ILLINOIS
Natural History Survey
BULLETIN

Largemouth Bass and Other Fishes in Ridge Lake, Illinois 1941-1963

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CONTENTS

This report is printed by authority of the State of Illinois, IRS Ch. 127, Par. 58.12. It is a contribution from the Section of Aquatic Biology of the Illinois Natural History Survey.

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Largemouth Bass and Other Fishes in Ridge Lake, Illinois, 1941–1963

George W. Bennett
H. Wickliffe Adkins
William F. Childers

THE RESULTS OF STUDIES of fishes in the small artificial impoundment known as Ridge Lake (Frontispiece) in Fox Ridge State Park, Coles County, Illinois, have been presented in several publications. The first two were semipopular articles on the efficiency of various baits for largemouth bass, *Micropterus salmoides* (Lacépède), (Durham & Bennett 1949, 1951). Also in 1951 the same authors published an Illinois Natural History Survey Biological Note, *Cost of Bass Fishing at Ridge Lake, Coles County, Illinois,* in which they estimated that fishermen were spending approximately $1.22 per hour for travel, meals, equipment, and licenses to fish in the lake. When these average hourly costs were assigned to the average catch in pounds of bass per hour, the money spent to catch a pound of bass was calculated to be $8.66.

In 1954 the senior author prepared a bulletin entitled *Largemouth Bass in Ridge Lake, Coles County, Illinois* (Bennett 1954*a*) which covered the complete Ridge Lake investigation from its beginning in 1941 through a 10-year period of biennial drainings and censusings of the fishes. This report was followed by a preliminary one on "The Effects of a Late-Summer Drawdown on the Fish Population of Ridge Lake, Coles County, Illinois" (Bennett 1954*b*), describing the changes in the fish population resulting from two severe early September drawdowns by comparing it with the fish populations exposed in the five draining censuses of the previous 10 years.

Experiments with the Ridge Lake fish population have continued, and during the years since 1953 we have made additional studies of the effects of drawdowns, stable water levels, and the introduction of hybrid sunfishes. This report will carry these studies (in part) through 1963.

Ridge Lake has been of particular interest in experimental fish management because it can be drained completely and because it was built on a watershed somewhat larger than necessary or recommended on the basis of Illinois rainfall and runoff. Consequently, we know that when we drain the lake basin completely or partially in late fall or early spring, it will refill again in a minimum time. Since 1941 the lake has always refilled during the winter following fall drawdowns or drainings and has completely refilled following six spring drainings out of eight (between March and May). In those springs when it did not refill completely, the lake basin was more than half full by June.

This large watershed also has had its disadvantages in that the extent of soil erosion has been greater than it would have been in a smaller drainage basin. This factor and the fact that ravines above the lake are steep sided and the soil is light have made silting in the upper reservoir of sufficient magnitude to reduce the lake surface area by about 1 acre (0.4 hectare) in 10 years; that is, while the original surface area of the lake in 1941 was 18 acres (7.28 hectares), its area by 1951 had been reduced to 17 acres (6.88 hectares) and by 1963 to about 16 acres, or 6.48 hectares.

At this point it is evident that we are about to become involved in the confusion of English versus metric systems of measurements, and to give both En-

glish and metric measurements in a report of this length becomes redundant. Therefore, throughout this report the metric system will be followed. For those unfamiliar with or who have forgotten the English-metric equivalents, we are including them here.

Area:	1 hectare	2.471 acres
	1 acre	0.4047 hectare
Weight:	1 kilogram	2.205 pounds
	1 pound	453.6 grams or 0.4536 kilogram
Length:	1 meter	39.37 inches
	1 inch	25.4 millimeters or 2.54 centimeters
	1 kilometer	0.621 mile
	1 mile	1.609 kilometers

Pounds per acre may be converted to kilograms per hectare by multiplying the former by 1.121.

Kilograms per hectare may be converted to pounds per acre by multiplying by 0.892.

Some physical, chemical, and limnological characteristics of Ridge Lake have already been described (Bennett 1954*a*) and will not be repeated here except to restate that the growing season for fishes is 6–6½ months.

Under conditions of stable water levels Ridge Lake might be expected to support a mixed fish population of around 100,000 individuals larger than 65 mm total length, or 12,000–15,000 per hectare, weighing around 280 kg per hectare.

The lake shows intermediate "natural" fertility because the soil type in which it is built is less fertile than the black prairies of central Illinois and more fertile than the Ozark hills of southern Illinois. The fertility of the lake may have been increased somewhat over the past 23 years because of an influx of leaves and other organic matter from the surrounding hills and because nearly all flat lands in the Ridge Lake watershed are now rather intensively fertilized for increased production of corn and soybeans.

One of the more important aspects of the Ridge Lake study is that, because it is a long-term investigation, it demonstrates the variability of a fairly simple population of common fishes, not only in numbers and total weight, but also in the yield obtainable from angling. These variations are partly related to the application of various management techniques, but they are more importantly related to the incomplete ecosystem represented by the habitat and its plant and animal associations—incomplete because certain components are absent. This situation, we believe, is more or less the case with all artificial lakes and reservoirs and of many natural lakes.

ACKNOWLEDGMENTS

Nearly everyone who has been employed on the permanent or temporary staff of the Aquatic Biology Section of the Illinois Natural History Survey since 1941 has assisted in some capacity in the Ridge Lake investigation. In the early years Mr. Bruno von Limbach, Dr. Louis A. Krumholz, and Dr. Philip W. Smith contributed much time to general collections. On draining censuses the crew consisted of six to eight individuals and has included (in the order of the first census on which each worked) Dr. Donald F. Hansen, Mr. von Limbach, Dr. Krumholz, Mr. Jacob H. Lemm (deceased), Mr. Daniel Avery (deceased), Mr. Paul G. Barnickol, Dr. Arthur Witt, Jr., Dr. Leonard Durham, Dr. R. Weldon Larimore, Dr. William C. Starrett, Dr. James S. Jordan, Dr. William F. Childers, Dr. Robert C. Hiltibran, Mr. H. Wickliffe Adkins, Mr. Richard Ward, Mr. Howard Crum, Mr. Robert T. Crompton, Mr. Richard Bass, Mr. David McGinty, Mr. Ronald Havelka, and others. Also several members of the Illinois Department of Conservation have helped with one or several censuses: Mr. Sam A.

Parr (deceased), Mr. William J. Harth, Mr. Glee Fogelman (deceased), Mr. James Holmes (deceased), Mr. Quentin Pickering, Mr. George Kuhn (deceased), Mr. Ora Price, Mr. Bruce Muench, Mr. Arnold Fritz, and Mr. Rudy Stinauer.

As members of the Survey staff for varying periods, several persons gathered limnological samples and statistics on the anglers' catch: Mr. Robert G. Rennels, Dr. Smith, Mr. Vernon A. Anderson, Mr. Charles D. Kemp, Mr. W. W. Fleming, Dr. Morris Brehmer, and Mr. Adkins.

Mr. G. H. Boewe, Mr. Frank C. Bellrose, and Mr. Fleming made special studies of the flora of the lake. Dr. Witt and Dr. Durham studied the growth of Ridge Lake bass and bluegills from scale collections. The manuscript of this paper was read and criticized by Dr. Horace W. Norton, Professor of Statistical Design and Analysis, Department of Animal Science, University of Illinois, and it was edited by Mr. Robert M. Zewadski.

ORIGINAL STOCKING AND HISTORY

In 1963 the Ridge Lake experiment was in its 23rd year. In the spring of 1941 this newly completed 7.28-ha artificial impoundment was stocked with 435 largemouth bass, *Micropterus salmoides* (Lacépède), (Bennett 1954*a*: 236). These bass multiplied and their offspring have constituted the bass population of Ridge Lake during the entire period of its existence. More than 29,700 bass have been permanently removed from Ridge Lake by pole-and-line fishing and by Survey biologists during lake draining operations. The bass appeared to be as numerous in 1963 as in 1942. There was some evidence, however, that they were more difficult to catch in 1963–1968 than they were 25 years earlier.

Bluegills, *Lepomis macrochirus* Rafinesque, were first stocked in Ridge Lake in June and July 1944 when 129 were released (Bennett 1954*a*:236). These began to produce young almost at once, and it was estimated that more than 10,000 small ones were present when the lake was drained in the early spring of 1945. About 390,000 bluegills have been permanently removed from Ridge Lake through fishing and draining operations.

On the basis of the number of bluegills removed in 20 years as compared with the largemouth bass removed in 23 years, it was evident that the bluegills were much more prolific and/or capable of surviving than were the bass. When the lake was drained in the spring of 1949, we made a first attempt to remove the bluegills completely. However, enough bluegills gained entrance from outside sources or survived in the feeder stream, in spite of an attempt to poison them, to repopulate the lake with their next spawn.

In the spring of 1949, 138 warmouths, *Chacnobryttus gulosus* (Cuvier), were stocked in Ridge Lake. In contrast to the bluegill population, the number of warmouths has always remained small, and this fish has contributed very little to the hook-and-line yield.

Four stocks of channel catfish, *Ictalurus punctatus* (Rafinesque), have been released in Ridge Lake. Those released prior to 1963 were:

May 1, 1951, 675 fish 23–33 cm total length

November 5, 1952, 599 fish 13–46 cm total length

December 17, 1957, 473 fish 19–29 cm total length

The catfish were furnished by the Illinois Department of Conservation and were trapped in backwaters of the Mississippi River. Channel catfish grew well in Ridge Lake, and to fishermen they represented a "bonus" fish. They were never stocked in large enough numbers to contribute, in any 1 year, more than 20–30 percent of the total weight of the catch. One of these catfish grew to

weigh 7.7 kg and several have weighed more than 4.5 kg; these large fish added to the general excitement of fishing at Ridge Lake by usually breaking lines when hooked.

In 1960, after an attempt was made to remove the bluegills by leaving the lake basin dry over the winter of 1959–1960 (Fig. 1), approximately 4,500 small hybrid sunfishes were stocked. This operation will be described in greater detail in a later section.

Also in 1960, 585 lake chubsuckers, *Erimyzon sucetta* (Lacépède), were stocked. Other fishes which found their way into Ridge Lake were green sunfish, *Lepomis cyanellus* Rafinesque; longear sunfish, *Lepomis megalotis* (Rafinesque); yellow bullheads, *Ictalurus natalis* (Lesueur); black bullheads, *Ictalurus melas* (Rafinesque); carp, *Cyprinus carpio* Linnaeus; black buffaloes, *Ictiobus niger* (Rafinesque); white suckers, *Catostomus commersoni* (Lacépède); and several species of stream minnows. The only members of this list which contributed to the fishermen's catch were green sunfish, yellow bullheads, black bullheads, and carp. All of these miscellaneous fishes were removed from the lake whenever found in draining censuses. These fishes probably moved into the lake from above as inhabitants of the Dry Run Creek watershed or were illegally stocked by persons unkown.

CREEL CENSUSES

From 1942 through 1963 (the end of the period covered by this report) Ridge Lake has been open to public fishing from eight Survey-owned boats during June, July, and August of each year except 1943. The lake was closed to fishing on Mondays and Tuesdays and open during the other 5 days of the week. Boats were furnished free and could be reserved in advance for the period from 6 to 10 AM or for 3 to 8 PM. When boats were not reserved, anyone could obtain permission to use them during the morning or afternoon periods.

Fishermen were checked out onto the lake in boats by the biologist at the laboratory pier and off the lake when they returned to record their catches and retrieve their state fishing licenses,

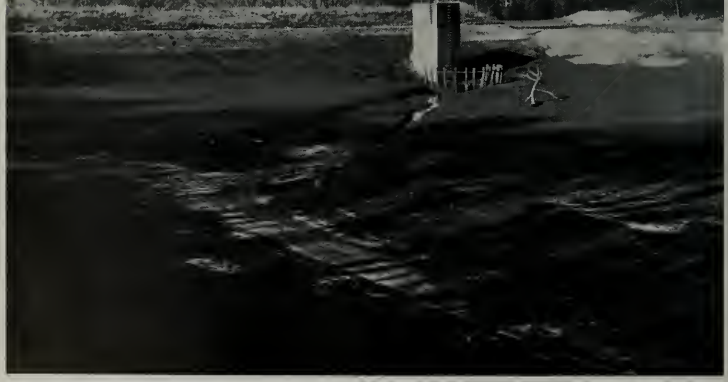

Fig. 1.— The dry basin of Ridge Lake during the winter of 1959–1960. The basin was allowed to dry completely and Dry Run Creek was permitted to run unimpeded through the lake basin to the Embarras River below the lake.

held by the biologist during each fishing period. Thus it was possible to collect information on the time spent in fishing; the catch in kinds, numbers, and weights; and the types of baits used. No restrictions were placed on baits, but if live minnows were brought to the lake, the biologist inspected them to forestall the escape of any carp, goldfish, or other undesirable species.

This method of taking a creel census gave a complete record of the time spent in fishing and the fishes caught. Signs on the lake dam and on the park roads warned that the lake was closed to fishing except from boats in this specific summer period, and it is believed that very little poaching took place.

DRAINING CENSUSES

A description of the method used in making a draining census at Ridge Lake was given in an earlier bulletin (Bennett 1954*a*:231–236). In the 1956 census a Wolf-type weir (Wolf 1951) built in the drain tunnel opening on the downstream side of the dam replaced the permanent vertical screen supported by concrete uprights and located about 15 meters below the outlet. The Wolf-type weir is an open-end box frame that is secured with its open end upstream in the lake outlet tunnel (Fig. 2). The sloping bottom of this frame as well as its sides are covered with 25-mm mesh hardware cloth, allowing a flow of water through its bottom as well as its sides. Water falls through the weir bottom by gravity. This arrangement is much more efficient in passing water than a vertical screen and much less likely to become clogged with leaves and debris.

Fishes entering the weir with the water were deposited on the sloping

Fig. 2. — Body of the Wolf-type weir that fits in the outlet tunnel on the down stream side of the Ridge Lake dam. A wire mesh covered holding box (not shown) fits tightly against the open end of the weir (held by the biologist) and extends down into the water below while the weir is supported above the stream bottom. Water from the lake outlet enters the weir (at right) and falls through the mesh bottom of the weir, leaving the fishes to flop down the slope into the holding box.

hardware cloth bottom as the water passed through and they flopped down the sloping bottom into a submersed wire-mesh catch basin at the downstream end of the weir. The fact that the weir was in the outlet of the drain tunnel instead of in the stream channel some distance below eliminated the need to pump out pools and pockets in the stream channel between the outlet and the vertical screen to capture the last few fishes escaping from the lake.

Except for using the weir instead of the vertical screen, the draining censuses were all made in about the same manner. However, the census of 1959 was made in October, while all others were made in late March or early April. The fall of 1959 was a poor time to drain Ridge Lake because very little water was flowing in Dry Run Creek; consequently, many of the fishes that remained longest in the lake basin above the gate valve were forced to move about in an emulsion-like suspension of silt and water that tended to clog the fishes' gills and apparently had a high biological oxygen demand. This mud "soup" was quickly toxic to the fishes, and many died before we could get them into clean water. In spring draining operations a small stream of clean water was always flowing in Dry Run Creek, and fishes that collected in the lake basin immediately above the outlet were supplied with a source of clear, oxygenated water.

During all draining operations some very small fishes escaped being washed out of the lake with the water or being captured in the screen and censused by remaining in pools of Dry Run Creek above the dam. Later, when water was again impounded behind the dam, they moved down into the refilling basin where they were subjected to predation from the larger fishes put back after the census.

There is also a possibility that small numbers of fishes escaped from farm ponds in the Ridge Lake watershed in times of floods and passed down Dry Run Creek into Ridge Lake. These ponds may have been the source of the bluegills and warmouths that appeared in Ridge Lake in 1960 after the lake basin had remained dry during the fall and winter of 1959–1960. Such typical pond species as bluegills and warmouths, if washed from a pond into a stream, usually would move downstream in search of quiet water.

A work camp for processing the fishes was set up between the stilling basin and the lake outlet channel below the dam (Fig. 3). Fishes to be returned to Ridge Lake after a census were held alive in the water filled stilling basin of the surface spillway until the censusing was complete. Then, after a small volume of water had collected in the lake basin above the dam, the fishes were recaptured (Fig. 4), weighed, measured, "scaled" for age determinations, and returned to Ridge Lake.

All of the largemouth bass returned to the lake after a census bore fin clip marks (either the new mark of the current census or a mark of some previous census) prior to release; therefore, any unmarked bass taken in a fishing season following a spring census (except the current year-class spawned in the lake) were fish that had escaped being captured in the draining operation. Bluegills were not usually fin clipped, because even when censuses were made at 2-year intervals, the high mortality rate of bluegills assured that relatively few marked ones would be present at the next census.

The 25-mm mesh used in the fish screens and in the construction of the Wolf-type weir allowed small fishes to escape with the water as the lake was drained. No attempt was generally made to estimate the number of fishes that escaped through the mesh, but at certain censuses many more small fishes were present than at others. The census tabulations (unless otherwise specified) represent bluegills 64 mm or more in total length and largemouth bass 100 mm or more in total length.

During the first 10 years the lake was

drained completely and the fishes were censused at 2-year intervals (1943, 1945, 1947, 1949, and 1951) Following each census small fishes were culled. About half of the small bass were removed in the 1943 census, bass smaller than 25 cm total length were removed in the 1945 and 1947 censuses, bass smaller than 23 cm were removed in the 1949 census, and those smaller than 20 cm were re-

Fig. 3. — Fish censusing "camp" at the time of a spring draining census. Fishes to be replaced in the lake are stored in the water filled stilling basin (right) until enough water collects in the lake basin to allow the fishes to be returned.

Fig. 4. — Recapturing fishes held in the stilling basin. When it is time to return the fishes stored in the stilling basin to the lake, the water is pumped from the basin and the fishes are recaptured with nets and short seines.

moved in the 1951 census. Bluegills were drastically culled at every census after they were introduced, and attempts were made to remove them completely in 1949 and 1959. The period 1941–1951 constituted the "Biennial Draining Period."

A period of testing September drawdowns of the lake level began in 1951 and extended to the spring draining census of 1956, with an additional draining census in the spring of 1953.

A period of stable water levels when no management practices were applied to either the lake or the fish population extended from the spring of 1956 to October 1959 and included four complete fish growing seasons. The lake was drained completely in October 1959, the bass and catfish were removed to a nearby hatchery pond for winter storage, and the basin of Ridge Lake was allowed to dry for about 3 months.

In early 1960 Ridge Lake was allowed to refill, the bass and catfish were moved back from the hatchery pond, and hybrid sunfishes and lake chubsuckers were stocked from outside sources.

In the following pages we will consider the variations found in the fish populations supported by the lake at the times of the various censuses. Our major objectives are to consider the differences in the nine populations of fishes and the variability of the standing fish crops; to measure the negative relationships in numbers and weights between bass and bluegills; to consider reasons why Ridge Lake appears to have a maximum carrying capacity for largemouth bass; to reappraise the effects of early fall drawdowns upon the bass and bluegills of Ridge Lake; and to demonstrate the contrasting effects of stable and fluctuating water levels upon the fish populations of this lake.

STANDING CROPS OF FISHES

Table 1 shows the numbers and weights of largemouth bass, bluegills, and other fishes taken in the nine draining censuses of Ridge Lake. Bass numbered between 1,500 and 6,200, and their total weight varied between 205 and 412 kg. Bluegills numbered between 7,500 and 93,000 and weighed (exclu-

Table 1. — Numbers and weights of largemouth bass, bluegills, and other fish taken in nine draining censuses of Ridge Lake.

Census Year	*Largemouth Bass*		*Bluegills*		*Other Fishes*		*Totals*	
	Number	Weight in Kilograms	Number	Weight in Kilograms	Number	Weight in Kilograms	Number	Weight in Kilograms
1943	4,771	393.4	0	...	36	4.1	4,807	397.5[a]
1945	1,641	323.3	10,061	57.6	762[b]	210.1[b]	12,464	591.0
1947	2,509	257.0	66,629	1,577.8	663[c]	257.7[c]	69,801	2,092.5
1949	2,039[d]	411.7[d]	19,714	709.4	110	23.6	21,863	1,144.8
1951	1,510	407.5	51,963	858.4	1,101[e]	70.8	54,574	1,336.7
1953[f]	1,964	204.8	7,476	449.1	937	247.1	10,377[f]	901.0[f]
1956[g]	2,242	289.3	17,180	924.6	886[h]	324.9[h]	20,308[g]	1,538.8[g]
1959[i]	2,354	240.0	92,669	1,246.5	2,289[j]	419.4[j]	97,312	1,905.9
1963	6,218	359.8	85,600[k]	1,051.4[k]	7,973[l]	445.6	99,791	1,856.8

[a]Only largemouth bass stocked; other fishes indigenous to Dry Run Creek watershed.
[b]These fishes were 544 black bullheads weighing 194.6 kg and 218 green sunfish weighing 15.5 kg.
[c]These fishes were 482 black bullheads weighing 73.9 kg, 56 carp weighing 176.8 kg, 1 black buffalo, and 124 green sunfish.
[d]Most satisfactory bass population from the standpoint of bass angling.
[e]These fishes were 916 warmouths, 159 black bullheads, 4 carp, and 22 minnows and small white suckers.
[f]This population was subjected to two 69-percent surface reduction drawdowns.
[g]This population was subjected to three 35-percent surface reduction drawdowns.
[h]These fishes were 622 warmouths weighing 35.3 kg, 237 channel catfish weighing 281.0 kg, and a few black bullheads.
[i]This census followed four growing seasons of stable water levels.
[j]These fishes were 172 channel catfish weighing 155.9 kg, 2,068 warmouths weighing 101.9 kg, 44 carp weighing 160.4 kg, and a few other miscellaneous fishes.
[k]Includes 72 hybrid sunfishes weighing 7.53 kg.
[l]Lake chubsuckers, warmouths, and channel catfish.

Table 2. — Numbers, total weights, and average weights of fish returned to or stocked in Ridge Lake following nine censuses.

Census Year	*Largemouth Bass*			*Bluegills*			*Warmouths*			*Channel Catfish*			*Lake Chubsuckers*		
	Number	Total Weight in Kilograms	Average Weight in Grams	Number	Total Weight in Kilograms	Average Weight in Grams	Number	Total Weight in Kilograms	Average Weight in Grams	Number	Total Weight in Kilograms	Average Weight in Grams	Number	Total Weight in Kilograms	Average Weight in Grams
1943	1,988	174.5	88	0	...	...	0	...	...	0	...	...	0	...	...
1945	647	233.9	362	61	11.6	190	0	...	...	0	...	...	0	...	...
1947	392	221.0	564	1,761	128.8	73	0	...	...	0	...	...	0	...	...
1949	1,027	365.0	355	0	...	...	0	...	...	0	...	...	0	...	...
1951	803	345.7	430	656	59.3	90	597	23.3	39	0	...	...	0	...	...
1953	604	166.1	275	1,477	127.8	86	173	24.4	141	601	194.0	323	0	...	...
1956	651	118.9	183	1,008	120.7	120	321	23.8	74	203	236.1	1,163	0	...	...
1960 (Fall 1959)	299	66.5	222	4,503[a]	121.6	27	0	...	...	41	36.9	900	585[b]	61.5	105
1963	2,386	203.2	85	4,492	122.5	27	1,335	29.4	22	11	44.8	4,073	1,020	110.4	108

[a]Bluegill x warmouth hybrids stocked after all bluegills were removed from lake; 448 red-ear x warmouth hybrids stocked in May 1961.
[b]Stocked from outside sources.

sive of the 1945 census when the bluegill population was just beginning to expand) from nearly 450 to about 1,580 kg. Before 1951 the other fishes were largely black bullheads, green sunfish, and carp, and from 1951 on, warmouths, channel catfish, carp, and lake chubsuckers. In three of the censuses, those of 1947, 1959, and 1963, the total population exceeded 1,800 kg in weight, but it varied from 398 kg when the population was almost entirely bass to 2,100 kg when the largest weight of bluegills was present.

In the two or more spawning and growing seasons between censuses, populations of bass, bluegills, green sunfish, warmouths, black bullheads, channel catfish, carp, and other species had an opportunity to expand. However, largemouth bass, channel catfish, and warmouths received greater consideration than bluegills, as most of the larger individuals were returned to the lake after the censuses. This was partly because these species were known to have low population expansion potentials (none at all for the channel catfish) and, in the case of largemouths, because we were particularly interested in managing bass as sport fish.

Actually, the reduction in the weight of largemouth bass put back after a census represented the removal of small fish and accidental losses of larger fish resulting from handling. The greatest reduction of bass occurred over the winter of 1959–1960 when the bass and channel catfish were held in a hatchery pond about 19 km from Ridge Lake. When these fishes were recaptured by draining the hatchery pond in the spring of 1960, the total weight of the bass found in the pond was reduced by 72.3 percent from the weight released there in October 1959.

Bluegills were severely reduced during each of the censuses. In no case were more than 4,500 of the larger bluegills put back after a census; usually the number returned was less than 2,000 (Table 2). Bluegills always showed great capacity for population expansion. As will be discussed later, the factors having a dampening effect on the rate of bluegill population expansion were

Table 3. — Numbers per hectare and weights per hectare of largemouth bass, bluegills, and other fish taken in nine draining censuses of Ridge Lake.

Census Year	*Largemouth Bass, Per Hectare*		*Bluegills, Per Hectare*		*Other Fish, Per Hectare*		*Totals, Per Hectare*	
	Number	Weight in Kilograms	Number	Weight in Kilograms	Number	Weight in Kilograms	Number	Weight in Kilograms
1943	655	54.0	0	...	5	0.6	660	54.6[a]
1945	225	44.4	1,382	7.9	105[b]	28.8[b]	1,712	81.1
1947	345	35.3	9,152	216.7	91	35.4[c]	9,588	287.4
1949	280[d]	56.6[d]	2,708	97.4	15	3.2	3,003	157.2
1951	207	56.0	7,138	117.9	151	9.7	7,496	183.6
1953[e]	285	29.8	1,087	65.3	136	35.9[f]	1,508	131.0
1956[g]	326	42.0	2,497	134.4	129[h]	47.2[h]	2,952	223.7
1959[i]	342	34.9	13,469	181.2	333[j]	61.0[j]	14,144	277.0
1963	904	52.3	12,442[k]	152.8	1,159[l]	64.8[l]	14,504	269.9

[a]Only largemouth bass stocked; other fishes indigenous to Dry Run Creek watershed.
[b]These fishes were black bullheads, 75 per hectare averaging 0.356 kg each, and a few green sunfish.
[c]About 10 kg of black bullheads, almost 25 kg of carp per hectare, and a few other fishes.
[d]Most satisfactory bass population from the standpoint of bass angling.
[e]This population had been subjected to two 69-percent surface reduction drawdowns.
[f]Channel catfish, at 31.2 kg per hectare, and warmouths.
[g]This population had been subjected to three 35-percent surface reduction drawdowns.
[h]Mostly warmouths and channel catfish.
[i]After four growing seasons of stable water levels.
[j]Channel catfish, warmouths, and carp.
[k]Includes a few hybrid sunfishes.
[l]Lake chubsuckers, warmouths, and channel catfish.

Table 4.— Numbers per hectare and weights per hectare of largemouth bass, bluegills, warmouths, channel catfish, and lake chubsuckers returned to or stocked in Ridge Lake following nine censuses.

Census Year	*Largemouth Bass, Per Hectare*		*Bluegills, Per Hectare*		*Warmouths, Per Hectare*		*Channel Catfish, Per Hectare*		*Lake Chubsuckers, Per Hectare*		*Totals, Per Hectare*	
	Number	Weight in Kilograms	Number	Weight in Kilograms	Number	Weight in Kilograms	Number	Weight in Kilograms	Number	Weight in Kilograms	Number	Weight in Kilograms
1943	273[a]	24.0	0	...	0	...	0	...	0	...	273	24.0
1945	89	32.1	8	1.6	0	...	0	...	0	...	97	33.7
1947	54	30.3	242	17.7	0	...	0	...	0	...	296	48.0
1949	141	50.1	0	...	0	...	0	...	0	...	141	50.1
1951	110	47.5	90	8.1	82	3.2	0	...	0	...	282	58.8
1953	88	24.1	215	18.6	25	3.5	87	28.2	0	...	415	74.4
1956	95	17.3	146	17.5	47	3.5	30	34.3	0	...	318	72.6
1959[b]	43	9.7	654[c]	17.7	0	...	6	5.4	85	9.0	788	41.8
1963	347	29.5	653	17.8	194	4.3	2	6.5	148	16.0	1,344	74.1

[a]Includes an estimated 65 small bass that escaped the 1943 census.

[b]Fall census; lake remained dry for 3 months and was restocked in spring of 1960.

[c]Bluegill x warmouth hybrids.

predation by large populations of largemouths and artificial drawdowns of the lake level.

Those who study fish populations may more easily visualize the fishes inhabiting ponds and lakes if numbers and weights are expressed in numbers and kilograms per hectare. For this reason we have included Table 3, giving the numbers and weights per hectare of the fishes found in the nine censuses, and Table 4, which gives the numbers and weights of fishes per hectare returned to the lake following each of the nine censuses.

The data shown in Table 3 indicated that the maximum weight of fishes that Ridge Lake would support in bass, bluegills, and such other fishes as have been present was around 280 kg per hectare (250 pounds per acre). This weight was exceeded slightly in the 1947 census, and the total weights of fishes were only slightly lower than that figure in the 1959 and 1963 censuses. In each of these censuses bluegills made up by far the greatest part of the fish population, both in numbers and weight.

Standing Crops of Largemouth Bass

When the populations of the species that were most abundant at Ridge Lake are considered as separate units, it may be conjectured that largemouth bass, bluegills, and warmouths have population maxima beyond which expansion is limited. For example, in the censuses of 1943, 1949, 1951, and 1963 the population of largemouth bass varied numerically between 207 and 904 fish per hectare although in each of these censuses the total bass weight was around 56 kg per hectare (54.0, 56.6, 56.0, 52.3). In the 1943 census the bass practically represented a one-species fish population for Ridge Lake, constituting 99 percent of both total number and total weight of all fishes (Table 5). At the other extreme when 904 bass per hectare were present (1963 census) and there was a large population of lake chubsuckers to produce young for bass forage, the total weight of bass was only 52.3 kg per hectare. At that time bass made up only 6 percent by number and 19 percent by weight of the entire fish population.

If the standing crop of fishes and the fish-carrying capacity of a body of water are related strictly to available food, we must assume that as much bass food was available when the entire population of the lake was composed of bass as was available when a variety of fishes was present. This may have been true, as Ridge Lake usually supports a large population of the crayfish, *Orconectes virilis* (Hagen), which is used extensively by largemouths.

In the censuses of 1945, 1947, 1956, and 1959 the total weight of bass supported by Ridge Lake ranged from 34.9 to nearly 45 kg per hectare (the 1953 census was excluded because its bass population was affected by the severe drawdowns). With the exception of the 1945 census when most of the fishes other than bass were bluegill fingerlings, these low weights per hectare of bass were associated with high weights per hectare of other kinds of fishes, suggesting competition between largemouth bass and certain other species.

Standing Crops of Bluegills

Bluegill numbers and total weights were lowest in seasons following the spring censuses because few were restocked (Table 4), and in the March census of 1945 after the initial stocking of 129 bluegills in June and July 1944. While the number of bluegills restocked after a census varied from none in 1949 and 1960 (in the latter year we attempted to replace bluegills with 654 bluegill x warmouth and red-ear x warmouth hybrids per hectare) to 653 per hectare in 1963, there was obviously no relationship between the number restocked and the number found in the census 2–4 years later.

For example, following the 1945 census, the rate of restocking was eight large bluegills per hectare, yet the weight

Table 5. — Percentages by species of total numbers and total weights of fish taken in nine draining censuses of Ridge Lake, with the total standing crops of fish.

Census Year	*Largemouth Bass*		*Bluegills*		*Warmouths*		*Catfish*		*Carp*		*Others*		*Total Weight in Kilograms Per Hectare*
	Percent of Number	Percent of Weight	Percent of Number	Percent of Weight	Percent of Number	Percent of Weight	Percent of Number	Percent of Weight	Percent of Number	Percent of Weight	Percent of Number	Percent of Weight	
1943	99	99	0	0	0	0	0.5	0.8	0	0	0.5	0.2	54.6
1945	13	55	81	10	0	0	4	33	0	0	2	2	81.2
1947	4	12	95	75	0	0	1	3	tr[a]	9	tr	tr	287.4
1949	9	36	90	62	0	0	tr	2	0	0	tr	tr	157.2
1951	3	30	95	64	2	2	tr	2	tr	1	tr	tr	183.6
1953[b]	19	23	72	50	2	3	6	24	0	0	tr	tr	131.0
1956[c]	11	19	85	60	3	2	1	18	0	0	tr	tr	223.7
1959	2	13	95	65	2	5	tr	8	tr	8	tr	tr	277.0
1963	6	19	86	57	5	5	tr	3	0	0	3	16	269.9

[a]tr = Trace; less than 0.1 percent.

[b]Lake level lowered to reduce surface area from 6.88 to 2.12 ha in early September of 1951 and 1952 prior to spring draining of 1953.

[c]Lake level lowered to reduce surface area from 6.88 to 4.45 ha in early September of 1953, 1954, and 1955 prior to spring draining of 1956.

of bluegills per hectare in the 1947 census 2 years later exceeded that of any other year (Table 3). The 1959 census exposed 13,469 bluegills per hectare. This was the largest number in any census and appeared at the end of four growing seasons of stable water levels, suggesting that stable waters were favorable to the buildup of bluegill numbers. However, the number of bluegills produced over the three growing seasons of 1960, 1961, and 1962 and exposed in the March census of 1963 was almost as large (12,442 per hectare), and bluegills were not even supposed to be present in the lake.

In considering the populations of bluegills in the censuses after that of 1945 but excluding those of 1953 and 1956 (censuses following fall drawdowns), it was evident that there was much variation in the numbers and weights of these fish. Bluegills, unlike largemouth bass whose weights in four censuses were quite similar, achieved no weights similar enough to indicate a maximum standing crop figure for bluegills in Ridge Lake. The figure of 216.7 kg per hectare found in the 1947 census (Table 3) might suggest that the maximum carrying capacity for bluegills may be around 225 kg per hectare. There were no indications of relationships between the total weights of bluegills and of other fishes except largemouth bass. In years when largemouth bass weights per hectare were highest, bluegill weights per hectare were lowest, and vice versa. This relationship will be considered in more detail later.

Standing Crops of Warmouths

The warmouth is considered a very satisfactory pond fish (Larimore 1957). It was introduced into Ridge Lake in the summer of 1949 when 138 adult fish were released so that we could gain comparative information about the warmouth and the bluegill. Even though after each census warmouths were given a special restocking advantage over bluegills (much higher percentages of total populations were returned to the lake), warmouths never made up more than 5 percent of the total numbers and weights of all fishes in any census (Table 5). Total numbers of warmouths in the five censuses after 1949 were 916 in 1951, 252 in 1953, 622 in 1956, 2,068 in 1959, and 4,768 in 1963. Warmouths have contributed comparatively little to the Ridge Lake fish population.

BIENNIAL CULLING OF THE FISH POPULATION

During 1941–1951 Ridge Lake was drained and censused at 2-year intervals and only selected fishes were returned. This operation was described in detail in a previous publication (Bennett 1954*a*: 231–236) and will only be summarized here. The original stocking of the lake and the methods of operating creel censuses and making draining censuses have been described earlier.

Briefly, the culling procedure was to remove all bass smaller than 25 cm in the 1945 and 1947 censuses, 23 cm in the 1949 census, and 20 cm in the 1951 census (Table 6). In the 1943 census there were 4,771 bass between 15 and 20 cm. More than half of these fish were removed (2,783) to correct the overpopulation that had resulted in their stunting.

Nearly all of the bluegills were removed during each census, and the extent of these removals can be seen in Table 6. Removals of warmouths were relatively small in most censuses. The channel catfish removed were fish that were killed or injured in handling, as we tried to return as many of this species as possible. All other fishes except lake chubsuckers were completely removed from the lake during each census. These "other fishes" were largely bullheads, *I. melas* and *I. natalis;* green sunfish; and carp.

Small bass (less than 20 cm) and bluegills were culled as a final part of each census after the initial 10-year period. As may be seen in Table 6, the totals of fishes permanently removed from the

Table 6. — Numbers per hectare and weights per hectare of largemouth bass, bluegills, warmouths, channel catfish, and other fish permanently removed from Ridge Lake in draining operations, and totals for the entire lake, 1943–1963.

Census Year	*Largemouth Bass, Per Hectare*		*Bluegills, Per Hectare*		*Warmouths, Per Hectare*		*Channel Catfish, Per Hectare*		*Other Fish,*[a] *Per Hectare*	
	Number	Weight in Kilograms	Number	Weight in Kilograms	Number	Weight in Kilograms	Number	Weight in Kilograms	Number	Weight in Kilograms
				Biennial Draining Period						
1943	382	30.0	0	...	0	...	0	...	5	0.6
1945	136[b]	12.3	1,374	6.3	0	...	0	...	105	28.8
1947	291[b]	5.0	8,910	199.0	0	...	0	...	91	35.4
1949	139[c]	6.4	2,708	97.4	0	...	0	...	15	3.2
1951	97[d]	8.5	7,048	109.8	44	1.2	0	...	25	5.3
				Drawdown Period						
1953	198[d]	5.6	872	46.7	12	0.7	7	2.9	5	0.6
1956	231[d]	24.8	2,351	116.8	42	1.7	5	6.5	5	1.2
				Stable Water Level Period						
1959	299[d]	25.2	12,815	163.5	215	7.5	20	17.3	7	21.8
				Hybrid Sunfishes Period						
1963	557[d]	22.8	11,789[e]	135.0[e]	499	8.7	tr[f]	1.8	316[g]	27.6[g]
Totals for entire lake (not per hectare), 1943–1963										
	16,451[d]	*992.0*	*337,334*	*6,182.6*						

[a]Unless otherwise designated, these fishes consisted largely of black bullheads, green sunfish, and a few carp and miscellaneous minnows.
[b]Consisted almost entirely of largemouth bass of less than 25 cm.
[c]Consisted almost entirely of largemouth bass of less than 23 cm.
[d]Consisted almost entirely of largemouth bass of less than 20 cm.
[e]Included 72 hybrid sunfishes weighing 7.3 kg.
[f]tr = Trace; less than one fish per hectare.
[g]Included 2,162 lake chubsuckers and 10 golden shiners.

lake in the nine censuses were about 16,400 bass, 337,300 bluegills, and about 9,500 other fishes (totals not shown in Table 6). This culling operation increased the success of bass spawning (Table 10 and Bennett 1954*a*:246) because it removed many of the small bluegills and small bass that would have preyed upon bass fry and fingerlings of the new year-classes. It also increased the average growth rate of both bass and bluegills by reducing the numbers of smaller individuals of both species, which reduced the competition for food.

In a later section the effects of biennial culling on angling will be considered.

PERIOD OF ANNUAL FALL DRAWDOWNS

Drawdown studies were made during the 5 years from 1951 to 1956. This period may be subdivided into a 2-year period when severe fall drawdowns were made in 1951 and 1952 followed by a draining census in March 1953 and a 3-year period of less severe fall drawdowns in 1953, 1954, and 1955 followed by a draining census in March 1956. Results of the 1951–1953 severe drawdown studies have already been described (Bennett 1954*b*).

In brief, beginning in early September 1951 after the spring draining census and summer angling period, the lake level was lowered 4.6 meters in 96 hours by opening the drain outlet to allow the slow escape of lake water (Fig. 5). This release reduced the lake surface area from 6.88 ha to 2.12 ha and the maximum depth from 7.6 meters to 3.0 meters. The reduction in surface area amounted to 69 percent, and the reduction in total volume of water was considerably greater (Fig. 6).

All of the fishes and many of the larger aquatic invertebrates that inhabited the shallows of the lake were stranded on the exposed and drying bottom where they died, or if they moved down with the water, they were forced out of the debris and aquatic vegetation common to the shallow water and concentrated in water devoid of protective cover. In this open water the larger fishes could readily capture the smaller ones and the aquatic invertebrates. Thus, the numbers of small fishes and aquatic animals were rapidly reduced by being eaten by larger fishes or stranded.

The lake bottom was exposed to allow drying and oxidation of decaying organic materials. The drawdown level was maintained throughout September and October through the release of additional water when runoff from the watershed raised the level of the lake. Once the water temperature dropped below 18° C. (64.4° F.) in late October, the lake was allowed to refill. A similar program of water release was followed during the fall of 1952. In both years the lake had refilled by early March.

After the March draining census and the summer fishing period of 1953, a less severe September drawdown operation was begun. Instead of lowering the lake level 4.6 meters to give a lake surface area of 2.12 ha, the level was lowered only 3 meters to give a surface area of about 4.5 ha. This was a surface reduction of about 35 percent. After 3-meter fall drawdowns were made in 1953, 1954, and 1955, the lake was completely drained and censused in the spring of 1956.

The effects of the drawdown periods on the fish population of Ridge Lake may be seen in Tables 1 and 3. The total weight of fishes in the 1953 census (131 kg per hectare) was 26 kg per hectare less than in the lowest of the seven censuses, 1947 on, in which substantial populations of both largemouth bass and bluegills were present. However, when the fish population was figured on the basis of a 2.12-ha lake (resulting from the severe drawdowns of 1951 and 1952), the total weight of the fishes was considerably larger than 280 kg per hectare (630 kg per hectare). Evidently the downward adjustment of the weight of fishes to conform to the new lake area was only partly attained during the fall warm weather period when such adjust-

ment might be expected to take place.

As suggested above, the effects of the drawdowns should be felt more among the small fish than among the large ones although actual stranding of fish by the receding water would depend to some extent on the behavior of individual species. Those species that normally frequent open waters away from the shore would be less likely to be trapped than would the species that use the plant growth and debris of shallow water for protection. Because small bass are more prone to move about in open water and bluegills tend to hide themselves among aquatic vegetation, there is a definite selection against the survival of small bluegills. On the other hand, open-water fishes (bass in this case) may become trapped in pools on an uneven lake bottom when the water level drops and leaves large pools that may be as much as 30 cm deep and 0.1 ha or more in extent. Of course, if these pools dry up before being reflooded, the trapped fishes of all kinds and sizes are lost.

The effects of the severe drawdowns of 1951 and 1952 were evident in the census of 1953. The weight of the bass population, 29.8 kg per hectare, was about one-half of the theoretical bass carrying capacity for the full lake, and as the number of bass in the 1953 census was comparable to the bass populations of other censuses, it may be assumed that there were fewer large bass than in most years (Table 3). This point will be considered in a later section when size distributions of these populations are discussed.

The most striking effects of the drawdowns were in the number of bluegills in the 1953 census as compared with bluegill numbers found in nondraw-

Fig. 5. — The outlet gate at Ridge Lake being opened by a hand-cranked jack on top of the outlet tower. In this photograph the lake level has been lowered about 4 meters. The ladder steps on the tower are approximately 30.5 cm (1 foot) apart.

down censuses and the sizes of the bluegills that survived. Only about 7,500 bluegills were taken, or 1,087 per hectare. The bluegill population found in other censuses ranged approximately from 2,500 to 13,500 per hectare. Still more striking was the fact that of the 7,500 bluegills that were present, more than half were of desirable sizes for angling (15 cm or larger) (Table 9), and those that were less than 15 cm total length were mostly within the 12.5–15 cm range. Other fishes in the 1953 census were warmouths and channel catfish. The drawdown may have improved the average size of the warmouths; it had no measurable effect on the channel catfish.

Three consecutive fall drawdowns of comparatively less severity (as described above) did not reduce the total weight of the Ridge Lake fish population beyond the range of variation of the nondrawdown censuses. Excluding the two censuses prior to the bluegill expansion of 1946, the standing crop of 223.7 kg per hectare found in the postdrawdown census of 1956 (Table 3) was exceeded in only three censuses and was greater in total weight than was found in three censuses.

Numbers and weights of largemouth bass were within the range of the other censuses. The 326 bass per hectare weighing 42.0 kg per hectare of the 1956 census were a more desirable bass population for angling than that of 1947 with 345 bass weighing 35.3 kg per hectare or that of 1959 with 342 bass weighing 34.9 kg per hectare.

Again in 1956 the bluegills showed the effects of the drawdowns. The total bluegill population numbered only about 17,200 (2,497 per hectare), about 2,500 less than the number in the census of 1949, the smallest nondrawdown census population of bluegills (19,700, or 2,708 per hectare). In most other censuses the numbers of bluegills ranged from slightly more than 50,000 to nearly 93,000 (or 7,000–13,500 per hectare).

Also in the 1956 census the number of bluegills 15 cm and larger exceeded those of less than 15 cm total length. As will be described in a later section, a larger total number of bluegills of desirable sizes was found in 1956 than was found in any other census, including

Fig. 6. — Ridge Lake, showing the outlet tower and laboratory after a 4-meter drawdown. Although not visible here, the lake basin is dry from a point opposite the laboratory to the upper end.

those of 1947 and 1959 in which the total bluegill populations numbered 66,600 and 92,700, respectively.

Again in 1956 other fishes consisted of warmouths and channel catfish and a few black bullheads. The warmouths appeared to benefit from the drawdowns, for during the drawdown period their average size was larger than in other periods. The channel catfish were also larger, but no cause could be assigned.

STABLE WATER PERIOD

Prior to the drawdown periods, 1951–1953 and 1953–1956, Ridge Lake had been drained, the fish population had been censused, and the lake had been restocked at 2-year intervals. The fishes that were held alive during each census to be replaced in the lake were rather severely culled. Population shifts observed at these 2-year intervals prior to 1951 gave only minor indications of what changes might take place in the relative abundance of the several kinds of fishes in the population if the lake were left alone for a longer period. Thus, it seemed worthwhile to leave Ridge Lake without draining censuses or drawdowns for at least four growing seasons.

The period of stable or nearly stable water levels began when Ridge Lake refilled in April after the draining census of March 1956 and continued until the draining census of October 12–16, 1959. This period included four growing seasons for fishes at Ridge Lake (Bennett 1954*a*:227; Markus 1932). During the four summers, 1956–1959, Ridge Lake was open to fishing as usual. The water level of the lake in this period varied from tower spillway crest level to a minimum of about 0.75 meter below the crest of the tower spillway. These fluctuations were believed to have had little influence on the fish population because they were "natural" fluctuations and because they made only a relatively small change in the area of the lake.

Tables 1 and 3 show that a numerically large population of bluegills developed in the 4-year stable water period, although the total number of all fishes was not as great as was found in the 1963 census, and the total weight of all fishes was less than was observed in the 1947 census.

The largemouth bass segment of the population appeared to be decreasing in weight although this point could not be verified statistically. The total number of bass, 2,354, or 342 per hectare, was intermediate and about the same as was found in the censuses of 1947 and 1956; the total weight of bass, 240.0 kg, or 34.9 kg per hectare, was the lowest of all nondrawdown censuses although that of 1947 was only slightly higher (Table 3).

In contrast to the bass, the bluegill population had increased to the numerical maximum found in any census, 92,700, or 13,469 per hectare. The total weight per hectare of the bluegill population, 181.2 kg, was exceeded only by that found in the 1947 census of 216.7 kg per hectare.

It is perhaps unfortunate that this fish population was not allowed to continue without a draining inventory for 2 or more additional years, as it appeared to be heading in the direction of reduced numbers of largemouth bass and overpopulation and stunting of bluegills. As will be shown in a later section, a large number of bluegills were caught by anglers during this period although after 1956 their average size was small.

COMPETITION: HYBRID SUNFISHES VERSUS BLUEGILLS

In 1960 we wished to begin testing the usefulness of two types of hybrid sunfishes in a location where we could obtain a complete creel census and check fishermen's minnow buckets for sunfishes that might contaminate a hybrid sunfish population. We chose Ridge Lake as the test site, and to prevent contaminating the hybrid population, we wished to remove all bluegills from the lake. An unsuccessful attempt to remove bluegills by poisoning the water after the 1949 census made it almost a

certainty that they could not be successfully eliminated by rotenone treatment if such treatment were attempted in March (water temperature about 5° C.). Greater certainty of their elimination was expected if the lake were drained in October when Dry Run Creek was dry except when heavy rains gave temporary flow. Then if the gate valve in the Ridge Lake dam were left open over the winter so that no water would be left standing in the lake basin, any bluegills that survived anywhere in the watershed or lake basin would have a great opportunity to move downstream during periods of high runoff, finally arriving at the Embarras River several kilometers below the lake.

The lake was drained and censused October 12–15, 1959, and the largemouth bass and channel catfish to be restocked were stored in a state fish hatchery pond for the winter. The bass were saved so that we might retain the original strain that had been stocked in Ridge Lake 18 years before. The only reason for retaining the catfish was that they were of catchable sizes.

In all, 321 large bass weighing 161 kg and 200 small ones weighing 8.2 kg were placed in the hatchery pond along with 172 channel catfish weighing 156 kg. When the pond was drained in the spring it contained only 299 bass weighing 66.5 kg and 41 channel catfish weighing 36.9 kg (Table 2). It is quite possible that the missing bass and catfish were injured in handling or died from adverse conditions under the ice although there was no evidence of a general winterkill in the pond. All of the bass and catfish appeared emaciated when the pond was drained and many showed skin lesions that resembled furunculosis. In spite of their poor condition the 299 bass and 41 catfish were released in Ridge Lake in April 1960.

Bluegill x warmouth hybrids from a 1-ha nursery pond were moved to Ridge Lake during April 1960. These 4,503 fish ranged in length from 6.5 to 12.5 cm and weighed about 35 per kg. At the same period 585 lake chubsuckers were captured at a limestone quarry near Fairmount, Ill., and moved to Ridge Lake. In 1961, 448 red-ear x warmouth hybrid sunfish were added. These were also in the 6.5–12.5 cm range.

The experiment with the hybrid sunfishes was not a success because bluegills gained entrance to Ridge Lake and multiplied to compete with the hybrids. Also the hybrids were too easily caught by hook and line. As we had a 17.5-cm minimum length for taking these hybrids, a large number were captured and thrown back, many of which may have sustained injuries that later caused their deaths.

The creel record for 1960–1962 was the lowest of any period and was believed to reflect the interaction of the several factors mentioned above. The draining census of 1963 showed that the bass and the small number of remaining channel catfish had recovered from the effects of wintering in the hatchery pond. The lake chubsuckers had expanded their population to 3,200 from the original stocking of 585.

SIZE DISTRIBUTION OF LARGEMOUTH BASS AND BLUEGILLS

When a fish population is exposed in total, as occurs during a draining census, one has an opportunity to appraise the size distribution of the various species making up the population. The total number and the length distribution of a single species reflect its ability to compete with the other fish species present. The length frequency distribution also reflects the success of the individual year-classes constituting the life span of the fish species that is in review.

Angling demands maximum numbers of fishes of suitable sizes for sport and table use. It seems to matter not at all that these two criteria are antagonistic; that is, as the numerical size of a population increases, less food is available for each individual fish with the result that the opportunities for fishes to grow

Table 7. — Numbers and total weights of designated length-weight groups of largemouth bass taken in nine draining censuses of Ridge Lake.

Census Year	Length Range: 12.7–24.9 cm / Weight Range: 0.068–0.222 kg		25.0–31.6 cm / 0.223–0.450 kg		31.7–36.7 cm / 0.451–0.903 kg		36.8–41.7 cm / 0.904–1.356 kg		41.8–46.9 cm / 1.357–1.810 kg		47.0–58.4 cm / 1.811–2.082 kg	
	Number	Weight in Kilograms	Number	Weight in Kilograms	Number	Weight in Kilograms	Number	Weight in Kilograms	Number	Weight in Kilograms	Number	Weight in Kilograms
Biennial Draining Period												
1943	4,754	368.4	0	...	0	...	2	2.1	15	22.9	0	...
1945	930	64.9	691	236.5	10	4.8	1	0.9	3	4.3	6	11.9
1947	2,105	39.8	233	77.0	87	45.9	34	33.6	49	57.7	1	3.0
1949	1,666	147.7	165	48.1	68	40.8	74	67.8	40	56.3	26	51.0
1951	948	79.3	270	77.6	108	58.6	157	146.5	14	18.7	13	26.8
Drawdown Period												
1953	1,823	96.6	61	13.8	5	3.3	37	32.9	28	37.5	10	20.7
1956	1,982	163.7	204	47.9	12	5.6	7	6.6	23	31.4	14	34.1
Stable Water Level Period												
1959	2,230	101.9	29	11.0	36	20.2	7	6.8	12	16.8	40	83.3
Hybrid Sunfishes Period												
1963	6,042	109.9	4	1.2	16	10.5	43	44.0	89	135.1	24	59.1

rapidly to desirable sizes are decreased. The reverse is also true; smaller numbers of fishes are usually associated with more rapid growth rates and larger sizes except in a few situations where the growth of certain pelagic fishes seems to be unrelated to the density of a population.

Where growth rates and large average sizes of fishes are density dependent, fish management must be a compromise. Maximum population numbers must be sacrificed in part to maintain a rate of growth that will produce fishes of catchable sizes; maximum growth rates and the development of fishes of maximum sizes must be sacrificed in part for the production of suitable numbers for reasonably successful angling. Often it is impossible to apply management at the same efficiency level to several species of fishes inhabiting the same water that one might apply if he were interested in one species to the exclusion of others. In a simple two-species combination such as the bass-bluegill, one might effectively manage for bass production and disregard the bluegills or manage for bluegills and disregard maximum production of bass. While the production of fishes for angling can be materially improved in either direction, it may be difficult or impossible to attain the maximum for both species at the same time.

In the Ridge Lake studies several management techniques were applied. Analyses of the size distribution and hook-and-line yields of the fishes should indicate the effectiveness of the techniques in question. These analyses will be presented in the following sections. A consideration of size distribution will come first.

Largemouth Bass

The size distribution of largemouth bass found in the nine censuses of Ridge Lake is shown in Tables 7 and 8. Table 7 gives the numbers and weights of largemouths divided into six length-weight categories. If we consider the numbers and total weights of fish in the four length categories from 25.0 cm to 46.9 cm, inclusive, it is quite evident that with the exception of 1943, the

Table 8. — Numbers and weights of largemouth bass of small and large sizes found in nine draining censuses of Ridge Lake.

Census Year	*Small* (12.7–24.9 cm)			*Large* (25.0–58.4 cm)			*Totals*	
	Number	Total Weight in Kilograms	Average Weight in Grams	Number	Total Weight in Kilograms	Average Weight in Grams	Number	Weight in Kilograms
				Biennial Draining Period				
1943	4,754	368.4	77.5	17[a]	25.0	1,470.6	4,771	393.4
1945	930	64.9	69.8	711	258.4	363.4	1,641	323.3
1947	2,105	39.8	18.9	404	217.2	537.6	2,509	257.0
1949	1,666	147.7	88.7	373	264.0	708.0	2,039	411.7
1951	948	79.3	83.6	562	328.2	584.0	1,510	407.5
				Drawdown Period				
1953	1,823	96.6	53.0	141	108.2	767.4	1,964	204.8
1956	1,982	163.7	82.6	260	125.6	483.1	2,242	289.3
				Stable Water Level Period				
1959	2,230	101.9	45.7	124	138.1	1,113.7	2,354	240.0
				Hybrid Sunfishes Period				
1963	6,042	109.9	18.2	176	249.9	1,419.9	6,218	359.8

[a]Survivors of the original bass stocking of 1941.

Table 9. — Numbers, total weights, and average weights of bluegills in three length classes taken in nine censuses of Ridge Lake, and the total numbers and weights of all bluegills in each of the censuses.

Census Year	*Small* (6.4–14.9 cm)			*Minimum Useful Sizes* (15.0–19.9 cm)			*Large Useful Sizes* (20.0–25.1 cm)			*Totals*	
	Number	Total Weight in Kilograms	Average Weight in Grams	Number	Total Weight in Kilograms	Average Weight in Grams	Number	Total Weight in Kilograms	Average Weight in Grams	Number	Weight in Kilograms
					Biennial Draining Period						
1943	0	...	...	0	...	...	0	...	...	0	...
1945	10,000[a]	46.0[a]	5	0	...	...	61	11.6	190	10,061	57.6
1947	59,754	1,076.5	18	6,873	500.9	73	2	0.4	200	66,629	1,577.8
1949	16,625	418.8	25	3,089	290.6	94	0	...	...	19,714	709.4
1951	51,300	798.3	16	663	60.1	91	0	...	...	51,963	858.4
					Drawdown Period						
1953	3,057	103.8	34	4,383	338.5	77	36	6.8	189	7,476	449.1
1956	8,519	207.7	24	8,620	709.2	82	41	7.7	188	17,180	924.6
					Stable Water Level Period						
1959	88,200	842.9	10	4,469	403.6	90	0	...	...	92,669	1,246.5
					Hybrid Sunfishes Period						
1963	85,524	1,043.6	12	4	0.27	68	0	...	...	85,528	1,043.9

[a]Estimated.

largest numbers and weights of bass were found in the period of biennial draining, 1941–1951.

Table 8 shows a simplified breakdown of large and small bass taken in the nine censuses. In each census during the first 10 years except that of 1943 when an overpopulation of small bass resulted from the 1941 spawn, the total number and weight of bass 25 cm or longer were more than 370 weighing 215 kg or more. In none of the censuses after 1951 did the number of large bass approach 370 and only in the 1963 census was the total weight of large bass more than 215 kg. Thus, the censuses during the biennial draining period, 1941–1951, indicate the usefulness of this technique in building up populations of large bass. The relatively high weight of large bass in the 1963 census was chiefly due to the presence of 89 bass in the 1.4–1.8 kg category, which, as will be shown later, were nearly immune to capture by angling.

Bluegills

The total numbers, total weights, and average weights in three length classes of bluegills are shown in Table 9. The first census when numbers of bluegills were available was in 1947, and they have since continued to be present in substantial populations.

The largest numbers of bluegills 6.4 cm and longer were present in 1947, 1951, 1959, and 1963, but the best potential populations for angling were present in the census of 1947, 1953, 1956, and 1959.

By far the largest population of bluegills of useful sizes was exposed in the 1956 census after three consecutive seasons of mild early fall drawdowns. The 8,661 large bluegills (15 cm and over) weighing about 715 kg were about one-third larger in numbers than the next best population (that of 1947) and about two or more times as large in numbers of large bluegills as most other populations. Even following 2 years of severe fall drawdowns the 4,419 large bluegills in the 1953 census were numerically almost equal to the 4,469 large bluegills of the 1959 census after four seasons of stable water levels. Here is evidence of the importance of drawdowns in bluegill management.

Bluegills of 20 cm or more total length were found in the censuses of 1945 and 1947 (survivors of the original stocking of 1944) and in the censuses of 1953 and 1956 during the period of drawdowns. In contrast, neither the biennial culling technique nor the periods of stable water levels, 1956–1959 and 1960–1963, produced *any* bluegills as long as 20 cm.

BASS SPAWN INVENTORY

The idea of making an annual inventory of the schools of bass fry originated on May 29, 1941, when the first schools of young spawned by the original stock were in evidence along the lake shallows (Bennett 1954*a*:245). Between May 30 and June 7, 1941, we made daily counts of these schools of fry. The number of schools gradually increased until 38 were counted on June 5. After that date the number of schools decreased, and bass fry from schools that had broken up were scattered along the lake edges in the shallow water over the shore ledge (formed by wave action) where the slope of the natural bank was steep. The estimate of bass fry in the 38 schools was 76,000, or nearly 21,000 per hectare on the basis of the 3.64-ha surface area of the lake at that time. This estimate indicates an average of 2,000 fry per school. Our estimate was probably conservative, but it was not considered desirable or possible to capture an entire school and count the fry. Rough counts were made by estimating the numbers of fry in groups of 100, and it was seldom that a school was estimated at more than 3,000 fish; usually they appeared to number 2,000 or less. However, in 1951 a huge school was located around the concrete spillway tower that was estimated at 10,000 fry and probably contained more. This school was found around three sides of the tower, a linear

distance of 10 meters; extended about 2.5 meters out from the tower; and occupied at least 0.6 meter in depth.

Conditions for censusing bass fry varied from year to year. Turbid water and wave action sometimes reduced visibility. The schools of fry often moved under floating mats of algae (present in some years) and were difficult to locate. However, rooted vegetation growing on the bottom had not grown sufficiently by late May or early June to obscure the schools.

A maximum count of schools usually was recorded 3–6 days after the first school was located, and this maximum was considered the number of bass fry for each season. In Table 10 the fry estimates are given in terms of numbers per hectare. While the numbers estimated are in no way meaningful as such, the fact that we followed similar methods using identical personnel from year to year has led us to believe that these counts have comparative value.

In some years no schools of fry could be found. This did not mean that none were present; rather it probably meant that the number of schools was so small that we were unable to find them or that predation by yearling fishes took place so rapidly that the schools were decimated before the individual fry progressed much beyond the free-swimming stage.

The fact that large numbers of fry were found in a given year did not necessarily mean that a large year-class of bass would develop from them. As we shall see in the following section, there were large differences in survival rates from year to year, and it was impossible to predict survival for any given year.

The bass fry estimates given in Table 10 have been separated into three groups on the basis of management operations that we believe may have influenced bass fry numbers. The greatest numbers of fry were associated with biennial lake draining and culling operations. These operations removed almost all of the small yearling fishes that would feed upon bass eggs and fry, reduced numbers of large crayfish that might disturb bass nests, and probably also reduced predacious insect larvae which are known to attack fry. The average number of fry associated with the culling operations in nine draining censuses was 7,917 per hectare.

Fall drawdowns of Ridge Lake were believed to have similar but less severe effects upon the small fishes, crayfish, and other aquatic invertebrates. Here the data are less convincing because only 3 years were represented. Thus, the average number of young bass in the censuses associated with drawdowns (3,243 per hectare) suggested that such operations were only about 40 percent as efficient as draining and culling in promoting the successful production of bass fry.

There were 10 years when seasons of stable water levels without any type of population reduction preceded bass spawnings. With two exceptions the fry production or fry survival in those years was relatively small. The first exception was in 1942 when the fry count was 3,570 per hectare. At that time the population of Ridge Lake was composed almost entirely of bass, including a few of the original spawners and the 1941 year-class, fishes ranging in length from 18 to 28 cm. These bass were not interested in eating fishes of fry sizes.

In 1957 the bass fry estimate was 4,880 per hectare. Why the survival of fry to the schooling stage in this year was reasonably good is unknown. When the 2 exceptional years are included, the average number of fry in seasons following a year of stable water levels is 1,023 per hectare. If these 2 years had been omitted, the average would have been around 220 per hectare. Thus, the differences in the numbers of bass fry associated with two types of management as compared with the numbers of fry associated with no management appear to be very significant.

Several questions arise when large numbers of schooling bass fry are in

Table 10. — Estimated numbers of largemouth bass fry per hectare in seasons following culling operations for small bluegills and age classes 0+ and 1+ bass, 1 or more years of stable water levels, and 1 or more years of early fall drawdowns.

Spawning Seasons Following					
Biennial Draining and Culling		*Stable Water Levels*		*Fall Drawdowns*	
Year	Estimated Number of Fry Per Hectare	Year	Estimated Number of Fry Per Hectare	Year	Estimated Number of Fry Per Hectare
1941[a]	20,860[b]	1942	3,570	1952	5,010
1943[a]	2,470	1944	140	1954	2,760
1945	15,920	1946	340	1955	1,960
1947	5,080	1948	0[c]		
1949	5,390[d]	1950	0[c]		
1951	4,390	1957	4,880		
1953	10,460	1958	430		
1956	3,630	1959	580		
1960	3,050	1961	0[c]		
		1962	290		
Total	*71,250*		*10,230*		*9,730*
Average	*7,917*		*1,023*		*3,243*

[a]Fish population almost entirely largemouth bass.
[b]Calculations for year based on actual water level, giving a surface area of about 3.6 ha (Bennett 1954a:248).
[c]No schools of young bass were found.
[d]Estimate based on lake surface area of 4.4 ha (Bennett 1954a:231).

evidence: (i) Does this mark the beginning of a strong new year-class? (ii) What is the survival rate; that is, how many young from these schools will survive to become yearling bass and be found in the next draining census? (iii) How many sexually mature bass were present in the lake when this large spawn was produced? (iv) What was the composition and density of the fish population (bass and other fish) that allowed the substantial fry survival? In the following sections we have attempted to unravel some of these relationships.

SURVIVAL RATIOS OF BASS: FRY TO 2-YEAR-OLDS

In the period of biennial draining and culling, 1941–1951, the fish thinning operation associated with each lake draining was followed by a relatively successful spawn of bass in the next spawning season. This new year-class usually showed good (probably exceptional) survival of fry, at least to the free-swimming stage. As mentioned earlier, this survival was the result of the reduction in numbers of the fauna which normally might attack bass as embryos, yolk-sac fry, or schooling fry by the draining operation and the removal of small fishes of the 0+ age group.

After we had counted the schools and estimated the number of bass fry produced following each lake draining, we had the opportunity to count the numbers of 21-month-old bass, resulting from these fry, present in the succeeding draining census. If we added to the small 1+-year-old bass found in the draining censuses the small bass of the same age group taken by fishermen in the interim, we could set up a rough ratio of the number of bass fry required in a 2-year period to produce one bass of 0+ to 21 months of age.

Such a ratio would be affected by all mortality factors including angling. In Table 11 (from Bennett 1954*a*:251) we have listed the estimated numbers of bass fry per hectare, the 1+ bass caught

Table 11. — Estimated number of largemouth bass fry per hectare in each of five year-classes produced in Ridge Lake, the number of bass per hectare of each year-class either caught by fishermen in the next two fishing seasons after spawning or appearing in the next draining census about 21 months after spawning, and the ratio of fry to fish subsequently taken. These figures indicate survival of fry to become yearlings. Calculations involving water surface area were based on 7.28 ha except where stated otherwise.[a]

Year-Class	*Estimated Number of Fry Per Hectare*	*Number Per Hectare of Bass of Designated Year-Class Taken in the 21 Months After Spawning*			*Ratio of Fry to Subsequent Take*
		By Fishermen	In Draining Census	Total	
1941	20,860[b]	69	657[c]	726	29 to 1
1943	2,470	. .	62	62	40 to 1
1945	15,920	37	44	81	196 to 1
1947	5,080	42	126	168	30 to 1
1949[d]	5,390	49	111	160	34 to 1

[a]From Bennett (1954*a*:251).
[b]Calculations for this year based on actual water area of about 3.6 ha at spawning time.
[c]Figure includes an estimated 473 bass that escaped the 1943 census.
[d]Calculations for 1949 based on actual lake surface area of 4.4 ha during the summer.

by fishermen, and those found in the draining censuses. The ratios of fry to 1+ yearlings varied between 29 to 1 and 196 to 1. Because of the exceptional survival of bass fry following each culling, all of these ratios are probably abnormally low.

It is evident from the table that, in Ridge Lake at least, a large number of fry does not necessarily result in the formation of a strong new year-class. In 1941 a dominant year-class was formed when bass fry were numerous (20,860 per hectare), and the survival ratio was estimated to be approximately 29 to 1. In 1945 a strong year-class was not formed even though there were about 15,900 fry per hectare. Poor post-fry survival resulted in a ratio of almost 200 to 1 for the 2-year period.

RELATIONSHIPS BETWEEN BASS SPAWNERS, BASS FRY, AND TOTAL FISH POPULATION DENSITY

In each draining census we made an appraisal of the numbers of sexually mature bass, small immature bass, large and small bluegills, and other fishes. These components of the populations were compared with the estimated number of bass fry enumerated during the following spawning season in the 1941–1953 period when biennial population censuses were conducted. The results are shown in Table 12, in part from Bennett (1954*a*:248) and in part from new data.

It quickly became obvious that there was a negative relationship or no relationship between the number of spawners per hectare and the estimated numbers of bass fry produced. The largest numbers of fry were found in 1941, 1945, and 1953, and in those years the numbers of bass spawners in the lake were 27, 89, and 88 per hectare, respectively. In 1948, 96 bass spawners per hectare produced so few schooling fry that none were seen; in 1949, 176 bass spawners per hectare produced an estimated 5,390 fry per hectare.

More significant relationships were evident when we compared bass survival rates with the relative abundance of small bluegills. When 2,800 or more small bluegills were present per hectare, as in 1946, 1948, and 1950, bass fry survival was low. Prior to 1944 when no bluegills were present with the bass, the estimated number of young bass surviving to the fry stage was always

Table 12. — Estimated numbers of bass, bluegills, and other fish per hectare shortly prior to spawning time, and of largemouth bass fry at spawning time, 1941–1953, at Ridge Lake. Calculations involving water surface area were based on 7.28 ha before the 1951 fishing period and 6.88 ha from that time on.[a]

Year	*Largemouth Bass Per Hectare*		*Bluegills Per Hectare*		*Other Fish Per Hectare*		*All Fish Per Hectare*		*Estimated Bass Fry Per Hectare*
	25 cm or Longer	Less Than 25 cm	15 cm or Longer	Less Than 15 cm	Large	Small	Large	Small	
				Biennial Draining Period					
1941	27[b]	0	0	0	0	0	27	0	20,860
1942	69[c]	653	0	0	5	0	74	653	3,570
1943	2	271	0	0	0	0	2	271	2,470
1944	162	128	0	0	72	37	234	165	140
1945	89	0	8	0	0	0	97	0	15,920
1946	105	290	1,045	6,965	42	79	1,192	7,334	340
1947	54	0	242	0	0	0	296	0	5,080
1948	96	273	740	2,768	40	10	876	3,051	0
1949[d]	176	57[e]	0	0	0	0	233[f]	0	5,390
1950	105	173	144	7,117	49	138	298	7,428	0
1951	72	38[g]	90	0	6[h]	76[h]	168	114	4,390
				Drawdown Period					
1952	40	359	863	676	156	17	1,059	1,052	5,010
1953	88	0	215	0	112	0	415	0	10,460

[a]In part from Bennett (1954a:248).
[b]Calculations for 1941 based on actual water area of 3.6 ha at spawning time.
[c]Includes only 7 bass of spawning age per hectare.
[d]Calculations for 1949 based on actual water area of 4.4 ha during summer.
[e]None less than 23 cm.
[f]Small bass are included in the large-fish category here because they were all at least 23 cm and therefore were uninterested in fry-sized prey.
[g]None less than 20 cm.
[h]Warmouths only.

2,400 or more per hectare (Table 10). Estimated numbers of bass fry were large from 1951 to 1953, inclusive, probably because the numbers of small bluegills were held in check by the severe drawdowns of that period.

Table 12 was not carried beyond 1953 because there were no further 2-year intervals between drainings, and it was therefore impossible to estimate populations in a sequence of years such as was followed until 1953.

EXPANSION POTENTIAL OF BLUEGILLS IN RIDGE LAKE

As described in the introductory sections, bluegills showed great ability to expand their populations in Ridge Lake. This expansion was positively related to time (two, three, or four growing seasons) and negatively related to "dominant" bass populations and drawdowns. There seemed to be no relationship between numbers of large bluegills returned to the lake after a census and the numbers present in the next succeeding census 2, 3, or 4 years later.

Table 13 shows the numbers of bluegills restocked after seven censuses, including the census of 1945 after bluegills were originally stocked in 1944 and all later ones. These censuses are arranged in order of increasing numbers of bluegills returned, ranging from zero in 1949 and 1959 to 242 per hectare in 1947.

The fact that there appears to be no relationship between the number of bluegills restocked and the number present two, three, or four growing seasons later may relate to two phenomena: (i) the high reproductive potential and survival of bluegills in the lake and (ii) the fact that unknown numbers of very small bluegills may have survived the cen-

Table 13. — Number of bluegills restocked per hectare following a named census and number per hectare taken in the following census 2, 3, or 4 years later. Data are arranged in order of numbers of bluegills restocked.

Census Year	*Next Census Year*	*Growing Seasons Between Censuses*	*Bluegills Restocked Per Hectare Following Census (Col. 1)*			*Bluegills Per Hectare Present in Census Following Restocking (Col. 2)*		
			Number	Total Weight in Kilograms	Average Weight in Grams	Number	Total Weight in Kilograms	Average Weight in Grams
1949	1951	2	0	...	...	7,138	117.9	16
1959	1963	3	0[a]	...	...	12,442	152.8	12
1945	1947	2	8	1.6	200	9,152	216.7	24
1951	1953	2	90	8.1	90	1,087[b]	65.3	60
1956	1959 (Fall)	4	146	17.5	120	13,469	181.2	13
1953	1956	3	215	18.6	86	2,497[c]	134.4	54
1947	1949	2	242	17.7	73	2,708	97.4	36

[a]An unknown number of bluegills entered the lake from the watershed or an undetermined source.
[b]Subjected to 4.6-meter drawdown 1951 and 1952.
[c]Subjected to 3-meter drawdown 1953, 1954, and 1955.

suses by staying in Dry Run Creek pools until water again accumulated behind the dam. This escapement was evident in 1949 when the creek above and within the lake basin was treated with a strong dosage of rotenone. Obviously the treatment was unsuccessful, probably because the water temperature was below 13° C. and rotenone is fairly inefficient in cold water. Although no bluegills were restocked after the census, enough were present to expand to a population of 7,138 per hectare by 1951.

The two smallest bluegill populations were found in the censuses following drawdowns (1953 and 1956). Only slightly larger than the number found in 1956 was that found in 1949 which developed in a period when the bass population was at its weight peak (Table 3).

MORTALITY FACTORS AND LENGTH OF LIFE

Most species of fishes are relatively short lived even if they are entirely protected from predation or disease. In aquatic habitats away from human influences, mortality factors for fishes are so numerous that of the thousands of small fishes produced at a single spawning only a few survive to become adults. Most of this mortality takes place in the larval and post-larval stages when the fishes are very small. Fishes of large species that survive to the second growing season are subjected to predation from far fewer predators, and as the fishes become still larger, the predators are progressively fewer until the largest fishes may be preyed upon only by a few large mammals and birds.

Large fishes that survive to "old" age for their species may eventually become emaciated and die, perhaps because of their inability to capture sufficient food. The authors have seen a number of large bass that were emaciated to the point that they were "all head." One of these bass, which was 63.5 cm in total length and weighed 2.7 kg, would, if of average plumpness, have weighed 4.5–5.4 kg. There is some satisfaction in seeing fishermen catch these senile bass, because one can be certain that such fish would soon die of old age.

At Ridge Lake bass ages were determined by the presence of annuli on their scales and by fins clipped at the time of each draining census from fishes not

previously so marked. Bass marked at a previous census were not re-marked but were weighed, measured, and "scaled," and the previous fin clip was recorded.

After each census a recorded number of marked bass bearing the fin clip of the current census or those of previous censuses were restocked in the lake to be caught by fishermen in the next two, three, or four fishing seasons or to appear as marked individuals in the next draining census.

In eight draining censuses prior to the 1963 census 5,373 unmarked bass were fin clipped and restocked in Ridge Lake. As any marked fish may survive one or more periods between censuses, the restocking numbers in Tables 14 and 15 show a total somewhat larger than the total number of bass actually fin clipped. Of the fish restocked, about 59 percent were caught by fishermen, 18 percent were recovered in succeeding draining censuses, and only 23 percent disappeared. Periods between marking and recensusing were 2, 3, and 4 years.

Table 14. — Rates of exploitation and unaccountable losses of marked largemouth bass in Ridge Lake.[a]

Period	*Total Marked Bass of Each Period*	*Marked Bass Per Hectare*[b]	*Percent Recoveries and Losses*	*Annual Exploitation Rate,*[c] *Percent*
1941–1943				
1941 Original Stock	435	60	0.0	0.0
1942 Creel	41	6	9.4	9.4
1943 Census	17	2	3.9	0.0
Unaccountable loss	*377*	*52*	*86.7*	*0.0*
1943–1945				
1943 Restocking	1,515	208	0.0	0.0
1944 Creel	469	64	31.0	31.0
1945 Census	553	76	36.5	0.0
Unaccountable loss	*493*	*68*	*32.5*	*0.0*
1945–1947				
1945 Restocking	647	89	0.0	0.0
1945 Creel	404	56	62.4	62.4
1946 Creel	88	12	13.6	36.2
1947 Census	84	12	13.0	0.0
Unaccountable loss	*71*	*10*	*11.0*	*0.0*
1947–1949				
1947 Restocking	392	54	0.0	0.0
1947 Creel	137	19	34.9	34.9
1948 Creel	107	15	27.3	42.0
1949 Census	110	15	28.1	0.0
Unaccountable loss	*38*	*5*	*9.7*	*0.0*
1949–1951				
1949 Restocking	1,027	141	0.0	0.0
1949 Creel	575	79	56.0	56.0
1950 Creel	148	20	14.4	32.7
1951 Census	190	26	18.5	0.0
Unaccountable loss	*114*	*16*	*11.1*	*0.0*

[a]Lake area from 1941 to 1951 restocking, 7.28 ha; from 1951 creel to 1963, 6.88 ha.
[b]Rounded to the nearest whole number.
[c]Exploitation rate is based on theoretical number of marked fish present in the lake at the beginning of the fishing season.

In only a few instances could we finally account for all of the bass in a group of similarly marked fish that were returned to Ridge Lake after a draining census. There were a number of ways, other than being caught, in which a fish might be removed from the population: (i) Some of the smaller marked bass (20–23 cm) may have been preyed upon by larger bass or may have moved out of the lake over the surface spillway in times of floods. (ii) Some bass of all sizes injured in the draining, censusing, and restocking operation may have died some time after restocking and been torn to pieces on the lake bottom; additionally, a very few large bass may have become buried in the soft mud of the lake basin during the late stages of a census and may not have been recovered. (iii) Individual fishes dying of senile degeneration in the period between censuses may have been torn to pieces by crayfish and turtles so that their carcasses never floated to the surface. (iv) Some fish injured by hooking or trapped on broken lines, on lost stringers, or in lost wire or string mesh fish holding baskets may have died and disintegrated without coming to the surface. (v) A few marked bass may have been taken by large bird predators, such

Table 14. — Continued

Period	*Total Marked Bass of Each Period*	*Marked Bass Per Hectare*[b]	*Percent Recoveries and Losses*	*Annual Exploitation Rate,*[c] *Percent*
1951–1953				
1951 Restocking	803	110	0.0	0.0
1951 Creel	486	68	60.5	60.5
1952 Creel	129	18	16.1	40.7
1953 Census	80	11	10.0	0.0
Unaccountable loss	*108*	*15*	*13.4*	*0.0*
1953–1956				
1953 Restocking	604	88	0.0	0.0
1953 Creel	381	55	63.1	63.1
1954 Creel	124	18	20.5	55.6
1955 Creel	12	2	2.0	12.1
1956 Census	29	4	4.8	0.0
Unaccountable loss	*58*	*8*	*9.6*	*0.0*
1956–Fall, 1959				
1956 Restocking	651 (652)[d]	95	0.0	0.0
1956 Creel	346	50	53.1	53.1
1957 Creel	143	21	22.0	46.9
1958 Creel	29	4	4.4	17.9
1959 Creel	10	1	1.5	7.5
1959 Census	41	6	6.3	0.0
Unaccountable loss	*82*	*12*	*12.6*	*0.0*
1960–1963				
1960 Restocking	299	43	0.0	0.0
1960 Creel	44	6	14.7	14.7
1961 Creel	48	7	16.0	18.8
1962 Creel	15	2	5.0	7.2
1963 Census	86	12	28.8	0.0
Unaccountable loss	*106*	*15*	*35.4*	*0.0*

[d]One more marked bass was caught than was recorded as restocked in 1956.

Table 15. — Fishermen's catches and unaccountable losses of Ridge Lake largemouth bass marked in spring draining censuses of 1943, 1945, 1947, 1949, 1951, 1953, 1956, 1959 (fall), and 1963. Numbers in parentheses below restocked fish numbers show average weights (grams) of fish restocked.

Fish Group	*Original Stock*[a]						*1941–1942 Group* (Left Pectoral)		*1943–1944 Group*[b] (Right Pectoral)		*1945–1946 Group* (Left Pelvic)		*1947–1948 Group* (Dorsal)	
	Left Pectoral		Right Pectoral		Dorsal									
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
1941 Original stock[a]	58	...	42	...	335	...	...	...	...	...	...	...	...	...
1942 Creel	11	19.0	14	33.3	16[c]	4.8	...	...	...	...	...	...	...	...
1943 Census	3	5.2	12	28.6	2	0.6	...	...	...	...	...	...	...	...
Unaccountable loss	*44*	*75.8*	*16*	*38.1*	*317*	*94.6*	...	...	...	...	...	...	...	...
1943 Restocking	3	...	10	...	2	...	1,500	...	...	...	...	...	...	...
	(1,542)		(1,501)		(1,043)		(77)							
1944 Creel	3[d]	100.0	1[d]	10.0	1[e]	50.0	464	30.9	...	...	...	...	...	...
1945 Census	0	0.0	9	90.0	1	50.0	543	36.2	...	...	...	...	...	...
Unaccountable loss	*0*	*0.0*	*0*	*0.0*	*0*	*0.0*	*493*	*32.9*	...	...	...	...	...	...
1945 Restocking	...	...	9	...	...	...	496	...	142	...	...	...	...	...
			(1,769)				(349)		(322)					
1945 Creel	...	...	3	33.3	...	...	337	68.0	64	45.1	...	...	...	...
1946 Creel	...	...	0	0.0	...	...	69	13.9	19	13.4	...	...	...	...
1947 Census	...	...	1	11.1	...	...	63	12.7	20	14.1	...	...	...	...
Unaccountable loss	...	...	*5*	*55.6*	...	...	*27*	*5.4*	39	*27.4*	...	...	...	...
1947 Restocking	...	...	1	...	...	...	61	...	20	...	310	...	...	...
			(3,062)				(1,107)		(1,098)		(413)			
1947 Creel	...	...	0	0.0	...	...	18	29.5	3	15.0	116	37.5	...	...
1948 Creel	...	...	0	0.0	...	...	14	23.0	3	15.0	90	29.0	...	...
1949 Census	...	...	1	100.0	...	...	23	37.7	9	45.0	77	24.8	...	...
Unaccountable loss	...	...	*0*	*0.0*	...	...	*6*	*9.8*	*5*	*25.0*	*27*	*8.7*	...	...

[a]Original stock with left pectoral fin clipped was from Crab Orchard Lake, that with right pectoral fin clipped was from Lake Chautauqua, and that with dorsal fin clipped was from Lake Glendale.

[b]Some of the fish of this group were spawned in 1941 or 1942, escaped the 1943 census, and appeared as unmarked fish in the census of 1945, when they were given the same mark as the fish spawned in 1943 and 1944.

[c]One of these fish was taken in 1941.

[d]One of these fish with left pectoral fin clipped and the one with right pectoral fin clipped were taken in 1943.

[e]This fish was found dead July 7, 1943.

Table 15. — Continued

Fish Group	*1941–1942 Group* (Left Pectoral)		*1943–1944 Group* (Right Pectoral)		*1945–1946 Group* (Left Pelvic)		*1947–1948 Group* (Dorsal)		*1949–1950 Group* (Left Pectoral)		*1951–1952 Group* (Right Pectoral)		*1953–1955 Group* (Dorsal)	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
1949 Restocking	...	...	1	...	...	...	23	...	9	...	77	...	917	...
			(3,175)				(1,796)		(1,687)		(1,188)		(231)	
1949 Creel	...	...	1	100.0	...	...	10	43.5	5	55.6	59	76.6	500	54.5
1950 Creel	...	...	0	0.0	...	...	0	0.0	0	0.0	0	0.0	148	16.1
1951 Census	...	...	0	0.0	...	...	4	17.4	2	22.2	11	14.3	173	18.9
Unaccountable loss	...	...	*0*	*0.0*	...	...	*9*	*39.1*	*2*	*22.2*	*7*	*9.1*	*96*	*10.5*
1951 Restocking	3	...	2	...	9	...	170	...	619	...	...	...	...	...
	(2,254)		(2,064)		(1,819)		(894)		(268)					
1951 Creel	0	0.0	1	50.0	3	33.3	117	68.8	365	59.0	...	...	...	...
1952 Creel	0	0.0	0	0.0	0	0.0	2	1.2	127	20.5	...	...	...	...
1953 Census	2	66.7	1	50.0	2	22.2	31	18.2	44	7.1	...	...	...	...
Unaccountable loss	*1*	*33.3*	*0*	*0.0*	*4*	*44.5*	*20*	*11.8*	*83*	*13.4*	...	...	...	...
1953 Restocking	2	...	1	...	1	...	31	...	44	...	525	...	...	...
	(2,767)		(1,996)		(2,268)		(1,433)		(898)		(136)			
1953 Creel	0	0.0	0	0.0	0	0.0	12	38.7	21	47.7	348	66.3	...	...
1954 Creel	0	0.0	0	0.0	0	0.0	7	22.6	12	27.3	105	20.0	...	...
1955 Creel	0	0.0	0	0.0	0	0.0	1	3.2	0	0.0	11	2.1	...	...
1956 Census	1	50.0	0	0.0	0	0.0	8	25.8	3	6.8	17	3.2	...	...
Unaccountable loss	*1*	*50.0*	*1*	*100.0*	*1*	*100.0*	3	*9.7*	*8*	*18.2*	*44*	*8.4*	...	...
1956 Restocking	...	...	...	...	...	...	2	...	3	...	6 (7)	...	640	...
							(2,268)		(1,964)		(1,284)		(159)	
1956 Creel	...	...	...	...	...	...	0	0.0	1	33.3	0	0.0	345	53.9
1957 Creel	...	...	...	...	...	...	0	0.0	0	0.0	3	42.9	140	21.9
1958 Creel	...	...	...	...	...	...	0	0.0	0	0.0	0	0.0	29	4.5
1959 Creel	...	...	...	...	...	...	0	0.0	0	0.0	4[f]	57.1	6	1.0
1959 Census (fall)	...	...	...	...	...	...	0	0.0	1	33.3	0	0.0	40	6.2
Unaccountable loss	...	...	...	...	...	...	*2*	*100.0*	*1*	*33.4*	*0*	*0.0*	*80*	*12.5*

[f]One more bass with the right pectoral fin clipped was caught than was recorded in the restocking after the 1956 census.

Table 15.—Continued

Fish Group	1945–1946 Group (Left Pelvic)		1947–1948 Group (Dorsal)		1949–1950 Group (Left Pectoral)		1951–1952 Group (Right Pectorial)		1953–1955 Group (Dorsal)		1956–1959 Group (Left Pectoral)		1960–1962 Group (Right Pectoral)	
	Number	Per-cent	Number	Per-cent	Number	Per-cent	Number	Per-cent	Number	Per-cent	Number	Per-cent	Number	Per-cent
1960 Restocking	...	...	...	...	...	...	...	...	14	...	20	...	265	...
									(1,656)		(1,080)		(816)	
1960 Creel	...	...	...	...	...	...	...	...	3	21.4	...	...	41	15.5
1961 Creel	...	...	...	...	...	...	...	...	...	...	...	...	48	18.1
1962 Creel	...	...	...	...	...	...	...	...	...	...	...	...	15	5.7
1963 Census	...	...	...	...	...	...	...	...	11	78.6	13	65.0	62	23.4
Unaccountable loss	...	...	...	...	...	...	...	...	*0*	*0.0*	*7*	*35.0*	*99*	*37.3*

as great blue herons or an osprey that visited the lake occasionally; a few bass may have been taken by poachers at times when the lake was closed to fishing. However, losses of fishes to birds and poachers are considered very minor.

In Table 14 nine periods of 2–3½ years, each delimited by draining censuses, are shown with the numbers of marked bass of all sizes returned after a census, the numbers and percentages of marked fish in the catches of fishermen, the numbers and percentages of marked bass in the next draining census, and the numbers and percentages of marked fish that disappeared between the two censuses.

The annual exploitation rate was calculated by dividing the number of marked fish caught by fishermen during a given season by the number of marked fish that were supposed to be present at the beginning of that fishing season. The exploitation rate for the first fishing season after a census was considered to be the percentage of restocked marked fishes recaptured by fishermen in that season. The exploitation rate for the second fishing season after a census takes into account the fishes taken by angling in the first season, i.e., if 500 fishes were returned and 100 were recaptured in the first fishing season, the exploitation rate for the second season would be based on 400 rather than 500 fishes. The exploitation rate figures have not been adjusted for the unaccountable losses because it was impossible to assign exact times for the occurrence of such losses within the period. Because of the unaccountable losses in intercensus periods, the actual exploitation rates were somewhat higher than shown.

When bass belonging to the various mark groups were separated to show the numbers of each group in successive intercensus periods (Table 15), it was evident that significant variations in the mortality rates of fishes of various sizes and ages were indicated by the unaccountable losses. For example, in the 1941–1942 group (marked left pectoral) the unaccountable losses in the 1943–

1945 period when the fish were still quite small (18–28 cm) was 32.9 percent. In the next two 2-year periods, 1945–1947 and 1947–1949, the fish were 4–8 years old and increased in weight from about 0.34 kg each to about 1.8 kg each. The unaccountable mortality rate for the 1945–1947 period was 5.4 percent and for the 1947–1949 period, 9.8 percent. At least one of these bass lasted for 7 more years, and after 1949 the unaccountable mortality rate again became greater than 30 percent.

This change from high natural mortality among small bass, followed by low mortality until the fish passed the age of 7–8 years, followed again by high mortality among the older fish seemed to be fairly characteristic of most of the mark groups (Fig. 7). These data have been summarized in Table 16. Natural mortality rates among bass greater than 1.8 kg were relatively high in Ridge Lake, and these fish were very difficult to catch with hook and line. It was evident from the data presented in Table 16 that more of these large fish died from natural causes than were caught.

The oldest largemouth recorded at Ridge Lake was a 1941 year-class fish taken in the 1956 draining census at the age of 15 years. Only four of this year-class lived to be 10 years of age.

Table 16. — Natural, nonfishing mortality rates of various weight ranges of marked largemouth bass in Ridge Lake, tabulated at the beginnings and ends of six 2-year periods and three 3-year periods, 1941–1963. Mortality rates for the 3-year periods were not significantly different from those of the 2-year periods.

Weight Range in Kilograms	*Natural Mortality as Average Percent of Marked Bass*
0.07–0.34	33.0
0.35–1.13	13.4
1.14–1.81	14.6
1.82–2.27	39.0
2.28–2.72	72.9

In the 1943–1944 marked group one fish attained the age of 11 or 12 years, in the 1945–1946 group one fish reached the age of 10 or 11 years, and in the 1947–1948 group two fish reached the age of 9 or 10 years. Most of the bass were lost at ages between 7 and 10 years.

The high unaccountable losses in the 1941–1943 period were based on the marked bass originally stocked and were due to the very high death rate of these fish. Apparently many of the adult and yearling bass released in Ridge Lake in the initial stocking in 1941 were injured prior to release, and they probably died within a short time afterwards. This loss has been described in more detail by Bennett (1954*a*:265–266).

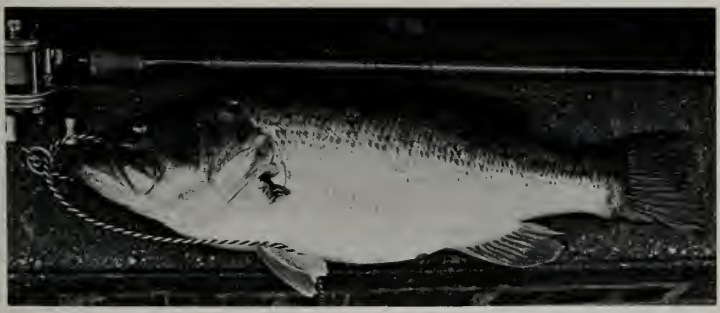

Fig. 7. — Largemouth boss showing partial regeneration of the left pectoral fin that was clipped to mark the fish when the bass was about 22 cm long. This fish had appeared in three draining censuses prior to being caught by a fisherman. It was 56 cm long, weighed 3.0 kg, and was 9 years old when captured.

EFFECTS OF CENSUSING AND OF CULLING SMALL FISHES ON THE EXPLOITATION RATE

The marking and counting of bass and large bluegills returned to the lake following each draining census and the complete creel census made in each fishing season allowed us to compare the exploitation rates of largemouth bass and bluegills in the fishing seasons immediately before and after draining censuses. In postdraining creel censuses the effects of the culling operation were indicated because the March draining eliminated a great many of the small fishes, crayfish, and aquatic invertebrates of value as fish foods. With the impoundment of new water in April and May the numbers of small aquatic animals, including fishes, undoubtedly increased rapidly, but these remained of such small sizes until well into the summer that they were of little interest to the bass of 20 cm and larger. This was not true for bluegills, because all sizes of these fish normally feed on entomostraca and small aquatic insect larvae.

We have assumed that the fishes put back after a census in March comprised the population of catchable-sized fish present in June when the lake was opened to controlled fishing. Table 17 shows the bass and bluegills per hectare released after each of the eight censuses (not including the 1943 census because the lake was not open to fishing in 1943), the fishes caught per hectare in the following fishing season, and the percentages caught of the total numbers and weights of marked fishes. The bass returned in March probably increased in weight very little during April and May because of a shortage of their larger items of food. Bluegills may have achieved average to rapid growth because of the rapid expansion of populations of entomostraca.

Table 17 indicates that the exploitation rates of bass numbers in single fishing seasons following draining and culling operations were usually between 37 and 63 percent. The exploitation rate of bass weight reached as high as 73.7 percent. There was no evidence that such exploitation represented overfishing although the total numbers and weights of bass available for replacement after a census varied a good deal.

Although Table 17 shows that the removal of bass by angling averaged around 56 percent of these fish in most spring draining census years, this was not true in 1960 and 1963. In 1960 the number of bass brought back to Ridge Lake from the hatchery where they had been kept during the winter was comparatively small. In 1963 only 116 large bass were available for restocking, but each of these fish exceeded 1 kg in weight. There was a very noticeable shortage of bass in the length range of 25–35 cm (weight range 0.25–0.45 kg). Bass smaller than 25 cm exceeded 6,000 in the census, and more than 2,000 of these small bass were fin clipped and restocked. Fishermen apparently caught and kept relatively few of these small bass.

In seasons of postcensus fishing the catch of bluegills returned after censusing varied between 32 and 41 percent. An exception occurred in 1963 when 966 bluegills of 15 cm or more in length and 3,500 bluegills of less than 15 cm were returned after the draining. This total restocking of almost 4,500 bluegills was not followed by a proportionately large catch of these fishes.

It was also possible to estimate less exactly the bass and bluegill exploitation rates in summers immediately preceding draining censuses. An estimation of the total populations of bass and bluegills was made by adding the catch figures for the summer in question to the catchable-sized fish found in the draining following that summer. Obviously, large fish in the draining censuses were present in the lake during the preceding fishing summers and were available to the anglers.

Table 18 shows the estimated numbers and weights of bass and bluegills

Table 17. — Percentages of numbers and weights of marked bass and bluegills caught by fishermen in the fishing seasons immediately following draining censuses.

Census Year	*Marked Fish Returned After Census, Per Hectare*				*Marked Fish Caught in Season Following Census, Per Hectare*				*Percent of Available Fish Caught by Anglers*			
	Largemouth Bass		Bluegills		Largemouth Bass		Bluegills		Largemouth Bass		Bluegills	
	Number	Weight in Kilograms	Number	Weight in Kilograms	Number	Weight in Kilograms	Number	Weight in Kilograms	Percent of Number	Percent of Weight	Percent of Number	Percent of Weight
1945	89	32.1	8	1.6	56	22.2	tr[a]	tr	62.9	69.2	...	...
1947	54	30.3	242	17.7	20	11.6	88	7.0	37.0	38.3	36.4	39.5
1949	141	50.1	0	...	79	33.6	2	0.1	56.0	67.1	...	...
1951	110	47.5	90	8.1	68	35.0	31	4.3	61.8	73.7	34.4	53.1
1953	88	24.1	215	18.6	55	14.5	89	11.4	62.5	60.2	41.4	61.3
1956	95	17.3	146	17.5	50	11.2	47	7.4	52.6	64.7	32.2	42.3
1960 (Fall 1959)	43	9.7	654[b]	17.7	6	2.3	10[c]	0.7	14.0[d]	23.7	...	...
1963	347	29.5	653	17.8	25	7.1	52	3.3	7.2[e]	24.1	8.0	18.5
							Average[f]		*55.9*	*62.6*	*38.1*	*49.1*

[a]tr = Trace; less than one fish or less than 0.1 kg per hectare.

[b]Hybrid sunfishes stocked from a nursery pond; no bluegills returned to lake.

[c]Hybrid sunfish; catch of hybrids restricted by a 175-mm minimum length.

[d]Bass population abnormally small and in poor physical condition in 1960.

[e]Most of the bass returned after the 1963 census were too small to interest anglers.

[f]Averages exclusive of 1960 and 1963 percentages.

Table 18. — Estimated numbers and weights of bass and bluegills available for angling in seasons prior to draining censuses, numbers and weights of these fish caught, and percentages of available fish taken by anglers.[a]

Precensus Year	*Large Fish Censused Plus Fish Caught in Season Before Census, Per Hectare*				*Fish Caught in Season Before Census, Per Hectare*				*Percent of Available Fish Taken by Angling*			
	Largemouth Bass		Bluegills		Largemouth Bass		Bluegills		Largemouth Bass		Bluegills	
	Number	Weight in Kilograms	Number	Weight in Kilograms	Number	Weight in Kilograms	Number	Weight in Kilograms	Percent of Number	Percent of Weight	Percent of Number	Percent of Weight
1944	162	52.3	0	...	64	16.8	0	...	39.5	32.1	...	...
1946	105	46.2	1,176	83.1	50	16.4	232	14.2	47.6	35.5	19.7	17.1
1948	135	63.7	1,225	91.4	89	28.6	800	51.4	65.9	44.9	65.3	56.2
1950	143	65.6	214	15.7	71	20.6	123	7.5	49.6	31.4	57.5	47.7
1952	134	33.8	1,095	85.0	114	18.1	453	34.8	85.1	53.6	41.4	40.9
1955	225	43.8	1,951	164.9	187	25.5	692	60.7	83.1	58.2	35.5	36.8
1959[b]	100	34.7	1,794	143.6	81	14.9	1,144	84.9	81.0	42.9	63.8	59.1
1962	69	49.0	616	24.9	21	7.3	398	16.0	30.4	14.9	64.6	64.2
								Average	*60.3*	*39.2*	*49.7*	*46.0*

[a]Fishes considered available for angling were bass 25 cm or longer and bluegills 15 cm or longer and some smaller fishes actually caught and kept by anglers.

[b]Census of October 1959.

per hectare in the lake during the summers preceding draining censuses, the numbers caught by angling, and the percentages of total numbers and weights that these catches represented. In contrast to the exploitation rates for bass in draining years, the rates in nondraining years were usually somewhat higher in number, averaging about 60 percent, and lower in weight, with an average of about 39 percent.

Exploitation rates for large bluegills were both larger and smaller than in the postcensus fishing seasons and much less constant. This variation was associated in part with varying numbers of large bluegills available. In some years large bluegills were relatively scarce; in others they were much more abundant. Except in the drawdown period the small bluegills always greatly exceeded large ones in number. In 1948 and 1959 unusually large catches of bluegills were made.

ANGLING AS A TEST FOR MANAGEMENT TECHNIQUES

As described in the section on the creel census, Ridge Lake was opened to controlled public fishing in all years after 1941 except 1943. Table 19 shows the numbers and weights of fishes per hectare taken by angling during these years. Bass removed in 1941 and 1943 were those taken by our own staff to follow the growth of undesirable-sized bass. The catch of 1963 was included to show the number of fishes caught of those returned after the 1963 census.

Table 20 gives the annual intensity of fishing in man-hours per hectare and the seasonal average rate of catch in number and weight of fish per man-hour of fishing. These rates are based on catches of all kinds of fishes. The fishing pressure after the war years reflected in part the attractiveness of the fishing. Fishing pressure reached a maximum of 791 man-hours per hectare in 1948 and exceeded 700 man-hours per hectare through most of the 1950's.

The rate of catch exceeded a seasonal average of one fish per man-hour in 1948, 1955, 1958, 1959, and 1962 (Table 20). Best years from the standpoint of weight of fish caught per man-hour were 1948, 1954, 1955, 1957, 1958, and 1959.

The two best bass fishing seasons were 1949 and 1951. In each of these years the catch was more than 500 bass, weighing 245.1 and 247.4 kg, respectively. After the March 1949 census 1,027 bass weighing 365 kg were returned to Ridge Lake for the 1949 fishing season (Table 2). In the 1949 season we took away the small bass and bluegills and many of the crayfish in the usual biennial culling operation. We also concentrated the larger bass that had developed in 7.28 ha of water surface in a lake of only 4.45 ha surface area, because rainfall in the spring of 1949 was subnormal. The level was down throughout the 1949 fishing season, but the lake refilled in the fall and winter.

Following the 1951 census, 803 bass weighing 345.7 kg were returned to the lake, which filled by the end of June (Table 2). However, as usual in a spring draining year, these fish had a reduced food supply.

In 1949 following the draining and culling, which reduced the food supply of bass, and concentration of bass in a smaller than usual water volume, fishermen took 56 percent of the total bass available and 67 percent of the weight of bass put back (Table 17), which, of course, did not represent the weight available at any instant during the 1949 season.

Similarly, in 1951 fishermen took nearly 62 percent of the bass available and 74 percent of the weight of bass returned after the census (Table 17).

In 1950 and 1952, after the exceptional yields of bass in 1949 and 1951, the numbers of bass caught by anglers were not significantly lower (515 and 784, respectively), but the weight of the bass caught was lower because the faster-growing bass (cannibals) of the

Table 19. — Largemouth bass, bluegills, warmouths, channel catfish, and other fish permanently removed from Ridge Lake by angling, 1941–1963.

Year	*Largemouth Bass, Per Hectare*		*Bluegills, Per Hectare*		*Warmouths, Per Hectare*		*Channel Catfish, Per Hectare*		*Other Fish, Per Hectare*	
	Number	Weight in Kilograms	Number	Weight in Kilograms	Number	Weight in Kilograms	Number	Weight in Kilograms	Number	Weight in Kilograms
1941	7	0.5	0	...	0	...	0	...	0	...
1942	67	16.9	0	...	0	...	0	...	0	...
1943	4	1.1	0	...	0	...	0	...	0	...
1944	64	16.8	0	...	0	...	0	...	4	2.3
1945	56	22.2	tr[a]	tr	0	...	0	...	1	0.3
1946	50	16.4	232	14.2	0	...	0	...	39	2.8
1947	25	12.2	88	7.0	0	...	0	...	5	0.4
1948	89	28.6	801	51.4	0	...	0	...	33	6.5
1949	82	33.7	2	0.1	tr	0.1	0	...	tr	0.1
1950	71	20.6	123	7.5	7	0.3	0	...	31[b]	5.0
1951	75	36.0	122	9.3	7	1.0	21	4.4	tr	0.4
1952	114	18.1	453	34.8	10	1.3	20	9.4	5	0.7
1953	76	16.9	110	12.2	10	1.8	18	9.2	1	0.1
1954	178	23.4	239	27.5	11	2.2	17	16.0	6	0.8
1955	187	25.5	692	60.7	74	7.4	4	4.9	3	0.4
1956	81	13.0	218	25.2	15	1.8	12	16.6	8	2.2
1957	213	30.5	526	44.0	51	5.9	5	11.0	20	4.0
1958	118	16.0	722	47.4	36	1.6	11	4.6	5	1.4
1959	82	14.9	1,144	84.9	116	9.2	12	7.8	1	0.2
1960	6	2.3	0	...	0	...	tr	0.3	9[c]	0.7
1961	13	5.6	20	0.6	3	0.5	tr	1.9	29[d]	3.4
1962	21	7.3	398	16.0	15	0.7	0	...	176[e]	14.8
1963	43	12.7	52	3.3	7	0.3	0	...	2	0.1
Total	*1,722*	*391.2*	*5,942*	*446.1*	*362*	*34.1*	*120*	*86.1*	*378*	*46.6*

[a]tr = Trace; less than one fish or less than 0.1 kg per hectare.
[b]These fishes were 36 green sunfish weighing 2.13 kg and 187 black bullheads weighing 66.92 kg.
[c]Bluegill x warmouth hybrids, 178 mm or longer.
[d]These fishes were 194 bluegill x warmouth hybrids and 6 red-ear x warmouth hybrids.
[e]These fishes were 1,075 bluegill x warmouth hybrids and 134 red-ear x warmouth hybrids.

preceding year-classes made up much of the catch.

On the basis of the catch of bass by anglers in 1948 and 1950 we must assume that large numbers of bass were present in those years. Otherwise, the potential would not have been present for the superior bass fishing of 1949 and 1951. The fact that superior bass fishing reoccurred in 1951 after an outstanding year in 1949 indicates that bass are capable of replacing their populations of useful-sized fish very rapidly provided there is sufficient survival to replace those taken but not such excessive survival of a year-class as to create overpopulation and stunting.

When a program of biennial draining is in operation, the spawning season following a March draining may see the production of excessive numbers of young bass. The cannibals and other faster-growing individuals of this year-class will, if not taken by anglers or otherwise killed, be incorporated into the population at the time of the next draining and censusing; also, at this time the bass that have failed to grow to at least 20 cm in two growing seasons will be eliminated through the culling operation, and even the number of bass exceeding 20 cm may be reduced if we find a total population of more than 2,000 bass, or around 280–290 per hectare.

With the exception of the fishing season of 1948, bluegill yields during the 10-year period of biennial draining and

Table 20. — Annual intensity of fishing in man-hours per hectare and seasonal average rate of catch in number and weight of fish per man-hour of fishing in Ridge Lake, 1942–1963.

Year	*Man-Hours of Fishing Per Hectare*	*Catch Per Man-Hour*	
		Number	Weight in Grams
1942	524	0.1	32
1944[a]	222	0.3	76
1945[b]	260	0.2	86
1946	415	0.8	80
1947[b]	383	0.3	51
1948	791	1.2	109
1949[b]	544	0.2	62
1950	554	0.4	60
1951[b]	751	0.3	68
1952	714[c]	0.8	90
1953[b]	455	0.5	88
1954	702	0.6	100
1955	731	1.3	135
1956[b]	714	0.5	82
1957	786	1.0	121
1958	704	1.3	101
1959	768	1.8	152
1960[b]	240	0.1	14
1961	410	0.2	29
1962	410	1.5	95
1963[b]	264	0.4	62

[a]Ridge Lake was closed to public fishing in 1943 after spring draining.
[b]Lake drained and population culled of small fish in early spring prior to fishing season, except that lake was drained in October 1959, left dry during winter, and restocked in spring of 1960.
[c]After 1951 lake surface area estimated at 6.88 ha.

culling were small. In 1948 fishermen caught 5,800 bluegills; in other years of this period fewer than 1,700 bluegills were caught. This was partly due to the severe culling of bluegills of all sizes at each census. Excessive numbers of small bluegills are good for little except to cause slow growth among all sizes of bluegills, and in most years the bass seemed unable to provide any degree of control of this species. For these reasons it was customary to return fewer than 2,000 bluegills to Ridge Lake after a census. Exceptions were 1960 when 4,500 hybrid sunfishes were stocked to replace the former bluegill population and 1963 when 4,500 bluegills were returned.

The best bluegill fishing seasons after 1951 were 1952, 1955, 1957, 1958, and 1959, with the largest catch being made in 1959 when 7,868 of these fish, weighing 584.1 kg (1,144 per hectare weighing 84.9 kg), were taken. Two of these superior bluegill seasons were during the period of drawdowns (1952, 1955) and three were in the period of stable water levels (1957, 1958, and 1959).

Again, hunger appeared to influence the catch of fish. It has been shown in a preceding section that fewer small bluegills and more bluegills of desirable sizes were present during the drawdown period, 1951–1956, than at any other time. We have also shown that there were almost *twice* as many bluegills of desirable sizes in the 1956 census, after 3 years of moderate drawdowns, as there were in any other census except that of 1947. In spite of this fact the yield of large bluegills in 1955 (3,437) prior to the 1956 spring census was second to that taken in 1959 (5,475) after four seasons of stable water levels. In this latter season there were 92,600 bluegills of all sizes in Ridge Lake (13,469 per hectare), and they were competing for the available food supply. In 1955 with only around 22,000 present (about 3,200 per hectare) the competition for food must have been much lessened. The severity of the competition for food was reflected in a higher rate of catch in 1959 than in 1955 and a slightly higher rate of fisherman use in 1959 (Table 20).

WARMOUTHS IN RIDGE LAKE

As described in the introductory pages, adult warmouths were stocked in Ridge Lake in the spring of 1949. These fish first appeared in the catch in 1950 and some were taken in every fishing season except that of 1960 (Table 21). The fact that warmouths appeared in Ridge Lake again after the lake basin remained dry for several months over the winter of 1959–1960 suggests that warmouths and bluegills may have wintered in the same water area, possibly somewhere in Dry Run Creek.

Warmouths were of interest to fishermen because they often were caught on small surface plugs and artificial

Table 21. — Warmouths taken by fishermen, 1950–1963, showing large and small fish, numbers and weights per hectare, and man-hours of fishing per hectare.

Year	*15 cm or Larger*		*Less Than 15 cm*		*All Warmouths*		*Number Per Hectare*	*Weight in Kilograms Per Hectare*	*Man-Hours of Fishing Per Hectare*
	Number	Weight in Kilograms	Number	Weight in Kilograms	Number	Weight in Kilograms			
1950	3	0.5	50	1.4	53	1.9	7	0.3	554
1951	51	6.8	0	...	51	6.8	7	1.0	751
1952	63	8.8	6	0.4	69	9.2	10	1.3	714
1953	68	12.2	1	0.1	69	12.3	10	1.8	455
1954	72	15.1	2	0.1	74	15.2	11	2.2	702
1955	405	45.3	104	5.8	509	51.1	74	7.4	731
1956	105	12.3	0	...	105	12.3	15	1.8	714
1957	211	36.0	139	4.7	350	40.7	51	5.9	786
1958	20	2.2	227	9.1	247	11.3	36	1.6	704
1959	549	49.5	246	13.7	795	63.2	116	9.2	768
1960	0	...	0	...	0	...	0	...	240
1961	21	3.4	0	...	21	3.4	3	0.5	410
1962	13	2.6	89	2.2	102	4.8	15	0.7	410
1963	0	...	49	2.4	49	2.4	7	0.3	264

Table 22. — Channel catfish taken by fishermen, 1951–1963, showing large and small fish, numbers and weights per hectare, and man-hours of fishing per hectare.

Year	*30 cm or Larger*		*Less Than 30 cm*		*All Channel Catfish*		*Number Per Hectare*	*Weight in Kilograms Per Hectare*	*Man-Hours of Fishing Per Hectare*
	Number	Weight in Kilograms	Number	Weight in Kilograms	Number	Weight in Kilograms			
1951	0	...	143	30.2	143	30.2	21	4.4	751
1952	138	64.4	0	...	138	64.4	20	9.4	714
1953	121	63.5	0	...	121	63.5	18	9.2	455
1954	120	110.3	0	...	120	110.3	17	16.0	702
1955	27	33.6	0	...	27	33.6	4	4.9	731
1956	86	114.3	0	...	86	114.3	12	16.6	714
1957	33	75.4	0	...	33	75.4	5	11.0	786
1958	36	25.4	37	6.1	73	31.5	11	4.6	704
1959	80	52.2	6	1.4	86	53.6	12	7.8	768
1960	2	1.8	0	...	2	1.8	tr[a]	0.3	240
1961	5	13.2	0	...	5	13.2	tr	1.9	410
1962	0	...	0	...	0	...	0	...	410
1963	0	...	0	...	0	...	0	...	264

[a]Trace: less than one fish or less than 0.1 kg per hectare.

flies, and these fish were much heavier than bluegills for any given length. The anglers' catch was usually comparatively small (Table 21). As with bluegills, the largest catches of desirable-sized warmouths were made in 1955 and 1959.

CHANNEL CATFISH IN RIDGE LAKE

In the opening pages we described the several introductions of channel catfish, the first in May 1951 and others in the fall of 1952 and the winter of 1957. Usually a stocking consisted of about 450–700 fish (62 to somewhat less than 100 per hectare).

At Ridge Lake only a few anglers fished for these catfish (with specialized baits), and usually catches were accidental. Most of the channel cats were caught on night crawlers, *Lumbricus terrestris,* and live or dead minnows. Table 22 shows the catches of channel catfish made in the fishing seasons of 1951–1963, inclusive.

Some channel catfish were accidentally injured or killed during every draining census, partly because of their behavior. They demonstrated a strong tendency to remain in the lake basin instead of moving through the gate valve with the outgoing water. As a consequence, many of these fish were suffocated before they could be placed in the holding basin for live fishes. In addition, 131 catfish died in the hatchery pond at Mattoon over the winter of 1959–1960. When we add to the 834 channel cats caught by anglers the 13 found in the 1963 census and the 212 lost in other operations, the catfish that were accountable amounted to 1,059 of the 1,747 stocked in Ridge Lake, giving a return of 60.6 percent over a 13-season period. This must be considered a very reasonable return on wild fish trapped in the Mississippi River, handled, and hauled several hundred kilometers by tank truck.

Channel catfish grew well in Ridge Lake (Fig. 8). The 13 fish taken in the 1963 census had an average weight of almost 4.45 kg, and the largest weighed 7.71 kg.

The greatest weight of channel catfish was taken by angling in 1956; the catch was 86 fish weighing 114.3 kg. This catch represented 28.6 percent of the total weight of all fishes caught at Ridge Lake in 1956.

Catches of channel catfish after stockings of 60–100 per hectare in Ridge Lake exceeded those of Crance & McBay (1966) in Alabama where 247–492

Fig. 8. — Channel catfish caught at Ridge Lake. Catfish are considered a bonus fish by Ridge Lake anglers.

per hectare were stocked along with established populations of bass and bluegills. It is probable that the advantage shown by the Ridge Lake experiment may have been because the channel cats there were 180–300 mm long when stocked, while those stocked by Crance and McBay were only 76–200 mm long, well within the size range for bass forage.

OTHER FISHES IN RIDGE LAKE

As mentioned previously, other fishes in Ridge Lake were mostly green sunfish, black and yellow bullheads, and carp. When both bluegills and hybrid sunfishes were present, the hybrids are included in the "Other Fish" column of Table 19. On several occasions the total weight of "Other Fish" taken by angling exceeded 23 kg and may be of particular interest. For example, the catch in this category in 1948 amounted to 47.1 kg, of which 33.1 kg were black bullheads averaging almost 0.45 kg. These bullheads were all of about the same size and probably represented a single year-class and perhaps part of a single school of bullhead fry produced in the lake or in a Dry Run Creek pool.

In 1950, 187 black bullheads were caught along with 36 green sunfish, but the bullheads were considerably smaller than those caught in 1948, and two size classes were present. Black bullheads and green sunfish nearly disappeared after 1953 although 117 black bullheads were in the catch of 1957 along with one carp and 19 bluegill x warmouth hybrids of small sizes. The 1957 bullheads were of two size categories; 86 were longer than 200 mm and their total weight was 24 kg; 31 smaller bullheads averaged 318 grams.

The fishes in the "Other Fish" column in 1961 and 1962 were hybrid sunfishes and were supposed to be the only sunfishes in the lake. In the 1961 catch 194 bluegill x warmouth and 6 red-ear x warmouth hybrids totaled 23.4 kg. In 1962 the catch was 1,075 bluegill x warmouth hybrids weighing 94.8 kg and 134 red-ear x warmouth hybrids weighing 6.8 kg. Many more of these had been caught in 1961 and thrown back because they were less than the then-required 180 mm total length.

In general one may say that black bullheads and green sunfish were considerably more numerous in the lake prior to the introduction of warmouths and channel catfish. Whether this was in any measure due to competition from the introduced species is unknown.

RELATIONSHIPS BETWEEN THE FISH POPULATION AND THE HOOK-AND-LINE CATCH

We assume that there is a positive relationship between the catch of fishes by anglers and the population of fishes from which the catch is taken; this vari-

Table 23. — Yields per hectare of all fishes taken by anglers from Ridge Lake, 1942–1963, and man-hours of fishing effort. The lake was not open to public fishing in 1941 and 1943.

Year	*Yield in Kilograms Per Hectare*	*Fishing Intensity in Man-Hours Per Hectare*
1942	16.9[a]	524
1944	19.1[a]	222
1945	22.6[a]	260
1946	33.4	415
1947	19.6[b]	383
1948	86.5[c]	791
1949	34.0	544
1950	33.4[b]	554
1951	51.1	751
1952	64.3	714
1953	40.2	455
1954	69.9	702
1955	98.9[c]	731
1956	58.8	714
1957	95.4	786
1958	71.0	704
1959	117.0[c]	768
1960	3.3[d]	240
1961	12.0[d]	410
1962	38.8	410
1963	16.4[b]	264
Average	*47.7*	*540*

[a]Population composed largely of bass; these years omitted from averages.
[b]Poor years for angling.
[c]Good years for angling.
[d]Hybrid sunfishes catch restricted; bass and channel catfish recovering from overwintering in hatchery pond; bluegills nearly absent.

able relationship is affected by species composition, size distribution, density, and behavior of the species involved.

At Ridge Lake there was a great deal of variation in hook-and-line yields during the 21 seasons covered by this report when the lake was opened to controlled public fishing (Table 23). From 1941 to 1945 the fish population of Ridge Lake was composed mainly of largemouth bass, and this was reflected in the catches of 1942, 1944, and 1945. After 1945, when numbers of both bass and bluegills were present, the yields ranged from a low of 3.3 kg per hectare in 1960 to a high of 117.0 kg per hectare in 1959, with an average annual yield of 47.7 kg per hectare.

The extent of use of the lake for fishing varied directly from season to season as the catch varied. Generally, in years when large weights (and numbers) of fishes were caught, the fishing intensity increased, and vice versa. The average fisherman-use level for post-World War II years was 574 man-hours per hectare per season with a range of 240–791. Good and poor fishing years might be defined on the basis of rate of catch and total numbers and weights of fish caught by anglers. These criteria used at Ridge Lake failed to reflect the success of bass fishing in any year.

To explore further the relationships between composition of the fish population and catch, we selected 3 of the poorest fishing years, 1947, 1950, and 1963, when the rates of catch per man-hour were

Table 24. — Composition of the anglers' catch at Ridge Lake for 3 of the poorest years of fishing. All data are per hectare.

Species	*1947 (383 Man-Hours Per Hectare)*		*1950 (554 Man-Hours Per Hectare)*		*1963 (264 Man-Hours Per Hectare)*	
	Number	Weight in Kilograms	Number	Weight in Kilograms	Number	Weight in Kilograms
Largemouth bass						
Large[a]	20	11.6	32	16.0	10	12.2
Small[a]	4	0.6	38	4.6	33	0.5
Bluegills						
Large	57	5.9	58	5.2	40	2.2
Small	31	1.1	65	2.3	12	1.1
Warmouths						
Large	0	...	tr[b]	tr	0	...
Small	0	...	8	0.3	7	0.3
Channel catfish						
Large	0	...	0	...	0	...
Others[c]						
Large	3	0.3	27	4.9	tr	tr
Small	2	0.1	4	0.1	2	0.1
Total						
Large	*80*	*17.8*	*117*	*26.1*	*50*	*14.4*
Small	*37*	*1.8*	*115*	*7.3*	*54*	*2.0*
Grand total	*117*	*19.6*	*232*	*33.4*	*104*	*16.4*

[a]The definitions of size categories are:

	Large	Small
Largemouth bass	25 cm or longer	Less than 25 cm
Bluegills	15 cm or longer	Less than 15 cm
Warmouths	15 cm or longer	Less than 15 cm
Channel catfish	30 cm or longer	Less than 30 cm
Other fish	Depends upon species	

[b]tr = Trace; less than one fish or 0.1 kg per hectare.
[c]Mostly black bullheads and green sunfish in 1947 and 1950; hybrid sunfishes in 1963.

0.3, 0.4, and 0.4 fishes, respectively, and 3 of the best fishing years, 1948, 1955, and 1959, when the rates of catch were 1.1, 1.2, and 1.6 fishes per man-hour. Details of the composition of the catches in the selected poor and good fishing years are shown in Tables 24 and 25.

The most obvious differences in the groupings shown in these two tables are in the numbers of fishes caught. In the 3 poor years the average number of fishes caught each season was 151 per hectare, while in the good years the average number was 1,078 per hectare, or more than seven times as many. These differences were also evident in the average weights of the catches. For the poor years the average weight of the catch was 23.1 kg per hectare; for the good years it was 100.8 kg per hectare. The ratio of large to small fishes caught was about the same in the good fishing seasons as it was in the poor ones.

Length frequency distributions of bluegills and largemouth bass in the contrasted fishing seasons are shown in Tables 26 and 27. While on the average about 69 percent of the bluegills taken in the good fishing seasons were 15 cm or longer, only about 63 percent of those taken in the poor seasons were 15 cm or more (Table 26). However, these differences are not significant.

The length frequency distribution for bass shows that more bass 43 cm and longer were caught in the poor year of 1963 than in any good year and more bass of less than 23 cm (689) were

Table 25. — Composition of the anglers' catch at Ridge Lake for 3 of the best years of fishing. All data are per hectare.

Species	*1948 (791 Man-Hours Per Hectare)*		*1955 (731 Man-Hours Per Hectare)*		*1959 (768 Man-Hours Per Hectare)*	
	Number	Weight in Kilograms	Number	Weight in Kilograms	Number	Weight in Kilograms
Largemouth bass						
Large[a]	50	24.6	26	8.2	42	12.2
Small[a]	39	4.0	161	17.3	39	2.7
Bluegills						
Large	476	31.8	546	51.6	796	67.7
Small	324	19.6	145	9.1	348	17.2
Warmouths						
Large	0	...	59	6.6	79	7.2
Small	0	...	15	0.8	36	2.0
Channel catfish						
Large	0	...	4	4.9	12	7.8
Others[b]						
Large	23	6.0	3	0.4	1	0.2
Small	10	0.5	0	...	0	...
Total						
Large	*549*	*62.4*	*638*	*71.7*	*930*	*95.1*
Small	*373*	*24.1*	*321*	*27.2*	*423*	*21.9*
Grand total	*922*	*86.5*	*959*	*98.9*	*1,353*	*117.0*

[a]The definitions of size categories are:

	Large	Small
Largemouth bass	25 cm or longer	Less than 25 cm
Bluegills	15 cm or longer	Less than 15 cm
Warmouths	15 cm or longer	Less than 15 cm
Channel catfish	30 cm or longer	Less than 30 cm
Other fish	Depends upon species	

[b]Green sunfish and black bullheads in 1948; black bullheads and a few naturally produced hybrid sunfishes in 1955 and 1959.

caught in the good year of 1955 than in any other year of those shown in Table 27. The length frequency distribution for bass caught in 1949 is included in Table 27 because the rate of catch for largemouths in that year exceeded that of any other. However, the overall fish yield for 1949 was not particularly high because very few fish other than largemouth bass were present. In considering the size distribution of bass caught in 1949 and comparing this distribution with others in Table 27, it was evident that more bass 25–37 cm long were caught in 1949 than in any other season shown. At the same time 53 bass were caught that ranged from 41 to 56 cm and from about 0.9 to 2.7 kg each.

In Tables 28 and 29 we have made estimates of the numbers and weights of largemouth bass and bluegills per hectare in poor (Table 28) and good (Table 29) fishing seasons and compared them with numbers and weights per hectare of fishes caught in those same years. Fishes were separated into large and small categories as defined in Tables 24 and 25. In some census years, such as 1947, no small bass or small bluegills were put back after the census. In 1963, another census year, 2,270 small bass were marked and restocked, and some bluegills 13–15 cm were restocked. This restocking of small fishes represents rather large differences in numbers restocked; yet fishing was poor in both years. The years 1948, 1950, 1955, and 1959 all preceded censuses so that it was possible to estimate the total population by adding the fish caught in the preceding fishing season to the population subsequently exposed in the draining census.

Upon comparing the data shown in Tables 28 and 29, it became evident that the higher rates of catch in fish per man-hour were dependent upon the catches of bluegills, and high catches of bluegills combined with high rates of catch were related to large populations of

Table 26.—Length frequency distribution of bluegills caught during "good" and "poor" fishing years at Ridge Lake.

Length Class Center in Centimeters	*Poor Fishing Years*			*Good Fishing Years*		
	1947	1950	1963	1948	1955	1959
			Small Sizes			
7.6		13			42	5
8.9	10	65		10	84	34
10.3	35	120	1	74	84	45
11.4	48	67	8	433	157	210
12.7	71	63	15	812	246	524
14.0	64	143	62	1,033	387	1,575
			Desirable Sizes			
15.2	78	208	211	1,117	914	2,448
16.5	104	121	58	679	1,410	2,414
17.8	204	42	2	940	767	580
19.0	26	27	1	502	386	22
20.3	4	15		216	230	11
21.6		8		15	37	
22.9					11	
24.1					5	
Total	*644*	*892*	*358*	*5,831*	*4,760*	*7,868*
Percent small sizes	35.4	52.8	24.0	40.5	21.0	30.4
Percent desirable sizes	64.6	47.2	76.0	59.5	79.0	69.6

these fish. Bluegill fishing was satisfactory if the estimated bluegill population exceeded 2,500 fish per hectare of which more than 1,000 were 15 cm or longer. However, in 1950 the catch of bluegills was poor in spite of the fact that the lake contained 7,138 of these fish per hectare (Table 3). The poor catch may have occurred because only 149 of the 7,138 bluegills were of desirable sizes (15 cm or longer) and fishermen were soon disappointed by the fact that they were unable to catch bluegills of worthwhile sizes.

Table 30 shows the average numbers of large and small bass and large and small bluegills and their total weights, respectively, per hectare in 3 poor fishing years and 3 good ones. These data are computed from data in Tables 28 and 29. Important differences in bluegill average numbers and weights in

Table 27. — Length frequency distribution of largemouth bass caught during "good" and "poor" fishing years at Ridge Lake.

Length Class Center in Centimeters	*Poor Fishing Years*			*Good Fishing Years*			*Best Year for Bass*
	1947	1950	1963	1948	1955	1959	1949
				Small Sizes			
Less than 22.9	16	177	223	230	689	223	12
22.9	8	54	2	29	271	17	27
24.1	8	48	3	28	146	29	67
				Desirable Sizes			
25.4[a]	10	32	1	49	99	71	107
26.7	8	26	...	32	32	100	83
27.9	12	15	1	48	9	63	62
29.2	10	5	...	47	3	21	43
30.5	23	7	2	41	3	13	32
31.8	13	19	...	17	1	2	11
33.0	11	39	2	21	1	2	17
34.3	7	41	...	8	4	1	13
35.6	13	19	5	22	6	1	25
36.8	14	13	3	19	5	1	20
38.1	5	9	7	16	7	2	13
39.4	5	4	7	11	7	...	9
40.6	6	2	4	5	2	...	15
41.9	2	2	5	10	1	2	8
43.2	6	2	12	5	...	1	4
44.4	3	...	5	4	...	3	10
45.7	1	1	9	3	1	1	7
47.0			3	2		1	4
48.3			1	...		...	1
49.5			1	1		...	3
50.8			...			1	...
52.1			...			...	...
53.3			1			...	...
54.6			1			1	1
55.9			1				
Total	*181*	*515*	*299*	*648*	*1,287*	*556*	*594*
Percent small sizes	17.7	54.2	76.3	44.3	85.9	48.4	17.8
Percent desirable sizes	82.3	45.8	23.7	55.7	14.1	51.6	82.2

[a]Minimum legal size prior to 1951.

Table 28. — Population estimates of largemouth bass and bluegills per hectare in Ridge Lake in 3 of the poorest fishing years, with fishing pressures and rates of catch.

Year	*Species*	*Population Estimate Per Hectare*		*Man-Hours of Fishing Per Hectare*	*Catch Per Hectare*		*Rate of Catch Per Hectare*	
		Number	Weight in Kilograms		Number	Weight in Kilograms	Number Per Man-Hour	Weight in Kilograms Per Man-Hour
1947	Largemouth bass							
	Large[a]	54	30.3		25	12.2		
	Bluegills							
	Large	242	17.7		88	7.0		
1947 Total		*296*	*48.0*	383	*113*	*19.2*	*0.3*	*0.050*
1950	Largemouth bass							
	Large	105	61.0		32	16.0		
	Small	38	4.6		38	4.6		
	Total	*143*	*65.6*		*70*	*20.6*		
	Bluegills							
	Large	144	13.4		58	5.2		
	Small	70	2.3		65	2.3		
	Total	*214*	*15.7*		*123*	*7.5*		
1950 Total		*357*	*81.3*	*554*	*193*	*28.1*	*0.4*	*0.051*
1963	Largemouth bass							
	Large	17	22.8		10	12.2		
	Small	330	6.1		33	0.5		
	Total	*347*	*28.9*		*43*	*12.7*		
	Bluegills							
	Large	140	8.3		40	2.2		
	Small	512	9.5		12	1.1		
	Total	*652*	*17.8*		*52*	*3.3*		
1963 Total		*999*	*46.7*	*264*	*95*	*16.0*	*0.4*	*0.061*

[a]The definitions of size categories are:

	Large	Small
Largemouth bass	25 cm or longer	Less than 25 cm
Bluegills	15 cm or longer	Less than 15 cm

Table 29. — Population estimates of largemouth bass and bluegills per hectare in Ridge Lake in 3 of the best fishing years, with fishing pressures and rates of catch.

Year	Species	Population Estimate Per Hectare		Man-Hours of Fishing Per Hectare	Catch Per Hectare		Rate of Catch Per Hectare	
		Number	Weight in Kilograms		Number	Weight in Kilograms	Number Per Man-Hour	Weight in Kilograms Per Man-Hour
1948	Largemouth bass							
	Large[a]	96	59.7		50	24.6		
	Small	273	25.5		39	4.0		
	Total	*369*	*85.2*		*89*	*28.6*		
	Bluegills							
	Large	740	71.7		476	31.8		
	Small	2,768	76.7		324	19.6		
	Total	*3,508*	*148.4*		*800*	*51.4*		
1948 Total		*3,877*	*233.6*	*791*	*889*	*80.0*	*1.1*	*0.101*
1955	Largemouth bass							
	Large	64	26.4		26	8.2		
	Small	161	17.4		161	17.3		
	Total	*225*	*43.8*		*187*	*25.5*		
	Bluegills							
	Large	1,759	155.8		546	51.6		
	Small	192	9.1		145	9.1		
	Total	*1,951*	*164.9*		*691*	*60.7*		
1955 Total		*2,176*	*208.7*	*731*	*878*	*86.2*	*1.2*	*0.118*
1959	Largemouth bass							
	Large	60	32.0		42	12.2		
	Small	40	2.7		39	2.7		
	Total	*100*	*34.7*		*81*	*14.9*		
	Bluegills							
	Large	1,446	126.4		796	67.7		
	Small	348	17.2		348	17.2		
	Total	*1,794*	*143.6*		*1,144*	*84.9*		
1959 Total		*1,894*	*178.3*	*768*	*1,225*	*99.8*	*1.6*	*0.130*

[a]The definitions of size categories are:

	Large	Small
Largemouth bass	25 cm or longer	Less than 25 cm
Bluegills	15 cm or longer	Less than 15 cm

Table 30. — Estimated average numbers and weights of largemouth bass and bluegills per hectare in Ridge Lake in 3 years when fishing was good and 3 years when fishing was poor.

	Largemouth Bass Per Hectare		*Bluegills Per Hectare*	
	Average Number	Average Weight in Kilograms	Average Number	Average Weight in Kilograms
Poor Years				
Large	59		175	
Small	123		194	
Total	*182*	*41.6*[a]	*369*	*17.1*[a]
Good Years				
Large	73		1,315	
Small	158		1,103	
Total	*231*	*54.6*[a]	*2,418*	*152.3*[a]

[a]These weights may be 10–20 percent higher than the actual weights in the lake at the time of fishing because of weight gains in the uncaptured segments of the population in the time between the catch and the next draining census or between the return of fishes after a census and the catch.

good and poor years are much greater than are differences in largemouth bass numbers and weights. Also clearly evident are the great differences in the numbers of catchable bluegills per hectare in the good and poor years.

THE EFFECTS OF MANAGEMENT TECHNIQUES ON FISH POPULATIONS AND ANGLING

Four operational techniques were followed at Ridge Lake in the 1941–1963 period; the results of one of these (the use of hybrid sunfishes) must be disregarded because circumstances prevented a true test. The others were (i) the biennial draining and culling operation, (ii) the fall drawdowns, and (iii) the period of stable water levels. Each of these operational techniques influenced the catch of fish; they also had marked effects upon the fish populations as exposed by draining censuses.

The period of biennial draining and culling extended over 10 years, and the culling operations could have affected the catch of fish in 1943–1951. However, the lake was closed to fishing in 1943, and so a consideration of fishing results must be limited to the other 8 years.

In all cases fishing during the season immediately following a March draining and culling operation must have been different from fishing during the second fishing season of the biennium because of the spawns of fishes and the growth of fishes to catchable sizes that took place in both years of each 2-year period. Also the period between March 1949 and March 1951 must have been at variance with the others because of the fishes' crowded living conditions in 1949 brought on by the failure of the lake to refill completely. Certainly spawn survival in 1949 must have been lower than usual because of the greater than usual density of the bass population during that season.

One would expect the effects of the first September drawdown of the lake level to be evident in the catch of fishes in the 1952 fishing season. The drawdown of September 1952 undoubtedly had an effect on the fish population exposed in the March draining census of 1953. In view of the facts that not all of the fishes taken in the 1953 draining census were returned to the lake and that the complete draining of the lake changed the food-feeder relationships, it would be unreasonable to consider the 1953 catch as being wholly influenced by the drawdown.

After the 1953 census and fishing season, drawdowns were made in the Septembers of 1953, 1954, and 1955. These drawdowns affected the fishing seasons of 1954 and 1955, and their effects were further exposed in the draining census of 1956. Thus, drawdown-oriented fishing seasons were those of 1952, 1954, and 1955. Of these, that of 1952 was affected by a lake surface area reduction of 69 percent and those of 1954 and 1955 by an area reduction of about 35 percent. These differences had varying effects upon the fish populations (as shown by the censuses of 1953 and 1956) and must have affected the hook-and-line catch also.

The stable water period described elsewhere lasted from April 1956 when

the lake had refilled after the March 1956 draining to October 1959 when the lake was again drained. Thus the period of stable waters lasted for three winters and four growing seasons for fishes (April to October). During this period the numbers of fishes were allowed to increase without any culling or the restrictive effect of the drawdown. Fishing in 1956 was more influenced by the spring draining than by the nearly stable water levels that were present during the summer fishing season. However, the constantly stable lake in 1957, 1958, and 1959 must have affected the fish population and the fishing. Thus, the stable water period may be considered to have lasted about 3 years.

In Table 31 an attempt has been made to compare the average catches of desirable-sized bass (25 cm or longer), bluegills, and warmouths (15 cm or longer) made under the three operational techniques described above, including eight seasons of biennial culling, three seasons of annual fall drawdowns, and three consecutive seasons of stable water levels. It is evident from this table that larger average numbers and total weights of bass were taken per season during the period of biennial culling than under the other management techniques. Annual fall drawdowns stimulated annual spawns of largemouth bass and increased the numbers of small ones without apparently improving the catch of large bass. The catch of large bass was even smaller under stable waters than under the influence of drawdowns. This reduced catch may have been the result of a large, constantly available supply of small bluegills suitable for bass forage; however, the draining census of 1959 showed that only 124 bass longer than 24.9 cm were present after the four growing seasons of stable waters (Table 8) although 651 bass longer than 20 cm were put back after the census of 1956 (Table 2). This reduction in mature bass indicates that the bass population was not holding its numerical strength during this period.

Table 31.—Average numbers and weights of fish of desirable sizes caught in Ridge Lake under three systems of management.

Number of Years	Management Practice	Average Annual Catch of Fish Per Hectare: Largemouth Bass 25 cm or Longer			Bluegills 15 cm or Longer			Warmouths 15 cm or Longer		
		Number	Total Weight in Kilograms	Average Weight in Grams	Number	Total Weight in Kilograms	Average Weight in Grams	Number	Total Weight in Kilograms	Average Weight in Grams
8	Biennial draining	47	19.2	408	133	13.0	98	0	. . .	. . .
3	Annual fall drawdowns	30	11.7	390	304	33.2	109	27	3.4	126
3	Stable water levels	27	12.1	448	472	41.9	89	37	4.3	116

Fig. 9. — Fishermen with their catches on the laboratory pier. Their fish are weighed, measured, and "scaled" for age determination. These data, the time spent in fishing, and the kinds of bait and tackle used are recorded on individual creel cards. When all of this information has been collected for each fisherman, his state fishing license, which has been held at the laboratory, is returned to him.

The greatest average numbers and weights of bluegills and warmouths were caught under stable water conditions (Fig. 9) although the average sizes of the fishes caught were greater during the drawdown period. As mentioned previously, the large catch in the stable water period probably was the result of high population density and food competition; the draining census indicated that bluegills and warmouths of desirable sizes were more numerous during the drawdown period. With the constant gradual buildup of bluegills during the stable water period, the bluegill population might have eventually become so dense as to cause severe food competition and stunting. This competition would have created a situation in which many bluegills might have been caught but few would have been of desirable sizes.

DISCUSSION

The study of the management of the fishes of Ridge Lake over the period 1941–1963 (which still continues) is possibly the longest continuous investigation ever made of a warmwater fish population in a small artificial lake. In this 23 years the lake was drained completely and the fish population was censused nine times. Following these censuses certain numbers and sizes of fishes of one or several species were returned to the partially reflooded lake basin above the dam and the lake basin was allowed to refill.

Each summer, except for those of 1941 and 1943, the lake was opened to controlled public fishing to allow us to gather a complete record of fishing; number of fishermen; time spent; catch by species, numbers, and sizes; and kinds of tackle and baits used, inclu-

ding a comprehensive breakdown of types and colors of a huge variety of artificial fish lures. Data presented in this paper do not include an analysis of fishing other than the time spent in fishing and the catch of fishes, and these are cited for their relevance to the management techniques that were applied. The real test of management lies in the relative numbers and sizes of fish caught under each system.

No attempt has been made to include growth data based on scale collections made from creel censuses and during lake drainings since 1951. Some of these scales were read to furnish growth data shown in the report of 1954 (Bennett 1954*a*). Comparative growth of the important species of fish in Ridge Lake under various management techniques will be presented in a future paper.

The fish population of Ridge Lake has shown a great deal of variability in species abundance, size distribution, and standing crops and has demonstrated the complexity of fish population dynamics. This complexity suggests that one might question the validity of certain types of "results" from population studies of short duration. Present and future observations of the responses of this warmwater fish population to new management practices will be particularly valuable because of the backlog of data dealing with this population's past variations.

At the time the Ridge Lake study was begun, fishermen generally held the misconception that natural reproduction and survival were inadequate to maintain populations of game fishes and panfishes and that an annual stocking of fingerlings was necessary to insure good fishing. Now, 27 years later, no one familiar with fisheries literature believes that natural reproduction of warmwater fishes is unable to maintain their populations. Thus, one of the original purposes of the study has disappeared: that of testing the natural fecundities of several important species of warmwater fishes.

In this connection it is of some interest to note that the 435 largemouth bass released in Ridge Lake in 1941 were the only source of 29,700 bass that have been permanently removed from the lake since then (1941–1967) and that the 129 bluegills released in 1944 have produced more than 400,000 living offspring of which 390,000 have been permanently removed. These figures for the two species probably indicate something of their relative abilities to expand their populations in Ridge Lake, i.e., the bluegills in this environment were at least 10 times as effective in expanding their populations as were largemouth bass. Within this bass-bluegill complex, warmouths stocked in 1949 (138 fish) produced no more than 10,000 fish (6.5 cm and larger) in 18 years.

As was expected, channel catfish failed to reproduce successfully in Ridge Lake. A stream fish that grows well in lakes, the channel cat must have special spawning conditions or it cannot maintain its numbers. One channel catfish fingerling was captured in one draining census, indicating that these fish had attempted to reproduce or gained access to the lake by some other means.

Black bullheads, yellow bullheads, carp, white suckers, and green sunfish were indigenous to the Ridge Lake watershed and were exposed as inhabitants of Ridge Lake in one or more draining censuses; black bullheads and green sunfish were sometimes caught by fishermen. However, the removal of these fishes whenever they appeared in a draining census was sufficient to keep them from significantly increasing their populations. For unknown reasons, green sunfish and black bullheads were much less common in the census of 1953 and thereafter than they had been in the period 1941–1951.

After we compared fishermen's catches made in a season immediately prior to a draining census with the fishes exposed in the draining census, it became evident to us that one should use caution in appraising a fish population on the basis of the annual hook-and-line

catch. For example, in 1962 fishermen caught 145 bass, of which 80 were between 25 and 45 cm and the rest smaller. This was a poor catch of bass, and fishermen agreed openly that the lake contained no large ones. When the lake was drained in March of the following year, it was found to contain 90 bass ranging in length from 46 to 58 cm and in weight from 1.6 to 4.1 kg; in fact, 11 bass belonged to the oldest fin mark group (8–10 years old) and averaged more than 2.9 kg. For unknown reasons fishermen had been unable to catch these large fish.

The concept presented by Swingle & Smith (1938, 1939) that single species or mixed populations of warmwater fishes build up to a maximum constant weight within one growing season and then remain at about that weight for an indefinite time has not been demonstrated by the Ridge Lake censuses. Largemouth bass total weights have varied from 240 kg to 412 kg (exclusive of the 1953 census after 2 years of severe drawdowns, when the bass weight was 205 kg); bluegill total weights have ranged from 709 to 1,578 kg, and the total weight for all fishes has varied (after 1945 and exclusive of 1953) from a low of 1,336.7 kg to nearly double that amount–2,092.5 kg (Table 1).

In view of such large variations in standing crops of fishes at Ridge Lake, it seems ridiculous to assume that fish populations remain constant in total weight or that annual hook-and-line yields do not vary greatly. D. Homer Buck and Charles F. Thoits have found similar unexplained variations in single-species populations of fishes in 0.4-ha ponds (personal communication 1968 and in press).

Saila (1958) published a paper using Ridge Lake data from the 1954 report (Bennett 1954*a*) in which he attempted to demonstrate mathematically that a size limit on largemouth bass would eventually assure a greater number of large fish in the catch than was possible without a size limit. In the early years of fishing at Ridge Lake (1942, 1944, and 1945) we imposed a minimum length limit of 25 cm (10 inches), while beginning in 1946 fishermen were asked to bring in all bass regardless of length. This change in policy resulted in periods with and without length limits on bass.

However, these periods were also marked by different culling lengths for bass in the draining censuses, a point apparently not recognized by Dr. Saila. After about half of the stunted 1941 brood of bass (average length about 18 cm) were removed in the 1943 census, the minimum culling length was 25 cm (10 inches) in the 1945 and 1947 censuses, followed by 23 cm (9 inches) in the 1949 census and 20 cm (8 inches) in the 1951 census. These lengths were represented by the following average weights for the smallest bass returned to the lake after these censuses: in 1945, 142 fish averaged 0.33 kg (0.72 pound); in 1947, 310 fish averaged 0.41 kg (0.91 pound); in 1949, 917 fish averaged 0.23 kg (0.51 pound); and in 1951, 619 fish averaged 0.27 kg (0.59 pound). These differences in sizes and numbers of fish returned were great enough to influence the numbers and sizes of fish caught by anglers, and it was simply circumstance that controlled the timing of the periods when length limits were enforced and when they were taken off to match the larger and smaller bass culling sizes.

In comparing populations of largemouth bass and bluegills exposed in the nine censuses, it was of particular interest that the bass population equaled or approached 56 kg per hectare in four of the censuses, once when the lake contained a nearly pure culture of bass and twice when numbers of bluegills were present. This suggests that 56 kg per hectare may be about the maximum carrying capacity of the lake for bass.

No comparable maximum for bluegills was suggested by the census data. The heaviest population of bluegills was found in the census of 1947 when 216.7 kg per hectare were present. The next largest population by weight appeared

in 1959 after four growing seasons of constant water levels when 181.2 kg per hectare of bluegills were present. Other censuses showed lesser weights of bluegills.

There appeared to be an inverse relationship between weights of bass and bluegills ($r = -0.91$). The lowest weights of bluegills (exclusive of the drawdown period) were present when bass weights were highest and vice versa.

The biennial draining operations with the culling of all bass of less than 25, 23, or 20 cm and all bluegills except 1,000–4,500 of the larger ones resulted in a buildup of desirable-sized bass and relatively high hook-and-line catches of these fish. This management technique did not stimulate the development of large bluegill populations, and with one exception seasonal catches of bluegills were much less than 50 kg per hectare.

Severe early fall drawdowns that reduced the lake surface area by 69 percent reduced the total weight of the fish population but not in proportion to the lake surface area or volume reduction. More moderate fall drawdowns (3 meters, 35-percent surface area reduction) had no significant effect on the total weight of fish. The drawdown technique appears to be the single most important tool in the management of warmwater fish populations inhabiting lakes that can be artificially reduced in area by the release of water.

Prior to 1956 we believed that a 50-percent reduction in lake surface area was necessary to effect significant changes in a fish population. After the 1956 draining census which followed 3 successive years of moderate September drawdowns (35-percent reduction of the lake surface area) it was obvious that drawdowns to reduce the lake surface area by less than 50 percent were having a beneficial culling effect upon the smaller sunfish species of Ridge Lake without causing any significant reduction in the overall weight of fish that the lake was supporting (Table 3). Bass in the 1956 census were represented by a larger total weight of small fish (less than 25 cm total length) than in any other census except that of 1943 and a smaller weight of large fish than in any preceding census except those of 1943 and 1953 (Table 8). After the mild drawdowns the lake was supporting a substantial population of small bass due to the annual culling action of the drawdowns on the small sunfishes (largely bluegills) that might attack bass fry and limit their survival.

The severe drawdowns of 1951 and 1952 caused a drastic reduction in bluegills so that only 7,500 (1,087 per hectare) were present in the 1953 census (Table 3). More than half of these were larger than 15 cm and the rest smaller (Table 9), giving a catchable population of about 640 bluegills per hectare. According to our creel records, this population of large bluegills was numerically too small to give satisfactory bluegill fishing (one or more fish per man-hour). After the period of moderate drawdowns in 1953, 1954, and 1955 the bluegill population numbered 17,180 (2,497 per hectare) (Table 3) of which slightly more than half (8,661, or 1,258 per hectare) were of desirable sizes (Table 9).

Bluegill fishing was quite good in 1955 (a year prior to a draining census; the catch was almost one fish—0.94—per man-hour), and the bluegill population contained more large fish than in any other year of the 19 years when bluegills were present in Ridge Lake. The fact that the fishermen's catch of bluegills in several other years exceeded that of 1955 suggests that a certain amount of food competition is important in the production of high pole-and-line yields. The knowledge of how to produce superior numbers of catchable-sized bluegills has been carried further since 1963 in a study which will be reported at a later date (Fig. 10).

Many small artificial reservoirs receive heavy human use, and as a consequence the normal fish predators, such

as herons, kingfishers, cormorants, and other wild fish-eating birds, are scarce or absent. Also in recent years the numbers of fish-eating birds are believed to have become considerably smaller than formerly because of their reduced fecundity reportedly caused by their ingesting pesticides carried by fishes (Wurster & Wingate 1968). This reduction in the numbers of fish predators has removed a natural check on overpopulation, giving the drawdown technique increased importance as a population regulator. One of the problems associated with drawdowns is to educate fishermen to the usefulness of an annual or biennial water release which may leave unsightly mud flats around the lake edges in early fall and winter. Hopefully, the reservoir will refill again by the next fishing season when the improvement in the fish population will be reflected in better fishing.

There is no longer any question whether a drawdown will cull certain kinds of the smaller fishes in a population, an action always followed by improved survival of bass fry. This observation has also been recorded by Pierce, Frey, & Yawn (1965) in their drawdowns of Georgia ponds and by Lantz, Davis, Hughes, & Schafer (1967) in their drawdowns of Louisiana reservoirs.

Whether these fry will survive in proportional numbers to augment the adult bass population is related to the abundance of predators of fingerling and yearling bass. However, the evidence indicates that bass are most vulnerable to predation in the embryo, yolk-sac fry, free-swimming fry, and small fingerling states, i.e., from the time the eggs are laid to the time the small bass are about 25 mm long. During this period they may be affected adversely by weather changes and they are vulnerable to attack by small fishes (such as stunted bluegills) and predacious aquatic insects. When they reach lengths approximating 50 mm, they become strong swimmers and are too large to be eaten by fishes other than the fish-eating species, such as larger bass, pickerel, gars, and others. Thus, the chances of survival of a new year-class of bass beyond the fry and small fingerling stages may be poor if a lake already contains a large population of yearling bass (13–18 cm) ready to prey upon them. Actually, with

Fig. 10. — Fishermen angling for bluegills in deep water using night crawlers or catalpa worms (larvae of the catalpa sphinx moth) for bait. The distance from the boat to the pier is about 35 meters.

a large yearling bass population already present, there is little need for a strong new year-class to maintain a high population and replace bass caught by angling.

Unfortunately, in planning a drawdown for a specific lake it is impractical to apply "cookbook" methods. Adequate sampling should indicate the level of overpopulation and stunting, and the severity of the drawdown should vary directly with the severity of stunting. If overpopulation were the only consideration, the situation still might be fairly simple. However, lake habitats vary in amounts of protective cover, and basin contours differ to such an extent that a drawdown designed to give a selected surface area reduction in one lake may not produce a comparable surface area reduction in another. The knowledge of how to use the drawdown as a management tool in a specific lake must come through trials and appraisals of their effects. Lantz *et al.* (1967) and Hulsey (1959) mention an additional value of drawdowns in controlling potamogetons and naiads. However, drawdowns may be responsible for increasing vegetation of certain kinds, such as *Potamogeton crispus L.*, which may be given an opportunity to get started in deeper water while the lake level is down.

Whether a drawdown should be made every year is still an open question and probably depends upon the severity of the stunting problem prior to the preliminary test. At Ridge Lake 2 successive years of severe drawdowns were believed to have reduced the population more than was necessary (Tables 1 and 3, 1953 census). Perhaps the lesser drawdowns of 1953–1955 would have improved the bluegill population more than they did if they had been started in 1951 and carried through 1955 without the 1953 draining census. It is evident that testing the drawdown technique is a promising field for a great deal of additional research.

The period of stable water levels that extended from April 1956 to the draining census of October 1959 constituted a period of "no management" of the fish population. During this period the bass population reached a weight low (except for the census of 1953 after 2 successive years of severe drawdowns), and the bluegills reached a numerical high of 13,469 per hectare (Table 3) and a weight high second only to that of 1947.

As mentioned above, bluegill numbers were curtailed by drawdowns and biennial cullings. The latter gave the bluegills two growing seasons to make a comeback (Table 13), and the maximum weight buildup for these 2-year periods occurred in 1945 and 1946, with 9,152 individuals per hectare exposed in the 1947 census. Stable water levels actually existed in the four growing seasons of 1956–1959, terminated by the fall census of October 1959, and in the three growing seasons of 1960–1962, terminated by the spring draining census of March 1963. The bluegill population was numerically larger in 1963 after 3 years without drainings or drawdowns (Table 13) than it had been in any of the 10 previous 2-year periods between drainings, 1941–1951, and was even larger in 1959 after four seasons without drainings or drawdowns than it had been after three such seasons. While these data are not conclusive, they suggest that the bluegills in Ridge Lake, if left alone, would constantly increase in numbers until within a relatively short time the lake would become overpopulated with a stunted population of these fish.

As described in the section on the stable water period, the test of the usefulness of hybrid sunfishes in Ridge Lake was invalidated when the lake was contaminated by bluegills and warmouths, the parent types of the bluegill x warmouth hybrids being tested. Neither of these two pure species appeared in the creel census of 1960, but a few bluegills were observed in the lake in 1960 and a few of both species were caught by fishermen in 1961 (Table 19). Both

species were common during the summers of 1961 and 1962, but the original source of these fishes is unknown.

So that Ridge Lake fishermen could legally keep only the largest hybrids, we placed a minimum length limit of 17.5 cm on these fishes. In 1960 fishermen caught 3,772 of the 4,503 hybrids that had been stocked in April, returning 3,708 and keeping 64. In 1961, after 448 additional hybrids (red-ear x warmouth) had been added in May, fishermen caught 4,890 hybrids, keeping 194 bluegill x warmouth and 6 red-ear x warmouth hybrids and returning 4,690. Because the fishermen could not with certainty or did not separate the two kinds of hybrids among the fishes released, it was impossible to compute the ratio of the two kinds in the catch.

In 1962 all length restrictions on the hybrids were removed, and fishermen caught and kept 1,075 bluegill x warmouth and 134 red-ear x warmouth hybrids. After the 1962 fishing season when hybrids of any length could be taken, the population remaining to be exposed in the 1963 spring draining census consisted of only 8 bluegill x warmouth and 64 red-ear x warmouth hybrids.

The small numbers of hybrid sunfishes in the anglers' catch of 1962 and in the spring draining census of 1963 suggest that many of these hybrids died as a result of hooking injuries sustained in being caught and released. This hybrid study was reported in a junior author's recent publication on hybrid sunfishes (Childers 1967:189). The hybrid sunfishes in Ridge Lake showed biting characteristics similar to those of hybrid sunfishes in other tests, i.e., they were highly aggressive and bold in taking fishing baits and were very easily caught. It was estimated that in 1962 at Ridge Lake 65 percent of the 1,209 hybrid sunfishes were caught in the first 5 days of fishing and 81 percent were caught in the first 10 days.

The catch of largemouth bass during the hybrid sunfishes period, 1960–1962, inclusive, was the poorest of any period between draining censuses (Table 19). This poor catch may have been influenced by two factors: (i) the small number and poor physical condition of the bass returned to Ridge Lake after spending the winter of 1959–1960 in a hatchery pond (which probably slowed the rebuilding of the bass population) and (ii) the introduction in 1960 of 585 lake chubsuckers into the lake (which may have increased the bass food supply and made them less vulnerable to angling). In 1960 the estimated number of bass fry was 3,050 per hectare (Table 10). This fry population could have been the origin of a large new year-class of bass. In 1961 no schools of young were seen, and in 1962 only one school was observed. Yet, in the 1963 draining census we found the numerically largest bass population exposed in any census (Table 1), 6,218 bass, of which 6,042 ranged in size from 12.7 to 25 cm and were quite obviously members of the 1962 year-class. A comparatively small number of larger bass (176) was also present, of which 86 were fin clipped from previous censuses. Of the 299 bass moved back to the lake in 1960, 44 were caught in 1960, 48 in 1961, and 15 in 1962, a total of 107 of the 299. Eighty-six marked bass were taken in the 1963 draining census, and only 62 bass representing the 1960 and 1961 year-classes were present. Fishermen had caught 156 bass of these same year-classes in 1961 and 1962. These figures indicate that the bass population was characterized by low production and survival rates in 1960 and 1961. Only in 1962 was there an unusually high survival of a relatively small spawn. It therefore seems reasonable that, at least prior to 1962, the presence of a dynamic population of lake chubsuckers had little effect on the bass population or on bass fishing although from 1960 to 1963 the chubsuckers increased from 585 to 3,182.

One of the most interesting points to

come from the study of the fishes of Ridge Lake was the capacity of the largemouth bass and bluegills to expand their populations when their numbers were decimated by artificial culling such as was done in the biennial draining period 1941–1951 and every time we drained the lake thereafter. One might assume from the way these populations recovered that such adversity was common and that these fishes had evolved under environmental catastrophies that produced severe stresses. Even what might appear to be abnormal losses of larger bass through angling—56–63 percent of the available numbers of marked bass per fishing season (Table 17)—were quickly replaced through recruitment and growth.

In contrast, stable water levels and insufficient culling (i.e., protection of small fishes) eventually resulted in less desirable fish populations, at least from the standpoint of numbers of large fishes available for angling. This fact indicates that there is a great deal of room for improvement in fish management to provide better fish populations for angling. But such a potential for improvement cannot become a reality until anglers and fish managers modify much of their present thinking.

SUMMARY

1. — Ridge Lake was stocked with 335 yearling largemouth bass and 100 adults in 1941, 129 bluegills in 1944, 138 warmouths in 1949, and varying numbers of channel catfish in 1951, 1952, and 1957. After an attempt to remove all bluegills by draining the lake and leaving the lake basin empty over the winter of 1959–1960, 585 lake chubsuckers and 4,500 hybrid sunfishes were stocked in the spring of 1960.

Since the beginning of this study in 1941, 29,700 largemouth bass, 390,000 bluegills, and about 10,000 warmouths have been permanently removed from the lake. The lake now (1968) contains adequate numbers of all species stocked except channel catfish, which did not reproduce successfully in standing water.

2. — A complete creel census has been conducted at Ridge Lake each summer except in 1941 and 1943, when the lake was closed to public fishing. In addition, the lake was drained and the fishes were censused in the springs of 1943, 1945, 1947, 1949, 1951, 1953, 1956, 1959 (fall), and 1963, and selected kinds, sizes, and numbers of fish were held alive and restocked (Tables 1–4).

3. — In the nine draining censuses at Ridge Lake bass total numbers varied between 1,500 and 6,000 and their total weights between 205 and 412 kg (Table 1). Bluegill total numbers ranged from 7,500 to 93,000 and their weights from nearly 450 to about 1,580 kg. Warmouth populations varied but were always small. The total weight of channel catfish varied with the number present; a few grew to more than 4.5 kg each. Lake chubsuckers were stocked in 1960. Other fishes in the lake probably came from the watershed and were mainly green sunfish, black bullheads, yellow bullheads, carp, and minnows. These never made up more than a small part of the population.

4. — Standing crops of largemouth bass varied between 35 and 56.6 kg per hectare (Table 3). In four censuses the standing crops of bass approached or slightly exceeded 56 kg per hectare, suggesting that this weight may represent the maximum this lake will support. There was no increase in the standing crop of bass when bluegills were present over that of bass by themselves. Standing crops of bluegills varied from 65.3 to 216.7 kg per hectare. There was no suggestion of a maximum standing crop of bluegills. The standing crop of warmouths never made up more than 5 percent of the total number or weight of any fish population exposed in a draining census.

5. — When substantial numbers of both bass and bluegills were present (Table 3), the standing crops of all fish

in the censuses of Ridge Lake varied between 157.2 and 287.4 kg per hectare. Usually when bass weight increased, bluegill weight decreased, and vice versa.

6. — Biennial lake draining with the culling of small bass and bluegills increased the numbers of large bass and was selective for fast growing ones, i.e., bass that did not attain lengths of 20–25 cm in two growing seasons were permanently removed from the lake.

7. — Early fall drawdowns drastically reduced the numbers of small bluegills and allowed an increase in the numbers of large ones because of increased growth rate (Table 9). Drawdowns maintained large numbers of small bass but did not increase the numbers of large ones (Table 7). The reasons for reduced populations of large bass are unknown.

8. — Four growing seasons without lake drainings or drawdowns resulted in the production of a large numerical population of bluegills and a small population of largemouth bass (Tables 1 and 3).

9. — Hybrid sunfishes were more easily caught than the pure parent species, but offered little competition to the parent species in Ridge Lake.

10. — Bass fry production after a draining and culling of small fishes of all kinds averaged 7,917 per hectare; after drawdowns, 3,243 per hectare; and after 1 or more years of stable water levels, 1,023 per hectare (Table 10).

11. — The ratios between estimated numbers of bass fry produced in census years during the 10-year period of biennial drainings and censusings and the number of yearlings of the same year-class caught by fishermen or appearing in the next census 21 months later varied from 29 to 1 (greatest survival rate) to 196 to 1 (lowest survival rate) (Table 11). Probably all of these ratios were abnormal, as during postcensus summers the numbers of bass fry predators, such as small fishes and predacious aquatic invertebrates, were much reduced.

12. — There was no relationship or a negative relationship between the estimated numbers of bass spawners and the estimated numbers of fry produced (Table 12). However, there appeared to be a definite negative relationship between large numbers of small bluegills and numbers of bass fry. In 1946, 1948, and 1950 when 2,500 or more small bluegills per hectare were present, bass fry survival was negligible (Table 12).

13. — Expansion of the bluegill population in Ridge Lake was positively related to time and negatively related to drawdowns and to "dominant" populations of bass (Table 13). However, bass were unable to control bluegills completely except when given the assistance of fall drawdowns.

14. — One largemouth bass belonging to the 1941 year-class and marked in 1943 was taken for the last time in the census of 1956. A few other marked bass lived for 10, 11, and 13 years, but most marked bass disappeared at ages 7–10 years.

Seasonal exploitation rates from catches of marked largemouth bass ranged from 1.5 to 63 percent (Table 14). But even with the higher exploitation rates there was no evidence of overfishing, and replacement rates were increased through recruitment and accelerated growth rates.

15. — Natural, nonfishing mortality for largemouth bass at Ridge Lake (figured for 2-year periods) was 33 percent for bass weighing 0.07–0.34 kg, about 14 percent for sizes between 0.35 and 1.81 kg, 39 percent for sizes between 1.82 and 2.27 kg, and 73 percent for sizes over 2.27 kg (Table 16).

16. — The nine draining censuses with the culling of small fish and invertebrate fish foods influenced the hook-and-line catch in the postcensus angling seasons to the extent that yields averaged 55.9 percent of the bass available (representing 62.6 percent of their weight) (Table 17), while in precensus fishing seasons, not influenced by culling, an average of 60.3 percent of the number of bass available (representing 39.2 percent of

their total weight) were captured (Table 18). Comparable averages for bluegills for postcensus seasons were 38.1 percent (representing 49.1 percent of weight) and for precensus seasons 49.7 percent (representing 46.0 percent of the total weight of bluegills).

17. — Fishing pressures (from boats only; no bank fishing) at Ridge Lake varied from 222 man-hours to 791 man-hours per hectare per season (Table 20). Average seasonal rates of catch ranged from 0.1 to 1.8 fish per man-hour; these catches represented average seasonal rates of 7–34 hours to catch 1 kg of fish. These averages include all of the unproductive time spent in fishing by fishermen who caught nothing as well as productive time spent by those who caught fish.

18. — Rates of catch varied so that seasonal fish yields ranged from 3.3 to 117.0 kg per hectare, giving an average for 21 years of 47.7 kg per hectare (Table 23). Five to 10 times as many fishes were caught in good fishing years as in poor ones.

19. — In 3 poor fishing years the average number of large bass present per hectare was 59, and small ones averaged 123, a total of 182 per hectare. For bluegills the average number of large fish per hectare was 175, and small bluegills averaged 194, a total of 369 per hectare (Tables 28 and 30). In 3 good fishing years the average number of large bass present per hectare was 73; the number of small, 158; the total 231 per hectare. For bluegills the average number of large fish per hectare was 1,315; the number of small, 1,103; the total, 2,418 per hectare (Tables 29 and 30). Numbers (and weights) of fish were the most important differences between good and poor fishing years. The competition, presumably for the available food, produced by large numbers of fishes made fishing returns greater when populations were larger.

20. — The average annual catch of desirable-sized largemouth bass (25 cm or longer) per hectare was 47, weighing 19.2 kg. under biennial draining and culling; 30 per hectare, weighing 11.7 kg, under drawdowns; and 27 per hectare, weighing 12.1 kg, under stable water levels. For desirable-sized bluegills (15 cm or larger) the average annual catch per hectare was 133, weighing 13.0 kg, under biennial culling; 304 per hectare, weighing 33.2 kg, under drawdowns; and 472 per hectare, weighing 41.9 kg, under stable water levels (Table 31).

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INDEX

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