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FARM FISH PONDS

By
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Preface

War has brought an increased demand for most all food products, but particularly for animal proteins. Our lands must now produce food not only for our civilian population and our fighting forces, but for many of our Allies as well. We must, therefore, reexamine our resources and our agricultural methods to find and test every opportunity for increasing production of essential foods. The use of the farm pond as a fish pond is such an opportunity.

The farm pond is well known as a recreational spot for small boys and as a source of an occasional meal of fish, but with proper management it will produce a crop of fish--a substantial part of the meat requirements of a family. Fish farming is no more difficult than vegetable growing, and the harvesting of the crop is sport rather than work. The farm pond may be managed as wisely as any other part of the farm and its per-acre yield of meat may, in some cases, be the highest on the farm. An increase in the production of animal products would be to the national good, therefore the potentialities of the fish pond must not be overlooked.

Recent investigations have established new methods of fish farming. These methods are not widely known and the publications in which they have been reported are often difficult to obtain. The objective of this bulletin is to state the underlying principles of fish culture and to provide an outline of the management methods that have been tested and proven. It is hoped that this will stimulate interest in fish farming, to the extent that new ponds will be built and old as well as new ponds will be used for fish farming.

Modern fish farming involves procedures that are contrary to almost all commonly accepted ideas of fish culture. It is now known that the greatest fish production can be obtained when fish ponds have no rooted aquatic plants, are stocked with 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 welfare of fish. Unusual as these may appear to be, they have nevertheless been demonstrated to be sound.

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. I am indebted to Messrs. Swingle and Smith for personally discussing and explaining their work.

The Development of Fish Farming

The raising of pond fish is an old and a widespread type of farming. In Europe and in the Orient it has been an important agricultural pursuit for centuries. In 1934, Poland had approximately 185,000 acres of ponds and the total yield from these was estimated to be 22,000,000 pounds of fish. About 40 percent of the ordinary farms producing field crops had fish ponds (12). In the Philippines in 1940 there were 141,564 acres devoted to fish ponds for raising milkfish (*Chanos chanos*). It was estimated that these ponds annually produced 98,000,000 pounds of fish and that the milkfish industry was worth not less than fifty million pesos (21). These figures suggest the importance that fish farming may assume. Similar statistics might be offered for other regions, but suffice it to say that in many parts of the world the fish raised in controlled ponds are a material addition to diet and income.

In the United States, interest in the culture of pond fish has been local and sporadic. The earlier efforts to stimulate such interest were directed almost entirely toward raising carp (Cyprinus carpio). From 1875 to 1900 much was printed extolling the food value of carp and the ease with which this fish might be produced. As with so many other kinds of wildlife, the early enthusiasm was for an exotic species and it was only after many years had passed that any attention was directed toward native forms. Carp did not appeal to the American taste in fish and possibly the general disinterest in fish ponds was due partly to a long-standing impression that the carp was the only fish that could be easily raised.

Although pond culture is centuries old its development has been slow and often was hindered by superstition, prejudice, and secrecy. In the modern era of fish culture, great advances have been made in hatchery work and in marine fisheries, but comparatively little has been done on the management of ponds. In recent years, however, considerable research has been done on pond fish and there is now sufficient evidence upon which to base a pond management program.

The Aquatic Environment

The aquatic environment provided by the small pond is extremely 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 are generally 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 is 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 it is refilled such plants and animals as are desired may be returned to it, and much can be done toward preventing 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 productivity of meat may be increased by fertilization.

Fish Food

All animals derive their food, directly or indirectly, from plants. Plants are the source of all food since they alone convert carbon dioxide, water, and other 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, floating plants known as phytoplankton, instead of the large rooted plants, that are the source of food. In a pond, the insect eats the phytoplankton, the bluegill eats the insect, and the bass eats the bluegill.

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. They are responsible for the decomposition and conversion of dead organic matter into simple chemical compounds available for plant growth (22). Normally they are quantitatively unimportant as food for other organisms. 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, 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-mouthed 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-mouthed black bass feed upon microscopic animals--the zoo-plankton. Soon, though, they start feeding on insect larvae and from that time on, insect larvae is the primary food of the bluegill (Table 1). The young bass, however, quickly change to a diet of fish, and when weighing two ounces they eat the same type of food as do bass weighing two pounds (Table 1). Both bluegill bream and large-mouthed black bass are predacious--they feed upon animals and they take plants only when there is insufficient animal food (4). Aquatic insects, therefore, are the link between phytoplankton and fish.

The insects commonly found in water are the groups represented by stoneflies, 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 (4).

Carnivorous fish are also cannibalistic; they will eat fish smaller than themselves, whether of another species or of their own. This cannibalism is often decried by fish culturists, but it is a normal and essential feature of a balanced fish population (18). 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 it is now recognized that 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 can't eat it and men won't, but a large bluegill is a fine pan fish.

In so far as fish are concerned, the rooted aquatic plants--cat-tails, water lilies, and such--are unproductive and often detrimental. Comparatively few organisms feed upon these plants, and 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 (10, 18). 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 too much protection is available to the forage fish, the carnivorous fish are unable to capture them and the pond will become overpopulated with small fish. Filamentous algae is also undesirable since it harbors mosquitoes and interferes with fishing.

Fish Production

There has been little uniformity in the manner of expressing fish production. It is therefore important that the various terms be understood before comparisons are made.

It has been customary to state the production of fish hatcheries in number of fry or fingerlings 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 because the weight of a fish depends upon the amount of food that has been available (18).

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 (18). The results of most of the recent studies in pond fish production have been stated in weight per unit of surface area and this is the standard used here.

In agriculture, the term "production" is commonly used with animal crops while "yield" refers to plant crops. Both are on a yearly basis, and neither considers the seed or stock necessary to establish the crop. For example, the yield of wheat from an acre of land may be stated as 30 bushels, but this does not take into consideration that one or two bushels must be retained as seed to replant the crop. Planting stock must also be retained in fish farming.

In fish culture, 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 annual production; the second is the standing crop; and the third is the harvestable crop. The first is synonymous with "production" in agriculture.

The weight of fish that a given area of water can support depends upon the kind of fish and the amount of food (18). With a given 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 only by changing 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.

Fish Population

A successful fish pond must produce fish of the kinds and sizes that are acceptable for sport or 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-mouthed bass, bluegill and bullhead, are much 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 (20). In fertilized ponds in the Southeast, the annual production for plankton feeders, such as goldfish and golden shiners, was 750 to 1100 pounds per acre; for insect feeders, such as bluegill and bullhead, it was 500 to 600 pounds per acre; and for carnivorous fish, like large-mouthed bass and white crappie, it was 150 to 200 pounds per acre (18). One cannot obtain as large a crop of bass and bluegill as one can of carp, and in making comparisons of pond productivity, one must 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. Three fertilized ponds in Alabama were stocked with fingerling bluegill at the rate of 6400, 3200, and 1300 individuals per acre (13, 18). At the end of one year each pond contained approximately 300 pounds of fish per acre. In the first pond the bluegill averaged 0.8 ounce each, 1.5 ounces in the second, and 3.8 ounces in the third. In another experiment, two ponds were stocked with bluegills at the rate of 180,000 and 1500 per acre. At the end of a year the first pond contained 280 pounds of fish and the second 320 pounds 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-mouthed bass, white crappies, and bullheads, large populations brought decreased size.

The fish population of artificial as well as natural ponds usually consists of a large number of species and individuals. In Illinois, nine artificial lakes with a total area of 50 acres had an average standing crop of 600 pounds of fish per acre, and contained 46 kinds of fish (20). Only ten of these contributed one or more percent to the crop, yet these ten composed 96.5 percent of the crop. The three leading species were redmouth 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.

The large number of species in these Illinois lakes was attributed to floods and indiscriminate stocking. Regardless of 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.

Ponds are managed for the production of edible fish--fish that are considered to be good food and are large enough to be used as such. To obtain this objective, the kinds of fish and the number of individuals in a pond must be limited. Neither forage nor carnivorous fish can alone be raised to a large size. A pond stocked only with bluegill will, soon after the first spawning, be filled with thousands of small bluegills. Since these young fish compete with the older fish for food, all stop growing and the older bluegills lose weight (15). 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.

Experiments have been conducted with the stocking, in various species combinations, of bluegill, white crappie, large-mouthed black bass, top minnows (Gambusia sp.), and golden shiners (15). Bluegill alone did not do well because they quickly overpopulated the pond without producing many large fish. Combinations of bluegill and white crappie usually resulted in ponds overstocked with either or both species. Combinations of bluegill, golden shiner and large-mouthed bass gave good bass production, but poor bluegill production. The best results were obtained from a combination of bluegill and bass. Fish planting stock is classified as to size: fry are newly hatched fish less than one inch long, fingerlings are young fish between one and three inches long. All these experiments were conducted with fingerling planting stock; the use of adult stock resulted in overcrowding of some species and failure of others.

The large-mouthed black bass proved superior to the white crappie in balancing ponds stocked with bluegill. The crappie was unsuccessful because the ponds became overstocked with bluegills and crappie that were too small for the pan but too large for the older crappie to eat. The large-mouthed bass, however, reduced both the bluegills and the bass to the number that the pond could support. From these experiments, the conclusion reached was that to obtain best results in the Southeast, all ponds should contain a balanced population of bluegills and large-mouthed black bass.

In successful ponds, varying in age from one to three years, the ratio of weight of carnivorous to weight of forage fish varied from 1:2

to 1:3.5. The ratio of 1:2 appeared to be the more successful one and was accepted as the ratio for stocking. In a pond that can support 150 pounds of fish there would be at this ratio, 50 pounds of carnivorous fish and 100 pounds of forage fish. In one year after stocking, bluegills will weigh approximately four ounces and bass one pound; thus, a pond that can support 150 pounds of fish would have 400 bluegills and 50 bass; a pond that can support 600 pounds of fish would have 1500 bluegills and 200 bass. In stocking, the number of bass are reduced by one-half, so the recommendations for one acre (17) are: 400 fingerling bluegills and 30 fingerling bass for non-fertilized ponds, and 1500 bluegills and 100 bass for fertilized ponds. If desired, approximately one-fourth of the bass may be substituted with an equal number of crappie; or one-fourth of the bluegills substituted with bullheads at the ratio of 25 bullheads for 100 bluegills. In ponds without an existing fish population the per acre stocking rates of these three combinations are (19):

I. Combination of bluegill bream and large-mouthed black bass.

Non-fertilized pond: 400 bluegill fingerlings stocked in late summer, autumn, or winter.

30 bass fingerlings stocked in autumn or winter.

Fertilized pond: 1500 bluegill fingerlings stocked in late summer, autumn, or winter.

100 bass fingerlings in autumn or winter.

II. Combination of bluegill bream, white crappie, and large-mouthed black bass.

Non-fertilized pond:	400	bluegill fingerlings stocked in late summer, autumn, or winter.
	20	bass fingerlings in autumn or winter.
	10	crappie fingerlings or fry stocked at the same time as the bass.
Fertilized pond:	1500	bluegill fingerlings stocked in late summer, autumn, or winter.
	75	bass fingerlings in autumn or winter.
	25	crappie fingerlings or fry stocked at the same time as the bass.

III. Combination of bluegill bream, bullhead catfish, and large-mouthed black bass.

Non-fertilized pond:	300	bluegill fingerlings stocked in late summer, autumn, or winter.
	25	catfish fingerlings in autumn.
	30	bass fingerlings in autumn or winter.
Fertilized pond:	1200	bluegill fingerlings stocked in late summer, autumn, or winter.
	75	catfish fingerlings in autumn.
	100	bass fingerlings in autumn or winter.

When ponds are stocked in autumn or winter with bluegill and bass fingerlings of the same size and at these rates, both usually will spawn the following 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 as soon as, but not before, the bass have reached this size.

These are recommendations that have been developed and tested in the Southeast. It is impossible to state that they will apply equally well elsewhere. However, they are based on experimental evidence, so it is wise to use them wherever bluegill and large-mouthed bass are known to thrive. Where these species do not do well, others must be substituted, but the same principles of balanced population should be followed. Planting stock can be obtained from federal, state and, in some localities, private fish hatcheries.

Fertilization

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, and potassium. During growth processes, plants use carbon dioxide and release oxygen, while animals consume oxygen and release carbon dioxide. In pond water, the balance of these gases depends to a considerable extent upon this exchange between plants and animals, although some oxygen is absorbed from the atmosphere. Pond waters contain nitrogen, phosphorus, and potassium in varying amounts depending upon the fertility of the soils over which they have flowed, or through which they have percolated. 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 bottom-living organisms. Some dead organic solids are eaten by fish and insect larvae, but for these solids 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 non-fertilized ponds supported from 40 to 200 pounds of pan and game fish per acre (19). 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 (20). 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 (20). Soil fertility varies in different parts of the country, and so also does water fertility. Poor soil will produce a poor crop, whether it is corn or fish.

To increase the yield of corn on a poor soil, a farmer applies fertilizer in the form of barnyard manures, crop residues, or commercial fertilizers. The productivity of a pond may be increased in exactly the same way by adding fertilizer to the water. 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 with fertilizers shows increases in production of 28 to 300 percent resulting from the use of various kinds of fertilizers (2). In many of the European experiments, the best results were obtained when nitrogen, phosphorus and potassium were added rather than when one or two of these were used. Elements other than these three 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. 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 doubled (Table 2) (14).

From experiments conducted with distilled water inoculated with a plankton culture, it has been found (14) that the most efficient production of plankton is obtained when the water contains four parts per million of nitrogen (N), one part per million of phosphorus (P) and one part per million of potassium (K). This is a ratio of 4:1:1 parts per million of these elements (N-P-K). Ammonia nitrogen is superior to nitrate nitrogen for plankton production, but excess acidity develops when ammonium sulphate 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 maximum plankton production is obtained when the ratio of N-P-K-$CaCO_3$ 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 $1:\frac{1}{2}:\frac{1}{4}$ parts per million at weekly intervals. The recommended amounts of commercial fertilizers for fertilizing ponds will give this concentration in one acre of water three 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 ratio of $1:\frac{1}{2}:\frac{1}{4}$ parts per million. The fertilizer that is used must contain these elements in this ratio. The ratio $1:\frac{1}{2}:\frac{1}{4}$ is, expressed in whole numbers, equivalent to 8:4:2. This ratio, converted to terms of N - P_2O_5 - K_2O is approximately 8-9-3 (Conversion: P x 2.3 = P_2O_5; K x 1.2 = K_2O). A commercial mixture near to this ratio is 6-8-4. This is short on nitrogen, but 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 of N - P_2O_5 - K_2O (about equal to 8-4-2 of N-P-K).

Various mixtures of commercial fertilizers may be used to fertilize ponds (17). The following quantities are required for one application per surface acre:

I. Commercial mixed fertilizer.

Neutral or acid waters:	100 pounds 6-8-4 mixture
	10 pounds nitrate of soda
	Applied separately or mixed.
Alkaline waters:	100 pounds 6-8-4 mixture
	10 pounds sulphate of ammonia
	Applied separately or mixed.

II. Non-mixed chemical fertilizers.

Neutral or acid waters:	40 pounds sulphate of ammonia
	60 pounds superphosphate (16 percent)
	5 pounds muriate of potash
	15 pounds finely ground limestone
	Mix all ingredients before applying.

Alkaline waters: 40 pounds sulphate of ammonia

60 pounds superphosphate (16 percent)

5 pounds muriate of potash

Mix all ingredients before applying.

The second mixture (II) costs less than the first and is the one to use 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 superphosphate, 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:

I. 100 pounds 4-8-4 mixture

20 pounds nitrate of soda or sulphate of ammonia

II. 100 pounds 3-8-3 mixture

25 pounds nitrate of soda or sulphate of ammonia

III. 100 pounds 3-8-5 mixture

25 pounds nitrate of soda or sulphate of ammonia

IV. 50 pounds 8-16-8 mixture

20 pounds nitrate of soda or sulphate of ammonia

V. 100 pounds 8-8-4 mixture

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

These quantities are sufficient for one application for one acre of pond surface. They must be increased or decreased accordingly as the pond is larger or smaller than one 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, by obscuring the bottom, is an indicator of fertility. When the bottom can be seen in eighteen inches of water, another application of fertilizer is needed. After the third or fourth weekly application, fertilizer is added every four weeks or whenever the bottom is visible in one and one-half feet of water. Fertilization is continued until September or October, and a total of 8 to 14 applications will be required.

In ponds up to four or five acres in area, the fertilizer is applied by broadcasting it from the shore toward the center. In large ponds, it is broadcast from a boat over the areas where the water is from one to six feet deep. It should not be distributed in areas deeper than six feet. 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.

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

Organic Fertilizers

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.

The organic fertilizers that have been used in fish culture may be roughly divided into four classes: (1) farm manures, (2) seed meals, 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, materials such as bone meal are unsatisfactory since they are not only 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, one ton of manure is equivalent to 100 pounds of 10-5-10 mixed fertilizer (5). 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.

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 undesirable filamentous algae and is therefore undesirable.

The seed meals, such as that of cottonseeds and soybeans, are commonly used in 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, and that of soybean meal is similar (Table 3). The fertilizer materials in these meals are not soluble and the meals must decay before they are available. Seed meals are fish foods as well as fertilizer, and considerable of their beneficial action is due to fish eating the meals before they decompose.

Hay may be used as a fertilizer in regions where farm manure is scarce or where it is necessary to fertilize ponds with inexpensive farm products. The fertilizer formulae 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.

Sewage sludge, tankage and other such organic by-products are used extensively in European pond culture, but practically not at all in this country. However, these should receive consideration since in some localities they may be cheaply obtained.

Experiments have been conducted at Fairport, Iowa to determine the effect of various organic fertilizers on the production of plankton and bass fingerlings (2). A 3 to 1 mixture, by weight, of sheep manure and bone meal gave only fair results, possibly because the phosphorus in bone meal 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 and the greatest increase, 681 percent, was 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 1000 pounds per acre per season, and be distributed in small amounts at short intervals.

In Europe all 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 three tons of cow manure is used in one season to fertilize one acre of hatchery pond.

When farm manures are used for pond fertilization, the possibility of the transmission of diseases--both of livestock and humans--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 that are 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 do grass hays, and therefore should be applied in small amounts at frequent intervals.

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

Manures. Horse and cow manure at two to three 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 one or two tons per season.

Seed Meals. A mixture of either soybean or cottonseed meal and superphosphate at the ratio of 3 to 1, by weight; 700 to 1000 pounds per season; in applications of 100 pounds per month.

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

All of these materials should be well scattered over the surface of the pond where the depth is six feet or less. The frequency of application can be determined as it is with commercial fertilizers, by the murky condition of the water. If the bottom can be seen in one and one-half feet of water, another application of fertilizer is needed. It should be remembered that all of these organic materials are low in content of phosphoric acid; therefore, their action can be improved by the addition of superphosphate.

Comparative Effectiveness of Fertilizers

The action of commercial and of organic fertilizers is not alike. The nitrogen, phosphorus and potassium of commercial fertilizers is in a soluble form, immediately available to plants. When commercial fertilizers are used in ponds, a heavy growth of phytoplankton usually results, and when the amount of plankton is doubled the fish carrying capacity is approximately doubled.

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 (7) (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) Seed meals are eaten 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. (2) Organic material is eaten by insect larvae and zooplankton organisms and the phytoplankton stage is eliminated. (3) A considerable portion of the fertilizing elements is not available until after slow bacterial decomposition of the organic material.

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.

Harvesting the Fish Crop

Under a given set of management practices, a pond can support a definite weight of fish. This carrying capacity will not appreciably increase with the passage of time. If the maximum returns are to be obtained from a pond, a high percentage of the large fish must be caught. It is pointless to raise a great number of fish unless they are to be used (8).

Ponds that are stocked in the autumn with the proper number of fingerling bluegill and large-mouthed bass will produce pan sized fish in one year. Fishing should start as soon as the bass have reached this size. When a pond properly stocked with bluegill and large-mouthed bass has reached carrying capacity, about 80 percent of the standing crop will be fish of a usable size. For a pond to produce a good crop by hook and line fishing, it 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.

Ponds

Ponds varying in size from one-quarter to 70 acres have been successfully managed with the practices previously outlined (17). Although large ponds can be managed, the expense and labor involved makes it unprofitable to the average individual. Fertilization, stocking, and the control of weeds and mosquitoes are easy in a pond of one or two acres, but are expensive and laborious in large ponds (8). 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 practical 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 one year. However, if space and water are limited, a one-quarter acre pond will provide considerable food and sport for one or two persons.

The depth of water at the deepest part should be eight or more feet and the shore must slope off steeply to three feet so that, with the fluctuation of water level, shore vegetation will not be encouraged. In new ponds, facilities for draining must be provided so that should the fish population become unbalanced or the pond choked with weeds, it may be drained, cleaned and restocked. Special spawning beds and shelters should not be provided. These are unnecessary and interfere with fishing, harbor mosquitoes, and provide too much protective cover to young fish. 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 a manual on pond construction (3).

Rooted aquatic plants, either emergent or submerged, must not be permitted to become established. These plants and any brush or debris should be removed as soon as they appear. Submerged aquatic plants may be killed by applying either of the previously described commercial fertilizers, directly over the plants, at monthly intervals during the winter. The addition of fertilizer at this time of the year results in a heavy growth of filamentous algae which shades the plants and causes them to die (9, 11). 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 *Naja*, *Potomogeton*, *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 cannot penetrate the water. The productivity of these ponds cannot be improved by fertilization.

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 best done by seining. Fishing often does not show up in correct proportion the numbers of small and rough fish.

If the pond contains pan and game fish, but most of them are small and thin, it is overcrowded and steps must be taken to reduce the population: (1) 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 non-fertilized pond. (2) If bass are present, the number of bluegill should be reduced by seining or heavy fishing and the food increased by fertilization (19). 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 (19).

When 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,

Table 1.--Food of bluegill bream and large-mouthed black bass in Alabama (4).

Kind of fish	Food item	Percent of stomachs in which item was first in relative volume.	Percent of stomachs in which item occurred.
Bluegill bream	Water mites	0	4.4
	Mayfly nymphs	6.6	11.1
	Dragon fly nymphs	17.7	33.3
	Damsel fly nymphs	0	2.2
	Water-boatmen	0	6.6
	Water-striders	2.7	4.4
	Parnid beetle	0	2.2
	Caddice worms	13.3	33.3
	Phantom midge larvae	2.2	11.1
	Black fly 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-mouthed black bass	Dragon fly nymphs	20.0	33.3
	Water-boatmen	0	13.3
	Water-striders	0	6.6
	Midge larvae	0	20.0
	Shrimp	0	6.6
	Micro-crustacea	0	6.6
	Fish	80.0	86.6

Table 2.--Plankton and fish production of fertilized ponds in Alabama, September 9 to May 1 (14).

Pond	Fertilizer	Milligrams of plankton per liter	Pounds of fish per acre
1	None	4.8	90
2	Superphosphate	3.5	134
3	Superphosphate + $NaNO_3$	6.5	156
4*	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

* Pond No. 4 developed excessive acidity.

Table 3.--Percentages of fertilizing elements in various organic materials (1, 5, 6).

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

Table 4.--Effect of various fertilizers on plankton production at Fairport, Iowa (2).

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

Table 5.--Plankton production and fish carrying capacity in ponds fertilized with organic and inorganic fertilizers (7)[1].

Pond No.	Fertilizer	Plankton production (p.p.m.)	Fish Carrying capacity (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
	uperphosphate + Ammonium sulphate + basic slag	31.0	588.0

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

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