ILLINOIS NATURAL HISTORY SURVEY
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EXPERIMENTS carried on in the United States during the past 30 years have shown that the total weight of fish in a pond, that is, the standing crop, may be increased two to six times through the use of fertilizers (Davis & Wiebe 1931; Smith & Swingle 1939; Smith & Moyle 1945; Surber 1945, 1948*b*; Swingle 1947; Ball 1949; Ball & Tait 1952).

These experiments have quite naturally led to the speculation that fertilization is a means of improving hook-and-line fishing. While the practice of fertilizing ponds has been widely recommended to pond owners, few attempts have been made to measure the effect of fertilization on angling results. In published studies of angling in ponds (King 1943; Swingle 1945; Smith 1952, 1954) results have been inconclusive with respect to the effect of fertilization on catch of fish per hour.

Studies of the effects of fertilization on aquatic plant life, on animals eaten by fish, and on fish crops have been reviewed by Neess (1949), Maciolek (1954), and Mortimer & Hickling (1954).

The objective of the pond fertilization experiment reported in this paper was to measure the effect of certain fertilization practices on sport fishing for largemouth bass, *Micropterus salmoides* (Lacépède), and bluegills, *Lepomis macrochirus* Rafinesque, in small ponds located in a region of relatively unproductive soils. From catch records gathered over a 6-year period, 1947–1952, from three fertilized ponds and three unfertilized or control ponds, we have been able to compare the sizes of the fish caught, the annual hook-and-line yields, and the catch rates in terms of fish per fisherman-hour. The six ponds used in the experiment are located at the University of Illinois College of Agriculture Dixon Springs Experiment Station in Pope County, southern Illinois.

The methods of stocking and fertilizing were, in part, variations of those first proposed by Swingle & Smith (1941:224–5, 1942:12–3, 16–8). Recommendations of Swingle & Smith for minimum fertilization were followed closely during the last 2 years of the 6-year study.

A census of the fish population of each of the ponds was made in the fall of 1953. In the census operations all fish in the ponds were killed with rotenone so that we were able to compare standing crops of fishes in the ponds that had been treated with fertilizer for an extended period (7 years) with the standing crops in the ponds that had not been treated with fertilizer. In addition, we were able to compare the standing crop of fishes in each pond with the hook-and-line fish yields and catch rates recorded during the last 3 years of angling.

Published data on angling success in ponds stocked with only largemouth bass and bluegills are scarce. The present study demonstrates the value of this popular combination of fishes, as well as the effect of fertilization, in southern Illinois ponds.

ACKNOWLEDGMENTS

Information on soils and soil treatments at the Dixon Springs Experiment Station was furnished by C. A. Van Doren of the United States Soil Conservation Service and by the following persons from the University of Illinois College of Agriculture: W. G. Kammlade, Leah M. Dunn, George E. McKibben, and Leland E. Gard. The following persons, all with the College of Agriculture, were consulted on general questions pertaining to soils and soil fertility: A. L. Lang,

*Robert J. Webb is Superintendent and John M. Lewis is Assistant Superintendent of the University of Illinois College of Agriculture Dixon Springs Experiment Station.

Lawrence B. Miller, Roger H. Bray, Russell T. Odell, Herman L. Wascher, J. B. Fehrenbacher, and the late Robert F. Fuelleman. H. W. Norton, Professor of Agricultural Statistical Design and Analysis, Animal Science Department, has examined the data and has verified certain conclusions reached in this study.

Water samples from the experimental ponds were analyzed by T. E. Larson of the Illinois Water Survey. Fishing boats were provided by the Illinois Department of Conservation through the courtesy of Sam A. Parr, formerly Superintendent of the Division of Fisheries, now Administrative Assistant. Help with fertilizing the ponds or with the rotenone census was given by R. Weldon Larimore, William N. Nuess, Robert Crompton, and the late Dan Avery, employed by the Illinois Natural History Survey, and by Ray Brown, Guy Bellamy, Leonard Durham, and Oliver Dick, employed by the Department of Conservation.

Charles Stubbs in 1947, Maurice G. Kellogg in 1948, 1949, and 1950, Stacy Gebhards in 1951, and Charles R. Peters in 1952 served as test anglers. The photograph for the frontispiece and the aerial photographs were made by Charles Scott, formerly employed by the Illinois Natural History Survey and now picture editor of the Milwaukee *Journal*. The other photograph was taken by George W. Bennett. The manuscript was read by William C. Starrett and edited by James S. Ayars and Mrs. Diana R. Braverman, all of the Illinois Natural History Survey staff.

EXPERIMENTAL PONDS AND THEIR WATERSHEDS

The ponds selected for use in this experiment—Lauderdale, Hooker, Phelps, Wells, Boaz, and Elam, figs. 1–6—are stock-watering ponds built at the Dixon Springs Experiment Station in the period 1935–1940. All have earthen dams. All are fenced and, during the years of the experiment, cattle seldom had access to them. They are all within a 2-mile radius of the Experiment Station headquarters.

In September, 1951, at a time when these ponds were full of water, they ranged in surface area from 0.92 to 1.55 acres, and from 8.5 to 15.0 feet in maximum depth, table 1. Since the only source of water for the ponds was surface runoff, there was always a reduction in water area and in depth during dry weather of late summer. Presumably these water level reductions varied in the six ponds in accordance with relative size of drainage areas, number of domestic animals using the water, shape of the pond basins, and rates of runoff, evaporation, and underground seepage. In the fall of 1953, after one of the driest summers on record, the reduction in surface area of the various ponds ranged from 13 per cent in one pond to 49 per cent in another, table 1. There was little difference between the late summer levels of 1953 and those of 1952, another dry year. We have estimated from general observations that late summer water levels in 1952 and 1953 were 1 to 2 feet lower than those of most other years represented in this study. Although in 1953 Wells Pond showed the greatest reduction in surface area, in most years Phelps Pond showed the greatest reduction.

The test anglers made weekly measurements of surface water temperatures through the summers of 1947 and 1948. Temperatures above 90 degrees F. were rarely encountered in the series of weekly readings. The maximum surface temperature reading at any of the ponds was 94 degrees, observed at Boaz Pond, first on July 29 and again on August 5, 1947, and at Phelps Pond on July 12, 1948.

Temperature measurements made at 2-foot depth intervals on August 12, 13, and 14, 1947, table 2, showed marked thermal stratification in five of the six ponds.

Chemical analyses of water from the ponds, table 3, were made from samples collected March 19, 1947, before the fertilization experiment was begun. The watersheds of all of these ponds had been fertilized prior to the time the water analyses were made, but Lauderdale Pond was the only one that had received direct fertilization. Before the experiment reported here was planned, this pond had been treated on two occasions in an attempt to improve fishing: on August 17, 1945, with 80 pounds of ammonium sulfate, 32 pounds of 63 per cent superphos-

Fig. 1.—Aerial view of Lauderdale Pond, 0.9 acre, October, 1950. The fields on two sides of the pond had been plowed and reseeded a few weeks before the picture was made.

Fig. 2.—Aerial view of Hooker Pond, 1.33 acres, October, 1950.

Table 1.—Depth and area of each of the six Dixon Springs ponds used in fertilization study, as observed at full stage in September, 1951, and at the time of the rotenone census, September, 1953. The levels observed in 1953 were probably as low as or lower than any levels that occurred during the fishing period.

Pond	Full Stage, September, 1951		Lowest Observed Drought Stage, September, 1953		Reduction in Area, Per Cent
	Depth in Feet	Area in Acres	Depth in Feet	Area in Acres	
Fertilized					
Lauderdale	11.5	0.92	9.8	0.76	17
Hooker	14.0	1.33	10.6	1.03	23
Phelps	8.5	1.04	4.5	0.70	33
Unfertilized					
Wells	15.0	0.97	12.0	0.49	49
Boaz	10.5	1.01	6.8	0.66	35
Elam	9.0	1.55	6.8	1.35	13

phate, and 25 pounds of ground limestone; and on September 8, 1945, with 80 pounds of ammonium sulfate, 100 pounds of 20 per cent superphosphate, and 25 pounds of ground limestone.

An unusual characteristic of the Dixon Springs ponds was their relatively low total hardness; according to T. E. Larson, Illinois Water Survey, these waters are among the softest surface waters in Illinois.

Under the crop rotation systems followed by University of Illinois agronomists at the Dixon Springs Experiment Station, the fields surrounding the ponds were kept in pasture most of the time. New rotations were begun on the watershed of each of these ponds within the period of the study: Phelps in 1948, Hooker in 1949, Wells and Lauderdale in 1950, Boaz (east half) in 1949, Boaz (west half) in 1951, and Elam in 1952. In each pasture reseeding, winter wheat or rye was planted with various grasses in the fall of the year, while legumes were broadcast the following spring. Corn was planted in the spring prior to the fall seeding on the Boaz west field in 1951 and on the Elam watershed in 1952.

Until dense pasture growth was reestablished, silt from the fields was washed into the ponds after each hard rain. Silting occurred even though grass buffer strips surrounded the ponds.

The Dixon Springs Experiment Station lies in an unglaciated region where the

Table 2.—Water temperature (in degrees F.) measured at 2-foot intervals and on bottom in the six Dixon Springs ponds, August 12–14, 1947.

Depth in Feet	Lauderdale (Depth 8 Feet)* August 12	Hooker (Depth 10 Feet)* August 12	Phelps (Depth 5 Feet)* August 13	Wells (Depth 10 Feet)* August 12	Boaz (Depth 8½ Feet)* August 13	Elam (Depth 6 Feet)* August 14
Surface	89.2	85.8	86.4	87.1	86.0	83.1
2	84.6	83.1	83.1	85.6	82.0	83.1
4	83.1	82.8	81.7	84.9	72.7	84.2†
6	77.7	80.6	....	75.6	66.9	82.4
8	72.0	72.7	....	72.7	64.8	....
Bottom	72.0	68.0	78.4	68.7	64.4	82.4

*Depth of water at point of temperature readings, not necessarily the greatest depth in the pond at the time. The bottom reading is for this depth. Examples: The bottom reading for Lauderdale is for a depth of 8 feet; the bottom reading for Hooker is for a depth of 10 feet.

†This figure probably represents an error in recording.

Fig. 3.—Aerial view of Phelps Pond, 1.04 acres, October, 1950. Exposed mud flats resulting from loss of water may be seen around the margin of the pond.

Fig. 4.—Aerial view of Wells Pond, 0.97 acre, October, 1950. The cypress trees in the water and the pines in the fenced area surrounding the pond had been planted.

Table 3.—Mineral composition (parts per million) of water collected from the six Dixon Springs ponds on March 19, 1947, prior to fertilization.

Mineral	Lauderdale*	Hooker*	Phelps*	Wells	Boaz	Elam
Iron—filtered	0.3	0.3	0.6	0.3	1.7	0.7
Iron—unfiltered	0.6	0.4	1.1	0.5	2.8	1.0
Phosphate†	0.2	0.2	0.2	0.3	0.8	0.6
Calcium	8.1	6.0	8.8	6.6	7.0	7.6
Magnesium	1.3	0.2	0.4	0.0	0.0	0.0
Sodium and potassium	1.8	4.6	0.0	0.9	4.4	3.4
Sulfate	11.7	10.5	8.2	7.0	12.3	10.1
Nitrate‡	1.0	0.4	0.5	0.5	2.0	0.8
Chloride	1.0	5.0	2.0	2.0	3.0	3.0
Methyl orange alkalinity	16.0	8.0	12.4	8.0	9.0	12.0
Total hardness	26.0	16.0	24.0	16.0	18.0	19.0

*Pond selected for fertilization.
†As orthophosphate PO_4 (includes organic phosphorus).
‡Includes N in the form of ammonia and nitrate but not in the form of nitrite or as organic nitrogen.

terrain is a mixture of gently rolling land and steep hills. Numerous sandstone outcrops are present. The region was completely forested at the time of settlement, and considerable woodland still exists. During the many decades in which the cleared land was used extensively for growing corn and wheat, most of the slopes suffered from erosion. With the recent trend toward permanent pastures or crop rotations that include pasture, the rate of erosion on slopes has been greatly retarded.

The level of productivity of a fish pond and its capacity for providing good fishing are generally assumed to be determined to a great extent by the level of plant nutrients in the soils of the pond bottom and of the watershed. In common with soils over most of Pope County, those at the Experiment Station have low natural fertility. Recent tests of soils in Pope and Hardin counties showed 96 per cent of the samples deficient in available phosphorus (Thor & Jacob 1955). The soils on the watersheds of the ponds used in the pond fertilization study belong to two soil types. Grantsburg silt loam covers the hilltops and lesser slopes, and Manitou silt loam covers the steeper slopes (Fehrenbacher 1959).

These soil types, which are closely related, are described by Fehrenbacher (1959) as grayish yellow or brownish

Table 4.—Available phosphorus and potassium (as pounds per acre in the upper 6 2/3 inches of soil) and the pH of soils of the fields draining into four of the six Dixon Springs ponds. The ratings, such as "high," are based on a system used by the University of Illinois Soil Testing Laboratory.

Name of Pond Watershed	Most Recent Year of Soil Treatment Preceding Soil Test*	Date of Soil Sample	Pounds Per Acre		pH
			Available Phosphorus	Available Potassium	
Phelps	1948	January 6, 1957	66 (Medium to high)	187 (High)	6.3
Wells	1952	February 10, 1956	84 (High)	110 (Slight)	6.2
Boaz†	1936	August 14, 1951	10 (Very low)	265 (Very high)	6.0
Elam	1952‡	August 8, 1952	12 (Very low)	95 (Slight)	5.9

*Kinds and amounts of fertilizer materials used are shown in table 5.
†The soil test was made on the west half of the Boaz watershed.
‡Spring.

Fig. 5.—Aerial view of Boaz Pond, 1.01 acres, October, 1950.

Fig. 6.—Aerial view of Elam Pond, 1.55 acres, October, 1950.

gray silt loams, which, if untreated, are strongly acid, low to very low in available phosphorus, low to medium in available potassium, and low in organic matter. University of Illinois agronomists have found that in order to farm these soils at a profit it is generally necessary to treat them with crushed limestone and with either rock phosphate or superphosphate. They have also found that it may be profitable to use complete fertilizers on seed beds and as top dressing on poorly growing pastures.

Soil tests were available for the fields draining into four of the six experimental ponds, table 4; tests were not available for the other two fields. The fact that the soil tests on these fields show only slight acidity and that some of them show high amounts of available phosphorus and potassium is explained by the soil treatments made in connection with field crop studies. Table 5 is a record of all soil treatments applied in the period 1935–1953 to the fields draining into the six ponds. Prior to the soil tests recorded in table 4, all of

Table 5.—Soil treatment dates and materials (in pounds per acre) applied to the fields draining into the six Dixon Springs ponds. The east and west halves of Hooker and Boaz watersheds were treated separately. The manner of treatment, where known, is indicated by a letter.* The watershed area indicated for each pond includes pasture but not woodland.

Watershed Name and Area	Date of Soil Treatment	Limestone	Rock Phosphate	Superphosphate 20 Per Cent	Superphosphate 32–36 Per Cent	Superphosphate 45–48 Per Cent	Ammonium Nitrate 33 Per Cent	Muriate of Potash 60 Per Cent	Complete Fertilizer 2-12-6	Complete Fertilizer 4-16-16	Complete Fertilizer 5-20-20	Complete Fertilizer 8-8-8	Barnyard Manure
Lauderdale,	1937	8,000T			200								
5 acres	1950 (fall)‡	6,000M	1,000M	100 D							180		
	1952 (spring)						100T			100T			
	1952 (fall)						100T			100T			
	1953 (spring)					150T		150T					
Hooker,	1935	8,000T											
east half,	1949 (fall)‡	8,000M	1,000M										
9–10 acres	1953 (spring)									200T			
Hooker,†	1946–1948†	?†							200 D				
west half,	1949 (spring)			?†					?†				
9–10 acres	1951 (fall)								200 D				
Phelps,	1937	8,000T											
5 acres	1948 (fall)‡	8,000M	600M										
Wells,	1937 (fall)	7,000T			200								
3–5 acres	1950 (fall)‡	8,000M	1,000M								350 D		
	1952 (fall)									200T			
Boaz, east	1936	8,000T											
half, 4–5	1949 (fall)‡	8,000M	1,000M										
acres	1953 (spring)					130T		43T					
Boaz, west	1936	8,000T											
half, 4–5	1951 (spring)**	4,000M	1,000M										
acres	1951 (fall)**	8,000M	1,000M			100 D					100 D		
	1953 (spring)									200 T			
Elam,	1936	8,000T			200								
6–7 acres	1952 (spring)‡	6,000M	1,000M									200	8,000
	1952 (fall)									200 D			

*The letter following quantity signifies manner of application, where known: T = top dressing; M = mixed with upper 4 to 6 inches of soil; D = drilled with seed 1 or 2 inches below soil surface.

†The west half of the Hooker watershed is privately owned; the record of fertilization was based on the owner's memory. The soil had probably been treated with limestone, according to the owner, at some time within the period 1946–1948. Treatment with fertilizer was made in the spring of 1949 and consisted of 100 pounds per acre of either superphosphate or 2-12-6 applied with a seed drill.

‡At time of reseeding of field.

**Limestone and rock phosphate applied to part of west half of Boaz in spring and to remainder of west half in fall.

the pond watersheds had been treated with crushed limestone to reduce acidity; three watersheds, Phelps, Wells, and Elam, had been treated with phosphate. The west half of Boaz had not been treated with phosphate at the time of the soil test. The phosphate treatment on the Elam watershed was made a few months before the soil test, but the phosphate had not yet become well mixed with the soil. The Wells and Elam watersheds had been treated with potassium through applications of complete fertilizer a few months before the soil tests.

EXPERIMENTAL PROCEDURES

Each of the six Dixon Springs ponds used in the fertilization study was stocked at the beginning of the experiment with known numbers of bass and bluegills. Chemical fertilizers were added to three of the ponds, Lauderdale, Hooker, and Phelps. The other three, Wells, Elam, and Boaz, were maintained as controls. Records were kept of the stocking rates, the times and rates of fertilization, the numbers of hours of fishing, and the numbers and weights of fish caught in each of the ponds.

Fish populations that were in the six ponds previous to the beginning of the experiment had been eliminated by rotenone treatment 2 to 6 months before the experimental stocking was done: Lauderdale (fertilized) and Wells (control) in May, 1946; Hooker (fertilized), Phelps (fertilized), Boaz (control), and Elam (control) in September of the same year.

Stocking the Ponds

The rates at which the Dixon Springs ponds were stocked with bass and bluegills were close approximations of the rates suggested by Swingle & Smith (1942:13) for ponds in Alabama; these authors recommended 100 bass and 1,500 bluegill fingerlings per acre in ponds that were to be fertilized, 30 bass and 400 bluegill fingerlings per acre in ponds that were not to be fertilized. The actual numbers of fish used in the Dixon Springs ponds and the per-acre rates, based on area of the ponds at full stage, are given in table 6. On the basis of reduced late summer water areas of these ponds, the stocking rates were of course higher than those shown.

The ponds were stocked between October 30 and November 9, 1946. The largemouth bass used for stocking were 6 to 10 inches long (total length) and bluegills were all about 1 inch long. All fish used in stocking had been collected from nearby Lake Glendale during the draining of the lake in October, 1946. Other bass of 9 to 10 inches obtained from Lake Glendale during the draining operation were found, when aged by scale examination, to be in their third, fourth, fifth, or possibly sixth years. The 9- to 10-inch bass in their fifth or sixth years were considered somewhat stunted. It is assumed that the 1-inch bluegills and 6-

Table 6.—Number of largemouth bass and bluegills, and number of fish per acre, released in the six Dixon Springs ponds October 30–November 9, 1946. The bass measured 6.0 to 10.0 inches, the bluegills 1.0 inch, at the time of release.

Pond (With Surface Areas in Acres)	Largemouth Bass		Bluegills	
	Total Number	Number Per Acre	Total Number	Number Per Acre
Fertilized				
Lauderdale (0.92)	100	109	1,500	1,630
Hooker (1.33)	118	89	1,500	1,127
Phelps (1.04)	95	91	1,300	1,250
Unfertilized				
Wells (0.97)	35	36	400	412
Boaz (1.01)	30	30	400	396
Elam (1.55)	33	21	480	310

Table 7.—Fertilization record of Lauderdale, Hooker, and Phelps ponds, showing dates of application, number of treatments per year, and per-acre rates of application of chemical fertilizers and ground limestone.

Year	Period of Treatment	Lauderdale (0.92 Acre)			Hooker (1.33 Acres)			Phelps (1.04 Acres)		
		Number of Treatments	Pounds Per Acre at Each Treatment		Number of Treatments	Pounds Per Acre at Each Treatment		Number of Treatments	Pounds Per Acre at Each Treatment	
			Chemical Fertilizer*	Limestone		Chemical Fertilizer*	Limestone		Chemical Fertilizer*	Limestone
1947. . .	May 26–Sept. 13†	4	100 (9.0-13.6-2.8)	17	4	100 (7.2-10.8-2.3)	14	4	100 (6.9-10.3-2.2)	13
1948. . .	May 10–July 30	4	100 (9.0-13.6-2.8)	17	4	100 (7.2-10.8-2.3)	14	4	100 (6.9-10.3-2.2)	13
1949. . .	May 13–Sept. 14	4	100 (9.0-13.6-2.8)	17	4	100 (7.2-10.8-2.3)	14	4	100 (6.9-10.3-2.2)	13
1950. . .	April 11–Aug. 11‡	9	100 (9.1-9.0-4.5)	0	6	100 (7.2-7.2-3.6)	0	5	100 (6.9-6.9-3.5)	0
1951. . .	April 18–Aug. 16	8	100 (9.1-9.0-4.5)	0	8	100 (7.2-7.2-3.6)	0	8	100 (6.9-6.9-3.5)	0
1952. . .	April 17–Aug. 8	8	100 (9.1-9.0-4.5)	0	8	100 (7.2-7.2-3.6)	0	8	100 (6.9-6.9-3.5)	0
1953. . .	May 13–July 23	8	100 (7.6-7.8-3.8)	0	8	100 (7.8-7.9-3.8)	0	8	100 (7.7-7.8-3.8)	0

*Weight of fertilizer including fillers. In parentheses: the N-P-K formula or pounds of nitrogen as N, phosphorus as P_2O_5, and potassium as K_2O in 100 pounds of material applied. Nitrogen was supplied by ammonium sulfate (1947–1949) or ammonium nitrate (1950–1953). Phosphorus and potassium were supplied by superphosphate and muriate of potash.

†Last treatment dates in 1947: Lauderdale, July 25; Hooker, September 13; Phelps, July 19.

‡Last treatment dates in 1950: Lauderdale and Hooker, August 11; Phelps, July 14.

inch bass were hatched in 1946. Green sunfish that later were caught occasionally in two of the ponds, Phelps and Boaz, may have been placed there accidentally with the 1-inch bluegills. The sizes of the fish used were the sizes most readily available from Lake Glendale. Whereas Swingle & Smith (1942:13) suggested the use of fingerling bass and bluegills where both species were to be used in stocking in the fall of the year, we departed from their recommendation by using small adult bass as well as bass fingerlings.

Each of the largemouth bass placed in the ponds was marked by removal of a pectoral fin clipped close to the body; the bluegills were not marked.

Fertilizing the Ponds

Chemical fertilizers, which contained nitrogen, phosphorus, and potassium (N-P-K), were applied to Lauderdale, Hooker, and Phelps each year, 1947–1953; no fertilizer was used in Wells, Boaz, or Elam.

Numbers of treatments, periods of treatments in different years, and N-P-K formulas are given in table 7. In terms of the number of treatments given and total quantity of nitrogen, phosphorus, and potassium introduced during any single year, fertilization was lighter during the first 3 years than during the last 4, except that in 1950 the quantity of phosphorus applied to Phelps was slightly less than was applied in any of the previous 3 years. As recommended by Swingle & Smith (1942:16), crushed limestone was used in addition to the nitrogen, phosphorus, and potassium fertilizers when ammonium sulfate was used to supply nitrogen (1947–1949). It was intended that the three ponds to be fertilized should be dosed at the same rates. Dosages applied were computed from areas obtained from the best maps available in 1947. When the ponds were mapped by plane table in 1951, the maps that had been used were found to contain errors. These errors account for the different amounts of N-P-K applied to the three ponds in the years previous to 1953, table 7.

The methods of treating the three fertilized ponds in the Dixon Springs experiment were similar to those described by Swingle & Smith (1942:16–8). These authors recommended a formula for the amount of fertilizer to be used at each application but allowed for considerable flexibility in the number of applications to be given within a year. The N-P-K formula used in the ponds at Dixon Springs in 1947–1949 was similar to, but was heavier in phosphorus than, the one described by Swingle & Smith. The dosage rate used at Dixon Springs in 1950–1953 was a still closer approximation of the Swingle & Smith rate. The Swingle & Smith technique of dosing ponds as often as necessary to maintain blooms of plankton algae was followed only in 1950. Numbers of applications in other years (four per year in the period 1947–1949 and eight per year in the period 1951–1953) were selected arbitrarily. The Swingle & Smith recommendation that fertilization be delayed in the spring until danger of overflow is past, usually April or May in Alabama, could not easily be followed at Dixon Springs, where rains heavy enough to cause overflow of the ponds often occur as late as June or July.

Dosages were based on pond areas at full stage and were not reduced when pond areas shrank in midsummer. No attempt was made to replace fertilizer losses which may have occurred through overflow of water.

The chemical compounds used as sources of nitrogen, phosphorus, and potassium were ammonium sulfate (or nitrate), superphosphate, and muriate of potash. These compounds were weighed separately as needed, then mixed, and broadcast into the shallow water along the shore of each of the three ponds selected for fertilization; most of the fertilizer fell where the water was 2 to 4 feet deep. Distribution of fertilizer was always made around the entire pond.

When the ponds were treated only four times a year (1947–1949) the individual treatments were usually spaced 2 to 4 weeks apart. Treatments were postponed if blooms of algae were so dense as to obscure the Secchi disc at a depth of 24 inches or less.

They were postponed in 1947, also, during the period of decay of aquatic plants (mainly *Chara* spp.) that had been killed by earlier treatments. When the ponds were treated eight times a year (1951–1953) many of the treatments were given at 1-week intervals, without regard to the density of the blooms, or to the transparency of the water, as measured by the depth at which a Secchi disc was visible. There was no indication that these closely spaced treatments had any adverse effect upon the fish populations; dead fish were not reported in any of the ponds.

Collecting Fishing Data

Creel data were obtained through controlled public fishing and through test fishing by Illinois Natural History Survey employees. Since two of the ponds—Lauderdale and Wells—were fished almost exclusively by the test anglers and since certain data presented here from all six ponds were gathered entirely by the test anglers, it is appropriate to describe test fishing routines in some detail.

At least one test angler fished each pond once a week from early June to early September, or about 12 times a summer. Occasionally one of the test anglers was joined by another fisherman, usually a fellow staff member. The test angler fished one fertilized pond and one control pond on each fishing day; Lauderdale was paired with Wells, Hooker with Boaz, and Phelps with Elam. Each pond was fished alternately in the morning of one week and the afternoon of the following week. The senior author of this paper, as well as the regular test angler, fished the six ponds throughout the summers of 1948 and 1949. In the other years of the experiment the test fishing was done principally by one man.

Ordinarily a test angler fished the ponds for 2 hours on each visit, spending about 1 hour fishing with fly rod and/or casting rod with artificial baits and 1 hour fishing with fly rod and natural baits, usually worms.

All captured fish were placed on stringers until the end of the 2-hour fishing period; then each fish was measured and weighed. Bass measuring 10.0 inches (total length) or longer and bluegills measuring 6.0 inches (total length) or longer were kept; the others were returned to the pond. Considerable mortality occurred in hot weather, notably among small fish.

The fish caught by the test anglers were measured to the nearest tenth of an inch and they were weighed to the nearest 4-gram interval on a John Chatillon & Sons 1,000-gram spring scale. The weights were later converted to pounds.

Public fishing was allowed in four of the ponds, Hooker, Phelps, Boaz, and Elam, under a special permit system. A grocery in Glendale and the Lake Glendale bathhouse were used as permit stations. Fishermen were allowed to fish in Lauderdale and Wells if they accompanied the test anglers on regularly scheduled trips; few permit fishermen took advantage of this arrangement. Lauderdale and Wells were excluded as regular permit ponds in order to be assured of an equal or nearly equal amount of fishing time on one fertilized pond and one control pond. Under the now widely used permit system, each fisherman selected the pond where he wished to fish and was issued a 1-day permit for that pond in exchange for his state fishing license. At the end of his period of angling the fisherman submitted his fish for counting and weighing and recovered his state fishing license. Information recorded for each permit fishing period included time spent, types of baits used (plugs, flies, worms), and, for each species of fish, weight of the fish kept and an estimate of the number thrown back. The fish caught by the permit fishermen were not measured or weighed individually.

One boat was kept on each pond for use by test anglers and permit fishermen. Fishermen supplied their own oars or sculling paddles. The use of minnows for bait was prohibited in order to guard against contamination of the ponds with unwanted species. Earthworms or catalpa worms were by far the most popular baits used by permit fishermen; plugs were next in popularity.

Throughout the experiment, anglers were limited by state law to 10 bass a day; they were also limited to 50 bluegills a day until that limit was removed on July 1, 1951. These creel limits were seldom approached by either the test anglers or the permit fishermen. A 10-inch legal size limit on bass was in force throughout the state until July 1, 1951. People fishing on the six Dixon Springs ponds were asked to continue observing the 10-inch limit until termination of the experiment. The ponds were open to fishing each day from 6 A.M. to 9 P.M., May 15 through the first Monday in September.

The permit fishermen were not informed as to which ponds were treated with fertilizer, nor were they often reminded that a test of pond fertilization was in progress.

Although fishing regulations were posted at each pond there were some violations, including poaching.

Censusing the Fish Populations

In order to determine the standing crops of fish (numbers and weights) in the Dixon Springs ponds, we killed the fish with rotenone and censused the populations in the period September 8–17, 1953.

Cube powder (5 per cent rotenone content) was applied to the ponds at the rate of 3 pounds of powder per acre-foot of water. Fish were collected, counted, and weighed on the day the rotenone was introduced and on each of the succeeding three days. Because insignificant numbers of fish were found on the fourth day after treatment, no counts were made on that day or later.

POND FERTILIZATION AND PLANT LIFE

The use of chemical fertilizers in the Dixon Springs ponds resulted in increased abundance of plankton algae in each of the treated ponds and in periodic heavy growths of filamentous algae, particularly in one pond. The fertilization program was detrimental to the growth of rooted aquatics.

Blooms of plankton algae, similar to those described by Swingle & Smith (1942), appeared in the fertilized ponds each year. The blooms occurred after two to four applications of fertilizer. The number of treatments required to produce these blooms varied with the pond and the year. Blooms were much heavier in some years than others. They were light at Lauderdale, for example, in 1950 and 1951. The effect of blooms on water transparency may be seen in table 8. Light blooms were sometimes observed in the control ponds but these blooms seldom lasted for more than 1 week at a time.

Once the blooms were established in the fertilized ponds they lasted as long as 2 to 8 weeks without further additions of fertilizer. When a bloom began to disappear, an additional application of fertilizer usually resulted in an increase in its density within 1 or 2 days. Ball & Tanner (1951: 9) found that in North Twin Lake, Michigan, an increase in plankton followed each application of fertilizer.

In the Dixon Springs ponds, surface growths of filamentous algae—probably stimulated by the pond treatments—were a hindrance to fishing in some years, but perhaps did not seriously affect fish yields or catch rates. Such growths were present in all three fertilized ponds in the summer of 1947, the first year in which fertilizer was used, and were especially heavy at Lauderdale Pond in the summers of 1948, 1950, and 1951. At various times during these 3 years filamentous algae covered 25 to 75 per cent of the surface of Lauderdale Pond, fig. 7. Anglers sometimes had to clear away algae before fishing their favorite spots. However, Lauderdale produced by far the best fishing in spite of this growth of filamentous algae. Surface growths were sometimes observed on the control ponds, but they covered only small areas and were present for only very short periods. The floating algae on Lauderdale was identified as *Rhizoclonium* sp.

Heavy growths of filamentous algae in chemically fertilized ponds have been re-

Table 8.—Average depths (in inches) at which a Secchi disc was visible below the surface of each of the six Dixon Springs ponds (weekly observations averaged by months), monthly averages for fertilized and for unfertilized ponds, and differences between monthly averages. The lower transparency of the fertilized ponds generally resulted from blooms of plankton algae.

Year and Month	Fertilized				Unfertilized				Difference Between Averages	
	Lauderdale	Hooker	Phelps	Average	Wells	Boaz	Elam	Average	Fertilized Clearer	Unfertilized Clearer
1947										
June*	56	......	......	*56*	36	......	......	*36*	....	....
July	51	33	51	*45*	41	11	62	*38*	7	....
August	15	17	15	*16*	36	6†	63	*35*	....	19
1948										
June	17	26	25	*23*	31	16	30	*26*	....	3
July	17	21	22	*20*	37	20	31	*29*	....	9
August	20	16	18	*18*	25	21	29	*25*	....	7
1949										
June	30	21	23	*25*	37	33	30	*33*	....	8
July	14	20	19	*18*	39	35	33	*36*	....	18
August	22	19	12	*18*	39	35	36	*37*	....	19
1950										
June	39	13	16	*22*	28	28	33	*30*	....	8
July	34	12	11	*19*	29	39	36	*35*	....	16
August	58‡	15	12	*28*	30	36	38	*35*	....	7
1951										
June	14	39	14	*22*	26	23	38	*29*	....	7
July	35	33	20	*29*	50	35	42	*42*	....	13
August	43	27	13	*28*	20	48	56	*41*	....	13
1952										
June	12	13	9	*11*	31	44	39	*38*	....	27
July	14	12	12	*13*	14	40	22	*25*	....	12
August	11	19	9	*13*	16	39	20	*25*	....	12

*Readings were begun late in the month. A single reading at Hooker was recorded as "very clear." A single reading at Elam was recorded as 38 inches; no readings were made at Phelps or Boaz during June.

†The low readings at Boaz in 1947 were the result of nearly continuous muddiness, for which no cause could be found.

‡The reading was 108 inches at Lauderdale Pond on August 27, 1950. This was the highest reading made at any time in any of the six ponds.

Fig. 7.—Lauderdale Pond, August, 1950, with surface partially covered with a growth of filamentous algae, after the pond had been fertilized.

ported by Patriarche & Ball (1949:29) in southern Michigan, by Surber (1945: 388) in West Virginia, by Zeller (1953: 286) in Missouri, and by Smith & Swingle (1942) in Alabama.

Bottom-inhabiting filamentous algae (unidentified) were sometimes present in both fertilized and unfertilized ponds at Dixon Springs, but usually for only brief periods. However, such algae were found to be a nuisance to fishermen at Lauderdale throughout the summer of 1952.

Dense stands of *Chara* in the three fertilized ponds died in 1947, after three fertilizer applications; for as long as fertilizer was used (from the spring of 1947 through the summer of 1953) this plant remained extremely scarce. *Chara* nearly covered the bottoms of the three control ponds throughout the study. An increase in abundance of *Chara* was seen in Lauderdale, Hooker, and Phelps during 1954 and 1955, the first years after 1947 in which no fertilizer was used; however, in 1956 *Chara* had still not regained its prefertilization abundance.

The disappearance of submerged weeds in ponds treated with chemical fertilizers was observed by Swingle & Smith (1942). These authors recommended winter fertilization to destroy undesirable submerged aquatic plants and periodic fertilization to prevent their re-establishment. Surber (1948*a*) reported that a variety of rooted aquatic plants had been killed after use of a chemical fertilizer at Deer Lake, New Jersey. Ball & Tanner (1951: 11) found that chemical fertilizer all but destroyed *Chara* and *Potamogeton* in North Twin Lake, Michigan, but that each returned to its former abundance the year following termination of fertilization of the lake.

POND FERTILIZATION AND FISHING SUCCESS

The pond fertilization program at Dixon Springs can be evaluated by comparing the three fertilized ponds, Lauderdale, Hooker, and Phelps, with the three control or unfertilized ponds, Wells,

Table 9.—Numbers of largemouth bass, in various length classes, caught by Illinois Natural History Survey test anglers in three fertilized ponds at Dixon Springs. Bass of less than 10 inches in length were returned to the water. Numerals in boldface type represent bass (marked by fin removal) used in stocking the ponds.

LENGTH CLASS, INCHES*	LAUDERDALE						HOOKER						PHELPS					
	1947	1948	1949	1950	1951	1952	1947	1948	1949	1950	1951	1952	1947	1948	1949	1950	1951	1952
4.5.....								1										
5.0.....		1						2										1
5.5.....		1		3				2	1					1	1			
6.0.....		1	3			2				3	1				1			1
6.5.....	1		2	7		3			2	1		4			1			1
7.0.....			2	9		1		2	7	2		7		3	2			1
7.5.....		1	4	3					15	4	2		**1**		2	2		2
8.0.....	1		2	2	1	1	**2**		14	2	4	3	**3**		1			
8.5.....	1 **1**	2	2			1	**5**	1	11	4	4	2	**6**	2	6	1		1
9.0.....	**5**	5	1		5		**7**	3	2	9	9		**8**		18	1		3
9.5.....	**10**	1	2		7	1	**4**	2	3	6	8	1	**6**	**4**	2 **2**	1	2	
10.0.....	**15**	1	5	8	4		**3**	1	2	8	7		**4**	**9**	3 **2**	1	1	
10.5.....	**5**		1	9	2	8	**2**	**2**	2	1	8			**7**		1		1
11.0.....	**20**		3	3	2	5	**1**	**3**	1		6				**2**			
11.5.....	**5**	**6**	2	5	1	6		**3**			2						1 **1**	
12.0.....	**3**	**3**	1 **1**	3		4	**1**									1	2	1
12.5.....	**2**	**1**	**1**			1												1
13.0.....			**1**	1	1	3											1	1
13.5.....				1	1													
14.0.....					1						1							
14.5.....				1														
15.0.....																		
15.5.....						1												
16.0.....				**1**														
16.5.....			**1**															
17.0.....				**1**	**1**													
17.5.....						1												
18.0.....																		
18.5.....																		
19.0.....																		
19.5.....																		
20.0.....																		
20.5.....						**1**												
Total.....	*69*	*23*	*34*	*57*	*26*	*39*	*25*	*22*	*60*	*40*	*52*	*17*	*28*	*26*	*43*	*8*	*8*	*14*
Number in 10-inch class or larger..	50	11	16	33	13	30	7	9	5	9	24	0	4	16	7	3	6	4
Average length of fish, 10-inch class or larger..	10.8	11.7	11.4	11.4	11.7	12.0	10.6	10.9	10.4	10.1	10.6	....	10.0	10.2	10.3	10.8	11.7	12.0
Per cent in 10-inch class or larger..	72	48	47	58	50	77	28	41	8	23	46	0	14	61	16	38	75	29

*Each number designating inches represents the mid-point in a length class; for example, the number 4.5 includes the bass of 4.3–4.7 inches total length.

Table 10.—Numbers of largemouth bass, in various length classes, caught by Illinois Natural History Survey test anglers in three unfertilized ponds at Dixon Springs. Bass of less than 10 inches in length were returned to the water. Numerals in boldface type represent bass (marked by fin removal) used in stocking the ponds.

Length Class, Inches*	Wells						Boaz						Elam					
	1947	1948	1949	1950	1951	1952	1947	1948	1949	1950	1951	1952	1947	1948	1949	1950	1951	1952
5.0		1												1	2			
5.5						1								6	3			
6.0		3		1							1			7	2	1	1	1
6.5		5	4			1		2	4					4	1	5		2
7.0		5	2					3	1		1			4	8	6	1	1
7.5		5		1	1			1	3	1	1			8	9	5		1
8.0		3	3	1		3		2	7	4	1				15	1	4	2
8.5		5	6		1				7	4	2			3	7	3	2	1
9.0		4	4	1			**1**		4	4		1		3	8	3	5	
9.5		8	10	4	1				2	9	3	3		2	7	8	3	1
10.0	**3**	1	3	2	1	2	**2**	1	1	3	2	3	**1**	1	3	7	6	
10.5	**3**	1	3	6	4	2	**4**		1	2	2	1		1	1	4	6	1
11.0	**3**	1	4		1					4		1	**5**	2		6	6	1
11.5	**1**		1	1	1	3	**2**				1		**2**					4
12.0	**3**	**1**	2	2	4	2				2		2			3		2	4
12.5	**2**	**1**	1		2	3					1					1		1
13.0		**3**			2	1				1	1	1						1
13.5		**2**			1	1		**1**				1						
14.0						2		**1**										
14.5						1		**1**										
15.0		**1**	**1**											**1**	**1**			
15.5				1														
16.0															**1**			
16.5																		
17.0																		
17.5																		
18.0																		
18.5																		
19.0																		
19.5																		
20.0																		
20.5																		
Total	*15*	*50*	*44*	*20*	*19*	*22*	*9*	*12*	*30*	*34*	*16*	*13*	*8*	*43*	*71*	*50*	*36*	*21*
Number in 10-inch class or larger	15	11	15	12	16	17	8	4	2	12	7	9	8	5	9	18	20	12
Average length of fish, 10-inch class or larger	11.1	12.4	11.2	11.2	11.7	12.1	10.6	13.0	10.3	11.0	11.2	11.3	11.0	11.5	11.9	10.6	10.7	11.8
Per cent in 10-inch class or larger	100	22	34	60	84	77	89	33	7	35	44	69	100	12	13	36	56	57

*Each number designating inches represents the mid-point in a length class; for example, the number 5.0 includes the bass of 4.8–5.2 inches total length.

Boaz, and Elam, with respect to the sizes of fish caught, the annual fish yields, and the catches per fisherman-hour.

Sizes of Fish Caught

Length distributions of all bass and all bluegills caught by the test anglers are shown for the six ponds in tables 9, 10, 12, and 13; these tabulations include the bass under 10 inches and the bluegills under 6 inches that were put back in the ponds after measurement. The average weights of fish caught and kept by test anglers and permit fishermen are shown in tables 11 and 14; lengths of fish caught by permit fishermen were not recorded.

Few of the bass caught by test anglers measured more than 13 inches; the only

Table 11.—Average weights (in pounds) of individual largemouth bass harvested by hook and line from each of the Dixon Springs ponds in each of 6 years. Data from which the figures were derived are in table 20.

POND	1947	1948	1949	1950	1951	1952	AVERAGE
FERTILIZED							
Lauderdale	0.60	0.71	0.57	0.68	0.83	0.70	0.68
Hooker	0.63*	0.72	0.63	0.60	0.63	0.53	0.62
Phelps	0.50*	0.43	0.50*	0.53	0.71	0.75	0.57
Average	....	....	....	....	....	....	*0.62*
UNFERTILIZED							
Wells	0.73	0.92	0.63	0.71	0.68	0.92	0.77
Boaz	0.67*	1.13	0.57	0.58	0.64	0.83	0.74
Elam	0.63*	0.64	0.91	0.64	0.72	0.74	0.71
Average	....	....	....	....	....	....	*0.74*

*Average based on fewer than 10 specimens, as shown in table 20.

Table 12.—Numbers of bluegills, in various length classes, caught by Illinois Natural History Survey test anglers in three fertilized ponds at Dixon Springs. Bluegills of less than 6 inches in length were returned to the water.

LENGTH CLASS, INCHES*	LAUDERDALE					HOOKER					PHELPS				
	1948	1949	1950	1951	1952	1948	1949	1950	1951	1952	1948	1949	1950	1951	1952
3.0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
3.5	....	1	....	....	1	....	....	....	....	....	....	....	2	....	....
4.0	1	....	2	....	....	....	1	1	....	....	1	....	4	....	6
4.5	1	3	6	2	3	....	....	4	1	....	4	1	4	1	5
5.0	4	1	13	1	....	2	3	3	1	3	3	....	3	....	5
5.5	6	1	27	9	4	....	6	7	2	2	1	4	4	2	9
6.0	19	9	40	5	6	1	2	7	4	2	2	9	3	10	16
6.5	60	17	27	16	19	7	3	10	22	1	2	15	2	21	8
7.0	20	25	17	30	43	19	5	8	27	1	20	11	4	12	8
7.5	1	16	33	37	40	3	9	1	4	....	4	24	4	4	7
8.0	....	1	14	22	22	....	8	3	2	....	....	1	5	4	9
8.5	....	....	1	11	5	....	....	3	....	....	....	....	....	1	3
Total	*112*	*74*	*180*	*133*	*143*	*32*	*37*	*47*	*63*	*9*	*37*	*65*	*35*	*55*	*76*
Number in 6-inch class or larger	100	68	132	121	135	30	27	32	59	4	28	60	18	52	51
Average length of fish, 6-inch class or larger	6.5	6.9	6.8	7.4	7.3	6.9	7.3	6.9	6.8	6.4	7.0	6.9	7.2	6.8	6.9
Per cent in 6-inch class or larger	89	92	73	91	94	94	73	68	94	44	76	92	51	94	67

*Each number designating inches represents the mid-point in a length class; for example, the number 4.0 includes the bluegills of 3.8–4.2 inches total length.

ones over 16 inches were caught in a fertilized pond, Lauderdale. The bass of 10 inches or longer taken by the test anglers from fertilized ponds, table 9, were smaller on an average than those from the control ponds, table 10; those from the three fertilized ponds averaged 11.5, 10.5, and 10.8 inches; those from the three control ponds averaged 11.6, 11.2, and 11.3 inches. The individual bass harvested by test anglers and permit fishermen from the control ponds had a higher average weight than those from the fertilized ponds, table 11.

The number of captures of marked bass, those with which the ponds had been stocked in 1946, are indicated in tables 9 and 10. Few marked bass were caught after the second season of fishing. The marked bass grew faster in some ponds

Table 13.—Numbers of bluegills, in various length classes, caught by Illinois Natural History Survey test anglers in three unfertilized ponds at Dixon Springs. Bluegills of less than 6 inches in length were returned to the water.

Length Class, Inches*	Wells					Boaz					Elam				
	1948	1949	1950	1951	1952	1948	1949	1950	1951	1952	1948	1949	1950	1951	1952
3.0	....	....	....	2	1	....	....	....	1	....	....	1	....	....	....
3.5	....	5	1	2	1	1	1	....	....	....	....	1	2	1	3
4.0	2	5	4	5	1	3	1	1	4	....	1	23	6	5	4
4.5	8	16	6	8	3	12	....	6	4	1	3	22	7	10	4
5.0	....	12	37	11	3	16	6	17	2	1	9	9	14	16	2
5.5	1	11	23	11	7	4	9	8	11	3	12	8	22	35	1
6.0	5	5	13	13	15	2	25	9	24	2	7	4	24	31	8
6.5	16	5	13	11	7	6	10	8	28	6	13	9	14	51	49
7.0	7	19	18	17	8	6	4	3	36	5	12	15	12	16	45
7.5	....	8	4	18	13	2	2	1	4	....	1	3	1	2	1
8.0	....	....	....	5	8	....	1	....	1	1	....	....	1	1	....
8.5	....	....	....	....	4	....	....	....	....	....	....	....	....	....	....
Total	*39*	*86*	*119*	*103*	*71*	*52*	*59*	*53*	*115*	*19*	*58*	*95*	*103*	*168*	*117*
Number in 6-inch class or larger	28	37	48	64	55	16	42	21	93	14	33	31	52	101	103
Average length of fish, 6-inch class or larger	6.5	6.9	6.6	6.9	7.0	6.8	6.3	6.4	6.6	6.7	6.6	6.8	6.4	6.5	6.7
Per cent in 6-inch class or larger	72	43	40	62	77	31	71	40	81	74	·57	33	50	60	88

*Each number designating inches represents the mid-point in a length class; for example, the number 4.0 includes the bluegills of 3.8–4.2 inches total length.

Table 14.—Average weights (in pounds) of individual bluegills harvested by hook and line from each of the Dixon Springs ponds in each of 5 years. Data from which the figures were derived are in table 20.

Pond	1948	1949	1950	1951	1952	Average
Fertilized						
Lauderdale	0.21	0.25	0.26	0.32	0.28	0.26
Hooker	0.24	0.28	0.31	0.27	0.27	0.27
Phelps	0.25	0.28	0.32	0.31	0.31	0.29
Average	....	....	....	....	....	*0.27*
Unfertilized						
Wells	0.23	0.21	0.21	0.24	0.28	0.24
Boaz	0.22	0.20	0.20	0.19	0.26	0.21
Elam	0.22	0.17	0.30	0.20	0.20	0.22
Average	....	....	....	....	....	*0.22*

than in others. The rate of stocking of the fertilized ponds, which was three times that of the control ponds, may have resulted in at least a temporary state of overcrowding and a consequent retardation in growth of the bass placed in two of the fertilized ponds, Phelps and Hooker. Size distributions of bass caught by test fishermen in 1947 and 1948 indicated no overcrowding in Lauderdale or in any of the controls.

While the size distributions of bluegills caught from fertilized and control ponds were similar, the fertilized ponds yielded bluegills of larger average size, and more bluegills of extra large size (8–8½ inches), than the control ponds, tables 12 and 13. The individual bluegills kept by the test anglers and permit fishermen, 1948–1952, averaged at least one-fourth pound every year at Phelps and in 4 out of 5 years at Lauderdale and Hooker, table 14. In each of the control ponds, Wells, Boaz, and Elam, the individual bluegills averaged one-fourth pound or heavier in only 1 out of 5 years. For all years combined, bluegills harvested from the fertilized ponds averaged 0.27 pound per fish, those from the controls 0.22 pound.

The three largest bluegill specimens caught by the test anglers came from the fertilized ponds; their lengths and weights were 8.6 inches and 0.51 pound, 8.7 inches and 0.53 pound, 8.7 inches and 0.55 pound. However, these were not the largest bluegills caught in the fertilized ponds. On June 3, 1951, a permit fisherman on Phelps Pond caught 12 bluegills that averaged 0.63 pound per fish.

Annual Hook-and-Line Yields

The recorded hook-and-line yields from the ponds in this experiment are probably not the maximum yields of which the ponds were capable. More fishing might have been done, and more fish might have been removed, if the ponds had been open to year-round fishing, and if there had not been many other places to fish in the neighborhood—other farm ponds, Lake Glendale, and large and small streams. Some fishermen may have avoided the experimental ponds because they preferred fishing where permission to fish and reporting of catches were not required. The true hook-and-line yields were somewhat higher than the recorded yields because the records did not include the fish taken by poachers.

Fishing effort in man-hours per acre and yield in terms of the number and weight of bass and bluegills harvested per acre are given in table 15. The actual recorded numbers and weights of fish removed from the ponds, data from which per-acre yields were computed, are shown in table 20. Yields of bluegills from most ponds increased somewhat between the early and late years of the experiment. During 1947, in the first summer of fishing, the yield of bass measuring 10 inches or larger was much greater from Lauderdale Pond than from Hooker or Phelps or from any of the control ponds, table 15. This high 1947 yield, 51 fish per acre (47 fish), was not equaled in later years at Lauderdale or at any of the other ponds during the period of the study reported here.

The annual hook-and-line yield of bass and bluegills combined averaged 48 pounds per acre from the fertilized ponds and 25 pounds per acre from the control ponds, table 16. The highest recorded 1-year yield from a fertilized pond (Lauderdale) was 88 pounds per acre, from a control pond (Boaz) 42 pounds per acre, table 15. Presumably, higher yields from the fertilized ponds can be attributed for the most part to the better bluegill fishing. It should be noticed that the fertilized ponds were fished more intensively than the controls. In fertilized and control ponds where total hours of fishing were about the same for the whole experiment (Lauderdale and Wells, Phelps and Boaz), the bluegill yields of fertilized ponds exceeded the bluegill yields of the controls in both numbers and pounds per acre, table 16.

For the control ponds in the 5 years in which both species were caught, the total bass yield in pounds (actual, not per acre) almost equaled the total yield of bluegills, table 17; the bass yield exceeded the bluegill yield in two of the control ponds. In the fertilized ponds the total bluegill yield in pounds was three times the bass yield.

Published data showing the effect of pond fertilization on hook-and-line yields are scarce; no such data have been found for ponds stocked with bass and bluegills alone. Dugan (1951:415) published annual yields of a number of fertilized ponds in West Virginia, some of which contained a bass-bluegill combination, but he did not have yield data from unfertilized ponds containing this combination. In two of the West Virginia ponds, yields of bass and bluegills were higher than the yields in the fertilized ponds at the Dixon Springs Experiment Station, but the West Virginia ponds were fished more intensively.

In Alabama, Swingle (1945:305) showed a large difference in annual hook-and-line yields between a fertilized pond and an unfertilized pond, each containing

Table 15.—Man-hours of fishing per acre and number and weight of fish per acre removed by hook and line from each Dixon Springs pond during the years 1947–1952. Catch data from which figures were derived are in table 20. Years in which fertilizers were applied to pond watersheds are indicated by S (for spring preceding the fishing season) and F (for fall near the end of the fishing season). Additional data on watershed fertilization are shown in table 5.

Pond	Year	Man-Hours of Fishing Per Acre	Largemouth Bass		Bluegills		Total Pounds Per Acre
			Number Per Acre	Pounds Per Acre	Number Per Acre	Pounds Per Acre	
Fertilized							
Lauderdale	1947	42	51	30	....	....	30
(0.92 acre)	1948	70	15	11	129	27	38
	1949	78	25	14	101	25	39
	1950F	58	37	25	151	39	64
	1951	56	13	11	150	48	59
	1952SF	58	36	25	223	63	88
Hooker	1947	71	6	3	....	....	3
(1.33 acres)	1948	151	19	14	131	32	46
	1949S*F*	216	30	19	127	36	55
	1950	162	19	11	133	41	52
	1951F*	108	18	11	217	59	70
	1952	120	14	7	72	20	27
Phelps	1947	32	2	1	....	....	1
(1.04 acres)	1948F	93	13	6	35	9	15
	1949	50	8	4	66	18	22
	1950	105	14	8	101	33	41
	1951	101	13	10	110	34	44
	1952	151	12	9	160	49	58
Unfertilized							
Wells	1947	28	15	11	....	....	11
(0.97) acre	1948	74	13	12	27	6	18
	1949	76	20	12	48	10	22
	1950F	52	14	10	58	12	22
	1951	50	20	13	70	16	29
	1952F	47	25	23	59	16	39
Boaz	1947	24	6	4	....	....	4
(1.01 acres)	1948	134	15	17	62	14	31
	1949F*	151	14	8	119	24	32
	1950	36	12	7	30	6	13
	1951S*F*	57	14	9	88	17	26
	1952	109	40	33	35	9	42
Elam	1947	16	5	3	....	....	3
(1.55 acres)	1948	35	7	5	24	5	10
	1949	45	7	6	43	7	13
	1950	76	25	16	26	8	24
	1951	32	12	8	74	15	23
	1952SF	58	12	9	114	23	32

*Only part of watershed treated with fertilizer in this season.

Table 16.—Average annual number of man-hours of fishing per acre and average annual hook-and-line yield of largemouth bass and bluegills per acre for the 5-year period 1948–1952 at the six Dixon Springs ponds. Data for individual years are shown in table 15.

Pond	Man-Hours of Fishing Per Acre	Largemouth Bass		Bluegills		Total Pounds of Fish Per Acre
		Number Per Acre	Pounds Per Acre	Number Per Acre	Pounds Per Acre	
Fertilized						
Lauderdale	64	25	17	151	40	57
Hooker	151	20	12	136	38	50
Phelps	100	12	7	94	29	36
Average	....	*19*	*12*	*127*	*36*	*48*
Unfertilized						
Wells	60	18	14	52	12	26
Boaz	97	19	15	67	14	29
Elam	49	13	8	56	12	20
Average	....	*17*	*12*	*58*	*13*	*25*

Table 17.—Total weight of largemouth bass and bluegills harvested from the Dixon Springs ponds over the 5 years 1948–1952, the ratio of bass weight to bluegill weight for each pond, and, for each species, the ratio of weight harvested from fertilized ponds to weight harvested from controls. Basic data from which figures were derived are in table 20; the 1947 data have been omitted because in that year bluegills had not reached sizes that most fishermen would keep.

Pond	Five-Year Yield		Bass: Bluegills
	Largemouth Bass, Pounds	Bluegills, Pounds	
Fertilized			
Lauderdale	79	186	1 : 2.4
Hooker	83	250	1 : 3.0
Phelps	37	148	1 : 4.0
Average	*66*	*195*	*1 : 3.0*
Unfertilized			
Wells	69	60	1 : 0.9
Boaz	74	70	1 : 0.9
Elam	69	90	1 : 1.3
Average	*71*	*73*	*1 : 1.0*
$\frac{\text{Fertilized}}{\text{Unfertilized}}$	$\frac{0.9}{1.0}$	$\frac{2.7}{1.0}$	....

six hook-and-line species including bass and bluegills. Swingle showed that over a 5-year period the yield of the fertilized pond was almost 10 times the yield of the other pond. The extent to which this difference in yield may have been due to a difference in the total hours of fishing on the two ponds was not indicated.

A creel census at Broadacres Lake, North Carolina (King 1943:209), showed the annual yield of largemouths, bluegills, and rough fish was higher the year before chemical fertilizer was used than the year the fertilizer was applied. However, the decline in yield after fertilization was not so pronounced in Broadacres Lake as in nearby Kinney Cameron Lake, which had not been fertilized.

Catch Rates

Before we consider the catch rates for fish that were actually harvested from the Dixon Springs ponds, we shall examine the catch rates for fish of various sizes

Table 18.—Numbers of largemouth bass in various length categories captured per hour of fishing by Illinois Natural History Survey test anglers in the period 1947–1952. Catch data on which figures are based are in tables 9 and 10. Bass measuring 10.0 inches or larger were the only ones kept by the test fishermen.

Length Category, Inches*	Fertilized Ponds							Unfertilized Ponds						
	Lauderdale (229 Hours)		Hooker (178 Hours)		Phelps (179 Hours)		Three-Pond Average, Number Per Hour	Wells (220 Hours)		Boaz (160 Hours)		Elam (189 Hours)		Three-Pond Average, Number Per Hour
	Number	Number Per Hour	Number	Number Per Hour	Number	Number Per Hour		Number	Number Per Hour	Number	Number Per Hour	Number	Number Per Hour	
4 or larger	248	1.08	216	1.21	127	0.71	1.00	170	0.77	114	0.71	229	1.21	0.90
6 or larger	243	1.06	210	1.18	124	0.69	0.98	168	0.76	114	0.71	217	1.15	0.87
8 or larger	204	0.89	160	0.90	104	0.58	0.79	140	0.64	96	0.60	150	0.79	0.68
10 or larger	153	0.67	54	0.30	40	0.22	0.40	86	0.39	42	0.26	72	0.38	0.34
12 or larger	37	0.16	2	0.01	7	0.04	0.07	39	0.18	12	0.08	15	0.08	0.11
14 or larger	9	0.04	1	...	...	...	...	6	0.03	2	0.01	3	0.02	0.02
16 or larger	6	0.03	...	...	...	...	...	...	...	...	...	1	...	...
18 or larger	1	...	...	...	...	...	...	...	...	...	...	...	...	...
20 or larger	1	...	...	...	...	...	...	...	...	...	...	...	...	...

*Each length category is based on a length class from table 9 or 10; for example the length category "6 or larger" includes bass of 5.8 inches total length and larger.

Table 19.—Numbers of bluegills in various length categories captured per hour of fishing by Illinois Natural History Survey test anglers in the period 1948–1952. Catch data on which figures are based are in tables 12 and 13. Bluegills measuring 6.0 inches total length or larger were the only ones kept by the test fishermen.

Length Category, Inches*	Fertilized Ponds							Unfertilized Ponds						
	Lauderdale (195 Hours)		Hooker (151 Hours)		Phelps (159 Hours)		Three-Pond Average, Number Per Hour	Wells (195 Hours)		Boaz (141 Hours)		Elam (164 Hours)		Three-Pond Average, Number Per Hour
	Number	Number Per Hour	Number	Number Per Hour	Number	Number Per Hour		Number	Number Per Hour	Number	Number Per Hour	Number	Number Per Hour	
3 or larger	642	3.29	188	1.24	268	1.69	2.07	418	2.14	298	2.11	541	3.30	2.52
4 or larger	640	3.28	188	1.24	266	1.67	2.06	406	2.08	295	2.09	533	3.25	2.47
5 or larger	622	3.19	181	1.20	240	1.51	1.97	348	1.78	263	1.87	448	2.73	2.13
6 or larger	556	2.85	152	1.01	209	1.31	1.72	232	1.19	186	1.32	320	1.95	1.49
7 or larger	338	1.73	93	0.62	121	0.76	1.04	129	0.66	66	0.47	110	0.67	0.60
8 or larger	76	0.39	16	0.11	23	0.14	0.21	17	0.09	3	0.02	2	0.01	0.04

*Each length category is based on a length class from table 12 or 13; for example, the length category "4 or larger" includes bluegills of 3.8 inches total length and larger.

caught by the test anglers; these fish included some too small to keep.

The efforts of fish managers often are directed toward increasing the numbers of large fish in a population by reducing the abundance of small fish, that is, by thinning stunted populations. These efforts may not be appreciated by a group of fishermen who are less concerned with the size of fish than with the number of fish they catch. This group includes many children and some adults.

The rates at which the test anglers at the Dixon Springs ponds caught bass and bluegills above certain minimum lengths are shown in tables 18 and 19. The catch rates for bass less than 10 inches long and bluegills less than 6 inches long are not harvest rates, since these fish were returned to the ponds after they were measured; some of these fish may have been caught more than once.

The fisherman who prizes any fish, no matter how small, would have found the fertilized ponds slightly better than the control ponds for bass fishing but the control ponds slightly better than the fertilized ponds for bluegill fishing. The control ponds proved better than the fertilized ponds for the capture of bluegills measuring 5 inches or larger. The fisherman interested in keeping only the fish of moderate to large sizes, for example, bass over 12 inches and bluegills over 7 inches, might have found the control ponds a little more satisfactory for bass fishing and the fertilized ponds a little more satisfactory for bluegill fishing. The bass fisherman interested in keeping only extra large fish would have found all of the ponds disappointing.

Catch Rates for Fish That Were Harvested.—We turn now to a consideration of catch rates based on fish that were actually harvested.

The hook-and-line catch rates for fish harvested from the six ponds at Dixon Springs are given in table 20. It is evident from this table that Lauderdale produced better fishing each year (bass rates added to bluegill rates) in terms of both number and pounds per man-hour than any of the other ponds. It was the only fertilized pond that consistently produced better catch rates (bass and bluegill combined) than any of the control ponds.

Lauderdale produced better bass fishing, in terms of number of fish per man-hour, than any of the controls in 5 out of 6 years and, in terms of pounds per man-hour, than any of the controls in 3 out of 6 years, figs. 8 and 9. In 4 out of 6 years the other fertilized ponds produced poorer bass fishing than any of the control ponds. However, as mentioned earlier, bass fishing in Phelps Pond may have been poorer than it should have been in the first year of fishing as a result of relatively heavy stocking.

In each year but 1949 Lauderdale led all other ponds in bluegill fishing, figs. 10 and 11; in that year Phelps led in both number and pounds of bluegills per man-hour. In several different years some of the control ponds had bluegill catch rates that were equal to or better than the catch rates in Hooker or Phelps.

The catch rates averaged for six seasons of bass fishing and five of bluegill fishing are shown for each pond at the bottom of table 20. Lauderdale ranked well above any of the other ponds in catch rates (bass rates added to bluegill rates). Hooker and Phelps ranked below Wells and Elam and about on a par with Boaz.

The three fertilized ponds ranked 1, 5, and 6 in terms of both number and weight of bass kept per hour; 1, 3, and 4 in terms of number of bluegills kept per hour; and 1, 2, and 3 in terms of weight of bluegills kept per hour. In terms of the weight of bluegills kept per hour, two of the fertilized ponds, Phelps and Hooker, outranked the controls by very small margins. However, the fact that all three fertilized ponds outranked the three controls is a strong indication that fertilization was a benefit to bluegill fishing, though the benefit may have been small.

At Broadacres Lake, North Carolina, King (1943:209) found that the catch rate was a little lower the year fertilizer was used than the year before. At Crecy Lake in New Brunswick, Smith (1954:2) observed a better catch rate of brook trout after the lake had been fertilized, but this better catch rate may have been due in part to other management efforts carried on at the same time, for example, the addition of young trout.

There is a statistical possibility that the fertilized ponds, Lauderdale, Hooker,

Table 20.—Hook-and-line yield and rate of yield (number and weight per man-hour of fishing) of largemouth bass and bluegills removed from Dixon Springs ponds, 1947–1952. At bottom of table (all years), hours of fishing and numbers and pounds of fish are given as totals for entire experiment; rates of catch are averages of averages given in upper part of table, rather than rates obtainable by dividing total catch by total man-hours of fishing.

Year and Pond	Actual Man-Hours of Fishing	Man-Hours of Fishing Per Acre	Largemouth Bass				Bluegills			
			Number Kept	Number Kept Per Hour	Pounds Kept	Pounds Kept Per Hour	Number Kept	Number Kept Per Hour	Pounds Kept	Pounds Kept Per Hour
1947										
Fertilized										
Lauderdale	39	42	47	1.21	28	0.72	...	...	...	...
Hooker	95	71	8	0.08	5	0.05	...	...	...	...
Phelps	33	32	2	0.06	1	0.03	...	...	...	...
Average	...	...	...	*0.45*	...	*0.27*	...	...	...	...
Unfertilized										
Wells	27	28	15	0.56	11	0.41	...	...	...	...
Boaz	24	24	6	0.25	4	0.17	...	...	...	...
Elam	25	16	8	0.32	5	0.20	...	...	...	...
Average	...	...	...	*0.38*	...	*0.26*	...	...	...	...
1948										
Fertilized										
Lauderdale	64	70	14	0.22	10	0.16	119	1.86	25	0.39
Hooker	201	151	25	0.12	18	0.09	175	0.87	42	0.21
Phelps	97	93	14	0.14	6	0.06	36	0.37	9	0.09
Average	...	...	...	*0.16*	...	*0.10*	...	*1.03*	...	*0.23*
Unfertilized										
Wells	72	74	13	0.18	12	0.17	26	0.36	6	0.08
Boaz	135	134	15	0.11	17	0.13	63	0.47	14	0.10
Elam	54	35	11	0.20	7	0.13	37	0.69	8	0.15
Average	...	...	...	*0.16*	...	*0.14*	...	*0.51*	...	*0.11*
1949										
Fertilized										
Lauderdale	72	78	23	0.32	13	0.18	93	1.29	23	0.32
Hooker	288	216	40	0.14	25	0.09	169	0.59	48	0.17
Phelps	52	50	8	0.15	4	0.08	69	1.33	19	0.37
Average	...	...	...	*0.20*	...	*0.12*	...	*1.07*	...	*0.29*
Unfertilized										
Wells	74	76	19	0.26	12	0.16	47	0.64	10	0.14
Boaz	153	151	14	0.09	8	0.05	120	0.78	24	0.16
Elam	70	45	11	0.16	10	0.14	66	0.94	11	0.16
Average	...	...	...	*0.17*	...	*0.12*	...	*0.79*	...	*0.15*

1950										
FERTILIZED										
Lauderdale	53	58	34	0.64	23	0.43	139	2.62	36	0.68
Hooker	215	162	25	0.12	15	0.07	177	0.82	55	0.26
Phelps	109	105	15	0.14	8	0.07	105	0.96	34	0.31
Average				*0.30*		*0.19*		*1.47*		*0.42*
UNFERTILIZED										
Wells	50	52	14	0.28	10	0.20	56	1.12	12	0.24
Boaz	36	36	12	0.33	7	0.19	30	0.83	6	0.17
Elam	118	76	39	0.33	25	0.21	40	0.34	12	0.10
Average				*0.31*		*0.20*		*0.76*		*0.17*
1951										
FERTILIZED										
Lauderdale	52	56	12	0.23	10	0.19	138	2.65	44	0.85
Hooker	143	108	24	0.17	15	0.10	289	2.02	79	0.55
Phelps	105	101	14	0.13	10	0.10	114	1.09	35	0.33
Average				*0.18*		*0.13*		*1.92*		*0.58*
UNFERTILIZED										
Wells	49	50	19	0.39	13	0.26	68	1.39	16	0.33
Boaz	58	57	14	0.24	9	0.16	89	1.53	17	0.29
Elam	49	32	18	0.37	13	0.26	115	2.35	23	0.47
Average				*0.33*		*0.23*		*1.76*		*0.36*
1952										
FERTILIZED										
Lauderdale	53	58	33	0.62	23	0.43	205	3.87	58	1.09
Hooker	160	120	19	0.12	10	0.06	96	0.60	26	0.16
Phelps	157	151	12	0.08	9	0.06	166	1.06	51	0.32
Average				*0.27*		*0.18*		*1.84*		*0.52*
UNFERTILIZED										
Wells	46	47	24	0.52	22	0.48	57	1.24	16	0.35
Boaz	110	109	40	0.36	33	0.30	35	0.32	9	0.08
Elam	90	58	19	0.21	14	0.16	177	1.97	36	0.40
Average				*0.36*		*0.31*		*1.18*		*0.28*
All years										
FERTILIZED										
Lauderdale	333	362	163	0.54	107	0.35	694	2.45	186	0.67
Hooker	1,102	828	141	0.13	88	0.08	906	0.98	250	0.27
Phelps	553	532	65	0.12	38	0.07	490	0.96	148	0.28
Average				*0.26*		*0.17*		*1.47*		*0.41*
UNFERTILIZED										
Wells	318	327	104	0.37	80	0.28	254	0.95	60	0.23
Boaz	516	511	101	0.23	78	0.17	337	0.79	70	0.16
Elam	406	262	106	0.27	74	0.19	435	1.26	90	0.26
Average				*0.29*		*0.21*		*1.00*		*0.22*

and Phelps, would have ranked better as bluegill fishing ponds than the controls even if no fertilizer had been used. H. W. Norton, statistician in the University of Illinois Animal Science Department, tells us that where relative productivity of ponds is unknown the random selection of the three most productive ponds as the

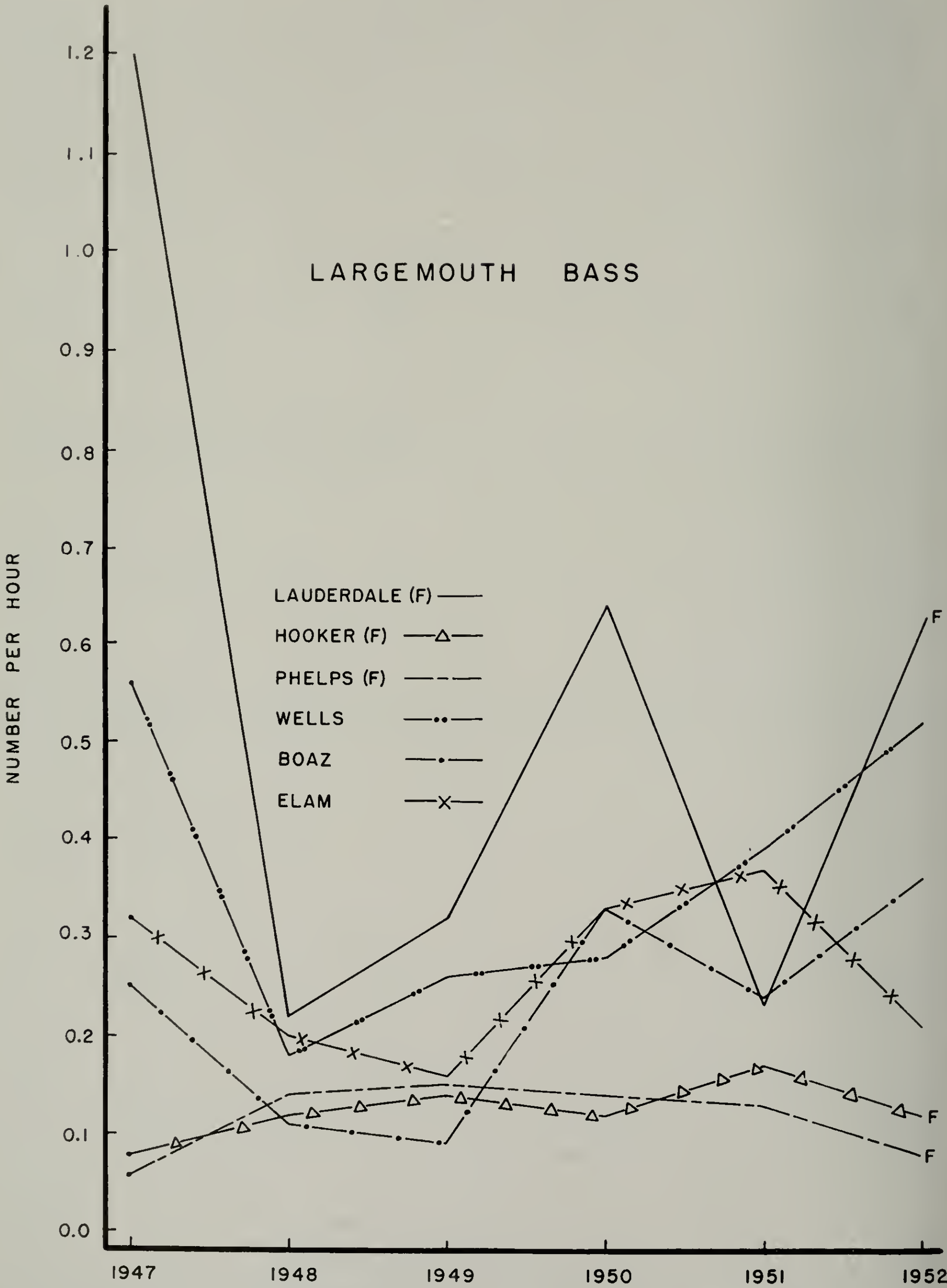

Fig. 8.—Number of largemouth bass kept per man-hour of angling in fertilized (F) and unfertilized ponds; data from table 20.

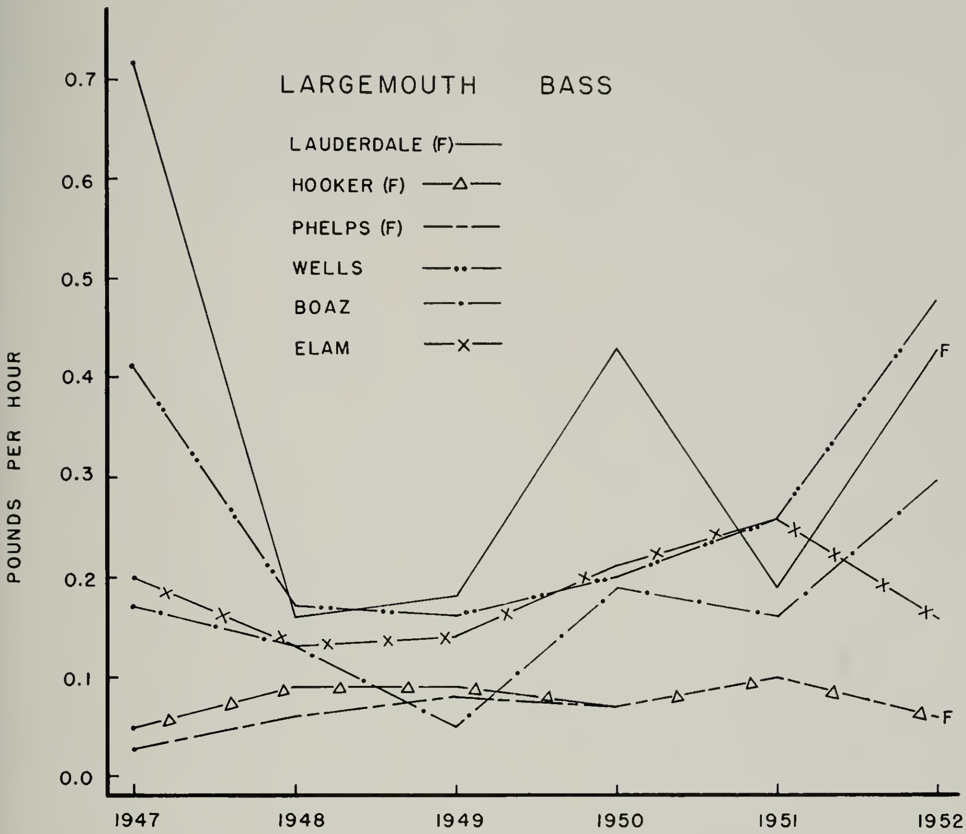

Fig. 9.—Weight of largemouth bass kept per man-hour of angling in fertilized (F) and unfertilized ponds; data from table 20.

ones to receive treatment could occur once in 20 times. Although the ponds were chosen for fertilization on an arbitrary rather than on a purely random basis, we had no advance knowledge of how the six ponds might rank as fish-producing waters.

The wide variation in catch rates for the three fertilized ponds at Dixon Springs points to the need for studies of catch rates on ponds before, as well as after, fertilization. A study of this kind is now in progress. Wells, Boaz, and Elam, the three control ponds of the study reported here, were restocked in 1954 and fertilized for two seasons. Bluegill catch rates in each of these ponds were better after fertilization than before.

The fact that bass fishing in both Hooker and Phelps for the period 1947–1952 was inferior to bass fishing in each of the control ponds, table 20, suggests several possible conclusions: (1) fertilization was of no help to bass fishing, (2) the benefits of fertilization varied greatly from pond to pond, or (3) no positive correlation existed between the fish population of a pond and the catch rate. The rotenone census of the fish populations showed that poor bass fishing in Hooker and Phelps may not have been due to scarcity of usable-sized fish in these ponds so much as to the difficulty of catching them.

That fishing for both bass and bluegills was generally much better in Lauderdale than in the other fertilized ponds is not easily explained, unless possibly by the lighter fishing pressure, as discussed in the section "Fishing Pressures and Catch Rates." At the time of the 1953 rotenone census, the number per acre of usable-sized bass was smaller in Lauderdale than in Phelps; the number per acre of usable-

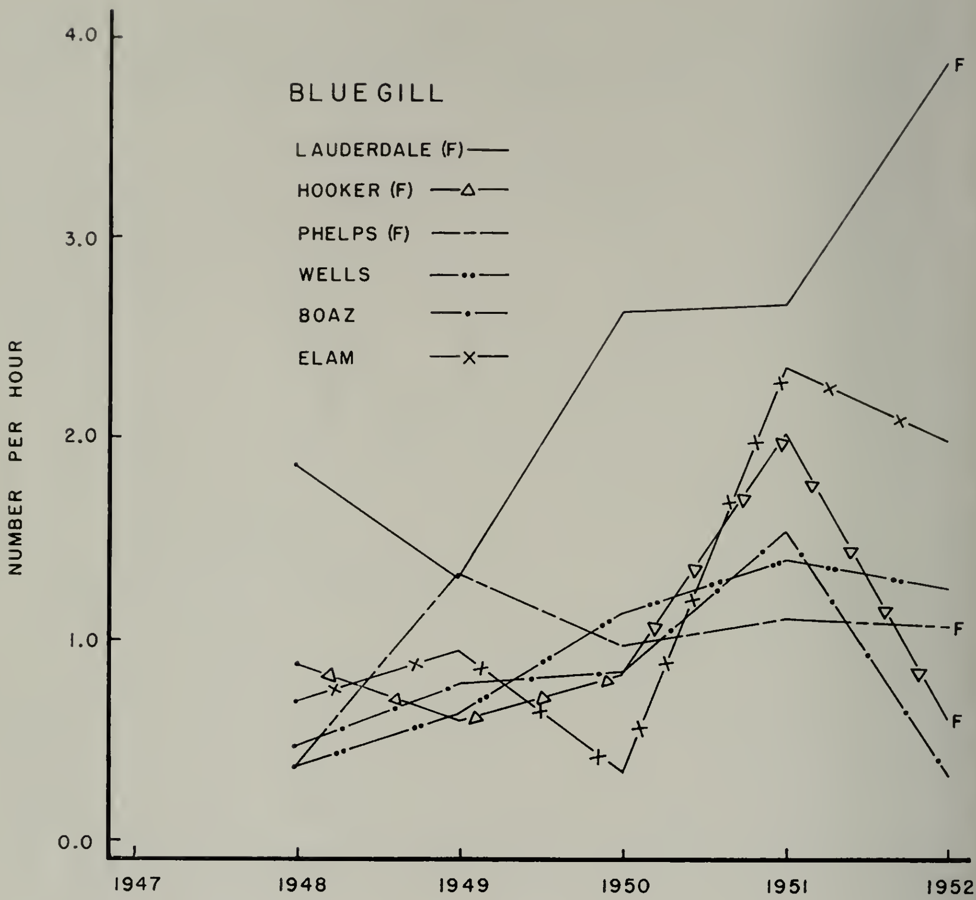

Fig. 10.—Number of bluegills kept per man-hour of angling in fertilized (F) and unfertilized ponds; data from table 20.

sized bluegills was smaller in Lauderdale than in Phelps or Hooker, table 24.

Three factors may have been favorable to the growth of fish in Lauderdale for 1 or 2 years at the beginning of the study but not during the last 4 years. (1) Before the stocking of the ponds for the experiment reported here, fish-food organisms—invertebrates as well as larval amphibians—had a longer time to build up their populations in Lauderdale than in Hooker or Phelps. In 1946 Lauderdale was without fish for 6 months prior to stocking (May to November), Hooker and Phelps for only 2 months (September to November). Brown & Ball (1943: 267) showed that certain fish-food organisms as well as fish were destroyed by the rotenone treatment of Third Sister Lake, Michigan. Ball & Hayne (1952: 44–5) showed evidence of an expansion in fish-food organisms in a lake after all fish had been removed. (2) In November, 1946, Lauderdale was given a slightly heavier stocking in terms of fish per acre than the other ponds; this heavier stocking might account for the better bass fishing in 1947. Presumably the initial advantage in numbers would have ceased to be a factor in 1948 or 1949, when the offspring of the fish used in stocking the pond reached harvestable size. (3) Lauderdale had been dosed with fertilizer in 1945.

As a result of an error in the reported area of the pond, Lauderdale received more fertilizer in terms of pounds per acre at full stage than either Hooker or Phelps. However, water levels in midsummer were always much lower in Phelps than in Lauderdale, so that Phelps was probably dosed at least as heavily as Lauderdale after about the middle of July each year.

We have shown in table 8 that Lauderdale was often clearer than Hooker and Phelps, a condition that might have assisted fish both in finding food and in locating baits. On the other hand, it is possible that the clearer water increased the chances that the fish might be frightened by fishermen.

Trends in Catch Rates.—Certain trends in the yearly catch rates were observed for both fertilized and unfertilized ponds at Dixon Springs, but trends differed from one pond to another. In some

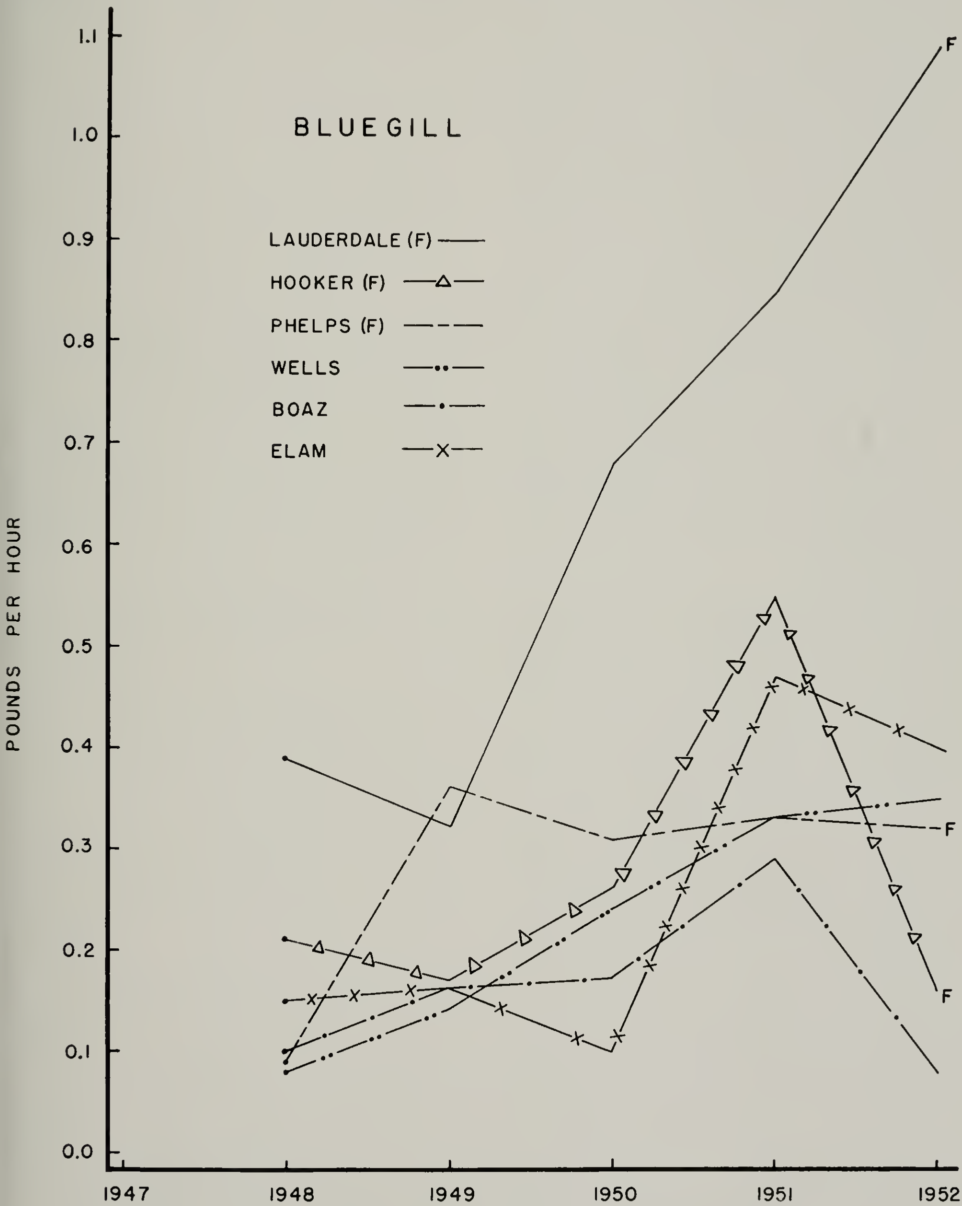

Fig. 11.—Weight of bluegills kept per man-hour of angling in fertilized (F) and unfertilized ponds; data from table 20.

Table 21.—Hook-and-line yield and rate of yield (number and weight per man-hour of fishing) of largemouth bass and bluegills from selected Dixon Springs ponds; fertilized (F) and unfertilized or control (C) ponds having similar fishing intensities are paired or grouped. Data are from table 20.

Year and Pond	Actual Hours of Fishing	Hours of Fishing Per Acre	Largemouth Bass				Bluegills			
			Number Kept	Number Kept Per Hour	Pounds Kept	Pounds Kept Per Hour	Number Kept	Number Kept Per Hour	Pounds Kept	Pounds Kept Per Hour
1947										
Phelps (F)	33	32	2	0.06	1	0.03	....	....	....	....
Wells (C)	27	28	15	0.56	11	0.41	....	....	....	....
1948										
Lauderdale (F)	64	70	14	0.22	10	0.16	119	1.86	25	0.39
Wells (C)	72	74	13	0.18	12	0.17	26	0.36	6	0.08
1949										
Lauderdale (F)	72	78	23	0.32	13	0.18	93	1.29	23	0.32
Wells (C)	74	76	19	0.26	12	0.16	47	0.64	10	0.14
Phelps (F)	52	50	8	0.15	4	0.08	69	1.33	19	0.37
Elam (C)	70	45	11	0.16	10	0.14	66	0.94	11	0.16
1950										
Lauderdale (F)	53	58	34	0.64	23	0.43	139	2.62	36	0.68
Wells (C)	50	52	14	0.28	10	0.20	56	1.12	12	0.24
1951										
Lauderdale (F)	52	56	12	0.23	10	0.19	138	2.65	44	0.85
Wells (C)	49	50	19	0.39	13	0.27	68	1.39	16	0.33
Boaz (C)	58	57	14	0.24	9	0.16	89	1.53	17	0.29
1952										
Lauderdale (F)	53	58	33	0.62	23	0.43	205	3.87	58	1.09
Elam (C)	90	58	19	0.21	14	0.16	177	1.97	36	0.40
Hooker (F)	160	120	19	0.12	10	0.06	96	0.60	26	0.16
Boaz (C)	110	109	40	0.36	33	0.30	35	0.32	9	0.08

ponds, bass catch rates changed only slightly during the experiment; in others, catch rates were high at the beginning, dropped off for 1 or 2 years, and then improved toward the end of the experiment. The notion of many fishermen in Pope and Johnson counties that bass fishing in small ponds is best the first year they are fished was borne out in the fishing results only at Lauderdale and Wells, figs. 8 and 9.

The observed depression in bass catch rates seen in some of the ponds in the second or third year after being stocked probably was due to a reduction in the numbers of the original stock of bass as a result of angling and natural mortality, combined with a delay in population replacement through reproduction.

In all of the ponds except Phelps and Lauderdale, figs. 10 and 11, bluegill catch rates were highest during the fourth year of bluegill fishing (the fifth year after stocking). Phelps Pond furnished its best bluegill fishing in the second year and Lauderdale in the fifth year of bluegill fishing. The most common trend in bluegill catch rates—one that was exhibited by four of the six ponds—was a general improvement in rates over the first 4 years of bluegill fishing, 1948–1951. Three of these four ponds showed conspicuous declines in catch rates in the fifth year, 1952.

Fishing Pressures and Catch Rates.—Bennett & Weiss (1959) recently showed that ponds in Illinois subjected to comparatively light fishing pressures—Ridge Lake, Big Pond, and the ponds in the present experiment—provided better catch rates than ponds in the Busch Wildlife Area, Missouri, that were subjected to extremely heavy fishing pressures.

Although we were unable to discover a clearcut relationship between fishing pressures and catch rates in the Dixon Springs ponds, we found that the two ponds with the smallest total number of man-hours of fishing, Lauderdale (fertilized) and Wells (unfertilized), had the highest catch rates of bass of desirable sizes, table 20.

We have tried in the following discussion to eliminate fishing pressure as a possible factor in catch rate calculations by comparing only those ponds that were fished at approximately equal rates, table 21.

Under equal or nearly equal fishing pressures, bass fishing was in some instances better in the fertilized ponds, in other instances better in the controls, but bluegill fishing was consistently better in the fertilized ponds.

The catch rates shown for Lauderdale (fertilized) and Wells (control) are of special interest because fishing in these two ponds was done almost entirely by the Natural History Survey test anglers, assuring that not only the number of hours but fishing skills and fishing methods were nearly the same in a given year.

In the 4 years that Lauderdale and Wells are represented in table 21, bluegill fishing in terms of number of fish caught per hour was 1.9 to 5.2 times as good in Lauderdale as in Wells—in terms of pounds caught per hour, 2.3 to 4.9 times as good in Lauderdale as in Wells. In the same 4 years, bass fishing was notably better in Lauderdale than in Wells in 1 year, better in Wells than in Lauderdale in 1 year.

Over the entire period of study, total hours of fishing were nearly equal for Lauderdale (fertilized) and Wells (unfertilized), each fished about 300 hours, and for Phelps (fertilized) and Boaz (unfertilized), each fished in the neighborhood of 500 hours, table 20 (bottom). The catch rates for bass, in 6 years of fishing, were better in Lauderdale than in Wells but better in Boaz than in Phelps. The catch rates for bluegills, in 5 years of fishing, were considerably better in Lauderdale than in Wells and somewhat better in Phelps than in Boaz.

Fertilization Rates and Catch Rates.—As described in the section "Fertilizing the Ponds," the N-P-K formulas used in the period 1947–1949 were different from the ones used in later years, table 7. As a consequence of changes in the fertilizer formula and in the number of treatments, the ponds received about 2.0 times as much nitrogen, 1.3 times as much phosphorus (P_2O_5), and about 3.2 times as much potassium (K_2O) in 1951 and in later years as they had received each year in the period 1947–1949. Although the number of fertilizer applica-

Table 22.—Catch rates (number and weight of fish per man-hour of fishing) of largemouth bass and bluegills from Dixon Springs ponds in two periods, one of comparatively light (1947–1949) and one of comparatively heavy (1951, 1952) fertilization. Details of pond fertilization program are shown in table 7. Figures were derived from data in table 20.

Period of Fertilization	Largemouth Bass		Bluegills*	
	Number Per Hour	Pounds Per Hour	Number Per Hour	Pounds Per Hour
Light (1947–1949)				
Fertilized ponds	0.27	0.16	1.05	0.26
Unfertilized ponds	0.23	0.17	0.65	0.13
Difference	*+0.04*	*−0.01*	*+0.40*	*+0.13*
Heavy (1951, 1952)				
Fertilized ponds	0.23	0.16	1.88	0.55
Unfertilized ponds	0.35	0.27	1.46	0.32
Difference	*−0.12*	*−0.11*	*+0.42*	*+0.23*

*Bluegill fishing in 1948, 1949, 1951, and 1952 but not in 1947.

tions given annually in 1951–1953 was double the number given in 1947–1949, the amount of phosphorus (the component generally considered to be most important in pond fertilization) was increased only about one-third.

Catch rates may be compared for the years under the lighter treatment (1947–1949 for bass, 1948 and 1949 for bluegills) with the years under the heavier rates (1951 and 1952), table 22. Bass fishing, as judged by differences in catch rates between fertilized and unfertilized ponds, was relatively better under the lighter treatment; bluegill fishing—especially in pounds caught per hour—was better under the heavier treatment. Since bluegill catch rates improved in the control ponds as well as in the fertilized ponds during the period of the heavier treatments, bluegill fishing might have improved in the fertilized ponds even if the rate of fertilization had not been increased.

POND FERTILIZATION AND STANDING CROPS

When the standing crops of the Dixon Springs ponds were determined by rotenone censuses in September, 1953, the ponds had been closed to all fishing for the 12-month period preceding the census. Fertilization of Lauderdale, Hooker, and Phelps had been continued during the summer of 1953 in approximately the same manner as in 1951 and 1952, table 7. For each pond the standing crop in pounds per acre was computed from the reduced area of the pond at the time of the census, rather than from the area at full stage. Both full stage and reduced areas are shown in table 1.

Studies by Brown & Ball (1943), Ball (1948), Carlander & Lewis (1948), and Krumholz (1950*a*) demonstrated that in some situations considerable percentages of the populations of fish killed by rotenone are not recovered in the census operations. A possible hindrance to the recovery of fish in the control ponds at Dixon Springs was a dense growth of *Chara* in which dying and dead fish might have become entangled. The possibility that the *Chara* interfered with the recovery of fish was not investigated by underwater examination. We know of no reason other than the possible effect of *Chara* to believe that the percentage of fish recovered was different in fertilized than in unfertilized ponds.

Bass collected from the ponds after the rotenone treatment were grouped into two length categories—those 10.0 inches (total length) or larger and those smaller than 10.0 inches. The bluegills collected from the first four ponds examined (Lauderdale, Phelps, Wells, and Boaz) were divided into four length categories as follows: 1.0–1.9, 2.0–3.4, 3.5–5.9, and 6.0 inches or larger. Natural size groupings permitted the rapid sorting of fish into the various length categories, for the most part without actual measurement. Bluegills collected from the other two ponds (Hooker and Elam) were grouped into two categories: under 6.0 inches and 6.0 inches or larger.

The populations of the first four ponds varied considerably with respect to abundance of bluegills in the four length categories, table 23. The variations appear to have been unrelated to the fertilization program. Lauderdale Pond was characterized by an absence of bluegills 1.0–1.9 inches long, by an abundance of bluegills 2.0–3.4 inches long, and a relative scarcity of bluegills 3.5–5.9 inches long and 6.0 inches or larger. This pond, in which bluegill fishing had been better than in any other, was more remarkable for the weight of 2.0–3.4-inch bluegills (95 pounds per acre) than for the weight of bluegills measuring 6.0 or larger.

Two population characteristics were seen in these four ponds, table 23. (1) While the ponds appeared to be quite densely populated with bluegills under 3.5 inches, they showed no evidence of overpopulation with bluegills of 3.5 inches or longer. (2) In number of bluegills per acre in each of the four ponds, great differences existed between the two smaller length categories and only minor differences between the two greater length categories.

Of the fish that, according to tables 12 and 13, were likely to be caught by anglers (those 3.5 inches or larger), the ones measuring 3.5–5.9 inches were about as numerous as those of greater lengths.

The number and weight of bass and bluegills (in two length categories for each species) recovered from each of the six ponds in the rotenone census are shown in table 24. Just as there was overlap in the catch rates for fertilized and unfertilized ponds, there was also overlap in the standing crops. Bass 10 inches or larger, bluegills 6 inches or larger, and bluegills smaller than 6 inches were a little more abundant in the fertilized ponds, while bass smaller than 10 inches were more abundant in the control ponds, table 24. Bass of all lengths were more abundant in the control ponds, while bluegills of all lengths were more abundant in the fertilized ponds. The weight per acre of bass of all lengths was nearly the same in fertilized as in control ponds; the weight per acre of bluegills of all lengths was higher in the fertilized ponds.

The three fertilized ponds averaged 292 pounds of fish per acre (bass and bluegills of all lengths); the controls averaged 238 pounds per acre (ratio 1.2:1).

In Alabama ponds treated nine times a season with 6-8-4 fertilizer at the rate of 100 pounds per acre per treatment and $NaNO_3$ at the rate of 10 pounds per acre per treatment—roughly equivalent to the annual treatments applied at Dixon Springs in the period 1951–1953—Swingle (1947:24) found that the average standing crop (weight per acre) of bass and bluegills of all sizes in three fertilized ponds was about double the standing crop in the control pond (ratio 2.0:1). In this Alabama observation, an overlap was

Table 23.—Standing crops, in terms of number and weight (per acre), of bluegills recovered in the rotenone censuses of four of the six Dixon Springs ponds, September 8–17, 1953; the fish were separated into four length categories. The data from Hooker and Elam ponds are not included in this table because the bluegills from those ponds were separated into only two length groups, under 6 inches and 6 inches and longer.

Total Length, Inches	Fertilized Ponds				Unfertilized Ponds			
	Lauderdale		Phelps		Wells		Boaz	
	Number Per Acre	Pounds Per Acre	Number Per Acre	Pounds Per Acre	Number Per Acre	Pounds Per Acre	Number Per Acre	Pounds Per Acre
1.0–1.9	....	....	9,070	10	12,428	27	921	1
2.0–3.4	11,531	95	227	3	408	6	3,925	21
3.5–5.9	314	21	676	50	451	27	876	56
6.0 or larger	463	129	706	146	463	108	624	133

Table 24.—Standing crops, in terms of number and weight (per acre), of largemouth bass and of bluegills recovered from the Dixon Springs ponds treated with rotenone, September 8–17, 1953, and, for each species, the ratio (in number and weight per acre) between fertilized and unfertilized ponds. Large bass were those 10.0 inches total length or longer; large bluegills were those 6.0 inches total length or longer.

Pond	Largemouth Bass						Bluegills						Species and Sizes Combined	
	Large		Small		Total		Large		Small		Total			
	Number Per Acre	Pounds Per Acre	Number Per Acre	Pounds Per Acre	Number Per Acre	Pounds Per Acre	Number Per Acre	Pounds Per Acre	Number Per Acre	Pounds Per Acre	Number Per Acre	Pounds Per Acre	Number Per Acre	Pounds Per Acre
FERTILIZED														
Lauderdale	58	70	117	3	175	73	463	129	11,845	116	12,308	245	12,483	318
Hooker	49	43	229	8	278	51	629	147	5,378	57	6,007	204	6,285	255
Phelps	64	67	92	26	156	93	706	146	9,973	63	10,679	209	10,835	302
Average	*57*	*60*	*146*	*12*	*203*	*72*	*599*	*141*	*9,065*	*79*	*9,665*	*219*	*9,868*	*292*
UNFERTILIZED														
Wells	55	45	255	24	310	69	463	108	13,287	60	13,750	168	14,060	237
Boaz	59	62	253	35	312	97	624	133	5,722	78	6,346	211	6,658	308
Elam	24	21	183	22	207	43	442	81	4,721	45	5,163	126	5,370	169
Average	*46*	*43*	*230*	*27*	*276*	*70*	*510*	*107*	*7,910*	*61*	*8,420*	*168*	*8,696*	*238*
Fertilized / Unfertilized	1.24 / 1.00	1.40 / 1.00	0.63 / 1.00	0.44 / 1.00	0.74 / 1.00	1.03 / 1.00	1.17 / 1.00	1.32 / 1.00	1.15 / 1.00	1.30 / 1.00	1.15 / 1.00	1.30 / 1.00	1.13 / 1.00	1.23 / 1.00

found between fertilized and control ponds in standing crops of bass but not of bluegills.

In another experiment in which Alabama ponds were treated 12 times a season with 6.6-8-2, each time at the rate of 120 pounds per acre, Swingle (1947:22) found that the average of the standing crops of bass and bluegills of all sizes in three fertilized ponds was nearly three times the standing crop in the control pond (ratio 2.9:1).

That Alabama ponds showed a better response to fertilization than the Dixon Springs ponds under similar treatment is possibly explained by differences in natural fertility of the Alabama and Illinois ponds in question. It might be easier through direct fertilization to double or triple a low standing crop of fish in an area of low soil fertility than in one of somewhat higher soil fertility. The untreated Alabama ponds, 6 to 12 months after being stocked, contained 100 to 125 pounds of bass and bluegills per acre (Swingle 1947:22, 24), whereas the three untreated ponds at Dixon Springs, 6 years after being stocked, contained 169 to 308 pounds of bass and bluegills per acre, table 24. It is possible that in the 6- to 12-month periods between the stocking and draining of the Alabama ponds the standing crops had not had time to reach maximum levels. Krumholz (1948:405, 409) found that ponds stocked in May or June with bluegills alone or with bluegills, largemouth bass, and other species contained much larger standing crops the second October than the first October after being stocked.

Ball & Tait (1952:6, 17) used somewhat less fertilizer in southern Michigan ponds than was used at Dixon Springs in 1951–1953 and obtained a slightly better response from the treatments. Three Michigan ponds were treated five times a season with 10-6-4 fertilizer at the rate of 100 pounds per acre each time. The fertilized ponds had standing crops of bass and bluegills that averaged 365 pounds per acre, and three similar, unfertilized ponds had standing crops that averaged 261 pounds per acre (ratio 1.4:1). There was a very wide range in the standing crops of the fertilized ponds, 165 to 721 pounds per acre; the standing crops of the unfertilized ponds ranged from 209 to 379 pounds per acre.

In West Virginia, Surber (1948*b*) studied the effect of various rates of application of 10-5-5 fertilizer on the bluegill production in hatchery ponds. Three groups of ponds were treated five to seven times a growing season at rates of 100, 200, or 300 pounds of 10-5-5 fertilizer per treatment. Combining the data of Surber (1948*b*:201–2) for summer and fall hatchery crops (but omitting the data from a pond in which there was abnormally high mortality) we find that crop weights were 1.9, 2.3, and 2.3 times as large in the three groups of fertilized ponds as in the control ponds.

STANDING CROPS AND FISHING SUCCESS

For many years aquatic biologists have been interested in the standing crops of lakes and ponds as a basis for predicting hook-and-line yields. Thompson (1941:213) thought that central Illinois lakes stocked with bass, bluegills, and crappies could give sustained annual hook-and-line yields that would amount to half their carrying capacities. He thought that the corresponding yields for southern Illinois lakes might be close to three-fourths of their carrying capacities. By carrying capacity, Thompson meant the total amount of fish in a lake at saturation point, or the maximum standing crop. Krumholz (1950*b*:29) estimated that Indiana ponds were capable of giving sustained annual yields of "as much as half and perhaps more" of their standing crops. Neither Thompson nor Krumholz speculated on the amount of fishing time that might be required to bring about such yields.

We may now compare the hook-and-line yields of the Dixon Springs ponds during the last 3 years of fishing with the standing crops as observed in the 1953 censuses, table 25. The hook-and-line yields were for the most part made up of bass more than 10 inches and bluegills more than 6 inches total length; the standing crops included all fish, irrespective of size.

For each Dixon Springs pond, the 1952 yield alone, as well as the average yield for the years 1950, 1951, and 1952, amounted to a much smaller percentage of the standing crop, as observed in September, 1953, table 25, than the sustained yield estimates of Thompson and Krumholz. Percentages were higher in the fertilized than in the control ponds. The most heavily fished ponds in 1952 were Hooker, Phelps, and Boaz. The 1952 fish yields in these three ponds were respectively 11, 19, and 14 per cent of their observed standing crops. The largest yield in relation to standing crop (28 per cent) was recorded from Lauderdale Pond, where fishing in 1952 was lighter, rather than heavier, than in Hooker, Phelps, or Boaz. If, as is possible, fewer fish were recovered in the rotenone censuses than were actually present, the true percentage values would be even lower than those shown. On the other hand, if unreported yields of fish taken by poachers could be determined and included in the calculations, the percentages for at least some of the ponds might be higher than those shown.

Figures representing the 1952 bass harvest and the numbers and weights of harvestable bass in the ponds at the time of the 1953 census are shown in table 26. Similar figures for bluegills are shown in table 27. If the 1953 fish census gave a close approximation of the population of harvestable fish in 1952, the efficiency of the 1952 fish harvest (the fish caught in relation to the fish present) appears to have been greater for bass in the control ponds and for bluegills in the fertilized ponds.

The relations between catch per hour and the abundance of fish of desirable sizes are shown for bass in table 28 and for bluegills in table 29. Data in these tables, especially the ratios expressed, seem to indicate that in the fertilized ponds bass fishing was poorer than would be expected from the numbers of 10-inch or larger bass present and that bluegill fishing was better than would be expected from the populations of 6-inch or larger bluegills.

Swingle (1945: 305) observed that the catch in fertilized ponds was usually greater than would be expected from the increases in their fish-carrying capacities, but he did not say whether his observation applied to both bass and bluegills. He attributed the phenomenon to the blooms of microscopic algae, which he believed helped to conceal the anglers from the fish they were trying to catch. Results of the Dixon Springs experiment indicate that if plankton algae helped to conceal the fishermen from the bass it may also have helped to conceal baits from these fish.

We have ordinarily assumed that the pond containing the largest population of

Table 25.—Standing crop of largemouth bass and bluegills (fish of all sizes) in the 1953 rotenone census of the six Dixon Springs ponds, and the hook-and-line yield of largemouth bass and bluegills during the last years of the experiment, 1950–1952. Yield data are from table 15, standing crop data from table 24.

Pond	Standing Crop, Pounds per Acre	Annual Hook-and-Line Yield, Pounds per Acre		Yield as a Percentage of Standing Crop	
		1952	1950–1952 Average	1952	1950–1952 Average
Fertilized					
Lauderdale	318	88	70	28	22
Hooker	255	27	50	11	20
Phelps	302	58	48	19	16
Average	...	...	...	*20**	*19**
Unfertilized					
Wells	237	39	30	16	13
Boaz	308	42	27	14	9
Elam	169	32	26	19	15
Average	...	...	...	*16**	*12**

*Average of three percentages directly above.

fish of desirable sizes is the one likely to provide the best fishing. However, surprisingly little correlation was found between numbers of bass and bluegills of

Table 26.—The 1952 hook-and-line yield of largemouth bass (number and pounds per acre) as a percentage of the 1953 rotenone census figure in each of the Dixon Springs ponds; also the ratio of fertilized to unfertilized ponds in number and pounds of bass per acre. Basic data are from tables 15 and 24.

Pond	Largemouth Bass 10-inches or Larger, 1953 Rotenone Census		Largemouth Bass Yield, 1952 Fishing Season*		1952 Yield as a Percentage of 1953 Census Figure	
	Number Per Acre	Pounds Per Acre	Number Per Acre	Pounds Per Acre	Number Per Acre	Pounds Per Acre
FERTILIZED						
Lauderdale....	58	70	36	25	62	36
Hooker.......	49	43	14	7	29	16
Phelps........	64	67	12	9	19	13
Average.......	*57*	*60*	*21*	*14*	*37*†	*22*†
UNFERTILIZED						
Wells.........	55	45	25	23	45	51
Boaz.........	59	62	40	33	68	53
Elam.........	24	21	12	9	50	43
Average.......	*46*	*43*	*26*	*22*	*54*†	*49*†
Fertilized / Unfertilized	1.24 / 1.00	1.40 / 1.00	0.81 / 1.00	0.64 / 1.00	....	....

*The hook-and-line yields of bass from Lauderdale and Wells were made up of fish measuring at least 10.0 inches total length. No measurements of bass caught by permit fishermen were recorded, but these fishermen were supposed not to keep bass less than 10.0 inches in length.
†Average of three percentages directly above.

Table 27.—The 1952 hook-and-line yield of bluegills (number and pounds per acre) as a percentage of the 1953 rotenone census figure for each of the Dixon Springs ponds; also the ratio of fertilized to unfertilized ponds in number and pounds of bluegills per acre. Basic data are from tables 15 and 24.

Pond	Bluegills 6 Inches or Larger, 1953 Rotenone Census		Bluegill Yield, 1952 Fishing Season*		1952 Yield as a Percentage of 1953 Census Figure	
	Number Per Acre	Pounds Per Acre	Number Per Acre	Pounds Per Acre	Number Per Acre	Pounds Per Acre
FERTILIZED						
Lauderdale....	463	129	223	63	48	49
Hooker.......	629	147	72	20	11	14
Phelps........	706	146	160	49	23	34
Average.......	*599*	*141*	*151*	*44*	*27*†	*32*†
UNFERTILIZED						
Wells.........	463	108	59	16	13	15
Boaz.........	624	133	35	9	6	7
Elam.........	442	81	114	23	26	28
Average.......	*510*	*107*	*69*	*16*	*15*†	*17*†
Fertilized / Unfertilized	1.18 / 1.00	1.31 / 1.00	2.19 / 1.00	2.75 / 1.00	....	....

*The hook-and-line yields of bluegills from Lauderdale and Wells were made up of bluegills measuring at least 6.0 inches total length. The sizes of fish taken from the other ponds were not governed by restrictions on fishermen.
†Average of three percentages directly above.

desirable sizes in the several ponds in the 1953 census and the record of fishing success in the same ponds in the preceding years, tables 26–29. Lauderdale, the pond

Table 28.—Number and pounds (per acre) of largemouth bass of at least 10.0 inches total length in the 1953 rotenone census, the hook-and-line catch rate for 1952, and the average annual hook-and-line catch rate for 1950–1952 in each of the Dixon Springs ponds; also the ratio of fertilized to unfertilized ponds in number and pounds of bass per acre and per hour. Basic data are from tables 20 and 24.

Pond	Largemouth Bass 10 Inches or Larger, 1953 Rotenone Census		Largemouth Bass, Catch Per Man-Hour*			
			1952		1950–1952 Average	
	Number Per Acre	Pounds Per Acre	Number Per Hour	Pounds Per Hour	Number Per Hour	Pounds Per Hour
Fertilized						
Lauderdale....	58	70	0.62	0.43	0.50	0.35
Hooker.......	49	43	0.12	0.06	0.14	0.08
Phelps........	64	67	0.08	0.06	0.12	0.08
Average.......	*57*	*60*	*0.27*	*0.18*	*0.25*	*0.17*
Unfertilized						
Wells.........	55	45	0.52	0.48	0.39	0.32
Boaz.........	59	62	0.36	0.30	0.31	0.22
Elam.........	24	21	0.21	0.16	0.30	0.21
Average.......	*46*	*43*	*0.36*	*0.31*	*0.33*	*0.25*
Fertilized / Unfertilized	1.24 / 1.00	1.40 / 1.00	0.75 / 1.00	0.58 / 1.00	0.76 / 1.00	0.68 / 1.00

*Information on the sizes of bass in the catch is in the first footnote to table 26.

Table 29.—Number and pounds (per acre) of bluegills of at least 6.0 inches total length in the 1953 rotenone census, the hook-and-line catch rate for 1952, and the average annual hook-and-line catch rate for 1950–1952 in each of the Dixon Springs ponds; also the ratio of fertilized to unfertilized ponds in number and pounds of bluegills per acre and per hour. Basic data are from tables 20 and 24.

Pond	Bluegills 6 Inches or Larger, 1953 Rotenone Census		Bluegills, Catch Per Man-Hour*			
			1952		1950–1952 Average	
	Number Per Acre	Pounds Per Acre	Number Per Hour	Pounds Per Hour	Number Per Hour	Pounds Per Hour
Fertilized						
Lauderdale....	463	129	3.87	1.09	3.05	0.88
Hooker.......	629	147	0.60	0.16	1.15	0.32
Phelps........	706	146	1.06	0.32	1.03	0.32
Average.......	*599*	*141*	*1.84*	*0.52*	*1.74*	*0.51*
Unfertilized						
Wells.........	463	108	1.24	0.35	1.25	0.31
Boaz.........	624	133	0.32	0.08	0.89	0.18
Elam.........	442	81	1.97	0.40	1.55	0.32
Average.......	*510*	*107*	*1.18*	*0.28*	*1.23*	*0.27*
Fertilized / Unfertilized.....	1.17 / 1.00	1.32 / 1.00	1.56 / 1.00	1.86 / 1.00	1.41 / 1.00	1.85 / 1.00

*Information on sizes of bluegills in the catch is in the first footnote to table 27.

that had generally furnished the highest yields and catch rates did not at the time of the census contain the largest population of fish of desirable sizes, while Phelps, which had consistently furnished poorer fishing than Lauderdale, contained a relatively large population of bass and bluegills of desirable sizes, tables 28 and 29.

Assuming that our data were adequate for the comparison just made, we may conclude that our failure to find a closer relationship between standing crops and fishing success was due to one or both of the following reasons: (1) the standing crops were not the same in all years of the experiment; (2) catch rates were greatly affected by some factor other than the size of the standing crops.

FIELD FERTILIZATION AND FISHING SUCCESS

The application of chemical fertilizers to fields draining into ponds is sometimes thought to be a benefit to fish production and fishing in such bodies of water. This line of thinking is consistent with the widely accepted idea that fertility of the land comprising the watershed of a lake or river has a profound effect on fish production. Little has been said in the literature of pond fertilization, however, concerning the extent of the benefits to pond fishing that may be derived from watershed treatment.

The quantity of fertilizer that might reach a pond in runoff from its watershed would vary from one pond to another and would be difficult to estimate. It would depend, for example, on the size of watershed, the kind and amount of fertilizer used, and the extent to which it was mixed with the soil as it was applied. It would also depend on the time lapse between fertilizer applications and occurrence of rainstorms, the severity of the storms, the tendency of the soil to erode, and the density of protective vegetation. Part of the fertilizer washed from fields into ponds would later be lost over the pond spillway.

Phosphorus applied to fields as rock phosphate is slowly soluble and, theoretically, would be of less benefit to a pond than phosphorus applied as superphosphate, which is readily soluble. However, phosphorus applied to fields in the form of superphosphate combines rapidly, in the presence of moisture, with elements in the soil to form slowly soluble calcium phosphate and relatively insoluble compounds with iron and aluminum. Except for the superphosphate that might be washed from a field into a pond very soon after a soil treatment, the phosphorus carried into a pond from its watershed would be in a relatively insoluble state. Nitrogen and potassium would be present in runoff for a comparatively short time, probably less than a year. Nitrogen is taken up quickly by plants or is lost into the air, while potassium salts tend to leach downward into the soil, where they cannot be removed by water running over the soil surface.

In the period 1935–1937, previous to the beginning of the study reported here, fields surrounding each of the Dixon Springs ponds were given an application of crushed limestone, and fields surrounding three of the six ponds (Lauderdale, Wells, and Elam) were treated with superphosphate, table 5.

In the course of the study, the watershed of each pond was again treated with crushed limestone; for the first time each watershed was treated with rock phosphate and each watershed except that of Phelps was treated one or more times with chemical fertilizers supplying nitrogen, phosphorus, and potassium, separately or all three in combination, table 5. Barnyard manure was applied to one of the fields.

Actual demonstrations of the effect, on fishing success, of crushed limestone aoplied to ponds or pond watersheds in the United States seem to be lacking. In Europe, Schaeperclaus (1933:162) reported that applying lime to pond bottoms protects the health of fish and produces favorable "biological conditions, which react to increase the yield." Because the watersheds of all Dixon Springs ponds received approximately equal applications of limestone, no conclusions can be drawn as to what effect, if any, liming of the watersheds had on fishing success in these ponds.

Although phosphorus is generally believed to be important as a pond fertilizer, its value to fishing when applied to pond watersheds is difficult or impossible to determine from data gathered in the Dixon Springs experiment.

The water of Boaz, the only control pond that had no record of superphosphate, rock phosphate, or complete fertilizer application to its watershed until 1949, had a higher phosphate content in 1947 than the water of any of the other five ponds at Dixon Springs, table 3.

It is interesting to compare catch rates in Boaz with catch rates in the other control ponds before rock phosphate was applied to part of the Boaz watershed in the fall of 1949. Superphosphate had been applied to the Elam watershed in 1936 and to the Wells watershed in 1937. In the years 1947–1949, bass fishing was not so good in Boaz as in Wells or Elam. In 1948 and 1949, bluegill fishing was slightly better in Boaz than in Wells but not quite so good as in Elam, table 30.

Table 30.—Catch rates (number and pounds of fish removed per hour of fishing) at Dixon Springs ponds, 1947–1952. Years in which fertilizers were applied to pond watersheds are indicated by S (for spring preceding the fishing season) and F (for fall near the end of the fishing season). Data are from table 20. Additional data on watershed fertilization are in table 5.

Pond	Year	Largemouth Bass		Bluegills	
		Number Per Hour	Pounds Per Hour	Number Per Hour	Pounds Per Hour
FERTILIZED					
Lauderdale	1947	1.21	0.72	...	...
	1948	0.22	0.16	1.86	0.39
	1949	0.32	0.18	1.29	0.32
	1950F	0.64	0.43	2.62	0.68
	1951	0.23	0.19	2.65	0.85
	1952SF	0.62	0.43	3.87	1.09
Hooker	1947	0.08	0.05	...	...
	1948	0.12	0.09	0.87	0.21
	1949S*F*	0.14	0.09	0.59	0.17
	1950	0.12	0.07	0.82	0.26
	1951F*	0.17	0.10	2.02	0.55
	1952	0.12	0.06	0.60	0.16
Phelps	1947	0.06	0.03	...	...
	1948F	0.14	0.06	0.37	0.09
	1949	0.15	0.08	1.33	0.36
	1950	0.14	0.07	0.96	0.31
	1951	0.13	0.10	1.08	0.33
	1952	0.08	0.06	1.06	0.32
UNFERTILIZED					
Wells	1947	0.56	0.41	...	...
	1948	0.18	0.17	0.36	0.08
	1949	0.26	0.16	0.64	0.14
	1950F	0.28	0.20	1.12	0.24
	1951	0.39	0.26	1.39	0.33
	1952F	0.52	0.48	1.24	0.35
Boaz	1947	0.25	0.17	...	...
	1948	0.11	0.13	0.47	0.10
	1949F*	0.09	0.05	0.78	0.16
	1950	0.33	0.19	0.83	0.17
	1951S*F*	0.24	0.16	1.53	0.29
	1952	0.36	0.30	0.32	0.08
Elam	1947	0.32	0.20	...	...
	1948	0.20	0.13	0.68	0.15
	1949	0.16	0.14	0.94	0.16
	1950	0.33	0.21	0.34	0.10
	1951	0.37	0.26	2.35	0.47
	1952SF	0.21	0.16	1.97	0.40

*Only part of watershed treated with fertilizer in this season.

Bass catch rates improved in Wells Pond in 1951, following fertilizer treatment of its watershed in the fall of 1950, and in Boaz Pond in 1950 and 1952, following treatment of half of its watershed in 1949 and the other half in 1951, table 30. A drop in the bass catch rate occurred in Elam Pond in 1952, after treatment of its watershed in the spring of that year.

Bluegill catch rates rose slightly in Boaz in 1950, following treatment of half of its watershed in the fall of 1949, and in Wells Pond in 1951, following treatment of its watershed the previous fall. The bluegill catch rates improved in Boaz in 1951, following treatment of part of the watershed in the spring of that year, but they declined in 1952, after treatment of another part of the watershed in the autumn of 1951. They declined in Elam in 1952, following application of fertilizer to its watershed in the spring of that year.

That the field treatments may not have been the cause of improved bluegill catch rates in Wells is indicated by the trend in catch rates leading up to the field treatment of 1950; bluegill catch rates were showing year-to-year improvement before this treatment.

Examination of the catch rates for the directly fertilized ponds, Lauderdale, Hooker, and Phelps, in the fishing seasons following both direct and indirect fertilization shows that in some cases bluegill fishing was better in the season after a field treatment than before, table 30. However, in most of the cases the improved fishing could have been caused by the increased rates of pond fertilization, which were begun in the spring of 1950, rather than by the field fertilization.

While the evidence that field fertilization may have helped fishing in the Dixon Springs ponds is inconclusive, we should perhaps state our conclusion on pond fertilization as follows: that, in addition to any improvement in fishing success that might have resulted from watershed treatments, there is evidence of improvement in bluegill fishing from direct fertilization of the ponds. The pond owner who strives for better bluegill fishing should therefore not depend upon field fertilization, but should apply fertilizer directly to the pond.

ECONOMICS OF POND FERTILIZATION

Some pond owners will be interested in knowing whether the higher fish yields from fertilized ponds offset the cost of the fertilizers.

At current (1960) prices quoted by dealers in farm fertilizers, the treatments used on the Dixon Springs ponds in 1947–1949 would cost approximately \$10 per surface acre of water per year; the various treatments used on the three ponds in 1950 would average close to \$15 an acre, and the treatments used in 1951–1953 would cost \$20 per acre per year. In the following computations, cost for fertilizing the ponds does not include wages for men to do the mixing and spreading.

For the 5-year period 1948–1952, the average annual hook-and-line yield (bass and bluegills combined) from the fertilized ponds was 48 pounds per acre and from the control ponds 25 pounds per acre, table 16. Although the fertilized ponds were fished somewhat more heavily than the controls, we will assume that most of the 23 pounds greater annual yield of the fertilized ponds was attributable to fertilization. Dressed weights of bass and bluegills would amount to about two-thirds of their live weights. The 23 pounds additional fish yield would therefore shrink to about 15 pounds in dressing. The average yearly cost for fertilizer over the 5 years, 1948–1952, was about \$15 per acre; therefore the cost of the extra yield was approximately \$1.00 per pound of dressed fish.

Using data in table 16, we can make a similar computation for the same period for certain fertilized and unfertilized ponds having nearly equal fishing pressures: Lauderdale and Phelps to represent the fertilized ponds, Wells and Boaz the untreated ponds. The total fishing pressure for the two fertilized ponds (164 hours per acre per year) was nearly the same as that for the two control ponds (157 hours per acre per year). The per-acre yield averaged 47 pounds annually from the two fertilized ponds, 28 pounds annually from the two controls, a difference of 19 pounds as live fish or 13 pounds as dressed fish. Here the larger yield of the fertilized ponds was obtained at a cost of about $1.15 per pound of dressed fish.

Using selected data in table 15, we can compare costs for the periods of comparatively light and comparatively heavy fertilizer treatments. In the following computations, we have omitted data for 1947, as before, and have also omitted data for 1950, when the three ponds were fertilized at three different rates. For 1948 and 1949, the annual yields from the fertilized ponds averaged 15 pounds per acre more than the yields from the controls—10 pounds in terms of dressed fish. Since the annual cost of fertilizer in 1948 and 1949 was about $10 per acre, the additional yield of dressed fish cost approximately $1.00 per pound. For 1951 and 1952, the annual yield was 26 pounds greater per acre in the fertilized ponds than in the controls, or 17 pounds dressed weight. The cost of fertilizer during this period was about $20 an acre, making the cost of the additional yield approximately $1.18 per pound of dressed fish.

Also, we can estimate the cost per pound of fish attributed to fertilization in each of 4 years by comparing the records for Lauderdale and Wells, two ponds that were fished at nearly the same rates in most years, especially 1948–1951, and were fished in nearly the same way by the test anglers. As table 15 shows, the per-acre yield of bass and bluegills from Lauderdale was greater than that from Wells by 20 pounds in 1948, 17 pounds in 1949, 42 pounds in 1950, and 30 pounds in 1951. When we divide the appropriate cost figures, $10 an acre in 1948 and 1949, $20 an acre in 1950 and 1951, by the dressed weights (13, 11, 28, and 20 pounds), we find that the greater yields from Lauderdale Pond cost approximately $0.77 a pound in 1948, $0.91 in 1949, $0.71 in 1950, and $1.00 in 1951.

In the vicinity of Dixon Springs, the approximate retail price of dressed carp from the Ohio River is 25 cents a pound, of dressed channel catfish 60 cents a pound. If we were to judge the pond fertilization program at Dixon Springs solely by the dollar and cents food value of the fish produced, we should conclude that fertilization was not economically justified.

However, as a rule pond owners will not base their decisions to fertilize or not to fertilize their ponds solely on economic grounds. Instead, they will base such decisions largely on the belief that fertilization will or will not provide them and their families with more fishing fun.

In some instances, the size of the pond, the type of ownership, and the financial position of the owner will influence the decision. For example, a pond of an acre or more might be left unfertilized and a pond of one-half acre might be fertilized, because the smaller pond requires a smaller outlay for fertilizer. A pond owned by a single individual might be left unfertilized and an equivalent pond owned by a club might be fertilized, because the cost of the club-owned pond can be borne by several members and requires no great outlay for any one individual. A pond might be left unfertilized if owned by a person who has a small cash income, or who fishes principally for food, and an equivalent pond might be fertilized if owned by an individual who has a moderate or large cash income, or who fishes principally for sport.

As the Dixon Springs experiment shows, ponds seem to differ in their responses to fertilization; fertilization might be economically profitable in some ponds but not in others.

ANGLERS' EVALUATION OF PONDS

While we have shown that pond fertilization was of some benefit to bluegill fishing, there is a question whether the differences between fertilized and unfertilized ponds in the quality of fishing were great enough to be detected by fishermen. No comments were heard or reported that would indicate that the permit fishermen thought that Hooker and Phelps (the two permit ponds that were fertilized) provided them with better fishing than the unfertilized permit ponds or other unfertilized ponds in the neighborhood. The test anglers, who visited all six ponds at weekly intervals, generally had the most success at Lauderdale Pond. Their preferences were recorded only after the 1952 fishing season, but it was obvious from our conversations with them that Lauderdale was the favorite among the six ponds.

Charles R. Peters, test angler in 1952, stated that Lauderdale had given him the most pleasure, and he rated the other ponds in the following order: Elam, Phelps, Wells, Boaz, and Hooker. Thus, he ranked the fertilized ponds first, third, and sixth. Examination of his catch records suggests that his reaction to various ponds might have been affected more strongly by his success in catching bluegills than by his success in catching bass.

Use by the public was somewhat more intensive for the two permit ponds that were fertilized (Hooker and Phelps—especially Hooker) than for the two that were not (Boaz and Elam), table 20. It seems doubtful, however, if catch rates were enough higher for the fertilized ponds to explain their greater popularity with fishermen. Hooker and Phelps ponds were seldom as good as the unfertilized ponds for bass fishing and in some years were not so good as one or more unfertilized ponds for bluegill fishing. Time spent by permit fishermen in the 6 years of the experiment totaled 924 hours at Hooker, 374 hours at Phelps, 356 hours at Boaz, and 217 hours at Elam. The 6-year average catch-per-man-hour rate for bass in the most heavily fished fertilized pond (Hooker) was below the rate for the least fished control pond open to the public (Elam). The bluegill fishing in Hooker was inferior to that in Elam in terms of number of fish per hour but essentially the same in pounds per hour.

The differences in fishing pressure on the four permit ponds may have been related to the various inconveniences fishermen put up with in getting to and from each pond, such as the number of gates to be opened and closed, the number of fences to be climbed, or the walking distance to the pond. Hooker Pond was the easiest to reach, Elam Pond the most difficult. The inconveniences of reaching Phelps and Boaz were about equal. Quite possibly the availability of shade, ease of walking around the ponds, and general attractiveness of the ponds were factors that made the fishermen decide to fish certain ponds more often than others. Fishermen were not guided to the fertilized ponds by news releases or other publicity; only a few of them knew that some ponds were being treated.

SUMMARY

1. Six ponds, each of about 1–1½ acres, in southern Illinois were used in an experiment, 1947–1952, to measure the effect of pond fertilization on sport fishing. The effect of fertilization was measured by the sizes of the fish caught, the annual hook-and-line yields, and the catch rates per fisherman-hour.

2. The ponds were stocked with largemouth bass 6 to 10 inches long (total length) and bluegills about 1 inch long.

3. Three of the ponds were treated with chemical fertilizers containing nitrogen, phosphorus, and potassium, in some years at rates less than, and in others at rates approximately equal to, the minimum rate suggested for ponds in Alabama by Swingle & Smith (1942:16–8). The other three ponds (the controls) were not treated.

4. Creel data were obtained through (1) public fishing under a permit system that allowed fishermen relatively free access to four of the ponds and (2) test fishing by anglers (one each year) employed by the Illinois Natural History Survey to fish each of the six ponds for a 2-hour period each week.

5. In 1953, after the ponds had been closed to fishing for a year, the fish in all six ponds were killed with rotenone, and a census was made of the fish population of each pond.

6. Growths of filamentous algae, which appeared on the fertilized ponds in some years, were at times a hindrance to fishermen.

7. Dense stands of a water plant, *Chara* spp., died in the fertilized ponds in the first summer of treatment, while equally dense stands of this plant continued to grow in the control ponds.

8. Blooms of plankton algae were denser and more prolonged in the fertilized than in the control ponds.

9. The bass taken from the fertilized ponds averaged smaller but the bluegills larger than those from the control ponds. Bluegills of 8–8½ inches were more common from fertilized than from unfertilized ponds.

10. During the 5 years of fishing for both bass and bluegills (in the year after the ponds were stocked, bluegills were too

small to be kept), the total harvest of bass, by weight, was slightly less from the fertilized ponds than from the controls; the bluegill harvest from the fertilized ponds was 2.7 times that from the controls. The ratio by weight of bass to bluegills was 1 : 3 in the fertilized ponds, 1 : 1 in the controls.

11. One of the fertilized ponds was superior to all others in both bass and bluegill fishing. The three fertilized ponds ranked 1, 5, and 6 in terms of both number and weight of bass harvested per hour; 1, 3, and 4 in terms of number of bluegills harvested per hour; and 1, 2, and 3 in terms of weight of bluegills harvested per hour.

12. There is a statistical possibility that through chance alone the fertilized ponds would have ranked better than the controls as bluegill fishing ponds even if no fertilizer had been used.

13. No well-defined year-to-year trend in catch rates for bass was observed during the experiment. The trend in bluegill fishing in both fertilized and control ponds was toward year-to-year improvement in the first 4 years of bluegill fishing.

14. The two ponds, one fertilized and one control, with the smallest total number of man-hours of fishing had the highest catch rates of harvestable bass. Under equal or nearly equal fishing pressures, bass fishing was in some instances better in the fertilized ponds, in other instances better in the controls; bluegill fishing was consistently better in the fertilized ponds.

15. In September, 1953, the standing crops of bass and bluegills (all sizes) in the three fertilized ponds averaged 292 pounds per acre, in the three controls 238 pounds per acre (ratio 1.2:1). The number of bass 10 inches or longer was approximately the same in fertilized as in control ponds; the number of bluegills 6 inches or longer was 1.3 times as great in fertilized as in unfertilized ponds.

16. The hook-and-line yields of bass and bluegills in 1952, the last year the ponds were fished, were equivalent to 20 per cent of the 1953 standing crops in the fertilized ponds and 16 per cent of the standing crops in the control ponds.

17. Judged by the populations of fish of desirable sizes present at the time of the 1953 census (bass 10 inches or longer, bluegills 6 inches or longer), the hook-and-line harvest appears to have been more efficient for bass in the control ponds and more efficient for bluegills in the fertilized ponds.

18. Surprisingly little correlation was found between numbers of bass and bluegills of harvestable sizes in the ponds in 1953 and the record of fishing success in the preceding years.

19. The fertilization program used at Dixon Springs was of apparent benefit to bluegill fishing but of doubtful benefit to bass fishing; any benefits derived from direct fertilization of ponds were in addition to benefits that may have resulted from fertilization of the pond watersheds.

20. Comparison of yields from the fertilized and unfertilized ponds at Dixon Springs shows that the greater yields of fish from the fertilized ponds were obtained at costs estimated to range from \$0.71 to \$1.18 a pound.

21. Whether the improvement in the quality of bluegill fishing attributed to fertilization was great enough to be detected by fishermen is questionable for at least two of the three fertilized ponds.

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