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J. Larry Wilson, Major Professor

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Date May 29, 1986

EVALUATION OF THE 14-INCH MINIMUM LENGTH LIMIT ON THE BLACK BASS IN NORRIS RESERVOIR, TENNESSEE

A Thesis

Presented for the

Master of Science

Degree

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Elizabeth M. Schilling

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ABSTRACT

Following the imposition of the 14-inch minimum length limit at Norris Reservoir, frequencies of legal-sized largemouth and black bass decreased, indicating a stockpiling of smaller bass. Proportional stock density values for largemouth bass prior to (1977-1978) and after (1982-1984) the imposition of the limit were 40 and 66, and 82, 36, and 26, respectively; relative stock density$_{15}$ values were 10 and 20, and 46, 14, and 3, respectively. The post-limit increase in mean relative weights of largemouth bass from electrofishing samples may have been due to an increase in forage fish in 1983-1984 as compared to 1977-1978. Mean relative weights of creeled largemouth bass between 12.0-14.9 inches were lower in 1983 and 1984 as compared to 1981 and 1982 while those of bass 15 inches or greater in length remained fairly constant from 1981 through 1984 with the exception of a slight increase in 1982. Prior to the length limit an average of 8.5 hours of fishing was required to harvest a black bass whereas, following the limit, 43.5 hours were required of fishing on the average. Mean pounds per acre of harvested black bass decreased following the limit while intended black bass trips per acre increased. Post-limit catch-and-release fishing increased substantially with sub-legal fish being the primary contributor. Angler compliance values for the 4 years following the limit were 75.0, 87.1, 95.8, and 82.9%, respectively. Cove rotenone data indicated that intermediate and harvestable size black bass exhibited trends in abundance similar to those of young-of-year forage fish.

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CHAPTER I

INTRODUCTION

During recent years, there has been increasing fishing pressure on the black bass, which include largemouth, smallmouth, and spotted bass. These fish are extremely important, both economically and ecologically (Stroud 1975), with nearly 50% of all fishing pressure in warmwater impoundments directed towards the largemouth bass (Nazary 1982). Carlander (1975) noted that in lakes, largemouth bass are generally the major game species. Largemouth bass are the most sought after game species in Bull Shoals and Beaver lakes in Arkansas and Missouri, in the Piedmont of North Carolina, and Lake Oconee, Georgia (Houser and Rainwater 1975; Van Horn, Chapman, and Harris 1981; Martin and Hess 1984). Paragamian (1977) stated that largemouth bass are the main predator and a popular game fish in many of Iowa's man-made lakes. Smallmouth bass are one of the most abundant and important sport fish in the major streams of northeast Iowa (Paragamian 1980, 1983, 1984c).

In recent years, there has been an increasing interest in reservoir management and the use of minimum size limits to meet the increased fishing pressures. Many studies have been completed to understand better the effects of size limits (Choate 1970; Farabee 1974; Hickman and Congdon 1974; Johnson and Anderson 1974; Paragamian 1977, 1983) on bass population dynamics. The Tennessee Wildlife Resources Agency (TWRA) recognized the need for research to evaluate minimum length limits for fish in Tennessee waters. Due to creel census data from Norris Reservoir which indicated a decrease in the catch rate of black bass from 1974 to 1978, TWRA imposed a 14-inch minimum size limit on all black bass harvested from Norris Reservoir beginning in January of 1981.

This study was initiated some three years after the limit was imposed to determine the effects of the 14-inch minimum length limit on the black bass in Norris Reservoir. The objectives of this study were to determine trends in: (1) population structure, (2) relative weight, (3) age and growth, (4) harvest, (5) estimated harvest, (6) opinion poll results; (7) creel, and (8) cove rotenone data. In keeping with the TWRA policy of recording data in English units (i.e., inches, pounds, miles), the data in this paper will remain as recorded and therefore are not converted into metric units.

CHAPTER II

LITERATURE REVIEW

Due to increasing fishing pressure on black bass, length limits have gained an increasing interest as a management tool for these populations. Size limits on black bass have been used to achieve different results such as: reducing overcrowding of small and intermediate size bluegills, reducing exploitation of a population, increasing size of harvested fish, as a method of protecting different size groups, and to increase catch-and-release fishing. Choate (1970) studied the effects of a 12-inch size limit on largemouth bass in a Missouri impoundment. The limit increased predation on a crowded bluegill population yet had no effect on bluegill growth rates. It reduced the exploitation rate of largemouth bass and increased the catch-and-release of bass without affecting fishing pressure. Rasmussen and Michaelson (1974) evaluated the effects of a 12-inch length limit on largemouth bass in three Missouri lakes. The limit was used in an attempt to prevent overharvest of bass and eliminate stunting of bluegill by reducing their numbers. The result of the length limit to nearly double the size of the bass population within one year, primarily due to a stockpiling of bass less than the minimum length. In one of the lakes, bass experienced severe crowding and subsequently ran short of forage and began to stunt.

Johnson and Anderson (1974) and Farabee (1974) studied the effects of a 12-inch size limit on largemouth bass and its effects on bluegill in three Missouri lakes. They found a stockpiling of non-legal adult bass with correspondingly slow growth rates. The bluegill populations responded to the increased predation with increased growth and adults of greater length and larger numbers. Hickman and Congdon (1974) attempted to limit overharvest of largemouth bass with size limits on five Missouri lakes. The 12-inch size limits were found to improve both bass and bluegill populations. Large numbers of bass were produced which in turn reduced the numbers of small bluegill which allowed for better bluegill growth. One lake had a 15-inch limit imposed. In this lake, the larger numbers of bass exhausted the forage supply which resulted in slower growth. Hoey and Redmond (1974) evaluated a 14-inch length limit on bass which had been imposed to prevent overharvest when the lake was opened to fishing. Desirable bass and bluegill populations were achieved. Growth of bass was considered relatively good even though there was some stockpiling of bass under the 14-inch limit.

Ming and McDonald (1975) studied the effects of a 12-inch length limit on largemouth bass in an overharvested bass population in a Missouri lake. The limit resulted in increased bass catch rates and decreased growth rates, and the resulting predation on bluegill created a fast growing bluegill population. Pelzman (1979) determined that the 12-inch limit on largemouth bass in a California reservoir reduced angler harvest over 50% without decreasing fishing pressure. Van Horn, Chapman, and Harris (1981) evaluated the results of an 18-inch length limit on largemouth bass in four North Carolina reservoirs. The objective of increasing the numbers of bass greater than 8 inches was successful on three of the four lakes. On the fourth lake, the numbers of larger bass did not increase and fish condition remained poor. Paragamian (1977, 1982) found catch-and-release of largemouth bass equaled or exceeded population estimates under a 14-inch length limit for a new impoundment. Catch rates and the average weight of creeled bass were also much higher than state-wide averages.

Surber (1968) studied the effects of a 12-inch size limit on smallmouth bass in the Shenandoah River. The number and catch rate of sub-legal bass increased dramatically even though there was a decrease in fishing pressure. Paragamian (1983, 1984b) found an increase in catch-and-release fishing for smallmouth bass with a 12-inch size limit. In addition, the mean weight of bass in the harvest increased.

Anderson (1976) proposed a slot limit as a solution to stockpiling of fish below a length limit. It was thought that a slot limit of 12-15 inches would allow harvest of surplus smaller bass (ages I and II), protect bass of ages III and IV, increase the number and harvest of bass greater than 15 inches, and maintain balanced bluegill populations. From this proposal, studies have been done to evaluate slot limits. Nazary (1982) studied the effects of an 11-15 inch slot limit on largemouth bass in three Mississippi impoundments. The slot limit had a variable degree of success on the bass populations. In Lake Lamar Bruce, the bass population structure did not change. There remained an over-abundance of small bass with low condition factors. In Lake Claude Bennett bass population structure did not change much except for an increase in the number of bass less than 10 inches. Condition factors were slightly lower than average for fish under 15 inches and slightly higher than average for fish over 15 inches. In Lake Mike Conner, there was an increase in the number of larger bass while condition of individual fish fluctuated.

Martin and Hess (1984) evaluated a slot limit of 11-14 inches on largemouth bass in a Georgia reservoir. Largemouth bass standing crop increased while individual fish maintained adequate growth. Although bass harvest rates decreased, overall catch was comparable to other Georgia reservoirs.

Gabelhouse (1984b) evaluated a 12-15 inch slot limit on five Kansas impoundments. The slot limit did not substantially increase the numbers of largemouth bass harvested. In three of the impoundments, largemouth bass densities increased sufficiently enough to influence bluegill populations, with only one of three reservoirs showing an improvement in bluegill fishing. It was hoped that the 12-15 inch slot limit would allow harvest of fish below 12 inches. Catch-and-release may have increased after the slot limit, but creel data indicated that most fishermen did not keep fish less than 12 inches. Therefore, these slot limits in effect acted as a minimum length limit of 15 inches rather than a slot limit of 12-15 inches.

Eder (1984) found a 12-15 inch slot limit improved a slow growing, high density largemouth bass population in a Missouri impoundment. The bluegill population structure was improved; however, there was a slight decrease in growth rates which produced fewer bluegills larger than 7.5 inches.

CHAPTER III

METHODS

Description of Study Area

Norris Reservoir is a multi-purpose impoundment on the Powell and Clinch rivers (Figure 1). It was formed by Norris Dam located at Clinch River Mile 79.8. Norris Dam was the first dam built by the Tennessee Valley Authority (TVA) and was completed in March of 1936. It was constructed for flood control, recreation, and hydroelectric power. At full pool (elevation 1019 feet above sea level), the reservoir extends 72 miles up the Clinch River and 56 miles up the Powell River. There are 800 miles of shoreline and a total surface area of 34,200 acres. Annual water level fluctuation may be 50 to 60 feet. The reservoir has a maximum depth of approximately 200 feet and mean depth of 75 feet.

Population Structure

In the fall of 1981, collection of data was begun to determine trends in population structure, age, growth, and creel. Prior to and following the implementation of the size limit, black bass were collected by TWRA personnel by boat with a boom-type shocker. Bass were identified to species, weighed to the nearest tenth of a pound, and measured to 0.1 inch (total length). During the 1977 and 1978 collection periods, fish were collected primarily in April, May, and June. These fish were collected throughout the entire reservoir. From

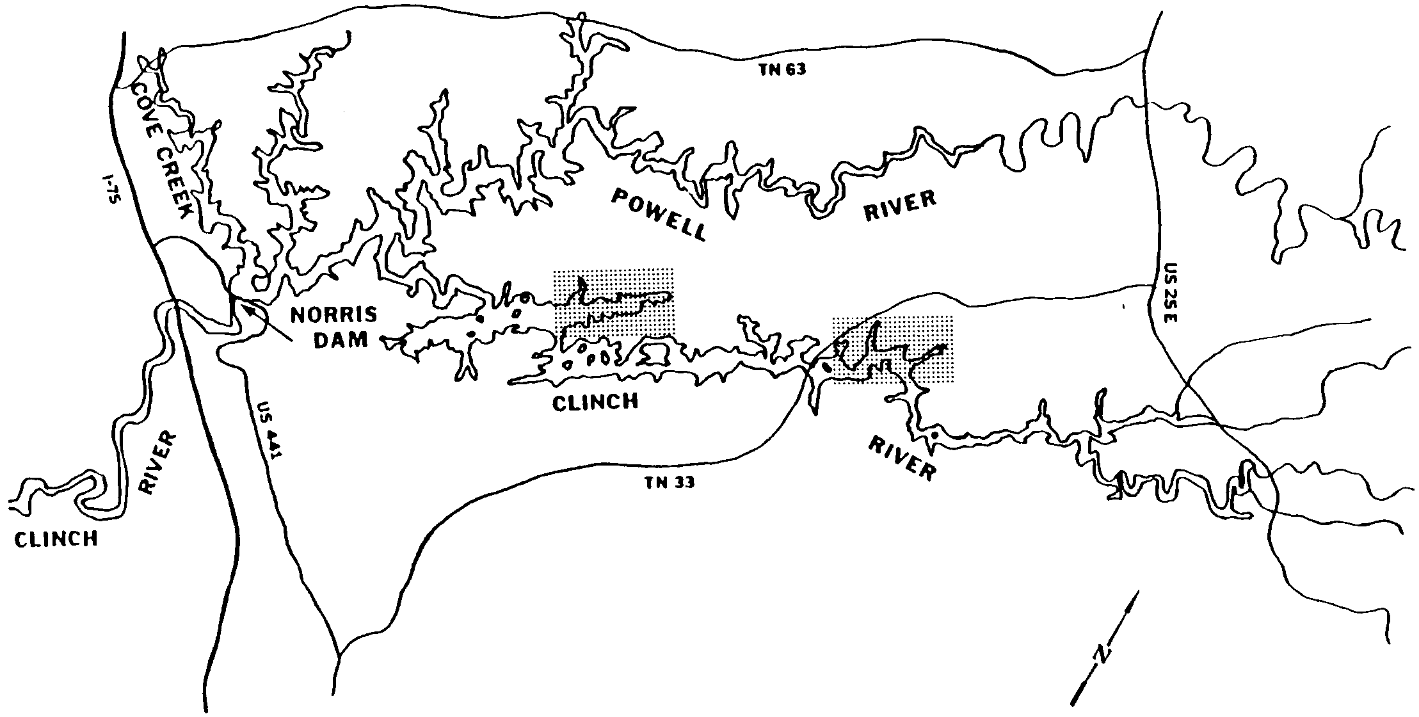

Figure 1. Norris Reservoir, Tennessee. Shaded area indicates site of electrofishing samples for 1982-1984.

the fall of 1981 through the spring of 1984, fish were sampled quarterly from Straight Creek and Needham Hollow (Figure 1). Due to the fact that fish collections in 1977 and 1978 were made in the spring, only the data from the spring collections of 1982 through 1984 were used in the analyses of population structures.

Population structures of black bass were evaluated by using length frequency distributions, proportional stock density (PSD), and relative stock density (RSD). Anderson (1976) defined PSD as the percentage of stock size fish that have attained a quality size:

$$PSD = \frac{\text{number of fish} \geq \text{quality size}}{\text{number of fish} \geq \text{stock size}} \times 100$$

Proposed stock and quality lengths for largemouth bass are 8.0 and 12.0 inches, respectively, and 7.0 and 11.0 inches, respectively, for both smallmouth and spotted bass (Anderson and Weithman 1978; Gabelhouse 1984a). RSD can be used to describe any preferred size group in the stock (Wege and Anderson 1978; Anderson 1980). In this study RSD values of 15 inches were calculated as:

$$RSD_{15} = \frac{\text{number of fish} \geq 15 \text{ inches}}{\text{number of fish} \geq \text{stock size}} \times 100$$

Relative Weight

Data from spring electrofishing samples were also used to determine relative weights (Wr) for largemouth bass. Wr can be used as a measure of plumpness or the condition of a fish (Wege and Anderson 1978). Wr was calculated by the following formula:

$$Wr = \frac{\text{actual weight}}{\text{standard weight}} \times 100$$

with the standard weight for each length as determined by Wege and Anderson (1978). In this study, Wr was calculated for individual largemouth bass. Mean Wr values were determined for fish length groups of 1.0-7.9, 8.0-11.9, 12.0-14.9, and 15 inches and greater prior to and after the imposition of the length limit. Mean Wr was not calculated for smallmouth and spotted bass due to the fact that standard weights were not available for these species.

Age and Growth

Age and growth of black bass were determined from scales collected during the electrofishing census of October through March from 1981 through 1984. Since fish were considered to have stopped growing in the fall and had not begun growing in the early part of the following year, the scale margin was considered to be an annulus. Scale samples were not used from late spring and summer collections.

Scale impressions for age determination were made on 1 x 3-inch cellulose acetate slides using a roller press. Slides were viewed at 20X with a microfiche reader. Scales showing signs of regeneration were discarded. Measurements for back-calculations were made from the focus along the anterior scale radius. Back-calculated lengths at each annulus were determined on the basis of direct proportional expansion of the Dahl-Lea Method (Lagler 1956). The formula used to determine lengths at age was:

$$Ln = \frac{L_t}{S_t} \times S_n$$

where L_n = total length at the nth year of life,

L_t = total length of the fish at capture,

S_t = total scale length at capture, and

S_n = length on the scale at the nth year of life.

Once the age of each fish was determined, fish were grouped by year class and mean lengths were determined at each year of life for each of the three species of black bass.

Fish having scales without annuli were not used in this study. These age I fish were consistently larger than the average back-calculated length for other fish at age I. Collection methods may have been biased towards collecting fish larger than 7.0 inches; therefore, not many smaller (3-5 inch) one-year old fish were collected.

<u>Harvest</u>

Harvest and estimated harvest data were provided by TWRA in the form of monthly summaries from daytime roving sport fishing creel surveys from 1974 through 1984. Data included numbers and pounds caught, hours sampled, estimated numbers and pounds caught, estimated hours fished for black bass, estimated total number of trips and hours, number of bass fishermen, and total number of fishermen. Data from monthly summaries were combined for each year.

Harvest and estimated harvest calculations included the following:

1. Mean weight - pounds caught divided by number caught.
2. Number per hour - number caught divided by hours sampled.
3. Pounds per hour - pounds caught divided by hours sampled.
4. Estimated pounds per acre - estimated pounds caught divided by the surface area of Norris Reservoir.
5. Estimated pounds per trip - estimated pounds caught divided by the estimated number of trips.
6. Estimated number per trip - estimated number caught divided by the estimated number of trips.
7. Estimated intended black bass trips per acre - black bass estimated hours divided by average trip length and then divided by surface acres. The average trip length was determined by dividing the number of estimated total hours by the estimated total number of trips.
8. Percentage of fishermen fishing for bass - number of bass fishermen divided by the total number of fishermen.

Creel and Opinion Poll

Creel data and opinion poll data were also provided by TWRA. Data were collected at the time of the roving creel survey for the years 1981 through 1984. The fish creeled were identified to species, with length and weight recorded for each individual fish. Mean relative weights were calculated for largemouth bass for two length groups, 12.0-14.9 inches and greater than or equal to 15 inches.

The opinion poll consisted of three questions which were posed to encountered fishermen:

1. For which species are you fishing?
2. How many bass have you caught and released that were greater than or less than 14 inches?
3. Are you in favor of the 14-inch minimum length limit on black bass?

Cove Rotenone

Cove rotenone data were provided by TVA for the years 1975-1984 with a minimum of 1 to a maximum of 10 coves being sampled each year. Prior to sampling, the coves were selected, the area of each cove was determined, and block nets were set. Emulsified rotenone (5% active ingredient) was applied at a concentration of 1.0 parts per million using a pump with a weighted hose in the deeper portions of the coves; the shallow areas were surface- sprayed. Fish were picked up over a two-day period. Fish were sorted by species and within species into 25 mm size groups. Numbers and weights (in kilograms) were recorded for first day pick-up while numbers only were recorded for second day pick-up. Second day weights were estimated from first day weights. Numbers and weights per hectare for each year were determined for each species by size classes which included young-of-year, intermediate, and harvestable size fish. Data were later converted to English units for this study.

Analysis of Data

For various reasons the data were not amenable to statistical analysis. Therefore, it should be pointed out that differences noted in the results and discussion are to be viewed as trends and have not been assigned a level of statistical significance.

CHAPTER IV

RESULTS AND DISCUSSION

Population Structure

Spring electrofishing prior to and after the limit was imposed yielded a total of 4578 black bass during the five years of collecting (Table 1). Largemouth bass represented 75.4% of all bass while smallmouth and spotted bass represented 10.9 and 13.7%, respectively. Jenkins (1975) noted that largemouth bass abundance was negatively related to smallmouth bass abundance while largemouth and spotted bass are found together more often. Schumacher and Eschmeyer (1942) found spotted bass not as abundant as largemouth bass in Norris Reservoir. Environmental factors generally determine the relative abundance of largemouth and spotted bass with spotted bass crops gradually decreasing after impoundment in most reservoirs (Jenkins 1975).

Due to the fact that smallmouth and spotted bass made up only a small portion of the black bass, length-frequency distributions were compiled only for largemouth bass and all black bass combined (Figures 2-5). Prior to the imposition of the length limit 23.8% of the largemouth bass were greater than 14 inches in length (Figure 2). After the imposition of the length limit, there was a 40% decrease in the number of fish greater than 14 inches in length (Figure 3). Prior to the limit, the majority (70%) of the fish were 9 to 14.9 inches in length. After the limit, there was a dramatic increase in numbers of

Table 1. Numbers of black bass collected annually during spring electrofishing in Norris Reservoir, 1977-1978 and 1982-1984.

Year	LMB	SMB	SPB	All Black Bass
1977	1648	214	154	2016
1978	1312	192	396	1900
1982	182	30	19	231
1983	147	13	49	209
1984	159	51	9	219
Total	3448	500	627	4575

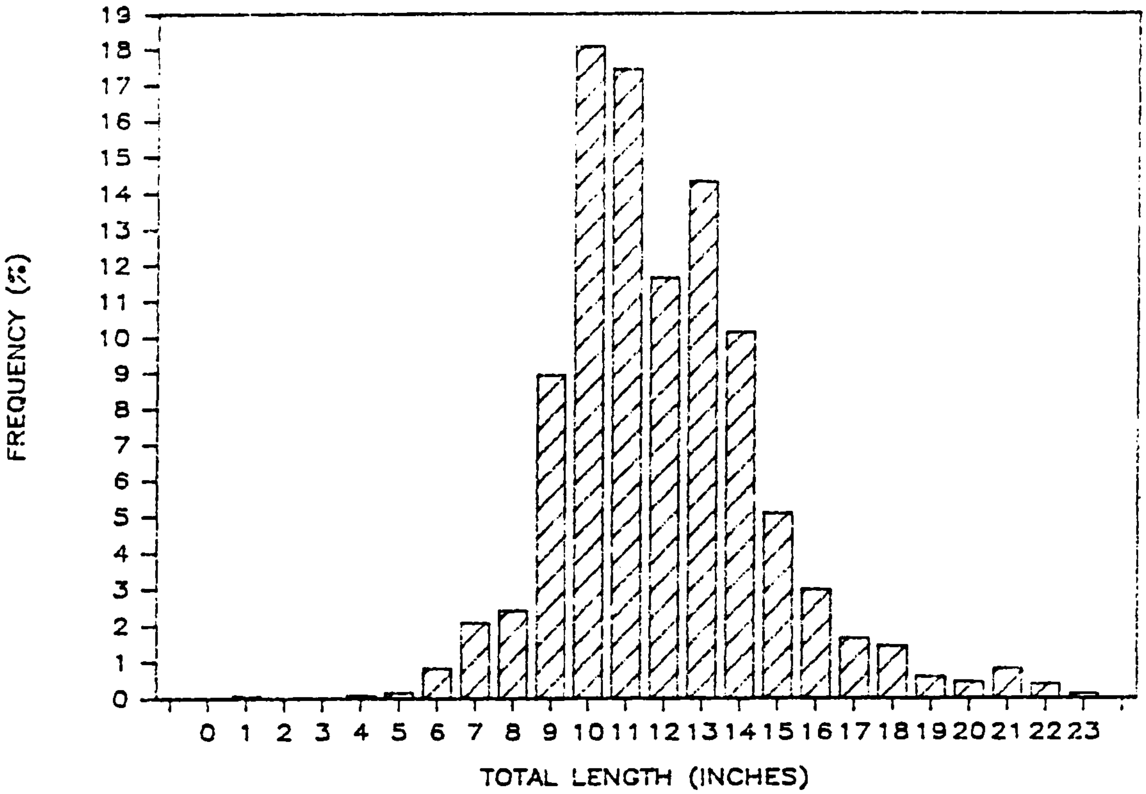

Figure 2. Length frequency distribution of 2960 largemouth bass collected by electrofishing prior to (1977-1978) the imposition of the length limit on Norris Reservoir.

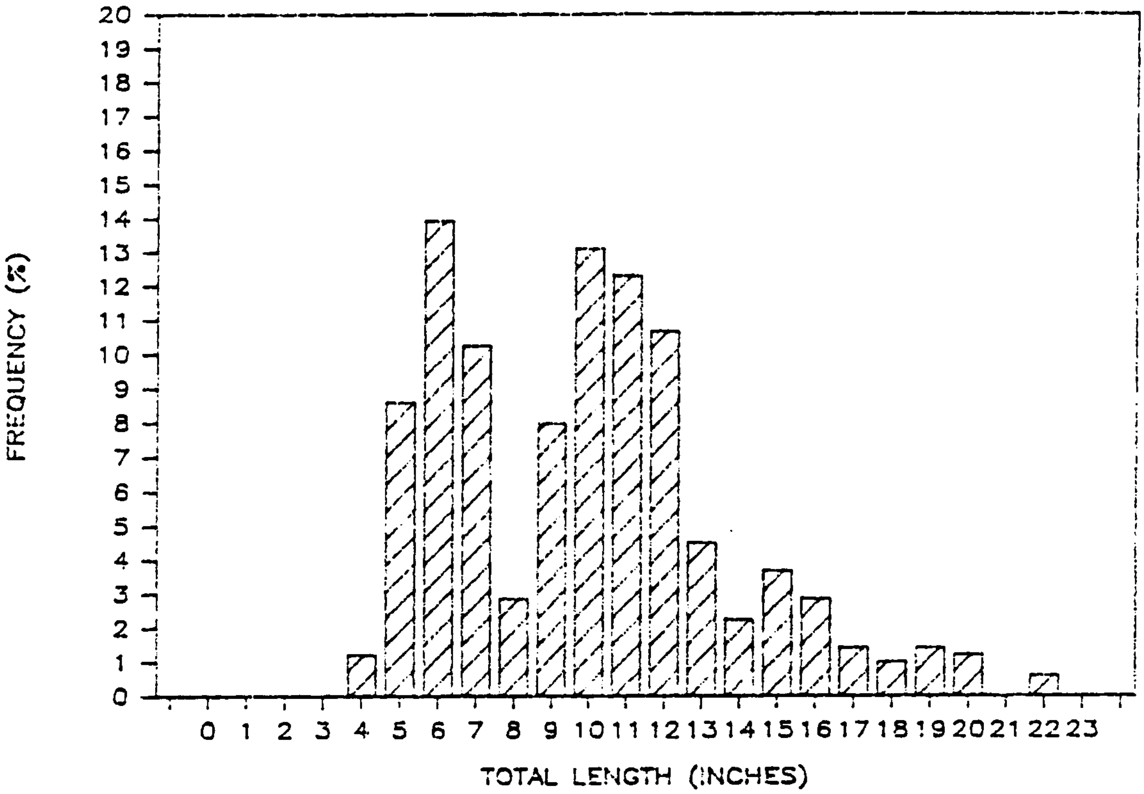

Figure 3. Length frequency distribution of 488 largemouth bass collected by electrofishing after (1982-1984) the imposition of the length limit on Norris Reservoir.

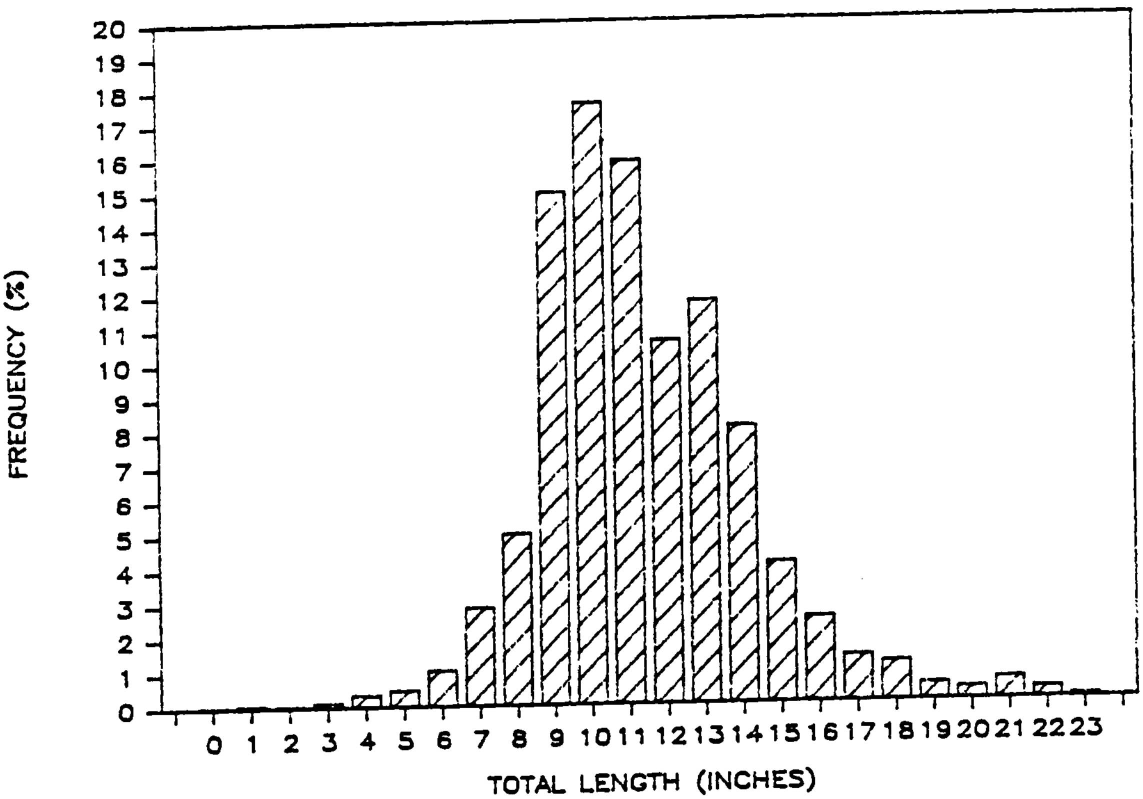

Figure 4. Length frequency distribution of 3916 black bass collected by electrofishing prior to (1977-1978) the imposition of the length limit on Norris Reservoir.

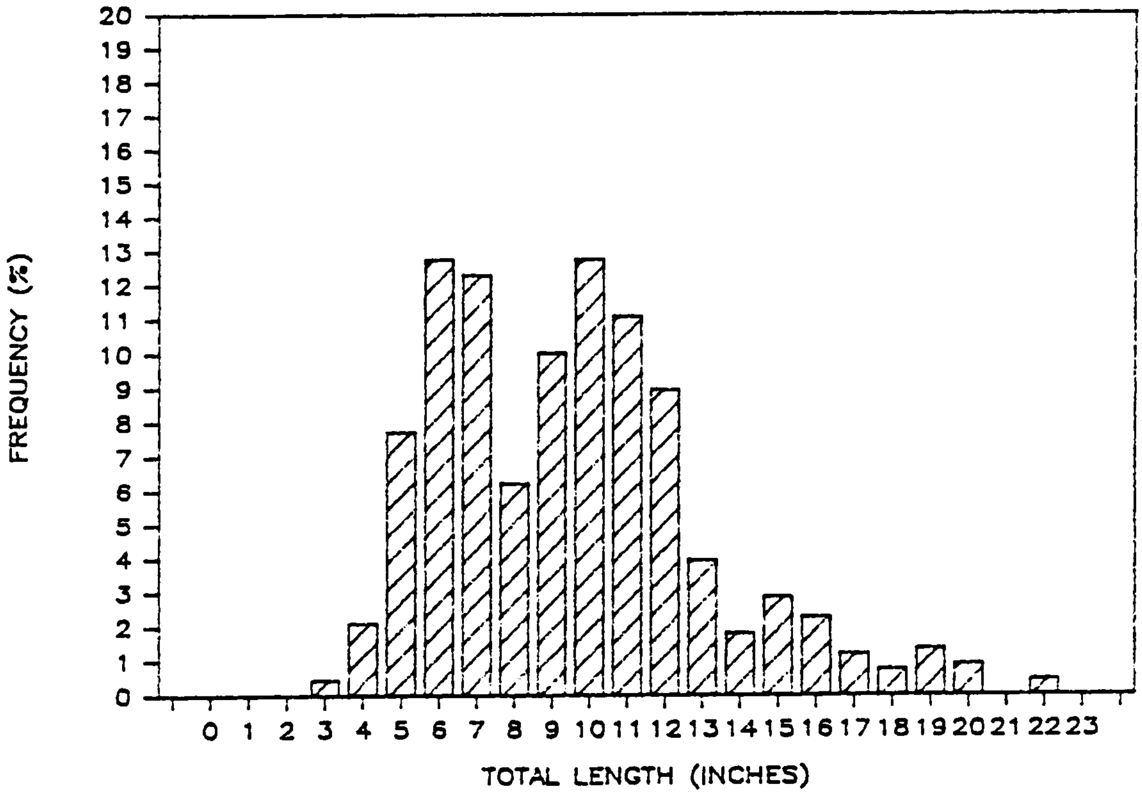

Figure 5. Length frequency distribution of 659 black bass collected by electrofishing after (1982-1984) the imposition of the length limit on Norris Reservoir.

fish between 5 and 7.9 inches in length. There was a 40% increase in the frequency of largemouth bass below 12 inches (Table 2).

The length-frequency distributions of all black bass were similar to those of largemouth bass. Prior to the limit, the majority of the fish were between 9 and 14.9 inches (Figure 4) and after the limit, there were fewer 9-14.9 inch fish and a greater proportion of fish between 5 and 7.9 inches (Figure 5). Based on all the data, the length-frequency distributions of largemouth and black bass indicated an overall stockpiling of bass under 14 inches after the imposition of the length limit.

For both largemouth and black bass, there was an increase in the frequencies of bass less than 14 inches (Figures 2-5). It is possible that the lower frequencies of bass between 5 and 7.9 inches prior to the length limit were due to the fact that collections in 1977 and 1978 may have been biased towards bass larger than 8 inches as these bass were to be used in another study. The bimodal distribution in length frequencies of largemouth bass and black bass following the length limit may be due to the collection of age I^+ bass. Although there may have been a bias for bass larger than 8 inches prior to the length limit, substantial numbers of bass smaller than 8 inches were collected during that period.

Gablehouse (1984b) found electrofishing catch rates of largemouth bass greater or equal to 8 inches and greater than or equal to 15 inches increased following the imposition of slot limits on largemouth bass

Table 2. Frequency distribution of largemouth bass by length group prior to and after imposition of the 14-inch length limit in Norris Reservoir.

	Frequency Distribution (%)	
Length Group (inches)	Before Limit N = 2960	After Limit N = 488
1.0- 7.9	3.3	34.0
8.0-11.9	46.9	36.3
12.0-14.9	36.1	17.4
15.0-23.9	13.7	12.3

populations. In contrast, the results of this study indicated a decrease in catch rates of largemouth bass greater than or equal to 8 inches of 35.2, 31.2, and 28.6 per hour from spring electrofishing for the years 1982 through 1984, respectively. In addition, the numbers of largemouth bass greater than or equal to 15 inches per hour of electrofishing were 16.8, 4.3, and 0.8 for the same collection periods.

PSD and RSD values have been used as an alternative approach to length frequency distributions to determine population structure (Anderson 1976; Wege and Anderson 1978). Anderson (1980) suggested that a balanced largemouth bass population should have a PSD value from 40 to 70 and RSD_{15} value from 10 to 25.

PSD and RSD_{15} values of fish collected prior to the length limit (1977 and 1978) indicated a balanced largemouth bass population (Table 3). In 1982, PSD and RSD_{15} values were higher than those for a balanced population. Reynolds and Babb (1978) suggested that a population with a PSD greater than 60 indicated that the population contained too few small fish. Anderson (1980) proposed that a population with high PSD and RSD_{15} values indicated low reproduction and/or a low rate of mortality for quality bass. Anderson (pers. commun.) suggested that these high values in 1982 indicated low recruitment from the 1981 year class.

PSD values in 1983 and 1984 were below those which are suggested for a balanced population. RSD_{15} in 1983 was acceptable but, in 1984, it was extremely low. PSD values below 40 indicate too few large fish

Table 3. Proportional stock density (PSD) and relative stock density (RSD_{15}) from black bass (LMB = largemouth bass; SMB = smallmouth bass; SPB = spotted bass) collected during spring electrofishing in Norris Reservoir. The number (N) used to calculate PSD and RSD_{15} was a portion of total black bass (4575) collected.

Year	LMB			SMB			SPB		
	N	PSD	RSD_{15}	N	PSD	RSD_{15}	N	PSD	RSD_{15}
1977	1625	40	10	205	46	5	144	13	1
1978	1238	66	20	183	31	7	371	22	0
1982	88	82	46	20	45	20	14	43	0
1983	94	36	14	7	14	0	47	11	0
1984	136	26	3	39	23	3	8	0	0

(Reynolds and Babb 1978). Therefore, these low values for PSD and RSD_{15} indicated the stockpiling of fish below the quality size of 12 inches for populations in 1983 and 1984.

Anderson and Weithman (1978) suggested PSD ranges of 30 to 60 for balanced populations of smallmouth bass. Prior to the length limit, PSD values of Norris smallmouth bass fell within this range as did the 1982 value (Table 3). The RSD_{15} value was high in 1982. These 1982 values may indicate low recruitment from the previous year. PSD values for 1983 and 1984 were below the ranges for a balanced smallmouth population which suggested a stockpiling of bass below the quality size of 11 inches.

PSD values for spotted bass and RSD_{15} values for smallmouth and spotted bass have not been reported in the literature. This is probably due to the fact that management of black bass has been primarily designed for the largemouth.

Relative Weight

The mean Wr for largemouth bass in the 1.0-7.9 inch group decreased after the imposition of the length limit, while the mean Wr for all other length groups increased (Table 4). The decrease in the mean Wr value for fish in the 1.0-7.9 inch may be associated with the increased frequency of fish in this group after the imposition of the length limit (Table 2). Increased numbers of fish within this group may have led to an increase in competition for food, thereby decreasing overall

Table 4. Mean relative weights of largemouth bass from electrofishing collections before (1977-1978) and after (1982-1984) the length limit in Norris Reservoir.

	Mean Relative Weights	
Length Group (Inches)	Before Limit N = 2960	After Limit N = 488
1.0- 7.9	109	92
8.0-11.9	87	93
12.0-14.9	85	89
15.0-23.9	85	95

plumpness of these fish. It is also possible that prior to the length limit only very plump bass less than 8.0 inches were collected. Sampling crews were collecting bass that were generally larger than 9.0 inches but may have collected these more robust smaller fish. This type of biased collection may have produced samples of fish with higher relative weights prior to the imposition of the length limit.

The decrease in the frequency of fish in the length groups greater than or equal to 8.0 inches may have resulted in reduced competition for food followed by increased mean Wr values for those fish. Even though frequencies of fish in the 8.0-11.9 and 12.0-14.9 inch groups decreased, actual numbers of these fish probably increased after the imposition of the length limit due to the fact that it was illegal to harvest fish less than 14 inches. If this were the case, mean Wr values would be expected to have decreased after the length limit due to increased competition. It could be that an increase in available food produced plumper fish after the limit was imposed.

Wege and Anderson (1978) suggested that optimum values of Wr appear to be 100 during the spring in large reservoirs, while Wr values below 95 may indicate competition for food within various size groups. The data in this study (Table 4) indicated that fish smaller than 15 inches may be competing for a limited food supply. Increased removal of these fish may reduce this competition and thus increase the relative plumpness of fish.

Age and Growth

Age was determined for 285 largemouth bass, 117 smallmouth bass, and 114 spotted bass collected during the 4-year period. The mean length at annulus formation by year class is presented for each species in Tables 5-7. Although three largemouth bass in these collections attained seven years of age, Stroud (1948) noted that most bass in Norris Reservoir seldom lived longer than five years and most died of old age. Weighted mean lengths of all species at each age in this study were also smaller than those found by Stroud (1948). Age and growth determinations from 1936 through 1973 revealed that all species and age groups of black bass grew slower as Norris Reservoir aged (Chance et al. 1975). On an overall basis, largemouth and smallmouth grew faster than spotted bass, while largemouth bass grew faster than smallmouth bass.

Largemouth bass attained greater lengths during their first two years of life following the imposition of the length limit. Lengths for ages III through V decreased after the limit. There were no fish sampled that attained ages VI and VII prior to the imposition of the length limit. Lengths at ages I and II were expected to decrease after the length limit due to the stockpiling of fish below 14 inches. Largemouth bass, both before and after the limit, reached 14 inches during the fourth year of growth. The imposition of the length limit did not produce largemouth bass of 14 inches in a shorter amount of time.

Age and growth of smallmouth and spotted bass were more similar to

Table 5. Average back-calculated lengths (inches) at age of 285 largemouth bass for year classes 1976-1982 from electrofishing collections in Norris Reservoir. Numbers in parentheses indicate the number of fish in the sample.

	Average back-calculated lengths at age						
Year Class	I	II	III	IV	V	VI	VII
1976	4.7 (3)	10.0 (3)	13.8 (3)	16.8 (3)	18.4 (3)	19.1 (3)	21.0 (1)
1977	3.4 (7)	9.5 (7)	12.9 (7)	15.5 (7)	17.6 (7)	20.0 (2)	21.2 (1)
1978	4.3 (28)	9.6 (28)	13.7 (28)	16.0 (28)	17.8 (11)	19.6 (4)	
1979	4.5 (43)	9.1 (43)	13.2 (43)	15.7 (15)	16.9 (8)		
1980	5.3 (57)	10.9 (57)	13.4 (12)	15.6 (4)			
1981	5.3 (99)	10.7 (99)	13.0 (37)				
1982	5.0 (48)	10.3 (48)					

Table 6. Average back-calculated lengths (inches) at age of 117 smallmouth bass for year classes 1978-1982 from electrofishing collections in Norris Reservoir. Numbers in parentheses indicate the number of fish in the sample.

Year Class	Average back-calculated lengths at age I	II	III	IV	V
1978	2.1 (5)	6.7 (5)	10.0 (5)	13.7 (5)	15.0 (1)
1979	3.5 (14)	7.1 (14)	11.5 (14)	15.2 (1)	
1980	4.0 (17)	9.1 (17)	11.8 (8)	14.5 (4)	
1981	3.8 (39)	8.9 (39)	12.6 (10)		
1982	3.7 (42)	8.7 (42)			

Table 7. Average back-calculated lengths (inches) at age of 114 spotted bass for year classes 1978-1982 from electrofishing collections in Norris Reservoir. Numbers in parentheses indicate the number of fish in the sample.

	Average back-calculated lengths at age					
Year Class	I	II	III	IV	V	VI
1978	2.7 (5)	6.9 (5)	10.2 (5)	12.4 (5)	16.0 (1)	16.7 (1)
1979	3.3 (15)	7.5 (15)	10.9 (15)	12.7 (8)	13.7 (3)	
1980	3.4 (27)	8.8 (27)	11.0 (13)	12.7 (3)		
1981	3.6 (43)	7.3 (43)	9.1 (27)			
1982	3.7 (24)	8.1 (24)				

each other than to largemouth bass (Tables 5-7). Ages I through III for both smallmouth and spotted bass attained greater lengths following the imposition of the length limit. Fish entering their fourth year of life did so after the length limit was established. There were no fish sampled that entered their fourth year of life prior to the limit. Therefore, no comparisons could be made for fish older than three years of age. Again, growth of fish less than 14 inches was expected to have decreased due to stockpiling of fish.

The length of 14 inches was obtained by largemouth and smallmouth bass during the fourth year of growth and by spotted bass during the fifth year of growth. Therefore, a large proportion of the black bass may die of old age before reaching the age of five years as Stroud (1948) suggested, with only a few fish living more than a year or two after attaining 14 inches in length.

Additional data are necessary to verify the apparent trends of growth for black bass after the establishment of the length limit. With only three years of growth data after the limit, there may not have been enough time to determine accurate trends in age and growth. Changes in growth rates may be related to other factors such as changes in food supply, length of growing season, summer water levels, and composition of the fish population (Stroud 1948).

Harvest

Overall harvest in terms of numbers and pounds of all bass decreased after the imposition of the size limit as would be expected

(Tables 8-11). Mean weights of harvested largemouth, smallmouth, and spotted bass increased slightly, while combined black bass mean weights remained the same following the length limit. Paragamian (1977, 1982) recorded mean weights of harvested largemouth bass of 2.1 pounds while the 14-inch minimum length limit was in effect. This was much greater than the Iowa state-wide average of 0.9 pounds per harvested largemouth bass.

Mean numbers of bass harvested per hour decreased following the introduction of the limit. Prior to the length limit, it took an average of 18.9 and 8.5 hours, respectively, to harvest a largemouth or black bass. Following the limit imposition, an average of 125 and 43.5 hours, respectively, were required to harvest a legal-sized largemouth or black bass. Choate (1970) found that the exploitation rate of largemouth bass decreased due to a 12-inch minimum length limit. Paragamian (1977,1982) found the catch rate of one legal size largemouth bass required 33 to 100 hours of fishing in an Iowa lake having a 14-inch minimum length limit. Mean pounds of bass harvested per hour also decreased after the length limit was imposed.

Estimated Harvest

Mean values for pounds per acre, pounds per trip, and number per trip of the estimated harvest of largemouth bass decreased after the imposition of the length limit as expected (Table 12). For both smallmouth and spotted bass, mean pounds per acre increased slightly, while pounds per trip and number per trip decreased (Tables 13 and 14).

Table 8. Largemouth bass harvest from TWRA creel data, 1974-1978 and 1981-1984.

Year	Number Caught	Pounds Caught	Average Weight	Number Per Hour	Pounds Per Hour	Hours Sampled
1974	904	1857.3	2.05	.064	.132	14104.6
1975	493	1145.8	2.32	.056	.131	8739.7
1976	151	253.9	1.68	.034	.057	4488.0
1977	57	74.0	1.30	.025	.033	2272.2
1978*	8	15.1	1.89	.009	.016	916.6
Mean Value			2.07	.053	.110	
1981**	21	44.9	2.14	.005	.011	3926.2
1982	79	183.6	2.32	.012	.028	6479.3
1983	60	139.0	2.32	.006	.013	10567.5
1984*	47	81.6	1.74	.008	.013	6109.8
Mean Value			2.17	.008	.017	

* Data available for January-June

**Data available for July-December

Table 9. Smallmouth bass harvest from TWRA creel data, 1974-1978 and 1981-1984.

Year	Number Caught	Pounds Caught	Average Weight	Number Per Hour	Pounds Per Hour	Hours Sampled
1974	839	1534.7	1.83	.059	.109	14104.6
1975	846	1705.1	2.02	.097	.195	8739.7
1976	128	203.5	1.59	.029	.045	4488.0
1977	37	49.1	1.33	.016	.022	2272.0
1978*	11	15.1	1.37	.012	.016	916.6
Mean Value			1.88	.061	.115	
1981**	50	92.0	1.84	.012	.023	3926.2
1982	89	201.7	2.27	.014	.031	6479.3
1983	87	168.7	1.94	.008	.016	10567.5
1984*	125	224.4	1.80	.020	.037	6109.8
Mean Value			1.96	.013	.025	

* Data available for January-June

**Data available for July-December

Table 10. Spotted bass harvest from TWRA creel data, 1974-1978 and 1981-1984.

Year	Number Caught	Pounds Caught	Average Weight	Number Per Hour	Pounds Per Hour	Hours Sampled
1974	31	61.2	1.97	.004	.004	14104.6
1975	15	27.1	1.81	.002	.003	8739.7
1976	43	30.1	0.7	.010	.007	4488.0
1977	8	7.7	0.96	.004	.003	2272.2
1978*	1	0.5	0.5	.001	<.001	916.6
Mean Value			1.29	.003	.004	
1981**	8	10.1	1.26	.002	.003	3926.2
1982	39	51.3	1.32	.006	.008	6479.3
1983	5	6.7	1.34	<.001	<.001	10567.5
1984*	4	5.3	1.33	<.001	<.001	6109.8
Mean Value			1.31	.002	.003	

* Data available for January-June

**Data available for June-December

Table 11. Combined black bass harvest from TWRA creel data, 1974-1978 and 1981-1984.

Year	Number Creeled	Pounds Creeled	Average Weight	Number Per Hour	Pounds Per Hour	Hours Sampled
1974	1774	3453.2	1.95	.126	.245	14104.6
1975	1354	2878.0	2.13	.155	.329	8739.7
1976	322	487.5	1.51	.072	.109	4488.0
1977	102	130.8	1.28	.045	.058	2272.2
1978**	20	30.7	1.54	.022	.033	916.6
Mean Value			1.95	.117	.229	
1981**	79	147.0	1.86	.020	.037	3926.2
1982	207	436.6	2.11	.032	.067	6479.3
1983	152	314.4	2.07	.014	.030	10567.5
1984*	176	311.3	1.77	.029	.051	6109.8
Mean Value			1.97	.023	.045	

* Data available for January-June

**Data available for July-December

Table 12. Estimated largemouth bass harvest from TWRA creel data, 1976-1978 and 1981-1984.

Year	Number	Pounds	Pounds Per Acre	Pounds Per Trip	Number Per Trip
1976	16251	28200.8	.825	.353	.204
1977	3701	4563.7	.133	.119	.096
1978*	829	1675.0	.049	.099	.049
Mean Value			.336	.190	.116
1981**	1042	2408.3	.070	.052	.023
1982	8088	18184.7	.532	.124	.055
1983	2272	5206.5	.152	.058	.025
1984*	1916	2968.1	.087	.057	.036
Mean Value			.210	.073	.034

* Estimates for January-June

**Estimates for July-December

Table 13. Estimated smallmouth bass harvest from TWRA creel data, 1976-1978 and 1981-1984.

Year	Number	Pounds	Pounds Per Acre	Pounds Per Trip	Number Per Trip
1976	13341	21494.9	.629	.269	.167
1977	1825	2247.0	.066	.058	.047
1978*	788	1307.6	.038	.078	.047
Mean Value			.244	.135	.087
1981**	2681	5044.2	.147	.109	.058
1982	9097	19720.4	.577	.135	.062
1983	3238	5949.5	.174	.967	.036
1984*	3789	6507.8	.190	.124	.072
Mean Value			.272	.109	.057

* Estimates for January-June

**Estimates for July-December

Table 14. Estimated spotted bass harvest from TWRA creel data, 1976-1978 and 1981-1984.

Year	Number	Pounds	Pounds Per Acre	Pounds Per Trip	Number Per Trip
1976	3890	2755.3	.081	.035	.049
1977	631	432.7	.013	.011	.016
1978*	32	16.0	<.001	<.001	.002
Mean Value			.031	.016	.222
1981**	395	502.5	.015	.011	.009
1982	2629	3920.6	.115	.027	.018
1983	131	194.5	.006	.002	.001
1984*	132	174.4	.005	.003	.003
Mean Value			.035	.011	.008

* Estimates for January-June

**Estimates for July-December

Black bass mean estimated harvest in pounds per acre, pounds per trip, and number per trip decreased following the length limit (Table 15). The mean number of black bass trips per acre increased by 46% while there was only a decrease of approximately 2.0% in the proportion of people fishing for black bass following the length limit. The length limit has not had a tremendous effect on the percentage of people fishing for all black bass combined. However, the length limit has almost doubled the amount of estimated black bass fishing trips per acre required to harvest the same approximate pounds per acre.

Opinion Poll

Fishing preference for the black bass declined from 1981 through 1984 except for a slight increase in 1982 (Table 16). The percentages of people fishing for black bass were greater in the opinion poll than those determined from the estimated harvest data except for 1984. Data from both the opinion poll and estimated harvest indicated an overall decrease in fishing preference for black bass in the four years following the imposition of the length limit.

Total numbers of fish caught and released increased substantially during the four-year period following the length limit (Table 16). Fish smaller than 14 inches were the primary contribution to catch-and-release fishing. These smaller fish increased from 86 to over 98% of the catch-and-release fishery from 1981 through 1984. Surber (1968) and Choate (1970) found increases in catch-and-release of sub-legal bass following a 12-inch minimum length limit. Paragamian (1977,1982) noted

Table 15. Estimated black bass harvest from TWRA creel data, 1976-1978 and 1981-1984.

Year	Number	Pounds	Pounds Per Acre	Pounds Per Trip	Number Per Trip	Intended Trips Per Acre	Percent Fishing For Black Bass
1976	33482	52451.0	1.530	.657	.420	.487	21.83
1977	6157	7243.4	.212	.188	.160	.296	27.79
1978*	1649	2998.6	.088	.178	.098	.093	24.44
Mean Value			.610	.464	.306	.292	24.69
1981**	4118	7955.0	.233	.172	.089	.274	21.66
1982	19814	41825.7	1.223	.286	.135	.679	27.03
1983	5641	11350.5	.332	.127	.063	.509	23.72
1984*	5837	9650.3	.282	.184	.111	.247	22.28
Mean Value			.517	.212	.106	.427	23.95

* Estimates for January-June

**Estimates for July-December

Table 16. TWRA opinion poll, including fishing preference, numbers of black bass caught and released, and numbers of fishermen in in favor of the 14-inch length limit.

	1981		1982		1983		1984	
	N	%	N	%	N	%	N	%
Fishing Preference For:								
Black Bass	170	26.15	288	30.77	862	26.05	948	20.86
Crappie	144	22.15	246	26.28	914	27.62	947	20.84
Striped Bass	109	16.77	123	13.14	363	10.97	864	19.01
Sunfish	48	7.38	58	6.2	229	6.92	429	9.44
Walleye	57	8.77	75	8.01	507	15.32	730	16.07
Sauger	0	0	0	0	0	0	65	1.43
Catfish	20	3.08	32	3.42	254	7.68	126	2.77
Any	99	15.23	105	11.22	180	5.44	435	9.57
Other	3	.46	9	.96	0	0	0	0
Total	650		936		3309		4544	
Catch-and-Release:								
Under 14"	370	86.65	1064	89.19	2545	98.07	7328	98.09
Over 14"	57	13.35	129	10.81	50	1.93	143	1.91
Total	427		1193		2595		7471	
In Favor of Limit:								
Yes	405	67.5	570	64.55	2819	83.45	3824	84.08
No	147	24.5	239	27.07	347	10.27	419	9.21
No opinion	48	8.0	74	8.38	212	6.28	305	6.71
Total	600		883		3378		4548	

that catch-and-release of sub-legal bass equaled or exceeded estimates of the population size by up to three times under a 14-inch length limit. The increase in catch-and-release fishing may be of great value due to the added recreation furnished. Johnson and Anderson (1974) also noted that size limits have been used to increase catch-and-release fishing.

Angler support of the length limit increased throughout the four years following the length limit with the exception of 1982 (Table 16). The slight decrease in the acceptance of the length limit might correspond with the slight increase of intended bass fishermen in 1982.

Creel Data

Numbers of bass creeled from the fall of 1981 through 1984 are presented in Table 17. Angler compliance with the 14-inch minimum size limit was lowest in 1981. This may have been a result of the novelty of the regulation or possibly due to the fact that creel data were collected for only three months. Angler compliance improved in 1982 and 1983 and decreased in 1984. Overall angler compliance was 85.7% for the four-year period following the length limit. Paragamian (1984a) found an 86% angler compliance with a 12-inch minimum length limit for smallmouth bass in Iowa streams to be satisfactory.

Mean relative weight of creeled largemouth bass in the 12.0-14.9 inch group increased from 1981 to 1982 and then decreased dramatically (Figure 6). The 1981 and 1982 values were within satisfactory ranges as given by Wege and Anderson (1978), while the 1983 and 1984 values were

Table 17. TWRA creel data for black bass from Norris Reservoir, 1981-1984.

Year	Total Number Black Bass Creeled	Total Number Black Bass Creeled Over 14 Inches	Angler Compliance (Percent)
1981*	56	42	75.0
1982	170	148	87.1
1983	119	114	95.8
1984	292	242	82.9

*Data for October-December only.

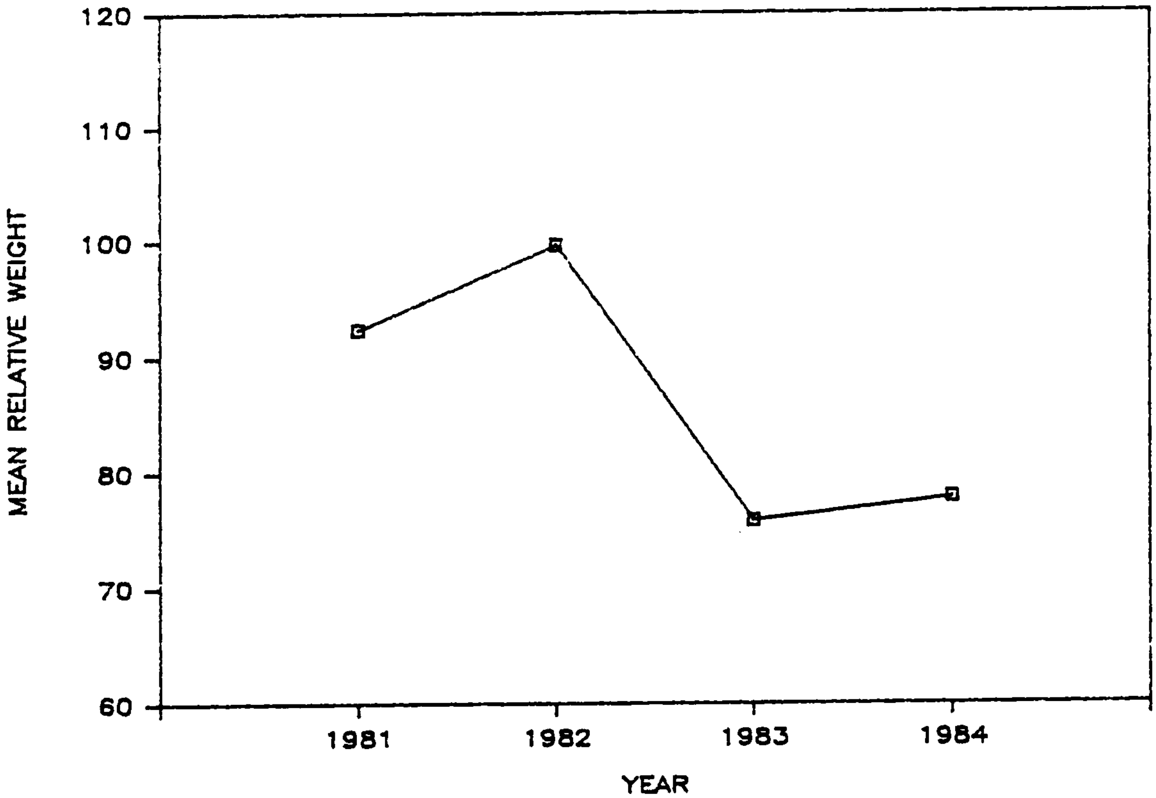

Figure 6. Mean relative weights of largemouth bass from Norris Reservoir in the size group 12.0-14.9 inches from TWRA creel data for the years 1981-1984.

lower. These low values may have been due to increased competition for food due to the stockpiling of bass below the 14-inch length limit.

Mean relative weight of creeled largemouth bass equal to or greater than 15 inches followed the same general trend as the mean relative weight for creeled largemouth bass of the 12.0-14.9 inch group (Figure 7). Values for 1981, 1983, and 1984 were similar. It was possible that 1982 was a good year for weight gain in bass greater than 15 inches.

Cove Rotenone

Threadfin shad, bluntnose minnows, and bluegill were the most abundant forage from the cove rotenone samples. Young-of-year threadfin shad and bluegill were defined as those less than 4.9 inches and 3.0 inches, respectively. All sizes of bluntnose minnows were considered to be available forage. Lawrence (1957) estimated sizes of forage fish which largemouth bass could swallow. It was determined that harvestable size largemouth (greater than 8.9 inches) and smallmouth and spotted bass (greater than 7.9 inches) could utilize the young-of-year threadfin shad, bluntnose minnows, and bluegill. The numbers per acre of these potential forage fishes are illustrated in Figure 8.

Young-of-year black bass were defined as those less than 4.0 inches. Intermediate smallmouth and spotted bass ranged from 4.0 through 7.9 inches, while intermediate largemouth bass were defined as those from 4.0 through 8.9 inches. Some of the intermediate black bass, and an even smaller portion of the young-of-year, were able to utilize the young-of-year forage.

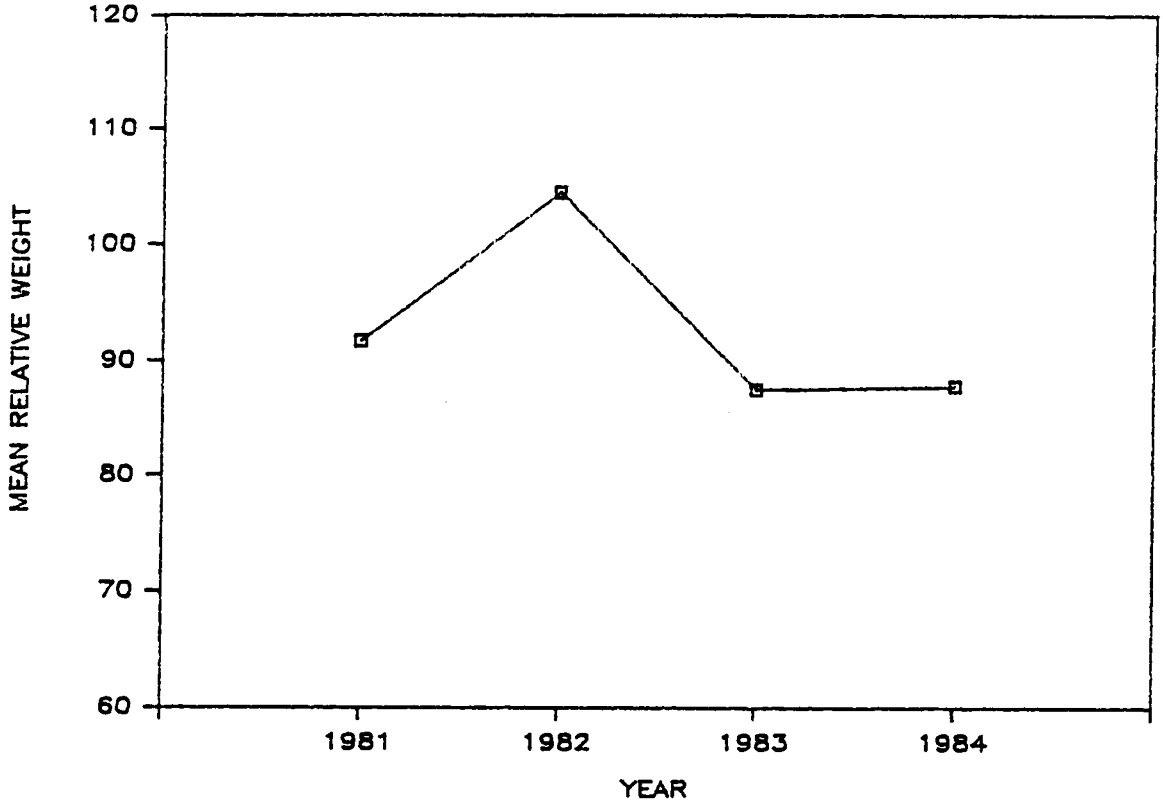

Figure 7. Mean relative weights of largemouth bass from Norris Reservoir in the size group 15.0-23.9 inches from TWRA creel data for the years 1981-1984.

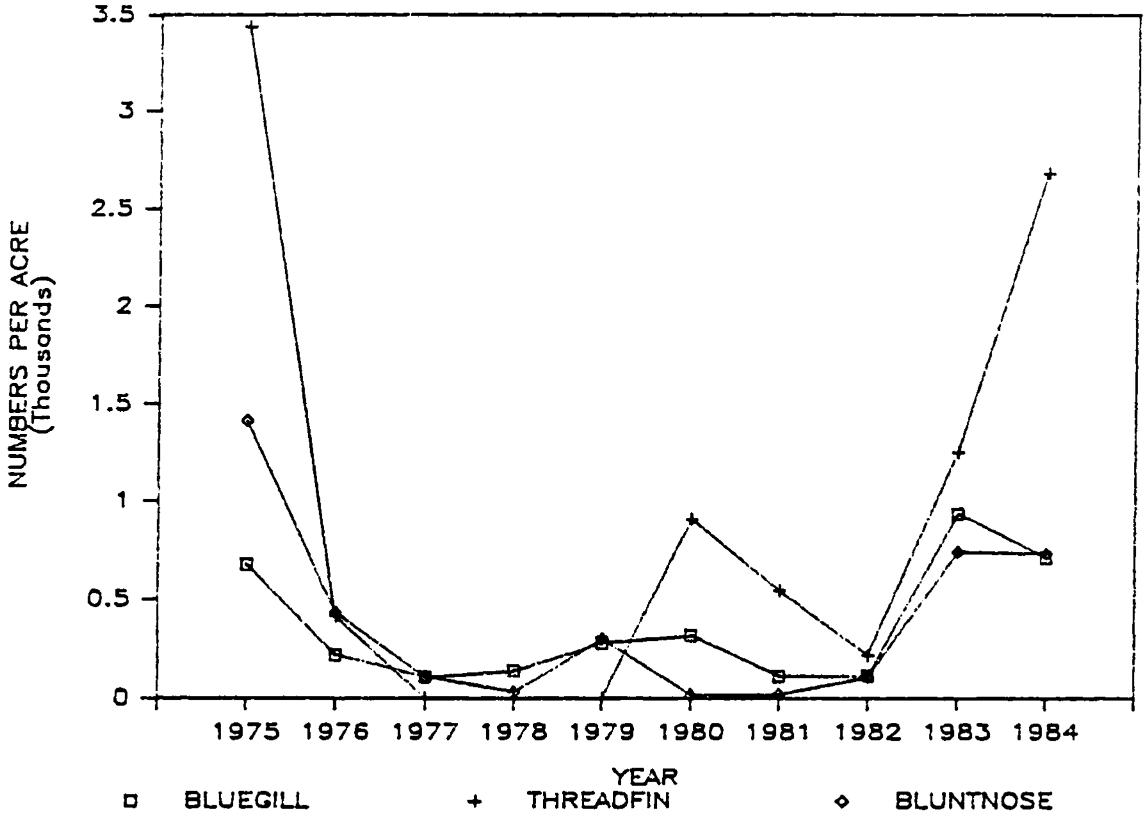

Figure 8. Abundance of the primary young-of-year forage available to intermediate and harvestable black bass in Norris Reservoir from TVA cove rotenone data.

Trends in the abundance of intermediate and harvestable black bass (Figure 9) tended to follow the abundance of forage. It was difficult to determine what effect the length limit has had due to the variations in numbers of the three size groups of black bass.

Recommendations

Data from this study indicate that a stockpiling of bass under the 14-inch minimum length limit has occurred. This stockpiling of small bass has resulted in an unbalanced black bass population structure. Farabee (1974), Hickman and Congdon (1974), Johnson and Anderson (1974), and Ramussen and Michaelson (1974) also found stockpiling of largemouth bass of sizes less than the minimum length after imposition of length limits. All of these studies also reported reductions in growth rates in the black bass population after imposition of a length limit. In contrast, the current study did not find a consistent decrease in growth rates of black bass; some age classes actually exhibited an increase in growth rate after the length limit. The availability of only two years of growth data following the limit and the different effects on different age classes make it difficult to determine the overall effect of the length limit on growth rates.

It is recommended that additional data be gathered and analyzed to determine trends in population structure and growth under the limit. Even if further investigations indicate the the bass population has not been adversely affected by the length limit, managers must decide what type of fishery is desired. If a catch-and-release fishery with some

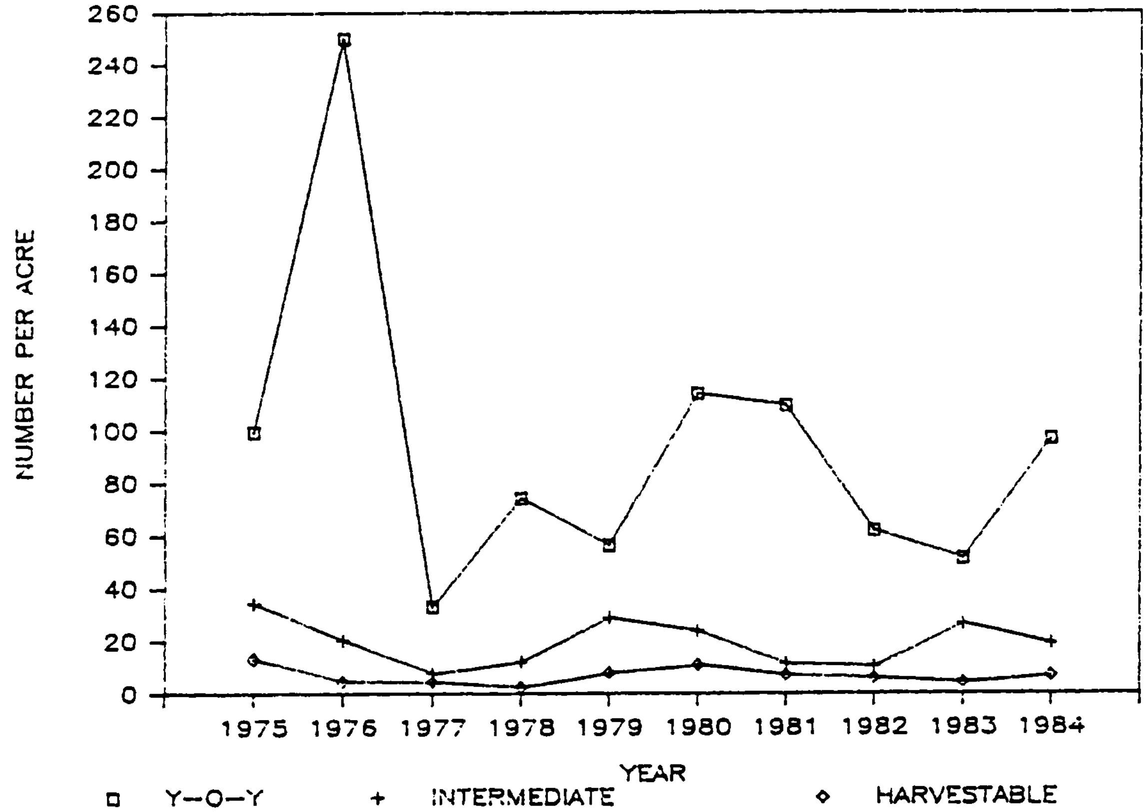

Figure 9. Black bass abundance in Norris Reservoir from TVA cove rotenone data.

actual harvest of larger bass is the object, then a minimum length such as the one currently in effect may be used. One possible solution to the stockpiling is the use of a slot limit which would allow the harvest of the smaller bass while still protecting a portion of the population. This would also be a desirable management technique if growth rates of fish less than the length limit have decreased.

CHAPTER V

SUMMARY

1. Largemouth bass represented approximately 75% of the black bass sampled by electrofishing.
2. Following the imposition of the 14-inch minimum length limit, frequencies of largemouth and black bass greater than or equal to 14 inches decreased in the electrofishing samples.
3. PSD and RSD_{15} values prior to the length limit (1977, 1978) indicated a balanced largemouth bass population. PSD and RSD_{15} values following the length limit (1983, 1984) indicated a stockpiling of fish smaller than the quality size of 12 inches.
4. Mean relative weights of largemouth bass from electrofishing samples increased after the length limit. This may have been due to an increase in forage fish in 1983 and 1984 as compared to 1977 and 1978 as indicated by the cove rotenone data. Mean relative weights of largemouth bass smaller than 15 inches were unsatisfactory and may indicate competition for food.
5. The majority of bass collected during the course of the study were four years or younger with only a very few being five years of age or older.
6. Mean lengths of largemouth bass at ages I and II and mean lengths of smallmouth and spotted bass at ages I, II, and III were slightly higher following the length limit. Mean lengths of largemouth bass

at ages III through V were slightly smaller following the length limit.

7. Largemouth bass attained a length of 14 inches during the fourth year of growth both before and after the length limit. Smallmouth and spotted bass attained a length of 14 inches during the fourth and fifth years of growth, respectively.
8. Harvest in terms of numbers and pounds of black bass decreased following the length limit. Mean weight of harvested black bass increased slightly while number per hour and pounds per hour of harvested bass decreased after the length limit was imposed.
9. Estimated pounds per acre, pounds per trip, and number per trip of harvested black bass decreased after the length limit. The estimated number of intended black bass trips per acre almost doubled while the estimated percent of people fishing for black bass decreased slightly following the length limit.
10. Data from the opinion poll indicated a slight decrease in fishing preference for black bass from 1981 through 1984.
11. Catch-and-release fishing increased dramatically from 1981 through 1984 with sub-legal fish being the primary contributor.
12. Data from the opinion poll indicated fishermen acceptance of the 14-inch minimum length limit increased from 1981 to 1984.

13. Creel data indicated angler compliance with the 14-inch minimum length limit increased from 75% in 1981 to 95.8% in 1983 and then decreased 82.7% in 1984.

14. Mean relative weight of creeled largemouth bass in the size group of 12.0 through 14.9 inches declined from 1981 through 1984 with the exception of a slight increase in 1982. Mean relative weight of creeled largemouth bass 15 inches or greater remained fairly constant from 1981 through 1984 with the exception of a slight increase in 1982.

15. Cove rotenone data indicated that young-of-year threadfin shad, bluntnose minnows, and bluegill were the most abundant forage fishes available to the black bass. The abundance of intermediate and harvestable black bass tended exhibited similar trends in abundance as the young-of-year forage fish. The effect of the 14-inch minimum length on forage was difficult to determine due to variations in numbers of forage fishes and black bass during the 10-year period of cove rotenone collections.

LITERATURE CITED

LITERATURE CITED

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

Anderson, R.O. 1980. Proportional stock density (PSD) and relative weight (Wr): interpretive indices for fish populations and communities. Pages 27-33 in S. Gloss and B. Shupp, editors. Practical fisheries management: more with less in the 1980's. Workshop proceedings. New York Chapter, American Fisheries Society, Ithaca, NY.

Anderson, R.O., and A.S. Weithman. 1978. Concept of balance for coolwater fish populations. Pages 371-381 in R.L. Kendall, editor. A symposium of selected coolwater fishes of North America. American Fisheries Society, Special Publication No. 11.

Carlander, K.D. 1975. Community relations of bass, large natural lakes. Pages 125-130 in R.H. Stroud and H. Clepper, editors. Black bass biology and management. Sport Fishing Institute, Washington, DC.

Chance, C.J., A.O. Smith, J.A. Holbrook II, and R.B. Fitz. 1975. Norris Reservoir: a case history in fish management. Pages 399-407 in R.H. Stroud and H. Clepper, editors. Black bass biology and management. Sport Fishing Institute, Washington, DC.

Choate, J.L. 1970. Effects of size limit regulation on largemouth bass in an impoundment. M.S. Thesis. The University of Missouri, Columbia, MO.

Eder, L.S. 1984. Effectiveness of an imposed slot length limit of 12.0-14.9 inches on largemouth bass. North American Journal of Fisheries Management 4: 469-478.

Farabee, G.B. 1974. Effects of a 12-inch length limit on largemouth bass and bluegill populations in two northeast Missouri lakes. Pages 95-99 in J.L. Funk, editor. Symposium on overharvest and management of largemouth bass in small impoundments. North Central Division, American Fisheries Society, Special Publication No. 3.

Gablehouse, D.W. 1984a. A length-categorization system to assess fish stocks. North American Journal of Fisheries Management 4: 273-285.

Gablehouse, D.W. 1984b. An assessment of largemouth bass slot length limits in five Kansas lakes. Federal Aid Project FW-9-P-3. Kansas Fish and Game Commission, Emporia, KS.

Hickman, G.D., and J.C. Congdon. 1974. Effects of length limits on fish populations of five North Missouri lakes. Pages 84-94 in J.L. Funk, editor. Symposium on overharvest and management of largemouth bass in small impoundments. North Central Division, American Fisheries Society, Special Publication No. 3.

Hoey, J.W., and L.C. Redmond. 1974. Evaluation of opening Binder Lake with a length limit for bass. Pages 100-105 in J.L. Funk, editor. Symposium on overharvest and management of largemouth bass in small impoundments. North Central Division, American Fisheries Society, Special Publication No. 3.

Houser, A., and W.C. Rainwater. 1975. Production of largemouth bass in Beaver and Bull Shoals Lakes. Pages 310-316 in R.H. Stroud and H. Clepper, editors. Black bass biology and management. Sport Fishing Institute, Washington, DC.

Jenkins, R.M. 1975. Black bass crops and species associations in reservoirs. Pages 114-124 in R.H. Stroud and H. Clepper, editors. Black bass biology and management. Sport Fishing Institute, Washington, DC.

Johnson, D.L., and R.O. Anderson. 1974. Evaluation of a 12-inch length limit on largemouth bass in Philips Lake, 1966-1973. Pages 106-113 in J.L. Funk, editor. Symposium on overharvest and management of largemouth bass in small impoundments. North Central Division, American Fisheries Society, Special Publication No. 3.

Lagler, K.F. 1956. Freshwater fishery biology, 2nd edition. Wm. C. Brown and Company, Dubuque, IA.

Lawrence, J.M. 1957. Estimated sizes of various forage fishes largemouth bass can swallow. Proceedings of the Annual Conference Southeastern Association of Game and Fish Commissioners 11: 271-275.

Martin, C.R., and T.B. Hess. 1984. Analysis of the fish population and fishery of Lake Oconee. Federal Aid Fish Restoration Completion Report Project Number F-26-5. Georgia Department of Natural Resources, Atlanta, GA.

Ming, A., and W.E. McDonald. 1975. Effects of length limit on an overharvested largemouth bass population. Pages 416-424 in R.H. Stroud and H. Clepper, editors. Black bass biology and management. Sport Fishing Institute, Washington, DC.

Nazary, W.F. 1982. Effect of length limits and slot limits on bass populations in Mississippi waters. Federal Aid Project F-55, Report 22. Mississippi Department of Wildlife Conservation, Jackson, MS.

Paragamian, V.L. 1977. Evaluation of the 14-inch length limit on largemouth bass at Big Creek Lake. Federal Aid to Fish Restoration, Completion Report, Project No. F-88-R. Iowa Conservation Commission, Des Moines, IA.

Paragamian, V.L. 1980. Population dynamics of smallmouth bass in the Maquoketa River and other Iowa streams. Federal Aid Fish Restoration Completion Report, Project No. F-89-R. Iowa Conservation Commission, Des Moines, IA.

Paragamian, V.L. 1982. Catch rates and harvest results under a 14.0-inch minimum length limit for largemouth bass in a new Iowa impoundment. North American Journal of Fisheries Management 2: 224-231.

Paragamian, V.L. 1983. Assessment of a 12-inch minimum length limit on smallmouth bass in the Maquoketa River. Federal Aid Fish Restoration Completion Report, Project No. F-89-R. Iowa Conservation Commission, Des Moines, IA.

Paragamian, V.L. 1984a. Angler compliance with a 12-inch minimum length limit for smallmouth bass in Iowa streams. North American Journal of Fisheries Management 4: 228-229.

Paragamian, V.L. 1984b. Evaluation of a 12.0-inch minimum length limit on smallmouth bass in the Maquoketa River, Iowa. North American Journal of Fisheries Management 4: 507-513.

Paragamian, V.L. 1984c. Population characteristics of smallmouth bass in five Iowa streams and management recommendations. North American Journal of Fisheries Management 4: 497-506.

Pelzman, R.J. 1979. Effects of a 305 mm (12.0-inch) minimum size limit on largemouth bass, *Micropterus salmoides*, at Merle Collins Reservoir. California Fish and Game 65(3): 141-150.

Ramussen, J.L., and S.M. Michaelson. 1974. Attempts to prevent largemouth bass overharvest in three northwest Missouri lakes. Pages 69-83 *in* J.L. Funk, editor. Symposium on overharvest and management of largemouth bass in small impoundments. North Central Division, American Fisheries Society, Special Publication No. 3.

Reynolds, J.B., and L.R. Babb. 1978. Structure and dynamics of largemouth bass populations. Pages 50-61 *in* G.D. Novinger and J.G. Dillard, editors. New approaches to the management of small impoundments. North Central Division, American Fisheries Society, Special Publication No. 5.

Schumacher, F.X., and R.W. Eschmeyer. 1942. The recapture and distribution of tagged bass in Norris Reservoir, Tennessee. Journal of the Tennessee Academy of Science 15: 253-268.

Stroud, R.H. 1948. Growth of the basses and black crappie in Norris Reservoir, Tennessee. Journal of the Tennessee Academy of Science 23: 31-99.

Stroud, R.H. 1975. Introduction to national bass symposium. Pages 3-4 in R.H. Stroud and H. Clepper, editors. Black bass biology and management. Sport Fishing Institute, Washington, DC.

Surber, E.W. 1968. Effects of a 12-inch size limit on smallmouth bass populations and fishing pressure in the Shenandoah River, Virginia. Proceedings of the Annual Conference Southeastern Association of Game and Fish Commissioners 22: 300-311.

Van Horn, S.L., W.R. Chapman, and F.A. Harris. 1981. Results of a 45 cm (18-inch) minimum size regulation on largemouth bass populations. Proceedings of the Annual Conference Southeastern Association of Fish and Wildlife Agencies 35: 424-429.

Wege, G.J., and R.O. Anderson. 1978. Relative weight (Wr): a new index of condition for largemouth bass. Pages 79-91 in G.D. Novinger and J.G. Dillard, editors. New approaches to the management of small impoundments. North Central Division, American Fisheries Society, Special Publication No. 5.

VITA

Elizabeth M. Schilling was born in Cincinnati, Ohio, on October 14, 1957. In 1975 she graduated from Oak Ridge High School, Tennessee. She attended Iowa State University from August, 1975, until December, 1977. She received her Bachelor of Science degree with high honors in Wildlife and Fisheries, from the University of Tennessee, Knoxville, in June of 1980. In June of 1986, she received the Master of Science degree in Ecology from the University of Tennessee, Knoxville.