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TECHNIQUES OF FISHPOND MANAGEMENT

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FOREWORD

The program of the Soil Conservation Service is based on the treatment of farms and ranches in their entirety. It involves soil- and water-conservation operations directed at the best use of land and the rain that falls on the land.

Contour cultivation, terracing, strip cropping, and many other practices are used to control erosion and conserve rainfall in the soil for crop use. Rainfall is likewise stored in ponds and reservoirs.

Farm ponds and reservoirs are not only a source of stock water, a refuge for waterfowl, and a home for fur-producing muskrats, but also under suitable conditions they may be made as productive of protein and vitamin-rich food, acre for acre, as is highly developed livestock pasture. To make every acre productive of the crop that it can yield best, the land operator will want to stock properly and manage his pond or reservoir for a crop of food fish.

Farm ponds are already contributing materially to the Nation's wartime food-production program. With proper management they can contribute a great deal more. Managed ponds on American farms and ranches have a potential production of 100 million pounds of palatable fish annually. Every pound of fish so produced supplements our domestic meat requirement and aids in overcoming the pronounced reduction in our supply of marine food fish.

H. H. Bennett, *Chief,*
Soil Conservation Service.

Washington, D. C. Issued November 1943

TECHNIQUES OF FISHPOND MANAGEMENT

By LAWRENCE V. COMPTON, *formerly associate biologist, Biology Division, Soil Conservation Service*

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INTRODUCTION [1]

The raising of pond fish is an old and widespread type of farming in many parts of the world.

In the United States interest in pond fish culture has been local and sporadic. Early efforts were directed almost entirely toward raising carp (*Cyprinus carpio*). Possibly the general disinterest that has existed in the development of farm fishponds has been partly a result of the long-standing impression that the carp is the only fish that can be easily raised. Recent investigations have, however, established successful methods of raising large-mouth black bass, bream, and other equally valuable food fish.

In Europe and in the Orient the culture of pond fish has been an important pursuit for centuries. Ever since the Middle Ages the farmers of France have raised fish for food and fertilizer on flooded grain fields as part of a regular crop rotation (*8*).[2] In 1934 Poland had approximately 185,000 acres of ponds and the total yield from these was estimated to be 22 million pounds of fish (*18*). In the Philippines in 1940 there were 141,564 acres devoted to ponds for raising milkfish (*Chanos chanos*). It was estimated that these ponds produced annually 98 million pounds of fish and that the milkfish industry was worth not less than 50 million pesos (*27*). These figures suggest the importance that fish farming may assume.

Successful fishpond management involves procedures that are contrary to most commonly accepted ideas on fish culture. It has been demonstrated, for example, that the greatest fish production can be obtained when ponds have no rooted aquatic plants, are stocked with

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[1] The material presented here has been gathered from many sources and is a review of the pertinent literature on fish farming. It must be emphasized that many of the procedures of management are those that have been developed by H. S. Swingle and E. V. Smith of the Alabama Agricultural Experiment Station at Auburn to whom the author is indebted for personally discussing and explaining their work and for reviewing the manuscript. O. Lloyd Meehean, T. S. Kibbe, and Eugene W. Surber of the U. S. Fish and Wildlife Service also contributed materially by their review of the manuscript. Further acknowledgment is made to Edward H. Graham, Chief of the Biology Division, Soil Conservation Service, and William R. Van Dersal, formerly of the Biology Division, for stimulating the preparation of this paper and for aiding in its completion.

[2] Italic numbers in parentheses refer to Literature Cited, p. 21.

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comparatively few kinds and numbers of fish, and are fertilized. The elimination of rooted plants is perhaps the most revolutionary of these practices, for it has long been felt that such plants were essential to the production of fish. In this publication are presented some of the underlying principles of fish culture in farm ponds and an outline of management methods that have been tested and proved.

PRODUCTION AND YIELD

There has been little uniformity in the manner of discussing fish production. It is therefore important that the various terms be understood before comparisons are made. The production of fish hatcheries has been customarily stated in number of fry or fingerlings [3] per surface acre of water. Some population studies have also been expressed in number of fish of specified lengths per acre of water. Such figures are approximations since fish of identical length may vary greatly in weight. The weight of a fish depends upon the amount of food that has been available (*24*).

Some production figures have been stated in weight of fish per unit volume of water. This procedure is laborious and may be misleading since in ponds the depth of water has little effect upon the per-acre production (*24*). The results of most of the recent studies in pond-fish production have been stated in weight per acre of surface area and this is the standard used here.

In fish culture, the terms "production" and "yield" have been loosely applied. Each has been used to mean: (1) The amount of fish produced in a given period of time, usually a year, after a pond is newly stocked; (2) the amount of fish in a pond regardless of elapsed time; and (3) the amount of fish that may be harvested from a pond without adversely affecting the breeding stock. Obviously, these are three very different things. Correctly the first is the production, usually stated as an annual average; the second is the standing crop; and the third is the harvestable crop.

THE AQUATIC ENVIRONMENT

The aquatic environment provided by the small pond is rather complicated, yet it lends itself readily to investigation and management. The plants and animals in a pond are dependent upon water for their survival and their wanderings generally are restricted to it or its environs. All are dependent, directly or indirectly, upon the gases and mineral nutrients in the water and in the soil that forms the bottom of the pond. One may, by various means of sampling, determine at any time the species and approximate numbers of the organisms living in it. The composition of plant and animal species may be altered by selective removal or addition and by other management practices. The fertility may be increased by adding fertilizers. Often a pond may be drained and all the aquatic organisms, except those with special means for withstanding desiccation, removed or destroyed; when the pond is refilled such plants and animals as are desired may be returned to it, and much can be done toward prevent-

[3] Fry are very small newly hatched fish; fingerlings are young fish roughly the size of a finger.

ing the re-entry of some of the undesirable forms. A pond is much like a pasture—the amount and kinds of animals and plants may be counted and regulated, and the production of meat may be increased by fertilization.

THE POND

Ponds ranging in size from ¼ acre to 70 acres have been successfully managed with the practices outlined in this publication (*23*). Although large ponds can be managed, the expense and labor involved make it unprofitable for the average individual. Fertilization, stocking, and the control of weeds and mosquitoes are easy in a pond of 1 or 2 acres but are expensive and laborious in large ponds (*13*). These facts should be kept in mind when new ponds are built—a small pond for a family, a large pond for a community or a fishing club. A pond of one-half acre is about as small as is practicable for one family. A pond of this size, if fertilized, will have a carrying capacity of about 250 pounds, and from it there can be caught by hook and line approximately 100 pounds of fish in the course of 1 year. However, if a site for a larger pond is not available, a one-quarter acre pond will provide considerable food and sport for one or two persons. (fig. 1).

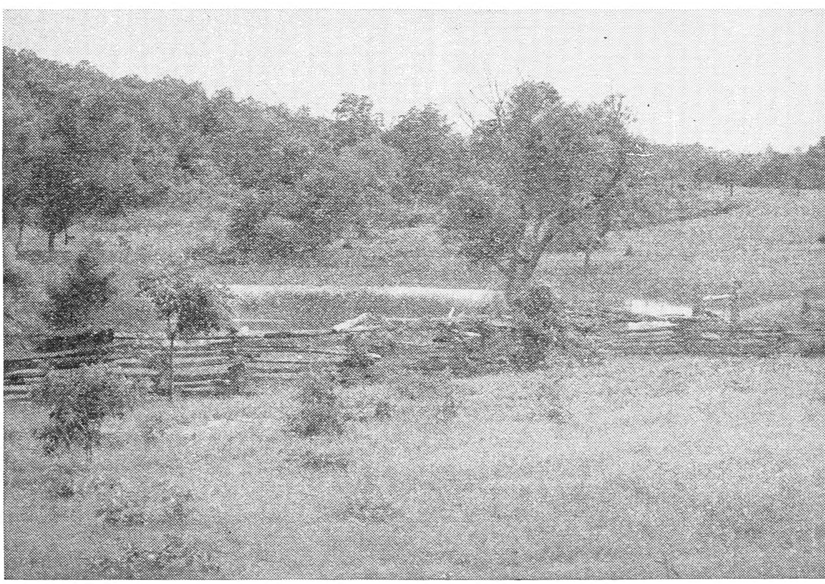

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FIGURE 1.—Even a small farm pond, properly managed, can provide a family with many pounds of fish.

The depth of water at the deepest part should be 6 or more feet and the shore should slope off steeply to about 3 feet so that, with the fluctuation of water level, shore vegetation will not be encouraged. In new ponds, facilities for draining should be provided so that should the fish population become unbalanced or the pond choked with weeds, it may be drained, cleaned, and restocked. Farmers are sometimes concerned about the loss of fish through pond outlets and believe it necessary to screen the outlet. Such losses, however, are seldom serious, and obstructions to overflow water are likely to cause damage to the dam. Special spawning beds and shelters are unnecessary. Pond fish will spawn in adequate numbers without the aid of special facilities. The design of dams and spillways is best determined by an engineer or by reference to instructions to be found in such publications as Low Dams (*9*), Stock-Water Developments (*5*), Fish for Food From Farm Ponds (*4*), and others (*1*, *7*).

Rooted aquatic plants, either emergent or submerged, must not be permitted to become established. These plants and any brush or debris should be removed soon after they appear. Submerged aquatic plants may be killed by applying either of the commercial fertilizers described later, directly over the plants, at monthly intervals during the winter. The addition of fertilizer at this time of the year, at least in the Southeast, results in a heavy growth of filamentous algae which shades the plants and causes them to die (*15*, *16*). The dead weeds will decompose and contribute to the fertility of the water. Rapid decomposition of a large quantity of aquatic plants may reduce the oxygen content of the water to the point where fish will suffocate. Therefore, the application of fertilizer should be discontinued when most of the plants are decaying. This method has been successful in the control of various species of *Najas*, *Potamogeton*, *Nitella*, *Chara*, and *Myriophyllum*.

Ponds with only a small overflow, or none at all, will prove most economical to operate since from these only a small amount of fertilizer and plankton will be lost. Ponds with continuously muddy water have a low natural productivity since sufficient light for the growth of phytoplankton (microscopic water plants) cannot penetrate the water. The productivity of these ponds cannot be profitably improved by fertilization.

FISH FOOD

All animals derive their food, directly or indirectly, from plants because plants convert inorganic mineral matter into living tissue. The mouse eats the grass, and the fox eats the mouse. In water, the same conditions exist, but here it is the microscopic plants and animals known as plankton, instead of the large rooted plants, that are the source of food. In a pond the insect eats the plankton, the bluegill eats the insect, and the bass eats the bluegill. This relationship is sometimes called a food chain.

Plankton is the assemblage of minute, often microscopic, plants and animals that live in water. Collectively, the plants are known as phytoplankton and the animals as zooplankton. The phytoplankton consists mainly of algae which include the diatoms, desmids, green algae, and blue-green algae. It is these organisms that tint pond waters green or brown, make the green scum on the surface, and cause the effect known as water bloom. Bacteria are also part of the phytoplankton, although they usually are quantitatively unimportant as food for other organisms. They are responsible, however, for the decomposition and conversion of dead organic matter into simple chemical compounds available for plant growth (*28*). Since algae convert into organic matter the carbon dioxide, water, and minerals held in solution by the water, the phytoplankton is the basic organic resource of the water and upon it depends the life of all animals in the pond.

The zooplankton consists primarily of protozoans, rotifers, and crustaceans. Most of these animals feed upon microscopic plants or phytoplankton; some are carnivorous and feed on other minute animals. The crustaceans are the largest animals in the zooplankton and include the cladocerans, copepods, and ostracods. They are an important source of food for insect larvae and young fish.

Although phytoplankton is the basic food in a pond, few fish feed directly upon it. The goldfish (*Carassius auratus*) and the golden shiner (*Notemigonus crysoleucas*) feed primarily on plankton organisms, but most pan and sport fish feed on either insects or other fish. The bluegill bream (*Lepomis machrochirus*) and the bullhead (*Ameiurus natalis*) are largely insectivorous. The large-mouth black bass (*Huro salmoides*) and the white crappie (*Pomoxis annularis*) are primarily carnivorous and feed on any fish smaller than themselves. The very young of bluegill bream and of large-mouth black bass feed upon the zooplankton. Soon, though, they start feeding on insect larvae and from that time on, insect larvae are the primary food of the bluegill (table 1). The young bass, however, quickly change to a diet of fish, and when weighing 2 ounces they eat the same type of food as do bass weighing 2 pounds (table 1). Both bluegill bream and large-mouth black bass are predaceous—they feed upon animals and take plants only when there is insufficient animal food (*6*). Aquatic insects, therefore, are the link between plankton and fish.

TABLE 1.—*Food taken from stomachs of bluegill bream and large-mouth black bass* [1] *from ponds in various sections of Alabama* (*6*)

Kind of fish	Food item	Stomachs in which item was first in relative volume	Stomachs in which item occurred
		Percent	*Percent*
Bluegill bream	Water mites	0	4.4
	Mayfly nymphs	6.6	11.1
	Dragonfly nymphs	17.7	33.3
	Damsel fly nymphs	0	2.2
	Waterboatmen	0	6.6
	Waterstriders	2.7	4.4
	Parnid beetles	0	2.2
	Caddisworms	13.3	33.3
	Phantom midge larvae	2.2	11.1
	Blackfly larvae	0	2.2
	Midge larvae	35.5	71.1
	Ceratopogonid larvae	6.6	31.1
	Micro-crustacea	6.6	31.1
	Fish	4.4	11.1
	Plant material	4.4	15.5
Large-mouth black bass	Dragonfly nymphs	20.0	33.3
	Waterboatmen	0	13.3
	Waterstriders	0	6.6
	Midge larvae	0	20.0
	Shrimps	0	6.6
	Micro-crustacea	0	6.6
	Fish	80.0	86.6

[1] Bream weighed 1 ounce or more and bass 2 ounces or more.

The insects commonly found in water are from the groups represented by stone flies, Mayflies, dragonflies, dobson flies, caddisflies, water bugs, water beetles, moths, and true flies. The larvae of these insects are the staple food of insectivorous fish. In Alabama the three most important foods of the bluegill bream are the larvae and pupae of midges, the nymphs of dragonflies, and the larvae of caddisflies (*6*).

Carnivorous fish will eat fish smaller than themselves, whether of another species or of their own. Cannibalism under hatchery conditions is often decried by fish culturists, but it is a normal and essential feature of balanced fish populations in lakes or other bodies of water (*24*). The fish upon which a carnivorous species preys are known as forage fish. If a carnivorous fish is to grow to a size large enough for human use, there must be an adequate supply of forage fish for it to feed upon. It was formerly thought that special forage species, such as the golden shiner, should be available, but the forage species should be one that, when it becomes too large to be eaten by carnivorous fish, will be acceptable as a pan fish. A large golden shiner is worthless since bass cannot eat it and men will not, but a large bluegill is a fine pan fish.

Insofar as managed farm ponds are concerned, the rooted aquatic plants—cattails, waterlilies, and such—are detrimental and should be removed as already stated. The nutrients which they contain are not available to phytoplankton until the plants decay. The leaves and stems of most rooted aquatic plants die in the autumn, decay in the winter, and grow in the summer. Fish grow comparatively little in the winter and during this period are not able to benefit from the nutrients released by the decaying vegetation (*14*, *24*). Thus these plants tie up nutrients during the summer, release them upon decay in the winter, and retake them the following summer. Aquatic plants grow so luxuriantly in warm climates, small ponds, and shallow waters that they often fill a pond, make fishing difficult, cause a mosquito hazard, and provide too much protection to small fish. If the forage fish are protected, the carnivorous fish are unable to capture them and the pond will become overpopulated with small fish. Filamentous algae are also undesirable since they harbor mosquitoes and interfere with fishing.

FISH POPULATIONS

A successful fishpond must produce fish of the kinds and sizes that are acceptable for sport and food. Carp, suckers, and golden shiners are among the kinds known as rough and forage fish. They may be produced in large quantities, but in many places are not considered highly as game or food. The sport and pan fish, such as large-mouth bass, bluegill, and crappie, are lower in productivity.

Rough, pan, and game fish have progressively longer food chains, and their differences in productivity are probably due to the differences in food (*26*). In fertilized ponds in the Southeast, the annual production for plankton feeders, such as golden shiners, was 750 to 1,100 pounds per acre; for insect feeders, such as bluegill and bullhead, it was 500 to 600 pounds per acre; and for carnivorous fish, such as large-mouth bass and white crappie, it was 150 to 200 pounds per acre (*24*). One cannot obtain as large a crop of bass and bluegill as one can of carp, and in making comparisons of pond productivity, it is necessary to consider the kinds of fish being produced.

The number of fish in a pond affects the size to which the fish will grow but not the carrying capacity of the pond (fig. 2). Three fertilized ponds in Alabama were stocked with fingerling bluegill at the rate of 6,400, 3,200, and 1,600 individuals per acre (*19, 24*). At the end of 1 year each pond contained approximately 300 pounds of fish per acre. In the first pond the bluegill averaged 0.8 ounce each; in the second, 1.5 ounces; and in the third, 3.8 ounces. In another experiment, two ponds were stocked with bluegill at the rate of 180,000 and 1,500 per acre. At the end of a year the first pond contained 280 pounds and the second 320 pounds of fish per acre. In the first pond, the fish averaged 0.025 ounce and in the second they were slightly more than 3 ounces. In each of these experiments and in others conducted with large-mouth bass, white crappie, and bullhead, large populations brought decreased size.

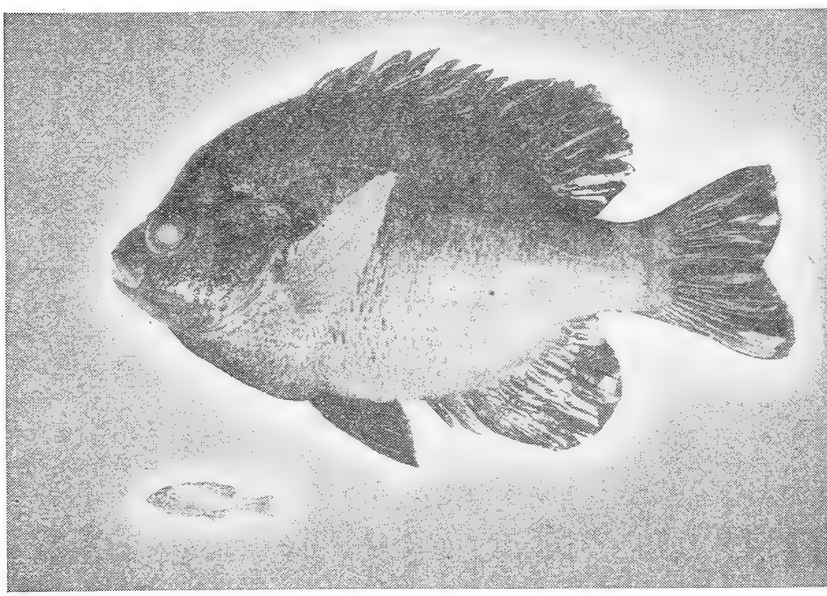

FIGURE 2.—The large bluegill came from a pond stocked at the rate of 1,500 per surface acre and weighed 4 ounces at the end of 1 year. The small one came from a pond stocked with 180,000 bluegill per acre and weighed 0.02 ounce at the end of the same period (after Ala. Agr. Expt. Sta. Bul. 254).

The fish population of artificial as well as natural ponds usually consists of a large number of species and individuals. In Illinois, 9 artificial lakes with a total area of 50 acres had an average standing crop of 600 pounds of fish per acre and contained 46 species of fish (*26*), of which 10 composed 96.5 percent of the crop. The three leading species were red-mouth buffalo, gizzard shad, and carp; these and other rough and forage fish made up 80.9 percent of the crop. The more desirable species, such as bluegill, crappie, bullhead, and bass, totaled only 15.6 percent. Although the standing crop in these ponds was 600 pounds per acre, only 93 pounds were of desirable kinds.

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The large number of species in these Illinois lakes was attributed to floods and indiscriminate stocking. Regardless of the cause, the figures are somewhat representative of the fish population in the average pond—a great number of species and individuals, with the undesirable kinds composing a large percentage of the standing crop. Often it is impossible to get any appreciable number of usable fish from such ponds because the competition for food is so great that the game and pan fish that are present cannot grow to an acceptable size. For successful management, these ponds usually require that the existing fish population be removed and the pond be stocked with the correct species and numbers.

In order to obtain edible fish of sufficient size, the kinds and the number of individuals in a pond must be limited. Neither forage nor carnivorous fish can be raised to as large size alone as when they occur together. A pond stocked only with bluegill will, soon after the first spawning, be filled with thousands of small bluegill. Since these young fish compete with the older fish for food, all stop growing and the older bluegill lose weight (*21*). Ponds with such populations do not produce fish of a usable size. A pond must contain sufficient forage fish to support the carnivorous fish, and there must be enough carnivorous fish to prevent the forage fish from overpopulating the pond. The determination of the species combination and the number to be planted are essential parts of pond management.

It is often difficult to improve the fishing in old ponds. Poor fishing may be due to several factors: (1) Too many fish, (2) the wrong kinds of fish, (3) low fertility, and (4) a congestion of aquatic rooted plants. Before anything can be done to improve old ponds, the existing fish population must be sampled. This may be done by hook and line fishing but is better done by seining. Fishing often does not show up the numbers of small and rough fish in correct proportion.

If the pond contains pan and game fish most of which are small and thin, it is overcrowded and steps must be taken to reduce the population. If no bass are present, they should be added at the rate of 100 fingerlings per acre of fertilized pond or 30 per acre of nonfertilized pond. If bass are present, the number of bluegill should be reduced by seining or heavy fishing and the food increased by fertilization (*25*). If most of the bluegill are large and most of the bass are small, the number of bass should be reduced by seining or fishing, and the food increased by fertilization (*25*).

If a pond contains a large number of carp or other undesirable kinds of fish, all the fish should be removed by draining the pond. It may then be correctly stocked. Most old ponds with an existing fish population can be brought into efficient production more quickly by draining and proper stocking than by any other method.

Rotenone is sometimes used to destroy fish in a pond that cannot be drained (*17*). This poison does not render the fish inedible nor is it injurious to air-breathing vertebrates in concretions useful for this purpose. Poisoning is accomplished by drawing sacks of derris root (5-percent rotenone) through the water, and 0.25 parts per million are required. Ponds should not be restocked for at least a month after application of this material. Rotenone should not be used without the approval of the State fish and game department.

The weight of fish that a given area of water can support is dependent upon the kind of fish and the amount of food (*24*). With a given combination of fish species and water fertility a pond will support an almost definite poundage of fish, regardless of the number of individuals. This fish-carrying capacity of a pond can be altered by changing either the species of fish or the fertility of the water. The size to which the fish will grow depends upon the combination of fish species, the number of fish, and the amount of food. Therefore, pond management is mainly the manipulation of two factors, (1) fish population and (2) water fertility.

STOCKING

Experiments have been conducted with the stocking, in various species combinations, of bluegill, white crappie, large-mouth black bass, top minnows (*Gambusia sp.*), and golden shiner (*22*). Bluegill alone did not do well because they quickly overpopulated the pond without producing many large fish. Combinations of bluegill and white crappie were unsuccessful because the ponds became overstocked with bluegill and crappie that were too small for the pan but too large for the older crappie to eat. Combinations of bluegill, golden shiner, and large-mouth bass gave good bass production, but poor bluegill production. The best results were obtained from a combination of bluegill and large-mouth bass, for the bass reduced both the bluegill and their own young to the number that the pond could support. It is desirable to have a large proportion of the weight of bluegill in pan-size fish. The bass help to accomplish this by eating most of the small bluegill, thus removing them as competitors for food. Those that remain can then obtain enough food to grow large.

The conclusion reached from these experiments was that to obtain best results in the Southeast, all ponds should contain a balanced population of bluegill and large-mouth black bass. All these experiments were conducted with fingerling planting stock; the use of adult stock resulted in overcrowding of some species and failure of others.

In successful ponds, ranging in age from 1 to 3 years, the ratio of weight of carnivorous to weight of forage fish ran from 1:2 to 1:3.5. On the average, one-third of the total weight of fish in the pond will be composed of carnivorous fish, and two-thirds of forage fish. In a pond that can support 150 pounds of fish there would be, therefore, about 50 pounds of bass and 100 pounds of bluegill. In order for the bluegill to reach quarter-pound size, 4 fish are stocked for each pound of forage fish that the pond can support. In order for the bass to reach a maximum of 2-pound size, 1 fish is stocked for each 2 pounds of carnivorous fish that the pond can support, and usually a few are added. Thus the pond that will support 150 pounds of fish is stocked with approximately 400 bluegill and 30 bass. A fertilized pond of 1 acre may support 500 to 600 pounds of fish and, hence, would be stocked with approximately 1,500 bluegill and 100 bass (*23*). If desired, approximately one-fourth of the bass may be substituted with an equal number of crappie, or one-fourth of the bluegill with bullhead at the ratio of 25 bullhead for 100 bluegill.

In new ponds or ponds without an existing fish population, the per acre stocking rates of these three combinations are (*25*):

1. Combination of bluegill bream and large-mouth black bass:
   - Nonfertilized pond:
     - 400 bluegill fingerlings stocked in late summer, autumn, or winter.
     - 30 bass fingerlings stocked in autumn or winter, or 30 fry the following spring.
   - Fertilized pond:
     - 1,500 bluegill fingerlings stocked in late summer, autumn, or winter.
     - 100 bass fingerlings in autumn or winter, or 100 fry the following spring.
2. Combination of bluegill bream, white crappie, and large-mouth black bass:
   - Nonfertilized pond:
     - 400 bluegill fingerlings stocked in late summer, autumn, or winter.
     - 20 bass fingerlings in autumn or winter, or 20 fry the following spring.
     - 10 crappie fingerlings or fry stocked at the same time as the bass.
   - Fertilized pond:
     - 1,500 bluegill fingerlings stocked in late summer, autumn, or winter.
     - 75 bass fingerlings in autumn or winter, or 75 fry the following spring.
     - 25 crappie fingerlings or fry stocked at the same time as the bass.
3. Combination of bluegill bream, bullhead catfish, and large-mouth black bass:
   - Nonfertilized pond:
     - 300 bluegill fingerlings stocked in late summer, autumn, or winter.
     - 25 catfish fingerlings in autumn or 25 fry the following spring.
     - 30 bass fingerlings in autumn or winter, or 30 fry the following spring.
   - Fertilized pond:
     - 1,200 bluegill fingerlings stocked in late summer, autumn, or winter.
     - 75 catfish fingerlings in autumn or 75 fry the following spring.
     - 100 bass fingerlings in autumn or winter, or 100 fry the following spring.

When ponds are stocked in autumn or winter with bluegill and bass fingerlings of the same size and at these rates, the bluegill usually will spawn the following summer and the bass the first or, more rarely, the second spring. The bluegill will be pan size by the middle of the summer, the bass will be pan size by early autumn, and fishing should start after the bream have reached pan size and the bass have spawned. Various States have determined minimum size limits below which fish cannot be legally taken.

These are recommendations that have been developed and tested in the Southeast. They may not apply equally well elsewhere but they serve as a guide since they are based on experimental evidence. It may be desirable to substitute other species but the same principles of balanced population should be followed. In some parts of the country, size at stocking time may be more important than age. For example, in more northern waters, bluegill 2½ to 3 inches long may not be produced in a single season, but that size is most desirable for stocking. Under such conditions yearling bluegill or well-fed fingerlings equivalent to the bass in size may be stocked. Although bluegill bream are generally supplied by hatcheries, most of the other kinds of bream are acceptable substitutes for bluegill. Planting stock can be obtained from Federal, State, and, in some localities, private fish hatcheries.

FERTILIZING

Pure water will not sustain living organisms; to do so water must contain in solution certain gases and mineral salts, mainly oxygen, carbon dioxide, nitrogen, phosphorus, calcium, and potassium. Pond waters contain nitrogen, phosphorus, calcium, and potassium in varying amounts depending upon the fertility of the soils over which they have flowed or through which they percolated. Most of the carbon dioxide results from decomposition of organic matter, although some oxygen and carbon dioxide are absorbed from the atmosphere. During growth processes, plants use carbon dioxide and release oxygen, and animals consume oxygen and release carbon dioxide. In pond water, the balance of these gases depends to some extent upon this exchange between plants and animals.

In addition to dissolved substances, there are suspended inorganic and organic solids in pond water. Most suspended inorganic solids are insoluble and do not contribute to the fertility of the water. Silt reduces the productivity by diminishing the light that may enter the water and by smothering the organisms living on the bottom of the pond. Some dead organic solids are eaten by fish and insect larvae, but if these solids are to go into solution they must decay through bacterial action. Algae can convert into living tissue only the dissolved substances in the water.

In Alabama, it was found that nonfertilized ponds supported from 40 to 200 pounds of pan and game fish per acre (*25*). This productivity was directly related to the fertility of the soil in the pond drainage; in poor soil the productivity was low, in good soil it was high. Illinois lakes with a mixed fish population had an average standing crop of 600 pounds per acre (*26*). Ten percent of this total was game and pan fish. In lakes supporting only game and pan fish the standing crop was 200 to 300 pounds per acre. In Michigan, glacial lakes with low fertility had a standing crop of 92 pounds per acre, of which 84 pounds were game and pan fish (*26*). Soil fertility varies in different parts of the country and so also does water fertility. Poor soil will produce a poor crop, whether it be corn or fish.

To increase the productivity of a poor soil, a farmer applies fertilizer in the form of barnyard manures, crop residues, or commercial fertilizers. Similarly, the productivity of a pond may be increased by adding fertilizer to the water (fig. 3). The use of fertilizer in ponds to increase fish production is an established practice in Europe and the Orient. Many different organic substances have been used—bone, fish, cottonseed and soybean meals, grain and grain threshings, sewage and sewage sludge, tankage, hay, and manure are a few of them. A large number of commercial fertilizers and combinations of commercial fertilizers with manures and other organic materials have also been used.

A review of European experience shows increases in production of 28 to 300 percent resulting from the use of various kinds of fertilizers (*3*). In many of the European experiments, the best results were obtained when nitrogen, phosphorus, and potassium were all added rather than only one or two. Elements other than these, and possibly calcium, are ordinarily present in sufficient quantities for plant growth.

COMMERCIAL FERTILIZERS

Since there is a direct relation between the plankton content of pond water and its fish productivity, an increase in plankton will lead to an increase in fish (table 2) (*20*). The application of commercial fertilizer to pond water increases the amount of plankton and when sufficient fertilizer is applied to double the plankton content the amount of fish supported by the pond is about doubled.

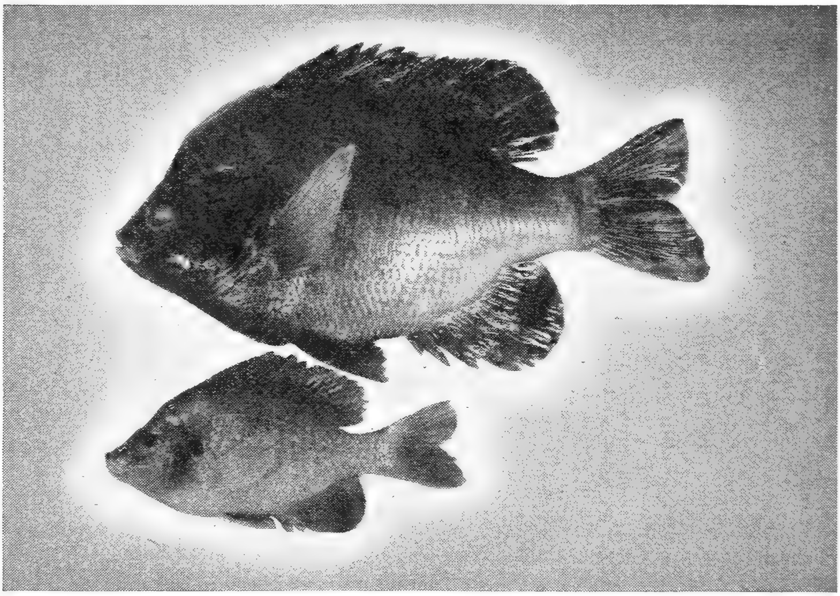

FIGURE 3.—The large bluegill came from a fertilized pond in which this species averaged 4 ounces in weight. The small one came from an unfertilized pond in which the fish averaged a weight of 1.1 ounces. Both ponds were stocked at the rate of 1,500 bluegill per surface acre of water (after Ala. Agr. Expt. Sta. Bul. 254).

TABLE 2.—*Plankton and fish production of fertilized ponds in Alabama, September 9 to May 1* (*20*)

Pond No.	Fertilizer	Production of—	
		Plankton per liter	Fish per acre
		Milligram	*Pounds*
1	None	4.8	90
2	Superphosphate	3.5	134
3	Superphosphate+$NaNO_3$	6.5	156
4[1]	Superphosphate+$(NH_4)_2SO_4$	11.7	174
5	Superphosphate+$NaNO_3$+KCl	8.0	251
6	Superphosphate+$NaNO_3$+KCl+$CaCO_3$	24.4	330
7	$NaNO_3$	4.5	79

[1] Developed excessive acidity.

From experiments conducted with distilled water inoculated with a plankton culture, it has been found (*20*) that the most efficient production of plankton is obtained when the water contains 4 parts per million of nitrogen (N), 1 part per million of phosphorus (P) and 1 part per million of potassium (K). This is a ratio of 4:1:1 p. p. m. of nitrogen, phosphorus, and potassium (N–P–K). Ammonia nitrogen is superior to nitrate nitrogen for plankton production, but in some waters excessive acidity develops when ammonium sulfate is used as the source of the nitrogen. To neutralize this acidity, it is necessary to add lime (calcium carbonate—$CaCO_3$). In distilled water cultures, maximum plankton production is obtained when the ratio of N–P–K–Ca is 4:1:1:8 p. p. m. A considerable quantity of the phosphorus is tied up by the soil of a pond bottom, and to compensate for this the amount of phosphorus should be doubled, making the ratio 4:2:1:8 p. p. m. In pond fertilization it was found that light applications of fertilizer at frequent intervals gave better plankton production than did heavy applications at less frequent intervals. Best plankton production was obtained when nitrogen, phosphorus, and potassium were added at the ratio of 1:½:¼ p. p. m. at weekly intervals. The recommended amounts of commercial fertilizers will give this concentration in 1 acre of water 3 feet deep.

It is customary to express the fertilizing value of fertilizers in terms of the percentages of available nitrogen (N), phosphoric acid (P_2O_5), and potash (K_2O). A fertilizer that contains 6 percent of nitrogen, 8 percent of phosphoric acid, and 4 percent of potash is known as a 6–8–4 fertilizer. Commercial mixed fertilizers are offered in many variations of these percentages.

For fertilizing small ponds, it is more convenient to use a mixed fertilizer than to obtain separate ingredients and mix a fertilizer that will meet the requirements of plankton production. For plankton production, nitrogen, phosphorus, and potassium must be added at the rate of 1:½:¼ p. p. m. of the elements. This ratio, expressed in whole numbers, is 8:4:2. Since the composition of fertilizers is usually given by stating the percentage of the oxides of P and K (conversion: $P \times 2.3 = P_2O_5$; $K \times 1.2 = K_2O$), the desired ratio of the elements would be very nearly supplied by an 8–9–3 fertilizer. A commercial mixed fertilizer near to this ratio except that it is short on nitrogen is 6–8–4. By adding 10 pounds of sodium nitrate for every 100 pounds of 6–8–4 mixture, the ratio is brought to approximately 8–8–4, which supplies the elements N, P, and K in about the right proportion.

Various mixtures of commercial fertilizers may be used to fertilize ponds (*23*). The following quantities are required for one application per surface acre:

Commercial mixed fertilizer.
- Neutral or acid waters:
  - 100 pounds 6–8–4 mixture
  - 10 pounds nitrate of soda
    - Apply separately or mixed.
- Alkaline waters (Above pH=8):
  - 100 pounds 6–8–4 mixture
  - 10 pounds sulfate of ammonia
    - Apply separately or mixed.

Nonmixed chemical fertilizer.
- Neutral or acid waters:
  - 40 pounds sulfate of ammonia
  - 60 pounds superphosphate (16 percent)
  - 5 pounds muriate of potash
  - 15 pounds finely ground limestone
    - Mix all ingredients before applying.
- Alkaline waters (Above pH=8):
  - 40 pounds sulfate of ammonia
  - 60 pounds superphosphate (16 percent)
  - 5 pounds muriate of potash
    - Mix all ingredients before applying.

The unmixed fertilizers cost less than the standard mixtures and should be used when many ponds or a large pond is to be fertilized. Superphosphate is offered in various strengths of available phosphoric acid; these may be used in the following quantities:

60 pounds superphophate, 16 percent
30 pounds superphosphate, 32 percent
20 pounds superphosphate, 48 percent

The 6-8-4 mixture is a cotton fertilizer and is easily obtained in the Southeastern States. Elsewhere it is not used extensively and often is not available. Other commercial mixtures may be used:

1. 100 pounds 4–8–4 mixture[4]
   20 pounds nitrate of soda or sulfate of ammonia
2. 100 pounds 3–8–3 mixture
   25 pounds nitrate of soda or sulfate of ammonia
3. 100 pounds 3–8–5 mixture
   25 pounds nitrate of soda or sulfate of ammonia
4. 50 pounds 8–16–8 mixture
   20 pounds nitrate of soda or sulfate of ammonia
5. 100 pounds 8–8–4 mixture

The nitrate of soda should be used where waters are neutral or acid, and the sulfate of ammonia where waters are alkaline. In alkaline waters the acidity developed by the sulfate of ammonia will be neutralized by the lime or other alkaline compounds that are present.

These quantities are sufficient for one application for 1 acre of pond surface. They must be increased or decreased accordingly as the pond is larger or smaller than 1 acre. Ponds that overflow should receive the first application as soon as the spring flood season is past; ponds with little or no overflow should receive the first application early in the spring. Follow the first fertilization with two or three more at weekly intervals. Soon after the first or second application, the growth of plankton will cause clear water to be murky and of a green or brown color. This murky condition, which obscures the bottom, is an indicator of fertility. When the bottom can be seen at a depth of 18 inches, another application of fertilizer is needed. After the third or fourth weekly application, fertilizer is added about every 4 weeks or whenever the bottom is visible in 18 inches of water. Fertilization is continued until September or October, by which time a total of 8 to 14 applications will have been required.

In ponds up to 4 or 5 acres in area, the fertilizer is applied by broadcasting it from the shore toward the center (fig. 4). In larger ponds, it is broadcast from a boat over the areas where the water is from 1 to 6 feet deep. It should not be distributed in areas deeper than 6 feet.

[4] This fertilizer or 4-10-4 may be more readily available than 6-8-4 and if applied at more frequent intervals will not require the addition of nitrate of soda or sulfate of ammonia.

Wave action will distribute both the fertilizer and the plankton that is formed so it is not necessary to attempt even and complete coverage of the pond surface.

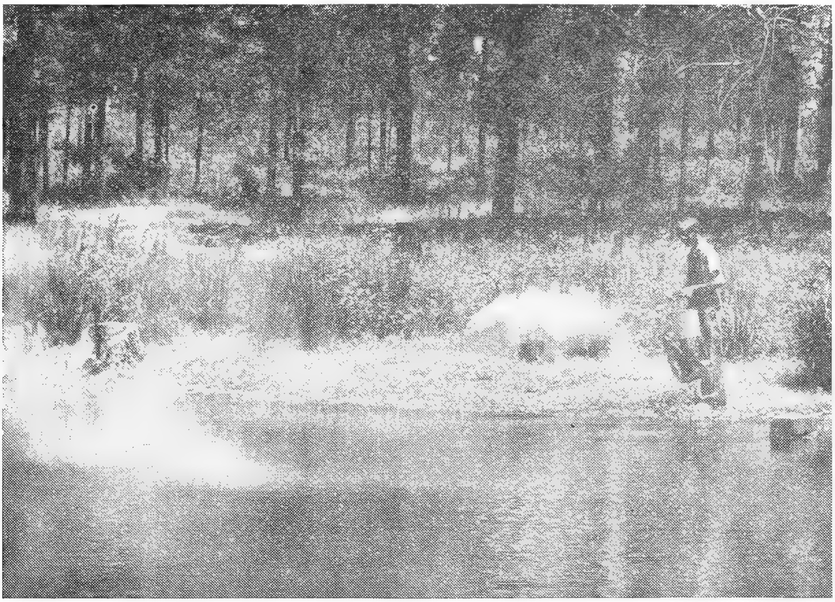

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Figure 4.—Fertilizer may be applied to the pond water by broadcasting it from the shore or a boat.

The annual cost of this type of fertilization will range from $11 to $20 per acre.

The use of fertilizer does not permanently increase the carrying capacity of a pond. Fertilization must be done at regular intervals and throughout the growing season if satisfactory results are to be obtained. The first few applications of fertilizer bring the carrying capacity to a certain level; subsequent applications keep it at this level. If fertilization is at infrequent intervals, the fish are alternately well fed and starved. Ponds should be fertilized only when the increased production will be utilized.

ORGANIC FERTILIZERS [5]

There are few data upon which to base recommendations for the kind and rate of application of organic fertilizers. Many of the reports on the use of such materials are vague as to mixtures, amounts, and manner of application. There are good reasons, however, for testing organic fertilizers in farm fishponds. Commercial fertilizers may not be readily available during time of war, their cost is sometimes beyond the financial means of those who wish to use them, and in some parts of the country people are not familiar with them.

The organic fertilizers that have been used in fish culture may be roughly divided into four classes: (1) Farm manures, (2) seed meals,

[5] The effects of organic fertilizers on fish production, mosquito production, and on filamentous algae and pondweeds have not been determined experimentally. Therefore, these fertilizers cannot yet be *recommended* for use by farmers without reservation.

such as cottonseed and soybean meals, (3) hay and plant compost, and (4) offal, such as sewage, garbage, and tankage. Materials of the first three classes are the main ones used in this country. To obtain results within a growing season, organic fertilizers should contain considerable soluble material or should decay and go into solution without too great lapse of time. For this reason, such materials as bonemeal are unsatisfactory since they not only are insoluble but also decay very slowly.

Farm manure is a mixture of animal excrement and straw or other bedding materials. Its quality as fertilizer varies greatly with the animal source, the amount of bedding material, the manner in which it has been collected and stored, and its age (table 3). The percentage of nitrogen, phosphoric acid, and potash in manure is approximately 0.5–0.25–0.5, which means that its content of fertilizer materials is low in comparison with that of commercial fertilizer. At this ratio, 1 ton of manure is equivalent to 100 pounds of 10–5–10 mixed fertilizer (*10*). For plankton production it is distinctly low in content of phosphoric acid and for this reason superphosphate often must be added when manure is used as a pond fertilizer. Manure from chickens is much higher in content of nitrogen and phosphoric acid than is that from other farm animals (table 3). In all manures, 50 percent or more of the fertilizer materials are in soluble form and do not require decay to become available for plant growth.

TABLE 3.—*Percentages of fertilizing elements in various organic materials* (*2, 10, 11*)

Organic material	Nitrogen	Phosphoric acid (P_2O_5)	Potash (K_2O)	Organic material	Nitrogen	Phosphoric acid (P_2O_5)	Potash (K_2O)
	Percent	*Percent*	*Percent*		*Percent*	*Percent*	*Percent*
Horse manure	0.50	0.30	0.24	Sewage sludge (activated)	5.0	3.5	0.2
Cow manure	.32	.21	.16	Sewage sludge (Imhoff)	2.5	1.0	.1
Sheep manure	.65	.46	.23	Alfalfa hay	2.3	.5	.9
Hog manure	.60	.46	.44	Bluegrass hay	1.5	.5	1.5
Chicken manure	1.00	.80	.40	Timothy hay	.8	.2	.6
Cottonseed meal	7.0	2.5	2.0				

There is considerable question as to the desirability of rotting manure before it is used either on land or in ponds. In pond fertilization, fresh manure may be superior to rotted manure because in the process of rotting it will have lost much of its nitrogen. A reduction of nitrogen appears to stimulate the growth of unwanted filamentous algae and is therefore undesirable. During the process of decay of large quantities of manure or other organic fertilizer, the supply of oxygen dissolved in the water may be depleted and the fish may suffocate. The danger of thus removing oxygen is much greater in warm, quiet water than in cold, rough water in which decomposition is retarded and wave action adds oxygen to the water from the air.

The seed meals, such as those of cottonseeds and soybeans, are commonly used in hatchery pond fertilization. These are produced by pulverizing the cake that remains after the extraction of oil from the seeds. The fertilizer formula of cottonseed meal is about 7–2.5–2;

that of soybean meal is similar or slightly lower (table 3). The fertilizer materials in these meals are not soluble and the meals must decay before they are available. Seed meal is fish food as well as fertilizer; the fish sometimes eat the meal before it decomposes.

Hay may be tried as a fertilizer in regions where farm manure is scarce or where it is necessary to fertilize ponds with inexpensive farm products. The fertilizer formulas for various hays are: Alfalfa hay 2.3–0.5–0.9; bluegrass hay 1.5–0.5–1.5; and timothy hay 0.8–0.2–0.6. All hays must decay before they fertilize the water.

Experiments have been conducted at Fairport, Iowa, to determine the effect of various organic fertilizers on the production of plankton and bass fingerlings (*3*). A 3-to-1 mixture, by weight, of sheep manure and bonemeal gave only fair results, possibly because the phosphorus in bonemeal is insoluble. Various mixtures of sheep manure and superphosphate were tried and it was concluded that a 1-to-1 mixture gave the best results and is preferable to a 3-to-1 mixture. The effect of various fertilizers on plankton production was tested with the results shown in table 4. Each of the fertilizers increased plankton production, the greatest increase, 681 percent, being obtained with soybean meal. The fertilizers were applied from June to October and the amount varied from 472 to 742 pounds per acre for the season. With a 3-to-1 mixture of sheep manure and superphosphate, best results were obtained when 550 pounds were applied; 472 pounds of a 3-to-2 mixture gave good results. The maximum production of bass fingerlings was obtained when soybean meal was used at the rate of 700 pounds per acre. The conclusion reached was that, for the production of fingerling bass, these fertilizers should be used at the rate of 500 to 1,000 pounds per acre per season and be distributed in small amounts at short intervals.

Sewage sludge, tankage, and other such organic byproducts have been used experimentally in Europe but practically not at all in this country. However, these should receive consideration since in some localities they may be obtained cheaply.

TABLE 4.—*Plankton production at Fairport, Iowa, as affected by various fertilizers (3)*

Fertilizer	Crustacea per liter	Increase	Fertilizer	Crustacea per liter	Increase
	Number	*Percent*		*Number*	*Percent*
Superphosphate	484.41	182	None	265.72	----------
Soybean meal	1,812.21	681	Sheep manure	660.40	248
Shrimp bran	621.40	232			

In Europe manures have been used in carp and tench (*Tinca* sp.) production, but in this country, the use of farm manures for pond fertilization is experimental. Sheep and cow manures have been used to increase hatchery production of fingerling warm-water fishes. As much as 3 tons of cow manure is used in one season to fertilize 1 acre of hatchery pond.

When farm manures are used for pond fertilization, the possibility of the transmission of parasites and diseases—both livestock and human—must be constantly borne in mind. The two most likely to cause trouble are liver flukes and Bang's disease. In localities where either of these occur, ponds fertilized with manure should not be used for stock water.

The use of hay for fertilization is also experimental. Legume hays decay more rapidly in water than grass hay and, therefore, should be applied in small amounts at frequent intervals.

In the light of present knowledge, the following trials may be made for the use of organic fertilizers on a per acre basis.

Manures. Horse and cow manure at 2 to 3 tons per season, in applications of 500 pounds at monthly intervals. Sheep and hen manure are higher in percentages of nitrogen and phosphorus and these manures may be used at the rate of 1 or 2 tons per season.

Seed Meals. A mixture of either soybean or cottonseed meal and superphosphate at the ratio of 3 to 1, by weight; 800 to 1,000 pounds or more per season; in applications of 100 pounds per week until a water bloom is established. The use of lime with cottonseed meal may be beneficial in soft waters.

Hay. One to three tons per season in applications of 500 pounds at monthly intervals.

All these materials should be well scattered over the surface of the pond where the depth is 6 feet or less. The frequency of application can be determined by the growth of filamentous algae. When it appears, fertilizing should be terminated. It should be remembered that all of these organic materials are low in phosphoric acid; therefore, their action can be improved by the addition of superphosphate.

COMPARATIVE EFFECTIVENESS OF FERTILIZERS

A proportionate relationship between plankton production and carrying capacity is not found when a comparison is made between the results obtained with commercial and organic fertilizers (*12*) (table 5). With organic fertilization, the fish production may be doubled but the plankton production is increased only slightly. This difference is partly explained by three factors: (1) A considerable portion of the fertilizing elements is not available until after slow bacterial decomposition of the organic material. (2) Organic material is eaten by insect larvae and zooplankton organisms and the phytoplankton stage is eliminated. (3) Seed meals are eaten in small quantity by fish and that part which is eaten increases fish production but does not fertilize the water. The plankton and insect larvae are thus eliminated as stages in the food chain leading to fish.

TABLE 5.—*Plankton production and fish-carrying capacity in ponds fertilized with organic and inorganic fertilizers (12)*[1]

Pond No.	Fertilizer	Plankton production	Fish-carrying capacity
		Parts per million	*Pounds*
5	None	5.1	92.7
4	Cottonseed meal	7.8	295.4
6	Laying mash	10.6	451.8
18	Cottonseed meal+superphosphate	15.4	578.8
15	Superphosphate+ammonium sulfate+basic slag	31.0	588.0

[1] Experiment conducted from May 22 to November 18.

HARVESTING

If the maximum returns are to be obtained from a pond, a high percentage of the large fish must be caught (*13*). It is pointless to raise a great number of fish unless they are to be used.

Ponds that are stocked in the autumn with the proper number of fingerling bluegill and large-mouth bass will produce pan-sized fish in 1 year. Bream fishing should start when they have reached pan size. Bass should not be fished before they have spawned. Bass will usually spawn the first spring after they have been stocked, that is, about May and June. When a pond properly stocked with bluegill and large-mouth bass has reached carrying capacity, about 80 percent of the standing crop will be fish of usable size. To maintain a well-balanced crop by hook and line fishing, a pond must be fished regularly. There is little danger of overfishing a well-managed pond. Good fishing tends to be self-regulating—as fish are taken from a pond, the competition for food among the remaining fish is reduced and they are less likely to take the hook. When fish are not "biting" the ardor of fishermen falls and intensity of fishing is reduced. Within a year, about 50 percent of the pan-sized fish can be taken out by hook and line fishing.

HOW TO OBTAIN FISH FOR FARM PONDS

Fish for stocking farm ponds may be obtained from Federal and some State hatcheries. Procedure for procuring fish by application to State fish and game departments varies, so that the applicant should apply for fish directly to that department in his State.

Applications to the United States Fish and Wildlife Service are reviewed by the central office to determine that the number of fish is in accord with sound stocking requirements. Then the applications are forwarded to the appropriate regional office which assigns delivery to the hatchery nearest the point of application.

Applications made to the Fish and Wildlife Service may be filled from either a State or Federal hatchery. Delivery may be made by either State or Federal fish-distribution trucks. In some States arrangements have been made whereby delivery of fish is made from the nearest State or Federal hatchery, regardless of whether the application was sent to the State or to the Fish and Wildlife Service.

In most regions applications must be filed before a given date in order to receive attention during the season in which they are filed. This date varies, but is usually about June 1. In a few States applications filed in a given year are filled the following year.

About 3 weeks before distribution the applicant will be notified of the approximate date and place of delivery by the hatchery official. A few days before delivery he will notify the applicant of the exact day and hour of delivery. The applicant should acknowledge both notifications to the hatchery official, indicating that he is ready to receive the fish. If he cannot appear in person, he should have someone receive them for him since considerable planning and work is involved in getting the applications filled on schedule. The fish are usually delivered to railway depots or truck stations in milk cans.

Fingerling fish are supplied for farm ponds only at certain times of the year. The time varies with the spawning season which in turn varies with the section of the country and methods of propagation. Consequently, in the South the applicant may expect to receive bass and bluegill fingerlings in the fall of the year usually in September or October, but sometimes as early as August. Or he may occasionally receive bluegill and bass fingerlings in the spring of the year, beginning in March. Finally, he may receive bass fry in the spring following the introduction of the bluegill fingerlings which were delivered in the fall. Fingerlings of most other species are supplied in the fall. In the North the applicant can expect to receive bluegill fingerlings and bass fry in June or July, and bass fingerlings in the late fall and in the spring.

SUMMARY

The raising of pond fish is an old and widespread type of farming in many parts of the world. Until recently, however, it has received little attention in the United States. Modern fish production in farm and ranch ponds is based upon the maintenance of a rather easily managed food chain. Nutrient elements are added to the water of the pond by the application of fertilizers. These support microscopic plants which in turn serve as food for minute animals. Water insects feed upon these animals and the microscopic plants. In their turn, the insects and small animals, such as rotifers and crustaceans, provide food for forage fish such as the bluegill bream. The forage fish are eaten by carnivorous species, for example, the large-mouth bass. Both the bream and bass furnish food for man.

In order for the food chain to maintain itself, it is necessary that the numbers of forage and carnivorous fish be properly proportioned. This proportion should represent a ratio of approximately 1 pound of carnivorous fish to 2 pounds of forage fish. One year after stocking, bluegill bream weigh approximately one-fourth pound and bass weigh about 1 pound. Thus a properly fertilized pond of 1 acre of water surface will be stocked with 1,500 bluegill to 100 bass fingerlings.

The fertilizer applied to furnish the nutrient elements which form the base of the food chain may consist of commercial fertilizers or, for experimental purposes, their chemical equivalents in organic fertilizers. Highly acid or highly alkaline waters require the addition of neutralizing agents.

The objective of producing quantities of fish in farm ponds is man's use of them for food and pleasure. If maximum returns are to be obtained from a pond, a high percentage of the large fish must be caught. The management methods recommended will provide fish of usable size about a year after the pond is first stocked, and the pond can then be fished regularly. Fish for stocking ponds may be easily obtained from Federal and some State hatcheries.

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