LARGEMOUTH BASS GROWTH IN RELATIONSHIP TO ANNUAL VARIATIONS IN MEAN POOL ELEVATIONS IN LAKE CARL BLACKWELL, OKLAHOMA[1]

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ABSTRACT

The growth history of largemouth bass in Lake Carl Blackwell is described. Variation in annual increments in growth of largemouth bass age groups I-III are examined in relationships to mean annual water level 1962 through 1967, when the annual average lake level was declining. Weighted mean average total lengths (mm) to the end of each year of life, i.e., to annulus formation which occurred in May, were: 140 (I); 279 (II); 369 (III); 425 (IV); 462 (V); 485 (VI); 504 (VII); and 531 (VIII). Growth in the first year was positively correlated ($r=0.85$, $P<.035$) to the average annual lake level. In the second year the relationship was negative ($r = -0.95$, $P<.004$), that is, annual increments in growth in the second year of life were inversely related to lake level. Growth increments in the third and fourth years also were negatively correlated with lake level but the correlation was non-significant ($P>.05$). It is hypothesized that first year growth declined with declining lake level because of a negative effect of the drawdown on littoral zone invertebrates upon which bass feed in the first year. Second year growth increased with declining lake levels because of greater vulnerability of forage fish to predation by the larger piscivorous bass.

Comparisons were made of the growth history of largemouth bass in Lake Carl Blackwell with the Oklahoma average and median growth from other U.S. locations cited in the literature. Largemouth bass growth rates in Lake Carl Blackwell were about equal to growth rates in Missouri, Tennessee, Louisiana, California and other Oklahoma waters, but much better than growth rates in the northern tier states, Great Lakes, and northeastern states.

INTRODUCTION

Growth rates of largemouth bass, *Micropterus salmoides* (Lacepede) were determined from samples collected in 1968, 1969 and 1971 in Lake Carl Blackwell, Oklahoma. Back-calculated lengths from these collections provided a growth history of largemouth bass in Lake Carl Blackwell for the years 1961 to 1970. During this interval, lake levels declined 3.9 meters. Comparison of lake levels and growth were made as certain trends in growth with average annual water level were indicated. This report presents a description of a ten-year growth history of largemouth in Lake Carl Blackwell during a prolonged drought. The data also provides a basis for comparative study of largemouth bass growth in the U.S.

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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, 287.7 m, m.s.l. (median sea level), the surface area of the reservoir is 1335 ha and the volume is 67 million cubic meters. Turbidity ranges from about 20 Jackson turbidity units in the deeper portion to 180 units in the shallower western portion during periods of high winds.

High average wind velocities and shallow water depths result in nearly continuous mixing of the reservoir. A weak thermocline usually develops in summer, but is quickly destroyed by wind action. Complete exhaustion of hypolimnetic oxygen occurs quickly during thermal stratification of the lake (Loomis, 1951; Norton, 1968), but throughout the year, vertical oxygen and temperature profiles are generally orthograde.

Below average rainfall in Payne County, with the exception of three spring rises in 1967, 1968, and 1969, resulted in a continuous decline of lake level of Carl Blackwell 1962 to 1971. A record low of 282.9m,m.s.l. (4.9m below spillway level) was reached on 17 September 1971. Drought reduced the lake surface area to 60 percent of the area at spillway level and total volume to only 29 percent of maximum volume. The shoreline during the six years from 1962 to 1967 was characterized by barren mud banks sparsely populated by vegetation. The 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 two meters and flooded the shoreline vegetation.

METHODS

A total of 1166 largemouth bass were collected by shoreline electrofishing between 1 June 1968 and 1 November 1969 and between 7 June and 15 September 1971. In addition to electrofishing, several specimens were captured in cove rotenone samples in 1971. The 1968-69 samples were collected as part of Zweiacker's study (1972) of largemouth bass population dynamics, and the 1971 samples were collected as part of Johnson's (1973) study of fish population trends.

Bass were weighed to the nearest ounce, total length measured in millimeters and scale samples taken on the left side below the lateral line where the margin of the pectoral fin meets the body.

Sex could not be reliably determined by external morphological features. Recognition of males by occurrance of worn caudal fins during spawning, as observed by Snow (1963), was documented by dissection in the laboratory as a inaccurate procedure for sex determination in the present study.

Body-scale relationships were calculated from a representative sample of 100 fish from the 1968-69 collections and from 43 fish from the 1971 collection. Linear and curvilinear (2nd degree polynomial) regressions were calculated for body-scale relationships.

Scale impressions were made with a roller press on plastic slides using at least three scales per fish. Plastic slides were preheated before scale impressions were made with a 100 watt light bulb beneath a metal surface. Scale impressions were examined at 40 magnifications using a scale projector with a 16mm microtessar lens.

Back-calculated lengths from 1968, 1969 and 1971 collections were combined to provide a ten-year growth history. Weighted mean lengths at each year of life and growth increments were calculated for the combined sample. Linear regression equations and correlations coefficients were calculated for growth at the end of the first, second and third year of life with mean annual water levels between 1962 and 1967. It was during this period that water levels declined at a nearly continuous rate with little annual fluctuation.

RESULTS AND DISCUSSION

Body-Scale Relationship

The linear and curvilinear regressions calculated for body-scale relationship for all collections were significant ($P<0.005$). The linear regression of the total body length in mm (Y) on the total scale radius (mm) for the combined 1968 and 1969 collections was : $Y= 37.67 + 1.29X$ with a correlation coefficient (r) of 0.97. The linear regression for the 1971 collection was $Y = 8.04 + 1.69X$ with a correlation coefficient of 0.95. Curvilinear regression for the 1968-69 collections was $Y = 18.6 + 1.4X + 0.0004X^2$, and $Y = 33.93 + 1.38X + 0.00078X^2$ for the 1971 collection. Reduction due to curvilinearity was not significant ($P>.10$) for either sample, therefore, the linear relationships were used in the back-calculation of growth rates.

Mraz and Threinen (1955) in Brown's Lake, Wisconsin calculated a body-scale relationship of $S = 0.1813L^{1.3613}$ with total length (L) and scale radius (S) measured in inches. Thompson (1964) calculated for bass in Clear Lake, Iowa a body-scale relationship of $Y = 1.00 + 1.496X$ ($r = 0.969$) with total length and scale radius measured in inches.

Annulus Formation

Time of annulus formation was determined by comparison of 1968 and 1969 scales taken at time of tagging, with scales taken at recapture from the same fish that had over-wintered since tagging. In most bass, the new annulus was formed by May.

Back-calculated growth of largemouth bass for Oklahoma reservoirs has been validated in several studies, including the report by Jenkins and Hall (1953). Annuli on scales of bass in Louisiana were observed to correspond well to known age bass (Muncy, 1965). Prather (1966) observed that 83.8% of annuli on bass scales in Alabama corresponded to known age of the fish. Caldwell, Odum, Hellier and Berry (1955) observed annuli formed in winter on Florida bass, even without a change in water temperature. They attributed this to a change in photo-period.

Comparative Growth History

The weighted mean total length in the first year of life (140 mm) for bass in Lake Carl Blackwell (Table 1) was equal to the Oklahoma average (Table 3). It was greater than that calculated for age I bass in some Oklahoma waters (Jenkins and Hall, 1953; Jenkins, 1949; Jenkins, Leonard and Hall, 1952; and Finnell, 1954) (Table 4), but less than the average total length of age I bass in Grand Lake, Lake Eucha and Spavinaw Lake, Oklahoma (Thompson, 1950; Jackson, 1965) (Table 2). Compared with bass growth outside Oklahoma, first year growth of Lake Carl Blackwell bass was less than that calculated for 1 year olds in Bull Shoals Reservoir, Missouri (Hanson, 1962); Norris Reservoir in Tennessee; Louisiana waters; and Sutherland Reservoir, California (Calhoun, 1966; Munch, 1965) (Table 2). First year growth of bass in Lake Carl Blackwell was greater than median age 1 bass for 31 citations from the U. S., largely because of slow growth for entries from the northern tier, Great Lakes and New England States (Tables 2 and 3).

The weighted mean total length at the end of second and third years for bass in Lake Carl Blackwell was 279 and 369 mm, respectively. This is greater than reported in most other waters (Table 2), except in Lake Eucha and Spavinaw Lake, Oklahoma (Jackson, 1965); Norris Reservoir, Tennessee and Sutherland Reservoir, California (Calhoun, 1966), and second and third year growth of bass in Lake Carl Blackwell was considerably greater than the U.S. median. Weighted mean total length at the end of the fourth year of life in Lake Carl Blackwell was 425 mm which is greater than growth of bass in all waters recorded but Sutherland Reservoir, California (Calhoun, 1966). The 462 mm weighted mean total length for age V bass in Lake Carl Blackwell was less than those reported for Grand Lake, Oklahoma (Thompson, 1950); Lake Lake Eucha and Spavinaw Lake, Oklahoma (Jackson, 1965); and Sutherland Reservoir, California (Calhoun, 1966). The 485 mm length for age VI bass in Lake Carl Blackwell was less than those reported for Illinois River, Oklahoma (Jenkins, Leonard and Hall, 1952); Grand Lake, Oklahoma (Thompson, 1950); Lake Eucha and Spavinaw Lake, Oklahoma (Jackson, 1965); Norris Reservoir, Tennessee (Calhoun, 1966); and Louisiana (Muncy, 1965). Weighted mean total length of age VI bass in Lake Carl Blackwell was 504 mm which is less than those reported for Claremore Lake. Oklahoma (Jenkins, Leonard and Hall, 1952); Lake Eucha and Spavinaw Lake, Oklahoma (Jackson, 1965) and Norris Reservoir, Tennessee (Calhoun, 1966).

Relationship Between Growth and Water Level

A lee's phenomenon in back-calculated growth histories gives slower growths in the first years of life when calculated from older fish; however, a reverse Lee's phenomenon was observed, in which growth in the first year was faster in back-calculations from progressively older fish.

Correlation coefficients of growth increments in the first, second, third and fourth year of life and mean annual lake level between the years 1962 to 1967 were calculated (Table 4). The correlation between growth increments and lake level in the first year of life was 0.85 which was significant at the 3.5% level ($P<0.035$). The regression for the relationship between first year growth (Y1) and lake level (X) was $Y1 = -2118 + 9.9X$ (Figure 1). In the second year, the correlation coefficient was strongly negative ($r = -0.95$) and also highly significant ($P<0.004$). The regression equation for the second year of life was $Y2 = 1341 - 4.2X$ (Figure 2). The correlation coefficients for the relationship between growth in the third and fourth years of life were non-significant ($P>0.05$) although the coefficients (0.50 and 0.83, respectively) were related and could become significant with additional years (i.e., giving more degrees of freedom). The significant correlations were obtained for years 1962-1967 when lake levels declined regularly. The equations are not intended to predict growth at future lake levels. For example, low and fluctuating water levels 1968-1970 were associated with poor growth increments. They could not have been predicted from the equation for 1962-67 (Figure 1). Connecting all points of first year growth in Figure 1 (solid circles) produces a hyperbolic curve where optimum growth is at a lake level ca. 286 m, m.s.l.

Changes in water levels effect reservoir fish and fish foods. Lowering of water levels adversly effect the year-class strength of certain fishes by destroying spawning sites and subjecting young fishes to increased predation (Shields, 1957; Pierce, Frey and Yawn, 1965; Riel, 1965; Heman, Campbell and Redmond, 1969; Bennett, Wickliffe and Childers, 1969). Also, it is generally assumed that an increase in vulnerability and intensification of predation provides the basis for thinning over-abundant centrarchid populations by lake drawdown.

Table 1. Mean calculated total length (mm) at end of each year of life and mean annual growth increment oflargemouth bass in Lake Carl Blackwell, 1961-1970.

Year Class	Avg. Ann. water level[b]	I T.L.	I Inc.	II T.L.	II Inc.	III T.L.	III Inc.	IV T.L.	IV Inc.	V T.L.	V Inc.	VI T.L.	VI Inc.	VII T.L.	VII Inc.	VIII T.L.	VIII Inc.
		Total length (T.L.) and growth increments (Inc.) for each year of life[a]															
1970	284.4	118 (9)	118														
1969	284.0	114 (16)	114	218 (16)	104												
1968	284.1	128 (114)	128	239 (12)	120	320 (12)	81										
1967	283.9	129 (488)	129	268 (221)	138	262 (2)	54	304 (2)	42								
1966	284.6	149 (120)	149	286 (120)	137	368 (52)	78										
1965	285.6	153 (166)	153	289 (166)	137	374 (166)	85	425 (102)	51	467 (1)	65	494 (1)	27				
1964	286.1	160 (149)	160	286 (149)	127	368 (149)	82	428 (149)	59	460 (95)	36	493 (1)	19	513 (1)	20		
1963	287.0	152 (82)	152	281 (82)	129	368 (82)	87	424 (82)	56	465 (82)	41	484 (47)	20	497 (1)	53		
1962	287.6	168 (20)	168	294 (20)	125	376 (20)	82	430 (20)	54	466 (20)	36	490 (20)	24	508 (10)	21		
1961	287.8	145 (2)	145	267 (2)	122	329 (2)	62	375 (2)	46	420 (2)	45	455 (7)	35	481 (2)	26		
Weighted means lengths		140		279		369		425		462		485		504		531	
Total No.		1166		788		485		357		200		71		14		1	
Mean annual increments			140		139		90		57		37		23		19		27
Annual % mortality[c]			32.4		38.4		34.1		44.0		62.5		80.3		92.9		

[a] Number in ( ) = number in group
[b] mean sea level in meters
[c] average annual mortality was 54.3% and i = .80.

Table 2. Calculated total length in millimeters of largemouth bass at each annulus in different areas of the United States[a]

Authors	Location	Age (Years) I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII
Jenkins & Hall, 1953	Oklahoma average	139	246	317	378	434	472	505	531	574				
Jenkins, 1949	Oklahoma	114	216	323	378	442	467	505						
Jenkins, Leonard & Hall, 1952	Oklahoma	117	198	264	333	401	503							
Jenkins, Leonard & Hall, 1952	Oklahoma	94	198	264	335	378	472	526						
Jenkins, Leonard & Hall, 1952	Oklahoma	127	203	282	315	355	381	406	424					
Jenkins, Leonard & Hall, 1952	Oklahoma	-	201	351	391	455	498							
Thompson, 1950	Oklahoma	160	269	358	411	467	498							
Jackson, 1965	Oklahoma	163	302	386	424	480	508	546	574					
Jackson, 1965	Oklahoma	155	295	355	416	495	528	544	561	574				
Finnell, 1954	Oklahoma	124	193	282	351	404								
Applegate, Mullan & Morais, 1966	Missouri	152	211											
Hanson, 1962	Missouri	165	282	361	388	409	426	439	449					
Stroud, 1959	Tennessee	142	259	328	328	363	386							
Calhoun, 1966	Tennessee	175	309	373	409	444	490	528						
Schoffman, 1962	Tennessee	-	239	278	309	340	367	397	463	475	508	536	-	565
Muncy, 1965	Louisiana	208	264	292	355	388	498							
Calhoun, 1966	California	170	299	376	479	477								
Calhoun, 1966	California	107	206	295	261	449	462	469						
Tharratt, 1966	California	147	274	338	381	416	447							
Brown & Logan, 1960	Montana	48	96	145	195	201	292	328	351	373	351			
Thompson, 1964	Iowa	104	242	327	376	405	431	453	480	469				
Calhoun, 1966	Minnesota	89	170	236	292	333	383	414	447	459				
Calhoun, 1966	Minnesota	94	178	266	317	371	414	444	455	511				
Calhoun, 1966	Wisconsin	86	168	231	282	317	353	396						
Threinen & Mraz, 1954	Wisconsin	91	168	231	277	302	335	404	457	-	-	-	549	
Mraz & Threinen, 1955	Wisconsin	91	170	228	272	304	345	411	452	467	477	498	521	511
Bennett, 1937	Wisconsin	71	165	246	297	335	353	386	424	449	469	490	485	490
Bennett, 1937	Wisconsin	94	221	302	343	378	411	439	464	485	500	490	508	
Lagler & DeRoth, 1952	Michigan	84	162	239	295	294	330	356	378	442				
Calhoun, 1966	Michigan	-	168	241	297	333	366	391	419	455	457	477		
Calhoun, 1966	Ohio	89	178	249	297	356	391	416	457					
Calhoun, 1966	Connecticut	129	211	272	328	373	411	444						
Calhoun, 1966	Massachusetts	102	233	325	381	416	444	467	477	439				
Grice, 1959	Massachusetts	94	152	206	351									

[a] Fork Length measurements were converted to total length by: TL = 1.04 F.L.

Table 3. Comparative growth history of largemouth bass in present study, median growth for U.S. literature (Table 2), and average growth for Oklahoma.

	1	2	3	4	5	6	7	8
U. S. Literature								
No. citations	31	34	33	33	32	30	24	18
Range	48-208	96-309	145-386	195-479	201-495	292-528	328-546	351-574
Median	114	211	282	335	378	426	439	452
Annual increment[a]	114	97	71	53	43	48	13	13
Oklahoma[b]								
Average	140	246	317	378	434	472	505	531
Increment[a]	140	106	71	61	56	34	33	26
Present study								
Mean	140	279	369	425	462	485	504	531
Increment[c]	140	139	90	57	37	23	19	21

[a]Increment calculated as difference in median total length at each year of life.
[b]The Oklahoma average was from Jenkins and Hall, 1953.
[c]Increments are weighted means of the difference between total lengths for each year of life separately for each year class.

Table 4. Relationship between growth increments for largemouth bass and average annual lake level, 1962-1967, when water levels were declining.

Year	Avg. Ann. water level	Growth increments in total length (mm) for year shown I	II	III	IV
1967	283.9	129	137	85	59
1966	284.6	149	137	82	56
1965	285.6	153	127	87	54
1964	286.1	160	129	82	46
1963	287.0	152	125	62	-
1962	287.6	168	122	-	-
Correlation coefficient		0.85	-0.95	-0.71	-0.91
Coefficient of determination (%)		72	90	50	83
Degrees freedom		4	4	3	2
Probability of r		P<0.035	P<0.004	P<0.183	

There have been few actual attempts to relate water level fluctuations to fish growth. Stroud (1948) noted that there appeared to be a strong correlation between growth of basses and black crappie and the long term cycle of maximum water levels in spring and early summer months in Norris Reservoir. Stroud believed that these long term fluctuations in water level were beneficial to the fish population as a whole, as it appears to result in periodic increases in the food supply. Al Rawi (1971) attempted to relate growth of gizzard shad and white crappie to fluctuations in water level of Lake Keystone, Oklahoma, but lacked sufficient years of growth data to demonstrate a definite relationship. An eight foot drop in the water level of Lake Spavinaw, Oklahoma, from 1951 through 1953 had the effect of retarding the growth of white crappie to a marked degree (Jackson, 1957). The 1951 year-class of crappie lagged a full year's growth behind the average rate of growth during a ten-year period from 1944 to 1954. Keeton (1963) found a significant negative correlation between water level and growth of age I river carpsucker in the Des Moines River. In Lake Carl Blackwell, a definite decrease in growth of age I channel catfish from 1961 to 1967 was noted by Jearld (1970). This reverse Lee's phenomenon observed in back-calculated lengths was presumed to have resulted from poor growth due to the receding water level. Mauck's (1971) calculated growth of age I carp was not observed to decrease with lake level in Lake Carl Blackwell. There was, however, an increase in growth of young-of-the-year carp in 1968 which was presumably related to an enhanced food supply due to a spring rise in water level which flooded terrestrial vegetation.

Hypothesizing on the observed relationships between declining first year growth of largemouth bass in Lake Carl Blackwell during a six-year decline in lake level, it seems that a reduction would occur in littoral zone invertebrate fauna which would adversely affect the growth of young-of-the-year largemouth bass since they would be expected to be mainly invertebrate feeders during their first summer of life. In 1967, a 68% reduction in lake volume could have increased the vulnerability of forage fish to predation by the age I and older bass.

Bass > 178 mm in Lake Carl Blackwell are known to be mainly piscivorous (Zweiacker, 1971) as with larger bass elsewhere. The growth of a predatory fish like bass should be enhanced by reduced lake levels, thus, accounting for the better than average bass growth in Lake Carl Blackwell in the second and third years.

Annual Mortality Rates

Assuming recruitment remains constant from year to year, frequency of occurrence of year classes for the combined 1968, 1969 and 1970 collections were used as a catch curve to estimate annual mortality rates between ages I and VIII (Table 1). Annual mortality increased between ages IV through VIII compared with mortality between ages I and IV. This increased total mortality of older fish appears related to increased fishing mortality for largemouth bass in Lake Carl Blackwell when bass exceed 424 mm total length. A few largemouth bass in Lake Carl Blackwell spawn at beginning of their third summer (age II fish), but most do not spawn until the commencement of their fourth summer (age III fish) when they are about 369 mm in total length. Fishing mortality appears to be most effective when largemouth bass were spawning because in Lake Carl Blackwell bass are highly concentrated in windprotected coves during this time, making the adult bass highly vulnerable to fishing pressure as suggested by the sharp increase in annual mortality rate for bass older than age III.

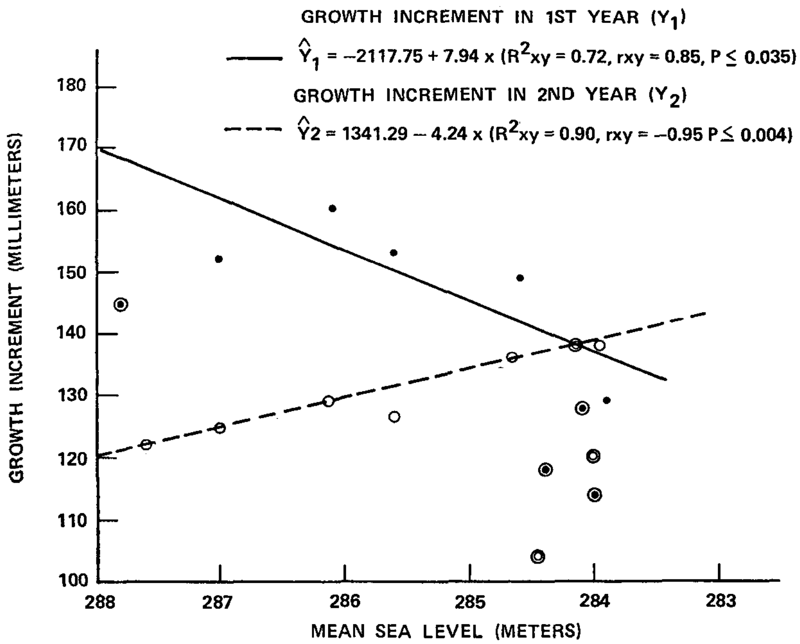

Figure 1. Relationship between first and second year growth of largemouth bass and lake level of Lake Carl Blackwell 1962-1967. Data points (open circles and solid) with surrounding circles represent years (1961, and 1968-1970- not included in the regressions.

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