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AGE AND GROWTH OF LARGEMOUTH BASS IN LAKE SHELBYVILLE, ILLINOIS

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ABSTRACT

Age and growth of largemouth bass, *Micropterus salmolides*, in Lake Shelbyville, Illinois, were determined based on electrofishing collections made in September of 1979-81. Age-structure analysis indicated that recruitment of largemouth bass was variable; stronger year classes were associated with years that had mean water levels higher than the previous summer. Weighted mean lengths at annulus formation for age I-IV largemouth bass were 133, 247, 311, and 356 mm, respectively. Corresponding calculated weights were 27, 198, 413, and 635 g. The scarcity of largemouth bass older than age IV indicated high mortality after harvestable size ($\geq$356 mm TL) was attained. Analysis of length-frequency distributions indicated a desirable size structure during this study. A decrease in proportional stock density (PSD) from 1979 to 1981, reflected variable recruitment. The percentage of harvestable-size bass ($\geq$356 mm TL) increased from 1979 to 1981, reflecting variable recruitment and reduced mortality caused by imposition of a 356-mm length limit in 1978. Management strategies should be directed toward increasing recruitment of largemouth bass to age I rather than attempting to increase growth rates or improve the condition of older fish.

INTRODUCTION

The largemouth bass, *Micropterus salmoides*, is one of the most important game fish in Illinois. Comparative estimates of age and growth of this species are needed to develop effective management strategies. Although data are available on growth of largemouth bass in smaller bodies of water in Illinois (Carlander 1977), there is little information on growth rates in larger reservoirs.

From scale samples collected in 1975 and 1976, Joy and Tranquilli (1979) reported the growth of this bass in Lake Shelbyville, Illinois, during the first 5 years of impoundment (1971-1975). The purpose of this paper is to describe age and growth of largemouth bass in Lake Shelbyville during the second 5 years of impoundment (1976-1980).

STUDY AREA

Lake Shelbyville, a flood control reservoir in central Illinois, was established in 1970; its major tributaries are the Kaskaskia and West Okaw Rivers. At normal summer pool (182.8 m msl) the reservoir has a surface area of 4,490 ha with mean and maximum depths of 4.9 and 18.0 m, respectively. A draw down of 1.2 m occurs in October. Refill begins the following May. For chemical characteristics see Davis and Storck (1983).

Largemouth bass were sampled at two stations in the reservoir: I in the lower main body and II in the Kaskaskia arm (Figure 1). In January 1978, a 356-mm (14-in) length limit was established for largemouth bass. The principal forage of age I and older largemouth bass is gizzard shad, *Dorsoma cepedianum* (Storck et al. 1982).

METHODS

Largemouth bass were collected in mid-September of 1979, 1980, and 1981 using 230-v, AC boat-mounted electrofishing gear. Collections were made at the two stations on consecutive days; sampling techniques consisted of continuous electrofishing along the shoreline, emphasizing the same area each year. All largemouth bass taken were measured to the nearest millimeter total length (TL) and weighed to the nearest gram.

Scale samples, from all fish collected, were removed below the lateral line at the tip of the pectoral fin, cleaned, impressed on cellulose acetate strips, and examined on a microprojector (26.5X). Age was determined by counting annuli on non-regenerated scales. Total scale radius (distance from the focus to the margin measured along the anteriomedian radius) and distance to each annulus were measured to calculate growth history.

The body length-scale radius relationship was determined from pooled data for all 3 years ($n = 847$) by plotting the mean total length against scale radius for fish in 10-mm length groups. The resulting plot revealed a curvilinear relationship and a line was fitted by eye (Figure 2). Means of total length, scale radius, and distance to each annulus were calculated for each age group in each year and adjusted to fit the line (Bagenal and Tesch 1978). Using the adjusted values, corresponding mean lengths at annulus formation for each age group were determined from the graph. Weighted mean lengths at annulus formation were also established for each age group and for all age groups combined.

The length-weight relationship was determined from 532 largemouth bass age I and older. Age 0 fish were not included because the field scale did not accurately weigh small fish. Log-log plots of mean length against mean weight for fish in 10-mm length groups revealed a linear relationship ($r^2 = 0.995$) that was best described by the equation

$$\log WT = 3.1925(\log TL) - 5.4327 \qquad (1)$$

To evaluate condition, relative weights (Wr, Wege and Anderson 1978) were calculated for individual fish using the equation

$$Wr = W/Ws \times 100 \qquad (2)$$

where W = the actual weight of the fish and Ws = a standard weight determined for fish of the same length. Standard weights were determined using the equation

$$\log Ws = -5.316 + 3.191 \log TL \qquad (3)$$

(Wege and Anderson 1978). Mean Wr values were calculated for each age group and for all age groups combined.

To assess the balance of the largemouth bass population in Lake Shelbyville, proportional stock density values (PSD, Anderson 1976) were determined for each year. PSD (%) was determined by dividing the number of quality-size largemouth bass ($\geq$300 mm TL) by the number of stock-size bass ($\geq$200 mm TL).

Relative stock densities (RSD, Wege and Anderson 1978) of bass $\geq$356 mm TL were determined to evaluate the percentage of harvestable-size bass in the stock. RSD (%) was determined by dividing the number of fish $\geq$356 mm TL by the number of fish $\geq$200 mm TL.

Mean reservoir elevation (meters above mean sea level) from April through October, the normal growing season of largemouth bass in Lake Shelbyville (Joy and Tranquilli 1979), was obtained for each year from data compiled by the U.S. Army Corps of Engineers.

RESULTS AND DISCUSSION

Age Structure

The age structure of largemouth bass collected indicated that recruitment in Lake Shelbyville was highly variable (Figure 3). During 1979 and 1980, the 1977 year class was dominant, comprising 64 and 40% of age I and older fish captured. In 1981 no year class was clearly dominant, excluding young-of-the-year; however, the 1980 year class was most abundant. The strength of the 1978 year class was apparently underestimated in 1979 because greater numbers were collected in 1980 and 1981 (Figure 3).

Growth

Weighted mean lenghts at annulus formation for ages I-IV largemouth bass were 133, 247, 311, and 356 mm, respectively (Table 1). Corresponding calculated weights at annulus formation were 27, 198, 413, and 635 g, respectively. Growth beyond age IV was not determined, because few older fish were collected and their scales were difficult to interpret.

The pooled length-frequency distribution of all bass collected was compared with weighted mean lengths at annulus formation determined by back-calculation (Figure 4). Successive modes in the length-frequency distribution corresponded to weighted mean lengths at annulus formation for age I-IV largemouth bass. Considerable overlap occurred, however, in the length distributions of age II and older fish. The back-calculated mean length of bass at the first annulus was considerably larger than the mean length of young-of-the-year collected in the fall (Figure 4). Back-calculated lengths at the first annulus for the 1979 and 1980 year classes were 116 and 126 mm, respectively; but, mean lenghts of those year classes in September of their first year were 99 and 110 mm. Because little growth occurs between late September and the time of annulus formation, mortality was greater for smaller members of the two year classes between fall of their first and second years of life. Joy (1976) reported an increase in mean total length of young-of-the-year largemouth bass in Lake Shelbyville from 100 mm in December 1975 to 118 mm in March 1976, attributing the increase to greater winter mortality of smaller individuals due to predation and exhaustion of stored energy reserves. Higher winter mortality of smaller members of a year class of largemouth bass has also been reported for Bull Shoals reservoir (Aggus and Elliott 1975) and for Dryden Lake, New York (Green 1982).

The 1977 and 1978 year classes of largemouth bass exhibited the greatest first-year growth in this study, while the 1979 year class exhibited the slowest growth (Table 1). The 1977 and 1978 year classes were considerably stronger than the 1979 year class (Figure 3). Several authors have linked the development of strong year classes and rapid first-year growth of largemouth bass to maintenance of high water levels during most of the growing season (Patriarche and Campbell 1957, von Geldern 1971, Aggus and Elliott 1975, Keith 1975). High levels usually result in an abundance of flooded terrestrial vegetation that increases the food supply and offers protection to young largemouth bass from predation (Aggus and Elliott 1975). In 1977, the mean summer water level was not abnormally high (Table 1) but had increased over 2 m relative to the mean of the previous summer. In 1978, the mean water level again increased nearly 1 m over that in 1977. In both years, large areas of terrestrial vegetation were inundated. In 1979, however, the mean water level differed little from that in 1978, and consequently , little terrestrial vegetation was flooded. Thus, survival and growth of young-of-the-year largemouth bass in Lake Shelbyville were greater in the 2 years in which large areas of terrestrial vegetation were inundated. If winter survival was dependent upon length attained during the first growing season, the rapid growth of fish in the 1977 and 1978 year classes may have enhanced recruitment to age I.

Few largemouth bass older than age IV were collected (Figure 3), indicating high mortality of older age groups. Because largemouth bass generally reach legal size (>356 mm TL) at age IV (Table 1), fishing harvest is the likely cause of this mortality. This hypothesis is supported by lower back-calculated estimates of length for the 1977 and 1978 year classes between years (Lee's phenomenom, Ricker 1975), resulting from the selective removal of faster growing individuals as they attained a harvestable size (Ricker 1975). Further research using population estimates and creel survey data are needed to determine what fraction of this mortality can be attributed to fishing and what fraction to natural causes.

Typically, growth and production of largemouth bass populations in new impoundments are high initially by decline in subsequent years (Bennett 1962). The initial peak in production, usually lasting only 2 or 3 years, results from an abundant food supply and lack of competition. As the reservoir ages, however, inter- and intraspecific competition becomes more severe. In Lake Shelbyville, length attained at annulus I was greater during the first 5 years of impoundment (Joy and Tranquilli 1979, Table 2); but, growth to each subsequent annulus was slightly greater during the second 5 years. Thus, a decrease in the growth of age I and older largemouth bass was not associated with the increasing age of Lake Shelbyville during the initial 10 years of impoundment. In contrast, other authors have reported that after an initial peak, growth of older largemouth bass declined over an extended interval (Patriarche and Campbell 1957, McCrain and Mullan 1960, Bryant and Houser 1971, Chance et al. 1975).

Growth of largemouth bass in Lake Shelbyville was generally greater than reported for other Illinois waters (Table 2). Growth to annulus I was less than the Illinois average (Lopinot 1972) but greater to each subsequent annulus. Growth of largemouth bass in Lake Sangchris and Coffeen Lake, two large impoundments in central Illinois, was substatially greater than that in Lake Shelbyville (Table 2); however, these lakes are cooling reservoirs and have an extended growing season (Joy and Tranquilli 1979, Perry and Tranquill 1983).

CONDITION

The slope of the length-weight regression of largemouth bass was significantly greater than 3.0 (t test, $P < 0.05$), indicating allometric growth. Therefore, traditional measures of condition could not be used to compare fish of different lengths (Ricker 1975). Relative weights (Wr) were calculated instead because they compensate for the inherent change in body form with increasing length and, thus, can be used to compare condition of fish of different lengths (Wege and Anderson 1978, Table 3).

A Wr value of 100 indicates that 75% of the populations of largemouth bass summarized from Carlander (1977) had a lower mean weight for that particular length. A Wr value of 93 indicates that only 50% of the populations had a lower mean weight for that particular length. Average Wr values for largemouth bass at the end of their second through fifth year of growth were 98.1, 93.6, 94.5, and 97.0, respectively (Table 3). Mean Wr values for the population of age II through IV largemouth bass increased from 94.7 to 95.9 from 1979 to 1981 (Table 3). These results indicate that largemouth bass in Lake Shelbyville during this study were in relatively good condition as compared to other populations from which standard weights have been derived.

Changes in Size Structure (1979-81)

Proportional stock density (PSD), an index used to assess the size structure of a species, is based upon the length-frequency distribution of the stock (Anderson 1976). Reynolds and Babb (1978) proposed target PSD values of 40-60% for largemouth bass in small midwestern impoundments dominated by the bass-bluegill combination. Anderson and Weithman (1978) recommended a PSD from 50 to 70% for largemouth bass in Missouri impoundments where gizzard shad is the dominant prey species. PSD values in Lake Shelbyville decreased from 68% in 1979 to 64% in 1980 and to 59% in 1981, indicating that a desirable size structure of largemouth bass was present during all 3 years.

PSD in Lake Shelbyville fluctuated in response to variable recruitment. In 1979, the 1977 year class was dominant (Figure 2). A majority of fish in this year class were ≥300 mm TL, resulting in the high PSD value for 1979 (68%). It is likely, however, that PSD was overestimated because the strength of the 1978 year class was underestimated. In 1980, the dominance of the 1977 and 1978 year classes, in conjunction with the relatively weak 1979 year class, resulted in a high PSD value (64%). A decrease in PSD in 1981 (59%) resulted from the recruitment of the 1978 year class into the sport fishery and their subsequent decline in abundance; also, the 1980 year class, which had reached stock size (≥200 mm TL), was the most abundant age group in the sample.

Relative stock density (RSD) is the percentage of any defined size group in the stock (Wege and Anderson 1978). RSD values for largemouth bass ≥ 356 mm TL increased from 16% in 1979 to 27% in 1980 to 39% in 1981. This increase in percentage of harvestable largemouth bass reflected the entry of the strong 1977 and 1978 year classes into the sport fishery and a reduction in fishing mortality due to the 356-mm (14-in) length limit imposed in 1978.

Management Implications

The largemouth bass population in Lake Shelbyville is characterized by highly variable recruitment, satisfactory growth and condition, and a high mortality rate of older age groups after they attain a harvestable size (>356 mm TL). Management strategies to enhance the largemouth bass fishery, therefore, should try to increase recruitment rather than growth rates.

The results of this study indicate that growth and survival of young-of-the-year largemouth bass were greatest in years when large areas of terrestrial vegetation were inundated. Consequently, the size of the largemouth bass population may be managed by manipulating water levels. However, the lake is a flood control reservoir, and therefore, this strategy cannot be consistently applied. Alternative strategies to enhance recruitment may involve supplemental stocking of fingerling largemouth bass during years of inadequate reproductive success, or seeding of the reservoir fluctuation zone (Strange et al. 1982) to provide additional food and cover for young-of-the-year. Because our data suggest that winter mortality of young-of-the-year largemouth bass may be size-selective for smaller individuals, recruitment may be enhanced by methods that increase growth of smaller individuals. The effect of differential mortality on subsequent year class strength, however, requires further investigation.

PSD values obtained during this study indicated a desirable size structure of largemouth bass in Lake Shelbyville. It is believed that this is due, in part, to the imposition of the 356-mm length limit in 1978. Changes in the current size limit would affect angler catch and harvest rates of largemouth bass; but, further research in to the causes of high mortality of the older age groups is needed before further changes are proposed.

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LITERATURE CITED

Anderson, R.O. 1976. Management of small warmwater impoundments. Fisheries 1(6):5-7, 26-28.

Anderson, R.O. and A.S. Weithman. 1978. The concept of balance for coolwater fish populations, p. 371-381. *In* R.L. Kendall (ed.) Selected coolwater fishes of North America. Am. Fish. Soc. Spec. Publ. 11.

Aggus, L.R., and G.V. Elliott. 1975. Effects of cover and food on year-class strength of largemouth bass, p. 317-322. *In* R.H. Stroud and H. Clepper (eds.) Black bass biology and management. Sport Fishing Institute, Washington, D.C.

Bagenal, T.B., and F.W. Tesch. 1978. Age and growth, p. 101-137. *In* T. Bagenal (ed.) Methods for assessment of fish production in fresh waters. Blackwell Scientific Publications, Oxford, England.

Bennett, G.W. 1954. Largemouth bass in Ridge Lake, Coles County, Illinois. Ill. Nat. Hist. Surv. Bull. 26(2):217-276.

Bennett, G.W. 1962. Management of artificial lakes and ponds. Reinhold Publishing Corp., New York. 283 p.

Bryant, H.E., and A. Houser. 1971. Population estimates and growth of largemouth bass in Beaver and Bull Shoals Reservoirs, p. 349-357. *In* G.E. Hall (ed.) Reservoir fisheries and limnology. Am. Fish. Soc. Spec. Publ. 8.

Carlander, K.D. 1977. Handbook of freshwater fishery biology, vol. 2. The Iowa State University Press, Ames. 432 p.

Chance, C.J., A.O. Smith, J.A. Holbrook II, and R.B. Fritz. 1975. Norris Reservoir: a case history in fish management, p. 399-407. *In* R.H. Stroud and H. Clepper (eds.) Black bass biology and management. Sport Fishing Institute, Washington, D.C.

Davis, R., and T. Storck. 1983. Annual summary of water quality and biological investigations in Lake Shelbyville basin, 1981-1982. Ill. Nat. Hist. Surv. annual report to U.S. Army Corps of Engineers, St. Louis Mo.

Green, D.M. 1982. Population dynamics and management of largemouth bass (*Micropterus salmoides*) and chain pickeral (*Esox niger*) in Dryden lake, New York. Ph.D. Dissertation, Cornell Univ., Ithaca, N.Y. 163 p.

Joy. T. 1976. Lake Shelbyville fish populations. p.4.12-4.35. *In* J.M. McNurney and R.W. Larimore (eds.) Evaluation of a cooling lake fishery. Ill. Nat. Hist. Surv. first annual report to Electric Power Research Institute, Palo Alto, Ca.

Joy, T., and J.A. Tranguilli. 1979. Annual growth of largemouth bass in Lake Sangchris. Lake Shelbyville, and other midwestern waters, p.10.1-10.14. *In* J.M. McNurney and R.W. Larimore (eds.) Evaluation of a cooling lake fishery. vol. III. Ill. Nat. Hist. Surv. final report to Electric Power Research Institute. Palo Alto. Ca.

Keith, W.E. 1975 Management by water level manipulation. p.489-497. *In* R.H. Stroud and H. Clepper (eds.) Black bass biology and management. Sport Fishing Institute, Washington, D.C.

Lopinot. A.C. 1972. Pond fish and fishing in Illinois. Ill. Dep. Conserv. Fish. Bull. 5., Springfield. 72 p.

McCaig, R.S., and J.W. Mullan. 1960. Growth of eight species of fishes in Quabbin Reservoir. Massachusetts. in relation to age of reservoir and introduction of smelt. Trans. Am. Fish. Soc. 89(1):27-31.

Patriarche, M.H., and R.S. Campbell. 1957. The development of the fish population in a new flood control reservoir in Missouri, 1948 to 1954. Trans. Am. Fish. Soc. 87:240-258.

Perry, L.G., and J.A. Tranquilli. 1983. Age and growth of largemouth bass in a thermally altered reservoir as determined from otoliths. N. Am. J. Fish. Manage. (in press).

Price, O.M. 1966. A summary of eleven years of fishery management on Red Hills Lake. 1953 to 1963. Ill. Dep. Conserv. Spec. Fish. Rep. 12, Springfield. p. 34-35.

Reynolds, J.B., and L.R. Babb. 1978. Structure and dynamics of largemouth bass populations, p. 50-62. *In* G.D. Novinger and J. Dillard (eds.) New approaches to the management of small impoundments. N. Central Div.. Am. Fish. Soc. Spec. Fish. Publ. 5.

Ricker. W. 1975. Computations and interpretations of biological statistics of fish populations. Fish. Res. Bd. Can. Bull. 191, Ottawa, Canada. 382 p.

Rock L.F. 1966. A summary of nine years of fishery management on Johnson Sauk Trail Lake, 1956 to 1964. Ill. Dep. Conserv. Spec. Fish. Rep. 12. Springfield. p. 2-14.

Seneidermeyer. F., and W.M. Lewis. 1956. Utilization of gizzard shad by largemouth bass. Prog. Fish-Cult. 18(3):137-138.

Starrett, W.C., and A.W. Fritz. 1965. A biological investigation of the fishes of Lake Chautauqua, Illinois. Ill. Nat. Hist. Surv. Bull. 29(1):29-42.

Stinauer, R. 1966. A summary of ten years of fishery management on Ramsey Lake, 1953 to 1962. Ill. Dep. Conserv. Spec. Fish. Rep. 12, Springfield. p. 24-33.

Storck, T.W., B. Dimond, and S. Miller. 1982. Determinatin of factors affecting the survival of larval fish and an evaluation of their utilization as food by predators. Federal Aid in Fish Restoration Project F-31-R, Final report submitted to the Ill. Dep. Conserv., Springfield.

Strange, R.J., W.B. Kittrell. and T.D. Broadbent. 1982. Effects of seeding reservoir fluctuation zones on young-of-the-year black bass and associated species. N. Am. J. Fish. Manage. 2(4):307-315.

Thompson, D.H., and G.W. Bennett. 1949. Lake management reports 2. Fork Lake near Mount Zion. Illinois. Ill. Nat. Hist. Surv. Biol. Notes 9:1-14.

von Geldern. C.E., Jr. 1971. Abundance and distribution of fingerling largemouth bass. *Micropterus salmoides*, as determined by electrofishing in Lake Nacimiento, California Calif. Fish Game 57(4):228-245.

Wege. G.J., and R.O. Anderson. 1978. Relative weight (Wr): a new index condition for largemouth bass. p.79-91. *In* G.D. Novinger and J. Dillard (eds.) New approaches to the management of small impoundments. N. Central Div., Am. Fish. Soc. Spec. Publ. 5.

Table I. Calculated lengths (mm) and average growth increments of largemouth bass from Lake Shelbyville. Sample sizes of each age group are in parentheses. Water level is an average from April through October (mmsl).

Year Class	Water Level	Age Group I	II	III	IV
1981	602.8				
1980	599.0	126 (52)			
1979	602.4	116 (57)	228 (23)		
1978	602.3	138 (134)	247 (106)	309 (28)	
1977	599.5	141 (228)	254 (228)	313 (120)	351 (29)
1976	592.1	116 (48)	225 (48)	308 (48)	363 (16)
Weighted mean		133	247	311	356
Annual increment		133	114	64	45
Average weight at annulus formation (g)	27	198	413	635	

Table 2. Calculated total length (mm) at each annulus of large bass from various Illinois waters.

	Age Group						
Body of water	I	II	III	IV	V	n	Source
L. Shelbyville	133	247	311	356	-	527	Present study
L. Shelbyville	153	244	306	330	361	1288	Joy & Tranquilli 1979
Illinois average	160	229	295	343	401	-	Lopinot 1972
L. Sangchris	121	275	358	411	444	69	Joy & Tranquilli 1979
Coffeen L.	168	329	400	434	454	439	Perry & Tranquilli 1983
Ridge L.	206	262	320	348	363	4373	Bennett 1954
Crab Orchard L.	114	241	330	394	439	637	Schneidermeyer et al. 1956
Sportsman's L.	97	206	290	338	378	144	Thompson & Bennett 1949
Johnson Sauk Trail L.	102	183	277	330	386	1750	Rock 1966
Ramsey L.	109	224	287	348	386	1399	Stinauer 1966
Red Hills L.	119	196	267	302	335	1771	Price 1966
L. Chautauqua	163	249	312	363	404	505	Starrett & Fritz 1965

Table 3. Relative weights (Wr) of largemouth bass collected from Lake Shelbyville, September 1979-81. Sample sizes are in parentheses.

Age	Year Collected 1979	1980	1981	Mean for all 3 years
I +	93.3 (23)	99.1 (30)	99.6 (52)	98.1 (105)
II +	95.1 (112)	91.9 (75)	91.5 (23)	93.6 (210)
III +	94.5 (35)	95.7 (89)	91.0 (29)	94.5 (153)
IV +	94.2 (6)	97.1 (12)	97.6 (29)	97.0 (47)
Total	94.7 (176)	94.9 (206)	95.9 (133)	

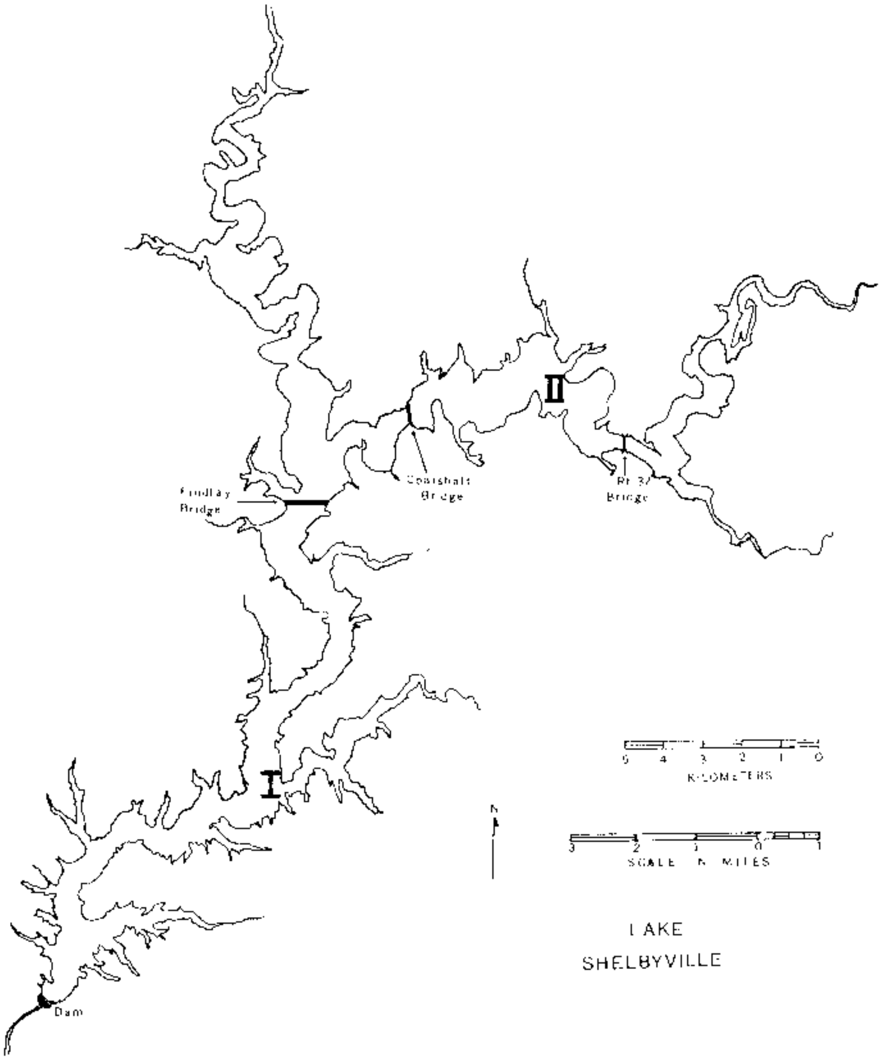

Figure 1. Lake Shelbyville, Illinois, showing stations sampled for largemouth bass.

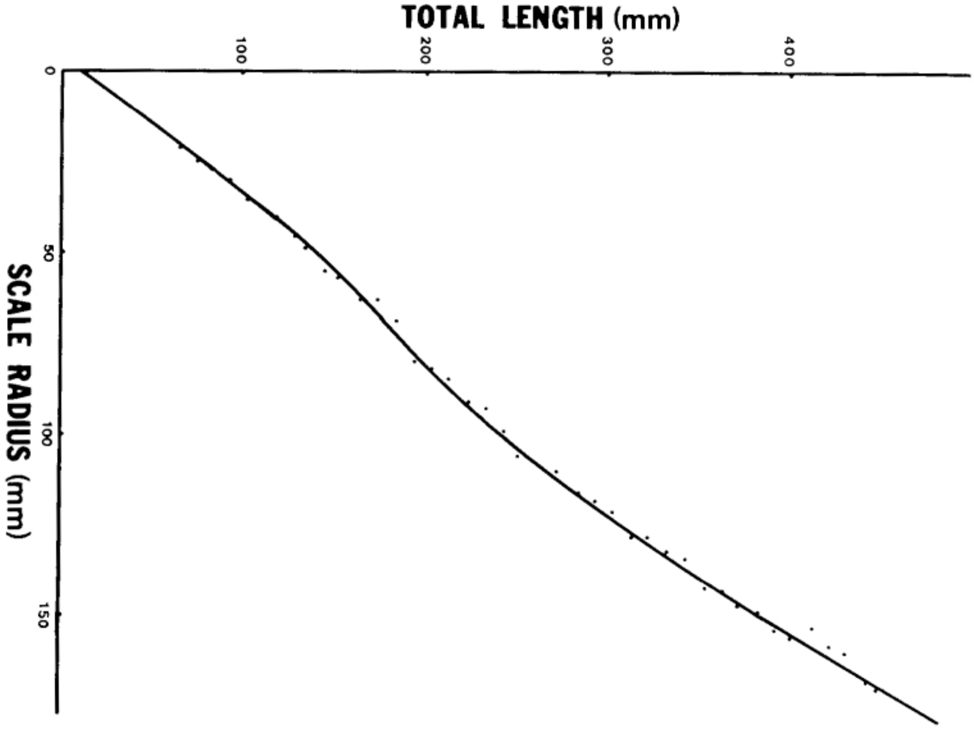

Figure 2. Relation between scale radius (x26.5) and total fish length for largemouth bass collected from Lake Shelbyville, September 1979-1981.

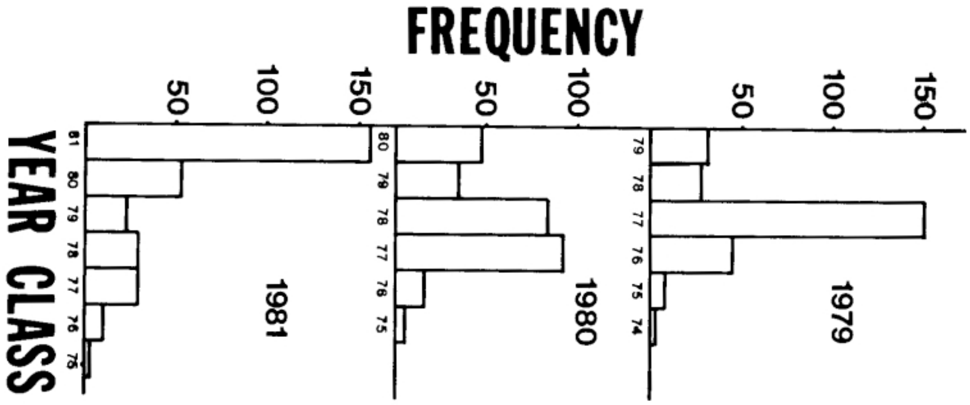

Figure 3. Age structure of largemouth bass collected from Lake Shelbyville, September 1979-1981.

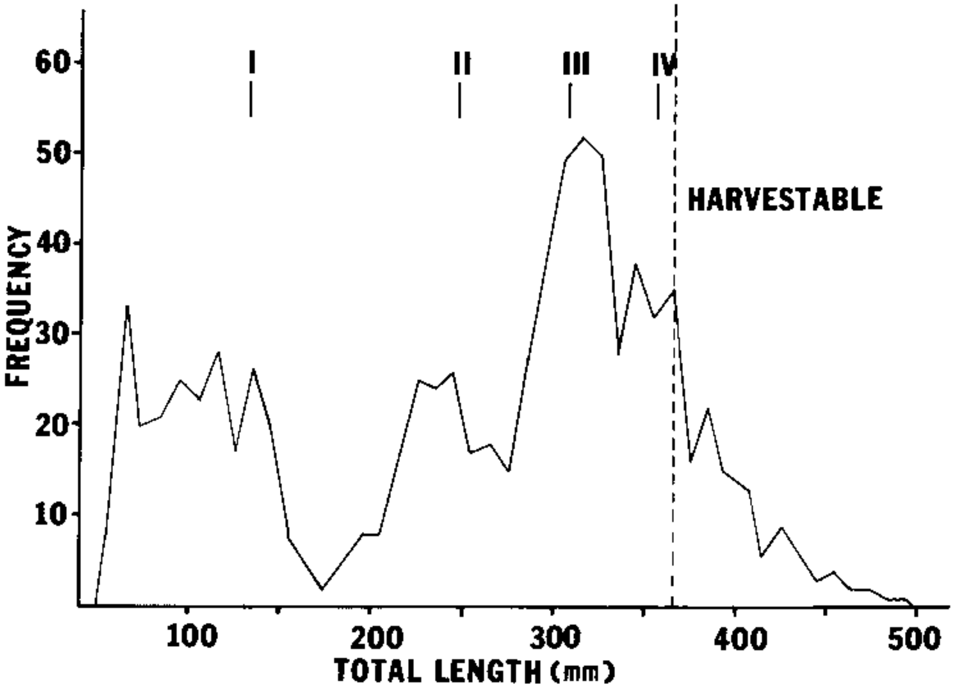

Figure 4. Length frequency distributions of largemouth bass collected from Lake Shelbyville, September 1979-1981, and mean lenghts at annulus formation based on back-calculation.