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HARLOW B. MILLS, *Chief*

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CONTENTS

The frontispiece shows wing nets being set in Fork Lake, 1939. In the first year of cropng, only two or three wing nets were required and these were set with individual leads that d no relation to one another. In other years, six wing nets were required and were arranged such a way as to trap fish in all but the deepest part of the pond.

The Bass-Bluegill Combination in a Small Artificial Lake

GEORGE W. BENNETT

TEN years ago, Fork Lake, a pond of 1.38 acres on the farm of Paul S. Smith near Mount Zion, Illinois, was probably typical of many of the older man-made ponds in central Illinois. When this pond was assigned for study to aquatic biologists of the Illinois Natural History Survey in 1938, it was 18 years old and had been used extensively for fishing, waterfowl shooting, and general outdoor recreation. A brief history of the recreational benefits derived from the pond has been published elsewhere (Thompson & Bennett 1939*a*).

With the outlawing of duck baiting and use of live decoys in 1935, the success of waterfowl shooting on Fork Lake was limited. Fishing, which was considered good from 1926 to 1930, had become poor through the development of large populations of black bullheads, carp, and buffaloes. These undesirable fishes apparently were limiting the success of reproduction and curtailing the growth rates of largemouth bass, crappies, bluegills, and other sunfish in the pond.

Fish in the pond were poisoned with rotenone on June 7, 1938, and a census was made of them (Thompson & Bennett 1939*a*). At this time, Fork Lake contained 5,350 fish weighing 774 pounds and consisting of 16 species. The rough fish, mostly carp and redmouth buffalo, made up 47.5 per cent by weight of all fish, and bullhead (plus four channel catfish) 41.2 per cent. Largemouth bass and panfish totaled only 6.3 per cent of the weight of all fish. The weight of fish per acre was 539 pounds, which indicated a moderately high natural fertility for the pond. At the time of the census, Fork Lake contained only 145 fish of desirable species and of a size large enough to interest anglers.

The pond was restocked between June 11 and 18 with 270 stunted adult bluegills, *Lepomis macrochirus* Rafinesque, weighing about 40 pounds and 1,440 largemouth bass fry, *Micropterus salmoides* Lacépède, weighing 0.15 pound. Both the bluegills and the bass were taken from Homewood Lake, near Decatur, Illinois. The bluegills began to spawn almost at once; on June 22, 27 bluegill nests were counted. The bass averaged 0.87 inch total length when stocked, and, during October, 74 taken on fly-rod lures averaged 6.45 inches. Some of the young bluegills that were spawned in 1938 and escaped being eaten by bass were nearly 3.75 inches long by October; others were less than 0.75 inch.

Early in 1939 the decision was made to crop the new fish population by using 1-inch-mesh wing nets, 1-inch-mesh (bar) seines, and hook and line, and to determine the effect of such cropping upon this bass-bluegill population.

Cropping efforts resulted in a substantial yield of fish in 1939 (Bennett, Thompson, & Parr 1940). The annual yields of bluegills were smaller in 1940 and 1941. The yields of bass, although numerically smaller in 1940 and 1941 than in 1939, increased in total weight each year from 1939 to 1941, inclusive.

In the case of the bluegills, the first brood spawned in the lake grew more rapidly than all the others. Each successive brood of bluegills grew less rapidly than the preceding brood in spite of intensive cropping, which might have been expected to reduce the competition for food and result in improved rates of growth. Successive yearly yields in pounds of bluegills also progressively decreased. I believe that counter forces that reduced the food available for bluegills were responsible for the decline in yield and the absence of growth compensation.

Two possible causes for a reduction in bluegill foods, which may be assumed to have been responsible for a reduced yield of bluegills, were (1) loss of fertility of the pond resulting from the removal of a large poundage of fish and (2) the spread of rooted aquatic plants to reduce greatly the area of open water.

The Fork Lake experiment was terminated by run-off water from a 4-inch rain that washed out the dam on July 8, 1942. As no Natural History Survey personnel were present at the time the actual break occurred, fish collected were those that remained in the pond after about two-thirds of the water had flowed out through the break, carrying with it a part of the fish population. In spite of this unfortunate circumstance, which eliminated the possibility of a final complete census of the fish, the partial census and the collections of previous years gave interesting and significant information on the bass-bluegill combination.

Acknowledgments

Many persons assisted in the Fork Lake investigation. Dr. David H. Thompson initiated the study in 1938 and cooperated with the author on the field investigations in 1939 and on the preparation of the two preliminary Fork Lake reports. Mr. Sam A. Parr, formerly an Inspector with the Illinois Department of Conservation and now Superintendent of Fisheries with that Department, gave invaluable assistance in field observations and cropping. Assistance in collecting monthly quotas of fishes was given by many members of the Natural History Survey staff, among whom were Dr. Donald F. Hansen, Dr. Louis A. Krumholz, Dr. Lee E. Yeager, Mr. Bruno von Limbach, Mr. Francis X. Lueth, Dr. C. L. Schloemer, and Dr. Gernon P. Hesselschwerdt. I am indebted to Mrs. Mary Shanor and Dr. Marian F. James, employed by the Natural History Survey for making stomach analyses of bass and bluegills. Dr. Herbert H. Ross, Systematic Entomologist of the Survey, and his staff gave valuable assistance to Mrs. Shanor and Dr. James in the identification of aquatic insects.

To Mr. Paul S. Smith, owner of Fork Lake, I am grateful for the use of the pond and for the many pertinent observations that he made during the early years of the experiment.

Cropping Procedure

It was not feasible to take a large annual crop of fish by hook and line from Fork Lake; the Natural History Survey staff was unequal to the task and local people who cared to fish and who would keep records were few. Moreover, since many fish were needed for laboratory study, and a uniform sequence of collections was desirable, it was decided to crop the pond with nets and to augment the net catches with hook-and-line fishing. Nearly all anglers condemn the man who uses a trap net or seine as a game-fish poacher (whether the use of nets for commercial fishing is legal or not). Because such gear is frequently considered responsible for the

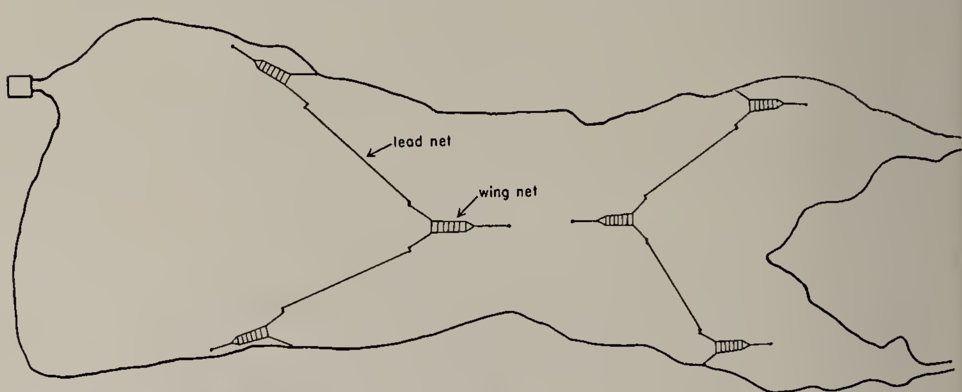

Fig. 1.—Outline map of Fork Lake, showing the customary set position of wing nets and lead nets used in cropping the pond during 1940, 1941, and 1942. It was not always possible to block off the pond completely as is shown, for the bottom near shore was often hard and frequently would not support the outer wing pole of a net. With the arrangements of nets shown here, no fish could swim for any great distance without running into a lead or net.

Fig. 2.—Six wing nets were needed to crop the fish in Fork Lake in 1940, 1941, and 1942. These nets were set in groups of three, with leads blocking the pond between them, as shown in fig. 1.

depletion of our game fishes, it seemed of considerable value to use this type of equipment in cropping the pond.

For a number of years, members of the aquatic biology staff of the Natural History Survey have used a wing net or fyke net for sampling fish populations in Illinois lakes and streams. This net, similar to the wing nets used by commercial fishermen on the Illinois River, consists of a tapered cylinder of webbing supported by hoops, open at the large end and closed at the small end by a drawstring. Inside are two funnels composed of webbing, the first located just inside the open end of the net and the second about two-thirds of the distance from front to back. Attached to the hoop at the large open end of the net are two pieces of webbing, the wings, that are spread when the net is set and that function in leading fish into the net much as the wing fences on a cattle chute lead in the cattle, fig. 1. A separate lead net (much like a gill net or seine) is often used with a wing net to form an underwater "drift fence"; occasionally wing nets are set at both ends of such a lead net. Fish are believed to swim up to this lead, and follow it along until they find themselves within the mouth of the wing net. Wing nets are not ordinarily baited except for catfish; fish wander into the nets and are unable to find a way out. In shallow water these nets and leads are supported by long poles forced into the bottom mud. The webbing of legal commercial nets in Illinois must measure a minimum of 1.5 inches between knots on each of the four corners of a square mesh. Wing nets used at Fork Lake were of somewhat smaller mesh (0.50 to 0.75 inch) and would hold bass as small as 5 inches in length and bluegills of 3.5 inches.

Most of the cropping of Fork Lake was accomplished in 1939 by using two or three wing nets of 3.5 feet and 4.5 feet in hoop diameter. In 1940 and later years, it became necessary to use six wing nets, four having front hoops of 3.5 feet in diameter and two having front hoops of 4.5 feet, fig. 2. In 1939, each wing net was supplied with a separate lead net; in 1940, 1941, and 1942, the six nets were set in two groups of three nets each with lead nets blocking the pond between them, as shown in fig. 1. With this arrangement, no fish could swim for any great distance without running into a lead or wing net.

Usually at 24-hour to 48-hour intervals after being set, nets were raised and the fish removed. Nets were moved frequently if they failed to catch fish. An attempt was made to fish the wing nets for a period each month from March to November of each year, beginning in March, 1939, and ending with the washout in July, 1942. Most of the fish caught were taken to the Urbana laboratories alive or iced, where they were weighed, measured, scaled, and dissected for stomachs and gonads. A small number of fish from Fork Lake were used to stock several new ponds constructed on farms near Mount Zion.

Some collections in early spring and late fall were made by seine hauls with a 100-yard, 1-inch-mesh seine. These hauls were necessary because the fish did not move enough to be caught in sufficient numbers in wing nets. Although some fish were taken with the seine, a satisfactory haul was difficult because of brush and snags in the bottom of the pond.

Table 1 lists the net-days of fishing in Fork Lake for the years 1939, 1940, 1941, and 1942.

The length of time that nets were fished each month usually depended upon the catch. If good catches (15 to 25 pounds of fish) were made, the nets were removed after two raises. If catches were poor, the nets were left in the lake as long as practicable. Table 1 indicates that more net-days of fishing were required with each succeeding year, and table 5 shows that in spite of an increase in net-days of fishing the total yield in pounds went down each year. This decrease in the fish yield produced by nets may have been influenced by one or both of two possibilities: (1) a reduction in the fish production of the pond and (2) a gradual improvement in the ability of the fish to avoid the nets or find a way out of them. Bass were much more successful in avoiding nets than were bluegills. Even in 1939 so few bass entered the nets that angling was necessary to produce adequate samples. As the original bass fry grew larger, 1939–1942, they became more and more difficult to catch in nets. Bass of later broods, also, were caught more readily when small (5 to 7 inches) than when larger.

Bluegills were taken in nets most readily in the spring throughout April and May and more readily in fall than in summer. They were sometimes induced to move by violent storms or the flowing of warm water into the pond from the watershed. For example, nets set on March 9, 1942, caught few fish until a warm rain during the night of March 16 drained from the surrounding lands into the pond. When the nets were raised on March 17, they contained so many bluegills that some were replaced in the pond.

The amount of hook-and-line fishing done in Fork Lake to augment the catch of bass by nets was moderate. Nearly always done from a boat, fishing was with fly rod or bait rod and usually with artificial baits. Angling periods were usually short (one-half to 3 hours) and represented such time as was available on days when net raising or observations necessitated a trip to the pond. Hook-and-line catches varied from 16 fish per man-hour on May 6, 1941, to zero catches on several occasions. Table 2 gives the hook-and-line catch summary for years of the study and shows man-hours of fishing catch per man-hour, and numbers of bass and bluegills taken.

It is difficult to explain why no fish were caught on hook and line in 1942. Part of the failure to catch fish was due to a late, cold spring accompanied by excessive rainfall, which increased the turbidity of the pond and kept the water abnormally cold. The larger bass present (between 12 and 15 inches long and 1.0 and 1.5 pounds in weight) had become increasingly difficult to catch in 1941, and apparently had learned through observation (because bass were seldom returned to the water when caught) to ignore artificial lures. In 1942 the poorness of fishing gave the picture of a pond "fished out" for bass. That the lake was not "fished out" was shown by the catch of bass in the washout described later. Actually, during the spring of 1942,

Table 1.—Net-days of fishing with 1-inch-mesh wing nets in Fork Lake, March, 1939, to June, 1942.

Month	Net-days of Fishing			
	1939	1940	1941	1942
March	S-6*	S-3*	48	48
April	14	36	30	36
May	8	36	60	36
June	6	20	36	48
July	8	18	36	—
August	8	24	24	—
September	15	—	54	—
October	15	48	42	—
November	18	S-2*	—	—
Total	92	182	330	168

*S designates that hauls were made with a 100-yard, 1 inch-mesh seine; the numeral following the S indicates the number of such hauls.

Table 2.—Hook-and-line catch of largemouth bass and bluegills from Fork Lake, 1939, 1940, 1941, 1942.*

Year	Total Man-Hours of Fishing	Average Catch per Man-Hour	Number of Large-mouth Bass	Number of Blue-gills
1939	27.0	1.37	34	3
1940	36.3	3.20	116	1
1941	42.3	2.90	122	28
1942*	26.5	0.00	0	0

* March–June only in 1942. All other years March–October.

Fork Lake contained more than 75 bass of over 10 inches in length and many more of smaller sizes.

Fish were removed from Fork Lake when captured in wing nets, seines, or by angling, except in a few cases when the catch was less than 5 individuals, and in a single case (March 17, 1942) when more fish were caught than could be processed. By arrangement with the State Department of Conservation, state fish code restrictions were dispensed with; bass were taken during the closed season, and no length limits or creel limits were observed on either bass or bluegills.

On several occasions fish from Fork Lake were used for stocking other ponds. Adult fish used for this purpose were weighed and measured when caught. Bass and bluegill fry were measured and counted, and an estimate was made of their total weight.

Fish Yield

The total yield of bass for the years 1939–1941 and the early part of 1942 is shown in table 3. The 1938 brood (original fry stocked) made up 87 per cent of the yield (weight) for all years, and, in the years in which cropping continued through November, the total weight of bass taken remained fairly constant at around 50 pounds (51.0, 53.9, and 57.7). No bass were spawned in 1939 because the original stock was not sexually mature in that year. Neither the 1940 nor the 1941 broods of bass were well represented in the net or hook-and-line catches, presumably because these broods were preyed upon by the original brood.

The number of bluegills taken from Fork Lake is shown in table 4. The original stock was sexually mature and produced a brood of young in 1938. Each year the bluegills produced a new brood, which usually appeared in large numbers in the nets during the following season. In 1940 some bluegill fry of the year were seined for stocking a nearby pond and some were trapped in the nets by strands of *Spirogyra* and failed to fall through the meshes. While it was readily possible to separate the original stock and the 1938 brood fish from later broods, the range in size of the individuals of the 1939, 1940, and 1941 broods overlapped so that separation of most bluegills into their various broods was done on the basis of scale studies. The original stock made up 16.5 per cent by weight of the total catch during the study, the 1938 brood 55.8 per cent, the 1939 brood 19.9 per cent, and the 1940 brood 7.7 per cent.

Table 5 gives a summary of the total yield of largemouth bass and bluegills taken from Fork Lake by netting and angling during the study. The yield of bass (1939–1941) showed a slight rise from 51 to 58 pounds, but that of bluegills dropped from 172 pounds in 1939 to 72 pounds in 1941. As may be seen from tables 1 and 2, the intensity of fishing both with nets and angling devices was increased with each successive year. The yield for the first 4 months of 1942 suggests that, if the cropping could have been continued through November, the 1942 yield of bluegills might have been nearly equal to that of 1941.

Table 3.—Largemouth bass removed from Fork Lake, March–November, 1939, 1940, 1941; and March–June, 1942.

Brood	1939 Number	1939 Weight, Pounds	1940 Number	1940 Weight, Pounds	1941 Number	1941 Weight, Pounds	1942 Number	1942 Weight, Pounds	Total Number	Total Weight, Pounds	Per Cent of Total Weight
1938*	349	51.0	208	52.7	72	39.6	10	17.4	639	160.7	86.6
1940	—	—	105	1.2	23	7.3	3	1.8	131	10.3	5.5
1941	—	—	—	—	91	10.8	27	3.7	118	14.5	7 9
Total	349	51.0	313	53.9	186	57.7	40	22.9	888	185.5	100.0

*Original stock.

Table 4.—Bluegills removed from Fork Lake, March–November, 1939, 1940, 1941; and March–June, 1942.

Brood	1939 Number	1939 Weight, Pounds	1940 Number	1940 Weight, Pounds	1941 Number	1941 Weight, Pounds	1942 Number	1942 Weight, Pounds	Total Number	Total Weight, Pounds	Per Cent of Total Weight
Original stock	162	57.0	27	12.2	2	1.4	—	—	191	70.6	16.5
1938	773	115.0	427	108.0	35	13.3	7	2.7	1,243	239.0	55.8
1939	5	0.4	312	25.8	336	51.8	35	7.3	687	85.3	19.9
1940	—	—	246	0.3	145	5.5	193	27.2	584	33.0	7.7
1941	—	—	—	—	19	0.2	18	0.4	37	0.6	0.1
Total	940	172.4	1,012	146.3	537	72.2	253	37.6	2,742	428.5	100.0

Table 5.—Yield of largemouth bass and bluegills from Fork Lake, March–November, 1939, 1940, 1941; and March–June, 1942.

Species	1939 Number	1939 Weight, Pounds	1940 Number	1940 Weight, Pounds	1941 Number	1941 Weight, Pounds	1942 Number	1942 Weight, Pounds
Largemouth bass........	349	51.0	313	53.9	186	57.7	40	22.9
Bluegills.......	940	172.4	1,012	146.3	537	72.2	253	37.6
Total........	1,289	223.4	1,325	200.2	723	129.9	293	60.5
Per acre.....	934	161.9	960	145.1	524	94.1	212	43.8

Dam Failure

The Fork Lake cropping experiment was suddenly terminated by run-off from a 4-inch rain that occurred within a few hours, early in the morning of July 8, 1942, when the Fork Lake dam, fig. 3, constructed without expert engineering assistance and apparently riddled with muskrat burrows above the normal water level, gave way near the middle, probably some time between 10:00 A.M. and noon. Dr. G. P. Hesselschwerdt and I were approaching Fork Lake at about 12:45 P.M. and, before we arrived within sight of the pond, we could hear the roar of water and realized the dam had washed out. At 12:45 about two-thirds of the total volume of water had poured out through the break. Much of the water must have flowed out with the initial failure of the dam, as the corn stalks were flattened in the field below over a much wider area than the flow covered at the time of our arrival. Probably any fish that were in the pond area immediately adjacent to the break at the time it occurred were washed across the cornfield and into the stream that winds through the valley below. Water continued to flow out of the basin until 2:20 P.M.

At the time of our arrival, we staked a short piece of 1-inch-mesh netting across the break in the dam to trap the larger fish still within the pond basin. Fifty-four bass and 10 large bluegills were taken in the net set across the break. All these fish made an active attempt to leave the lake with the water. Most of the bass held back until only about a foot of water remained in the basin; then many swam with the outflowing water into the net. Bluegills seemed less able to adjust themselves to the situation and most of them were stranded in the pond basin.

When we attempted to collect the stranded fish by walking into the pond basin, fig. 4, each of us in turn became mired in hip-deep silt a few feet from the former shore line. Because of the impossibility of collecting the fish, we made a careful count by walking around the shore line and listing the bass and bluegills as belonging to the various broods on the basis of size. As the pond was long and relatively narrow, we found it possible to walk along each side and count fish lying stranded in the strip of bottom from the shore line to the trickle of water running through the center of the basin. Probably some fish had become buried in the soft mud, and so escaped being counted.

Fig. 3.—Lower end of Fork Lake, showing the dam. Riprapping of broken concrete was held by fencing of wire mesh. This riprapping prevented washing from wave action but was attractive to burrowing muskrats.

The band of vegetation completely encircling the shore line and filling the upper one-fourth of the pond (see map, fig. 5) flattened down over the mud when the water flowed out of the lake and may have hidden a few additional large fish. This vegetation was covered by hundreds of small bass and bluegills that had wriggled to the surface of the vegetation mat with their dying exertions. We estimated that there were at least 10,000 bluegills between one-half and 2 inches long, and not less than 5,000 bass between 1 and 4 inches. After the count was completed, the bass and bluegills that were captured in the seine were taken to the laboratory and processed. Table 6 gives an estimate of the total number and weight of fish observed. The weight amounted to approximately 260 pounds.

Many bullfrog tadpoles, *Rana catesbeiana* Shaw, were also in the vegetation. As the last of the water was running out of the lake, several small muskrats left their burrows and ran around in the mud of the pond basin as if lost. Six adult bullfrogs crawled around in the mud. Many large clams, *Anodontia grandis* Say, were exposed and died after moving a few feet.

Fig. 4.—The basin of Fork Lake at the time of the dam failure, July 8, 1942. The break in the dam occurred near the center, supposedly as a result of a heavy rain and muskrat tunneling above the normal water line. The bottom of the white exposed portion of the gage board (upper left) marks the former water level.

Experience in draining ponds for making fish censuses indicates that, when a body of water is rapidly drained, bass swim against the current and usually most of them remain in the pond until the water has been lowered to a certain level, when they appear to reverse their behavior and attempt to move through the outlet. Bluegills are weaker swimmers and consequently many are washed out with the water before the bass begin to appear in numbers at the outlet.

The break in the dam at Fork Lake was V–shaped. The initial flow of water was large and probably carried away many

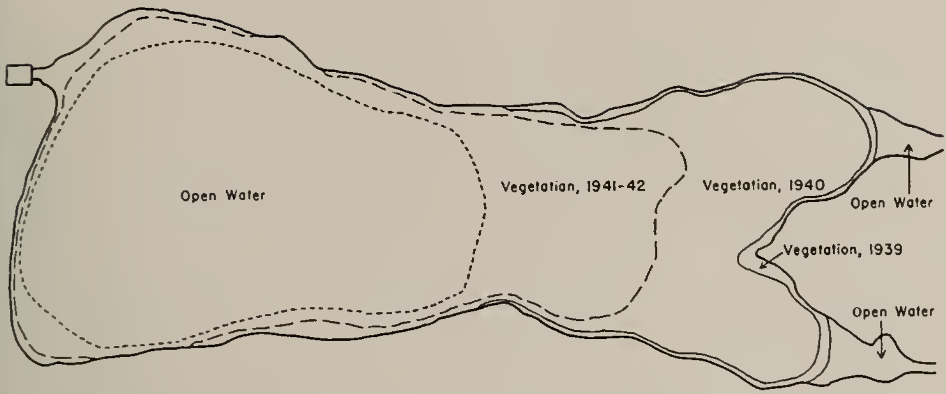

Fig. 5.—Outline map of Fork Lake, showing encroachment of the pondweed, *Potamogeton foliosus* Rafinesque, on the pond shallows. In 1939, plants of this species occupied a narrow band around the shore of the upper one-third of the pond; in 1940, it spread into water 3 to 4 feet in depth and encircled the pond shore line; in 1941 and 1942, it filled the shallows up to 5 or 6 feet in depth, leaving only a little more than one-half of the pond area in open water. Open water was always present in the upper forks of the pond because overhanging trees completely shaded these pockets.

more bluegills than bass. What the total weight of the population was can be only conjectured. The deep, open water in the region of the dam was of a type attractive to bluegills beyond the size range of bass food. Certainly the numbers of fish actually observed indicate that the pond contained a large fish population in spite of 3½ years of heavy cropping with nets, and the many small fish inhabiting the vegetation indicate a very successful spawn in 1942.

Pond Habitat

No attempt was made to study the plankton or the invertebrate or vertebrate fauna of Fork Lake other than the fish, except when an abnormal abundance of some species could not escape observation or when plants or animals other than fish appeared in the nets.

The most obvious change in the pond habitat during the 4½ years it was under observation resulted from the spread of a

Table 6.—Fish observed at Fork Lake at the time of the dam failure of July 8, 1942.

Brood	Measured and Weighed Individually			Counted but Not Weighed		Estimate of Total Observed Population	
	Number	Total Weight, Pounds	Average Weight, Pounds	Number	Estimated Weight, Pounds	Number	Weight, Pounds
Largemouth bass							
1938	34	59.7	1.76	32	56.3	66	116.0
1940	4	4.7	1.17	7	8.1	11	12.8
1941	16	12.6	0.79	16	12.5	32	25.1
1942	—	—	—	—	—	5,000	15.0
Total	54	77.0	—	55	76.9	5,109	168.9
Bluegills							
1938	10	5.7	0.57	20	11.3	30	17.0
1939 and 1940	—	—	—	278	50.0	278	50.0
1941 and 1942	—	—	—	—	—	10,000	25.0
Total	10	5.7	—	298	61.3	10,308	92.0

species of rooted aquatic vegetation, namely the fine-leaved pondweed, *Potamogeton foliosus* Rafinesque. Previous to the complete removal of fish in 1938, the pond contained no aquatic vegetation because the activities of bottom-rooting fish kept the water very turbid. The replacement of these fish by largemouth bass and bluegills allowed the silt to settle, and after June of 1938 the pond was turbid only following heavy rains. The source of silt was a clay fill for a road about 150 yards above the pond. Most of the rest of the drainage basin was in timber and grass. The reduced turbidity of the pond was not immediately followed by a growth of aquatic plants; a few bunches of fine-leaved pondweed appeared in the late summer of 1938.

By midsummer of 1939 a dense, narrow band of *Potamogeton foliosus* was growing in water from the shore out to a depth of 2 feet along the shore line of the upper one-third of the pond. In 1940, the fine-leaved plant spread into deeper water at the upper end of the pond and extended its distribution to form a band along the entire shore line of the pond—the edge of this band farthest from shore extended into water between 3 and 4 feet in depth. A vegetation map of the pond was made at the period of maximum plant growth in early August, fig. 5. When the open water of the pond was measured with a planimeter on this vegetation map, it was found to be slightly more than 0.95 acre, as compared with an open water area of 1.25 acres in 1939. The plants in this band of vegetation extended to the surface and were so thick that it was difficult to row a boat through them.

The following year (1941) the potamogeton extended its growth into still deeper water, fig. 5. The maximum depth at which the plants reached the surface was 6 feet, and most of the shore band of plants extended to depths a little beyond 5 feet. A measurement of the open water as outlined on a vegetation map made July 28 gave an area of 0.64 acre.

By the time the 1941 vegetation map was made, a circular area of approximately 10 feet in diameter, at a point near shore immediately between the forks of the upper end of the lake, had become completely denuded of plants. As a heavy growth of plants had been present in this location earlier in the summer, the barren area was recorded. The water in the barren area was clear and it was possible to see bottom there. The water depth of this area ranged from 1 foot near shore to 3 feet at the outer edge of the opening.

The pond was not visited again until August 19, 23 days after the vegetation was mapped. On this date the *Potamogeton foliosus* was completely gone, except for a few scattered stalks at the water's edge, and the water was turbid with a "bloom" of algae, *Aphanizomenon flos-aquae* (Linnaeus), that obscured a Secchi disk lowered to 1.2 feet. Whether the small open area observed the latter part of July represented the beginning of a progressive die-off of the potamogeton is not known. A few small bunches of *Potamogeton nodosus* Poiret growing in shallow water along the south shore seemed to be unchanged. This phenomenon of a sudden die-off of *P. foliosus* in midsummer had been observed in one other experimental pond. In both instances, however, it was a "before and after" observation; neither pond was observed during the progress of the die-off.

The cause of this sudden die-off is unknown and it is believed to be of uncommon occurrence. Usually, dense mats of *Potamogeton foliosus* remain until late September, when they gradually break loose from their attachments and float free for some time before finally disintegrating. The phytoplankton "bloom" that followed the disappearance of the potamogeton is believed to have resulted from the release of plant nutrients into the pond water.

In 1942, in spite of a late, wet season, the fine-leaved pondweed again appeared in abundance and by the latter part of June had grown to fill the same parts of the pond that had been filled the preceding year.

It is probable that the application of the rotenone in June of 1938 killed not only the fishes but also the Entomostraca and, where excessive concentrations occurred, a part of the insect larvae of the littoral zone and the benthos (Smith 1940; Brown & Ball 1943). The rapid growth of bass fry and bluegills during the summer indicates that replenishment of small aquatic invertebrates must have taken place within a very short time. The result of a sudden catastrophe, such as rotenone treatment of a pond, is often a simplification of the invertebrate fauna, some species disappearing entirely and other forms disappearing temporarily but reappearing later in eruptive numbers. This reaction is assumed to have taken place in 1938 in Fork Lake, particularly among the smaller invertebrates.

Fork Lake contained a number of adult bullfrogs, *Rana catesbeiana*, and their tadpoles were extremely numerous throughout the summer of 1938. The only other year in which tadpoles were present in large numbers was 1941, although a few could be seen at almost any time among the aquatic vegetation.

Crayfish, *Cambarus virilis* Hagen and *C. propinquus* Girard, must have been fairly abundant throughout the period of cropping of the pond, as large adults were taken often in wing nets. Both snapping, *Chelydra serpentina* (Linnaeus), and painted turtles, *Chrysemys picta marginata* (Agassiz), found a way into nets and frequently were drowned before the nets were raised. In some raises the poundage of turtles greatly exceeded that of fish. Snapping turtles removed from the pond in 1939 were 9 weighing 28.7 pounds; in 1940, 11 weighing 23.2 pounds; in 1941, 5 weighing 14.5 pounds; and in 1942, 3 weighing 7.1 pounds. The painted turtles removed in 1939 were 32 weighing 20.3 pounds; in 1940, 8 weighing 7.6 pounds; in 1941, 6 weighing 6.8 pounds; and in 1942, 4 weighing 5.3 pounds. Turtles found dead in the nets were removed from the pond. Some of the live turtles caught in nets were removed for laboratory study or for table use. Others caught were released.

Vegetation vs. Fish Yield

At the same time that the annual poundage of fish from Fork Lake went steadily downward from 1939 through 1941, in spite of an increased intensity of fishing with nets and an increase in man-hours of angling, the mat-forming aquatic vegetation continued to spread. While other factors undoubtedly reduced the yield of fish from the pond, I believe that the increased abundance of plants was the most important factor.

A comparison of the yields of fish with the areas of open water is shown in table 7. The yields of fish are, of course, not exactly proportional to the areas of open water in the pond. But even though netting and angling pressures were increased during the 3 years, and many other factors probably influenced the fish yield, a remarkably close parallel existed between the fish yields and the open pond acreages, table 7. Swingle (1945) investigated a pond that became filled with a heavy growth of naiad, *Najas guadalupensis* (Sprengel), during years when this plant was not shaded out by muddy water. He concluded that the rank plant growths did not reduce the production of fish but did materially reduce the hook-and-line yield. Although information on the total weight of the fish population of Fork Lake, before and after the plants became abundant, is not available, the evidence presented in table 7 and the fact that the growth rate of bluegills became slower in spite of heavy cropping (see section following) suggest that the production of food available to fish in the pond was actually reduced by *Potamogeton foliosus*.

Growth Rates

The growing season for Fork Lake fish (water temperature above 55 degrees F.) was determined to be about 6 months long in 1939 (Bennett, Thompson, & Parr

Table 7.—Yield of fish, fishing effort, and approximate area of open water in Fork Lake, 1939, 1940, and 1941.

Year	Yield		Area of Open Water		Net-Fishing Intensity		Angling Intensity	
	Pounds	Per Cent of 1939 Yield	Acres	Per Cent of 1939 Area	Net-Days	Per Cent of 1939 Net-Fishing	Man-Hours	Per Cent of 1939 Angling
1939	223.4	100.0	1.25	100.0	92	100.0	27.0	100.0
1940	200.2	89.6	0.95	76.0	182	197.8	36.3	134.4
1941	129.9	58.1	0.64	51.2	330	358.7	42.3	156.7

1940), and probably the growing season length varied from this time no more than a few weeks in other years.

These relatively small differences in the growing seasons had less influence upon fish growth than such factors as available food and related competition for food.

Frequent collections and examinations of fish from Fork Lake gave total length measurements that were useful in plotting average lengths of the various broods, figs. 6 and 7. Whenever possible, the broods of each species were separated by a study of scale patterns and counts of annuli. In a few cases, where fish were used for stocking other waters, no scales were taken. These fish were assigned to various broods on the basis of size.

The growth of the 1938 brood bass seined from Homewood Lake and stocked in Fork Lake on June 23, 1938, was at first very rapid. When released these bass fry averaged 0.87 inch, and 74 of them caught in October, 1938, averaged 6.45 inches total length (Thompson & Bennett 1939*a*). One hundred sixty-one were collected and preserved between late June and mid-September, 1938.

The 270 bluegills that were moved to Fork Lake from Homewood Lake between June 11 and 18 were very thin and were between 5 and 7 inches total length. On the basis of the first spring collection of the following year, these fish may be said to have grown rapidly in 1938; they averaged 7.6 inches in March, 1939. Many of them had increased in weight more than three times. The spawn (1938 brood) of these bluegills averaged 3.5 inches in March, 1939.

A number of fish were taken by angling and minnow seining in 1938 as a means of following growth rates of the two species: 161 bass, 2 adult bluegills, and 34 of the 1938 brood bluegills. Thus, when systematic cropping was begun in March 1939, the original fish population had been reduced to a figure that did not exceed 1,279 bass and 268 bluegills. Throughout the period of study only 866 bass and 19 bluegills of the original stock were recaptured.

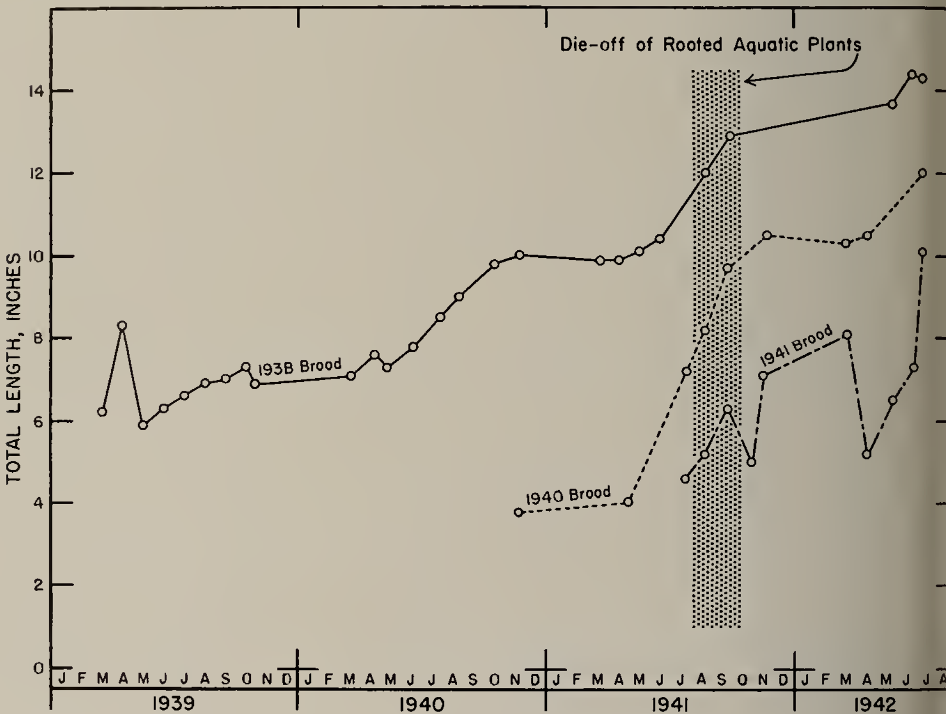

Fig. 6.—Average rates of growth of 1938, 1940, and 1941 broods of largemouth bass in Fork Lake.

In 1939, the bass increased in length ery little, presumably because so many ass were present in the pond that the vailable food supply was inadequate for heir requirements. Bass collected in

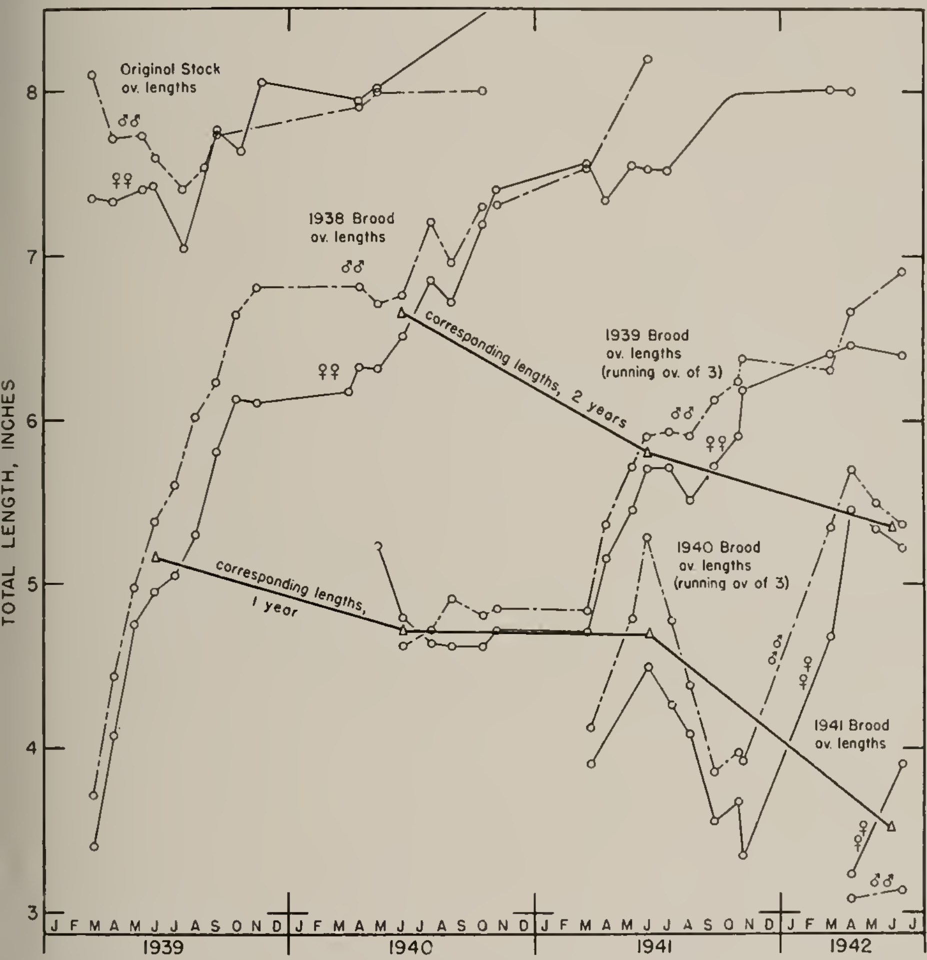

Fig. 7.—Average rates of growth of original stock and the four broods of bluegills spawned n Fork Lake, 1938–1941. As males usually average larger than females, the curves representng the sexes are separated. Corresponding average lengths of fish of the several broods at 1 nd at 2 years of age are indicated to show the decrease in growth rate throughout the period f sampling.

March averaged 6 inches. A number of 'cannibals" (Cooper 1937) collected in April materially raised the average length or that month; the average length of bass aken in October was only 7 inches, fig. 6. The original bluegills, with an indicated average length of about 7.5 inches by the all of 1938, showed a fluctuation in average length of fish caught during 1939, fig. 7, which may denote some growth, although this is largely obscured by a considerable variation in sizes (and ages) of individuals trapped. As male bluegills usually average larger than females for any given age, points representing the average lengths of males and of females in fig. 7 are separated.

The growth of the 1938 brood bluegills was rapid in 1939, fig. 7; fish taken from the pond averaged 3.5 inches in March and nearly 6.5 inches in October. The indicated increase in average size of these bluegills between March and April, 1939, may not have been due entirely to growth; it is presumed that many of the smaller fish of this brood were eaten by bass at this time and so were unavailable to influence the average lengths of later collections. This assumption is substantiated by the appearance of annuli on the scales of the 1938 brood bluegills. The annuli appeared largely between the April and May collecting periods (Bennett, Thompson, & Parr 1940, fig. 6) and were believed to mark the resumption of growth in the spring.

The large number of bass fry used in stocking the pond reduced the numbers of the 1938 brood bluegills to a point where those that escaped capture made excellent growth in 1939. Yet the increase in size of the bass increased their own food requirements to such an extent that the spawn of the remaining original bluegills plus that of the now sexually mature 1938 brood could not furnish sufficient food for the bass. This situation resulted partly because bass raided the bluegill nests and ate the newly hatched fry before they attained a substantial size. Thus, in 1939, growth conditions in Fork Lake were favorable for bluegills too large for bass to eat (above 3.5 inches in length) but were unfavorable for bass.

Similar conditions obtained in the early part of the 1940 growing season, although the number of bass had been reduced by 349, more than half (162 of 268) of the original bluegills had been taken, and 773 of an unknown number of 1938 brood bluegills had been netted and removed in 1939. The bass showed little growth in the first 3 collecting months. After the advent of the 1940 spawning season, when both young bass and young bluegills were available for food, the average lengths in the 1938 brood bass collections increased from about 7 to 10 inches.

Bluegills of the original stock and the 1938 brood continued to grow at a satisfactory rate in 1940. The number of the original stock taken was small (27) and lengths varied as in 1939. Bluegills of the 1938 brood, which averaged about 6.5 inches at the beginning of the 1940 growing season, averaged about 7.4 inches by November. Four hundred twenty-seven of the 1938 brood were taken in 1940 and, as in 1939, this brood made up the bulk of the bluegill crop. A few 1939 brood bluegills were taken in October, 1939; they appeared again in nets in May and June, 1940, and were present in all later collections. The average size of the members of this brood in collections did not increase during the season. This lack of size increase was due probably to net selectivity; that is, the collections of early months contained only the larger fish of this brood. Two hundred forty-six bluegill fry of the 1940 brood were taken during the summer and most of these were used to stock other ponds.

By March, 1941, 718 of the 1,440 original stock of bass had been recaptured; many more had probably been lost through cannibalism and other causes. The remaining bass made little growth during the spring and early summer months of 1941.

The 1940 brood bass, the first brood spawned in the pond, appeared in the November collection of that year; the average length of 8 of these was 4.0 inches as compared with an average length of 6.45 inches for 74 of the 1938 brood bass at the end of their first season of growth. Few of the 1940 brood bass were taken until the latter part of July, 1941, when those collected averaged 7.2 inches in length. The plant die-off early in August left small bass and small bluegills without the protection of the mats of vegetation. In the next 3 months, August through October, the increase in average lengths of bass collected indicated that individuals of all broods made remarkable growth. In the collections, the 1938 brood bass averaged less than 10.5 inches in June and 13.0 inches in October; the 1940 brood, 7.0 in June and 10.5 inches in October; and the 1941 brood (spawned that season) nearly 6.5 inches in October.

By 1941 the original and the 1938 brood bluegills were becoming scarce. Only 2 of the original and 35 of the 1938 brood bluegills were taken in that year. Bluegills of the 1939 brood, which made up the bulk of the 1941 bluegill catch, were less numerous and averaged so much smaller in size than the 1938 brood when of comparable age that the total weight of the 1941 bluegill crop was less than half of that of the 1940 crop, table 5. The 1939 brood bluegills collected averaged about 4.8 inches in March of 1941 and 6.3 inches at the end of the growing season.

The sizes of individuals in the collections of 1940 brood bluegills in 1941 varied over a large range, and the growth curve as plotted in fig. 7 shows a continuous decrease in average length from a high in June to a low in November. This decrease was due in part to the selectivity of nets; early in the season the nets held only the largest members of the brood, which were few in number, while later the more numerous smaller members had grown large enough to be held by 1-inch mesh. The average length of these second-year fish in June was 4.7 and in October–November 3.8 inches. Although 145 of these fish were taken in 1941, their combined weight was only 5.5 pounds.

The average sizes of bluegills taken during and after the plant die-off of August, 1941, showed no increase comparable to that found in bass, and it must be assumed, therefore, that no comparable improvement in bluegill food supply resulted from the "bloom" of algae that followed the potamogeton die-off.

Relatively few bass were taken in the March–June collecting period of 1942 but, of the fish collected after the wash-out, 34 bass of the original stock averaged 14.2 inches and 1.76 pounds at 4 years; 4 of the 1940 brood, 12 inches and 1.17 pounds at 2 years; and 16 of the 1941 brood, 10 inches and 0.79 pound at 1 year. The large size of the bass of the 1940 and 1941 broods was due largely to growth made during the plant die-off period of 1941.

Four broods of bluegills were represented in the 1942 collections: 7 bluegills of the 1938 brood averaged 8.0 inches at 4 years; 35 of the 1939 brood, about 6.6 inches at 3 years; 193 of the 1940 brood, about 5.5 inches at 2 years; and 18 of the 1941 brood, about 3.5 inches at 1 year. Bluegill growth was consistently poorer with each successive year, fig. 7, in spite of heavy cropping. This slow growth rate is believed to have resulted from a reduction in the available food supply associated with the spread of the plant, *Potamogeton foliosus*.

Condition and Growth

Condition, or relative plumpness, of fish is a measurement of some value in pond management. A high average condition usually indicates an abundance of available food in relation to the number of fish present, and a low average condition denotes slow growth and undue food competition.

The index figure indicating condition of bass and bluegills, as calculated by any of several recognized formulas, increases with an increase in the length of the fish even for fish apparently of the same relative plumpness. The form of both bass and bluegills changes somewhat throughout their length range.

In this manuscript the Index of Condition formula (Thompson & Bennett 1939*b*) has been used:

$$\text{Index of Condition} = \frac{W\ 10{,}000}{L^3}.$$

W represents weight to the nearest hundredth pound, and L represents total length to the nearest tenth inch.

When this formula is used on lengths and weights of bass within the length range of 5 to 15 inches, an Index of Condition figure of 3.5 to 4.5 denotes a fish in poor flesh; 4.6 to 5.5, one of about average or normal plumpness; and 5.6 to 6.5, a very fat fish.

In bluegills, the increase in index figure with increasing size is more pronounced than in bass, but in fish of 5 to 8 inches an Index of Condition figure of 7.0 or below denotes a fish in poor flesh; 7.1 to 8.0, one of normal or average plumpness; and above 8.0, one of unusual plumpness.

The condition curve for 1938 bass in 1939, plotted in fig. 8, shows that fish of this brood were within the range of normal condition during April, May, and June, then dropped into the thin classification, and remained there until July, 1940. This period coincides with the period of very small length increase (March, 1939–June, 1940) cited above in the discussion of growth. After the bass and bluegills had spawned in 1940, bass of the 1938 brood began to grow, and their condition curve rose gradually to 5.0 and slightly above. These bass remained within the range of normal plumpness until the period of vegetation die-off and "bloom," when they became very fat and their condition curve rose rapidly to 6.15. A drop to normal followed, but in 1942 the condition curve of the 1938 brood again rose above 6.0. The spectacular rise in the condition curve of bass of the 1938 brood dur-

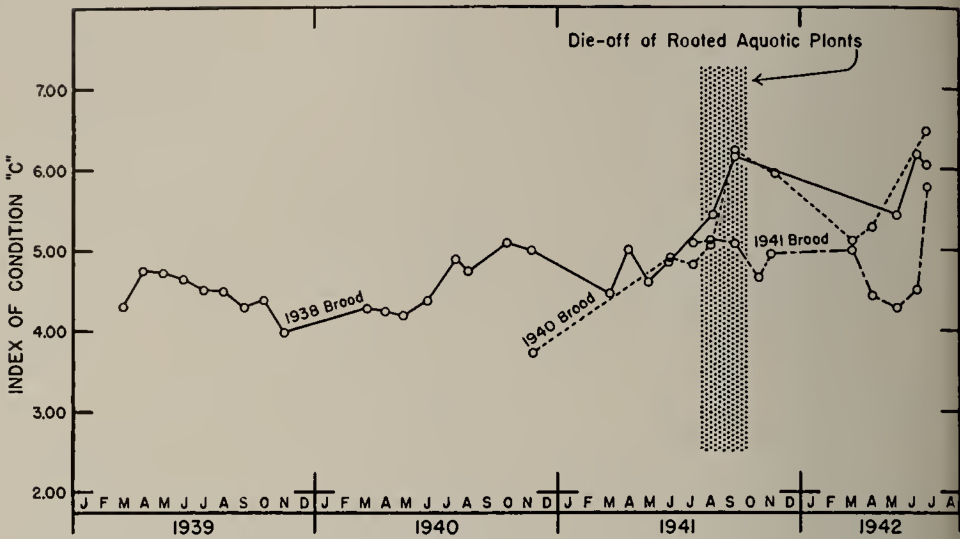

Fig. 8.—Average Indexes of Condition of the 1938, 1940, and 1941 broods of bass in Fork Lake, 1939–1942. An Index of Condition of 3.5 to 4.5 denotes a fish in poor flesh; 4.6 to 5.5, about average or normal; and 5.6 to 6.5, very fat.

ing the "bloom" of 1941 is paralleled by a similar rise for bass of the 1940 brood, and in each brood the rise is followed by a drop in the late fall and early spring following and a rise with the last collections of 1942.

Bass of the 1941 brood appeared in the catch about the time of the "bloom" and showed less influence from it. However, these bass were much smaller than the members of the other broods, and their Index of Condition of 5.10 is considered

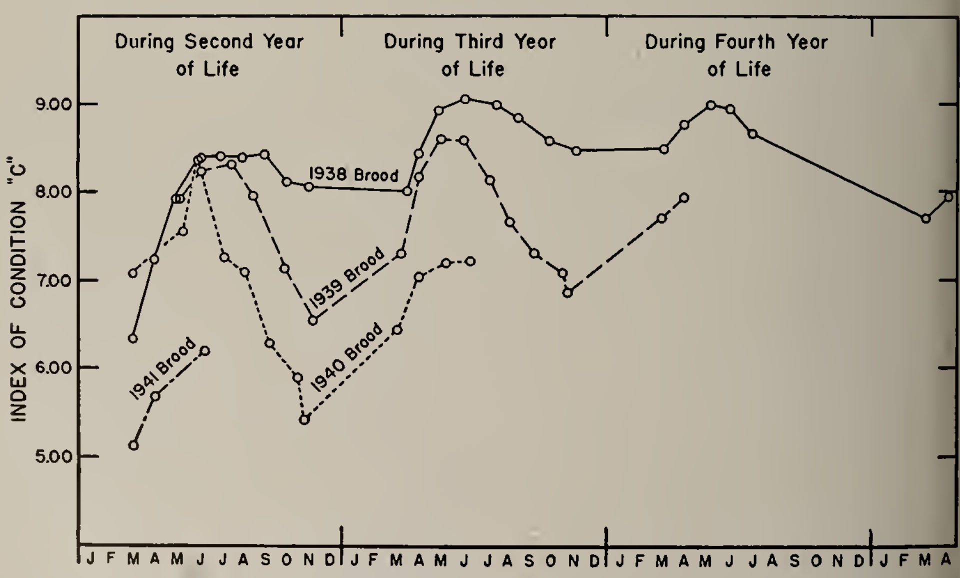

Fig. 9.—Average Indexes of Condition of the several broods of bluegills spawned in Fork Lake, 1938–1941, arranged to show average condition of these fish at comparable ages. The condition cycle of bluegills in Fork Lake is characterized by a high in May and a low in November. Bluegills with a condition factor of 7.0 or below are thin; those with a factor of 7.1 to 8.0 are normal or average; and those above 8.0 are unusually plump.

high. The early spring collections of 1942 showed a marked drop in Index of Condition of the 1941 brood, but improvement to 5.77 in early July.

As bluegills showed no increase in length or improvement in condition coinciding with the 1941 plant die-off, condition curves for bluegills are plotted to show comparable conditions of the several broods of bluegills at comparable ages, fig. 9. Throughout the period of study (except for the first few months when the fish were very small) the average condition for the 1938 brood bluegills was highest in early summer, but the curve remained always above 8.0, indicating that the fish were unusually plump. Other broods showed a rise in condition during the spring months to a point above 8.0, followed by a severe drop in or after July to a low in November. The drop was much more pronounced in the 1939 and 1940 broods than in that of 1938. A regular cycle of condition, probably influenced by spawning, seems to be characteristic of this species. The cycle reaches a high in early summer and a low in late fall. The fluctuations in the bluegill cycle must be considered when judging the condition of bluegills from a selected body of water on the basis of a single collection.

Scale Analysis

Annual rings, or annuli, that appear on fish scales are used frequently by aquatic technicians to determine age of fish. The validity of this practice has been tested for only a few species, although fisheries biologists, including the author, have applied the practice of "scale reading" to many species of fresh-water fishes.

This study of bass and bluegills in Fork Lake gave a good opportunity to determine the validity of the scale method of age determination in these species, particularly in the original bass stocked as fry in 1938 and in the 1938 brood bluegills. As the original bass fry did not become sexually mature in 1939, no new brood of bass appeared until June, 1940, so that throughout the period of study the original bass could be separated from the 1940 and 1941 broods on the basis of size. The 1938 brood bluegills grew rapidly during their first 2 years (1938–1939) in the pond; this rapid growth, and the fact that body length, weight increases, and scale growth were followed from month to month throughout the growing seasons of 1939, 1940, 1941, and a part of 1942, gave assurance as to the correct identification of this brood in all collections.

In a previous study of the scales of Fork Lake bass and bluegills collected in 1939 (Bennett, Thompson, & Parr 1940), the annuli were found to appear on the scales at about the time growth was resumed following a period of dormancy (winter). The length of the period during which individual fish of a given brood were in the process of forming annuli seemed to depend upon the amount of food available for that species of fish within the brood size range at the beginning of the growing season. If acceptable food was abundant, the beginning of growth was controlled by the temperature of the warming water, and most of the fish began to grow at about the same time. The appearance of the annulus, being dependent upon the addition of concentric ridges of new material (circuli) on the scale margins, was closely associated with a length increase of the fish body. If acceptable food was relatively scarce at a time when temperature conditions were favorable for rapid growth, the beginning of body growth within a brood of fish was delayed until the individual members were able to ingest a quantity of food in excess of body maintenance requirements, and annulus formation was prolonged over a much greater period than when food was abundant. There is no evidence to indicate that the annuli on the scales of warm-water fishes are more than visible marks produced by alternate periods of scale growth and growth stoppage. While the cessation of body growth and scale growth of fishes in winter is the result of low water temperatures which reduce the rate of metabolism, conditions might occur during the growing season (summer) which would stop growth, and, if growth were resumed later, produce false annuli.

False annuli, which appeared on the scales of both the 1938 brood bass (original stock) and 1938 brood bluegills in midsummer of 1939, were quite common (Bennett, Thompson, & Parr 1940). While these marks were indistinct on the scales of many fish, on others they were very definite and were indistinguishable from true annuli formed earlier in the season. The identification of these clear marks as false annuli aroused questions as to the validity of the scale method of age determination. Therefore, it was important to determine the percentage of clear false annuli among the broods of bass and bluegills in Fork Lake. In the 1938 brood bluegills taken in 1939, 10.0 per cent had clear false annuli, formed in midsummer, that were in no way distinguishable from a true annulus. The false mark was in each case laid down outside of the first annulus (in the second summer of life). In the collections of 1940, 11.3 per cent of 329 fish of this brood (1938) showed a clear false annulus in the same position as those found in 1939, although in fish collected after May, when the 1940 annulus had formed, the false annulus lay between the first and second true annuli. In the collections of 1941, 5 of 35 fish (14.3 per cent) of the 1938 brood showed a clear false annulus in the same position. Thus, throughout the period of study, from 10.0 to 14.3 per cent of the 1938 brood bluegills collected each year showed a clear false annulus that formed during the summer of 1939 (outside the first true annulus). This false annulus was in no way distinguishable from the true annuli.

The scales of the 1938 brood bluegills were carefully checked for the presence of clear false annuli, other than those formed during the summer of 1939. Only 12 were found on fish collected in 1940 and later. These 12, located outside the second true annulus, appeared on the scales during the summer of 1940.

The 1939 and 1940 brood bluegills grew less rapidly than the 1938 brood and, while the exact identification of members of these broods is less certain than of members of the 1938 brood, monthly collections failed to show clear false annuli with any degree of frequency. Table 8 gives the percentages of clear false annuli on the scales of 1939 and 1940 brood bluegills.

Clear false annuli were common on largemouth bass scales. About 6 per cent of the 1938 brood bass caught in 1939 showed a false annulus that might be confused with true annuli. In the 1940 collections of 1938 brood bass, 15.3 per cent of the fish showed a false annulus outside the first true annulus (false annuli formed in the summer of 1939). In the 1941 and 1942 collections of the same brood bass, false annuli were found on the scales of 6.9 per cent and 4.5 per cent, respectively. No distinct false annuli were found in the 1938 brood bass other than those that were formed during the summer of 1939, located between the first and second true annuli. No clear false annuli were present on the scales of either the 1940 or 1941 brood bass.

Other abnormalities associated with the scales of 1938 brood bass were found in this scale study. Some 1938 brood bass did not grow at all in 1939 and on the scales of these fish (three in number) the 1940 annulus replaced the annulus that should have appeared in the summer of 1939. Thus, these fish showed one less annulus than should have been present.

In nine other bass of the 1938 brood, the increase in length was very small in 1939. This small growth was reflected on the scales in an addition of only three or four circuli outside the 1939 annulus and these in only the anterior field of the scale. When the 1940 annulus formed, the interspace between it and the 1939 annulus consisted of the few circuli in the anterior field, and the two rings coincided in the lateral and posterior fields of the scale. Thus, a confusing partly double ring was formed, which probably would ordinarily be interpreted by a scale reader as a single

Table 8.—Percentage of clear false annuli observed on the scales of 1939 and 1940 brood bluegills in 1940, 1941, and 1942.

Brood	1940			1941			1942		
	Number of Fish	Number with False Annuli	Per Cent with False Annuli	Number of Fish	Number with False Annuli	Per Cent with False Annuli	Number of Fish	Number with False Annuli	Per Cent with False Annuli
1939..	312	6	1.9	336	8	2.4	35	0	0.0
1940..	—	—	—	129	1	0.8	194	4	2.1

annulus. In the scales of two other fish of this brood, the 1939 and 1940 annuli were entirely distinct, but so close together as to throw suspicion on their validity. None of these abnormalities was accompanied by serious scale erosion and none was found on the scales of 1940 and 1941 brood bass.

Most of the annulus abnormalities given above—false annuli, skipped annuli, overlapping annuli, and close spacing of annuli—were associated with the 1938 broods of bass and bluegills, and most of the abnormalities were laid down on the scales during the growing season of 1939.

During this period (1939), the 1938 brood bluegills were growing rapidly and the 1938 brood bass very slowly (see preceding section on growth). Later broods of bluegills were subjected to more competition for food (growth was less rapid) and later broods of bass were subjected to less food competition. Therefore, I am inclined to follow the theory that scale abnormalities as related to annulus formation are more common in fish growing at an abnormally rapid rate, or at an abnormally slow rate, than in those subjected to moderate food competition, resulting in "average" growth.

Some information on the way false annuli may arise on the scales of "wild" fish was gained through experiments in feeding fishes confined in aquariums. Bruno von Limbach (unpublished experiments at Urbana) attempted to feed individual bluegills (one fish to an aquarium) on a heavy diet of earthworms (8 to 10 per cent of body weight per day). These fish fed well and gained rapidly for a few weeks. Then for no apparent reason they went "off feed" and refused to eat their quota of worms. In some individuals, this condition persisted for several months, during which they continued to eat only enough to maintain their body weight. In others, heavy feeding was resumed after a "rest" of 1 or several weeks. In the latter fish, the periods of self-imposed starvation, followed by a resumption of feeding, produced false annuli on the scales. It cannot, of course, be proved that "wild" fish go "off feed" when food is abundant, but the possibility is worth considering.

In other experiments in which bluegills were forced to alternate between periods of feeding and starvation, clear false annuli were produced on the scales if the starvation period between two 4-week periods of feeding was 3 or more weeks in length. Lesser periods of starvation produced inconspicuous false rings. It is conceivable that, under conditions of crowding in natural or artificial waters, individual fish might go practically without food for as long as several weeks, later to be supplied with comparatively large quantities of food from a hatch of aquatic insects or a spawn of young fish.

Skipped annuli, partly double annuli, and close spacing of annuli are easily explained as resulting from degrees of starvation extending throughout an entire growing season.

Spawning and Young Fish

No nests of largemouth bass were observed in Fork Lake during the period covered by this report. At the time of the dam failure, after all the water had drained from the pond basin, several craters were noted that may have been made by nesting bass in the spring of 1942. The nests of bluegills could be observed at almost any time during any summer and were most numerous in shallow water along the north shore of the pond near the spillway and on a submerged dome of earth at the east end between the forks. Nest-guarding males were nearly always present in these areas, where the nests of 5 to 10 inches in diameter were only a few inches apart, but more males were counted at the onset of the spawning season in May or early June than at any other period. Nesting males were least numerous on the spawning grounds from mid-June until the latter part of July. Later, the number of nest-guarding males increased.

In 1939, young bluegills were scarce, although bluegill nests were in use throughout the summer. The 1938 brood bass (stocked as fry) were then 6 to 10 inches long and on a number of occasions were observed to enter bluegill nests and feed upon bluegill fry in the yolk sac stage. No young bass were observed in 1939.

On May 27, 1940, 15 bluegill nests were counted in the spillway spawning grounds, fig. 10, and several thousand fry were schooling near these nests. The bass fry stocked in 1938 became sexually mature in 1940 and, on June 3 of that year, 11 schools of fry were counted. Throughout the summer both young bluegills and young bass could be seen amidst the submerged vegetation.

The 1940 broods of bass and bluegills made poor growth in their first year, and many small bluegills were in evidence in the early spring of 1941. When nets were lifted on March 22, 1941, "showers" of small bluegills "rained" through the meshes and fell back into the pond. On April 15, 76 small bluegills were trapped, as a net was lifted, by a mat of *Spirogyra*. These fish averaged 1.48 inches long; the largest were 2.0 inches.

Nineteen bluegill nests containing eggs were seen on May 6, 1941, and, on May 20, five large schools of bass fry were counted, each containing several thousand fish. On July 19, schools of small fish—both bass and bluegills—were everywhere along the edge of the pond in the fine-leaved potamogeton. When nests were raised on September 24, small bluegills and bass dropped through the meshes; most of the bass were less than 3 inches long and the bluegills less than 2 inches. Their numbers seemed scarcely less than in July, although all rooted submerged vegetation had disappeared in early August.

Fig. 10.—A group of bluegill nests near the spillway of Fork Lake. These nests were exposed by low water levels during August, 1940.

In 1942, the spawning season was unusually late, due to a cold, wet spring, and neither young bass nor young bluegills were seen as late as May 26. The first schools of bass were observed on June 2;

on this date 17 bluegill nests were found to contain eggs, but no bluegill fry were then in evidence. Throughout June the young of both species were again very numerous.

Each year of the Fork Lake study, with the exception of 1938 and 1939 when no mature bass were present, large numbers of young bass and bluegills were to be found in the pond. A minnow seine haul along the shore any time after June would have taken large numbers of both species.

Swingle (1945) recommended minnow seining in ponds as a method of testing the "balance" of a bass-bluegill population. The presence of the young of both species in such seine hauls was said to indicate that the fish population of the pond was in "balance" and the pond should produce good fishing. While the adult bass and bluegills in Fork Lake produced a successful spawn each year (1940–1942), this spawn production bore little relationship to the annual fish yield, average sizes of adult fish in the pond, or the catch of fish per man-hour.

It indicated, however, that the adult population of fish was not crowded to the extent that reproduction in either species was curtailed.

Sexual Cycle

In the process of determining by dissection the sex of largemouth bass and bluegills from Fork Lake, it was noted that changes in the appearance of the ovaries and testes occurred that could be readily identified. In immature fish of both species, the sex was easily told, although the sex organs were often very small. In these fish, the ovaries were spindle shaped and granular, while the testes were almost threadlike. In late fall and early spring the gonads of the larger adult fish resembled those of the smaller immature fish, except that they were larger. As the spring advanced, the gonads of mature fish began to swell and change in shape and color, until in May these organs reached a maximum size, and soon after the reproductive products were ready for deposition. At this stage the ripe males would give off milt when gently pressed in the lower abdomen and females would pass eggs that were translucent, yellow, and sticky. After the spawning period, the ovaries and testes appeared smaller and flabby, and pink or red with blood. In the fall the gonads again would assume an immature appearance.

In order to identify these changes with time in both species, a brief description of the stages was formulated. The classification given below was published in a previous Fork Lake report (Bennett, Thompson, & Parr 1940):

Immature. Testes slender, translucent cords; ovaries small, translucent, and grayish pink.

Poorly developed. Testes slightly enlarged, opaque, and white; ovaries somewhat enlarged, opaque, pale yellow, and developing eggs with a granular appearance.

Enlarged. Testes greatly enlarged, flattened, with wavy edges, opaque, and white; ovaries greatly enlarged, oval with large, distinct, solid, opaque, yellow eggs.

Spawning condition. Testes as above, but giving off milt when gently pressed; ovaries as above, but turgid, giving off eggs when gently pressed. Eggs semiliquid, translucent, yellow, and sticky.

Partly spent. Testes (after May) same as next above but less swollen; ovaries smaller, but very similar to conditions described as enlarged.

Completely spent. Testes small and pinkish; ovaries flabby at first, contracted later, pinkish, with granular appearance.

The divisions of this classification, while intergrading from one to another, were distinct enough for practical use. However, it was unknown what these stages represented microscopically and whether the classification was valid on a histological basis.

In order to determine the validity of the above classification and to answer other questions associated with reproduction in Fork Lake bass and bluegills, a histological study was begun in 1940 by Dr. Marian F. James (1946). From March, 1940, until July, 1942, gonads of 742 bluegills and 218 bass were removed from Fork Lake fish (samples every month except December, January, and February) and turned over to Dr. James for study. Supplementary gonads from bass of known ages were obtained from Ridge Lake near Charleston in east-central Illinois and from Lake Glendale near Robbs in southern Illinois.

A histological study of these gonads shows a well-founded basis for the macroscopic classification in both bass and bluegills. None of the larger 1-year-old bass from Fork Lake or Lake Glendale was sexually mature, and, although a few of the larger male bass that were hatched in Ridge Lake in May, 1941, developed small numbers of sperms in May, 1942, none of the female bass produced mature eggs. Many of these yearling bass were more than 10 inches in length and weighed 0.5 to 0.6 pound.

The larger and medium-sized 1-year-old bluegills from Fork Lake produced mature eggs or sperms, but those less than 2 inches long collected during the spawning season contained only small oocytes, indicating that they were sexually immature.

The time schedule of the sexual cycle of bluegills in 1940 was essentially the same as in 1939. Gonads of about 90 per cent of the bluegills examined were "poorly developed" in the period March 14–25; some were classified thus as late as August 19–22. "Enlarged" gonads were collected from April 12 to July 23; the higher percentages were in April, May, and June. Gonads in "spawning condition" first appeared May 20 and were present in the August 19–22 collections but not later. "Partly spent" testes first appeared June 13–19, and "partly spent" ovaries, July 17–23; no partly spent ovaries or testes appeared after September. Four per cent of the testes were "completely spent" June 13–19; only 58 per cent of the testes and 80 per cent of the ovaries were completely spent September 17–24. Gonads of all bluegills collected during the latter part of October and early November were completely spent and were in advanced reorganization stages (spermatogonia and small oocytes). Each year during the reorganization period, which followed after the completion of spawning, the spermatogonial cells and oocytes that became the spermatozoa and eggs for the next season were differentiated.

The timing of the sexual cycle in bass was a little in advance of that of bluegills. In the March 14–20 collecting period, 100 per cent of the gonads of 2-year-old bass were in the "enlarged" stage. In the May 6–26 collections, 27 per cent of the testes were in "spawning condition," and 73 per cent were "partly spent," while 67 per cent of the ovaries were "enlarged," 25 per cent in "spawning condition," and 8 per cent "partly spent." No sexually mature bass were taken in June or July, but those taken in August or later contained reorganized gonads.

These studies indicate an intermittent spawning season for bluegills, in 1940 beginning the latter part of May and lasting through September. The bass spawning season was confined to May, beginning probably a little earlier than that of the bluegills. Field observers often recorded schools of young bass in Fork Lake by the time the bluegills were guarding eggs. In both species the males appeared to come into spawning condition a little before the females.

The histological study of James (1946) offers conclusive evidence that in Illinois bluegills mature at 1 year and bass at 2 years; some of the larger bass males produced a few sperms as yearlings. In the South, according to Swingle & Smith (1943), bluegills may reproduce at 4 months under unusually favorable conditions, but normally not until 1 year of age; bass commonly reproduce at 10 to 12 months unless stunted. These differences in the ages at which the two species reach sexual maturity in the North and in the South must be considered in stocking new ponds with bass and bluegill fry.

Foods

Stomachs for food analysis were collected from Fork Lake bass and bluegills during 1939, 1940, and 1941. In 1941, the collections of bluegill stomachs were discontinued after May, but those of bass were continued throughout that season. The numbers of fish stomachs containing food taken through the months of collecting during these years were as follows: bluegills, 671 in 1939, 504 in 1940, 108 in March, April, and May, 1941; bass, 299 in 1939, 175 in 1940, 121 in 1941. As the stomachs were removed from the fish, each stomach was given an accession number and preserved in alcohol. Corresponding accession numbers on the scale envelopes made it possible to relate the stomachs to fish of known ages, lengths, and weights. Methods of determining volume of stomach contents were those described in a previous Fork Lake report (Bennett, Thompson, & Parr 1940).

Although, in the years of this study the most pronounced change in the pond environment was caused by the gradual spread of *Potamogeton foliosus,* other less obvious changes may have affected the relative abundance of fish foods during the period of this study. No quantitative samples of aquatic invertebrates were made, and therefore changes in abundance of these animals were unrecorded except as indicated by field observations and stomach analyses.

Fluctuations in the numerical abundance in individual broods of bass and bluegills in Fork Lake probably affected the degree of food competition at various times during the 3½ years of study. The degree of competition for a "staple" food often determines whether an individual fish is able to select this in preference to some less satisfactory substitute. Two species of fish that compete but little for food in a favorable aquatic environment may, under crowded conditions, be forced to change their normal feeding habits and become highly competitive.

In 1938, after the pond was restocked with adult bluegills and bass fry, there was apparently little competition for food, as indicated by the growth of the stocked fish and the 1938 spawn of the bluegills.

It is likely that in March, April, and May of 1939 some of the smaller bluegills of the 1938 brood were still available for bass food, although bass stomachs collected in March did not contain any fish (Bennett, Thompson, & Parr 1940). Small bluegills were observed in the fall of 1938. Also, the increase from March to April, 1939, in the average lengths of 1938 brood bluegills collected, fig. 7, hardly can be explained as growth, because of low water temperatures at that period; rather this length increase in the collections suggests the elimination of the smaller individuals of the brood. In March, bass stomach contents consisted of 80 per cent water boatmen and back swimmers, 4 per cent aquatic beetle larvae, 15 per cent terrestrial insects, and 1 per cent insect fragments. In April, fish and crayfish made up a total of 37 per cent of the diet, Entomostraca—largely *Daphnia*—25 per cent, and water boatmen, back swimmers, aquatic beetle larvae, and insect fragments the remaining 38 per cent. In May, fish and crayfish constituted 18.2 per cent of the diet. Other items, in addition to a trace of snails and coarse aquatic plants, consisted of insects, of which more than 25 per cent were adults—mostly dragonflies, damselflies, and midges. The extensive use of insects during this period indicates a scarcity of fish and crayfish of sizes that could be handled by 6-inch bass.

During the spring period of 1939, the bluegills of the original stock and the 1938 brood fed heavily on Cladocera, midge larvae, and snails; other aquatic insects were somewhat less important in the diet. Competition between bass and bluegills for any single group of insects was not obvious, but bass made wide use of the varieties of insects available. The nest robbing activities of bass on the bluegill spawning ground, mentioned previously, indicate the extent of the shortage of bass foods. In the collections of July, 1939, very small bluegills made up 51.4 per cent of the bass diet, but the figure dropped to less than 30 per cent in August and September and less than 10 per cent in October. Both bass and bluegills depended upon aquatic insects (mostly larval) during the latter part of the 1939 collecting season—feeding most heavily on Diptera larvae and water boatmen.

In 1939 the competition for insects between these two species of fish had no appreciable effect upon the growth rate of either the original or 1938 brood bluegills, fig. 7. Cladocera and midge larvae were more or less staple foods for the smallmouthed bluegills, but apparently Cladocera and aquatic insects were not conducive to rapid growth in bass.

In 1940, when aquatic vegetation began to appear in Fork Lake in abundance, stomach collections taken from March through June were largely from bass and bluegills of the 1938 broods, table 9. In March and April, both species fed largely on midge larvae, and the quantity of fish and crayfish in bass stomachs was insignificant. In May only one bass stomach was obtained and it contained 95 per cent crayfish. Contents of the bluegill stomachs collected in May consisted of *Daphnia* (50 per cent of the total), insects, and a few miscellaneous items; Diptera larvae constituted nearly 21 per cent of the total.

Table 9.—Results of stomach analyses of bass and bluegills taken from Fork Lake in 1940. In the columns designating types of food, figures not in parentheses represent percentages of total weight of stomach contents; figures in parentheses represent frequencies of occurrence on the basis of 100 stomachs.

Month and Group of Fish	Number of Stomachs		Total Food, Grams	Diptera		Ephemerida		Trichoptera Larvae	Damselflies	
	Empty	With Food		Larvae	Adults	Nymphs	Adults		Nymphs	Adults
March										
1938 Bass	1	52	45.254	57.8 (100)	—	1.8 (27)	—	—	3.2 (40)	—
1938 Bluegills	0	10	8.500	95.8 (100)	—	0.2 (10)	—	—	1.4 (40)	—
April										
1938 Bass	3	40	35.370	71.9 (100)	0.4 (5)	—	—	—	1.4 (18)	—
1938 Bluegills	11	79	35.758	43.6 (89)	—	0.6 (6)	—	—	1.0 (8)	—
May										
1938 Bass	1	1	1.500	—	—	—	—	—	—	—
1938 Bluegills	2	83	27.658	20.8 (61)	—	1.3 (8)	—	0.3 (4)	—	—
June										
1938 Bass	0	11	11.432	—	—	—	—	0.5 (9)	19.1 (46)	—
1938 Bluegills	0	7	1.842	61.5 (71)	—	—	—	6.3 (43)	—	—
July										
1938 Bass	0	1	0.750	35.0 (100)	—	—	—	—	35.0 (100)	—
1938 Bluegills	0	5	2.015	16.6 (60)	—	—	—	2.5 (40)	—	—
1939 Bluegills	0	29	10.867	46.6 (83)	—	0.6 (7)	—	5.3 (41)	2.7 (24)	—
August										
1938 Bass	5	34	13.738	0.6 (6)	—	—	—	—	1.8 (6)	—
1938 Bluegills	1	7	3.330	30.2 (7)	—	1.8 (14)	—	1.5 (14)	2.3 (14)	—
1939 Bluegills	1	45	17.140	32.5 (76)	—	0.3 (4)	—	5.6 (36)	1.2 (13)	—
October										
1938 Bass	1	19	10.741	tr. (11)	—	—	—	—	0.5 (5)	—
1938 Bluegills	1	23	9.239	26.2 (74)	—	—	—	—	2.8 (13)	—
1939 Bluegills	9	110	35.849	25.6 (69)	—	1.0 (13)	—	1.2 (16)	7.5 (31)	—
November										
1938 Bass	2	9	8.716	—	—	—	—	—	3.9 (11)	—
1940 Bass	1	7	0.973	tr. (14)	—	—	—	—	16.4 (29)	—
1938 Bluegills	0	3	2.200	32.5 (100)	—	8.6 (67)	—	3.5 (67)	3.6 (33)	—
1939 Bluegills	2	90	28.319	45.3 (32)	—	4.5 (28)	—	2.6 (22)	9.2 (43)	—

Table 9 (continued)

Month and Group of Fish	Entomostraca			Mollusca		Coarse Aquatic Plants	Algae	Water Mites	Sand and Scales	Miscellaneous
	Daphnia	Cyclops	Cypris	Snails	Sphaeriids					
March										
1938 Bass	—	—	tr. (4)	—	—	tr. (2)	—	—	—	—
1938 Bluegills	2.5 (90)	—	—	—	—	—	—	—	—	—
April										
1938 Bass	tr. (5)	—	tr. (3)	—	—	—	—	—	—	—
1938 Bluegills	28.7 (75)	tr. (1)	tr. (3)	0.2 (3)	—	—	—	—	—	—
May										
1938 Bass	—	—	—	—	—	—	—	—	—	—
1938 Bluegills	50.0 (73)	—	—	2.2 (16)	—	1.5 (8)	tr. (1)	—	—	1.4 (16)
June										
1938 Bass	—	—	—	—	—	1.0 (18)	—	—	—	0.5 (18)
1938 Bluegills	—	—	—	3.1 (29)	—	1.3 (29)	1.0 (14)	—	—	2.7 (43)
July										
1938 Bass	—	—	—	—	—	—	—	—	—	—
1938 Bluegills	—	0.3 (40)	—	10.7 (20)	—	—	—	—	—	2.5 (40)
1939 Bluegills	—	1.4 (38)	—	4.3 (34)	—	0.4 (14)	1.8 (14)	tr. (3)	—	tr. (7)
August										
1938 Bass	—	tr. (3)	—	6.3 (24)	—	1.4 (12)	0.6 (3)	—	—	tr. (3)
1938 Bluegills	—	—	—	25.4 (86)	—	0.5 (14)	7.3 (29)	—	—	0.3 (14)
1939 Bluegills	—	2.6 (31)	—	9.2 (40)	—	8.3 (24)	3.2 (22)	—	—	6.5 (29)
October										
1938 Bass	2.6 (5)	0.5 (5)	—	0.9 (5)	—	—	2.6 (16)	—	—	tr. (5)
1938 Blugills	8.1 (30)	3.0 (17)	3.7 (30)	24.7 (65)	—	2.5 (22)	7.4 (43)	—	—	1.0 (30)
1939 Bluegills	17.5 (53)	5.3 (54)	0.9 (18)	8.5 (37)	—	2.0 (14)	9.4 (44)	—	—	0.5 (17)
November										
1938 Bass	—	—	—	—	—	—	0.7 (22)	—	—	—
1940 Bass	tr. (14)	—	—	—	—	—	—	—	—	—
1938 Bluegills	35.0 (100)	2.3 (33)	6.4 (33)	2.3 (33)	—	—	1.4 (33)	—	—	—
1939 Bluegills	28.1 (96)	2.4 (57)	2.4 (29)	0.9 (10)	—	—	2.0 (22)	—	—	tr. (2)

Table 9 (concluded)

Month and Group of Fish	Dragonflies		Water Boatmen	Water Striders	Aquatic Beetles		Terrestrial Insects and Worms	Insect Fragments	Fish	Crayfish
	Nymphs	Adults			Larvae	Adults				
March										
1938 Bass	33.0 (62)	—	2.8 (21)	—	—	—	0.5 (2)	—	—	0.9 (2)
1938 Bluegills	—	—	—	—	—	—	—	—	—	—
April										
1938 Bass	4.0 (13)	—	5.1 (28)	tr. (3)	—	0.5 (3)	2.5 (20)	7.9 (35)	3.7 (5)	2.5 (3)
1938 Bluegills	—	—	—	—	tr. (1)	tr. (1)	—	25.6 (53)	—	—
May										
1938 Bass	—	—	—	5.0 (100)	—	—	—	—	—	95.0 (100)
1938 Bluegills	—	—	tr. (4)	—	tr. (1)	—	tr. (1)	21.9 (45)	—	—
June										
1938 Bass	21.7 (36)	—	10.2 (18)	2.5 (64)	—	—	—	18.9 (27)	—	25.6 (36)
1938 Bluegills	—	—	—	—	—	—	—	24.2 (43)	—	—
July										
1938 Bass	—	—	—	—	—	—	—	30.0 (100)	—	—
1938 Bluegills	—	—	—	—	—	—	—	67.5 (80)	—	—
1939 Bluegills	0.4 (7)	—	—	0.2 (3)	12.6 (24)	—	—	23.7 (69)	—	—
August										
1938 Bass	3.5 (9)	—	—	1.2 (3)	—	—	—	6.7 (9)	73.5 (85)	3.9 (6)
1938 Bluegills	6.0 (14)	—	—	—	—	—	—	24.8 (71)	—	—
1939 Bluegills	2.0 (2)	—	tr. (2)	tr. (2)	3.2 (22)	—	0.4 (2)	24.7 (73)	—	—
October										
1938 Bass	6.8 (11)	—	tr. (5)	—	—	—	—	3.4 (11)	81.2 (90)	—
1938 Bluegills	4.3 (4)	—	—	tr. (4)	—	—	—	16.1 (57)	—	—
1939 Bluegills	1.2 (5)	—	tr. (5)	—	0.4 (5)	—	1.1 (8)	17.7 (45)	—	—
November										
1938 Bass	—	—	—	—	—	—	—	3.2 (11)	88.3 (100)	3.9 (11)
1940 Bass	—	—	—	—	—	—	—	14.3 (14)	69.0 (71)	—
1938 Bluegills	—	—	—	—	—	—	—	4.5 (33)	—	—
1939 Bluegills	tr. (1)	—	—	—	0.9 (10)	—	—	0.5 (3)	1.2 (1)	—

The large spawn of both bass and bluegills in late May and early June, 1940, probably improved the food situation for bass, although the heavy stand of aquatic vegetation offered excellent protection for young fish. The growth curve for 1938 brood bass indicates that most of the length increase occurred after June, fig. 6. In contrast to the spring diet of bass, which was largely insects, the late summer and fall diet consisted of more than 70 per cent fish, many of which were young bass. Other items of importance were crayfish, snails, and miscellaneous aquatic insect larvae. Diptera larvae were commonly found in the stomachs of bluegills of all sizes throughout 1940, and entomostracans were important from March through May and in October and November. Except that smaller numbers of *Corixa* and *Notonecta* were taken in 1940 than in 1939, bluegill foods were essentially the same in the 2 years. The 1939 brood bluegills grew less rapidly in 1940 than the 1938 brood when of comparable age (during 1939), fig. 7.

At the beginning of 1941, Fork Lake contained two broods of bass (1938 and 1940) and three broods of bluegills (1938, 1939, and 1940), as well as the few remaining original adult bluegills. No bass stomachs were taken in March, but, in April, 9 of the total of 15 original stock bass collected (1938 brood) contained fish and 7 contained crayfish, table 10. These two items together made up 54 per cent of the weight of all food taken. Other important items were Diptera larvae, dragonfly nymphs, and miscellaneous insect fragments. As indicated previously, growth of the broods of bass was slow until the plant die-off in August. In August and September, after the rooted plants disappeared, stomach contents of bass of all broods (1938, 1940, and 1941) showed a smaller variety of foods and a higher percentage of fish than in any other 2-month period, and growth was very rapid. It is of some interest to note here that in August and September a few of the small 1941 brood bass ate small leopard frogs and their metamorphosing tadpoles. Although bullfrog tadpoles were always numerous in Fork Lake, they were found rarely in bass stomachs.

In 1941, as in previous years, bluegills fed largely on Diptera larvae, damselfly nymphs, dragonfly nymphs, *Daphnia*, and snails.

Table 11 represents a summary of food items for all years shown as percentages of the total weights of all foods taken. Any figure of less than 4 per cent has been omitted. This table also lists the average lengths of the broods of bass and bluegills collected at the beginning and end of each collecting season, so that a comparison may be made between length increment and kind of food consumed.

Although Diptera larvae appeared to be very important in the diet of bluegills, as did Entomostraca and snails, no difference in growth of 1938 and 1939 brood bluegills can be shown to be associated with certain foods.

The importance of specific types of food in the diet of bass is obvious. In the 1938 brood bass, the only brood of this species present throughout all years of this study, there seemed to be a direct relationship between rate of growth and the percentage by weight of fish and crayfish in the diet. In 1939, collections of bass indicated that this brood increased 1 inch in length and made a relatively small weight increase; the percentages of fish and crayfish in the diet were 13.8 and 9.2, respectively, table 11. In 1940, the average length of 1938 brood bass in the collections increased from 7 to 10 inches and the weight more than doubled; the percentages of fish and crayfish in the diet were 21.2 and 13.0, respectively. In 1941, in spite of the fact that bass in the collections averaged 10 inches and about 0.5 pound in weight at the beginning of the collecting season, they increased an average of 3 inches in length and nearly tripled their weight in that year; the percentages of fish and crayfish in their diet were 34.5 and 34.4, respectively. In both the 1940 and the 1941 broods of bass, growth was rapid on a diet of fish, small frogs, and tadpoles.

The more common forms of Diptera larvae found in bass and bluegill stomachs were the Chironomidae (midges)—*Chironomus* and *Tanypus;* Chaoboridae—*Chaoborus;* Ceratopogonidae (biting midges)—*Palpomyia, Bezzia,* and *Probezzia;* Simuliidae (black flies)—*Simulium;* Stratiomyidae (soldier flies)—*Stratiomys, Odontomyia;* and Culicidae (mosquitoes)—*Culex.* No attempt was made to identify families or genera of Mayfly nymphs. The

Table 10.—Results of stomach analyses of bass and bluegills taken from Fork Lake in 1941. In the columns designating types of food, figures not in parentheses represent percentages of total weight of stomach contents; figures in parentheses represent frequencies of occurrence on the basis of 100 stomachs. Analyses of bluegill stomachs were discontinued after May.

Month and Group of Fish	Number of Stomachs		Total Food, Grams	Diptera		Ephemerida		Trichoptera Larvae	Damselflies	
	Empty	With Food		Larvae	Adults	Nymphs	Adults		Nymphs	Adults
March										
1938 Bluegills	1	7	4.557	76.8 (86)	—	—	—	—	9.5 (29)	—
1939 Bluegills	1	38	14.520	60.2 (89)	—	tr. (3)	—	—	3.1 (24)	—
April										
1938 Bass	2	15	18.206	11.4 (47)	—	2.1 (20)	—	—	0.8 (13)	—
1938 Bluegills	0	3	2.200	62.7 (100)	—	0.9 (33)	—	—	—	—
1939 Bluegills	5	21	7.093	24.0 (43)	—	—	—	—	15.7 (19)	—
May										
1938 Bass	3	19	20.493	1.2 (11)	—	tr. (5)	—	—	9.4 (16)	4.9 (11)
1938 Bluegills	1	2	0.071	4.2 (50)	—	—	—	—	—	—
1939 Bluegills	0	37	20.692	43.4 (54)	tr. (3)	—	—	0.8 (8)	0.6 (19)	tr. (5)
June										
1938 Bass	1	2	2.000	—	—	—	—	—	2.5 (50)	—
1940 Bass	0	1	1.200	—	—	—	—	—	—	—
July										
1940 Bass	1	4	1.835	1.3 (50)	—	—	—	—	0.5 (25)	—
1941 Bass	0	2	0.370	—	—	—	—	—	4.5 (50)	—
August										
1938 Bass	0	2	1.566	—	—	—	—	—	—	—
1940 Bass	3	6	6.500	—	—	—	—	—	—	—
1941 Bass	4	18	6.361	—	—	—	—	—	—	—
September										
1938 Bass	2	3	7.000	—	—	—	—	—	—	—
1940 Bass	0	3	4.250	—	—	—	—	—	—	—
1941 Bass	12	39	22.459	—	—	—	—	—	2.6 (3)	—
October										
1941 Bass	2	4	0.068	2.0 (25)	—	—	—	—	—	—
November										
1941 Bass	2	3	1.850	—	—	—	—	—	—	—

Table 10 (continued)

Month and Group of Fish	Dragonflies: Nymphs	Dragonflies: Adults	Water Boatmen	Water Striders	Aquatic Beetles: Larvae	Aquatic Beetles: Adults	Terrestrial Insects and Worms	Insect Fragments	Fish	Crayfish
March										
1938 Bluegills	—	—	0.6 (14)	—	—	—	—	—	—	—
1939 Bluegills	1.2 (8)	—	1.4 (13)	0.2 (3)	tr. (5)	tr. (3)	0.7 (3)	9.5 (39)	—	—
April										
1938 Bass	9.7 (20)	—	5.7 (27)	—	5.9 (7)	—	—	16.3 (53)	28.5 (60)	25.5 (47)
1938 Bluegills	0.9 (33)	—	—	—	—	—	—	—	—	—
1939 Bluegills	—	—	—	—	—	—	—	6.4 (10)	—	—
May										
1938 Bass	12.4 (21)	—	—	1.8 (11)	—	5.3 (5)	tr. (5)	5.9 (37)	25.9 (37)	17.0 (26)
1938 Bluegills	—	—	—	—	39.4 (100)	—	—	9.9 (50)	—	—
1939 Bluegills	0.4 (8)	—	tr. (5)	—	20.8 (76)	—	0.6 (22)	11.9 (41)	—	—
June										
1938 Bass	10.0 (50)	—	—	—	—	—	—	—	70.0 (100)	—
1940 Bass	—	—	—	—	—	—	—	—	100.0 (100)	—
July										
1940 Bass	—	—	—	—	tr. (25)	—	0.5 (25)	25.0 (25)	25.0 (25)	—
1941 Bass	—	—	—	—	—	—	—	10.0 (50)	45.0 (50)	—
August										
1938 Bass	—	—	—	—	—	—	—	50.0 (100)	50.0 (50)	—
1940 Bass	—	—	—	—	—	—	—	—	83.3 (83)	—
1941 Bass	—	—	—	—	—	—	—	13.9 (17)	56.1 (61)	—
September										
1938 Bass	—	—	—	—	—	—	—	—	100.0 (100)	—
1940 Bass	—	—	—	—	—	—	—	—	100.0 (100)	—
1941 Bass	—	—	—	—	—	—	—	26.7 (28)	57.9 (62)	—
October										
1941 Bass	—	—	—	—	—	25.0 (25)	—	25.0 (25)	—	—
November										
1941 Bass	—	—	—	—	—	—	25.0 (33)	8.3 (33)	65.0 (66)	—

Table 10 (concluded)

Month and Group of Fish	Entomostraca			Mollusca		Coarse Aquatic Plants	Algae	Water Mites	Sand and Scales	Miscellaneous
	Daphnia	Cyclops	Cypris	Snails	Sphaeriids					
March										
1938 Bluegills	tr. (14)	—	—	11.7 (43)	—	—	0.3 (29)	—	0.2 (14)	0.7 (14)
1939 Bluegills	13.3 (53)	—	—	9.3 (34)	—	—	0.5 (24)	—	tr. (5)	tr. (5)
April										
1938 Bass	—	—	—	—	—	—	0.9 (40)	—	—	—
1938 Bluegills	26.8 (66)	—	—	6.4 (66)	—	—	2.3 (33)	—	—	—
1939 Bluegills	46.5 (95)	—	—	3.2 (19)	—	—	2.6 (33)	—	tr. (5)	1.5 (10)
May										
1938 Bass	—	—	—	0.5 (5)	—	2.6 (5)	2.1 (11)	—	1.1 (5)	—
1938 Bluegills	—	—	—	—	—	—	46.5 (50)	—	—	—
1939 Bluegills	8.5 (49)	—	—	3.4 (46)	tr. (3)	tr. (3)	6.9 (57)	—	1.3 (19)	tr. (11)
June										
1938 Bass	—	—	—	—	—	—	—	—	17.5 (50)	—
1940 Bass	—	—	—	—	—	—	—	—	—	—
July										
1940 Bass	—	—	—	—	—	22.5 (50)	25.0 (50)	—	—	—
1941 Bass	—	—	—	—	—	—	—	—	—	—
August										
1938 Bass	—	—	—	—	—	—	—	—	—	—
1940 Bass	—	—	—	—	—	—	—	—	—	16.7 (17)
1941 Bass	—	—	—	—	—	2.2 (6)	—	—	5.6 (6)	27.8 (28)[1]
September										
1938 Bass	—	—	—	—	—	—	—	—	—	—
1940 Bass	—	—	—	—	—	—	—	—	—	—
1941 Bass	—	—	—	—	—	tr. (3)	—	—	—	12.6 (13)[1]
October										
1941 Bass	48.0 (50)	—	—	—	—	—	—	—	—	—
November										
1941 Bass	—	—	—	—	—	—	—	—	—	—

houses of caddis worms were largely those of *Oecetis inconspicua* (Walker), *Molanna, Oxyethira,* and *Orthotrichia.* The damselflies were largely of the genus *Enallagma.* Dragonfly nymphs were *Epicordulia* and others; aquatic Hemiptera were *Corixa* and *Notonecta.* Water striders were *Gerris.* The beetle larvae were Dytiscidae *(Dytiscus),* Hydrophilidae *(Enochrus* and *Berosus),* and Haliplidae *(Haliplus* and *Peltodytes).* Terrestrial invertebrates were ants, moths, a wasp, terrestrial beetles, leafhoppers, ichneumonid wasps, March flies, bees, chalcid wasps, house flies, June beetles, grasshoppers, earthworms, and spiders.

Fish were, of course, largemouth bass and bluegills; crayfish were *Cambarus virilis* and *C. propinquus.*

Entomostraca were *Daphnia* and *Ceriodaphnia, Cyclops* and *Diaptomus,* as well as *Cypris.* Mollusks were both *Physa* and planorbis type snails and *Musculium.* Coarse plants were *Potamogeton foliosus* and *Anacharis canadensis* (Michaux).

Water mites were not identifiable. Items of infrequent occurrence included leopard frogs, *Rana pipiens* Schreber, and tadpoles of both leopard frogs and bullfrogs, *R. catesbeiana,* hairworms *(Gordius),* seeds, a millepede, slugs, stoneflies, and grass.

Discussion

The investigation of Fork Lake was originally planned to study the effect of heavy cropping upon the combination of largemouth bass and bluegills in a small artificial lake or pond. The results obtained were influenced by the unexpected spread of *Potamogeton foliosus* in this pond, and a proposed final fish census was rendered impossible by a washout of the dam in 1942.

In 1938, at the time the pond was cleared of its old fish population and restocked with a known number of bass and bluegills, little careful experimental work had been done on fish stocking. The number of largemouth bass fry (1,440) placed in the pond proved to be too large; after making rapid growth in 1938, these fish practically stopped growing until their numbers had been considerably reduced by fishing. At the time of stocking it was believed that cannibalism among the young bass and predation by the adult bluegills would result in the survival of fewer of these fish.

The decision on the number of bluegills to stock was based on the assumption that the adult bluegills would spawn in 1938 and furnish bluegill fry and fingerlings for bass food. It was believed that the adults themselves would add enough flesh in that season to give a harvestable crop of about 100 pounds of large bluegills in 1939, and yet leave adequate available food for rapid growth in the surviving bluegill spawn. Therefore, it was decided that a stocking of 200 to 250 sexually mature bluegills should be adequate, and 240 were stocked.

The number of bluegills stocked was more nearly correct for Fork Lake than was the number of bass. The original bluegill stock increased in weight to 0.35 or 0.40 pound each by 1939 and produced a large spawn, a part of which survived and grew rapidly to good sizes. These 1938 brood bluegills furnished most of the bluegill yield during 1939 and 1940.

Since 1938, Smith & Swingle (1943) have furnished valuable information on the survival of bass and bluegill fry stocked in new ponds in the South. The intensive cropping of Fork Lake with small-mesh wing nets did not deplete the bass or seriously reduce the number of bluegills, in spite of the fact that these nets caught 5.0-inch bass and 3.5-inch bluegills and that practically all fish trapped in nets were removed from the pond. Some growth compensation must have resulted from cropping during 1939 in the 1938 brood bluegills, and during 1939 and 1940 in the 1938 brood bass. These bass probably would have remained at about 6 to 8 inches had their numbers not been reduced. The fact that this small pond contained at least 66 bass of the 1938 brood after 3½ years of intensive net fishing suggests that this type of gear is inefficient in catching this species, or perhaps that bass learn by observation to avoid wing nets. The total yield of bass would have been much lower had no attempt been made to crop them by angling. Sportsmen often assume that the nets of commercial fishermen are to blame for an apparent scarcity of bass. The Fork Lake experiment seems to indicate that this assumption is unfounded.

Table 11.—Percentages of total weight of all food items in the stomachs of bass and bluegills taken each year from Fork Lake, 1939, 1940, 1941. Percentages of less than 4.0 have been omitted.

Year and Group of Fish	Average Length, Inches		Diptera Larvae	Damselflies		Dragonflies		Water Boatmen
	Beginning	End		Nymphs	Adults	Nymphs	Adults	
1939								
1938 Bass	6.0	7.0	9.9	—	10.2	4.6	4.0	21.3
Original bluegills	7.5	7.7	33.9	—	—	—	—	8.3
1938 Bluegills	3.5	6.5	31.2	—	—	—	—	—
1940								
1938 Bass	7.0	10.0	34.0	—	—	19.8	—	—
1938 Bluegills	6.5	7.4	38.8	—	—	—	—	—
1939 Bluegills	4.7[1]	4.8	35.5	6.3	—	—	—	—
1940 Bass[2]	—	4.0	—	4.4	—	—	—	—
1941								
1938 Bass	10.0	13.0	—	—	—	11.9	—	—
1938 Bluegills[3]	7.6	7.8	71.7	6.3	—	—	—	—
1939 Bluegills[3]	4.8	6.3	45.9	—	4.0	—	—	—
1940 Bass	4.0	10.5	—	—	—	—	—	—
1941 Bass[2]	—	6.5	—	—	—	—	—	—

[1] June.
[2] Fall only.
[3] Spring months only.

Table 11 (concluded)

Year and Group of Fish	Aquatic Beetles		Insect Fragments	Fish	Crayfish	Cladocera	Snails	Coarse Aquatic Plants	Algae	Miscellaneous
	Larvae	Adults								
1939										
1938 Bass	—	—	12.3	13.8	9.2	—	—	—	—	—
Original bluegills	—	—	—	—	—	8.4	11.5	6.8	8.8	—
1938 Bluegills	—	—	7.1	—	—	29.7	9.2	—	—	—
1940										
1938 Bass	—	—	—	21.2	13.0	—	—	—	—	—
1938 Bluegills	—	—	21.5	—	—	28.5	4.5	—	—	—
1939 Bluegills	—	—	14.4	—	—	15.4	5.8	—	5.0	—
1940 Bass[1]	—	—	—	95.2	—	—	—	—	—	—
1941										
1938 Bass	—	4.1	4.0	34.5	34.4	—	—	—	—	—
1938 Bluegills[2]	—	—	—	—	—	8.7	9.9	—	—	—
1939 Bluegills[2]	10.2	—	10.2	—	—	16.5	5.4	—	4.0	—
1940 Bass	—	—	—	79.1	—	—	—	—	—	14.7[3]
1941 Bass[1]	—	—	5.5	75.3	—	—	—	—	—	17.1[3]

[1] Fall only.
[2] Spring months only.
[3] Frogs and tadpoles.

The yield of fish decreased during the period of cropping. Theoretically, as fish are continually being removed from a body of water, and the fertility of the water is maintained at a nearly constant level, those fish that remain will have more available food per individual, and, because fish growth follows no definite pattern correlated with age, this increase in food for each individual fish will allow rapid growth to continue throughout the life span of each individual, or until it in turn is captured and removed. In spite of heavy cropping of bluegills, growth rate of the bluegills escaping the nets did not improve; in fact, the growth rate of this species decreased with each successive year. The decrease can be explained, in my opinion, only on the basis that the total food supply of the omnivorous bluegills in Fork Lake was reduced so rapidly from year to year by the spread of potamogeton that constant cropping did not increase the per capita food supply.

The pond was thermally stratified throughout each summer with only a trace of oxygen below 4 feet (Bennett, Thompson, & Parr 1940) so that throughout much of the fish growing season only bottom forms such as *Chaoborus* were found in the deeper open waters of the pond. Such bottom organisms as were able to live among the roots of the aquatic plants may have been largely unavailable to larger fishes when the plant growths were rank. Very small fish were nearly always visible within the protective borders of the plant growths. These fish were relatively safe from the larger fishes that would use them for food, but their poor growth rate indicated that their food supply within the plant mats was limited. It may be assumed that the dissolved oxygen in the water among the rank plant growths fluctuated from supersaturation in the day time, when the plants were able to carry on photosynthesis, to absence of oxygen or very low oxygen tension in the period preceding dawn. If the assumption is true, the small fishes may have moved out to the edges of the vegetation, but zooplankton that required oxygen and had only weak powers of locomotion may have suffocated within the plant mats. Thus, the dense mats of vegetation may have acted as traps to many forms of the Entomostraca and caused reduction of these forms in the pond. Cladocera made up a large percentage of the stomach contents of bluegills in spring and fall, before the rooted vegetation had become dense and after it had died down. Maximum numbers of Entomostraca in large deep lakes are found usually in spring and fall, but according to Pennak (1946), the peak numbers of Entomostraca do not occur with any regularity in smaller lakes and ponds.

It must be considered that the rooted plants were competing with algae for the dissolved plant nutrients in the water. These nutrients were bound up within the bodies of the rooted plants during much of the growing season of fish and, as these plants were not a source of food for fish or many of the fish food organisms, they may have reduced the carrying capacity of the pond for fish.

The removal of a large poundage of fish from Fork Lake each year might be expected to reduce the productivity of the pond, if the water entering from the drainage basin were relatively sterile. However, the watershed of Fork Lake is good corn land, pasture, and timber.

The above are hypotheses that may explain in part the reduced yield of fish from Fork Lake and the absence of growth compensation in bluegills, despite heavy cropping.

The study of foods ingested by largemouth bass, table 11, demonstrates that fish and crayfish are essential for rapid growth in this important fish species.

During the die-off of vegetation and the "bloom" period in 1941, the bass made excellent growth because the vegetation-inhabiting small fish suddenly were made available for food at a time when the water was warm enough for rapid assimilation and growth. It must be assumed, because of lack of a similar increase in growth rate of bluegills, that the death of the plants released no comparable supply of food for bluegills and that no large source of invertebrate food developed as a result of the algal "bloom." Failure of the invertebrate population of Fork Lake to expand as a result of the algal "bloom" may have been due to the specific kind of algae that developed, or it may have been that the season or physical conditions in the pond were not right for an eruption of Entomostraca or a sizable increase of insect larvae.

Summary

1. The fish in Fork Lake, a pond of 1.38 acres near Mount Zion, Illinois, were poisoned and the pond restocked with 1,440 largemouth bass fry and 240 adult bluegills in June, 1938.

2. Beginning in March, 1939, the fish were cropped with 1-inch-mesh wing nets and with hook and line: nets were fished, March through November, in 1939, 1940, 1941, and, March through June, in 1942; with few exceptions, fish caught were removed from the pond. The yield was 223.0 pounds in 1939, 200.0 pounds in 1940, 130.0 pounds in 1941, and 60.5 pounds in 1942 (4 months). During the years in which cropping continued through November, the bass yield remained at about 50 to 60 pounds.

3. On July 8, 1942, the dam was washed out by a 4-inch rain. The part of the fish population trapped in a net across the break and in the pond basin amounted to 169 pounds of bass and 92 pounds of bluegills or a total of 261 pounds. Sixty-six of the original bass stocked in the pond as fry in 1938 were taken in the washout.

4. The most noticeable change in the pond habitat during the years of cropping was an increase in the abundance of fine-leaved pondweed, *Potamogeton foliosus*. In 1939, plants of this species reduced the area of open water to 1.25 acres, in 1940 to 0.95 acre, and in 1941 to 0.64 acre. The progressive annual decrease in fish yield seemed to show a positive relationship to the progressive decrease in the area of open water.

5. Bass growth was slow in 1939 and in the March–June period of 1940 and 1941, fig. 6. Some improvement occurred in the July–October period of 1940 after both bass and bluegill young were available for food. In August, 1941, a sudden die-off of *Potamogeton foliosus* occurred and was followed by a "bloom" of algae, *Aphanizomenon flos-aquae*. With the disappearance of the protective mats of potamogeton, the small fish became available for food, and the bass began to grow at a very rapid rate. Despite intensive cropping, each successive brood of bluegills spawned in the pond grew less rapidly than the preceding brood; bluegills showed no improvement in growth rate as a result of the plant die-off of August, 1941.

6. Improvement in condition (relative plumpness) of bass paralleled periods of rapid growth; in bluegills a regular yearly cycle of condition was shown by all broods, with a high condition in spring and a low in November. No improvement in condition of bluegills followed the plant die-off of 1941.

7. Scales of the 1938 broods of both bass and bluegills showed abnormalities such as false annuli, skipped annuli, and close spacing of annuli; nearly all of these abnormalities appeared during the growing season of 1939. Scales of later broods presented almost no false rings or unusual spacing of annuli. It is believed that the abnormalities of 1939 were associated with very rapid growth in the bluegills and with very slow growth in the bass.

8. Broods of young bluegills were produced in the pond each year. The bass fry stocked in 1938 first became sexually mature in 1940 and large broods of bass were produced in that year and the years following.

9. A histological study of the sexual cycle of bass and bluegills made by Dr. Marian F. James (1946) indicated a short spawning season for bass (May) and a longer season for bluegills (May through September). Bluegills became sexually mature at an age of 12 months unless badly stunted; although several of the larger male bass produced a few sperms at 1 year, no females produced mature eggs until 2 years of age.

10. Stomach analyses of Fork Lake bass and bluegills indicated that, when fish and crayfish were scarce, bass competed with the bluegills for insects and Entomostraca and made poor growth. The rate of growth in bass was apparently correlated with the percentages of fish and crayfish in the diet. Bluegills of all sizes fed largely on Diptera larvae, Entomostraca, and snails; no correlation was found between growth rate and the ingestion of certain kinds of food in bluegills.

11. Bluegills in Fork Lake grew at a decreasing rate throughout the years of cropping, and the yearly yield in pounds of these fish was progressively smaller each year. Together, these phenomena indicate a diminishing supply of food in the pond for these fish. If the food supply had remained constant in total volume from year to year, the removal each year of a large

crop of bluegills from 3.5 to 9.0 inches in length would have increased the food supply for those fish remaining and resulted in an accelerated growth rate. The mats of aquatic vegetation probably greatly reduced the production of invertebrate fish foods in the pond shallows and thereby more than nullified the effect of cropping.

LITERATURE CITED

Bennett, George W., David H. Thompson, and Sam A. Parr
1940. Lake Management Reports. 4. A second year of fisheries investigations at Fork Lake, 1939. Ill. Nat. Hist. Surv. Biol. Notes 14. 24 pp., 10 figs., 4 pls.

Brown, C. J. D., and Robert C. Ball
1943. An experiment in the use of derris root (rotenone) on the fish and fish-food organisms of Third Sister Lake. Am. Fish. Soc. Trans. 72(1942):267-84. 1 fig.

Cooper, Gerald P.
1937. Food habits, rate of growth and cannibalism of young largemouth bass *(Aplites salmoides)* in state-operated rearing ponds in Michigan during 1935. Am. Fish. Soc. Trans. 66(1936):242-66. 4 figs.

James, Marian F.
1946. Histology of gonadal changes in the bluegill, *Lepomis macrochirus* Rafinesque, and the largemouth bass, *Huro salmoides* (Lacépède). Jour. Morph. 79(1):63-92. 2 figs., 2 pls.

Pennak, Robert W.
1946. The dynamics of fresh-water plankton populations. Ecol. Mono. 16:339-56. 7 figs.

Smith, E. V., and H. S. Swingle
1943. Percentages of survival of bluegills *(Lepomis macrochirus)* and largemouth black bass *(Huro salmoides)* when planted in new ponds. Am. Fish. Soc. Trans. 72(1942):63-7.

Smith, M. W.
1940. Copper sulphate and rotenone as fish poisons. Am. Fish. Soc. Trans. 69(1939):141-57.

Swingle, H. S.
1945. Improvement of fishing in old ponds. N. Am. Wildlife Conf. Trans. 10(1945):299-308.

Swingle, H. S., and E. V. Smith
1943. Factors affecting the reproduction of bluegill bream and largemouth black bass in ponds. Ala. Poly. Inst. Ag. Exp. Sta. Circ. 87. 8 pp.

Thompson, David H., and George W. Bennett
1939*a*. Lake management reports. 2. Fork Lake near Mount Zion, Illinois. Ill. Nat. Hist. Surv. Biol. Notes 9. 14 pp., 4 figs., 1 map.

Thompson, David H., and George W. Bennett
1939*b*. Lake management reports. 3. Lincoln Lakes near Lincoln, Illinois. Ill. Nat. Hist. Surv. Biol. Notes 11. 24 pp., 8 figs.

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