



Texas Catfish Production in Ponds



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Catfish farming in the U.S. has grown rapidly since it began in the 1960s. In 2003, 178,000 acres of water were used to produce 661 million pounds (live weight) of farm-raised catfish. About 1,900 acres of water were used in commercial catfish production in Texas in 2004. Most Texas production is on family farms that also produce other agricultural commodities.

More than 90 percent of the catfish produced in the U.S. is sold to processors. Some producers sell live or dressed catfish through local outlets. A few producers develop their ponds for commercial fee-fishing, and others sell their catfish to live-fish haulers who deliver primarily to recreational fishing lakes or live-fish markets.

Catfish can be grown in ponds, cages and raceways, but more than 95 percent of all catfish are produced in earthen ponds. Channel catfish need warm water for good growth; 80 to 85 degrees F is the optimum temperature, though some growth occurs at temperatures as low as 60 degrees F. All regions of Texas are suitable for commercial catfish production. Northeast Texas has about 200 days per year when water temperature is above 60 degrees F, while South Texas may have more than 320 days. Other factors being equal, the longer the growing season, the greater the annual production and return on investment.

The future for catfish farming in Texas is bright. The Texas climate is nearly ideal for production and more catfish is consumed in Texas than in any other state. There are challenges such as uncertain markets, controlling off-flavor, water quality management, bird predation, harvesting difficulties, disease management, and effluent discharge regulations. While the risks are not too different from those of other agricultural enterprises, much more time and effort are needed to manage catfish production than most other crop or livestock enterprises. This publication discusses the basic requirements for successful catfish farming in Texas to help you decide whether this enterprise is right for you.

Production Economics

Could catfish farming be a wise investment for you? Or, could a higher return be earned by some other agricultural or non-agricultural venture?

To answer these questions, the prospective producer should evaluate the economics of a catfish operation separately from other farming operations to determine its possible profitability. If the estimates of yearly costs and returns are promising, a whole-farm analysis should be performed to measure the impact of adding a catfish operation to the farm business. For help with evaluating the economic feasibility of catfish farming, contact the Farm Management Program in the Agricultural Economics Department at Texas A&M University at (887) 826-7475 or <http://ruralbusiness.tamu.edu/aquaculture>. Request sample budgets and spreadsheet software.

The economic feasibility of catfish production will depend on your own situation and resources. Having a realistic evaluation, on paper, will improve your chances of success.

Investment Requirements

There are many start-up costs, such as the items listed below.

Land	Feed storage bins
Pond construction	Tractor
Drain pipe and fittings	Mower
Wells	Oxygen meter
Water pumps and pipe	Water testing equipment
Electric power lines	Seines
Aerators (electrical and/or PTO)	Dip nets
Boat and motor	Feed wagon/blower
Hauling tanks	Waders and boots
Agitators	Baskets and buckets
Truck equipment	Storage buildings
	Miscellaneous equipment

Some equipment and facilities already may be available. Other equipment is unique to aquaculture and must be purchased. In the economic analysis, include only the portion of costs dedicated to the catfish enterprise. Generally speaking, the larger the operation, the lower the cost per unit of production.

Enterprise Budgeting

Estimating the costs and returns for a particular enterprise is called developing an enterprise budget. The budget shows the economic outcome of producing a specific crop (catfish) using a given set of inputs and following selected production practices. Potential profitability can be estimated by comparing estimated revenues with estimated production costs plus an amortized portion of investment costs.

Two types of costs must be considered in developing enterprise budgets: **variable** and **fixed** (overhead). Variable costs vary with the level of production. They include feed, fingerlings, chemicals, etc., and account for 80 percent of annual production costs. Fixed costs do not change regardless of the

level of production. Fixed costs include depreciation, interest on investment, insurance, taxes, etc.

Figures 1 and 2 are example enterprise budgets based on actual situations in the Texas Coastal Bend. Some producers try catfish production on a trial basis, starting with a 5-acre pond to see if production works on their properties and if they enjoy it. Those who decide to produce catfish on a commercial scale might consider a minimum of about 100 acres of production. This is about what one person can manage with a little help from part-time, hired labor.

The sample budget in Figure 1 is for a 5-acre pond. The pond is stocked in the spring with 4,000 6-inch (58.8 pounds per 1,000) fingerlings per acre of pond surface. Using a feed conversion ratio of 2:1 (pounds of feed per pound of gain), the fish will be harvested in the fall at an average weight of 1.4 pounds. Efficiency factors such as feed conversion, death loss, and disease treatment costs are typical of a new operation. As the producer gains experience, efficiency in these areas can improve by 25 percent or more, thereby reducing production costs.

Net returns above total costs for the 5-acre pond are \$4,545 (\$909 per acre) with the production assumptions, input costs, and expected price shown in Figure 1. It will take a price of \$0.60 per pound to cover variable costs and \$0.74 per pound to cover total costs, or to break even. It is important to note that this 5-acre pond scenario has a significant net return only because a price of \$1.00 per pound was assumed. Producers cannot expect price levels this high unless they sell to niche markets rather than to commercial processors. Niche markets include live sales to fish-out operations and direct sales to consumers. The price paid by a commercial processor normally would not cover total costs, but probably would cover variable costs in this scenario.

The sample budget in Figure 2 is for 100 acres of production. Overall net returns to total costs are estimated to be \$21,008, or \$210 per acre, at a selling price of \$0.70 per pound. It will take \$0.57 per pound to cover variable costs and \$0.65 per pound to cover total costs. In this scenario it is assumed that the producer sells directly to a commercial processor.

It is important to remember that these sample budgets do not include a cost for land or a return on the owner's labor and management. The estimated net returns represent the funds available to cover these and any other expenses not included in the budgets. For example, hiring a manager and/or labor to substitute for the owner/operator would substantially increase the break-even cost of production.

Figure 1. Economic estimates for a 5-acre “beginner” operation.

Pond acres:	5		
Number of ponds:	1		
Yield per acre:	3,500		
Feed cost per ton:	\$329		
Fingerlings per acre:	4,000		
Cost per fingerling:	\$0.07		
Initial investment items			
Pond construction		\$7,500	
per acre	\$1500		
Feed storage		\$1,000	
Mower		\$150	
Truck		\$1,500	
Oxygen meters		\$100	
Tractor		\$1,500	
Feeding system		\$100	
Boat		\$200	
Feed truck		\$0	
Aerators		\$600	
per pond	\$600		
Well		\$0	
Water acquisition		\$500	
Pond pipe		\$700	
Electrical power source		\$500	
Miscellaneous equipment		\$500	
Total		\$14,850	
per acre	\$2,970		
Estimated Revenue			
Price per lb		\$1	
Production (lbs)		17,500	
Annual operating costs			
Variable costs			Pct of TVC
Fingerlings		\$1,400	13%
Feed		\$5,758	55%
conversion rate			
(lbs feed/lb gain)	2.00		
Chemicals		\$500	5%
Utilities		\$500	5%
Repairs		\$200	2%
Hired labor		\$0	0%
Fuel and lube		\$100	1%
Water		\$0	0%
Pond management services		\$100	1%
Fish insurance		\$50	0%
Pumping cost		\$250	2%
Supplies		\$200	2%
Miscellaneous expenses		\$200	2%
Harvesting costs			
Custom harvest		\$525	5%
cost per lb	0.03		
Interest on operating expenses		\$648	6%
Percent (annual basis)	7%		
Total variable and harvest costs		\$10,430	Pct of TC
per acre			81%
per lb sold	\$2,086		
	\$0.60		
Amortized investment		\$1,485	11%
depreciation length (yrs)	10		
per acre	\$297		
annual interest on			
capital investment	7%	\$1,040	8%
Total annual costs		\$12,955	
per acre	\$2,591		
Break-even per lb sold		\$0.74	
Revenue less total expenses		\$4,545	

Figure 2. Economic estimates for a 100-acre commercial operation.

Pond acres:	100		
Number of ponds:	10		
Yield per acre:	4,500		
Feed cost per ton:	\$329		
Fingerlings per acre:	5,000		
Cost per fingerling:	\$0.07		
Initial investment items			
Pond construction		\$150,000	
per acre	\$1500		
Feed storage		\$5,000	
Mower		\$1,500	
Truck		\$3,000	
Oxygen meters		\$1,175	
Tractor		\$10,000	
Feeding system		\$4,000	
Boat		\$1,500	
Feed truck/wagon		\$6,500	
Aerators		\$6,000	
per pond	\$600		
Well		\$2,500	
Water acquisition		\$6,500	
Pond pipe		\$3,000	
Electrical power source		\$2,500	
Miscellaneous equipment		\$10,000	
Total		\$213,175	
per acre	\$2,132		
Estimated Revenue			
Price per lb		\$0.70	
Production (lbs)		450,000	
Annual operating costs			
Variable costs			Pct of TVC
Fingerlings		\$35,000	14%
Feed		\$155,453	60%
conversion rate			
(lbs feed/lb gain)	2.10		
Chemicals		\$6,000	2%
Utilities		\$12,000	5%
Repairs		\$6,000	2%
Hired labor		\$4,000	2%
Fuel and lube		\$5,000	2%
Water		\$0	0%
Pond management services		\$2,000	1%
Fish insurance		\$250	0%
Pumping cost		\$850	0%
Supplies		\$1,500	1%
Miscellaneous expenses		\$1,500	1%
Harvesting costs			
Custom harvest		\$13,500	5%
cost per lb	0.03		
Interest on operating expenses		\$14,700	6%
Percent (annual basis)	7%		
Total variable and harvest costs		\$257,752	Pct of TC
per acre			88%
per lb sold	\$2,578		
	\$0.57		
Amortized investment		\$21,318	7%
depreciation length (yrs)	10		
per acre	\$213		
annual interest on			
capital investment	7%	\$14,922	5%
Total annual costs		\$293,992	
per acre	\$2,940		
Break-even per lb sold		\$0.65	
Revenue less total expenses		\$21,008	

Each producer will face unique challenges and have his or her own set of resources upon which to build a catfish enterprise. These budgets are only starting points for determining the feasibility of such an enterprise. Each prospective producer must develop a budget and a business plan that fits his or her own situation.

Cash Flow Statement

Budgets are planning tools that evaluate the potential profitability of enterprises. A projected (pro forma) cash flow statement is even more important in evaluating the feasibility of an enterprise. For a new enterprise, this statement should include estimates of cash inflows and outflows at least on a monthly basis for the first year, and probably quarterly for the next 2 years. It is critical to estimate where cash surpluses and shortages will occur so you can make arrangements for credit and can determine your loan repayment capacity. Whole-farm cash flow projections are helpful if additional money is needed to supplement the catfish operation during the start-up period. Generally, it is 18 to 24 months from the first earth moving for pond construction until the first fish sale or positive cash flow.

Sensitivity Analysis of Price and Production Factors

As with any business, managers should pay close attention to fluctuations in the factors that significantly affect profits. Table 1 summarizes the sensitivity of major price and production efficiency factors and their effect on profit potential. For example, an increase of \$500 per acre in the cost of pond construction would increase the cost of production by nearly \$0.02 per pound. However, increasing the yield per acre by 1,000 pounds would decrease the cost of production by about \$0.03 per pound.

A great deal of capital is required to start a commercial catfish operation and producers should prepare for that. It is not unusual for a producer to invest as much as \$4,500 to \$5,000 per acre before the first fish are harvested—\$2,600 in operating costs, \$700 in machinery and equipment, and \$1,500 to \$2,000 in pond construction.

Successful catfish producers are both good managers and good merchandisers. Producers new to the business are advised to:

- ✓ **Gain knowledge.** Gather all the information you can before you make your investment.

- ✓ **Plan.** Lay a firm groundwork for financing, production and marketing before the business begins.
- ✓ **Start small.** Limit your investment of time and money to minimize the risk for yourself and your farm.
- ✓ **Grow with success.** Expand the operation as you have the earnings to pay for it.

Permits

In Texas, a permit is required for all types of commercial aquaculture. Aquaculture permits are obtained from the Texas Department of Agriculture (TDA). In 2004, the cost of a 2-year fish farming license was \$120. A fish farming vehicle license (\$120 for 2 years) is needed for vehicles from which fish are sold directly to the public. TDA shares aquaculture permit information with the Texas Commission on Environmental Quality (TCEQ) and the Texas Parks and Wildlife Department (TPWD).

The TCEQ is the state environmental regulatory agency concerned with contamination of groundwater and discharges into environmentally sensitive areas. TCEQ requires that all aquacultural facilities either register for an exemption (\$100 fee) or have a discharge permit. Discharge permits (up to a \$5,000 annual fee) are generally needed to discharge into environmentally sensitive areas, including the coastal zone (defined as south and east of State Highway 35).

TPWD is the state natural resources agency. It is concerned with, among other things, the introduction of exotic (non-native) species, the protection of endangered or threatened species, and the destruction of critical habitats (e.g., wetlands). Since the channel catfish, the primary species cultured in Texas, is native to Texas, no permit is needed from TPWD. However, TPWD will oppose any aquaculture facility that would destroy critical habitat or harm threatened or endangered species.

Table 1. Sensitivity of price and production factors and their effect on the break-even cost of a 10-pond, 100-acre catfish production system.

Item	Unit change	Dollars per lb sold (break-even)
Pond construction	\$500/ac increase	\$0.02 increase
Pond bank yield	1,000 lb increase	\$0.03 decrease
Feed cost	\$15/ton increase	\$0.01 increase
Feed conversion rate	0.1 lb/lb gain increase	\$0.02 increase

Pond Construction

The site and design of the pond(s) may be the most important factors to the profitability of the catfish farm. Ponds that leak, have irregular bottoms, flood, or routinely suffer from a shortage of water will not produce consistent crops of catfish.

Levee ponds built on flat land are most suitable for commercial catfish production. Figure 3 shows a typical layout for levee-type ponds. While much of the Texas coastal plain is suited to this type of pond construction, parts of Texas that are rolling, rocky, sandy or hilly are not. In hilly terrain, ponds must be built by constructing dams across valleys between hillsides so that runoff from rain-fall on the watershed will be stored behind the dam. Naturally, any site that does not have a reliable source of water will not be suitable for catfish production.

Pond size depends on terrain and market options. Commercial catfish farmers selling to processors usually build 5- to 10-acre ponds. Larger ponds can be harvested more often than smaller ponds because the inventory of food-size fish will be larger. However, small ponds may be easier to feed and to manage for water quality and diseases. All ponds must have smooth, flat bottoms with no obstructions and 3:1 or 4:1 interior levee slopes so that they can be seined efficiently. Levee ponds should be 4 to 6 feet, usually with a 6-inch-per-100-foot (0.5 percent) bottom slope toward the drain (depending on the size of the pond).

The steps in constructing a levee pond are:

1. removing vegetation and topsoil and stockpiling the topsoil (Fig. 4);
2. digging the core trench for the levee into good clay subsoil;
3. placing the water supply lines and drain lines (Fig. 5);

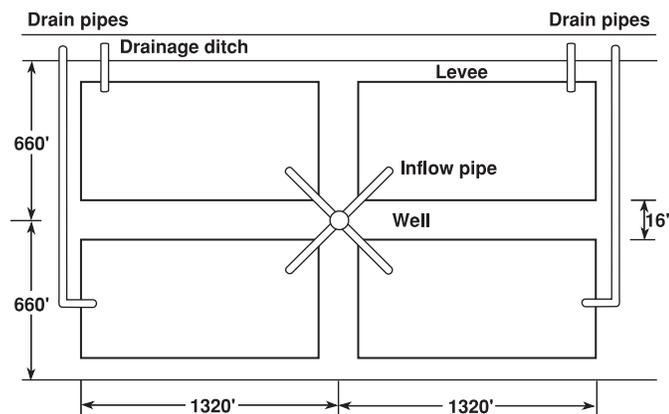


Figure 3. Layout of a typical levee-type catfish pond.

4. filling and compacting the core with the best clay from the pond site;
5. completing the levee and its slopes with other pond site soils; and
6. covering the above-the-waterline levee surfaces with the previously removed topsoil.

Levee tops should be at least 14 feet wide to support vehicles. Levees should be seeded with appropriate grasses immediately after construction to control erosion, and levee tops may need some gravel so vehicles can travel during wet seasons. Figure 6 illustrates typical levee construction.



Figure 4. Pond construction using a laser-guided pan behind a tractor.



Figure 5. Standpipe drain with concrete balast in a newly constructed pond.

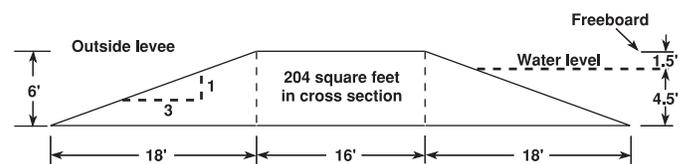


Figure 6. Cross-section of a typical levee for a commercial catfish pond. Each linear foot of this levee contains 7.6 cubic feet of fill material.



Figure 7. Completed levee ponds.

Water Supplies

Water to fill and maintain levee ponds along the Texas coastal plain usually comes entirely from groundwater (wells) or irrigation canals, although runoff and other surface water (springs, streams and reservoirs) can be a supplemental source. Watershed ponds are usually filled entirely from rainwater runoff. The ratio of watershed to water-surface acreage should be large enough so that ponds fill and sometimes overflow during rainy months but drop no more than 2 feet during drier months. The best ratio of watershed to water surface varies according to the type of land/watershed on which the pond is built.

When a watershed is too small to supply enough water for a pond, another source of water is needed during dry periods. Water from wells, streams, reservoirs or irrigation canals can be pumped into the pond if the producer has the proper permits or water rights. Surface water may contain wild fish and must be properly filtered to keep them out of the pond. A good rule-of-thumb is that a minimum of 30 gallons per surface acre per minute is needed to fill and maintain ponds. At 30 gallons per minute, it takes 181 hours or 7.5 days to pump 1 acre-foot of water (325,850 gallons per acre-foot). Therefore, a 10-acre pond with an average depth of 5 feet, or a total of 50 acre-feet, would require 375 days to fill without considering evaporation or seepage. Obviously, water sources of hundreds to thousands of gallons per minute are necessary to fill ponds in a reasonable amount of time.

When ponds are built in series down a valley, less watershed is needed to maintain them. With watershed or levee-type ponds, water can be pumped or drained from one pond to another for storage, which allows a producer to refill ponds with stored water immediately after harvest and eliminates the possibility of draining nutrients into nearby natural waters. Many producers use pond water to irrigate fields and pastures.

Generally, ponds are never filled to the top of the standpipe drain. Instead, ponds are filled to within 3 inches of the top of the standpipe. When the pond falls to 6 inches below the top of the standpipe, water is added to the pond to return it to the 3-inch level. This conserves water because the pond can trap up to 3 inches of rainfall.

Soil Characteristics

Good quality soil that is at least 20 percent clay is necessary for building dams and levees. This includes clay, silty-clay and sandy-clay soils. Soil should be sampled with multiple borings to determine if the clay foundation is sufficient.

A good source of clay for dams and levees often can be found nearby. It is best not to use clay soil from the bottom of the pond if removing it will uncover rock formations, sand or gravel in the pond bottom.

Pond construction in limestone areas can be especially risky because of the possibility of underlying cracks and sinks that may cause the pond to leak. Where the soil of the proposed pond bottom

could result in a leaky pond, soils should be bored to check for quality. Approximately four borings per acre are sufficient unless there are variations in soil type in the pond bottom.

Soils in the pond area should be checked for pesticide contamination. Crop land that has a long history of pesticide application may be contaminated and some pesticides are extremely toxic to catfish. Check the soil in several areas, particularly in any area used for filling spray equipment, as this is the area most likely to be contaminated. Remove contaminated soil and/or incorporate it into the outside of the levees so it will not pose a problem to catfish production. Contact your county Extension office or the Soil and Water Testing Laboratory at Texas A&M University (<http://soiltesting.tamu.edu/>) for information on companies qualified to perform these tests.

Topography

Topography will greatly affect the size and shape of a watershed pond. Generally, steep slopes in V-shaped valleys require dams of larger volume per water surface acre than sites with gently sloping hills and wide, flat valleys. Therefore, ponds built in steep terrain usually cost more per surface acre than those built in gently rolling terrain.

Ideally, watershed ponds used for fish production should be less than 10 feet deep at the drain. This depth allows the producer to harvest the pond without completely draining it. Deeper ponds must be drained of much of their water before they can be seined for a complete harvest.

Some sites with gentle slopes and large flood plains allow for the construction of two-sided and three-sided watershed ponds. These ponds are usually constructed parallel to hills bordering a creek. Runoff is used as a water source, but the dam does not cross a hollow or draw. The great advantage of this kind of pond is that it is a "seine-through" pond: it does not have to be drained for harvest.

Other Considerations

Ponds should be built where it is possible for pipes and valves to drain the pond completely. The proposed shoreline should be excavated to create a depth of at least 3 feet around the edge of the pond. Pond bottoms should be smooth and slope gently to the drain pipe. Remember, a poorly constructed pond with an uneven bottom is more difficult to harvest.

Make sure that floods from nearby rivers will not flow over the dam and that flooding within the watershed will not weaken the dam. Ponds constructed in flood plains should be located so they will not cause damage to adjacent property if

dams fail. Information on floods and their 100-year potential is available from the USDA Natural Resource Conservation Service field office in your county.

After deciding on a dam site, mark off the permanent waterline and the potential flood-stage waterline of the proposed pond to make sure water will not encroach on other properties. Also, if the pond site contains 1 acre or more of natural wetland, the U.S. Army Corps of Engineers will need to be contacted, and a permit may be required before the pond can be constructed

Cost of Construction

The cost of pond construction varies greatly depending on soil types and local expertise. When you get cost estimates, be sure they include clearing, earthfill, excavation, water lines and drains, concrete, seeding and road gravel. Excavation costs are usually about \$0.50 to \$0.75 per cubic yard. For levee-type ponds, excavation costs are about \$1,500 per surface acre in the Texas Coastal Bend area.

See page 28 for sources of additional information on site selection and pond construction.

Wild Fish

Any wild fish in the pond must be eliminated before stocking catfish. Sunfish, minnows, carp, shad and bullheads will eat feed, harm water quality, and possibly transmit diseases to the catfish. If wild fish are harvested along with catfish, you could have difficulty selling to live-haulers and will have weight/price deductions from processors.

If possible, eliminate wild fish from any surface water supply. Saran screen with a minimum of 40 meshes per centimeter can be used to filter out unwanted fish and fish eggs. Saran can be used as a sock to fit over the water supply pipe, or it can be framed into a box when large flows of water must be filtered. If wild fish are already in your pond, drain it completely and leave it dry for several weeks. Rotenone (5 percent wettable powder or liquid formulation) applied to remaining pockets of water at more than 3 parts per million (10 pounds per acre-foot) should eliminate any remaining fish. In warm weather, rotenone detoxifies in 7 to 10 days. In winter, rotenone may remain toxic for more than 30 days.

Largemouth bass fingerlings can be stocked with the catfish at a rate of 50 per acre. Bass will eat small wild fish and prevent a rapid increase in their numbers. Bass do not tolerate low oxygen as well as catfish. If the bass are larger than 1 pound, catfish fingerlings should be more than 8 inches long so the bass will not eat them.

Stocking the Pond

Several species of catfish can be grown commercially in Texas, including the channel, the blue, and the channel x blue hybrid. The channel catfish is the one most commonly used because it is readily available and has good characteristics for commercial production. Blues and hybrids are often in demand by fee-fishing operations because they are easier for anglers to catch (less “hook-shy”). The number of fish to stock in a pond depends on the following:

- ✓ the size of the pond
- ✓ the aeration system
- ✓ the experience of the producer and access to labor
- ✓ the length of the growing season
- ✓ the desired market size
- ✓ the acceptable risk

The most important of these factors is the size of the pond. Fish should be stocked according to the surface area of the pond. Overestimating the area can result in more fish per acre than can be safely grown. Pond depth is not a factor in determining stocking rate.

Experienced producers may stock up to 10,000 fish per acre to produce 8,000 or more pounds per acre per year. However, inexperienced producers should stock no more than 6,000 fish per acre. A lower stocking density reduces the amount of feed needed, shortens grow-out time, and lowers the risk of losses to oxygen depletions and diseases. In time, a new producer will gain the management experience that allows higher stocking rates.

Average production in the industry is only 4,470 pounds per acre per year. So for every pond that produces 6,000 pounds per acre, there are many ponds producing only 3,000 to 3,500 pounds per acre. Texas catfish producers on the upper coastal plain consistently produce about 9,000 pounds per acre per year. This production rate is higher than in most traditional catfish producing areas and appears to be related to the longer growing season and moderate temperatures along the coast. Occasionally a pond will produce more than 10,000 pounds per acre, but such ponds are **rare**. In general, new ponds produce more pounds per acre with fewer problems than old ponds that have built up a lot of organic matter in the bottom sediment.

Fingerlings can be stocked at any time during the year. However, it is best to transport fingerlings when the water is cool to reduce stress on the

fish. Fingerlings are more quickly trained to accept feed when temperatures begin to moderate, usually during February and March.

It is important to purchase fingerlings of a strain with proven production characteristics. Catfish do not all grow, resist diseases, or dress-out equally. Much research is being done on genetic improvement of catfish and improved strains are available. Also, many commercial hatcheries vaccinate fingerlings against ESC (Enteric Septicemia of Catfish). This disease can cause catastrophic losses. **Producers would be wise to stock vaccinated fingerlings.**

Catfish farmers should ask fingerling vendors to provide a recent fish diagnostic report that describes the health of the fish they will purchase. The report should indicate that a representative sample of the fingerling population in question has been analyzed by routine histology by a qualified aquatic pathology lab, within 7 to 14 days of the sale, and that the animals were found to be free of disease.

Tempering

Before stocking fish in a pond, adjust the water in the transport tank holding the fingerlings to match the pond water temperature, pH, alkalinity and hardness. This can be done by putting small quantities of water into the tank from the pond (called tempering) so that the tank water is eventually similar to that of the pond.

As a rule, catfish can withstand a 5-degree F change in temperature without severe stress and a 10-degree F change if the water is tempered over a period of 30 minutes. For greater differences, care must be taken to slowly equalize water temperatures before moving the fingerlings from the tank to the pond. Adjust water temperature 1 degree F every 10 minutes. Tempering is especially important if fish are going from cool water to warm water. Adjusting pH is also very important. Generally, catfish can take a pH change of 1 unit without severe stress, but a 2-unit pH change should be tempered over a period of 30 minutes or more.

Insufficient tempering can kill the fish. If the fish are not killed outright by the shock, they may be weakened, which lowers their resistance to disease. Catfish fingerlings not tempered properly often become ill and start dying 1 to 7 days after stocking.

Starting with good quality, healthy fingerlings of known genetic background is very important to profitability. Purchase fingerlings from a producer who has a reputation for producing good quality fish, who knows how to treat fish for diseases,

who has the equipment and the know-how to handle fish without causing excessive stress, and who delivers accurate counts and weights. Fingerling producers usually supply a few extra fingerlings per delivery to cover any inaccuracies in estimated counts. This almost always leads to overstocking, which is a common problem.

Feeding

Catfish ponds are underwater or aquatic feedlots! The big differences between a pond and a terrestrial feedlot are that the farmer cannot easily see aquatic animals or remove their wastes. However, ponds are amazing water treatment systems. In catfish farming, the trick is to feed sufficiently to grow the fish rapidly while not destroying the pond's water quality. Ponds actually respond best to relatively consistent feeding rates because this creates stability in the pond decomposition processes. This is one of the reasons why the "multi-batch" culture system works well. The multi-batch system, with its several groups of catfish of different sizes, allows you to feed at a relatively uniform rate based on water temperature and biomass.

Catfish grown at high densities require a nutritionally complete feed for good growth and health. Commercially prepared catfish feeds, available in bulk and in bags, should contain 26 to 36 percent crude protein plus all essential vitamins and minerals. These are complete feeds. Feeds containing 28 to 32 percent crude protein are adequate and the most economical. Feeds with 26 percent crude protein can be used in winter and by people who produce small quantities of catfish for home use.

Both sinking (pelleted) and floating (extruded) feed can be fed to catfish. Both types, if complete, give adequate growth under normal conditions. Floating feeds are more expensive but allow the producer to observe feeding activity. Watching fish feed is extremely important in determining how much to feed, and it is usually the best opportunity the producer has to judge the health and vigor of the fish. In Texas, producers normally feed only floating feeds year-around so the fish can be observed.

Catfish feeds come in various sizes. Crumbles, which are crushed pellets, can be fed when fingerlings are less than 3 inches long. Fish larger than 3 inches can be fed a $\frac{3}{16}$ -inch pellet. Fish are usually fed $\frac{1}{4}$ -, $\frac{5}{16}$ - or $\frac{3}{8}$ -inch pellets once they weigh $\frac{1}{2}$ pound.

Feeding Rates

One of the challenges of catfish production is knowing how much to feed each day. Catfish will

grow at their maximum rate when fed all they will eat, a state called satiation. However, trying to satiate the fish can result in overfeeding, which wastes money and can cause water quality problems. The pond has to process all the wastes from the fish, as well as any uneaten feed. The pond's capacity to do this depends on temperature, existing water quality, aeration and other factors. **All in all, it is better to stock fewer fish, feed to near satiation, and harvest sooner than to stock heavily, underfeed, and thus extend the production cycle.**

Timed Feeding Method. Research has shown that catfish in commercial ponds grow most efficiently when fed about 90 percent of all they will eat. This optimum feeding rate is generally reached when catfish are fed only the amount they will consume in 5 to 10 minutes.

Most managers feed based on the fishes' feeding response. They feed a portion (30 to 50 percent) of the estimated or calculated total feed needed, then observe the response. If the fish are feeding aggressively, the manager continues feeding until the total feed amount has been fed. If the fish do not respond well to the feed, the total feed amount is reduced and the cause is investigated.

The other methods described below are not generally used on catfish farms; they are presented here as methods of estimating what consumption should be. If not calculated properly, the amounts of feed determined by these methods may be too large.

Feed Conversion Method. One way to estimate the amount to feed during summer months is to calculate the total weight of the fish in the pond and feed the percentage of body weight recommended in Table 2 each day for a 2-week period. Every 2 weeks, the weight gain can be estimated based on the initial total weight of the fish, the total amount of feed (pounds) already fed, and the



Figure 8. Feeding catfish using a truck-mounted feed blower.

expected feed conversion ratio (FCR). The formulas for this procedure and an example computation are shown in Table 3. In the example, 185 pounds of feed would be fed each day for the next 2 weeks. Then a new feeding rate would be calculated. This method is only as good as one's ability to estimate the FCR.

Many producers use growth simulation, feeding, and inventory software programs to help them calculate feeding rates. Of the software programs used, FISHY from the Mississippi State University Department of Agricultural Economics is probably the most popular. The most recent version is the Windows-based FISHY 2001. It is available on the Web at <http://www.agecon.msstate.edu>.

Fish Sampling Method. A third method of calculating feeding rates is to estimate the total weight of the fish based on the weight of a sample. Although research has shown that average sample weights can deviate from true average weights by 8 to 19 percent, this method may still be effective.

At 2-week intervals, the producer captures a sample of 100 fish at random with a net (not hook and line) and weighs them. The producer then calculates the next feeding rate by estimating the total fish weight in the pond from this sample. The formulas for these calculations and a sample estimate are shown in Table 4. Producers do not normally use this method, but if problems such as a large fish kill occur, this method can be used to estimate the size of fish remaining in the pond so that accurate feeding rates can be restored.

In the example in Table 4, 150 pounds of feed would be fed each day for the next 2 weeks. Then a new feeding rate would be recalculated based on another sample.

Using Table 2, the daily feed allowance, as a percentage of body weight, can be estimated as fish grow. Table 2 is a guide for feeding catfish during the spring, summer and early fall. Remember, this table is only a guide; fish may respond differently from day to day and from pond to pond.

If adequate supplemental aeration equipment is available, fish can be fed 120 to 150 pounds or more per acre per day. However, many commercial producers try to keep feeding rates below 120 pounds of feed per acre per day to grow out large numbers of fish while minimizing risk. This is an average, and on any given day a pond may receive more than 120 pounds per acre; but during the growing season the average should not exceed 120 pounds per acre per day.

Feeding Schedule

Feeding fish twice each day can be advantageous when fish weigh less than ½ pound. Twice-daily feedings should be at least 6 hours apart to allow time for digestion. Research has shown that small catfish fed twice a day will eat and gain more than those fed once a day. In most large commercial operations catfish are fed only once daily because of the time and labor involved with multiple feedings.

Catfish can be trained to eat at nearly any time of day. During the summer, it is not advisable to feed too early in the morning or after sundown because

Table 2. Typical feeding schedule.*

Date	Water temperature	Fish size	Feed allowance	Weight of feed
	°F	lb	per day percent of fish weight	per acre per day per 1,000 fish
			%	lb
4-15	68	0.04	2.2	0.9
4-30	72	0.06	2.8	1.7
5-15	78	0.11	3.0	3.3
5-30	80	0.16	3.0	4.8
6-15	83	0.21	3.0	6.3
6-30	84	0.28	3.0	8.4
7-15	85	0.35	3.0	10.5
7-30	85	0.42	2.8	11.8
8-15	86	0.60	2.4	14.4
8-30	86	0.75	2.0	15.0
9-15	83	0.89	1.8	16.0
9-30	79	1.01	1.6	16.0
10-15	73	1.10	1.2	13.2

*For channel catfish in ponds stocked with 5-inch fingerlings.

Table 3. Feed conversion method.

Estimated weight gain = total pounds of feed fed x 0.556 (FCR = 1:1.8)
New total fish weight in pond = estimated weight gain + last total fish weight
New daily feeding rate = new total weight of fish x (percentage of body weight from Table 2)
Example: A 5-acre pond is stocked at 4,000 fish per acre, and the total fish weight is 5,000 pounds. For 2 weeks, the fish are fed at 3 percent (150 pounds per day or 2,100 pounds per 2 weeks).
Estimated weight gain = 2,100 x 0.556 = 1,167.6 or 1,168 (lbs gain)
New total fish weight = 5,000 + 1,168 = 6,168
New daily feeding rate = 6,168 x 0.03 (from Table 2) = 185.04 or 185 lbs/day

Table 4. Fish sampling method.

Average weight of individual fish = weight of 100 fish ÷ 100
New total fish weight = average weight x number of fish in the pond
New daily feeding rate = new total fish weight x (percentage of body weight from Table 2)
Example: A 5-acre pond is stocked at 4,000 fish per acre. A sample of 100 fish weighs 25 pounds.
Average weight of fish = 25 ÷ 100 = 0.25 lb. per fish
New total fish weight = 0.25 x 20,000 = 5,000 lb
New daily feeding rate = 5,000 x 0.03 (from Table 2) = 150 lbs/day

of potential problems with low dissolved oxygen. However, research has shown that catfish will consume more feed and grow faster if fed near dusk. Fish do not consume as much feed if oxygen is low, and the process of digestion increases oxygen uptake. It is a good practice to base the summer feeding schedule on dissolved oxygen concentration.

Once a feeding schedule is established, it is best to maintain it. Catfish will feed better if a daily routine is followed. For the same reason, try to feed in the same location each day, although the location may have to be changed to account for wind direction when using floating feed.

Feed catfish 7 days a week. They will grow more slowly if they are fed less often. **Remember: no feed, no gain, and no gain, no profit.**

Catfish are naturally aggressive, so larger fish will dominate smaller fish. Therefore, it is a good idea

to spread the feed over as large an area of the pond as practical to give smaller, less aggressive fish a chance to feed. This practice will result in a more uniform size at harvest.

Winter Feeding

The growth of channel catfish slows during the winter, but feeding is still important because without feed catfish will lose weight and will not be in good condition. This is particularly important if catfish are to be harvested during the winter. Catfish do feed at low temperatures, once they adjust to them, but not as often.

A satisfactory winter feeding schedule is to feed about 1 percent of fish body weight every other day when the water temperature is between 55 and 65 degrees F. Feed 1 percent of body weight twice a week when the water temperature is between 45 and 54 degrees F. Feed in the afternoon, when the temperature is highest, and on sunny days. As with summer feeding, look for feeding response before distributing the total amount you intend to feed.

Feed Conversion

Good feed conversion depends on good management. A producer with small ponds who manages the catfish well can achieve feed conversions of 1.5 to 2 pounds of feed to 1 pound of fish gain. Each tenth of a pound of improved feed conversion increases profits by 1 to 2 cents per pound of fish, depending on the price of feed (Table 5). The industry-wide feed conversion average is 2 to 2.7:1.

Table 5. Cost of feed (in cents*) to produce a pound of catfish at various feed prices and feed conversion ratios (FCR).

FCR	Feed price/ton						
	\$230	\$250	\$270	\$290	\$310	\$330	\$350
1.3	15.0	16.3	17.6	18.9	20.2	21.5	22.8
1.4	16.1	17.5	18.9	20.3	21.7	23.1	24.5
1.5	17.3	18.8	20.3	21.8	23.3	24.8	26.3
1.6	18.4	20.0	21.6	23.2	24.8	26.4	28.0
1.7	19.6	21.3	23.0	24.7	26.4	28.1	29.8
1.8	20.7	22.5	24.3	26.1	27.9	29.7	31.5
1.9	21.9	23.8	25.7	27.6	29.5	31.4	33.3
2.0	23.0	25.0	27.0	29.0	31.0	33.0	35.0
2.1	24.2	26.3	28.4	30.5	32.6	34.7	36.8
2.2	25.3	27.5	29.7	31.9	34.1	36.3	38.5
2.3	26.5	28.8	31.1	33.4	35.7	38.0	40.3
2.4	27.6	30.0	32.4	34.8	37.2	39.6	42.0
2.5	28.8	31.3	33.8	36.3	38.8	41.3	43.8

*Rounded to the nearest tenth of a cent.

Feed Storage

Store feeds in a cool, dry place. Damp storage areas (bins or rooms) can cause mold to grow on feeds. Heat causes loss of vitamins. Do not use feeds that have been stored for more than 8 weeks during warm weather. Never use feeds that are moldy or clumped together. Eating contaminated or vitamin-deficient feed can slow growth, lower resistance to disease, and cause deformities or death.

Water Quality

One of the most serious threats to catfish in ponds is poor water quality. Water quality is not constant. It varies with the time of day, season, weather conditions, water source, soil type, temperature, stocking density, feeding rate, and chemical treatments.

A successful catfish producer understands pond dynamics, the effect of catfish production on water quality, and the management of water-quality problems. Important components of water quality include:

- ✓ temperature
- ✓ dissolved oxygen (DO)
- ✓ pH
- ✓ ammonia
- ✓ nitrite
- ✓ alkalinity
- ✓ hardness
- ✓ carbon dioxide
- ✓ chloride

Water temperature does not change very rapidly except in small, shallow ponds. Dissolved oxygen, pH and carbon dioxide levels fluctuate daily. Ammonia, nitrite, alkalinity, hardness and chloride usually change slowly, except under extreme conditions. Relatively inexpensive and easy-to-use chemical and electronic tests are available for checking these water quality factors.

Pond Dynamics

Adjacent ponds are seldom alike in their color, water quality, and growth rate of the fish, even though they are stocked and fed at the same rates. Even in a single pond, color and water quality vary from day to day. These differences may be related to soil conditions, algae (microscopic plants called phytoplankton), and bacteria in the pond. That is why pond aquaculture is as much art as science.

Temperature

Water temperature is one of the most important factor in ponds and has the greatest influence on pond dynamics. The metabolic rates of plants, bacteria and fish depend on the water temperature. Catfish perform most efficiently at warm temperatures (approximately 80 to 85 degrees F). At temperatures above 90 degrees F, respiration rates are high, feed conversion is poorer, and overall growth is reduced. Channel catfish will die if water temperature stays above 96 degrees F.

Temperatures below the optimum range reduce metabolic rate, feed consumption and growth. Very low temperatures impair the immune system and lower resistance to disease. Rapid changes in temperature, especially during hauling and stocking, stress fish and may reduce feeding and increase susceptibility to disease. The great advantage of the Texas coast over traditional catfish production areas is the warmer climate.

Algae

Algae have a powerful influence on a pond's water quality. Algae produce most of the oxygen in the pond and remove most of the carbon dioxide and many of the nutrients. Algae also consume oxygen, produce carbon dioxide, cause pH to fluctuate, and release nutrients into the water as they die.

Algae populations change continuously because different species flourish at distinct temperatures and pH and nutrient conditions. When algae populations, called "blooms," die off, it can deplete dissolved oxygen and possibly kill fish. An efficient fish farmer continuously monitors and keeps records of bloom conditions, dissolved oxygen concentrations, and other water quality factors.

Dissolved Oxygen

Low dissolved oxygen is by far the most common water quality problem in catfish production. Ponds get oxygen from two sources: the air and photosynthesis. Oxygen diffuses into water from the air. Diffusion is a slow process unless it is aided by wind or some type of mechanical agitation that mixes air and water.

Most pond oxygen comes from photosynthesis, the process by which plants make food from carbon dioxide, water, nutrients and sunlight. The important by-product of photosynthesis is oxygen. On sunny days, algae produce and release oxygen, which dissolves into the water. At night, no oxygen is produced and the respiration of the algae, fish and bacteria (decomposing wastes) remove oxygen from the pond. Under natural conditions, more oxygen is produced by photosynthesis than is removed by respiration.

However, aquaculture ponds are aquatic feedlots and are not under natural conditions. Figure 9 shows a general oxygen cycle for ponds during warm weather.

The amount of oxygen that will dissolve in water depends on temperature, salinity and atmospheric pressure. Salinity and atmospheric pressure are of little consequence in freshwater catfish production areas. Temperature, however, is an important regulator of dissolved-oxygen levels in ponds.

Cold water holds more dissolved oxygen than warm water. The amount of oxygen that will dissolve in water at different temperatures (saturation) is shown in Table 6.

The amount of dissolved oxygen in water is very small compared to the oxygen concentration of the atmosphere. The atmosphere contains about 20 percent oxygen, or 200,000 ppm (parts per million). Water at saturation at 85 degrees F contains less than 8 ppm oxygen, while the saturation level of water at or near freezing is 14 ppm. Ponds can supersaturate with oxygen on sunny days when algae are dense (heavy bloom). Very high concentrations of oxygen (more than twice saturation) during the day sometimes indicate that an oxygen depletion will occur that night.

Table 6. Dissolved oxygen concentrations at saturation for different temperatures.

Temperature, degrees (*)	Dissolved oxygen, ppm	Temperature, degrees (*)	Dissolved oxygen, ppm
0 (32)	14.60	18 (64)	9.45
1 (34)	14.19	19 (66)	9.26
2 (36)	13.81	20 (68)	9.07
3 (37)	13.44	21 (70)	8.90
4 (39)	13.09	22 (72)	8.72
5 (41)	12.75	23 (73)	8.56
6 (43)	12.43	24 (75)	8.40
7 (44)	12.12	25 (77)	8.24
8 (46)	11.83	26 (78)	8.09
9 (48)	11.55	27 (80)	7.95
10 (50)	11.27	28 (82)	7.81
11 (52)	11.01	29 (84)	7.67
12 (53)	10.76	30 (86)	7.54
13 (55)	10.52	31 (88)	7.41
14 (57)	10.29	32 (90)	7.28
15 (59)	10.07	33 (92)	7.16
16 (61)	9.95	34 (93)	7.05
17 (62)	9.65	35 (95)	6.93

*Numbers in parentheses are degrees F.

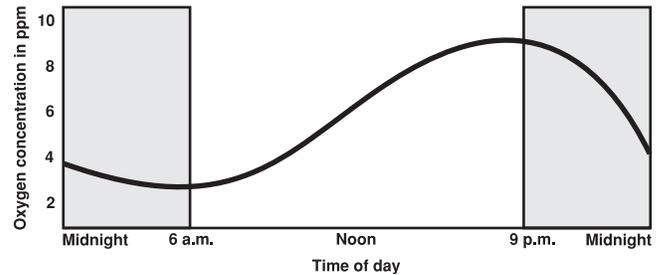


Figure 9. General 24-hour oxygen cycle in ponds.

Critically low dissolved-oxygen concentrations usually can be predicted. Low levels occur because of one of the following:

- ✓ Extremely high oxygen demands caused by nighttime respiration of dense algae blooms plus fish respiration and bacterial waste decomposition.
- ✓ Excessive bacterial decomposition from algae bloom die-offs and over-feeding.
- ✓ Reduced oxygen production from photosynthesis because of cloud cover or fog.
- ✓ Lack of water agitation from wind.
- ✓ Rapid reduction in algae population and photosynthesis from a die-off.
- ✓ Water turn-overs related to weather changes such as rain, wind and cold air (occurs in deep, stratified ponds only).

Most problems with low oxygen occur between May and September. During this period, temperatures are warm, feeding and decomposition rates are high, algae blooms are heavy, and fish are growing rapidly. These conditions can cause more oxygen to be removed from the pond at night than is produced and stored by the water during the day. Also, windless and overcast days may reduce the amount of oxygen produced by photosynthesis. When oxygen is depleted, fish may die.

Oxygen concentrations should be kept above 3 ppm when possible if catfish are to grow well. Feeding and growth can be severely affected when the oxygen level remains below 2.5 ppm for even short periods. Stress caused by chronically low oxygen will reduce feed consumption, slow growth, and lower resistance to disease. **All stress reduces profitability.**

Predicting Low Oxygen

Producers should monitor oxygen concentration with electronic or chemical methods. Electronic oxygen meters are relatively expensive but have become standard equipment on commercial catfish operations (Figure 10). They require mainte-

nance and calibration, but are quick and accurate. Chemical dissolved-oxygen tests are accurate if directions are followed precisely, but they take several minutes to complete and reading color changes with the chemical method is difficult at night and in poor light. For this reason, chemical tests are not recommended on farms with more than one pond.

Some producers now install automatic dissolved-oxygen sensors. These automatic systems measure dissolved oxygen continuously, usually at 15-minute intervals. They can turn aerators on and off automatically, telephone the owner/manager, and send constant read-outs to personal computers so that ponds can be monitored off-site. Many diversified farms are using these automatic oxygen-monitoring systems to reduce labor requirements.

Graphic Projection Method. Low dissolved oxygen usually can be predicted with the graphic projection method. This method relies on the fact that oxygen generally declines at a constant rate throughout the night as it is steadily used by algae, bacteria and fish. Based on this steady decline, low oxygen can be predicted by graphing the rate of decline and projecting this decline until morning.

To use this method, take oxygen readings near dusk and again 2 to 4 hours later. Mark graph paper as shown in Figure 12, with oxygen concentrations along the Y axis (vertical). Mark time along the X axis (horizontal). Next, mark the two oxygen readings on the graph and draw a straight line through them to the X axis. If this line indicates that the oxygen concentrations will fall below 3 ppm before sunrise, aeration probably will be necessary.



Figure 10. Commonly used electronic oxygen meters.



Figure 11. Automatic oxygen-monitoring system in pond (snake to discourage birds).

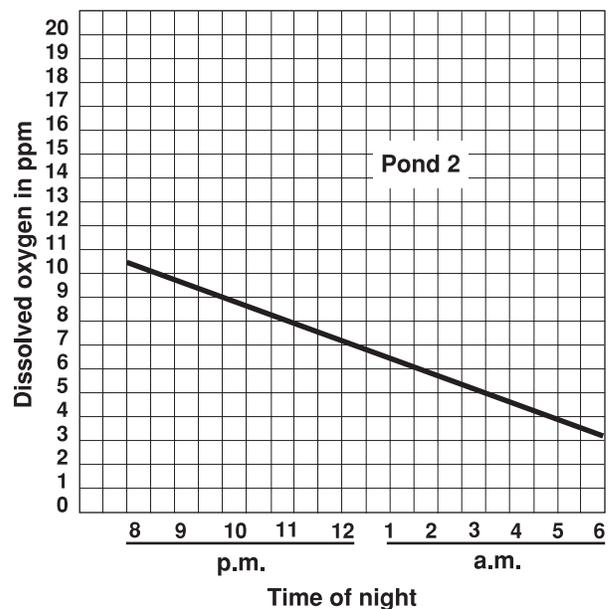
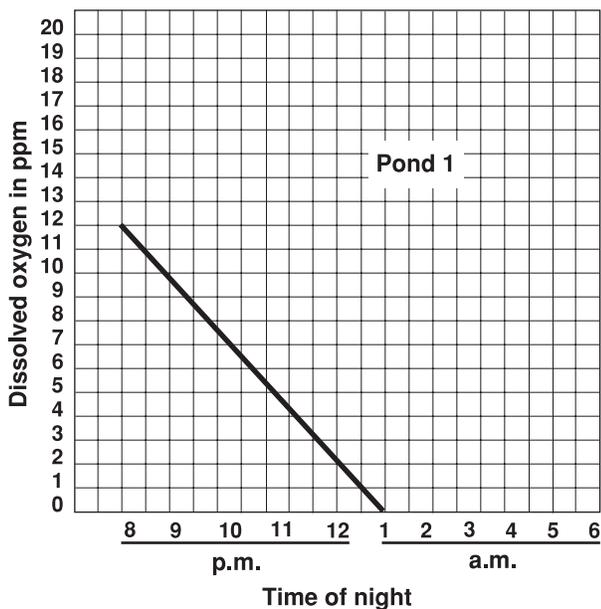


Figure 12. Graphic method of predicting oxygen depletions.

One word of caution: This method only predicts low oxygen so that the manager has time to take appropriate action. It is not foolproof. Oxygen still must be monitored to prevent unanticipated problems.

In Pond 1 (Fig. 12), the dissolved-oxygen concentration at 8:00 p.m. is 12 ppm, and at 10:30 p.m. it is 6 ppm. Drawing a line through these two points indicates that the oxygen concentration will fall below 4 ppm between 11:00 and 11:30 p.m. Emergency aeration should begin before midnight.

In Pond 2, the dissolved-oxygen concentration at 8:00 p.m. is 10.5 ppm, and at 11:00 p.m. it is 8.5 ppm. Drawing a line through these two points indicates that oxygen concentration will not fall below 4 ppm by sunrise. In this case, emergency aeration is probably not necessary.

Pond Record Method. Another method of predicting low oxygen was developed by analyzing actual fish farm records. These records show that if the oxygen concentration at dawn is 5 ppm or more and if at dusk it is the same as or greater than the day before at dusk, then no oxygen depletion will occur during the coming night. But if the oxygen concentration is less than 5 ppm at dawn and is less at dusk than it was the day before, then an oxygen depletion can be expected during the coming night. Figure 13 shows a sample graphic pond record predicting that a nighttime oxygen depletion will occur.

Successful pond managers monitor oxygen every day at daybreak, at nightfall, and during the night throughout the growing season. Decreasing morning oxygen levels from day to day, low evening readings, and increasing supersaturation levels usually warn of coming problems. It is important to take readings at the same time and at the same location each day. In ponds larger than 5 acres, oxygen readings should be taken at two ends of the pond because oxygen levels may vary widely within the same pond.

Keeping a chart (Fig. 14) of daily oxygen readings will help you predict developing problems. **Do not rely on memory. Maintain good records and use them.**

Aeration

Commercial production in high-density catfish ponds requires aeration. Aeration strategies are either supplemental or emergency.

Supplemental aeration involves operating aerators at night to maintain acceptable oxygen concentrations. Aerators are run for 5 to 7 hours each night beginning about midnight and ending about dawn.

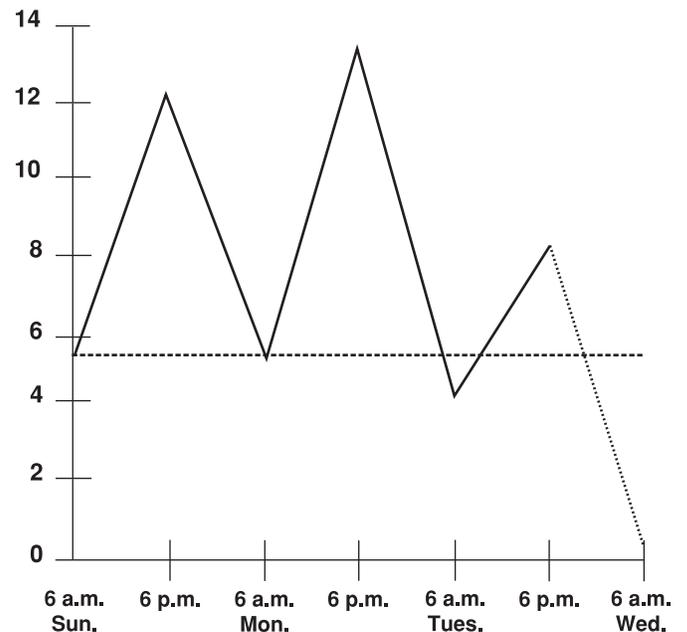


Figure 13. Graphic pond record predicting that a nighttime oxygen depletion will occur because the oxygen concentration is less than 5 ppm at dawn and was less at dusk than the day before.

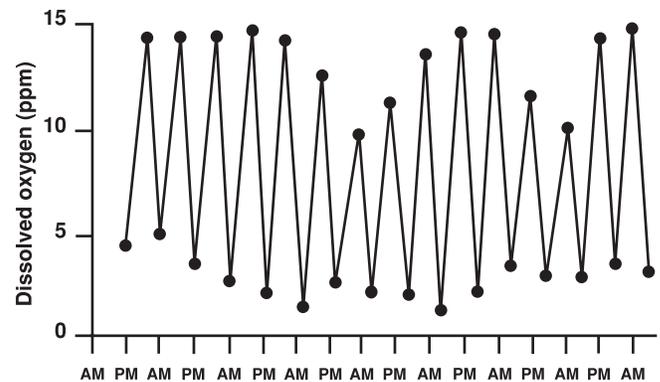


Figure 14. Chart of daily oxygen readings.

Supplemental aeration requires 2 to 3 horsepower of paddlewheel-type aeration per surface acre.

When the stocking and feeding rates are moderate (5,000 pounds of fish per acre and a maximum feeding rate of 120 pounds per acre per day), supplemental aeration that keeps the dissolved oxygen above 2.5 ppm appears to increase feed consumption and total pounds of catfish produced more than emergency aeration does. With higher stocking and feeding rates, additional supplemental aeration may not increase production.

Emergency aeration is used when the dissolved-oxygen concentration drops to a critical level and fish may die if not assisted. Emergency aeration is usually done with tractor PTO- (power-take-off) driven aerators. Emergency aerators must be available on all farms.

Once emergency aeration is begun, it should continue until the oxygen level is above 4 ppm and the fish no longer gasp for air at the surface or swim in the discharge from the aerators. This usually occurs after an extended period of aeration, after sunrise when photosynthesis begins, or when cloudy conditions break up during daylight.

Aerators

Many types of aerators are commercially available. Aerators can be powered by electricity, diesel engines, or the PTO of a tractor. The efficiency of an aerator can be determined by its ability to transfer oxygen into water. Aerators are rated in terms of pounds of oxygen transferred per horsepower per hour.

Most producers prefer stationary, three-phase, electric paddlewheel aerators for supplemental aeration. Electrical aerators usually are more efficient and less expensive to operate and maintain than other types. As a rule, 2 to 3 horsepower per surface acre is sufficient capacity for supplemental aeration and for some emergencies, except in extreme situations such as an algae bloom die-off.

Sometimes portable emergency aerators, such as PTO-driven paddlewheels (Fig. 15), are needed in addition to the stationary aerators in the pond.

Both electric paddlewheel (Fig. 16) and pump-sprayer (Fig. 17) aerators are effective in emergencies. Both agitate the water and create a current. The sprayed water rapidly saturates with oxygen, and the current moves the oxygenated water and increases its absorption (from wave action) across the surface of the pond. The current also attracts fish to the aerated zone. It is important to train fish to the location of the aerators before you need to use them. Turning the aerators on periodically will train the fish to find them when oxygen is low.



Figure 15. Tractor powered (PTO) "sidewinder" type paddlewheel aerator.



Figure 16. Electric paddlewheel aerators.



Figure 17. Pump-sprayer or "bankwasher" type diesel aerator.

In emergency situations, spray- or vertical-pump surface aerators that lift water are usually not as efficient as paddlewheels or pump sprayers. However, they may be useful in small ponds.

Propeller-aspirator pump aerators have high-speed propellers with hollow drive shafts. As the propeller turns, air is drawn down the shaft and mixed into the water. These are not as efficient as paddlewheel aerators but come in many sizes and may be useful for small ponds.

Diffuser aerators are operated by compressors or air blowers that release bubbles of air into the water. Diffusers are not very effective in large ponds.

Well Water. Pumping water with high oxygen content from a well, stream or adjacent pond is a good way to aerate in an emergency. However, well water is often low in oxygen and must be splashed or sprayed before it enters the pond. Water from streams or other ponds is not as desirable as well water because it can be a source of wild fish and disease.

To aerate ponds in this way, equipment that will pump at least 100 gallons per minute for each acre of pond is needed. Drain some water from the pond bottom while adding water at the surface. This is more effective than allowing excess surface water to pass through the pond standpipe or spillway.

Chemicals. Claims that chemicals such as potassium permanganate and phosphate fertilizers alleviate oxygen problems are untrue and may complicate the problem. **No chemical method of increasing dissolved oxygen is economically practical.**

Placement of Aerators

Stationary aerators should be placed where they will create the most circulation in the pond. Do not place them in the corners of the pond. Instead, in rectangular ponds place them in the center of the longest levee or side, with the discharge toward the middle of the pond. In this position, water is directed perpendicularly to the longest side and moves across the pond to create currents that reach most areas of the pond. Place aerators so they take advantage of the natural wind directions—usually against the southern or southeastern levee in Texas. Use portable aerators at other locations as needed during harvest.

Most aerators will not deliver adequate oxygen throughout the pond but will create oxygen-rich areas to which fish will be attracted and in which they can survive. Portable emergency aerators should be used before fish are stressed to the point that they cannot reach the aerated area. The best placement for an emergency aerator is in the area of the pond with the highest oxygen concentration because fish will be gathered there.

If two aerators are needed, place them near each other (30 to 50 feet apart). If one aerator fails, the other can hold the fish in the area and keep them alive until the problem is fixed. If there is only a single aerator and it fails, the fish will move into oxygen-poor areas in search of more oxygen. The fish may be dead by the time another aerator is moved to the pond.

Fish cover the surface of the pond, particularly along the banks, when they are severely stressed by low oxygen. Place aerators in the areas where the most fish are congregated and try to attract them to the aerator. In a hill-type pond, fish will usually go to the shallow end in search of oxygen. Be prepared to operate an aerator in shallow water. "Bankwasher" aerators are effective at quickly providing oxygen to fish along the shoreline.

Most producers do not have enough paddlewheel or pump sprayer aerators for all ponds and must move them from pond to pond as needed. One portable aerator for every three to four ponds is adequate. If you do not have enough for all ponds, then the ponds with the fastest falling oxygen levels or the most valuable fish should be aerated first.

A portable paddlewheel or pump sprayer aerator can be difficult to situate properly in a pond without damaging it or the tractor. Before emergencies arise, try running aerators in several probable locations around each pond so that placement becomes more or less routine. This is particularly important because most aerator maneuvering is done at night.

See page 28 for sources of additional information on aeration.

Carbon Dioxide

The same factors that produce low dissolved-oxygen concentrations in ponds also contribute to high carbon dioxide (CO₂) concentrations. Carbon dioxide increases through the night because of respiration. Carbon dioxide levels also can increase rapidly after an algae bloom die-off or over-feeding.

Carbon dioxide interferes with oxygen uptake at the gills, so fish will show signs of oxygen stress even though oxygen readings may be in a safe range. A carbon dioxide concentration higher than 25 ppm is usually harmful to catfish and may kill them.

Aeration is the best way to help rid the pond of carbon dioxide and increase oxygen levels. Up to 100 pounds per acre of hydrated lime, Ca(OH)₂, may be added in extreme cases to remove some of the carbon dioxide. Hydrated lime should not be added to low-alkalinity waters.

pH

The pH is measured using a 14-point scale. A pH of 7 is neutral. A pH below 7 is acidic, and above 7 is basic or alkaline. Changes in the pH of a pond occur during a 24-hour cycle because of respiration and photosynthesis.

Carbon dioxide from nighttime respiration reacts with water to form carbonic acid. Carbonic acid drives pH downward, making the water more acidic. During the daytime, pH moves upward (the water becomes more alkaline) because the carbon dioxide is removed for photosynthesis. Therefore, from a management perspective, it is most useful to compare pH readings taken at the same time each day.

The optimum pH for catfish ponds is 6.5 to 8.5. However, in production ponds pH can vary from 6.0 to 9.5 without severely stressing the fish. The pH of the pond is usually checked only before certain chemicals are added or if ammonia levels are high. The pH of the pond affects the toxicity of chemicals such as copper and ammonia. The pH of the pond water is strongly influenced by the pH of the pond mud, the soils in the watershed, and the mineral content of the water.

The only way to modify pH in ponds is to add chemicals such as lime, gypsum, alum, bicarbonate, etc. This should be done only in extreme circumstances and with the guidance of an experienced aquaculturist.

Alkalinity and Hardness

Alkalinity is a measure of bases such as hydroxides, carbonates and bicarbonates. Alkalinity is related to, but not the same as, pH. Alkalinity acts as a buffer to keep pH stable. Alkalinity affects the toxicity of copper treatments in ponds, so alkalinity should be checked before copper is added.

Hardness is a measure of divalent (+ 2) ions, mostly calcium and magnesium. Low hardness can be a problem in catfish hatcheries, so the hardness of hatchery water (pond or well) should be checked before the spawning season.

In chemical tests, both alkalinity and hardness are measured as ppm of calcium carbonate equivalence, which leads many people to think that they are the same. If alkalinity and hardness are both derived from limestone soils, they usually have similar values. It is possible, however, to have water that is high in alkalinity and low in hardness and vice versa.

Alkalinity and hardness should be kept above 20 ppm. Alkalinity can be increased by adding agricultural limestone, hydrated lime, quick lime, sodium bicarbonate or sodium hydroxide. Hardness can be increased by adding agricultural limestone, hydrated lime, quick lime, gypsum or calcium chloride. Agricultural lime is usually the least expensive and most predictable chemical for adjusting alkalinity and hardness.

See page 28 for sources of additional information on these water quality factors.

Nitrogen Wastes

Catfish produce nitrogen wastes, primarily ammonia. Ammonia is excreted into the water from the gills and kidneys of the fish. Ammonia is also produced as bacteria decompose the proteins in uneaten feed and dead animals and plants. About 2.2 pounds of ammonia is produced from each 100 pounds of feed.

Ammonia in the pond can be absorbed by algae or bacteria. Algae use ammonia as a nutrient for growth and reproduction. Certain aerobic (oxygen-requiring) bacteria use ammonia as a food source in a process called "nitrification." Nitrification is an important process by which bacteria convert toxic nitrogen wastes to nitrite and then nitrate. Ammonia and nitrite are both toxic to catfish; nitrate is not.

Ammonia Toxicity. Ammonia in water dissolves into two compounds—ionized and un-ionized ammonia. Un-ionized ammonia is extremely toxic to catfish, while ionized ammonia is relatively non-toxic. At 0.06 ppm, un-ionized ammonia can reduce fish growth and damage tissue. Levels as low as 0.4 ppm can kill small fish.

The amount of the total ammonia nitrogen (TAN) that is in the un-ionized form depends on temperature and pH (Table 7). The amount of toxic un-ionized ammonia increases as temperature and pH increase. Under reasonable feeding rates and good water quality conditions, ammonia is seldom a problem. But ammonia can become a serious problem if fish are overfed, a sudden algae die-off occurs, or a high afternoon pH drives the un-ionized ammonia concentration to a toxic level.

Ammonia levels should be checked each week and whenever an algae die-off occurs. High ammonia levels can occur at any time of the year but are most likely during the summer because of heavy feeding rates. It is hard to manage high ammonia levels. It is important to maintain good dissolved-oxygen levels (ammonia damages the gills), though the common practice of reducing feeding rates does not seem to control ammonia.

Nitrite Toxicity. Nitrite is also toxic to catfish. Under normal conditions nitrite does not accumulate to toxic levels, but it can if bacterial decomposition (nitrification) is disrupted. Most nitrite problems occur during fall and winter when sudden changes in water temperature disrupt bacterial activity.

Nitrite passes through the gills of fish and attaches to hemoglobin in the blood, forming methemoglobin. Methemoglobin causes the blood to change in color from red to chocolate-brown. For this reason, nitrite toxicity is called "brown blood" disease. If you suspect "brown blood," check the gill color or cut off the tail of a fish and look for chocolate-colored blood.

Normal hemoglobin carries oxygen through the bloodstream, but methemoglobin cannot. Fish in this condition are under severe respiratory stress and show signs of oxygen depletion. Nitrite toxicity is affected mainly by temperature, dissolved oxygen, and chloride ions. A nitrite concentration as low as 0.5 ppm can cause stress in catfish.

Table 7. Percentage of un-ionized ammonia in solution at different pH and temperatures.

pH	Temperature °C								
	16	18	20	22	24	26	28	30	32
7.0	0.30	0.34	0.40	0.46	0.52	0.60	0.70	0.81	0.95
7.2	0.47	0.54	0.63	0.72	0.82	0.95	1.00	1.27	1.50
7.4	0.74	0.86	0.99	1.11	1.30	1.50	1.73	2.00	2.36
7.6	1.17	1.35	1.56	1.79	2.05	2.35	2.72	3.13	3.69
7.8	1.84	2.12	2.45	2.80	3.21	3.68	4.24	4.88	5.72
8.0	2.88	3.32	3.83	4.37	4.99	5.71	6.55	7.52	8.77
8.2	4.49	5.16	5.94	6.76	7.68	8.75	10.00	11.41	13.22
8.4	6.93	7.94	9.09	10.30	11.65	13.20	14.98	16.96	19.46
8.6	10.56	12.03	13.68	15.40	17.28	19.42	21.83	24.45	27.68
8.8	15.76	17.82	20.08	22.38	24.88	27.64	30.68	33.90	37.76
9.0	22.87	25.57	28.47	31.37	34.42	37.71	41.23	44.84	49.02
9.2	31.97	35.25	38.69	42.01	45.41	48.96	52.65	56.30	60.38
9.4	42.68	46.32	50.00	53.45	56.86	60.33	63.79	67.12	70.72
9.6	54.14	57.77	61.31	64.54	67.63	70.67	73.63	76.39	79.29
9.8	65.17	68.43	71.53	74.25	76.81	79.25	81.57	83.68	85.85
10.0	74.78	77.46	79.92	82.05	84.00	85.82	87.52	89.05	90.58
10.2	82.45	84.48	86.32	87.87	89.27	90.56	91.75	92.80	93.84

Nitrite concentrations can rise from 0 ppm to lethal levels in 2 to 3 days, so it is very important to test for nitrite regularly. Producers should check nitrite concentrations three times per week from August 15 to January 1 and throughout April and May. Checking nitrite one or two times a week is sufficient the rest of the year. Producers should also monitor nitrites closely after algae die-offs.

Chloride ions (**not** chlorine) in the water can block nitrite from entering across the gills and protect the fish from “brown blood.” Research has shown that a minimum of 3 parts of chloride should be present for each part nitrite in the pond. Generally, a chloride to nitrite ratio of 10:1 is best. Salt (sodium chloride) is commonly used to increase chloride concentrations in ponds. Calcium chloride is also used, but it is more expensive. Most producers try to keep chloride concentrations at a minimum of 100 ppm. Applying 45 pounds of salt per 1 acre-foot of water will bring the chloride level to 10 ppm. To achieve 100 ppm, 450 pounds (45 x 10) are needed for each acre-foot of water. In a 10-acre pond with an average depth of 4 feet (or a total of 40 acre-feet), 18,000 pounds of salt must be added to bring the chloride concentration to 100 ppm (Fig. 18).

Whenever nitrite levels rise, check chloride levels and add salt as needed. Ponds lose chloride when they overflow from rainfall. Test regularly and keep good records! After the “brown blood” problem is corrected, watch the fish closely for bacteri-

al infections, which often occur a few days after “brown blood” outbreaks.



Figure 18. Applying salt to a 10-acre catfish pond.

Other Toxicity Problems. There are other chemical compounds that can be harmful to fish. **Copper** and **zinc** in small concentrations can be extremely toxic. Galvanized equipment, such as pipes, containers, screens, and tanks used in holding and transporting fish, may give up enough zinc to be toxic. Copper from algae treatment, pipes and other equipment can be toxic to fish in containers.

Catfish are very sensitive to **chlorine**. Water from city supplies should not be used in hauling or holding tanks.

Some **pesticides** are also toxic to fish. Fish in ponds built on cultivated watersheds are always in danger of pesticide poisoning. Before stocking fish in these ponds, find out which chemicals have been used and their toxicity to fish. (See page 28 for sources of additional information on pesticide toxicity.) Establish vegetative barriers between fields and ponds. Make sure that workers who apply chemicals prevent them from drifting over ponds. Be aware that constant use of chemicals near ponds may eventually cause a serious problem.

One of the strongest selling points for aquaculture products is their lack of chemical contamination. Keep dangerous chemicals away from your ponds and assure the consumer of the highest quality product.

Table 8. Recommended water-quality requirements for catfish production.

Component	Recommended value or range
Dissolved oxygen	3 ppm or more
Carbon dioxide	less than 20 ppm
pH	6 to 9.5
Total alkalinity	20 ppm or more
Total hardness	20 ppm or more
Un-ionized ammonia	less than 0.05 ppm
Nitrite	less than 0.5 ppm
Temperature change	less than 5 °F as rapid change

Parasites and Diseases

The stress caused by low dissolved oxygen, handling, crowding, transporting, and poor nutrition makes fish more susceptible to parasites and diseases. If fish feed slowly or stop altogether, appear sick, or die, analyze the situation immediately.

First, test the water to see if the condition could be caused by low oxygen, high carbon dioxide, ammonia or nitrite toxicity, or pesticide pollution.

If these problems can be eliminated, watch the fish closely. Are the fish:

- ✓ not eating?
- ✓ lying lazily in shallow water or at the surface and not swimming off rapidly when disturbed?
- ✓ nervous or irritable?
- ✓ flashing or swimming erratically?

Catch some fish that seem sick. Do they have:

- ✓ worn-away areas on gills, fins, mouths or skin?
- ✓ open sores?
- ✓ heavy mucus (slime) covering all or parts of their bodies?
- ✓ pale or swollen gills?
- ✓ protruding eyes?
- ✓ swollen or sunken bellies?
- ✓ skinny or emaciated bodies?



Figure 19. Channel catfish fingerling showing signs of disease—swollen belly, protruding eyes and skinny body.



Figure 20. Protruding and opaque eyes, open sores and eroded skin are signs of disease.

These are all signs of disease. If you see any of these signs, get a diagnosis immediately. Early diagnosis is essential for effective treatment.

The Texas Veterinary Medical Diagnostic Laboratory (TVMDL) can diagnose fish diseases. This is a fee-based service. TVMDL working hours are Monday through Friday, 8 a.m. to 5 p.m. Call (888) 646-5623 or (979) 845-3414.

To get a good diagnosis, a sample must be collected and transported properly and quickly. Include a separate water sample along with the fish so water quality can be checked. Contact TVMDL for shipping methods and information. Bacterial diagnosis takes 2 or 3 days. The pond owner will be notified of the results.

See page 28 for sources of additional information on disease diagnosis.

Chemicals

Chemicals should be used in fish culture only when there is no alternative. Ponds may require chemical treatment for

- ✓ controlling disease
- ✓ sterilizing ponds
- ✓ managing water quality
- ✓ reducing algal blooms
- ✓ eliminating undesirable fish
- ✓ controlling undesirable insects and weeds

Few chemicals are approved for use in food fish ponds. Check with your county Extension agent or Extension fisheries specialist for the latest recommendations.

When chemical treatment is prescribed, you must know how to calculate the amount of chemical needed to get the required concentration. Before treating any body of water, consider these things.

The fish – How much of the chemical can fish tolerate?

The water – In the pond to be treated, what water quality factors will affect the chemical being used? Could hardness or muddiness increase the toxicity of, or render ineffective, the chemicals being used?

The chemical – What percentage of active ingredient is in the chemical formulation?

The pond size – What is the exact volume of water to be treated? Many fish have been killed because the pond volume was exaggerated. Overestimating the pond size will cause an overdose, while underestimating the size may make

the treatment ineffective. Know the volume of your tanks and ponds and keep a record of them.

To calculate the volume of a square or rectangular body of water, multiply length times width times average depth of water. This will give you cubic measurements of volume. Cubic feet (ft³) and acre-feet are the measurements most commonly used. The area and volume of irregularly shaped ponds are much more difficult to determine. See page 28 for sources of additional information.

One very accurate way to measure pond volume is with a chloride test.

1. Take a water sample from the pond and test it for chloride (ppm). Reserve this sample so it can be compared to later samples.
2. Broadcast 50 pounds of salt per surface acre of the pond. The total pounds of salt added must be known, but the pond acreage can be estimated.
3. Allow the salt to dissolve. Usually one day is sufficient.
4. Take several water samples from different areas and depths of the pond. Test these new samples for chloride concentration.
5. Calculate the average chloride concentration by adding the chloride concentrations of all the samples together and then dividing by the number of samples.
6. Calculate the change in chloride concentration. Subtract the beginning chloride concentration (the concentration of the very first sample) from the average chloride concentration.

7. Calculate the pond volume using this formula:

Volume (in acre-feet) = (weight of salt applied x 0.6) ÷ (2.71 x change in chloride concentration (ppm)).

Measure accurately! Since 1 acre-foot of water weighs 2.7 million pounds, then 2.7 (2.71 in the formula above) pounds of any material (or active ingredient) dissolved in 1 acre-foot of water gives a solution of 1 part per million (1 ppm). This method will not work in hill-type ponds that are stratified.

The volume of water in ponds (particularly watershed ponds) may vary considerably from month to month. A producer should know the volume of ponds at different depths so chemicals can be applied correctly.

Table 9 shows the weights of chemicals that must be added to 1 unit volume of water to get a concentration of 1 ppm.

Table 9. Chemical active ingredients needed to produce 1 ppm concentrations.

Amount active ingredients	Unit of volume	Parts per million
2.7 pounds	acre-foot	1 ppm
1,235 grams	acre-foot	1 ppm
1.24 kilograms	acre-foot	1 ppm
0.0283 grams	cubic foot	1 ppm
1 milligram	liter	1 ppm
8.34 pounds	million gallons	1 ppm
0.0038 grams	gallon	1 ppm

Table 10. Conversions for treatment calculations.

1 acre-foot = surface acre of water 1 foot deep = 43,560 cubic feet = 2,718,000 pounds of water = 326,000 gallons of water
1 cubic foot = 7.5 gallons = 62.4 pounds of water = 28,355 grams of water
1 gallon = 8.34 pounds of water = 3,800 cubic centimeters = 3,800 grams of water
1 quart = 950 cubic centimeters = 950 grams of water
1 pint = 475 cubic centimeters = 475 grams of water
1 cup = 240 grams of water
1 tablespoon = 14.8 grams of water
1 teaspoon = 4.9 grams of water
1 pound = 454 grams = 16 ounces
1 ounce = 28.35 grams
1 liter = 1,000 grams of water

Table 10 contains conversions that are helpful in calculating treatments. See page 28 for additional sources of information on calculating volume and treatment dosages.

Off-flavor

The presence of objectionable flavors in the fishes' flesh—off-flavor—is a significant problem for producers of farm-raised fish. Intense off-flavor makes fish unmarketable. Because off-flavor is a complicated problem, producers must understand the probable causes, possible cures, and, most important, how to check the fish before they are marketed.

Off-flavors can be described in many ways, such as earthy, musty, rancid, woody, nutty, stale, moldy, metallic, painty, weedy, putrid, sewage,

petroleum, and lagoon-like. During the fall, more than 50 percent of production ponds may have off-flavor fish. This means that ponds cannot be harvested and harvest and processing schedules are disrupted. Producers are left feeding and maintaining these fish, which increases production costs, disrupts cash flow, and extends risks.

Off-flavor is caused by chemical compounds that enter the fish across the gills. Some of these compounds are produced by certain pond algae and bacteria. Blue-green algae are the most common cause of off-flavor in catfish ponds. These algae are most abundant in the summer and fall. They thrive in nutrient-rich ponds and can dominate other types of algae. Blue-green algae often float and form paint-like scums or a “soupy” layer near the surface. The causes of some off-flavors have yet to be identified.

Off-flavor compounds are eliminated from the flesh of the fish over time, once the compounds are no longer present in the pond. Depending on temperature and other factors, it can take from a few days to more than a month for the off-flavor itself to dissipate.

It is extremely difficult to control blue-green algae in a pond. Herbicides are only somewhat effective. Diuron herbicide is approved under a special U.S. Environmental Protection Agency (EPA) Section 18 exemption for use in catfish ponds to control specific blue-green algae. However, this is a year-to-year exemption and only for specific counties in Texas. Check with your county Extension agent, Extension fisheries specialists, or the Texas Department of Agriculture (http://www.agr.state.tx.us/pesticide/exemptions/pes_catfish04.htm) before purchasing diuron. Diuron is applied at a rate of 0.5 ounce per acre-foot every 7 days, not to exceed nine applications per year. As of this writing, only one company has an aquatic label for its diuron product, and it is illegal to purchase diuron products for aquatic use from other companies.

Research in Arkansas has found that stocking catfish ponds with tilapia (usually in cages) reduces the occurrence of off-flavor. However, there may be problems obtaining tilapia fingerlings, controlling reproduction, and finding a market for them.

Copper compounds such as copper sulfate, complexed coppers and chelated copper can be used to kill algae and reduce off-flavor if applied before a major problem develops. There are two common methods of applying copper sulfate (CuSO₄):

1. Apply ¼ ppm of CuSO₄ per acre-foot per week (works well for total hardness in the range of 100 mg/L or more); or

2. Apply 80 percent of the maximum dose rate of CuSO_4 if the temperature is below 70 degrees F, 75 percent of the maximum dose rate if the temperature is 70 to 80 degrees F, and 60 percent of the maximum dose rate if the temperature is above 80 degrees F. The maximum dose of CuSO_4 is calculated by dividing the total hardness by 100, multiplying that number by the total acre-feet of pond water, and then multiplying that number by 2.71.

Many complexed copper compounds are more effective in hard and alkaline waters than copper sulfate. Check the product label to be sure it is registered for aquatic use, and apply according to directions.

Purging the fish by placing them in clean water is another way to eliminate off-flavor. This method is costly in terms of facilities, labor, energy, time, and weight loss of the fish being held.

Processors check fish for off-flavor before scheduling harvests. Producers also should check fish for off-flavor. Begin checking when fish reach harvest size. Test at least 2 weeks before a planned harvest, again 3 days before harvest, and finally on the day of harvest. Fish can go off-flavor within a few hours and even during harvest operations. If off-flavor is found, continue testing weekly. The future of the catfish industry depends on delivering a high-quality product.

To test catfish for off-flavor:

1. Select two fish from each pond.
 2. Head and gut, but do not skin, the fish. This step can be skipped if you do not plan to eat the rest of the fish later.
 3. Cut off the tail section (the last third) with skin intact. Use this part for the test.
 4. Cook the tail section until the flesh is flaky, using one of the following methods. **Do not season the fish with any spices, not even salt.**
 - Wrap the fish in foil and bake at 425 degrees F for about 20 minutes.
- OR
- Place the fish in a small paper or plastic bag or a covered dish and microwave at high power for 1 ½ minutes per ounce.
5. After cooking, smell the steam coming from the fish. Do you notice any foul odors?
 6. Next, taste the fish. Do you notice any bad flavors?

If the fish smells or tastes foul, it is off-flavor and should not be processed! Learn to check your fish

and recognize off-flavor problems. And remember, a first-time catfish consumer who eats an off-flavor fish may be a one-time customer.

Harvest

A market for fish must be arranged before harvesting. Most buyers prefer fish that weigh $\frac{3}{4}$ to 4 pounds.

Methods

There are two ways to harvest a catfish pond. In a **complete harvest**, all the fish are taken out of the pond. This can be done only by seining and draining the pond. Levee ponds are seined several times to remove the catfish. Hill ponds are seined several times as soon as the water is lowered to about 5 to 8 feet deep at the drain. In both cases, the remaining fish are captured by seines and dip nets from the small pool of water remaining near the drain after the pond is drained.

Although draining is the best way to harvest all the fish at one time, it is costly to refill ponds, and the discharge of effluents may be prohibited. In watershed ponds, where refilling depends mainly on rainfall, drained ponds may be out of production for awhile during dry periods. One solution to this problem is to drain or pump water from the pond being harvested into other near-by ponds for temporary storage. Then, refill the harvested pond from the storage pond(s). If you are harvesting from a series of ponds, start at the lowest pond and end at the uppermost pond to conserve water.

Partial harvesting is another harvest method. Most levee-type ponds are partially harvested two to four times per year and drained only every 7 to 10 years so that levees can be repaired and silt removed. Partial harvesting involves pulling a seine and live-car of a specified mesh size (Table 11) through the pond with tractors. Catfish are concentrated in the live-car and held during the grading process.

Concentrating the fish in a live-car, or in a small area when water is drawn down, may cause an oxygen depletion and a fish kill. Careful supervision is required during this procedure. To prevent problems, aerated well water should be pumped in, aerators placed near the live-car, or pure oxygen (liquid) supplied to the live-car during harvest (Figure 21). If all the fish cannot be hauled to market in a reasonably short time, the aerators, well water or pure oxygen will have to remain on until fish can be loaded onto hauling trucks. Do not direct high-velocity aerators directly at the live car. This can cause swimming exhaustion and death.

Table 11. Mesh sizes and sizes of fish caught.

Mesh size	Fish size
1 inch	5 ounces and larger
1 1/4 inches	7 ounces and larger
1 3/8 inches	8 ounces and larger
1 1/2 inches	12 ounces and larger
1 5/8 inches	1 pound and larger
1 3/4 inches	1 1/2 pounds and larger
1 7/8 inches	1 3/4 pounds and larger
2 inches	2 pounds and larger



Figure 21. Fish being removed from a grading-sock with an aerator running to keep dissolved oxygen high.

Partial harvest also can be done by angling, trot line, trapping or seining, though angling, trot lines and box traps are too inefficient for commercial harvest. Most hill ponds are too deep and uneven to seine without draining. However, a seine can be used for trapping the fish. This method is especially useful when small quantities of fish are being harvested for local sales.

Generally, a seine 150 to 200 feet long and 6 to 8 feet deep should be used for trap-seining. Set the seine in a location that has a smooth bottom and is about 3 to 4 feet deep at a distance of 50 feet from shore. Stretch the seine parallel to the shore at a distance of approximately 50 feet. Coil 50 feet of the seine at each end and connect ropes from each coiled end to the shore. The seine can also be set in the center of a finger or bay of the pond if the seine is 1 1/2 times the width of the bay.

Set the trap and begin feeding between the seine and the shore for several days before attempting a harvest. Sometimes feed must be spread outside the catch area to lead fish into it. The fish will be

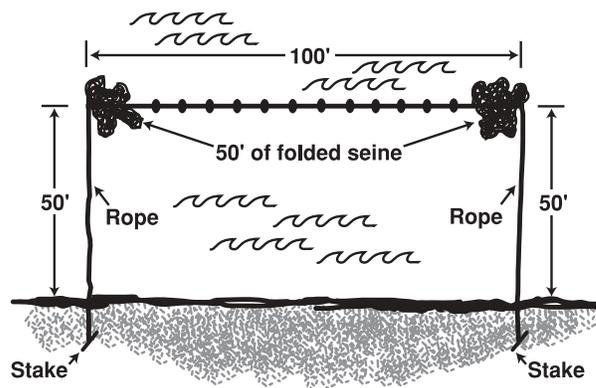


Figure 22. Trap-seine placement drawing.

ready to trap after several days, when they are accustomed to feeding within the area. At harvest, put a small amount of feed within the trapping area and pull the ends of the seine to shore when the fish are feeding. Then draw the entire seine to shore and harvest the fish. Figure 22 shows the placement of a trap-seine.

The trap-seine method of partial harvest usually cannot be used more often than every 7 to 10 days because fish become wary of the trap. However, harvesting can be alternated among ponds or at different locations within larger ponds. Remember to feed fish at the time of day you plan to trap.

Equipment

The type and size of harvest equipment a producer needs depends on the size of the operation and the market served. Some producers harvest their own fish, but most depend on custom harvesters so they will not have to invest in equipment.

Seines. Three feet of seine length is needed for every 2 feet of pond width to be seined. The same ratio applies to pond depth. Floats can be made of Styrofoam® or plastic attached on 18-inch centers. Most catfish seines have a mud line on the bottom of the net. A mud line is made of many strands of rope or a roll of menhaden netting bound together. As the seine is drawn across the pond bottom, the mud line stays on top of the mud, eliminating the digging effect of lead-weighted lines.

Seines should be made of polyethylene or nylon. Catfish spines will not catch in polyethylene material, but nylon netting must be treated to prevent spines from entangling. The mesh size varies according to the minimum size of the fish to be captured. With the proper mesh seine for your operation you will capture only fish that are large enough for your market. Table 11 lists the size of fish that can be caught by various sizes of mesh. All sizes are given as bar mesh, which is the

smallest distance between knots. The size of the fish caught varies somewhat with the condition and activity of the fish. Fish do not grade as well when water is cold.

Live-cars. Live fish usually must be held and graded, especially in multi-batch systems. They may have to be held for some time if the market cannot take all the catch in one day, if there is a delay between capture and hauling fish to market, or if you want to sell directly to consumers. Live-cars, or “socks,” are net enclosures (sides and bottom) attached to the seine to concentrate and grade the fish. They also can be used to temporarily hold the fish (Fig. 23). They are made of the same materials and use the same mesh size as seines.

Use caution when holding fish in live-cars. Diseases, oxygen stress, bruising and scraping, weight loss, and poaching are common problems. It usually is necessary to aerate near the live-car, particularly in warm weather. Limit the time the fish are held to only a few days to reduce weight loss and prevent disease. Disease can occur in holding devices during any season but is much more common in hot weather. Poachers can easily steal fish from unguarded holding facilities.



Figure 23. Basket removing catfish from live-car.

Other equipment. For harvesting fish, producers also need

- ✓ a seine reel for hauling in and storing the seine,
- ✓ seine stakes,
- ✓ tractors,
- ✓ sturdy dip nets,
- ✓ baskets,
- ✓ boots and/or chest waders,
- ✓ scales,
- ✓ a boom with a loading basket,
- ✓ a boat and motor,
- ✓ a pump for filling hauling tanks, and
- ✓ fish hauling tanks (Figure 24).

When To Harvest

Harvest dates must be coordinated to meet the needs of the market, whether the fish go to processors or to your own private outlet. Make sure the fish are the size the buyer wants. Live-haulers for ethnic markets and fish-out operations want larger fish.

Catfish fingerlings stocked in winter or early spring are ready to harvest in the fall or early winter, which can cause a glut of fish in the market at that time of year. To avoid this situation, most producers now stock fingerlings of varying sizes at different times of the year. Usually fingerlings are restocked after a harvest, in numbers estimated to replace the fish harvested plus enough extra to counter production mortality. This strategy may not result in optimum growth, but the higher prices generally paid for market-size fish during the spring and summer can make up for any production inefficiencies.



Figure 24. A live-haul truck for transporting fingerlings and food fish.

Transporting Live Catfish

The transporting of live fish must be done carefully. In transport, fish are crowded into a relatively small amount of water. The dissolved-oxygen content of the transport water often determines whether the fish live or die. Agitators, blowers, compressed air, compressed oxygen or liquid oxygen can be used individually or in combination to keep the fish alive in hauling tanks. Transport containers are usually made of wood, fiberglass or aluminum. Many types are available.

If the transport time will be less than 6 hours, do not feed fish for at least 24 hours in warm weather and at least 48 hours in cool weather. For transport periods longer than 6 hours, withhold feed for 48 hours before hauling in warm weather and 72 hours in cool weather. These periods give fish time to purge their digestive systems of feed and feces so that wastes do not accumulate in transport water. Fish wastes and regurgitated feed consume large quantities of oxygen and can produce ammonia and carbon dioxide problems in hauling tanks.

Transporting fish in cool weather and/or in cool water increases overall survival. Cool water holds more oxygen than warm water, and fish consume less oxygen at lower temperatures because of slowed metabolism. It is a good practice to have an oxygen probe in the hauling tank with the meter in the cab of the truck so oxygen concentration can be monitored during transport.

Fish health and survival depend on limiting stress. Stress from netting, loading, hauling and stocking weakens fish and makes them more susceptible to disease and water quality problems. **The less stress, the healthier the fish.**

Table 12 has general guidelines for hauling live catfish. The numbers are in pounds of fish per gallon of water in tanks using agitators or blowers for aeration. Assume that the water temperature is 65 degrees F. Decrease the load by 25 percent for each 10-degree F increase in water tempera-

Table 12. Load limits for hauling catfish, in pounds of fish per gallon of water.*

Size of fish	Duration of transport			
	1 hr.	6 hr.	12 hr.	24 hr.
	pounds of fish per gallon of water			
2-inch fingerlings	2	1½	1	1
8-inch fingerlings	3	3	2	1½
14-inch adult fish	4	4	3	2

*Adapted from Transport of Live Fish by S. K. Johnson, Texas A&M University.

ture. The same calculation can be used for increasing the load as temperature decreases. Loads can be increased by about 25 percent when pure oxygen is used for aeration. Ice can be used to cool the water in hauling tanks. Salt should be added to the water to reduce metabolic stress. Be sure to temper the fish before stocking or loading them into water of a different temperature or water quality. See page 28 for sources of additional information on hauling and tempering fish.

Marketing Catfish

Before the first ponds are built or fish are stocked into existing ponds, producers should know where they can sell their fish and the current market price. Market options include:

- ✓ large processors
- ✓ small processors
- ✓ fish-out or fee fishing
- ✓ on-farm sales
- ✓ local retail sales
- ✓ live-haulers

Analyze these options carefully, and select a market on the basis of potential profits from an operation the size of yours.

Large processors generally harvest fish for producers within a short distance (50 to 75 miles) of the processing plant. Some accept fish delivered live by the producer. Producers within range of large processing plants should discuss possible sales to them before fingerlings are stocked.

Many producers want to sell their fish in the fall, creating an oversupply of fish for processors. Catfish harvested in the spring or summer usually command a higher price because demand is higher and supplies are lower. Some producers are able to market their fish more profitably during times of short supplies by manipulating the fingerling size and/or the stocking date and density, and by partial harvesting.

Small-scale processors in some areas process small quantities of catfish for sale to local businesses and individuals. These processors often produce much of their own fish but, at times, buy from local producers. Your county Extension agent will have information about processors in your area.

Fish-out, or fee-fishing, is another market option for catfish producers. A fish-out business depends on the number of fishermen in the area and their ability to catch fish. Fishing ponds near cities are usually more in demand than those in remote areas.

Small, densely stocked ponds are best for fish-out or fee-fishing purposes. Catfish should be replenished when stocks become low so that the fish will keep biting. Many successful fee-fishing operations buy fish from other producers or produce them in their own ponds to stock fish-out ponds. This makes customers more successful in catching fish and increases sales.

Owners of fee-fishing operations must take proper safety precautions before opening ponds to the public. Insurance protection against liability claims is a must. See page 28 for sources of additional information on fee-fishing.

Live catfish can be sold at retail or wholesale to local customers. Fish can be captured to order or captured and held live for later sale. Newspaper ads, road signs and word-of-mouth can rapidly establish a good market. Remember that customer demand can be maintained by providing a consistent supply of high-quality catfish throughout the year.

Live-haulers, people who buy and haul live catfish from producers to retail outlets, are important buyers of farm-raised catfish. Usually these haulers want producers to harvest and load the fish into their tank trucks. Live-haulers often transport fish to fee-fishing ponds or other live markets near large cities. A producer catering to live-haulers exclusively should have all the necessary equipment for seining and loading, plus all-weather roads around the ponds.

Bird Predation

Bird predation is an increasingly serious problem for catfish producers. Most birds that cause problems are migratory and are therefore protected under the federal Migratory Bird Treaty Act (MBTA). Predation varies greatly depending on migration patterns, time of the year, migratory concentrations, and the location of catfish ponds. Ponds near nesting or rookery sites can have particular problems.

The MBTA often is confused with the endangered species laws. Under the MBTA, most migratory birds may not be killed or trapped without permits. The exception is double-crested cormorants, which can be controlled at a licensed commercial aquaculture facility. All bird species can be scared or harassed in an effort to make them leave an aquaculture facility. Harassment techniques include propane cannons, fireworks, screamers, sirens, scarecrows, lasers, flashing lights, reflectors, etc. While all of these work somewhat, the key seems to be to use a combination of techniques and to vary their use and location fre-

quently. See page 28 for sources of additional information on controlling predation.

Besides eating fish, birds can damage property and are known to transmit fish diseases. Predatory birds consume the individual fish that are easiest to catch. Fish that are easily caught are often those that are diseased. So, the birds pick up diseases and transmit them to other ponds through excrement, bodily contact, and the movement of diseased fish. Recent research suggests that 80 percent of catfish consumed by herons and egrets are diseased.

Catfish are preyed upon by cormorants, egrets, herons, white pelicans and anhingas (water turkeys). Ospreys and kingfishers also prey on catfish but seldom cause economic damage. Frequent visits by flocks of anhingas, herons, egrets, pelicans and cormorants can be devastating, however, especially in ponds with small fish.

Permits to control bird depredation can be obtained for some of these species if a producer can document losses and has kept good records of harassment techniques tried. Contact Wildlife Services at (210) 472-5451 to get information and assistance on depredation permits.

Genetics and Breeding

Much of the improvement in the last 40 years in all phases of agricultural production, both plant and animal, has resulted from genetic selection and hybridization. Faster growth, higher yield, better feed conversion, and increased resistance to disease can all be improved through genetic manipulation.

Several universities in the Southeast and the USDA Agricultural Research Service at Stoneville, Mississippi, are involved in catfish genetic research. Scientists are doing work in selection, strain identification and evaluation, cross-breeding, hybridization, polyploidy, sex reversing, and gene splicing.

Domesticated strains of catfish have better growth rates than wild strains. However, domesticated strains vary in their growth rates, body conformation (which influences dress-out percentage), and resistance to disease. Crossbreeding has improved growth rates, spawning success and disease resistance (attributable to hybrid vigor). Of course, not all strains or crossbreeds perform equally at different geographic locations.

Crossing female channel catfish with male blue catfish has produced a hybrid with better growth, feed conversion, disease resistance, catchability, and dress-out percentage than pure channel cat-

fish. However, production of the channel female x blue male hybrid can be difficult. The two species do not spawn naturally and spawn inconsistently even when hormone injections are used. Research is continuing, and this hybrid may be available to producers in the future.

Producers should work with superior domesticated strains and fish that have been vaccinated against ESC (Enteric Septicemia of Catfish). Buy from a fingerling producer who is practicing mass selection or who is working with improved strains. If you produce your own fingerlings, know what strain you have, try mass selection of your fastest growing fish, try to obtain improved strains for cross-breeding, and, most importantly, do not inbreed.

Conclusion

Catfish farming is one of the most intensive forms of large-scale agriculture. It requires considerable capital investment, and it is a high-risk venture not appropriate for everyone. The industry is still in its infancy, and many researchers, Extension workers, government agencies and fish farmers are working to solve the problems it faces.

Additional Information

These publications from the Southern Regional Aquaculture Center are available from your county Extension office. They are also on the Web at <http://srac.tamu.edu>.

Site selection and pond construction

No. 100, "Site Selection of Levee-type Fish Production Ponds"

No. 101, "Construction of Levee-type Ponds for Fish Production"

No. 102, "Watershed Fish Production Ponds"

Aeration

No. 370, "Pond Aeration"

No. 371, "Pond Aeration: Types and Uses of Aeration Equipment"

Alkalinity and hardness

No. 464, "Interactions of pH, Carbon Dioxide, Alkalinity, and Hardness in Fish Ponds"

No. 410, "Calculating Treatments for Ponds and Tanks"

No. 4100, "Liming Ponds for Aquaculture"

Pesticides

No. 4600, "Toxicities of Agricultural Pesticides to Selected Aquatic Organisms"

Sampling for disease diagnosis

No. 472, "Submitting a Sample for Fish Kill Investigation"

Calculating pond size and treatments

No. 103, "Calculating Area and Volume of Ponds and Tanks"

No. 410, "Calculating Treatments of Ponds and Tanks"

Transporting fish

No. 390, "Transportation of Warmwater Fish: Equipment and Guidelines"

No. 391, "Sorting and Grading Warmwater Fish"

No. 392, "Transportation of Warmwater Fish: Procedures and Loading Rates"

No. 393, "Transportation of Warmwater Fish: Loading Rates and Tips by Species"

No. 394, "Harvesting Warmwater Fish"

No. 395, "Inventory Assessment Methods for Aquaculture Ponds"

Building a small-scale processing plant

No. 442, "Small-Scale, On-farm Fish Processing"

Fee-fishing

No. 479a, "Fee-Fishing: An Introduction"

No. 480, "Fee-Fishing Ponds: Management of Food Fish and Water Quality"

No. 481, "Development and Management of Fishing Leases"

No. 482, "Fee-Fishing: Location, Site Development and Other Considerations"

Bird predation

No. 400, "Avian Predators on Southern Aquaculture"

No. 401, "Avian Predators: Frightening Techniques for Reducing Bird Damage"

No. 402, "Control of Bird Predation at Aquaculture Facilities: Strategies and Cost"

Genetics and breeding

No. 190, "Production of Hybrid Catfish"

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