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Management of Small Artificial Lakes

A Summary of Fisheries Investigations, 1938–1942

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Above, Illinois Natural History Survey laboratory and instrument pier on Ridge Lake, Fox Ridge State Park, near Charleston, Ill. This new 18-acre artificial lake is an experimental area for limnology and fish management studies. The laboratory is equipped for many phases of lake work and also furnishes living quarters for Survey technicians. The instrument pier, in lake at left, houses recording instruments for air and water temperatures, a rain gage, a water level recorder, and wind direction and velocity indicators. Ridge Lake, which was stocked in the spring of 1941 with largemouth bass only, was opened to public fishing in 1942.

Below, the dam and outlet tower at Ridge Lake, April, 1941, when the lake was beginning to fill. The tower was designed to take care of small rises of water. The water enters the tower at its base, and, when the lake level reaches a point about 3 feet from the top of the tower, the water spills over a partition in the tower and flows through a concrete tunnel to the other side of the dam. A surface spillway (not shown in illustration) carries off flood waters. A valve at the base of the tower allows the lake to be completely drained. The face of the earth dam is shown being rip-rapped with concrete blocks to prevent washing.

Management of Small Artificial Lakes

A Summary of Fisheries Investigations, 1938-1942

GEORGE W. BENNETT

THE management of lakes for fishing should not be confused with fish culture as generally practiced in the United States. Lake management may require the products of fish culture, but its concept is much broader in that it attempts to discover and apply fundamental biological principles and relationships associated with fishes in natural or artificial waters, with the practical object of increasing fish yields and maintaining them. While current literature dealing with the physical, chemical and biological aspects of fish environment is voluminous, little is known concerning the ecological interrelationships of the fishes themselves, and this field offers a great deal of promise to those investigators who are called upon to find a solution to the ever increasing fishing pressure of a recreation-minded public.

Artificial lakes, although often lacking some of the scenic beauty of natural waters, can be made attractive as centers of recreation throughout much of our country. From the standpoint of fish management, they have an advantage over natural waters in that they are usually smaller, and often can be drained or otherwise rid of undesirable fish. However, large natural lakes as well as large artificial lakes are practically beyond the scope of the fish manager, once they become filled with undesirable fish. Large-scale netting operations on such waters may reduce the numbers of these undesirable species, but offer little assurance of permanent improvement.

The material in this paper includes information from several sources. That gathered by Dr. David H. Thompson, Illinois Natural History Survey Zoologist, and the author, from censusing the fish of 22 small artificial lakes in Illinois has been of great value in determining the kinds of fish suited to this type of habitat. It has also revealed some of the causes for poor fish yields, as well as information on the compatibility of various species. Angling records supplemented by hoopnet samples from several lakes provide a means of measuring the effects of underfishing and overfishing on fish populations. The case histories of many experimental lakes in which various combinations of fishes have been stocked suggest the degree of usefulness of the different combinations in fish management.

Objectives of Fish Management

The primary objective of fish management is to produce and maintain "good fishing." A definition of "good fishing" should include the element of numbers of fish caught per unit of time or effort, as well as that of size of individual fish. Numbers and sizes can hardly be defined satisfactorily for all cases, because of variation in the kinds of fish involved as well as in desires of the fishermen. However, the fish manager has need of some criterion useful (although not entirely satisfactory) in comparing the "goodness" of fishing waters. There is some agreement on the criterion of numbers placed at one fish per man-hour. In Illinois, where nearly all catches are bass, crappies, sunfish (centrarchids) or catfish, we have defined "desirable size" for several common species (Bennett, Thompson & Parr 1940, p. 3).

This represents approximately the minimum size for table use. For example, in the bluegill this minimum has been set at 6 inches total length or about 0.25 pound; in the crappie, 8 inches or about 0.30 pound. A suggested definition of a good fishing lake is one which produces an average catch of one fish of desirable size per man-hour of effort during the fishing season, and one which will maintain this rate year after year. Swingle & Smith (1938) in their *Management of Farm Fish Ponds* and in other publications (1939, 1941, 1942) say little about maintaining sustained yields, except through periodic draining and restocking.

The fish manager should have some knowledge of the carrying capacities of his lakes, and the kinds of fish that are present, as well as the intensity of fishing pressure. He can assume through experience some reasonable poundage figure (based on normal increment of the fish and carrying capacity of the lake) for cropping each lake, to serve as a guide in the yearly harvest of fish. Only by controlling the fishing pressure within a minimum range around the actual optimum yield can he have any assurance of sustained good fishing. Moreover, he should have the ability not only to recognize, but to control, certain outside influences which may limit or upset his planned yield. For example, the introduction of rough fish, such as carp and buffalo, through use of bait minnows may in time so restrict the size and abundance of hook-and-line species as greatly to reduce the yearly catch.

The importance of rough fish in limiting good fishing in artificial lakes has often been underestimated or overlooked. When carp or buffalo gain entrance into these lakes, they greatly influence the success of more desirable kinds. A change in the status of the game-fish population may come about through disturbance during the spawning period of the nest-building fishes, or rough fish may cause (through greatly increased turbidity) such a modification of the environment that it becomes unsuitable to the game and pan fish. Roily artificial lakes in Illinois invariably contain many rough fish or bullheads and small numbers of stunted crappies and sunfish. In lakes containing large populations of rough fish, additional stocking of centrarchids will not improve fishing. When the rough fish are entirely removed, the lakes become clear, and there is a marked improvement in size, condition and numbers of the game-fish population.

In some waters poor fishing may be due to an abundance of so-called forage fish, those species that are popularly supposed to serve as food for the desirable game fish. How these limit the numbers of more desirable fish is unknown, but crowding and food competition may be important factors.

Popular misconceptions have led Illinois fishermen or their organizations to insist upon the introduction into artificial lakes of several species of valuable fishes that are not suited to this environment. The most common fishes of this classification are the smallmouth bass and white bass. Other important fishes somewhat less commonly stocked are the walleyed-pike, northern pike, lake trout and muskellunge—the lake fishes of the north. The warm water and low oxygen concentrations seasonally characteristic of artificial lakes insure the early death of such fish. In a few instances in which they managed to survive for a time, they were unable to reproduce successfully.

There are, however, a few species of warm water fish apparently well suited to artificial lakes; these include largemouth bass, crappies, bluegills and bullheads. Upon these the Illinois lake fisherman must depend for angling. Yet problems arise when these fish are used, because of their great reproductive potential and the lack of natural predators. Stunting is the most common cause for poor fishing in artificial lakes stocked with these species. Although the largemouth bass is the most predatory of these fish, it seems unable to control populations of bluegills and crappies without the assistance of heavy hook-and-line fishing.

Evaluation of Species

More than 40 species of fish were found in 22 artificial lakes of Illinois in the course of censusing their fish populations. While most of these lakes furnished little or no fishing for a time previous to renovation, several represented average fishing waters, and a few were producing excellent catches. Past yield and stocking records are vague for many of these lakes. Such information may be gathered from lake owners or fishermen, but at best it is somewhat inaccurate. In a few instances the censuses correlated nicely with verbal historical information. Usually, however, the older waters had been stocked so many times, and from so many sources, that it was impossible to determine the origin of their fish. In a few instances this historical information indicated that unfavorable changes in fishing had taken place within the past 5 or 6 years; earlier these lakes had produced good fishing, but gradually had changed until they produced little or none.

A perusal of fish censuses of the 22 lakes gives information not only as to what species do well in artificial lakes but also something of their potential value in fish management. For example, if green sunfish, *Lepomis cyanellus* Rafinesque, were found in nearly all lakes, but never of sizes large enough to interest fishermen, it might be conceded that stocking this fish in other artificial lakes would offer little in return for the effort. With the purpose of making a rough evaluation of common fishes, the censuses were carefully studied.

Tables 1 and 2 present a partial summary of these lake censuses. Table 1 lists the lakes and ponds with the composition of their fish populations for more common species given as per cents of total weight of fish. Table 2 lists the same lakes and ponds with their locations, areas, types of basins, transparencies in feet at the time their fish populations were removed, and the total poundage of fish removed per acre.

The status of the more important species could have been expressed in table 1 as per cents of the total populations by numbers instead of by weights, but it is felt that the use of weights rather than numbers gives a better indication of the importance of individual species.

The designation of "old" and "new" under types of basins in table 2 is as follows: "New" lakes and ponds are less than 5 years old, while "old" are from 5 to 50 years. The transparencies listed in the next column are only relative, as considerable variation may be found during any year. However, it may be seen that there is some correlation between low transparencies given in table 2, and high percentages of carp, buffalo, bullheads and gizzard shad, listed in table 1. The column "Total Weight of Fish, Pounds per Acre," table 2, is the result of dividing the total poundage of fish taken from the lake by its surface area in acres. It will be noted that the older waters usually support the higher poundages of fish and that lakes containing large percentages of rough and forage fish show greater poundages than those containing mostly desirable fish.

In the following paragraphs, important species are considered separately and on the basis of the census work outlined in tables 1 and 2. The status of each species was determined in each lake where it occurred, and each species was considered in relation to other species present. The arrangement of these fish in the following paragraphs is not systematic.

Largemouth Bass

Huro salmoides (Lacépède)

Contrary to general belief, the largemouth bass does not require a habitat of large size. It was found in 18 of the 22 Illinois lakes censused, and the bass populations averaged better in small than in large lakes, both in numbers and in size of individuals. Population densities varied from a fraction to 129 fish per acre of water. In five lakes, the bass population made up from 14 to 25 per cent of the weight of the total fish population. Only one of these five lakes contained more than a very few rough fish. Forage fish were present in only one of the three lakes containing the highest percentages of bass. Bass made up 25 per cent of the total population (by weight) in a lake that was overfished. Here angling was restricted during the spawning season, but intensive at other times.

In the 13 other lakes in which they were found, bass were less numerous. By weight they represented less than 4 per cent of the fish populations. All of these lakes contained large poundages of rough fish and forage fish (gizzard shad, golden shiners and other minnows) and all but three contained large populations of crappies. Most of these lakes were muddy throughout the year.

Successful largemouth bass populations were found in clear water. Repeated stocking of bass in muddy lakes containing large numbers of rough fish did not increase the bass population permanently. Small bass populations are frequently asso-

Table 1.—Composition of the fish populations of the lakes listed in table 2; for each important species of fish is recorded its per cent by weight of the total fish population of each lake.

Body of Water	Largemouth Bass	Smallmouth Bass	White Crappie	Black Crappie	Bluegill	Warmouth Bass	Green Sunfish	Pumpkinseed Sunfish	Orange-Spotted Sunfish	Yellow Perch	Yellow Bass	Black Bullhead	Yellow Bullhead	Speckled Bullhead	Carp	Redmouth Buffalo	Mongrel Buffalo	Smallmouth Buffalo	Gizzard Shad	Golden Shiner
Weldon Springs Lake	2.9	—	3.6	2.4	2.2	—	tr.	—	tr.	tr.	—	9.3	tr.	—	18.4	—	2.7	—	56.4	tr.
Southside Country Club Lake	2.2	—	3.0	2.7	4.1	tr.	tr.	tr.	—	tr.	2.8	tr.	tr.	tr.	8.6	2.5	1.5	tr.	65.1	5.3
Lower Twin Lake	3.5	—	6.1	4.4	20.3	1.0	tr.	—	—	—	—	tr.	tr.	—	—	13.4	11.4	37.3	—	1.6
Homewood Lake	2.3	—	5.0	2.2	12.4	tr.	1.3	tr.	tr.	tr.	1.2	tr.	tr.	—	18.8	14.7	1.8	—	26.3	1.3
Fork Lake	1.1	—	2.0	—	tr.	tr.	2.1	—	tr.	—	—	40.6	—	—	7.9	37.8	tr.	—	—	5.1
Farmer City Golf Course Lake	3.0	—	tr.	tr.	5.4	tr.	tr.	tr.	tr.	—	—	3.2	tr.	—	26.3	—	—	—	50.1	tr.
Edwards Pond	—	—	—	5.9	—	—	4.8	—	—	—	—	73.4	tr.	—	1.4	—	—	—	—	14.3
Upper Twin Lake	14.8	—	11.0	4.1	26.1	tr.	tr.	—	—	—	—	2.0	1.5	—	—	—	11.9*	5.9†	—	21.2
Crystal Lake Club No. 1 Lake	tr.	—	4.1	tr.	3.9	—	tr.	—	—	—	—	47.3	—	—	32.0	—	—	—	—	5.3
Black Jack Lake	tr.	—	tr.	tr.	2.6	tr.	1.6	—	—	—	—	38.8	tr.	—	42.1	9.7	2.3	—	tr.	tr.
Delta Pond	21.0	—	28.0	—	40.4	10.7		—	—	—	—	—	—	—	—	—	—	—	—	—
Kline's Lake	—	4.3	—	—	—	—	13.1	—	—	—	—	70.0	tr.	—	tr.	—	—	—	—	—
Jack's Lake	tr.	—	38.4	—	tr.	—	20.3	—	—	—	tr.	5.0	—	—	6.5	—	—	—	—	27.7
Shell Lake	—	tr.	1.9	24.9	6.4	—	2.8	—	—	—	—	62.9	—	—	—	—	—	—	—	—
Onized Lake	24.6	—	—	tr.	52.7	6.5	1.5	—	—	—	tr.	tr.	8.4	—	2.7	—	—	—	—	1.6
Waltonian Pond	18.9	—	—	—	20.7	—	57.3	tr.	—	—	—	—	—	—	—	—	—	—	—	—
Buck's Pond	tr.	—	tr.	tr.	tr.	—	tr.	—	tr.	—	—	5.6	tr.	—	16.1	72.8	4.4	tr.	tr.	—
Crystal Lake	—	—	—	1.3	tr.	—	tr.	—	tr.	—	—	4.0	tr.	—	92.6	—	—	—	—	tr.
Duck Pond, Pollywog Association	3.0	tr.	2.2	tr.	8.3	1.1	tr.	—	—	tr.	tr.	tr.	tr.	—	17.2	—	—	—	60.7	tr.
Triangle Pond, Pollywog Association	3.9	—	1.5	tr.	20.1	1.5	tr.	tr.	tr.	tr.	—	tr.	tr.	—	23.3	—	—	—	48.3	tr.
Duck Island Farm Lake	3.1	—	12.3	tr.	3.0	tr.	tr.	—	tr.	tr.	tr.	1.0	tr.	tr.	17.9	49.8	tr.	tr.	8.2	tr.
Sportsmen's Lake	13.8	—	9.8	tr.	6.8	tr.	tr.	—	tr.	tr.	tr.	tr.	tr.	—	1.4	37.2	5.1	tr.	15.2	tr.

tr. = less than 1 per cent. * 2 individual fish. † 1 individual fish.

Table 2.—A summary of the fish censuses of 22 artificial lakes in Illinois, showing lake areas, types of basin, transparency of water, and total poundages of fish collected per acre.

Body of Water	Location	Surface Area, Acres	Type of Basin	Transparency, in Feet*	Total Weight of Fish, Pounds per Acre
Weldon Springs Lake	Near Clinton	12.10	Old reservoir	—	409
Southside Country Club Lake	Near Decatur	8.40	Old reservoir	—	719
Lower Twin Lake	Near Decatur	1.36	Old pond	1.7	778
Homewood Lake	Decatur	2.83	Old pond	1.5	699
Fork Lake	Near Mount Zion	1.38	Old pond	0.6	539
Farmer City Golf Course Lake	Farmer City	0.75	Old pond	1.2	455
Edwards Pond	Near Kincaid	1.00	Old pond	1.0	398
Upper Twin Lake	Near Decatur	1.08	Old pond	0.5	392
Crystal Lake Club No. 1 Lake	Illinois, near Burlington, Iowa	0.75	Old pond	—	358
Black Jack Lake	Illinois, near Burlington, Iowa	4.00	Old pond	—	280
Delta Pond	Jonesboro	0.80	New pond	4.0	234
Kline's Lake	Near Le Roy	1.30	New pond	2.0	230
Jack's Lake	Near Decatur	1.50	New pond	2.3	221
Shell Lake	Near Clinton	1.50	Old pond	0.7	215
Onized Lake	Near Alton	2.14	Old pond	2.5	206
Waltonian Pond	Near Rudemont	1.10	New pond in forest land	3.0	71
Buck's Pond	Near Monticello	8.60	Old oxbow	0.5	1,145
Crystal Lake	Urbana	6.30	Old oxbow	0.8	658
Duck Pond, Pollywog Association	Near Oakwood	3.10	Old strip mine	2.2	673
Triangle Pond, Pollywog Association	Near Oakwood	2.50	Old strip mine	2.1	487
Duck Island Farm Lake	Near Banner	4.90	New gravel pit	1.5	316
Sportsmen's Lake	Near Lincoln	3.70	Old gravel pit	3.0	341
Average		3.23		1.73	446.5

*Secchi disc transparency at time of renovation.

ciated with large crappie populations and vice versa, as crappies seem to be the main competitors of bass.

Smallmouth Bass

Micropterus dolomieu Lacépède

The smallmouth bass is not suited to artificial lakes that depend on surface drainage for water supply. It was present in only 3 of the 22 lakes censused, although it had been stocked in others. One lake contained only two specimens, both of legal size. Another lake of 1.3 acres contained 21 of these fish, the largest weighing 1.25 pounds; a few small ones were collected, indicating partial spawning success. Associated with these smallmouth bass in the 1.3-acre lake were small bullheads, green sunfish and more than 8,500 blunt-nosed minnows.

The smallmouth is common in most Illinois streams and is frequently stocked in artificial lakes from this source. Almost without exception, the species of fish seined from small swift rivers are worthless for stocking lakes, either because they cannot tolerate lake conditions, or because they are of little value in angling. A few smallmouth bass, as well as several spotted bass, were taken from a strip-mine pond in Vermilion County that had been flooded by an adjacent stream.

White Crappie

Pomoxis annularis Rafinesque

The white crappie was present in 17 of the 22 lakes, and in one lake constituted 38 per cent of the total fish population. This species is well suited to artificial lakes and reproduces very successfully. In 13 of the 17 lakes the white crappies were stunted. Fourteen of the lakes contained black crappies as well as white. In all but two, the white crappies were more numerous.

In one lake where the white crappies were of good size (and amounted to 28 per cent of the weight of the population), they were associated with largemouth bass, warmouth bass and bluegills. The most pronounced stunting of white crappies occurred in shallow muddy lakes, where they were associated with large numbers of rough fish. In general, white crappies do well with other centrarchids, but must be thinned at frequent intervals to prevent stunting.

Black Crappie

Pomoxis nigro-maculatus (Le Sueur)

Although black crappies were present in 17 of the 22 lakes, they were usually less numerous than the white and of larger average size. Stunting was common, due to overpopulation and to competition with rough fish. Reproduction in the black crappie seems to be somewhat less successful than in the white. In the overfished lake mentioned in connection with the largemouth bass, the population of black crappies had been greatly reduced in number by two seasons of intensive hook-and-line fishing. In an underfished lake, a badly stunted population of black crappies made up nearly 25 per cent of the total population. Here they were associated with white crappies, bluegills, green sunfish and bullheads. In the lake containing the second largest population of black crappies, this species represented only about 6 per cent of the total weight of fish, and in other lakes it constituted only a small fraction of the total populations (4.4 per cent or less).

Bluegill

Lepomis macrochirus Rafinesque

The bluegill is the most common as well as one of the best fishes for artificial lakes. It was present in 20 of the 22 lakes censused. Associated with other centrarchids, it sometimes makes up as much as half of the population. It stands up under heavy fishing better than any other fish and produces more fish of desirable size than other sunfish. However, because it reproduces in such tremendous numbers, underfishing allows it to become stunted in many waters. In six lakes, bluegills made up from 20 to 53 per cent of the weight. Smaller percentages of bluegills were associated with large populations of rough fish, forage fish and bullheads. Stunting was common under these conditions.

Warmouth Bass

Chaenobryttus gulosus (Cuvier)

The warmouth, present in 13 of the 22 lakes, is much less desirable than the bluegill. By weight it never represented more than 11 per cent of any population and usually much less. This species shows a wide range of sizes among individuals belonging to a single brood, a peculiarity similar to that found in the largemouth bass. In most lakes, only a small number of fish were large enough to interest fishermen, while the greater number were small. The ratio was about one or two large fish to several hundred small ones. For all practical purposes the warmouth bass adds little to the fish populations of artificial lakes in Illinois.

Green Sunfish

Lepomis cyanellus Rafinesque

The green sunfish, found in 21 of the 22 lakes, is the species most frequently introduced into lakes from small streams. In lakes it multiplies very successfully, but seldom produces fish of desirable size. In four newly constructed and improperly stocked lakes, it made up from 5 to 57 per cent of the fish populations. The entire populations of many lakes did not include any green sunfish large enough for angling. The green sunfish must be considered detrimental in artificial lakes, because it competes with more desirable fish and usually does not reach an attractive size itself. This voracious fish remains close to shore and makes bank fishing for more desirable kinds difficult.

Pumpkinseed Sunfish

Lepomis gibbosus (Linnaeus)

The pumpkinseed was found in only 5 of the 22 lakes. It was never numerous and rarely of good size. Although somewhat more desirable than the green sunfish, it is much less so than the bluegill.

Orange-Spotted Sunfish

Lepomis humilis (Girard)

Although present in 9 of the 22 lakes, the orange-spotted sunfish never grows to a desirable size and should never be stocked in artificial lakes. In one recorded instance, fish of this species reached an estimated population of 15,000 per acre and crowded out other centrarchids.

Yellow Perch

Perca flavescens (Mitchill)

The yellow perch, common in artificial lakes of some western states, does poorly in Illinois. In 7 of the 22 lakes censused, it was represented by a few individuals of small size. It seems unable to spawn successfully in Illinois lakes and adds little or nothing to fishing.

Yellow Bass

Morone interrupta Gill

The yellow bass was found in 7 of the 22 lakes. In only one instance had it reproduced successfully. The yellow bass populations were made up of a few individuals large enough to interest panfish anglers. Because of its inability to reproduce successfully, and its small average size, this fish is of little value in small artificial lakes in Illinois.

Black Bullhead

Ameiurus melas melas (Rafinesque)

The black bullhead was found in 20 of the 22 lakes. It is a fish well suited to artificial lakes and of importance in lake management. Large populations of stunted fish are common and often necessitate artificial thinning in order to produce bullheads of good size. In 6 of the 20 lakes, populations of black bullheads made up from 39 to 73 per cent of the weight of fish present. Bullheads of large size were found in lakes containing small numbers of these fish. The bullhead is desirable not only because it reproduces successfully, but because it bites readily and is easily taken by inexperienced fishermen. Although it tends to keep shallow lakes and ponds roily, it will survive under unfavorable conditions longer than most other Illinois fish.

Yellow Bullhead

Ameiurus natalis natalis (Le Sueur)

The yellow bullhead, less common than the black in artificial lakes, was present in 16 of the 22 lakes censused. Populations in this species are usually much smaller than in the black. In 5 lakes it made up from 0.4 to 8.4 per cent of the total fish population; only a few were present in the other 11 lakes. Black and yellow bullheads are often found together, but in most lakes the blacks are more numerous. The yellow bullhead seems less likely to become overnumerous and stunted than the black species, but it is somewhat less desirable as a pan fish.

Speckled Bullhead

Ameiurus nebulosus marmoratus (Le Sueur)

The speckled bullhead, common in the Illinois River and connecting bottomland lakes, was taken from only 2 of the 22 artificial lakes. One of these had been recently flooded by the Illinois River, and the other had received stock from that source. This fish ordinarily does not reproduce successfully in artificial lakes, although some young were found in one instance. It grows well, but cannot be counted upon to maintain its numbers.

Carp

Cyprinus carpio Linnaeus

Carp were found in 17 of the 22 lakes, although no records could be found that any of these lakes had been stocked with this fish. In several lakes flooded occasionally by rivers, they could have entered with flood waters. Young carp are sometimes introduced through the use of live bait; and the adults swim upstream and jump the spillways into many lakes during high water. In no lake was a large carp population found with a good game-fish population. Always where carp were numerous, the hook-and-line fish were not only small in numbers, but were small in size and in poor condition. In several lakes a small number of large carp were present. This seems to indicate that young are not produced every year, or if produced do not survive. Carp and buffalo are responsible for much of the roily condition of the water in artificial lakes, as their removal is always followed by a pronounced increase in transparency.

Redmouth Buffalo

Megastomatobus cyprinella (Valenciennes)

Eight of the 22 lakes contained redmouth buffalo, constituting from 2.5 to 73 per cent of their total populations. These and other kinds of buffalo enter lakes on flood waters. Sometimes, however, lakes containing these fish were some distance from rivers and it is impossible to say how they had entered, unless through irresponsible stocking.

Mongrel Buffalo

Ictiobus niger (Rafinesque)

Ten of the 22 lakes contained this species, although it was rarely as numerous as the redmouth. The mongrel buffalo made up from 0.4 to 12 per cent of the populations containing them.

Smallmouth Buffalo

Ictiobus bubalus (Rafinesque)

Smallmouth buffaloes were present in 6 of the 22 lakes and were usually large in size. Two fish from Upper Twin Lake averaged 25 pounds each; 24 fish averaging 12.1 pounds each made up 37 per cent of the fish population of Lower Twin Lake. This buffalo is usually less numerous than the other two, but all three often are found together. The buffaloes should be excluded from artificial lakes, as they are rarely caught on hook-and-line and, like the carp, are associated with roily water and poor populations of game and pan fish.

Gizzard Shad

Dorosoma cepedianum (Le Sueur)

Gizzard shad were present in 10 of the 22 lakes. In some cases they were introduced by floods from nearby streams. In others they were stocked as forage fish. They are not satisfactory for this purpose in artificial lakes because they reproduce in tremendous numbers and rapidly become too large to be eaten by the game fish present. In almost every case, large shad populations were associated with small numbers of bass. In 5 of the 10 lakes the shad constituted from 48 to 65 per cent of the entire fish populations (by weight), and the game and pan fish were small and stunted. This species is obviously not useful in artificial lake management.

Golden Shiner

Notemigonus crysoleucas auratus (Rafinesque)

The golden shiner, found in 17 of the 22 lakes, was probably introduced as forage for bass. In these lakes there was no correlation between good bass populations and an abundance of golden shiners. In the six lakes containing the largest numbers of shiners, only one was maintaining a good bass population. Shiners may serve as forage fish when they are small, but often become too large to be useful. They seem to serve little purpose in artificial lakes and they compete with more desirable fish for food.

Other Fish

Other fish found in small numbers in one or several of the 22 Illinois lakes censused are listed in table 3. Most of these species are relatively unimportant, either because of their lack of angling value, inability to compete with other species or inability to reproduce successfully in the artificial lake habitat. The list contains several fish of economic importance, namely the channel and flathead cats, white bass and sheepshead, which are unable to maintain their numbers. It also includes several minnows of relatively small size which reproduce successfully and are therefore suitable as forage species for bass and crappies, if furnished adequate protection.

Many of these fish were introduced into the lakes through actual flooding of these bodies of water by nearby streams in times of high water. When the water receded the stream fish were left stranded in the lakes. Others probably represent escaped bait, brought in by fishermen.

Small numbers of hybrid sunfish were present in six lakes. Most of these were

Table 3.—List of fishes of lesser importance in the 22 artificial lakes listed in table 2; showing occurrence, per cent of total fish populations by weight, number per acre, and ability to reproduce in small artificial lakes.

KIND OF FISH	SCIENTIFIC NAME	OCCURRENCE, NUMBER OF LAKES	PER CENT OF TOTAL POPULATION BY WEIGHT, RANGE	NUMBER PER ACRE IN MAXIMUM POPULATION	ABILITY TO REPRODUCE
Bowfin	*Amia calva* Linnaeus	2	4.5–tr.	4	Moderate
Quillback	*Carpiodes cyprinus* (Le Sueur)	8	5.0–tr.	23	Good
Common sucker	*Catostomus commersonii* (Lacépède)	8	tr.	8	Poor
Chub sucker	*Erimyzon sucetta kennerlii* (Girard)	4	tr.	1—	Poor
Spotted sucker	*Minytrema melanops* (Rafinesque)	5	6.5–tr.	50	Moderate
Northern redhorse	*Moxostoma aureolum* (Le Sueur)	4	tr.	1	None?
Silver redhorse	*Moxostoma anisurum* (Rafinesque)	1	tr.	1—	None?
Horned dace	*Semotilus a. atromaculatus* (Mitchill)	3	tr.	1—	None
Common shiner	*Notropis cornutus* (Rafinesque)	2	tr.	1—	None
Bullhead minnow	*Ceratichthys perspicuus* (Girard)	2	tr.	52+	Moderate?
Blunt-nosed minnow	*Hyborhynchus notatus* (Rafinesque)	4	12.2–tr.	6,674	Excellent
Channel cat	*Ictalurus lacustris punctatus* (Walbaum)	6	7.0–tr.	26	None
Flathead cat	*Pilodictis olivaris* (Rafinesque)	1	tr.	1—	None
Tadpole cat	*Schilbeodes gyrinus* (Mitchill)	4	tr.	80	Moderate
Grass pike	*Esox vermiculatus* Le Sueur	3	tr.	5	None?
Top minnow	*Fundulus notatus* (Rafinesque)	4	tr.	7	Good
White bass	*Lepibema chrysops* (Rafinesque)	1	tr.	1—	None
Log perch	*Percina caprodes* (Rafinesque)	2	tr.	1—	None
Johnny darter	*Boleosoma n. nigrum* (Rafinesque)	1	tr.	1—	None?
Long-eared sunfish	*Lepomis megalotis peltastes* Cope	2	tr.	20	Moderate
Hybrid sunfish	*Lepomis macrochirus* x *L. cyanellus* and others	6	tr.	15	None
Brook silverside	*Labidesthes sicculus sicculus* (Cope)	3	tr.	18	Moderate
Sheepshead	*Aplodinotus grunniens* Rafinesque	4	3.4–tr.	57	?

tr. = trace.

bluegill x green sunfish, and bluegill x pumpkinseed sunfish with smaller numbers of bluegill x warmouth bass. In one lake some of the hybrids were larger than the largest parent types.

Cropping

A satisfactory yield of hook-and-line fish may be taken from an artificial lake when adequate numbers of fast-growing fish are present. Swingle & Smith (1939, 1941, 1942) and others have indicated that the carrying capacity of a lake depends upon its fertility, and that the use of fertilizers will increase the number of pounds of fish a lake will support. However, the application of fertilizers to lakes is expensive and in Illinois may be impractical or unnecessary. There is little object in adding fertilizers to a lake unless the surrounding soil is very poor, or the fishing intensity demands a heavy fish production. Fertilizers added to an uncropped lake are wasted. Artificial ponds on rich land cannot be fertilized without indirectly endangering the survival of fish, as fertilizers reduce the amount of dissolved oxygen in the water. Swingle & Smith (1941, p. 221), working on artificial lakes in Alabama, state that high fish production cannot be maintained over a period of years without fertilization. In Illinois, however, high production has been maintained in some artificial lakes for many years without the use of fertilizers.

Several farm ponds recently built by the U. S. Soil Conservation Service in Illinois have been located below barn lots so that these lots may act as sources of fertilizer. Lakes thus located are usually on eroded soil. They are benefited by the inwash of animal waste, provided precautions outlined by the Service are followed; that is, by-passing of barnyard drainage, so that it cannot flush directly into the pond, and adequate planting and protection of steep hillsides adjacent to the ponds, fig. 1. In two instances, however, adequate by-passes were not built, and hillsides were not properly protected by the lake owners; as a consequence, fish were unable to survive in the lakes, fig. 2.

Fig. 1.—A farm pond in Adams County, Ill., built by the U. S. Soil Conservation Service. Although located below a barn lot, this pond is protected from yard drainage by a levee. No loss of fish from pollution has ever occurred here.

The observations of Swingle & Smith (1939) in Alabama ponds, and the fish yields for several years from Fork Lake (see section following), indicate that a lake once stocked with fish approaches its maximum carrying capacity within a single year. However, lakes in regions with a short growing season, and large reservoirs stocked with small numbers of fish, may require two seasons.

The carrying capacity of an individual lake may vary with the kinds of fish introduced; a lake reaches its maximum capacity when the most efficient use is made of its food resources.

As a fish population multiplies and its total weight approaches the maximum carrying capacity, the growth rate of the fishes gradually decreases until actual stunting begins. Unless measures are taken to reduce the population, conditions unfavorable to growth will continue, and the lake will produce few fish of desirable sizes. A rapid growth rate must be maintained in order to produce fish of large size before they live out their life span. Therefore, it is obvious that the population level should be held at a figure below the maximum carrying capacity of the lake. In natural waters, especially in those away from human habitation, a continuous reduction of the fish population may come about through predators. These predators are largely absent in artificial waters.

From age analyses of the complete fish populations of several lakes, it has been found that the broods of fish of the several kinds present vary in numbers from year to year. Creel census records over a period of years likewise show fluctuations in the abundance of the various kinds of fish caught. These fluctuations in brood sizes are related not only to the success of spawning but, more especially, to the survival of young fish during their first season. Fluctuations in the numbers of young fish surviving after their first season are a source of trouble to the fish manager. If large broods escape severe losses during the early months of life, their members may grow rapidly until their food requirements begin to tax the food resources of the lake. Then they grow very slowly or become stunted. On the other hand, very small broods may have little food competition and make rapid growth to desirable size, but they may not be numerous enough to bear the fishing load when their members should make up the bulk of the hook-and-line catch. Abnormally large or small broods tend, therefore, to make fishing uncertain. A successful method of cropping must be adjusted to cover these variations.

The average length of life of important pond fishes is variable but, in Illinois, 6 years is near the maximum for most species. Hansen (ms. unpublished), working on the fish of Lake Decatur, reports that dominant broods of crappies and gizzard shad practically disappear in 4 years. Largemouth bass sometimes reach the age of more than 10 years, but few attain this age in the warm waters of artificial lakes. Cropping for high yields, year after year, involves a consideration of the number of broods making up a population. Theoretically these broods (for convenience we will use six) can be arranged to form a pyramid of numbers, such as is illustrated in fig. 3. The brood of the year, forming the base of the pyramid, is the largest. The smallest and oldest brood forms the apex of the pyramid.

It has been estimated by Dr. Thompson, in his work on the bottomland lakes of the Illinois River, and by Dr. D. F. Hansen, Assistant Zoologist of the Illinois Natural History Survey, in his study of Lake Decatur, that the normal or accidental death rate (exclusive of angling) of fishes reduces the numbers of any given brood during the earlier years about one-half within a year's time. If this is true, and if spawning is equally successful in all years, at any given time the number of individuals belonging to a selected brood is twice that of the brood spawned in the preceding year, and one-half as numerous as the one of the following year. As the natural death rate of fish 6 or more years old is very high, cropping should remove all of these older fish, and a fraction of each of the other broods, amounting to at least one-fourth of their total numbers. Some means should be devised for removing a portion of the fingerlings less than a year old and yearlings still too small to be of value for food or angling, fig. 3.

As the crop is being taken, the fish re-

Fig. 2.—A farm pond built by the U. S. Soil Conservation Service in Schuyler County, Ill. Measures outlined by the S. C. S. for by-passing barnyard sewage around the lake were not followed and the first fish stocked died from lack of dissolved oxygen. Later, fencing and planting of the slopes and by-passing most of the runoff from the barn lot so improved water conditions that fish could live.

maining in the lake are growing rapidly and gradually moving up in their relative positions in the pyramid of numbers. The effect of controlled cropping is to hold the total weight of fish present at a level somewhat lower than the maximum carrying capacity of the lake. This cropping insures an abundance of food at all times, which in turn supplies the nourishment necessary for rapid growth. Meanwhile, the population, composed of individuals covering a wide range of sizes, is making efficient use of the food resources. The food resources of a lake are utilized most efficiently when the largest possible percentage goes to produce new flesh and the smallest percentage to maintain metabolism in the fish population. If the lake is overpopulated it is conceivable that all food will be used to maintain metabolism. If it is underpopulated the fish may grow very rapidly but use only a small portion of the available food. Somewhere between these extremes is an optimum population in which the greatest amount of new flesh may be produced from the food resources of an area unit of water.

Several experiments now in progress indicate that this type of cropping reduces the numbers in all broods so that no single brood of any species may dominate the lake. From the standpoint of the angler, the fish grow rapidly, reach large sizes and are numerous enough to maintain good fishing.

The illegality of taking small fish in many states makes the application of this cropping plan difficult. Technicians should make arrangements within their states to demonstrate the effects of this method.

Equal cropping of all broods in a lake assumes that all kinds of fish present are of equal value in fishing. Frequently this is not the case. Often fishermen are aware that a more valuable species is being replaced by one of less value, but are at a loss as to what should be done. In these cases special effort must be made to crop the less desirable species much more heavily than the others, especially among the younger broods.

In the artificial lakes of Illinois, underfishing is a serious problem. As may be seen in fig. 3, underfishing takes a very small slice from the top of the pyramid of numbers. In a lake that has been underfished for several seasons, only the oldest fish are of desirable size. In a lake that is

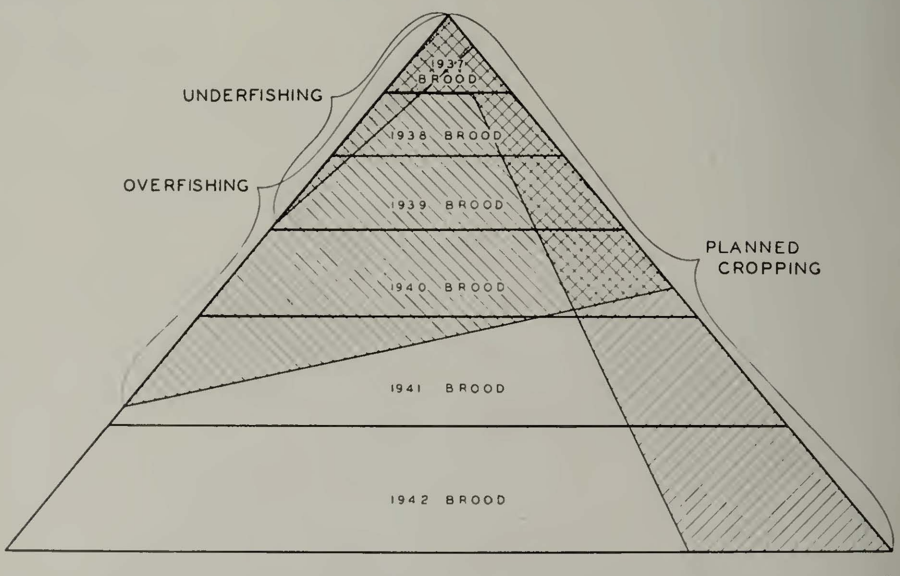

Fig. 3.—Pyramid of numbers representing a theoretical population of fishes in an artificial lake. The population is divided into six annual broods (including all species). Successively smaller sections of the diagram from the base to the apex indicate reduction in the numbers of fish in each brood from natural or accidental causes (exclusive of angling). In an underfished population, anglers remove only a small slice of the pyramid, composed of a fraction of the older broods. Overfishing removes nearly all of the older and larger fish, leaving principally young fish too small to be taken. A theoretical plan of cropping proposes the removal of all of the oldest brood, and a fraction of the other broods equal to approximately one-fourth of each.

underfished, the total poundage of fish remains at or near the maximum carrying capacity of the lake. The fish are living on a subsistence basis and grow very slowly, if they grow at all. Frequently fish that are long enough to interest anglers are so emaciated that they are not kept when caught. Commonly, fish in these crowded lakes are about the same size as fish one-half their age in properly cropped waters.

Although we have records of a number of lakes that have produced high fish yields, in only one instance do we have a complete story of overfishing. In this case, Onized Lake, fig. 4, the body of water was relatively small and the fishing intensity very heavy. During the 1939 fishing season the hook-and-line yield was almost 350 pounds per acre. The yield study covered a period of two seasons and part of a third. The yield was very high during the first season, but lower and lower during the next two seasons. In the middle of the third summer, the remaining fish were censused by poisoning the lake. A comparison of this census with the theoretical pyramid of numbers indicates that overfishing removes the top from the pyramid, fig. 3. The census included a large number of fish, nearly all belonging to the three youngest age groups. Overfishing decreased the catch per manhour as well as the average size of the fish caught, until few fish of desirable size were taken. The effect of overfishing on the growth rate of the population remaining at the time of poisoning is being determined by scale studies. Apparently the young fish that had escaped the anglers were growing exceptionally fast. These young fish were very numerous, suggesting that, as the population thinned, the survival of spawn increased. None of the species present when intensive fishing was begun had been eliminated. Closing the lake to fishing for one season would have allowed many of these young fish to attain

Fig. 4.—Onized Lake on the recreation grounds of the Owens-Illinois Glass Company near Alton, Ill. This lake, which produced a hook-and-line yield of nearly 350 pounds of fish per acre in 1939, represents the only overfished lake ever observed by the Illinois Natural History Survey.

desirable size, and all evidence of overfishing would have disappeared.

In comparing the average size of the fish caught and the catch per man-hour from this lake, while it was overfished, with catches from several underfished waters, a striking similarity was found. In both, the catch per man-hour was low. In both, a very large per cent of the fish caught were small. It is little wonder that the average fisherman confuses underfishing with overfishing. The relation between size and age in fishes is the best criterion for judging the status of a population. For example, scales from 6-inch bluegills taken from an overfished lake show that the fish were less than 2 years old. Scales from bluegills of the same size taken from underfished lakes typically show from four to six annual rings. Laymen can often distinguish between fish from an overpopulated lake and an underpopulated lake by the fact that those from the former are usually thin bodied, have large heads and unusually prominent eyes.

Experimental Combinations of Fish

The meagerness of hook-and-line fishing furnished by many unmanaged artificial lakes leaves little doubt as to the necessity of proper management for the production and maintenance of good fish yields. The more common causes for poor yields are summarized as follows:

1. Indiscriminate stocking—the introduction of fish physiologically unsuited to the artificial lake habitat or those of little or no angling value.
2. Undesirable populations — those in which rough fish or other species not useful in fishing make up a large part of the populations and compete with the hook-and-line species.
3. Overpopulation — as in lakes containing only desirable fish but so densely populated that stunting results, which in turn means poor fishing.

All of these causes may be controlled in small artificial lakes, or in large lakes that can be drained.

Lakes controlled by fishing clubs sometimes produce good sustained yields of fish but, although the yearly crop and the catch per man-hour remain at satisfactory levels, there are great fluctuations in the abundance of the various species from year to year. To fishermen who have preferences in fishing, these fluctuations are perhaps an annoyance. The study made by Thompson (ms. unpublished) of the catch records of Rinaker Lake near Carlinville illustrates the extent of these variations. In Rinaker Lake, where complete catch records are available from 1932 to date, the important species are largemouth bass, white crappies, bluegills and bullheads. The catch of bluegills remained most nearly constant throughout this period of years, at 1.25 to 2.25 pounds per fisherman-day. Good catches of bass were made from 1932 through 1936, and the crappie catch was poor for these years. In 1937 the catch of crappies reached an all-time high of 2.5 pounds per fisherman-day, and the catch of bass was very low (less than 0.25 pound per fisherman-day). Since 1937 the bass catch has been steadily improving and that of crappies decreasing. Bullheads have remained at a low population level throughout all years, but individuals caught are of exceptionally large size. The total hook-and-line yield for this lake has averaged about 4 pounds per fisherman-day and 100 pounds per acre per year during this period.

A more or less constant yield of bluegills, with large fluctuations in catches of crappies, bass and bullheads, seems to be typical of lakes containing these species. Usually, however, when crappies or bullheads reach their peak of abundance they are not taken in sufficient numbers to prevent stunting and to give bass an opportunity to make a "comeback." Fluctuations of this kind make fishing for selected species uncertain. In lakes such as Rinaker, the fish manager should attempt to control the size of broods of young fish produced each year, with the object of maintaining a more nearly uniform proportion among the different species.

The great seasonal variation in the success of fishing for a selected species in lakes containing many kinds of fish has led to experimentation with single species and simple combinations of more important fish. In the stocking of many new ponds and several large reservoirs in Illinois, an attempt is being made to discover some means of maintaining good bass fishing. The combination of largemouth bass and bluegills has the following points in its favor:

1. Both species are well suited to the artificial lake habitat and are much sought by anglers. The largemouth bass is Illinois' most important large game fish, and the bluegill is a favorite pan fish with fly fishermen.

2. The bluegill is very prolific and spawns throughout the summer. Enough young are produced to maintain an adequate population for angling, as well as to furnish forage for bass.

3. There is little food competition between these two species. Bass feed upon young bluegills, crayfish, adult aquatic and terrestrial insects and the nymphs of dragonflies and damselflies; bluegills on entomostraca, midge larvae and aquatic vegetation (particularly algae).

4. The use of these fish allows lakes to remain clear, thereby increasing their recreational and aesthetic value.

A yield study of the bass-bluegill combination was made at Fork Lake, near Mount Zion, Ill. The area of this pond during the past 4 years has varied between 1.00 and 1.38 acres; the maximum depth from 7 to 9 feet, depending on the water level. Two publications give in detail the results of investigations in 1938 and 1939 (Thompson & Bennett 1939; Bennett, Thompson & Parr 1940). In 1938 the lake was poisoned because it contained many undesirable fish, and restocked with 270 stunted adult bluegills and 1,440 largemouth bass fry. No more fish have been placed in the lake since this restocking in 1938. Intensive cropping was begun in 1939, use being made of both hoopnets and hook-and-line fishing. Six 1-inch-mesh hoopnets were fished for 1 week each month from March to November, inclusive, during 1939, 1940, 1941 and part of 1942, and all fish caught were removed from the lake. Hook-and-line fishing was more effective than hoopnets in removing largemouth bass. The total yields for these years are shown in table 4.

Table 4.—Fish yields from Fork Lake, near Mount Zion, Ill., 1939, 1940, 1941 and 1942.*

Year	Bluegills			Largemouth Bass		
	Number	Total Weight, Pounds	Average Weight, Pounds	Number	Total Weight, Pounds	Average Weight, Pounds
1939	940	172.4	0.183	349	51.0	0.146
1940	778	146.2	0.188	217	52.9	0.224
1941	503	71.8	0.145	185	57.3	0.309
1942*	253	37.5	0.148	40	22.7	0.568
Total	2,474	427.9		791	183.9	

Combined yield—3,265 fish, weighing 611.8 pounds.

* Cropped from March through June, 1942.

As the lake was cropped, no attempt was made to protect either bass or bluegills during the spawning season, and the lower size limit of the fish taken was controlled ordinarily by the mesh of the nets used. On some net raises, however, very small fish were trapped when the meshes became bunched. A small number of bluegills less than 2 inches long were caught in this manner. In 1941, the yield of bluegills was smaller than in previous years, although the bass yield was somewhat larger. This small yield of bluegills in 1941 was due in part to the poor survival of bluegill fry until late summer in 1939. During most of the bluegill spawning season in 1939, young bass 5 to 7 inches long fed upon bluegill fry before they left the nests. A field observation on this point was verified by stomach analyses of many bass.

Further analyses of the fish yields for these years show that 39.2 per cent of the bluegills taken in 1939 were of desirable size or larger (6 or more inches); 60.6 per cent in 1940 and 38.4 per cent in 1941. Legal bass (10 inches or larger) made up 0.85 per cent of the catch in 1939; 8.8 per cent in 1940 and 29.5 per cent in 1941.

The largest bluegill taken weighed 0.74 pound, and half-pound bluegills were fairly numerous. The growth of bass was about average for most Illinois waters, fig. 5.

The hook-and-line catch in Fork Lake was 2.84 fish per man-hour in 1939; 3.23 fish per man-hour in 1940 and 2.98 in 1941. This catch was made up almost exclusively of bass, as artificial baits having hooks too large for bluegills were commonly used. The figures on catch per man-hour are based on both illegal and legal bass, as all were kept. The maximum catch was made in April, 1940, when 27 small bass were taken in 2 man-hours of fishing.

Previous to the removal of rough fish and bullheads in 1938, Fork Lake was very muddy and devoid of aquatic vegetation. When these fish were removed and replaced by bass and bluegills, the water cleared and remained clear, and after a few weeks the water weed, *Potamogeton foliosus* Rafinesque, appeared. This weed spread during 1939, 1940 and 1941, until it formed dense mats in all shallow water up to 5 feet in depth. These dense tangles of coarse vegetation offered excellent protection for young bluegills, but very little food. During the summer of 1941 when this vegetation was most abundant, small bluegills and bass of all sizes grew slowly because large numbers of young bluegills swarmed in the plant mats, but found little nourishment, and the bass were unable to use them for food. However, in August the weed practically disappeared within a few weeks and almost concurrently the bass became very fat, probably through assimilation of the overabundant small bluegills.

Higher aquatic plants are a detriment to small artificial lakes in that they promote the survival of too many young fish, fig. 6, and during their growing season they take up nutrient materials and light that would otherwise produce algae, the basic food of the aquatic environment.

On July 8, 1942, the Fork Lake experiment was suddenly terminated by abnormal precipitation. On this date, a rain of approximately 4 inches caused the dam to break near the center, and a part of the

Fig. 5.—Largemouth bass and bluegills from Fork Lake, near Mount Zion, Ill., April, 1941, showing 1938 brood bass and 1938, 1939 and 1940 brood bluegills.

fish population was washed across a cornfield and into a small creek below. By chance Mr. Gernon P. Hesselschwerdt and the author arrived at the lake when about two-thirds of the water had passed out of the basin. The larger fish remaining in the lake at that time were captured pounds. These bass had become so "educated" that few of them would enter hoopnets or bite on artificial baits.

About 30 large bluegills, belonging to the 1938 brood (4 years old; weight between 0.50 and 0.75 pound each) were taken, but most of the bluegills caught in

Fig. 6.—Aquatic vegetation planted by the U. S. Soil Conservation Service around a farm pond in Adams County, Ill. This type of vegetation, while useful in controlling soil erosion, promotes the survival of too many young fish and often becomes so dense that bank fishing is nearly impossible.

by placing a section of hoopnet lead across the break. As it was impossible to estimate the numbers of bass and bluegills that had been washed out of the lake, particular attention was directed to the remnants of the original stock of fish. Thirty-four of the original bass, averaging 1.76 pounds each, were caught in the net and 32 were left stranded in the lake basin. Apparently the initial rush of water through the broken levee was considerable, as corn stalks were flattened over a wide area in the field below the lake. Any fish near the point of break must have been washed out shortly after the dam gave way. It therefore does not seem unreasonable to assume that nearly 100 of the original bass may have been present. The bass population, including the original stock, 1940, 1941 and 1942 broods, probably numbered several thousand. The total weight of those observed was estimated at about 200 the net were 1939 and 1940 brood fish and averaged 6 inches long. Thousands of young bluegills of the 1942 brood were left stranded in beds of *Potamogeton foliosus*. None of the original bluegills were taken.

Fish technicians and sportsmen have long been interested in returns from fish stocked in various waters, but little concrete information is available, except from trout stream investigations.

The recognition of the original stock of bass and bluegills recaptured from Fork Lake was possible because scale samples were taken from all fish. Moreover, as the adult bluegills were 2 or more years old when placed in the lake, they were easily separated from the younger fish. Largemouth bass were stocked as fry in 1938, and no young were spawned until 1940. Thus no difficulty was encountered in distinguishing them from the 1940 and

1941 broods of bass. Table 5 gives the numbers of these fish recaptured in four fishing seasons since the bass and bluegills were placed in Fork Lake.

These returns must be considered nearly "optimum" because the lake contained no other fish when the bass and bluegills were introduced, and food competition was kept at a minimum by constant cropping. The original bluegills could have suffered no predation from the bass as they were always too large to be taken. Smaller returns from the bass are undoubtedly the result of cannibalism during 1938 and 1939.

Fourteen other lakes have been stocked with bass and bluegills and followed as carefully as time would allow. The information from Fork Lake, and other lakes containing bass and bluegills, suggests the following points of interest in regard to the use of this combination:

1. There is a marked improvement in fishing, especially for bass, over that furnished by mixed populations of several species of fish.

2. Under moderate fishing intensity, largemouth bass are unable to control the numbers of bluegills. Therefore, in stocking a new or renovated lake, it is unnecessary and possibly undesirable to stock more breeder bluegills than breeder bass.

3. As bass spawn at the age of 2 years and bluegills at 1 year, it is better to stock both adult bass and adult bluegills, rather than adult bluegills and bass fry or fingerlings less than a year old.

4. A large crayfish population was in evidence in several lakes where bass growth was exceptionally rapid. In lakes poor in crayfish, the bass-bluegill combination might be improved by introducing crustaceans of species locally abundant.

5. Bass and bluegills will maintain their numbers under intensive fishing. It is estimated that Fork Lake was cropped to the extent of about one-half of its carrying capacity for these species during the 4 years covered by the study.

6. In some lakes where the fishing pressure is light, it may be necessary to destroy bluegill nests, or remove substantial numbers of bluegill fry, in order to maintain a rapid growth of this species.

Table 5.—Returns from the original planting of 270 adult bluegills and 1,440 largemouth bass fry in Fork Lake, June, 1938.

Year	Bluegills		Largemouth Bass	
	Number	Per Cent of Original Stock	Number	Per Cent of Original Stock
1939	162	60.0	349	24.2
1940	27	10.0	217	15.1
1941	2	0.7	74	5.1
1942	0	0.0	66*	4.6*
Total	191	70.7	706	49.0

* Collections from March through June plus fish salvaged from washout.

In lakes where bass fishing is of primary interest, attention is being directed toward the use of largemouth bass alone. Ridge Lake, an experimental body of water of about 18 acres, near Charleston, Ill., has been reserved as a study area for this species. Although the bass investigation is less than 2 years old, its progress may be of some interest. The lake, built in the valley of an intermittent stream, began to fill after April 17, 1941. During May, 100 breeder bass were stocked in about 6 acres of water that had collected behind the dam. These fish spawned in early June, and 38 broods of approximately 2,000 fish each, or 76,000 fry, were counted. In July, 336 yearling bass (5 to 7 inches long) were added to reduce the number of young produced in the lake. All fish stocked, both as breeders and yearlings, were fin clipped for later identification.

The growth of the 1941 brood fish produced in the lake has been extremely rapid. Collections made in October, when these fish were 4½ months old, included individuals as large as 10.5 inches, and many were from 8.5 to 10.0 inches. The smallest fish taken was 4.5 inches long. A few of the planted yearling bass were caught and identified by their clipped dorsal fin. These had grown from less than 7 inches at the time of their introduction, to between 11.5 and 12.5 inches by October.

Fig. 7.—Bluegills from a new farm pond built by the U. S. Soil Conservation Service in Adams County, Ill. These fish averaged 0.10 pound when stocked in June of 1939 and 0.72 pound when recaptured, July, 1940. By 1941 this bluegill population had become badly stunted, because of overpopulation resulting from natural spawn. No more large bluegills such as these will be produced in this pond until the population is properly thinned.

Two other experimental lakes, one containing bass and one bass and *Gambusia affinis* (Baird & Girard), are being studied. Neither has been followed long enough to give much pertinent information. However, several inferences based on studies of bass populations in other lakes seem to favor the use of this fish alone or in combination with some minnow of small size:

1. Stunting (4 or 5 years to reach legal length) in bass is apparently rare in Illinois artificial lakes, as no stunted populations, such as frequently occur in small glacial lakes, have been observed. This difference is probably due to a greater variety and abundance of foods, other than fish, that are available.

2. A lake containing only bass should maintain a larger population of these fish than was found in most lakes inhabited by mixed populations. In the lake census work the largest bass population found averaged 58 pounds per acre and this represented only 14.8 per cent of the total fish population (see tables 1 and 2).

3. A single brood of bass may show a great deal of variation in the size of individual fish shortly after the brood becomes scattered. The fact that smaller individuals are eaten by the larger fish of the same brood partially eliminates the danger of dominant slow-growing broods of bass.

4. Although bass fry and fingerlings

are probably not so efficient as some other small fish in utilizing the food resources of a lake, their nutritive value as forage for larger bass is certainly equal to that available from so-called forage species.

5. The use of a single large species like the bass relieves the feeding pressure on the small aquatic animals and may allow the development of stocks of larger predatory invertebrates which furnish food for bass.

6. Reasonable cropping of adults should insure the survival of enough young to maintain a well-balanced population from the standpoint of the theoretical pyramid of numbers.

7. An abundance of crayfish may play a significant role where bass are used alone, as they form an important source of food and thereby increase the survival of young bass.

Other combinations of fishes are being tested in 10 new farm ponds built by the U. S. Soil Conservation Service. These are as follows:

1. White crappies and bluegills.
2. Black crappies and bluegills.
3. White and black crappies and bluegills.
4. Black bullheads and bluegills.

In these lakes, now followed for 3 years, the original stock grew very rapidly, fig. 7, and produced large broods of young during the first year. Young fish were stunted during the second and third years because their food requirements became greater than the lakes could supply. Unless efficient methods of limiting the spawn are intensively applied, the combinations listed above will invariably result in large stunted populations of small fish, valueless to hook-and-line fishermen.

Summary

1. The chief causes for poor hook-and-line fishing in Illinois artificial lakes are past improper stocking, large populations of rough fish, or other species of little value in angling, and stunting as a result of overpopulation.

2. Fishes well suited to Illinois artificial lakes are largemouth bass, white and black crappies, bluegills and black and yellow bullheads. Other fish are apparently of little value in hook-and-line fishing.

3. Lakes should be cropped in order to produce and maintain good yields. A cropping plan should include measures to control the numbers of fish of small size as well as the total poundage of large fish taken by anglers.

4. Simple combinations of fishes are being tested to determine their value in angling. The bass-bluegill combination appears to be one of the most satisfactory. Information on the use of largemouth bass alone is as yet inconclusive. Combinations of crappies and bluegills or bluegills and bullheads result in stunted populations. Unmanaged but heavily fished waters containing bass, crappies, bluegills and bullheads show marked fluctuations in numbers of bass, crappies and bullheads.

LITERATURE CITED

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

Hansen, D. F.
**** Studies on the white crappie, *Pomoxis annularis* Rafinesque, in Illinois. Ms. Unpublished.

Swingle, H. S., and E. V. Smith
1938. Management of farm fish ponds. Ala. Poly. Inst. Ag. Exp. Sta. 6 pp. Mimeographed.
1939. Increasing fish production in ponds. Fourth N. Am. Wildlife Conf. Trans. 4:332-8. Illus.
1941. The management of ponds for the production of game and pan fish. A symposium on hydrobiology, pp. 218-26. Wis. Univ. Press. 5 figs.
1942. Management of farm fish ponds. Ala. Poly. Inst. Ag. Exp. Sta. Bul. 254. 23 pp. Illus.

Thompson, David H., and George W. Bennett
1939. Lake management reports. 2. Fork Lake near Mount Zion, Ill. Ill. Nat. Hist. Surv. Biol. Notes 9. 14 pp. Illus.

Thompson, David H.
**** Creel census of Rinaker Lake near Carlinville, Ill., 1932–1939. Ms. Unpublished.

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