FISHERIES SESSION

COMPARISON OF THE LENGTH-WEIGHT RELATIONSHIP OF SEVERAL SPECIES OF FISH FROM TWO DIFFERENT, BUT CONNECTED, HABITATS

By WILLIAM H. HERKE
Florida Game and Fresh Water Fish Commission
Vero Beach, Florida

ABSTRACT

Length and weight data were gathered during a short time-period on several species of fish from a large lake and a connecting marsh canal. The marsh had recently gone dry, forcing the fish to crowd into the canal.

Analysis of covariance was used to compare the length-weight relationship of largemouth black bass (*Micropterus salmoides*), redear sunfish (*Lepomis microlophus*) and bluegill (*Lepomis macrochirus*) from both habitat types. The bass from the canal were found to be significantly heavier for their length than those from the lake. Various possible explanations for this phenomenon are discussed. The author's conclusion is that the most logical explanation for the phenomenon is increased feeding by the bass under these crowded conditions. No detectable difference was found in the length-weight relationship of redear sunfish and bluegill from the two habitats.

No chain pickerel (*Esox niger*) were captured in the lake but several hundred were taken in the canal. The length-weight relationship is also given for this species.

INTRODUCTION

It is the opinion of many biologists that predatory fish grow more rapidly during periods when low water levels cause crowding of the fish, provided this crowding is not too severe. At such times the forage fish are concentrated where the predators can more easily get at them. Theoretically the predators consequently feed more heavily and grow faster. While the idea seems quite logical, only a few definite statements in support of the theory were found during a limited search of the literature. (Due to unavoidable circumstances time was not available for a thorough search of the literature.)

Forbes (1925) wrote the following about crowding because of receding water levels:

> As the waters retire, the lakes are again defined; the teeming life which they contain is restricted within daily narrower bounds, and a fearful slaughter follows; the lower and more defenceless animals are penned up more and more closely with their predaceous enemies, and these thrive for a time to an extraordinary degree.

Eschmeyer (1954) also mentioned that bass feed more heavily during periods of low water levels.

One of the most positive assertions found was made by Hulsey (1959) concerning impoundments in Arkansas, in which he declared:

> . . . In early fall, after the summer crop of food (various insects and small forage fishes) has been produced, the water level is lowered and the fishes concentrated. The predator species (bass, crappie, large bream, channel catfish and others) will eat most of the "bugs" and small forage fishes. As a result, the bass and crappie grow faster and bigger, and since the bream are thinned, those remaining will eventually grow to a larger size which makes them more desirable to the fisherman.

If predators really feed more heavily during periods when fish populations are somewhat crowded together, it may be reasoned that their general condition should be better under these circumstances. "Condition" is a term used to denote the relative plumpness of a fish. While the condition factors of individual fish may be compared, Carlander (1953) points out comparisons between populations cen be better made through study of the length-weight relationships.

Between December 18, 1958 and February 4, 1959 the author and an assistant conducted a fish tagging program in Indian River County, Florida. Since returns are still being received on tagged fish, tagging results will not be dealt with in this paper; but during this tagging program reasonably accurate length and weight data were obtained on nearly 1600 fish of various species. These measurements furnished the information required for the calculation of the logarithmic relationship between length and weight for largemouth black bass (*Micropterus salmoides*), redear sunfish (*Lepomis microlophus*) and bluegill (*Lepomis macrochirus*) taken from crowded and uncrowded habitats. Sufficient length-weight data were also obtained (in the crowded habitat only) on the chain pickerel (*Esox niger*) to compute a length-weight relationship for this species.

If bass (predators) grow faster under crowded conditions they should become heavier for their length than bass from uncrowded conditions. Conversely, it would seem that non-predators (e. g., bluegill and redear sunfish) should not grow more rapidly when forced into crowded conditions.

By use of the above information, this paper seeks to furnish further support to the theory of increased growth by predators during periods of moderate crowding.

DESCRIPTION OF THE HABITATS

Fish samples for this study were taken from two habitat types, a lake (Blue Cypress Lake) and a connecting marsh canal (Canal 34). Figure 1 shows a sketch of the relative location of the two habitats.

Vegetation and Topography:

Sincock (1958) has adequately described the vegetation of the watershed, including the marsh through which Canal 34 passes. The dominant plant communities of the marsh are given as sawgrass (*Cladium jamaicense*), maidencane (*Panicum hemitomon*), pickerel weed (*Pontederia lanceolata*), arrowhead (*Sagittaria lancifolia*), wax myrtle (*Myrica cerifera*) and white water lily (*Nymphaea odorata*). The dominant plant in Canal 34 itself is yellow water lily (*Nuphar advena*).

The topography of the marsh is very flat with an extremely gentle downward slope to the east. Ground level where Canal 34 intersects State Road 512 is 1 to 1½ feet lower than it is 4 miles farther west.

Canal 34 extends in a zigzag fashion, as shown in Figure 1, for roughly 11 miles from Canal M (which serves as an outlet for Blue Cypress Lake) to State Road 512. It is bounded on the north and east by a levee; on the south and west by the marsh. The canal averages about 50 feet wide and 6 to 12 feet deep. The side bordering the levee is very steep; that bordering the marsh slopes more gently. Water in the canal is brownish, but not as darkly stained as the lake water.

Blue Cypress Lake is fairly large and shallow, roughly elliptical and surrounded by marsh and swamp. Water level fluctuations cause some variation in its surface area, but the lake averages about 4½ miles, at the longest, and 3 miles at the widest spots. Maximum depths average about 10 to 12 feet. The eastern shore line is bordered by a dense sawgrass and maidencane marsh. The remainder of the lake is bordered by cypress (*Taxodium*) swamp containing a mixture of other swamp trees and underbrush. The cypress trees often extend for 50 yards or so out into the lake. Yellow water lilies also extend 50 to 150 yards out from the shore around much of the lake. The water of the lake is darkly stained, and extensive beds of vegetation do not seem to exist in the deeper parts of the lake.

Both the lake and canal contain most of the species of fish common to southern and central Florida. For a more complete evaluation of the fishery the reader is referred to a report on the area by Herke and Horel (1958).

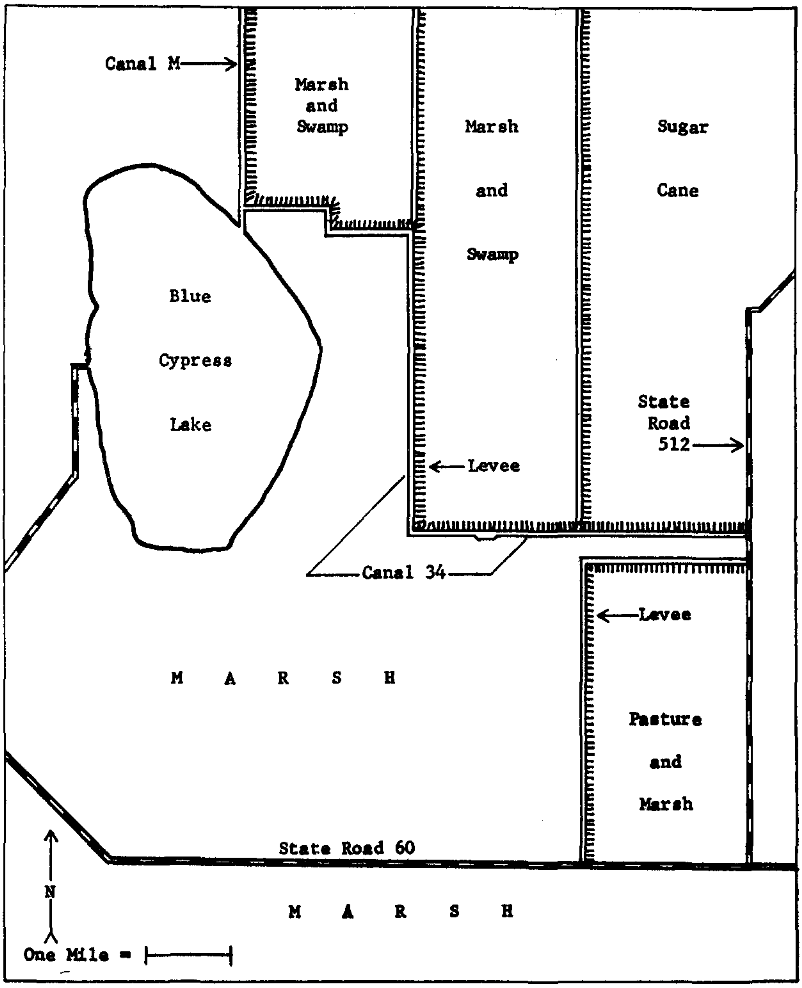

Figure 1. -- Relative locations of Blue Cypress Lake and Canal 34.

Water Levels:

A permanent recording water gauge is located in Blue Cypress Lake. Therefore accurate water level records are available for the lake and approximate water levels can be inferred (from these records) for the marsh and canal.

The daily water level record was studied from January 20, 1959 back to October, 1956. Between October 1956 and mid-May 1958 water depths in the marsh varied between a minimum of about 1.0 foot in the area near the lake to a maximum of about 4.5 feet near State Road 512. However, by about late June 1958 water levels had receded below the ground surface in the marsh between the lake and a point about two miles west of State Road 512. Water in the remainder of the marsh between this point and the road was only about a foot to a foot and a half deep at this time. Water levels continued to recede and by mid-December the entire marsh was dry.

In early 1959 much of the marsh vegetation burned. A careful inspection afterward revealed no trace of fish skeletons in the burned-over marsh. Apparently nearly all the sizeable fish in the marsh had migrated to the adjacent canals and lake as the marsh dried. Since Canal 34 covered only a small surface area in relation to the adjoining marsh, the large number of fish forced into it produced a crowded situation. The marsh nearest the lake dried first, so probably only a few fish migrated to the lake, and since the lake is large a crowded situation did not result. The receding water level therefore created two connected habitats, inhabited by fish of the same genetic strain, wherein one population was crowded and the other was not.

METHODS

Fish Collections:

Before beginning fish collection a map of the area was marked off into quadrants one-half mile on a side. Each quadrant was given a separate number.

Fish collections were made with an electric shocker. The shocker was not effective in the deeper sections of the lake; therefore lake collections were made around the shore line. Lake fish for this study were taken from the majority of the quadrants covering the shore line. The shocker was also ineffective in the two and one-quarter miles of Canal 34 closest to Canal M. Only three or four fish were taken in this stretch. Canal fish for this study came from nearly every quadrant in the remainder of Canal 34.

Weights and Lengths:

As fish were captured they were placed in a tub of water until a sufficient number were collected to justify stopping to weigh and measure. Fish under two pounds were weighed on a comparatively accurate spring scale graduated in ounces and eighths of an ounce. Fish over two pounds were weighed on a spring scale graduated in pounds and ounces. Due to circumstances not pertinent to this study, it was necessary to take measurements of the total length in inches and eighths of an inch.

Handling of Data:

Weights, lengths and other necessary data were recorded on conventional type forms in the field. Later pertinent facts on each fish were transferred to an IBM card. At this time all weights were converted to ounces and tenths of an ounce and total lengths were converted to inches and tenths of an inch.

For a comparison of the length-weight relationship between two fish populations it is desirable that all the fish be collected within a short, continuous time-span. To meet the short time-span requirement only fish collected through the following dates were used:

Bass: Canal 34—Dec. 30, 1958–Jan. 5, 1959
Blue Cypress—Dec. 18-23, 29 and 31 1958 and Jan. 6-8 and 12, 1959

Redear: Canal 34—Dec. 31, 1958–Jan. 5, 1959 and Jan. 13, 1959
Blue Cypress—Dec. 18-23, 29 and 31, 1958 and Jan. 6-8 and 12, 1959

Bluegill: Canal 34—Dec. 31, 1958–Jan. 5, 1959
Blue Cypress—Dec. 18-23, 29 and 31, 1958 and Jan. 6-8, 1959

Pickerel: Canal 34—Dec. 30-31, 1958 and Jan. 2-5, 13, 15 and 20, 1959

There should likewise be a good representation of size groups. Since the data were on IBM cards it was an easy matter to group the fish according to species, habitat and date of capture through use of an IBM card sorter. After this was done each species to be compared was broken down into inch-groups. This was done separately for each species from the crowded and uncrowded habitats. Then up to ten fish in each inch-group were randomly selected for the length-weight study. Individual total-lengths and weights of the fish selected for use in this study are presented in Table I.

TABLE I

TOTAL LENGTH AND WEIGHT OF INDIVIDUAL FISH USED FOR COMPUTATIONS SUMMARIZED IN TABLES II, III AND IV

	Canal 34				*Blue Cypress Lake*			
	Inches	*Ounces*	*Inches*	*Ounces*	*Inches*	*Ounces*	*Inches*	*Ounces*
LARGEMOUTH BLACK BASS	5.9	1.5	12.0	15.3	8.5	4.0	16.6	42.0
	7.4	3.1	12.0	15.1	8.5	4.6	16.7	38.0
	7.4	3.0	12.1	18.0	8.7	4.6	16.9	42.0
	7.7	3.0	12.1	17.0	9.3	5.7	17.1	40.0
	7.9	3.7	12.1	16.0	9.3	6.0	17.5	35.6
	7.9	4.0	12.3	14.5	9.5	6.4	18.1	47.0
	7.9	3.5	12.3	15.1	9.5	7.1	18.7	48.7
	7.9	3.5	12.3	15.3	9.5	6.4	19.5	54.0
	8.0	3.9	12.7	17.5	9.5	6.3	21.0	86.0
	8.0	3.9	12.9	14.9	9.5	5.1	21.3	64.7
	8.0	3.4	13.3	17.0	9.6	6.0	21.6	112.0
	8.0	4.0	13.3	17.9	9.9	7.4	21.7	101.0
	8.3	3.9	13.5	26.6	10.0	6.9	22.4	90.0
	8.4	4.5	13.9	24.5	10.1	7.6	22.6	115.0
	8.4	4.1	14.3	23.7	10.3	8.0	23.3	132.0
	8.6	5.4	14.3	24.0	10.3	7.9	24.1	173.0
	8.9	5.9	14.4	27.0	10.4	8.9	24.7	160.0
	9.1	6.3	14.7	28.9	10.5	8.3	...	...
	9.3	6.6	15.0	28.0	10.5	8.6	...	...
	9.3	6.1	15.0	34.6	10.5	9.1	...	...
	9.4	5.9	15.0	35.0	10.6	9.3	...	...
	9.5	6.0	15.1	32.7	10.7	8.6	...	...
	9.6	7.4	15.3	36.0	11.0	10.0	...	...
	9.6	6.0	15.4	36.0	11.0	10.3	...	...
	9.7	7.5	15.5	27.5	11.0	8.9	...	...
	9.7	6.5	15.6	37.0	11.0	10.4	...	...
	9.9	7.4	15.7	35.0	11.3	10.5	...	...
	10.0	9.0	15.9	27.5	11.6	11.0	...	...
	10.0	7.7	16.0	40.0	11.7	12.1	...	...
	10.0	9.9	16.6	44.0	11.9	12.0	...	...
	10.0	6.3	16.6	41.0	12.0	14.6	...	...
	10.0	7.6	16.9	44.0	12.0	13.0	...	...
	10.0	7.5	16.9	55.0	12.0	13.3	...	...
	10.0	8.5	17.0	42.0	12.6	14.5	...	...
	10.1	7.7	17.5	57.0	13.4	15.6	...	...
	10.3	7.7	17.7	60.0	13.5	23.0	...	...
	10.5	8.7	18.4	67.0	13.9	23.9	...	...
	11.0	11.5	18.6	71.0	14.3	26.0	...	...
	11.0	11.6	19.0	72.0	14.5	24.0	...	...
	11.0	9.5	19.3	62.0	14.9	28.3	...	...
	11.0	10.7	19.6	64.5	15.0	28.4	...	...
	11.3	9.7	19.9	46.0	15.0	35.0	...	...
	11.4	12.1	20.3	60.0	15.3	28.0	...	...
	11.5	11.1	20.4	85.0	15.7	21.5	...	...
	11.5	11.9	20.7	76.0	16.4	37.0	...	...
	11.6	12.4	22.0	82.0	16.4	32.3	...	...
	11.6	12.0	...	...	16.5	36.0	...	...

Table I—*Continued*

Total Length and Weight of Individual Fish Used for Computations Summarized in Tables II, III and IV

	Canal 34				*Blue Cypress Lake*			
	Inches	*Ounces*	*Inches*	*Ounces*	*Inches*	*Ounces*	*Inches*	*Ounces*
Redear Sunfish	5.3	1.5	9.3	9.9	6.5	3.0	8.0	6.1
	7.0	4.3	9.4	9.1	6.5	3.5	8.0	5.4
	7.1	3.9	9.5	9.9	6.5	3.0	8.1	6.1
	7.3	4.0	9.5	9.9	6.7	3.0	8.5	6.7
	7.5	5.3	9.9	10.6	6.7	3.6	8.6	8.0
	7.6	5.5	10.0	13.4	6.7	3.3	8.6	7.7
	7.6	5.1	10.0	10.5	6.9	3.6	8.6	6.7
	7.7	5.0	10.0	12.9	6.9	3.7	8.7	8.0
	7.9	5.4	..	...	6.9	3.4	8.9	8.1
	8.0	5.7	...	...	7.0	4.0	9.1	8.6
	8.3	6.6	...	...	7.1	3.4	9.3	8.7
	8.3	6.6	...	...	7.3	4.4	9.3	10.1
	8.4	7.1	...	...	7.4	3.9	9.3	8.9
	8.5	6.0	...	...	7.5	5.4	9.5	9.9
	8.6	7.4	...	...	7.5	4.4	9.5	8.3
	9.1	8.7	...	...	7.6	5.1	9.5	9.6
	9.1	9.0	...	...	7.6	5.4	9.9	10.9
	9.1	8.1	...	...	7.7	6.1	10.0	11.9
	9.1	9.0	...	...	7.9	5.9	10.0	13.0
	9.3	9.3	...	...	8.0	5.7	10.1	11.3
Bluegill	5.6	2.1	7.5	4.5	5.7	2.3	7.1	3.6
	5.6	2.3	7.6	5.1	5.7	2.4	7.3	4.6
	5.7	1.9	7.7	5.3	5.7	2.0	7.4	4.3
	5.7	2.1	7.9	6.4	5.7	1.9	7.5	4.9
	5.9	2.1	8.0	6.3	5.9	2.4	7.5	5.0
	5.9	2.3	8.1	6.5	5.9	2.0	7.6	4.9
	6.1	2.9	8.3	7.3	5.9	2.5	7.6	4.6
	6.3	2.7	8.4	7.5	5.9	2.6	7.7	5.6
	6.4	3.1	8.4	7.7	5.9	2.7	7.9	6.4
	6.4	3.1	8.5	7.1	6.0	2.6	8.0	6.0
	6.5	2.9	8.5	7.1	6.1	2.3	8.0	6.1
	6.6	3.3	8.6	7.6	6.3	3.0	8.0	6.6
	6.7	3.9	..	..	6.4	3.0	8.1	5.7
	6.9	3.7	..	..	6.5	3.5	8.3	7.3
	7.0	3.9	..	..	6.5	3.0	8.3	6.1
	7.1	4.0	..	..	6.6	3.5	8.4	7.4
	7.3	4.5	..	..	6.6	3.3	8.5	7.0
	7.4	5.0	..	..	6.7	3.6	8.6	8.0
	7.4	4.1	..	..	6.9	3.4	8.6	7.9
	7.5	5.6	..	..	7.0	3.6	..	..

	Canal 34 Only							
	Inches	*Ounces*	*Inches*	*Ounces*	*Inches*	*Ounces*	*Inches*	*Ounces*
Chain Pickerel	9.1	2.1	13.7	8.9	14.4	12.1	15.4	12.7
	11.5	5.4	13.7	6.7	14.5	12.0	15.4	12.7
	11.7	5.5	13.9	8.1	14.7	10.4	15.6	12.4
	11.7	4.9	13.9	8.7	14.7	10.3	15.7	13.1
	12.3	6.3	14.0	9.4	15.0	11.4	15.9	13.0
	12.3	11.0	14.3	8.0	15.3	11.3	16.0	10.1
	13.3	7.1	14.3	9.0	15.3	11.1	16.0	16.9
	13.4	7.4	14.3	8.5	15.3	15.0	16.3	14.1
	13.5	6.6	14.4	9.5	15.3	11.3	16.3	15.5

TABLE I—*Continued*

TOTAL LENGTH AND WEIGHT OF INDIVIDUAL FISH USED FOR COMPUTATIONS SUMMARIZED IN TABLES II, III AND IV

Canal 34 Only

	Inches	*Ounces*	*Inches*	*Ounces*	*Inches*	*Ounces*	*Inches*	*Ounces*
CHAIN PICKEREL	16.4	15.4	18.0	21.0	19.3	25.0	20.6	34.0
	16.6	14.9	18.1	19.0	19.4	19.5	20.9	33.0
	16.7	15.1	18.4	18.9	19.5	33.0	21.0	31.1
	16.7	15.3	18.4	21.4	19.5	26.5	21.0	48.0
	17.0	17.0	18.5	18.7	19.7	25.6	21.0	31.4
	17.0	15.1	18.6	24.1	19.7	26.0	21.1	40.0
	17.1	16.0	18.6	21.1	20.0	34.0	21.1	30.1
	17.1	16.6	18.7	20.1	20.0	28.5	21.3	36.0
	17.4	20.1	18.9	23.3	20.1	26.3	21.3	36.0
	17.5	17.9	19.1	22.4	20.3	31.0	21.4	36.0
	17.6	17.5	19.1	26.0	20.3	28.7	21.6	39.0
	17.9	16.7	19.3	27.3	20.3	26.4	22.3	29.4
	18.0	16.9	19.3	30.0	20.5	27.0	. . .	. . .

The weights and lengths of the individual fish were converted to logarithms. Then the linear regression of the logarithm of the weight on the logarithm of the length was computed for each group of fish according to the methods given in chapter six of Snedecor (1956). The regression lines for the length-weight relationship of the largemouth black bass, redear sunfish and bluegill from the crowded and uncrowded habitats were compared (by species) through the use of analysis of covariance. Tests of significance were at the 5 percent level unless otherwise noted. Analysis of covariance is dealt with in Chapter 13 of Snedecor (1956). The procedure has been used by several authors for the comparison of length-weight relationships in separate fish populations. An especially good explanation of the application of the procedure to fish population studies is given by Mottley (1941). Erickson (1952) and Hennemuth (1955) also used analysis of covariance.

LENGTH-WEIGHT RELATIONSHIPS

Largemouth Black Bass:

Length-weight data were used for 93 bass from Canal 34 (crowded habitat) ranging in length between 5.9 and 22.0 inches with a mean of 12.0 inches. Weights of these fish ranged from 1.5 to 85.0 ounces with a mean of 14.2 ounces. The logarithmic formula expressing the linear regression of weight on length of these fish was calculated to be $\text{Log } W = 3.25040 \text{ Log } L - 2.35433$.

Length-weight data were used for 64 bass from Blue Cypress Lake (uncrowded habitat). The length of these fish ranged from 8.5 to 24.7 inches and the mean was 13.3 inches; the weight range was from 4.0 ounces to 173.0 ounces and the mean was 18.5 ounces. The logarithmic formula expressing the linear regression of weight on length of these fish was calculated to be $\text{Log } W = 3.28447 \text{ Log } L - 2.42504$.

The comparison of the two regression lines by analysis of covariance is presented in Table II.

Comparison of the mean square deviations from regression in lines 1 and 2 of Table I shows no detectable difference in the variance of the two groups of fish. (One of the basic assumptions for the use of analysis of covariance is that the samples are drawn from populations having a common variance.)

TABLE II

COMPARISON BY ANALYSIS OF COVARIANCE OF THE LENGTH-WEIGHT RELATIONSHIP OF LARGEMOUTH BLACK BASS FROM CANAL 34 (CROWDED HABITAT) AND BLUE CYPRESS LAKE (UNCROWDED HABITAT)

Body of Water	*f*	Σx^2	Σxy	Σy^2	*Reg. Coef.*	*Deviations from Regression*		
						f	$\Sigma y^2 - (\Sigma xy)^2/\Sigma x^2$	*Mean Square*
Canal 34 ...	92	1.56451	5.08528	16.75423	3.25040	91	0.22504	0.00247
Blue Cypress	63	1.10634	3.63374	12.10094	3.28447	62	0.16603	0.00268
Within	..	......	......	....	......	153	0.39107	0.00256
Reg. Coef. ..	..	......	......	....	......	1	0.00077	0.00077
Common ...	155	2.67085	8.71902	28.85517	3.26451	154	0.39184	0.00254
Adj. Means	..	......	......	....	......	1	0.04014	0.04014
TOTAL	156	2.74972	8.91938	29.36414	......	155	0.43198	......

To test for differences between the regression coefficients, the null hypothesis $H_o: b_1 = b_2$ was formulated.

$$F = \frac{0.00077}{0.00256} = 0.30 \qquad f = 1,\ 153$$

This F-value is nonsignificant. It was therefore concluded there was no detectable difference in the slope of the two regression lines.

Next the null hypothesis of no difference between adjusted means was tested by use of an F-test.

$$F = \frac{0.04014}{0.00254} = 15.80^{**} \qquad f = 1,\ 154$$

An F-value this large is highly significant. The elevation of one of the regression lines is therefore considerably above the other when the lengths and weights of both are adjusted to a common mean. This indicates that fish from one of the two habitats are significantly heavier for their length than fish from the other habitat. Therefore, the curvilinear length-weight relationships of the two groups in true units of measurement, rather than after transformation into logarithms, were plotted as a scattergram. Curves were fitted by eye to the two sets of data. The result is shown in Figure 2. From this figure it can be seen that it is the bass from Canal 34 which are the heavier for their length.

Since most of the calculations were already performed, it was decided to test the hypothesis that the weight increased as a cube function of the length. This was done by means of a t-test. The sample standard errors of the regression coefficients and t-tests were as follows:

Canal 34: $S_b = 0.03976$; $H_o: b = 3$

$$t = \frac{3.25040 - 3.00000}{0.03976} = 6.298^{**} \qquad d.f. = 91$$

Blue Cypress Lake: $S = 0.04920$; $H_o: b = 3$

$$t = \frac{3.28447 - 3.00000}{0.04920} = 5.782^{**} \qquad d.f. = 62$$

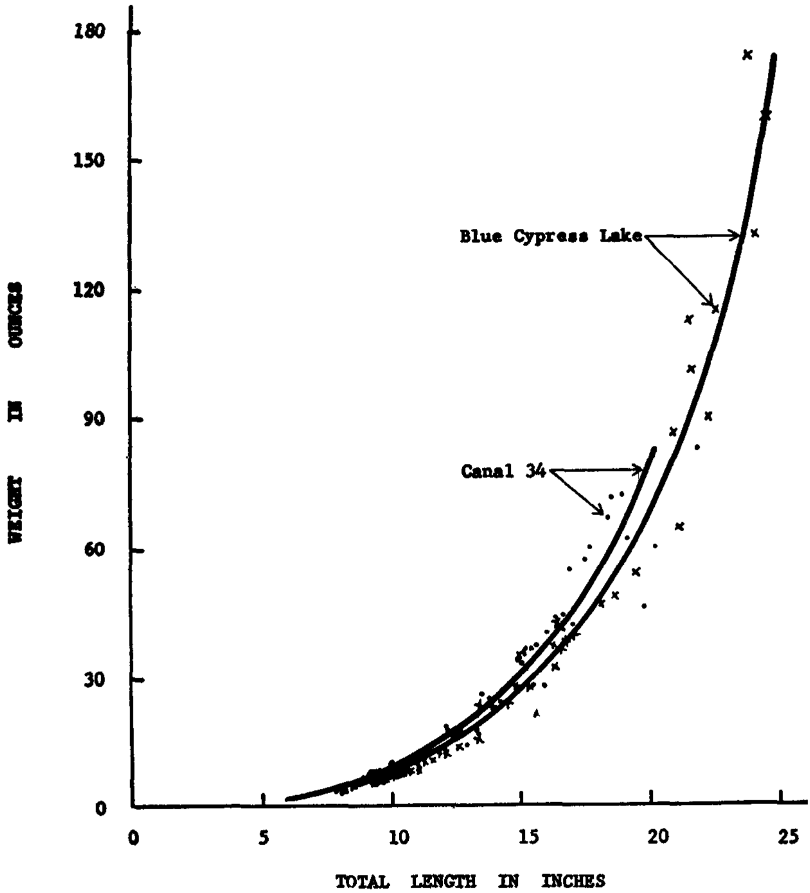

Figure 2. -- Length-weight relationships of largemouth black bass from Blue Cypress Lake and Canal 34.

The t-values for both tests are significant at the 1% level. Apparently the weight of the bass from both habitats increased at a rate greater than a cube function of the length.

Redear Sunfish:

Length-weight data were used for 28 redear sunfish from Canal 34. The mean length of these fish was 8.4 inches and the range was from 5.3 to 10.0 inches. The mean weight was 6.9 ounces and the range was from 1.5 to 13.4 ounces. The logarithmic formula expressing the linear regression of weight on length of these fish was calculated to be $\text{Log } W = 3.15359 \text{ Log } L - 2.08295$.

Length-weight data were used for 40 redear sunfish from Blue Cypress Lake. The mean length of these fish was 8.0 inches and the range was from 6.5 to 10.1 inches. The mean weight was 5.9 ounces and the range was from 3.0 to 13.0 ounces. The logarithmic formula expressing the linear regression of weight on length for these fish was calculated to be $\text{Log } W = 3.08926 \text{ Log } L - 2.02636$.

The comparison of the two regression lines by analysis of covariance is presented in Table III.

TABLE III

COMPARISON BY ANALYSIS OF COVARIANCE OF THE LENGTH-WEIGHT RELATIONSHIP OF REDEAR SUNFISH FROM CANAL 34 (CROWDED HABITAT) AND BLUE CYPRESS LAKE (UNCROWDED HABITAT)

						Deviations from Regression		
Body of Water	*f*	Σx^2	Σxy	Σy^2	*Reg. Coef.*	*f*	$\Sigma y^2 - (\Sigma xy)^2/\Sigma x^2$	*Mean Square*
Canal 34 ...	27	0.10333	0.32586	1.05378	3.15359	26	0.02615	0.00101
Blue Cypress	39	0.14351	0.44334	1.41758	3.08926	38	0.04799	0.00126
Within	..	......	......	......	......	64	0.07414	0.00116
Reg. Coef. ..	..	......	......	......	......	1	0.00025	0.00025
Common ...	66	0.24684	0.76920	2.47136	3.11619	65	0.07439	0.00114
Adj. Means	..	......	......	......	......	1	0.00035	0.00035
TOTAL	67	0.25428	0.79317	2.54886	3.11928	66	0.07474	.....

Comparison of the mean square deviation from regression in lines 1 and 2 of Table III shows no detectable difference in the variance of the two groups of fish.

To test for differences between the regression coefficients, an F-test was again used.

$$F = \frac{0.00025}{0.00116} = 0.215 \qquad f = 1,\ 64$$

This F-value is nonsignificant. There was no detectable difference in the slope of the two regression lines.

Next the null hypothesis of no difference between adjusted means was tested

$$F = \frac{0.00035}{0.00114} = 0.307 \qquad f = 1,\ 65$$

This F-value is also nonsignificant.

Since there was no detectable difference in either the slopes or the adjusted means of the two regression lines, it was concluded that the population regressions probably coincided and that the length-weight relationships of redear sunfish from the crowded and uncrowded habitats were likely the same. By reason of the above fact the data on redear sunfish from the two habitats were combined and the logarithmic regression of weight on length was calculated from the total information. The resulting formula was Log W = 3.11928 Log L — 2.05254. Further, a t-test on the regression coefficient did not show it to differ significantly from 3.0. Therefore, the redear sunfish tested apparently increased in weight as a cube function of their length.

Bluegill:

It was originally intended that data be used from 40 bluegills from Blue Cypress Lake and 50 from Canal 34. However, when the analysis of covariance was begun for these two groups of fish it was noticed that the variance of the group from Canal 34 was significantly greater than the variance of the group from Blue Cypress Lake. Therefore analysis of covariance was not used on these two complete groups. However, as a matter of record, the formulas expressing the logarithmic regression of weight on length of the two groups were as follows:

Canal 34: Log W = 2.85898 Log L — 1.81576
Blue Cypress Lake: Log W = 2.94007 Log L — 1.88066

The group of bluegills from Blue Cypress Lake ranged in total-length from 5.6 to 8.6 inches; the total-length range of the Canal 34 bluegills was from 5.0 to 9.9 inches. Because the length range of the Canal 34 bluegills was fairly wide (for bluegills) the null hypothesis, $H_o:b = 3$, was put to the t-test. As a result of the test, the null hypothesis was rejected. It was concluded that the weight of this group increased at a rate less than a cube function of the length.

Graphing the weight in ounces against the total length in inches, of the two groups of fish, revealed that the majority of the variation in the Canal 34 bluegills was caused by five considerably underweight fish over 8.6 inches long. Inasmuch as no bluegills over 8.6 inches were captured in the lake (between December 18 and January 8) it was not known if similar variation occurred there. The decision was reached that comparison should be made of the length-weight relationship of bluegills between 5.6 and 8.6 inches from the two habitats.

There were 32 bluegills from Canal 34 and 39 from Blue Cypress Lake between 5.6 and 8.6 inches long. The logarithmic regression of weight on length for each group is expressed by the following formulas:

$$\text{Canal 34: Log W} = 3.16872 \text{ Log L} - 2.07386$$
$$\text{Blue Cypress Lake: Log W} = 3.06254 \text{ Log L} - 1.98818$$

The comparison of the two regression lines by analysis of covariance is presented in Table IV.

TABLE IV

COMPARISON BY ANALYSIS OF COVARIANCE OF THE LENGTH-WEIGHT RELATIONSHIP OF BLUEGILLS BETWEEN 5.6 AND 8.6 INCHES LONG, FROM CANAL 34 (CROWDED HABITAT) AND BLUE CYPRESS LAKE (UNCROWDED HABITAT)

Body of Water	*f*	Σx^2	Σxy	Σy^2	*Reg. Coef.*	Deviations from Regression: *f*	Deviations from Regression: $\Sigma y^2 - (\Sigma xy)^2/\Sigma x^2$	Deviations from Regression: *Mean Square*
Canal 34	31	0.11297	0.35797	1.16524	3.16872	30	0.03093	0.00103
Blue Cypress	38	0.13895	0.42554	1.35183	3.06254	37	0.04860	0.00131
Within	..	......	......	......	......	67	0.07953	0.00119
Reg. Coef.	..	......	......	......	......	1	0.00071	0.00071
Common	69	0.25192	0.78351	2.51707	3.11015	68	0.08024	0.00118
Adj. Means	..	......	......	......	......	1	0.00016	0.00016
TOTAL	70	0.25224	0.78498	2.52328	3.11204	69	0.08040	......

Comparison of the mean square deviation from regression in lines 1 and 2 of Table IV now shows no detectable difference in the variance of the two groups of fish.

Once more, a possible difference in the slope of the regression lines was tested.

$$F = \frac{0.00071}{0.00119} = 0.60 \qquad f = 1,\ 67$$

This F-value is nonsignificant so there was no detectable difference in the slope of the two regression lines.

Finally, the null hypothesis of no difference between adjusted means was tested.

$$F = \frac{0.00016}{0.00118} = 0.13 \qquad f = 1,\ 68$$

This F-value is also nonsignificant.

Absence of a detectable difference in slopes and adjusted means of the two regression lines led to the conclusion that there was probably no difference in the length-weight relationship of bluegills from the two habitats over the size range tested. The data from the two groups, therefore, were combined and the formula

$$\text{Log } W = 3.11204 \text{ Log } L - 2.02806$$

was computed from the total information.

A t-test was performed on the null hypothesis $H_o: b = 3$. ($S_b = 0.02149$).

$$t = \frac{3.11204 - 3.00000}{0.02149} = 5.214^{**} \quad \text{d. f.} = 69$$

This t-value is highly significant; bluegills between 5.6 and 8.6 inches apparently increased in weight at a rate faster than a cube function of their length.

Chain Pickerel:

Only one chain pickerel was sighted during shocking operations in the lake. For this reason there can be no comparison of the length-weight relationship of chain pickerel from the two habitats. Nevertheless, usable length-weight data were obtained on several hundred chain pickerel from Canal 34. Of these pickerel, 87 fish (well distributed over the total-length range between 9.1 and 22.3 inches) were selected for determination of the length-weight relationship. The mean total-length was 16.9 inches, the mean weight was 16.3 ounces and the weight range was from 2.1 to 48.0 ounces.

The regression of weight on length of the above fish was calculated to be

$$\text{Log } W = 3.09778 \text{ Log } L - 2.59046$$

Standard error of the regression coefficient was $S_b = 0.09418$. The t-test of the null hypothesis $H_o: b = 3$ was nonsignificant. Therefore the weight of these fish may well have increased as a cube function of the length. This, of course, is just another way of saying there probably was no real change in general body shape over the size range tested.

DISCUSSION

The most important fact requiring discussion is the significantly greater weight, for a given length, of the largemouth black bass from Canal 34. The following are some of the possible explanations as to why the canal bass had a greater relative plumpness than the lake bass:

(1) The canal bass were originally from the marsh; possibly bass reared in the marsh normally are more plump than lake bass.

(2) Canal bass may have been more sexually mature than lake bass. Plumpness, of course, increases as the gonads mature.

(3) The canal fish may have had greater amounts of food in their stomachs.

(4) Because of the crowded conditions in the canal, the canal bass fed more heavily, grew faster and were in better condition than the lake bass.

Let us now analyze these explanations individually.

Water levels were favorable in the marsh between October 1956 and May 1958. Fish production was undoubtedly high. By late June 1958, water levels had receded below the ground surface over most of the marsh. Only that area within two miles of State Road 512 still retained surface water to any degree, and even here the water was only about a foot to a foot and a half deep. Moreover, water levels continued to decline, and the marsh was completely dry by mid-December. Presumably most of the marsh fish had been forced into the canal by late June 1958, or shortly thereafter. Nothing is known of the relative plumpness of the bass at this time; it may have been high. However, none of the canal bass used in this study were captured until several months later. Even if their condition had been unusually good at the time they left the marsh, they should have been in poor condition when captured if the canal were not favorable habitat. Therefore, it seems that explanation (1) does not suffice.

It is more difficult to refute explanation (2). The fish were captured for a tagging program, so examination of the gonads was impractical. However, it seems doubtful that an important difference in sexual maturity existed. The two habitats were within a few miles of each other, and were therefore subject to the same climatic conditions. Also, the bass were of the same genetic strain. Nevertheless, explanation (2) can not be completely discounted.

"Explanation" (3) really can not be divorced from explanation (4), even though at first glance it appears to be a separate possible explanation. No stomach samples were taken, of course, since the fish were collected primarily for tagging. It may very well be that the canal bass did contain more food in their stomachs. This is especially probable since a scarcity of small forage fish was noticed during the tagging operation. The predators were therefore feeding on relatively large prey. At one time a 1-pound bowfin (*Amia calva*) was protruding (and subsequently pulled out) from the mouth of a six-pound bass. The outline of 4- to 6-inch blugills often distended the belly of pickerel, which may have only weighed a pound or so themselves. Nevertheless, even if the canal bass did have more food in their stomachs, this only tends to reinforce explanation (4). The time required to digest a meal does not increase in direct proportion to the size of the meal. Hunt (Ms. in preparation) in feeding experiments with gar (*Lepisosteus*) found that increasing the size of the meal approximately nine times only about doubled the time required for digestion. Therefore, bass consuming larger than average meals should still get hungry, and consequently feed, nearly as often as bass consuming smaller meals. Total food consumption by bass consuming larger than average meals should consequently be considerably greater than normal, and growth rate should be rapid. For this reason acceptance of "explanation" (3) inevitably leads to acceptance of explanation (4).

Further support for explanation (4) is furnished by the apparent agreement between the length-weight relationships of the lake and canal redear sunfish and bluegill. These species are non-predators and therefore would not be expected to grow faster under crowded conditions. But if explanation (1) or (2) correctly explains why the canal bass were heavier for their length than the lake bass, then it would seem the canal redear and bluegill should have also been heavier for their length.

For the above reasons, the author believes explanation (4) involving increased feeding by the bass in Canal 34 offers the most logical interpretation of why the bass in this canal were heavier for their length than the lake bass.

Acceptance of explanation (4), however, still leaves at least two questions for which an answer is unknown. Both questions involve the fact that the Canal 34 bass were apparently feeding on larger than normal prey.

First of all, if their prey were larger than normal, why was the mean square deviation from regression of the canal bass in line 1 of Table II, not significantly larger than the corresponding mean square for the lake bass? One possible explanation is that because of the increased rate of digestion, and greater availability of prey, the canal bass may have fed about as often as the lake bass. If so, the average weight of food in the canal bass stomachs would be considerably greater than that in the lake bass stomachs, but the variation in relative weight of stomach contents would be similar. It is also quite possible that the prey taken by the canal bass were not actually larger than normal; perhaps the lake bass also fed on relatively large prey.

The second question is of more significance. If we accept the fact that the prey taken by the canal bass were larger than normal, and digestion rate consequently more rapid, then would the canal bass have been in equally good condition if smaller prey had been abundantly available? In other words, would these bass have consumed meals as large as they did (and consequently been in as good a condition) if their meals could have been made up of several smaller fish; or did these bass consume large meals only because they were forced to prey on fish of such size that each was a large meal in itself? If the latter is true, it could have important management implications. Unless bass will feed more heavily than normal under crowded conditions, when small prey are available, it will do little good to have a drawdown in impoundments containing a high percentage of small, stunted forage fish. Similarly, if bass consume greater food quantities per unit of time when their prey are large, faster growth rates could be obtained under controlled conditions by furnishing them with relatively large prey.

The final matter for discussion involves the bluegills. It will be remembered that the weight of the Canal 34 bluegills in the size range from 5.0 to 9.9 inches was found to increase at a rate significantly less than a cube function of the length. Yet the weight of the combined Canal 34 and Blue Cypress Lake bluegills in the size range from 5.6 to 8.6 inches increased at a rate significantly greater than a cube function of the length. (There was no detectable difference in the slope of the length-weight regression lines for bluegills, in this size range, from the two habitats.) The most logical explanation for this apparent discrepancy is that the five underweight Canal 34 bluegills over 8.6 inches long decreased the slope of the entire regression line considerably. One may well wonder, though, why these five fish were so underweight; but the answer is not known. It is doubtful that such variation is normal in this size range. It may be that under the crowded condition in which the canal fish were living food was becoming scarce for the larger bluegills, and some of them were beginning to lose weight.

ACKNOWLEDGMENTS

Special thanks are due Dr. Kenneth D. Carlander, Department of Zoology, Iowa State College, Ames, Iowa, and Mr. Scott Overton, Institute of Statistics, North Carolina State College, Raleigh. These two men were particularly generous with their time in early discussions concerning preparation of this paper. However, since not all their suggestions were followed, and the paper was completed too late for their review, any errors in the paper are strictly the responsibility of the author.

Thanks are also due Miss Anne Baldwin, and Messrs. Frank Arrendale and Virgil Wilson, of the Florida Game and Fresh Water Fish Commission, for their assistance in the more monontonous drudgery concerned with logarithmic transformations, typing, etc.

This study was made possible by the D-J Federal Aid to Fisheries program.

LITERATURE CITED

Carlander, Kenneth D. 1953. Handbook of Freshwater Fishery Biology With the First Supplement. Wm. C. Brown Company, Dubuque, Iowa, pp. 8-9.

Erickson, James G. 1952. Age and Growth of the Black and White Crappies, *Pomoxis nigro-maculatus* (LeSueur) and *P. annularis* Rafinesque, in Clear Lake, Iowa. Ia. St. Coll. Jour. Sci., Vol. 26, No. 3, pp. 491-505.

Eschmeyer, R. W. 1955. Fish Conservation Fundamentals. Reprint from Sport Fishing Institute, Bond Bldg., Washington 5, D. C., 30 pp.

Forbes, Stephen A. 1925. The Lake As A Microcosm. Ill. Nat. Hist. Surv. Bul., Vol. 15, Art. 9, pp. 537-550.

Hennemuth, Richard C. 1955. Growth of Crappies, Bluegill, and Warmouth in Lake Ahquabi, Iowa. Ia. St. Coll. Jour. Sci., Vol. 30, No. 1, pp. 119-137.

Herke, William H. and George Horel. 1958. Fishery Evaluation of the U. S. Corps of Engineers Proposed Water Storage Plan for the Upper St. Johns River. Mimeo. Rpt., Fla. Game and Fresh Water Fish Comm., Tallahassee, Fla., vi + 89 pp.

Hulsey, Andrew H. 1959. A Proposal for the Management of Reservoirs for Fisheries. Proc. Twelfth Ann. Conf. S. E. Assoc. Game and Fish Comm. (1958, printed at Columbia, S. C.).

Hunt, Burton P. Digestion Rate and Food Consumption of Florida Spotted Gar, Warmouth, and Largemouth Black Bass. Ms. in preparation; presented at the Eighty-Ninth Annual Meeting of the American Fisheries Society, Clearwater, Fla.

Mottley, C. McC. 1941. The Effect of Increasing the Stock in a Lake on the Size and Condition of Rainbow Trout. Trans. Am. Fish. Soc., Vol. 70 (1940), pp. 414-420.

Sincock, John L. 1958. Waterfowl Ecology in the St. Johns River Valley as Related to the Proposed Conservation Areas and Changes in the Hydrology

From Lake Harney to Ft. Pierce, Florida. Mimeo. Rpt., Fla. Game and Fresh Water Fish Comm., Tallahassee, Fla., vi + 122 pp.

Snedecor, George W. 1956. Statistical Methods. Iowa St. Coll. Press, Ames, Iowa, xiii + 534 pp.

SUGGESTED STANDARD METHODS OF REPORTING FISH POPULATION DATA FOR RESERVOIRS PREPARED FOR THE RESERVOIR COMMITTEE, SOUTHERN DIVISION OF THE AMERICAN FISHERIES SOCIETY

By EUGENE W. SURBER

Branch of Federal Aid, Bureau of Sport Fisheries and Wildlife

Atlanta, Georgia

During a meeting of the Southern Division's Reservoir Committee on June 1, 1959, the writer was directed by the Committee to review methods of reporting fish population data for reservoirs and to recommend a standard method.

In carrying out this project, it was necessary to keep in mind certain of the objectives in presenting population data. Reservoir workers, Wiebe (1942), Smith and Miller (1943), Tarzwell (1942), have observed that rough fish have increased in numbers following the early years of good sport fishing. The importance of determining the ratios of game fishes to rough fishes in large impoundments has been emphasized by Eschmeyer, Stroud, and Jones (1944), Trazwell (1945) and more recently by Hall (1951).

Carter (1958) listed a number of reasons for collecting fish population data by rotenone sampling. Among them were the determination of species composition, standing crop, abundance of adult fish, success of natural reproduction, and information on year classes.

Southern biologists have been uniform in methods of collecting and recording the basic data. Field data sheets have invariably recorded each species of fish present in a population sample in one inch size classes. The weights of fish in each size class are generally recorded, therefore the two prime basic units for calculation of population dynamics are generally available. As stated by Chance (1958), "Interpretations and manipulations beyond this point depend on the need, use and inclination of the investigator."

Jenkins (1958) observed the need for extension and refinement of our ability to estimate the size and composition of fish populations as well as methods of field estimation, statistical treatment and presentation. He considered standard forms for recording the original field data a prime requisite.

A STANDARD METHOD

The following Tables I-V, labelled "Summary of Fish Population Data for Reservoir . . . .," represents the organization of the field data approved by the Reservoir Committee. The actual field data may be recorded on a simple form (included in this report) which gives the size class of each species of fish, the total number of each species, and the total number and weight of fish of available size, or the harvestable fish.