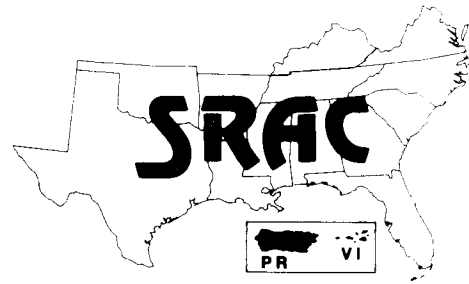


Southern Regional Aquaculture Center



December, 1988

What is Cage Culture?

Michael P. Masser*

Fish are raised commercially in one of four culture settings: **open ponds, raceways, tanks, or cages**. Cage culture of fish utilizes existing water resources but encloses the fish in a cage or basket which allows water to pass freely between the fish and the pond.

The origins of cage culture are a little vague. It is likely that the first cages were used by fishermen as holding structures until fish could be accumulated for market. The first true cages for producing fish were seemingly developed in Southeast Asia around the end of the last century. These early cages were constructed of wood or bamboo, and the fish were fed trash fish and food scraps.

Modern cage culture began in the 1950s with the advent of synthetic materials for cage construction. In the United States universities did not begin conducting research on cage rearing of fish until the 1960s. Cage research has been limited mostly because large scale open

pond culture was more economically viable and, therefore, received most of the research focus.

Today cage culture is receiving more attention by both researchers and commercial producers. Factors such as increasing consumption of fish, some declining wild fish stocks, and a poor farm economy have produced a strong interest in fish production in cages. Many of America's small or limited resource farmers are looking for alternatives to traditional agricultural crops. Aquaculture appears to be a rapidly expanding industry and one that may offer opportunities even on a small scale. Cage culture also offers the farmer a chance to utilize existing water resources which in most cases have only limited use for other purposes.

It should be emphasized that cage culture of fish is not foolproof or simple. To the contrary, cage production can be more intensive in many ways than pond culture and should probably be considered as a commercial alternative **only where open pond culture is not practical.**

Considerations for cage culture

As with any production scheme cage culture of fish has advantages and disadvantages that should be considered carefully before cage production becomes the chosen method.

Advantages

Cage culture does have some distinct advantages which include:

- Many types of water resources can be used, including lakes, reservoirs, ponds, strip pits, streams and rivers which could otherwise not be harvested. (Specific state laws may restrict the use of "public waters" for fish production; check with your state fish and wildlife agency.)
- A relatively low initial investment is all that is required in an existing body of water.
- Harvesting is simplified.
- Observation and sampling of fish is simplified.
- Allows the use of the pond for sport fishing or the culture of other species.

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These advantages are appealing. A potential fish farmer can produce fish in an existing pond without destroying its sportfishing; does not have to invest large amounts of capital for construction or equipment; and can, therefore, try fish culture without unreasonable risks.

Disadvantages

Cage culture also has some distinct disadvantages. These include:

- Feed must be nutritionally complete and kept fresh.
- Low Dissolved Oxygen Syndrome (LODOS) is an everpresent problem and may require mechanical aeration.
- The incidence of disease can be high and diseases may spread rapidly.
- Vandalism or poaching is a potential problem.

The potential for loss of fish due to poor nutrition, LODOS, disease and poaching is real and should not be taken lightly. Feeds must be **complete** and provide all the necessary proteins, carbohydrates, fats, vitamins and minerals needed for growth and health. Feeds cannot be allowed to deteriorate during storage. Low Dissolved Oxygen Syndrome may occur within a cage and not affect the fish free in the pond. Because fish in cages are crowded and confined, aeration may be more necessary for a cage system than it would be if the fish were loose in the pond. Diseases must be identified and treated rapidly. Vandalism is a problem which has to be anticipated and precautions must be taken. It should be emphasized that cages do not increase the amount of fish (i.e., pounds) that can be produced in a pond. This is particularly true in ponds with wild fish populations.

Species selection

Research in the United States on production of freshwater fish in cages has centered primarily on channel catfish and rainbow trout. Other species such as tilapia, hybrid sunfish, red drum, hybrid striped bass, bullhead catfish and blue catfish have received some attention and may have potential for cage production. Before attempting to raise any species in cages a careful examination of the site, water quality, construction costs, market outlets and legal requirements should be considered.

This is the beginning of a series of Cage Culture publications which will attempt to answer questions on how to build and where to locate cages, which species to select, how to evaluate water quality, how to handle and feed caged fish, how to recognize problems, and how to evaluate cage success and economics. Please refer to the following Cage Culture publications for additional information:

SRAC Publication No. 161, Cage Culture--Site Selection and Water Quality

SRAC Publication No. 162, Cage Culture--Cage Construction and Placement

SRAC Publication No. 163, Cage Culture--Species Suitable for Cage Culture

SRAC Publication No. 164, Cage Culture--Handling and Feeding Caged Fish

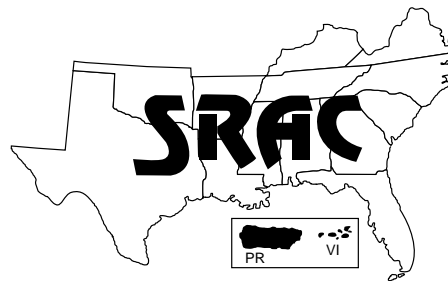
SRAC Publication No. 165, Cage Culture--Cage Culture Problems

SRAC Publication No. 166, Cage Culture--Harvesting and Economics.

References

- Basset, B.K. and J.G. Dillard. 1985. *Raising Catfish in Floating Cages*. Cooperative Extension Service, University of Missouri-Lincoln University. 26 pp.
- Beem, M., and G. Gebhart, *Cage Culture of Rainbow Trout*. Langston University. Langston, OK. 4 pp.
- Beveridge, M.C.M. 1987. *Cage Aquaculture*. Fishing News Books LTD. Farnham, Surrey, England. 352 pp.
- Boyd, C.E. 1979. *Water Quality in Warm Water Fish Ponds*. Alabama Agricultural Experiment Station, Auburn University, Auburn, AL. 359 pp.
- Collins C.M. 1974. *Catfish Cage Culture--Fingerlings to Food Fish*. The Kerr Foundation, Inc., Publication No. 13. Poteau, OK. 22 pp.
- Helfrich, L.A., J.C. Dean, D.L. Garling, and D.L. Weigmann. 1984. *Catfish Farming in Cages in Virginia's Warmwater Ponds and Lakes*. Virginia Cooperative Extension Service, Virginia Tech and Virginia State, Virginia's Land-Grant Universities. 13 pp.
- Schwedler, T.E., M.L. Berry, and D.R. King, 1986. *Raising Catfish in a Cage*. Clemson University Cooperative Extension Service, Clemson University, Clemson, SC. 23 pp.
- Stickney, R.R. 1979. *Principles of Warm Water Aquaculture*. Wiley Interscience, New York. 375 pp.
- Strange, D. and S. Van Gorder. 1980. *Small-scale Culture of Fish in Cages*. Rodale Press, Kutztown, PA. 34 pp.
- Williams, K., D.P. Schwartz, and G.E. Gebhart. 1983. *Small-Scale Caged Fish Culture in Oklahoma Farm Ponds*. Cooperative State Research Service, Langston University, Langston, OK. 25 pp.

Southern Regional Aquaculture Center



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Cage Culture Site Selection and Water Quality

Michael P. Masser*

In the U.S. the majority of cage culture is practiced in ponds or quarries. Not all ponds and quarries are suitable for cage culture of fish. Many failures in cage production have occurred because of poor site selection. Before attempting cage culture make sure the body of water chosen will support the increased biological demand placed upon it.

Site criteria

Many different sites may be adapted to cage culture. Potential sites include lakes, reservoirs, ponds, quarries, rivers and streams. Each state may have specific laws governing the use of "public waters." These laws may restrict private individuals from engaging in fish farming in public waters or may require permits for use of public waters. Check with the Department of Natural Resources, Department of Fish and Wildlife, or with the Cooperative Extension Service's fisheries (or aquaculture) specialist in your state before using public waters for cage culture. Many ponds and quarries are not suitable for culturing fish in cages. The following are criteria that

should be considered before attempting cage culture in an existing pond or quarry.

- The surface area should be at least one half acre and preferably an acre or larger (but should not include weed infested areas of the pond).
- The pond should be at least 6 feet deep over a sizable area, and most of the pond should be more than 3 feet deep.
- The pond must have good water quality and should be located where prevailing winds blow across it.
- The pond should not have direct access by livestock or large numbers of livestock in the watershed.
- The pond should not have a highly erodible watershed or one that allows the accumulation of large amounts of organic debris.
- The water level of the pond should not fluctuate greatly (2 to 3 feet) during the summer.
- The pond should not have chronic problems with aquatic weeds, surface scums, overpopulations of wild fish, or oxygen depletion problems.

- The pond should have an all-weather access road.

Pond problems

Problems frequently arise when small ponds (less than one acre) are used for cage culture. Those problems usually center around water quality deterioration, low oxygen, ammonia or nitrite buildup, and excessive algal blooms. These problems may also occur in ponds larger than one acre but are not as common. Adequate depth of the pond (6 feet or greater) is important for keeping the fish wastes away from the cage, maintaining adequate circulation through the cage, and for reducing the chance of weed encroachment around the cage. Very deep ponds are more likely to experience low dissolved oxygen problems in the summer.

The characteristics of the pond's watershed can be critical to successful cage culture. Livestock with direct access to the pond, or located in large numbers within the watershed, may cause water quality problems. Livestock wastes can overfertilize the pond leading to severe algal blooms, water quality deterioration, and eventually disaster. This is partic-

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ularly true of small ponds (less than 5 acres). Livestock should be fenced out of the pond and not allowed to use the immediate pond watershed as a loafing area. As shorelines are trampled, erosion increases and ponds age prematurely. Even ponds frequented by livestock in previous years may contain large amounts of organic matter.

Highly erodible watersheds may cause turbidity/silting problems which can irritate the gills of fish and cause reduced dissolved oxygen concentrations. Watersheds where large amounts of organic matter wash into the pond can result in oxygen depletions due to rapid bacterial decomposition of the detritus.

Ponds that have a greater watershed than is needed to fill and maintain the water level can also have problems. Excessively large watersheds can cause rapid temperature changes, turnovers, and associated oxygen depletions due to water exchanges after heavy rains.

Ponds that have chronic problems such as severe weed infestations, surface scums, fish kills, stunted wild fish populations, and severe water level changes during the summer are not good candidates for cage culture. These problems must be brought under control first. It may be necessary to treat chemically for weeds or to stock grass carp (check state regulations), remove wild fish, and/or renovate (rebuild) the pond. Finally, an all-weather access road to the pond is essential to the maintenance, health and survival of the caged fish. A day or more without access to the pond could lead to a catastrophe.

Water quality

Water quality management is a key ingredient in a successful fish operation. Most periods of poor growth, disease and parasite outbreaks, and fish kills can be traced to water quality problems. Water quality management is

undoubtedly one of the most difficult problems facing the fish farmer. Water quality problems are even more difficult to predict and to manage. A more thorough discussion of water quality problems and equipment needs can be found in other Extension-Aquaculture publications.

Oxygen

Oxygen stress is the most frequently encountered water quality problem in cage culture of fish. The concentration and availability of dissolved oxygen (DO) are critical to the health and survival of caged fish.

Critical dissolved oxygen levels will vary depending on species being reared and with interactions with other water quality parameters; e.g., carbon dioxide, ammonia and nitrite. In general, warmwater species such as catfish and tilapia need a dissolved oxygen concentration of 4 mg/l DO (or ppm) or greater to maintain good health and feed conversion. Healthy warmwater fish can tolerate 1 mg/l DO for short periods of time but will die if exposure is prolonged. Prolonged exposure to 1.5 mg/l DO causes tissue damage, and any prolonged exposure to low dissolved oxygen levels will halt growth and increase the incidence of secondary diseases, apparently by reducing the fishes' ability to resist infection. Many parasites, diseases and chemical agents can damage the gill filaments affecting oxygen transport across the gills. This can cause the fish to behave as though the dissolved oxygen concentration is low, when in reality the cause is a disease problem.

The concentration of dissolved oxygen in any body of water varies over time and is affected by physical, biological and chemical factors. Physical controllers of dissolved oxygen are temperature, atmospheric pressure and salinity. As temperature and salinity increase, and as atmospheric pressure decreases, the solubility of

oxygen will decrease. Temperature is an important physical controller of dissolved oxygen. As water temperature increases 10°F the amount of oxygen that will dissolve in water decreases by approximately 10 percent. The physical transfer of oxygen between the atmosphere and water occurs across the water surface when dissolved oxygen concentrations are above or below saturation. The rate of this transfer is regulated by turbulence across the water surface.

Biological factors which affect dissolved oxygen are plant photosynthesis (both phytoplanktonic and macrophytic), and plant and animal respiration (fish, invertebrates, bacteria, etc.). Most of the oxygen in aquaculture ponds is produced by plant photosynthesis during sunlight hours. Planktonic algae (phytoplankton) usually produce the bulk of this oxygen. High densities of aquatic macrophytes (rooted underwater plants) usually reduce phytoplankton growth and water circulation and, therefore, can cause dissolved oxygen problems in cage production ponds.

Plant and animal respiration are the most important oxygen reducing processes in aquaculture ponds. Fish must compete with all other living organisms for the ponds' available dissolved oxygen. This is particularly acute at night when plants in the pond are also consuming oxygen through the process of respiration. In most aquaculture ponds nighttime phytoplankton respiration is the major consumer of oxygen. Respiration rates are temperature-driven in cold-blooded animals (i.e., fish) and plants, increasing oxygen consumption with rising temperatures. Total plant and fish biomass is also usually greatest during warm weather and high light intensity conditions. For all of these reasons, summer nights, with high water temperatures and respiration and low wind turbulence, bring most oxygen problems.

In cage culture situations low dissolved oxygen is particularly acute because the fish are crowded into such small areas. Most fish kills, disease outbreaks and poor growth in cage situations are directly or indirectly due to low dissolved oxygen.

Turnovers and plankton die-offs are two other situations in which dissolved oxygen levels may fall below critical levels. Turnovers occur during cold rains, heavy winds and prolonged cold spells in summer. These conditions cause the upper oxygenated layer of water to mix with the cold oxygen-depleted layer of water on the bottom of the pond. The mixing of the two layers reduces the total dissolved oxygen in the whole pond to critical levels due to both dilution and chemical reduction. Turnovers can be particularly common in deep ponds with large watersheds.

Plankton die-offs can occur as a natural consequence of algal population dynamics due to seasonal changes in temperature, pH, light intensity, nutrients, diseases, parasites, toxins, or other factors which are not clearly understood. Plankton die-offs can also occur as a consequence of nighttime low dissolved oxygen. In this case, the density and biomass of the plankton become so great that a critical dissolved oxygen concentration is reached in the pond due to nighttime respiration demands. The plankton dies from lack of oxygen along with the fish.

Dissolved oxygen management is one of the most critical management techniques that must be learned by a fish farmer. Dissolved oxygen management includes both biological and mechanical manipulation. Biological manipulation can include fertilization and submerged aquatic plant control to maintain a healthy phytoplankton bloom. Mechanical manipulation through aeration may help maintain adequate dissolved oxygen concentrations and may save fish during chronic low DOs, turn-

overs, and plankton die-offs. See SRAC publications 370, *Pond Aeration*; 371, *Pond Aeration—Types and Uses of Aeration Equipment*; 372, *Selecting the Proper Pump*; 374, *Open Channel Flow in Aquaculture*; and 375, *Powering Aquaculture Equipment on pond aeration and equipment*.

Temperature

Temperature is the single most important physical factor controlling the life of a cold-blooded animal. Temperature is critical in growth, reproduction and sometimes survival. Each species of fish has an optimum temperature range for growth, as well as upper and lower lethal temperatures. Below the optimum temperature feed consumption and feed conversion decline until a temperature is reached at which growth ceases and feed consumption is limited to a maintenance ration. Below this temperature is a lower lethal temperature at which death occurs. Above the optimum temperature feed consumption increases while feed conversion declines.

Refer to SRAC Publication No. 163, *Species Suitable for Cage Culture*, for species specific information on temperature optima and tolerances.

pH

pH is a measure of the relative acidity of the water. The pH in a pond fluctuates daily due to uptake and release of CO₂ during photosynthesis and respiration. The pH is lowest at or near dawn and highest at mid-afternoon. The desirable range of early morning pH for fish production is from 6.5 to 9. The acid death point is a pH of approximately 4 and the alkaline death point is approximately pH 11. When the pH is outside the desirable range, fish growth is slowed, reproduction reduced, and susceptibility to disease increased (see SRAC Publication No. 464, *Interactions of pH, Carbon Dioxide, Alkalinity and Hardness in Fish Ponds*).

Ponds with acidic bottom muds and soft water usually are not productive fish ponds. Lime can be added to these ponds to increase the pH and alkalinity (total concentration of bases). Limed ponds have fewer pH, dissolved oxygen and other related problems. A total alkalinity of 20 mg/l is considered the minimum concentration for a pond used in fish production.

For more information on liming ponds contact your county Extension office or state fisheries (or aquaculture) specialist.

Ammonia and nitrite

Ammonia is the primary nitrogenous waste produced by fish from protein digestion. Mammals produce urea, which is a complex of ammonia and carbon. Any nitrogenous waste from manure runoff into the pond, inorganic fertilizer, plant decomposition, and/or uneaten feed is transformed into ammonia by bacteria in the pond. Bacteria of the genus *Nitrosomonas* convert ammonia into nitrite. Both ammonia and nitrite are toxic to fish. The level of ammonia toxicity depends on the species of fish, water temperature and pH. The level of nitrite toxicity depends on the species of fish and the chloride ion concentration in the pond water. Sublethal levels of ammonia are known to cause gill and tissue damage, poor growth and increased susceptibility to disease. Nitrite at sublethal levels reduces oxygen transport into the fish, resulting in poor feed conversion, reduced growth and increased susceptibility to disease.

At stocking densities normally recommended for cage culture, neither ammonia or nitrite toxicity problems should be encountered. In ponds where higher density cage culture is attempted, where livestock manure can wash into the pond during rains, or where a plankton die-off has occurred, the level of ammonia (and later nitrite) may pose problems.

For more information on the nitrogen cycle and problems associated with nitrite and ammonia, refer to SRAC publication numbers 462, *Nitrite in Fish Ponds*, and 463, *Ammonia in Fish Ponds*.

Turbidity

Turbidity is the degree to which light penetrates the water. Light penetration is blocked by suspended soil, organic material (detritus), and the plankton (floating or suspended microscopic plants and animals) of the pond. Turbidity caused by suspended soil and detritus (muddy color) may reduce photosynthesis and, therefore, oxygen production. Ponds which always have a moderate amount of suspended clay (i.e., muddy) may actually prevent wild fluctuations in oxygen

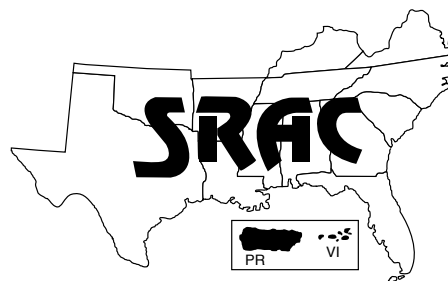
levels. Large quantities of suspended soil particles washed into a pond during heavy rains, however, may cause irritation and clogging of the gills which can lead to secondary diseases. In general, high concentrations of suspended soil or detritus in a pond are not desirable.

Since photosynthesis can occur only to the depth of light penetration into the pond, plankton turbidity is a measure or index of a healthy phytoplankton bloom (green color) in the pond. A healthy bloom will produce oxygen, reduce undesirable macrophytic plant growth, and reduce fish stress because of reduced visibility. Reduced visibility in ponds used for cage culture reduces stress on the fish caused by reactions to seeing people and possi-

bly other animals in close proximity.

A healthy phytoplankton bloom (green water) is one with a Secchi disc visibility of 15 to 24 inches. Clear ponds with a visibility above 24 inches indicate a need for additional fertilization and possible liming (check with your Extension agent). Visibility of less than 12 inches indicates a plankton bloom which is too dense and may cause low dissolved oxygen problems. Visibility of less than 6 inches is critical. Low visibilities due to intense plankton blooms are usually associated with high feeding levels and may necessitate aeration and a reduction in the daily feed ration (see SRAC Publication No. 164, *Cage Culture—Handling and Feeding of Caged Fish*).

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Cage Culture

Cage Construction, Placement, and Aeration

Michael P. Masser*

Cages for fish culture have been constructed from a variety of materials and in practically every shape and size imaginable. Basic cage construction requires that cage materials be strong, durable, and non-toxic. The cage must retain the fish yet allow maximum circulation of water through the cage. Adequate water circulation is critical to the health of the fish, in bringing oxygen into the cage, and removing wastes from the cage. Location of the cage in the pond is critical to proper circulation through the cage. Mechanical circulation and aeration through the cage may be necessary if stocking densities are high (Figure 1), cages are large, or water quality deteriorates during production (see SRAC Publication No. 161, *Cage Culture – Site Selection and Water Quality*).

Cage materials

Cage components consist of a frame, mesh or netting, feeding ring, lid, and flotation. Cage shape may be round, square, or rectangular. Shape does not appear to affect production with most freshwater species.

Cage size depends on the size of the pond, the availability of aeration, and the method of harvest. Most fish farming supply companies sell manufactured cages, cage kits, or materials for constructing cages. The most common cage sizes utilized in ponds are: cylindrical—4x4 (diameter x depth) feet; square—4x4x4 feet and 8x8x4 feet (length x width x depth); and rectangular—8x4x4 and 12x6x4 feet (see figures).

The frame of the cage can be constructed from wood (preferably redwood or cypress), iron, steel, aluminum, fiberglass, or PVC. Frames of wood, iron, and steel (unless galvanized) should be coated with a water-resistant substance like epoxy, or an asphalt-based or swimming pool paint.

Bolts or other fasteners used to construct the cage should be of rust-resistant materials. Mesh or netting materials that can be used include plastic coated welded wire, solid plastic mesh, and nylon netting (knotted or knottless). Mesh size should be no smaller than 1/2 inch to assure good water circulation through the cage while holding relatively small fingerlings (4 to 5 inch) at the start of the production cycle. A larger mesh size can be used if large fingerlings are stocked. The feeding ring or collar can be made of 1/8- or 3/16-inch mesh and should be 12 to 15 inches in width. The feeding ring keeps the floating feed from washing through the cage sides.

All cages should have lids to assure that fish do not escape and that predators (including people) do not have access to the cage. Lids may be made from the same mesh material as the rest of the cage or can be made of other materials, such as plywood, masonite, or light gauge aluminum or steel. Plywood, masonite, and steel will need to be painted with exterior or epoxy paint. Some cage enthusiasts believe that opaque lids (particularly in clear ponds) reduce stress on fish by limiting their visual



Fig. 1. Caged fish are held at extremely high densities. Example shows catfish at seven per cubic foot.

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contact with outside disturbances. No scientific research has been performed to support or dispute this observation. It should be remembered, however, that the manager of the cage needs to be able to observe feeding behavior and have easy access to the cage to remove uneaten feed and any dead fish.

Flotation of the cage can be provided by styrofoam, water-proofed foam rubber, sealed PVC pipe, or plastic bottles. Cages can also be suspended from docks. Plastic bottles should be made of sturdy plastic (e.g., antifreeze or bleach bottles) and should have their caps waterproofed with silicon sealer. Floats should be placed around the cage so that it floats evenly with the lid about 6 inches out of the water.

Cage construction

The simplest cage design to construct is a 4x4 feet cylindrical cage fashioned from 1/2-inch plastic mesh (Figure 2). The mesh comes in a roll 4 feet wide, and a total of 21 feet of plastic mesh is used per cage. Thirteen feet of mesh is used for the cylinder with two 4-foot panels for the bottom and lid. The cylinder is formed around two metal, PVC, polypropylene, or fiberglass hoops at the top and bottom of the cage. A third hoop is used to form the lid. Cages can be laced together with 18-gauge bell wire (plastic coated solid copper wire), stainless steel wire, hog rings, or black plastic cable ties (white

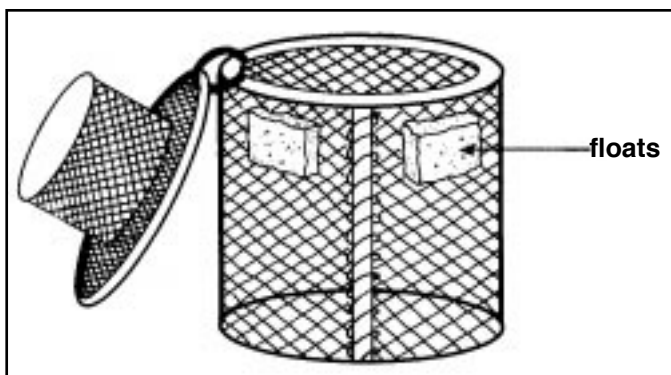


Fig. 2. The 4' x 4' cylindrical cage design.

cable ties should not be used as they deteriorate in sunlight). For detailed instructions on the design of a 4x4 round cage see SRAC Publication No. 340, *4-H Aquatic Science Project, Guide to Raising Catfish in a Cage* and Publication No. 341, *4-H Aquatic Science - Catfish Cage Culture Record Keeping Project*.

Figure 3 shows the design of a 12x6x4 cage which is popular in commercial cage culture of catfish. These cages are usually made from coated (a commercially available plastic net coating) knotted nylon netting and floated with a 4-inch PVC frame. Lead weights along the bottom seams of the cage maintain the cage's shape in the water.

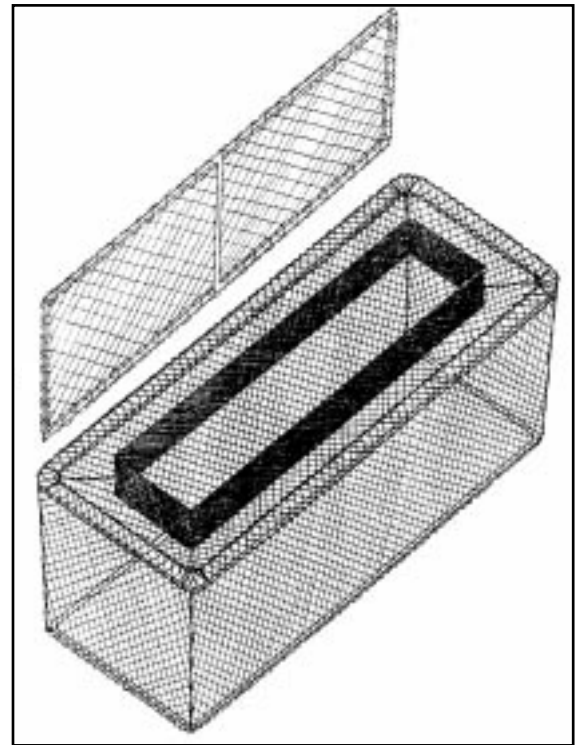


Fig. 3. The 12' x 6' x 4' commercial cage design.

All cages need feeding rings to keep floating feed inside the cage. Feeding rings should be about 15 inches in width and should be attached to the cage so as to extend 3 inches above the water level with 12 inches extending into the water. Feeding rings can be attached to the cage or suspended from the lid. Suspending the feeding ring from the lid reduces the amount of fouling around the sides of the cage. The feeding ring is prone to fouling because of its smaller mesh size. Even with a feeding ring some feed will be washed out of the cage by aggressively feeding fish.

Some cages have been constructed with solid or fine mesh bottoms so that sinking feed can be fed during cold weather. Fouling has been observed as a problem with these cages. If sinking feed is going to be fed,

it is probably better to construct a removable feeding tray with 3-inch or higher sides (to keep feed from being swept off the tray by the swimming action of the fish). Feed can be dropped into the cage above the tray and the tray can be removed to check for feeding response and cleaned as needed.

Cage lids should be attached so they are not readily dislodged by wouldbe predators yet can be easily opened to remove dead fish. Lids are commonly attached so that they hinge along one side of the cage and are wired or hooked along the other sides for easy access.

Cage placement

Location of the cage in the pond can be critical to its success. Two factors to consider in cage placement are access to the cage and maintenance of water quality. Daily feeding and management of the cage necessitate easy access under almost any weather condition. Access may be by pier or by boat. Probably more critical to the success of the cage will be a location in the pond that allows for good water circulation.



Fig. 4. Cages properly separated across pond with no pier.

Critical factors

Critical factors for locating a cage to maximize water quality are:

Windswept. It is important that the cage be in an area where it will receive maximum natural circulation of water through the cage. Usually, this is in an area that is swept by the prevailing winds (usually prevailing summer winds are from the southwest).

At least 6 feet of water depth. A minimum of 2 feet of water is needed under the cage to keep cage wastes away from the fish.

Away from coves and weed beds. Coves, weed beds and overhanging trees can reduce wind circulation and potentially cause problems.

Away from frequent disturbances from people and/or other animals (e.g., dogs, ducks, etc.) Disturbances from people frequently walking on the dock, fishing or swimming near the cage,

and/or from animals which frequent that area of the pond will excite the fish and can cause stress, injury, reduced feeding, and secondary disease. Fish are shy creatures and should never be disturbed needlessly.

At least 10 feet between cages (unless aeration is available). Cages should not be too close together (Figure 4). Close proximity to other cages may increase the likelihood of low dissolved oxygen (See SRAC Publication No. 161, *Cage Culture – Site Selection and Water Quality*) and spread of diseases between cages. Access to electricity or to a location where a tractor-driven paddlewheel, irrigation pump, or other aeration device can deliver aerated water to the cages should be considered when locating cages.

Aeration

Aeration can enhance water quality, reduce stress, improve feed conversion efficiency, and increase growth and production rates. Research has shown that aeration can improve cage production by 20 percent or more. Aeration is most commonly needed at night or during still, overcast days. Aeration for cages can be provided by several types of mechanical aerators. The key to aeration of cages is to create a current that moves water through the cage. Mechanical aerators like paddlewheels, vertical

pumps, or propeller-aspirators can be placed near cages where they create currents through the cages. These types of aerators work well to aerate cages near them and within their current pattern. However, aerators may not work well in creating currents that aerate multiple cages, particularly cages staggered along both sides of a pier.

Air-lift pumps powered by high-volume, low-pressure regenerative blowers can be an efficient and cost effective means of aerating many cages spaced along a pier. Placing air stones in cages appears to agitate and stress catfish, while aerated water pouring into the top of the cage from air-lifts does not disturb them. Figure 5 shows how air-lifts can be constructed from 3-inch (or 4-inch) PVC pipe and connected by 5/8-inch garden hose to a 2-inch or larger air supply manifold attached to the pier. Each air-lift will move approximately 60 gallons per minute into the cage. One air-lift is usually sufficient to aerate a single small cage (4x4 or 6x6 foot cages), but larger cages (12x6 feet) need 2 or more air-lifts.

As many as 27 air-lifts can be powered from a single 1-horsepower regenerative blower. The keys to using multiple air-lifts in multiple cages are:

- construct all air-lifts to exact dimensions (so all are identical), place or attach all air-lifts at the same depth in relation to the water surface, and

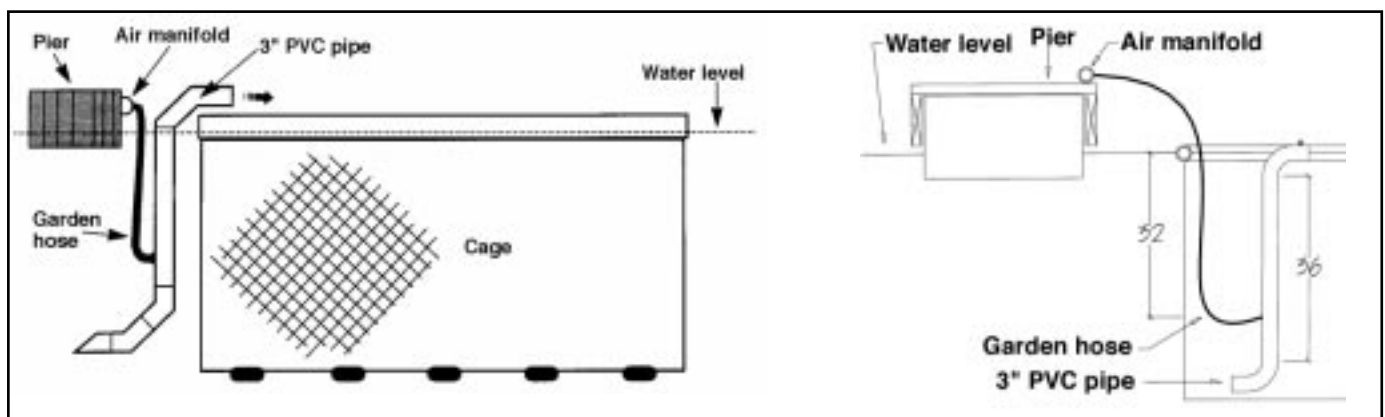


Fig. 5. Cage along a pier with air-lifts mounted over the top of the cage (left) and inside the cage (right).

- construct restriction orifices at the connection of the air manifold and the air line (going to each air-lift).

Most air-lifts should be constructed to be approximately 36 inches long with an “elbow” at the upper end (elbows at the bottom are optional). Air-lifts can be attached to the outside of the cage or hung in the cage (see Figure 6). Air-lifts will not lift water more than a few inches above the pond’s surface and therefore should be attached to the cage as close to the water surface as possible. Air-lifts must be attached to the cage(s) at the same level and held straight vertically, not tilted. The place the hose connects to the air-lift must be between 30 and 34 inches below water level, and all air-lifts must have hoses attached at the same level. A constriction orifice (see Figure 7) must be placed in the air line going to each air-lift, where it attaches to the air manifold. Orifice size should be between 1/8 and 3/16 inch in diameter (3/16-inch diameter is common) and all the same size. The constriction orifice equally distributes air to all air-lifts and stabilizes water flow through each air-lift.

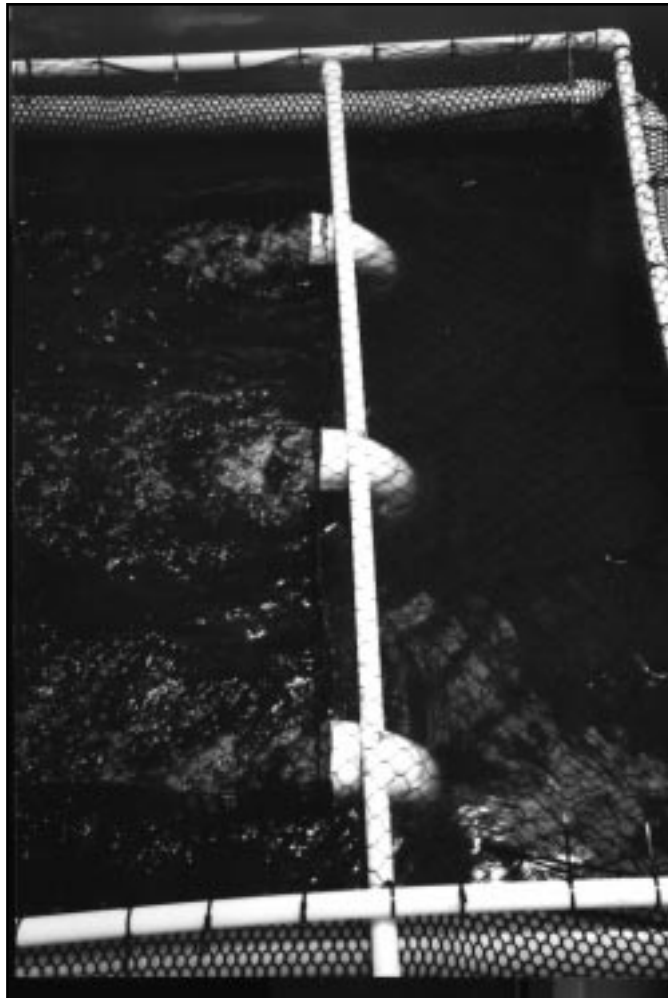


Fig. 6. Air-lifts inside cage.

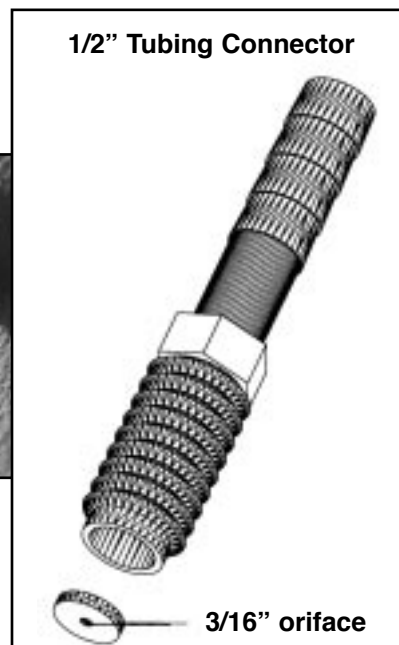
Large cages

Larger cages than the ones described here have been built and utilized particularly in large lakes, reservoirs, rivers, bays, and estuaries. Many times large cages are called net pens because they are constructed from nylon netting. Most commercial ventures in warmwater cage culture using large cages (e.g., 20x20x12) have failed. Most of these failures appear to have been caused by water quality and associated disease problems. Some research and demonstration projects have been conducted in the southeastern states using large cages with aeration devices. These aerated cages have worked well in producing fish but little effort has been made

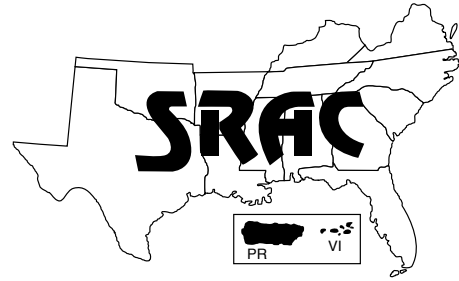
to evaluate the cost effectiveness of these systems. It would appear, however, that large cages can be designed which will maximize the number of fish sustainable by the pond and actually support increased densities above present recommended levels by including aeration systems in the design. For further information on these cages contact your state Extension fisheries or aquaculture specialist.



Fig. 7. PVC tubing connectors with constriction orifice.



Southern Regional Aquaculture Center



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Cage Culture Species Suitable for Cage Culture

Michael P. Masser*

Many species of fish are suitable for cage culture. Species which have been researched and successfully reared in cages in the southeastern region of the U.S. include: **catfish, trout, tilapia, striped bass, red drum, bluegill sunfish, crappie, and carp.** Other species may be suitable for cage culture but research has lagged behind other aquaculture research in recent years. Interest in cage culture has been revived as an alternative crop for farmers outside traditional fish farming areas and in areas with topography not conducive to levee ponds. As this interest continues to increase, more research into cage culture techniques and alternate species will no doubt occur.

A great deal of variability exists in the research and commercial literature about suitable pond sizes, growing season, stocking densities, and size of fingerlings to stock. Stocking rates or densities are dependent on species, cage volume and mesh size, pond surface area, availability of aeration, and desired market size. In general, stocking densities are calculated

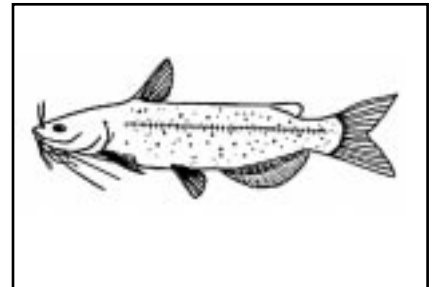
on the number of pounds of fish which can be reared per surface acre of pond and per cubic foot of cage. A pond without aeration can produce from 500 to 1,500 pounds of fish per surface acre. In a pond with aeration, 2,500 to 4,000 pounds of fish per acre have been achieved. The maximum pounds of production per cubic foot of cage seldom exceed 14 pounds in small cages and 11 pounds in large cages (< 270 cubic feet). Commonly, cage production will be between 5 and 8 pounds per cubic foot.

Cage production is possible in ponds, lakes, reservoirs, strip pits, rivers and streams, and in cages which range in size from 27 cubic feet to several thousand cubic feet (in large reservoirs). In this fact sheet, ponds will be the frame of reference and only cages smaller than 300 cubic feet will be considered.

Catfish

The channel catfish is the species most commonly cage cultured today in the Southeast. Channel catfish have a well established market and fingerlings are generally available. They tolerate many extremes in water quality and generally adapt to cages.

Channel catfish are warmwater fish. Optimum growing temperature for channel catfish is between 80 and 85°F. Good growth occurs between 70 and 90°F. Above 95°F fish feeding is reduced and deaths may occur. Below 70°F feeding slows and, therefore, growth slows. Feeding essentially stops below 45°F.



Channel catfish

Channel catfish should be stocked only in a certain range of water temperatures. Handling stress associated with stocking and quality of fingerlings stocked are critical factors to be considered (see SRAC Publication No. 164, *Cage Culture—Handling and Feeding Caged Fish*). Channel catfish can be stocked into cages almost any time when the water temperature is above 50°F. However, stocking

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at temperatures above 80°F may adversely stress the fish and lead to disease and possibly death. Stocking poor quality fingerlings before the water reaches 60°F (when predictable feeding occurs) can lead to handling stress compounded by nutritional stress from the lack of food intake. For these reasons it is probably best to stock when water temperatures are between 60 and 70°F. Of course, fish farmers may have to learn how to handle and stock fingerlings at any range of temperatures to be competitive and meet their marketing objectives.

Size of catfish fingerlings to be stocked depends on the length of growing season, availability, and marketing strategy. The minimum size fingerling which can be stocked into a cage made of 1/2-inch mesh is approximately 5 inches. Generally 6- to 8-inch fingerlings are stocked into cages. If a 1 1/4- to 1 1/2-pound fish is the desired market size at harvest it may be necessary to stock a larger fingerling or stock at a lower stocking rate. A larger fingerling must be stocked in the northern part of the southeastern region (or at high elevations) where the growing season is shorter. It is not uncommon to stock 8- to 10-inch fingerlings where the growing season is 180 days or less.

Availability and cost of larger fingerlings may make stocking these sizes prohibitive. A fingerling over 10 inches in length may not adapt well to a cage.

Uniformity of fingerling size is also important. Research has shown that catfish fingerlings of uniform size (all within 1/2 inch of the same length) will grow more homogeneously, reaching a larger average size and increasing total cage production over fingerlings with a 1 inch or longer variation in length.

The strain or variety of channel catfish stocked into cages can make a great difference in production or yield. Different strains have been developed or selected at both public and private hatch-

eries throughout the Southeast. Not all of these strains do equally well in cages even though they may grow well in open ponds. In fact, strain research in cages suggest that some strains can grow as much as 50 percent faster than other strains. Therefore, probably the best general advice is to talk to other cage producers in your area and ask which fingerling source they like and have been successful with. Research done at Auburn University has shown that strains with a Kansas or Marion (named after the Federal hatcheries) ancestry do well in cage conditions. This same research has shown that many private hatcheries, but certainly not all, have channel catfish strains that grow well in cages. Ask other cage producers and use a strain that has a good reputation.

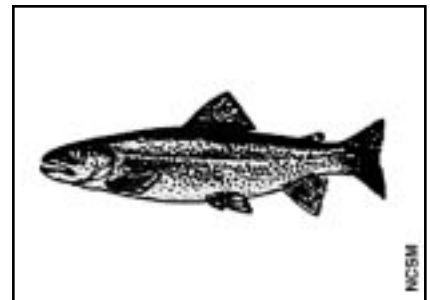
Stocking densities for catfish fingerlings in cages range from 5 to 14 per cubic foot of cage. This equates to 250 to 600 fish in a 4 x 4 feet cylindrical cage. Generally speaking it is best to stock at the low densities (5 to 8 per cubic foot) when first attempting cage culture, particularly if supplemental aeration is not present. Do not stock below a density of 5 per cubic foot or catfish may fight, leading to injury and disease. Some recommended stocking rates for small cages are given in Table 1. Even with supplemental aeration available it may be advantageous, for stress reasons, to stock additional cages rather than overstock individual cages. Overstocking can reduce growth and increase disease problems.

Cage Size	Stocking Rates
4 x 4 feet (round)	250 - 400
4 x 4 x 4 feet	320 - 500
8 x 4 x 4 feet	640 - 1,000
8 x 8 x 4 feet	1,280 - 2,000
6 x 12 x 4 feet	1,500 - 2,300

Blue catfish, hybrid catfish (blue catfish male x channel catfish female), and bullhead catfish have been stocked in cages with limited success. Blue and hybrid catfish do not grow as well in cages as channel catfish. Bullhead catfish have been raised in cages and appear to do relatively well. Recommended stocking size is a 6-inch fingerling. Bullheads do not grow as large as channel catfish, however, and are expected to get to only 1/2 pound in a growing season. Bullhead fingerlings are generally difficult to find and may be expensive.

Trout

Rainbow, brown, and brook trout can all be reared in cages. Rainbow trout are most often cultured because of the availability of fingerlings, established market, and adaptability to cages. Basic culture of all three species is similar. Rainbow trout will be described here, but the information should apply to other trout species.



Rainbow trout

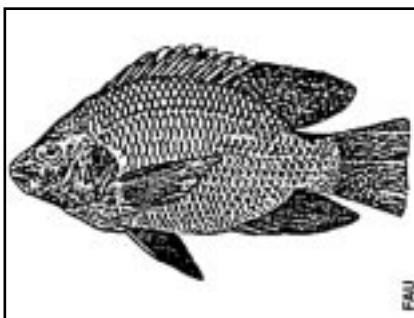
Trout are coldwater species. Optimum growth temperature for trout is between 55 and 65°F, but good growth is attained between 50 and 68°F. At 70°F severe heat stress begins, usually followed by death if exposure is prolonged. Below 45°F feed conversion drops significantly and, therefore, growth. These temperature regimes make cage culture of trout a wintertime only activity in most of the southeastern United States, except where cold spring water or high altitude lowers summertime water temperatures.

It is necessary to stock a 6- to 8-inch fingerling trout in most of the Southeast to obtain 1/2- to 1-pound trout by the end of the growing season. Stocking should begin in the fall as soon as the water temperature drops below 65°F. Failure to harvest before water temperatures reach 70°F in the spring will mean loss of your product and profit.

Stocking densities for trout in cages may be a little higher than those for catfish. The higher oxygen levels maintained by cooler water and smaller sizes at harvest allow trout to be stocked at the higher densities (Table 1) without much concern for low dissolved oxygen problems. In fact densities as high as 15 trout per cubic foot may be acceptable.

Tilapia

Several species of tilapia and their hybrids have been reared in cages. Species most often cultured are *T. nilotica*, Florida red tilapia, Taiwanese red tilapia, Aurea red tilapia, and *T. aurea*. Some tilapia species or hybrids are illegal or restricted in many states. Check with your state Department of Natural Resources, Fish and Wildlife, or an Extension fisheries (or aquaculture) specialist before culturing these species.



Tilapia

Tilapia are truly a tropical fish with origins in central Africa. They tolerate high temperatures well, can feed on plankton and detritus, are resistant to water quality deterioration, reproduce

readily, and have excellent flesh quality. For these reasons they have been stocked all over the tropical world and probably rank as the most widely cultured tropical freshwater fish. In temperate climates, however, they cannot survive winter water temperatures. Optimum temperatures for tilapia are from 80 to 90°F, but good growth is maintained between 75 and 95°F. Death occurs at approximately 50 to 55°F depending on the species, and diseases become common below 60°F. Tilapia should not be stocked until the water temperature reaches 70°F.

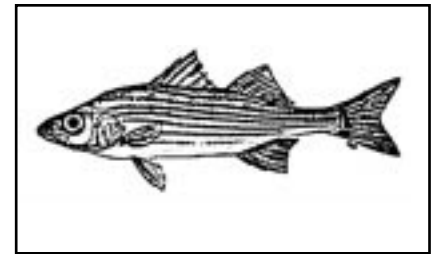
Fingerlings should be stocked at 4 to 5 inches long (or larger) and can be stocked at the densities described in Table 1. One distinct advantage in the cage culture of tilapia is that they are unable to reproduce in cages and, therefore, do not overpopulate the pond. Better growth is achieved if all-male populations are stocked. At the lower stocking densities tilapia will have excellent feed conversion because they filter feed on plankton passing through the cage. Tilapia should be harvested before water temperature reaches 60°F.

Tilapia can be stocked in the same cage with channel catfish (called polyculture). Research has shown that tilapia polycultured with catfish will increase catfish growth because they stimulate the catfish to feed more aggressively, increasing feed consumption. In polyculture with catfish, tilapia should be stocked at rates between 1 and 3 tilapia per 10 catfish.

Striped bass

Striped bass and their hybrids have been successfully reared in cages. Striped bass are illegal or restricted in many states. Check with your state Department of Natural Resources, Fish and Wildlife, or an Extension fisheries (or aquaculture) specialist before culturing these species.

Striped bass temperature tolerances and preferences are similar to those for channel catfish (described previously). One observed problem with striped bass is their poor growth and survival in soft water. Because of this, it is recommended that striped bass and their hybrids should be stocked in waters with total alkalinity of at least 50 ppm. Stocking densities recommended are the same as given in Table 1.



Striped bass

At present the greatest problem in cage culture of striped bass is the availability of large or advanced fingerlings. Most fingerlings are sold at sizes too small to be stocked into cages. A minimum 4-inch fingerling is needed for stocking and 8-inch fingerlings would be preferable. Fingerlings should be graded closely as cannibalism is a problem in young striped bass.

Red drum

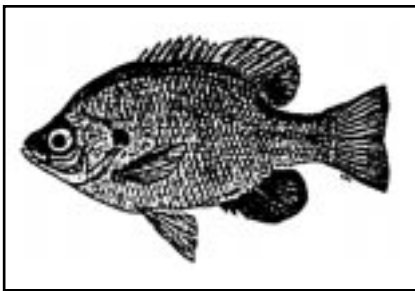
The culture of red drum (redfish) is a recent phenomenon. The research in cage culture of red drum is very limited. At present temperature tolerances and preferences of red drum appear to be about the same as those for channel catfish (described previously), except that red drum do not appear to tolerate rapid temperature drops and require water of high alkalinity and total hardness. For this reason, harvest is recommended before the temperature drops sharply in the late fall. Do not overwinter these fish in cages.

At present the greatest problem with red drum, like hybrid striped bass, is the availability of large

fingerlings for stocking. The recommended stocking size is a 6- to 8-inch fingerling. Cannibalism is also a problem in red drum, so fingerlings need to be graded closely.

Bluegill

Bluegill sunfish and their hybrids have been reared in cages with some success. Temperature tolerances and preferences of bluegill are similar or slightly lower than those for channel catfish (described previously). Bluegill are aggressive and will take food at lower temperatures than catfish and should be stocked before the water temperatures reach 60°F. Limited research on bluegill culture in cages has shown poor feed conversions.



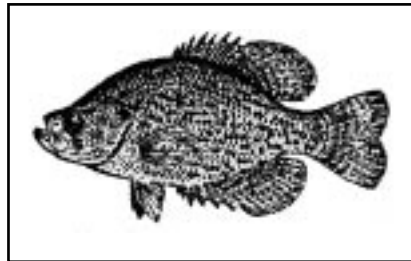
Bluegill

Fingerling bluegill/hybrids should be 3 to 4 inches or larger at stocking and should be graded carefully to assure uniformity. Stocking densities for bluegill should be in the upper range of those given in Table 1.

Crappie

Limited research has been conducted on the cage culture of crappie (black, white and hybrids) in the Midwest. These crappie were captured from the wild then transported and stocked into cages. Results of these preliminary studies indicate that black crappie adapted best to cage conditions but overall survival and growth

were poor. The fish were fed a high protein (43 percent) semi-soft diet. More research needs to be conducted on the culture of crappies in cages.



Crappie

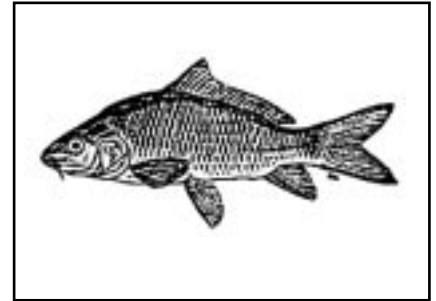
Carp

Common carp (including German, Israeli, mirror, and other varieties) have been successfully cultured in cages and are commercially produced in cages in much of Europe, Asia and the Middle East. Total production of common carp in cages is usually higher than that of most other species. It is not uncommon to produce up to 400 pounds of common carp per cubic yard of cage.

Chinese carp (grass, silver, big-head, and silver x bighead hybrids) also have been reared in cages. These Chinese carp are **illegal** or restricted in many states. Check with your state Department of Natural Resources, Fish and Wildlife, or an Extension fisheries (or aquaculture) specialist before culturing these species.

Common, grass, silver, and big-head carp (and silver x bighead hybrids) have approximately the same temperature preferences and tolerances as channel catfish (described previously). Fingerlings should be stocked into cages at a minimum of 4 to 5 inches in length at the same stocking densities listed in Table 1. Common and grass carp are usually fed a 32 to 36 percent protein complete floating pellet. Silver and bighead carp (and their hybrid) are filter feed-

ers and can be placed in cages in nutrient rich ponds (eutrophic) without any supplemental feeding. The reason for stocking grass carp in cages is to produce a larger fingerling for stocking into recreational ponds (for weed control) with large predatory fish.



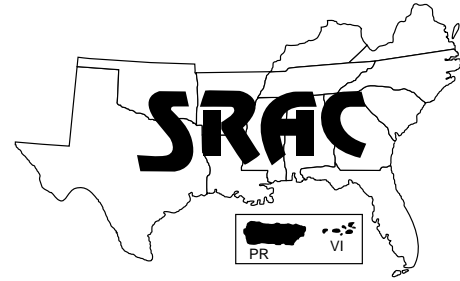
Carp

One research study has been done using silver x bighead carp hybrids cultured in cages. The hybrids were stocked at densities of approximately two per cubic foot or 120 in 8 x 4 x 4 rectangular cages. The cages were not fed and no artificial water circulation provided. These fish fed on plankton and grew quickly from 10 inches to average 3.7 pounds in one growing season.

Choose species carefully

Picking the fish species that will do well in cages in your particular location is important. For example, it is difficult to get enough growth on trout during the short winters in Gulf coastal plain locations but not in the longer winters in states like Kentucky. Probably the most important decision in determining which species you should culture in cages is: Is there a market for them? Furthermore, is that market local or must they be transported for long distances? Is it a live market or a processed market? What size is preferred in the market? All potential producers should evaluate markets before selecting the species to be cultured.

Southern Regional Aquaculture Center



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Cage Culture

Handling and Feeding Caged Fish

Michael P. Masser*

Fish stress induced by handling and poor feeding practices is a common cause of cage culture problems. Handling stress occurs whenever fish are captured, moved, or confined. Handling stress is usually associated with seining, holding, hauling, or stocking of fish. Problems associated with incorrect feeding practices are particularly acute in cages since no natural foods are usually available to the caged fish, and water quality deterioration from waste feed has a more direct effect on confined fish. Feeding problems common in cage culture include poor quality feed, incomplete feed, inadequate feeding or underfeeding, overfeeding and feeding at the wrong time of the day. Many of these problems have no simple solution and some degree of stress will occur. In most cases the management goal must simply be to reduce the total stress placed on the fish by handling and feeding practices.

Handling

Caged fish are confined at high densities in a small area. It should be obvious, therefore, that the caged fish are in a situation where

frequent stresses are likely to occur.

Most cage culturists do not start out producing their own fingerlings. If fingerlings are purchased from outside sources, it is possible that they may have already been stressed in handling.

Common handling stressors during harvest, holding and transport from fingerling ponds to the culture pond include heat or cold shock, oxygen deficiencies, exposure to disease, high ammonia or nitrite levels, pH, shock, overcrowding and rough handling. The first encounter the fish culturist usually has with the fingerlings is at purchase. Therefore, it is at purchase that the culturist must make a determination of the fingerlings' health (i.e., quality). Stocking quality fingerlings that are free of disease and of uniform size is essential to successful cage production.

Purchase fish from a reputable producer who will guarantee his product. If possible, the fingerlings should be inspected by a certified fish disease specialist. If that is not possible look for signs of disease and stress, such as:

- skin abrasions or discolorations, thin bodies and variation of skin color within the group;

- condition of the fins and gills, frayed fins or pale, swollen and eroded gills;
- odd behavior, weak or erratic swimming, piping and lack of net avoidance.

All of these are indicators of problems. Starting with stressed or diseased fish will probably lead to disaster and not make cage culture a positive experience.

Stocking into the cage is always stressful on the fish. Appropriate equipment and experience are important in transporting fish. Transport the fish in a well oxygenated container with water the same temperature as the water the fish were in when purchased. To reduce stress and remove certain parasites during transport, add salt to the hauling container (see SRAC publications 390, *Transportation of Warmwater Fish—Equipment and Guidelines*; 392, *Transportation of Warmwater Fish—Procedures and Loading Rates*; and 393, *Transportation of Warmwater Fish—Loading Rates and Tips by Species*). Stock at pond temperatures which will not stress the fish (see SRAC Publication No. 163, *Species Suitable for Cage Culture*). If the temperatures of the pond and the hauling water differ by more than a few degrees, temper the fish by slowly adding pond water

*Auburn University

to equalize the temperature. A wait of at least 20 minutes is needed for a 10°F change in water temperature. Failure to properly adjust the temperature can lead to immediate death or can lower the fingerlings' ability to resist infections and lead to secondary diseases or parasites. Finally, do not feed the fish for 1 or 2 days after stocking. Let the fish recover from the haul and adjust to the cage.

Problems which occur immediately after stocking were either brought in with the fingerlings, occurred during stocking, or are an indication of severe pond problems. A cage culturist should know his pond and its water quality before stocking, and not stock fish into a pond with problems. (See SRAC Publication No. 161, *Cage Culture—Site Selection and Water Quality*.)

During the growing season the fish should be disturbed as little as possible. Moving the cage, lifting the cage to look at the fish, netting the fish, swimming or fishing near the cage, or placing the cage where it is disturbed by other animals can stress the fish. Stress can lead to reduced feed consumption (i.e., reduced growth) and increased incidence of disease.

Feeding practices

Nutritional stress is common in cage culture. In fact, most of the failures of both research and commercial cage culture prior to 1975 can be related to feed quality. Today the science of fish nutrition has progressed to the point that balanced and complete diets can be formulated for the important commercial species. These complete diets are available from commercial feed mills and are essential to the health and growth of caged fish. Caged fish in most cases will receive no natural food and, therefore, must have a nutritionally complete diet which has adequate protein and energy levels, is balanced in amino acids and in essential fatty acids, and is supplemented with a complete

array of vitamins and minerals. Many commercial feed mills manufacture both supplemental and complete diets. The cage producer must be sure he is purchasing a **complete diet**—one that is suitable for the species being cultured.

Caged fish should be fed a floating pelleted feed. Floating feed is trapped inside the feeding ring and will allow the fish farmer the opportunity to observe the fish. Sinking feed will fall through the cage (unless the cage has a bottom) and not be eaten by the fish. In general, warmwater species such as catfish, tilapia, bluegill and carp can be successfully reared from large-sized fingerlings on 32 percent protein complete diets although many fish farmers prefer 36 percent. Red drum and striped bass (and its hybrids) need diets with 38 to 42 percent protein. Coldwater species such as trout need a higher protein diet of 40 to 42 percent. Pellet sizes normally available include 1/8, 3/16, and 1/4-inch diameters. Usually large fingerlings can accept 1/4-inch pellets. Small fingerlings and species with small mouths (e.g., bluegill) may need to be started on 1/8-inch pellets.

Fish will feed most aggressively near their preferred or optimum temperature and when oxygen levels are high (i.e., above 60 percent of saturation). Oxygen is usually at acceptable levels (unless heavily overcast) between mid morning and late afternoon. From a temperature standpoint, warmwater fish such as catfish will feed better as the temperature rises in late afternoon in the spring, but prefer mid morning during the heat of the summer. Generally fish will adapt to any feeding time as long as it is consistent. Changes in the feeding schedule should be made gradually (e.g., not changing more than 30 minutes per day). Most studies have shown that fish will grow faster and have better feed conversion if their daily feed ration is divided into two feedings given at least 6 hours apart. This is particularly

true of small catfish, trout, tilapia and bluegill.

Recent research on cage culture of catfish has shown that dusk feeding can increase growth and improve feed efficiency. Dusk is the natural feeding time for many species of fish. **Dusk feeding cannot be practiced without a means of nighttime aeration.** (See SRAC Publication No. 162, *Cage Culture—Cage Construction, Placement, and Aeration*.) Dusk feeding can begin within 1 hour of sunset and can continue for an hour or more after sunset. The key to dusk feeding is not to overfeed (see page 3). If mechanical aeration is not available, do not consider dusk feeding.

Correctly feeding the proper amount of feed is extremely important. Overfeeding wastes feed and money, and can cause water quality deterioration leading to stress and increased incidence of disease. Underfeeding reduces the growth rate, total production and profit. A general rule of thumb for most warmwater fish is to feed fish all they will eat in 10 to 30 minutes when the water temperature is above 70°F. Caged fish, particularly catfish, are sometimes shy and may not start feeding immediately. Also, when fish are first stocked into a cage they usually adjust slowly to feeding. **Keeping good feeding records is essential to becoming a successful fish producer.**

It is a good practice to offer caged fish one-half of the amount of feed they consumed the previous day, so as not to overfeed if there is a weather, water quality or disease problem that reduces consumption. After adding feed observe the feeding response, adding more feed as needed at 20- to 30-minute intervals. If the fish have not consumed the feed after 20 to 30 minutes, do not add more feed. Many producers and researchers have found that catfish will continue to consume feed for several hours if fed at dusk. The key is to get as much feed into the fish as they want to eat (satiation) without leaving or

wasting feed. The more feed eaten the more fish produced!

Demand feeders have been used successfully with caged fish. The problems with demand feeders are:

- 1) the fish must be trained to use the feeders,
- 2) the feeders need frequent adjustment, and
- 3) the producer must observe feeding behavior of the fish to head off water quality and disease problems.

Demand feeders should only be used by **experienced producers** who have produced fish using hand-feeding and feel they know how to observe fish behavior.

Demand feeders should be filled daily at the time when feeding normally begins, so that feeding behavior can be observed immediately. Since species like catfish tend to feed on demand feeders at dusk or after dark, it is best to fill these at dusk. Again, **dusk feeding** (and demand feeding of species that feed at night) **should not be practiced unless nighttime aeration is available!**

Fish in cages should be fed at least 6 days a week, unless precluded by bad weather, poor water quality, or disease. The daily amount of feed fed will need to be increased as the fish grow. Feeding should be discontinued during periods of heavy overcast weather (unless aeration is available) and if water temperatures exceed 95°F.

Feeding rates

Feeding rates for fish are calculated on a percent of body weight per day basis, based on the fish size and water temperature. Small fish consume a larger percentage of their body weight than larger fish, and all fish increase consumption as water temperatures approach optimum temperature range. Small fingerlings will usually eat 4 to 5 percent of their

body weight. After they reach advanced fingerling size the rate will decrease to 3 percent and nearing harvest size will drop to only 2 percent or less (see Table 1).

Experienced cage culturists prefer to estimate feeding rates. There are two methods commonly used to determine proper feed amounts. One method estimates growth based on feed conversion and adjusts feeding rates weekly to this estimate. The second method estimates growth based on a sample of fish from the cage and adjusts feeding rates based on this sample.

Feed conversion method

This method requires that the initial weight of the fish stocked be known and that records be kept on the total weight of feed fed each week.

For the first week start by determining the average individual stocking weight of the fish (total weight of fish stocked in pounds divided by number of fish stocked). Use Table 1 to find the percent body weight which fish that size should consume. Multiply the percent body weight by the total weight of fish stocked into the cage. This gives the amount of feed that should be

consumed each day for the first week.

A new estimate should be recalculated each week, based on estimated growth. Estimated growth is calculated by multiplying the total amount of feed (in pounds) fed during the week by the estimated feed conversion ratio (FCR) of 1.0/1.8 (1 pound of gain for each 1.8 pounds of feed eaten or 0.556). This estimated growth weight is added to the total weight at the beginning of the week. This new total weight is divided by the number of fish (less any deaths) to get a new weight of individual fish. Use Table 1 to get the estimated percent body weight the fish should now consume and multiply this by the total cage weight. This is the new amount of feed that should be fed daily for the next week. This sounds complicated but with a little practice it becomes easy. The formulas and example which follow should help.

In this example, the fish were averaging 1/2 pound (0.5) each at week 10 and there had been no deaths; therefore, 300 fish x 0.5 = 150 pounds = total cage weight. At that cage weight they were consuming 3.75 pounds of feed each day for 6 days or 22.5 pounds of feed during the week.

Average weight/ length per fish (pounds/inches)	% Body weight consumed
0.02 / 4	5.00
0.04 / 5	4.00
0.06 / 6	3.00
0.25 / 9.5	2.75
0.50 / 12	2.50
0.75 / 13.5	2.25
1.00 / 15	2.00
1.50 / 17	1.75

*Applicable to most warmwater species.

Feed Conversion Method:

Estimated wt gain = total pounds of feed consumed x 0.556 (FCR)

New total cage wt = estimated wt gain + last week's total cage wt

Avg wt of individual fish = new total cage wt/total no. of fish in cage

New daily feed wt = new total cage wt x % body wt consumed (Tbl 1)

Example for week 10, cage of 300 fish, feed 6 days per week:

Estimated wt gain (wk 10) = 22.5 x 0.556 = 12.5 pounds

New total cage wt (wk 11) = 12.5 + 150 pounds = 162.5 pounds

Avg wt of individual fish = 162.5/300 = 0.54 pounds

New daily feed wt = 162.5 x 0.025 (2.5/100%) = 4.1 pounds

Consuming 22.5 pounds of feed with a feed conversion of 1.0/1.8 (or 0.556) gives an estimated weight gain of 12.5 pounds during week 10. Adding this 12.5 pounds of weight gain to the 150 pounds of fish (estimated) in the cage at the start of week 10 gives a new total cage weight of 162.5 pounds. Since 300 fish weigh 162.5 pounds, or 0.54 pounds each, they will eat 2.5 percent (or 2.5/100 percent = 0.025) of their body weight according to Table 1. Therefore, the new feeding rate (pounds) is 162.5 x 0.025 or 4.1 pounds of feed daily. This amount should be fed each day for six days the next week.

Measured growth estimate

This method calculates feeding rates based on the weight of a sample of fish from the cage. This should be done at 2-week intervals and usually requires that at least 10 fish be weighed from each cage. The total weight of the sample of fish is divided by the number of fish sampled, to get the average individual fish weight. This weight is used with Table 1 to estimate the percent body

weight consumed. The average fish weight is multiplied by the number of fish in the cage to get the total cage weight, which is then multiplied by the percent body weight consumed to get the new daily feeding rate. The formulas and example which follow should aid understanding.

In this example the fish were averaging more than a half pound (0.54) each at week 10 and there had been no deaths; therefore, 300 fish x 0.54 = 162.5 pounds = total cage weight. At 0.54 pounds each of the fish should be consuming 2.5 percent (or 2.5 divided by 100 percent = 0.025) of their body weight per day (Table 1). Therefore, the new feeding rate (pounds) is 162.5 x 0.025 or 4.1 pounds of feed daily. This amount should be fed each day for the next 2 weeks.

Handling is stressful on the fish, not only those handled but the other fish in the cage trying to avoid capture. During periods of questionable water quality or extremely hot weather conditions it may be best to avoid handling the fish and estimate the weight gain.

Sampling Method:

Avg of individual fish = wt of 10 fish/10

New total cage wt = average wt of individual fish x number in cage

New daily feed wt = new total cage wt x % body wt consumed (Tbl 1)

Example for week 10, cage of 300 fish:

Avg wt of individual fish = 5.4/10 = 0.54 (pounds)

New total cage wt = 0.54 x 300 = 162.5

New daily feed wt = 162.5 x 0.025 = 4.1

Winter feeding

Many species of warmwater fish can be overwintered in cages. Tilapia are the exception and will die as water temperatures reach about 55°F. Caged fish can be fed during the winter at a reduced feeding level. Table 2 gives general guidelines for feeding catfish during the winter in cages. Floating feed can continue to be fed throughout the winter in the Southeast. Feeding is usually most successful if done on warm, sunny afternoons. Research has shown that catfish can gain 10 to 20 percent of their body weight over the winter if fed, but feed conversion is poor (>3.0). Research has also shown that catfish can survive the winter without being fed and may be more resistant to bacterial diseases if deprived of feed.

Finally, probably the most important aspect of feeding: Do not over-feed the pond. The pond must decompose and detoxify all organic matter it receives. Included in this organic matter are plant materials from inside and outside the pond, runoff of nutrients from fields and pastures (possibly including livestock wastes), all fish wastes and uneaten feed. Dumping pound after pound of feed into the pond puts a tremendous burden on these natural decomposition systems which use oxygen. If the systems are overloaded the pond will become depleted of oxygen and the fish will die. Unless livestock or fertilizer runoff is a problem, the greatest organic load placed on the pond is from the fish feed.

In general, the recommended maximum pond feeding rate is not more than 35 pounds of feed per surface acre of pond per day (35 pounds/acre/day). Even at this feeding rate problems may occur in some ponds. Mother Nature is unpredictable and unforgiving! At this feeding rate the greatest number of pounds of fish which should be cultured in cages would be 1,750 pounds/acre, calculating that a 1-pound

Table 2. Winter feeding schedule for caged fish.

Temperature °F	% of Total fish weight to feed	Feeding frequency
66 - 70	2.0	every other day
61 - 65	1.5	every other day
56 - 60	1.0	every other day
51 - 55	1.0	twice per week
45 - 50	0.5	once per week

fish will eat 2 percent of its body weight daily ($1,750 \times 0.02 = 35$).

Recommended pond feeding levels can be increased if aeration is available. Aeration can help maintain dissolved oxygen con-

centrations and support higher decomposition rates, or at least, keep the fish alive during times of low oxygen. The recommended maximum feeding rate with aeration is 60 pounds/acre/day. At

this rate the greatest number of pounds of fish which should be cultured in cages would be 3,000 pounds/acre ($3,000 \times 0.02 = 60$).

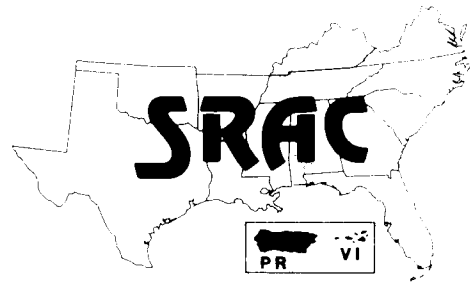
Feeding rates above these levels are practiced by many experienced cage producers. The key word is experienced. Beginning cage producers should not push their ponds until they have gained experience in water quality and fish management. Unfortunately, much of this experience is usually gained by killing fish.

Guidelines on feeds and feeding

1. Observation of the fish at feeding time is vital. Feeding behavior is the best index of overall health. Actively feeding fish indicate everything is all right, for the moment. Poor feeding behavior should always be viewed with suspicion (see SRAC Publication No. 165, *Cage Culture Problems*).
2. Reduce feeding levels when water temperatures drop below 60° or above 90°F.
3. Reduce or stop feeding on heavily overcast and windless days. These weather conditions reduce oxygen production and diffusion, particularly if sequential, and can lead to low dissolved oxygen. Feeding will only complicate the problem. Run aeration if available.
4. Feed quality must be excellent. Purchase feed which is known to be complete and keep it stored in a very dry, cool place. Feed should be fed within 90 days of the manufacture date.
5. Never feed moldy or discolored feed.
6. Automatic or demand feeders are not recommended for most warmwater species because of the need to observe the fish feeding (except for experienced producers with aeration systems).
7. Keep accurate records on the amount of feed fed.
8. Never feed more than 35 pounds of feed/acre/day without aeration or 60 pounds of feed/acre/day with aeration.

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Southern Regional Aquaculture Center



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Cage Culture Cage Culture Problems

Michael P. Masser*

High density aquaculture has been described by the United States Department of Agriculture as the most intensive form of agriculture practiced on a large scale in this country today. Cage culture is one of the most intense forms of aquaculture. Due to its intense nature, cage culture can have problems. Anticipation can solve at least some of them.

Signs of fish stress

One problem with most types of fish culture is that the fish are difficult to observe. Ponds are usually turbid and observation of the fish impossible. Fish are generally shy and attempt to hide from people. Sampling fish to observe them may stress the fish and lead to secondary diseases. This is why observation during feeding is critical. Feeding is the only time when the fish will readily come to the surface for observation. Cages are collections of individual fish and many times behave differently, not unlike groups of people. Some cages of fish will feed readily with people all around them. Others will wait until people are gone and all is quiet.

It is critical to watch closely and note the behavior of the fish feeding in order to recognize behavior changes. Usually changes in behavior are caused by changes in their environment (i.e., the pond) or in their health. These changes may be the first signs of stress. Learn to recognize the common signs of stress which may include:

- a reduction in the amount of feed eaten,
- feeding stops suddenly,
- fish are at the surface gulping for air,
- fish are swimming erratically,
- discolorations are seen on the skin of the fish,
- dead or dying fish,
- and any other strange behaviors.

If any of the above signs appear, ask yourself why? Do not let the question go unanswered for long, or a new question can appear: Where do I bury the fish? Try to analyze the problem and come up with a solution or reason for the behavior. Here are a few possible reasons or problems which could have produced these behaviors. This is by no means

a complete discussion and should be taken as only some of the possibilities.

A reduction in feeding could mean disease, parasite load, low oxygen, or one of several water quality problems (e.g., ammonia, etc.). Has the weather changed? Has the pond water color changed? If it is a heavily overcast and windless day, it may simply be a temporary low but not critical oxygen problem. If the pond is changing color or a surface scum has suddenly appeared, it may also be low oxygen (see Signs of pond stress which follows). A sudden halt to feeding usually suggests oxygen problems; diseases, parasites and other water quality problems usually do not disrupt all the fish immediately. Likewise, fish at the surface gulping for air (usually observed at or before dawn), when the day before everything seemed fine, is a sign of critically low oxygen. Aerate now--in 30 minutes it may be too late!

Skin discolorations, spots, fin erosion, erratic swimming, or other strange behaviors are usually signs of diseases or parasites. If diseases or parasites are the problem, then dead fish usually start to appear soon. A few dead fish each day usually indicate some type of slowly

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spreading disease or parasite problem. Progressively more dead fish each day is a sign of a very serious disease problem. Dying fish or fish with suspected diseases or parasites should be diagnosed immediately. Take a live sample of fish and a water sample to your nearest fish disease diagnostic lab. Many state fisheries Extension programs offer disease diagnosis. Contact your county Extension office or state fisheries (aquaculture) specialist for information on how to properly package and ship fish samples.

Any disease diagnostic lab will be able to give you the best treatment alternatives for the disease or parasite. If diagnosed as an internal bacterial disease, the most practical treatment is usually to feed a medicated feed (e.g., Terramycin). If an external bacteria or parasite is the problem a water treatment may be necessary.

Depending on the disease, water treatment may require treating the entire pond or it may be possible to bag the cage in plastic and treat just the cage. Treating the entire pond may be too expensive to be justified, but some parasites can be eliminated only by treating the entire pond. Bag treatment can cause serious oxygen stress if supplemental aeration is not provided in the bag and should only be used for certain diseases which are not spread from the pond.

Signs of pond stress

Ponds can also be stressed from an accumulation of nutrients and/or from overfeeding (see SRAC Publication No. 161, Cage Culture--Site Selection and Water Quality and SRAC Publication No. 164, Cage Culture--Handling and Feeding Caged Fish). Pond stress in this case is synonymous with water quality problems. Common examples of pond problems are:

- excessive plankton blooms (pea green),
- surface scums,
- strong odors,

- excessive weed growth (macrophytes),
- or a rapid change in water color.

All of these are symptomatic of excessive nutrients and can become problems in any pond as it ages (a process called eutrophication). In most aquaculture ponds it is symptomatic of overstocking and/or overfeeding. Excessive plankton blooms (less than 12 inches visibility on a Secchi disk) can cause oxygen depletions at night or on heavily overcast days. The same is true of excessive macrophytic growth. Also, surface scums can shade out the rest of the phytoplankton bloom, causing oxygen depletions, and have been identified with off-flavor problems. Strong odors are identified with decaying plant material and usually signal pending oxygen depletions caused by decay. Rapid changes in color also signal phytoplankton die-offs and pending oxygen depletions. In some cases chemical control of the plants may be warranted. In most cases supplemental aeration will be necessary to maintain the fish. At times of severe plankton die-offs supplemental aeration may not be able to keep oxygen above critical levels in the cage. In these cases it may be necessary to release the fish into the pond hoping that they can spread out and survive, or move them into another pond.

The ability to recognize and prevent potential oxygen problems is usually better than trying to save the fish after the dissolved oxygen has dropped in the pond. Remember that dissolved oxygen stress is one of the chief causes of secondary infections. Contact your county agent or state fisheries (or aquaculture) specialist for information on diseases or how to measure and predict dissolved oxygen levels in ponds.

Signs of human error

Of course we could blame ourselves for all of the above, and in most cases we would be justified. Aside from that, common errors made by people include:

- picking ponds with pre-existing problems,
- poor cage construction,
- stocking undersized or poor quality fingerlings,
- stocking too many fish per cage,
- stocking too many fish per pond,
- stocking too few fish per cage,
- feeding poor quality feed,
- overfeeding,
- disturbing and poor handling of the fish,
- and not observing the fish.

These problems are very common, particularly with beginning cage culturists. All of these problems have been discussed in this and other SRAC publications in this series.

Other problems and observations

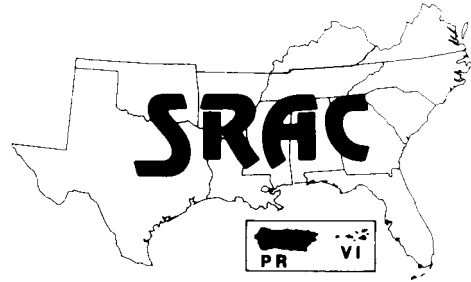
Biofouling is a common cage problem. Biofouling is the growth of algae and bryozoans (soft bodied, jelly-like animals) on the sides of the cage. These creatures restrict water flow through the cage and cause water quality problems (LODOS).

Periodically check the sides of the cage (but do not lift the cage out of the water) and remove any biofouling organisms with a stiff brush or broom. **Do not stress the fish.**

Overwintering in cages is another problem. Some species overwinter better than others, but in general, overwintering should be discouraged. Try to feed your fish on warm and sunny winter days and be prepared to give medicated feed to the fish if bacterial problems develop in the spring.

All fish farming, including cage production, is "crisis management." Visit the pond and observe the fish daily. Plan ahead and be prepared for emergencies. If you are inexperienced and a problem arises, **get help.**

Southern
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Cage Culture

Harvesting and Economics

Michael P. Masser*

Being successful at raising fish in cages is not enough. Harvesting, keeping records, marketing, and looking at the economics of the venture are also essentials in successful cage culture. This is particularly true if the goal is to increase farm income.

Harvesting

Harvesting cages is simply a matter of removing the fish from the cage with a dip net. This is one of the major advantages of cages and usually the reason people picked cage culture in the first place.

Harvesting can begin whenever the fish reach market size. The market size depends on the species being raised and the market that has been identified. Time for fish to reach market size usually depends on the size of the fingerlings stocked and the overall conditions during the growing season. In the case of warmwater fish, harvest usually begins in September or October in

the southeastern region. Trout and other coldwater species are usually harvested in March and April. Tilapia must be harvested before the water temperature drops much below 60° F in the fall. Trout must be harvested before the water temperature rises above 70° F in the spring. Most other warmwater species can be left in cages during the winter months and harvested at any time. This may help in planning markets.

Fish do not all grow at the same rate. Some fish that reach harvest size early may be removed. However, it should be cautioned that reducing the stocking density by partial harvest, before the water temperature drops to around 60° F, may induce stress and increase fighting among the remaining fish due to the lower density. Fighting may also occur if fish in the cage get too large. Increased fighting may lead to injuries and related bacterial diseases.

Before harvesting it is important to sample the fish for possible off-flavor. Off-flavor is caused by more than one agent. Off-flavor is most common in the warmer months but

can occur at any time of the year. If the fish taste muddy, musty, oily, or have any strange flavor, you should wait and harvest them at a later date. Off-flavor will go away given time (usually about two weeks) and good water quality. Your marketing efforts will be harmed if you sell off-flavor fish.

Stop feeding 2 days before harvest. This gives the fish time to empty their digestive systems and reduces holding and processing problems. At harvest record the number of fish harvested and their weight (length records could also be useful). These records will be necessary to analyze the success of your venture.

Marketing

Ideally, identify your market before you stock, but **always** plan your marketing before you harvest. Having no marketing plan will mean frustration and reduce your chances of a profitable venture. Most fish can be sold either live or dressed (processed). If you plan to process your fish you must be in compliance with state health laws. Contact your state Department of Health or the fisheries

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(or aquaculture) specialist with the Extension Service for information on processing regulations.

Several possible markets exist for your fish. Which markets are best for you may depend on the number or volume of fish you have to sell, your ability to transport the fish, your ability to process the fish, and your proximity to known markets. Possible markets include:

- live sales direct to consumers,
- direct sales to consumers of processed fish,
- live sales to fee-fishing lakes or live-haulers,
- sales to local processing plants,
- and sales to local restaurants or grocery stores.

Small producers, with only a few hundred fish to sell will probably find their greatest profit in selling directly to the consumer. Direct sales of live or dressed fish reduce middleman costs and bring all the profit back to the fish farmer. Live sales at the pond bank or at local farmers' markets also eliminate the need to process the fish. Live sales markets may take a while to develop, but are exceptionally profitable markets.

Fee-fishing, fish-out, or pay lakes are good markets for live fish. Fish-out lakes usually buy fish to stock on a regular basis through the spring and summer and pay premium prices. However, harvesting of your fish in the fall is a problem, in that fish-out lakes may not want to stock close to the winter months. Also, it may be necessary to haul the fish to these fish-out lakes. If you do not have the ability to haul your own fish you may want to contract with a live-hauler. The live-hauler may buy the fish directly from you or he may want a percentage of the sale price.

Finally, if your volume is great enough you may decide to start a processing operation or if you are close to existing processing plants you may wish to sell to them. This latter option is probably the least profitable but is also the most convenient and least time consuming.

Whenever marketing farm-raised fish stress quality and freshness. In the case of cage-raised fish emphasize that they have been completely away from the mud that they were grain fed, and that they were grown in a pollution-free environment. Many producers believe that cage-raised fish are better tasting than those raised loose in ponds.

Record keeping

Any business must keep good records to be profitable and successful. Fish farming is no different. Good record keeping is essential to understanding the successes, failures and profitability of your fish farming venture. Records which should be kept include:

- cost of cage materials and other equipment,
- cost of fingerlings and their weight and length,
- cost of miscellaneous items (e.g., chemicals, etc.),
- cost of feed and total pounds purchased,
- stocking and harvesting dates,
- number and total weight of fish harvested
- income from the sale of fish,
- and daily observations of the pond and fish.

Most of the above are self explanatory. The daily observations should include the amount of feed fed, weather conditions, pond conditions, fish appearance and fish behavior.

This information will be invaluable in understanding and predicting problems now and in the future.

Economics

The range of variability throughout the southeastern region in fingerling prices, feed prices, materials and equipment prices, length of growing season, and general weather conditions makes it very difficult to produce good regional budgets.

Fingerling prices for 6-to 8-inch channel catfish, for example, may range from \$0.10 to \$0.55. Feed costs may vary by \$100.00 per ton or more, depending on volume and location. Live weight price, again for channel catfish, varies from about \$0.70 per pound at large processing plants to \$1.50 or more per pound for direct consumer sales or delivered to fee-fishing lakes. Contact your local county Extension office or state fisheries (or aquaculture) specialist for budgets specific to your area.

Table 1 gives some estimates on freed costs of cage materials and equipment. Cage and equipment costs are usually depreciated over 5 years or more.

Table 2 illustrates approximate production costs calculated on fingerling price and feed price, based on a feed conversion rate of 1.8 (it would take 1.8 pounds of feed to produce 1.0 pound of fish). As with most enterprises there are some economies of size. Cage materials, fingerling costs, and time involved per individual cage all diminish with increasing scale.

Any discussion on economics should probably include emphasizing the risks. Fish farming is a high risk type of agriculture. All agriculture has a degree of risk simply because it is at the whims of nature. This is particularly true of fish farming and cage culture.

Table 1. Fixed costs estimates of materials and equipment for cage culture.

Item	Cost/cage	Cost/5 cages
Cage materials ¹	75.00 ²	160.00
Dip nets	50.00	50.00
Scales ³	45.00	45.00
Miscellaneous	30.00	65.00
Total	\$200.00	\$320.00
Total/cage	\$200.00	\$64.00

¹Calculated for a 4 x 4 foot cylindrical cage, purchasing the netting and hoops only.

²Calculated on buying an entire roll of netting (50 feet). Two rolls of netting will make 5 cages (second example).

³Used for weighing fish and feed.

⁴Includes chemicals, buckets, rope, etc. Cost for aerators is not included. Depending on pond size and stocking density, costs for aeration could range from \$300 to \$1,800.

Table 2. Production costs based on various fingerling and feed prices.¹

Cost per fingerling	Feed costs (per 50-pound bag)					
	7.20	8.20	9.20	10.20	11.20	12.20
0.10	0.36	0.40	0.43	0.47	0.50	0.54
0.15	0.41	0.45	0.48	0.52	0.55	0.59
0.20	0.46	0.50	0.53	0.57	0.60	0.64
0.25	0.51	0.55	0.58	0.62	0.65	0.69
0.30	0.56	0.60	0.63	0.67	0.70	0.74
0.35	0.61	0.65	0.68	0.72	0.75	0.79
0.40	0.66	0.70	0.73	0.77	0.80	0.84
0.50	0.76	0.80	0.83	0.87	0.90	0.94

¹Calculated in cents/pound for producing a 1-pound fish with a feed conversion of 1.8.

