GROWTH OF WHITE CRAPPIE AND CHANNEL CATFISH IN RELATION TO VARIATIONS IN MEAN ANNUAL WATER LEVEL OF LAKE CARL BLACKWELL, OKLAHOMA

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ABSTRACT

Variations in annual increments of growth of white crappie, *Pomoxis annularis* Rafinesque, and channel catfish, *Ictalurus punctatus* (Rafinesque), are examined in relation to mean annual water level of Lake Carl Blackwell, 1962-1967, when lake level was declining. The occurrence of lee's phenomenon precluded a correlative comparison of white crappie growth with water level, but decrease in growth at age 1 and the increase at older ages is attributed to the decline in water level. The crappie body-scale relationship changed from curvilinear to linear as growth improved during the drawdown period. Correlations of channel catfish growth with lake level were significant for age 1 (r= -0.84, P 0.05), age 2 (r= -0.92, P 0.01) and age 6 (r= -0.81, P 0.05). We hypothesized that the declining water level increaded the growth of channel catfish through reduced intraspecific and interspecific competion. The reduction in competition is believed to result from decreased spawning success and increased predation upon small channel catfish by piscivorous fishes such as largemouth bass and flathead catfish.

INTRODUCTION

Natural or aritficially induced water level fluctuations occur in most reservoirs and are known to greatly affect fish production and the composition of fish populations. Rising water levels are known to provide spawning sites for certain species, and year-class strength of many reservoir fishes is positively correlated with water level at time of spawning (Walburg and Nelson 1966, Bross 1969, VonGeldern 1971, and others). Conversely, lowering water levels adversely affects year-class strength of certain fishes by destroying spawning sites (Shields 1957, Riel 1965) and subjecting young fishes to increased predation (Lantz et al. 1965, Heman et al. 1969, Bennett et al. 1969). Increase in prey vulnerability can result in increased growth of piscivorous fishes (Lewis and Helms 1964, Lewis 1967). Declining water levles can also have the effect of reducing littoral zone production of invertebrate fauna (Bennett 1954).

During the period 1962 through 1971, below average rainfall, high evaporative rates and increased domestic water use in Payne County, Oklahoma resulted in nearly a 5 m decline in the water level of Lake Carl Blackwell. Zweiacker et al. (1973) demonstrated that significant correlations existed between growth of Lake Carl Blackwell largemouth bass, *Micropterus salmoides* (Lacepede), and mean annual water level during this drought period. Decreased growth of young-of-the-year bass, which depends upon benthic macroinvertebrates for food, paralleled declining water levels. Growth of yearling bass, which are piscivorous, increased with declining lake levels, presumably due to increased vulnerability of their prey. The objective of the present study

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was to determine if correlations existed between mean annual water level and growth of Lake Blackwell white crappie, *Pomoxis annularis* Rafinesque, and channel catfish, *Ictalurus punctatus* (Rafinesque), during the period of water level decline. Life history studies of Lake Carl Blackwell white crappie (Burris 1956) and channel catfish (Jearld and Brown 1971) as well as white crappie scale collections made in 1966, 1967, and 1968, by personnel of the Oklahoma Cooperative Fishery Unit provided growth data that were utilized with data from collections in 1971. Growth histories of these fishes were compared to lake water levels for 1962-67.

STUDY AREA

Lake Carl Blackwell is a turbid reservoir in the Permian redbeds of north-central Oklahoma, approximately 11 km west of Stillwater, Payne County, Oklahoma. At spillway elevation, 287.8 m, mean sea level (m.s.l.), the surface area of the reservoir is 1335 ha, and the volume in 67 million cubic meters. Turbidity ranges upward from about 20 Jackson turbidity units in the deeper portion of the lake during periods of high winds.

The steady decline in lake water level that began in 1962 reached a record low of 282.9 m, m.s.l. (4.9 m below spillway level) on 17 September 1971. Drought reduced the lake surface area to 48% of the area at spillway level and reduced total volume to only 29% of maximum volume. The shoreline during the six years from 1962 to 1967 was characterized by barren mud banks sparsely populated by vegetation. Littoral areas were essentially void of submergent and emergent vegetation. A succession of terrestrial vegetation advanced as the water receded. In the spring of 1968, the lake level rose nearly 2 m and flooded shoreline vegetation.

MATERIALS AND METHODS

Fish were collected from June through September 1971, with experimental gill nets, electrofishing aparatus, and rotenone. Six major reservoir areas were sampled, each presumably representing a different habitat type. Weight was recorded to the nearest ounce for fish heavier than 1000 grams and to the nearest gram for smaller fish. Total length was recorded to the nearest millimeter. Scale and spine samples were taken at random from fish collected by all methods throughout the summer. Impressions of at least three scales per fish were made on preheated plastic slides with a roller press.

Scale measurements (in millimeters) were made using a scale projecter and two or more scales were examined to verify the number of annuli on a scale. Scale radius for crappie was measured from the center of the focus to the most anterior margin of the scale.

The entire left pectoral spine was removed from channel catfish by disarticulation from the locked position by a clock-wise rotation. Cross-sections of the spines were cut at the distal end of the basal groove to insure consistency in that location of each section and measurements were made along the longest spine radius.

Regression analyses were used to determine body-scale and body-spine relationships for each collection year. Both linear and curvilinear regressions were calculated for the relationship between scale radius in mm (X) and body length in mm (Y). Analysis of variance was used to test whether fitting a second-degree term caused a significant reduction of variance from that attributed to a linear fit.

All lake levels used in this study were recorded by the USDA Agriculture Research Service, Water Conservation Structures Laboratory, Oklahoma State

University. Mean annual lake levels through 1965 were calculated from the only available readings which were usually taken on or near the first and fifteenth of each month.

Water levels for years 1962-67 were chosen for calculations of correlation with growth because this was a period of nearly steady decline in water level.

RESULTS AND DISCUSSION

Linear and curvilinear regressions were calculated for white crappie body-scale relationships from collections of 98 fish in 1966, 224 fish in 1967, 26 fish in 1968, and 92 fish in 1971. Linear and curvilinear regressions of total body length in mm (Y) on total scale radius in mm (X) were significant for all collection years ($P<0.01$). Linear and curvilinear regression equations for the four years are:

Year	Linear Regression	Linear Correlation Coefficient	Curvilinear Regression
1966	$Y = 54.2 + 0.65X$	0.94	$Y = 87.3 + 0.28X + 0.009X^2$
1967	$Y = 61.9 + 0.60X$	0.83	$Y = 80.4 + 0.37X + 0.0006X^2$
1968	$Y = 33.9 + 1.45X$	0.94	$Y = 43.8 + 1.27X + 0.0007X^2$
1971	$Y = 19.0 + 1.5X$	0.95	$Y = 6.7 + 1.7X - 0.0006X^2$

Reduction of variance due to inclusion of the second degree term was significant ($P<0.01$) only for the 1966 and 1967 collections. Therefore, back-calculations of total length at each annulus for these years were performed using the second-degree polynomial formulae. Back-calculations of length for the 1968 and 1971 collections were performed using Lee's formula with the intercept values derived from the linear regressions. Sexes were combined in the calculations.

Curvilinearity

Significant curvilinear regressions for body-scale relationships of white crappie have been observed by other investigators. Burris (1956) and Brown and Jossell (1970) described this relationship for white crappie of Boomer Lake Oklahoma which are slow growing and considered to be stunted. Burris (1956) also found the body scale relationship for Lake Carl Blackwell white crappie to be significantly curvilinear. Burris attributed the cause of curvilinearity to fish between 127 and 178 mm total length. He also found that the same size fish had low coefficients of condition and concluded that low coefficients of condition and curvilinear body-scale relationships were characteristics of stunted white crappie populations.

Comparison of White Crappie Growth with Mean Annual Water Levels

Growth histories from the four collection years were originally combined to form a ten-year growth history that was to be analyzed in relation to mean annual water levels during the years 1962-67. However, examination of individual growth histories revealed the occurrence of Lee's phenomenon in the first year of life which would give a spurious negative correlation of growth with water levels. For example, back-calculated length at age 1 for the 1964 year class, decreased from 109 mm to 78 mm as it was calculated from successively older fish (Table

1). This phenomenon occurred in most other year classes. In addition to this apparent decrease in growth, a real decrease in the growth occurred in one year old fish. Growth of age 1 white crappie decreased 30 mm (107 mm to 77 mm) in the 6 years from 1966 to 1971 (Table 1).

A comparison of growth data from the present study with that reported by Burris (1956) for lake Carl Blackwell white crappie shows that growth in the first year of life was greater in the 1940s than it was in the 1960s (Table 2). Mean length at age 1 from data reported by Burris is 23 mm greater than the weighted mean length at age 1 for the 1971 collection. However, all growth increments after age 1 were greater in the 1960s than in the 1940s. For example, the weighed

Table 1. Mean back-calculated lengths at age 1 for Lake Carl Blackwell white crappie.

	Collection Year			
Year Class	1966	1967	1968	1971
1970				77
1969				69
1968				67
1967				74
1966		104	96	73
1965	107	105	81	82
1964	109	102	84	78
1963	105	98	77	
1962	102	97	70	
1961	101	101		
1060	98	99		

Table 2. Weighted mean back-calculated total length (mm) at age of Lake Carl Blackwell white crappies from five collection years.

	Collection Year				
Age	1951*	1966	1967	1968	1971
1	95	106	103	83	72
2	127	132	130	128	138
3	154	151	146	155	192
4	185	167	156	218	250
5	219	186	187	255	284
6	224	289	222	262	317
7	**	**	212	**	328
Year classes represented	1945 to 1949	1960 to 1965	1960 to 1966	1962 to 1967	1964 to 1970

*Data from Burris (1956)

**No age 7 fish collected

mean length of age 6 fish from the 1971 collections is 93 mm greater than that reported by Burris for age 6 fish. Also, as back-calculated growth past age 1 improved, calculated from 1966 to 1971 collections, the body-scale relationships changed from curvilinear to linear. This change supports Burris's hypothesis that the curvilinear body-scale relationship is a characteristic of stunted white crappie populations.

Although Lee's phenomenon precludes a correlative comparison of growth with mean annual water levles, the change in growth of crappies since the 1940s suggests a causal relationship with water levles (Table 2). The reduction in lake volume during the 1960's and subsequent increase in vulnerability of prey fishes to the piscivorous crappies could account for the increased growth of crappies beyond age 1. Furthermore, reduced littoral zone production of invertebrate fauna is the likely explanation for the observed decrease in age 1 white crappie growth that occurred between 1966 and 1971. Macro-invertebrate production in Lake Carl Blackwell is largely limited to the shallow water areas due to anoxic conditions that develop in the hypolimnion during transient stratification of the lake's water (Norton 1968). Therefore, water level changes probably have profound effects on the macroinvertebrate productive capacity of the lake.

Effects of fluctuating water levels on crappie growth in other lentic waters have varied. Johnson (1945) observed that low water levels retarded the growth of white crappie in Lake Greenwood, Indiana. In Oklahoma, a 2.4 m drop in water level of Lake Spavinaw, from 1951 through 1953 had the effect of retarding crappie growth (Jackson 1958). Other investigators have found little relationship between water level and growth of white crappies. Bartholomew (1956) believed crappie growth in Isabella Reservoir, California to be independent of annual water volume fluctuations. Neal (1963) found no correlation between mean annual water levels and crappie growth in Clear Lake, Iowa. No correlation between Lake Keystone water levels and white crappie growth could be demonstrated by Al Rawi (1971) although he believed that additional data might provide such a correlation.

Fluctuating water levels during the crappie spawning season result in a weak year class (Ercole 1969) and could subsequently reduce intraspecific competition for food and increase growth of the remaining fish.

CHANNEL CATFISH

Body-Spine Relationship

Linear and curvilinear regressions for body-spine relationship calculated from 63 channel catfish collected in 1971 are both significant ($P < 0.005$). Linear regression of total body length in mm (Y) on total spine radius in mm (X) is: $Y = -131.3 + 3.3X$ with a correlation coefficient of 0.93. The curvilinear regression is: $Y = 141.0 - 0.98X + 0.016X^2$. Reduction of variance due to curvilinearity is significant ($P < 0.005$).

The second-degree polynomial forumla was used for back-calculations of length at each annulus for the 1971 collections. Sexes were combined as Jearld and Brown (1971) found no significant difference in growth between the sexes for Lake Carl Blackwell channel catfish.

A significant curvilinear body-spine relationship for Lake Carl Blackwell channel catfish was described earlier by Jearld and Brown (1971) although they used their linear relationship in their back-calculations.

Jearld and Brown (1971) noted that back-calculated lengths at annulus 1 decreased as they were calculated from successively younger age groups. Jearld and Brown attributed the negative Lee's phenomenon to actual changes in growth and suggested that the decline in lake level may be related to the decrease in growth of age 1 fish. A correlation of growth at age 1 with mean annual lake levels was non-significant but they suggested that further study might be successful in demonstrating this correlation.

Ricker (1969), in a discussion of the effects of size-selective mortality and sampling bias on estimates of growth, indicates that sampling bias does not produce negative Lee's phenomenon. Since use of a linear regression model for back-calculation for data that are curvilinear may produce Lee's phenomenon (Tesch 1971), we considered the possibility that selection of an inappropriate regression model for use in back-calculation of growth might also produce reverse Lee's phenomenon. Back-calculation of first year growth of channel catfish collected in 1971 using the second degree polynomial showed no indication of reverse Lee's phenomenon. Therefore, the data of Jearld and Brown were used to re-calculate growth increments during the first year for channel catfish collected in 1967 using the second degree polynomial formula they had derived. The re-calculated growth increments show no reverse Lee's phenomenon for age 1 fish (Table 3). This suggests that the reverse Lee's phenomenon found by Jearld and Brown may be attributed to use of the linear method of back-calculation when the curvilinear method was appropriate.

Comparison of Channel Catfish Growth with Mean Annual Water Levels

Correlation coefficients for mean annual water levels for the years 1962-67 with growth increments in the first 8 years of life were calculated for both the present study and the re-calculated data of Jearld and Brown. No significant correlations with water level were found for growth calculated from the present study, although all correlations coefficients were negative (Table 4). Significant negative correlations were found for growth increments with water levels in years 2, 3, and 6 for re-calculated data from Jearld and Brown (Table 3). The regressions for the relationship between year of growth (Y) and mean annual lake level (X) are:

Age	Regression
2	$Y^2 = 2186.4 - 7.6X$
3	$Y^3 = 1018.9 - 3.5X$
6	$Y^6 = 798.8 - 2.7X$

Although channel catfish were found to comprise only a small portion of the diet of largemough bass (Zweiacker 1972) and flathead catfish (Turner 1971), the two principle piscivorous fishes in Lake Carl Blackwell, these negative correlations appear to support the hypothesis of Zweiacker et al. (1973) that the water level decline in Lake Carl Blackwell has increased the vulnerability of prey species by forcing them into a new littoral zone having inadequate cover. We further hypothesize that increased predation on young channel catfish may have resulted in a reduction in competiton for food and a subsequent increase in growth. Carroll and Hall (1964) found no growth acceleration of older channel catfish following an extreme drawdown of Norris Reservoir, but growth at all ages improved in the first year class after drawdown.

There is a possibility that Lee's phenomenon produced the negative correlations observed for growth of channel catfish with water level. However, there is an absence of heavy fishing pressure on this species that might cause selective mortality, and the combination of collection methods used in sampling tends to rule out sampling bias as a cause of Lee's phenomenon. Moreover, lowering water levels would likely cause negative size-selection mortality. That is, predation would increase on the smaller, slower growing individuals.

POTENTIAL FOR APPLICATION TO MANAGEMENT

We realize that single variable analyses of warm-water reservoir fish populations are complicated by interactions of: Frequency and severity of

Table 3. Relationship between growth increments for Lake Carl Blackwell channel catfish and mean annual lake level, 1962-1967, when water level was declining. Growth is recalculated from data of Jearld and Brown (1971) using their derived second degree body-spine relationship.

Year	Avg. Ann. water level	Growth increments in total length (mm) at each age for year shown							
		1	2	3	4	5	6	7	8
1967	283.9	*	39	28	24	26	34	30	32
1966	284.6	149	17	21	23	19	29	32	26
1965	285.6	146	9	19	18	24	29	31	34
1964	286.1	146	8	16	20	24	25	31	34
1963	287.0	146	7	15	20	21	20	34	23
1962	287.6	146	6	14	20	18	26	33	29
Correlation coefficient		-	-0.84	-0.92	-0.69	-0.55	-0.81	76	-0.49
Coefficient of determination (%)		-	0.70	0.85	0.48	0.30	0.66	0.58	0.24
Degrees freedom		-	4	4	4	4	4	4	4
Probability of r		-	$P< 0.05$	$P<0.01$	$P>0.05$	$P>0.05$	$P<0.05$	$P>0.05$	$P>0.05$

*No fish collected.

Table 4. Relationship between growth increments for Lake Carl Blackwell channel catfish collected in 1971 and mean annual lake level, 1962-67, when water level was declining.

Year	Avg. Ann. Water level	Growth increments in total length (mm) at each age for year shown							
		1	2	3	4	5	6	7	8
1967	283.9	131	9	23	14	19	13	29	41
1966	284.6	128	12	13	12	10	22	32	24
1965	285.6	128	14	9	15	11	22	18	13
1964	286.1	127	7	15	11	20	14	15	31
1963	287.0	127	4	12	15	11	8	24	*
1962	287.6	128	6	9	7	10	16	*	*
Correlation coefficient		-	-0.63	-0.71	-0.47	-0.40	-0.45	-0.52	
Coefficient of determination (%)		-	0.40	0.50	0.11	0.16	0.20	0.27	-
Degrees freedom		-	4	4	4	4	4	3	-
Probability of r		-	$P>0.05$	$P>0.05$	$P>0.05$	$P>0.05$	$P>0.05$	$P>0.05$	-

*No fish collected.

prevailing winds, temperature and short-term water level fluctuations, and intraspecific and interspecific competition with differential effects on total mortality. Ultimately, enough data will be assembled to construct multivariate models that will have strong predictive values. Until this is accomplished, variables that contribute to the explanation of the observed population fluxes should be monitored to determine the role that each plays. Although "mean water level" cannot be considered the most important variable affecting multispecific population dynamics, we feel that longterm trends in changes of reservoir water level is one factor that plays a significant part in the growth of each class and should be of imminent concern to warm-water fisheries biologists.

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