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Observations on the Life History of Channel Catfish, *Ictalurus Punctatus* (Rafinesque) in Utah Lake, Utah

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OBSERVATIONS ON THE LIFE HISTORY OF CHANNEL CATFISH, *ICTALURUS PUNCTATUS* (RAFINESQUE), IN UTAH LAKE, UTAH

by

Robert E. Lawler

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Robert E. Lawler

TABLE OF CONTENTS

Page

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDIX TABLES

INTRODUCTION

The channel catfish, *Ictalurus punctatus* (Rafinesque), was first introduced into Utah Lake in the summer of 1911, and has since been stocked in the lake on numerous occasions. It has only been in the last few years that the channel catfish has become an important game fish in Utah. As the value of the channel catfish, as a game fish, increased, it has become increasingly important to the state to maintain this species for present and future generations. This study was initiated in 1958 and completed in 1960, and was financed by the Utah State Department of Fish and Game.

Data on certain phases of the channel catfish life history were investigated to provide information to aid in management of this species. The following phases were studied: age and rate of growth; age composition of the population; reproduction success; food habits; movements; and extent of the fishing pressure.

HABITAT CHARACTERISTICS

Physical

Utah Lake (Figure 1) is a eutrophic lake located in Utah County, north central Utah, in the center of a semi-arid valley with an average annual rainfall of 15 inches. The north-south axis of Utah Lake is slightly over 20 miles long. The east-west axis is slightly over 6 miles wide. Surface area at maximum capacity, as recorded by the U. S. Geological Survey, is 95,900 acres. Average depth in August, 1959 was 6.6 feet. At compromise level the lake has a maximum depth of 15.25 feet.

Water supply.--The water supply of Utah Lake comes from a watershed of 3,000 square miles. Demands for water for culinary and irrigation purposes on tributaries of the lake have resulted in Deer Creek Reservoir on the Provo River and several small diversion dams on the Provo and Spanish Fork Rivers. Diversion dams have been constructed on four of the secondary tributary streams (Figure 1). During the summer irrigation period, American Fork Creek, Provo River, Spanish Fork River, and Hobble Creek, all tributaries of Utah Lake, are dry in sections. Any water in the lower section of these tributaries is the result of seepage. Benjamin Slough, Battle Creek, and Spring Creek have fairly regular waterflows.

Water temperatures.--Average maximum surface temperatures (Figure 2) rarely exceeded 80° F. during the period of this study. The highest daily surface temperature recorded was 86° F. Average maxi-

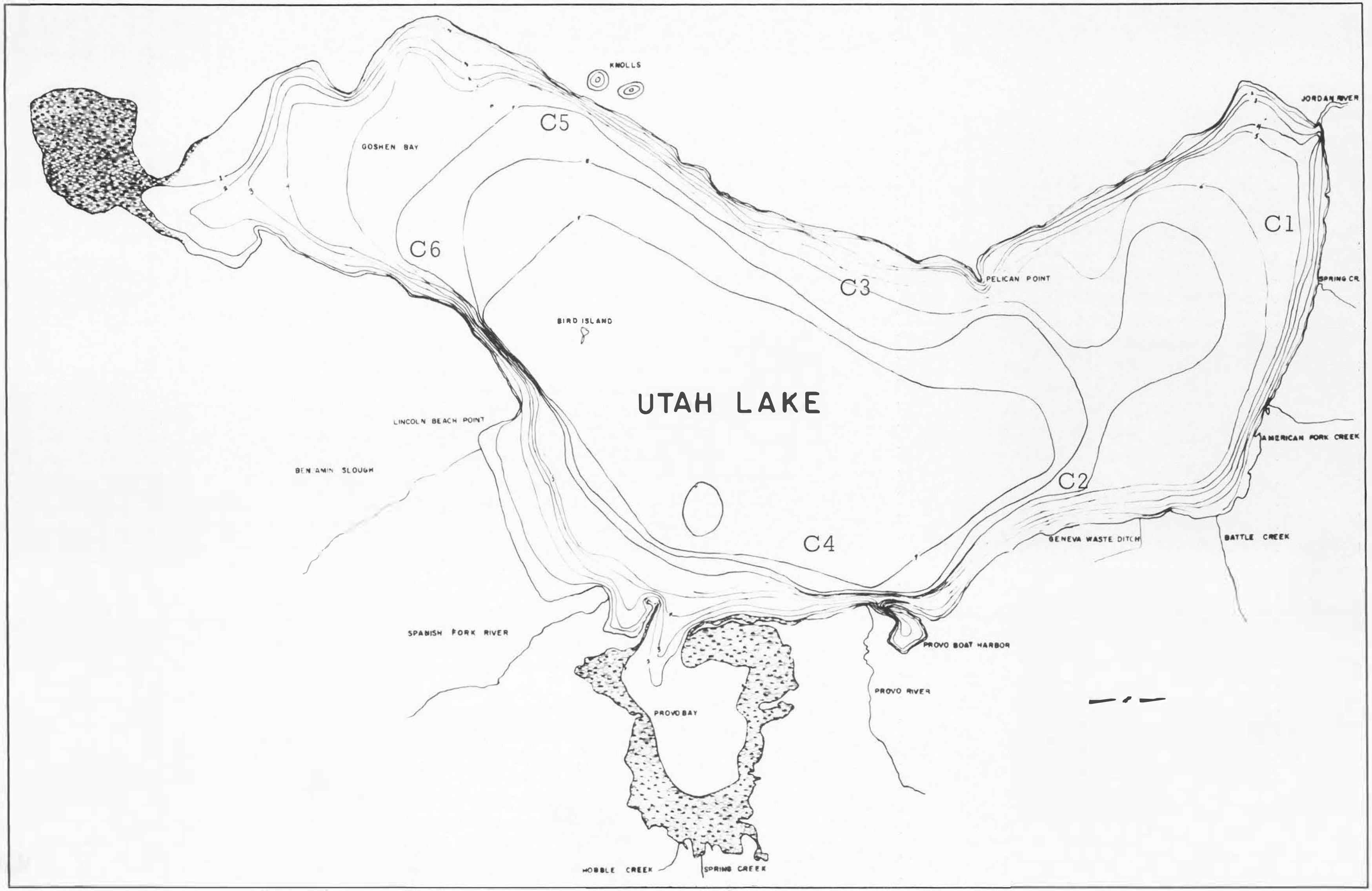

Figure 1. Contour map of Utah Lake showing major tributaries and control gill net stations - August, 1959.

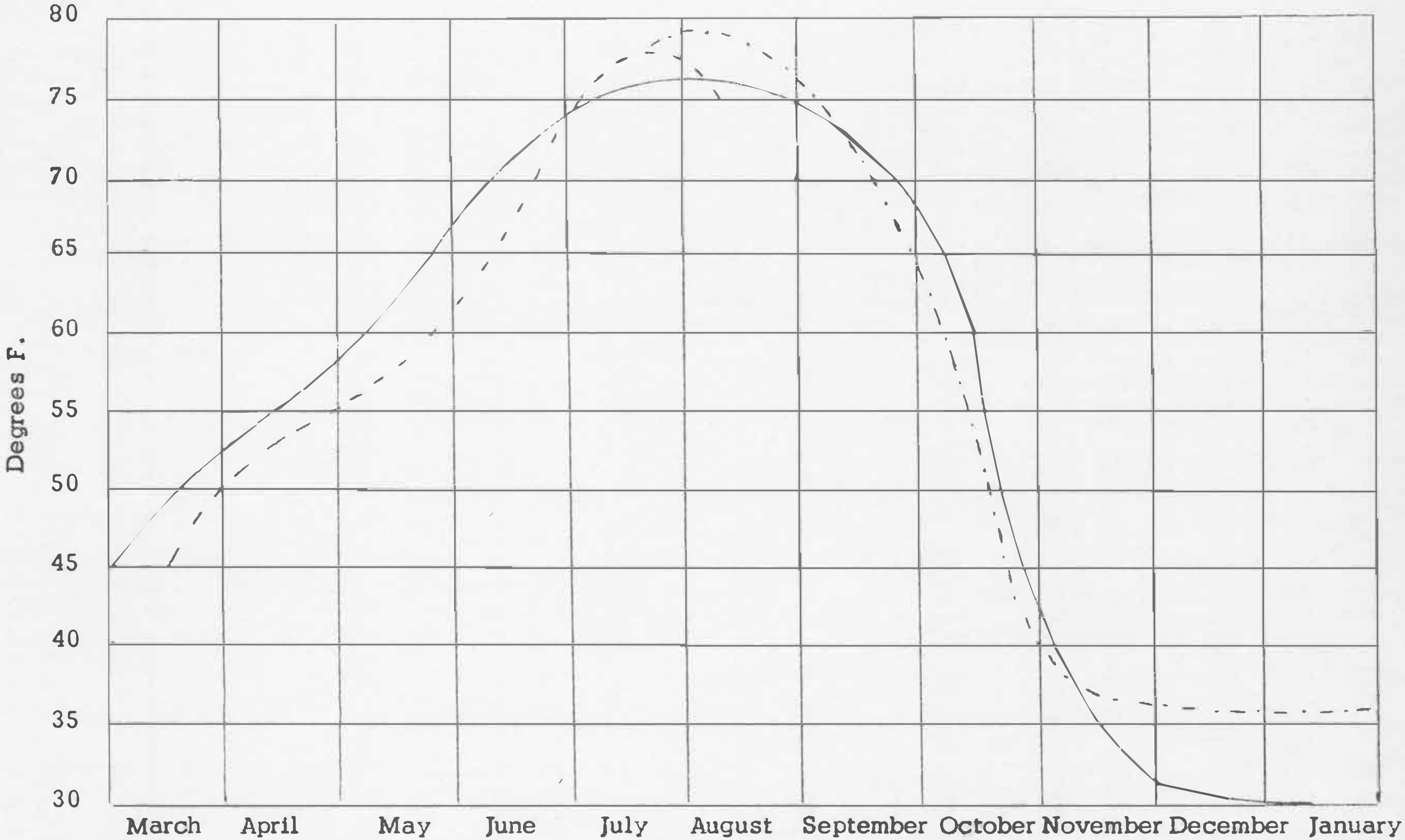

Figure 2. Mean monthly surface temperature of Utah Lake (solid line) 1929 to 1939*, (broken line) 1959, (dot-dash line) 1958

*Tanner (1960)

mum surface temperatures during 1958-59 occurred during July and August. Average temperatures during these months were 78° F. and 79° F. respectively. Tanner (1960) presents a 10-year average monthly surface temperature for the period from 1929 to 1939 (Figure 2). Average monthly maximum surface temperature for this period occurs during the last week of July and first week of August, with an average temperature of 76.5° F. which corresponds with figures for 1958-59. Good correlation can be found when comparing Tanner's (1960) data with the data collected during this study.

Although Utah Lake is rather shallow, a fairly rapid drop in water temperature is found from the surface to a depth of four feet. From the four-foot level there is a gradual decline in water temperatures to the lake bottom. It is doubtful that a true thermocline ever exists.

Surface temperatures are higher on the east shore than on the west shore in the northern half of the lake. This situation is reversed on the southern end of the lake. In both cases it is believed that prevailing winds push warmer surface water towards either shore, causing the increase in surface temperature.

Utah Lake is usually covered with ice from December to March. During the winter of 1958-59, the lake froze over solidly for only a short period of time. After this period, wind action sporadically caused a broken ice cover with patches of open water.

Turbidity.--Turbidity readings were taken at 11 stations with a Hellige Turbidity Meter, and ranged from 7.5 to 45.0 ppm of SiO_2 (Table 1). Table 1 shows some indication that turbidity of Utah Lake water increases during period of increased wind velocity. The gentle

Table 1. Turbidity in ppm of SiO_2 equivalents of Utah Lake and its tributaries, 1959

Date		Location	ppm	Wind velocity and direction (mph)
August	10	Control No. 3	35.0	none
	12	Control No. 5	18.0	east wind (10)
	12	Middle of lake	38.0	east wind (10)
	12	Control No. 4	13.0	none
	24	Control No. 2	7.5	none
	24	Skipper Bay	9.0	none
	31	Provo River mouth	43.0	northwest wind (30)
	31	Saratoga Bay	45.0	northwest wind (30)
	31	Control No. 1	45.0	northeast wind (20)
Sept.	16	Spring Creek	13.3	none
	16	Battle Creek	19.0	none

slope of the basin of the lake combined with shallow depth allows the wind actions to stir mud and silt on the bottom of the lake into the water. Particles in the water are small, nearly colloidal particles of calcareous clay. Constant wind action during the spring, summer, and fall seldom permit the silt to settle. Under winter's ice cover, Utah Lake's waters are clear.

Bottom types.--The bottom types of Utah Lake were classified by Ekman dredge samples, and are divided into four major classes: 1) mud and sand (includes calcareous clay, organic detritus, black muck and sand), 2) coarse gravel, 3) fine gravel, and 4) rubble (interspersed with ledge rock and boulders). The mud and sand classification covers roughly 95 percent of the lake's bottom. Rubble areas are of great importance because they offer the only major channel catfish spawning areas in the lake.

Chemical

Water chemistry.--Very little agreement can be found between the previous water analysis (Appendix Table 1) of Utah Lake, and the analysis in Appendix Table 2. The variability between these available samples can be attributed to the different locations in the lake from which water samples were taken. Free carbon dioxide is seldom found. Calcium and magnesium carbonate hardness of the water is rather high, about 400 ppm. The pH content ranges from 7.5 to 9.1.

Biological

Utah Lake is not a good example of a rich eutrophic lake. It does not have a plentiful supply of nutritive material but does possess most of the other characteristics attributed to a eutrophic lake. Organic material is found on the bottom and large aquatic plants are abundant in the littoral zone. Phytoplankton blooms are noted annually in shallow protected areas and in large marsh and swampy areas near shore.

Aquatic plants.--Softstem bulrush, three-square bulrush, narrowleaf cattail, common cattail, and pondweed are the most abundant aquatic plants in Utah Lake (Appendix Table 3). The bulrush-cattail association comprises nearly 95 percent of the aquatic plant beds in the lake. Bulrushes are dominant, with the softstem bulrush being the predominant individual plant. Three-square bulrush ranks second and pondweed is third.

Bottom organisms.--Neuhold (1955) found in 147 samples the following four groups of bottom organisms: 1) diptera larvae, 2) tubifex worms, 3) hemiptera, and 4) freshwater shrimp. General observations while sampling bottom types indicated that these were still the predominant organisms existing in Utah Lake. In 1959, fewer tubifex worms and more freshwater shrimp were found.

MATERIALS AND METHODS

Collection of samples

Channel catfish were collected with gill nets, fyke nets, and seines, and hook and line. The number of specimens collected by hook and line were small, but the fish were exceptionally large. Nearly all channel catfish over two years of age were collected in gill and fyke nets, and seines.

Standard experimental nets and small-mesh Japanese gill nets were employed during the study. Mesh size on the Japanese nets was 1/2 and 3/4 inch bar-mesh, and the nets ranged in length from 30 to 100 feet. Experimental gill nets (mesh sizes: 3/8, 3/4, 1, 1-1/4, 1-1/2 inch bar-mesh) ranged in length from 90 to 125 feet. Variation in size of the experimental nets was due to removal of damaged sections.

Gill-net sampling in Utah Lake included control and random sets. Six control gill-net stations were established (Figure 1) but usually one control station was sampled during a gill-net day. Two or more random sets were also sampled during the same gill-net day. Most gill nets were set perpendicular to shore.

Seines with a bar-mesh size larger than one inch were quite ineffective in taking channel catfish two years or younger. Commercial seines were most effective in taking channel catfish 10 inches and larger. Small 1/4 inch bar-mesh minnow type seines were used to collect young channel catfish.

Four sizes of fyke nets were used: 1/4, 1/2, 3/4, and 1 inch bar-mesh. Fyke nets were set in tributary streams and parallel to shore, just outside emergent vegetation.

The right pectoral spine was collected from all samples taken during 1958-59. Ease of removal determined its use (Sneed, 1950). Standard, fork, and total lengths were taken from most fish. All lengths were measured to the nearest millimeter from a measuring board, with the aid of a long-bladed knife. Standard length was measured from the tip of the snout, with the mouth closed, to the crease formed by flexing the tail. Total length was obtained by moving the two lobes of the tail together until the maximum reading was obtained. Considerable deviation was found in comparing measurements of fork to total length, due to excessive wear on lobes of the caudal fin.

Conversion of standard lengths to fork or total lengths may be made with factors given in Table 2. There is a slight discrepancy in lengths calculated in the smaller and larger size groups, due to the small sample size at either end of the sample.

Sexing the fish

Channel catfish ranging over 150 millimeters total length were sexed with confidence either by eye or with a magnifying glass. Ovaries of young female channel catfish were found to be granular in appearance, while those of the male were quite feathery and irregular. A magnifying glass was used to determine sex where these features could not be determined by eye.

Table 2. Factors for the conversion of standard, fork, and total lengths of Utah Lake channel catfish*

T. L. to S. L. (no change in units)	0.82
T. L. (inches) to S. L. (millimeters)	20.77
S. L. to T. L. (no change in units)	1.22
S. L. (millimeters) to T. L. (inches)	0.08
F. L. to S. L. (no change in units)	0.96
F. L. (inches) to S. L. (millimeters)	24.28
S. L. to F. L. (no change in units)	1.05
S. L. (millimeters) to F. L. (inches)	0.04
T. L. to F. L. (no change in units)	0.86
F. L. to T. L. (no change in units)	1.17

*S. L. = Standard length; F. L. = Fork length; T. L. = Total length. The factors involve 312 fish ranging in standard length from 116 to 583 millimeters.

Methods for external sexing of channel catfish are described by Doze (1925), Toole (1951), Canfield (1947), and Davis (1959). In this study, all channel catfish were sexed by internal examination. Maturity of each individual was recorded as either immature or adult. Only two classifications were used due to difficulty in ascertaining an in-between state of maturity. If developing eggs could be seen by the naked eye, the fish was classified as a mature female. The degree of featheriness of the gonads was used to determine the degree of maturity of the male. If the feather-like protuberances on the gonads were long and whitish, the fish was recorded as a mature male; otherwise, it was recorded as an immature male.

Preparation and examination of spine samples

Each spine was cleaned by boiling it in water for two minutes. It was next rubbed with a cloth to remove attached skin. After cleaning, it was sectioned with a saw as described by Schoffman (1954). Each section was cut as described by Sneed (1950) at the distal end of the basal groove. The sections were then ground by hand to a thickness of less than 10/1000ths of an inch, and mounted on a slide.

All measurements for the growth study were made along the anterior radius of the spine as recommended by Marzolf (1955). Growth along this radius is most uniform and subject to the least variation.

Ages of all fish were read four times without reference to the previous reading. Data on 27 channel catfish (8.5 percent) from the original sample were discarded because of the inability of the author to interpret the annulus formation with confidence. All fish discarded were 10 years of age or older.

Determination of age

Determination of age of channel catfish was based on counting the number of growth rings present on the pectoral spine cross section. Validity of these growth rings used as a year mark was verified by Sneed (1950), and Marzolf (1955).

Figure 3 illustrates pictorially a cross section taken from a Utah Lake channel catfish spine in its first, second, third, fourth, and fifth year of life. In its first year the spine does not have any annulus (Figure 3). The first annulus appears as the fish begins its second summer. Figure 3 further illustrates how the first annulus formed moves toward the lumen of the spine as the spine increases in size with age. The annulus for the completed fifth year has not yet been formed; therefore, it does not appear in Figure 3.

Computations of individual growth histories for fish one year or older were made with the aid of a nomograph similar to one described by Carlander and Smith (1944). Growth calculations were made using -18, rather than zero, as a base, since the body-spine relationship was represented by a straight line with a negative intercept of 18 millimeters.

Validity of annulus as a year mark

Dominance of three age classes during the study afford good evidence of the validity of the annulus as a year mark (Table 3). In 1958-59, the samples collected were predominantly fish from the 1952, 1953, and 1954-year classes. The 1953-year class was the most dominant, with 1952 and 1954 following respectively (Table 3). According to Hile (1941), this is the best evidence which substantiates the interpretation of the annulus as a year mark.

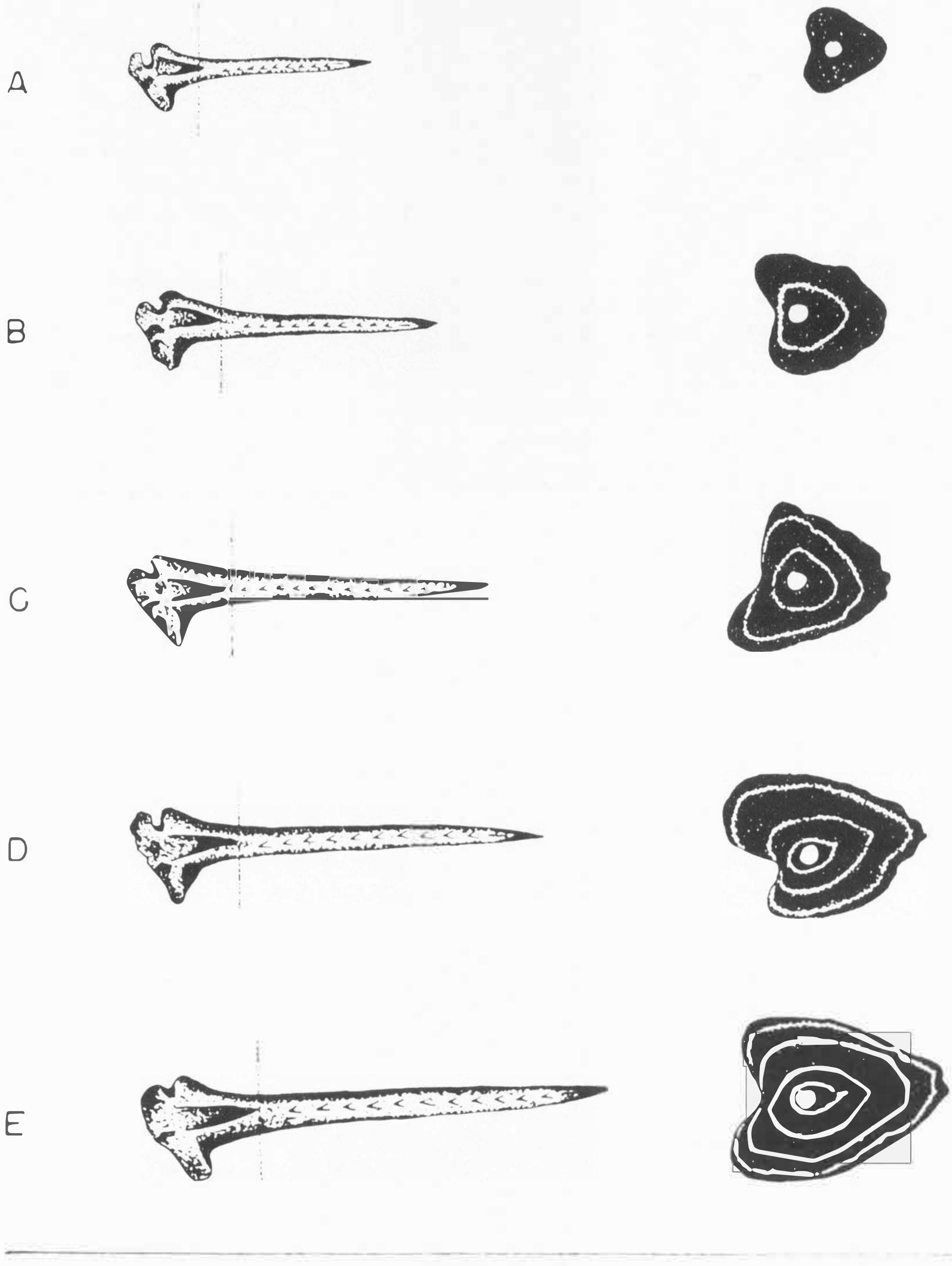

Figure 3. Whole channel catfish spines of ages 1 through 5 inclusive, and cross sections from each. Cross sections A, B, C, D, and E show the formation of the first annulus and the movement of the first annulus toward the lumen of the spine due to the enlargement of the basal groove. Art work by Phil Dotson.

Table 3. Number of channel catfish in succeeding year classes from 1948 to 1959 collected from Utah Lake in 1958-59

Calendar year	Succeeding year classes											
	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959
1958	1	5	4	13	58	71	41	19	13	1	1	...
1959	1	...	5	8	14	22	20	4	3	2	1	5

Figure 4 presents a comparison of the modes of length-frequency distribution for the entire sample with those for the individual age classes. There is good agreement between peaks of each distribution to indicate validity of the annulus as a year mark. Comparison of calculated length with empirical length (Table 4) verifies use of the annulus as a year mark.

Stomach analysis

Stomach samples were taken from channel catfish caught in gill nets and commercial seines. Date and location of each collection was recorded for each sample. Stomachs were taken from fish ranging in size from 300 millimeters and larger. No records were kept of individual size of fish from which stomach samples were taken. Organisms contained in each stomach were identified as to genera and species when possible. In each stomach the volume of each organism was measured by displacement.

Marking fish

Channel catfish were marked to study their movements in Utah Lake with the realization that the scope of the study would not permit an intensive marking and recapture program. Fin clipping was selected as a mark for its simplicity and speed of operation. Marked fish ranged in size from 340 to 550 millimeters. This size group was selected simply because it represented the most readily available size group of fish.

Fish were taken from the seines of commercial seiners, marked, and released where they were captured. The lake was divided into six areas, and each was given a combination of two clips. Channel catfish were marked in only four of the six areas.

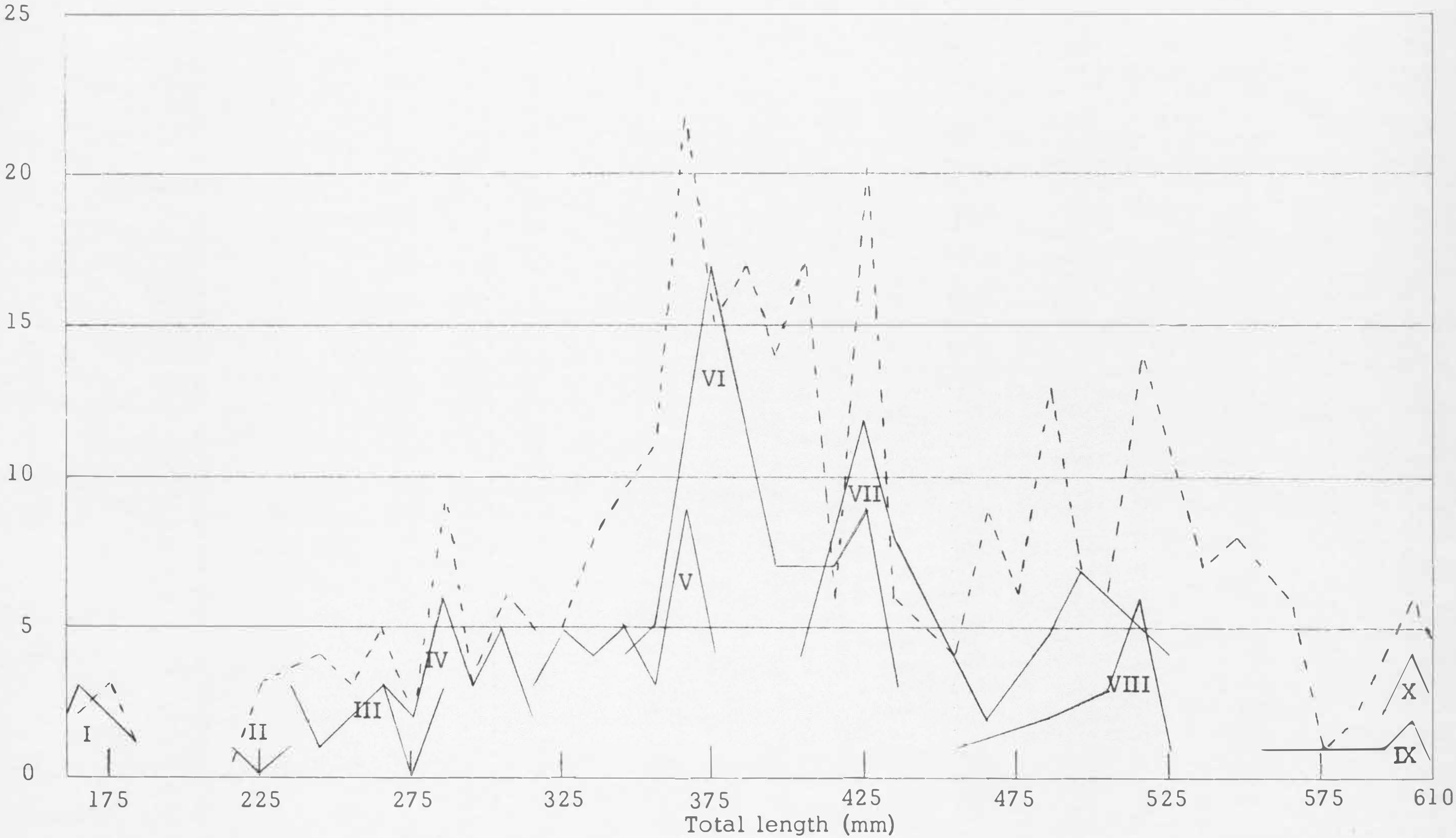

Figure 4. Length frequency of sample of channel catfish (broken line) collected in Utah Lake, 1958-59, compared with length frequencies of fish assigned to each age class (solid line). Roman numerals indicate successive age classes.

Table 4. Mean calculated standard lengths and increments of growth of 312 channel catfish collected from Utah Lake in 1958-59

Age class	Number of fish	Standard length at capture	Calculated length at end of each year of life											
			1	2	3	4	5	6	7	8	9	10	11	12
I	6	130	61											
II	2	179	71	158										
III	15	204	44	120	182									
IV	22	224	42	108	159	206								
V	45	283	48	117	168	226	268							
VI	91	324	53	126	174	233	279	309						
VII	80	377	59	146	198	254	307	340	363					
VIII	29	415	65	151	205	264	323	362	385	402				
IX	11	474	76	167	222	284	346	376	411	438	457			
X	9	484	81	178	231	284	335	389	425	445	458	472		
XI	1	514	113	171	203	245	310	365	399	425	450	480	495	
XII	1	498	55	168	231	305	394	415	430	453	462	471	480	489
Total	312													
Average			64	146	197	256	320	365	402	433	457	474	487	489
Increments of growth			64	78	51	57	50	45	25	20	16	15	12	9
Equivalent total length in inches			3.1	6.9	9.4	12.1	14.5	16.7	17.9	18.9	19.7	20.6	21.2	21.6
Number of fish			312	306	304	289	267	222	131	51	22	11	2	1

No adverse effects were observed on fish due to fin clipping. Individual fish were found that had lost fins or portions of fins naturally, and showed no adverse effects. Subsequently, it was learned that clips made on the caudal fin would be regenerated within a year. Caudal fin regeneration could readily be identified by the oblique angle of new fin ray growth from the origin of the cut.

FISH POPULATIONS

Checklist of species present

A checklist of common and scientific names of fish found in Utah Lake during the study is presented in Appendix Table 4. Only species actually collected are recorded.

Abundance of species

Game species.--Nine gamefish species were found in Utah Lake (Appendix Table 4). Three species, mountain whitefish, cutthroat and rainbow trout, are believed to be incidental to the lake, reaching it through drifting downstream from tributaries. Largemouth bass, cutthroat and rainbow trout, and smallfin redsided shiner were combined for convenience. The dominant game species in order of abundance are: channel catfish, yellow perch, walleye pike, black bullhead, and white bass. Data are based on the total number caught in experimental gill nets (Appendix Table 5).

Rough fish.--The dominant rough fish in order of abundance are: carp, Utah chub, Utah sucker, and rosyside sucker. In Appendix Tables 5 and 6, both species of suckers were combined to simplify handling.

AGE AND GROWTH

Body-spine relationship

Calculated annual growth of 312 channel catfish was determined from right pectoral spine cross sections. No regenerated spines were found during the study. Relationship between standard length and the anterior spine radius (X-77) of each fish was determined to serve as a basis for calculating growth rate. Data were grouped in 20 millimeter standard-length intervals, and mean body length, mean spine measurements, and body-spine ratio were determined for each interval (all ages and sexes combined). Body-spine (L/Sp) ratio increased progressively as the length of the fish increased (Table 5); that is, the spine becomes smaller in relation to the length of the fin.

A regression line having a y-intercept (length axis) of minus 18 millimeters was found by the least squares method to fit the plotted data (Figure 5). The smallest channel catfish captured measured 40 millimeters, total length, and it was found that spines on this fish had not yet completely calcified. All fish over 50 millimeters standard length were found with completely calcified spines.

In calculating the data (Figure 5), twenty-two 20 millimeter length intervals were used. Over the entire length range a straight line relationship fitted the plotted data. The greatest deviation from the regression line occurs at the extremes in body length and represents only a small group of fish. An examination of the body-spine relationship of male and female channel catfish failed to reveal consistent differences between sexes.

Table 5. Body-spine relationship (L/Sp) of 312 channel catfish in 20 mm. standard length intervals with all age classes combined

Mean standard length	Mean spine measurement (X-77)	Calculated lengths	L/Sp ratio	Number of fish
111-130	77.66	97.79	1.3	3
131-150	88.00	118.78	1.3	3
151-170	87.00	116.75	1.3	1
171-190	125.66	195.17	1.5	6
191-210	129.40	202.77	1.6	10
211-230	141.38	227.07	1.6	13
231-250	159.85	264.54	1.6	14
251-270	171.10	287.36	1.7	10
271-290	188.18	322.01	1.7	33
291-310	197.76	341.44	1.7	41
311-330	206.08	358.32	1.7	30
331-350	212.48	371.30	1.7	29
351-370	219.08	384.69	1.7	13
371-390	222.81	392.26	1.7	17
391-410	224.10	394.87	1.7	22
411-430	237.29	421.63	1.8	27
431-450	239.30	425.71	1.8	11
451-470	253.33	454.71	1.8	11
471-490	271.00	490.01	1.8	3
491-510	246.75	440.82	1.8	8
511-530	251.00	449.44	1.8	5
531-550	......	......	...	0
551-570	......	......	...	0
571-590	310.00	569.13	1.8	1

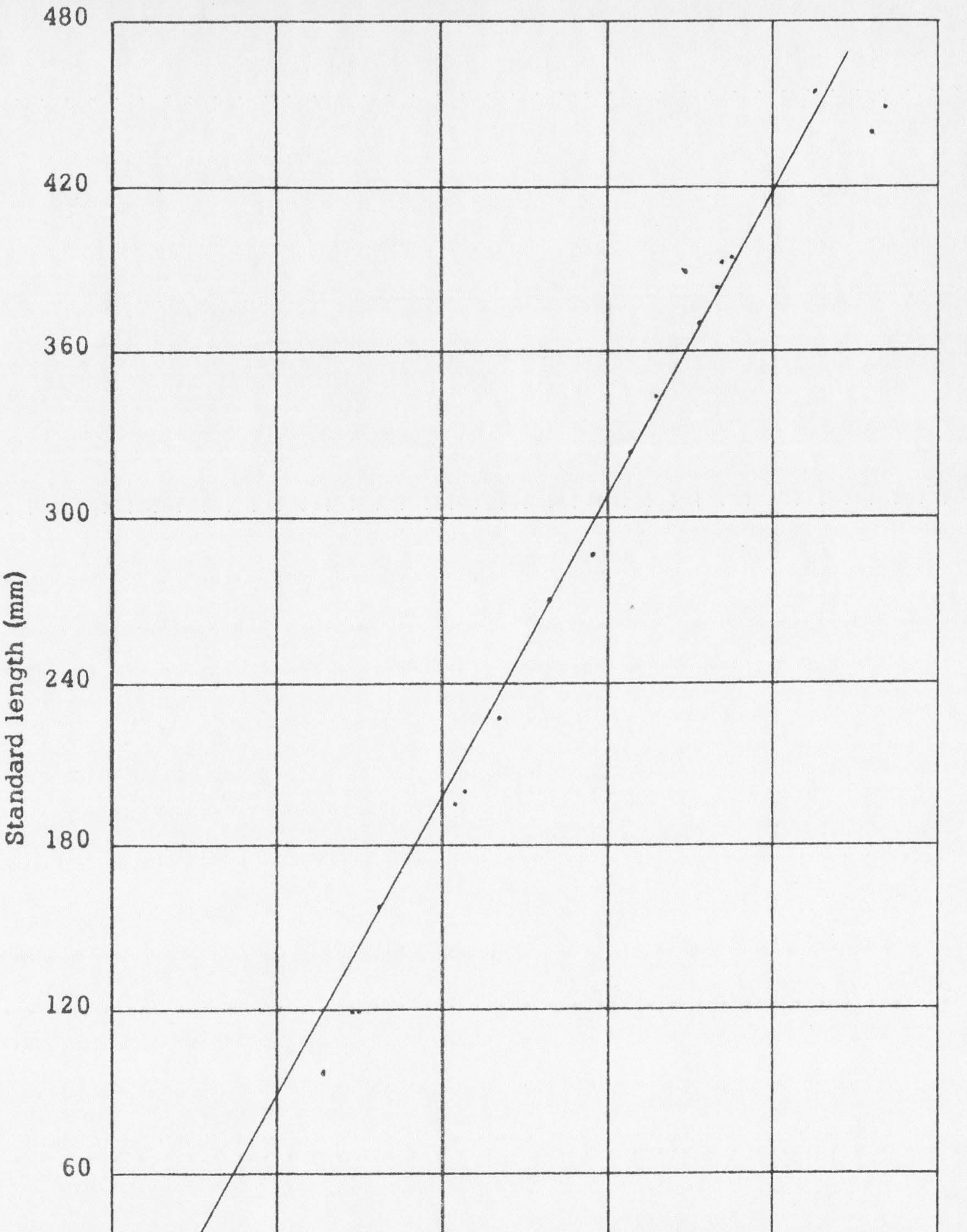

Figure 5. Body-spine relationship (L/Sp) of channel catfish, 1958-59

Rate of growth

Calculated lengths of both sexes in both years of collection have been combined for the growth study. Lengths and increments of growth (Table 4) are the mean calculated standard lengths and mean calculated increments for all age classes with sexes combined.

Increment of growth (78 millimeters) was greatest during the second year. This may be due to the rather long spawning season (June to September) which causes a great variation in length of the growing season during the first year. Most studies of other fish show that usually the first year produces the greatest growth for fish spawned early in the season. In Utah Lake, young channel catfish in their second year have a growing season of 7-1/2 months, while those in their first year only have a one to four month growing season. After the eighth year, the yearly increment of growth is small and decreases with additional years. Downward slope of the growth curve (Figure 6) indicates the reduction of growth during the later years of the fish.

A high degree of overlap in lengths exists among the IV to X age classes (Table 6). This overlap of size in the same age class is no indication of error in method of age determination (Appelget and Smith, 1950). Appelget and Smith found a range in length in known-age channel catfish in the III-year class from 3.1 to 5.9 inches respectively.

Year classes

The year classes, 1952 (14.5 percent), 1953 (29.2 percent), and 1954 (25.6 percent), were the predominant age classes in Utah Lake (Table 7), during 1958-59.

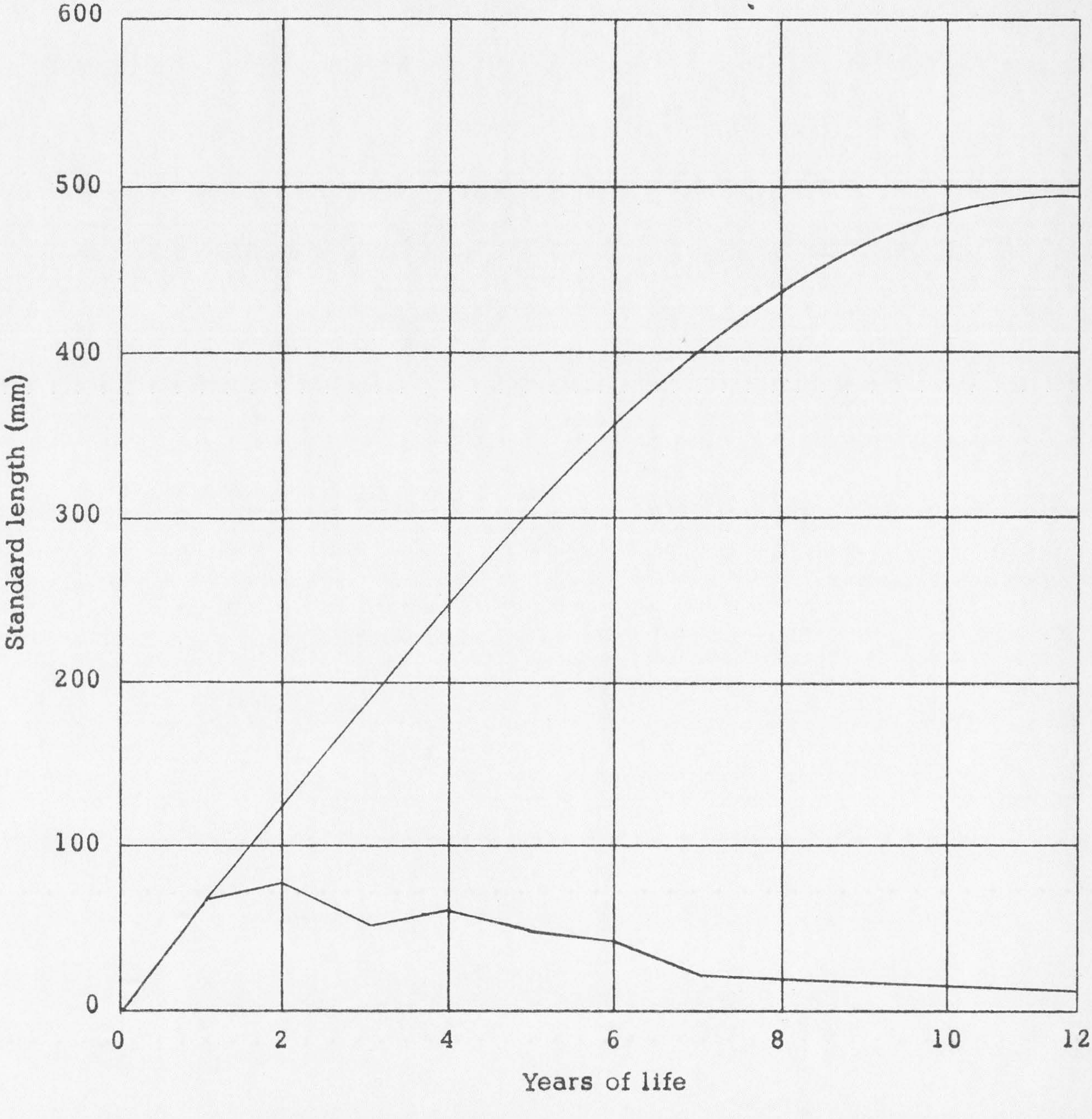

Figure 6. Mean calculated lengths and annual increments of growth of channel catfish based on Table 3.

Table 6. Number of individuals in each age class of channel catfish collected from Utah Lake in 1958-59, expressed in 20 mm. intervals

Length groups	Age class												Total
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
571-590										1			1
511-530								2	2		1		5
491-510									3	4		1	8
471-490							1		2				3
451-470							3	4	1	3			11
431-450						2	5	3	1				11
411-430					1	3	11	10	2	1			28
391-410					1	5	14	2					22
371-390				1		2	12	2					17
351-370						5	6	2					13
331-350					1	16	9	3					29
311-330					2	15	12	1					30
291-319					10	25	6						41
271-290					15	17	1						33
251-270			1	1	7	1							10
231-250			1	6	7								14
211-230			3	9	1								13
191-210			6	4									10
171-190		2	3	1									6
151-170			1										1
131-150	3												3
110-130	3												3
Total	6	2	15	22	45	91	80	29	11	9	1	1	312

Table 7. Distribution of channel catfish by age class and percentage of sample size collected in Utah Lake, 1958-59

Age class	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Number of Individuals	6	2	15	22	45	91	80	29	11	9	1	1
Percentage of total sample	2.0	0.6	4.8	7.1	14.5	29.2	25.6	9.2	3.5	2.9	0.3	0.3

Length of growing season and time of annulus formation

Number of individuals used in this portion of the study is very small. Therefore, the data are weak but are indicative of the period of growth in Utah Lake.

The amount of growth completed at different periods in the year was estimated by the method reported by Sigler (1949). Total calculated growth for the entire year was used to determine the percentage of growth actually completed during different periods of the year. Individual fish were classified according to their date of capture. Amount of growth for that year was recorded and compared with the total calculated growth for the entire year to determine the amount of growth completed at various intervals (Table 8).

The small number of individuals captured in the early spring may be the reason why no growth is recorded before July 5. Even though no growth was recorded up to this time, stomach analyses indicate that the channel catfish start feeding in late March and early April. Examination of spines of fish captured between June 10 and 30, 1958, indicate some growth during this period. Apparently the growing season of Utah Lake channel catfish commences early in April and continues until early in November, about 180 to 200 days duration. Nearly 75 to 80 percent of the growth is completed by September 15.

Appearance of newly formed annulus on the spine section ranges over a five-week period in April and May (Table 9). Some exceptions to this period of annulus formation were found. Generally, this data agrees closely with data available from Oklahoma (Finnell and Jenkins, 1954).

Table 8. Percentage of annual growth completed at time of capture for some Utah Lake channel catfish, 1958*

Age class	Collection dates	Number of fish	Mean standard length in millimeters: At capture	Calculated at end of previous year	Growth for current year	Calculated growth for entire current year	Calculated percent of annual growth completed
III	7-1 to 7-25	4	201	201	0	51	0
	8-1 to 8-21	2	193	214	17	51	33
IV	6-10 to 6-30	4	236	236	0	57	0
	7-5 to 7-19	7	236	260	24	57	42
V	8-21 to 8-29	5	258	305	47	50	94
	9-8 to 9-15	5	294	336	42	50	74
VI	8-13 to 8-31	12	318	338	20	45	44
	9-1 to 9-22	4	333	365	32	45	71
	11-1 to 11-5	2	282	338	56	45	124
VII	8-14 to 8-31	7	380	400	20	25	80
	9-8 to 9-22	13	332	361	29	25	116

*Calculated increments for entire growing period were based on data from combined age classes

Table 9. Percentage of channel catfish in various age classes with newly formed annulus in the spring of 1959*

Month	Week of month	Age Classes IV	V	VI	VII	VIII	IX	X
March	1	...	...	...	...	...	...	...
	2	...	0(1)	0(3)	0(1)	...	0(1)	0(2)
	3	...	...	0(1)	0(1)	0(1)	...	...
	4	...	...	...	0(3)	0(2)	0(3)	...
April	1	...	...	...	...	...	...	...
	2	...	0(1)	0(1)	...	...	...	...
	3	...	...	...	...	...	...	...
	4	...	...	50(2)	...	50(2)	0(1)	...
May	1	...	59(7)	20(5)	0(3)	...	100(1)	...
	2	...	...	...	100(1)	...	...	...
	3	...	...	...	...	...	...	...
	4	...	...	...	100(1)	...	...	...
June	1	...	...	...	100(1)	100(1)	...	...
	2	100(3)	100(8)	100(2)	...	...	...	...
	3	...	...	100(1)	...	...	...	...
	4	100(1)	...	100(1)	100(1)	...	...	...
July	1	100(3)	...	...	...	...	...	...
	2	100(2)	...	...	...	...	...	...
	3	100(2)	...	...	...	...	...	...
	4	...	...	...	...	...	...	...

*Number of fish in parentheses

Age at maturity

No channel catfish in Utah Lake in the first four years of life were regarded as mature. In successive year classes (IV, V, VI, VII, and VIII), percentage of maturity develops as follows: 9, 59, 94, 99, and 100 percent (Table 10). Buck (1956) states that turbid environment retards sexual development. This is believed to be the reason for the long period of time needed for Utah Lake channel catfish to mature. By the eighth year, all Utah Lake channel catfish collected were mature.

Length-weight relationship and coefficient of condition

Data for determination of length-weight relationship of channel catfish were obtained by combining sexes and both years' collections in order to obtain as large a sample as possible (Table 11). It is believed that the combination of sexes and years will not appreciably influence the length-weight relationship calculations. The following equation was determined by the least squares method (Sigler, 1953):

$$\text{Log } W = -4.814 + 3.025 \text{ Log } L.$$

The coefficient of condition (K factor) was determined by the equation:

$$K = \frac{W \times 10^5}{L^3}$$

where

W = the weight in grams

and

L = standard length in millimeters.

Table 10. Percentage of immature and mature channel catfish by age class and percentage of sex composition of mature individuals collected from Utah Lake in 1958-59

Age class	Percentage of fish		Percentage of mature	
	Immature	Mature	Males	Females
I	100	0	0	0
II	100	0	0	0
III	100	0	0	0
IV	100	0	0	0
V	44	56	52	48
VI	6	94	46	44
VII	1	99	57	43
VIII	0	100	33	67
IX	0	100	50	50
X	0	100	50	50
XI	0	100	0	100
XII	0	100	0	100

Table 11. Length-weight relationship of 397 channel catfish arranged in 20 mm. standard length intervals with all age classes combined

Mean standard length	Weight in grams Actual mean	Weight in grams Calculated mean	Difference in actual and calculated wt.	Mean K	Number of fish
109	35	22	13	2.70	1
124	44	33	-11	2.31	3
135	50	43	- 7	2.06	4
166	77	79	2	1.69	2
181	123	104	-19	2.09	7
200	153	140	-13	2.00	9
222	198	192	- 6	1.81	12
243	244	257	13	1.70	16
262	299	317	18	1.66	21
283	366	401	35	1.62	52
300	437	478	41	1.62	81
319	522	575	53	1.61	42
340	603	698	95	1.54	34
361	739	837	98	1.57	13
381	847	985	138	1.54	17
401	967	1,001	34	1.51	21
423	1,194	1,354	160	1.58	25
441	1,345	1,533	188	1.56	11
459	1,506	1,730	224	1.56	11
477	1,936	1,943	7	1.79	3
498	2,120	2,214	94	1.72	7
520	2,427	2,523	96	1.72	5

Based on the formula Log W = -4.814 + 3.025 Log L

Table 11 and Figure 7 indicate that the equation fits the empirical data reasonably well. As channel catfish become larger in length and weight, the variation between actual and calculated weights is greater. This is true excepting the last three length groups which show a reduction in deviation between empirical and calculated data. It will be further noted that these three length groups of fish also have an increased K factor. Muncy (1959) in Iowa, and Finnell and Jenkins (1954) in Oklahoma, used a ponderal index and condition index instead of a K factor but both found that condition increased with increases in length and weight of the fish.

The K factors of Utah Lake channel catfish decrease with considerable irregularity (Table 11) until the fish reach a standard length of 477 millimeters. After reaching this size, K factors continue to increase as the size of the fish increases (Figure 8). The initial decrease in the K factor may be attributable to the turbidity of Utah Lake. Buck (1956) indicates that turbid waters cause an increase in survival rate of channel catfish spawn and retard the growth rate. The increase in surviving individuals each year places a greater demand on the reduced food supply, which is caused by the turbidity of the water. Possibly, the individual fish in this study showing a decline in K factor are those dieting heavily on aquatic insects. As the fish grows, and changes its diet from insects to mainly fish, its weight increases.

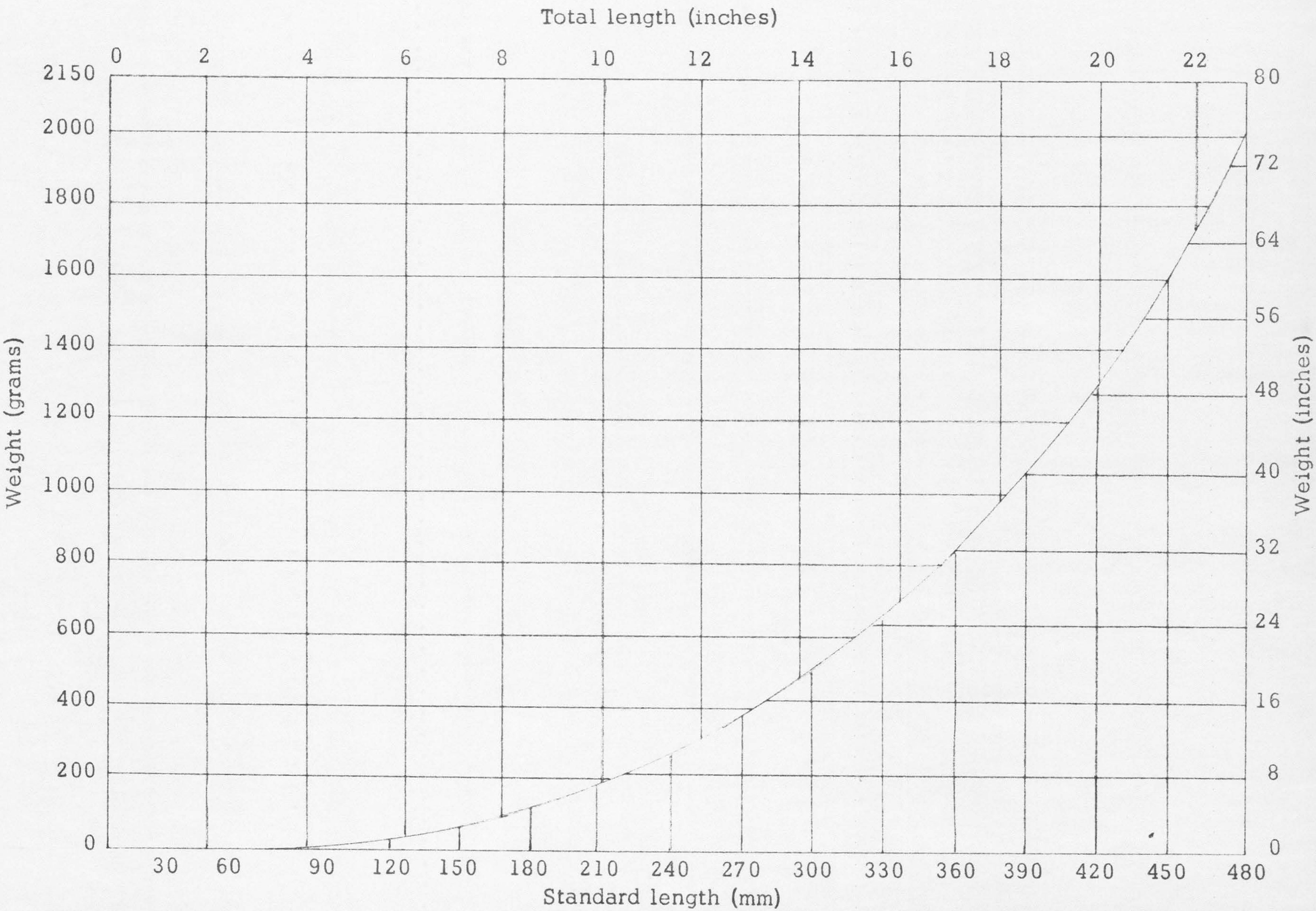

Figure 7. Length-weight relationship of 397 channel catfish based on equation Log W = Log a+ b Log L

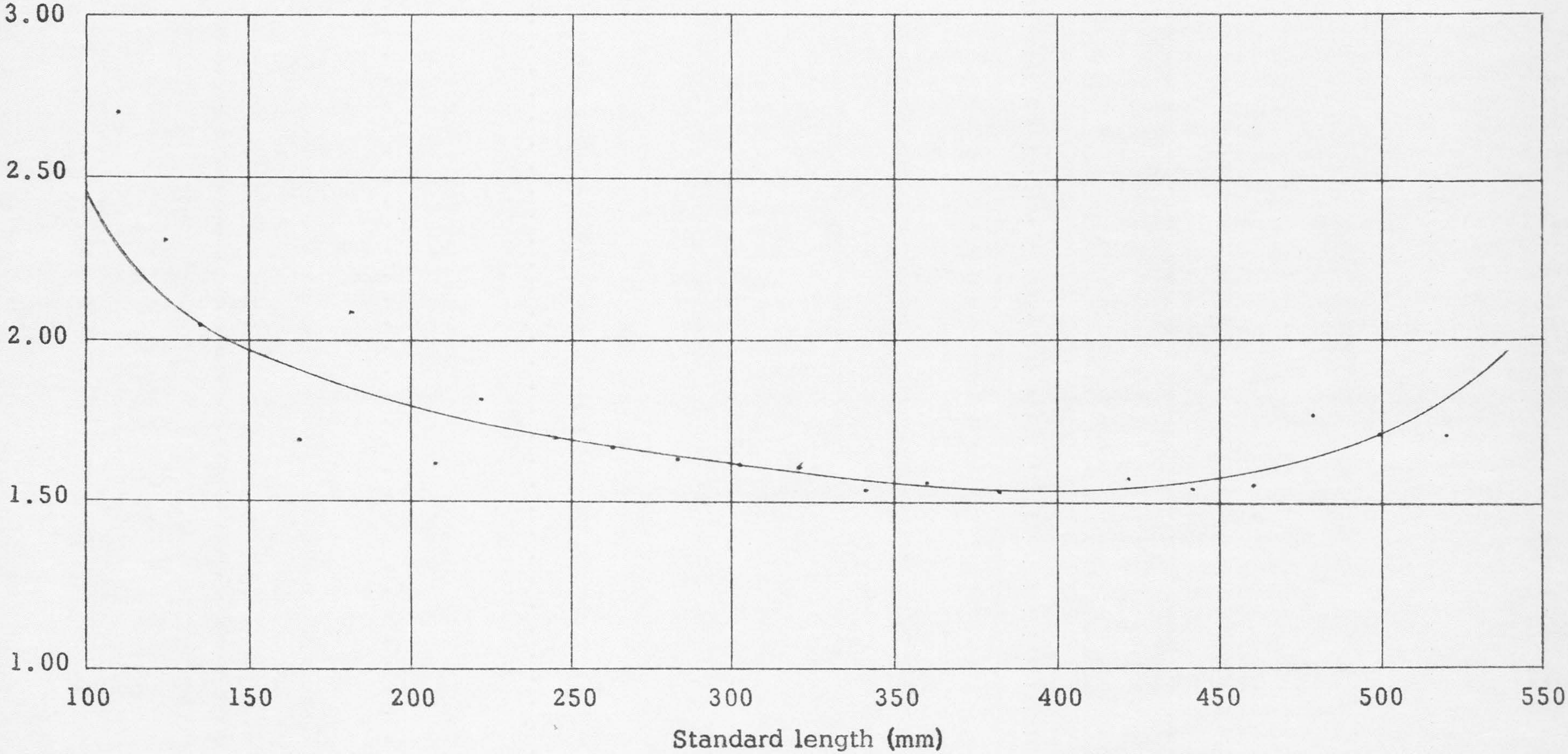

Figure 8. Relationship between standard length and K factor of channel catfish, 1958-59

FOOD HABITS

Previous food studies of channel catfish

Forbes (1888) examined 43 specimens from the Illinois and Mississippi Rivers. Insects were the principal food consumed; they constituted 44 percent of the volume and occurred in 28 stomachs. Aquatic insects were taken most often and some terrestrial insects were also consumed. Mollusks and water snails were found in 15 of the 43 stomachs.

Shira (1917) examined 72 young channel catfish stomachs and concluded that midge larvae were the major items taken.

Boesel (1938) analyzed 61 channel catfish stomachs collected in 1929-30 in Lake Erie and found midge larvae comprised 53 percent, and crustacea 33 percent, of the volume of food taken.

McCormick (1940) analyzed 14 channel catfish stomachs collected in Reelfoot Lake, Tennessee and found the following percentages of volume of food consumed: caddis fly larvae--38; filamentous algae--28; midge larvae--26; and fish--7.

Dill (1944) analyzed 38 channel catfish stomachs collected in the West Main Ditch, Imperial Valley, California. Midge larvae, caddis flies, odonata, terrestrial insects, and higher plants were the chief food items taken. Fish were infrequently taken.

Menzel (1945) concluded from his stomach sampling in Virginia that filamentous algae, crabs, and white perch were the principal foods taken.

Dendy (1946) analyzed 75 stomachs taken from Morris Reservoir catfish in Tennessee and concluded that gizzard shad and insects were the chief food items. Quantity of fish taken as a food item increases with the increase in size of the catfish.

Bailey and Harrison (1945) analyzed 912 (most comprehensive study) stomachs collected in the Des Moines River, Iowa. They concluded that by percentage of volume, insects were predominant in the diet until channel catfish reached a size of 12 inches or larger. At this stage, fish, mainly minnows, ranked over insects in importance in the diet.

Food habits of Utah Lake channel catfish

In this investigation, 209 stomachs were examined and 168 samples (80.4 percent) contained food. Fish, insects, crustacea, plant and inorganic materials composed the bulk of the diet of the channel catfish. Channel catfish are omnivorous in feeding as revealed in the variation of their diet.

More than all other food items combined, fish comprised the greatest volume of food consumed (Figure 9). Occurrence of food items in the sample is expressed as a percentage of the total food items occurring in the sample (Figure 9). Carp is believed to be the most abundant fish in Utah Lake and is the predominant species consumed by channel catfish. Utah chub is believed to be the second-most abundant fish in Utah Lake and second in rate of consumption by channel catfish. Carp, Utah chub, yellow perch, and black bullheads were the main fish in the diet of channel catfish. Significance of fish in the diet increases with the growth of the channel catfish. Fragments of larger fish found in the stomachs were probably picked from fish which were killed and thrown back into the lake by fishermen.

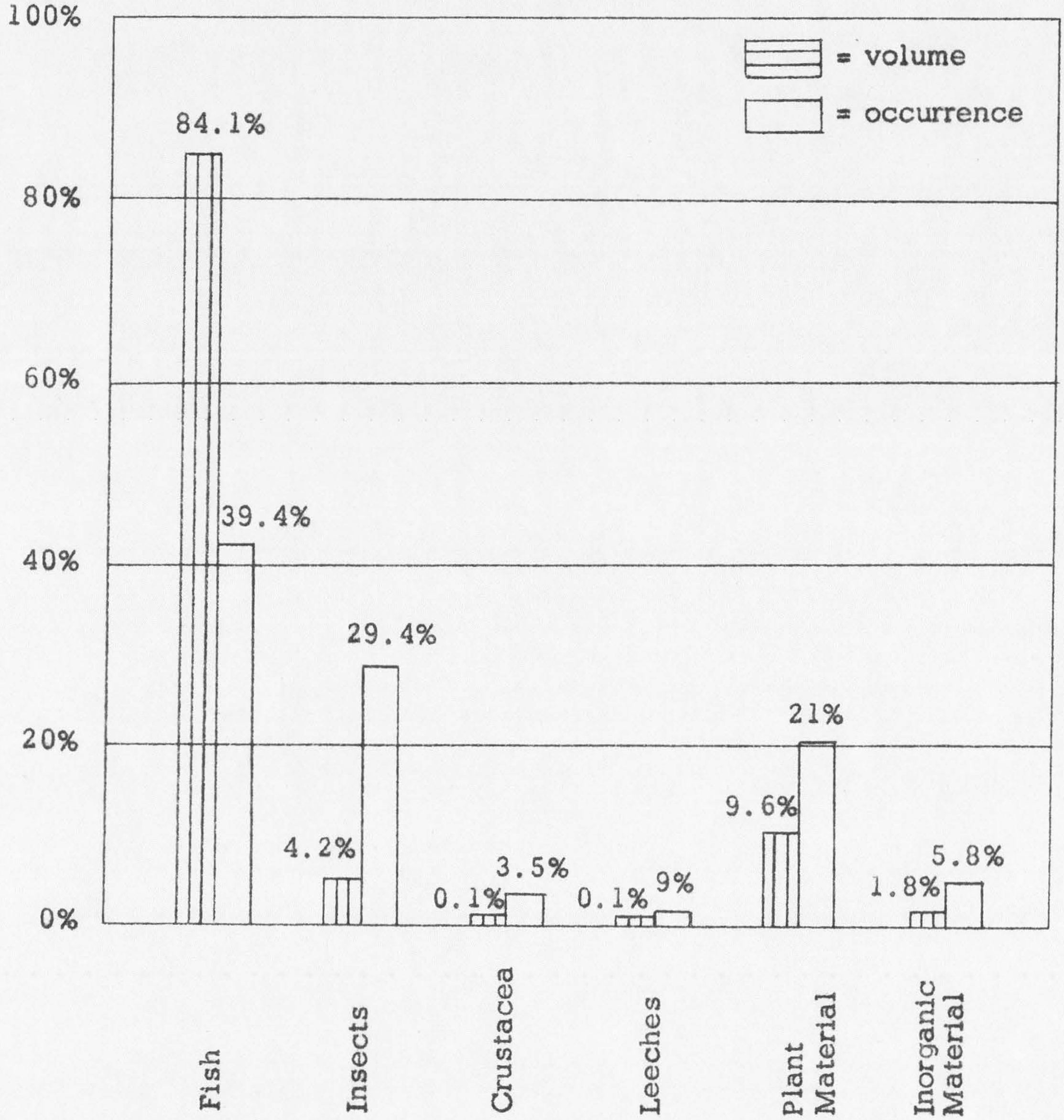

Figure 9. Food of channel catfish expressed as percentage of volume and occurrence, 1958-59

Young channel catfish in Iowa fed exclusively on aquatic insects (Bailey and Harrison, 1945). This is also true of young channel catfish in Utah Lake. Young channel catfish (less than 150 millimeters, total length) are hard to obtain in Utah Lake and the few captured contained only aquatic insects, mostly diptera larvae.

Insects comprised 27.3 percent of volume of food taken by the channel catfish during 1958-59 (Appendix Table 7). Diptera, hemiptera, odonata, and coleoptera (respectively) were the four major orders of insects taken by channel catfish. Midge larvae and the water boatman were the two most important insects found in the diet of channel catfish representing 93 percent of identified insects consumed. Bailey and Harrison (1945) list some 50 families of insects taken by channel catfish in Iowa. Aquatic and terrestrial insects and fish comprise the stable food of the channel catfish. The number of individual items occurring in the stomach samples are directly related to availability of the item to the fish. Gammaris were the only larger crustaceans found in the stomach samples.

Plant material is readily available as a food item. It occurred in 25 percent of the stomachs and comprised 8.8 percent of total food volume consumed. Filamentous algae, fragments of higher plants, and terrestrial plant seeds composed the bulk of the plant material consumed. Inorganic material (ranging from sand and mud to aluminum foil) comprised only 1.6 percent of the total food volume.

Seasonal trends

Seasonal changes in the diet of channel catfish showed a gradual change, due to availability of various foods. Bailey and Harrison (1945) found a close correlation between the number of fish found in a given area with the number of the same species taken as food by the channel catfish. They also found no marked preference for specific fish as food items by channel catfish. Some species were taken in greater numbers than others, but this is attributed to vulnerability rather than selectivity (Bailey and Harrison, 1945).

Periodicity in feeding

Bailey and Harrison (1945) frequently found empty stomachs in fish collected early in the evening, indicating that feeding had just begun. The generally accepted theory that channel catfish feed nocturnally does not apply to Utah Lake channel catfish. Turbidity serves as a protective shield and the channel catfish feed at all hours of the day, attested to by anglers catch success throughout the day. Due to turbidity (up to 45 ppm) in Utah Lake, it is believed that time of capture will not have any effect on the stomach contents.

REPRODUCTION

Sex ratio

In Utah Lake channel catfish the sex ratio is 1.04 males per female (Table 12). Appelget and Smith (1950) found the sex ratio of channel catfish in the Mississippi River near Lansing, Iowa to be 1.12 males per female and a one to one sex ratio in nest-building fish is to be expected.

Effect of turbidity on breeding

Buck (1956) found that turbidity does not have any direct influence on the fish's ability to reproduce, except in the instance of retarding maturity. Marzolf (1957) found some correlation between turbidity and reproduction and in waters where a Secchi disc disappears at 20 inches, fingerling channel catfish will be found, if spawning sites are available. During the summer months, a Secchi disc is not visible at a depth of 12 inches in Utah Lake.

Spawning habits of channel catfish

Channel catfish spawning is most successful in waters that are turbid to some degree. Seclusion afforded by overhead cover is also needed for successful spawning. Marzolf (1957) found no reproduction in turbid water which provided no overhead cover; little reproduction was ever found in clear ponds. Although Utah Lake has the necessary turbidity for successful spawning, few areas in the lake supply overhead cover. With the exception of a few isolated spots, the entire northern half of

Table 12. Sex ratios of Utah Lake channel catfish collected in 1958-59

	Calendar year 1958				Calendar year 1959		
Age class	Number of fish	Percentage of males	Percentage of females	Age class	Number of fish	Percentage of males	Percentage of females
I	0	0	0	I	0	0	0
II	0	0	0	II	1	0	100
III	1	0	100	III	2	50	50
IV	10	40	60	IV	3	0	100
V	30	57	43	V	3	0	100
VI	67	63	37	VI	20	40	60
VII	51	61	39	VII	21	48	52
VIII	13	31	69	VIII	11	36	64
IX	4	50	50	IX	8	50	50
X	4	75	25	X	4	25	75
XI	1	0	100	XI	0	0	0
XII	0	0	0	XII	1	0	100
Combined	181	57	43		74	38	62
Grand total and average for both years					255	51	49

Utah Lake has little overhead cover. Most of the available nesting sites are in the southern half of Utah Lake. The Provo Bay area (Figure 1) of Utah Lake contains many dead trees, affording numerous spawning sites. Most channel catfish spawning sites are located, however, in the waters surrounding Bird Island, off Lincoln Beach northward to Bird Island, and in the area adjacent to the Knolls (Figure 1). These areas are honeycombed with rock outcrops and ledges affording crevices between rocks, under ledges, and under edges of numerous potholes.

Channel catfish spawning is regulated by water temperatures. Spawning occurs only after the water temperature has risen above 70° F., (Harlan and Speaker, 1951, Canfield, 1947, and Marzolf, 1957). The dates of channel catfish spawning vary with the section of the country from which they were collected. Marzolf (1957) sets the spawning period in Missouri as May 30 to July 15 with the major part of the spawning completed in June. Doze (1925) found spawning extends into July or later in Kansas. Toole (1951) found that spawning starts as early as April 15 in Texas and continues into August. In Iowa, Harlan and Speaker (1951) indicated that the channel catfish spawn in July. In Utah Lake, spawning begins about the middle of June, and continues until September. Fingerling channel catfish start appearing in the seine hauls about the first of September and range from 1-1/2 to 2 inches in length.

The number of eggs produced in each ovary collected was estimated by counting the eggs in a cubic centimeter sample from each ovary. This number was then multiplied by the volume (in cubic centimeters) of eggs in each ovary sample. The percentage of body weight produced as eggs was also determined for each ovary collected (Table 13). One pound females in

Table 13. Egg count of known and unknown age channel catfish collected in Utah Lake from March, 1958 to September, 1959

Standard length in mm.	Body weight in grams	Weight of eggs in grams	Percent of body wt. produced as eggs	Number of eggs
295	485	59.0	12	6,150
305	500	34.7	7	2,040
319	550	28.6	5	7,097
326	631	71.7	11	6,457
333	606	98.6	16	8,339
340	325	58.7	18	3,312
345	300	88.7	29	5,855
347	669	125.6	19	6,387
357	600	100.3	17	6,539
365	365	85.5	24	5,878
370	425	43.7	10	3,312
371	703	27.3	4	6,541
375	375	111.3	29	5,831
375	550	80.3	15	4,288
380	420	73.7	17	3,627
390	580	142.3	25	10,394
398	575	104.2	18	5,393
411	1,275	28.4	2	7,216
Range		27.3 to 142.3	2 to 29 percent	2,040 to 10,394

Utah Lake produce on an average 4,636 eggs. One and one-half pound females in Utah Lake produced on an average of 6,105 eggs. These figures are higher than those indicated by Canfield (1947). Canfield gives the following figures: 14-ounce channel catfish produced 3,100 eggs; 1-1/2-pound channel catfish produced 4,000 eggs; and a 4-pound channel catfish produced approximately 8,000 eggs.

Two sizes of eggs were found in the ovaries of a number of females. The smaller of these two groups of eggs is white and only half the size of a normal egg which is light orange. A normal egg, completely developed, ranges in size from .100 to .125 thousandths of an inch in diameter. These small white eggs are found randomly scattered in with the normal size eggs within the developing ovaries, and are believed to be residual eggs left over from the previous year's spawn.

Channel catfish ovaries were observed in various stages of development during 11 months of the year. The first spent female channel catfish were found in late June and spent females were also found in August and September. The bulk of the spent females were found during the last two weeks of July. Female channel catfish were found throughout the summer with ovaries containing eggs completely developed.

MOVEMENTS

During the course of this study 1,957 channel catfish were fin clipped in an effort to obtain information on their movement in Utah Lake. Fin-clipping operations were conducted during a 14-month period (Appendix Table 8). Only 18 fin-clipped fish were recaptured, representing 0.9 percent of the original number of fish marked. All fish recaptured were caught in the commercial seiners' nets.

Only four of the 18 recaptured fish were found in an area outside the location in which they were released. Two of these moved about five miles, while the other two moved nearly 10 miles. Studies conducted by Muncy (1958), Harrison (1953), and McCammon (1956), indicate that channel catfish are of a sedentary nature. All of these studies covered channel catfish inhabiting rivers and no studies could be found covering the movement of channel catfish in lakes or reservoirs. Returns of marked fish in Utah Lake indicate that channel catfish in this habitat are also sedentary. Gill-net catches revealed some local movement. During early summer, channel catfish move towards shore. After mid-August, channel catfish move away from shore into deeper water. Prior to spawning, there is movement into locations with numerous spawning sites, such as the waters about Bird Island, Lincoln Beach, and the Knolls.

During feeding periods channel catfish move more than during other periods of the day (Bailey and Harrison, 1946; Harlan and Speaker, 1951). In Utah Lake movements connected with the feeding periods are not restricted to the dark hours because of the cover afforded by turbidity.

Channel catfish feed throughout the day; yet a greater amount of movement is found during the dark hours. The most consistent movement pattern covering Utah Lake channel catfish is to and from the spawning sites. McCammon (1956) found that channel catfish in the Colorado River also exhibited considerable movement prior to spawning season.

PARASITISM

One external and two internal parasites (Table 14) were collected from channel catfish in Utah Lake. Table 14 lists the parasites found in and on channel catfish collected in Utah Lake during this investigation. These include one each of the following classes: cestoda, hirudinea, and nematoda.

External parasites

A small leech (less than one-half inch in total length) was the most prevalent parasite on Utah Lake channel catfish. All channel catfish larger than 100 millimeters in length were host at some time to this parasite. This leech attaches itself to the skin or fins, and leaves a tell-tale pock mark at point of attachment. Eighty percent of the channel catfish examined had these small leeches attached to either their fins or skin.

Internal parasites

Roundworm.--This is the predominant internal parasite of the Utah Lake channel catfish and nine percent of the fish handled were infested. In Iowa, this roundworm was found by Forney (1955) as a parasite of the black bullhead. No studies were found covering the roundworm as a parasite of channel catfish.

Tapeworm.--This is the second-most predominant internal parasite of Utah Lake channel catfish. Not more than three tapeworms were found at one time in the stomach or intestine of the channel catfish and no apparent effect was obvious on infested fish.

Table 14. Frequency of occurrence of important parasites in Utah Lake channel catfish expressed as percentage of 254 fish examined in 1959

Parasites	Percentage of fish parasitized
Myzobdella moorei	80.0
Ophiotaenia fragila	2.7
Contracaecum spiculigerum	9.0

CREEL CENSUS

A limited creel census program was conducted in conjunction with the life history study of channel catfish in Utah Lake. It was deemed advisable to obtain some information on catch per hour and species composition of the creel.

It was impossible to conduct a creel census by means of an instantaneous count because of the size of Utah Lake. A running count creel census was conducted. All shore and boat fishermen were counted and interviewed. Counts were set for one day of each week but due to bad weather no more than three counts were made in any month.

Five boat liveries operate on the lake's perimeter and 11 boat launching sites exist for privately-owned boats. There are four public access areas on Utah Lake. The public has free access to nearly 50 percent of the lake's shore. Fishermen on shore are found only where roads permit easy access to the lake's shore.

Rate of catch

Average rate of catch of channel catfish per hour was 0.40 fish per hour in 1958 and 0.45 fish per hour in 1959. Boat fishermen had a higher rate of catch success than did shore fishermen and fished fewer hours than did shore fishermen.

Species caught

Channel catfish, black bullhead, yellow perch, and an occasional largemouth bass and white bass are taken by fishermen on Utah Lake but the channel catfish is the primary game fish. Black bullhead and channel catfish constitute 90 percent of the fishermen's creel.

The fishing season is never closed on Utah Lake and channel catfish fishing is very popular before opening of the general trout season. There is no appreciable drop in fishing pressure during the trout season.

DISCUSSION

Growth of Utah Lake channel catfish is rather poor when compared with fish from other areas. Channel catfish in Utah Lake require four to five years to reach a length that channel catfish in Oklahoma attain in two or three years. Turbidity in Utah Lake averages about 25 ppm during the growing season. Although the turbidity permits an increased survival rate for channel catfish, it also causes a reduction in the food produced by the lake. These combined factors result in the reduced growth rate of a fish with a much greater growth potential.

With growth in length of Utah Lake channel catfish, a steady decline is found in the condition factor (K), continuing until a total length of 477 millimeters is reached. At this point the K factor of the fish starts to increase. This turnabout in the length-weight relationship of Utah Lake channel catfish is attributed to a change in feeding habits, from insects to fish. Fish as a food item increases in importance as the channel catfish grow larger in length and weight. Diptera larvae, corixidae, carp, Utah chub, yellow perch, and black bullheads are the principal food items of Utah Lake channel catfish. These food items are the most abundant and readily available in Utah Lake.

Channel catfish reproduction occurs throughout the lake with the major portion thereof occurring around Bird Island, Lincoln Beach and the Knolls. Male channel catfish mature earlier than females. No channel catfish were found mature before the fourth year and all fish were mature by the eighth year. Turbid conditions retard the maturity of fish in Utah

Lake. Egg production of Utah Lake channel catfish averages 4,636 eggs per one pound fish and 6,105 eggs per 1-1/2 pound fish.

There is little movement of Utah Lake channel catfish. Major movement occurs just prior to spawning and daily movement is concerned with feeding.

A tapeworm, roundworm, and leech, were found parasitizing Utah Lake channel catfish. No harm to the overall condition of the fish could be attributed to these parasites.

Angling pressure for channel catfish is slight, with no adverse effect on the population because the number of fishermen and rate of catch success are low. Average catch is about 0.40 fish per hour. Boat fishermen are more successful than shore fishermen. Channel catfish are caught as readily during the day as they are at night.

SUMMARY

1. Spines from 312 channel catfish from Utah Lake, captured by gill nets, seines, and hook and line, were employed to determine rate of growth of this species.

2. Growth was calculated to each annulus and all mean calculated lengths presented are based on total mean (weighted) calculated standard lengths.

3. All channel catfish were collected between March 1, 1958 and October 1, 1959.

4. Channel catfish averaged 3.1 inches in total length at the end of the first year and during successive years averaged: 6.9, 9.4, 12.1, 14.5, 16.7, 17.9, 18.9, 19.7, 20.6, 21.2, and 21.6 inches.

5. The length-weight relationship of the channel catfish is expressed by the equation: $\text{Log } W = -4.814 + 3.025 \text{ Log } L$ (standard length).

6. Three strong year classes were found in the population--1952-53-54.

7. Annulus formation usually takes place during the period from the last week in April through the first week in June.

8. Comparison of growth of Utah Lake channel catfish with channel catfish from turbid waters in Oklahoma and Kansas impoundments indicates that Utah Lake fish grow at a slightly faster rate.

9. Softstem bulrush, three-square bulrush, narrow-leaf cattail, common cattail, and pondweed are the predominant aquatic vegetation.

10. Carp, Utah chub, chironomidae larvae, and corixidae are the bulk of food items taken by Utah Lake channel catfish.

11. As the channel catfish increase in size, fish become more important in their diet.

12. Successful spawning requires overhead cover or isolation with a water temperature of 70° to 75° F. to initiate spawning.

13. Three small spawning areas are present in Utah Lake.

14. One pound female channel catfish produce an average of 4,636 eggs per pound of body weight in Utah Lake, and a one and one-half pound female produces on an average of 6,105 eggs.

15. Movement of channel catfish in Utah Lake is restricted to migration to and from spawning sites and short daily moves in search of food.

16. One roundworm, one tapeworm, and one small leech infest Utah Lake channel catfish.

17. The channel catfish population in Utah Lake could withstand greater fishing pressure. Rate of catch is less than 0.50 fish per hour. Angling pressure is insignificant.

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APPENDIX

Appendix Table 1. Chemical analysis of the water of Utah Lake

Compounds or elements	Percentage*						ppm*
	A	B	C	D	E	F	G
Cl	4.04	35.48	26.23	24.74	26.87	285	307
SO_4	42.68	26.53	28.43	28.25	30.14	327	375
Na	5.81	26.20	19.28	18.19	18.34	199	186
K	. . .	. . .	2.34	2.17	1.75	33	13
SiO_2	3.27	. . .	. . .	2.00	2.23	35	22
Ca	18.24	7.58	6.25	5.90	5.34	108	60
Mg	6.08	1.55	7.18	6.18	6.85	47	61
CO_3	19.88	2.66	10.23	12.35	8.48	10	. .
$CaCO_3$ hardness	. . .	. . .	. . .	. . .	. . .	. .	400
Free CO_2	. . .	. . .	. . .	. . .	. . .	. .	16
Fe & Al oxides	. . .	. . .	. . .	. . .	. . .	. .	8
pH	. . .	. . .	. . .	. . .	. . .	. .	8.4
Total alkalinity	. . .	. . .	. . .	. . .	. . .	. .	194
Dissolved solids	. . .	. . .	. . .	. . .	. . .	. .	1223
Salinity (ppm)	306	892	1281	1165	1254	1113	. .
HCO_3	. . .	. . .	. . .	. . .	. . .	. .	118

*From the personal papers of Tanner (1960)

A Clarke, F. W. (1884)
B Cameron, F. K. (1899)
C Brown, B. E. (1903)
D Seidell, A. (1904)
E Brown, B. E. (1904)
F Decker, L. B., and C. E. Maw (1933)
G Lachlan, N. E. (1940)

Appendix Table 2. Water chemistry (analyzed by Peterson Lab., Salt Lake City, Utah) taken at 3 locations in Utah Lake, expressed as ppm, January, 1960

Compounds or Elements	Control Station No. 1	West of Provo Harbor	Control Station No. 6
Cl	152.0	48.0	312.0
SO_4	132.0	25.0	48.0
Na	160.0	52.0	320.0
K	22.0	10.0	30.0
SiO_2	1.0	1.0	1.0
Fl	5.0	3.0	5.0
PO_4	5.0	3.0	3.0
NH_3	0.4	0.12	0.13
$CaCO_3$ & $MgCO_3$ hardness	388.0	268.0	456.0
Free CO_2	. . .	. . .	. . .
Fe & Al oxides	0.7	0.3	0.3
pH	8.5	8.0	8.5
Total alkalinity	211.0	. . .	189.0
Total solids	805.0	420.0	1310.0
Fixed solids	680.0	320.0	1070.0
NO_2 & NO_3	1.7	0.4	0.3
Organic matter	20.0	45.0	30.0
Organic & volatile matter	125.0	100.00	240.0

Appendix Table 3. Common and scientific names of plants found in and around Utah Lake

Common name	Scientific name
Alfalfa, Lucerne	Medicago sativa
Aster	Aster oregonus
Baltic rush	Juncus balticus
Big sagebrush	Artemisia tridentata
Begger tick	Bidens frondosa
Bunch grass	Agropyron spicatum
Buttercup	Ranunculus sp.
Cheatgrass	Bromus tectorum
Cocklebur	Xanthium italicum
Common cattail	Typha latifolia
Dandelion	Taraxacum officinale
Dock	Rumex maritimus
Duck weed	Lemna minor
Flat sedge	Cyperus strigosus
Fleabane	Erigeron annuus
Glasswort, Pickelweed	Salicornia rubra
Gum plant	Grindelia squarrosa
Heliotrope	Heliotropium spathulatum
Horse Weed	Leptilon canadensis
Iodine bush	Allenrolfea occidentalis
Licorice	Glycyrrhiza lepidota
Love grass	Eragrostis hynaides
Marsh cress	Rorippa
Milkweed	Asclepias speciosa
Muskgrass	Chara sp.
Narrow-leaf cattail	Typha angustifolia
Necklace poplar	Populus deltoides
Patata, Patota	Monolepsis nuttalliana
Phragmites, Reedgrass	Phragmites communis
Pondweed	Potamogeton filiformis
Poverty weed, Marsh elder	Iva axillaris
Rabbitbrush	Chrysothamus nauseosus
Rabbitfoot grass, False millet	Polypogon monspeliensis
Russian thistle	Salsola pestifer
Salt grass	Distichlis stricta

Appendix Table 3. Continued

Common name	Scientific name
Saltbush	*Atriplex sp.*
Sedge	*Carex spp.*
Smartweed	*Polygonum sp.*
Softstem bulrush	*Scirpus validus*
Sow thistle	*Sonchus asper*
Speedwell	*Veronica sp.*
Sprangletop	*Leptochloa fascicularis*
Star duckweed	*Lemna trisulca*
Sunflower	*Helianthus annuus*
Sweet clover	*Melilotus alba*
Tamarix	*Tamarix gallica*
Three-square bulrush	*Scirpus americanus*
Watercress	*Nasturtium spp.*
Wild barley	*Hordeum jubatum*
Wild millet	*Echinochloa crus-galli*
Willow	*Salix amygdaloides*
Willow	*Salix exigua*
Willow herb	*Epilobium sp.*

Appendix Table 4. Common and scientific names of fish found in Utah Lake during 1958-59

Common name	Scientific name
Black bullhead	Ictalurus melas
Bluegill sunfish	Lepomis macrochirus
Carp	Cyprinus carpio
Channel catfish	Ictalurus punctatus
Cutthroat trout	Salmo clarki
Green sunfish	Lepomis cyanellus
Largemouth bass	Micropterus salmoides
Mosquitofish	Gambusia affinus
Mountain whitefish	Coregonus williamsoni
Rainbow trout	Salmo gairdneri
Rosyside sucker	Catostomus ardens
Smallfin redsided shiner	Gila balteata
Utah chub	Gila atraria
Utah sucker	Catostomus fecundus
Walleye pike	Stizostedion vitreum
White bass	Roccus chrysops
Yellow perch	Perca flavescens

Appendix Table 5. Results of experimental gill netting in Utah Lake from June, 1958 to October, 1959

Month	Net hours	Species and number caught									Total fish
		Carp	Utah chub	C. cat-fish	Yellow perch	Suckers	Wall-eye pike	Black bull-head	White bass	Other*	
1958											
June	225	343	411	140	7	34	26	13	2	0	976
July	401	636	539	169	70	53	57	33	1	3	1,561
Aug.	263	485	145	151	45	17	28	57	18	1	947
Sept.	174	232	159	48	18	19	21	24	1	1	523
Oct.	137	74	127	21	32	22	64	27	5	2	374
Nov.	160	45	96	11	52	8	8	7	1	0	228
Dec.	203	24	162	0	134	17	14	8	4	1	364
1959											
Jan.	260	32	91	1	56	33	5	0	2	0	220
Feb.	266	41	58	18	11	12	16	5	3	0	164
March	58	8	48	3	3	15	14	1	1	0	93
April	234	195	360	46	12	9	32	33	9	2	698
May	220	152	187	33	19	59	4	4	1	0	459
June	132	58	25	55	2	47	17	5	3	0	212
July	245	660	322	90	1	19	19	9	2	19	1,141
Aug.	156	319	202	36	33	4	1	28	3	0	626
Sept.	200	190	244	31	18	34	18	46	3	18	602
Total	3,334	3,494	3,176	853	513	402	344	300	59	47	9,188

*Represents smallfin redsided shiner, largemouth bass, and two species of trout.

Appendix Table 6. Rate of catch per hour by experimental gill nets in Utah Lake from May, 1958 to October, 1959

Month	Net hours	Species and number per net hour									
		Carp	Utah chub	Channel catfish	Yellow perch	Suckers	Walleye pike	Black bullhead	White bass	Other*	Total fish
1958											
June	225	1.52	1.83	0.62	0.03	0.15	0.12	0.06	0.01	0.00	976
July	401	1.59	1.35	0.42	0.18	0.13	0.14	0.08	0.00	0.01	1,561
Aug.	263	1.85	0.55	0.57	0.17	0.06	0.11	0.22	0.07	0.00	947
Sept.	174	1.33	0.92	0.28	0.10	0.11	0.12	0.14	0.00	0.00	523
Oct.	137	0.54	0.93	0.15	0.23	0.16	0.47	0.20	0.04	0.02	374
Nov.	160	0.28	0.61	0.07	0.32	0.05	0.05	0.04	0.00	0.00	228
Dec.	203	0.12	0.80	0.00	0.66	0.08	0.07	0.04	0.02	0.00	364
1959											
Jan.	260	0.12	0.35	0.00	0.22	0.13	0.02	0.00	0.01	0.00	220
Feb.	266	0.16	0.22	0.07	0.04	0.05	0.06	0.02	0.01	0.00	164
March	58	0.14	0.83	0.05	0.05	0.26	0.24	0.02	0.02	0.00	93
April	234	0.85	1.52	0.20	0.05	0.04	0.14	0.14	0.04	0.00	698
May	220	0.69	0.85	0.15	0.09	0.27	0.02	0.02	0.00	0.00	459
June	132	0.44	0.19	0.42	0.02	0.36	0.13	0.04	0.02	0.00	212
July	245	2.69	1.32	0.37	0.00	0.08	0.08	0.04	0.01	0.00	1,141
Aug.	156	2.04	1.29	0.23	0.21	0.03	0.01	0.18	0.02	0.00	626
Sept.	200	0.95	1.22	0.15	0.09	0.17	0.09	0.23	0.02	0.09	602
Total	3,334	15.31	14.78	3.60	2.46	2.13	1.87	1.47	0.29	0.12	9,188
Weighted averages		0.96	0.92	0.23	0.15	0.13	0.12	0.09	0.02	0.00	574

*Represents smallfin redsided shiner, largemouth bass, and two species of trout.

Appendix Table 7. Food of the channel catfish from Utah Lake, Utah in 1958-59 expressed as percentages of frequencies of occurrence and as percentages of total volume of food organisms

	Number of occurrences	Percent of occurrence	Volume in cc.	Percent of volume
Animal	162	75.00	619.43	89.6
Undetermined	65	26.10	57.43	8.3
Determined	122	48.90	562.00	81.3
Fish	102	26.2	533.96	77.1
Undetermined	84	20.1	249.56	36.0
Determined	25	6.1	284.40	41.1
Carp	16	3.6	146.40	21.2
Yellow perch	2	0.5	18.70	2.7
Utah chub	4	1.0	104.00	15.0
Catfish	4	1.0	15.30	2.2
Insect	77	19.8	27.37	4.0
Undetermined	31	6.2	9.59	1.4
Determined	69	13.7	17.78	2.6
Odonata	3	0.4	1.0	0.2
Hemiptera	31	4.4	4.45	0.6
Coleoptera	2	0.3	0.25	0.1
Diptera (chironomidae)	61	8.6	12.08	1.7
Crustacea (scuds)	9	2.3	1.0	0.1
Hirudinea (leeches)	2	0.6	0.4	0.1
Plant material	54	25.00	61.20	8.8
Filamentous algae	35	14.8	41.80	6.0
Higher aquatic plants	20	8.5	18.60	2.7
Seeds of plants	4	1.7	0.80	0.1
Inorganic material	15	0	11.10	1.6

Appendix Table 8. Total number of channel catfish recorded in marking and recapture program at Utah Lake from July, 1958 to October, 1959

Date	Total no. of channel catfish captured	Number of channel catfish marked	Number of marked fish captured
1958			
July	513	513	0
August	414	231	3
September	567	486	3
October	22	0	0
November	11	0	0
1959			
February	19	0	0
March	823	0	6
April	313	255	2
May	36	0	0
June	55	0	0
July	264	156	0
August	352	316	3
September	49	0	0
October	198	0	1
Total	3,636	1,957	18