LENGTH-WEIGHT RELATIONSHIPS, AGE COMPOSITION, GROWTH, AND CONDITION FACTORS OF CARP IN LAKE CARL BLACKWELL

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This report presents length-weight relationships, age composition, and condition factors for carp in Lake Carl Blackwell, Oklahoma. The study is based upon examinations of a total of 619 carp collected, chiefly by electrofishing, in 12 monthly samples from December, 1967 through November, 1968.

Carp (*Cyprinus carpio* Linnaeus) are ubiquitous in the lower mainstream of most major U.S. rivers and occur in all large mainstream impoundments in Oklahoma (1-4). Carp generally comprise a sizeable percentage of the standing crop of fishes in Oklahoma reservoirs. Additional knowledge of the biology of carp is needed to assess their role in the function of these ecosystems. The objective of this report is to describe aspects of growth and condition of carp in Lake Carl Blackwell.

LAKE CARL BLACKWELL

Lake Carl Blackwell is a turbid, shallow reservoir located in north-central Oklahoma, approximately 9 miles west of Stillwater on State Highway 51C. The dam is situated in Section 3, Township 19 N, Range 1 W in Payne County. The majority of the lake lies within Payne County but a small finger extends northward into Noble County. The reservoir was formed in 1937 by damming Stillwater Creek, thus providing a water supply and a recreational area for the City of Stillwater. The reservoir first reached spillway level in 1945. The maximum surface area at spillway level is 1,486 hectares, the volume 79.9 million m^3 (5).

Due to below average rainfall from 1961 through 1967, the water level of the lake receded approximately 4 meters below the spillway level at which time the surface area was 856 hectares and the volume was 33.9 million m^3. Growth of young-of-the-year channel catfish showed a progressive decline between 1962 and 1968, when rainfall was below average (6). In the seven dry years, succession of terrestrial vegetation advanced down former beaches behind the receding water level. In the spring of 1968, the lake level rose about 1.6 meters which caused flooding of the terrestrial vegetation on the perimeter of the lake.

The main body of water in Lake Carl Blackwell lies in an east-west direction, with the deepest section being in the old stream channel near the dam and the shallowest section occurring in the west end of the lake. The north shore of the lake has gradual sloping contours forming many shallow mud flats, while the south shore has numerous rocky outcroppings and fewer mud flats. The basin of the lake is quite level except in the former channel of Stillwater Creek and its tributaries.

The low, unprotected landscape of the watershed surrounding the lake and the relatively shallow water depth permit the winds to promote vertical circulation. The intensity of the circulation varies with density differences in the water column and variations in direction and intensity of the wind. The water mass stratifies for short intervals in June, July and August, when high ambient temperature and diminished winds allow this. The wind-driven circulation, which is so prevalent, causes high turbidity, uniform vertical temperatures, and uniform dissolved oxygen levels (5).

The majority of fish in this study were collected by electrofishing in the shallow, wind-protected arms that lie to the north or south of the main east-west axis of the lake.

[1] Cooperators are the Oklahoma Department of Wildlife Conservation, Oklahoma State University Research Foundation, and the Bureau of Sport Fisheries and Wildlife.

The water of these areas usually ranged in depth from 1 to 2 meters.

METHODS

Age and growth

Age and back-calculation of growth were made from scales of 262 carp collected by all methods and during all months of the study. The total length in millimeters and the weight in grams were recorded for each fish.

A plastic impression of at least three scales per fish was made with a roller press. The age determinations of the scales were made on a scale projector using a 72 mm microtessar lens which gave a total magnification of 17X.

Fish collections

A total of 619 carp were collected in 12 monthly samples from December 1967 through November 1968. Electrofishing accounted for 89%, rotenone cove samples 6%, and gill netting 4% of the total collection. The remaining 1% were collected by trap nets, wire traps and barrel traps.

RESULTS

Length—weight relationships

Length-weight relationships were calculated for all carp collected. The relationship was first determined separately for male and female carp, but when an analysis of covariance indicated no apparent differences in the length-weight regression coefficients and adjusted means for either sex, the data for both sexes were pooled.

The length-weight relationships were derived by using the formula: $W=cL^n$, where W = weight in grams; L = length in millimeters; and c and n are constants. Following the conversion of lengths and weights to logarithmic form, the linear relationship was found to be: $\text{Log } W = -10.5355 + 2.8638 \text{ Log } L$, where $W = .00002658\ L^{2.8638}$. The slope of the regression line (2.8638) was less than 3.0, indicating that carp in Lake Carl Blackwell tend to become less robust with growth. Carlander (7) also reported that the regression slopes were usually less than 3.0 for carp populations sampled in Iowa, Oklahoma, and Utah.

Coefficient of condition

Coefficients of condition (ponderal index or condition factor) expressing the relative plumpness or degree of well-being of the carp were computed using the formula: $K\ (TL) = \frac{W\,10^5}{L^3}$, where W = weight in grams, and L = total length in millimeters. Seasonal changes in coefficients of condition of 210 males and 279 females were calculated, separately and combined, for all months, except February when no males were collected (Table 1). Males and fe-

TABLE 1. *Seasonal changes in coefficients of condition (K_{TL}) with 95% confidence intervals for carp from Lake Carl Blackwell.**

Month	Year	Male	Female	Combined
Dec	1967	1.13 ± (1)	1.19 ± 0.10 (8)	
Jan	1968	1.23 ± 0.07 (7)	1.12 (2)	1.20 ± 0.06 (9)
Feb	1968		1.23 ± 0.11 (7)	1.23 ± 0.11 (7)
Mar	1968	1.13 ± 0.06 (19)	1.14 ± 0.06 (17)	1.13 ± 0.04 (36)
Apr	1968	1.22 ± 0.08 (9)	1.19 ± 0.10 (12)	1.20 ± 0.06 (21)
May	1968	1.13 ± 0.07 (23)	1.09 ± 0.11 (16)	1.18 ± 0.07 (39)
Jun	1968	1.26 ± 0.06 (19)	1.22 ± 0.06 (39)	1.23 ± 0.04 (58)
Jul	1968	1.21 ± 0.04 (60)	1.24 ± 0.04 (73)	1.23 ± 0.04 (133)
Aug	1968	1.23 ± 0.03 (47)	1.24 ± 0.05 (68)	1.24 ± 0.04 (115)
Sep	1968	1.19 ± 0.08 (15)	1.27 ± 0.29 (14)	1.23 ± 0.14 (29)
Oct	1968	1.16 ± 0.14 (6)	1.19 ± 0.07 (16)	1.18 ± 0.06 (22)
Nov	1968	1.10 ± 0.15 (4)	1.18 ± 0.11 (7)	1.15 ± 0.07 (11)

*Number of specimens in parentheses

males were combined since there was no significant difference in their length-weight regression coefficients.

The average K values, with 95% confidence intervals, for males ranged between 1.10±0.15 in November to 1.26±0.06 in June. The average K for all months combined for males was 1.20 as compared to 1.21 for females. The ponderal index values for males fluctuated from December through August, but declined in the fall months. The average K values for females ranged between 1.09±.11 in May to 1.27±0.29 in September. Spawning occurred in April and May, but K values did not increase conspicuously in pre-spawning fish. The low K value for females in May might have been the result of a large percentage of spawned fish in the May samples.

The average K values of all (619) carp sampled (even though the sex was not known) were calculated using 20 mm size classes (Table 2). The K values generally increased to the 200 mm size class and then declined with an increase in length. However, the correlation coefficient, r=.39, between the K values and average length for size groups 200 through 616 mm (when K values decline with size) was not significant at the 5% level. A decrease in ponderal index values with increase in length was also noted by Frey (8) in Wisconsin lakes;

TABLE 2. *Variation of cofficients of condition (KTL) and 95% confidence intervals for carp from Lake Carl Blackwell within 20 mm size classes.*

20 mm Size classes	Number fish	K_{TL}	95% C.I.	Average length (mm)	Average weight (g)
70- 89	3	1.24	0.47	81	07
90-109	8	1.23	0.14	97	11
110-129	14	1.37	0.09	119	23
130-149	13	1.35	0.06	137	34
150-169	7	1.17	0.22	155	43
170-189	6	1.42	0.34	178	78
190-209	6	1.48	0.31	200	117
210-229	9	1.41	0.06	221	151
230-249	10	1.26	0.10	237	166
250-269	30	1.32	0.06	256	221
270-289	30	1.33	0.13	278	277
290-309	19	1.28	0.11	298	333
310-329	11	1.28	0.22	318	403
330-349	44	1.22	0.05	340	479
350-369	70	1.26	0.03	361	588
370-389	101	1.21	0.02	379	654
390-409	80	1.16	0.03	398	729
410-429	48	1.17	0.03	418	856
430-449	28	1.15	0.06	438	957
450-469	24	1.12	0.04	457	1068
470-489	10	1.06	0.12	477	1121
490-509	15	1.07	0.06	500	1337
510-529	11	1.07	0.06	518	1468
530-549	5	1.03	0.21	539	1593
550-569	4	1.03	0.07	561	1821
570-589	2	1.04		575	1970
590-609	—	—	—	—	—
610-629	2	1.14		616	2664
Total	619	Av 1.22		Av 338	Av 465

Shields (9) in Fort Randall Reservoir, South Dakota, Sigler (10) in Utah, and Hancock (11) in Canton Reservoir, Oklahoma. No decrease occurred in condition factors with age of comparable size carp in Grand Lake, Oklahoma (12) or in most U.S. localities (7).

The overall average K value was found to be 1.22, similar to the K value of 1.23 calculated from lengths and weights of 351 carp sampled by Jenkins (12) in Grand Lake, Oklahoma. However, the K values of carp in Lake Carl Blackwell (Table 2) were below average compared with K values reported for carp from other U. S. lakes or reservoirs as tabulated by Carlander (7).

Body-scale relationship

The body-scale relationship was determined from 262 carp ranging in length from 70 mm to 616 mm. Both linear and curvilinear regressions were computed to determine the best model describing this relationship. The mean total length and mean scale radius was calculated for successive 20 mm length intervals of all fish beginning with 70 mm (Table 3).

The linear regression for Lake Carl Blackwell carp was found to be $L = -8.484 + 2.478X$, where L = total length in millimeters and X = scale radius in millimeters times 17. The correlation coefficient of the body length-scale radius relationship was .97. The calculated F value used to test linearity was 3552.6 (with 1 and 261 degrees of freedom) where $F_{.005}$ is 7.88 (13). The reduction in variance due to curvilinearity was tested using an analysis of variance. The calculated F value was 2.05 (with 1 and 260 degrees of freedom) where $F_{.10}$ is 2.71. Therefore, the linear model was used for back-calculations in this study.

Age and growth

Total length at time of annulus formation was back-calculated from the scales of 215 carp from Lake Carl Blackwell collected January through November 1968 (Table 4). The maximum scale radius was obtained by measuring the distance from the focus to the anterior-lateral margin. The following formula was used in back-calculating size at each scale annulus: $L \; + a \frac{S_i}{S} (L\text{-}a)$, where L = total length at capture; L_i = estimated length of fish at time of formation of annulus i; S = scale radius; S_i = scale radius to each annulus; and a = hypothetical length of the fish before the appearance of its scales, estimated from the intercept value of the linear body-scale regression, according to the Lee method as cited by Chugunova (14). A mean calculated total length for each age group and year class (for males, females, and both sexes combined) was

TABLE 3. *Mean total length (mm) and mean scale radii (mm) (X17) calculated for 262 carp, grouped in 20 mm size intervals, from Lake Carl Blackwell.*

Number fish	Total length (mm)	Scale radius (mm)	Number fish	Total length (mm)	Scale radius (mm)
3	81.3	36.7	26	361.5	148.5
8	96.9	41.6	35	378.5	153.7
13	119.4	53.2	26	397.8	161.8
12	136.8	61.7	15	420.5	167.1
7	155.3	64.4	11	439.5	179.0
3	178.3	72.7	11	456.8	186.8
3	200.3	91.3	9	480.9	180.1
7	222.1	103.0	8	501.1	201.1
4	238.8	115.5	4	521.8	211.0
14	255.4	119.1	1	536.0	216.0
6	281.0	129.7	2	564.0	236.0
4	298.8	133.5	2	575.0	242.5
7	319.0	135.6	2	615.5	237.0
19	338.9	143.1			

omputed as well as an unweighted mean otal length for all age groups for these fish. ecause differences between the mean annual growth increments for males and females were small, a combined average growth for both sexes (Table 4) was used in the following discussion.

Ricker (15) noted that few investigators have calculated the variance associated with length of the fish being studied. The corresponding variances of these calculated lengths were also computed (Table 5).

Often lengths of the fish in a year-class vary less when back-calculated from older as opposed to younger fish. This reduction in variability apparently results from selective mortality. Reduction in variation of lengths back-calculated from older year-class fish was observed for carp (Table 5).

Length increased at each successive annulus (Table 4) indicating indefinite growth, albeit at a progressively slower rate. The calculated annual growth increment in the first summer was faster than all other

TABLE 4. *Mean calculated total length (mm) with 95% confidence intervals of carp (males and females combined) from Lake Carl Blackwell.*

Year class	Age group	Number fish	Size at annulus 1	2	3	4	5	6	7	8	9	10	11
1967	I	29	105 ±12										
1966	II	14	96 ±23	186 ±40									
1965	III	37	128 ±11	225 ±12	325 ±13								
1964	IV	73	118 ± 6	210 ± 7	290 ± 8	366 ± 9							
1963	V	25	106 ± 8	194 ±10	275 ±10	349 ±11	417 ±40						
1962	VI	20	106 ±10	198 ±15	269 ±14	335 ±17	402 ±19	441 ±19					
1961	VII	8	115 ±17	192 ±23	263 ±26	320 ±20	394 ±30	443 ±37	482 ±45				
1960	VIII	7	102 ± 8	180 ±23	252 ±17	329 ±26	386 ±31	440 ±38	480 ±40	519 ±50			
1959	IX	1	101	149	206	323	394	467	512	528	547		
1958	X	0	—	—	—	—	—	—	—	—	—		
1957	XI	1	100	184	248	276	343	403	440	464	491	517	577
Unweighted mean			108	191	266	328	389	439	479	504	519	517	577
Mean annual increment			108	83	75	62	61	50	40	25	15		60
Number of fish			215	186	172	135	62	37	17	9	2	1	1

TABLE 5. *Variance of calculated length (mm) of carp from Lake Carl Blackwell.*

Year class	Age group	Number fish	1	2	3	4	5	6	7	8
'67	I	29	953							
66	II	14	1606	4810						
65	III	37	1046	1289	1562					
64	IV	73	601	891	1195	1616				
63	V	25	381	590	583	754	9499			
62	VI	20	463	1080	946	1361	1655	1724		
61	VII	8	397	752	1012	582	1279	1995	2884	
60	VIII	7	70	593	330	785	1140	1705	1888	2975

annual increments (Table 4). Faster growth in the first year of life was also observed in other Oklahoma waters: Linton (4) in the Arkansas River; Buck and Cross (2) in Canton Lake; Houser (16) in Lake Lawtonka. Carlander (7) also notes this phenomenon in other areas in the country. English (17), however, stated that carp in Clear Lake, Iowa grew most rapidly in the second summer. The average length of young-of-the-year carp (Table 4) in the 1965 year class was greater than that of carp in other years. The 1965 year class maintained this comparative advantage as 2-and 3-year olds compared with growth rates of fish of the same age from other year classes.

Jearld (6) reported a decrease in back-calculated length at age 1 year for channel catfish in Lake Carl Blackwell from 1961-1967. This reversed Lee's phenomenon was apparently caused by receeding water levels. Johnson (18) stated that extremely low water levels retarded the growth of crappie in Greenwood Lake, Indiana. The prolonged drought in the Lake Carl Blackwell watershed had little noticeable retarding effects on the growth of age I carp from 1961-1967 (Table 4). However, total lengths of young-of-the-year in September and October 1968 ranged from 144 to 156 mm which was 34 to 48 mm greater than the mean lengths of carp during the first year of life in the years from 1961 to 1967. Either spawning or survival of carp was apparently reduced in 1966 as judged by a conspicuous scarcity of that age group (Table 4). Yearling carp were more numerous in the summer of 1969 than 1968, suggesting that a strong year-class resulted from the 1.6 meter increase in average water level in 1968.

The size of carp from Lake Carl Blackwell is generally smaller than that of carp of the same age from other bodies of water (Table 6). This is especially true of the first 2-year

TABLE 6. *Comparisons of size at age (total length in millimeters) of carp from various localities.**

Locality and reference	Average calculated total length (mm) at each annulus												
	1	2	3	4	5	6	7	8	9	10	11	12	13
Lake Carl Blackwell, Okla. Present study	108	191	266	328	389	439	479	504	519	517			
Grand Lake, Okla. Thompson, 1950	172	254	315	391	432	528							
Grand Lake, Okla. Jenkins, 1953	203	350	439	508	559	607	653	716					
Rock Creek Drainage, Okla. Sandoz, 1960	172	353	518	635	691	716	724	721					
Arkansas River, Okla. Linton, 1961	51	142	211	279	338	381	410	452	467	482	531	553	678
Ogden Bay, Utah Sigler, 1958	127	231	360	457	518	599	609						
Bear Lake, Utah Sigler, 1958	131	200	246	302	350	371	399	421	457	472			
Spirit Lake, Iowa Youn, 1962	122	195	264	310	355	388	429	470	551	599			
Clear Lake, Iowa Effendie, 1968	228	327	411	490	589	683	726						
Des Moines River, Iowa Rehder, 1959	201	361	498	537	573	581	565	582					

*All values were given in inches and converted to millimeters from Conversion Tables, Lagler (1956) except values listed for Lake Carl Blackwell, Oklahoma and Clear Lake, Iowa.

classes. The calculated total length for Lake Carl Blackwell carp at annulus 1 was 108 mm and 191 at annulus 2. The growth rate of carp in this study is much less than reported by Thompson (19) and Jenkins (12) for Grand Lake, Oklahoma. We believe that the poor growth of carp is related to a low density of benthic invertebrates (283 organisms/M^2 and only 2.0 grams wet wt./M^2 in this reservoir (5) compared with other reservoirs in this region (20). It is presumed that the sparse benthos in Lake Carl Blackwell results from low transparency and the unstable substrate caused by strong, wind-induced, vertical currents.

SUMMARY

A total of 619 carp were collected during the sampling period from December, 1967 through November, 1968. The majority of the fish were collected by electrofishing which was effective in capturing carp along the shoreline of the lake when the water temperature was above 8 C. Electrofishing was not effective during winter months because carp moved into deeper waters during this time.

An analysis of covariance indicated no apparent differences in the length-weight regression coefficients and adjusted means for either sex. The linear relationship was found to be: Log W = $-10.5355 + 2.8638$ Log L, where W = $.00002658\ L^{2.8638}$. The slope of the regression line was less than 3.0 indicating that carp in Lake Carl Blackwell usually became less robust with increased body length.

The coefficients of condition were calculated according to sex, month and size. No apparent difference in condition existed between males and females. Monthly variations in condition of carp showed no definite seasonal trends. The average K values for all months combined for males was 1.20 as compared to 1.21 for females. The condition factor increased in small carp until the 200 mm size class and then declined with an increase in length. The average K value for 619 fish was calculated to be 1.22.

The body-scale relationship was determined from 262 carp ranging in length from 0 mm to 616 mm. The linear regression was found to be: L = $-8.484 + 2.478X$, with a correlation coefficient (r) of .97.

The total length at time of annulus formation was back-calculated from the scales of 215 carp collected during January through November, 1968. A mean calculated total length for each group and year class (for males, females, and combined sexes) was computed as well as an unweighted mean total length for all age groups.

No apparent difference in growth was observed between males and females. The calculated growth rates show that carp grew most rapidly during their first summer of growth. A gradual reduction in mean annual growth increment occurred with an increase in age. Age groups III, IV and V comprised 62.8% of the total number of fish in the sample. Young-of-the-year and yearling fish (age group I) were poorly sampled with the electrofishing gear.

An Oklahoma average growth rate was not available for comparison, but carp in Lake Carl Blackwell grew slower than in other Oklahoma impoundments for which data were available.

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