21	31	415	141	140									
1963	V	34	110	438	419	557	686								
1962	VI	52	145	311	348	756	1026	1354							
1961	VII	36	72	5106	432	683	1107	1518	1927						
1960	VIII	34	152	241	657	823	1294	2074	3018	3853					
1959	IX	35	173	467	686	811	1175	2047	2935	4040	4687				
1958	X	18	278	452	659	626	880	1665	2623	3796	6617	8754			
1957	XI	10	187	322	533	1357	1985	1680	2288	2894	4248	6001	6415		
1956	XII	1	0	0	0	0	0	0	0	0	0	0	0	0	
1955	XIII	3	104	50	103	132	161	558	301	49	409	58	273	361	1603

TABLE X

MEAN CALCULATED TOTAL LENGTHS IN MILLIMETERS WITH 95% CONFIDENCE LIMITS OF FEMALE CHANNEL CATFISH FROM LAKE CARL BLACKWELL

Year Class	Age Group	Number of Fish	Size at Annulus 1	2	3	4	5	6	7	8	9	10	11	12	13
1965	III	2	68 ±76	115 ±330	158 ±203										
1964	IV	5	78 ± 7	116 ± 21	151 ± 13	181 ±15									
1963	V	15	78 ± 4	120 ± 12	159 ± 12	190 ±14	215 ±15								
1962	VI	26	84 ± 6	125 ± 9	165 ± 9	195 ±14	219 ±16	244 ±19							
1961	VII	15	82 ± 4	117 ± 9	154 ± 11	186 ±13	214 ±16	241 ±20	262 ± 23						
1960	VIII	14	92 ± 9	132 ± 10	168 ± 12	203 ±18	238 ±24	267 ±30	296 ± 37	322 ± 43					
1959	IX	19	93 ± 7	130 ± 11	164 ± 13	207 ±12	240 ±16	272 ±24	300 ± 27	330 ± 31	357 ± 32				
1958	X	8	100 ±18	137 ± 20	184 ± 24	213 ±27	240 ±33	268 ±46	298 ± 54	332 ± 64	373 ± 81	402 ± 89			
1957	XI	3	107 ±20	134 ± 10	165 ± 30	199 ±17	243 ±13	281 ±96	333 ±180	356 ±187	385 ±203	432 ±201	464 ±223		
1956	XII	1	134	153	195	220	254	293	335	360	360	517	601	635	
1955	XIII	1	139	183	236	280	309	349	375	403	422	482	554	595	636
Unweighed Means			96	133	173	208	240	277	314	350	394	459	540	615	636
Mean Annual Increment			96	37	40	35	32	37	37	36	44	65	81	75	21
Number of Fish			0	0	109	107	102	87	61	46	32	13	5	2	1

TABLE XI

VARIANCE OF CALCULATED LENGTHS OF FEMALE CHANNEL CATFISH FROM LAKE CARL BLACKWELL

Year Class	Age Group	Number of Fish	Size at Annulus 1	2	3	4	5	6	7	8	9	10	11	12	13
1965	III	2	72	1352	512										
1964	IV	5	35	271	112	143									
1963	V	15	49	480	497	632	752								
1962	VI	26	165	431	451	1147	1585	2121							
1961	VII	15	57	280	423	551	829	1356	1642						
1960	VIII	14	222	311	419	914	1678	2717	4108	5424					
1959	IX	19	189	551	682	657	1116	2432	3053	4199	4461				
1958	X	8	471	561	828	1049	1553	3001	4179	5800	9349	11431			
1957	XI	3	64	14	145	48	26	1505	5250	5642	6643	6577	8017		
1956	XII	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1955	XIII	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE XII

MEAN CALCULATED TOTAL LENGTHS IN MILLIMETERS WITH 95% CONFIDENCE LIMITS OF MALE CHANNEL CATFISH FROM LAKE CARL BLACKWELL

Year Class	Age Group	Number of Fish	Size at Annulus 1	2	3	4	5	6	7	8	9	10	11	12	13
1965	III	3	70 ± 1	114 ±77	144 ±50										
1964	IV	5	75 ± 6	127 ±17	160 ±11	184 ±12									
1963	V	11	82 ± 10	131 ±15	165 ±15	190 ±18	214 ± 22								
1962	VI	24	81 ± 5	121 ± 6	152 ± 6	177 ± 7	201 ± 8	225 ± 10							
1961	VII	19	82 ± 4	146 ± 4	158 ±11	190 ±14	215 ± 19	241 ± 21	268 ± 23						
1960	VIII	16	88 ± 5	130 ± 6	168 ±10	202 ±15	233 ± 17	265 ± 22	293 ± 26	319 ±28					
1959	IX	14	94 ± 7	129 ±10	171 ±15	208 ±17	239 ± 19	267 ± 22	301 ± 28	333 ±35	368 ±39				
1958	X	10	101 ± 18	141 ±15	178 ±17	213 ±14	243 ± 15	372 ± 20	308 ± 29	340 ±36	374 ±52	410 ±63			
1957	XI	6	117 ± 14	154 ±14	195 ±19	237 ±43	279 ± 54	311 ± 49	339 ± 39	374 ±44	434 ±60	496 ±82	530 ±81		
1955	XIII	2	133 ±121	185 ±89	223 ±83	263 ±76	298 ±140	337 ±286	369 ±216	403 ±89	457 ±45	485 ±95	526 ±19	567 ±127	608 ±464
Unweighed Mean			92	138	172	207	240	274	313	354	408	464	528	567	608
Mean Annual Increment			92	46	34	35	33	34	39	41	54	56	64	39	41
Number of Fish			0	0	110	107	102	91	67	48	-32	18	8	0	2

TABLE XIII

VARIANCE OF CALCULATED LENGTHS OF MALE CHANNEL CATFISH FROM LAKE CARL BLACKWELL

Year Class	Age Group	Number of Fish	Size at Annulus 1	2	3	4	5	6	7	8	9	10	11	12	13
1965	III	3	0	972	408										
1964	IV	5	22	180	73	87									
1963	V	11	252	504	463	733	1096								
1962	VI	24	136	212	192	247	372	2384							
1961	VII	19	85	9309	496	872	1470	1865	2384						
1960	VIII	16	86	131	319	824	968	1676	2421	2885					
1959	IX	14	145	301	640	892	1074	1398	2573	3572	4544				
1958	X	10	158	409	582	365	450	799	1659	2627	5226	7618			
1957	XI	6	188	188	337	1701	2636	1945	1355	1708	3233	6064	5985		
1955	XIII	2	181	98	85	72	242	1013	578	98	25	113	5	200	2665

preceeding year class. Appleget and Smith (1951) reported that older fish grew more slowly and continuously through the growing season from the upper Mississippi River at Lansing, Iowa.

A comparison of the calculated total lengths in millimeters at each annulus for channel catfish from Lake Carl Blackwell with channel catfish from other bodies of water in Oklahoma and elsewhere can be seen in Table XIV. Lake Carl Blackwell, according to Finnell and Jenkins (1954), would be classified as an old reservoir over 500 acres. The calculated total length in millimeters for channel catfish from Lake Carl Blackwell at annulus one is equal to 91 as is annulus one for state-wide reservoirs in the same class. However, starting at annulus 2 through 14, total lengths are much lower for Lake Carl Blackwell. Beginning with annulus 4 through 10, the length in millimeters from old reservoirs over 500 acres is 100 mm or more greater than fish from the present study. At annulus 10 the two are not grossly different. It appears in Table XIV that channel catfish 10 years old and older from all waters are not grossly different except for small lakes and ponds in Oklahoma and Lake Moultrie in South Carolina which had a comparatively fast growth rate. Finnell and Jenkins (1954) reported that channel catfish grew faster in clear waters in Oklahoma. Channel catfish from Lake Carl Blackwell also fell below the state average between annulus 1 and annulus 12. Except for annulus 1 and 2, channel catfish from Lake Carl Blackwell fell below each the length at annulus for waters in all other states listed in Table XIV except Lake of the Ozarks, Missouri. Since the growing season is perhaps less in Iowa and South Dakota due to climate, one would expect the growth rate to be less than that for Lake Carl Blackwell in Oklahoma with a longer growing season. However, the channel

TABLE XIV

TOTAL LENGTH (MILLIMETERS) OF CHANNEL CATFISH FOR EACH YEAR OF LIFE BACK-CALCULATED FROM PECTORAL SPINE SECTIONS[a]

Water	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Lake Carl Blackwell, Okla.	91	134	173	208	241	277	315	353	407	472	550	606	617	
New Reservoirs over 500 acres[b,c]	116	274	335	444	525	522	642							
Old Reservoirs over 500 acres[c]	91	177	248	304	362	416	472	530	576	601	589	571	657	700
Large Lakes (111-500 acres)[c]	91	182	251	309	368	413	477	482	528	540	568	632	652	761
Small Lakes (5-110 acres)[c]	111	233	340	416	472	512	586	660	731	759	782	774		
Ponds (less than 5 acres)[c]	108	218	309	373	373	412	436	520	589	619	672	800		
Streams[c]	106	195	279	347	408	472	495							
Clear Reservoirs[c]	96	190	258	317	383	441	502	561	657	705	746			
Turbid Reservoirs[c]	75	152	213	261	309	357	421	479	467	497	510			
Oklahoma Average 1946-1954[c]	101	215	301	368	408	451	505	555	606	629	644	647		
Lake of the Ozarks, Missouri[d]	53	108	157	180	233	263	291	329						
Des Moines River, Iowa[e]	20	124	195	256	312	380	441	489	545	616	644	639	675	
Lewis and Clark Lake, Nebraska & South Dakota[f]	108	157	205	248	284	327	378	446	505					
Lake Moultrie and Sanctuary South Carolina[g]	86	185	284	368	441	530	601	665	726	771	795	840	902	890

[a]All values were given in inches by Miller (1966) and converted to millimeters from Conversion Tables, Lagler (1956) except values listed for Lake Carl Blackwell, Oklahoma.

[b]Reservoirs less than 4 years old at time of collection.

[c]Finnell and Jenkins, 1954.

[d]Marzolf, 1955.

[e]Muncy, 1959.

[f]Walburg, 1964.

[g]Stevens, 1959.

catfish from the bodies of water in these two states listed in Table XIV grew faster for each annulus except annulus 1 for the Des Moines River in Iowa.

A number of speculations can be listed as to why Lake Carl Blackwell has such a poor growth rate compared with Oklahoma and other state growth rates. The growth of channel catfish from Lake Carl Blackwell may be a reflection of a sparse food supply. This lake supports only a sparse flora, perhaps because of its high turbidity. The lake is almost devoid of rooted vegetation, thus reducing suitable habitat for invertebrates. Vegetation except for phytoplankton and materials digested beyond recognition, represented only 1% of the total food volume. Finnell and Jenkins (1954) reported that environmental factors, including age, turbidity and extent of successful reproduction, appeared to influence rate of growth more than the water area. The majority of poor-growing channel catfish populations were found in turbid waters with dense populations of catfish.

The greatest length increment occurred in the first year of life (Table VIII). The increment for the succeeding years was progressively smaller as Sneed (1951) and Sneed and Leonard (1959) found to be evident in Grand Lake, and Lake Texoma, respectively in Oklahoma. The second year had the greatest increment for channel catfish in the Mississippi River (Appleget and Smith, 1951). Such growth patterns may be due to seasonal conditions with longer growing seasons in warmer areas. The seasonal differences for different areas as well as yearly fluctuation in water levels in the same area may have marked effects on available food.

Channel catfish from the present study had a calculated unweighted mean total length of 91 millimeters for the first year of growth (Table IX). This was higher than that obtained by Appleget and Smith (1951) (74 mm) or Sneed (1951) (77 mm). However, the 91 mm was less than the 138 mm for average total length for all year classes obtained by Sneed and Leonard (1959) from Lake Texoma, Oklahoma.

Back calculated size at annulus for channel catfish from Lake Carl Blackwell gradually decreased in length starting from the older back calculated age group to the younger age groups (Table VIII). This is a reverse of Lee's phenomenon. Sneed (1951) calculated growth of channel catfish taken from Grand Lake, Oklahoma, from sections of the pectoral spine using an assumed straight line and also found an apparent reversal of Lee's phenomenon. Marzolf (1955) and Sneed and Leonard (1959) concluded from back calculated lengths that Lee's phenomenon was present to some degree. Appleget and Smith (1951) studied age and growth of channel catfish from the Mississippi River using vertebral markings and found no indication of Lee's phenomenon.

Lee's phenomenon has been the subject of many studies such as Graham (1929), Van Oosten (1929), Hile (1936), Bruyzgin (1963) and others. Ricker (1969) states that it was shown early that the possible causes are of three different types:

1. Technical--use of incorrect scale:body relations
2. Biased sampling
3. Selective mortality

After the study of effects of size-selective mortality and sampling bias on estimates of growth, mortality, production, and yield; Ricker (1969) indicated that sampling bias does not produce negative

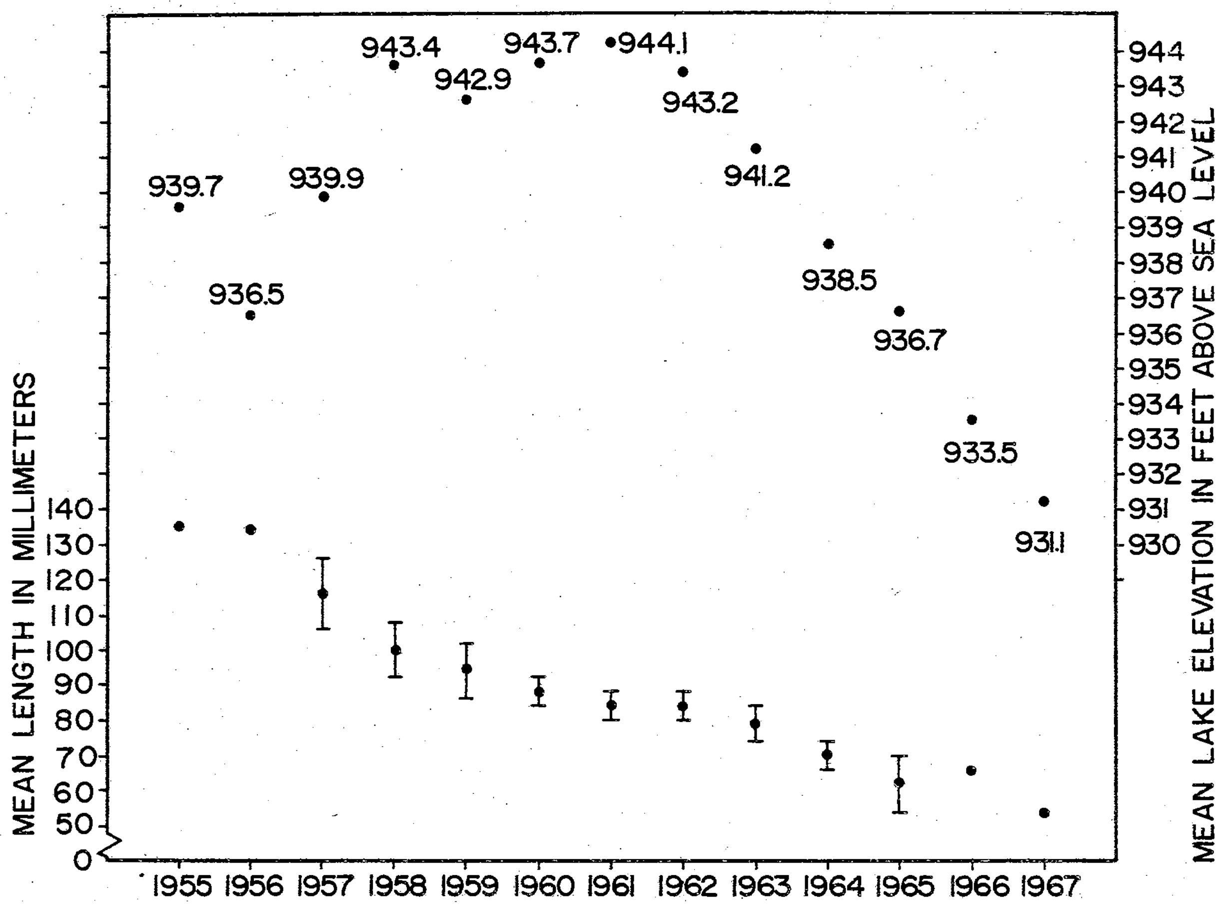
Lee's phenomenon (at any rate with likely patterns of growth and vulnerability to sampling gear). Thus any examples observed must reflect actual change, provided random variability is excluded as a cause.

Water level fluctuations have been reported as having some effect on fish growth. Stroud (1948) indicated that growth increases when water levels in the lake rise after the spawning period. In Greenwood Lake, Indiana, Johnson (1945) noted a retardation of crappie growth due to extremely low water levels.

The yearly averages of the water levels for Lake Carl Blackwell are given along with the mean calculated total length in millimeters for annulus 1 with 95% confidence intervals of age one for the corresponding year classes from 1955 through 1967 (Figure 8). The water level was at 944.05 ft. above mean sea level in 1961 which was the highest peak for the thirteen year span. Even though the water level increased from 939.87 ft. in 1957 to 943.70 ft. in 1960. The 944.05 ft. for 1961 is probably not representative of the true average water level for that year since there were only five months included in the average and three of these months (April, May and September) were months when rainfall is the greatest for the area of the lake location. The lake began decreasing in water level in 1961 and there was a deficit in rainfall for the years 1962 through 1968. The respective deficits in rainfall in inches for 1962 through 1968 were 5.74, 6.64, 5.53, 7.81, 8.08, 2.08, 2.97, 1.60. The lake was at its lowest level of 931.09 ft. in 1967 which was 13.08 feet below spillway elevation.

From Figure 8 it can be seen that there was an increase in length from 1967 to 1955 (the reverse of Lee's phenomenon) and an increase in water level from 1967 to 1958. A correlation coefficient was computed

Figure 8. Back-calculated mean length (mm) at age 1 with 95% confidence intervals for channel catfish from Lake Carl Blackwell for the 1955-1967 year class and annual mean, Lake Carl Blackwell, water elevations in feet above mean sea level from 1955-1967.



939.7
936.5
939.9
943.4
942.9
943.7
944.1
943.2
941.2
938.5
936.7
933.5
931.1
MEAN LENGTH IN MILLIMETERS
140
130
120
110
100
90
80
70
60
50
0
1955 1956 1957 1958 1959 1960 1961 1962 1963 1964 1965 1966 1967
944
943
942
941
940
939
938
937
936
935
934
933
932
931
930
MEAN LAKE ELEVATION IN FEET ABOVE SEA LEVEL

for yearly average lake level and year one mean calculated total length. The coefficient of correlation was 35.8 which was not significant at the 0.05 level. To have a significant correlation of that magnitude, it would be necessary to have 30 years of average water levels and mean fish lengths. It might be possible to obtain a larger correlation value by correlating mean lengths with seasons of the year and periods when food production is greatest. This should be the subject of further research.

CHAPTER IV

SUMMARY

The objective of this study was to compile data on the life history of the channel catfish, Ictalurus punctatus (Rafinesque) in Lake Carl Blackwell, Oklahoma, to provide information for the better management of this species to improve the sport fishery in this and similar bodies of water.

Channel catfish were collected from October, 1967, through August, 1968. The major portion of the fish were collected by the use of gill nets and to a lesser extent by the use of a Great Lakes trap net, barrel traps, wire traps, rotenone cove samples and electrofishing.

An attempt was made to collect mature channel catfish, channel catfish eggs and/or yearling channel catfish by a can sampling technique. This method proved to be unsuccessful. The potential for success was possibly reduced, due in part to a high incidence of vandalism and can removal.

The major foods by frequency of occurrence were insects, fish and detritus (Table I). By number insects had an occurrence of 79.1% with chironomid larvae and mayfly niads being most abundant. There was a distinct seasonal cycle in the percent frequency of occurrence of invertebrates present in stomach contents analyzed. The frequency of occurrence of invertebrates increased during the spring and summer reaching a peak of 99% in June.

Fish in the stomachs showed no monthly cycle in frequency of occurrence. A peak in the first quarter was due to relatively large channel catfish caught during January, February, and March. At approximately 300 mm the channel catfish became progressively more dependent on a diet of fish. Identifiable and unidentifiable fish occurred in all seasons and in all size groups, with whole eaten fish occurring in larger size groups. Fish represented 87% of the total volume of food contents in stomachs analyzed (Table I). Gizzard shad, Dorosoma cepedianum, was the most utilized fish accounting for 33.6% of the total volume.

The stomach contents were analyzed according to length classes. Length classes up to 320 mm were dominated by insects whereas larger length classes contain higher percentages of fish. This is in agreement with other studies and as was pointed out by Busbee (1968), no size class analyzed was found to contain a predominance of any one food type including those size classes found to be piscivorous.

The mean condition factor for combined sexes was 7.74±.27 which fell in the lower range for the same size fish for state-wide length-weight values reported by Finnell and Jenkins (1954). Channel catfish in this study as compared with state-wide and some out-of-state condition factors appeared to be in poor condition. Females showed a seasonal change in gonadal-body weight index with 7.35% being its highest peak. Males however, perhaps due to the small percentage of mature males in the sample, had a gonosomatic ratio of low magnitude through the study. The low magnitude of gonosomatic ratios in males indicates that gonadal development apparently exerted little influence on general body conditions.

Based on seasonal changes in the gonosomatic ratio, condition factors for females, egg counts, observations of sexual dimorphism, and spent females the spawning period of channel catfish in Lake Carl Blackwell was assumed to have occurred from late May to the middle of June.

Fecundity estimates were made from 20 females collected from March through June, 1968, with ages ranging from V to XI. Linear and curvilinear regressions were computed for egg number versus total length and egg number versus weight. Egg number increased with increase in length and both regressions were found significant at the 0.05 level. The egg number did not increase significantly with increase in body weight. This failure was assumed to be indicative of the time ovaries were collected as some of the older and heavier fish were taken in early development stages of the ovaries. The mean number of eggs for these 20 fish was 13,777 with a range of 1,052 to 64,629.

Since there were no appreciable difference in condition factors for males and females, the length-weight relationship was calculated by combining both sexes. The resulting equation was

$$\log_e W = -13.63738 + 3.3229 \log_e L$$

A linear and curvilinear regression of body length on spine radius was computed for the body-spine relationship using 255 channel catfish. The linear and the curvilinear regressions proved to be significant at the 0.05 level and there was a significant reduction due to the curvilinear term. The linear equation:

$$L = 41.2 + 2.4\ X$$

was used in the back calculations in this study.

Age and growth determinations were made from measurements of cross-sections from the left pectoral spines of 255 channel catfish. Lengths were back calculated for individual fish, the means for each age group separately for each year class were then computed and an unweighted mean was calculated for these values.

There was no obvious difference in growth between sexes. Fish grew faster in older age groups. The largest percentage of fish aged fell between five and nine years. Growth of channel catfish from Lake Carl Blackwell fell below the state average and also below the range of most out-of-state bodies of water (Table XIV). But average length at the end of the first year of life was higher than several other locations in Oklahoma except Lake Texoma.

Back calculated size at annulus gradually decreased in length starting from the older back calculated age groups to the younger age groups (Table IX); thus, appearing in the reverse form of Lee's phenomenon.

Poor growth and the reversal of Lee's phenomenon was perhaps due to a number of unfavorable biotic and abiotic conditions prevalent during the life span of the fish used for this study including a continually decreasing water level.

Future management investigations should be aimed at improving the growth rate of channel catfish in Lake Carl Blackwell to provide larger size fish in the most abundant age groups.

LITERATURE CITED

Adams, L. A. 1942. Age determination and rate of growth of *Polydon spathula* by means of growth rings on the otoliths and dentary bone. Amer. Midland Natur. 28(3):617-630.

Appelget, J., and L. L. Smith, Jr. 1951. Determination of age and rate of growth of channel catfish (*Ictalurus lacustris punctatus*) of the Upper Mississippi River from vertebrae. Trans. Amer. Fish. Soc. 80:119-139.

Bailey, R. M., and H. M. Harrison, Jr. 1948. Food habits of the southern channel catfish (*Ictalurus lacustris punctatus*) in the Des Moines River, Iowa. Trans. Amer. Fish. Soc. 75:110-138.

Barney, R. L. 1925. A confirmation of Borodin's scale method of age determination of Connecticut River shad. Trans. Amer. Fish. Soc. 54:168-177.

Barnickol, P. G., and W. C. Starret. 1951. Commercial and sport fishes of the Mississippi River between Caruthersville, Missouri, and Dubuque, Iowa. Bull. Ill. Nat. Hist. Surv. 25(5):267-350.

Berner, L. M. 1947. A limnological survey of the Missouri River from its mouth to the Iowa State line during the summer of 1945. Master's Thesis. Univ. of Missouri. 167 p.

Brown, L. 1942. Propagation of the spotted channel catfish (*Ictalurus lacustris punctatus*). Kan. Acad. Sci., Trans. 45:311-314.

Brown, B. E. 1965. A two year study of a bass-channel catfish population exposed to flooding and angling. Proc. S. E. Assoc. Game and Fish. Comm. 17:367-372.

Bruner, W. E. 1931. The vegetation of Oklahoma. Ecol. Monogr. 1:99-188.

Bruyzgin, V. L. 1963. Methods of studying growth of fishes using scales, bones and otoliths. Vopr. Ikhtiol. 3:347-365. (In Russian) Fish. Res. Bd. Can. Transl. 553.

Busbee, R. L. 1968. Piscivorous activities of the channel catfish. Prog. Fish-Cult. 31(1):32-34.

Carlander, K. D. 1950. Handbook of freshwater fishery biology. W. C. Brown Co., Dubuque, Iowa. 281 p.

________. 1953. First supplement to handbook of freshwater fishery biology. W. E. Brown Co., Dubuque, Iowa. p. 281-429.

Carlton, W. G., and W. B. Jackson. 1964. The use of spines for age determination of fish. Turtox News. 42(11):282-283.

Chugunov, N. L. 1926. Determination of the age and growth rates of fishes by the bones. Siberian Ichthy. Lab. 3372. Krasnoyarsk.

Classen, T. E. A. 1944. Age and rate of growth of the sturgeon. Age at sexual maturity. Section VIII of: Estudio Rio-Estadistico del Esturion O Sollo del Guadalquivie, Aeipenser sturio L. Institute Espanol de Oceanografia, Madrid. Trabajo. Numero 19. 1944:52-70.

Clemens, H. P. 1954. Pre-impoundment study of summer food of three species of fishes in Tenkiller and Fort Gibson Reservoirs, Oklahoma. Okla. Acad. Sci. Proc. 33:72-79.

________., and K. E. Sneed. 1957. The spawning behavior of the channel catfish, Ictalurus punctatus. U.S.D.I. Spec. Sci. Rep. Fish. 219. 11 p.

Cross, F. B. 1967. Handbook of the fishes of Kansas. Univ. Kan. Mus. Nat. Hist., Misc. Publ. 21. 156 p.

Cuerrier, J. P. 1951. The use of pectoral fin rays for determining age of sturgeon and other species of fish. Can. Fish Cult. 11:1-9.

Cunningham, J. T. 1905. Zones of growth in the skeletal structures of Gadidae and Pleuronectidae, p. 125-140. 23rd Annual Report 1904. Part III. Fish. Bd. Scotland.

Davis, J. T., and L. E. Posey, Jr. 1958. Length at maturity of channel catfish in Louisiana. Proc. S. E. Assoc. Game and Fish. 12:72-75.

Davis, O. 1959. Management of channel catfish in Kansas. Univ. Kan. Mus. Nat. Hist., Misc. Publ. 21. 156 p.

Deacon, J. E. 1959. Biology of the flathead catfish in Kansas. Trans. Amer. Fish. Soc. 88:344-355.

DeRoth, G. C. 1965. Age and growth studies of channel catfish in Western Lake Erie. J. Wildl. Manage. 29(2):280-286.

Dill, W. A. 1944. The fishery of the lower Colorado River. Calif. Fish and Game 30(3):109-211.

Eddy, S., and T. Surber. 1947. Northern fishes with special reference to the upper Mississippi Valley. Univ. Minnesota Press. Minneapolis, Minn. 276 p.

Finnell, J. C., and R. M. Jenkins. 1954. Growth of channel catfish in Oklahoma water. Okla. Fish. Res. Lab. Rep. No. 41. 37 p.

Forbes, S. A., and R. E. Richardson. 1920. The fishes of Illinois. Ill. Nat. Hist. Surv. 136:357.

Geibel, G. E., and P. J. Murray. 1961. Channel catfish culture in California. Prog. Fish-Cult. 23(3):99-105.

Graham, M. 1929. Studies of age determination in fish. Part II. A survey of the literature. Fish. Invest. London. (Ser. 2) 11:1-50.

Hall, G. E., and R. M. Jenkins. 1954. The rate of growth of channel catfish Ictalurus punctatus, in Oklahoma waters. Okla. Acad. Sci., Proc. 33:121-128.

Hankinson, T. L. 1908. A biological survey of Walnut Lake, Michigan. Mich. State Biol. Surv. Rep. for 1907. 156-288 p.

Harlan, R. H., and E. B. Speaker. 1956. Iowa fish and fishing. Iowa State Cons. Comm. 377 p.

Heard, W. R. 1959. Cotton rats, Sigmodon hispidus, as food of channel catfish, Ictalurus punctatus. Okla. Acad. Sci., Proc. 39:200-201.

Hile, R. 1936. Age and growth of the cisco, Leucichthys artedii (LeSueur), in the lakes of the Northeastern Highlands, Wisconsin. U. S. Bur. Fish. Bull. 48:211-317.

Hooper, F. F. 1949. Age analysis of a population of the ameiurid fish, Schilbeodes mollis. Copeia. 1949. (1):34-38.

Hoopes, D. T. 1960. Utilization of mayflies and caddis flies by some Mississippi River fishes. Trans. Amer. Fish. Soc. 89(1):32-34.

Houser, A. 1960. A collapsible nylon fish trap for pond sampling. Prog. Fish-Cult. 22:129-133.

Hubbs, C. L., and K. F. Lagler. 1958. Fishes of the Great Lake region. Cranbrook Inst. Sci., Bull. 26:213 p.

Ihm, W. J. 1968. Mounting fish spine sections rapidly and permanently. Prog. Fish-Cult. 30(1):46.

Jenkins, R. M., and E. M. Leonard. 1954. Initial effects of impoundment on the growth-rate of channel catfish in two Oklahoma Reservoirs. Okla. Acad. Sci., Proc. 33:79-86.

Jenkins, R. M., E. M. Leonard, and G. E. Hall. 1952. An investigation of the fisheries resources of the Illinois River and preimpoundment study of Tenkiller Reservoir, Oklahoma. Okla. Fish. Res. Lab. Rept. 26, 136 p. (mimeo).

Johnson, W. L. 1945. Age and growth of the black crappie of Greenwood Lake. Invest. Ind. Lakes and Streams. 2:298-324.

Jordan, D. S., and B. W. Everman. 1896. The fishes of north and middle America. U. S. National Mus., Bull. 47. 954 p.

Kuhne, E. R. 1939. A guide to the fishes of Tennessee and the Mid-South. Tenn. Dept. Cons., Div. Fish and Game, Nashville. 124 p.

Lenz, G. 1947. Propagation of catfish. Prog. Fish. Bult. 9(4):231-233. Reprint from Outdoor Nebraska, 25(1):4-6. 1947.

Leonard, E. M., and K. E. Sneed. 1951. Instrument to cut catfish spines for age and growth determinations. Prog. Fish-Cult. 13(4):232.

Lewis, W. M. 1949. The use of vertebrae as indicators of the age of the northern black bullhead, <u>Ameiurus melas melas</u>. Iowa State Coll. J. Sci. 13:209-218.

McCamman, G. W., and D. A. LaFaunce. 1961. Mortality rates and movement in the channel catfish population of the Sacramento Valley. Calif. Fish and Game. 47(1):5-26.

Marzolf, R. C. 1955. Use of pectoral spines and vertebrae for determining age and rate of growth of the channel catfish. J. Wildl. Mgmt. 19(2):243-249.

________. 1957. The reproduction of channel catfish in Missouri ponds. Jour. Wildl. Mgmt., 21(1):22-28.

Miller, E. E. 1966. Channel catfish p. 440-463. In A. Calhoun (ed.) Inland Fisheries Management. Dept. of Fish and Game, California.

Moen, T. 1959. Sexing of channel catfish. Trans. Amer. Fish. Soc. 88:149.

Moore, G. A. 1957. Fishes, pp. 31-210. In W. F. Blair, A. P. Blair, P. Brodkorb, F. R. Cagle, and G. A. Moore. Vertebrates of the United States. McGraw-Hill Book Co., Inc. New York. 819 p.

Morris, J. W. 1960. Growth of the channel catfish in the Platte River Nebraska. Master's Thesis, Univ. of Missouri. 59 p.

Muncy, R. J. 1959. Age and growth of channel catfish from the Des Moines River, Boone County, Iowa, 1955 and 1956. Iowa St. J. Sci. 34(2):127-137.

Murphree, J. M. 1940. Channel catfish propagation. T. J. Rennick. (Private Printing). 24 p.

Norton, J. R. 1968. The distribution, character, and abundance of sediments in 3000-acre impoundment in Payne County, Oklahoma. Master's Thesis, Oklahoma State University. 77 p.

Perry, W. G. 1969. Food habits of blue and channel catfish collected from a brackish-water habitat. Prog. Fish-Cult. 31(1):47-50.

Ricker, W. E. 1969. Effect of size-selection mortality and sampling bias on estimates of growth, mortality, production, and yield. J. Fish. Res. Bd. Can. 26(3):479-541.

Russell, T. R. 1965. Effects of channelization on the limnology of the Missouri River, Nebraska, with emphasis on food habits and growth of the channel catfish. Master's Thesis, Univ. of Missouri. 144 p.

Saksena, V. P., K. Yamamoto, and C. D. Riggs. 1961. Early development of the channel catfish. Prog. Fish-Cult., 23(4):156-160.

Schafer, H., P. L. Posey, and G. Davidson. 1966. The use of cans in harvesting catfish. Proc. S. E. Assoc. Game and Fish Comm. 19:210-216.

Schoffman, R. J. 1967. Age and rate of growth of the channel catfish in Reelfoot Lake for 1960 and 1966. J. Tenn. Acad. Sci. 42(1):12-14.

Scholl, R. 1968. A rapid decalcifying method for sectioning channel catfish pectoral spines. Trans. Amer. Fish. Soc. 97(2):210-211.

Shebley, W. H. 1917. History of the introduction of food and game fishes into the waters of California. Calif. Fish and Game, 3(1):3-12.

Sneed, K. E. 1951. A method for calculating the growth of channel catfish, Ictalurus lacustris punctatus. Trans. Amer. Fish. Soc. 80:174-183.

________., and E. M. Leonard. 1959. Age and growth of the channel catfish Ictalurus punctatus, in Lake Texoma. Okla. Acad. Sci. 37:73-78.

Speirs, J. M. 1952. Nomenclature of the channel catfish and the burbot of North America. Copeia 1952(2):99-102.

Stevens, R. E. 1959. The white and channel catfishes of the Santee-Cooper Reservoir and tailrace sanctuary. Proc. S. E. Assoc. Game and Fish. Comm. 13:203-219.

Stroud, R. H. 1948. Growth of basses and black crappie in Norris Reservoir Tennessee. J. Tenn. Acad. Sci. 23(1):31-99.

Swingle, H. S. 1954. Fish populations in Alabama rivers and impoundments. Trans. Amer. Fish. Soc. 83:47-57.

Taylor, W. R. 1954. Records of fishes in the John N. Lowe Collection from the upper Peninsula of Michigan. Misc. Publ. Mus. Zool. Univ. Mich. 87:1-50.

Tiemeier, O. W., and J. B. Elder. 1960. Growth of stunted channel catfish. Prog. Fish-Cult. 22(4):172-176.

Trautman, M. B. 1957. The fishes of Ohio. Waverly Press, Inc. Baltimore, Maryland. 683 p.

Van Oosten, J. 1929. Life history of lake herring, Leucichthys artedii (LaSueur) of Lake Huron, as revealed by its scales, with a critique of the scale method. U. S. Bur. Fish. Bull. 44:265-448.

Walburg, C. H. 1964. Fish population studies, Lewis and Clark, Missouri River, 1956 to 1962. U. S. Fish and Wild. Service, Spec. Sci. Rep. 482:27 p.

Witt, A., Jr. 1961. An improved instrument to section bones for age and growth determination of fish. Prog. Fish-Cult. 23(2):94-96.

VITA

Ambrose Jearld, Jr.

Candidate for the Degree of

Master of Science

Thesis: FECUNDITY, FOOD HABITS, AGE AND GROWTH, LENGTH-WEIGHT RELATIONSHIPS AND CONDITION OF CHANNEL CATFISH, _ICTALURUS PUNCTATUS_ (RAFINESQUE), IN A 3300-ACRE TURBID OKLAHOMA RESERVOIR

Major Field: Zoology

Biographical:

Personal Data: Born in Annapolis, Maryland, March 6, 1944, the son of Ambrose Jearld, Sr. and Katherine Marie Smith Jearld.

Education: Graduated from Wiley H. Bates High School, Annapolis, Maryland, 1961; received Bachelor of Science in Biological Science degree, Maryland State College, a Division of the University of Maryland at Princess Anne, Maryland, May, 1965; completed requirements for the Master of Science degree in May, 1970, at Oklahoma State University, Stillwater, Oklahoma.

Professional experience: September, 1963, to May, 1964, September, 1964, to May, 1965, Laboratory Assistant, Maryland State College, a Division of the University of Maryland at Princess Anne, Maryland; September, 1965, to August, 1967, Analytical Chemist, Publickers Industry, Inc., Philadelphia, Pennsylvania; September, 1967, to July, 1969, Graduate Research Assistant, Oklahoma Cooperative Fishery Unit.

Membership: American Fisheries Society