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SUBPOPULATIONS OF WHITE BASS,

MORONE CHRYSOPS (RAFINESQUE),

IN LAKE TEXOMA

A DISSERTATION

SUBMITTED TO THE GRADUATE FACULTY

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degree of

DOCTOR OF PHILOSOPHY

By

RAYMOND EUGENE BAGLIN, JR.

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SUBPOPULATIONS OF WHITE BASS,

MORONE CHRYSOPS (RAFINESQUE),

IN LAKE TEXOMA

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SUBPOPULATIONS OF WHITE BASS,

MORONE CHRYSOPS (RAFINESQUE),

IN LAKE TEXOMA

CHAPTER I

INTRODUCTION

The white bass, *Morone chrysops* (Rafinesque), is a member of the temperate zone bass family Percichthyidae. This family was recently separated from the bass family Serranidae (Gosline, 1966). Darlington (1963) believes that freshwater white bass populations have been derived locally from migrating or fully marine ancestors.

White bass are abundant in Lake Texoma, one of the largest man-made lakes in the world, an impoundment of the Red and Washita rivers. White bass are native to the Red River (Jenkins and Elkins, 1957), and probably have occurred in the Washita River for an extensive period of time, although there is no record of this according to the University of Oklahoma Biological Survey. The natural distribution of the white bass ranges from the Great Lakes to the Mississippi River drainages but this range has been extended by stocking and by formation of numerous impoundments. In Oklahoma, 19 reservoirs have been stocked with white bass from 1938-1966 (unpublished data, Ricardo Gomez, Oklahoma Conservation Department).

Fish production in many reservoirs declines markedly after the first few years of existence (Ellis, 1937). The white bass has proven to be a valuable species in that it often maintains a sport fishery in older reservoirs as the initial high production of game fishes declines. According to Jenkins (1957), harvest estimates for 1955 showed that about three million white bass, weighing approximately 1,134 metric tons, were taken in Oklahoma. This was equal to about 15% of the number and 20% of the weight of all fish caught in Oklahoma. Jenkins also reported that in 1955, sport fishermen spent about $7 million in catching white bass. Jenkins (1970) estimated that expenditures by fishermen would exceed $600 million annually on large reservoirs, and that one-fourth of all freshwater fishing now occurs on man-made lakes, such as Texoma. He further predicted that about 550,000 angler days would be spent on Lake Texoma in 1972 (personal communication).

The white bass is a fast-growing, relatively short-lived fish with a high reproductive potential; therefore, a high harvest rate is deemed desirable. Thus, Oklahoma's management policy concerning the white bass has been to allow no length, creel, or season limit. An annual harvest of approximately 10% of the Lake Texoma white bass population was indicated by return records of a tagging study (Bonn, 1956). An intensive tagging study conducted on a state-wide basis by the Oklahoma Wildlife Department and the Schlitz Brewing Company should produce additional data on this species.

To date, there has been no published work determining whether races or subpopulations of white bass are present in Lake Texoma.

Racial studies are important since thay provide information on the extent of migrations and interbreeding occurring between populations. Each population has its own separate distribution, fecundity, natural mortality, growth rate, and other biological features. It is important, therefore, to measure changes and fluctuations in populations, but it is necessary to know the characteristics first. As exploitation of the white bass increases, it will become increasingly important to know if catches are coming from a single population or several subpopulations, so that appropriate management strategy can be implemented prior to a failure of the fishery.

Lake Texoma presents a rather unique situation. It is a large reservoir formed by two rivers. Although the rivers are similar thermally, some chemical and physical parameters differ markedly. White bass are known to spawn in both rivers, thus presenting the opportunity to evaluate the effect of spawning segregation on subpopulation development. Since the white bass has a well developed homing behavior (Horrall, 1961), a spawning isolating mechanism is present which could facilitate the process of subpopulation development.

The purpose of this study was to investigate selected characteristics of spawning aggregations of white bass to determine their degree of heterogeneity prior to determining whether subpopulation development has occurred. In carrying out this study, several fish collections were made prior to spawning to assure that there was no bias in sampling due to segregation by age, size, or sex. Since different subpopulations may mingle in feeding areas, it was paramount to collect fish on their spawning runs for subpopulation analysis.

The following parameters were examined to determine whether subpopulations of white bass were present in Lake Texoma: fecundity, measurements, counts, age, growth, and blood protein analysis. These parameters were selected as they have proven to be useful in separating subpopulations of fish. In addition, water analysis, sex ratio, and spawning were studied.

CHAPTER II

MATERIALS AND METHODS

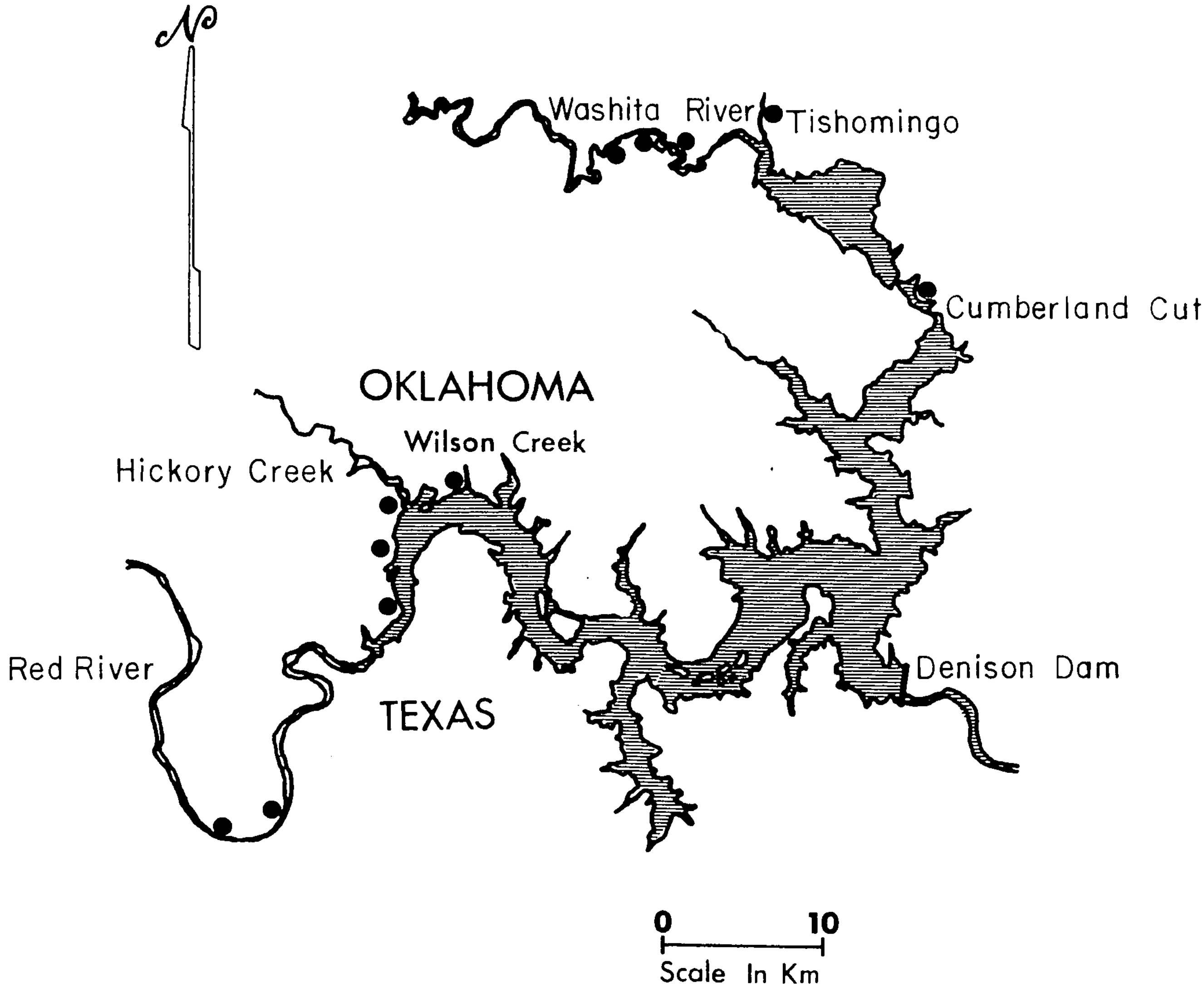
Description of Study Area

In 1942, Lake Texoma, an impoundment of the Red and Washita rivers, was formed for flood control, hydroelectric power, and recreation. The Lake lies in Cooke and Grayson counties in Texas, and in Love, Marshall, Johnson, and Bryan counties in Oklahoma. At power pool level, Texoma has a surface area of over 36,423 ha, or 90,000 acres (Dover, Leonard, and Laine, 1968). It is divided into two major arms, the Red River and the Washita River (Fig. 1). The Red River Arm is characterized by turbid, shallow water from Wilson Creek to Hickory Creek. The Washita River Arm at Cumberland Cut is characterized by deep, clear water. The Lake usually remains unstratified because it is shallow and unprotected from the wind. Additional information is given in Sublette (1953), and U. S. Army Corps of Engineers pamphlets (1948, 1961).

Collection Procedure

A total of 1,743 white bass was collected from September 1969 through July 1972. Of these, 762 were from the Red River Arm and 910

Figure 1. Schematic representation of Lake Texoma and designated sampling sites within the two river systems of the reservoir.


Washita River
Tishomingo
Cumberland Cut
OKLAHOMA
Wilson Creek
Hickory Creek
Red River
TEXAS
Denison Dam
0
10
Scale In Km

were from the Washita River Arm of the Lake.

Gill nets from 1.5 inch to 2 inch bar-mesh were the main gear used. An electroshocker mounted on a 14 ft flatbottom boat with a 220 v generator also was used. Seining and angling were other methods of capture.

After capture, fish were measured for total length to the nearest millimeter, blotted dry, and weighed to the nearest gram. Gonads were removed, and also blotted dry and weighed to the nearest gram. Fish and gonads were labeled and preserved in 10% formalin. Scale samples were taken from under the tip of the left pectoral fin and stored in coin envelopes. Later six scales from each fish were mounted between two glass slides, and projected on a standard micro-projector with a magnification of 32 diameters, and age was determined for a total of 497 fish by counting annuli as year marks.

Water Analysis

The physical-chemical conditions of each study area were analyzed. Water samples were taken from each arm of the reservoir, and transported on ice to the lab where a Hach model DR-EL portable water engineer's kit was used to determine some selected chemical properties of the water, e.g., alkalinity, salinity, hardness, pH, conductivity, and turbidity. A model RC16B2 conductivity bridge was used to measure electrolytic conductance. Water temperature was taken at about 0.3 m (1 ft) below the surface.

Sex Ratios and Spawning

The sex was determined for 1,540 white bass, 642 from the Red

River, and 898 from the Washita River. Immature fish were sexed by removing a thin cross sectional slice from the gonad and placing it on a glass slide with a drop or two of aceto-orcein, and a cover slip was then added. This technique allowed the detection of immature ova in the females. Mature males could readily be identified by having milt extrude from them after exerting a slight press on their abdomen. Mature females were hard and full in shape. Also, as noted by Sigler (1949), females have separate openings for the genital ducts and urinary tracts. Males have a common urogenital pore.

The number of males and females moving up and down each river was recorded for some gill net collections. The fish from each area were divided into three categories - spawning, non-spawning, and total collected, and a chi-square test was conducted to determine whether there was any significant deviation from an expected 1:1 sex ratio.

An attempt was made to induce spawning in 0.1 ha (¼ acre) holding ponds at the University of Oklahoma Fisheries Research Center at Noble, Oklahoma. A total of 7 Red River (at Hickory Creek), and 86 Washita (at Cumberland Cut) white bass, collected by electroshocker on April 4, 1970, were transported to Noble. Of the Red River fish, four were males and three were females. These were placed together in a holding pond. All the Washita River white bass collected for this experiment were males, and were stocked in a separate pond. On April 19, 1970, 46 females were collected from the Washita River, transported to the Fisheries Research Center, and added to the pond containing males which had been previously collected. The fish were fed goldfish, small carp, and minnows.

Some mature fish were removed from the ponds and placed in concrete tanks at the University of Oklahoma Insectory Building. Ten mg/454 g body weight of a suspension of carp pituitary powder (10 mg/ml in distilled water) was injected daily into the peritoneal cavity of adult fish to induce spawning. Normally, two days of injecting were sufficient. The fish were transferred to a constant temperature room set at 13 C. Eggs were stripped from the female white bass and collected in clean plastic bowls. Milt from two or three males was then added. The contents were then gently mixed with a paint brush and a few drops of filtered pond water were added to activate the sperm. More water was added and the contents were spread out in a porcelain pan with the paint brush. The water was either aerated with an air pump or oxygen was added by use of an oxygen cylinder.

In an attempt to collect larval white bass from both rivers, eggs were taken from ripe fish and fertilized in a manner similar to the one previously described but wide mouth gallon jars were used. The eggs readily adhered to the glass. These jars were returned to each river for approximately one day and then transported while submerged in a large container supplied with oxygen to the Noble lab. Also, in the Washita River, burlap sacks were cut open and held on the bottom with rocks. These sacks were left overnight and collected the following morning. The eggs adhering to the sacks were transported to the Fisheries Research Center and set out in a 0.1 ha (¼ acre) pond.

Fecundity

The egg size to be considered mature for fecundity estimates was determined by measuring the diameters of 2,025 eggs selected randomly from mature, ripe, and spent fish. The ova were not spherical, partly due to the crowding in the lumen, and also due to preservation. They were measured with an ocular micrometer at 30X magnification. Orientation was random with respect to the micrometer scale. Clark (1934) found this technique to be satisfactory for measuring sardine eggs which were not spherical in shape.

Fecundity, defined as the potential number of mature eggs which could be spawned in one spawning season, was determined for 31 Red River and 37 Washita River white bass.

Only fish with a gonadal-somatic index (defined as the ovary weight divided by the body weight, multiplied by 100) greater than 10 were used for fecundity estimates. The use of fish with a high gonadal-somatic index assures the use of mature fish. Peterson (1961) used the gonadal-somatic index and egg size as criteria for selecting specimens for fecundity estimates of anchovy. For each fish used to estimate fecundity, 30 mature eggs were measured randomly to compare the average mature egg size between spawning aggregations from each river.

Various methods have been employed to estimate fecundity. The volumetric method seems to work best with large eggs such as trout eggs (Vladykov and Legendre, 1940), but Borodin (1925), working with sturgeon eggs, found the gravimetric method more accurate than the volumetric method. Leong (1967) compared wet and dry gravimetric methods for estimating smelt fecundity and found the dry method to be significantly better.

A dry gravimetric method was used in this study. The procedure was to separate the eggs in both ovaries by teasing them from the ovarian tissue over a wire screen under running water. After the eggs were separated, a subsample of approximately 1% was removed at random, and all mature ova were counted. The subsample and the remaining eggs from each fish were dried separately at 60 C in a drying oven for 48 hr. The sample was then weighed on a Sartorius balance, to the nearest 0.1 mg. Fecundity was calculated from the relationship: $C = \frac{AD}{B} + A$ where A is the number of mature ova in the subsample, B is the weight of ova in the subsample, C is the number of mature ova, and D is the weight of ova from both ovaries. Fecundity estimates were rounded off to the nearest hundred mature eggs.

Fecundity-length, fecundity-weight, and fecundity-age regressions were determined for fish from each locality and compared by covariance analysis. The correlation coefficient r, expressing the degree of relationship between fecundity and length, weight, and age, was determined according to the procedures outlined by Sokal and Rohlf (1969). Also, r^2, the proportion of the variation in fecundity which could be attributed to changes in length, weight, and age, was computed. An analysis of variance was used to determine whether any significant difference of mature egg size was present between localities.

Morphometric Characters

A table of random numbers (Rohlf and Sokal, 1969) was used to select 350 pre-spawning white bass for analysis. Of this group, 15 were rejected due to damage incurred during handling.

Eight morphometric characters were used on 171 Red River and 164 Washita River pre-spawning fish. These fish were collected just prior to the spawning seasons in 1970 and 1971, after they had started their river migrations. The characters used were: least depth of caudal peduncle, pectoral to dorsal distance, head length, left pectoral length, predorsal length, body depth, lateral line to dorsal fin distance, and total length (Fig. 2). All measurements, except total length, were made to the nearest millimeter with a set of fine point dividers and a meter stick. Total length, to the nearest millimeter, was obtained by use of a standard measuring board.

Regression analysis was computed for total length against all other measurements. The total length was used as the independent variable in all comparisons; all other characters measured were used as dependent variables. An analysis of covariance was used to analyze these results.

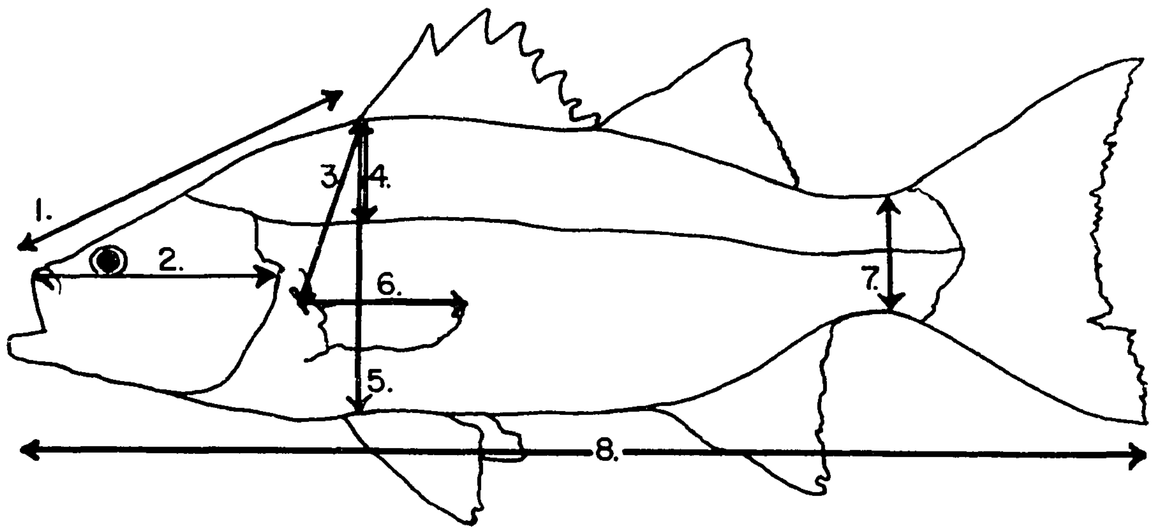
Meristic Characters

Counts were made on a total of 133 fish, 60 from the Red River, and 73 from the Washita River. Dorsal, anal, left pectoral, and pelvic soft rays and spines were counted for each of the fish studied. An analysis of variance was conducted.

Age and Growth

A total length-scale length relationship was determined separately for 179 Red River and 280 Washita River white bass, which were

Figure 2. Body measurements used in morphometric analysis.



1. PREDORSAL LENGTH
2. HEAD LENGTH
3. PECTORAL-DORSAL DISTANCE
4 LATERAL LINE-DORSAL DISTANCE
5. BODY DEPTH
6. LEFT PECTORAL LENGTH
7. LEAST DEPTH OF CAUDAL PEDUNCLE
8. TOTAL LENGTH

collected during January through April 1970 and 1971. Little difference of this relationship was observed between the sexes, therefore, they were combined. An analysis of covariance comparing body-scale relationships between the two populations of white bass was computed.

The length-weight relationship was calculated for white bass collected from the Red River (232) and Washita River (351). All specimens were collected during January through April 1970 and 1971.

A total of 203 young-of-the-year white bass were collected from the Lake in July 1972, with a 9.1 m (30 ft) seine. The total length was measured and the mean length and coefficient of variation were determined.

Scales of 126 males and 93 females from the Red River Arm, and 134 males and 144 females from the Washita River Arm of Lake Texoma, taken from September 1969 through June 1971, were read using a microprojector at a magnification of 32X. The distance from the focus to the anterior margin of the scale and to each annulus on the 32X image was measured to the nearest millimeter and recorded. Age was determined by counting the number of annuli present. Also, fish captured between January 1 and the time of actual annulus formation, were assigned an additional annulus at the edge of the scale. Ward (1951), from observations of white bass of known age, established the validity of the annulus as a true year mark for this species.

Calculations of length at each annulus were made using the following formula: $L_1 = a + \frac{S_1}{S}(L-a)$ where L_1 is the average total length at each annulus, a is the total length of the fish at the time of scale formation, S_1 is the average scale length at each annulus, S is the average scale length at the time of capture, and L is the average total length of the fish at the time of capture.

Blood Protein Analysis

Blood samples from white bass were taken in the field by cardiac puncture and kept on ice. Each sample was centrifuged at 1,500 rpm for 15 min in a cold-room maintained at 5 C. The serum was then stored at -70 C.

Acrylamide gel electrophoresis was used to analyze blood protein patterns for 92 white bass. Components of the lower and upper buffers were prepared according to the procedures outlined for anionic gel systems by Buchler Instruments (mimeo, 1966). Two plexiglass chambers, each holding 12 tubes, were kept at approximately 3 C.

Serum samples were mixed with an equal volume of 10% sucrose. Ten microliter samples were run with a trace of bromophenol blue at 2 ma per tube until the tracer dye reached the small pore acrylamide gel layer, then run at 4 ma per tube until the tracer dye reached the end of the gel.

The serum proteins were fixed and stained for a minimum of 1 hr with 1% Amido Schwarz in 7% acetic acid. After de-staining, samples were stored in 7% acetic acid. The distance of migration for each protein band was measured to the nearest millimeter, and converted to a percentage, with the distance from the origin to the tracer band being 100%. The mean, coefficient of variation, and standard error were determined for each band. Also, the frequency of occurrence of each band was determined for mature fish of each sex from both rivers.

CHAPTER III

RESULTS

Water Analysis

From the chemical analysis conducted at the sampling sites (Table 1), several observations can be made. Total alkalinity, which represents all the titratable bases present, was almost twice as great at the Washita River site (330 ppm), compared to the Red River area (180 ppm). Cumberland Cut showed a higher alkalinity than Hickory Creek, while Wilson Creek had the lowest total alkalinity (140 ppm).

The concentration of salt in the form of sodium chloride was very high in the Red River (4,166 ppm), more than 10 times the concentration found in the Washita River (371 ppm). The salinity of Hickory Creek (363 ppm) was similar to the salinity found in the Washita River. The lowest salinity was recorded at Cumberland Cut. Total hardness, which reflects mainly calcium, magnesium, and strontium ions, was greatest for the Red River (900 ppm); twice that found for the Washita River (450 ppm). Total hardness was slightly greater at Cumberland Cut than it was at Hickory Creek. Wilson Creek had a value of total hardness slightly greater than Cumberland Cut. The water in each area was slightly alkaline (pH 7.5 - 8.4). There was little variation in the weekly recordings from each area. However, on July 20, 1970, when

Table 1. Water chemistry of sampling sites.

Location and Date	Total Alkalinity ppm $CaCO_3$	NaCl ppm	Cl^- ppm	Total Hardness ppm $CaCO_3$	Hardness Ca^{++}	Hardness Mg^{++}	pH	Conductivity micromhos	Turbidity JTU
<u>Red River Arm</u>									
<u>Hickory Creek</u>									
1970 June 23	170	363	220	240			7.5	460	
30	160			220			7.6	450	
July 7	150			240			7.6	420	40
14	152			240			7.5	420	35
20	155			250			8.2	410	90
<u>Wilson Creek</u>									
1971 Feb. 27	140			370			8.4		
<u>Red River</u>									
1971 Apr. 17	180	4,166	2,525	900	590	310	8.4		20
<u>Washita River Arm</u>									
<u>Cumberland Cut</u>									
1970 July 7	150	82	50	280			8.0	290	50
14	210			284			8.0	290	40
20	205			300			8.2	280	70
1971 Mar. 7	240			340	220	120	8.3		60
<u>Washita River</u>									
1971 Apr. 16	330	371	225	450	290	160	8.3		50

these localities were studied, there was a rise of almost a whole pH unit at Hickory Creek. The conductivity, expressed in micromhos, was greater at Hickory Creek than at Cumberland Cut. Turbidity, measured in Jackson Turbidity Units, was lowest at the Red River, and about the same at the other areas. The turbidity increased greatly on July 20, 1970.

Extreme differences in the water chemistry of the two rivers have also been recorded by the United States Geological Survey. At low flows of about 6 cfs, the chloride concentration of the Red River water has been recorded at about 6,000 ppm. In one day, 340 tons of salt may be swept downstream. In 1956, the average chloride concentration of the Washita River flowing into Lake Texoma was only 62 ppm, compared to an average chloride concentration of 533 ppm for the Red River entering Texoma (Dover, Leonard, and Laine, 1968). According to unpublished data furnished by Richard Orth, hydrologist with the United States Geological Survey, in March and April 1968, the mean values for hardness and dissolved solids for the Red River were 539 mg/l and 1766 mg/l, and for the Washita River, 268 mg/l and 422 mg/l respectively.

Water temperature was taken for each locality (Table 2). There was little difference between the two rivers. The Washita was usually slightly cooler, but there were greater fluctuations within each river. The frequent changes in flow rate and water level in each river probably account for the fluctuations.

<u>Sex Ratios and Spawning</u>

Data on sex ratios for white bass from each arm of Lake Texoma

Table 2. Water temperatures recorded for the Red and Washita rivers.

Date		Temperature in C Red River	Washita River
1970			
Feb.	21	-	9
	28	17	-
March	7	13	13
	24	18	-
	31	11	-
April	2	-	12
	4	15	14
	11	19	-
May	6	23	-
	26	26	-
June	19	27	27
	30	30	-
July	7	28	27
	14	28	27
	20	26	27
Aug.	3	32	-
Oct.	31	3	-
Nov.	27	13	-
1971			
Jan.	23	8	7
Feb.	14	7	7
March	6	-	9
	20	7	7
	28	17*	16*
April	4	16*	18
	10	21	19
	17	19	18
	20	18	19
May	3	22*	17*
	16	22*	20*
	30	23	23
June	7	26*	26*
1972			
April	1	-	16
	17	-	22

*Data provided by J. L. Arter, University of Oklahoma are given separately in Tables 3 and 4. Schooling by sex was noted in the white bass, especially prior to the spawning season. A mass migration of male white bass was observed passing through Cumberland Cut on April 4, 1970. Of the 86 fish collected, all were males (water temperature 14 C). On April 17, 1972, of 100 white bass captured in the Washita River near Tishomingo, only three were males (water temperature 22 C). Unisexual schooling was noted by Riggs (1955) in both Lake Shafer and Lake Texoma. Collections taken from gill nets which were placed across each river and in deeper water in the Lake also verified Riggs' findings that the mature males migrated upstream first, while the mature females remained in the deeper water of the Lake.

White bass, collected on their spawning migrations in the Red River, consisted of 229 males and 149 females taken from January through April 1970, 1971, and 1972. The sex ratio for this period was significantly different from the expected 1:1 ratio ($\chi^2_{1df} = 16.9$) with a ratio of 1.5:1 in favor of males. The sex ratio for the fish captured during the non-spawning period (May through December, 1970 and 1971) did not deviate from the expected 1:1 ratio ($\chi^2_{1df} = 0.742$). A total of 354 male and 288 female white bass were collected from the Red River from September 1969 through April 1972. This deviated from the expected 1:1 ratio ($\chi^2_{1df} = 6.78$) with a ratio of 1.2:1 in favor of males.

White bass, collected on their spawning migrations in the Washita River, consisted of 394 male and 412 female fish taken from January through April 1970, 1971, and 1972. The sex ratio for this period did not deviate from the expected 1:1 ratio ($\chi^2_{1df} = 1.40$). The

Table 3. Numbers of male and female white bass from the Red River Arm of Lake Texoma.

Date			Male	Female
1969	Sept.	20	28	34
	Oct.	11	4	10
	Nov.	15	7	5
1970	Feb.	9	27	32
		14	28	14
		28	29	11
	March	1	55	16
		7	3	1
		21	19	3
		24	1	0
	April	4	4	3
		11	4	8
		25	2	1
	May	5	0	2
		14	8	6
		26	2	3
	June	4	6	3
		19	1	2
		22	2	2
		28	1	0
	July	3	8	17
		7	34	33
		12	3	2
		16	0	2
	Aug.	5	4	2
	Oct.	31	6	4
	Nov.	27	10	8
1971	Jan.	23	6	2
	Feb.	15	3	4
		27	14	20
	March	13	1	0
		14	8	8
		19	14	8
	April	10	3	9
		20	7	8
	May	30	1	3
	June	3	0	1
1972	April	29	1	1
Totals			354	288

Table 4. Numbers of male and female white bass from the Washita River Arm of Lake Texoma.

Date			Male	Female
1970	Feb.	21	5	30
	March	1	7	17
		7	24	11
		31	1	0
	April	4	86	0
		14	8	2
		19	39	46
	May	4	1	0
		12	3	2
		25	4	3
	June	19	2	11
	Nov.	27	15	41
1971	Jan.	23	32	33
	Feb.	14	55	94
	March	6	13	13
		21	1	0
	April	4	3	6
		9	62	32
		19	5	9
		20	50	21
		24	0	1
	May	15	2	8
1972	April	1	0	0
		17	3	97
Totals			421	477

sex ratio for fish collected during the non-spawning period (May through December, 1970 and 1971) showed a significant difference from the expected ratio (χ^2_{1df} = 15.7) with a ratio of 2.4:1 in favor of females. For the total time period studied, February 1970 through April 1972, there was a total of 898 white bass collected with 421 males and 477 females. This did not deviate from the expected 1:1 ratio (χ^2_{1df} = 3.49).

The white bass is a potamodromous type of fish (Riggs, 1955). It annually migrates up streams entirely within fresh water to spawn. After spawning, it returns to the lake. It may be seen (Table 5) that there was movement in each river during the spawning period. However, as the season progressed, a greater number of individuals were collected while moving downstream. Most Red River samples were taken approximately 24 km (15 miles) upstream from Hickory Creek. Riggs (1955) mentioned that white bass have been seen in Cache Creek and Medicine Creek as far up as Lawton every spring since Lake Texoma was filled, but are not observed during other seasons of the year. In the present study, most white bass were taken from the Washita River near the Tishomingo Wildlife Refuge. However, on April 14, 1970, one collection, consisting of eight males and two females, was taken by electroshocking in Wild Horse Creek, a tributary which enters into the Washita River approximately 161 km (100 miles) from Texoma. Ranchers in this area said that they only catch white bass there in the spring.

White bass were observed spawning in the Washita River near Tishomingo on April 20, 1971 (water temperature 19 C, 9:00 a.m.). The

Table 5. Stream migrations of white bass in the Red and Washita rivers during the 1971 and 1972 spawning seasons, as revealed by gill net collections.

Date			Red River Upstream M	Red River Upstream F	Red River Downstream M	Red River Downstream F	Washita River Upstream M	Washita River Upstream F	Washita River Downstream M	Washita River Downstream F
1970	Feb.	28	23	9	6	2	-	-	-	-
	March	7	2	1	1	0	-	-	-	-
		21	12	3	7	0	-	-	-	-
1971	March	6	-	-	-	-	11	13	2	0
		14	8	8	0	0	-	-	-	-
		19	4	3	1	0	-	-	-	-
		20	7	4	2	1	-	-	-	-
	April	4	-	-	-	-	3	6	0	0
		9	-	-	-	-	48	27	14	5
		10	2	3	1	6	-	-	-	-
		19	-	-	-	-	4	7	1	2
		20	-	-	-	-	28	4	22	17
		24	-	-	-	-	0	0	0	1
	May	15	-	-	-	-	0	0	2	8
1972	April	1	-	-	-	-	0	0	0	0
		17	-	-	-	-	3	92	0	5
		29	0	0	1	1	-	-	-	-

- Denotes no gill net set

water was fairly swift and quite turbid. Most activity occurred around some partly submerged tree stumps in water about 1 m deep. It was difficult to observe the actual spawning act with much precision due to the turbidity of the water. However, one larger fish, believed to have been the female, was surrounded and chased by five smaller white bass. There was a good deal of movement and splashing for about five minutes. The fish then swam deep, and could no longer be seen. In a gill net set approximately 15 m downstream, strung the width of the river, a female which was in a ripe condition, but which appeared partially spent, and two smaller males were taken. These fish were caught in the net approximately 1 m below the water surface. After removing the fish from the net, at the area where spawning activity was observed, what appeared to be white bass eggs were found attached to the stumps and debris. Riggs (1955) gives a similar description of spawning behavior of the white bass in Shafer Lake.

No evidence of spawning was observed in either of the two holding ponds at Noble. No eggs obtained by artificial spawning and fertilization of pituitary injected females hatched. However, one female that had previously been injected with carp pituitary spawned in a concrete tank. A few larvae were collected later. The time of spawning was not known, therefore, the exact age of the larvae could not be determined.

Other attempts to collect larval white bass were also unsuccessful. Eggs taken from ripe white bass stored in wide mouth gallon jars were attacked by a fungal growth. The next time this method was tried, a concentration of 1:200,000 malachite green was added. This checked the fungal growth, however the eggs died before hatching. The eggs adhering to burlap sacks and kept in a holding pond also failed to hatch. A plankton net was towed through the water and no white bass larvae were found.

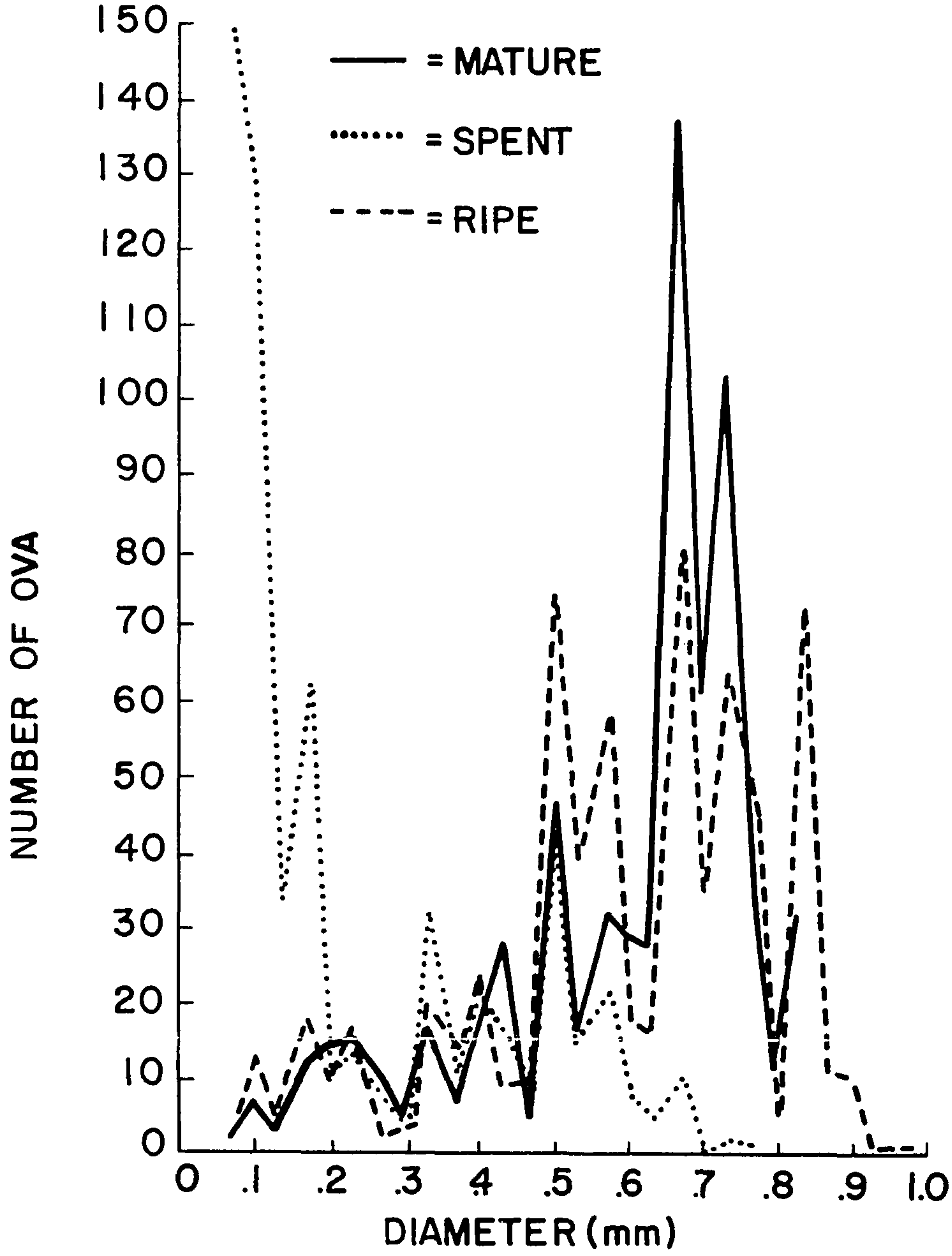
The spawning period ranged from late March through April in each year studied, as evidenced by the gonadal-somatic index and deposit of eggs. All female white bass collected in May were in a spent or spawned-out condition.

Fecundity

Mature fish were characterized by having large, fully developed ovaries which were hard. If extensive pressure was applied to these fish, only clumped yellow ova and blood was forced out. These fish generally had gonadal-somatic indexes greater than 10. Kilpatrick (1959), conducting a detailed study of the gonadal-somatic index of white bass on Lake Texoma, found it a good index of maturity. Fish were considered ripe when, after a gentle squeezing, clear, unclumped ova were extruded. Spent fish were individuals with small ovaries which contained small ova and larger eggs undergoing reabsorption.

Both ovum diameter frequencies and condition of the ova were used to determine mature egg size. From the ovum diameter frequency distribution of mature, ripe, and spent white bass (Fig. 3), several conclusions can be drawn. There are higher peaks from about 0.50 mm to 0.85 mm for the mature white bass. The ripe white bass also has higher peaks from about 0.50 mm to 0.85 mm. It can be seen from the plot of the ovum diameters from the spent fish, that few of the larger

Figure 3. Frequency distribution of ovum diameters for mature, spent, and ripe white bass.



= MATURE
= SPENT
= RIPE
NUMBER OF OVA
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
0
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0
DIAMETER (mm)

ova that were present in the mature and ripe fish remained. In the spent fish, some of these ova were undergoing reabsorption. Therefore, by examining the condition of the eggs and their sizes, ova 0.57 mm in diameter and larger were included in fecundity estimates. Immature ova were small and translucent. Intermediate ova were opaque and whitish in color. The mature eggs contained a large amount of yolk and were yellow in color. A large volume of the ovaries of mature fish was occupied by mature eggs.

The fecundity of 31 white bass from the Red River and 37 from the Washita River ranged from 61,700 to 510,700, and from 111,900 to 452,300 ova, respectively. Figures 4, 5, and 6 show the relationship between fecundity and fish length, weight, and age for each locality. A linear regression by the method of least squares was fitted to the data for each locality. The linear regression equations obtained for fecundity vs total length were:

Red River $F = -533{,}680 + 2{,}193.2L$

Washita River $F = -475{,}180 + 2{,}159.4L$

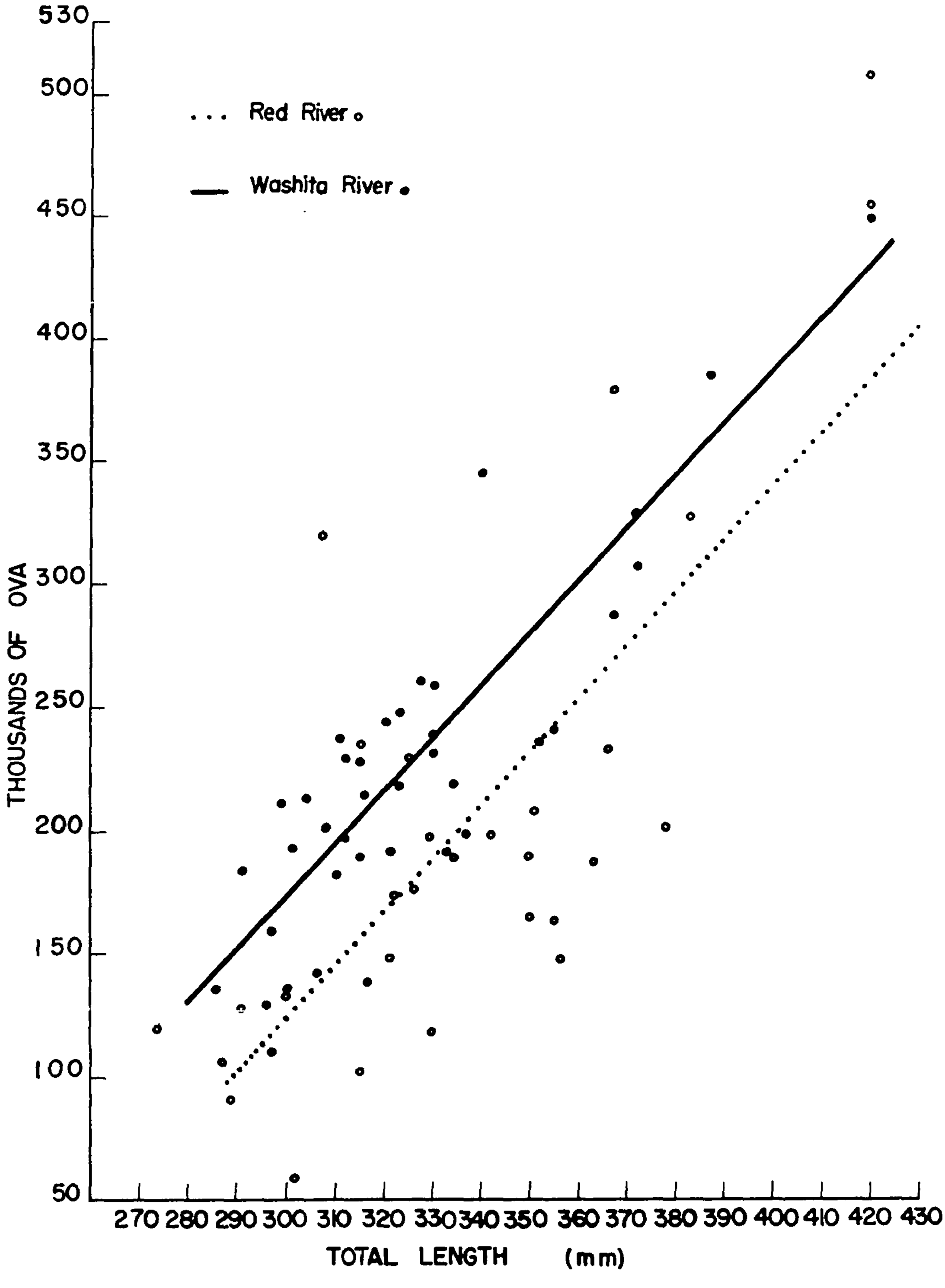
where F is the estimated fecundity, and L is the total length of the fish in millimeters. Covariance analysis showed no significant differences in the regression coefficients at the 0.01 level of significance (Table 6). There was a significant difference, however, at the 0.01 level between the adjusted means. Estimated fecundity adjusted to a total fish length of 300 mm was 124,300 for the Red River and 172,600 for the Washita River sample (Table 7).

The regression equations obtained by the method of least squares for fecundity vs fish weight were:

Figure 4. Scatter diagram showing relationship of fecundity to fish length.

Red River: $F = -533{,}680 + 2{,}193.2L$

Washita River: $F = -475{,}180 + 2{,}159.4L$

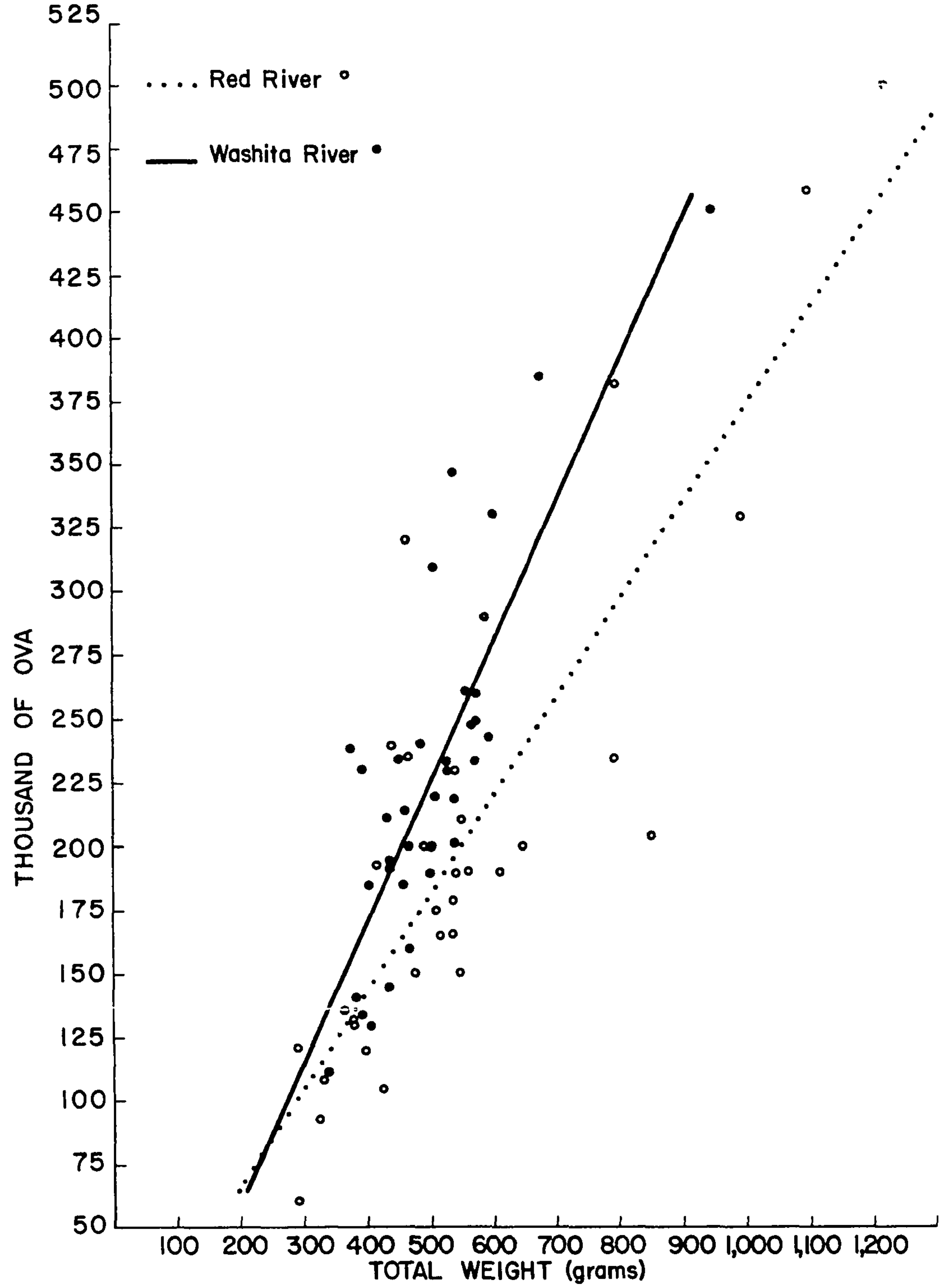


530
500
450
400
350
300
250
200
150
100
50
THOUSANDS OF OVA
Red River
Washita River
270 280 290 300 310 320 330 340 350 360 370 380 390 400 410 420 430
TOTAL LENGTH (mm)

Figure 5. Scatter diagram showing relationship of fecundity to fish weight.

Red River: $F = -9{,}750.3 + 384.32W$

Washita River: $F = -49{,}280 + 551.00W$

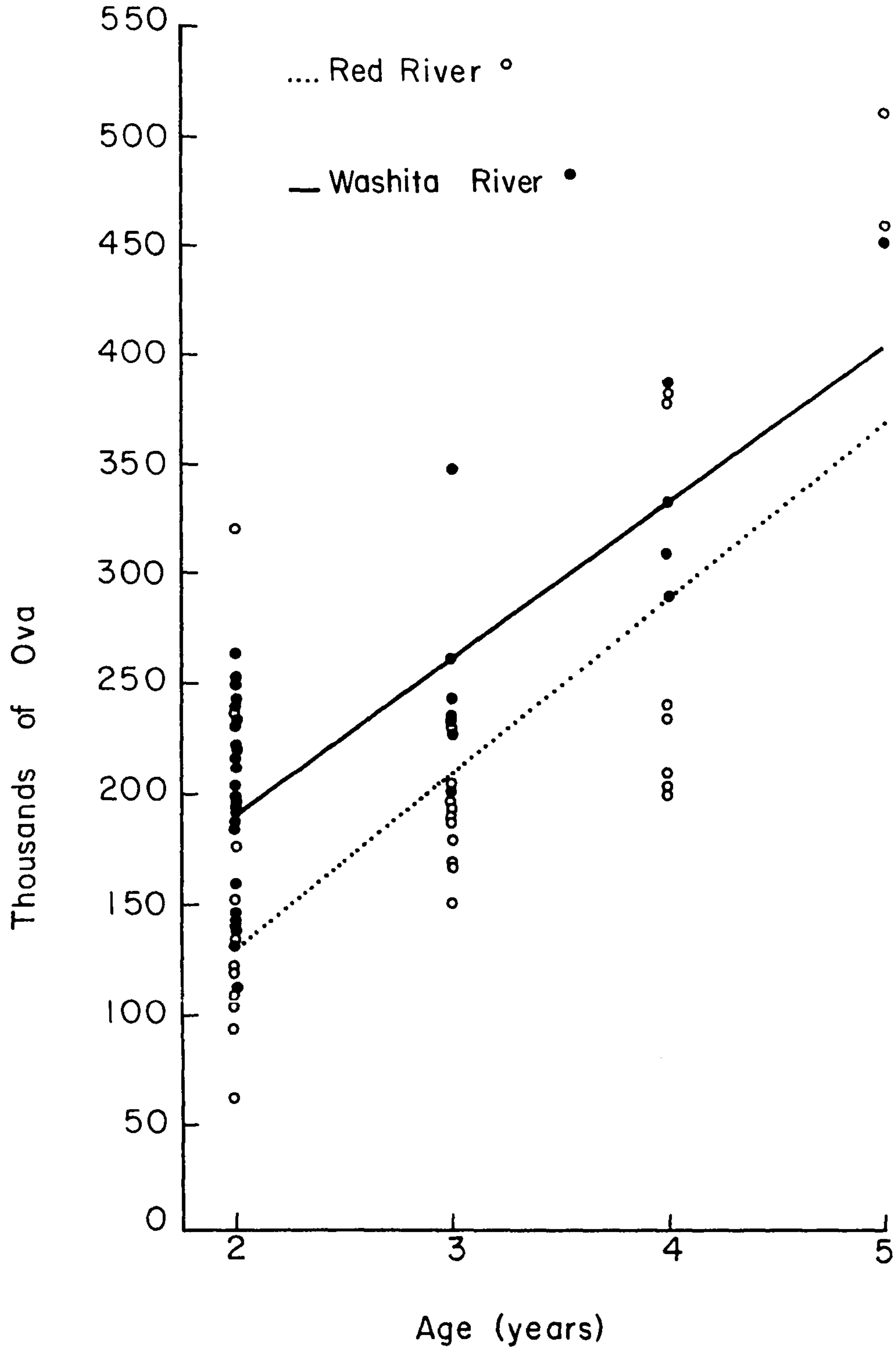


525
500
475
450
425
400
375
350
325
300
275
250
225
200
175
150
125
100
75
50
THOUSAND OF OVA
Red River
Washita River
100 200 300 400 500 600 700 800 900 1,000 1,100 1,200
TOTAL WEIGHT (grams)

Figure 6. Scatter diagram showing relationship of fecundity to fish age.

Red River: $F = -34{,}475 + 81{,}021A$

Washita River: $F = 49{,}954 + 71{,}241A$



550
500
450
400
350
300
250
200
150
100
50
0
.... Red River
Washita River
Thousands of Ova
2
3
4
5
Age (years)

Table 6. Comparisons of the regressions of fecundity-length, fecundity-weight, and fecundity-age for white bass from the Red and Washita rivers, by covariance analysis.

Source	Degrees of Freedom	Mean Square	F
<u>Fecundity-length</u>			
Red River	29	4,468,954,090	
Washita River	35	1,214,028,166	
within	64	2,688,916,475	
regression	1	19,194,784	0.01
common	65	2,647,843,834	
adjusted	1	36,503,671,497	13.8**
<u>Fecundity-weight</u>			
Red River	29	2,796,717,170	
Washita River	35	1,542,565,165	
within	64	2,110,852,792	
regression	1	9,349,795,416	4.4*
common	65	2,222,221,140	
adjusted	1	34,982,205,568	15.7**
<u>Fecundity-age</u>			
Red River	29	4,628,049,101	
Washita River	35	1,895,628,134	
within	64	3,133,756,384	
regression	1	1,194,093,482	0.4
common	65	3,103,915,417	
adjusted	1	52,523,317,859	16.9**

* Significant at the 0.05 level
**Significant at the 0.01 level

Table 7. Regression equations and fecundities (rounded off to the nearest hundred mature eggs), adjusted to a total length of 300 millimeters, 500 grams, and 2 years, of white bass from both the Red and Washita rivers.

Locality	Regression Equation	Adjusted Fecundity
Red River Arm	F = - 533,680 + 2,193.2L	124,300 (Length = 300 mm)
Washita River Arm	F = - 475,180 + 2,159.4L	172,600 (Length = 300 mm)
Red River Arm	F = - 9,750.3 + 384.32W	182,400 (Weight = 500 g)
Washita River Arm	F = - 49,280 + 551.00W	226,200 (Weight = 500 g)
Red River Arm	F = - 34,475 + 81,021A	127,600 (Age = 2 years)
Washita River Arm	F = + 49,954 + 71,241A	192,400 (Age = 2 years)

F = Calculated fecundity
L = Total length (mm)
W = Total weight (g)
A = Age (years)

Red River F = -9,750.3 + 384.32W

Washita River F = -49,280 + 551.00W

where F is the estimated fecundity, and W is the total weight of the fish in grams. Covariance analysis showed no significant difference in the regression coefficients at the 0.01 level (Table 6). There was a significant difference at the 0.01 level between the adjusted means. Fecundity estimates adjusted to a total fish weight of 500 grams were 182,400 for the Red River and 226,200 for the Washita River (Table 7).

The linear regression equations obtained for fecundity vs age were:

Red River F = -34,475 + 81,021A

Washita River F = 49,954 + 71,241A

where F is the estimated fecundity and A is the age of the fish in years. Covariance analysis again showed no difference in the regression coefficients at the 0.01 level of significance (Table 6). There was a significant difference at the 0.01 level between the adjusted means. Fecundity estimates of white bass adjusted to an age of two years were 127,600 for the Red River and 192,400 for the Washita River sample (Table 7).

For the Red River sample, fecundity was most highly correlated with weight (r = 0.86), with 74% of variation in fecundity due to variation in weight. It was next most highly correlated with length (r = 0.76) with 58% of variation in fecundity due to variation in total length. It was least correlated with age (r = 0.75), with 57% of variation in fecundity due to variation in age.

For the Washita River sample, fecundity was most highly correlated with length (r = 0.88), with 77% of variation in fecundity due to variation in length. It was next most highly correlated with weight (r = 0.84), with 71% of variation in fecundity due to variation in weight. It was least correlated with age (r = 0.80), with 64% of variation in fecundity due to variation in age. The fecundity-length, fecundity-weight, and fecundity-age regression equations, along with standard error and other quantities necessary for determination of confidence limits, are given in Appendix A.

A total of 2,040 ovum diameters was measured randomly from 30 mature ova of each white bass used for fecundity estimates. An analysis of variance was conducted using the mean mature ovum diameter determined for each egg sample. The mean ovum diameter for the Red River fish was 20.85 ocular micrometer units, or 0.69 mm. The Washita River mean mature ovum diameter was 20.20, or 0.67 mm. There was no significant difference in egg diameters between the two localities (Table 8).

Morphometric Characters

The original data for each of the morphometric comparisons is plotted in the form of scatter diagrams (Figs. 7, 8, 9, and 10). It can be seen from the scatter diagrams that the data appear to have a linear relation. The regression equations obtained by the least squares method (Figs. 11, and 12) for the morphometric data were:

Total length - least depth of caudal peduncle

Red River $Y = 0.90610 + 0.096746X$

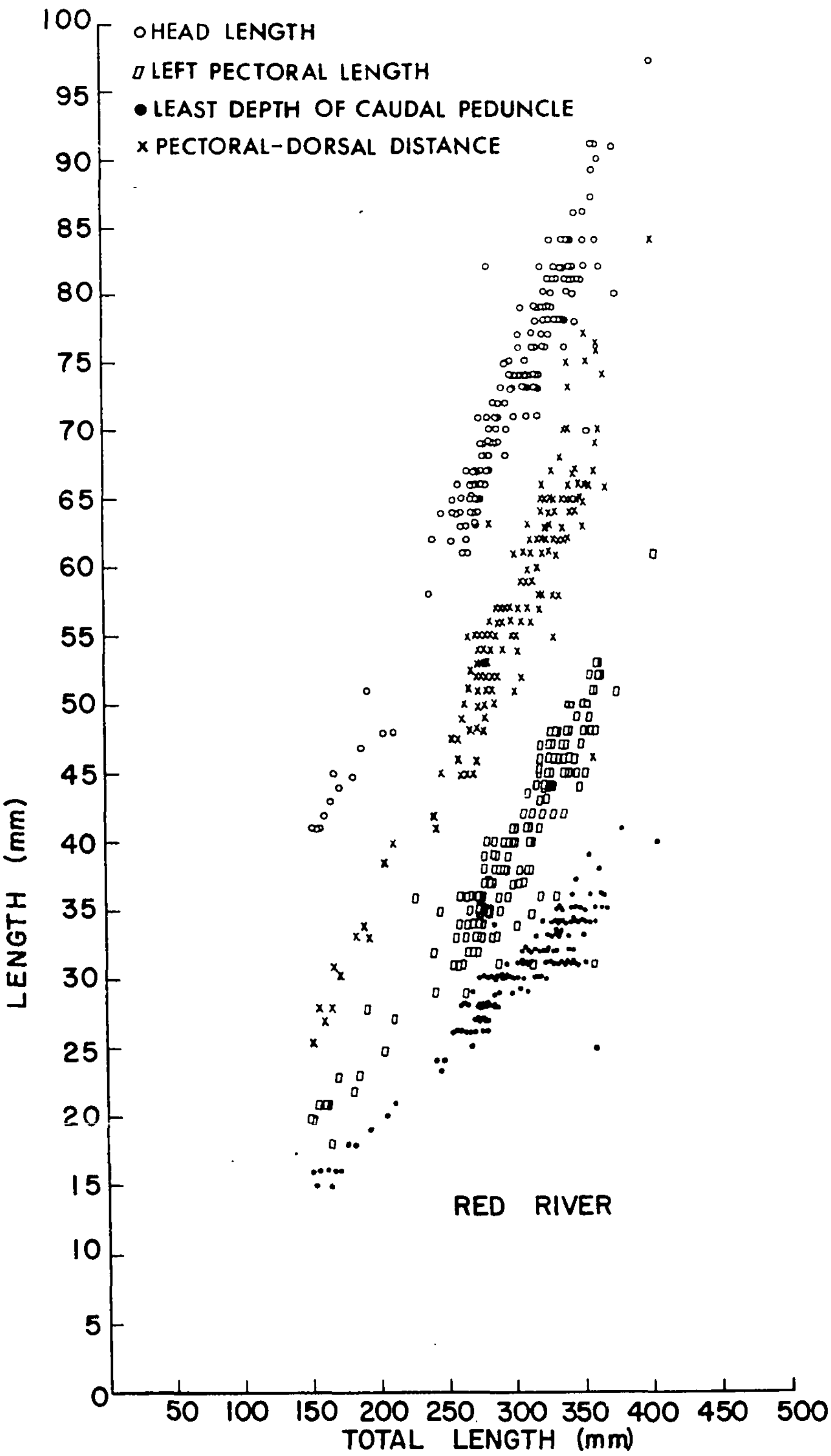
Washita River $Y = 5.7471 + 0.080322X$

Table 8. Analysis of variance comparing the mean of 30 mature ovum diameters from 31 Red River and 37 Washita River white bass (2,040 measurements).

Source of Variance	Sum of Squares	Degrees of Freedom	Mean Squares	F
Between groups	1.970	1	1.970	1.6
Within groups	79.984	66	1.212	
Total	81.954	67		

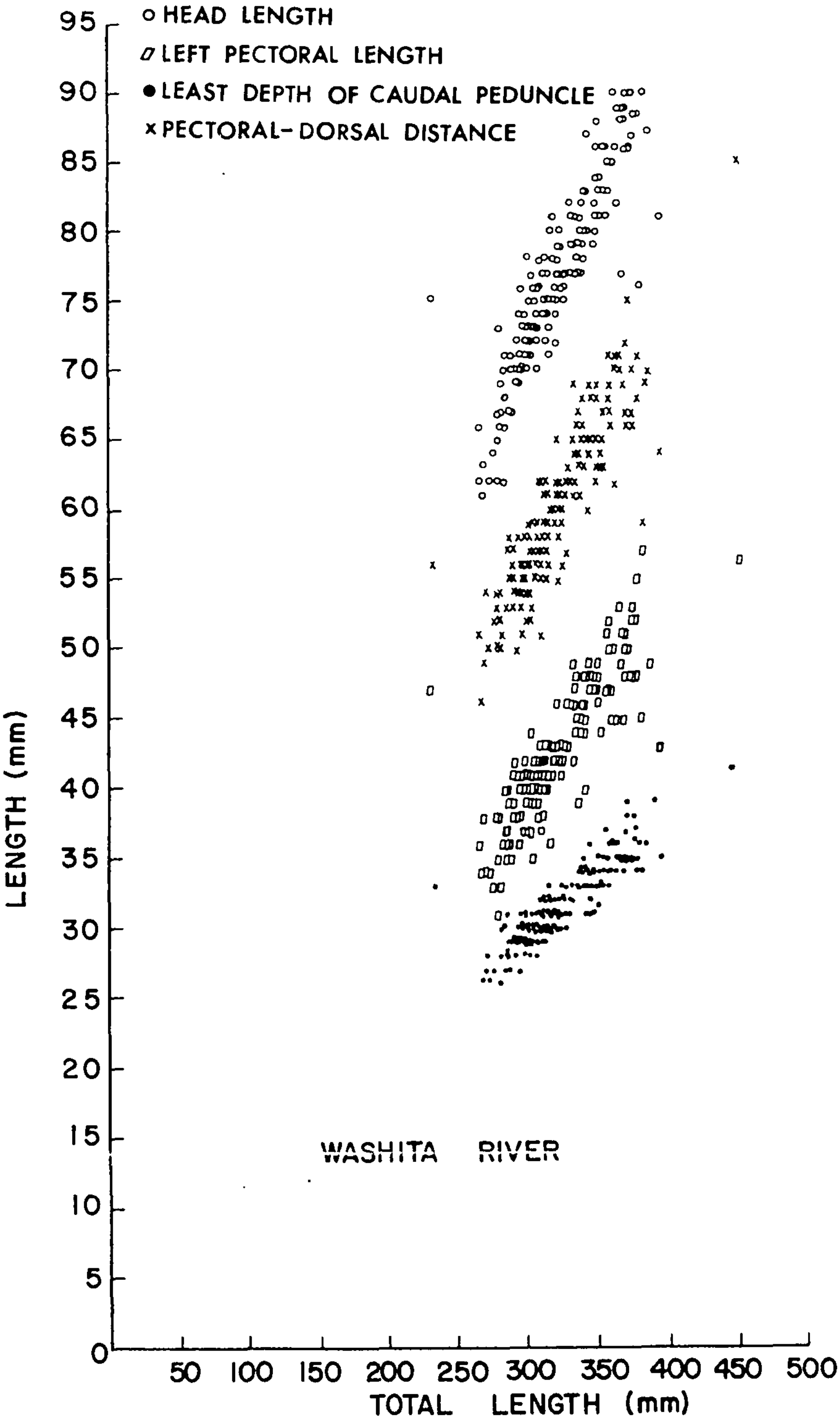
$F_{0.05(1,66)} = 4.0$

Figure 7. Scatter diagram showing relationship of total length to head length, left pectoral length, least depth of caudal peduncle, and pectoral-dorsal distance for the Red River sample.



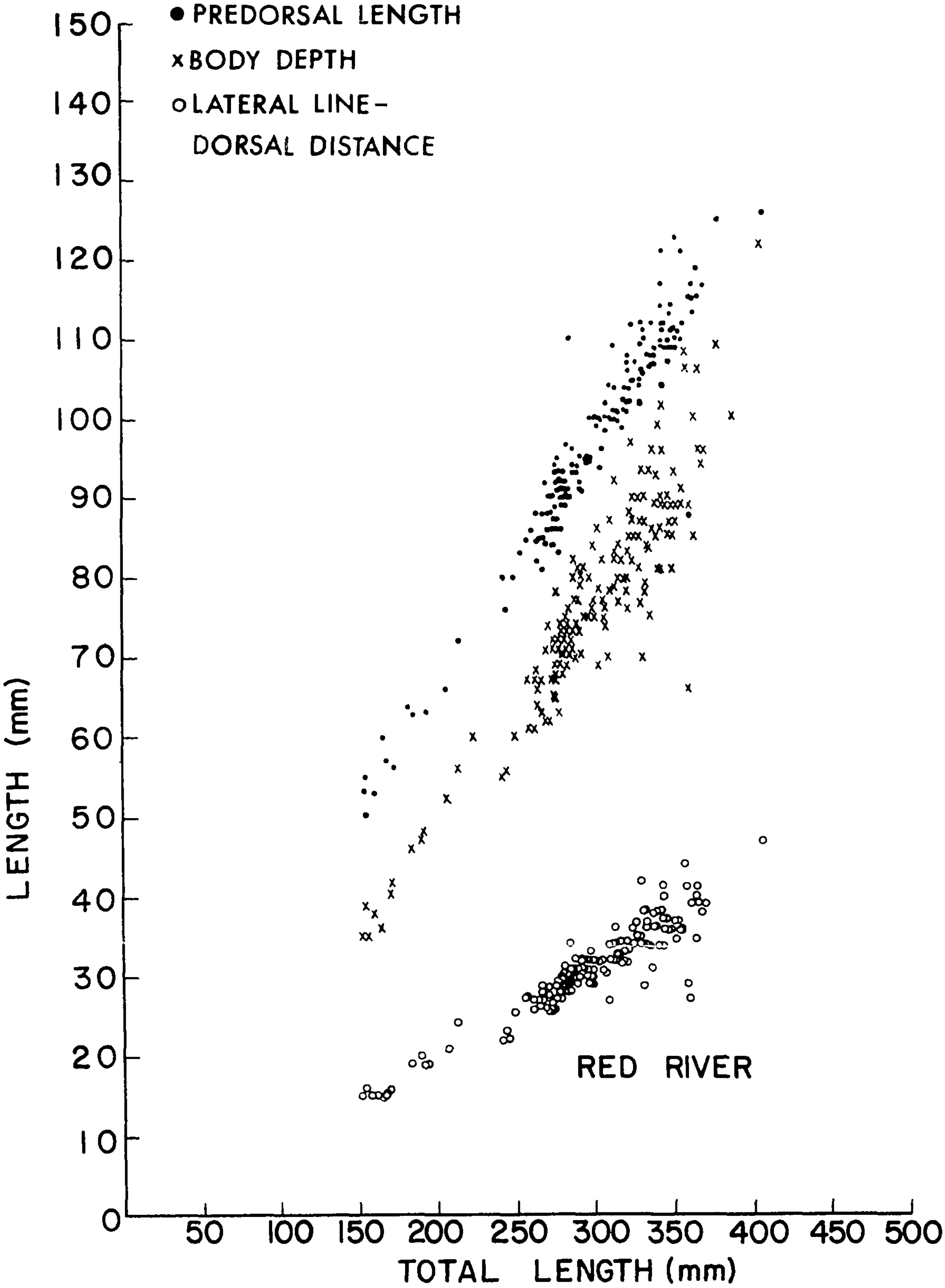
HEAD LENGTH
LEFT PECTORAL LENGTH
LEAST DEPTH OF CAUDAL PEDUNCLE
PECTORAL-DORSAL DISTANCE
RED RIVER
LENGTH (mm)
TOTAL LENGTH (mm)
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
50
100
150
200
250
300
350
400
450
500

Figure 8. Scatter diagram showing relationship of total length to head length, left pectoral length, least depth of caudal peduncle, and pectoral-dorsal distance for the Washita River sample.



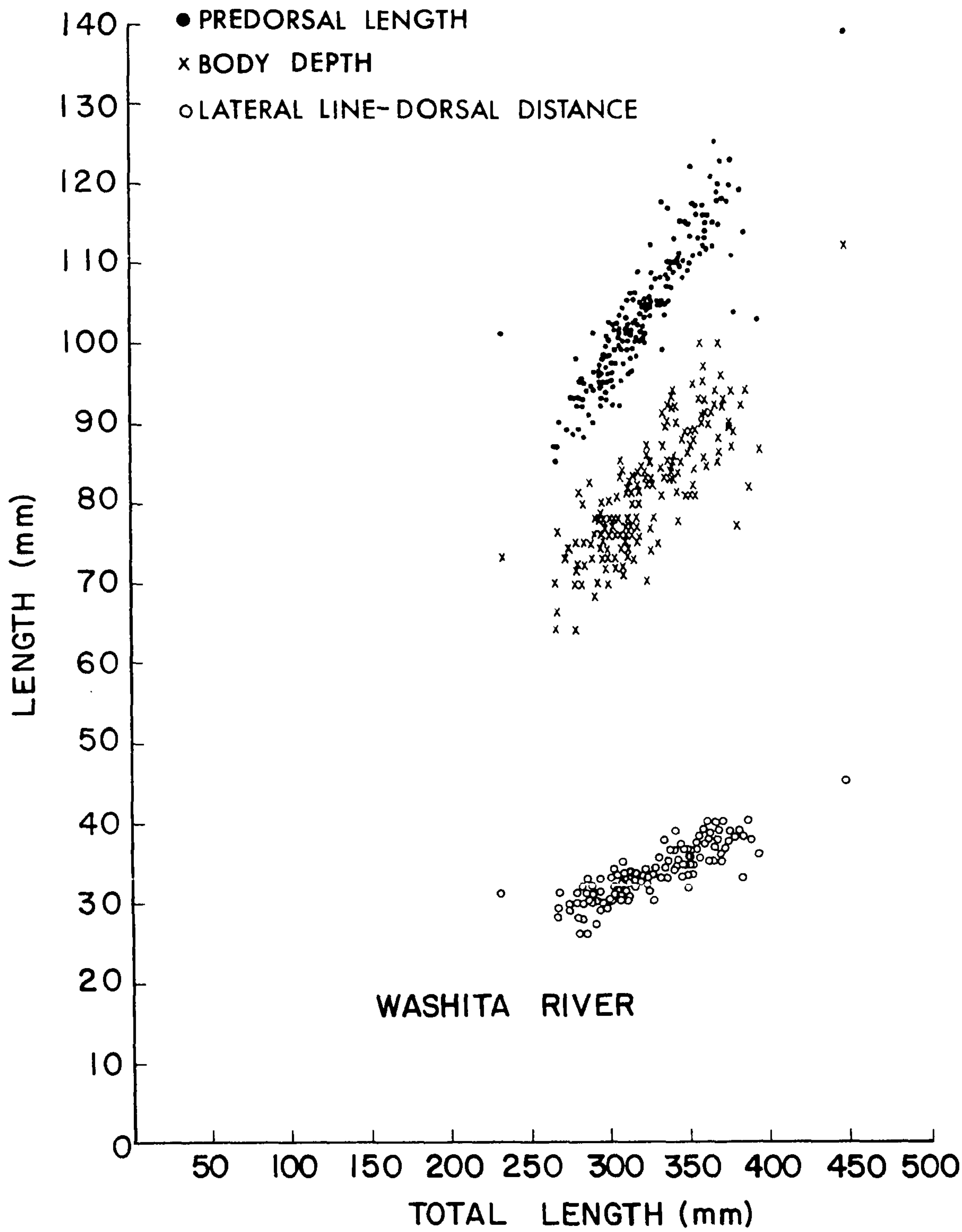
○ HEAD LENGTH
▱ LEFT PECTORAL LENGTH
● LEAST DEPTH OF CAUDAL PEDUNCLE
× PECTORAL-DORSAL DISTANCE
LENGTH (mm)
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
WASHITA RIVER
50
100
150
200
250
300
350
400
450
500
TOTAL LENGTH (mm)

Figure 9. Scatter diagram showing relationship of total length to predorsal length, body depth, and lateral line - dorsal distance for the Red River sample.



● PREDORSAL LENGTH
× BODY DEPTH
○ LATERAL LINE-DORSAL DISTANCE
LENGTH (mm)
TOTAL LENGTH (mm)
RED RIVER

Figure 10. Scatter diagram showing relationship of total length to predorsal length, body depth, and lateral line - dorsal distance for the Washita River sample.



● PREDORSAL LENGTH
x BODY DEPTH
o LATERAL LINE-DORSAL DISTANCE
LENGTH (mm)
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
50
100
150
200
250
300
350
400
450
500
TOTAL LENGTH (mm)
WASHITA RIVER

Figure 11. Regression lines of least depth of caudal peduncle, left pectoral length, pectoral-dorsal distance, and body depth on total length of white bass by locality.

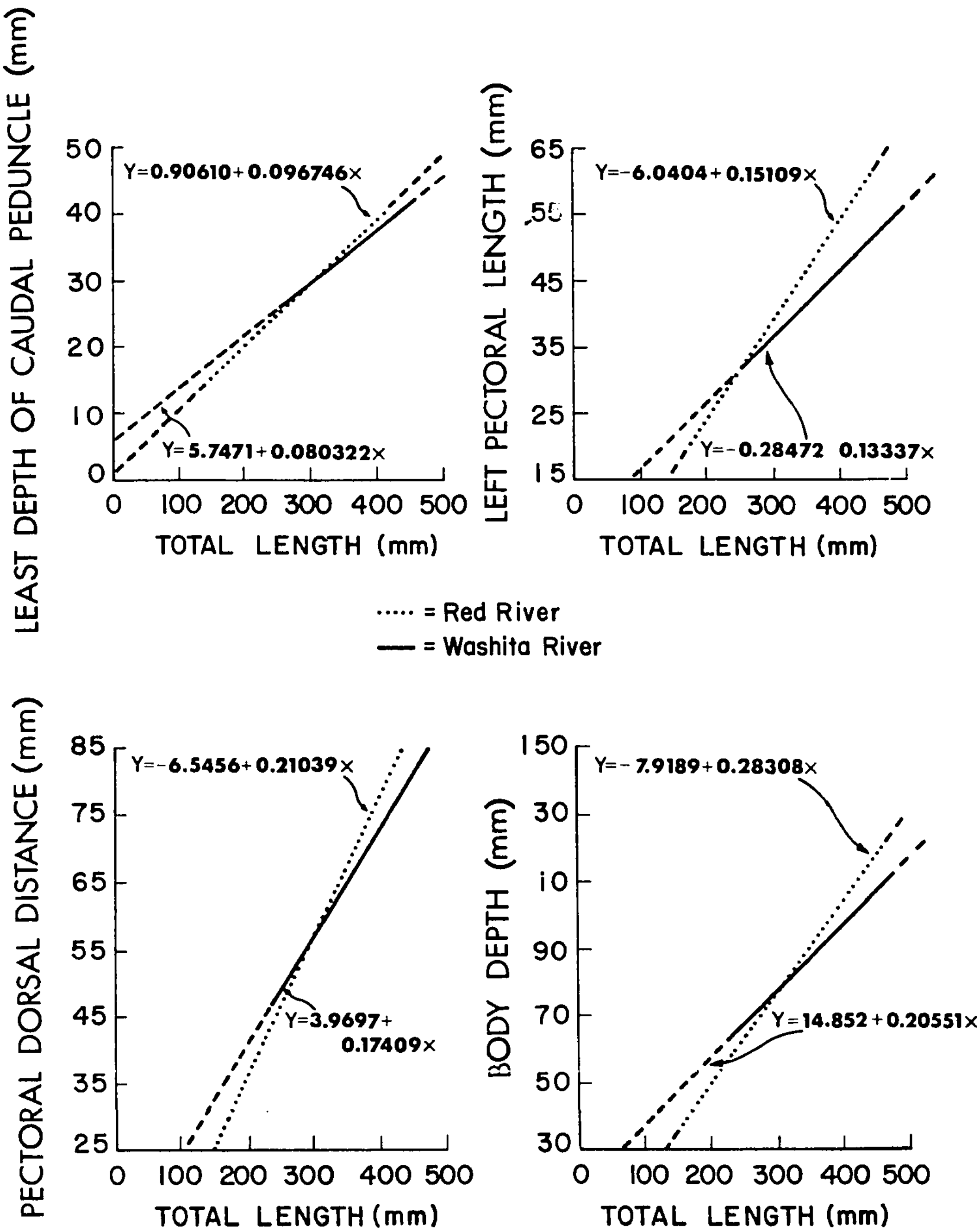
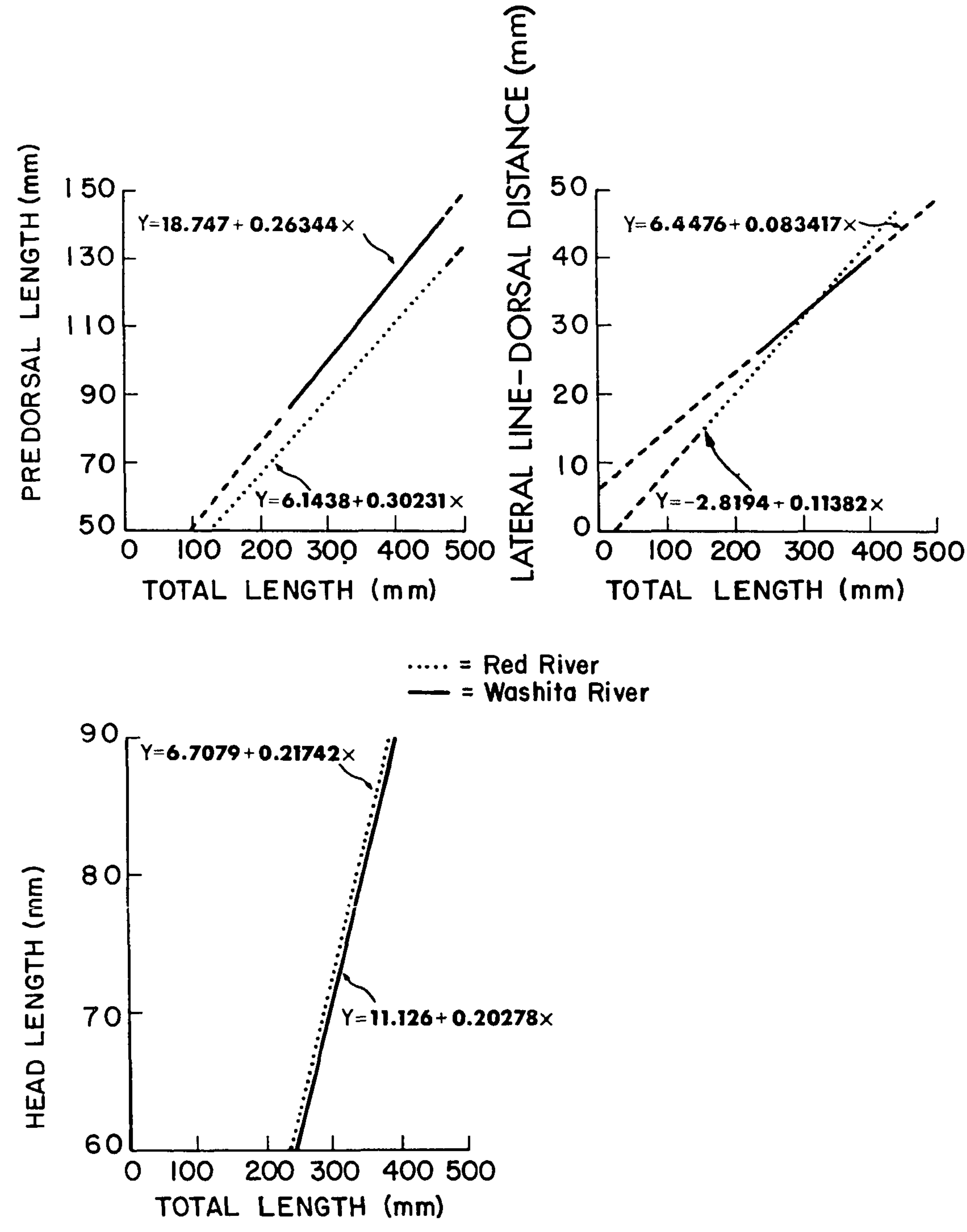

LEAST DEPTH OF CAUDAL PEDUNCLE (mm)
50
40
30
20
10
0
Y=0.90610+0.096746x
Y=5.7471+0.080322x
0 100 200 300 400 500
TOTAL LENGTH (mm)
LEFT PECTORAL LENGTH (mm)
65
55
45
35
25
15
Y=-6.0404+0.15109x
Y=-0.28472 0.13337x
0 100 200 300 400 500
TOTAL LENGTH (mm)
····· = Red River
—— = Washita River
PECTORAL DORSAL DISTANCE (mm)
85
75
65
55
45
35
25
Y=-6.5456+0.21039x
Y=3.9697+
0.17409x
0 100 200 300 400 500
TOTAL LENGTH (mm)
BODY DEPTH (mm)
150
30
10
90
70
50
30
Y=-7.9189+0.28308x
Y=14.852+0.20551x
0 100 200 300 400 500
TOTAL LENGTH (mm)

Figure 12. Regression lines of predorsal length, lateral line - dorsal distance, and head length on total length of white bass by locality.



PREDORSAL LENGTH (mm)
150
130
110
90
70
50
Y=18.747+0.26344x
Y=6.1438+0.30231x
0 100 200 300 400 500
TOTAL LENGTH (mm)
LATERAL LINE-DORSAL DISTANCE (mm)
50
40
30
20
10
0
Y=6.4476+0.083417x
Y=-2.8194+0.11382x
0 100 200 300 400 500
TOTAL LENGTH (mm)
..... = Red River
—— = Washita River
HEAD LENGTH (mm)
90
80
70
60
Y=6.7079+0.21742x
Y=11.126+0.20278x
0 100 200 300 400 500
TOTAL LENGTH (mm)

Total length - pectoral-dorsal distance

Red River Y = -6.5456 + 0.21039X

Washita River Y = 3.9697 + 0.17409X

Total length - head length

Red River Y = 6.7079 + 0.21742X

Washita River Y = 11.126 + 0.20278X

Total length - left pectoral length

Red River Y = -6.0404 + 0.15109X

Washita River Y = -0.28472 + 0.13337X

Total length - predorsal length

Red River Y = 6.1438 + 0.30231X

Washita River Y = 18.747 + 0.26344X

Total length - body depth

Red River Y = -7.9189 + 0.28308X

Washita River Y = 14.852 + 0.20551X

Total length - lateral line to dorsal distance

Red River Y = -2.8194 + 0.11382X

Washita River Y = 6.4476 + 0.083417X

An analysis of covariance was used to determine if any significant differences were present (Table 9). The 0.05 level of significance was first used to test whether or not the data could be represented by one line. The comparisons of total length to both head length and left pectoral length were not significantly different for white bass from each arm of Texoma. All the other comparisons were significantly different. Next, to determine whether there was any significant difference in slopes, the 0.01 probability level was used. Significant

Table 9. Covariance analysis of regression lines obtained from seven body measurements compared to total length for white bass collected from the Red and Washita rivers.

Source	Degrees of Freedom	Mean Squares	F
Total length - least depth of caudal peduncle			
Red River	169	2.350	
Washita River	162	1.731	
within	331	2.048	
regression	1	31.170	15.2**
common	332	2.135	
adjusted	1	8.830	
Total length - pectoral-dorsal distance			
Red River	169	11.900	
Washita River	162	8.247	
within	331	10.112	
regression	1	152.269	15.1**
common	332	10.540	
adjusted	1	66.750	
Total length - head length			
Red River	169	7.274	
Washita River	162	9.586	
within	331	8.405	
regression	1	24.794	3.0
common	332	8.455	
adjusted	1	3.128	0.4
Total length - left pectoral length			
Red River	169	8.150	
Washita River	162	7.389	
within	331	7.778	
regression	1	36.277	4.7*
common	332	7.863	
adjusted	1	2.095	0.3

Table 9 (continued)

Source	Degrees of Freedom	Mean Squares	F
Total length - predorsal length			
Red River	169	14.477	
Washita River	162	17.322	
within	331	15.870	
regression	1	174.555	11.0**
common	332	16.348	
adjusted	1	8.925	
Total length - body depth			
Red River	169	30.159	
Washita River	162	20.800	
within	331	25.579	
regression	1	695.247	27.2**
common	332	27.596	
adjusted	1	219.877	
Total length - lateral line to dorsal distance			
Red River	169	3.626	
Washita River	162	2.940	
within	331	3.290	
regression	1	106.790	32.5**
common	332	3.602	
adjusted	1	7.969	

* Significant at the 0.05 level
** Significant at the 0.01 level

differences in regression coefficients were found between the populations from the two rivers for total length vs least depth of caudal peduncle, pectoral-dorsal distance, predorsal length, body depth, and lateral line to dorsal distance (Table 9). There was no significant difference at the 0.01 level for regression coefficients between the two localities for white bass total length vs both head and left pectoral lengths (Table 9). Since there was no significant difference found for these two characters, it was possible to test for the adjusted mean F. The 0.01 level of significance was also used for this test. Total length to head and left pectoral lengths were not significantly different between localities. The regression equations, along with standard error and other quantities necessary for determination of confidence limits, are given in Appendix B. The F values, by covariance analysis, of the morphometric data are summarized in Table 10.

Meristic Characters

Anal, dorsal, left pectoral, and pelvic soft rays and spines were counted for each of the fish studied. An analysis of variance with a 0.01 probability level (Table 11) was used to determine if any significant differences were present. No significant difference was found between fish from the two areas when the number of rays of the anal fin were compared. The mean anal ray count was 15.85 for the Red River, and 15.67 for the Washita River white bass. There was no significant difference between the number of rays of the second dorsal fin, with a mean of 14.93 for the Red River, and 14.92 for the Washita River white bass. Numbers of spines in the first dorsal fin were practically invariable,

Table 10. Summary of F values obtained by covariance analysis of morphometric characters of white bass from the Red and Washita river arms of Lake Texoma.

Relationship	One Line	Slope	Adjusted Mean
Total length - least depth of caudal peduncle	9.8**	15.2**	
Total length - pectoral-dorsal distance	10.8**	15.1**	
Total length - head length	1.7	3.0	0.4
Total length - left pectoral length	2.5	4.7*	0.3
Total length - predorsal length	5.8**	11.0**	
Total length - body depth	17.9**	27.2**	
Total length - lateral line to dorsal distance	17.4**	32.5**	

* Significant at the 0.05 level
** Significant at the 0.01 level

Table 11. Analysis of variance of meristic characters of white bass collected from both the Red and Washita rivers

Source of Variance	Sum of Squares	Degrees of Freedom	Mean Squares	F
Anal fin				
Between groups	1.052	1	1.052	2.0
Within groups	67.760	131	0.517	
Total	68.812	132		
Left pectoral fin				
Between groups	4.793	1	4.793	14.4**
Within groups	43.508	131	0.332	
Total	48.301	132		

** Significant at the 0.01 level

usually consisting of nine spines, and the number of spines and rays in the pelvic fin were also consistent. A significant difference at the 0.01 level was found, however, between fish from the two areas in the number of rays in the left pectoral fin (Table 11). It may be seen from Table 12, that no significant difference in the left pectoral fin rays was found between the 1967, 1968, and 1969 year classes of Red River white bass. No significant difference in the left pectoral fin rays was found between the 1967, 1968, and 1969 year classes of white bass from the Washita River. There was a significant difference in the left pectoral fin rays at the 0.01 level between the Red and Washita river 1968 year class, but no significant difference was found between the 1967 and 1969 year classes of each area. The mean count for the Red River population's left pectoral fin in the 1967 year class was 16.00, in the 1968 year class it was 15.53, and in the 1969 year class it was 15.47. The mean count for the left pectoral fin for the Washita River population was 16.18 for the 1967 year class, 16.00 for the 1968 year class, and 15.78 for the 1969 year class. Therefore, the mean count for the left pectoral fin rays was consistently higher for white bass from the Washita River population, compared to similar counts for the Red River population. It was only significantly higher for the 1968 year class.

Age and Growth

The body-scale relationship for the Red River white bass can be described by the equation:

$$Y = 36.956 + 1.3712X$$

Table 12. Analysis of variance of the mean number of soft rays in the left pectoral fin for 1967, 1968, and 1969 year classes of white bass from the Red and Washita rivers.

Source of Variance	Sum of Squares	Degrees of Freedom	Mean Squares	F
Left pectoral for Red River, 1967, 1968, 1969				
Between groups	1.137	2	0.568	1.5
Within groups	21.208	55	0.386	
Total	22.345	57		
Left pectoral for Washita River, 1967, 1968, 1969				
Between groups	1.548	2	0.774	2.8
Within groups	19.105	69	0.277	
Total	20.653	71		
Left pectoral for Red River vs Washita River 1967 year class				
Between groups	0.114	1	0.114	0.4
Within groups	3.636	14	0.260	
Total	3.750	15		
Left pectoral for Red River vs Washita River 1968 year class				
Between groups	3.466	1	3.466	10.3**
Within groups	20.471	61	0.336	
Total	23.937	62		
Left pectoral for Red River vs Washita River 1969 year class				
Between groups	1.128	1	1.128	3.4
Within groups	16.206	49	0.331	
Total	17.334	50		

** Significant at the 0.01 level

The Washita River white bass body-scale relationship was found to be:

$Y = 38.252 + 1.3665X$

where Y is the calculated length, and X is the scale radius (32X). These equations, along with the standard error and other quantities necessary for determination of confidence limits, are given in Appendix C. An analysis of covariance (Table 13) showed that there was no significant difference in the regression coefficients or adjusted means for the body-scale relationships of the white bass taken from the two rivers.

Length-weight data are presented separately by sex for each area (Fig. 13). The following equations were obtained by the method of least squares:

Red River males

$\log W = -5.0039 + 3.0563 \log L$

Washita River males

$\log W = -4.3617 + 2.7926 \log L$

Red River females

$\log W = -5.0123 + 3.0628 \log L$

Washita River females

$\log W = -4.2869 + 2.7746 \log L$

where W is the weight in grams, and L is the total length in millimeters. These equations, along with the standard error and other quantities necessary for determining confidence limits, are given in Appendix C. From the above equations, it can be seen that there was little difference in the length-weight relationship between the sexes from one area. An analysis of covariance showed a significant difference, however, in the

Table 13. Covariance analysis of regression lines obtained for total length-scale length (both sexes combined), and length-weight (log transformations), for male and female white bass from the Red and Washita river arms of Lake Texoma.

Source	Degrees of Freedom	Mean Squares	F
<u>Total length-scale length</u>			
Red River	177	358.308	
Washita River	278	341.552	
within	455	348.070	
regression	1	3.499	0.01
common	456	347.315	
adjusted	1	17.858	0.05
<u>Male length-weight</u>			
Red River	124	0.00146	
Washita River	186	0.00374	
within	310	0.00283	
regression	1	0.04124	14.6**
common	311	0.00295	
adjusted	1	0.00003	
<u>Female length-weight</u>			
Red River	104	0.00271	
Washita River	161	0.00380	
within	265	0.00337	
regression	1	0.02927	8.7**
common	266	0.00347	
adjusted	1	0.00517	

** Significant at the 0.01 level

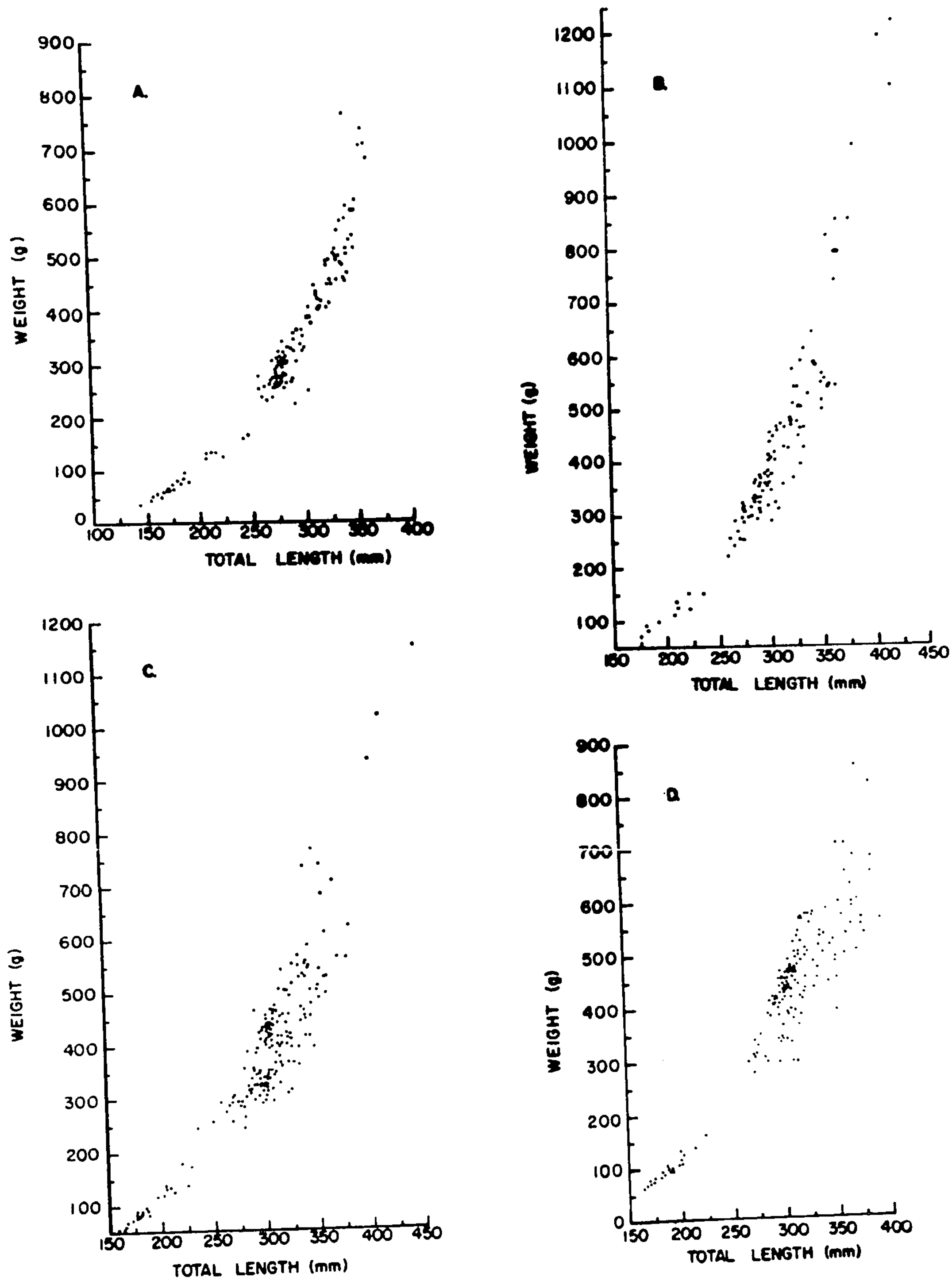
Figure 13. The length-weight relationship of Lake Texoma white bass.

A. Red River males: $\log W = -5.0039 + 3.0563 \log L$

B. Red River females: $\log W = -5.0123 + 3.0628 \log L$

C. Washita River males: $\log W = -4.3617 + 2.7926 \log L$

D. Washita River females: $\log W = -4.2869 + 2.7746 \log L$


A.
WEIGHT (g)
900
800
700
600
500
400
300
200
100
0
100 150 200 250 300 350 400
TOTAL LENGTH (mm)
B.
WEIGHT (g)
1200
1100
1000
900
800
700
600
500
400
300
200
100
150 200 250 300 350 400 450
TOTAL LENGTH (mm)
C.
WEIGHT (g)
1200
1100
1000
900
800
700
600
500
400
300
200
100
150 200 250 300 350 400 450
TOTAL LENGTH (mm)
D.
WEIGHT (g)
900
800
700
600
500
400
300
200
100
0
150 200 250 300 350 400
TOTAL LENGTH (mm)

regression coefficients between the two areas for each sex at the 0.01 level (Table 13).

A total of 203 young-of-the-year white bass were collected from Lake Texoma during July 1972. The average total length was 70.1 mm, with a range of 50 mm to 98 mm, and a coefficient of variation equal to 12.7.

The calculated growth for males from the Red River is given in Table 14. The oldest male captured was four years of age. The greatest growth in length occurred during the first two years, and weight increased most during the second year of life. The oldest Red River female was six years of age (Table 14). The most growth in length for the Red River fish also occurred during the first two years of life. The greatest increase in weight occurred during the second year of life. Females from the Red River were, on the average, larger than males from the Red River. The calculated growth of males from the Washita River is given in Table 15. The oldest males from this area belonged to age group V. The most growth in length occurred in the first two years, however, the greatest weight increase occurred in the fifth year. The calculated growth for females from the Washita River is presented in Table 15. The oldest female from this area belonged to age group VI. The greatest increase in length also was in the first two years, and, the greatest increase in weight was in the second year. No differential growth rate was observed between the sexes.

Comparing the growth rates between the two river systems, the Washita River white bass, on the average, were larger than the Red River white bass. The length frequency distribution of yearling and older

Table 14. Average calculated total lengths (mm) and weights (g), and average length and weight increments for each age group of male and female white bass from the Red River Arm of Lake Texoma during 1969, 1970, and 1971. (Number of fish in parenthesis)

Year Class	Year Collected	Age Group	Mean Calculated Length at each Annulus by Sex: 1 M	1 F	2 M	2 F	3 M	3 F	4 M	4 F	5 M	5 F	6 M	6 F	Mean Length at Capture M	Mean Length at Capture F
1968	1969	I	206 (13)	209 (7)											278	270
1967		II	194 (2)	209 (3)	279 (2)	275 (3)									312	319
1966		III	222 (5)	205 (5)	279 (5)	270 (5)	314 (5)	314 (5)							336	336
1968	1970	II	213 (42)	214 (13)	284 (42)	283 (13)									284	283
1967		III	227 (13)	207 (7)	298 (13)	299 (7)	338 (13)	331 (7)							338	331
1966		IV	209 (4)	203 (4)	262 (4)	264 (4)	314 (4)	309 (4)	348 (4)	350 (4)					348	350
1970	1971	I	178 (18)	192 (14)											178	194
1969		II	219 (21)	213 (17)	282 (21)	290 (17)									290	305
1968		III	228 (7)	235 (19)	298 (7)	303 (19)	334 (7)	338 (19)							339	340
1967		IV	256 (1)	202 (2)	296 (1)	294 (2)	337 (1)	334 (2)	358 (1)	374 (2)					358	374
1966		V		216 (1)		280 (1)		306 (1)		344 (1)		383 (1)				383
1965		VI		242 (1)		318 (1)		338 (1)		380 (1)		393 (1)		407 (1)		407
Average length-weighted mean			211 (126)	213 (93)	285 (95)	290 (72)	330 (30)	330 (39)	350 (5)	359 (8)		388 (2)		407 (1)		
Increment of average calculated lengths			211	213	74	77	45	40	20	29		29		19		
Average weight from length-weight formula			124 (126)	132 (93)	311 (95)	338 (72)	487 (30)	503 (39)	583 (5)	651 (8)		826 (2)		956 (1)		
Increment of average calculated weights			124	132	187	206	176	165	96	148		175		130		

Table 15. Average calculated total lengths (mm) and weights (g), and average length and weight increments for each age group of male and female white bass from the Washita River Arm of Lake Texoma during 1970 and 1971. (Number of fish in parenthesis)

Year Class	Year Collected	Age Group	Mean Calculated Length at each Annulus by Sex: 1 M	1 F	2 M	2 F	3 M	3 F	4 M	4 F	5 M	5 F	6 M	6 F	Mean Length at Capture M	Mean Length at Capture F
1968	1970	II	216 (16)	236 (12)	294 (16)	308 (12)									296	308
1967		III	239 (8)	202 (10)	318 (8)	308 (10)	344 (8)	344 (10)							344	344
1966		IV		210 (4)		293 (4)		344 (4)		377 (4)						377
1965		V	219 (1)	234 (1)	311 (1)	318 (1)	368 (1)	373 (1)	400 (1)	406 (1)	410 (1)	420 (1)			410	420
1970	1971	I	201 (11)	181 (24)											201	181
1969		II	219 (64)	208 (35)	293 (64)	294 (35)									301	299
1968		III	229 (25)	213 (46)	299 (25)	293 (46)	336 (25)	327 (46)							337	328
1967		IV	217 (9)	224 (10)	282 (9)	288 (10)	333 (9)	342 (10)	359 (9)	371 (10)					361	371
1966		V		248 (1)		310 (1)		334 (1)		366 (1)		387 (1)				387
1965		VI		243 (1)		327 (1)		362 (1)		384 (1)		419 (1)		440 (1)		450
Average length-weighted mean			220 (134)	209 (144)	295 (123)	296 (120)	338 (43)	334 (73)	363 (10)	375 (17)	410 (1)	409 (3)		440 (1)		
Increment of average calculated lengths			220	209	75	87	43	38	25	41	47	34		31		
Average weight from length-weight formula			152 (134)	140 (144)	344 (123)	368 (120)	503 (43)	514 (73)	614 (10)	709 (17)	862 (1)	902 (3)		1105 (1)		
Increment of average calculated weights			152	140	192	228	159	146	111	195	248	193		203		

white bass collected during January through April 1970 and 1971, is presented in Figure 14.

Blood Protein Analysis

Acrylamide gel electrophoresis yielded a total of 17 serum proteins for the 12 males from the Red River (Table 16). Band numbers 3, 10, and 17 occurred 100% of the time. A total of 17 different serum proteins were also found for 15 females from the Red River (Table 16). However, no band occurred 100% of the time.

It may be seen (Table 17) that 18 bands were found for the 29 males from the Washita River. Band number 3 occurred 100% of the time. The 36 females from the Washita River had 19 different proteins present (Table 17). None of the 19 different bands occurred 100% of the time.

Figure 14. Length frequency distribution of yearling and older white bass collected during January through April 1970 and 1971, by locality.

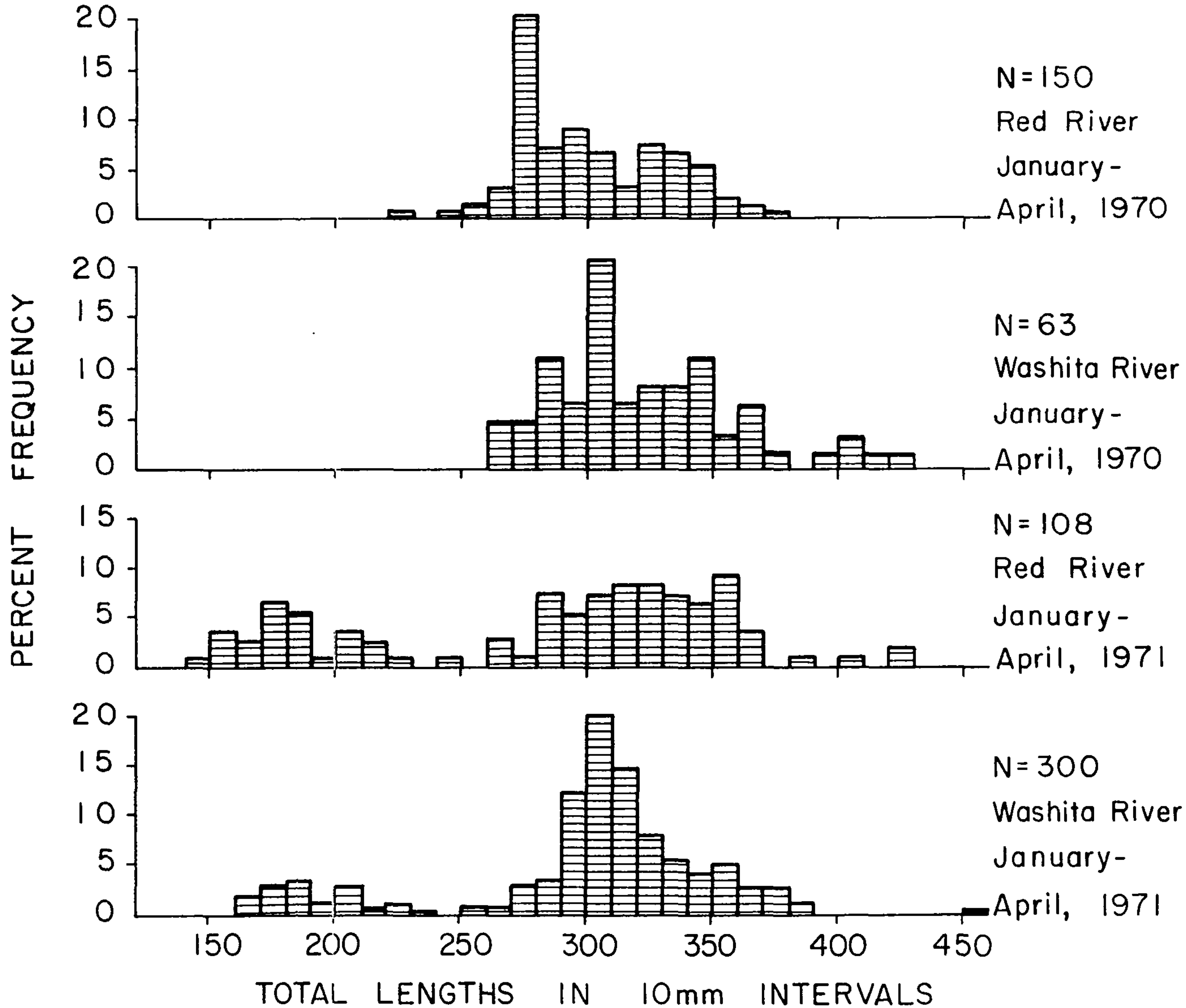

PERCENT FREQUENCY
N=150
Red River
January-
April, 1970
N=63
Washita River
January-
April, 1970
N=108
Red River
January-
April, 1971
N=300
Washita River
January-
April, 1971
TOTAL LENGTHS IN 10mm INTERVALS
150
200
250
300
350
400
450
0
5
10
15
20

Table 16. Electrophoretic analysis of serum proteins from 12 male and 15 female white bass collected from the Red River.

Band	N	%	$\bar{Y}R_f$	CV	$S_{\bar{Y}}$
Male					
1	1	8	3.8	-	-
2	2	17	7.4	1.0	0.04
3	12	100	9.7	5.6	0.16
4	4	33	11.6	2.3	0.13
5	10	83	14.5	7.7	0.35
6	10	83	18.4	3.0	0.17
7	9	75	20.0	3.9	0.26
8	3	25	21.3	0.5	0.06
9	10	83	22.9	2.2	0.16
10	12	100	26.4	3.9	0.30
11	7	58	29.4	3.5	0.38
12	4	33	34.1	2.9	0.50
13	1	8	36.4	-	-
14	7	58	45.5	4.8	0.82
15	7	58	49.4	1.6	0.29
16	3	25	54.7	3.9	1.24
17	12	100	66.2	3.4	0.65
Female					
1	1	7	3.7	-	-
2	3	20	7.6	8.8	0.38
3	14	93	9.6	4.0	0.10
4	3	20	11.7	1.8	0.12
5	12	80	14.0	9.3	0.37
6	10	67	17.6	3.0	0.17
7	10	67	19.8	3.9	0.25
8	6	40	21.3	1.1	0.10
9	13	87	22.9	2.3	0.14
10	8	53	26.9	3.8	0.36
11	9	60	30.5	2.9	0.30
12	7	47	34.1	3.1	0.40
13	7	47	38.7	4.2	0.61
14	9	60	45.4	3.8	0.57
15	10	67	49.4	2.0	0.32
16	11	73	55.8	2.7	0.46
17	13	87	65.2	2.9	0.52

Table 17. Electrophoretic analysis of serum proteins from 29 male and 36 female white bass collected from the Washita River.

Band	N	%	$\overline{Y}R_f$	CV	$S_{\overline{Y}}$
Male					
1	7	24	3.6	20.3	0.28
2	5	17	6.6	15.0	0.44
3	29	100	9.6	3.5	0.06
4	6	21	11.4	2.5	0.12
5	23	79	14.4	3.6	0.25
6	22	76	18.1	3.2	0.12
7	17	59	20.0	3.2	0.16
8	6	21	21.3	0.8	0.07
9	25	86	23.1	3.4	0.16
10	16	55	26.6	3.4	0.22
11	16	55	30.0	3.4	0.25
12	21	72	34.0	3.0	0.22
13	14	48	37.7	3.3	0.33
14	17	59	45.4	4.7	0.52
15	16	55	49.7	2.3	0.29
16	23	79	54.2	3.6	0.40
17	18	62	66.5	1.7	0.27
18	10	34	72.0	4.4	1.01
Female					
1	5	14	3.4	18.7	0.28
2	10	28	7.5	9.9	0.24
3	30	83	9.7	4.5	0.08
4	6	17	11.6	2.0	0.10
5	27	75	14.1	8.6	0.23
6	21	58	18.2	2.8	0.11
7	25	69	20.1	2.8	0.11
8	10	28	21.5	1.0	0.07
9	28	78	23.3	3.1	0.14
10	29	80	26.4	3.9	0.19
11	19	53	30.1	3.2	0.22
12	19	53	34.0	3.2	0.24
13	14	39	37.5	3.6	0.36
14	13	36	46.3	3.2	0.40
15	27	75	49.5	2.3	0.22
16	26	72	54.4	3.4	0.36
17	25	69	66.2	2.5	0.33
18	13	36	72.1	4.0	0.80
19	2	6	83.0	2.0	1.20

CHAPTER IV

DISCUSSION

Water Analysis

In conducting a population study, a knowledge of the organisms' immediate environment is essential. Water quality has been shown to have a profound influence on aquatic organisms (Hubbs, 1926, and Tåning, 1952).

Carlander (1955) demonstrated a positive correlation between total alkalinity and standing crop of fish. The total alkalinity present in the Washita River was greater than that in the Red River. Although the standing crop was not determined, the Washita River seemed to support a greater population of white bass.

Salinity has been defined by Hutchinson (1957) as the concentration of all ionic constituents present including sodium, potassium, magnesium, calcium, carbonate, sulphate, and halide. He said that the mean salinity of all rivers that have been studied is 146 ppm. The salinity found in the Red River is much greater than this average. Natural pollution from salt and gypsum deposits produces very poor quality water in the Red River. The high salt concentration may affect the white bass by causing an increase in osmotic pressure. The osmotic pressure that the white bass can tolerate would probably depend, to a large extent, on acclimatization. There may also be a direct toxic effect induced. Radtke and Turner (1967) found that concentrations of total dissolved solids as high as 350 ppm blocked spawning migrations of striped bass, Morone saxatilis (Walbaum), in the San Joaquin River in California. Specific conductance was assumed to be directly related to dissolved solids content. They also found that striped bass require a lower concentration of dissolved solids for spawning than that which limits their upstream movement. The concentration of total dissolved solids which limits white bass spawning is unknown. However, the concentration seems to be higher than that which has been reported for the striped bass. Jenkins (1970) compiled data for 140 large impoundments. Using a partial correlation analysis, he found a positive effect of total dissolved solids on white bass standing crop. The mean value for the 140 reservoirs studied was 162 ppm total dissolved solids. Barlow (1961) noted that high salinities have been found to retard development, thus producing higher counts in meristic structures. In this study, of the meristic structures studied, only the left pectoral fin was significantly different between the two populations. The 1968 year class from the Washita River, with the lower salinity, had a higher mean count (16.00) than the same year class from the Red River (15.53). Evidently, other factors had a greater influence than salinity in determining the number of fin rays present in the left pectoral fin.

Olmsted and Kilambi (1971) found an inverse relationship between feeding intensity and pH. Little variation in pH was noted in the present study, and probably was not a major contribution to the differences observed in the white bass from each arm of Lake Texoma. They also found that water conductivity and transparency in Beaver Reservoir, Arkansas had a direct influence on the feeding intensity of white bass.

Developmental rate varies directly with temperature. Normally, lower temperatures are responsible for the production of higher counts in meristic structures (Barlow, 1961). Most of the meristic structures studied were not significantly different between the two areas. The large temperature fluctuations present in each river may have been responsible for this. The fact that the mean left pectoral fin ray counts were only significantly different in the 1968 year class also supports this belief. Temperature has also been shown to affect fecundity. Rounsefell (1957) correlated higher temperatures with lower fecundity in salmon. Hodder (1965) suggested that differences in fecundity were related to temperature at certain critical periods during the initial development and early maturation of haddock ova. However, he said that low temperature may be related to low fecundity. The fecundity of the white bass from the Washita River was generally greater than that of the Red River. The effect of temperature on white bass fecundity is unknown. Little difference was noted between water temperature in the two rivers, but a difference may have been present in the lake water where the populations spend most of their lives. The large fluctuations in temperature in each river would be especially harmful to species which have a long developmental time. The white bass is especially well adapted to spawning in this type of environment because it has a short development time. Yellayi and Kilambi (1969) found that white bass eggs hatched in approximately 50 hr at about 16 C.

Duncan and Myers (unpublished data, 1969) found that about a 3 C drop in temperature was sufficient to cause mass mortality in white bass larvae. Therefore, temperature fluctuations probably have a great influence on young white bass in the Red and Washita rivers.

Sex Ratios and Spawning

In this study, especially during the spawning season, individual collections often consisted of mainly one sex. Riggs (1955) also noted that the numerical relationship of males to females does not remain static through all seasons of the year. Extreme differences in the sex ratios did occur, especially during spawning migrations. However, for the entire spawning season, there was no significant difference found for the Washita River population. The significant difference found for the Washita River non-spawning fish may have been partly due to the small sample size. The 1:1 sex ratio found over the total time interval for the Washita River and for the non-spawning time period for the Red River, should be expected. The significant difference found for the Red River spawning population was large enough to cause the total period to be significantly different from the expected 1:1 ratio. Olson (1968) has concluded that variations in sex ratios are probably the result of environmental factors, including fish population density. Movement up and down river throughout the spawning period has not been previously described for the white bass, but was evident in this study. However, the total distance that these fish travel in each direction has not been determined. As would be expected, as the spawning season progressed, more downstream movement was observed. With the large concentration of white bass in these rivers, the food supply is probably soon exhausted. Riggs (1955) said both sexes feed during their spawning migrations. The water temperature is constantly rising, and the current flow is generally decreasing. Also, in the Red River, there was an extremely large gar population. However, no estimate of the amount of gar predation on the white bass was determined.

It is not known whether the white bass return annually to the site of first spawning or to their natal spawning site. Horrall (1961) released 9,071 white bass and recaptured 1,384 of which 88.8% had "homed" correctly. Hasler, et al (1958) marked 1,366 white bass and displaced them 2.4 km. Of 181 recaptures, less than 9% erred. The fish that were released at the spawning grounds were recaptured in no greater proportion than those displaced and released in the middle of the lake. The authors proposed that the white bass use a biological clock, that the sun serves as a point of reference for white bass in open water, and that the animal compensates for its movement by a biological chronometer. They proposed that other methods were used by white bass when near shore. Horrall (1961) described an experiment in which cotton plugs were placed in white bass olfactory sacs. Fewer of these fish returned to their previous spawning ground, but the exact effect the plugs had on the fish was unknown.

The observations on the spawning behavior seem to agree with what Riggs (1955) observed in Lake Shafer, Indiana, and with what Webb and Moss (1967) observed in Center Hill Reservoir, Tennessee. Shelton (1972) observed several white bass spawning together with gizzard shad, Dorosoma cepedianum (Lesueur), in Glasses Creek of Lake Texoma on April

21, 1970. He also noted that during a period of one day, the water temperature changed from about 16 C to 26 C. Very few gizzard shad were taken from the Washita River proper. However, gill nets that were placed in the open lake contained, on an average, approximately 20 gizzard shad for each white bass. The gizzard shad was numerous in the Red River and its spawning period probably overlapped that of the white bass.

Difficulty is often found in hatching and raising young white bass. Riggs (1955) was unsuccessful in getting any white bass eggs to hatch. Dietz (1965) used chorionic gonadotrophin to induce spawning in white bass that were held in Texas ponds. None of his white bass hatched. He suggested that using a fish pituitary injection might be more successful. Yellayi and Kilambi (1969) however, were successful in raising some Beaver Reservoir white bass larvae for 150 hr, but after 24 hr, fungus had killed most of their eggs. Duncan and Myers (unpublished data, 1969) have hatched White River white bass in 71 hr, 15 min after fertilization at a water temperature of approximately 17 C. They used malachite green to control fungus and filtered lake water to remove predacious copepods. Using this method, they were able to study development for a period of 46 days.

Fecundity

The determination of 0.57 mm in diameter and larger as mature egg size to be used for fecundity estimates, agrees with Newton (1968) who counted ova 0.57 mm and larger for fecundity estimates of white bass in Beaver Reservoir, and Ruelle (1970) who determined 0.60 mm to be minimum size of mature white bass eggs in Lewis and Clark Lake, South Dakota. Kilpatrick (1959) determined ova 0.62 mm in diameter to be mature for three year old Lake Texoma white bass. Riggs (1955), studying white bass from Shafer Lake and Lake Texoma, said the average diameter of 100 eggs was 0.81 mm. Sigler (1949) found a mean egg diameter of 0.79 mm for white bass in Spirit Lake, Iowa. The eggs in the present study and the eggs Newton (1968) measured were preserved. Neither Riggs (1955) nor Sigler (1949) mentioned whether the ova they measured had been fresh or preserved. The large range in size found for the mature eggs may be due partly to the effect of formalin altering the shape of the ova and crowding in the lumen. Shelton (1972) noted that freshly released shad eggs were irregular in shape, but soon rounded out when in contact with water.

The range of fecundity from 61,700 to 510,000 found in this study for the white bass, agrees with the range of 280,100 to 567,200 reported by Ruelle (1970). Larger estimates of white bass fecundity have been reported by Sigler (1949), with a range of 650,000 to 970,000 ova; Riggs (1955), with a range of 241,000 to 933,000 ova; Newton (1968), with a range of 140,000 to 994,000; and Arakie (1969), who said that white bass fecundity ranged from 1,000,000 to 15,000,000 ova. The higher fecundity estimates may be due to environmental differences present in each study, or to differences in technique. Sigler's range in fecundity was determined by a weight method based on only three fish. Riggs estimated the fecundity for 12 white bass using a volumetric method. However, the volumetric method is usually used for estimating fecundity for fish with large eggs (Vladykov and Legendre, 1940).

Phillips (1969) determined that the gravimetric method was more accurate than the volumetric method for the redbelly dace, Chrosomus erythrogaster Rafinesque. For one collection, he found an average absolute percentage error for the gravimetric method of 17.1%, and 144.5% for the volumetric method. Riggs counted eggs from two fish and got 241,000 and 465,000 ova. He did not mention whether he was counting only mature ova, but assuming he was, the fecundity of these two fish fall within the range found in this study. Newton used a wet weight method. Arakie failed to mention where or how he got his unusually high estimates.

From the regression equations calculated for the Lake Texoma white bass, predictions of potential number of mature eggs can be made knowing only the location where the fish were collected, and one of the following three characters: total length, weight, or age. Covariance analysis showed that there was no significant difference in the slopes, but there was a significant difference at the 0.01 level for adjusted means. Therefore, for a given length, weight, or age, a Washita River white bass will normally have a higher fecundity than a Red River white bass. Fecundity for the Red River fish was most highly correlated with weight, next with length, and least with age. MacGregor (1957) found a similar relationship in the Pacific sardine, Sardinops sagax (Jenyns). Fecundity for the Washita River fish was most highly correlated with length, next with weight, and least with age. Lehman (1953), studying the American shad, Alosa sapidissima (Wilson), found fecundity correlated in the same manner as the Washita River sample. It is difficult to explain the differences in correlation for fecundity-length and weight for the two populations. The least amount of correlation was found for fecundity-age for both populations. This may be the result of difficulties in determining the age of older white bass which may not always form annuli.

The mean mature ovum diameter for the Washita River fish (0.67 mm) was slightly smaller than that of 0.69 mm for white bass from the Red River, although the difference was not significant. Thompson (1962) concluded that smaller average size of mature fish may be compensated for by a smaller egg size, and therefore, is accompanied by a larger number of eggs per unit of body weight. This relation does not hold true when comparing white bass from the Red and Washita rivers. Scott (1956) stated that the size of the eggs of a species is genetically controlled, however, the number of eggs of a species is also influenced by the environment. Incerpi and Warner (1969) said that fish size and source have a direct effect on the size of their eggs. Vladykov (1956) believed that an important factor affecting fecundity was the abundance of food supply during several months preceding spawning. Scott (1962) carried out experimental diet restrictions on rainbow trout, Salmo gairdneri Richardson, and found that starvation during months preceding spawning influenced the number of eggs by increasing the rate of atresia. Some reabsorption of ova was observed in white bass ovaries, but no quantitative measurements were conducted. Rounsefell (1957) believed that the temperature of water affected fecundity, higher temperature yielding lower fecundity. He believed that different conditions present in various rivers could alter egg size. Hodder (1965) has suggested that differences in fecundity annually are related to temperature at certain critical periods during the initial development and early maturation of the ova. Bagenal (1966) also correlated high population density with low fecundity.

Incerpi and Warner (1969) stated that age and size of females at maturity, differences in lake productivity, genetic differences, and annual variations affect fecundity of fishes, causing variations in populations. Although differences in fecundity between the Red and Washita river populations of Lake Texoma may be genetic in origin, environmental differences such as temperature, population density, and availability of food may bring about the observed differences between white bass from the two arms of Lake Texoma. Whether environmental or genetic in origin, the significant differences found indicate that subpopulations of white bass are present within the Lake.

Morphometric Characters

Regression coefficients for total length to head and left pectoral lengths were not significant. Results from the covariance analysis, when the factor of total length was adjusted, indicated no significant difference between Red and Washita River white bass with respect to head length and left pectoral length. Therefore, these two characters cannot be used in separating the two populations. Each of the other morphometric relationships studied, namely, total length - least depth of caudal peduncle, total length - pectoral dorsal distance, total length - predorsal length, total length - body depth, and total length - lateral line to dorsal distance showed a significant difference in the regression coefficients. Therefore, each of these relationships shows that the white bass present in the spawning aggregations of the

Red and Washita rivers are not homogeneous.

What actually caused the differences that were encountered in body form of the white bass is subject to speculation. Hubbs (1941) said that some changes in body form are likely to have a genetic cause. Martin (1949) has shown that early development is important in determination of the relative size of body parts. He has also shown that temperature and diet during the early growth period yield differences in body form. He has also found that growth rate is not always correlated with body form, and because of the common correlation between body proportions and the number of meristic characters, he suggests that body form is to some extent determined early in life. Also, he found inflections at the time certain fish reach maturity. Therefore, the environmental conditions present when the fish is in its early stage of development, and the time when it reaches maturity, will have a great effect on the morphometric character. Wilder (1952), using analysis of covariance to study populations of brook trout, Salvelinus fontinalis (Mitchill), found that trout reared at higher temperatures had larger body parts. Even if the morphometric characters which were found to be significantly different were not genetically fixed, they could still be used as indicators for separating the white bass populations present in Lake Texoma.

Meristic Characters

Of the five meristic characters studied, only the left pectoral ray counts were significantly different at the 0.01 level between the two spawning populations. Krumholz and Cavanah (1968) found stability among all the meristic characters that they studied for the freshwater drum, Aplodinotus grunniens Rafinesque, from the lower Ohio River, Kentucky, and Lake Winnebago, Wisconsin. This stability has existed since early postglacial times. Hill (1968), studying vertebrae numbers in the yoke darter, Etheostoma juliae Meek, found siginificant differences between fish taken from the same river. Since there have been no previous meristic studies conducted on the white bass, it is not known what amount of meristic stability is present in this species.

Comparing the left pectoral counts for different year classes from both rivers, a significant difference was revealed only between the 1968 year class from each river. The fact that this was the only time that a significant difference occurred, seems to indicate that differences in water temperature, or perhaps other factors such as amount of salinity or other chemical conditions present, occurred during larval life at the time when the pectoral fin ray number was determined.

Low temperatures, high salinity, and low oxygen tensions cause longer development periods which usually produce higher meristic counts (Tåning, 1952). The number of fin and vertebral elements are determined during a short time period in early development. Tåning (1952) called this the sensitive period. He also found that the sensitive periods of different structures do not always coincide. It is difficult to determine whether differences are due to a selective adaptation or due to a phenotypic response to environmental influences. Hubbs (1955) said that the dorsal and anal fin ray numbers in subpopulations of mosquito fish, Gambusia affinis (Baird and Girard), are determined by the action of a single gene. Gabriel (1944) has shown a genetic basis for meristic variation in killifish, Fundulus heteroclitus (Linnaeus).

Age and Growth

Houser and Bryant (1970) found that the distribution of plotted body-scale measurements for some white bass from Bull Shoals Reservoir, in Arkansas and Missouri, followed complex curvilinear paths. Weese (1951), using standard lengths, also found the body length - scale length relationship for Lake Texoma white bass to be curvilinear. However, the relationship found between length and anterior scale radius in the present study agrees with that of Sigler (1949), Pelren (1970), and Priegel (1971), who worked on other bodies of water, and found a linear relationship to exist for the white bass body-scale relationship. No significant difference was found between the body-scale relationship for the two spawning populations in this study. This can be attributed to the fact that the same direct relationship between scale length and body length was present.

It is known that most species of fish change their shape as they grow, therefore, b is not equal to 3 (Martin, 1949). But b is often constant for fish of the same sex, stage of maturity, and from the same general locality. Therefore, the length-weight relationship can be used as a character for the differentiation of small taxonomic units like any other morphometric relationship (LeCren, 1951). Therefore, the significant difference found in the regression coefficients of the length-weight relationship between the two areas suggests that sub-populations exist.

There appears to be a great deal of variation in growth of the white bass during the first months of life. Bonn (1952) conducted a food and growth study of young white bass in Lake Texoma. He found increased growth rate of the young-of-the-year directly related to high water level in the spring, and a heavy diet of fish. The great variation in the length of the young white bass in the present study may be indicative of a prolonged spawning period.

The growth of Lake Texoma white bass from 1969 through 1971 appears, on the average, to be less than that reported for Texoma by Jenkins and Elkin (1957). The growth observed during the first year of life, however, was greater in the present study than they found. Compared to a study done by Webb and Moss (1967) on white bass from Center Hill Reservoir, white bass growth in Texoma is about equal the first year, but from the second year on, it is greater at Center Hill Reservoir. Growth of white bass during the first year of life in Lake Texoma is faster than that reported by Houser and Bryant (1970) for white bass from Bull Shoals Reservoir. However, after the first year, growth is faster in Bull Shoals Reservoir. As would be expected due to a longer growing season, Texoma white bass have a faster rate of growth than what has been reported in Indiana by Riggs (1953), and in New York by Forney and Taylor (1963). The differences observed in the growth of the two populations may be attributed to differences in the water quality of each river. Differences could also be attributed to fish feeding in different areas of the lake throughout the year, and different gene pools may be present, acting to produce differences in the growth of the two populations.

Blood Protein Analysis

The Washita River white bass had a greater number of protein bands present than the Red River fish, however, few bands were present 100% of the time. Wright and Hasler (1967), studying the serum protein patterns of white bass in Wisconsin, also found that most bands did not occur all of the time.

Houston and Fenwick (1965) have found that acclimation to higher temperature causes a decrease in the total protein present in the plasma of goldfish, *Carassius auratus* (Linnaeus). Pollard and Pichot (1971) said that the protein composition of blood serum varies with such factors as age, sex, sexual maturity, nutrition, and disease. Only mature fish were used for the blood protein analysis. Most of these fish were collected by gill nets and were undoubtedly under a certain amount of stress.

CHAPTER V

SUMMARY

A total of 1,743 white bass was collected from September 1969 through July 1972 from both the Red and Washita river arms of Lake Texoma. A study was conducted to determine whether two distinct subpopulations of white bass were present in the Lake. The following parameters were examined: fecundity, measurements, counts, age, growth, and blood protein analysis.

A chemical analysis of the water present in each area revealed a great difference in salinity and hardness, the Red River showing substantially higher values.

Sex ratios were found to vary greatly for individual collections, indicating segregation by sex, under both river and lake conditions.

Spawning activity was observed in the Washita River. A considerable amount of movement up- and downstream was detected by gill net collections in both rivers. Mature male white bass migrated upstream first, and were later joined by mature females. The spawning season started in late March and was completed by late April.

There was found to be no significant difference in mean mature egg size of white bass from the two river systems (Red River = 0.69 mm, and Washita River = 0.67 mm).

The fecundity of 31 white bass from the Red River and 37 from the Washita River ranged from 61,700 to 510,700, and from 111,900 to 452,300 ova respectively.

Adjusted mean values, determined by covariance analysis, of the Red and Washita river white bass regressions of fecundity-length, fecundity-weight, and fecundity-age were significantly different, with the Washita River population having the greatest fecundity.

A total of eight morphometric characters was measured on 171 Red River and 164 Washita River pre-spawning fish. Regressions of measurements of seven of the morphometric characters versus total length were analyzed by covariance analysis. Five of the morphometric comparisons could be used to separate the two populations.

Counts were conducted on 60 white bass from the Red River and 73 white bass from the Washita River. The number of rays in the left pectoral fin were significantly different for the 1968 year class fish from each area.

A body-scale relationship was determined separately for 179 Red River and 280 Washita River white bass. An analysis of covariance revealed no significant differences in the body-scale relationship between the two localities.

The length-weight relationship was determined for 232 Red River and 351 Washita River fish. An analysis of covariance revealed a significant difference in the regression coefficients for the length-weight relationship.

A total of 203 young-of-the-year white bass collected in July 1972, had an average total length of 70.1 mm.

Scales from 126 males and 93 females from the Red River Arm, and 134 males and 144 females from the Washita River Arm were read using a microprojector. Most growth occurred during the first two years of life. The oldest individuals collected were six years of age. The Washita River fish had a greater growth rate than the Red River fish.

Acrylamide gel electrophoresis was used to analyze blood protein patterns for 12 males and 15 females from the Red River, and 29 males and 36 females from the Washita River. Differences were detected in the protein bands for each sex and between the two localities.

On the basis of this study, heterogeneity among the white bass populations of the Red River Arm and the Washita River Arm of Lake Texoma was established.

LITERATURE CITED

Arakie, D. H. 1969. Fisheries Blue Book. David H. Arakie pub., Brooklyn, New York, 343 pp.

Bagenal, T. B. 1966. The ecological and geographical aspects of the fecundity of plaice, Pleuronectes platessa. J. Marine Biol. Assoc. United Kingdom 46(1):161-186.

Barlow, G. W. 1961. Causes and significance of morphological variation in fishes. Syst. Zool. 10(3):105-117.

Bonn, E. W. 1952. The food and growth rate of young white bass (Morone chrysops) in Lake Texoma. Trans. Amer. Fish. Soc. 82:213-221.

_________. 1956. White bass tagging experiment in Lake Texoma. Fisheries Investigations and Surveys of the Waters of Region 2-B, Texas, Dingell-Johnson Project F-8-R.

Borodin, N. 1925. The Atlantic sturgeon. Trans. Amer. Fish. Soc. 55:184-190.

Buchler Instruments. 1966. Polyanalyst, an analytical temperature regulated disc electrophoresis apparatus. Buchler Instruments, Inc., Fort Lee, New Jersey, (mimeo) 10 pp.

Carlander, K. D. 1955. The standing crop of fish in lakes. J. Fish. Res. Bd. Canada 12(4):543-570.

Clark, F. N. 1934. Maturity of the California sardine, (Sardinia caerulea), determined by ova diameter measurements. Calif. Div. Fish and Game, Fish. Bull. No. 42:1-49.

Darlington, P. J. Jr. 1963. Zoogeography, the Geographical Distribution of Animals. John Wiley and Sons, Inc., New York and London, 675 pp.

Dietz, E. M. 1965. Experimental artificial propagation of white bass (Roccus chrysops). Federal Aid in Fisheries Restoration Act, Texas. Federal Aid Project No. F-9-R-12, Job No. E-3, 4 pp.

Dover, T. B., A. R. Leonard, and L. L. Laine. 1968. Water for Oklahoma. Geological Survey Water Supply Paper 1890, 107 pp.

Duncan, T. O., and M. R. Myers, Jr. 1962. Artificial rearing of white bass, Roccus chrysops (Rafinesque). Unpub. data.

Ellis, M. M. 1937. Some fishery problems in impounded waters. Trans. Amer. Fish. Soc. 66:63-75.

Forney, J. L., and C. B. Taylor. 1963. Age and growth of white bass in Oneida Lake, New York. New York Fish and Game J. 10(2): 194-200.

Gabriel, M. L. 1944. Factors affecting the number and form of vertebrae in Fundulus heteroclitus. J. Exptl. Zool. 95:105-143.

Gosline, W. A. 1966. The limits of the fish family Serranidae, with notes on other lower percoids. Proc. Calif. Acad. Sci. 33(6): 91-112.

Hasler, A. D., R. M. Horrall, W. J. Wisby, and W. Bramer. 1958. Sun orientation and homing in fishes. Limnol. and Oceanogr. 3(4): 353-361.

Hill, L. G. 1968. Inter- and intrapopulation variation of the vertebral numbers of the yoke darter, Ethoestoma juliae. Southwest. Nat. 13(2):175-191.

Hodder, V. M. 1965. The possible effects of temperature on the fecundity of Grand Bank haddock. Internat. Comm. for the N. W. Atlantic Fisheries. Spec. Pub. No. 6, ICNAF Environ. Sympos. Dartmouth, N. S. Canada, p. 515-522.

Horrall, R. M. 1961. A comparative study of two spawning populations of the white bass, Roccus chrysops (Rafinesque) in Lake Mendota, Wisconsin, with special reference to homing behavior. Doctor's Dissertation, Univ. Michigan, 181 pp.

Houser, A., and H. E. Bryant. 1970. Age, growth, sex composition, and maturity of white bass in Bull Shoals Reservoir. Bureau of Sport Fisheries and Wildlife Technical Paper No. 49:3-11.

Houston, A. H., and J. C. Fenwick. 1965. Thermoacclimatory variations in the plasma proteins of goldfish, Carassius auratus. (Abstract) Amer. Zool. No. 5 p. 695.

Hubbs, C. L. 1926. The structural consequences of modifications of the developmental rate in fishes considered in reference to certain problems in evolution. Amer. Nat. 60:57-81.

________. 1941. The relation of hydrological conditions to speciation of fishes. Sympos. on Hydrobiol. Univ. Wisconsin Press, p. 182-195.

________. 1955. Hybridization between fish species in nature. Syst. Zool. 4(1):1-20.

Hutchinson, G. E. 1957. A Treatise on Limnology. Vol. I, John Wiley & Sons, Inc., New York, 1015 pp.

Incerpi, A., and K. Warner. 1969. Fecundity of landlocked salmon, Salmo salar. Trans. Amer. Fish. Soc. 98(4):720-723.

Jenkins, R. M. 1957. Dollars and sense in this business of fishing. Okla. Game and Fish News 13(2):9-10.

________. 1970. The influence of engineering design and operation and other environmental factors on reservoir fishery resources. Water Res. Bull. 6:(1).

________., and R. E. Elkin. 1957. Growth of white bass in Oklahoma. Okla. Fish. Res. Lab. Rept. No. 60, 21 pp.

Kilpatrick, E. B. 1959. Seasonal cycle in the gonads of the white bass (Roccus chrysops), in Lake Texoma, Oklahoma. Doctor's Dissertation, Univ. Oklahoma, 45 pp.

Krumholz, L. A., and H. S. Cavanah. 1968. Comparative morphometry of freshwater drum from two midwestern localities. Trans. Amer. Fish. Soc. 97(4):429-441.

LeCren, E. D. 1951. The length-weight relationship and seasonal cycle in gonad weight and condition of the perch (Perca fluviatilis). J. Anim. Ecol. 20(2):201-219.

Lehman, B. A. 1953. Fecundity of Hudson River shad. Fish and Wild. Serv. Res. Rept. No. 33:1-8.

Leong, C. C. 1967. Fecundity of surf smelt, Hypomesus pretiosus (Girard) in the State of Washington. Master's Thesis, Univ. Washington, 85 pp.

MacGregor, J. S. 1957. Fecundity of the Pacific sardine, Sardinops caerulea. U. S. Fish and Wild. Serv., Fish Bull. 57(121): 427-449.

Martin, W. R. 1949. The mechanics of environmental control of body form in fishes. Univ. Toronto Studies Bull., Series No. 58, Ontario Fish. Res. Lab. Pub. No. 70, 91 pp.

Newton, S. 1968. Fecundity of white bass, Roccus chrysops (Rafinesque) in Beaver Reservoir. Master's Thesis, Univ. Arkansas, 61 pp.

Olmsted, L. L., and R. V. Kilambi. 1971. Interrelationships between environmental factors and feeding biology of white bass in Beaver Reservoir, Arkansas. Res. Fish. and Limnol., Gordon Hall editor, No. 8 Amer. Fish. Soc., Washington D. C., 511 pp.

Olson, D. E. 1968. Sex ratios of young-of-year walleyes in Minnesota rearing ponds and lakes. Prog. Fish. Cult. 30(4):196-202.

Pelren, D. W. 1970. Age and growth of white bass from pool 19 of the Mississippi River. Iowa State J. of Sci. 44(4):471-479.

Peterson, C. L. 1961. Fecundity of the anchoveta, (Cetengraulis mysticetus) in the Gulf of Panama. Inter-Amer. Trop. Tuna Comm. Bull. 6(2):55-68.

Phillips, G. L. 1969. Accuracy of fecundity estimates for the minnow (Chrosomus erythrogaster) (Cyprinidae). Trans. Amer. Fish. Soc. 98(3):524-526.

Pollard, D. A., and P. Pichot. 1971. The systematic status of the mediterranean centracanthid fishes of the genus Spicara, and in particular S. chryselis (Valenciennes), as indicated by electrophoretic studies of their eye-lens proteins. J. Fish. Biol. 3(1):59-72.

Priegel, G. R. 1971. Age and rate of growth of the white bass in Lake Winnebago, Wisconsin. Trans. Amer. Fish. Soc. 100(3):567-569.

Radtke, L. D., and J. L. Turner. 1967. High concentrations of total dissolved solids block spawning migrations of striped bass, Roccus saxatilis, in the San Joaquin River, California. Trans. Amer. Fish. Soc. 96(4):405-407.

Riggs, C. D. 1953. Studies of the life history of the white bass, Lepibema chrysops (Rafinesque), with special reference to Shafer Lake, Indiana. Doctor's Dissertation, Univ. Michigan, 224 pp.

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

Rohlf, F. J., and R. R. Sokal. 1969. Statistical Tables. W. H. Freeman and Co., San Francisco, 253 pp.

Rounsefell, G. A. 1957. Fecundity of North American Salmonidae. U. S. Fish and Wild. Serv. Fish. Bull. 57(122):451-468.

Ruelle, R. 1970. White bass in Lewis and Clark Lake. Prog. Sport Fish. Res. 1969. U. S. Dept. Interior Fish and Wild. Serv. Bur. Sport Fish. and Wild., Washington Res. Pub., 88:228-229.

Scott, D. P. 1956. Effect of food quality on the fecundity of kamloops trout, Salmo gairdneri, Kamloops, Jordan. Master's Thesis, Univ. British Columbia, 108 pp.

________. 1962. Effect of food quantity on fecundity of rainbow trout, Salmo gairdneri. J. Fish. Res. Bd. Canada 19(4):715-731.

Shelton, W. L. 1972. Comparative reporductive biology of the gizzard shad, Dorosoma cepedianum (Lesueur), and the threadfin shad, Dorosoma petenense (Gunther), in Lake Texoma, Oklahoma. Doctor's Dissertation, Univ. Oklahoma, 232 pp.

Sigler, W. F. 1949. Life history of the white bass, Lepibema chrysops (Rafinesque) of Spirit Lake, Iowa. Iowa Agri. Exp. Sta. Res. Bull. 366:201-244.

Sokal, R. R., and F. J. Rohlf. 1969. Biometry. The Principles and Practice of Statistics in Biological Research. W. H. Freeman and Co., San Francisco, 776 pp.

Sublette, J. E. 1953. The ecology of the macroscopic bottom fauna in Lake Texoma. Doctor's Dissertation, Univ. Oklahoma.

Tåning, A. V. 1952. Experimental study of meristic characters in fishes. Biol. Rev. Cambridge Philos. Soc. 27:169-193.

Thomson, J. A. 1962. On the fecundity of Pacific cod (Gadus macrocephalus Tillsius) from Hecate Strait, British Columbia. J. Fish. Res. Bd. Canada 19(3):497-500.

United States Army Corps of Engineers. 1948. Denison Dam and Lake Texoma information pamphlet, Red River, Texas and Oklahoma, Revision March 1948, (mimeo) 22 pp.

________. 1961. Water resources development by the U. S. Army Corps of Engineers in Oklahoma, (mimeo) 51 pp.

Vladykov, V. D. 1956. Fecundity of wild speckled trout, Salvelinus fontinalis, in Quebec lakes. J. Fish. Res. Bd. Canada 13(6): 799-841.

________., and V. Legendre. 1940. The determination of the number of eggs in ovaries of brook trout (Salvelinus fontinalis). Copeia, No. 4:218-220.

Ward, H. C. 1951. A study of fish populations, with special reference to the white bass, Lepibema chrysops (Rafinesque) in Lake Duncan, Oklahoma. Proc. Oklahoma Acad. Sci. 30:69-84.

Webb, J. F., and D. D. Moss. 1967. Spawning behavior and age and growth of white bass in Center Hill Reservoir, Tennessee. Proc. 21st Ann. Conf. Southeast. Assoc. Game and Fish Comm., p. 343-357.

Weese, A. O. 1951. Age and growth of *Lepibema chrysops*, in Lake Texoma. Proc. Oklahoma Acad. Sci. 30:45-48.

Wilder, D. G. 1952. A comparative study of anadromous and freshwater fish populations of brook trout (*Salvelinus fontinalis*, Mitchill). J. Fish. Res. Bd. Canada 9(4):169-203.

Wright, T. D., and A. D. Hasler. 1967. An electrophoretic analysis of the effects of isolation and homing behavior upon the serum proteins of the white bass (*Roccus chrysops*) in Wisconsin. Amer. Nat. 101(921):401-413.

Yellayi, R. R., and R. V. Kilambi. 1969. Observations of early development of white bass, *Roccus chrysops* (Rafinesque). Proc. 23rd Ann. Conf. Southeast. Assoc. Game and Fish Comm., p. 261-264.

Appendix A. The regression equations, unexplained mean square, sum of squares of x, number, and standard error calculated for the fecundity-length, fecundity-weight, and fecundity-age relationships of white bass from the Red and Washita river arms of Lake Texoma.

$Y = \bar{Y} + b(X-\bar{X})$	$S^2_{Y \cdot X}$	Σx^2	N	S_b
Fecundity - length (Red River)				
205,975.419 + 2,193.2(X-337.258)	4,468,954,090	37,764	31	344.005
Fecundity - length (Washita River)				
227,094.297 + 2,159.4(X-325.216)	1,214,028,166	30,414	37	199.791
Fecundity - weight (Red River)				
205,975.419 + 384.32(X-561.319)	2,796,717,170	1,558,130	31	42.366
Fecundity - weight (Washita River)				
227,094.297 + 551.00(X-501.589)	1,542,565,165	429,265	37	59.946
Fecundity - age (Red River)				
205,975.419 + 81,021(X-2.968)	4,628,049,101	26.967	31	13,100.343
Fecundity - age (Washita River)				
227,094.297 + 71,241(X-2.486)	1,895,628,134	23.243	37	9,030.888

Appendix B. The regression equations, unexplained mean square, sum of squares of x, number, and standard error calculated for seven morphometric characters on total length of white bass from the Red and Washita river arms of Lake Texoma.

$Y = \bar{Y} + b(X-\bar{X})$	$S^2_{Y \cdot X}$	Σx^2	N	S_b
Total length - least depth of caudal peduncle (Red River)				
29.743 + 0.096746(X-298.064)	2.350	371,104.292	171	0.002
Total length - least depth of caudal peduncle (Washita River)				
31.720 + 0.080322(X-323.354)	1.731	167,803.487	164	0.003
Total length - pectoral-dorsal distance (Red River)				
56.164 + 0.21039(X-298.064)	11.900	371,104.292	171	0.006
Total length - pectoral-dorsal distance (Washita River)				
60.262 + 0.17409(X-323.354)	8.247	167,803.487	164	0.007
Total length - head length (Red River)				
71.515 + 0.21742(X-298.064)	7.274	371,104.292	171	0.004
Total length - head length (Washita River)				
76.695 + 0.20278(X-323.354)	9.586	167,803.487	164	0.008
Total length - left pectoral length (Red River)				
38.994 + 0.15109(X-298.064)	8.150	371,104.292	171	0.005
Total length - left pectoral length (Washita River)				
42.842 + 0.13337(X-323.354)	7.389	167,803.487	164	0.007
Total length - predorsal length (Red River)				
96.251 + 0.30231(X-298.064)	14.477	371,104.292	171	0.006
Total length - predorsal length (Washita River)				
103.933 + 0.26344(X-323.354)	17.322	167,803.487	164	0.010
Total length - body depth (Red River)				
76.456 + 0.28308(X-298.064)	30.159	371,104.292	171	0.009
Total length - body depth (Washita River)				
81.304 + 0.20551(X-323.354)	20.800	167,803.487	164	0.011
Total length - lateral line to dorsal distance (Red River)				
31.105 + 0.11382(X-298.064)	3.626	371,104.292	171	0.003
Total length - lateral line to dorsal distance (Washita River)				
33.421 + 0.083417(X-323.354)	2.940	167,803.487	164	0.004

Appendix C. The regression equations, unexplained mean square, sum of squares of x, number, and standard error calculated for the body-scale relationships and the length-weight relationships of white bass from the Red and Washita river arms of Lake Texoma.

$Y = \bar{Y} + b(X-\bar{X})$	$s^2_{Y \cdot X}$	Σx^2	N	s_b
Body-scale relationship (Red River)				
288.441 + 1.3712(X-183.408)	358.308	271,919.229	179	0.036
Body-scale relationship (Washita River)				
304.650 + 1.3665(X-194.954)	341.552	375,740.396	280	0.030
Length-weight relationship (Red River males)				
2.451 + 3.0563(X-2.440)	0.002	1.119	126	0.036
Length-weight relationship (Washita River males)				
2.531 + 2.7926(X-2.468)	0.004	1.307	188	0.054
Length-weight relationship (Red River females)				
2.571 + 3.0628(X-2.476)	0.003	0.493	106	0.074
Length-weight relationship (Washita River females)				
2.573 + 2.7746(X-2.473)	0.004	1.198	163	0.056

Appendix D. Age, total length (mm), body weight (g), ovary weight (g), gonadal-somatic index, and estimated fecundity (rounded off to the nearest hundred mature eggs), of mature Red River white bass collected in 1970 and 1971.

Total Length	Body Weight	Ovary Weight	Gonadal-somatic Index	Estimated Fecundity
2 year old fish				
307	461	73	15.8	320,700
315	428	60	14.0	104,100
322	509	82	16.1	175,300
315	462	71	15.4	236,000
289	323	34	10.5	93,000
302	289	29	10.0	61,700
287	332	35	10.5	107,700
274	293	36	12.3	121,000
291	374	38	10.2	129,800
330	396	52	13.1	119,600
321	472	62	13.1	150,600
300	373	39	10.4	133,800
3 year old fish				
333	426	54	12.7	193,200
329	502	54	10.8	200,300
355	534	57	10.7	165,500
350	561	64	11.4	191,600
357	542	70	12.9	149,900
326	538	61	11.3	178,500
342	644	68	10.6	199,500
350	514	52	10.1	167,300
325	536	64	11.9	232,000
334	610	92	15.1	191,300
4 year old fish				
383	992	108	10.9	330,000
363	540	60	11.1	190,900
378	851	94	11.0	204,400
367	794	113	14.2	382,900
366	792	85	10.7	235,400
353	439	47	10.7	240,000
351	548	59	10.8	210,600
5 year old fish				
420	1100	114	10.4	458,300
420	1223	137	11.2	510,700

Appendix E. Age, total length (mm), body weight (g), ovary weight (g), gonadal-somatic index, and estimated fecundity (rounded off to the nearest hundred mature eggs), of mature Washita River white bass collected in 1970 and 1971.

Total Length	Body Weight	Ovary Weight	Gonadal-somatic Index	Estimated Fecundity
2 year old fish				
311	378	63	16.7	238,800
299	439	62	14.1	211,600
316	541	69	12.8	218,900
320	564	63	11.2	248,300
321	437	63	14.4	193,900
297	466	65	13.9	159,300
286	387	49	12.7	137,000
291	406	47	11.6	186,400
306	434	56	12.9	144,600
315	531	91	17.1	230,200
312	524	72	13.7	233,500
323	511	65	12.7	220,200
300	367	45	12.3	137,000
312	503	77	15.3	198,800
317	386	60	15.5	141,000
323	577	95	16.5	251,000
301	443	53	12.0	194,100
310	456	55	12.1	183,200
304	463	61	13.2	215,000
327	559	75	13.4	262,800
308	466	67	14.4	202,400
330	485	73	15.0	241,200
297	340	40	11.8	111,900
315	498	64	12.8	190,600
296	406	43	10.6	130,500
3 year old fish				
330	571	78	13.7	260,000
352	451	52	11.5	234,000
334	393	52	13.2	230,000
340	538	114	21.2	348,100
330	576	90	15.6	233,800
337	541	78	14.4	199,900
355	598	82	13.7	243,200

Appendix E (continued)

Total Length	Body Weight	Ovary Weight	Gonadal-somatic Index	Estimated Fecundity
4 year old fish				
367	588	86	14.6	289,800
372	505	61	12.1	310,100
387	680	100	14.7	387,300
372	600	64	10.7	331,500
5 year old fish				
420	950	148	15.6	452,300