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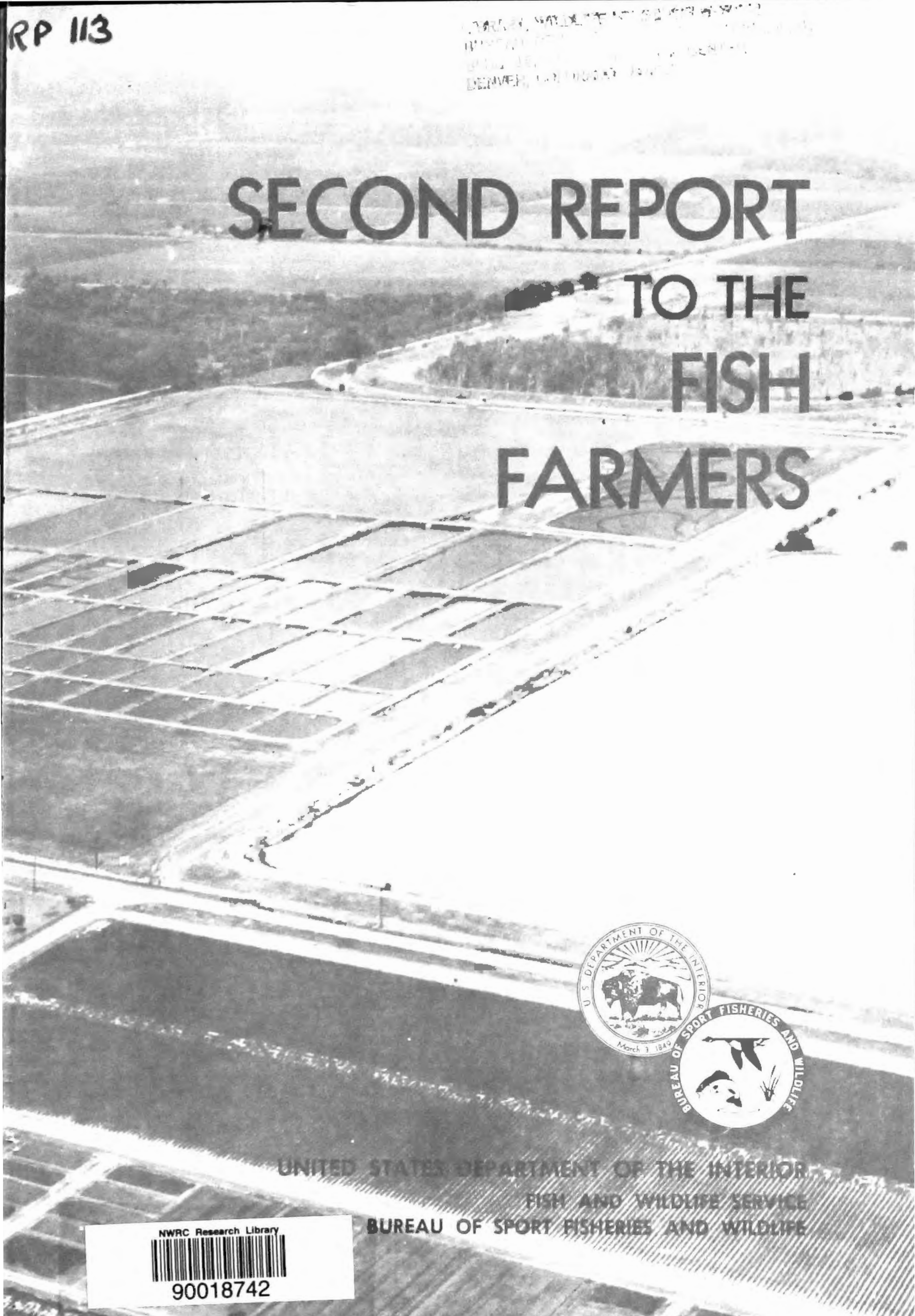


SECOND REPORT TO THE FISH FARMERS

UNITED STATES DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
BUREAU OF SPORT FISHERIES AND WILDLIFE

As the Nation's principal conservation agency, the Department of the Interior has basic responsibilities for water, fish, wildlife, mineral, land, park, and recreational resources. Indian and Territorial affairs are other major concerns of this department of natural resources.

The Department works to assure the wisest choice in managing all our resources so that each shall make its full contribution to a better United States now and in the future.

Cover: Aerial view of the Fish Farming Experimental Station of the Bureau of Sport Fisheries and Wildlife and of part of the Rice Branch Experiment Station of the University of Arkansas, Stuttgart, Ark.

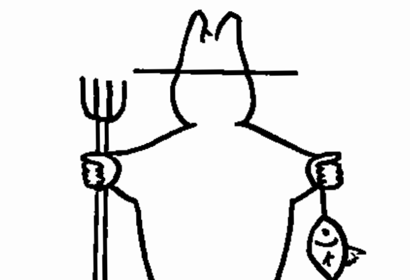
SECOND REPORT TO THE FISH FARMERS

The Status of Warmwater Fish Farming and Progress in Fish Farming Research

Edited by

Fred P. Meyer, Kermit E. Sneed, and Paul T. Eschmeyer

Contributors: Kenneth O. Allen, John J. Giudice, Waldon H. Hastings, Fred P. Meyer, Harry K. Dupree, Ortus L. Green, J. Mayo Martin, Dewey L. Tackett, and Kermit E. Sneed



Resource Publication 113
Published by the Bureau of Sport Fisheries and Wildlife
Washington, D.C. • June 1973

UNITED STATES DEPARTMENT OF THE INTERIOR
Rogers C. B. Morton, *Secretary*

Nathaniel P. Reed, *Assistant Secretary for Fish and Wildlife and Parks*
FISH AND WILDLIFE SERVICE

BUREAU OF SPORT FISHERIES AND WILDLIFE
Spencer H. Smith, *Director*

For sale by the Superintendent of Documents,
U.S. Government Printing Office, Washington, D.C. 20402
Price $2.10 Domestic postpaid or $1.75 GPO Bookstore
Stock Number 2410-00346

Prefatory Note

In 1970, the Bureau of Sport Fisheries and Wildlife published *Report to the Fish Farmers*, an immediately successful handbook that was soon recognized as the authoritative work in its field. The entire original stock is now exhausted. Developments in fish culture have proceeded at such a rapid pace since 1970 that it is again time to take stock.

Second Report to the Fish Farmers is offered as an accounting of today's position in aquaculture—the production and farming of food fish, baitfish, sport fish, and crayfish. The entire text of the original report has been revised, many sections have been updated, and new sections have been added. It is hoped that the essentials of fish farming brought together here will enable the reader to understand the present state of the industry and to appreciate its potential importance to the agriculture, recreation, and economy of the South.

The purpose here is to tell, in straightforward language, what fish farming is about—how to do it, what research has been done, how research has affected fish farming, and what answers are needed for the future if aquaculture is to realize its vast potential.

Contents

WARMWATER FISH FARMING: AN AQUACULTURAL SUCCESS STORY

Private warmwater fish culture was probably born in the late 1920's and early 1930's, when a few individuals began raising minnows to supply the growing demand for fish bait for sport fishing.

Shortly after World War II, with the boom in farm pond and reservoir construction and the many water conservation projects inspired by the dust-bowl years of the 1930's, the demand for minnows increased. By the late 1940's a dozen or more private operators were successfully producing baitfish. By 1953, the number had increased enormously, and farmers had also begun raising buffalofish, bass, and crappies. Many of these early attempts at fish husbandry failed because the operators were not experienced in fish culture, because ponds were not properly constructed, or because low-value species were stocked.

From 1955 to 1959, the U.S. Fish and Wildlife Service, with funds from the Saltonstall-Kennedy Act for Commercial Fisheries, sponsored research on channel catfish at the University of Oklahoma to learn how to improve production methods in National Fish Hatcheries and to develop a basis for commercial fish farming. Other agencies and universities also became interested in channel catfish as a commercial and sport species. During the next few years, the Bureau of Sport Fisheries and Wildlife established three warmwater fish cultural research facilities: the Southeastern Fish Cultural Laboratory, Marion, Ala. (1959); the Fish Farming Experimental Station, Stuttgart, Ark. (1960); and the Fish Farming Development Center, Rowher, Ark. (1963). These stations began research mainly with catfishes and baitfishes, but other species were added later.

By 1961 the fish farming industry was again expanding; this time it was based on a better background of experience and on the early results of research—especially that concerned with catfishes, which have proved to be the most desirable species for fish farming in the Grand Prairie and Delta areas. In 1963 about 16,870 acres in the United States were under intensive warmwater fish culture, of which 2,370 acres were being used for raising catfish. By 1969 the estimated totals were 68,000 and 40,000 acres, respectively. This comparison dramatically attests to the explosive growth of the industry, especially the part directed toward catfish production. The 1969 crop of catfish had a wholesale value of more than $33 million and generated an estimated $75-million retail business.

What relation, if any, does this developing industry have to field crops? First, fish farming in the Lower Mississippi Valley is now so well established that it is a basic part of the agricultural program of the area. Second, fish is the only crop developed in the past generation that offers an opportunity to diversify the agriculture of this area. Third, fish farming is a natural addition to the cultural practices now used in rice-soybean farming. That is, it completes a triad of rice-fish-bean rotation. Fourth, even in its present primitive state, fish farming can be profitable, and sometimes yields gross income and net profits that exceed those of rice (table 1).

Many farmers have idle land which cannot be planted in cotton, rice, or beans, either because of Government crop controls or because of the low margin of profit; this land can produce a valuable fish crop. The Soil Conservation Service estimated that in 1968 about 10,000 acres of ponds in Arkansas yielded $4 million worth of fish. Since the State has about 3.5 million acres of land that could be used for fish farming, the potential income is staggering.

In contrast to this high production from fish farms, the nearly 2.3 million acres of natural habitat and man-made impoundments (larger than 1,000 acres) open to commercial fishing in the Missouri River Basin yield less than 3 million pounds of fish per year, with a value well under $1 million. The prospect of improving that fishery is poor, whereas the prospect for increasing pond production in the South-Central States is limited only by technological development, farmer enterprise, and product merchandising.

A market for fish is there, waiting to be developed. Currently, the industry is not attaining its full market potential because the supply is not continuous, the products are not standardized, and product promotion is inadequate. More than 70 percent of all fish products used in this country are still being imported. The growing consumption of fish products and the growing population will increase the need for fish.

Fish farming has a number of fringe benefits. One of these is the increased yields of rice and soybeans that follow the use of an area for raising fish. Rice plants require large amounts of nitrogen ($7 to $14 worth per acre) to produce high yields. Much of the usable nitrogen can come from the soil, and aquaculture is one of the

Table 1.—*Annual returns per acre from various farming practices in Arkansas*

Crop	Returns	
	Gross	Net [1]
Rice (yield 50 cwt.; price $4.80)	$243.36	$107.40
Soybeans, irrigated (yield 38 bu.; price $2.35)	97.48	45.73
Soybeans, nonirrigated (yield 30 bu.; price $2.35)	88.97	47.50
Oats (yield 70 bu.; price $0.80)	46.80	8.22
Catfish, intensive	654.47	133.47
Catfish, fingerlings •	1,387.98	693.99
Mixed fish species	24.00	20.00
Golden shiners	326.50	201.50
Fathead minnows	417.00	292.00
Goldfish [2]	660.00	535.00
Sport fish, fingerlings	200.00	100.00
Sport fish, food size	17.86	12.86
Trout [2]	43,666.00	15,260.00
Fee fishing, extensive	15.00	12.00
Fee fishing, catfish [2]	1,156.94	635.94

[1] These estimates reflect 1970 yields attained by the better farmers. The values are not true net, but represent return to capital invested in land, to operator's management, and to risk of staying in business. Land investment cost of about $27 per acre ($450 per acre at 6 percent) should be subtracted from "production net" to calculate real "net."

[2] Specialized types of culture.

Much of the demand for farm-raised catfish is due to its excellent table quality and delicious flavor.

least expensive ways to make it available to the plants. The Rice Experiment Station, Stuttgart, Ark., found as much as 224 pounds of nitrogen per acre in pond soils, most of it in the form of highly stable ammonium. Although rice may grow rank and lodge in the presence of too much nitrogen, lodging may be prevented; if soybeans follow fish in the rotation, much of the excess nitrogen is removed.

Rice farming holds some water on the land, delaying its return to the sea, but fish farming holds much more water for a longer time, thus conserving this important resource. And fish farming does more: It improves the subsoil moisture, improves the texture of the soil, and may provide a supplemental source of irrigation water. In addition, some fish-rice farmers are gaining benefits from pumping water through fish ponds and then irrigating rice from the ponds. The advantages of this procedure appear to be considerable: (1) The aeration of groundwater in the ponds removes iron, which is present in most water from wells. (2) Since the vegetation in the ponds desalts the water, more crops of rice can be harvested before rotation becomes essential. (3) Since nitrogen levels are relatively unaffected by the procedure, lodging is probably not a danger.

There are still other fringe benefits from fish farming. This water use is in keeping with the Nation's philosophy of total conservation of natural resources, and at the same time it allows the harvest of a cash crop, produces large poundages per acre of

Rice farming is an integral part of diversified agricultural operations closely related to fish farming.

needed animal protein, and beautifies the landscape. In addition, it increases recreational values of land for duck hunting, sport fishing, frog hunting, and trapping, and esthetic values for photographers and nature lovers.

What are the future limitations, problems, and pitfalls that await the fish farmer?

Many fish husbandry problems have been reasonably well solved. Scientists working with the industry feel confident that the fundamentals of spawning, disease control, and feeding are understood well enough to enable the knowledgeable fish farmer to grow a profitable crop. In the last 5 years several farmers have learned to raise up to 2,000 pounds of channel catfish per acre.

One problem still not fully solved is that of handling large quantities of live fish, as when, for example, a producer seines as much as 40,000 to 50,000 pounds of fish from a 40-acre pond in a single haul. It is impossible to count, weigh, and load this many fish by hand rapidly enough to prevent death or spoilage. Mechanical harvesting and better logistics are obviously needed to get the fish to market in first-class condition. Research is underway to solve this problem, however, and some recent developments have improved the situation.

Another limitation on expansion in the distant future may be the lack of adequate water, but here again, research in progress is directed toward reclaiming, reconditioning, and reusing water.

The use of some abandoned land, such as diverted cotton acreage, may be impossible owing to the accumulation of pesticides such as endrin, toxaphene, dieldrin, and others. These chemicals are not readily degraded in aquatic or arable crop environments.

Where do we stand, then? A fledgling industry is off the ground. It is based on sufficiently sound foundations to merit financial backing. There is a growing demand for fish, both for food and for sport fishing. Fish farming is a sound conservation practice with many fringe benefits. Not only can it improve the yields of rice and beans, but fish is often a more profitable crop than beans and even promises to be more profitable than rice. Fish give a high return per acre in protein; this protein is needed and the markets for fish can be developed. Millions of acres of land are still available for the expansion of fish farming, and, if water is properly used, the supply is adequate.

What happens from here on will depend upon research—both basic and applied—and the confidence that landowners have in that research.

CHANNEL CATFISH CULTURE METHODS

The channel catfish (*Ictalurus punctatus*) is the species most often raised on commercial warmwater fish farms. It adapts readily to pond conditions, accepts artificial feeds, and tolerates crowded conditions associated with intensive culture. Techniques for the propagation of the species have been developed to the extent that large numbers of fingerlings can now be produced.

Channel catfish are esteemed for the high quality of their flesh, especially in southern States where the fish is a traditional delicacy. Dressed catfish retain their high quality when packed in ice and sold through conventional fish marketing channels. Frozen fish can be stored for extended periods if adequately packaged and refrigerated.

These attributes, plus its good public image, form the background for the expanding catfish industry. The following sections describe the fundamentals of the commercial production of catfish.

Selection and Care of Brood Stock

Source of Brood Stock

The channel catfish is native to streams and lakes of eastern United States and southern Canada. Originally, brood stock was obtained from these sources; by now, however, the species has been cultured for nearly 50 years, and most present-day brood stock is hatchery raised. Wild catfish brought into the hatchery do not always make good brood stock the first year, although fish taken from natural waters shortly before the spawning season will usually spawn.

Selection of Brood Stock

Channel catfish—especially the males, which are rather dark—are sometimes confused with blue catfish (*Ictalurus furcatus*). The two species have a similar appearance, and both have forked tails. They can be distinguished, however, by the shape and fin ray count of the anal fin: The anal fin of the channel catfish has a rounded margin and 24 to 29 supporting rays, whereas that of the blue catfish has a straight margin and 30 to 36 rays.

Large catfish usually spawn earlier than smaller ones and produce more eggs. Culturists prefer 2- to 10-pound brooders, although catfish may mature when they weigh as little as ¾ pound; fish larger than 10 pounds are difficult to handle. *Channel catfish brood stock can be raised and reliably spawned in 3 years.*

In the selection of brood stock, fish should be examined before they are fed, to insure that abdominal fullness reflects the size of the gonads rather than the amount of food in the gut. The best characteristic indicative of spawning condition in the female is a well-rounded abdomen, the fullness of which extends posteriorly past the pelvis to the genital orifice. The ovaries should be palpable and soft, and the genitals swollen and reddish. Less attention needs to be given to selection of the male. However, males with prominent secondary sexual characteristics—a heavily muscled head wider than the body, dark pigmentation under the jaw, and a large, protruding genital papilla—usually have well-developed testes. Such males may be used successfully for a second or a third time during one season, whereas those with poor secondary sexual characteristics may not adequately fertilize more than one lot of eggs. Individuals with abnormally shaped fins, spinal deformities, or other defects should be culled from the brood stock.

Determining Sex

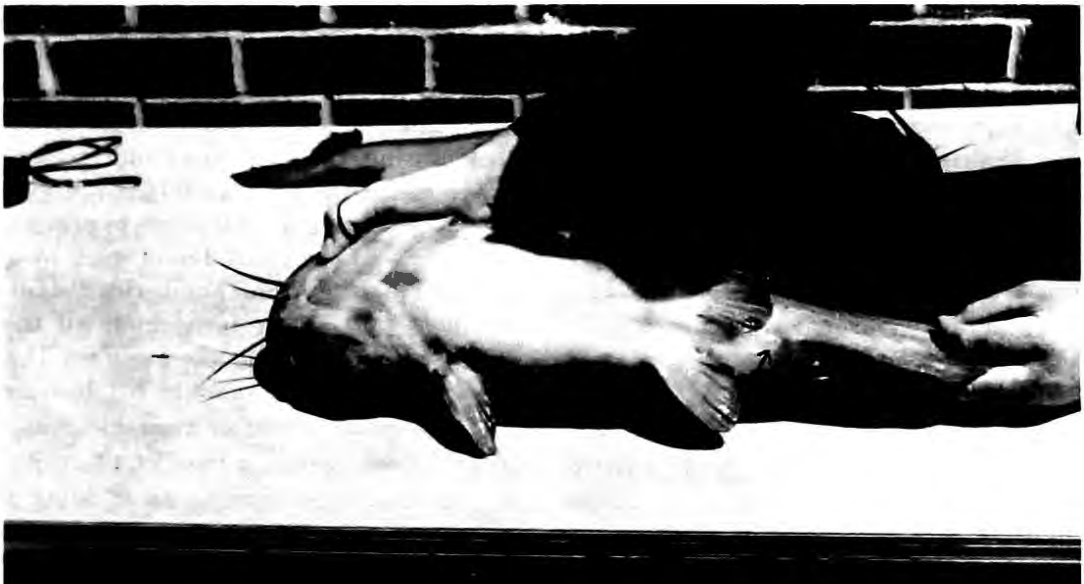
Sex of brood fish must be determined so that the fish introduced into a pond for breeding will have a sex ratio that has proved to be effective, or so that a pair can be placed in an aquarium or pen.

The female can be recognized during the breeding season by the folds of skin on each side of the urinary and genital openings, which are raised and divided by a groove. The male has a wider head, thickened lips, pronounced development of the head muscles, and is usually darker than the female during the spawning season. Occasionally, when the sex of the fish is not readily apparent, the culturist may apply other techniques to determine sex. The tip of a broom straw thrust forward from the anal fin toward the genital opening will hang on the papilla of a male, but will penetrate the genital pore of a female.

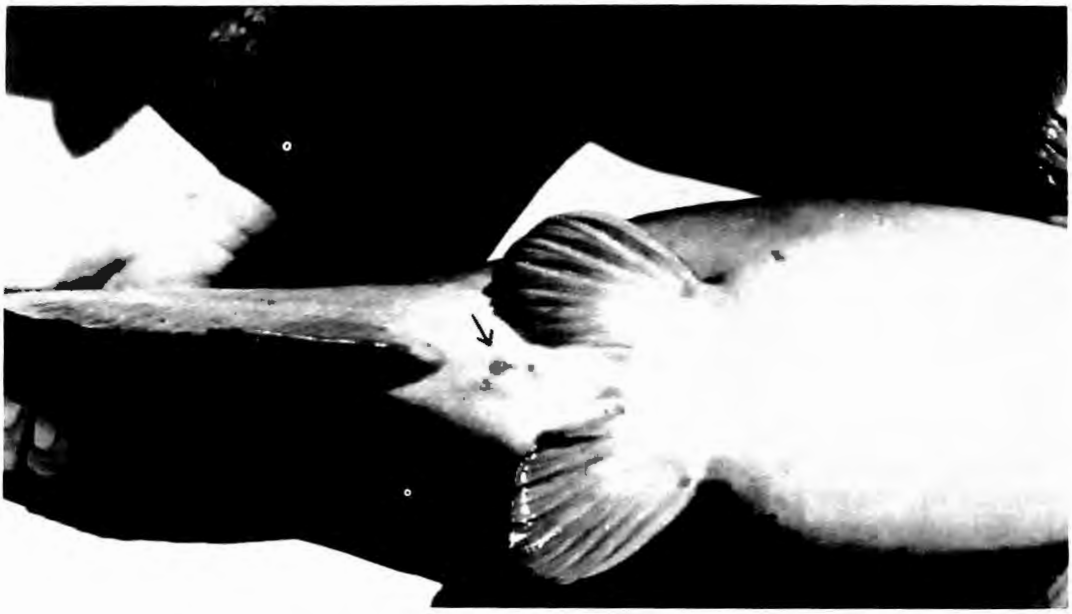
Pairing

Successful pairing of fish, which is an essential part of pen and aquarium spawning, depends on the skill of the culturist in sexing and selecting the fish. Sex determination is slightly less important in pond spawning.

Channel catfish fight during the spawning season. Their bites are often deep enough to break the skin, and the resulting wounds may become infected. Fish sometimes die from severe bites. For this reason, special care must be taken to pair fish properly in pens and aquariums. If the female, in particular, is not ready to spawn, the male will fight with her, and in the confinement of an aquarium may inflict enough injuries in 15 or 20 minutes to kill her. In spawning pens, the condition of the female is not quite as important, since the pen is usually large enough for her to escape from the attacking male. Even so, it is not uncommon to see bite marks on the female in a pen. When fish reproduce in ponds, they pair when they are ready to spawn, and fighting is not a serious prob-



Ventral view of a male channel catfish. Note the gray color under the jaws and fleshy tubular genital papilla (arrow).



Ventral view of a female channel catfish. Note the round, button-like genitals (arrow) as compared with the narrow fleshy papilla of males.

lem. This method should be used if the fish are in marginal spawning condition.

Other factors must also be considered in pairing fish. Culls should not be mixed with good brood stock in a pond. Although most culturists prefer or require that the male be slightly larger than the female, biologists who have observed hundreds of pairs spawned in aquariums under different experimental conditions have concluded that males and females of similar size should be used. If the male is considerably larger than the female, spawning is usually successful; if the female is much the larger, however, she usually attacks the male and may not mate with him.

Care and Handling

Since brooding channel catfish sometimes fight savagely, it is inadvisable to hold them longer than necessary in close quarters such as a trough, kettle, or truck tank. They can be safely transported long distances during the spawning season, however, if they are tranquilized or if each fish is placed in a separate burlap bag or other container.

Immediately after the spawning season, brood stock may be placed in a pond at the rate of 150 fish per acre. Although the fish are easily frightened, 90 to 95 percent of the fish held in small ponds will learn to come for feed within 1 week. If this same number of fish is held in a 1-acre or larger pond, 25 or 30 percent may never come for feed, and consequently will be in poor condition and undesirable for brood stock during the next spawning season. One recommended practice is that of dividing the fish among several ponds to prevent destruction of the entire brood stock by a possible epizootic. Some hatcheries distribute the adult catfish throughout all the available ponds during the summer. The scattered fish then need not be fed, because sufficient natural food is available. Since crayfish predominate in the diet, this practice has the added advantage of being a method of crayfish control. When the ponds are drained in the fall and winter, the catfish from the several ponds are returned to a single pond and fed until time for spawning. *The feeding of brood stock is important because diet quality and quan-*

tity largely govern the number and size of eggs, spawning time, and general health.

Brood fish that weigh 2 to 3 pounds should be stocked at the rate of 300 to 400 pounds per acre when additional growth is desired. Larger fish should be stocked at the rate of 800 pounds per acre if further growth is not wanted. The feeding rate and diet depend partly on water temperature. Brood fish should be fed 2 to 3 percent of their body weight on each of 3 or 4 days a week when water temperature is above 55° F. Since brood stock channel catfish feed sparingly even when the water temperature is as low as 45° F., they should be fed only on the warmer days during periods of cold weather. When it is very cold, catfish feed better on meat or diets high in animal protein than they do on cereal feeds. Meat diets can be readily utilized by the fish, and it is generally accepted that fresh or frozen meat or fish should be included in the brood stock diet. The addition of forage fish to the brood stock holding ponds may adequately meet this need.

Number of Eggs Laid

Females that weigh 1 to 4 pounds and are in good condition produce about 4,000 eggs per pound of body weight; larger fish usually yield about 3,000 per pound. Fish in poor condition produce fewer eggs.

Estimating Numbers of Eggs and Fry

Numbers of eggs can be roughly estimated by weighing egg masses. At intervals over a period of 3 to 4 hours, females release small numbers of eggs, which are fanned into a single mass as they are laid. The completed spawn is a small mound which varies greatly in diameter and depth. Since the eggs are adhesive, the mass can be easily handled. Egg numbers range from 450 to 700 per ounce. Spawns weigh 1/3 to 6½ pounds and average 1 to 2½ pounds. The estimate of number of eggs on the basis of weight is usually not highly accurate because the egg mass, like a sponge, contains an amount of water that varies with the size and shape of the mass, and to some extent with its age. More water drains from older spawns than from younger ones, and eggs decrease in weight slightly as they near hatching.

Numbers of fry can be estimated rather accurately by counting a volumetrically measured sample of the yolk-sac fry. A simple technique is to siphon the fry into a graduated measuring cup. Numbers of yolk-sac fry per fluid ounce range from 750 to 1,800 and average about 1,000.

Egg Development and Incubation

The number of days required for eggs to reach various developmental stages varies according to temperature. Channel catfish spawn at 70° to 85° F.; the optimum temperature is about 80° F. The incubation period ranges from 10 days at 70° to 5 days at 85°F. At incubation temperatures above 85° F., many deformed fry are produced.

The male channel catfish assumes a position over the eggs after spawning is finished, and cares for the eggs during the incubation period. Although the female aerates the eggs during spawning, she is driven away like other intruders after the male takes possession. The male's pelvic fins work alternately in a continuous beat. He generally faces in the same direction. Occasionally he circles away from the eggs and then returns. The most striking activity of the male is the vigorous shaking of his body as he presses and packs the eggs with the side of his pelvic fins in a manner that moves the entire egg mass. Apparently this act helps aerate the developing eggs, especially those deep within the mass, but it may also serve to move the embryos within the eggs.

Many fish farmers who produce fingerlings for sale prefer to collect spawns and hatch them in artificial hatching systems. Good incubation and hatching are obtained at some hatcheries by the paddle wheel method (described later), which simulates the male's agitation of the eggs.

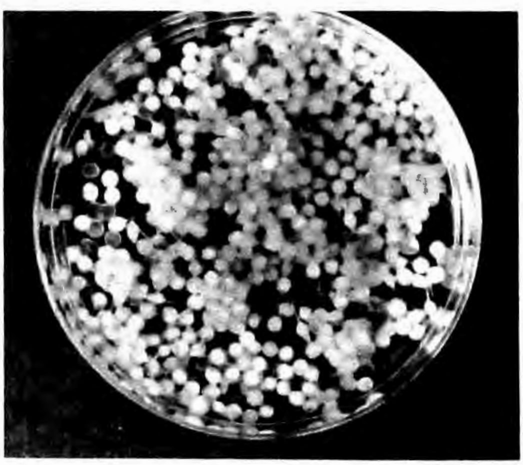
Posthatching Activity

After the eggs hatch, the fry accumulate on the bottom and remain there for about 2 days before coming to the surface. At this time the yolk is greatly reduced, and the skin pigment is visible. By the third day, the fry start to feed and swim actively.

Pond Method of Spawning

In early attempts to induce spawning, tiles, beer kegs, nail kegs, or boxes were partly embedded in the bank of a pond, about 2 or 3 feet below the water surface. After the brood fish placed in the pond had spawned, the newly hatched fish were removed from the containers and transferred to a clean pond. In later years, the egg masses were removed from the pond for incubation; continuous-motion paddles were used to agitate the water and the eggs. This system for hatching catfish eggs is still in use.

The pond method remains essentially unchanged. Brooders are placed in small, usually shallow ponds, ranging up to about 7 feet deep. Equal numbers of males and females are placed in the pond at a stocking rate of 24 to 150 fish per acre.



Newly hatched fry of channel catfish are pink and have large yolk sacs. They absorb the yolk and turn gray after 5 to 7 days.

Preparation of Spawning Sites

Ten-gallon milk cans and small drums are popular spawning containers. Ordinarily it is not necessary to provide a spawning receptacle for each pair of fish, since not all fish spawn at the same time. Most culturists allow two or three receptacles for each four pairs of fish. Usually they place the cans or drums with the open end toward the center of the pond. Fish have spawned in containers in water as shallow as 6 inches and as deep as 5 feet. The receptacles can be most easily checked if they are in water no deeper than arm's length.

Checking for Spawns

Frequency of examination of spawning containers depends on the number of brood fish in the pond, and the rate at which spawning is progressing. Caution should be used, because an attacking male can bite severely. In checking a container, the culturist gently raises it to the surface. If this is done quitely and carefully, the male is not disturbed. If the water is not clear, the container may be slowly tilted and partly emptied, until the bottom can be checked for eggs or fry.

Handling Eggs or Fry

Spawns may be handled in different ways by the fish farmer. In the pond method, he may remove eggs or fry or leave them in the spawning receptacle. Removal of the eggs has several advantages: It minimizes the spread of diseases and parasites from adults to young; provides protection from predation; and may increase the percentage hatched. The main reason for removing fry is to improve control of stocking rates, although it also protects them from predation. Fry or eggs are often removed when spawns are produced for stocking other ponds. Large-scale producers commonly use special brood ponds.

If eggs and fry are left in the pond, the brood stock should be removed with a large-mesh seine (1-inch mesh or larger, bar measure). Periodic seining with a small-mesh seine provides information about numbers and growth of fingerlings.

Advantages of the Pond Method

The pond method is inexpensive because it requires only a pond and spawning containers as minimal facilities, and does not place demands on the farmer for critically, selecting, sexing, and pairing his brood stock. The fish in the pond continue to feed and develop until they pair and spawn. If the brood fish are of marginal quality, the pond method is more likely to produce spawns than are the other methods (described below).

Pen Method of Spawning

Pen Construction

Pens about 10 feet long and 5 feet wide are used commonly by Federal and State hatcheries and by a few private hatcheries. The pens are constructed of wood, wire fencing, or concrete blocks. They may be enclosed on four sides, or the bank of the pond may be used as one side. The sides should be embedded in the pond bottom and should extend at least 12 inches above the water surface to prevent the escape of the fish. Water in the pen should be 2 to 3 feet deep.

Preparation of the Spawning Site

Location of the spawning receptable in the pen is not critical, but generally the opening faces the center of the pond; the receptacle should be staked down. Ten-gallon milk cans, 100-pound grease drums, and earthenware crocks are popular spawning containers. After spawning, eggs or fry and parent fish may be removed and a new pair placed in the pen. Alternatively, the female may be removed as soon as an egg mass is found, and the male then allowed to hatch the eggs.

Advantages of the Pen Method

The pen method has several advantages: (1) It provides close control over the time of spawning, since it may be delayed by separating females from males; (2) it offers the advantage of pairing selected individuals; (3) it facilitates removal of spent fish to a separate pond where they can be given special care; (4) the pen protects the spawning pair from intruding

In the open-pond spawning method, spawning receptacles are staked at regular intervals in the pond.

fish; (5) the pen allows the use of hormones.

To succeed with the pen method, the culturist must know his fish well enough to be able to pair the right fish at the right time.

Aquarium Method of Spawning

The aquarium method provides still greater control than the pen. A pair of fish is placed in an aquarium with running water and induced to spawn by the injection of hormones (described below). The method capitalizes on limited facilities, use of hormones, and expert brood fish selection. It is an intensive type of culture; many pairs can be successively spawned in a single aquarium during the breeding season, since eggs are immediately removed to a mechanical hatching trough. The technique is used in Federal, State, and a few private hatcheries.

In this method only well-developed females nearly ready to spawn should be used. Males need not be injected with hormones, but should be about the same size as the females with which they are paired. If the male attacks the female, he should be removed until after the female has been given one to three hormone injections. He then may be placed with the female again. Males may be left to attend the eggs in the aquarium, or preferably, the eggs are removed to a mechanical hatching trough.

Aquarium Apparatus

Catfish may be induced to spawn in aquariums with capacities of 30 to 50 gallons. Troughs divided into compartments are less satisfactory. Each aquarium must be supplied with flowing water, and tar paper mats are placed on the bottom of each so that the eggs can be readily removed. Aquariums with at least two glass sides are the most satisfactory spawning containers.

Use of Hormones

Induced spawning with fish pituitary injections is an established method, although it is not often used for channel catfish. A few fish farmers use the technique for blue catfish or flathead catfish (*Pylodictis olivaris*). Spawning may be induced in catfish by injecting the female with pituitary material from carp, buffalofish, flathead catfish, or channel catfish. Potency of the pituitaries differs little among these species, and is not affected by the date of collection. The total amount of acetone-dried pituitary material required varies widely. However, most females require about 6 milligrams per pound—that is, three injections of 2 milligrams per pound of body weight at 24- to 48-hour intervals. Most fish begin spawning within 16 to 24 hours after the injection.

Human chorionic gonadotropin at a dosage of about 800 international units (IU) per pound has been used successfully. A single injection is usually sufficient.

Fish spawned by the hormone method are not particularly disturbed by people moving around the area.

Advantages of the Aquarium Method

The aquarium method has several advantages: (1) Spawn can be obtained at a convenient time. The hormone injections eliminate such environmental variables as spawning areas, light, and temperature and other climatic conditions. (2) The spawning period can be altered within reasonable limits, and total spawn-taking time reduced. (3) Fish that will not spawn naturally sometimes can be induced to spawn. (4) Culture ponds can be stocked with fry of uniform age and size. (5) Disease transmission from brood stock to offspring, as well as predation by adults, is minimized.

Controlling Spawning Time

Natural Spawning Season

The date and length of the spawning season for channel catfish varies from year to year and among localities. In various natural waters, the season may begin as early as April and end as late as August. At four National Fish Hatcheries in Texas, spawning usually began in mid to late May and lasted 11 to 51 days; peak spawning dates came as early as May 16 and as late as June 17 (table 2).

Encouraging Spawning

In June and early July, fish in pens occasionally spawn for a few days and then completely stop. *Raising the water level rapidly several inches sometimes will cause spawning to resume immediately.*

Some farmers inject brood females with human chorionic gonadotropin before transferring them to the spawning pond. Others have advanced the spawning time about 2 weeks by taking advantage of the warmer water of small, shallow brood ponds.

Delaying Spawning

Spawning can be delayed 20 to 30 days by keeping the sexes separated. It may also be delayed by holding the fish at water temperatures of 62° to 65° F. during May, June, and July. A farmer who needs a late hatch of fish can use small adults obtained from streams in late July or August. Since it is usually difficult to induce such fish to spawn, they should be injected with hormones.

Hatching Eggs

For egg incubation, avoid temperatures below 65° and above 85° F. Temperatures between 78° and 82° F. are considered optimal. In this range, the eggs will hatch in about 6 days.

Color is an important index of the condition and stage of catfish eggs. Under

Table 2.—*Spawning dates of channel catfish at National Fish Hatcheries in Texas, as reported by Harry Bishop, National Fish Hatchery, Austin, Tex.*

Location and year	Spawning period	Peak spawning dates
Austin:		
1964	May 4–June 23	May 18 and 25.
1965	May 20–July 1	May 21 and 28.
1966	May 19–June 19	May 29 and June 6.
Fort Worth:		
1962	May 28–June 22	June 8.
1963	May 23–June 22	June 14.
1964	May 26–June 22	June 5 and 17.
1965	May 28–June 15	May 28 and June 15.
1966	May 31–June 13	May 31 and June 4.
Inks Dam:		
1962	May 26–June 25	May 27.
1963	April 29–May 25	May 17.
1964	May 9–June 19	May 27.
1965	May 27–June 10	May 28.
1966	May 27–June 13	May 28 and June 3.
Uvalde:		
1964	May 20–May 30	May 22 and 23.
1965	May 14–June 16	May 16 and 17.
1966	May 18–June 10	May 21 and 22.

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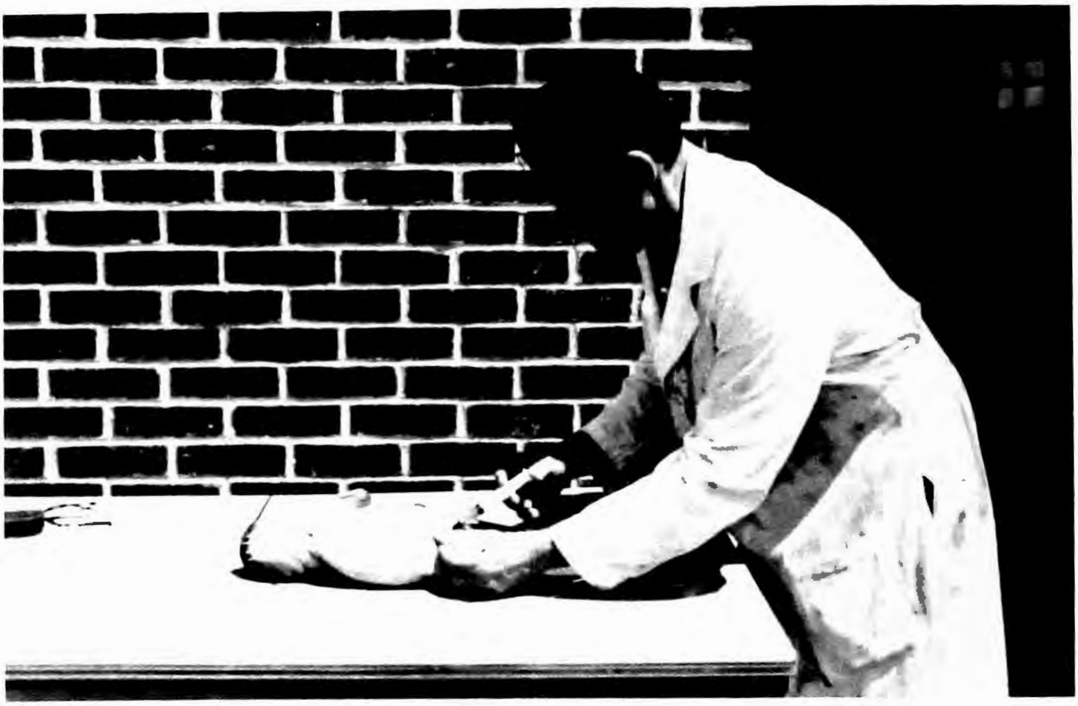


Spawning in pens or aquariums can be hastened by the injection of hormones into the body cavity of the female. The fish should be held firmly or anesthetized.

proper conditions, the yellow eggs turn pink as the embryo develops and establishes its blood supply. Unfertilized or dead eggs turn white and enlarge.

All hatching devices must provide sufficient agitation to supply the entire egg mass with oxygenated water of a suitable temperature. Although hatching jars have been used for incubating catfish eggs, they generally give poor results; consequently troughs are much more commonly used.

When eggs are hatched in troughs, they are agitated with paddles driven by an electric motor or a water wheel. The agitation should be sufficient to move the whole spawn, but not enough to throw eggs out of the holding baskets. If well water is used, it must be aerated and of suitable temperature and quality. For example, water with a high iron content is not considered desirable. Gravity-fl[illegible] water should be used if available, because this system is not likely to fail.

Trough hatching systems may be constructed from a variety of materials. Aluminum is commonly used but wood or steel serves equally well. Typical hatching troughs are 20 inches wide, 10 feet long, and 10 inches deep. Some producers use 30-inch-diameter steel pipes that have been split lengthwise and closed at the ends. A divider can be placed at midlength to strengthen the tank or to separate spawns of different ages. One-inch collars and nipples in each section serve adequately as drain or overflow structures.

Bearings at the middle of the top edge at each end and at midlength support a 1-inch pipe which serves as the turning shaft for the paddles. Paddles are constructed of galvanized tin and attached to the shaft, spaced to allow three spawn baskets in each half of the tank. These paddles are commonly 4 inches wide and long enough to dip well below the bottom of the baskets as they turn. The pitch of the paddles is adjusted as required, to insure vigorous movement of spawns in the baskets.

The shaft is fitted with a pulley at one end and is belt-driven by an electric motor (frequently ½ hp.). The preferred speed is 30 r.p.m. Combinations of pulley sizes or a variable-speed gear box may be used to deliver the desired speed of rotation.

Spawn baskets are constructed of ¼-inch hardware cloth, 18 inches long, 12 inches wide, and 4 inches deep. Each basket is divided into four equal sections and fitted with wire hooks so that it can be hung on the sides of the trough with the top edge 1 inch above the water.

A flow of about 2.5 gallons per minute of well-aerated water should be provided. Optimal hatching temperatures are 78° to 82° F.; extremes above or below this range adversely affect development and may kill the embryos.

It is important that spawns in each section of trough be of the same age, because the mixing of spawns of different ages may prevent the use of prophylactic treatments.

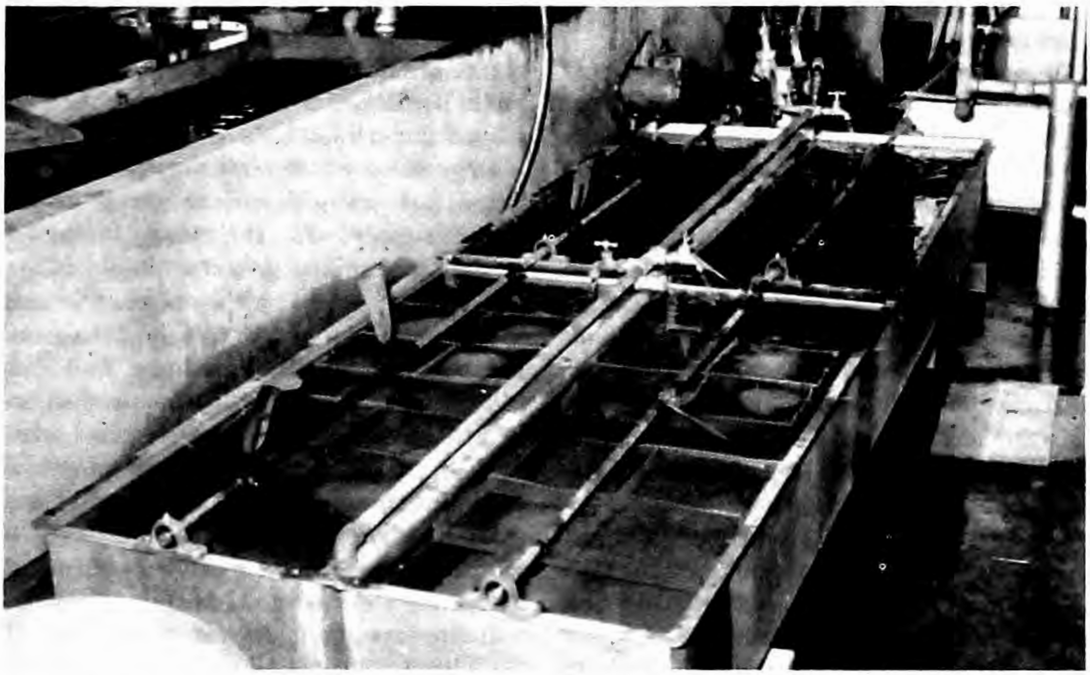
A flush treatment of malachite green at about 2 parts per million (p.p.m.) may be introduced at the head of the trough once or twice per day if needed to control fungus. Fungi grow on dead eggs and spread to living ones, eventually destroying the whole spawn. *Do not apply this chemical within 24 hours of hatching. If fry are present, it will kill them.*

Rearing Fry

To remove fry from the hatching trough, the culturist simply siphons them from the trough with a hose into a washtub or pail. To remove fry from a pond spawning receptacle, he first removes the male, usually by frightening him away, then lifts the spawning container to the surface and carefully pours out part of the water. The remaining water with the fry can then be emptied into a floating tub that contains an inch or two of water. Fry should be counted and then moved to either a rearing trough or a pond.

Trough Method

Rearing troughs may be made of wood, metal, fiberglass, or plastic. Typical troughs are 8 to 10 feet long, 1 foot deep, and 8 to 20 inches wide. Each trough must



A typical artificial hatching unit for incubating catfish eggs. Note the subdivided wire baskets which suspend egg masses between the paddles.

be supplied with running water and equipped with a drain and an 8-inch standpipe. The fry from one or two spawns are put into each trough. A flow of about 5 gallons of fresh oxygenated water per minute is sufficient. Standpipes are screened so the fry are not washed over the standpipe and down the drain.

Fry begin to feed shortly after the yolk sac is absorbed and the fish begin to develop a grayish color. This usually occurs at 3 days of age. *It is mandatory that suitable feed be available at this time.* Channel catfish fry eat a variety of feeds. Feeding frequencies and particle size are important considerations. Young fry should be fed every 2 to 4 hours around the clock for the first week. Thereafter the fry should be fed about four times a day. Diets for channel catfish fry are now available commercially.

Fry may be raised to the fingerling stage in troughs or they may be moved to a rearing pond at any time.

Pond Method

Although the area of rearing ponds for channel catfish varies from $\frac{1}{10}$ to 5 acres and larger, it is usually about 1 acre.

Predatory insects are often a problem in the pond culture of fry. If a pond is not filled until immediately before it is stocked with fry, establishment of the insects is prevented. If water has been standing in the pond for several days, or if surface water is used, it should be treated with a nonresidual insecticide 2 or 3 days before the pond is stocked. *The operator should use extreme care, because insecticides are dangerous to man.* An old accepted practice is the application of 2 to 4 gallons of diesel fuel or kerosene per surface acre. The addition of inexpensive or used motor oil at the rate of 1 pint per gallon of diesel oil strengthens the surface film. Applications should be made twice weekly, on days when there is either no wind or just enough to move the mixture slowly across the pond.

Fry can either be released directly into the open pond, or be held for the first few days in floating cages made of screen or of a wooden frame with a screen bottom. They are then protected, and can be fed during this vulnerable period. If a pond has a basin, fry may be placed in it and the rest of the pond kept dry. As the fry get larger, the pond is gradually filled.

Fry are stocked at the rate of 50,000 to 250,000 per acre, depending on the size of fingerlings sought at the end of the growing season. *The young fish are fed daily along most of the shoreline at a rate of about 4 to 5 percent of their body weight at each feeding.*

Rearing Fry to Fingerlings

Channel catfish fingerlings are reared in either ponds or troughs. In ponds, low-cost pelleted fish feed may be used, but in troughs a more expensive, balanced feed is required. In the two environments, different methods and techniques are used to stock, feed, and harvest the fish. Some farmers prefer to start the fry in rearing troughs and transfer the fingerlings to ponds after they are actively feeding. The choice of method depends on facilities and labor available, and on the number and size of fingerlings to be produced.

Regardless of the rearing method selected, attention should be given to the water supply. In the trough rearing method, the incoming water should range between 75° and 85° F. and contain not less than 6 p.p.m. of dissolved oxygen. Factors such as pH, hardness, and dissolved iron content influence production of fish in troughs that are supplied with well water. When water from ponds is used for trough culture, these conditions may be disregarded; then, however, a Saran screen or sand filter between pond and trough is desirable. In pond rearing, a major problem is fry-eating insects and fish. Predatory fish can be controlled by filling the pond with fish-free well water

Large, healthy fingerlings are essential if catfish are to reach market size in one growing season.

or by using a fine-mesh screen to filter water from other sources; fish-eating insects can be controlled by treating weekly with oil or kerosene (as described earlier), until the fish are about 1½ inches long.

Trough culture of fingerling catfish begins with yolk-sac fry from the hatching trough or from spawning containers in the ponds. It is a good practice if time and facilities permit, because it gives the culturist complete control of the small fish. When fry about ¾ inch long are stocked in rearing ponds, 60 to 90 percent can be harvested in the following fall.

Troughs may be wood or metal and 8 to 12 feet long, 12 to 15 inches wide, and 8 to 10 inches deep. Water should enter at the head of the trough at the rate of 1 to 5 gallons per minute, and drain through a screened standpipe at the lower end. No more than 25,000 sac fry should be stocked per gallon-per-minute inflow.

Techniques for feeding catfish fry are extremely important, particularly when the fry are learning to feed. For about the first 3 or 4 days after hatching, fry subsist on yolk and remain on the bottom of the pond or trough. After they have absorbed the yolk sac they become known as "swim-up" fry. When they are seen swimming along the sides and surface of the trough in search of food they must be fed at once. Fry that do not learn to feed during the first few days after absorption of the yolk sac will die.

In pond culture, either sac fry, swim-up fry, or feeding fingerlings may be stocked. Stocking rates vary, depending on the fingerling size desired. If the fish are to be harvested at 2- to 4-inch lengths after about 120 days, they are stocked at the rate of 100,000 to 150,000 per acre. If 6- to 8-inch fish are desired, the stocking rate should be reduced to 14,000 to 20,000 per acre. A combination of these methods may be used: The fish can be stocked at the maximum rate initially, and then partially harvested for sale or transfer to other ponds when they reach the 2- to 4-inch size.

Several methods may be used to estimate the number to be stocked. Since female channel catfish usually produce about 3,000 to 4,000 eggs per pound of body weight, the fish-culturist can use the weight of the brood stock to estimate the number of fry that can be expected. A better method of estimation is that based on numbers of fry by weight or volume. Channel catfish sac fry less than 7 days old number about 1,000 per fluid ounce. A measuring cup or a plastic graduated cylinder is suitable for volumetric measurements. When fish 1/4 to 1 inch long are stocked, the counted number in a unit of volume or weight (such as a dipperful) determines the number of units (dipperfuls) of fry needed.

When all the fingerling catfish in a pond are to be harvested, as many as 75 percent of the fish may be removed by seining the feeding areas, before the pond is drained. In summer it is best to harvest the fish early in the morning, while water and air are cool. Care should be taken to avoid excessive muddying of the water. If possible, sites with a firm obstacle-free bottom should be selected as feeding and seining areas. After the seining is completed, the pond is drained to recover the rest of the fish.

Rearing Fingerlings to Market Size

A large healthy fingerling, a good environment, and a conscientious feeding program are necessary for a profitable food-fish production program. *If market-sized fish are to be produced in one growing season, fingerlings 6 to 8 inches long or longer must be stocked.* Such fingerlings will weigh at least 1 pound after about 210 days, if properly cared for.

Control of predators such as snakes, bullfrogs, and fish-eating birds should be emphasized. Snakes can be controlled by keeping the grassy banks and surrounding areas closely mowed and free of debris. Bullfrogs can be kept under control by harvesting them, by manual removal of their eggs, or by sprinkling a few crystals of copper sulfate on the egg masses. Bullfrog tadpoles are considered competitors of catfish because they occupy space and eat fish feed. Most water birds are protected by Federal or State law. Kingfishers, herons, grebes, mergansers, and diving ducks are probably the most serious bird predators of fingerling catfish, and pose a serious problem if present in large numbers. Unfortunately, fireworks and other noise- and light-producing devices are of only limited value in keeping these predators out of ponds.

Turtles do not usually present a serious problem. The common "snapper" is the only pond turtle of importance as a fish predator, and it is rarely common enough to be a problem. The common pond turtles, or "sliders," do not eat fish, but do eat their feed, and are a nuisance at harvest time. Turtles can be controlled by trapping.

Time of stocking is not as critical as some believe. A pond should be stocked whenever it is ready to receive fish. A 2-inch fish stocked in July will be only 9 to 10 inches long by November and must be reared to market size the next summer.

The poorest stocking months are December and January because of the low water temperature. Fish feed least at this time of the year and sometimes do not resume feeding readily after they are moved. The fish that die after stocking at this time of year may never be seen.

Fish should be fed during winter, but the feeding rate should be reduced as the

Predators such as snakes may consume large numbers of fish unless controlled.

water cools. Self-feeders are useful under such conditions. At low water temperatures, fish move slowly, and do not seek out feed as they do when the water is warm; they also consume less food at each feeding and digest it much more slowly.

It is very important that fingerlings start feeding immediately after they are stocked in a pond. Well-fed, healthy fish are more resistant than others to parasites, disease, and predators, and reach marketable size sooner. Fish soon learn to feed if food is provided along the entire edge of the pond on the day after they are stocked.

Once the fish start eating, a good feeding program should be initiated and followed. Food allowances are 3 to 6 percent per day of the estimated weight of fish in the pond; rates are lower (1½ to 2 percent) during unusually hot or cold periods. Feed is offered in the early morning and late afternoon in summer but only in late afternoon during the cooler seasons. If sinking pellets are used, it is desirable to scatter them along the shallow pond margin where feeding activity of the fish can be observed. Floating feeds may be scattered over the entire surface of the pond. Feeding activity is a good index of the well-being of the fish; rapid and vigorous consumption of the food suggests good environmental conditions and good health.

Catfish are being raised successfully in water from many sources. Well water is best, but other uncontaminated supplies such as clean streams or springs are acceptable if they are free of fish and disease organisms.

It is not economically feasible to grow a mixture of catfish and wild fish. If the water source contains wild fish, it must be filtered through woven Saran or other fine-mesh screen. The stocking of 50 fingerling largemouth bass per acre sometimes controls wild fish but this practice is not always reliable. A registered and commercially available selective fish toxicant (Fintrol) kills sunfishes and most other species without harming catfish.

Oxygen depletion is the greatest fish farming problem. Most oxygen-depletion kills are preceded by a phytoplankton die-off and decay. This situation is aggravated by the decomposition of uneaten fish feeds and fecal waste. *When excessively thick blooms of phytoplankton (algae) occur, it is desirable to add fresh water to the pond.* Feed should be reduced in amount or withheld entirely until the condition has improved.

Catfish culture is also influenced by aquatic vegetation. Although rooted aquatic plants and filamentous algae are not as troublesome in the pond rearing of catfish as they are in some other forms of fish culture, they should be removed if they appear. Manual removal and some chemical controls are feasible.

A few herbicides are registered for use in fish ponds. The restrictions on the labels should be observed. When treating a pond with chemicals, the culturist should be aware that the chemical may be toxic to the fish, and that killing too much vegetation at one time can result in an oxygen-depletion mortality. Ponds should be carefully checked for low oxygen each day for 7 to 10 days after applications of herbicides.

The cultural techniques described for channel catfish also apply to blue catfish and white catfish (*Ictalurus catus*). The blue catfish grows more uniformly, learns to feed at the pond surface more readily, and has a higher dress-out rate than either the channel or white catfish. However, it is more difficult to propagate and transport than the other two species. The white catfish is more tolerant of crowding, high water temperatures, and low oxygen than the channel or blue catfish but has a lower dress-out rate. Some fee-fishing pond operators prefer the white catfish because it bites well—even when the weather is cold or extremely hot.

Each of these three species has its characteristic feeding habits, and production may be increased by stocking a combination of species. For the beginning fish farmer the channel catfish offers the best chance of success but the more experienced grower should not overlook the potential of the blue and white catfish.

CATFISH FEEDS AND FEEDING

The objective of any animal husbandry is to convert low-cost feedstuffs into high-value, high-quality protein. Fish farming is no exception.

Catfish are desirable for recreation and food. They may be raised in still water, flowing water raceways, tanks, troughs, and cages and may be fed wet or dry feeds prepared as meals, sinking pellets, floating pellets, blocks, or crumbles. *Predictable values for fish growth are now available for such variables as feed quality, feed quantity, feeding frequency, stocking size, stocking rate, and species.* When stocked at high population densities in a restricted area, catfish soon exceed the production limit of natural foods and must depend on artificial feeds for growth.

Proteins and Catfish

Chemically, fish consist of an assemblage of amino acids formed into specific tissue proteins; the largest mass is muscle (flesh). For growth, channel catfish are known to require the following amino acids in their diet: arginine, histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, and valine. The exact levels of each of these, and their proportion to energy in the feed are subjects of research in progress.

Catfish can break down the protein of most natural or commercial feeds into amino acids, which are then absorbed and carried through the blood to various organs. Here the amino acids are changed into specific proteins characteristic of each organ. *It is important that the daily feed intake provide protein both for growth and maintenance because animals do not accumulate a protein reserve. Any excess is changed into a form that can be excreted by kidneys and gills. A deficiency in the diet even for 1 day thus causes a protein loss from body tissues.* The amount of protein in feed and its balance of amino acids must be adequate, but not excessive, for two reasons: (1) energy from feed is required to convert (digest and absorb) protein into tissue and weight gain, but the elimination of any excess requires additional energy; and (2) protein is the most expensive nutrient component in feed.

Growth With Purified Diets

Channel catfish have been reared in aquariums on diets containing known levels of purified nutrients. *Good growth resulted from purified diets containing 28 to 39 percent protein* (table 3). No information is yet available about mineral requirements.

Temperature is a factor in the utilization of protein. Diets containing only soybean meal as the protein source are much less efficient at low than at high temperatures, and the utilization of wheat gluten diets is extremely poor. However, animal protein (such as casein) is efficient over a wide temperature range. *Water tempera-*

Table 3.—*Nutrient requirements for channel catfish*

Purified nutrient	Dietary level (percent) producing best growth	Range for acceptable rate of growth (percent)
Protein	28	28–39
Carbohydrate	20	10–20
Fat	10	5–10
Fiber	10	10–20

tures and the protein content of diets affect energy requirements, as reflected in weight gains. More nutrient energy is required for each increment of weight gain at lower than at higher temperatures. More energy is required for each unit of weight gain when protein is fed at rates higher or lower than the optimum. More energy is needed for growth than for maintenance alone.

Practical Formulas

Experimental feeding of catfish at the Fish Farming Experimental Station has established the feed formulation guidelines shown in table 4, and a practical formula based on these guidelines is shown in table 5. Although it is not a "least-cost" or a "maximum performance" formula, it, and all modifications suggested, has proved economical. In pond tests over a 6-month period, channel catfish fingerlings stocked at 1,500 per acre showed an average net gain of more than 1 pound and a feed conversion of 1.3 (1 pound of fish produced for each 1.3 pounds of feed).

When sorghum grains or wheat millfeeds are used in place of rice byproducts, additional fat and protein may be needed. A recommended replacement for 900 pounds of rice bran and byproduct fractions is: 800 pounds milo, 40 pounds feather meal (if poultry byproduct meal is used as the source of animal protein), and 60 pounds chicken fat or soybean oil.

Table 4.—*Formulation guide for catfish feeds*

[Metabolizable energy required, 1,200 calories per pound]

Diet element	Percent of total feed
Crude protein, more than	30
Digestible protein, more than	25
Animal protein, more than	14
Fish meal protein, more than	5
Crude fat, more than	6
Crude fiber, more than	8
Crude fiber, less than	20

This modified formula provides less fiber than is shown to be required in table 5, but if the materials are properly texturized by grinding and then conditioned with high temperature by the use of dry steam before they are pelleted, they can be formulated into a product with good physical properties. The feed conversion factor is poorer when sorghum grains are used as a replacement for rice bran, possibly owing to the lower fat content of the sorghum.

Growth of fish improves in proportion to the level of fish meal in the feed. However, when survival rates, gains per acre, and feed cost per pound of gain are considered, an economical minimum level of fish meal in the diet is 10 to 12 percent. Until the digestibility, nutrient balance, and lure provided by fish meal can be supplied from other ingredients, *fish meal should be included in catfish feeds.* Milk byproducts (whey and delactosed whey) may be used to replace some of the fish meal. In some areas of the South, poultry offal from dressing plants is processed into a high-quality dried meal and may be used as a source of animal protein.

Table 5.—*Modified feed formula that simplifies production and inventory control*

Ingredients	Amount in pounds
Fish meal (menhaden)	240
Soybean meal (solvent) [1]	400
Feather or blood meal [2]	200
Distillers solubles [3]	160
Rice bran [4]	700
Rice byproduct fractions [4]	200
Alfalfa meal	90
Vitamin premix [5]	10
Total	2, 000

[1] 200 pounds of corn gluten meal may replace an equal amount of soybean meal.
[2] Poultry byproduct meal may replace feather or blood meal.
[3] Distillers grains with solubles may be used if finely ground.
[4] Ground sorghum grains or wheat millfeed may be used for rice byproducts.
[5] A vitamin premix designed to fortify a layer-breeder poultry feed is suggested.

Feather and blood meals serve better as sources of amino acids than as direct protein sources, due to their varied digestibility. These meals can serve as excellent supplements to vegetable protein nutrient sources. Two to five percent of either product (or a total of 5 percent) may be included in a formula containing a total of 30 percent crude protein. Meat and bone meal can be an excellent feedstuff and contains digestible protein. However, it often has considerable bone (average of 30 percent ash), which does not provide a complete protein for fish. Unpulverized bone particles also impair pellet quality by weakening the binding effect of other ingredients. Distillers or brewers byproducts contain high concentrations of digestible protein, as well as B-complex vitamins, and are a distinctive lure.

Energy From Feeds

The proportions of energy from protein, fat, and carbohydrate have not been traced for most ingredients or for the different stages of fish growth. The source of cereals and cereal byproducts used as filler and bulk in feed varies with the location of the feed mill. Physical properties are almost as important as nutrient content for these products. The amount of carbohydrate (starch) in a feed is established by summing the required protein, fat, ash, moisture, and fiber and subtracting the total from 100 percent. There is evidence that the concentration of starch-digesting enzymes in fish meal may limit starch levels to about 20 percent of the diet. If more than this amount is digested, its usefulness as a source of energy is limited. Excess energy is stored in the liver and visceral fat. Evidence of fatty infiltration of the liver, leading to its malfunction, has been observed in catfish fed certain manufactured feeds. Excessively large fat deposits in the abdomen are also common.

Because fish require protein to make tissue protein, and because growth increases with the amount of protein in the diet, a high-nutrient density feed is recommended for catfish. A 30 percent protein feed yields the lowest feed cost per pound of fish gain; it also yields the best growth, the highest total production, tbe fewest small fish, the most uniformly sized fish, and the highest dress-out rates; such feed also has the least unfavorable effect on water chemistry.

Feeds for Raceway and Cage Culture

In warmwater ponds, fingerlings usually are stocked at the rate of 2,000 per acre, whereas in raceways they may be stocked at 150 fish per cubic yard. *Feeds for raceway and cage culture should contain more high-quality protein and more vitamins and minerals than those used in general pond culture.* Vitamin premixes have been found to be good supplements to nutrients in the natural ingredients of catfish feed. The premix characterized in table 6 has improved catfish growth by 15 percent, and has proved suitable for aquarium culture.

Feed Processing

Fish feeds can be manufactured as dry meals, crumbles, extruded (hard or sinking) pellets, expanded (floating) pellets,

Table 6.—*Contents of a successful vitamin premix for use in catfish feeds*

Nutrient	Amount per ton of feed
Vitamin A	6 million U.S.P. units.
Vitamin D	2 million IC units.
Riboflavin	4,000 milligrams.
d-Pantothenic acid	12,000 milligrams.
Niacin	50,000 milligrams.
Choline chloride	700,000 milligrams.
Vitamin B–12	12 milligrams.
Vitamin E	5,000 international units.
Menadione sodium bisulfite.	2,000 milligrams.
Folic acid	500 milligrams.
Pyridoxine	20,000 milligrams.
Antioxidant	90 grams.

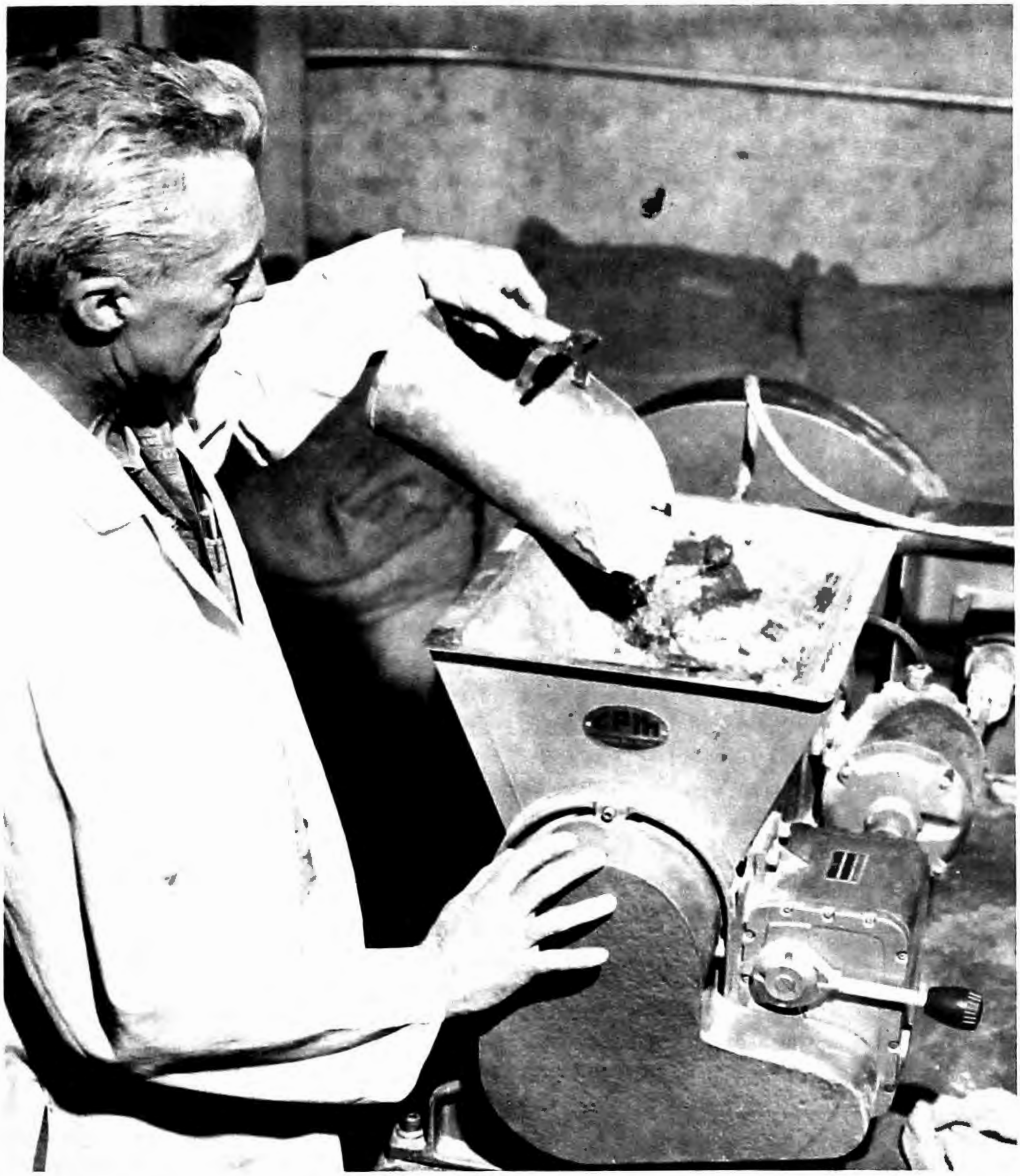
Fish feeds are available as hard sinking pellets (left) or as expanded, floating pellets (right).

blocks, semimoist pellets, and agglomerates. The most common form manufactured for catfish is the hard pellet because processing costs are low and the involved compaction prevents ingredient selection by the fish. Such pellets are easily handled in bulk and can be dispensed with blowers or demand feeders.

Hard Pellets

To produce satisfactory pellets, the feed manufacturer must exercise rigid quality control in the selection of ingredients and in the pelleting process to insure stability of the food in water. The average hog and poultry concentrate pellet disintegrates completely after 10 minutes immersion in

Catfish can be trained to operate mechanical feeders, which release pellets whenever the fish activate or trip the mechanism. Many farmers use such feeders to reduce labor costs.



All experimental feeds are carefully formulated and pelleted in the laboratory.

water. To develop a meal that can be formed into a relatively water-stable pellet, the operator should not only select fibrous ingredients that will increase compression during pelleting but should grind these finely (to increase the surface area), and regrind the complete mix to further reduce the particle size of other coarse, flaky, or lumpy ingredients. Test feeds used at the Fish Farming Experimental Station are made in laboratory milling equipment by grinding each 200-pound batch through the 1/8-inch screen of a 10-hp. hammer mill before pelleting it in a thick die rotating at 305 r.p.m. Dry steam applied to the soft feed just before it enters the pellet chamber lubricates it, brings the moisture content to about 15 percent, and raises the temperature to 190° F. Some raw starch gelatinizes. The pelleted feed is cooled to room temperature within about 5 minutes after extrusion, so that very little nutrient value is lost due to heat. Overfortification with the vitamin premix compensates for partial destruction of certain vitamins by heat.

Pellets manufactured according to these processing specifications remain 90 percent available to the fish after 10 minutes immersion in water.

Blocks

High-protein blocks, such as those used to feed range cattle in winter, have been adapted to fish-feed formulas and are accepted by minnows and catfish. In the production of the blocks, soft feed is conditioned by the addition of molasses and the application of heat and low pressure, and then formed into 8½-inch cubes. In the water, baitfish swarm around the blocks and eat particles as they become loosened. In tests made at the Fish Farm Experimental Station, yearling catfish fed fish-feed blocks grew slightly slower than those that received the same amount of feed in hard $^{3}/_{16}$-inch-diameter pellets. In addition, the use of the blocks increased predation by snakes, which were attracted to catfish fingerlings concentrated around the blocks.

Expanded Pellets

Floating pellets are made at high temperature and pressure, in the presence of moisture. Under these conditions, raw starch is quickly gelatinized and made soft and pliable. Controlled expansion forms pellets of variable density. After expanded pellets are dried in a "cooker" to reduce moisture content to 10 to 12 percent, they resist wetting and float for an extended time.

Although processing by expansion may result in destruction of certain vitamins, amino acids, and fats, the lost materials may be replaced by spraying them on expanded pellets before the pellets are packaged, to provide a complete ration. Distinctive colors or flavors may also be added by spraying.

Most fish can be trained to accept floating feed. However, wind action may move floating pellets against the shore, where they become inaccessible and are wasted. *If the price of expanded feed is more than $20 per ton higher than that of hard pellets, the advantages do not justify the additional cost.*

Crumbles

Hard pellets, after being rollcracked and sieved, may be provided in a variety of sizes to accommodate preferences of different sizes of fish. *Very small fingerling catfish require feed in crumble form.* These fish soon learn to search the pond bottom for food, and readily eat pelleted feeds as they disintegrate in water. For catfish 1 inch long or longer, however, pellets may be used to better advantage than crumbles. (Buffalofish of any size eat crumbles.)

Semimoist Feed

With some modification in formula, fish feeds may be formed into pellets, cubes, or disks containing 25 to 30 percent water. Mold inhibitors, hygroscopic chemicals, or refrigeration must be used to protect semimoist feeds against spoilage.

Fingerlings of some species prefer a soft feed, similar in texture to natural foods. The cost of preparing, handling, and storing semimoist feeds is higher than that for dry feeds. Although semimoist feeds may be used to wean fish from natural foods to a dry formula feed, they are not usually needed.

Agglomerates

Finely ground dry-formula feeds may be rolled into balls by the addition of a suitable liquid. No pressure is used, but a slight increase in temperature is required. After drying, "agglomerates" or "balled-up feed" may be sieved into selected particle sizes. Such feeds are accepted readily by fry and young fish. A commercial product that we tested lasted for 1 hour without disintegrating.

Feed Conversion

Table 7 shows feed-conversion records for 1-, 2-, and 3-year-old channel catfish fed a basic diet at the Fish Farming Experimental Station.

Stress conditions in ponds add to body maintenance requirements. Feed used for gonad development and spawning activity does not produce growth, as may be noted by the reduced feed conversions in some third-year fish (table 7). Heavily stocked fish use feed less efficiently than those stocked lightly. If low dissolved-oxygen concentrations persist for several days, digestive rates, food consumption, and feed conversion factors all decrease.

In general, well cared-for catfish fry hatched in June become 6-inch fingerlings by October, at a feed conversion rate of 0.9 to 1.0 Yearlings stocked at 8 inches in March or April attain market size of over 1 pound by November, with a feed conversion of 1.3 to 1.5. Three-year-old fish grow slowly for 5 weeks during May and June because they use energy for gonad development and spawning. They have a conversion ratio of 2.0 or slightly more for the full third summer.

Growth of Catfish

Channel Catfish

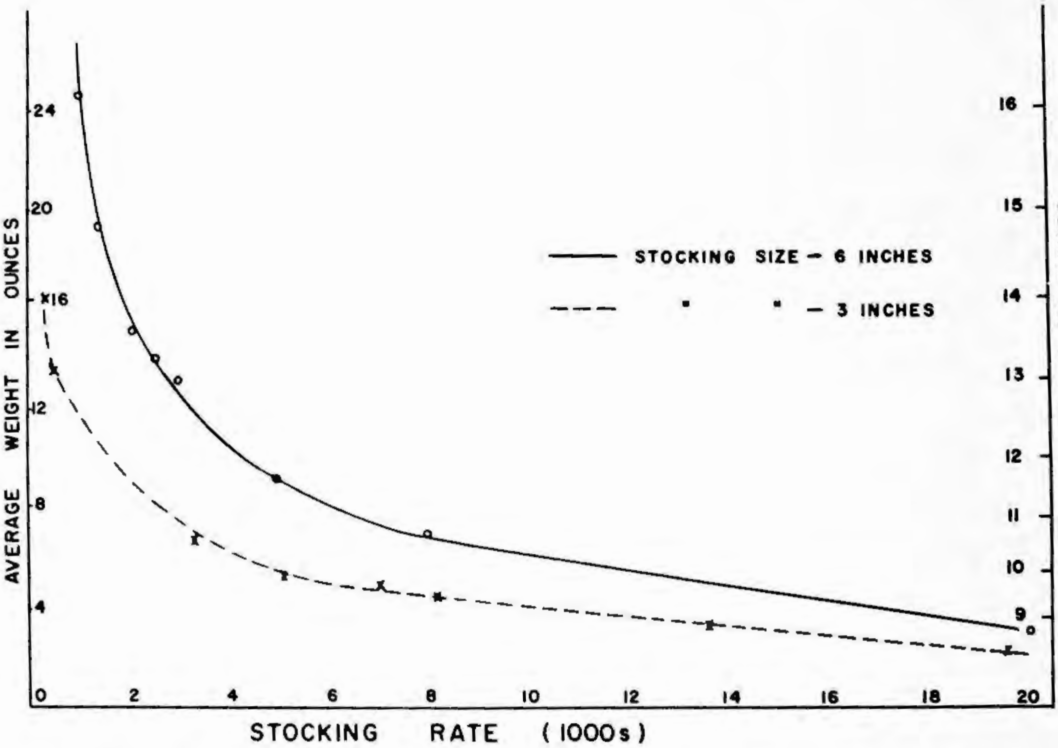
In good water, catfish growth is influenced primarily by the stocking rate and the food supply. Fingerlings 3 to 6 inches long, stocked 1,000 to 20,000 per acre in still-water ponds had attained the weights shown in the accompanying graph by the end of a 180-day growing season. *The best stocking rate to yield fish of an average weight of 1 pound was 1,500 fingerlings per acre, and the best rate to yield an average weight of 0.7 pound was 3,000 per acre.* Although 0.7 pound is not prime market weight, there are certain advantages in

Table 7.—*Feed conversion rate for three species of catfish fed a basic feed*

[Feeds contained added vitamins in 1965 and 1966]

Species, and year of life	Year of record	Stocking rate (number of fish per acre)	Feed conversion factor [1]
Channel catfish:			
First	1963	12, 000	0. 9
Second	1964	1, 500	2. 2
Second	1965	1, 500	1. 3
Second	1966	1, 500	1. 3
Third	1965	1, 000	1. 8
Third	1965	1, 500	3. 2
Blue catfish:			
First	1963	12, 000	1. 0
Second	1964	1, 500	2. 7
Third	1965	1, 000	2. 5
White catfish:			
First	[illegible]	12, 000	. 9
Second	[illegible]	1, 500	2. 4
Third	[illegible]	1, 000	2. 0

[1] Number of pounds of feed needed to yield 1 pound of fish.



Average length and weight attained by channel catfish when stocked at length and stocking rate indicated and fed for a 180-day growing season (April–October).

raising large numbers of fish to this size: (1) They are suitable for stocking in fee-fishing or "catch-out" ponds; and (2) many of the larger fish can be selectively harvested and sold during the early part of the following year, thereby permitting the remaining fish to grow faster.

Blue Catfish and White Catfish

Blue catfish and white catfish are adaptable to intensive culture and can be raised in sufficient numbers to justify artificial feeding. Data from 2 years of study showed that feed conversion of these species was closely si ilar to that of channel catfish (table 8).

Blue catfish fingerlings stocked at weights of 11 to 35 grams reach about 80 percent of the final weight ordinarily attained by channel catfish during the second year. *No difference in response to hard (sinking) or expanded (floating) pellets in either species has been observed at the Fish Farming Experimental Station.* Blue catfish become predators at a smaller size than channel catfish, and eat forage fish during their second and third years. In their third year they grow faster than channel catfish. *Stocking a combination of blue and channel catfish increases total production* in a pond, perhaps because the two species occupy slightly different niches in the pond environment. Blue catfish are easily injured during handling, spine themselves readily in confinement and, in general, have higher oxygen requirements than channel catfish. In cages, the growth rate of blue catfish appears to be about the same as that of channel catfish.

Table 8.—*Weight and feed conversion of three species of catfish stocked as fingerlings at the rate of 1,500 per acre in ¼-acre ponds and fed a commercial feed for 180 days*

Species and feeding method	Initial weight (grams)	Final weight (grams)	Conversion factor
Channel catfish:			
Hand fed	11.0	320	1.7
Demand fed	11.0	392	1.7
Blue catfish:			
Hand fed	12.5	290	1.8
Demand fed	12.0	310	1.8
White catfish:			
Hand fed	16.0	420	1.7

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DEALING WITH PARASITES AND DISEASES

Intensive production of any domestic animal increases the incidence and severity of disease. High production levels and population densities (crowding) increase the probability of epizootics. The poultry industry is a good example of intensive production—and it must constantly combat such diseases as coccidiosis, typhoid, cholera, and fowl pox. Many poultry producers employ a full-time veterinarian to alert them to impending epizootics, because a single outbreak might destroy a large part of their stock.

Many fish farmers have learned, to their dismay, that fish do indeed have diseases, some of which may destroy an entire crop. Although the number of cases referred to the diagnostic laboratory at the Fish Farming Experimental Station is high, our experience indicates that only about 5 percent of all fish farmers are likely to have critical disease problems in any one year. Diseases may occur more frequently, but when water quality is good and feed is adequate, they seldom reach epidemic proportions. Poor management is a contributing factor in many disease problems.

A farmer who faces a disease problem for the first time should request technical assistance at the nearest source. The many such requests that come to the Fish Farming Experimental Station provide an accurate record of the incidence of the various diseases. Awareness of diseases in fish has been increased by better techniques for rapid diagnosis, improved experience and better training, and an increase in the number of sp ialists in fish diseases.

Diagnosis

Techniques for diagnosis and treatment of fish diseases are similar to those used in human and veterinary medicine. The water environment, however, calls for specialized techniques and handling. With few exceptions, fish must be treated in water; removing them for treatment increases labor costs and probably causes unnecessary deaths from handling stress. Fish disease must be treated by either adding chemicals to the water or medication to the diet. Both techniques are discussed later.

Fish are subject not only to infectious bacterial diseases, but also to viral and fungal infections, parasitic diseases (worms, fish lice, and protozoans), and nutritional deficiencies. Also, there are congenital diseases, tumors, and poorly understood growth disorders.

The identification of a disease may require laboratory examination by a specialist, but sick fish can be recognized by an observant fish farmer. Four common symptoms are changes in behavior, reduced vitality, failure to feed, and the presence of lesions.

1. *Changes in behavior.*—Fish in good health cannot be seen in ponds except during feeding periods. Should the fish gather in the vegetation, near the incoming water supply, or in any particular area of the pond where they can be readily seen, disease should be suspected. The presence of parasites may cause the fish to try to dislodge them on vegetation, and the resulting swimming behavior may make the fish conspicuous.

2. *Signs of reduced vitality.*—Healthy fish swim quickly away from disturbances along the bank. If fish do not rush away when the fish farmer approaches, he should suspect some type of disorder. Other symptoms include drooping fins, loss of balance, or general sluggishness.

Proper storage of fish food prevents waste and contamination, and offers economy and convenience.

3. *Failure to feed.*—Under good water conditions, healthy fish feed vigorously, often taking food immediately after it is provided. Low oxygen concentrations or high water temperatures, as well as diseases, may cause fish to stop feeding, but failure of the fish to accept feed is a positive sign that pond conditions are not good. The farmer should take immediate steps to find out why his fish are not feeding.

Certain parasitic infestations act slowly, and may cause emaciation long before death. A gaunt belly, a tight skin over the head, and a long, thin body are signs the fish have not been feeding. Again, the reason should be determined as soon as possible.

4. *Lesions.*—Lesions or sores are common in diseases that attack warmwater fishes. The obvious ones are open ulcers or large discolored areas on the body. Others include hemorrhagic areas on the head, body, or fins; cysts in the skin, muscles, or internal organs; and inflamed areas surrounding a parasite. Presence of any lesion is positive evidence of injury or disease, and calls for a careful examination.

Correct diagnosis of a disease is the first step toward control. Next, before any treatment, (1) know the water, (2) know the fish, and (3) know the chemical. Even though fish are treated with the chemical of choice at the prescribed dosage, they may be killed unless their condition and that of the water are taken into consideration.

Environment and Disease

Knowing the water means more than just knowing its source. Every farmer must know, for each of his ponds, the area, average depth, and as much as possible about the physical features. If these are known, calculation of the water volume can be made immediately, at the time it is most needed. *Knowing the volume of water is important, but the chemical* *nature of the water is just as important.* This includes such characteristics as total hardness, pH, alkalinity, and the presence of metals or minerals. The chemical composition of the pond water may affect the activity of added chemicals, reducing or increasing their toxicity to fish.

Susceptibility of fish to chemicals varies with the species and age of the fish, and with the water temperature. No one can anticipate all the possible problems which might arise. A farmer should avoid using more than suggested levels of chemicals and should have needed information in hand *before* treating. He should know, for example, that malachite green is far less toxic to catfish than to members of the sunfish family, whereas benzene hexachloride is highly toxic to catfishes and sunfishes but only mildly toxic to minnows. Relative toxicities of possible treatments should be known before the chemicals are applied. When a farmer uses a chemical for the first time he should test it on a small lot of fish before he uses it on a large scale.

Solvents, emulsifiers, and other ingredients which make up commercial formulations of chemicals can drastically affect the toxicity of the materials to fish. This principle is well illustrated by the experience of an Arkansas minnow producer who had safely used a wettable-powder formulation of benzene hexachloride (BHC) for several years to control anchor parasites. When an emulsifiable oil formulation, which contains exactly the same level of active ingredient and is much easier and cheaper to apply, came on the market he applied it at the same rate as he had applied the wettable powder. Four hours later, all the minnows in the treated ponds were dead of acute poisoning. The oil carrier, in this case, made the insecticide more deadly.

The presence or absence of certain chemical elements in the water greatly affects the toxicity of compounds to fish. Copper sulfate can be applied at levels exceeding 2 p.p.m. in waters with a carbonate hardness of over 200 p.p.m.; but when water hardness is only 20 p.p.m., concentrations as low as 0.02 p.p.m. may kill fish. The presence of zinc greatly increases the toxicity of malachite green to all species of fish; culturists are warned to specify zinc-free malachite green when they purchase this chemical. *Galvanized containers should not be used for mixing or distributing the material.*

Temperature also affects chemical action. High temperatures speed up the breakdown of such organophosphate insecticides as malathion, parathion, and Dylox. Consequently the use of such compounds is likely to be more effective in cool than in hot weather, and it may be possible to obtain excellent results with reduced amounts of chemical during cold weather. On the other hand, the toxicities of many chemicals increase as temperature increases.

It is usually hazardous to treat fish with more than one chemical at a time. Mixtures should be used only with the advice of a specialist. Some chemicals are synergistic—they increase the activity of others and may produce a toxicity to fish greater than the sum effect of the compounds alone. A good example of this type of effect results when formalin and copper sulfate are mixed. Even though the amount of each chemical used may be well below the danger level, the mixture is deadly. Again preliminary treatment and observation of a small lot of fish will protect the farmer from a major loss.

Every treatment must not only be effective; it must also be practical and economical. Not every chemical that is effective and safe to use on fish is feasible for commercial use. For example, laboratory tests have demonstrated that a certain antibiotic is remarkably effective against bacterial infections, but at the current market price of $185 per pound, fish farmers cannot afford to use it. Furthermore, the decision on whether to treat is not always readily resolved. If the rate of fish loss is low, the disease might clear up without treatment. The cost of the chemical as opposed to the value of the fish crop should be carefully weighed. Although fish farmers routinely treat their pond when necessary, it is seldom economical to treat recreational farm ponds because the value of the fish may be less than the cost of chemicals and labor needed for the treatment. Notable exceptions occur when the owner places a high value on the recreation provided by his pond.

Although we have stressed the precautions associated with application of chemicals to fish ponds, the choice of treatment always rests upon identification of the disease-causing agent. Assistance is readily available through the local county agricultural agent. Cooperative Extension Service, Soil Conservation Service, biologists of the State Game and Fish Commission, National Fish Hatchery biologists, and the Fish Farming Experimental Station.

Principal Diseases

It is not the intent here to discuss each of the organisms that may cause disease in fish or to list the identifying features of each. Rather, the reader is referred to publications of the U.S. Bureau of Sport Fisheries and Wildlife (available from the Fish Farming Experimental Station) and other agencies, which are listed in the section "What to Read," near the end of this report.

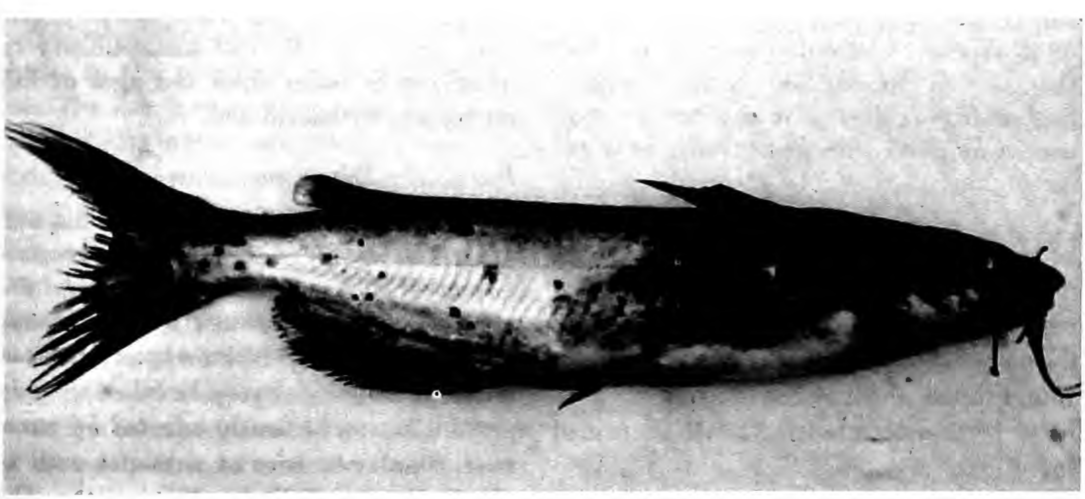
Three major diseases or groups of diseases are considered here—bacterial infections, catfish virus, and parasitic diseases.

Bacterial Infections

Bacterial infections have become increasingly apparent in fish-farming ponds during the past few years. Hemorrhagic septicemia, *Pseudomonas* infections, and columnaris disease are serious problems on fish farms. Each of these diseases, if unchecked, can wipe out entire populations.

Hemorrhagic septicemia has been and continues to be a serious disease of golden shiners and fingerling and subadult catfish, and occasionally threatens bass, bluegill, and crappie populations. *Aeromonas liquefaciens*, its causative agent, also freqently causes losses of brood fish just before and during the spawning season and may cause failure to spawn.

Pseudomonas infections are common in catfish. Most cases have been observed in adults during the spawning season, but recently epizootics caused by this group of



A channel catfish with an advanced bacterial infection caused by *Aeromonas liquefaciens.*

bacteria have appeared in fish being raised for market.

Columnaris disease has been a continuous threat to the minnow producer. Adverse environmental conditions during July and August, and again during the winter, are almost invariably accompanied by this disease. Although losses in the ponds may be low, any attempt to move infected fish to holding facilities or to areas where they can be graded may result in catastrophic losses. Although the disease has been uncommon in catfishes, it is sometimes encountered among fingerlings when the fish are crowded and under stress.

The severity of an epizootic depends on many factors. The stage at which the disease is recognized, the presence of parasites or other pathogens, the general physical condition of the fish, and the quality of the environment all play a part in determining what the ultimate fate of a diseased population will be. If fish are crowded, starved, or subjected to chronic low oxygen levels they are likely candidates for bacterial infections. Other stresses, such as high water temperatures, rapid changes in water temperature, or handling may also contribute to the onset of disease. Many of these factors are encountered on farms where the owner is raising fish for the first time. If the farmer manages to financially survive an epizootic, it will have been a most expensive lesson, emphasizing a fact that is well documented in other animal husbandries: *Most diseases can be prevented by good management and constant care.*

Catfish Virus

A virus was identified as the cause of a major loss of fingerling channel catfish in the summer of 1968, and has since been found in fish from 11 States. Heavy losses have been associated with all identified infections.

The virus is highly infective and contagious and the disease is readily transmitted to healthy fish if they come in contact with infected fish. Since healthy fish in water previously inhabited by infected fish can also contract the disease, contaminated gear and hauling units must also be considered as probable sources of infection.

Channel catfish virus disease cannot be treated. No drugs are known to be effective. Quarantine and destruction of diseased fish, coupled with disinfection of the facilities, are currently the only means of combating its spread. Techniques are needed to provide rapid diagnosis for presence of the virus. Fish carriers that show no symptoms must be identified if we hope to control further spread. Serological studies now underway may provide the required techniques.

Research is needed on the path of entry of the virus and its course of infection within the fish, and on the nature of the damage that kills the fish. Survival of the virus under various environmental conditions, under different chemical treatments, and in processed catfish must also be determined. If the virus can survive in offal, methods of neutralizing or destroying the virus must be developed before wastes from fish processing plants can be used in catfish feeds.

Outbreaks of channel catfish virus disease usually have occurred in fingerlings during summer when water temperatures were above 80° F. The susceptibility or resistance of other sizes and ages of fish remains to be determined.

Parasitic Diseases

With few exceptions, parasitic diseases are not serious for large fish. *The greatest impact of such infections is on fry and fingerlings, although adults of such small-sized fish as the golden shiner, fathead minnow, or goldfish may be killed. Fry, in particular, are seriously affected by parasites.* Small numbers of parasites such as *Trichodina* or *Chilodonella* can cause fry to stop feeding. Even though death may result from starvation, the loss must be blamed on the parasites. Moderate to high numbers of these protozoans kill fry. It is common to observe heavy infections in sac fry that have been reared with older fish. Although adult fish may be harboring only a chronic infection, the parasites readily transfer to the fry, where the disease immediately becomes acute. Survival of fry may be small or nil.

Because the treating of brood fish before they are placed in spawning areas will help reduce protozoan parasites in fry, producers of fingerlings should give serious consideration to such prophylactic measures.

Ichthyophthirius multifiliis, the cause of the dreaded "Ich" disease of catfish, continues to be difficult to control. No chemical has proved universally effective, although a mixture of malachite green and formalin has given excellent control. Formalin, malachite green, and copper sulfate have also been effective but none of them is a sure cure. A Polish worker recently reported that he cultured the parasite in an artificial medium; this breakthrough should represent a major step toward development of a control for the disease. It may eventually be possible to immunize fish against this organism, but research on this problem to date has been only preliminary.

Ichthyophthirius is probably the major threat to the producer of fingerling catfish. The fish farmer who stocks his ponds in the spring when water temperatures are rising and growing conditions are optimal, and harvests market-sized fish in the fall, is less likely to encounter this parasite than the one who stocks and harvests at other times. Farmers who raise fingerlings in the same pond with the brood fish frequently experience epizootics of this disease. The entrance of wild fish is also likely to introduce the parasite. *Prevention* and early detection hold the key to success in controlling *Ichthyophthiriasis*.

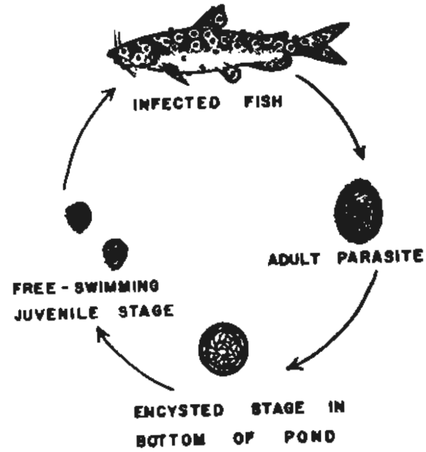
Additional diseases have appeared as potentially serious threats to the fish farmer. *Plistophora ovariae*, a protozoan parasite which localizes in the ovaries of the golden shiner, can destroy reproductive ability. Although the parasite has been known for several years, to date its effect on the production of shiners is poorly known. This parasite appears to be increasing in importance; no inspected fish farm has been found free of it. No treatment is known. Since infections become increasingly severe in older fish, farmers troubled with this parasite should use their youngest available brood fish.

Another, no less serious, disease is caused by an unidentified organism believed to be a parasitic alga. It has been found on many species of fish brought to the Fish Farming Experimental Station. We have seen the parasite in epithelial tissues of gills, skin, and fins of all of the important cultured fishes we have examined. It can be lethal to golden shiners, goldfish, carp, and catfish, and has caused severe distress in fathead minnows.

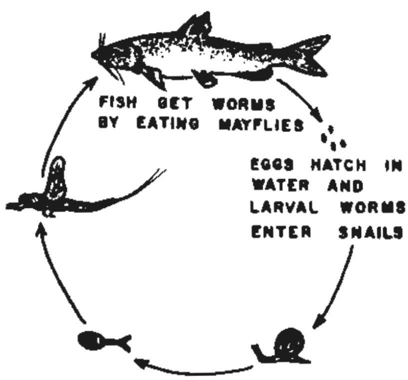
External fluke parasites are serious problems primarily to the producers of baitfish or ornamental fish. Survival is often poor, and parasitized fish are difficult to market. Minnows infected with flukes frequently congregate in dense schools and swim along the shorelines. Predation is heavy under such circumstances and losses may be high. Parasitized minnows also fail to survive during grading and marketing. Frequently they "pipe" at the surface of the tank, exhibiting symptoms similar to those of oxygen distress; prospective purchasers are reluctant to buy fish in such condition.

External protozoan and fluke parasites have not drastically limited fish production although their control may reduce net income. Chemicals for their control are well known and are readily available in most areas. Formalin is most frequently applied for both groups of these parasites,

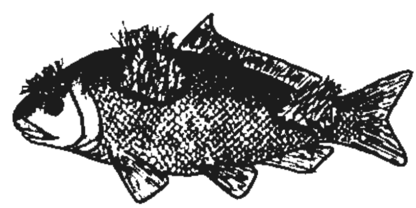
ANCHOR WORM



THE LIFE CYCLE OF ICHTHIOPHTHIRIUS



THE LIFE CYCLE OF A FLUKE



FUNGUS

although potassium permanganate may also be helpful. Recently, research has shown that Dylox, an organophosphate insecticide, controls external flukes The chemical is currently in wide use in Israel for this purpose.

Although the anchor parasite once caused severe losses to minnow producers, it is no longer a major problem. Dylox has replaced benzene hexachloride (BHC) as the standard treatment in most minnow-producing areas. The anchor parasite has begun to show resistance to BHC in areas with a history of prolonged use, but thus far it has shown no sign of resistance to Dylox. Treatment is most effective if the infestation is detected in its early stages, especially in the spring. Treatment during hot summer months generally is less successful.

Seasonal Incidence of Diseases

Records from case histories of diseased fish which have passed through the diagnostic laboratory of the Fish Farming Experimental Station, when compiled by month, showed that frequency of disease was highest in April (table 9). Nearly one-fifth of all case histories were recorded during this month, and the number was one-third greater than during July, the next highest month. The season from March through July was a continuous period of potential danger to fish stocks. This period includes the spawning seasons of both channel catfish (usually mid-May into July) and golden shiners (March through May) and reflects the problems associated with infections in or on very young fish.

Since the danger period includes the spawning period of both shiners and catfish, the importance of having parasite-free brood fish cannot be overemphasized. Treatments should be made periodically throughout the year to keep parasite burdens on brood fish to a minimum. Prophylactic treatments are effective; incidence of parasitic diseases was significantly lower on fish farms where prophylactic measures and sanitation were practiced than on others.

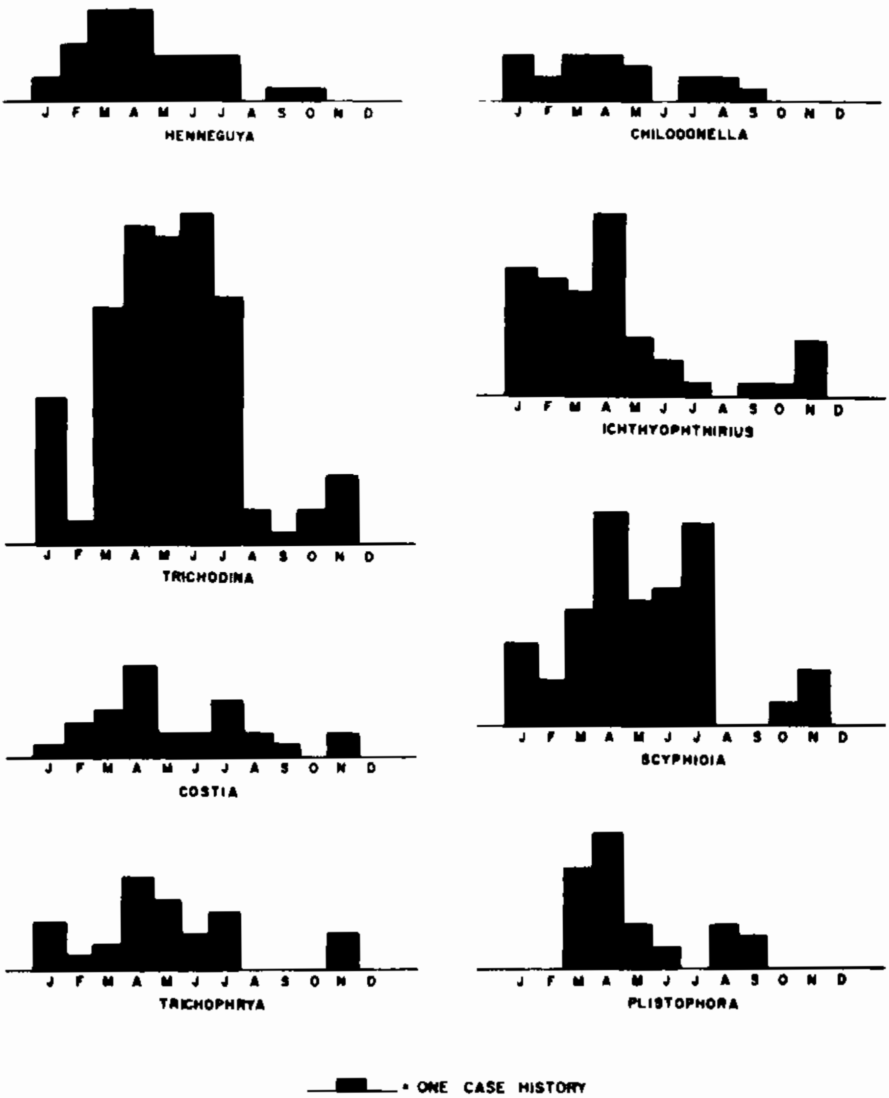
Parasite problems encountered in young-of-the-year fish could, with few exceptions, be traced to parasitized brood fish. Some farmers, who made no effort to reduce the number of parasites on adult fish before the spawning season, suffered losses of 1-hour-old catfish fry due to *Trichodina*. Open-pond spawning methods in which adults and their off-spring were left in the same pond throughout the growing season also resulted in more parasite problems than did the practice of moving eggladen mats to rearing ponds (golden shiners) or the use of artificial hatching units (catfish).

It is also relevant that large numbers of fish were handled during March and April, either for marketing, for stocking of brood fish, or for stocking fingerlings in rearing ponds. This handling stress is believed to be a factor in increasing the incidence of disease during these months.

Aeromonas liquefaciens infections were most prevalent in June through August,

Table 9.—*Monthly distribution of 855 disease cases reported to the Fish Farming Experimental Station over a 5-year period, July 1963–July 1968*

Cause	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Scyphidia	7	4	10	19	11	12	18	0	0	2	5	0
Ichthyophthirius	11	10	9	12	5	3	1	0	1	1	5	0
Chilodonella	4	2	4	4	3	0	2	2	1	0	0	0
Costia	1	3	4	8	2	2	5	2	1	0	2	0
Trichodina	12	2	21	28	27	29	22	3	1	3	6	0
Plistophora ovariae	0	0	9	12	4	2	0	4	3	0	0	0
Henneguya	2	5	8	8	4	4	4	0	1	1	0	0
Trichophrya	4	1	2	8	6	3	5	0	0	0	3	0
Lernaea	0	0	0	5	4	7	7	3	9	2	0	0
Cleidodiscus	7	6	5	13	8	10	16	0	1	0	3	0
Gyrodactylus	4	3	9	16	11	1	1	0	0	0	0	0
Dactylogyrus	1	0	7	10	9	5	1	1	0	0	0	0
Myxobacteria	3	1	3	11	5	8	9	10	5	4	0	1
Pseudomonas sp	1	0	2	0	2	2	2	3	0	0	2	0
Aeromonas liquefaciens	6	3	5	11	9	13	19	15	7	5	4	2
Oxygen depletions	0	0	0	1	2	13	15	8	3	0	0	0
Totals	63	40	98	166	112	114	127	51	33	18	30	3
Percentage of total	7.4	4.7	11.5	19.4	13.1	13.3	14.8	6.0	3.9	2.1	3.5	0.3

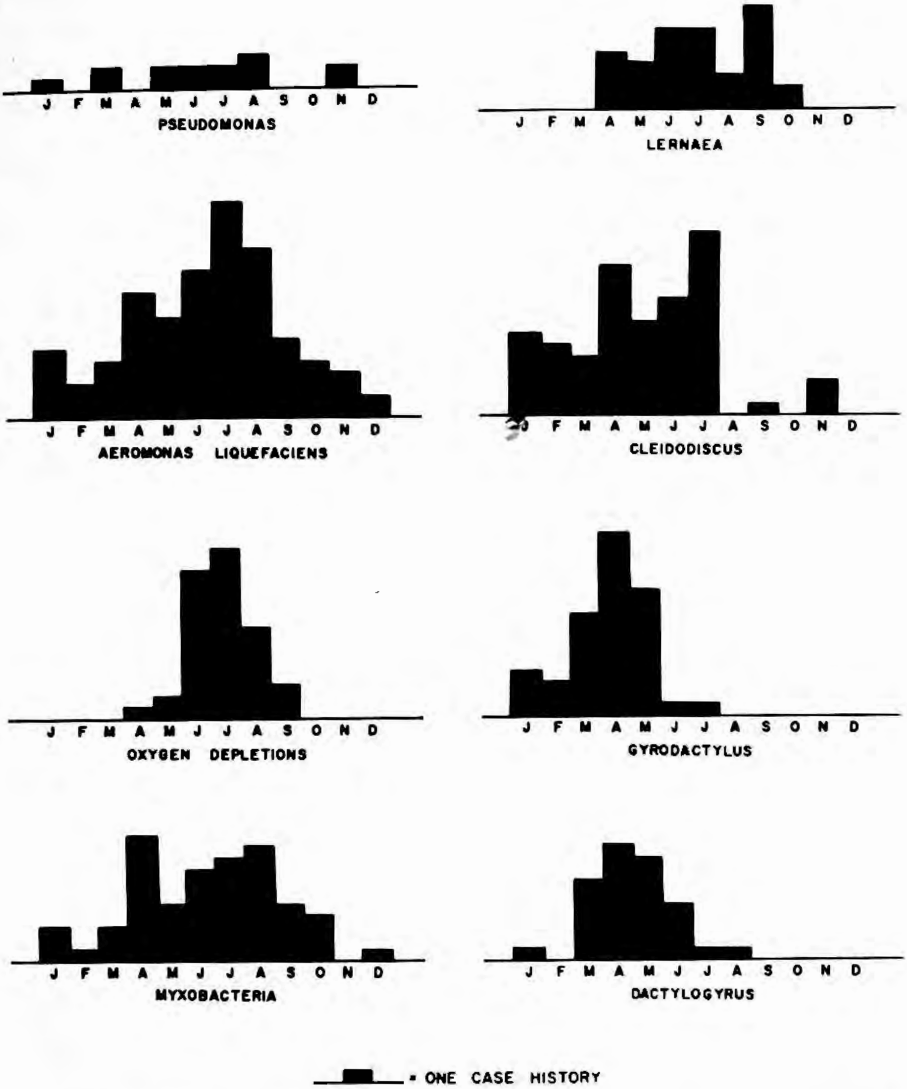


Seasonal incidence of protozoan diseases in warmwater fish farms.

but a peak was also noted in April. The two peaks represented infections of different hosts. Outbreaks in April were usually associated with spawning of golden shiners but may also have reflected temperature stresses, whereas epizootics in June through August involved catfish in rearing ponds and coincided with periods when oxygen levels were lowest.

Low-oxygen stress is considered to be a major factor in outbreaks of *Aeromonas liquefaciens* during the summer, as indicated in the accompanying graph. Many of the infections reported occurred 10 days to 2 weeks after the period when the fish had been subjected to the stresses associated with low levels of dissolved oxygen.

The occurrence of these outbreaks only in rearing ponds gives a further indication of their relation to water conditions in the ponds. Oxygen deficiencies in ponds pass unobserved on many fish farms, and their role in initiating bacterial infections is often unsuspected. Although periods during which low oxygen is common are shown on the accompanying graph, the

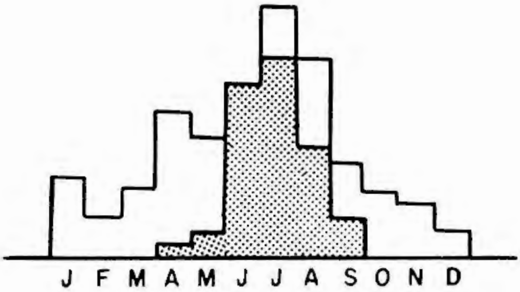


Seasonal incidence of bacterial infections, monogenetic trematodes, and other conditions on warmwater fish farms.

number of occurrences of oxygen deficiencies is actually much higher. It is vital that fish producers observe their ponds daily for signs of unfavorable pond conditions, as indicated by the "piping" of fish at the surface in the early morning, musty odors, heavy blooms of algae, slicks or streaks at the surface of the water, or sudden color changes in the water. Immediate corrective action should be initiated whenever any of these symptoms appear.

Although the role of dissolved oxygen concentrations in the incidence of *Aeromonas liquefaciens* infections appears obvious, other possible factors are spawning stresses, water temperature, pH changes, and carbon dioxide, sulfides, and other decomposition products associated with low oxygen levels.

The low number of disease cases during December resulted from several factors. The harvest of fish from rearing ponds drastically reduced the number of stocked



Occurrence of oxygen depletions (shaded area) and *Aeromonas liquefaciens* infections (open and shaded areas combined) on fish farms.

ponds during November and December. Fish not marketed at harvest were usually placed in holding ponds for winter storage, often under heavily crowded conditions. Apparently parasites did not have time to increase to troublesome levels in storage ponds until some time in January. The sudden increase from three cases in December to 63 in January (table 9) is believed to be a direct reflection of these winter storage conditions. A further factor contributing to the small number of cases reported in December is the diversion of fish farmers' attention from the fish stocks during the hunting season and the Christmas-New Year holidays.

Disease outbreaks were prevalent during periods when fish were handled in large numbers. Stresses of handling appear to be a major factor in the development of diseases from chronic to acute proportions. The need for sanitation and prophylactic treatments during these periods should be obvious to all fish culturists.

Farmers who practiced preventive sanitation or employed prophylactic treatments had fewer disease problems than those who did not. Overcrowding, malnutrition, and unfavorable water conditions were also believed to be associated with disease outbreaks.

Treatment

External parasites are treated by the addition of chemicals to water in which

Trichodina is a serious parasite and may kill small fish.

Chilodonella populations may reach numbers sufficient to kill even large fish.

the fish are held. Internal infections must be treated either by supplying medication in fish feed or by injection. The addition of a chemical to the water is ineffective in combating systemic diseases because the treatment does not reach the site of the infection; such treatment would be likened to applying iodine to the skin for the treatment of pneumonia. Each type of infection dictates the method of application.

At present, few chemicals have been approved by the Food and Drug Administration for use in treating diseases of fish produced for human consumption.

When problems arise, farmers should refer to publications listed in the "What to Read" section near the end of this report, or consult with specialists or experienced biologists about possible treatments.

Preventive Measures

A discussion of fish disease control must include those factors which aggravate the development of disease outbreaks. Overcrowding, chronic low oxygen, or underfeeding contribute to the onset of disease. Wild fish that enter fish farming reservoirs frequently introduce external parasites. For example, during a training session at the Fish Farming Experimental Station, biologists found no external parasites in fish in a farmer's pond. However, when they examined wild fish from a drainage ditch less than 100 feet from the pond, they found six species of parasites, all of which are potential threats to a fish crop. *Failure to exclude wild fish is the cause of many avoidable parasite outbreaks.*

Another simple precautionary measure that helps avoid difficulties is the treatment of brood stock or fingerlings before stocking. Producers who market fingerlings to be stocked in ponds for intensive culture have a moral obligation to provide healthy fish. The buyer invests his money on the premise that the fish he buys are healthy and as free of parasites as the producer can render them. *Most cases of parasitism on fry and fingerlings can be traced to parasitized brood stock.* Treatment of adults before they are stocked in the spawning ponds or pens helps avoid serious outbreaks. Such measures benefit not only the buyer but are profitable to the producer. Parasitic infestations are most serious to newly hatched fry and fingerlings; increases of 100 percent in fry survival are not uncommon after treatment of the brood stock.

The best control for any disease is prevention. Although it is impossible to shield fish from exposure to all potential threats to their health, fish farmers can keep the fish in good physical condition by proper water management, adequate nutrition, and prophylactic treatment. Fish raised under optimum conditions ward off most of the diseases with which they come into contact.

Clearance of Chemicals and Registration for Use

One of the most pressing problems of the fish farming industry stems from the fact that few of the chemicals which are effective in combating disease have been approved by the Food and Drug Administration. The use of a drug on food fish is allowed only after extensive testing and proof that its use presents no hazard to human or animal health. It must be demonstrated that a drug is indeed an effective control for a disease and that it does not leave harmful residues in the flesh; the time required for it to enter and leave the tissues of the fish must also be shown. Securing data for the clearance of a chemical is expensive, and unless the market for the drug is substantial, a chemical manufacturer will not bear the cost of the necessary research. The Bureau of Sport Fisheries and Wildlife conducts research to help in the registration process. When fish farmers need information on the registration status of chemicals, they should consult fishery specialists for the latest rulings.

POND MANAGEMENT

Proper management of a pond or lake for catfish or baitfish production starts before the pond is filled. Whenever possible the pond bottom should be completely dry, and free of depressions, obstacles, and vegetation. Disking the bottom is usually sufficient preparation for a dry pond, unless leveling is necessary to fill large depressions.

Filling the Pond

In filling the pond, the farmer must prevent or minimize the establishment of aquatic vegetation (by completing the operation as quickly as possible), and bar the entrance of wild fish (by proper construction of the system if well water is used, and by filtration if surface water is used). Saran screen [1] has proved to be an effective filter for surface water. It is inexpensive, easy to fabricate, and allows the passage of large volumes of water.

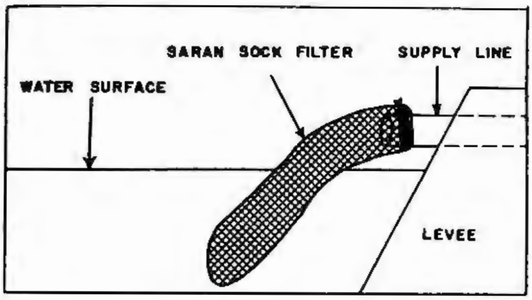
The accompanying figures illustrate two types of filter construction that have been used effectively at the Fish Farming Experimental Station. A sock-type filter is made by sewing two pieces of 3-foot-wide Saran material into a cylinder and fitting each end of it with a drawstring closure. The sock is 12 feet long and presents no problems when relift pumps with capacities up to 1,000 gallons per minute are used. The drawstring closures allow easy removal and cleaning. To prevent excessive strain on the material, the farmer should use this filter only on inlet pipes that discharge near the water surface.

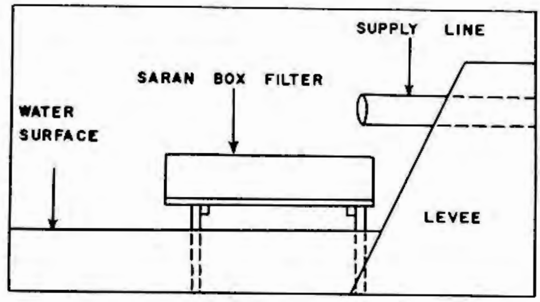
[1] National Filter Media Corp., 691 North Third West St., Salt Lake City, UT 84110.

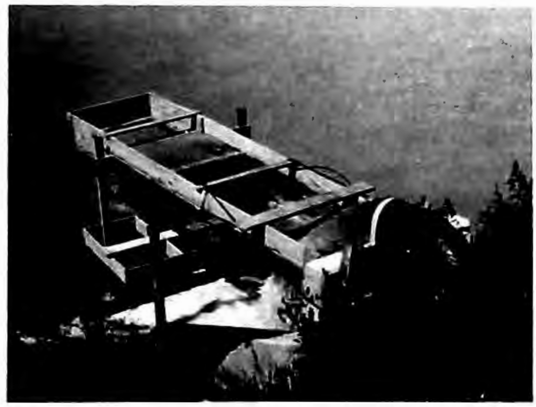
A box filter is constructed by securing Saran screen to the bottom of a wooden box 8 feet long, 3 feet wide, and 2 feet deep. A filter of this size is also suitable for use with relift pumps delivering up to 1,000 gallons per minute. The screen bottom is supported by a wooden grid with 1- by 2-foot openings, which prevents excessive stress and stretching. The filter may be mounted in a fixed position between the inlet water line and water surface, or may be equipped with floats that maintain it in a constant position in relation to changing water levels. If the inlet water line is not too high above the reservoir water level, a floating filter is preferred. In a floating filter box, the Saran material is below the water surface; this arrangement prolongs service because the impact of falling water on the screen is reduced and direct sunlight is excluded.

Fertilization

Fish farmers often use commercial fertilizers in the culture of minnows and fingerling catfish, to increase natural food production and assist in aquatic plant control. Fertilization maintains populations of plankton (microscopic plants and animals) for the benefit of small fish. However, commercial fertilizers should be used only when blooms fail to appear within a few days after a pond has been filled and not until the water has warmed to about 65° F. A 16–20–0 fertilizer should then be placed on stationary platforms just below the water surface or in floating devices that permit slow seepage of the nutrients into the water. This method of application





Saran sock attached to the water inlet line (left). Saran box filter in fixed position (right). The box filter may also be used in a floating position.

produces an even bloom of plankton with a minimal amount of fertilizer. Occasionally organic matter such as barnyard manure, hay, or soybean meal is used in ponds where it is difficult to get a bloom started.

Heavy blooms are required to shade out unwanted vegetation. If aquatic plants develop before the bloom, however, fertilizers should not be used. Overgrowths of aquatic plants are best controlled by the application of registered herbicides.

Chemical Control of Wild Fish

If the surface water supply of a pond contains so much mud or debris that it cannot be effectively filtered, ponds can be filled and then treated with chemicals to kill stray fish. Rotenone is relatively inexpensive, moderately effective, and is registered and labeled for this purpose. It should be applied at a rate of 0.5 to 2.0 p.p.m. Its chief disadvantage is that it requires up to 2 weeks to lose its toxicity in warm water, and even longer in cold water. Furthermore, some fishes such as bullheads and mosquito fish or other gambusias are not always killed.

Another registered fish toxicant, Antimycin A, which is sold as Fintrol ®, is a selective poison that can be used to eliminate scaled fish in the presence of catfish. It may be used at any time after ponds are stocked, whenever wild fish are a problem. Fintrol does not kill bullheads, however, which are undesirable in channel catfish culture ponds. Because the chemical varies in activity in relation to water chemistry and temperature, the instructions on the label should be closely followed, or expert advice sought in special cases.

Care must also be taken to insure against stocking unwanted fish, especially sunfishes, with the catfish or minnows. Usually minnows and catfish are examined on a counting table at the time of stocking and the unwanted fish of other species are discarded. Catfish may also be treated in a trough with 5 parts per billion of Fintrol to destroy unwanted species.

Predator Control

Animals which prey on fish (otters, crayfish, frogs, snapping turtles, birds, insects, and carnivorous fish) may cause serious losses. Control of these species depends on the ingenuity of the farmer. Since a special license or permit is required in some States before nuisance animals can be killed or removed, the fish farmer should consult the local conservation officer or the State Game and Fish Commission.

Of these predators, aquatic insects cause the heaviest losses of fry or fingerlings in rearing ponds. Unless insect control is practiced, losses may be total. Aquatic beetles and other surface-breathing insects may be destroyed by applying 2 to 4 gallons of diesel fuel per surface acre. Motor oil is often added to the diesel fuel (1 pint per gallon) to strengthen the surface film produced by the application. The diesel fuel does not harm fry or small fingerlings but feeding should be discontinued until the oil film is gone.

Water Quality

Complex interactions of physical, chemical, and biological forces are going on continuously in pond waters. Physical forces include such factors as water temperature, turbidity, and agitation resulting from wind movement. Some of the chemical forces include the interaction of the bottom mud with the overlying water, the precipitation of iron, and the deposition of calcium and magnesium carbonates. Hardness and pH are other important chemical properties of water. Common biological actions are respiration and photosynthesis, degradation of organic matter by bacteria, and release of metabolites from living and dead organisms. Interactions of these constantly varying forces are further complicated by the influence of atmospheric pres-

In some areas, otters are serious predators on fish.

sure, temperature, wind speed, and light intensity. Knowledge of these forces and their interactions is of considerable value in the management of fishponds.

Water Temperature

Water temperature may be the single most important factor that affects the welfare of a fish during its life. Water temperature influences activity, feeding, growth, and reproduction of all fish. It also determines the amount of dissolved oxygen in the water—the higher the temperature, the lower the amount of dissolved oxygen the water can hold.

Water normally weighs 62.4 pounds per cubic foot, but this weight changes slightly with temperature—it is about 0.2 pound per cubic foot lighter at 80° F. than at 40° F. It has a high heat absorbing capacity—i.e., it can absorb large amounts of heat with little rise in temperature. This characteristic helps prevent sudden changes in water temperature and has a moderating effect on weather changes.

The seasons of the year induce a cycle of changes in water through changes in atmospheric temperature. In the spring, water temperatures are nearly equal at all depths throughout a pond; consequently the weight or density of the water is the same from top to bottom. This characteristic permits wind to mix the entire water mass and its nutrients, plankton, metabolic products, and oxygen. Data collected at the Fish Farming Experimental Station suggest that this wind movement must exceed 2 miles per hour to mix the water completely to a depth of 4 feet in a 1-acre pond.

As summer approaches, the surface water warms, becomes lighter in weight, and remains at the surface above the denser, colder water. In shallow ponds the temperatures of layers of water 6 inches apart may differ by as much as 5° F. Circulation of the colder bottom water is restricted due to its greater weight, and the exchange of its gases with those in the atmosphere is entirely prevented. The result is that only water near the surface has direct contact with the atmosphere, and the bottom water receives no oxygen. *Accumulation and decay of feces, dead animals and plants, and wasted fish feed further reduce the dissolved oxygen near the pond bottom. Respiration of living animals and plants consumes dissolved oxygen and reduces the oxygen level in upper water layers during the night.* The higher the temperature, the higher the rate of respiration.

In the fall, water temperatures begin to drop at the surface. The cooled surface water then sinks toward the bottom and eventually a uniform water temperature, like that present in spring, is again temporarily established. This process is controlled by air temperature, pressure, and wind.

This seasonal periodicity of water temperature and density not only controls the distribution of nutrients and oxygen, but also the length of the growing season, and hence the annual production of fish.

There is also a daily periodicity of water temperature—it falls during the night and rises during the day. This daily variation may be considerable, depending on changes in air temperature. Generally, the daily change ranges up to 10° F. in summer.

Temperature requirements of certain fish vary throughout their lives. *Hatching of channel catfish eggs is best when the temperature is in the high 70's. Best growth and feed utilization are at about 84° F. Feeding is markedly reduced below 60° and above 95° F.*

Sudden changes in water temperature can cause death of fish from temperature shock. When changing water on fish or transferring fish from a hauling unit to ponds, the culturist must be sure there is little difference in temperature between the two waters. If there is a difference of 5° F. or more, conditioning (tempering) is nec-

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essary. Catfish require at least 1 hour to become fully adjusted to the new temperature.

As water temperature increases, fish require more dissolved oxygen. This need can present a problem, because the capacity of the water to hold oxygen decreases as the temperature rises.

Dissolved Oxygen

The emphasis on market-size catfish production has led to an increase in the number of oxygen-depletion fish kills on fish farms. *Heavy stocking, accompanied by high feeding levels in limited volumes of water, results in enrichment.* Nevertheless, with good management, oxygen can be maintained at adequate levels to support the fish despite the continuing increase in fertility caused by their waste products. *Adverse weather conditions, coupled with miscalculations of the growth rate of the fish (and subsequent overfeeding), may lead to an oxygen loss which can kill the entire fish population in a single night.* The financial loss may be great, because the fish are usually over half-grown when a fish kill occurs. Moreover, many diseases are aggravated by chronic low oxygen levels. It is most important, therefore, that the fish farmer understand the factors affecting production and depletion of oxygen in ponds.

Water at 80° F., when in equilibrium with the atmosphere, holds 8 p.p.m. of dissolved oxygen; at 40° F. it holds 12.5 p.p.m. The dissolved oxygen content of water tends to approach equilibrium with the dissolved oxygen content of the atmosphere; at equilibrium it is 100 percent saturated. Water in fishponds is seldom at equilibrium and seldom is saturated with dissolved oxygen because temperatures are constantly changing, and physical, chemical, biochemical, or biological activities continuously use or liberate oxygen.

Oxygen in the water comes from several sources. Some is absorbed directly from the air and much of it is produced by aquatic plants by a process called photosynthesis. The amount of oxygen diffused and absorbed from the overlying air into an undisturbed pond surface is insignificant. Fortunately, however, undisturbed water is rare in nature. The smallest wind movement which produces turbulence increases oxygen uptake. Winds move the water and cause more water surface to come into contact with the air. The amounts of water brought into contact with the air are increased by such devices as baffle boards, water sprays, and mechanical agitators, and by the injection of compressed air or oxygen into ponds, holding tanks, or hauling units. These same methods reduce the content of dissolved oxygen and other gases if the water is more than 100 percent saturated (supersaturated). When efficient mechanical aeration methods are used, the water remains saturated with oxygen.

Most photosynthesis in ponds takes place in microscopic green plants called phytoplankton, which give the water the greenish color commonly seen. Phytoplankton, which is scattered throughout the water, requires light to carry on photosynthesis and liberate oxygen. The more intense the light, the more oxygen is liberated. Consequently the daily process of liberating oxygen begins slowly at sunrise, increases as the day progresses, and reaches a maximum in midafternoon. The rate then decreases with the lowering intensity of the light and falls to nil during darkness. At night the phytoplankton uses dissolved oxygen for its own respiration.

The intensity of light diminishes as it passes downward through water; therefore, the rate of oxygen production decreases progressively with increasing depth. Suspended microscopic plants and animals, silt, stains, detergent foams, dense mats of floating algae, or debris all reduce light penetration. Light intensity also varies with the season of the year.

A good supply of well water is necessary for efficient fish farming.

Different concentrations of dissolved oxygen occur at different depths in ponds, as a result of differences in rates of photosynthesis, circulation, diffusion, and respiration, and differences in temperature and density of the water. During high winds, surface water may be saturated with oxygen and that portion just below the surface may be supersaturated. At the same time, the bottom layer may contain no dissolved oxygen. Measurements made in late afternoon may show 20 p.p.m. of oxygen 6 inches below the surface and none at a depth of 4 feet. Farmers should be aware that very high oxygen concentrations during the day (above 14 p.p.m.) are usually followed by low concentrations at night. *Dissolved oxygen is usually lowest just before sunrise and highest in midafternoon.* Maximum daily differences in dissolved oxygen, like daily differences in water temperature, are greater just below the surface than at a depth of 4 feet.

The development of meters for oxygen measurement in recent years has enabled the biologist and farmer to make oxygen determinations quickly and easily. Meters permit measurements in different areas and depths in the same pond with little time lag between measurements, or continuous measurements at one location or depth. This capacity allows a better understanding of oxygen consumption and production, and the use of meters should help prevent the loss of an entire fish crop due to oxygen depletion.

Some oxygen is removed from pond water by loss to the air if the surface water is supersaturated; far more, however, is removed by the life activities of animals, bacteria, and plants. Decomposition of organic matter by bacteria contributes most significantly to demand for oxygen. Fortunately, manufacture of oxygen by green plants during daylight helps overcome consumption of oxygen by animals, plants, bacteria, and decaying organic matter. As long as this incoming oxygen exceeds or equals the amount used, and the water can hold more oxygen than is needed to sustain life through the night, all is well and the fish should grow and prosper.

Intensive feeding increases the amount of organic material in the ponds, enhances fertility, causes heavy green algal blooms, and sometimes results in the accumulation of wasted food on the bottom. All of these factors increase the demand for oxygen and lower the dissolved oxygen content. If this oxygen consumption rate exceeds the rate of manufacture, dissolved-oxygen content of the water declines. When these conditions exist, fish may stop growing, may become susceptible to disease, or, if the decline is not reversed, may die.

Knowing the conditions that bring about oxygen depletions helps the fish farmer take corrective action. Since the dissolved oxygen in the bottom water is the first to be depleted, measuring oxygen 2 feet below the surface and near the bottom of the pond, just before sunrise, is one of the best methods for determining the pond's condition with respect to oxygen. As long as the dissolved oxygen content remains nearly constant, conditions are satisfactory. When the level begins to decline, however, remedial action should be taken. Water should be drained from the bottom during the day and replaced with fresh water during the night. If the fresh water is from a well, it should be sprayed into the air, run over baffles, or otherwise aerated. If water is drawn from an adjacent pond, it should be pumped from near the surface—never from the bottom. Water replacement or exchange should be continued until danger of an oxygen deficit is passed. Fish should not be fed while low-oxygen conditions are being corrected.

Flushing ponds with fresh water is the basis for the concept of raising fish in

Oxygen depletions cause major losses since they usually occur when the fish crop is nearly ready for market.

raceways. If adequate water flows through ponds or raceways, there is no accumulation of metabolic products or excess feed and no development of heavy algal blooms that add to heavy oxygen demand.

Control of Oxygen Depletion

Oxygen depletion is a major hazard in the fish farming industry and may cause the loss of an entire fish population. Routine observations of all ponds should be made at sunrise during June, July, August, and September, the period when the problem is most acute. Low oxygen concentrations should be suspected when fish, snails, or tadpoles appear at the surface of the water, crayfish come to the margin of the pond, or dark streaks appear in the water. Oxygen depletion is often accompanied by musty odors or the odor of methane and hydrogen sulfide. Low concentrations or depletion of oxygen may be verified by the use of water chemistry kits or oxygen meters, if necessary.

If the oxygen content 18 inches below the surface of the water is 2 p.p.m. or less, or if fish are surfacing and showing signs of distress, immediate corrective action should be taken. The situation can usually be remedied temporarily by partly draining the pond and refilling it with well water, or adding large volumes of water from near the surface of an adjacent pond. If these measures are not possible and the fish appear to be in danger of suffocation, applications of up to 6 p.p.m. potassium permanganate also provide temporary relief. Fresh water and the reduction of fertility provide the most lasting solution. *During periods when the culturist is attempting to correct low-oxygen conditions, the fish should not be fed.*

If the dissolved oxygen content is less than 3 p.p.m. at daybreak and does not rise during the day in the presence of bright sunlight, it can be assumed that either there is no photosynthetic activity (i.e., no living algae remain) or bacterial decay is using the oxygen faster than it can be produced. In this situation, or when the oxygen content is known to be low (but the fish are not in obvious danger), the farmer may apply 25 to 50 pounds of hydrated lime (also called slaked lime or calcium hydroxide) per surface acre to kill bacteria and oxidize organic matter. Treatments may be repeated as often as needed but the lime should always be distributed uniformly over the pond surface.

If too few algae are present, the addition of 20 pounds of 10–20–0 or 13–16–0 ammonium phosphate fertilizer per surface acre will rapidly restore the bloom. *Do not add fertilizer if an algal bloom is present.*

Fish that weigh less than 1 ounce use more oxygen per unit of weight than fish that weigh 1 pound or more. Fish of all sizes use more oxygen at high temperatures than at low temperatures.

Control of Aquatic Vegetation

Successful vegetation control depends in large measure on pond construction. Most ponds with severe vegetation problems have extensive shallow-water areas. It is impossible to correct faulty construction after a pond is filled and fish have been stocked. The time to insure proper construction, or correct faulty construction, is when the pond is empty.

Ponds should be constructed so that a minimum depth of 3 feet can be maintained. The sides of the levees should be as steep as soil stability will permit, so that the 3-foot minimum depth can be maintained near the shoreline. Even though it may be costly to modify the bottoms of existing ponds, it should be done if needed.

Ideally, the best technique for controlling aquatic plants would be to convert them to protein through the use of herbivorous animals. A plant-eating fish would be ideal for this kind of biological control.

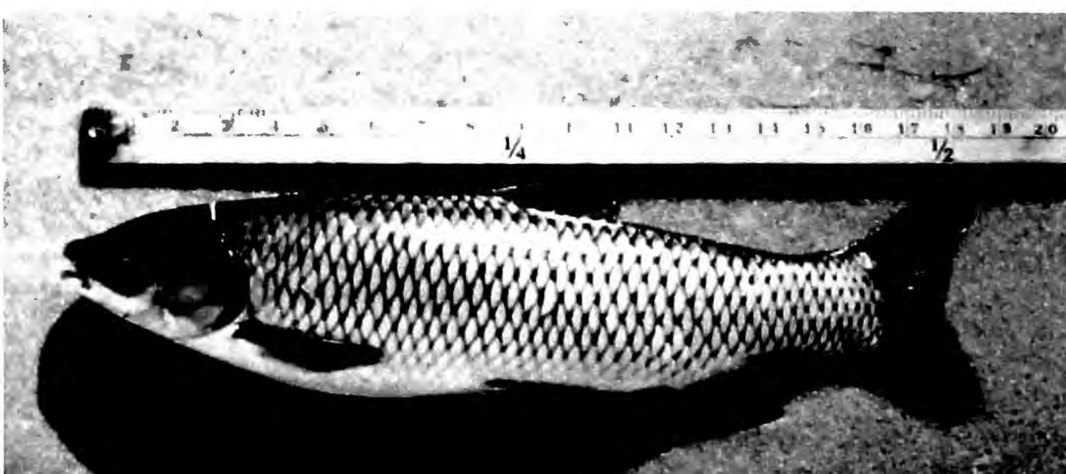
A number of species have been considered for this purpose, including the white amur, Israeli carp, and *Tilapia*. Experiments have indicated that the numbers of Israeli carp and *Tilapia* required to control plants effectively are so large that these fish would compete for space and interfere with the production of other, more desirable species.

The white amur is known to feed actively on aquatic plants. Under experimental conditions, it has controlled nuisance growths of aquatic weeds in ponds and lakes. However, the number of fish of a given size that would be required per acre remains to be determined. In addition, since the white amur does not consume all species of plants with equal relish, it may not control all of them effectively. Studies have also shown that this fish is not the strict herbivore it was first considered to be: it eats both plants and animals. Continuing research may develop answers to these questions and find ways to control reproduction of the white amur. If so, the fish may serve as a useful biological control for plants in ponds or fish farms.

Aquatic plants compete with each other for sunlight and nutrients. Unicellular algae can be used to discourage the growth of rooted plants and filamentous algae. These algae respond quickly to fertilization, and it is sometimes possible to develop heavy blooms within a short time. If sufficiently abundant, the algae prevent sunlight from reaching the lower depths of the pond and shade out rooted plants or filamentous algae on the bottom. Fertilization to encourage blooms is recommended in both baitfish and fingerling catfish culture. However, fertilization is seldom needed in ponds used to grow food fish, since the daily feeding provides ample fertility.

Every effort should be made to encourage algal blooms early in the spring, before rooted plants germinate. Ponds should be observed closely and fertilized whenever the bloom begins to diminish. Overfertilization, however, may cause algae to become so abundant that they restrict light penetration and compete for oxygen during the night. Excessive algal blooms should not be allowed, because they may lead to oxygen depletions and loss of fish.

When rooted plants or filamentous algae have become established, it is too late for control through fertilization because the added nutrients will only encourage further growth of the unwanted forms.



The white amur (*Ctenopharyngodon idellus*) is under study as a possible biological control for aquatic vegetation.

Rather, chemical control of the plants is usually needed. If small areas of rooted plants become established, spot treatment with chemicals may control them before they become overabundant.

Although most herbicides have a low toxicity to humans, livestock, wildlife, and fish, a few are highly toxic. When chemical control is feasible (it is sometimes prohibitively expensive), *use must be in accordance with recommendations and restrictions given on the herbicide label.* The chemical should not be used if the label does not give instructions for the proposed use.

It is essential that all herbicides be applied in a manner fully consistent with the protection of the environment. Any contemplated use of these chemicals must take into account both known and possible unknown environmental effects. When there is a reasonable doubt about the environmental effects of use, the chemicals should not be used.

Chemical control of plants is a temporary measure. Unless the environment is changed to correct the conditions that favor plants, they are sure to return.

Oxygen depletion may result from the decay of large amounts of vegetation killed by the application of herbicides. Some chemicals kill so rapidly that huge masses of plants may die and decay in a short period and cause oxygen levels to decline—especially if an entire pond is treated at one time. This loss of oxygen—not toxicity due to the herbicides—is usually the major reason for the fish kills that commonly follow application of a herbicide. An adequate supply of well-aerated water should be available to counteract such oxygen depletions. It is also advisable to drain water from the bottom of the pond to make room for the addition of a fresh supply.

A number of precautions should always be taken when herbicides are used: Follow all instructions on the label and store chemicals only in the original labeled container. Avoid inhalation and prevent repeated or prolonged contact with the skin. Wash thoroughly after handling herbicides, and always remove contaminated clothing as soon as possible. Prevent livestock from drinking the water during the posttreatment period specified on the label. Do not release treated water to locations that may be damaged by activity of the chemical. Avoid overdoses and spillages. Avoid use near sensitive crops and reduce drift hazards as much as possible; do not apply herbicides on windy days. Clean all application equipment in areas where the rinsing solutions will not contaminate other areas or streams.

HARVESTING THE FISH CROP

Harvesting is a facet of fish farming that is poorly understood by many producers who lack experience with commercial fishing gear and are unfamiliar with the techniques required for handling large numbers of fish. Costs associated with harvesting are frequently underestimated. Harvesting by inefficient methods often greatly reduces the fish farmer's margin of profit.

The development of more efficient harvesting techniques is vital to the continued growth of the industry. Methods for the handling of live fish must be improved because most processing plants insist that the fish be delivered alive. Techniques for year-round harvesting must be perfected so that fish farmers can regularly deliver fish to processing plants.

Harvesting Techniques

Ponds 3 feet deep can be readily seined with a net 8 feet deep. Short seines may be used in large ponds if fish are baited into the harvest area. At least 80 percent of the population should be removed by seining before the pond is drained.

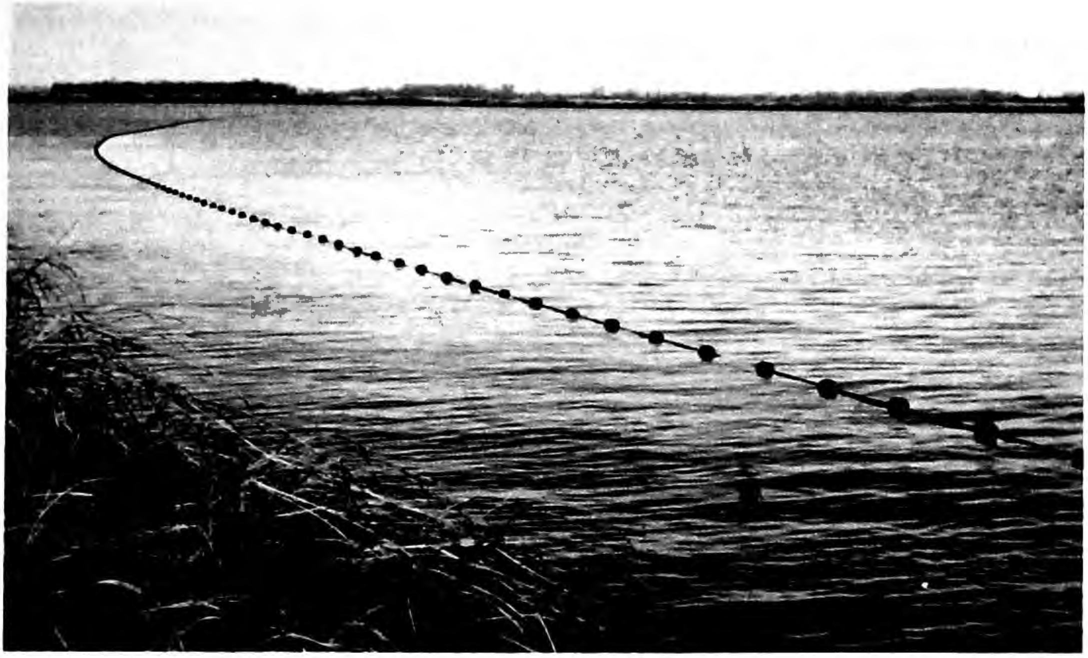
Originally, a "drain and seine" concept was visualized as a suitable method of harvesting. In this method, the pond level was lowered until water remained only in a specially constructed harvest basin. This basin made up 2 to 5 percent of the full-pond area and could be seined with a minimum amount of gear. Since the fish were concentrated, farmers had ready access to them when they were needed.

When larger ponds were built, several major shortcomings of the drain-and-seine method immediately became apparent: (1) The number of fish was often so large that they could not be held confined in a small volume of water, particularly during warm weather, because the danger of oxygen depletion was too high. Large ponds could be drained only during the winter owing to these temperature and potential oxygen depletion problems. This restriction placed a strict seasonal limitation on harvesting. (2) Drawdowns for each partial harvest, followed by refilling, were too expensive, due to the high cost of pumping. (3) When pond levels were drawn down, the edge of the water usually receded from the base of the levee, with the result that the fish were netted at a considerable distance from trucks waiting to receive the fish. If the trucks were loaded by hand, the fish had to be carried across a muddy area and up the levee, and labor cost became excessive.

Seining of full ponds, with much larger seines, then became the method of choice. It has a number of advantages: (1) The fish can be handled without danger of oxygen depletion. (2) Excess fish can readily be released if too many are caught in one haul. (3) If ample supplies of water are available, large quantities of fish can be held in the seine for several days. (4) Ponds can be seined during any season of the year.

Full-pond seining increases the flexibility of the harvest program even though complete harvest still requires use of the "drain and seine" technique to remove the final 15 or 20 percent of the crop.

Full-pond seining requires larger equipment (nets may be 200 to 1,600 feet long) but permits increased mechanization. The seines can be pulled by tractors or me-



The harvesting of fish from large ponds requires long seines and heavy equipment.

chanical seine haulers. Ropes attached to toggles serve as hauling lines to pull the seine. Essentially the process is as follows:

The net is payed out from a barge along the levee opposite the landing site. Haul lines fastened to ends of the seine are led through snatch blocks (pulleys) installed along the lateral pond banks (to keep the ends of the net spread and close to the shoreline), and thence to a powered line hauler. As the net ends approach the blocks, the haul lines are released from the blocks and taken along the bank to the next set of snatch blocks, or to the landing site. The seine is detached from the haul lines as it reaches the take-out area, and is stacked at the pond edge. Usually, hauling is stopped while the bag section of the seine is still well out in the pond to avoid premature overcrowding of the fish. When the catch is exceptionally large—especially during warm weather—a small seine is used inside the large seine to concentrate 1 or 2 tons of fish at a time. Fish may also be moved to live cars for holding, if desired. The fish can be tightly concentrated by reducing the size of net just before they are scooped into a brailing bag, which is then lifted to the hauling truck by a powered boom winch.

The use of boom winches to lift fish from the seine to hauling trucks speeds transfer of the fish (thus increasing chances of survival) and reduces the amount of hand labor needed. Placement of an in-line scale on the winch, which permits weighing of the fish during the loading process, further reduces time and labor requirements.

An additional technique that may be used to harvest fish involves the use of traps. Although it is unlikely that all of the crop can be removed with traps, farmers can collect enough fish to provide limited quantities for local retail markets. If large numbers of fish are caught in the traps, however, and they are held in the nets too long, the resulting stress may be great enough to cause bacterial infections to become acute. Hauling such fish for long distances may result in heavy losses.

Small seines are used within large seines to confine fish for loading trucks.

Consequently, traps should be emptied daily.

Although construction is hardly a part of the harvesting process, physical characteristics of ponds play an important part in the efficient harvest of a crop. Removal of all stumps, roots, and logs is an absolute necessity if harvesting by seines is to be successful. The pond bottom should be relatively smooth and engineered to provide adequate grade for complete drainage. Inside borrow ditches or low places away from the harvest basin should be avoided at all costs, because fish congregate in such areas as the water level drops. Drain lines should be as large as practical; multiple 12-inch drains are not too large. Standpipes that swivel on an elbow can be connected to the drain line and raised or lowered to control the water level in a pond.

All levees should be substantial enough to support tractor traffic, and those in the landing area should permit the operation of large trucks and heavy equipment.

During hot weather, wells that supply fresh cool water in the harvest area can be used to attract and acclimatize fish before they are harvested. Fresh water also helps insure survival when large numbers of fish are confined in a seine.

Harvesting Costs

Full-pond seining and mechanized loading cost about 2 cents per pound of fish harvested; hauling fish to the processing plant usually adds an additional 1 cent per pound. Where custom harvesting is available, the charge usually is a set minimum fee or 4 cents per pound, whichever is the larger. These figures are exclusive of the cost of the harvesting gear, trucks, and other equipment needed.

The cost of "drain and seine" harvesting methods varies rather widely. If the pond drains well to the harvest basin and the fish are loaded mechanically, costs are similar to those associated with full-pond techniques. Costs of harvest in poorly constructed ponds, however—especially those

Boom loaders remove much of the manual labor from loading trucks.

with inside borrow ditches—are excessive. It is not unusual for costs to exceed 12 cents per pound under such circumstances. If fish must be caught by hand out of shallow pools or picked up from the mud, losses due to mortality (immediate and delayed) and shrinkage increase costs enormously. The farmer is not likely to make a profit under such conditions.

If numerous partial harvests are required, labor costs become excessive. If laborers are hired on a yearly basis, however, such a harvest system can be used without an apparent increase in costs.

MARKETING AND PROCESSING

The lack of a coordinated marketing system now looms as a threat to the orderly growth of the catfish industry. Temporary overproduction has preceded the development of markets in some areas. Until 1970, farmers encountered little difficulty in selling catfish at a relatively high price, and no problem had arisen that indicated the need for a systematic marketing program.

The first catfish processing plants began operation in 1968. In earlier years, the fish produced were either dressed at the farm for sale or hauled alive to areas near large cities, where they were stocked in fee-fishing lakes. Very few of the farm-raised fish entered the widely distributed traditional markets established for wild fish caught in natural waters by commercial fishermen. Even after processing plants were built, few farmers, and none of the plants, entered the traditional fish marketing system. Each operator preferred to market his own fish.

Some of the early processing plants were owned and operated by farmers who, for the most part, had no knowledge or appreciation of the need for marketing and how it differed from "selling." At the same time, farmers were unwilling to tax themselves to finance a program of market promotion and market research.

Market promotion has not been attempted, owing largely to the lack of a uniform product and a consistent supply. Market surveys to determine geographical limits of possible markets, preferences for product forms, and acceptable variations in processing techniques, remain to be conducted. Although limited efforts have been made by governmental agencies toward studies of existing markets and of marketing systems, it has been a case of "too little and too late."

Until the fall of 1970, a seller's market had existed in which livehaulers and processing plants competed for fish. In addition, most fish produced could be sold near the production area with little marketing effort. In fact, until 1969, less than 1 percent of the production was being sold in supermarkets; the hotel, institutional, and restaurant trade was purchasing the processed fish. Many more could have been sold to the institutional trade had the industry been able to consistently supply a uniform, portion-controlled product.

Beginning in the fall of 1970, production was sufficient to overload the processing and marketing capability of the industry. This situation, however, did not necessarily mean overproduction in terms of exceeding potential markets.

Markets for catfish can be grouped into two major and distinct groups: (1) the sale of dressed fish for food and (2) the sale of live fish for recreational fishing.

Catfish to be dressed at processing plants are delivered alive or on ice, depending on the management of the plant. Live catfish are electrocuted before they are dressed. This technique causes most of the blood to leave the muscle tissue and results in a consistently high-quality product. Skinning and dressing is often done by hand but may be mechanized.

Quality control represents a major problem facing catfish processors. Occasionally, fish having a musty flavor are processed, frozen, and packaged. Such fish are unacceptable to consumers and destroy the market image of good quality fish. Another problem is the lack of knowledge about packaging of the dressed product to make it attractive and still maintain high quality. Packaging in plastic bags has been unsuitable thus far because the bags often puncture, become frosted, and allow dehydration and freezer burn. No coating or glazing of the fish has been attempted, as is practiced by the trout industry.

A lack of working capital required to maintain an inventory of frozen catfish has plagued some of the processing plants. As a consequence, many plants sell only fresh fish and no longer maintain an inventory of frozen fish. The sale of fresh fish corresponds to the traditional, already established, market for fresh river fish.

Few processors have shown a profit to date because they have not operated at full capacity, have not had adequate capital to maintain large inventories, or have been unable to buy fish during the summer (when they were often outbid by live-fish haulers).

The sale of live fish to be dressed by the purchaser represents an important market outside the processing plants. The hauling of live fish from fish farms to other areas, where they are sold for food, is a rapidly expanding business. Many pounds of live catfish are hauled from Arkansas and Mississippi to other States, especially to Texas. Many are sold in other States to fish farmers who are unable to produce enough fish to supply the local markets. Upon delivery, the fish are put in storage ponds or holding tanks until they are used. Most of these sales involve about 4,000 to 5,000 pounds per purchase, although the amount may be as high as 12,000 pounds. Prices paid to farmers ranged from 30 cents to 35 cents per pound in 1971, and the fish were resold at prices of 40 cents to 65 cents.

The hauling of live fish for sport fishing is generally to the north-central portion of the Nation, primarily in a belt extending from Kansas City east to the Allegheny Mountains—and especially near large cities where an old established fee-fishing industry exists. An early survey indicated that in the North, 63 percent of the fee-fishing lakes had been in business more than 8 years, whereas in the South, 89 percent had been in operation less than 3 years.

Most northern fee-fishing lake operators depend primarily on wild fish caught from the Great Lakes, other nearby lakes, or from east coast rivers. These operators use large numbers of low-cost fish, such as carp and bullheads, and supplement these with higher priced channel catfish, black bass, and other species.

Many northern buyers are reluctant to use farm-raised fish due to the small average size of the fish (1¼ pounds); 2- to 4-pound catfish are preferred. Most haulers sell farm-raised channel catfish in the North for 50 cents to 55 cents per pound. Wild channel catfish can be purchased for 25 cents per pound, bullheads for 10 cents to 22 cents, and carp for 6 cents to 7 cents.

In the past, live-haulers paid 40 cents per pound or more for farm-raised channel catfish. Because of the recent increase in production, however, the price has fallen and it is likely that many more channel catfish will be hauled northward to fee-fishing ponds.

Fish farmers should not look to the live-fish market as the answer to their future marketing problems unless they are located near fee-fishing lakes. Live-hauling has primarily served to increase stability of the market. However, the logistics and cost of hauling live fish 500 or more miles limits the total sales to this market. In future years, a lower sale price should encourage more haulers and fee-fishing lake operators to use farm-raised fish.

Operators of fee-fishing lakes list the following desirable features:

1. Stock 4,000 to 10,000 pounds per acre, depending on the availability of fresh

Channel catfish are eagerly sought by anglers at fee-fishing lakes.

water. Restock as needed when the population is reduced.

2. Ponds should be narrow, so that anglers can cast to the middle of the ponds, but should not be excessively long because many of the anglers are elderly and are not able or willing to walk long distances.

3. Provide good parking areas, located away from the ponds so that the customers must walk to the ponds. (This precaution reduces the likelihood of fish being stolen.)

4. Charge about 60 cents per pound for the fish taken plus a fee of 50 cents to $1 per pole (1971 prices).

5. Provide a fish-cleaning service for a fee; charge as much as 15 cents per fish.

6. Provide shade, and a stand for the sale of refreshments and fish bait.

7. Keep the grounds neat and attractive and the levees grassed.

8. Increase interest by offering prizes for tagged or albino fish, or stock and publicize the presence of a few huge "tacklebuster" fish.

9. Liability insurance is an absolute necessity.

It is desirable to stock at least three species of catfish (channel, blue, and white) plus some panfish, such as bluegills, in fee-fishing ponds. During cold winter weather, as well as at 100° F. summer temperatures, white catfish support the fishing. Some operators think that fish should be added to ponds weekly and that several ponds should be available to anglers. Since children have a short interest span, ponds stocked with panfish serve to keep them busy and happy.

An alternative to the sales of live fish to fish-haulers is on-the-farm sales. Since most of these are winter sales involving small lots, the selling price is relatively high. Usually 50 cents per pound or more is charged for live fish sold from holding tanks. In areas far from the major fish farming areas, the price may be 65 cents per pound or more for live fish and $1.10 for dressed fish. Even in areas where there are large acreages, most farmers sell what they can at the farm because local sales provide income to pay employee wages during the winter months.

Catfish are offered for sale at many locations in the south-central States.

Farm-raised catfish are likely to have serious competition from imported foreign catfish. In 1970, approximately 5 million pounds of dressed catfish was imported. Most imports now come from Brazil and Mexico. Brazilian fish are harvested from the Amazon River by commercial fishermen, and it is likely that the river can support a much larger sustained yield of catfish than is currently being harvested.

It is noteworthy that the companies involved in importing catfish have been willing to make large investments on marketing research and development. The willingness to make this expenditure is in marked contrast to the fish-farming industry which, thus far, has been unwilling to do so.

Other competition with farm-raised fish arises from the sale of a myriad of other fishes listed as "catfish." These may include bullheads, sea catfishes, wolffishes, codfishes, and others; many of these varieties are of inferior quality. Nevertheless, some restaurants have sold these substitutes, advertising and featuring them as farm-raised catfish.

The largest competitor of farm-raised catfish is wild fish caught from rivers and lakes in the United States. Buyers of fish handle more catfish obtained from U.S. rivers and lakes than from any other source. A Government survey of restaurants and institutional feeders indicated that 39 percent of the total catfish used in restaurants in the United States in 1970 were wild fish.

HIGH-DENSITY CULTURE METHODS

Specialized catfish culture systems have received much publicity in recent years, and several high-density methods are currently under investigation. These include the use of cages; earthen, metal, or concrete raceways; and various tank systems. At our present state of knowledge, these systems are applicable only under special conditions and are not suitable for general use. High-density fish culture requires not only highly skilled and knowledgeable management, but also provisions for the adequate addition of oxygen and removal or dilution of wastes. *Diets must be of high quality and meet all nutritional requirements of the fish.*

Cage Culture

Cage culture of fish involves the confinement of large numbers of fish in small enclosures consisting of wire or fiber mesh stretched over a supporting frame. The cages are attached to floats and anchored in rivers, lakes, or large ponds. Water currents or wind action carry away waste products and must continually provide oxygenated water. In deep lakes, solid wastes settle to the bottom, and thus cause no significant depletion of water quality in the zone where the fish are held.

Although research has revealed some of the problems and limitations of cage culture, the fish farming industry undoubtedly has a place for it, along with raceway and tank culture, as a means of intensifying production. Much more information is needed, however, before profitable operation can be assured.

The following comments serve merely as a summary of the existing research and present some of the results of applied cage culture. To date, few cage culture efforts have been completed without mishap and most have resulted in a considerable loss of money.

Cage culture is readily adapted to water areas which cannot be drained or otherwise harvested. Food fish can be cultured in waters already containing populations of wild fish. Fish in cages can be easily observed and farmers can keep accurate checks on their fish. Under *ideal* conditions, excellent growth has been achieved. Experimental production has been as high as 24 pounds of fish per cubic foot of cage space in the heated effluent water from a powerplant.

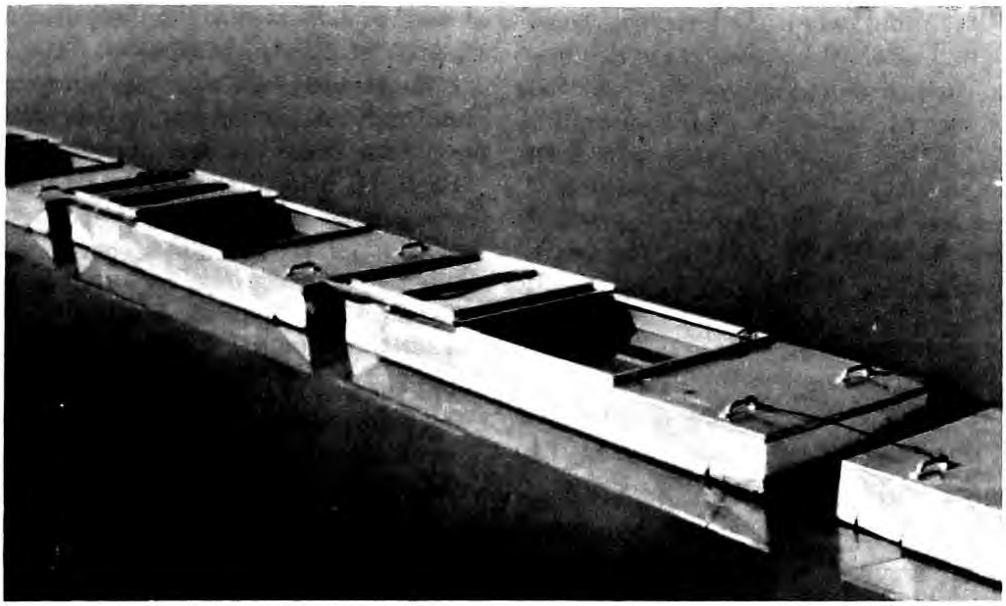
Stocking

Most workers agree that cages should be stocked when water temperatures are below 60° F. If food fish are to be produced in one growing season, large fingerlings free of disease and of good quality must be used. In areas north of Arkansas, fingerlings weighing up to 4 ounces may be required.

Stocking density figures reported range from 160 to 600 fish per cubic meter. In studies that were completed without interruption, stocking densities ranging from 160 to 325 fish per cubic meter produced marketable fish (weight, 0.9 to 1.5 pounds) in 180 days.

Feed Conversion

Nutritional problems have been encountered in cage culture whenever a standard food ration was used. *Diets must be nutritionally complete.* Present-day



Cages may offer a way to raise fish in certain environments if nutritional problems can be solved.

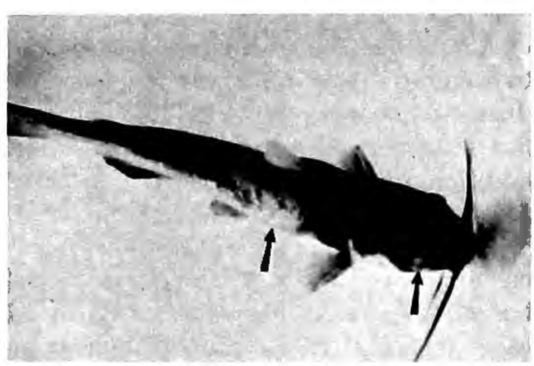
catfish feeds must be heavily supplemented with trout feed that may cost up to 2½ times as much as regular catfish pond feed. The expense of such feeds allows no room for inefficiency on the part of the fish or the fish culturist. Unless feed conversion is good and fish survival is high, cage culture is not feasible.

Feed conversion values reported by those engaged in cage culture research ranged from 0.9 to 3.0 pounds of feed per pound of fish produced, and averaged about 1.4. In commercial production in ponds, the average conversion factor is near 2.0.

Positioning of Cage

Oxygen depletions cause catastrophic fish losses whenever they occur, and the cage culture method is not immune from this problem. Fish that are free in ponds can move to areas with higher oxygen concentrations, or disperse when dissolved oxygen levels drop. Caged fish, however, cannot escape from the enclosure; consequently losses are often complete because the many closely crowded fish deplete the oxygen faster than circulation can supply it.

Good water circulation through the cage is essential for aeration and waste removal. This circulation is greatly dependent on wind-induced water currents, but is aided by the swimming action of the fish. Cage placement should be such that the longest side is perpendicular to



Fish fed nutritionally deficient diets may have broken vertebrae or be excessively dark or blind.

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the prevailing wind. The recommended minimum interval between cages is a distance equal to the length of the cage, but a distance of 20 feet or more is desirable. Cages should be positioned over deep water so that solid wastes sink to the bottom, where water stratification (described earlier) keeps them out of circulation with the water inhabited by the fish.

Cage Culture in Warmwater Effluents

Experimental cage culture in warmwater effluents of powerplants has been extremely successful; the findings, though limited, suggest that production may be very high in such situations.

One worker reported that 958 channel catfish held in 1-cubic-meter cages and fed for 89 days gained 852 pounds in weight. In another study, fish weight increased 44-fold in 159 days; conversion values were 1.3 at temperatures up to 98° F. (Some fish survived at a temperature of 106° F., but all died at 108° F.)

Labor Requirements

Labor requirements for cage culture are high, and use of machines has been extremely limited. Feeding and treatment for disease are still done by hand.

Disease Control

Disease control has been difficult; losses of 5 to 59 percent of the stocked fish due to bacterial disease have been reported. All diseases commonly found in pond-cultured fish have been observed in caged fish. In addition, other parasitic forms usually found only on wild fish have been noted.

Treatment of parasitized fish is a laborious and expensive task. Effective concentrations of chemicals dissipate rapidly in cages, making disease control difficult or impossible. Each cage of fish must be handled separately, either by removing it for dipping or by enclosing it in some form of container. Labor and time requirements are great and costs are high.

If substandard diets are used and nutritional deficiencies develop, opportunities for disease outbreaks are increased.

Bacterial infections must be treated by feeding a medicated floating feed. Such feeds are not yet available from commercial sources.

Present Status of Cage Culture

The success, or lack of it, in cage culture by private industry has varied with the individuals who have attempted it. Some have reported phenomenal success, but many have lost thousands of dollars in a single year. Many people plan to try again because they realize the potential and hope that a lack of knowledge and human error are at fault. The prominent errors or deficiencies to date have been: (1) Poor handling of fish before they were stocked; (2) use of fingerlings that were diseased, of low quality, or too small to reach market size by the end of the growing season; (3) substandard water conditions or continuing periods of low oxygen; (4) suspension of cages in bodies of water too small to allow adequate waste dispersal; (5) poor cage construction; and (6) use of incomplete feeds. Other problems have resulted from improper positioning of cages, disease, inclement weather, pollution, predation, and poaching.

The current state of knowledge does not provide the needed insight to overcome all these problems. When the various problems are solved, cage culture may become economically feasible.

Raceway and Tank Culture

Raceway or tank culture is feasible only if large quantities of cheap, high-quality water are available for a "once-through" or "open" system, or if the water can be recirculated and wastes efficiently removed for a "closed" system.

If good water quality can be maintained, very large numbers of fish can be stocked in each raceway. Manipulation of stocks and harvesting are readily accomplished because the fish are concentrated and accessible.

Disease control is very important, since an outbreak readily spreads throughout the population. Use of incomplete diets leads to nutritional deficiencies and increases the severity of infectious or parasitic diseases.

The present level of technology is inadequate to produce fish in closed systems at a commercially profitable level. *High quality water, complete diets, and disease-free fish* are absolute requirements in such systems. Metabolites and other wastes must be effectively removed at minimal cost if recirculating systems are to prove feasible.

Labor requirements for recirculating systems are high, due to the need for continuing maintenance and observation. Mechanical failure in any unit of the system can spell disaster. Standby electrical generators and backup pumps are required in the event of power or equipment failures.

Raceways and recirculating systems will probably be employed in the future. At present, however, large-scale operations have not proved profitable, even though small pilot experiments by research organizations or private individuals have been highly promising.

Long, narrow earthen ponds (100 x 15 to 20 feet), operated as raceways with either "once-through" water or recirculated water after it has been reconditioned in 5-acre or larger ponds, have been reported to be successful in Georgia. About 2,500 pounds of food fish reportedly were raised per 100 feet of raceway in recirculated water. More could be reared in "once-through" flow systems. However, many of the problems of disease and diet experienced in other intensive container-type cultures are also encountered in raceway systems.

In spite of these known and other unknown hazards of container culture, many knowledgeable fishery biologists and fish farmers believe that this type of culture will be used increasingly in the future, especially in heated effluent waters from powerplants, in nondrainable lakes, and in streams.

Experiments are now underway to determine the feasibility of raising fish in small tanks.

IMPROVING STOCKS OF CHANNEL CATFISH

So far, we have emphasized water management, proper diets and feeding, and disease and parasite prevention and control. All of these presuppose that the fish being raised on fish farms are of the highest quality obtainable. This may not be so. It may be possible to effect improvements, however, by hybridization (the crossing of different species, such as channel catfish and flathead catfish), selective breeding (the purposeful choosing of individuals from different strains of a single species), or crossbreeding (mating of unrelated strains of the same species to avoid inbreeding).

Hybridization of other species of animals suggests that hybrid vigor can be anticipated in catfish crosses as well as in those of salmonids, sunfishes, *Tilapia*, and buffalofish. Hybridization or crossbreeding has resulted in growth increases as great as 100 percent. Other benefits from hybridization might be increased disease resistance, increased tolerance to adverse physical or chemical conditions, and easier harvesting.

Hybridization

If a fish culturist or researcher wanted to develop a fish with the small head of a channel catfish and the large body of a flathead catfish, hybridization is the tool he would use. Such crossing for special features has been accomplished by the Southeastern Fish Cultural Laboratory and the Fish Farming Experimental Station. A potential added bonus, which is not yet fully understood, is known as "heterosis" or "hybrid vigor," the possession by hybrids of qualitie or capabilities that exceed those of either or both of the parents. Not all hybrids possess this quality, and the offspring of hybrids (the F_2 generation) seldom do.

Hybridization may be accomplished in two ways: (1) "Commercial crossing" involves the production of first-generation hybrids for commercial use. The hybrids are not retained as brood stock, since the second generation seldom shows hybrid vigor. (2) "Synthetic crossing" is the mating of two or more kinds of fishes with the hope of developing an entirely new variety. This is a difficult procedure that involves long-term breeding and selection.

The development of new varieties of fish should be left to research, because it requires a long time and is very complex. Even today, State and Federal organizations do not have the wealth of facilities and manpower required for effective hybridization studies; those made thus far have been only preliminary.

Hybridization techniques have produced a long list of first-generation hybrids and a few second-generation hybrids. Almost all possible crosses among the major native species of catfishes have been performed in the laboratory, but an easy and adequate method of producing large numbers of first-generation hybrids on a commercial basis has not yet been perfected.

In testing of hybrid catfish in the laboratory, close attention has been given to growth rates and feed conversion. Two hybrids, the white catfish × channel catfish and the channel catfish × blue catfish, perform well; the former shows a slightly better feed conversion and faster growth rate than the latter.

One investigator, who stocked channel catfish × blue catfish hybrids in combination with channel catfish and blue catfish, found that growth of the hybrids in an 18-month period was 22 percent greater than that of channel catfish stocked alone and 57 percent greater than that of blue catfish stocked alone. When the fish were stocked in the same pond at the rate of 500 of each per acre, the hybrids grew to 1.1 pounds, compared with 0.9 pound for channel catfish and 0.7 pound for blue catfish. At 26 months the hybrid was 32 percent larger than the channel catfish and 43 percent larger than the blue catfish.

At a market price of $0.35 per pound, the hybrids in the study described above would bring the farmer $105 more per acre than would channel catfish. These results appear to be encouraging, but, as indicated earlier, methods of producing hybrid fingerlings on a commercial scale have not been fully developed. Continued study is needed to perfect ways to achieve this goal.

To solve the problem of supply, we mated hybrids and tested the offspring at the Fish Farming Experimental Station. In this work we compared success of reproduction with hybrid matings and the survival of their respective offspring, as well as weight gains and feed conversions. Hybrids were fertile and some fingerlings were produced. Spawns were usually incomplete, however, and relatively small. Growth of the second generation (F_2) channel catfish × blue catfish hybrid was, as expected, inferior to that of the F_1 hybrid and of the parent stock.

Recently we have taken another approach to the problem, namely, that of "out-crossing" and "back-crossing." Outcrossing combines features of three or more species, as in mating a hybrid with an individual from a species not used in producing the hybrid. Channel catfish × blue catfish hybrids readily mated with white catfish. Preliminary sampling of a mixed population of channel catfish, white catfish, and out-cross hybrids showed that the out-cross hybrid grew more slowly than channel catfish. Backcrossing, the mating of a hybrid individual with one of its parental species, is currently under study.

Selective Breeding

Although selective breeding often means mating the largest individuals in a given lot, this is not necessarily true. Some specimens may be large because of nongenetic factors such as favorable environmental conditions early in life or a physiological advantage such as large size at stocking time.

The steps in a selection program are as follows:

1. Select the largest males and females in a population. The fish should be of the same age and general stock, and preferably be 4 years old. Remember that size is directly related to stocking density, and that low stocking rates may yield large fish which do not necessarily have a genetic basis for fast growth.
2. From these large fish, select those with the best body form, secondary sex characteristics, and color.
3. Brand or otherwise mark the chosen fish for permanent identification.
4. Mate the best male with the best female and *keep their spawn completely isolated from spawns of other fish.*
5. Harvest the fingerlings at the age of 1 to 2 months and select the largest 10 percent.
6. Return these to the ponds; when they are 4 to 5 months old, select the best 5 percent for restocking. Continue to keep them isolated for further development.
7. When the fish are 18 months old, examine them again and retain only the best 5 percent for potential brood stock.
8. At 36 months, select and mark the best males and females. In selection, consider such characteristics as early appearance and prominence of secondary sex characteristics, desirable body conformation, and color.

9. Mate these individuals with fish selected in the same manner from an unrelated strain. *Keep track of the individual fish that were mated and keep all spawns strictly separated so that the results can be traced to individual parents.*

For the first selection it is important to mate the largest pair; the assumption is that this pair became large due to inherent capacity for fast growth and that the spawn will provide the largest possible number of fingerlings from a single mating. Mating more than one pair in this first selection may help insure a successful spawn, but the different lots of eggs must be kept separated.

Periodically, select the best fish and dispose of the remainder. This selection process leaves only the individuals that grew rapidly as fingerlings and yearlings, and were the largest fish at a given age.

Since males often are larger than females of the same age, males and females must be judged separately. At the time you select fish from your own stock, acquire and select adult fish from an unrelated strain. When final selections are made, mate males of one group with females of the other, and vice versa, keeping accurate records of all matings so you can identify the parent fish involved. Choose the cross which gives the best results so that the offspring can be used as future brood stock.

The fish farmer can use this selection process to try to improve any particular feature—e.g., size of head, dress-out rate, color, texture of flesh, and bone structure. If the selection is carefully done, the quality of the stock should improve.

As this description shows, selective breeding is complex and difficult. Segregation of individual spawns, fingerlings, and brood stock requires many ponds, especially since channel catfish usually do not reach sexual maturity until they are 3 years old.

Crossbreeding of Strains

Crossing of unrelated strains of the same species to avoid inbreeding is likely to give more immediate benefits than selective breeding. Investigators who worked with carp in Israel showed that inbreeding of full brothers and sisters was responsible for a 20 percent growth suppression in one generation. Inbreeding depression also reduced viability and significantly increased the number of abnormal fish.

These researchers suggested that on the basis of this experience, the single and simple step of using unrelated mates for the production of commercial fry should not only improve growth rates and yields of carp, but also increase uniformity. It would seem that stocks of channel catfish would be subject to the same generalization.

We believe that inbreeding has already degraded the present production of channel catfish—as evidenced by the increasing numbers of fish with crooked spines, no tails, no eyes, and malformed mouths, as well as by the wide variation in individual size. If inbreeding is responsible for anomalies and slow growth in channel catfish, cross-breeding may be a simple, inexpensive means of correcting these conditions.

In contrast to channel catfish, blue catfish have few abnormalities and show great uniformity of size, probably because hatcheries have only recently started to culture this species.

Crossbreeding of strains is by far the most promising step for immediate use by the industry, since few fish are required and the results become evident in a relatively short time. In crossbreeding, the fast-growing individuals of a population are mated with selected males and females of an unrelated strain. The fry from this mating often exhibit a vigor that more than compensates for the inbreeding in the initial strain.

Other features that might be readily incorporated into present fish stocks with the proper strains of fish include a high dress-out rate, good disease resistance, tolerance of adverse environmental conditions, spawning at a low temperature, or absence of objectionable fin spines.

Fish farmers can begin a crossbreeding program by mating their current channel catfish brood stock with channel catfish from a totally unrelated source. They can obtain brood stock from some place distant from the fish farming area, exchange fish with other farmers, or use fish taken from natural waters, outside the local watershed. Regardless of source, the fish must of course be free of disease. If some inbreeding has already taken place in the acquired strain, crossing of the two strains should restore vigor.

The process of crossing strains should be as follows:

1. Upon receipt of the unrelated strain, mark all fish by branding or other means.
2. *Cross females with unrelated males, and vice versa.* Present methods of spawning may be used—in pens, aquariums, or open ponds.

Crossbreeding of strains, because of the ease with which it may be carried out and the speed with which results can be obtained, could be adopted by the fish farming industry with little expense. Most farmers already have the required facilities. Crossbreeding of unrelated strains of channel catfish will stop the degradation of the species and begin a trend toward improved production.

Male and female channel catfish brood stock. The wide head with muscular pads is characteristic of the male (left).

HOW TO DO IT

Thus far in this report we have emphasized the principles underlying the practice of fish farming, and explained some of the physical, chemical, and biological changes that take place in ponds and among fish. We now offer a compilation of suggestions that we hope will assist the fish farmer in the day-to-day details of managing ponds and fish populations. Although many of these are simple, they are based on experience with methods that may not be completely obvious to all those who raise warmwater fish. Some of the important points discussed in previous sections are repeated here for emphasis.

Chemical Treatments

The calculation of the amounts of chemicals to be used in fish farming may involve English and metric units, or combinations of them that may be confusing to some pond owners. Units of measurement and of treatment are described here, and conversion factors are offered.

Fish farmers are thoroughly familiar with such units of measurement as pounds, acres, and gallons. Less familiar standard units used in fish culture are described here.

Units of Measure

A *cubic foot* of water, a unit of volume measuring 1 foot square and 1 foot high, weighs 62.4 pounds and contains about 7.5 gallons. The number of cubic feet in a pond equals the length × the width × the average depth (all measurements in feet).

An *acre-foot* is a unit of volume having an area of 1 surface acre and a depth of 1 foot. One ac -foot of water contains 43,560 cubic feet, 326,000 gallons, or 2,718,144 pounds. Acre-feet are computed by multiplying the area in acres by the average depth in feet.

One *gallon* (4 quarts or 8 pints) equals 3,800 cubic centimeters. One gallon of water weighs about 8.34 pounds or 3,800 grams.

One *pound* (16 ounces) equals 453.6 grams and 1 ounce equals 28.35 grams.

Weights are expressed in the metric system as grams and kilograms. A *kilogram* equals 1,000 grams, or 2.2 pounds. Volumes are expressed in *cubic centimeters* (cc.) or *milliliters*. One thousand cubic centimeters or milliliters make up 1 *liter*. One gallon contains 3.8 liters (or 3,800 cc.).

Metric units are frequently used for measuring small amounts of chemical. Thus, we may apply a certain number of grams of chemical per gallon, grams per cubic foot, cubic centimeters per gallon, or cubic centimeters per cubic foot. Since large units of volume require large units of weight, it is most convenient to consider such treatments in terms of pounds per acre-foot.

Units of Treatment

In the treatment of fish, it is a common practice to add enough chemicals to the water to produce a desired concentration. Concentrations are generally expressed as parts of chemical per million parts of water (usually written as p.p.m.). For example, the addition of 1 pound of chemical to 999,999 pounds of water gives a concentration of 1 p.p.m. in a total weight of 1 million pounds of solution. The amounts of chemical needed to produce 1 p.p.m. in each of the standard units of water volume are:

2.7 pounds per acre-foot
0.0038 gram per gallon
0.0283 gram per cubic foot.

Another method of treatment is the incorporation of a chemical in fish feed. Such treatment is based on the weight of the fish. Standard units of treatment are given in grams of chemical per 100 pounds of fish per day. If 100 pounds of fish are to be treated with Terramycin at the rate of 2.5 grams per 100 pounds of fish per day, the amount of feed fed each day must contain 2.5 grams of the drug. Generally speaking, fish are fed at the rate of about 3 percent of their body weight per day—or 3 pounds of feed to each 100 pounds of fish. For treatment, the feed requires 2.5 grams of Terramycin in every 3 pounds of ration. The amount of Terramycin per 100 pounds of feed therefore is $100/3 \times 2.5$, or 83.3 grams.

Formulations

In the above examples, it was assumed that all of the chemicals were pure compounds, or were 100 percent active ingredient; however, few of the compounds used in fish culture are pure chemicals. Most are mixtures, and the percentage of active ingredient is stated on the label, *unless* the recommended use specifically indicates otherwise. To find how much of such a mixture is required, divide 100 by the percentage of active ingredient in the formulation. For example, assume that the chemical to be used contains 25 percent active ingredient; the division of 100 by 25 shows that four times as much of this formulation is required as of pure chemical.

Formulations of antibiotics generally have the drug in a premix form that can be incorporated into feeds. Usually such formulations contain 25 grams of activity per pound of material. If you wish to incorporate 2.5 grams of active ingredient from such formulation into a certain quantity of feed, divide 2.5 by 25 to determine that you need 0.1 pound of the formulation. Other ways to express this quantity are $0.1 \times 16 = 1.6$ ounces, or $0.1 \times 454 = 45.4$ grams.

Some chemicals are provided as liquids containing a stated number of pounds per gallon. Typical products of this type contain 4 pounds of active ingredient per gallon. In this case, it is easier to work with the cubic centimeter instead of the gallon. Since a gallon contains 3,800 cc., a 4-pound-per-gallon formulation contains 1,816 grams (4×454)—or 1,816 divided by $3{,}800 = 0.48$ gram per cc. *Always remember to use the weight of the active chemical when computing parts per million to be used.*

Other chemicals may be liquids in pure form. A typical one of this type is formaldehyde solution (formalin). This solution contains only 38 percent formaldehyde gas, but the liquid is a pure compound for fish cultural purposes. In using a chemical such as this, it is necessary to know how its weight compares with that of water. If it is heavier than water, fewer cubic centimeters are needed to deliver the desired weight of chemical.

Calculating Treatments

We consider here some of the typical situations in which treatments are made.

For a tank treatment, unless the volume is known in gallons, it is best to measure the length and width of the tank, and the water depth (all measurements in feet). Multiplying these measurements gives the volume of the tank in cubic feet.

A formula for determining the amount of a chemical to use is the *volume* × *amount of chemical needed to produce 1 p.p.m. in each unit of volume* × *p.p.m. desired.*

Assume that you wish to treat a tank measuring 12 feet × 2.5 feet × 2 feet with 0.25 p.p.m. of malachite green. The calculation is $12 \times 2.5 \times 2 = 60$ cubic feet. Since it takes 0.0283 gram to yield 1 p.p.m. in 1 cubic foot, you multiply 60 (cubic feet) × 0.0283 (gram) × 0.25 (p.p.m.) = 0.42 gram of chemical.

If a chemical contains only a part as active ingredient, an additional factor must be added to the computation. This factor is 100 divided by the percentage of active ingredient, as described in the preceding section on units of treatment. Thus, the formula for determining how much chemical is needed to treat a 28,000-cubic-foot pond with 2 p.p.m. of a 25 percent active formulation is as follows: 28,000 (cubic feet) × 0.0283 (gram) × 2 (p.p.m.) × 100/25 = 7,924 grams, or 17.45 pounds.

Another approach to the problem is to convert the number of cubic feet to acre-feet by dividing by 43,560 (the number of cubic feet in 1 acre-foot), a calculation that yields a volume of 0.8 acre-foot. The calculation then becomes: 0.8 (acre-foot) × 2.7 (pounds needed to give 1 p.p.m. in 1 acre-foot) × 2 (p.p.m.) × 100/25 = 17.45 pounds of the 25 percent formulation. Slight differences between amounts of chemical determined by the two methods, which result from rounding of numbers, are too small to affect the treatment.

If the area of a pond is known in acres, you must determine average depth to compute the number of acre-feet. To compute average depth, take soundings over much of the pond, sum the measurements, and then divide by the number of readings. Be sure to make measurements in both the deep and shallow areas of the pond. If the pond is uniform in shape, one transect through the center along the long axis and another along the short axis is adequate. *Do not rely on an estimate or a guess;* many fish have been killed by overdoses resulting from reliance on such slipshod procedures. An engineer can help you determine the area and volume of large reservoirs. *Every fish farmer should know the volume of his ponds before a treatment is needed, to avoid loss of valuable time when a crisis is at hand.*

If you wish to treat a tank that holds 500 gallons of water, the calculation is 500 gallons × 0.0038 (conversion factor to give 1 p.p.m., in 1 gallon of water) × p.p.m. desired × 100 divided by the percentage of active ingredient in the formulation. For example, a treatment with pure malachite green at the rate of 0.25 p.p.m. in this tank is computed as 500 × 0.0038 × 0.25 × 100/100, or 0.475 gram. A treatment with 25 p.p.m. of formaldehyde is calculated in the same way, but involves an extra factor because formalin is heavier than water (specific gravity, 1.08). The calculation is: 500 × 0.0038 × 25 × 100/100 × 1/1.08 = 43.98 cc. of formalin.

A slightly different procedure must be followed to determine the volume of water in a round tank. Volume is again computed as area times depth. To find the area, measure the diameter of the tank and divide by 2 to determine the radius. The formula for the area is 3.14 × the square of the radius. The volume is computed by multiplying the area by the depth. Here is the computation for a round tank with a diameter of 5 feet and a water depth of 3 feet:

3.14 × 2.5 (the radius) × 2.5 (the radius) = 19.625 square feet (the area).

Then, 19.625 × 3 (depth in feet) = 58.875 cubic feet (the volume of water in the tank).

Chemical treatments for round tanks are computed as for other tanks: volume × conversion factor × p.p.m. desired × 100 divided by the percentage of active ingredient in the formulation to be used equals the amount of chemical needed to treat at the desired level.

In computing the amount of a chemical to be used, you can begin with any unit of volume. In the calculation, however, you must be sure to use the conversion factor that will yield 1 p.p.m. in the unit of volume with which you are working.

Table of Equivalents

1 acre-foot = 1 acre of surface area covered by 1 foot of water
= 43,560 cubic feet
= 2,718,144 pounds of water
= 326,000 gallons of water

1 cubic foot = 7.5 gallons
= 62.4 pounds of water
= 28,354.6 grams of water

1 gallon = 8.34 pounds of water
= 3,800 cc.
= 3,800 grams of water

1 quart = 950 cc.
= 950 grams of water

1 pound = 453.6 grams (454)
= 16 ounces

1 ounce = 28.35 grams

1 p.p.m. requires:
2.7 pounds per acre-foot
0.0038 gram per gallon
0.0283 gram per cubic foot
0.0000623 pound per cubic foot

Grading

The grading of fish to a uniform size before stocking improves accuracy in estimating numbers and (more important) reduces the number of fish that are too small to sell when the ponds are harvested. Sorting tables and grading boxes are used for grading. The use of sorting tables (usually for small lots of fish) also permits culling of undesirable individuals but may be injurious to the fish if they are carelessly or roughly handled.

Most producers use grading panels which are the same width as their holding tanks so they can grade the fish without handling them with dipnets. Others use floating grading boxes with panels of metal bars on the sides or bottom. Spacing between the bars determines the size of fish that are retained; fish small enough to pass between the bars escape.

Grader sizes for minnows and channel catfish are as follows:

Minnows, inches		*Channel catfish, inches*	
Spacing between bars	*Length of fish held*	*Spacing between bars*	*Length of fish held*
11/64	1½	27/64	3
12/64	1¾	32/64	4
13/64	2	40/64	5
14/64	2¼	48/64	6
15/64	2½	56/64	7
16/64	2¾	64/64	8

A 96/64- or 1½-inch grader holds ¾-pound channel catfish.

Grading should not be attempted until several hours after the fish have been removed from the pond. The quantity of fish in the grader at any one time should not exceed 5 pounds per cubic foot of grader capacity. Small fish can be driven from the grader by splashing the water within the grader. Large fish should be graded out of the population first, followed by successively smaller ones. Catfish pass most readily through the bottom of a grader and minnows through the side.

Hauling

Recently harvested fish should not be transported over long distances until the fish have voided their stomach contents. This may take up to 36 hours, but the delay is necessary to prevent an accumulation of fecal material in the water in which the fish are being hauled.

If the fish carry external parasites, treatments should be made at least 12 hours before they are hauled. *Do not treat fish which have not voided their stomach contents.* Keep all fish being treated under close observation.

Water used in hauling should be well aerated and as free from pollutants as possible. If available, hard, alkaline water

Harvesting channel catfish at Fish Farming Experimental Station.

should be used. The fish should be conditioned (tempered) before hauling if the water in which they are hauled differs substantially in temperature and water chemistry from the water in which they were raised. Later they should be tempered before they are stocked if the temperature of the receiving water differs by more than 5° F. The water temperature should remain between 50° and 60° F. during hauling but may be allowed to rise during the final hours of transit if the temperature of the water to which the fish are to be transferred is known to be much higher.

Polyethylene bags made of stock 4 mils (0.004 inch) thick or more can be used for transporting fish. The bags are filled with water to about one-fourth of capacity, fish are added, all air is pressed out of the bag, and it is then filled with oxygen. Compressed air is sometimes used if the holding or transport time is short. Tempering precautions should also be taken. Spines of catfish may have to be blunted or removed to prevent puncturing of the bags. Do not place the bags in direct contact with ice during transport. If contact occurs while sac fry are being transported, the bottom waters of a bag may be chilled far below the levels ordinarily tolerated by this developmental stage.

In most hauling units, agitators are used to stir the water surface during transport. Agitators usually provide sufficient oxygen if the fish load is not too large and the depth of the water is less than 2 feet. If depths are greater than 2 feet, bottom water must be agitated by the introduction of oxygen or air. As a rule of thumb, a 4-cubic-foot volume of water, 1 foot deep and at 65° F., agitated with 1 cubic foot per minute of air introduced at the bottom, will hold 60 pounds of 1-pound channel catfish for 24 hours. No firm rule can be given on the amount of fish that can be hauled, since this depends on water hardness, alkalinity, temperature, agitator efficiency, and the size, condition, and species of fish.

On very long hauls it may be desirable to change the water during hauling, although usually changes are unnecessary.

Production

Brood Stock

Brood fish should be at least 4 years old, although 3-year-olds will spawn. They should have a good outward appearance, have no deformities, and possess prominent secondary sex characteristics.

Treat for parasites and bacteria before the fish are handled.

Wild fish may provide good brood stock, if they are taken shortly before the spawning season and appropriate precautions for disease control are observed.

Provide the brood stock with an abundance of live forage fish, meat, and commercial fish food throughout the year.

Eggs

Incubate catfish eggs at temperatures between 77° and 82° F.

Use malachite green dip for control of fungus, if necessary, but never use it within 24 hours of hatching.

Provide a flow of 2.5 gallons per minute through the incubator; increase the flow if water turns milky, foams, or has an odor.

Fry

Feed fry in rearing troughs or screen boxes for up to 10 days with finely ground feed, supplemented with ground liver, fish, or a canned, fish-flavored cat food.

Maintain a minimum flow of 5 gallons per minute through the trough. Siphon fecal matter and excess feed from the troughs daily.

Move fry to freshly filled ponds free of insects. Apply diesel fuel, if necessary, to kill the insects before the fry are stocked.

Treat fry for parasites before transferring them to ponds.

Determine numbers of fry volumetrically at stocking time. If a 6-inch fingerling is desired for stocking in the spring, stock 30,000 fry per acre. Larger numbers of fry may be stocked if the population is reduced to this number after the fish become 2 inches long.

Provide feed around the margins of the entire pond.

Check ponds twice weekly for the presence of aquatic insects. Treat the ponds with diesel fuel whenever necessary.

Observe ponds daily for dead or sick fish. If some are seen, determine the cause as soon as possible and take corrective action.

Feed two or more times per day until the fish are at least 2 inches long.

Screen or filter all incoming water to prevent the entry of wild fish.

Feed at a reduced rate as weather cools during winter.

Yearlings

At the latitude of Stuttgart, Ark., fingerlings 6 to 8 inches long or longer are needed if they are to reach market size in one growing season after stocking. In northern latitudes the fish must be at least 8 to 10 inches long.

Treat fingerlings prophylactically before stocking.

Lower and refill ponds periodically to maintain good water quality; do this whenever algal blooms become so dense that the hand cannot be seen 18 inches below the surface.

The continuous addition of fresh water increases production and improves your control of environmental conditions.

Reduce or discontinue feeding if fish do not feed actively. Check water quality frequently—especially for low oxygen.

Examine sluggish or weak fish for disease.

Examine ponds early each morning to watch for low oxygen or adverse water conditions.

Thoroughly investigate any unusual condition.

Harvest salable fish throughout the growing season, if possible. During harvest, remove small or deformed fish from the population. Remove 80 percent or more of the population by seining before completely draining a pond.

Control feeding carefully; overfeeding results in oxygen depletions, whereas maximal feeding results in maximal production.

Small ponds are easier to manage than larger ones and produce more pounds per unit area.

CATFISH FARMING COSTS

Prospective fish farmers should carefully appraise construction costs, operating expenses, risks, and methods used by successful fish farmers before choosing a type of fish farming to undertake. Well-managed fish farms are profitable if close attention is given to all phases of the operation.

Recent innovations in fish production include raceway and cage culture. Each has specific requirements which may increase or decrease costs according to the existing situation. Since both require the use of nutritionally complete rations, feed costs are considerably higher. Although a few figures are available, they are not adequate to allow an accurate estimation of production costs. At the present time, few, if any, cage and raceway culturists have achieved profitable production.

Cost and construction details of fish ponds for the intensive rearing of fish vary with the number, size, and depth of ponds, water availability, soil composition, and land topography. Initial investments for construction include levee construction, pump installation, and supply and drain lines. Total costs are $250 to $1,000 per acre.

A 1970 survey by the University of Arkansas showed that the average price for construction of levees of ponds smaller than 20 acres was $189 per acre. Although larger ponds cost less per acre and may be rotated with land crops, levees are more expensive to maintain because waves erode them. Levees of small ponds also gradually erode, and must be repaired after 10 to 15 years. Maintenance and repair of roads on levees of ponds of all sizes is an annual expense.

Water in ponds should be at least 3 feet deep in the shallow end and the bottom should slope to one or more harvest basins in the deep end.

Pipes and drain gates cost $6 to $12 per acre in ponds of 10 or more acres. Some farmers install pipes to supply water; other use canals until they can afford pipes. If canals are used, extreme care and screening must be used to prevent the entrance of wild fish.

Effective pond drainage systems may be seen on most fish farms. Each is designed to meet the needs of the particular situation involved.

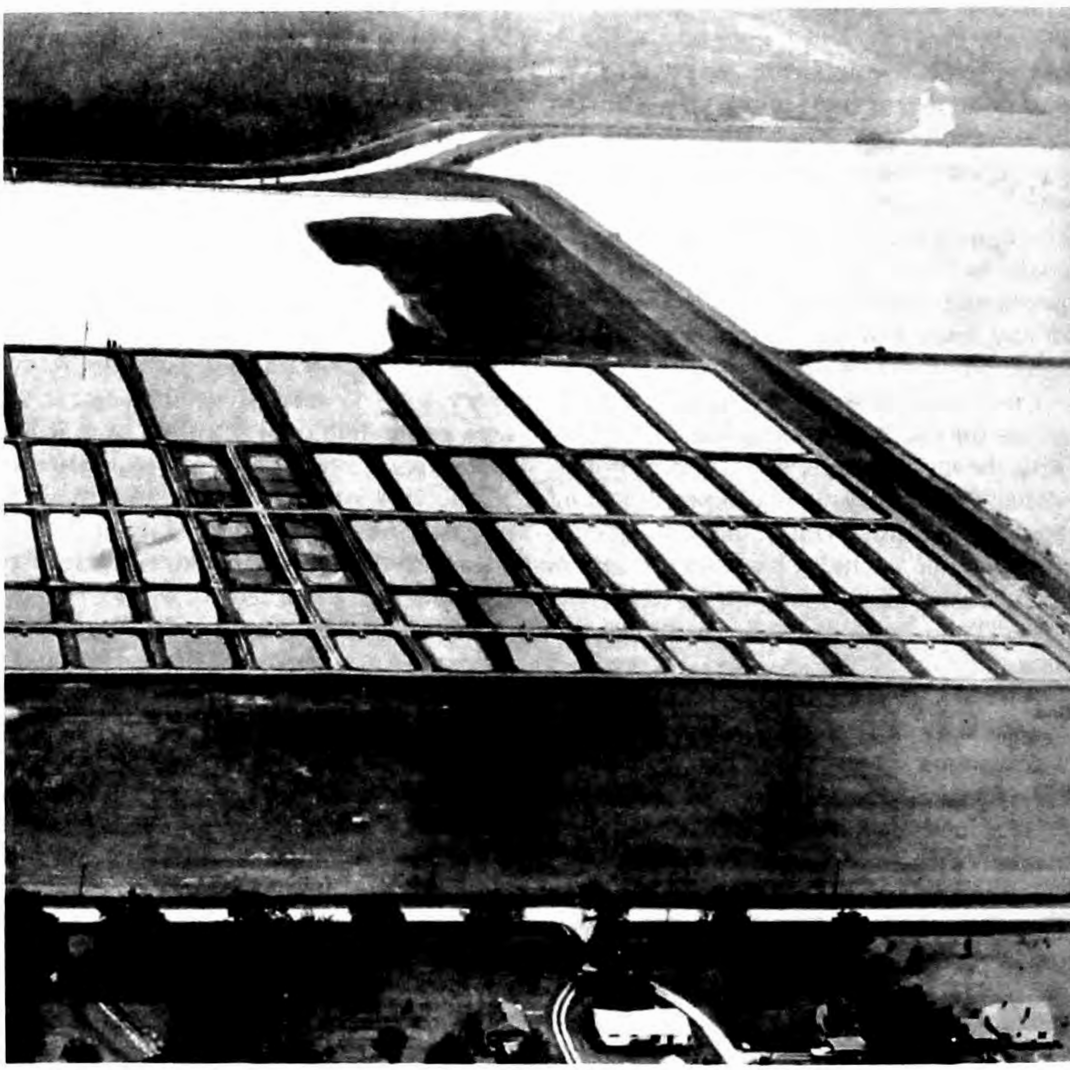
A well is the best source of water for fish ponds because there is little chance of introducing diseases and wild fish. Farmers should plan a water supply system capable of providing 50 gallons per minute for every surface acre of ponds (e.g., a 40-acre pond should be supplied by a 2,000-gallon-per-minute well). If ponds are supplied with surface water, use filters to prevent the introduction of wild fish, or chemically eradicate introduced fish after the pond has been filled.

Pump installation, not including the motor, costs $2,500 to $5,000, depending on the location and depth of the well. The cost is generally $10 to $12 per foot for an 8-inch hole and casing, plus the costs of a pump and powerplant. If large ponds are constructed, placement of the well in the center of the levee that forms a hub for four ponds reduces costs for water lines. Total pumping costs average $10 to $14 per acre per year.

Costs of labor and supervision are difficult to estimate. One or two men can manage an 80-acre food fish farm, except during harvesting when additional labor is required. Six or seven laborers and a supervisor can efficiently operate a minnow farm of 150 acres or perhaps even larger. In diversified operations, farmers use regular farm labor diverted from other jobs for such work as stocking and fertilizing of ponds.

Feed costs depend on the species and size of fish being raised. Feeding is most intensive during a 180-day period in the summer when the water temperature is above 60° F. When the temperature is below 60°, about one-third of the amount of food used in summer is ample and the fish need to be fed only twice per week. Channel catfish feed costs $100 to $150 per acre during a growing season. The present average yield of fish is 1,600 to 1,750 pounds per acre per season, from an initial stocking rate of 1,500 yearling catfish. The total cost for rearing market-sized channel catfish ranges from 30 cents to 34 cents per pound, of which 10 cents to 15 cents is for feed.

Comparisons of the returns derived from fish culture with those from arable land indicate that fish farming is an increasingly important enterprise in the southern United States. Net returns from



A well-constructed fish farm suitable for all species.

well-managed fish farms were equal to or better than those from rice or soybean crops.

The level of profit in fish farming is closely tied to management skills. It has been reported that in Mississippi in 1970, fish farmers could expect a net loss of $26 per acre at a production rate of 1,000 pounds of catfish per acre, and net gains of $99 at a production of 1,500 pounds and $179 at a production of 2,000 pounds per acre. Since 1970, however, market prices have declined, costs have risen, and profits have decreased by 50 percent.

In 1970, at a production rate of 1,500 pounds per acre, food-sized catfish were raised at a cost of 29.5 cents per pound in Arkansas and at about 34.7 cents per pound in Mississippi. When production costs are as high as these, many fish farms fail to show a profit. Furthermore, as the total production of catfish rises, it is anticipated that the price paid to farmers will fall. To offset this decline, farmers must increase the efficiency and volume of their operations.

A typical cost-return report from a better than average catfish farmer in northwest Louisiana is shown in table 10. The feed conversion rate in this operation was 1.53 to 1 (48,980 pounds of fish harvested, minus 2,500 pounds of fingerlings planted =46,480 pounds of fish produced by feeding 71,200 pounds of food).

Table 10.—*Cost returns in catfish farming for food fish production*

[Based on 1970 costs and 1971 prices; taken in part from figures supplied by the Soil Conservation Service, U.S. Department of Agriculture]

Item	Cost
Initial costs:	
Pond construction (2 10-acre ponds, levee type; 32,000 cubic yards	$10, 633. 75
Well, 10-inch diameter, with 500-g.p.m. pump and motor, prorated [1]	1, 575. 20
Drain pipe, 10" w/valves	920. 21
Fence, 0.8 mile, 4-barb	400. 00
Road and gravel	500. 00
Boats and motors	600. 00
Seine, prorated cost [1]	235. 20
Oxygen kit, prorated cost [1] ($47.80÷42.5 acres×20 acres)	22. 40
Total	14, 916. 76
Average cost per acre of pond	745. 84
Annual fixed costs:	
Pond construction, amortized @ 6% 20 years ($10,663.75×0.08718)	929. 66
Well, pump, and motor amortized @ 6%, 15 years ($1,575.20×0.10296)	162. 18
Pipes and valves, amortized @ 6%, 10 years ($920.21×0.13588)	125. 04
Fence and road, amortized @ 6%, 5 years ($900×0.23740)	213. 66
Boats and motors (2), amortized @ 6%, 5 years ($600×0.23740)	142. 44
Seine, amortized @ 6%, 3 years ($235.20×0.37411)	87. 99
Pond maintenance, 0.25% of construction cost	26. 66
Annual maintenance—well, pump, motors, road, and fence 3%	119. 86
Total annual fixed costs	1, 807. 49
Adjusted for 8 years of production in 10-year period [2]	2, 259. 36

See footnotes at end of table.

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Table 10.—*Cost returns in catfish farming for food fish production*—Continued

Item	Cost
Annual production costs:	
Pumping costs (electricity)	$400. 00
Stocking—2,000 catfish per acre @ 5 cents each, ×20 acres	2, 000. 00
Feed—35.6 tons @ $145.80	5, 226. 08
Fertilizer and chemicals	31. 60
Labor (family)	960. 00
Truck or other vehicles, 2,500 miles @ 10 cents per mile	250. 00
Taxes on land	40. 00
Telephone	30. 00
Interest on operating capital @ 8%—6 months ($5,226.08+$2,000+$31.60)	290. 30
Harvest cost—3 cents per pound×48,980 pounds (includes hauling)	1, 469. 40
Total production costs	10, 697. 38
Total annual costs ($10,697.38+$2,259.36)	12, 956. 74
Gross returns per acre:	
48,980 pounds @ 30 cents per pound ($14,694÷20 acres)	734. 70
Less annual costs ($12,956.74÷20 acres)	647. 84
Average net returns per acre to land and management	86. 86
Average cost of fish production per pound ($12,956.74÷46,480)	0. 279

[1] Total cost of well, pump, and motor ($3,347.50), seine ($500), and oxygen kit ($47.80) prorated to include 2 other ponds; total area, 42.5 acres.

[2] Ponds are used for fish production 8 out of 10 years. Fixed costs are adjusted to cover 2 idle years.

CHANNEL CATFISH IN NATIONAL FISH HATCHERIES

The National Fish Hatcheries comprise 100 stations, of which about 25 produce warmwater species—principally largemouth bass and bluegills. These fish are distributed as fry or small fingerlings for one-time stocking of farm ponds sponsored by the Soil Conservation Service. A few fish of other species—redear sunfish, green sunfish, black crappies, white crappies, bullheads, and white bass—are reared in small numbers to meet particular stocking needs.

In recent years, and paralleling to some extent the growth of private fish farming, there has been a growing interest in stocking channel catfish in combination with the usual bass and bluegills in multiple-use farm ponds. Responding to the interest of farmers and the Soil Conservation Service, several National Fish Hatcheries have reared channel catfish for this purpose. In 1969, production was 8.3 million fish (8 million fingerlings and 0.3 million larger fish for use on federally managed areas). By weight, total production was slightly over 168,000 pounds. Commercial operators raised 35 to 36 million pounds of channel catfish in the same year. Consequently, the Bureau of Sport Fisheries and Wildlife encourages owners of farm ponds who are interested in stocking channel catfish to look to commercial producers (fish farmers) as a source of fish.

CULTURE OF MIXED SPECIES OF FISH

One method of possibly increasing poundages and profits in fish farming is to raise several species of fish in a pond at the same time. Several benefits may result. For example, a few buffalofish stocked per acre in catfish ponds will consume fine particles of feed that are otherwise wasted, thereby helping to keep the pond from becoming overly fertile. Other species may help control vegetation. Species that are omnivorous and active feeders, like *Tilapia*, may help prevent septic conditions by cropping the natural food and manure. In Israel, stocking of *Tilapia aurea* increased total production of fish by 30 percent when 1,000 to 1,200 per acre were stocked along with 1,000 carp. Production also increased when *Tilapia* and two species of mullet were stocked in carp ponds.

In experiments at Auburn University, the stocking of a mixture of 500 *Tilapia mossambica* and 1,800 channel catfish per acre increased production by 400 pounds per acre over that in ponds stocked only with channel catfish, without affecting feed conversion rates. The combined culture of channel catfish with rough fish also increased the total yield. When 2,000 3-inch channel catfish were stocked with 1,000 4-inch blacktail redhorse, the average yield of catfish was 1,563 pounds per acre, survival was 97 percent, feed conversion rate was 2.3, and average weight of the fish was 0.8 pound. The yield of blacktail redhorse was 219 pounds per acre, survival rate was 75 percent, and average weight was 0.3 pound. In control ponds where only catfish were stocked, the yield was only 982 pounds per acre, survival was 87 percent, and the feed conversion factor was identical (2.3). When 8,000 *T. aurea* and 20,000 channel catfish were stocked per acre, the combination yielded 5,800 total pounds per acre more than the yield in ponds in which catfish were stocked alone. The only cost of the *Tilapia* production was the cost of fingerlings, since the fish apparently consumed catfish feces and plankton.

Species combinations that have been used in the United States include: several species of catfish; catfish and buffalofish; catfish and minnows; catfish, buffalofish, and largemouth bass; and catfish and crappies. The catfish-buffalofish combination is most common. Usually 1,000 to 1,500 channel catfish fingerlings are stocked with 50 to 125 buffalofish per acre. Fingerlings stocked must be large enough to reach salable size in one growing season. If the fish are left in a pond for a second growing season, the buffalofish often spawn and the resulting young fish compete for food and space.

A farmer raising catfish with buffalofish should use hybrid buffalofish, but few now do so. In a stocking combination of 1,500 catfish and 100 hybrid buffalofish per acre, the hybrids grew from a length of 8 inches to an average weight of 5 pounds in a single season. The catfish grew at the normal rate.

Minnows and catfish can also be raised together successfully, and this combination is used by a number of farmers. Minnow farmers often stock small numbers of catfish in their rearing ponds, hoping to harvest a supplemental crop of food fish. This type of fish farming can be profitable. On large minnow farms the addition of catfish provides employment to the labor

Muskrats must be controlled on fish farms. Although they cause little damage to fish stocks, their burrowing often causes serious damage to levees.

force during slack periods of the growing season, as they can sort, harvest, and sell catfish. Another advantage is that this combination will produce more total pounds than can be produced by raising either catfish or minnows alone—if all things go well.

The minnow and catfish combination has several disadvantages, however: (1) Minnow farmers use a number of chemicals that do not have USDA or FDA approval for use on food fish; consequently they cannot use some of the chemicals that are needed to raise minnows if they must also be concerned about food fish. (2) If catfish are allowed to grow to more than 1 pound in size they may eat so many minnows that they reduce the crop, and consequently the profit. (3) Large catfish often injure minnows in the seine during harvest operations.

Channel catfish fingerlings can be raised with minnows. One of the simplest methods of doing so is to stock 10 to 15 pounds of yearling, ungraded golden shiners per surface acre in April, when the water temperature reaches 65° to 70° F. These fish are allowed to spawn. Care should be taken to insure that predaceous insects and wild fish are killed before the fish are stocked. There should also be ample vegetation along the shoreline on which the shiners can deposit their eggs. When minnow fry are seen, feed should be spread along the entire pond margin for about 3 weeks to insure good survival.

As soon as there is a good crop of shiners, catfish spawning containers can be placed in the pond and three pairs of small channel catfish brood fish, or two males and three females, stocked per surface acre. Usually the catfish can be placed in the pond near the end of May. Since it is important that insects be kept under close control, the pond should be treated regularly with diesel fuel.

Farmers using this technique usually produce 6,000 to 10,000 channel catfish fingerlings per acre but occasionally the catfish do not spawn. It is desirable not to exceed this level of production because, at harvest, the catfish fingerlings must be large enough to be graded out of the minnows.

Some farmers report achieving yields of 700 pounds of each species per acre in the intensive, combined culture of fingerling catfish and minnows.

If shiner ponds are stocked by introducing egg-laden mats and small catfish are added later, it is important that the catfish be 1 inch long or longer before they are released in the ponds.

When good-sized catfish are raised with minnows, shiners may be stocked at the rate of 20 pounds of adults per acre, or egg mats may be placed in the pond. From 100 to 1,000 large channel catfish fingerlings per acre are then placed in the ponds after the minnows have become advanced fry. Usually only 100 catfish per acre are stocked and the fish are fed daily, as in regular catfish culture. Some farmers use catfish food, others use "minnow mash"; both give good results. An additional benefit derived from raising catfish to marketable size with minnows is that the catfish eat the crayfish.

Poundages produced per acre will be less for each species than is normally achieved when each species is raised alone, but the gross cash return will probably be greater. The catfish should be removed with a large-mesh seine before the minnows are harvested.

Catfish farmers often add fathead minnows to ponds after the catfish are large enough to be aggressively predaceous on forage fish—or 11 to 14 inches long. Blue catfish become predaceous at a shorter length (7 to 8 inches). Any minnows that survive till harvest time can be sold for bait.

Another species combination is that of catfish and black or white crappies. Both fingerlings and food fish are cultured in combination. In food fish culture, 1,500 to 2,000 fingerling channel catfish (6–10 inches long) and about 200 small crappies (2–4 inches) are stocked per acre. The crappie fingerlings must be small to insure that they will not spawn, and overpopulate the pond. In this combination, catfish usually attain a size of 1 pound or more and the crappies about three-fourths of a pound in one growing season.

State Game and Fish Commissions sometimes raise fingerling crappies and fingerling catfish to make maximum use of pond space. It is important that not more than 15,000 to 20,000 catfish and less than 100,000 crappies be raised per acre if the catfish are to be large enough to permit separation by the use of grading boxes.

SPECIAL CULTURE METHODS FOR SPECIES OTHER THAN CATFISH

Although the fish farming industry of the South is overwhelmingly dominated by the production of catfish, a number of other species have been raised successfully. These include two baitfishes, the golden shiner and fathead minnow; one combination baitfish and ornamental species, the goldfish; a food fish, the buffalofish; and two game species, the largemouth bass and smallmouth bass. Culture methods are also being developed for two other game species, white bass and striped bass, both of which appear to be adaptable to artificial culture. Crayfish are a profitable farm crop in some areas of the South. The culture of each of these species or species groups is briefly discussed in the accounts that follow.

Golden Shiner

The golden shiner (*Notemigonus crysoleucas*) is the baitfish raised most often in the United States. Its bright, flashing appearance makes it the most popular live bait used by anglers. Typically, this fish is green when viewed from above and has large, gold- or silver-colored scales; a body which is deep and thin; and a characteristic downward curve in the lateral line. A local southern strain has orange or red fins. This strain has an exceedingly nervous temperament and too often jumps out of tanks or bait buckets.

Golden shiners prefer lakes but may commonly be found in the shallow water of large streams throughout the central and eastern United States. They readily adapt to pond conditions on fish farms and can be produced in large numbers. The fish grow rapidly and reach a length of 2 to 3 inches and become sexually mature by the end of the first year of life. The fish has a life span of at least 8 years and attains a length of 10 inches.

Spawning begins when water temperatures reach 70° F. (in March in Arkansas) and may continue over a lengthy period (through June in Arkansas). A second spawning may occur in August, but this is not common. Spawning may be delayed by heavily crowding brood fish before the spawning season and holding them until eggs are desired. When the crowded fish are stocked in a freshly filled pond at a reduced density, spawning soon begins.

Golden shiners lay their eggs on aquatic vegetation if it is available. If not, the eggs may be laid on detritus, brush, or roots. If vegetation is excluded or eliminated from a spawning pond, the shiners readily deposit their eggs on specially constructed mats of Spanish moss or synthetic fiber.

A large female may produce up to 10,000 eggs. Most farmers, however, prefer to use 1-year-old fish for brood stock because a protozoan parasite, *Plistophora ovariae*, often destroys large portions of the ovaries in older fish. Brood fish are selected from ungraded 1-year-old fish which have not been heavily crowded and which do not have a high incidence of *Plistophora*.

The eggs of golden shiners become adhesive when fertilized and cling to vegetation, detritus, or spawning mats. After spawning, the adults leave the eggs unattended. Hatching requires 4 to 7 days.

For extensive culture, the farmer should stock about 15 to 20 pounds of brood fish per surface acre. The pond should have some vegetation along the shoreline for the fish to spawn on. Rows of rye grass may be planted for this purpose. Ponds with areas up to 80 acres can be used for the extensive culture of golden shiners, but smaller ponds yield a higher production per acre.

For intensive culture, 400 to 800 pounds of brood fish per surface acre of spawning pond should be stocked. Spawning ponds should be free of vegetation and have been recently filled with fresh well water. When fish begin to congregate near shore, it is time to distribute a few spawning mats.

The spawning mats (preferably about 3 feet long and 2 feet wide) should be placed along the shoreline, about 1 inch under the surface of the water. The outside edge of the mats (toward the center of the pond) should be supported so that each mat lies horizontally.

If the brood fish do not spawn in 48 hours, remove the mats and replace them with fresh ones. If the fish spawn heavily, leave the mats for 12 to 24 hours or until each is one-fourth covered with eggs. Remove and replace the mats as needed, according to daily spawning intensity.

Spawning mats covered with eggs can be transported for several hours if they are kept moist. Usually 50 to 75 egg-laden mats per acre are placed in nursery ponds, but as few as 25 and as many as 100 have been used. The lower rates produce fast growth due to the smaller number of fish that develop. Nursery ponds may range from 1 to 40 acres. At times it is better to overstock nursery ponds rather than attempt to induce late-season spawning, because normal growth can be restored in stunted fingerlings.

If the hatch is successful, numerous fry appear around the edge of the pond in about 10 days. If the hatch appears to have been a failure, poison the pond or drain and refill it. Begin anew by placing fresh egg-laden mats along the shoreline as before.

When the young fish reach lengths of 3/4 to 1 inch, they can be moved from nursery ponds and stocked in rearing ponds at the rate of 150,000 to 250,000 fish per surface acre. To have fish of the correct size to meet market demands, the farmer may vary the time of spawning or vary the density of fish in the nursery or growing ponds. Growth of golden shiners is rapid at a density of 75,000 fish per surface acre, moderate at 150,000, and slow (but not

Spawning mats should be stacked on the bank to air dry before they are reused.

stunted) at 200,000. If fingerlings in the growing ponds are not growing rapidly enough to meet market demands, reduce the density by distributing the fish among several ponds or by harvesting the shiners of marketable size and leaving the smaller ones for further growth.

It is easier to estimate numbers of fry than to estimate potential fry production from egg-laden mats. First, count the number of fry in 1 fluid ounce and then determine the number of ounces required to stock a pond at the density selected. You can conveniently use a bucket graduated in quarts (32 fluid ounces per quart) to transfer fry. For example, if the count shows 200 fry per fluid ounce, you must stock 31¼ quarts per acre to yield a stocking rate of 200,000 fry per acre.

Young shiners feed on various microscopic plants and animals. It is therefore important that a good plankton bloom be present when you stock the nursery or growing ponds with eggs or fry. You can produce a bloom by adding commercial inorganic fertilizers or organic manure shortly after the pond is filled. Do not fill a nursery or growing pond more than 3 days before it is needed. *Apply diesel fuel weekly to kill air-breathing predaceous insects.*

As the fish grow, supplemental feed in the form of a finely ground meal may be provided. When the fry are very small, the meal should be as finely ground as possible (like flour) so that the tiny fish can ingest it. When the fish are 1 inch or more in length, up to 20 pounds of feed per acre should be provided, depending on the condition of the plankton bloom and number of fish present. Since small shiners can readily be grown to a larger size when needed, the fish should be prevented from becoming too large, either by reducing the amount of feed or by crowding the fish.

Shiners are harvested by seining, and since they are delicate fish, they must be handled with care to avoid injury. They should be carefully dipped from the seine and transported quickly to the truck that transports them to holding tanks. During hot weather, the use of bacteriostats in holding tanks greatly reduces the incidence of infection in the minor wounds the fish receive during handling.

Fathead Minnow

The fathead minnow (*Pimephales promelas*) is probably the most easily propagated bait minnow. Although its maximum size is small (about 4 inches), it grows rapidly. It is a popular baitfish in some areas, but is unpopular in other localities because of the dark color of spawning males. Another drawback in the cultivation of this species is the almost complete mortality of brood fish after spawning; the life span is only 1 to 3 years.

Sexual maturity is attained at the end of the first year of life. Good brood fish are about 2½ inches long. Just before spawning, males and females differ greatly in appearance: The male is black with vertical bands of golden brown, has a blunt head covered with small bluntly pointed bumps (pearl organs), and has a swollen pad on the back just behind the head. The

Plankton organisms provide important food items for very young fish.

female is silvery to olive green, lacks pearl organs, and has a more pointed head than the male.

Spawning begins when the temperature of the water nears 65° F. and continues through June. If water temperature exceeds 85° F., spawning stops. Occasionally, the fish may spawn again for a short period in the fall.

Males prepare spawning sites by using the pearl organs to clean the undersurface of plants, boards, rocks, or other materials. Females join the males only briefly to spawn; the males guard the fertilized eggs, which are attached to the cleaned surfaces.

The fathead minnow will deposit eggs on the undersurface of almost any kind of material, but floating boards are usually provided, at the rate of 16 linear feet of 1-inch by 4-inch boards per 100 males. The boards are attached to a wire suspended between two stakes. Incubation time is 5 to 7 days, depending on water temperature.

A single female lays from 200 to 500 eggs per spawn, a small number at a time, attaching them to the underside of objects in shallow water. Females may spawn repeatedly. One is reported to have produced more than 4,000 offspring from 12 spawns in an 11-week period. Eggs from several females may be in a single nest, which the male guards until the fry emerge.

Since the sorting of a large quantity of adult fish requires considerable labor, most farmers use pond-run fish as brood stock. Since there is a general size difference between male and female fathead minnows, the sexes can be sorted rather accurately by using graders (probably $^{15}/_{64}$- or $^{16}/_{64}$-inch bar). If more accuracy is desired, the handsorting of several samples from the two size groups will make it possible to estimate the error involved in sorting with graders. This error can then be taken into account when stocking.

In extensive and semi-intensive culture operations, the young are left in the pond with the adults. Therefore, stocking rates of 500 to 2,000 adults per surface acre should be used. Higher stocking rates result in the production of too many young, and stunting. Since the male fathead minnow is typically larger than the female, the culturist should avoid selecting only the largest fish for brood stock. Extensive culture of fathead minnows can be done in ponds as large as 20 or 30 acres, but smaller ponds are better. Salable-sized fish are removed as needed, in lift nets or traps, or by baiting and seining.

In highly intensive culture, young fish are removed from the spawning ponds and restocked into rearing ponds. If a minnow farmer stocks 20,000 brood fish per surface acre, with a sex ratio of five females to each male, he can expect a production of as many as 3 million young. Young fish should be removed several times during the summer, since spawning continues for a considerable period. Seines or lift nets are the two best gears for removal of fish. The mesh of the netting should be ⅛ inch, bar measure.

The young should be stocked into previously fertilized rearing ponds at rates of 100,000 to 300,000 per surface acre. In actual practice, fish are stocked by weight rather than by number because weighing is more efficient than counting. To convert the number of fish desired to the pounds of fish needed: (1) count the number of fish in a ½-pound sample; (2) multiply by 2 to get number of fish per pound; and (3) divide the number of fish desired for stocking by the number of fish per pound to get pounds needed. Fish should be weighed in a small amount of water. In stocking small fish, allowance should be made for a mortality of 25 to 50 percent. Before the fish are stocked, predaceous insects (back swimmers and diving beetles) should be killed by the application of diesel oil, as recommended earlier.

Young-of-the-year fathead minnows, if they are to be large enough for sale in fall and winter markets, must be stocked at low densities (100,000 or fewer fish per surface acre) to obtain maximum growth. Although the weight of individual fish increases rapidly at low densities, total weight does not approach carrying capacity because the total number of fish is small. Consequently, pond space is used inefficiently; however, this procedure is sometimes necessary to meet market demand. If the farmer wants salable yearlings for the late spring and early summer markets, his best choice is a medium stocking density (about 200,000 fish per surface acre). At medium densities, growth of individual fish is slower, but total weight increases rapidly and pond space is used more efficiently. At high densities (up to 300,000 fish per surface acre) salable fish are produced during the second summer rather than the first.

Size of fingerlings at time of stocking also affects the length of time required to produce salable fish. Fathead minnows averaging about 1,000 fish per pound easily reach salable size in one growing season. However, those averaging more than 8,000 fish per pound will not reach salable size in one season unless stocking density is low. Growth slows as the fish approach salable size, because the fish are nearing the maximum lengths attained by the species. Optimum harvest time is as soon after growth slows as possible; rearing costs are relatively low while growth is rapid, but increase rapidly, without benefit to the farmer, after the onset of the normal decrease in growth rate.

Overwinter survival of small fish (more than 5,000 fish per pound) is low, but larger fish readily survive the winter.

Goldfish

Farmers considering the production of goldfish (*Carassius auratus*) should give careful thought to the entire program, i.e., acquisition of brood fish, pond construction, water supply (only well water should be used), labor costs, special handling facilities, shipping costs, and marketing *before* beginning. The production of fancy varieties of goldfish requires many small ponds, sizable capital outlay, and much hand labor, and faces a strongly competitive market situation.

Since there are many varieties of goldfish, the producer should select those best suited to his facilities, experience, and available market. Rarely should a farmer consider raising all of the various strains. Since goldfish are sold as ornamental fish, it is important that the farmer acquaint himself with such terms as "commons," "fans," "shubunkins," "calicoes," and "black moors," that are used to describe the various varieties. The characteristics that directly affect the value of a quality goldfish should be carefully studied, either under the supervision of an experienced goldfish breeder or from reference books on the subject.

Acquisition of Brood Stock

The acquisition of good brood stock is not as easy as it might first seem. Since the market for goldfish is highly competitive, producers of goldfish are very reluctant to sell selected, top-quality brood fish. Although large producers may be able to travel to Japan to purchase brood fish, the beginning farmer can rarely afford to do so.

Brood fish may be developed from several sources. It is sometimes possible to purchase individual top quality fish, but often only at a high cost. Instead, a farmer should be able to develop his own brood stock by selective breeding. To begin, he purchases large numbers of small fish at low cost from several of the large producers in the country. These fish are then reared and carefully observed as they grow. The fish that develop color quickly, have good eye development, consistent physical characteristics, and good body conformation are selected from the population and restocked for rearing as future brood stock. Continued grading and culling is practiced as the fish mature so that the individuals selected for breeding are uniform, fast developing individuals.

An alternative approach is for the farmer to purchase large fish such as those used in outdoor pools. By carefully checking such fish to assure uniform physical characteristics, he can then spawn them and begin the selection process on their progeny in a manner similar to that described above.

Each year thereafter, the farmer should carefully select the best individuals from his annual production to rear for future brood fish. After several seasons, he should have a uniform strain of fish. It cannot be overemphasized that fish for future brood stock must be kept separate from the production fish; this means setting aside special ponds to be used only for this purpose.

When raising goldfish for bait, the farmer may find that the market requires both orange and olive-colored fish. He can produce orange fish in a separate pond, using a strain of common goldfish which colors at an early age. He can produce an entire population of olive-colored fish by mating olive-colored shubunkin males with olive-colored shubunkin females.

Spawning

Goldfish may be produced in several ways but most farmers use what may be termed the "wild-spawning method." In this type of culture, brood fish are stocked in a freshly filled pond. Some farmers use ponds in which rooted plants such as rye grass have been planted. Others provide artificial spawning material (e.g., mats of Spanish moss, or cedar boughs). On the day the brood fish are placed in the pond, 50 pounds of commercial inorganic fertilizer (20–20–0) per surface acre and about 300 pounds of organic fertilizer per acre should be added, to stimulate plankton development.

Carefully treat all brood fish for external parasites before they are released in the spawning pond. Remember that when fry become infected with parasites, their parents are nearly always the source.

Stocking too many brood fish per pond is a common mistake made by goldfish culturists. If the fish are large (½ pound or larger), 80 fish per surface acre is adequate. Some farmers use 100 fish per acre but restrict the number of females to 30 or 40 per acre.

The sex of goldfish is readily determined. Males have conspicuous serrations on the top (trailing) edge of the pectoral fins, but females do not.

The "egg transfer method" is used by many large producers. In this type of culture, a special breeding pond is prepared for each variety, from which all eggs are collected. These ponds must be completely devoid of vegetation or other spawning substrate. Consequently, many producers either concrete the pond banks or line them with black polyethylene sheeting to completely exclude the growth of plants. If concrete is used, the banks should be inclined at a 1½ to 1 or 2 to 1 slope to permit egg collectors to walk along the shallow water. It is also important that a concrete footing extend about 12 inches into the pond bottom, to prevent wave action from undercutting the wall.

The breeding ponds should be small—25 to 50 feet square is ideal—so that the farmer can control spawning. Depth should be 2 feet at the shallow end and 3 feet at the deep end.

Spawning mats may be made of a variety of materials. Mats of Spanish moss measuring 2 feet by 4 feet on a rigid metal framework are commonly used. Since Spanish moss has been in short supply in recent years, some farmers have begun using synthetic fiber brushes or similar products. Not all of these materials are equally suitable, however; a beginner is advised to consult with other fish farmers as to the merits of a particular product.

Brood fish should be stocked at the rate of 150 to 200 per 25-foot-square breeding pond. Overstocking tends to reduce spawning activity. As stated previously, *it is mandatory that the brood fish be treated for external parasites before they are stocked in the breeding pond.*

The spawning season for goldfish varies greatly with latitude. Spawning begins when water temperatures continuously exceed 60° F. In Arkansas, this occurs during April, and the peak spawning period is usually in early May.

When the temperature reaches the 58° to 70° F. range, place a few mats near the shore along one end of the breeding ponds, sloped downward and outward so that they are covered with 2 to 10 inches of water. Distribute the mats in groups of three or four at intervals along one or more sides of the pond. As spawning intensity increases, add more mats—but do not exceed the number that the crew can handle in a day.

Goldfish often spawn in cycles. They may spawn at intervals as long as 5 days early in the spawning season, and on alternate days during the height of the season. If more than one breeding pond is being used, the farmer can safely withhold the mats for one or more days after a heavy spawn, to help concentrate the collection of eggs.

Spawning usually begins at daybreak and may continue until about 10 a.m. (seldom later). Collection of egg-laden spawning mats may begin after 9 a.m. If the spawning is very heavy, it may be necessary for the collectors to begin earlier, or to cover the mats to avoid the accumulation of excessive numbers of eggs. Do not permit the eggs to become so crowded that fungal growths can readily spread from egg to egg. If mat collection begins early (before 9 a.m.), replace the mats removed with fresh ones. Also, place additional mats along the shoreline to increase available spawning sites. If mats covered with eggs cannot be removed immediately, place fresh mats over them to prevent the brood fish from eating the eggs.

It is important that it be possible to drive a pickup truck around all sides of the breeding pond, so that eggs can be readily collected. Mats with eggs may be stacked in the bed of the truck; in hot weather they should be covered with wet burlap bags. The mats are trucked to the rearing pond and placed at an angle beneath the surface in shallow water so that wave action gently washes the mats. To insure fish of similar age (for size control), mats should not be left in a rearing pond for more than 3 successive days after hatching begins.

If the fry are to be reared for bait, 25 to 60 mats per acre provide ample numbers of fry. Fry of fancy varieties that are to be reared for the pet shop market and therefore must be kept small, should be stocked much more heavily; as many as 250 to 325 mats of eggs can be used per acre of pond.

Time of hatching depends on prevailing water temperatures. The eggs may hatch within 48 hours at temperatures above 85° F. or require up to 7 days at temperatures below 70° F.

Obtaining Spawn

If the brood fish do not spawn readily or in adequate numbers to provide the desired number of eggs, spawning may sometimes be stimulated by lowering the water level in the breeding pond and then quickly restoring it by adding fresh water. In other cases, it may be necessary to combine temperature shock with a rapidly rising water level: Lower the water to a very low level long enough to allow the water temperature to rise and then quickly refill the pond with cold well water.

In difficult cases, late in the season, or in handling particularly valuable individual specimens, the farmer may induce spawning by the injection of dried fish pituitary glands or human chorionic gonadotropins (HCG). Since each fish must be handled and injected separately, however, the labor cost is very high. (See the section on the aquarium method of spawning catfish for a discussion of this technique.)

Postspawning Care

After the spawning season, brood fish should be removed from the breeding pond, treated for external parasites, and restocked in ponds at a rate of 2,000 pounds per acre, or less. They should then be fed a ration containing a double component of fish meal at a rate of about 1 to 2 percent of their body weight. Regular observations for parasites or disease should be made.

Feeding

Feeds for fry are considered to be supplemental only. It is most important that natural food organisms be immediately available when the fry first begin to feed. Such food is provided by the application of commercial (20–20–0) and organic fertilizers on the day when the brood fish or eggs are stocked in the ponds.

As soon as eggs hatch, feeding should be started around the entire margin of the pond. Commercial fry feeds are acceptable but they must be ground very finely—flour-fine if possible. As an initial rate, provide 1 pound of feed per acre daily for 3 days. Thereafter, increase the amount of feed by 3 ounces each day. It is beneficial to feed several times each day, especially if fry were obtained late in the season.

Young goldfish consume up to 5 percent of their body weight each day. As they approach salable size, the feeding rate should be reduced and the ration changed to a maintenance diet. Such diets usually contain more carbohydrates and less protein than are used in regular rations.

When the young fish reach 1 inch in length, their fe d may be changed from a meal to small pellets. Train the fish to take the pelleted feeds by providing a mixture of meal and pellets for several days before changing to pellets only.

The following summary provides guidelines for feeds to be used at various stages:

Fry—texture must be flour-fine, 38 to 40 percent protein.

Starter feed—use small diameter, short cut-off pellets, 38 to 40 percent protein, for 1 to 2 months.

Grower feed—increase diameter of pellets; 30 to 32 percent protein is adequate.

Maintenance feed—reduce the amount of animal protein in the grower feed by half and increase the carbohydrate level.

Brood stock feed—double the proportion of fish meal in the grower ration.

Winter feed—increase the proportion of alfalfa meal and animal protein in the grower ration.

Holding Yearling Fish

A major problem in marketing goldfish is the disposal of oversized fish. Prevention of growth in yearling fish without causing debilitation is difficult. Because goldfish tolerate very fertile water and yield high poundages per acre under normal growing conditions, it is often necessary to concentrate large numbers of small, yearling fish; rates of 4,000 to 5,000 pounds per acre are not uncommon. Feeding under such conditions should be for maintenance only. Since crowded conditions are conducive to outbreaks of parasitic infections, the fish must be kept under daily observation.

Pond Management for Goldfish

Do not fill ponds for breeding or rearing until just before use. After you stock eggs or adult fish, apply 50 pounds of commercial fertilizer (20–20–0) and about 300 pounds of organic fertilizer per acre, to insure the presence of plankton of the proper size when the fry are ready to begin feeding. Fertilization must be carefully timed. If you fertilize too far in advance of stocking, many of the plankton organisms will become too large for the small fish to ingest; furthermore, certain large plankton organisms will prey on newly hatched fry.

When the fish are small, it is extremely important that you provide feed around the entire margin of the pond. Begin feeding on the day the eggs hatch or when the fry are first seen near the shoreline. Since newly hatched goldfish are very small, they are often difficult to see under pond conditions. A round, flat, aluminum disk about 6 inches in diameter, attached to a lightweight handle, can be used to help locate the fry. Submerge the disk to a depth of several inches and slowly move it about in the shallow water and around vegetation. If fry are present, you will be able to see them readily above the surface of the disk.

In rearing ponds, adjust the amount of feed provided in accordance with the growth of the fish. If the fish stop growing, check closely for external parasites. If no parasites are present, remove the larger individuals from the population and transfer them to a pond stocked with fish of similar size. Such grading of the population serves several purposes: It removes large fish which may become cannibalistic; it reduces the population density to encourage growth; and it improves control over the size range of the fish in the pond. A large-mesh seine that selectively removes the larger individuals serves adequately for grading.

Predation on fancy goldfish is often a serious problem. Because many varieties have deformed bodies, oversized or multiple fins, or other disabling physical features, they are poor swimmers—and therefore exceedingly vulnerable to predators. Cannibalistic fish, bullfrogs, snakes, and fish-eating birds must be controlled. Since tadpoles interfere with the management of goldfish ponds, egg masses of bullfrogs should be removed with a small-mesh dip-net.

Check all ponds daily for evidence of disease or parasitism. Observe the fish for such symptoms as flashing, listlessness, failure to feed, or collecting in vegetation or at the site of incoming water flows, and check the downwind side of the pond for dead fish.

After a pond has been harvested, the bottom should be allowed to dry completely. If possible, disk the bottom of the dried pond to a depth of several inches. For ponds that seep or do not have sufficient slope to drain properly, add enough water to cover the bottom, and then sterilize with chemicals like hydrated lime or calcium hypochlorite.

If snails are present, cover the bottom with water and treat with a molluscicide. After killing the snails, drain the pond (after the chemical dissipates) and permit it to dry thoroughly. This drying will kill snail eggs and other organisms which might have survived the molluscicide. Snail eggs on spawning mats will be killed if the mats are thoroughly dried before reuse.

Marketing

Although millions of goldfish are sold annually in the United States, it may be difficult for a beginner to find a market. Farmers should realize that only certain sizes are accepted by the public. Usually only about 30 percent of the fish in a given pond fall within the desirable length range of 1½ to 2 inches. Although fish longer than 3 inches may sometimes be sold for trotline bait, those 2½ to 3 inches long have little market value. Consequently, all fish harvested from a pond must be carefully hand-sorted, a task that is slow and laborious unless an adequate supply of labor is at hand.

If fancy goldfish such as black moors, telescopes, calicoes, fantails, and celestials are reared, the degree of hand labor required is correspondingly higher because culling is based on additional characteristics other than size. The cull rate on color alone may run as high as 25 to 60 percent.

A beginning farmer may find a market for fast-coloring commons or comet goldfish $1\frac{1}{2}$ to $2\frac{1}{2}$ inches long by contacting department stores where free goldfish are used to attract customers during sales or store openings. Beginners who raise fancy varieties might be able to establish marketing outlets through one of the large, established corporations.

Buffalofish

Three species of buffalofish (genus *Ictiobus*) occur in the United States—the smallmouth (*I. bubalus*), the bigmouth (*I. cyprinellus*), and the black (*I. niger*). The following characters differentiate the species: The smallmouth buffalo has a compressed body, elevated back, pointed nose and turned-down mouth; the bigmouth buffalo has an elliptical, robust body, blunt nose, and turned-up mouth; and the black buffalo has an elliptical, robust body and a turned-down mouth. All three species thrive in rivers, but the smallmouth buffalo predominates: the bigmouth ranks second and the black third. Usually only the bigmouth buffalofish is found in northern lakes, whereas the other two species (the black predominating) occur in southern lakes.

Brood stock should be selected from fast-growing, disease-free, and uninjured fish. Fish of known age that were reared in ponds or reservoirs are the best because they are usually of uniform age, size, and condition and are probably easier to obtain than fish from other sources. Brood fish should be caught and handled in small numbers to avoid overexcitement and injury. It is advantageous to cover tubs with cloth or burlap while handling the fish, as they quickly calm down in the darkened tub.

Fish of 3 to 8 pounds are recommended for brood stock because they can be more easily handled and transported than larger fish, and are less likely to be injured. Satisfactory spawn can be obtained from 2-year-old bigmouth buffalo weighing $1\frac{1}{2}$ pounds, but fish weighing at least 3 pounds or more give best results. One-year-old fish are usually unsatisfactory as sources of spawn.

Brood fish should be held in wintering or holding ponds. A well-fertilized, 1-acre pond easily accommodates 400 to 600 pounds of brood fish without supplemental feeding. Overcrowding may cause the fish to lose weight, break out with disease and parasites, or die. Satisfactory spawning cannot be expected unless the fish are in good physical condition. Holding ponds of $\frac{3}{4}$-acre having a maximum depth of 6 feet and an average depth of $3\frac{1}{2}$ feet are excellent.

Buffalofish that are sexually mature can be easily sexed at or near spawning time.

***Daphnia* is one of the food organisms most preferred by fish.**

The vent of the female is larger, redder, and more protruding than that of the male. A slight pressure near the vent of the male produces a small amount of white milt. At spawning time, female buffalo feel relatively smooth, whereas males feel like sandpaper owing to the numerous breeding tubercles on their scales and fins.

Pond Method of Spawning

Spawning ponds should be stocked in the spring when water temperatures rise to between 65° and 70° F. and remain in this range for several days. Ponds may be of various sizes, but 1-acre ponds are excellent. Spawning ponds should be kept dry during the winter and refilled with well water just before the brood fish are introduced.

Fertilizers should be applied when the brood fish are stocked, to insure the presence of a plankton bloom when the eggs hatch. Inorganic fertilizer (16–20–0) at 100 pounds per acre and organic fertilizer (chicken or sheep manure, alfalfa meal, or soybean meal) at 200 to 300 pounds per acre should provide the desired results. Applications should be repeated as needed to maintain the plankton bloom.

If the fry are to be raised to large fingerling size in the spawning pond, only two or three pairs of adults per acre are needed, but if small fingerlings are to be transferred to rearing ponds, 8 to 10 pairs of brood fish may be stocked. Unless hybrids are desired, only one species should be stocked in a spawning pond.

Although the culture of buffalofish has only a minor role in fish farming, some producers still raise fingerlings for use in multiple-species operations.

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If the spawning pond lacks vegetation, spawning mats of Spanish moss or synthetic fiber should be provided. Spawning often begins within 24 hours after the fish are stocked, and the eggs hatch in 72 to 96 hours (at water temperatures of 66° to 75° F.). Fry may be seen swimming in schools along the shoreline 7 to 10 days after spawning has been completed.

When fry are seen, supplemental feed in the form of flour-fine meal should be provided. Rations used to feed minnows are adequate if the particle size is small enough. Even though not all feed will be consumed at the outset, 2 to 3 pounds per acre should be provided daily. As the fingerlings grow, the amount should be increased in accordance with consumption and fish growth. When fingerlings are 1½ inches long the feed should be provided in the form of "crumbles" or small pellets, at rates up to 10 pounds per acre. Natural food organisms should be maintained through the application of fertilizers as described above.

When fry are present, insect control is vital. Each week 2 to 4 gallons of diesel fuel (to which inexpensive motor oil has been added at the rate of 1 pint per gallon) should be applied per acre. These applications should be continued until the fingerlings are 1½ inches long.

When the fingerlings reach 1½ inches, they should be transferred to growing ponds. Fingerlings 7 to 8 inches long can be produced by stocking at the rate of 2,000 per acre, and fingerlings 4 inches long by stocking at the rate of 10,000 per acre.

Regular fertilization and supplemental feeding should be maintained throughout the growing season to insure an adequate food supply.

Artificial Method of Spawning

Since buffalofish are easily stripped, eggs and milt can be collected without difficulty. When water temperatures reach 65° to 70° F., adult fish should be transferred from ponds to holding tanks. For jar culture, which requires large numbers of fertilized eggs at one time, hormonal stimulation is commonly used. Injections of either dried carp pituitary or human chorionic gonadotropin (HCG) provide adequate results. Usually only females require injections of hormones, since the milt of the males flows freely throughout the spawning period.

Injections are administered into the body cavity by inserting the needle of a hypodermic syringe into the "pit" of the pelvic fin. Carp pituitary should be ground and reconstituted in distilled water before injection. As a rule, 2 to 4 milligrams of carp pituitary is given per pound of fish. If dried carp pituitary is not available, a fresh pituitary from a carp or from a similar-sized buffalofish may be used. Human chorionic gonadotropin, administered at 500 to 800 international units per pound of fish, gives results that are adequate, but not as good as those achieved through the use of pituitary materials.

The fish usually becomes ripe 16 to 18 hours after injection; consequently females should be injected during the afternoon so that eggs can be collected the following morning. If ovulation has not occurred, the injections should be repeated and the fish returned to the holding tank.

The appearance of a few eggs in the tank is an indication that spawning is imminent. Females should be carefully netted and slight pressure applied to the abdomen. If eggs flow freely, the fish can be stripped as follows: Grasp the caudal peduncle (fleshy part of the tail) with the left hand and tuck the head and body under the right arm, holding the female in an upright position. Wipe water from the body of the fish with a cloth and gently apply pressure to the abdomen by stroking it with the right hand. Collect the eggs in a dry porcelain pan. When no more eggs can be taken, place the fish in a tank for return to the pond for holding brood fish. Next, grasp a male in the same way, wipe the body, and strip milt into the pan containing the eggs. Mix the eggs and milt by stirring them slowly with a wing feather from a turkey. After 15 minutes, begin slowly adding water. Stir the eggs continuously throughout the addition of water. Since fertilized eggs become adhesive, laundry starch, kaolin, or fine clay should be added to the water to reduce clumping. *Continuous stirring must be continued for as long as several hours, until the eggs have become water hardened, and are no longer adhesive.*

Water-hardened eggs are transferred to standard hatching jars supplied with well-aerated water at 65° to 75° F. Two quarts of eggs are usually placed in each jar. Care should be taken to insure that the flow is adequate to slowly roll *all* eggs in the jar. Eggs which are not agitated sufficiently, or which clump, soon die and develop fungal growths that endanger survival of the rest of the eggs.

Hatching should occur in 72 to 96 hours at 65° to 75° F. Buffalofish fry leave the jar soon after hatching; they should be collected in a rearing trough or in small floating boxes with bottoms or walls of Saran fabric (60 meshes per inch). If the boxes are used, fry must be transferred to a rearing trough. Drains from rearing troughs should also be covered with Saran screen to prevent the loss of fry.

Feed should be offered 72 hours after hatching and regular feeding should begin at 96 hours. *Finely ground* trout feed, *finely ground* commercial fish feed, or pulverized yolk from an egg boiled for 15 minutes are all acceptable as beginning feeds. The egg yolk appears most desirable as initial feed because it yields a cloudy suspension of very small particles when it is crushed between the fingers in a small amount of water. Boiled yolks can be frozen and stored until needed.

Fry should be fed several times throughout each day and night until they are 7 to 10 days old. At that time, they may be transferred to the specially prepared rearing ponds described earlier. Insect control must be stressed at this time.

If jar culture is not possible, freshly fertilized eggs may be scattered over mats of Spanish moss, artificial fiber, or cedar boughs while they are still adhesive and before they have become water hardened. After 2 hours (for water hardening), the egg-laden mats can be transferred to freshly filled rearing ponds for hatching. Insect control is most important if this method is used.

Hybrid Buffalofish

Hybrid buffalofish can readily be produced by mixing eggs from one species with milt from another. Techniques described in the foregoing section on artificial culture apply to hybridization as well.

Not all buffalofish crosses produce desirable hybrids. The best cross in both laboratory and field tests has proved to be that between female bigmouth and male black buffalo. At the end of the second year of life, the hybrid is one-third heavier than nonhybrid fish. In a field test in which a 102-acre pond was stocked at the rate of 125 hybrids, 125 bigmouth buffalo, and 750 channel catfish per acre, hybrid fingerlings grew to 3 pounds while bigmouth buffalo reached only 1 pound. The fish were fed three times per week, at the rate of 3 percent of their body weight.

Production of Food-Sized Fish

Currently the market for edible-sized buffalofish does not justify large-scale production of these species in a single-species culture. However, the stocking of either hybrids or nonhybrid buffalo in combination with other species yields a considerable production of large fish. (See the section on "Mixed Culture of Fish" for suggested stocking rates.)

To command top market prices, buffalofish should be large and uniform in size.

Black Bass

Research by the Bureau of Sport Fisheries and Wildlife has developed culture methods that routinely yield 3,000 to 4,000 pounds of bass (genus *Micropterus*) per acre; before a farmer starts raising bass, however, he should be aware that the market is limited because almost none are sold for food fish, and many States completely prohibit the sale of black bass. Some live fish are marketed for stocking fee-fishing ponds, club lakes, and private ponds. The suitability of largemouth bass (*M. salmoides*) as a game species for farm ponds and small lakes also creates a demand for this species.

Indications are that demand for largemouth bass for stocking ponds will continue to increase, since new waters are being built each year and fish management is becoming increasingly intensive. Bass are in demand for fee-fishing ponds, not only to contribute to the fishing but also to control the reproduction of carp, bullheads, and sunfish. Large fingerling bass, called "stockers," are needed for corrective stocking in small ponds and lakes. Since the bass are actively sought by anglers, it is common for a high percentage of them to be harvested from fee-fishing ponds. The result is that too many small sunfishes and other forage species survive and these then overpopulate the pond or lake. Largemouth bass are also used by fish farmers and pond owners to control wild fish that gain entrance to their ponds.

Three species of black bass have been propagated by Federal and State hatcheries for many years. The largemouth and the smallmouth bass (*M. dolomieui*) show the greatest promise for use in fish farming. Future research may reveal that the closely related spotted bass (*M. punctulatus*) also has potential as a fish farming species.

Bass brood stock should be fed forage fish before and after the spawning season throughout the year, but forage should be excluded from spawning ponds. Ideally, about 600 pounds of forage is needed for each 100 pounds of brood bass per acre.

Some of the forage fishes used are *Tilapia*, goldfish, carp, golden shiners, fathead minnows, and bluegills or other sunfishes. *Tilapia* and goldfish seem to function best but are not ideal; *Tilapia* die during the winter in most areas, and goldfish often carry *Lernaea*, the anchor parasite. Some hatcheries have used fantail goldfish because bass can catch them more easily than others. Carp grow so rapidly that they soon become too large for bass to swallow. The production of sunfishes on a weight per acre basis is low and they are not preferred by bass.

Well-fed, healthy brood bass usually spawn readily. Although it is possible to strip eggs from bass, most fish culturists prefer to let the fish spawn naturally in specially prepared spawning ponds of ½ to 3 acres (although ponds of any size can be used).

Spawning ponds must be prepared differently for smallmouth bass than for largemouth bass. Before filling smallmouth bass ponds, place low heaps of gravel a short distance from the shore in areas where the water will be 2 to 3 feet deep after the pond is filled. These gravel mounds serve as nesting sites. This procedure is usually unnecessary in largemouth bass ponds, but is a recommended practice in old ponds with soft mud bottoms. Usually bass brood ponds are not fertilized and have no forage fish. Fill the ponds about 2 weeks before they are stocked.

Bass culturists are in general agreement that females should outnumber males in the brood stock. A good ratio appears to be two males to three females, although a larger proportion of females also gives excellent results.

One of the better methods for distinguishing sex of bass is based on the shape of the scaleless area surrounding and immediately adjacent to the urogenital openings. This area is nearly circular in males and elliptical in females. Sex may also be determined by stripping the fish. Because the sex ratio is not highly critical, the culturist can obtain satisfactory results by stocking fish of undertermined sex.

The number of brood fish stocked varies greatly, depending on the size of the fish. Federal hatcheries use 20 to 50 pairs of brood fish per acre. Excellent results are obtained with 18 to 20 pairs of 3- to 4-pound fish or about 35 pairs of ¾- to 1-pound fish. Overstocking results in a decrease in the number of young produced. For 2-pound fish, as few as 10 males and 15 females per acre produce a satisfactory crop. It is not necessary to use large fish; many fish culturists favor fish weighing ¾ to 2 pounds. Two-year-old fish are ideal but 1-year-olds are adequate if they have attained a weight of ¾ pound. The health and condition of the brood stock is more important than size. Old bass are usually not as good for brood stock as younger fish.

Bass seldom spawn at temperatures less than 64° F., and 68° to 70° is most favorable for egg development. As in the rest of the sunfish family, the male builds the nest and guards the eggs and fry. The nest of the smallmouth bass is more elaborate than that of the largemouth bass, which is sometimes so inconspicuous that it is difficult to find. After the nest is built, a male and female spawn while side by side, facing in the same direction. Occasionally, two or more females spawn with a single male in the same nest.

When the bass become advanced fry, they are transferred from the spawning pond to specially prepared rearing ponds. These rearing ponds should be kept dry during the winter whenever possible. Ten days to 4 weeks before the fry are stocked, the ponds should be filled. Usually both organic and inorganic fertilizer is applied at this time to encourage plankton blooms. Because bass fry eat mostly zooplankton, especially Cladocera (water fleas), fertilizers that promote their growth should be used. Some fish culturists prefer leafy hay, alfalfa meal, soybean meal, or solvent-extracted cottonseed meal, and some use Torula wood yeast or barnyard manure. Organic fertilizers are applied at weekly intervals. A suggested program of fertilization is 50 pounds of ammonium phosphate (16–20–0), 300 pounds of leafy hay, and 200 pounds of soybean meal per acre. Variations can be made to fit local situations. For example, superphosphate and sodium nitrate can be used in acid-water ponds, rather than ammonium phosphate.

Some fish culturists fertilize bass rearing ponds by growing rye grass during the spring over half of the pond bottom. The grass is slowly covered with water to provide fertilization. If all of the grass were submerged at one time, the excessive amount of dying grass could cause oxygen depletion.

Two important precautions must be taken in stocking bass rearing ponds: (1) *One day before stocking, apply 2 to 4 gallons of diesel fuel per acre to the pond surface to kill air-breathing predaceous insects.* (2) Stock the pond with fish of uniform size, to avoid cannibalism. A pond should be completely stocked in 1 day. There is little agreement among culturists about the number of fry to stock per acre; generally about 15,000 to 40,000 give good results. State and Federal hatcheries may stock as many as 50,000 to 75,000 per acre but the fish they produce for stocking lakes are only 1½ to 2 inches long.

The technique used to capture fry for transfer to growing ponds is different for largemouth than for smallmouth bass. Largemouth bass fry usually stay in compact schools for as long as 1 month after hatching, and schools may merge to form larger schools. Schools of advanced fry are often seined with a short bobbinet seine, usually less than 10 feet long. In windy weather the surface is sometimes covered with fish oil so that the schools of fry can be seen. Other fish-culturists trap largemouth bass fry near the shore with a V-trap having a lead running from the bank to the center of the V in the trap.

Many fish culturists prefer to transfer largemouth bass fry when they are about ½ to ¾ inch long, because they are easy to count and handle at this size. However, many are transferred at a smaller size; fry can be transferred at any time after they rise from the nest.

Smallmouth bass fry are usually captured by imprisoning the fry before they leave the nest. A cylindrical frame 3 feet in diameter and about 40 inches deep, covered with plastic or aluminum window screen, is placed over each nest before the the fry leave it. Since the fry usually hover around the nest for only a short time after hatching, and then scatter, they are very difficult to catch if they are not contained by a cylinder. After they are properly stocked in a well-prepared pond, the fry grow uniformly for a time. If some grow larger than others, cannibalism becomes a problem. This is especially true after they are 1½ to 2 inches long and the zooplankton becomes depleted. It is for this reason that State and Federal hatcheries usually stock smallmouth bass fingerlings at a small size.

Numbers of bass fry are estimated in various ways. One method consists of counting a known number (usually 1,000) into a tub and then placing fry in other tubs until the density appears to be the same as in the "known" tub. It is helpful to paint the bottoms of the tubs white or silver. Large white enamel pans may also be used.

It is important that the large, fastest growing fish be taken out of a pond before cannibalism begins. Some fish culturists drain the pond and grade the fish. Others use a seine that allows small bass to pass through but captures large ones. Still others seine out the fish and pond-grade them with a box grader. Since several large cannibals are often left in the pond, however, this technique is not always successful.

Since bass fingerlings require forage, some fish culturists provide it—usually fathead minnows—from a separate rearing pond. Another method is to stock about 10,000 closely graded 1½-inch bass per acre in a fathead minnow pond that was prepared by stocking 2,000 adult fathead minnows 1 month previously. Additional minnows may have to be added if the forage supply becomes low, to prevent cannibalism.

Artificial feed can also be used to raise bass. Training fingerlings to accept such food is a problem, since the natural food of bass is live organisms. Patience and hours of careful attention may be required. The use of mechanical or demand feeders removes some of the tedium of this task.

Early fish culturists fed mostly chopped fish, liver, and heart to small bass. One reported a maximum per-acre production of about 29,000 smallmouth bass fingerlings weighing 2,181 pounds. Several State Game and Fish Commissions still feed bass these foods. In some States, an ample supply of large gizzard shad can be easily obtained from natural waters, for use as feed for bass and trout.

More recently, the Bureau of Sport Fisheries and Wildlife has been developing methods of training largemouth bass to accept artificial foods. Essentially the methods are as follows: Three-inch fingerlings are removed from ponds and placed in holding tanks. At the outset, the fish are trained to take a ration consisting of half ground fish and half commercial trout food, which is offered five times daily. The fish portion of the diet is gradually reduced over a 2-week training period. An alternative training diet which has achieved excellent results is Oregon Moist Pellets. Routine cleaning and prophylaxis of the tanks must be performed daily.

After the training period, the fingerlings are graded to eliminate nonfeeders and cannibals. Then the fish are stocked in small earthen rearing ponds at rates of 5,000 to 20,000 per acre.

At this time, they are fed either Oregon Moist Pellets or a floating trout food. In 98 to 140 days, standing crops of fish of 1,881 to 7,153 pounds per acre have been reported. Feed and labor costs of producing 1 pound of bass averaged $0.52.

Oregon Moist Pellets, developed by scientists of the Oregon Fish Commission and Oregon State University, are composed of a mixture of wet and dry ingredients, and have a moist, soft consistency. They must be stored frozen until shortly before they are fed. More recently, after feeding the fish for a time on Oregon Moist Pellets, researchers have found that they can train the fingerlings to accept floating trout food as soon as they are large enough to swallow the pellets. This change yields substantial savings in food costs.

Some catfish farmers who stock largemouth bass in their catfish ponds to control wild fish have noted that the bass learn to take pelleted feed released from demand feeders by catfish.

Limited tests at the Fish Farming Experimental Station indicate that largemouth bass in troughs or very small ponds can be trained to take the following feeds (in succession): a mixture of chopped fish and moistened trout food; moistened trout food; dry trout food; and finally hard pellets like those fed to catfish.

White Bass

The white bass (*Morone chrysops*) may also have potential for use in fish farming, although it has received little attention from Federal and State fish culturists. The reproductive potential of the species is so great that only a few pairs of adults are needed to stock a large reservoir. New populations can be readily established in some natural waters by merely transferring adult fish.

White bass begin spawning when water temperatures reach 55° to 58° F. and may spawn over a 2- to 3-week period.

White bass have been spawned successfully through the use of hormone injections. Nearly ripe females have also been held in cages until they matured and could be stripped. Other workers have taken fingerlings from natural waters and held them in ponds for 1 year to acclimate them as future brood stock to be spawned under pond conditions.

In one experiment, researchers successfully spawned white bass by injecting each male and female with 2 milligrams of acetone-dried carp pituitary and holding the fish in a tank lined with Spanish moss spawning mats on the bottom and around the edges. Seventeen hours after injection, the fish had not spawned, but after the females were injected a second time, spawning occurred within 3 hours. Microscopic examination revealed that 60 percent of the eggs obtained were fertile through 48 hours. One mat was placed in a pond but no fry were found—perhaps due to the presence of snails (*Physa*), which were observed eating the eggs.

In artificial spawning, eggs are stripped into a pan and then fertilized with sperm from two male fish. During water hardening, clumping of the eggs must be prevented. Table salt (6 grams per liter), cornstarch, kaolin, and fine clay have been used for this purpose in work with other fishes, and should work for white bass. Stirring during the water hardening process is advisable (turkey wing feathers work well for this purpose). White bass eggs must be water hardened before they are transported.

Sudden lowering of the water temperature kills incubating eggs and recently hatched fry.

Certain plankton organisms (e.g., the copepod *Cyclops*) prey on very small white bass fry. Since it is helpful to feed natural food to fry and postlarval stages, pond water should be filtered to exclude zooplankters.

Small white bass fry appear to eat flour-fine food. Regular fish feed ground in a mortar and pestle, and trout starter feeds are fine enough to be consumed. A good fry feed can be mixed at a mill with flour-fine ingredients such as milk replacer, powdered milk, live yeast, fish flour, and red dog flour. It cannot be overemphasized that the particle size of all ingredients must be exceedingly small. The addition of a vitamin mixture similar to that used in trout feeds is advisable.

After the fry are too large to be consumed by zooplankters, they should be transferred to rearing ponds prepared in the same way as those for largemouth bass fry.

No information is yet available on the pond-rearing of fingerlings to adult size.

Striped Bass

The Bureau of Sport Fisheries and Wildlife and various State Game and Fish Commissions have conducted research on the culture of the striped bass (*Morone saxatilis*). The findings indicate that it may have a potential use in fish farming. A mean gain of 1,438 pounds per acre (range, 1,313–1,537 pounds) has been achieved in ponds when striped bass were stocked at the rate of 25,000 fish per acre and fed ground herring. To date, large poundages have not been successfully raised on artificial diets, although it has been demonstrated that the fish will accept artificial feed.

Hormone-induced spawning of striped bass has been successfully used to produce large numbers of fry. Hybrids of striped bass and white bass can also be produced by this procedure. Artificial spawning of striped bass is possible only where a sizable adult population is available. Either brood fish can be transported to a hatchery, or portable pumps, holding boxes, and hatching jars can be moved to the collection site.

Females should be kept individually separated in holding boxes for close observation. Each female should be injected with 127 international units of chorionic gonadotropin per pound of body weight. Although the period between injection and spawning varies, the average time is about 45 hours. Females should be checked regularly for ripeness throughout the period following injection of the hormone, because overripe fish may yield eggs that are of poor quality or fry that have a low survival rate.

To determine ripeness after injection, the culturist inserts a small glass tube or catheter (4 millimeters in diameter) into the oviduct to take samples of eggs. The eggs are checked with a microscope. As the eggs mature, they increase in diameter and transparency.

Females are anesthetized with MS-222 before the eggs are taken, to relax them so that they can be manually stripped. Usually the anesthetic is sprayed onto the gills with a hypodermic syringe or a plastic wash bottle.

Eggs are stripped into a dry pan and milt from two males is then added. Water is added and the eggs are left undisturbed for 1 minute. The fertilized eggs can then be transferred to hatching jars supplied with a constant supply of aerated fresh water. Water temperatures during hatching should be between 56° and 72° F. Dissolved oxygen concentration should be at least 5 p.p.m. and pH should be 7.0 to 8.0.

Hatching begins in 30 to 70 hours, depending on the water temperature. After hatching, the fry should be collected in containers fitted with a very fine mesh cover over the drain. Saran fabric of 50 to 60 meshes per inch is satisfactory. The fry are very tiny and readily escape if the drain is not protected. Care should be taken in designing the drain cover, to prevent clogging of the screen overflow of the container and escape of the fry.

For transfer, 50,000 to 75,000 fry are placed in plastic bags containing 2 gallons of water. The air is then replaced with oxygen and the bag sealed. Care should be taken not to overinflate the bags, because excess pressure may injure the fry. Sudden temperature changes are also lethal. Such changes can be avoided by placing the bags in protective styrofoam boxes.

Before release of the fry in rearing troughs, water temperature in the bag should be slowly raised or lowered to equal that in the trough. Water should be sprayed at an oblique angle against the side of the trough, at each end and at opposite corners, to establish a constant current. This current prevents the fry from settling to the bottom and is vital to their survival. Its importance cannot be overemphasized.

Fry should be held in the trough for 5 to 6 days, until their mouth parts are developed and the yolk sac has been absorbed. They can then be placed in ponds at the rate of 50,000 to 125,000 per acre. Ponds should be prepared in advance as they are for largemouth bass culture. The same precautions to control insects must be taken.

At the outset, the fry feed entirely on small zooplankton. After 20 days, they begin to take larger organisms, and after 60 days they may be fed ground herring or a commercial trout feed. Ground herring has not been accepted before the fry are 60 days old, and feeds other than ground fish have not proved successful.

Crayfish

In the lower Mississippi River Delta and nearby freshwater drainages, crayfish (genus *Procambarus*) are highly esteemed—both as human food and as bait for angling. Many tons of crayfish are harvested annually from natural waters, and the amounts produced in ponds and flooded rice fields have increased in recent years.

Nearly all crayfish farming in the United States is in southern Louisiana. The Soil Conservation Service reported that in 1970 a total of 14,250 acres on 196 farms were devoted solely to crayfish farming in the State and 2,515 additional acres were used in crayfish-rice rotations. The acreage has been increasing each year. Crayfish prodnction is slowly spreading to other areas, especially to south Texas. Large-scale production is unlikely in more northerly areas, where crayfish stop growing during the winter.

In Louisiana, some of the production results from the flooding of the stubble in rice fields during winter. The mild winter weather permits excellent growth and the crayfish can be harvested before the spring rice planting. Other Louisiana farmers grow crayfish in special ponds, and some introduce various plants to provide food and protection from predators. Alligator weed and water primrose are favored plant species. Production of crayfish averages about 500 pounds per acre, but a few farmers raise up to 1,000 pounds per acre.

Farming in the midsouth is more intensive. Farmers often provide fish feed, chicken feed, or a combination of feed and green hay. Some farmers raise crayfish alone and others harvest crayfish from their minnow ponds.

The harvest of crayfish from minnow ponds or fingerling catfish ponds for sale as bait for angling is practiced throughout the Nation. Wild crayfish are caught and sold in most States where regulations permit.

Crayfish are an extremely popular food among people of French or Scandinavian descent. Most sales of crayfish for food in the United States are in southern Louisiana. Export trade to Europe has increased annually; crayfish are considered a gourmet food there and sell at high prices.

A limited market exists in cities on the West Coast for crayfish taken from natural waters in California and Oregon. A few restaurants in St. Louis, Mo., also serve crayfish, but there the crop is primarily a byproduct of baitfish culture in the area.

Returns from crayfish farming vary with fluctuations in the harvest from natural waters. When the production from these waters is low, prices are high and returns per acre climb. In good years, farmers may gross $300 per acre, of which $50 is likely to be net profit. Farmers who process their crayfish themselves may be able to double the net return.

The only commercial crayfish processing plants now in operation are in Louisiana. Lists of these plants, as well as literature on crayfish farming, can be obtained from the Cooperative Extension Service, Knapp Hall, Louisiana State University, Baton Rouge, LA 70803; Louisiana Game and Fish Commission, Post Office Box 44095, Capitol Station, Baton Rouge, LA 70804; or the Soil Conservation Service, Post Office Box 1630, Alexandria, LA 71301.

Crayfish are an increasingly significant source of income for farmers in south Louisiana and Texas.

ROTATION OF FISH CROPS WITH ARABLE LAND CROPS

The original concept of fish farming was developed with the idea that fish crops might be included in an annual rotation with rice. It was hoped that fish farming would provide a means of using fields forced to lie idle due to the rice acreage allotment system imposed by the U.S. Department of Agriculture. However, this concept has failed to develop into accepted agricultural practice. At the present time, less than 10,000 acres of fish ponds are rotated with other crops in the entire Nation. Farmers who do rotate fish crops with dry land crops are primarily minnow producers, although limited numbers of catfish and crayfish farmers occasionally use these rotations.

Although fish and rice crops are raised concurrently in the Orient, this practice is impossible in the United States due to the intermittent flooding techniques used here. Limited studies have indicated that the species of fish acceptable to the American consumer could not be raised efficiently in rice fields even if the "paddy" method of keeping the fields permanently flooded were to be adopted.

Most farmers agree that fish farming improves the friability of the soil. Organic matter that accumulates as the result of feeding fish may add up to 225 pounds of available nitrogen per acre. Wave action and the feeding activity of certain species of fish, such as carp and buffalofish, also have the effect of leveling the land.

Although not all soils yield higher production of dry land crops following use for fish production, those low in organic matter often yield significant increases of rice, wheat, soybeans, or corn after a field has been used to raise fish for several years.

The age of fish may be determined by counting annual rings on their scales or vertebrae. The rings on this catfish vertebra indicate that the fish was 8 years old.

Ponds that have been used for a number of years for intensive fish production often have an excess of available nitrogen in the bottom soil. This abundant nitrogen may cause excessive growth, with the result that rice lodges badly before the crop can mature. One rotation that has been suggested to overcome this problem is to follow a 3-year rotation plan in which the sequence is fish-soybeans-rice-fish. Soybeans readily use the excess nitrogen and produce a much higher yield at little extra cost. The nitrogen left after the soybeans are harvested is still adequate to boost rice yields as well.

As an experimental practice, studies were conducted at the Fish Farming Experimental Station in which rice seed was sowed from an airplane while a pond was being drained for the harvest of a minnow crop. By the time the fish were harvested, the rice was growing vigorously. Herbicides and a small amount of fertilizer were also applied from the air. Irrigation was by the intermittent flood technique. At the end of the season, a good crop of rice was harvested. The only machine that entered the field throughout the year was the combine that harvested the rice. The yield exceeded 100 bushels per acre. This "minimum tillage" technique has been tried on several farms in the area with considerable success.

Several conditions must be met before minimum tillage can be practiced on a farm. Seed used to plant the fields must be free of chemicals such as fungicides or insecticides normally used to protect seedlings or to insure establishment of the seedling. Harvesting of the fish must be delayed until the rice-planting season. Drawdown of the pond must be sufficiently rapid to avoid excessive water depths during the germination of the seed, and to prevent uprooting of the rice plants by wind action.

A variation of the minimum tillage concept is one in which soybeans are sowed by air over the dried bottom of a fish pond and then lightly covered with soil by using a disk. No fertilization or cultivation is needed but the use of selective or preemergent herbicides is important to the success of this method of farming.

A few farmers plant varieties of paddy rice in rotation with fish. These older varieties of rice tolerate deep flooding; they grow in water up to 20 inches deep. Farmers can then use the pond levees during irrigation instead of numerous small levees inside the pond area.

Although it cannot be considered as a form of crop rotation, the multiple use of water, for more than one crop, may also provide a benefit from fish farming that

Ponds for fish farming require substantial outside levees but rice can readily be grown on the pond bottoms without extensive renovation.

is often overlooked. By designing a water management system in which water from wells first enters fish ponds and then is gravity-fed to rice or soybean fields, a farmer may derive a double benefit: Water is warmed before it is applied to the grain crops; minerals such as calcium carbonate, magnesium carbonate, and various chlorides precipitate in the pond; and, as the season progresses and fertility in the pond climbs steadily with the feeding rate, the enriched water can be siphoned off and used to advantage by the grain crop before a low-oxygen problem develops in the fish pond. Should a low-oxygen condition develop in the pond, however, it is not recommended that the foul water be used for irrigation.

COASTAL FARMING OF FISH AND SHELLFISH

Many efforts are being made to grow fish and shellfish in our Nation's coastal waters. This particular type of fish farming has been termed mariculture and may involve either saline or brackish waters. As presently practiced or envisioned, mariculture is conducted in bays, inlets, estuaries, and artificial impoundments constructed along the edge of the sea and in coastal marshes. Although mariculture is not within the scope of the research efforts of the Bureau of Sport Fisheries and Wildlife, it is included here because it is expanding rapidly and will undoubtedly be increasingly important in the future.

Mariculture has been practiced for centuries in Asia and other parts of the world, but is relatively new to the United States. Like freshwater fish farming, mariculture is undergoing a worldwide expansion. With the exception of oyster farming, mariculture is less advanced than freshwater fish farming. Most of the efforts to date have been experimental, and few enterprises are yet commercially profitable.

Because of the failure of commercial marine fisheries to keep pace with the demand for fishery products, however, mariculture is being considered as an alternate source of fish and shellfish and is receiving a great deal of attention.

Most of the research has been by governmental agencies or universities, and, more recently, by large, well-financed private companies. With a few exceptions, mariculture is too complicated and still too poorly understood to be considered by individuals as a commercial venture. As more information is obtained about the life history of various species and their food requirements, however, sound cultural methods will ultimately be developed for a number of seafood organisms.

Shrimp are now probably receiving the most attention. The annual demand for shrimp in the United States has been steadily increasing, and domestic commercial shrimp fishermen have not been able to supply the demand for the past 15 years. Annual imports of shrimp are valued at about $150 million and are increasing at the rate of about 5 percent per year.

Although commercial shrimp culture is already underway in Japan, a number of problems remain to be solved before it can become a reality in the United States. One of the major problems concerns the availability of juvenile shrimp for stocking. Hatching and cultural methods for early stages (larvae and postlarvae) are now being developed. Shrimp, like most other estuarine animals, have complicated life histories. Environmental and food requirements differ at each stage of the life history. Cultural methods and feeds must therefore be developed for each stage. Feeds as presently formulated for fish are not suitable for shrimp, since shrimp feed in an entirely different manner.

Mollusks can be reared on the bottom, in racks, or hanging from rafts. Fish, shrimp, prawns, crabs, and lobsters can be cultured in cages, fenced areas, tanks, semi-impoundments, and impoundments.

Some of the kinds of fish currently being studied for culture in marine or brackish waters include pompano, mullet, croaker, *Tilapia*, redfish, spotted sea trout, and salmon. In addition, freshwater catfishes have demonstrated good growth potential in brackish waters that do not exceed 12 parts per thousand salinity. Shellfish being studied for culture include oysters, clams, mussels, shrimp, prawns, lobsters, and crabs.

Many problems remain to be resolved in mariculture. The survival, growth, and marketability of fish and shellfish are affected by industrial or municipal pollutants, pesticides, and siltation. Theft may be a problem in heavily populated areas. Predators, such as the oyster drill, can limit production. As cultural methods are intensified, parasites and disease will become a problem.

Methods of spawning most species have not been developed. The mariculturist currently depends on natural stocks of juveniles for stocking, the supply of which is highly variable. In addition, it is not likely that harvesting of juveniles from natural waters will be permitted to continue indefinitely.

In addition to Federal restrictions on the use of estuaries and navigable waters, many States have laws that prohibit mariculture, especially in public waters, since development for fish farming may destroy vital nursery areas of important game or food fishes.

RESEARCH IN FISH FARMING

Organizations Conducting Research

Research by the agencies concerned with fish farming covers a broad range of subjects, including basic nutrition, practical diets, stocking and feeding rates, harvesting, spawning, behavior, cage and raceway culture, silo culture, hybridization, and disease.

The Warmwater Fish Cultural Laboratories of the Bureau of Sport Fisheries and Wildlife conduct a broad range of research associated with fish culture—especially with catfish and baitfish farming. Harvesting research is performed at the Fish Farming Development Center, Rohwer (Kelso), Ark. The Bureau is also conducting surveys and research concerned with the processing and marketing of farm-raised catfish.

Non-Federal organizations are also engaged in catfish research, most of which is done by graduate students who are usually supported by Federal money or a combination of Federal and State funds. Research on the commercial production of fish is conducted at Auburn University, Southern Illinois University, University of Oklahoma, Oklahoma State University, State College of Arkansas, University of Georgia, Colorado State University, Nevada Southern University, Illinois Natural History Survey, and the Skidaway Institute (Georgia), among others. In 1970, about $500,000 were spent by the States on channel catfish or baitfish projects, mostly supported by Federal funds under Public Law 88 309, an act for the enhancement of commercial fisheries. The Agricultural Experiment Stations of 13 southeastern States are also conducting research under a cooperative project to study problems related to fish farming.

Despite the seemingly large number of programs in catfish research, information is being generated too slowly to keep ahead of the rapidly expanding industry. All areas of work need expansion in scope, staff, and monetary support.

Research Needs

Total research currently underway does not represent a concerted effort in all problem areas. Deficiencies in funding, staffing, or facilities often limit the scope and type of research conducted at a given laboratory. Certain areas that have been identified as being particularly important to the growth of the fish farming industry are discussed here.

Nutrition

Nutrition research should be greatly increased. At present, up to 40 percent of the total cost of producing food-sized catfish is for feed.

One of the goals of intensive fish culture is to enhance the inherent growth capacity of fish species. Attention to breeding, management, and disease control permits a certain growth potential, but this will not be reached if the nutrient requirements for growth are not supplied.

Theoretically and practically, the amount of feed required per pound of gain in weight is less for catfish than for warm-blooded domestic animals. However, catfish feed costs are high because of the high nutrient density required. Continued research is needed to identify low-cost feed materials and suitable substitutes for ingredients which may have seasonally high prices. One of the major research projects in nutrition is aimed at replacement of expensive animal proteins (fish meal, dried skim milk, meat scraps, poultry by-product meal) with vegetable proteins plus synthetic amino acids. Many other specialty feeds compete with catfish feeds for the animal protein currently available to the feed industry; this also forces the cost up. Costs of collecting, handling, and processing are higher for animal proteins than for vegetable proteins in soybean meal, cottonseed meal, corn gluten meal, and other forms.

Complete rations remain to be developed for use in cage or raceway culture. Such rations may also help reduce pond feeding costs and increase efficiency.

Research also is needed to determine an efficient nutrient density for fish feeds for different environments, at different sizes and ages of fish, and during each season. This information is needed to reduce the effects of undigested and metabolized feed components deposited in the water, since these create water conditions which are unfavorable for optimal growth.

To date, there is no major nutrient difference in feeds used for fry, fingerlings, or brood stock. In the absence of natural foods (as in raceway and cage culture), young fish may require different amounts of vitamins and amino acids than older fish, to insure vigorous growth and good survival. If so, we must learn what the requirements are.

Virology

A virus disease was identified as the cause of major losses of fingerling channel catfish during the summer of 1968, and losses from this disease have been identified each year since then.

The channel catfish virus is highly infective and contagious. Healthy fish in water previously inhabited by infected fish contract the disease, suggesting that contaminated gear and hauling units must be considered as probable sources of infection. At present, we are unable to control the disease with drugs.

Techniques are urgently needed for rapid diagnosis of the presence of the virus. Fish that are carriers of the disease but show no symptoms must be identified.

Research is needed to learn the path of entry of the virus, its course of infection within the fish, and the nature of the damage which ultimately kills the fish. The survival of the virus under various environmental conditions, under various chemical treatments, and in processed catfish must also be determined. If the virus can survive in catfish offal, methods of neutralizing or destroying it must be developed before processing plant wastes can be used as a feedstuff for catfish.

Outbreaks of channel catfish virus disease have occurred primarily during the summer in fingerling fish, but the susceptibility of other sizes of fish remains to be established. The influence of temperature and other water conditions on development of infections is also unknown.

Selective Breeding and Hybridization

Husbandry of most domestic plants and animals has greatly benefited from research in genetics, resulting in faster growth, disease resistance, and improved quality (corn, poultry, and hogs are well-known examples).

Limited research at the Warmwater Fish Cultural Laboratory and in foreign laboratories points to the need for additional work in hybridization and selective breeding. Many contributions are possible that could benefit both fish farming and sport fishing. At present, the brood fish being used are very similar to wild fish. It can be reasonably assumed that selection coupled with crossbreeding of different strains will yield excellent results for catfish husbandry.

Sperm Preservation

Sperm preservation will allow geneticists and fishery biologists to crossbreed

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Maximum aeration and circulation in fish holding facilities insures high quality fish and large holding capacity.

species for which males and females are not available at the same time. In addition, breeding from specific males, in genetic studies, could be carried on during several breeding cycles, even if the original males died. Moreover, sperm from pedigreed males could be widely distributed, to improve stocks.

Drug and Herbicide Clearance

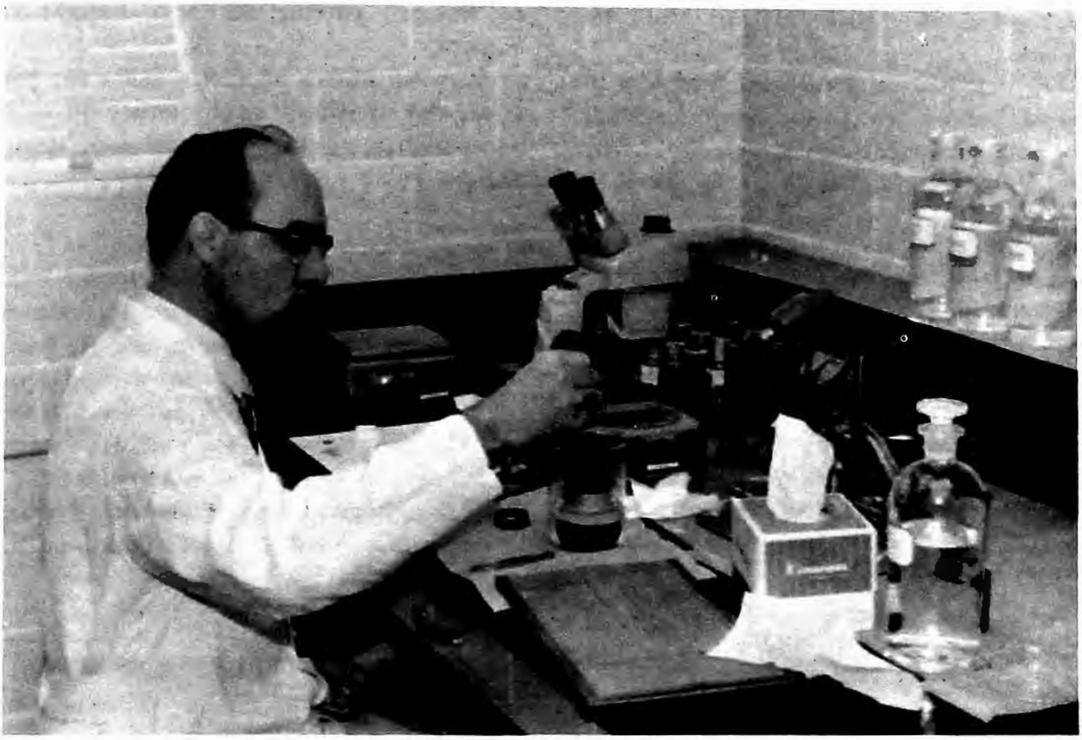
Very few drugs or other chemicals of any significant efficacy have been cleared for use on food fish. At least one cleared broad-spectrum antibiotic, one herbicide, one pesticide for predatory insect control, and one parasiticide are vitally needed.

Culture in Heated Water

Fish production in powerplant cooling water might be a feasible method of utilizing waste heat, and might help to reduce the temperature of effluent waters. In northern areas, the water would then have a suitable temperature for return to cold water habitats, although it would be considerably enriched with nutrients. Such a "cooling farm" for aquaculture would cost less than conventional cooling systems and might also return a profit on the investment. This development might also enlarge the geographical area suitable for catfish farming.

Confined Culture

The Fish Farming Experimental Station is studying the culture of catfish in closely confined quarters, such as long, narrow, dirt or concrete channels or tanks supplied with large amounts of flowing water. The station has also completed limited studies of such culture in long, narrow ponds with limited water flows. The addition of even small amounts of flow-through water has yielded an increase of 1,000 pounds of fish per acre over the production in static ponds. Limited testing in aquariums and tanks indicates that at least 2 pounds of catfish per cubic foot of water can be produced by this method.



Another new method is the use of vertical tanks such as silos. Trout have been produced in such systems and it is possible that catfish can also be raised in such space-savers. Spiral raceways may also be suitable since they provide long raceways in a small area.

Catfish and many other species of fish, both freshwater and marine, can be reared in cages. These cages may be placed in the water of creeks, rivers, lakes, ponds, reservoirs, inlets, strip pits, old quarries, and gravel or sand pits. Carp have been raised in cages in Asia and marine fish in Japan.

In this country, Auburn University, Southern Illinois University, State College of Arkansas, and the Kerr Foundation have experimented with catfish in cages, but many unanswered questions remain about feeds and feeding (development of a nutritionally complete ration is mandatory), holding capacities, and disease control.

In another culture method, closed water systems are used in which water is conserved by recirculating it. Some research has already been completed by the Bureau of Sport Fisheries and Wildlife with trout and salmon by using a method of reconditioning, filtering, reoxygenating, and warming or cooling the water but much more work is needed before these techniques are commercially feasible.

Other Important Subjects for Research

Fish disease investigations—continuation of current work.

Electronic or behavioral harvesting.

Marketing, product technology, testing, promotion, and development of national trade names.

Economics of various culture methods in which ponds, raceways, flowing water, automatic or manual feeding, and different types of construction are used.

Baitfish culture, feeding, and management.

Use of wastes from fish processing plants for pet food, catfish food, or other purposes.

Reclamation and reuse of water by biological, chemical, and mechanical means.

Environmental, biological, and chemical studies as related to management, i.e., to disease, production, and vegetation control.

Growing native or exotic fishes for pet food, fish meal, or high-quality protein concentrates, perhaps in polluted, static waters.

THE FUTURE FOR THE FISH AND THE FARMER

The future for fish farming depends on the implementation of the research discussed above, the success of such research, and the adoption of the research findings by the fish-farming industry. We believe that, once the research continues and expands, further positive results will become available to the fish farmer. There is little doubt that new research results will be accepted and used in fish farming: The industry has eagerly received and used the technical information offered it in the past.

What will this mean to the fish and the farmer? It will mean that fish of better quality will be raised, that the cost of raising them will be reduced, that the fish farmer will have the opportunity to develop a more profitable enterprise, and that the quality of the fish-farming environment will be improved.

PUBLICATIONS TO READ

Various publications on technical aspects of fish farming, on local or regional solutions to problems, and on the future of the industry will help the fish farmer get the most from his effort and investment. The references listed here are arranged under broad subjects corresponding to some of the sections in this *Second Report to the Fish Farmers*.

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PEOPLE TO TALK TO

Many sources of information are available to the fish farmer who needs advice. The Bureau of Sport Fisheries and Wildlife provides information on all phases of fish farming: Cultural aspects, diets, spawning, disease diagnosis and control, pond management, harvesting, marketing, and economics. The Bureau's Fish Farming Experimental Station, Stuttgart, Ark., in cooperation with Mississippi State University, conducts an annual 2-week training course in fish diseases and parasites. The U.S. Department of Agriculture, through its Soil Conservation Service offices in each State and its Federal Extension Service offices in some States, advises fish farmers on warmwater pond design and management. State governments have fish and game agencies, headquartered at the capitols, whose personnel are familiar with local conditions and can provide information on many facets of fish farming. Several universities and colleges have experts in fishery biology and fish husbandry. A private organization equipped to answer questions on warmwater fish farming is the Catfish Farmers of America, Little Rock, Ark. In addition, three trade magazines carry information of current interest to fish farmers.

The following offices of the Bureau of Sport Fisheries and Wildlife have fish farming advisory services:

Regional Offices (For general advice on warmwater fish farming):

- Pacific Region, 730 Northeast Pacific Street, Portland, OR 97208.
- Denver Region, Federal Center, Building 67, Denver, CO 80225.
- Southwest Region, Federal Building, 500 Gold Avenue, Albuquerque, NM 87103.
- North Central Region, Federal Building, Fort Snelling, Twin Cities, MN 55111.
- Southeast Region, 17 Executive Park Drive, NE., Atlanta, GA 30329.

Sport Fishery Research Laboratories (For technical problems on warmwater fish farming):

- Fish Farming Experimental Station, Post Office Box 860, Stuttgart, AR 72160.
- Southeastern Fish Cultural Laboratory, Marion, AL 36756.

Fishery Services Offices (For general advice on warmwater fish farming):

- Leader, Cooperative Fishery Unit—
  - Auburn University, Auburn, Ala. 36830.
  - University of Arizona, Tucson, Ariz. 87521.
  - Humboldt State College, Arcata, Calif. 95521.
  - University of Georgia, Athens, Ga. 30601.
  - Louisiana State University, Baton Rouge, La. 70803.
  - University of Missouri, Columbia, Mo. 65201.
  - North Carolina State University, Raleigh, N.C. 27607.
  - Oklahoma State University, Stillwater, Okla. 74074.
  - Virginia Polytechnic Institute, Blacksburg, Va. 24061.
- Fishery Biologist—
  - Central States Fishery Station, Post Office Box 18, Princeton, IN 47570.
  - Fort Niobrara National Wildlife Refuge, Hidden Timber Star Route, Valentine, NE 69201.
  - BSFW Biologist, Soil Laboratory, Bureau of Indian Affairs, Gallup, NM 87301.

Hatchery Biologist Offices (For disease and parasite problems):

- Coleman National Fish Hatchery, Route 1, Box 2105, Anderson, CA 96007.
- National Fish Hatchery, Post Office Box 158, Pisgah Forest, NC 28768.
- National Fish Hatchery, Springville, Utah 84663.
- National Fish Hatchery, Post Office Box 252, Genoa, WI 54632.
- Hatchery Biologist, Box 292, Stuttgart AR 72160.

The following offices of the National Marine Fisheries Services offer advice on fish farming:

Regional Office:

- Federal Building, 144 First Avenue South, St. Petersburg, FL 33701.

Marketing Office:

- Post Office and Courts Building, 600 West Capitol Avenue, Little Rock, AR 72201.

U. S. GOVERNMENT PRINTING OFFICE : 1973 O - 495-839