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POPULATION DYNAMICS AND CATCH SUSCEPTIBILITY OF SMALLMOUTH BUFFALO IN ROUGH RIVER RESERVOIR

Department of Fish and Wildlife Resources

Arnold L. Mitchell, Commissioner

POPULATION DYNAMICS AND CATCH SUSCEPTIBILITY OF SMALLMOUTH BUFFALO IN ROUGH RIVER RESERVOIR

By

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ABSTRACT

The population dynamics of the smallmouth buffalo in Rough River Reservoir (= Lake) were studied from July 1974 through June 1976. One thousand four hundred ten smallmouth buffalo were recovered from 51 collections. The population in the lake was estimated to range from 135,000 to 194,000 fish and was considered to be an underestimate. Eleven year classes were represented with the majority in two age groups. Year classes spawned in 1969-70 dominated, comprising 70% of the population. No individuals less than 200 mm total length were taken. Growth in length was greatest during the first four years of life, while growth in weight was greatest in years V through XI. Growth in length and weight decreased from the first to second year of the study. Eighty-five percent of all specimens ranged from 400 to 550 mm TL. This group included fish from three through eight years of age. Fish spawned in 1965-67 showed greater first year's growth than did the remaining year classes. Condition was greatest in the smaller size individuals and progressively decreased in the larger, older individuals. Females were in slightly better condition than males. The buffalo appeared to be overcrowded and showed reduced growth from 400 mm TL and longer. Movements were greatest during March and April when fish congregated in headwater effluents to spawn. Flag nets were the most efficient type of tackle used while 3-inch mesh was the most efficient mesh size. The largest average size fish were taken in 4-inch mesh. Spawning occurred from mid-March through May. Males reached sexual maturity in the life cycle and annual reproductive condition earlier than females. Gonad development was bimodal, being closely correlated with water temperature and photoperiod. Larger, older females produced the greatest number and largest diameter mature ova. Reproductive development did not appear to be adversely affected by the population structure and density. Selective harvesting of three- to five-pound buffalo is recommended to restore a balanced age group structure and eliminate year class dominance.

Population Dynamics and Catch Susceptibility of Smallmouth Buffalo in Rough River Reservoir

Introduction

The recent development and implementation of fishery biology techniques as sound, logical resource management practices has been overshadowed only by the worldwide need for them. As pointed out by Huxley (1970), the world population grows by about 150,000 individuals each 24 hours, and, at the present rate, doubles itself every 35 years. Consistent with this increase in population size is the need for biological sustenance. In the past ten years, the world's harvest of fish, about 50 million tons in 1965, (Cushing, 1968), has doubled and has played no small part in relieving part of man's ever-pressing food problem. It is obvious then that mankind has and must continue to direct his attention to maximum utilization of existing fish stocks if he is to fare successfully on a worldwide basis. Consequently, the biology of all exploitable stocks must be described in depth and the most accurate management techniques developed and employed to insure maximum sustainable yields. This study reflects the continued interest of the Kentucky Department of Fish and Wildlife Resources and the National Marine Fisheries Service, United States Department of Commerce, in properly managing commercially valuable fishes and shellfish and providing for their maximal commercial utilization.

The smallmouth buffalo, Ictiobus bubalus (Rafinesque), is an important commercial reservoir species in growing to a large size (13.62 kg [30 pounds]) and producing large populations of harvestable individuals. The species ranges from the lower Hudson Bay region south through the Ohio, Missouri and Mississippi River drainages, with an isolated population occurring in central New Mexico (Moore, et al., 1957). It inhabits deep, clear waters (Trautman, 1957) and is an opportunistic benthic feeder with a diet consisting mainly of zooplankton and attached algae (McComish, 1967).

This species may function as a limiting factor on game fish populations and, according to Jester (1973), has one "redeeming" feature in contributing to the human food supply through commercial harvest. The smallmouth buffalo represents, in all probability, the most significant biomass component of the ichthyofauna of Rough River Lake. Its commercial harvest is being overlooked as a financial venture by fishermen and existing commercial fishing regulations are seemingly ineffective in managing the present population (Hoyt and Flynn, 1974).

The objectives of this study were to: 1) determine the size of the harvestable smallmouth buffalo population, record growth increments, and establish movement and distribution patterns, 2) determine the efficiency of different types of gear in harvesting smallmouth buffalo, and 3) describe the reproductive biology of the smallmouth buffalo in Rough River Lake, Kentucky.

Study Area

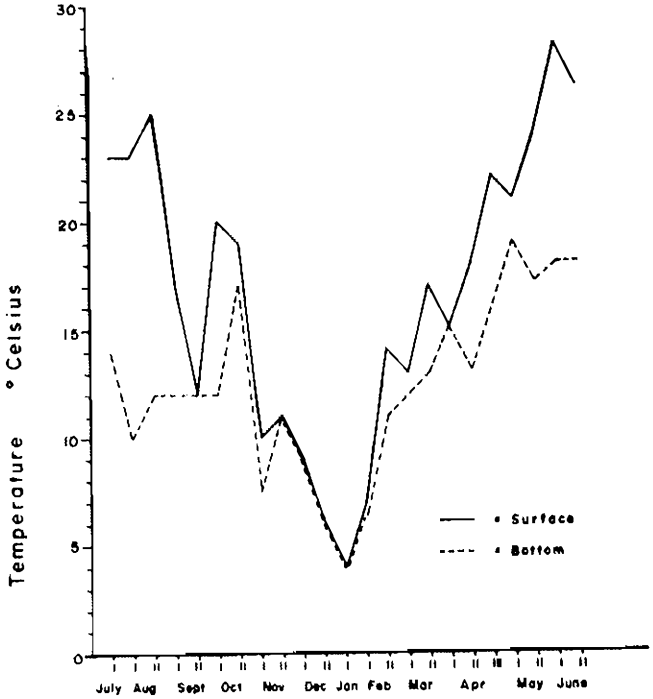
Rough River Lake is a small impoundment in the Green River watershed in west-central Kentucky. Rough River Lake was impounded in 1961 with the construction of an earthen-fill dam at River Mile 89.3. The lake impounds 39 miles of the Rough River at seasonal pool with a surface acreage of 5,100 acres and a total volume of 99,840 acre-feet of water. The lake has a drainage area of 454 square miles in Breckinridge, Grayson and Hardin Counties. The Rough River has an average gradient of 1.5 feet per mile along the floor of the impoundment (Hoyt and Flynn, 1974).

Rough River Lake and its complete drainage area is all part of the Pennyroyal physiographic region (Carter, 1968).

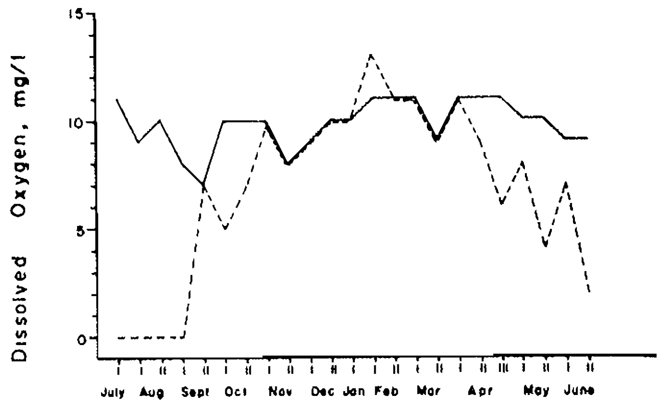
Rough River is a uniformly shallow water body and underwent mixing from November to April (Fig. 1). Surface and bottom temperatures, dissolved oxygen and pH characteristics were similar throughout this mixing. Surface water temperatures averaged 15.4 C (extremes 4 - 28) while bottom temperatures averaged slightly lower, 12.1 C (4 - 25). Dissolved oxygen concentrations averaged 10.3 ppm (7 - 13) on the surface and 7.4 ppm (0 - 13) on the bottom. pH values averaged 8.1 on the surface and 7.5 on the bottom.

Extremely high water levels were recorded from mid-February through April, 1975, reaching flood levels well above summer pool. Water levels were relatively stable for their appropriate seasonal levels during 1976.

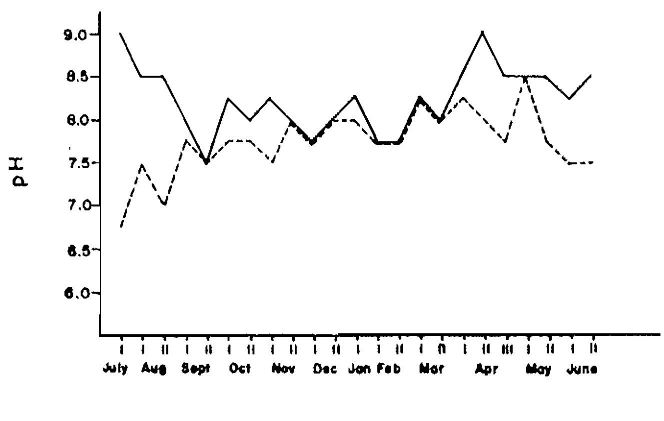
Figure 1. Monthly records of water temperature, in degrees Celsius, dissolved oxygen, in parts per million, and hydrogen ion concentration from the surface and bottom of Rough River Lake, Kentucky, July 1975 through June 1976.



Temperature °Celsius
30
25
20
15
10
5
0
— = Surface
---- = Bottom
July Aug Sept Oct Nov Dec Jan Feb Mar Apr May June



Dissolved Oxygen, mg/l
15
10
5
0
July Aug Sept Oct Nov Dec Jan Feb Mar Apr May June



pH
9.0
8.5
8.0
7.5
7.0
6.5
6.0
July Aug Sept Oct Nov Dec Jan Feb Mar Apr May June

Methods and Materials

Fifty-one collections were made at Rough River Lake from July 1974 through June 1976. Samples were normally taken semi-monthly with three collections being taken during the spawning run in April. Forty-five collections were made using netting tackle and six with emusifiable rotenone. Six collections were made in the North Fork of the lake and 45 in the South Fork. More collections were made in the South Fork due to its larger surface area and fewer sport fishermen. The study consisted of two 12-month segments, Segment One from June 1974 through June 1975, and Segment Two from July 1975 through June 1976.

Net tackle used in the first segment of the project consisted of one, 100-yard (91.44 meters) stretch of 3.0-inch (7.62 cm) mesh gill net (6.0-inch stretch mesh), one, 100-yard (91.44 m) stretch of 3.5-inch (8.9 cm) mesh gill net (7.0-inch stretch mesh), three, 100-yard (91.44 m) stretches of experimental mesh, 2.5-inch (6.35 cm), 3.0-inch (7.62 cm) and 3.5-inch (8.9 cm) flag nets, one 100-yard (91.44 m) stretch of 4.0-inch (10.2 cm) mesh flag net, one 50-yard (45.72 m) stretch of 4.0-inch (10.2 cm) mesh trammel net and two, seven-hoop 3.0-inch (7.62 cm) mesh hoop nets with a 30-yard (27.43 m) wing net of 1.0-inch (2.54 cm) mesh. Gill nets used were eight foot in depth (2.44 m) and were not "hobbled", that is the float and lead lines were not tied together allowing for freedom of movement in the meshing. Experimental flag nets included three 100-foot (30.5 m) units of eight foot (2.44 m) drop 2.5-, 3.0- and 3.5-inch mesh netting tied together so as to provide every possible combination of mesh placement, i.e., 2.5"-3.0"-3.5"; 2.5"-3.5"-3.0"; etc. Floats and weights were arbitrarily placed on the flag nets according to the method of fishing, shallow, deep, etc. Tackle during the second phase of the study was modified by the addition of a 100-yard (91.44 m), 4.0-inch (10.2 cm) gill net and a 100-yard (91.44 m) stretch of 4.0-inch (10.2 cm) trammel net. Also, all gill nets and the 100-yard trammel net were hobbled as described earlier.

All lineal netting was tied along the bank and fished perpendicular to the river channel. Hoop nets were unbaited and fished in submerged creek channels and along the river flood plains. All habitats were fished.

Collecting stations were randomly selected throughout the entire lake (Appendix A). Collecting periods included two three day sampling periods per month beginning on Friday, 5 a.m. and ending Sunday at 3 p.m. Considering the time required to set and retrieve the tackle, each collecting period included approximately 48 hours of fishing time.

Total weights of all fish, buffalo and non-buffalo, were recorded in ounces on a platform spring scale and total length (TL) in millimeters (mm) on a meter measuring board. Five scales were taken from the left side between the lateral line and dorsal fin origin of 1,312 smallmouth buffalo, cleaned and stored in individual coin envelopes. During the first segment of the study, each fish taken in net tackle was placed in a tub of water immediately upon capture and weighed, measured, scale sample taken and tagged in the ventral opercular membrane across the branchi-ostegal rays with a #4, numbered monel self-piercing tag. Fish were released in shoreline areas where recovery activity could be observed. Only 3 of 800 fish taken with net tackle were dead in the nets or were observed to not recover upon release.

Toxicant studies were carried out by Kentucky Department of Fish and Wildlife personnel and were limited to cove areas. The coves sampled were sealed off with block nets to prevent inflow and outflow of fishes and were sampled according to standard fisheries procedures.

Age determinations were based upon the length frequency distribution method and scale analysis. Lengths of all fish were arranged in 10 mm increments and expressed as a percentage of all fish taken for that month. Age groups were based upon a normal distribution of individuals among each age group. Scale analysis employed the counting of growth rings on the scales. Scales were read with a binocular dissecting microscope. Annuli observed on the smallmouth buffalo scale were most obvious on the lateral fields and characterized most vividly by the "cutting over" of circuli. Annuli were counted at the margin of the lateral and anterior fields. Radius length and distances between respective annuli were measured along the left lateral anterior field margin with an ocular micrometer in a binocular microscope.

Total lengths of fish in each age group at time of annulus formation were determined by back calculation using first the corrected direct proportion method of Lee (1920), $L = a + bS$, where L = total length in millimeters, a and b are empirically derived constants and S = scale radius length, to determine the relationship between scale length and body length, and secondly, the formula $L' = \frac{(S')}{(S)} L$ (Everhart, et al., 1975), where

L' = length of the fish at annulus formation,

L = length of the fish at the time of scale sample,

S' = distance of radius to annulus on scale, and

S = distance of radius from center of scale to margin,

was used to back calculate the respective total lengths of the fish at each annulus formation.

Back calculated growths of each age group were analyzed and the mean, standard error of the mean, standard deviation and range shown graphically for each.

The relationship between growth in length and weight was established with the formulae $\log W = a + n \log L$, and $W = aL^n$, where W is total weight in grams, a and n are empirically derived constants and L = total length in millimeters.

Condition was determined by the formula $K_{TL} = \frac{W \times 10^5}{L^3}$, where K_{TL} is condition for total length in millimeters, W is total body weight in grams and L = total length in millimeters.

Water temperatures were recorded monthly at the surface and bottom with a standard Celsius thermometer. Dissolved oxygen and pH were likewise determined with a Hach Field Chemical Kit, Model AL-36-WR.

During the second segment of the study, specimens were retained monthly for reproductive analysis. The first 15 specimens taken each collecting trip and every other specimen above 15 was held for study. Specimens used for reproductive analysis were killed in 10% formalin, weighed to the nearest gram, total length recorded to the nearest millimeter, scale samples taken from the left side and the gonads excised and fixed in 10% formalin.

Spawning chronology was determined by calculating gonosomatic ratios and by recording the diameters of mature ova. The gonads of 319 males and 207 females were weighed to the nearest milligram on an electric balance and their weights converted to a percent of the total body weight. Since only mature ova are true indicators of spawning condition, they alone were measured during the spawning season, while the larger ova were measured the remainder of the year. The diameters of 20 mature ova were randomly selected from one ovary of 203 females and measured to the nearest 0.01 mm.

Fecundity was determined by counting and estimating the number of mature ova from the ovaries of 36 females taken from March through June 1976. Egg numbers were taken by actual count of 2 pair of ovaries and estimated gravimetrically for 34 pair. An average percent error of 7% was determined for the estimation method versus actual counting.

The chi-square test was applied to 526 male and female smallmouth buffalo to determine any deviation from a 1:1 sex ratio.

Results

Job I Title: Population dynamics of the smallmouth buffalo.

A total of 1,410 smallmouth buffalo were taken from Rough River Lake from July 1974 through June 1976 (758 in Segment One and 652 in Segment Two). An additional 71 specimens taken in a toxicant study June 22-24, 1976, were used to estimate total population size but were not used in any other analyses. One thousand twenty-one specimens (587 in Segment One and 534 in Segment Two) were caught in various types of net tackle and 289 (171 in Segment One and 118 in Segment Two) were taken in toxicant samples. Smallmouth buffalo taken in this study ranged from 228 mm TL, 2.86 lbs (1.3 kg), to 920 mm TL, 29.0 lbs (13.14 kg), with an average of 460 mm and 3.47 lbs (1.574 kg). The average total length increased from the first to second segment of the study, 454 mm to 467 mm, while average total weight decreased, 3.55 lbs (1.61 kg) to 3.38 lbs (1.533 kg).

Population Size - The size of the smallmouth buffalo population could not be determined on the basis of mark and recapture methods. Five hundred fifty-nine captured buffalo were tagged and released during the first segment of the project and 213 during the second segment. Only one tagged specimen (released April 10, 1975) was recaptured, a year after release (May 1, 1976). Fourteen specimens, 1.8% of all tagged releases, were recaptured during the same 3-day period in which they were initially tagged and all appeared in good health with good tag retention.

Based upon toxicant sample data from 1973 through 1976, population size ranged from a 4-year average of 134,385 fish, to a 1976 estimate of 193,800 (Table 1). The number of fish, (with the exception of 1974), and their weight increased regularly from 1973 through 1976. The estimated standing crop for the 4-year period was 360,152 lbs (163,362 kg); for 1976, 643,416 lbs (291,849 kg). The average weight for buffalo taken with toxicants (2.68 lbs, 1.22 kg) was slightly less than that of fish taken with net tackle (3.665 lbs, 1.66 kg).

Table 1. Standing crop (numbers) and biomass (weight) estimations of smallmouth buffalo in Rough River Lake, Kentucky, from 1973 through 1976, based upon toxicant population samples.

Site	1973		1974		1975		1976	
	No.	Wt. lbs. kg.	No.	Wt. lbs. kg.	No.	Wt. lbs. kg.	No.	Wt. lbs. kg.
Walter Creek 2.21 acres	74	108.43 49.22	44	69.08 31.36	113	324.8 147.5	84	278.9 126.5
North Fork 1.35 acres	34	99.21 45.04	29	91.43 41.51	43	159.45 72.39	-- --	--- ---
Cave Creek 3.17 acres	32	70.23 31.88	10	25.96 11.79	75	224.12 101.75	-- --	--- ---

	1973	1974	1975	1976
Average fish wt. lbs	1.98	2.24	3.07	3.32
kg	.90	1.02	1.39	1.51
Avg. biomass/acre lbs	41.28	27.70	105.26	126.20
kg	19.20	12.58	47.79	57.16
Estimated population				
Number	106,080	62,730	174,930	193,800
Weight lbs	210,038	140,515	537,035	643,416
kg	95,272	63,737	243,595	291,849

1973-76 Average Fish Wt. = 2.68 lbs. (1.22 kg) Avg. biomass/acre = 70.62 lbs (32.03 kg).

1973-76 Average Population Size Estimate = 134,385 fish, 360,152 lbs (163,362 kg).

Age - Age group determinations using the length-frequency distribution method were useless in aging smallmouth buffalo due to the excessive overlap between age groups (Figs. 2 & 3). Overlap in length became apparent at the end of the second year of life and completely obscured year class distinction by the end of the fourth year's growth.

Scale examinations indicated a maximum of 11 year classes represented in the study, 10 in the first segment and 11 in the second. Of 1,250 scale examinations, 760 fish, or 61%, were in Age Groups IV and V (Table 2). Two year classes dominated the population during both segments of the study. Spawn from the years 1969 and 1970, Age Groups IV and V in Segment One and V and VI in Segment Two represented 78% and 62% of the total population, respectively. However, the age group distribution differed markedly for the two study segments, being skewed toward the lower age groups in Segment One and showing almost a perfect bell shaped curve in Segment Two (Fig. 4). An interesting feature of the scale analysis was the complete absence of recruitment individuals less than 228 mm TL representing Age Groups I and II. Only three individuals having two annuli were taken in Segment One and ten in Segment Two.

Growth in Length - The body-scale relationship, L = 0.166066 + 0.020696 TL for Segment One and L = 3.69242 + 0.020918 TL for Segment Two (Fig. 5), were determined and used as the basis for back calculating body lengths using scale annuli. Since the intercept fell on the "y" axis, no correction factor was used in the formula $L' = \frac{(S')}{(S)} L$. Based upon lengths back-calculated

Figure 2. Length frequencies at monthly intervals of 758 smallmouth buffalo from Rough River Lake, Kentucky, July 1974 through June 1975.

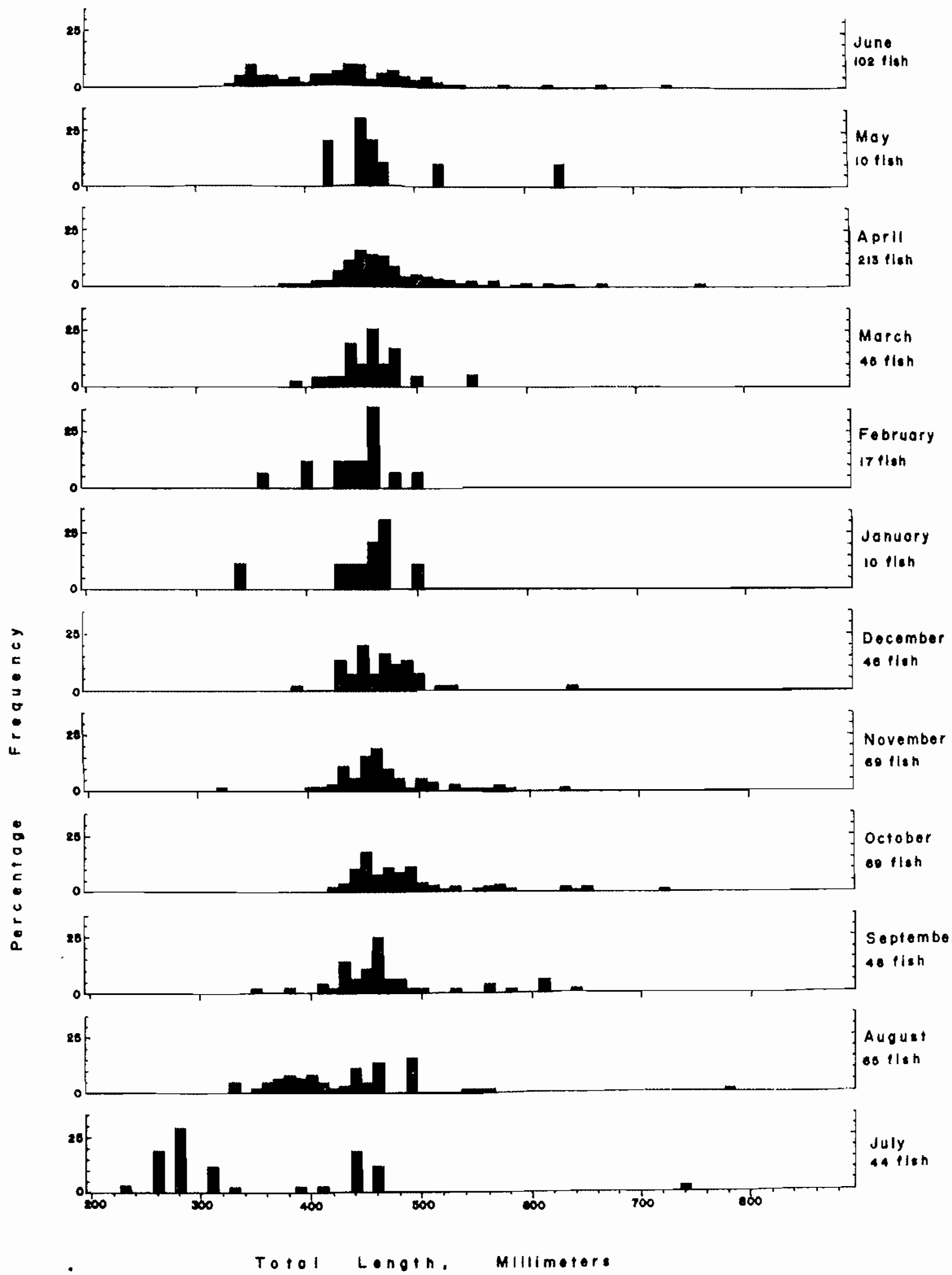
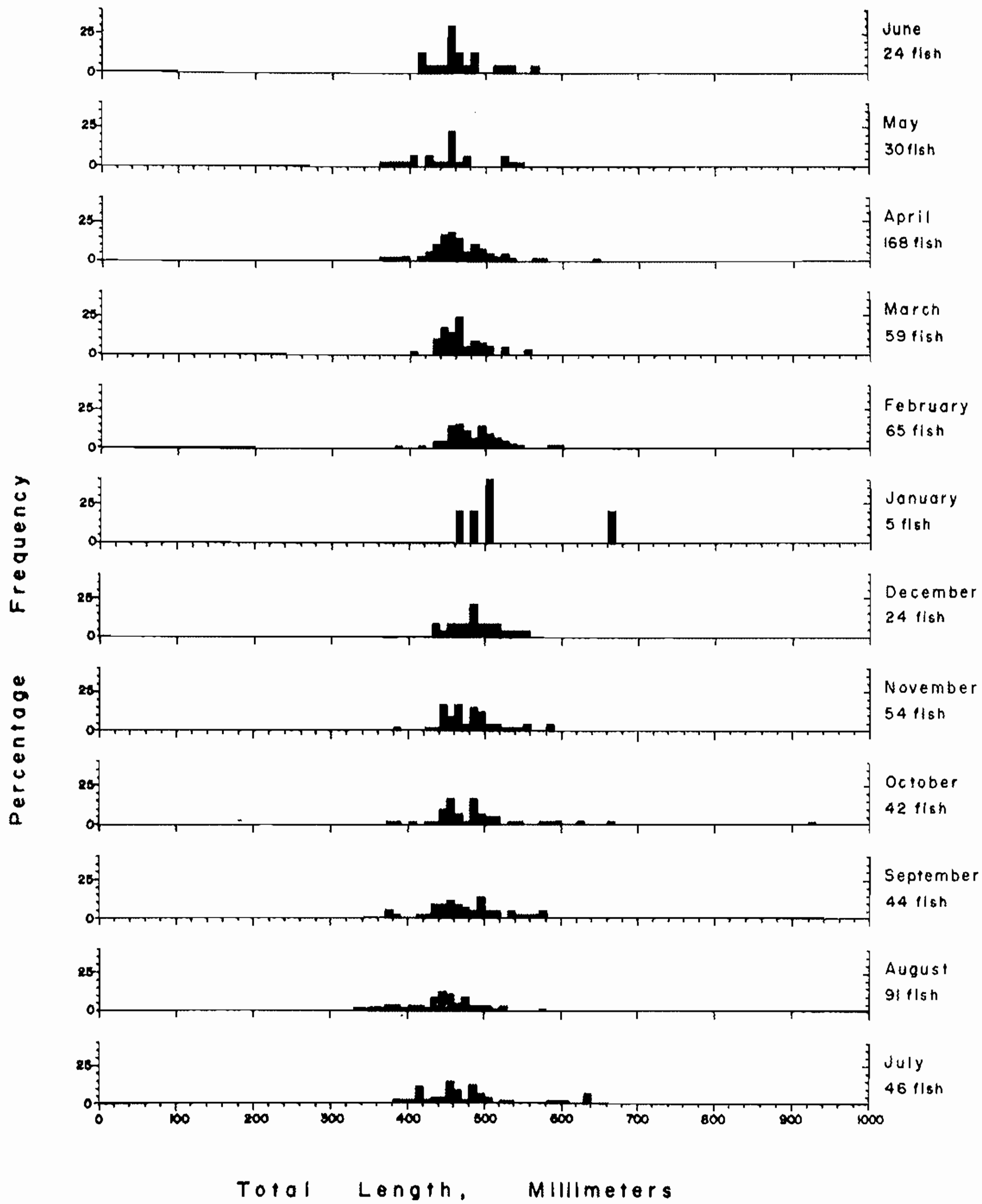

June
102 fish
May
10 fish
April
213 fish
March
46 fish
February
17 fish
January
10 fish
December
46 fish
November
69 fish
October
69 fish
September
48 fish
August
65 fish
July
44 fish
Percentage Frequency
25
0
200
300
400
500
600
700
800
Total Length, Millimeters

Figure 3. Length frequencies at monthly intervals of 652 smallmouth buffalo from Rough River Lake, Kentucky, July 1975 through June 1976.



Percentage Frequency
June
24 fish
May
30 fish
April
168 fish
March
59 fish
February
65 fish
January
5 fish
December
24 fish
November
54 fish
October
42 fish
September
44 fish
August
91 fish
July
46 fish
25
0
0
100
200
300
400
500
600
700
800
900
1000
Total Length, Millimeters

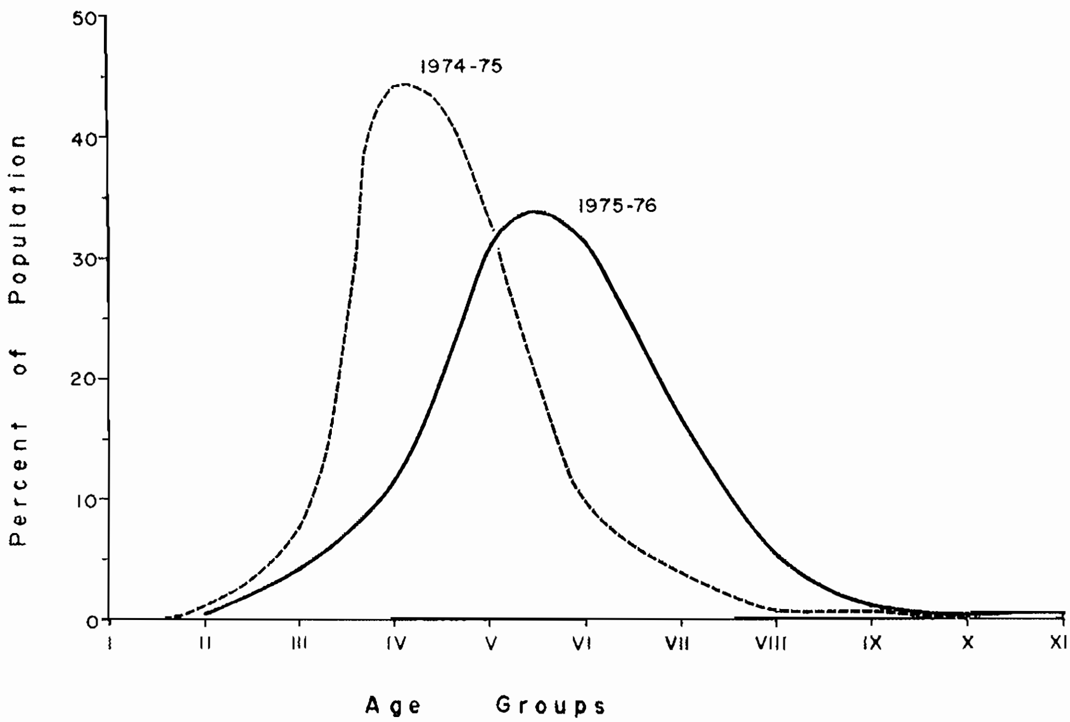
Table 2A. Age class composition and monthly growth increments in millimeters of 1250 smallmouth buffalo taken from Rough River Lake in Segment One, 1974-1975, and Segment Two, 1975-1976. Number of fish taken per age group per month in parentheses.

Month	Age Groups									
	II		III		IV		V		VI	
Segment	1	2	1	2	1	2	1	2	1	2
July						417 (7)		443 (10)		445 (8)
August	330 (3)		390 (10)	376 (13)	433 (24)	425 (13)	431 (11)	447 (23)		477 (16)
Sept			344 (1)	378 (3)	467 (20)	421 (2)	463 (20)	447 (7)	522 (6)	462 (12)
Oct			445 (9)	410 (2)	463 (45)	435 (5)	490 (18)	463 (9)	587 (6)	486 (13)
Nov			418 (2)		447 (40)	414 (3)	478 (14)	459 (13)	496 (2)	479 (23)
Dec			420 (3)		445 (19)	455 (2)	473 (14)	475 (7)	483 (6)	468 (7)
Jan					428 (6)		460 (2)			484 (2)
Feb			414 (5)	388 (1)	410 (10)	437 (1)		459 (16)	474 (1)	476 (20)
Mar			406 (3)		445 (19)	463 (1)	461 (18)	459 (21)	498 (2)	474 (25)
Apr			407 (6)	381 (4)	456 (71)	437 (24)	472 (83)	456 (56)	506 (25)	473 (44)
May			447 (1)	362 (1)	431 (2)	394 (5)	460 (3)	455 (12)		454 (8)
June			364 (10)		387 (34)	412 (2)	458 (39)	453 (9)	479 (12)	466 (7)
Avg. in mm.	330	---	406	379	437	428	465	455	506	472
No.	3		50	24	290	65	222	183	60	185

Table 2B. Age class composition and monthly growth increments in millimeters of 1250 smallmouth buffalo taken from Rough River Lake in Segment One, 1974-1975, and Segment Two, 1975-1976. Number of fish taken per age group per month in parentheses.

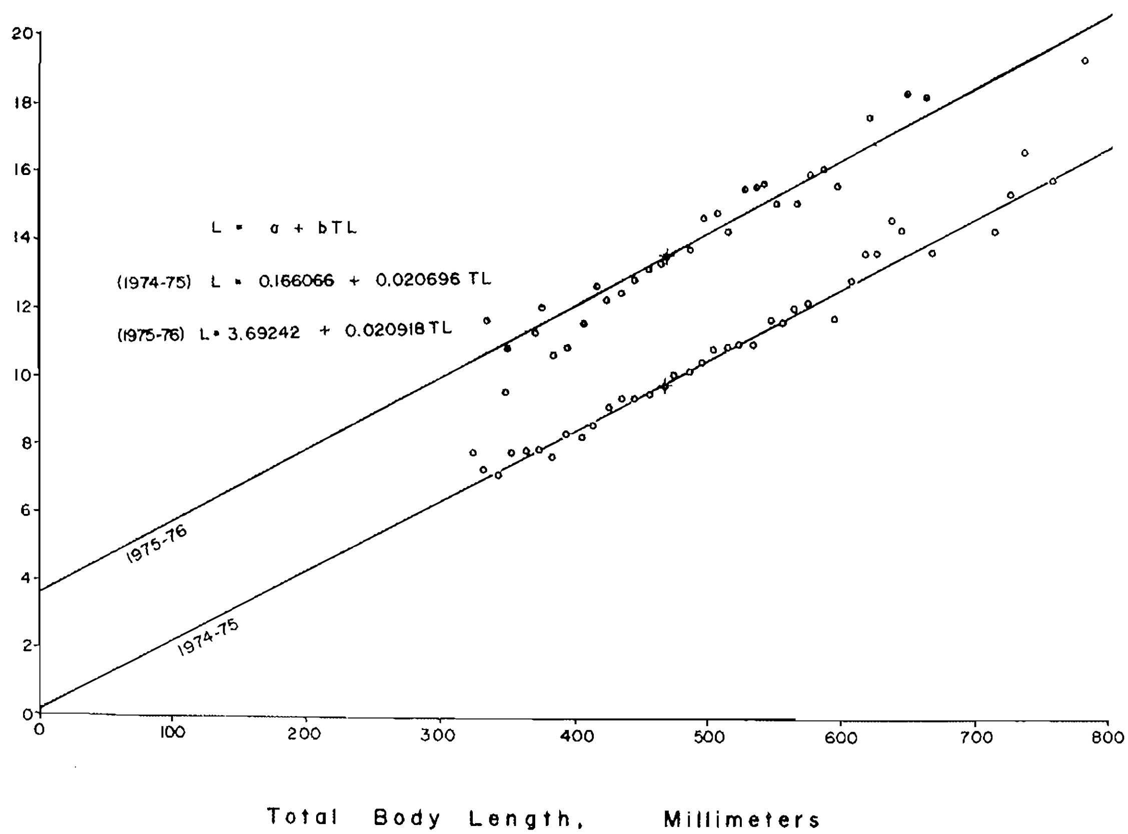
Month	Age Groups									
	VII		VIII		IX		X		XI	
Segment	1	2	1	2	1	2	1	2	1	2
July		468 (2)		584 (1)						
August	430 (1)	481 (11)		500 (1)						
Sept	556 (1)	501 (15)		563 (3)	708 (2)	537 (1)				
Oct	609 (3)	504 (5)	632 (1)	564 (4)		620 (1)				920 (1)
Nov	560 (4)	516 (9)		538 (3)						
Dec	640 (1)	510 (7)		537 (1)						
Jan		499 (2)				661 (1)				
Feb		500 (19)		550 (2)		583 (1)				
Mar	513 (2)	486 (4)		484 (4)						
Apr	555 (9)	502 (19)	469 (2)	521 (6)	687 (2)	527 (1)	637 (1)			
May	569 (2)	442 (1)		523 (3)						
June	598 (3)	527 (4)		518 (1)			724 (1)			
Avg. in mm.	559	500	551	532	698	586	681			920
No.	26	98	3	29	4	5	2			1

Figure 4. Age Group distribution of smallmouth buffalo taken from Rough River Lake, Kentucky, July 1974 through June 1975 and July 1975 through June 1976.



50
40
30
20
10
0
1974-75
1975-76
Percent of Population
I
II
III
IV
V
VI
VII
VIII
IX
X
XI
Age Groups

Figure 5. Body-scale relationship of 583 smallmouth buffalo from Rough River Lake, Kentucky, July 1974 through June 1975 and 596 from July 1975 through June 1976.



L = a + bTL
(1974-75) L = 0.166066 + 0.020696 TL
(1975-76) L = 3.69242 + 0.020918 TL
1975-76
1974-75
0
2
4
6
8
10
12
14
16
18
20
0
100
200
300
400
500
600
700
800
Total Body Length, Millimeters

to time of annulus formation, obvious differences in growth patterns were observed between fishes of Segment One and Two. In Segment One specimens, growth in length was greatest during the first four years of life, during which 61% of the average maximum total length was attained; in Segment Two fish only 40% of the average maximum total length was reached (Table 3). Average annual length increments progressively decreased with increasing age, except in Age Groups IX, X, and XI in Segment Two (Table 3). Average total lengths of each age group and average annual length increments were lower in Segment Two fish for Age Groups I through VI, but higher than Segment One fish for Age Groups VII through XI (Table 3; Fig. 6).

The average lengths of each age group observed in this study were somewhat higher than the back-calculated lengths for the first four or five age groups and lower for the older groups (Tables 2 & 3). Based upon data observed in this study, the greatest and most uniform monthly increment of growth among all age groups occurred in March and April and September and October (Table 2). By far the great majority (85%) of specimens ranged from 400 - 550 mm TL (Table 4). Although growth in length continued up to 920 mm, only 5.9% of the fish collected exceeded 550 mm TL. Only Age Groups IX, X, and XI failed to have any individuals 550 mm or less in length.

In back calculating body lengths at time of annulus formation, noticeable differences in first year growth increments were observed among the various age groups of Segment One and between

Table 3. Growth in length at time of annulus formation of smallmouth buffalo taken from Rough River Lake, July 1974 through June 1976, based upon back calculations of 59 scale samples from Segment One and 99 scale samples from Segment Two.

Segment One	Age Groups									
	I	II	III	IV	V	VI	VII	VIII	IX	X
Average TL in mm	126	244	332	416	491	551	589	629	657	681
% of max. TL	18.5	35.8	48.8	61.0	72.0	81.0	86.0	92.0	96.5	100.0
Growth inc. in mm	126	118	88	84	75	60	38	40	28	24
% increase	100	48.3	26.5	20.2	15.3	10.9	6.5	6.4	4.3	3.5

Segment Two	Age Groups										
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI
Average TL in mm	105	199	286	349	410	461	506	558	638	838	863
% of max. TL	12.3	23.1	33.1	40.4	47.5	53.4	58.7	64.6	73.9	97.1	100.0
Growth inc. in mm	105	94	86	63	61	51	46	52	80	200	25
% increase	100	47.4	30.2	18.0	14.9	11.0	9.0	9.3	12.6	23.9	2.9

Figure 6. Growth profiles of each of eleven age groups of smallmouth buffalo taken from Rough River Lake, Kentucky, July 1974 through June 1975 and July 1975 through June 1976. Data based on back-calculated growth data of 59 specimens in 1974-75 and 99 in 1975-76. Graphic analysis includes the mean (horizontal line in center), one standard error of the mean (small dark box), one standard deviation (large open box), and the range of each age group.

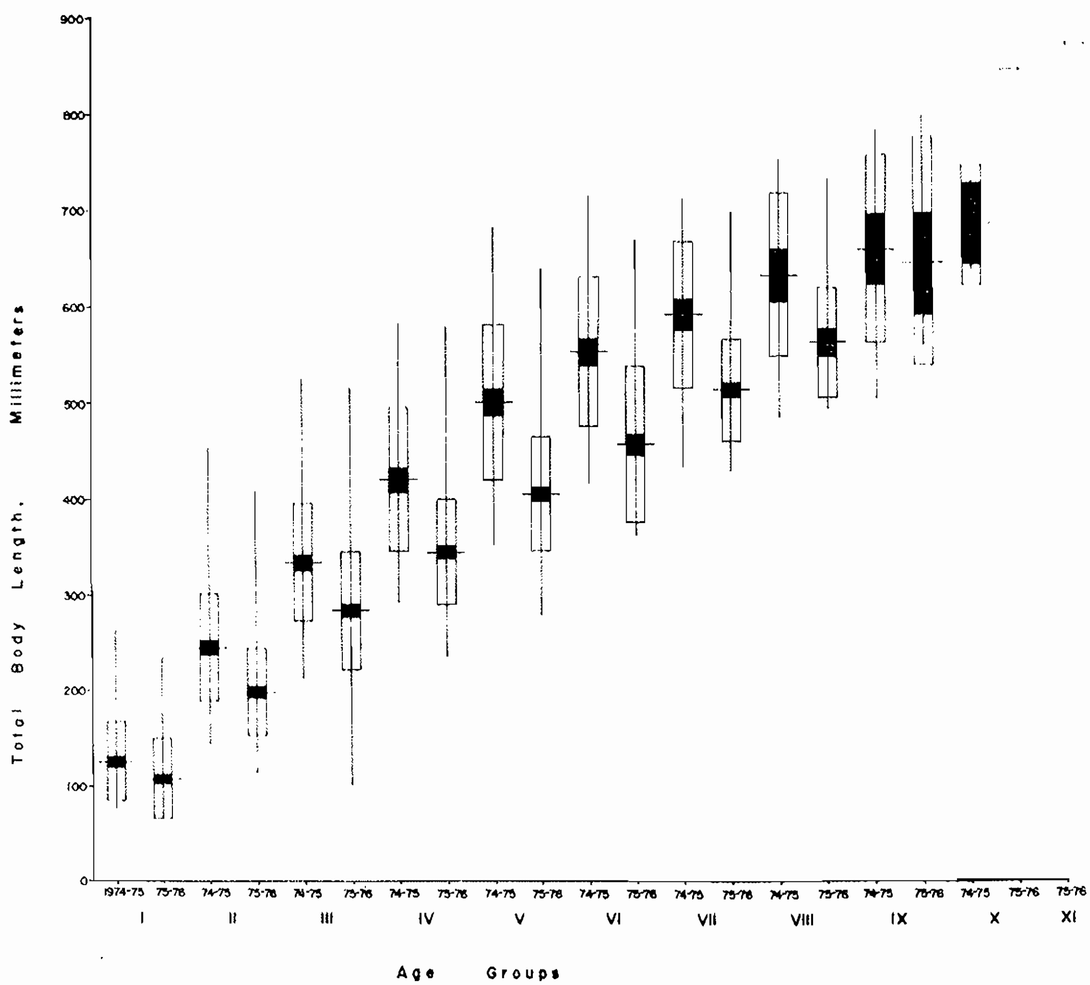

Total Body Length, Millimeters
900
800
700
600
500
400
300
200
100
0
1974-75
75-76
74-75
75-76
74-75
75-76
74-75
75-76
74-75
75-76
74-75
75-76
74-75
75-76
74-75
75-76
74-75
75-76
74-75
75-76
75-76
I
II
III
IV
V
VI
VII
VIII
IX
X
XI
Age Groups

Table 4. Average length-weight and condition data by 10 mm groups of 1405 smallmouth buffalo taken from Rough River Lake, Kentucky, July 1974 through June, 1976.

Size Group	Segment	No. Fish	Average Length mm	Average Weight Grams	Calculated Weight Grams	Condition K
220-229	I	1	228.0	286.0	202.2	2.39
	II	--				
250-259	I	8	254.0	269.0	277.0	1.61
	II	--				
270-279	I	13	279.0	319.3	364.3	1.46
	II	--				
300-309	I	5	305.0	370.4	472.5	1.30
	II	--				
320-329	I	2	324.5	775.0	584.0	2.31
	II	--				
330-339	I	7	332.1	668.1	605.4	1.82
	II	1	335.0	540.3	580.1	1.42
340-349	I	10	343.2	603.8	667.0	1.53
	II	1	347.0	653.8	644.9	1.58
350-359	I	10	352.2	755.7	719.0	1.70
	II	2	350.0	685.5	661.9	1.60
360-369	I	9	364.0	828.3	791.4	1.71
	II	4	363.0	717.3	738.6	1.50
370-379	I	6	372.5	984.7	846.4	1.91
	II	9	375.0	799.0	814.5	1.51
380-389	I	12	382.1	1018.8	912.0	1.88
	II	11	384.6	844.4	878.9	1.49
390-399	I	9	391.9	1019.3	982.0	1.69
	II	6	395.0	912.5	952.4	1.47
400-409	I	18	403.8	1178.7	1071.5	1.80
	II	9	404.0	1130.5	1019.2	1.72
410-419	I	18	413.4	1234.4	1147.6	1.75
	II	18	414.3	1089.6	1099.5	1.71

Table 4. cont.

Size Group	Segment	No. Fish	Average Length mm	Average Weight Grams	Calculated Weight Grams	Condition K
420-429	I	46	424.5	1279.1	1248.0	1.67
	II	17	424.5	1207.6	1183.0	1.58
430-439	I	77	433.6	1322.4	1318.6	1.63
	II	48	434.9	1266.7	1272.4	1.54
440-449	I	87	444.1	1427.6	1414.2	1.66
	II	79	444.5	1389.2	1358.8	1.64
450-459	I	109	454.7	1498.4	1514.3	1.58
	II	91	455.2	1530.0	1459.6	1.82
460-469	I	71	466.2	1637.0	1629.3	1.64
	II	81	464.6	1484.6	1552.2	1.55
470-479	I	51	474.4	1741.7	1717.1	1.61
	II	40	474.9	1693.4	1658.1	1.55
480-489	I	41	484.0	1819.0	1816.8	1.60
	II	61	486.5	1752.4	1812.1	1.56
490-499	I	28	494.5	1969.0	1935.1	1.63
	II	49	496.7	1906.8	1897.9	1.59
500-509	I	25	502.7	2117.4	2029.6	1.67
	II	31	504.0	2024.8	1983.1	1.58
510-519	I	11	514.3	2172.3	2169.2	1.60
	II	22	513.3	2120.2	2095.3	1.58
520-529	I	13	523.2	2369.0	2281.4	1.66
	II	22	525.0	2392.6	2242.4	1.42
530-539	I	8	533.9	2513.9	2418.8	1.58
	II	11	534.6	2474.3	2368.1	1.66
540-549	I	8	546.8	2636.1	2591.8	1.60
	II	6	540.8	2619.6	2451.7	1.66
550-559	I	9	554.6	2433.4	2704.0	1.43
	II	6	550.2	2410.7	2582.2	1.41
560-569	I	9	563.2	2636.8	2828.1	1.42
	II	3	565.7	2624.1	2807.4	1.62

Table 4. cont.

Size Group	Segment	No. Fish	Average Length mm	Average Weight Grams	Calculated Weight Grams	Condition K
570-579	I	5	573.6	2399.0	2982.6	1.28
	II	5	575.0	2701.3	2948.6	1.42
580-589	I	--				
	II	5	586.6	2742.1	3131.3	1.25
590-599	I	4	593.8	3428.0	3300.7	1.64
	II	3	595.3	3141.7	3273.1	1.49
600-609	I	4	606.8	3090.8	3481.0	1.40
	II	1	609.0	3859.0	3505.1	1.78
610-619	I	3	615.7	3377.7	3667.8	1.46
	II	--				
620-629	I	5	624.8	3109.8	3831.8	1.53
	II	1	620.0	3686.5	3699.1	1.57
630-639	I	3	635.0	4266.3	4013.3	1.67
	II	3	635.0	4213.1	3975.1	1.65
640-649	I	3	642.0	4393.3	4142.0	1.67
	II	1	646.0	4344.8	4185.9	1.61
660-669	I	2	666.0	3768.5	4612.1	1.27
	II	2	662.5	4512.8	4516.0	1.57
710-719	I	1	713.0	5026.0	5627.3	1.39
	II	--				
720-729	I	1	724.0	7196.0	5881.7	1.90
	II	--				
730-739	I	1	737.0	5848.0	6198.7	1.47
	II	--				
750-759	I	1	755.0	7577.0	6646.6	1.76
	II	--				
780-789	I	1	780.0	9988.0	7311.4	2.12
	II	--				
920-929	I	--				
	II	1	920.0	13138.8	12132.1	1.46

Segment One and Two (Table 5). Segment One Age Groups VII, VIII, and IX, spawned in 1967-65, respectively, showed a distinctly greater first years growth than the other groups. Segment One year classes spawned from 1968 through 1972 (Age Groups VI through II) showed reduced first year increments ranging from 108 to 113 mm. Segment Two first year growth data showed a similar pattern but of less magnitude than Segment One. Average annual growth increments in millimeters were consistently lower among Segment Two age groups but were markedly higher in the two oldest age groups, X and XI. No individuals were taken having only one annulus, consequently, all first year growth data was back-calculated.

Growth in Weight - Growth in weight showed the greatest percentage increases during the early years of life, but showed the greatest absolute increases during the latter years (Table 6). Marked differences were observed in the weight increments of Segment One and Segment Two fish. Segment One fish gained 56% of the maximum observed total weight during the years V through VIII while Segment Two fish gained 64.8% of this total in years IX and X.

Length-Weight Relationship - The relationship between growth in length and weight was expressed by the formulae $\log W = -4.5728 + 2.9172 \log L$, or $W = 2.67 \times 10^{-5}\ TL^{2.9172}$ for Segment One and $\log W = -4.836 + 3.01 \log L$, or $W = 0.145902 \times 10^{-4}\ TL^{3.01}$ for Segment Two fish (Table 4; Fig. 7). Females showed a greater proportionate growth in weight per unit length than males as indicated by $\log W = -5.023 + 3.082 \log L$, or $W = 0.94759 \times 10^{-5}\ TL^{3.082}$, and $\log W = -4.69 + 2.953 \log L$, or $W = 0.20473 \times 10^{-4}$

Table 5. Back calculated growth increments in millimeters of smallmouth buffalo from Rough River Lake, July 1974 through June 1976.

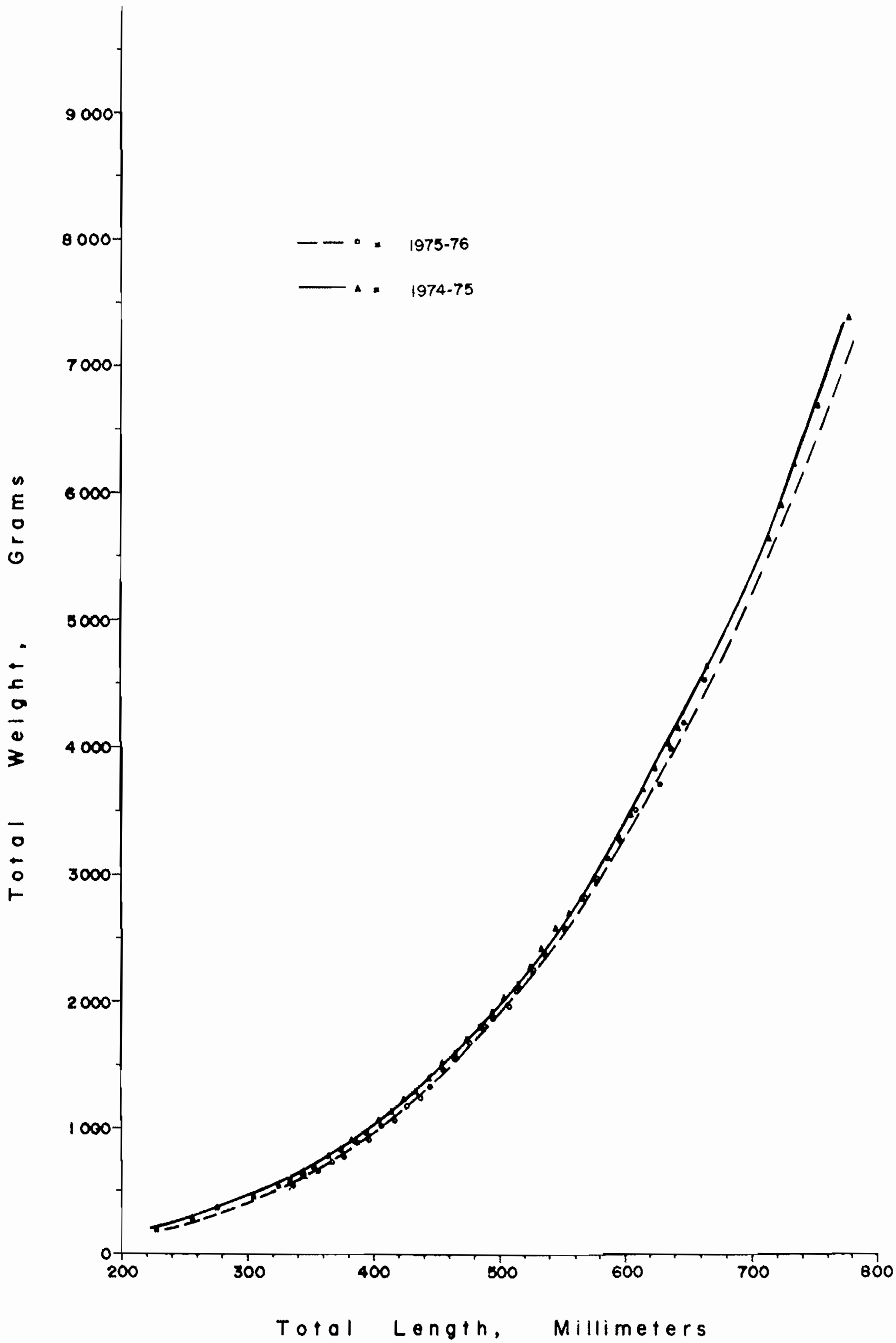
	Age Groups									
	III	IV	V	VI	VII	VIII	IX	X	XI	Average Growth mm
Segment I N=	17	9	5	8	11	2	5	2	0	
Segment II N=	20	10	11	23	19	12	3	0	1	
First Year										
Segment I	112	108	113	109	153	199	170	113	---	126
Segment II	115	102	97	97	97	103	122	---	235	105
Second Year										
Segment I	239	211	216	245	274	319	275	200	---	244
Segment II	228	203	192	193	179	164	212	---	407	199
Third Year										
Segment I	317	308	303	338	363	397	357	319	---	332
Segment II	339	284	272	273	260	237	276	---	514	286
Fourth Year										
Segment I		371	368	441	439	459	426	433	---	416
Segment II		362	353	339	335	321	365	---	578	349
Fifth Year										
Segment I			410	515	501	523	506	483	---	491
Segment II			408	403	396	389	428	---	635	410
Sixth Year										
Segment I				541	554	566	561	535	---	551
Segment II				459	454	453	477	---	663	461
Seventh Year										
Segment I					583	614	599	578	---	589
Segment II					498	501	513	---	692	506
Eighth Year										
Segment I						629	634	617	---	629
Segment II						545	553	---	727	558
Ninth Year										
Segment I							658	653	---	657
Segment II							587	---	792	638
Tenth Year										
Segment I								681	---	681
Segment II								---	838	838
Eleventh Year										
Segment I									---	---
Segment II									863	863

Table 6. Growth in weight at time of annulus formation of smallmouth buffalo taken from Rough River Lake, July 1974 through June 1976, based upon calculated weights of 758 specimens from Segment One and 652 specimens from Segment Two.

Segment One	Age Groups										
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI
Average Wt. in grams	36	246	605	1167	1895	2661	3222	3905	4433	4919	---
% of max. Wt.	.7	5.0	12.3	23.7	38.5	54.1	65.5	79.4	90.1	100.0	
Growth inc. in grams	36	210	359	562	728	766	561	683	528	486	---
% increase	100	85.4	59.3	48.2	38.4	28.8	17.4	17.5	11.9	9.9	--

Segment Two	Age Groups										
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI
Average Wt. in grams	18	122	359	653	1054	1512	2009	2691	4030	9170	10004
% of max. Wt.	.2	1.2	3.6	6.5	10.5	15.1	20.1	26.9	40.2	91.7	100.0
Growth inc. in grams	18	104	238	295	400	460	497	682	1339	5140	834
% increase	100	85.5	66.2	45.1	38.0	30.3	24.7	25.3	33.2	56.1	8.3

Figure 7. Relationship between total length and weight in smallmouth buffalo from Rough River Lake, Kentucky, July 1974 through June 1975 and July 1975 through June 1976.



9 000
8 000
7 000
6 000
5 000
4 000
3000
2 000
1 000
0
200
300
400
500
600
700
800
1975-76
1974-75
Total Weight, Grams
Total Length, Millimeters

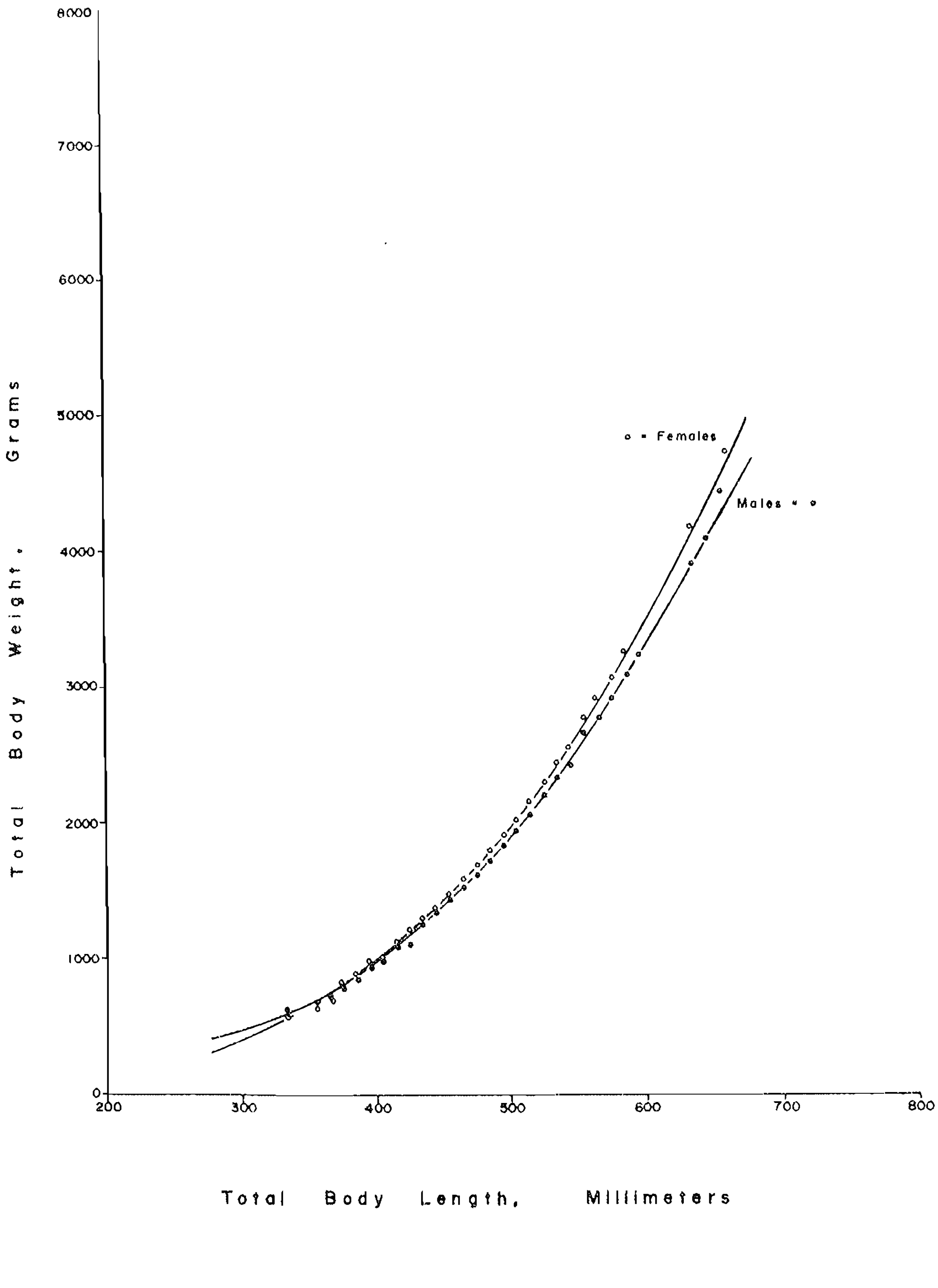
$TL^{2.953}$, respectively (Fig. 8). Also, as indicated by the exponents 3.082 for females and 2.953 for males, females more closely conformed to the expected cubic response in growth dimensions than did males.

<u>Condition</u> - The average coefficient of condition for 1,410 smallmouth buffalo examined was 1.60 (Table 4). Average coefficients decreased from 1.64 in Segment One specimens to 1.55 for Segment Two fish (Table 4; Fig. 9). Average coefficients were greater in smaller specimens and progressively decreased in larger fish. Segment One fish from 228 to 399 mm TL (12.2% of the total) averaged 1.68, those from 400 to 550 mm 1.65 (81.0% of the total), and from 551 to 780 mm 1.49 (6.8% of the total). Segment Two fish showed a slightly different pattern with the smaller fish (5.2%) averaging 1.50, 400 to 550 mm specimens 1.63 (90%) and the larger individuals 1.47 (4.8%).

Females had slightly higher condition values than males, 1.58 and 1.51, respectively (Fig. 10). Females showed an annual low in body condition following spawning in July and August but recovered by September, reaching the annual high in October. Both males and females showed a similar annual trend with noticeable post-spawning lows and autumnal and winter highs.

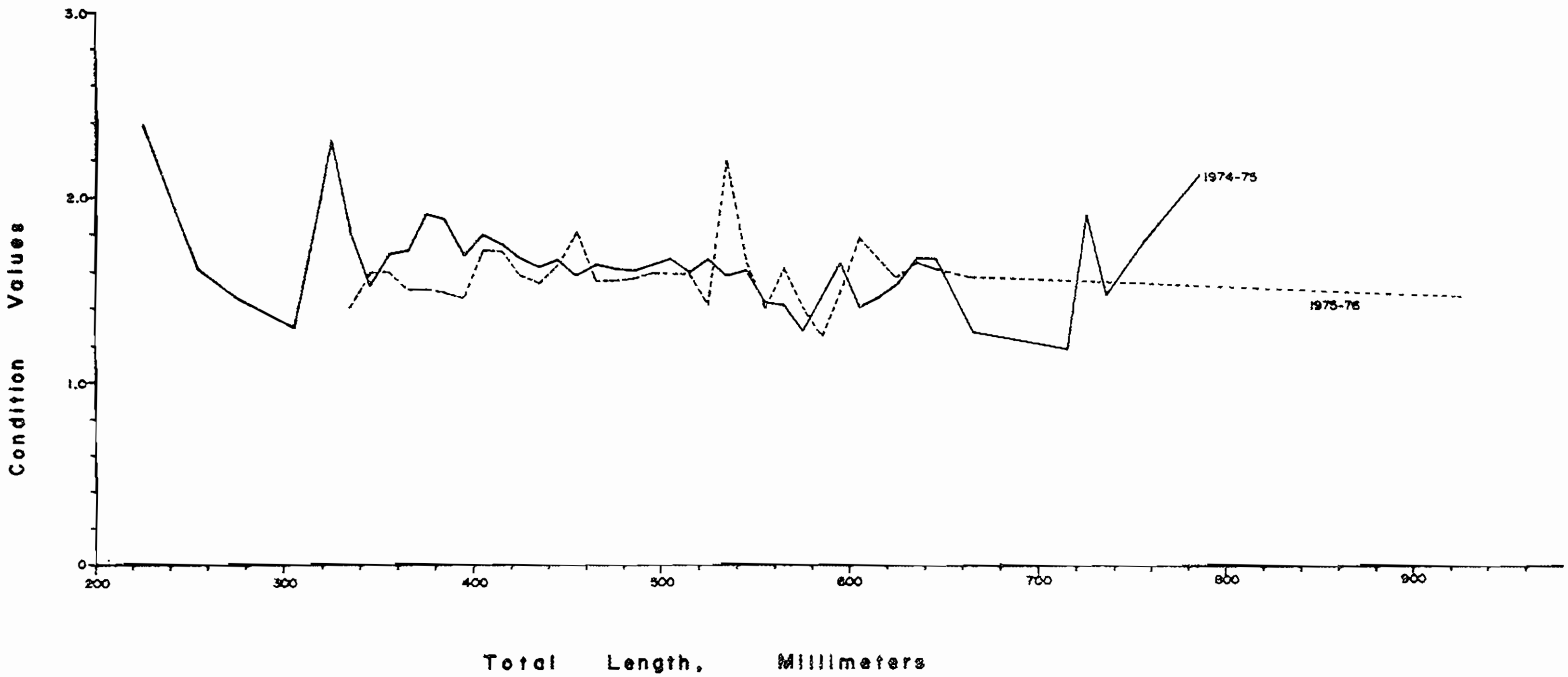
<u>Distribution and Movements</u> - Of 1,410 buffalo taken in this study, 1,220 were collected from stations along the South Fork of Rough River Lake, while 190 were taken from the North Fork (Appendix A). Movements could not be monitored due to the absence of multiple tagged returns; however, the recapture on May 1, 1976 of a specimen tagged and released on April 15, 1975 gave some evidence

Figure 8. Relationship between total length and total body weight in male and female smallmouth buffalo from Rough River Lake, Kentucky, July 1975 through June 1976.



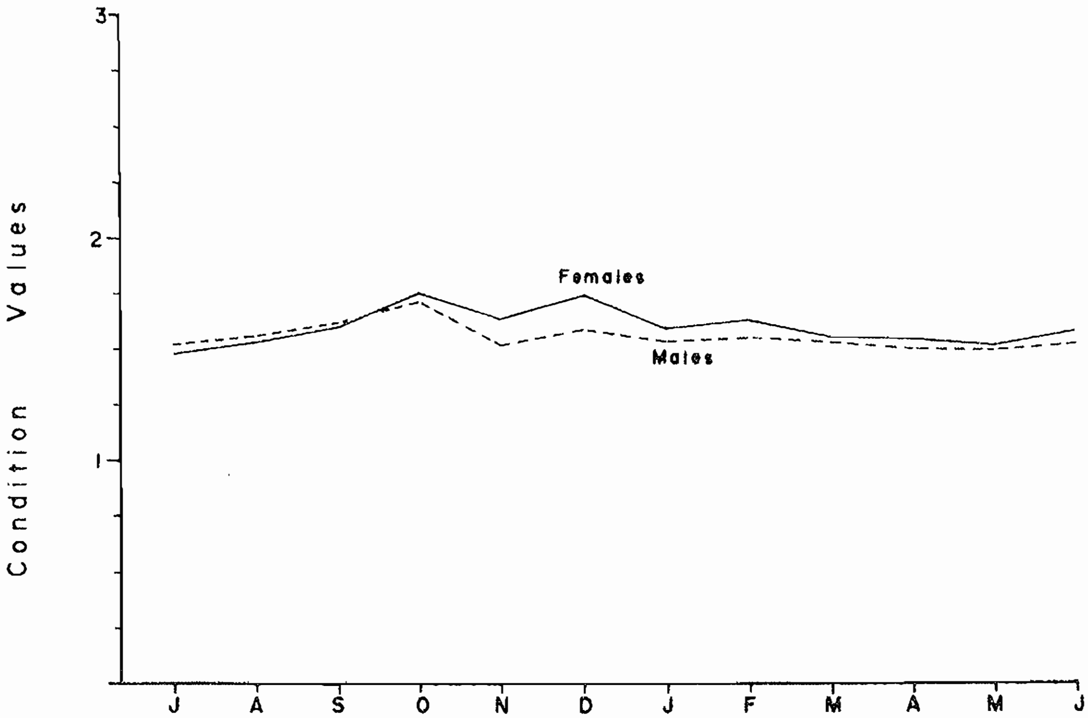
8000
7000
6000
5000
4000
3000
2000
1000
0
200
300
400
500
600
700
800
Total Body Weight, Grams
Total Body Length, Millimeters
o = Females
Males = o

Figure 9. Coefficient of condition (K) of smallmouth buffalo from Rough River Lake, Kentucky, July 1974 through June 1975 and July 1975 through June 1976.



3.0
2.0
1.0
0
Condition Values
200
300
400
500
600
700
800
900
Total Length, Millimeters
1974-75
1975-76

Figure 10. Average monthly coefficients of condition (K) of male and female smallmouth buffalo from Rough River Lake, Kentucky, July 1975 through June 1976.


Condition Values
3
2
1
Females
Males
J
A
S
O
N
D
J
F
M
A
M
J

of the distance travelled by the species. This individual was captured over one year later, approximately 18 miles from the point of release, and while it had grown 4 millimeters in length, it weighed 26 grams, or almost one ounce, less at recapture than when released.

Movements were most obvious during this study during the spawning season, March and April, at which time large numbers of gravid females and ripe males moved into headwater streams.

Job II Title: Commercial tackle selectivity in harvesting smallmouth buffalo.

The majority (72.2%) of the buffalo taken in net tackle were captured with flag nets, followed by gill nets (25.1%), trammel nets (2.6%), and hoop nets (0.1%) (Table 7). The percentage of buffalo caught with gill netting increased markedly from Segment One to Segment Two, while that of flag netting decreased. Of the various mesh sizes used, three-inch (7.62 cm) and 2.5-inch (6.35 cm) were the most successful (49.6% and 26.1%, respectively), followed in order by 3.5-inch (8.9 cm), 4.0-inch (10.2 cm), and 3.0-inch (7.62 cm) hoop nets (Table 8).

The most efficient tackle and mesh size was the 3.0-inch flag net which captured 32.6% of all net captured specimens (Table 9). This was followed closely by the 2.5-inch flag net taking 26.1% and distantly by 3.0-inch gill netting and 3.5-inch flag netting with 17.1% and 11.3%, respectively.

The total fishing effort expended in the study was 2,010.5 net days (one net day = 100' of net fished 24 hours) with the majority, 973 days (48.4%), directed to flag netting (Table 10).

Table 7. Weight classes and number of smallmouth buffalo taken by various tackle types from Rough River Lake, Kentucky, July 1974 through June 1976.

Weight Groups	Tackle Type							
	Flag		Gill		Trammel		Hoop	
Segment	I	II	I	II	I	II	I	II
0 - 1 lb 0 - .45 kg	-	-	-	-	-	-	-	-
1 - 2 lbs .45 - .9 kg	5	14	-	-	-	-	-	-
2 - 3 lbs .9 - 1.36 kg	98	74	8	30	1	-	-	-
3 - 4 lbs 1.37 - 1.8 kg	248	133	57	101	3	2	1	-
4 - 5 lbs 1.8 - 2.26 kg	83	81	11	43	-	1	-	-
5 - 6 lbs 2.27 - 2.7 kg	24	18	4	10	3	5	-	-
6 - 7 lbs 2.7 - 3.1 kg	12	5	3	3	2	5	-	-
7 - 8 lbs 3.1 - 3.6 kg	5	2	1	1	3	-	-	-
8 - 9 lbs 3.6 - 4.0 kg	-	-	2	2	2	-	-	-
9 - 10 lbs 4.0 - 4.5 kg	2	2	3	-	-	-	-	-
10 - 11 lbs 4.5 - 4.9 kg	-	-	1	-	-	1	-	-
11 + lbs 4.993 + kg	2	1	1	-	1	-	-	-
Total	479	330	91	190	15	14	1	0

Table 8. Weight classes and number of smallmouth buffalo taken by various mesh sizes from Rough River Lake, Kentucky, July 1974 through June 1976.

Weight Groups	2.5"		3.0"		3.5"		4.0"		Hoop	
Segment	I	II	I	II	I	II	I	II	I	II
0 - 1 lb 0 - .45 kg	-	-	-	-	-	-	-	-	-	-
1 - 2 lbs .45 - .9 kg	5	10	-	2	-	2	-	-	-	-
2 - 3 lbs .9 - 1.36 kg	56	32	41	54	9	17	1	1	-	-
3 - 4 lbs 1.37 - 1.8 kg	91	48	174	165	35	21	8	2	1	-
4 - 5 lbs 1.8 - 2.26 kg	20	19	42	50	30	48	2	8	-	-
5 - 6 lbs 2.27 - 2.7 kg	5	2	9	9	10	16	7	6	-	-
6 - 7 lbs 2.7 - 3.1 kg	1	1	2	2	5	5	9	5	-	-
7 - 8 lbs 3.1 - 3.6 kg	1	-	1	1	1	1	6	1	-	-
8 - 9 lbs 3.6 - 4.0 kg	-	-	-	-	-	1	4	1	-	-
9 - 10 lbs 4.0 - 4.5 kg	-	-	1	1	1	-	3	1	-	-
10 - 11 lbs 4.5 - 4.9 kg	-	-	-	-	-	-	1	1	-	-
11 + lbs 4.993 + kg	1	-	1	1	-	-	2	-	-	-
Total	180	112	271	285	91	111	43	26	1	0

Table 9. Weight classes and number of smallmouth buffalo taken by various tackle types and mesh sizes from Rough River Lake, Kentucky, July 1974 through June 1976.

Weight Groups	Flag								Gill						Trammel		Hoop	
	2.5"		3.0"		3.5"		4.0"		3.0"		3.5"		4.0"		4.0"		3.0"	
Segment	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II
0 - 1 lb	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1 - 2 lbs	5	10	-	2	-	2	-	-	-	-	-	-	-	-	-	-	-	-
2 - 3 lbs	56	32	35	30	7	11	-	1	6	24	2	6	-	-	1	-	-	-
3 - 4 lbs	91	48	135	74	17	11	5	-	39	91	18	10	-	-	3	2	1	-
4 - 5 lbs	20	19	37	31	24	27	2	4	5	19	6	21	-	3	-	1	-	-
5 - 6 lbs	5	2	8	4	7	11	4	1	1	5	3	5	-	-	3	5	-	-
6 - 7 lbs	1	1	2	1	4	3	5	-	-	1	1	2	2	-	2	5	-	-
7 - 8 lbs	1	-	1	1	1	1	2	-	-	-	-	-	1	1	3	-	-	-
8 - 9 lbs	-	-	-	-	-	-	-	-	-	-	-	1	2	1	2	-	-	-
9 - 10 lbs	-	-	1	1	-	-	1	1	-	-	1	-	2	-	-	-	-	-
10 - 11 lbs	-	-	1	-	-	-	-	-	-	-	-	-	1	-	-	1	-	-
11 + lbs	1	-	1	1	-	-	-	-	-	-	-	-	1	-	1	-	-	-
Total	180	112	220	145	60	66	19	7	51	140	31	45	9	5	15	14	1	0

Table 10. Fishing effort and catch efficiency of various tackle types and mesh sizes for smallmouth buffalo on Rough River Lake, Kentucky, July 1974 through June 1976.

Tackle		No. of fish		Net days		Fish/ unit effort		Weight/ unit effort		Total weight lbs		Average weight lbs		Total average weight lbs
	Segment	I	II	I	II	I	II	I	II	I	II	I	II	
Flag	2.5"	180	112	120	135	1.50	0.83	5.11	2.65	613.3	358.3	3.41	3.2	3.33
	3.0"	220	145	120	128	1.83	1.13	6.54	4.25	787.6	544.4	3.58	3.75	3.65
	3.5"	60	66	120	128	0.50	0.50	2.11	2.15	253.3	274.6	4.22	4.16	4.19
	4.0"	19	7	84	138	0.23	0.05	1.23	0.26	103.6	36.2	5.45	5.16	5.38
Total		479	330	444	529	1.08	0.62	3.95	2.29	1755	1213	3.67	3.68	3.67
Gill	3.0"	51	140	114	108	0.45	1.30	1.55	4.50	176.5	486.3	3.46	3.47	3.47
	3.5"	31	45	126	138	0.25	0.33	0.98	1.38	124.1	189.9	4.00	4.22	4.13
	4.0"	9	5	36	108	0.25	0.05	2.13	0.27	76.8	29.1	8.53	5.82	7.57
Total		91	190	276	354	0.33	0.54	1.37	1.99	377.4	705.3	4.15	3.71	3.84
Trammel	4.0"	15	14	28	184.5	.54	0.08	3.60	0.45	100.7	82.3	6.71	5.87	6.31
Hoop	3.0"	1	0	72	123	0.01	0.00	0.05	0.00	3.4	00.0	3.38	0.00	3.38
Total		586	534	820	1190.5	.71	.45	2.73	1.69	2237	2001	3.82	3.75	3.78

This was followed by gill netting with 630 net days, trammel netting with 212.5 days, and hoop nets with 195 days.

The greatest average size buffalo were taken with 4.0-inch mesh gill netting (avg. 7.57 lbs [3.43 kg]) followed by 4.0-inch trammel (6.31 lbs [2.86 kg]) and 4.0-inch flag netting (5.38 lbs [2.44 kg]). However, the greatest efficiency in capture in terms of number and weight per unit effort was produced by the 3.0-inch flag net in Segment One and 3.0-inch gill net in Segment Two with 1.83 individuals and 6.54 lbs and 1.3 individuals and 4.5 lbs per net day, respectively. The next most efficient tackle per unit time was the 2.5-inch flag net in Segment One and 3.0-inch flag in Segment Two. Although fishing effort in net days increased during Segment Two, the total catch in number of fish, total weight, and catch per unit time decreased from that of Segment One.

Mortality - As observed in this study, mortality of the smallmouth buffalo was attributable to three causes: natural mortality; fishing mortality due to legal-size commercial tackle, i.e., 4-inch and greater mesh sizes and 3.0-inch hoop netting; and that fishing mortality due to experimental, non-legal, sub-four-inch mesh tackle employed in this study.

Qualitatively, natural mortality differed between the two segments of the study. In the first year, noticeable reduction in number of individuals per age group was observed between the fourth and fifth years of life, with a 10% drop in the total population number, followed by the most extreme mortality, a 25% population loss of older individuals between the fifth and sixth years (Table 2). In the second segment, the age groups represented an almost perfect population curve (Fig. 4) with the greatest mortalities, 14.7% and 11.7%, occurring between the sixth and seventh and seventh and eighth years of life, respectively (Table 2).

Legal commercial tackle mortality, as observed in this study (Table 10), concentrated on those individuals averaging 6.5 lbs and larger having an average age of over six years. Fishing results using experimental, sub-legal tackle (Table 10), was most efficient in harvesting those individuals with an average weight of 3.5 lbs, averaging 3.5 to 5 years of age and representing 80% of the population.

Associated Species - Twelve species (796 specimens) other than the smallmouth buffalo were also taken and represented 41.5% of the total catch (Table 11). Of these species, black basses, bluegill, crappies, white bass, and walleye represented 16.2% of the total catch. Of these species, white bass represented the most common species, making up 9.8% of the total catch (Table 11).

The smaller mesh sizes were the most efficient in taking game species as well as total species. The 2.5-inch mesh took 58.2% and the 3.0-inch mesh 32.8%, or a combined total of 91% of the total game species.

Job III Title: The reproductive biology of the smallmouth buffalo.

The gonosomatic index, average ova diameter and fecundity provided a relatively clear picture of the spawning cycle of the smallmouth buffalo in Rough River Lake. Spawning activity was initiated in March, reached its peak in April and concluded in

Table 11. Fish species taken by various mesh sizes from Rough River Lake, Kentucky, July 1974 through June 1976.

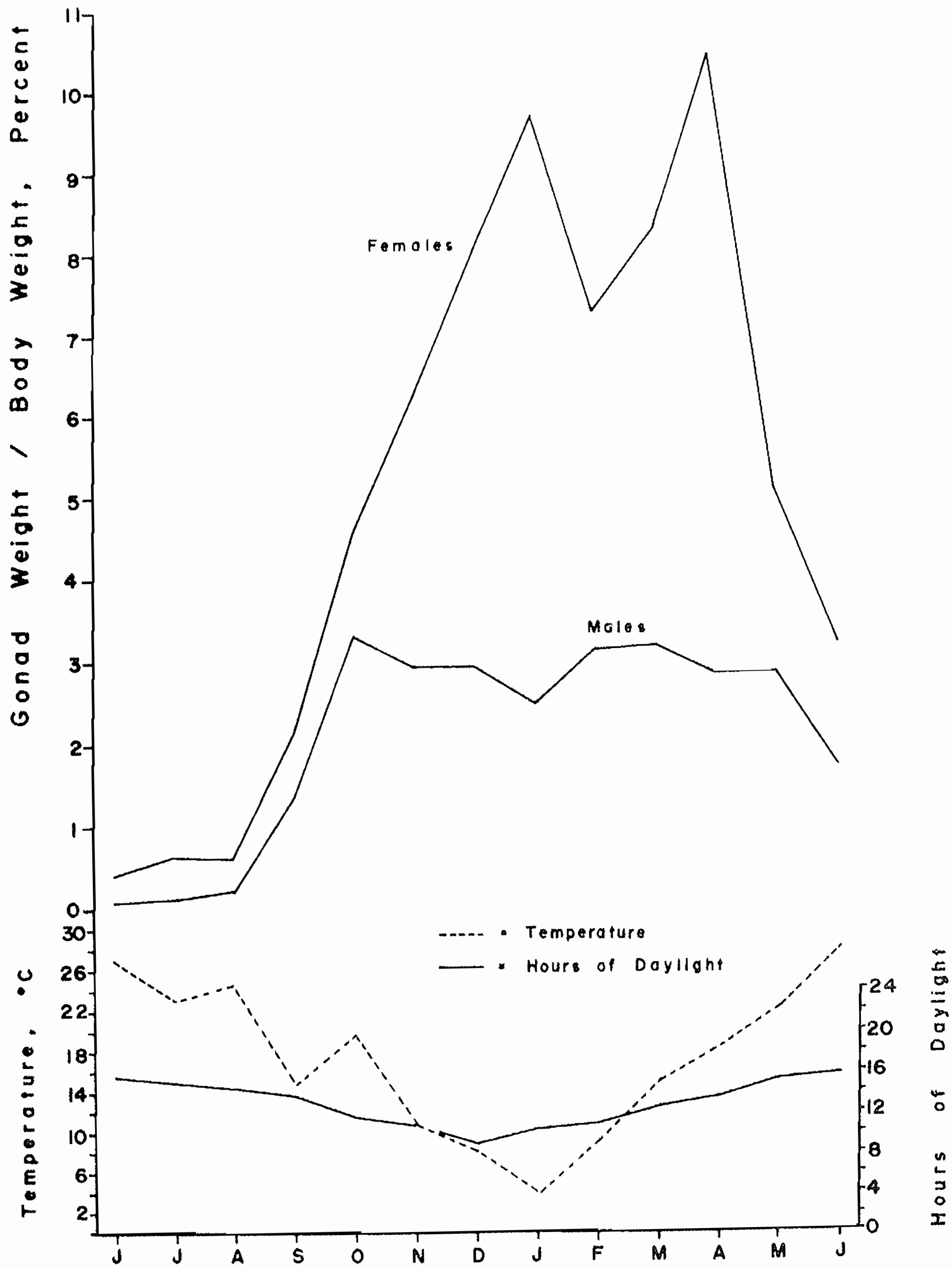
Species	2.5"		3.0"		3.5"		4.0"		Hoop Net	
Segment	I	II	I	II	I	II	I	II	I	II
Smallmouth buffalo	180	112	271	285	91	111	43	26	1	0
Carp	33	46	66	60	24	37	9	6	0	0
Channel catfish	4	5	5	5	3	6	1	1	2	0
Flathead catfish	9	9	9	14	5	21	0	13	0	0
Freshwater drum	9	8	6	7	1	1	0	3	0	0
Golden redhorse	0	1	1	2	0	0	0	0	0	0
Spotted sucker	0	2	0	0	0	1	0	0	0	0
Longnose gar	5	4	5	8	9	2	1	1	13	2
Blackbass	8	9	15	19	2	5	4	1	2	0
Bluegill	0	1	1	1	0	1	0	1	0	0
Crappie	5	10	4	2	1	2	0	1	0	0
White bass	90	44	36	13	3	1	0	1	0	0
Walleye	3	11	3	8	0	1	0	1	0	1
Total	346	262	422	424	139	189	58	55	18	3

mid-May as indicated by female gonosomatic ratios of 8.28% in March, 10.4% in April, and 5.1% in May (Fig. 11). Spent females were taken in mid-May and early June but were not prominent during the peak of spawning activity. Males showed a gonadal development trend similar to the females, but of lesser magnitude, and reached spawning condition in February, one month earlier than females. Males also showed a high state of gonadal development over a longer period, February through May, than did females (Fig. 11). The greatest gonosomatic index recorded was 14% for an 8-year-old female collected in March 1976 and 4.9% for a 5-year-old male taken in February 1976. Average annual gonosomatic indices for females ranged from 0.04% for Age Group II, to 7.3% for Age Group VIII, and from 0.03% for Age Group II, to 2.56% for Age Group VI males (Table 12).

Sexually mature individuals, as based upon gonadal condition, were 400 mm TL and completing their fourth year of life for males and 425-450 mm TL and five years of age for females. Age Group V was the most important age group among reproducing males, followed by Age Groups VI and VII, while Age Group VI was the most abundant group of females, followed by Age Groups V and VII (Table 12).

Gonadal condition for males and females represented a bimodal curve with gonad development occurring in the late fall and winter and again in late winter and early spring (Fig. 11). These periods of gonad development were closely correlated with water temperatures of 19 C and day light periods of 13 hours (Fig. 11). The January peak was of less magnitude than the spring peak in females but was greater in males.

Figure 11. Average monthly gonosomatic ratios of 319 male and 207 female smallmouth buffalo from Rough River Lake, Kentucky, July 1975 through June 1976.



Gonad Weight / Body Weight, Percent
Females
Males
Temperature
Hours of Daylight
Temperature, °C
Hours of Daylight
J J A S O N D J F M A M J

Table 12. Numerical composition, gonosomatic ratios, and average annual ova diameters of age groups of smallmouth buffalo, Rough River Lake, Kentucky, July 1974 through June 1976.

	Age Groups										
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI
No. of Males	0	8	16	51	90	60	28	12	4	0	1
% of Total	0	3.0	6.0	18.9	33.3	22.2	10.4	4.4	1.5	0	0.3
No. of Females	0	2	11	22	46	56	45	10	0	0	0
% of Total	0	1.0	5.7	11.5	24.0	29.2	23.4	5.2	0	0	0

Average Annual Gonosomatic Index	Age Groups									
	II	III	IV	V	VI	VII	VIII	IX	X	XI
Males	0.03	0.4	1.3	1.9	2.6	1.9	2.5	2.4		0.1
Females	0.04	0.4	1.3	3.6	4.9	4.8	7.3			

Average Annual Ova Diameter mm	Age Groups									
	II	III	IV	V	VI	VII	VIII	IX	X	XI
	.11	.19	.30	.61	.82	.79	1.15			

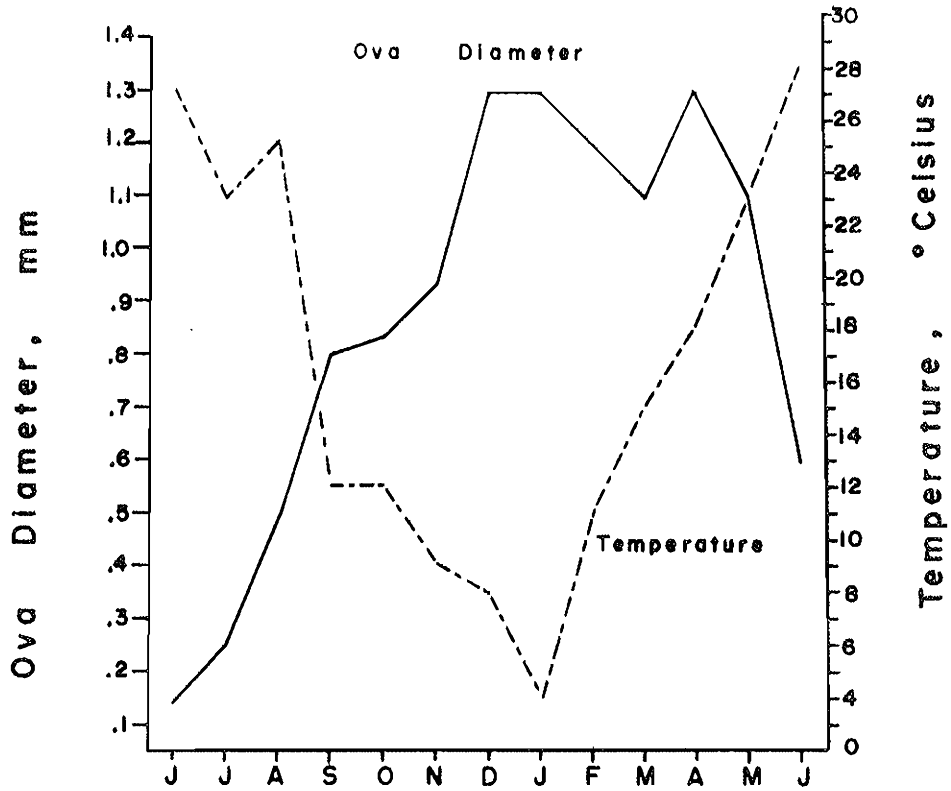
Ova diameters, as indicators of reproductive condition, showed developmental trends very similar to those of gonad development (Fig. 12). Average monthly diameters of ova were greatest in December, January, and April, measuring 1.3 mm. Annual low measurements were recorded in June, 0.14 mm, immediately following the spawning season. The largest ovum recorded in the study was 1.6 mm, taken from an Age Group VII, 507 mm, specimen in April 1976. Mature ova diameters during March, April, and May averaged 1.21 mm, while the annual average diameter of the largest ova present was 0.68 mm. Age Group VIII females had the greatest annual average ova diameter of 1.15 mm, followed by Age Group VI, 0.82 mm, and VII, 0.79 mm (Table 12).

Mature ova first appeared in large numbers in mid-March and disappeared following spawning by mid-June (Fig. 13). The average fecundity throughout the spawning period was 113,073 and was greatest (133,812 and 126,101) during mid- and late April. Age Group VIII females had the highest average fecundity with 143,882, followed in order by Age Groups VII, VI, V, and IV (Table 12).

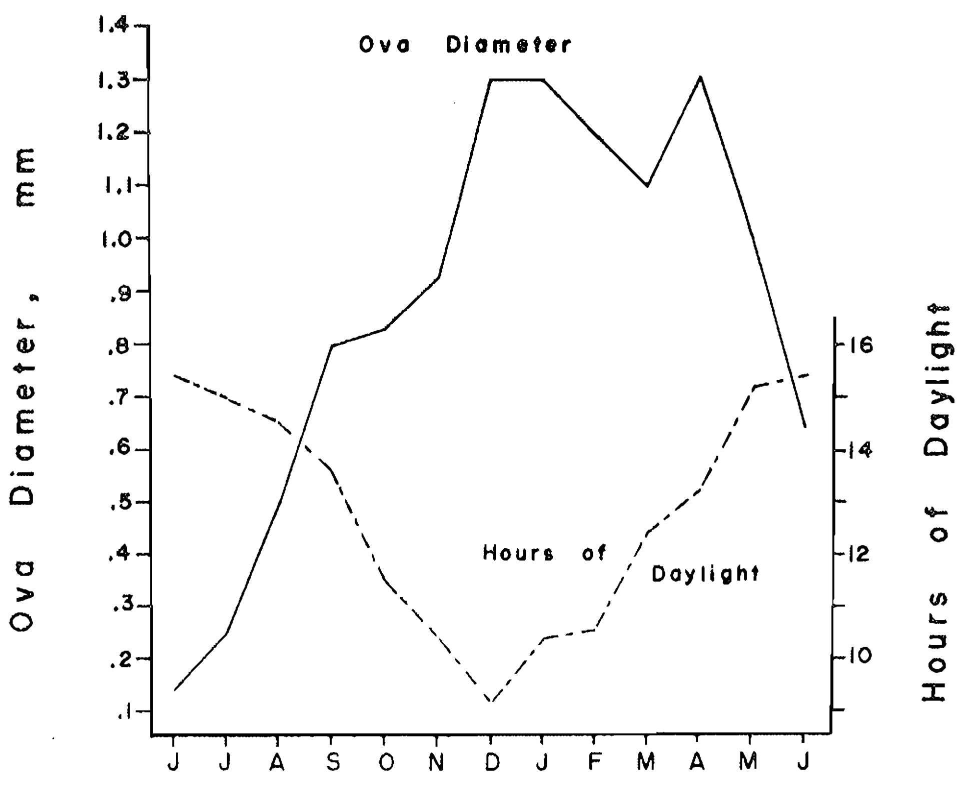
Males were significantly more abundant than females in the study (0.05% level chi-square), 319 compared to 207, or 1.54:1.0 males to females. A 1:1 ratio existed in July and August with males becomine more numerous with the onset of reproductive development (Table 13). The greatest ratios, 2.2:1, 1.88:1, 2.2:1, 3.14:1, and 1.9:1 occurred in November, December, March, April, and May, respectively.

Tuberculation of males represented the most obvious sexual dimorphism and was concurrent with the development of the gonads. Tubercle development occurred over the surface of the nape,

Figure 12. Average monthly ova diameters of 207 female smallmouth buffalo from Rough River Lake, Kentucky, July 1975 through June 1976.



Ova Diameter
Temperature
Ova Diameter, mm
Temperature, °Celsius
J J A S O N D J F M A M J



Ova Diameter
Hours of Daylight
Ova Diameter, mm
Hours of Daylight
J J A S O N D J F M A M J

Figure 13. Average number of mature ova per collection of 36 gravid female smallmouth buffalo from Rough River Lake, Kentucky, July 1975 through June 1976.

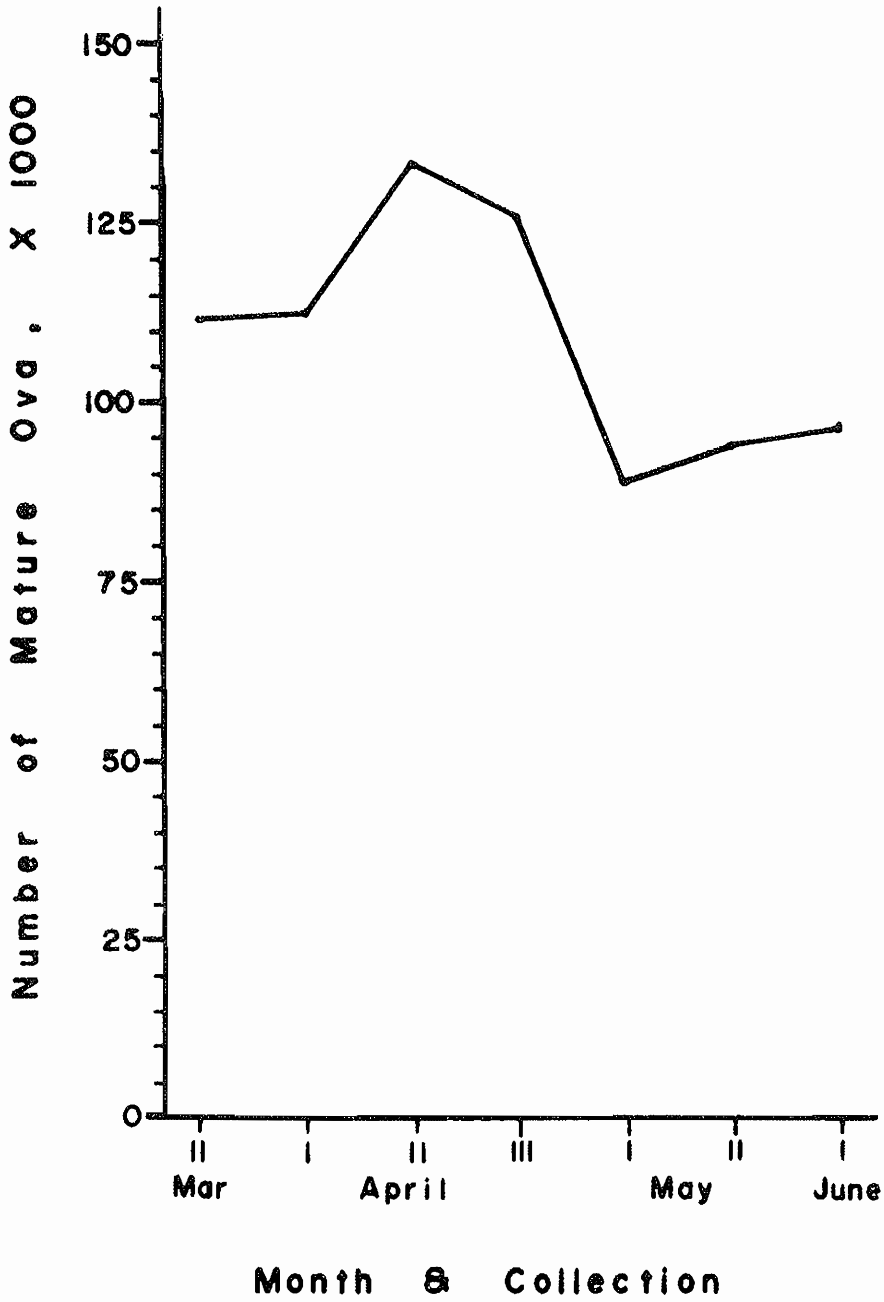

Number of Mature Ova. X 1000
150
125
100
75
50
25
0
II
I
II
III
I
II
I
Mar
April
May
June
Month & Collection

Table 13. Ratio of male to female smallmouth buffalo taken from Rough River Lake, Kentucky, June 1975 through June 1976.

	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June
Males	46	13	40	20	14	22	15	3	19	24	69	19	15
Females	41	13	43	15	8	10	8	2	17	11	22	10	7
Sex Ratio	1.12:1	1:1	.93:1	1.33:1	1.75:1	2.2:1	1.88:1	1.5:1	1.12:1	2.2:1	3.14:1	1.9:1	2.14:1

dorsal and lateral head surfaces, and base of the pectoral fins.

Discussion

Although more than 770 buffalo were tagged and released in apparent good health in Rough River Lake, only one long-term recapture was made during the study. Several factors might explain this condition: a) high mortality due to handling, time spent out of water, or shock from tag application; b) poor tag retention with short term loss of tags; or c) the resident buffalo population was so large that the probability of recapture was unlikely. From data observed in this study, the first two hypotheses were excluded due to the short term recaptures (captures the same 3-day period as the release) of 2% of the marked specimens and their subsequent good health and tag retention, including having been entangled in net meshing. The last alternative, in view of toxicant sampling data, appeared the most plausible and accepted.

The size of the smallmouth buffalo population in Rough River Lake ranged from a 4-year averaged estimate of 134,385 to as high as a 1976 estimate of 193,800. Both of these figures represent conservative estimates and do not adequately represent the actual size when, in general, ratio estimates tend to be under-estimates, and no individuals less than 228 mm TL, 2 years of age, i.e., the recruitment component of the population, were taken either with toxicant or net sampling in this study. Whatever the size of the population, one obvious feature shown by the toxicant data was the increase in the size of the population from 1974 through 1976. Also, during this period, the average estimated number of buffalo per acre increased from a 1974 low of 12.3/acre to 38.0/acre in 1976.

It was concluded from data in this study that young-of-the-year smallmouth buffalo represented a distinct population in Rough River Lake, one that does not integrate with the larger members of the species nor segregates its members until they are at least 1 to 1.5 years of age and 200 mm TL. Beckman and Elrod (1971) reported taking young-of-the-year smallmouth buffalo in Lake Oahe, North and South Dakota, with 100-foot seines, but made no mention of adults in their collections or recruitment of young-of-the-year. Walburg and Nelson (1966) reported smallmouth buffalo specimens from Lewis and Clark Lake, South Dakota, ranging from 52 to 139 mm TL but gave no information regarding method of capture (gill netting versus trawl) or recruitment. Patterson (1968) reported data similar to that of this study in that no captures of members of Age Groups 0 or I using stretch meshes as small as 2 inches were made in Elephant Butte Lake, New Mexico. Martin, et al. (1964) reported smallmouth buffalo to be sedentary for up to two years following hatching. His contention was that this sedateness prevented entanglement of the young fish in passive lineal tackle. In Rough River Lake this did not seem to be the case as even sedate members would be taken in random toxicant samples. It is suggested from these data that young-of-the-year smallmouth buffalo in Rough River Lake form an independent, segregated population that confines its presence to deep reservoir locales, or more likely, headwater stream reaches up to at least the second growing season. However, no information was obtained indicating the size of this component of the population in Rough River Lake, the exact time or extent of recruitment of young-of-the-year, or even the success of reproduction in recent spawns.

As determined by scale analysis, 11 age groups were represented in this study. This longevity appeared to generally typify the smallmouth buffalo as studies in New Mexico (Moody, 1970), Oklahoma (Jenkins, 1953), South Dakota (Bureau of Commercial Fisheries, 1965), and Tennessee (Schoffman, 1944) all indicated a 9 to 11 year life span. However, extremes of up to 15 years have been presented by Patterson (1968), Martin et al. (1964), and Purkett (1958).

Concerning aging of smallmouth buffalo by annulus enumeration, it should be pointed out that in some cases in this study, annuli showed markedly different formations among similar age groups. Some individuals had obvious false annuli just before the true annulus while other members of the same year class failed to show such patterns. Only distinct, morphological bodies were counted, excluding in those instances bodies felt to be false annuli. Consequently, if aging in this study was biased, it was toward underaging the population.

Growth of Rough River buffalo was typical of that of most fishes, growing rapidly in length early in life and in weight during the latter years. Buffalo in this study showed markedly different growth patterns, reaching 61% of their maximum observed TL by the fourth year in the first segment of the study, while reaching only 40% by the fourth year during the second segment. Also, with increasing age, growth increments decreased. This reduced growth was closely correlated with the increased density and dominating influence of buffalo spawned in 1969 and 1970 (Age Groups IV and V in Segment One and V and VI in Segment Two). Smallmouth buffalo populations exhibit strong and weak year classes cyclically through time (Walburg, 1964; Walburg and Nelson, 1966; Jester, 1973) and the effects of these year classes may be evidenced in reduced growth as well as reduced fecundity and reproductive success. Upon reaching 400 - 410 mm TL by the fourth or fifth year, growth in length markedly decreased, requiring an additional 4 - 5 years to reach 550 mm TL. During this slowdown in growth, younger age classes caught up producing a great mixture of age groups in a 150 mm size range. Eighty-five percent of all buffalo taken in this study were present in this size range. The dominant year classes observed, 1969 and 1970, were products of successful spawns the first two years the lake was intensively commercially fished.

The average total length of all buffalo taken in this study was 460 mm, indicating the majority of fish to be on the lower end of the 400 - 550 mm range. These data are suggestive of an overcrowded, slow-growing population. However, Schoffman (1944) presented data from Reelfoot Lake, Tennessee, buffalo in which 76% of the population ranged from 3 through 6 years of age and 389 through 554 mm TL, and Patterson (1968) reported 84% of Elephant Butte Lake, New Mexico, buffalo to range from 400 - 550 mm TL and 4 - 15 years of age. These findings were very similar to those observed in this study, yet those authors made no implications regarding density-growth or dominating year class problems.

Growth of the smallmouth buffalo in Rough River Lake was above average when compared with information in the literature. However, certain year classes of Rough River fish showed better first year growth than others. Segment One fish spawned from 1965 through 1967 averaged 174 mm growth the first year compared to an average of 111 mm for the 1964 and 1968 through 1971 spawns. Segment Two fish for the same time periods averaged 126 mm and 105 mm, respectively. Growth patterns of the buffalo during these years conform to the hypothesis of Bennett (1971) describing fish cycles in reservoirs. During the first years of impoundment (1963-1967), the buffalo began to take hold in the lake and in reasonably low numbers reproduced. Initial reproductive success was high and annual growth increments increased until population densities reached a high enough level that competition among similarly sized fish began having an adverse affect upon growth.

During the period October 1967 through October 1968, six years following the impoundment of Rough River, contracted commercial fishing was first allowed on the reservoir with the removal of 4958 buffalo averaging 8.8 lbs (Laflin and Renaker, 1969). In 1969, commercial fishing was opened to the public with an initial heavy removal of large buffalo. Since the first years of public commercial fishing, netting pressure has progressively decreased due to the reduced catch of large (10 - 30 lb) fish and increased tackle vandalism (Hoyt and Flynn, 1974), until 1974 when less than 3,000 lbs of buffalo were removed from the lake by netting tackle and 1976 when commercial fishing by lineal netting was prohibited.

During this period of commercial fishing, lineal net mesh size was limited to a minimum of 4-inch bar mesh and hoop net meshing of 3-inch bar mesh. As reported by Hoyt and Flynn (1974), and observed in this study, buffalo less than six pounds are not subject to capture in 4.0-inch mesh netting. Based on these findings, and data reported by Laflin and Renaker (1969), it can be assumed that the larger, older component of the population, six years and older and six pounds and larger, were cropped off in this early harvest and kept in low frequency by the subsequent selectivity of the 4.0-inch legal mesh restriction. Concurrent with this harvest of the older individuals was the successful spawning of medium to large size buffalo in 1969 and 1970 and the eventual recruitment of these large spawns into the population as dominant year classes. With the early rapid growth of buffalo, these recruited 1969-1972 spawns grew in length to 400 - 550 mm TL and presently comprise the majority of the population. It can be hypothesized that, on the basis of their numbers, this large number of similarly sized fish are in competition for habitat, space, and food, causing altered, reduced growth rates. The small percentage of the population present greater than 550 mm TL was due to natural mortality, plus fishing mortality coupled with existing density controlled reduced growth and not entirely a result of inherent natural mortality patterns of the species.

Growth in weight of smallmouth buffalo in Rough River Lake conformed to that reported by Schoffman (1944) in Reelfoot Lake, Tennessee. Data presented by Jester (1973) and Patterson (1968) was much lower for each year class than that observed in this study. Weights for 14-year-old fish reported by Patterson (1968) were very similar to that of 10-year-old fish in this study and for 9 and 10-year-old fish of Schoffman (1944). As reported earlier, analysis of buffalo scales was difficult and the age and weight differences observed between these studies might well be due to discrepancies in annuli enumeration rather than biological features.

An interesting growth characteristic between Segment One and Segment Two fish was indicated by the length-weight formula exponent n. Segment One fish had greater length and weight growth increments than Segment Two fish, but contrastingly had a lower n value, 2.9172 versus 3.082. While growth was greater in Segment One fish, that growth in length and weight was disproportionate, not conforming to the cubic response, while in the slower growing Segment Two fish, that growth in length and weight was proportional to the cubic response, even though of lesser magnitude.

The condition of Rough River buffalo, grand mean 1.60, was greater than those condition values reported by Carlander (1969), Swingle (1965), Patterson (1968), Padilla (1972), and Moody (1970), which ranged from 1.29 to 1.53. These data indicate that, in spite of crowding in the lake, Rough River Lake does provide excellent habitat for buffalo which show excellent, but lessening condition values. The influence of the dominant age groups, IV and V in Segment One and V and VI in Segment Two, on the population was also evidenced in condition values among different size groups of buffalo. During the first segment of the study, the smallest fish had the highest average condition, indicating a rapid rate of growth in the early years with a lack of stress due to the influence of large numbers of similar sized, multi-aged individuals. The oldest, largest individuals, 551+ mm, had the lowest conditions indicating continued stress with poor growth patterns. In the second segment, growth patterns were altered such that condition values of the smallest specimens were lower than medium-sized fish but the largest fish still showing the lowest condition.

Females had slightly higher average condition values than males, but this difference, rather than being a result of different growth patterns, was probably a result of the larger gonads of the females.

Buffalo appeared to be evenly distributed throughout Rough River Lake. Fish were caught throughout all vertical strata, but more commonly nearer the bottom than surface. A size difference was noted between those fish taken in the toxicant studies and netting tackle indicating that smaller sized fish tended to stay in the coves while the larger specimens generally favored the lake proper.

Greater fishing effort was directed to the South Fork of the lake due to the greater surface area capable of being fished and the fewer water recreation enthusiasts. Buffalo movements were most obvious during the spawning season when a "run" was made up into headstream effluents. This run began in late March and reached its peak intensity in mid-April.

The most efficient tackle used in this study was the flag net. This type of tackle does not employ permanent weights or floats and consequently presents less of a vertical barrier in the water column, thereby reducing its chances of detection by fishes. Gill nets used were both "hobbled" and "non-hobbled". Those gill nets that were hobbled provided some of the same advantage as that of the flag nets in hanging loose in the water and were consequently more efficient in taking buffalo than the non-hobbled nets. Hoop nets, unbaited, were used, but during the spawning season, the time of maximum fish movement, water levels were so high that the nets could not be placed in former creek beds and channels, thereby reducing the success of this type of tackle.

Three-inch-mesh tackle proved to be the most efficient mesh size used. This was a result of the size composition of the population being majoritively 400 - 550 mm TL and 3.5 to 4.0 lbs. Martin, et al. (1964) and Patterson (1968) reported buffalo 400 - 420 mm TL and larger to be consistently captured in 3.0-inch mesh (6.0-inch stretch mesh). Those data agreed with that observed in this study.

While on the average the larger mesh caught the largest fish, the largest buffalo taken in this study with net tackle weighed 22.0 pounds and was taken in 2.5-inch mesh. The largest buffalo taken from Rough River Lake during the study was a

31.0 pound fish taken in the 1976 June toxicant study.

The spawning season of the smallmouth buffalo extended from early March through May at a temperature range of 15 C to 23 C. The most intense period of reproductive activity occurred from the second through the fourth week of April at a temperature of 19 C and an average daylight period of 13 hours. The spawning period for the species has been reported from March and April at 15.5 C (Heard, 1958), April through June at 20 C to 24.5 C (Moody, 1970), and from early May into September at 19.1 C to 27.5 C (Padilla, 1972).

Males reached sexual maturity at an earlier age and time of the season than did females and maintained a longer annual period of sexual development. The 1969-70 year classes dominated the reproductive population. Reproductive activity appeared to be closely tied to water temperature and daily light and/or dark periods. As water temperature approached 15 C and day lengths increased to 12 hours in the late winter and early spring, gonad development and ova diameters increased. Following the post-spawning summer period, when day lengths decreased to approximately 13 hours and water temperatures ranged from 12 to 14 C, a second period of gonad development was recorded. An unusual water temperature increase in October succeeded in bringing about a gonadal development equal in some respects to that of the spring. Males did exhibit tubercle development and milt discharge during this period.

Eighty-six percent of all females collected during the spawning season were gravid. While Age Groups V and VI comprised

85% of the total population in Segment Two, females of these age groups made up 58% of the spawning females and 54% of all mature eggs. The number of mature eggs produced was directly proportional to the age of the fish. Males were more abundant than females in the study: 1.54:1. Patterson (1968) reported a ratio of 1.9:1 males to females and Padilla (1972) reported 1.4:1. Males in Rough River Lake also tended to outlive females, contrary to that reported by Jester (1973).

Spawning in Rough River Lake occurred primarily in small headwater streams and in the upper headwaters area. No observations of actual spawning behavior were made, but on the basis of sex ratios and the depth of the water at capture, it was concluded that each female was attended to by more than one male and that the eggs were spread randomly over a mud and gravel bottom at depths ranging from 10 to 20 feet. Jester (1973) and Padilla (1972) suggested similar hypotheses regarding smallmouth buffalo spawning activity and reported vegetation to be used as a spawning substrate only when available.

The dominance of the 1969-70 year classes in the population could not be determined to have any adverse affects on spawning. However, the degree of reproductive success appeared to have been altered as indicated by the lack of recruitment of 200 - 350 mm individuals into the population. An additional two to three year's data would be necessary to confirm the effects of this population structure on reproductive success.

Management practices to correct the density, year class dominance conditions of the Rough River Lake smallmouth buffalo would include an intensive, selective removal of three to five pound specimens with subsequent annual harvest quotas of three pound and larger individuals.

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Appendix A. Location, size, number and weight of fish taken per collection station, Rough River Lake, Kentucky, July 1974 through June 1976.

Collection	No. of Fish	Wt. of Fish	Surface Acres	Location
SEGMENT ONE				
I July, 1974 (toxicant)	44	72.75	2.21	South Fork, 2 mi down from mouth of Little Clifty Ck.
I Aug, 1974	5	18.45	50.40	South Fork, 2 mi down from mouth of Little Clifty Ck.
II Aug, 1974 (toxicant)	29	89.90	1.35	North Fork, 1/4 mi up from confluence of North and South Fork.
III Aug, 1974	31	104.86	20.40	South Fork, 1/2 mi up from mouth of Peter Cave Ck.
I Sept, 1974	25	110.71	39.00	North Fork, 2 mi up from Hgwy. 259.
II Sept, 1974	23	72.08	39.30	South Fork, 2 mi down from mouth of Peter Cave Ck.
I Oct, 1974	47	174.97	36.90	South Fork, 1/2 mi down from mouth of Little Clifty Ck.
II Oct, 1974	42	123.40	43.30	South Fork, 1/4 mi up from mouth of Panther Ck.
I Nov, 1974	51	184.25	73.60	South Fork, 1/2 mi up from confluence of North and South Fork.
II Nov, 1974	18	60.03	32.50	North Fork, 1/2 mi up from confluence of North and South Fork.
I Dec, 1974	37	139.84	43.30	South Fork, from mouth of Cave Ck to 1/4 mi upstream.
II Dec, 1974	9	30.69	58.00	South Fork, 3/4 mi up from confluence of North and South Fork.

Appendix A. (continued)

Collection	No. of Fish	Wt. of Fish	Surface Acres	Location
I Jan, 1975	2	5.93	55.70	South Fork, 1.5 mi up from mouth of Panther Ck.
II Jan, 1975	8	28.95	20.40	South Fork, 1/2 mi up from mouth of Peter Cave Ck.
I Feb, 1975	8	26.20	21.40	South Fork, 3/4 mi down from mouth of Peter Cave Ck.
II Feb, 1975	9	30.73	36.90	South Fork, 1/2 mi down from mouth of Little Clifty Ck.
I Mar, 1975	21	65.43	18.50	South Fork, from Hgwy 737 bridge to mouth of Peter Cave Ck.
II Mar, 1975	24	87.25	18.50	South Fork, 1/4 mi up from mouth of Peter Cave Ck.
I Apr, 1975	99	331.07	18.50	South Fork, 1/4 mi up from mouth of Peter Cave Ck.
II Apr, 1975	47	180.07	18.50	South Fork, 1/4 mi up from mouth of Peter Cave Ck.
III Apr, 1975	67	288.12	18.50	South Fork, 1/4 mi up from mouth of Peter Cave Ck.
I May, 1975	0	----	18.50	South Fork, 1/4 mi up from mouth of Peter Cave Ck.
II May, 1975	10	39.78	36.90	South Fork, 1/2 mi down from mouth of Little Clifty Ck.
I June, 1975	4	14.82	43.30	South Fork, 1/4 mi up from mouth of Panther Ck.
II June, 1975 (toxicant)	113	324.80	2.21	South Fork, 2 mi down from mouth of Little Clifty Ck.
SEGMENT TWO				
I July, 1975	3	19.32	39.00	North Fork, 2 mi up from Hgwy. 259.
II July, 1975 (toxicant)	43	159.53	1.35	North Fork, 1/4 mi up from confluence of North and South Fork.

Appendix A. (continued)

Collection	No. of Fish	Wt. of Fish	Surface Acres	Location
I Aug, 1975	9	31.01	50.40	South Fork, 2 mi down from mouth of Little Clifty Ck.
II Aug, 1975	7	28.28	40.30	North Fork, 1.5 mi down from Hgwy. 259.
III Aug, 1975 (toxicant)	75	224.12	3.17	South Fork, cove at mouth of Cave Ck.
I Sept, 1975	15	58.46	39.30	South Fork, 2 mi down from mouth of Peter Cave Ck.
II Sept, 1975	29	116.31	36.90	South Fork, 1/2 mi down from mouth of Little Clifty Ck.
I Oct, 1975	22	84.04	20.40	South Fork, 1/2 mi up from mouth of Peter Cave Ck.
II Oct, 1975	20	119.36	43.30	South Fork, 1/4 mi up from mouth of Panther Ck.
I Nov, 1975	43	162.61	43.30	South Fork, from mouth of Cave Ck to 1/4 mi upstream.
II Nov, 1975	11	45.78	97.90	South Fork, from mouth of Cave Ck to 1/2 mi upstream.
I Dec, 1975	13	49.78	32.50	South Fork, at mouth of Cave Ck.
II Dec, 1975	11	48.71	58.00	South Fork, 3/4 mi up from confluence of North and South Fork.
I Jan, 1976	5	26.26	63.40	South Fork, 1/4 mi down from confluence of North and South Fork.
I Feb, 1976	9	41.76	58.00	South Fork, 3/4 mi up from confluence of North and South Fork.
II Feb, 1976	56	215.42	18.50	South Fork, 1/4 mi up from mouth of Peter Cave Ck.

Appendix A. (continued)

Collection	No. of Fish	Wt. of Fish	Surface Acres	Location
I Mar, 1976	20	65.75	18.50	South Fork, 1/4 mi up from mouth of Peter Cave Ck.
II Mar, 1976	39	137.94	21.40	South Fork, 3/4 mi down from mouth of Peter Cave Ck.
I Apr, 1976	79	266.26	18.50	South Fork, 1/4 mi up from mouth of Peter Cave Ck.
II Apr, 1976	41	135.92	18.50	South Fork, 1/4 mi up from mouth of Peter Cave Ck.
III Apr, 1976	48	168.57	18.50	South Fork, 1/4 mi up from mouth of Peter Cave Ck.
I May, 1976	15	46.10	18.50	South Fork, 1/4 mi up from mouth of Peter Cave Ck.
II May, 1976	15	45.90	18.50	South Fork, 1/4 mi up from mouth of Peter Cave Ck.
I June, 1976	17	51.89	21.40	South Fork, 3/4 mi down from mouth of Peter Cave Ck.
II June, 1976	7	25.88	18.50	South Fork, 3/4 mi down from mouth of Peter Cave Ck.