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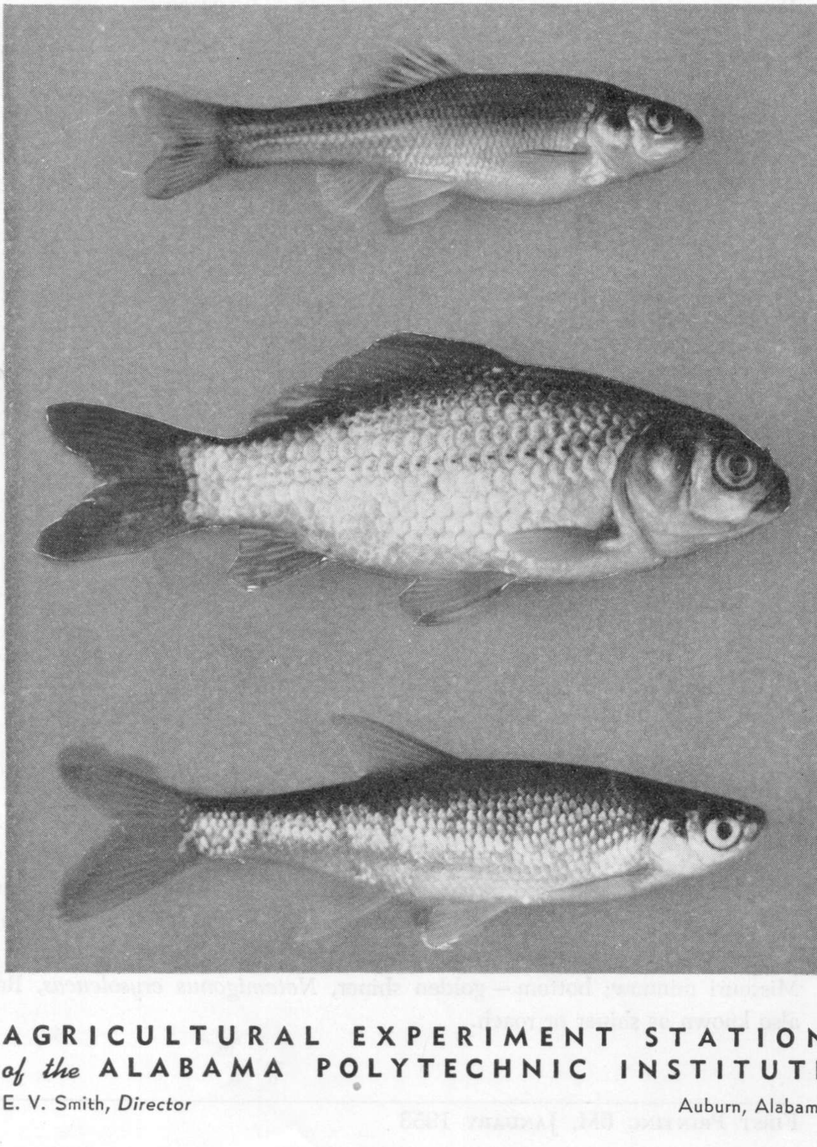
PRODUCTION *of* BAIT MINNOWS *in the* SOUTHEAST



AGRICULTURAL EXPERIMENT STATION
of the ALABAMA POLYTECHNIC INSTITUTE
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CONTENTS

***The* COVER . . .** The three most important bait minnows in the Southeast: top — fathead, *Pimephales promelas,* Raf., also known as tuffy minnow; center — goldfish, *Carassius auratus,* (Lin.), also known as Indiana or Missouri minnow; bottom — golden shiner, *Notemigonus crysoleucas,* Raf., also known as shiner or roach.

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PRODUCTION *of* BAIT MINNOWS *in the* SOUTHEAST

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A GENERATION ago minnows for use as bait were easily obtained by seining the margins of lakes, ponds, or streams. However, with the present tremendously increased number of fishermen and fishing areas, the demand for minnows not only far exceeds the supply of these natural waters, but also that of commercial minnow producers. Within the last 10 years, approximately 7,000 farm ponds have been constructed in Alabama, and new ones are now being built at the rate of about 1,000 a year. The number of ponds reported in other Southern States is even greater. In addition to these private waters, the impoundment of large areas such as those flooded by the T.V.A., Army Engineers, and other agencies has greatly increased the acreage of inland fisheries. Alabama alone has an estimated 400,000 acres of fishing waters, and currently the supply of live minnows does not meet the demand in most areas. It is conservatively estimated that fishermen would buy 20,000,000 minnows annually in Alabama, and a comparable number could be sold in each of the other Southeastern States. Obviously, efficiently operated minnow hatcheries would prove profitable to their operators.

The Agricultural Experiment Station of the Alabama Polytechnic Institute has conducted experiments on production of several species of bait minnows; resulting information regarding construction and management of commercial minnow hatcheries is reported in this publication.

HATCHERY CONSTRUCTION

Successful production of minnows depends to a large extent upon the physical aspects of the hatchery. Therefore, great care must be used in the selection of the hatchery site. While select-

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[2] Resigned.

ing a suitable location and planning the construction of minnow ponds, considerable thought should be devoted to topography of the area, type of subsoil present, and available water supply. These are the more important features to be considered, and the area finally selected should meet certain minimum requirements regarding each. To more clearly understand the recommendations that follow concerning the construction of minnow ponds, it might be well to visualize the completed series of hatchery ponds that you intend to build.

The ponds will lie in a compact unit, preferably in a row or series so that a minimum of travel will be necessary to accomplish the daily chores essential to proper management. They will be separated by well-sodded, properly constructed dams, some of which being wide enough for use as roadways. An additional road will traverse the entire series at the deep end of the ponds to facilitate removal of the minnows to trucks when harvested. Each pond will have a drain pipe for draining it independently of the others and the pond bottoms will be sloped toward the drain pipe so that all of the water and fish may be removed. The area in which the ponds are built will be lower than the source of water in order that the ponds may be filled as the water flows downhill through its conduit; each pond will have an inlet pipe and valve, which together with the drain pipe furnishes a positive and separate water control for each pond. The water supply itself will be permanent, adequate for the size hatchery involved, free of mud and all species of fish, and its chemical nature will be suitable for fish production.

With this in view, the means to such a system are discussed separately, and in some detail.

SELECTION *of the* HATCHERY SITE

Topography. An ideal location for minnow ponds is a relatively flat, gently sloping area of bottom land (Figure 1). Areas of this type facilitate the flow of water to the ponds by gravity, allow the ponds to be readily drained, and insure good drainage of the soil surrounding the ponds. Although bottom land is desirable, boggy areas and those subject to floods during rainy periods should not be used.

Unfortunately ideal hatchery sites are difficult and sometimes impossible to find in some areas, and less desirable ones may have to be used. Flat areas may be drained by the proper use

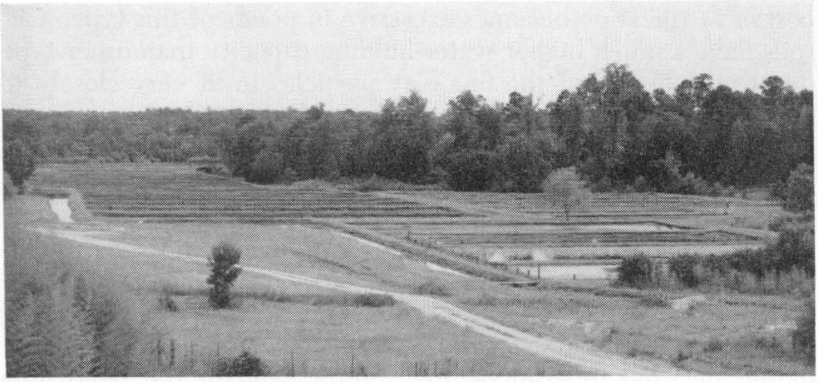


FIGURE 1. A relatively flat, gently sloping area with a tight clay subsoil makes an ideal location for construction of a hatchery.

FIGURE 2. Where the soil is sufficiently water-tight, ponds can be located on hillsides in a terrace-like pattern.

of ditches, and on sharply sloping land the ponds may be built on terraces around the hillsides (Figure 2). In the latter case runoff water from the pond area should be localized and carried from the land in channels sodded to reduce erosion.

An area should be selected that is large enough to allow for future expansion.

Subsoil. An area, no matter how well it is adapted otherwise as a hatchery location, must have a subsoil that is compact enough to prevent excessive seepage, hence loss of water. Even though the water supply may be adequate to maintain the desired water levels in ponds built in less impervious soils, the seepage water will carry off much of the fertility of the ponds as dissolved salts. Naturally, production is markedly decreased or the cost of fertilization becomes excessive in ponds of this type. Clay soils have a much higher water-holding capacity than other types due to the ability of the fine clay particles to fit very closely together when compacted and to swell when wet.

Soils that are an admixture of sand and clay are also suitable for constructing ponds provided the clay content is sufficiently high. If a handful of moist soil squeezed into a ball and tossed lightly into the air is caught without cracking, the soil contains enough clay to make it sufficiently impervious to water. Soils that crack in such tests are unsuited for pond construction. In testing the soil in a proposed location, a soil auger or post-hole digger should be used to examine the subsoil beneath the pond area. Tests should be made at intervals throughout the entire site. At least a 3-foot layer of impervious soil of the type just described should underlay the pond bottoms. The type of top soil in an area is of less importance. Even though the bottoms of shallow ponds do not extend below a pervious topsoil, the impervious layer beneath will prevent seepage after the topsoil has become saturated. Whenever possible the clay for the dams should come from within the pond area. However, in some instances the type of soil near the surface makes this impractical. In such a case additional soil samples should be taken from near-by hillsides to determine if there is sufficient clay soil at hand from which to build the dams.

Water Supply. In selecting a hatchery site, careful consideration must be given the available water supply. The source of water should remain free of mud most of the time. It should furnish sufficient water during all seasons of the year to adequately maintain a hatchery of the desired size. For the sake of economy, it should be situated so that all of the ponds may be filled by gravity flow. Possible sources of water that meet these requirements are springs, artesian wells, and streams. Springs and artesian wells are the more desirable sources of water. However, springs and streams are probably more widely used since artesian wells may be drilled in only certain areas.

The quantity of water needed for any particular hatchery would necessarily depend upon the number, area, and depth of the ponds involved, and also upon the rate of seepage and the number of times the ponds are to be drained each year. It is difficult to estimate accurately the number of acres of water that can be supported by a stream of a given size. However, the following estimates should be considered the minimum under average conditions:

NORMAL SUMMER FLOW OF STREAM	SIZE OF HATCHERY
Square inches	*Acres*
78	50-60
50	30-40
28	15-20
12	8-10
7	2- 5
3	1

The normal summer flow of the stream in square inches may be estimated by multiplying the average width by the average depth in inches.

CONSTRUCTION *of* PONDS

Designing *the* Hatchery. Before actual construction is begun, a complete survey of the hatchery site should be made and plans be drawn showing the location and size of each pond, the proposed water supply system, the position of the individual drain pipes, and the hatchery roadways. Careful planning at this stage insures the most effective utilization of the area involved, reduces costly mistakes during construction, and increases the operation efficiency of the completed hatchery.

Instruments necessary to accomplish a satisfactory survey of a hatchery site include some sort of leveling device, such as a surveyor's transit and rod, and a steel tape or "chain"; in lieu of a transit, a simple farm terracing level will do very well.

Care should be taken that each pond is so situated that the desired water level is lower than the water supply, thus insuring complete filling by gravity. The drain pipes should be located to discharge at a point where there is a natural grade or where a grade may be established sufficient to carry off the water when the ponds are drained.

The steel tape is used in determining the total area of the hatchery site and in laying off the ponds and dams to the desired size. Sufficient space should be allocated for roadways throughout the area, and it is advisable to bring the roads as close as possible to the deep end of each pond to facilitate the removal of minnows to a truck as the ponds are drained.

Clearing. All trees and brush should be removed from the areas in which the ponds are to be built. Clearing heavily wooded land is expensive at best. However, as a rule it is done more cheaply by a tractor with a bulldozer attachment than by other methods. The tractor will be able to push down all brush, small trees, and stumps; larger trees should be cut and sold for lumber. If the tractor is unable to remove the larger stumps, they may be first loosened with dynamite and then pushed away. A root-rake attachment, if available, is more satisfactory than the 'dozer for piling brush and stumps to be burned. It will loosen and sift most of the soil from the roots in the process of piling.

Size of Ponds. Ponds from 0.1 to 0.3 acre in size are most desirable for minnow production; however, slightly larger or smaller ones are quite satisfactory. From 100,000 to 350,000 minnows may be produced per acre under proper management. Because of the difficulty in handling large numbers of minnows while draining, ponds exceeding one acre are impracticable. Too, if all the minnows from larger ponds are not disposed of at once, considerable losses might be suffered since most mortality occurs while minnows are being held under crowded conditions.

Depth of Ponds. In the Southeast, little or no oxygen is present in the water of small ponds at a depth greater than about 5 feet during summer months. This oxygenless water is uninhabitable for fish, thereby rendering the nutritive material that collects on the bottom below this depth unavailable. Therefore, the maximum depth for minnow ponds should not be greater than 5 feet, and 4 feet would be ample; in ponds of less than 4 feet maximum depth, there is some danger of losing fish during extremely cold weather. The edges of the ponds should slope rapidly to a depth of at least 18 inches to facilitate weed control along the margins.

Construction of Dams. Assuming that a relatively impervious subsoil is available, seepage through dams may be kept to a minimum by proper construction procedures. The principle involved is properly joining impervious upright walls (the dams) to impervious bottoms (the subsoil), thus forming reasonably water-tight containers. The joint between the walls and bottoms of these containers is accomplished by digging a trench into the subsoil along the center lines of the dams (Figure 3), packing this trench with the best clay available and extending the core thus formed to the top of the completed dam. In effect, this is much the same as the mortise employed by a good carpenter to strengthen his work.

FIGURE 3. The base for the dams should be excavated with a tractor down into an impervious layer of clay to form a water-tight seal between the bottom and sides of the pond.

STAKING OUT THE DAMS. Prior to cutting the core trench, the hatchery plans should be consulted and the top width of each dam marked off by stakes. The top width of the dams should not be less than 6 feet. Where the dams are to be used as roadways, the top width should not be less than 12 feet. A stake should also be set at each end of the dams midway between the top-width stakes to serve as a centerline guide while excavating the core trench. An additional stake should be set in line with the center-line stakes but outside of the construction area. This is done so that the center line of each dam may be relocated after the stakes marking off the dam have been pushed over or covered with soil.

CUTTING THE CORE TRENCH. After the top width of the dams has been staked off, a bulldozer should be used to remove the porous topsoil from between the stakes. The core trench may then be extended into the subsoil with the 'dozer, a ditch-digger, or similar equipment. It is important that the core extend at least 3 feet into the subsoil; where seepage channels are exposed in cutting the trench, the core should extend 3 feet below the lowest one.

If a 'dozer is used to excavate the trench, it is probable that the soil will become too boggy to support the tractor before the desired depth is reached. In this event the trench may be deepened most economically with ditching dynamite, a nitroglycerine explosive specially prepared for blasting ditches in wet soil. This material is relatively unstable and is sensitive to shock. If set in a series of holes about 12 inches apart, the series may be detonated by a single blasting cap attached to the charge in one of the holes. When the capped charge is set off, the shock is transmitted to each successive charge through the soil water. A ditch several hundred feet long may be excavated by this method *(2)*. The depth of the holes and the amount of dynamite that should be loaded in each depends upon the desired depth of the ditch to be blown. A hole 3 feet deep loaded with two sticks of dynamite will make an excavation 4 to 6 feet deep and 6 to 10 feet wide at the top, depending upon the moisture content and type of soil. A piece of galvanized water pipe about 6 feet long, and from 1½ to 2 inches in diameter fitted with a steel point is a suitable tool for punching the holes to be charged. A person familiar with explosives should be consulted before attempting to excavate a core trench with ditching dynamite. County Agents and Extension Specialists are usually proficient in this field.

FILLING THE CORE TRENCH. The core trench should be filled with the best clay available in the area. If the soil that was removed from the trench has a high clay content, it may be used to refill the trench: if not, better materials should be brought in from near-by hillsides. Soil may be moved from outside the pond area most economically by a tractor and pan. If necessary, the soil may be piled close to the trench by this method and then pushed into the trench with a 'dozer (back filled). While filling the trench the soil should be laid down in thin layers to insure maximum compaction. Usually a heavy tractor running back and forth while filling the trench is sufficient to pack the soil. If additional packing is necessary, a sheep's-foot or similar roller may be used to advantage.

FILLING ABOVE-GROUND PORTION OF DAM. When the core trench has been filled to ground level, the bulldozer may be used to push up the above-ground portion of the dam (Figure 4). Usually one-half or more of the soil for the dams may be obtained from inside the pond area. This should be used wherever possible since this allows the pond bottom to be deepened and shaped and the dam built in the same operation. The base of the dam should be wide enough to allow the sides to taper to the desired top width of the dam at the rate of 1½ feet in for each 1 foot in height. For example, a dam that is 4 feet high and has a top width of 6 feet should be 18 feet wide at the level of the pond bottom

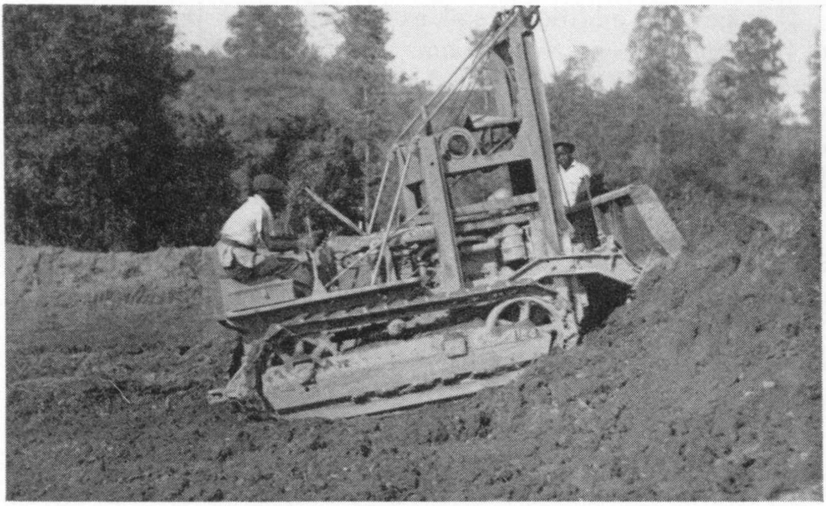


FIGURE 4. When a bulldozer is used to push up the dams, the dirt can be packed sufficiently by running the tractor up and down the sides and on top of the fill.

(Figure 5). On dams with slopes of less than 1½-to-1, there is some danger of the soil slipping when it becomes moist. On the other hand, dams with slopes of more than 1½-to-1 are unnecessary for ponds of this type, and result in more shallow water where weeds may become objectionable. While pushing soil from within the pond area, the tractor operator should use care to leave the pond bottom sloped so that all of the water will drain toward the drain pipe. If depressions are left in the bottom or it does not slope sharply toward the drain pipe, many minnows will remain stranded when the pond is drained.

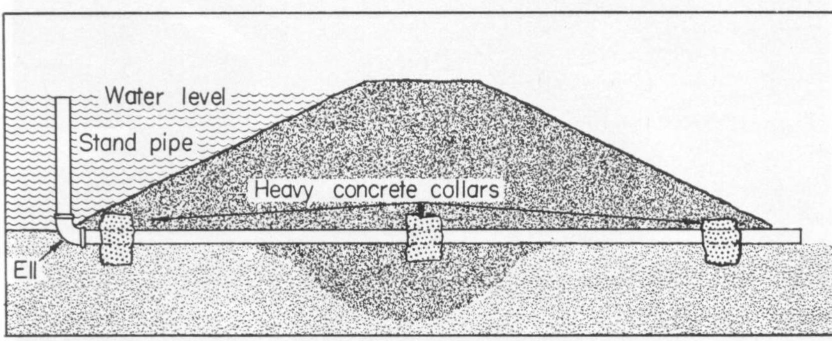


FIGURE 5. Cross sectional diagram of a dam showing filled core trench, the drain pipe with concrete collars to prevent seepage, and a threaded standpipe for draining the pond.

If necessary, additional soil may be brought in from outside of the pond to complete the dam. The best clay should be placed along the center line to extend the core to the top of the dam, which should be 12 inches above the level of the water. The top of the dam should be planted to centipede or some other type of low-growing grass that forms a heavy sod.

INSTALLATION OF DRAIN. Since most species of bait minnows cannot be harvested efficiently without draining the pond completely, it is necessary to have some type of drain in each pond. Various types of drain pipes and valves are used with success. However, one of the simplest and most economical types for small ponds consists of a standpipe inside the pond that is attached by an ell to a pipe running beneath the dam (Figure 5). The standpipe should be just long enough to extend within 12 inches of the top of the dam when vertical. In this position it removes the excess water entering the pond and maintains the water level at the desired height. The pond may be drained or the water level regulated to any height below the maximum by pushing the top of the standpipe to the desired position. Threaded galvanized iron pipe is commonly used for this purpose and has proven satisfactory in experimental ponds at Auburn. Pipe having a diameter of 4 inches is adequate for ponds of 0.1 to 0.5 of an acre in size.

To prevent interference with the bulldozer, the drain pipe can be installed after the dam, through which it is to extend, has

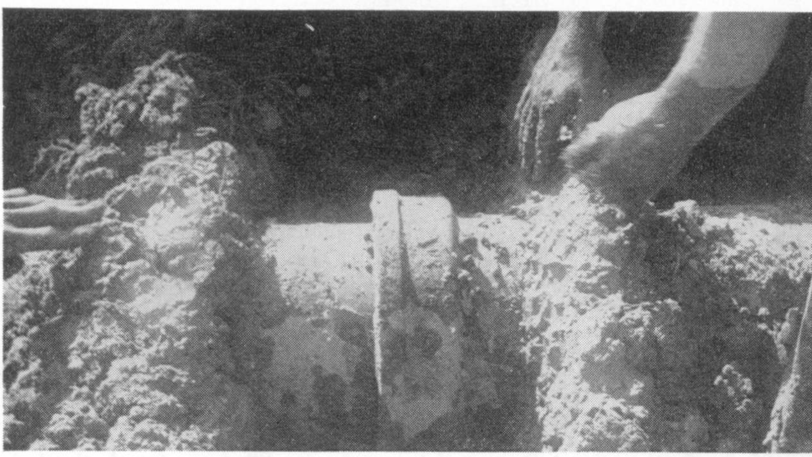


FIGURE 6. To prevent leakage and seepage, concrete collars are poured between the clay forms and around the connecting cast iron pipe joints.

been completed; at this time a trench may be dug through the dam and the pipe installed. To prevent seepage along the drain pipe, concrete collars should be poured at intervals along its length (Figure 5). On dams less than 20 feet wide at the base two collars should be sufficient, one near each end of the pipe. On wider dams they should be poured at 15-foot intervals. Forms for the collars are easily made of earth (Figure 6). The collars should be at least 4 inches thick and should extend 6 inches on all sides of the pipe. Care should be taken to install the drain pipe in such a way that when the standpipe is lying flat on the pond bottom, its open end lies in the deepest part of the pond. There should be at least one foot of fall from the end of the pipe in the pond to its discharge end in order to insure a rapid flow of water through the pipe when the pond is being drained.

When refilling the drain pipe trench (through dam), the soil should be moistened and put down in thin, well-packed layers to prevent it from sliding or washing out when the pond is filled.

Catch Basin

A catch basin similar to that shown in Figure 7 greatly facilitates the harvest of minnows and reduces mortality and losses normally encountered while draining minnow ponds. The basin

FIGURE 7. A catch basin about 12" deep and 10'-0" to 15'-0" square facilitates the harvest of minnows when the pond is drained.

should be constructed around the drain pipe in the deepest part of the pond. It should be about 15 feet square for ponds up to 0.3 of an acre in size. It may be constructed of 2 × 12-inch planks, concrete blocks, bricks, or similar material. However, it is more durable and serviceable if made of concrete. Both the walls and the bottom should be at least 4 inches thick to prevent cracking, and the basin should be approximately 12 inches deep. The walls of the basin should not extend above the level of the pond bottom so that the last of the fish and water will be completely within the basin when the pond is drained. The usual method of removing the minnows from the catch basin is by seining with an ordinary quarter-inch mesh minnow seine. The standpipe previously described makes this operation somewhat difficult. Where catch basins are to be used, it might be expedient to replace the standpipe with a gate valve or the less expensive shear-gate valve (Figure 8). Gate valves are available with threaded ends that fit threaded galvanized iron pipe; however, shear-gate valves

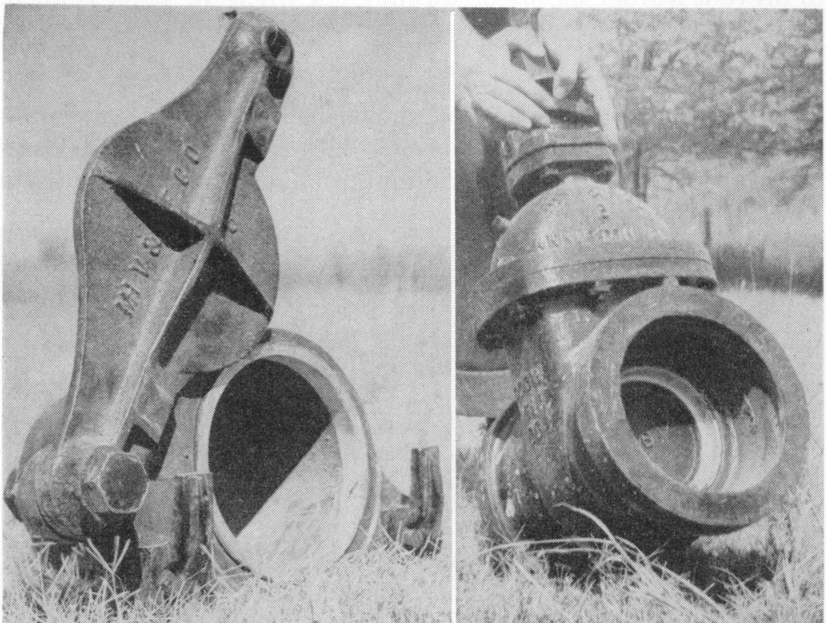


FIGURE 8. The shear-gate valve at left is cast iron with brass fittings for long wear. The flap may be attached to a rod extending above water and is opened and closed by pulling or pushing the rod. The cast iron gate valve at right is brass-fitted for long service under water, and it can be operated by a rod extending above water. A revolving worm gear opens and closes the valve. The shear-gate valve (left), which is simpler in construction and cheaper, is equally as satisfactory as the cast iron gate valve (right).

are not equipped with threaded ends and must be attached to the drain pipe by concrete and oakum, or leaded joints.

Water Supply

Springs *and* Streams. Since the water flow from springs and small streams usually is spread over a comparatively wide and shallow area, it is often necessary to impound the water at the point from which it is to be diverted into the hatchery supply system. This is accomplished easily by erecting a small masonry or earthen dam across the stream channel. The take-off pipe for carrying the water to the ponds should be installed a foot or more above the bottom of the reservoir to prevent the entrance of excessive sand, silt, and trash that normally will collect behind the dam. The dam should be high enough to raise the level of the water supply an additional 12 inches above the top of the take-off pipe in order to give sufficient "head," or pressure, to completely fill the pipe. The pipe should be either galvanized iron, asbestos cement, or cast-iron soil pipe. It need not be larger than the normal flow of the water supply in question. The pipe should be equipped with a valve to regulate the flow of water into the pond system. A valve at this point is useful in preventing muddy water from entering the ponds after heavy rains.

An additional pipe and valve should be installed in the dam at the lowest point in the reservoir bottom in order to completely drain the reservoir. The sand, silt, and debris that normally collect behind dams in flowing streams may be periodically eliminated

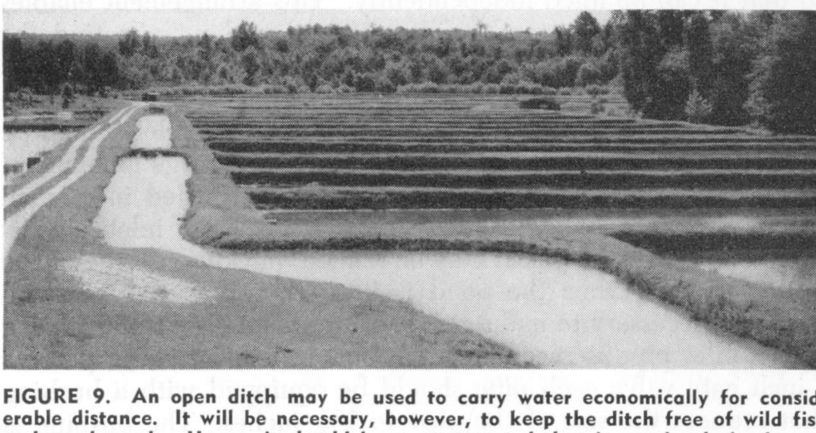


FIGURE 9. An open ditch may be used to carry water economically for considerable distance. It will be necessary, however, to keep the ditch free of wild fish and pond weeds. Hence, it should be so constructed that it can be drained completely.

by opening the valve on the drain pipe, which should not be less than 8 inches in diameter to facilitate the passage of these waste materials.

From the point of take-off, the water may be carried directly to the ponds in pipes, or if the volume is great or the distance to be traversed is long, an open ditch, or aqueduct, may be economical (Figure 9). In either case each pond should have its own inlet pipe and valve, which may be operated independently of the other ponds.

Artesian Wells. In areas where artesian wells may be drilled, the well may be capped with a pipe and valve, and the water directed to the ponds through pipes or open ditches as just described. However, in some cases dissolved iron in artesian water makes it unfit for fish production unless certain precautions are taken. The presence of this material may be detected by examining the area over which the water is discharged for a rusty brown deposit. This deposit is an insoluble form of iron that is precipitated from water of high iron content upon contact with air. If such a precipitate is present, the well water should be thoroughly aerated by running it in a shallow stream across a rocky or gravelly area at some point before it enters the pond. In most instances the dissolved iron will be removed and the water sufficiently oxygenated to render it suitable for fish production by this method.

Inlet Pipe. Each pond should have an inlet pipe and valve so that it can be filled independently. This arrangement enables the operator to drain and refill any pond without affecting the others. It also prevents the movement of parasites and diseases from pond to pond, which often happens in hatcheries where the ponds drain and fill in series. Where possible the inlet should be located near the drain pipe or catch basin since large amounts of fresh water are needed when minnows are crowded in a small volume of water while being harvested. A large inlet pipe is desirable so that the ponds may be refilled quickly after they have been drained. Once the pond is filled, however, only a small stream is necessary to maintain the water level. In view of this, a 4-inch inlet pipe is recommended, but, instead of the expensive 4-inch gate valve each pipe should be equipped with a bushing that reduces the size of the pipe to 1¼ inches. The bushing is then fitted with a 1¼-inch nipple and a 1¼-inch gate valve

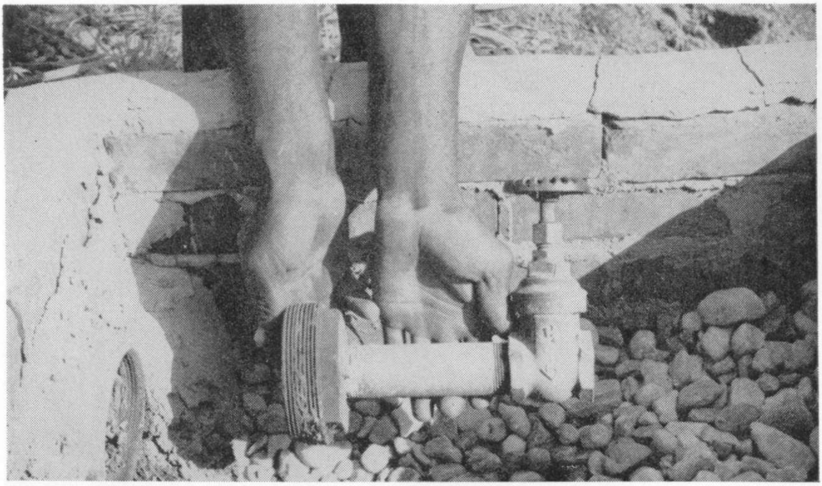


FIGURE 10. A 4″ inlet pipe may be used to fill the pond, and a bushing equipped with a 1¼″ nipple and gate valve then screwed in. The gate valve may be regulated to maintain the water level.

(Figure 10). Whenever a 4-inch stream is needed, the bushing is removed; when the pond has filled, the bushing is replaced and the water level is maintained by regulating the 1¼-inch valve.

Water Filter. One of the prime requisites for production of bait minnows is that the ponds be kept free of other species of fish. Wherever the source of water is artesian wells or small springs in which no fish are present, no further precautions are necessary. However, most larger springs and streams are populated by wild fish and some method must be used to prevent these fish from entering the minnow ponds.

The usual tendency among hatchery operators is to tie a piece of screen wire around the inlet pipe to each pond to prevent contamination by undesirable species. This method, though better than none, has not been found to be effective in excluding the newly-hatched fry of most species of fish. Gravel filters (Figure 11), however, have proved very satisfactory for this purpose if properly constructed. They should be included as an important feature in all minnow ponds. The filter shown in Figure 11 is merely a chimney of bricks enclosing the inlet pipe and valve. The chimney should be built on a concrete footing. It should be about 24 inches square and should be high enough to extend 24 inches above water level when the pond is full. On the side of the filter away from the pond edge, the bricks in the bottom two

FIGURE 11. A gravel filter similar to the one above should be used to prevent the entry of wild fish into minnow ponds. The filter must be periodically cleaned to maintain its effectiveness.

layers should be set approximately 2 inches apart to allow the water to flow from the filter into the pond after passing through the gravel. The chimney should be filled to the pond water level with gravel 1 inch, or less, in diameter. Gravel less than 1 inch in diameter tends to become quickly clogged with silt and debris, which may cause some danger of the water flowing over the top of the filter and contaminating the pond with wild fish. For this reason it is usually necessary to periodically stir the gravel in filters to maintain the proper flow of water. An iron rod, pipe, or shovel should be kept on hand for this purpose. The effort expended in maintaining the filter properly will pay big dividends in increased minnow production.

Holding Facilities

Facilities to which the fish may be removed when the ponds are drained must be available at all minnow hatcheries. These facilities must not only be adequate to hold all of the minnows from the largest pond on the hatchery but at the same time be compact enough to allow easy removal of minnows in relatively small numbers for counting, sorting into size groups, and sale.

Probably the cheapest type of holding facility and one that is especially suited to hatcheries with small water supplies is a pool with earthen sides and bottom and similar to the rearing ponds. In this pool the minnows are held in wire cages (Figure 12). The size of pool required of course, depends on the number of minnows that would be on hand at any one time. However, regardless of the surface area, the depth should be at least 4 feet to provide a volume of water large enough that will not become easily fouled by the feces and respiratory wastes of the minnows. The cages should be made of light weight material, such as 2 × 2-inch lumber or small metal rods covered with ¼-inch hardware cloth. They will last much longer if treated with tar. Holding cages approximately 2 feet wide, 3 feet deep, and 6 feet long are of a desirable size. They are large enough to hold several hundred to several thousand minnows and yet small enough to be easily lifted in or out of the pool. The cages should be suspended at least a foot above the pond bottom to allow the feces to fall through. They should be in easy reach so that the hatcheryman may dip minnows from them without wading in the pool and causing the water to become muddy. In addition to having a row of cages along the margin, walkways or docks

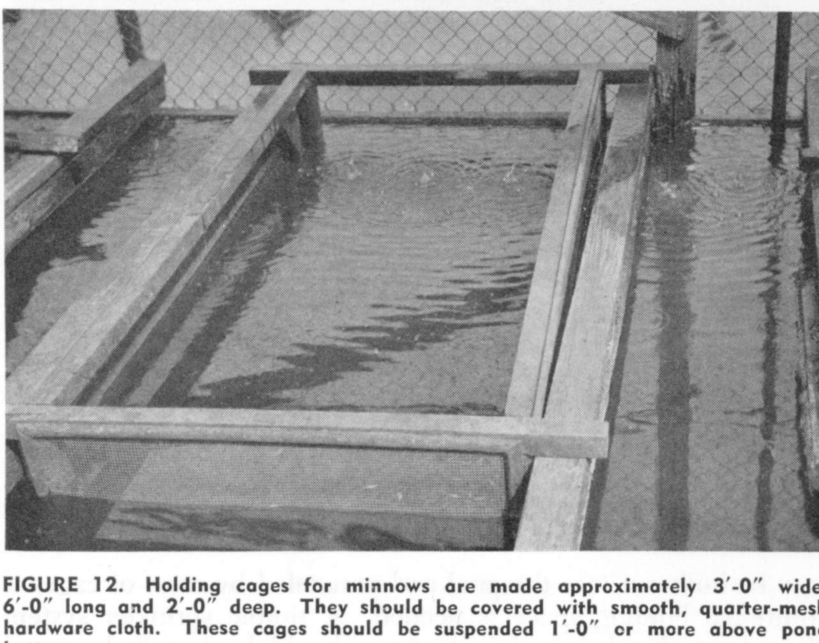


FIGURE 12. Holding cages for minnows are made approximately 3′-0″ wide, 6′-0″ long and 2′-0″ deep. They should be covered with smooth, quarter-mesh hardware cloth. These cages should be suspended 1′-0″ or more above pond bottom.

FIGURE 13. Arrangement that is used at the Gish Minnow Hatchery, Athens, Ala., for holding minnows in an earthen pond. The screened area tends to prevent theft and the spray falling in and around the holding cages aerates and circulates the water.

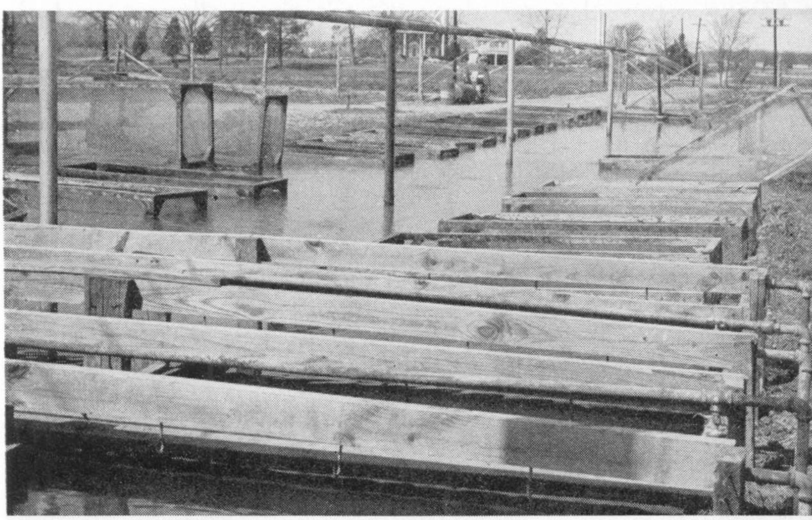


FIGURE 14. Concrete holding pond, holding cages, and overhead sprinkler system that are used at Clark's Minnow Hatchery, Decatur, Ala. This pond can be drained and cleaned when necessary.

may be built out into the pool and paralleled by rows of cages if additional holding space is needed. A simple sprinkler system of perforated galvanized iron pipes should be installed several feet above the cages; water from the pool is sprayed onto the water's surface in and around the cages (Figure 13). A small electric centrifugal pump may be used to circulate the water through the system. The number of minnows that may be held in cages of the size just described and the number of cages per unit area will vary from hatchery to hatchery. However, a little experience will enable the hatcheryman to determine the number that may be held in his particular pool.

A more expensive but perhaps a better holding facility is a concrete pool large enough to hold the desired number of cages (Figure 14). The pool need only be deep enough to fill the cages to within about 6 inches of the top when they are suspended 2 to 3 inches above the pool bottom. Fresh water is allowed to enter continuously in pools of this type, the foul water being carried off by a discharge pipe set even with the bottom of the pool. The desired water level is maintained by a standpipe installed outside of the pool. The fresh water entering the pool should be sprayed in and around the cages by an overhead sprinkler system. This type of pool is suited only to hatcheries having a large, permanent water supply. Holding pools should be located as close to the counting and sorting sheds as possible. They should be protected from fish-eating birds and other animals by fences or other devices.

Minnows in the quantity desired may be removed from the cages with long-handled dip nets. The dip nets should be square or rectangular to permit dipping in the corners and along the sides of the cages. Fine netting is available from most of the large net and twine companies. It should be used on the dip nets because coarse material will scale the fish, causing them to be more susceptible to disease.

METHODS *of* HATCHERY MANAGEMENT *for* BAIT MINNOW PRODUCTION

Good minnow pond management is impossible, or extremely difficult, with poorly constructed ponds or inadequate facilities. On the other hand, the best minnow plant that could be built would be an unproductive aquatic farm without the application of the proper techniques of stocking, rearing, handling, and disposing of minnows. It is not the purpose of this circular to emphasize either hatchery construction or pond management, but to treat them as an integrated system of minnow production.

Propagation and rearing of minnows is not an exceptionally complex procedure. By using proper techniques, however, production per unit area may be markedly increased over haphazard methods.

Detailed methods of hatchery operations for the production of goldfish, fathead, and golden shiner minnows have been developed at this Experiment Station. These methods as well as information on parasites, pests, and their control and related subjects are presented in the sections that follow.

Goldfish Production

The goldfish is perhaps the best species of minnow to raise commercially for bait in the Southeastern States. It lives well in crowded containers even during hot weather, reproduces in large numbers in small ponds, and attains a desirable size within a few months. Depending upon the size of the minnow, it can be used as bait for crappie, catfish, jackfish, and bass.

Since goldfish and carp belong to the same family (Cyprinidae), many people have the mistaken idea that the two fish have similar habits and that the goldfish will, therefore, root around on the pond bottom and cause the pond to be muddy. Even in very crowded rearing ponds, however, goldfish do not roil the water.

Although there are numerous published statements to the contrary, experiments at Auburn, Alabama, over a period of 12 years have shown that goldfish are not harmful to ponds and lakes stocked with largemouth bass and bluegills.

Observations on several hundred ponds and lakes in the Southeast in which goldfish have been used for bait by fishermen have shown that this species was not detrimental since the numerous bluegills prevented the goldfish from reproducing successfully by eating their eggs *(5)*. The few goldfish that evaded the largemouth bass often grew to a size of 3 to 5 pounds each, but in no pond had the goldfish become numerous or harmful.

Florida prohibits the use of goldfish and some other states may also limit their sale. Therefore, local regulations should be checked before a goldfish hatchery is contemplated. Such information may be obtained by writing the state game and fish commission or from the local county judge or game warden.

In the production of goldfish for bait, there are several methods that can be used to rear the young. These methods may vary with the individual operator, but regardless of the method used there are certain features that are common to all methods. These features will be discussed under the following headings: spawning habits, selection of brood stock, raising brood stock, wintering brood stock, and sexing.

Spawning Habits. Goldfish normally begin laying eggs when the water temperature approaches 60° F. in the spring. They will continue to spawn throughout the summer while the water temperature is above 60° F. if well fed and not crowded by either other adults or young goldfish. At Auburn, Ala., the first

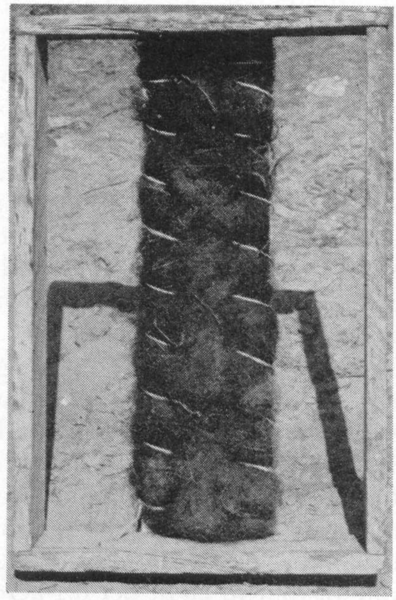


FIG. 15. Spawning mats are constructed by making a rectangular wooden frame approximately 18″ x 36″ of 1″ x 2″ stock. A strip of 1″ mesh chicken wire 6″ x 3′-0″ covered with Spanish moss, wood excelsior, or similar material is stapled to this frame.

FIG. 16. The spawning mat is staked along the edge of the pond within easy reach. Goldfish are shown below swimming across the pad of Spanish moss in the act of spawning.

goldfish eggs are usually found in late February. However, each year most of these early eggs are killed by subsequent cold weather, leaving only a small number of young goldfish from these early eggs.

The peak of egg laying occurs on sunny days in the early morning just after sunrise, although eggs also may be deposited in the late afternoon or at any time on cloudy days. As the laying period approaches, the males may be observed "driving" or chasing the females around the pond.

In early spring, when the water reaches about 60° F., the female begins laying eggs on grass, roots, leaves, or similar material. The eggs are fertilized almost immediately by the males. The eggs are adhesive and stick to any object they touch. In the absence of grass, leaves, or roots, the eggs are laid along the edge of the pond just under the water surface and adhere to rocks, sand, or clay on the pond bottom. Consequently, it is essential that the water be maintained at a constant level during the spawning period in ponds where floating or submerged mats are not used to collect spawn.

Spawning mats are light-weight wooden frames, rectangular or square in shape with a narrow band of chicken wire or some similar material across the middle of one side (Figure 15). Spanish moss, excelsior, or grass is attached to the chicken wire with twine. These mats should float with the padded side up and about 2 inches beneath the surface of the water (Figure 16). They should be staked around the edges of the pond (Figure 17) at the rate of four to eight per 0.1-acre pond. The number of spawning mats in a pond should be sufficient to prevent the eggs from overlapping as this reduces the hatch. Since the eggs are adhesive, they adhere to one another quite readily and where they are touching the percentage of hatch is lowered.

At water temperatures of about 60° F., eggs usually hatch in 6 to 7 days. Only 3 days are required for hatching when the water temperature increases to about 80° F. The eggs are clear when laid. As they develop a brown spot forms in them but the margins remain clear. When the egg is not fertilized or the embryo dies, the egg turns cloudy and opaque. The dead eggs become covered with mold if allowed to remain in the pond for several days (Figure 18).

Each female may deposit 2,000 to 4,000 or more eggs at a single laying and may spawn several times in the spring. The parent goldfish give no protection to the eggs or young fish. If

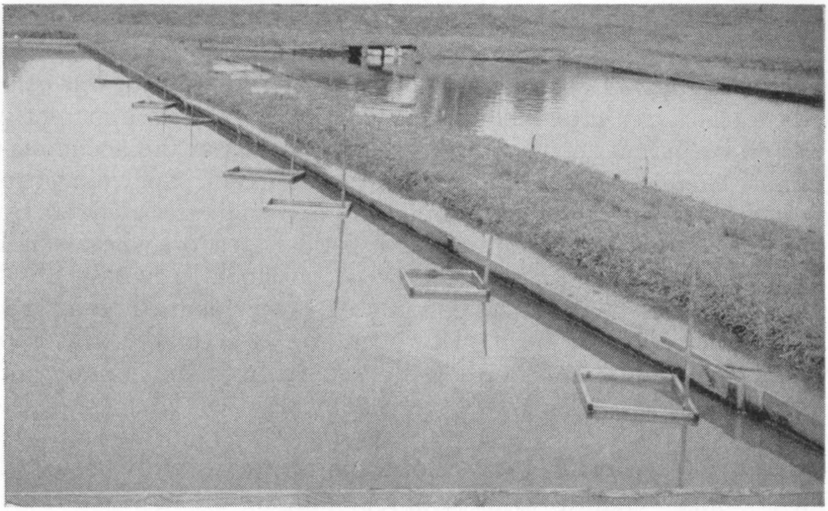


FIGURE 17. Where goldfish eggs are to be transferred (Methods II and III), the sides of the pond are boarded up so that the goldfish cannot lay on grass or roots along pond edge. Spawning mats are staked inside the board-enclosed area at the rate of 4 to 8 per each tenth-acre pond.

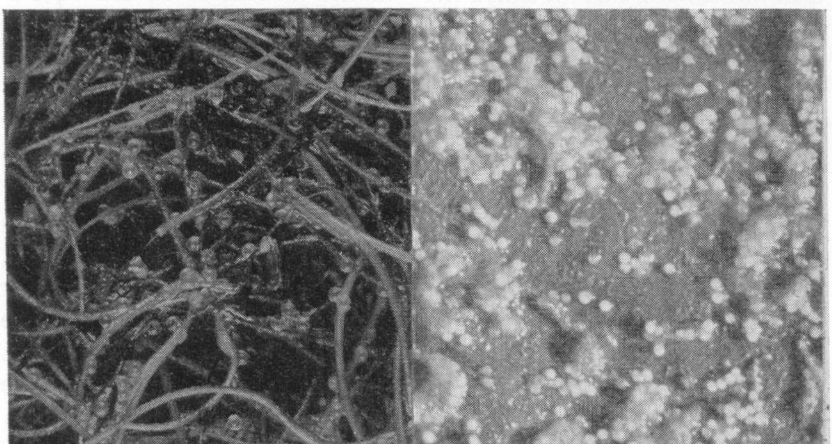


FIGURE 18. At left are good, live goldfish eggs as they appear on Spanish moss. Right: Dead goldfish eggs turn white and become covered with mold.

eggs are not transferred to other ponds, spawning usually continues for several weeks or until the fry are about 1 inch long. When that size is reached, the fry begin to eat the eggs, and the brood fish quit laying. The fact that goldfish quit spawning when crowded is a unique method of birth control not too well understood. When eggs are laid on mats and are transferred from brood ponds, egg laying continues over a much longer period, but usually it decreases after about 1 or 2 months. This is apparently caused by hatches of young in the brood ponds or the accumulation of chemical agents preventing reproduction. Spawning can be started again by flushing out the pond with fresh water, by partially draining and refilling with fresh water, or, where small fish are present, by transfer of the brood stock to freshly filled new ponds. Hatches have been produced by this method as late as October 15 at Auburn. However, the later in the year the brood stock were transferred, the smaller was the number of eggs laid.

Selection of Brood Stock. Goldfish approximately 8 to 12 inches long, weighing ¼ to ¾ of a pound, are the most desirable as brood fish, although smaller ones about 4 inches long can be used. Initially, these brood goldfish can be purchased from some hatchery as adults or raised from fingerlings. They should be examined with care because they should be free of external parasites (see page 58) and be in good condition. In many cases the selection of parasitized brood stock has resulted in the loss of the entire crop. Once these parasites are introduced, it is necessary to destroy the brood stock and poison the pond to eradicate them (see page 64). The importance of obtaining brood fish free of parasites cannot be overemphasized.

Fishermen seem to prefer the common dusky brown- or straw-colored goldfish for bait rather than the highly colored red ones, although fish apparently are not as particular. Fortunately for the bait raiser, only small percentages of the young minnows are so highly colored as to be objectionable to the average fisherman. However, in stocking ponds, brown-colored brood fish should be used.

Raising Brood Goldfish. To raise brood stock, large selected brown goldfish fingerlings should be stocked in ponds chosen for this purpose. These ponds should be stocked in the summer at a low rate and be fertilized and fed. This is necessary so that the fish will grow rapidly and will be suitable for use as brood stock during the second year of growth. New brood fish for replacement will have to be raised annually since there is a loss of about one-third of the brood stock each year.

The procedure for raising brood goldfish is as follows:

(1) Stock selected brown goldfish minnows at the rate of 5,000 per acre.

(2) In Alabama, stock the ponds approximately August 1; for areas farther north, stock up to one month earlier.

(3) Fertilize with the equivalent of an 8-8-2 fertilizer (see page 38) at the rate of 200 pounds per acre per application. The first application should be applied when the pond is filled. The second and third applications should follow at 2-week intervals; subsequent applications should follow at 3-week intervals until the water temperature drops below 50° F.

(4) Feed soybean meal or hog supplement-poultry laying mash mixture (see page 39) at the following rates for Alabama and neighboring states:

Month	*Rate per acre per day*
First (August)	10 lb.
Second (September)	20 lb.
Third (October)	30 lb.
Fourth (November)	40 lb.
Fifth (December)	30 lb.

(Check ponds and reduce feeding when food is not being utilized because of low water temperature.)

(5) Drain pond in December, or January, and concentrate fish in a wintering pond.

Wintering *the* Brood Stock. The brood fish for the current year's production should be concentrated in small wintering ponds and kept in a crowded condition during the period of January to March. This is necessary to prevent, or at least reduce, egg laying until the danger of cold weather is passed.

Where this is not done, goldfish may lay heavily during the first warm days in February or March and subsequent cold weather will kill most of the eggs. As a result only small numbers of goldfish hatch. After the young fish are a few days old they will eat practically all eggs subsequently laid or stocked in the pond.

While the fish should be kept crowded, they must also be kept in good condition if heavy egg production is to be expected. This makes feeding necessary while the fish are in the wintering ponds.

The procedure for wintering brood fish in the Southeast where ice and snow are not problems is as follows:

1. Select for wintering ponds 0.1-acre ponds with steep sides, free of trash and grass and with depths not over 5 feet. Fill with water.
2. Stock each 0.1-acre wintering pond with 3,000 to 5,000 brood fish in late December or January.
3. Feed the brood stock in these ponds each day with 6 pounds of soybean cake or meal, or with a mixture of 3 pounds of hog supplement and 3 pounds of poultry laying mash. If the fish are not utilizing the food, the rate should be reduced.
4. Subsequently, regulate the water intake so that the water level is maintained but do not allow a heavy stream of water to flow through the pond as this will stimulate spawning.
5. Drain the wintering ponds when severe cold spells appear to be over (the last of March at Auburn, Ala.).
6. Transfer the brood fish immediately to the brood ponds (see page 30) or the combination brood and rearing ponds.

How *to* Determine *the* Sex *of* Brood Fish

During the spawning season, males may be easily distinguished from females by the presence of tiny tubercles, commonly called whiskers, on the sides of the head and on the front edges of the pectoral fins. These tubercles are quite small and both look and feel like tiny grains of sand or a stubble beard. They are present only during the spawning season.

Goldfish Rearing Methods

Three methods of rearing goldfish are explained. The basic differences among the three methods are as follows:

METHOD I, (Simple Combination Method). Egg laying, hatching, and growing of young to bait size all occur in the same pond.

METHOD II, (Egg Transfer Method). A brood pond is provided for egg laying and the eggs are then transferred to separate ponds for rearing the young to bait size.

METHOD III, (Fry Transfer Method). A brood pond is provided for egg laying, the eggs are transferred to hatching ponds and troughs, and the newly-hatched fry are subsequently moved to rearing ponds.

Factors influencing the selection of the method used are the amount of pond space available, the know-how of the producer, and the demand for bait. Probably Method I is in widest use because it is adapted to the needs of a small inexperienced producer. Large producers may use either Methods II or III since they allow better utilization of pond space. The new producer must consider his own situation and select the method or combination of methods best suited to him.

METHOD I, (Simple Combination Method). In this method the pond is stocked with brood goldfish at the rate of 200 to 300 per acre after danger of frost has passed. Sexes should be approximately equal in number. Spawning mats should be placed in the ponds to supplement the grass and trash already present. The young fish are allowed to hatch out and remain in the same pond with the adults.

This method is quite simple, takes very little experience or supervision, and may be used in both single ponds or in a series of ponds. The disadvantages of this method are that there is less control of the number of young produced and more of a possibility of parasites being transferred from adults to young. Parasites may become a serious problem in hatcheries where adequate measures are not taken against introduction and for control.

From this method production of 80,000 to 350,000 with an average of 120,000 bait minnows per acre may be expected from one crop. The poundage and resulting size of the minnows depend on the rate of feeding and fertilization, and whether one or two crops are raised each year. Just as many pounds per acre can be raised by this method as by any other under normal conditions; but due to variable hatches there is danger of raising oversized fish unless the ponds are examined monthly and rates of feeding adjusted. When ponds are managed by this method, regular fertilization (page 38) and supplemental feeding rate No. I (Table 5) should be followed. Periodic checks on the size of the minnows with a seine will assist in proper management. From the average size of goldfish found in the seine, the feeding can be increased or decreased to obtain the size minnow desired. If only one crop per year is to be raised, the goldfish should reach a desirable size by December so that they have 2 months in which to "harden" before harvest. "Hardening" is a process whereby goldfish that are grown rapidly are carried on a reduced feeding program for from 2 to 4 weeks. This causes a small loss in weight but produces a hardier minnow. In any event, fertilization should not be stopped until cold weather as this represents the cheapest form of production.

The procedure for rearing goldfish by Method I is as follows:

1. Fill the pond about March 1, or 1 to 2 weeks before stocking and begin fertilization immediately at the rate of 200 pounds of 8-8-2 per acre or its equivalent.

Second and third applications should follow at 2-week intervals and subsequent applications at 3-week intervals until the pond is drained or until the water temperature drops below 50° F. in the fall.

2. Stock the brood goldfish at the rate of 200 to 300 per acre (½ males and ½ females) after the danger of frost is passed. (The last of March at Auburn, Alabama.)

3. Immediately after stocking start supplemental feeding at the rate of 10 pounds per acre per day (see feeds, page 39) and subsequently adjust to obtain the size of minnow desired.

4. If the minnows are of usable size and the demand warrants, the minnow ponds can be drained 2 to 4 months after stocking (about July 1-15 at Auburn, Alabama) or they can be carried over to the fall, winter or spring.

5. If the crop is harvested in the summer, the pond should be refilled and restocked as is shown in steps 1 and 2 above.

6. The second crop will be ready for harvest the following January to March.

METHOD II (Egg Transfer Method). This method requires a series of at least 8 to 10 ponds and considerable experience in hatchery operations; also daily supervision is a necessity during the spawning season. Its advantages are that some control over the number of goldfish in a pond may be exercised by regulation of the number of eggs stocked, and the transmission of parasites from brood fish to the young is reduced.

The brood goldfish are stocked after the danger of frost is over unless heating facilities are available to hatch eggs in the event of sudden cold. Depending on their size, they are stocked at the rate of 300 to 2,000 for each 0.1-acre – that is a 0.3-acre pond would be stocked with 900 to 6,000 brood goldfish. The brood ponds should be boarded up around the sides from 2 feet below to 1 foot above the water level and the grass and trash in the water removed to discourage spawning other than on the spawning mats.

Spawning mats to collect the eggs are staked around the pond at the approximate rate of 4 to 8 for each 0.1-acre (Figure 17). The mats are transferred to rearing ponds twice daily and the young minnows hatch and are reared in these ponds. Since the goldfish may start eating eggs soon after the absorption of the yolk sac, additional mats should not be transferred to a rearing pond for more than 7 days after the initial ones. *The rearing ponds should be filled just prior to the transfer of the spawning mats.* This prevents an accumulation of aquatic insects that destroy the eggs and young goldfish.

As the mats are transferred, the total number of eggs should be estimated. Normally, only half of the eggs transferred from brood to rearing ponds can be expected to survive; thus a production of not more than 200,000 to 300,000 goldfish per acre can be expected from a transfer of from 400,000 to 600,000 eggs.

Before the pond is stocked, the size goldfish that will be most readily salable should be known. Then with one of the regular fertilization and feeding programs the pond can be stocked to obtain the maximum number of minnows of the desired size.

Suppose, for example, it is desired to produce goldfish 2.1 to 2.4 inches long, using fertilization plus a heavy rate of feeding (Rate III, Table 5). In Table 1, the number of eggs that must be stocked to raise approximately this size minnow is given as 675,000 per acre. If the pond is 0.2 acre, then the number to be stocked will be:

$$675{,}000 \times 0.2 = 135{,}000 \text{ eggs}$$

On the average, half the above eggs or newly hatched fish will die, resulting in approximately 67,500 minnows of the desired size

TABLE 1. THE ESTIMATED NUMBER OF EGGS THAT SHOULD BE STOCKED IN REARING PONDS TO PRODUCE MINNOWS OF VARIOUS SIZES FOR GIVEN POND TREATMENTS

Pond treatment[1]	Production per acre	Eggs to stock per acre to obtain bait minnows of the following average total length in inches				
		1.6-2.0	2.1-2.4	2.5-2.8	2.9-3.2	3.3-3.6
Soybean meal[2]	*Pounds*	*Number*	*Number*	*Number*	*Number*	*Number*
Rate I (2,530 lbs.)	1,800	850,000	550,000	300,000	200,000	150,000
Rate II (4,470 lbs.)	2,100	975,000	650,000	340,000	250,000	175,000
Rate III (6,410 lbs.)	2,250	1,000,000	675,000	350,000	260,000	190,000

[1] All treatments received fertilizer at the rate of 2,600 pounds of 6-8-4 and 130 pounds ammonium nitrate per acre. (See page 38.)

[2] Feeding schedules for the rates are given on page 41.

in the 0.2-acre pond at harvest. It must be kept in mind that the presence of large number of predaceous water bugs or of wild fish will greatly reduce the survival of goldfish. Where this occurs, a smaller number of goldfish of larger size will result.

The procedure for rearing goldfish by Method II is as follows:

1. Select as brood ponds 0.2- to 0.4-acre ponds with steep sides, free of trash and grass and with depths not over 5 feet. Board up the side of the ponds from 2 feet below to 1 foot above water level.
2. After the danger of frost is passed, stock prepared brood ponds with brood goldfish (equal numbers of male and female goldfish) at the rate of 300 to 2,000 per 0.1-acre. With the heavier rates of stocking, a constant stream of fresh water must be run continuously through the brood ponds during the egg-laying period to stimulate heavy spawning.
3. Fertilization should be started in the brood ponds at the time of stocking and continued until frost in the fall (See Fertilization, page 37).
4. Feeding should be started in the brood ponds at the time of stocking and continued throughout the summer at the rate of 6 pounds of soybean cake per 0.1-acre per day.
5. As soon as the brood fish are stocked, spawning mats should be added to the brood pond at the rate of 4 to 8 per 0.1-acre.
6. Examine the mats at least once and preferably twice each day. When eggs are found (see Figure 18), the number on each mat should be estimated, and the mat should be removed and replaced with a new mat.
7. The mats bearing eggs should be moved to the freshly filled rearing pond. Exposure of the eggs to air for periods not in excess of 30 minutes is not harmful to the eggs, if they are shaded from strong sunlight and protected from drying winds.
8. Mats should be staked in rearing ponds, as illustrated in Figure 19, so that they will float up or down with changes in water level, yet may be easily reached from the bank for removal after the eggs hatch.
9. After the eggs have hatched the mats may be removed from the rearing pond.
10. All eggs should be placed in a given rearing pond within a 7-day period.
11. Spawning mats can be transferred to new rearing ponds throughout the summer as long as spawning continues. When

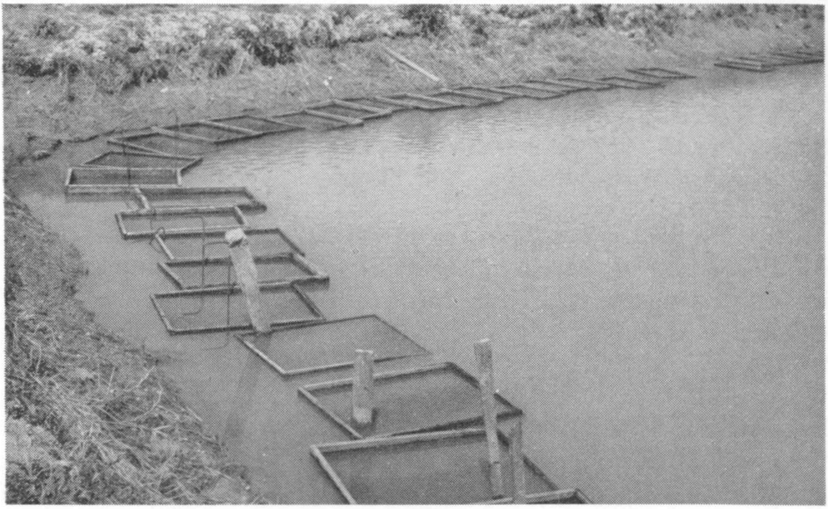


FIGURE 19. Mats containing eggs are removed from the brood ponds daily and are staked out in a rearing pond, as shown here. After the eggs hatch, the mats are removed, dried in the sun, and are then again ready for use.

spawning decreases or stops in July or August and the brood fish are in good condition, the brood pond should be examined for the presence of small fish. If small fish are present spawning can usually be started again by draining the brood pond, removing all fish and then refilling and returning the brood stock to the pond. If no small fish are present, spawning can be induced by partially draining and refilling the pond with fresh water.

12. Fertilization of the rearing pond should be begun immediately after it is filled and should be continued until the pond is drained or until the first frost (see Fertilization, page 37 for rates and frequency).

13. Feeding according to the selected program (either rate I, II, or III, Table 5) should begin immediately after the rearing ponds are stocked and continue until the pond is drained. Sampling with a seine to determine the size of the minnows will indicate whether the feeding rate needs to be regulated. If food is not being utilized, the feeding rate should be reduced; if the minnows are not growing at a satisfactory rate it should be increased.

14. The crop of fish can be partially harvested by seining after some of the minnows are of salable size. The large minnows to be removed can be separated by the use of fish graders (page 66).

15. When a pond is drained it should be allowed to remain dry or should be partially refilled and poisoned (page 64) to kill the remaining fish.

16. When a rearing pond is drained in the summer (June-September 15), it can be restocked using the same procedures followed in the spring if eggs are available.

METHOD III. (Fry Transfer Method). In Method III as in Method II the brood fish are concentrated in brood ponds during the egg-laying period. However, in this method, when the mats covered with eggs are transferred they are placed in tanks or troughs where the eggs hatch. These tanks may be covered or the water heated to prevent the death of eggs and newly hatched fry from sudden cold waves. This insures early hatches, but, where there is no attempt to raise minnows for market in 3 or 4 months, early hatches are not necessary. After the fry are 3 to 5 days old the numbers are carefully estimated and they are transferred to rearing ponds. The number of goldfish can be estimated with sufficient accuracy by counting a given number into a white-bottom pan containing 1 to 2 inches of water and then adding fish to similar pans until they appear to contain equal numbers (Figure 20). While matching the numbers, the pans should be rotated slightly to cause the fish to arrange themselves more or less uniformly throughout the water. With a little practice the numbers can be estimated with less than a 10 per cent error. Fry should be handled carefully with fine nylon netting or by

FIGURE 20. In transferring goldfish fry to rearing ponds, the numbers are estimated by comparison, as shown here. Into the pan at left, 500 minnows were carefully counted. Without counting, minnows were then added to the pan at right until their density appeared equal to that on left. The actual number in the pan at right was 489.

use of a dipper to prevent heavy loss. In handling fry an average mortality of 25 per cent should be expected and allowed for.

This method requires more labor than either I or II because of the extra step. The advantages are that early hatches are possible where heat or protection from cold is available, the numbers stocked may be controlled and the transmission of parasites to the young from the brood fish is greatly reduced or eliminated.

If the desired length of salable minnows is known, refer to Table 2 for pond treatment and numbers of fry to be stocked to produce this length minnow. For example, if fertilization plus soybean meal, Rate III, is the treatment to be used, approximately 700,000 fry will have to be stocked per acre to obtain a production of 2,250 pounds of minnows averaging 1.6 to 2.0 inches in length.

TABLE 2. ESTIMATED NUMBER OF FRY THAT SHOULD BE STOCKED TO PRODUCE MINNOWS OF VARIOUS SIZES FOR GIVEN POND TREATMENTS

Pond treatment[1]	Production per acre	Number of fry to stock per acre to obtain bait minnows of following sizes. Total length in inches				
		1.6-2.0	2.1-2.4	2.5-2.8	2.9-3.2	3.3.-3.6
Soybean Meal[2]	*Pounds*	*Number*	*Number*	*Number*	*Number*	*Number*
Rate I (2,530 lbs.)	1,800	550,000	350,000	200,000	140,000	100,000
Rate II (4,470 lbs.)	2,100	650,000	425,000	225,000	160,000	110,000
Rate III (6,410 lbs.)	2,250	700,000	450,000	250,000	170,000	125,100

[1] All treatments received fertilizer at the rate of 2,600 pounds of 6-8-4 and 130 pounds ammonium nitrate per acre (see page 38).

[2] Schedules for the feeding rates are given on page 41.

The procedure for raising goldfish by Method III is as follows:

1. For brood ponds select 0.2- to 0.4-acre ponds with steep sides, free of trash and grass and with depths not over 5 feet. Prepare the ponds by boarding up the sides from 2 feet below to 1 foot above water level.

2. After the danger of frost, stock prepared brood ponds with brood goldfish (approximately equal in sexes) at the rate of 300 to 2,000 per 0.1 acre. With the heavier rates of stocking, a constant stream of fresh water must be run continuously through the brood pond during the egg-laying period to stimulate heavy spawning.

3. Fertilization should be started in the brood ponds at the time of stocking and continued until frost in the fall (see Fertilization, page 37).

4. Feeding should be started in the brood ponds at the time of stocking and continued through the summer at the rate of 6 pounds per 0.1 acre. Either soybean meal or cake or a mixture of 50 per cent poultry laying mash and 50 per cent hog supplement can be used as a food. (See page 39.)

5. Immediately upon stocking the brood fish, spawning mats should be added to the brood pond at the rate of 4 to 8 per 0.1 acre.

6. Examine the mats at least once, and preferably twice each day. When eggs are found (see Figure 18) the mats are removed and replaced with new mats.

7. The mats bearing eggs should be moved to hatching tanks or troughs.

8. When the young fry are three or more days old, they are ready to be stocked.

9. The rearing pond should be filled just 1 week prior to stocking to prevent an accumulation of aquatic insects that are predators on young fish.

10. Lower the water in the hatching tank or trough and remove goldfish either with a fine net or by carefully dipping them out with the remaining water.

11. Stock fry in rearing ponds at the desired rate.

12. Fertilization of the rearing pond should be begun immediately after it is filled and should be continued until the pond is drained or until the first frost. (See Fertilization, page 37 for rates and frequency.)

13. Feeding according to the selected program (rates I, II, or III, Table 5) should be begun immediately after the rearing pond is stocked and be continued until the pond is drained. The feeding can be regulated when shown necessary by sampling with a seine to determine whether or not food is being used. If food is not being utilized, the feeding rate should be reduced; if the minnows are not growing at a satisfactory rate it should be increased.

14. The crop of fish can be partially harvested by seining after some of the minnows are of salable size. The large minnows to be removed can be separated by the use of fish graders (page 66).

15. When the pond is drained it should be allowed to remain dry or should be partially refilled and poisoned (page 65) to kill stray fish that remain.

16. When a rearing pond is drained in the summer (June-

September 15), it can be restocked using the same procedures followed in the spring if eggs are available. However, it should be remembered that the peak of egg laying occurs early in the spring and that large numbers of young will not be available in late summer.

GENERAL GOLDFISH HATCHERY PROCEDURES

Fertilization

The production of goldfish in unfertilized ponds and without feeding is not profitable since the amount of food in such waters is small. Commercial fertilizers will increase the production of microscopic plants and animals (plankton) upon which the goldfish feed. While it is most profitable to raise goldfish with fertilization plus the use of supplemental feeds, fertilization alone will produce about 900 pounds of goldfish per acre per year.

Fertilizers, if properly used, will prevent weed growths that hinder draining operations and utilization of feeds by the fish. When the water has a dense plankton growth, underwater weeds are shaded out and will die.

Fertilizers do not greatly increase food production for fish in ponds that remain muddy for long periods of time nor where there is constantly a very heavy flow of water. Since microscopic plants utilize the fertilizer materials only in the presence of light, it is essential for highest production that the water supply remain free of mud so that the light can penetrate the water and promote growth. Fertilizer and fish foods are lost in water flowing from ponds. The inlet valve usually should be regulated so that the pond remains full but does not overflow.

Kinds *of* Fertilizer *to* Use. The fertilizers normally used in fish ponds *(6)* are satisfactory for use in minnow ponds. Experiments have shown that a fertilizer containing 8 per cent available nitrogen, 8 per cent available P_2O_5 and 2 per cent available K_2O produces plankton most economically in this region. In some areas an 8-8-2 commercial fertilizer is available especially for use in ponds. Where an 8-8-2 is not available, equally good results can be obtained with 6-8-4 if sufficient ammonium nitrate or nitrate of soda is added to bring the nitrogen content up to 8 per cent. If neither 8-8-2 nor 6-8-4 is available, a readily available fertilizer may be purchased and the ratio adjusted with additional nitrogen and superphospate.

Rate *of* Fertilization *per* Acre. Minnow ponds should receive one of the following amounts of fertilizers per acre at each application:

1. 200 pounds of 8-8-2
   or
2. 200 pounds of 6-8-4,
   plus
   20 pounds of nitrate of soda
   or
3. 200 pounds of 6-8-4,
   plus
   10 pounds of ammonium nitrate
   or
4. any mixture that will give approximately
   16 pounds available nitrogen
   16 pounds available P_2O_5 (phosphoric acid)
   4 pounds available K_2O (potassium)

Frequency *and* Method *of* Application. The first application of the selected fertilizer mixture should be made 2 to 4 weeks before the brood fish are added in Method I (page 29) or as soon as the pond is filled. In Methods II (page 30) and III (page 34) fertilization should be started when the rearing ponds are filled. The next two applications should be made at 2-week intervals, and subsequent applications at 3- or 4-week intervals, so that the pond will remain highly colored with the tiny plants upon which goldfish feed. For highest production the food supply must be maintained by periodic fertilization. A total of 13 or 14 applications should be used each year. Fertilization should be discontinued in the fall at the advent of the first frost.

The fertilizer should be broadcast from the bank into the shallow areas of the pond. Since the plant nutrients go rapidly into solution and wind and wave action usually distribute them adequately, it is not necessary to broadcast the fertilizer over the entire pond.

Supplemental Feeding

The highest production of goldfish has been obtained as a result of daily supplemental feeding in addition to fertilization. Numerous concentrates including wheat shorts, low-grade wheat flour, rolled oats, cornmeal, poultry laying mash, hog supplement, cottonseed meal, and soybean meal are frequently used. Stomach analyses and field observations indicate that goldfish consume these supplemental feeds quite readily. In addition, those materials not utilized directly as food act as organic fertilizers and increase plankton production considerably. Also, Swingle *(4)* indicated that organic materials increased fish production when used in combination with inorganic fertilizers by supplying additional carbon dioxide which is believed to be an important limiting factor on plankton production in recently filled ponds.

Experiments conducted at this Station to date indicate that most efficient goldfish production is obtained from feeds having a protein content of from 30 to 40 per cent (Tables 3 and 4). Since there was little difference in the cost of the feeds used in this experiment, the use of the two materials that gave the highest production was obviously most profitable.

Feeds for goldfish production listed in order of decreasing value are:

1. Mixture (50 pounds hog supplement, and 50 pounds poultry laying mash).
2. Soybean meal or cake.
3. Peanut meal.
4. Poultry laying mash, Wheat shorts, Red dog flour, Cottonseed meal — No significant difference in goldfish production from these feeds. Select the feed with the lowest cost.

TABLE 3. PRODUCTION OF GOLDFISH ATTAINED IN 161 DAYS BY USE OF SUPPLEMENTAL FEEDS

Treatments[1]	Goldfish production per acre: Total[2]	Goldfish production per acre: Due to supplemental feeding	Feed required to produce a pound of goldfish
	pounds	*pounds*	*pounds*
Fertilizer only	283.6		
Fert. + wheat shorts (17% protein)	1,036.1	752.5	5.09
Fert. + poultry laying mash (20% protein)	937.7	654.1	5.85
Fert. + poultry laying mash + hog supplement (30% protein)	1,426.1	1,142.5	3.35
Fert. + soybean meal (41% protein)	1,288.7	1,005.1	3.81

[1] Ponds stocked at rate of 26,000 goldfish per acre; fertilizer treatment, six applications of 200 pounds each of 8-8-2 per acre; supplemental feed, 3,828 pounds per acre.

[2] Average results of two experiments run at different times.

TABLE 4. PRODUCTION OF GOLDFISH ATTAINED IN 175 DAYS BY THE USE OF SUPPLEMENTAL FEEDS

Treatments[1]	Goldfish production per acre		Feed required to produce a pound of goldfish
	Total[2]	Due to supplemental feeding	
	Pounds	*Pounds*	*Pounds*
Fert. only	305.9		
Fert. + wheat shorts (17% protein)	848.9	543.0	6.27
Fert. + cottonseed meal (36% protein)	890.9	585.0	5.82
Fert. + red dog flour (18% protein)	906.5	600.6	5.67
Fert. + poultry laying mash (20% protein)	1,127.5	821.6	4.14

[1] Ponds stocked at the rate of 26,000 per acre. Fertilizer treatment, four applications of 200 pounds each of 8-8-2 per acre; supplemental feed, 3,406 pounds per acre.

[2] Average of three replications.

It should be noted that although the cost of producing a pound of goldfish was cheapest where soybean meal was used, the highest poundage of goldfish per acre was obtained with a mixture of laying mash and hog supplement.

Method of Applying Supplemental Feeds. For best results the materials used in supplemental feeding should be fed daily at about the same hour and at the same location. After several days the fish become accustomed to regular feeding periods and congregate near the areas where they are fed much the same as do chickens and hogs.

It is not necessary to mix water with feeds. The dry materials are usually thrown by hand into shallow water along one side of the pond much the same as in fertilization.

Daily rate of feeding per acre. Supplemental feeding rates for young goldfish in rearing ponds (Table 5) appear to be satisfactory where there is little or no overflow of water.

Recently hatched goldfish fry are quite small and, therefore, need only small quantities of supplemental feed in addition to the tiny plants and animals upon which they normally feed. Although many hatcherymen feed recently hatched fry every 2 to 3 hours for the first several days, such frequent feeding is not necessary since the young fish have abundant quantities of nat-

TABLE 5. FEEDING SCHEDULE FOR RATES I, II, AND III

Age of goldfish in months	Pounds of feed per acre per day		
	Rate I	Rate II	Rate III
	pounds	*pounds*	*pounds*
0-1 (Apr.)	10	10	10
1-2 (May)	10	10	10
2-3 (June)	10	20	30
3-4 (July)	10	20	30
4-5 (Aug.)	10	20	30
5-6 (Sept.)	10	20	30
6-7 (Oct.)	10	20	30
7-8 (Nov.)	10	20	30
8-9 (Dec.)	10	20	30
Fish production per acre from fertilization + feed	1,800 lb.	2,100 lb.	2,250 lb.

ural food present in fertilized ponds. A higher rate of feeding is obviously required as the minnows increase in size.

The rates of feeding shown in Table 5 can be fed safely in shallow ponds with no danger of fish being killed. Higher rates of feeding can be used. This Station has fed 50 pounds of feed per acre per day safely in shallow ponds with no overflow water without killing fish; commercial producers occasionally use up to 100 pounds of feed per acre per day where water is available to flush ponds in event of low oxygen. In hot weather, ponds should be inspected frequently where heavier rates of feeding than those listed are used since the decomposition of feces, uneaten food, and dead plankton organisms may cause the supply of oxygen to become dangerously low.

This condition is more apt to occur during long periods of cloudy weather when little oxygen is produced by the microscopic plants. When fish are found in distress from lack of oxygen, flushing the pond with fresh water should be sufficient to relieve this condition.

Goldfish, although apparently requiring as much oxygen as other minnows, can stand a low oxygen concentration for short periods because of their ability to gulp air at the surface of the water. This characteristic makes possible supplemental feeding to attain high production of this species.

The prospective minnow hatchery operator would do well to study Table 6 before deciding upon a feed or feeding rate to use. The method of producing minnows at the lowest rate per pound on a thousand fish is not necessarily the most profitable. Since the margin between cost of production and sales price is great even when the more expensive feeds and higher feeding rates

TABLE 6. THE EFFECTS OF VARIOUS RATES OF FEEDING PLUS FERTILIZATION ON THE PRODUCTION OF GOLDFISH IN 255 DAYS[1]

Treatment	Pounds feed per pound gain	Cost per pound of goldfish	Pounds of goldfish per acre
Fertilizer, 2,600 lbs. 8-8-2 (applied in 13 applications)		$ .055	996.8
Fertilizer + 3,460 lbs. poultry laying mash[2]	4.9	.143	1,703.5
Fertilizer + 2,530 lbs. soybean meal[2]	3.2	.086	1,795.2
Fertilizer + 4,470 lbs. soybean meal[2]	4.1	.111	2,090.3
Fertilizer + 6,410 lbs. soybean meal[2]	5.2	.138	2,234.6

[1] Experiments started April 4 and discontinued December 14.
[2] Approximately 2,600 pounds of 8-8-2 per acre applied in 13 applications in each experiment.

are used, the hatcheryman should be interested in the method that will produce the *highest number* of a given size minnow.

By referring to Table 6 it may be seen that fertilizer alone produced 996.8 pounds of goldfish at a cost of 5.5 cents per pound or $54.92; while fertilizer plus 6,410 pounds of soybean meal produced 2,234.6 pounds of minnows at a cost of 13.8 cents per pound or $308.37. Assuming a weight of 8 pounds per thousand fish, which is the maximum for medium grade goldfish listed on page 43, and a sales price of $20.00 per thousand, it may be seen that there was $2,492.00 worth of goldfish produced in the pond that received fertilizer only, and $5,166.00 worth of goldfish produced in the one to which soybean meal had been added. The difference in return between the two ponds after deducting fertilizer and feed costs was $2,421.00 with only the additional expense of adding feed daily to the more profitable pond.

Draining *and* Grading

When only a small portion of the minnows present are to be sold immediately, the pond can be seined or trapped. However, draining is the only satisfactory method for harvesting the entire crop.

Before a pond is drained, there must be facilities to haul, grade, hold and dispose of the minnows harvested.

When the minnows are needed, the pond can be partially drained and the minnows concentrated in either the catch basin or holding pool. If the minnows are concentrated for an hour or more, fresh water should be passed through the catch basin. Fish concentrated in this manner can be removed quite readily with a small minnow seine or dip net and transferred to tanks or drums of water.

The fish can be counted and graded for size when harvested or held ungraded in holding pens or tanks. If the minnows are in poor condition as the result of harvesting, they should be held in tanks for 12 to 24 hours to allow the fish to overcome the shock connected with handling.

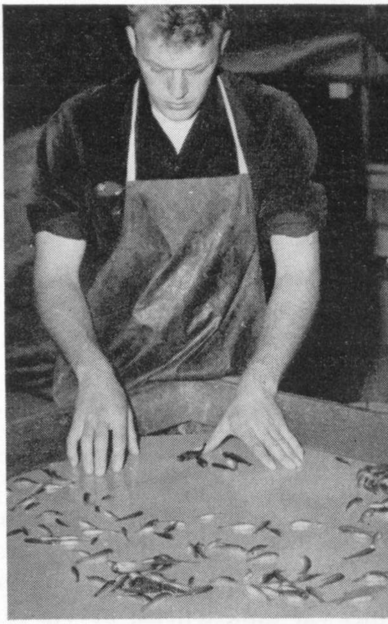


FIG. 21. Fish may be graded and counted on sorting tables surfaced with linoleum, aluminum, or plate glass. Slots are left in each corner so that the counted fish may dropped into pails of water.

Minnows can be effectively graded to size with mechanical fish graders (page 66). They may also be graded and counted simultaneously on a table (Figure 21) with a rim around the edges to prevent the fish from flopping off; slots at the corners allow the fish to be dropped into buckets of water beneath the table as they are counted. The surface of the table must be made of smooth material such as glass or lineoleum and should have a scale graduated in inches painted on it, to facilitate sorting the minnows into the size groups shown in Table 7. When the sorting table is wet, it does not injure the fish and the person grading can easily count and grade the fish and then drop them through the appropriate slot into a can of water. Usually in counting fish, it is easier and faster to count them in groups of five than singly.

TABLE 7. COMMONLY ACCEPTED GRADES OF GOLDFISH

Grade	Length	Approximate weight per thousand goldfish
	Inches	*Pounds*
Small	1 - 2	¾ to 2¼
Medium	2 - 3	2¼ to 8
Large	3 - 4	8 to 17
Extra Large	4 and over	17 and over

Each group may be counted as one and when 100 is reached, a total of 500 fish has been counted.

Where large quantities of fish are being handled, weighing is the quickest method of approximating the number. Find the average weight per thousand of the fish that are to be estimated by counting and weighing a portion, approximately 5,000 to 10,000 depending upon the total number involved. The remainder of the minnows can then be weighed and the average weight per thousand divided into the total weight of the uncounted minnows to give the number of minnows weighed.

Transportation

Hatcherymen who produce large quantities of minnows and whose retail walk-in trade is small, usually sell at wholesale prices to bait dealers and fishing camps. This necessitates transporting the minnows distances sometimes as great as a thousand miles. Large numbers of minnows are usually transported in specially constructed tank trucks; small numbers are sometimes shipped in cans via tank trucks, or via railway express. Regardless of the method used, certain precautions should be taken to insure delivery of a high percentage of lively minnows.

Since the condition of the minnows at harvest is an important factor in the success with which they may be transported, they are usually "hardened" before the rearing ponds are drained. Hardening is accomplished by reducing the feeding rate for a period of 3 to 4 weeks before draining the ponds. This results in a slight loss in weight, but produces a tougher minnow. Hardening is especially important for minnow crops that are to be harvested when less than one year old.

After the ponds are drained, the minnows should be held without food in tanks or cages (see Figure 12) for 24 to 48 hours to allow them to pass body wastes that would otherwise foul the shipping water. If, at the end of this time the fish appear to be in poor condition, they should be returned to a pond to recover.

Although minnows can be hauled in containers such as milk cans or drums, specially constructed tanks are more suitable for trips of more than 4 to 8 hours duration (Figure 22). Tanks of this type also permit larger numbers of minnows to be transported for short periods of time than could be hauled in cans or drums. Tank trucks of various designs are used successfully by bait dealers throughout the country. Probably the more satisfactory ones incorporate either a water filter and spray system,

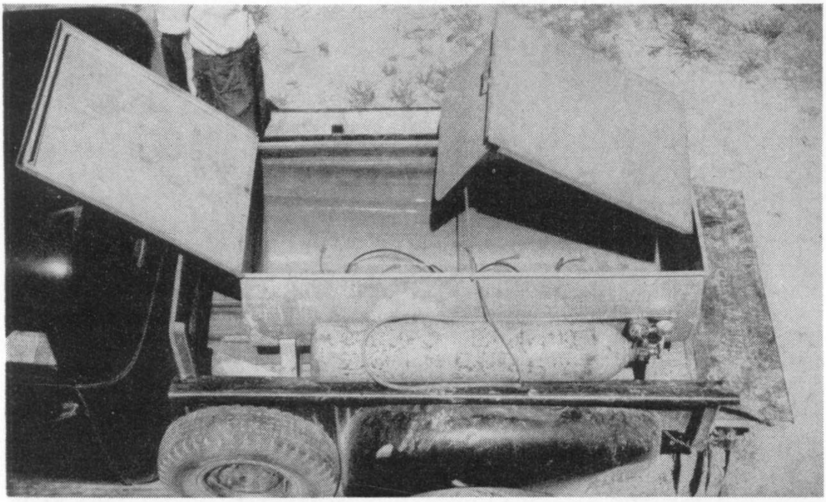


FIGURE 22. A 200-gallon transport tank may be constructed of stainless steel or aluminum. The baffle is welded to the removable lid so that it will not interfere with netting the fish. The truck also carries a tank of compressed oxygen and an oxygen regulator connected by rubber tubing to the aerator stones lying under water in the tank.

a system of aerating the water by passing oxygen through it, or a combination of the two.

In the filter and spray system the water is removed from the bottom of the tank by a small centrifugal pump and pumped through a filter containing cheese cloth or other fine material. The water thus cleansed of solid wastes is sprayed back into the tank for aeration. The spray should not fall directly on the surface of the water when transporting golden shiners (page 57).

In tanks where water circulation is not employed, aeration can be effected by bubbling oxygen through the water. The oxygen may be in pure form or it may be atmospheric oxygen. Atmospheric oxygen is pumped into the water by a common air compressor of a suitable size, while pure oxygen may be purchased in 3,000 to 6,000 liter cylinders under pressure. In either form the oxygen should be released into the water through carborundum aerator stones that break it up into fine bubbles exposing more surface and greatly increasing its rate of absorption into the water. Small valves, tees, rubber tubing and aerator stones (Figure 23) may be purchased from many of the aquarium supply companies whose advertisements appear in the aquarium trade magazines. The aerator stones should be spaced at intervals of 2 to 3 feet along the bottom of the tank to facilitate complete

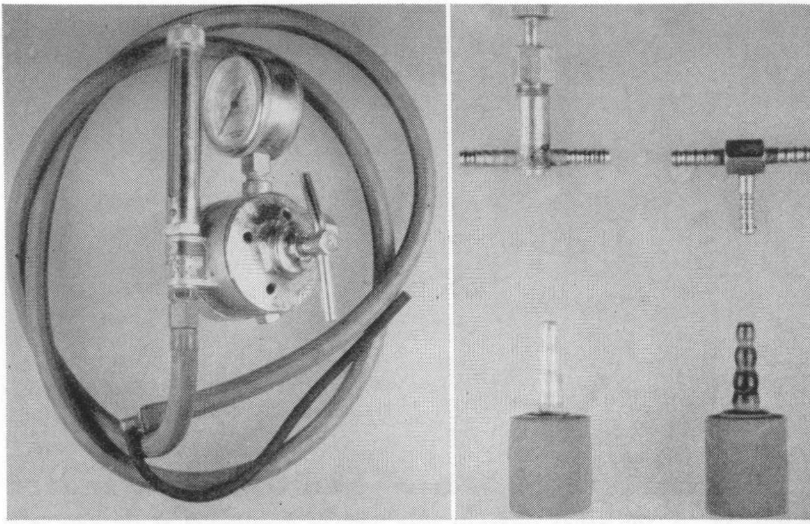


FIGURE 23. Shown here is the equipment for aeration of fish tanks with compressed oxygen. Left: Therapeutic type of oxygen regulator that can be set to release from 0.5 to 15 liters of oxygen per minute from the compressed oxygen cylinder. This is usually set to deliver between 0.5 to 3 liters per minute during transportation of fish. Right: Type of aquarium valve (top left) placed in the line to each aerator stone to regulate amount of oxygen each releases; aquarium tees (top right) used to connect several aerator stones; carborundum aerator stones (bottom) which break up oxygen into fine bubbles.

aeration of the water. A valve at each stone is necessary to regulate the amount of oxygen that passes through it; a large amount is wasteful since it does not become wholly dissolved. In addition to the valves and tees, an oxygen regulator similar to the one in Figure 23 must be used to control the tremendous pressure of the bottled gas. The type used by hospitals for therapeutic use is satisfactory and fairly inexpensive. Under normal usage the 3,000 liter cylinder will last 36 hours and the 6,000 liter one 72 hours at the approximate cost of ten cents an hour.

Minnows withstand transportation best when the water temperature is approximately 60° to 70° F. Under this condition goldfish often can be transported for short distances at the rate of 2 pounds per gallon of water. With experience, the new hatcheryman should learn the numbers of fish that he may safely transport under different conditions with his particular equipment.

In shipping minnows via railway express, the shipper assumes the major responsibility for the minnows reaching the consignee in good condition. The express company has no rigid requirements for shipping minnows; however, it has some suggestions based on experience that should be followed.

Only hardy minnows such as goldfish should be shipped, and they should be in good condition and free from fungus. Minnows that are to be shipped should have been held in tanks for at least 24 hours after removal from the pond to permit the fish to overcome shock and to pass waste products that would foul shipping water. These minnows then can be safely shipped if shipping precautions are followed.

The shipping containers may be of various sizes and shapes but should have a large diameter so that a large water surface is exposed to the air. The water should be 2 or 3 inches below the shoulder of the container if a shoulder is present or sufficiently far below the lid so that the fish are not buffeted against it. The lid should be perforated and inset below the top of the can so that ice may be placed on top of it to cool the water in transit. Small openings should be provided in the side of the can at the desired water level to drain excess water caused from melting ice and refilling the can. A shipping container considered ideal for railway express is shown in Figure 24 and one

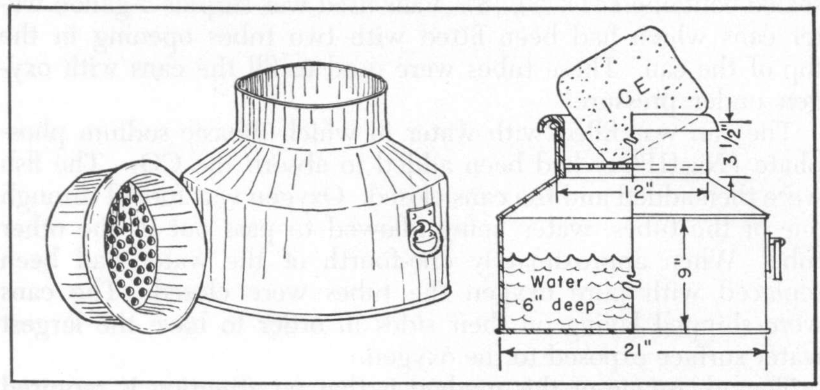
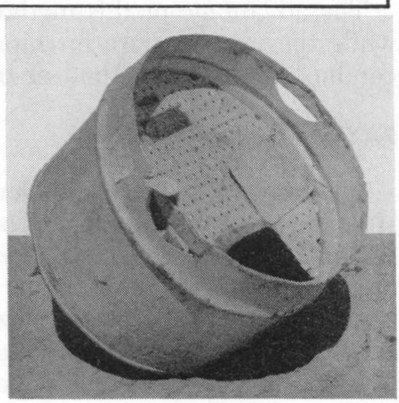


FIG. 24. Type of shipping container considered satisfactory for shipment of minnows by railway express. The recessed, perforated lid allows use of ice as illustrated.

FIG. 25. Type of container devised and used by the Clark's Minnow Hatchery, Decatur, Ala., for shipping minnows by express.



used by a large minnow producer in Figure 25. Containers should be cleaned and inspected before each shipment to see that they are in good condition and free from leaks.

Shown below is the number of goldfish railway express considers safe to be shipped in a 10 gallon container, from October 1 to March 1:

Grades	Total length	Goldfish per 10-gallon container
	Inches	*Number*
Small	1½ - 2½ inches	250 - 450
Medium	2½ - 3½ inches	150 - 250
Large	3½ - 4½ inches	50 - 150

It is desirable to reduce the number 30 per cent from March 1 to October 1 as less fish can be safely transported in warm weather.

In several other countries experimental work has been conducted to determine a method whereby fish can be shipped in sealed containers *(1)*, *(3)*, *(8)*. Vaas used war surplus 5-gallon water cans which had been fitted with two tubes opening in the top of the can. These tubes were used to fill the cans with oxygen under pressure.

The can was filled with water in which dibasic sodium phosphate (Na_2HPO_4) had been added to absorb the CO_2. The fish were then added and the cans closed. Oxygen was forced through one of the tubes, water being allowed to pass out of the other tube. When approximately one-fourth of the water had been replaced with pure oxygen the tubes were closed. The cans were shipped laying on their sides in order to have the largest water surface exposed to the oxygen.

The advantage of this method is that no attention is required while the minnows are in shipment. No experiments have been conducted on this method of transport with native minnows.

FATHEAD PRODUCTION

The fathead is a small slender minnow found naturally in many streams in the northern part of the United States. Although it seldom grows to a length of more than 3½ inches, there is a heavy demand for them in the spring of the year, especially for crappie fishing. The larger sizes are used for bass fishing and are preferred by some fishermen to either goldfish or shiners.

Fatheads can be raised in ponds and, next to goldfish are the most desirable commercial minnow. However, they cannot be easily handled in hot weather and are relatively short-lived.

Selection of Brood Stock

Fatheads may reproduce when the males are approximately 2 inches and the females 1½ inches in length; however, brood stock over 2½ inches are desirable since they usually give better results. It should not be difficult to obtain minnows of this size for brood stock since most fatheads sold for bait are at least this large.

The brood stock should be free of external parasites and in good condition; consequently, the initial brood stock should be purchased from a reliable dealer who operates a parasite-free hatchery (see Parasites, page 58). After the initial year, brood stock should be selected from the previous year's production.

Care of Brood Stock

When a pond is drained, the brood stock should be selected from the larger fish. Depending upon the time of draining, these can be restocked immediately or held in holding ponds. If they are held in holding ponds, they should be fed soybean meal or one of the two mixtures shown on page 39. They should be removed from holding ponds and stocked before the water reaches 62° F. as they will lay eggs even when held at the rate of 120,000 per acre.

Stocking

Fatheads should be stocked between February 15 and May 1 at the rate of 1,000 per acre. The sexes should be approximately equal. Cold waves following warm weather will result in loss of some eggs but this apparently does not materially reduce production.

TABLE 8. THE EFFECTS OF VARIOUS STOCKING RATES ON THE NUMBERS OF FATHEADS PRODUCED PER ACRE[1]

Stocking rate per acre	Average production per acre
Number	*Number*
500	140,000
1,000	168,000
2,000	283,000
10,000	94,000

[1] Ponds stocked February and March: Fertilization only until fall.

Sexing

The males can be distinguished from the females during the breeding season by their darker color, the presence of tubercles on the nose, and a pad on the back extending from the head to the dorsal fin. In fish of the same age, the males are always larger than females.

Spawning Habits

At Auburn, Alabama, spawning begins in the spring when the water temperature reaches 60° to 62° F. and continues throughout the summer. Spawning has been recorded as late as October 1.

The eggs are laid in shallow water on the underside of rocks, boards, and large roots (Figure 26). However, the fathead will spawn in deeper water and on trash if preferred locations are not present. When all nesting material was purposely removed from a pond, eggs were laid on the underside of leaves, small sticks, and hard clay.

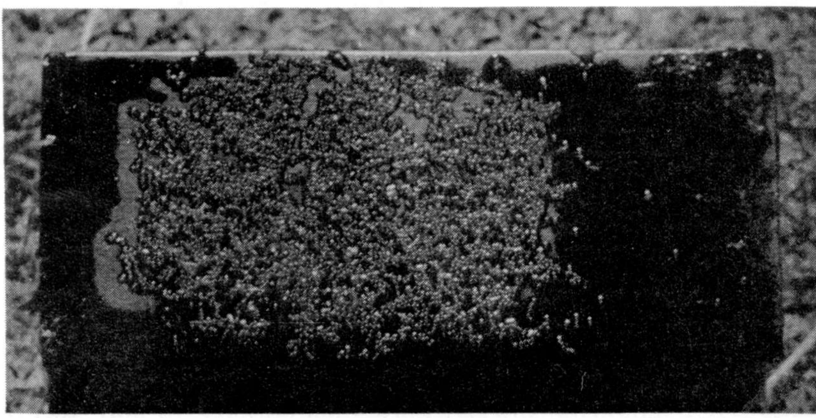


FIGURE 26. Fathead eggs are laid on the under side of firm objects, such as bricks (above), rocks, boards, and similar materials.

FIG. 27. The male fathead minnow sweeps out a nesting place underneath a rock on the pond bottom.

The male usually prepares the nest by clearing the underside of rocks and boards (Figure 27). The eggs are then deposited by the females on these surfaces. Several females often lay together, forming a layer of eggs that often covers 36 square inches. The males tend the nest constantly, rubbing the eggs with the pad that is present on the top of the head. This action by the male is apparently necessary since on several occasions where the eggs were removed and incubated without the male, a poor hatch was obtained. After spawning activity, the males begin to die and will continue to die throughout the summer. Some females die also but in smaller numbers than the males.

Management

The pond should be prepared for fatheads by placing flat rocks or spawning boards (Figure 28) in the shallow water (1 foot deep). Spawning boards are used to supplement the rocks and consist of 1 × 4-inch boards 4 to 12 feet long, staked about 3 inches above the pond bottom.

The fertilization program should be started 2 weeks before stocking and continued throughout the summer. Where feeding is started in the summer, reproduction is so heavy that it is impossible to raise all of the fatheads to a marketable size without transferring part of them to other ponds. Consequently feeding should not be started until the water has cooled sufficiently to prevent spawning. (October 1 to 15 at Auburn, Alabama.)

Feeding should be started in the fall, at the rate of 20 pounds

FIGURE 28. Spawning boards for fathead minnows are staked in the pond where the water is about 1′ deep. The boards are 1″ x 4″, 10′-0″ long, and usually are placed not over 6″ above the pond bottom.

TABLE 9. THE EFFECT OF VARIOUS RATES OF FEEDING ON FATHEAD PRODUCTION IN FERTILIZED PONDS

Treatments[1]	Feeding period	Gain over fertilization only	Total production per acre
		Pounds	*Pounds*
Fertilizer only			148.0
Fertilizer + 2,750 lbs. poultry laying mash	Nov. 1 - Feb. 18	360.4	508.4
Fertilizer + 2,900 lbs. soybean cake	Oct. 1 - Feb. 25	715.5	863.5
Fertilizer + 3,760 lbs. soybean cake	Oct. 1 - Apr. 4	1,042.8	1,190.8

[1] Fertilized Feb. 3, to Sept. 8, with 1,600 pounds 6-8-4 and 40 pounds nitrate of soda.

per acre per day. The same rate may be continued until harvest or may be increased in January or February to 40 pounds per acre per day if the minnows have not reached marketable size. Since fatheads will utilize the same supplemental feeds as goldfish, those shown on page 39 can be used.

Stocking with 1,000 adults will give an average production of 168,000 fatheads per acre per year (Table 8). With fertilization plus heavy feeding during the period October to April, a weight of approximately 1,200 pounds can be expected (Table 9) and the minnows will average approximately 2.4 inches in length. As this was the largest number of usable size fatheads that could be produced per acre at Auburn, it was not advantageous to stock brood fish at rates that produced young in greater quantity. If the pond is overstocked or higher reproduction than usual is attained, the fish must be fed at a higher rate or part of the minnows removed and transferred to new ponds. They should be stocked in these ponds at the rate of 100,000 to 150,000 per acre.

When the rearing ponds are drained, the larger fatheads, usually 85 per cent of the total crop, should be held and sold. The undersized minnows should be retained and fed one of the feeds shown on page 39. The small minnows should be transferred in January or February so that they will reach marketable size before spawning. The transfer ponds should be drained when the first eggs appear or when the water temperature approaches 60° to 62° F.

When minnows one inch or more in length are transferred an average survival of 75 per cent can be expected: the smaller the minnows the lower is the percentage survival. Therefore, if possible all minnows should be over 1 inch in length before being transferred to rearing ponds.

The procedure for raising fatheads by the fertilization-winter feeding method is as follows:

1. About 2 weeks before the anticipated spawning date, select ponds not over 0.5 acre in size and less than 5 feet deep. Place stones or spawning boards in water not over 2 feet deep.

2. Immediately upon filling the ponds, fertilization should be started at the rate of 200 pounds per acre per application (see page 38). The second and third applications should follow at 2-week intervals and subsequent applications should be made at 3- or 4-week intervals until the first frost.

3. When the water temperature approaches 60° to 62° F. (March 20 to April 15 at Auburn, Alabama) stock ponds with adult fatheads at the rate of 1,000 per acre, using approximately equal numbers of each sex.

4. Feeding should begin in the fall when the water is sufficiently cool to prevent further spawning. (October 1 to October 15 at Auburn, Alabama.)

5. Feed any of the suitable feeds shown on page 39 at the rate of 20 pounds per acre per day. The rate may be increased to 40 pounds per acre per day in January or February if most of the minnows have not reached a marketable size.

6. Rearing ponds are usually drained during the period January 1 to March 1. At this time 85 per cent of the minnows should be of salable size.

7. Those minnows too small to sell can be restocked at the rate of 100,000 per acre and grown to usable size provided there is at least one month between the time of stocking and the normal spawning period (water temperature 60° to 62° F. about March 20-25 at Auburn, Alabama).

8. The fish in the transfer ponds should be fed at the rate of 20 pounds soybean meal or cake per acre per day. This rate may be adjusted to attain the desired size minnow by harvest time.

9. All of these ponds should be drained when spawning activity is noticed and the usable minnows concentrated for disposal. Fatheads are usually not sold as bait during the period June to October because of the increased mortality from handling and transportation in warm weather.

Draining *and* Grading

The draining procedure for fatheads is the same as for goldfish (page 42); however the fatheads are not as hardy as goldfish, and must be handled with greater speed and care. Since fatheads cannot stand crowding in tanks or buckets, the use of oxygen is recommended when holding or transporting them (Figure 22).

Fatheads are graded much the same as goldfish but instead of several size groups they are separated into those large enough and those too small for bait. The size usually used for bait is 2 inches or larger but may be smaller in some localities. The smaller minnows are discarded or restocked and allowed to reach marketable size.

In minnow ponds that are in production from spring to spring, considerable difficulty is usually experienced with tadpoles.

When the fathead ponds are drained in the spring only the larger bullfrog tadpole remains. These are of such size that they can be separated from the minnows with a ⅝- or ¾-inch grader (see page 66).

Transportation

Ordinarily, fatheads are not shipped by railway express since they are not as hardy as goldfish and do not stand shipment as well. In transporting fatheads the same equipment can be used that is used for transporting goldfish. However, fatheads cannot be loaded as heavily as goldfish and greater precaution is necessary to insure safe arrival. In Alabama the transportation of fatheads is confined to the winter and spring since they may not be handled safely in summer.

GOLDEN SHINER PRODUCTION

The golden shiner is found in lakes and sluggish waters throughout the United States east of the Rocky Mountains. It grows to a length of 10 to 12 inches. There is a heavy demand for shiners in some areas of the Southeast, especially Florida, where they are the preferred bass bait.

The golden shiner can be raised in ponds but when compared with goldfish and fatheads it is the least desirable commercially. It is a soft minnow and even when handled under favorable conditions bruises easily and is subject to heavy fungus infection. In warm weather it cannot be handled at all without heavy losses.

From experiments at this Station it does not appear that golden shiners can be produced as intensively as goldfish but require an extensive type of culture.

Selection of Brood Stock

Golden shiners may reach sexual maturity when they are 3½ to 4 inches long. However, brood stock over 6 inches are desirable and usually give the best results. Under similar conditions the females are usually larger than the males so that the brood stock should not be selected on the basis of size alone.

The brood stock should be free of external parasites and in good condition; consequently, the initial stock should be purchased from a reliable dealer who operates a parasite-free hatchery or may be seined from natural waters. Regardless of where obtained, these fish should be held for a sufficient time to insure freedom from external parasites. (See Parasites and Disease of Bait Minnows, page 58). Following the initial year, brood stock should be selected from the previous year's production.

Care of Brood Stock

The brood fish should be selected when a pond is drained, and depending on the date, can be restocked in brood-rearing ponds or placed in holding ponds. If the fish are placed in holding ponds, they can be fed soybean meal at a low rate not to exceed 5 pounds per acre per day. They should not be held crowded after the water exceeds 60° F. since heavy losses sometimes occur as the result of fungus infestation.

Stocking

Golden shiners can be stocked from March 1 to May 1 at the rate of 800 to 1,000 per acre. There is no known method of externally determining the sex of shiners.

Spawning Habits

The golden shiner spawns later in the spring than either the goldfish or fathead. At Auburn, Alabama, spawning begins when the water temperature reaches 68° F. and continues throughout the summer with as many as four distinct spawns in one pond. Under natural conditions the eggs are laid in shallow water on weeds, trash, and filamentous algae. No protection is given to the eggs or recently hatched fry by the parents.

Management

The ponds used for shiner production should be filled and the fertilization program started 2 weeks before stocking and continued throughout the summer. Care should be taken to keep the ponds free of other species of fish; green sunfish, bluegills, and top minnows, are extremely detrimental in shiner ponds, reducing production severely.

The pond surface should be sprayed with diesel fuel or kerosene (see page 61) at the time of stocking and one month later to control air-breathing aquatic insects that eat small fish. Additional spraying may be necessary for predaceous aquatic insects during the summer if seining indicates they are numerous.

In experiments at this Station a kill from oxygen depletion has occurred in all ponds where shiners were fed in the summer. Consequently, in this region golden shiners should not be fed during this period. A low rate of feeding, not to exceed 10 pounds of soybean cake or meal per acre per day can be used in the winter without too much danger of loss from oxygen depletion.

While feeding cannot be used in the summer, fertilization can be used safely to increase production when a pond is stocked properly. From 30,000 to 235,000 shiners weighing 375 to 600 pounds can be raised per acre per year. If 600 pounds per acre are produced, the maximum number that can be raised to an average length of 3 inches is 70,000 per acre.

Where the procedures recommended below were followed, the average production was approximately 75,000 minnows and 500 pounds per acre. Of these minnows, 80 to 90 per cent were 3 inches or larger.

Since the production rate of fatheads or goldfish is two to four times that of golden shiners from an equal pond area and bring virtually the same price per thousand, golden shiners are the least profitable to raise.

The procedure for raising golden shiners is as follows:

1. Fill the pond with water about February 1 to 15.

2. Fertilize immediately and continue fertilization until fall as directed on page 38.

3. About March 1, spray the water surface with kerosene to kill predaceous water insects (see page 61).

4. Stock the pond with 800 to 1,000 brood golden shiners per acre between March 1 and May 1.

5. Since eggs are laid near the water surface, maintain a constant water level until after the eggs hatch.

6. Check the pond at monthly intervals with a fine-mesh seine. If large numbers of predaceous insects are present, respray with kerosene as directed in step 3 above.

7. Drain ponds between December and February, and sort and sell minnows of suitable size.

8. Minnows too small to sell should be restocked in ponds at a rate not in excess of 50,000 per acre. Fertilize every 2 weeks (see page 38) and feed soybean cake at the rate of 10 pounds per acre per day. Drain the ponds and sell the minnows within 2 months or before they spawn.

Draining *and* Grading

The draining procedure for golden shiners is the same as for goldfish (page 42). Since golden shiners are not as hardy as either goldfish or fatheads they must be handled with speed and care. As shiners cannot be crowded, the use of oxygen is recommended in holding them. It is imperative that the container in which they are handled be covered to prevent loss from jumping.

Golden shiners are graded in the same manner as goldfish but instead of several size groups they are separated into those large enough for bait and those too small. Only shiners 3 or more inches in length are used for bait. The smaller minnows are discarded or restocked and allowed to reach a marketable size.

Tadpoles may cause considerable difficulty in shiner ponds; however, when the ponds are drained in the spring the tadpoles that remain can be removed with a fish grader having a ½- or ⅝-inch bar opening without injury to the shiners.

Transportation

The transportation of golden shiners is limited to the cooler months of the year. They are never shipped via railway express.

When water sprays ordinarily used for goldfish transportation are applied directly on the water, shiners have a tendency to jump causing many injuries. This can be alleviated by baffling the spray so that it does not strike the water directly.

For trips of 12 hours or less in duration, it is preferable to use oxygen alone (page 45). With this method, up to 7,500 shiners 4 to 5 inches in length can be hauled per 100 gallons of water without injury if the temperature is 65° F. or lower.

PARASITES *and* DISEASES *of* BAIT MINNOWS

There are many parasites and diseases that attack bait minnows but there is little information on the extent of injury. Some of the more important parasites and diseases that can be easily recognized are anchor parasites, fish lice, grubs, fungus disease, and fin rot.

Anchor Parasites

The anchor parasite (*Lernea* sp.) is found in many natural waters throughout the United States and is probably the most detrimental parasite present in minnow hatcheries. The adult female (Figure 29), which is most readily found on parasitized fish, resembles a small white stick with a bulb attached at the end. This bulb has two egg sacs which can be readily separated. These parasites infest all common minnows, game fish, and some tadpoles.

There have been instances where the infestation was so heavy that the entire crop of minnows was lost. This was particularly true with shiners and fatheads since they did not appear to be as resistant as goldfish. Tidd *(7)* reports that after being infested, goldfish showed signs of distress and exhaustion with large inflamed areas on the side and back. Where the infestation was limited to three to five female parasites to a 2-inch goldfish it did not cause death, but where the infestation was 10 to 15 per fish many goldfish died in 10 to 20 days.

Minnows parasitized with anchor parasites should not be used

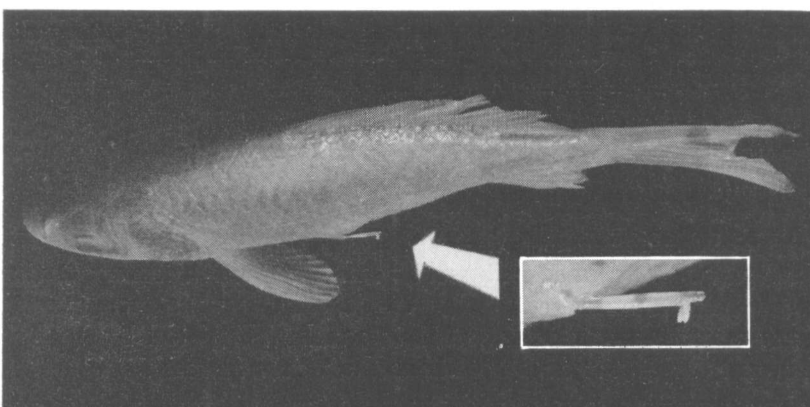


FIGURE 29. The anchor parasite (*Lernea* sp.) is shown here attached to a goldfish minnow. The point of attachment usually is red and inflamed and often has the appearance of an ulcer. Insert: Close-up view of the female anchor parasite attached to a fish and showing two egg sacs.

as bait since there is a possibility that parasites may be introduced into regions where they did not previously occur. Anchor parasites will attach themselves to game fish, causing sores and inflamed areas at the point of attachment. These sores and inflamed areas render many hard sought gamefish unusable to the fisherman because of their obnoxious appearance.

Control. There is no known treatment that will completely control anchor parasites on large numbers of minnows. Prevention must be practiced by obtaining fish for brood stock that are free of anchor parasites. When the brood fish are first obtained they should be inspected, and even if they appear to be free of anchor parasites they should be kept in a holding pond where the water temperature is 82° F. or above and checked at intervals for 16 to 18 days. If at the end of this period the fish appear to be free of anchor parasites they can be stocked.

When brood fish are infested with anchor parasites, it is usually desirable to poison all fish and tadpoles in the hatchery (see page 64), and start over with parasite-free brood fish.

Treatment of brood fish with potassium permanganate at weekly intervals is often resorted to, but will not eradicate this parasite.

Fish Lice

Fish lice (*Argulus* sp., Figure 30) may be found externally on most species of bait minnows. The extent of injury is unknown but where there are large numbers of fish lice in hatchery ponds some injury probably results.

While there is no known treatment for large numbers of minnows, a small number may be treated by placing them in a 3 per cent salt solution for 10 minutes or until they show signs of distress. This solution can be prepared by dissolving common table salt in water at the rate of one-quarter pound per gallon.

Contaminated ponds may be treated by draining and allowing them to dry. If it is impossible to completely dry the ponds they may be sterilized with either hydrated lime (cal-

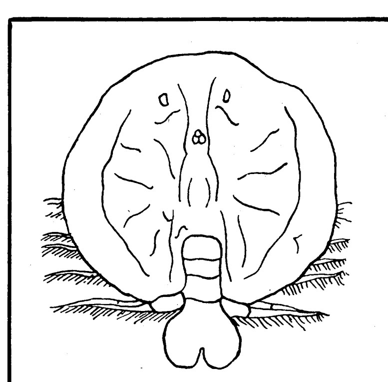


FIG. 30. The fish louse (*Argulus* sp.) is often found in large numbers on bait minnows.

cium hydroxide) or chlorinated lime (bleaching powder). Since chlorinated lime is costly, it should only be used for tanks or small ponds.

Hydrated lime is used by mixing it with water to form a milk that can be sprayed with an orchard type sprayer. The mixture is sprayed over the entire pond bottom giving especial attention to platforms, valves and drains. The mixture should be prepared fresh for each application as it loses strength rapidly when exposed to air.

If chlorinated lime is to be used, the chemical should contain not less than 70 per cent available chlorine. This material may be used by broadcasting lightly over the moist pond bottom; better results will probably be obtained by partially refilling the pond to cover areas which will not dry out and broadcasting the chlorinated lime over the water surface at the rate of 60 pounds to each acre-foot of water.

Grubs

The black grub (*Neascus* spp.), yellow grub (*Clinostomum marginatum*), and the white grub of the liver (*Posthodiplostomum minimum*) may all be found in bait minnows. The extent to which these grubs injure fish is unknown; however, most fishermen object to purchasing diseased fish. These parasites are spread in ponds by fish-eating birds such as herons and kingfishes. In areas where such birds are numerous a high infestation may be expected. No trouble is experienced from grubs in hatcheries where aquatic birds are not found.

Water Mold

Water mold (*Saprolegnia* spp.) is a common fungus disease that appears on fish. It is similar in appearance to mold on bread and can be seen plainly when the fish are in water. *Saprolegnia* spp. is not usually the primary cause of trouble but generally follows injuries and conditions such as those caused by handling, crowding, or low oxygen. In shiner populations this fungus appears in epidemic proportions in ponds where there is low oxygen even when the fish have not been handled or have no visible injuries. It is more prevalent in warm water than in cold.

Control. The dead and diseased fish should be removed from the ponds daily to prevent the production of spores for infection. Potassium permanganate at the rate of 2 p.p.m. is commonly used in hatcheries to treat entire ponds. Six pounds of potassium permanganate crystals are required to give this concentration in one acre of water one foot deep and are applied by broadcasting them over the water surface. This treatment can be repeated daily if necessary. Where the minnows are confined in tanks a dip in 3 per cent salt solution for 10 minutes or until the minnows show distress is helpful.

Fin Rot

This infection is observed frequently in bait minnows where they are held in tanks or troughs. It is usually characterized by a white margin on the outer edge of the fin. As the disease progresses inward toward the base of the fin, the fin rays are left bare and frayed and the entire fin may rot away.

Control. Since this disease is usually present when fish are confined to tanks, the fish can be treated with potassium permanganate (one-quarter teaspoonful potassium permanganate dissolved in 100 gallons of water), or a 3 per cent salt solution for 10 minutes. All fish that have the disease so far advanced that the fin rays are exposed should be removed.

PESTS *and* THEIR CONTROL

Pests do not usually offer a serious problem unless they are extremely numerous. Since all of the pests listed below with the exception of muskrats and tadpoles will eat fish, the more numerous they are the lower the production of minnows. The more common pests and their controls are discussed below.

Insects

Some aquatic insects are predaceous upon small fish and other insects. The most troublesome kinds such as the back swimmer and water tiger are easily controlled with oils. Kerosene or diesel fuel will control air-breathing aquatic insects if applied at the rate of 2 to 4 gallons per acre. A garden sprinkler or spray can be used to apply the oil on the surface.

Frogs

Large frogs cause some loss by eating small minnows. Tadpoles of large frogs, principally *Rana* spp., consume large quantities of food and interfere with sorting and draining operations. In some ponds the weight of tadpoles has reached 2,000 pounds per acre.

Control. The only practical method for control of frogs is to fence the ponds with ¼-inch mesh hardware cloth. The fence should be buried approximately 6 inches and extend 36 inches or more above the ground. Ponds should be fenced in the spring or early summer while they are drained and free from frogs or tadpoles. Where the ponds are not fenced the number of frogs and tadpoles can be reduced by shooting the adults and removing the eggs daily with a dip net.

Crayfish

Crayfish, although usable as bait, create a problem in minnow ponds since the burrowing forms tunnel through narrow dams causing leaks and thus lowering the water level. Considerable loss by predation is also caused during draining and sorting operations when the minnows are concentrated.

Control. Burrowing forms of crayfish can be killed by placing 1 teaspoonful of lye in each burrow. When a pond is drained, crayfish at large in the pond can be controlled with chlorinated lime (see page 59).

Muskrats

Muskrats burrow through the dams in minnow hatcheries causing them to leak.

Control. Muskrats can be controlled with either poison baits or traps. For poison baits strychnine sulfate is used as the poison and quartered mellow apples as bait. To poison an apple a match stem is inserted in the apple and then into the powdered strychnine. Enough strychnine to be poisonous to the muskrat will adhere to the match. This poison is then inserted in the previously punched hole. The poisoned apples are placed in the burrows.

If there are sufficient muskrats present to make the furs worth harvesting they can be trapped with fish traps baited with an apple, or with steel traps placed in front of the burrow.

Snakes

Fish are an important item in the food of some snakes; it is therefore expected that they would cause some loss of fish.

Control. Snakes can be controlled by shooting if marginal weeds and other hiding places around the pond are removed.

Turtles

Snapping turtles and some other types are known to eat fish. Snapping turtles can best be controlled by underwater traps (Figures 31 and 32). Both may also be controlled by shooting.

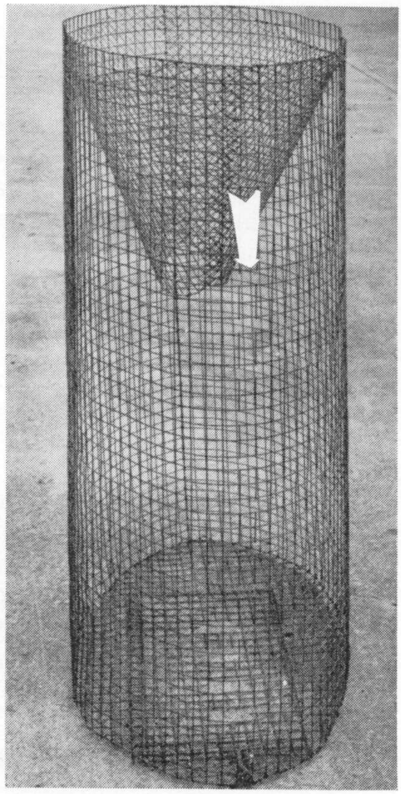
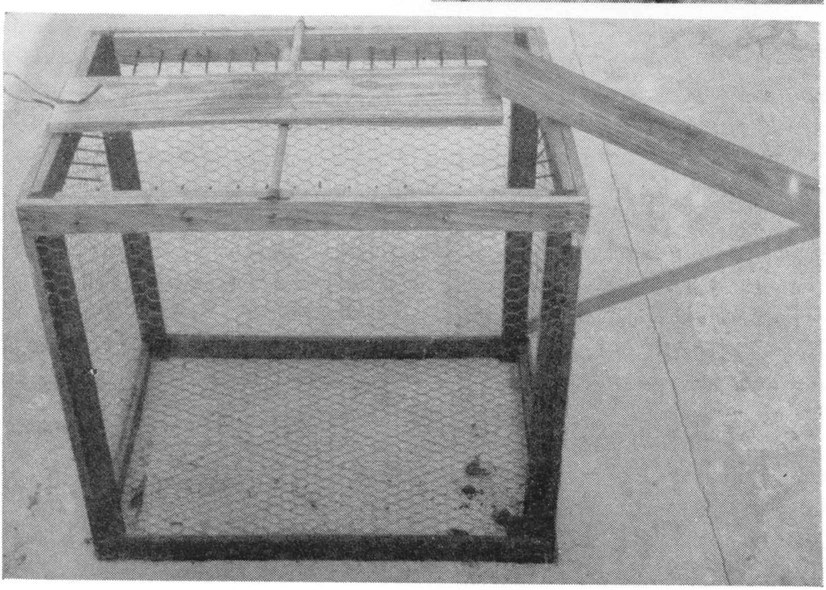


FIG. 31. A simple underwater trap for turtles may be constructed of welded wire. The muzzle opening should be oval, and vertical slots (see arrow) should be cut in the sides and end to allow the escape of fish.

FIG. 32. An inexpensive tilt-board trap is effective for capturing the basking types of turtles. A weight attached to the underside of the tilt-board (on left side of pivot rod in photo) resets the trap. The trap is placed so that the top is about 8″ to 12″ above surface of the water.



Fish-Eating Birds

Herons. There are several kinds of herons that frequent hatchery ponds. In this region the great blue heron, the little blue heron, and the green heron are prevalent. These birds are often present in large numbers and consume a number of fish. Where fish are concentrated in holding ponds these birds may practically eliminate the entire crop. Some herons also serve as the final host for grubs that infest minnows and distribute parasites from pond to pond.

Although protected by federal law these birds are a nuisance around hatcheries. A hatcheryman is fortunate if the number that frequents his ponds is small. Some species of herons may be kept away by stringing wire or cord across the pond and attaching pieces of cloth or shiny tin-foil to it.

King fishers. Like the herons these birds consume large quantities of fish and serve as the final host for the black grub that infests fish. They are also believed to be the cause of some obnoxious fish being present in minnow ponds.

Although protected by law in some states, these birds are a nuisance around hatcheries and should be kept out wherever possible.

ELIMINATION *of* UNDESIRABLE FISH *by* POISONING

It is important that all fish be removed from hatchery ponds before they are restocked since any remaining fish will seriously reduce production in the succeeding crop. Usually time does not allow these ponds to be completely dried, so that poisons must be used. The poisons recommended are powdered derris, powdered cube, or emulsifiable rotenone each containing at least 5 per cent rotenone. Any of these poisons used at the rate of 3 pounds for each acre-foot of water and thoroughly mixed with the water in the pond will kill most fish usually present in hatcheries if the water temperature is above 60° F. Where the pond is treated with chlorinated lime or hydrated lime as a disinfectant as recommended on page 59, it is not usually necessary to poison as the lime will kill the undesirable fish.

Emulsifiable rotenone gives the best results and is the easiest to handle since it is a liquid and requires no mixing before application to the pond. The price of emulsifiable rotenone is 2½ times higher than that of powdered derris or cube which require preliminary mixing with water. Emulsifiable rotenone is the most effective of the three in controlling top minnows when it is thoroughly stirred into the pond water. When the powdered forms are used very often some of the top minnows are not killed because it is difficult to mix the poison with the thin upper layer of water even when the pond is stirred by an outboard motor.

The procedure for poisoning a pond is as follows.

1. Partially refill the pond so that all wet places are covered with water.

2. Carefully estimate the area and average depth of the water to be treated.

3. From the surface area and average depth find the amount of poison necessary in the table below. The figures in Table 10 represent ounces by weight if a powder is used, or fluid ounces if emulsifiable rotenone is used.

TABLE 10. AMOUNT OF CUBE, DERRIS, OR EMULSIFIABLE ROTENONE REQUIRED TO KILL FISH IN PONDS OF VARIOUS SIZES AND DEPTHS

Surface area in acres	Average depth of water in inches					
	3	6	9	12	15	18
	Ounces	*Ounces*	*Ounces*	*Ounces*	*Ounces*	*Ounces*
1/10	2	3	4	5	6	8
1/5	3	5	8	10	12	15
1/4	3	6	9	12	15	18
2/10	4	8	11	15	18	22
2/5	5	10	15	20	24	29
1/2	6	12	18	24	30	36
3/5	8	15	22	29	36	44
3/4	9	18	27	36	45	54

4. Weigh or measure the amount of poison required. If powdered derris or cube is used it should be mixed with a small amount of water to form a paste. Then the paste should be diluted with additional water sufficiently to permit even dispersion of the poison. The emulsifiable rotenone may be diluted with water before application.

5. Place an outboard motor mounted on a sawhorse in the pond. Gradually pour the diluted poison into the "prop wash" of motor, stirring until the poison is evenly distributed. By moving the motor the pond can be treated from several positions, giving more thorough coverage. This is desirable when the surface area of the pond treated is over ¼ acre.

6. After the pond is completely stirred, wait 24 to 48 hours or more, then drain it completely. If the hatchery drains directly

into streams, it will be necessary to hold this poisoned water for 2 weeks or to dilute it with about five times the volume of water in the hatchery pond so that it is no longer toxic to fish before releasing it into the stream. This material is not poisonous to livestock.

7. The pond can then be completely refilled and is ready for use. Care should be taken that higher concentrations of poison than those recommended are not used and that the poison that remains after draining is sufficiently diluted that it will not kill fish.

MECHANICAL FISH GRADERS

Mechanical fish graders speed the grading of minnows without the danger of injury encountered when fish are graded across a table. There are several types of fish graders (Figure 33) but they all grade fish by the width of the body. The size of the grader (distance between bars) determines which fish are retained.

To grade fish properly there should be graders of various sizes since the fish vary in size from pond to pond. The graders should be constructed with 1/16-inch changes in distance between bars in each size grader. The bars should be made of stainless steel or aluminum alloy of sufficient hardness to withstand blows. For best service the graders should float. There is usually enough bouyancy in the wooden sides to do this; however, where the graders will not float, cork can be nailed to the sides to increase the bouyancy of the grader.

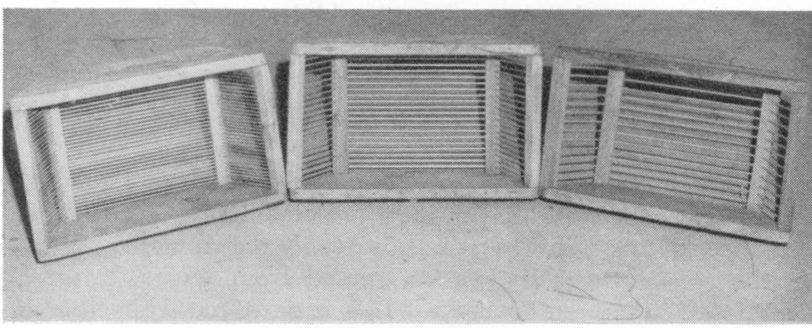


FIGURE 33. Fish graders may be used to separate tadpoles and various sizes of minnows. They may be made of aluminum rods or similar material inserted into wood frames. Spacing between rods shown above are: left 3/16", center 7/16", and right 11/16".

With experience the hatcheryman will learn the size graders necessary to separate each grade of minnow. The graders may then be floated in a holding tank, or tub, and fish put in them in large enough numbers that they are badly crowded. Under these conditions those fish too small to be retained by the grader will quickly swim out into the tanks. If the fish that have escaped are to be resorted into smaller grades, they may then be run through another grader that will sort the next smaller grade, and so on. Gentle shaking of the grader by the hatcheryman will speed up the process.

WEED CONTROL

The growth of higher aquatic plants and certain types of filamentous algae in hatchery ponds should be discouraged since they reduce production. In ponds that have heavy growths of these plants production is reduced because of the incomplete recovery of fish on draining, and because the supplemental food is not completely utilized. In addition in some areas weeds harbor malarial mosquito larvae.

Rooted aquatic plants do not normally present a problem in well managed minnow ponds except along the margins in water less than about 6 inches deep. However, these marginal growths and filamentous algae may become objectionable and in improperly fertilized hatcheries deep water forms may appear. The methods for controlling pond weeds in general are discussed under the following headings: submerged weeds, emergent weeds, marginal weeds, and filamentous algae.

Submerged Weeds

Submerged or underwater weeds usually have roots and stems and grow on the bottom, but do not usually grow to the surface of the water. However, *Chara* which is a submerged plant is an alga. Some examples of submerged weeds are *Najas,* coontail, pondweeds (*Potomogeton*), and Elodea.

Control. Since all green plants require sunlight to survive, its restriction prevents their growth. In ponds managed for the maximum production of minnows as outlined in the sections of fertilization and supplemental feeding in this circular, submerged vegetation does not become a problem. This is because in well-managed ponds dense growth or bloom of microscopic algae prevents sunlight from penetrating to the bottom in waters deeper than about 6 inches. However, care should be taken that fertilization be commenced immediately upon flooding the ponds as rooted plants may appear very quickly in clear water. During the first year a hatchery pond is in operation some delay might be experienced in obtaining a good plankton growth after fertilization is begun; in subsequent years the organic residue remaining in the pond will stimulate a bloom almost overnight with fertilization.

If submerged vegetation becomes established there are several known methods of controlling it. Probably the best method for hatchery ponds that are drained at least once a year, is to spray the vegetation with sodium arsenite solution as soon as the pond is drained. Sodium arsenite containing 70 per cent arsenious acid should be purchased, mixed with equal parts of water, and sprayed directly on the plants. Enough spray solution should be used to completely cover the vegetation. The pond may be refilled 24 hours later. Care should be exercised in the use of sodium arsenite as it is toxic to livestock and is caustic to the skin.

Emergent Plants *and* Marginal Weeds

Emergent plants are those plants that are rooted to the bottom but produce leaves and seed heads above the surface of the water. Some examples are pennywort, watershield, and water lily.

Marginal weeds grow along the pond bank and in shallow water. Examples of these weeds are sedges, cattails, arrowhead, and pickerel weed.

Control. These plants may be controlled by using a solution of 2,4-D in oil. One measuring cup (8 fluid ounces) of a 2,4-D ester (containing around 40 per cent acid) should be used to each 5 gallons of diesel oil. The ingredients should be thoroughly mixed and applied with a knapsack or low-pressure garden sprayer. The vegetation should be completely covered which takes an average of 100 gallons of spray per acre for most plants. If it rains immediately after the spray is applied retreatment will be necessary. The sprayers should be thoroughly cleaned before used for other purposes as these materials will kill most plants, including orchard trees.

Filamentous Algae

Filamentous algae begins growth on the pond bottom or on submerged plants and trash. When growth is advanced they will float to the surface in mats sometimes covering the entire surface of the pond. Filamentous algae do not have roots, stems, or leaves but resemble a mass of green threads or hair. The hairlike strands may be straight or branched depending upon the type.

Control. The forms that grow in the winter, principally *Spirogyra* in this region, usually disappear when the water begins to warm up. If they persist, stirring with an outboard motor will often start decomposition.

Copper sulphate snow is most frequently used to control winter forms of algae, but in high concentrations it will kill fish. To kill algae growing on the pond bottom, make a water solution containing 3 pounds of copper sulphate snow for each acre-foot of water to be treated. Mix the solution thoroughly and apply with a sprayer or mix it into the water with an outboard motor.

Floating mats of winter algae may be treated by broadcasting copper sulphate snow over the masses at the rate of 3 pounds per 1,000 square feet of surface treated. No more than one-fourth the surface area of a pond should be treated at one time, otherwise a lethal concentration of copper for fish may be reached, or the oxygen may be dangerously lowered by the decaying algae.

Copper sulphate treatments may be repeated several times at weekly intervals without danger to the fish.

The summer-growing branched algae *(Pithophora)* cannot be controlled until after the pond is drained. Before refilling the pond, the damp masses of algae should be sprinkled with copper sulfate snow at the rate of 3 pounds per each 1,000 square feet. This will usually prevent regrowth of this pest the following year if the pond is adequately fertilized.

AVERAGE WEIGHT PER THOUSAND OF MINNOWS OF VARIOUS SIZE GROUPS

Total length	Weight per 1,000
Inches	*Pounds*
GOLDFISH:	
1½	2.9
2	5.4
2½	9.0
3	17.0
3½	24.5
4	40.0
BROOD GOLDFISH:	
7	210
8	320
9	475
10	630
11	750
FATHEADS:	
1½	1.9
2	3.6
2½	8.6
3	15.0
3½	21.5
GOLDEN SHINERS:	
2	3.9
2½	5.4
3	8.6
3½	13.5
4	19.0
4½	31.5
5	44.0
5½	60.0

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